

# $b$ -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 mesons<sup>1</sup>, except for a few lepton-flavour- and lepton-number-violating decays reported in section 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 Chapter 3 of the latest HFLAV publication. We perform fits of the full likelihood function and do not use the approximation described in Section 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 Section 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 ( $\sigma$ ), 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 are at 90% confidence level (CL), unless mentioned otherwise. For observables that are not BFs, such as  $A_{CP}$  or polarization fractions, we include in our averages all the available

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<sup>1</sup>The 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.

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 Chapter 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 non-resonant component. When it applies we detail the model used for the non-resonant 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 2021 Review of Particle Physics (PDG 2021) [2]. In most of the tables the averages are compared to those from PDG 2021. 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  $\chi^2$  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. Secs. 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^+ \rightarrow K^0\pi^+)^1$	Belle [3]	$23.97 \pm 0.53 \pm 0.71$	$23.5 \pm 0.7$ $23.7 \pm 0.8$
	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] <sup>2</sup>		
$\mathcal{B}(B^+ \rightarrow K^+\pi^0)$	Belle [3]	$12.62 \pm 0.31 \pm 0.56$	$13.2 \pm 0.5$ $12.9 \pm 0.5$
	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]	$71.5 \pm 1.3 \pm 3.2$	$68.9 \pm 2.3$ $70.4 \pm 2.5$
	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] <sup>3</sup>		
$\mathcal{B}(B^+ \rightarrow \eta'K^*(892)^+)$	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]	$6.0^{+2.2}_{-2.0} \pm 0.9$	$6.0 \pm 2.3$ none
$\mathcal{B}(B^+ \rightarrow \eta'K_0^*(1430)^+)$	BaBar [16]	$5.2 \pm 1.9 \pm 1.0$ <sup>4</sup>	$5.2 \pm 2.1$
$\mathcal{B}(B^+ \rightarrow \eta'K_2^*(1430)^+)$	BaBar [16]	$28.0^{+4.6}_{-4.3} \pm 2.6$	$28.0 \pm 5.2$
			$28.0^{+5.3}_{-5.0}$

<sup>1</sup> The PDG average is a result of a fit including input from other measurements.

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

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

<sup>4</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow \eta K^+)^1$	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]	$12.9 \pm 1.8 \pm 1.8$ <sup>3</sup> $18.2 \pm 3.7$
$\mathcal{B}(B^+ \rightarrow \eta K_2^*(1430)^+)$	BaBar [19]	$9.1 \pm 2.7 \pm 1.4$ $9.1 \pm 3.0$
$\mathcal{B}(B^+ \rightarrow \eta(1295)K^+) \times \mathcal{B}(\eta(1295) \rightarrow \eta\pi\pi)$	BaBar [21]	$2.9^{+0.8}_{-0.7} \pm 0.2$ $2.9^{+0.8}_{-0.7}$
$\mathcal{B}(B^+ \rightarrow \eta(1405)K^+) \times \mathcal{B}(\eta(1405) \rightarrow \eta\pi\pi)$	BaBar [21]	$< 1.3$ $< 1.3$
$\mathcal{B}(B^+ \rightarrow \eta(1405)K^+) \times \mathcal{B}(\eta(1405) \rightarrow K^*K)$	BaBar [21]	$< 1.2$ $< 1.2$
$\mathcal{B}(B^+ \rightarrow \eta(1475)K^+) \times \mathcal{B}(\eta(1475) \rightarrow K^*K)$	BaBar [21]	$13.8^{+1.8+1.0}_{-1.7-0.6}$ $13.8^{+2.1}_{-1.8}$
$\mathcal{B}(B^+ \rightarrow f_1(1285)K^+) \times \mathcal{B}(f_1(1285) \rightarrow \eta\pi\pi)$	BaBar [21]	$< 0.8$ none
$\mathcal{B}(B^+ \rightarrow f_1(1420)K^+) \times \mathcal{B}(f_1(1420) \rightarrow \eta\pi\pi)$	BaBar [21]	$< 2.9$ $< 2.9$
$\mathcal{B}(B^+ \rightarrow f_1(1420)K^+) \times \mathcal{B}(f_1(1420) \rightarrow K^*K)$	BaBar [21]	$< 4.1$ $< 4.1$
$\mathcal{B}(B^+ \rightarrow \phi(1680)K^+) \times \mathcal{B}(\phi(1680) \rightarrow K^*K)$	BaBar [21]	$< 3.4$ $< 3.4$
$\mathcal{B}(B^+ \rightarrow f_0(1500)K^+)$	BaBar [22]	$17 \pm 4 \pm 12$ <sup>4</sup>
	BaBar [22]	$20 \pm 10 \pm 27$ <sup>5</sup> $4 \pm 2$
$\mathcal{B}(B^+ \rightarrow \omega(782)K^+)^6$	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]	$< 7.4$ $< 7.4$
$\mathcal{B}(B^+ \rightarrow \omega(782)(K\pi)_0^{*+})$	BaBar [26]	$27.5 \pm 3.0 \pm 2.6$ $27.5 \pm 4.0$
$\mathcal{B}(B^+ \rightarrow \omega(782)K_0^*(1430)^+)$	BaBar [26]	$24.0 \pm 2.6 \pm 4.4$ $24.0 \pm 5.1$
$\mathcal{B}(B^+ \rightarrow \omega(782)K_2^*(1430)^+)$	BaBar [26]	$21.5 \pm 3.6 \pm 2.4$ $21.5 \pm 4.3$
$\mathcal{B}(B^+ \rightarrow a_0(980)^+K^0) \times \mathcal{B}(a_0(980)^+ \rightarrow \eta\pi^+)$	BaBar [27]	$< 3.9$ $< 3.9$
$\mathcal{B}(B^+ \rightarrow a_0(980)^0K^+) \times \mathcal{B}(a_0(980)^0 \rightarrow \eta\pi^0)$	BaBar [27]	$< 2.5$ $< 2.5$

<sup>1</sup> The PDG uncertainty includes a scale factor.

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

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

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

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

<sup>6</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\pi^+)$	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]	$3.89 \pm 0.47^{+0.43}_{-0.41}{}^1$
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^0\pi^+)$ <sup>7</sup>	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]	$< 15.0{}^1$

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

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

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

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

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

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

<sup>7</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^+ \rightarrow K^+\pi^0\pi^0)$	BaBar [31]	$16.2 \pm 1.2 \pm 1.5$	$16.2 \pm 1.9$
$\mathcal{B}(B^+ \rightarrow f_0(980)K^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^0\pi^0)$	BaBar [31]	$2.8 \pm 0.6 \pm 0.5$	$2.8 \pm 0.8$
$\mathcal{B}(B^+ \rightarrow K^-\pi^+\pi^+)$	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]	$75.3 \pm 6.0 \pm 8.1$	$75 \pm 10$
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$4.6 \pm 1.0 \pm 0.4$	$4.6 \pm 1.1$
$\mathcal{B}(B^+ \rightarrow f_0(980)K^*(892)^+) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [43]	$4.2 \pm 0.6 \pm 0.3$	$4.2 \pm 0.7$
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+K^0)$	BaBar [44]	$34.9 \pm 5.0 \pm 4.4$	$34.9 \pm 6.7$
$\mathcal{B}(B^+ \rightarrow b_1(1235)^+K^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^+)$	BaBar [48]	$9.6 \pm 1.7 \pm 0.9$	$9.6 \pm 1.9$
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\rho^+(770))$	BaBar [45]	$9.6 \pm 1.7 \pm 1.5$	$9.2 \pm 1.5$
	Belle [46]	$8.9 \pm 1.7 \pm 1.2$ <sup>3</sup>	
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+\rho^0(770))$	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]	$9.1 \pm 1.7 \pm 1.0$	$9.1 \pm 2.0$
$\mathcal{B}(B^+ \rightarrow b_1(1235)^+K^*(892)^0) \times \mathcal{B}(b_1(1235)^+ \rightarrow \omega(782)\pi^+)$	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]	$< 6.7$	$< 6.7$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> See also Ref. [51].

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

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

<sup>1</sup> The PDG average is a result of a fit including input from other measurements.

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

<sup>3</sup> PDG uses the BABAR result including the  $\chi_{c0}$  intermediate state.

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

<sup>5</sup> 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  $\chi_{c0}$  intermediate state.

<sup>6</sup> The nonresonant amplitude is modelled using a polynomial function of order 2.

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

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

<sup>9</sup> LHCb uses a model of non-resonant 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.

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

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

<sup>12</sup> 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.

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

<sup>1</sup> 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.

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

<sup>3</sup> The PDG uncertainty includes a scale factor.

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

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

<sup>6</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>8</sup> Measurement of  $\mathcal{B}(B^+ \rightarrow K^+K^-\pi^+)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$  used in our fit.

<sup>9</sup> Measurement of  $\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$  used in our fit.

<sup>10</sup> Measurement of  $\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-)/\mathcal{B}(B^+ \rightarrow K^+K^+K^-)$  used in our fit.

<sup>11</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ K^+ K^-)$	BaBar [42]	$36.2 \pm 3.3 \pm 3.6$	$36.2 \pm 4.9$
$\mathcal{B}(B^+ \rightarrow \phi(1020) K^*(892)^+)^1$	BaBar [64]	$11.2 \pm 1.0 \pm 0.9$ <sup>2</sup>	
	Belle [65]	$6.7^{+2.1+0.7}_{-1.9-1.0}$	$10.6 \pm 1.1$
	Belle II [61]	$21.7 \pm 4.6 \pm 1.9$	$10.0 \pm 2.0$
	CLEO [63]	$10.6^{+6.4+1.8}_{-4.9-1.6}$	
$\mathcal{B}(B^+ \rightarrow \phi(1020)(K\pi)_0^{*+})$	BaBar [66]	$8.3 \pm 1.4 \pm 0.8$	$8.3 \pm 1.6$
$\mathcal{B}(B^+ \rightarrow K_1(1270)^+ \phi(1020))$	BaBar [66]	$6.1 \pm 1.6 \pm 1.1$	$6.1 \pm 1.9$
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+ \phi(1020))$	BaBar [66]	$< 3.2$	$< 3.2$
$\mathcal{B}(B^+ \rightarrow K^*(1410)^+ \phi(1020))$	BaBar [66]	$< 4.3$	$< 4.3$
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^+ \phi(1020))$	BaBar [66]	$7.0 \pm 1.3 \pm 0.9$	$7.0 \pm 1.6$
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^+ \phi(1020))$	BaBar [66]	$8.4 \pm 1.8 \pm 1.0$	$8.4 \pm 2.1$
$\mathcal{B}(B^+ \rightarrow K_2(1770)^+ \phi(1020))$	BaBar [66]	$< 15.0$	$< 15$
$\mathcal{B}(B^+ \rightarrow \phi(1020) K_2(1820)^+)$	BaBar [66]	$< 16.3$	$< 16$
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+ K^*(892)^0)$	BaBar [67]	$< 3.6$	$< 3.6$
$\mathcal{B}(B^+ \rightarrow \phi(1020)\phi(1020)K^+)^1$	BaBar [68]	$5.6 \pm 0.5 \pm 0.3$ <sup>3</sup>	$4.98 \pm 0.52$
	Belle [69]	$2.6^{+1.1}_{-0.9} \pm 0.3$ <sup>3</sup>	$4.22^{+0.82}_{-0.79}$
$\mathcal{B}(B^+ \rightarrow \eta'\eta' K^+)$	BaBar [70]	$< 25.0$	$< 25$
$\mathcal{B}(B^+ \rightarrow \phi(1020)\omega(782)K^+)$	Belle [71]	$< 1.9$	$< 1.9$
$\mathcal{B}(B^+ \rightarrow X(1812)K^+) \times \mathcal{B}(X(1812) \rightarrow \phi(1020)\omega(782))$			
	Belle [71]	$< 0.32$	$< 0.32$
$\mathcal{B}(B^+ \rightarrow h^+ X^0(\text{Familon}))^4$	CLEO [72]	$< 49$	$< 49$

<sup>1</sup> The PDG uncertainty includes a scale factor.

<sup>2</sup> 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.

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

<sup>4</sup>  $h = \pi, K$ .

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0)^1$	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 [73]	$15.2 \pm 0.6^{+1.3}_{-1.2}{}^{3,4,5}$
$\mathcal{B}(B^+ \rightarrow \rho^0(770)\pi^+)$	LHCb [74]	$8.82 \pm 0.10 \pm 0.50^{3,6,5,7}$
	BaBar [73]	$8.1 \pm 0.7^{+1.3}_{-1.6}{}^{3,5}$
	Belle [75]	$8.0^{+2.3}_{-2.0} \pm 0.7$
	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 [73]	$< 1.5^3$
$\mathcal{B}(B^+ \rightarrow f_2(1270)\pi^+) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	LHCb [74]	$1.43 \pm 0.05 \pm 0.27^{3,6,5,7}$
	BaBar [73]	$0.9 \pm 0.2^{+0.3}_{-0.1}{}^{3,5}$
$\mathcal{B}(B^+ \rightarrow f_2(1270)\pi^+) \times \mathcal{B}(f_2(1270) \rightarrow K^+K^-)$	LHCb [56]	$0.377 \pm 0.040 \pm 0.040^{8,9}$
		none
$\mathcal{B}(B^+ \rightarrow \rho(1450)^0\pi^+) \times \mathcal{B}(\rho(1450)^0 \rightarrow \pi^+\pi^-)$	LHCb [74]	$0.83 \pm 0.05 \pm 0.89^{3,6,5,7}$
	BaBar [73]	$1.4 \pm 0.4^{+0.5}_{-0.8}{}^{3,5}$
$\mathcal{B}(B^+ \rightarrow \rho(1450)^0\pi^+) \times \mathcal{B}(\rho(1450)^0 \rightarrow K^+K^-)$	LHCb [56]	$1.544 \pm 0.060 \pm 0.089^{8,9}$
		none
$\mathcal{B}(B^+ \rightarrow \rho_3(1690)^0\pi^+) \times \mathcal{B}(\rho_3(1690)^0 \rightarrow \pi^+\pi^-)$	LHCb [74]	$0.08 \pm 0.02 \pm 0.16^{3,6,5,7}$
		none
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-) S\text{-wave}$	LHCb [74]	$4.04 \pm 0.08 \pm 0.64^{10,5,7}$
		none
$\mathcal{B}(B^+ \rightarrow f_0(1370)\pi^+) \times \mathcal{B}(f_0(1370) \rightarrow \pi^+\pi^-)$	BaBar [73]	$< 4.0^3$
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^-\pi^+(\text{NR}))$	BaBar [73]	$5.3 \pm 0.7^{+1.3}_{-0.8}{}^{11,5}$
		$5.3^{+1.4}_{-1.0}$ $5.3^{+1.5}_{-1.1}$

<sup>1</sup> The PDG uncertainty includes a scale factor.

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

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

<sup>4</sup> Charm and charmonium contributions are subtracted.

<sup>5</sup> Multiple systematic uncertainties are added in quadrature.

<sup>6</sup> 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. [76].

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

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

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

<sup>10</sup> LHCb accounts the  $S$ -wave component using a model that comprises the coherent sum of a  $\sigma$  pole. See Ref. [74] for details.

<sup>11</sup> 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 <sup>-6</sup> ]	Measurements	Average <sup>HFLAV PDG</sup>
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0\pi^0)$	Belle [77] $19.0 \pm 1.5 \pm 1.4$ ARGUS [78] $< 890$	$19.0 \pm 2.1$ $< 890.0$
$\mathcal{B}(B^+ \rightarrow X_{\pi^0\pi^0}^0 \pi^+) \times \mathcal{B}(X^0(\pi^0\pi^0) \rightarrow \pi^0\pi^0)$	Belle [77] $6.9 \pm 1.1 \pm 1.1$ <sup>1,2</sup>	$6.9 \pm 1.5$ none
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0\pi^0(\text{NR}))$	Belle [77] $< 0.6$	$< 0.60$ none
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\pi^0)$	Belle [77] $11.2 \pm 1.1$ <sup>+1.2</sup> <sub>-1.8</sub> <sup>2</sup> BaBar [79] $10.2 \pm 1.4 \pm 0.9$	$10.6 \pm 1.3$ $10.9$ <sup>+1.4</sup> <sub>-1.5</sub>
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^-\pi^0)$	ARGUS [78] $< 4000$	$< 4000$
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [80] $23.7 \pm 1.4 \pm 1.4$ Belle II [81] $23.2$ <sup>+2.2</sup> <sub>-2.1</sub> $\pm 2.7$ Belle [82] $31.7 \pm 7.1$ <sup>+3.8</sup> <sub>-6.7</sub>	$23.8 \pm 1.7$ $24.0 \pm 1.9$
$\mathcal{B}(B^+ \rightarrow f_0(980)\rho^+(770)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [80] $< 2.0$	$< 2.0$
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+\pi^0)$	BaBar [83] $26.4 \pm 5.4 \pm 4.1$	$26.4 \pm 6.8$
$\mathcal{B}(B^+ \rightarrow a_1(1260)^0\pi^+)$	BaBar [83] $20.4 \pm 4.7 \pm 3.4$	$20.4 \pm 5.8$
$\mathcal{B}(B^+ \rightarrow \omega(782)\pi^+)$	BaBar [24] $6.7 \pm 0.5 \pm 0.4$ Belle [84] $6.9 \pm 0.6 \pm 0.5$ CLEO [25] $11.3$ <sup>+3.3</sup> <sub>-2.9</sub> $\pm 1.4$ LHCb [74] <sup>3,4,2,5</sup>	$6.60 \pm 0.46$ $6.88 \pm 0.49$
$\mathcal{B}(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26] $15.9 \pm 1.6 \pm 1.4$	$15.9 \pm 2.1$
$\mathcal{B}(B^+ \rightarrow \eta\pi^+)$	Belle [18] $4.07 \pm 0.26 \pm 0.21$ BaBar [10] $4.00 \pm 0.40 \pm 0.24$ CLEO [14] $1.2$ <sup>+2.8</sup> <sub>-1.2</sub>	$4.02 \pm 0.27$ $4.02$ <sup>+0.27</sup> <sub>-0.26</sub>
$\mathcal{B}(B^+ \rightarrow \eta\rho^+(770))^6$	BaBar [85] $9.9 \pm 1.2 \pm 0.8$ Belle [20] $4.1$ <sup>+1.4</sup> <sub>-1.3</sub> $\pm 0.4$ CLEO [14] $4.8$ <sup>+5.2</sup> <sub>-3.8</sub>	$6.9 \pm 1.0$ $7.0$ <sup>+2.9</sup> <sub>-2.8</sub>
$\mathcal{B}(B^+ \rightarrow \eta'\pi^+)^6$	BaBar [10] $3.5 \pm 0.6 \pm 0.2$ Belle [11] $1.76$ <sup>+0.67</sup> <sub>-0.62</sub> <sup>+0.15</sup> <sub>-0.14</sub> CLEO [14] $1.0$ <sup>+5.8</sup> <sub>-1.0</sub>	$2.68 \pm 0.46$ $2.70$ <sup>+0.87</sup> <sub>-0.84</sub>
$\mathcal{B}(B^+ \rightarrow \eta'\rho^+(770))$	BaBar [16] $9.7$ <sup>+1.9</sup> <sub>-1.8</sub> $\pm 1.1$ CLEO [14] $11.2$ <sup>+11.9</sup> <sub>-7.0</sub> Belle [17] $< 5.8$	$9.8 \pm 2.1$ $9.7$ <sup>+2.2</sup> <sub>-2.1</sub>

<sup>1</sup>  $X_{\pi^0\pi^0}^0$  corresponds to a structure observed in Ref. [77], likely arising due to multiple resonances.

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>4</sup> 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. [76].

<sup>5</sup> 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.

<sup>6</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow \phi(1020)\pi^+)$	BaBar [86] < 0.24 Belle [87] < 0.33 LHCb [56] <sup>1,2</sup>	$0.031^{+0.015}_{-0.014}$ $0.032 \pm 0.015$
$\mathcal{B}(B^+ \rightarrow \phi(1020)\rho^+(770))$	BaBar [88] < 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 [78] < 860	< 860
$\mathcal{B}(B^+ \rightarrow a_1(1260)^+\rho^0(770))$	CLEO [89] < 620.0 <sup>3</sup>	< 620
$\mathcal{B}(B^+ \rightarrow a_2(1320)^+\rho^0(770))$	CLEO [89] < 720.0 <sup>3</sup>	< 720
$\mathcal{B}(B^+ \rightarrow b_1(1235)^0\pi^+) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	BaBar [49] $6.7 \pm 1.7 \pm 1.0$	$6.7 \pm 2.0$
$\mathcal{B}(B^+ \rightarrow b_1^+\pi^0)$	BaBar [48] < 3.3	< 3.3
$\mathcal{B}(B^+ \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^0)$	ARGUS [78] < 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 [78] < 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

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

<sup>2</sup> 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.

<sup>3</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow K^+\pi^-)$	Belle [3]	$20.00 \pm 0.34 \pm 0.60$	
	BaBar [90]	$19.1 \pm 0.6 \pm 0.6$	
	Belle II [5]	$18.0 \pm 0.9 \pm 0.9$	$19.5 \pm 0.5$
	CLEO [6]	$18.0^{+2.3+1.2}_{-2.1-0.9}$	$19.6 \pm 0.5$
	CDF [91] <sup>1,2</sup> , [92] <sup>3,4</sup> , [93] <sup>5,6</sup>		
	LHCb [94] <sup>3,4,1</sup> , [95] <sup>5,6</sup>		
$\mathcal{B}(B^0 \rightarrow K^0\pi^0)$	Belle [3]	$9.68 \pm 0.46 \pm 0.50$	
	BaBar [96]	$10.1 \pm 0.6 \pm 0.4$	$10.03 \pm 0.47$
	Belle II [97]	$11.0 \pm 1.2 \pm 1.0$	$9.93 \pm 0.49$
	CLEO [6]	$12.8^{+4.0+1.7}_{-3.3-1.4}$	
$\mathcal{B}(B^0 \rightarrow \eta'K^0)^7$	BaBar [10]	$68.5 \pm 2.2 \pm 3.1$	
	Belle [11]	$58.9^{+3.6}_{-3.5} \pm 4.3$	$65.0 \pm 2.8$
	Belle II [12]	$59.9^{+5.8}_{-5.5} \pm 2.7$	
	CLEO [14]	$89.0^{+18.0}_{-16.0} \pm 9.0$	$66.1^{+4.5}_{-4.4}$
	LHCb [98] <sup>8,9</sup>		
$\mathcal{B}(B^0 \rightarrow \eta'K^*(892)^0)$	Belle [99]	$2.6 \pm 0.7 \pm 0.2$	$2.8 \pm 0.6$
	BaBar [16]	$3.1^{+0.9}_{-0.8} \pm 0.3$	
$\mathcal{B}(B^0 \rightarrow \eta'K_0^*(1430)^0)$	BaBar [16]	$6.3 \pm 1.3 \pm 0.9$ <sup>10</sup>	$6.3 \pm 1.6$
$\mathcal{B}(B^0 \rightarrow \eta'(K\pi)_0^{*0})$	BaBar [16]	$7.4^{+1.5}_{-1.4} \pm 0.6$	$7.4 \pm 1.6$
		none	
$\mathcal{B}(B^0 \rightarrow \eta'K_2^*(1430)^0)$	BaBar [16]	$13.7^{+3.0}_{-2.9} \pm 1.2$	$13.7 \pm 3.2$
			$13.7^{+3.2}_{-3.1}$

<sup>1</sup> 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.

<sup>2</sup> 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.

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

<sup>4</sup> 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.

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

<sup>6</sup> 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.

<sup>7</sup> The PDG uncertainty includes a scale factor.

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

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

<sup>10</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow \eta K^0)$	Belle [18]	$1.27^{+0.33}_{-0.29} \pm 0.08$	$1.23 \pm 0.25$
	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]	$16.5 \pm 1.1 \pm 0.8$	$15.9 \pm 1.0$
	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]	$11.0 \pm 1.6 \pm 1.5$	$11.0 \pm 2.2$ none
$\mathcal{B}(B^0 \rightarrow \eta K_0^*(1430)^0)$	BaBar [19]	$7.8 \pm 1.1 \pm 1.1$ <sup>1</sup>	$7.8 \pm 1.5$ $11.0 \pm 2.2$
$\mathcal{B}(B^0 \rightarrow \eta K_2^*(1430)^0)$	BaBar [19]	$9.6 \pm 1.8 \pm 1.1$	$9.6 \pm 2.1$
$\mathcal{B}(B^0 \rightarrow \omega(782)K^0)$	Belle [23]	$4.5 \pm 0.4 \pm 0.3$	$4.78 \pm 0.43$
	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 [101]	$< 1.9$	$< 1.9$
$\mathcal{B}(B^0 \rightarrow b_1(1235)^- K^+) \times \mathcal{B}(b_1(1235)^- \rightarrow \omega(782)\pi^-)$	BaBar [49]	$7.4 \pm 1.0 \pm 1.0$	$7.4 \pm 1.4$
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 K^*(892)^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	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 [101]	$< 3.1$	$< 3.1$
$\mathcal{B}(B^0 \rightarrow K_S^0 X^0(\text{Familon}))$	CLEO [72]	$< 53$	$< 53$
$\mathcal{B}(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$2.2 \pm 0.6 \pm 0.2$	$2.04 \pm 0.49$
	Belle [100]	$1.8 \pm 0.7 \pm 0.3$	
$\mathcal{B}(B^0 \rightarrow \omega(782)(K\pi)_0^{*0})$	BaBar [26]	$18.4 \pm 1.8 \pm 1.7$	$18.4 \pm 2.5$
$\mathcal{B}(B^0 \rightarrow \omega(782)K_0^*(1430)^0)$	BaBar [26]	$16.0 \pm 1.6 \pm 3.0$	$16.0 \pm 3.4$
$\mathcal{B}(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$10.1 \pm 2.0 \pm 1.1$	$10.1 \pm 2.3$
$\mathcal{B}(B^0 \rightarrow \omega(782)K^+\pi^-(\text{NR}))$	Belle [100]	$5.1 \pm 0.7 \pm 0.7$ <sup>2</sup>	$5.1 \pm 1.0$

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

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

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\pi^0)$	BaBar [102]	$38.5 \pm 1.0 \pm 3.9$ <sup>1</sup>	$37.9 \pm 2.7$ $37.8 \pm 3.2$
	Belle II [33]	$38.1 \pm 3.5 \pm 3.9$	
	Belle [103]	$36.6^{+4.2}_{-4.1} \pm 3.0$	
$\mathcal{B}(B^0 \rightarrow \rho^-(770)K^+)$	BaBar [102]	$6.6 \pm 0.5 \pm 0.8$ <sup>1</sup>	$7.01 \pm 0.92$
	Belle [103]	$15.1^{+3.4+2.4}_{-3.3-2.6}$ <sup>2</sup>	
$\mathcal{B}(B^0 \rightarrow \rho(1450)^-K^+)$	BaBar [102]	$2.4 \pm 1.0 \pm 0.6$ <sup>1</sup>	$2.4 \pm 1.2$
$\mathcal{B}(B^0 \rightarrow \rho(1700)^-K^+)$	BaBar [102]	$0.6 \pm 0.6 \pm 0.4$ <sup>1</sup>	$0.6 \pm 0.7$
$\mathcal{B}(B^0 \rightarrow K^+\pi^-\pi^0(\text{NR}))$	BaBar [102]	$2.8 \pm 0.5 \pm 0.4$ <sup>3</sup>	$2.8 \pm 0.6$
	Belle [103]	$< 9.4$	
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-) \times \mathcal{B}((K\pi)_0^{*+} \rightarrow K^+\pi^0)$	BaBar [102]	$34.2 \pm 2.4 \pm 4.1$ <sup>1</sup>	$34.2 \pm 4.8$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\pi^0) \times \mathcal{B}((K\pi)_0^{*0} \rightarrow K^+\pi^-)$	BaBar [102]	$8.6 \pm 1.1 \pm 1.3$ <sup>1</sup>	$8.6 \pm 1.7$
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0\pi^0)$	BaBar [104]	$< 4.0$ <sup>1</sup>	$< 4.0$
$\mathcal{B}(B^0 \rightarrow K^*(1680)^0\pi^0)$	BaBar [104]	$< 7.5$ <sup>1</sup>	$< 7.5$
$\mathcal{B}(B^0 \rightarrow K_x^{*0}\pi^0)$	Belle [103]	$6.1^{+1.6+0.5}_{-1.5-0.6}$ <sup>4</sup>	$6.1 \pm 1.6$
			$6.1^{+1.7}_{-1.6}$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> The nonresonant amplitude is taken to be constant across the Dalitz plane.

<sup>4</sup>  $1.1 < m_{K\pi} < 1.6$  GeV/ $c^2$ .

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)^{1,2}$	BaBar [105]	$50.15 \pm 1.47 \pm 1.76$ <sup>3,4</sup>
	Belle [106]	$47.5 \pm 2.4 \pm 3.7$ <sup>3</sup>
	CLEO [41]	$50.0^{+10.0}_{-9.0} \pm 7.0$
	LHCb [107] <sup>4,5,6,7,8</sup> , [108] <sup>9</sup> , [109] <sup>10,11</sup> , [109] <sup>10,12</sup> , [109] <sup>10,13</sup> , [109] <sup>10,14</sup> , [109] <sup>10,15</sup>	
		$49.7 \pm 1.8$
$\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-(\text{NR}))^{16}$	LHCb [110]	$12.60 \pm 0.67 \pm 3.05$ <sup>3,17,4,18</sup>
	BaBar [105]	$11.07^{+2.51}_{-0.99} \pm 0.90$ <sup>3,19,4</sup>
	Belle [106]	$19.9 \pm 2.5^{+1.7}_{-2.0}$ <sup>3,20</sup>
		$14.0 \pm 1.7$ <sub>p=1.6‰</sub>
$\mathcal{B}(B^0 \rightarrow \rho^0(770)K^0)^{16}$	BaBar [105]	$4.36^{+0.71}_{-0.62} \pm 0.31$ <sup>3,4</sup>
	LHCb [110]	$1.97^{+0.57}_{-0.83} \pm 0.42$ <sup>3,4,18</sup>
	Belle [106]	$6.1 \pm 1.0^{+1.1}_{-1.2}$ <sup>3</sup>
		$3.45 \pm 0.48$ <sub>p=1.6‰</sub>
		$3.41^{+1.08}_{-1.14}$

<sup>1</sup> The PDG average is a result of a fit including input from other measurements.

<sup>2</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>4</sup> Multiple systematic uncertainties are added in quadrature.

<sup>5</sup> 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.

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

<sup>7</sup> 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.

<sup>8</sup> 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.

<sup>9</sup> 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.

<sup>10</sup> Regions corresponding to  $D$ ,  $A_c^+$  and charmonium resonances are vetoed in this analysis.

<sup>11</sup> 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.

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

<sup>13</sup> 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.

<sup>14</sup> 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.

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

<sup>16</sup> The PDG uncertainty includes a scale factor.

<sup>17</sup> The nonresonant component is modelled as a flat contribution over the Dalitz plane.

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

<sup>19</sup> 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.

