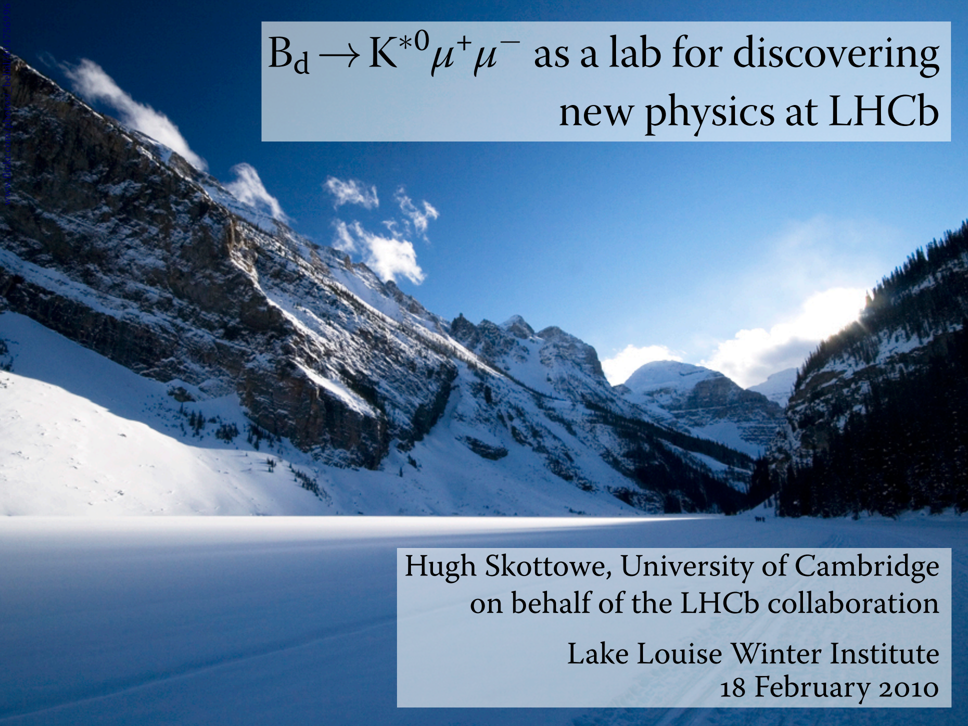
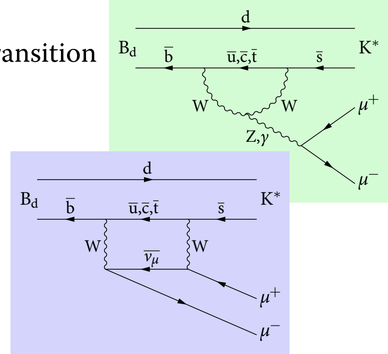


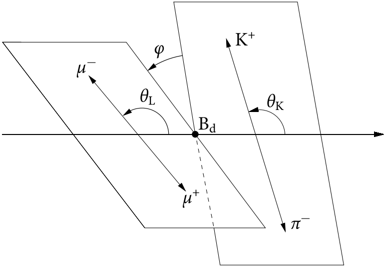
$B_d \to K^{*0}\mu^+\mu^-$ as a lab for discovering new physics at LHCb

Hugh Skottowe, University of Cambridge
on behalf of the LHCb collaboration

Lake Louise Winter Institute
18 February 2010

- Flavour changing neutral current: b→s transition
- Proceeds via loop and box diagrams
- Has been observed, with [PDG09]:
  $BR = (9.8 \pm 2.1) \times 10^{-7}$
- Decay described by three angles θ_L, θ_K, ϕ & $\mu\mu$ invariant mass squared q^2 (or s)
- Many interesting observables for new physics
- e.g. forward-backward asymmetry of muons, A_{FB}
- A_{FB} formed from helicity angle θ_L and varies with q^2

