Heavy FLavor AVeraging group (HFLAV) - December 2017

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	$K_3^*(1780)^+\gamma$	< 9900			< 39	[6]			< 39
444	$K_3^*(2045)^+\gamma$	< 39			< 39	[6]			< 39
445	$\rho^+\gamma$	0.98 ± 0.25	$1.20^{+0.42}_{-0.37} \pm 0.20$	[14]	$0.87^{+0.29+0.09}_{-0.27-0.11}$	[15]			$0.98^{+0.25}_{-0.24}$
495	$p\overline{\Lambda}\gamma$	$2.4^{+0.5}_{-0.4}$			$2.45^{+0.44}_{-0.38} \pm 0.22$	[16]			$2.45^{+0.49}_{-0.44}$
499	$p\overline{\Sigma^0}\gamma$	< 4.6			< 4.6	[17]			< 4.6
534	$\pi^+\ell^+\ell^-$	< 0.049	< 0.066	[18]	< 0.049	[19]			< 0.049
535	$\pi^+e^+e^-$	< 0.080	< 0.125	[18]	< 0.080	[19]			< 0.080
536	$\pi^+\mu^+\mu^-$	$0.0179 \pm 0.0022 \pm 0.0005$	< 0.055	[18]	< 0.069	[19]	$0.0179 \pm 0.0022 \pm 0.0005$	[20]	0.0180 ± 0.0020
537	$\pi^+\nu\overline{\nu}$	< 98	< 100	[21]	< 98	[22]			< 98
538	$K^+\ell^+\ell^-$	0.451 ± 0.023	$0.48 \pm 0.09 \pm 0.02$	[23]	$0.53^{+0.06}_{-0.05} \pm 0.03$	[24]			0.51 ± 0.05
539	$K^+e^+e^-$	0.55 ± 0.07	$0.51^{+0.12}_{-0.11} \pm 0.02$	[23]	$0.57^{+0.09}_{-0.08} \pm 0.03$	[24]			0.55 ± 0.07
540	$K^+\mu^+\mu^-$	0.443 ± 0.024	$0.41^{+0.16}_{-0.15} \pm 0.02$	[23]	$0.53 \pm 0.08^{+0.07}_{-0.03}$	[24]	$0.429 \pm 0.007 \pm 0.021$	[25]	0.435 ± 0.021
541	$K^+\tau^+\tau^-$	< 2250	< 2250	[26]					< 2250
542	$K^+\nu\overline{\nu}$	< 16	< 16	[27]	< 16	[28]			< 16
543	$\rho^+\nu\overline{\nu}$	< 213			< 30	[28]			< 30
	$\pi^+\nu\overline{\nu}$				< 14	[28]			< 14
544	$K^{*+}\ell^+\ell^-$	1.01 ± 0.11	$1.40^{+0.40}_{-0.37} \pm 0.09$	[23]	$1.24^{+0.23}_{-0.21} \pm 0.13$	[24]	$0.924 \pm 0.093 \pm 0.067$	[29]	$1.009^{+0.101}_{-0.100}$
545	$K^{*+}e^+e^-$	$1.55^{+0.40}_{-0.31}$	$1.38^{+0.47}_{-0.42} \pm 0.08$	[23]	$1.73^{+0.50}_{-0.42} \pm 0.20$	[24]			$1.55^{+0.35}_{-0.32}$
546	$K^{*+}\mu^+\mu^-$	0.96 ± 0.10	$1.46^{+0.79}_{-0.75} \pm 0.12$	[23]	$1.11^{+0.32}_{-0.27} \pm 0.10$	[24]	$0.924 \pm 0.093 \pm 0.067$	[29]	$0.958^{+0.107}_{-0.104}$
547	$K^{*+}\nu\overline{\nu}$	< 40	< 64	[27]	< 40	[22]			< 40
548	$K^+\pi^+\pi^-\mu^+\mu^-$	0.44 ± 0.04					$0.436^{+0.029}_{-0.027} \pm 0.028$ [1]	[30]	$0.436^{+0.040}_{-0.039}$
549	$K^+\phi\mu^+\mu^-$	$0.079^{+0.021}_{-0.017}$					$0.082^{+0.019+0.029}_{-0.017-0.027}$	[30]	$0.082^{+0.035}_{-0.032}$

Channels with no RPP# are not reported by PDG.

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.

