B-physics at the LHC

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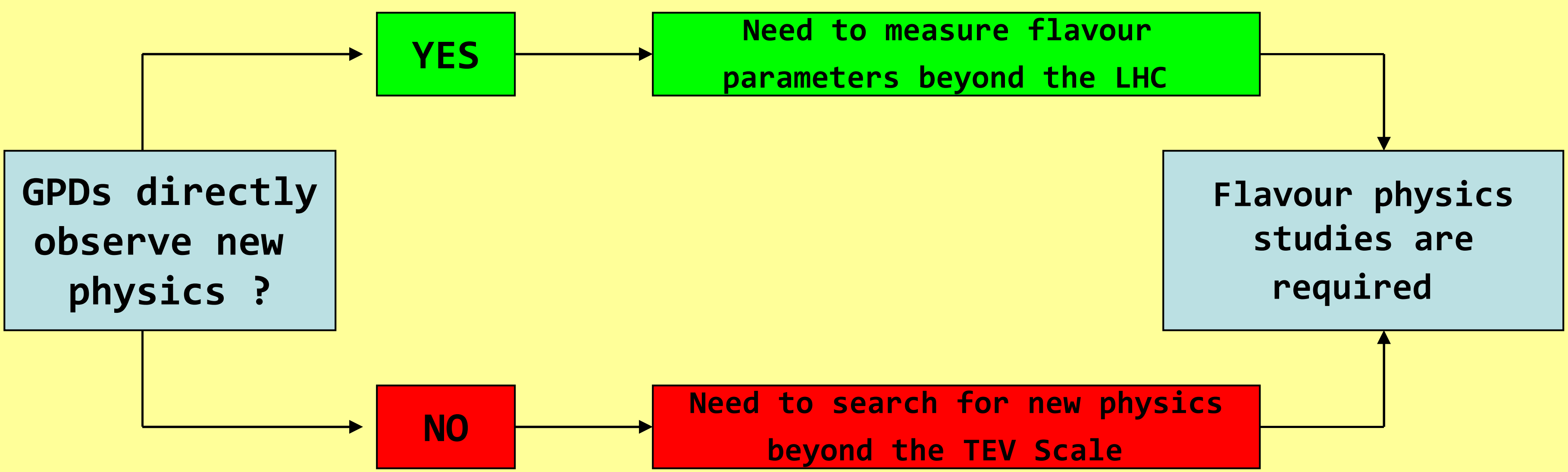
On behalf of the LHCb collaboration
Science and Technology Facility Council
Rutherford Appleton Laboratory

Beyond 2010, 1 - 6 february

WHY B (FLAVOUR) PHYSICS ?

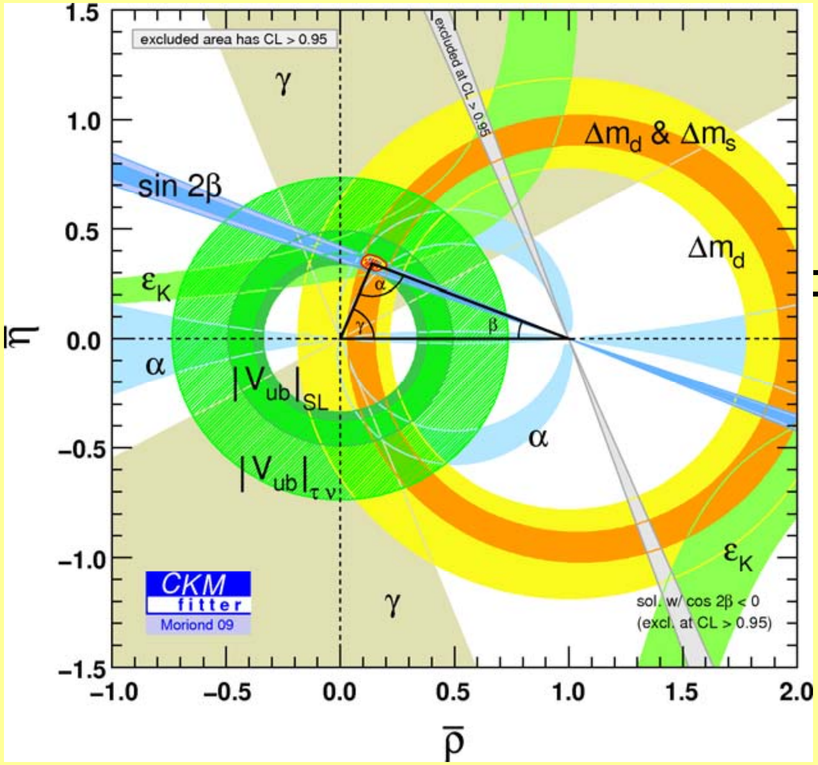
Search for (and understand the nature of) new physics by looking at processes dominated by loop-diagrams

→ These involve "virtual" particles
Sensitivity to particles order of magnitude above the center of mass energy



B-PHYSICS IN 2010

→ The CKM picture of CP violation is well established, but there are still possibilities for new physics in precision measurements of the Unitarity Triangles



Angles precision limited by
imental measurements:

→ σ(α) ~ 5°

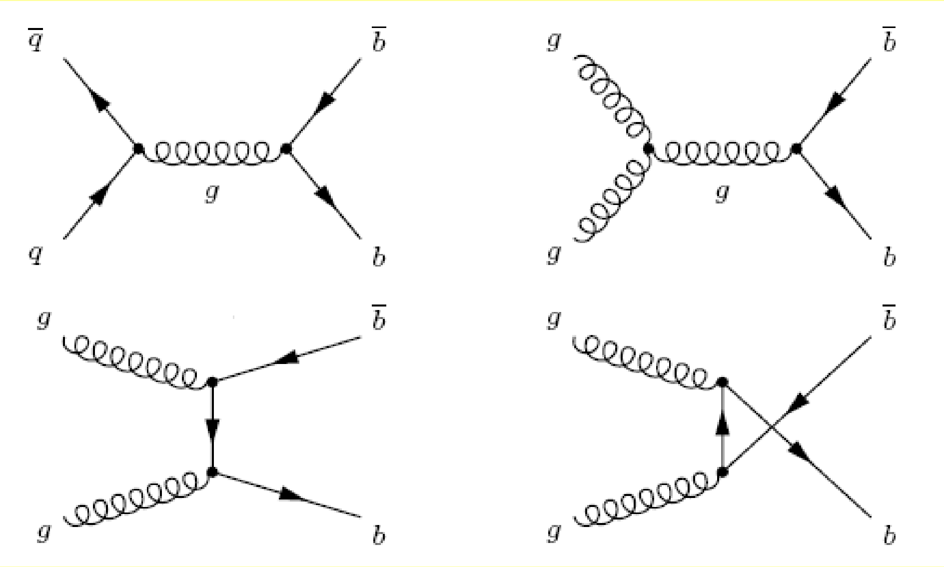
→ σ(β) ~ 1°

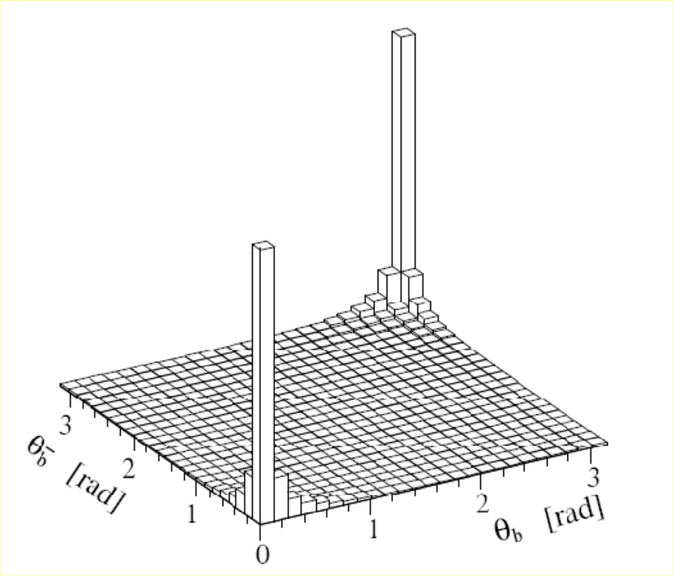
→ σ(γ) ~ 20°

(B_s system is less tested)

→ σ(ϕ_s) not measured

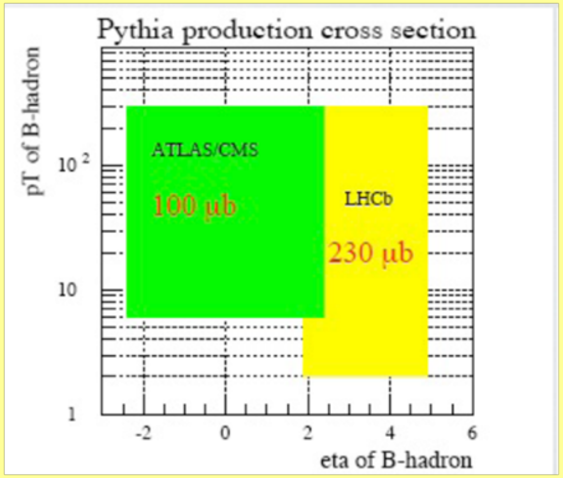
B-PHYSICS AT THE LHC





- B-hadrons are mostly produces in the forward (or backward direction)

- $b\bar{b}$ cross section at 14 TeV: 0.5mb

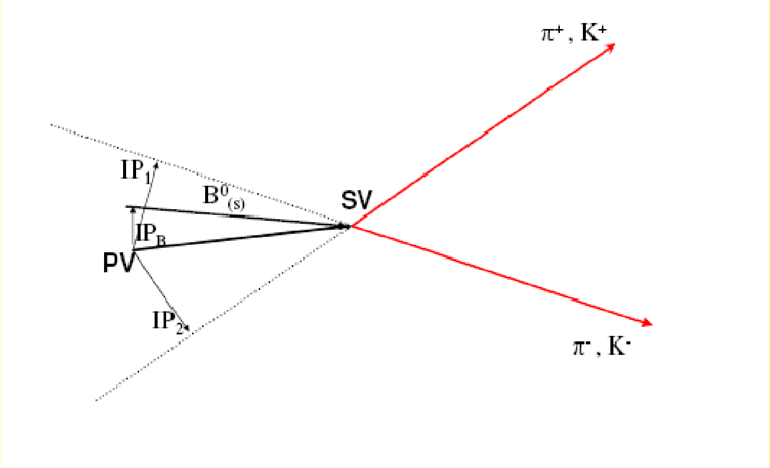


Different flavour production:
B_d : 40% ; B_u : 40%; B_s : 10%; B_c : ~0.1%
B-Baryons : 10%