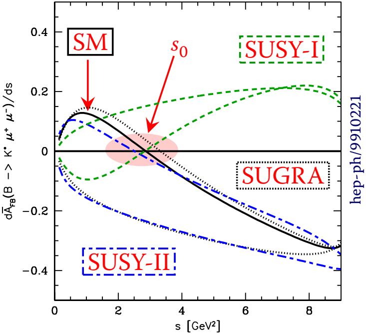


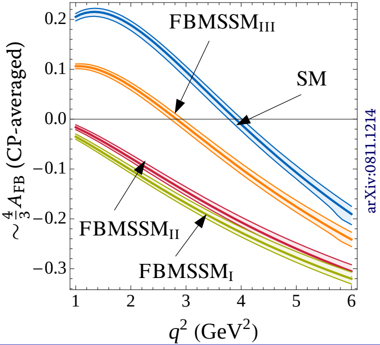


Introduction *cont.*

- $A_{\rm FB}$ can be predicted precisely in Standard Model
- Hadronic uncertainties cancel at zero-crossing point, s_0, of $A_{\rm FB}$
- Best theoretical control in $1 < q^2 < 6\,\mathrm{GeV}^2$

- Use model-independent Operator Product Expansion
- Dominated by Wilson coefficients $\mathcal{C}_7, \mathcal{C}_9, \mathcal{C}_{10}$ in Standard Model



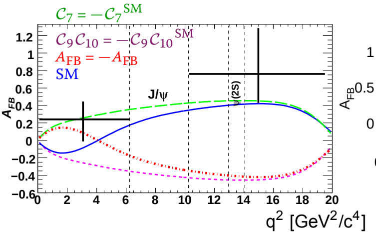


Status

- BaBar, Belle and CDF have each observed $\mathcal{O}(100)$ events
- Measurements of branching ratio and $A_{\text{FB}}(q^2)$

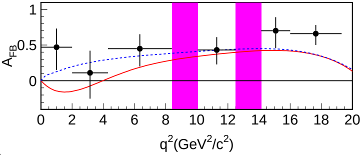
(384 M $B\bar{B}$ pairs)

PRD **79** 031102 (0804.4412)

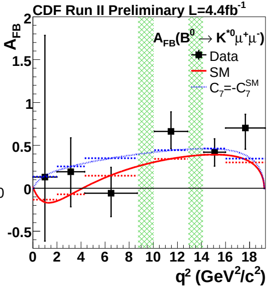


(657 M $B\bar{B}$ pairs)

PRL **103** 171801 (0904.0770)

