Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B^+ Semi-leptonic and Radiative Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*		Belle		LHCb		Our Avg.
428	$K^{*+}\gamma$	42.1 ± 1.8	$42.2 \pm 1.4 \pm 1.6$	[1]	$37.6 \pm 1.0 \pm 1.2$	[2]			39.2 ± 1.3
429	$K_1^+(1270)\gamma$	44^{+7}_{-6}	$44.1^{+6.3}_{-4.4} \pm 5.8$ †	[3]	$43 \pm 9 \pm 9$	[4]			$43.8^{+7.1}_{-6.3}$
430	$K^+\eta\gamma$	7.9 ± 0.9	$7.7 \pm 1.0 \pm 0.4$	[5]	$8.4 \pm 1.5^{+1.2}_{-0.9}$	[6]			7.9 ± 0.9
431	$K^+\eta'\gamma$	$2.9^{+1.0}_{-0.9}$	$1.9^{+1.5}_{-1.2} \pm 0.1$	[7]	$3.6 \pm 1.2 \pm 0.4$	[8]			$2.9^{+1.0}_{-0.9}$
432	$K^+\phi\gamma$	2.7 ± 0.4	$3.5 \pm 0.6 \pm 0.4$	[9]	$2.48 \pm 0.30 \pm 0.24$	[10]			2.71 ± 0.34
433	$K^+\pi^-\pi^+\gamma$	25.8 ± 1.5	$25.9 \pm 0.7 \pm 1.0$ †¶	[3, 11]	$25.0 \pm 1.8 \pm 2.2$ ‡	[4]			25.8 ± 1.1
434	$K^{*0}\pi^+\gamma$ §	23.3 ± 1.2	$23.4 \pm 0.9^{+0.8}_{-0.7}$ †	[3]	$20^{+7}_{-6} \pm 2$	[12]			$23.3^{+1.2}_{-1.1}$
435	$K^+\rho^0\gamma$ §	$8.2 \pm 0.4 \pm 0.8$ †	$8.2 \pm 0.4 \pm 0.8$ †	[3]	< 20	[12]			8.2 ± 0.9
	$(K\pi)_0^{*0}\pi^+\gamma$		$10.3^{+0.7+1.5}_{-0.8-2.0}$ †	[3]					$10.3^{+1.7}_{-2.2}$
436	$K^+\pi^-\pi^+\gamma$ (N.R.) §	< 9.2	$9.9 \pm 0.7^{+1.5}_{-1.9}$ †	[3]	< 9.2	[12]			$9.9^{+1.7}_{-2.0}$
440	$K_0^*(1430)\pi^+\gamma$	$1.32^{+0.09+0.24}_{-0.10-0.30}$ †	$1.32^{+0.09+0.24}_{-0.10-0.30}$ †	[3]					$1.32^{+0.26}_{-0.32}$
437	$K^0\pi^+\pi^0\gamma$	46 ± 5	$45.6 \pm 4.2 \pm 3.1$ †	[11]					45.6 ± 5.2
438	$K_1^+(1400)\gamma$	$9.7^{+4.6+2.9}_{-2.9-2.4}$ †	$9.7^{+4.6+2.9}_{-2.9-2.4}$ †	[3]	< 15	[4]			$9.7^{+5.4}_{-3.8}$
439	$K^{*+}(1410)\gamma$	$27.1^{+5.4+5.9}_{-4.8-3.7}$ †	$27.1^{+5.4+5.9}_{-4.8-3.7}$ †	[3]					$27.1^{+8.0}_{-6.1}$
441	$K_2^*(1430)^+\gamma$	14 ± 4	$13.8^{+3.5+1.5}_{-3.2-1.0}$ †◇	[3, 13]					$13.8^{+3.8}_{-3.4}$
442	$K^{*+}(1680)\gamma$	$66.7^{+9.3+14.4}_{-7.8-11.4}$ †	$66.7^{+9.3+14.4}_{-7.8-11.4}$ †	[3]					$66.7^{+17.1}_{-13.8}$
443	$K_3^*(1780)^+\gamma$	< 39			< 39	[6]			< 39
444	$K_3^*(2045)^+\gamma$	< 9900	< 9900 [2]	[14]					< 9900 [2]
