Selected measurements of rare decays at LHCb

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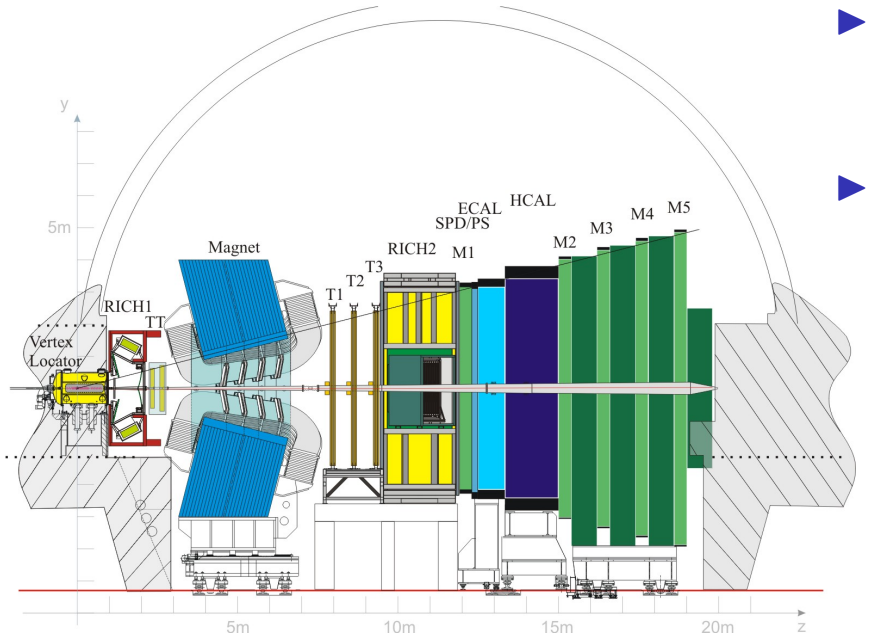
LHCb experiment



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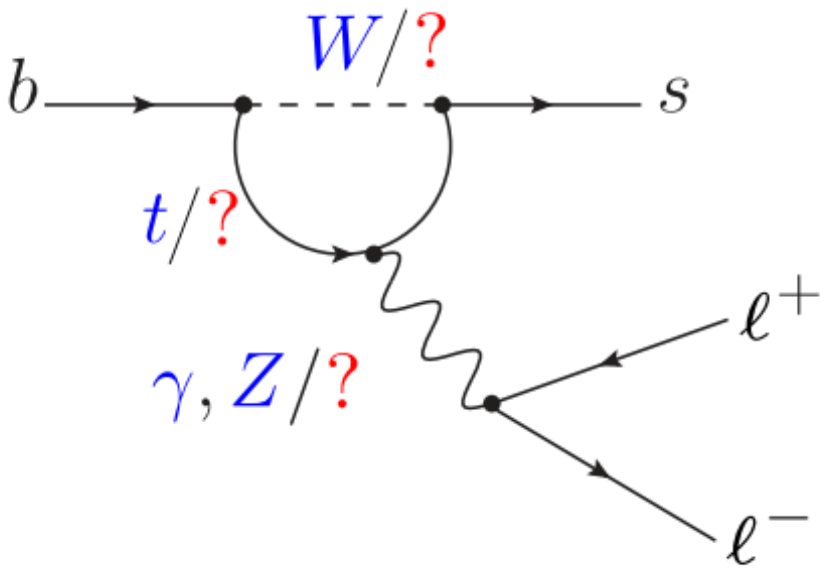
- the dedicated heavy flavour physics experiment at the LHC
- looking for indirect evidence of new physics in CP violation and rare decays
- it's advantages:
  - momentum resolution ($\Delta p/p = 0.4\%$ at 5 GeV to 0.6% at 100 GeV),
  - impact parameter resolution ($\sigma_{IP} \sim 20\mu m$),
  - primary vertex resolution ($13\mu m$ in x and y and $71\mu m$ in z),
  - decay time resolution($\sigma_\tau \sim 50fs$),
  - excellent particle identification.

