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Angular analysis of $B^0 \to K^{*0}\ell^+\ell^-$ decays at LHCb

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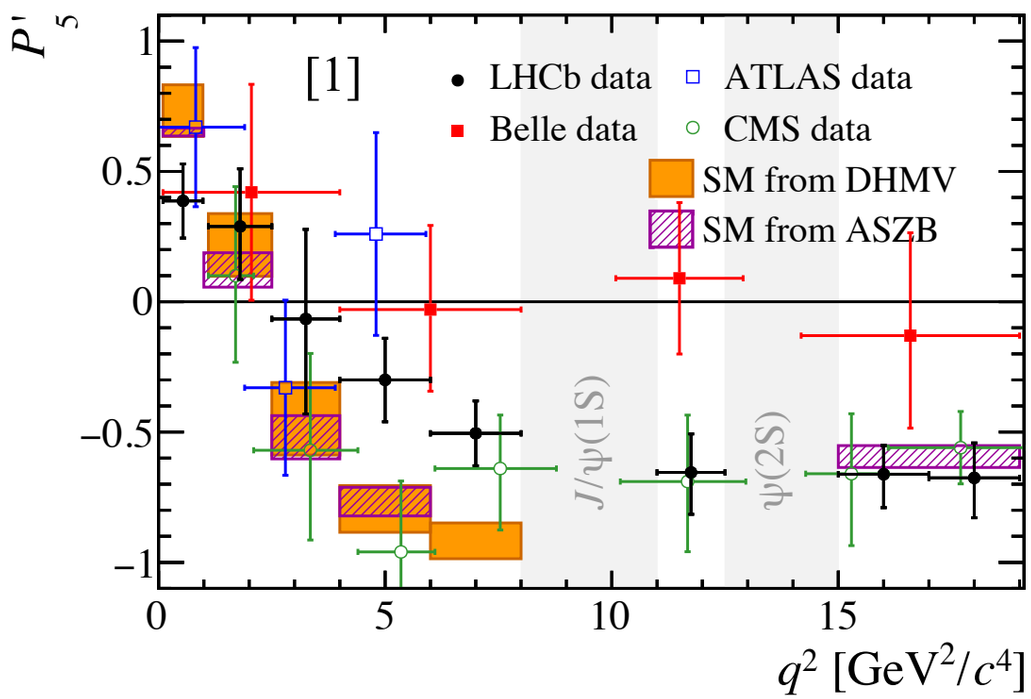
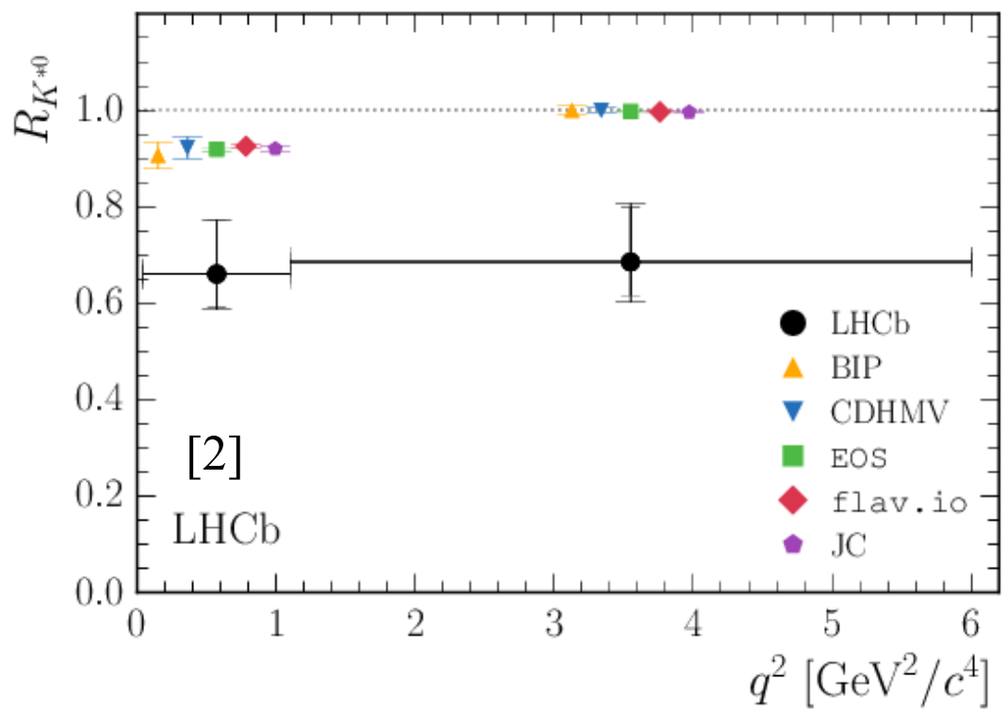
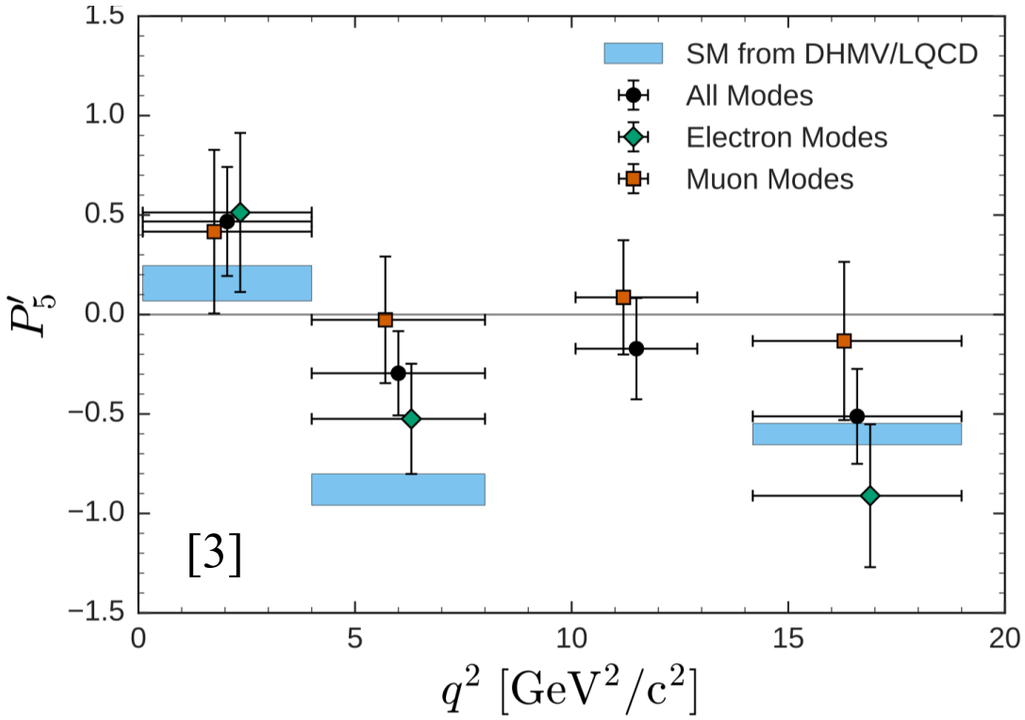
$B^0 \to K^{*0}\ell^+\ell^-$ angular analysis

Remember P_5'?