445	$\rho^+\gamma$	0.98 ± 0.25	$1.20^{+0.42}_{-0.37} \pm 0.20$	[15]	$0.87^{+0.29+0.09}_{-0.27-0.11}$	[16]			$0.98^{+0.25}_{-0.24}$
495	$p\overline{\Lambda}\gamma$	$2.4^{+0.5}_{-0.4}$			$2.45^{+0.44}_{-0.38} \pm 0.22$	[17]			$2.45^{+0.49}_{-0.44}$
499	$p\overline{\Sigma^0}\gamma$	< 4.6			< 4.6	[18]			< 4.6
534	$\pi^+\ell^+\ell^-$	< 0.049	< 0.066	[19]	< 0.049	[20]			< 0.049
535	$\pi^+e^+e^-$	< 0.080	< 0.125	[19]	< 0.080	[20]			< 0.080
536	$\pi^+\mu^+\mu^-$	$0.0179 \pm 0.0022 \pm 0.0005$	< 0.055	[19]	< 0.069	[20]	$0.0179 \pm 0.0022 \pm 0.0005$	[21]	0.0180 ± 0.0020
537	$\pi^+\nu\overline{\nu}$	< 98	< 100	[22]	< 98	[23]			< 98
538	$K^+\ell^+\ell^-$	0.451 ± 0.023	$0.48 \pm 0.09 \pm 0.02$	[24]	$0.53^{+0.06}_{-0.05} \pm 0.03$	[25]			0.51 ± 0.05
539	$K^+e^+e^-$	0.55 ± 0.07	$0.51^{+0.12}_{-0.11} \pm 0.02$	[24]	$0.57^{+0.09}_{-0.08} \pm 0.03$	[25]			0.55 ± 0.07
540	$K^+\mu^+\mu^-$	0.443 ± 0.024	$0.41^{+0.16}_{-0.15} \pm 0.02$	[24]	$0.53 \pm 0.08^{+0.07}_{-0.03}$	[25]	$0.429 \pm 0.007 \pm 0.021$	[26]	0.435 ± 0.021
541	$K^+\tau^+\tau^-$	< 2250	< 2250	[27]					< 2250
542	$K^+\nu\overline{\nu}$	< 16	< 16	[28]	< 16	[29]			< 16
543	$\rho^+\nu\overline{\nu}$	< 213			< 30	[29]			< 30
	$\pi^+\nu\overline{\nu}$				< 14	[29]			< 14
544	$K^{*+}\ell^+\ell^-$	1.01 ± 0.11	$1.40^{+0.40}_{-0.37} \pm 0.09$	[24]	$1.24^{+0.23}_{-0.21} \pm 0.13$	[25]	$0.924 \pm 0.093 \pm 0.067$	[30]	$1.009^{+0.101}_{-0.100}$
545	$K^{*+}e^+e^-$	$1.55^{+0.40}_{-0.31}$	$1.38^{+0.47}_{-0.42} \pm 0.08$	[24]	$1.73^{+0.50}_{-0.42} \pm 0.20$	[25]			$1.55^{+0.35}_{-0.32}$
546	$K^{*+}\mu^+\mu^-$	0.96 ± 0.10	$1.46^{+0.79}_{-0.75} \pm 0.12$	[24]	$1.11^{+0.32}_{-0.27} \pm 0.10$	[25]	$0.924 \pm 0.093 \pm 0.067$	[30]	$0.958^{+0.107}_{-0.104}$
547	$K^{*+}\nu\overline{\nu}$	< 40	< 64	[28]	< 40	[23]			< 40
548	$K^+\pi^+\pi^-\mu^+\mu^-$	0.44 ± 0.04					$0.436^{+0.029}_{-0.027} \pm 0.028$ [1]	[31]	$0.436^{+0.040}_{-0.039}$
549	$K^+\phi\mu^+\mu^-$	$0.079^{+0.021}_{-0.017}$					$0.082^{+0.019+0.029}_{-0.017-0.027}$	[31]	$0.082^{+0.035}_{-0.032}$
	$\Lambda p\nu\overline{\nu}$		< 30	[32]					< 30

