Rare B Decays
Standard Model @ LHC 2012, Copenhagen, Denmark

Michelle Nicol, on behalf of the LHCb collaboration

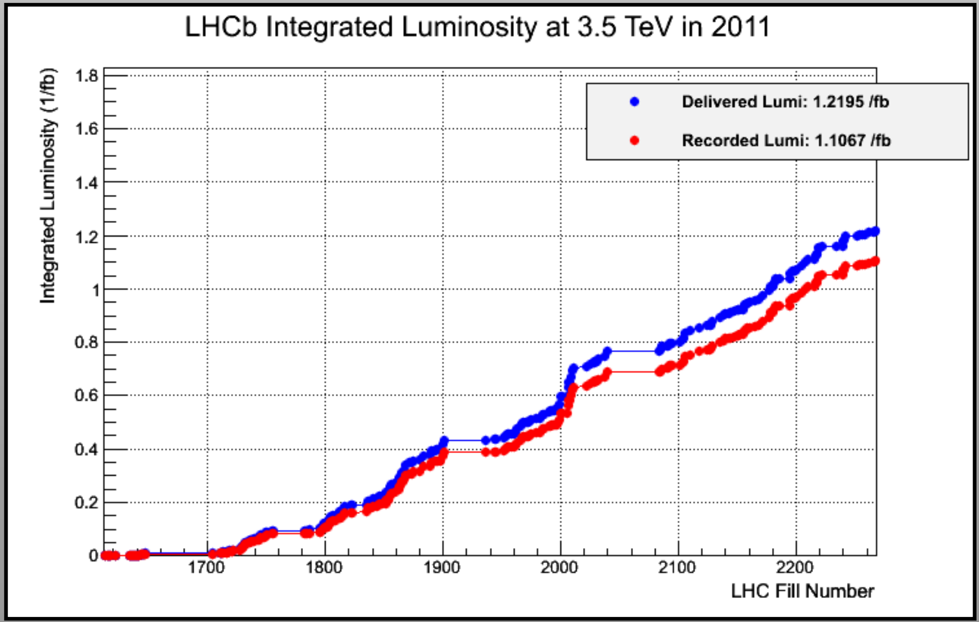
(Some!) Rare B decay results from LHCb

Results presented here probe Flavour Changing Neutral Currents (FCNC)

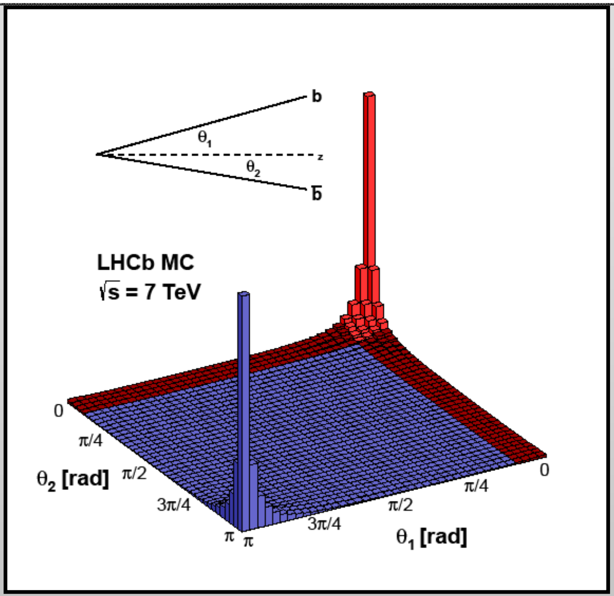
- Forbidden at tree level in the SM
- Sensitive to new physics, as new particles could manifest in the loop, and cause deviations from standard model predictions. Can change branching fractions, angular distributions, CP violation.
- Indirect searches complimentary to direct searches at the GPDs.

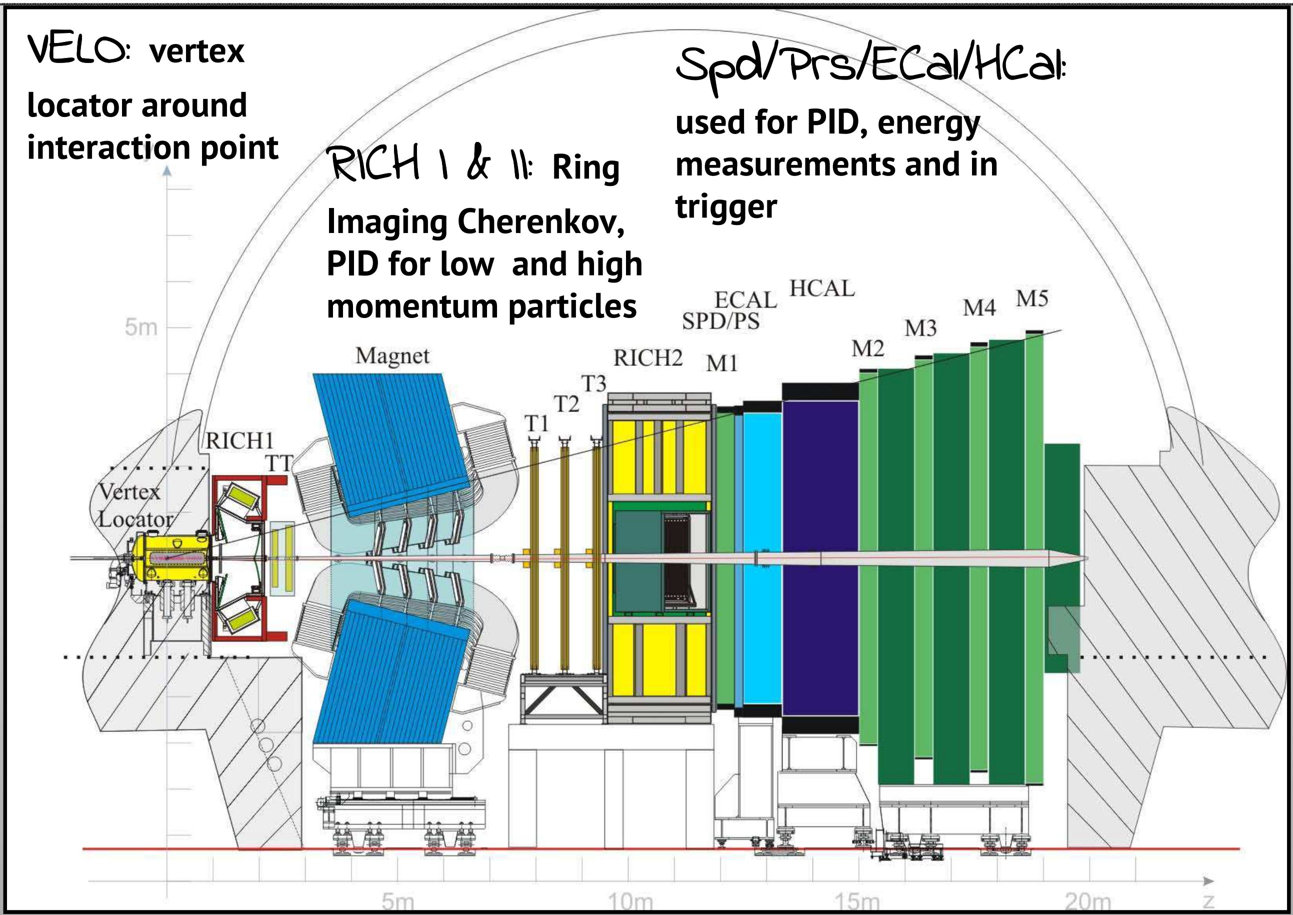
With 1 fb^{-1} of LHCb data, collected in 2011:

