Coulomb corrections in rare decays of neutral B mesons with $\ell^+\ell^-$-pair in final state

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[https://arxiv.org/abs/2602.07934]

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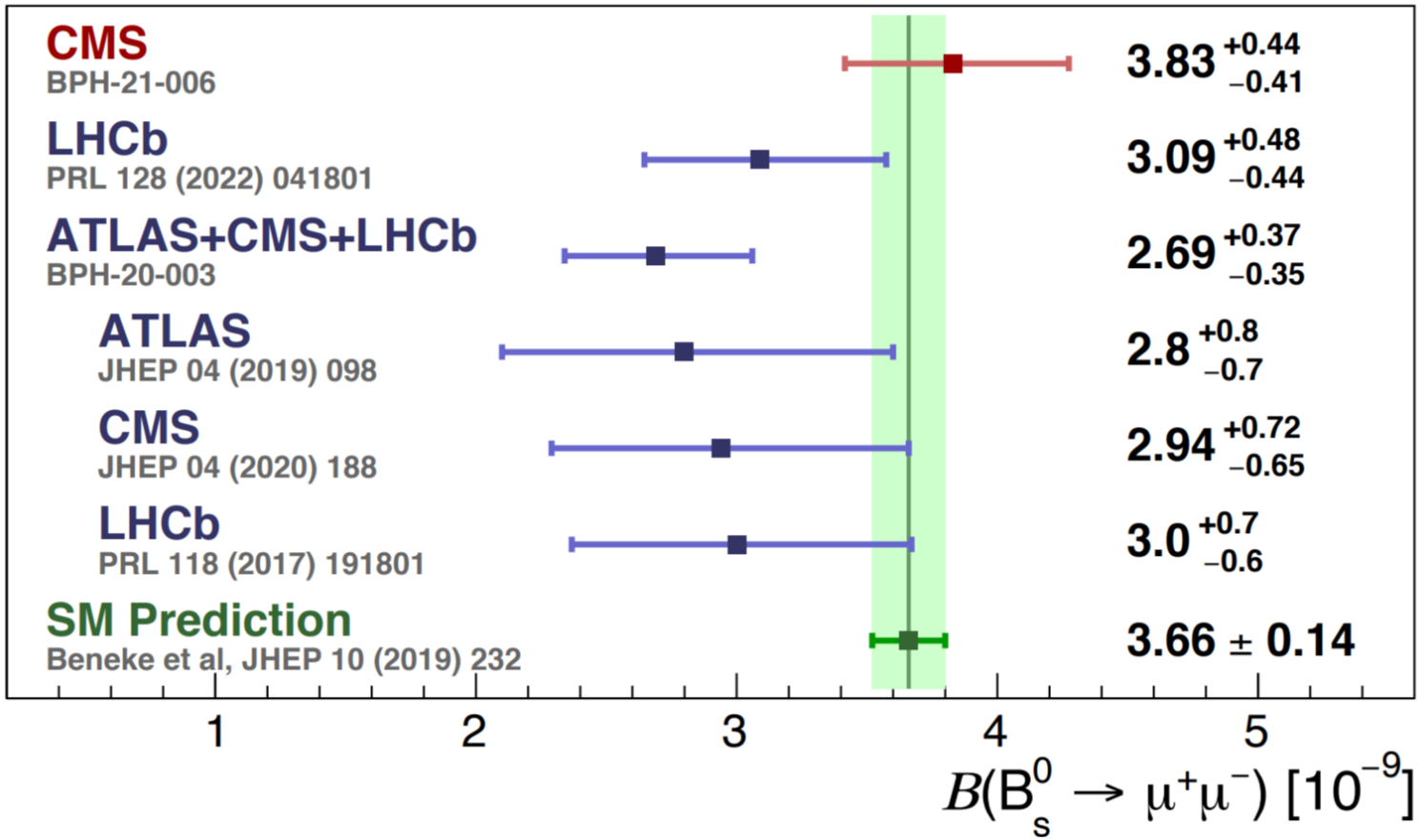
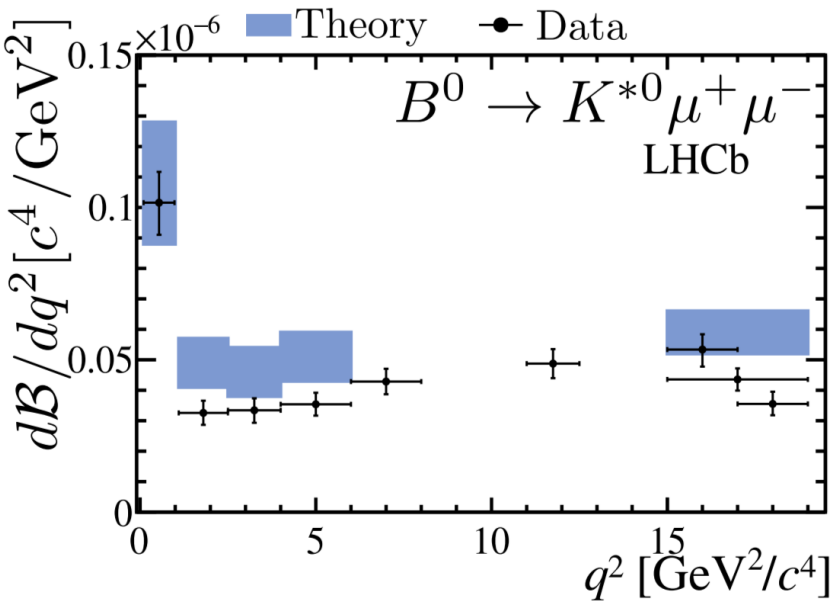
Experimental data

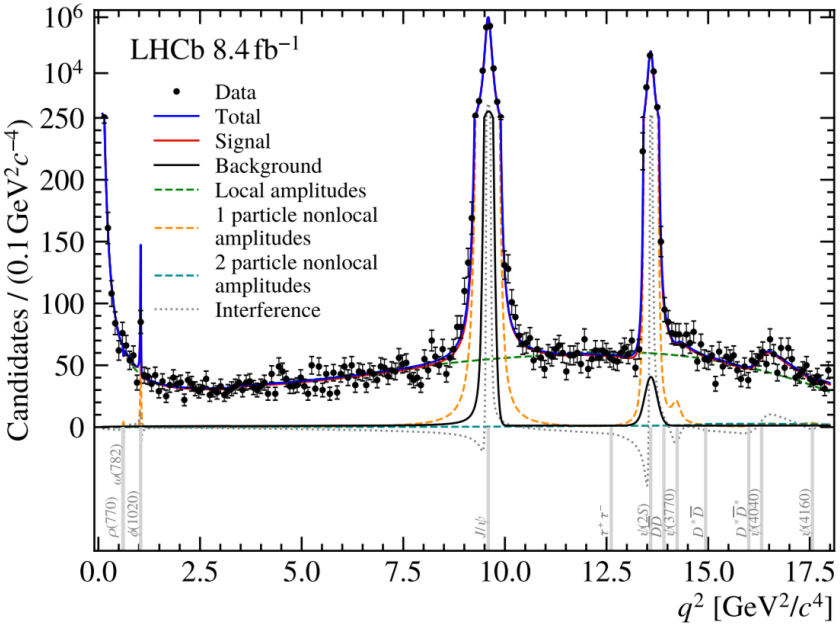


The partial decay width of $B_s^0 \to \mu^+\mu^-$, measured in various experiments, as well as the averaged predictions of the Standard Model

