

b -hadron decays to charmless final states

This section provides branching fractions (BF), polarization fractions, partial rate asymmetries (A_{CP}) and other observables of b -hadron decays to final states that do not contain charm hadrons or charmonium mesons¹, except for a few lepton-flavour- and lepton-number-violating decays reported in Sec. 6.

Four categories of B^0 and B^+ decays are reported: mesonic (*i.e.*, final states containing only mesons), baryonic (hadronic final states with baryon-antibaryon pairs), radiative (including a photon or a lepton-antilepton pair) and semileptonic/leptonic (including/only leptons). We also report measurements of B_s^0 , B_c^+ and b -baryon decays, and measurements of final-state polarization in b -hadron decays. Results of CKM-matrix parameters obtained from A_{CP} measurements are listed and described by the HFLAV Unitary triangle angles group. Measurements included in our averages are those supported with public notes, including journal papers, conference contributed papers, preprints or conference proceedings, except when a result has not led to a journal publication after an extended period of time.

The averaging procedure follows the methodology described in Sec. 3 of the latest HFLAV publication. We perform fits of the full likelihood function and do not use the approximation described in Sec. 3.1. For the cases where more than one measurement is available, in total 235 fits are performed, with on average (maximally) 1.3 (20) parameters and 2.9 (23) measurements per fit. Systematic uncertainties are taken as quoted without the scaling of multiplicative uncertainties discussed in Sec. 3.3. In our tables, the individual measurements and average of each parameter p_j are shown in one row. We quote numerical values of all direct measurements of a parameter p_j . We also show numerical values derived from measurements of branching-fraction ratios p_j/p_k , performed with respect to the branching fraction p_k of a normalization mode, as well as measurements of products $p_j p_k$ of the branching fraction of interest with that of a daughter decay. In these cases, the quoted value and uncertainty of the measurement are determined with the fitted value of p_k , and the uncertainty of p_k is included in the systematic uncertainty. A footnote “Using p_k ” is added in these cases. Note that the fit uses p_j/p_k or $p_j p_k$ directly and not the derived value of p_j , which is quoted in our table in order to give a sense of the contribution of the measurement to the average. When the measurement depends on p_j in some other way, it is also included in our fit for p_j , but in the tables no derived value is shown. Instead, the measured function f of parameters is given in a footnote “Measurement of f used in our fit”. Where available, correlations between measurements are taken into account. We consider correlations not only between measurements of the same parameter, as done in our previous publication [1], but also among parameters. The correlation coefficients among parameters are quoted in the detailed version of the tables in this web page.

If one or more experiments report a BF measurement with a significance of more than three standard deviations (σ), all available central values for that BF are used in our average. For BFs that do not satisfy this criterion, the most stringent limit is used. Quoted upper limits

¹The treatment of intermediate charm or charmonium states differs between observables and sometimes among results for the same observable. In the latter case, when these results are averaged, we indicate the differences by footnotes.

are at 90% confidence level (C.L.), unless mentioned otherwise. For observables that are not BFs, such as A_{CP} or polarization fractions, we include in our averages all the available results, regardless of their significance. Most of the branching fractions from *BABAR* and *Belle* assume equal production of charged and neutral B -meson pairs. The best measurements to date show that this is still a reasonable approximation (see Sec. 4 of the latest HFLAV publication), and we make no correction for it. At the end of some of the sections, we list results that were not included in the tables. Typical cases are measurements of distributions, such as differential branching fractions or longitudinal polarizations, which are measured in different binning schemes by the different collaborations, and thus cannot be directly used to obtain averages.

Observables obtained by Dalitz-plot analyses are marked by footnotes. In these analyses, different experimental collaborations often use different models, in particular for the nonresonant component. When it applies we detail the model used for the nonresonant component in a footnote. In addition to this, Dalitz-plot analyses often yield multiple solutions. In this case, we take the results corresponding to the global minimum and follow the conclusions of the papers.

The order of entries in the tables of this section corresponds in most cases to that in the 2022 Review of Particle Physics (PDG 2022) [2]. In most of the tables the averages are compared to those from PDG 2022. When this is done, the ‘‘Average’’ column quotes the PDG averages (in grey) only if they differ from ours. In general, this is due to different input parameters, differences in the averaging methods and different rounding conventions. Unlike the PDG, no error scaling is applied in our averages when the fit χ^2 is greater than 1. On the other hand, the fit p -value is quoted if it is below 1%. Input values that appear in red are not included in the PDG 2021 average. They are new results published since the closing of PDG 2021 and before the closing of this report in June 2021. Input values in blue are results that were unpublished at the closing of this report (unpublished results are never included in the PDG averages).

Sections 1 and 2 provide compilations of branching fractions of B^0 and B^+ to mesonic and baryonic charmless final states, respectively. Sections 3 and 4 give branching fractions of b -baryon and B_s^0 -meson charmless decays, respectively. In Sec. 6 observables of interest are given for radiative decays and FCNC decays with leptons of B^0 and B^+ mesons, including limits from searches for lepton-flavour/number-violating decays. Sections 7 and 8 give CP asymmetries and results of polarization measurements, respectively, in various b -hadron charmless decays. Finally, Sec. 5 gives branching fractions of B_c^+ meson decays to charmless final states.

1 Mesonic decays of B^+ and B^0 mesons

This section provides branching fractions of charmless mesonic decays. Tables 1 to 10 are for B^+ and Tables 11 to 24 are for B^0 mesons. For both, decay modes with and without strange mesons in the final state appear in different tables. Finally, Tables 25 and 26 detail several relative branching fractions of B^+ and B^0 decays, respectively. Figure 1 gives a graphic representation of a selection of high-precision branching fractions given in this section.

Table 1: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^+ \rightarrow K^0\pi^+)^1$	Belle [3]	$23.97 \pm 0.53 \pm 0.71$	23.5 ± 0.7 23.7 ± 0.8
	BaBar [4]	$23.9 \pm 1.1 \pm 1.0$	
	Belle II [5]	$21.4^{+2.3}_{-2.2} \pm 1.6$	
	CLEO [6]	$18.8^{+3.7}_{-3.3} {}^{+2.1}_{-1.8}$	
	LHCb [7] ²		
$\mathcal{B}(B^+ \rightarrow K^+\pi^0)$	Belle [3]	$12.62 \pm 0.31 \pm 0.56$	13.2 ± 0.5 12.9 ± 0.5
	BaBar [8]	$13.6 \pm 0.6 \pm 0.7$	
	Belle II [9]	$14.30 \pm 0.69 \pm 0.79$	
	CLEO [6]	$12.9^{+2.4}_{-2.2} {}^{+1.2}_{-1.1}$	
$\mathcal{B}(B^+ \rightarrow \eta'K^+)$	BaBar [10]	$71.5 \pm 1.3 \pm 3.2$	68.9 ± 2.3 70.4 ± 2.5
	Belle [11]	$69.2 \pm 2.2 \pm 3.7$	
	Belle II [12]	$63.4^{+3.4}_{-3.3} \pm 3.4$	
	Belle [13]	$61^{+10}_{-8} \pm 1$	
	CLEO [14]	$80^{+10}_{-9} \pm 7$	
	LHCb [15] ³		
$\mathcal{B}(B^+ \rightarrow \eta'K^*(892)^+)$	BaBar [16]	$4.8^{+1.6}_{-1.4} \pm 0.8$	$4.8^{+1.8}_{-1.6}$
	Belle [17]	< 2.9	
$\mathcal{B}(B^+ \rightarrow \eta'(K\pi)_0^{*+})$	BaBar [16]	$6.0^{+2.2}_{-2.0} \pm 0.9$	6.0 ± 2.3 none
$\mathcal{B}(B^+ \rightarrow \eta'K_0^*(1430)^+)$	BaBar [16]	$5.2 \pm 1.9 \pm 1.0$ ⁴	5.2 ± 2.1
$\mathcal{B}(B^+ \rightarrow \eta'K_2^*(1430)^+)$	BaBar [16]	$28.0^{+4.6}_{-4.3} \pm 2.6$	28.0 ± 5.2 $28.0^{+5.3}_{-5.0}$

¹ The PDG average is a result of a fit including input from other measurements.

² Measurement of $\mathcal{B}(B^+ \rightarrow K^+\bar{K}^0)/\mathcal{B}(B^+ \rightarrow K^0\pi^+)$ used in our fit.

³ Measurement of $\mathcal{B}(B_s^0 \rightarrow \eta'\eta')/\mathcal{B}(B^+ \rightarrow \eta'K^+)$ used in our fit.

⁴ Multiple systematic uncertainties are added in quadrature.

Table 2: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow \eta K^+)^1$	Belle [18]	$2.12 \pm 0.23 \pm 0.11$
	BaBar [10]	$2.94^{+0.39}_{-0.34} \pm 0.21$
	CLEO [14]	$2.2^{+2.8}_{-2.2}$
$\mathcal{B}(B^+ \rightarrow \eta K^*(892)^+)$	BaBar [19]	$18.9 \pm 1.8 \pm 1.3$
	Belle [20]	$19.3^{+2.0}_{-1.9} \pm 1.5$
	CLEO [14]	$26.4^{+9.6}_{-8.2} \pm 3.3$
$\mathcal{B}(B^+ \rightarrow \eta(K\pi)_0^{*+})$	BaBar [19]	$18.2 \pm 2.6 \pm 2.6$ none
$\mathcal{B}(B^+ \rightarrow \eta K_0^*(1430)^+)^2$	BaBar [19]	$12.9 \pm 1.8 \pm 1.8$ ³ 18.2 ± 3.7
	BaBar [19]	$9.1 \pm 2.7 \pm 1.4$
$\mathcal{B}(B^+ \rightarrow \eta(1295)K^+) \times \mathcal{B}(\eta(1295) \rightarrow \eta\pi\pi)$	BaBar [21]	$2.9^{+0.8}_{-0.7} \pm 0.2$
$\mathcal{B}(B^+ \rightarrow \eta(1405)K^+) \times \mathcal{B}(\eta(1405) \rightarrow \eta\pi\pi)$	BaBar [21]	< 1.3
$\mathcal{B}(B^+ \rightarrow \eta(1405)K^+) \times \mathcal{B}(\eta(1405) \rightarrow K^*K)$	BaBar [21]	< 1.2
$\mathcal{B}(B^+ \rightarrow \eta(1475)K^+) \times \mathcal{B}(\eta(1475) \rightarrow K^*K)$	BaBar [21]	$13.8^{+1.8+1.0}_{-1.7-0.6}$
$\mathcal{B}(B^+ \rightarrow f_1(1285)K^+) \times \mathcal{B}(f_1(1285) \rightarrow \eta\pi\pi)$	BaBar [21]	< 0.8 none
	BaBar [21]	< 2.9
$\mathcal{B}(B^+ \rightarrow f_1(1420)K^+) \times \mathcal{B}(f_1(1420) \rightarrow \eta\pi\pi)$	BaBar [21]	< 2.9
$\mathcal{B}(B^+ \rightarrow f_1(1420)K^+) \times \mathcal{B}(f_1(1420) \rightarrow K^*K)$	BaBar [21]	< 4.1
$\mathcal{B}(B^+ \rightarrow \phi(1680)K^+) \times \mathcal{B}(\phi(1680) \rightarrow K^*K)$	BaBar [21]	< 3.4
$\mathcal{B}(B^+ \rightarrow f_0(1500)K^+)$	BaBar [22]	$17 \pm 4 \pm 12$ ⁴
	BaBar [22]	$20 \pm 10 \pm 27$ ⁵
$\mathcal{B}(B^+ \rightarrow \omega(782)K^+)^6$	Belle [23]	$6.8 \pm 0.4 \pm 0.4$
	BaBar [24]	$6.3 \pm 0.5 \pm 0.3$
	CLEO [25]	$3.2^{+2.4}_{-1.9} \pm 0.8$
$\mathcal{B}(B^+ \rightarrow \omega(782)K^*(892)^+)$	BaBar [26]	< 7.4
$\mathcal{B}(B^+ \rightarrow \omega(782)(K\pi)_0^{*+})$	BaBar [26]	$27.5 \pm 3.0 \pm 2.6$
$\mathcal{B}(B^+ \rightarrow \omega(782)K_0^*(1430)^+)$	BaBar [26]	$24.0 \pm 2.6 \pm 4.4$
$\mathcal{B}(B^+ \rightarrow \omega(782)K_2^*(1430)^+)$	BaBar [26]	$21.5 \pm 3.6 \pm 2.4$
$\mathcal{B}(B^+ \rightarrow a_0(980)^+K^0) \times \mathcal{B}(a_0(980)^+ \rightarrow \eta\pi^+)$	BaBar [27]	< 3.9
$\mathcal{B}(B^+ \rightarrow a_0(980)^0K^+) \times \mathcal{B}(a_0(980)^0 \rightarrow \eta\pi^0)$	BaBar [27]	< 2.5

¹ The PDG uncertainty includes a scale factor.

² The PDG entry corresponds to $\mathcal{B}(B^+ \rightarrow \eta(K\pi)_0^{*+})$.

³ Multiple systematic uncertainties are added in quadrature.

⁴ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^+K^-$ decays.

⁵ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0K_S^0K^+$ decays.

⁶ The measurement from the Dalitz-plot analysis of $B^+ \rightarrow K^+\pi^+\pi^-$ decays [28] was not included in this average. It is quoted as a separate entry.

Table 3: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\pi^+)$	BaBar [28]	$10.8 \pm 0.6^{+1.2}_{-1.4}{}^1$
	Belle [29]	$9.67 \pm 0.64^{+0.81}_{-0.89}{}^1$
	BaBar [30]	$14.6 \pm 2.4^{+1.4}_{-1.5}{}^{2,3}$
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\pi^0)$	BaBar [30]	$9.2 \pm 1.3^{+0.7}_{-0.8}{}^{2,3}$
	BaBar [31]	$8.2 \pm 1.5 \pm 1.1$
	CLEO [25]	$7.1^{+11.4}_{-7.1} \pm 1.0$
$\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-)$	LHCb [32]	$57.71 \pm 0.37 \pm 1.45{}^4$
	BaBar [28]	$54.4 \pm 1.1 \pm 4.6{}^1$
	Belle [29]	$48.8 \pm 1.1 \pm 3.6{}^1$
	Belle II [33]	$67.0 \pm 3.3 \pm 2.3$
$\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-(\text{NR}))$	BaBar [28]	$9.3 \pm 1.0^{+6.9}_{-1.7}{}^{1,5}$
	Belle [29]	$16.9 \pm 1.3^{+1.7}_{-1.6}{}^1$
$\mathcal{B}(B^+ \rightarrow \omega(782)K^+ (K^+\pi^+\pi^-)){}^6$	BaBar [28]	$5.9^{+8.8}_{-9.0}{}^{+0.5}_{-0.4}{}^1$
$\mathcal{B}(B^+ \rightarrow f_0(980)K^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [28]	$10.3 \pm 0.5^{+2.0}_{-1.4}{}^1$
	Belle [29]	$8.78 \pm 0.82^{+0.85}_{-1.76}{}^1$
$\mathcal{B}(B^+ \rightarrow f_2(1270)K^+)$	Belle [29]	$1.33 \pm 0.30^{+0.23}_{-0.34}{}^1$
	BaBar [28]	$0.89^{+0.38}_{-0.33}{}^{+0.01}_{-0.03}{}^1$
$\mathcal{B}(B^+ \rightarrow f_0(1370)K^+) \times \mathcal{B}(f_0(1370) \rightarrow \pi^+\pi^-)$	BaBar [34]	$< 10.7{}^1$
$\mathcal{B}(B^+ \rightarrow \rho(1450)^0K^+) \times \mathcal{B}(\rho(1450)^0 \rightarrow \pi^+\pi^-)$	BaBar [34]	$< 11.7{}^1$
$\mathcal{B}(B^+ \rightarrow f'_2(1525)K^+) \times \mathcal{B}(f'_2(1525) \rightarrow \pi^+\pi^-)$	BaBar [34]	$< 3.4{}^1$
$\mathcal{B}(B^+ \rightarrow \rho^0(770)K^+)$	BaBar [28]	$3.56 \pm 0.45^{+0.57}_{-0.46}{}^1$
	Belle [29]	$3.89 \pm 0.47^{+0.43}_{-0.41}{}^1$
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^0\pi^+)$ ⁷	BaBar [28]	$32.0 \pm 1.2^{+10.8}_{-6.0}{}^1$
	Belle [29]	$51.6 \pm 1.7^{+7.0}_{-7.5}{}^1$
	BaBar [30]	$50.0 \pm 4.8^{+6.7}_{-6.6}{}^{2,3}$
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^0\pi^+)$	BaBar [28]	$5.6 \pm 1.2^{+1.8}_{-0.8}{}^1$
	Belle [35]	$< 6.9{}^1$
$\mathcal{B}(B^+ \rightarrow K^*(1410)^0\pi^+)$	Belle [35]	$< 45.0{}^1$
$\mathcal{B}(B^+ \rightarrow K^*(1680)^0\pi^+)$	Belle [35]	$< 12.0{}^1$
	BaBar [34]	$< 15.0{}^1$

¹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+\pi^+\pi^-$ decays.

² Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0\pi^+\pi^0$ decays.

³ Multiple systematic uncertainties are added in quadrature.

⁴ Using $\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$.

⁵ The total nonresonant contribution is obtained by combining a exponential nonresonant component with the effective-range part of the LASS lineshape.

⁶ This result was not included in the main entry of $\mathcal{B}(B^+ \rightarrow \omega(782)K^+)$.

⁷ The PDG uncertainty includes a scale factor.

Table 4: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 4).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^+ \rightarrow K^+\pi^0\pi^0)$	BaBar [31]	$16.2 \pm 1.2 \pm 1.5$	16.2 ± 1.9
$\mathcal{B}(B^+ \rightarrow f_0(980)K^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^0\pi^0)$	BaBar [31]	$2.8 \pm 0.6 \pm 0.5$	2.8 ± 0.8
$\mathcal{B}(B^+ \rightarrow K^-\pi^+\pi^+)$	LHCb [36]	< 0.046	< 0.046
	BaBar [37]	< 0.95	
	Belle [38]	< 4.5	
$\mathcal{B}(B^+ \rightarrow K^-\pi^+\pi^+(\text{NR}))$	CLEO [39]	< 56	< 56
$\mathcal{B}(B^+ \rightarrow K_1(1270)^0\pi^+)$	BaBar [40]	< 40	< 40
$\mathcal{B}(B^+ \rightarrow K_1(1400)^0\pi^+)$	BaBar [40]	< 39	< 39
$\mathcal{B}(B^+ \rightarrow K^0\pi^+\pi^0)$	CLEO [41]	< 66.0	< 66
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^+\pi^0)$	BaBar [30]	$17.2 \pm 2.4^{+1.5}_{-3.0}{}^{1,2}$	$17.2^{+2.8}_{-3.8}$
			$11.9^{+2.0}_{-2.3}$
$\mathcal{B}(B^+ \rightarrow \rho^+(770)K^0)$	BaBar [30]	$9.4 \pm 1.6^{+1.1}_{-2.8}{}^{1,2}$	$9.4^{+1.9}_{-3.2}$
			$7.3^{+1.0}_{-1.2}$
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\pi^+\pi^-)$	BaBar [42]	$75.3 \pm 6.0 \pm 8.1$	75 ± 10
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$4.6 \pm 1.0 \pm 0.4$	4.6 ± 1.1
$\mathcal{B}(B^+ \rightarrow f_0(980)K^*(892)^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [43]	$4.2 \pm 0.6 \pm 0.3$	4.2 ± 0.7
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+K^0)$	BaBar [44]	$34.9 \pm 5.0 \pm 4.4$	34.9 ± 6.7
$\mathcal{B}(B^+ \rightarrow b_1(1235)^+K^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^+)$	BaBar [48]	$9.6 \pm 1.7 \pm 0.9$	9.6 ± 1.9
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\rho^+(770))$	BaBar [45]	$9.6 \pm 1.7 \pm 1.5$	9.2 ± 1.5
	Belle [46]	$8.9 \pm 1.7 \pm 1.2$ ³	
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+\rho^0(770))$	ARGUS [47]	< 780	< 780
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^+\rho^0(770))$	ARGUS [47]	< 1500	< 1500
$\mathcal{B}(B^+ \rightarrow b_1(1235)^0K^+) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [49]	$9.1 \pm 1.7 \pm 1.0$	9.1 ± 2.0
$\mathcal{B}(B^+ \rightarrow b_1(1235)^+K^*(892)^0) \times \mathcal{B}(b_1(1235)^+ \rightarrow \omega(782)\pi^+)$	BaBar [50]	< 5.9	< 5.9
$\mathcal{B}(B^+ \rightarrow b_1(1235)^0K^*(892)^+) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [50]	< 6.7	< 6.7

¹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0\pi^+\pi^0$ decays.

² Multiple systematic uncertainties are added in quadrature.

³ See also Ref. [51].

Table 5: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 5).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow K^+\bar{K}^0)^1$	Belle [3]	$1.11 \pm 0.19 \pm 0.05$
	LHCb [7]	$1.51 \pm 0.21 \pm 0.10$ ²
	BaBar [4]	$1.61 \pm 0.44 \pm 0.09$
$\mathcal{B}(B^+ \rightarrow \bar{K}^0 K^+ \pi^0)$	CLEO [41]	< 24.0
$\mathcal{B}(B^+ \rightarrow K^+ K_S^0 K_S^0)^3$	Belle [52]	$10.42 \pm 0.43 \pm 0.22$
	BaBar [22]	$10.1 \pm 0.5 \pm 0.3$ ^{4,5}
$\mathcal{B}(B^+ \rightarrow f_0(980)K^+) \times \mathcal{B}(f_0(980) \rightarrow K_S^0 K_S^0)$	BaBar [22]	$14.7 \pm 2.8 \pm 1.8$ ⁴
		14.7 ± 3.3
$\mathcal{B}(B^+ \rightarrow f_0(1710)K^+) \times \mathcal{B}(f_0(1710) \rightarrow K_S^0 K_S^0)$	BaBar [22]	$0.48^{+0.40}_{-0.24} \pm 0.11$ ⁴
		$0.48^{+0.41}_{-0.26}$
$\mathcal{B}(B^+ \rightarrow K^+ K_S^0 K_S^0(\text{NR}))$	BaBar [22]	$19.8 \pm 3.7 \pm 2.5$ ⁶
$\mathcal{B}(B^+ \rightarrow K_S^0 K_S^0 \pi^+)$	BaBar [53]	< 0.51
	Belle [52]	< 0.87
$\mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+)$	LHCb [32]	$5.12 \pm 0.14 \pm 0.29$ ⁷
	Belle [54]	$5.38 \pm 0.40 \pm 0.35$ ⁸
	BaBar [55]	$5.0 \pm 0.5 \pm 0.5$
$\mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+(\text{NR}))$	LHCb [56]	$1.625 \pm 0.075 \pm 0.221$ ^{9,10}
		$1.62^{+0.24}_{-0.23}$ 1.68 ± 0.26
$\mathcal{B}(B^+ \rightarrow \bar{K}^*(892)^0 K^+)$	BaBar [57]	< 1.1
	LHCb [56] ^{11,12}	$0.57^{+0.07}_{-0.06}$ 0.59 ± 0.08
$\mathcal{B}(B^+ \rightarrow \bar{K}_0^*(1430)^0 K^+)$	BaBar [57]	< 2.2
	LHCb [56] ^{11,13}	$0.37^{+0.13}_{-0.12}$ 0.38 ± 0.13

¹ The PDG average is a result of a fit including input from other measurements.

² Using $\mathcal{B}(B^+ \rightarrow K^0 \pi^+)$.

³ PDG uses the BABAR result including the χ_{c0} intermediate state.

⁴ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0 K_S^0 K^+$ decays.

⁵ All charmonium resonances are vetoed. The analysis also reports $\mathcal{B}(B^+ \rightarrow K_S^0 K_S^0 K^+) = (10.6 \pm 0.5 \pm 0.3) \times 10^{-6}$ including the χ_{c0} intermediate state.

⁶ The nonresonant amplitude is modelled using a polynomial function of order 2.

⁷ Using $\mathcal{B}(B^+ \rightarrow K^+ K^+ K^-)$.

⁸ Also measured in bins of $m_{K^+ K^-}$ and $m_{K^+ \pi^-}$.

⁹ LHCb uses a model of nonresonant obtained from a phenomenological description of the partonic interaction that produces the final state. This contribution is called single pole in the paper, see Ref. [56] for details.

¹⁰ Using $\mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+)$.

¹¹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+ K^- \pi^+$ decays.

¹² Measurement of $(\mathcal{B}(B^+ \rightarrow \bar{K}^*(892)^0 K^+) \mathcal{B}(K^*(892)^0 \rightarrow K \pi) 2/3) / \mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+)$ used in our fit.

¹³ Measurement of $(\mathcal{B}(B^+ \rightarrow \bar{K}_0^*(1430)^0 K^+) \mathcal{B}(K^*(1430) \rightarrow K \pi) 2/3) / \mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+)$ used in our fit.

Table 6: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 6).

Parameter [10 ⁻⁶]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+) \pi\pi \leftrightarrow KK$ rescattering	LHCb [56]	$0.825 \pm 0.040 \pm 0.065$ ^{1,2}
		$0.825^{+0.078}_{-0.075}$ 0.853 ± 0.094
$\mathcal{B}(B^+ \rightarrow K^+K^+\pi^-)$	LHCb [36] BaBar [37] Belle [38]	< 0.011 < 0.16 < 2.4
		< 0.011
$\mathcal{B}(B^+ \rightarrow f_2'(1525)K^+)^3$	BaBar [22] BaBar [22] Belle [35]	$1.56 \pm 0.36 \pm 0.30$ ⁴ $2.8 \pm 0.9^{+0.5}_{-0.4}$ ⁵ < 8.0 ⁴
		1.79 ± 0.42 1.79 ± 0.48
$\mathcal{B}(B^+ \rightarrow f_J(2220)K^+) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$	Belle [58]	< 0.41
		< 0.41
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\pi^+K^-)$	BaBar [42]	< 11.8
		< 12
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\bar{K}^*(892)^0)$	Belle [59] BaBar [60]	$0.77^{+0.35}_{-0.30} \pm 0.12$ $1.2 \pm 0.5 \pm 0.1$
		0.91 ± 0.30 $0.91^{+0.30}_{-0.27}$
$\mathcal{B}(B^+ \rightarrow K^*(892)^+K^+\pi^-)$	BaBar [42]	< 6.1
		< 6.1
$\mathcal{B}(B^+ \rightarrow K^+K^+K^-)^{3,6}$	BaBar [22] Belle [35] Belle II [33] LHCb [61] ^{8,9,10} , [32] ^{11,12,13}	$34.6 \pm 0.6 \pm 0.9$ ^{4,7} $30.6 \pm 1.2 \pm 2.3$ ⁴ $35.8 \pm 1.6 \pm 1.4$ $35.8 \pm 1.6 \pm 1.4$
		33.9 ± 0.7 34.0 ± 1.4
$\mathcal{B}(B^+ \rightarrow \phi(1020)K^+)^3$	BaBar [22] Belle [35] Belle II [62] CDF [63] CLEO [64]	$9.2 \pm 0.4^{+0.7}_{-0.5}$ ⁴ $9.60 \pm 0.92^{+1.05}_{-0.85}$ ⁴ $6.7 \pm 1.1 \pm 0.5$ $7.6 \pm 1.3 \pm 0.6$ $5.5^{+2.1}_{-1.8} \pm 0.6$
		8.53 ± 0.47 $8.83^{+0.67}_{-0.57}$
$\mathcal{B}(B^+ \rightarrow f_0(980)K^+) \times \mathcal{B}(f_0(980) \rightarrow K^+K^-)$	BaBar [22]	$9.4 \pm 1.6 \pm 2.8$ ⁴
		9.4 ± 3.2
$\mathcal{B}(B^+ \rightarrow a_2(1320)^0K^+) \times \mathcal{B}(a_2(1320)^0 \rightarrow K^+K^-)$	Belle [35]	< 1.1 ⁴
		< 1.1
$\mathcal{B}(B^+ \rightarrow \phi(1680)K^+) \times \mathcal{B}(\phi(1680) \rightarrow K^+K^-)$	Belle [35]	< 0.8 ⁴
		< 0.8
$\mathcal{B}(B^+ \rightarrow f_0(1710)K^+) \times \mathcal{B}(f_0(1710) \rightarrow K^+K^-)$	BaBar [22]	$1.12 \pm 0.25 \pm 0.50$ ⁴
		1.12 ± 0.56
$\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ (NR)	Belle [35] BaBar [22]	$24.0 \pm 1.5^{+2.6}_{-6.0}$ ⁴ $22.8 \pm 2.7 \pm 7.6$ ¹⁴
		$23.7^{+3.0}_{-4.9}$ $23.8^{+2.8}_{-4.9}$

¹ LHCb uses a dedicated lineshape to take into account $\pi\pi \leftrightarrow KK$ rescattering, which is particularly significant in the region $1 < m_{KK} < 1.5$ GeV/ c^2 . See Ref. [56] for details.

² Using $\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+)$.

³ The PDG uncertainty includes a scale factor.

⁴ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^+K^-$ decays.

⁵ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0K_S^0K^+$ decays.

⁶ Treatment of charmonium intermediate components differs between the results.

⁷ All charmonium resonances are vetoed, except for χ_{c0} . The analysis also reports $\mathcal{B}(B^+ \rightarrow K^+K^+K^-) = (33.4 \pm 0.5 \pm 0.9) \times 10^{-6}$ excluding χ_{c0} .

⁸ Measurement of $\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-K^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

⁹ Measurement of $\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

¹⁰ Measurement of $\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow p\pi^-\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

¹¹ Measurement of $\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

¹² Measurement of $\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

¹³ Measurement of $\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$ used in our fit.

¹⁴ The nonresonant amplitude is modelled using a polynomial function including S-wave and P-wave terms.

Table 7: Branching fractions of charmless mesonic B^+ decays with strange mesons (part 7).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ K^+ K^-)$	BaBar [42]	$36.2 \pm 3.3 \pm 3.6$	36.2 ± 4.9
$\mathcal{B}(B^+ \rightarrow \phi(1020) K^*(892)^+)^1$	BaBar [65]	$11.2 \pm 1.0 \pm 0.9$ ²	
	Belle [66]	$6.7^{+2.1+0.7}_{-1.9-1.0}$	10.6 ± 1.1
	Belle II [62]	$21.7 \pm 4.6 \pm 1.9$	10.0 ± 2.0
	CLEO [64]	$10.6^{+6.4+1.8}_{-4.9-1.6}$	
$\mathcal{B}(B^+ \rightarrow \phi(1020)(K\pi)_0^{*+})$	BaBar [67]	$8.3 \pm 1.4 \pm 0.8$	8.3 ± 1.6
$\mathcal{B}(B^+ \rightarrow K_1(1270)^+ \phi(1020))$	BaBar [67]	$6.1 \pm 1.6 \pm 1.1$	6.1 ± 1.9
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+ \phi(1020))$	BaBar [67]	< 3.2	< 3.2
$\mathcal{B}(B^+ \rightarrow K^*(1410)^+ \phi(1020))$	BaBar [67]	< 4.3	< 4.3
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^+ \phi(1020))$	BaBar [67]	$7.0 \pm 1.3 \pm 0.9$	7.0 ± 1.6
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^+ \phi(1020))$	BaBar [67]	$8.4 \pm 1.8 \pm 1.0$	8.4 ± 2.1
$\mathcal{B}(B^+ \rightarrow K_2(1770)^+ \phi(1020))$	BaBar [67]	< 15.0	< 15
$\mathcal{B}(B^+ \rightarrow \phi(1020) K_2(1820)^+)$	BaBar [67]	< 16.3	< 16
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+ K^*(892)^0)$	BaBar [68]	< 3.6	< 3.6
$\mathcal{B}(B^+ \rightarrow \phi(1020)\phi(1020)K^+)^1$	BaBar [69]	$5.6 \pm 0.5 \pm 0.3$ ³	4.98 ± 0.52
	Belle [70]	$2.6^{+1.1}_{-0.9} \pm 0.3$ ³	$4.22^{+0.82}_{-0.79}$
$\mathcal{B}(B^+ \rightarrow \eta'\eta' K^+)$	BaBar [71]	< 25.0	< 25
$\mathcal{B}(B^+ \rightarrow \phi(1020)\omega(782)K^+)$	Belle [72]	< 1.9	< 1.9
$\mathcal{B}(B^+ \rightarrow X(1812)K^+) \times \mathcal{B}(X(1812) \rightarrow \phi(1020)\omega(782))$			
	Belle [72]	< 0.32	< 0.32
$\mathcal{B}(B^+ \rightarrow h^+ X^0(\text{Familon}))^4$	CLEO [73]	< 49	< 49

¹ The PDG uncertainty includes a scale factor.

² Combination of two final states of the $K^*(892)^\pm$, $K_S^0\pi^\pm$ and $K^\pm\pi^0$. In addition to the combined results, the paper reports separately the results for each individual final state.

³ Measured in the $\phi\phi$ invariant mass range below the η_c resonance ($M_{\phi\phi} < 2.85 \text{ GeV}/c^2$).

⁴ $h = \pi, K$.

Table 8: Branching fractions of charmless mesonic B^+ decays without strange mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0)^1$	Belle [3]	$5.86 \pm 0.26 \pm 0.38$
	BaBar [8]	$5.02 \pm 0.46 \pm 0.29$
	Belle II [9]	$6.12 \pm 0.53 \pm 0.53$
	CLEO [6]	$4.6^{+1.8+0.6}_{-1.6-0.7}$
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)$	LHCb [32]	$16.54 \pm 0.17 \pm 0.47^2$
	BaBar [74]	$15.2 \pm 0.6^{+1.3}_{-1.2}{}^{3,4,5}$
$\mathcal{B}(B^+ \rightarrow \rho^0(770)\pi^+)$	LHCb [75]	$8.82 \pm 0.10 \pm 0.50^{3,6,5,7}$
	BaBar [74]	$8.1 \pm 0.7^{+1.3}_{-1.6}{}^{3,5}$
	Belle [76]	$8.0^{+2.3}_{-2.0} \pm 0.7$
	CLEO [25]	$10.4^{+3.3}_{-3.4} \pm 2.1$
$\mathcal{B}(B^+ \rightarrow f_0(980)\pi^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [74]	$< 1.5^3$
$\mathcal{B}(B^+ \rightarrow f_2(1270)\pi^+) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	LHCb [75]	$1.43 \pm 0.05 \pm 0.27^{3,6,5,7}$
	BaBar [74]	$0.9 \pm 0.2^{+0.3}_{-0.1}{}^{3,5}$
$\mathcal{B}(B^+ \rightarrow f_2(1270)\pi^+) \times \mathcal{B}(f_2(1270) \rightarrow K^+K^-)$	LHCb [56]	$0.377 \pm 0.040 \pm 0.040^{8,9}$
		$0.377^{+0.058}_{-0.056}$ none
$\mathcal{B}(B^+ \rightarrow \rho(1450)^0\pi^+) \times \mathcal{B}(\rho(1450)^0 \rightarrow \pi^+\pi^-)$	LHCb [75]	$0.83 \pm 0.05 \pm 0.89^{3,6,5,7}$
	BaBar [74]	$1.4 \pm 0.4^{+0.5}_{-0.8}{}^{3,5}$
$\mathcal{B}(B^+ \rightarrow \rho(1450)^0\pi^+) \times \mathcal{B}(\rho(1450)^0 \rightarrow K^+K^-)$	LHCb [56]	$1.544 \pm 0.060 \pm 0.089^{8,9}$
		1.54 ± 0.11 1.60 ± 0.14
$\mathcal{B}(B^+ \rightarrow \rho_3(1690)^0\pi^+) \times \mathcal{B}(\rho_3(1690)^0 \rightarrow \pi^+\pi^-)$	LHCb [75]	$0.08 \pm 0.02 \pm 0.16^{3,6,5,7}$
		0.08 ± 0.16 none
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)$ S -wave	LHCb [75]	$4.04 \pm 0.08 \pm 0.64^{10,5,7}$
		none
$\mathcal{B}(B^+ \rightarrow f_0(1370)\pi^+) \times \mathcal{B}(f_0(1370) \rightarrow \pi^+\pi^-)$	BaBar [74]	$< 4.0^3$
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^-\pi^+(\text{NR}))$	BaBar [74]	$5.3 \pm 0.7^{+1.3}_{-0.8}{}^{11,5}$
		$5.3^{+1.4}_{-1.0}$ $5.3^{+1.5}_{-1.1}$

¹ The PDG uncertainty includes a scale factor.

² Using $\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$.

³ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow \pi^+\pi^+\pi^-$ decays.

⁴ Charm and charmonium contributions are subtracted.

⁵ Multiple systematic uncertainties are added in quadrature.

⁶ This analysis uses three different approaches: isobar, K -matrix and quasi-model-independent, to describe the S -wave component. The results are taken from the isobar model with an additional error accounting for the different S -wave methods as reported in Appendix D of Ref. [77].

⁷ Using $\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)$.

⁸ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^-\pi^+$ decays.

⁹ Using $\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+)$.

¹⁰ LHCb accounts the S -wave component using a model that comprises the coherent sum of a σ pole. See Ref. [75] for details.

¹¹ The nonresonant amplitude is modelled using a sum of exponential functions.

Table 9: Branching fractions of charmless mesonic B^+ decays without strange mesons (part 2).

Parameter [10 ⁻⁶]	Measurements	Average ^{HFLAV PDG}
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0\pi^0)$	Belle [78] $19.0 \pm 1.5 \pm 1.4$ ARGUS [79] < 890	19.0 ± 2.1 < 890.0
$\mathcal{B}(B^+ \rightarrow X_{\pi^0\pi^0}^0 \pi^+) \times \mathcal{B}(X^0(\pi^0\pi^0) \rightarrow \pi^0\pi^0)$	Belle [78] $6.9 \pm 1.1 \pm 1.1$ ^{1,2}	6.9 ± 1.5 none
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0\pi^0(\text{NR}))$	Belle [78] < 0.6	< 0.60 none
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\pi^0)$	Belle [78] 11.2 ± 1.1 ^{+1.2} _{-1.8} ² BaBar [80] $10.2 \pm 1.4 \pm 0.9$	10.6 ± 1.3 10.9 ^{+1.4} _{-1.5}
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-\pi^0)$	ARGUS [79] < 4000	< 4000
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [81] $23.7 \pm 1.4 \pm 1.4$ Belle II [82] 23.2 ^{+2.2} _{-2.1} ± 2.7 Belle [83] 31.7 ± 7.1 ^{+3.8} _{-6.7}	23.8 ± 1.7 24.0 ± 1.9
$\mathcal{B}(B^+ \rightarrow f_0(980)\rho^+(770)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [81] < 2.0	< 2.0
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+\pi^0)$	BaBar [84] $26.4 \pm 5.4 \pm 4.1$	26.4 ± 6.8
$\mathcal{B}(B^+ \rightarrow a_1(1260)^0\pi^+)$	BaBar [84] $20.4 \pm 4.7 \pm 3.4$	20.4 ± 5.8
$\mathcal{B}(B^+ \rightarrow \omega(782)\pi^+)$	BaBar [24] $6.7 \pm 0.5 \pm 0.4$ Belle [85] $6.9 \pm 0.6 \pm 0.5$ CLEO [25] 11.3 ^{+3.3} _{-2.9} ± 1.4 LHCb [75] ^{3,4,2,5}	6.60 ^{+0.46} _{-0.45} 6.88 ± 0.49
$\mathcal{B}(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26] $15.9 \pm 1.6 \pm 1.4$	15.9 ± 2.1
$\mathcal{B}(B^+ \rightarrow \eta\pi^+)$	Belle [18] $4.07 \pm 0.26 \pm 0.21$ BaBar [10] $4.00 \pm 0.40 \pm 0.24$ CLEO [14] 1.2 ^{+2.8} _{-1.2}	4.02 ± 0.27 4.02 ^{+0.27} _{-0.26}
$\mathcal{B}(B^+ \rightarrow \eta\rho^+(770))^6$	BaBar [86] $9.9 \pm 1.2 \pm 0.8$ Belle [20] 4.1 ^{+1.4} _{-1.3} ± 0.4 CLEO [14] 4.8 ^{+5.2} _{-3.8}	6.9 ± 1.0 7.0 ^{+2.9} _{-2.8}
$\mathcal{B}(B^+ \rightarrow \eta'\pi^+)^6$	BaBar [10] $3.5 \pm 0.6 \pm 0.2$ Belle [11] 1.76 ^{+0.67} _{-0.62} ^{+0.15} _{-0.14} CLEO [14] 1.0 ^{+5.8} _{-1.0}	2.68 ± 0.46 2.70 ^{+0.87} _{-0.84}
$\mathcal{B}(B^+ \rightarrow \eta'\rho^+(770))$	BaBar [16] 9.7 ^{+1.9} _{-1.8} ± 1.1 CLEO [14] 11.2 ^{+11.9} _{-7.0} Belle [17] < 5.8	9.8 ± 2.1 9.7 ^{+2.2} _{-2.1}

¹ $X_{\pi^0\pi^0}^0$ corresponds to a structure observed in Ref. [78], likely arising due to multiple resonances.

² Multiple systematic uncertainties are added in quadrature.

³ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow \pi^+\pi^+\pi^-$ decays.

⁴ This analysis uses three different approaches: isobar, K -matrix and quasi-model-independent, to describe the S -wave component. The results are taken from the isobar model with an additional error accounting for the different S -wave methods as reported in Appendix D of Ref. [77].

⁵ Measurement of $(\mathcal{B}(B^+ \rightarrow \omega(782)\pi^+)\mathcal{B}(\omega(782) \rightarrow \pi^+\pi^-))/\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)$ used in our fit.

⁶ The PDG uncertainty includes a scale factor.

Table 10: Branching fractions of charmless mesonic B^+ decays without strange mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow \phi(1020)\pi^+)$	BaBar [87] < 0.24 Belle [88] < 0.33 LHCb [56] ^{1,2}	0.031 ± 0.014 0.032 ± 0.015
$\mathcal{B}(B^+ \rightarrow \phi(1020)\rho^+(770))$	BaBar [89] < 3.0	< 3.0
$\mathcal{B}(B^+ \rightarrow a_0(980)^0\pi^+) \times \mathcal{B}(a_0(980)^0 \rightarrow \eta\pi^0)$	BaBar [27] < 5.8	< 5.8
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-)$	ARGUS [79] < 860	< 860
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+\rho^0(770))$	CLEO [90] < 620.0 ³	< 620
$\mathcal{B}(B^+ \rightarrow a_2(1320)^+\rho^0(770))$	CLEO [90] < 720.0 ³	< 720
$\mathcal{B}(B^+ \rightarrow b_1(1235)^0\pi^+) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [49] $6.7 \pm 1.7 \pm 1.0$	6.7 ± 2.0
$\mathcal{B}(B^+ \rightarrow b_1^+\pi^0)$	BaBar [48] < 3.3	< 3.3
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^0)$	ARGUS [79] < 6300	< 6300
$\mathcal{B}(B^+ \rightarrow b_1(1235)^+\rho^0(770)) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^+)$	BaBar [50] < 5.2	< 5.2
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+a_1(1260)^0)$	ARGUS [79] < 13000	< 13000
$\mathcal{B}(B^+ \rightarrow b_1(1235)^0\rho^+(770)) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [50] < 3.3	< 3.3

¹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^-\pi^+$ decays.

² Measurement of $(\mathcal{B}(B^+ \rightarrow \phi(1020)\pi^+)\mathcal{B}(\phi(1020) \rightarrow K^+K^-))/\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+)$ used in our fit.

³ CLEO assumes $\mathcal{B}(\Upsilon(4S) \rightarrow B^0\bar{B}^0) = 0.43$. The result has been modified to account for a branching fraction of 0.50.

Table 11: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^0 \rightarrow K^+\pi^-)$	Belle [3]	$20.00 \pm 0.34 \pm 0.60$	19.5 ± 0.5 19.6 ± 0.5
	BaBar [91]	$19.1 \pm 0.6 \pm 0.6$	
	Belle II [5]	$18.0 \pm 0.9 \pm 0.9$	
	CLEO [6]	$18.0^{+2.3+1.2}_{-2.1-0.9}$	
	CDF [92] ^{1,2} , [93] ^{3,4} , [94] ^{5,6}		
	LHCb [95] ^{3,4,1} , [96] ^{5,6}		
$\mathcal{B}(B^0 \rightarrow K^0\pi^0)$	Belle [3]	$9.68 \pm 0.46 \pm 0.50$	10.03 ± 0.47 9.93 ± 0.49
	BaBar [97]	$10.1 \pm 0.6 \pm 0.4$	
	Belle II [98]	$11.0 \pm 1.2 \pm 1.0$	
	CLEO [6]	$12.8^{+4.0+1.7}_{-3.3-1.4}$	
$\mathcal{B}(B^0 \rightarrow \eta'K^0)^7$	BaBar [10]	$68.5 \pm 2.2 \pm 3.1$	65.0 ± 2.8 $66.1^{+4.5}_{-4.4}$
	Belle [11]	$58.9^{+3.6}_{-3.5} \pm 4.3$	
	Belle II [12]	$59.9^{+5.8}_{-5.5} \pm 2.7$	
	CLEO [14]	$89.0^{+18.0}_{-16.0} \pm 9.0$	
	LHCb [99] ^{8,9}		
$\mathcal{B}(B^0 \rightarrow \eta'K^*(892)^0)$	Belle [100]	$2.6 \pm 0.7 \pm 0.2$	2.8 ± 0.6
	BaBar [16]	$3.1^{+0.9}_{-0.8} \pm 0.3$	
$\mathcal{B}(B^0 \rightarrow \eta'K_0^*(1430)^0)$	BaBar [16]	$6.3 \pm 1.3 \pm 0.9$ ¹⁰	6.3 ± 1.6
$\mathcal{B}(B^0 \rightarrow \eta'(K\pi)_0^{*0})$	BaBar [16]	$7.4^{+1.5}_{-1.4} \pm 0.6$	7.4 ± 1.6
		none	
$\mathcal{B}(B^0 \rightarrow \eta'K_2^*(1430)^0)$	BaBar [16]	$13.7^{+3.0}_{-2.9} \pm 1.2$	13.7 ± 3.2
			$13.7^{+3.2}_{-3.1}$

¹ Measurement of $(\mathcal{B}(B_s^0 \rightarrow K^-\pi^+)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

² Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))(f_{\Lambda_b^0}/f_d)$ used in our fit.

³ Measurement of $\mathcal{B}(B^0 \rightarrow \pi^+\pi^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-)$ used in our fit.

⁴ Measurement of $(\mathcal{B}(B_s^0 \rightarrow K^+K^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

⁵ Measurement of $\mathcal{B}(B^0 \rightarrow K^+K^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-)$ used in our fit.

⁶ Measurement of $(\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

⁷ The PDG uncertainty includes a scale factor.

⁸ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\eta)/\mathcal{B}(B^0 \rightarrow \eta'K^0)$ used in our fit.

⁹ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\eta')/\mathcal{B}(B^0 \rightarrow \eta'K^0)$ used in our fit.

¹⁰ Multiple systematic uncertainties are added in quadrature.

Table 12: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^0 \rightarrow \eta K^0)$	Belle [18]	$1.27^{+0.33}_{-0.29} \pm 0.08$	1.23 ± 0.25
	BaBar [10]	$1.15^{+0.43}_{-0.38} \pm 0.09$	$1.23^{+0.27}_{-0.24}$
$\mathcal{B}(B^0 \rightarrow \eta K^*(892)^0)$	BaBar [19]	$16.5 \pm 1.1 \pm 0.8$	15.9 ± 1.0
	Belle [20]	$15.2 \pm 1.2 \pm 1.0$	
	CLEO [14]	$13.8^{+5.5}_{-4.6} \pm 1.6$	
$\mathcal{B}(B^0 \rightarrow \eta(K\pi)_0^{*0})$	BaBar [19]	$11.0 \pm 1.6 \pm 1.5$	11.0 ± 2.2 none
$\mathcal{B}(B^0 \rightarrow \eta K_0^*(1430)^0)$	BaBar [19]	$7.8 \pm 1.1 \pm 1.1$ ¹	7.8 ± 1.5 11.0 ± 2.2
$\mathcal{B}(B^0 \rightarrow \eta K_2^*(1430)^0)$	BaBar [19]	$9.6 \pm 1.8 \pm 1.1$	9.6 ± 2.1
$\mathcal{B}(B^0 \rightarrow \omega(782)K^0)$	Belle [23]	$4.5 \pm 0.4 \pm 0.3$	4.78 ± 0.43
	BaBar [24]	$5.4 \pm 0.8 \pm 0.3$	
	CLEO [25]	$10.0^{+5.4}_{-4.2} \pm 1.4$	
$\mathcal{B}(B^0 \rightarrow a_0(980)^0 K^0) \times \mathcal{B}(a_0(980)^0 \rightarrow \eta\pi^0)$	BaBar [27]	< 7.8	< 7.8
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 K^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [48]	< 7.8	< 7.8
$\mathcal{B}(B^0 \rightarrow a_0(980)^- K^+) \times \mathcal{B}(a_0(980)^- \rightarrow \eta\pi^-)$	BaBar [102]	< 1.9	< 1.9
$\mathcal{B}(B^0 \rightarrow b_1(1235)^- K^+) \times \mathcal{B}(b_1(1235)^- \rightarrow \omega(782)\pi^-)$	BaBar [49]	$7.4 \pm 1.0 \pm 1.0$	7.4 ± 1.4
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 K^*(892)^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [50]	< 8.0	< 8.0
$\mathcal{B}(B^0 \rightarrow b_1(1235)^- K^*(892)^+) \times \mathcal{B}(b_1(1235)^- \rightarrow \omega(782)\pi^-)$	BaBar [50]	< 5.0	< 5.0
$\mathcal{B}(B^0 \rightarrow a_0(1450)^- K^+) \times \mathcal{B}(a_0(1450)^- \rightarrow \eta\pi^-)$	BaBar [102]	< 3.1	< 3.1
$\mathcal{B}(B^0 \rightarrow K_S^0 X^0(\text{Familon}))$	CLEO [73]	< 53	< 53
$\mathcal{B}(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$2.2 \pm 0.6 \pm 0.2$	2.04 ± 0.49
	Belle [101]	$1.8 \pm 0.7 \pm 0.3$	
$\mathcal{B}(B^0 \rightarrow \omega(782)(K\pi)_0^{*0})$	BaBar [26]	$18.4 \pm 1.8 \pm 1.7$	18.4 ± 2.5
$\mathcal{B}(B^0 \rightarrow \omega(782)K_0^*(1430)^0)$	BaBar [26]	$16.0 \pm 1.6 \pm 3.0$	16.0 ± 3.4
$\mathcal{B}(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$10.1 \pm 2.0 \pm 1.1$	10.1 ± 2.3
$\mathcal{B}(B^0 \rightarrow \omega(782)K^+\pi^-(\text{NR}))$	Belle [101]	$5.1 \pm 0.7 \pm 0.7$ ²	5.1 ± 1.0

¹ Multiple systematic uncertainties are added in quadrature.

² $0.755 < M_{K\pi} < 1.250 \text{ GeV}/c^2$.