Heavy FLavor AVeraging group (HFLAV) - December 2017

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	[31]			< 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	$K^0_1(1270)\gamma$	< 58			< 58	[4]			< 58
378	$K^0_1(1400)\gamma$	< 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	$0.97^{+0.24}_{-0.22} \pm 0.06$	[14]	$0.78^{+0.17+0.09}_{-0.16-0.10}$	[15]			$0.86^{+0.15}_{-0.14}$
384	$\rho^0X(214), X(214) \to \mu^+\mu^-$	< 0.0173			< 0.0173	[31]			< 0.0173
385	$\omega\gamma$	$0.44^{+0.18}_{-0.16}$	$0.50^{+0.27}_{-0.23} \pm 0.09$	[14]	$0.40^{+0.19}_{-0.17} \pm 0.13$	[15]			$0.44^{+0.18}_{-0.16}$
386	$\phi\gamma$	< 0.1	< 0.85	[32]	< 0.1	[33]			< 0.1
447	$p\bar{\Lambda}\pi^-\gamma$				< 0.65	[34]			< 0.65
503	$\pi^0\ell^+\ell^-$	< 0.053	< 0.053	[18]	< 0.154	[19]			< 0.053
504	$\pi^0 e^+e^-$	< 0.084	< 0.084	[18]	< 0.227	[19]			< 0.084
505	$\pi^0\mu^+\mu^-$	< 0.069	< 0.069	[18]	< 0.184	[19]			< 0.069
506	$\eta\ell^+\ell^-$	< 0.064	< 0.064	[18]					< 0.064
507	ηe^+e^-	< 0.108	< 0.108	[18]					< 0.108
508	$\eta\mu^+\mu^-$	< 0.112	< 0.112	[18]					< 0.112
509	$\pi^0\nu\bar{\nu}$	< 69			< 9	[28]			< 9
510	$K^0\ell^+\ell^-$	$0.31^{+0.08}_{-0.07}$	$0.21^{+0.15}_{-0.13} \pm 0.02$	[23]	$0.34^{+0.09}_{-0.08} \pm 0.02$	[24]			$0.31^{+0.08}_{-0.07}$
511	$K^0 e^+e^-$	$0.16^{+0.10}_{-0.08}$	$0.08^{+0.15}_{-0.12} \pm 0.01$	[23]	$0.20^{+0.14}_{-0.10} \pm 0.01$	[24]			$0.16^{+0.10}_{-0.08}$
512	$K^0\mu^+\mu^-$	0.339 ± 0.034	$0.49^{+0.29}_{-0.25} \pm 0.03$	[23]	$0.44^{+0.13}_{-0.10} \pm 0.03$	[24]	$0.327 \pm 0.034 \pm 0.017$	[29]	$0.343^{+0.036}_{-0.035}$
513	$K^0\nu\bar{\nu}$	< 49	< 49	[27]	< 26	[28]			< 26
514	$\rho^0\nu\bar{\nu}$	< 208			< 40	[28]			< 40
515	$K^{*0}\ell^+\ell^-$	$0.99^{+0.12}_{-0.11}$	$1.03^{+0.22}_{-0.21} \pm 0.07$	[23]	$0.97^{+0.13}_{-0.11} \pm 0.07$	[24]			$0.99^{+0.13}_{-0.11}$
516	$K^{*0}e^+e^-$	$1.03^{+0.19}_{-0.17}$	$0.86^{+0.26}_{-0.24} \pm 0.05$	[23]	$1.18^{+0.27}_{-0.22} \pm 0.09$	[24]			$1.03^{+0.19}_{-0.17}$
517	$K^{*0}\mu^+\mu^-$	1.03 ± 0.06	$1.35^{+0.40}_{-0.37} \pm 0.10$	[23]	$1.06^{+0.19}_{-0.14} \pm 0.07$	[24]	$1.036^{+0.018}_{-0.017} \pm 0.071$ [1]	[35]	$1.049^{+0.067}_{-0.065}$
518	$K^{*0}X(214), X(214) \to \mu^+\mu^-$	< 0.001					< 0.001	[36]	< 0.001
519	$\pi^+\pi^-\mu^+\mu^-$	$0.021 \pm 0.005 \pm 0.001$					$0.0211 \pm 0.0051 \pm 0.0022$ ◇	[37]	0.0210 ± 0.0060
520	$K^{*0}\nu\bar{\nu}$	< 55	< 120	[27]	< 55	[22]			< 55
523	$\phi\nu\bar{\nu}$	< 127			< 127	[22]			< 127
525	$\pi^0 e^\pm\mu^\mp$	< 0.14	< 0.14	[38]					< 0.14
526	$K^0 e^\pm\mu^\mp$	< 0.27	< 0.27	[39]					< 0.27
527	$K^{*0}e^+\mu^-$	< 0.53	< 0.53	[39]					< 0.53
528	$K^{*0}e^-\mu^+$	< 0.34	< 0.34	[39]					< 0.34
529	$K^{*0}e^\pm\mu^\mp$	< 0.58	< 0.58	[39]					< 0.58
532	$\Lambda_c^+\mu^-$	< 1.4	< 1.4	[40]					< 1.4
533	$\Lambda_c^+ e^-$	< 4	< 4	[40]					< 4

Results for LHCb are relative BFs converted to absolute BFs.

CLEO upper limits that have been greatly superseded are not shown.

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

‡ $M_{K\pi\pi} < 1.8$ GeV/c^2.

§ Average of BABAR results from [3] and [11].