Why rare decays?

- flavour changing neutral current (FCNC) - in the SM forbidden at tree level, allowed at loop level
- this processes are suppressed in the SM - Rare decays
- these loops are sensitive for New Physics

Choosen $b \to sll$ decays:

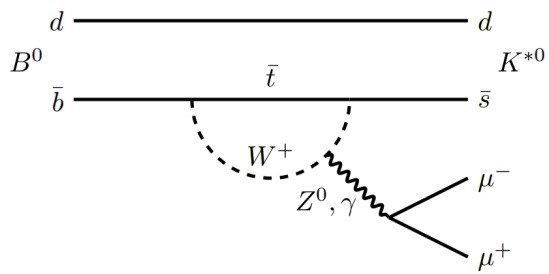
1. $B^0 \to K^{*0}\mu^+\mu^-$
2. $B^0 \to K^{*0}e^+e^-$
3. $\Lambda_b \to \Lambda\mu^+\mu^-$
4. $B_s^0 \to \phi\mu^+\mu^-$



$B^0 \to K^{*0}(\to K^+\pi^-)\mu^+\mu^-$

- combined B^0 and $\bar{B}^0$ angular distribution - many observables sensitive to new physics

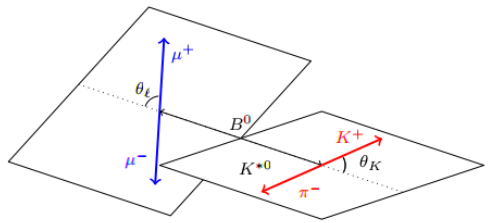
$$\frac{d^4\Gamma}{dq^2\ d\cos\theta_l\ d\cos\theta_K\ d\phi} = \frac{9}{32\pi}\Big[J_1^s \sin^2\theta_K + J_1^c \cos^2\theta_K + J_2^s \sin^2\theta_K \cos 2\theta_l + J_2^c \cos^2\theta_K \cos 2\theta_l + J_3 \sin^2\theta_K \sin^2\theta_l \cos 2\phi + J_4 \sin 2\theta_K \sin 2\theta_l \cos\phi + J_5 \sin 2\theta_K \sin\theta_l \cos\phi + J_6 \sin^2\theta_K \cos\theta_l + J_7 \sin 2\theta_K \sin\theta_l \sin\phi + J_8 \sin 2\theta_K \sin 2\theta_l \sin\phi + J_9 sin^2\theta_K \sin^2\theta_l \sin 2\phi\Big]$$



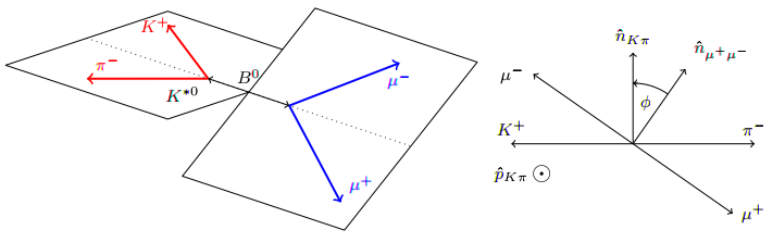
- *CP* averaged coefficients (S_j) and asymmetries (A_j):

$$S_j = (J_j + \bar{J}_j)/\Big(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\Big) \quad A_j = (J_j - \bar{J}_j)/\Big(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\Big)$$

