Future LHCb measurements?

T. Blake on behalf of the LHCb collaboration

Edinburgh workshop on $b \to s \ell\ell$ decays

Introduction

- Future measurements at LHCb?
  - ➡ We have (in my opinion) managed to perform an impressive number of measurements using our run I dataset.
  - ➡ Aim of this talk is to explore:
    - ✦ What more we can learn from our run I dataset?
    - ✦ What should we do differently in run II?

Setting the scene

- Some modes are no longer particularly "rare", we have large samples of some decays already in run I.
- Extrapolating to the future:

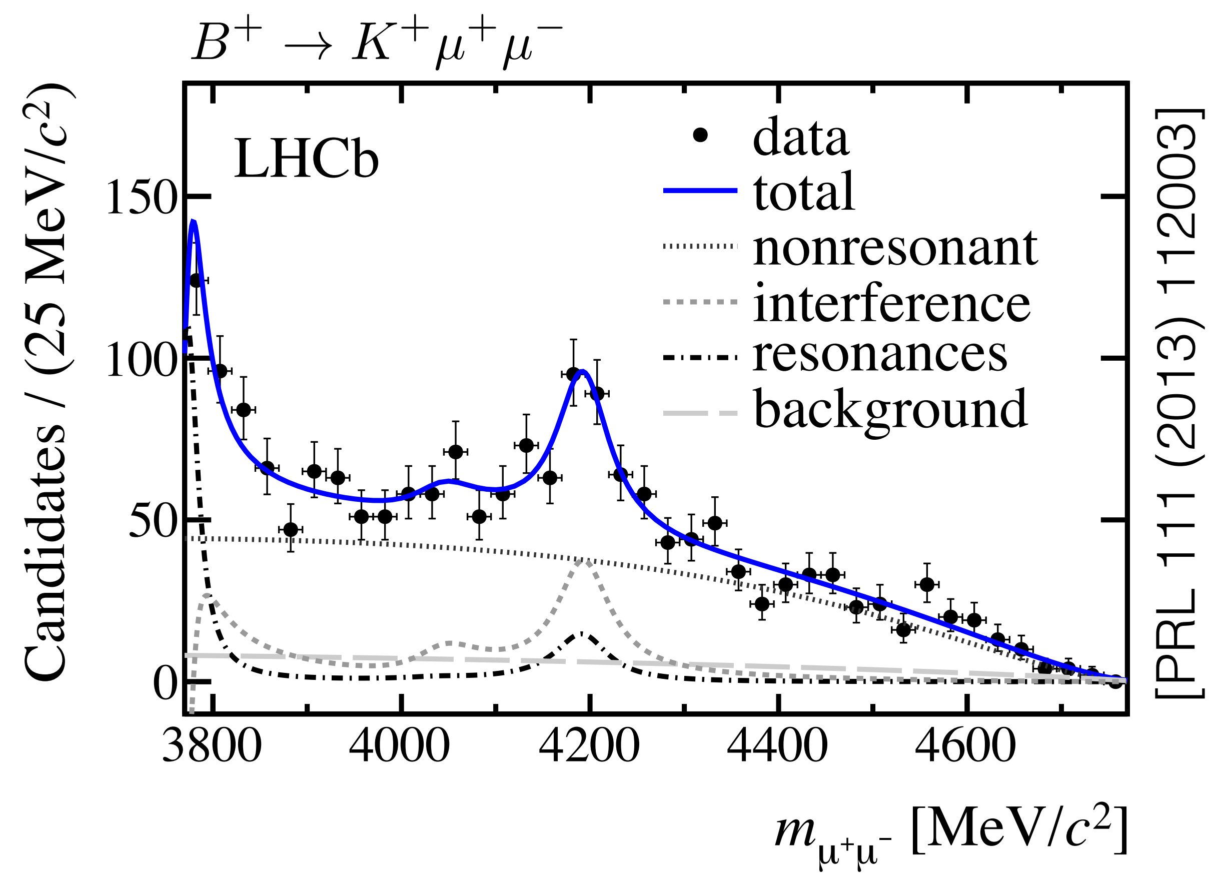
	channel	1fb^{-1}	3fb^{-1}	run II	upgrade	
	$B^0 \to K^{*0}\mu^+\mu^-$	883	2,400	10,500	85,000	
	$B^+ \to \pi^+\mu^+\mu^-$	25	80	360	2500	
	$B_s^0 \to \mu^+\mu^-$	–	15	65	520	
	$B^0 \to K^{*0}\gamma$	5,300	17,000	76,000	500,000	} challenge to retain trigger efficiency in run II
[low q^2]	$B^0 \to K^{*0}e^+e^-$	–	150	650	5,200	