¶ $1.0 < M_{K\pi\pi} < 2.0$ 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 $0.5 < m(\pi^+\pi^-) < 1.3$ 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	[41]			< 1.27
69	$K_2^*(1430)\gamma$	17^{+6}_{-5}					$17 \pm 6 \pm 1$	[41]			17 ± 6
71	$K_3^*(1780)\gamma$	< 37			< 37 §	[6]					< 37 §
78	$s\gamma$ †	349 ± 19	341^{+28}_{-28} ¶	[42–44]	328^{+20}_{-20} ¶	[45–47]	$329 \pm 44 \pm 29$[48]				332 ± 15
77	$s\gamma$ $^\diamond$		308 ± 22 ¶	[42–44]	305^{+16}_{-16} ¶	[46, 47]					306 ± 12
79	$d\gamma$	9.2 ± 3.0	$9.2 \pm 2.0 \pm 2.3$	[49]							9.2 ± 3.0
85	$\rho\gamma$	1.39 ± 0.25	$1.73^{+0.34}_{-0.32} \pm 0.17$	[14]	$1.21^{+0.24}_{-0.22} \pm 0.12$	[15]					$1.39^{+0.22}_{-0.21}$
86	$\rho/\omega\gamma$	1.30 ± 0.23	$1.63^{+0.30}_{-0.28} \pm 0.16$	[14]	$1.14 \pm 0.20^{+0.10}_{-0.12}$	[15]					$1.30^{+0.18}_{-0.19}$
121	se^+e^- ‡	6.7 ± 1.7	$7.69^{+0.82+0.71}_{-0.77-0.60}$	[50]	$4.05 \pm 1.30^{+0.87}_{-0.83}$	[51]					6.67 ± 0.82
120	$s\mu^+\mu^-$ ‡	4.3 ± 1.0	$4.41^{+1.31+0.63}_{-1.17-0.50}$	[50]	$4.13 \pm 1.05^{+0.85}_{-0.81}$	[51]					$4.27^{+0.98}_{-0.91}$
123	$s\ell^+\ell^-$ ‡	5.8 ± 1.3	$6.73^{+0.70+0.60}_{-0.64-0.56}$	[50]	$4.11 \pm 0.83^{+0.85}_{-0.81}$	[51]					5.84 ± 0.69
124	$\pi\ell^+\ell^-$	< 0.059	< 0.059	[18]	< 0.062	[19]					< 0.059
125	πe^+e^-	< 0.110	< 0.110	[18]							< 0.110
126	$\pi\mu^+\mu^-$	< 0.050	< 0.050	[18]							< 0.050
127	Ke^+e^-	0.44 ± 0.06	$0.39^{+0.09}_{-0.08} \pm 0.02$	[23]	$0.48^{+0.08}_{-0.07} \pm 0.03$	[24]					0.44 ± 0.06
128	$K^*e^+e^-$	1.19 ± 0.20	$0.99^{+0.23}_{-0.21} \pm 0.06$	[23]	$1.39^{+0.23}_{-0.20} \pm 0.12$	[24]					$1.19^{+0.17}_{-0.16}$
129	$K\mu^+\mu^-$	0.44 ± 0.04	$0.41^{+0.13}_{-0.12} \pm 0.02$	[23]	$0.50 \pm 0.06 \pm 0.03$	[24]			$0.42 \pm 0.04 \pm 0.02$[52]		0.44 ± 0.04
130	$K^*\mu^+\mu^-$	1.06 ± 0.09	$1.35^{+0.35}_{-0.33} \pm 0.10$	[23]	$1.10^{+0.16}_{-0.14} \pm 0.08$	[24]			$1.01 \pm 0.10 \pm 0.05$[52]		1.06 ± 0.09
131	$K\ell^+\ell^-$	0.48 ± 0.04	$0.47 \pm 0.06 \pm 0.02$	[53]	$0.48^{+0.05}_{-0.04} \pm 0.03$	[24]					0.48 ± 0.04
132	$K^*\ell^+\ell^-$	1.05 ± 0.10	$1.02^{+0.14}_{-0.13} \pm 0.05$	[53]	$1.07^{+0.11}_{-0.10} \pm 0.09$	[24]					1.05 ± 0.10
133	$K\nu\bar{\nu}$	< 17	< 17	[27]	< 16	[28]					< 16
134	$K^*\nu\bar{\nu}$	< 76	< 76	[27]	< 27	[28]					< 27
	$\pi\nu\bar{\nu}$				< 9	[28]					< 9
	$\rho\nu\bar{\nu}$				< 30	[28]					< 30
136	$\pi e^\pm\mu^\mp$	< 0.092	< 0.092	[38]							< 0.092
137	$\rho e^\pm\mu^\mp$	< 3.2					< 3.2	[54]			< 3.2
138	$Ke^\pm\mu^\mp$	< 0.038	< 0.038	[39]							< 0.038
139	$K^*e^\pm\mu^\mp$	< 0.51	< 0.51	[39]							< 0.51

Channels with no RPP# are not reported by PDG.

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. [55].

‡ 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.