B-PHYSICS REQUIREMENTS

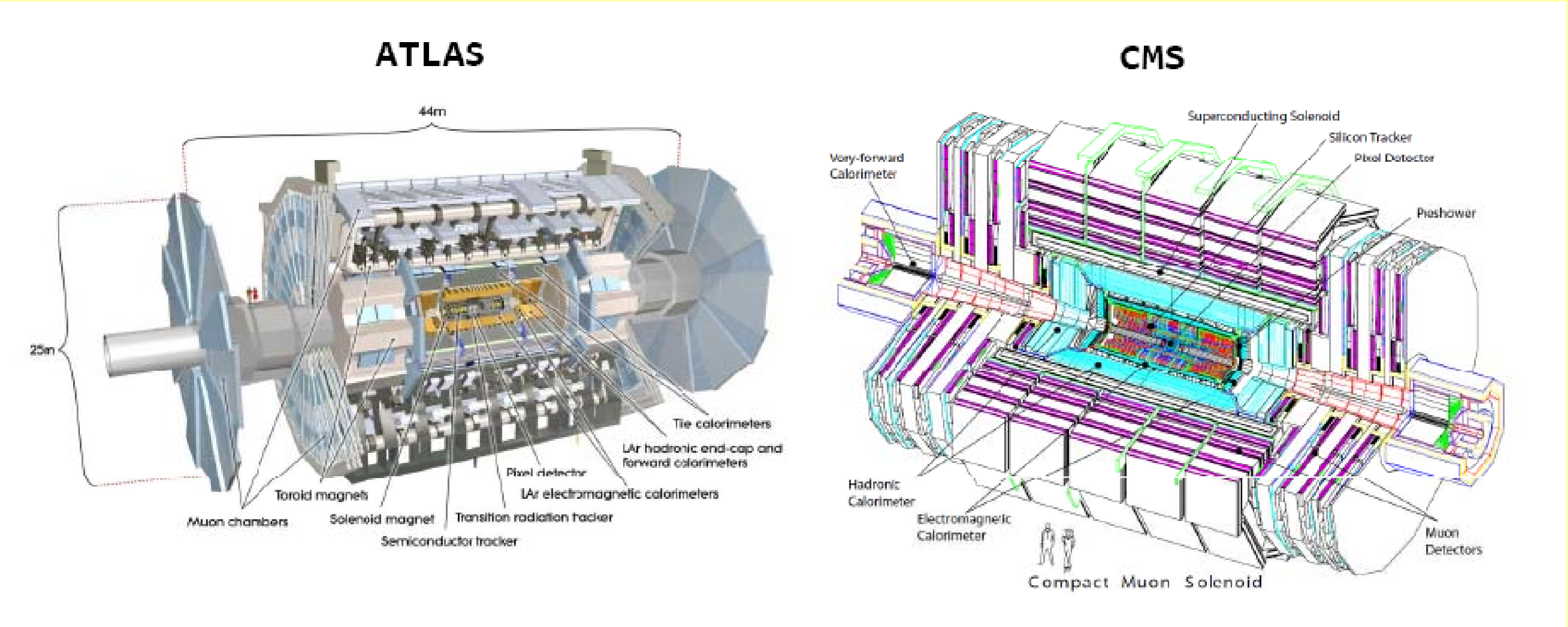
- Precise vertexing for lifetime measurements
  → Separate B decay vertex from primary vertex

- Particle ID for final states
  → Distinguish π/K and identify leptons over large momentum range



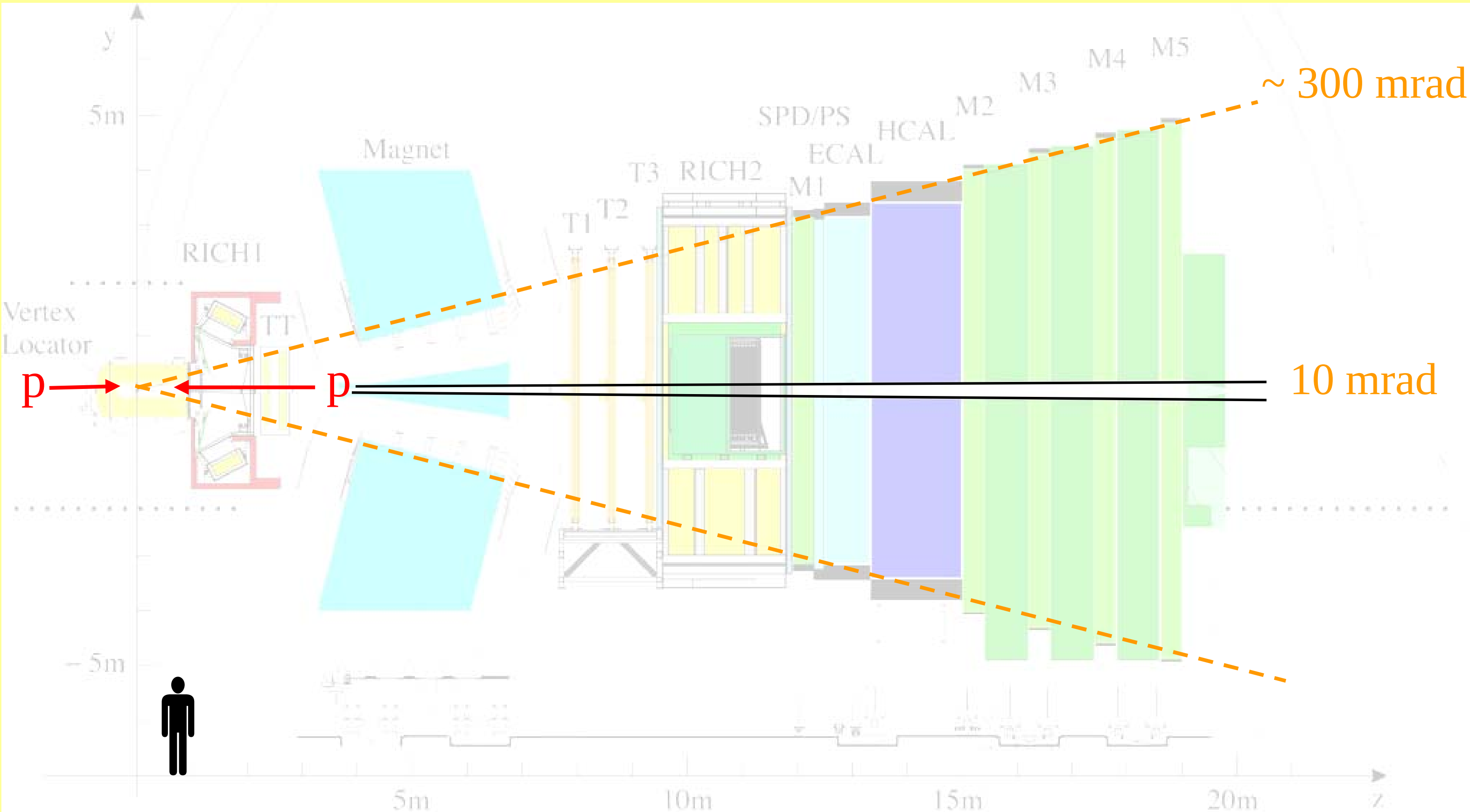
- Efficient triggering
  → Triggering on leptons for GPDs
  → Triggering on both leptons and hadrons in LHCb
  → Many different channels have low branching ratios
  → Reduction factor up to 1/7500

The general purpose detectors



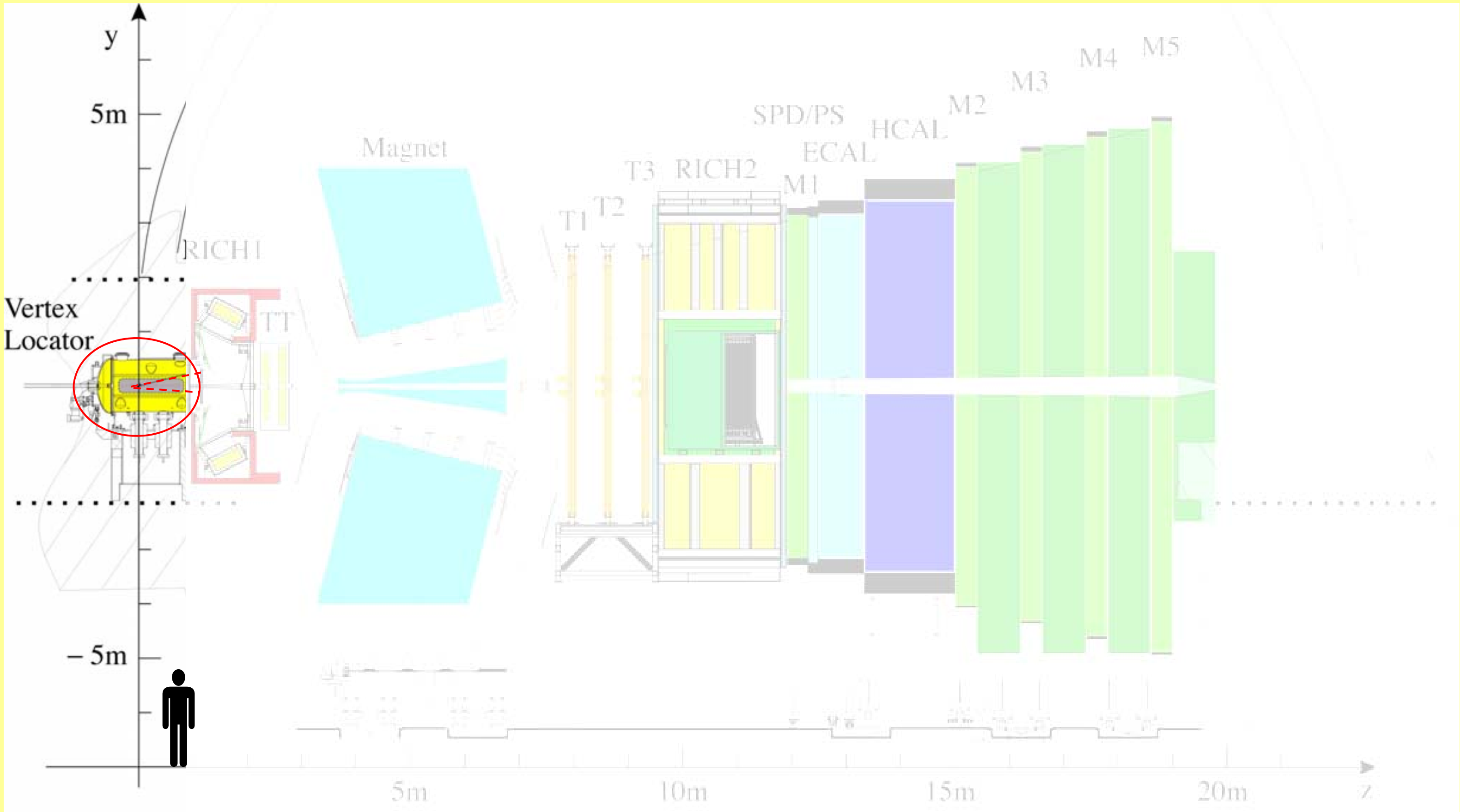
- Design luminosity $10^{34} cm^{-2}s^{-1}$
- B physics up to $10^{33} cm^{-2}s^{-1}$
- Annual integrated luminosity $10 fb^{-1}$ in nominal year of data
- Excellent muon-ID
- Trigger on high pt muons

LHCb



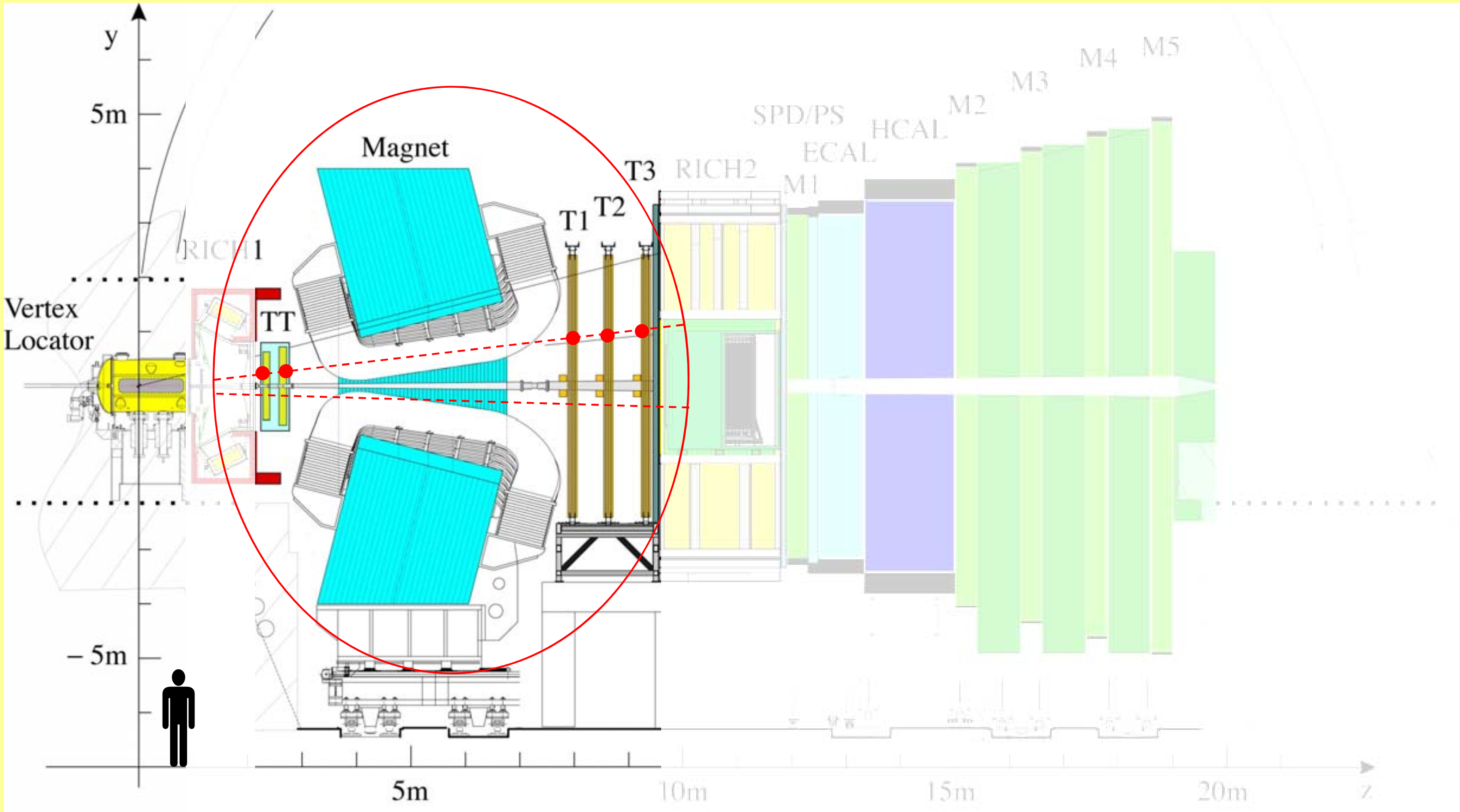
- Forward spectrometer (running in pp collider mode)
- Design luminosity $10^{32}cm^{-2}s^{-1}$
- Annual integrated luminosity $2fb^{-1}$ in nominal year of data