- clean observables $P'_{4,5} = S_{4,5}/\sqrt{F_L(1-F_L)}$



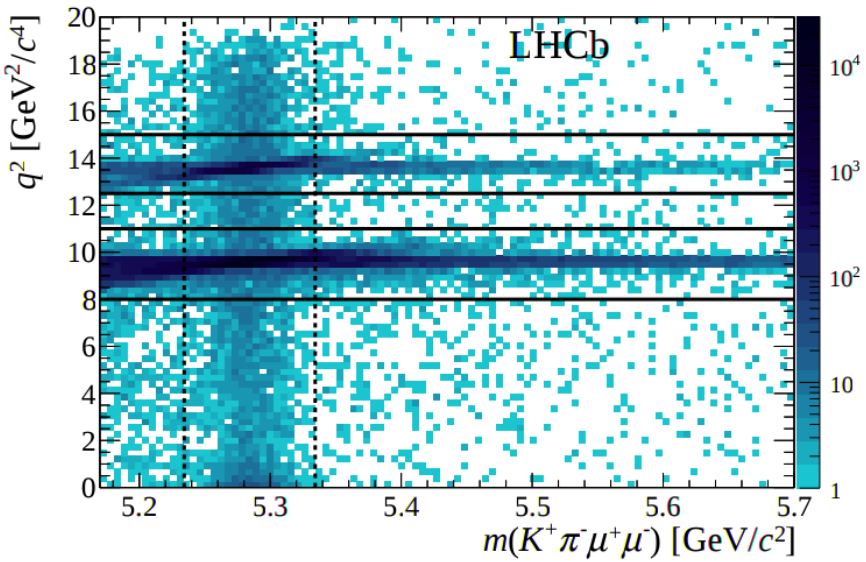
(a) θ_K and θ_ℓ definitions for the B^0 decay