Table 13: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\pi^0)$	BaBar [103]	$38.5 \pm 1.0 \pm 3.9$ ¹
	Belle II [33]	$38.1 \pm 3.5 \pm 3.9$
	Belle [104]	$36.6^{+4.2}_{-4.1} \pm 3.0$
$\mathcal{B}(B^0 \rightarrow \rho^-(770)K^+)$	BaBar [103]	$6.6 \pm 0.5 \pm 0.8$ ¹
	Belle [104]	$15.1^{+3.4+2.4}_{-3.3-2.6}$ ²
$\mathcal{B}(B^0 \rightarrow \rho(1450)^-K^+)$	BaBar [103]	$2.4 \pm 1.0 \pm 0.6$ ¹
$\mathcal{B}(B^0 \rightarrow \rho(1700)^-K^+)$	BaBar [103]	$0.6 \pm 0.6 \pm 0.4$ ¹
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\pi^0(\text{NR}))$	BaBar [103]	$2.8 \pm 0.5 \pm 0.4$ ³
	Belle [104]	< 9.4
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-) \times \mathcal{B}((K\pi)_0^{*+} \rightarrow K^+\pi^0)$	BaBar [103]	$34.2 \pm 2.4 \pm 4.1$ ¹
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\pi^0) \times \mathcal{B}((K\pi)_0^{*0} \rightarrow K^+\pi^-)$	BaBar [103]	$8.6 \pm 1.1 \pm 1.3$ ¹
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0\pi^0)$	BaBar [105]	< 4.0 ¹
$\mathcal{B}(B^0 \rightarrow K^*(1680)^0\pi^0)$	BaBar [105]	< 7.5 ¹
$\mathcal{B}(B^0 \rightarrow K_x^{*0}\pi^0)$	Belle [104]	$6.1^{+1.6+0.5}_{-1.5-0.6}$ ⁴
		$6.1^{+1.7}_{-1.6}$

¹ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K^+\pi^-\pi^0$ decays.

² Multiple systematic uncertainties are added in quadrature.

³ The nonresonant amplitude is taken to be constant across the Dalitz plane.

⁴ $1.1 < m_{K\pi} < 1.6$ GeV/ c^2 .

Table 14: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 4).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)^{1,2}$	BaBar [106]	$50.15 \pm 1.47 \pm 1.76$ ^{3,4}
	Belle [107]	$47.5 \pm 2.4 \pm 3.7$ ³
	CLEO [41]	$50.0^{+10.0}_{-9.0} \pm 7.0$
	LHCb [108] ^{4,5,6,7,8} , [109] ⁹ , [110] ^{10,11} , [110] ^{10,12} , [110] ^{10,13} , [110] ^{10,14} , [110] ^{10,15}	
		49.7 ± 1.8
$\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-(\text{NR}))^{16}$	LHCb [111]	$12.60 \pm 0.67 \pm 3.05$ ^{3,17,4,18}
	BaBar [106]	$11.07^{+2.51}_{-0.99} \pm 0.90$ ^{3,19,4}
	Belle [107]	$19.9 \pm 2.5^{+1.7}_{-2.0}$ ^{3,20}
		14.0 ± 1.7 _{p=1.6‰}
$\mathcal{B}(B^0 \rightarrow \rho^0(770)K^0)^{16}$	BaBar [106]	$4.36^{+0.71}_{-0.62} \pm 0.31$ ^{3,4}
	LHCb [111]	$1.97^{+0.57}_{-0.83} \pm 0.42$ ^{3,4,18}
	Belle [107]	$6.1 \pm 1.0^{+1.1}_{-1.2}$ ³
		3.45 ± 0.48 _{p=1.6‰}
		$3.41^{+1.08}_{-1.14}$

¹ The PDG average is a result of a fit including input from other measurements.

² Treatment of charmonium intermediate components differs between the results.

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0\pi^+\pi^-$ decays.

⁴ Multiple systematic uncertainties are added in quadrature.

⁵ Measurement of $\mathcal{B}(A_b^0 \rightarrow p\bar{K}^0\pi^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

⁶ Measurement of $\mathcal{B}(A_b^0 \rightarrow pK^0K^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

⁷ Measurement of $\frac{f_{\Xi_b^0}}{f_d}\mathcal{B}(\Xi_b^0 \rightarrow p\bar{K}^0\pi^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

⁸ Measurement of $\frac{f_{\Xi_b^0}}{f_d}\mathcal{B}(\Xi_b^0 \rightarrow p\bar{K}^0K^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

⁹ Measurement of $\mathcal{B}(B^0 \rightarrow K^*(892)^0\bar{K}^0 + \text{c.c.})/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹⁰ Regions corresponding to D , A_c^+ and charmonium resonances are vetoed in this analysis.

¹¹ Measurement of $\mathcal{B}(B^0 \rightarrow K^0K^+\pi^- + \text{c.c.})/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹² Measurement of $\mathcal{B}(B^0 \rightarrow K^0K^+K^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹³ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^0\pi^+\pi^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹⁴ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^0K^+\pi^- + \text{c.c.})/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹⁵ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^0K^+K^-)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

¹⁶ The PDG uncertainty includes a scale factor.

¹⁷ The nonresonant component is modelled as a flat contribution over the Dalitz plane.

¹⁸ Using $\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$.

¹⁹ This value includes the flat NR component and the effective range of the LASS lineshape. The value corresponding to the flat component alone is also given in the article.

²⁰ The nonresonant component is modelled using a sum of two exponential functions.

Table 15: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 5).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)$	BaBar [106]	$8.29^{+0.92}_{-0.81} \pm 0.82$ ^{1,2}	7.64 ± 0.44 _{p=1.6%}
	BaBar [103]	$8.0 \pm 1.1 \pm 0.8$ ³	
	Belle [107]	$8.4 \pm 1.1^{+1.0}_{-0.9}$ ¹	
	CLEO [41]	$16.0^{+6.0}_{-5.0} \pm 2.0$	
	LHCb [112] ^{4,5} , [111] ^{1,2,6}		
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^+\pi^-)$ ⁷	BaBar [106]	$29.9^{+2.3}_{-1.7} \pm 3.6$ ^{1,2}	$33.6^{+3.8}_{-4.0}$
	Belle [107]	$49.7 \pm 3.8^{+6.8}_{-8.2}$ ¹	$33.5^{+7.4}_{-7.2}$
$\mathcal{B}(B^0 \rightarrow K_x^{*+}\pi^-)$	Belle [104]	$5.1 \pm 1.5^{+0.6}_{-0.7}$ ⁸	5.1 ± 1.6 _{-1.7}
$\mathcal{B}(B^0 \rightarrow K^*(1410)^+\pi^-) \times \mathcal{B}(K^*(1410)^+ \rightarrow K^0\pi^+)$	Belle [107]	< 3.8 ¹	< 3.8
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-) \times \mathcal{B}((K\pi)_0^{*+} \rightarrow K^0\pi^+)$	LHCb [111]	$16.95 \pm 0.73 \pm 1.12$ ^{1,2,9}	18.6 ± 1.1 _{p=1.6%}
	BaBar [106]	$22.7^{+1.7}_{-1.3} \pm 1.3$ ^{1,2}	16.2 ± 1.3
$\mathcal{B}(B^0 \rightarrow f_0(980)K^0) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$ ⁷	LHCb [111]	$9.64 \pm 0.41 \pm 0.79$ ^{1,2,9}	8.38 ± 0.61
	BaBar [106]	$6.92 \pm 0.77 \pm 0.56$ ^{1,2}	$8.15^{+0.78}_{-0.79}$ _{p=1.6%}
	Belle [107]	$7.6 \pm 1.7^{+0.9}_{-1.3}$ ¹	$0.17^{+0.26}_{-0.16}$ _{p=1.6%}
$\mathcal{B}(B^0 \rightarrow f_0(500)K^0)$	LHCb [111]	$0.166^{+0.207}_{-0.041} \pm 0.155$ ^{1,2,9}	$0.16^{+0.25}_{-0.16}$
$\mathcal{B}(B^0 \rightarrow f_0(1500)K^0) \times \mathcal{B}(f_0(1500) \rightarrow \pi^+\pi^-)$	LHCb [111]	$1.348 \pm 0.280 \pm 0.734$ ^{1,2,9}	1.35 ± 0.79 _{p=1.6%}
			1.29 ± 0.75
$\mathcal{B}(B^0 \rightarrow f_2(1270)K^0)$	BaBar [106]	$2.71^{+0.99}_{-0.83} \pm 0.87$ ^{1,2}	2.7 ± 1.3
	Belle [107]	< 2.5 ^{1,10}	$2.7^{+1.3}_{-1.2}$
$\mathcal{B}(B^0 \rightarrow f_x(1300)^0K^0) \times \mathcal{B}(f_x(1300)^0 \rightarrow \pi^+\pi^-)$	BaBar [106]	$1.81^{+0.55}_{-0.45} \pm 0.48$ ^{1,2}	$1.81^{+0.73}_{-0.66}$

¹ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0\pi^+\pi^-$ decays.

² Multiple systematic uncertainties are added in quadrature.

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K^+\pi^-\pi^0$ decays.

⁴ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^*(892)^-\pi^+)/\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)$ used in our fit.

⁵ Measurement of $\mathcal{B}(B^0 \rightarrow K^*(892)^-K^++c.c.)/\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)$ used in our fit.

⁶ Measurement of $(\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)/2)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$ used in our fit.

⁷ The PDG uncertainty includes a scale factor.

⁸ $1.1 < m_{K\pi} < 1.6$ GeV/ c^2 .

⁹ Using $\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$.

¹⁰ Using $\mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$.

Table 16: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 6).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^0)$	BaBar [103] $3.3 \pm 0.5 \pm 0.4$ ¹ Belle [104] < 3.5	3.3 ± 0.6
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^+ \pi^-)$	Belle [107] < 6.3 ² BaBar [105] < 16.2 ¹ LHCb [111] ^{2,3,4}	3.82 ± 0.36 $3.65^{+0.34}_{-0.33}$
$\mathcal{B}(B^0 \rightarrow K^*(1680)^+ \pi^-)$	Belle [107] < 10.1 ² BaBar [105] < 25.0 ¹ LHCb [111] ^{2,3,5}	14.7 ± 1.4 14.1 ± 1.0
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ \pi^-)$	DELPHI [113] < 230	< 230
$\mathcal{B}(B^0 \rightarrow \rho^0(770) K^+ \pi^-)$	Belle [114] $2.8 \pm 0.5 \pm 0.5$ ⁶	2.8 ± 0.7
$\mathcal{B}(B^0 \rightarrow f_0(980) K^+ \pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	Belle [114] $1.4 \pm 0.4^{+0.3}_{-0.4}$ ⁶	$1.4^{+0.5}_{-0.6}$
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ \pi^- (\text{NR}))$	Belle [114] < 2.1 ^{6,7}	< 2.1
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^+ \pi^-)$	BaBar [115] $54.5 \pm 2.9 \pm 4.3$	54.5 ± 5.2
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \rho^0(770))^8$	BaBar [116] $5.1 \pm 0.6^{+0.6}_{-0.8}$ Belle [114] $2.1^{+0.8+0.9}_{-0.7-0.5}$	3.88 ± 0.77 $3.88^{+1.33}_{-1.25}$
$\mathcal{B}(B^0 \rightarrow f_0(980) K_0^*(892)^0) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)^8$	Belle [114] $1.4^{+0.6+0.6}_{-0.5-0.4}$ BaBar [116] $5.7 \pm 0.6 \pm 0.4$	3.90 ± 0.55 $3.90^{+2.12}_{-1.85}$

¹ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K^+ \pi^- \pi^0$ decays.

² Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0 \pi^+ \pi^-$ decays.

³ Multiple systematic uncertainties are added in quadrature.

⁴ Measurement of $(\mathcal{B}(B^0 \rightarrow K_2^*(1430)^+ \pi^-) \mathcal{B}(K_2^*(1430)^+ \rightarrow K\pi) 2/3) / \mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$ used in our fit.

⁵ Measurement of $(\mathcal{B}(B^0 \rightarrow K^*(1680)^+ \pi^-) \mathcal{B}(K^*(1680)^+ \rightarrow K\pi) 2/3) / \mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$ used in our fit.

⁶ $0.75 < M(K\pi) < 1.20$ GeV/ c^2 .

⁷ $0.55 < M(\pi\pi) < 1.20$ GeV/ c^2 .

⁸ The PDG uncertainty includes a scale factor.

Table 17: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 7).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K_1(1270)^+\pi^-)$	BaBar [40] < 30	< 30
$\mathcal{B}(B^0 \rightarrow K_1(1400)^+\pi^-)$	BaBar [40] < 27	< 27
$\mathcal{B}(B^0 \rightarrow a_1(1260)^-K^+)$	BaBar [44] $16.3 \pm 2.9 \pm 2.3$	16.3 ± 3.7
$\mathcal{B}(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [116] $10.3 \pm 2.3 \pm 1.3$	10.3 ± 2.6
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\rho^-(770)) \times \mathcal{B}((K\pi)_0^* \rightarrow K\pi)$	BaBar [116] < 48	< 48 none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^+\rho^-(770))$	BaBar [116] $28 \pm 10 \pm 6$ ¹	28 ± 12
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0\rho^0(770))$	ARGUS [47] < 3000	< 3000
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\rho^0(770)) \times \mathcal{B}((K\pi)_0^* \rightarrow K\pi)$	BaBar [116] $31 \pm 4 \pm 3$	31.0 ± 5.0 none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\rho^0(770))$	BaBar [116] $27 \pm 4 \pm 4$ ¹	27.0 ± 5.4 27.0 ± 5.7
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi) \times \mathcal{B}((K\pi)_0^* \rightarrow K\pi)$	BaBar [116] $3.1 \pm 0.8 \pm 0.7$	3.1 ± 1.1 none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	BaBar [116] $2.7 \pm 0.7 \pm 0.6$ ¹	2.7 ± 0.9
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	BaBar [116] $8.6 \pm 1.7 \pm 1.0$	8.6 ± 2.0
$\mathcal{B}(B^0 \rightarrow K^+K^-)$	LHCb [96] $0.0774 \pm 0.0126 \pm 0.0084$ ² Belle [3] $0.10 \pm 0.08 \pm 0.04$ CDF [94] $0.23 \pm 0.10 \pm 0.10$ ² BaBar [91] < 0.5	0.080 ± 0.015 0.078 ± 0.015
$\mathcal{B}(B^0 \rightarrow K^0\bar{K}^0)$	Belle [3] $1.26 \pm 0.19 \pm 0.05$ BaBar [4] $1.08 \pm 0.28 \pm 0.11$	1.21 ± 0.16
$\mathcal{B}(B^0 \rightarrow K^0K^+\pi^- + \text{c.c.})$	LHCb [110] $6.11 \pm 0.45 \pm 0.78$ ^{3,4} Belle [117] $7.20 \pm 0.66 \pm 0.30$ BaBar [118] $6.4 \pm 1.0 \pm 0.6$	6.7 ± 0.5
$\mathcal{B}(B^0 \rightarrow K^*(892)^-K^+ + \text{c.c.})$	LHCb [112] < 0.38 ⁵	< 0.4
$\mathcal{B}(B^0 \rightarrow K^*(892)^0\bar{K}^0 + \text{c.c.})$ ⁶	LHCb [109] < 1.0 ⁴ BaBar [119] < 1.9	< 0.99 < 0.96

¹ Multiple systematic uncertainties are added in quadrature.

² Using $\mathcal{B}(B^0 \rightarrow K^+\pi^-)$.

³ Regions corresponding to D , A_c^+ and charmonium resonances are vetoed in this analysis.

⁴ Using $\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$.

⁵ Using $\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)$.

⁶ $0.75 < M(K\pi) < 1.20$ GeV/ c^2 .

Table 18: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 8).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^+K^-\pi^0)$	Belle [120] $2.17 \pm 0.60 \pm 0.24$	2.17 ± 0.65
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\pi^0)$	BaBar [121] < 0.9	< 0.9
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\eta)$	BaBar [121] < 1.0	< 1.0
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\eta')$	BaBar [121] < 2.0	< 2.0
$\mathcal{B}(B^0 \rightarrow K^0K^+K^-)$	LHCb [110] $27.29 \pm 0.89 \pm 1.90$ ^{1,2}	26.8 ± 1.0 26.8 ± 1.1
	BaBar [22] $26.5 \pm 0.9 \pm 0.8$ ^{3,4}	
	Belle [38] $28.3 \pm 3.3 \pm 4.0$	
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)$	BaBar [22] 7.1 ± 0.6 ^{+0.4} _{-0.3} ³	7.25 ± 0.60 7.32 ^{+0.69} _{-0.63}
	Belle II [62] $5.9 \pm 1.8 \pm 0.7$	
	Belle [66] 9.0 ^{+2.2} _{-1.8} ± 0.7	
	LHCb [122] ⁵ , [123] ^{6,7}	
$\mathcal{B}(B^0 \rightarrow f_0(980)K^0) \times \mathcal{B}(f_0(980) \rightarrow K^+K^-)$	BaBar [22] 7.0 ^{+2.6} _{-1.8} ± 2.4 ³	7.0 ^{+3.5} _{-3.0}
$\mathcal{B}(B^0 \rightarrow f_0(1500)K^0)$	BaBar [22] 13.3 ^{+5.8} _{-4.4} ± 3.2 ³	13.3 ^{+6.6} _{-5.4}
$\mathcal{B}(B^0 \rightarrow f_2'(1525)K^0)$	BaBar [22] 0.29 ^{+0.27} _{-0.18} ± 0.36 ³	0.29 ^{+0.45} _{-0.40}
$\mathcal{B}(B^0 \rightarrow f_0(1710)K^0) \times \mathcal{B}(f_0(1710) \rightarrow K^+K^-)$	BaBar [22] $4.4 \pm 0.7 \pm 0.5$ ³	4.4 ± 0.9
$\mathcal{B}(B^0 \rightarrow K^0K^+K^-(\text{NR}))$	BaBar [22] $33 \pm 5 \pm 9$ ⁸	33 ± 10

¹ Regions corresponding to D , Λ_c^+ and charmonium resonances are vetoed in this analysis.

² Using $\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$.

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0K^+K^-$ decays.

⁴ All charmonium resonances are vetoed, except for χ_{c0} . The analysis also reports $\mathcal{B}(B^0 \rightarrow K^0K^+K^-) = (25.4 \pm 0.9 \pm 0.8) \times 10^{-6}$ excluding χ_{c0} .

⁵ Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\phi(1020))/\mathcal{B}(B^0 \rightarrow \phi(1020)K^0))(f_{\Lambda_b^0}/f_d)2$ used in our fit.

⁶ Multiple systematic uncertainties are added in quadrature.

⁷ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^0\bar{K}^0)/\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)$ used in our fit.

⁸ The nonresonant amplitude is modelled using a polynomial function including S-wave and P-wave terms.

Table 19: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 9).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 K_S^0)^1$	BaBar [124] $6.19 \pm 0.48 \pm 0.19$ ^{2,3} Belle [38] $4.2^{+1.6}_{-1.3} \pm 0.8$	6.04 ± 0.50 $6.04^{+0.53}_{-0.52}$
$\mathcal{B}(B^0 \rightarrow f_0(980)K_S^0) \times \mathcal{B}(f_0(980) \rightarrow K_S^0 K_S^0)$	BaBar [124] $2.7^{+1.3}_{-1.2} \pm 1.3$ ^{2,3}	2.7 ± 1.8
$\mathcal{B}(B^0 \rightarrow f_0(1710)K_S^0) \times \mathcal{B}(f_0(1710) \rightarrow K_S^0 K_S^0)$	BaBar [124] $0.50^{+0.46}_{-0.24} \pm 0.11$ ^{2,3}	$0.50^{+0.47}_{-0.26}$
$\mathcal{B}(B^0 \rightarrow f_2(2010)K_S^0) \times \mathcal{B}(f_2(2010) \rightarrow K_S^0 K_S^0)$	BaBar [124] $0.54^{+0.21}_{-0.20} \pm 0.52$ ^{2,3}	0.54 ± 0.56
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 K_S^0(\text{NR}))$	BaBar [124] $13.3^{+2.2}_{-2.3} \pm 0.6$ ^{4,3}	13.3 ± 2.3 $13.3^{+3.1}_{-3.2}$
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 K_L^0)$	BaBar [125] < 16 ⁵	< 16
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 K^+ K^-)$	BaBar [115] $27.5 \pm 1.3 \pm 2.2$	27.5 ± 2.6
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	BaBar [126] $9.7 \pm 0.5 \pm 0.5$ Belle [127] $10.4 \pm 0.5 \pm 0.6$ Belle II [62] $11.0 \pm 2.1 \pm 1.1$ CLEO [64] $11.5^{+4.5+1.8}_{-3.7-1.7}$ LHCb [128] ^{3,6} , [129] ^{3,7} , [130] ^{3,8} , [131] ⁹	10.08 ± 0.48 10.04 ± 0.52
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ K^- (\text{NR}))$	Belle [132] < 71.7 ¹⁰	< 72
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^+ K^-)$	BaBar [115] $4.6 \pm 1.1 \pm 0.8$ Belle [132] $2.11^{+5.63+4.85}_{-5.26-4.75}$ ¹⁰	4.5 ± 1.3
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)^1$	LHCb [133] $0.832 \pm 0.063 \pm 0.156$ ^{3,11} Belle [132] $0.26^{+0.33+0.10}_{-0.29-0.08}$ BaBar [134] $1.28^{+0.35}_{-0.30} \pm 0.11$	0.83 ± 0.15 $0.83^{+0.25}_{-0.23}$

¹ The PDG uncertainty includes a scale factor.

² Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0 K_S^0 K_S^0$ decays.

³ Multiple systematic uncertainties are added in quadrature.

⁴ The nonresonant amplitude is modelled using an exponential function.

⁵ $0.75 < M(K\pi) < 1.20$ GeV/ c^2 .

⁶ Measurement of $\mathcal{B}(B_s^0 \rightarrow \phi(1020)\bar{K}^*(892)^0)/\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$ used in our fit.

⁷ Measurement of $\mathcal{B}(B_s^0 \rightarrow K^*(892)^0\bar{K}^*(892)^0)/\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$ used in our fit.

⁸ Measurement of $\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))/\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$ used in our fit.

⁹ Measurement of $\mathcal{B}(B^0 \rightarrow \rho^0(770)\rho^0(770))/\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$ used in our fit.

¹⁰ $0.70 < M(K\pi) < 1.70$ GeV/ c^2 .

¹¹ Using $\mathcal{B}(B_s^0 \rightarrow K^*(892)^0\bar{K}^*(892)^0)$.

Table 20: Branching fractions of charmless mesonic B^0 decays with strange mesons (part 10).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^+\pi^-K^+\pi^-(\text{NR}))$	Belle [132] < 6.0 ¹	< 6.0
$\mathcal{B}(B^0 \rightarrow K^*(892)^0K^+\pi^-)$	BaBar [115] < 2.2 Belle [132] < 7.6 ¹	< 2.2
$\mathcal{B}(B^0 \rightarrow K^*(892)^0K^*(892)^0)$	Belle [132] < 0.20 BaBar [134] < 0.41	< 0.2
$\mathcal{B}(B^0 \rightarrow K^*(892)^+K^*(892)^-)$	BaBar [135] < 2.0	< 2.0
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0\phi(1020))$	ARGUS [47] < 5000	< 5000
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\phi(1020))$	Belle [127] $4.3 \pm 0.4 \pm 0.4$ BaBar [126] $4.3 \pm 0.6 \pm 0.4$	4.30 ± 0.45
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\phi), 1.60 < M_{K\pi} < 2.15 \text{ GeV}/c^2$.	BaBar [136] < 1.7	< 1.7
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\pi^+K^-)$	Belle [132] < 31.8 ¹	< 32
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\bar{K}^*(892)^0)$	Belle [132] < 3.3	< 3.3
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\bar{K}_0^*(1430)^0)$	Belle [132] < 8.4	< 8.4
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_0^*(1430)^0)$	BaBar [126] $3.9 \pm 0.5 \pm 0.6$	3.90 ± 0.78
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0K^*(892)^0)$	Belle [132] < 1.7	< 1.7
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0K_0^*(1430)^0)$	Belle [132] < 4.7	< 4.7
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(1680)^0)$	BaBar [136] < 3.5	< 3.5
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_3^*(1780)^0)$	BaBar [136] < 2.7	< 2.7
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_4^*(2045)^0)$	BaBar [136] < 15.3	< 15
$\mathcal{B}(B^0 \rightarrow \rho^0(770)K_2^*(1430)^0)$	ARGUS [47] < 1100	< 1100
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)^2$	Belle [127] $5.5_{-0.7}^{+0.9} \pm 1.0$ BaBar [126] $7.5 \pm 0.9 \pm 0.5$	6.8 ± 0.8 $6.8_{-0.9}^{+1.0}$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\phi(1020)K^0)$	BaBar [69] $4.5 \pm 0.8 \pm 0.3$ ³	4.5 ± 0.9 3.7 ± 0.7
$\mathcal{B}(B^0 \rightarrow \eta'\eta'K^0)$	BaBar [71] < 31.0	< 31

¹ $0.70 < M(K\pi) < 1.70 \text{ GeV}/c^2$.

² The PDG uncertainty includes a scale factor.

³ Measured in the $\phi\phi$ invariant mass range below the η_c resonance ($M_{\phi\phi} < 2.85 \text{ GeV}/c^2$).

Table 21: Branching fractions of charmless mesonic B^0 decays without strange mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-)$	LHCb [95]	$5.10 \pm 0.18 \pm 0.35$ ¹	5.15 ± 0.19 5.12 ± 0.19
	Belle [3]	$5.04 \pm 0.21 \pm 0.18$	
	CDF [93]	$5.04 \pm 0.33 \pm 0.33$ ¹	
	BaBar [91]	$5.5 \pm 0.4 \pm 0.3$	
	Belle II [5]	$5.8 \pm 0.7 \pm 0.3$	
	CLEO [6]	$4.5^{+1.4+0.5}_{-1.2-0.4}$	
$\mathcal{B}(B^0 \rightarrow \pi^0\pi^0)^2$	Belle [137]	$1.31 \pm 0.19 \pm 0.19$	1.51 ± 0.16 1.59 ± 0.26
	BaBar [97]	$1.83 \pm 0.21 \pm 0.13$	
	Belle II [138]	$1.27 \pm 0.25 \pm 0.17$	
$\mathcal{B}(B^0 \rightarrow \eta\pi^0)$	Belle [139]	$0.41^{+0.17+0.05}_{-0.15-0.07}$	0.41 ± 0.17 $0.41^{+0.18}_{-0.17}$
	BaBar [86]	< 1.5	
	CLEO [14]	< 2.9	
$\mathcal{B}(B^0 \rightarrow \eta\eta)$	BaBar [10]	< 1.0	< 1.0
$\mathcal{B}(B^0 \rightarrow \eta'\pi^0)^2$	BaBar [86]	$0.9 \pm 0.4 \pm 0.1$	1.2 ± 0.4 1.2 ± 0.6
	Belle [11]	$2.79^{+1.02+0.25}_{-0.96-0.34}$	
$\mathcal{B}(B^0 \rightarrow \eta'\eta')$	BaBar [10]	< 1.7	< 1.7
	Belle [17]	< 6.5	
$\mathcal{B}(B^0 \rightarrow \eta'\eta)$	BaBar [86]	< 1.2	< 1.2
	Belle [17]	< 4.5	
$\mathcal{B}(B^0 \rightarrow \eta'\rho^0(770))$	Belle [17]	< 1.3	< 1.3
	BaBar [16]	< 2.8	
$\mathcal{B}(B^0 \rightarrow f_0(980)\eta') \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [16]	< 0.9	< 0.9
$\mathcal{B}(B^0 \rightarrow \eta\rho^0(770))$	BaBar [102]	< 1.5	< 1.5
	Belle [20]	< 1.9	
$\mathcal{B}(B^0 \rightarrow f_0(980)\eta) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [102]	< 0.4	< 0.4
$\mathcal{B}(B^0 \rightarrow \omega(782)\eta)$	BaBar [10]	$0.94^{+0.35}_{-0.30} \pm 0.09$	$0.94^{+0.36}_{-0.31}$

¹ Using $\mathcal{B}(B^0 \rightarrow K^+\pi^-)$.

² The PDG uncertainty includes a scale factor.

Table 22: Branching fractions of charmless mesonic B^0 decays without strange mesons (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow \omega(782)\eta')$	BaBar [10] $1.01^{+0.46}_{-0.38} \pm 0.09$ Belle [17] < 2.2	$1.01^{+0.47}_{-0.39}$
$\mathcal{B}(B^0 \rightarrow \omega(782)\rho^0(770))$	BaBar [26] < 1.6	< 1.6
$\mathcal{B}(B^0 \rightarrow f_0(980)\omega(782)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [26] < 1.5	< 1.5
$\mathcal{B}(B^0 \rightarrow \omega(782)\omega(782))$	BaBar [140] $1.2 \pm 0.3^{+0.3}_{-0.2}$	1.2 ± 0.4
$\mathcal{B}(B^0 \rightarrow \phi(1020)\pi^0)$	Belle [88] < 0.15 BaBar [87] < 0.28	< 0.15
$\mathcal{B}(B^0 \rightarrow \phi(1020)\eta)$	BaBar [10] < 0.5	< 0.5
$\mathcal{B}(B^0 \rightarrow \phi(1020)\eta')$	Belle [17] < 0.5 BaBar [10] < 1.1	< 0.5
$\mathcal{B}(B^0 \rightarrow \phi(1020)\pi^+\pi^-)$	LHCb [141] $0.182 \pm 0.025 \pm 0.043^{1,2}$	0.182 ± 0.050
$\mathcal{B}(B^0 \rightarrow \phi(1020)\rho^0(770))$	BaBar [89] < 0.33	< 0.33
$\mathcal{B}(B^0 \rightarrow f_0(980)\phi(1020)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [89] < 0.38	< 0.38
$\mathcal{B}(B^0 \rightarrow \omega(782)\phi(1020))$	BaBar [140] < 0.7	< 0.7
$\mathcal{B}(B^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [142] < 0.027 BaBar [89] < 0.2	< 0.027
$\mathcal{B}(B^0 \rightarrow a_0(980)^+\pi^- + \text{c.c.}) \times \mathcal{B}(a_0(980)^+ \rightarrow \eta\pi^+)$	BaBar [102] < 3.1	< 3.1
$\mathcal{B}(B^0 \rightarrow a_0(1450)^+\pi^- + \text{c.c.}) \times \mathcal{B}(a_0(1450)^+ \rightarrow \eta\pi^+)$	BaBar [102] < 2.3	< 2.3
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^0)$	ARGUS [79] < 720	< 720
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\pi^0)$	Belle [143] $3.0 \pm 0.5 \pm 0.7^3$ BaBar [144] $1.4 \pm 0.6 \pm 0.3$ CLEO [25] $1.6^{+2.0}_{-1.4} \pm 0.8$	2.0 ± 0.5
$\mathcal{B}(B^0 \rightarrow \rho^+(770)\pi^- + \text{c.c.})$	Belle [143] $22.6 \pm 1.1 \pm 4.4^3$ BaBar [145] $22.6 \pm 1.8 \pm 2.2$ CLEO [25] $27.6^{+8.4}_{-7.4} \pm 4.2$	23.0 ± 2.3
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^+\pi^-)$	Belle [146] $< 11.2^4$ BaBar [147] $< 23.1^5$	< 11

¹ $400 < M(\pi^+\pi^-) < 1600 \text{ MeV}/c^2$.

² Multiple systematic uncertainties are added in quadrature.

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow \pi^+\pi^-\pi^0$ decays.

⁴ $0.52 < m_{\pi^+\pi^-} < 1.15 \text{ GeV}/c^2$.

⁵ $0.55 < m_{\pi^+\pi^-} < 1.050 \text{ GeV}/c^2$.

Table 23: Branching fractions of charmless mesonic B^0 decays without strange mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\pi^+\pi^-)$	BaBar [147] < 8.8 ¹ Belle [146] < 12.0 ²	< 8.8
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\rho^0(770))$	LHCb [131] $0.95 \pm 0.17 \pm 0.10$ ³ Belle [146] $1.02 \pm 0.30 \pm 0.15$ BaBar [147] $0.92 \pm 0.32 \pm 0.14$	0.96 ± 0.15
$\mathcal{B}(B^0 \rightarrow f_0(980)\pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	Belle [146] < 3.0 ²	< 3.0
$\mathcal{B}(B^0 \rightarrow f_0(980)\rho^0(770)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	Belle [146] $0.78 \pm 0.22 \pm 0.11$ BaBar [147] < 0.40	0.78 ± 0.25
$\mathcal{B}(B^0 \rightarrow f_0(980)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [147] < 0.19 Belle [146] < 0.2	< 0.19
$\mathcal{B}(B^0 \rightarrow f_0(980)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow K^+K^-)$	BaBar [89] < 0.23	< 0.23
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+\pi^- + \text{c.c.})$ ⁴	Belle [148] $22.2 \pm 2.0 \pm 2.8$ BaBar [149] $33.2 \pm 3.8 \pm 3.0$	25.9 ± 2.8 25.9 ± 5.2
$\mathcal{B}(B^0 \rightarrow a_2(1320)^+\pi^- + \text{c.c.})$	Belle [148] < 6.3	< 6.3
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^0\pi^0)$	ARGUS [79] < 3100	< 3100
$\mathcal{B}(B^0 \rightarrow \rho^+(770)\rho^-(770))$	Belle [150] $28.3 \pm 1.5 \pm 1.5$ BaBar [151] 25.5 ± 2.1 ^{+3.6} _{-3.9} Belle II [152] $26.7 \pm 2.8 \pm 2.8$	27.5 ± 1.7 27.7 ± 1.9
$\mathcal{B}(B^0 \rightarrow a_1(1260)^0\pi^0)$	ARGUS [79] < 1100	< 1100
$\mathcal{B}(B^0 \rightarrow \omega(782)\pi^0)$	BaBar [86] < 0.5 Belle [85] < 2.0	< 0.5
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^+\pi^-\pi^-\pi^0)$	ARGUS [79] < 9000	< 9000
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+\rho^-(770) + \text{c.c.})$	BaBar [153] < 61.0	< 61
$\mathcal{B}(B^0 \rightarrow a_1(1260)^0\rho^0(770))$	ARGUS [79] < 2400	< 2400

¹ $0.55 < m_{\pi^+\pi^-} < 1.050 \text{ GeV}/c^2$.

² $0.52 < m_{\pi^+\pi^-} < 1.15 \text{ GeV}/c^2$.

³ Using $\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$.

⁴ The PDG uncertainty includes a scale factor.

Table 24: Branching fractions of charmless mesonic B^0 decays without strange mesons (part 4).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow b_1(1235)^+ \pi^- + \text{c.c.}) \times \mathcal{B}(b_1(1235)^+ \rightarrow \omega(782)\pi^+)$	BaBar [49] $10.9 \pm 1.2 \pm 0.9$	10.9 ± 1.5
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 \pi^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [48] < 1.9	< 1.9
$\mathcal{B}(B^0 \rightarrow b_1(1235)^- \rho^+(770)) \times \mathcal{B}(b_1(1235)^- \rightarrow \omega(782)\pi^-)$	BaBar [50] < 1.4	< 1.4
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 \rho^0(770)) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [50] < 3.4	< 3.4
$\mathcal{B}(B^0 \rightarrow \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^-)$	ARGUS [79] < 3000	< 3000
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+ a_1(1260)^-) \times \mathcal{B}(a_1(1260)^+ \rightarrow \pi^+ \pi^+ \pi^-) \times \mathcal{B}(a_1(1260)^- \rightarrow \pi^- \pi^- \pi^+)$	BaBar [154] $11.8 \pm 2.6 \pm 1.6$	11.8 ± 3.1
$\mathcal{B}(B^0 \rightarrow \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- \pi^0)$	ARGUS [79] < 11000	< 11000

Table 25: Relative branching fractions of charmless mesonic B^+ decays.

Parameter	Measurements	Average
$\frac{\mathcal{B}(B^+ \rightarrow K^+ K^- \pi^+)}{\mathcal{B}(B^+ \rightarrow K^+ K^+ K^-)}$	LHCb [32] $0.151 \pm 0.004 \pm 0.008$	0.151 ± 0.009
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \pi^+ \pi^-)}{\mathcal{B}(B^+ \rightarrow K^+ K^+ K^-)}$	LHCb [32] $1.703 \pm 0.011 \pm 0.022$	1.703 ± 0.025
$\frac{\mathcal{B}(B^+ \rightarrow \pi^+ \pi^+ \pi^-)}{\mathcal{B}(B^+ \rightarrow K^+ K^+ K^-)}$	LHCb [32] $0.488 \pm 0.005 \pm 0.009$	0.488 ± 0.010

Table 26: Relative branching fractions of charmless mesonic B^0 decays.

Parameter	Measurements	Average	
$\frac{\mathcal{B}(B^0 \rightarrow K^+K^-)}{\mathcal{B}(B^0 \rightarrow K^+\pi^-)}$ $[10^{-3}]$	LHCb [96] CDF [94]	$3.98 \pm 0.65 \pm 0.42$ $12 \pm 5 \pm 5$	4.07 ± 0.77
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^+K^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)}$ $[10^{-2}]$	LHCb [112]	< 5	< 5.0
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K_S^0 \pi^+ \pi^-)}$ $[10^{-2}]$	LHCb [109]	< 2	< 2.0
$\frac{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K^+ \pi^-)}$	LHCb [95] CDF [93]	$0.262 \pm 0.009 \pm 0.017$ $0.259 \pm 0.017 \pm 0.016$	0.261 ± 0.015
$\frac{\mathcal{B}(B^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [110]	$0.123 \pm 0.009 \pm 0.015$ ¹	0.123 ± 0.017
$\frac{\mathcal{B}(B^0 \rightarrow K^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [110]	$0.549 \pm 0.018 \pm 0.033$ ¹	0.549 ± 0.038
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}{\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}$ $[10^{-2}]$	LHCb [133]	$7.58 \pm 0.57 \pm 0.30$ ²	7.58 ± 0.64
$\frac{f_s \mathcal{B}(B^0 \rightarrow K^+ K^-)}{f_d \mathcal{B}(B_s^0 \rightarrow K^+ K^-)}$ $[10^{-2}]$	LHCb [95]	$1.8^{+0.8}_{-0.7} \pm 0.9$	1.8 ± 1.2
$\frac{\mathcal{B}(B^0 \rightarrow \rho^0(770)\rho^0(770))}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$ $[10^{-2}]$	LHCb [131]	$9.4 \pm 1.7 \pm 0.9$	9.4 ± 1.9
$\frac{\mathcal{B}(B^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B_s^0 \rightarrow K^0 \bar{K}^0)}$ $[10^{-2}]$	LHCb [123]	$7.5 \pm 3.1 \pm 0.6$ ²	7.5 ± 3.2
$\frac{\mathcal{B}(B^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)}$	LHCb [123]	$0.17 \pm 0.08 \pm 0.02$	0.17 ± 0.08
$\frac{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^- \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(K^{*0} \rightarrow K^+ \pi^-)}$ $[10^{-4}]$	LHCb [155]	$4.1 \pm 1.0 \pm 0.3$ ^{3,4}	4.1 ± 1.0

¹ Regions corresponding to D , Λ_c^+ and charmonium resonances are vetoed in this analysis.

² Multiple systematic uncertainties are added in quadrature.

³ The mass windows corresponding to ϕ and charmonium resonances decaying to $\mu\mu$ are vetoed.

⁴ $0.5 < m_{\pi^+\pi^-} < 1.3 \text{ GeV}/c^2$.

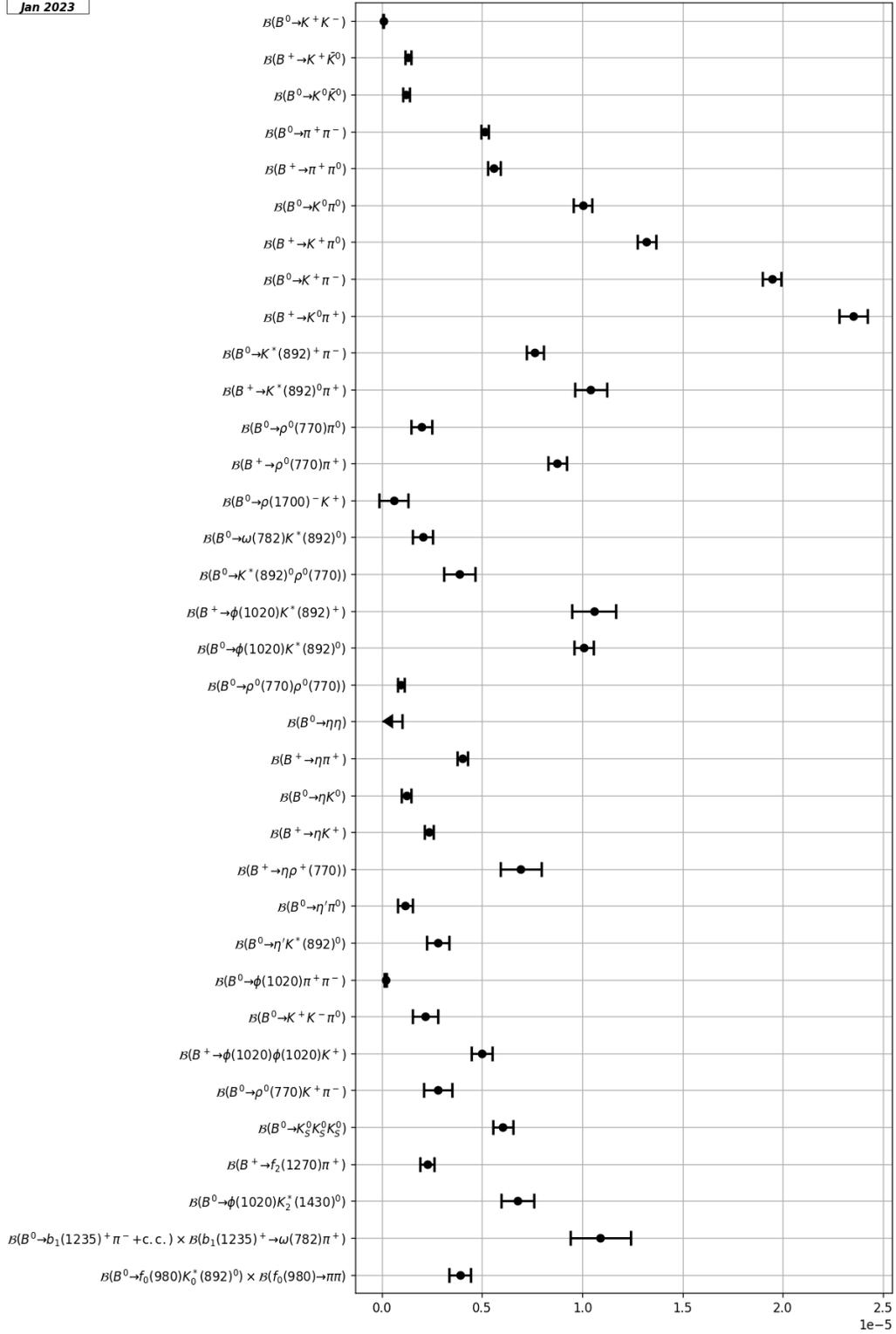


Figure 1: A selection of high-precision charmless mesonic B meson branching fraction measurements.

2 Baryonic decays of B^+ and B^0 mesons

This section provides branching fractions of charmless baryonic decays of B^+ and B^0 mesons in Tables 27-28 and 29-30, respectively. Relative branching fractions are given in Table 31. Figures 2 and 3 show graphic representations of a selection of results given in this section.

Table 27: Branching fractions of charmless baryonic B^+ decays (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow p\bar{n}\pi^0)$	Belle [156] < 6.1	< 6.1 none
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+)$	Belle [157] $1.60^{+0.22}_{-0.19} \pm 0.12$ ¹ BaBar [158] $1.69 \pm 0.29 \pm 0.26$ ²	1.62 ± 0.21 $1.62^{+0.21}_{-0.19}$
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [159] ³	1.00 ± 0.10 none
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+(\text{NR}))$	CLEO [39] < 53	< 53
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+\pi^0)$	Belle [160] $4.58 \pm 1.17 \pm 0.67$ ⁴	4.6 ± 1.3
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+\pi^+\pi^-)$	ARGUS [161] < 520	< 520
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+)^5$	Belle [157] $5.54^{+0.27}_{-0.25} \pm 0.36$ ¹ BaBar [162] $6.7 \pm 0.5 \pm 0.4$ ²	5.9 ± 0.4 5.9 ± 0.5
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [163] ⁶	4.37 ± 0.29 none
$\mathcal{B}(B^+ \rightarrow \Theta^{++}(1710)\bar{p}) \times \mathcal{B}(\Theta^{++}(1710) \rightarrow pK^+)^7$	Belle [58] < 0.091	< 0.091
$\mathcal{B}(B^+ \rightarrow f_J(2220)K^+) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$	Belle [58] < 0.41	< 0.41
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}(1520))$	BaBar [162] < 1.5 LHCb [159] ⁸	$0.305^{+0.084}_{-0.081}$ 0.315 ± 0.055
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+(\text{NR}))$	CLEO [39] < 89	< 89

¹ The charmonium mass regions are vetoed.

² Charmonium decays to $p\bar{p}$ have been statistically subtracted.

³ Measurement of $\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2 / (\mathcal{B}(B^+ \rightarrow J/\psi\pi^+)\mathcal{B}(J/\psi \rightarrow p\bar{p}))$ used in our fit.

⁴ $m_{\pi^+\pi^0} < 1.3 \text{ GeV}/c^2$.

⁵ The PDG uncertainty includes a scale factor.

⁶ Measurement of $\mathcal{B}(B^+ \rightarrow p\bar{p}K^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2 / (\mathcal{B}(B^+ \rightarrow J/\psi K^+)\mathcal{B}(J/\psi \rightarrow p\bar{p}))$ used in our fit.

⁷ Pentaquark candidate.

⁸ Measurement of $(\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}(1520))\mathcal{B}(\bar{\Lambda}(1520) \rightarrow K^+p)) / (\mathcal{B}(B^+ \rightarrow J/\psi K^+)\mathcal{B}(J/\psi \rightarrow p\bar{p}))$ used in our fit.

Table 28: Branching fractions of charmless baryonic B^+ decays (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^*(892)^+)$	Belle [164]	$3.38^{+0.73}_{-0.60} \pm 0.39$ ¹
	BaBar [158]	$5.3 \pm 1.5 \pm 1.3$ ²
$\mathcal{B}(B^+ \rightarrow f_J(2220)K^*(892)^+) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$	BaBar [158]	< 0.77
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0)$	LHCb [165]	$0.24^{+0.10}_{-0.08} \pm 0.03$
	Belle [166]	< 0.32
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^0)$	Belle [167]	$3.00^{+0.61}_{-0.53} \pm 0.33$
$\mathcal{B}(B^+ \rightarrow p\bar{\Sigma}(1385)^0)$	Belle [167]	< 0.47
$\mathcal{B}(B^+ \rightarrow \Delta(1232)^+\bar{\Lambda}^0)$	Belle [167]	< 0.82
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^+\pi^-)$	Belle [168]	$11.28^{+0.91}_{-0.72} \pm 1.03$
		$11.3^{+1.4}_{-1.3}$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^+\pi^-(\text{NR}))$	Belle [168]	$5.92^{+0.88}_{-0.84} \pm 0.69$
		5.9 ± 1.1
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\rho^0(770)) \times \mathcal{B}(\rho^0(770) \rightarrow \pi^+\pi^-)$	Belle [168]	$4.78^{+0.67}_{-0.64} \pm 0.60$
		4.8 ± 0.9
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0f_2(1270)) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	Belle [168]	$2.03^{+0.77}_{-0.72} \pm 0.27$
		2.0 ± 0.8
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0K^+K^-)$	Belle [169]	$4.10^{+0.45}_{-0.43} \pm 0.50$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\phi(1020))$	Belle [169]	$0.795 \pm 0.209 \pm 0.077$
$\mathcal{B}(B^+ \rightarrow \bar{p}\Lambda^0K^+K^-)$	Belle [169]	$3.70^{+0.39}_{-0.37} \pm 0.44$
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0\pi^+)$	Belle [170]	< 0.94 ^{3,4}
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0K^+)$	Belle [170]	$3.38^{+0.41}_{-0.36} \pm 0.41$ ³
		$3.4^{+0.6}_{-0.5}$
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^+)$	Belle [170]	$2.19^{+1.13}_{-0.88} \pm 0.33$ ^{3,4}
$\mathcal{B}(B^+ \rightarrow \Lambda(1520)\bar{\Lambda}^0K^+)$	Belle [169]	$2.23 \pm 0.63 \pm 0.25$
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)\Lambda^0K^+)$	Belle [169]	< 2.08
$\mathcal{B}(B^+ \rightarrow \bar{\Delta}(1232)^0p)$	Belle [157]	< 1.38
$\mathcal{B}(B^+ \rightarrow \Delta^{++}\bar{p})$	Belle [157]	< 0.14

¹ The charmonium mass region has been vetoed.

² Charmonium decays to $p\bar{p}$ have been statistically subtracted.

³ The charmonium mass regions are vetoed.

⁴ $M_{\Lambda^0\bar{\Lambda}^0} < 2.85 \text{ GeV}/c^2$.

Table 29: Branching fractions of charmless baryonic B^0 decays (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow p\bar{p})$	LHCb [171]	$0.0127 \pm 0.0013 \pm 0.0006$ ^{1,2}
	Belle [166]	< 0.11
	BaBar [172]	< 0.27
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-)$	LHCb [173]	$2.7 \pm 0.1 \pm 0.2$ ^{3,2}
		2.7 ± 0.2 2.9 ± 0.2
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-), m_{\pi^+\pi^-} < 1.22 \text{ GeV}/c^2$	Belle [160]	$0.83 \pm 0.17 \pm 0.17$ ⁴
		0.8 ± 0.2 none
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)$	LHCb [173]	$5.9 \pm 0.3 \pm 0.5$ ^{3,2}
		5.90 ± 0.58 6.27 ± 0.52
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^0)$	Belle [164]	$2.51^{+0.35}_{-0.29} \pm 0.21$ ⁵
	BaBar [158]	$3.0 \pm 0.5 \pm 0.3$ ⁶
$\mathcal{B}(B^0 \rightarrow \Theta(1540)^+\bar{p}) \times \mathcal{B}(\Theta(1540)^+ \rightarrow pK_S^0)$ ⁷	BaBar [158]	< 0.05
	Belle [58]	< 0.23
		< 0.05
$\mathcal{B}(B^0 \rightarrow f_J(2220)K^0) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$	BaBar [158]	< 0.45
		< 0.45
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^*(892)^0)$	Belle [164]	$1.18^{+0.29}_{-0.25} \pm 0.11$ ⁵
	BaBar [158]	$1.47 \pm 0.45 \pm 0.40$ ⁶
$\mathcal{B}(B^0 \rightarrow f_J(2220)K^*(892)^0) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$		$1.24^{+0.28}_{-0.25}$
	BaBar [158]	< 0.15
		< 0.15

¹ Run I and run II combination.

² Multiple systematic uncertainties are added in quadrature.

³ $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$.

⁴ $0.46 < m_{\pi^+\pi^-} < 0.53 \text{ GeV}/c^2$ invariant mass region has been excluded.

