

New physics searches with EW penguins and radiative b decays at LHCb

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on behalf of the LHCb collaboration

EPS CONFERENCE ON HIGH ENERGY PHYSICS

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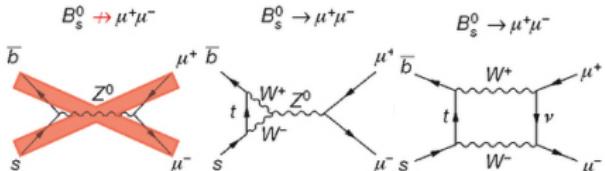


Outline

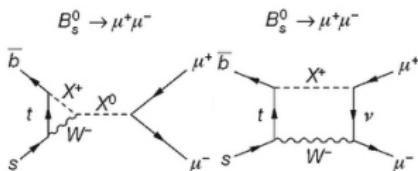
- Introduction:
 - ▶ Rare (FCNC) b decays
- Electro-weak b decays:
 - ▶ Differential BR
 - ▶ Angular observables
- Radiative b decays:
 - ▶ Photon polarisation

Rare decays of b hadrons

- Flavour Changing Neutral Currents (FCNC) **forbidden at tree-level** in the SM:



- Sensitive to new particles entering the loop diagrams:



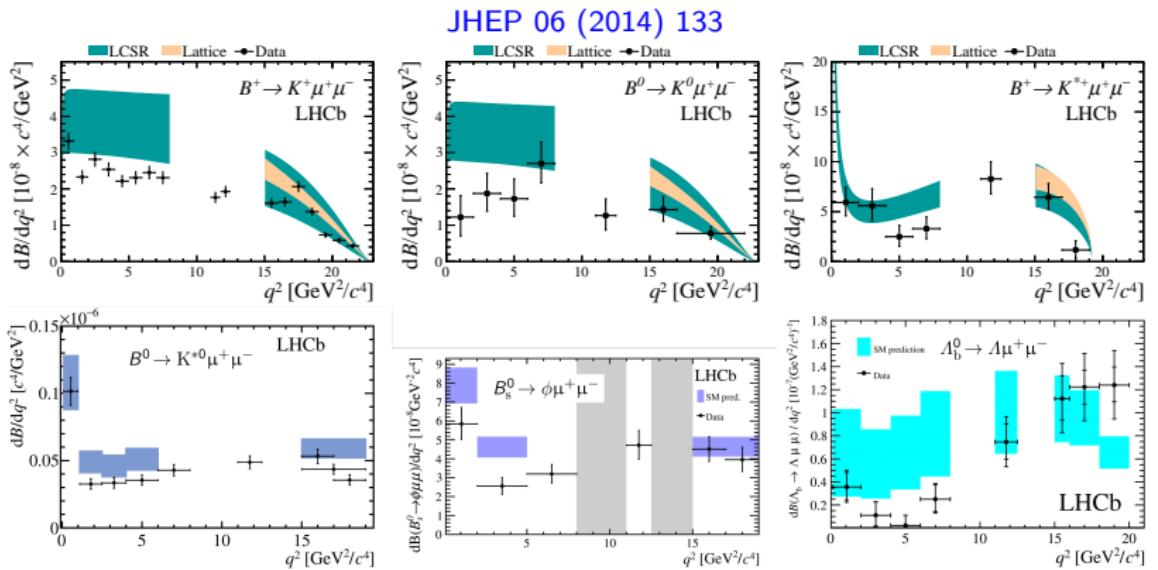
- Model-independent description: Operator Product Expansion.

$$H_{\text{eff}} \propto \sum_i \left(C_i^{SM} + C_i^{NP} \right) \cdot O_i$$

- Wilson Coefficients (C_i) are extracted from global fits to the data.
- Any deviation from SM calculations would point to New Physics effects.

Differential Branching Ratios in $b \rightarrow s\ell^+\ell^-$ decays

- Several measurements systematically below the SM at low q^2 :



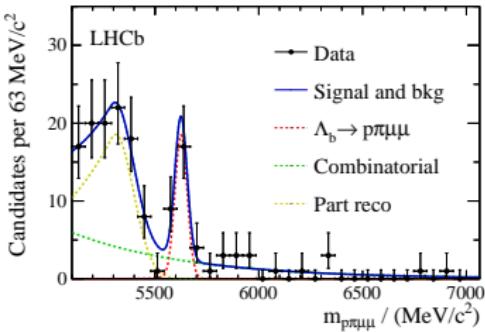
JHEP 04 (2017) 142 , JHEP 09 (2015) 179 , JHEP 06 (2015) 115

- Trend not observed so far in $b \rightarrow d\ell^+\ell^-$ but precision is lower.