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

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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 [56]	< 0.98 † [57]					< 0.98 †
32	$\mu^+\nu$	< 1.0	< 1.0 [56]	< 1.7 † [57]					< 1.0
33	$\tau^+\nu$	109 ± 24	$183^{+53}_{-49} \pm 24$ ‡[58]	$125 \pm 28 \pm 27$ ‡[59]					144 ± 31
34	$\ell^+\nu_\ell\gamma$	< 3.5	< 15.6 [60]	< 3.5 [61]					< 3.5
35	$e^+\nu_e\gamma$	< 6.1	< 17 [60]	< 6.1 [61]					< 6.1
36	$\mu^+\nu_\mu\gamma$	< 3.4	< 24 [60]	< 3.4 [61]					< 3.4
495	$\gamma\gamma$	< 0.32	< 0.32 [62]	< 0.62 [63]					< 0.32
458	e^+e^-	< 0.083	< 0.113 [64]	< 0.19 [65]	< 0.083 [66]				< 0.083
497	$e^+e^-\gamma$	< 0.12	< 0.12 [67]						< 0.12
498	$\mu^+\mu^-$	$0.00018^{+3.1}_{-3.1}$	< 0.052 [64]	< 0.16 [65]	< 0.0038[68]	< 0.00034 ¶[69]	< 0.00110 ¶[70]	$-0.25^{+0.20}_{-0.20}$ ¶[71]	$0.00039^{+0.00016}_{-0.00014}$ §
499	$\mu^+\mu^-\gamma$	< 0.16	< 0.16 [67]						< 0.16
500	$\mu^+\mu^-\mu^+\mu^-$	< 0.0053				< 0.0053 ¶ [72]			< 0.0053 ¶
501	$SP, S \to \mu^+\mu^-, P \to \mu^+\mu^-$	< 0.0051				< 0.0051 ¶ [72]			< 0.0051 ¶
502	$\tau^+\tau^-$	< 4100	< 4100 [73]			< 1600 [74]			< 1600
524	$e^\pm\mu^\mp$	< 0.0028	< 0.092 [64]	< 0.17 [65]	< 0.064 [66]	< 0.001 [75]			< 0.001
530	$e^\pm\tau^\mp$	< 28	< 28 [76]						< 28
532	$\mu^\pm\tau^\mp$	< 22	< 22 [76]						< 22
521	$\nu\bar\nu$	< 24	< 24 [77]	< 130 [78]					< 24
522	$\nu\bar\nu\gamma$	< 17	< 17 [77]						< 17

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

† More recent results exist, with hadronic tagging [79], that do not improve the limits (< 3.5 and < 2.7) for $e^+\nu$ and $\mu^+\nu$, respectively).

‡ The authors make the average with their previous results, derived from statistically independent samples [80, 81].

§ This is the combined result obtained by the LHCb and CMS collaborations [82].

¶ UL at 95% CL.

Heavy FLavor AVeraging group (HFLAV) - December 2017

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	$10^4 \times \mathcal{B}(K^+\pi^+\pi^-\mu^+\mu^-)/\mathcal{B}(\psi(2S)K^+)$	$6.95^{+0.46}_{-0.43}\pm0.34$			$6.95^{+0.46}_{-0.43}\pm0.34$ [30]	$6.95^{+0.57}_{-0.55}$
549/274	$10^4 \times \mathcal{B}(K^+\phi\mu^+\mu^-)/\mathcal{B}(\psi(2S)K^+)$	$1.58^{+0.36+0.19}_{-0.32-0.07}$			$1.58^{+0.36+0.19}_{-0.32-0.07}$ [30]	$1.58^{+0.41}_{-0.33}$
536/540	$\mathcal{B}(\pi^+\mu^+\mu^-)/\mathcal{B}(K^+\mu^+\mu^-)$ †	$0.053\pm0.014\pm0.01$			$0.038\pm0.009\pm0.001$[20]	0.038 ± 0.009
	$\mathcal{B}(K^+\mu^+\mu^-)/\mathcal{B}(K^+e^+e^-)$ ‡			$1.00^{+0.31}_{-0.25}\pm0.07$ [53]		$1.00^{+0.32}_{-0.26}$
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ §		$0.83\pm0.17\pm0.08$ [24]			0.83 ± 0.19
	$\mathcal{B}(K^*\mu^+\mu^-)/\mathcal{B}(K^*e^+e^-)$ ¶			$1.013^{+0.34}_{-0.26}\pm0.010$[53]		$1.013^{+0.340}_{-0.260}$
	$\mathcal{B}(K^{*0}\mu^+\mu^-)/\mathcal{B}(K^{*0}e^+e^-)$ ◇				$0.66^{+0.11}_{-0.07}\pm0.03$ [83]	$0.66^{+0.11}_{-0.08}$
	$\mathcal{B}(K^{*0}\mu^+\mu^-)/\mathcal{B}(K^{*0}e^+e^-)$ 1				$0.69^{+0.11}_{-0.07}\pm0.05$ [83]	$0.69^{+0.12}_{-0.09}$
	$\mathcal{B}(B^0 \to K^{*0}\gamma)/\mathcal{B}(B_s^0 \to \phi\gamma)$		$1.10\pm0.16\pm0.09\pm0.18$[2]		$1.23\pm0.06\pm0.11$ [84]	1.21 ± 0.11

Channels with no RPP# are not reported by PDG.