EPJ Web Conf. **274**, 01006 (2022)

Experimental data





Differential decay width of $B^0 \to K^{0*}\mu^+\mu^-$ - predictions of the Standard Model, experimental values.
arXiv:1606.04731v2 → arXiv:2405.17347v3

Experimental data

Lepton Flavor Universality

$$R_K = \frac{\mathcal{B}(B^+ \to K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \to K^+ e^+ e^-)}.$$

Numerical values:

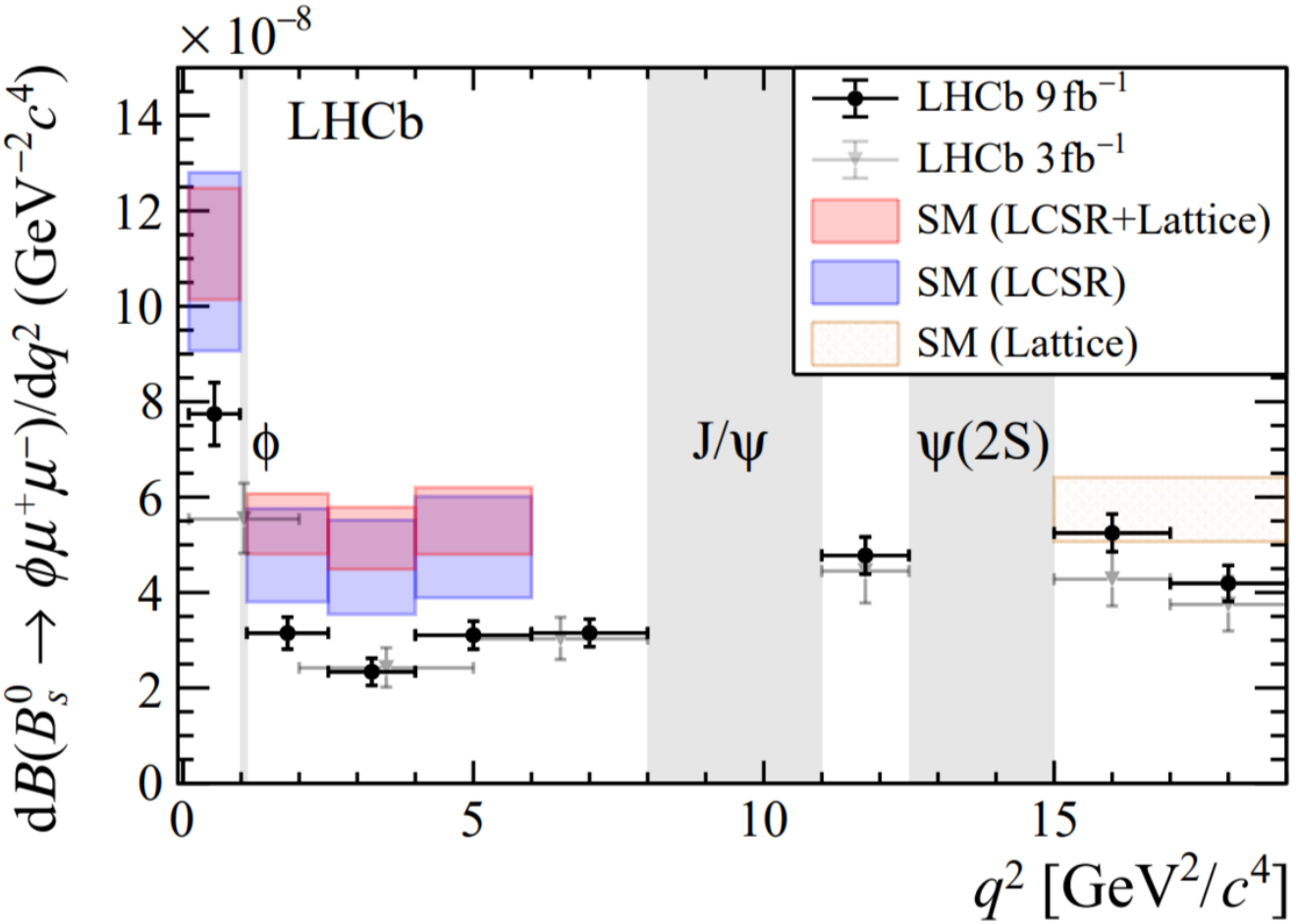
$$R_K = 0.745^{+0.090}_{-0.074} \pm 0.036 \quad \text{(LHCb 2014, } 2.6\sigma\text{)}$$

$$R_K = 0.685^{+0.113}_{-0.069} \pm 0.047 \quad \text{(LHCb 2014, } 3.1\sigma\text{)}$$

$$R_K = 0.949 \pm 0.042 \quad \text{(LHCb 2022)}$$

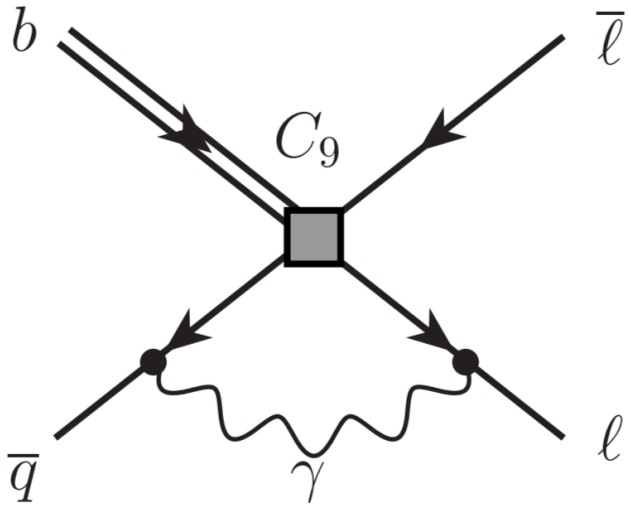
Phys. Rev. Lett. **113**, 151601 (2014) → Phys. Rev. Lett. **131**№5, 051803 (2023)