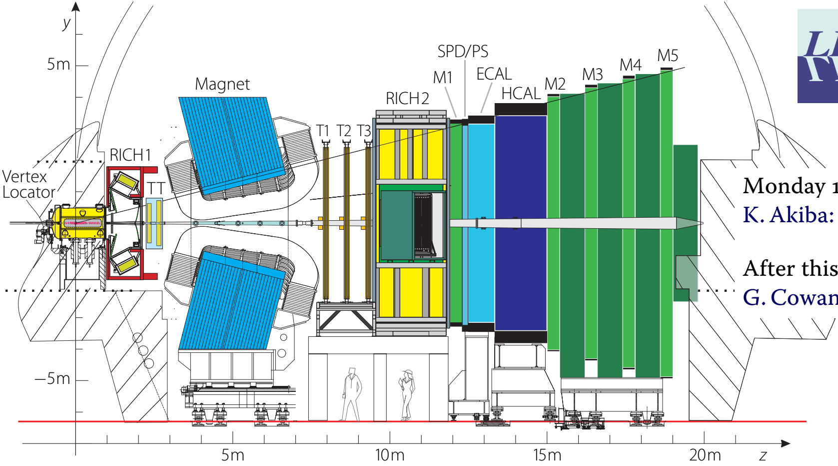


CDF note 10047



Note: opposite sign convention to previous slide for A_{FB}

The LHCb experiment

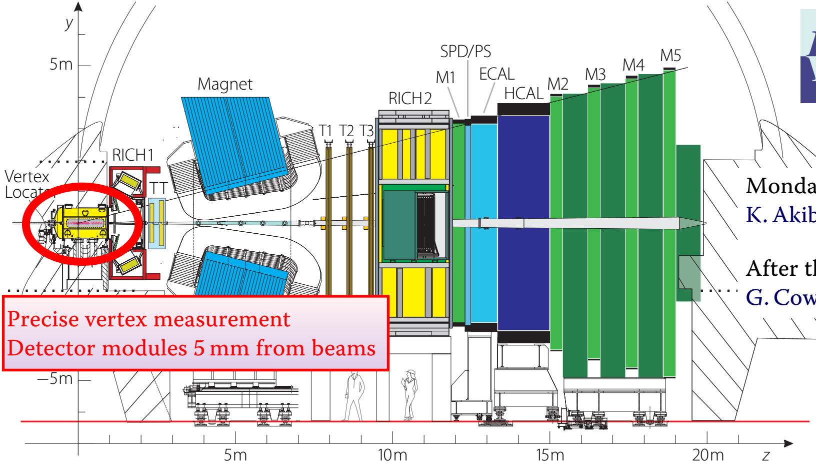


Monday 17:30:
K. Akiba: 2009 run

After this talk:
G. Cowan: $B_s \to J/\psi\,\phi$

- Dedicated b-physics experiment at the LHC

The LHCb experiment



Precise vertex measurement
Detector modules 5 mm from beams

Monday 17:30:
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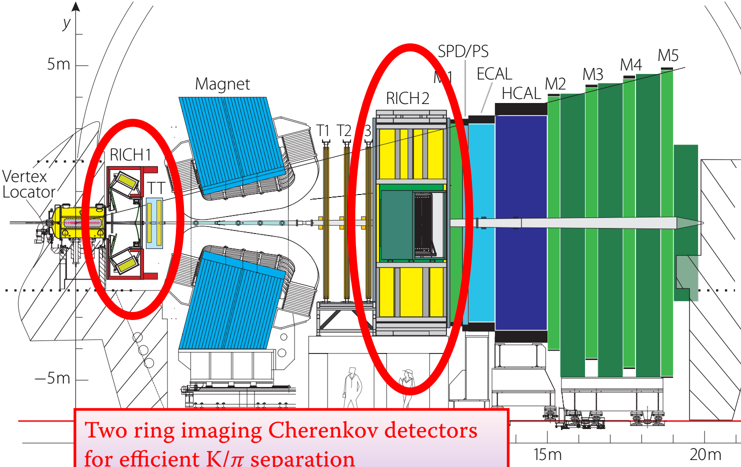
The LHCb experiment



Two ring imaging Cherenkov detectors
for efficient K/π separation

Monday 17:30:
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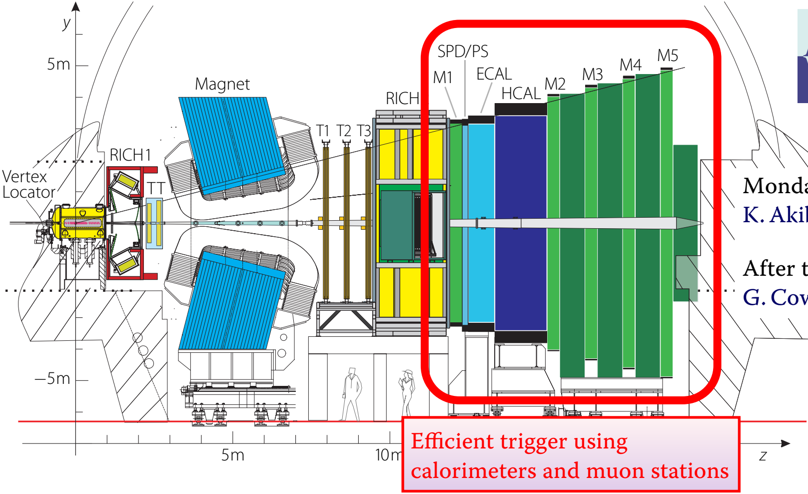
- Dedicated b-physics experiment at the LHC

The LHCb experiment



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- Dedicated b-physics experiment at the LHC

Event trigger and selection

Hardware ('Level 0') trigger:

- Cuts on single μ p_T, or $\left(p_{T,\mu 1} + p_{T,\mu 2}\right)$
- $\sim$93% efficiency

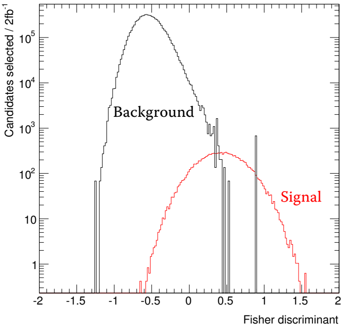
Software ('High Level') trigger:

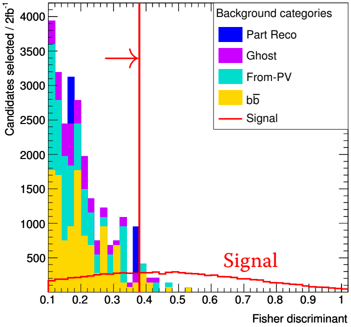
- Cuts on Impact Parameter & p_T of single μ, or IP & vertex displacement of μ+track
- $\sim$95% efficiency

Offline event selection:

- Cut on Fisher discriminant
  - Relies mostly on B_d vertex χ^2, p_T, flight distance, Kaon ID
- Veto possible mis-ID backgrounds from $B_s \to \phi\mu\mu$ and $B_d \to (X \to Y\pi)(J/\psi \to \mu\mu)$
- Expected event yields / 2 fb^{-1}:
  - $S = 6200^{+1700}_{-1500}$
  - $B = 1550 \pm 310$

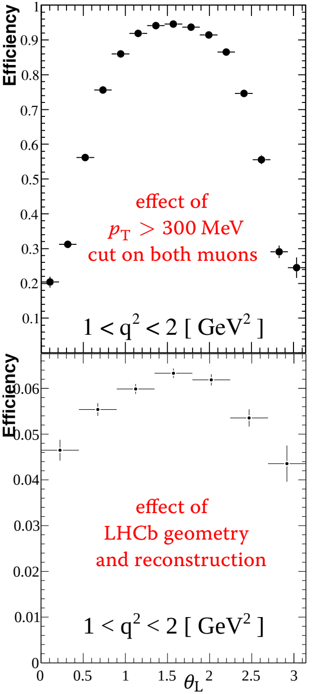
LHCb-2009-009





Acceptance correction

- Acceptance can vary with θ_L, and therefore shift measured value of A_{FB}
- Can be caused by p,p_T cuts on both muons, detector geometry, or reconstruction
- Have avoided such cuts in trigger and selection
- Largest effect is from LHCb geometry: requirement for muons to reach muon detectors is equivalent to $p > 3$ GeV cut on both muons
- Acceptance correction using $B_d \to J/\psi K^{*0}$ control channel also under investigation
- Correction is under control

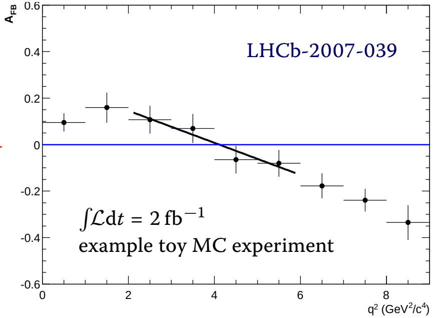


arXiv:0912.4179

Measuring A_{FB}

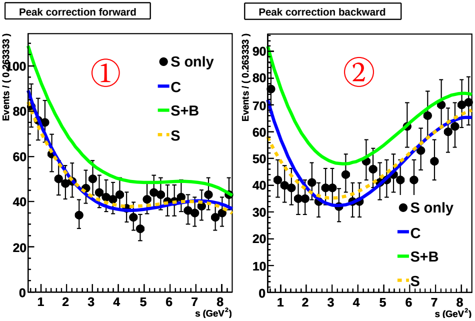
Two options considered:

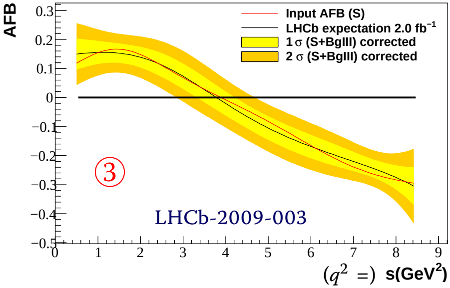
- Count forward and backward events in bins of q^2



Or:

- Fit forward ① and backward ② events and subtract polynomials ③

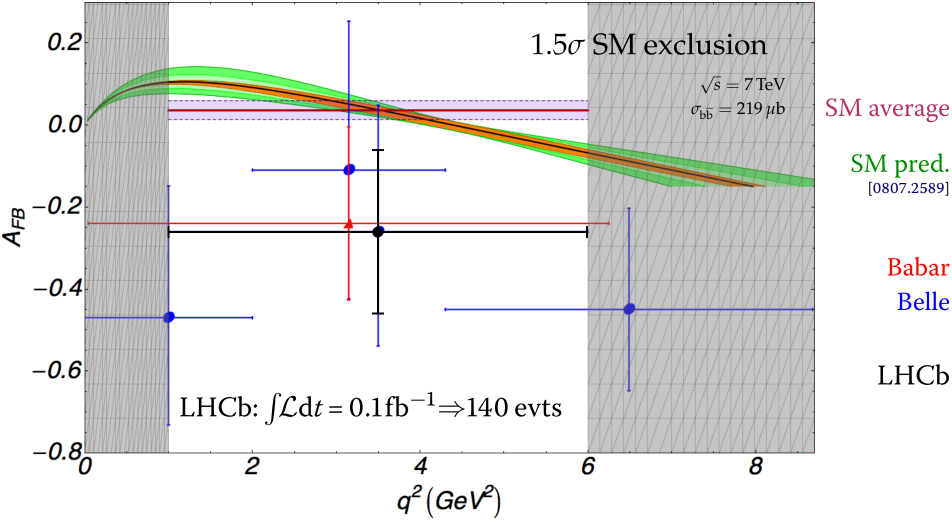




- Both methods perform similarly: $\sigma(s_0) = 0.5\,\text{GeV}^2$ after $2\,\text{fb}^{-1}$

LHCb's sensitivity to $A_{\rm FB}$: what can we do with early data?

- 3.5+3.5 TeV running recently announced, for first 18-24 months
  $\Rightarrow$ $b\bar{b}$ production cross-section reduced by $\sim$2 from nominal 7+7 TeV



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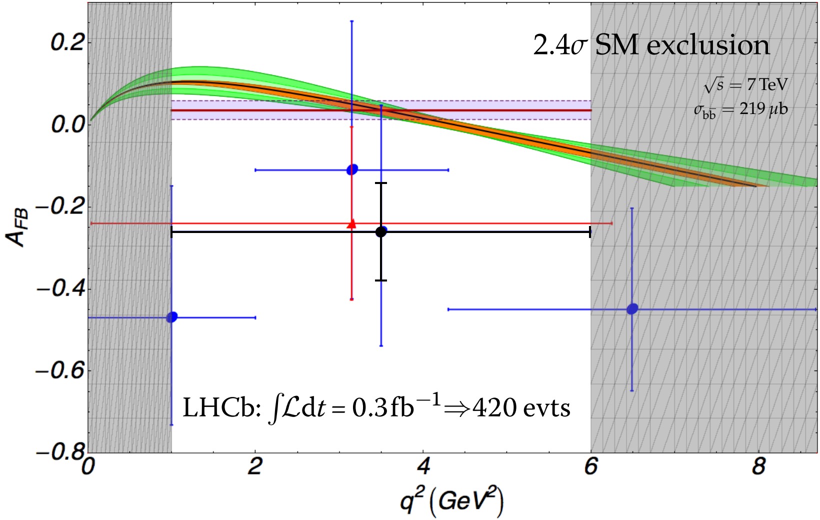

SM average

SM pred.
[0807.2589]

Babar
Belle

LHCb

LHCb's sensitivity to A_{FB}: what can we do with early data?