- $B_{d,s} \to \mu\,\mu$
- $B_{d,s} \to \mu\,\mu\,\mu\,\mu$
- $B^{+} \to \pi^{+}\mu\,\mu$
- $B^{0} \to K^{*}\gamma$: A_{CP}
- $B^{0} \to K^{*}\mu\,\mu$



The LHCb detector





VELO: **vertex locator around interaction point**

RICH I & II: **Ring Imaging Cherenkov, PID for low and high momentum particles**

Spd/Prs/ECal/HCal: **used for PID, energy measurements and in trigger**

Optimised for B physics:

2×10^{11} B hadrons in LHCb acceptance in 2011

Excellent PID, efficient trigger, precision vertexing and tracking

other LHCb talks this conference

Jet measurements in LHCb and their relevance for pdfs: Marcin Kucharczyk
Electroweak results at LHCb: Katharina Mueller
Phi_s measurements: Conor Fitzpatrick
Gamma from B→DK: Sneha Malde
CPV in B→ hh: Luigi Li Gioi
Charm results: Chris Thomas

$B_{d,s} \rightarrow \mu\ \mu$

$B_{d,s} \to \mu\mu$: Analysis outline

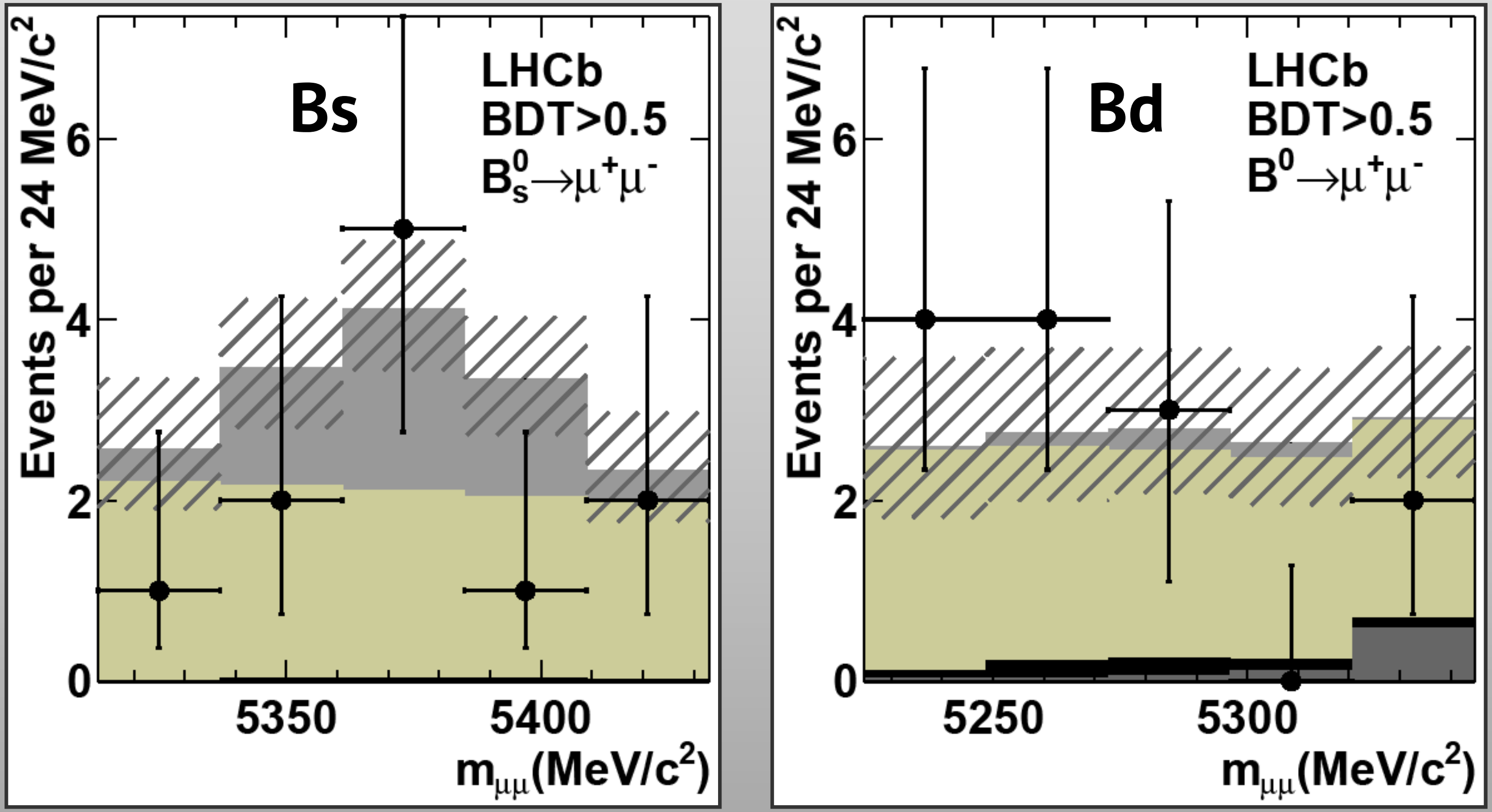
Branching ratios in SM predicted to be:

$BR(B_s \to \mu\mu) = (3.2 \pm 0.2) \times 10^{-9}$, $BR(B_{d,} \to \mu\mu) = (0.1 \pm 0.01) \times 10^{-9}$ A. J. Buras [1 ,2]

Can be significantly enhanced by scalar and pseudo-scalar operators (MSSM, $BR(B_s \to \mu\mu) \sim \tan^6\beta$.)

At LHCb:

- Background reduced using a Boosted Decision Tree (Multivariate discriminant trained on MC using kinematical and geometrical variables (eg Vertex Chi2, impact parameters, direction between B momentum and direction, PT.)
- BDT response and mass PDFs are calibrated from data using $B \to hh$ and dimuon resonances.
- Use three normalization modes. Allows for evaluation of different systematics, and the weighted average is used as final result.
- Divide the data into 8 bins of BDT output and 9 mass bins (optimised with MC toys)
- For each bin, compute the expected signal and background and count the candidates observed.
- Compatibility of observed distribution with given BR computed using CLs method [3]



More sensitive BDT bins

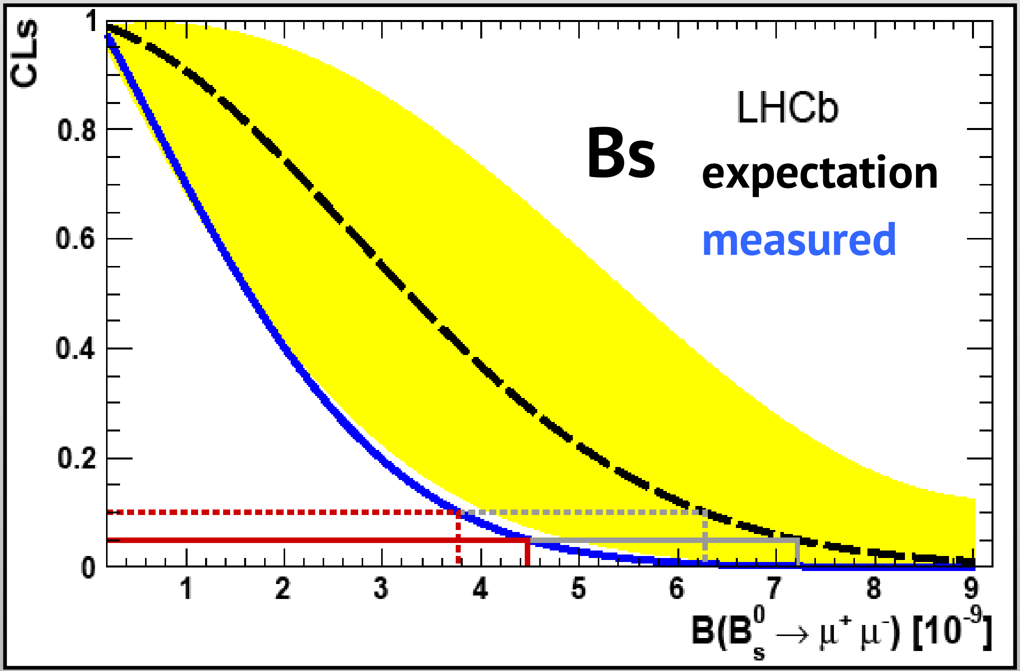
signal

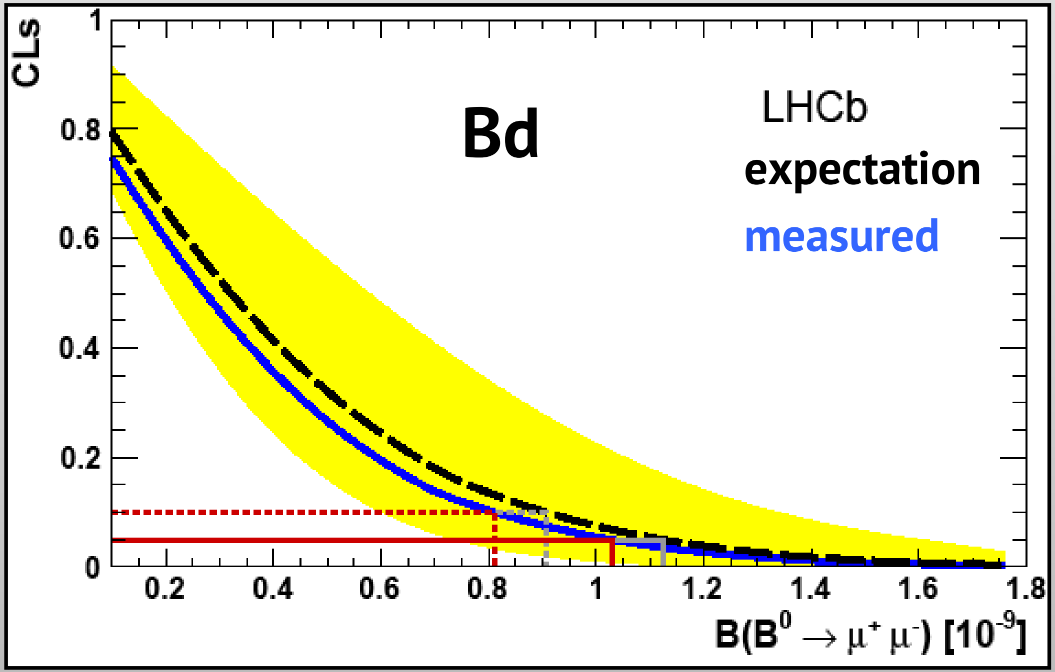
combinatorics

cross-feed

B→hh

Events observed with 1 fb^{-1} at LHCb consistent with expected background and SM signal