scaling naively by luminosity, assuming $\sigma_{b\bar{b}}$ scales linearly with $\sqrt{s}$

Resonance structure

- See large resonant contributions from $c\bar{c}$ states at large dimuon masses.
- We can fit this with a Breit-Wigner ansatz (but only after assuming some q^2 parameterisation for the non-resonant part) to extract magnitudes and relative phases.

i.e. use a shape



comparison with expectation from vacuum polarisation → large non-factorisable effects

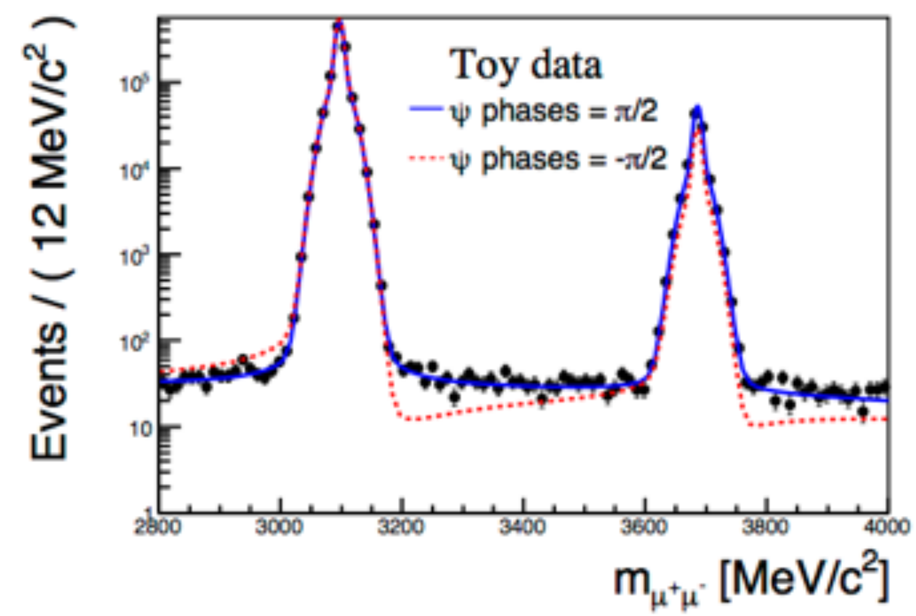
$$\text{phsp} \times (|\mathcal{A}_\text{V}(m_{\mu\mu}) + \sum_i e^{i\phi_i}\mathcal{A}_i(m_{\mu\mu}, \mu_i, \Gamma_i)|^2 + |\mathcal{A}_A|^2) f_+^2(m_{\mu\mu})$$

for narrow states this needs to be convoluted by our experimental resolution

Resonance structure

- Using toy experiments it looks like we might also have sensitivity to the interference of the non-resonant contribution with the J/ψ.
  - ➡ Difficult measurement, we really need to understand our experimental resolution and the impact of bremsstrahlung/FSR.
- Can we learn anything useful from light-resonances at low q^2?
  - ➡ These are suppressed but should be visible in our run II/upgrade dataset.