⁵ The charmonium mass region has been vetoed.

⁶ Charmonium decays to $p\bar{p}$ have been statistically subtracted.

⁷ Pentaquark candidate.

Table 30: Branching fractions of charmless baryonic B^0 decays (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^+K^-)$	LHCb [173] $0.113 \pm 0.028 \pm 0.014$ ^{1,2}	0.113 ± 0.031 0.121 ± 0.032
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^0)$	Belle [174] $0.50 \pm 0.18 \pm 0.06$	0.50 ± 0.19
$\mathcal{B}(B^0 \rightarrow pp\bar{p}\bar{p})$	BaBar [175] < 0.2	< 0.2
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0\pi^-)$	BaBar [176] $3.07 \pm 0.31 \pm 0.23$ Belle [167] $3.23^{+0.33}_{-0.29} \pm 0.29$	3.14 ± 0.28 $3.14^{+0.29}_{-0.28}$
$\mathcal{B}(B^0 \rightarrow p\bar{\Sigma}(1385)^-)$	Belle [167] < 0.26	< 0.26
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^+\bar{p}+\text{c.c.})$	Belle [174] < 1.6	< 1.6
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^0\bar{\Lambda}^0)$	Belle [167] < 0.93	< 0.93
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0K^-)$	Belle [177] < 0.82	< 0.82
$\mathcal{B}(B^0 \rightarrow p\bar{\Sigma}^0\pi^-)$	Belle [177] < 3.8	< 3.8
$\mathcal{B}(B^0 \rightarrow \bar{\Lambda}^0\Lambda^0)$	Belle [166] < 0.32	< 0.32
$\mathcal{B}(B^0 \rightarrow \bar{\Lambda}^0\Lambda^0K^0)$	Belle [170] $4.76^{+0.84}_{-0.68} \pm 0.61$ ³	$4.8^{+1.0}_{-0.9}$
$\mathcal{B}(B^0 \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^0)$	Belle [170] $2.46^{+0.87}_{-0.72} \pm 0.34$ ³	$2.46^{+0.93}_{-0.80}$
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^0\bar{\Delta}(1232)^0)$	CLEO [90] < 1500 ⁴	< 1500
$\mathcal{B}(B^0 \rightarrow \Delta^{++}\bar{\Delta}^{--})$	CLEO [90] < 110 ⁴	< 110
$\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})$	LHCb [178] ⁵	$0.0222^{+0.0040}_{-0.0039}$ none

¹ $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$.

² Multiple systematic uncertainties are added in quadrature.

³ The charmonium mass regions are vetoed.

⁴ CLEO assumes $\mathcal{B}(\Upsilon(4S) \rightarrow B^0\bar{B}^0) = 0.43$. The result has been modified to account for a branching fraction of 0.50.

⁵ Measurement of $\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})/(\mathcal{B}(B^0 \rightarrow J/\psi K^*(892)^0)\mathcal{B}(J/\psi \rightarrow p\bar{p})\mathcal{B}(K^*(892)^0 \rightarrow K\pi)2/3)$ used in our fit.

Table 31: Baryonic relative branching fractions.

Parameter	Measurements	Average	
$\frac{\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+, m_{p\bar{p}} < 2.85 \text{ GeV}/c^2)}{\mathcal{B}(B^+ \rightarrow J/\psi\pi^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [159]	$12.0 \pm 1.2 \pm 0.3$	12.0 ± 1.2
$\frac{\mathcal{B}(B^+ \rightarrow p\bar{p}K^+)}{\mathcal{B}(B^+ \rightarrow J/\psi K^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [163]	$4.91 \pm 0.19 \pm 0.14$ ¹	4.91 ± 0.24
$\frac{\mathcal{B}(B^+ \rightarrow p\bar{p}K^+, m_{p\bar{p}} < 2.85 \text{ GeV}/c^2)}{\mathcal{B}(B^+ \rightarrow J/\psi\pi^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [163]	$2.02 \pm 0.10 \pm 0.08$	2.02 ± 0.13
$\frac{\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)p) \times \mathcal{B}(\bar{\Lambda}(1520) \rightarrow K^+\bar{p})}{\mathcal{B}(B^+ \rightarrow J/\psi\pi^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [159]	$0.033 \pm 0.005 \pm 0.007$	0.033 ± 0.009
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+K^-)}{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)}$	LHCb [173]	$0.019 \pm 0.005 \pm 0.002$ ²	0.019 ± 0.005
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-)}{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)}$	LHCb [173]	$0.46 \pm 0.02 \pm 0.02$ ²	0.46 ± 0.03
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \mathcal{B}(J/\psi \rightarrow p\bar{p}) \mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}$	LHCb [178]	$0.0124 \pm 0.0021 \pm 0.0004$	0.0124 ± 0.0021
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})}{\mathcal{B}(B^0 \rightarrow J/\psi\phi) \mathcal{B}(J/\psi \rightarrow p\bar{p}) \mathcal{B}(\phi \rightarrow K^+K^-)}$	LHCb [178]	$0.021 \pm 0.009 \pm 0.002$	0.0210 ± 0.0092

¹ Includes contribution where $p\bar{p}$ is produced in charmonium decays.

² $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$.

Measurements that are not included in the tables:

- In Ref. [179], Belle searches for B^0 mesons decaying into a final state containing a Λ baryon and missing energy. Upper limits on the branching fractions are set in the range $2.1 - 3.8 \times 10^{-5}$.

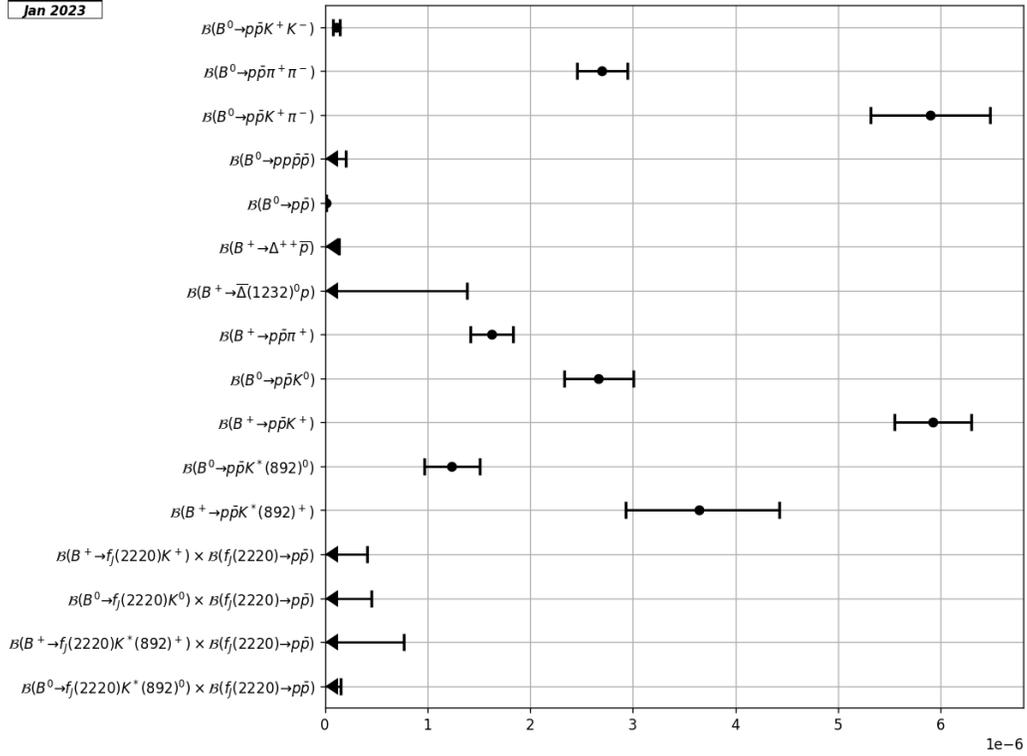


Figure 2: Branching fractions of charmless baryonic B^+ and B^0 decays into nonstrange baryons.

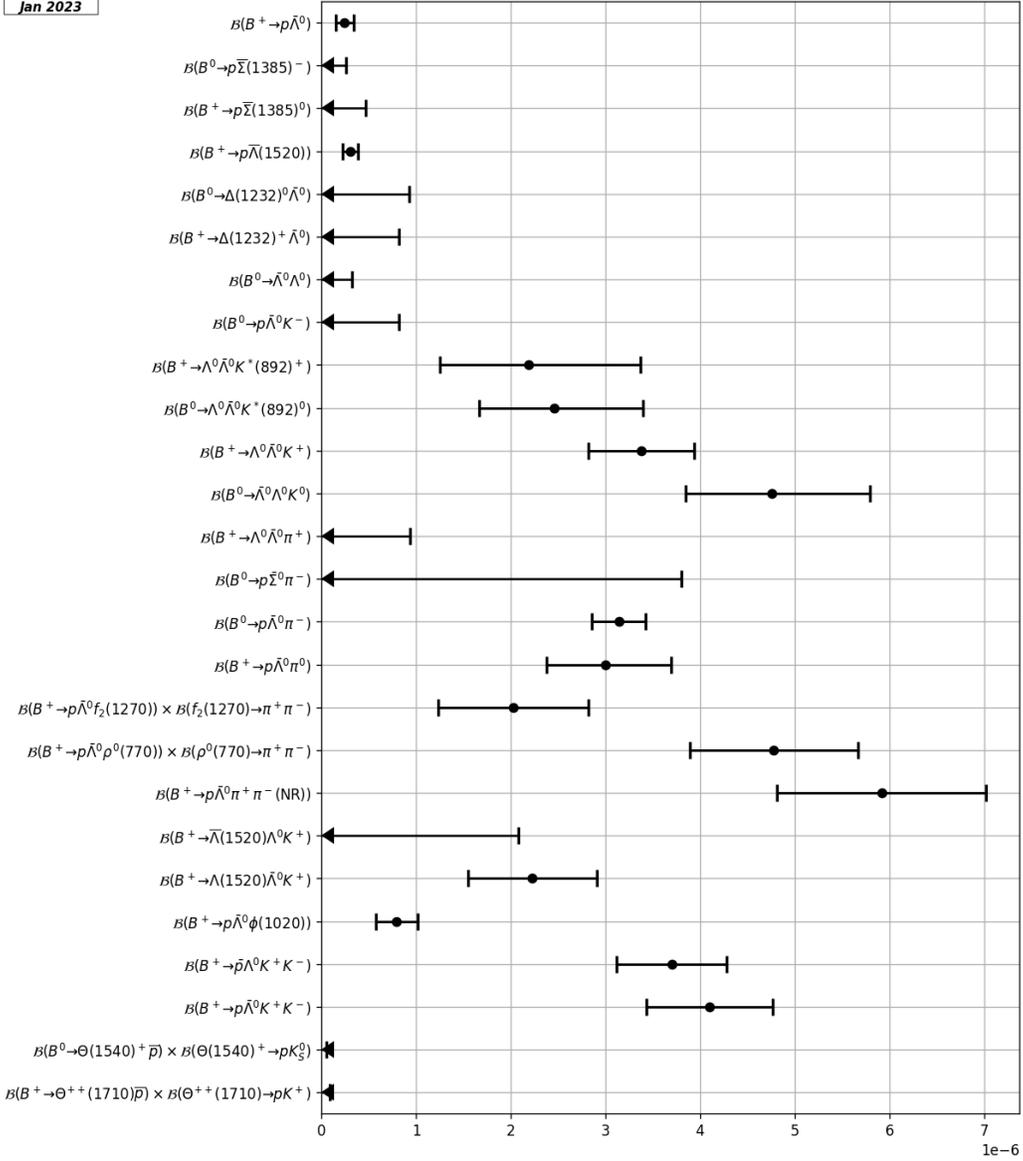


Figure 3: Branching fractions of charmless baryonic B^+ and B^0 decays into strange baryons.

3 Decays of b baryons

A compilation of branching fractions of Λ_b^0 baryon decays is given in Tables 32 and 33. Table 34 provides the partial branching fractions of $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$ decays in intervals of $q^2 = m^2(\mu^+ \mu^-)$. Compilations of branching fractions of Ξ_b^0 , Ξ_b^- and Ω_b^- baryon decays are given in Tables 35, 36, and 37, respectively. Finally, ratios of branching fractions of Λ_b^0 , Ξ_b^0 and Ω_b^- baryon decays are detailed in Tables 38, 39 and 40, respectively. Figure 4 shows a graphic representation of branching fractions of Λ_b^0 decays.

Table 32: Branching fractions of charmless Λ_b^0 decays (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(\Lambda_b^0 \rightarrow p \bar{K}^0 \pi^-)$	LHCb [108] $12.4 \pm 2.0 \pm 3.6$ ^{1,2}	12.4 ± 4.2 12.6 ± 4.1
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^0 K^-)$	LHCb [108] < 3.5 ²	< 3.5
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^-)^3$	LHCb [95] $4.68 \pm 0.44 \pm 0.95$ ⁴ CDF [92] ⁵	$4.5^{+0.9}_{-0.8}$ 4.5 ± 0.8
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^-)^3$	CDF [92] $6.3 \pm 1.2 \pm 0.8$ LHCb [95] ⁶	5.4 ± 1.1 5.4 ± 1.0
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \mu^+ \mu^-)$	LHCb [180] $0.955 \pm 0.186 \pm 0.249$ ^{1,7} CDF [181] $1.520 \pm 0.366 \pm 0.387$ ⁷	$1.09^{+0.34}_{-0.29}$ 1.08 ± 0.28
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^- \mu^+ \mu^-)$	LHCb [182] ⁸	$0.068^{+0.027}_{-0.023}$ $0.069^{+0.025}_{-0.024}$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- e^+ e^-)$	LHCb [183] $0.314^{+0.045}_{-0.042} {}^{+0.064}_{-0.055}$ ^{9,10}	$0.31^{+0.08}_{-0.07}$ $0.31^{+0.07}_{-0.06}$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- \mu^+ \mu^-)$	LHCb [183] $0.269 \pm 0.013^{+0.052}_{-0.044}$ ^{11,10}	$0.269^{+0.054}_{-0.045}$ $0.265^{+0.051}_{-0.041}$

¹ Multiple systematic uncertainties are added in quadrature.

² Using $\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$.

³ The PDG average is a result of a fit including input from other measurements.

⁴ Using $\mathcal{B}(\Lambda_b^0 \rightarrow p K^-)$.

⁵ Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^-)/\mathcal{B}(B^0 \rightarrow K^+ \pi^-))(f_{\Lambda_b^0}/f_d)$ used in our fit.

⁶ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^-)/\mathcal{B}(\Lambda_b^0 \rightarrow p K^-)$ used in our fit.

⁷ Using $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda^0)$.

⁸ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^- \mu^+ \mu^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi p \pi^-)\mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-))$ used in our fit.

⁹ Measured in the $m_{\ell^+ \ell^-}^2$ bin $[0.1, 6.0]$ GeV^2/c^4 and for $m_{pK} < 2.6$ GeV/c^2 .

¹⁰ Using $\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi p K^-)$.

¹¹ measured in the $m_{\ell^+ \ell^-}^2$ bin $[0.1, 6.0]$ GeV^2/c^4 and for $m_{pK} < 2.6$ GeV/c^2 .

Table 33: Branching fractions of charmless Λ_b^0 decays (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \gamma)$	LHCb [184] ¹	6.9 ± 1.5 7.1 ± 1.7
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \eta)$	LHCb [99]	$9.23^{+7.15}_{-5.20} \pm 0.40$ ² $9.2^{+7.2}_{-5.2}$ $9.4^{+7.3}_{-5.3}$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \eta')$	LHCb [99]	< 3.05 ² < 3.1
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \pi^+ \pi^-)$	LHCb [185] ³	4.7 ± 1.9 4.6 ± 1.9
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ \pi^-)$	LHCb [185] ⁴	$5.7^{+1.3}_{-1.2}$ 5.6 ± 1.2
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ K^-)$	LHCb [185] ⁵	$16.1^{+2.4}_{-2.2}$ 16.0 ± 2.2
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \phi(1020))$	LHCb [122] ⁶	$10.1^{+2.9}_{-2.5}$ 9.8 ± 2.6
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^+ \pi^- \pi^-)$	LHCb [186] ^{7,8,9}	$21.1^{+2.4}_{-2.3}$ 21.0 ± 2.2
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ \pi^-)$	LHCb [186] ^{8,10}	$4.06^{+0.66}_{-0.61}$ 4.04 ± 0.61
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- \pi^+ \pi^-)$	LHCb [186] ^{8,11}	$50.5^{+5.6}_{-5.3}$ 50.2 ± 5.1
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ K^-)$	LHCb [186] ^{8,12}	$12.6^{+1.5}_{-1.4}$ 12.6 ± 1.3

¹ Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \gamma)/\mathcal{B}(B^0 \rightarrow K^*(892)^0 \gamma)) \frac{f_{\Lambda_b^0}}{f_d}$ used in our fit.

² Using $\mathcal{B}(B^0 \rightarrow \eta' K^0)$.

³ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \pi^+ \pi^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 \pi^+))$ used in our fit.

⁴ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ \pi^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 \pi^+))$ used in our fit.

⁵ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ K^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 \pi^+))$ used in our fit.

⁶ Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \phi(1020))/\mathcal{B}(B^0 \rightarrow \phi(1020) K^0))(f_{\Lambda_b^0}/f_d)2$ used in our fit.

⁷ Vetoes on charm and charmonium resonances are applied.

⁸ Multiple systematic uncertainties are added in quadrature.

⁹ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^+ \pi^- \pi^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

¹⁰ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ \pi^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

¹¹ Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p K^- \pi^+ \pi^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

¹² Measurement of $\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ K^-)/(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-)\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

Table 34: Partial branching fractions of $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$ decays in intervals of $m_{\mu^+ \mu^-}^2$.

Parameter [10^{-7}]	Measurements	Average ^{HFLAV} _{PDG}
$m_{\mu^+ \mu^-}^2 < 2.0 \text{ GeV}^2/c^4$	LHCb [187]	$0.72^{+0.24}_{-0.22} \pm 0.14$
	CDF [181]	$0.15 \pm 2.01 \pm 0.05$
$2.0 < m_{\mu^+ \mu^-}^2 < 4.3 \text{ GeV}^2/c^4$	LHCb [187]	$0.253^{+0.276}_{-0.207} \pm 0.046$
	CDF [181]	$1.84 \pm 1.66 \pm 0.59$
$4.3 < m_{\mu^+ \mu^-}^2 < 8.68 \text{ GeV}^2/c^4$	LHCb [180]	$0.66 \pm 0.72 \pm 0.16$
	CDF [181]	$-0.20 \pm 1.64 \pm 0.08$
$10.09 < m_{\mu^+ \mu^-}^2 < 12.86 \text{ GeV}^2/c^4$	LHCb [187]	$2.08^{+0.42}_{-0.39} \pm 0.42$
	CDF [181]	$2.97 \pm 1.47 \pm 0.95$
$14.18 < m_{\mu^+ \mu^-}^2 < 16.00 \text{ GeV}^2/c^4$	LHCb [187]	$2.04^{+0.35}_{-0.33} \pm 0.42$
	CDF [181]	$0.96 \pm 0.73 \pm 0.31$
$m_{\mu^+ \mu^-}^2 > 16.00 \text{ GeV}^2/c^4$	CDF [181]	$6.97 \pm 1.88 \pm 2.23$

Table 35: Branching fractions of charmless Ξ_b^0 decays.

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\frac{f_{\Xi_b^0}}{f_d} \mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 \pi^-)$	LHCb [108] < 1.5 ¹	< 1.5 < 1.6
$\frac{f_{\Xi_b^0}}{f_d} \mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 K^-)$	LHCb [108] < 1.0 ¹	< 0.99 < 1.10
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda \pi^+ \pi^-)$	LHCb [185] < 1.7	< 1.7
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda K^- \pi^+)$	LHCb [185] < 0.8	< 0.8
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda K^+ K^-)$	LHCb [185] < 0.3	< 0.3
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ \pi^-)$	LHCb [186] ^{2,3}	1.91 ^{+0.41} _{-0.38} 1.91 \pm 0.40
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^- K^- \pi^+)$	LHCb [186] ^{2,4}	1.72 ^{+0.33} _{-0.30} 1.73 \pm 0.32
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^+ K^- K^-)$	LHCb [186] ^{2,5}	0.18 \pm 0.10

¹ Using $\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$.

² Multiple systematic uncertainties are added in quadrature.

³ Measurement of $\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ \pi^-) / (\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

⁴ Measurement of $\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^- K^- \pi^+) / (\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

⁵ Measurement of $\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^+ K^- K^-) / (\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+))$ used in our fit.

Table 36: Relative branching fractions of charmless Ξ_b^- decays.

Parameter [10^{-2}]	Measurements	Average	
$\frac{f_{\Xi_b^-}}{f_u} \frac{\mathcal{B}(\Xi_b^- \rightarrow pK^-K^-)}{\mathcal{B}(B^- \rightarrow K^+K^-K^-)}$	LHCb [61]	$0.2650 \pm 0.0350 \pm 0.0470$	0.265 ± 0.059
$\frac{f_{\Xi_b^-}}{f_u} \frac{\mathcal{B}(\Xi_b^- \rightarrow p\pi^-\pi^-)}{\mathcal{B}(B^- \rightarrow K^+K^-K^-)}$	LHCb [61]	< 0.1470	< 0.15
$\frac{f_{\Xi_b^-}}{f_u} \frac{\mathcal{B}(\Xi_b^- \rightarrow pK^-\pi^-)}{\mathcal{B}(B^- \rightarrow K^+K^-K^-)}$	LHCb [61]	$0.2590 \pm 0.0640 \pm 0.0490$	0.259 ± 0.081
$\frac{\mathcal{B}(\Xi_b^- \rightarrow p\pi^-\pi^-)}{\mathcal{B}(\Xi_b^- \rightarrow pK^-K^-)}$	LHCb [61]	< 56	< 56
$\frac{\mathcal{B}(\Xi_b^- \rightarrow pK^-\pi^-)}{\mathcal{B}(\Xi_b^- \rightarrow pK^-K^-)}$	LHCb [61]	$98 \pm 27 \pm 9$	98 ± 28
$\frac{\mathcal{B}(\Xi_b^- \rightarrow \Xi^- \gamma)}{\mathcal{B}(\Xi_b^- \rightarrow \Xi^- J/\psi)}$	LHCb [188]	< 8	< 8.0

 Table 37: Branching fractions of charmless Ω_b^- decays.

Parameter [10^{-8}]	Measurements	Average	
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-K^-)$	LHCb [61]	$< 0.61^1$	< 0.61
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-\pi^-)$	LHCb [61]	$< 1.73^1$	< 1.7
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow p\pi^-\pi^-)$	LHCb [61]	$< 3.69^1$	< 3.7

¹ Using $\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$.

Table 38: Relative branching fractions of charmless Λ_b^0 decays.

Parameter	Measurements	Average	
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-)}$	LHCb [95]	$0.86 \pm 0.08 \pm 0.05$	0.86 ± 0.09
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\eta)}{\mathcal{B}(B^0 \rightarrow \eta'K^0)}$	LHCb [99]	$0.142^{+0.110}_{-0.080}$	$0.14^{+0.11}_{-0.08}$
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-)}{\mathcal{B}(B^0 \rightarrow K^+\pi^-)}$	CDF [92]	$0.042 \pm 0.007 \pm 0.006$	0.042 ± 0.009
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-)}{\mathcal{B}(B^0 \rightarrow K^+\pi^-)}$	CDF [92]	$0.066 \pm 0.009 \pm 0.008$	0.066 ± 0.012
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\phi)}{\mathcal{B}(B^0 \rightarrow K_S^0\phi)}$	LHCb [122]	$0.55 \pm 0.11 \pm 0.04$	0.55 ± 0.12
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi p\pi^-) \times \mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)}$	LHCb [182]	$0.044 \pm 0.012 \pm 0.007$	0.044 ± 0.014
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [185]	$0.073 \pm 0.019 \pm 0.022$	0.073 ± 0.029
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [185]	$0.089 \pm 0.012 \pm 0.013$	0.089 ± 0.018
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [185]	$0.253 \pm 0.019 \pm 0.019$	0.253 ± 0.027
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [186]	$0.0685 \pm 0.0019 \pm 0.0033^1$	0.0685 ± 0.0038
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [186]	$0.164 \pm 0.003 \pm 0.007^1$	0.164 ± 0.008
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-K^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [186]	$0.0132 \pm 0.0009 \pm 0.0013^1$	0.0132 ± 0.0016
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-K^+K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [186]	$0.0411 \pm 0.0012 \pm 0.0020^1$	0.0411 ± 0.0023
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\bar{K}^0\pi^-)}{\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)}$	LHCb [108]	$0.25 \pm 0.04 \pm 0.07^1$	0.25 ± 0.08
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\bar{K}^0K^-)}{\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)}$	LHCb [108]	< 0.07	< 0.07
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)}$	LHCb [180]	$0.00154 \pm 0.00030 \pm 0.00020^1$	0.00154 ± 0.00036
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-e^+e^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi pK^-)}$	LHCb [183]	$0.00098^{+0.00014}_{-0.00013} \pm 0.00008^2$	0.00098 ± 0.00016
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi pK^-)}$	LHCb [183]	$0.00084 \pm 0.00004 \pm 0.00004^2$	0.000840 ± 0.000057
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-e^+e^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-)}$	LHCb [183]	$1.17^{+0.18}_{-0.16} \pm 0.07^2$	$1.17^{+0.19}_{-0.17}$

¹ Multiple systematic uncertainties are added in quadrature.

² Measured in the $m_{\ell^+\ell^-}$ bin $[0.1, 6.0]$ GeV^2/c^4 and for $m_{pK} < 2.6$ GeV/c^2 .

Table 39: Relative branching fractions of charmless Ξ_b^0 decays.

Parameter [10^{-2}]	Measurements	Average
$\frac{f_{\Xi_b^0}}{f_d} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 \pi^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [108] < 3	< 3.0
$\frac{f_{\Xi_b^0}}{f_d} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 K^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [108] < 2	< 2.0
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p K^- K^+ K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)}$	LHCb [186] $0.057 \pm 0.028 \pm 0.013$ ¹	0.057 ± 0.031
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ \pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)}$	LHCb [186] $0.62 \pm 0.08 \pm 0.08$ ¹	0.62 ± 0.11
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)}$	LHCb [186] $0.56 \pm 0.06 \pm 0.06$ ¹	0.560 ± 0.088

¹ Multiple systematic uncertainties are added in quadrature.

Table 40: Relative branching fractions of charmless Ω_b^- decays.

Parameter [10^{-3}]	Measurements	Average
$\frac{f_{\Omega_b^-}}{f_u} \frac{\mathcal{B}(\Omega_b^- \rightarrow p K^- K^-)}{\mathcal{B}(B^- \rightarrow K^+ K^- K^-)}$	LHCb [61] < 0.180	< 0.18
$\frac{f_{\Omega_b^-}}{f_u} \frac{\mathcal{B}(\Omega_b^- \rightarrow p \pi^- \pi^-)}{\mathcal{B}(B^- \rightarrow K^+ K^- K^-)}$	LHCb [61] < 1.090	< 1.1
$\frac{f_{\Omega_b^-}}{f_u} \frac{\mathcal{B}(\Omega_b^- \rightarrow p K^- \pi^-)}{\mathcal{B}(B^- \rightarrow K^+ K^- K^-)}$	LHCb [61] < 0.510	< 0.51

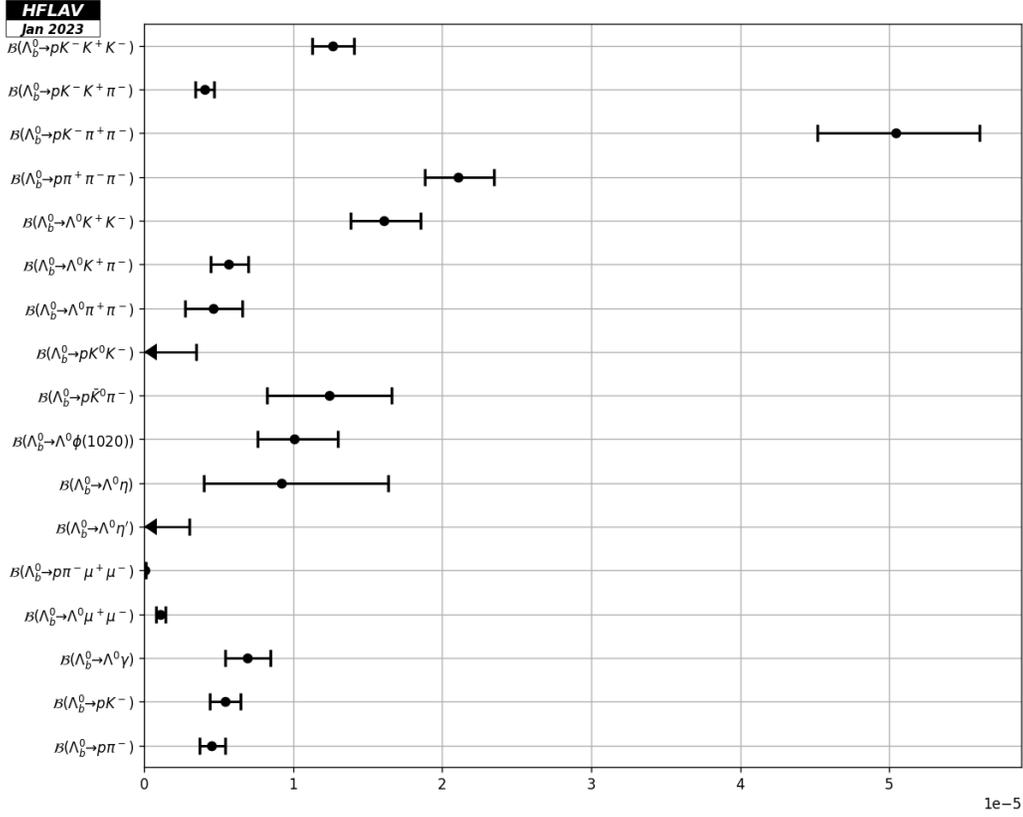


Figure 4: Branching fractions of charmless Λ_b^0 decays.

Measurements that are not included in the tables:

- In Ref. [189], LHCb measures angular observables of the decay $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$, including the lepton-side, hadron-side and combined forward-backward asymmetries of the decay in the low recoil region $15 < m^2(\ell\ell) < 20 \text{ GeV}^2/c^4$.
- In Ref. [190], LHCb performs a search for baryon-number-violating Ξ_b^0 oscillations and set an upper limit of $\omega < 0.08 \text{ ps}^{-1}$ on the oscillation rate.
- In Ref. [191], LHCb measures the photon polarization in $\Lambda_b \rightarrow \Lambda \gamma$ decays to be $\alpha_\gamma = 0.82^{+0.17}_{-0.26} {}^{+0.04}_{-0.13}$.

4 Decays of B_s^0 mesons

Tables 41 to 45 and 46 to 47 detail branching fractions and relative branching fractions of B_s^0 meson decays, respectively. Figures 5 and 6 show graphic representations of a selection of results given in this section.

Table 41: Branching fractions of charmless B_s^0 decays (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-)$	Belle [192] < 12 CDF [94] ¹ LHCb [96] ¹	$0.72^{+0.11}_{-0.10}$ 0.70 ± 0.10
$\mathcal{B}(B_s^0 \rightarrow \pi^0\pi^0)$	Belle [193] < 7.7	< 7.7 < 210.0
$\mathcal{B}(B_s^0 \rightarrow \eta\pi^0)$	L3 [194] < 1000	< 1000
$\mathcal{B}(B_s^0 \rightarrow \eta\eta)$	Belle [195] < 144 ²	< 144 < 143
$f_s \times \mathcal{B}(B_s^0 \rightarrow \eta\eta)$	Belle [195] < 29	< 29 none
$\mathcal{B}(B_s^0 \rightarrow \rho^0(770)\rho^0(770))$	SLD [196] < 320	< 320
$\mathcal{B}(B_s^0 \rightarrow \eta'\eta')$	LHCb [15] $32.4 \pm 6.2 \pm 3.0$ ³	32 ± 7 33 ± 7
$\mathcal{B}(B_s^0 \rightarrow \eta'\phi(1020))$	LHCb [197] < 0.82	< 0.82
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	LHCb [141] $1.12 \pm 0.16 \pm 0.14$ ⁴	1.12 ± 0.21
$\mathcal{B}(B_s^0 \rightarrow f_2(1270)\phi(1020)) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	LHCb [141] $0.61 \pm 0.13^{+0.13}_{-0.08}$ ⁴	$0.61^{+0.19}_{-0.15}$ $0.61^{+0.18}_{-0.15}$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\rho^0(770))$	LHCb [141] $0.27 \pm 0.07 \pm 0.03$ ⁴	0.27 ± 0.08
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\pi^+\pi^-)$	LHCb [141] $3.48 \pm 0.23 \pm 0.39$ ^{5,4}	3.48 ± 0.45
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [130] $18.5 \pm 0.5 \pm 1.6$ ^{4,6} CDF [198] $18.5 \pm 1.5 \pm 2.2$ ⁷	18.5 ± 1.4
$\mathcal{B}(B_s^0 \rightarrow K^-\pi^+)$	Belle [192] < 26 CDF [92] ⁸ LHCb [95] ⁸	$5.9^{+0.9}_{-0.8}$ 5.8 ± 0.7
$\mathcal{B}(B_s^0 \rightarrow K^+K^-)$	Belle [192] $38^{+10}_{-9} \pm 7$ ⁴ CDF [93] ⁹ LHCb [95] ⁹	$26.6^{+3.2}_{-2.7}$ 26.6 ± 2.2
$\mathcal{B}(B_s^0 \rightarrow K^0\bar{K}^0)$	LHCb [123] $16.7 \pm 2.9 \pm 2.1$ ^{4,10} Belle [199] $19.6^{+5.8}_{-5.1} \pm 2.2$ ⁴	17.4 ± 3.1 $17.6^{+3.2}_{-3.1}$

¹ Measurement of $(\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

² Using f_s .

³ Using $\mathcal{B}(B^+ \rightarrow \eta'K^+)$.

⁴ Multiple systematic uncertainties are added in quadrature.

⁵ $400 < M(\pi^+\pi^-) < 1600$ MeV/ c^2 .

⁶ Using $\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)$.

⁷ Using $\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))$.

⁸ Measurement of $(\mathcal{B}(B_s^0 \rightarrow K^-\pi^+)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

⁹ Measurement of $(\mathcal{B}(B_s^0 \rightarrow K^+K^-)/\mathcal{B}(B^0 \rightarrow K^+\pi^-))\frac{f_s}{f_d}$ used in our fit.

¹⁰ Using $\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)$.

Table 42: Branching fractions of charmless B_s^0 decays (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B_s^0 \rightarrow K^0 \pi^+ \pi^-)$	LHCb [110] $9.49 \pm 1.34 \pm 1.67$ ^{1,2}	9.5 ± 2.1
$\mathcal{B}(B_s^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})$	LHCb [110] $84.5 \pm 3.5 \pm 8.0$ ^{1,2}	84.5 ± 8.7 84.5 ± 8.8
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^- \pi^+)$	LHCb [112] $2.98 \pm 0.99 \pm 0.42$ ³	3.0 ± 1.1 _{p=1.6%} 2.9 ± 1.1
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^+ K^- + \text{c.c.})$	LHCb [200] $18.6 \pm 1.2 \pm 4.5$ ^{4,5}	18.6 ± 4.7
$\mathcal{B}(B_s^0 \rightarrow (K\pi)_0^{*+} K^- + \text{c.c.})$	LHCb [200] $24.9 \pm 1.8 \pm 20.2$ ^{4,5}	25 ± 20 none
$\mathcal{B}(B_s^0 \rightarrow K_0^*(1430)^+ K^- + \text{c.c.})$	LHCb [200] $31.3 \pm 2.3 \pm 25.3$ ^{4,5}	31 ± 25
$\mathcal{B}(B_s^0 \rightarrow K_2^*(1430)^+ K^- + \text{c.c.})$	LHCb [200] $10.3 \pm 2.5 \pm 16.4$ ^{4,5}	10 ± 17
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^0 + \text{c.c.})$	LHCb [200] $19.8 \pm 2.8 \pm 5.0$ ^{4,5}	19.8 ± 5.7
$\mathcal{B}(B_s^0 \rightarrow (K\pi)_0^{*0} \bar{K}^0 + \text{c.c.})$	LHCb [200] $26.2 \pm 2.0 \pm 7.8$ ^{4,5}	26.2 ± 8.1 none
$\mathcal{B}(B_s^0 \rightarrow K_0^*(1430)^0 \bar{K}^0 + \text{c.c.})$	LHCb [200] $33.0 \pm 2.5 \pm 9.8$ ^{4,5}	33 ± 10
$\mathcal{B}(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}^0 + \text{c.c.})$	LHCb [200] $16.8 \pm 4.5 \pm 21.3$ ^{4,5}	17 ± 22
$\mathcal{B}(B_s^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})$	LHCb [109] $17.1 \pm 3.6 \pm 2.4$ ^{5,6}	17.1 ± 4.3 _{p=1.6%} 16.4 ± 4.1

¹ Regions corresponding to D , Λ_c^+ and charmonium resonances are vetoed in this analysis.

² Using $\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$.

³ Using $\mathcal{B}(B^0 \rightarrow K^*(892)^+ \pi^-)$.

⁴ Result extracted from Dalitz-plot analysis of $B_s^0 \rightarrow K_S^0 K^+ \pi^-$ decays.

⁵ Multiple systematic uncertainties are added in quadrature.

⁶ Using $\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$.

Table 43: Branching fractions of charmless B_s^0 decays (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B_s^0 \rightarrow K^0 K^+ K^-)$	LHCb [110] $1.29 \pm 0.55 \pm 0.36$ ^{1,2}	1.29 ± 0.66 1.29 ± 0.65
$\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \rho^0(770))$	SLD [196] < 767	< 767
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)$	LHCb [129] $11.2 \pm 2.2 \pm 1.5$ ^{3,4} LHCb [133] ^{3,5}	11.0 ± 2.0 11.1 ± 2.7
$\mathcal{B}(B_s^0 \rightarrow \phi(1020) \bar{K}^*(892)^0)$	LHCb [128] $1.14 \pm 0.24 \pm 0.17$ ^{3,4}	1.14 ± 0.29 1.14 ± 0.30
$\mathcal{B}(B_s^0 \rightarrow p\bar{p})$	LHCb [171] < 0.0044	< 0.0044 < 0.0150
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+K^-)$	LHCb [173] $4.2 \pm 0.3 \pm 0.4$ ^{6,3}	4.2 ± 0.5 4.5 ± 0.5
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+\pi^-)$	LHCb [173] $1.3 \pm 0.2 \pm 0.2$ ^{6,3}	1.3 ± 0.3 1.4 ± 0.3
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}\pi^+\pi^-)$	LHCb [173] < 0.66 ⁶	< 0.66 0.43 ± 0.20
$\mathcal{B}(B_s^0 \rightarrow p\bar{\Lambda}^0 K^- + \text{c.c.})$	LHCb [201] $5.46 \pm 0.61 \pm 0.82$ ³	5.5 ± 1.0
$\mathcal{B}(B_s^0 \rightarrow \gamma\gamma)$	Belle [202] < 3.1	< 3.1
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\gamma)$	LHCb [203] $34.1 \pm 1.7 \pm 3.1$ ⁷ Belle [202] $36.0 \pm 5.0 \pm 7.0$	34.4 ± 3.3 34.2 ± 3.6

¹ Regions corresponding to D , Λ_c^+ and charmonium resonances are vetoed in this analysis.

² Using $\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)$.

³ Multiple systematic uncertainties are added in quadrature.

⁴ Using $\mathcal{B}(B^0 \rightarrow \phi(1020) K^*(892)^0)$.

⁵ Measurement of $\mathcal{B}(B^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0) / \mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)$ used in our fit.

⁶ $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$.

⁷ Using $\mathcal{B}(B^0 \rightarrow K^*(892)^0 \gamma)$.

Table 44: Branching fractions of charmless B_s^0 decays (part 4).

Parameter [10 ⁻⁶]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)^1$	CMS [204]	$0.00383^{+0.00038}_{-0.00036} {}^{+0.00024}_{-0.00021} {}^2$
	LHCb [205]	$0.00309^{+0.00046}_{-0.00043} {}^{+0.00015}_{-0.00011}$
	ATLAS [206]	$0.0028^{+0.0008}_{-0.0007}$
	CDF [207]	$0.013^{+0.009}_{-0.007}$
		0.00345 ± 0.00029
$\mathcal{B}(B_s^0 \rightarrow e^+e^-)$	LHCb [208]	< 0.0094
	CDF [209]	< 0.28
	Belle [210]	< 15.3
		< 0.0094
$\mathcal{B}(B_s^0 \rightarrow \tau^+\tau^-)^3$	LHCb [211]	< 5200
		< 6800
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-\gamma)^4$	LHCb [205]	$< 0.0015 {}^5$
		none
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-\mu^+\mu^-)$	LHCb [212]	$< 0.00086 {}^6$
		< 0.00250
$\mathcal{B}(B_s^0 \rightarrow aa) \times \mathcal{B}(a \rightarrow \mu^+\mu^-) \times \mathcal{B}(a \rightarrow \mu^+\mu^-)$	LHCb [212]	$< 0.00058 {}^{7,8,6}$
		none
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\mu^+\mu^-)^{9,10}$	LHCb [213]	$0.832 \pm 0.022^{+0.035}_{-0.036} {}^{2,11}$
	CDF [181]	$1.18 \pm 0.20^{+0.08}_{-0.09} {}^{11}$
		$0.838^{+0.042}_{-0.041}$
$\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0\mu^+\mu^-)$	LHCb [214]	$0.029 \pm 0.010 \pm 0.004 {}^2$
		0.029 ± 0.011
$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)$	LHCb [155] ^{12,13}	0.084 ± 0.016
		0.084 ± 0.017
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\nu\bar{\nu})$	DELPHI [113]	< 5400
		< 5400

¹ The ATLAS measurement is correlated with $\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$. This correlation is not taken into account in our average. For more information see Ref. [215].

² Multiple systematic uncertainties are added in quadrature.

³ PDG shows the result obtained at 95% CL.

⁴ $m_{\mu\mu} > 4.9 \text{ GeV}/c^2$.

⁵ with $m_{\mu^+\mu^-} > 4.9 \text{ GeV}/c^2$.

⁶ At CL=95 %.

⁷ The mass windows corresponding to ϕ and charmonium resonances decaying to $\mu\mu$ are vetoed.

⁸ a is a promptly decaying scalar particle with a mass of $1 \text{ GeV}/c^2$

⁹ The PDG uncertainty includes a scale factor.

¹⁰ Treatment of charmonium intermediate components differs between the results.

¹¹ Using $\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))$.

¹² $0.5 < m_{\pi^+\pi^-} < 1.3 \text{ GeV}/c^2$.

¹³ Measurement of $\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)/(\mathcal{B}(B^0 \rightarrow J/\psi K^*(892)^0)\mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)\mathcal{B}(K^*(892)^0 \rightarrow K\pi)2/3)$ used in our fit.

Table 45: Branching fractions of charmless B_s^0 decays (part 5).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B_s^0 \rightarrow e^+\mu^- + \text{c.c.})$	LHCb [216] < 0.0054 CDF [209] < 0.2	< 0.0054
$\mathcal{B}(B_s^0 \rightarrow \tau^+e^- + \text{c.c.})$	Belle [217] < 1410	< 1410 none
$\mathcal{B}(B_s^0 \rightarrow \tau^+\mu^- + \text{c.c.})^1$	LHCb [218] < 34.0 Belle [217] < 370	< 34 < 42
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)e^+\mu^- + \text{c.c.})$	LHCb [219] < 0.0160	< 0.016 none
$\mathcal{B}(B_s^0 \rightarrow p\mu^-)$	LHCb [220] < 0.0121	< 0.012 none
$\mathcal{B}(B_s^0 \rightarrow \eta'\eta)$	Belle [221] < 65	< 65 none
$\mathcal{B}(B_s^0 \rightarrow f_2'(1525)\mu^+\mu^-)$	LHCb [213] $0.161 \pm 0.020 \pm 0.011$ ^{2,3}	0.161 ± 0.022 none
$\mathcal{B}(B_s^0 \rightarrow \eta' X_{s\bar{s}})$	Belle [222] < 1400 ⁴	< 1400 none
$\mathcal{B}(B_s^0 \rightarrow \eta' K_S^0)$	Belle [223] < 8.16 ⁵	< 8.2 none
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}p\bar{p})$	LHCb [178] ⁶	0.0227 ± 0.0100 none

¹ PDG shows the result obtained at 95% CL.

² Multiple systematic uncertainties are added in quadrature.

³ Using $\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))$.

⁴ $M(X_{s\bar{s}}) < 2.4 \text{ GeV}/c^2$

⁵ Using f_s .

⁶ Measurement of $\mathcal{B}(B_s^0 \rightarrow p\bar{p}p\bar{p})/(\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))\mathcal{B}(J/\psi \rightarrow p\bar{p})\mathcal{B}(\phi(1020) \rightarrow K^+K^-))$ used in our fit.

Table 46: Relative branching fractions of charmless B_s^0 decays (part 1).

Parameter [10^{-2}]	Measurements	Average	
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K^+ \pi^-)}$	LHCb [96] CDF [94]	$0.915 \pm 0.071 \pm 0.083$ $0.8 \pm 0.2 \pm 0.1$	0.893 ± 0.098
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^-)}$	LHCb [95]	$5.0^{+1.1}_{-0.9} \pm 0.4$	$5.0^{+1.2}_{-1.0}$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))_1}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	CDF [198]	$1.78 \pm 0.14 \pm 0.20$	1.78 ± 0.24
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [130]	$184 \pm 5 \pm 13^2$	184 ± 14
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow K^+ \pi^-)}{\mathcal{B}(B_d^0 \rightarrow K^+ \pi^-)}$	LHCb [95] CDF [92]	$7.4 \pm 0.6 \pm 0.6$ $7.1 \pm 1.0 \pm 0.7$	7.30 ± 0.70
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow K^+ K^-)}{\mathcal{B}(B_d^0 \rightarrow K^+ \pi^-)}$	LHCb [95] CDF [93]	$31.6 \pm 0.9 \pm 1.9$ $34.7 \pm 2.0 \pm 2.1$	32.7 ± 1.7
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [110]	$19.1 \pm 2.7 \pm 3.3^{3,2}$	19.1 ± 4.3
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [110]	$170 \pm 7 \pm 15^{3,2}$	170 ± 16
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [110]	$< 5.1^3$	< 5.1
$\frac{\mathcal{B}(B_s^0 \rightarrow K^*(892)^- \pi^+)}{\mathcal{B}(B^0 \rightarrow K^*(892)^+ \pi^-)}$	LHCb [112]	$39 \pm 13 \pm 5$	39 ± 14
$\frac{\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [129]	$111 \pm 22 \pm 13^2$	111 ± 26
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\bar{K}^*(892)^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [128]	$11.3 \pm 2.4 \pm 1.6^2$	11.3 ± 2.9
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	LHCb [213] CDF [181]	$0.0800 \pm 0.0021 \pm 0.0016^2$ $0.113 \pm 0.019 \pm 0.007$	0.0806 ± 0.0026

¹ The PDG average is a result of a fit including input from other measurements.

² Multiple systematic uncertainties are added in quadrature.

³ Regions corresponding to D , Λ_c^+ and charmonium resonances are vetoed in this analysis.

Table 47: Relative branching fractions of charmless B_s^0 decays (part 2).

Parameter [10^{-2}]	Measurements		Average
$\frac{\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+\pi^-)}{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)}$	LHCb [173]	$22 \pm 4 \pm 2$ ^{1,2}	22 ± 5
$\frac{\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+\pi^-)}{\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+K^-)}$	LHCb [173]	$31 \pm 5 \pm 2$ ¹	31 ± 5
$\frac{\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi \bar{K}^*(892)^0) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)}$	LHCb [214]	$1.4 \pm 0.4 \pm 0.1$ ²	1.4 ± 0.4
$\frac{\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(\bar{B}^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}$	LHCb [214]	$3.3 \pm 1.1 \pm 0.4$ ²	3.3 ± 1.2
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020)\phi(1020))}{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))}$	LHCb [224]	$11.7 \pm 3.0 \pm 1.5$	11.7 ± 3.4
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)}$	LHCb [123]	$230 \pm 40 \pm 22$ ²	230 ± 46
$\frac{\mathcal{B}(B_s^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K_S^0 \pi^+ \pi^-)}$	LHCb [109]	$33 \pm 7 \pm 4$ ²	33 ± 8
$\frac{\mathcal{B}(B_s^0 \rightarrow f_2'(1525)\mu^+\mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	LHCb [213]	$0.0155 \pm 0.0019 \pm 0.0008$ ²	0.0155 ± 0.0021
$\frac{\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \times \mathcal{B}(J/\psi \rightarrow \mu^+\mu^-) \times \mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}$	LHCb [155]	$0.167 \pm 0.029 \pm 0.013$ ³	0.167 ± 0.032
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})}{\mathcal{B}(B^0 \rightarrow J/\psi\phi)\mathcal{B}(J/\psi \rightarrow p\bar{p})\mathcal{B}(\phi \rightarrow K^+K^-)}$	LHCb [178]	$2.1 \pm 0.9 \pm 0.2$	2.10 ± 0.92

¹ $m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$.

² Multiple systematic uncertainties are added in quadrature.

³ $0.5 < m_{\pi^+\pi^-} < 1.3 \text{ GeV}/c^2$.

Measurements that are not included in the tables (the definitions of observables can be found in the corresponding experimental papers):

- In Ref. [213], LHCb reports the differential $B_s^0 \rightarrow \phi \mu^+ \mu^-$ branching fraction in bins of $m^2(\mu^+ \mu^-)$.
- In Ref. [225], LHCb performs an angular analysis of $B_s^0 \rightarrow \phi \mu^+ \mu^-$ decays and reports F_L , S_3 , S_4 , S_7 , A_5 , A_{FB}^{CP} , A_8 and A_9 in bins of $m^2(\mu^+ \mu^-)$.
- In Ref. [226], LHCb reports the photon polarization in $B_s^0 \rightarrow \phi \gamma$ decays.

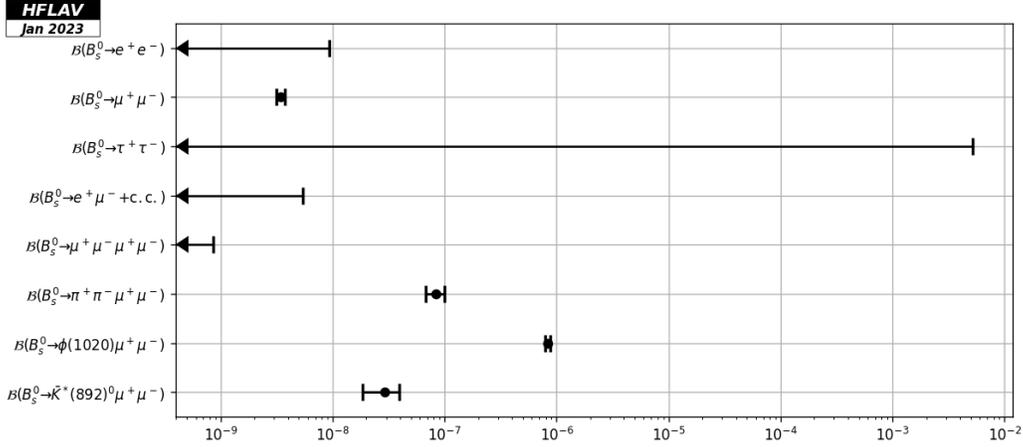


Figure 5: Branching fractions of charmless leptonic B_s^0 decays.