Experimental data



Differential decay width of $B^0 \to \phi\mu^+\mu^-$ - predictions of the Standard Model, experimental values.
arXiv:2105.14007v2

Theoretical frontiers

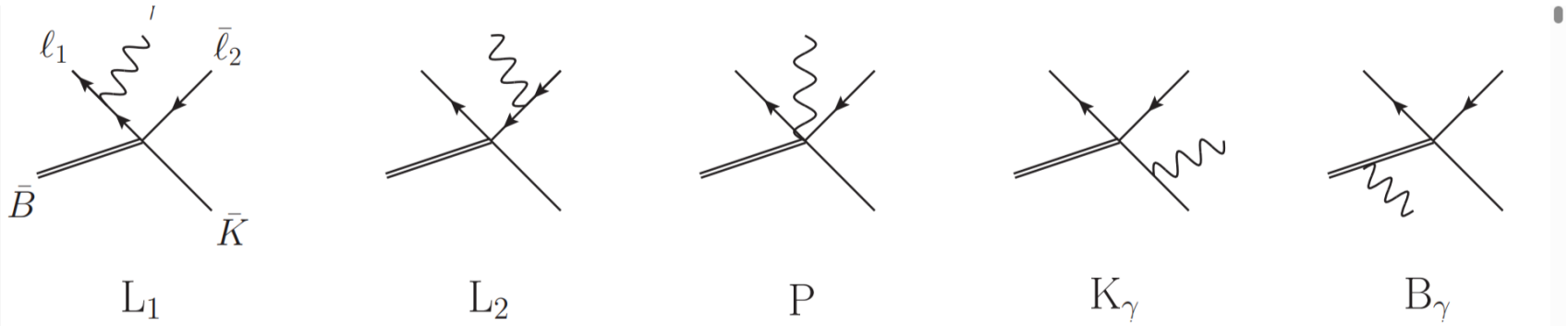


Structure-dependent QED corrections

- Power enhancement: QED correction $\sim m_b/\Lambda \cdot \alpha_e/4\pi$.
- Arises from virtual photon exchange between soft spectator quark and final muons.
- Involves B-meson LCDA $\phi_+(\omega)$, not only f_{B_q}.
- Two-step SCET: hard scale $(m_b) \to$ hard-collinear scale $(\sqrt{m_b\Lambda})$.

Beneke et al. JHEP 10 (2019) 232

Theoretical frontiers



Structure-independent QED corrections

- For $B \to K\ell^+\ell^-$ decays, these corrections were evaluated using the slicing method
- Soft and hard-collinear photon radiation is accounted for at the double-differential level.
- Mesons are treated as point-like particles.

G. Isidori et al. JHEP 12 (2020) 104

IR-finite decay rate

- Only a suitably defined decay rate is IR-finite:

$$\Gamma = \Gamma_{\text{non-rad}} + \sum_{\gamma} \Gamma_{\gamma}\, \theta\Big(\Delta E - \sum E_{\gamma}\Big)$$

- Non-radiative part includes virtual corrections; the sum over γ accounts for real undetected photons with $E_{\gamma} < \Delta E$.
- Soft-photon emission from final-state leptons is simulated with PHOTOS.
- The experimental branching fraction is interpreted as the non-radiative one.

A. J. Buras et. al. Eur. Phys. J. C 72, 2172 (2012), 1208.0934.

Soft photon QED correction

$$\mathcal{K}_{QED} = \frac{d\Gamma^{(QED)}}{d\Gamma^{(free)}} = \mathcal{K}_{\text{soft}} \cdot \mathcal{K}_{\text{C}} \cdot \left[1 - \frac{\alpha}{\pi}(F + H^{\text{IR}})\right], \text{ where}$$
$$\mathcal{K}_{\text{soft}} = \left(\frac{2\Delta E}{M}\right)^{\frac{2\alpha_{\text{em}}}{\pi} \cdot \frac{1}{4v} \ln\left(\frac{1+v}{1-v}\right)}; \quad \mathcal{K}_{\text{C}} = \frac{2\pi\alpha_{\text{em}}/v}{1 - e^{-2\pi\alpha_{\text{em}}/v}} \tag{1}$$

where $v = v_{\text{rel}} = \frac{\sqrt{1-4m^2/s}}{1-2m^2/s}$ is the relative velocity of the final-state charged.

$(F + H^{\text{IR}}) \sim \mathcal{O}(\alpha_{\text{em}}/\pi) \sim 0.2\%$ so it can be safely neglected.

A. Arbuzov and T. Kopylova, JHEP 04, 009 (2012), 1111.4308.
G. Isidori, Eur. Phys. J. C 53, 567 (2008), 0709.2439.

Why Coulomb?

- PHOTOS models real soft radiation $\mathcal{K}_{soft}$ but does not include the Coulomb interaction $\mathcal{K}_C$ between charged final-state particles.
- Existing QED corrections for leptonic decays of neutral B mesons omit the Coulomb effect.
- Exceptions: $\bar{B}^0 \to D^+ \ell^- \bar{\nu}_\ell$ and inclusive $B \to X_c \ell \nu$.

S. Cali et al. Eur. Phys. J. C 79, 744 (2019), 1905.02702.
D. Bigi et al. JHEP 11, 163 (2023), 2309.02849.

Coulomb interaction in $B^0_{s,d} \to \ell^+\ell^-$.

Coulomb interaction in $B^0_{s,d} \to \ell^+\ell^-$

Decay	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\Delta\mathcal{K}_C$
$B^0_s \to \mu^+\mu^-[10^{-9}]$	$3.83^{+0.44}_{-0.41}$	3.66 ± 0.14	3.75 ± 0.14	2.3%
$B^0 \to \mu^+\mu^-[10^{-11}]$	< 19 (95% CL)	1.03 ± 0.05	1.05 ± 0.05	2.3%
$B^0_s \to e^+e^-[10^{-14}]$	$< 9.4 \cdot 10^5$ (95% CL)	8.60 ± 0.36	8.79 ± 0.37	2.3%
$B^0 \to e^+e^-[10^{-15}]$	$< 3.0 \cdot 10^6$ (95% CL)	2.41 ± 0.13	2.47 ± 0.13	2.3%
$B^0_s \to \tau^+\tau^-[10^{-7}]$	$< 6.8 \cdot 10^6$ (95% CL)	6.94 ± 1.88	7.11 ± 1.93	2.4%
$B^0 \to \tau^+\tau^-[10^{-8}]$	$< 2.1 \cdot 10^7$ (95% CL)	1.99 ± 0.22	2.04 ± 0.23	2.4%

Table: Comparison of experimental data (CMS 2021, PDG), theoretical SM predictions without Coulomb interaction (Beneke), and predictions including this interaction. $\Delta\mathcal{K}_C \equiv \mathcal{K}_C - 1$.