LHCb



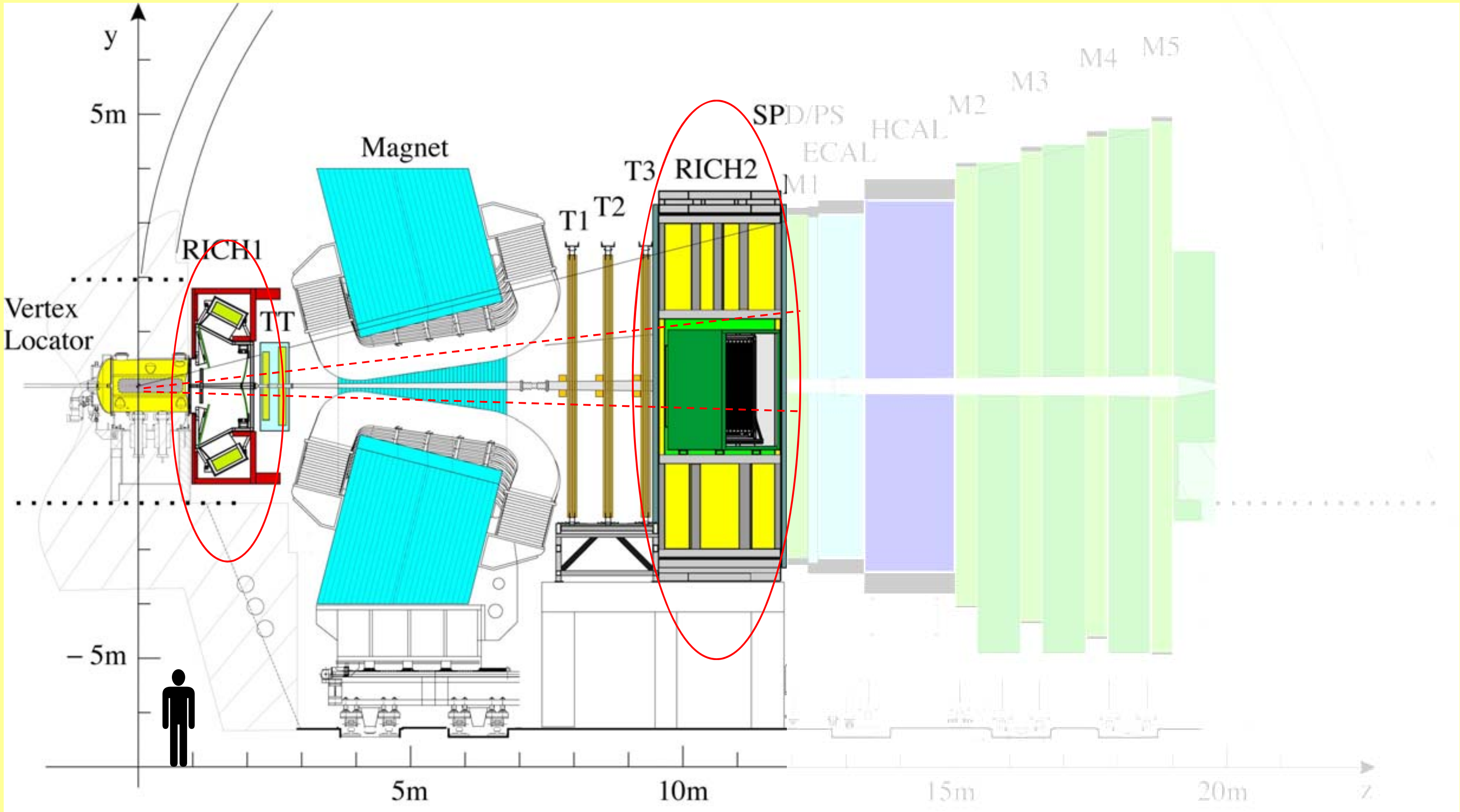
- Vertex locator around the interaction region
  → proper time resolution ~ 40fs

LHCb



• Tracking system and dipole magnet to measure angles and momenta → $\delta p/p$ ~0.4% and B mass resolution 16 - 20 MeV

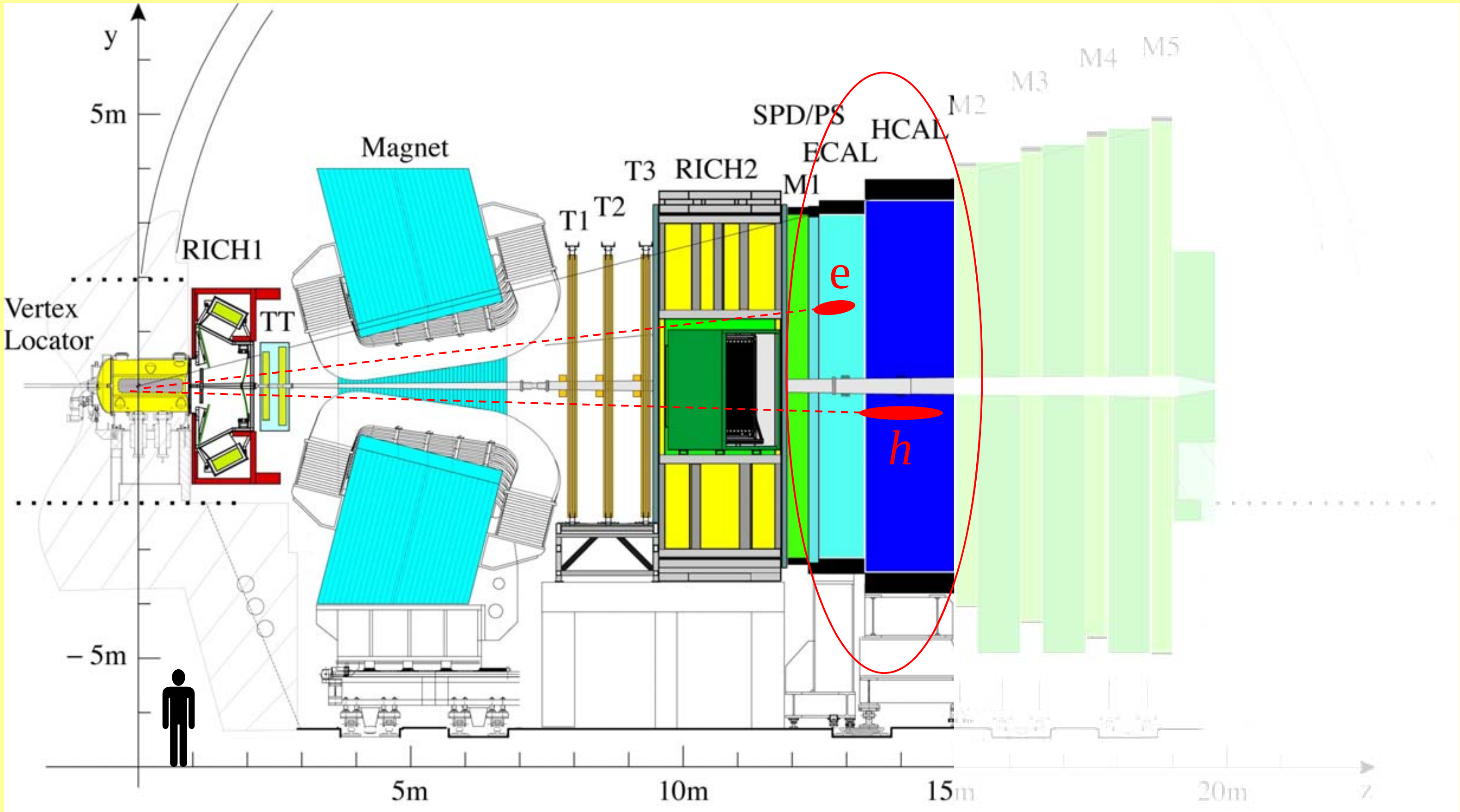
LHCb



- Two RICH detectors for charged hadron identification

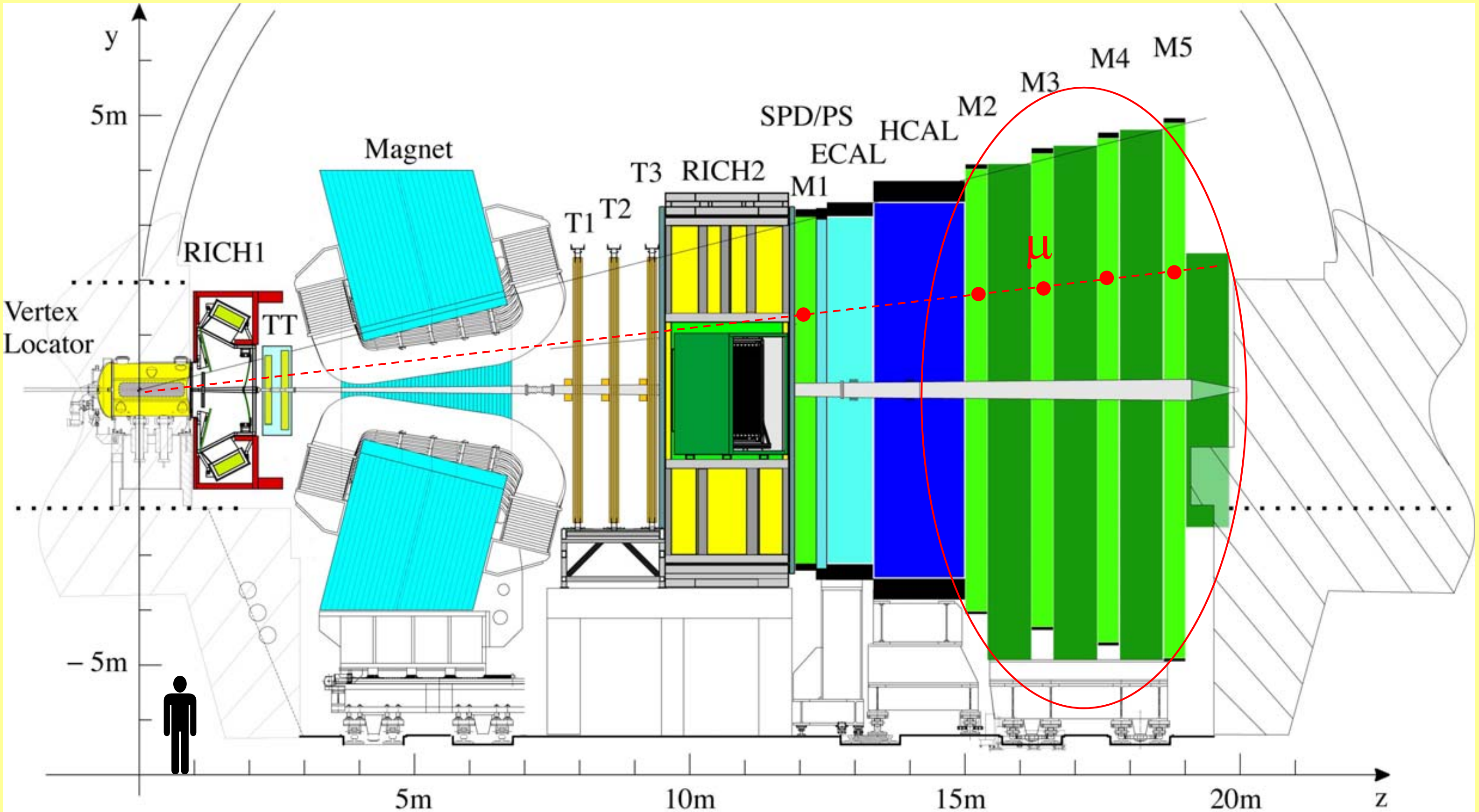
→ Provide > 3σ π/K separation for 3 < *p* < 100 GeV