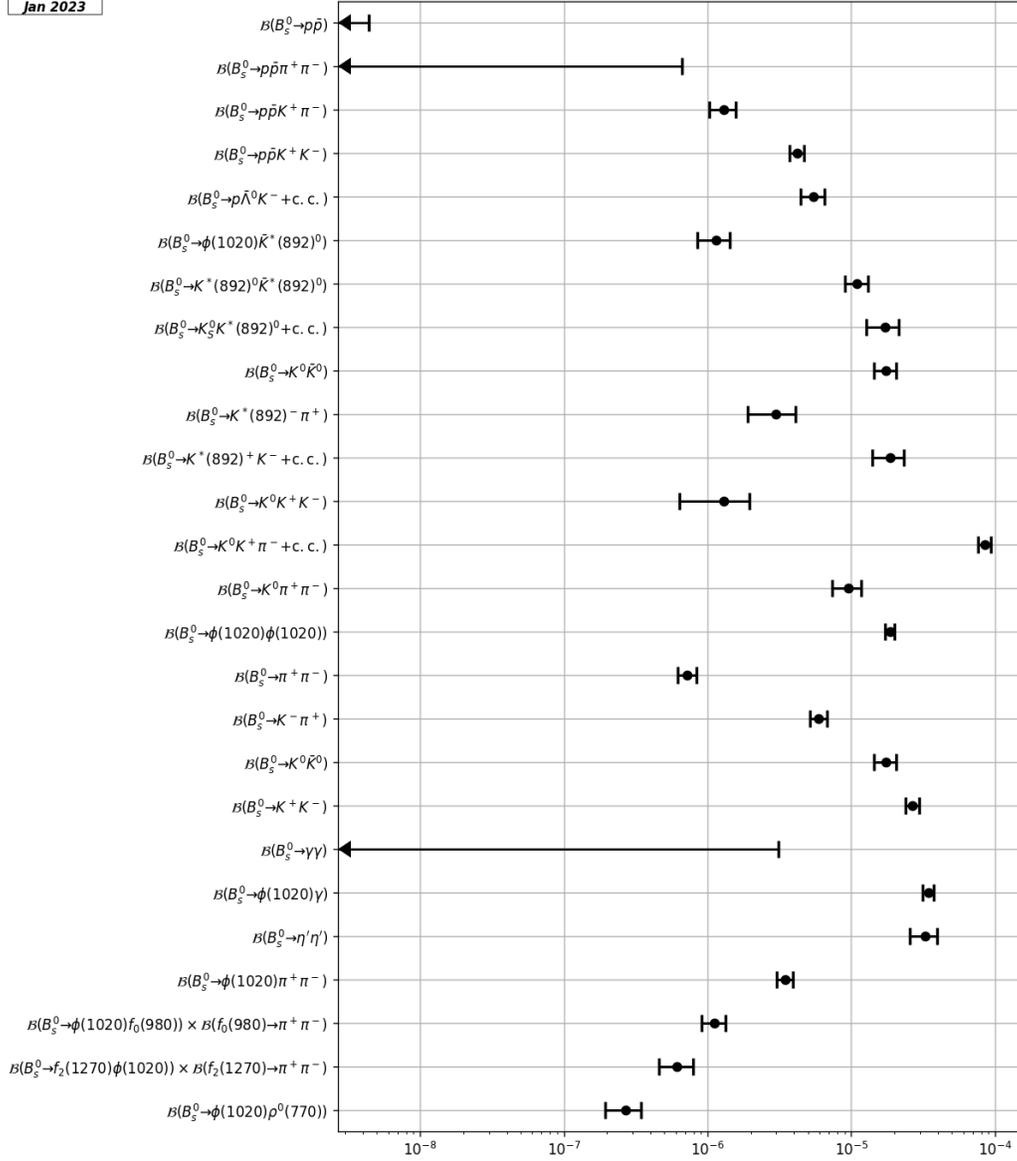


Figure 6: Branching fractions of charmless nonleptonic B_s^0 decays.

5 Decays of B_c^+ mesons

Table 48 details branching fractions and ratios of branching fractions of B_c^+ meson decays to charmless hadronic final states.

Table 48: Branching fractions and relative branching fractions of B_c^+ decays.

Parameter	Measurements	Average
$\mathcal{B}(B_c^+ \rightarrow p\bar{p}\pi^+) \times \frac{f_c}{f_u} [10^{-8}]$	LHCb [227] < 2.8 ¹	< 2.8
$\frac{\mathcal{B}(B_c^+ \rightarrow K^+ K_S^0)}{\mathcal{B}(B^+ \rightarrow K_S^0 \pi^+)} \times \frac{f_c}{f_u} [10^{-2}]$	LHCb [7] < 5.8	< 5.8
$\mathcal{B}(B_c^+ \rightarrow K^+ \bar{K}^0)^2 [10^{-4}]$	LHCb [7] < 4.6	< 4.6
$\mathcal{B}(B_c^+ \rightarrow K^+ K^- \pi^+) \times \frac{f_c}{f_u} [10^{-7}]$	LHCb [228] < 1.50 ³	< 1.5
$\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \frac{f_c}{f_s} [10^{-3}]$	LHCb [229] $2.37 \pm 0.31^{+0.20}_{-0.17}$ ^{4,5}	2.37 ± 0.36
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \mathcal{B}(B_s^0 \rightarrow J/\psi \phi) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(\phi \rightarrow K^+ K^-)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)} [10^{-2}]$	LHCb [230] $4.53 \pm 0.61 \pm 0.37$	4.53 ± 0.71
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \mathcal{B}(B_s^0 \rightarrow D_s^- \pi^+) \times \mathcal{B}(D_s^- \rightarrow K^+ K^- \pi^-)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)}$	LHCb [230] $0.267 \pm 0.050 \pm 0.028$	0.267 ± 0.057
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)}$	LHCb [230] $91 \pm 10 \pm 9$ ^{6,5}	91 ± 13

¹ Measured in the region $m(p\bar{p}) < 2.85 \text{ GeV}/c^2$, $p_T(B) < 20 \text{ GeV}/c$ and $2.0 < y(B) < 4.5$.

² Derived from the ratio in the previous entry using $\mathcal{B}(B^+ \rightarrow K^0 \pi^+) = (23.97 \pm 0.53 \pm 0.71) \times 10^{-6}$, $f_u = 0.33$ and $f_c = 0.001$.

³ Measured in the annihilation region $m_{K^+ \pi^+} < 1.834 \text{ GeV}/c^2$, and in the fiducial region $p_T(B) < 20 \text{ GeV}/c$ and $2.0 < y(B) < 4.5$

⁴ In the pseudorapidity range $2 < \eta(B) < 5$.

⁵ Multiple systematic uncertainties are added in quadrature.

⁶ Value computed by LHCb and not by HFLAV. Refer to the paper for more details.

6 Rare decays of B^0 and B^+ mesons with photons and/or leptons

This section reports different observables for radiative decays, lepton-flavour/number-violating (LFV/LNV) decays and flavour-changing-neutral-current (FCNC) decays with leptons of B^0 and B^+ mesons. In all decays listed in this section, charmonium intermediate states are vetoed. Tables 49 to 51, 52 to 55 and 56 to 58 provide compilations of branching fractions of radiative and FCNC decays with leptons of B^+ mesons, B^0 mesons and their admixture, respectively. Tables 55 and 58 also include LFV/LNV decays. Tables 59 and 60 contain branching fractions of leptonic and radiative-leptonic B^+ and B^0 decays. These are followed by Tables 61 and 62, which give relative branching fractions of B^+ and B^0 decays, then Table 64, which gives a compilation of inclusive decays. In the modes listed in Table 64, the radiated particle is a gluon, which is an exception in this section. Table 65 contains isospin asymmetry measurements. Finally, Tables 66 to 67 and 68 provide compilations of branching fractions of B^+ and B^0 mesons to lepton-flavour/number-violating final states, respectively. Figures 7 to 12 show graphic representations of a selection of results given in this section.

Table 49: Branching fractions of charmless radiative and FCNC decays with leptons of B^+ mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\gamma)^1$	Belle [231]	$37.6 \pm 1.0 \pm 1.2$	39.9 ± 1.2 39.2 ± 2.2
	BaBar [232]	$42.2 \pm 1.4 \pm 1.6$	
	Belle II [233]	$52 \pm 4 \pm 3$	
	CLEO [234]	$37.6^{+8.9}_{-8.3} \pm 2.8$	
$\mathcal{B}(B^+ \rightarrow K^+\pi^0\gamma)$	Belle [231]	$39.1 \pm 1.6 \pm 1.6$ ²	40.7 ± 1.9
	BaBar [232]	$43.8 \pm 1.9 \pm 2.6$ ³	none
$\mathcal{B}(B^+ \rightarrow K_S^0\pi^+\gamma)$	Belle [231]	$36.9 \pm 1.2 \pm 1.2$ ²	38.4 ± 1.4 none
	BaBar [232]	$41.3 \pm 1.8 \pm 1.6$ ³	
$\mathcal{B}(B^+ \rightarrow K_1(1270)^+\gamma)$	BaBar [235]	$44.1^{+6.3}_{-4.4} \pm 5.8$ ⁴	$43.8^{+7.0}_{-6.3}$ $43.8^{+7.1}_{-6.3}$
	Belle [236]	$43.0 \pm 9.0 \pm 9.0$ ⁵	
$\mathcal{B}(B^+ \rightarrow \eta K^+\gamma)$	BaBar [237]	$7.7 \pm 1.0 \pm 0.4$ ⁶	7.89 ± 0.92 $7.88^{+0.94}_{-0.92}$
	Belle [238]	$8.4 \pm 1.5^{+1.2}_{-0.9}$ ⁷	
$\mathcal{B}(B^+ \rightarrow \eta' K^+\gamma)$	Belle [239]	$3.6 \pm 1.2 \pm 0.4$ ⁸	2.9 ± 1.0 $2.9^{+1.0}_{-0.9}$
	BaBar [240]	$1.9^{+1.5}_{-1.2} \pm 0.1$ ⁶	
$\mathcal{B}(B^+ \rightarrow \phi(1020)K^+\gamma)^1$	Belle [241]	$2.48 \pm 0.30 \pm 0.24$	2.71 ± 0.34 2.71 ± 0.42
	BaBar [242]	$3.5 \pm 0.6 \pm 0.4$ ⁹	
$\mathcal{B}(B^+ \rightarrow K^+\pi^-\pi^+\gamma)^1$	BaBar [235]	$24.5 \pm 0.9 \pm 1.2$ ¹⁰	24.6 ± 1.3 25.8 ± 1.5
	Belle [236]	$25.0 \pm 1.8 \pm 2.2$ ⁵	
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\pi^+\gamma)$	BaBar [235]	$23.4 \pm 0.9^{+0.8}_{-0.7}$ ¹⁰	23.3 ± 1.2 $23.3^{+1.2}_{-1.1}$
	Belle [243]	$20.0^{+7.0}_{-6.0} \pm 2.0$ ¹¹	
$\mathcal{B}(B^+ \rightarrow K^+\rho^0(770)\gamma)$	BaBar [235]	$8.2 \pm 0.4 \pm 0.8$ ¹⁰	8.2 ± 0.9
	Belle [243]	< 20.0 ¹¹	
$\mathcal{B}(B^+ \rightarrow (K\pi)_0^{*0}\pi^+\gamma) \times \mathcal{B}((K\pi)_0^{*0} \rightarrow K^+\pi^-)^{12}$			$10.3^{+1.7}_{-2.2}$
	BaBar [235]	$10.3^{+0.7}_{-0.8}{}^{+1.5}_{-2.0}$ ¹⁰	none
$\mathcal{B}(B^+ \rightarrow K^+\pi^-\pi^+\gamma(\text{NR}))$	BaBar [235]	$9.9 \pm 0.7^{+1.5}_{-1.9}$ ^{10,13}	$9.9^{+1.7}_{-2.0}$
	Belle [243]	< 9.2 ¹⁴	

¹ The PDG uncertainty includes a scale factor.

² $M_{K\pi} < 2.0 \text{ GeV}/c^2$.

³ $0.79 < M_{K\pi} < 1.0 \text{ GeV}/c^2$.

⁴ Multiple systematic uncertainties are added in quadrature.

⁵ $1 < M_{K\pi\pi} < 2 \text{ GeV}/c^2$.

⁶ $M_{K\eta^{(\prime)}}$ $< 3.25 \text{ GeV}/c^2$.

⁷ $M_{K\eta} < 2.4 \text{ GeV}/c^2$.

⁸ $M_{K\eta'} < 3.4 \text{ GeV}/c^2$.

⁹ $M_{\phi K} < 3.0 \text{ GeV}/c^2$.

¹⁰ $M_{K\pi\pi} < 1.8 \text{ GeV}/c^2$.

¹¹ $M_{K\pi\pi} < 2.4 \text{ GeV}/c^2$.

¹² This corresponds to the $(K\pi)$ S -wave obtained with LASS parameterisation [244].

¹³ $M_{K\pi} < 1.6 \text{ GeV}/c^2$.

¹⁴ $1.25 < M_{K\pi} < 1.6 \text{ GeV}/c^2$ and $M_{K\pi\pi} < 2.4 \text{ GeV}/c^2$.

Table 50: Branching fractions of charmless radiative and FCNC decays with leptons of B^+ mesons (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow K^0 \pi^+ \pi^0 \gamma)$	BaBar [245] $45.6 \pm 4.2 \pm 3.1$ ¹	45.6 ± 5.2
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+ \gamma)$	BaBar [235] $9.7^{+4.6+2.9}_{-2.9-2.4}$ ^{1,2} Belle [236] < 15.0	$9.7^{+5.4}_{-3.8}$
$\mathcal{B}(B^+ \rightarrow K^*(1410)^+ \gamma)$	BaBar [235] $27.1^{+5.4+5.9}_{-4.8-3.7}$ ^{1,2}	$27.1^{+8.0}_{-6.1}$
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^0 \pi^+ \gamma)$	BaBar [235] $1.32^{+0.09+0.24}_{-0.10-0.30}$ ^{1,2}	$1.32^{+0.26}_{-0.31}$ $1.32^{+0.26}_{-0.32}$
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^+ \gamma)$	BaBar [246] $14.5 \pm 4.0 \pm 1.5$ BaBar [235] $8.7^{+7.0+8.7}_{-5.3-10.4}$ ^{1,2}	13.8 ± 4.0
$\mathcal{B}(B^+ \rightarrow K^*(1680)^+ \gamma)$	BaBar [235] $66.7^{+9.3+14.4}_{-7.8-11.4}$ ^{1,2}	67^{+17}_{-14}
$\mathcal{B}(B^+ \rightarrow K_3^*(1780)^+ \gamma)$	Belle [238] < 9.7	< 9.7 < 39.0
$\mathcal{B}(B^+ \rightarrow K_4^*(2045)^+ \gamma)$	ARGUS [247] < 9900	< 9900
$\mathcal{B}(B^+ \rightarrow \rho^+(770) \gamma)$	Belle [248] $0.87^{+0.29+0.09}_{-0.27-0.11}$ BaBar [249] $1.2 \pm 0.4 \pm 0.2$	0.98 ± 0.24 $0.98^{+0.25}_{-0.24}$
$\mathcal{B}(B^+ \rightarrow p \bar{\Lambda}^0 \gamma)$	Belle [167] $2.45^{+0.44}_{-0.38} \pm 0.22$	$2.45^{+0.49}_{-0.44}$
$\mathcal{B}(B^+ \rightarrow p \bar{\Sigma}^0 \gamma)$	Belle [250] < 4.6	< 4.6
$\mathcal{B}(B^+ \rightarrow \pi^+ \ell^+ \ell^-)^3$	Belle [251] < 0.049 BaBar [252] < 0.066	< 0.049
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ e^-)^3$	Belle [251] < 0.08 BaBar [252] < 0.125	< 0.08
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \mu^-)^3$	BaBar [252] < 0.055 Belle [251] < 0.069 LHCb [253] ^{4,5}	0.0178 ± 0.0023
$\mathcal{B}(B^+ \rightarrow \pi^+ \nu \bar{\nu})$	Belle [254] < 14.0 BaBar [255] < 100.0	< 14

¹ $M_{K\pi\pi} < 1.8 \text{ GeV}/c^2$.

² Multiple systematic uncertainties are added in quadrature.

³ Treatment of charmonium intermediate components differs between the results.

⁴ LHCb also reports the branching fraction in bins of $m_{\ell^+\ell^-}^2$.

⁵ Measurement of $\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \mu^-)/(\mathcal{B}(B^+ \rightarrow J/\psi K^+) \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-))$ used in our fit.

Table 51: Branching fractions of charmless radiative and FCNC decays with leptons of B^+ mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^+ \rightarrow K^+\ell^+\ell^-)^1$	LHCb [256]	$0.429 \pm 0.007 \pm 0.021$ ²	0.463 ± 0.019 <small>p=3.3%</small>
	BELLE [257]	$0.599^{+0.045}_{-0.043} \pm 0.014$	
	BaBar [258]	$0.476^{+0.092}_{-0.086} \pm 0.022$	
$\mathcal{B}(B^+ \rightarrow K^+e^+e^-)^1$	BELLE [257]	$0.575^{+0.064}_{-0.061} \pm 0.015$	0.561 ± 0.056
	BaBar [258]	$0.51^{+0.12}_{-0.11} \pm 0.02$	
$\mathcal{B}(B^+ \rightarrow K^+\mu^+\mu^-)^{3,1}$	LHCb [256]	$0.429 \pm 0.007 \pm 0.021$	0.450 ± 0.021 0.453 ± 0.035
	BELLE [257]	$0.624^{+0.065}_{-0.061} \pm 0.016$	
	BaBar [258]	$0.41^{+0.16}_{-0.15} \pm 0.02$	
$\mathcal{B}(B^+ \rightarrow K^+\tau^+\tau^-)$	BaBar [259]	< 2250.0	< 2250
$\mathcal{B}(B^+ \rightarrow K^+\nu\bar{\nu})$	BaBar [260]	< 16.0	< 16
	Belle [254]	< 19.0	
	Belle II [261]	< 41.0	
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\nu\bar{\nu})$	Belle [254]	< 30.0	< 30
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\ell^+\ell^-)^{3,1}$	LHCb [256]	$0.924 \pm 0.093 \pm 0.067$ ²	1.010 ± 0.099 $1.009^{+0.113}_{-0.112}$
	Belle [262]	$1.24^{+0.23}_{-0.21} \pm 0.13$	
	BaBar [258]	$1.40^{+0.40}_{-0.37} \pm 0.09$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+e^+e^-)^1$	BaBar [258]	$1.38^{+0.47}_{-0.42} \pm 0.08$	1.55 ± 0.33 $1.55^{+0.36}_{-0.31}$
	Belle [262]	$1.73^{+0.50}_{-0.42} \pm 0.20$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\mu^+\mu^-)^1$	LHCb [256]	$0.924 \pm 0.093 \pm 0.067$	0.96 ± 0.10
	Belle [262]	$1.11^{+0.32}_{-0.27} \pm 0.10$	
	BaBar [258]	$1.46^{+0.79}_{-0.75} \pm 0.12$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\nu\bar{\nu})$	Belle [263]	< 40.0	< 40
	Belle [254]	< 61.0	
	BaBar [260]	< 64.0	
$\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-\mu^+\mu^-)$	LHCb [264]	$0.4337^{+0.0287}_{-0.0268} \pm 0.0254$ ⁴	0.434 ± 0.038 $0.433^{+0.038}_{-0.037}$
$\mathcal{B}(B^+ \rightarrow \phi(1020)K^+\mu^+\mu^-)$	LHCb [264]	$0.0790^{+0.0180}_{-0.0160} \begin{smallmatrix} +0.0114 \\ -0.0072 \end{smallmatrix}$ ⁵	$0.079^{+0.022}_{-0.017}$ $0.079^{+0.021}_{-0.017}$
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 p\nu\bar{\nu})$	BaBar [265]	< 30.0	< 30

¹ Treatment of charmonium intermediate components differs between the results.

² Only muons are used.

³ The PDG uncertainty includes a scale factor.

⁴ Using $\mathcal{B}(B^+ \rightarrow \psi(2S)K^+)$.

⁵ Using $\mathcal{B}(B^+ \rightarrow J/\psi\phi(1020)K^+)$.

Table 52: Branching fractions of charmless radiative and FCNC decays with leptons of B^0 mesons (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0\gamma)^1$	Belle [231]	$39.6 \pm 0.7 \pm 1.4$	42.1 ± 1.1 41.8 ± 2.5
	BaBar [232]	$44.7 \pm 1.0 \pm 1.6$	
	Belle II [233]	$45 \pm 3 \pm 2$	
	CLEO [234]	$45.5^{+7.2}_{-6.8} \pm 3.4$	
	LHCb [203] ² , [184] ³		
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\gamma)$	Belle [231]	$39.5 \pm 0.7 \pm 1.4$ ⁴	41.4 ± 1.2
	BaBar [232]	$44.5 \pm 1.0 \pm 1.7$ ⁵	4.6 ± 1.4
$\mathcal{B}(B^0 \rightarrow K_S^0\pi^0\gamma)$	Belle II [266]	$7.3 \pm 1.8 \pm 1.0$ ⁶	18.8 ± 1.7
	Belle [231]	$40.0 \pm 2.7 \pm 2.4$ ⁴	$p=0.0\%$
	BaBar [232]	$46.6 \pm 3.7 \pm 3.5$ ⁷	none
$\mathcal{B}(B^0 \rightarrow K^*(1410)^0\gamma)$	Belle [243]	< 130.0 ⁸	< 130
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\gamma(\text{NR}))$	Belle [243]	< 2.6 ⁸	< 2.6
$\mathcal{B}(B^0 \rightarrow \eta K^0\gamma)$	BaBar [237]	$7.1^{+2.1}_{-2.0} \pm 0.4$ ⁹	7.6 ± 1.8
	Belle [238]	$8.7^{+3.1}_{-2.7} {}^{+1.9}_{-1.6}$ ¹⁰	$7.6^{+1.8}_{-1.7}$
$\mathcal{B}(B^0 \rightarrow \eta' K^0\gamma)$	Belle [239]	< 6.4 ¹¹	< 6.4
	BaBar [240]	< 6.6 ⁹	
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^0\gamma)$	Belle [241]	$2.74 \pm 0.60 \pm 0.32$	2.74 ± 0.68
	BaBar [242]	< 27 ¹²	
$\mathcal{B}(K^{*0}X(214)) \times \mathcal{B}(X(214) \rightarrow \mu^+\mu^-)$	Belle [267]	< 0.0226 ¹³	< 0.023
	BaBar [235]	$20.5 \pm 2.0^{+2.6}_{-2.2}$ ¹⁴	19.9 ± 1.8
BaBar [245]	$18.5 \pm 2.1 \pm 1.2$ ¹⁴		
Belle [236]	$24.0 \pm 4.0 \pm 3.0$ ¹⁵		
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\pi^0\gamma)$	BaBar [245]	$40.7 \pm 2.2 \pm 3.1$ ¹⁴	40.7 ± 3.8
$\mathcal{B}(B^0 \rightarrow K_1(1270)^0\gamma)$	Belle [236]	< 58.0	< 58

¹ The PDG uncertainty includes a scale factor.

² Measurement of $\mathcal{B}(B_s^0 \rightarrow \phi(1020)\gamma)/\mathcal{B}(B^0 \rightarrow K^*(892)^0\gamma)$ used in our fit.

³ Measurement of $(\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\gamma)/\mathcal{B}(B^0 \rightarrow K^*(892)^0\gamma))\frac{f_{\Lambda_b^0}}{f_d}$ used in our fit.

⁴ $M_{K\pi} < 2.0 \text{ GeV}/c^2$.

⁵ $0.78 < M_{K\pi} < 1.1 \text{ GeV}/c^2$.

⁶ Measured in the region dominated by the K^{*0} resonance, $M_{K\pi} < 1.1 \text{ GeV}/c^2$.

⁷ $0.82 < M_{K\pi} < 1.0 \text{ GeV}/c^2$.

⁸ $1.25 < M_{K\pi} < 1.6 \text{ GeV}/c^2$.

⁹ $M_{K\eta^{(\prime)}}$ $< 3.25 \text{ GeV}/c^2$.

¹⁰ $M_{K\eta} < 2.4 \text{ GeV}/c^2$.

¹¹ $M_{K\eta'} < 3.4 \text{ GeV}/c^2$.

¹² $M_{\phi K} < 3.0 \text{ GeV}/c^2$.

¹³ $X(214)$ is searched in the mass range $[212, 300] \text{ MeV}/c^2$.

¹⁴ $M_{K\pi\pi} < 1.8 \text{ GeV}/c^2$.

¹⁵ $1 < M_{K\pi\pi} < 2 \text{ GeV}/c^2$.

Table 53: Branching fractions of charmless radiative and FCNC decays with leptons of B^0 mesons (part 2).

Parameter [10^{-6}]	Measurements		Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 \gamma)$	Belle [268]	< 0.58 ¹	< 0.58 none
$\mathcal{B}(B^0 \rightarrow f_2(1270)\gamma) \times \mathcal{B}(f_2(1270) \rightarrow K_S^0 K_S^0)$	Belle [268]	< 0.31 ²	< 0.31 none
$\mathcal{B}(B^0 \rightarrow f_2'(1525)\gamma) \times \mathcal{B}(f_2'(1525) \rightarrow K_S^0 K_S^0)$	Belle [268]	< 0.21 ³	< 0.21 none
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0 \gamma)$	Belle [236]	< 12.0	< 12
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0 \gamma)$	BaBar [246] Belle [243]	$12.2 \pm 2.5 \pm 1.0$ $13.0 \pm 5.0 \pm 1.0$	12.4 ± 2.4
$\mathcal{B}(B^0 \rightarrow K_3^*(1780)^0 \gamma)$	Belle [238]	< 21	< 21 < 83
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\gamma)$	Belle [248] BaBar [249]	$0.78^{+0.17}_{-0.16} +0.09_{-0.10}$ $0.97^{+0.24}_{-0.22} \pm 0.06$	0.86 ± 0.15
$\mathcal{B}(\rho^0 X(214)) \times \mathcal{B}(X(214) \rightarrow \mu^+ \mu^-)$	Belle [267]	< 0.0173 ⁴	< 0.017
$\mathcal{B}(B^0 \rightarrow \omega(782)\gamma)$	Belle [248] BaBar [249]	$0.40^{+0.19}_{-0.17} \pm 0.13$ $0.50^{+0.27}_{-0.23} \pm 0.09$	0.44 ± 0.17 $0.44^{+0.18}_{-0.16}$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\gamma)$	Belle [269] BaBar [270]	< 0.1 < 0.85	< 0.1
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0 \pi^- \gamma)$	Belle [271]	< 0.65	< 0.65
$\mathcal{B}(B^0 \rightarrow \pi^0 \ell^+ \ell^-)^5$	BaBar [252] Belle [251]	< 0.053 < 0.154	< 0.053
$\mathcal{B}(B^0 \rightarrow \pi^0 e^+ e^-)^5$	BaBar [252] Belle [251]	< 0.084 < 0.227	< 0.084
$\mathcal{B}(B^0 \rightarrow \pi^0 \mu^+ \mu^-)^5$	BaBar [252] Belle [251]	< 0.069 < 0.184	< 0.069

¹ Measured in bins of $M_{K_S^0 K_S^0}$. We report the result for the full range, $1.0 \text{ GeV}/c^2 < M_{K_S^0 K_S^0} < 3.0 \text{ GeV}/c^2$.

² Measured in bins of $M_{K_S^0 K_S^0}$. We report the result for the full range, $1.00 \text{ GeV}/c^2 < M_{K_S^0 K_S^0} < 1.44 \text{ GeV}/c^2$.

³ Measured in bins of $M_{K_S^0 K_S^0}$. We report the result for the full range, $1.44 \text{ GeV}/c^2 < M_{K_S^0 K_S^0} < 1.63 \text{ GeV}/c^2$.

⁴ $X(214)$ is searched in the mass range $[212, 300] \text{ MeV}/c^2$.

⁵ Treatment of charmonium intermediate components differs between the results.

Table 54: Branching fractions of charmless radiative and FCNC decays with leptons of B^0 mesons (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow \eta \ell^+ \ell^-)$	BaBar [252] < 0.064	< 0.064
$\mathcal{B}(B^0 \rightarrow \eta e^+ e^-)$	BaBar [252] < 0.108	< 0.11
$\mathcal{B}(B^0 \rightarrow \eta \mu^+ \mu^-)$	BaBar [252] < 0.112	< 0.11
$\mathcal{B}(B^0 \rightarrow \pi^0 \nu \bar{\nu})$	Belle [254] < 9.0	< 9.0
$\mathcal{B}(B^0 \rightarrow K^0 \ell^+ \ell^-)^1$	LHCb [256] $0.327 \pm 0.034 \pm 0.017$ ²	0.328 ± 0.032
	BELLE [257] $0.351^{+0.069}_{-0.060} \pm 0.010$	
	BaBar [258] $0.21^{+0.15}_{-0.13} \pm 0.02$	
$\mathcal{B}(B^0 \rightarrow K^0 e^+ e^-)^1$	BELLE [257] $0.306^{+0.098}_{-0.086} \pm 0.008$	0.249 ± 0.072
	BaBar [258] $0.08^{+0.15}_{-0.12} \pm 0.01$	
$\mathcal{B}(B^0 \rightarrow K^0 \mu^+ \mu^-)^1$	LHCb [256] $0.327 \pm 0.034 \pm 0.017$	0.341 ± 0.034
	BELLE [257] $0.394^{+0.096}_{-0.084} \pm 0.012$	
	BaBar [258] $0.49^{+0.29}_{-0.25} \pm 0.03$	
$\mathcal{B}(B^0 \rightarrow K^0 \nu \bar{\nu})$	Belle [254] < 26.0	< 26
	BaBar [260] < 49.0	
$\mathcal{B}(B^0 \rightarrow \rho^0(770) \nu \bar{\nu})$	Belle [254] < 40.0	< 40
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \ell^+ \ell^-)^1$	Belle [262] $0.97^{+0.13}_{-0.11} \pm 0.07$	0.99 ± 0.12
	BaBar [258] $1.03^{+0.22}_{-0.21} \pm 0.07$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)^1$	Belle [262] $1.18^{+0.27}_{-0.22} \pm 0.09$	1.04 ± 0.17
	BaBar [258] $0.86^{+0.26}_{-0.24} \pm 0.05$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)^1$	LHCb [272] $0.904^{+0.016}_{-0.015} \pm 0.062$ ³	0.94 ± 0.06
	Belle [262] $1.06^{+0.19}_{-0.14} \pm 0.07$	
	BaBar [258] $1.35^{+0.40}_{-0.37} \pm 0.10$	

¹ Treatment of charmonium intermediate components differs between the results.

² Only muons are used.

³ Multiple systematic uncertainties are added in quadrature.

Table 55: Branching fractions of charmless radiative and FCNC decays with leptons of B^0 mesons (part 4).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)$	LHCb [155] ^{1,2,3}	0.021 ± 0.005
$\mathcal{B}(B^0 \rightarrow K^*(892)^0\nu\bar{\nu})$	Belle [254]	< 18.0
	Belle [263]	< 55.0
	BaBar [260]	< 120.0
$\mathcal{B}(B^0 \rightarrow \phi(1020)\nu\bar{\nu})$	Belle [263]	< 127
$\mathcal{B}(B^0 \rightarrow \pi^0e^+\mu^- + c.c.)$	BaBar [273]	< 0.14
$\mathcal{B}(B^0 \rightarrow K^0e^+\mu^- + c.c.)$	BELLE [257]	< 0.038
	BaBar [274]	< 0.27
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^+\mu^-)$	LHCb [219]	< 0.0068
	Belle [275]	< 0.16
	BaBar [274]	< 0.53
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^-\mu^+)$	LHCb [219]	< 0.0057
	Belle [275]	< 0.12
	BaBar [274]	< 0.34
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^+\mu^- + c.c.)$	LHCb [219]	< 0.0101
	Belle [275]	< 0.18
	BaBar [274]	< 0.58
$\mathcal{B}(B^0 \rightarrow \Lambda_c^+\mu^-)$	BaBar [276]	< 1.4
$\mathcal{B}(B^0 \rightarrow \Lambda_c^+e^-)$	BaBar [276]	< 4.0
$\mathcal{B}(B^0 \rightarrow \phi(1020)\mu^+\mu^-)$	LHCb [277]	< 0.0032 ⁴ none

¹ The mass windows corresponding to ϕ and charmonium resonances decaying to $\mu\mu$ are vetoed.

² $0.5 < m_{\pi^+\pi^-} < 1.3$ GeV/ c^2 .

³ Measurement of $\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)/(\mathcal{B}(B^0 \rightarrow J/\psi K^*(892)^0)\mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)\mathcal{B}(K^*(892)^0 \rightarrow K\pi)2/3)$ used in our fit.

⁴ LHCb also reports an upper limit at 2.3×10^{-9} excluding the ϕ and charmonium regions.

Table 56: Branching fractions of charmless radiative, FCNC decays with leptons and LFV/LNV decays of B^\pm/B^0 admixture (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} PDG
$\mathcal{B}(B \rightarrow K\eta\gamma)$	Belle [238] $8.5 \pm 1.3^{+1.2}_{-0.9}$ ¹	$8.5^{+1.8}_{-1.6}$
$\mathcal{B}(B \rightarrow K_1(1400)\gamma)$	CLEO [234] < 127	< 127
$\mathcal{B}(B \rightarrow K_2^*(1430)\gamma)$	CLEO [234] $16.6^{+5.9}_{-5.3} \pm 1.3$	$16.6^{+6.0}_{-5.5}$
$\mathcal{B}(B \rightarrow K_3^*(1780)\gamma)$	Belle [238] < 9.3	< 9.3 < 37.0
$\mathcal{B}(B \rightarrow X_s\gamma)$	Belle [278] $351 \pm 15 \pm 41$ ^{2,3} BaBar [279] $331 \pm 16 \pm 31$ ^{2,4} Belle [280] $375 \pm 18 \pm 35$ ^{2,5} BaBar [281] $352 \pm 20 \pm 51$ ^{2,5} CLEO [282] $328 \pm 44 \pm 28$ ^{2,6} Belle II [283] $366 \pm 81 \pm 86$ ^{2,4} BaBar [284] $390 \pm 91 \pm 64$ ^{2,5}	349 ± 19
$\mathcal{B}(B \rightarrow X_d\gamma)$	BaBar [285] $9.2 \pm 2.0 \pm 2.3$	9.2 ± 3.0
$\mathcal{B}(B \rightarrow \rho\gamma)$ ⁷	Belle [248] $1.21^{+0.24}_{-0.22} \pm 0.12$ BaBar [249] $1.73^{+0.34}_{-0.32} \pm 0.17$	1.40 ± 0.22 $1.39^{+0.25}_{-0.24}$
$\mathcal{B}(B \rightarrow \rho/\omega\gamma)$ ⁷	Belle [248] $1.14 \pm 0.20^{+0.10}_{-0.12}$ BaBar [249] $1.63^{+0.30}_{-0.28} \pm 0.16$	1.30 ± 0.18 $1.30^{+0.23}_{-0.24}$
$\mathcal{B}(B \rightarrow X_s e^+ e^-)$ ^{7,8,9}	BaBar [286] $7.69^{+0.82}_{-0.77} \pm 0.71$ ¹⁰ Belle [287] $4.04 \pm 1.30^{+0.87}_{-0.83}$	6.67 ± 0.83 $6.67^{+1.76}_{-1.63}$
$\mathcal{B}(B \rightarrow X_s \mu^+ \mu^-)$ ^{8,9}	Belle [287] $4.13 \pm 1.05^{+0.85}_{-0.81}$ BaBar [286] $4.41^{+1.31}_{-1.17} \pm 0.63$ ¹⁰	4.27 ± 0.95 $4.27^{+0.99}_{-0.92}$
$\mathcal{B}(B \rightarrow X_s \ell^+ \ell^-)$ ^{8,7,9}	BaBar [286] $6.73^{+0.70}_{-0.64} \pm 0.60$ ¹⁰ Belle [287] $4.11 \pm 0.83^{+0.85}_{-0.81}$	5.84 ± 0.69 $5.84^{+1.31}_{-1.23}$

¹ $M_{K\eta} < 2.4 \text{ GeV}/c^2$.

² Measurement extrapolated to $E_\gamma > 1.6 \text{ GeV}$ using the method from Ref. [288].

³ The systematic error includes a shape-function systematic of 0.01.

⁴ The systematic error includes a shape-function systematic of 0.02.

⁵ The systematic error includes a shape-function systematic of 0.04.

⁶ The systematic error includes a shape-function systematic of 0.06.

⁷ The PDG uncertainty includes a scale factor.

⁸ Belle uses $m_{\ell^+\ell^-} > 0.2 \text{ GeV}/c^2$, BABAR uses $m_{\ell^+\ell^-} > 0.1 \text{ GeV}/c^2$.

⁹ Treatment of charmonium intermediate components differs between the results.

¹⁰ Multiple systematic uncertainties are added in quadrature.

Table 57: Branching fractions of charmless radiative, FCNC decays with leptons and LFV/LNV decays of B^\pm/B^0 admixture (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B \rightarrow \pi \ell^+ \ell^-)^1$	BaBar [252] < 0.059 Belle [251] < 0.062	< 0.059
$\mathcal{B}(B \rightarrow \pi e^+ e^-)$	BaBar [252] < 0.11	< 0.11
$\mathcal{B}(B \rightarrow \pi \mu^+ \mu^-)$	BaBar [252] < 0.05	< 0.05
$\mathcal{B}(B \rightarrow K e^+ e^-)^1$	Belle [262] $0.48^{+0.08}_{-0.07} \pm 0.03$ BaBar [258] $0.388^{+0.090}_{-0.083} \pm 0.020$	0.44 ± 0.06
$\mathcal{B}(B \rightarrow K^* e^+ e^-)^{2,1}$	Belle [262] $1.39^{+0.23}_{-0.20} \pm 0.12$ BaBar [258] $0.99^{+0.23}_{-0.21} \pm 0.06$ Belle II [289] $1.42 \pm 0.48 \pm 0.09$ ^{3,4}	1.22 ± 0.16 $1.19^{+0.21}_{-0.19}$
$\mathcal{B}(B \rightarrow K \mu^+ \mu^-)^1$	CDF [181] $0.42 \pm 0.04 \pm 0.02$ Belle [262] $0.50 \pm 0.06 \pm 0.03$ BaBar [258] $0.41^{+0.13}_{-0.12} \pm 0.02$	0.442 ± 0.036
$\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)^1$	CDF [181] $1.01 \pm 0.10 \pm 0.05$ Belle [262] $1.10^{+0.16}_{-0.14} \pm 0.08$ Belle II [289] $1.19 \pm 0.31^{+0.08}_{-0.07}$ ³ BaBar [258] $1.35^{+0.35}_{-0.33} \pm 0.10$	1.07 ± 0.09 1.06 ± 0.09
$\mathcal{B}(B \rightarrow K \ell^+ \ell^-)^1$	Belle [262] $0.48^{+0.05}_{-0.04} \pm 0.03$ BaBar [290] $0.47 \pm 0.06 \pm 0.02$	0.48 ± 0.04
$\mathcal{B}(B \rightarrow K^* \ell^+ \ell^-)^1$	Belle [262] $1.07^{+0.11}_{-0.10} \pm 0.09$ BaBar [290] $1.02^{+0.14}_{-0.13} \pm 0.05$ Belle II [289] $1.25 \pm 0.30^{+0.08}_{-0.07}$ ^{3,4}	1.07 ± 0.10 1.05 ± 0.10

¹ Treatment of charmonium intermediate components differs between the results.

² The PDG uncertainty includes a scale factor.

³ J/ψ and $\psi(2S)$ regions are vetoed.

⁴ $M_{e^+e^-} > 0.14 \text{ GeV}/c^2$.

Table 58: Branching fractions of charmless radiative, FCNC decays with leptons and LFV/LNV decays of B^\pm/B^0 admixture (part 3).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B \rightarrow K\nu\bar{\nu})$	Belle [254] < 16.0	< 16
	BaBar [260] < 17.0	
$\mathcal{B}(B \rightarrow K^*\nu\bar{\nu})$	Belle [254] < 27.0	< 27
	BaBar [260] < 76.0	
$\mathcal{B}(B \rightarrow \pi\nu\bar{\nu})$	Belle [254] < 8.0	< 8.0
$\mathcal{B}(B \rightarrow \rho\nu\bar{\nu})$	Belle [254] < 28.0	< 28
$\mathcal{B}(B \rightarrow \pi e^\pm\mu^\mp)$	BaBar [273] < 0.092	< 0.092
$\mathcal{B}(B \rightarrow \rho e^\pm\mu^\mp)$	CLEO [291] < 3.2	< 3.2
$\mathcal{B}(B \rightarrow Ke^\pm\mu^\mp)$	BaBar [274] < 0.038	< 0.038
$\mathcal{B}(B \rightarrow K^*e^\pm\mu^\mp)$	BaBar [274] < 0.51	< 0.51

Table 59: Branching fractions of charmless leptonic and radiative-leptonic B^+ and B^0 decays (part 1).

Parameter [10^{-7}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow e^+\nu_e)$	Belle [292] < 9.8	< 9.8
	BaBar [293] < 19	
$\mathcal{B}(B^+ \rightarrow \mu^+\nu_\mu)$	Belle [294] < 8.6	< 8.6
	BaBar [293] < 10	
	Belle [295] < 10.7	
$\mathcal{B}(B^+ \rightarrow \tau^+\nu_\tau)^1$	Belle [296] $720^{+270}_{-250} \pm 110$	1094 ± 208
	Belle [297] $1250 \pm 280 \pm 270$	
	BaBar [298] $1830^{+530}_{-490} \pm 240$	
	BaBar [299] $1700 \pm 800 \pm 200$	
$\mathcal{B}(B^+ \rightarrow \ell^+\nu_\ell\gamma)$	Belle [300] < 30^2	< 30
	BaBar [301] < 156	
$\mathcal{B}(B^+ \rightarrow e^+\nu_e\gamma)$	Belle [300] < 43^2	< 43
	BaBar [301] < 170	
$\mathcal{B}(B^+ \rightarrow \mu^+\nu_\mu\gamma)$	Belle [300] < 34^2	< 34
	BaBar [301] < 260	
$\mathcal{B}(B^0 \rightarrow \gamma\gamma)$	BaBar [302] < 3.3	< 3.3
	Belle [303] < 6.2	< 3.2
$\mathcal{B}(B^0 \rightarrow e^+e^-)$	LHCb [208] < 0.025	< 0.025
	CDF [209] < 0.83	
	BaBar [304] < 1.13	
	Belle [305] < 1.9	
$\mathcal{B}(B^0 \rightarrow e^+e^-\gamma)$	BaBar [306] < 1.2	< 1.2
$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$	CMS [204] < 0.0015	< 0.0015
	ATLAS [206] < 0.0021^3	
	LHCb [205] < 0.0023	
	CDF [207] < 0.038	
	BaBar [304] < 0.52	
	Belle [305] < 1.6	

¹ The PDG uncertainty includes a scale factor.

² $E_\gamma > 1$ GeV.

³ At CL=95%.

Table 60: Branching fractions of charmless leptonic and radiative-leptonic B^+ and B^0 decays (part 2).

Parameter [10^{-7}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^- \gamma)$	BaBar [306] < 1.5	< 1.5 < 0.0
$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^- \mu^+ \mu^-)$	LHCb [212] < 0.0018 ^{1,2}	< 0.0018 < 0.0069
$\mathcal{B}(B^0 \rightarrow SP) \times \mathcal{B}(S \rightarrow \mu^+ \mu^-) \times \mathcal{B}(P \rightarrow \mu^+ \mu^-)$	LHCb [311] < 0.006 ^{1,2}	< 0.0060
$\mathcal{B}(B^0 \rightarrow aa) \times \mathcal{B}(a \rightarrow \mu^+ \mu^-) \times \mathcal{B}(a \rightarrow \mu^+ \mu^-)$	LHCb [212] < 0.0023 ^{1,3,2}	< 0.0023 none
$\mathcal{B}(B^0 \rightarrow \tau^+ \tau^-)^4$	LHCb [211] < 16000 BaBar [307] < 41000	< 16000 < 21000
$\mathcal{B}(B^0 \rightarrow \nu \bar{\nu})$	BaBar [308] < 240 Belle [309] < 780	< 240
$\mathcal{B}(B^0 \rightarrow \nu \bar{\nu} \gamma)$	Belle [309] < 160 ⁵ BaBar [308] < 170 ⁶	< 160
$\mathcal{B}(B^+ \rightarrow \mu^+ \mu^- \mu^+ \nu_\mu)$	LHCb [310] < 0.16 ²	< 0.16

¹ The mass windows corresponding to ϕ and charmonium resonances decaying to $\mu\mu$ are vetoed.

² At CL=95%.

³ a is a promptly decaying scalar particle with a mass of 1 GeV/ c^2

⁴ PDG shows the result obtained at 95% CL.

⁵ $E_\gamma > 0.5$ GeV.

⁶ $E_\gamma > 1.2$ GeV.

Table 61: Relative branching fractions of charmless radiative and FCNC decays with leptons of B mesons (part 1).

Parameter	Measurements	Average	
$\frac{\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}$, $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [253]	$0.038 \pm 0.009 \pm 0.001$	0.038 ± 0.009
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, Full $m_{\ell^+ \ell^-}^2$ range	BELLE [257]	$1.08^{+0.16}_{-0.15} \pm 0.02$	1.08 ± 0.16
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, $0.1 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	LHCb [312]	$0.994^{+0.090}_{-0.082} {}^{+0.029}_{-0.027}$	0.994 ± 0.090
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [312]	$0.949^{+0.042}_{-0.041} \pm 0.022$	0.949 ± 0.047
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, $0.10 < m_{\ell^+ \ell^-}^2 < 8.12 \text{ GeV}^2/c^4$ and $m_{\ell^+ \ell^-}^2 > 10.11 \text{ GeV}^2/c^4$	BaBar [290]	$1.00^{+0.31}_{-0.25} \pm 0.07$	$1.00^{+0.32}_{-0.26}$
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ ¹	BELLE [257]	$1.39^{+0.36}_{-0.33} \pm 0.02$	1.39 ± 0.35
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K_S^0 e^+ e^-)}$, Full $m_{\ell^+ \ell^-}^2$ range	BELLE [257]	$1.29^{+0.52}_{-0.45} \pm 0.01$	$1.29^{+0.52}_{-0.45}$
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K_S^0 e^+ e^-)}$, $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ ¹	BELLE [257]	$0.55^{+0.46}_{-0.34} \pm 0.01$	$0.55^{+0.46}_{-0.34}$
$\frac{\mathcal{B}(B \rightarrow K \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K e^+ e^-)}$, Full $m_{\ell^+ \ell^-}^2$ range	BELLE [257]	$1.10^{+0.16}_{-0.15} \pm 0.02$	1.10 ± 0.16
$\frac{\mathcal{B}(B \rightarrow K \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K e^+ e^-)}$, $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ ¹	BELLE [257]	$1.03^{+0.28}_{-0.24} \pm 0.01$	$1.03^{+0.28}_{-0.24}$

¹ For the other bins see the article.

Table 62: Relative branching fractions of charmless radiative and FCNC decays with leptons of B mesons (part 2).

Parameter	Measurements	Average	
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$, Full $m_{\ell^+ \ell^-}^2$ range	Belle [262]	$0.83 \pm 0.17 \pm 0.08$	0.83 ± 0.19
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$, $0.10 < m_{\ell^+ \ell^-}^2 < 8.12 \text{ GeV}^2/c^4$ and $m_{\ell^+ \ell^-}^2 > 10.11 \text{ GeV}^2/c^4$	BaBar [290]	$1.13^{+0.34}_{-0.26} \pm 0.10$	$1.13^{+0.35}_{-0.28}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$, $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	Belle [313]	$0.52^{+0.36}_{-0.26} \pm 0.06$	$0.52^{+0.36}_{-0.27}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$, $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	Belle [313]	$0.96^{+0.45}_{-0.29} \pm 0.11$	$0.96^{+0.46}_{-0.31}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$, $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [313]	$1.18^{+0.52}_{-0.32} \pm 0.11$	$1.18^{+0.53}_{-0.34}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$, $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	Belle [313]	$0.46^{+0.55}_{-0.27} \pm 0.13$	$0.46^{+0.56}_{-0.30}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$, $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [312] Belle [313]	$1.027^{+0.072}_{-0.068} \text{ }^{+0.027}_{-0.026}$ $1.06^{+0.63}_{-0.38} \pm 0.14$	1.028 ± 0.074
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$, $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [313]	$1.12^{+0.61}_{-0.36} \pm 0.10$	$1.12^{+0.62}_{-0.37}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$, $0.1 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	LHCb [312]	$0.927^{+0.093}_{-0.087} \text{ }^{+0.036}_{-0.035}$	0.927 ± 0.097
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$, $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	Belle [313]	$0.62^{+0.60}_{-0.36} \pm 0.09$	$0.62^{+0.61}_{-0.37}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$, $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	Belle [313]	$0.72^{+0.99}_{-0.44} \pm 0.15$	$0.7^{+1.0}_{-0.5}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$, $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [313]	$1.40^{+1.99}_{-0.68} \pm 0.12$	$1.4^{+2.0}_{-0.7}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$, $0.045 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [314]	$0.70^{+0.18}_{-0.13} \text{ }^{+0.03}_{-0.04}$	$0.70^{+0.18}_{-0.14}$

Table 63: Relative branching fractions of charmless radiative and FCNC decays with leptons of B mesons (part 3).

Parameter	Measurements	Average
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \gamma)}{\mathcal{B}(B_s^0 \rightarrow \phi(1020) \gamma)}$	LHCb [203] $1.23 \pm 0.06 \pm 0.11$ ¹ Belle [231] $1.10 \pm 0.16 \pm 0.20$ ¹	1.21 ± 0.11
$\frac{\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-)}$ [10 ⁻²]	LHCb [205] < 8.1	< 8.1
$\frac{\mathcal{B}(B^0 \rightarrow \phi(1020) \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow \phi(1020) \mu^+ \mu^-)}$ [10 ⁻³]	LHCb [277] < 4.4 ²	< 4.4
$\frac{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^- \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(K^{*0} \rightarrow K^+ \pi^-)}$ [10 ⁻⁴]	LHCb [155] $4.1 \pm 1.0 \pm 0.3$ ^{3,4}	4.1 ± 1.0

¹ Multiple systematic uncertainties are added in quadrature.

² ϕ and charmonium regions excluded from the dimuon spectrum.

³ The mass windows corresponding to ϕ and charmonium resonances decaying to $\mu\mu$ are vetoed.

⁴ $0.5 < m_{\pi^+\pi^-} < 1.3 \text{ GeV}/c^2$.