- 3.5+3.5 TeV running recently announced, for first 18-24 months

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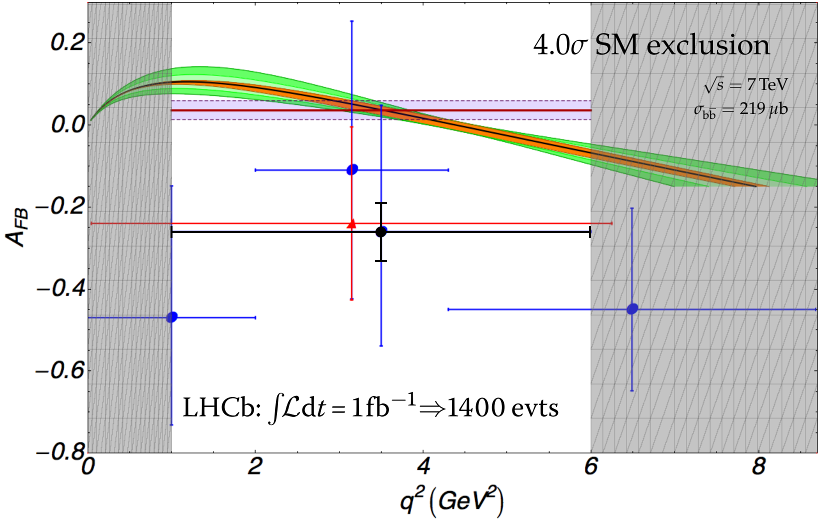


SM average

SM pred.
[0807.2589]

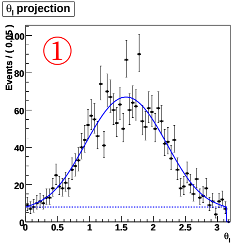
Babar

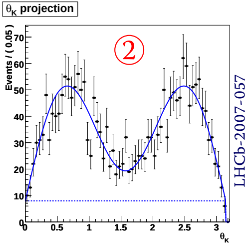
Belle

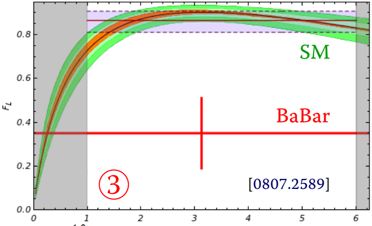
LHCb

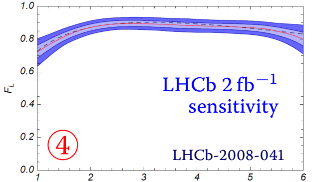
What can LHCb do with more data?

- Access other observables
- Angular projections ①,②
  $\Rightarrow$ longitudinal polarization F_L ③,④

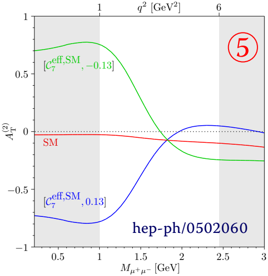


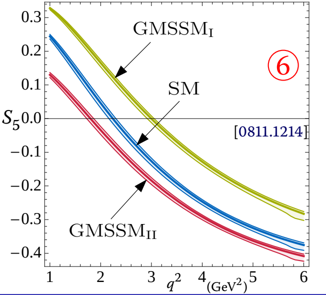






- Full angular fit
  — Need $> 2\ \text{fb}^{-1}$ for fits to converge
  $\Rightarrow$ More observables e.g. $A_T^{(2)}$ ⑤, S_5 ⑥