Channels with no RPP# were not included in PDG Live as of Dec. 31, 2017.
Results for LHCb are relative BFs converted to absolute BFs.
CLEO upper limits that have been greatly superseded are not shown.

† $M_{K\pi\pi} < 1.8$ GeV/c^2.
‡ $1.0 < M_{K\pi\pi} < 2.0$ GeV/c^2.
§ $M_{K\pi\pi} < 2.4$ GeV/c^2.
¶ Average of *BABAR* results from [3] and [11].
◇ Average of *BABAR* results from [3] and [13].
[1] Differential BF in bins of $m(\mu^+\mu^-)$ is also available.
[2] Result from ARGUS. Cited in the *BABAR* column to avoid adding a column to the table.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B^0 Semi-leptonic and Radiative Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*		Belle		LHCb		Our Avg.
367	$K^0\eta\gamma$	7.6 ± 1.8	$7.1^{+2.1}_{-2.0} \pm 0.4$	[5]	$8.7^{+3.1+1.9}_{-2.7-1.6}$	[6]			$7.6^{+1.8}_{-1.7}$
368	$K^0\eta'\gamma$	< 6.4	< 6.6	[7]	< 6.4	[8]			< 6.4
369	$K^0\phi\gamma$	2.7 ± 0.7	< 2.7	[9]	$2.74 \pm 0.60 \pm 0.32$	[10]			2.74 ± 0.68
370	$K^+\pi^-\gamma$ §	4.6 ± 1.4			$4.6^{+1.3+0.5}_{-1.2-0.7}$	[12]			4.6 ± 1.4
371	$K^{*0}\gamma$	43.3 ± 1.5	$44.7 \pm 1.0 \pm 1.6$	[1]	$39.6 \pm 0.7 \pm 1.4$	[2]			41.7 ± 1.2
372	$K^*(1410)^0\gamma$	< 130			< 130	[12]			< 130
373	$K^+\pi^-\gamma$ (N.R.) †	< 2.6			< 2.6	[12]			< 2.6
374	$K^{*0}X(214), X(214) \to \mu^+\mu^-$	< 0.0226			< 0.0226	[33]			< 0.0226
375	$K^0\pi^+\pi^-\gamma$	19.9 ± 1.8	$19.2 \pm 1.4 \pm 1.1$ ‡§	[3, 11]	$24 \pm 4 \pm 3$ ¶	[4]			19.7 ± 1.7
376	$K^+\pi^-\pi^0\gamma$	41 ± 4	$40.7 \pm 2.2 \pm 3.1$ ‡	[11]					40.7 ± 3.8
377	$K_1^0(1270)\gamma$	< 58			< 58	[4]			< 58
378	$K_1^0(1400)\gamma$	< 12			< 12	[4]			< 12
379	$K_2^*(1430)^0\gamma$	12.4 ± 2.4	$12.2 \pm 2.5 \pm 1.0$	[13]	$13 \pm 5 \pm 1$	[12]			12.4 ± 2.4
381	$K_3^*(1780)^0\gamma$	< 83			< 83	[6]			< 83
383	$\rho^0\gamma$	0.86 ± 0.15	$0.97^{+0.24}_{-0.22} \pm 0.06$	[15]	$0.78^{+0.17+0.09}_{-0.16-0.10}$	[16]			$0.86^{+0.15}_{-0.14}$
384	$\rho^0X(214), X(214) \to \mu^+\mu^-$	< 0.0173			< 0.0173	[33]			< 0.0173
385	$\omega\gamma$	$0.44^{+0.18}_{-0.16}$	$0.50^{+0.27}_{-0.23} \pm 0.09$	[15]	$0.40^{+0.19}_{-0.17} \pm 0.13$	[16]			$0.44^{+0.18}_{-0.16}$
386	$\phi\gamma$	< 0.1	< 0.85	[34]	< 0.1	[35]			< 0.1
447	$p\overline{\Lambda}\pi^-\gamma$				< 0.65	[36]			< 0.65
503	$\pi^0\ell^+\ell^-$	< 0.053	< 0.053	[19]	< 0.154	[20]			< 0.053
504	$\pi^0e^+e^-$	< 0.084	< 0.084	[19]	< 0.227	[20]			< 0.084
505	$\pi^0\mu^+\mu^-$	< 0.069	< 0.069	[19]	< 0.184	[20]			< 0.069
506	$\eta\ell^+\ell^-$	< 0.064	< 0.064	[19]					< 0.064
507	ηe^+e^-	< 0.108	< 0.108	[19]					< 0.108
508	$\eta\mu^+\mu^-$	< 0.112	< 0.112	[19]					< 0.112
509	$\pi^0\nu\overline{\nu}$	< 69			< 9	[29]			< 9
510	$K^0\ell^+\ell^-$	$0.31^{+0.08}_{-0.07}$	$0.21^{+0.15}_{-0.13} \pm 0.02$	[24]	$0.34^{+0.09}_{-0.08} \pm 0.02$	[25]			$0.31^{+0.08}_{-0.07}$
511	$K^0e^+e^-$	$0.16^{+0.10}_{-0.08}$	$0.08^{+0.15}_{-0.12} \pm 0.01$	[24]	$0.20^{+0.14}_{-0.10} \pm 0.01$	[25]			$0.16^{+0.10}_{-0.08}$
512	$K^0\mu^+\mu^-$	0.339 ± 0.034	$0.49^{+0.29}_{-0.25} \pm 0.03$	[24]	$0.44^{+0.13}_{-0.10} \pm 0.03$	[25]	$0.327 \pm 0.034 \pm 0.017$	[30]	$0.343^{+0.036}_{-0.035}$
513	$K^0\nu\overline{\nu}$	< 49	< 49	[28]	< 26	[29]			< 26
514	$\rho^0\nu\overline{\nu}$	< 208			< 40	[29]			< 40
515	$K^{*0}\ell^+\ell^-$	$0.99^{+0.12}_{-0.11}$	$1.03^{+0.22}_{-0.21} \pm 0.07$	[24]	$0.97^{+0.13}_{-0.11} \pm 0.07$	[25]			$0.99^{+0.13}_{-0.11}$
516	$K^{*0}e^+e^-$	$1.03^{+0.19}_{-0.17}$	$0.86^{+0.26}_{-0.24} \pm 0.05$	[24]	$1.18^{+0.27}_{-0.22} \pm 0.09$	[25]			$1.03^{+0.19}_{-0.17}$
517	$K^{*0}\mu^+\mu^-$	1.03 ± 0.06	$1.35^{+0.40}_{-0.37} \pm 0.10$	[24]	$1.06^{+0.19}_{-0.14} \pm 0.07$	[25]	$1.036^{+0.018}_{-0.017} \pm 0.071$ [1]	[37]	$1.049^{+0.067}_{-0.065}$
518	$K^{*0}X(214), X(214) \to \mu^+\mu^-$	< 0.001					< 0.001	[38]	< 0.001
519	$\pi^+\pi^-\mu^+\mu^-$	$0.021 \pm 0.005 \pm 0.001$					$0.0211 \pm 0.0051 \pm 0.0022$ ◇	[39]	0.0210 ± 0.0060
520	$K^{*0}\nu\overline{\nu}$	< 55	< 120	[28]	< 55	[23]			< 55
523	$\phi\nu\overline{\nu}$	< 127			< 127	[23]			< 127
525	$\pi^0e^\pm\mu^\mp$	< 0.14	< 0.14	[40]					< 0.14
526	$K^0e^\pm\mu^\mp$	< 0.27	< 0.27	[41]					< 0.27
527	$K^{*0}e^+\mu^-$	< 0.53	< 0.53	[41]					< 0.53
528	$K^{*0}e^-\mu^+$	< 0.34	< 0.34	[41]					< 0.34
529	$K^{*0}e^\pm\mu^\mp$	< 0.58	< 0.58	[41]					< 0.58
532	$\Lambda_c^+\mu^-$	< 1.4	< 1.4	[42]					< 1.4
533	$\Lambda_c^+e^-$	< 4	< 4	[42]					< 4