Table 64: Branching fractions of $B^+/B^0 \rightarrow \bar{q}$ gluon decays.

Parameter [10 ⁻⁴]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B \rightarrow \eta X)$	Belle [315] 2.610 ± 0.300 ^{+0.440} _{-0.740} ¹ CLEO [316] < 4.400 ²	2.61 ^{+0.53} _{-0.80}
$\mathcal{B}(B \rightarrow \eta' X)$	BaBar [317] $3.90 \pm 0.80 \pm 0.90$ ³ CLEO [318] $4.60 \pm 1.10 \pm 0.60$ ³	4.24 ± 0.87
$\mathcal{B}(B \rightarrow K^+ X)$	BaBar [319] < 1.87 ⁴	< 1.9
$\mathcal{B}(B \rightarrow K^0 X)$	BaBar [319] 1.95 ^{+0.51} _{-0.45} ± 0.50 ⁴	1.95 ± 0.69 1.95 ^{+0.71} _{-0.67}
$\mathcal{B}(B \rightarrow \pi^+ X)$	BaBar [319] 3.72 ^{+0.50} _{-0.47} ± 0.59 ⁵	3.72 ± 0.76 3.72 ^{+0.77} _{-0.75}

¹ $0.4 < m_X < 2.6 \text{ GeV}/c^2$.

² $2.1 < p_\eta < 2.7 \text{ GeV}/c$.

³ $2.0 < p^*(\eta') < 2.7 \text{ GeV}/c$.

⁴ $p^*(K) < 2.34 \text{ GeV}/c$.

⁵ $p^*(\pi^+) < 2.36 \text{ GeV}/c$.

Table 65: Isospin asymmetry in radiative and FCNC decays with leptons of B mesons. In some of the B -factory results it is assumed that $\mathcal{B}(\Upsilon(4S) \rightarrow B^+B^-) = \mathcal{B}(\Upsilon(4S) \rightarrow B^0\bar{B}^0)$, and in others a measured value of the ratio of branching fractions is used. See original papers for details. The averages quoted here are computed naively and should be treated with caution.

Parameter	Measurements	Average ^{HFLAV} _{PDG}
$\Delta_{0-}(B \rightarrow X_s\gamma)$	Belle [320] $-0.0048 \pm 0.0149 \pm 0.0150$ ^{1,2}	-0.005 ± 0.020
	BaBar [321] $-0.006 \pm 0.058 \pm 0.026$ ^{1,2}	
$\Delta_{0-}(B \rightarrow X_{s+d}\gamma)$	BaBar [284] $-0.06 \pm 0.15 \pm 0.07$ ³	-0.06 ± 0.17
$\Delta_{0+}(B \rightarrow K^*\gamma)$	Belle [231] $0.062 \pm 0.015 \pm 0.013$ ²	0.063 ± 0.017
	BaBar [232] $0.066 \pm 0.021 \pm 0.022$	
$\frac{\Gamma(B^+ \rightarrow \rho^+\gamma)}{2\Gamma(B^0 \rightarrow \rho^0\gamma)} - 1$	Belle [248] $-0.48^{+0.21}_{-0.19} +0.08_{-0.09}$	-0.46 ± 0.17
	BaBar [249] $-0.43^{+0.25}_{-0.22} \pm 0.10$	
$\Delta_{0-}(B \rightarrow K\ell^+\ell^-)^4$	LHCb [256] $-0.10^{+0.08}_{-0.09} \pm 0.02$ ⁵	$-0.191^{+0.073}_{-0.071}$ -0.150 ± 0.060
	BELLE [257] $-0.31^{+0.13}_{-0.11} \pm 0.01$ ⁶	
	BaBar [290] $-0.41 \pm 0.25 \pm 0.01$ ⁶	
$\Delta_{0-}(B \rightarrow K^*\ell^+\ell^-)^4$	BaBar [290] $-0.20^{+0.30}_{-0.23} \pm 0.03$ ⁶	$-0.01^{+0.11}_{-0.09}$ $-0.03^{+0.08}_{-0.07}$
	Belle [262] $0.33^{+0.37}_{-0.43} \pm 0.08$ ⁶	
	LHCb [256] $0.00^{+0.12}_{-0.10} \pm 0.02$ ⁵	
$\Delta_{0-}(B \rightarrow K^{(*)}\ell^+\ell^-)^4$	Belle [262] $-0.30^{+0.12}_{-0.11} \pm 0.08$ ⁷	-0.45 ± 0.10
	BaBar [258] $-0.64^{+0.15}_{-0.14} \pm 0.03$ ⁸	

¹ $M_{X_s} < 2.8 \text{ GeV}/c^2$.

² Multiple systematic uncertainties are added in quadrature.

³ $E_\gamma > 2.2 \text{ GeV}$.

⁴ The PDG uncertainty includes a scale factor.

⁵ Only muons are used, $1.1 < m_{\ell^+\ell^-}^2 < 6.0 \text{ GeV}^2/c^4$.

⁶ $1.0 < m_{\ell^+\ell^-}^2 < 6.0 \text{ GeV}^2/c^4$.

⁷ $m_{\ell^+\ell^-}^2 < 8.68 \text{ GeV}^2/c^4$.

⁸ $0.1 < m_{\ell^+\ell^-}^2 < 7.02 \text{ GeV}^2/c^4$.

Table 66: Branching fractions of charmless semileptonic B^+ decays to LFV and LNV final states (part 1).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \mu^- + \text{c.c.})$	BaBar [273] < 0.17	< 0.17
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \tau^-)$	BaBar [322] < 74.0	< 74
$\mathcal{B}(B^+ \rightarrow \pi^+ e^- \tau^+)$	BaBar [322] < 20.0	< 20
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \tau^- + \text{c.c.})$	BaBar [322] < 75.0	< 75
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \tau^-)$	BaBar [322] < 62.0	< 62
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^- \tau^+)$	BaBar [322] < 45.0	< 45
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \tau^- + \text{c.c.})$	BaBar [322] < 72.0	< 72
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^-)$	LHCb [323] < 0.0070	< 0.007
	BELLE [257] < 0.03	
	BaBar [274] < 0.091	
$\mathcal{B}(B^+ \rightarrow K^+ e^- \mu^+)$	LHCb [323] < 0.0064	< 0.0064
	BELLE [257] < 0.085	
	BaBar [274] < 0.13	
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^- + \text{c.c.})$	BaBar [274] < 0.091	< 0.091
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \tau^-)$	BaBar [322] < 43.0	< 43
$\mathcal{B}(B^+ \rightarrow K^+ e^- \tau^+)$	BaBar [322] < 15.0	< 15
	Belle [210] < 15.1	
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \tau^- + \text{c.c.})$	BaBar [322] < 30.0	< 30
$\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \tau^-)$	Belle [210] < 24.5	< 24
	BaBar [322] < 45.0	
$\mathcal{B}(B^+ \rightarrow K^+ \mu^- \tau^+)$	Belle [210] < 5.9	< 5.9
	BaBar [322] < 28.0	
	LHCb [324] < 39.0	
$\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \tau^- + \text{c.c.})$	BaBar [322] < 48.0	< 48
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ \mu^-)$	BaBar [274] < 1.30	< 1.3
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^- \mu^+)$	BaBar [274] < 0.99	< 0.99
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ \mu^- + \text{c.c.})$	BaBar [274] < 1.40	< 1.4
$\mathcal{B}(B^+ \rightarrow \pi^- e^+ e^+)$	BaBar [325] < 0.023	< 0.023
$\mathcal{B}(B^+ \rightarrow \pi^- \mu^+ \mu^+)$	LHCb [326] < 0.0040 ¹	< 0.004
	BaBar [325] < 0.107	
$\mathcal{B}(B^+ \rightarrow \pi^- e^+ \mu^+)$	BaBar [327] < 0.15	< 0.15
$\mathcal{B}(B^+ \rightarrow \rho^-(770) e^+ e^+)$	BaBar [327] < 0.17	< 0.17
$\mathcal{B}(B^+ \rightarrow \rho^-(770) \mu^+ \mu^+)$	BaBar [327] < 0.42	< 0.42
$\mathcal{B}(B^+ \rightarrow \rho^-(770) e^+ \mu^+)$	BaBar [327] < 0.47	< 0.47

¹ At CL=95%.

Table 67: Branching fractions of charmless semileptonic B^+ decays to LFV and LNV final states (part 2).

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^+ \rightarrow K^- e^+ e^+)$	BaBar [325] < 0.030	< 0.030
$\mathcal{B}(B^+ \rightarrow K^- \mu^+ \mu^+)$	LHCb [328] < 0.041 BaBar [325] < 0.067	< 0.041
$\mathcal{B}(B^+ \rightarrow K^- e^+ \mu^+)$	BaBar [327] < 0.16	< 0.16
$\mathcal{B}(B^+ \rightarrow K^*(892)^- e^+ e^+)$	BaBar [327] < 0.40	< 0.40
$\mathcal{B}(B^+ \rightarrow K^*(892)^- \mu^+ \mu^+)$	BaBar [327] < 0.59	< 0.59
$\mathcal{B}(B^+ \rightarrow K^*(892)^- e^+ \mu^+)$	BaBar [327] < 0.30	< 0.30
$\mathcal{B}(B^+ \rightarrow D^- e^+ e^+)$	BaBar [327] < 2.6 BELLE [329] < 2.6	< 2.6
$\mathcal{B}(B^+ \rightarrow D^- e^+ \mu^+)$	BELLE [329] < 1.8 BaBar [327] < 2.1	< 1.8
$\mathcal{B}(B^+ \rightarrow D^- \mu^+ \mu^+)$	LHCb [330] < 0.69 ¹ BELLE [329] < 1.0 BaBar [327] < 1.7	< 0.69
$\mathcal{B}(B^+ \rightarrow D^*(2010)^- \mu^+ \mu^+)$	LHCb [330] < 2.4 ¹	< 2.4
$\mathcal{B}(B^+ \rightarrow D_s^- \mu^+ \mu^+)$	LHCb [330] < 0.58 ¹	< 0.58
$\mathcal{B}(B^+ \rightarrow \bar{D}^0 \pi^- \mu^+ \mu^+)$	LHCb [330] < 1.5 ¹	< 1.5
$\mathcal{B}(B^+ \rightarrow \Lambda^0 \mu^+)$	BaBar [276] < 0.061	< 0.061 < 0.060
$\mathcal{B}(B^+ \rightarrow \Lambda^0 e^+)$	BaBar [276] < 0.032	< 0.032
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 \mu^+)$	BaBar [276] < 0.062	< 0.062 < 0.060
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 e^+)$	BaBar [276] < 0.081	< 0.081 < 0.080

¹ At CL=95 %.

Table 68: Branching fractions of charmless semileptonic B^0 decays to LFV and LNV final states.

Parameter [10^{-6}]	Measurements	Average ^{HFLAV} _{PDG}
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^- \mu^+)$	LHCb [219] < 0.0057 Belle [275] < 0.12 BaBar [274] < 0.34	< 0.0057 < 0.1200
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ \mu^-)$	LHCb [219] < 0.0068 Belle [275] < 0.16 BaBar [274] < 0.53	< 0.0068 < 0.1600
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ \mu^- + \text{c.c.})$	LHCb [219] < 0.0101 Belle [275] < 0.18 BaBar [274] < 0.58	< 0.010 < 0.180
$\mathcal{B}(B^0 \rightarrow K^0 e^+ \mu^- + \text{c.c.})$	BELLE [257] < 0.038 BaBar [274] < 0.27	< 0.038
$\mathcal{B}(B^0 \rightarrow \pi^0 e^+ \mu^- + \text{c.c.})$	BaBar [273] < 0.14	< 0.14
$\mathcal{B}(B^0 \rightarrow e^+ \mu^- + \text{c.c.})$	LHCb [216] < 0.0010 CDF [209] < 0.064 BaBar [304] < 0.092 Belle [305] < 0.17	< 0.001
$\mathcal{B}(B^0 \rightarrow e^+ \tau^- + \text{c.c.})$	BaBar [331] < 28.0	< 28 < 16
$\mathcal{B}(B^0 \rightarrow \mu^+ \tau^- + \text{c.c.})$	LHCb [218] < 12.0 BaBar [331] < 22.0	< 12 < 14
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \tau^+ \mu^-)$	LHCb [332] < 10	< 10 none
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \tau^- \mu^+)$	LHCb [332] < 8.2	< 8.2 none
$\mathcal{B}(B^0 \rightarrow \tau^\pm \mu^\mp)$	Belle [333] < 15	< 15 none
$\mathcal{B}(B^0 \rightarrow \tau^\pm e^\mp)$	Belle [333] < 16	< 16 none
$\mathcal{B}(B^0 \rightarrow p \mu^-)$	LHCb [220] < 0.0026	< 0.0026 none

Measurements that are not included in the tables (the definitions of observables can be found in the corresponding experimental papers):

- In Ref. [334], LHCb reports the up-down asymmetries in bins of the $K\pi\pi\gamma$ mass of the $B^+ \rightarrow K^+\pi^-\pi^+\gamma$ decay.
- For the $B \rightarrow K\ell^-\ell^+$ channel, LHCb measures F_H and A_{FB} in 17 (5) bins of $m^2(\ell^+\ell^-)$ for the K^+ (K_s^0) final state [335]. Belle measures F_L and A_{FB} in 6 $m^2(\ell^+\ell^-)$ [262].
- For the $B \rightarrow K^*\ell^-\ell^+$ analyses, partial branching fractions and angular observables in bins of $m^2(\ell^+\ell^-)$ are also available:
 - $B^0 \rightarrow K^{*0}e^-e^+$: LHCb reports F_L , $A_T^{(2)}$, A_T^{Im} , A_T^{Re} in the $[0.0008, 0.257]$ GeV^2/c^4 bin of $m^2(\ell^+\ell^-)$ putting constraints on the $B \rightarrow K^{*0}\gamma$ photon polarization [336]. In Ref. [337], LHCb determines the branching fraction in the dilepton mass region $[0.0009, 1.0]$ GeV^2/c^4 .
 - $B \rightarrow K^*\ell^-\ell^+$: Belle measures F_L , A_{FB} , isospin asymmetry in 6 $m^2(\ell^+\ell^-)$ bins [262] and P'_4 , P'_5 , P'_6 , P'_8 in 4 $m^2(\ell^+\ell^-)$ bins [338]. In a more recent paper [339], they report measurements of P'_4 and P'_5 , separately for $\ell = \mu$ or e , in 4 $m^2(\ell^+\ell^-)$ bins and in the region $[1, 6]$ GeV^2/c^4 . The measurements use both B^0 and B^+ decays. They also measure the LFU observables $Q_i = P_i^\mu - P_i^e$, for $i = 4, 5$. BABAR reports F_L , A_{FB} , P_2 in 5 $m^2(\ell^+\ell^-)$ bins [340].
 - $B^0 \rightarrow K^{*0}\mu^-\mu^+$: LHCb measures F_L , A_{FB} , $S_3 - S_9$, $A_3 - A_9$, $P_1 - P_3$, $P'_4 - P'_8$ in 8 $m^2(\ell^+\ell^-)$ bins [341]. An updated measurement of the CP -averaged observables is presented in Ref. [342]. CMS measures F_L and A_{FB} in 7 $m^2(\ell^+\ell^-)$ bins [343], as well as P_1 , P'_5 [344]. ATLAS measures F_L , $S_{3,4,5,7,8}$ and $P'_{1,4,5,6,8}$ in 6 $m^2(\ell^+\ell^-)$ bins [345].
 - $B^+ \rightarrow K^{*+}\mu^-\mu^+$: LHCb reports the full set of CP -averaged angular observables in 8 $m^2(\ell^+\ell^-)$ bins [346]. CMS measures F_L and A_{FB} in 3 $m^2(\ell^+\ell^-)$ bins [347].
- $B \rightarrow X_s\ell^-\ell^+$ (where X_s is a hadronic system with an s quark): Belle measures A_{FB} in bins of $m^2(\ell^+\ell^-)$ with a sum of 10 exclusive final states [348].
- $B^0 \rightarrow K^+\pi^-\mu^+\mu^-$, with $1330 < m(K^+\pi^-) < 1530$ GeV/c^2 : LHCb measures the partial branching fraction in bins of $m^2(\mu^+\mu^-)$ in the range $[0.1, 8.0]$ GeV^2/c^4 , and reports angular moments [349].
- In Ref. [350], LHCb measures the phase difference between the short- and long-distance contributions to the $B^+ \rightarrow K^+\mu^+\mu^-$ decay. The measurement is based on the analysis of the dimuon mass distribution in the regions of the J/ψ and $\psi(2S)$ resonances and far from their poles, to probe long and short distance effects, respectively.
- In Ref. [351], CMS performs the study of the angular distribution of the $B^+ \rightarrow K^+\mu^+\mu^-$ channel and measures, in 7 $m^2(\mu^+\mu^-)$ bins, A_{FB} and the contribution F_H from the pseudoscalar, scalar and tensor amplitudes to the decay.
- In Ref. [352], LHCb performs a search for a hidden-sector boson χ decaying into two muons in $B^0 \rightarrow K^{*0}\mu^+\mu^-$ decays. Results are given as function of mass and lifetime in the range $214 < m(\chi) < 4350$ MeV/c^2 and $0 < \tau(\chi) < 1000$ ps.

- In Ref. [353], LHCb performs a search for a hypothetical new scalar particle χ , assumed to have a narrow width, through the decay $B^+ \rightarrow K^+ \chi (\mu^+ \mu^-)$ in the ranges of mass $250 < m(\chi) < 4700 \text{ MeV}/c^2$ and lifetime $0.1 < \tau(\chi) < 1000 \text{ ps}$. Upper limits are given as a function of $m(\chi)$ and $\tau(\chi)$.

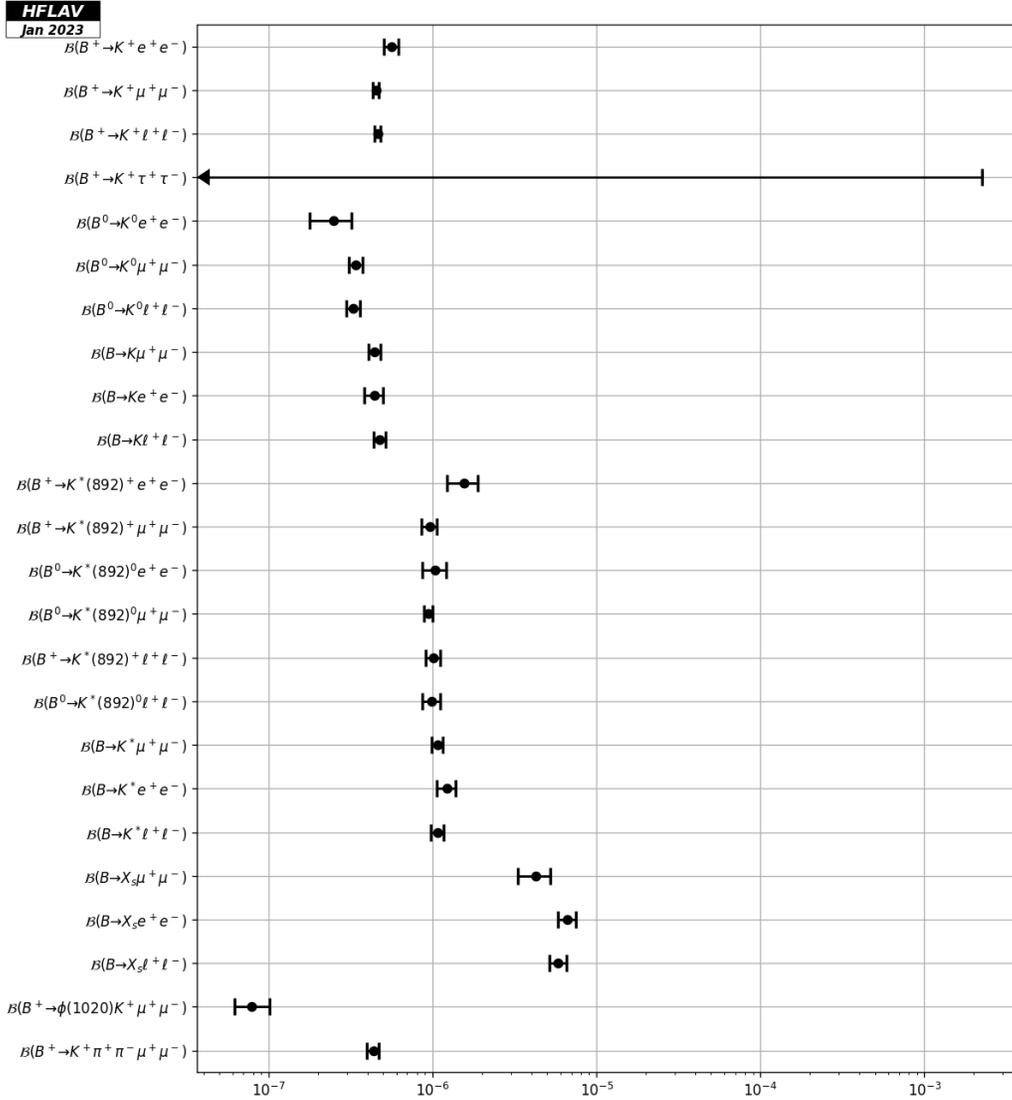


Figure 7: Branching fractions of B^+ and B^0 decays of the type $b \rightarrow s \ell^+ \ell^-$.

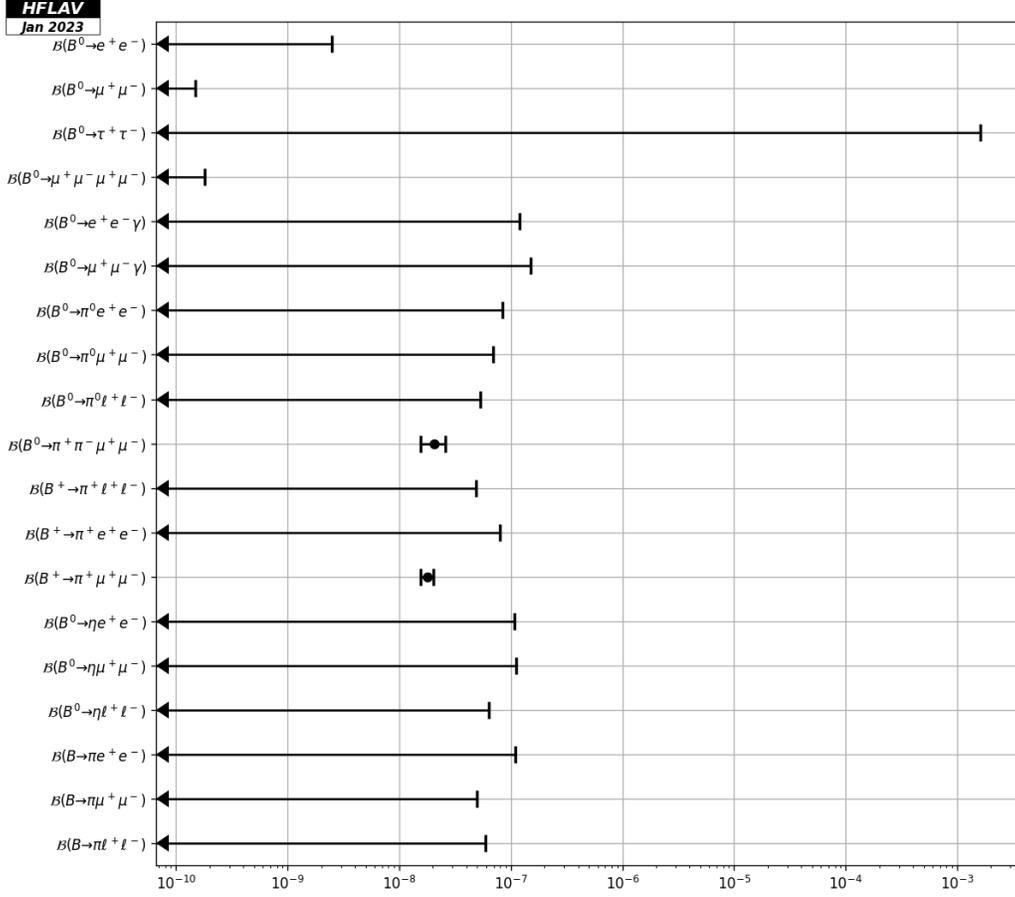


Figure 8: Branching fractions of B^+ and B^0 decays of the type $b \rightarrow u\ell^+\ell^-$, purely leptonic and leptonic radiative.

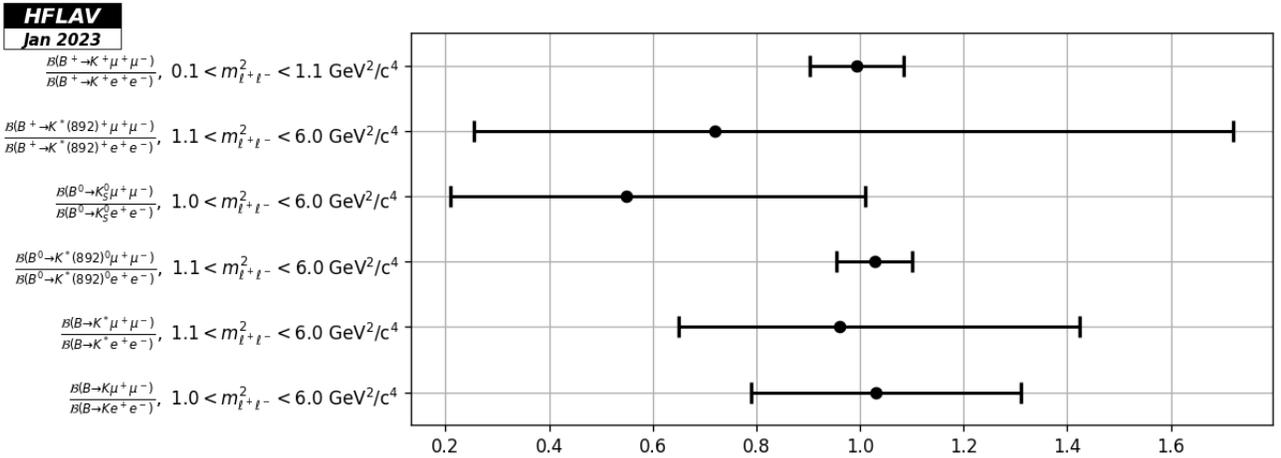


Figure 9: Compilation of $R_K^{(*)}$ ratios in the low dilepton invariant-mass region. These are ratios between branching fractions of B -meson decays to $K^{(*)} \mu^+ \mu^-$ and $K^{(*)} e^+ e^-$, which provide information on lepton universality.

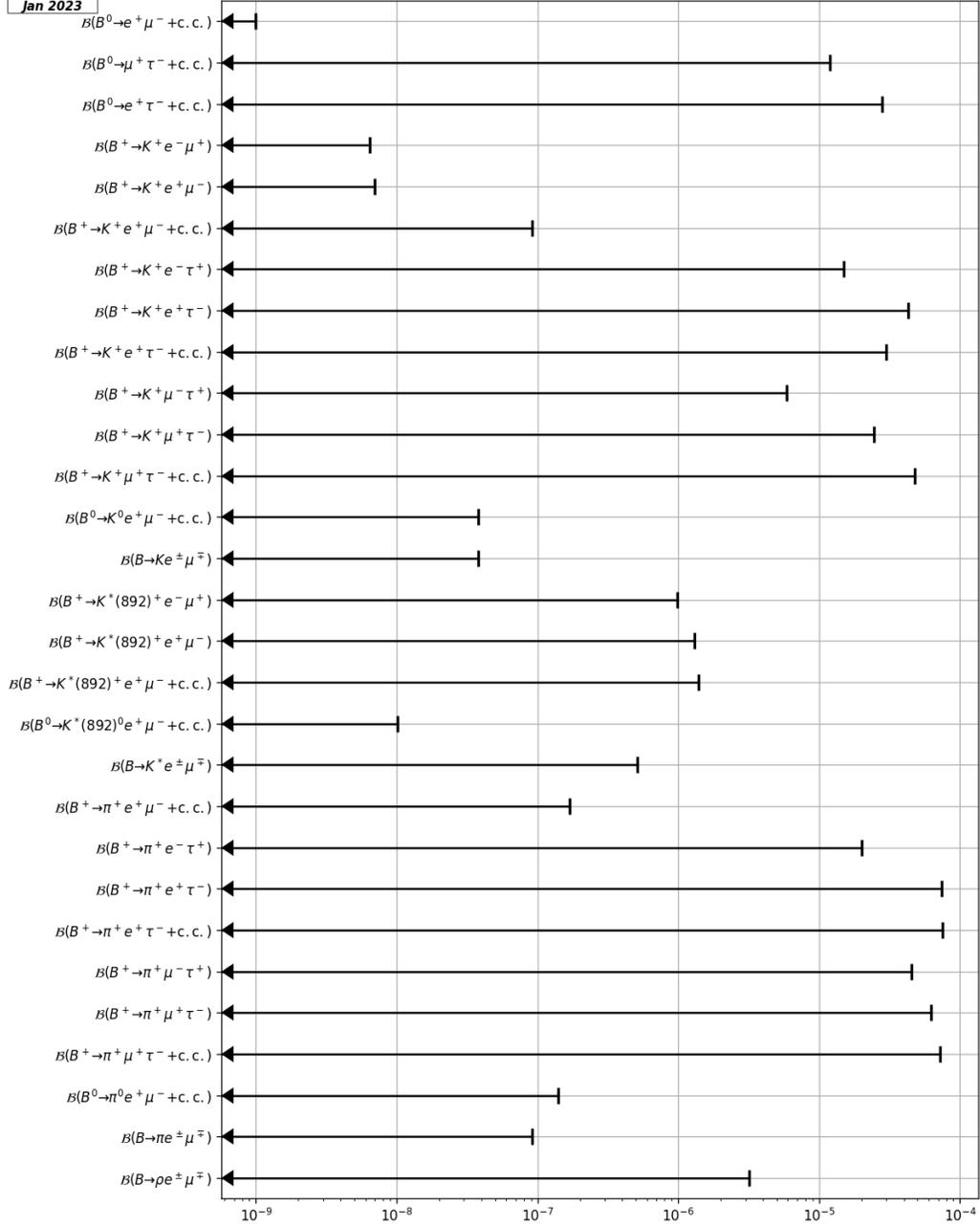


Figure 10: Limits on branching fractions of lepton-flavour-violating B^+ and B^0 decays.

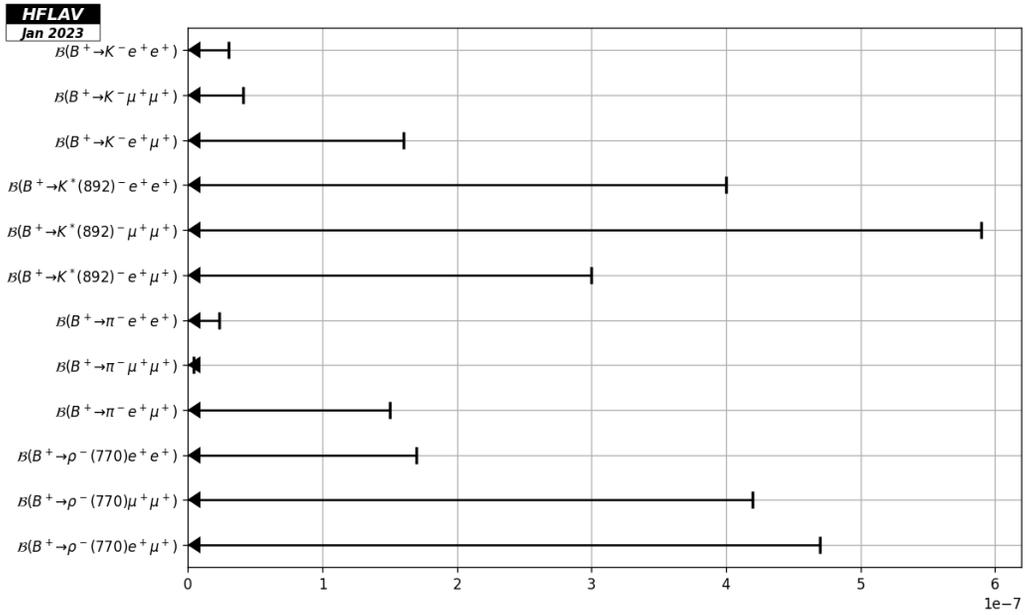


Figure 11: Limits on branching fractions of lepton-number-violating B^+ and B^0 decays.

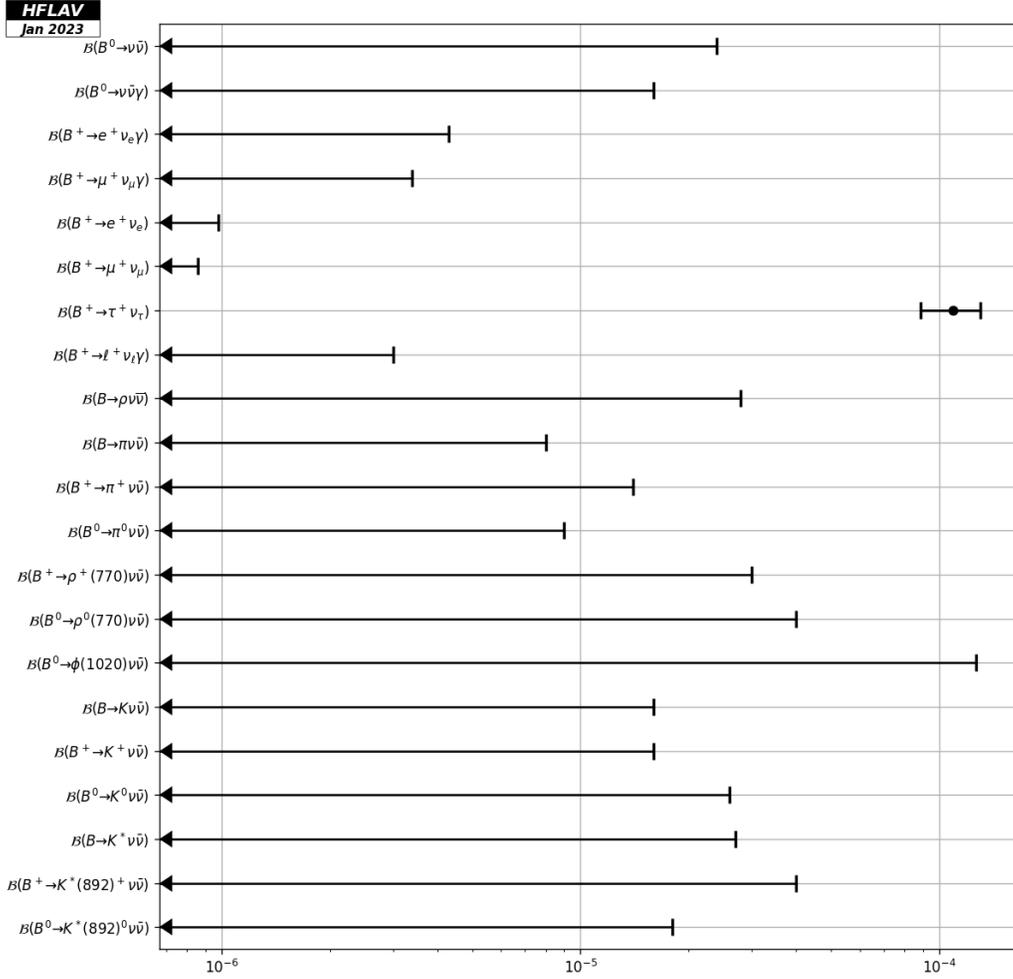


Figure 12: Branching fractions of charmless B decays with neutrinos.

7 Charge asymmetries in b -hadron decays

This section contains, in Tables 69 to 82, compilations of CP asymmetries in decays of various b -hadrons: B^+ , B^0 mesons, B^\pm/B^0 admixtures, B_s^0 mesons and finally Λ_b^0 baryons. The CP asymmetry is defined as

$$A_{CP} = \frac{N_b - N_{\bar{b}}}{N_b + N_{\bar{b}}}, \quad (1)$$

where N_b ($N_{\bar{b}}$) is the number of hadrons containing a b (\bar{b}) quark decaying into a specific final state (the CP -conjugate state). This definition is consistent with that of Eq. (96) in Sec. 6.2.1 of the HFLAV 2021 publication [354]. Measurements of time-dependent CP asymmetries are not listed here but are discussed in Sec. 6 of the HFLAV publication. Figure 13 shows a graphic representation of a selection of results given in this section.

Table 69: CP asymmetries of charmless hadronic B^+ decays (part 1).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K_S^0 \pi^+)$	Belle [3]	$-0.011 \pm 0.021 \pm 0.006$	-0.016 ± 0.015
	LHCb [7]	$-0.022 \pm 0.025 \pm 0.010$	
	BaBar [4]	$-0.029 \pm 0.039 \pm 0.010$	
	Belle II [5]	$-0.01 \pm 0.08 \pm 0.05$	
	CLEO [355]	$0.18 \pm 0.24 \pm 0.02$	
$A_{CP}(B^+ \rightarrow K^+ \pi^0)$	LHCb [356]	$0.025 \pm 0.015 \pm 0.007^1$	0.029 ± 0.012
	Belle [3]	$0.043 \pm 0.024 \pm 0.002$	
	BaBar [8]	$0.030 \pm 0.039 \pm 0.010$	
	Belle II [9]	$0.014 \pm 0.047 \pm 0.010$	
	CLEO [355]	$-0.29 \pm 0.23 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \eta' K^+)$	LHCb [15]	$-0.002 \pm 0.012 \pm 0.006^1$	0.004 ± 0.011
	BaBar [10]	$0.008^{+0.017}_{-0.018} \pm 0.009$	
	Belle [11]	$0.028 \pm 0.028 \pm 0.021$	
	CLEO [355]	$0.03 \pm 0.12 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \eta' K^*(892)^+)$	BaBar [16]	$-0.26 \pm 0.27 \pm 0.02$	-0.26 ± 0.27
$A_{CP}(B^+ \rightarrow \eta'(K\pi)_0^{*+})$	BaBar [16]	$0.06 \pm 0.20 \pm 0.02$	0.06 ± 0.20
$A_{CP}(B^+ \rightarrow \eta' K_2^*(1430)^+)$	BaBar [16]	$0.15 \pm 0.13 \pm 0.02$	0.15 ± 0.13
$A_{CP}(B^+ \rightarrow \eta K^+)$	BaBar [10]	$-0.36 \pm 0.11 \pm 0.03$	-0.37 ± 0.08
	Belle [18]	$-0.38 \pm 0.11 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta K^*(892)^+)$	BaBar [19]	$0.01 \pm 0.08 \pm 0.02$	0.02 ± 0.06
	Belle [20]	$0.03 \pm 0.10 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta(K\pi)_0^{*+})$	BaBar [19]	$0.05 \pm 0.13 \pm 0.02$	0.05 ± 0.13
$A_{CP}(B^+ \rightarrow \eta K_2^*(1430)^+)$	BaBar [19]	$-0.45 \pm 0.30 \pm 0.02$	-0.45 ± 0.30
$A_{CP}(B^+ \rightarrow \omega(782)K^+)$	Belle [23]	$-0.03 \pm 0.04 \pm 0.01$	-0.025 ± 0.036
	BaBar [24]	$-0.01 \pm 0.07 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \omega(782)K^*(892)^+)$	BaBar [26]	$0.29 \pm 0.35 \pm 0.02$	0.29 ± 0.35
$A_{CP}(B^+ \rightarrow \omega(782)(K\pi)_0^{*+})$	BaBar [26]	$-0.10 \pm 0.09 \pm 0.02$	-0.10 ± 0.09
$A_{CP}(B^+ \rightarrow \omega(782)K_2^*(1430)^+)$	BaBar [26]	$0.14 \pm 0.15 \pm 0.02$	0.14 ± 0.15
$A_{CP}(B^+ \rightarrow K^*(892)^0 \pi^+)$	BaBar [28]	$0.032 \pm 0.052^{+0.016}_{-0.013}{}^{2,1}$	-0.04 ± 0.04
	Belle [29]	$-0.149 \pm 0.064 \pm 0.022{}^{2,1}$	
	BaBar [30]	$-0.12 \pm 0.21^{+0.08}_{-0.14}{}^{3,1}$	
$A_{CP}(B^+ \rightarrow K^*(892)^+ \pi^0)$	BaBar [30]	$-0.52 \pm 0.14^{+0.06}_{-0.04}{}^{3,1}$	-0.39 ± 0.13
	BaBar [31]	$-0.06 \pm 0.24 \pm 0.04$	

¹ Multiple systematic uncertainties are added in quadrature.

² Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+ \pi^+ \pi^-$ decays.

³ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0 \pi^+ \pi^0$ decays.

Table 70: CP asymmetries of charmless hadronic B^+ decays (part 2).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K^+\pi^+\pi^-)^1$	LHCb [357]	$0.011 \pm 0.002 \pm 0.004$ ^{2,3,4}	0.0146 ± 0.0041
	LHCb [358]	$0.025 \pm 0.004 \pm 0.008$ ^{5,4}	
	BaBar [28]	$0.028 \pm 0.020 \pm 0.023$ ^{6,4}	
	Belle [29]	$0.049 \pm 0.026 \pm 0.020$ ⁶	
	Belle II [33]	$-0.010 \pm 0.050 \pm 0.021$	
$A_{CP}(B^+ \rightarrow K^+K^+K^-(NR))$	BaBar [22]	$0.060 \pm 0.044 \pm 0.019$ ⁷	0.06 ± 0.05
$A_{CP}(B^+ \rightarrow f_0(980)K^+)$	BaBar [28]	-0.106 ± 0.050 ^{+0.036} _{-0.015} ^{6,4}	-0.08 ± 0.04
	Belle [29]	-0.077 ± 0.065 ^{+0.046} _{-0.026} ^{6,4}	
	BaBar [22]	$-0.08 \pm 0.08 \pm 0.04$ ⁸	
	BaBar [31]	$0.18 \pm 0.18 \pm 0.04$	
$A_{CP}(B^+ \rightarrow f_2(1270)K^+)$	BaBar [28]	-0.85 ± 0.22 ^{+0.26} _{-0.13} ^{6,4}	-0.67 ± 0.19
	Belle [29]	$-0.59 \pm 0.22 \pm 0.04$ ^{6,4}	
$A_{CP}(B^+ \rightarrow f'_2(1525)K^+)$	BaBar [22]	$0.14 \pm 0.10 \pm 0.04$ ⁸	0.14 ± 0.11
$A_{CP}(B^+ \rightarrow \rho^0(770)K^+)$	BaBar [28]	0.44 ± 0.10 ^{+0.06} _{-0.14} ^{6,4}	0.37 ± 0.12
	Belle [29]	0.30 ± 0.11 ^{+0.11} _{-0.04} ^{6,4}	
$A_{CP}(B^+ \rightarrow K^0\pi^+\pi^0)$	BaBar [30]	$0.07 \pm 0.05 \pm 0.04$ ^{9,4}	0.07 ± 0.06
$A_{CP}(B^+ \rightarrow K_0^*(1430)^0\pi^+)$	Belle [29]	0.076 ± 0.038 ^{+0.028} _{-0.022} ^{6,4}	0.084 ± 0.043
	BaBar [30]	0.14 ± 0.10 ^{+0.14} _{-0.06} ^{9,4}	
$A_{CP}(B^+ \rightarrow (K\pi)_0^*\pi^+)$	BaBar [28]	0.032 ± 0.035 ^{+0.034} _{-0.028} ^{6,4}	0.032 ± 0.046
$A_{CP}(B^+ \rightarrow K_0^*(1430)^+\pi^0)$	BaBar [30]	0.26 ± 0.12 ^{+0.14} _{-0.08} ^{9,4}	0.26 ^{+0.19} _{-0.14}
$A_{CP}(B^+ \rightarrow K_2^*(1430)^0\pi^+)$	BaBar [28]	0.05 ± 0.23 ^{+0.18} _{-0.08} ^{6,4}	0.05 ^{+0.29} _{-0.24}
$A_{CP}(B^+ \rightarrow K^+\pi^0\pi^0)$	BaBar [31]	$-0.06 \pm 0.06 \pm 0.04$	-0.06 ± 0.07
$A_{CP}(B^+ \rightarrow \rho^+(770)K^0)$	BaBar [30]	0.21 ± 0.19 ^{+0.24} _{-0.20} ^{9,4}	0.21 ^{+0.31} _{-0.28}
$A_{CP}(B^+ \rightarrow K^*(892)^+\pi^+\pi^-)$	BaBar [42]	$0.07 \pm 0.07 \pm 0.04$	0.07 ± 0.08
$A_{CP}(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$0.31 \pm 0.13 \pm 0.03$	0.31 ± 0.13
$A_{CP}(B^+ \rightarrow f_0(980)K^*(892)^+)$	BaBar [43]	$-0.15 \pm 0.12 \pm 0.03$	-0.15 ± 0.12

¹ Treatment of charmonium intermediate components differs between the results.

² Using run II dataset, corresponding to an integrated luminosity of 5.9fb^{-1} collected at a centre-of-mass energy of 13 TeV (2015 to 2018)

³ Also measured in several invariant mass regions.

⁴ Multiple systematic uncertainties are added in quadrature.

⁵ Using run I dataset, corresponding to an integrated luminosity of 3.0fb^{-1} collected at a centre-of-mass energy of 7 TeV (2011) and 8 TeV (2012)

⁶ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+\pi^+\pi^-$ decays.

⁷ The nonresonant amplitude is modelled using a polynomial function including S-wave and P-wave terms.

⁸ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^+K^-$ decays.

⁹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K_S^0\pi^+\pi^0$ decays.

Table 71: CP asymmetries of charmless hadronic B^+ decays (part 3).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow a_1(1260)^+ K^0)$	BaBar [44]	$0.12 \pm 0.11 \pm 0.02$	0.12 ± 0.11
$A_{CP}(B^+ \rightarrow b_1(1235)^+ K^0)$	BaBar [48]	$-0.03 \pm 0.15 \pm 0.02$	-0.03 ± 0.15
$A_{CP}(B^+ \rightarrow K^*(892)^0 \rho^+(770))$	BaBar [45]	$-0.01 \pm 0.16 \pm 0.02$	-0.01 ± 0.16
$A_{CP}(B^+ \rightarrow b_1(1235)^0 K^+)$	BaBar [49]	$-0.46 \pm 0.20 \pm 0.02$	-0.46 ± 0.20
$A_{CP}(B^+ \rightarrow K^+ K_S^0)$	LHCb [7]	$-0.21 \pm 0.14 \pm 0.01$	-0.086 ± 0.100
	Belle [3]	$0.014 \pm 0.168 \pm 0.002$	
	BaBar [4]	$0.10 \pm 0.26 \pm 0.03$	
$A_{CP}(B^+ \rightarrow K^+ K_S^0 K_S^0)^1$	Belle [52]	$0.016 \pm 0.039 \pm 0.009^2$	0.025 ± 0.032
	BaBar [22]	$0.04^{+0.04}_{-0.05} \pm 0.02^3$	
$A_{CP}(B^+ \rightarrow K^+ K^- \pi^+)^1$	LHCb [357]	$-0.114 \pm 0.007 \pm 0.004^{4,5,6}$	-0.1151 ± 0.0076
	LHCb [358]	$-0.123 \pm 0.017 \pm 0.014^{7,6}$	
	Belle [54]	$-0.170 \pm 0.073 \pm 0.017^8$	
	BaBar [55]	$0.00 \pm 0.10 \pm 0.03$	
$A_{CP}(B^+ \rightarrow K^+ K^- \pi^+(\text{NR}))$	LHCb [56]	$-0.107 \pm 0.053 \pm 0.035^9$	-0.107 ± 0.064
$A_{CP}(B^+ \rightarrow \bar{K}^*(892)^0 K^+)$	LHCb [56]	$0.123 \pm 0.087 \pm 0.045^{10}$	0.123 ± 0.098
$A_{CP}(B^+ \rightarrow \bar{K}_0^*(1430)^0 K^+)$	LHCb [56]	$0.104 \pm 0.149 \pm 0.088^{10}$	0.10 ± 0.17
$A_{CP}(B^+ \rightarrow \phi(1020) \pi^+)$	LHCb [56]	$0.098 \pm 0.436 \pm 0.266^{10}$	0.10 ± 0.51
$A_{CP}(B^+ \rightarrow K^+ K^- \pi^+) \pi\pi \leftrightarrow KK$ rescattering	LHCb [56]	$-0.664 \pm 0.038 \pm 0.019^{10}$	-0.664 ± 0.042

¹ Treatment of charmonium intermediate components differs between the results.

² A_{CP} is also measured in bins of $m_{K_S^0 K_S^0}$

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0 K^+ K^-$ decays.

⁴ Using run II dataset, corresponding to an integrated luminosity of 5.9fb^{-1} collected at a centre-of-mass energy of 13 TeV (2015 to 2018)

⁵ Also measured in several invariant mass regions.

⁶ Multiple systematic uncertainties are added in quadrature.

⁷ Using run I dataset, corresponding to an integrated luminosity of 3.0fb^{-1} collected at a centre-of-mass energy of 7 TeV (2011) and 8 TeV (2012)

⁸ Also measured in bins of $m_{K^+ K^-}$.

⁹ LHCb uses a model of nonresonant obtained from a phenomenological description of the partonic interaction that produces the final state. This contribution is called single pole in the paper, see Ref. [56] for details.

¹⁰ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+ K^- \pi^+$ decays.

Table 72: CP asymmetries of charmless hadronic B^+ decays (part 4).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K^+K^+K^-)$	LHCb [357]	$-0.037 \pm 0.002 \pm 0.004$ ^{1,2,3}	-0.036 ± 0.004
	LHCb [358]	$-0.036 \pm 0.004 \pm 0.007$ ^{4,3}	
	BaBar [22]	$-0.017^{+0.019}_{-0.014} \pm 0.014$ ⁵	
	Belle II [33]	$-0.103 \pm 0.042 \pm 0.020$	
$A_{CP}(B^+ \rightarrow \phi(1020)K^+)$	LHCb [15]	$0.017 \pm 0.011 \pm 0.006$ ^{4,3}	0.024 ± 0.012
	BaBar [22]	$0.128 \pm 0.044 \pm 0.013$ ⁵	
	Belle [66]	$0.01 \pm 0.12 \pm 0.05$	
	CDF [63]	$-0.07 \pm 0.17^{+0.03}_{-0.02}$	
$A_{CP}(B^+ \rightarrow K^*(892)^+K^+K^-)$	BaBar [42]	$0.11 \pm 0.08 \pm 0.03$	0.11 ± 0.09
$A_{CP}(B^+ \rightarrow \phi(1020)K^*(892)^+)$	Belle [359]	$-0.02 \pm 0.14 \pm 0.03$	-0.01 ± 0.08
	BaBar [65]	$0.00 \pm 0.09 \pm 0.04$ ⁶	
$A_{CP}(B^+ \rightarrow (K\pi)_0^{*+}\phi(1020))$	BaBar [67]	$0.04 \pm 0.15 \pm 0.04$	0.04 ± 0.16
$A_{CP}(B^+ \rightarrow K_1(1270)^+\phi(1020))$	BaBar [67]	$0.15 \pm 0.19 \pm 0.05$	0.15 ± 0.20
$A_{CP}(B^+ \rightarrow K_2^*(1430)^+\phi(1020))$	BaBar [67]	$-0.23 \pm 0.19 \pm 0.06$	-0.23 ± 0.20
$A_{CP}(B^+ \rightarrow \phi(1020)\phi(1020)K^+)$	BaBar [69]	$-0.10 \pm 0.08 \pm 0.02$ ⁷	-0.10 ± 0.08

¹ Using run II dataset, corresponding to an integrated luminosity of 5.9fb^{-1} collected at a centre-of-mass energy of 13 TeV (2015 to 2018)

² Also measured in several invariant mass regions.