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

‡ For $1.0 < m^2(\ell^+\ell^-) < 6.0$ 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 $1.1 < m^2(\ell^+\ell^-) < 6.0$ GeV$^2/c^4$.

Heavy FLavor AVeraging group (HFLAV) - December 2017

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}		$261 \pm 30^{+44}_{-74}$ [§][85]	< 440 [86]	261^{+53}_{-79}
81	$\eta' X$	420 ± 90	$390 \pm 80 \pm 90$ [†][87]		$460 \pm 110 \pm 60$ [†][88]	423 ± 86
83	$K^+ X$	< 187	< 187 [‡] [89]			< 187 [‡]
84	$K^0 X$	190^{+70}_{-70}	$195^{+51}_{-45} \pm 50$ [‡] [89]			195^{+71}_{-67}
95	$\pi^+ X$	370 ± 80	$372^{+50}_{-47} \pm 59$ [¶] [89]			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) - December 2017

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	$-0.01^{+0.06}_{-0.06}$ ‡	[42, 90]					-0.01 ± 0.06
$\Delta_{0+}(K^*\gamma)$	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	$-0.43^{+0.25}_{-0.22} \pm 0.10$	[14]	$-0.48^{+0.21+0.08}_{-0.19-0.09}$	[15]			$-0.46^{+0.17}_{-0.16}$
$\Delta_{0-}(K\ell\ell)$ †	-0.13 ± 0.06	$-0.58^{+0.29}_{-0.37} \pm 0.02$	[53]	$-0.31^{+0.17}_{-0.14} \pm 0.08$	[24]	$-0.10^{+0.08}_{-0.09} \pm 0.02$ §[29]		-0.17 ± 0.08
$\Delta_{0-}(K^*\ell\ell)$ †	-0.45 ± 0.17	$-0.64^{+0.15}_{-0.14} \pm 0.03$	[53]	$0.30^{+0.12}_{-0.11} \pm 0.08$	[24]	$0.00^{+0.12}_{-0.10} \pm 0.02$ § [29]		-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 [42, 90].

§ Only muons are used.

Heavy FLavor AVeraging group (HFLAV) - December 2017
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 [38]			< 0.17
553	$\pi^+ e^+ \tau^-$	< 74	< 74 [91]			< 74
554	$\pi^+ e^- \tau^+$	< 20	< 20 [91]			< 20
555	$\pi^+ e^\pm \tau^\mp$	< 75	< 75 [91]			< 75
556	$\pi^+ \mu^+ \tau^-$	< 62	< 62 [91]			< 62
557	$\pi^+ \mu^- \tau^+$	< 45	< 45 [91]			< 45
558	$\pi^+ \mu^\pm \tau^\mp$	< 72	< 72 [91]			< 72
559	$K^+ e^+ \mu^-$	< 0.091	< 0.091 [39]			< 0.091
560	$K^+ e^- \mu^+$	< 0.13	< 0.13 [39]			< 0.13
561	$K^+ e^\pm \mu^\mp$	< 0.091	< 0.091 [39]			< 0.091
562	$K^+ e^+ \tau^-$	< 43	< 43 [91]			< 43
563	$K^+ e^- \tau^+$	< 15	< 15 [91]			< 15
564	$K^+ e^\pm \tau^\mp$	< 30	< 30 [91]			< 30
565	$K^+ \mu^+ \tau^-$	< 45	< 45 [91]			< 45
566	$K^+ \mu^- \tau^+$	< 28	< 28 [91]			< 28
567	$K^+ \mu^\pm \tau^\mp$	< 48	< 48 [91]			< 48
568	$K^{*+} e^+ \mu^-$	< 1.3	< 1.3 [39]			< 1.3
569	$K^{*+} e^- \mu^+$	< 0.99	< 0.99 [39]			< 0.99
570	$K^{*+} e^\pm \mu^\mp$	< 1.4	< 1.4 [39]			< 1.4
571	$\pi^- e^+ e^+$	< 0.023	< 0.023 [92]			< 0.023
572	$\pi^- \mu^+ \mu^+$	< 0.013	< 0.107 [92]		< 0.004 [†][93]	< 0.004 [†]
573	$\pi^- e^+ \mu^+$	< 0.15	< 0.15 [94]			< 0.15
574	$\rho^- e^+ e^+$	< 0.17	< 0.17 [94]			< 0.17
575	$\rho^- \mu^+ \mu^+$	< 0.42	< 0.42 [94]			< 0.42
576	$\rho^- e^+ \mu^+$	< 0.47	< 0.47 [94]			< 0.47
577	$K^- e^+ e^+$	< 0.03	< 0.03 [92]			< 0.03
578	$K^- \mu^+ \mu^+$	< 0.041	< 0.067 [92]		< 0.041 [95]	< 0.041
579	$K^- e^+ \mu^+$	< 0.16	< 0.16 [94]			< 0.16
580	$K^{*-} e^+ e^+$	< 0.40	< 0.40 [94]			< 0.40
581	$K^{*-} \mu^+ \mu^+$	< 0.59	< 0.59 [94]			< 0.59
582	$K^{*-} e^+ \mu^+$	< 0.30	< 0.30 [94]			< 0.30
583	$D^- e^+ e^+$	< 2.6	< 2.6 [94]	< 2.6 [96]		< 2.6
584	$D^- e^+ \mu^+$	< 1.8	< 2.1 [94]	< 1.8 [96]		< 1.8
585	$D^- \mu^+ \mu^+$	< 0.69	< 1.7 [94]	< 1.1 [96]	< 0.69 [97]	< 0.69
586	$D_s^- \mu^+ \mu^+$	< 0.58			< 0.58 [97]	< 0.58
587	$\bar{D}^0 \pi^- \mu^+ \mu^+$	< 1.5			< 1.5 [97]	< 1.5
589	$\Lambda^0 \mu^+$	< 0.06	< 0.06 [40]			< 0.06
590	$\Lambda^0 e^+$	< 0.032	< 0.032 [40]			< 0.032
591	$\bar{\Lambda}^0 \mu^+$	< 0.06	< 0.06 [40]			< 0.06
592	$\bar{\Lambda}^0 e^+$	< 0.08	< 0.08 [40]			< 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.