Measure ***BR*($B_s \to \mu\mu$)< 4.5 x 10^{-9}** and ***BR*($B_d \to \mu\mu$)<1.03 x 10^{-9}** at 95% C.L.

cf ***BR*($B_s \to \mu\mu$)< 7.7 x 10^{-9}** [CMS-BPH-11-020] 5 fb^{-1}

***BR*($B_s \to \mu\mu$)< 22 x 10^{-9}** [ATLAS-CONF-2012-010] 2.4 fb^{-1}

By performing a simultaneous maximum likelikhood fit to the mass distributions in the 8 BDT bins, estimate branching fraction to be ***BR*($B_s \to \mu\mu$)=($0.8^{+1.8}_{-1.3}$)x 10^{-9}**

Increasingly constrains SUSY parameter space

$B_{d,s} \rightarrow \mu\ \mu\ \mu\ \mu$

$B_{d,s} \to \mu\ \mu\ \mu\ \mu$: The search

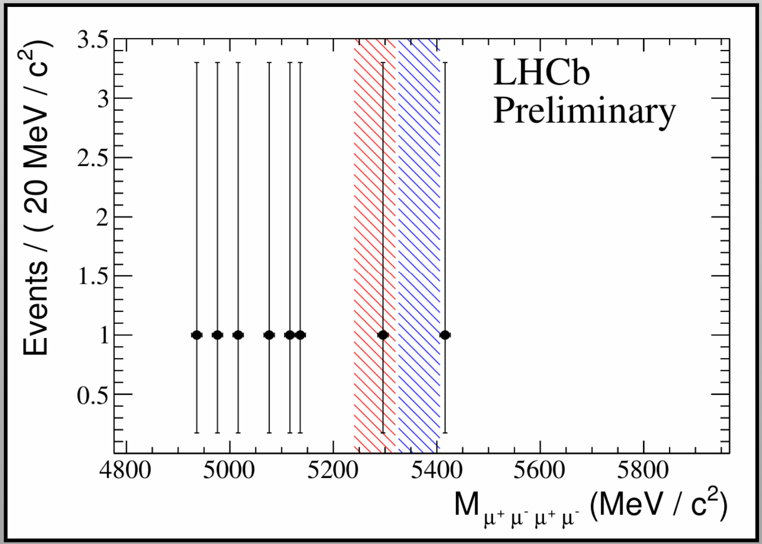
Strongly suppressed in SM.

Largest contribution from $B_s \to J/\Psi\Phi$, estimated *BR*= $(2.3\pm0.9) \times 10^{-8}$ [4]

Non-resonant decay predicted to be $<10^{-10}$ D. Melikhov and N. Nikitin [5]

Can be significantly enhanced by new particles decaying into dimuon pairs. S. Demidov and D. Gorbunov [6]

$B \to \mu\mu\mu\mu$ (Both J/Ψ and Φ resonance vetoed)



Bd signal window

Bs signal window

The observed events are consistent with the expected background yield.

First limits on branching fractions:

$BR(B_s \to \mu\ \mu\ \mu\ \mu) < 1.3 \times 10^{-8}$

$BR(B_{d,} \to \mu\ \mu\ \mu\ \mu) < 5.4 \times 10^{-9}$

at 95% C.L.

$B^+ \rightarrow \pi^+ \mu \mu$

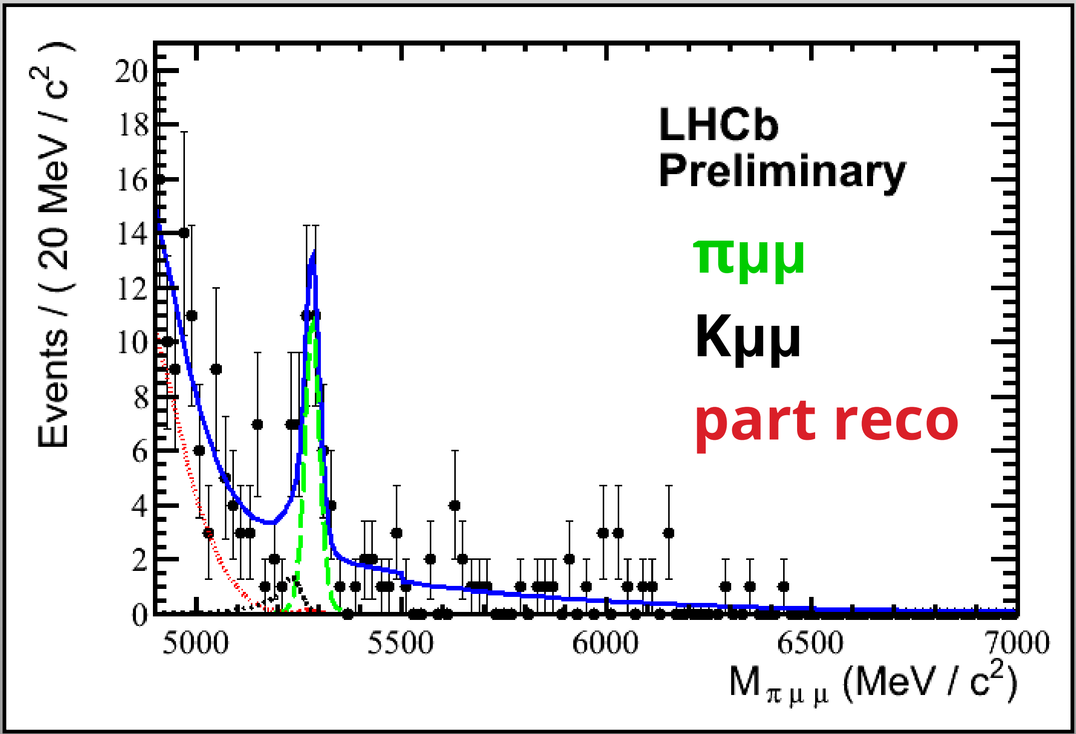
$B^+ \to \pi^+ \mu \mu$: First observation

No $b \to d\, l^+ l^-$ transition has previously been observed.