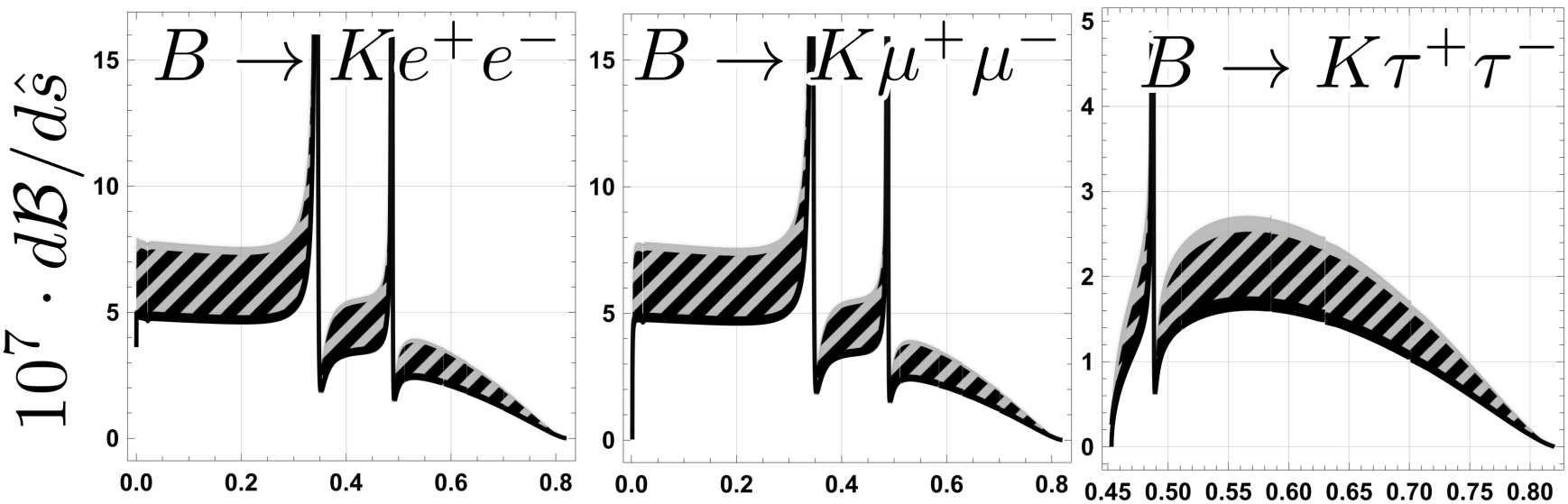
Coulomb interaction in $B^0_{s,d} \to \ell^+\ell^-$

Decay	$\mathcal{K}_C$	$\mathcal{K}_{\text{QED}}$ (0.05 GeV)	$\mathcal{K}_{\text{QED}}$ (0.1 GeV)	$\mathcal{K}_{\text{QED}}$ (0.5 GeV)
$B^0_s \to \mu^+\mu^-$	1.0231	0.9514	0.9635	0.9922
$B^0 \to \mu^+\mu^-$	1.0231	0.9520	0.9640	0.9926
$B^0_s \to e^+e^-$	1.0231	0.8648	0.8905	0.9531
$B^0 \to e^+e^-$	1.0231	0.8611	0.8874	0.9517
$B^0_s \to \tau^+\tau^-$	1.0241	1.0051	1.0084	1.0160
$B^0 \to \tau^+\tau^-$	1.0242	1.0056	1.0088	1.0163

Table: Full QED factors $\mathcal{K}_{\text{QED}} = \mathcal{K}_{\text{soft}} \cdot \mathcal{K}_C$ for the decays $B^0_{d,s} \to \ell^+\ell^-$ at different soft photon energy cutoffs $\Delta E = \{0.05, 0.1, 0.5\}$ GeV.

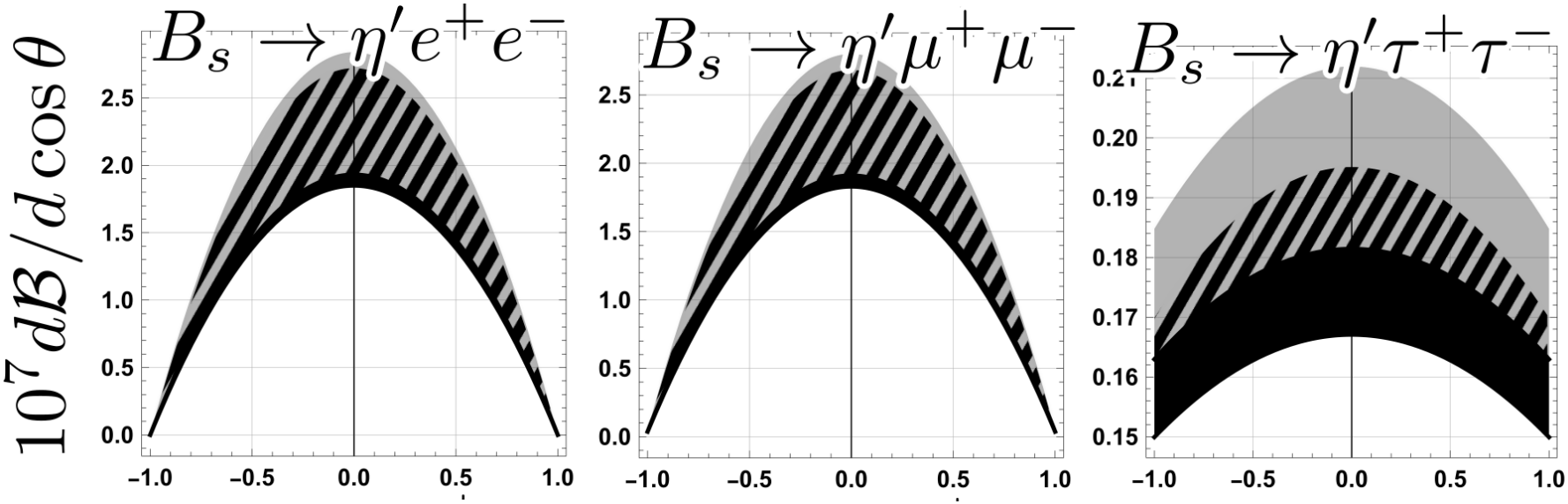
Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$.

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$



The differential decay width $10^7 \cdot \frac{1}{\Gamma^{(total)}} \frac{d\Gamma}{ds}$ as a function of s/M_B^2 where $s = (p_{B^0} - p_{K^0})^2$.

