Angular Analyses of $B^0 \to K^{*0} e^+ e^-$ decays at LHCb.

59th Rencontres de Moriond – Young Scientist Forum

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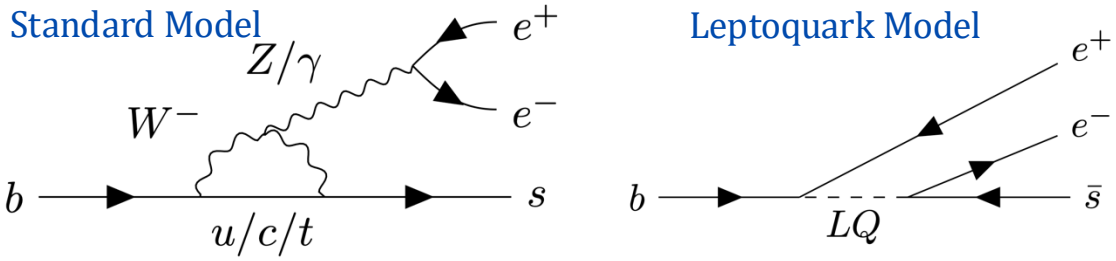
on behalf of the LHCb collaboration

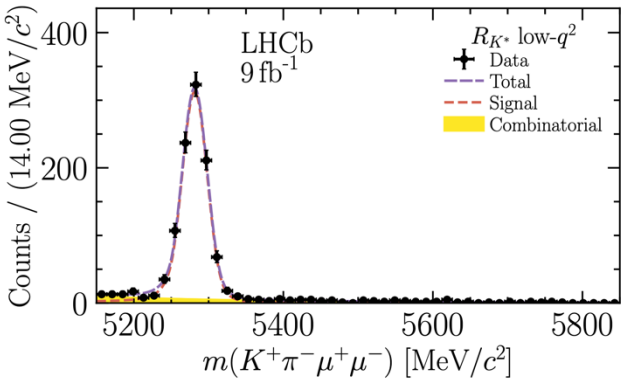
Motivation for $b \to s e^+ e^-$ studies

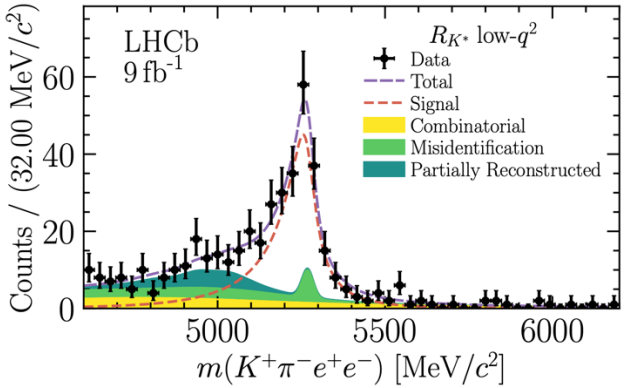
- $b \to s\ell^+\ell^-$ transitions are Flavour Changing Neutral Currents
  → Sensitive to potential New Physics (NP)!



- Studies of $b \to s\mu^+\mu^-$ have shown some tensions with SM predictions.
  → Could be non-perturbative QCD, or NP effects.

- Studies of $b \to s e^+ e^-$ are experimentally more challenging due to bremsstrahlung …





[Phys. Rev. D 108 (2023) 032002]

… but are necessary to test Lepton Flavour Universality (LFU) and to see if the tensions in the muon modes are also found in the electron modes.

Angular description of $B^0 \to K^{*0} e^+ e^-$ decays

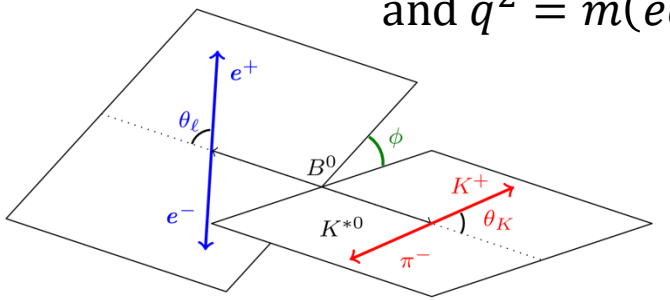
- CP-averaged differential signal decay-rate:

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\bar{\Gamma})}{\mathrm{d}q^2\mathrm{d}\Omega}\Big|_{\mathrm{P}} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + \frac{4}{3}A_{FB}\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