In SM, it is suppressed by a factor $|V_{td}/V_{ts}|^2$ relative to $b \to s\, l^+ l^-$

Can envisage new physics models where this suppression doesn't apply.

In SM, $BR(B^+ \to \pi^+ \mu \mu) = (1.96 \pm 0.21) \times 10^{-8}$ S. Hai-Zhen, L/ Lin-Xia and L. Gong-Ru [7]



Observe 25 $^{+6.7}_{-6.4}$ events with 5.2σ significance.

$BR(B^+ \to \pi^+ \mu \mu) = (2.4 \pm 0.6 \pm 0.2) \times 10^{-8}$

The rarest B decay ever observed.

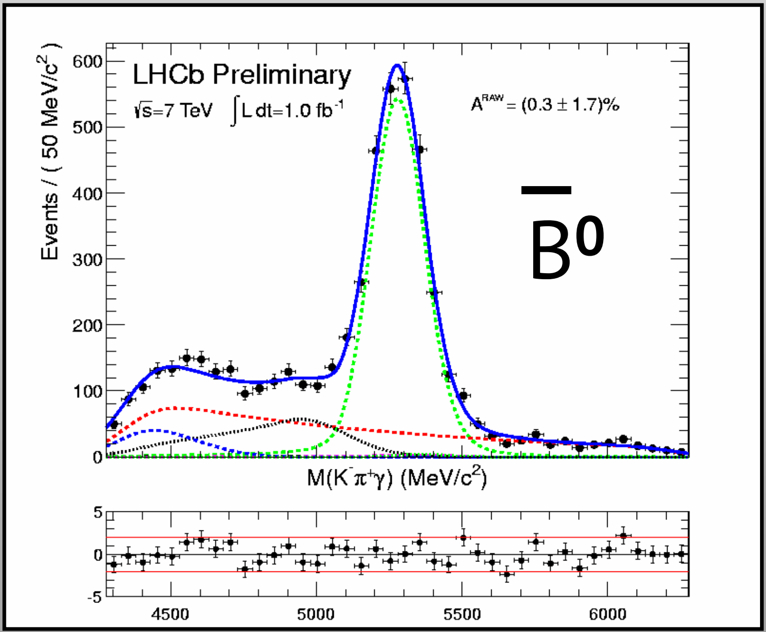
$B^0 \to K^* \gamma$

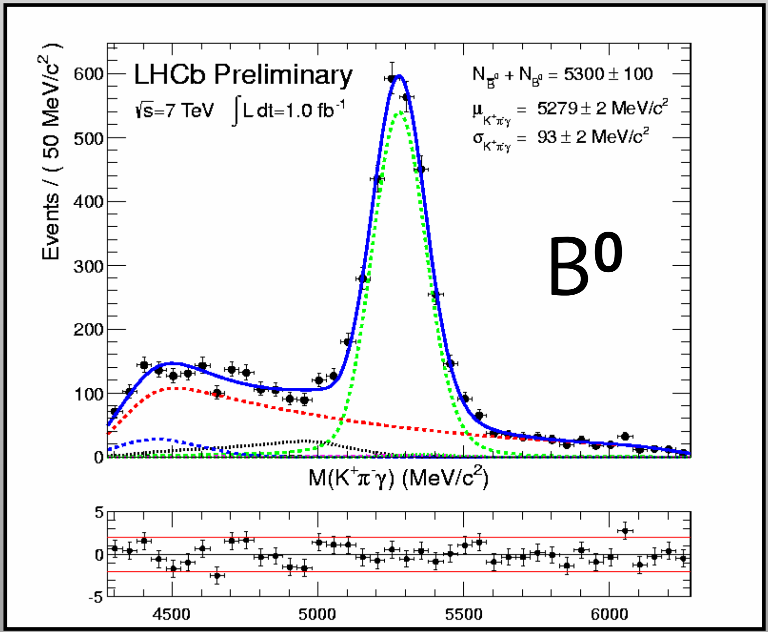
$B^0 \to K^*\gamma$: CP aysmmetry

The theoretical uncertainty on the SM prediction of direct CP asymmetry is smaller than that on the branching ratio prediction

$A_{CP}^{SM}(B^0 \to K^{*0}\gamma) = -0.0061 \pm 0.0043$ Y. Y. Keum, M. Matsumori and A. I. Sanda[8]

Extract raw asymmetry from unbinned simultaneous fit to the mass distributions of B^0 and $\bar{B}^0$ candidates.





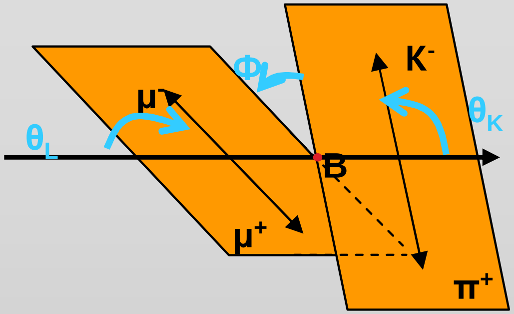
$A_{Raw}(B^0 \to K^{*0}\gamma) = A_{CP}(B^0 \to K^{*0}\gamma) - A_{Det}(K\pi) - \kappa A_{Prod}(B^0)$ (κ is dilution factor dure to B oscillation)

$A_{CP}(B^0 \to K^{*0}\gamma) = -0.008 \pm 0.017 \pm 0.009$ (LHCb preliminary)

cf. previous best measurement from BaBar: Acp=-0.016 ± 0.022 ±0.007 [9]

$B_d \rightarrow K^* \mu \mu$:

$B_d \to K^* \mu\mu$: Angular analysis



Fully described by three angles, θ_L, θ_K, Φ and q^2= Mass^2(μ μ).