[P. Owen, LHCb implications workshop]

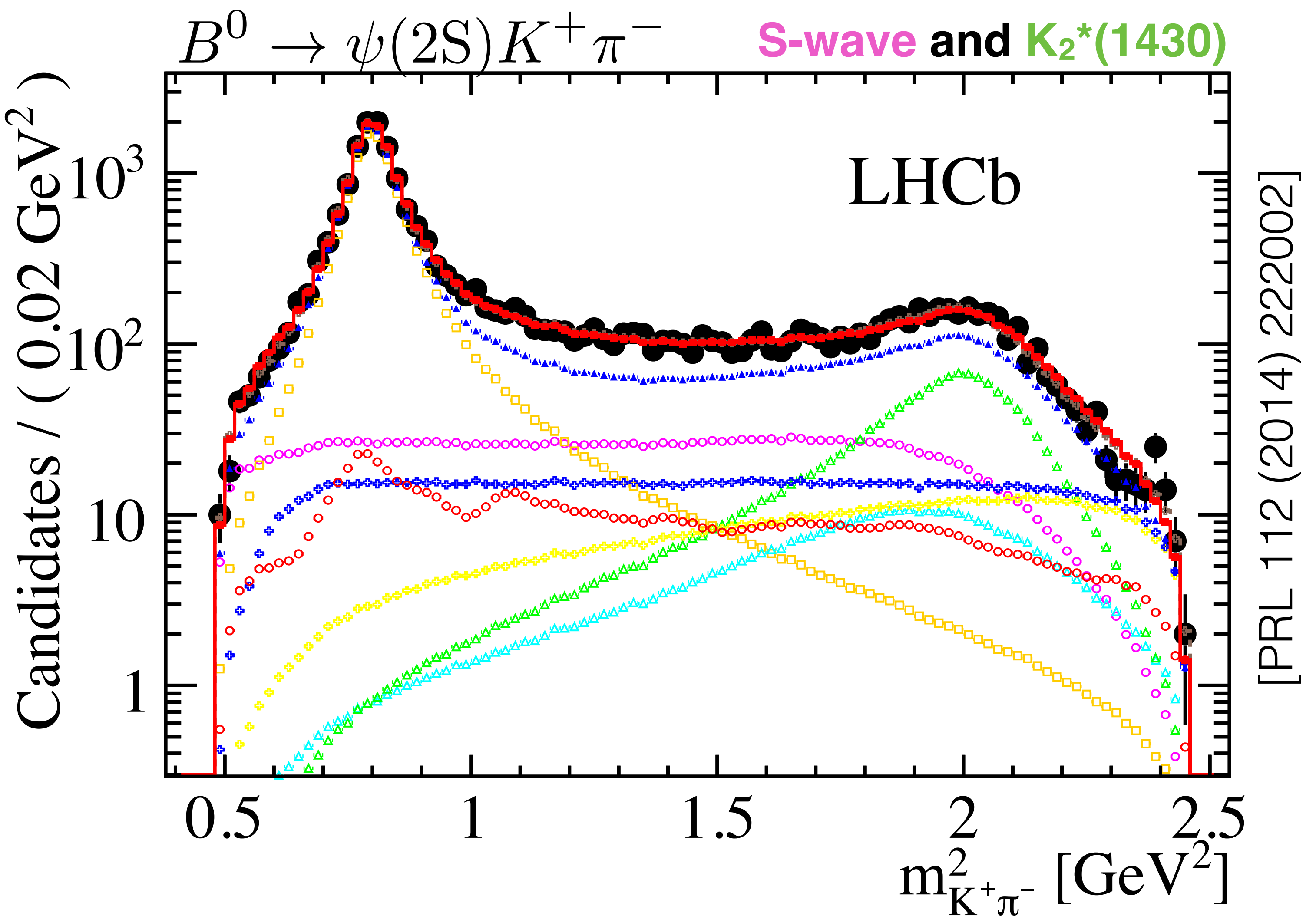


Toy experiment showing impact of the ψ phases on the visible dimuon spectrum.

B mass constraint applied to recover bremsstrahlung/FSR.