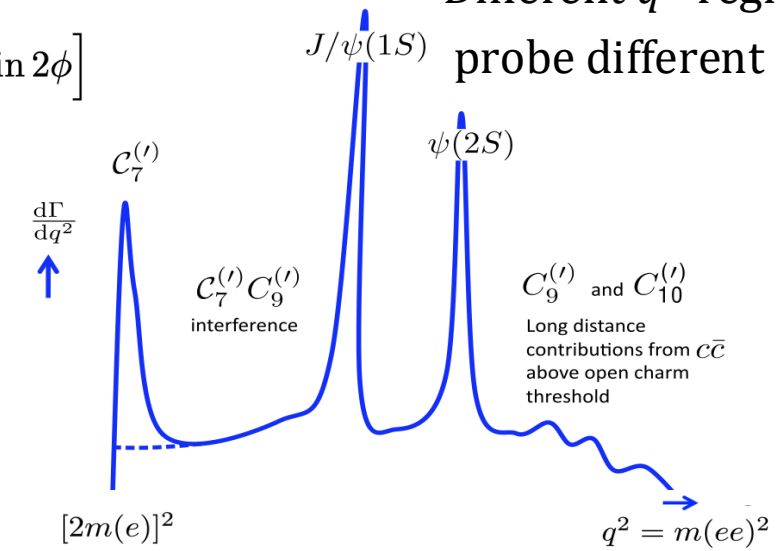
$$P_1 = \frac{2S_3}{(1-F_L)} \qquad P_2 = \frac{2}{3}\frac{A_{FB}}{(1-F_L)} \qquad P_3 = \frac{-S_9}{(1-F_L)} \qquad P'_{4,5,6,8} = \frac{-S_{4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$

- The observables F_L, A_{FB}, and S_i are sensitive to $C_i^{(\prime)}$ and form factors.
- Optimised $P_i^{(\prime)}$ "ratio" observables can be computed as well, where form factors uncertainties cancel at leading order. [JHEP 01 (2013) 048]

$B^0 \to K^{*0} e^+ e^-$ decays are fully described by the three angles: $cos(\theta_l)$, $cos(\theta_k)$, ϕ, and $q^2 = m(ee)^2$



Different q^2 regions probe different $C_i^{(\prime)}$



Strategy for angular analyses of $B^0 \to K^{*0} e^+ e^-$ decays at LHCb

- 4D fit to the mass and the three angles to extract F_L, A_{FB}, S_i and the associated optimised $P_i^{(\prime)}$ observables.
  - Benefit from the work of the published R_{K^*} (R_X) analysis [Phys. Rev. D 108 (2023) 032002].
  - Mass and ($\cos(\theta_l)$, $\cos(\theta_k)$, ϕ) are factorised.
  - Angular modelling:

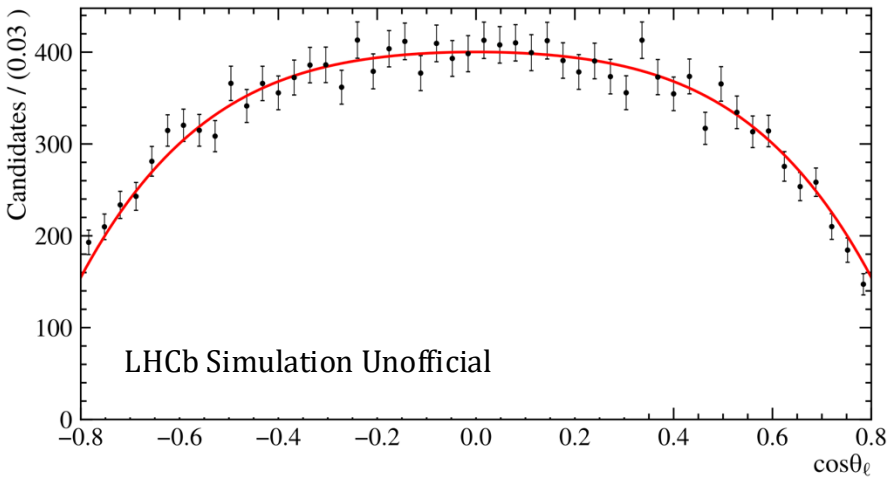
    What is observed:

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\bar{\Gamma})}{\mathrm{d}q^2\mathrm{d}\Omega} \times \epsilon(\cos\theta_l, \cos\theta_k, \phi, q^2)$$

