Measurement of the isospin asymmetry in $B \to K^{(*)}\mu^+\mu^-$ decays

2013 IOP meeting: HEPP & APP

Patrick Owen[1]
on behalf of the LHCb collaboration

9$^{\text{th}}$ April 2013

Imperial College London

LHCb

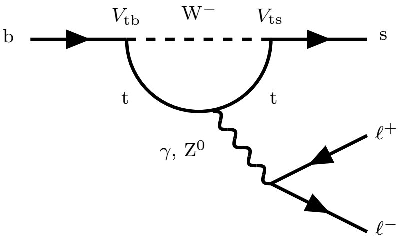
[1]patrickowen22@gmail.com

Outline

- Introduction
  - Rare decays and new physics
  - Isospin asymmetry of $B \to K^{(*)}\mu^+\mu^-$.
- Analysis
- Results [JHEP 1207:133, 2012]

New physics through rare decays

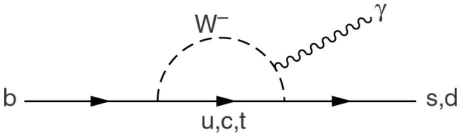
- Decays discussed today are flavour changing neutral current transitions.
- Forbidden at tree level in the SM, and must proceed through penguin/box diagrams.
- New particles can 'enter into the loop' and add possible diagrams, altering observables.



- Measurements usually depend on the 4-momentum transferred to the two muons, q^2.

New physics through rare decays

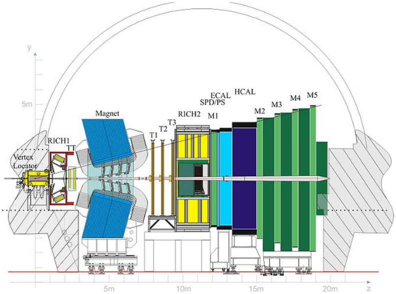
- Rare decays NP searches complementary to direct approach:
  - Probe particle masses beyond $\sqrt{s}$.
  - Model independant interpretation (Wilson Coefficients)
  - Study gauge structure of new physics.



- For example, new physics with electromagnetic gauge structure must be $>\sim$ 50 TeV for naive $\mathcal{O}(1)$ flavour violating couplings [JHEP 1208:121, 2012].

LHCb

- LHCb is a heavy flavour experiment situated at the LHC.
- Hadronic environment is tough, but make up for it due to huge heavy flavour cross-section at high energies.
- Good momentum resolution and particle identification crucial.
- Results presented today use $1\,\mathrm{fb}^{-1}$ of integrated luminosity - the 2011 dataset. Have another $2\,\mathrm{fb}^{-1}$ from 2012 running.



Isospin asymmetry of $B \to K^{(*)}\mu^+\mu^-$ decays

The isospin asymmetry of $B \to K^{(*)}\mu^+\mu^-$, A_I, is defined as:

$$A_I = \frac{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) - \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) + \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}$$

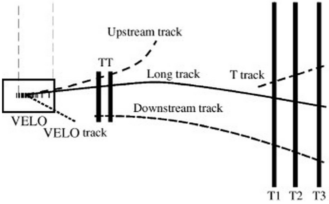
- A_I expected to be $\mathcal{O}(1\%)$ in the SM [JHEP 0301:074,2003],[JHEP 1302:010,2013].
- In 2009, BABAR measured a surprising $3.9\,\sigma$ deviation from zero at low q^2 [Phys. Rev. Lett. 102, 091803] .
- Now significance down to $\sim 2\ \sigma$ and only in the $B \to K\mu^+\mu^-$ mode.

Isospin asymmetry analysis

- Analysis boils down to branching fraction measurements of 4 decays:
  - $B^+ \to (K^{*+} \to K^0_S \pi^+)\mu^+\mu^-$
  - $B^0 \to (K^0 \to K^0_S)\mu^+\mu^-$
  - $B^0 \to (K^{*0} \to K^+\pi^-)\mu^+\mu^-$
  - $B^+ \to K^+\mu^+\mu^-$
- K^0_S mesons are reconstructed through the $K^0_S \to \pi^+\pi^-$ decay mode.
- Do not consider decays involving a π^0 or K^0_L
- K^0_S channels have lower reconstruction efficiency and visible branching fraction than K^+ channels.

