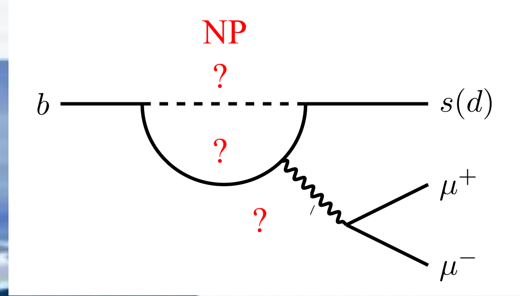


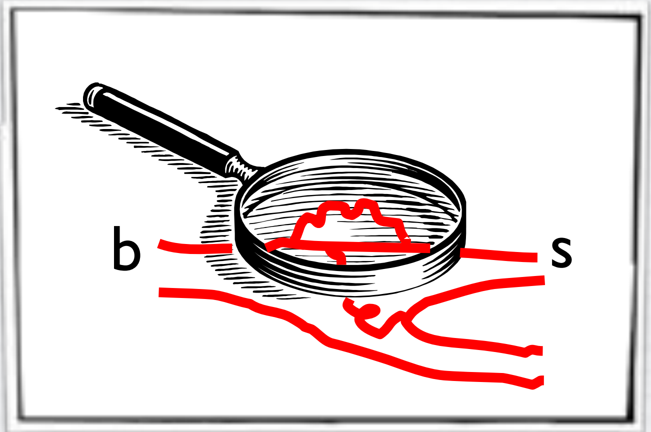
Rare Decays at LHCb

XXV International Workshop on Weak Interactions and Neutrinos
Heidelberg - 8-13 June 2015

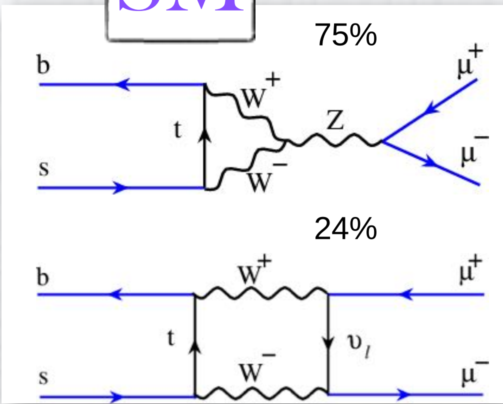
José Ángel Hernando Morata
Universidade de Santiago de Compostela, Spain
(**on behalf of the LHCb collaboration**)

Introduction

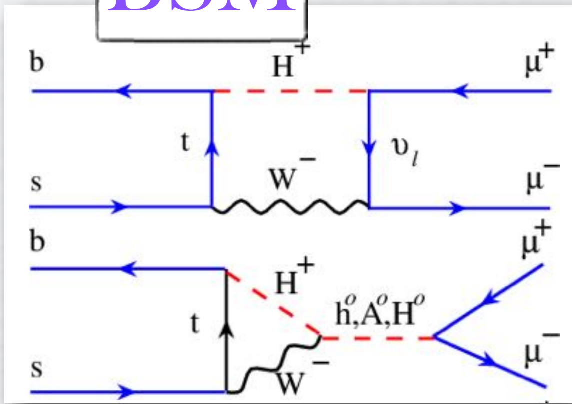
LHCb searches for NP in **FCNC** with B (and D) decays, where new dynamics (particles) can enter in the loops and penguins and modify the SM predictions of some observables! An indirect search!



SM



BSM



- Study **FCNC** processes with "precise" **SM prediction**
  - Measure *Branching fractions, angular distributions, CP asymmetries*
  - If no NP found, *models beyond SM are constrained*, or NP enters a higher energy scale!
- Also search for SM forbidden processes: **LFV** and **LNV**

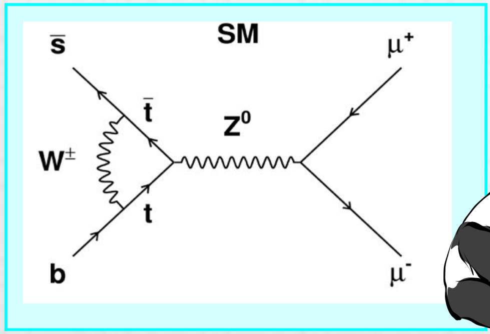
Introduction

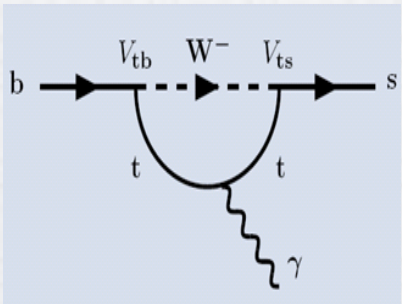
- FCNC can be described by an effective hamiltonian

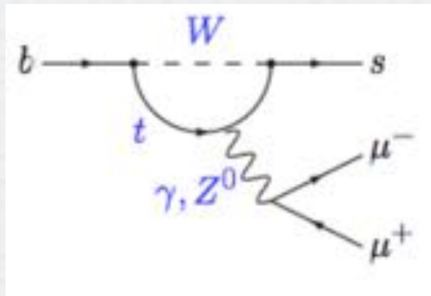
$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i [\underbrace{C_i(\mu) O_i(\mu)}_{\text{left-handed part}} + \underbrace{C_i'(\mu) O_i'(\mu)}_{\substack{\text{right-handed part}\\ \text{suppressed in SM}}}] + \sum \frac{c}{\Lambda_{NP}^2} O_{NP}$$

  - Wilson coefficients (C_i, Left H, C_i'Right H) are related with observables
  - Operators depends on hadronic form factors (theoretical uncertainties)

- Rare B decays and its relevant terms:
  - $B_s \rightarrow \mu^+\mu^-$ (C_{10}, C_S, C_P Scalar and Pseudo-scalar)
  - radiative decays (C_7 photon penguin)
  - $b \rightarrow s\, l^+l^-$ (C_7 and C_9, C_{10} EW penguin)







RD Analyses

Very rare decays

- **$B_{(s)} \to \mu\mu$** [arXiv:1411.4413, Nature **552** (2015) 68]

b→sll

- **$B \to K^{*}ee$** [arXiv:1501.03038, JHEP **04** (2015) 064]
- **Angular distributions $B \to K^{*}\mu\mu$** [LHCB-CONF-2015-002]
- **$B_s \to \phi\mu\mu$** [LHCB-PAPER-2015-023]
- $\Lambda_b \to \Lambda\mu\mu$ [arXiv:1503.07138]
- Diff. BR **$B \to K^{(*)}\mu\mu$** [arXiv:1403.8044, JHEP **06** (2014) 133]

Radiative decays

- $b \to s\gamma$, γ polarization [1fb^{-1}/arXiv:1402.6852, PRL **112** (2014) 161801]

Lepton Universality

- **$B^+ \to K^+\mu\mu$, $B^+ \to K^+ee$** [arXiv:1406.648, PRL **113** (2014) 151601]

"Forbidden" decays: LFV, LNV

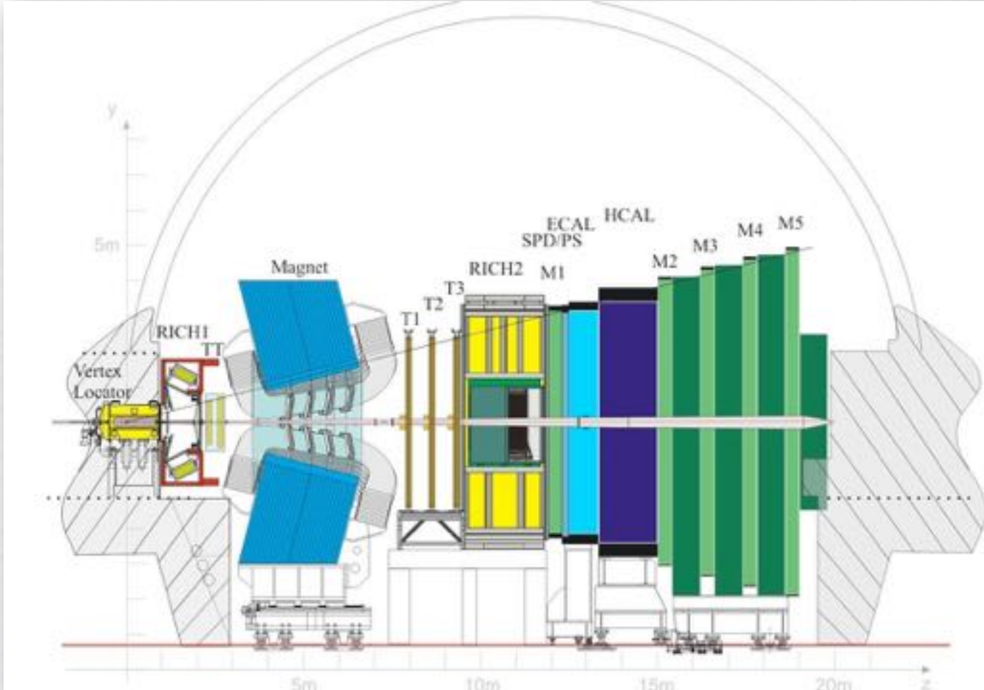
- $\tau \to 3\mu$ [arXiv:1409.8548, JHEP **02** (2015) 121]
- **$B^- \to \pi^+\mu^-\mu^-$** [arXiv:1401.5361, PRL **112** (2014) 131802]

LHCb detector

LHCb detector

- single-arm spectrometer ($2<\eta<5$)
- B, B_s, B^+,D,Λ_b, ... produced at LHCb
- trigger on μ e, hadrons with “low” P_T

  efficiency on dimuon channels ~90%
- precise vertex (IP ~20 μm at high P_T)
- excellent momentum resolution $\Delta p/p \simeq 0.5$ %
- good particle ID (>97% μ-eff, 1-3% mis-ID)



LHCb operation

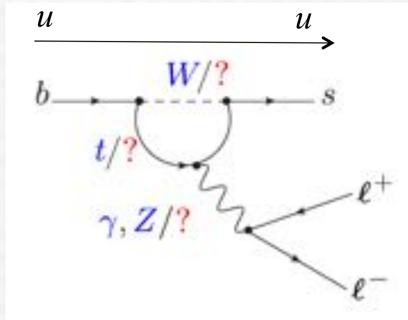
- “beautifully”
- operating @ 2 nominal luminosity
- Integrated luminosity **3 fb^{-1}**

  (2 fb^{-1} 8 TeV, 1 fb^{-1} 7 TeV)

Lepton Universality $B^+ \to K^+ l^+ l^-$

- Ratio of $B^+ \to K^+ \mu^+ \mu^-$, $B^+ \to K^+ e^+ e^-$ as test of lepton universality

$$R_K = \frac{\int_{q^2_{\min}}^{q^2_{\max}} \frac{d\Gamma[B^+ \to K^+ \mu^+ \mu^-]}{dq^2} dq^2}{\int_{q^2_{\min}}^{q^2_{\max}} \frac{d\Gamma[B^+ \to K^+ e^+ e^-]}{dq^2} dq^2},$$



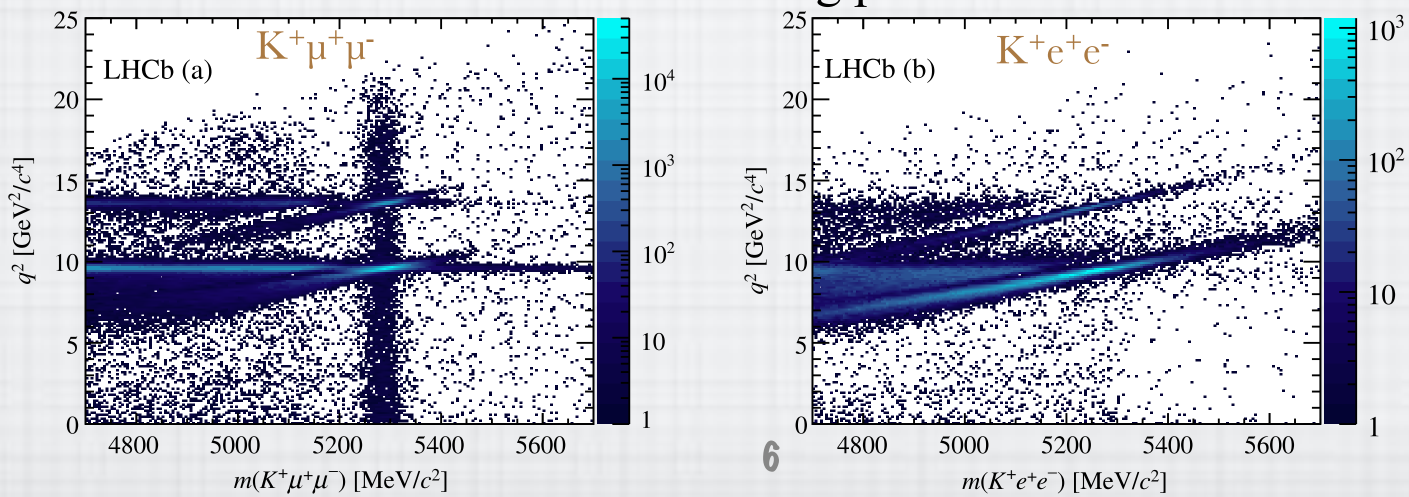
- uncertainties cancel on the ratio, q^2 [1,6] GeV^2/c^4
- in SM is almost one, deviations of $O(10^{-3})$