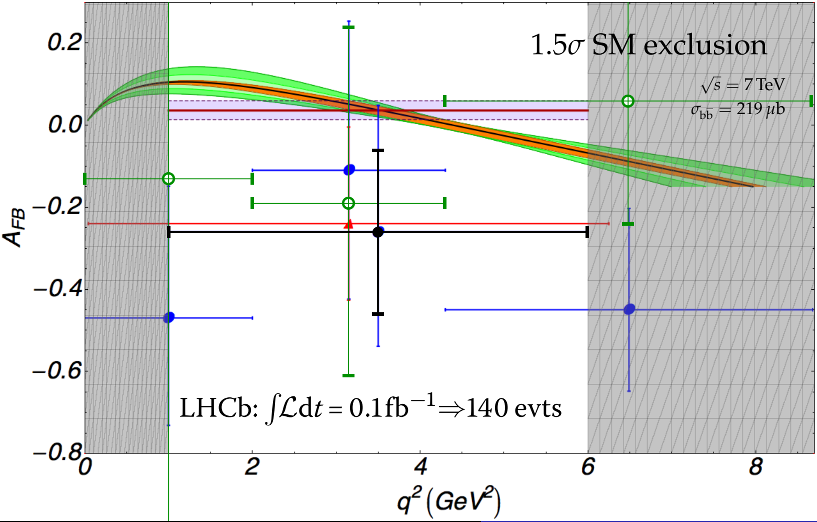


Summary

- $B_d \to K^{*0}\mu\mu$ has properties such as A_{FB} that are precisely predicted in Standard Model and other models
- Decay is very sensitive to new physics
- LHCb is ideally suited to study of this decay
- Yields will be comparable to B factories & CDF with $0.1\,fb^{-1}$
  $\Rightarrow$ Will quickly achieve precise measurements of A_{FB}
- Many further interesting observables will be measured precisely with $> 2\,fb^{-1}$

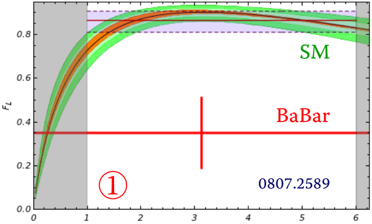
What can LHCb do with early data?

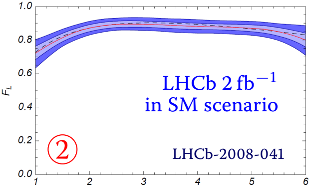
- CDF: dark green open circles

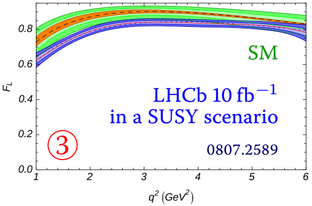


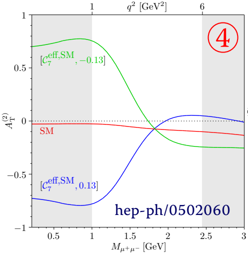
What can LHCb do with more data?

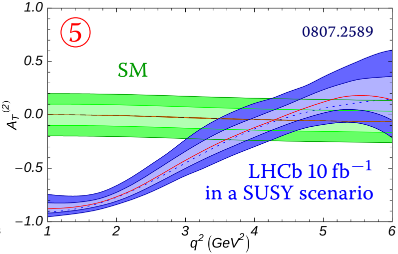
- Access other observables
- Angular projections
  e.g. longitudinal polarization F_L ①-③
- Full angular fit
  - Need $> 2\ \text{fb}^{-1}$ for fits to converge
  - More observables
  - e.g. transverse asymmetry $A_T^{(2)}$ ④,⑤
    – sensitive to sign and magnitude of $\mathcal{C}_7'$

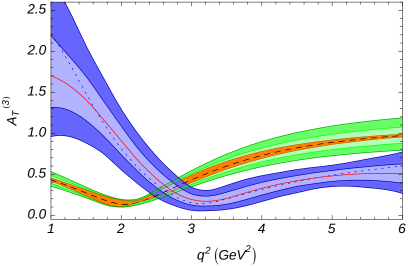


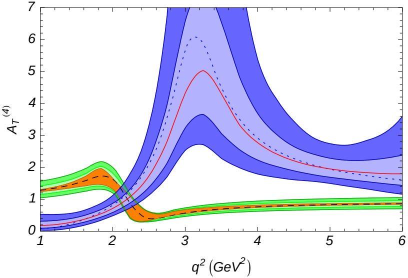












Green: SM prediction

Blue: LHCb 10 fb^{-1} sensitivity in a SUSY scenario

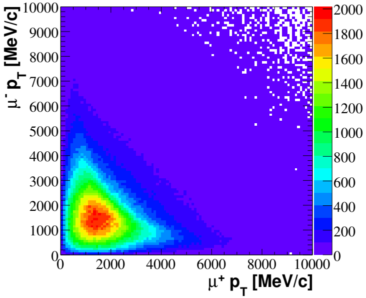
JHEP 11 (2008) 032 / 0807.2589

Acceptance correction with control channel

- $B_d \to K^{*0}(J/\psi \to \mu\mu)$ control channel has $q = m_{\mu\mu}$ constrained: $q = m_{J/\psi}$

  $\Rightarrow$ different kinematics

$B_d \to K^{*0}\mu\mu$



$B_d \to K^{*0}(J/\psi \to \mu\mu)$