References

[1] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **103**, 211802, (2009), `arXiv:0906.2177 [hep-ex]`.

[2] T. Horiguchi *et al.*, (Belle collaboration), Phys. Rev. Lett. **119**, no. 19, 191802, (2017), `arXiv:1707.00394 [hep-ex]`.

[3] P. del Amo Sanchez *et al.*, (*BABAR* collaboration), Phys. Rev. **D93**, 052013, (2016), `arXiv:1512.03579 [hep-ex]`.

[4] H. Yang *et al.*, (Belle collaboration), Phys. Rev. Lett. **94**, 111802, (2005), `arXiv:hep-ex/0412039 [hep-ex]`.

[5] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D79**, 011102, (2009), `arXiv:0805.1317 [hep-ex]`.

[6] S. Nishida *et al.*, (Belle collaboration), Phys. Lett. **B610**, 23, (2005), `arXiv:hep-ex/0411065 [hep-ex]`.

[7] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D74**, 031102, (2006), `arXiv:hep-ex/0603054 [hep-ex]`.

[8] R. Wedd *et al.*, (Belle collaboration), Phys. Rev. **D81**, 111104, (2010), `arXiv:0810.0804 [hep-ex]`.

[9] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D75**, 051102, (2007), `arXiv:hep-ex/0611037 [hep-ex]`.

[10] H. Sahoo *et al.*, (Belle collaboration), Phys. Rev. **D84**, 071101, (2011), `arXiv:1104.5590 [hep-ex]`.

[11] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **98**, 211804, (2007), `arXiv:hep-ex/0507031 [hep-ex]`, Erratum ibid. **100**, 199905, (2008).

[12] S. Nishida *et al.*, (Belle collaboration), Phys. Rev. Lett. **89**, 231801, (2002), `arXiv:hep-ex/0205025 [hep-ex]`.

[13] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D70**, 091105, (2004), `arXiv:hep-ex/0409035 [hep-ex]`.

[14] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D78**, 112001, (2008), `arXiv:0808.1379 [hep-ex]`.

[15] N. Taniguchi *et al.*, (Belle collaboration), Phys. Rev. Lett. **101**, 111801, (2008), `arXiv:0804.4770 [hep-ex]`, Erratum ibid. **101**, 129904, (2008).

[16] M. Z. Wang *et al.*, (Belle collaboration), Phys. Rev. **D76**, 052004, (2007), `arXiv:0704.2672 [hep-ex]`.

[17] Y. J. Lee *et al.*, (Belle collaboration), Phys. Rev. Lett. **95**, 061802, (2005), `arXiv:hep-ex/0503046 [hep-ex]`.

[18] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D88**, 032012, (2013), `arXiv:1303.6010 [hep-ex]`.

[19] J. T. Wei *et al.*, (Belle collaboration), Phys. Rev. **D78**, 011101, (2008), `arXiv:0804.3656` `[hep-ex]`.

[20] R. Aaij *et al.*, (LHCb collaboration), JHEP **10**, 034, (2015), `arXiv:1509.00414 [hep-ex]`.

[21] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **94**, 101801, (2005), `arXiv:hep-ex/0411061 [hep-ex]`.

[22] O. Lutz *et al.*, (Belle collaboration), Phys. Rev. **D87**, 111103, (2013), `arXiv:1303.3719` `[hep-ex]`.

[23] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **102**, 091803, (2009), `arXiv:0807.4119 [hep-ex]`.

[24] J. T. Wei *et al.*, (Belle collaboration), Phys. Rev. Lett. **103**, 171801, (2009), `arXiv:0904.0770` `[hep-ex]`.

[25] R. Aaij *et al.*, (LHCb collaboration), JHEP **02**, 105, (2013), `arXiv:1209.4284 [hep-ex]`.

[26] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **118**, 031802, (2017), `arXiv:1605.09637 [hep-ex]`.