Differential Branching Ratios in $b \rightarrow sl^+l^-$ decays

LHCb
THCP

- Interest to explore other decay modes.
 - **First observation** of $\Lambda_b^0 \rightarrow p\pi^- \mu^+ \mu^-$ and $\Lambda_b^0 \rightarrow pK^- \mu^+ \mu^-$:



JHEP 06 (2017) 108

$$\Delta\mathcal{A}_{CP} = (-3.5 \pm 5.0 \pm 0.2) \times 10^{-2}$$

$$a_{CP}^{\hat{T}-odd} = (1.2 \pm 5.0 \pm 0.7) \times 10^{-2}$$

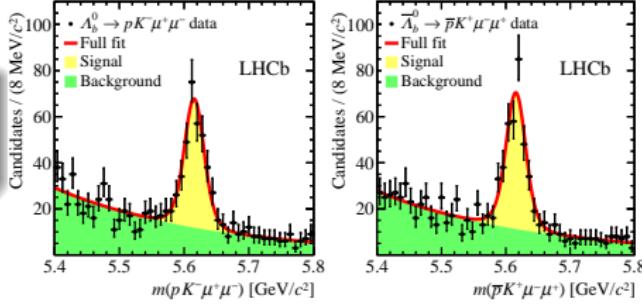
$$\Delta\mathcal{A}_{CP} = \mathcal{A}_{CP}(A_b^0 \rightarrow p\pi^-\mu^+\mu^-) -$$

$$- \mathcal{A}_{CP}(A_b^0 \rightarrow p\pi^- J/\psi)$$

JHEP 04 (2017) 029

$$\mathcal{B}(\Lambda_b^0 \rightarrow p \pi^- \mu^+ \mu^-) = (6.9 \pm 1.9 \pm 1.1^{+1.3}_{-1.0}) \times 10^{-8}$$

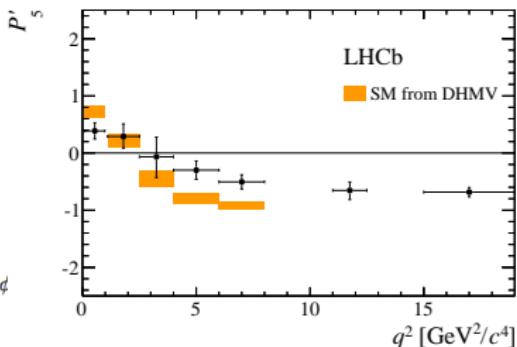
First observation of $b \rightarrow d$ transition in baryons!



Angular observables in $b \rightarrow s\ell^+\ell^-$

- Angular analysis of $B^0 \rightarrow K^{*0}\mu^+\mu^-$:

$$\frac{1}{d(\Gamma + \bar{\Gamma})/dq^2} \frac{d^4(\Gamma + \bar{\Gamma})}{dq^2 d\Omega} = \frac{9}{32\pi} \left[\frac{3}{4}(1 - F_L) \sin^2 \theta_K + F_L \cos^2 \theta_K \right. \\ \left. + \frac{1}{4}(1 - F_L) \sin^2 \theta_K \cos 2\theta_l \right. \\ \left. - F_L \cos^2 \theta_K \cos 2\theta_l + S_3 \sin^2 \theta_K \sin^2 \theta_l \cos 2\phi \right. \\ \left. + S_4 \sin 2\theta_K \sin 2\theta_l \cos \phi + S_5 \sin 2\theta_K \sin \theta_l \cos \phi \right. \\ \left. + \frac{4}{3}A_{FB} \sin^2 \theta_K \cos \theta_l + S_7 \sin 2\theta_K \sin \theta_l \sin \phi \right. \\ \left. + S_8 \sin 2\theta_K \sin 2\theta_l \sin \phi + S_9 \sin^2 \theta_K \sin^2 \theta_l \sin 2\phi \right]$$