LHCb



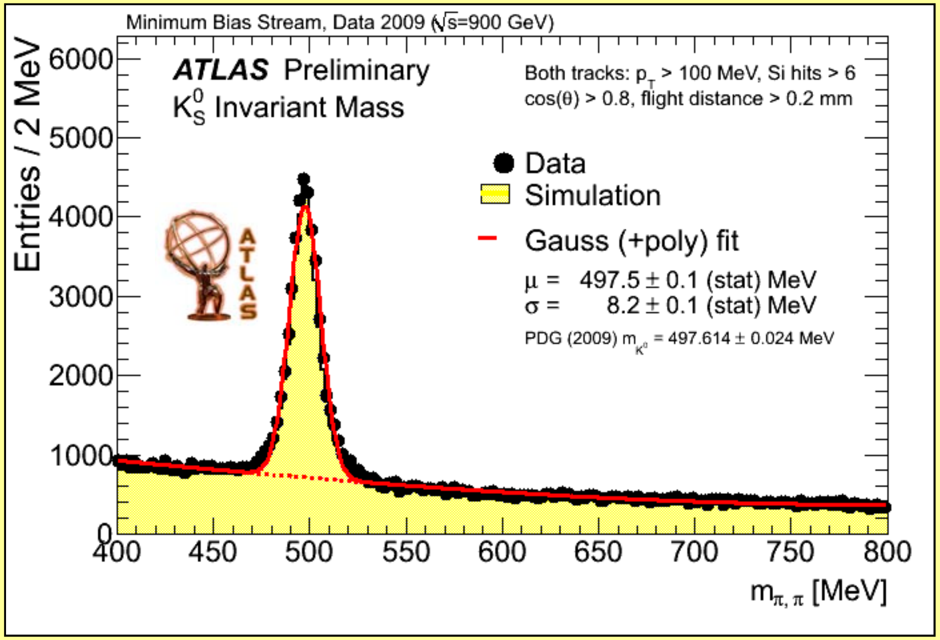
• Calorimeter system to identify electrons, hadrons and photons → Important for the first level of the trigger

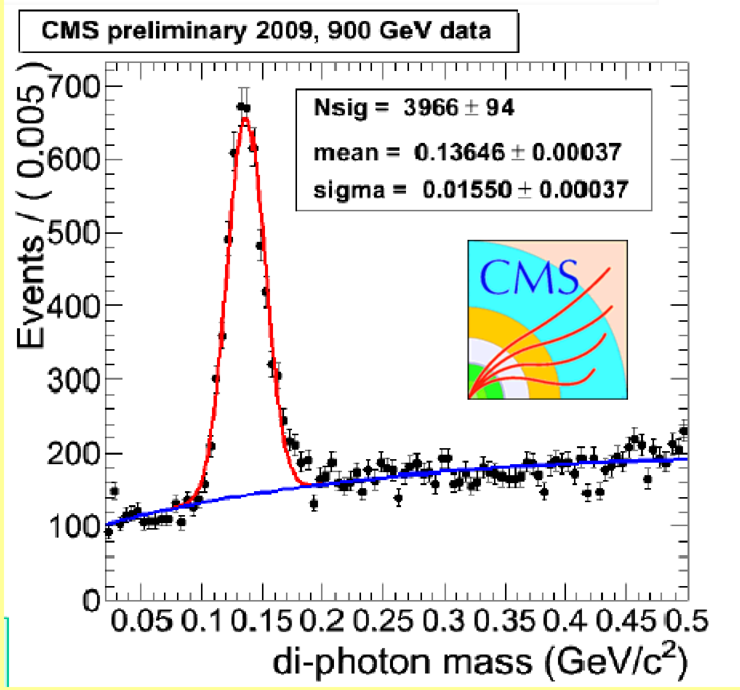
LHCb



• Muon system to identify muons, also used in first level of trigger

First collisions in 2009
(and they worked !!!)





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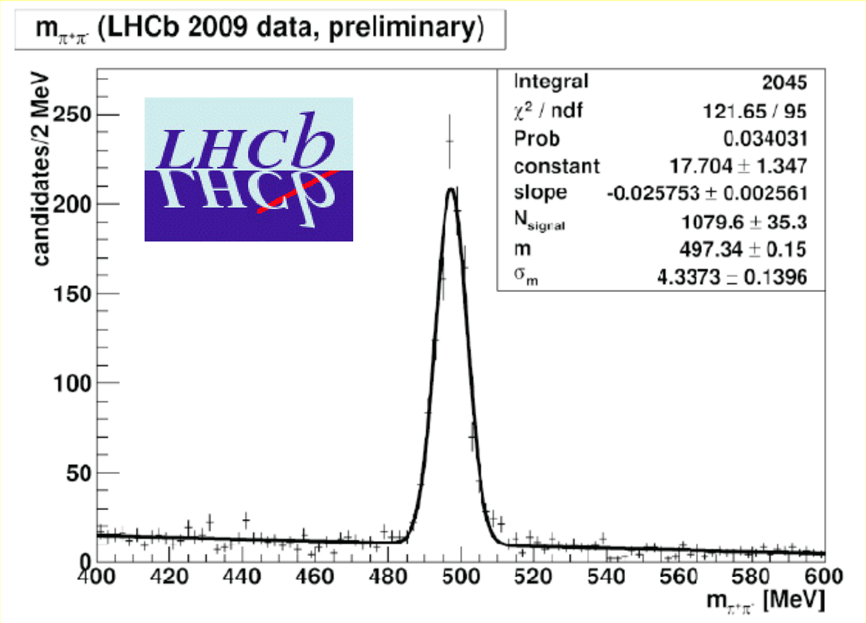

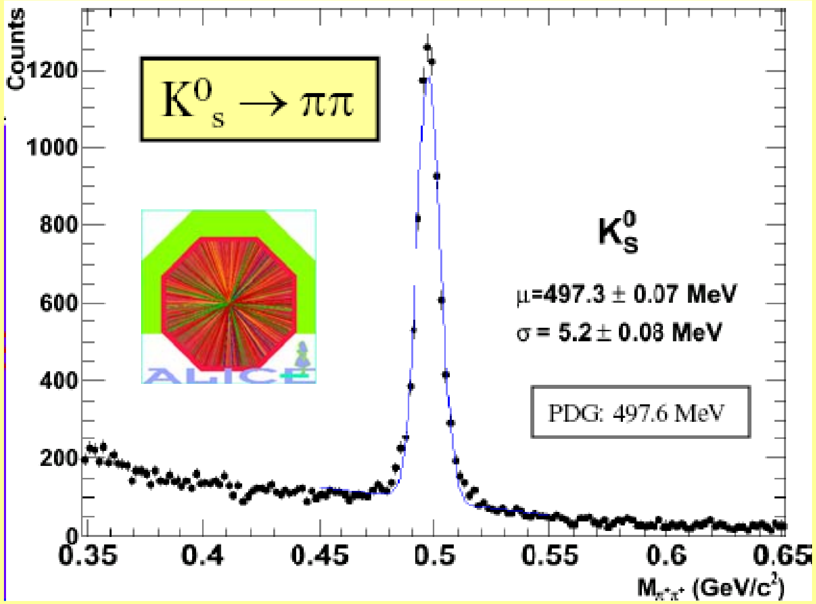

LHC scenario(s) for 2010

- LHC is due to restart in the 2nd half of February
- Energy up to 3.5 TeV per beam
- LHCb expect to collect 200 – 500 pb^{-1}

B-PHYSICS GOALS

B-hadron decays offer sensitivity to a wide range of New physics → We'll look over a few selected highlights

Rare decays	Observations or BR limits	$B_s \rightarrow \mu^+\mu^-$
	Angular analysis	$B_d \rightarrow K^*\mu^+\mu^-$
	Radiative penguins in $B_d \rightarrow K^*\gamma$	
	$b \rightarrow s\gamma$ transitions	$B_s \rightarrow \phi\gamma$

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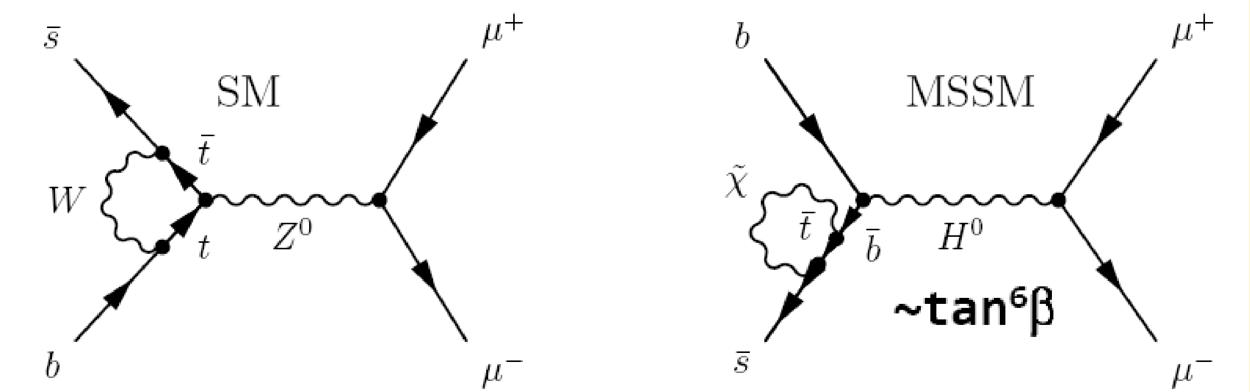
	Radiative penguins in $B_d \rightarrow K^*\gamma$ $b \rightarrow s\gamma$ transitions	 $B_s \rightarrow \phi\gamma$
CP Violation	Mixing phase ϕ_s	$B_s \rightarrow J/\Psi\phi$
	CKM angle γ from loop $B_d \rightarrow \pi^+\pi^-$ decays $B_s \rightarrow K^+K^-$	
	CKM angle γ from tree $B_s \rightarrow D_sK$ decays	 $B_d \rightarrow D^0K^{*0}$; $B^+ \rightarrow D^0K^+$