- LHCb analysis:

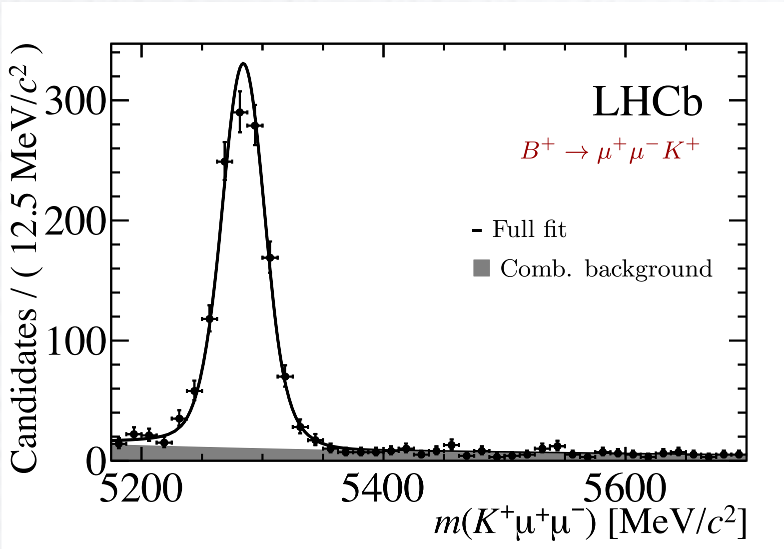
$$R_K = \left(\frac{\mathcal{N}_{K^+\mu^+\mu^-}}{\mathcal{N}_{K^+e^+e^-}}\right)\left(\frac{\mathcal{N}_{J/\psi(e^+e^-)K^+}}{\mathcal{N}_{J/\psi(\mu^+\mu^-)K^+}}\right) \times \left(\frac{\epsilon_{K^+e^+e^-}}{\epsilon_{K^+\mu^+\mu^-}}\right)\left(\frac{\epsilon_{J/\psi(\mu^+\mu^-)K^+}}{\epsilon_{J/\psi(e^+e^-)K^+}}\right),$$

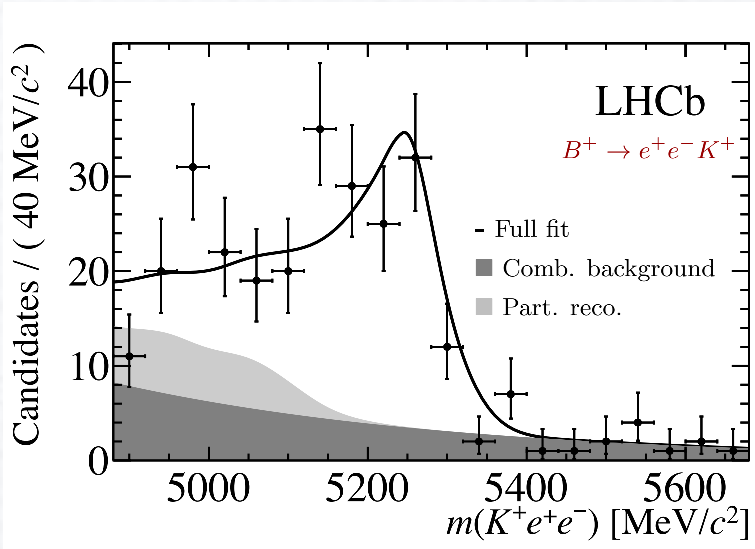
- relative measurement with respect $B^+ \to K^+ J/\psi(l^+l^-)$
- reconstruction of the e with bremsstrahlung photons

Phys. Rev. Lett **113** (2014) 151601



Lepton Universality $B^+ \to K^+ l^+ l^-$





e trigger
172±20 candidates

- Systematic dominated for the inv mass parameterization and trigger efficiencies

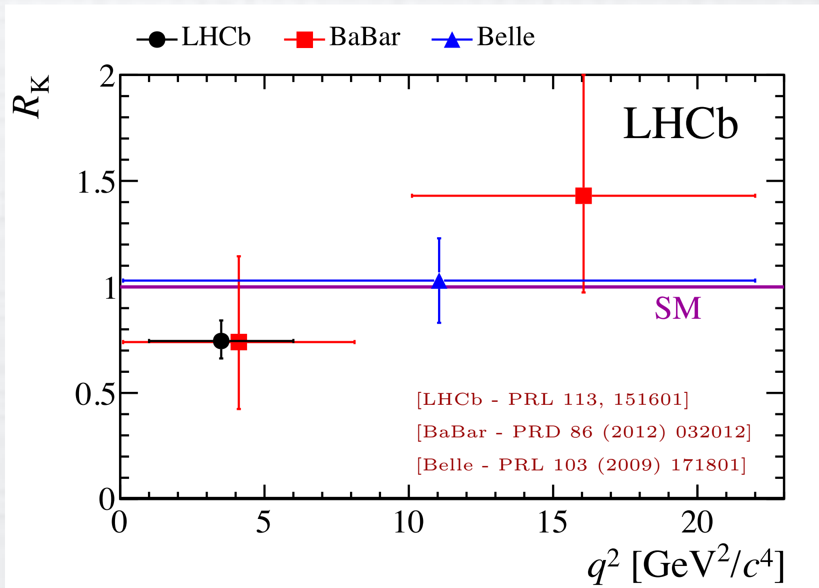
q^2 in [1,6] GeV^2/c^4

$$R_K = 0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{syst}).$$

- Consistent with SM at 2.6 σ
  - *A Z' with different coupling with e and μ?*
- Branching Ratio of $B^+ \to K^+ e^+ e^-$

$$[1.56^{+0.19}_{-0.15}(\text{stat})\ ^{+0.06}_{-0.04}(\text{syst})] \times 10^{-7}.$$

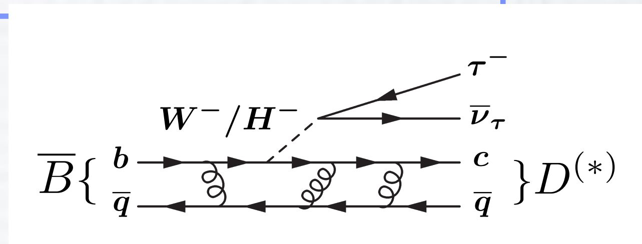
- Consistent with SM predictions!



LHCb q^2 [1,6] GeV^2/c^4

Phys. Rev. Lett **113** (2014) 151601

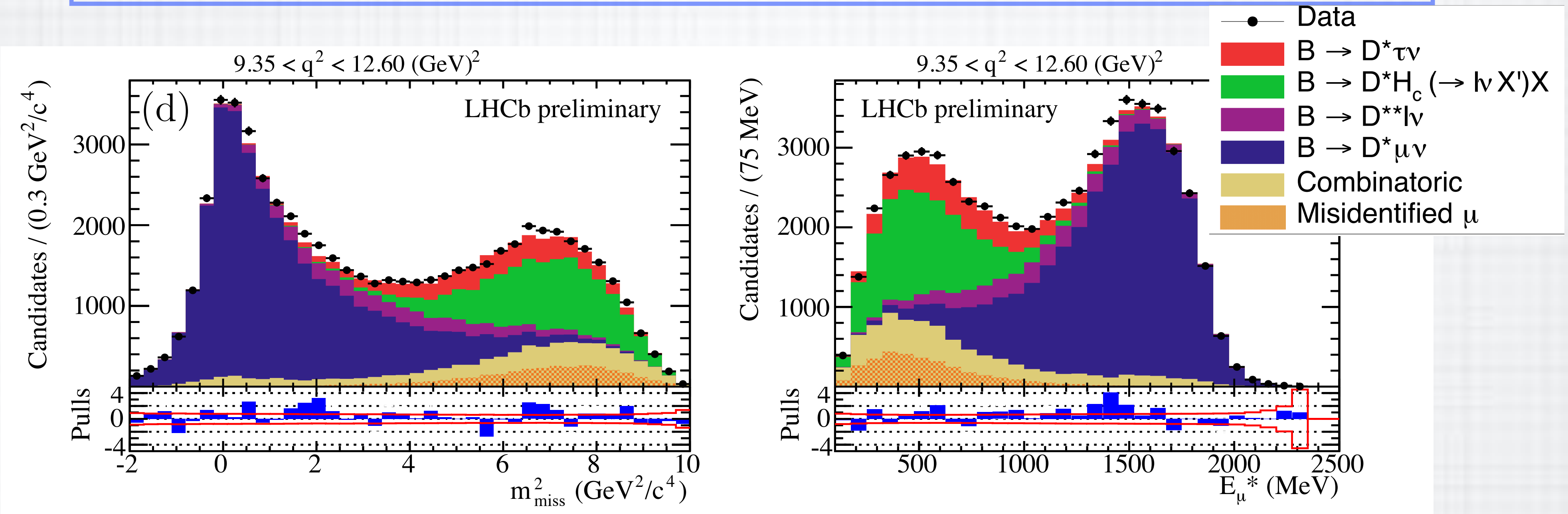
(Lepton Universality $B^+ \to D^{*+} l^- \nu$)



- Ratio of $B \to D^* \mu^- \nu$, $B \to D^* \tau^- \nu$ as test of lepton universality
  - Ratio affected for charged Higgs
  - BaBar published results on tension 2.7(2) σ for D*(D) ratios [PRD **88 (2013) 072012**], Belle preliminary (see this workshop)
- LHCb analysis:
  - trigger and selection without using μ to not bias kinematics
  - selecting: $\tau \to \mu^- \nu \nu$, $D^{*+} \to D^0(K\pi)\pi^+$
  - required separation and isolation of vertices: B, D*, τ using MVA
  - reconstruct kinematical variables: $p_{B,z} = p_{D^*,z} + p_{\mu,z}$, $M_{mis}^2 = (p_B - p_{D^*} - p_\mu)^2$
  - fit M_{mis}^2, q^2, E_μ using templates from simulation for signal and background but validated with data

LHCB-PAPER-2015-025

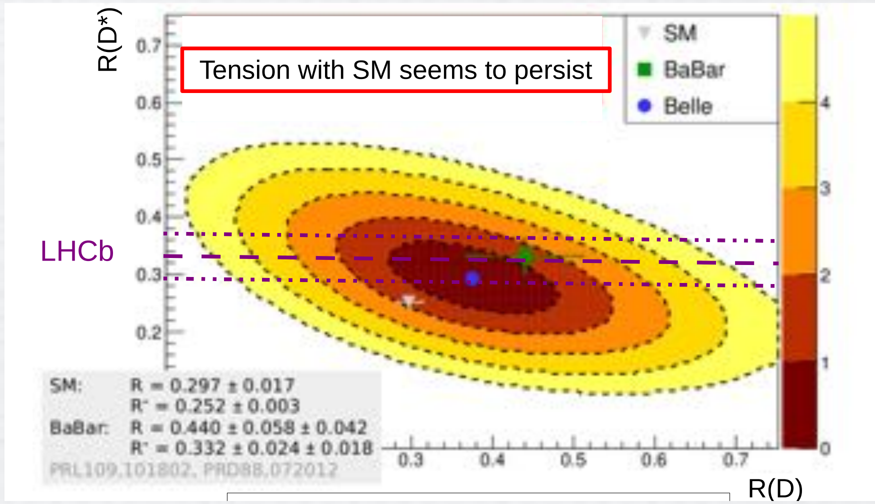
(Lepton Universality $B^+ \to D^{*+} l^- \nu$)



- systematic dominated by size of simulated samples and "μ-midid" efficiencies

$$\mathcal{R}(D^*) = 0.336 \pm 0.027\,(\text{stat}) \pm 0.030\,(\text{syst}).$$

- 2.1 σ deviation with respect SM

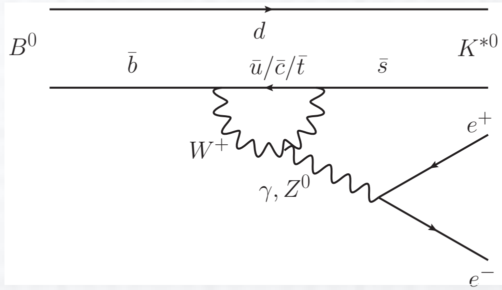


Belle preliminary, LHCB-PAPER-2015-025

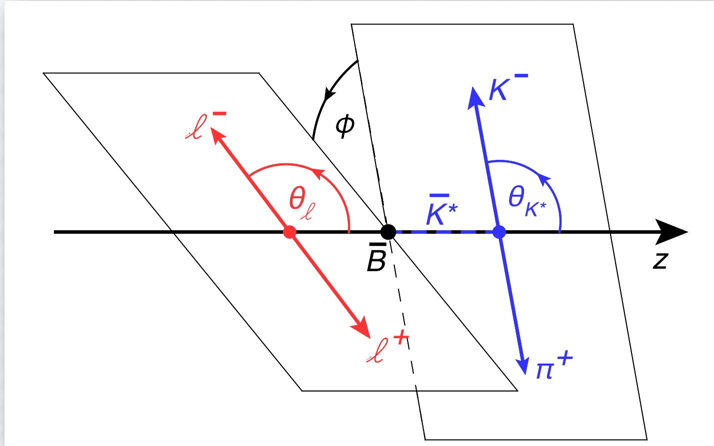
LHCB-PAPER-2015-025

Angular analysis B→K*e⁺e⁻ at low q²

- Angular analysis of $B \to K^* e^+ e^-$ at low q^2
  - q^2 in [0.002, 1.120] GeV^2/c^4, dominated by γ pole
  - sensible to C'_7, photon polarization ($b \to s\gamma$) SM LH!