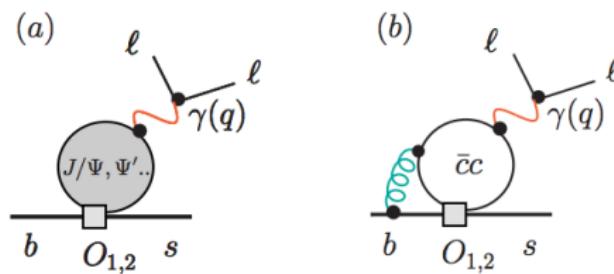


► Theoretically clean observables $P'_5 = \frac{S_5}{\sqrt{F_L(1-F_L)}}$ [JHEP 05 (2013) 137]

- Compatible results from Belle [BELLE-CONF-1603], Atlas [ATLAS-CONF-2017-023] and CMS [CMS PAS BPH-15-008] (CMS closer to SM).
- Angular analysis of other decay modes in agreement with SM predictions but not using such clean observables.

A sign of New Physics?

- Global fits point to additional contributions to C9
 - ▶ See f.i. JHEP 06 (2016) 092, Phys. J. C (2015) 75: 382 and Nucl Phys B 909 (2016) 737-777
- Could the anomalies be explained by hadronic effects within the SM?

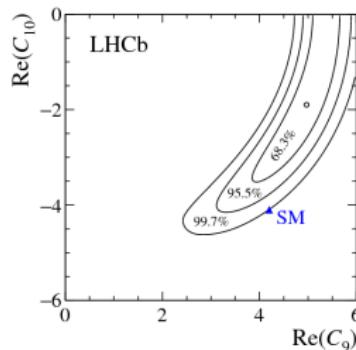
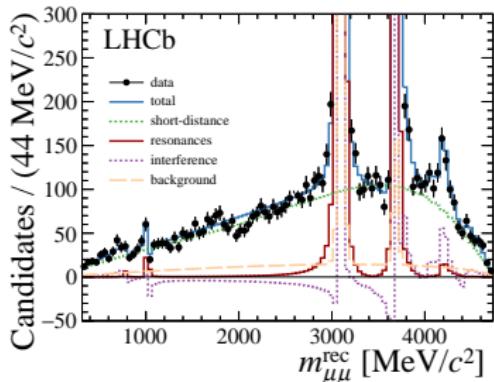


[arXiv:1406.0566]

Phase difference in $B^+ \rightarrow K^+ \mu^+ \mu^-$

EUR. PHYS. J. C (2017) 77: 161

- Charm resonances excluded in previous measurements.
- Fit to full dimuon mass spectrum including:
 $\rho, \omega, \phi, J/\psi, \psi(2S), \psi(3770), \psi(4040), \psi(4160), \psi(4415)$



- BR of short distance component compatible with previous results:

$$\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-) = (4.37 \pm 0.15 \pm 0.23) \times 10^{-7}$$

- Likelihood scan of C_9 and C_{10} points to a 3σ deviation wrt the SM.

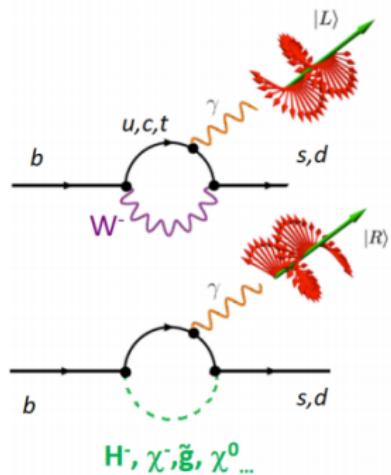


Radiative $b \rightarrow s\gamma$ decays

- BR and ΔCP measurements in good agreement with the SM [PDG]
- Still interesting observables like photon polarisation:
 - ▶ dominantly left-handed in SM due to absence of right-handed currents
 - ▶ up to 50% right-handed polarisation in SM extensions

[Atwood et al., Phys.Rev.Lett.79:185-188,1997]