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$



$10^7 \cdot d\mathcal{B}/d\cos\theta$ as a function of $\cos\theta$, where $\theta = \angle(\mathbf{p}_{\ell^+}, \mathbf{p}_K)$ in the rest frame of the lepton pair

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$

$$\langle \mathcal{K}_{\mathrm{C}} \rangle = \frac{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{Coulomb})}}{d\hat{s}}\, d\hat{s}}{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}}\, d\hat{s}} = \frac{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}} \cdot \mathcal{K}_{\mathrm{C}}(\hat{s})\, d\hat{s}}{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}}\, d\hat{s}}.$$

$$\langle \mathcal{K}_{\mathrm{QED}} \rangle = \frac{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{Coulomb+soft})}}{d\hat{s}}\, d\hat{s}}{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}}\, d\hat{s}} = \frac{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}} \cdot \mathcal{K}_{\mathrm{QED}}(\hat{s})\, d\hat{s}}{\displaystyle\int \frac{d\mathcal{B}^{(\mathrm{free})}}{d\hat{s}}\, d\hat{s}}.$$

$$\Delta\langle \mathcal{K}_{\mathrm{QED(C)}} \rangle = 1 - \langle \mathcal{K}_{\mathrm{QED(C)}} \rangle$$

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$

	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\Delta\langle\mathcal{K}_C\rangle$
$B^0 \to K^0 e^+ e^- [10^{-7}]$	$2.5^{+1.1}_{-0.9}$	3.34 ± 0.37	3.42 ± 0.39	2.3%
$B^0 \to K^0 \mu^+ \mu^- [10^{-7}]$	$3.39 \pm$ ± 0.35	3.33 ± 0.38	3.41 ± 0.38	2.3%
$B^0 \to K^0 \tau^+ \tau^- [10^{-8}]$	-	5.0 ± 2.1	5.18 ± 2.2	3.3%
$B^0 \to \pi^0 e^+ e^- [10^{-8}]$	< 8.4	1.17 ± 0.3	1.19 ± 0.3	2.3%
$B^0 \to \pi^0 \mu^+ \mu^- [10^{-8}]$	< 6.9	1.16 ± 0.3	1.19 ± 0.3	2.3%
$B^0 \to \pi^0 \tau^+ \tau^- [10^{-9}]$	$-$	3.05 ± 0.73	3.15 ± 0.76	3.0%

	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\Delta\langle\mathcal{K}_C\rangle$
$B_s^0 \to \eta e^+ e^- [10^{-7}]$	–	4.12 ± 0.79	4.22 ± 0.80	2.3%
$B_s^0 \to \eta \mu^+ \mu^- [10^{-7}]$	–	4.11 ± 0.79	4.21 ± 0.80	2.4%
$B_s^0 \to \eta \tau^+ \tau^- [10^{-8}]$	–	7.04 ± 1.2	7.28 ± 1.3	3.3%
$B_s^0 \to \eta' e^+ e^- [10^{-7}]$	–	3.04 ± 0.58	3.11 ± 0.59	2.3%
$B_s^0 \to \eta' \mu^+ \mu^- [10^{-7}]$	–	3.03 ± 0.58	3.10 ± 0.59	2.3%
$B_s^0 \to \eta' \tau^+ \tau^- [10^{-8}]$	–	2.37 ± 0.36	2.47 ± 0.38	**3.9**%
$B_s^0 \to K^0 e^+ e^- [10^{-8}]$	–	1.35 ± 0.34	1.38 ± 0.35	2.3%
$B_s^0 \to K^0 \mu^+ \mu^- [10^{-8}]$	–	1.34 ± 0.34	1.37 ± 0.35	2.4%
$B_s^0 \to K^0 \tau^+ \tau^- [10^{-9}]$	–	2.55 ± 0.59	2.64 ± 0.62	3.3%

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$

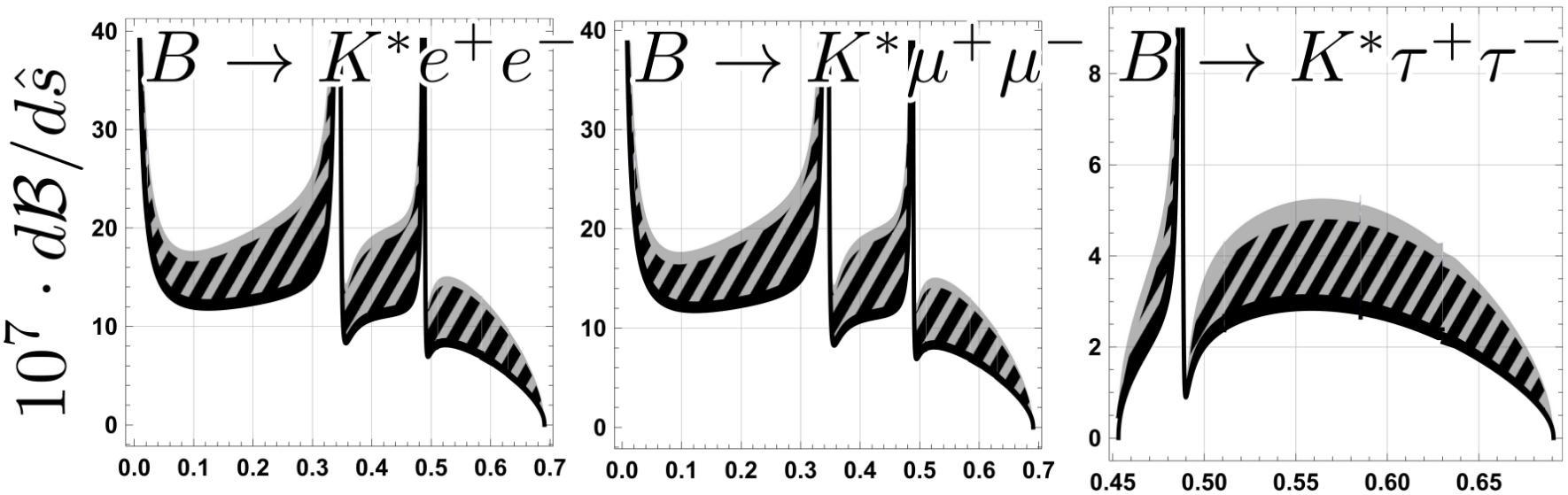
Decay	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.5 GeV)
$B^0 \to K^0 e^+ e^-$	1.0233	0.8754	0.8996	0.9584
$B^0 \to K^0 \mu^+ \mu^-$	1.0233	0.9657	0.9755	0.9987
$B^0 \to K^0 \tau^+ \tau^-$	1.0334	1.0206	1.0228	1.0280
$B^0 \to \pi^0 e^+ e^-$	1.0233	0.8735	0.8980	0.9575
$B^0 \to \pi^0 \mu^+ \mu^-$	1.0233	0.9636	0.9738	0.9978
$B^0 \to \pi^0 \tau^+ \tau^-$	1.0303	1.0164	1.0188	1.0245
$B^0_s \to \eta e^+ e^-$	1.0233	0.8743	0.8986	0.9575
$B^0_s \to \eta \mu^+ \mu^-$	1.0233	0.9649	0.9748	0.9982
$B^0_s \to \eta \tau^+ \tau^-$	1.0331	1.0201	1.0223	1.0276