<sup>20</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)$	BaBar [105]	$8.29^{+0.92}_{-0.81} \pm 0.82$ <sup>1,2</sup>
	BaBar [102]	$8.0 \pm 1.1 \pm 0.8$ <sup>3</sup>
	Belle [106]	$8.4 \pm 1.1^{+1.0}_{-0.9}$ <sup>1</sup>
	CLEO [41]	$16.0^{+6.0}_{-5.0} \pm 2.0$
	LHCb [111] <sup>4,5</sup> , [110] <sup>1,2,6</sup>	
		$7.64 \pm 0.44$ p=1.6%
		$7.50 \pm 0.44$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^+\pi^-)$ <sup>7</sup>	BaBar [105]	$29.9^{+2.3}_{-1.7} \pm 3.6$ <sup>1,2</sup>
	Belle [106]	$49.7 \pm 3.8^{+6.8}_{-8.2}$ <sup>1</sup>
		$33.6^{+3.8}_{-4.0}$
		$33.5^{+7.4}_{-7.2}$
$\mathcal{B}(B^0 \rightarrow K_x^{*+}\pi^-)$	Belle [103]	$5.1 \pm 1.5^{+0.6}_{-0.7}$ <sup>8</sup>
		$5.1 \pm 1.6$ $5.1^{+1.6}_{-1.7}$
$\mathcal{B}(B^0 \rightarrow K^*(1410)^+\pi^-) \times \mathcal{B}(K^*(1410)^+ \rightarrow K^0\pi^+)$	Belle [106]	$< 3.8$ <sup>1</sup>
		$< 3.8$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-) \times \mathcal{B}((K\pi)_0^{*+} \rightarrow K^0\pi^+)$	LHCb [110]	$16.95 \pm 0.73 \pm 1.12$ <sup>1,2,9</sup>
	BaBar [105]	$22.7^{+1.7}_{-1.3} \pm 1.3$ <sup>1,2</sup>
		$18.6 \pm 1.1$ p=1.6%
		$16.2 \pm 1.3$
$\mathcal{B}(B^0 \rightarrow f_0(980)K^0) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$ <sup>7</sup>	LHCb [110]	$9.64 \pm 0.41 \pm 0.79$ <sup>1,2,9</sup>
	BaBar [105]	$6.92 \pm 0.77 \pm 0.56$ <sup>1,2</sup>
	Belle [106]	$7.6 \pm 1.7^{+0.9}_{-1.3}$ <sup>1</sup>
		$8.38 \pm 0.61$ p=1.6%
		$8.15^{+0.78}_{-0.79}$
$\mathcal{B}(B^0 \rightarrow f_0(500)K^0)$	LHCb [110]	$0.166^{+0.207}_{-0.041} \pm 0.155$ <sup>1,2,9</sup>
		$0.17^{+0.26}_{-0.16}$ p=1.6%
		$0.16^{+0.25}_{-0.16}$
$\mathcal{B}(B^0 \rightarrow f_0(1500)K^0) \times \mathcal{B}(f_0(1500) \rightarrow \pi^+\pi^-)$	LHCb [110]	$1.348 \pm 0.280 \pm 0.734$ <sup>1,2,9</sup>
		$1.35 \pm 0.79$ p=1.6%
		$1.29 \pm 0.75$
$\mathcal{B}(B^0 \rightarrow f_2(1270)K^0)$	BaBar [105]	$2.71^{+0.99}_{-0.83} \pm 0.87$ <sup>1,2</sup>
	Belle [106]	$< 2.5$ <sup>1,10</sup>
		$2.7 \pm 1.3$
		$2.7^{+1.3}_{-1.2}$
$\mathcal{B}(B^0 \rightarrow f_x(1300)^0K^0) \times \mathcal{B}(f_x(1300)^0 \rightarrow \pi^+\pi^-)$	BaBar [105]	$1.81^{+0.55}_{-0.45} \pm 0.48$ <sup>1,2</sup>
		$1.81^{+0.73}_{-0.66}$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

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

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

<sup>6</sup> Measurement of  $(\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)2/3)/\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)$  used in our fit.

<sup>7</sup> The PDG uncertainty includes a scale factor.

<sup>8</sup>  $1.1 < m_{K\pi} < 1.6$  GeV/ $c^2$ .

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

<sup>10</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^0)$	BaBar [102] $3.3 \pm 0.5 \pm 0.4$ <sup>1</sup> Belle [103] $< 3.5$	$3.3 \pm 0.6$
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^+ \pi^-)$	Belle [106] $< 6.3$ <sup>2</sup> BaBar [104] $< 16.2$ <sup>1</sup> LHCb [110] <sup>2,3,4</sup>	$3.82 \pm 0.36$ $3.65^{+0.34}_{-0.33}$
$\mathcal{B}(B^0 \rightarrow K^*(1680)^+ \pi^-)$	Belle [106] $< 10.1$ <sup>2</sup> BaBar [104] $< 25.0$ <sup>1</sup> LHCb [110] <sup>2,3,5</sup>	$14.7 \pm 1.4$ $14.1 \pm 1.0$
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ \pi^-)$	DELPHI [112] $< 230$	$< 230$
$\mathcal{B}(B^0 \rightarrow \rho^0(770) K^+ \pi^-)$	Belle [113] $2.8 \pm 0.5 \pm 0.5$ <sup>6</sup>	$2.8 \pm 0.7$
$\mathcal{B}(B^0 \rightarrow f_0(980) K^+ \pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	Belle [113] $1.4 \pm 0.4^{+0.3}_{-0.4}$ <sup>6</sup>	$1.4^{+0.5}_{-0.6}$
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ \pi^- (\text{NR}))$	Belle [113] $< 2.1$ <sup>6,7</sup>	$< 2.1$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^+ \pi^-)$	BaBar [114] $54.5 \pm 2.9 \pm 4.3$	$54.5 \pm 5.2$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \rho^0(770))^8$	BaBar [115] $5.1 \pm 0.6^{+0.6}_{-0.8}$ Belle [113] $2.1^{+0.8+0.9}_{-0.7-0.5}$	$3.88 \pm 0.77$ $3.88^{+1.33}_{-1.25}$
$\mathcal{B}(B^0 \rightarrow f_0(980) K_0^*(892)^0) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)^8$	Belle [113] $1.4^{+0.6+0.6}_{-0.5-0.4}$ BaBar [115] $5.7 \pm 0.6 \pm 0.4$	$3.90 \pm 0.55$ $3.90^{+2.12}_{-1.85}$

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

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

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

<sup>4</sup> 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.

<sup>5</sup> 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.

<sup>6</sup>  $0.75 < M(K\pi) < 1.20$  GeV/ $c^2$ .

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

<sup>8</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K_1(1270)^+\pi^-)$	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] $16.3 \pm 2.9 \pm 2.3$	$16.3 \pm 3.7$
$\mathcal{B}(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [115] $10.3 \pm 2.3 \pm 1.3$	$10.3 \pm 2.6$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*+}\rho^-(770)) \times \mathcal{B}((K\pi)_0^* \rightarrow K\pi)$	BaBar [115] < 48	< 48 none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^+\rho^-(770))$	BaBar [115] $28 \pm 10 \pm 6$ <sup>1</sup>	$28 \pm 12$
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0\rho^0(770))$	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 [115] $31 \pm 4 \pm 3$	$31.0 \pm 5.0$ none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\rho^0(770))$	BaBar [115] $27 \pm 4 \pm 4$ <sup>1</sup>	$27.0 \pm 5.4$ $27.0 \pm 5.7$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi) \times \mathcal{B}((K\pi)_0^* \rightarrow K\pi)$	BaBar [115] $3.1 \pm 0.8 \pm 0.7$	$3.1 \pm 1.1$ none
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	BaBar [115] $2.7 \pm 0.7 \pm 0.6$ <sup>1</sup>	$2.7 \pm 0.9$
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi\pi)$	BaBar [115] $8.6 \pm 1.7 \pm 1.0$	$8.6 \pm 2.0$
$\mathcal{B}(B^0 \rightarrow K^+K^-)$	LHCb [95] $0.0774 \pm 0.0126 \pm 0.0084$ <sup>2</sup> Belle [3] $0.10 \pm 0.08 \pm 0.04$ CDF [93] $0.23 \pm 0.10 \pm 0.10$ <sup>2</sup> BaBar [90] < 0.5	$0.080 \pm 0.015$ $0.078 \pm 0.015$
$\mathcal{B}(B^0 \rightarrow K^0\bar{K}^0)$	Belle [3] $1.26 \pm 0.19 \pm 0.05$ BaBar [4] $1.08 \pm 0.28 \pm 0.11$	$1.21 \pm 0.16$
$\mathcal{B}(B^0 \rightarrow K^0K^+\pi^- + \text{c.c.})$	LHCb [109] $6.11 \pm 0.45 \pm 0.78$ <sup>3,4</sup> Belle [116] $7.20 \pm 0.66 \pm 0.30$ BaBar [117] $6.4 \pm 1.0 \pm 0.6$	$6.7 \pm 0.5$
$\mathcal{B}(B^0 \rightarrow K^*(892)^-K^+ + \text{c.c.})$	LHCb [111] < $0.38$ <sup>5</sup>	< 0.4
$\mathcal{B}(B^0 \rightarrow K^*(892)^0\bar{K}^0 + \text{c.c.})$ <sup>6</sup>	LHCb [108] < $1.0$ <sup>4</sup> BaBar [118] < 1.9	< 0.99 < 0.96

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>3</sup> Regions corresponding to  $D$ ,  $A_c^+$  and charmonium resonances are vetoed in this analysis.

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

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

<sup>6</sup>  $0.75 < M(K\pi) < 1.20$  GeV/ $c^2$ .

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^+K^-\pi^0)$	Belle [119] $2.17 \pm 0.60 \pm 0.24$	$2.17 \pm 0.65$
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\pi^0)$	BaBar [120] $< 0.9$	$< 0.9$
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\eta)$	BaBar [120] $< 1.0$	$< 1.0$
$\mathcal{B}(B^0 \rightarrow K_S^0K_S^0\eta')$	BaBar [120] $< 2.0$	$< 2.0$
$\mathcal{B}(B^0 \rightarrow K^0K^+K^-)$	LHCb [109] $27.29 \pm 0.89 \pm 1.90$ <sup>1,2</sup>	$26.8 \pm 1.0$ $26.8 \pm 1.1$
	BaBar [22] $26.5 \pm 0.9 \pm 0.8$ <sup>3,4</sup>	
	Belle [38] $28.3 \pm 3.3 \pm 4.0$	
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)$	BaBar [22] $7.1 \pm 0.6$ <sup>+0.4</sup> <sub>-0.3</sub> <sup>3</sup>	$7.25 \pm 0.60$ $7.32$ <sup>+0.69</sup> <sub>-0.63</sub>
	Belle II [61] $5.9 \pm 1.8 \pm 0.7$	
	Belle [65] $9.0$ <sup>+2.2</sup> <sub>-1.8</sub> $\pm 0.7$	
	LHCb [121] <sup>5</sup> , [122] <sup>6,7</sup>	
$\mathcal{B}(B^0 \rightarrow f_0(980)K^0) \times \mathcal{B}(f_0(980) \rightarrow K^+K^-)$	BaBar [22] $7.0$ <sup>+2.6</sup> <sub>-1.8</sub> $\pm 2.4$ <sup>3</sup>	$7.0$ <sup>+3.5</sup> <sub>-3.0</sub>
	BaBar [22] $13.3$ <sup>+5.8</sup> <sub>-4.4</sub> $\pm 3.2$ <sup>3</sup>	$13.3$ <sup>+6.6</sup> <sub>-5.4</sub>
$\mathcal{B}(B^0 \rightarrow f_2'(1525)K^0)$	BaBar [22] $0.29$ <sup>+0.27</sup> <sub>-0.18</sub> $\pm 0.36$ <sup>3</sup>	$0.29$ <sup>+0.45</sup> <sub>-0.40</sub>
$\mathcal{B}(B^0 \rightarrow f_0(1710)K^0) \times \mathcal{B}(f_0(1710) \rightarrow K^+K^-)$	BaBar [22] $4.4 \pm 0.7 \pm 0.5$ <sup>3</sup>	$4.4 \pm 0.9$
	BaBar [22] $33 \pm 5 \pm 9$ <sup>8</sup>	$33 \pm 10$

<sup>1</sup> Regions corresponding to  $D$ ,  $\Lambda_c^+$  and charmonium resonances are vetoed in this analysis.

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

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

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

<sup>5</sup> 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.

<sup>6</sup> Multiple systematic uncertainties are added in quadrature.

<sup>7</sup> 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.

<sup>8</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 K_S^0)^1$	BaBar [123]	$6.19 \pm 0.48 \pm 0.19$ <sup>2,3</sup>	$6.04 \pm 0.50$
	Belle [38]	$4.2^{+1.6}_{-1.3} \pm 0.8$	$6.04^{+0.53}_{-0.52}$
$\mathcal{B}(B^0 \rightarrow f_0(980)K_S^0) \times \mathcal{B}(f_0(980) \rightarrow K_S^0 K_S^0)$	BaBar [123]	$2.7^{+1.3}_{-1.2} \pm 1.3$ <sup>2,3</sup>	$2.7 \pm 1.8$
	BaBar [123]	$0.50^{+0.46}_{-0.24} \pm 0.11$ <sup>2,3</sup>	$0.50^{+0.47}_{-0.26}$
$\mathcal{B}(B^0 \rightarrow f_2(2010)K_S^0) \times \mathcal{B}(f_2(2010) \rightarrow K_S^0 K_S^0)$	BaBar [123]	$0.54^{+0.21}_{-0.20} \pm 0.52$ <sup>2,3</sup>	$0.54 \pm 0.56$
	BaBar [123]	$13.3^{+2.2}_{-2.3} \pm 0.6$ <sup>4,3</sup>	$13.3 \pm 2.3$ $13.3^{+3.1}_{-3.2}$
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 K_S^0(\text{NR}))$	BaBar [124]	$< 16$ <sup>5</sup>	$< 16$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 K^+ K^-)$	BaBar [114]	$27.5 \pm 1.3 \pm 2.2$	$27.5 \pm 2.6$
	BaBar [125]	$9.7 \pm 0.5 \pm 0.5$	$10.11 \pm 0.48$ $10.04 \pm 0.52$
Belle [126]	$10.4 \pm 0.5 \pm 0.6$		
Belle II [61]	$11.0 \pm 2.1 \pm 1.1$		
CLEO [63]	$11.5^{+4.5+1.8}_{-3.7-1.7}$		
	LHCb [127] <sup>3,6</sup> , [128] <sup>3,7</sup> , [129] <sup>3,8</sup> , [130] <sup>9</sup>		
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^+ K^- (\text{NR}))$	Belle [131]	$< 71.7$ <sup>10</sup>	$< 72$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \pi^+ K^-)$	BaBar [114]	$4.6 \pm 1.1 \pm 0.8$	$4.5 \pm 1.3$
	Belle [131]	$2.11^{+5.63+4.85}_{-5.26-4.75}$ <sup>10</sup>	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)^1$	LHCb [132]	$0.834 \pm 0.063 \pm 0.158$ <sup>3,11</sup>	$0.83 \pm 0.16$
	Belle [131]	$0.26^{+0.33+0.10}_{-0.29-0.08}$	$0.83^{+0.25}_{-0.23}$
	BaBar [133]	$1.28^{+0.35}_{-0.30} \pm 0.11$	

<sup>1</sup> The PDG uncertainty includes a scale factor.

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

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

<sup>4</sup> The nonresonant amplitude is modelled using an exponential function.

<sup>5</sup>  $0.75 < M(K\pi) < 1.20$  GeV/ $c^2$ .

<sup>6</sup> 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.

<sup>7</sup> 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.

<sup>8</sup> 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.

<sup>9</sup> 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.

<sup>10</sup>  $0.70 < M(K\pi) < 1.70$  GeV/ $c^2$ .

<sup>11</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^+\pi^-K^+\pi^-(\text{NR}))$	Belle [131] $< 6.0$ <sup>1</sup>	$< 6.0$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0K^+\pi^-)$	BaBar [114] $< 2.2$ Belle [131] $< 7.6$ <sup>1</sup>	$< 2.2$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0K^*(892)^0)$	Belle [131] $< 0.20$ BaBar [133] $< 0.41$	$< 0.2$
$\mathcal{B}(B^0 \rightarrow K^*(892)^+K^*(892)^-)$	BaBar [134] $< 2.0$	$< 2.0$
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0\phi(1020))$	ARGUS [47] $< 5000$	$< 5000$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\phi(1020))$	Belle [126] $4.3 \pm 0.4 \pm 0.4$ BaBar [125] $4.3 \pm 0.6 \pm 0.4$	$4.30 \pm 0.45$
$\mathcal{B}(B^0 \rightarrow (K\pi)_0^{*0}\phi), 1.60 < M_{K\pi} < 2.15 \text{ GeV}/c^2$ .	BaBar [135] $< 1.7$	$< 1.7$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\pi^+K^-)$	Belle [131] $< 31.8$ <sup>1</sup>	$< 32$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\bar{K}^*(892)^0)$	Belle [131] $< 3.3$	$< 3.3$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0\bar{K}_0^*(1430)^0)$	Belle [131] $< 8.4$	$< 8.4$
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_0^*(1430)^0)$	BaBar [125] $3.9 \pm 0.5 \pm 0.6$	$3.90 \pm 0.78$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0K^*(892)^0)$	Belle [131] $< 1.7$	$< 1.7$
$\mathcal{B}(B^0 \rightarrow K_0^*(1430)^0K_0^*(1430)^0)$	Belle [131] $< 4.7$	$< 4.7$
$\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(1680)^0)$	BaBar [135] $< 3.5$	$< 3.5$
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_3^*(1780)^0)$	BaBar [135] $< 2.7$	$< 2.7$
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_4^*(2045)^0)$	BaBar [135] $< 15.3$	$< 15$
$\mathcal{B}(B^0 \rightarrow \rho^0(770)K_2^*(1430)^0)$	ARGUS [47] $< 1100$	$< 1100$
$\mathcal{B}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)^2$	Belle [126] $5.5_{-0.7}^{+0.9} \pm 1.0$ BaBar [125] $7.5 \pm 0.9 \pm 0.5$	$6.8 \pm 0.8$ $6.8_{-0.9}^{+1.0}$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\phi(1020)K^0)$	BaBar [68] $4.5 \pm 0.8 \pm 0.3$ <sup>3</sup>	$4.5 \pm 0.9$ $3.7 \pm 0.7$
$\mathcal{B}(B^0 \rightarrow \eta'\eta'K^0)$	BaBar [70] $< 31.0$	$< 31$

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

<sup>2</sup> The PDG uncertainty includes a scale factor.

<sup>3</sup> Measured in the  $\phi\phi$  invariant mass range below the  $\eta_c$  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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-)$	LHCb [94]	$5.10 \pm 0.18 \pm 0.35$ <sup>1</sup>	$5.15 \pm 0.19$ $5.12 \pm 0.19$
	Belle [3]	$5.04 \pm 0.21 \pm 0.18$	
	CDF [92]	$5.04 \pm 0.33 \pm 0.33$ <sup>1</sup>	
	BaBar [90]	$5.5 \pm 0.4 \pm 0.3$	
	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 [136]	$1.31 \pm 0.19 \pm 0.19$	$1.51 \pm 0.16$ $1.59 \pm 0.26$
	BaBar [96]	$1.83 \pm 0.21 \pm 0.13$	
	Belle II [137]	$1.27 \pm 0.25 \pm 0.17$	
$\mathcal{B}(B^0 \rightarrow \eta\pi^0)$	Belle [138]	$0.41^{+0.17+0.05}_{-0.15-0.07}$	$0.41 \pm 0.17$ $0.41^{+0.18}_{-0.17}$
	BaBar [85]	$< 1.5$	
	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 [85]	$0.9 \pm 0.4 \pm 0.1$	$1.2 \pm 0.4$ $1.2 \pm 0.6$
	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 [85]	$< 1.2$	$< 1.2$
	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 [101]	$< 1.5$	$< 1.5$
	Belle [20]	$< 1.9$	
$\mathcal{B}(B^0 \rightarrow f_0(980)\eta) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [101]	$< 0.4$	$< 0.4$
$\mathcal{B}(B^0 \rightarrow \omega(782)\eta)$	BaBar [10]	$0.94^{+0.35}_{-0.30} \pm 0.09$	$0.94^{+0.36}_{-0.31}$

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

<sup>2</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow \omega(782)\eta')$	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 [139] $1.2 \pm 0.3^{+0.3}_{-0.2}$	$1.2 \pm 0.4$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\pi^0)$	Belle [87] $< 0.15$ BaBar [86] $< 0.28$	$< 0.15$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\eta)$	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 [140] $0.182 \pm 0.025 \pm 0.043$ <sup>1,2</sup>	$0.182 \pm 0.050$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\rho^0(770))$	BaBar [88] $< 0.33$	$< 0.33$
$\mathcal{B}(B^0 \rightarrow f_0(980)\phi(1020)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [88] $< 0.38$	$< 0.38$
$\mathcal{B}(B^0 \rightarrow \omega(782)\phi(1020))$	BaBar [139] $< 0.7$	$< 0.7$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [141] $< 0.027$ BaBar [88] $< 0.2$	$< 0.027$
$\mathcal{B}(B^0 \rightarrow a_0(980)^+\pi^- + \text{c.c.}) \times \mathcal{B}(a_0(980)^+ \rightarrow \eta\pi^+)$	BaBar [101] $< 3.1$	$< 3.1$
$\mathcal{B}(B^0 \rightarrow a_0(1450)^+\pi^- + \text{c.c.}) \times \mathcal{B}(a_0(1450)^+ \rightarrow \eta\pi^+)$	BaBar [101] $< 2.3$	$< 2.3$
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^0)$	ARGUS [78] $< 720$	$< 720$
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\pi^0)$	Belle [142] $3.0 \pm 0.5 \pm 0.7$ <sup>3</sup> BaBar [143] $1.4 \pm 0.6 \pm 0.3$ CLEO [25] $1.6^{+2.0}_{-1.4} \pm 0.8$	$2.0 \pm 0.5$
$\mathcal{B}(B^0 \rightarrow \rho^+(770)\pi^- + \text{c.c.})$	Belle [142] $22.6 \pm 1.1 \pm 4.4$ <sup>3</sup> BaBar [144] $22.6 \pm 1.8 \pm 2.2$ CLEO [25] $27.6^{+8.4}_{-7.4} \pm 4.2$	$23.0 \pm 2.3$
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^+\pi^-)$	Belle [145] $< 11.2$ <sup>4</sup> BaBar [146] $< 23.1$ <sup>5</sup>	$< 11$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

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

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

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\pi^+\pi^-)$	BaBar [146] $< 8.8$ <sup>1</sup> Belle [145] $< 12.0$ <sup>2</sup>	$< 8.8$
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\rho^0(770))$	LHCb [130] $0.95 \pm 0.17 \pm 0.10$ <sup>3</sup> Belle [145] $1.02 \pm 0.30 \pm 0.15$ BaBar [146] $0.92 \pm 0.32 \pm 0.14$	$0.96 \pm 0.15$
$\mathcal{B}(B^0 \rightarrow f_0(980)\pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	Belle [145] $< 3.0$ <sup>2</sup>	$< 3.0$
$\mathcal{B}(B^0 \rightarrow f_0(980)\rho^0(770)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	Belle [145] $0.78 \pm 0.22 \pm 0.11$ BaBar [146] $< 0.40$	$0.78 \pm 0.25$
$\mathcal{B}(B^0 \rightarrow f_0(980)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	BaBar [146] $< 0.19$ Belle [145] $< 0.2$	$< 0.19$
$\mathcal{B}(B^0 \rightarrow f_0(980)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-) \times \mathcal{B}(f_0(980) \rightarrow K^+K^-)$	BaBar [88] $< 0.23$	$< 0.23$
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+\pi^- + \text{c.c.})$ <sup>4</sup>	Belle [147] $22.2 \pm 2.0 \pm 2.8$ BaBar [148] $33.2 \pm 3.8 \pm 3.0$	$25.9 \pm 2.8$ $25.9 \pm 5.2$
$\mathcal{B}(B^0 \rightarrow a_2(1320)^+\pi^- + \text{c.c.})$	Belle [147] $< 6.3$	$< 6.3$
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\pi^0\pi^0)$	ARGUS [78] $< 3100$	$< 3100$
$\mathcal{B}(B^0 \rightarrow \rho^+(770)\rho^-(770))$	Belle [149] $28.3 \pm 1.5 \pm 1.5$ BaBar [150] $25.5 \pm 2.1$ <sup>+3.6</sup> <sub>-3.9</sub> Belle II [151] $26.7 \pm 2.8 \pm 2.8$	$27.5 \pm 1.7$ $27.7 \pm 1.9$
$\mathcal{B}(B^0 \rightarrow a_1(1260)^0\pi^0)$	ARGUS [78] $< 1100$	$< 1100$
$\mathcal{B}(B^0 \rightarrow \omega(782)\pi^0)$	BaBar [85] $< 0.5$ Belle [84] $< 2.0$	$< 0.5$
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^+\pi^-\pi^-\pi^0)$	ARGUS [78] $< 9000$	$< 9000$
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+\rho^-(770) + \text{c.c.})$	BaBar [152] $< 61.0$	$< 61$
$\mathcal{B}(B^0 \rightarrow a_1(1260)^0\rho^0(770))$	ARGUS [78] $< 2400$	$< 2400$

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

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

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

<sup>4</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow b_1(1235)^+ \pi^- + \text{c.c.}) \times \mathcal{B}(b_1(1235)^+ \rightarrow \omega(782)\pi^+)$	BaBar [49] $10.9 \pm 1.2 \pm 0.9$	$10.9 \pm 1.5$
$\mathcal{B}(B^0 \rightarrow b_1(1235)^0 \pi^0) \times \mathcal{B}(b_1(1235)^0 \rightarrow \omega(782)\pi^0)$	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 [78] $< 3000$	$< 3000$
$\mathcal{B}(B^0 \rightarrow a_1(1260)^+ a_1(1260)^-) \times \mathcal{B}(a_1(1260)^+ \rightarrow \pi^+ \pi^+ \pi^-) \times \mathcal{B}(a_1(1260)^- \rightarrow \pi^- \pi^- \pi^+)$	BaBar [153] $11.8 \pm 2.6 \pm 1.6$	$11.8 \pm 3.1$
$\mathcal{B}(B^0 \rightarrow \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- \pi^0)$	ARGUS [78] $< 11000$	$< 11000$

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

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 [95] CDF [93]	$3.98 \pm 0.65 \pm 0.42$ $12 \pm 5 \pm 5$	$4.07 \pm 0.77$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^+K^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^*(892)^+\pi^-)}$ $[10^{-2}]$	LHCb [111]	$< 5$	$< 5.0$
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K_S^0 \pi^+ \pi^-)}$ $[10^{-2}]$	LHCb [108]	$< 2$	$< 2.0$
$\frac{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K^+ \pi^-)}$	LHCb [94] CDF [92]	$0.262 \pm 0.009 \pm 0.017$ $0.259 \pm 0.017 \pm 0.016$	$0.261 \pm 0.015$
$\frac{\mathcal{B}(B^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [109]	$0.123 \pm 0.009 \pm 0.015$ <sup>1</sup>	$0.123 \pm 0.017$
$\frac{\mathcal{B}(B^0 \rightarrow K^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [109]	$0.549 \pm 0.018 \pm 0.033$ <sup>1</sup>	$0.549 \pm 0.038$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}{\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}$ $[10^{-2}]$	LHCb [132]	$7.58 \pm 0.57 \pm 0.30$ <sup>2</sup>	$7.58 \pm 0.64$
$\frac{f_s}{f_d} \frac{\mathcal{B}(B^0 \rightarrow K^+ K^-)}{\mathcal{B}(B_s^0 \rightarrow K^+ K^-)}$ $[10^{-2}]$	LHCb [94]	$1.8_{-0.7}^{+0.8} \pm 0.9$	$1.8 \pm 1.2$
$\frac{\mathcal{B}(B^0 \rightarrow \rho^0(770)\rho^0(770))}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$ $[10^{-2}]$	LHCb [130]	$9.4 \pm 1.7 \pm 0.9$	$9.4 \pm 1.9$
$\frac{\mathcal{B}(B^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B_s^0 \rightarrow K^0 \bar{K}^0)}$ $[10^{-2}]$	LHCb [122]	$7.5 \pm 3.1 \pm 0.6$ <sup>2</sup>	$7.5 \pm 3.2$
$\frac{\mathcal{B}(B^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)}$	LHCb [122]	$0.17 \pm 0.08 \pm 0.02$	$0.17 \pm 0.08$
$\frac{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^- \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(K^{*0} \rightarrow K^+ \pi^-)}$ $[10^{-4}]$	LHCb [154]	$4.1 \pm 1.0 \pm 0.3$ <sup>3,4</sup>	$4.1 \pm 1.0$

<sup>1</sup> Regions corresponding to  $D$ ,  $\Lambda_c^+$  and charmonium resonances are vetoed in this analysis.

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> The mass windows corresponding to  $\phi$  and charmonium resonances decaying to  $\mu\mu$  are vetoed.

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

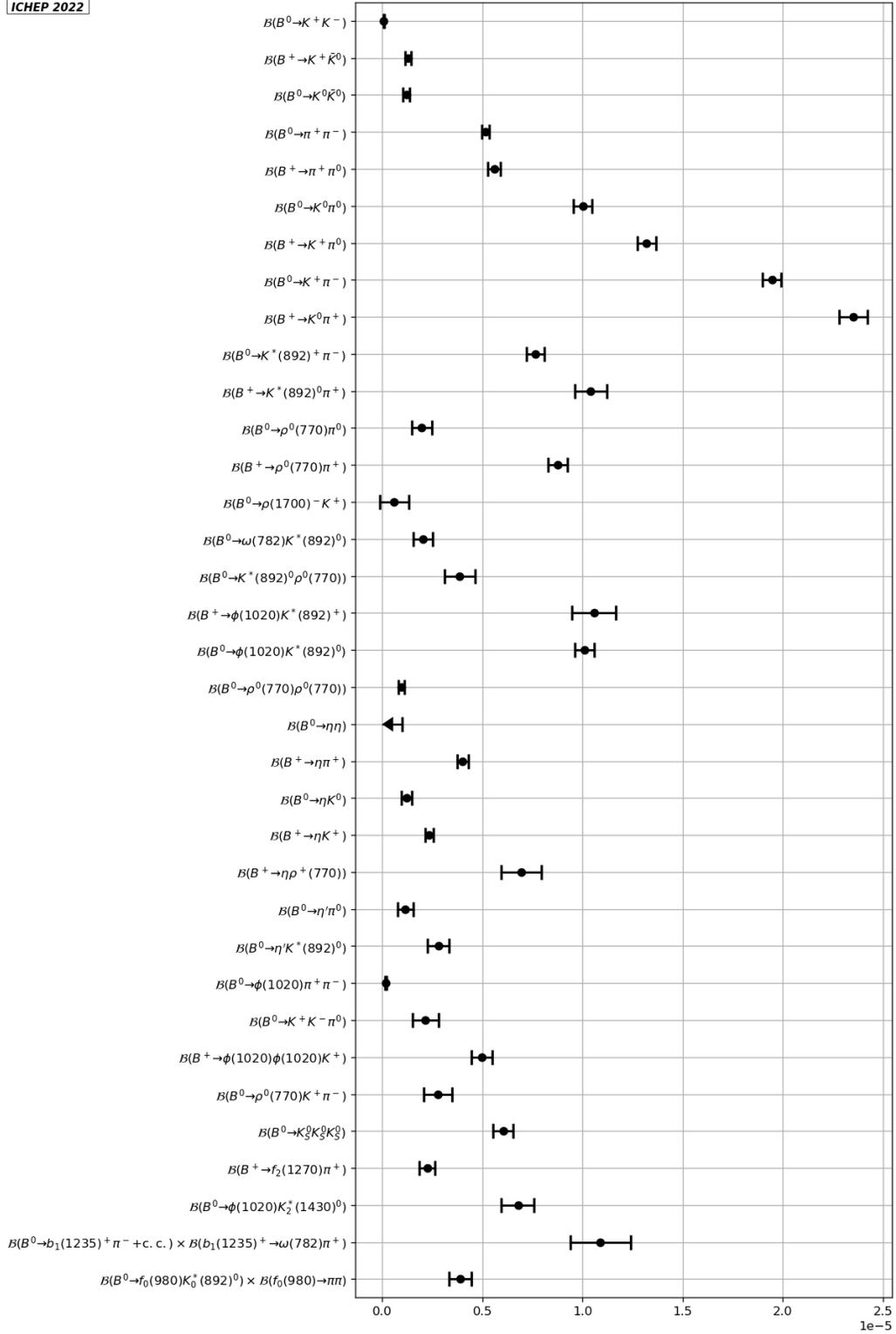


Figure 1: A selection of high-precision charmless mesonic  $B$  meson branching fraction measurements.

## 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+)$	Belle [155]	$1.60^{+0.22}_{-0.19} \pm 0.12$ <sup>1</sup>	$1.62 \pm 0.21$
	BaBar [156]	$1.69 \pm 0.29 \pm 0.26$ <sup>2</sup>	$1.62^{+0.21}_{-0.19}$
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [157] <sup>3</sup>	$1.00 \pm 0.11$ 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 [158]	$4.58 \pm 1.17 \pm 0.67$ <sup>4</sup>	$4.6 \pm 1.3$
$\mathcal{B}(B^+ \rightarrow p\bar{p}\pi^+\pi^+\pi^-)$	ARGUS [159]	$< 520$	$< 520$
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+)$ <sup>5</sup>	Belle [155]	$5.54^{+0.27}_{-0.25} \pm 0.36$ <sup>1</sup>	$5.9 \pm 0.4$
	BaBar [160]	$6.7 \pm 0.5 \pm 0.4$ <sup>2</sup>	$5.9 \pm 0.5$
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [161] <sup>6</sup>	$4.37^{+0.30}_{-0.29}$ none	
$\mathcal{B}(B^+ \rightarrow \Theta^{++}(1710)\bar{p}) \times \mathcal{B}(\Theta^{++}(1710) \rightarrow pK^+)$ <sup>7</sup>	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]	$< 0.41$	$< 0.41$
	BaBar [160]	$< 1.5$	$0.305^{+0.084}_{-0.081}$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}(1520))$	LHCb [157] <sup>8</sup>	$0.315 \pm 0.055$	
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^+(\text{NR}))$	CLEO [39]	$< 89$	$< 89$

<sup>1</sup> The charmonium mass regions are vetoed.