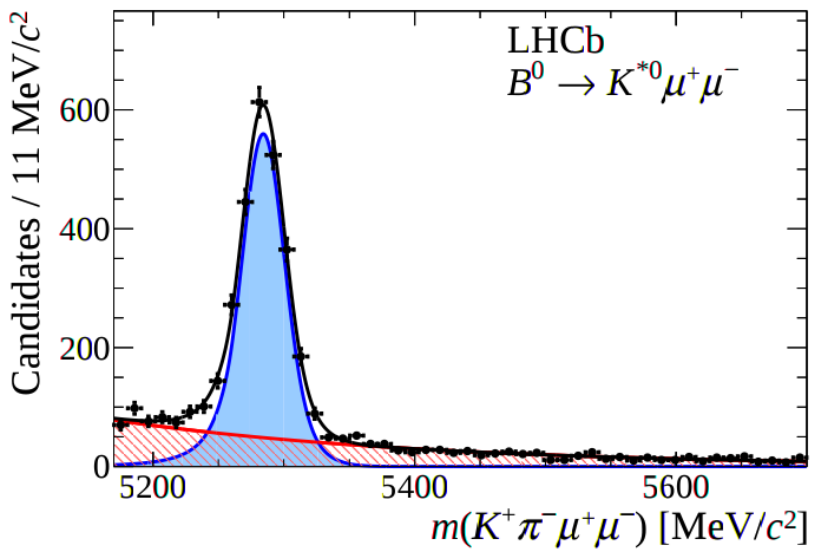


(b) ϕ definition for the B^0 decay

CERN-PH-EP-2015-314, LHCb-PAPER-2015-051, JHEP 1204 (2012) 104

$B^0 \to K^{*0}(\to K^+\pi^-)\mu^+\mu^-$ selection

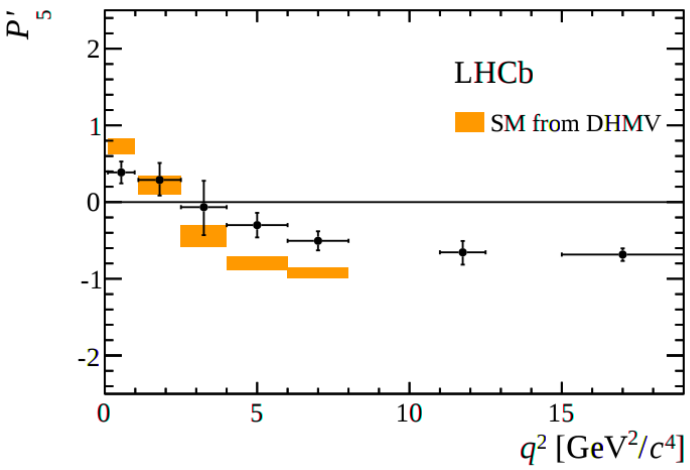


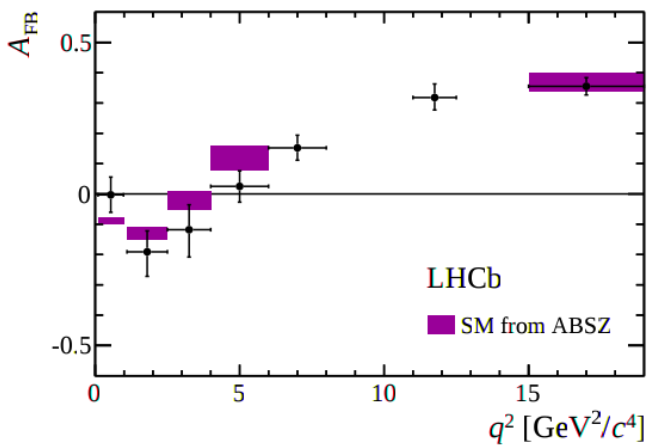


CERN-PH-EP-2015-314, LHCb-PAPER-2015-051

- signal yield integrated over q^2 bins: 2398 ± 57
- B^0 invariant mass in the range $5170 < m(K^+\pi^-\mu^+\mu^-) < 5700\ MeV/c^2$
- mass of the reconstructed $K^+\pi^-$ system in the range $796 < m(K^+\pi^-) < 996\ MeV/c^2$
- $B^0 \to J/\psi K^{*0}$ control channel
- BDT used to supress the background, variables used for training: PID, kinematics and geometric quantities, isolations

$B^0 \to K^{*0}(\to K^+\pi^-)\mu^+\mu^-$ results





CERN-PH-EP-2015-314, LHCb-PAPER-2015-051

- Tension in S_5 and in the related distribution $P'_5 = S_5/\sqrt{F_L(1-F_L)}$
- The SM central value for $Re(C_9)$ is 4.27, best fit-point corresponds to the $\Delta Re(C_9) = -1.04 \pm 0.25$ which corresponds to 3.4 standard deviations

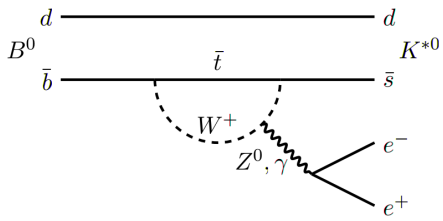
Eur. Phys. J. C (2014) 74:2897

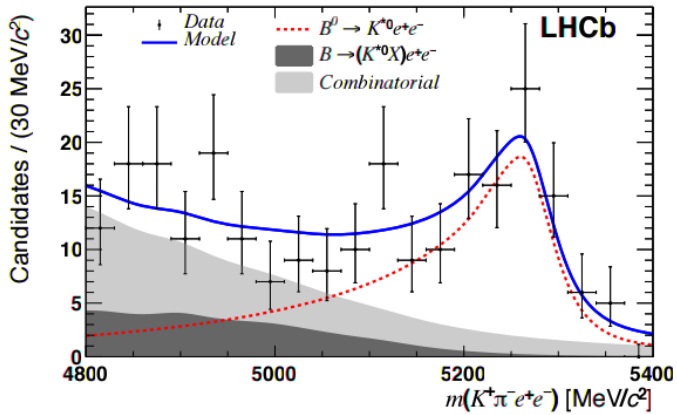
CERN-PH-EP-2015-314, LHCb-PAPER-2015-051