$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\bar{\Gamma})}{\mathrm{d}q^2\,\mathrm{dcos}\,\theta_\ell\,\mathrm{dcos}\,\theta_K\,\mathrm{d}\tilde{\phi}} = \frac{9}{16\pi}\Bigg[\frac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K + F_{\mathrm{L}}\cos^2\theta_K + \left(\frac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K - F_{\mathrm{L}}\cos^2\theta_K\right)\cos 2\theta_\ell + \frac{1}{2}(1-F_{\mathrm{L}})A_{\mathrm{T}}^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\tilde{\phi} + (1-F_{\mathrm{L}})A_{\mathrm{T}}^{\mathrm{Re}}\sin^2\theta_K\cos\theta_\ell + \frac{1}{2}(1-F_{\mathrm{L}})A_{\mathrm{T}}^{\mathrm{Im}}\sin^2\theta_K\sin^2\theta_\ell\sin 2\tilde{\phi}\Bigg].$$



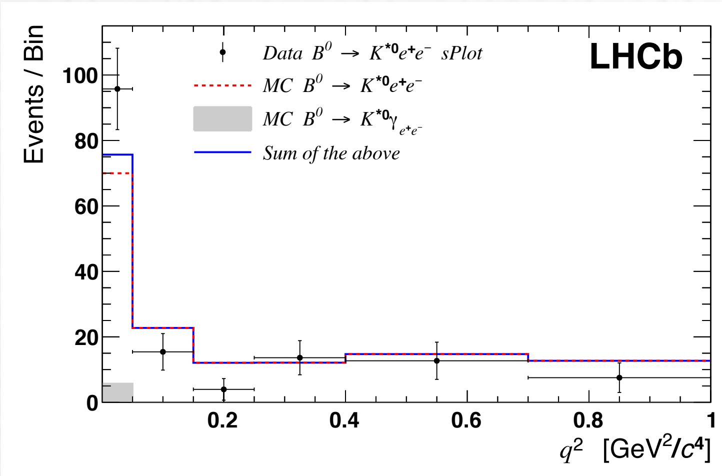
- LHCb analysis
  - Three angles θ_K, θ_l, ϕ. But ϕ folded due to limited statistics
  - Four observables F_T, $A_T^{(2)}$, $A_T^{(\mathrm{Im})}$, $A_T^{(\mathrm{Re})}$ related to Wilson Coefficients

$$A_{\mathrm{T}}^{(2)}(q^2\to 0) = \frac{2\mathcal{R}e(\mathcal{C}_7\mathcal{C}_7'^*)}{|\mathcal{C}_7|^2+|\mathcal{C}_7'|^2} \quad \text{and} \quad A_{\mathrm{T}}^{\mathrm{Im}}(q^2\to 0) = \frac{2\mathcal{I}m(\mathcal{C}_7\mathcal{C}_7'^*)}{|\mathcal{C}_7|^2+|\mathcal{C}_7'|^2}.$$

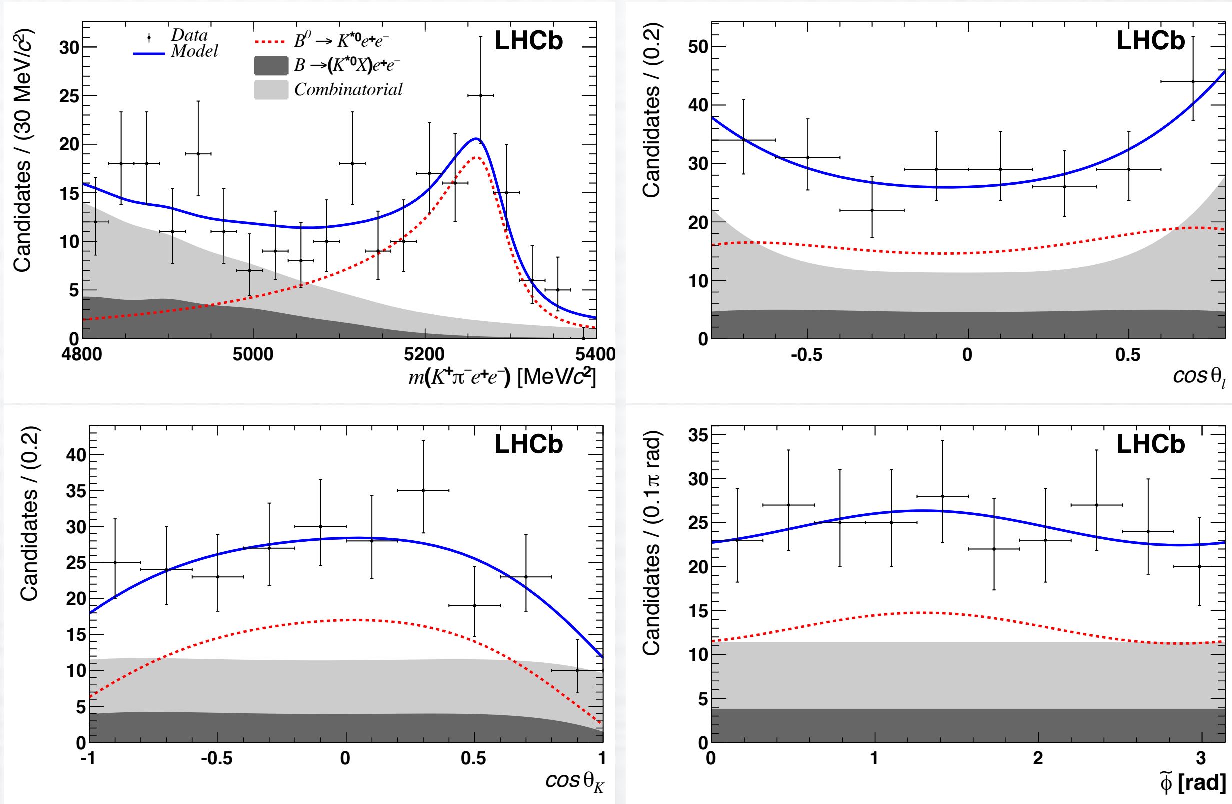
J. High Energy Phys **04** (2015) 064

Angular analysis B→K*e⁺e⁻ at low q²

q² distribution



124 candidates



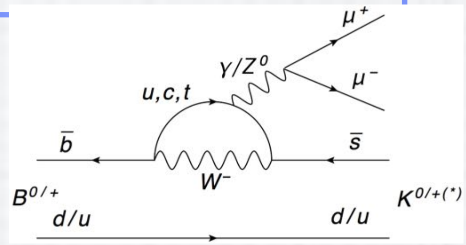
$$
\begin{aligned}
F_{\rm L} &= 0.16 \pm 0.06 \pm 0.03 \\
A_{\rm T}^{(2)} &= -0.23 \pm 0.23 \pm 0.05 \\
A_{\rm T}^{\rm Im} &= +0.14 \pm 0.22 \pm 0.05 \\
A_{\rm T}^{\rm Re} &= +0.10 \pm 0.18 \pm 0.05,
\end{aligned}
$$

- systematic dominated by angular acceptance and the combinatorial background angular distribution modeling

- Consistent with SM!
- ratio C'_7/C_7 is consistent with 0
- more precise than from radiative decays

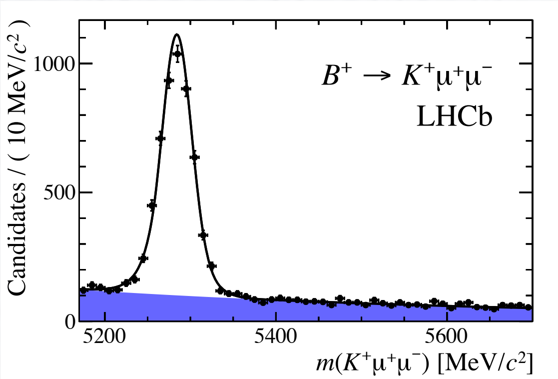
J. High Energy Phys **04** (2015) 064

Diff. Branching ratios $B \to K^{(*)}\mu^+\mu^-$

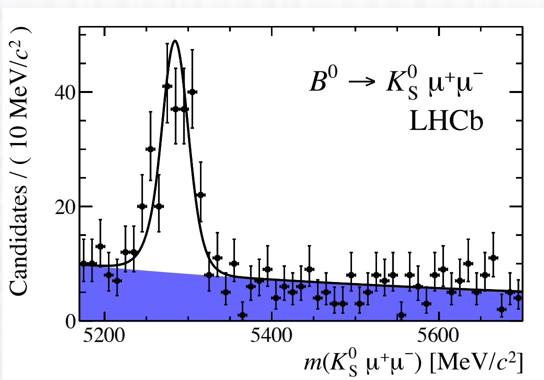


- Differential branching ratio $B \to K^{(*)}\mu^+\mu^-$ vs q^2
  - uncertainties from form factors, normalized to $B \to J/\psi K^{(*)}$

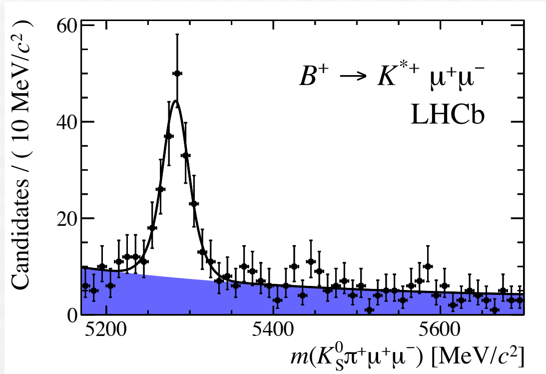
4756 candidates

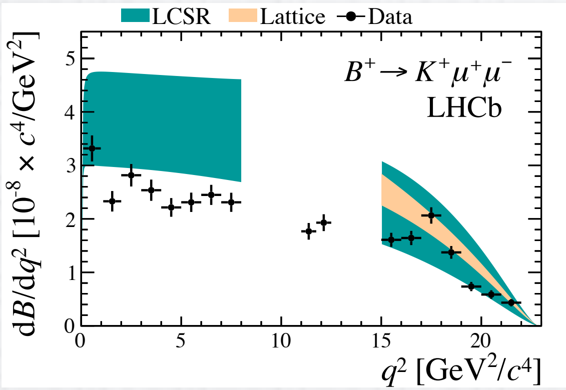


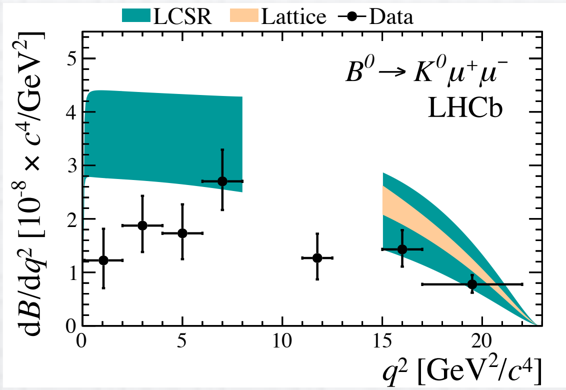
176 candidates

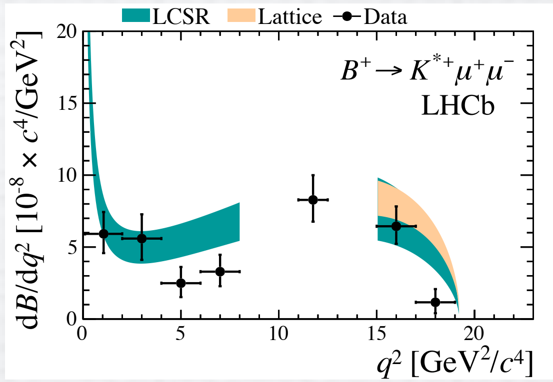


162 candidates







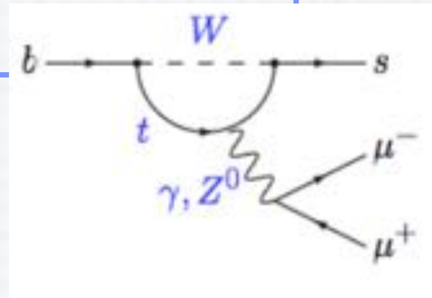


SM: JHEP **07** (2011) 067, arXiv:1105.0376
JHEP **01** (2012) 108, arXiv:1111.2558

- In agreement with SM prediction but measurements systematically below expectations

J. High Energy Phys **06** (2014) 133

Angular Analysis $B \to K^* \mu^+ \mu^-$

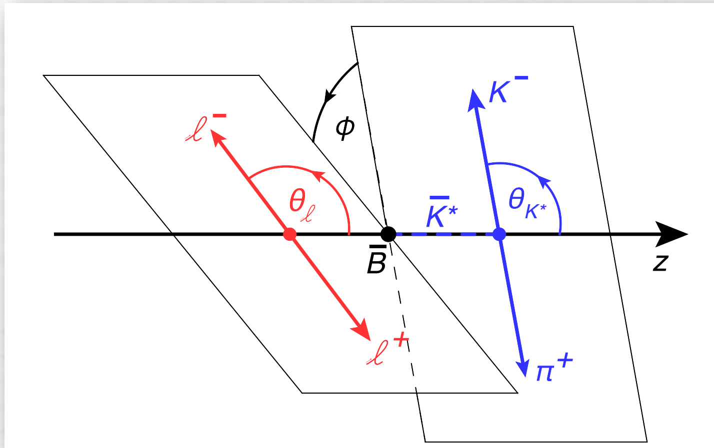


Angular Analysis $B \to K^* \mu^+ \mu^-$

SM: JHEP **08** (2013) 131

- Forward backward muon asymmetry, SM $q^2_0 \sim 4\ \mathrm{GeV}^2/c^4$
- Full angular distribution, observables sensible to $C^{(')}_7$, $C^{(')}_9$, $C^{(')}_{10}$ and form factors.