[27] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D87**, 112005, (2013), `arXiv:1303.7465` `[hep-ex]`.

[28] J. Grygier *et al.*, (Belle collaboration), Phys. Rev. **D96**, no. 9, 091101, (2017), `arXiv:1702.03224 [hep-ex]`.

[29] R. Aaij *et al.*, (LHCb collaboration), JHEP **06**, 133, (2014), `arXiv:1403.8044 [hep-ex]`.

[30] R. Aaij *et al.*, (LHCb collaboration), JHEP **10**, 064, (2014), `arXiv:1408.1137 [hep-ex]`.

[31] H. J. Hyun *et al.*, (Belle collaboration), Phys. Rev. Lett. **105**, 091801, (2010), `arXiv:1005.1450 [hep-ex]`.

[32] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D72**, 091103, (2005), `arXiv:hep-ex/0501038 [hep-ex]`.

[33] Z. King *et al.*, (Belle collaboration), Phys. Rev. **D93**, 111101, (2016), `arXiv:1603.06546` `[hep-ex]`.

[34] Y. T. Lai *et al.*, (Belle collaboration), Phys. Rev. **D89**, 051103, (2014), `arXiv:1312.4228` `[hep-ex]`.

[35] R. Aaij *et al.*, (LHCb collaboration), JHEP **11**, 047, (2016), `arXiv:1606.04731 [hep-ex]`.

[36] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. Lett. **115**, no. 16, 161802, (2015), `arXiv:1508.04094 [hep-ex]`.

[37] R. Aaij *et al.*, (LHCb collaboration), Phys. Lett. **B743**, 46, (2015), `arXiv:1412.6433` `[hep-ex]`.

[38] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **99**, 051801, (2007), `arXiv:hep-ex/0703018 [hep-ex]`.

[39] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D73**, 092001, (2006), `arXiv:hep-ex/0604007 [hep-ex]`.

[40] P. del Amo Sanchez *et al.*, (BaBar collaboration), Phys. Rev. **D83**, 091101, (2011), `arXiv:1101.3830 [hep-ex]`.

[41] T. E. Coan *et al.*, (CLEO collaboration), Phys. Rev. Lett. **84**, 5283, (2000), `arXiv:hep-ex/9912057 [hep-ex]`.

[42] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D77**, 051103, (2008), `arXiv:0711.4889 [hep-ex]`.

[43] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **109**, 191801, (2012), `arXiv:1207.2690 [hep-ex]`.

[44] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D86**, 052012, (2012), `arXiv:1207.2520 [hep-ex]`.

[45] A. Limosani *et al.*, (Belle collaboration), Phys. Rev. Lett. **103**, 241801, (2009), `arXiv:0907.1384 [hep-ex]`.

[46] T. Saito *et al.*, (Belle collaboration), Phys. Rev. **D91**, 052004, (2015), `arXiv:1411.7198 [hep-ex]`.

[47] A. Abdesselam *et al.*, (Belle collaboration), `arXiv:1608.02344 [hep-ex]`, (2016).

[48] S. Chen *et al.*, (CLEO collaboration), Phys. Rev. Lett. **87**, 251807, (2001), `arXiv:hep-ex/0108032 [hep-ex]`.

[49] P. del Amo Sanchez *et al.*, (*BABAR* collaboration), Phys. Rev. **D82**, 051101, (2010), `arXiv:1005.4087 [hep-ex]`.

[50] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **112**, 211802, (2014), `arXiv:1312.5364 [hep-ex]`.

[51] M. Iwasaki *et al.*, (Belle collaboration), Phys. Rev. **D72**, 092005, (2005), `arXiv:hep-ex/0503044 [hep-ex]`.

[52] T. Aaltonen *et al.*, (CDF collaboration), Phys. Rev. Lett. **107**, 201802, (2011), `arXiv:1107.3753 [hep-ex]`.

[53] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D86**, 032012, (2012), `arXiv:1204.3933 [hep-ex]`.

[54] K. W. Edwards *et al.*, (CLEO collaboration), Phys. Rev. **D65**, 111102, (2002), `arXiv:hep-ex/0204017 [hep-ex]`.

[55] O. Buchmuller and H. Flacher, Phys. Rev. **D73**, 073008, (2006), `arXiv:hep-ph/0507253 [hep-ph]`.

[56] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D79**, 091101, (2009), `arXiv:0903.1220 [hep-ex]`.

[57] N. Satoyama *et al.*, (Belle collaboration), Phys. Lett. **B647**, 67, (2007), `arXiv:hep-ex/0611045 [hep-ex]`.

[58] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D88**, 031102, (2013), `arXiv:1207.0698 [hep-ex]`.

[59] B. Kronenbitter *et al.*, (Belle collaboration), Phys. Rev. **D92**, 051102, (2015), arXiv:1503.05613 [hep-ex].

[60] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D80**, 111105, (2009), arXiv:0907.1681 [hep-ex].

[61] A. Heller *et al.*, (Belle collaboration), Phys. Rev. **D91**, 112009, (2015), arXiv:1504.05831 [hep-ex].