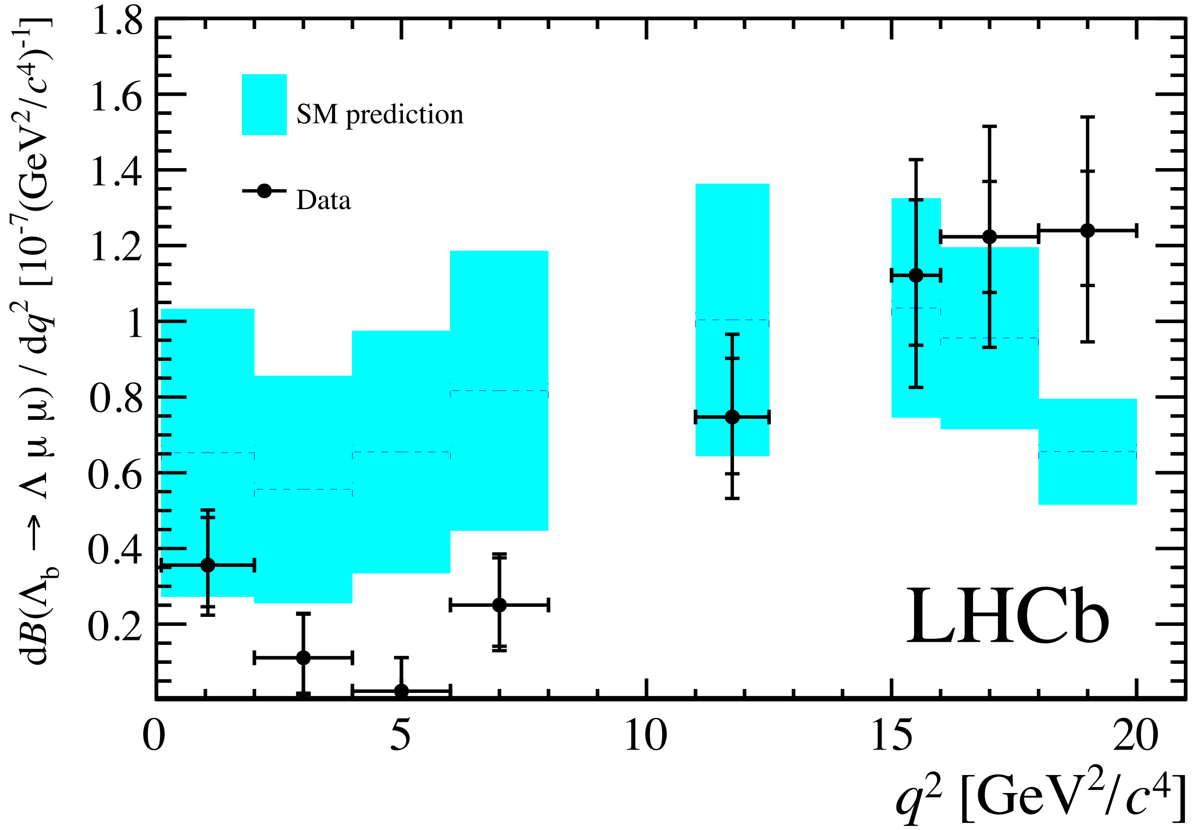
Higher K^* states?

- So far we have focussed on a ±100 MeV window about the K^{*0} pole mass.
- We could also perform measurements at higher masses, e.g. around the D-wave $K_2^*(1430)$.
- Would this be useful?
- Can we make predictions for the higher spin states?



Rare baryon decays

- We already have precise measurements of $\Lambda_b^0 \to \Lambda\mu^+\mu^-$
- Can we learn something from the strongly decaying Λ states? e.g the J = 3/2 Λ*(1520)
- Photon polarisation measurements with $\Lambda_b^0 \to \Lambda^{*0}\gamma$ decays are limited by the small production polarisation at the LHC (to be confirmed at 13TeV). Unfortunately, the $\Lambda\gamma$ final state is very difficult for us to reconstruct.



[arXiv:1503.07138]

Poor agreement in shape between SM predictions and data (especially at low q^2)?