Results for LHCb are relative BFs converted to absolute BFs.
CLEO upper limits that have been greatly superseded are not shown.
† $1.25\ \text{GeV}/c^2 < M_{K\pi} < 1.6\ \text{GeV}/c^2$.
‡ $M_{K\pi\pi} < 1.8\ \text{GeV}/c^2$.
§ Average of *BABAR* results from [3] and [11].
¶ $1.0 < M_{K\pi\pi} < 2.0\ \text{GeV}/c^2$.
◇ This result takes into account the S-wave fraction in the $K\pi$ system.
[1] Muon pairs do not originate from resonances and $0.5 < m(\pi^+\pi^-) < 1.3\ \text{GeV}/c^2$.

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Compilation of B Semi-leptonic and Radiative Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*		Belle		CLEO		CDF	Our Avg.
67	$K\eta\gamma$	$8.5^{+1.8}_{-1.6}$			$8.5^{+1.3}_{-1.2} \pm 0.9$	[6]				$8.5^{+1.6}_{-1.5}$
68	$K_1(1400)\gamma$	< 1.27					< 1.27	[43]		< 1.27
69	$K_2^*(1430)\gamma$	17^{+6}_{-5}					$17 \pm 6 \pm 1$	[43]		17 ± 6
71	$K_3^*(1780)\gamma$	< 37			< 37 §	[6]				< 37 §
78	$s\gamma$ †	349 ± 19	341^{+28}_{-28} ¶	[44–46]	328^{+20}_{-20} ¶	[47–49]	$329 \pm 44 \pm 29$	[50]		332 ± 15
78	$s\gamma$ ◇		308 ± 22 ¶	[44–46]	305^{+16}_{-16} ¶	[48, 49]				306 ± 12
79	$d\gamma$	9.2 ± 3.0	$9.2 \pm 2.0 \pm 2.3$	[51]						9.2 ± 3.0
85	$\rho\gamma$	1.39 ± 0.25	$1.73^{+0.34}_{-0.32} \pm 0.17$	[15]	$1.21^{+0.24}_{-0.22} \pm 0.12$	[16]				$1.39^{+0.22}_{-0.21}$
86	$\rho/\omega\gamma$	1.30 ± 0.23	$1.63^{+0.30}_{-0.28} \pm 0.16$	[15]	$1.14 \pm 0.20^{+0.10}_{-0.12}$	[16]				$1.30^{+0.18}_{-0.19}$
121	se^+e^- ‡	6.7 ± 1.7	$7.69^{+0.82+0.71}_{-0.77-0.60}$	[52]	$4.05 \pm 1.30^{+0.87}_{-0.83}$	[53]				6.67 ± 0.82
120	$s\mu^+\mu^-$ ‡	4.3 ± 1.0	$4.41^{+1.31+0.63}_{-1.17-0.50}$	[52]	$4.13 \pm 1.05^{+0.85}_{-0.81}$	[53]				$4.27^{+0.98}_{-0.91}$
123	$s\ell^+\ell^-$ ‡	5.8 ± 1.3	$6.73^{+0.70+0.60}_{-0.64-0.56}$	[52]	$4.11 \pm 0.83^{+0.85}_{-0.81}$	[53]				5.84 ± 0.69
124	$\pi\ell^+\ell^-$	< 0.059	< 0.059	[19]	< 0.062	[20]				< 0.059
125	πe^+e^-	< 0.110	< 0.110	[19]						< 0.110
126	$\pi\mu^+\mu^-$	< 0.050	< 0.050	[19]						< 0.050
127	Ke^+e^-	0.44 ± 0.06	$0.39^{+0.09}_{-0.08} \pm 0.02$	[24]	$0.48^{+0.08}_{-0.07} \pm 0.03$	[25]				0.44 ± 0.06
128	$K^*e^+e^-$	1.19 ± 0.20	$0.99^{+0.23}_{-0.21} \pm 0.06$	[24]	$1.39^{+0.23}_{-0.20} \pm 0.12$	[25]				$1.19^{+0.17}_{-0.16}$
129	$K\mu^+\mu^-$	0.44 ± 0.04	$0.41^{+0.13}_{-0.12} \pm 0.02$	[24]	$0.50 \pm 0.06 \pm 0.03$	[25]			$0.42 \pm 0.04 \pm 0.02$	[54] 0.44 ± 0.04
130	$K^*\mu^+\mu^-$	1.06 ± 0.09	$1.35^{+0.35}_{-0.33} \pm 0.10$	[24]	$1.10^{+0.16}_{-0.14} \pm 0.08$	[25]			$1.01 \pm 0.10 \pm 0.05$	[54] 1.06 ± 0.09
131	$K\ell^+\ell^-$	0.48 ± 0.04	$0.47 \pm 0.06 \pm 0.02$	[55]	$0.48^{+0.05}_{-0.04} \pm 0.03$	[25]				0.48 ± 0.04
132	$K^*\ell^+\ell^-$	1.05 ± 0.10	$1.02^{+0.14}_{-0.13} \pm 0.05$	[55]	$1.07^{+0.11}_{-0.10} \pm 0.09$	[25]				1.05 ± 0.10
133	$K\nu\overline{\nu}$	< 17	< 17	[28]	< 16	[29]				< 16
134	$K^*\nu\overline{\nu}$	< 76	< 76	[28]	< 27	[29]				< 27
	$\pi\nu\overline{\nu}$				< 9	[29]				< 9
	$\rho\nu\overline{\nu}$				< 30	[29]				< 30
136	$\pi e^\pm\mu^\mp$	< 0.092	< 0.092	[40]						< 0.092
137	$\rho e^\pm\mu^\mp$	< 3.2					< 3.2	[56]		< 3.2
138	$Ke^\pm\mu^\mp$	< 0.038	< 0.038	[41]						< 0.038
139	$K^*e^\pm\mu^\mp$	< 0.51	< 0.51	[41]						< 0.51