Isospin asymmetry analysis

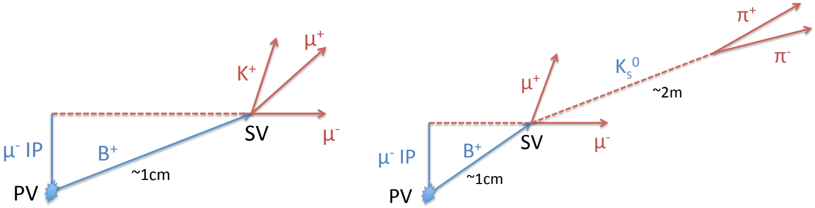
- Split data into categories depending on whether the K_{S}^{0} daughters leave hits in the vertex detector or not (long (L) and down (D)).



- Each decay is normalised to the corresponding $B \to (J/\psi \to \mu^+\mu^-)K^{(*)}$ decay, which have the identical final state.
- These normalisation decays proceed at tree level $\to \mathcal{O}(100)$ times more common than the signal.

Selection

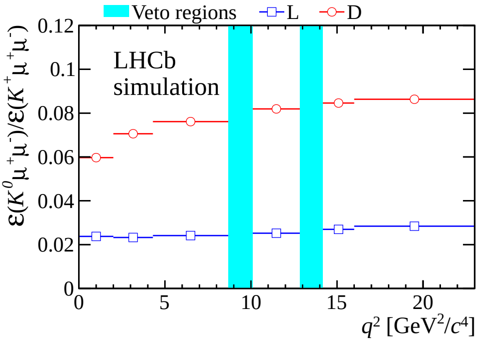
- Reduce combinatorial background using kinematic, geometric and particle identification (PID) information.
- Use multivariate techniques to boost sensitivity.
- Consider exclusive backgrounds and use PID/kinematics to reduce them - neglible after selection.



$B^+ \to K^+\mu^+\mu^-$ $\qquad$ $B^0 \to K^0_S\mu^+\mu^-$

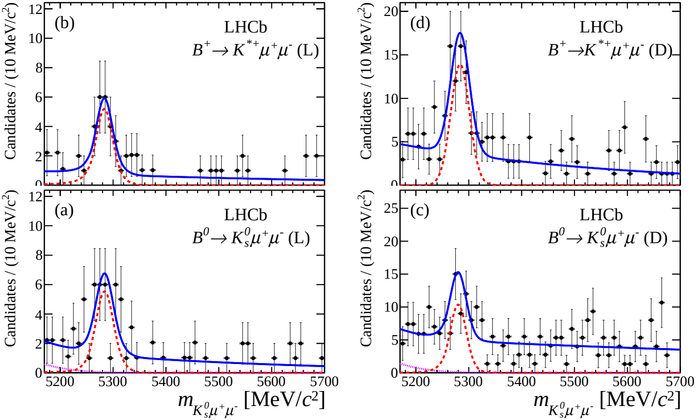
Acceptance correction

- Correct for acceptance effects due to geometry, trigger, reconstruction & selection.
- Bin this acceptance in q^2.
- $B \to (J/\psi \to \mu^+\mu^-)K^{(*)}$ decays are used to normalise each decay which simplifies systematic uncertainties.



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

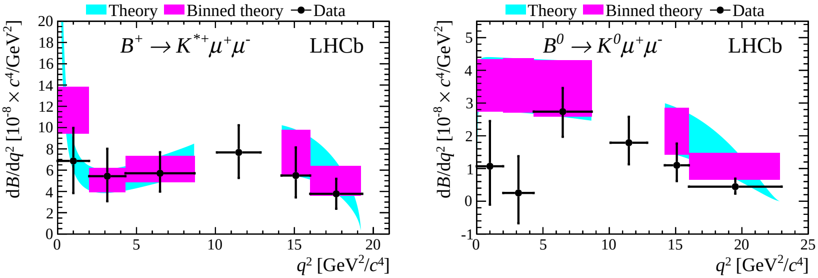
Signal yields determined using unbinned extended maximum likelihood fits.