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



- Depends on F_L, A_{FB}, S_i, observables, that are sensible to $C^{(')}_7$, $C^{(')}_9$, $C^{(')}_{10}$ and form factors.
- Additional "optimized" observables, with cancellation of leading form-factor uncertainties

$$P'_5 = \frac{S_5}{\sqrt{F_L(1-F_L)}}$$

JHEP **01** (2013) 048

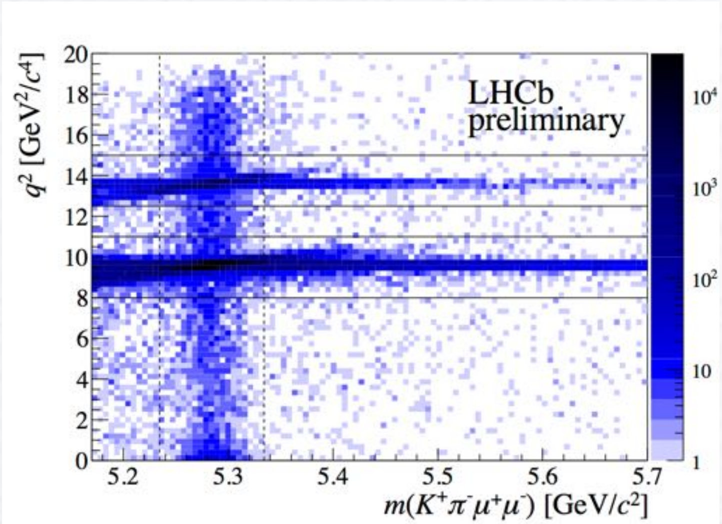
LHCB-CONF-2015-002

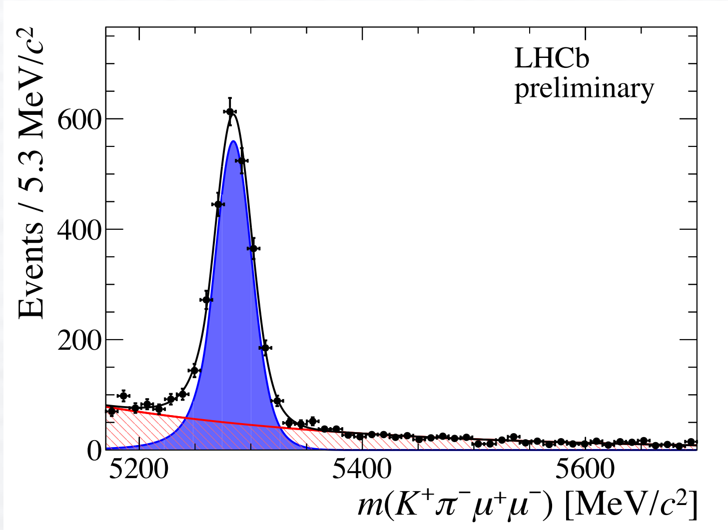
Angular Analysis $B \to K^* \mu^+ \mu^-$

B

$\psi(2S)$ ($\mu^+\mu^-$)

J/ψ ($\mu^+\mu^-$)





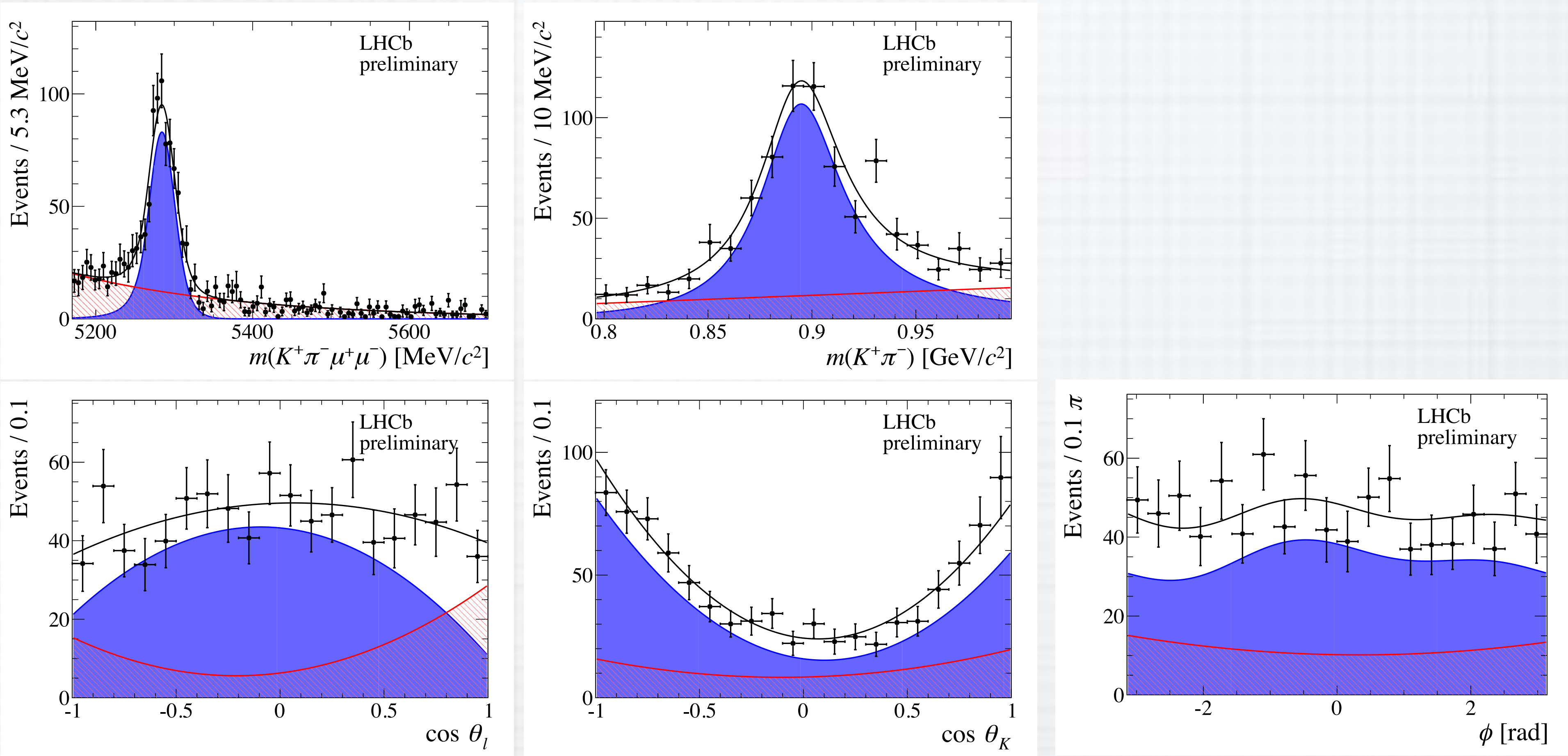
2390±57 candidates

- Control channel $B \to J/\psi(\mu^+\mu^-) K^*$, remove J/ψ, $\psi(2S)$ resonances
  - veto peaking background due to mis-id: $\Lambda_b \to pK^-\mu^+\mu^-$, $Bs \to \phi (K^+K^-)\mu^+\mu^-$
- Full fit in q^2 angles, mass and also K* mass and S-wave contribution
  - angular acceptance parameterized with Legendre polynomials, check with control channel
    - events are weighted according with acceptance
  - background angular distribution parameterized using Chebychev Polynomials (2nd degree)

LHCB-CONF-2015-002

Angular Analysis $B \to K^* \mu^+ \mu^-$

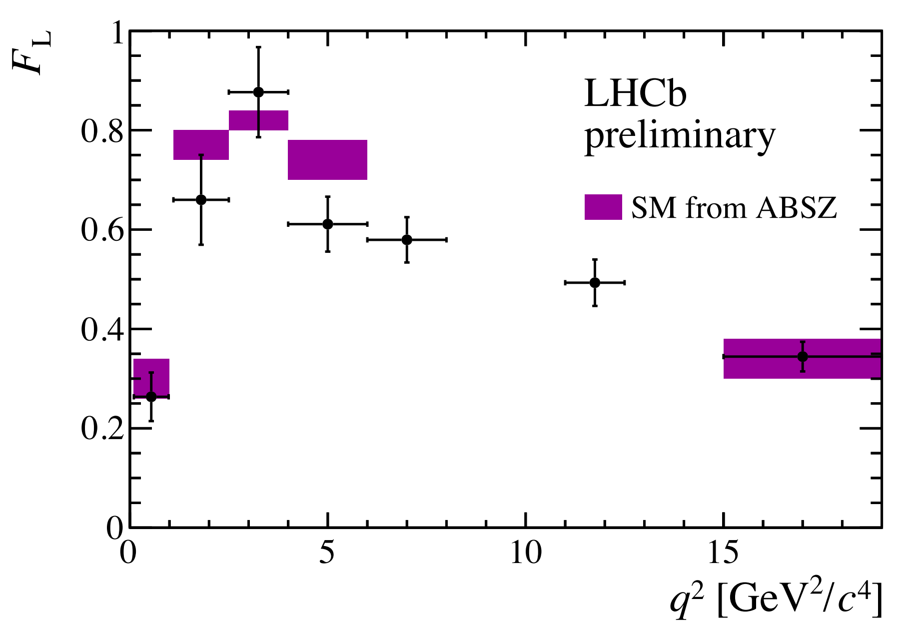
$1.1 < q^2 < 6\ GeV^2/c^2$

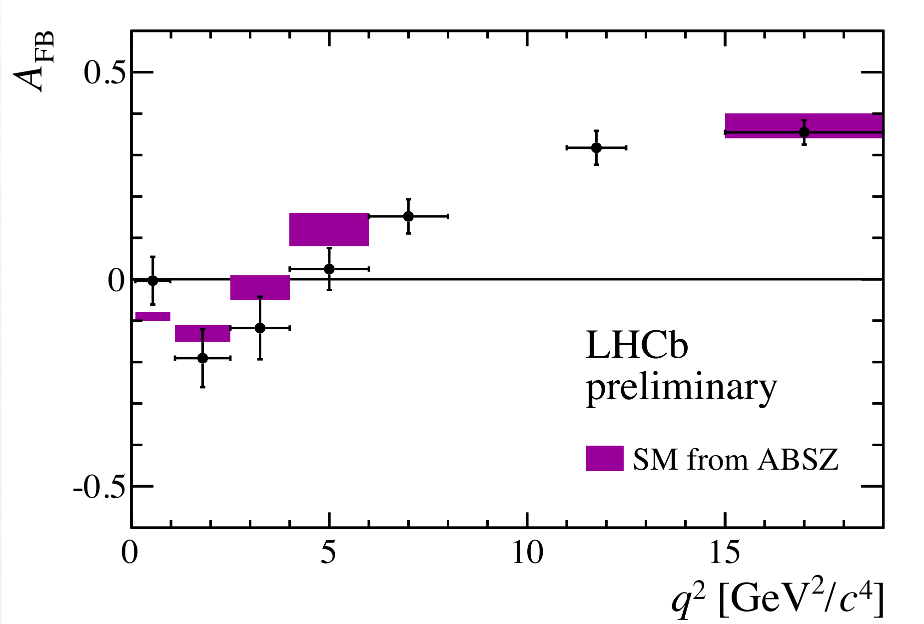


LHCB-CONF-2015-002

Angular Analysis $B \to K^* \mu^+ \mu^-$

SM: arXiv:1503.05534, arXiv:1411.3161

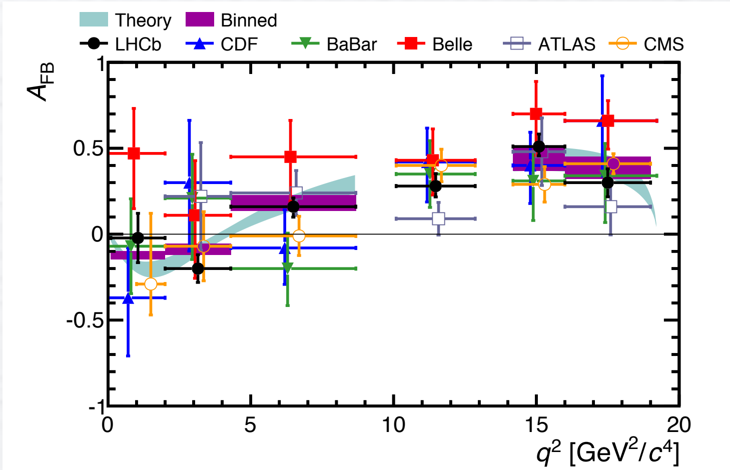




- LHCb has clarified the A_{FB} picture
- zero-crossing point of A_{FB} in agreement with SM

$$(3.7^{+0.8}_{-1.1})\ \mathrm{GeV}^2/c^4,$$

- but mild tension in A_{FB} with respect SM (<~1σ)