Channels with no RPP# were not included in PDG Live as of Dec. 31, 2017.
Results for CDF are relative BFs converted to absolute BFs.
CLEO upper limits that have been greatly superseded are not shown.

† Results extrapolated to $E_\gamma > 1.6$ GeV, using the method of Ref. [57].

‡ Belle: $m(\ell^+\ell^-) > 0.2$ GeV/c^2, *BABAR*: $m^2(\ell^+\ell^-) > 0.1$ GeV$^2/c^4$.

§ The value quoted is $\mathcal{B}(B \to K_3^*\gamma) \times \mathcal{B}(K_3^* \to K\eta)$. PDG gives the BF assuming $\mathcal{B}(K_3^* \to K\eta) = 11^{+5}_{-4}\%$.

¶ Average of several results, obtained with different methods.

◇ Only results originally measured in the interval $E_\gamma > 1.9$ GeV (also taken into account in the previous line).

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B^+ and B^0 Leptonic Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*	Belle	CDF	LHCb	CMS	ATLAS	Our Avg.
31	$e^+\nu$	< 0.98	< 1.9 [58]	< 0.98 † [59]					< 0.98 †
32	$\mu^+\nu$	< 1.0	< 1.0 [58]	< 1.07 [60]					< 1.0
33	$\tau^+\nu$	109 ± 24	179 ± 48 [61]	$91 \pm 19 \pm 11$ [62]					106 ± 19
34	$\ell^+\nu_\ell\gamma$	< 3.5	< 15.6 [63]	< 3.0 [64]					< 3.0
35	$e^+\nu_e\gamma$	< 6.1	< 17 [63]	< 4.3 [64]					< 4.3
36	$\mu^+\nu_\mu\gamma$	< 3.4	< 24 [63]	< 3.4 [64]					< 3.4
495	$\gamma\gamma$	< 0.32	< 0.32 [65]	< 0.62 [66]					< 0.32
458	e^+e^-	< 0.083	< 0.113 [67]	< 0.19 [68]	< 0.083 [69]				< 0.083
497	$e^+e^-\gamma$	< 0.12	< 0.12 [70]						< 0.12
498	$\mu^+\mu^-$	0.00018 ± 0.00031	< 0.052 [67]	< 0.16 [68]	< 0.0038 [71]	< 0.00034 ¶ [72]	< 0.00110 ¶ [73]	< 0.00021 ¶ [74]	< 0.00021 ¶
499	$\mu^+\mu^-\gamma$	< 0.16	< 0.16 [70]						< 0.16
500	$\mu^+\mu^-\mu^+\mu^-$	< 0.0053				< 0.0053 ¶ [75]			< 0.0053 ¶
501	$SP, S \to \mu^+\mu^-, P \to \mu^+\mu^-$	< 0.0051				< 0.0051 ¶ [75]			< 0.0051 ¶
502	$\tau^+\tau^-$	< 4100	< 4100 [76]			< 1600 [77]			< 1600
524	$e^\pm\mu^\mp$	< 0.0028	< 0.092 [67]	< 0.17 [68]	< 0.064 [69]	< 0.001 [78]			< 0.001
530	$e^\pm\tau^\mp$	< 28	< 28 [79]						< 28
532	$\mu^\pm\tau^\mp$	< 22	< 22 [79]						< 22
521	$\nu\bar{\nu}$	< 24	< 24 [80]	< 130 [81]					< 24
522	$\nu\bar{\nu}\gamma$	< 17	< 17 [80]						< 17
	$\mu^+\mu^-\mu^+\gamma$					< 0.016 ‡ [82]			< 0.016 ‡