Coulomb interaction in $B^0_{s,d} \to h^0 \ell^+ \ell^-$

Decay	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.5 GeV)
$B^0_s \to \eta' e^+ e^-$	1.0233	0.8761	0.9000	0.9583
$B^0_s \to \eta' \mu^+ \mu^-$	1.0233	0.9667	0.9763	0.9990
$B^0_s \to \eta' \tau^+ \tau^-$	1.0385	1.0266	1.0286	1.0334
$B^0_s \to K^0 e^+ e^-$	1.0233	0.8739	0.8982	0.9574
$B^0_s \to K^0 \mu^+ \mu^-$	1.0233	0.9645	0.9745	0.9980
$B^0_s \to K^0 \tau^+ \tau^-$	1.0326	1.0194	1.0217	1.0270

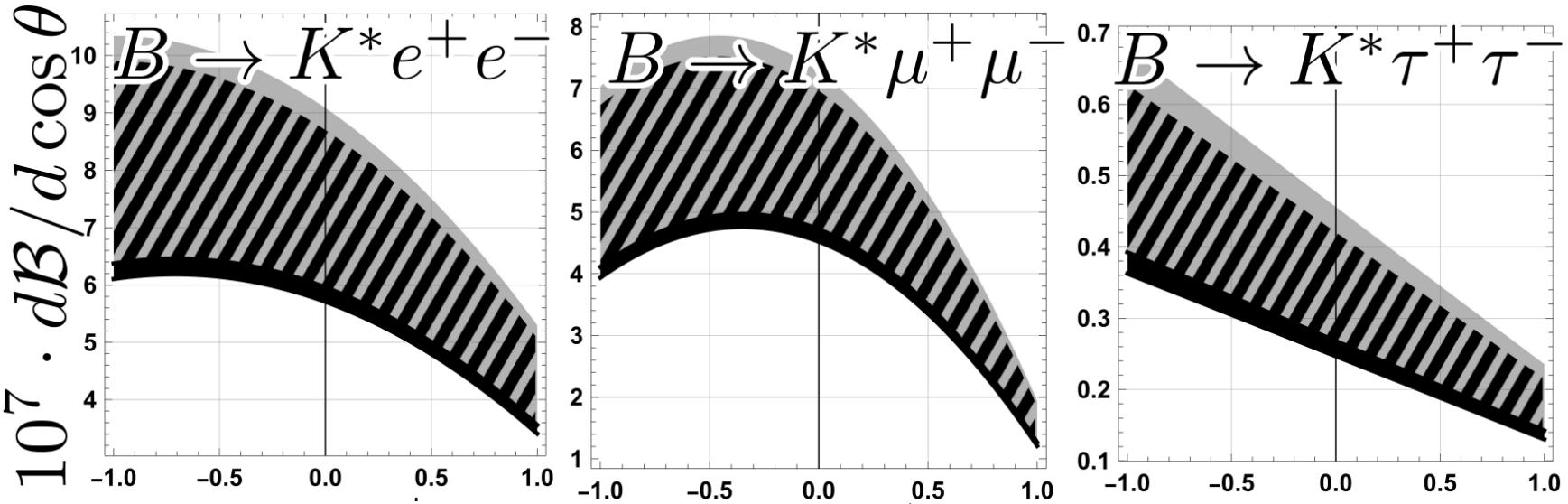
Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$.

Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$



The differential decay width $10^7 \cdot \frac{1}{\Gamma^{(total)}} \frac{d\Gamma}{ds}$ as a function of s/M_B^2 where $s = (p_{B^0} - p_{K^0})^2$.

Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$



$10^7 \cdot d\mathcal{B}/d\cos\theta$ as a function of $\cos\theta$, where $\theta = \angle(\mathbf{p}_{\ell^+}, \mathbf{p}_K)$ in the rest frame of the lepton pair

Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$

	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\Delta\langle\mathcal{K}_C\rangle$
$B^0 \to K^{0*} e^+ e^- [10^{-6}]$	$1.19 \pm \pm 0.20$	1.36 ± 0.15	1.40 ± 0.15	2.4%
$B^0 \to K^{0*} \mu^+ \mu^- [10^{-6}]$	$1.06 \pm \pm 0.09$	0.94 ± 0.11	1.02 ± 0.11	2.4%
$B^0 \to K^{0*} \tau^+ \tau^- [10^{-8}]$	–	6.67 ± 0.87	6.92 ± 0.90	3.7%
$B^0 \to \rho^0 e^+ e^- [10^{-6}]$	–	1.07 ± 0.18	1.10 ± 0.19	2.4%
$B^0 \to \rho^0 \mu^+ \mu^- [10^{-7}]$	–	8.9 ± 1.6	9.1 ± 1.7	2.4%
$B^0 \to \rho^0 \tau^+ \tau^- [10^{-7}]$	–	1.05 ± 0.19	1.09 ± 0.20	3.4%

	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\Delta\langle\mathcal{K}_C\rangle$
$B_s^0 \to \phi e^+ e^- [10^{-6}]$	–	1.52 ± 0.17	1.56 ± 0.17	2.4%
$B_s^0 \to \phi \mu^+ \mu^- [10^{-6}]$	$0.84\pm$ ± 0.4	1.15 ± 0.14	1.18 ± 0.15	2.4%
$B_s^0 \to \phi \tau^+ \tau^- [10^{-8}]$	–	8.11 ± 0.10	8.41 ± 0.11	3.8%
$B_s^0 \to K^{0*} e^+ e^- [10^{-8}]$	–	5.56 ± 0.65	5.69 ± 0.67	2.4%
$B_s^0 \to K^{0*} \mu^+ \mu^- [10^{-8}]$	$2.9\pm$ ± 1.1	4.42 ± 0.56	4.53 ± 0.57	2.4%
$B_s^0 \to K^{0*} \tau^+ \tau^- [10^{-9}]$	–	4.30 ± 0.50	4.45 ± 0.52	3.5%

Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$

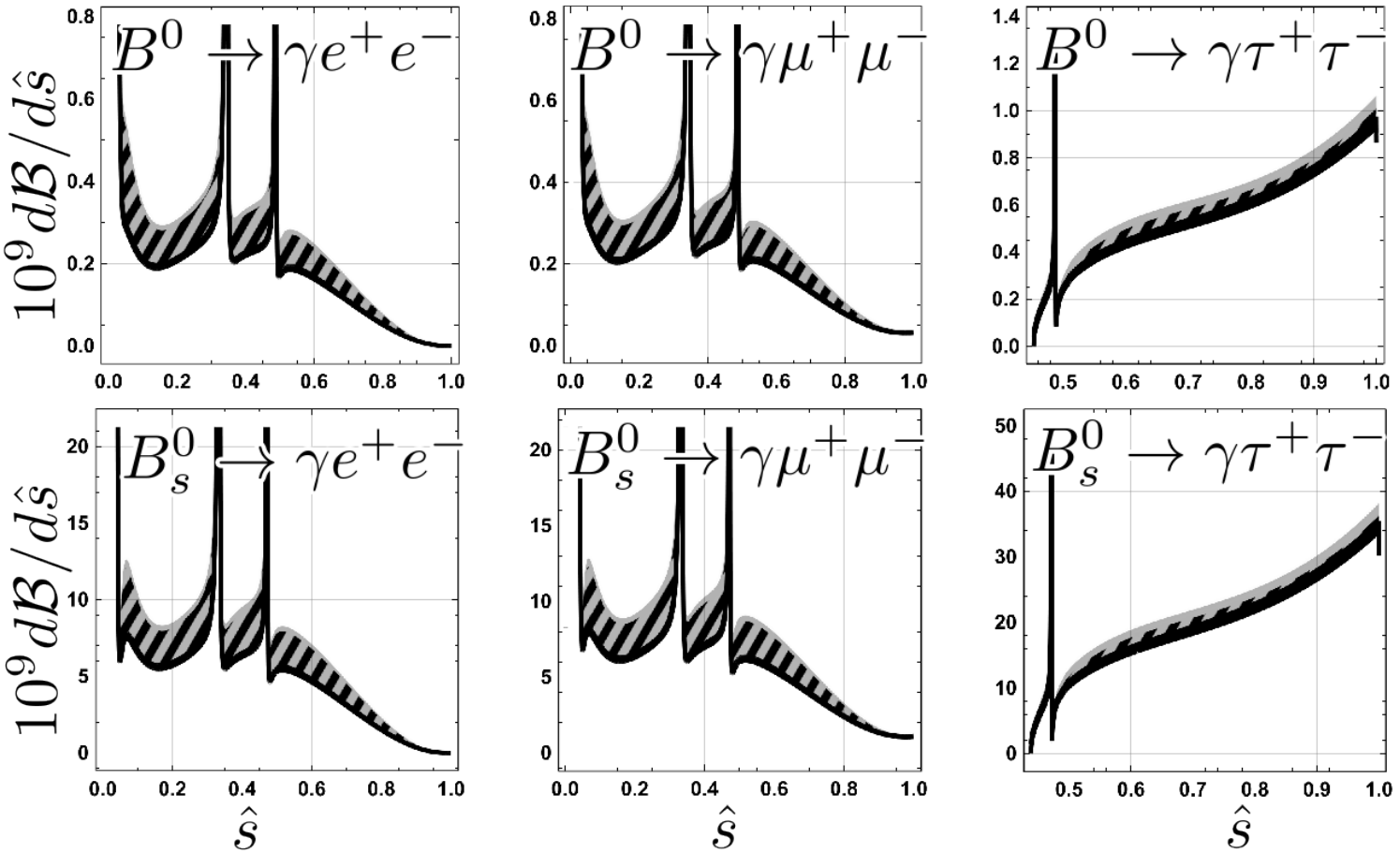
Decay	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.5 GeV)
$B^0 \to K^{0*} e^+ e^-$	1.0233	0.8989	0.9194	0.9690
$B^0 \to K^{0*} \mu^+ \mu^-$	1.0234	0.9676	0.9771	0.9996
$B^0 \to K^{0*} \tau^+ \tau^-$	1.0366	1.0244	1.0265	1.0315
$B^0 \to \rho^0 e^+ e^-$	1.0234	0.9134	0.9315	0.9754
$B^0 \to \rho^0 \mu^+ \mu^-$	1.0235	0.9696	0.9788	1.0005
$B^0 \to \rho^0 \tau^+ \tau^-$	1.0338	1.0212	1.0234	1.0285

Coulomb interaction in $B^0_{s,d} \to V^0 \ell^+ \ell^-$

Decay	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{\rm QED} \rangle$ (0.5 GeV)
$B^0_s \to \phi e^+ e^-$	1.0234	0.9207	0.9377	0.9785
$B^0_s \to \phi \mu^+ \mu^-$	1.0236	0.9728	0.9815	1.0018
$B^0_s \to \phi \tau^+ \tau^-$	1.0370	1.0249	1.0270	1.0319
$B^0_s \to K^{0*} e^+ e^-$	1.0234	0.9167	0.9342	0.9767
$B^0_s \to K^{0*} \mu^+ \mu^-$	1.0235	0.9712	0.9801	1.0011
$B^0_s \to K^{0*} \tau^+ \tau^-$	1.0352	1.0227	1.0248	1.0299