<sup>2</sup> Charmonium decays to  $p\bar{p}$  have been statistically subtracted.

<sup>3</sup> 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.

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

<sup>5</sup> The PDG uncertainty includes a scale factor.

<sup>6</sup> 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.

<sup>7</sup> Pentaquark candidate.

<sup>8</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow p\bar{p}K^*(892)^+)$	Belle [162]	$3.38^{+0.73}_{-0.60} \pm 0.39$ <sup>1</sup>
	BaBar [156]	$5.3 \pm 1.5 \pm 1.3$ <sup>2</sup>
$\mathcal{B}(B^+ \rightarrow f_J(2220)K^*(892)^+) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$	BaBar [156]	$< 0.77$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0)$	LHCb [163]	$0.24^{+0.10}_{-0.08} \pm 0.03$
	Belle [164]	$< 0.32$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^0)$	Belle [165]	$3.00^{+0.61}_{-0.53} \pm 0.33$
$\mathcal{B}(B^+ \rightarrow p\bar{\Sigma}(1385)^0)$	Belle [165]	$< 0.47$
$\mathcal{B}(B^+ \rightarrow \Delta(1232)^+\bar{\Lambda}^0)$	Belle [165]	$< 0.82$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^+\pi^-)$	Belle [166]	$11.28^{+0.91}_{-0.72} \pm 1.03$
		$11.3^{+1.4}_{-1.3}$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\pi^+\pi^- \text{ (NR)})$	Belle [166]	$5.92^{+0.88}_{-0.84} \pm 0.69$
		$5.9 \pm 1.1$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\rho^0(770)) \times \mathcal{B}(\rho^0(770) \rightarrow \pi^+\pi^-)$	Belle [166]	$4.78^{+0.67}_{-0.64} \pm 0.60$
		$4.8 \pm 0.9$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0f_2(1270)) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	Belle [166]	$2.03^{+0.77}_{-0.72} \pm 0.27$
		$2.0 \pm 0.8$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0K^+K^-)$	Belle [167]	$4.10^{+0.45}_{-0.43} \pm 0.50$
$\mathcal{B}(B^+ \rightarrow p\bar{\Lambda}^0\phi(1020))$	Belle [167]	$0.795 \pm 0.209 \pm 0.077$
$\mathcal{B}(B^+ \rightarrow \bar{p}\Lambda^0K^+K^-)$	Belle [167]	$3.70^{+0.39}_{-0.37} \pm 0.44$
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0\pi^+)$	Belle [168]	$< 0.94$ <sup>3,4</sup>
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0K^+)$	Belle [168]	$3.38^{+0.41}_{-0.36} \pm 0.41$ <sup>3</sup>
		$3.4^{+0.6}_{-0.5}$
$\mathcal{B}(B^+ \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^+)$	Belle [168]	$2.19^{+1.13}_{-0.88} \pm 0.33$ <sup>3,4</sup>
$\mathcal{B}(B^+ \rightarrow \Lambda(1520)\bar{\Lambda}^0K^+)$	Belle [167]	$2.23 \pm 0.63 \pm 0.25$
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)\Lambda^0K^+)$	Belle [167]	$< 2.08$
$\mathcal{B}(B^+ \rightarrow \bar{\Delta}(1232)^0p)$	Belle [155]	$< 1.38$
$\mathcal{B}(B^+ \rightarrow \Delta^{++}\bar{p})$	Belle [155]	$< 0.14$

<sup>1</sup> The charmonium mass region has been vetoed.

<sup>2</sup> Charmonium decays to  $p\bar{p}$  have been statistically subtracted.

<sup>3</sup> The charmonium mass regions are vetoed.

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

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow p\bar{p})$	LHCb [169]	$0.0127 \pm 0.0013 \pm 0.0006$ <sup>1,2</sup>
	Belle [164]	$< 0.11$
	BaBar [170]	$< 0.27$
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-)$	LHCb [171]	$2.7 \pm 0.1 \pm 0.2$ <sup>3,2</sup>
		$2.7 \pm 0.2$ $2.9 \pm 0.2$
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-), m_{\pi^+\pi^-} < 1.22 \text{ GeV}/c^2$	Belle [158]	$0.83 \pm 0.17 \pm 0.17$ <sup>4</sup>
		$0.8 \pm 0.2$ none
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)$	LHCb [171]	$5.9 \pm 0.3 \pm 0.5$ <sup>3,2</sup>
		$5.90 \pm 0.58$ $6.27 \pm 0.52$
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^0)$	Belle [162]	$2.51^{+0.35}_{-0.29} \pm 0.21$ <sup>5</sup>
	BaBar [156]	$3.0 \pm 0.5 \pm 0.3$ <sup>6</sup>
$\mathcal{B}(B^0 \rightarrow \Theta(1540)^+\bar{p}) \times \mathcal{B}(\Theta(1540)^+ \rightarrow pK_S^0)$ <sup>7</sup>	BaBar [156]	$< 0.05$
	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 [156]	$< 0.45$
		$< 0.45$
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^*(892)^0)$	Belle [162]	$1.18^{+0.29}_{-0.25} \pm 0.11$ <sup>5</sup>
	BaBar [156]	$1.47 \pm 0.45 \pm 0.40$ <sup>6</sup>
$\mathcal{B}(B^0 \rightarrow f_J(2220)K^*(892)^0) \times \mathcal{B}(f_J(2220) \rightarrow p\bar{p})$		$1.24^{+0.28}_{-0.25}$
	BaBar [156]	$< 0.15$
		$< 0.15$

<sup>1</sup> Run I and run II combination.

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

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

<sup>5</sup> The charmonium mass region has been vetoed.

<sup>6</sup> Charmonium decays to  $p\bar{p}$  have been statistically subtracted.

<sup>7</sup> Pentaquark candidate.

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

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow p\bar{p}K^+K^-)$	LHCb [171] $0.113 \pm 0.028 \pm 0.014$ <sup>1,2</sup>	$0.113 \pm 0.031$ $0.121 \pm 0.032$
$\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^0)$	Belle [172] $0.50 \pm 0.18 \pm 0.06$	$0.50 \pm 0.19$
$\mathcal{B}(B^0 \rightarrow pp\bar{p}\bar{p})$	BaBar [173] $< 0.2$	$< 0.2$
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0\pi^-)$	BaBar [174] $3.07 \pm 0.31 \pm 0.23$ Belle [165] $3.23^{+0.33}_{-0.29} \pm 0.29$	$3.14 \pm 0.28$ $3.14^{+0.29}_{-0.28}$
$\mathcal{B}(B^0 \rightarrow p\bar{\Sigma}(1385)^-)$	Belle [165] $< 0.26$	$< 0.26$
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^+\bar{p}+\text{c.c.})$	Belle [172] $< 1.6$	$< 1.6$
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^0\bar{\Lambda}^0)$	Belle [165] $< 0.93$	$< 0.93$
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0K^-)$	Belle [175] $< 0.82$	$< 0.82$
$\mathcal{B}(B^0 \rightarrow p\bar{\Sigma}^0\pi^-)$	Belle [175] $< 3.8$	$< 3.8$
$\mathcal{B}(B^0 \rightarrow \bar{\Lambda}^0\Lambda^0)$	Belle [164] $< 0.32$	$< 0.32$
$\mathcal{B}(B^0 \rightarrow \bar{\Lambda}^0\Lambda^0K^0)$	Belle [168] $4.76^{+0.84}_{-0.68} \pm 0.61$ <sup>3</sup>	$4.8^{+1.0}_{-0.9}$
$\mathcal{B}(B^0 \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^0)$	Belle [168] $2.46^{+0.87}_{-0.72} \pm 0.34$ <sup>3</sup>	$2.46^{+0.93}_{-0.80}$
$\mathcal{B}(B^0 \rightarrow \Delta(1232)^0\bar{\Delta}(1232)^0)$	CLEO [89] $< 1500$ <sup>4</sup>	$< 1500$
$\mathcal{B}(B^0 \rightarrow \Delta^{++}\bar{\Delta}^{--})$	CLEO [89] $< 110$ <sup>4</sup>	$< 110$
$\mathcal{B}(B^0 \rightarrow p\bar{p}p\bar{p})$	LHCb [176] $0.022 \pm 0.004 \pm 0.001$ <sup>2</sup>	$0.0220 \pm 0.0042$ none

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> The charmonium mass regions are vetoed.

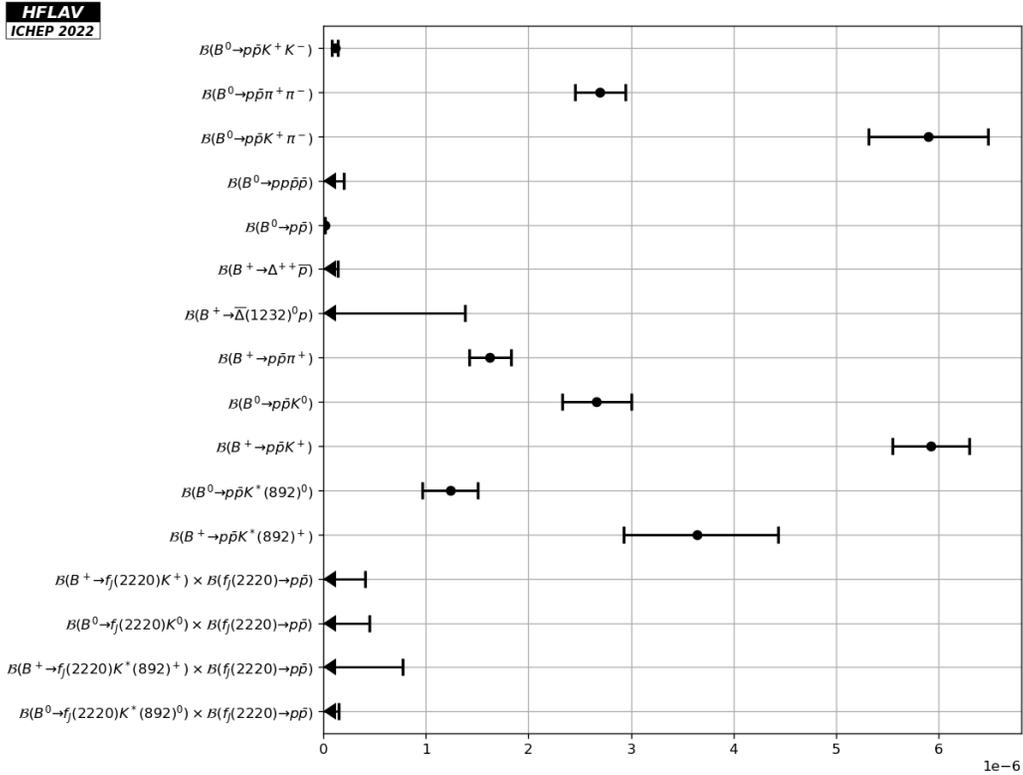
<sup>4</sup> CLEO assumes  $\mathcal{B}(\Upsilon(4S) \rightarrow B^0\bar{B}^0) = 0.43$ . The result has been modified to account for a branching fraction of 0.50.

Table 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 [157]	$12.0 \pm 1.2 \pm 0.3$	$12.0 \pm 1.2$
$\frac{\mathcal{B}(B^+ \rightarrow p\bar{p}K^+)}{\mathcal{B}(B^+ \rightarrow J/\psi K^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [161]	$4.91 \pm 0.19 \pm 0.14$ <sup>1</sup>	$4.91 \pm 0.24$
$\frac{\mathcal{B}(B^+ \rightarrow p\bar{p}K^+, m_{p\bar{p}} < 2.85 \text{ GeV}/c^2)}{\mathcal{B}(B^+ \rightarrow J/\psi\pi^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [161]	$2.02 \pm 0.10 \pm 0.08$	$2.02 \pm 0.13$
$\frac{\mathcal{B}(B^+ \rightarrow \bar{\Lambda}(1520)p) \times \mathcal{B}(\bar{\Lambda}(1520) \rightarrow K^+\bar{p})}{\mathcal{B}(B^+ \rightarrow J/\psi\pi^+) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})}$	LHCb [157]	$0.033 \pm 0.005 \pm 0.007$	$0.033 \pm 0.009$
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+K^-)}{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)}$	LHCb [171]	$0.019 \pm 0.005 \pm 0.002$ <sup>2</sup>	$0.019 \pm 0.005$
$\frac{\mathcal{B}(B^0 \rightarrow p\bar{p}\pi^+\pi^-)}{\mathcal{B}(B^0 \rightarrow p\bar{p}K^+\pi^-)}$	LHCb [171]	$0.46 \pm 0.02 \pm 0.02$ <sup>2</sup>	$0.46 \pm 0.03$

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

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


 Figure 2: Branching fractions of charmless baryonic  $B^+$  and  $B^0$  decays into non-strange baryons.

Measurements that are not included in the tables:

- In Ref. [177], Belle searches for  $B^0$  mesons decaying into a final state containing a  $\Lambda$  baryon and missing energy. Upper limits on the branching fractions are set in the range  $2.1 - 3.8 \times 10^{-5}$ .

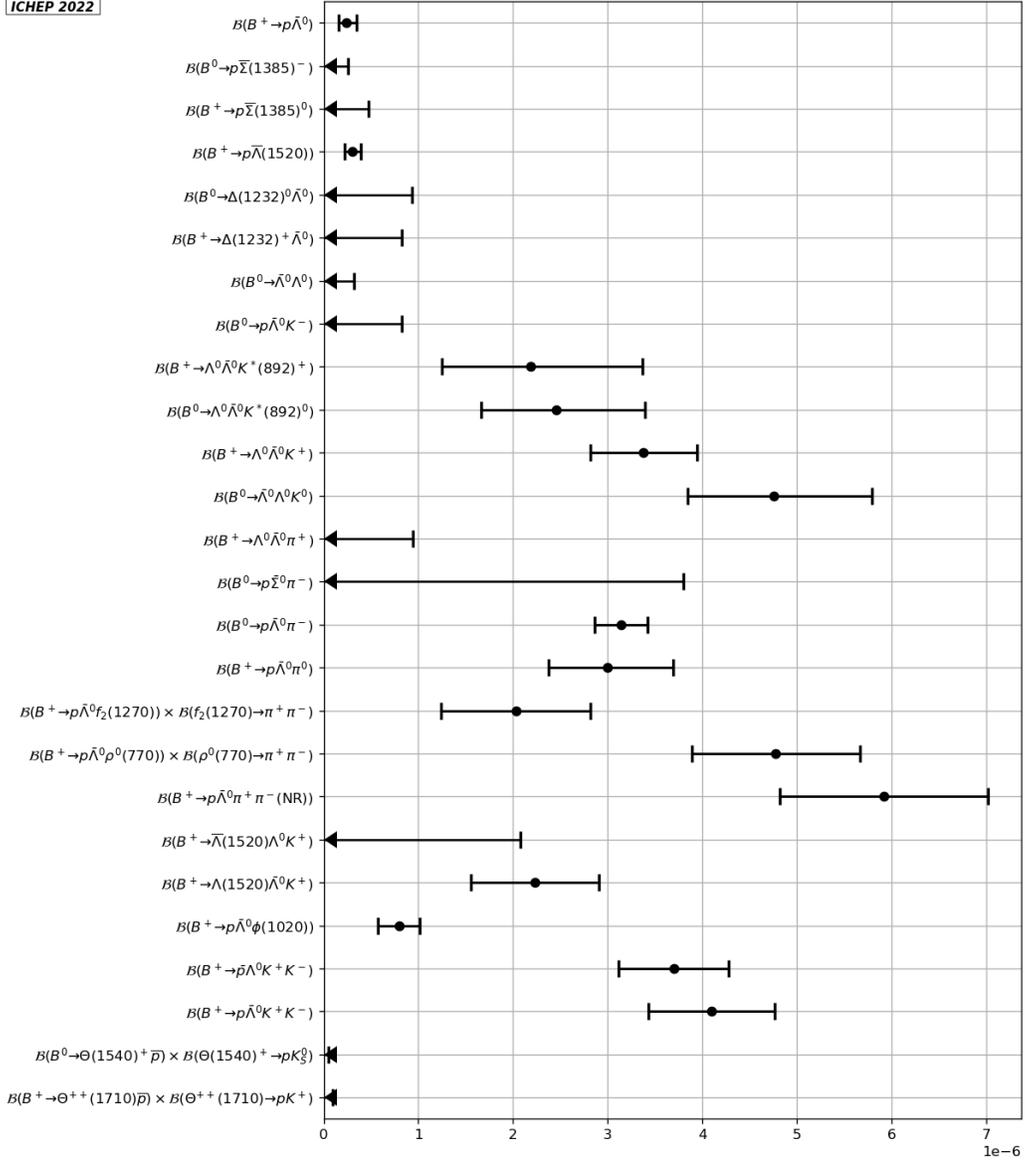


Figure 3: Branching fractions of charmless baryonic  $B^+$  and  $B^0$  decays into strange baryons.

### 3 Decays of $b$ baryons

A compilation of branching fractions of  $\Lambda_b^0$  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  $\Xi_b^0$ ,  $\Xi_b^-$  and  $\Omega_b^-$  baryon decays are given in Tables 35, 36, and 37, respectively. Finally, ratios of branching fractions of  $\Lambda_b^0$ ,  $\Xi_b^0$  and  $\Omega_b^-$  baryon decays are detailed in Tables 38, 39 and 40, respectively. Figure 4 shows a graphic representation of branching fractions of  $\Lambda_b^0$  decays.

Table 32: Branching fractions of charmless  $\Lambda_b^0$  decays (part 1).

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(\Lambda_b^0 \rightarrow p \bar{K}^0 \pi^-)$	LHCb [107] $12.4 \pm 2.0 \pm 3.6$ <sup>1,2</sup>	$12.4 \pm 4.2$ $12.6 \pm 4.1$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^0 K^-)$	LHCb [107] $< 3.5$ <sup>2</sup>	$< 3.5$
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^-)^3$	LHCb [94] $4.68 \pm 0.44 \pm 0.95$ <sup>4</sup> CDF [91] <sup>5</sup>	$4.5$ <sup>+0.9</sup> <sub>-0.8</sub> $4.5 \pm 0.8$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^-)^3$	CDF [91] $6.3 \pm 1.2 \pm 0.8$ LHCb [94] <sup>6</sup>	$5.4 \pm 1.1$ $5.4 \pm 1.0$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \mu^+ \mu^-)$	LHCb [178] $0.955 \pm 0.186 \pm 0.249$ <sup>1,7</sup> CDF [179] $1.520 \pm 0.366 \pm 0.387$ <sup>7</sup>	$1.09$ <sup>+0.34</sup> <sub>-0.29</sub> $1.08 \pm 0.28$
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^- \mu^+ \mu^-)$	LHCb [180] <sup>8</sup>	$0.069$ <sup>+0.027</sup> <sub>-0.023</sub> $0.069$ <sup>+0.025</sup> <sub>-0.024</sub>
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- e^+ e^-)$	LHCb [181] $0.311$ <sup>+0.044 +0.061</sup> <sub>-0.041 -0.051</sub> <sup>9,10</sup>	$0.31$ <sup>+0.08</sup> <sub>-0.06</sub> $0.31$ <sup>+0.07</sup> <sub>-0.06</sub>
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- \mu^+ \mu^-)$	LHCb [181] $0.266 \pm 0.013$ <sup>+0.050</sup> <sub>-0.040</sub> <sup>11,10</sup>	$0.266$ <sup>+0.052</sup> <sub>-0.041</sub> $0.265$ <sup>+0.051</sup> <sub>-0.041</sub>

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>3</sup> The PDG average is a result of a fit including input from other measurements.

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

<sup>5</sup> 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.

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

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

<sup>8</sup> 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.

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

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

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

Table 33: Branching fractions of charmless  $\Lambda_b^0$  decays (part 2).

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \gamma)$	LHCb [182] <sup>1</sup>	$6.9 \pm 1.5$ $7.1 \pm 1.7$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \eta)$	LHCb [98]	$9.23^{+7.15}_{-5.20} \pm 0.40$ <sup>2</sup> $9.2^{+7.2}_{-5.2}$ $9.4^{+7.3}_{-5.3}$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \eta')$	LHCb [98]	$< 3.05$ <sup>2</sup> $< 3.1$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \pi^+ \pi^-)$	LHCb [183] <sup>3</sup>	$4.7 \pm 1.9$ $4.6 \pm 1.9$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ \pi^-)$	LHCb [183] <sup>4</sup>	$5.7^{+1.3}_{-1.2}$ $5.6 \pm 1.2$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ K^-)$	LHCb [183] <sup>5</sup>	$16.1^{+2.4}_{-2.2}$ $16.0 \pm 2.2$
$\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 \phi(1020))$	LHCb [121] <sup>6</sup>	$10.1^{+2.9}_{-2.5}$ $9.8 \pm 2.6$
$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^+ \pi^- \pi^-)$	LHCb [184] <sup>7,8,9</sup>	$21.1^{+2.4}_{-2.3}$ $21.0 \pm 2.2$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ \pi^-)$	LHCb [184] <sup>8,10</sup>	$4.06^{+0.66}_{-0.61}$ $4.04 \pm 0.61$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- \pi^+ \pi^-)$	LHCb [184] <sup>8,11</sup>	$50.5^{+5.6}_{-5.3}$ $50.2 \pm 5.1$
$\mathcal{B}(\Lambda_b^0 \rightarrow p K^- K^+ K^-)$	LHCb [184] <sup>8,12</sup>	$12.6^{+1.5}_{-1.4}$ $12.6 \pm 1.3$

<sup>1</sup> 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.

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

<sup>3</sup> 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.

<sup>4</sup> 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.

<sup>5</sup> 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.

<sup>6</sup> 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.

<sup>7</sup> Vetoes on charm and charmonium resonances are applied.

<sup>8</sup> Multiple systematic uncertainties are added in quadrature.

<sup>9</sup> 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.

<sup>10</sup> 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.

<sup>11</sup> 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.

<sup>12</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$m_{\mu^+ \mu^-}^2 < 2.0 \text{ GeV}^2/c^4$	LHCb [185]	$0.72_{-0.22}^{+0.24} \pm 0.14$
	CDF [179]	$0.15 \pm 2.01 \pm 0.05$
$2.0 < m_{\mu^+ \mu^-}^2 < 4.3 \text{ GeV}^2/c^4$	LHCb [185]	$0.253_{-0.207}^{+0.276} \pm 0.046$
	CDF [179]	$1.84 \pm 1.66 \pm 0.59$
$4.3 < m_{\mu^+ \mu^-}^2 < 8.68 \text{ GeV}^2/c^4$	LHCb [178]	$0.66 \pm 0.72 \pm 0.16$
	CDF [179]	$-0.20 \pm 1.64 \pm 0.08$
$10.09 < m_{\mu^+ \mu^-}^2 < 12.86 \text{ GeV}^2/c^4$	LHCb [185]	$2.08_{-0.39}^{+0.42} \pm 0.42$
	CDF [179]	$2.97 \pm 1.47 \pm 0.95$
$14.18 < m_{\mu^+ \mu^-}^2 < 16.00 \text{ GeV}^2/c^4$	LHCb [185]	$2.04_{-0.33}^{+0.35} \pm 0.42$
	CDF [179]	$0.96 \pm 0.73 \pm 0.31$
$m_{\mu^+ \mu^-}^2 > 16.00 \text{ GeV}^2/c^4$	CDF [179]	$6.97 \pm 1.88 \pm 2.23$

Table 35: Branching fractions of charmless  $\Xi_b^0$  decays.

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\frac{f_{\Xi_b^0}}{f_d} \mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 \pi^-)$	LHCb [107] < 1.5 <sup>1</sup>	< 1.5 < 1.6
$\frac{f_{\Xi_b^0}}{f_d} \mathcal{B}(\Xi_b^0 \rightarrow p \bar{K}^0 K^-)$	LHCb [107] < 1.0 <sup>1</sup>	< 0.99 < 1.10
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda \pi^+ \pi^-)$	LHCb [183] < 1.7	< 1.7
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda K^- \pi^+)$	LHCb [183] < 0.8	< 0.8
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow \Lambda K^+ K^-)$	LHCb [183] < 0.3	< 0.3
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ \pi^-)$	LHCb [184] <sup>2,3</sup>	1.91 <sup>+0.41</sup> <sub>-0.38</sub> 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 [184] <sup>2,4</sup>	1.72 <sup>+0.33</sup> <sub>-0.30</sub> 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 [184] <sup>2,5</sup>	0.18 $\pm$ 0.10

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> 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.

<sup>4</sup> 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.

<sup>5</sup> 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  $\Xi_b^-$  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 [186] $0.2650 \pm 0.0350 \pm 0.0470$	$0.265 \pm 0.059$
$\frac{f_{\Xi_b^-}}{f_u} \frac{\mathcal{B}(\Xi_b^- \rightarrow p\pi^-\pi^-)}{\mathcal{B}(B^- \rightarrow K^+K^-K^-)}$	LHCb [186] $< 0.1470$	$< 0.15$
$\frac{f_{\Xi_b^-}}{f_u} \frac{\mathcal{B}(\Xi_b^- \rightarrow pK^-\pi^-)}{\mathcal{B}(B^- \rightarrow K^+K^-K^-)}$	LHCb [186] $0.2590 \pm 0.0640 \pm 0.0490$	$0.259 \pm 0.081$
$\frac{\mathcal{B}(\Xi_b^- \rightarrow p\pi^-\pi^-)}{\mathcal{B}(\Xi_b^- \rightarrow pK^-K^-)}$	LHCb [186] $< 56$	$< 56$
$\frac{\mathcal{B}(\Xi_b^- \rightarrow pK^-\pi^-)}{\mathcal{B}(\Xi_b^- \rightarrow pK^-K^-)}$	LHCb [186] $98 \pm 27 \pm 9$	$98 \pm 28$
$\frac{\mathcal{B}(\Xi_b^- \rightarrow \Xi^- \gamma)}{\mathcal{B}(\Xi_b^- \rightarrow \Xi^- J/\psi)}$	LHCb [187] $< 8$	$< 8.0$

Table 37: Branching fractions of charmless  $\Omega_b^-$  decays.

Parameter [ $10^{-8}$ ]	Measurements	Average
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-K^-)$	LHCb [186] $< 0.59^1$	$< 0.59$
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow pK^-\pi^-)$	LHCb [186] $< 1.68^1$	$< 1.7$
$\frac{f_{\Omega_b^-}}{f_u} \times \mathcal{B}(\Omega_b^- \rightarrow p\pi^-\pi^-)$	LHCb [186] $< 3.59^1$	$< 3.6$

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

Table 38: Relative branching fractions of charmless  $\Lambda_b^0$  decays.

Parameter	Measurements	Average
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-)}$	LHCb [94] $0.86 \pm 0.08 \pm 0.05$	$0.86 \pm 0.09$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\eta)}{\mathcal{B}(B^0 \rightarrow \eta'K^0)}$	LHCb [98] $0.142^{+0.110}_{-0.080}$	$0.14^{+0.11}_{-0.08}$
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-)}{\mathcal{B}(B^0 \rightarrow K^+\pi^-)}$	CDF [91] $0.042 \pm 0.007 \pm 0.006$	$0.042 \pm 0.009$
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-)}{\mathcal{B}(B^0 \rightarrow K^+\pi^-)}$	CDF [91] $0.066 \pm 0.009 \pm 0.008$	$0.066 \pm 0.012$
$\frac{f_{\Lambda_b^0}}{f_d} \frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\phi)}{\mathcal{B}(B^0 \rightarrow K_S^0\phi)}$	LHCb [121] $0.55 \pm 0.11 \pm 0.04$	$0.55 \pm 0.12$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi p\pi^-) \times \mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)}$	LHCb [180] $0.044 \pm 0.012 \pm 0.007$	$0.044 \pm 0.014$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [183] $0.073 \pm 0.019 \pm 0.022$	$0.073 \pm 0.029$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [183] $0.089 \pm 0.012 \pm 0.013$	$0.089 \pm 0.018$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0 K^+K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0\pi^+)}$	LHCb [183] $0.253 \pm 0.019 \pm 0.019$	$0.253 \pm 0.027$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^-\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [184] $0.0685 \pm 0.0019 \pm 0.0033^1$	$0.0685 \pm 0.0038$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [184] $0.164 \pm 0.003 \pm 0.007^1$	$0.164 \pm 0.008$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-K^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [184] $0.0132 \pm 0.0009 \pm 0.0013^1$	$0.0132 \pm 0.0016$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-K^+K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}$	LHCb [184] $0.0411 \pm 0.0012 \pm 0.0020^1$	$0.0411 \pm 0.0023$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\bar{K}^0\pi^-)}{\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)}$	LHCb [107] $0.25 \pm 0.04 \pm 0.07^1$	$0.25 \pm 0.08$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\bar{K}^0K^-)}{\mathcal{B}(B^0 \rightarrow K^0\pi^+\pi^-)}$	LHCb [107] $< 0.07$	$< 0.07$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda^0\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)}$	LHCb [178] $0.00154 \pm 0.00030 \pm 0.00020^1$	$0.00154 \pm 0.00036$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-e^+e^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi pK^-)}$	LHCb [181] $0.00098^{+0.00014}_{-0.00013} \pm 0.00008^2$	$0.00098 \pm 0.00016$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi pK^-)}$	LHCb [181] $0.00084 \pm 0.00004 \pm 0.00004^2$	$0.000840 \pm 0.000057$
$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-e^+e^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-)}$	LHCb [181] $1.17^{+0.18}_{-0.16} \pm 0.07^2$	$1.17^{+0.19}_{-0.17}$

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

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

Table 39: Relative branching fractions of charmless  $\Xi_b^0$  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 [107] < 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 [107] < 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 [184] $0.057 \pm 0.028 \pm 0.013$ <sup>1</sup>	$0.057 \pm 0.031$
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ \pi^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)}$	LHCb [184] $0.62 \pm 0.08 \pm 0.08$ <sup>1</sup>	$0.62 \pm 0.11$
$\frac{f_{\Xi_b^0}}{f_{\Lambda_b^0}} \times \frac{\mathcal{B}(\Xi_b^0 \rightarrow p K^- \pi^+ K^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-) \times \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)}$	LHCb [184] $0.56 \pm 0.06 \pm 0.06$ <sup>1</sup>	$0.560 \pm 0.088$

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

Table 40: Relative branching fractions of charmless  $\Omega_b^-$  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 [186] < 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 [186] < 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 [186] < 0.510	< 0.51

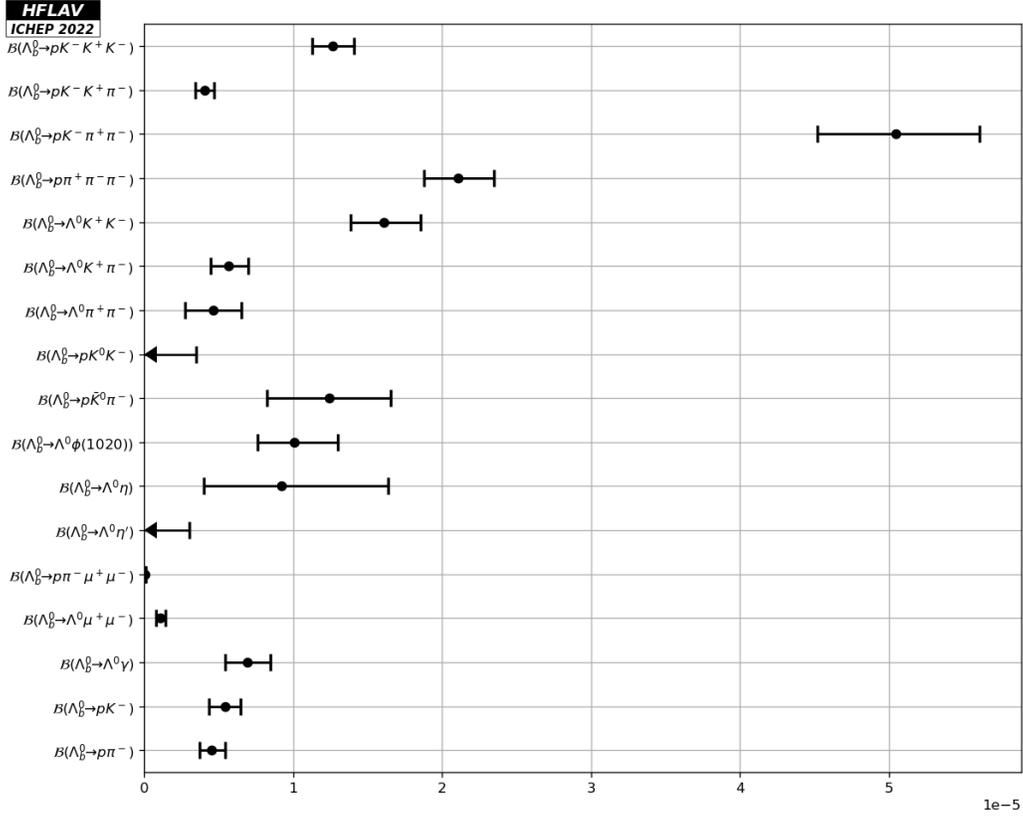


Figure 4: Branching fractions of charmless  $\Lambda_b^0$  decays.