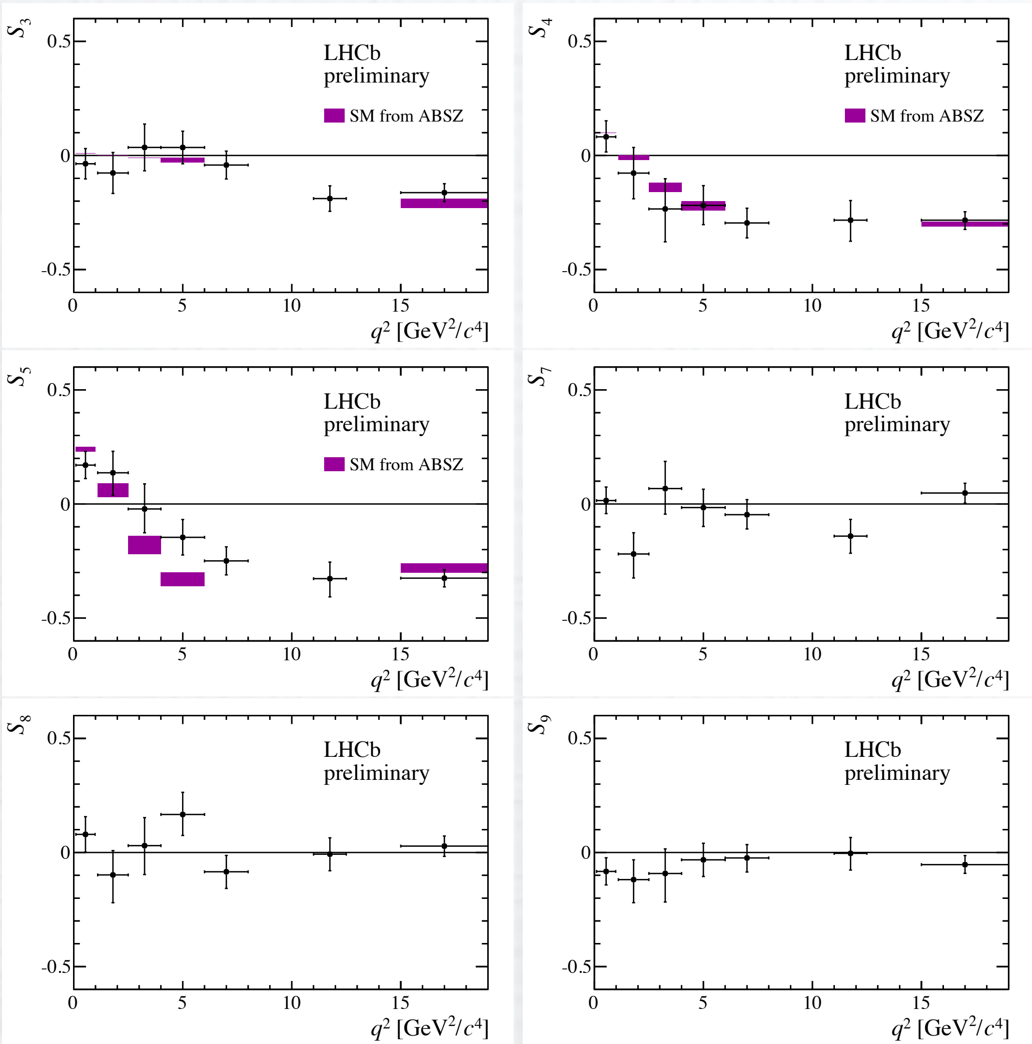


PLB 103 (2009)) 171801; PRD73 092001; PRL 108 081807; PRB 727 (2013) 77, ATLAS-CONF-2013-038, **JHEP 08 (2013) 131**

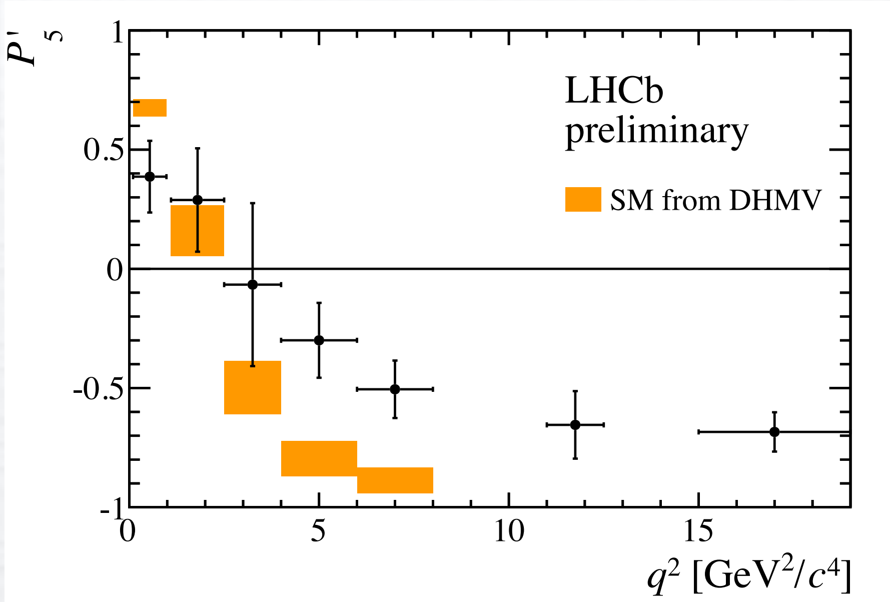
LHCB-CONF-2015-002

Angular Analysis $B \to K^* \mu^+ \mu^-$

SM: JHEP **07** (2011) 067, 1105.0376



SM: JHEP **1412** (2014) 124



- 2 bins with 2.9 σ
- naïve local significance 3.7 σ

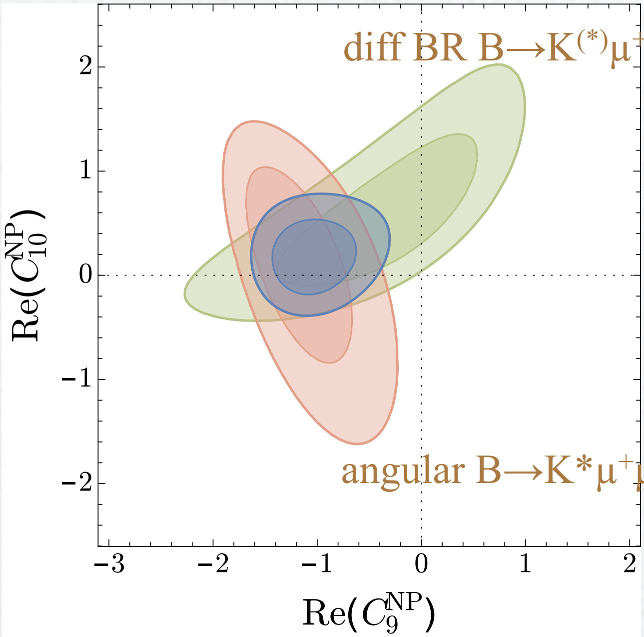
LHCB-CONF-2015-002

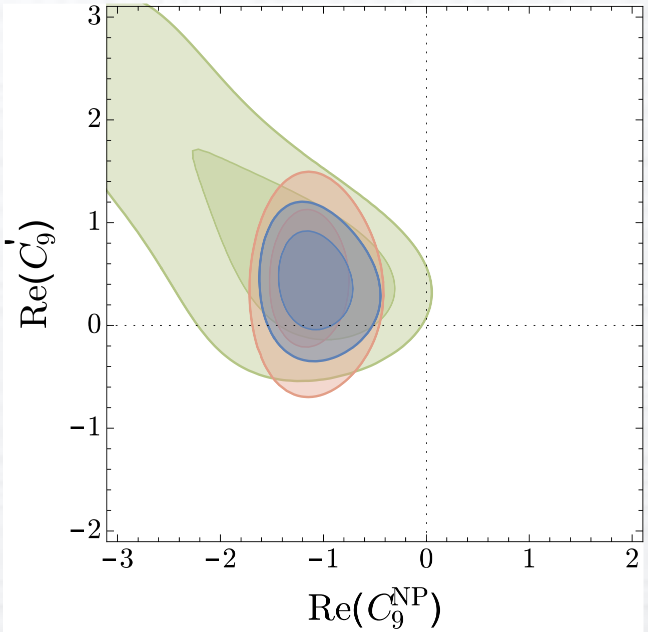
- Good agreement with SM
- But tension on S_5

Angular Analysis $B \to K^* \mu^+ \mu^-$

- **Wilson coefficients global fit from $b \to s\, \mu^+ \mu^-$**
  - Including results from LHCb but also ATLAS, CMS
  - Preferred solution: $C^{NP}_9 \sim -1.1$!

Altmannshofer and Straub
arXiv:1503.06199

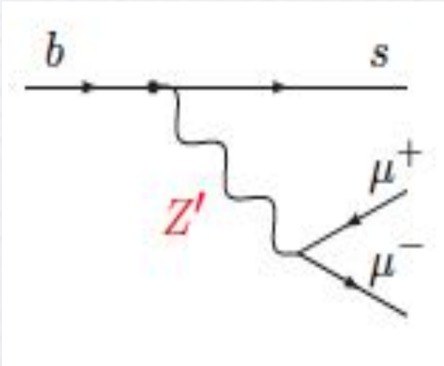




- **Several interpretations**
  - A possible Z' O(7 TeV) with FV coupling.
  - If different coupling to e, μ; it could explain R_K

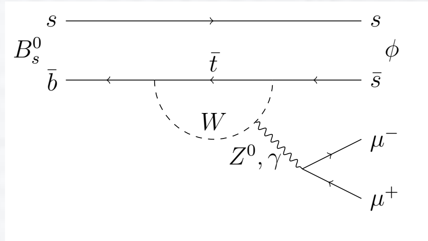
JHEP 1401 (2014) 069, JHEP 1402 (2014) 111,

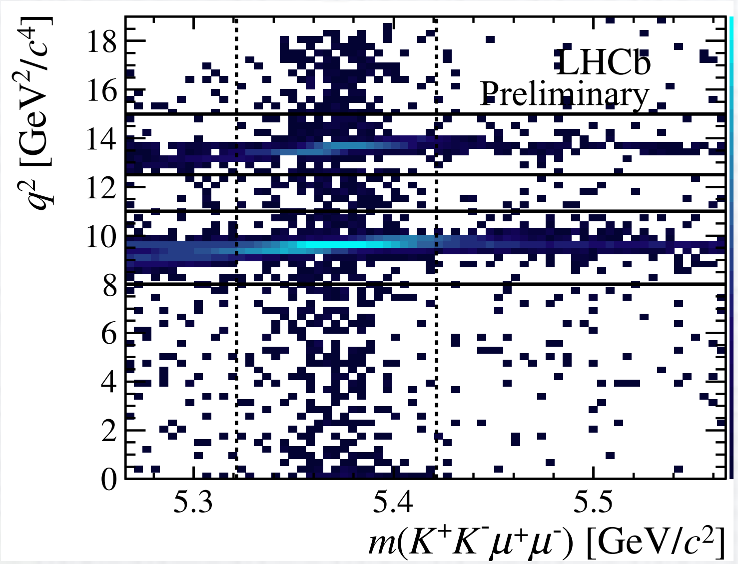
PRD 89 (2014) 095033



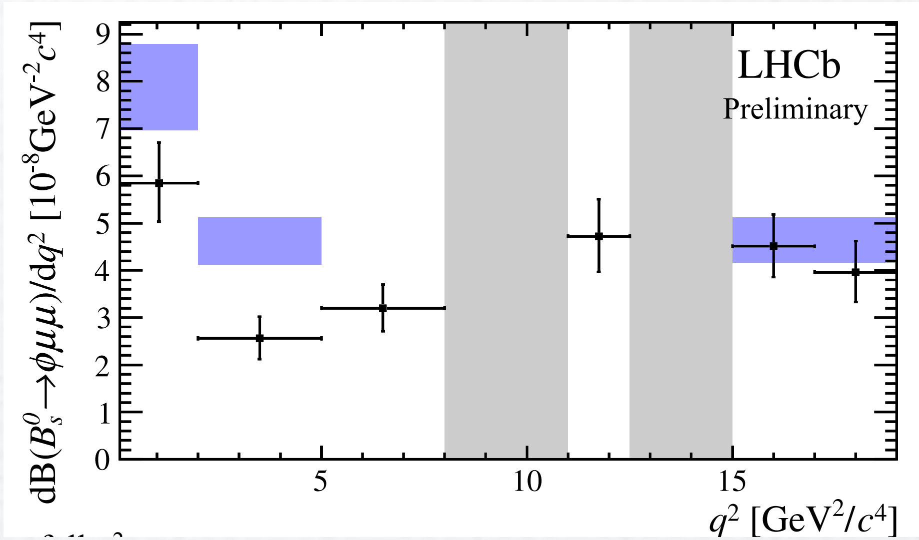
Branching ratio and Angular Analysis $B_s \to \phi(K^+K^-)\mu^+\mu^-$