See hints of lepton flavour universality (LFU) violation in R_{K^*} — what about angular observables?

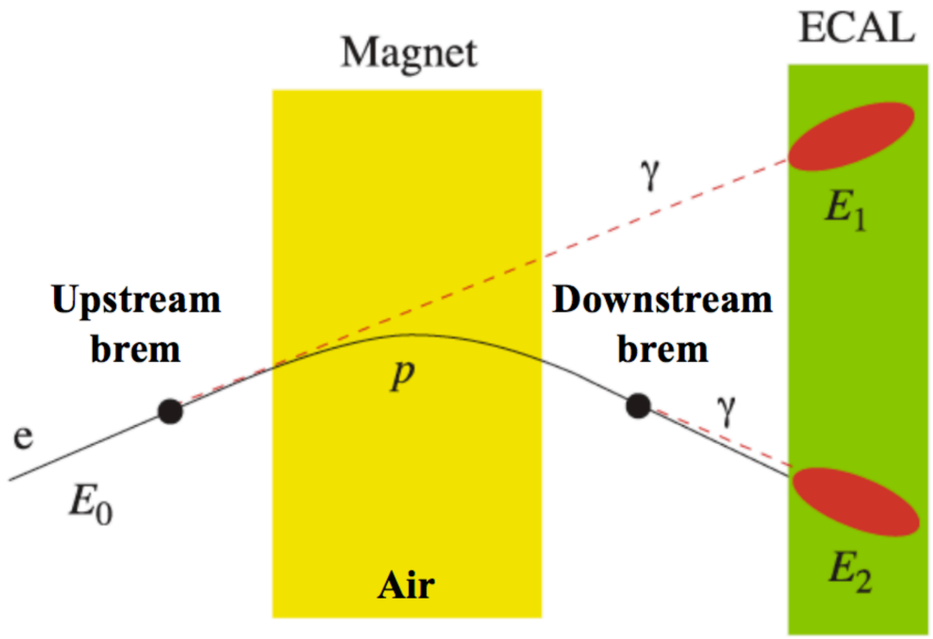


Electrons vs muons

- Muon reconstruction is relatively easy
- Electron reconstruction is more difficult due to large bremsstrahlung losses causing…