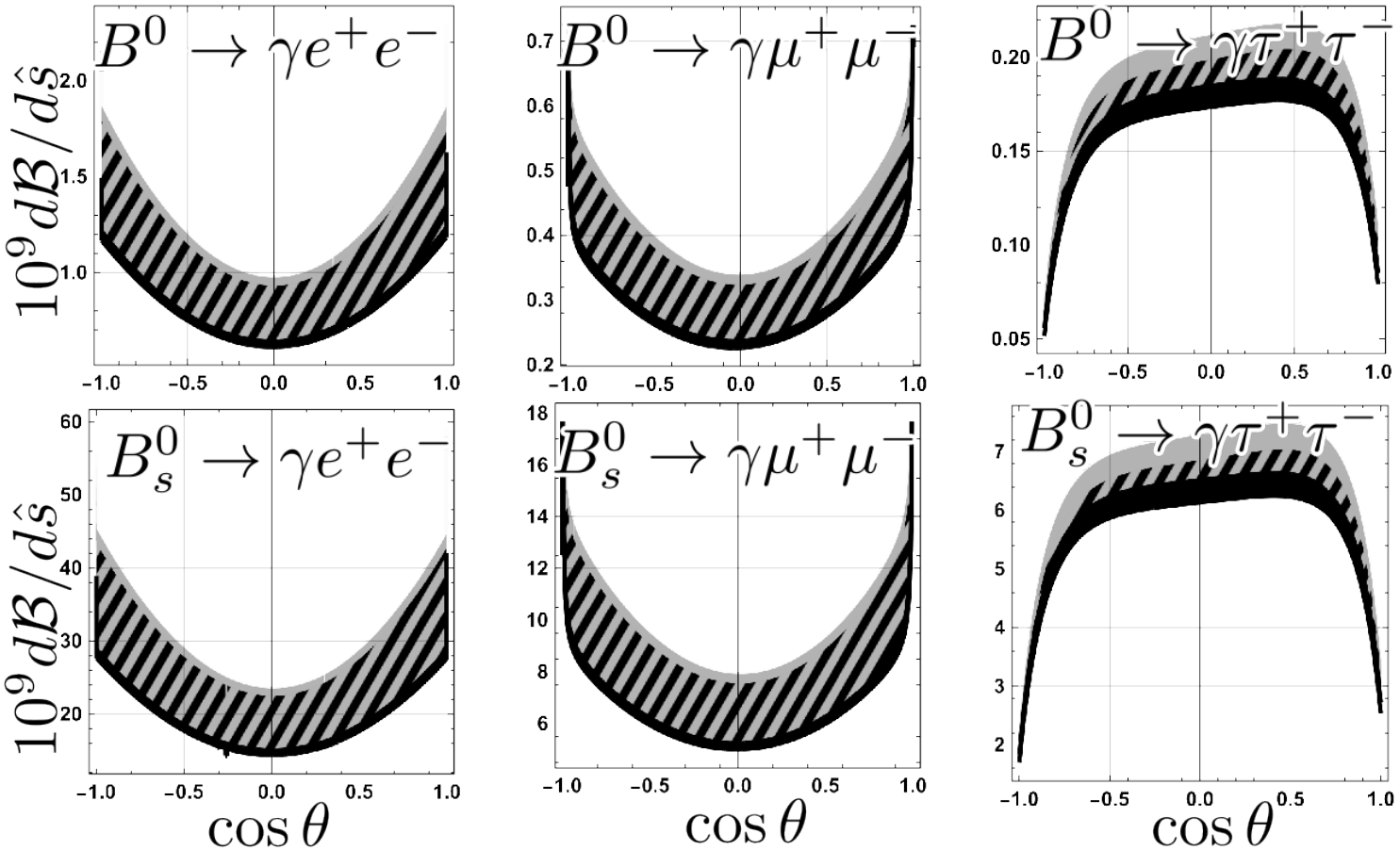
Coulomb interaction in $B^0_{s,d} \to \gamma \ell^+ \ell^-$.

Coulomb interaction in $B^0_{s,d} \to \gamma \ell^+ \ell^-$



The differential decay width $10^9 \cdot \frac{1}{\Gamma^{(total)}} \frac{d\Gamma}{ds}$ as a function of s/M_B^2 where $s = (p_{B^0} - p_\gamma)^2$.

Coulomb interaction in $B^0_{s,d} \to \gamma \ell^+ \ell^-$



$10^9 \cdot d\mathcal{B}/d\cos\theta$ as a function of $\cos\theta$, where $\theta = \angle(\mathbf{p}_{\ell^+}, \mathbf{p}_\gamma)$ in the rest frame of the lepton pair

$q^2 \in [1,6]$ GeV^2	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\langle \mathcal{K}_C \rangle$
$B_s^0 \to \gamma e^+ e^- [10^{-9}]$	–	$2.97 \pm$ ± 0.49	3.04 ± 0.50	2.4%
$B_s^0 \to \gamma \mu^+ \mu^- [10^{-9}]$	< 119 at 90% CL	$3.03 \pm$ ± 0.50	3.10 ± 0.50	2.4%
$B^0 \to \gamma e^+ e^- [10^{-12}]$	–	$5.09 \pm$ ± 0.59	5.21 ± 0.61	2.3%
$B^0 \to \gamma \mu^+ \mu^- [10^{-12}]$	–	$5.31 \pm$ ± 0.57	5.43 ± 0.58	2.3%

$q^2 \in [4m_\tau^2, M_{B_{d,s}}^2]$	$\mathcal{B}^{(exp)}$	$\mathcal{B}^{(free)}$	$\mathcal{B}^{(Coulomb)}$	$\langle \mathcal{K}_C \rangle$
$B_s^0 \to \gamma \tau^+ \tau^- [10^{-9}]$	–	$1.13 \pm$ ± 0.30	1.16 ± 0.31	2.7%
$B^0 \to \gamma \tau^+ \tau^- [10^{-11}]$	–	$3.10 \pm$ ± 0.93	3.19 ± 0.95	2.7%

$q^2 \in [1,6]$ GeV^2	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{QED} \rangle$ (0.5 GeV)
$B^0 \to \gamma e^+ e^-$	1.023	0.881	0.905	0.961
$B^0 \to \gamma \mu^+ \mu^-$	1.023	0.972	0.981	1.002
$B_s^0 \to \gamma e^+ e^-$	1.023	0.889	0.911	0.964
$B_s^0 \to \gamma \mu^+ \mu^-$	1.023	0.981	0.988	1.005

$q^2 \in [4m_\tau^2, M_{B_{d,s}}^2]$	$\langle \mathcal{K}_C \rangle$	$\langle \mathcal{K}_{QED} \rangle$ (0.05 GeV)	$\langle \mathcal{K}_{QED} \rangle$ (0.1 GeV)	$\langle \mathcal{K}_{QED} \rangle$ (0.5 GeV)
$B^0 \to \gamma \tau^+ \tau^-$	1.027	1.012	1.015	1.021
$B_s^0 \to \gamma \tau^+ \tau^-$	1.027	1.011	1.014	1.020

Conclusions: Coulomb correction in rare B decays

- Coulomb interaction between final charged particles matters for high-precision flavour physics because the Coulomb correction is not limited to the threshold region; it operates also in the relativistic regime.
- It has been computed for:
  - Leptonic $B^0_{d,s} \to \ell^+\ell^-$;
  - Semileptonic $B^0_{(s)} \to \{K^0, \pi^0, \eta^{(\prime)}, K^{0*}, \rho^0, \phi\}\ell^+\ell^-$;
  - Radiative $B^0 \to \gamma\ell^+\ell^-$.
- Impact on discrepancy $\delta = |\text{Th} - \text{Exp}|/\text{Exp}$ (%) with experimental errors:

Decay	δ_{before}	δ_{after}	Exp. error
$B^0_s \to \mu^+\mu^-$	5%	2%	11%
$B^0 \to K^{0*}\mu^+\mu^-$	11%	4%	8%
$B^0 \to K^{0*}e^+e^-$	14%	17%	17%
$B^0 \to K^0\mu^+\mu^-$	1.7%	0.5%	10%

- For $\tau^+\tau^-$ modes (e.g. η', ϕ) the correction reaches $\sim 4\%$ – a relevant systematic effect for future high-precision experiments.

Thank You for Your Attention!