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

• BR measurement sensitive to NP

• tanβ large most promising due to $\tan^6\beta$ enhancement in MSSM

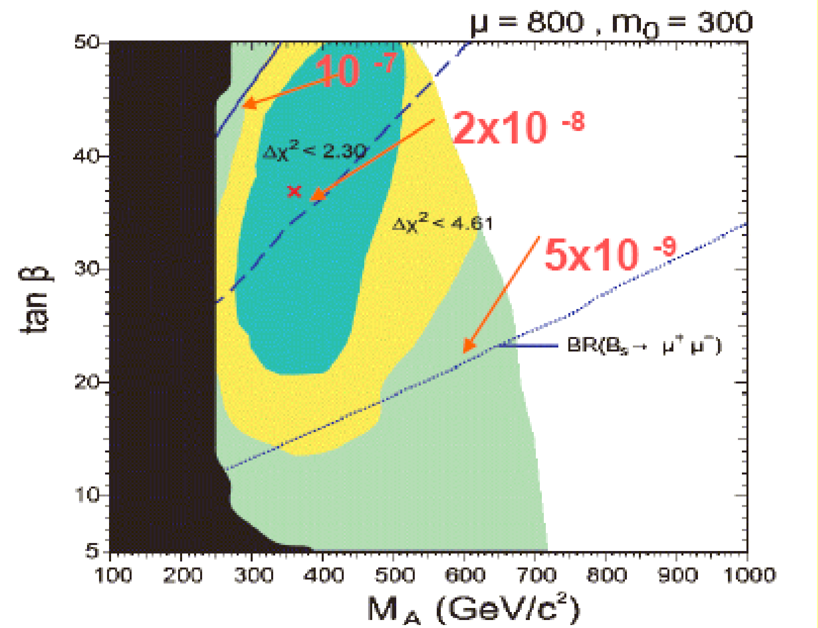


The lines indicate the excluded regions :

—— BR < 10^{-7}

- - - BR < 2×10^{-8}

······ BR < 5×10^{-9}

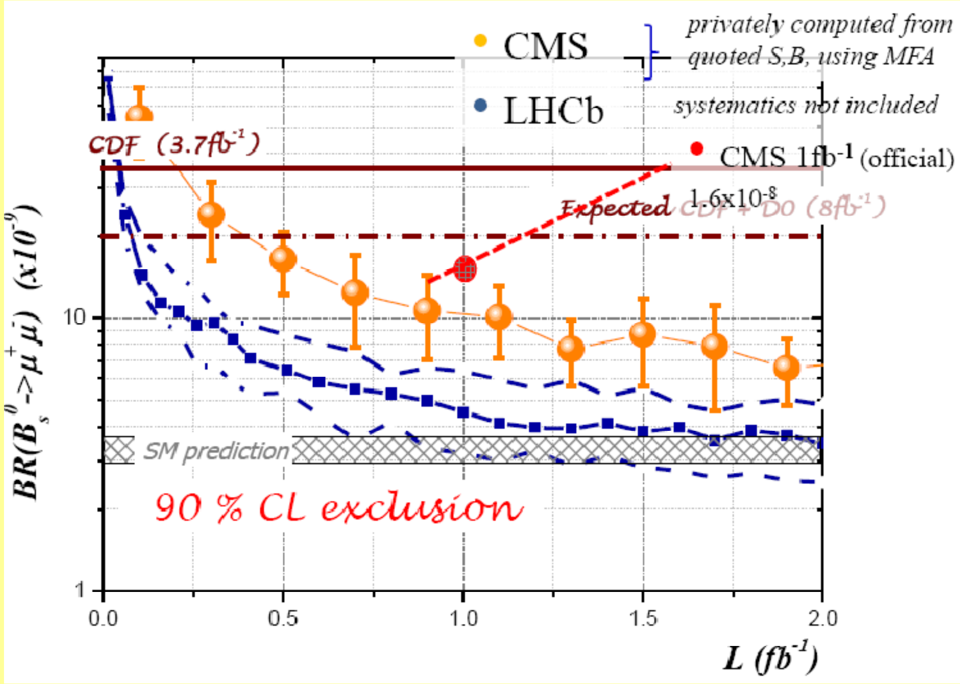


J.Ellis et. al. Phys.Rev.D76:115011, 2007[arXiv:0708.2079v4 [hep-ph]]

$B_s \rightarrow \mu^+\mu^-$ SENSITIVITIES

Best published limit is from CDF public note 9892:
- **$3.7 fb^{-1}$ of data**
- **$BR < 3.3 \times 10^{-8}$**

See LHCb roadmap document: hep-ex:0912/4179



Analysis challenges:

- **Need to normalize the BR with $B \rightarrow J/\Psi K^+$ and $B \rightarrow K^+\pi^-$**
- **Main systematic limitation from normalization with B_d/B_s**

$\rightarrow$ Large uncertainty in $f(B_d)/f(B_s)$

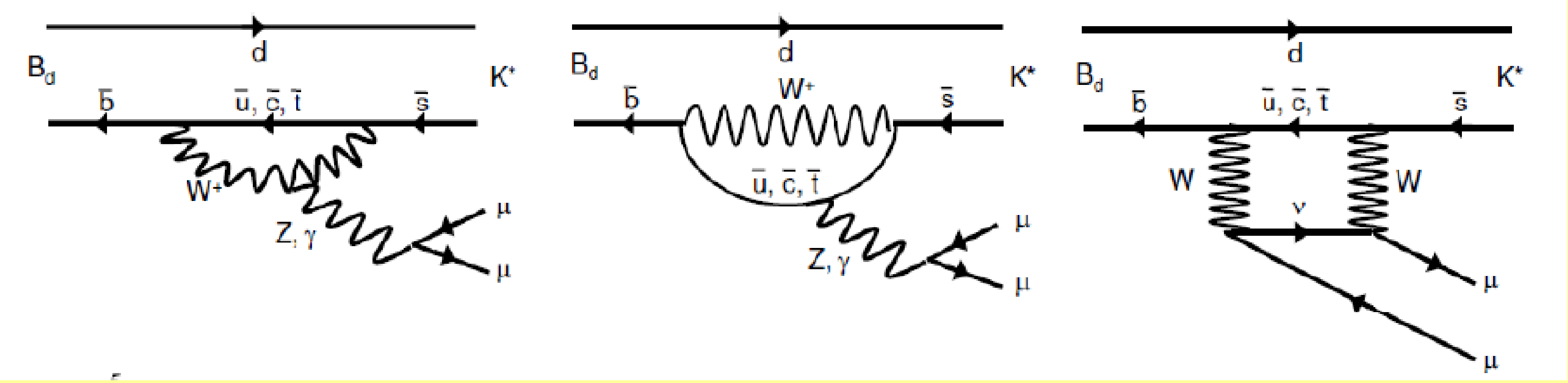
Sentivities at the LHC

	Int. Lum.	S_{ignal}	$B_{ackground}$
LHCb	$2\ fb^{-1}$	7.6	22
ATLAS	$10 fb^{-1}$	5.7	14
CMS	$10 fb^{-1}$	6.1	14

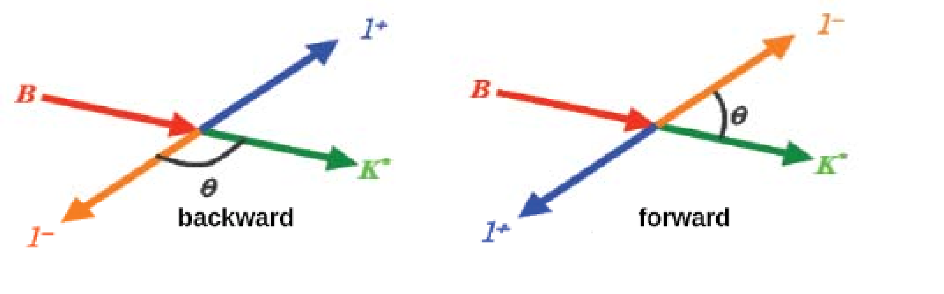
In the most sensitive region:
Total S = 21 and B = 180

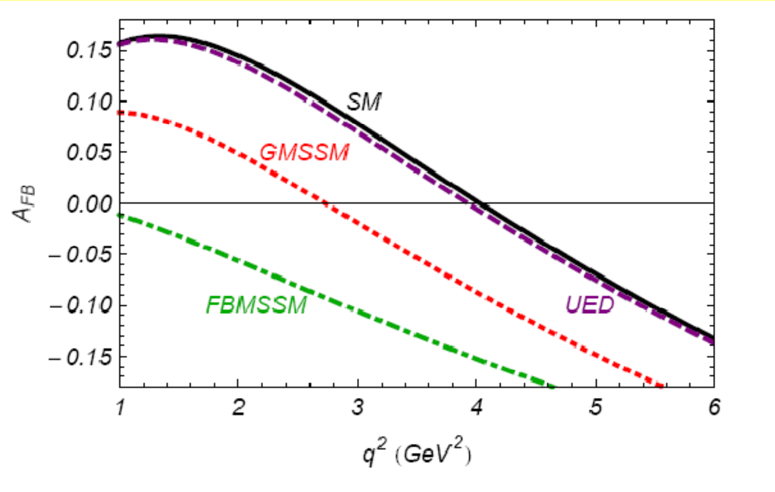
$B^0 \rightarrow K^* \mu^+\mu^-$ MOTIVATION

- Flavour changing Neutral Current highly sensitive to New Physics



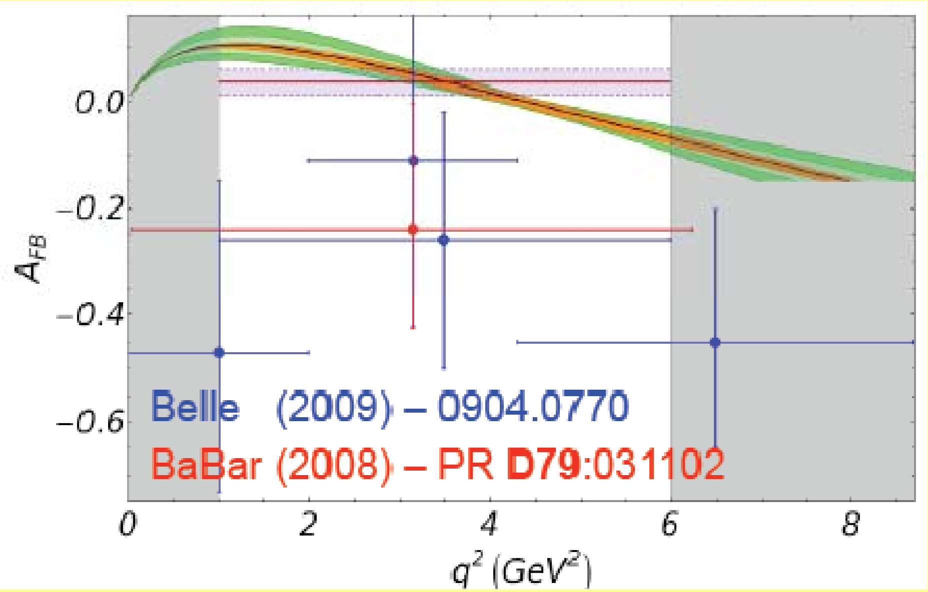
- Important to study angular distributions
- Forward backward asymmetry A_{FB}



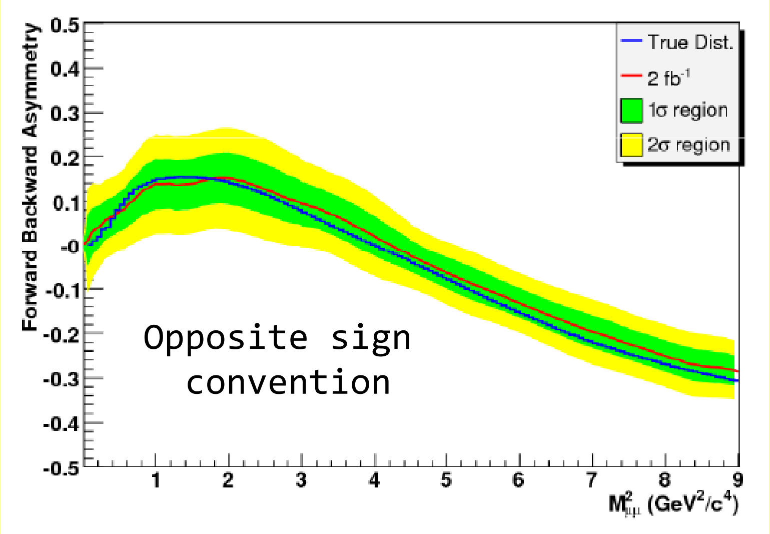


$B^0 \to K^* \mu^+\mu^-$ SENSITIVITIES

Belle analysis on 250 event, Babar on 100 events
LHCb should get the same statistics with $0.1fb^{-1}$ of data