Results for CDF, LHCb, CMS and ATLAS are relative BFs converted to absolute BFs.

† More recent results exist, with hadronic tagging [83], that do not improve the limits (< 3.5 and < 2.7) for $e^+\nu$ and $\mu^+\nu$, respectively).

‡ UL at 95% CL. The lower of the two $\mu^+\mu^-$ mass combinations is below 980 MeV/c^2.

¶ UL at 95% CL.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B Relative Semi-leptonic and Radiative Branching Fractions

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 AVG.	Belle		*BABAR*	LHCb		Our Avg.
548/298	$10^4 \times \mathcal{B}(K^+\pi^+\pi^-\mu^+\mu^-)/\mathcal{B}(\psi(2S)K^+)$	$6.95^{+0.46}_{-0.43} \pm 0.34$				$6.95^{+0.46}_{-0.43} \pm 0.34$	[31]	$6.95^{+0.57}_{-0.55}$
549/274	$10^4 \times \mathcal{B}(K^+\phi\mu^+\mu^-)/\mathcal{B}(\psi(2S)K^+)$	$1.58^{+0.36+0.19}_{-0.32-0.07}$				$1.58^{+0.36+0.19}_{-0.32-0.07}$	[31]	$1.58^{+0.41}_{-0.33}$
536/540	$\mathcal{B}(\pi^+\mu^+\mu^-)/\mathcal{B}(K^+\mu^+\mu^-)$ †	$0.053 \pm 0.014 \pm 0.01$				$0.038 \pm 0.009 \pm 0.001$	[21]	0.038 ± 0.009
	$\mathcal{B}(K^+\mu^+\mu^-)/\mathcal{B}(K^+e^+e^-)$ ‡					$0.846^{+0.060+0.016}_{-0.054-0.014}$	[84]	$0.846^{+0.062}_{-0.056}$
	$\mathcal{B}(K^+\mu^+\mu^-)/\mathcal{B}(K^+e^+e^-)$ ¶				$1.00^{+0.31}_{-0.25} \pm 0.07$		[55]	$1.00^{+0.32}_{-0.26}$
	$\mathcal{B}(K^+\mu^+\mu^-)/\mathcal{B}(K^+e^+e^-)$ §		$1.03 \pm 0.19 \pm 0.06$	[25]				1.03 ± 0.20
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ §		$0.83 \pm 0.17 \pm 0.08$	[25]				0.83 ± 0.19
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ ¶				$1.013^{+0.34}_{-0.26} \pm 0.010$		[55]	$1.013^{+0.340}_{-0.260}$
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ ◇		$0.52^{+0.36}_{-0.26} \pm 0.05$	[85]				$0.52^{+0.36}_{-0.27}$
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ ‡		$0.96^{+0.45}_{-0.29} \pm 0.11$	[85]				$0.96^{+0.46}_{-0.31}$
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ 1		$1.18^{+0.52}_{-0.32} \pm 0.10$	[85]				$1.18^{+0.53}_{-0.34}$
	$\mathcal{B}(K^{*0}\mu^+\mu^-)/\mathcal{B}(K^{*0}e^+e^-)$ ◇		$0.46^{+0.55}_{-0.27} \pm 0.07$	[85]		$0.66^{+0.11}_{-0.07} \pm 0.03$	[86]	$0.65^{+0.11}_{-0.07}$
	$\mathcal{B}(K^{*0}\mu^+\mu^-)/\mathcal{B}(K^{*0}e^+e^-)$ ‡		$1.06^{+0.63}_{-0.38} \pm 0.13$	[85]		$0.69^{+0.11}_{-0.07} \pm 0.05$	[86]	$0.71^{+0.12}_{-0.09}$
	$\mathcal{B}(K^{*0}\mu^+\mu^-)/\mathcal{B}(K^{*0}e^+e^-)$ 1		$1.12^{+0.61}_{-0.36} \pm 0.10$	[85]				$1.12^{+0.62}_{-0.37}$
	$\mathcal{B}(K^{*+}\mu^+\mu^-)/\mathcal{B}(K^{*+}e^+e^-)$ ◇		$0.62^{+0.60}_{-0.36} \pm 0.10$	[85]				$0.62^{+0.61}_{-0.37}$
	$\mathcal{B}(K^{*+}\mu^+\mu^-)/\mathcal{B}(K^{*+}e^+e^-)$ ‡		$0.72^{+0.99}_{-0.44} \pm 0.18$	[85]				$0.72^{+1.01}_{-0.47}$
	$\mathcal{B}(K^{*+}\mu^+\mu^-)/\mathcal{B}(K^{*+}e^+e^-)$ 1		$1.40^{+1.99}_{-0.68} \pm 0.11$	[85]				$1.40^{+1.99}_{-0.69}$
	$\mathcal{B}(B^0 \to K^{*0}\gamma)/\mathcal{B}(B_s^0 \to \phi\gamma)$		$1.10 \pm 0.16 \pm 0.09 \pm 0.18$	[2]		$1.23 \pm 0.06 \pm 0.11$	[87]	1.21 ± 0.11