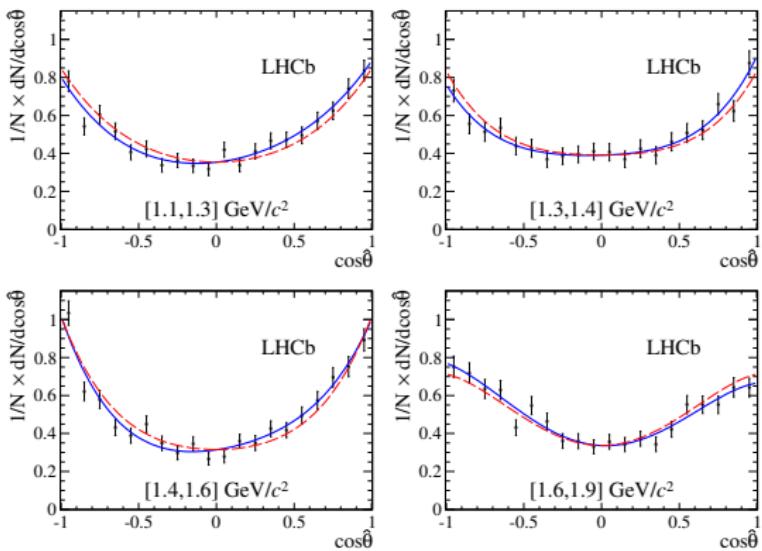
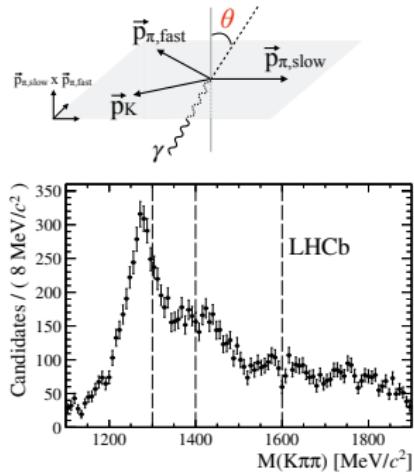
$$\alpha_{\gamma}^{SM} = \frac{P(\gamma_L) - P(\gamma_R)}{P(\gamma_L) + P(\gamma_R)} = 1 + \mathcal{O}\left(\frac{m_s}{m_b}\right)$$



Photon polarisation in $b \rightarrow s\gamma$ decays

PHYS. REV. LETT. 112, 161801 (2014)

- First observation of photon polarisation in $B^+ \rightarrow K^+\pi^+\pi^-\gamma$:



- Exact value of the polarisation depends on hadronic content
→ full amplitude analysis ongoing.

PHYS. REV. LETT. 118, 021801 (2017)

- First measurement of the photon polarisation in $B_s^0 \rightarrow \phi\gamma$.
 - ▶ Time-dependent decay rate is sensitive to photon polarisation:

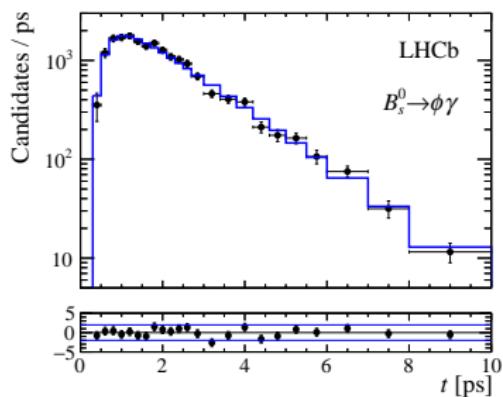
$$\Gamma_{B_s^0 \rightarrow \phi\gamma}(t) \propto e^{-\Gamma_s t} [\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^\Delta \sinh(\Delta\Gamma_s t/2)]$$

- ▶ SM prediction: $\mathcal{A}^\Delta = 0.047^{+0.029}_{-0.025}$ [PRB 664 (2008) 174]

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- $$\Gamma_{B_s^0 \rightarrow \phi\gamma}(t) \propto e^{-\Gamma_s t} [\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^\Delta \sinh(\Delta\Gamma_s t/2)]$$
- ▶ SM prediction: $\mathcal{A}^\Delta = 0.047^{+0.029}_{-0.025}$ [PRB 664 (2008) 174]
 - ▶ Measurement at LHCb with Run I dataset compatible with SM at 2.6σ :



$$\mathcal{A}^\Delta = -0.98^{+0.46}_{-0.52} (\text{stat.})^{+0.23}_{-0.20} (\text{syst.})$$

- Room for improvement → add flavour tagging information.