✗ decreased mass and q^2 resolution

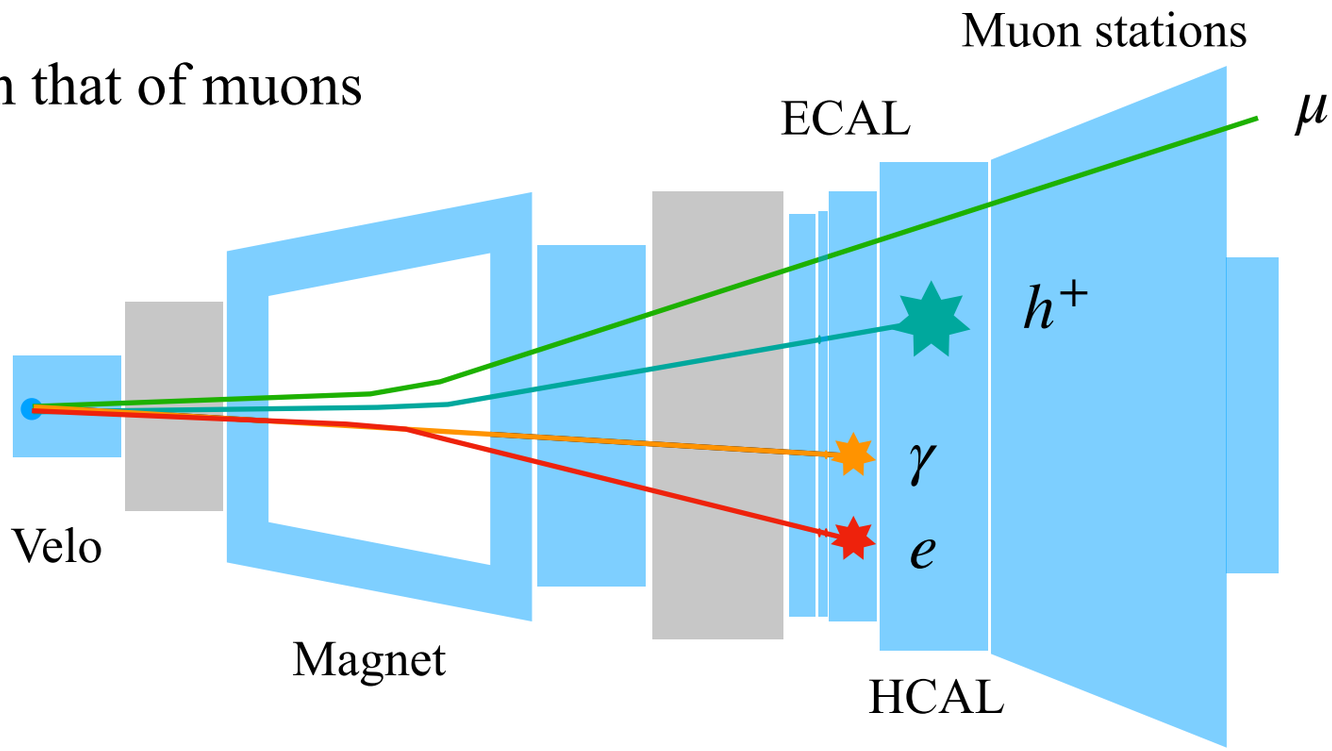
✗ more background in signal region



- Electron final states are less distinctive than that of muons

✗ Lower statistics due to decreased trigger efficiency

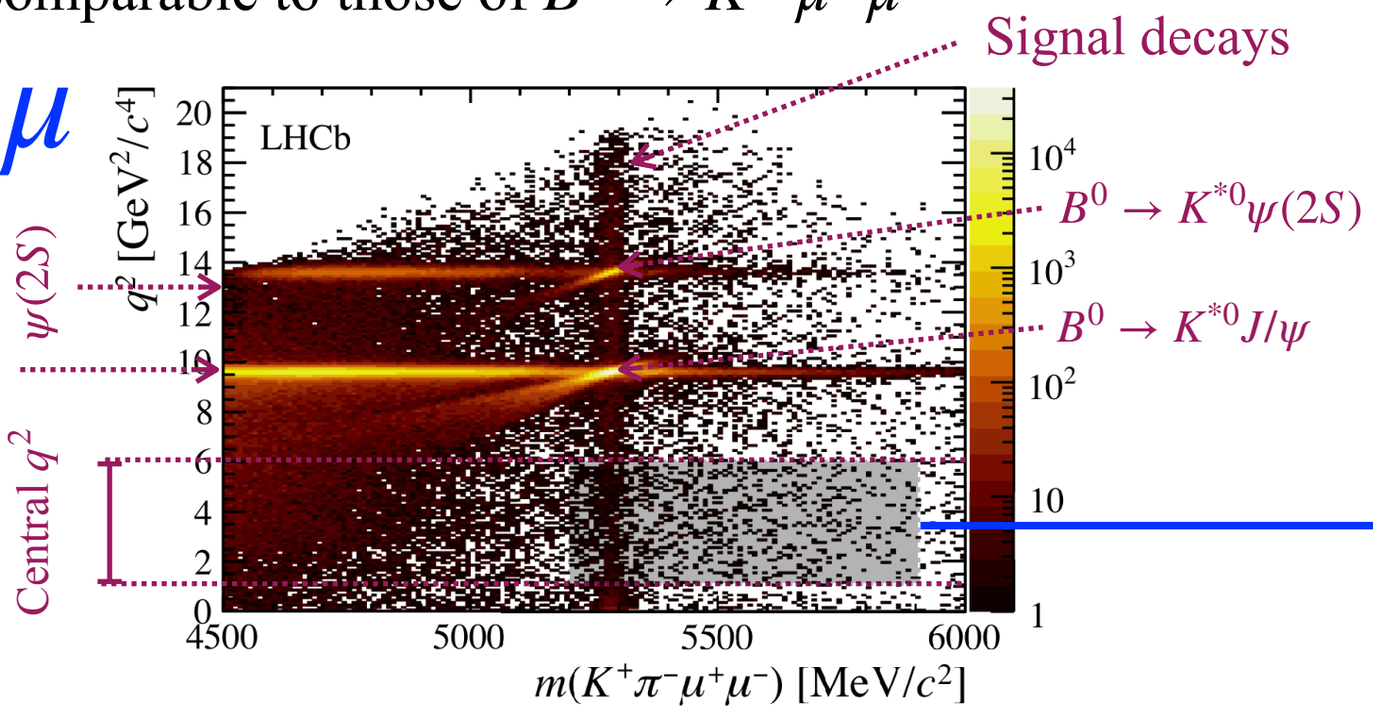
✗ Poorer PID performance

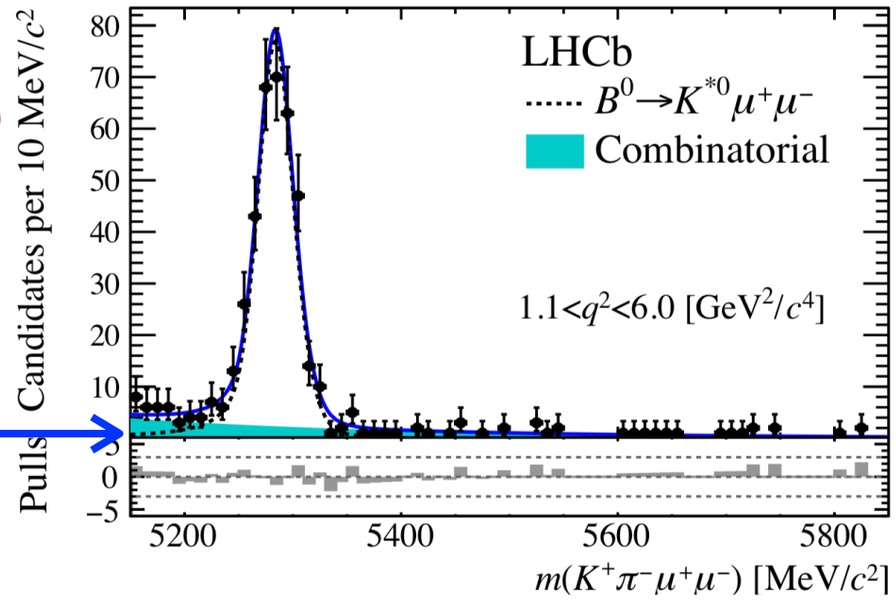


Electrons vs muons

- Electron channel more challenging — to date no $B^0 \to K^{*0}e^+e^-$ angular measurements at LHCb comparable to those of $B^0 \to K^{*0}\mu^+\mu^-$

$\mu\mu$





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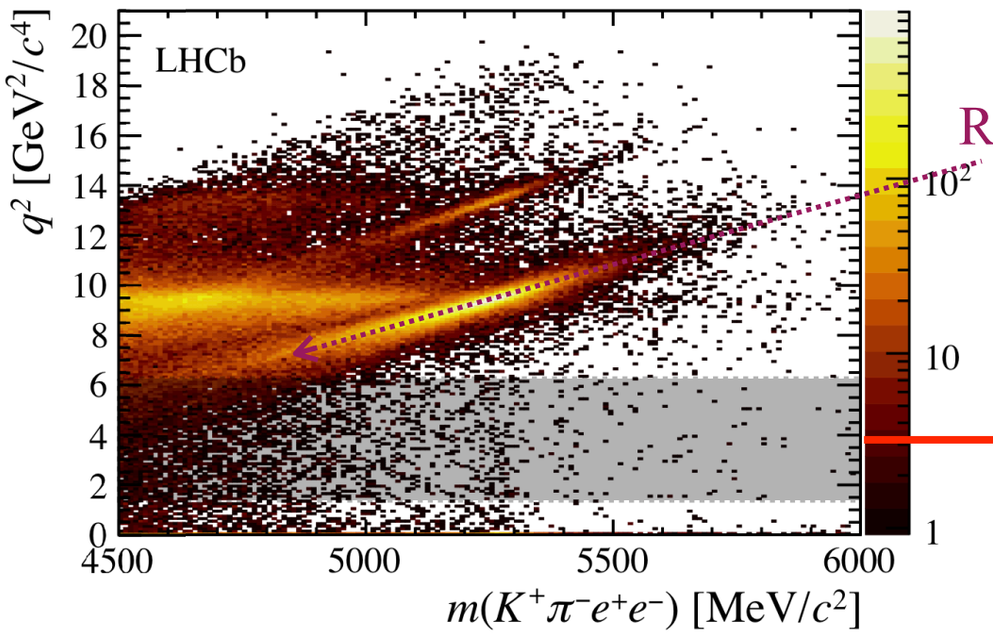
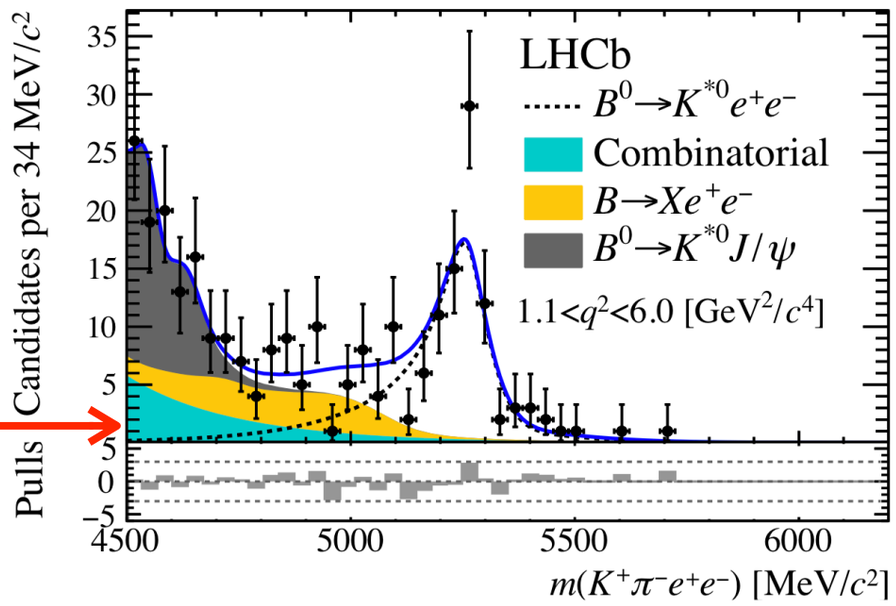