Channels with no RPP# were not included in PDG Live as of Dec. 31, 2017.

† For $0.1 < m^2(\ell^+\ell^-) < 6.0$ GeV$^2/c^4$.

‡ For $1.1 < m^2(\ell^+\ell^-) < 6.0$ GeV$^2/c^4$.

§ For the full $m^2(\ell^+\ell^-)$ range.

¶ For $0.10 < m^2(\ell^+\ell^-) < 8.12$ GeV$^2/c^4$ and $m^2(\ell^+\ell^-) > 10.11$ GeV$^2/c^4$.

◇ For $0.045 < m^2(\ell^+\ell^-) < 1.1$ GeV$^2/c^4$.

1 For $15 < m^2(\ell^+\ell^-) < 19$ GeV$^2/c^4$.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of Branching Fractions of B^+/B^0 to $\bar{q}$ gluon decays ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*	Belle	CLEO	Our Avg.
81	ηX	260^{+50}_{-80}		$261 \pm 30^{+44}_{-74}$ [§][88]	< 440 [89]	261^{+53}_{-79}
82	$\eta' X$	420 ± 90	$390 \pm 80 \pm 90$ [†][90]		$460 \pm 110 \pm 60$ [†][91]	423 ± 86
83	$K^+ X$	< 187	< 187 [‡] [92]			< 187 [‡]
84	$K^0 X$	190^{+70}_{-70}	$195^{+51}_{-45} \pm 50$ [‡] [92]			195^{+71}_{-67}
95	$\pi^+ X$	370 ± 80	$372^{+50}_{-47} \pm 59$ [¶] [92]			372^{+77}_{-75}

[†] $2.0 < p^*(\eta') < 2.7$ GeV/c.
[‡] $m_X < 1.69$ GeV/c^2.
[§] $0.4 < m_X < 2.6$ GeV/c^2.
[¶] $m_X < 1.71$ GeV/c^2.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Isospin Asymmetry

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

Parameter	PDG2017 Avg.	*BABAR*		Belle		LHCb	Our Avg.
$\Delta_{0^-}(X_s\gamma)$	-0.01 ± 0.06	$-0.01^{+0.06}_{-0.06}$ ‡	[44, 93]	$-0.0048 \pm 0.0149 \pm 0.0097 \pm 0.0115$	[94]		-0.0055 ± 0.0198
$\Delta_{0^+}(K^*\gamma)$	0.052 ± 0.026	$0.066 \pm 0.021 \pm 0.022$	[1]	$0.062 \pm 0.015 \pm 0.006 \pm 0.012$	[2]		0.063 ± 0.017
$\Delta_{\rho\gamma}$	-0.46 ± 0.17	$-0.43^{+0.25}_{-0.22} \pm 0.10$	[15]	$-0.48^{+0.21+0.08}_{-0.19-0.09}$	[16]		$-0.46^{+0.17}_{-0.16}$
$\Delta_{0^-}(K\ell\ell)$ †	-0.13 ± 0.06	$-0.58^{+0.29}_{-0.37} \pm 0.02$	[55]	$-0.31^{+0.17}_{-0.14} \pm 0.08$	[25]	$-0.10^{+0.08}_{-0.09} \pm 0.02$ §	[30] -0.17 ± 0.08
$\Delta_{0^-}(K^*\ell\ell)$ †	-0.45 ± 0.17	$-0.64^{+0.15}_{-0.14} \pm 0.03$	[55]	$0.30^{+0.12}_{-0.11} \pm 0.08$	[25]	$0.00^{+0.12}_{-0.10} \pm 0.02$ §	[30] -0.06 ± 0.07

In some of the B-factory results it is assumed that $\mathcal{B}(\Upsilon(4S) \to B^+B^-) = \mathcal{B}(\Upsilon(4S) \to B^0\overline{B}^0)$, and in others a measured value of the ratio of branching fractions is used. See original papers for details. The averages quoted above are computed naively and should be treated with caution.

† Results given for the bin $1 < m^2(\ell^+\ell^-) < 6$ GeV$^2/c^4$, see references for the other bins.

‡ Average of two independent measurements from *BABAR* [44, 93].