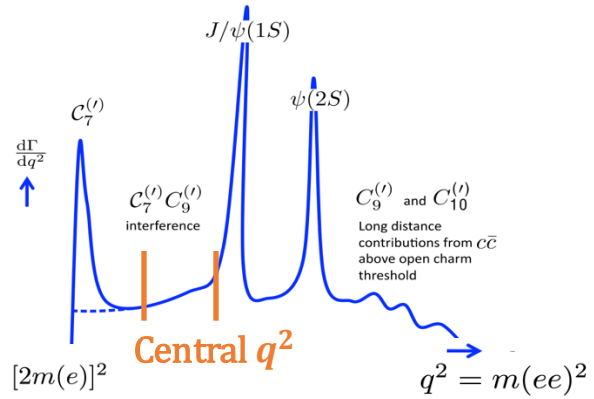
    Effects of the geometry of the LHCb detector, the reconstruction, the selection

    → Taken into account in the modelling.

Reconstructed $\cos(\theta_l)$ distribution that was generated flat:

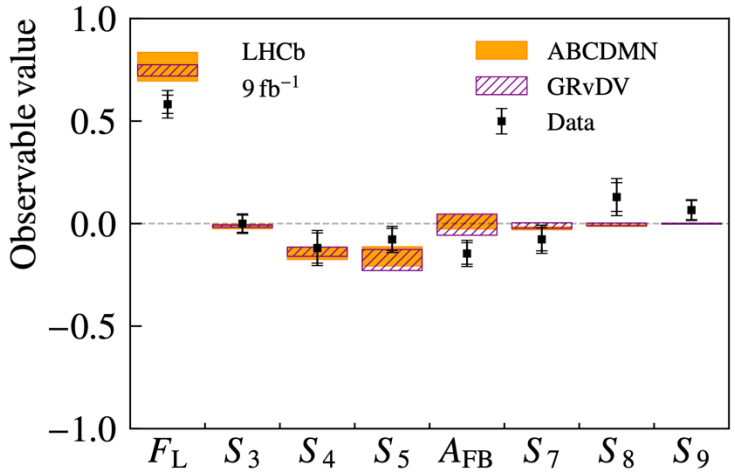


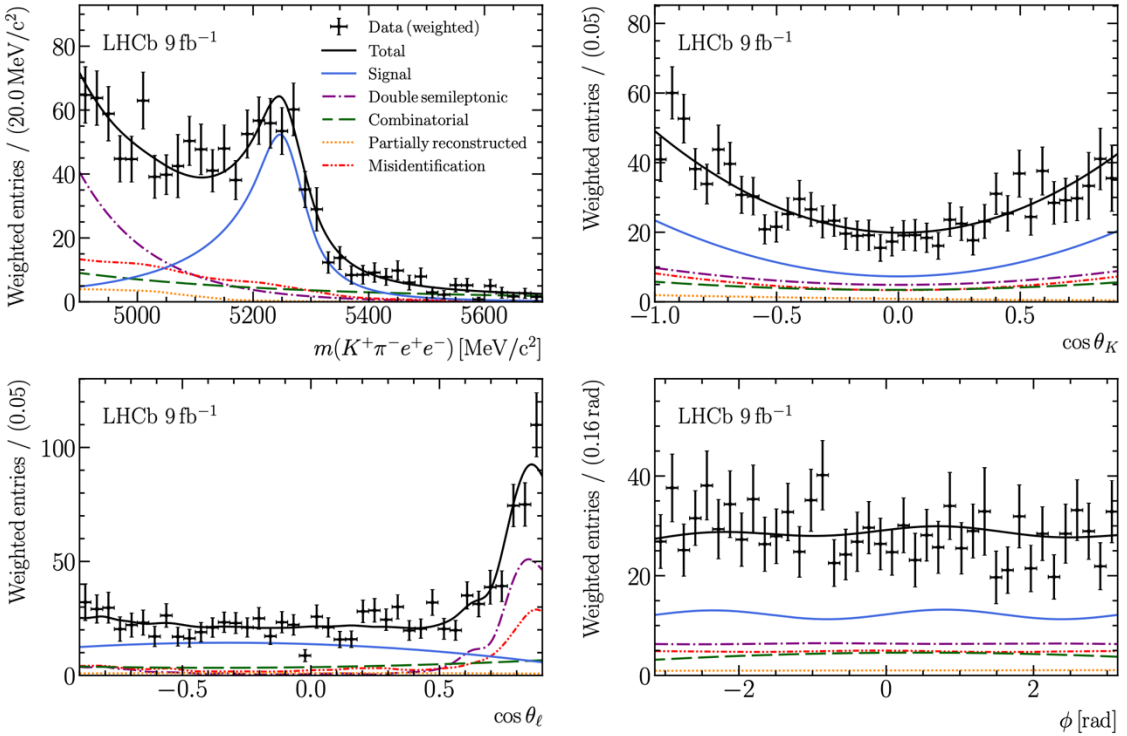
$B^0 \to K^{*0} e^+ e^-$ angular analysis in the central q^2 region