Performing angular analysis with 1 fb^{-1} of 2011 data measure the following parameters: [10]

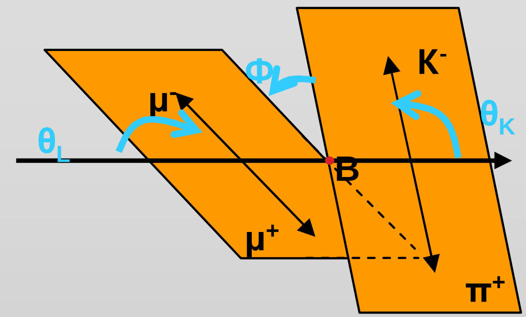
- A_{FB} Forward backward asymmetry of dimuon system
- F_L Fraction of longitudinal polarisation of the K^*
- S_3 Transverse asymmetry
- A_{im} T-odd CP asymmetry

And also differential branching ratio.

Gives access to $C_7^{(\prime)}$, $C_9^{(\prime)}$, $C_{10}^{(\prime)}$

$B_d \to K^* \mu\mu$: Angular analysis

Fully described by three angles, θ_L, θ_K, Φ and q^2= Mass^2($\mu\mu$).



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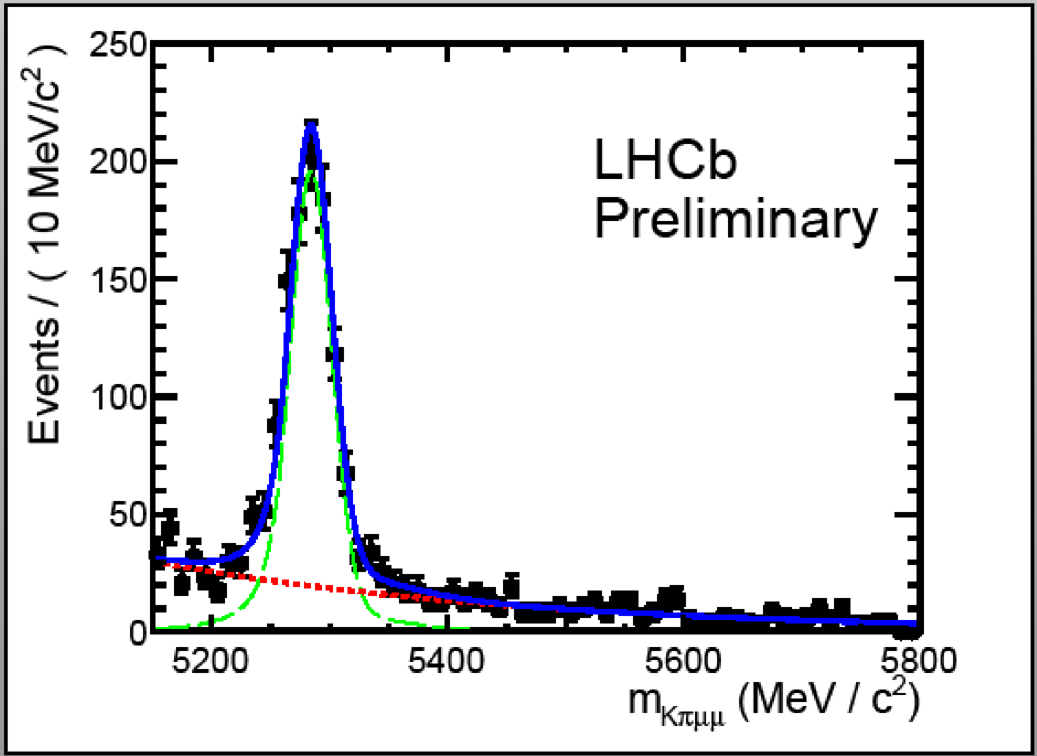
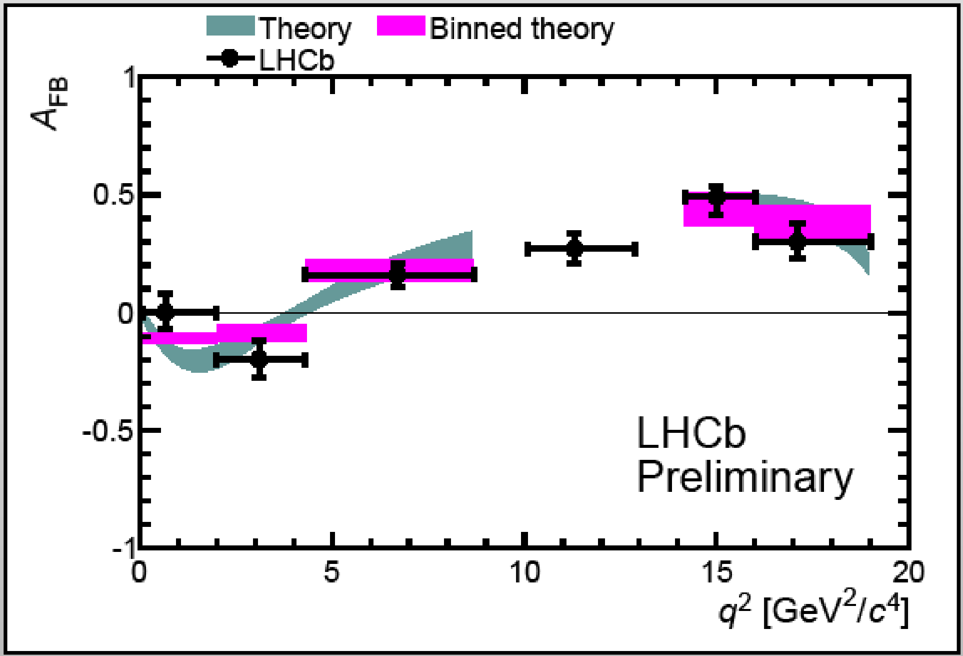
At LHCb, use BDT to reduce combinatorical background,and PID for peaking backgrounds.