Measurements that are not included in the tables:

- In Ref. [188], 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. [189], LHCb performs a search for baryon-number-violating  $\Xi_b^0$  oscillations and set an upper limit of  $\omega < 0.08 \text{ ps}^{-1}$  on the oscillation rate.
- In Ref. [190], 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 44 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-)$	Belle [191] $< 12$ CDF [93] <sup>1</sup> LHCb [95] <sup>1</sup>	$0.72^{+0.11}_{-0.10}$ $0.70 \pm 0.10$
$\mathcal{B}(B_s^0 \rightarrow \pi^0\pi^0)$	Belle [192] $< 7.7$	$< 7.7$ $< 210.0$
$\mathcal{B}(B_s^0 \rightarrow \eta\pi^0)$	L3 [193] $< 1000$	$< 1000$
$\mathcal{B}(B_s^0 \rightarrow \eta\eta)$	Belle [194] $< 144$ <sup>2</sup>	$< 144$ $< 143$
$f_s \times \mathcal{B}(B_s^0 \rightarrow \eta\eta)$	Belle [194] $< 29$	$< 29$ none
$\mathcal{B}(B_s^0 \rightarrow \rho^0(770)\rho^0(770))$	SLD [195] $< 320$	$< 320$
$\mathcal{B}(B_s^0 \rightarrow \eta'\eta')$	LHCb [15] $32.4 \pm 6.2 \pm 3.0$ <sup>3</sup>	$32 \pm 7$ $33 \pm 7$
$\mathcal{B}(B_s^0 \rightarrow \eta'\phi(1020))$	LHCb [196] $< 0.82$	$< 0.82$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)f_0(980)) \times \mathcal{B}(f_0(980) \rightarrow \pi^+\pi^-)$	LHCb [140] $1.12 \pm 0.16 \pm 0.14$ <sup>4</sup>	$1.12 \pm 0.21$
$\mathcal{B}(B_s^0 \rightarrow f_2(1270)\phi(1020)) \times \mathcal{B}(f_2(1270) \rightarrow \pi^+\pi^-)$	LHCb [140] $0.61 \pm 0.13^{+0.13}_{-0.08}$ <sup>4</sup>	$0.61^{+0.19}_{-0.15}$ $0.61^{+0.18}_{-0.15}$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\rho^0(770))$	LHCb [140] $0.27 \pm 0.07 \pm 0.03$ <sup>4</sup>	$0.27 \pm 0.08$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\pi^+\pi^-)$	LHCb [140] $3.48 \pm 0.23 \pm 0.39$ <sup>5,4</sup>	$3.48 \pm 0.45$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [129] $18.6 \pm 0.5 \pm 1.6$ <sup>4,6</sup> CDF [197] $19.1 \pm 1.5 \pm 2.5$ <sup>7</sup>	$18.7^{+1.5}_{-1.4}$ $18.5 \pm 1.4$
$\mathcal{B}(B_s^0 \rightarrow K^-\pi^+)$	Belle [191] $< 26$ CDF [91] <sup>8</sup> LHCb [94] <sup>8</sup>	$5.9^{+0.9}_{-0.8}$ $5.8 \pm 0.7$
$\mathcal{B}(B_s^0 \rightarrow K^+K^-)$	Belle [191] $38^{+10}_{-9} \pm 7$ <sup>4</sup> CDF [92] <sup>9</sup> LHCb [94] <sup>9</sup>	$26.6^{+3.2}_{-2.7}$ $26.6 \pm 2.2$
$\mathcal{B}(B_s^0 \rightarrow K^0\bar{K}^0)$	LHCb [122] $16.7 \pm 2.9 \pm 2.1$ <sup>4,10</sup> Belle [198] $19.6^{+5.8}_{-5.1} \pm 2.2$ <sup>4</sup>	$17.4 \pm 3.1$ $17.6^{+3.2}_{-3.1}$

<sup>1</sup> 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.

<sup>2</sup> Using  $f_s$ .

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

<sup>4</sup> Multiple systematic uncertainties are added in quadrature.

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

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

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

<sup>8</sup> 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.

<sup>9</sup> 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.

<sup>10</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B_s^0 \rightarrow K^0 \pi^+ \pi^-)$	LHCb [109]	$9.49 \pm 1.34 \pm 1.67$ <sup>1,2</sup>	$9.5 \pm 2.1$
$\mathcal{B}(B_s^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})$	LHCb [109]	$84.5 \pm 3.5 \pm 8.0$ <sup>1,2</sup>	$84.5 \pm 8.7$ $84.5 \pm 8.8$
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^- \pi^+)$	LHCb [111]	$2.98 \pm 0.99 \pm 0.42$ <sup>3</sup>	$3.0 \pm 1.1$ <small>p=1.6%</small> $2.9 \pm 1.1$
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^+ K^- + \text{c.c.})$	LHCb [199]	$18.6 \pm 1.2 \pm 4.5$ <sup>4,5</sup>	$18.6 \pm 4.7$
$\mathcal{B}(B_s^0 \rightarrow (K\pi)_0^{*+} K^- + \text{c.c.})$	<b>LHCb [199]</b>	$24.9 \pm 1.8 \pm 20.2$ <sup>4,5</sup>	$25 \pm 20$ none
$\mathcal{B}(B_s^0 \rightarrow K_0^*(1430)^+ K^- + \text{c.c.})$	LHCb [199]	$31.3 \pm 2.3 \pm 25.3$ <sup>4,5</sup>	$31 \pm 25$
$\mathcal{B}(B_s^0 \rightarrow K_2^*(1430)^+ K^- + \text{c.c.})$	LHCb [199]	$10.3 \pm 2.5 \pm 16.4$ <sup>4,5</sup>	$10 \pm 17$
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^0 + \text{c.c.})$	LHCb [199]	$19.8 \pm 2.8 \pm 5.0$ <sup>4,5</sup>	$19.8 \pm 5.7$
$\mathcal{B}(B_s^0 \rightarrow (K\pi)_0^{*0} \bar{K}^0 + \text{c.c.})$	<b>LHCb [199]</b>	$26.2 \pm 2.0 \pm 7.8$ <sup>4,5</sup>	$26.2 \pm 8.1$ none
$\mathcal{B}(B_s^0 \rightarrow K_0^*(1430)^0 \bar{K}^0 + \text{c.c.})$	LHCb [199]	$33.0 \pm 2.5 \pm 9.8$ <sup>4,5</sup>	$33 \pm 10$
$\mathcal{B}(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}^0 + \text{c.c.})$	LHCb [199]	$16.8 \pm 4.5 \pm 21.3$ <sup>4,5</sup>	$17 \pm 22$
$\mathcal{B}(B_s^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})$	LHCb [108]	$17.1 \pm 3.6 \pm 2.4$ <sup>5,6</sup>	$17.1 \pm 4.3$ <small>p=1.6%</small> $16.4 \pm 4.1$

<sup>1</sup> Regions corresponding to  $D$ ,  $\Lambda_c^+$  and charmonium resonances are vetoed in this analysis.

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

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

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

<sup>5</sup> Multiple systematic uncertainties are added in quadrature.

<sup>6</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B_s^0 \rightarrow K^0 K^+ K^-)$	LHCb [109] $1.29 \pm 0.55 \pm 0.36$ <sup>1,2</sup>	$1.29 \pm 0.66$ $1.29 \pm 0.65$
$\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \rho^0(770))$	SLD [195] $< 767$	$< 767$
$\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)$	LHCb [128] $11.2 \pm 2.2 \pm 1.5$ <sup>3,4</sup> LHCb [132] <sup>3,5</sup>	$11.0 \pm 2.0$ $11.1 \pm 2.7$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020) \bar{K}^*(892)^0)$	LHCb [127] $1.14 \pm 0.24 \pm 0.17$ <sup>3,4</sup>	$1.14 \pm 0.29$ $1.14 \pm 0.30$
$\mathcal{B}(B_s^0 \rightarrow p\bar{p})$	LHCb [169] $< 0.0044$	$< 0.0044$ $< 0.0150$
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+K^-)$	LHCb [171] $4.2 \pm 0.3 \pm 0.4$ <sup>6,3</sup>	$4.2 \pm 0.5$ $4.5 \pm 0.5$
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+\pi^-)$	LHCb [171] $1.3 \pm 0.2 \pm 0.2$ <sup>6,3</sup>	$1.3 \pm 0.3$ $1.4 \pm 0.3$
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}\pi^+\pi^-)$	LHCb [171] $< 0.66$ <sup>6</sup>	$< 0.66$ $0.43 \pm 0.20$
$\mathcal{B}(B_s^0 \rightarrow p\bar{\Lambda}^0 K^- + \text{c.c.})$	LHCb [200] $5.46 \pm 0.61 \pm 0.82$ <sup>3</sup>	$5.5 \pm 1.0$
$\mathcal{B}(B_s^0 \rightarrow \gamma\gamma)$	Belle [201] $< 3.1$	$< 3.1$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\gamma)$	LHCb [202] $34.1 \pm 1.7 \pm 3.1$ <sup>7</sup> Belle [201] $36.0 \pm 5.0 \pm 7.0$	$34.4 \pm 3.3$ $34.2 \pm 3.6$

<sup>1</sup> Regions corresponding to  $D$ ,  $\Lambda_c^+$  and charmonium resonances are vetoed in this analysis.

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

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>5</sup> 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.

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

<sup>7</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)^1$	CMS [203]	$0.00383^{+0.00038+0.00024}_-0.00036-0.00021$ <sup>2</sup>
	LHCb [204]	$0.00309^{+0.00046+0.00015}_-0.00043-0.00011$
	ATLAS [205]	$0.0028^{+0.0008}_-0.0007$
	CDF [206]	$0.013^{+0.009}_-0.007$
		$0.00345 \pm 0.00029$
		$0.00301^{+0.00036}_-0.00033$
$\mathcal{B}(B_s^0 \rightarrow e^+e^-)$	LHCb [207]	$< 0.0094$
	CDF [208]	$< 0.28$
		$< 0.0094$
$\mathcal{B}(B_s^0 \rightarrow \tau^+\tau^-)^3$	LHCb [209]	$< 5200$
		$< 6800$
		$< 5200$
		$< 6800$
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-\gamma)^4$	LHCb [204]	$< 0.0015$ <sup>5</sup>
		none
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-\mu^+\mu^-)$	LHCb [210]	$< 0.00086$ <sup>6</sup>
		$< 0.00250$
$\mathcal{B}(B_s^0 \rightarrow aa) \times \mathcal{B}(a \rightarrow \mu^+\mu^-) \times \mathcal{B}(a \rightarrow \mu^+\mu^-)$	LHCb [210]	$< 0.00058$ <sup>7,8,6</sup>
		none
		$< 0.00058$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\mu^+\mu^-)^{9,10}$	LHCb [211]	$0.859 \pm 0.023 \pm 0.061$ <sup>2,11</sup>
	CDF [179]	$1.21 \pm 0.20 \pm 0.11$ <sup>11</sup>
		$0.865^{+0.066}_-0.064$
		$0.841 \pm 0.041$
$\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0\mu^+\mu^-)$	LHCb [212]	$0.029 \pm 0.010 \pm 0.004$ <sup>2</sup>
		$0.029 \pm 0.011$
$\mathcal{B}(B_s^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)$	LHCb [154] <sup>12,13</sup>	
		$0.084 \pm 0.016$
		$0.084 \pm 0.016$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)\nu\bar{\nu})$	DELPHI [112]	$< 5400$
		$< 5400$
		$< 5400$
$\mathcal{B}(B_s^0 \rightarrow e^+\mu^- + c.c.)$	LHCb [213]	$< 0.0054$
	CDF [208]	$< 0.2$
		$< 0.0054$
$\mathcal{B}(B_s^0 \rightarrow \tau^+\mu^- + c.c.)^3$	LHCb [214]	$< 34.0$
		$< 42$
		$< 34$
		$< 42$
$\mathcal{B}(B_s^0 \rightarrow \phi(1020)e^+\mu^- + c.c.)$	LHCb [215]	$< 0.0160$
		none
		$< 0.016$
		none

<sup>1</sup> 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. [216].

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> PDG shows the result obtained at 95% CL.

<sup>4</sup>  $m_{\mu\mu} > 4.9 \text{ GeV}/c^2$ .

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

<sup>6</sup> At CL=95%.

<sup>7</sup> The mass windows corresponding to  $\phi$  and charmonium resonances decaying to  $\mu\mu$  are vetoed.

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

<sup>9</sup> The PDG uncertainty includes a scale factor.

<sup>10</sup> Treatment of charmonium intermediate components differs between the results.

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

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

<sup>13</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B_s^0 \rightarrow p\mu^-)$	LHCb [217] $< 0.0121$	$< 0.012$ none
$\mathcal{B}(B_s^0 \rightarrow \eta'\eta)$	Belle [218] $< 65$	$< 65$ none
$\mathcal{B}(B_s^0 \rightarrow f_2'(1525)\mu^+\mu^-)$	LHCb [211] $0.166 \pm 0.020 \pm 0.015$ <sup>1,2</sup>	$0.166^{+0.026}_{-0.024}$ none
$\mathcal{B}(B_s^0 \rightarrow \eta' X_{s\bar{s}})$	Belle [219] $< 1400$ <sup>3</sup>	$< 1400$ none
$\mathcal{B}(B_s^0 \rightarrow \eta' K_S^0)$	Belle [220] $< 8.16$ <sup>4</sup>	$< 8.2$ none
$\mathcal{B}(B_s^0 \rightarrow p\bar{p}p\bar{p})$	LHCb [176] $0.023 \pm 0.010 \pm 0.002$ <sup>1</sup>	$0.023 \pm 0.010$ none

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

<sup>2</sup> Using  $\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))$ .

<sup>3</sup>  $M(X_{s\bar{s}}) < 2.4 \text{ GeV}/c^2$

<sup>4</sup> Using  $f_s$ .

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 [95] CDF [93]	$0.915 \pm 0.071 \pm 0.083$ $0.8 \pm 0.2 \pm 0.1$	$0.893 \pm 0.098$
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow \pi^+ \pi^-)}$	LHCb [94]	$5.0^{+1.1}_{-0.9} \pm 0.4$	$5.0^{+1.2}_{-1.0}$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))_1}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	CDF [197]	$1.78 \pm 0.14 \pm 0.20$	$1.78 \pm 0.24$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [129]	$184 \pm 5 \pm 13^2$	$184 \pm 14$
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow K^+ \pi^-)}{\mathcal{B}(B_d^0 \rightarrow K^+ \pi^-)}$	LHCb [94] CDF [91]	$7.4 \pm 0.6 \pm 0.6$ $7.1 \pm 1.0 \pm 0.7$	$7.30 \pm 0.70$
$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \rightarrow K^+ K^-)}{\mathcal{B}(B_d^0 \rightarrow K^+ \pi^-)}$	LHCb [94] CDF [92]	$31.6 \pm 0.9 \pm 1.9$ $34.7 \pm 2.0 \pm 2.1$	$32.7 \pm 1.7$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 \pi^+ \pi^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [109]	$19.1 \pm 2.7 \pm 3.3^{3,2}$	$19.1 \pm 4.3$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 K^+ \pi^- + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [109]	$170 \pm 7 \pm 15^{3,2}$	$170 \pm 16$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 K^+ K^-)}{\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^-)}$	LHCb [109]	$< 5.1^3$	$< 5.1$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^*(892)^- \pi^+)}{\mathcal{B}(B^0 \rightarrow K^*(892)^+ \pi^-)}$	LHCb [111]	$39 \pm 13 \pm 5$	$39 \pm 14$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [128]	$111 \pm 22 \pm 13^2$	$111 \pm 26$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\bar{K}^*(892)^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^*(892)^0)}$	LHCb [127]	$11.3 \pm 2.4 \pm 1.6^2$	$11.3 \pm 2.9$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	LHCb [211] CDF [179]	$0.0800 \pm 0.0021 \pm 0.0016^2$ $0.113 \pm 0.019 \pm 0.007$	$0.0806 \pm 0.0026$

<sup>1</sup> The PDG average is a result of a fit including input from other measurements.

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> Regions corresponding to  $D$ ,  $\Lambda_c^+$  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 [171] $22 \pm 4 \pm 2$ <sup>1,2</sup>	$22 \pm 5$
$\frac{\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+\pi^-)}{\mathcal{B}(B_s^0 \rightarrow p\bar{p}K^+K^-)}$	LHCb [171] $31 \pm 5 \pm 2$ <sup>1</sup>	$31 \pm 5$
$\frac{\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi \bar{K}^*(892)^0) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)}$	LHCb [212] $1.4 \pm 0.4 \pm 0.1$ <sup>2</sup>	$1.4 \pm 0.4$
$\frac{\mathcal{B}(B_s^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(\bar{B}^0 \rightarrow \bar{K}^*(892)^0 \mu^+ \mu^-)}$	LHCb [212] $3.3 \pm 1.1 \pm 0.4$ <sup>2</sup>	$3.3 \pm 1.2$
$\frac{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020)\phi(1020))}{\mathcal{B}(B_s^0 \rightarrow \phi(1020)\phi(1020))}$	LHCb [221] $11.7 \pm 3.0 \pm 1.5$	$11.7 \pm 3.4$
$\frac{\mathcal{B}(B_s^0 \rightarrow K^0 \bar{K}^0)}{\mathcal{B}(B^0 \rightarrow \phi(1020)K^0)}$	LHCb [122] $230 \pm 40 \pm 22$ <sup>2</sup>	$230 \pm 46$
$\frac{\mathcal{B}(B_s^0 \rightarrow K_S^0 K^*(892)^0 + \text{c.c.})}{\mathcal{B}(B^0 \rightarrow K_S^0 \pi^+ \pi^-)}$	LHCb [108] $33 \pm 7 \pm 4$ <sup>2</sup>	$33 \pm 8$
$\frac{\mathcal{B}(B_s^0 \rightarrow f_2'(1525)\mu^+\mu^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi\phi(1020))}$	LHCb [211] $0.0155 \pm 0.0019 \pm 0.0008$ <sup>2</sup>	$0.0155 \pm 0.0021$
$\frac{\mathcal{B}(B_s^0 \rightarrow \pi^+ \pi^- \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(K^{*0} \rightarrow K^+ \pi^-)}$	LHCb [154] $0.167 \pm 0.029 \pm 0.013$ <sup>3</sup>	$0.167 \pm 0.032$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

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

- In Ref. [211], LHCb reports the differential  $B_s^0 \rightarrow \phi \mu^+ \mu^-$  branching fraction in bins of  $m^2(\mu^+ \mu^-)$ .
- In Ref. [222], 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. [223], LHCb reports the photon polarization in  $B_s^0 \rightarrow \phi \gamma$  decays.

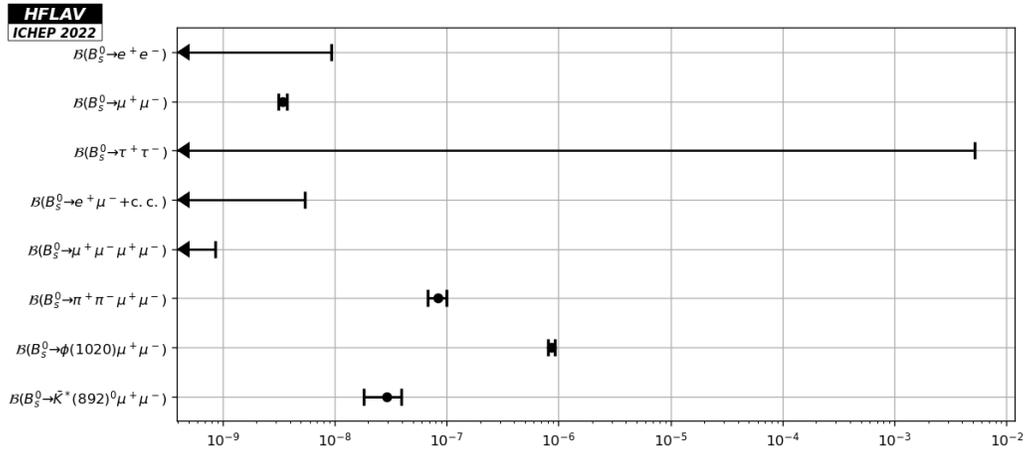


Figure 5: Branching fractions of charmless leptonic  $B_s^0$  decays.

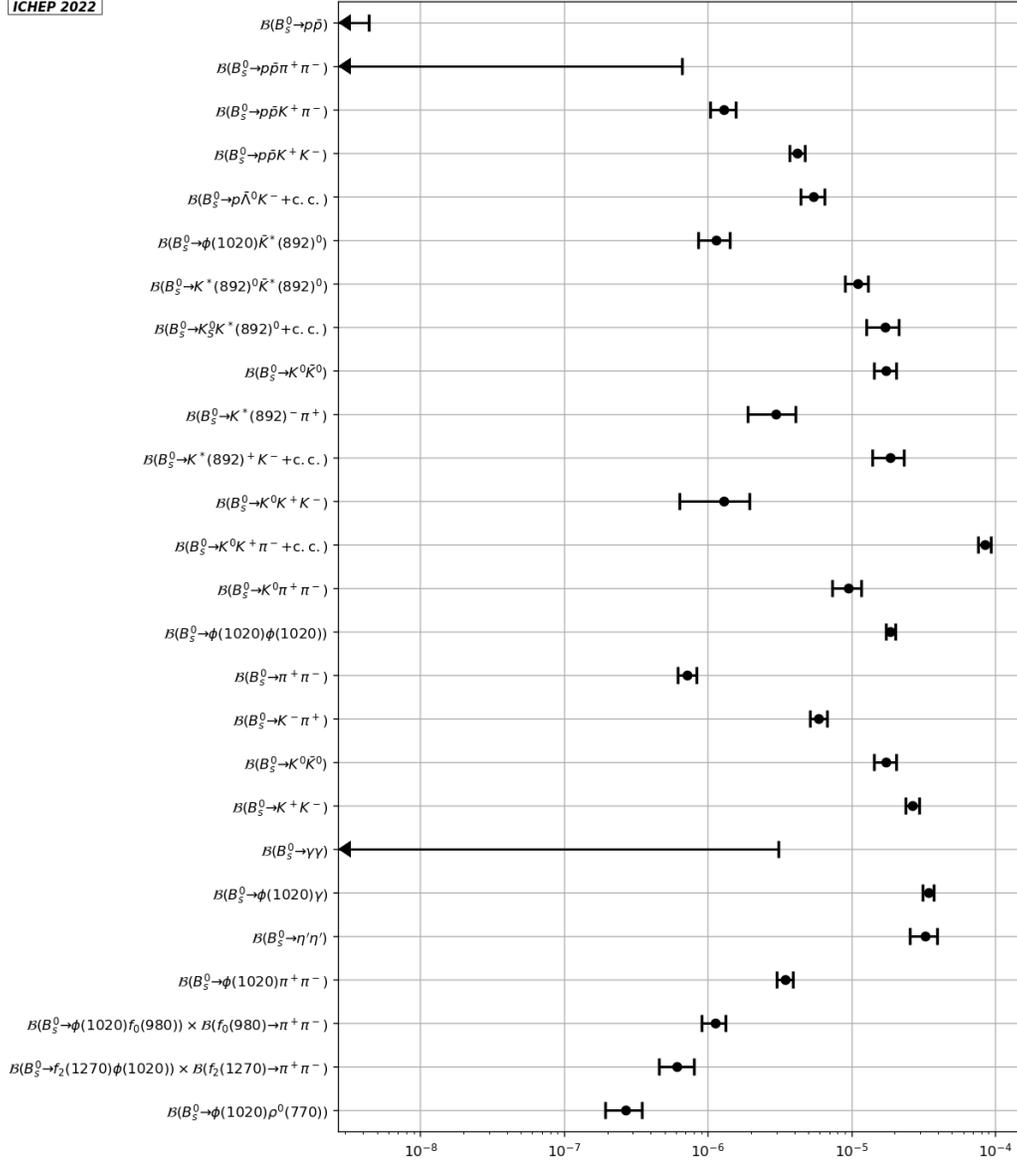


Figure 6: Branching fractions of charmless non-leptonic  $B_s^0$  decays.

## 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 [224] < 2.8 <sup>1</sup>	< 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 [225] < 1.50 <sup>3</sup>	< 1.5
$\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \frac{f_c}{f_s} [10^{-3}]$	LHCb [226] $2.37 \pm 0.31^{+0.20}_{-0.17}$ <sup>4,5</sup>	$2.37 \pm 0.36$
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \mathcal{B}(B_s^0 \rightarrow J/\psi \phi) \times \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-) \times \mathcal{B}(\phi \rightarrow K^+ K^-)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)} [10^{-2}]$	LHCb [227] $4.53 \pm 0.61 \pm 0.37$	$4.53 \pm 0.71$
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+) \times \mathcal{B}(B_s^0 \rightarrow D_s^- \pi^+) \times \mathcal{B}(D_s^- \rightarrow K^+ K^- \pi^-)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)}$	LHCb [227] $0.267 \pm 0.050 \pm 0.028$	$0.267 \pm 0.057$
$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)}$	LHCb [227] $91 \pm 10 \pm 9$ <sup>6,5</sup>	$91 \pm 13$

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

<sup>2</sup> 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  $f_c = 0.001$ .

<sup>3</sup> 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  $2.0 < y(B) < 4.5$

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

<sup>5</sup> Multiple systematic uncertainties are added in quadrature.

<sup>6</sup> 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 63, which gives a compilation of inclusive decays. In the modes listed in Table 63, the radiated particle is a gluon, which is an exception in this section. Table 64 contains isospin asymmetry measurements. Finally, Tables 65 to 66 and 67 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\gamma)^1$	Belle [228]	$37.6 \pm 1.0 \pm 1.2$
	BaBar [229]	$42.2 \pm 1.4 \pm 1.6$
	Belle II [230]	$52 \pm 4 \pm 3$
	CLEO [231]	$37.6^{+8.9}_{-8.3} \pm 2.8$
$\mathcal{B}(B^+ \rightarrow K_1(1270)^+\gamma)$	BaBar [232]	$44.1^{+6.3}_{-4.4} \pm 5.8$ <sup>2</sup>
	Belle [233]	$43.0 \pm 9.0 \pm 9.0$ <sup>3</sup>
$\mathcal{B}(B^+ \rightarrow \eta K^+\gamma)$	BaBar [234]	$7.7 \pm 1.0 \pm 0.4$ <sup>4</sup>
	Belle [235]	$8.4 \pm 1.5^{+1.2}_{-0.9}$ <sup>5</sup>
$\mathcal{B}(B^+ \rightarrow \eta' K^+\gamma)$	Belle [236]	$3.6 \pm 1.2 \pm 0.4$ <sup>6</sup>
	BaBar [237]	$1.9^{+1.5}_{-1.2} \pm 0.1$ <sup>4</sup>
$\mathcal{B}(B^+ \rightarrow \phi(1020)K^+\gamma)^1$	Belle [238]	$2.48 \pm 0.30 \pm 0.24$
	BaBar [239]	$3.5 \pm 0.6 \pm 0.4$ <sup>7</sup>
$\mathcal{B}(B^+ \rightarrow K^+\pi^-\pi^+\gamma)^1$	BaBar [232]	$24.5 \pm 0.9 \pm 1.2$ <sup>8</sup>
	Belle [233]	$25.0 \pm 1.8 \pm 2.2$ <sup>3</sup>
$\mathcal{B}(B^+ \rightarrow K^*(892)^0\pi^+\gamma)$	BaBar [232]	$23.4 \pm 0.9^{+0.8}_{-0.7}$ <sup>8</sup>
	Belle [240]	$20.0^{+7.0}_{-6.0} \pm 2.0$ <sup>9</sup>
$\mathcal{B}(B^+ \rightarrow K^+\rho^0(770)\gamma)$	BaBar [232]	$8.2 \pm 0.4 \pm 0.8$ <sup>8</sup>
	Belle [240]	$< 20.0$ <sup>9</sup>
$\mathcal{B}(B^+ \rightarrow (K\pi)_0^{*0}\pi^+\gamma) \times \mathcal{B}((K\pi)_0^{*0} \rightarrow K^+\pi^-)^{10}$		
	BaBar [232]	$10.3^{+0.7+1.5}_{-0.8-2.0}$ <sup>8</sup>
		$10.3^{+1.7}_{-2.2}$ none
$\mathcal{B}(B^+ \rightarrow K^+\pi^-\pi^+\gamma(\text{NR}))$	BaBar [232]	$9.9 \pm 0.7^{+1.5}_{-1.9}$ <sup>8,11</sup>
	Belle [240]	$< 9.2$ <sup>12</sup>
		$9.9^{+1.7}_{-2.0}$

<sup>1</sup> The PDG uncertainty includes a scale factor.

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup>  $1 < M_{K\pi\pi} < 2 \text{ GeV}/c^2$ .

<sup>4</sup>  $M_{K\eta^{(\prime)}}$   $< 3.25 \text{ GeV}/c^2$ .

<sup>5</sup>  $M_{K\eta} < 2.4 \text{ GeV}/c^2$ .

<sup>6</sup>  $M_{K\eta'}$   $< 3.4 \text{ GeV}/c^2$

<sup>7</sup>  $M_{\phi K} < 3.0 \text{ GeV}/c^2$ .

<sup>8</sup>  $M_{K\pi\pi} < 1.8 \text{ GeV}/c^2$ .

<sup>9</sup>  $M_{K\pi\pi} < 2.4 \text{ GeV}/c^2$ .

<sup>10</sup> This corresponds to the  $(K\pi)$   $S$ -wave obtained with LASS parameterisation [241].

<sup>11</sup>  $M_{K\pi} < 1.6 \text{ GeV}/c^2$ .