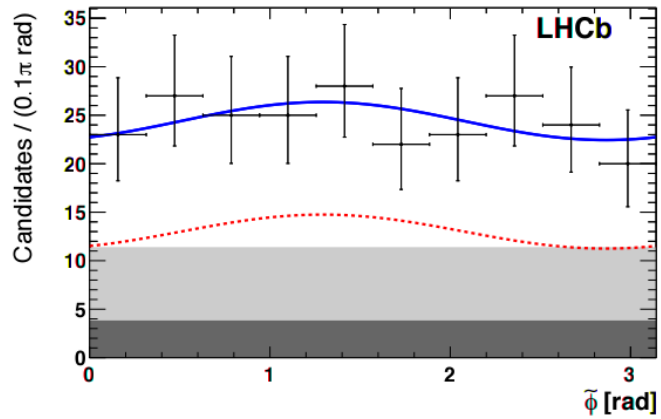
$$H_eff = -\frac{4G_f}{\sqrt{2}} VV'^* \sum_i [C_i(\mu)O_i(\mu) + C'_i(\mu)O'_i(\mu)]$$

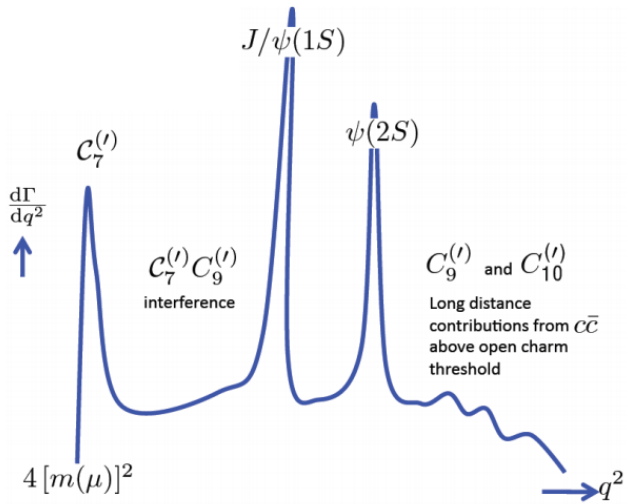
$B^0 \to K^{*0} e^+ e^-$

- difficulties: bremsstrahlung, triggering
- angular observables measured for the first time
- sensitive to C_7 Willson coefficients
- angular analysis, low q^2, $0.002 < q^2 < 1.120\ GeV^2/c^4$
- 124 signal events in B^0 mass window $4800 - 5400\ MeV/c^2$
- good agreement with SM