SM from Detmold et al.
Phys. Rev. D87 (2013) 074502,

Photon polarisation

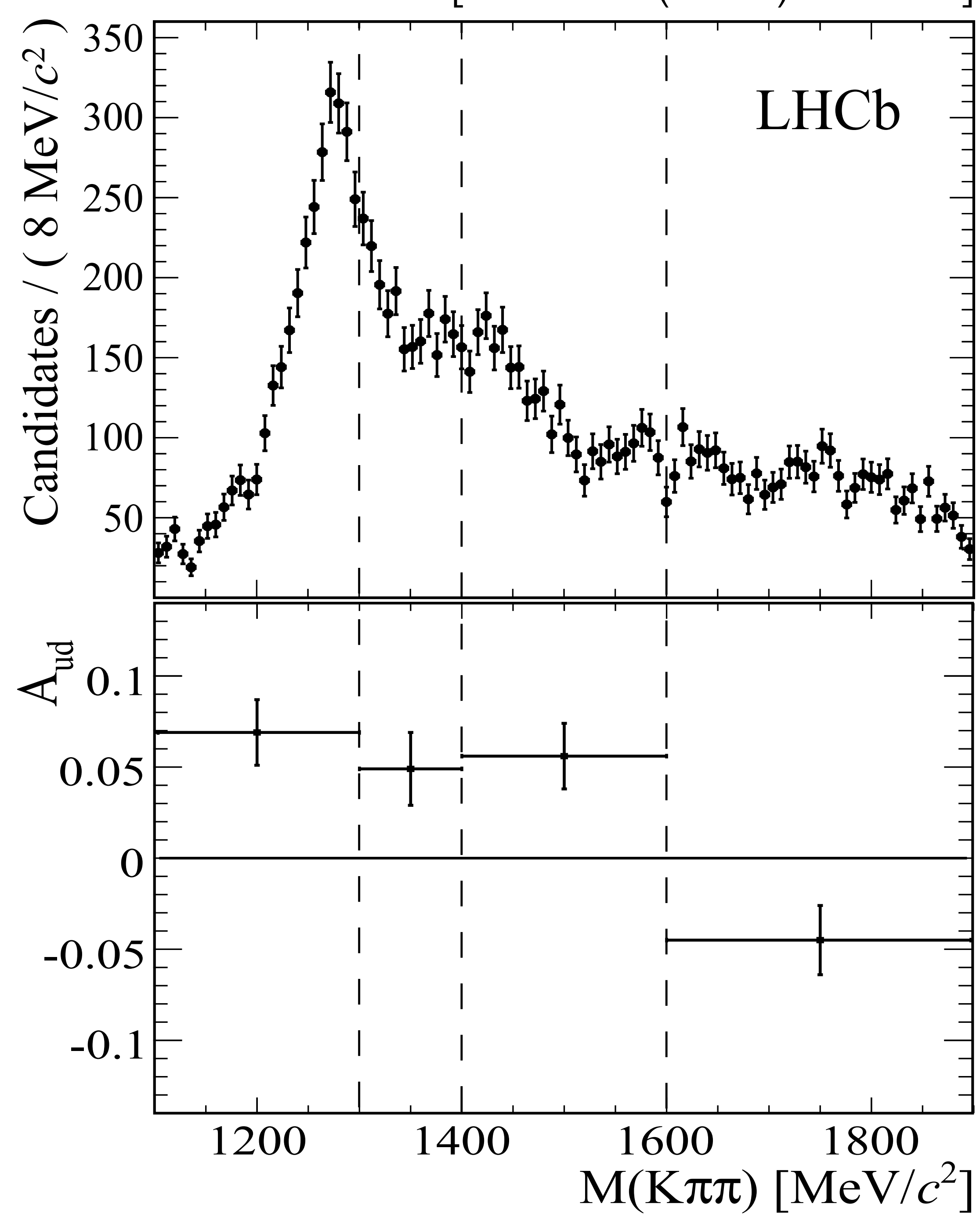
- Observe non-zero photon polarisation in $B^+ \to K^+\pi^-\pi^+\gamma$ decays.
  - ➡ Work ongoing to separate the different $K\pi\pi$ states (needed to determine C'_7)
- We also set strong constraints on C'_7 from A^T_2 and A^T_{Im} using $B^0 \to K^{*0}e^+e^-$ decays at low q^2.

$$A_{\mathrm{T}}^{(2)} = -0.23 \pm 0.23 \pm 0.05$$

$$A_{\mathrm{T}}^{\mathrm{Im}} = \quad 0.14 \pm 0.22 \pm 0.05$$

[JHEP 04 (2015) 064]

[PRL 112 (2014) 161801]



We know polarisation is non-zero but not if its SM-like

Effective lifetimes

- Untagged analysis:

$$\Gamma[B_q + \bar{B}_q](t) \propto e^{-\Gamma_q t} \left(\cosh\left(\frac{\Delta\Gamma_q}{2} t\right) - A^{\Delta\Gamma} \sinh\left(\frac{\Delta\Gamma_q}{2} t\right) \right)$$

$B_s^0 \to \phi\gamma$

$A^{\Delta\Gamma}$ is sensitive to the photon polarisation.