LHCb A_{FB} fit
with $2fb^{-1}$

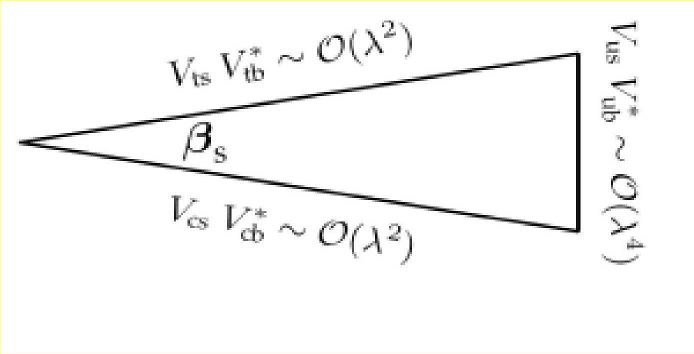


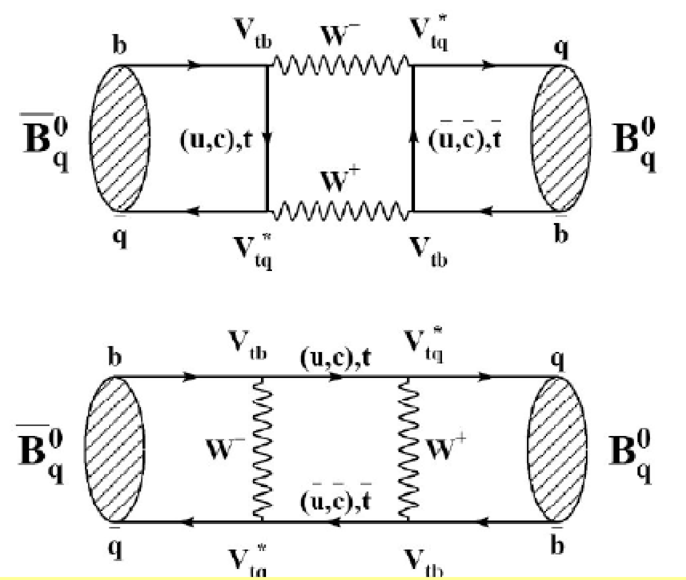
SENTIVITIES AT THE LHC

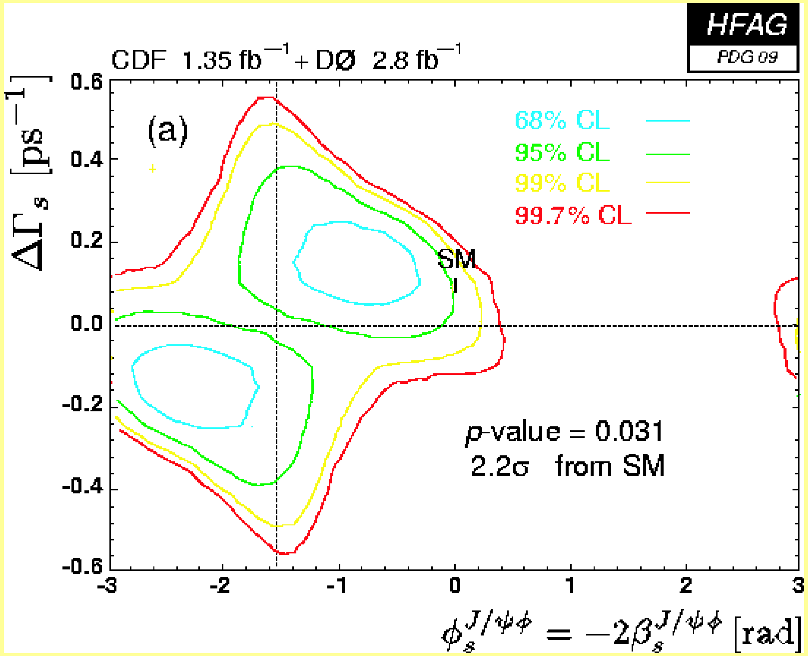
	Int.Lum.	S_{ignal}	B/S
LHCb	2 fb^{-1}	7100	0.2
ATLAS & CMS	Under study		

Mixing phase ϕ_s

Weak mixing phase is predicted to be ϕ_s = -0.036 ± 0.002 in SM







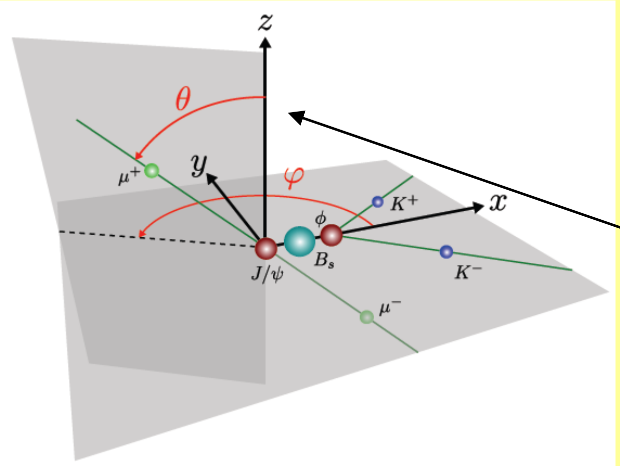
It is not constrained and indications of a large value from CDF/D0 create a tension with the SM which can be solved at the LHC

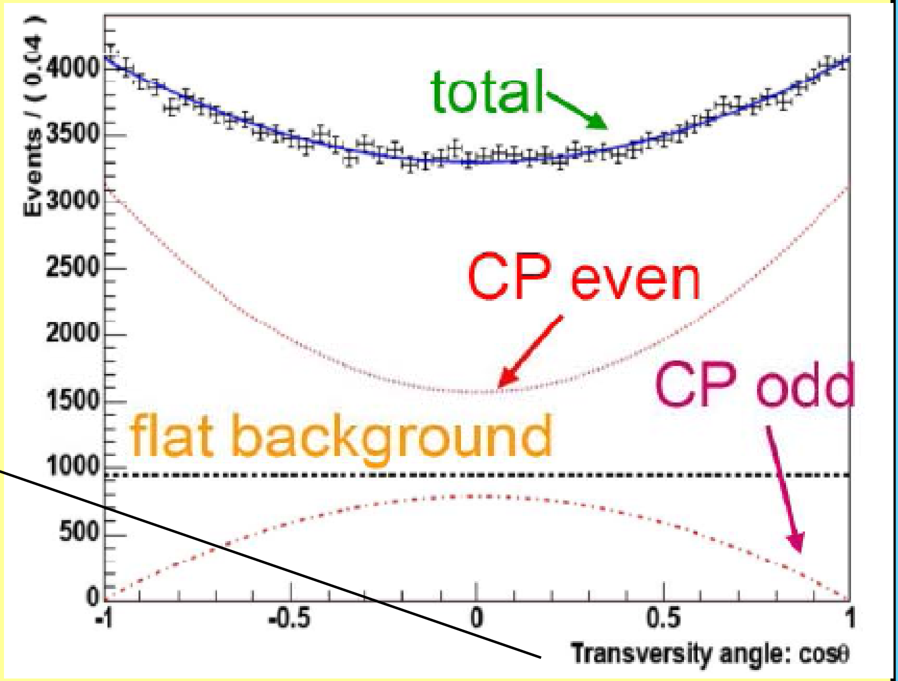
Mixing phase ϕ_s

Measure ϕ_s from a time dependent decay rate asymmetry

$$A_{CP}(t) = -\frac{\eta_f \sin\phi_s \sin(\Delta m_s t)}{\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \eta_f \cos\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right)}$$

- $B_s \to J/\Psi\phi$ is not a pure CP mode
- Need angular analysis to distinguish CP even and CP odd
- Need flavour tagging in analysis





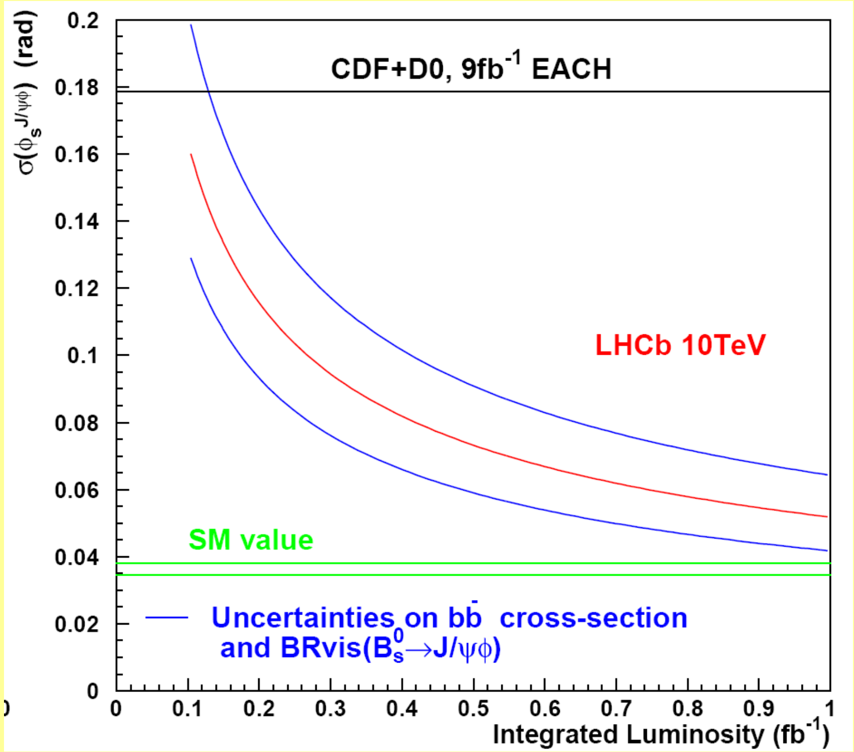
Mixing phase ϕ_s

Sentivities at the LHC

	Int.Lum.	S_{ignal}	B/S	$\sigma(\phi_s)$	$\sigma(\Delta\Gamma_s/\Gamma_s)$
LHCb	2 fb^{-1}	117k	2.1	0.03	0.01
ATLAS	10fb^{-1}	105k	0.3	Under study	
CMS	10fb^{-1}	109k	0.3	0.06	0.01

Lifetime unbiased selection has no cuts on IP of daughters → Huge prompt background well identified in ϕ_s fitting procedure

- Promising sensitivity with early data

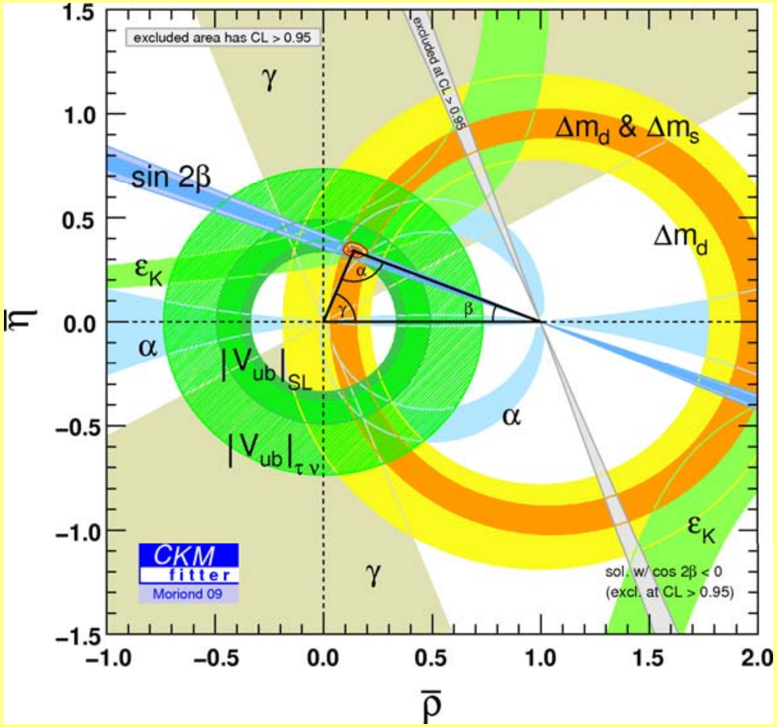


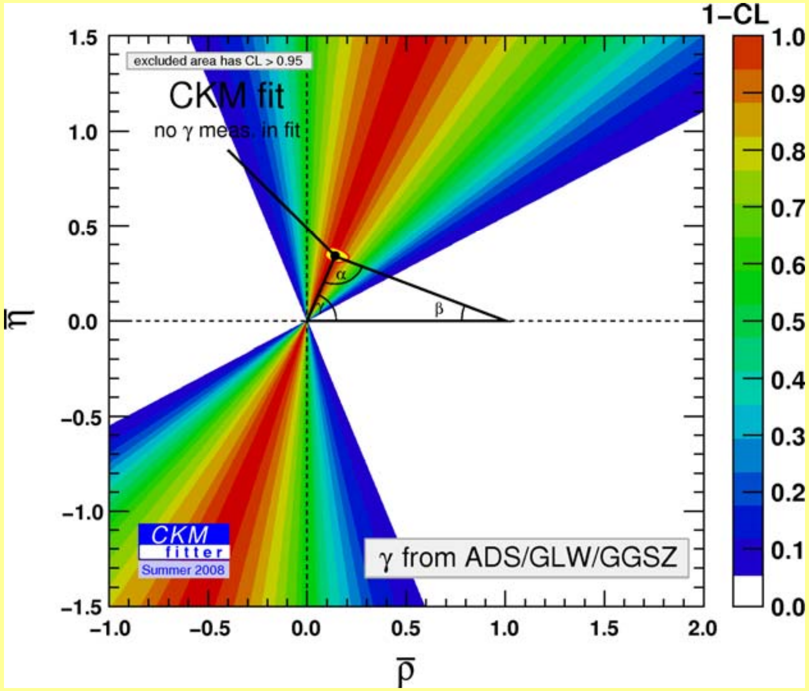
The CKM angle γ

Crucial to constrain the Unitarity Triangle !