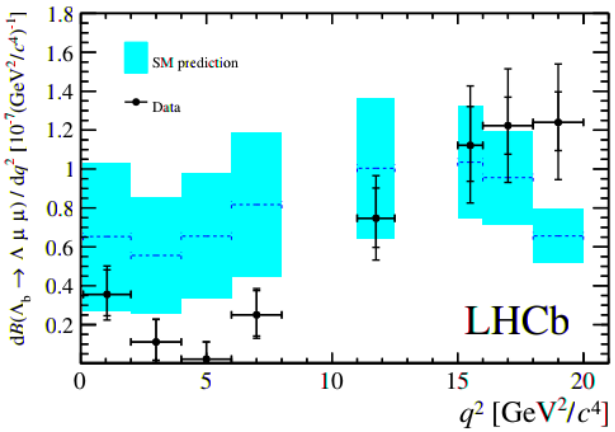


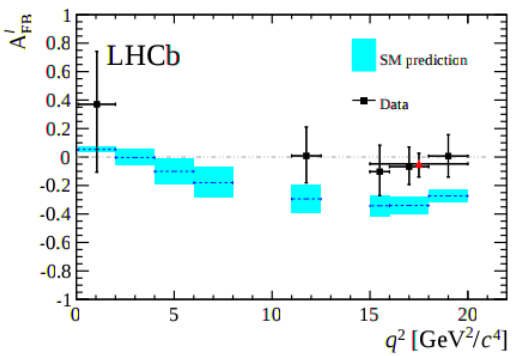


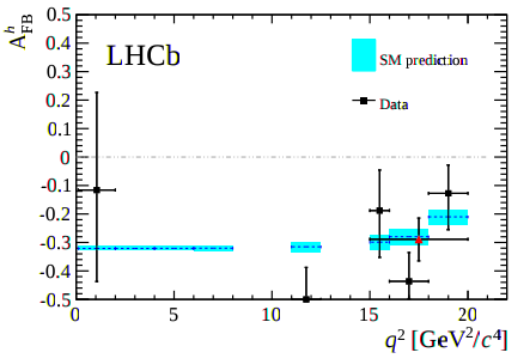
JHEP04(2015)064

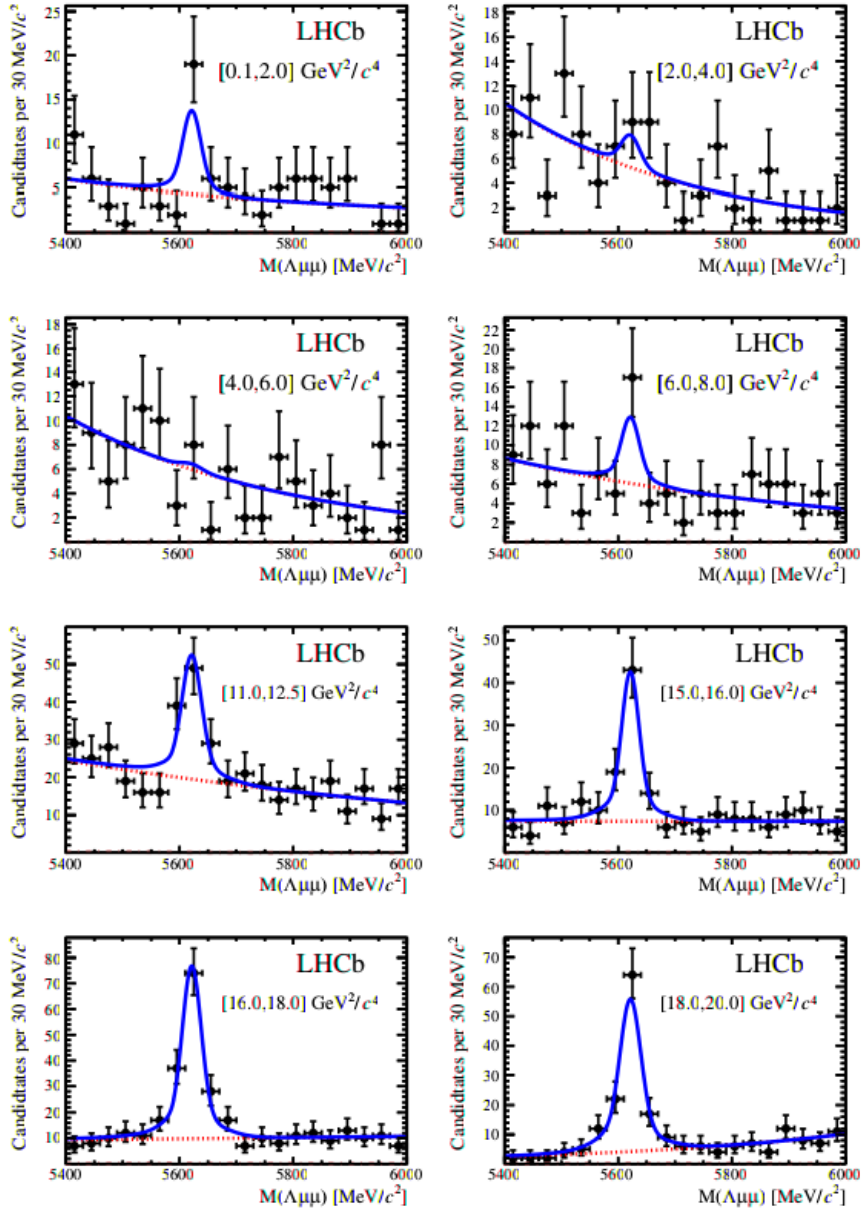
$\Lambda_b \to \Lambda(\to p\pi^-)\mu^+\mu^-$