<sup>12</sup>  $1.25 < M_{K\pi} < 1.6 \text{ GeV}/c^2$  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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow K^0 \pi^+ \pi^0 \gamma)$	BaBar [242] $45.6 \pm 4.2 \pm 3.1$ <sup>1</sup>	$45.6 \pm 5.2$
$\mathcal{B}(B^+ \rightarrow K_1(1400)^+ \gamma)$	BaBar [232] $9.7^{+4.6+2.9}_{-2.9-2.4}$ <sup>1,2</sup> Belle [233] $< 15.0$	$9.7^{+5.4}_{-3.8}$
$\mathcal{B}(B^+ \rightarrow K^*(1410)^+ \gamma)$	BaBar [232] $27.1^{+5.4+5.9}_{-4.8-3.7}$ <sup>1,2</sup>	$27.1^{+8.0}_{-6.1}$
$\mathcal{B}(B^+ \rightarrow K_0^*(1430)^0 \pi^+ \gamma)$	BaBar [232] $1.32^{+0.09+0.24}_{-0.10-0.30}$ <sup>1,2</sup>	$1.32^{+0.26}_{-0.31}$ $1.32^{+0.26}_{-0.32}$
$\mathcal{B}(B^+ \rightarrow K_2^*(1430)^+ \gamma)$	BaBar [243] $14.5 \pm 4.0 \pm 1.5$ BaBar [232] $8.7^{+7.0+8.7}_{-5.3-10.4}$ <sup>1,2</sup>	$13.8 \pm 4.0$
$\mathcal{B}(B^+ \rightarrow K^*(1680)^+ \gamma)$	BaBar [232] $66.7^{+9.3+14.4}_{-7.8-11.4}$ <sup>1,2</sup>	$67^{+17}_{-14}$
$\mathcal{B}(B^+ \rightarrow K_3^*(1780)^+ \gamma)$	Belle [235] $< 9.7$	$< 9.7$ $< 39.0$
$\mathcal{B}(B^+ \rightarrow K_4^*(2045)^+ \gamma)$	ARGUS [244] $< 9900$	$< 9900$
$\mathcal{B}(B^+ \rightarrow \rho^+(770) \gamma)$	Belle [245] $0.87^{+0.29+0.09}_{-0.27-0.11}$ BaBar [246] $1.2 \pm 0.4 \pm 0.2$	$0.98 \pm 0.24$ $0.98^{+0.25}_{-0.24}$
$\mathcal{B}(B^+ \rightarrow p \bar{\Lambda}^0 \gamma)$	Belle [165] $2.45^{+0.44}_{-0.38} \pm 0.22$	$2.45^{+0.49}_{-0.44}$
$\mathcal{B}(B^+ \rightarrow p \bar{\Sigma}^0 \gamma)$	Belle [247] $< 4.6$	$< 4.6$
$\mathcal{B}(B^+ \rightarrow \pi^+ \ell^+ \ell^-)^3$	Belle [248] $< 0.049$ BaBar [249] $< 0.066$	$< 0.049$
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ e^-)^3$	Belle [248] $< 0.08$ BaBar [249] $< 0.125$	$< 0.08$
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \mu^-)^3$	BaBar [249] $< 0.055$ Belle [248] $< 0.069$ LHCb [250] <sup>4,5</sup>	$0.0178 \pm 0.0023$
$\mathcal{B}(B^+ \rightarrow \pi^+ \nu \bar{\nu})$	Belle [251] $< 14.0$ BaBar [252] $< 100.0$	$< 14$

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>5</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^+ \rightarrow K^+\ell^+\ell^-)^1$	LHCb [253]	$0.429 \pm 0.007 \pm 0.021$ <sup>2</sup>	$0.463 \pm 0.019$ <small>p=3.3%</small>
	BELLE [254]	$0.599^{+0.045}_{-0.043} \pm 0.014$	
	BaBar [255]	$0.476^{+0.092}_{-0.086} \pm 0.022$	
$\mathcal{B}(B^+ \rightarrow K^+e^+e^-)^1$	BELLE [254]	$0.575^{+0.064}_{-0.061} \pm 0.015$	$0.561 \pm 0.056$ $0.560^{+0.058}_{-0.055}$
	BaBar [255]	$0.51^{+0.12}_{-0.11} \pm 0.02$	
$\mathcal{B}(B^+ \rightarrow K^+\mu^+\mu^-)^{3,1}$	LHCb [253]	$0.429 \pm 0.007 \pm 0.021$	$0.450 \pm 0.021$ $0.453 \pm 0.035$
	BELLE [254]	$0.624^{+0.065}_{-0.061} \pm 0.016$	
	BaBar [255]	$0.41^{+0.16}_{-0.15} \pm 0.02$	
$\mathcal{B}(B^+ \rightarrow K^+\tau^+\tau^-)$	BaBar [256]	$< 2250.0$	$< 2250$
$\mathcal{B}(B^+ \rightarrow K^+\nu\bar{\nu})$	BaBar [257]	$< 16.0$	$< 16$
	Belle [251]	$< 19.0$	
	Belle II [258]	$< 41.0$	
$\mathcal{B}(B^+ \rightarrow \rho^+(770)\nu\bar{\nu})$	Belle [251]	$< 30.0$	$< 30$
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\ell^+\ell^-)^{3,1}$	LHCb [253]	$0.924 \pm 0.093 \pm 0.067$ <sup>2</sup>	$1.010 \pm 0.099$ $1.009^{+0.113}_{-0.112}$
	Belle [259]	$1.24^{+0.23}_{-0.21} \pm 0.13$	
	BaBar [255]	$1.40^{+0.40}_{-0.37} \pm 0.09$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+e^+e^-)^1$	BaBar [255]	$1.38^{+0.47}_{-0.42} \pm 0.08$	$1.55 \pm 0.33$ $1.55^{+0.36}_{-0.31}$
	Belle [259]	$1.73^{+0.50}_{-0.42} \pm 0.20$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\mu^+\mu^-)^1$	LHCb [253]	$0.924 \pm 0.093 \pm 0.067$	$0.96 \pm 0.10$
	Belle [259]	$1.11^{+0.32}_{-0.27} \pm 0.10$	
	BaBar [255]	$1.46^{+0.79}_{-0.75} \pm 0.12$	
$\mathcal{B}(B^+ \rightarrow K^*(892)^+\nu\bar{\nu})$	Belle [260]	$< 40.0$	$< 40$
	Belle [251]	$< 61.0$	
	BaBar [257]	$< 64.0$	
$\mathcal{B}(B^+ \rightarrow K^+\pi^+\pi^-\mu^+\mu^-)$	LHCb [261]	$0.4337^{+0.0287}_{-0.0268} \pm 0.0254$ <sup>4</sup>	$0.434 \pm 0.038$ $0.433^{+0.038}_{-0.037}$
$\mathcal{B}(B^+ \rightarrow \phi(1020)K^+\mu^+\mu^-)$	LHCb [261]	$0.0790^{+0.0180}_{-0.0160} {}^{+0.0114}_{-0.0072}$ <sup>5</sup>	$0.079^{+0.022}_{-0.017}$ $0.079^{+0.021}_{-0.017}$
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 p\nu\bar{\nu})$	BaBar [262]	$< 30.0$	$< 30$

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

<sup>2</sup> Only muons are used.

<sup>3</sup> The PDG uncertainty includes a scale factor.

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

<sup>5</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>	
$\mathcal{B}(B^0 \rightarrow \eta K^0 \gamma)$	BaBar [234]	$7.1^{+2.1}_{-2.0} \pm 0.4$ <sup>1</sup>	$7.6 \pm 1.8$
	Belle [235]	$8.7^{+3.1}_{-2.7} {}^{+1.9}_{-1.6}$ <sup>2</sup>	$7.6^{+1.8}_{-1.7}$
$\mathcal{B}(B^0 \rightarrow \eta' K^0 \gamma)$	Belle [236]	$< 6.4$ <sup>3</sup>	$< 6.4$
	BaBar [237]	$< 6.6$ <sup>1</sup>	
$\mathcal{B}(B^0 \rightarrow \phi(1020) K^0 \gamma)$	Belle [238]	$2.74 \pm 0.60 \pm 0.32$	$2.74 \pm 0.68$
	BaBar [239]	$< 27$ <sup>4</sup>	
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \gamma)$	Belle [240]	$4.6^{+1.3}_{-1.2} {}^{+0.5}_{-0.7}$ <sup>5</sup>	$4.6 \pm 1.4$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \gamma)$ <sup>6</sup>	Belle [228]	$39.6 \pm 0.7 \pm 1.4$	$42.1 \pm 1.1$ $41.8 \pm 2.5$
	BaBar [229]	$44.7 \pm 1.0 \pm 1.6$	
	Belle II [230]	$45 \pm 3 \pm 2$	
	CLEO [231]	$45.5^{+7.2}_{-6.8} \pm 3.4$	
	LHCb [202] <sup>7</sup> , [182] <sup>8</sup>		
$\mathcal{B}(B^0 \rightarrow K^*(1410)^0 \gamma)$	Belle [240]	$< 130.0$ <sup>5</sup>	$< 130$
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \gamma(\text{NR}))$	Belle [240]	$< 2.6$ <sup>5</sup>	$< 2.6$
$\mathcal{B}(K^{*0} X(214)) \times \mathcal{B}(X(214) \rightarrow \mu^+ \mu^-)$	Belle [263]	$< 0.0226$ <sup>9</sup>	$< 0.023$
$\mathcal{B}(B^0 \rightarrow K^0 \pi^+ \pi^- \gamma)$	BaBar [232]	$20.5 \pm 2.0^{+2.6}_{-2.2}$ <sup>10</sup>	$19.9 \pm 1.8$
	BaBar [242]	$18.5 \pm 2.1 \pm 1.2$ <sup>10</sup>	
	Belle [233]	$24.0 \pm 4.0 \pm 3.0$ <sup>11</sup>	
$\mathcal{B}(B^0 \rightarrow K^+ \pi^- \pi^0 \gamma)$	BaBar [242]	$40.7 \pm 2.2 \pm 3.1$ <sup>10</sup>	$40.7 \pm 3.8$
$\mathcal{B}(B^0 \rightarrow K_1(1270)^0 \gamma)$	Belle [233]	$< 58.0$	$< 58$

<sup>1</sup>  $M_{K\eta^{(\prime)}}$   $< 3.25$  GeV/ $c^2$ .

<sup>2</sup>  $M_{K\eta}$   $< 2.4$  GeV/ $c^2$ .

<sup>3</sup>  $M_{K\eta'}$   $< 3.4$  GeV/ $c^2$ .

<sup>4</sup>  $M_{\phi K}$   $< 3.0$  GeV/ $c^2$ .

<sup>5</sup>  $1.25 < M_{K\pi} < 1.6$  GeV/ $c^2$ .

<sup>6</sup> The PDG uncertainty includes a scale factor.

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

<sup>8</sup> 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.

<sup>9</sup>  $X(214)$  is searched in the mass range [212, 300] MeV/ $c^2$ .

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

<sup>11</sup>  $1 < M_{K\pi\pi} < 2$  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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K_S^0 K_S^0 \gamma)$	Belle [264]	$< 0.58$ <sup>1</sup>	$< 0.58$ none
$\mathcal{B}(B^0 \rightarrow f_2(1270)\gamma) \times \mathcal{B}(f_2(1270) \rightarrow K_S^0 K_S^0)$	Belle [264]	$< 0.31$ <sup>2</sup>	$< 0.31$ none
$\mathcal{B}(B^0 \rightarrow f_2'(1525)\gamma) \times \mathcal{B}(f_2'(1525) \rightarrow K_S^0 K_S^0)$	Belle [264]	$< 0.21$ <sup>3</sup>	$< 0.21$ none
$\mathcal{B}(B^0 \rightarrow K_1(1400)^0 \gamma)$	Belle [233]	$< 12.0$	$< 12$
$\mathcal{B}(B^0 \rightarrow K_2^*(1430)^0 \gamma)$	BaBar [243] Belle [240]	$12.2 \pm 2.5 \pm 1.0$ $13.0 \pm 5.0 \pm 1.0$	$12.4 \pm 2.4$
$\mathcal{B}(B^0 \rightarrow K_3^*(1780)^0 \gamma)$	Belle [235]	$< 21$	$< 21$ $< 83$
$\mathcal{B}(B^0 \rightarrow \rho^0(770)\gamma)$	Belle [245] BaBar [246]	$0.78^{+0.17}_{-0.16}^{+0.09}_{-0.10}$ $0.97^{+0.24}_{-0.22} \pm 0.06$	$0.86 \pm 0.15$
$\mathcal{B}(\rho^0 X(214)) \times \mathcal{B}(X(214) \rightarrow \mu^+ \mu^-)$	Belle [263]	$< 0.0173$ <sup>4</sup>	$< 0.017$
$\mathcal{B}(B^0 \rightarrow \omega(782)\gamma)$	Belle [245] BaBar [246]	$0.40^{+0.19}_{-0.17} \pm 0.13$ $0.50^{+0.27}_{-0.23} \pm 0.09$	$0.44 \pm 0.17$ $0.44^{+0.18}_{-0.16}$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\gamma)$	Belle [265] BaBar [266]	$< 0.1$ $< 0.85$	$< 0.1$
$\mathcal{B}(B^0 \rightarrow p\bar{\Lambda}^0 \pi^- \gamma)$	Belle [267]	$< 0.65$	$< 0.65$
$\mathcal{B}(B^0 \rightarrow \pi^0 \ell^+ \ell^-)^5$	BaBar [249] Belle [248]	$< 0.053$ $< 0.154$	$< 0.053$
$\mathcal{B}(B^0 \rightarrow \pi^0 e^+ e^-)^5$	BaBar [249] Belle [248]	$< 0.084$ $< 0.227$	$< 0.084$
$\mathcal{B}(B^0 \rightarrow \pi^0 \mu^+ \mu^-)^5$	BaBar [249] Belle [248]	$< 0.069$ $< 0.184$	$< 0.069$

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

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

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

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

<sup>5</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow \eta \ell^+ \ell^-)$	BaBar [249] $< 0.064$	$< 0.064$
$\mathcal{B}(B^0 \rightarrow \eta e^+ e^-)$	BaBar [249] $< 0.108$	$< 0.11$
$\mathcal{B}(B^0 \rightarrow \eta \mu^+ \mu^-)$	BaBar [249] $< 0.112$	$< 0.11$
$\mathcal{B}(B^0 \rightarrow \pi^0 \nu \bar{\nu})$	Belle [251] $< 9.0$	$< 9.0$
$\mathcal{B}(B^0 \rightarrow K^0 \ell^+ \ell^-)^1$	LHCb [253] $0.327 \pm 0.034 \pm 0.017^2$	$0.328 \pm 0.032$
	BELLE [254] $0.351^{+0.069}_{-0.060} \pm 0.010$	
	BaBar [255] $0.21^{+0.15}_{-0.13} \pm 0.02$	
$\mathcal{B}(B^0 \rightarrow K^0 e^+ e^-)^1$	BELLE [254] $0.306^{+0.098}_{-0.086} \pm 0.008$	$0.249 \pm 0.072$
	BaBar [255] $0.08^{+0.15}_{-0.12} \pm 0.01$	
$\mathcal{B}(B^0 \rightarrow K^0 \mu^+ \mu^-)^1$	LHCb [253] $0.327 \pm 0.034 \pm 0.017$	$0.341 \pm 0.034$
	BELLE [254] $0.394^{+0.096}_{-0.084} \pm 0.012$	
	BaBar [255] $0.49^{+0.29}_{-0.25} \pm 0.03$	
$\mathcal{B}(B^0 \rightarrow K^0 \nu \bar{\nu})$	Belle [251] $< 26.0$	$< 26$
	BaBar [257] $< 49.0$	
$\mathcal{B}(B^0 \rightarrow \rho^0(770) \nu \bar{\nu})$	Belle [251] $< 40.0$	$< 40$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \ell^+ \ell^-)^1$	Belle [259] $0.97^{+0.13}_{-0.11} \pm 0.07$	$0.99 \pm 0.12$
	BaBar [255] $1.03^{+0.22}_{-0.21} \pm 0.07$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)^1$	Belle [259] $1.18^{+0.27}_{-0.22} \pm 0.09$	$1.04 \pm 0.17$
	BaBar [255] $0.86^{+0.26}_{-0.24} \pm 0.05$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)^1$	LHCb [268] $0.904^{+0.016}_{-0.015} \pm 0.062^3$	$0.94 \pm 0.06$
	Belle [259] $1.06^{+0.19}_{-0.14} \pm 0.07$	
	BaBar [255] $1.35^{+0.40}_{-0.37} \pm 0.10$	

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

<sup>2</sup> Only muons are used.

<sup>3</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow \pi^+\pi^-\mu^+\mu^-)$	LHCb [154] <sup>1,2,3</sup>	$0.021 \pm 0.005$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0\nu\bar{\nu})$	Belle [251]	$< 18.0$
	Belle [260]	$< 55.0$
	BaBar [257]	$< 120.0$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\nu\bar{\nu})$	Belle [260]	$< 127$
$\mathcal{B}(B^0 \rightarrow \pi^0e^+\mu^- + c.c.)$	BaBar [269]	$< 0.14$
$\mathcal{B}(B^0 \rightarrow K^0e^+\mu^- + c.c.)$	BELLE [254]	$< 0.038$
	BaBar [270]	$< 0.27$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^+\mu^-)$	LHCb [215]	$< 0.0068$
	Belle [271]	$< 0.16$
	BaBar [270]	$< 0.53$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^-\mu^+)$	LHCb [215]	$< 0.0057$
	Belle [271]	$< 0.12$
	BaBar [270]	$< 0.34$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0e^+\mu^- + c.c.)$	LHCb [215]	$< 0.0101$
	Belle [271]	$< 0.18$
	BaBar [270]	$< 0.58$
$\mathcal{B}(B^0 \rightarrow \Lambda_c^+\mu^-)$	BaBar [272]	$< 1.4$
$\mathcal{B}(B^0 \rightarrow \Lambda_c^+e^-)$	BaBar [272]	$< 4.0$
$\mathcal{B}(B^0 \rightarrow \phi(1020)\mu^+\mu^-)$	LHCb [273]	$< 0.0032$ <sup>4</sup> none

<sup>1</sup> The mass windows corresponding to  $\phi$  and charmonium resonances decaying to  $\mu\mu$  are vetoed.

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

<sup>3</sup> 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.

<sup>4</sup> LHCb also reports an upper limit at  $2.3 \times 10^{-9}$  excluding the  $\phi$  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 <sup>HFLAV</sup> PDG
$\mathcal{B}(B \rightarrow K\eta\gamma)$	Belle [235] $8.5 \pm 1.3^{+1.2}_{-0.9}$ <sup>1</sup>	$8.5^{+1.8}_{-1.6}$
$\mathcal{B}(B \rightarrow K_1(1400)\gamma)$	CLEO [231] $< 127$	$< 127$
$\mathcal{B}(B \rightarrow K_2^*(1430)\gamma)$	CLEO [231] $16.6^{+5.9}_{-5.3} \pm 1.3$	$16.6^{+6.0}_{-5.5}$
$\mathcal{B}(B \rightarrow K_3^*(1780)\gamma)$	Belle [235] $< 9.3$	$< 9.3$ $< 37.0$
$\mathcal{B}(B \rightarrow X_s\gamma)$	Belle [274] $347 \pm 15 \pm 40$ <sup>2</sup> BaBar [275] $332 \pm 16 \pm 31$ <sup>2</sup> Belle [276] $375 \pm 18 \pm 35$ <sup>2</sup> BaBar [277] $352 \pm 20 \pm 51$ <sup>2</sup> CLEO [278] $329 \pm 44 \pm 29$ <sup>2</sup> BaBar [279] $390 \pm 91 \pm 64$ <sup>2</sup>	$349 \pm 19$
$\mathcal{B}(B \rightarrow X_d\gamma)$	BaBar [280] $9.2 \pm 2.0 \pm 2.3$	$9.2 \pm 3.0$
$\mathcal{B}(B \rightarrow \rho\gamma)^3$	Belle [245] $1.21^{+0.24}_{-0.22} \pm 0.12$ BaBar [246] $1.73^{+0.34}_{-0.32} \pm 0.17$	$1.40 \pm 0.22$ $1.39^{+0.25}_{-0.24}$
$\mathcal{B}(B \rightarrow \rho/\omega\gamma)^3$	Belle [245] $1.14 \pm 0.20^{+0.10}_{-0.12}$ BaBar [246] $1.63^{+0.30}_{-0.28} \pm 0.16$	$1.30 \pm 0.18$ $1.30^{+0.23}_{-0.24}$
$\mathcal{B}(B \rightarrow X_s e^+ e^-)^{3,4,5}$	BaBar [281] $7.69^{+0.82}_{-0.77} \pm 0.71 \pm 0.60$ <sup>6</sup> Belle [282] $4.04 \pm 1.30^{+0.87}_{-0.83}$	$6.67 \pm 0.83$ $6.67^{+1.76}_{-1.63}$
$\mathcal{B}(B \rightarrow X_s \mu^+ \mu^-)^{4,5}$	Belle [282] $4.13 \pm 1.05^{+0.85}_{-0.81}$ BaBar [281] $4.41^{+1.31}_{-1.17} \pm 0.63 \pm 0.50$ <sup>6</sup>	$4.27 \pm 0.95$ $4.27^{+0.99}_{-0.92}$
$\mathcal{B}(B \rightarrow X_s \ell^+ \ell^-)^{4,3,5}$	BaBar [281] $6.73^{+0.70}_{-0.64} \pm 0.60 \pm 0.56$ <sup>6</sup> Belle [282] $4.11 \pm 0.83^{+0.85}_{-0.81}$	$5.84 \pm 0.69$ $5.84^{+1.31}_{-1.23}$

<sup>1</sup>  $M_{K\eta} < 2.4 \text{ GeV}/c^2$ .

<sup>2</sup> Measurement extrapolated to  $E_\gamma > 1.6 \text{ GeV}$  using the method from Ref. [283].

<sup>3</sup> The PDG uncertainty includes a scale factor.

<sup>4</sup> Belle uses  $m_{\ell^+\ell^-} > 0.2 \text{ GeV}/c^2$ , Babar uses  $m_{\ell^+\ell^-} > 0.1 \text{ GeV}/c^2$ .

<sup>5</sup> Treatment of charmonium intermediate components differs between the results.

<sup>6</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B \rightarrow \pi \ell^+ \ell^-)^1$	BaBar [249] $< 0.059$ Belle [248] $< 0.062$	$< 0.059$
$\mathcal{B}(B \rightarrow \pi e^+ e^-)$	BaBar [249] $< 0.11$	$< 0.11$
$\mathcal{B}(B \rightarrow \pi \mu^+ \mu^-)$	BaBar [249] $< 0.05$	$< 0.05$
$\mathcal{B}(B \rightarrow K e^+ e^-)^1$	Belle [259] $0.48^{+0.08}_{-0.07} \pm 0.03$ BaBar [255] $0.388^{+0.090}_{-0.083} \pm 0.020$	$0.44 \pm 0.06$
$\mathcal{B}(B \rightarrow K^* e^+ e^-)^{2,1}$	Belle [259] $1.39^{+0.23}_{-0.20} \pm 0.12$ BaBar [255] $0.99^{+0.23}_{-0.21} \pm 0.06$ Belle II [284] $1.42 \pm 0.48 \pm 0.09$ <sup>3,4</sup>	$1.22 \pm 0.16$ $1.19^{+0.21}_{-0.19}$
$\mathcal{B}(B \rightarrow K \mu^+ \mu^-)^1$	CDF [179] $0.42 \pm 0.04 \pm 0.02$ Belle [259] $0.50 \pm 0.06 \pm 0.03$ BaBar [255] $0.41^{+0.13}_{-0.12} \pm 0.02$	$0.442 \pm 0.036$
$\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)^1$	CDF [179] $1.01 \pm 0.10 \pm 0.05$ Belle [259] $1.10^{+0.16}_{-0.14} \pm 0.08$ Belle II [284] $1.19 \pm 0.31^{+0.08}_{-0.07}$ <sup>3</sup> BaBar [255] $1.35^{+0.35}_{-0.33} \pm 0.10$	$1.07 \pm 0.09$ $1.06 \pm 0.09$
$\mathcal{B}(B \rightarrow K \ell^+ \ell^-)^1$	Belle [259] $0.48^{+0.05}_{-0.04} \pm 0.03$ BaBar [285] $0.47 \pm 0.06 \pm 0.02$	$0.48 \pm 0.04$
$\mathcal{B}(B \rightarrow K^* \ell^+ \ell^-)^1$	Belle [259] $1.07^{+0.11}_{-0.10} \pm 0.09$ BaBar [285] $1.02^{+0.14}_{-0.13} \pm 0.05$ Belle II [284] $1.25 \pm 0.30^{+0.08}_{-0.07}$ <sup>3,4</sup>	$1.07 \pm 0.10$ $1.05 \pm 0.10$

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

<sup>2</sup> The PDG uncertainty includes a scale factor.

<sup>3</sup>  $J/\psi$  and  $\psi(2S)$  regions are vetoed.

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

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	<sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B \rightarrow K\nu\bar{\nu})$	Belle [251]	$< 16.0$	$< 16$
	BaBar [257]	$< 17.0$	
$\mathcal{B}(B \rightarrow K^*\nu\bar{\nu})$	Belle [251]	$< 27.0$	$< 27$
	BaBar [257]	$< 76.0$	
$\mathcal{B}(B \rightarrow \pi\nu\bar{\nu})$	Belle [251]	$< 8.0$	$< 8.0$
$\mathcal{B}(B \rightarrow \rho\nu\bar{\nu})$	Belle [251]	$< 28.0$	$< 28$
$\mathcal{B}(B \rightarrow \pi e^\pm\mu^\mp)$	BaBar [269]	$< 0.092$	$< 0.092$
$\mathcal{B}(B \rightarrow \rho e^\pm\mu^\mp)$	CLEO [286]	$< 3.2$	$< 3.2$
$\mathcal{B}(B \rightarrow Ke^\pm\mu^\mp)$	BaBar [270]	$< 0.038$	$< 0.038$
$\mathcal{B}(B \rightarrow K^*e^\pm\mu^\mp)$	BaBar [270]	$< 0.51$	$< 0.51$

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

Parameter [ $10^{-7}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow e^+\nu_e)$	Belle [287] < 9.8 BaBar [288] < 19	< 9.8
$\mathcal{B}(B^+ \rightarrow \mu^+\nu_\mu)$	Belle [289] < 8.6 BaBar [288] < 10 Belle [290] < 10.7	< 8.6
$\mathcal{B}(B^+ \rightarrow \tau^+\nu_\tau)^1$	Belle [291] $720^{+270}_{-250} \pm 110$ Belle [292] $1250 \pm 280 \pm 270$ BaBar [293] $1830^{+530}_{-490} \pm 240$ BaBar [294] $1700 \pm 800 \pm 200$	$1094 \pm 208$ $1094^{+247}_{-236}$
$\mathcal{B}(B^+ \rightarrow \ell^+\nu_\ell\gamma)$	Belle [295] < $30^2$ BaBar [296] < 156	< 30
$\mathcal{B}(B^+ \rightarrow e^+\nu_e\gamma)$	Belle [295] < $43^2$ BaBar [296] < 170	< 43
$\mathcal{B}(B^+ \rightarrow \mu^+\nu_\mu\gamma)$	Belle [295] < $34^2$ BaBar [296] < 260	< 34
$\mathcal{B}(B^0 \rightarrow \gamma\gamma)$	BaBar [297] < 3.3 Belle [298] < 6.2	< 3.3 < 3.2
$\mathcal{B}(B^0 \rightarrow e^+e^-)$	LHCb [207] < 0.025 CDF [208] < 0.83 BaBar [299] < 1.13 Belle [300] < 1.9	< 0.025
$\mathcal{B}(B^0 \rightarrow e^+e^-\gamma)$	BaBar [301] < 1.2	< 1.2
$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$	CMS [203] < 0.0015 ATLAS [205] < $0.0021^3$ LHCb [204] < 0.0023 CDF [206] < 0.038 BaBar [299] < 0.52 Belle [300] < 1.6	< 0.0015 $0.0007^{+0.0013}_{-0.0011}$

<sup>1</sup> The PDG uncertainty includes a scale factor.

<sup>2</sup>  $E_\gamma > 1$  GeV.

<sup>3</sup> 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^- \gamma)$	BaBar [301] $< 1.5$	$< 1.5$ $< 0.0$
$\mathcal{B}(B^0 \rightarrow \mu^+ \mu^- \mu^+ \mu^-)$	LHCb [210] $< 0.0018$ <sup>1,2</sup>	$< 0.0018$ $< 0.0069$
$\mathcal{B}(B^0 \rightarrow SP) \times \mathcal{B}(S \rightarrow \mu^+ \mu^-) \times \mathcal{B}(P \rightarrow \mu^+ \mu^-)$	LHCb [306] $< 0.006$ <sup>1,2</sup>	$< 0.0060$
$\mathcal{B}(B^0 \rightarrow aa) \times \mathcal{B}(a \rightarrow \mu^+ \mu^-) \times \mathcal{B}(a \rightarrow \mu^+ \mu^-)$	LHCb [210] $< 0.0023$ <sup>1,3,2</sup>	$< 0.0023$ none
$\mathcal{B}(B^0 \rightarrow \tau^+ \tau^-)^4$	LHCb [209] $< 16000$ BaBar [302] $< 41000$	$< 16000$ $< 21000$
$\mathcal{B}(B^0 \rightarrow \nu \bar{\nu})$	BaBar [303] $< 240$ Belle [304] $< 780$	$< 240$
$\mathcal{B}(B^0 \rightarrow \nu \bar{\nu} \gamma)$	Belle [304] $< 160$ <sup>5</sup> BaBar [303] $< 170$ <sup>6</sup>	$< 160$
$\mathcal{B}(B^+ \rightarrow \mu^+ \mu^- \mu^+ \nu_\mu)$	LHCb [305] $< 0.16$ <sup>2</sup>	$< 0.16$

<sup>1</sup> The mass windows corresponding to  $\phi$  and charmonium resonances decaying to  $\mu\mu$  are vetoed.

<sup>2</sup> At CL=95%.

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

<sup>4</sup> PDG shows the result obtained at 95% CL.

<sup>5</sup>  $E_\gamma > 0.5$  GeV.

<sup>6</sup>  $E_\gamma > 1.2$  GeV.

Table 61: Relative branching fractions of charmless radiative and FCNC decays with leptons of  $B^+$  and  $B^0$  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 [250]	$0.038 \pm 0.009 \pm 0.001$	$0.038 \pm 0.009$
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$ , Full $m_{\ell^+ \ell^-}^2$ range	BELLE [254]	$1.08^{+0.16}_{-0.15} \pm 0.02$	$1.08 \pm 0.16$
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$ , $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [307]	$0.846^{+0.042}_{-0.039} {}^{+0.013}_{-0.012}$ <sup>1</sup>	$0.846 \pm 0.042$
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$ , $0.10 < m_{\ell^+ \ell^-}^2 < 8.12 \text{ GeV}^2/c^4$ and $m_{\ell^+ \ell^-}^2 > 10.11 \text{ GeV}^2/c^4$	BaBar [285]	$1.00^{+0.31}_{-0.25} \pm 0.07$	$1.00^{+0.32}_{-0.26}$
$\frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$ , $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ <sup>2</sup>	BELLE [254]	$1.39^{+0.36}_{-0.33} \pm 0.02$	$1.39 \pm 0.35$
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K_S^0 e^+ e^-)}$ , Full $m_{\ell^+ \ell^-}^2$ range	BELLE [254]	$1.29^{+0.52}_{-0.45} \pm 0.01$	$1.29^{+0.52}_{-0.45}$
$\frac{\mathcal{B}(B^0 \rightarrow K_S^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K_S^0 e^+ e^-)}$ , $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ <sup>2</sup>	BELLE [254]	$0.55^{+0.46}_{-0.34} \pm 0.01$	$0.55^{+0.46}_{-0.34}$
$\frac{\mathcal{B}(B \rightarrow K \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K e^+ e^-)}$ , Full $m_{\ell^+ \ell^-}^2$ range	BELLE [254]	$1.10^{+0.16}_{-0.15} \pm 0.02$	$1.10 \pm 0.16$
$\frac{\mathcal{B}(B \rightarrow K \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K e^+ e^-)}$ , $1.0 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$ <sup>2</sup>	BELLE [254]	$1.03^{+0.28}_{-0.24} \pm 0.01$	$1.03^{+0.28}_{-0.24}$

<sup>1</sup> LHCb has also measured the branching fraction of  $B^+ \rightarrow K^+ e^+ e^-$  in the  $m_{\ell^+ \ell^-}^2$  bin  $[1.1, 6.0] \text{ GeV}^2/c^4$ .

<sup>2</sup> For the other bins see the article.

Table 62: Relative branching fractions of charmless radiative and FCNC decays with leptons of  $B^+$  and  $B^0$  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 [259]	$0.83 \pm 0.17 \pm 0.08$	$0.83 \pm 0.19$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$ , $0.10 < m_{\ell^+ \ell^-}^2 < 8.12 \text{ GeV}^2/c^4$ and $m_{\ell^+ \ell^-}^2 > 10.11 \text{ GeV}^2/c^4$	BaBar [285]	$1.13^{+0.34}_{-0.26} \pm 0.10$	$1.13^{+0.35}_{-0.28}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$ , $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	Belle [308]	$0.52^{+0.36}_{-0.26} \pm 0.06$	$0.52^{+0.36}_{-0.27}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$ , $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	Belle [308]	$0.96^{+0.45}_{-0.29} \pm 0.11$	$0.96^{+0.46}_{-0.31}$
$\frac{\mathcal{B}(B \rightarrow K^* \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^* e^+ e^-)}$ , $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [308]	$1.18^{+0.52}_{-0.32} \pm 0.11$	$1.18^{+0.53}_{-0.34}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$ , $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	LHCb [309] Belle [308]	$0.66^{+0.11}_{-0.07} \pm 0.03$ $0.46^{+0.55}_{-0.27} \pm 0.13$	$0.65^{+0.11}_{-0.07}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$ , $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [309] Belle [308]	$0.69^{+0.11}_{-0.07} \pm 0.05$ $1.06^{+0.63}_{-0.38} \pm 0.14$	$0.72^{+0.12}_{-0.09}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-)}{\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ e^-)}$ , $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [308]	$1.12^{+0.61}_{-0.36} \pm 0.10$	$1.12^{+0.62}_{-0.37}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$ , $0.045 < m_{\ell^+ \ell^-}^2 < 1.1 \text{ GeV}^2/c^4$	Belle [308]	$0.62^{+0.60}_{-0.36} \pm 0.09$	$0.62^{+0.61}_{-0.37}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$ , $1.1 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	Belle [308]	$0.72^{+0.99}_{-0.44} \pm 0.15$	$0.7^{+1.0}_{-0.5}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$ , $15 < m_{\ell^+ \ell^-}^2 < 19 \text{ GeV}^2/c^4$	Belle [308]	$1.40^{+1.99}_{-0.68} \pm 0.12$	$1.4^{+2.0}_{-0.7}$
$\frac{\mathcal{B}(B^+ \rightarrow K^*(892)^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ e^-)}$ , $0.045 < m_{\ell^+ \ell^-}^2 < 6.0 \text{ GeV}^2/c^4$	LHCb [310]	$0.70^{+0.18}_{-0.13}^{+0.03}_{-0.04}$	$0.70^{+0.18}_{-0.14}$
$\frac{\mathcal{B}(B^0 \rightarrow K^*(892)^0 \gamma)}{\mathcal{B}(B_s^0 \rightarrow \phi(1020) \gamma)}$	LHCb [202] Belle [228]	$1.23 \pm 0.06 \pm 0.11$ <sup>1</sup> $1.10 \pm 0.16 \pm 0.20$ <sup>1</sup>	$1.21 \pm 0.11$
$\frac{\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-)}$ [ $10^{-2}$ ]	LHCb [204]	$< 8.1$	$< 8.1$
$\frac{\mathcal{B}(B^0 \rightarrow \phi(1020) \mu^+ \mu^-)}{\mathcal{B}(B_s^0 \rightarrow \phi(1020) \mu^+ \mu^-)}$ [ $10^{-3}$ ]	LHCb [273]	$< 4.4$ <sup>2</sup>	$< 4.4$

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

<sup>2</sup>  $\phi$  and charmonium regions excluded from the dimuon spectrum.