CKM Fitter $\gamma = 73^{+22}_{-25}$

Constraints from γ compared to the prediction from the global CKM fit





THE CKM ANGLE γ

- Measurement unique at LHCb
- Several different approaches

Tree level decays

→ Direct CP violation

$B \rightarrow DK$ with ADS/GLW method

M. Gronau and D. London, Phys. Lett. B **253**, 483 (1991); M. Gronau and D. Wyler, Phys. Lett. B **265**, 172 (1991).

D. Atwood, I. Dunietz and A. Soni, Phys. Rev. Lett. **78**, 3257 (1997); D. Atwood, I. Dunietz and A. Soni, Phys. Rev. D **63**, 036005 (2001).

$B \rightarrow DK$ with GGSZ method

(Dalitz analysis with $D \rightarrow K_s\pi\pi$)

A. Giri, Yu. Grossman, A Soffer and J. Zupan, Phys. Rev. D **68**, 054018 (2003)

→ Time dependent measurement

$B_s \rightarrow D_sK$ (using $B_s \rightarrow D_s\pi$)

$B_s \rightarrow D_sK$ with $B \rightarrow D\pi$ using U-spin symmetry

Loop decays

$B \rightarrow hh$ decays using U-spin symmetry

Fleischer, PLB 459 (1999) 306

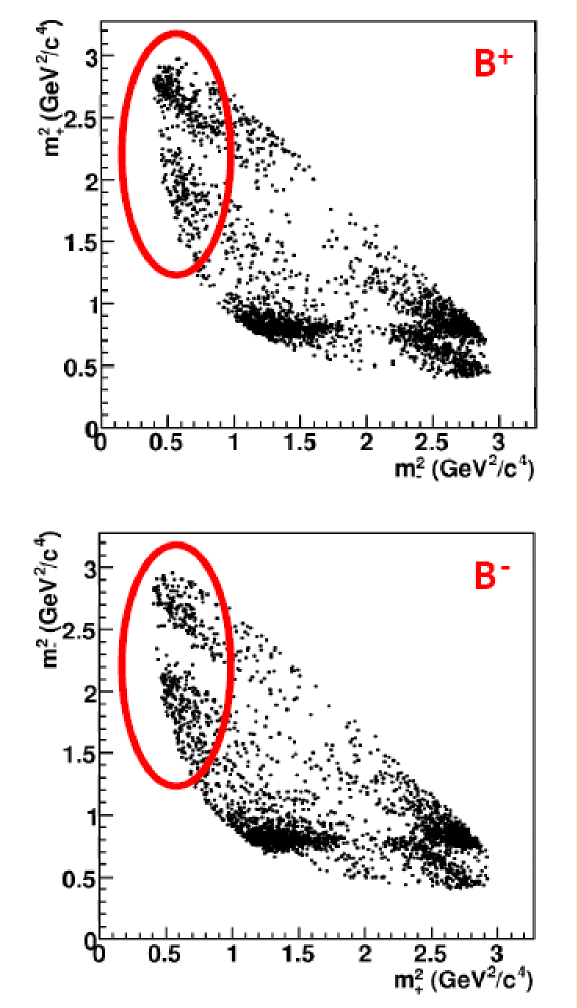
γ FROM TREES – GGSZ

Sensitivity to γ from differences in Dalitz plot for B^+ and B^- decays

- Two approaches to the Dalitz analysis

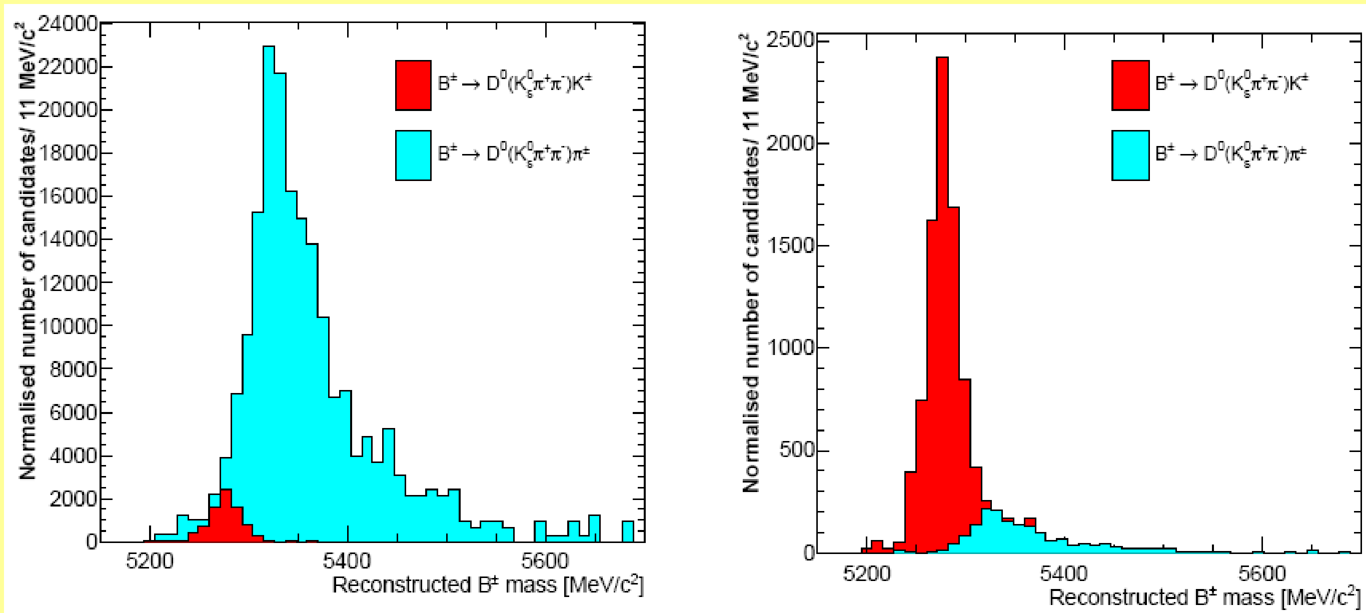
  → Unbinned fit using a model for the Dalitz plane. This approach makes full use of the statistics but incurs a systematic uncertainty of between 6° and 15°

  → A binned model-independent fit which relies on input from CLEO-c data. Model error replaced by uncertainty on strong phase parameters: 2°. Not full use of the statistics available



γ FROM TREES – GGSZ

Crucial role of PID in the analysis

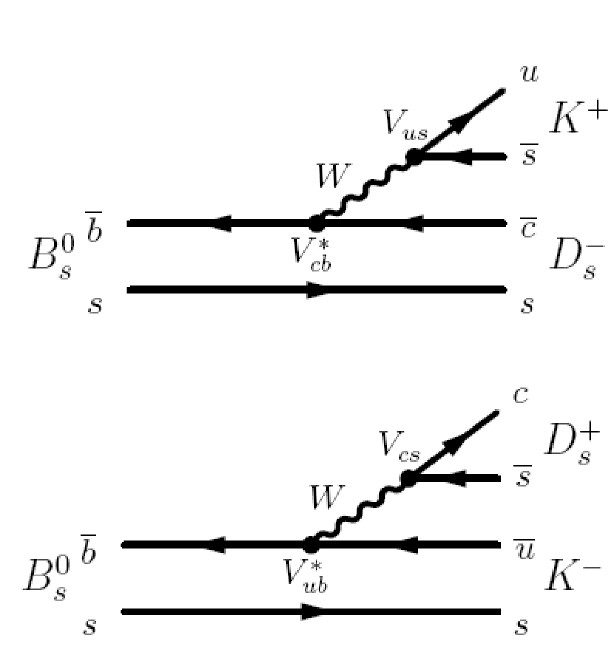


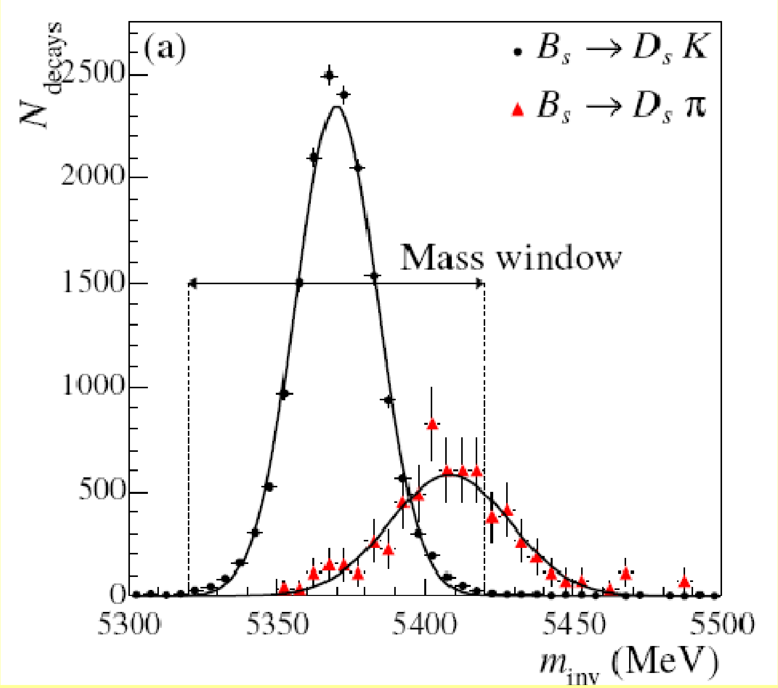
$B^{\pm} \rightarrow D(K_S\pi\pi)K^{\pm}$: Yield: 6800 in 2fb^{-1} and B/S < 1.1 @90%C.L.

γ FROM TREES – TIME DEPENDENT CPV

• Extraction of γ from interference in mixing and decay of $B_s \to D_s K$

Crucial role of PID





Simultaneous fit to $B_s \to D_s \pi$ allows extraction of Δm_s and $\Delta\Gamma_s$

Signal yield 14k

B/S < 0.45 @ 90% C.L.