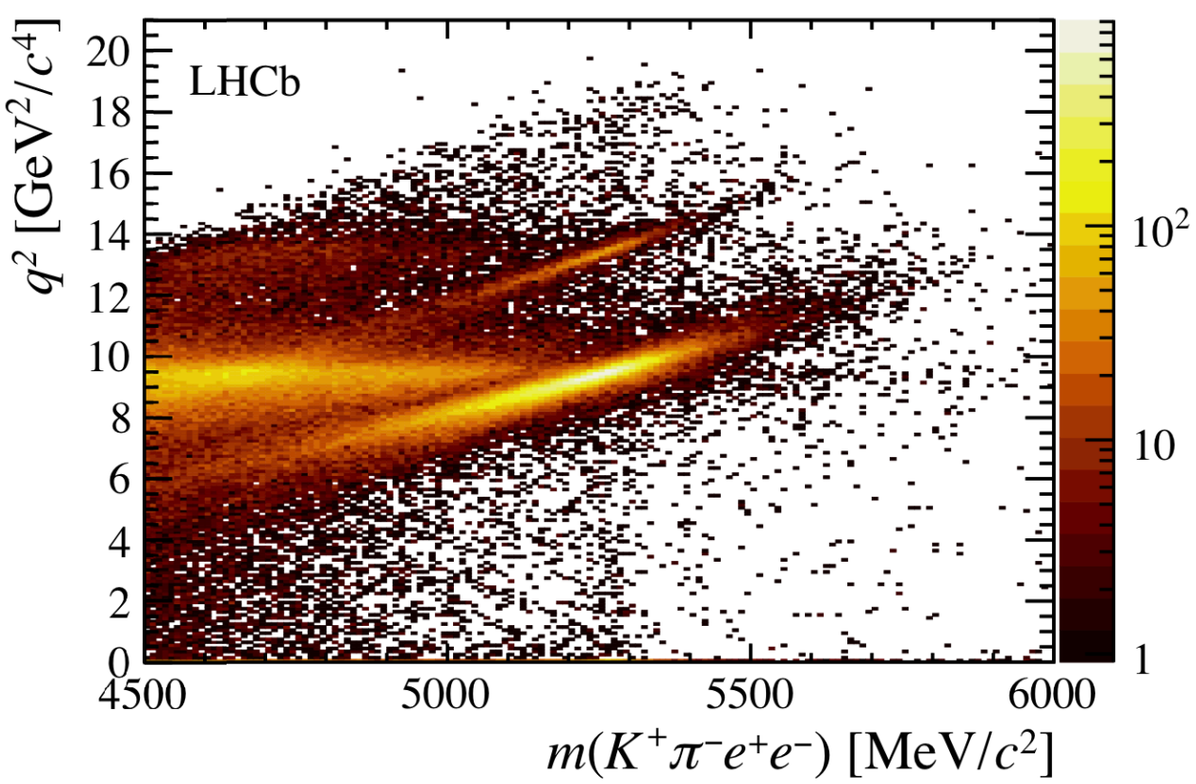


[4]

Electron strategy: constrained q^2

- Cutting on the q^2 with B^0 primary vertex and mass constraint allows for the extension of the analysis range up to 7.0 GeV^2/c^4

✓ Increase statistics without increasing background



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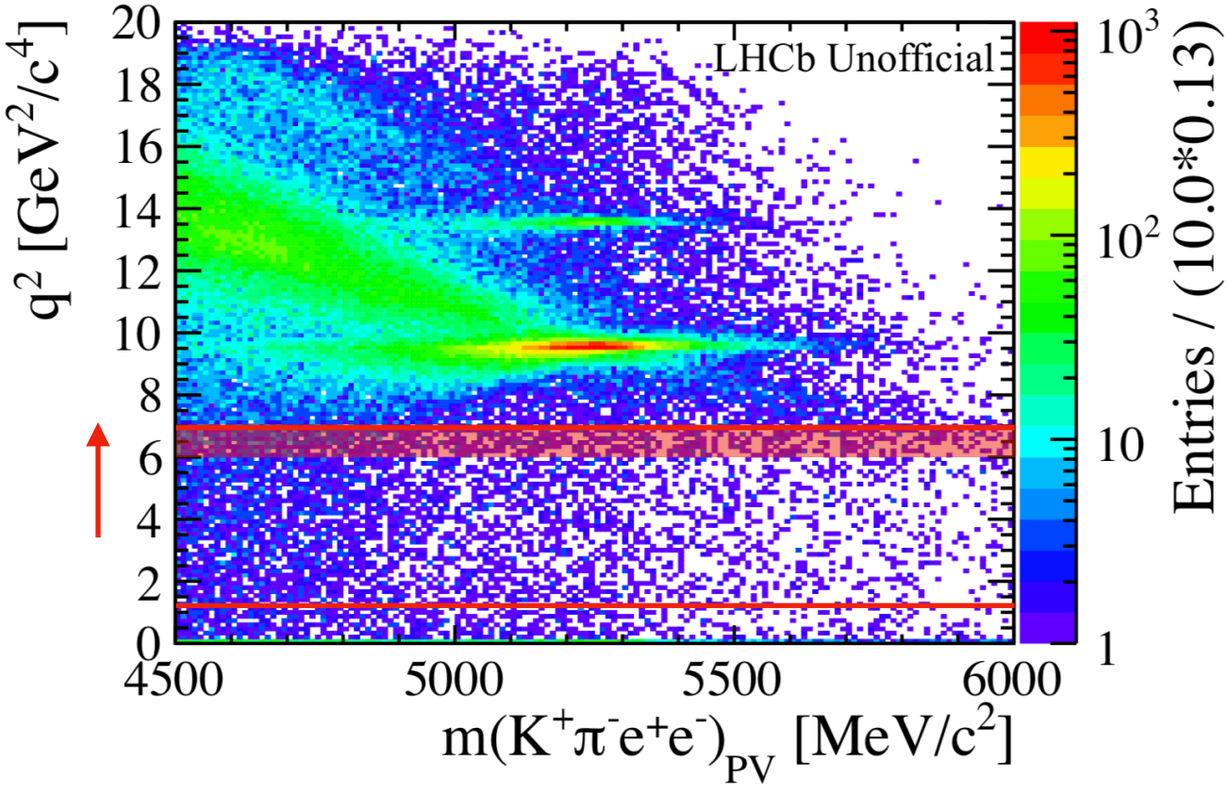
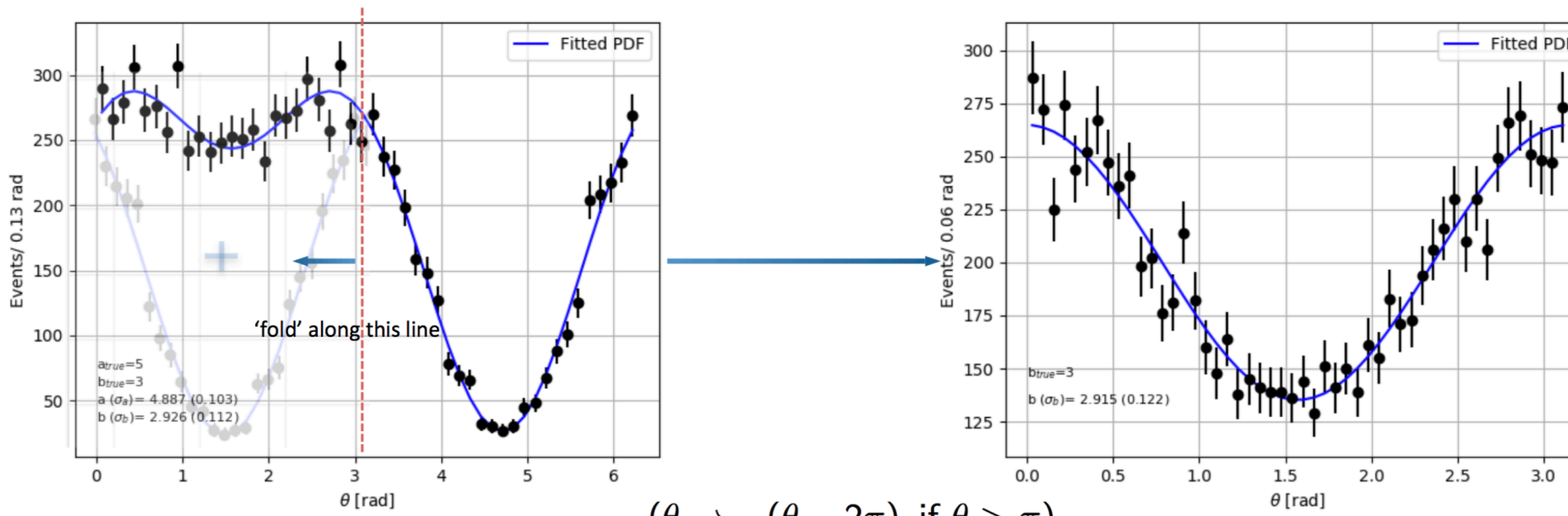