- measurement of differential branching fraction and first angular analysis of this channel, decay normalized to $\Lambda_b \to \Lambda J/\psi$
- no evidence for signal in low q^2 $(2 - 8\ GeV^2/c^4)$ region

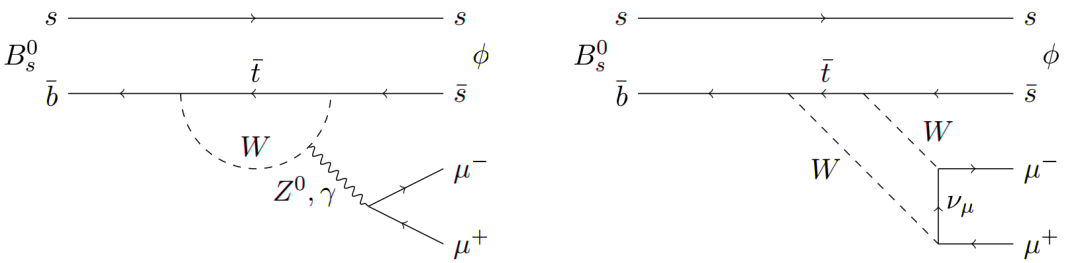


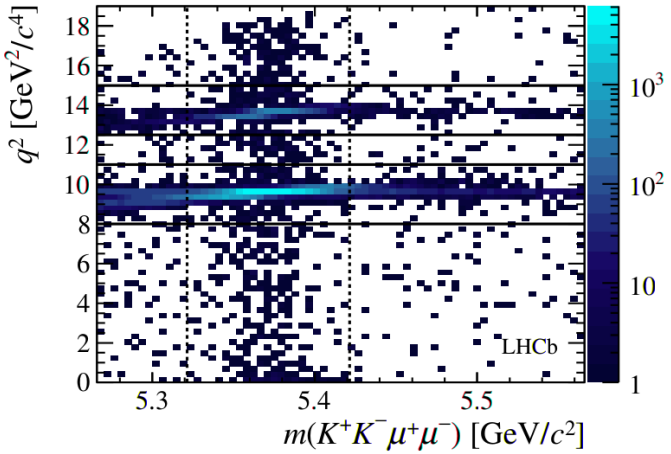




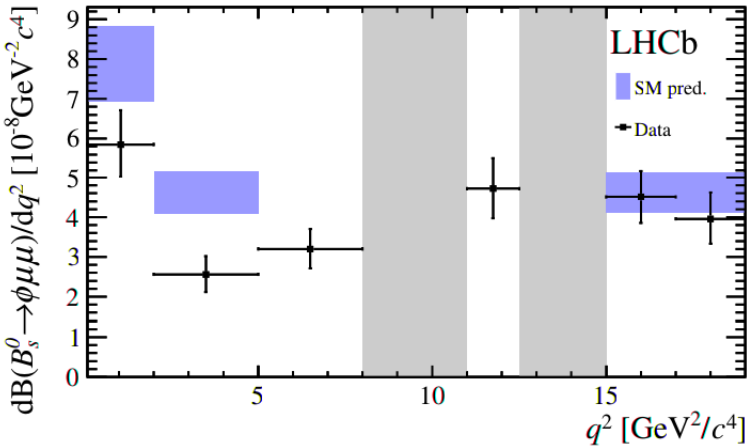


$B_s^0 \to \phi(\to K^+K^-)\mu^+\mu^-$





- similar decay to $K^*\mu\mu$, but final state $K^+K^-\mu^+\mu^-$ is not flavour-specific - accessible observables are F_L, $S_{3,4,7}$, $A_{5,6,8,9}$
- angular distributions - good agreement with SM
- branching fraction - differs from SM by 3.3σ



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Summary

- Rare decays are powerful tool for searching for signals of a NP
- Full angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$, tension in P_5'
- Other angular analyses - good agreement with SM
- Seen differences with SM in measurements of differential branching fraction vs q^2
- Measurements go to the same direction
- Many more analysis in the pipe line

Thank you for your attention.