Table 63: Branching fractions of  $B^+/B^0 \rightarrow \bar{q}$  gluon decays.

Parameter [ $10^{-4}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B \rightarrow \eta X)$	Belle [311]	$2.610 \pm 0.300^{+0.440}_{-0.740}$ <sup>1</sup>
	CLEO [312]	$< 4.400$ <sup>2</sup>
$\mathcal{B}(B \rightarrow \eta' X)$	BaBar [313]	$3.90 \pm 0.80 \pm 0.90$ <sup>3</sup>
	CLEO [314]	$4.60 \pm 1.10 \pm 0.60$ <sup>3</sup>
$\mathcal{B}(B \rightarrow K^+ X)$	BaBar [315]	$< 1.87$ <sup>4</sup>
$\mathcal{B}(B \rightarrow K^0 X)$	BaBar [315]	$1.95^{+0.51}_{-0.45} \pm 0.50$ <sup>4</sup>
		$1.95^{+0.71}_{-0.67}$
$\mathcal{B}(B \rightarrow \pi^+ X)$	BaBar [315]	$3.72^{+0.50}_{-0.47} \pm 0.59$ <sup>5</sup>
		$3.72 \pm 0.76$
		$3.72^{+0.77}_{-0.75}$

<sup>1</sup>  $0.4 < m_X < 2.6$  GeV/ $c^2$ .

<sup>2</sup>  $2.1 < p_\eta < 2.7$  GeV/ $c$ .

<sup>3</sup>  $2.0 < p^*(\eta') < 2.7$  GeV/ $c$ .

<sup>4</sup>  $p^*(K) < 2.34$  GeV/ $c$ .

<sup>5</sup>  $p^*(\pi^+) < 2.36$  GeV/ $c$ .

Table 64: 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 <sup>HFLAV</sup> <sub>PDG</sub>
$\Delta_{0-}(B \rightarrow X_s\gamma)$	Belle [316] $-0.0048 \pm 0.0149 \pm 0.0150$ <sup>1,2</sup>	$-0.005 \pm 0.020$
	BaBar [317] $-0.006 \pm 0.058 \pm 0.026$ <sup>1,2</sup>	
$\Delta_{0-}(B \rightarrow X_{s+d}\gamma)$	BaBar [279] $-0.06 \pm 0.15 \pm 0.07$ <sup>3</sup>	$-0.06 \pm 0.17$
$\Delta_{0+}(B \rightarrow K^*\gamma)$	Belle [228] $0.062 \pm 0.015 \pm 0.013$ <sup>2</sup>	$0.063 \pm 0.017$
	BaBar [229] $0.066 \pm 0.021 \pm 0.022$	
$\frac{\Gamma(B^+ \rightarrow \rho^+\gamma)}{2\Gamma(B^0 \rightarrow \rho^0\gamma)} - 1$	Belle [245] $-0.48^{+0.21}_{-0.19} +0.08_{-0.09}$	$-0.46 \pm 0.17$
	BaBar [246] $-0.43^{+0.25}_{-0.22} \pm 0.10$	
$\Delta_{0-}(B \rightarrow K\ell^+\ell^-)^4$	LHCb [253] $-0.10^{+0.08}_{-0.09} \pm 0.02$ <sup>5</sup>	$-0.191^{+0.073}_{-0.071}$ $-0.150 \pm 0.060$
	BELLE [254] $-0.31^{+0.13}_{-0.11} \pm 0.01$ <sup>6</sup>	
	BaBar [285] $-0.41 \pm 0.25 \pm 0.01$ <sup>6</sup>	
$\Delta_{0-}(B \rightarrow K^*\ell^+\ell^-)^4$	BaBar [285] $-0.20^{+0.30}_{-0.23} \pm 0.03$ <sup>6</sup>	$-0.01^{+0.11}_{-0.09}$ $-0.03^{+0.08}_{-0.07}$
	Belle [259] $0.33^{+0.37}_{-0.43} \pm 0.08$ <sup>6</sup>	
	LHCb [253] $0.00^{+0.12}_{-0.10} \pm 0.02$ <sup>5</sup>	
$\Delta_{0-}(B \rightarrow K^{(*)}\ell^+\ell^-)^4$	Belle [259] $-0.30^{+0.12}_{-0.11} \pm 0.08$ <sup>7</sup>	$-0.45 \pm 0.10$
	BaBar [255] $-0.64^{+0.15}_{-0.14} \pm 0.03$ <sup>8</sup>	

<sup>1</sup>  $M_{X_s} < 2.8 \text{ GeV}/c^2$ .

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

<sup>3</sup>  $E_\gamma > 2.2 \text{ GeV}$ .

<sup>4</sup> The PDG uncertainty includes a scale factor.

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

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

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

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

Table 65: Branching fractions of charmless semileptonic  $B^+$  decays to LFV and LNV final states (part 1).

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \mu^- + \text{c.c.})$	BaBar [269] < 0.17	< 0.17
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \tau^-)$	BaBar [318] < 74.0	< 74
$\mathcal{B}(B^+ \rightarrow \pi^+ e^- \tau^+)$	BaBar [318] < 20.0	< 20
$\mathcal{B}(B^+ \rightarrow \pi^+ e^+ \tau^- + \text{c.c.})$	BaBar [318] < 75.0	< 75
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \tau^-)$	BaBar [318] < 62.0	< 62
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^- \tau^+)$	BaBar [318] < 45.0	< 45
$\mathcal{B}(B^+ \rightarrow \pi^+ \mu^+ \tau^- + \text{c.c.})$	BaBar [318] < 72.0	< 72
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^-)$	LHCb [319] < 0.0070	
	BELLE [254] < 0.03	< 0.007
	BaBar [270] < 0.091	
$\mathcal{B}(B^+ \rightarrow K^+ e^- \mu^+)$	LHCb [319] < 0.0064	
	BELLE [254] < 0.085	< 0.0064
	BaBar [270] < 0.13	
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^- + \text{c.c.})$	BaBar [270] < 0.091	< 0.091
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \tau^-)$	BaBar [318] < 43.0	< 43
$\mathcal{B}(B^+ \rightarrow K^+ e^- \tau^+)$	BaBar [318] < 15.0	< 15
$\mathcal{B}(B^+ \rightarrow K^+ e^+ \tau^- + \text{c.c.})$	BaBar [318] < 30.0	< 30
$\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \tau^-)$	BaBar [318] < 45.0	< 45
$\mathcal{B}(B^+ \rightarrow K^+ \mu^- \tau^+)$	BaBar [318] < 28.0	< 28
	LHCb [320] < 39.0	
$\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \tau^- + \text{c.c.})$	BaBar [318] < 48.0	< 48
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ \mu^-)$	BaBar [270] < 1.30	< 1.3
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^- \mu^+)$	BaBar [270] < 0.99	< 0.99
$\mathcal{B}(B^+ \rightarrow K^*(892)^+ e^+ \mu^- + \text{c.c.})$	BaBar [270] < 1.40	< 1.4
$\mathcal{B}(B^+ \rightarrow \pi^- e^+ e^+)$	BaBar [321] < 0.023	< 0.023
$\mathcal{B}(B^+ \rightarrow \pi^- \mu^+ \mu^+)$	LHCb [322] < 0.0040 <sup>1</sup>	
	BaBar [321] < 0.107	< 0.004
$\mathcal{B}(B^+ \rightarrow \pi^- e^+ \mu^+)$	BaBar [323] < 0.15	< 0.15
$\mathcal{B}(B^+ \rightarrow \rho^-(770) e^+ e^+)$	BaBar [323] < 0.17	< 0.17
$\mathcal{B}(B^+ \rightarrow \rho^-(770) \mu^+ \mu^+)$	BaBar [323] < 0.42	< 0.42
$\mathcal{B}(B^+ \rightarrow \rho^-(770) e^+ \mu^+)$	BaBar [323] < 0.47	< 0.47

<sup>1</sup> At CL=95%.

Table 66: Branching fractions of charmless semileptonic  $B^+$  decays to LFV and LNV final states (part 2).

Parameter [ $10^{-6}$ ]	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^+ \rightarrow K^- e^+ e^+)$	BaBar [321] < 0.030	< 0.030
$\mathcal{B}(B^+ \rightarrow K^- \mu^+ \mu^+)$	LHCb [324] < 0.041 BaBar [321] < 0.067	< 0.041
$\mathcal{B}(B^+ \rightarrow K^- e^+ \mu^+)$	BaBar [323] < 0.16	< 0.16
$\mathcal{B}(B^+ \rightarrow K^*(892)^- e^+ e^+)$	BaBar [323] < 0.40	< 0.40
$\mathcal{B}(B^+ \rightarrow K^*(892)^- \mu^+ \mu^+)$	BaBar [323] < 0.59	< 0.59
$\mathcal{B}(B^+ \rightarrow K^*(892)^- e^+ \mu^+)$	BaBar [323] < 0.30	< 0.30
$\mathcal{B}(B^+ \rightarrow D^- e^+ e^+)$	BaBar [323] < 2.6 BELLE [325] < 2.6	< 2.6
$\mathcal{B}(B^+ \rightarrow D^- e^+ \mu^+)$	BELLE [325] < 1.8 BaBar [323] < 2.1	< 1.8
$\mathcal{B}(B^+ \rightarrow D^- \mu^+ \mu^+)$	LHCb [326] < 0.69 <sup>1</sup> BELLE [325] < 1.0 BaBar [323] < 1.7	< 0.69
$\mathcal{B}(B^+ \rightarrow D^*(2010)^- \mu^+ \mu^+)$	LHCb [326] < 2.4 <sup>1</sup>	< 2.4
$\mathcal{B}(B^+ \rightarrow D_s^- \mu^+ \mu^+)$	LHCb [326] < 0.58 <sup>1</sup>	< 0.58
$\mathcal{B}(B^+ \rightarrow \bar{D}^0 \pi^- \mu^+ \mu^+)$	LHCb [326] < 1.5 <sup>1</sup>	< 1.5
$\mathcal{B}(B^+ \rightarrow \Lambda^0 \mu^+)$	BaBar [272] < 0.061	< 0.061 < 0.060
$\mathcal{B}(B^+ \rightarrow \Lambda^0 e^+)$	BaBar [272] < 0.032	< 0.032
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 \mu^+)$	BaBar [272] < 0.062	< 0.062 < 0.060
$\mathcal{B}(B^+ \rightarrow \bar{\Lambda}^0 e^+)$	BaBar [272] < 0.081	< 0.081 < 0.080

<sup>1</sup> At CL=95 %.

Table 67: Branching fractions of charmless semileptonic  $B^0$  decays to LFV and LNV final states.

Parameter [ $10^{-6}$ ]	Measurements	Average	<sup>HFLAV</sup> <sub>PDG</sub>
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^- \mu^+)$	LHCb [215]	$< 0.0057$	$< 0.0057$
	Belle [271]	$< 0.12$	$< 0.1200$
	BaBar [270]	$< 0.34$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ \mu^-)$	LHCb [215]	$< 0.0068$	$< 0.0068$
	Belle [271]	$< 0.16$	$< 0.1600$
	BaBar [270]	$< 0.53$	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 e^+ \mu^- + \text{c.c.})$	LHCb [215]	$< 0.0101$	$< 0.010$
	Belle [271]	$< 0.18$	$< 0.180$
	BaBar [270]	$< 0.58$	
$\mathcal{B}(B^0 \rightarrow K^0 e^+ \mu^- + \text{c.c.})$	BELLE [254]	$< 0.038$	$< 0.038$
	BaBar [270]	$< 0.27$	
$\mathcal{B}(B^0 \rightarrow \pi^0 e^+ \mu^- + \text{c.c.})$	BaBar [269]	$< 0.14$	$< 0.14$
$\mathcal{B}(B^0 \rightarrow e^+ \mu^- + \text{c.c.})$	LHCb [213]	$< 0.0010$	
	CDF [208]	$< 0.064$	
	BaBar [299]	$< 0.092$	$< 0.001$
	Belle [300]	$< 0.17$	
$\mathcal{B}(B^0 \rightarrow e^+ \tau^- + \text{c.c.})$	BaBar [327]	$< 28.0$	$< 28$
		$< 16$	
$\mathcal{B}(B^0 \rightarrow \mu^+ \tau^- + \text{c.c.})$	LHCb [214]	$< 12.0$	$< 12$
	BaBar [327]	$< 22.0$	$< 14$
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \tau^+ \mu^-)$	LHCb [328]	$< 10$	$< 10$
		none	
$\mathcal{B}(B^0 \rightarrow K^*(892)^0 \tau^- \mu^+)$	LHCb [328]	$< 8.2$	$< 8.2$
		none	
$\mathcal{B}(B^0 \rightarrow \tau^\pm \mu^\mp)$	Belle [329]	$< 15$	$< 15$
		none	
$\mathcal{B}(B^0 \rightarrow \tau^\pm e^\mp)$	Belle [329]	$< 16$	$< 16$
		none	
$\mathcal{B}(B^0 \rightarrow p \mu^-)$	LHCb [217]	$< 0.0026$	$< 0.0026$
		none	

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

- In Ref. [330], 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  $A_{\text{FB}}$  in 17 (5) bins of  $m^2(\ell^+\ell^-)$  for the  $K^+$  ( $K_s^0$ ) final state [331]. Belle measures  $F_L$  and  $A_{\text{FB}}$  in 6  $m^2(\ell^+\ell^-)$  [259].
- 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  $F_L$ ,  $A_T^{(2)}$ ,  $A_T^{\text{Im}}$ ,  $A_T^{\text{Re}}$  in the  $[0.0008, 0.257]$   $\text{GeV}^2/c^4$  bin of  $m^2(\ell^+\ell^-)$  putting constraints on the  $B \rightarrow K^{*0}\gamma$  photon polarization [332]. In Ref. [333], LHCb determines the branching fraction in the dilepton mass region  $[0.0009, 1.0]$   $\text{GeV}^2/c^4$ .
  - $B \rightarrow K^*\ell^-\ell^+$  : Belle measures  $F_L$ ,  $A_{\text{FB}}$ , isospin asymmetry in 6  $m^2(\ell^+\ell^-)$  bins [259] and  $P'_4$ ,  $P'_5$ ,  $P'_6$ ,  $P'_8$  in 4  $m^2(\ell^+\ell^-)$  bins [334]. In a more recent paper [335], 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  $[1, 6]$   $\text{GeV}^2/c^4$ . 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  $F_L$ ,  $A_{\text{FB}}$ ,  $P_2$  in 5  $m^2(\ell^+\ell^-)$  bins [336].
  - $B^0 \rightarrow K^{*0}\mu^-\mu^+$  : LHCb measures  $F_L$ ,  $A_{\text{FB}}$ ,  $S_3 - S_9$ ,  $A_3 - A_9$ ,  $P_1 - P_3$ ,  $P'_4 - P'_8$  in 8  $m^2(\ell^+\ell^-)$  bins [337]. An updated measurement of the  $CP$ -averaged observables is presented in Ref. [338]. CMS measures  $F_L$  and  $A_{\text{FB}}$  in 7  $m^2(\ell^+\ell^-)$  bins [339], as well as  $P_1$ ,  $P'_5$  [340]. ATLAS measures  $F_L$ ,  $S_{3,4,5,7,8}$  and  $P'_{1,4,5,6,8}$  in 6  $m^2(\ell^+\ell^-)$  bins [341].
  - $B^+ \rightarrow K^{*+}\mu^-\mu^+$ : LHCb reports the full set of  $CP$ -averaged angular observables in 8  $m^2(\ell^+\ell^-)$  bins [342]. CMS measures  $F_L$  and  $A_{\text{FB}}$  in 3  $m^2(\ell^+\ell^-)$  bins [343].
- $B \rightarrow X_s\ell^-\ell^+$  (where  $X_s$  is a hadronic system with an  $s$  quark): Belle measures  $A_{\text{FB}}$  in bins of  $m^2(\ell^+\ell^-)$  with a sum of 10 exclusive final states [344].
- $B^0 \rightarrow K^+\pi^-\mu^+\mu^-$ , with  $1330 < m(K^+\pi^-) < 1530$   $\text{GeV}/c^2$ : LHCb measures the partial branching fraction in bins of  $m^2(\mu^+\mu^-)$  in the range  $[0.1, 8.0]$   $\text{GeV}^2/c^4$ , and reports angular moments [345].
- In Ref. [346], 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  $J/\psi$  and  $\psi(2S)$  resonances and far from their poles, to probe long and short distance effects, respectively.
- In Ref. [347], 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,  $A_{\text{FB}}$  and the contribution  $F_H$  from the pseudoscalar, scalar and tensor amplitudes to the decay.
- In Ref. [348], LHCb performs a search for a hidden-sector boson  $\chi$  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  $214 < m(\chi) < 4350$   $\text{MeV}/c^2$  and  $0 < \tau(\chi) < 1000$  ps.

- In Ref. [349], LHCb performs a search for a hypothetical new scalar particle  $\chi$ , 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  $\tau(\chi)$ .

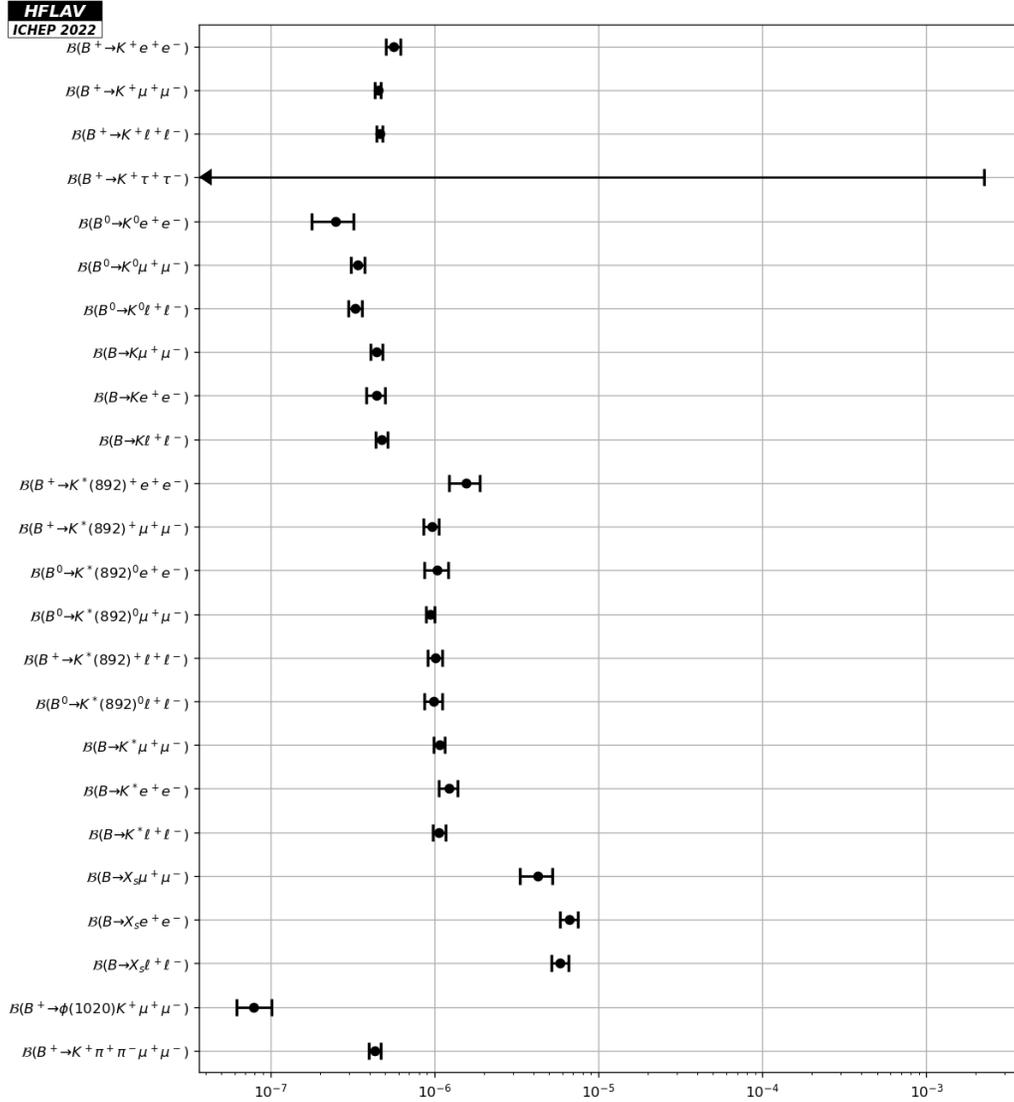


Figure 7: Branching fractions of  $B^+$  and  $B^0$  decays of the type  $b \rightarrow s \ell^+ \ell^-$ .

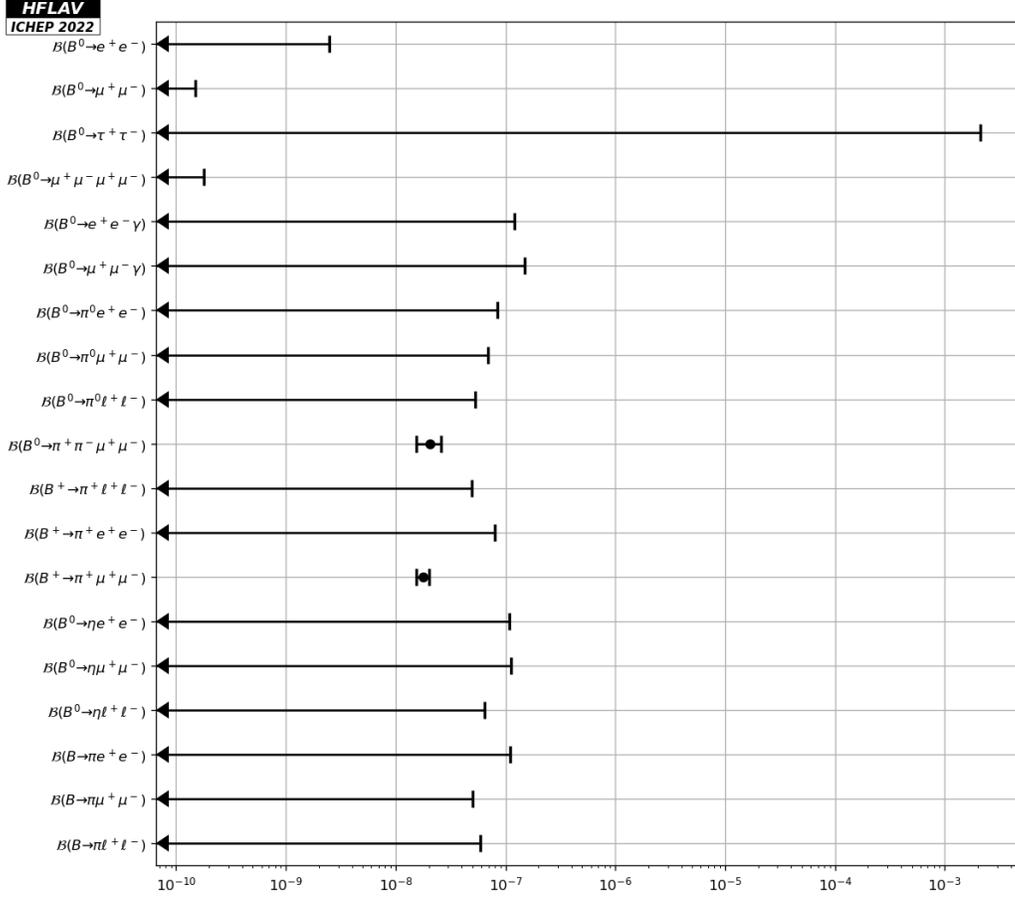


Figure 8: Branching fractions of  $B^+$  and  $B^0$  decays of the type  $b \rightarrow ul^+\ell^-$ , purely leptonic and leptonic radiative.

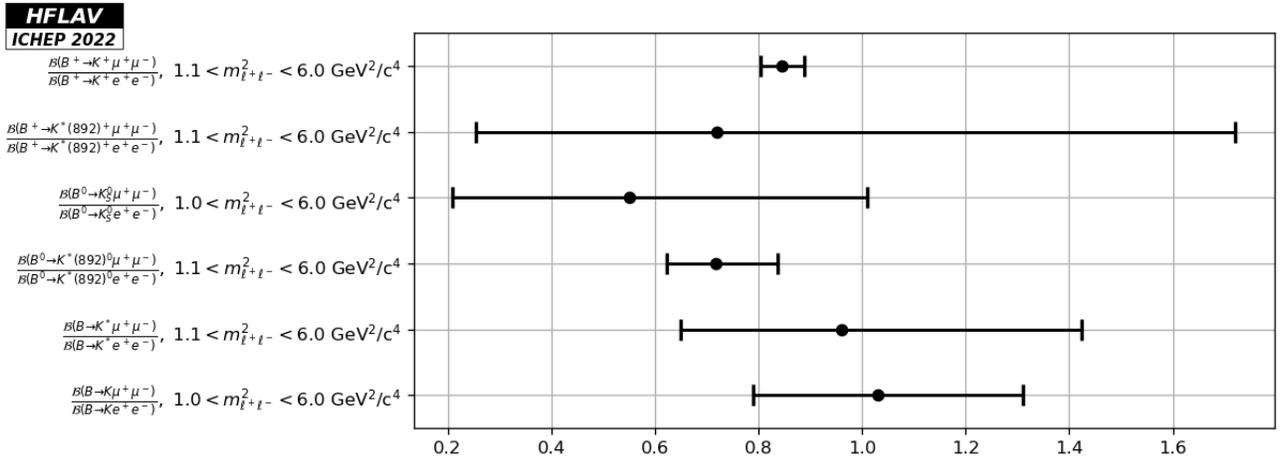


Figure 9: Compilation of  $R_K^{(*)}$  ratios in the low dilepton invariant-mass region. These are ratios between branching fractions of  $B$ -meson decays to  $K^{(*)}\mu^+\mu^-$  and  $K^{(*)}e^+e^-$ , which provide information on lepton universality.

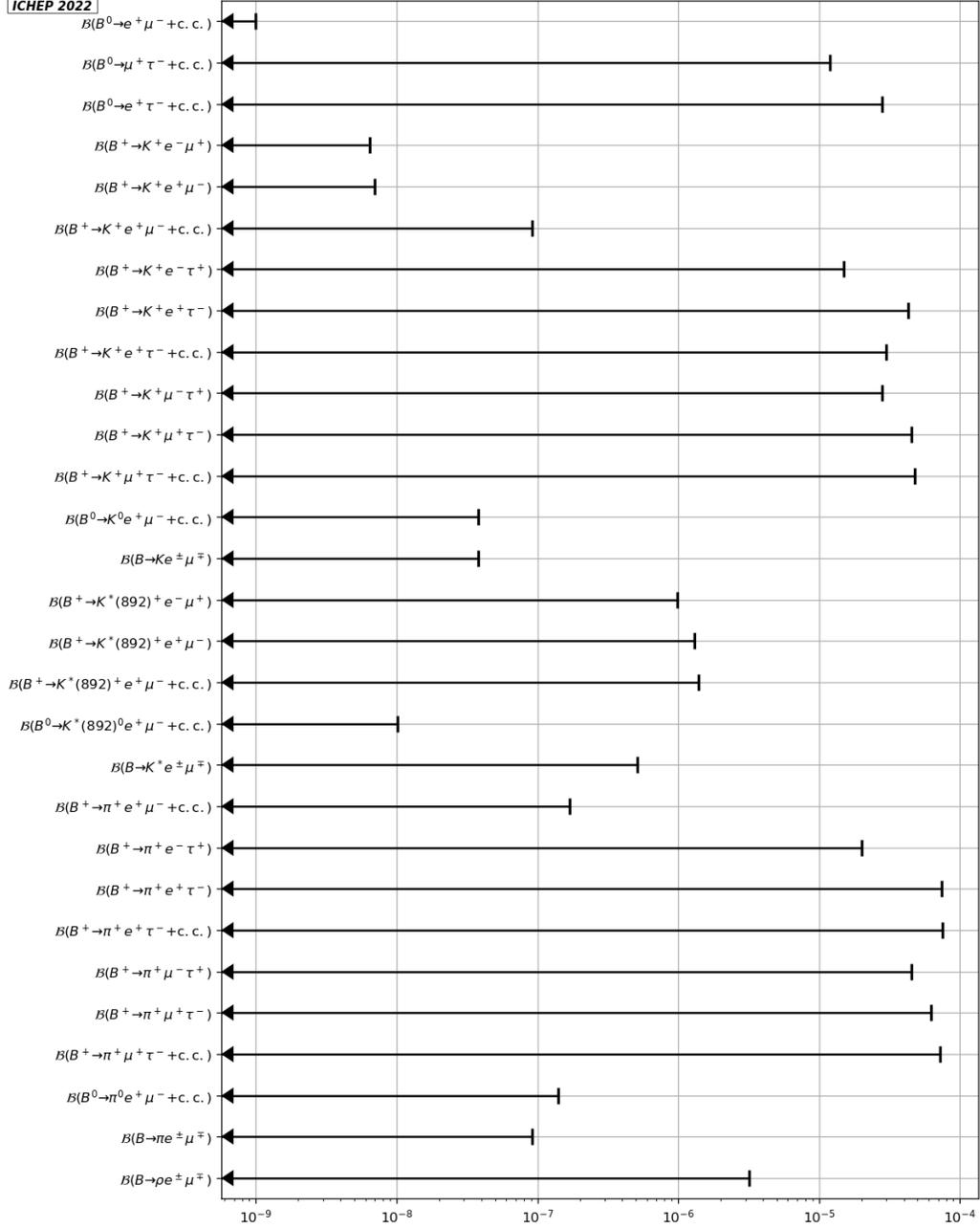


Figure 10: Limits on branching fractions of lepton-flavour-violating  $B^+$  and  $B^0$  decays.

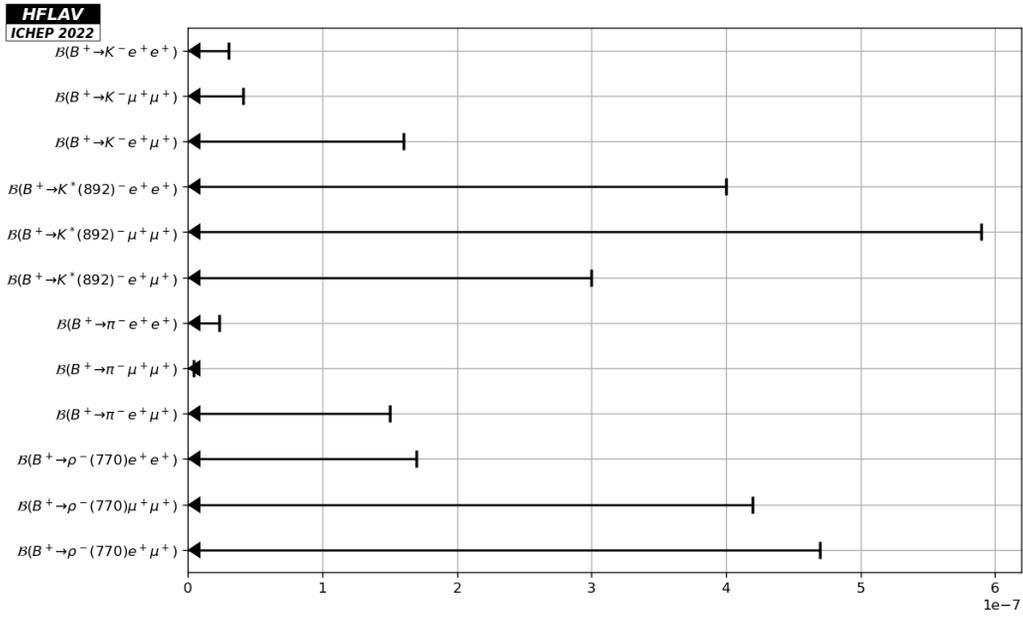


Figure 11: Limits on branching fractions of lepton-number-violating  $B^+$  and  $B^0$  decays.