[5]

Electron strategy: folding

- For electron channel 'fold' signal PDF to reduce impact of low statistics, e.g. for P_5'



$$f(\theta) = \frac{1}{18\pi}(\mathrm{a}\sin\theta + \mathrm{b}\cos 2\theta + 9) \xrightarrow{(\theta \to -(\theta - 2\pi) \text{ if } \theta > \pi)} f(\theta)_{\mathrm{fold}} = \frac{1}{9\pi}(\mathrm{b}\cos 2\theta + 9)$$

Reduced number of observables to be determined in fit

$$\frac{1}{\mathrm{d}(\Gamma+\overline{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\overline{\Gamma})}{\mathrm{d}q^2 d\vec{\Omega}} = \frac{9}{8\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + \frac{1}{2}(1-F_L)P_1\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \sqrt{F_L(1-F_L)}\,P_5'\sin 2\theta_K\sin\theta_\ell\cos\phi\Big]$$

$$\phi \to -\phi \text{ if } \phi < 0$$

$$\theta_\ell \to \pi - \theta_\ell \text{ if } \theta_\ell > \frac{\pi}{2}$$

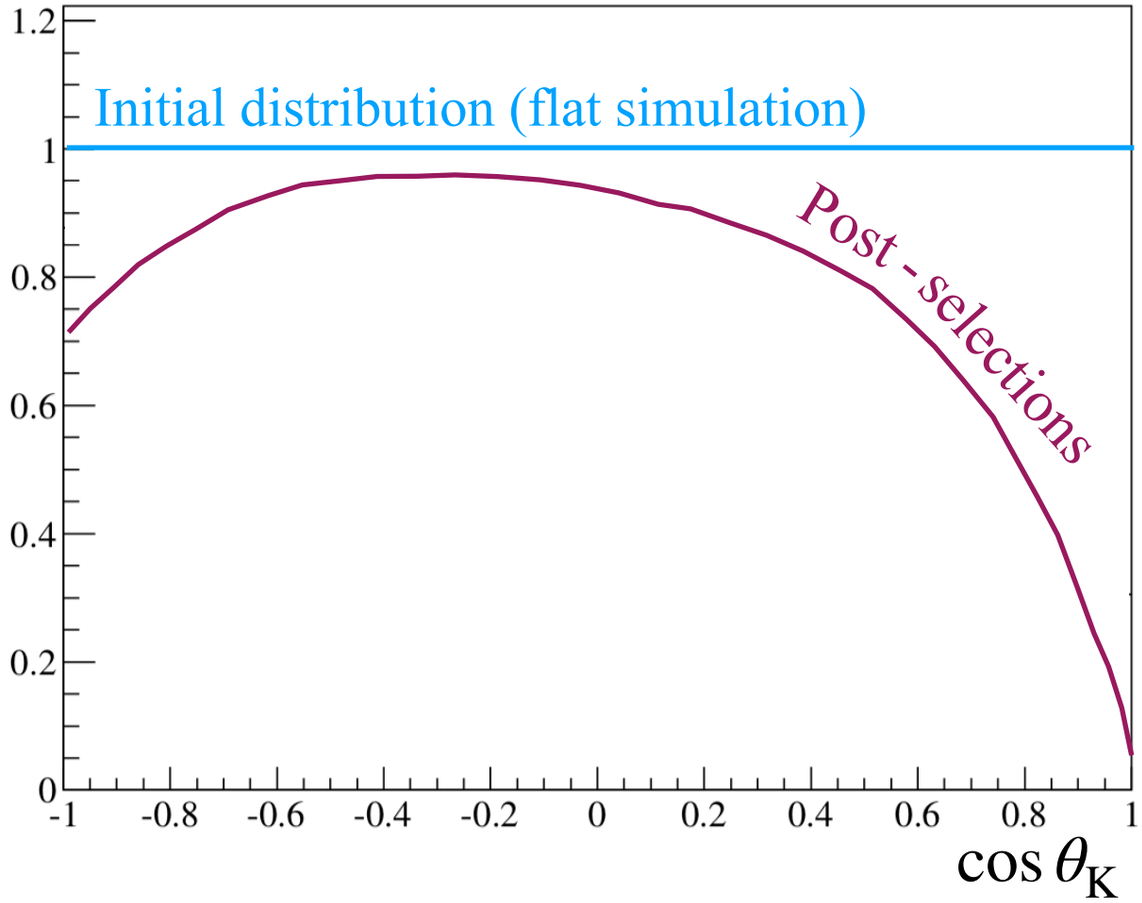
Angular acceptance

- Acceptance effect: distortions to the distributions of $\cos\theta_K$, $\cos\theta_\ell$, ϕ (and q^2) caused by reconstruction, triggering and selections
- Due to correlation between angles and q^2, acceptance does not factorise — parametrise in 4d

$$\epsilon(cos\theta_l, cos\theta_K\, \phi, q^2) = \sum_{ijmn} c_{ijmn}\, L_i(cos\theta_l)\, L_j(cos\theta_K)\, L_m(\phi)\, L_n(q^2)$$