³ Multiple systematic uncertainties are added in quadrature.

⁴ Using run I dataset, corresponding to an integrated luminosity of 3.0fb^{-1} collected at a centre-of-mass energy of 7 TeV (2011) and 8 TeV (2012)

⁵ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^+K^-$ decays.

⁶ Combination of two final states of the $K^*(892)^\pm$, $K_S^0\pi^\pm$ and $K^\pm\pi^0$. In addition to the combined results, the paper reports separately the results for each individual final state.

⁷ Measured in the $\phi\phi$ invariant mass range below the η_c resonance ($M_{\phi\phi} < 2.85 \text{ GeV}/c^2$).

Table 73: CP asymmetries of charmless hadronic B^+ decays (part 5).

Parameter	Measurements	Average
$A_{CP}(B^+ \rightarrow K^*(892)^+\gamma)$	Belle [231] $0.011 \pm 0.023 \pm 0.003$ BaBar [232] $0.018 \pm 0.028 \pm 0.007$	0.014 ± 0.018
$A_{CP}(B^+ \rightarrow K^+\pi^0\gamma)$	Belle [231] $0.010 \pm 0.036 \pm 0.003$ ¹ BaBar [232] $0.040 \pm 0.039 \pm 0.007$ ²	0.024 ± 0.027
$A_{CP}(B^+ \rightarrow K_S^0\pi^+\gamma)$	Belle [231] $0.013 \pm 0.029 \pm 0.004$ ¹ BaBar [232] $-0.006 \pm 0.041 \pm 0.007$ ²	0.007 ± 0.024
$A_{CP}(B^+ \rightarrow X_s\gamma)$	Belle [320] $0.0275 \pm 0.0184 \pm 0.0032$ ³	0.028 ± 0.019
$A_{CP}(B^+ \rightarrow \eta K^+\gamma)$	Belle [238] $-0.16 \pm 0.09 \pm 0.06$ ⁴ BaBar [237] $-0.090^{+0.104}_{-0.098} \pm 0.014$ ⁵	-0.12 ± 0.07
$A_{CP}(B^+ \rightarrow \phi(1020)K^+\gamma)$	Belle [241] $-0.03 \pm 0.11 \pm 0.08$ ⁶ BaBar [242] $-0.26 \pm 0.14 \pm 0.05$ ⁷	-0.13 ± 0.10
$A_{CP}(B^+ \rightarrow \rho^+(770)\gamma)$	Belle [248] $-0.11 \pm 0.32 \pm 0.09$	-0.11 ± 0.33

¹ $M_{K\pi} < 2.0 \text{ GeV}/c^2$.

² $0.79 < M_{K\pi} < 1.0 \text{ GeV}/c^2$.

³ $M_{X_s} < 2.8 \text{ GeV}/c^2$.

⁴ $M_{K\eta} < 2.4 \text{ GeV}/c^2$.

⁵ $M_{K\eta^{(\prime)}}$ $< 3.25 \text{ GeV}/c^2$.

⁶ $1.4 \leq E_\gamma^* \leq 3.4 \text{ GeV}/c^2$, where E_γ^* is the photon energy in the center-of-mass frame.

⁷ $M_{\phi K} < 3.0 \text{ GeV}/c^2$.

Table 74: CP asymmetries of charmless hadronic B^+ decays (part 6).

Parameter	Measurements	Average
$A_{CP}(B^+ \rightarrow \pi^+\pi^0)$	Belle [3]	$0.025 \pm 0.043 \pm 0.007$
	BaBar [8]	$0.03 \pm 0.08 \pm 0.01$
	Belle II [9]	$-0.085 \pm 0.085 \pm 0.019$
$A_{CP}(B^+ \rightarrow \pi^+\pi^+\pi^-)^1$	LHCb [357]	$0.080 \pm 0.004 \pm 0.004$ ^{2,3,4}
	LHCb [358]	$0.058 \pm 0.008 \pm 0.011$ ^{5,4}
	BaBar [74]	0.032 ± 0.044 ^{+0.040 6,4} _{-0.037}
$A_{CP}(B^+ \rightarrow \rho^0(770)\pi^+)$	LHCb [75]	$0.007 \pm 0.011 \pm 0.040$ ^{5,6,7,4}
	BaBar [74]	0.18 ± 0.07 ^{+0.05 6,4} _{-0.15}
$A_{CP}(B^+ \rightarrow f_2(1270)\pi^+)$	LHCb [75]	$0.468 \pm 0.061 \pm 0.103$ ^{6,7,4}
	LHCb [56]	$0.267 \pm 0.102 \pm 0.048$ ⁸
	BaBar [74]	0.41 ± 0.25 ^{+0.18 6,4} _{-0.15}
$A_{CP}(B^+ \rightarrow \rho(1450)^0\pi^+)$	LHCb [75]	$-0.129 \pm 0.033 \pm 0.421$ ^{6,7,4}
	LHCb [56]	$-0.109 \pm 0.044 \pm 0.024$ ⁸
	BaBar [74]	-0.06 ± 0.28 ^{+0.23 6,4} _{-0.40}
$A_{CP}(B^+ \rightarrow \rho_3(1690)^0\pi^+)$	LHCb [75]	$-0.801 \pm 0.114 \pm 0.511$ ^{6,7,4}
$A_{CP}(B^+ \rightarrow f_0(1370)\pi^+)$	BaBar [74]	$0.72 \pm 0.15 \pm 0.16$ ^{6,4}
$A_{CP}(B^+ \rightarrow \pi^+\pi^+\pi^-), S - \text{wave}$	LHCb [75]	$0.144 \pm 0.018 \pm 0.026$ ^{6,7,4}
$A_{CP}(B^+ \rightarrow \pi^+\pi^+\pi^-(\text{NR}))$	BaBar [74]	-0.14 ± 0.14 ^{+0.18 9,4} _{-0.08}
$A_{CP}(B^+ \rightarrow \rho^+(770)\pi^0)$	BaBar [80]	$-0.01 \pm 0.13 \pm 0.02$
	Belle [78]	0.080 ± 0.150 ^{+0.023} _{-0.075}
$A_{CP}(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [81]	$-0.054 \pm 0.055 \pm 0.010$
	Belle II [82]	$-0.069 \pm 0.068 \pm 0.060$
	Belle [83]	$0.00 \pm 0.22 \pm 0.03$

¹ Treatment of charmonium intermediate components differs between the results.

² Using run II dataset, corresponding to an integrated luminosity of 5.9fb^{-1} collected at a centre-of-mass energy of 13 TeV (2015 to 2018)

³ Also measured in several invariant mass regions.

⁴ Multiple systematic uncertainties are added in quadrature.

⁵ Using run I dataset, corresponding to an integrated luminosity of 3.0fb^{-1} collected at a centre-of-mass energy of 7 TeV (2011) and 8 TeV (2012)

⁶ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow \pi^+\pi^+\pi^-$ decays.

⁷ This analysis uses three different approaches: isobar, K -matrix and quasi-model-independent, to describe the S -wave component. The A_{CP} results are taken from the isobar model with an additional error accounting for the different S -wave methods as reported in Appendix D of Ref. [77].

⁸ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow K^+K^-\pi^+$ decays.

⁹ The nonresonant amplitude is modelled using a sum of exponential functions.

Table 75: CP asymmetries of charmless hadronic B^+ decays (part 7).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow \omega(782)\pi^+)$	LHCb [75]	$-0.048 \pm 0.065 \pm 0.049$ ^{1,2,3}	-0.041 ± 0.048
	BaBar [24]	$-0.02 \pm 0.08 \pm 0.01$	
	Belle [85]	$-0.02 \pm 0.09 \pm 0.01$	
	CLEO [355]	$-0.34 \pm 0.25 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26]	$-0.20 \pm 0.09 \pm 0.02$	-0.20 ± 0.09
$A_{CP}(B^+ \rightarrow \pi^+\pi^0\pi^0)$	Belle [78]	$0.092 \pm 0.068 \pm 0.007$	0.092 ± 0.068
$A_{CP}(B^+ \rightarrow \eta\pi^+)$	Belle [18]	$-0.19 \pm 0.06 \pm 0.01$	-0.14 ± 0.05
	BaBar [10]	$-0.03 \pm 0.09 \pm 0.03$	
$A_{CP}(B^+ \rightarrow \eta\rho^+(770))$	BaBar [86]	$0.13 \pm 0.11 \pm 0.02$	0.11 ± 0.11
	Belle [20]	$-0.04^{+0.34}_{-0.32} \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta'\pi^+)$	BaBar [10]	$0.03 \pm 0.17 \pm 0.02$	0.06 ± 0.15
	Belle [11]	$0.20^{+0.37}_{-0.36} \pm 0.04$	
$A_{CP}(B^+ \rightarrow \eta'\rho^+(770))$	BaBar [16]	$0.26 \pm 0.17 \pm 0.02$	0.26 ± 0.17
$A_{CP}(B^+ \rightarrow b_1(1235)^0\pi^+)$	BaBar [49]	$0.05 \pm 0.16 \pm 0.02$	0.05 ± 0.16
$A_{CP}(B^+ \rightarrow p\bar{p}\pi^+)$	BaBar [158]	$0.04 \pm 0.07 \pm 0.04$	0.04 ± 0.08
$A_{CP}(B^+ \rightarrow p\bar{p}\pi^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [159]	$-0.041 \pm 0.039 \pm 0.005$	-0.058 ± 0.037
	Belle [157]	$-0.17 \pm 0.10 \pm 0.02$	
$A_{CP}(B^+ \rightarrow p\bar{p}K^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [159]	$0.021 \pm 0.020 \pm 0.004$	0.007 ± 0.019
	Belle [157]	$-0.02 \pm 0.05 \pm 0.02$	
	BaBar [162]	$-0.16^{+0.07}_{-0.08} \pm 0.04$	
$A_{CP}(B^+ \rightarrow p\bar{p}K^*(892)^+)^4$	BaBar [158]	$0.32 \pm 0.13 \pm 0.05$	0.21 ± 0.11
	Belle [164]	$-0.01 \pm 0.19 \pm 0.02$	
$A_{CP}(B^+ \rightarrow p\bar{\Lambda}^0\gamma)$	Belle [167]	$0.17 \pm 0.16 \pm 0.05$	0.17 ± 0.17
$A_{CP}(B^+ \rightarrow p\bar{\Lambda}^0\pi^0)$	Belle [167]	$0.01 \pm 0.17 \pm 0.04$	0.01 ± 0.17

¹ Result extracted from Dalitz-plot analysis of $B^+ \rightarrow \pi^+\pi^+\pi^-$ decays.

² This analysis uses three different approaches: isobar, K -matrix and quasi-model-independent, to describe the S -wave component. The A_{CP} results are taken from the isobar model with an additional error accounting for the different S -wave methods as reported in Appendix D of Ref. [77].

³ Multiple systematic uncertainties are added in quadrature.

⁴ Treatment of charmonium intermediate components differs between the results.

Table 76: CP asymmetries of charmless hadronic B^+ decays (part 8).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K^+\ell^+\ell^-)$	Belle [262]	$0.04 \pm 0.10 \pm 0.02$	0.02 ± 0.08
	BaBar [290]	$-0.03 \pm 0.14 \pm 0.01$	
$A_{CP}(B^+ \rightarrow K^+e^+e^-)$	Belle [262]	$0.14 \pm 0.14 \pm 0.03$	0.14 ± 0.14
$A_{CP}(B^+ \rightarrow K^+\mu^+\mu^-)$	LHCb [360]	$0.012 \pm 0.017 \pm 0.001$ ^{1,2}	0.011 ± 0.017
	Belle [262]	$-0.05 \pm 0.13 \pm 0.03$ ³	
$A_{CP}(B^+ \rightarrow \pi^+\mu^+\mu^-)$	LHCb [253]	$-0.11 \pm 0.12 \pm 0.01$	-0.11 ± 0.12
$A_{CP}(B^+ \rightarrow K^*(892)^+\ell^+\ell^-)$	Belle [262]	$-0.13^{+0.17}_{-0.16} \pm 0.01$	-0.09 ± 0.14
	BaBar [258]	$0.01^{+0.26}_{-0.24} \pm 0.02$	
$A_{CP}(B^+ \rightarrow K^*(892)^+e^+e^-)$	Belle [262]	$-0.14^{+0.23}_{-0.22} \pm 0.02$	-0.14 ± 0.23
$A_{CP}(B^+ \rightarrow K^*(892)^+\mu^+\mu^-)$	Belle [262]	$-0.12 \pm 0.24 \pm 0.02$	-0.12 ± 0.24

¹ A_{CP} is also measured in bins of $m_{\mu^+\mu^-}$

² Mass regions corresponding to ϕ , J/ψ and $\psi(2S)$ are vetoed.

³ Mass regions corresponding to J/ψ and $\psi(2S)$ are vetoed.

Table 77: CP asymmetries of charmless hadronic B^0 decays (part 1).

Parameter	Measurements	Average	
$A_{CP}(B^0 \rightarrow K^+\pi^-)$	LHCb [361]	-0.0831 ± 0.0034 ¹	-0.0836 ± 0.0032
	CDF [362]	$-0.083 \pm 0.013 \pm 0.004$	
	Belle [3]	$-0.069 \pm 0.014 \pm 0.007$	
	BaBar [97]	-0.107 ± 0.016 $^{+0.006}_{-0.004}$	
	Belle II [5]	$-0.16 \pm 0.05 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \eta'K^*(892)^0)$	BaBar [16]	$0.02 \pm 0.23 \pm 0.02$	-0.07 ± 0.18
	Belle [100]	$-0.22 \pm 0.29 \pm 0.07$	
$A_{CP}(B^0 \rightarrow \eta'(K\pi)_0^{*0})$	BaBar [16]	$-0.19 \pm 0.17 \pm 0.02$	-0.19 ± 0.17
$A_{CP}(B^0 \rightarrow \eta'K_2^*(1430)^0)$	BaBar [16]	$0.14 \pm 0.18 \pm 0.02$	0.14 ± 0.18
$A_{CP}(B^0 \rightarrow \eta K^*(892)^0)$	BaBar [19]	$0.21 \pm 0.06 \pm 0.02$	0.19 ± 0.05
	Belle [20]	$0.17 \pm 0.08 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \eta(K\pi)_0^{*0})$	BaBar [19]	$0.06 \pm 0.13 \pm 0.02$	0.06 ± 0.13
$A_{CP}(B^0 \rightarrow \eta K_2^*(1430)^0)$	BaBar [19]	$-0.07 \pm 0.19 \pm 0.02$	-0.07 ± 0.19
$A_{CP}(B^0 \rightarrow b_1(1235)^-K^+)$	BaBar [49]	$-0.07 \pm 0.12 \pm 0.02$	-0.07 ± 0.12
$A_{CP}(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$0.45 \pm 0.25 \pm 0.02$	0.45 ± 0.25
$A_{CP}(B^0 \rightarrow \omega(782)(K\pi)_0^{*0})$	BaBar [26]	$-0.07 \pm 0.09 \pm 0.02$	-0.07 ± 0.09
$A_{CP}(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$-0.37 \pm 0.17 \pm 0.02$	-0.37 ± 0.17
$A_{CP}(B^0 \rightarrow K^+\pi^-\pi^0)$	BaBar [105]	-0.030 $^{+0.045}_{-0.051} \pm 0.055$ ²	0.06 ± 0.05
	Belle II [33]	$0.207 \pm 0.088 \pm 0.011$	
	Belle [104]	$0.07 \pm 0.11 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \rho^-(770)K^+)$	BaBar [103]	$0.20 \pm 0.09 \pm 0.08$ ²	0.20 ± 0.11
	Belle [104]	0.22 $^{+0.22+0.06}_{-0.23-0.02}$	
$A_{CP}(B^0 \rightarrow \rho(1450)^-K^+)$	BaBar [103]	$-0.10 \pm 0.32 \pm 0.09$ ²	-0.10 ± 0.33
$A_{CP}(B^0 \rightarrow \rho(1700)^-K^+)$	BaBar [103]	$-0.36 \pm 0.57 \pm 0.23$ ²	-0.36 ± 0.61
$A_{CP}(B^0 \rightarrow K^+\pi^-\pi^0(\text{NR}))$	BaBar [103]	$0.10 \pm 0.16 \pm 0.08$ ³	0.10 ± 0.18
$A_{CP}(B^0 \rightarrow K^0\pi^+\pi^-)$	BaBar [106]	$-0.01 \pm 0.05 \pm 0.01$ ⁴	-0.01 ± 0.05
$A_{CP}(B^0 \rightarrow K^*(892)^+\pi^-)$	LHCb [111]	$-0.308 \pm 0.060 \pm 0.016$ ^{4,5}	-0.274 ± 0.045
	BaBar [106]	$-0.21 \pm 0.10 \pm 0.02$ ^{4,5}	
	BaBar [103]	$-0.29 \pm 0.11 \pm 0.02$ ²	
	Belle [363]	$-0.21 \pm 0.11 \pm 0.07$ ⁴	

¹ LHCb combines results of the 1.9fb^{-1} run 2 data analysis with those based on Run 1 dataset [364]. The full statistical and systematic covariance matrices are used in the combination.

² Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K^+\pi^-\pi^0$ decays.

³ The nonresonant amplitude is taken to be constant across the Dalitz plane.

⁴ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0\pi^+\pi^-$ decays.

⁵ Multiple systematic uncertainties are added in quadrature.

Table 78: CP asymmetries of charmless hadronic B^0 decays (part 2).

Parameter	Measurements	Average
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-)$	LHCb [111]	$-0.032 \pm 0.047 \pm 0.031$ ^{1,2}
	BaBar [106]	$0.09 \pm 0.07 \pm 0.03$ ^{1,2}
	BaBar [103]	$0.07 \pm 0.14 \pm 0.01$ ³
$A_{CP}(B^0 \rightarrow K_2^*(1430)^+\pi^-)$	LHCb [111]	$-0.29 \pm 0.22 \pm 0.09$ ^{1,2}
$A_{CP}(B^0 \rightarrow K^*(1680)^+\pi^-)$	LHCb [111]	$-0.07 \pm 0.13 \pm 0.04$ ^{1,2}
$A_{CP}(B^0 \rightarrow f_0(980)K_S^0)$	LHCb [111]	$0.28 \pm 0.27 \pm 0.15$ ^{1,2}
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*0}\pi^0)$	BaBar [103]	$-0.15 \pm 0.10 \pm 0.04$ ³
$A_{CP}(B^0 \rightarrow K^*(892)^0\pi^0)$	BaBar [103]	$-0.15 \pm 0.12 \pm 0.04$ ³
$A_{CP}(B^0 \rightarrow K^*(892)^0\rho^+\pi^-)$	BaBar [115]	$0.07 \pm 0.04 \pm 0.03$
$A_{CP}(B^0 \rightarrow K^*(892)^0\rho^0(770))$	BaBar [116]	$-0.06 \pm 0.09 \pm 0.02$
$A_{CP}(B^0 \rightarrow f_0(980)K^*(892)^0)$	BaBar [116]	$0.07 \pm 0.10 \pm 0.02$
$A_{CP}(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [116]	$0.21 \pm 0.15 \pm 0.02$
$A_{CP}(B^0 \rightarrow K^*(892)^0K^+K^-)$	BaBar [115]	$0.01 \pm 0.05 \pm 0.02$
$A_{CP}(B^0 \rightarrow a_1(1260)^-K^+)$	BaBar [44]	$-0.16 \pm 0.12 \pm 0.01$
$A_{CP}(B^0 \rightarrow K^0\bar{K}^0)$	Belle [365]	$-0.58^{+0.73}_{-0.66} \pm 0.04$ ⁴
$A_{CP}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	Belle [127]	$-0.007 \pm 0.048 \pm 0.021$
	BaBar [126]	$0.01 \pm 0.06 \pm 0.03$
$A_{CP}(B^0 \rightarrow K^*(892)^0\pi^+K^-)$	BaBar [115]	$0.22 \pm 0.33 \pm 0.20$
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*0}\phi(1020))$	Belle [127]	$0.093 \pm 0.094 \pm 0.017$
	BaBar [126]	$0.20 \pm 0.14 \pm 0.06$
$A_{CP}(B^0 \rightarrow K_2^*(1430)^0\phi(1020))$	BaBar [126]	$-0.08 \pm 0.12 \pm 0.05$
	Belle [127]	$-0.155^{+0.152}_{-0.133} \pm 0.033$
$A_{CP}(B^0 \rightarrow K^*(892)^0\gamma)$	LHCb [203]	$0.008 \pm 0.017 \pm 0.009$
	Belle [231]	$-0.013 \pm 0.017 \pm 0.004$
	BaBar [232]	$-0.016 \pm 0.022 \pm 0.007$
$A_{CP}(B^0 \rightarrow K^+\pi^-\gamma)$	Belle [231]	$-0.013 \pm 0.017 \pm 0.004$ ⁵
	BaBar [232]	$-0.016 \pm 0.022 \pm 0.007$ ⁶
$A_{CP}(B^0 \rightarrow K_2^*(1430)^0\gamma)$	BaBar [246]	$-0.08 \pm 0.15 \pm 0.01$
$A_{CP}(B^0 \rightarrow X_s\gamma)$	Belle [320]	$-0.0094 \pm 0.0174 \pm 0.0047$ ⁷

¹ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K_S^0\pi^+\pi^-$ decays.

² Multiple systematic uncertainties are added in quadrature.

³ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow K^+\pi^-\pi^0$ decays.

⁴ Result extracted from a time-dependent analysis.

⁵ $M_{K\pi} < 2.0$ GeV/ c^2 .

⁶ $0.78 < M_{K\pi} < 1.1$ GeV/ c^2 .

⁷ $M_{X_s} < 2.8$ GeV/ c^2 .

Table 79: CP asymmetries of charmless hadronic B^0 decays (part 3).

Parameter	Measurements	Average	
$A_{CP}(B^0 \rightarrow \rho^+(770)\pi^-)$	BaBar [366]	$0.09^{+0.05}_{-0.06} \pm 0.04$ ¹	0.13 ± 0.05
	Belle [367]	$0.21 \pm 0.08 \pm 0.04$ ¹	
$A_{CP}(B^0 \rightarrow \rho^-(770)\pi^+)$	BaBar [366]	$-0.12 \pm 0.08^{+0.04}_{-0.05}$ ¹	-0.08 ± 0.08
	Belle [367]	$0.08 \pm 0.16 \pm 0.11$ ¹	
$A_{CP}(B^0 \rightarrow a_1(1260)^+\pi^- + \text{c.c.})$	Belle [148]	$0.01 \pm 0.11 \pm 0.09$ ²	0.05 ± 0.11
	BaBar [368]	$0.10 \pm 0.15 \pm 0.09$ ²	
$A_{CP}(B^0 \rightarrow b_1(1235)^+\pi^- + \text{c.c.})$	BaBar [49]	$-0.05 \pm 0.10 \pm 0.02$	-0.05 ± 0.10
$A_{CP}(B^0 \rightarrow p\bar{p}K^*(892)^0)^3$	BaBar [158]	$0.11 \pm 0.13 \pm 0.06$	0.05 ± 0.12
	Belle [164]	$-0.08 \pm 0.20 \pm 0.02$	
$A_{CP}(B^0 \rightarrow p\bar{\Lambda}^0\pi^-)$	BaBar [176]	$-0.10 \pm 0.10 \pm 0.02$	-0.06 ± 0.07
	Belle [167]	$-0.02 \pm 0.10 \pm 0.03$	
$A_{CP}(B^0 \rightarrow K^*(892)^0\ell^+\ell^-)$	Belle [262]	$-0.08 \pm 0.12 \pm 0.02$	-0.05 ± 0.10
	BaBar [258]	$0.02 \pm 0.20 \pm 0.02$	
$A_{CP}(B^0 \rightarrow K^*(892)^0e^+e^-)$	Belle [262]	$-0.21 \pm 0.19 \pm 0.02$	-0.21 ± 0.19
$A_{CP}(B^0 \rightarrow K^*(892)^0\mu^+\mu^-)$	LHCb [360]	$-0.035 \pm 0.024 \pm 0.003$ ^{4,5}	-0.034 ± 0.024
	Belle [262]	$0.00 \pm 0.15 \pm 0.03$ ⁶	

¹ Result extracted from Dalitz-plot analysis of $B^0 \rightarrow \pi^+\pi^-\pi^0$ decays.

² Result extracted from a time-dependent analysis.

³ Treatment of charmonium intermediate components differs between the results.

⁴ A_{CP} is also measured in bins of $m_{\mu^+\mu^-}$

⁵ Mass regions corresponding to ϕ , J/ψ and $\psi(2S)$ are vetoed.

⁶ Mass regions corresponding to J/ψ and $\psi(2S)$ are vetoed.

Table 80: CP asymmetries of charmless hadronic decays of B^\pm/B^0 admixture.

Parameter	Measurements	Average
$A_{CP}(B \rightarrow K^*\gamma)$	Belle [231] $-0.004 \pm 0.014 \pm 0.003$ BaBar [232] $-0.003 \pm 0.017 \pm 0.007$	-0.004 ± 0.011
$A_{CP}(B \rightarrow X_s\gamma)$	Belle [320] $0.0144 \pm 0.0128 \pm 0.0011$ ¹ BaBar [369] $0.017 \pm 0.019 \pm 0.010$ ²	0.015 ± 0.011
$A_{CP}(B \rightarrow X_{s+d}\gamma)$	Belle [370] $0.022 \pm 0.039 \pm 0.009$ ³ BaBar [279] $0.057 \pm 0.060 \pm 0.018$ ⁴	0.032 ± 0.034
$A_{CP}(B \rightarrow X_s\ell^+\ell^-)$	BaBar [286] $0.04 \pm 0.11 \pm 0.01$	0.04 ± 0.11
$A_{CP}(B \rightarrow K^*e^+e^-)$	Belle [262] $-0.18 \pm 0.15 \pm 0.01$	-0.18 ± 0.15
$A_{CP}(B \rightarrow K^*\mu^+\mu^-)$	Belle [262] $-0.03 \pm 0.13 \pm 0.02$	-0.03 ± 0.13
$A_{CP}(B \rightarrow K^*\ell^+\ell^-)$	Belle [262] $-0.10 \pm 0.10 \pm 0.01$ BaBar [290] $0.03 \pm 0.13 \pm 0.01$	-0.05 ± 0.08
$A_{CP}(B \rightarrow X_s\eta)$	Belle [315] -0.13 ± 0.04 ^{+0.02} _{-0.03} ⁵	-0.13 ^{+0.04} _{-0.05}
$A_{CP}(B \rightarrow K\ell^+\ell^-)$	BaBar [290] $-0.03 \pm 0.14 \pm 0.01$	-0.03 ± 0.14

¹ $M_{X_s} < 2.8 \text{ GeV}/c^2$.

² $0.6 < M_{X_s} < 2.0 \text{ GeV}/c^2$.

³ $E_\gamma^* \geq 2.1 \text{ GeV}$ where E_γ^* is the photon energy in the center-of-mass frame.

⁴ $2.1 < E_\gamma^* < 2.8 \text{ GeV}$ where E_γ^* is the photon energy in the center-of-mass frame.

⁵ $0.4 < m_X < 2.6 \text{ GeV}/c^2$.

Table 81: CP asymmetries of charmless hadronic B_s^0 decays.

Parameter	Measurements	Average
$A_{CP}(B_s^0 \rightarrow \pi^+K^-)$	LHCb [361] 0.225 ± 0.012 ¹ CDF [362] $0.22 \pm 0.07 \pm 0.02$	0.225 ± 0.012

¹ LHCb combines results of the 1.9fb^{-1} run 2 data analysis with those based on Run 1 dataset [364]. The full statistical and systematic covariance matrices are used in the combination.

Table 82: CP asymmetries of charmless hadronic Λ_b^0 decays.

Parameter	Measurements	Average
$A_{CP}(\Lambda_b^0 \rightarrow p\pi^-)$	LHCb [371]	$-0.035 \pm 0.017 \pm 0.020$
	CDF [362]	$0.06 \pm 0.07 \pm 0.03$
$A_{CP}(\Lambda_b^0 \rightarrow pK^-)$	LHCb [371]	$-0.020 \pm 0.013 \pm 0.019$
	CDF [362]	$-0.10 \pm 0.08 \pm 0.04$
$A_{CP}(\Lambda_b^0 \rightarrow p\bar{K}^0\pi^-)$	LHCb [108]	$0.22 \pm 0.13 \pm 0.03$
$A_{CP}(\Lambda_b^0 \rightarrow \Lambda^0 K^+\pi^-)$	LHCb [185]	$-0.53 \pm 0.23 \pm 0.11$
$A_{CP}(\Lambda_b^0 \rightarrow \Lambda^0 K^+K^-)$	LHCb [185]	$-0.28 \pm 0.10 \pm 0.07$

Measurements that are not included in the tables (the definitions of observables can be found in the corresponding experimental papers):

- In Ref. [372], LHCb reports the triple-product asymmetries ($a_{CP}^{\hat{T}^{-odd}}$, $a_P^{\hat{T}^{-odd}}$) for the decays $\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-$ and $\Lambda_b^0 \rightarrow p\pi^-K^+K^-$.
- In Ref. [373], LHCb reports $a_{CP}^{\hat{T}^{-odd}}$, $a_P^{\hat{T}^{-odd}}$ and $\Delta(A_{CP}) = A_{CP}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-) - A_{CP}(\Lambda_b^0 \rightarrow pK^-J/\psi)$.
- In Ref. [374], LHCb reports $a_{CP}^{\hat{T}^{-odd}}$ and $a_P^{\hat{T}^{-odd}}$ for the decays $\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-$, $\Lambda_b^0 \rightarrow pK^-K^+K^-$ and $\Xi_b^0 \rightarrow pK^-K^-\pi^+$.
- In Ref. [375] LHCb measures differences of CP asymmetries between Λ_b^0 and Ξ_b^0 charmless decays into a proton and three charged mesons and the decays to the same final states with an intermediate charmed baryon.

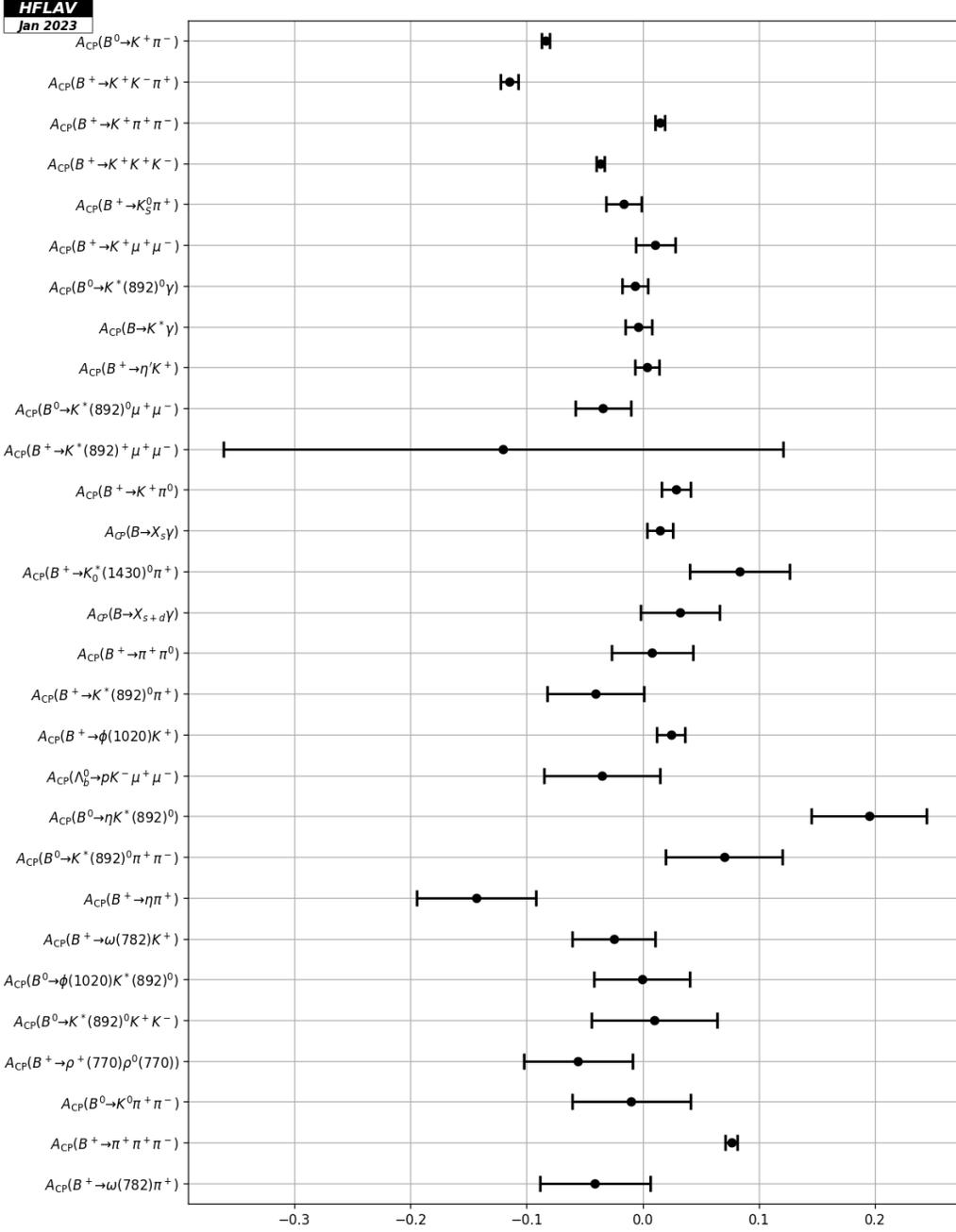


Figure 13: A selection among the most precise direct CP asymmetries (A_{CP}) measured in charmless B^+ and B^0 decay modes.

8 Polarization measurements in b -hadron decays

In this section, compilations of polarization measurements in b -hadron decays are given. Tables 83, 84, and 85 detail measurements of the longitudinal fraction, f_L , in $B^+ B^0$, and B_s^0 decays, respectively. They are followed by Tables 86, 87 and 88, which list polarisation fractions and CP parameters measured in full angular analyses of B^+ , B^0 and B_s^0 decays. Figures 14 and 15 show graphic representations of a selection of results shown in this section.

Most of the final states considered in the tables are pairs of vector mesons and thus, we detail below the corresponding definitions. For specific definitions, for example regarding vector-tensor final states or vector recoiling against dispin-half states, please refer to the articles. In the decay of a pseudoscalar meson into two vector mesons, momentum conservation allows for three helicity configurations: $H_0, H_{\pm 1}$. They can be expressed in terms of longitudinal polarisation amplitudes, $A_0 = H_0$, and transverse polarisation amplitudes, $A_{\perp} = (H_{+1} - H_{-1})/\sqrt{2}$ and $A_{\parallel} = (H_{+1} + H_{-1})/\sqrt{2}$ and their charge conjugates: $\overline{A}_0, \overline{A}_{\parallel}$, and \overline{A}_{\perp} . Using the definitions:

$$F_{k=0,\parallel,\perp} = \frac{|A_k|^2}{|A_0|^2 + |A_{\perp}|^2 + |A_{\parallel}|^2}, \quad \overline{F}_{k=0,\parallel,\perp} = \frac{|\overline{A}_k|^2}{|\overline{A}_0|^2 + |\overline{A}_{\perp}|^2 + |\overline{A}_{\parallel}|^2}, \quad (2)$$

the following CP conserving and CP violating observables, which are used in our tables, are defined:

$$f_{k=0,\parallel,\perp} = \frac{1}{2}(F_k + \overline{F}_k), \quad A_{CP}^{k=0,\perp} = \frac{F_k - \overline{F}_k}{F_k + \overline{F}_k}. \quad (3)$$

Note that, in the literature, f_0 and f_L are used interchangeably to denote the longitudinal polarization fraction.

Table 83: Longitudinal polarization fraction, f_L , in B^+ decays.

Parameter	Measurements	Average ^{HFLAV} _{PDG}	
$f_L(B^+ \rightarrow \omega(782)K^*(892)^+)$	BaBar [26]	$0.41 \pm 0.18 \pm 0.05$	0.41 ± 0.19
$f_L(B^+ \rightarrow \omega(782)K_2^*(1430)^+)$	BaBar [26]	$0.56 \pm 0.10 \pm 0.04$	0.56 ± 0.11
$f_L(B^+ \rightarrow K^*(892)^+\bar{K}^*(892)^0)$	BaBar [60]	$0.75^{+0.16}_{-0.26} \pm 0.03$	$0.82^{+0.13}_{-0.17}$
	Belle [59]	$1.06 \pm 0.30 \pm 0.14$	$0.82^{+0.15}_{-0.21}$
$f_L(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [65]	$0.49 \pm 0.05 \pm 0.03$ ¹	0.50 ± 0.05
	Belle [359]	$0.52 \pm 0.08 \pm 0.03$	
	Belle II [62]	$0.58 \pm 0.23 \pm 0.02$	
$f_L(B^+ \rightarrow \phi(1020)K_1(1270)^+)$	BaBar [67]	$0.46^{+0.12}_{-0.13}^{+0.06}_{-0.07}$	0.46 ± 0.14
$f_L(B^+ \rightarrow \phi(1020)K_2^*(1430)^+)$	BaBar [67]	$0.80^{+0.09}_{-0.10} \pm 0.03$	0.80 ± 0.10
$f_L(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$0.78 \pm 0.12 \pm 0.03$	0.78 ± 0.12
$f_L(B^+ \rightarrow K^*(892)^0\rho^+(770))$	BaBar [45]	$0.52 \pm 0.10 \pm 0.04$	0.48 ± 0.08
	Belle [46]	$0.43 \pm 0.11^{+0.05}_{-0.02}$ ²	
$f_L(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [81]	$0.950 \pm 0.015 \pm 0.006$	0.949 ± 0.015
	Belle II [82]	$0.943^{+0.035}_{-0.033} \pm 0.027$	
	Belle [83]	$0.948 \pm 0.106 \pm 0.021$	
$f_L(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26]	$0.90 \pm 0.05 \pm 0.03$	0.90 ± 0.06
$f_L(B^+ \rightarrow p\bar{p}K^*(892)^+)$	Belle [164]	$0.32 \pm 0.17 \pm 0.09$	0.32 ± 0.19

¹ Combination of two final states of the $K^*(892)^\pm$, $K_S^0\pi^\pm$ and $K^\pm\pi^0$. In addition to the combined results, the paper reports separately the results for each individual final state.

² See also Ref. [51].

Table 84: Longitudinal polarization fraction, f_L , in B^0 decays.

Parameter	Measurements	Average ^{HFLAV} _{PDG}
$f_L(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$0.72 \pm 0.14 \pm 0.02$
	LHCb [376]	$0.68 \pm 0.17 \pm 0.16$
	Belle [101]	$0.56 \pm 0.29^{+0.18}_{-0.08}$
$f_L(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$0.45 \pm 0.12 \pm 0.02$
$f_L(B^0 \rightarrow K^*(892)^0\bar{K}^*(892)^0)$	LHCb [133]	$0.724 \pm 0.051 \pm 0.016$
	BaBar [134]	$0.80^{+0.10}_{-0.12} \pm 0.06$
$f_L(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [377]	$0.497 \pm 0.019 \pm 0.015$
	Belle [127]	$0.499 \pm 0.030 \pm 0.018$
	BaBar [126]	$0.494 \pm 0.034 \pm 0.013$
	Belle II [62]	$0.57 \pm 0.20 \pm 0.04$
$f_L(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [127]	$0.918^{+0.029}_{-0.060} \pm 0.012$
	BaBar [126]	$0.901^{+0.046}_{-0.058} \pm 0.037$
$f_L(B^0 \rightarrow K^*(892)^0\rho^0(770))$	LHCb [376]	$0.164 \pm 0.015 \pm 0.022$
	BaBar [116]	$0.40 \pm 0.08 \pm 0.11$
$f_L(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [116]	$0.38 \pm 0.13 \pm 0.03$
$f_L(B^0 \rightarrow \rho^+(770)\rho^-(770))$	Belle [150]	$0.988 \pm 0.012 \pm 0.023$
	BaBar [151]	$0.992 \pm 0.024^{+0.026}_{-0.013}$
	Belle II [152]	$0.956 \pm 0.035 \pm 0.033$
$f_L(B^0 \rightarrow \rho^0(770)\rho^0(770))^1$	LHCb [131]	$0.745^{+0.048}_{-0.058} \pm 0.034$
	BaBar [147]	$0.75^{+0.11}_{-0.14} \pm 0.04$
	Belle [146]	$0.21^{+0.18}_{-0.22} \pm 0.15$
$f_L(B^0 \rightarrow a_1(1260)^+a_1(1260)^-)$	BaBar [154]	$0.31 \pm 0.22 \pm 0.10$
$f_L(B^0 \rightarrow p\bar{p}K^*(892)^0)$	Belle [164]	$1.01 \pm 0.13 \pm 0.03$
$f_L(B^0 \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^0)$	Belle [170]	$0.60 \pm 0.22 \pm 0.08$ ^{2,3}
$f_L(B^0 \rightarrow K^{*0}\mu^+\mu^-), 0.04 < q^2 < 6.0 \text{ GeV}^2/c^4$	ATLAS [345]	$0.50 \pm 0.06 \pm 0.04$
$f_L(B^0 \rightarrow K^{*0}e^+e^-), 0.002 < q^2 < 1.120 \text{ GeV}^2/c^4$	LHCb [378]	$0.16 \pm 0.06 \pm 0.03$

¹ The PDG uncertainty includes a scale factor.

² The charmonium mass regions are vetoed.

³ $M_{\Lambda^0\bar{\Lambda}^0} < 2.85 \text{ GeV}/c^2$.

Table 85: Longitudinal polarization fraction, f_L , in B_s^0 decays.

Parameter	Measurements	Average	^{HFLAV} _{PDG}
$f_L(B_s^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [142]	$0.381 \pm 0.007 \pm 0.012$	0.378 ± 0.013
	CDF [198]	$0.348 \pm 0.041 \pm 0.021$	
$f_L(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)$	LHCb [133]	$0.240 \pm 0.031 \pm 0.025$	0.24 ± 0.04
$f_L(B_s^0 \rightarrow \phi(1020) \bar{K}^*(892)^0)$	LHCb [128]	$0.51 \pm 0.15 \pm 0.07$	0.51 ± 0.17
$f_L(B_s^0 \rightarrow \bar{K}_2^*(1430)^0 K^*(892)^0)$	LHCb [379]	$0.911 \pm 0.020 \pm 0.165$	0.91 ± 0.17
$f_L(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}^*(892)^0)$	LHCb [379]	$0.62 \pm 0.16 \pm 0.25$	0.62 ± 0.30
$f_L(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}_2^*(1430)^0)$	LHCb [379]	$0.25 \pm 0.14 \pm 0.18$	0.25 ± 0.23

Table 86: Results of full angular analyses of B^+ decays.

Parameter	Measurements	Average	^{HFLAV} _{PDG}
$f_\perp(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [65]	$0.21 \pm 0.05 \pm 0.02$ ¹	0.20 ± 0.05
	Belle [359]	$0.19 \pm 0.08 \pm 0.02$	
$A_{CP}^0(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [65]	$0.17 \pm 0.11 \pm 0.02$ ¹	0.17 ± 0.11
$A_{CP}^\perp(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [65]	$0.22 \pm 0.24 \pm 0.08$ ¹	0.22 ± 0.25

¹ Combination of two final states of the $K^*(892)^\pm$, $K_S^0\pi^\pm$ and $K^\pm\pi^0$. In addition to the combined results, the paper reports separately the results for each individual final state.

Table 87: Results of full angular analyses of B^0 decays.

Parameter	Measurements	Average	HFLAV PDG
$f_{\perp}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [377]	$0.221 \pm 0.016 \pm 0.013$	0.224 ± 0.015
	Belle [127]	$0.238 \pm 0.026 \pm 0.008$	
	BaBar [126]	$0.212 \pm 0.032 \pm 0.013$	
$A_{CP}^0(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [377]	$-0.003 \pm 0.038 \pm 0.005$	-0.007 ± 0.030
	Belle [127]	$-0.030 \pm 0.061 \pm 0.007$	
	BaBar [126]	$0.01 \pm 0.07 \pm 0.02$	
$A_{CP}^{\perp}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [377]	$0.047 \pm 0.074 \pm 0.009$	-0.02 ± 0.06
	Belle [127]	$-0.14 \pm 0.11 \pm 0.01$	
	BaBar [126]	$-0.04 \pm 0.15 \pm 0.06$	
$f_{\perp}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)^1$	BaBar [126]	$0.002^{+0.018}_{-0.002} \pm 0.031$	$0.029^{+0.024}_{-0.026}$
	Belle [127]	$0.056^{+0.050}_{-0.035} \pm 0.009$	$0.027^{+0.031}_{-0.025}$
$A_{CP}^0(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [127]	$-0.016^{+0.066}_{-0.051} \pm 0.008$	-0.03 ± 0.04
	BaBar [126]	$-0.05 \pm 0.06 \pm 0.01$	
$A_{CP}^{\perp}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [127]	$-0.01^{+0.85}_{-0.67} \pm 0.09$	$-0.01^{+0.85}_{-0.68}$

¹ The PDG uncertainty includes a scale factor.

 Table 88: Results of full angular analyses of B_s^0 decays.

Parameter	Measurements	Average	HFLAV PDG
$f_{\perp}(B_s^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [142]	$0.290 \pm 0.008 \pm 0.007$	0.293 ± 0.010
	CDF [198]	$0.365 \pm 0.044 \pm 0.027$	0.292 ± 0.009
$f_{\parallel}(B_s^0 \rightarrow \phi(1020)\overline{K}^*(892)^0)$	LHCb [128]	$0.21 \pm 0.11 \pm 0.02$	0.21 ± 0.11
$f_{\perp}(B_s^0 \rightarrow K^*(892)^0\overline{K}^*(892)^0)$	LHCb [133]	$0.526 \pm 0.032 \pm 0.019$	0.526 ± 0.037
			0.380 ± 0.120
$f_{\parallel}(B_s^0 \rightarrow K^*(892)^0\overline{K}^*(892)^0)$	LHCb [133]	$0.234 \pm 0.025 \pm 0.010$	0.23 ± 0.03
			0.30 ± 0.05

Measurements that are not included in the tables (the definitions of observables can be found in the corresponding experimental papers):

- In the angular analysis of $B^0 \rightarrow \phi K^*(892)^0$ decays [377], in addition to the results quoted in Table 87, LHCb reports observables related to the S -wave component contributing the final state $K^+K^-K^+\pi^-$: $f_S(K\pi)$, $f_S(KK)$, $\delta_S(K\pi)$, $\delta_S(KK)$, $\mathcal{A}_S(K\pi)^{CP}$, $\mathcal{A}_S(KK)^{CP}$, $\delta_S(K\pi)^{CP}$, $\delta_S(KK)^{CP}$.
- In the amplitude analysis of $B_s^0 \rightarrow \phi\phi$ decays, in addition to the results quoted in Table 88, LHCb, in Ref. [142], extracts the CP -violating phase ϕ_s^{ss} and the CP -violating parameter $|\lambda|$ from a decay-time-dependent and polarisation independent fit. The CP -violating phases $\phi_{s,\parallel}$ and $\phi_{s,\perp}$ are obtained in a polarisation-dependent fit. A time-integrated fit is performed to extract the triple-product asymmetries A_U and A_V . CDF, in Ref. [198] also reports the triple-product asymmetries A_U and A_V .
- In Ref. [379], LHCb presents a flavour-tagged, decay-time-dependent amplitude analysis of $B_s^0 \rightarrow (K^+\pi^-)(K^-\pi^+)$ decays in the $K^\pm\pi^\mp$ mass range from 750 to 1600 MeV/ c^2 . The paper includes measurements of 19 CP -averaged amplitude parameters corresponding to scalar, vector and tensor final states as well as the first measurement of the CP -violating phase $\phi_s^{d\bar{d}}$.
- Reference [376] presents an amplitude analysis of $B^0 \rightarrow \rho K^*(892)^0$ realised by LHCb. Scalar (S) and vector (V) contributions to the final state $(\pi^+\pi^+)(K^+\pi^-)$ are considered through partial waves sharing the same angular dependence (VV , SS , SV , VS) and the corresponding amplitudes are extracted for each case. Triple product asymmetries are also reported.

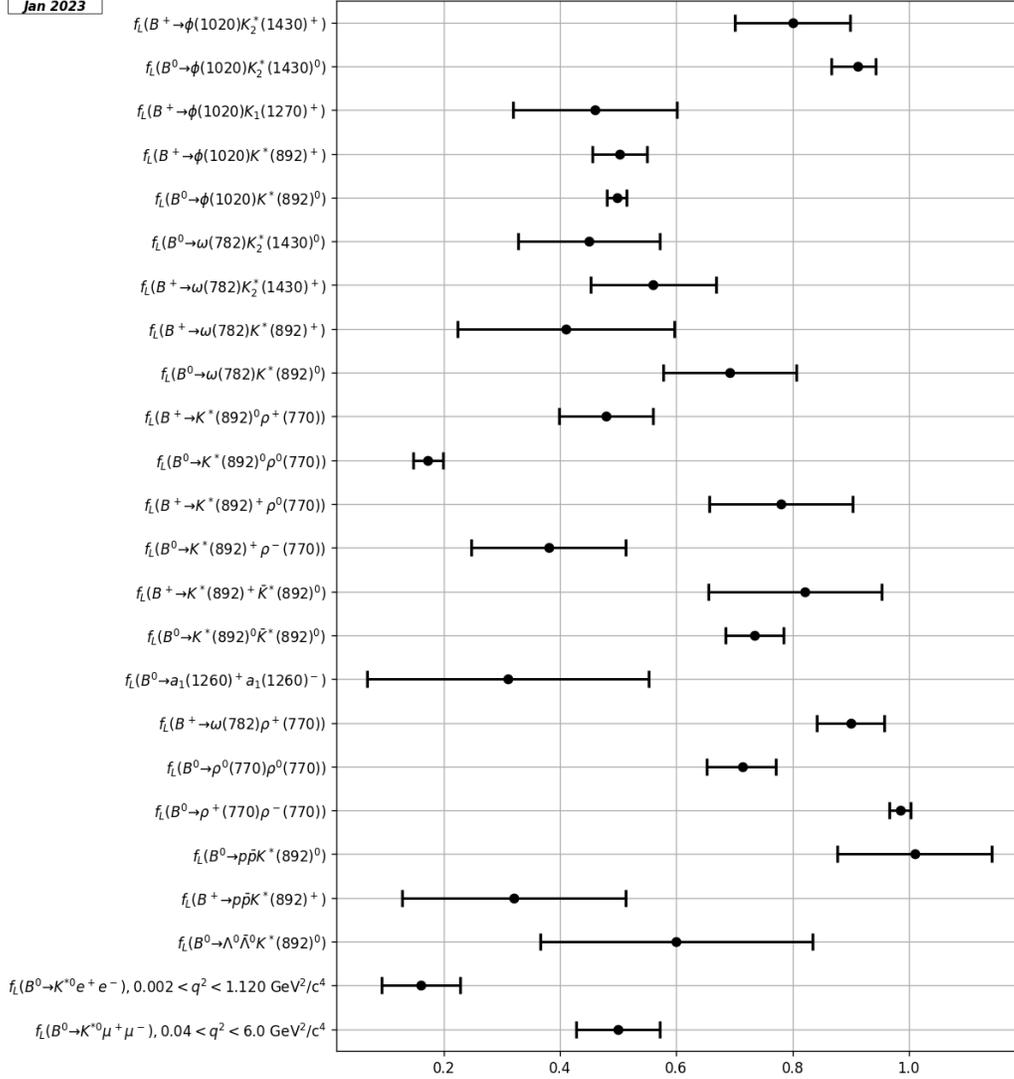


Figure 14: Longitudinal polarization fraction in charmless B decays.