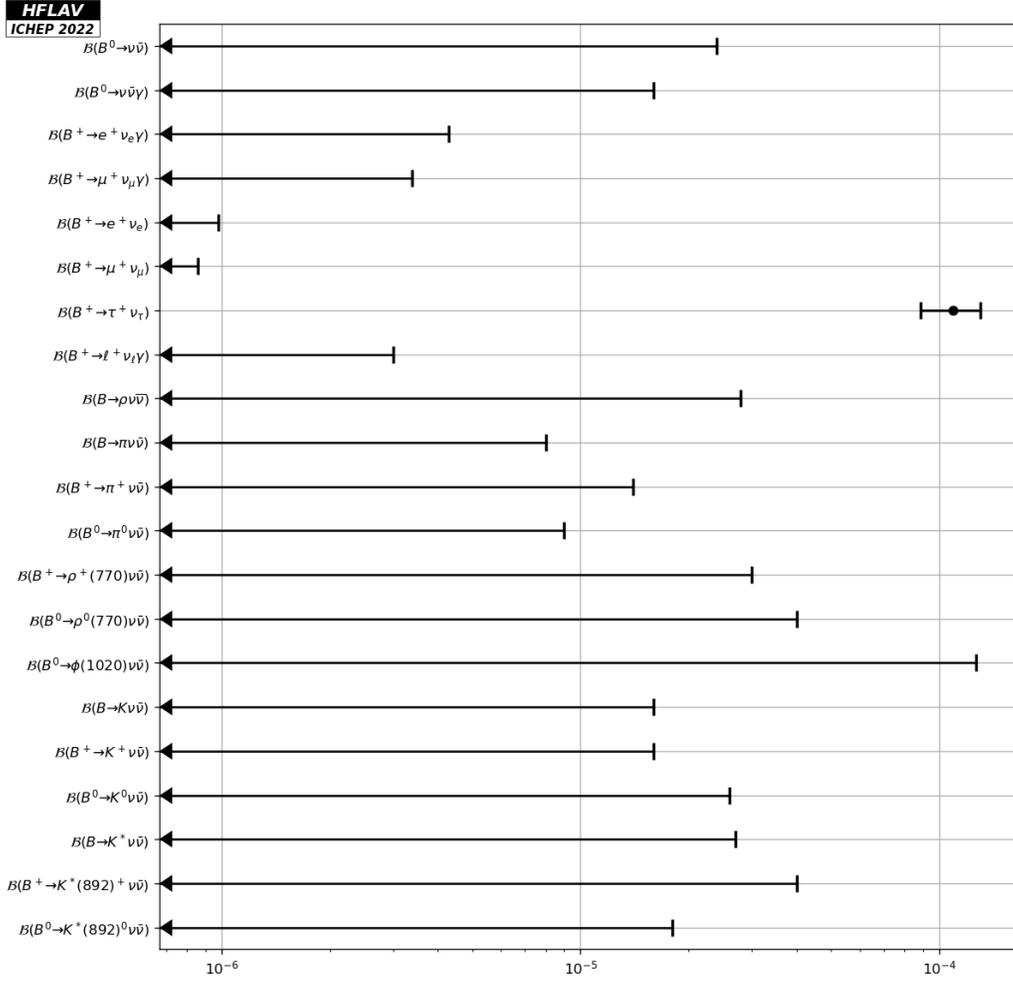


Figure 12: Branching fractions of charmless  $B$  decays with neutrinos.

## 7 Charge asymmetries in $b$ -hadron decays

This section contains, in Tables 68 to 80, 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  $\Lambda_b^0$  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 [350] 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 68:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 1).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K_S^0 \pi^+)$	Belle [3]	$-0.011 \pm 0.021 \pm 0.006$	$-0.016 \pm 0.015$
	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 [351]	$0.18 \pm 0.24 \pm 0.02$	
$A_{CP}(B^+ \rightarrow K^+ \pi^0)$	LHCb [352]	$0.025 \pm 0.015 \pm 0.007^1$	$0.029 \pm 0.012$
	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 [351]	$-0.29 \pm 0.23 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \eta' K^+)$	LHCb [15]	$-0.002 \pm 0.012 \pm 0.006^1$	$0.004 \pm 0.011$
	BaBar [10]	$0.008^{+0.017}_{-0.018} \pm 0.009$	
	Belle [11]	$0.028 \pm 0.028 \pm 0.021$	
	CLEO [351]	$0.03 \pm 0.12 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \eta' K^*(892)^+)$	BaBar [16]	$-0.26 \pm 0.27 \pm 0.02$	$-0.26 \pm 0.27$
$A_{CP}(B^+ \rightarrow \eta'(K\pi)_0^{*+})$	BaBar [16]	$0.06 \pm 0.20 \pm 0.02$	$0.06 \pm 0.20$
$A_{CP}(B^+ \rightarrow \eta' K_2^*(1430)^+)$	BaBar [16]	$0.15 \pm 0.13 \pm 0.02$	$0.15 \pm 0.13$
$A_{CP}(B^+ \rightarrow \eta K^+)$	BaBar [10]	$-0.36 \pm 0.11 \pm 0.03$	$-0.37 \pm 0.08$
	Belle [18]	$-0.38 \pm 0.11 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta K^*(892)^+)$	BaBar [19]	$0.01 \pm 0.08 \pm 0.02$	$0.02 \pm 0.06$
	Belle [20]	$0.03 \pm 0.10 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta(K\pi)_0^{*+})$	BaBar [19]	$0.05 \pm 0.13 \pm 0.02$	$0.05 \pm 0.13$
$A_{CP}(B^+ \rightarrow \eta K_2^*(1430)^+)$	BaBar [19]	$-0.45 \pm 0.30 \pm 0.02$	$-0.45 \pm 0.30$
$A_{CP}(B^+ \rightarrow \omega(782) K^+)$	Belle [23]	$-0.03 \pm 0.04 \pm 0.01$	$-0.025 \pm 0.036$
	BaBar [24]	$-0.01 \pm 0.07 \pm 0.01$	
$A_{CP}(B^+ \rightarrow \omega(782) K^*(892)^+)$	BaBar [26]	$0.29 \pm 0.35 \pm 0.02$	$0.29 \pm 0.35$
$A_{CP}(B^+ \rightarrow \omega(782)(K\pi)_0^{*+})$	BaBar [26]	$-0.10 \pm 0.09 \pm 0.02$	$-0.10 \pm 0.09$
$A_{CP}(B^+ \rightarrow \omega(782) K_2^*(1430)^+)$	BaBar [26]	$0.14 \pm 0.15 \pm 0.02$	$0.14 \pm 0.15$
$A_{CP}(B^+ \rightarrow K^*(892)^0 \pi^+)$	LHCb [353]	$-0.015 \pm 0.021 \pm 0.012$	$-0.02 \pm 0.02$
	BaBar [28]	$0.032 \pm 0.052^{+0.016}_{-0.013}{}^{2,1}$	
	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]	$-0.52 \pm 0.14^{+0.06}_{-0.04}{}^{3,1}$	$-0.39 \pm 0.13$
	BaBar [31]	$-0.06 \pm 0.24 \pm 0.04$	

<sup>1</sup> Multiple systematic uncertainties are added in quadrature.

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

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

Table 69:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 2).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K^+\pi^+\pi^-)^1$	LHCb [354]	$0.011 \pm 0.002 \pm 0.004$ <sup>2,3,4</sup>	$0.0146 \pm 0.0041$
	LHCb [355]	$0.025 \pm 0.004 \pm 0.008$ <sup>5,4</sup>	
	BaBar [28]	$0.028 \pm 0.020 \pm 0.023$ <sup>6,4</sup>	
	Belle [29]	$0.049 \pm 0.026 \pm 0.020$ <sup>6</sup>	
	Belle II [33]	$-0.010 \pm 0.050 \pm 0.021$	
$A_{CP}(B^+ \rightarrow K^+K^+K^-(NR))$	BaBar [22]	$0.060 \pm 0.044 \pm 0.019$ <sup>7</sup>	$0.06 \pm 0.05$
$A_{CP}(B^+ \rightarrow f_0(980)K^+)$	BaBar [28]	$-0.106 \pm 0.050$ <sup>+0.036</sup> <sub>-0.015</sub> <sup>6,4</sup>	$-0.08 \pm 0.04$
	Belle [29]	$-0.077 \pm 0.065$ <sup>+0.046</sup> <sub>-0.026</sub> <sup>6,4</sup>	
	BaBar [22]	$-0.08 \pm 0.08 \pm 0.04$ <sup>8</sup>	
	BaBar [31]	$0.18 \pm 0.18 \pm 0.04$	
$A_{CP}(B^+ \rightarrow f_2(1270)K^+)$	BaBar [28]	$-0.85 \pm 0.22$ <sup>+0.26</sup> <sub>-0.13</sub> <sup>6,4</sup>	$-0.67 \pm 0.19$
	Belle [29]	$-0.59 \pm 0.22 \pm 0.04$ <sup>6,4</sup>	
$A_{CP}(B^+ \rightarrow f'_2(1525)K^+)$	BaBar [22]	$0.14 \pm 0.10 \pm 0.04$ <sup>8</sup>	$0.14 \pm 0.11$
$A_{CP}(B^+ \rightarrow \rho^0(770)K^+)$	LHCb [353]	$0.150 \pm 0.019 \pm 0.011$	$0.160 \pm 0.021$
	BaBar [28]	$0.44 \pm 0.10$ <sup>+0.06</sup> <sub>-0.14</sub> <sup>6,4</sup>	
	Belle [29]	$0.30 \pm 0.11$ <sup>+0.11</sup> <sub>-0.04</sub> <sup>6,4</sup>	
$A_{CP}(B^+ \rightarrow K^0\pi^+\pi^0)$	BaBar [30]	$0.07 \pm 0.05 \pm 0.04$ <sup>9,4</sup>	$0.07 \pm 0.06$
$A_{CP}(B^+ \rightarrow K_0^*(1430)^0\pi^+)$	Belle [29]	$0.076 \pm 0.038$ <sup>+0.028</sup> <sub>-0.022</sub> <sup>6,4</sup>	$0.084 \pm 0.043$
	BaBar [30]	$0.14 \pm 0.10$ <sup>+0.14</sup> <sub>-0.06</sub> <sup>9,4</sup>	
$A_{CP}(B^+ \rightarrow (K\pi)_0^{*0}\pi^+)$	BaBar [28]	$0.032 \pm 0.035$ <sup>+0.034</sup> <sub>-0.028</sub> <sup>6,4</sup>	$0.032 \pm 0.046$
$A_{CP}(B^+ \rightarrow K_0^*(1430)^+\pi^0)$	BaBar [30]	$0.26 \pm 0.12$ <sup>+0.14</sup> <sub>-0.08</sub> <sup>9,4</sup>	$0.26$ <sup>+0.19</sup> <sub>-0.14</sub>
$A_{CP}(B^+ \rightarrow K_2^*(1430)^0\pi^+)$	BaBar [28]	$0.05 \pm 0.23$ <sup>+0.18</sup> <sub>-0.08</sub> <sup>6,4</sup>	$0.05$ <sup>+0.29</sup> <sub>-0.24</sub>
$A_{CP}(B^+ \rightarrow K^+\pi^0\pi^0)$	BaBar [31]	$-0.06 \pm 0.06 \pm 0.04$	$-0.06 \pm 0.07$
$A_{CP}(B^+ \rightarrow \rho^+(770)K^0)$	BaBar [30]	$0.21 \pm 0.19$ <sup>+0.24</sup> <sub>-0.20</sub> <sup>9,4</sup>	$0.21$ <sup>+0.31</sup> <sub>-0.28</sub>
$A_{CP}(B^+ \rightarrow K^*(892)^+\pi^+\pi^-)$	BaBar [42]	$0.07 \pm 0.07 \pm 0.04$	$0.07 \pm 0.08$
$A_{CP}(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$0.31 \pm 0.13 \pm 0.03$	$0.31 \pm 0.13$
$A_{CP}(B^+ \rightarrow f_0(980)K^*(892)^+)$	BaBar [43]	$-0.15 \pm 0.12 \pm 0.03$	$-0.15 \pm 0.12$

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>3</sup> Also measured in several invariant mass regions.

<sup>4</sup> Multiple systematic uncertainties are added in quadrature.

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

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

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

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

<sup>9</sup> 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 3).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow a_1(1260)^+ K^0)$	BaBar [44]	$0.12 \pm 0.11 \pm 0.02$	$0.12 \pm 0.11$
$A_{CP}(B^+ \rightarrow b_1(1235)^+ K^0)$	BaBar [48]	$-0.03 \pm 0.15 \pm 0.02$	$-0.03 \pm 0.15$
$A_{CP}(B^+ \rightarrow K^*(892)^0 \rho^+(770))$	BaBar [45]	$-0.01 \pm 0.16 \pm 0.02$	$-0.01 \pm 0.16$
$A_{CP}(B^+ \rightarrow b_1(1235)^0 K^+)$	BaBar [49]	$-0.46 \pm 0.20 \pm 0.02$	$-0.46 \pm 0.20$
$A_{CP}(B^+ \rightarrow K^+ K_S^0)$	LHCb [7]	$-0.21 \pm 0.14 \pm 0.01$	$-0.086 \pm 0.100$
	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]	$0.016 \pm 0.039 \pm 0.009^2$	$0.025 \pm 0.032$
	BaBar [22]	$0.04^{+0.04}_{-0.05} \pm 0.02^3$	
$A_{CP}(B^+ \rightarrow K^+ K^- \pi^+)^1$	LHCb [354]	$-0.114 \pm 0.007 \pm 0.004^{4,5,6}$	$-0.1151 \pm 0.0076$
	LHCb [355]	$-0.123 \pm 0.017 \pm 0.014^{7,6}$	
	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]	$-0.107 \pm 0.053 \pm 0.035^9$	$-0.107 \pm 0.064$
$A_{CP}(B^+ \rightarrow \bar{K}^*(892)^0 K^+)$	LHCb [56]	$0.123 \pm 0.087 \pm 0.045^{10}$	$0.123 \pm 0.098$
$A_{CP}(B^+ \rightarrow \bar{K}_0^*(1430)^0 K^+)$	LHCb [56]	$0.104 \pm 0.149 \pm 0.088^{10}$	$0.10 \pm 0.17$
$A_{CP}(B^+ \rightarrow \phi(1020) \pi^+)$	LHCb [56]	$0.098 \pm 0.436 \pm 0.266^{10}$	$0.10 \pm 0.51$
$A_{CP}(B^+ \rightarrow K^+ K^- \pi^+) \pi\pi \leftrightarrow KK$ rescattering	LHCb [56]	$-0.664 \pm 0.038 \pm 0.019^{10}$	$-0.664 \pm 0.042$

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

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

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

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

<sup>5</sup> Also measured in several invariant mass regions.

<sup>6</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>8</sup> Also measured in bins of  $m_{K^+ K^-}$ .

<sup>9</sup> LHCb uses a model of non-resonant 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.

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

Table 71:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 4).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow K^+K^+K^-)$	LHCb [354]	$-0.037 \pm 0.002 \pm 0.004$ <sup>1,2,3</sup>	$-0.036 \pm 0.004$
	LHCb [355]	$-0.036 \pm 0.004 \pm 0.007$ <sup>4,3</sup>	
	BaBar [22]	$-0.017^{+0.019}_{-0.014} \pm 0.014$ <sup>5</sup>	
	Belle II [33]	$-0.103 \pm 0.042 \pm 0.020$	
$A_{CP}(B^+ \rightarrow \phi(1020)K^+)$	LHCb [353]	$0.004 \pm 0.010 \pm 0.007$ <sup>1</sup>	$0.0142 \pm 0.0086$
	LHCb [15]	$0.017 \pm 0.011 \pm 0.006$ <sup>4,3</sup>	
	BaBar [22]	$0.128 \pm 0.044 \pm 0.013$ <sup>5</sup>	
	Belle [65]	$0.01 \pm 0.12 \pm 0.05$	
	CDF [62]	$-0.07 \pm 0.17^{+0.03}_{-0.02}$	
$A_{CP}(B^+ \rightarrow K^*(892)^+K^+K^-)$	BaBar [42]	$0.11 \pm 0.08 \pm 0.03$	$0.11 \pm 0.09$
$A_{CP}(B^+ \rightarrow \phi(1020)K^*(892)^+)$	Belle [356]	$-0.02 \pm 0.14 \pm 0.03$	$-0.01 \pm 0.08$
	BaBar [64]	$0.00 \pm 0.09 \pm 0.04$ <sup>6</sup>	
$A_{CP}(B^+ \rightarrow (K\pi)_0^{*+}\phi(1020))$	BaBar [66]	$0.04 \pm 0.15 \pm 0.04$	$0.04 \pm 0.16$
$A_{CP}(B^+ \rightarrow K_1(1270)^+\phi(1020))$	BaBar [66]	$0.15 \pm 0.19 \pm 0.05$	$0.15 \pm 0.20$
$A_{CP}(B^+ \rightarrow K_2^*(1430)^+\phi(1020))$	BaBar [66]	$-0.23 \pm 0.19 \pm 0.06$	$-0.23 \pm 0.20$
$A_{CP}(B^+ \rightarrow \phi(1020)\phi(1020)K^+)$	BaBar [68]	$-0.10 \pm 0.08 \pm 0.02$ <sup>7</sup>	$-0.10 \pm 0.08$
$A_{CP}(B^+ \rightarrow K^*(892)^+\gamma)$	Belle [228]	$0.011 \pm 0.023 \pm 0.003$	$0.014 \pm 0.018$
	BaBar [229]	$0.018 \pm 0.028 \pm 0.007$	
$A_{CP}(B^+ \rightarrow X_s\gamma)$	Belle [316]	$0.0275 \pm 0.0184 \pm 0.0032$ <sup>8</sup>	$0.028 \pm 0.019$
$A_{CP}(B^+ \rightarrow \eta K^+\gamma)$	Belle [235]	$-0.16 \pm 0.09 \pm 0.06$ <sup>9</sup>	$-0.12 \pm 0.07$
	BaBar [234]	$-0.090^{+0.104}_{-0.098} \pm 0.014$ <sup>10</sup>	
$A_{CP}(B^+ \rightarrow \phi(1020)K^+\gamma)$	Belle [238]	$-0.03 \pm 0.11 \pm 0.08$ <sup>11</sup>	$-0.13 \pm 0.10$
	BaBar [239]	$-0.26 \pm 0.14 \pm 0.05$ <sup>12</sup>	
$A_{CP}(B^+ \rightarrow \rho^+(770)\gamma)$	Belle [245]	$-0.11 \pm 0.32 \pm 0.09$	$-0.11 \pm 0.33$

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

<sup>2</sup> Also measured in several invariant mass regions.

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

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

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

<sup>6</sup> 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.

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

<sup>8</sup>  $M_{X_s} < 2.8 \text{ GeV}/c^2$ .

<sup>9</sup>  $M_{K\eta} < 2.4 \text{ GeV}/c^2$ .

<sup>10</sup>  $M_{K\eta^{(\nu)}} < 3.25 \text{ GeV}/c^2$ .

<sup>11</sup>  $1.4 \leq E_\gamma^* \leq 3.4 \text{ GeV}/c^2$ , where  $E_\gamma^*$  is the photon energy in the center-of-mass frame.

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

Table 72:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 5).

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 [354]	$0.080 \pm 0.004 \pm 0.004$ <sup>2,3,4</sup>
	LHCb [355]	$0.058 \pm 0.008 \pm 0.011$ <sup>5,4</sup>
	BaBar [73]	$0.032 \pm 0.044$ <sup>+0.040 6,4</sup> <sub>-0.037</sub>
$A_{CP}(B^+ \rightarrow \rho^0(770)\pi^+)$	LHCb [74]	$0.007 \pm 0.011 \pm 0.040$ <sup>5,6,7,4</sup>
	LHCb [353]	$-0.004 \pm 0.017 \pm 0.009$ <sup>2</sup>
	BaBar [73]	$0.18 \pm 0.07$ <sup>+0.05 6,4</sup> <sub>-0.15</sub>
$A_{CP}(B^+ \rightarrow f_2(1270)\pi^+)$	LHCb [74]	$0.468 \pm 0.061 \pm 0.103$ <sup>6,7,4</sup>
	LHCb [56]	$0.267 \pm 0.102 \pm 0.048$ <sup>8</sup>
	BaBar [73]	$0.41 \pm 0.25$ <sup>+0.18 6,4</sup> <sub>-0.15</sub>
$A_{CP}(B^+ \rightarrow \rho(1450)^0\pi^+)$	LHCb [74]	$-0.129 \pm 0.033 \pm 0.421$ <sup>6,7,4</sup>
	LHCb [56]	$-0.109 \pm 0.044 \pm 0.024$ <sup>8</sup>
	BaBar [73]	$-0.06 \pm 0.28$ <sup>+0.23 6,4</sup> <sub>-0.40</sub>
$A_{CP}(B^+ \rightarrow \rho_3(1690)^0\pi^+)$	LHCb [74]	$-0.801 \pm 0.114 \pm 0.511$ <sup>6,7,4</sup>
$A_{CP}(B^+ \rightarrow f_0(1370)\pi^+)$	BaBar [73]	$0.72 \pm 0.15 \pm 0.16$ <sup>6,4</sup>
$A_{CP}(B^+ \rightarrow \pi^+\pi^+\pi^-), S - \text{wave}$	LHCb [74]	$0.144 \pm 0.018 \pm 0.026$ <sup>6,7,4</sup>
$A_{CP}(B^+ \rightarrow \pi^+\pi^+\pi^- (\text{NR}))$	BaBar [73]	$-0.14 \pm 0.14$ <sup>+0.18 9,4</sup> <sub>-0.08</sub>
$A_{CP}(B^+ \rightarrow \rho^+(770)\pi^0)$	BaBar [79]	$-0.01 \pm 0.13 \pm 0.02$
	Belle [77]	$0.080 \pm 0.150$ <sup>+0.023</sup> <sub>-0.075</sub>
$A_{CP}(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [80]	$-0.054 \pm 0.055 \pm 0.010$
	Belle II [81]	$-0.069 \pm 0.068 \pm 0.060$
	Belle [82]	$0.00 \pm 0.22 \pm 0.03$

<sup>1</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>3</sup> Also measured in several invariant mass regions.

<sup>4</sup> Multiple systematic uncertainties are added in quadrature.

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

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

<sup>7</sup> 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. [76].

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

<sup>9</sup> The nonresonant amplitude is modelled using a sum of exponential functions.

Table 73:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 6).

Parameter	Measurements	Average	
$A_{CP}(B^+ \rightarrow \omega(782)\pi^+)$	LHCb [74]	$-0.048 \pm 0.065 \pm 0.049$ <sup>1,2,3</sup>	$-0.041 \pm 0.048$
	BaBar [24]	$-0.02 \pm 0.08 \pm 0.01$	
	Belle [84]	$-0.02 \pm 0.09 \pm 0.01$	
	CLEO [351]	$-0.34 \pm 0.25 \pm 0.02$	
$A_{CP}(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26]	$-0.20 \pm 0.09 \pm 0.02$	$-0.20 \pm 0.09$
$A_{CP}(B^+ \rightarrow \pi^+\pi^0\pi^0)$	Belle [77]	$0.092 \pm 0.068 \pm 0.007$	$0.092 \pm 0.068$
$A_{CP}(B^+ \rightarrow \eta\pi^+)$	Belle [18]	$-0.19 \pm 0.06 \pm 0.01$	$-0.14 \pm 0.05$
	BaBar [10]	$-0.03 \pm 0.09 \pm 0.03$	
$A_{CP}(B^+ \rightarrow \eta\rho^+(770))$	BaBar [85]	$0.13 \pm 0.11 \pm 0.02$	$0.11 \pm 0.11$
	Belle [20]	$-0.04^{+0.34}_{-0.32} \pm 0.01$	
$A_{CP}(B^+ \rightarrow \eta'\pi^+)$	BaBar [10]	$0.03 \pm 0.17 \pm 0.02$	$0.06 \pm 0.15$
	Belle [11]	$0.20^{+0.37}_{-0.36} \pm 0.04$	
$A_{CP}(B^+ \rightarrow \eta'\rho^+(770))$	BaBar [16]	$0.26 \pm 0.17 \pm 0.02$	$0.26 \pm 0.17$
$A_{CP}(B^+ \rightarrow b_1(1235)^0\pi^+)$	BaBar [49]	$0.05 \pm 0.16 \pm 0.02$	$0.05 \pm 0.16$
$A_{CP}(B^+ \rightarrow p\bar{p}\pi^+)$	BaBar [156]	$0.04 \pm 0.07 \pm 0.04$	$0.04 \pm 0.08$
$A_{CP}(B^+ \rightarrow p\bar{p}\pi^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [157]	$-0.041 \pm 0.039 \pm 0.005$	$-0.058 \pm 0.037$
	Belle [155]	$-0.17 \pm 0.10 \pm 0.02$	
$A_{CP}(B^+ \rightarrow p\bar{p}K^+), m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$	LHCb [157]	$0.021 \pm 0.020 \pm 0.004$	$0.007 \pm 0.019$
	Belle [155]	$-0.02 \pm 0.05 \pm 0.02$	
	BaBar [160]	$-0.16^{+0.07}_{-0.08} \pm 0.04$	
$A_{CP}(B^+ \rightarrow p\bar{p}K^*(892)^+)^4$	BaBar [156]	$0.32 \pm 0.13 \pm 0.05$	$0.21 \pm 0.11$
	Belle [162]	$-0.01 \pm 0.19 \pm 0.02$	
$A_{CP}(B^+ \rightarrow p\bar{\Lambda}^0\gamma)$	Belle [165]	$0.17 \pm 0.16 \pm 0.05$	$0.17 \pm 0.17$
$A_{CP}(B^+ \rightarrow p\bar{\Lambda}^0\pi^0)$	Belle [165]	$0.01 \pm 0.17 \pm 0.04$	$0.01 \pm 0.17$

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

<sup>2</sup> 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. [76].

<sup>3</sup> Multiple systematic uncertainties are added in quadrature.

<sup>4</sup> Treatment of charmonium intermediate components differs between the results.

Table 74:  $CP$  asymmetries of charmless hadronic  $B^+$  decays (part 7).

Parameter	Measurements	Average
$A_{CP}(B^+ \rightarrow K^+\ell^+\ell^-)$	Belle [259]	$0.04 \pm 0.10 \pm 0.02$
	BaBar [285]	$-0.03 \pm 0.14 \pm 0.01$
$A_{CP}(B^+ \rightarrow K^+e^+e^-)$	Belle [259]	$0.14 \pm 0.14 \pm 0.03$
$A_{CP}(B^+ \rightarrow K^+\mu^+\mu^-)$	LHCb [357]	$0.012 \pm 0.017 \pm 0.001$ <sup>1,2</sup>
	Belle [259]	$-0.05 \pm 0.13 \pm 0.03$ <sup>3</sup>
$A_{CP}(B^+ \rightarrow \pi^+\mu^+\mu^-)$	LHCb [250]	$-0.11 \pm 0.12 \pm 0.01$
$A_{CP}(B^+ \rightarrow K^*(892)^+\ell^+\ell^-)$	Belle [259]	$-0.13^{+0.17}_{-0.16} \pm 0.01$
	BaBar [255]	$0.01^{+0.26}_{-0.24} \pm 0.02$
$A_{CP}(B^+ \rightarrow K^*(892)^+e^+e^-)$	Belle [259]	$-0.14^{+0.23}_{-0.22} \pm 0.02$
$A_{CP}(B^+ \rightarrow K^*(892)^+\mu^+\mu^-)$	Belle [259]	$-0.12 \pm 0.24 \pm 0.02$

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

<sup>2</sup> Mass regions corresponding to  $\phi$ ,  $J/\psi$  and  $\psi(2S)$  are vetoed.

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

Table 75:  $CP$  asymmetries of charmless hadronic  $B^0$  decays (part 1).

Parameter	Measurements	Average	
$A_{CP}(B^0 \rightarrow K^+\pi^-)$	LHCb [358]	$-0.0831 \pm 0.0034$ <sup>1</sup>	$-0.0836 \pm 0.0032$
	CDF [359]	$-0.083 \pm 0.013 \pm 0.004$	
	Belle [3]	$-0.069 \pm 0.014 \pm 0.007$	
	BaBar [96]	$-0.107 \pm 0.016$ $^{+0.006}_{-0.004}$	
	Belle II [5]	$-0.16 \pm 0.05 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \eta'K^*(892)^0)$	BaBar [16]	$0.02 \pm 0.23 \pm 0.02$	$-0.07 \pm 0.18$
	Belle [99]	$-0.22 \pm 0.29 \pm 0.07$	
$A_{CP}(B^0 \rightarrow \eta'(K\pi)_0^{*0})$	BaBar [16]	$-0.19 \pm 0.17 \pm 0.02$	$-0.19 \pm 0.17$
$A_{CP}(B^0 \rightarrow \eta'K_2^*(1430)^0)$	BaBar [16]	$0.14 \pm 0.18 \pm 0.02$	$0.14 \pm 0.18$
$A_{CP}(B^0 \rightarrow \eta K^*(892)^0)$	BaBar [19]	$0.21 \pm 0.06 \pm 0.02$	$0.19 \pm 0.05$
	Belle [20]	$0.17 \pm 0.08 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \eta(K\pi)_0^{*0})$	BaBar [19]	$0.06 \pm 0.13 \pm 0.02$	$0.06 \pm 0.13$
$A_{CP}(B^0 \rightarrow \eta K_2^*(1430)^0)$	BaBar [19]	$-0.07 \pm 0.19 \pm 0.02$	$-0.07 \pm 0.19$
$A_{CP}(B^0 \rightarrow b_1(1235)^-K^+)$	BaBar [49]	$-0.07 \pm 0.12 \pm 0.02$	$-0.07 \pm 0.12$
$A_{CP}(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$0.45 \pm 0.25 \pm 0.02$	$0.45 \pm 0.25$
$A_{CP}(B^0 \rightarrow \omega(782)(K\pi)_0^{*0})$	BaBar [26]	$-0.07 \pm 0.09 \pm 0.02$	$-0.07 \pm 0.09$
$A_{CP}(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$-0.37 \pm 0.17 \pm 0.02$	$-0.37 \pm 0.17$
$A_{CP}(B^0 \rightarrow K^+\pi^-\pi^0)$	BaBar [104]	$-0.030$ $^{+0.045}_{-0.051} \pm 0.055$ <sup>2</sup>	$0.06 \pm 0.05$
	Belle II [33]	$0.207 \pm 0.088 \pm 0.011$	
	Belle [103]	$0.07 \pm 0.11 \pm 0.01$	
$A_{CP}(B^0 \rightarrow \rho^-(770)K^+)$	BaBar [102]	$0.20 \pm 0.09 \pm 0.08$ <sup>2</sup>	$0.20 \pm 0.11$
	Belle [103]	$0.22$ $^{+0.22+0.06}_{-0.23-0.02}$	
$A_{CP}(B^0 \rightarrow \rho(1450)^-K^+)$	BaBar [102]	$-0.10 \pm 0.32 \pm 0.09$ <sup>2</sup>	$-0.10 \pm 0.33$
$A_{CP}(B^0 \rightarrow \rho(1700)^-K^+)$	BaBar [102]	$-0.36 \pm 0.57 \pm 0.23$ <sup>2</sup>	$-0.36 \pm 0.61$
$A_{CP}(B^0 \rightarrow K^+\pi^-\pi^0(\text{NR}))$	BaBar [102]	$0.10 \pm 0.16 \pm 0.08$ <sup>3</sup>	$0.10 \pm 0.18$
$A_{CP}(B^0 \rightarrow K^0\pi^+\pi^-)$	BaBar [105]	$-0.01 \pm 0.05 \pm 0.01$ <sup>4</sup>	$-0.01 \pm 0.05$
$A_{CP}(B^0 \rightarrow K^*(892)^+\pi^-)$	LHCb [110]	$-0.308 \pm 0.060 \pm 0.016$ <sup>4,5</sup>	$-0.274 \pm 0.045$
	BaBar [105]	$-0.21 \pm 0.10 \pm 0.02$ <sup>4,5</sup>	
	BaBar [102]	$-0.29 \pm 0.11 \pm 0.02$ <sup>2</sup>	
	Belle [360]	$-0.21 \pm 0.11 \pm 0.07$ <sup>4</sup>	

<sup>1</sup> LHCb combines results of the  $1.9\text{fb}^{-1}$  run 2 data analysis with those based on Run 1 dataset [361]. The full statistical and systematic covariance matrices are used in the combination.