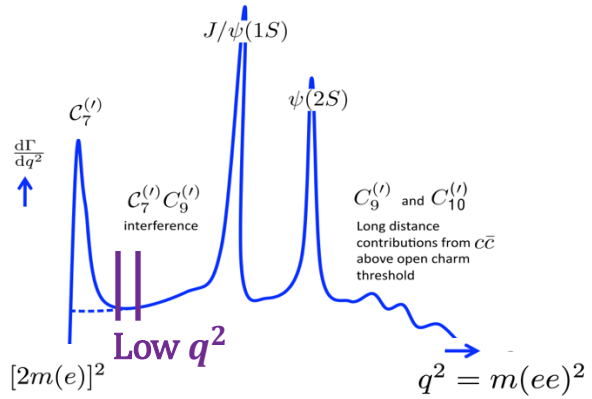
- Recently published [arXiv:2502.10291]
- Full Run 1 and Run 2.
- Most precise measurement to date but more statistics needed to conclude on the observed tensions in the muon mode [Phys. Rev. Lett. 125 (2020) 011802]

$q^2 \in [1.1, 6.0]\ \mathrm{GeV}^2/c^4$





$B^0 \to K^{*0} e^+ e^-$ angular analysis in the **low q^2** region

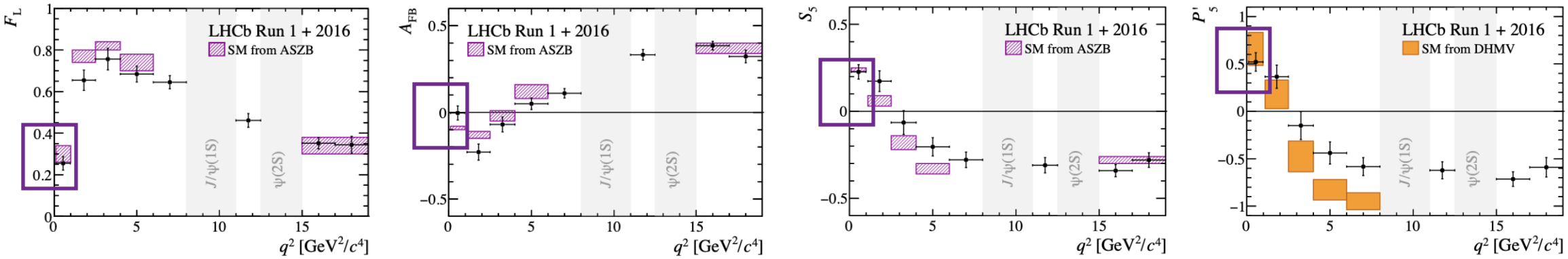


- Work on-going.
- Full Run 1 and Run 2.
- Closer to the photon-pole → More sensitive to the interference of $C_7^{(\prime)}$ and $C_9^{(\prime)}$.

$q^2 \in [0.1, 1.1]\ \mathrm{GeV}^2/c^4$

My PhD project

To be compared with published $B^0 \to K^{*0}\mu^+\mu^-$ angular analysis low q^2 results:
[Phys. Rev. Lett. 125 (2020) 011802]



Conclusion

- Recently published: First Angular analysis of $B^0 \to K^{*0} e^+ e^-$ decays in the **central q^2** region at LHCb. [arXiv:2502.10291]
- Work on-going: First Angular Analysis of $B^0 \to K^{*0} e^+ e^-$ decays in the **low q^2** region at LHCb.
  - Statistical uncertainty is expected to be $\sim$ 1.8 larger than the statistical uncertainty of the muon analysis [Phys. Rev. Lett. 125 (2020) 011802] (similar uncertainty scaling to the one in the central q^2).
  - Results are expected to be statistically dominated.
- Stay tuned for Run 3!