L_i — Legendre polynomials of order i $\quad$ c_{ijmn} — coefficients from moments analysis

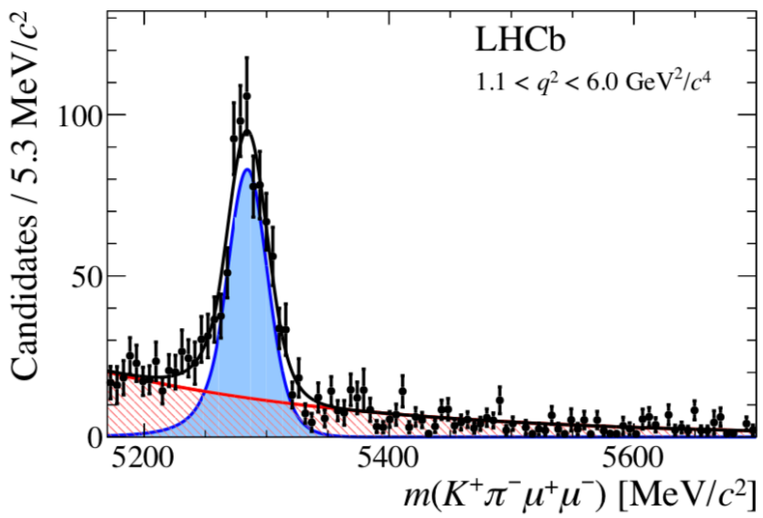
Selections, e.g. IP and P_T cuts on π/K, can alter $\cos\theta_K$ distribution

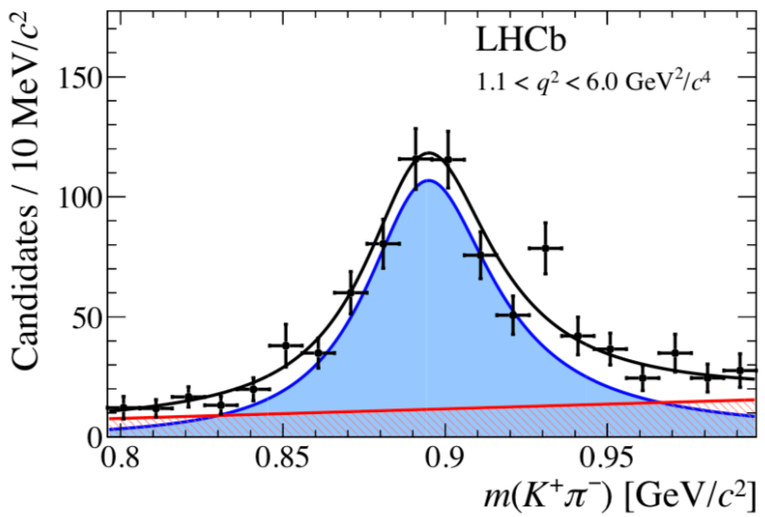


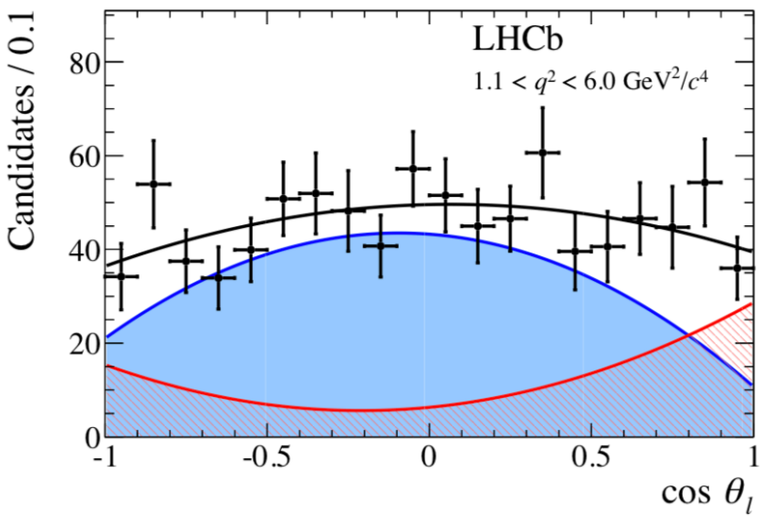
[6]

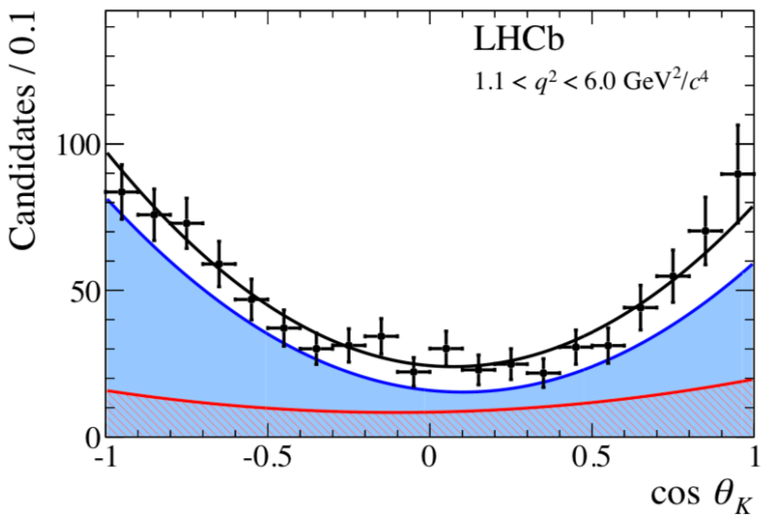
Mass and angular fit: muons

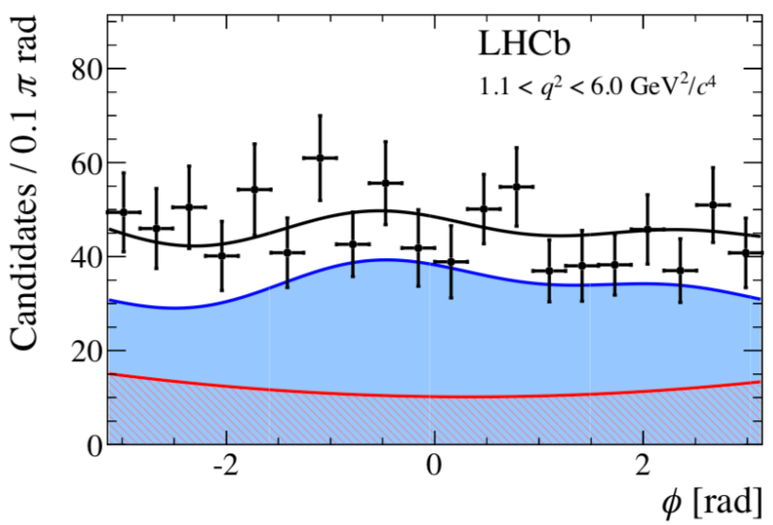
- Extract observables via unbinned maximum likelihood fit of $m(K^+\pi^-\mu^+\mu^-)$, $\cos\theta_K$, $\cos\theta_\ell$, ϕ, and $m(K^+\pi^-)$ after adjusting for acceptance