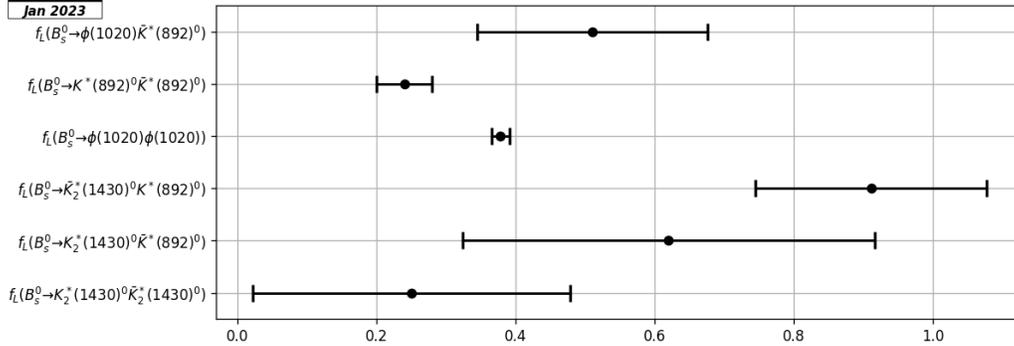


Figure 15: Longitudinal polarization fraction in charmless B_s^0 decays.

References

- [1] HFLAV collaboration, Y. S. Amhis *et al.*, *Averages of b -hadron, c -hadron, and τ -lepton properties as of 2018*, Eur. Phys. J. **C81** (2021) 226, [arXiv:1909.12524](#).
- [2] Particle Data Group, P. A. Zyla *et al.*, *Review of Particle Physics*, PTEP **2020** (2020) 083C01.
- [3] Belle collaboration, Y.-T. Duh *et al.*, *Measurements of branching fractions and direct CP asymmetries for $B \rightarrow K\pi$, $B \rightarrow K\pi\pi$ and $B \rightarrow KK$ decays*, Phys. Rev. D **87** (2013) 031103, [arXiv:1210.1348](#).
- [4] BaBar collaboration, B. Aubert *et al.*, *Observation of $B^+ \rightarrow \bar{K}^0 K^+$ and $B^0 \rightarrow K^0 \bar{K}^0$* , Phys. Rev. Lett. **97** (2006) 171805, [arXiv:hep-ex/0608036](#).
- [5] Belle-II collaboration, F. Abudinén *et al.*, *Measurements of branching fractions and direct CP asymmetries in $B^0 \rightarrow K^+\pi^-$, $B^+ \rightarrow K_S^0\pi^+$ and $B^0 \rightarrow \pi^+\pi^-$ using 2019 and 2020 data*, [arXiv:2106.03766](#).
- [6] CLEO collaboration, A. Bornheim *et al.*, *Measurements of charmless hadronic two body B meson decays and the ratio $\mathcal{B}(B \rightarrow DK)/\mathcal{B}(B \rightarrow D\pi)$* , Phys. Rev. D **68** (2003) 052002, [arXiv:hep-ex/0302026](#), [Erratum: Phys.Rev.D 75, 119907 (2007)].
- [7] LHCb collaboration, R. Aaij *et al.*, *Branching fraction and CP asymmetry of the decays $B^+ \rightarrow K_S^0\pi^+$ and $B^+ \rightarrow K_S^0K^+$* , Phys. Lett. B **726** (2013) 646, [arXiv:1308.1277](#).
- [8] BaBar collaboration, B. Aubert *et al.*, *Study of $B^0 \rightarrow \pi^0\pi^0$, $B^\pm \rightarrow \pi^\pm\pi^0$, and $B^\pm \rightarrow K^\pm\pi^0$ Decays, and Isospin Analysis of $B \rightarrow \pi\pi$ Decays*, Phys. Rev. D **76** (2007) 091102, [arXiv:0707.2798](#).
- [9] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of the branching fractions and CP asymmetries of $B^+ \rightarrow \pi^+\pi^0$ and $B^+ \rightarrow K^+\pi^0$ decays in 2019-2021 Belle II data*, [arXiv:2209.05154](#).
- [10] BaBar collaboration, B. Aubert *et al.*, *B meson decays to charmless meson pairs containing eta or eta' mesons*, Phys. Rev. D **80** (2009) 112002, [arXiv:0907.1743](#).
- [11] Belle collaboration, J. Schumann *et al.*, *Evidence for $B \rightarrow \eta'$ pi and improved measurements for $B \rightarrow \eta'$ K*, Phys. Rev. Lett. **97** (2006) 061802, [arXiv:hep-ex/0603001](#).
- [12] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of the branching fractions of $B \rightarrow \eta'K$ decays using 2019/2020 Belle II data*, [arXiv:2104.06224](#).
- [13] Belle collaboration, I. Adachi *et al.*, *Search for resonant $B^\pm \rightarrow K^\pm h \rightarrow K^\pm\gamma\gamma$ Decays at Belle*, Phys. Lett. B **662** (2008) 323, [arXiv:hep-ex/0608037](#).
- [14] CLEO collaboration, S. J. Richichi *et al.*, *Two-body B meson decays to eta and eta-prime: Observation of $B \rightarrow \eta' K^*$* , Phys. Rev. Lett. **85** (2000) 520, [arXiv:hep-ex/9912059](#).
- [15] LHCb collaboration, R. Aaij *et al.*, *Observation of the $B_s^0 \rightarrow \eta'\eta'$ decay*, Phys. Rev. Lett. **115** (2015) 051801, [arXiv:1503.07483](#).
- [16] BaBar collaboration, P. del Amo Sanchez *et al.*, *B -meson decays to $\eta'\rho$, $\eta'f_0$, and $\eta'K^*$* , Phys. Rev. D **82** (2010) 011502, [arXiv:1004.0240](#).

- [17] Belle collaboration, J. Schumann *et al.*, *Search for B decays into eta-prime rho, eta-prime K*, eta-prime phi, eta-prime omega and eta-prime eta-(prime) at Belle*, Phys. Rev. D **75** (2007) 092002, [arXiv:hep-ex/0701046](#).
- [18] Belle collaboration, C. T. Hoi *et al.*, *Evidence for Direct CP Violation in $B^\pm \rightarrow \eta h^\pm$ and Observation of $B^0 \rightarrow \eta K^0$* , Phys. Rev. Lett. **108** (2012) 031801, [arXiv:1110.2000](#).
- [19] BaBar collaboration, B. Aubert *et al.*, *Measurement of branching fractions and charge asymmetries in B decays to an eta meson and a K* meson*, Phys. Rev. Lett. **97** (2006) 201802, [arXiv:hep-ex/0608005](#).
- [20] Belle collaboration, C. H. Wang *et al.*, *Measurement of charmless B Decays to eta K* and eta rho*, Phys. Rev. D **75** (2007) 092005, [arXiv:hep-ex/0701057](#).
- [21] BaBar collaboration, B. Aubert *et al.*, *Study of B Meson Decays with Excited eta and eta-prime Mesons*, Phys. Rev. Lett. **101** (2008) 091801, [arXiv:0804.0411](#).
- [22] BaBar collaboration, J. P. Lees *et al.*, *Study of CP violation in Dalitz-plot analyses of $B^0 \rightarrow K^+ K^- K_S^0$, $B^+ \rightarrow K^+ K^- K^+$, and $B^+ \rightarrow K_S^0 K_S^0 K^+$* , Phys. Rev. D **85** (2012) 112010, [arXiv:1201.5897](#).
- [23] Belle collaboration, V. Chobanova *et al.*, *Measurement of branching fractions and CP violation parameters in $B \rightarrow \omega K$ decays with first evidence of CP violation in $B^0 \rightarrow \omega K_S^0$* , Phys. Rev. D **90** (2014) 012002, [arXiv:1311.6666](#).
- [24] BaBar collaboration, B. Aubert *et al.*, *Branching fraction and CP-violation charge asymmetry measurements for B-meson decays to eta K+-, eta pi+-, eta-prime K, eta-prime pi+-, omega K, and omega pi+-*, Phys. Rev. D **76** (2007) 031103, [arXiv:0706.3893](#).
- [25] CLEO collaboration, C. P. Jessop *et al.*, *Study of charmless hadronic B meson decays to pseudoscalar vector final states*, Phys. Rev. Lett. **85** (2000) 2881, [arXiv:hep-ex/0006008](#).
- [26] BaBar collaboration, B. Aubert *et al.*, *Observation of B Meson Decays to omega K* and Improved Measurements for omega rho and omega f0*, Phys. Rev. D **79** (2009) 052005, [arXiv:0901.3703](#).
- [27] BaBar collaboration, B. Aubert *et al.*, *Search for B-meson decays to two-body final states with a0(980) mesons*, Phys. Rev. D **70** (2004) 111102, [arXiv:hep-ex/0407013](#).
- [28] BaBar collaboration, B. Aubert *et al.*, *Evidence for Direct CP Violation from Dalitz-plot analysis of $B^\pm \rightarrow K^\pm \pi^\mp \pi^\pm$* , Phys. Rev. D **78** (2008) 012004, [arXiv:0803.4451](#).
- [29] Belle collaboration, A. Garmash *et al.*, *Evidence for large direct CP violation in $B^\pm \rightarrow \rho^0(770) K^\pm$ from analysis of the three-body charmless $B^\pm \rightarrow K^\pm \pi^+ \pi^-$ decay*, Phys. Rev. Lett. **96** (2006) 251803, [arXiv:hep-ex/0512066](#).
- [30] BaBar collaboration, J. P. Lees *et al.*, *Evidence for CP violation in $B^+ \rightarrow K^*(892)^+ \pi^0$ from a Dalitz plot analysis of $B^+ \rightarrow K_S^0 \pi^+ \pi^0$ decays*, Phys. Rev. D **96** (2017) 072001, [arXiv:1501.00705](#).
- [31] BaBar collaboration, J. P. Lees *et al.*, *Observation of the rare decay $B^{+-} \rightarrow K^+ \pi^0 \pi^0$ and measurement of the quasi-two body contributions $B^{+-} \rightarrow K^*(892)^+ \pi^0$, $B^{+-} \rightarrow f_0(980) K^+$ and $B^{+-} \rightarrow \chi_{c0} K^+$* , Phys. Rev. D **84** (2011) 092007, [arXiv:1109.0143](#).

- [32] LHCb collaboration, R. Aaij *et al.*, *Measurement of the relative branching fractions of $B^+ \rightarrow h^+ h'^+ h'^-$ decays*, Phys. Rev. D **102** (2020) 112010, [arXiv:2010.11802](#).
- [33] Belle-II collaboration, F. Abudinén *et al.*, *Measurements of branching fractions and CP-violating charge asymmetries in multibody charmless B decays reconstructed in 2019-2020 Belle II data*, [arXiv:2109.10807](#).
- [34] BaBar collaboration, B. Aubert *et al.*, *Dalitz-plot analysis of the decays $B^\pm \rightarrow K^\pm \pi^\mp \pi^\pm$* , Phys. Rev. D **72** (2005) 072003, [arXiv:hep-ex/0507004](#), [Erratum: Phys.Rev.D 74, 099903 (2006)].
- [35] Belle collaboration, A. Garmash *et al.*, *Dalitz analysis of the three-body charmless decays $B^+ \rightarrow K^+ \pi^+ \pi^-$ and $B^+ \rightarrow K^+ K^+ K^-$* , Phys. Rev. D **71** (2005) 092003, [arXiv:hep-ex/0412066](#).
- [36] LHCb collaboration, R. Aaij *et al.*, *Search for the suppressed decays $B^+ \rightarrow K^+ K^+ \pi^-$ and $B^+ \rightarrow \pi^+ \pi^+ K^-$* , Phys. Lett. B **765** (2017) 307, [arXiv:1608.01478](#).
- [37] BaBar collaboration, B. Aubert *et al.*, *Search for the highly suppressed decays $B^- \rightarrow K^+ \pi^- \pi^-$ and $B^- \rightarrow K^- K^- \pi^+$* , Phys. Rev. D **78** (2008) 091102, [arXiv:0808.0900](#).
- [38] Belle collaboration, A. Garmash *et al.*, *Study of B meson decays to three body charmless hadronic final states*, Phys. Rev. D **69** (2004) 012001, [arXiv:hep-ex/0307082](#).
- [39] CLEO collaboration, T. Bergfeld *et al.*, *A Search for nonresonant $B^+ \rightarrow h^+ h^- h^+$ decays*, Phys. Rev. Lett. **77** (1996) 4503.
- [40] BaBar collaboration, B. Aubert *et al.*, *Measurement of branching fractions of B decays to $K(1)(1270)\pi$ and $K(1)(1400)\pi$ and determination of the CKM angle α from $B^0 \rightarrow a(1)(1260)^+ \pi^-$* , Phys. Rev. D **81** (2010) 052009, [arXiv:0909.2171](#).
- [41] CLEO collaboration, E. Eckhart *et al.*, *Observation of $B \rightarrow K_0(S) \pi^+ \pi^-$ and evidence for $B \rightarrow K^{*+} \pi^-$* , Phys. Rev. Lett. **89** (2002) 251801, [arXiv:hep-ex/0206024](#).
- [42] BaBar collaboration, B. Aubert *et al.*, *Branching fraction measurements of charged B decays to $K^{*+} K^+ K^-$, $K^{*+} \pi^+ K^-$, $K^{*+} K^+ \pi^-$ and $K^{*+} \pi^+ \pi^-$ final states*, Phys. Rev. D **74** (2006) 051104, [arXiv:hep-ex/0607113](#).
- [43] BaBar collaboration, P. del Amo Sanchez *et al.*, *Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in $B^+ \rightarrow \rho^0 K^{*+}$ and $B^+ \rightarrow f_0(980) K^{*+}$ decays*, Phys. Rev. D **83** (2011) 051101, [arXiv:1012.4044](#).
- [44] BaBar collaboration, B. Aubert *et al.*, *Observation of $B^+ \rightarrow a(1)(1260) K^0$ and $B^0 \rightarrow a(1)(1260) K^+$* , Phys. Rev. Lett. **100** (2008) 051803, [arXiv:0709.4165](#).
- [45] BaBar collaboration, B. Aubert *et al.*, *Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in $B \rightarrow \rho K^*$ and $B \rightarrow f_0(980) K^*$ decays*, Phys. Rev. Lett. **97** (2006) 201801, [arXiv:hep-ex/0607057](#).
- [46] Belle collaboration, J. Zhang *et al.*, *Measurements of branching fractions and polarization in $B \rightarrow K^* \rho$ decays*, Phys. Rev. Lett. **95** (2005) 141801, [arXiv:hep-ex/0408102](#).
- [47] ARGUS collaboration, H. Albrecht *et al.*, *Search for $b \rightarrow s$ Gluon in B Meson Decays*, Phys. Lett. B **254** (1991) 288.

- [48] BaBar collaboration, B. Aubert *et al.*, *Observation of $B^+ \rightarrow b(1)+ K0$ and search for B -meson decays to $b(1)0 K0$ and $b(1) \pi0$* , Phys. Rev. D **78** (2008) 011104, [arXiv:0805.1217](#).
- [49] BaBar collaboration, B. Aubert *et al.*, *Observation of B -meson decays to $b(1) \pi$ and $b(1) K$* , Phys. Rev. Lett. **99** (2007) 241803, [arXiv:0707.4561](#).
- [50] BaBar collaboration, B. Aubert *et al.*, *Search for B -meson decays to $b(1 \rho)$ and $b(1) K^*$* , Phys. Rev. D **80** (2009) 051101, [arXiv:0907.3485](#).
- [51] Belle collaboration, J. Zhang *et al.*, *Measurements of branching fraction and polarization in $B^+ \rightarrow \rho^+ K^{*0}$ decay*, [arXiv:hep-ex/0505039](#).
- [52] Belle collaboration, A. B. Kaliyar *et al.*, *Measurements of branching fraction and direct CP asymmetry in $B^\pm \rightarrow K_S^0 K_S^0 K^\pm$ and a search for $B^\pm \rightarrow K_S^0 K_S^0 \pi^\pm$* , Phys. Rev. D **99** (2019) 031102, [arXiv:1812.10221](#).
- [53] BaBar collaboration, B. Aubert *et al.*, *Search for the decay $B^+ \rightarrow K0(S) K0(S) \pi^+$* , Phys. Rev. D **79** (2009) 051101, [arXiv:0811.1979](#).
- [54] Belle collaboration, *Angular analysis of the low $K^+ K^-$ mass enhancement in $B^+ \rightarrow K^+ K^- \pi^+$ decays*, [arXiv:2206.11445](#).
- [55] BaBar collaboration, B. Aubert *et al.*, *Observation of the Decay $B^+ \rightarrow K^+ K^- \pi^+$* , Phys. Rev. Lett. **99** (2007) 221801, [arXiv:0708.0376](#).
- [56] LHCb collaboration, R. Aaij *et al.*, *Amplitude analysis of $B^\pm \rightarrow \pi^\pm K^+ K^-$ decays*, Phys. Rev. Lett. **123** (2019) 231802, [arXiv:1905.09244](#).
- [57] BaBar collaboration, B. Aubert *et al.*, *Search for the decay $B^+ \rightarrow \bar{K}^* 0(892) K^+$* , Phys. Rev. D **76** (2007) 071103, [arXiv:0706.1059](#).
- [58] Belle collaboration, M.-Z. Wang *et al.*, *Study of the baryon-antibaryon low-mass enhancements in charmless three-body baryonic B decays*, Phys. Lett. B **617** (2005) 141, [arXiv:hep-ex/0503047](#).
- [59] Belle collaboration, Y. M. Goh *et al.*, *Search for the decay $B^+ \rightarrow \bar{K}^{*0} K^{*+}$ at Belle*, Phys. Rev. D **91** (2015) 071101, [arXiv:1502.00381](#).
- [60] BaBar collaboration, B. Aubert *et al.*, *Evidence for $B^+ \rightarrow \text{anti-}K^*0 K^{*+}$* , Phys. Rev. D **79** (2009) 051102, [arXiv:0901.1223](#).
- [61] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay $\Xi_b^- \rightarrow p K^- K^-$* , Phys. Rev. Lett. **118** (2017) 071801, [arXiv:1612.02244](#).
- [62] Belle-II collaboration, F. Abudinén *et al.*, *Rediscovery of $B \rightarrow \phi K^{(*)}$ decays and measurement of the longitudinal polarization fraction f_L in $B \rightarrow \phi K^*$ decays using the Summer 2020 Belle II dataset*, [arXiv:2008.03873](#).
- [63] CDF collaboration, D. Acosta *et al.*, *First evidence for $B_s^0 \rightarrow \phi \phi$ decay and measurements of branching ratio and A_{CP} for $B^+ \rightarrow \phi K^+$* , Phys. Rev. Lett. **95** (2005) 031801, [arXiv:hep-ex/0502044](#).
- [64] CLEO collaboration, R. A. Briere *et al.*, *Observation of $B \rightarrow \phi K$ and $B \rightarrow \phi K^*$* , Phys. Rev. Lett. **86** (2001) 3718, [arXiv:hep-ex/0101032](#).

- [65] BaBar collaboration, B. Aubert *et al.*, *Amplitude Analysis of the $B^\pm \rightarrow \phi K^*(892)^\pm$ Decay*, Phys. Rev. Lett. **99** (2007) 201802, [arXiv:0705.1798](#).
- [66] Belle collaboration, K. F. Chen *et al.*, *Measurement of branching fractions and polarization in $B \rightarrow \phi K^*$ decays*, Phys. Rev. Lett. **91** (2003) 201801, [arXiv:hep-ex/0307014](#).
- [67] BaBar collaboration, B. Aubert *et al.*, *Observation and Polarization Measurements of $B^\pm \rightarrow \phi K_1^\pm$ and $B^\pm \rightarrow \phi K_2^{*\pm}$* , Phys. Rev. Lett. **101** (2008) 161801, [arXiv:0806.4419](#).
- [68] BaBar collaboration, P. del Amo Sanchez *et al.*, *Search for B^+ meson decay to $a_1^+(1260)K^{*0}(892)$* , Phys. Rev. D **82** (2010) 091101, [arXiv:1007.2732](#).
- [69] BaBar collaboration, J. P. Lees *et al.*, *Measurements of branching fractions and CP asymmetries and studies of angular distributions for $B \rightarrow \phi \phi K$ decays*, Phys. Rev. D **84** (2011) 012001, [arXiv:1105.5159](#).
- [70] Belle collaboration, H.-C. Huang *et al.*, *Evidence for $B \rightarrow \phi \phi K$* , Phys. Rev. Lett. **91** (2003) 241802, [arXiv:hep-ex/0305068](#).
- [71] BaBar collaboration, B. Aubert *et al.*, *Search for B Meson Decays to $\eta' \eta' K$* , Phys. Rev. D **74** (2006) 031105, [arXiv:hep-ex/0605008](#).
- [72] Belle collaboration, C. Liu *et al.*, *Search for the $X(1812)$ in $B_{+-} \rightarrow K_{+-} \omega \phi$* , Phys. Rev. D **79** (2009) 071102, [arXiv:0902.4757](#).
- [73] CLEO collaboration, R. Ammar *et al.*, *Search for the ϕ meson via $B_{+-} \rightarrow \pi_{+-} X_0$, $B_{+-} \rightarrow K_{+-} X_0$, and $B_0 \rightarrow K_0(S) X_0$ decays*, Phys. Rev. Lett. **87** (2001) 271801, [arXiv:hep-ex/0106038](#).
- [74] BaBar collaboration, B. Aubert *et al.*, *Dalitz Plot Analysis of $B^\pm \rightarrow \pi^\pm \pi^\pm \pi^\mp$ Decays*, Phys. Rev. D **79** (2009) 072006, [arXiv:0902.2051](#).
- [75] LHCb collaboration, R. Aaij *et al.*, *Observation of Several Sources of CP Violation in $B^+ \rightarrow \pi^+ \pi^+ \pi^-$ Decays*, Phys. Rev. Lett. **124** (2020) 031801, [arXiv:1909.05211](#).
- [76] Belle collaboration, A. Gordon *et al.*, *Study of $B \rightarrow \rho \pi$ decays at BELLE*, Phys. Lett. B **542** (2002) 183, [arXiv:hep-ex/0207007](#).
- [77] LHCb collaboration, R. Aaij *et al.*, *Amplitude analysis of the $B^+ \rightarrow \pi^+ \pi^+ \pi^-$ decay*, Phys. Rev. D **101** (2020) 012006, [arXiv:1909.05212](#).
- [78] Belle collaboration, *First measurement of the $B^+ \rightarrow \pi^+ \pi^0 \pi^0$ branching fraction and CP asymmetry*, [arXiv:2208.01855](#).
- [79] ARGUS collaboration, H. Albrecht *et al.*, *Search for Hadronic $b \rightarrow u$ Decays*, Phys. Lett. B **241** (1990) 278.
- [80] BaBar collaboration, B. Aubert *et al.*, *Measurement of the $B^\pm \rightarrow \rho^\pm \pi^0$ Branching Fraction and Direct CP Asymmetry*, Phys. Rev. D **75** (2007) 091103, [arXiv:hep-ex/0701035](#).
- [81] BaBar collaboration, B. Aubert *et al.*, *Improved Measurement of $B^+ \rightarrow \rho^+ \rho^0$ and Determination of the Quark-Mixing Phase Angle α* , Phys. Rev. Lett. **102** (2009) 141802, [arXiv:0901.3522](#).

- [82] Belle-II collaboration, F. Abudinén *et al.*, *Angular analysis of $B^+ \rightarrow \rho^+ \rho^0$ decays reconstructed in 2019, 2020, and 2021 Belle II data*, arXiv:2206.12362.
- [83] Belle collaboration, J. Zhang *et al.*, *Observation of $B^+ \rightarrow \rho^+ \rho^0$* , Phys. Rev. Lett. **91** (2003) 221801, arXiv:hep-ex/0306007.
- [84] BaBar collaboration, B. Aubert *et al.*, *Evidence for charged B meson decays to $a_{+-}(1)(1260) \pi^0$ and $a_0(1)(1260) \pi^{+-}$* , Phys. Rev. Lett. **99** (2007) 261801, arXiv:0708.0050.
- [85] Belle collaboration, C.-M. Jen *et al.*, *Improved measurements of branching fractions and CP partial rate asymmetries for $B \rightarrow \omega K$ and $B \rightarrow \omega \pi$* , Phys. Rev. D **74** (2006) 111101, arXiv:hep-ex/0609022.
- [86] BaBar collaboration, B. Aubert *et al.*, *Observation of $B^+ \rightarrow \eta \rho^+$ and search for B^0 decays to $\eta' \eta$, $\eta \pi^0$, $\eta' \pi^0$, and $\omega \pi^0$* , Phys. Rev. D **78** (2008) 011107, arXiv:0804.2422.
- [87] BaBar collaboration, B. Aubert *et al.*, *Search for $B^+ \rightarrow \phi \pi^+$ and $B^0 \rightarrow \phi \pi^0$ Decays*, Phys. Rev. D **74** (2006) 011102, arXiv:hep-ex/0605037.
- [88] Belle collaboration, J. H. Kim *et al.*, *Search for $B \rightarrow \phi \pi$ decays*, Phys. Rev. D **86** (2012) 031101, arXiv:1206.4760.
- [89] BaBar collaboration, B. Aubert *et al.*, *Searches for B meson decays to $\phi \phi$, $\phi \rho$, $\phi f_0(980)$, and $f_0(980) f_0(980)$ final states*, Phys. Rev. Lett. **101** (2008) 201801, arXiv:0807.3935.
- [90] CLEO collaboration, D. Bortoletto *et al.*, *A Search for $b \rightarrow u$ Transitions in Exclusive Hadronic B Meson Decays*, Phys. Rev. Lett. **62** (1989) 2436.
- [91] BaBar collaboration, B. Aubert *et al.*, *Improved Measurements of the Branching Fractions for $B^0 \rightarrow \pi^+ \pi^-$ and $B^0 \rightarrow K^+ \pi^-$, and a Search for $B^0 \rightarrow K^+ K^-$* , Phys. Rev. D **75** (2007) 012008, arXiv:hep-ex/0608003.
- [92] CDF collaboration, T. Aaltonen *et al.*, *Observation of New Charmless Decays of Bottom Hadrons*, Phys. Rev. Lett. **103** (2009) 031801, arXiv:0812.4271.
- [93] CDF collaboration, T. Aaltonen *et al.*, *Measurements of Direct CP Violating Asymmetries in Charmless Decays of Strange Bottom Mesons and Bottom Baryons*, Phys. Rev. Lett. **106** (2011) 181802, arXiv:1103.5762.
- [94] CDF collaboration, T. Aaltonen *et al.*, *Evidence for the charmless annihilation decay mode $B_s^0 \rightarrow \pi^+ \pi^-$* , Phys. Rev. Lett. **108** (2012) 211803, arXiv:1111.0485.
- [95] LHCb collaboration, R. Aaij *et al.*, *Measurement of b -hadron branching fractions for two-body decays into charmless charged hadrons*, JHEP **10** (2012) 037, arXiv:1206.2794.
- [96] LHCb collaboration, R. Aaij *et al.*, *Observation of the annihilation decay mode $B^0 \rightarrow K^+ K^-$* , Phys. Rev. Lett. **118** (2017) 081801, arXiv:1610.08288.
- [97] BaBar collaboration, J. P. Lees *et al.*, *Measurement of CP Asymmetries and Branching Fractions in Charmless Two-Body B -Meson Decays to Pions and Kaons*, Phys. Rev. D **87** (2013) 052009, arXiv:1206.3525.
- [98] Belle-II collaboration, F. Abudinén *et al.*, *First decay-time-dependent analysis of $B^0 \rightarrow K_S^0 \pi^0$ at Belle II*, arXiv:2206.07453.

- [99] LHCb collaboration, R. Aaij *et al.*, *Search for the $\Lambda_b^0 \rightarrow \Lambda \eta'$ and $\Lambda_b^0 \rightarrow \Lambda \eta$ decays with the LHCb detector*, JHEP **09** (2015) 006, arXiv:1505.03295.
- [100] Belle collaboration, S. Sato *et al.*, *Observation of the decay $B^0 \rightarrow \eta' K^{*0}(892)$* , Phys. Rev. D **90** (2014) 072009, arXiv:1408.6343.
- [101] Belle collaboration, P. Goldenzweig *et al.*, *Evidence for Neutral B Meson Decays to omega K^{*0}* , Phys. Rev. Lett. **101** (2008) 231801, arXiv:0807.4271.
- [102] BaBar collaboration, B. Aubert *et al.*, *Search for Neutral B-Meson Decays to $a_0 \pi$, $a_0 K$, eta rho0, and eta f0*, Phys. Rev. D **75** (2007) 111102, arXiv:hep-ex/0703038.
- [103] BaBar collaboration, J. P. Lees *et al.*, *Amplitude Analysis of $B^0 \rightarrow K^+ \pi^- \pi^0$ and Evidence of Direct CP Violation in $B \rightarrow K^* \pi$ decays*, Phys. Rev. D **83** (2011) 112010, arXiv:1105.0125.
- [104] Belle collaboration, P. Chang *et al.*, *Observation of the decays $B^0 \rightarrow K^+ \pi^- \pi^0$ and $B^0 \rightarrow \rho^0 K^+$* , Phys. Lett. B **599** (2004) 148, arXiv:hep-ex/0406075.
- [105] BaBar collaboration, B. Aubert *et al.*, *Dalitz Plot Analysis of the Decay B^0 (anti- B^0) $\rightarrow K^\pm \pi^\mp \pi^0$* , Phys. Rev. D **78** (2008) 052005, arXiv:0711.4417.
- [106] BaBar collaboration, B. Aubert *et al.*, *Time-dependent amplitude analysis of $B^0 \rightarrow K^0(S) \pi^+ \pi^-$* , Phys. Rev. D **80** (2009) 112001, arXiv:0905.3615.
- [107] Belle collaboration, A. Garmash *et al.*, *Dalitz Analysis of Three-body Charmless $B^0 \rightarrow K^0 \pi^+ \pi^-$ Decay*, Phys. Rev. D **75** (2007) 012006, arXiv:hep-ex/0610081.
- [108] LHCb collaboration, R. Aaij *et al.*, *Searches for Λ_b^0 and Ξ_b^0 decays to $K_S^0 p \pi^-$ and $K_S^0 p K^-$ final states with first observation of the $\Lambda_b^0 \rightarrow K_S^0 p \pi^-$ decay*, JHEP **04** (2014) 087, arXiv:1402.0770.
- [109] LHCb collaboration, R. Aaij *et al.*, *First observation of the decay $B_s^0 \rightarrow K_S^0 K^{*0}(892)$ at LHCb*, JHEP **01** (2016) 012, arXiv:1506.08634.
- [110] LHCb collaboration, R. Aaij *et al.*, *Updated branching fraction measurements of $B_{(s)}^0 \rightarrow K_S^0 h^+ h'^-$ decays*, JHEP **11** (2017) 027, arXiv:1707.01665.
- [111] LHCb collaboration, R. Aaij *et al.*, *Amplitude analysis of the decay $\bar{B}^0 \rightarrow K_S^0 \pi^+ \pi^-$ and first observation of the CP asymmetry in $\bar{B}^0 \rightarrow K^{*0} \pi^+ \pi^-$* , Phys. Rev. Lett. **120** (2018) 261801, arXiv:1712.09320.
- [112] LHCb collaboration, R. Aaij *et al.*, *Observation of $B_s^0 \rightarrow K^{*\pm} K^\mp$ and evidence for $B_s^0 \rightarrow K^{*-} \pi^+$ decays*, New J. Phys. **16** (2014) 123001, arXiv:1407.7704.
- [113] DELPHI collaboration, W. Adam *et al.*, *Study of rare b decays with the DELPHI detector at LEP*, Z. Phys. C **72** (1996) 207.
- [114] Belle collaboration, S.-H. Kyeong *et al.*, *Measurements of Charmless Hadronic $b \rightarrow s$ Penguin Decays in the $\pi^+ \pi^- K^+ \pi^-$ Final State and Observation of $B^0 \rightarrow \rho^0 K^+ \pi^-$* , Phys. Rev. D **80** (2009) 051103, arXiv:0905.0763.
- [115] BaBar collaboration, B. Aubert *et al.*, *Measurements of the Branching Fractions of $B^0 \rightarrow K^{*0} K^+ K^-$, $B^0 \rightarrow K^{*0} \pi^+ K^-$, $B^0 \rightarrow K^{*0} K^+ \pi^-$, and $B^0 \rightarrow K^{*0} \pi^+ \pi^-$* , Phys. Rev. D **76** (2007) 071104, arXiv:0708.2543.

- [116] BaBar collaboration, J. P. Lees *et al.*, B^0 meson decays to $\rho^0 K^{*0}$, $f_0 K^{*0}$, and $\rho^- K^{*+}$, including higher K^* resonances, Phys. Rev. D **85** (2012) 072005, arXiv:1112.3896.
- [117] Belle collaboration, Y. T. Lai *et al.*, Measurement of branching fraction and final-state asymmetry for the $\bar{B}^0 \rightarrow K_S^0 K^\mp \pi^\pm$ decay, Phys. Rev. D **100** (2019) 011101, arXiv:1904.06835.
- [118] BaBar collaboration, P. del Amo Sanchez *et al.*, Observation of the Rare Decay $B^0 \rightarrow K^0(s) K^+ \pi^-$, Phys. Rev. D **82** (2010) 031101, arXiv:1003.0640.
- [119] BaBar collaboration, B. Aubert *et al.*, Search for the decay of a B^0 or anti- B^0 meson to anti- $K^{*0} K^0$ or K^{*0} anti- K^0 , Phys. Rev. D **74** (2006) 072008, arXiv:hep-ex/0606050.
- [120] Belle collaboration, V. Gaur *et al.*, Evidence for the decay $B^0 \rightarrow K^+ K^- \pi^0$, Phys. Rev. D **87** (2013) 091101, arXiv:1304.5312.
- [121] BaBar collaboration, B. Aubert *et al.*, Search for B^0 Meson Decays to $\pi^0 K^0(S) K^0(S)$, $\eta K^0(S) K^0(S)$, and η -prime $K^0(S) K^0(S)$, Phys. Rev. D **80** (2009) 011101, arXiv:0905.0868.
- [122] LHCb collaboration, R. Aaij *et al.*, Observation of the $\Lambda_b^0 \rightarrow \Lambda \phi$ decay, Phys. Lett. B **759** (2016) 282, arXiv:1603.02870.
- [123] LHCb collaboration, R. Aaij *et al.*, Measurement of the branching fraction of the decay $B_s^0 \rightarrow K_S^0 K_S^0$, Phys. Rev. D **102** (2020) 012011, arXiv:2002.08229.
- [124] BaBar collaboration, J. P. Lees *et al.*, Amplitude analysis and measurement of the time-dependent CP asymmetry of $B^0 \rightarrow K_S^0 K_S^0 K_S^0$ decays, Phys. Rev. D **85** (2012) 054023, arXiv:1111.3636.
- [125] BaBar collaboration, B. Aubert *et al.*, Search for the decay $B^0 \rightarrow K_s^0 K_s^0 K_L^0$, Phys. Rev. D **74** (2006) 032005, arXiv:hep-ex/0606031.
- [126] BaBar collaboration, B. Aubert *et al.*, Time-Dependent and Time-Integrated Angular Analysis of $B \rightarrow \phi K_s \pi^0$ and $B \rightarrow \phi K^+ \pi^-$, Phys. Rev. D **78** (2008) 092008, arXiv:0808.3586.
- [127] Belle collaboration, M. Prim *et al.*, Angular analysis of $B^0 \rightarrow \phi K^*$ decays and search for CP violation at Belle, Phys. Rev. D **88** (2013) 072004, arXiv:1308.1830.
- [128] LHCb collaboration, R. Aaij *et al.*, First observation of the decay $B_s^0 \rightarrow \phi \bar{K}^{*0}$, JHEP **11** (2013) 092, arXiv:1306.2239.
- [129] LHCb collaboration, R. Aaij *et al.*, Measurement of CP asymmetries and polarisation fractions in $B_s^0 \rightarrow K^{*0} \bar{K}^{*0}$ decays, JHEP **07** (2015) 166, arXiv:1503.05362.
- [130] LHCb collaboration, R. Aaij *et al.*, Measurement of the $B_s^0 \rightarrow \phi \phi$ branching fraction and search for the decay $B^0 \rightarrow \phi \phi$, JHEP **10** (2015) 053, arXiv:1508.00788.
- [131] LHCb collaboration, R. Aaij *et al.*, Observation of the $B^0 \rightarrow \rho^0 \rho^0$ decay from an amplitude analysis of $B^0 \rightarrow (\pi^+ \pi^-)(\pi^+ \pi^-)$ decays, Phys. Lett. B **747** (2015) 468, arXiv:1503.07770.
- [132] Belle collaboration, C.-C. Chiang *et al.*, Search for $B^0 \rightarrow K^{*0} \bar{K}^{*0}$, $B^0 \rightarrow K^{*0} K^{*0}$ and $B^0 \rightarrow K^+ \pi^- K^\mp \pi^\pm$ Decays, Phys. Rev. D **81** (2010) 071101, arXiv:1001.4595.
- [133] LHCb collaboration, R. Aaij *et al.*, Amplitude analysis of the $B_{(s)}^0 \rightarrow K^{*0} \bar{K}^{*0}$ decays and measurement of the branching fraction of the $B^0 \rightarrow K^{*0} \bar{K}^{*0}$ decay, JHEP **07** (2019) 032, arXiv:1905.06662.

- [134] BaBar collaboration, B. Aubert *et al.*, *Observation of $B^0 \rightarrow K^*0 \bar{K}^* 0$ and search for $B^0 \rightarrow K^*0 K^*0$* , Phys. Rev. Lett. **100** (2008) 081801, [arXiv:0708.2248](#).
- [135] BaBar collaboration, B. Aubert *et al.*, *Search for $B^0 \rightarrow K^{*+}K^{*-}$* , Phys. Rev. D **78** (2008) 051103, [arXiv:0806.4467](#).
- [136] BaBar collaboration, B. Aubert *et al.*, *Search for $B^0 \rightarrow \phi(K^+ \pi^-)$ decays with large $K^+ \pi^-$ invariant mass*, Phys. Rev. D **76** (2007) 051103, [arXiv:0705.0398](#).
- [137] Belle collaboration, T. Julius *et al.*, *Measurement of the branching fraction and CP asymmetry in $B^0 \rightarrow \pi^0 \pi^0$ decays, and an improved constraint on ϕ_2* , Phys. Rev. D **96** (2017) 032007, [arXiv:1705.02083](#).
- [138] *Ichep 2022*, <https://agenda.infn.it/event/28874/contributions/169326/attachments/93992/128864/pres.pdf>.
- [139] Belle collaboration, B. Pal *et al.*, *Evidence for the decay $B^0 \rightarrow \eta \pi^0$* , Phys. Rev. D **92** (2015) 011101, [arXiv:1504.00957](#).
- [140] BaBar collaboration, J. P. Lees *et al.*, *Evidence for the decay $B^0 \rightarrow \omega \omega$ and search for $B^0 \rightarrow \omega \phi$* , Phys. Rev. D **89** (2014) 051101, [arXiv:1312.0056](#).
- [141] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay $B_s^0 \rightarrow \phi \pi^+ \pi^-$ and evidence for $B^0 \rightarrow \phi \pi^+ \pi^-$* , Phys. Rev. D **95** (2017) 012006, [arXiv:1610.05187](#).
- [142] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP violation in the $B_s^0 \rightarrow \phi \phi$ decay and search for the $B^0 \rightarrow \phi \phi$ decay*, JHEP **12** (2019) 155, [arXiv:1907.10003](#).
- [143] Belle collaboration, A. Kusaka *et al.*, *Measurement of CP asymmetries and branching fractions in a time-dependent Dalitz analysis of $B^0 \rightarrow (\rho \pi)0$ and a constraint on the quark mixing angle $\phi(2)$* , Phys. Rev. D **77** (2008) 072001, [arXiv:0710.4974](#).
- [144] BaBar collaboration, B. Aubert *et al.*, *Measurement of branching fractions and charge asymmetries in $B^\pm \rightarrow \rho^\pm \pi^0$ and $B^\pm \rightarrow \rho^0 \pi^\pm$ decays, and search for $B^0 \rightarrow \rho^0 \pi^0$* , Phys. Rev. Lett. **93** (2004) 051802, [arXiv:hep-ex/0311049](#).
- [145] BaBar collaboration, B. Aubert *et al.*, *Measurements of branching fractions and CP-violating asymmetries in $B^0 \rightarrow \rho^\pm h^\mp$ decays*, Phys. Rev. Lett. **91** (2003) 201802, [arXiv:hep-ex/0306030](#).
- [146] Belle collaboration, I. Adachi *et al.*, *Study of $B^0 \rightarrow \rho^0 \rho^0$ decays, implications for the CKM angle ϕ_2 and search for other B^0 decay modes with a four-pion final state*, Phys. Rev. D **89** (2014) 072008, [arXiv:1212.4015](#), [Addendum: Phys.Rev.D 89, 119903 (2014)].
- [147] BaBar collaboration, B. Aubert *et al.*, *Measurement of the Branching Fraction, Polarization, and CP Asymmetries in $B^0 \rightarrow \rho^0 \rho^0$ Decay, and Implications for the CKM Angle α* , Phys. Rev. D **78** (2008) 071104, [arXiv:0807.4977](#).
- [148] Belle collaboration, J. Dalseno *et al.*, *Measurement of Branching Fraction and First Evidence of CP Violation in $B^0 \rightarrow a_1^\pm(1260) \pi^\mp$ Decays*, Phys. Rev. D **86** (2012) 092012, [arXiv:1205.5957](#).
- [149] BaBar collaboration, B. Aubert *et al.*, *Observation of B^0 Meson Decay to $a^{+-}(1260) \pi^-$* , Phys. Rev. Lett. **97** (2006) 051802, [arXiv:hep-ex/0603050](#).

- [150] Belle collaboration, P. Vanhoefer *et al.*, *Study of $B^0 \rightarrow \rho^+ \rho^-$ decays and implications for the CKM angle ϕ_2* , Phys. Rev. D **93** (2016) 032010, [arXiv:1510.01245](#), [Addendum: Phys.Rev.D 94, 099903 (2016)].
- [151] BaBar collaboration, B. Aubert *et al.*, *A Study of $B^0 \rightarrow \rho^+ \rho^-$ Decays and Constraints on the CKM Angle α* , Phys. Rev. D **76** (2007) 052007, [arXiv:0705.2157](#).
- [152] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of Branching Fraction and Longitudinal Polarization in $B^0 \rightarrow \rho^+ \rho^-$ Decays at Belle II*, [arXiv:2208.03554](#).
- [153] BaBar collaboration, B. Aubert *et al.*, *Search for the decay $B^0 \rightarrow a(1) \text{ +- } \rho^\pm$* , Phys. Rev. D **74** (2006) 031104, [arXiv:hep-ex/0605024](#).
- [154] BaBar collaboration, B. Aubert *et al.*, *Observation and Polarization Measurement of $B^0 \rightarrow a(1)(1260)^+ a(1)(1260)^-$ Decay*, Phys. Rev. D **80** (2009) 092007, [arXiv:0907.1776](#).
- [155] LHCb collaboration, R. Aaij *et al.*, *Study of the rare B_s^0 and B^0 decays into the $\pi^+ \pi^- \mu^+ \mu^-$ final state*, Phys. Lett. B **743** (2015) 46, [arXiv:1412.6433](#).
- [156] Belle collaboration, K.-N. Chu *et al.*, *Study of $B^+ \rightarrow p \bar{n} \pi^0$* , [arXiv:2211.11251](#).
- [157] Belle collaboration, J. T. Wei *et al.*, *Study of $B^+ \rightarrow p$ anti- p K^+ and $B^+ \rightarrow p$ anti- p π^+* , Phys. Lett. B **659** (2008) 80, [arXiv:0706.4167](#).
- [158] BaBar collaboration, B. Aubert *et al.*, *Evidence for the $B^0 \rightarrow p$ anti- p K^{*0} and $B^+ \rightarrow \eta(c) K^{*+}$ decays and Study of the Decay Dynamics of B Meson Decays into p anti-p h final states*, Phys. Rev. D **76** (2007) 092004, [arXiv:0707.1648](#).
- [159] LHCb collaboration, R. Aaij *et al.*, *Evidence for CP Violation in $B^+ \rightarrow p \bar{p} K^+$ Decays*, Phys. Rev. Lett. **113** (2014) 141801, [arXiv:1407.5907](#).
- [160] Belle collaboration, K. Chu *et al.*, *Study of $B \rightarrow p \bar{p} \pi \pi$* , Phys. Rev. D **101** (2020) 052012, [arXiv:1912.05999](#).
- [161] ARGUS collaboration, H. Albrecht *et al.*, *Observation of the Charmless B Meson Decays*, Phys. Lett. B **209** (1988) 119.
- [162] BaBar collaboration, B. Aubert *et al.*, *Measurement of the $B^+ \rightarrow p \bar{p} K^+$ branching fraction and study of the decay dynamics*, Phys. Rev. D **72** (2005) 051101, [arXiv:hep-ex/0507012](#).
- [163] LHCb collaboration, R. Aaij *et al.*, *Measurements of the branching fractions of $B^+ \rightarrow p \bar{p} K^+$ decays*, Eur. Phys. J. C **73** (2013) 2462, [arXiv:1303.7133](#).
- [164] Belle collaboration, J. H. Chen *et al.*, *Observation of $B^0 \rightarrow p$ anti- p K^{*0} with a large K^{*0} polarization*, Phys. Rev. Lett. **100** (2008) 251801, [arXiv:0802.0336](#).
- [165] LHCb collaboration, R. Aaij *et al.*, *Evidence for the two-body charmless baryonic decay $B^+ \rightarrow p \bar{\Lambda}$* , JHEP **04** (2017) 162, [arXiv:1611.07805](#).
- [166] Belle collaboration, Y.-T. Tsai *et al.*, *Search for $B^0 \rightarrow p$ anti- p , Λ anti- Λ and $B^+ \rightarrow p$ anti- Λ at Belle*, Phys. Rev. D **75** (2007) 111101, [arXiv:hep-ex/0703048](#).
- [167] Belle collaboration, M.-Z. Wang *et al.*, *Study of $B^+ \rightarrow p$ anti- Λ γ , p anti- Λ π^0 and $B^0 \rightarrow p$ anti- Λ π^-* , Phys. Rev. D **76** (2007) 052004, [arXiv:0704.2672](#).

- [168] Belle collaboration, P. Chen *et al.*, *Observation of $B^+ \rightarrow p$ anti-Lambda $\pi^+ \pi^-$ at Belle*, Phys. Rev. D **80** (2009) 111103, arXiv:0910.5817.
- [169] Belle collaboration, P.-C. Lu *et al.*, *Observation of $B^+ \rightarrow p \bar{\Lambda} K^+ K^-$ and $B^+ \rightarrow \bar{p} \Lambda K^+ K^+$* , Phys. Rev. D **99** (2019) 032003, arXiv:1807.10503.
- [170] Belle collaboration, Y.-W. Chang *et al.*, *Observation of $B^0 \rightarrow \Lambda$ anti-Lambda K^0 and B^0 to Lambda anti-Lambda K^{*0} at Belle*, Phys. Rev. D **79** (2009) 052006, arXiv:0811.3826.
- [171] LHCb collaboration, *Search for the rare hadronic decay $B_s^0 \rightarrow p \bar{p}$* , arXiv:2206.06673.
- [172] BaBar collaboration, B. Aubert *et al.*, *Search for the decay $B^0 \rightarrow p \bar{p}$* , Phys. Rev. D **69** (2004) 091503, arXiv:hep-ex/0403003.
- [173] LHCb collaboration, R. Aaij *et al.*, *Observation of charmless baryonic decays $B_{(s)}^0 \rightarrow p \bar{p} h^+ h'^-$* , Phys. Rev. D **96** (2017) 051103, arXiv:1704.08497.
- [174] Belle collaboration, B. Pal *et al.*, *Evidence for the decay $B^0 \rightarrow p \bar{p} \pi^0$* , Phys. Rev. D **99** (2019) 091104, arXiv:1904.05713.
- [175] BaBar collaboration, J. P. Lees *et al.*, *Search for the decay mode $B^0 \rightarrow p \bar{p} \bar{p}$* , Phys. Rev. D **98** (2018) 071102, arXiv:1803.10378.
- [176] BaBar collaboration, B. Aubert *et al.*, *Measurement of the Branching Fraction and anti-Lambda Polarization in $B^0 \rightarrow$ anti-Lambda $p \pi^-$* , Phys. Rev. D **79** (2009) 112009, arXiv:0904.4724.
- [177] Belle collaboration, M. Z. Wang *et al.*, *Observation of $B^0 \rightarrow p$ anti-Lambda π^-* , Phys. Rev. Lett. **90** (2003) 201802, arXiv:hep-ex/0302024.
- [178] LHCb collaboration, *Searches for the rare hadronic decays $B^0 \rightarrow p \bar{p} \bar{p}$ and $B_s^0 \rightarrow p \bar{p} \bar{p}$* , arXiv:2211.08847.
- [179] Belle collaboration, C. Hadjivasiliou *et al.*, *Search for B^0 meson decays into Λ and missing energy with a hadronic tagging method at Belle*, Phys. Rev. D **105** (2022) L051101, arXiv:2110.14086.
- [180] LHCb collaboration, R. Aaij *et al.*, *Measurement of the differential branching fraction of the decay $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$* , Phys. Lett. B **725** (2013) 25, arXiv:1306.2577.
- [181] CDF collaboration, T. Aaltonen *et al.*, *Observation of the Baryonic Flavor-Changing Neutral Current Decay $\Lambda_b \rightarrow \Lambda \mu^+ \mu^-$* , Phys. Rev. Lett. **107** (2011) 201802, arXiv:1107.3753.
- [182] LHCb collaboration, R. Aaij *et al.*, *Observation of the suppressed decay $\Lambda_b^0 \rightarrow p \pi^- \mu^+ \mu^-$* , JHEP **04** (2017) 029, arXiv:1701.08705.
- [183] LHCb collaboration, R. Aaij *et al.*, *Test of lepton universality with $\Lambda_b^0 \rightarrow p K^- \ell^+ \ell^-$ decays*, JHEP **05** (2020) 040, arXiv:1912.08139.
- [184] LHCb collaboration, R. Aaij *et al.*, *First Observation of the Radiative Decay $\Lambda_b^0 \rightarrow \Lambda \gamma$* , Phys. Rev. Lett. **123** (2019) 031801, arXiv:1904.06697.
- [185] LHCb collaboration, R. Aaij *et al.*, *Observations of $\Lambda_b^0 \rightarrow \Lambda K^+ \pi^-$ and $\Lambda_b^0 \rightarrow \Lambda K^+ K^-$ decays and searches for other Λ_b^0 and Ξ_b^0 decays to $\Lambda h^+ h'^-$ final states*, JHEP **05** (2016) 081, arXiv:1603.00413.