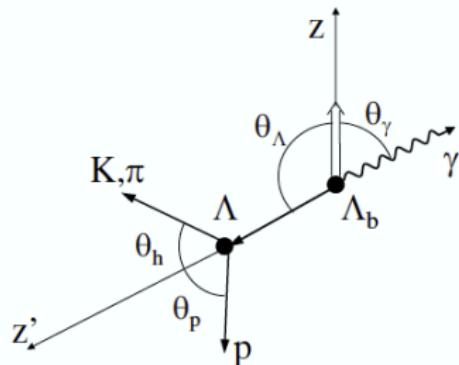
Photon polarisation in $b \rightarrow s\gamma$ decays

Baryon $b \rightarrow s\gamma$ decays can also give access to the photon polarisation:

- Angular analysis of $\Lambda_b^0 \rightarrow \Lambda\gamma$:

$$\frac{d\Gamma}{dcos\theta_\gamma} \propto 1 - \alpha_\gamma P_{\Lambda_b^0} cos\theta_\gamma$$

$$\frac{d\Gamma}{dcos\theta_p} \propto 1 - \alpha_\gamma \alpha_{p,1/2} cos\theta_p$$



- $P_{\Lambda_b^0} = (0.06 \pm 0.07)$ [Phys. Lett. B 724 (2013) 27]
- $\alpha_{p,1/2} = (0.642 \pm 0.013)$ [PDG]

- Other decays with richer angular distributions:

$$\Xi_b^- \rightarrow \Xi^- \gamma \text{ and } \Omega_b^- \rightarrow \Omega^- \gamma$$

Summary

- Rare FCNC b decays provide clean observables to test the SM
- EW penguin b decays:
 - ▶ Tensions wrt SM in both differential BR and angular observables
 - ▶ Updates and new analysis ongoing to confirm them
 - ▶ Recent $R_{K^{*0}}$ result points in the same direction (see talk by A. Puig)
- Radiative b decays:
 - ▶ First observation and measurement of the photon polarisation but room for improvement in precision
 - ▶ Updates ongoing with more information
 - ▶ b-baryon decays will help in precision measurements
- Exploitation of Run II data just started.

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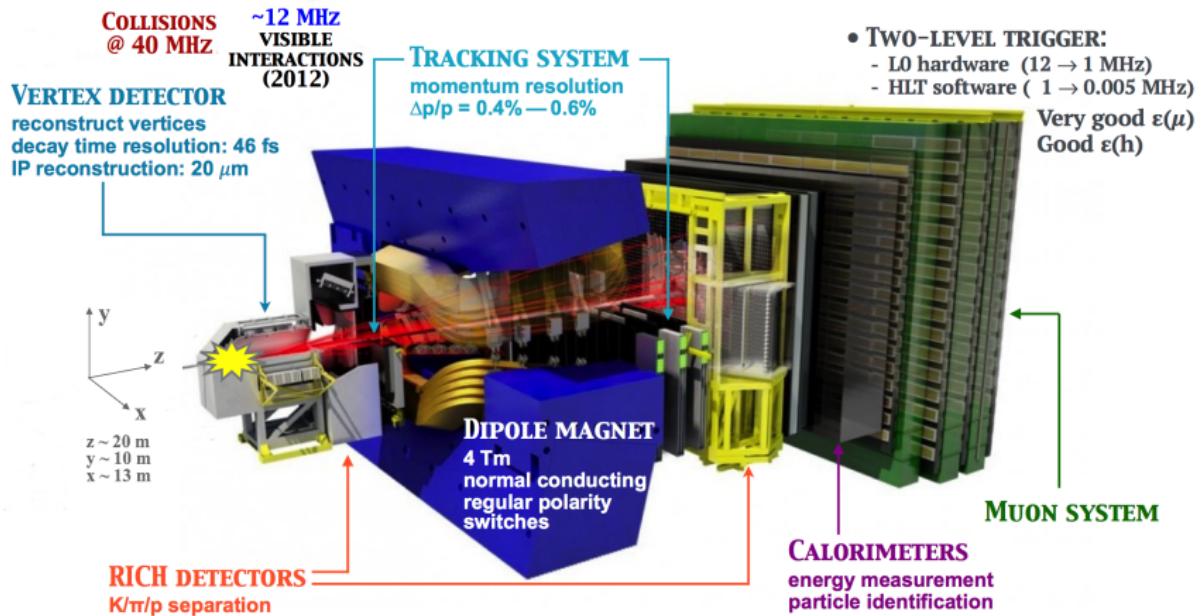
Stay tuned!

Thanks for the attention!

BACK-UP

The LHCb detector

JINST3 (2008) S08005



Excellent μ identification
Good momentum resolution

Neutral particle identification
Photon energy measurement

Differential Branching Ratios in $b \rightarrow s\ell^+\ell^-$ decays

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