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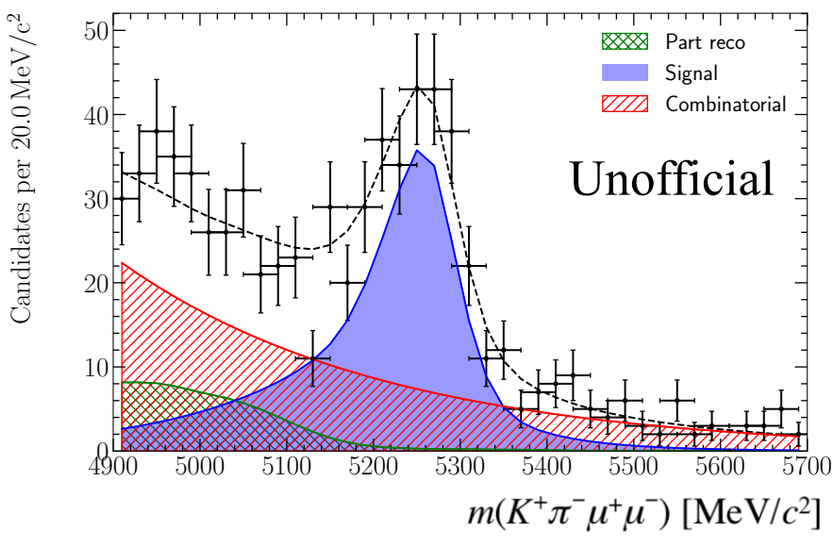
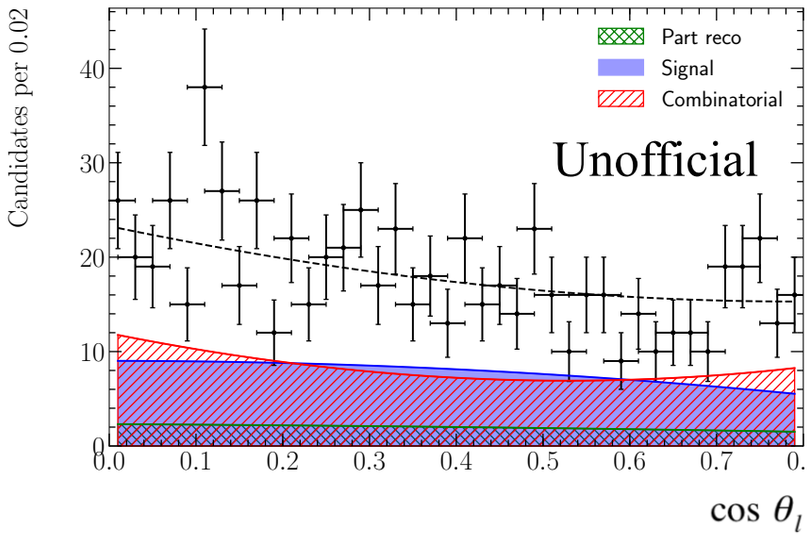
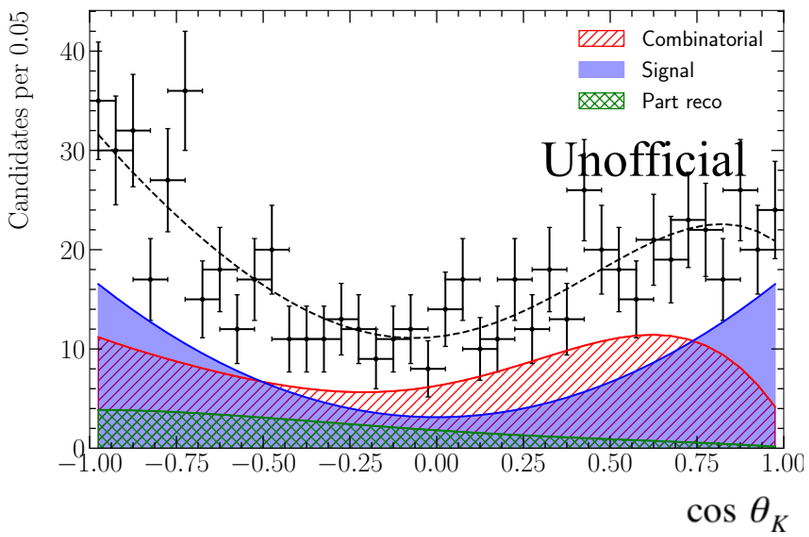
Mass and angular fit: electrons

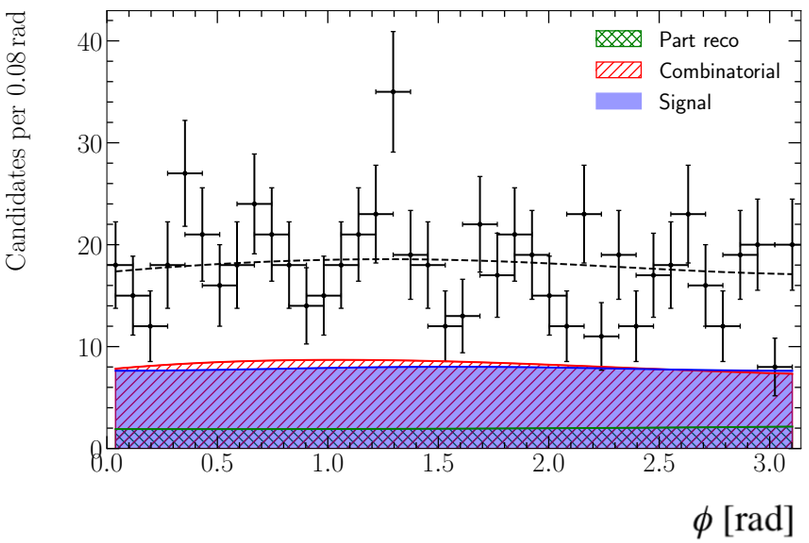
- Example (simulation) of a similar fit for the electron channel