[62] P. del Amo Sanchez *et al.*, (*BABAR* collaboration), Phys. Rev. **D83**, 032006, (2011), arXiv:1010.2229 [hep-ex].

[63] S. Villa *et al.*, (Belle collaboration), Phys. Rev. **D73**, 051107, (2006), arXiv:hep-ex/0507036 [hep-ex].

[64] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D77**, 032007, (2008), arXiv:0712.1516 [hep-ex].

[65] M. C. Chang *et al.*, (Belle collaboration), Phys. Rev. **D68**, 111101, (2003), arXiv:hep-ex/0309069 [hep-ex].

[66] T. Aaltonen *et al.*, (CDF collaboration), Phys. Rev. Lett. **102**, 201801, (2009), arXiv:0901.3803 [hep-ex].

[67] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D77**, 011104, (2008), arXiv:0706.2870 [hep-ex].

[68] T. Aaltonen *et al.*, (CDF collaboration), Phys. Rev. **D87**, 072003, (2013), arXiv:1301.7048 [hep-ex].

[69] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. Lett. **118**, no. 19, 191801, (2017), arXiv:1703.05747 [hep-ex].

[70] S. Chatrchyan *et al.*, (CMS collaboration), Phys. Rev. Lett. **111**, 101804, (2013), arXiv:1307.5025 [hep-ex].

[71] M. Aaboud *et al.*, (ATLAS collaboration), Eur. Phys. J. **C76**, 513, (2016), arXiv:1604.04263 [hep-ex].

[72] R. Aaij *et al.*, (LHCb collaboration), JHEP **03**, 001, (2017), arXiv:1611.07704 [hep-ex].

[73] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **96**, 241802, (2006), arXiv:hep-ex/0511015 [hep-ex].

[74] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. Lett. **118**, no. 25, 251802, (2017), arXiv:1703.02508 [hep-ex].

[75] R. Aaij *et al.*, (LHCb collaboration), (2017), arXiv:1710.04111 [hep-ex].

[76] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D77**, 091104, (2008), arXiv:0801.0697 [hep-ex].

[77] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D86**, 051105, (2012), arXiv:1206.2543 [hep-ex].

[78] C. L. Hsu *et al.*, (Belle collaboration), Phys. Rev. **D86**, 032002, (2012), arXiv:1206.5948 [hep-ex].

[79] Y. Yook *et al.*, (Belle collaboration), Phys. Rev. **D91**, 052016, (2015), arXiv:1406.6356 [hep-ex].

[80] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D81**, 051101, (2010), arXiv:0912.2453 [hep-ex].

[81] I. Adachi *et al.*, (Belle collaboration), Phys. Rev. Lett. **110**, 131801, (2013), arXiv:1208.4678 [hep-ex].

[82] V. Khachatryan *et al.*, (CMS and LHCb collaborations), Nature **522**, 68, (2015), arXiv:1411.4413 [hep-ex].

[83] R. Aaij *et al.*, (LHCb collaboration), arXiv:1705.05802 [hep-ex], (2017).

[84] R. Aaij *et al.*, (LHCb collaboration), Nucl. Phys. **B867**, 1, (2013), arXiv:1209.0313 [hep-ex].

[85] K. Nishimura *et al.*, (Belle collaboration), Phys. Rev. Lett. **105**, 191803, (2010), arXiv:0910.4751 [hep-ex].

[86] T. E. Browder *et al.*, (CLEO collaboration), Phys. Rev. Lett. **81**, 1786, (1998), arXiv:hep-ex/9804018 [hep-ex].

[87] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. Lett. **93**, 061801, (2004), arXiv:hep-ex/0401006 [hep-ex].

[88] G. Bonvicini *et al.*, (CLEO collaboration), Phys. Rev. **D68**, 011101, (2003), arXiv:hep-ex/0303009 [hep-ex].

[89] P. del Amo Sanchez *et al.*, (*BABAR* collaboration), Phys. Rev. **D83**, 031103, (2011), arXiv:1012.5031 [hep-ex].

[90] B. Aubert *et al.*, (*BABAR* collaboration), Phys. Rev. **D72**, 052004, (2005), arXiv:hep-ex/0508004 [hep-ex].

[91] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D86**, 012004, (2012), arXiv:1204.2852 [hep-ex].

[92] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D85**, 071103, (2012), arXiv:1202.3650 [hep-ex].

[93] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. Lett. **112**, 131802, (2014), arXiv:1401.5361 [hep-ex].

[94] J. P. Lees *et al.*, (*BABAR* collaboration), Phys. Rev. **D89**, 011102, (2014), arXiv:1310.8238 [hep-ex].

[95] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. Lett. **108**, 101601, (2012), arXiv:1110.0730 [hep-ex].

[96] O. Seon *et al.*, (BELLE collaboration), Phys. Rev. **D84**, 071106, (2011), arXiv:1107.0642 [hep-ex].

[97] R. Aaij *et al.*, (LHCb collaboration), Phys. Rev. **D85**, 112004, (2012), arXiv:1201.5600 [hep-ex].