- **Branching ratio and angular analysis**
  - Similar to $B\to K^*\mu^+\mu^-$, but production suppressed and not flavour specific final state

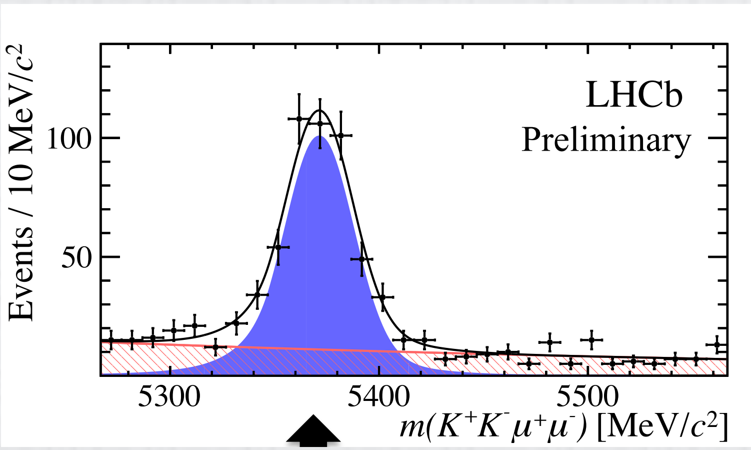




432±24 candidates



SM: arXiv:1503.05534, arXiv:1411.3161



- most precise measurement
- 3 σ tension in $1<q^2<6$ GeV$^2/c^2$

$$\frac{\mathcal{B}(B_s^0\to\phi\mu^+\mu^-)}{\mathcal{B}(B_s^0\to J/\psi\,\phi)} = (7.40^{+0.42}_{-0.40}\pm0.16\pm0.21)\times10^{-4},$$
$$\mathcal{B}(B_s^0\to\phi\mu^+\mu^-) = (7.97^{+0.45}_{-0.43}\pm0.18\pm0.23\pm0.60)\times10^{-7}$$

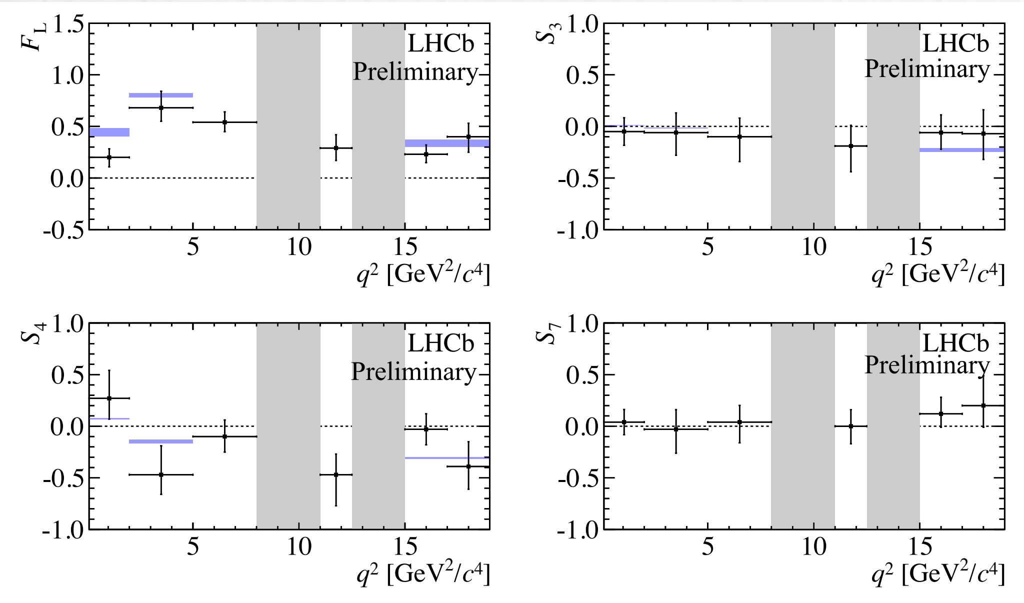
LHCB-PAPER-2015-023

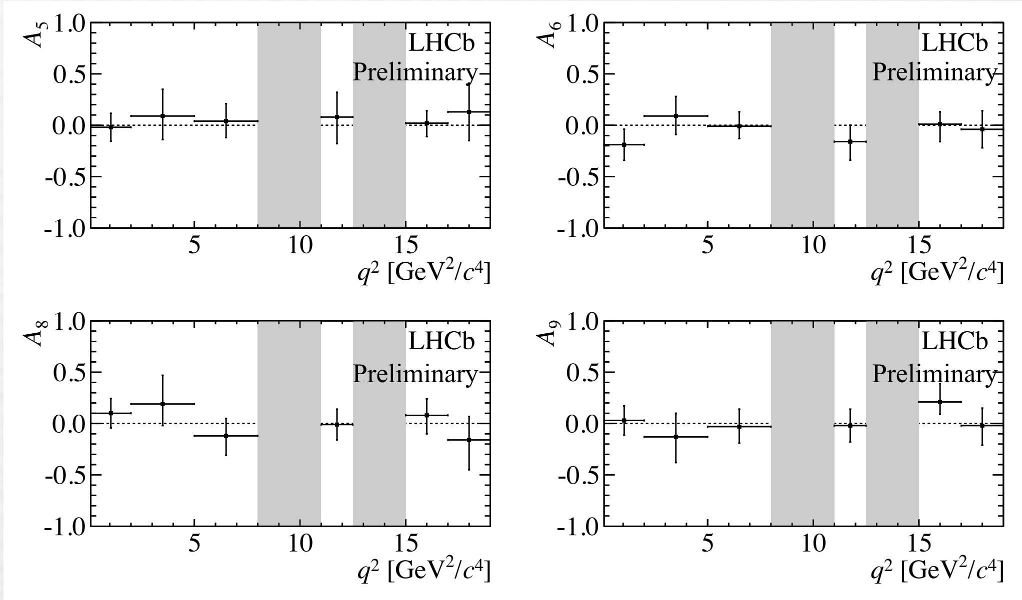
Branching ratio and Angular Analysis $B_s \rightarrow \phi(K^+K^-)\,\mu^+\mu^-$

LHCB-PAPER-2015-023

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^3\Gamma}{\mathrm{d}\cos\theta_l\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[\tfrac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K$$
$$+\tfrac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_l - F_\mathrm{L}\cos^2\theta_K\cos 2\theta_l$$
$$+S_3\sin^2\theta_K\sin^2\theta_l\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_l\cos\phi$$
$$+A_5\sin 2\theta_K\sin\theta_l\cos\phi + A_6^s\sin^2\theta_K\cos\theta_l$$
$$+S_7\sin 2\theta_K\sin\theta_l\sin\phi + A_8\sin 2\theta_K\sin 2\theta_l\sin\phi$$
$$+A_9\sin^2\theta_K\sin^2\theta_l\sin 2\phi\Big].$$

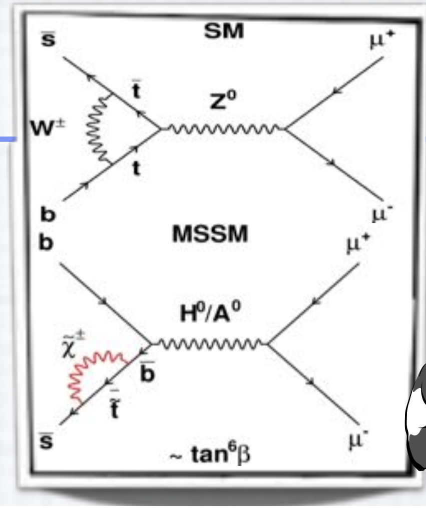
SM: arXiv:1503.05534
(if no band: SM prediction is zerol)





- In agreement with SM

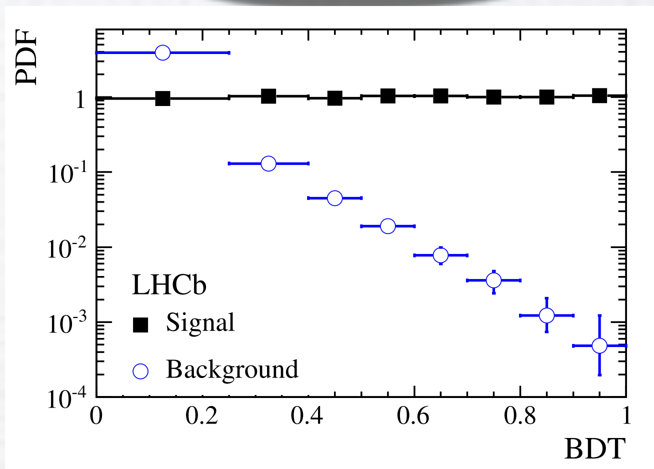
$B_{(s)} \to \mu\mu$



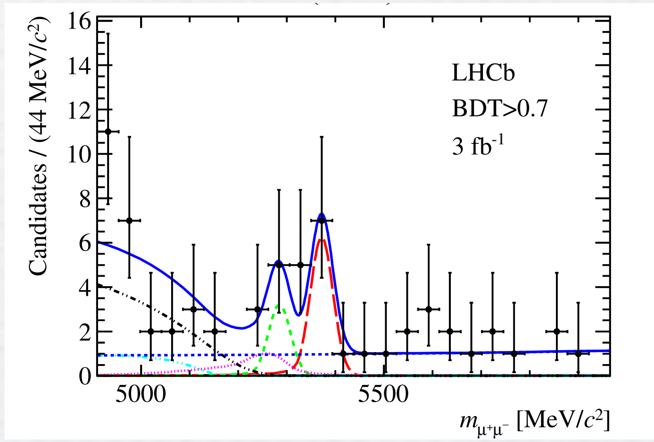
- **LHCb $B_{(s)} \to \mu\mu$ search**
  - Very rare decay, SM helicity suppressed
  - Very sensible to presence of new scalar (C_{10}, C_S, C_P)
  - Precise SM prediction

PRL **112** (2014) 101801

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.66 \pm 0.23) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.06 \pm 0.09) \times 10^{-10}$$



- **LHCb $B_{(s)} \to \mu\mu$ search**
  - Great invariant mass resolution ~23 MeV
  - separation signal/background with a BDT
    - calibrated with data $B_{(s)} \to hh$
  - Normalized to $B^+ \to J/\psi(\mu^+\mu^-)K^+$