No fit to $m(K^+\pi^-)$ — scalar contributions to be treated as systematic



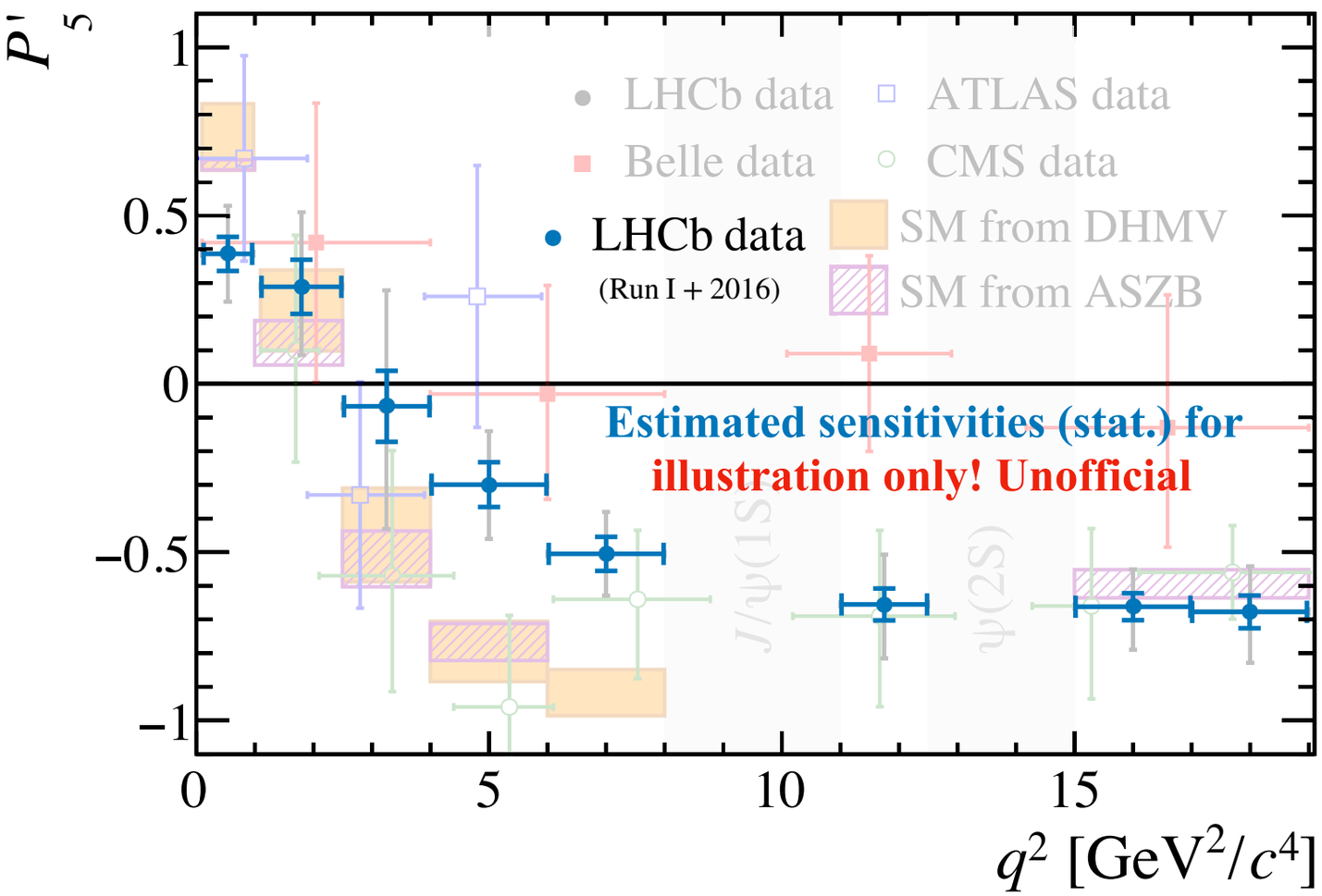


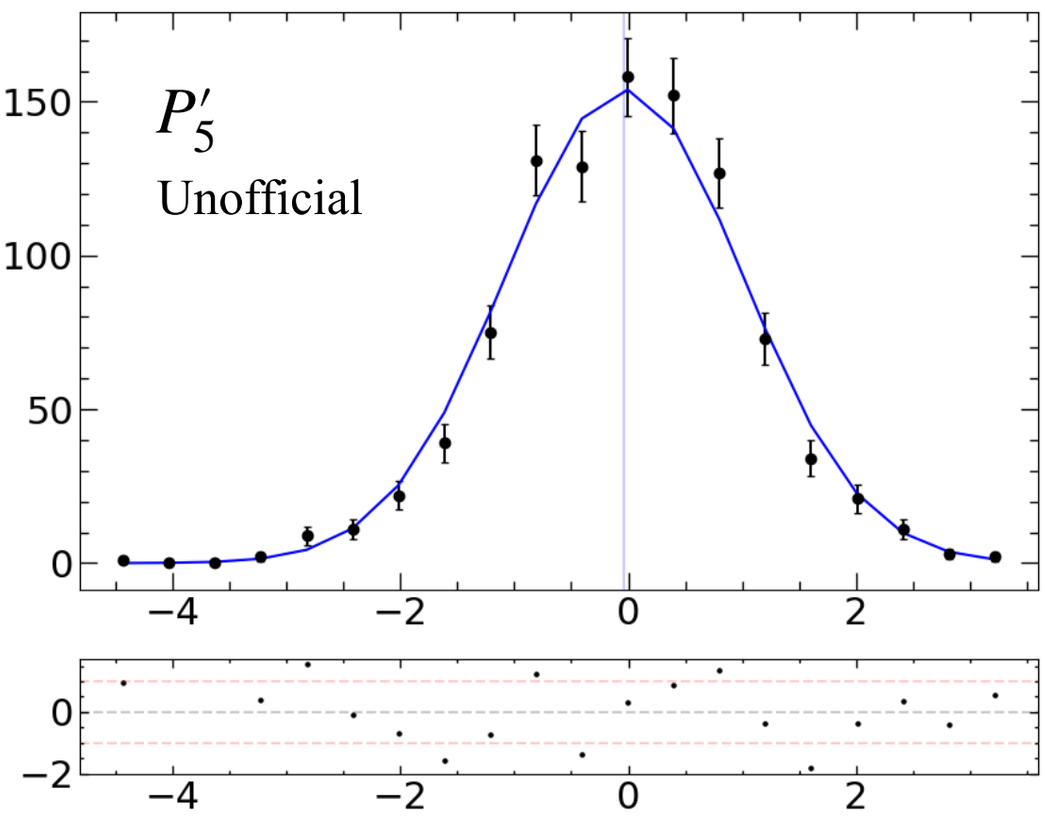


$B^0 \to K^{*0}\ell^+\ell^-$ angular analysis

Ongoing analyses

- $B^0 \to K^{*0}e^+e^-$ and $B^0 \to K^{*0}\mu^+\mu^-$ angular analyses (~5 fb^{-1}) are currently in progress
- Muon channel analysis at advanced stage and close to unblinding
- Electron channel requires more work (background studies)





Pull values

Summary

- Anomalous results in $B^0 \to K^{*0}\ell^+\ell^-$ angular and LFU observables motivate angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$ with increased statistics, as well as the analysis of $B^0 \to K^{*0}e^+e^-$

- Electron channel more difficult to study due to decreased resolution and selection efficiency

- Partial compensation possible through the usage of folding and constrained q^2

- Both $B^0 \to K^{*0}\mu^+\mu^-$ and $B^0 \to K^{*0}e^+e^-$ analyses using data corresponding to around 5 fb^{-1} of luminosity are in progress

References

$B^0 \to K^{*0}\ell^+\ell^-$ angular analysis

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[5] Constrained q^2 plot: Federica Lionetto. Measurement of Angular Observables of $B^0 \to K^{*0}\mu^+\mu^-$ and $B^0 \to K^{*0}e^+e^-$ Decays and the Upgrade of LHCb, Feb 2018. Presented 22 Mar 2018.

[6] $B^0 \to K^{*0}\mu^+\mu^-$ 3 fb^{-1} analysis: The LHCb collaboration, Aaij, R., Abellán Beteta, C. et al. J. High Energ. Phys. (2016) 2016: 104. https://doi.org/10.1007/JHEP02(2016)104