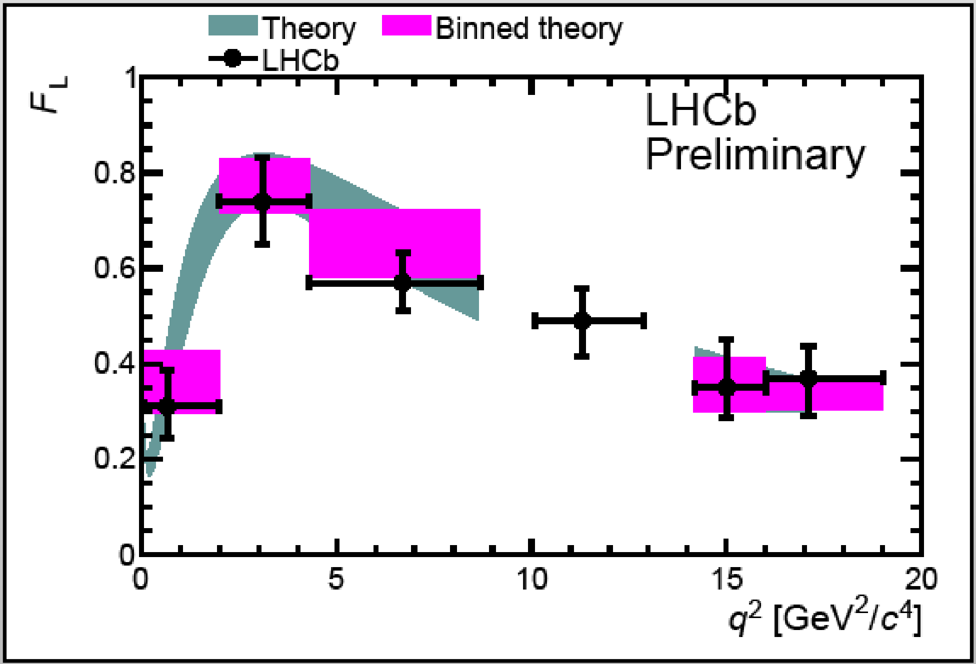
Analysis sensitive to angular acceptance. Care taken to avoid bias: No PT used in BDT

Observe 900 candidates (BaBar+Belle+CDF ~600 events)

Angular acceptance from detector corrected using simulation.







- A_{Im} ~and S3 shown in backup
- Points include both statistical and systematic uncertainties
- Systematic uncertainties typically small compared to statistical
- Theory predictions found in [11]

Most precise measurements of these quantities to date and fully consistent with SM predictions

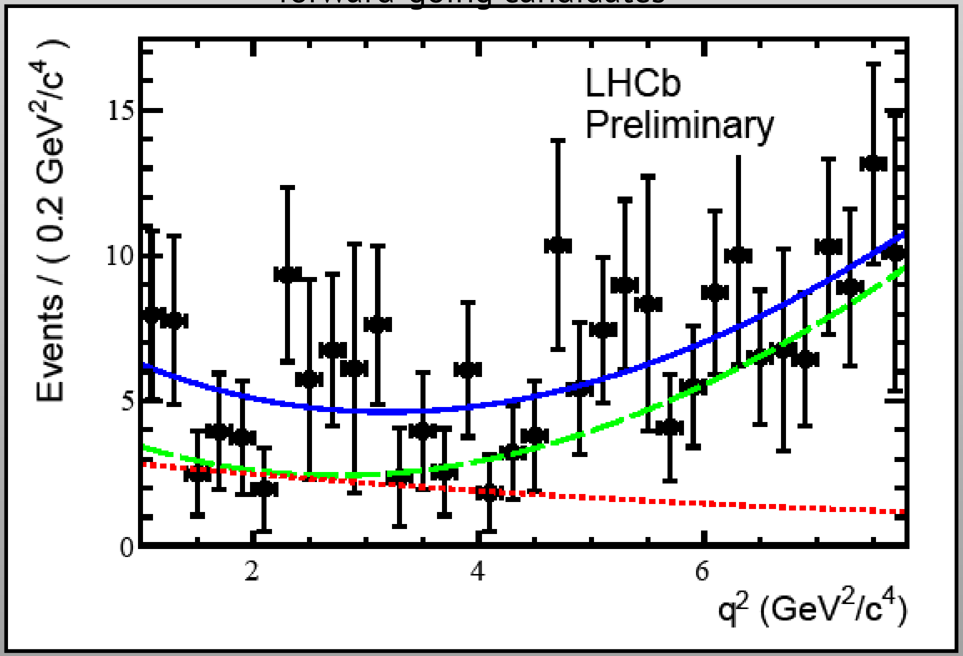
$B_d \to K^*\mu\mu$: zero crossing point

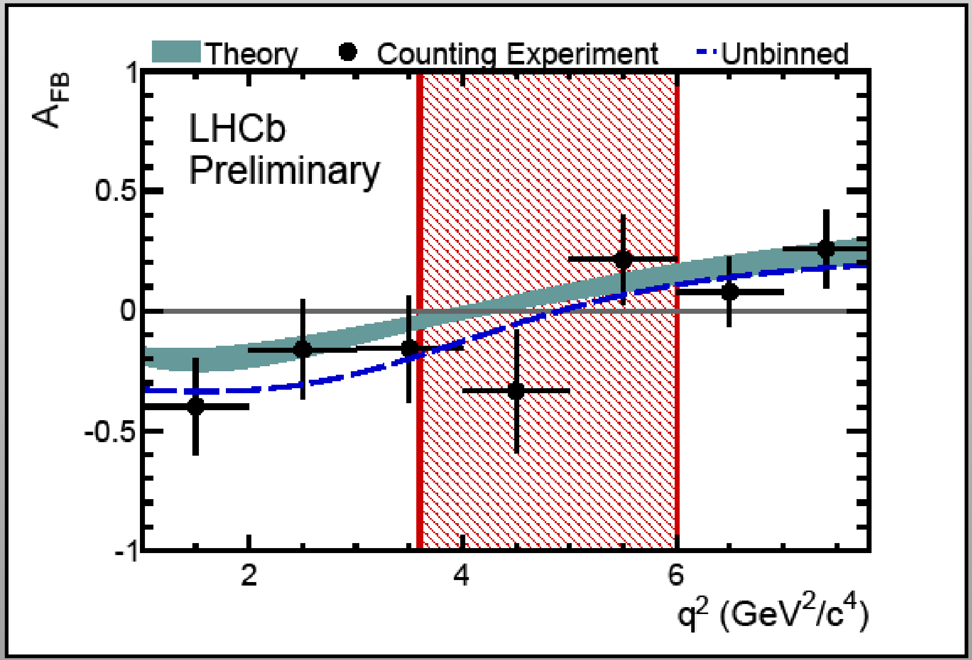
In SM, $A_{FB}(q^2)$ changes sign at well defined q_0^2, free from form-factor uncertainties.