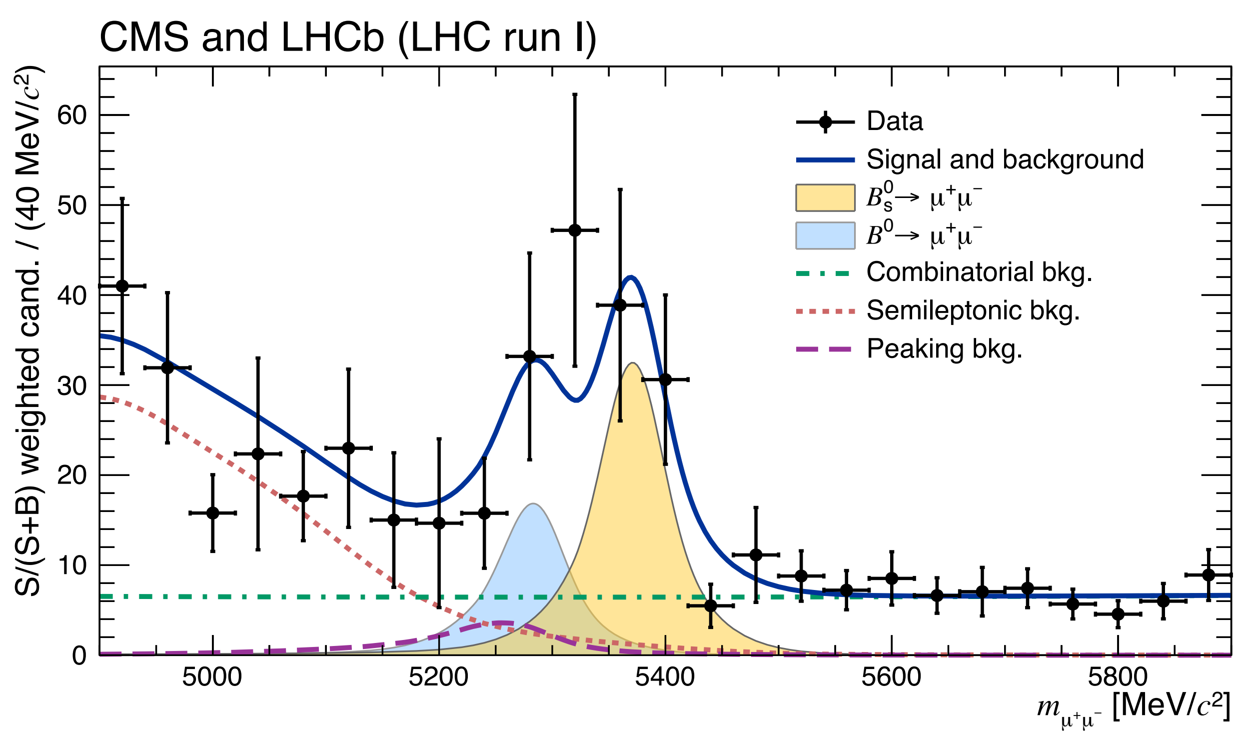


Phys. Rev. Lett **111** (2013) 101805

$B_{(s)} \to \mu\mu$

Combined LHCb and CMS search

- simultaneous analysis, shared signal and nuisance parameters



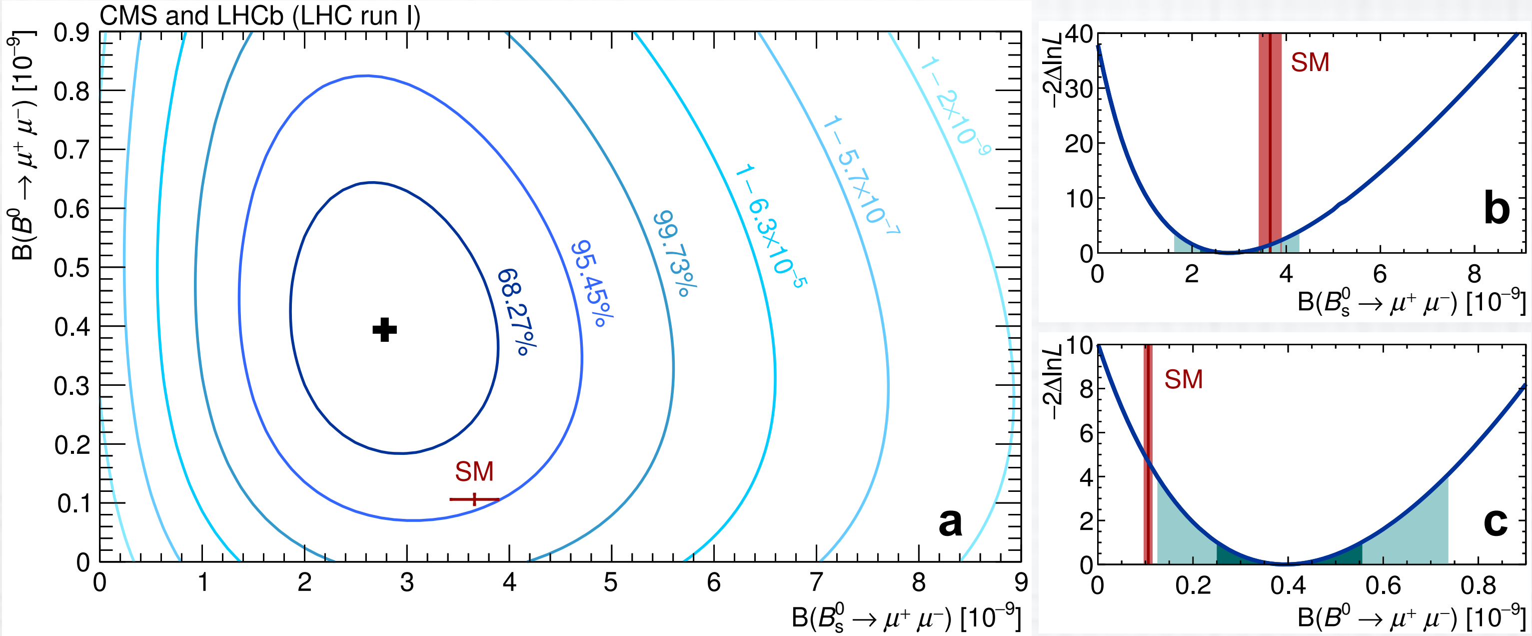
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(2.8\,^{+0.7}_{-0.6}\right) \times 10^{-9} \text{ and}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = \left(3.9\,^{+1.6}_{-1.4}\right) \times 10^{-10},$$

- $B_s \to \mu\mu$ first observation (6.2 σ) and $B \to \mu\mu$ with 3σ significance!
- In agreement with SM!, stringent constraint for BSM!

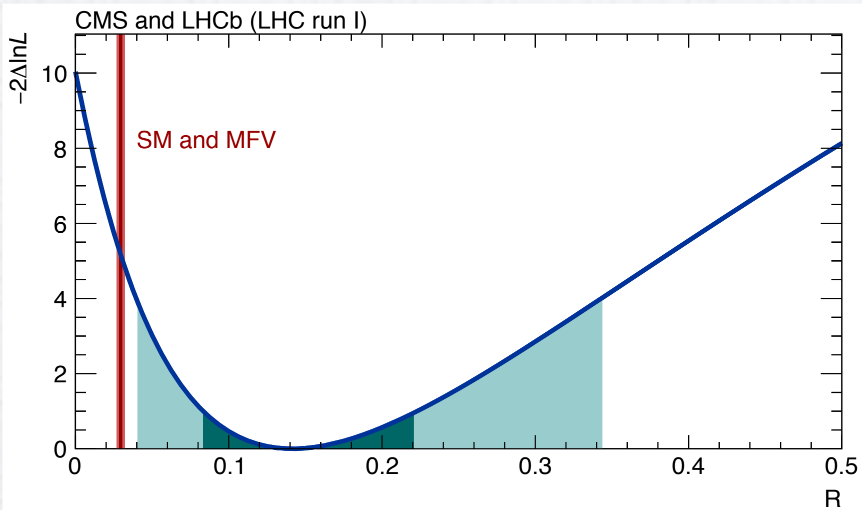
arXiv:1411.4413, Nature **552** (2015) 68

$B_{(s)} \to \mu\mu$

- likelihood scan



- Determination of the BR ratio



- SM ratio prediction PRL **112** (2014) 101801

$$0.0295^{+0.0028}_{\;0.0025}$$

- Measured for first time

$$R = \frac{\mathcal{B}(B^0 \to \mu\mu)}{\mathcal{B}(B^0_s \to \mu\mu)} = 0.14^{+0.08}_{-0.06}$$

- Compatible with SM at 2.3 σ

arXiv:1411.4413, Nature **552** (2015) 68

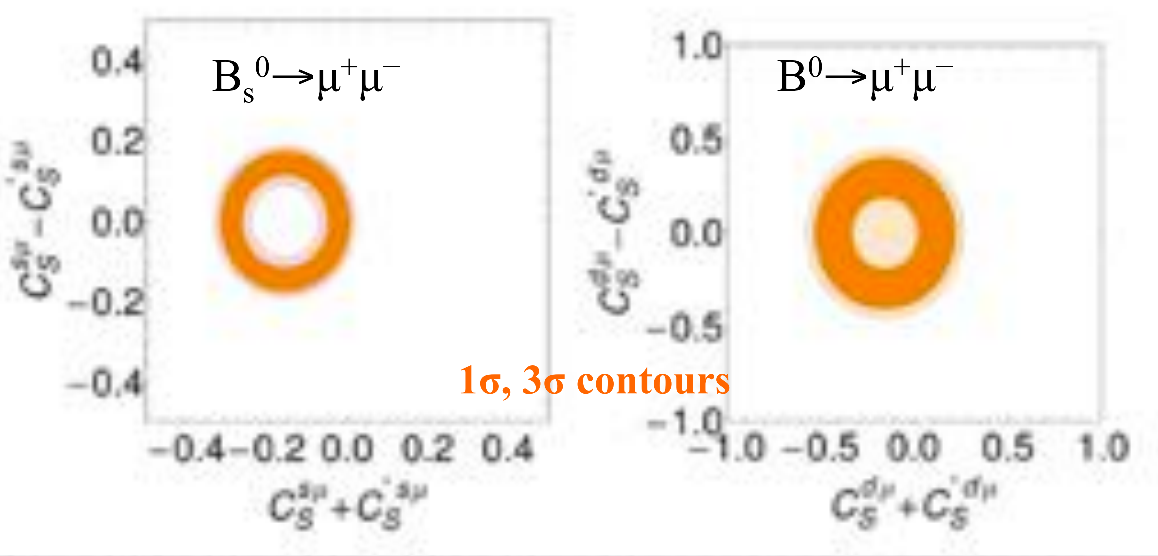
$B_{(s)} \to \mu\mu$

- BR is sensitive to:

$$BR(B_s \to \mu^+\mu^-) \propto m_\mu^2 \left(\left| (C_{10}^{SM} + C_{10}^{NP} - C'_{10}) - \frac{m_{B_s}}{2m_\mu}(C_{SP} + C'_{SP}) \right|^2 + \left| \frac{m_{B_s}}{2m_\mu}(C_{SP} - C'_{SP}) \right|^2 \right)$$

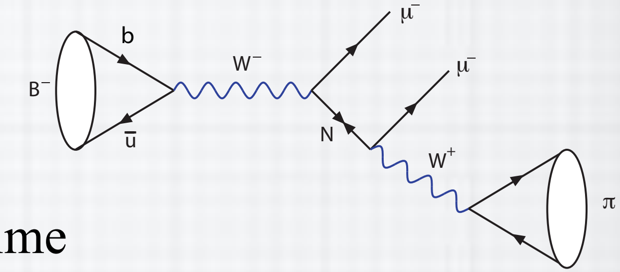
- LHCb+CMS measurements eliminates NP on C^{NP}_{10}- C'_{10}, and constrain C_s-C'_s

arXiv:14077044

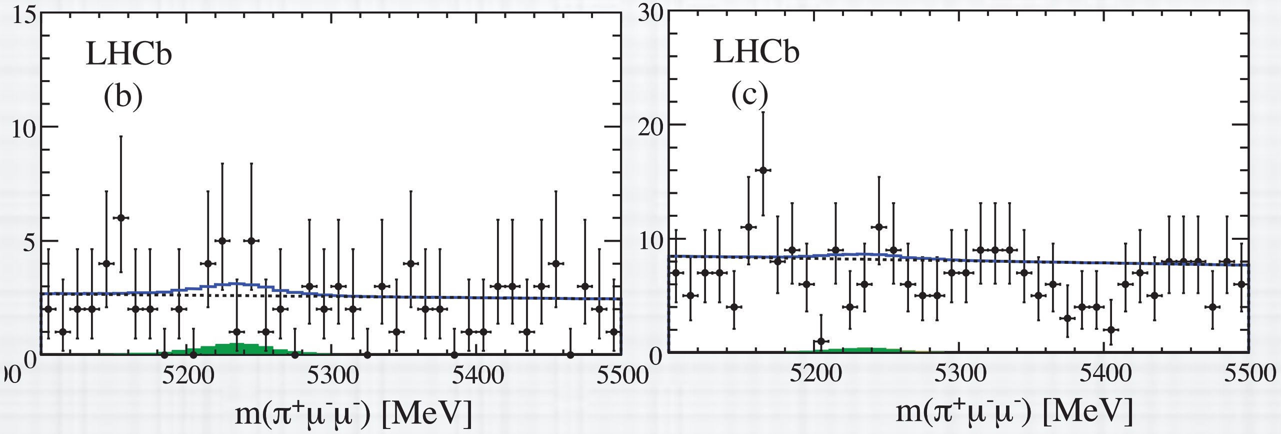


LNV: $B^- \to \pi^+ \mu^- \mu^-$

- Search for Majorana neutrinos using $B^- \to \pi^+ \mu^- \mu^-$
  - 250-5000 MeV and lifetimes <1000 ps
  - categories: detached or not (< 1ps): BR limit vs mass, lifetime