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

<sup>3</sup> The nonresonant amplitude is taken to be constant across the Dalitz plane.

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

<sup>5</sup> Multiple systematic uncertainties are added in quadrature.

Table 76:  $CP$  asymmetries of charmless hadronic  $B^0$  decays (part 2).

Parameter	Measurements	Average
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*+}\pi^-)$	LHCb [110]	$-0.032 \pm 0.047 \pm 0.031$ <sup>1,2</sup>
	BaBar [105]	$0.09 \pm 0.07 \pm 0.03$ <sup>1,2</sup>
	BaBar [102]	$0.07 \pm 0.14 \pm 0.01$ <sup>3</sup>
$A_{CP}(B^0 \rightarrow K_2^*(1430)^+\pi^-)$	LHCb [110]	$-0.29 \pm 0.22 \pm 0.09$ <sup>1,2</sup>
$A_{CP}(B^0 \rightarrow K^*(1680)^+\pi^-)$	LHCb [110]	$-0.07 \pm 0.13 \pm 0.04$ <sup>1,2</sup>
$A_{CP}(B^0 \rightarrow f_0(980)K_S^0)$	LHCb [110]	$0.28 \pm 0.27 \pm 0.15$ <sup>1,2</sup>
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*0}\pi^0)$	BaBar [102]	$-0.15 \pm 0.10 \pm 0.04$ <sup>3</sup>
$A_{CP}(B^0 \rightarrow K^*(892)^0\pi^0)$	BaBar [102]	$-0.15 \pm 0.12 \pm 0.04$ <sup>3</sup>
$A_{CP}(B^0 \rightarrow K^*(892)^0\pi^+\pi^-)$	BaBar [114]	$0.07 \pm 0.04 \pm 0.03$
$A_{CP}(B^0 \rightarrow K^*(892)^0\rho^0(770))$	BaBar [115]	$-0.06 \pm 0.09 \pm 0.02$
$A_{CP}(B^0 \rightarrow f_0(980)K^*(892)^0)$	BaBar [115]	$0.07 \pm 0.10 \pm 0.02$
$A_{CP}(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [115]	$0.21 \pm 0.15 \pm 0.02$
$A_{CP}(B^0 \rightarrow K^*(892)^0K^+K^-)$	BaBar [114]	$0.01 \pm 0.05 \pm 0.02$
$A_{CP}(B^0 \rightarrow a_1(1260)^-K^+)$	BaBar [44]	$-0.16 \pm 0.12 \pm 0.01$
$A_{CP}(B^0 \rightarrow K^0\bar{K}^0)$	Belle [362]	$-0.58^{+0.73}_{-0.66} \pm 0.04$ <sup>4</sup>
$A_{CP}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	Belle [126]	$-0.007 \pm 0.048 \pm 0.021$
	BaBar [125]	$0.01 \pm 0.06 \pm 0.03$
$A_{CP}(B^0 \rightarrow K^*(892)^0\pi^+K^-)$	BaBar [114]	$0.22 \pm 0.33 \pm 0.20$
$A_{CP}(B^0 \rightarrow (K\pi)_0^{*0}\phi(1020))$	Belle [126]	$0.093 \pm 0.094 \pm 0.017$
	BaBar [125]	$0.20 \pm 0.14 \pm 0.06$
$A_{CP}(B^0 \rightarrow K_2^*(1430)^0\phi(1020))$	BaBar [125]	$-0.08 \pm 0.12 \pm 0.05$
	Belle [126]	$-0.155^{+0.152}_{-0.133} \pm 0.033$
$A_{CP}(B^0 \rightarrow K^*(892)^0\gamma)$	LHCb [202]	$0.008 \pm 0.017 \pm 0.009$
	Belle [228]	$-0.013 \pm 0.017 \pm 0.004$
	BaBar [229]	$-0.016 \pm 0.022 \pm 0.007$
$A_{CP}(B^0 \rightarrow K_2^*(1430)^0\gamma)$	BaBar [243]	$-0.08 \pm 0.15 \pm 0.01$
$A_{CP}(B^0 \rightarrow X_s\gamma)$	Belle [316]	$-0.0094 \pm 0.0174 \pm 0.0047$ <sup>5</sup>

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

<sup>2</sup> Multiple systematic uncertainties are added in quadrature.

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

<sup>4</sup> Result extracted from a time-dependent analysis.

<sup>5</sup>  $M_{X_s} < 2.8 \text{ GeV}/c^2$ .

Table 77:  $CP$  asymmetries of charmless hadronic  $B^0$  decays (part 3).

Parameter	Measurements	Average	
$A_{CP}(B^0 \rightarrow \rho^+(770)\pi^-)$	BaBar [363]	$0.09^{+0.05}_{-0.06} \pm 0.04$ <sup>1</sup>	$0.13 \pm 0.05$
	Belle [364]	$0.21 \pm 0.08 \pm 0.04$ <sup>1</sup>	
$A_{CP}(B^0 \rightarrow \rho^-(770)\pi^+)$	BaBar [363]	$-0.12 \pm 0.08^{+0.04}_{-0.05}$ <sup>1</sup>	$-0.08 \pm 0.08$
	Belle [364]	$0.08 \pm 0.16 \pm 0.11$ <sup>1</sup>	
$A_{CP}(B^0 \rightarrow a_1(1260)^+\pi^- + \text{c.c.})$	Belle [147]	$0.01 \pm 0.11 \pm 0.09$ <sup>2</sup>	$0.05 \pm 0.11$
	BaBar [365]	$0.10 \pm 0.15 \pm 0.09$ <sup>2</sup>	
$A_{CP}(B^0 \rightarrow b_1(1235)^+\pi^- + \text{c.c.})$	BaBar [49]	$-0.05 \pm 0.10 \pm 0.02$	$-0.05 \pm 0.10$
$A_{CP}(B^0 \rightarrow p\bar{p}K^*(892)^0)^3$	BaBar [156]	$0.11 \pm 0.13 \pm 0.06$	$0.05 \pm 0.12$
	Belle [162]	$-0.08 \pm 0.20 \pm 0.02$	
$A_{CP}(B^0 \rightarrow p\bar{\Lambda}^0\pi^-)$	BaBar [174]	$-0.10 \pm 0.10 \pm 0.02$	$-0.06 \pm 0.07$
	Belle [165]	$-0.02 \pm 0.10 \pm 0.03$	
$A_{CP}(B^0 \rightarrow K^*(892)^0\ell^+\ell^-)$	Belle [259]	$-0.08 \pm 0.12 \pm 0.02$	$-0.05 \pm 0.10$
	BaBar [255]	$0.02 \pm 0.20 \pm 0.02$	
$A_{CP}(B^0 \rightarrow K^*(892)^0e^+e^-)$	Belle [259]	$-0.21 \pm 0.19 \pm 0.02$	$-0.21 \pm 0.19$
$A_{CP}(B^0 \rightarrow K^*(892)^0\mu^+\mu^-)$	LHCb [357]	$-0.035 \pm 0.024 \pm 0.003$ <sup>4,5</sup>	$-0.034 \pm 0.024$
	Belle [259]	$0.00 \pm 0.15 \pm 0.03$ <sup>6</sup>	

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

<sup>2</sup> Result extracted from a time-dependent analysis.

<sup>3</sup> Treatment of charmonium intermediate components differs between the results.

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

<sup>5</sup> Mass regions corresponding to  $\phi$ ,  $J/\psi$  and  $\psi(2S)$  are vetoed.

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

Table 78:  $CP$  asymmetries of charmless hadronic decays of  $B^\pm/B^0$  admixture.

Parameter	Measurements	Average
$A_{CP}(B \rightarrow K^*\gamma)$	Belle [228] $-0.004 \pm 0.014 \pm 0.003$ BaBar [229] $-0.003 \pm 0.017 \pm 0.007$	$-0.004 \pm 0.011$
$A_{CP}(B \rightarrow X_s\gamma)$	Belle [316] $0.0144 \pm 0.0128 \pm 0.0011$ <sup>1</sup> BaBar [366] $0.017 \pm 0.019 \pm 0.010$ <sup>2</sup>	$0.015 \pm 0.011$
$A_{CP}(B \rightarrow X_{s+d}\gamma)$	Belle [367] $0.022 \pm 0.039 \pm 0.009$ <sup>3</sup> BaBar [275] $0.057 \pm 0.060 \pm 0.018$ <sup>4</sup>	$0.032 \pm 0.034$
$A_{CP}(B \rightarrow X_s\ell^+\ell^-)$	BaBar [281] $0.04 \pm 0.11 \pm 0.01$	$0.04 \pm 0.11$
$A_{CP}(B \rightarrow K^*e^+e^-)$	Belle [259] $-0.18 \pm 0.15 \pm 0.01$	$-0.18 \pm 0.15$
$A_{CP}(B \rightarrow K^*\mu^+\mu^-)$	Belle [259] $-0.03 \pm 0.13 \pm 0.02$	$-0.03 \pm 0.13$
$A_{CP}(B \rightarrow K^*\ell^+\ell^-)$	Belle [259] $-0.10 \pm 0.10 \pm 0.01$ BaBar [285] $0.03 \pm 0.13 \pm 0.01$	$-0.05 \pm 0.08$
$A_{CP}(B \rightarrow X_s\eta)$	Belle [311] $-0.13 \pm 0.04$ <sup>+0.02</sup> <sub>-0.03</sub> <sup>5</sup>	$-0.13$ <sup>+0.04</sup> <sub>-0.05</sub>
$A_{CP}(B \rightarrow K\ell^+\ell^-)$	BaBar [285] $-0.03 \pm 0.14 \pm 0.01$	$-0.03 \pm 0.14$

<sup>1</sup>  $M_{X_s} < 2.8 \text{ GeV}/c^2$ .

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

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

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

<sup>5</sup>  $0.4 < m_X < 2.6 \text{ GeV}/c^2$ .

Table 79:  $CP$  asymmetries of charmless hadronic  $B_s^0$  decays.

Parameter	Measurements	Average
$A_{CP}(B_s^0 \rightarrow \pi^+K^-)$	LHCb [358] $0.225 \pm 0.012$ <sup>1</sup> CDF [359] $0.22 \pm 0.07 \pm 0.02$	$0.225 \pm 0.012$

<sup>1</sup> LHCb combines results of the  $1.9\text{fb}^{-1}$  run 2 data analysis with those based on Run 1 dataset [361]. The full statistical and systematic covariance matrices are used in the combination.

Table 80:  $CP$  asymmetries of charmless hadronic  $\Lambda_b^0$  decays.

Parameter	Measurements	Average
$A_{CP}(\Lambda_b^0 \rightarrow p\pi^-)$	LHCb [368] $-0.035 \pm 0.017 \pm 0.020$ CDF [359] $0.06 \pm 0.07 \pm 0.03$	$-0.025 \pm 0.025$
$A_{CP}(\Lambda_b^0 \rightarrow pK^-)$	LHCb [368] $-0.020 \pm 0.013 \pm 0.019$ CDF [359] $-0.10 \pm 0.08 \pm 0.04$	$-0.025 \pm 0.022$
$A_{CP}(\Lambda_b^0 \rightarrow p\bar{K}^0\pi^-)$	LHCb [107] $0.22 \pm 0.13 \pm 0.03$	$0.22 \pm 0.13$
$A_{CP}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ \pi^-)$	LHCb [183] $-0.53 \pm 0.23 \pm 0.11$	$-0.53 \pm 0.25$
$A_{CP}(\Lambda_b^0 \rightarrow \Lambda^0 K^+ K^-)$	LHCb [183] $-0.28 \pm 0.10 \pm 0.07$	$-0.28 \pm 0.12$

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

- In Ref. [369], 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. [370], 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. [371], 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. [372] LHCb measures differences of  $CP$  asymmetries between  $\Lambda_b^0$  and  $\Xi_b^0$  charmless decays into a proton and three charged mesons and the decays to the same final states with an intermediate charmed baryon.

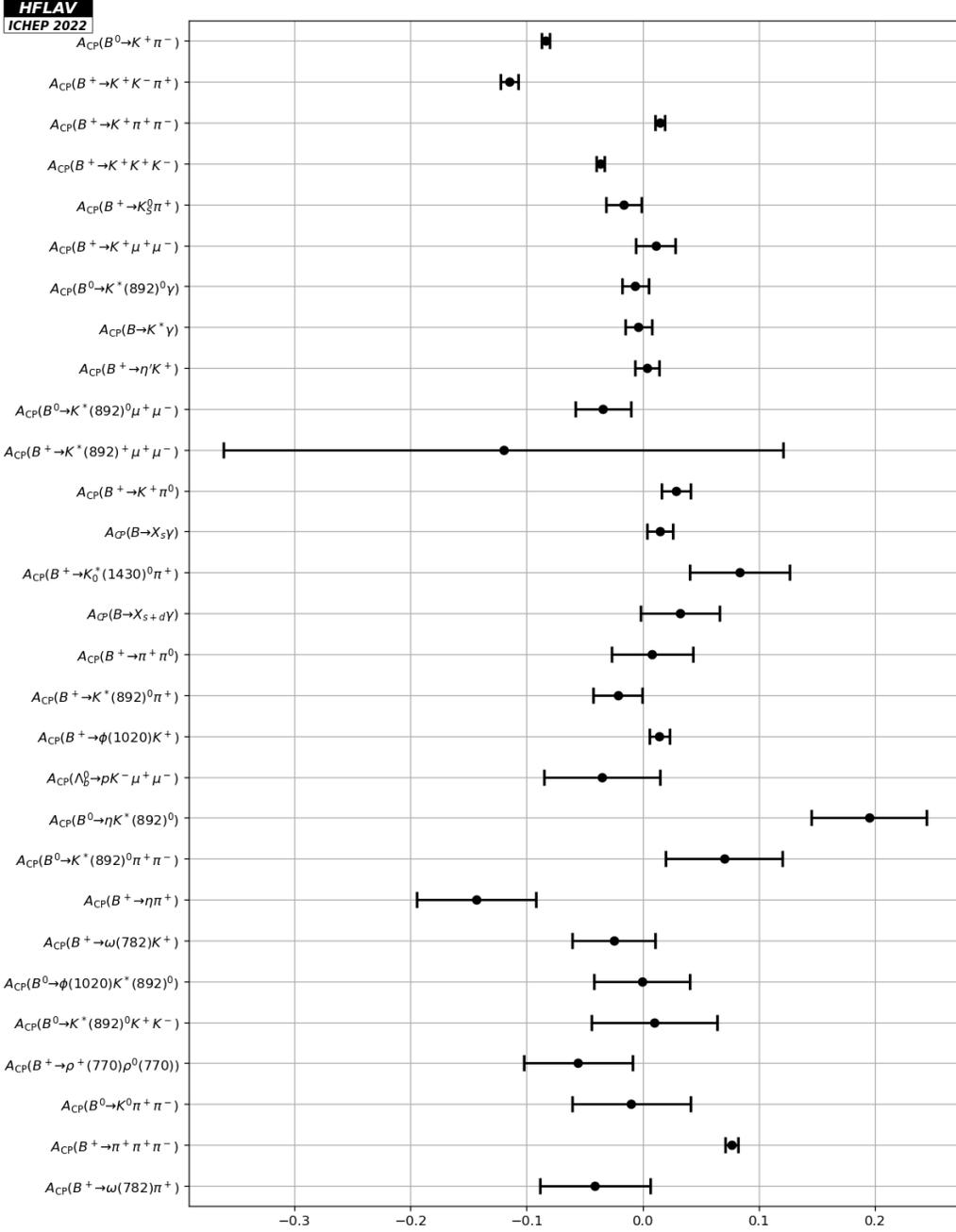


Figure 13: A selection among the most precise direct  $CP$  asymmetries ( $A_{CP}$ ) measured in charmless  $B^+$  and  $B^0$  decay modes.

## 8 Polarization measurements in $b$ -hadron decays

In this section, compilations of polarization measurements in  $b$ -hadron decays are given. Tables 81, 82, and 83 detail measurements of the longitudinal fraction,  $f_L$ , in  $B^+ B^0$ , and  $B_s^0$  decays, respectively. They are followed by Tables 84, 85 and 86, 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 di-spin-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 81: Longitudinal polarization fraction,  $f_L$ , in  $B^+$  decays.

Parameter	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>	
$f_L(B^+ \rightarrow \omega(782)K^*(892)^+)$	BaBar [26]	$0.41 \pm 0.18 \pm 0.05$	$0.41 \pm 0.19$
$f_L(B^+ \rightarrow \omega(782)K_2^*(1430)^+)$	BaBar [26]	$0.56 \pm 0.10 \pm 0.04$	$0.56 \pm 0.11$
$f_L(B^+ \rightarrow K^*(892)^+\bar{K}^*(892)^0)$	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 [64]	$0.49 \pm 0.05 \pm 0.03$ <sup>1</sup>	$0.50 \pm 0.05$
	Belle [356]	$0.52 \pm 0.08 \pm 0.03$	
	Belle II [61]	$0.58 \pm 0.23 \pm 0.02$	
$f_L(B^+ \rightarrow \phi(1020)K_1(1270)^+)$	BaBar [66]	$0.46^{+0.12}_{-0.13}^{+0.06}_{-0.07}$	$0.46 \pm 0.14$
$f_L(B^+ \rightarrow \phi(1020)K_2^*(1430)^+)$	BaBar [66]	$0.80^{+0.09}_{-0.10} \pm 0.03$	$0.80 \pm 0.10$
$f_L(B^+ \rightarrow K^*(892)^+\rho^0(770))$	BaBar [43]	$0.78 \pm 0.12 \pm 0.03$	$0.78 \pm 0.12$
$f_L(B^+ \rightarrow K^*(892)^0\rho^+(770))$	BaBar [45]	$0.52 \pm 0.10 \pm 0.04$	$0.48 \pm 0.08$
	Belle [46]	$0.43 \pm 0.11^{+0.05}_{-0.02}$ <sup>2</sup>	
$f_L(B^+ \rightarrow \rho^+(770)\rho^0(770))$	BaBar [80]	$0.950 \pm 0.015 \pm 0.006$	$0.949 \pm 0.015$
	Belle II [81]	$0.943^{+0.035}_{-0.033} \pm 0.027$	
	Belle [82]	$0.948 \pm 0.106 \pm 0.021$	
$f_L(B^+ \rightarrow \omega(782)\rho^+(770))$	BaBar [26]	$0.90 \pm 0.05 \pm 0.03$	$0.90 \pm 0.06$
$f_L(B^+ \rightarrow p\bar{p}K^*(892)^+)$	Belle [162]	$0.32 \pm 0.17 \pm 0.09$	$0.32 \pm 0.19$

<sup>1</sup> 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.

<sup>2</sup> See also Ref. [51].

Table 82: Longitudinal polarization fraction,  $f_L$ , in  $B^0$  decays.

Parameter	Measurements	Average <sup>HFLAV</sup> <sub>PDG</sub>
$f_L(B^0 \rightarrow \omega(782)K^*(892)^0)$	BaBar [26]	$0.72 \pm 0.14 \pm 0.02$
	LHCb [373]	$0.68 \pm 0.17 \pm 0.16$
	Belle [100]	$0.56 \pm 0.29^{+0.18}_{-0.08}$
$f_L(B^0 \rightarrow \omega(782)K_2^*(1430)^0)$	BaBar [26]	$0.45 \pm 0.12 \pm 0.02$
$f_L(B^0 \rightarrow K^*(892)^0\bar{K}^*(892)^0)$	LHCb [132]	$0.724 \pm 0.051 \pm 0.016$
	BaBar [133]	$0.80^{+0.10}_{-0.12} \pm 0.06$
$f_L(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [374]	$0.497 \pm 0.019 \pm 0.015$
	Belle [126]	$0.499 \pm 0.030 \pm 0.018$
	BaBar [125]	$0.494 \pm 0.034 \pm 0.013$
	Belle II [61]	$0.57 \pm 0.20 \pm 0.04$
$f_L(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [126]	$0.918^{+0.029}_{-0.060} \pm 0.012$
	BaBar [125]	$0.901^{+0.046}_{-0.058} \pm 0.037$
$f_L(B^0 \rightarrow K^*(892)^0\rho^0(770))$	LHCb [373]	$0.164 \pm 0.015 \pm 0.022$
	BaBar [115]	$0.40 \pm 0.08 \pm 0.11$
$f_L(B^0 \rightarrow K^*(892)^+\rho^-(770))$	BaBar [115]	$0.38 \pm 0.13 \pm 0.03$
$f_L(B^0 \rightarrow \rho^+(770)\rho^-(770))$	Belle [149]	$0.988 \pm 0.012 \pm 0.023$
	BaBar [150]	$0.992 \pm 0.024^{+0.026}_{-0.013}$
	Belle II [151]	$0.956 \pm 0.035 \pm 0.033$
$f_L(B^0 \rightarrow \rho^0(770)\rho^0(770))^1$	LHCb [130]	$0.745^{+0.048}_{-0.058} \pm 0.034$
	BaBar [146]	$0.75^{+0.11}_{-0.14} \pm 0.04$
	Belle [145]	$0.21^{+0.18}_{-0.22} \pm 0.15$
$f_L(B^0 \rightarrow a_1(1260)^+a_1(1260)^-)$	BaBar [153]	$0.31 \pm 0.22 \pm 0.10$
$f_L(B^0 \rightarrow p\bar{p}K^*(892)^0)$	Belle [162]	$1.01 \pm 0.13 \pm 0.03$
$f_L(B^0 \rightarrow \Lambda^0\bar{\Lambda}^0K^*(892)^0)$	Belle [168]	$0.60 \pm 0.22 \pm 0.08$ <sup>2,3</sup>
$f_L(B^0 \rightarrow K^{*0}\mu^+\mu^-), 0.04 < q^2 < 6.0 \text{ GeV}^2/c^4$	ATLAS [341]	$0.50 \pm 0.06 \pm 0.04$
	LHCb [375]	$0.16 \pm 0.06 \pm 0.03$

<sup>1</sup> The PDG uncertainty includes a scale factor.

<sup>2</sup> The charmonium mass regions are vetoed.

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

Table 83: Longitudinal polarization fraction,  $f_L$ , in  $B_s^0$  decays.

Parameter	Measurements	Average	<sup>HFLAV</sup> <sub>PDG</sub>
$f_L(B_s^0 \rightarrow \phi(1020)\phi(1020))$	LHCb [141]	$0.381 \pm 0.007 \pm 0.012$	$0.378 \pm 0.013$
	CDF [197]	$0.348 \pm 0.041 \pm 0.021$	
$f_L(B_s^0 \rightarrow K^*(892)^0 \bar{K}^*(892)^0)$	LHCb [132]	$0.240 \pm 0.031 \pm 0.025$	$0.24 \pm 0.04$
$f_L(B_s^0 \rightarrow \phi(1020) \bar{K}^*(892)^0)$	LHCb [127]	$0.51 \pm 0.15 \pm 0.07$	$0.51 \pm 0.17$
$f_L(B_s^0 \rightarrow \bar{K}_2^*(1430)^0 K^*(892)^0)$	LHCb [376]	$0.911 \pm 0.020 \pm 0.165$	$0.91 \pm 0.17$
$f_L(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}^*(892)^0)$	LHCb [376]	$0.62 \pm 0.16 \pm 0.25$	$0.62 \pm 0.30$
$f_L(B_s^0 \rightarrow K_2^*(1430)^0 \bar{K}_2^*(1430)^0)$	LHCb [376]	$0.25 \pm 0.14 \pm 0.18$	$0.25 \pm 0.23$

Table 84: Results of full angular analyses of  $B^+$  decays.

Parameter	Measurements	Average	<sup>HFLAV</sup> <sub>PDG</sub>
$f_\perp(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [64]	$0.21 \pm 0.05 \pm 0.02$ <sup>1</sup>	$0.20 \pm 0.05$
	Belle [356]	$0.19 \pm 0.08 \pm 0.02$	
$A_{CP}^0(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [64]	$0.17 \pm 0.11 \pm 0.02$ <sup>1</sup>	$0.17 \pm 0.11$
$A_{CP}^\perp(B^+ \rightarrow \phi(1020)K^*(892)^+)$	BaBar [64]	$0.22 \pm 0.24 \pm 0.08$ <sup>1</sup>	$0.22 \pm 0.25$

<sup>1</sup> 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 85: 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 [374]	$0.221 \pm 0.016 \pm 0.013$	$0.224 \pm 0.015$
	Belle [126]	$0.238 \pm 0.026 \pm 0.008$	
	BaBar [125]	$0.212 \pm 0.032 \pm 0.013$	
$A_{CP}^0(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [374]	$-0.003 \pm 0.038 \pm 0.005$	$-0.007 \pm 0.030$
	Belle [126]	$-0.030 \pm 0.061 \pm 0.007$	
	BaBar [125]	$0.01 \pm 0.07 \pm 0.02$	
$A_{CP}^{\perp}(B^0 \rightarrow \phi(1020)K^*(892)^0)$	LHCb [374]	$0.047 \pm 0.074 \pm 0.009$	$-0.02 \pm 0.06$
	Belle [126]	$-0.14 \pm 0.11 \pm 0.01$	
	BaBar [125]	$-0.04 \pm 0.15 \pm 0.06$	
$f_{\perp}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)^1$	BaBar [125]	$0.002^{+0.018}_{-0.002} \pm 0.031$	$0.029^{+0.024}_{-0.026}$
	Belle [126]	$0.056^{+0.050}_{-0.035} \pm 0.009$	
$A_{CP}^0(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [126]	$-0.016^{+0.066}_{-0.051} \pm 0.008$	$-0.03 \pm 0.04$
	BaBar [125]	$-0.05 \pm 0.06 \pm 0.01$	
$A_{CP}^{\perp}(B^0 \rightarrow \phi(1020)K_2^*(1430)^0)$	Belle [126]	$-0.01^{+0.85}_{-0.67} \pm 0.09$	$-0.01^{+0.85}_{-0.68}$

<sup>1</sup> The PDG uncertainty includes a scale factor.

 Table 86: 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 [141]	$0.290 \pm 0.008 \pm 0.007$	$0.293 \pm 0.010$
	CDF [197]	$0.365 \pm 0.044 \pm 0.027$	
$f_{\parallel}(B_s^0 \rightarrow \phi(1020)\overline{K}^*(892)^0)$	LHCb [127]	$0.21 \pm 0.11 \pm 0.02$	$0.21 \pm 0.11$
$f_{\perp}(B_s^0 \rightarrow K^*(892)^0\overline{K}^*(892)^0)$	LHCb [132]	$0.526 \pm 0.032 \pm 0.019$	$0.526 \pm 0.037$
			$0.380 \pm 0.120$
$f_{\parallel}(B_s^0 \rightarrow K^*(892)^0\overline{K}^*(892)^0)$	LHCb [132]	$0.234 \pm 0.025 \pm 0.010$	$0.23 \pm 0.03$
			$0.30 \pm 0.05$

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 [374], in addition to the results quoted in Table 85, LHCb reports observables related to the  $S$ -wave component contributing to 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 86, LHCb, in Ref. [141], extracts the  $CP$ -violating phase  $\phi_s^{ss}$  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. [197] also reports the triple-product asymmetries  $A_U$  and  $A_V$ .
- In Ref. [376], 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  $\phi_s^{d\bar{d}}$ .
- Ref. [373] 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.

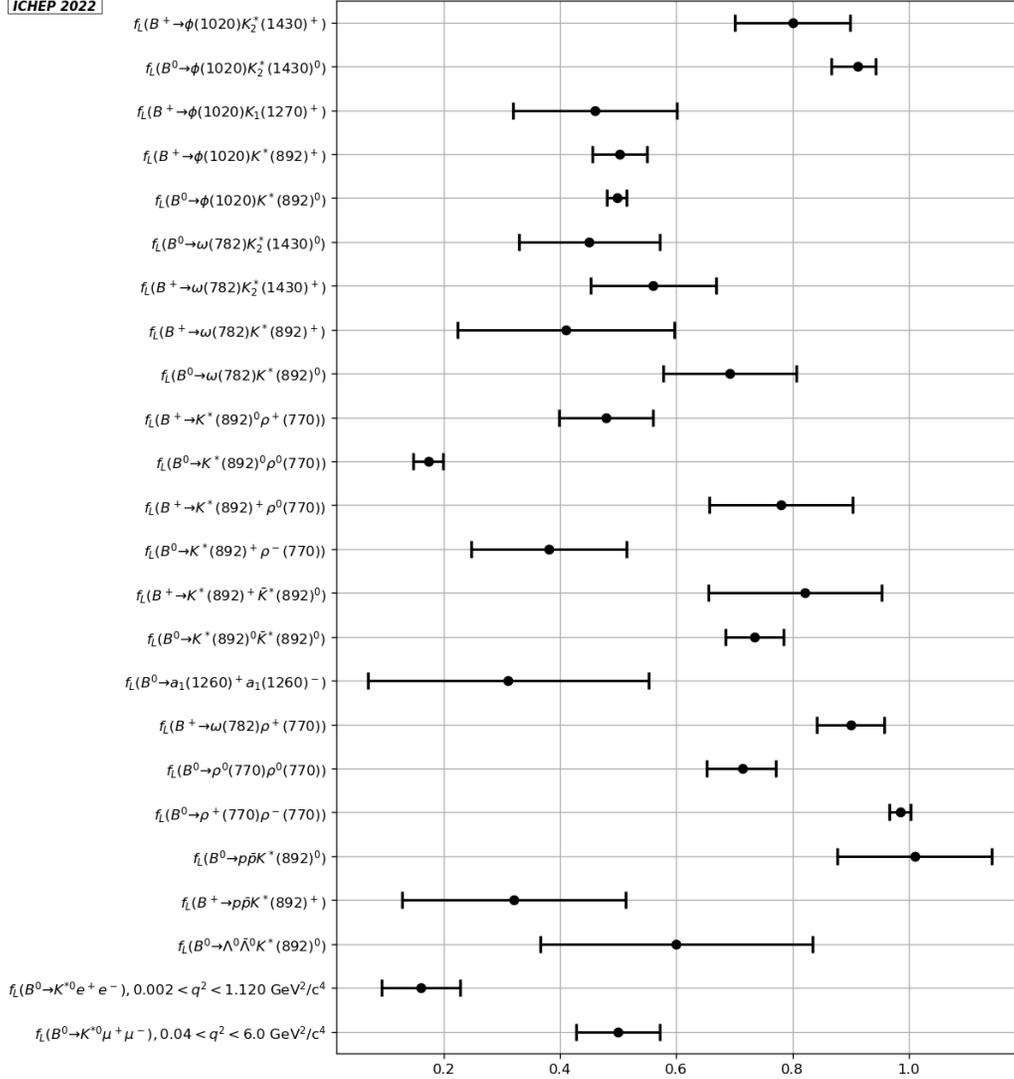


Figure 14: Longitudinal polarization fraction in charmless  $B$  decays.

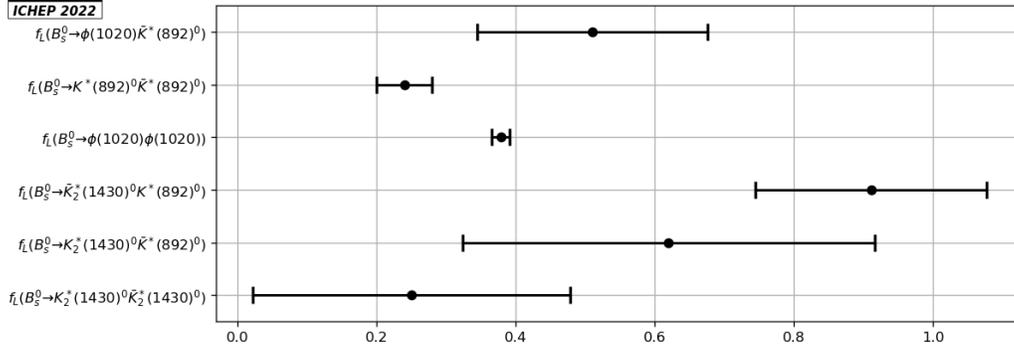


Figure 15: Longitudinal polarization fraction in charmless  $B_s^0$  decays.

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