60-70 signal candidates for the K^0_S channels.

dBF/q^2 ($B^0 \to K^0\mu^+\mu^-$)

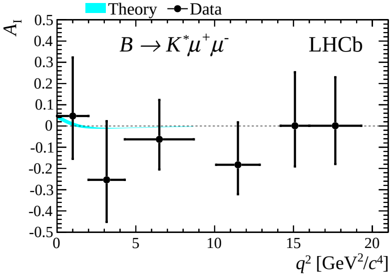
- Branching fraction results, errors are stat + syst.
- There is a deficit of $B^0 \to K^0\mu^+\mu^-$ signal in the q^2 regions which are not adjacent to the charmonium resonances.

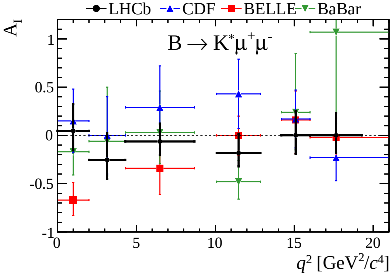


SM predictions based on [JHEP 1201:107, 2012] ($B^+ \to K^{*+}\mu^+\mu^-$) and [JHEP 1107:067,2011] ($B^0 \to K^0\mu^+\mu^-$).

Isospin asymmetry of $B \to K^* \mu^+ \mu^-$

- A_I for $B \to K^* \mu^+ \mu^-$ consistent with zero, as predicted by the SM.
- A_I $(B^0 \to K^* \gamma) = 0.07 \pm 0.03$.
- All experimental results agree with each other.

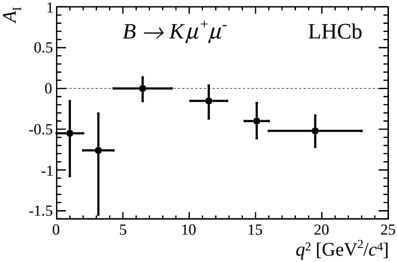


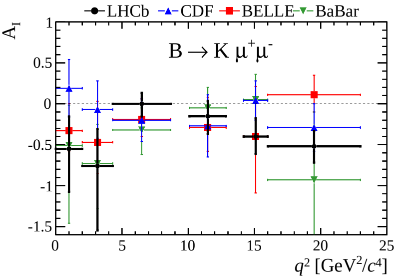


BELLE: [Phys. Rev. Lett. 103, 171801], BABAR: [Phys. Rev. D86, 032012], CDF: [CONF note 108xx]

Isospin asymmetry of $B \to K\mu^+\mu^-$

- A_I for $B \to K\mu^+\mu^-$ tends to sit below the SM prediction, due to the deficit of $B^0 \to K^0\mu^+\mu^-$ shown on the previous slide.
- LHCb measurements alone are over 4σ from zero.
- Nearly all the measurements of A_I are negative - see [HFAG combination] .





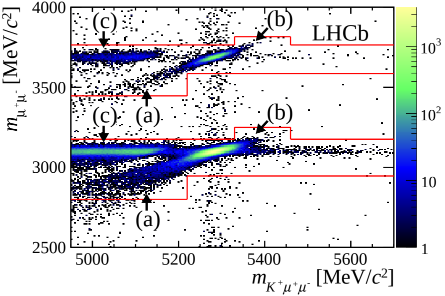
BELLE: [Phys. Rev. Lett. 103, 171801], BABAR: [Phys. Rev. D86, 032012], CDF: [CONF note 108xx]

Summary

- LHCb measurement of the isospin asymmetry in $B \to K\mu^+\mu^-$ decays is over 4σ away from zero ($\sim$ SM expectation).
- No physics model proposed yet can explain this result.
- Looking forward to updating to the full $3\,\text{fb}^{-1}$ dataset where we expect to halve the statistical errors.

Charmonium resonances

- $B \to (J/\psi \to \mu^+\mu^-)K^{(*)}$ and $B \to \psi(2S)h$ are irreducible backgrounds and are $\sim$ 100 and 10 times more common than signal.



- Regions (a) due to FSR, (b) due to mis-reconstruction and (c) due to partially reconstructed background.