Expect $\sigma(A^{\Delta\Gamma})$ ~ 0.3-0.4

[Zwicky et al, PLB 664 (2008)]

$B_s^0 \to \mu^+\mu^-$

$A^{\Delta\Gamma}$ is sensitive to non-zero scalar and pseudoscalar contributions.

[De Bruyn et al, PRL109 (2012) 041801]

- What about $B_s^0 \to \phi\mu^+\mu^-$?
  - ➡ Taking |q/p| = 1, the effective lifetime is sensitive to the asymmetry between the CP-odd/CP-even amplitudes.

Determining $|V_{td}/V_{ts}|$?

(and testing MFV)

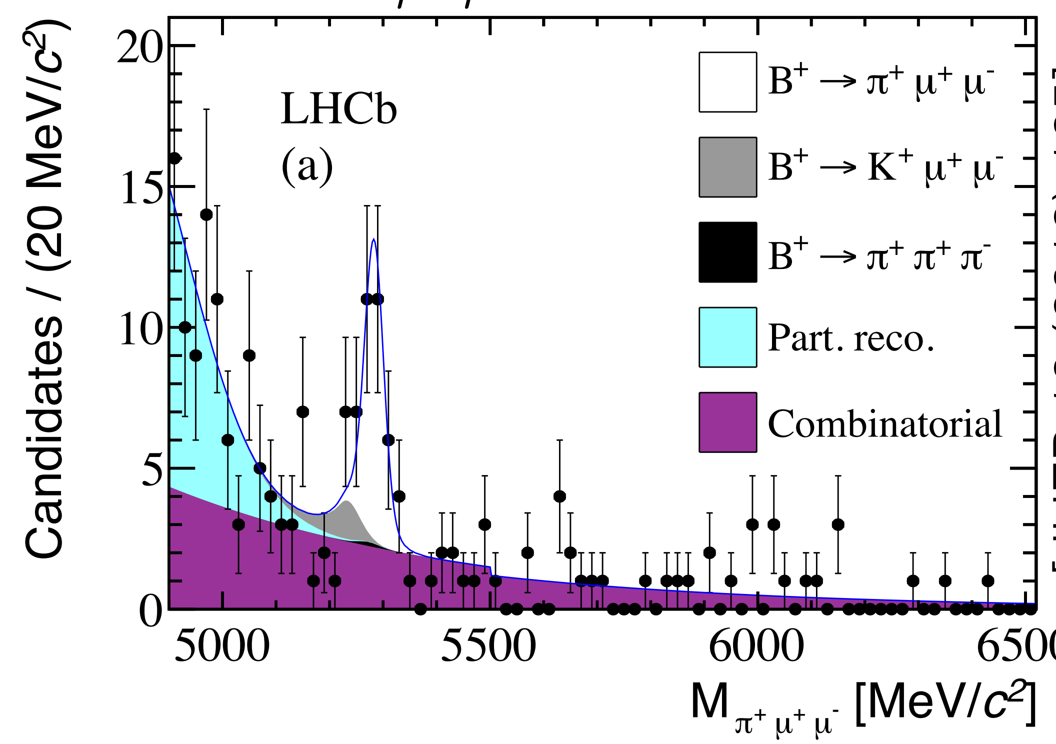
- Also see signals for CKM suppressed $b \to d$ decays in our run I dataset
- How should we treat form-factors in ratios? e.g. in

$$B^+ \to \pi^+\mu^+\mu^- \Big/ B^+ \to K^+\mu^+\mu^-$$

- Can anything be done, using SU(3) flavour, with $B_s^0 \to \overline{K}^{*0}\mu^+\mu^-$?
- We should also be able to improve the measurement of