- [186] LHCb collaboration, R. Aaij *et al.*, *Measurement of branching fractions of charmless four-body Λ_b^0 and Ξ_b^0 decays*, JHEP **02** (2018) 098, [arXiv:1711.05490](#).
- [187] LHCb collaboration, R. Aaij *et al.*, *Differential branching fraction and angular analysis of $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$ decays*, JHEP **06** (2015) 115, [arXiv:1503.07138](#), [Erratum: JHEP 09, 145 (2018)].
- [188] LHCb collaboration, R. Aaij *et al.*, *Search for the radiative $\Xi_b^- \rightarrow \Xi^- \gamma$ decay*, JHEP **01** (2022) 069, [arXiv:2108.07678](#).
- [189] LHCb collaboration, R. Aaij *et al.*, *Angular moments of the decay $\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^-$ at low hadronic recoil*, JHEP **09** (2018) 146, [arXiv:1808.00264](#).
- [190] LHCb collaboration, R. Aaij *et al.*, *Search for Baryon-Number Violating Ξ_b^0 Oscillations*, Phys. Rev. Lett. **119** (2017) 181807, [arXiv:1708.05808](#).
- [191] LHCb collaboration, R. Aaij *et al.*, *Measurement of the photon polarization in $\Lambda_b^0 \rightarrow \Lambda \gamma$ decays*, Phys. Rev. D **105** (2022) L051104, [arXiv:2111.10194](#).
- [192] Belle collaboration, C.-C. Peng *et al.*, *Search for $B_s^0 \rightarrow hh$ Decays at the $\Upsilon(5S)$ Resonance*, Phys. Rev. D **82** (2010) 072007, [arXiv:1006.5115](#).
- [193] Belle collaboration, J. Borah *et al.*, *Search for the decay $B_s^0 \rightarrow \pi^0 \pi^0$ at Belle*, [arXiv:2301.08587](#).
- [194] L3 collaboration, M. Acciarri *et al.*, *Search for neutral charmless B decays at LEP*, Phys. Lett. B **363** (1995) 127.
- [195] Belle collaboration, B. Bhuyan *et al.*, *Search for the decay $B_s^0 \rightarrow \eta \eta$* , Phys. Rev. D **105** (2022) 012007, [arXiv:2111.14437](#).
- [196] SLD collaboration, K. Abe *et al.*, *Search for charmless hadronic decays of B mesons with the SLD detector*, Phys. Rev. D **62** (2000) 071101, [arXiv:hep-ex/9910050](#).
- [197] LHCb collaboration, R. Aaij *et al.*, *Search for the $B_s^0 \rightarrow \eta' \phi$ decay*, JHEP **05** (2017) 158, [arXiv:1612.08110](#).
- [198] CDF collaboration, T. Aaltonen *et al.*, *Measurement of Polarization and Search for CP-Violation in $B_s^0 \rightarrow \phi \phi$ Decays*, Phys. Rev. Lett. **107** (2011) 261802, [arXiv:1107.4999](#).
- [199] Belle collaboration, B. Pal *et al.*, *Observation of the decay $B_s^0 \rightarrow K^0 \bar{K}^0$* , Phys. Rev. Lett. **116** (2016) 161801, [arXiv:1512.02145](#).
- [200] LHCb collaboration, R. Aaij *et al.*, *Amplitude analysis of $B_s^0 \rightarrow K_S^0 K^\pm \pi^\mp$ decays*, JHEP **06** (2019) 114, [arXiv:1902.07955](#).
- [201] LHCb collaboration, R. Aaij *et al.*, *First observation of a baryonic B_s^0 decay*, Phys. Rev. Lett. **119** (2017) 041802, [arXiv:1704.07908](#).
- [202] Belle collaboration, D. Dutta *et al.*, *Search for $B_s^0 \rightarrow \gamma \gamma$ and a measurement of the branching fraction for $B_s^0 \rightarrow \phi \gamma$* , Phys. Rev. D **91** (2015) 011101, [arXiv:1411.7771](#).
- [203] LHCb collaboration, R. Aaij *et al.*, *Measurement of the ratio of branching fractions $BR(B_0 \rightarrow K^{*0} \gamma) / BR(B_{s0} \rightarrow \phi \gamma)$ and the direct CP asymmetry in $B_0 \rightarrow K^{*0} \gamma$* , Nucl. Phys. B **867** (2013) 1, [arXiv:1209.0313](#).

- [204] CMS collaboration, *Measurement of the $B_s^0 \rightarrow \mu^+ \mu^-$ decay properties and search for the $B^0 \rightarrow \mu^+ \mu^-$ decay in proton-proton collisions at $\sqrt{s} = 13$ TeV*, arXiv:2212.10311.
- [205] LHCb collaboration, R. Aaij *et al.*, *Measurement of the $B_s^0 \rightarrow \mu^+ \mu^-$ decay properties and search for the $B^0 \rightarrow \mu^+ \mu^-$ and $B_s^0 \rightarrow \mu^+ \mu^- \gamma$ decays*, Phys. Rev. D **105** (2022) 012010, arXiv:2108.09283.
- [206] ATLAS collaboration, M. Aaboud *et al.*, *Study of the rare decays of B_s^0 and B^0 mesons into muon pairs using data collected during 2015 and 2016 with the ATLAS detector*, JHEP **04** (2019) 098, arXiv:1812.03017.
- [207] CDF collaboration, T. Aaltonen *et al.*, *Search for $B_s^0 \rightarrow \mu^+ \mu^-$ and $B^0 \rightarrow \mu^+ \mu^-$ decays with the full CDF Run II data set*, Phys. Rev. D **87** (2013) 072003, arXiv:1301.7048, [Erratum: Phys.Rev.D 97, 099901 (2018)].
- [208] LHCb collaboration, R. Aaij *et al.*, *Search for the Rare Decays $B_s^0 \rightarrow e^+ e^-$ and $B^0 \rightarrow e^+ e^-$* , Phys. Rev. Lett. **124** (2020) 211802, arXiv:2003.03999.
- [209] CDF collaboration, T. Aaltonen *et al.*, *Search for the Decays $B_s^0 \rightarrow e^+ \mu^-$ and $B_s^0 \rightarrow e^+ e^-$ in CDF Run II*, Phys. Rev. Lett. **102** (2009) 201801, arXiv:0901.3803.
- [210] Belle collaboration, L. Nayak *et al.*, *Search for $B_s^0 \rightarrow \ell^\mp \tau^\pm$ with the Semi-leptonic Tagging Method at Belle*, arXiv:2301.10989.
- [211] LHCb collaboration, R. Aaij *et al.*, *Search for the decays $B_s^0 \rightarrow \tau^+ \tau^-$ and $B^0 \rightarrow \tau^+ \tau^-$* , Phys. Rev. Lett. **118** (2017) 251802, arXiv:1703.02508.
- [212] LHCb collaboration, R. Aaij *et al.*, *Searches for rare B_s^0 and B^0 decays into four muons*, JHEP **03** (2022) 109, arXiv:2111.11339.
- [213] LHCb collaboration, R. Aaij *et al.*, *Branching Fraction Measurements of the Rare $B_s^0 \rightarrow \phi \mu^+ \mu^-$ and $B_s^0 \rightarrow f_2'(1525) \mu^+ \mu^-$ Decays*, Phys. Rev. Lett. **127** (2021) 151801, arXiv:2105.14007.
- [214] LHCb collaboration, R. Aaij *et al.*, *Evidence for the decay $B_s^0 \rightarrow \bar{K}^{*0} \mu^+ \mu^-$* , JHEP **07** (2018) 020, arXiv:1804.07167.
- [215] CMS Collaboration, LHCb Collaboration, ATLAS Collaboration, *Combination of the ATLAS, CMS and LHCb results on the $B_{(s)}^0 \rightarrow \mu^+ \mu^-$ decays*, CERN, Geneva, 2020.
- [216] LHCb collaboration, R. Aaij *et al.*, *Search for the lepton-flavour violating decays $B_{(s)}^0 \rightarrow e^\pm \mu^\mp$* , JHEP **03** (2018) 078, arXiv:1710.04111.
- [217] Belle collaboration, S. Watanuki *et al.*, *Search for the lepton flavour violating decays $B^+ \rightarrow K^+ \tau^\pm \ell^\mp$ ($\ell = e, \mu$) at Belle*, arXiv:2212.04128.
- [218] LHCb collaboration, R. Aaij *et al.*, *Search for the lepton-flavour-violating decays $B_s^0 \rightarrow \tau^\pm \mu^\mp$ and $B^0 \rightarrow \tau^\pm \mu^\mp$* , Phys. Rev. Lett. **123** (2019) 211801, arXiv:1905.06614.
- [219] LHCb collaboration, *Search for the lepton-flavour violating decays $B^0 \rightarrow K^{*0} \mu^\pm e^\mp$ and $B_s^0 \rightarrow \phi \mu^\pm e^\mp$* , arXiv:2207.04005.
- [220] LHCb collaboration, *Search for the baryon- and lepton-number violating decays $B^0 \rightarrow p \mu^-$ and $B_s^0 \rightarrow p \mu^-$* , arXiv:2210.10412.

- [221] Belle collaboration, N. K. Nisar *et al.*, *Search for the Decay $B_s^0 \rightarrow \eta'\eta$* , Phys. Rev. D **104** (2021) L031101, [arXiv:2106.09695](#).
- [222] Belle collaboration, S. Dubey *et al.*, *Search for $B_s^0 \rightarrow \eta'X_{s\bar{s}}$ at Belle Using a Semi-Inclusive Method*, Phys. Rev. D **104** (2021) 012007, [arXiv:2102.10266](#).
- [223] Belle collaboration, T. Pang *et al.*, *Search for the decay $B_s^0 \rightarrow \eta'K_S^0$* , [arXiv:2201.01851](#).
- [224] LHCb collaboration, R. Aaij *et al.*, *Study of charmonium production in b -hadron decays and first evidence for the decay $B_s^0 \rightarrow \phi\phi\phi$* , Eur. Phys. J. C **77** (2017) 609, [arXiv:1706.07013](#).
- [225] LHCb collaboration, R. Aaij *et al.*, *Angular analysis of the rare decay $B_s^0 \rightarrow \phi\mu^+\mu^-$* , JHEP **11** (2021) 043, [arXiv:2107.13428](#).
- [226] LHCb collaboration, R. Aaij *et al.*, *First experimental study of photon polarization in radiative B_s^0 decays*, Phys. Rev. Lett. **118** (2017) 021801, [arXiv:1609.02032](#), [Addendum: Phys.Rev.Lett. 118, 109901 (2017)].
- [227] LHCb collaboration, R. Aaij *et al.*, *Search for B_c^+ decays to the $p\bar{p}\pi^+$ final state*, Phys. Lett. B **759** (2016) 313, [arXiv:1603.07037](#).
- [228] LHCb collaboration, R. Aaij *et al.*, *Study of B_c^+ decays to the $K^+K^-\pi^+$ final state and evidence for the decay $B_c^+ \rightarrow \chi_{c0}\pi^+$* , Phys. Rev. D **94** (2016) 091102, [arXiv:1607.06134](#).
- [229] LHCb collaboration, R. Aaij *et al.*, *Observation of the Decay $B_c^+ \rightarrow B_s^0\pi^+$* , Phys. Rev. Lett. **111** (2013) 181801, [arXiv:1308.4544](#).
- [230] LHCb collaboration, *Measurement of the ratio of branching fractions $\mathcal{B}(B_c^+ \rightarrow B_s^0\pi^+)/\mathcal{B}(B_c^+ \rightarrow J/\psi\pi^+)$* , [arXiv:2210.12000](#).
- [231] Belle collaboration, T. Horiguchi *et al.*, *Evidence for Isospin Violation and Measurement of CP Asymmetries in $B \rightarrow K^*(892)\gamma$* , Phys. Rev. Lett. **119** (2017) 191802, [arXiv:1707.00394](#).
- [232] BaBar collaboration, B. Aubert *et al.*, *Measurement of Branching Fractions and CP and Isospin Asymmetries in $B \rightarrow K^*(892)\gamma$ Decays*, Phys. Rev. Lett. **103** (2009) 211802, [arXiv:0906.2177](#).
- [233] Belle II collaboration, F. Abudinén *et al.*, *Measurements of the branching fractions for $B \rightarrow K^*\gamma$ decays at Belle II*, [arXiv:2110.08219](#).
- [234] CLEO collaboration, T. E. Coan *et al.*, *Study of exclusive radiative B meson decays*, Phys. Rev. Lett. **84** (2000) 5283, [arXiv:hep-ex/9912057](#).
- [235] BaBar collaboration, P. del Amo Sanchez *et al.*, *Time-dependent analysis of $B^0 \rightarrow K_S^0\pi^-\pi^+\gamma$ decays and studies of the $K^+\pi^-\pi^+$ system in $B^+ \rightarrow K^+\pi^-\pi^+\gamma$ decays*, Phys. Rev. D **93** (2016) 052013, [arXiv:1512.03579](#).
- [236] Belle collaboration, H. Yang *et al.*, *Observation of $B^+ \rightarrow K(1)(1270)^+\gamma$* , Phys. Rev. Lett. **94** (2005) 111802, [arXiv:hep-ex/0412039](#).
- [237] BaBar collaboration, B. Aubert *et al.*, *Branching Fractions and CP-Violating Asymmetries in Radiative B Decays to $\eta K\gamma$* , Phys. Rev. D **79** (2009) 011102, [arXiv:0805.1317](#).
- [238] Belle collaboration, S. Nishida *et al.*, *Observation of $B^+ \rightarrow K^+\eta\gamma$* , Phys. Lett. B **610** (2005) 23, [arXiv:hep-ex/0411065](#).

- [239] Belle collaboration, R. Wedd *et al.*, *Evidence for $B \rightarrow K \eta'$ gamma Decays at Belle*, Phys. Rev. D **81** (2010) 111104, [arXiv:0810.0804](#).
- [240] BaBar collaboration, B. Aubert *et al.*, *Measurement of branching fractions in radiative B decays to ηK gamma and search for B decays to η' K gamma*, Phys. Rev. D **74** (2006) 031102, [arXiv:hep-ex/0603054](#).
- [241] Belle collaboration, H. Sahoo *et al.*, *First Observation of Radiative $B^0 \rightarrow \phi K^0 \gamma$ Decays and Measurements of Their Time-Dependent CP Violation*, Phys. Rev. D **84** (2011) 071101, [arXiv:1104.5590](#).
- [242] BaBar collaboration, B. Aubert *et al.*, *Measurement of B Decays to ϕK gamma*, Phys. Rev. D **75** (2007) 051102, [arXiv:hep-ex/0611037](#).
- [243] Belle collaboration, S. Nishida *et al.*, *Radiative B meson decays into $K \pi$ gamma and $K \pi \pi$ gamma final states*, Phys. Rev. Lett. **89** (2002) 231801, [arXiv:hep-ex/0205025](#).
- [244] D. Aston *et al.*, *A study of $K^- \pi^+$ scattering in the reaction $K^- p \rightarrow K^- \pi + n$ at 11 GeV/c*, Nucl. Phys. **B296** (1988) 493.
- [245] BaBar collaboration, B. Aubert *et al.*, *Measurement of branching fractions and mass spectra of $B \rightarrow K \pi \pi \gamma$* , Phys. Rev. Lett. **98** (2007) 211804, [arXiv:hep-ex/0507031](#), [Erratum: Phys.Rev.Lett. 100, 189903 (2008), Erratum: Phys.Rev.Lett. 100, 199905 (2008)].
- [246] BaBar collaboration, B. Aubert *et al.*, *Measurement of the $B^0 \rightarrow K_2^*(1430)^0 \gamma$ and $B^+ \rightarrow K_2^*(1430)^+ \gamma$ branching fractions*, Phys. Rev. D **70** (2004) 091105, [arXiv:hep-ex/0409035](#).
- [247] ARGUS collaboration, H. Albrecht *et al.*, *Search for $b \rightarrow s \gamma$ in Exclusive Decays of B Mesons*, Phys. Lett. B **229** (1989) 304.
- [248] Belle collaboration, N. Taniguchi *et al.*, *Measurement of branching fractions, isospin and CP -violating asymmetries for exclusive $b \rightarrow d$ gamma modes*, Phys. Rev. Lett. **101** (2008) 111801, [arXiv:0804.4770](#), [Erratum: Phys.Rev.Lett. 101, 129904 (2008)].
- [249] BaBar collaboration, B. Aubert *et al.*, *Measurements of Branching Fractions for $B^+ \rightarrow \rho^+ \gamma$, $B^0 \rightarrow \rho^0 \gamma$, and $B^0 \rightarrow \omega \gamma$* , Phys. Rev. D **78** (2008) 112001, [arXiv:0808.1379](#).
- [250] Belle collaboration, Y.-J. Lee *et al.*, *Observation of $B^+ \rightarrow p \bar{\Lambda}$ gamma*, Phys. Rev. Lett. **95** (2005) 061802, [arXiv:hep-ex/0503046](#).
- [251] Belle collaboration, J.-T. Wei *et al.*, *Search for $B \rightarrow \pi l^+ l^-$ Decays at Belle*, Phys. Rev. D **78** (2008) 011101, [arXiv:0804.3656](#).
- [252] BaBar collaboration, J. P. Lees *et al.*, *Search for the rare decays $B \rightarrow \pi \ell^+ \ell^-$ and $B^0 \rightarrow \eta \ell^+ \ell^-$* , Phys. Rev. D **88** (2013) 032012, [arXiv:1303.6010](#).
- [253] LHCb collaboration, R. Aaij *et al.*, *First measurement of the differential branching fraction and CP asymmetry of the $B^\pm \rightarrow \pi^\pm \mu^+ \mu^-$ decay*, JHEP **10** (2015) 034, [arXiv:1509.00414](#).
- [254] Belle collaboration, J. Grygier *et al.*, *Search for $B \rightarrow h \nu \bar{\nu}$ decays with semileptonic tagging at Belle*, Phys. Rev. D **96** (2017) 091101, [arXiv:1702.03224](#), [Addendum: Phys.Rev.D 97, 099902 (2018)].

- [255] BaBar collaboration, B. Aubert *et al.*, *A search for the decay $B^+ \rightarrow K^+ \nu \bar{\nu}$* , Phys. Rev. Lett. **94** (2005) 101801, [arXiv:hep-ex/0411061](#).
- [256] LHCb collaboration, R. Aaij *et al.*, *Differential branching fractions and isospin asymmetries of $B \rightarrow K^{(*)} \mu^+ \mu^-$ decays*, JHEP **06** (2014) 133, [arXiv:1403.8044](#).
- [257] BELLE collaboration, S. Choudhury *et al.*, *Test of lepton flavor universality and search for lepton flavor violation in $B \rightarrow K \ell \ell$ decays*, JHEP **03** (2021) 105, [arXiv:1908.01848](#).
- [258] BaBar collaboration, B. Aubert *et al.*, *Direct CP, Lepton Flavor and Isospin Asymmetries in the Decays $B \rightarrow K^{(*)} \ell^+ \ell^-$* , Phys. Rev. Lett. **102** (2009) 091803, [arXiv:0807.4119](#).
- [259] BaBar collaboration, J. P. Lees *et al.*, *Search for $B^+ \rightarrow K^+ \tau^+ \tau^-$ at the BaBar experiment*, Phys. Rev. Lett. **118** (2017) 031802, [arXiv:1605.09637](#).
- [260] BaBar collaboration, J. P. Lees *et al.*, *Search for $B \rightarrow K^{(*)} \nu \bar{\nu}$ and invisible quarkonium decays*, Phys. Rev. D **87** (2013) 112005, [arXiv:1303.7465](#).
- [261] Belle-II collaboration, F. Abudinén *et al.*, *Search for $B^+ \rightarrow K^+ \nu \bar{\nu}$ Decays Using an Inclusive Tagging Method at Belle II*, Phys. Rev. Lett. **127** (2021) 181802, [arXiv:2104.12624](#).
- [262] Belle collaboration, J.-T. Wei *et al.*, *Measurement of the Differential Branching Fraction and Forward-Backward Asymmetry for $B \rightarrow K^{(*)} \ell^+ \ell^-$* , Phys. Rev. Lett. **103** (2009) 171801, [arXiv:0904.0770](#).
- [263] Belle collaboration, O. Lutz *et al.*, *Search for $B \rightarrow h^{(*)} \nu \bar{\nu}$ with the full Belle $\Upsilon(4S)$ data sample*, Phys. Rev. D **87** (2013) 111103, [arXiv:1303.3719](#).
- [264] LHCb collaboration, R. Aaij *et al.*, *First observations of the rare decays $B^+ \rightarrow K^+ \pi^+ \pi^- \mu^+ \mu^-$ and $B^+ \rightarrow \phi K^+ \mu^+ \mu^-$* , JHEP **10** (2014) 064, [arXiv:1408.1137](#).
- [265] BaBar collaboration, J. P. Lees *et al.*, *Search for $B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu}$ with the BaBar experiment*, Phys. Rev. D **100** (2019) 111101, [arXiv:1908.07425](#).
- [266] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of the branching fraction of the $B^0 \rightarrow K_S^0 \pi^0 \gamma$ decay using 190 fb^{-1} of Belle II data*, [arXiv:2206.08280](#).
- [267] Belle collaboration, H. J. Hyun *et al.*, *Search for a Low Mass Particle Decaying into $\mu^+ \mu^-$ in $B^0 \rightarrow K^{*0} X$ and $B^0 \rightarrow \rho^0 X$ at Belle*, Phys. Rev. Lett. **105** (2010) 091801, [arXiv:1005.1450](#).
- [268] Belle collaboration, H. B. Jeon *et al.*, *Search for the radiative penguin decays $B^0 \rightarrow K_S^0 K_S^0 \gamma$ in the Belle experiment*, Phys. Rev. D **106** (2022) 012006.
- [269] Belle collaboration, Z. King *et al.*, *Search for the decay $B^0 \rightarrow \phi \gamma$* , Phys. Rev. D **93** (2016) 111101, [arXiv:1603.06546](#).
- [270] BaBar collaboration, B. Aubert *et al.*, *Search for the radiative decay $B \rightarrow \phi \gamma$* , Phys. Rev. D **72** (2005) 091103, [arXiv:hep-ex/0501038](#).
- [271] Belle collaboration, Y. T. Lai *et al.*, *Search for $B^0 \rightarrow p \bar{\Lambda} \pi^- \gamma$ at Belle*, Phys. Rev. D **89** (2014) 051103, [arXiv:1312.4228](#).
- [272] LHCb collaboration, R. Aaij *et al.*, *Measurements of the S-wave fraction in $B^0 \rightarrow K^+ \pi^- \mu^+ \mu^-$ decays and the $B^0 \rightarrow K^{*(892)^0} \mu^+ \mu^-$ differential branching fraction*, JHEP **11** (2016) 047, [arXiv:1606.04731](#), [Erratum: JHEP 04, 142 (2017)].

- [273] BaBar collaboration, B. Aubert *et al.*, *Search for the rare decay $B \rightarrow \pi l^+ l^-$* , Phys. Rev. Lett. **99** (2007) 051801, [arXiv:hep-ex/0703018](#).
- [274] BaBar collaboration, B. Aubert *et al.*, *Measurements of branching fractions, rate asymmetries, and angular distributions in the rare decays $B \rightarrow K l^+ l^-$ and $B \rightarrow K^* l^+ l^-$* , Phys. Rev. D **73** (2006) 092001, [arXiv:hep-ex/0604007](#).
- [275] Belle collaboration, S. Sandilya *et al.*, *Search for the lepton-flavor-violating decay $B^0 \rightarrow K^{*0} \mu^\pm e^\mp$* , Phys. Rev. D **98** (2018) 071101, [arXiv:1807.03267](#).
- [276] BaBar collaboration, P. del Amo Sanchez *et al.*, *Searches for the baryon- and lepton-number violating decays $B^0 \rightarrow \Lambda_c^+ l^-$, $B^- \rightarrow \Lambda l^-$, and $B^- \rightarrow \bar{\Lambda} l^-$* , Phys. Rev. D **83** (2011) 091101, [arXiv:1101.3830](#).
- [277] LHCb collaboration, R. Aaij *et al.*, *Search for the decay $B^0 \rightarrow \phi \mu^+ \mu^-$* , doi: 10.1007/JHEP05(2022)067 [arXiv:2201.10167](#).
- [278] Belle collaboration, A. Limosani *et al.*, *Measurement of Inclusive Radiative B-meson Decays with a Photon Energy Threshold of 1.7-GeV*, Phys. Rev. Lett. **103** (2009) 241801, [arXiv:0907.1384](#).
- [279] BaBar collaboration, J. P. Lees *et al.*, *Precision Measurement of the $B \rightarrow X_s \gamma$ Photon Energy Spectrum, Branching Fraction, and Direct CP Asymmetry $A_{CP}(B \rightarrow X_{s+d} \gamma)$* , Phys. Rev. Lett. **109** (2012) 191801, [arXiv:1207.2690](#).
- [280] Belle collaboration, T. Saito *et al.*, *Measurement of the $\bar{B} \rightarrow X_s \gamma$ Branching Fraction with a Sum of Exclusive Decays*, Phys. Rev. D **91** (2015) 052004, [arXiv:1411.7198](#).
- [281] BaBar collaboration, J. P. Lees *et al.*, *Exclusive Measurements of $b \rightarrow s \gamma$ Transition Rate and Photon Energy Spectrum*, Phys. Rev. D **86** (2012) 052012, [arXiv:1207.2520](#).
- [282] CLEO collaboration, S. Chen *et al.*, *Branching fraction and photon energy spectrum for $b \rightarrow s \gamma$* , Phys. Rev. Lett. **87** (2001) 251807, [arXiv:hep-ex/0108032](#).
- [283] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of the photon-energy spectrum in inclusive $B \rightarrow X_s \gamma$ decays identified using hadronic decays of the recoil B meson in 2019-2021 Belle II data*, [arXiv:2210.10220](#).
- [284] BaBar collaboration, B. Aubert *et al.*, *Measurement of the $B \rightarrow X_s \gamma$ branching fraction and photon energy spectrum using the recoil method*, Phys. Rev. D **77** (2008) 051103, [arXiv:0711.4889](#).
- [285] BaBar collaboration, P. del Amo Sanchez *et al.*, *Study of $B \rightarrow X \gamma$ Decays and Determination of $|V_{td}/V_{ts}|$* , Phys. Rev. D **82** (2010) 051101, [arXiv:1005.4087](#).
- [286] BaBar collaboration, J. P. Lees *et al.*, *Measurement of the $B \rightarrow X_s l^+ l^-$ branching fraction and search for direct CP violation from a sum of exclusive final states*, Phys. Rev. Lett. **112** (2014) 211802, [arXiv:1312.5364](#).
- [287] Belle collaboration, M. Iwasaki *et al.*, *Improved measurement of the electroweak penguin process $B \rightarrow X_s l^+ l^-$* , Phys. Rev. D **72** (2005) 092005, [arXiv:hep-ex/0503044](#).
- [288] O. Buchmuller and H. Flacher, *Fit to moment from $B \rightarrow X_c l \bar{\nu}$ and $B \rightarrow X_s \gamma$ decays using heavy quark expansions in the kinetic scheme*, Phys. Rev. D **73** (2006) 073008, [arXiv:hep-ph/0507253](#).

- [289] Belle-II collaboration, F. Abudinén *et al.*, *Measurement of the branching fraction for the decay $B \rightarrow K^*(892)\ell^+\ell^-$ at Belle II*, [arXiv:2206.05946](#).
- [290] BaBar collaboration, J. P. Lees *et al.*, *Measurement of Branching Fractions and Rate Asymmetries in the Rare Decays $B \rightarrow K^{(*)}l^+l^-$* , *Phys. Rev. D* **86** (2012) 032012, [arXiv:1204.3933](#).
- [291] CLEO collaboration, K. W. Edwards *et al.*, *Search for lepton flavor violating decays of B mesons*, *Phys. Rev. D* **65** (2002) 111102, [arXiv:hep-ex/0204017](#).
- [292] Belle collaboration, N. Satoyama *et al.*, *A Search for the rare leptonic decays $B^+ \rightarrow \mu^+ \nu(\mu)$ and $B^+ \rightarrow e^+ \nu(\nu)$* , *Phys. Lett. B* **647** (2007) 67, [arXiv:hep-ex/0611045](#).
- [293] BaBar collaboration, B. Aubert *et al.*, *Search for the Rare Leptonic Decays $B^+ \rightarrow l^+ \nu(l)$ ($l=e, \mu$)*, *Phys. Rev. D* **79** (2009) 091101, [arXiv:0903.1220](#).
- [294] Belle collaboration, M. T. Prim *et al.*, *Search for $B^+ \rightarrow \mu^+ \nu_\mu$ and $B^+ \rightarrow \mu^+ N$ with inclusive tagging*, *Phys. Rev. D* **101** (2020) 032007, [arXiv:1911.03186](#).
- [295] Belle collaboration, A. Sibidanov *et al.*, *Search for $B^- \rightarrow \mu^- \bar{\nu}_\mu$ Decays at the Belle Experiment*, *Phys. Rev. Lett.* **121** (2018) 031801, [arXiv:1712.04123](#).
- [296] Belle collaboration, I. Adachi *et al.*, *Evidence for $B^- \rightarrow \tau^- \bar{\nu}_\tau$ with a Hadronic Tagging Method Using the Full Data Sample of Belle*, *Phys. Rev. Lett.* **110** (2013) 131801, [arXiv:1208.4678](#).
- [297] Belle collaboration, B. Kronenbitter *et al.*, *Measurement of the branching fraction of $B^+ \rightarrow \tau^+ \nu_\tau$ decays with the semileptonic tagging method*, *Phys. Rev. D* **92** (2015) 051102, [arXiv:1503.05613](#).
- [298] BaBar collaboration, J. P. Lees *et al.*, *Evidence of $B^+ \rightarrow \tau^+ \nu$ decays with hadronic B tags*, *Phys. Rev. D* **88** (2013) 031102, [arXiv:1207.0698](#).
- [299] BaBar collaboration, B. Aubert *et al.*, *A Search for $B^+ \rightarrow \ell^+ \nu_\ell$ Recoiling Against $B^- \rightarrow D^0 \ell^- \bar{\nu} X$* , *Phys. Rev. D* **81** (2010) 051101, [arXiv:0912.2453](#).
- [300] Belle collaboration, M. Gelb *et al.*, *Search for the rare decay of $B^+ \rightarrow \ell^+ \nu_\ell \gamma$ with improved hadronic tagging*, *Phys. Rev. D* **98** (2018) 112016, [arXiv:1810.12976](#).
- [301] BaBar collaboration, B. Aubert *et al.*, *A Model-independent search for the decay $B^+ \rightarrow l^+ \nu(l) \gamma$* , *Phys. Rev. D* **80** (2009) 111105, [arXiv:0907.1681](#).
- [302] BaBar collaboration, P. del Amo Sanchez *et al.*, *Search for the Decay $B^0 \rightarrow \gamma\gamma$* , *Phys. Rev. D* **83** (2011) 032006, [arXiv:1010.2229](#).
- [303] Belle collaboration, S. Villa *et al.*, *Search for the decay $B^0 \rightarrow \gamma\gamma$* , *Phys. Rev. D* **73** (2006) 051107, [arXiv:hep-ex/0507036](#).
- [304] BaBar collaboration, B. Aubert *et al.*, *Search for decays of $B^0 \rightarrow$ mesons into e^+e^- , $\mu^+\mu^-$, and $e^\pm\mu^\mp$ final states*, *Phys. Rev. D* **77** (2008) 032007, [arXiv:0712.1516](#).
- [305] Belle collaboration, M. C. Chang *et al.*, *Search for $B^0 \rightarrow \ell^+\ell^-$ at BELLE*, *Phys. Rev. D* **68** (2003) 111101, [arXiv:hep-ex/0309069](#).
- [306] BaBar collaboration, B. Aubert *et al.*, *Search for the decays $B^0 \rightarrow e^+e^-\gamma$ and $B^0 \rightarrow \mu^+\mu^-\gamma$* , *Phys. Rev. D* **77** (2008) 011104, [arXiv:0706.2870](#).

- [307] BaBar collaboration, B. Aubert *et al.*, *A search for the rare decay $B^0 \rightarrow \tau^+ \tau^-$ at BABAR*, Phys. Rev. Lett. **96** (2006) 241802, arXiv:hep-ex/0511015.
- [308] BaBar collaboration, J. P. Lees *et al.*, *Improved Limits on B^0 Decays to Invisible Final States and to $\nu\bar{\nu}\gamma$* , Phys. Rev. D **86** (2012) 051105, arXiv:1206.2543.
- [309] Belle collaboration, Y. Ku *et al.*, *Search for B^0 decays to invisible final states ($+\gamma$) at Belle*, Phys. Rev. D **102** (2020) 012003, arXiv:2004.03826.
- [310] LHCb collaboration, R. Aaij *et al.*, *Search for the rare decay $B^+ \rightarrow \mu^+ \mu^- \mu^+ \nu_\mu$* , Eur. Phys. J. C **79** (2019) 675, arXiv:1812.06004.
- [311] LHCb collaboration, R. Aaij *et al.*, *Search for decays of neutral beauty mesons into four muons*, JHEP **03** (2017) 001, arXiv:1611.07704.
- [312] LHCb collaboration, *Measurement of lepton universality parameters in $B^+ \rightarrow K^+ \ell^+ \ell^-$ and $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ decays*, arXiv:2212.09153.
- [313] Belle collaboration, A. Abdesselam *et al.*, *Test of Lepton-Flavor Universality in $B \rightarrow K^* \ell^+ \ell^-$ Decays at Belle*, Phys. Rev. Lett. **126** (2021) 161801, arXiv:1904.02440.
- [314] LHCb collaboration, R. Aaij *et al.*, *Tests of lepton universality using $B^0 \rightarrow K_S^0 \ell^+ \ell^-$ and $B^+ \rightarrow K^{*+} \ell^+ \ell^-$ decays*, Phys. Rev. Lett. **128** (2022) 191802, arXiv:2110.09501.
- [315] Belle collaboration, K. Nishimura *et al.*, *First Measurement of Inclusive $B \rightarrow X_s \eta$ Decays*, Phys. Rev. Lett. **105** (2010) 191803, arXiv:0910.4751.
- [316] CLEO collaboration, T. E. Browder *et al.*, *Observation of high momentum eta-prime production in B decay*, Phys. Rev. Lett. **81** (1998) 1786, arXiv:hep-ex/9804018.
- [317] BaBar collaboration, B. Aubert *et al.*, *Study of high momentum η' production in $B \rightarrow \eta' X_s$* , Phys. Rev. Lett. **93** (2004) 061801, arXiv:hep-ex/0401006.
- [318] CLEO collaboration, G. Bonvicini *et al.*, *Study of the charmless inclusive $B \rightarrow \eta\prime X$ decay*, Phys. Rev. D **68** (2003) 011101, arXiv:hep-ex/0303009.
- [319] BaBar collaboration, P. del Amo Sanchez *et al.*, *Measurement of partial branching fractions of inclusive charmless B meson decays to K^+ , K^0 , and π^+* , Phys. Rev. D **83** (2011) 031103, arXiv:1012.5031.
- [320] Belle collaboration, S. Watanuki *et al.*, *Measurements of isospin asymmetry and difference of direct CP asymmetries in inclusive $B \rightarrow X_s \gamma$ decays*, Phys. Rev. D **99** (2019) 032012, arXiv:1807.04236.
- [321] BaBar collaboration, B. Aubert *et al.*, *Measurements of the $B \rightarrow X_s \gamma$ branching fraction and photon spectrum from a sum of exclusive final states*, Phys. Rev. D **72** (2005) 052004, arXiv:hep-ex/0508004.
- [322] BaBar collaboration, J. P. Lees *et al.*, *A search for the decay modes $B^\pm \rightarrow h^\pm \tau^\pm l^\mp$* , Phys. Rev. D **86** (2012) 012004, arXiv:1204.2852.
- [323] LHCb collaboration, R. Aaij *et al.*, *Search for Lepton-Flavor Violating Decays $B^+ \rightarrow K^+ \mu^\pm e^\mp$* , Phys. Rev. Lett. **123** (2019) 241802, arXiv:1909.01010.

- [324] LHCb collaboration, R. Aaij *et al.*, *Search for the lepton flavour violating decay $B^+ \rightarrow K^+ \mu^- \tau^+$ using B_s^{*0} decays*, JHEP **06** (2020) 129, arXiv:2003.04352.
- [325] BaBar collaboration, J. P. Lees *et al.*, *Search for lepton-number violating processes in $B^+ \rightarrow h^- l^+ l^+$ decays*, Phys. Rev. D **85** (2012) 071103, arXiv:1202.3650.
- [326] LHCb collaboration, R. Aaij *et al.*, *Search for Majorana neutrinos in $B^- \rightarrow \pi^+ \mu^- \mu^-$ decays*, Phys. Rev. Lett. **112** (2014) 131802, arXiv:1401.5361.
- [327] BaBar collaboration, J. P. Lees *et al.*, *Search for lepton-number violating $B^+ \rightarrow X^- \ell^+ \ell'^+$ decays*, Phys. Rev. D **89** (2014) 011102, arXiv:1310.8238.
- [328] LHCb collaboration, R. Aaij *et al.*, *Search for the lepton number violating decays $B^+ \rightarrow \pi^- \mu^+ \mu^+$ and $B^+ \rightarrow K^- \mu^+ \mu^+$* , Phys. Rev. Lett. **108** (2012) 101601, arXiv:1110.0730.
- [329] BELLE collaboration, O. Seon *et al.*, *Search for Lepton-number-violating $B^+ \rightarrow D^- l^+ l'^+$ Decays*, Phys. Rev. D **84** (2011) 071106, arXiv:1107.0642.
- [330] LHCb collaboration, R. Aaij *et al.*, *Searches for Majorana neutrinos in B^- decays*, Phys. Rev. D **85** (2012) 112004, arXiv:1201.5600.
- [331] BaBar collaboration, B. Aubert *et al.*, *Searches for the decays $B^0 \rightarrow \ell^\pm \tau^\mp$ and $B^+ \rightarrow \ell^+ \nu$ ($l=e, \mu$) using hadronic tag reconstruction*, Phys. Rev. D **77** (2008) 091104, arXiv:0801.0697.
- [332] LHCb collaboration, *Search for the lepton-flavour violating decays $B^0 \rightarrow K^{*0} \tau^\pm \mu^\mp$* , arXiv:2209.09846.
- [333] Belle collaboration, H. Atmacan *et al.*, *Search for $B^0 \rightarrow \tau^\pm \ell^\mp$ ($\ell = e, \mu$) with a hadronic tagging method at Belle*, Phys. Rev. D **104** (2021) L091105, arXiv:2108.11649.
- [334] LHCb collaboration, R. Aaij *et al.*, *Observation of Photon Polarization in the $b \rightarrow s \gamma$ Transition*, Phys. Rev. Lett. **112** (2014) 161801, arXiv:1402.6852.
- [335] LHCb collaboration, R. Aaij *et al.*, *Angular analysis of charged and neutral $B \rightarrow K \mu^+ \mu^-$ decays*, JHEP **05** (2014) 082, arXiv:1403.8045.
- [336] LHCb collaboration, R. Aaij *et al.*, *Strong constraints on the $b \rightarrow s \gamma$ photon polarisation from $B^0 \rightarrow K^{*0} e^+ e^-$ decays*, JHEP **12** (2020) 081, arXiv:2010.06011.
- [337] LHCb collaboration, R. Aaij *et al.*, *Measurement of the $B^0 \rightarrow K^{*0} e^+ e^-$ branching fraction at low dilepton mass*, JHEP **05** (2013) 159, arXiv:1304.3035.
- [338] Belle collaboration, A. Abdesselam *et al.*, *Angular analysis of $B^0 \rightarrow K^*(892)^0 \ell^+ \ell^-$* , in *LHC Ski 2016: A First Discussion of 13 TeV Results*, 2016, arXiv:1604.04042.
- [339] Belle collaboration, S. Wehle *et al.*, *Lepton-Flavor-Dependent Angular Analysis of $B \rightarrow K^* \ell^+ \ell^-$* , Phys. Rev. Lett. **118** (2017) 111801, arXiv:1612.05014.
- [340] BaBar collaboration, J. P. Lees *et al.*, *Measurement of angular asymmetries in the decays $B \rightarrow K^* \ell^+ \ell^-$* , Phys. Rev. D **93** (2016) 052015, arXiv:1508.07960.
- [341] LHCb collaboration, R. Aaij *et al.*, *Angular analysis of the $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ decay using 3 fb^{-1} of integrated luminosity*, JHEP **02** (2016) 104, arXiv:1512.04442.
- [342] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP-Averaged Observables in the $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ Decay*, Phys. Rev. Lett. **125** (2020) 011802, arXiv:2003.04831.

- [343] CMS collaboration, V. Khachatryan *et al.*, *Angular analysis of the decay $B^0 \rightarrow K^{*0}\mu^+\mu^-$ from pp collisions at $\sqrt{s} = 8$ TeV*, Phys. Lett. B **753** (2016) 424, [arXiv:1507.08126](#).
- [344] CMS collaboration, A. M. Sirunyan *et al.*, *Measurement of angular parameters from the decay $B^0 \rightarrow K^{*0}\mu^+\mu^-$ in proton-proton collisions at $\sqrt{s} = 8$ TeV*, Phys. Lett. B **781** (2018) 517, [arXiv:1710.02846](#).
- [345] ATLAS collaboration, M. Aaboud *et al.*, *Angular analysis of $B_d^0 \rightarrow K^{*0}\mu^+\mu^-$ decays in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector*, JHEP **10** (2018) 047, [arXiv:1805.04000](#).
- [346] LHCb collaboration, R. Aaij *et al.*, *Angular Analysis of the $B^+ \rightarrow K^{*+}\mu^+\mu^-$ Decay*, Phys. Rev. Lett. **126** (2021) 161802, [arXiv:2012.13241](#).
- [347] CMS collaboration, A. M. Sirunyan *et al.*, *Angular analysis of the decay $B^+ \rightarrow K^{*+}(892)\mu^+\mu^-$ in proton-proton collisions at $\sqrt{s} = 8$ TeV*, JHEP **04** (2021) 124, [arXiv:2010.13968](#).
- [348] Belle collaboration, Y. Sato *et al.*, *Measurement of the lepton forward-backward asymmetry in $B \rightarrow X_s\ell^+\ell^-$ decays with a sum of exclusive modes*, Phys. Rev. D **93** (2016) 032008, [arXiv:1402.7134](#), [Addendum: Phys.Rev.D 93, 059901 (2016)].
- [349] LHCb collaboration, R. Aaij *et al.*, *Differential branching fraction and angular moments analysis of the decay $B^0 \rightarrow K^+\pi^-\mu^+\mu^-$ in the $K_{0,2}^*(1430)^0$ region*, JHEP **12** (2016) 065, [arXiv:1609.04736](#).
- [350] LHCb collaboration, R. Aaij *et al.*, *Measurement of the phase difference between short- and long-distance amplitudes in the $B^+ \rightarrow K^+\mu^+\mu^-$ decay*, Eur. Phys. J. C **77** (2017) 161, [arXiv:1612.06764](#).
- [351] CMS collaboration, A. M. Sirunyan *et al.*, *Angular analysis of the decay $B^+ \rightarrow K^+\mu^+\mu^-$ in proton-proton collisions at $\sqrt{s} = 8$ TeV*, Phys. Rev. D **98** (2018) 112011, [arXiv:1806.00636](#).
- [352] LHCb collaboration, R. Aaij *et al.*, *Search for hidden-sector bosons in $B^0 \rightarrow K^{*0}\mu^+\mu^-$ decays*, Phys. Rev. Lett. **115** (2015) 161802, [arXiv:1508.04094](#).
- [353] LHCb collaboration, R. Aaij *et al.*, *Search for long-lived scalar particles in $B^+ \rightarrow K^+\chi(\mu^+\mu^-)$ decays*, Phys. Rev. D **95** (2017) 071101, [arXiv:1612.07818](#).
- [354] HFLAV collaboration, Y. Amhis *et al.*, *Averages of b -hadron, c -hadron, and τ -lepton properties as of 2021*, [arXiv:2206.07501](#).
- [355] CLEO collaboration, S. Chen *et al.*, *Measurement of charge asymmetries in charmless hadronic in b meson decays*, Phys. Rev. Lett. **85** (2000) 525, [arXiv:hep-ex/0001009](#).
- [356] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP Violation in the Decay $B^+ \rightarrow K^+\pi^0$* , Phys. Rev. Lett. **126** (2021) 091802, [arXiv:2012.12789](#).
- [357] LHCb collaboration, *Direct CP violation in charmless three-body decays of B^\pm mesons*, [arXiv:2206.07622](#).
- [358] LHCb collaboration, R. Aaij *et al.*, *Measurements of CP violation in the three-body phase space of charmless B^\pm decays*, Phys. Rev. D **90** (2014) 112004, [arXiv:1408.5373](#).
- [359] Belle collaboration, K.-F. Chen *et al.*, *Measurement of polarization and triple-product correlations in $B \rightarrow \phi K^*$ decays*, Phys. Rev. Lett. **94** (2005) 221804, [arXiv:hep-ex/0503013](#).

- [360] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP asymmetries in the decays $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ and $B^+ \rightarrow K^+ \mu^+ \mu^-$* , JHEP **09** (2014) 177, arXiv:1408.0978.
- [361] LHCb collaboration, R. Aaij *et al.*, *Observation of CP violation in two-body $B_{(s)}^0$ -meson decays to charged pions and kaons*, JHEP **03** (2021) 075, arXiv:2012.05319.
- [362] CDF collaboration, T. A. Aaltonen *et al.*, *Measurements of Direct CP -Violating Asymmetries in Charmless Decays of Bottom Baryons*, Phys. Rev. Lett. **113** (2014) 242001, arXiv:1403.5586.
- [363] Belle collaboration, J. Dalseno *et al.*, *Time-dependent Dalitz Plot Measurement of CP Parameters in $B^0 \rightarrow K^0(s) \pi^+ \pi^-$ Decays*, Phys. Rev. D **79** (2009) 072004, arXiv:0811.3665.
- [364] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP asymmetries in two-body $B_{(s)}^0$ -meson decays to charged pions and kaons*, Phys. Rev. D **98** (2018) 032004, arXiv:1805.06759.
- [365] Belle collaboration, K. Abe *et al.*, *Observation of B decays to two kaons*, Phys. Rev. Lett. **98** (2007) 181804, arXiv:hep-ex/0608049.
- [366] BaBar collaboration, J. P. Lees *et al.*, *Measurement of CP-violating asymmetries in $B^0 \rightarrow (\rho\pi)^0$ decays using a time-dependent Dalitz plot analysis*, Phys. Rev. D **88** (2013) 012003, arXiv:1304.3503.
- [367] Belle collaboration, A. Kusaka *et al.*, *Measurement of CP Asymmetry in a Time-Dependent Dalitz Analysis of $B^0 \rightarrow (\rho\pi)^0$ and a Constraint on the CKM Angle $\phi(2)$* , Phys. Rev. Lett. **98** (2007) 221602, arXiv:hep-ex/0701015.
- [368] BaBar collaboration, B. Aubert *et al.*, *Measurements of CP-Violating Asymmetries in $B^0 \rightarrow a_+^-(1) (1260) \pi^\mp$ decays*, Phys. Rev. Lett. **98** (2007) 181803, arXiv:hep-ex/0612050.
- [369] BaBar collaboration, J. P. Lees *et al.*, *Measurements of direct CP asymmetries in $B \rightarrow X_s \gamma$ decays using sum of exclusive decays*, Phys. Rev. D **90** (2014) 092001, arXiv:1406.0534.
- [370] Belle collaboration, L. Pesántez *et al.*, *Measurement of the direct CP asymmetry in $\bar{B} \rightarrow X_{s+d} \gamma$ decays with a lepton tag*, Phys. Rev. Lett. **114** (2015) 151601, arXiv:1501.01702.
- [371] LHCb collaboration, R. Aaij *et al.*, *Search for CP violation in $\Lambda_b^0 \rightarrow pK^-$ and $\Lambda_b^0 \rightarrow p\pi^-$ decays*, Phys. Lett. B **787** (2018) 124, arXiv:1807.06544.
- [372] LHCb collaboration, R. Aaij *et al.*, *Measurement of matter-antimatter differences in beauty baryon decays*, Nature Phys. **13** (2017) 391, arXiv:1609.05216.
- [373] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay $\Lambda_b^0 \rightarrow pK^- \mu^+ \mu^-$ and a search for CP violation*, JHEP **06** (2017) 108, arXiv:1703.00256.
- [374] LHCb collaboration, R. Aaij *et al.*, *Search for CP violation using triple product asymmetries in $\Lambda_b^0 \rightarrow pK^- \pi^+ \pi^-$, $\Lambda_b^0 \rightarrow pK^- K^+ K^-$ and $\Xi_b^0 \rightarrow pK^- K^- \pi^+$ decays*, JHEP **08** (2018) 039, arXiv:1805.03941.
- [375] LHCb collaboration, R. Aaij *et al.*, *Measurements of CP asymmetries in charmless four-body Λ_b^0 and Ξ_b^0 decays*, Eur. Phys. J. C **79** (2019) 745, arXiv:1903.06792.
- [376] LHCb collaboration, R. Aaij *et al.*, *Study of the $B^0 \rightarrow \rho(770)^0 K^*(892)^0$ decay with an amplitude analysis of $B^0 \rightarrow (\pi^+ \pi^-)(K^+ \pi^-)$ decays*, JHEP **05** (2019) 026, arXiv:1812.07008.

- [377] LHCb collaboration, R. Aaij *et al.*, *Measurement of polarization amplitudes and CP asymmetries in $B^0 \rightarrow \phi K^*(892)^0$* , JHEP **05** (2014) 069, [arXiv:1403.2888](#).
- [378] LHCb collaboration, R. Aaij *et al.*, *Angular analysis of the $B^0 \rightarrow K^{*0} e^+ e^-$ decay in the low- q^2 region*, JHEP **04** (2015) 064, [arXiv:1501.03038](#).
- [379] LHCb collaboration, R. Aaij *et al.*, *First measurement of the CP-violating phase $\phi_s^{\bar{d}}$ in $B_s^0 \rightarrow (K^+ \pi^-)(K^- \pi^+)$ decays*, JHEP **03** (2018) 140, [arXiv:1712.08683](#).