§ Only muons are used.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B^+ Semi-leptonic LFV & LNV Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*	BELLE	LHCb	Our Avg.
552	$\pi^+ e^\pm \mu^\mp$	< 0.17	< 0.17 [40]			< 0.17
553	$\pi^+ e^+ \tau^-$	< 74	< 74 [95]			< 74
554	$\pi^+ e^- \tau^+$	< 20	< 20 [95]			< 20
555	$\pi^+ e^\pm \tau^\mp$	< 75	< 75 [95]			< 75
556	$\pi^+ \mu^+ \tau^-$	< 62	< 62 [95]			< 62
557	$\pi^+ \mu^- \tau^+$	< 45	< 45 [95]			< 45
558	$\pi^+ \mu^\pm \tau^\mp$	< 72	< 72 [95]			< 72
559	$K^+ e^+ \mu^-$	< 0.091	< 0.091 [41]			< 0.091
560	$K^+ e^- \mu^+$	< 0.13	< 0.13 [41]			< 0.13
561	$K^+ e^\pm \mu^\mp$	< 0.091	< 0.091 [41]			< 0.091
562	$K^+ e^+ \tau^-$	< 43	< 43 [95]			< 43
563	$K^+ e^- \tau^+$	< 15	< 15 [95]			< 15
564	$K^+ e^\pm \tau^\mp$	< 30	< 30 [95]			< 30
565	$K^+ \mu^+ \tau^-$	< 45	< 45 [95]			< 45
566	$K^+ \mu^- \tau^+$	< 28	< 28 [95]			< 28
567	$K^+ \mu^\pm \tau^\mp$	< 48	< 48 [95]			< 48
568	$K^{*+} e^+ \mu^-$	< 1.3	< 1.3 [41]			< 1.3
569	$K^{*+} e^- \mu^+$	< 0.99	< 0.99 [41]			< 0.99
570	$K^{*+} e^\pm \mu^\mp$	< 1.4	< 1.4 [41]			< 1.4
571	$\pi^- e^+ e^+$	< 0.023	< 0.023 [96]			< 0.023
572	$\pi^- \mu^+ \mu^+$	< 0.013	< 0.107 [96]		< 0.004 † [97]	< 0.004 †
573	$\pi^- e^+ \mu^+$	< 0.15	< 0.15 [98]			< 0.15
574	$\rho^- e^+ e^+$	< 0.17	< 0.17 [98]			< 0.17
575	$\rho^- \mu^+ \mu^+$	< 0.42	< 0.42 [98]			< 0.42
576	$\rho^- e^+ \mu^+$	< 0.47	< 0.47 [98]			< 0.47
577	$K^- e^+ e^+$	< 0.03	< 0.03 [96]			< 0.03
578	$K^- \mu^+ \mu^+$	< 0.041	< 0.067 [96]		< 0.041 [99]	< 0.041
579	$K^- e^+ \mu^+$	< 0.16	< 0.16 [98]			< 0.16
580	$K^{*-} e^+ e^+$	< 0.40	< 0.40 [98]			< 0.40
581	$K^{*-} \mu^+ \mu^+$	< 0.59	< 0.59 [98]			< 0.59
582	$K^{*-} e^+ \mu^+$	< 0.30	< 0.30 [98]			< 0.30
583	$D^- e^+ e^+$	< 2.6	< 2.6 [98]	< 2.6 [100]		< 2.6
584	$D^- e^+ \mu^+$	< 1.8	< 2.1 [98]	< 1.8 [100]		< 1.8
585	$D^- \mu^+ \mu^+$	< 0.69	< 1.7 [98]	< 1.1 [100]	< 0.69 [101]	< 0.69
586	$D_s^- \mu^+ \mu^+$	< 0.58			< 0.58 [101]	< 0.58
587	$\bar{D}^0 \pi^- \mu^+ \mu^+$	< 1.5			< 1.5 [101]	< 1.5
589	$\Lambda^0 \mu^+$	< 0.06	< 0.06 [42]			< 0.06
590	$\Lambda^0 e^+$	< 0.032	< 0.032 [42]			< 0.032
591	$\bar{\Lambda}^0 \mu^+$	< 0.06	< 0.06 [42]			< 0.06
592	$\bar{\Lambda}^0 e^+$	< 0.08	< 0.08 [42]			< 0.08

Results for LHCb are relative BFs converted to absolute BFs.
CLEO upper limits that have been greatly superseded are not shown.
† UL at 95% CL.

Heavy FLavor AVeraging group (HFLAV) - April 2019

Compilation of B^0 Semi-leptonic LFV & LNV Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

Preliminary Updated results not included in PDG Live as of Dec. 31, 2017

RPP#	Mode	PDG2017 Avg.	*BABAR*	BELLE	LHCb	Our Avg.
	$K^{*0}\mu^+e^-$			< 0.12 [102]		< 0.12
	$K^{*0}\mu^-e^+$			< 0.16 [102]		< 0.16
	$K^{*0}\mu^\pm e^\mp$			< 0.18 [102]		< 0.18

Channels with no RPP# were not included in PDG Live as of Dec. 31, 2017.

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