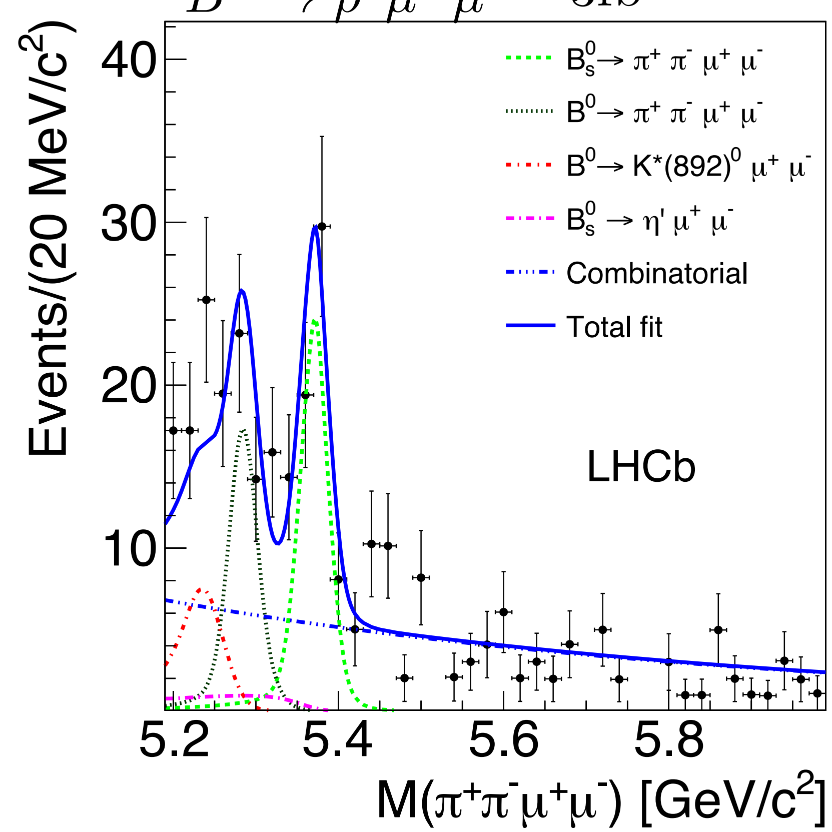
$$B^0 \to \rho\gamma \Big/ B^0 \to K^{*0}\gamma$$

$B^+ \to \pi^+\mu^+\mu^-$ 1fb^{-1}



[JHEP 12 (2012) 125]

$B^0 \to \rho^0\mu^+\mu^-$ 3fb^{-1}



[Phys. Lett. B 743 (2015) 46]

Decays with τ leptons?

- Experimentally challenging (particularly in a hadronic environment):
  - ➡ We only reconstruct a small number of the τ decay channels (e.g. μ^+ or $\pi^+\pi^-\pi^+$).
  - ➡ Difficult to separate missing neutrinos from other partially reconstructed *b*-hadron decays.
- Would limits of 10-100 x SM be interesting?

this is just a guess of what might be possible, proper studies need to be done to really understand our sensitivity.

Lepton flavour violation

- Using 1fb^{-1} of integrated luminosity we set limits

$$\mathcal{B}(B^0 \to e^{\pm}\mu^{\mp}) < 2.8 \times 10^{-9} \quad \text{at } 90\% \text{ C.L.}$$ [PRL 111 (2013) 141801]

- We expect to be able to reach limits of $O(10^{-9} - 10^{-8})$ for

$$B^0 \to K^{*0}e^{\pm}\mu^{\mp} \quad \text{or} \quad B^+ \to K^+e^{\pm}\mu^{\mp}$$

  using our run I data, compared to existing limits of $O(10^{-8} - 10^{-7})$ from the B-factories.

- What range of branching fractions is interesting?

  From [Hiller et al. arXiv:1503.01084] and [Glashow et al. PRL 114 (2015) 091801] it seems that these limits could already be interesting.

Anything else?