γ from trees – Summary

- Global fit to obtain the best sensitivity to γ

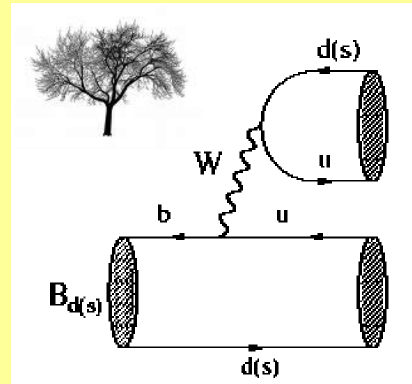
Sensitivity to γ

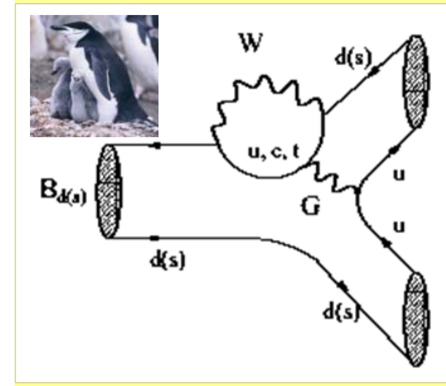
→ 2 fb^{-1} 4-5°

→ 0.5 fb^{-1} 8-10°

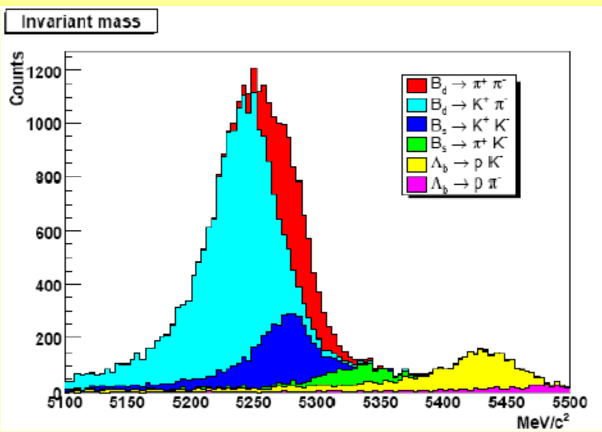
γ FROM LOOPS

• Sensitivity to γ from interference between trees and penguin diagrams

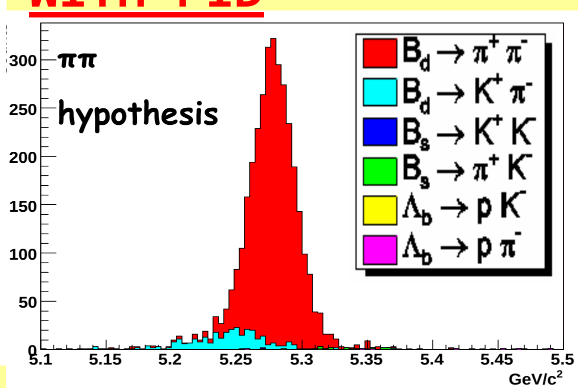




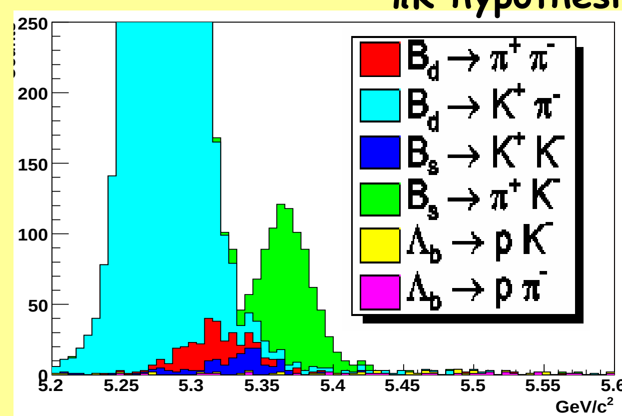
Crucial role of PID
and mass resolution



WITH PID



πK hypothesis



Loop diagrams sensitive to NP

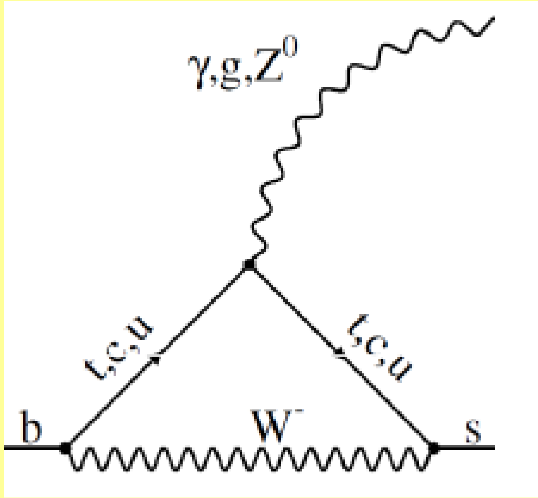
γ in loops could differ from γ in tree

Extraction of γ using U-spin symmetry

Radiative decays at the LHC

Loop decays, sensitivity to New Physics comes from many observables

→Detailed theoretical prediction available



Early measurement

- Direct CP asymmetry in B →$K^*\gamma$
- Ratio of B_s →$\phi\gamma$ and B →$K^*\gamma$ rates

Long term aims

- Photon polarization through CP violation measurement

Sensitivities at LHCb

	0.1 fb^{-1}	2fb^{-1}
B →$K^*\gamma$	4000	80000
B_s →$\phi\gamma$	550	1100
B^+ →$\phi K^+\gamma$	350	7000

Conclusions

- Only some selected measurements have been shown
- Many other interesting measurements will be performed (i.e. α,β)
- CPV with charm decays
- Etc.

- LEP, Tevatron and B-factories have established the SM picture in B-decays
- The LHC flavour physics program has the potential to go beyond the Standard Model
- All the experiments are ready !

BACKUP

$B^0 \rightarrow K^* \mu^+\mu^-$ MOTIVATION

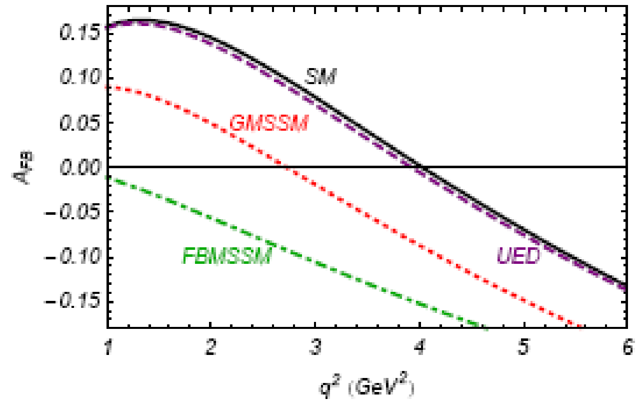
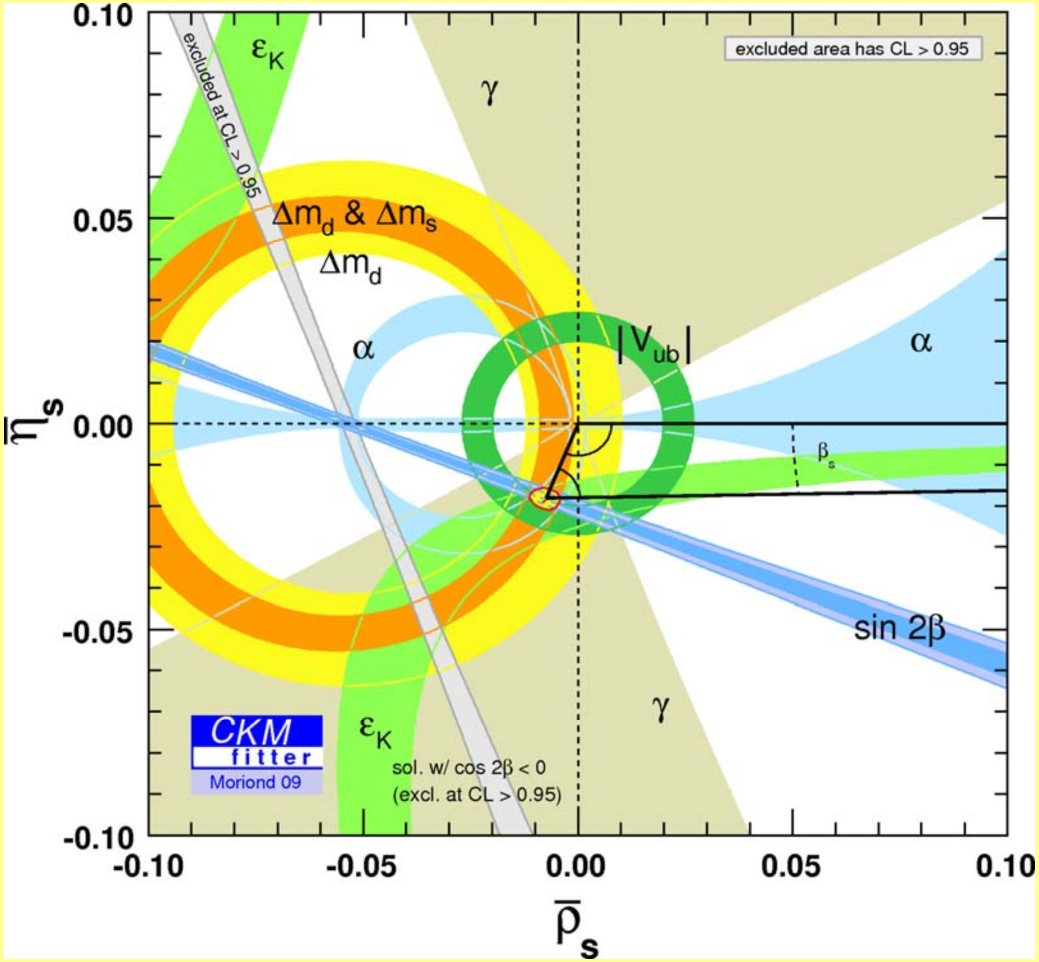


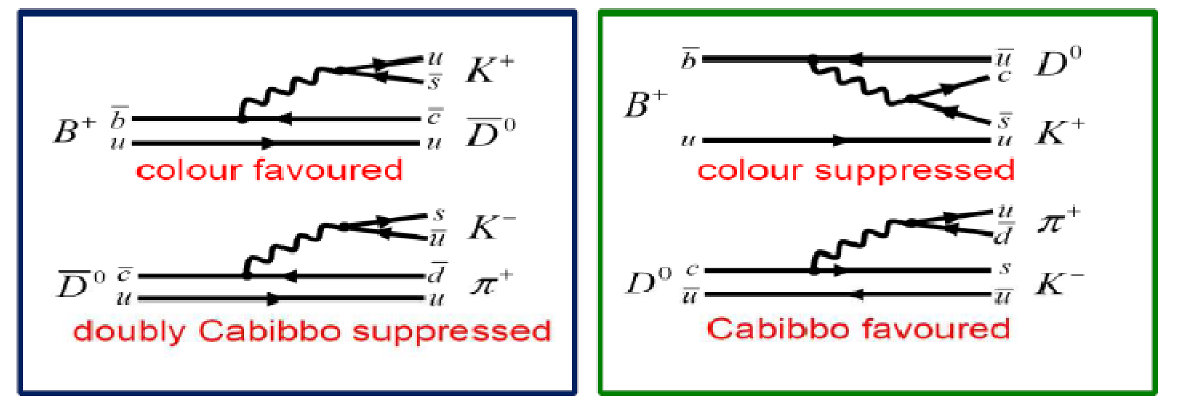
Figure 3: Theoretical A_{FB} distributions in a number of models. The solid line gives the SM prediction. The dashed lines show predictions from a universal extra dimensions (UED) model, a non-minimal flavour violating supersymmetric model (GMSSM) and a flavour blind supersymmetric model (FBMSSM). Details of these models can be found in Ref. [8].

MIXING PHASE ϕ_s



γ FROM TREES – ADS/GLW

- Combination of color suppressed B decays with Cabibbo favoured D decays increases the sensitivity to CP parameters.



Mode	Yield	B/S
$B^\pm \rightarrow D(K\pi)K^\pm$	84k	0.6
$B^\pm \rightarrow D_{sup}(K\pi)K^\pm$	1.6k	0.6
$B^\pm \rightarrow D(K\pi\pi\pi)K^\pm$	53k	0.2
$B^\pm \rightarrow D_{sup}(K\pi\pi\pi)K^\pm$	0.55k	3.1
$B^\pm \rightarrow D(hh)K^\pm$	11.4k	1.4
$B^0 \rightarrow D(K\pi)K^*$	3.2k	0.25
$B^0 \rightarrow D_{sup}(K\pi)K^*$	0.3k	< 10
$B^0 \rightarrow D(hh)K^*$	0.4k	< 8