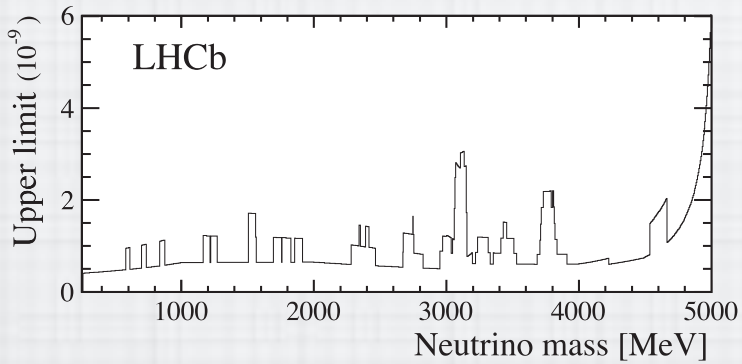


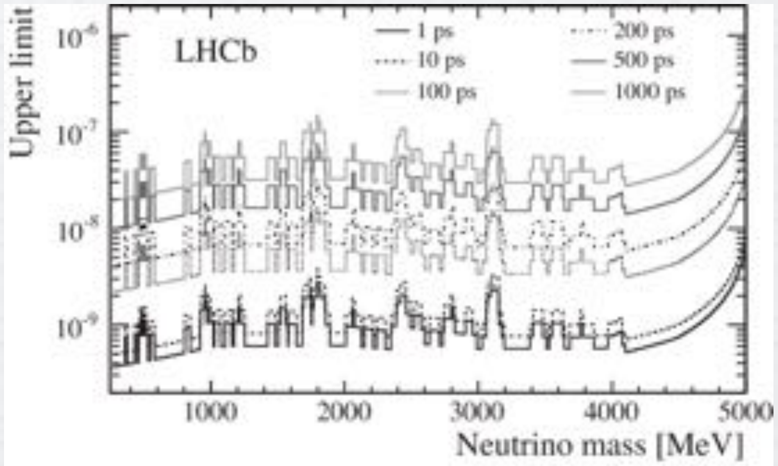
τ<1 ps 19 (17.8 bkg) candidates 60 (54.5 bkg) candidates 1<τ<1000 ps



$\mathcal{B}(B^- \to \pi^+ \mu^- \mu^-) < 4.0 \times 10^{-9}$ @ 95% C.L.

τ<1 ps





Phys. Rev. Lett. **112** (2014) 131802

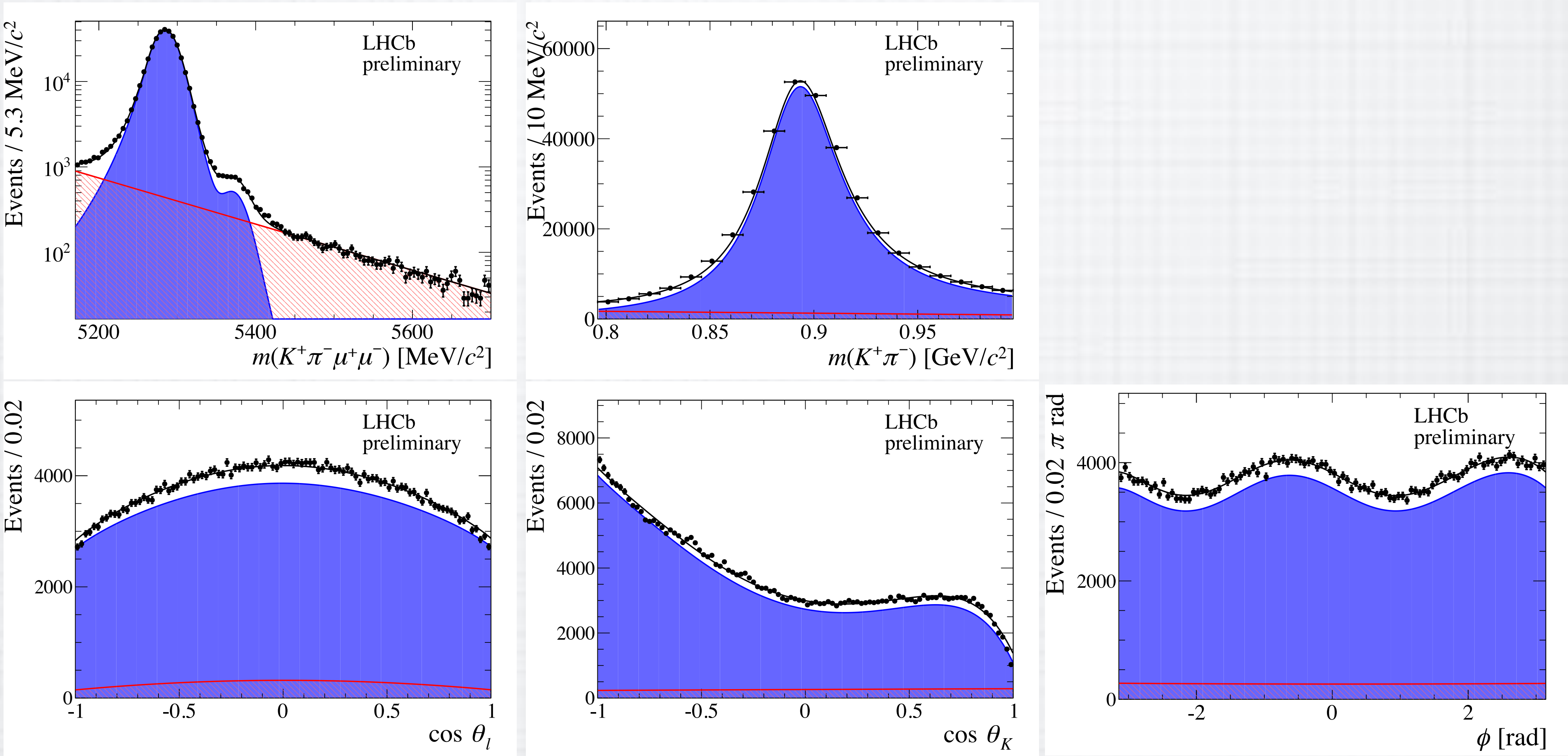
Conclusions

- Rare hadron b decays allow us to explore ***indirectly NP***
- Stringent constraints for BSM due to the LHCb+CMS observation of $B_s \to \mu\mu$ and the evidence of $B \to \mu\mu$ in agreement with SM
- LHCb rare B decays are largely in agreement with SM
- But there are some tantalizing tensions:
  - In the lepton universality ratio from $B^+ \to K^+ l^+ l^-$
  - In one observable, P'_5, of the angular distributions of $B \to K^* \mu^+ \mu^-$, there is a local discrepancy with SM at ~3.7 σ
  - They can be accommodated in a global fit of Wilson Coefficients, with preferred solution: $C^{NP}_9 \sim -1.1$
- LHCb is running again!
  - $B_{(s)} \to \mu\mu$ analysis will enter in a different era!
  - Expectation about updates on the angular distribution of $b \to s\mu\mu$ processes
  - And pay attention to the checks of the lepton universality

- backup!!!!!!!!!!!!!!!!!!!!!!!

Angular Analysis $B \to K^* \mu^+ \mu^-$

- Control channel $B \to J/\psi(\mu^+\mu^-) K^*$
  - consistent with current measurements

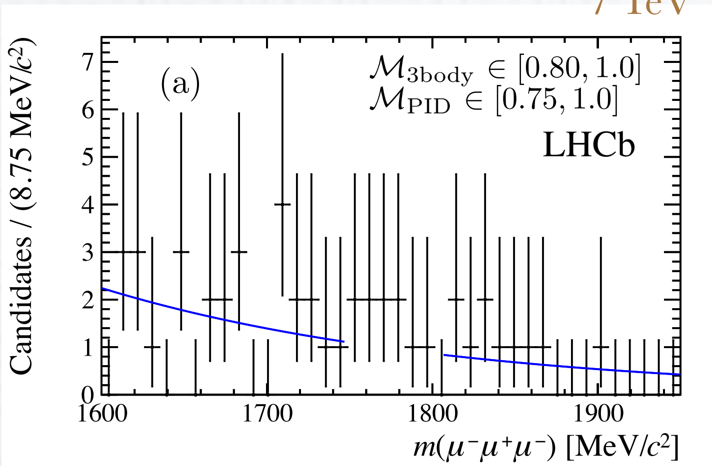


LHCB-CONF-2015-002

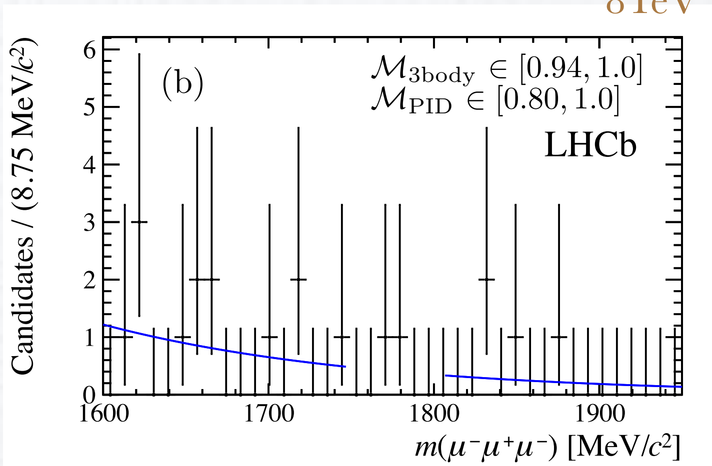
LFV: τ→3μ

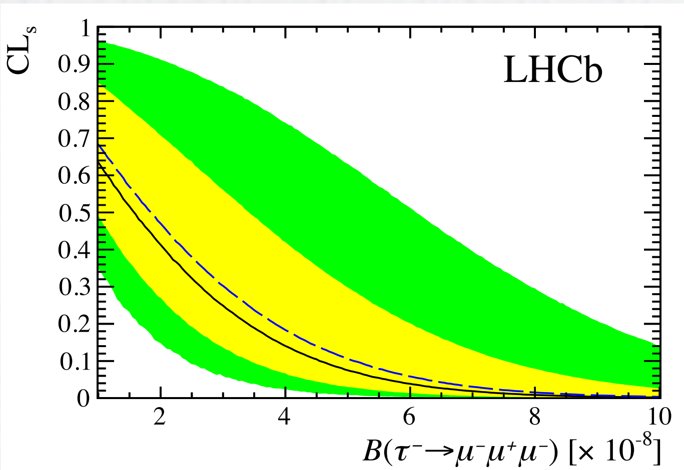
- Search for LFV with τ→3μ
  - large inclusive production from b,c
  - separation using two discriminants (geometric, 3 body, and PID) and τ mass
  - normalization and control channel $D^-_s \to \phi(\mu\mu)\pi^-$

7 TeV



8TeV





$$\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 4.6\ (5.6) \times 10^{-8}.$$

@ 90 (95)% C.L.

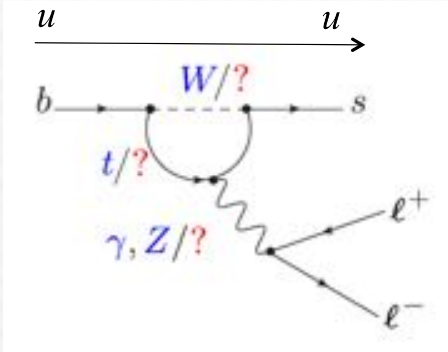
- appreaching current best 90% C.L limits from Babar, 3.3 10^{-8} and Belle, 2.1 10^{-8}

J High Energy Phys. **02** (2015) 121

Lepton Universality $B^+ \to K^+ l^+ l^-$

- Ratio of B+→K+μ+μ-, B+→K+e+e- as test of lepton universality

$$R_K = \frac{\int_{q^2_{min}}^{q^2_{max}} \frac{d\Gamma[B^+ \to K^+ \mu^+ \mu^-]}{dq^2} dq^2}{\int_{q^2_{min}}^{q^2_{max}} \frac{d\Gamma[B^+ \to K^+ e^+ e^-]}{dq^2} dq^2},$$



  - uncertainties cancel on the rations
  - in SM is almost one $0(10^{-3})$
- LHCb analysis
  - relative measurement with respect B+→K+J/ψ(l+l-)
  - reconstruction of the e with bremsstrahlung photons
  - in different trigger categories (e,h,other)
  - efficiencies from simulation, corrected with data
  - range q2 [1, 6] GeV2
  - systematic dominated by the B+→J/ψ(ee)K+ mass parameterization and the trigger

$$R_K = \left(\frac{\mathcal{N}_{K^+\mu^+\mu^-}}{\mathcal{N}_{K^+e^+e^-}}\right)\left(\frac{\mathcal{N}_{J/\psi(e^+e^-)K^+}}{\mathcal{N}_{J/\psi(\mu^+\mu^-)K^+}}\right) \times \left(\frac{\epsilon_{K^+e^+e^-}}{\epsilon_{K^+\mu^+\mu^-}}\right)\left(\frac{\epsilon_{J/\psi(\mu^+\mu^-)K^+}}{\epsilon_{J/\psi(e^+e^-)K^+}}\right),$$

$$R_K = 0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{syst}).$$