This is estimated by extracting the q^2 distribution for the forward- and backward-going candidates separately, using unbinned fits to m_{B0} and q^2.

The red hatched area is 68% confidence level on observed zero crossing point.

forward-going candidates





- world's first measurement: $q_0^2 = 4.9^{+1.1}_{-1.3}$ **GeV** (LHCb preliminary)
  - SM predictions range from 4.0-4.3 GeV [12-14]

Summary

World's most precise measurements:

- **$B_{d,s} \rightarrow \mu\, \mu$**

  Best limits to date

  Also measured (see charm talk by Chris Thomas) $D \rightarrow \mu\, \mu$ limits

  Coming soon: $K_s \rightarrow \mu\mu$

- **$B_d \rightarrow \mu\, \mu\, \mu\, \mu$**

  First limits

- **$B^+ \rightarrow \pi^+ \mu\, \mu$**

  First branching fraction measurement

- **$B^0 \rightarrow K^* \gamma$**

  direct CP asymmetry

  Coming soon: updated result with 1 fb^{-1} of $BR(B^0 \rightarrow K^* \gamma)$/ $BR(B_s \rightarrow \Phi\gamma)$

- **$B^0 \rightarrow K^* \mu\, \mu$**

  angular variables

  zero crossing point

  branching fraction

  Also measured $B_s^0 \rightarrow \Phi \mu\, \mu$ branching fraction

  Coming soon: Isospin asymmetry, $B^0 \rightarrow K^* ee$, $B^+ \rightarrow K^+ \mu\mu$, $B^0 \rightarrow K_s \mu\mu$, $\Lambda_b \rightarrow \Lambda^* \mu\mu$ ...

References

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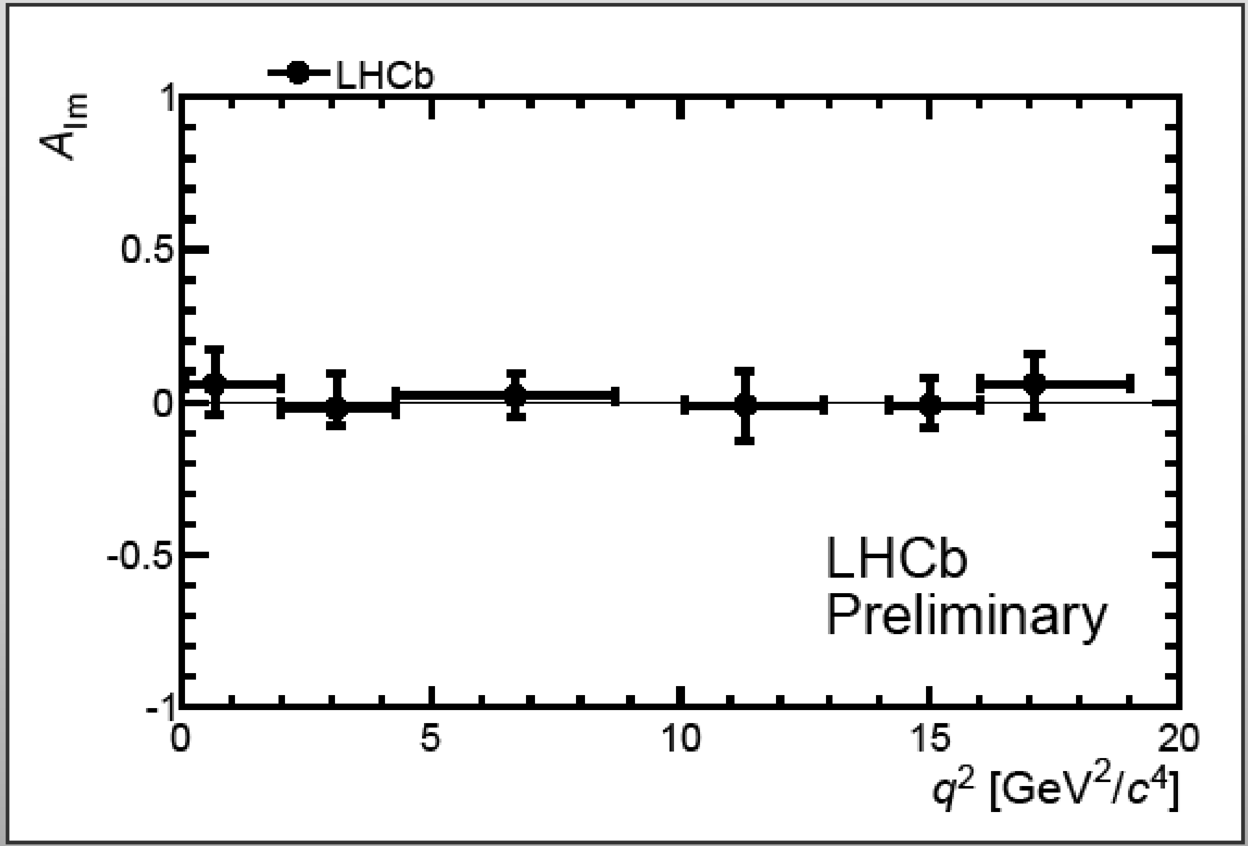
Backup



A_{Im} ~O(10^{-3}) in SM

$B_d \to K^*\mu\mu$: Angular analysis results

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