LHCb Physics and 2010-11 prospects

Stefano Perazzini

On behalf of LHCb Collaboration

MENU2010

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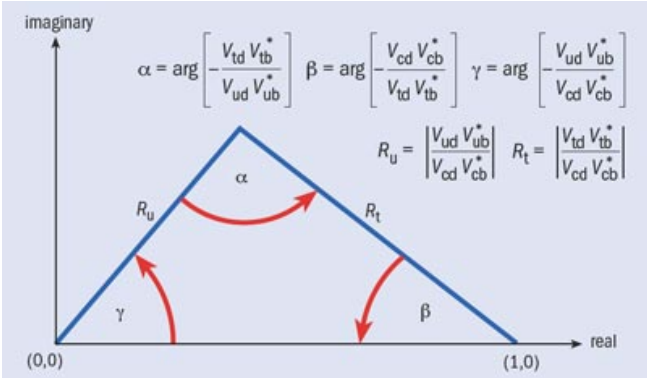
OUTLINE

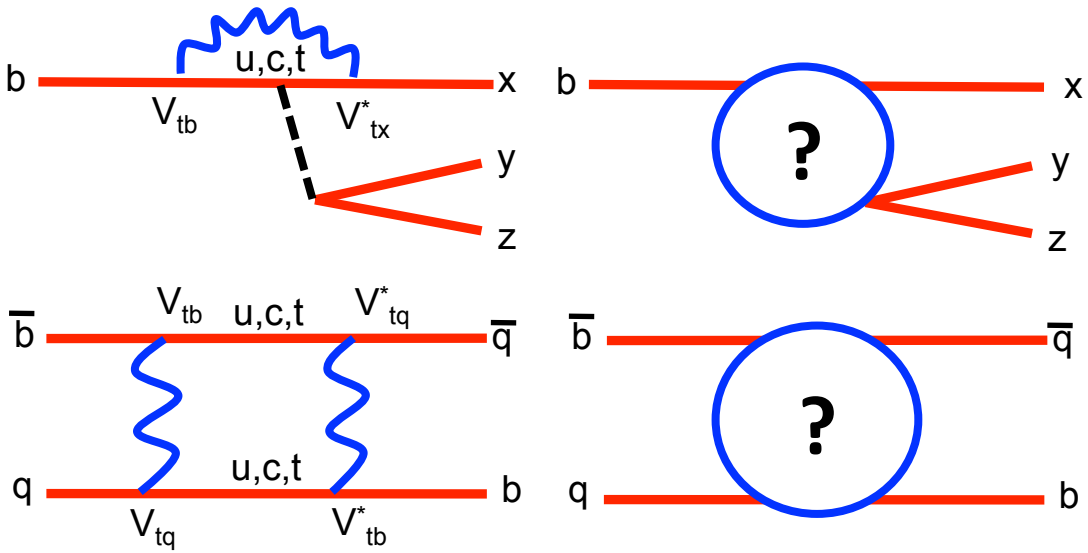
- Physics:
  - Flavor physics and CPV in the quark sector
  - Search for New Physics
- The LHCb Experiment
  - The detector
  - Data taking in 2010-11 run
- Core analyses and prospects for 2010-11

Flavor physics in quark sector

$$L_{\text{int}}^{CC} = -\frac{g}{\sqrt{2}}\begin{pmatrix}\bar{u} & \bar{c} & \bar{t}\end{pmatrix}\gamma^{\mu}V_{CKM}\begin{pmatrix}d\\ s\\ b\end{pmatrix} + h.c. \Rightarrow V_{CKM} = \begin{pmatrix}V_{ud} & V_{us} & V_{ub}\\ V_{cd} & V_{cs} & V_{cb}\\ V_{td} & V_{ts} & V_{tb}\end{pmatrix}$$

- Interacting (flavor) eigenstates are mixtures of mass eigenstates described in the SM by the CKM matrix
- New particles in loop diagrams may modify measured quantities related to V_{CKM} elements

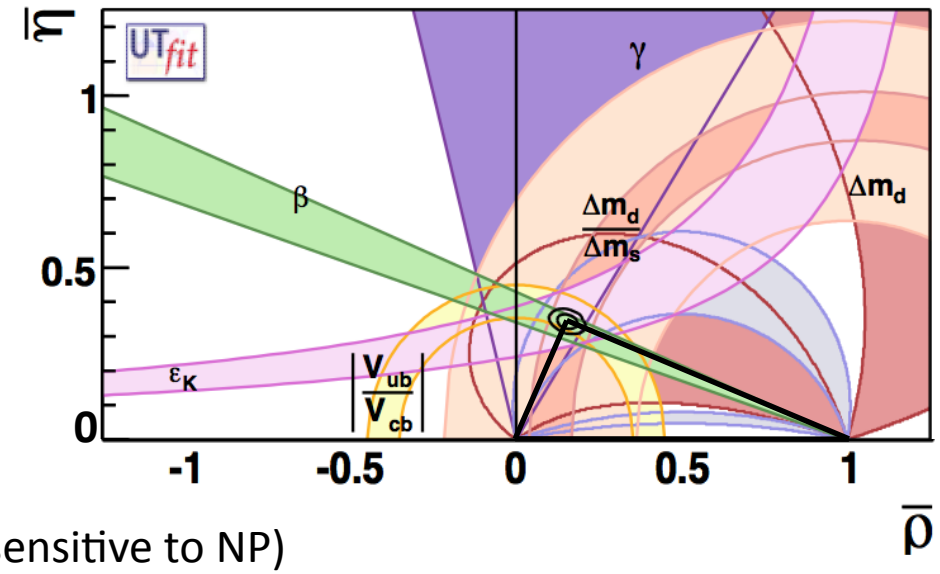




Measure differences in the behaviour of particles under CP transformation

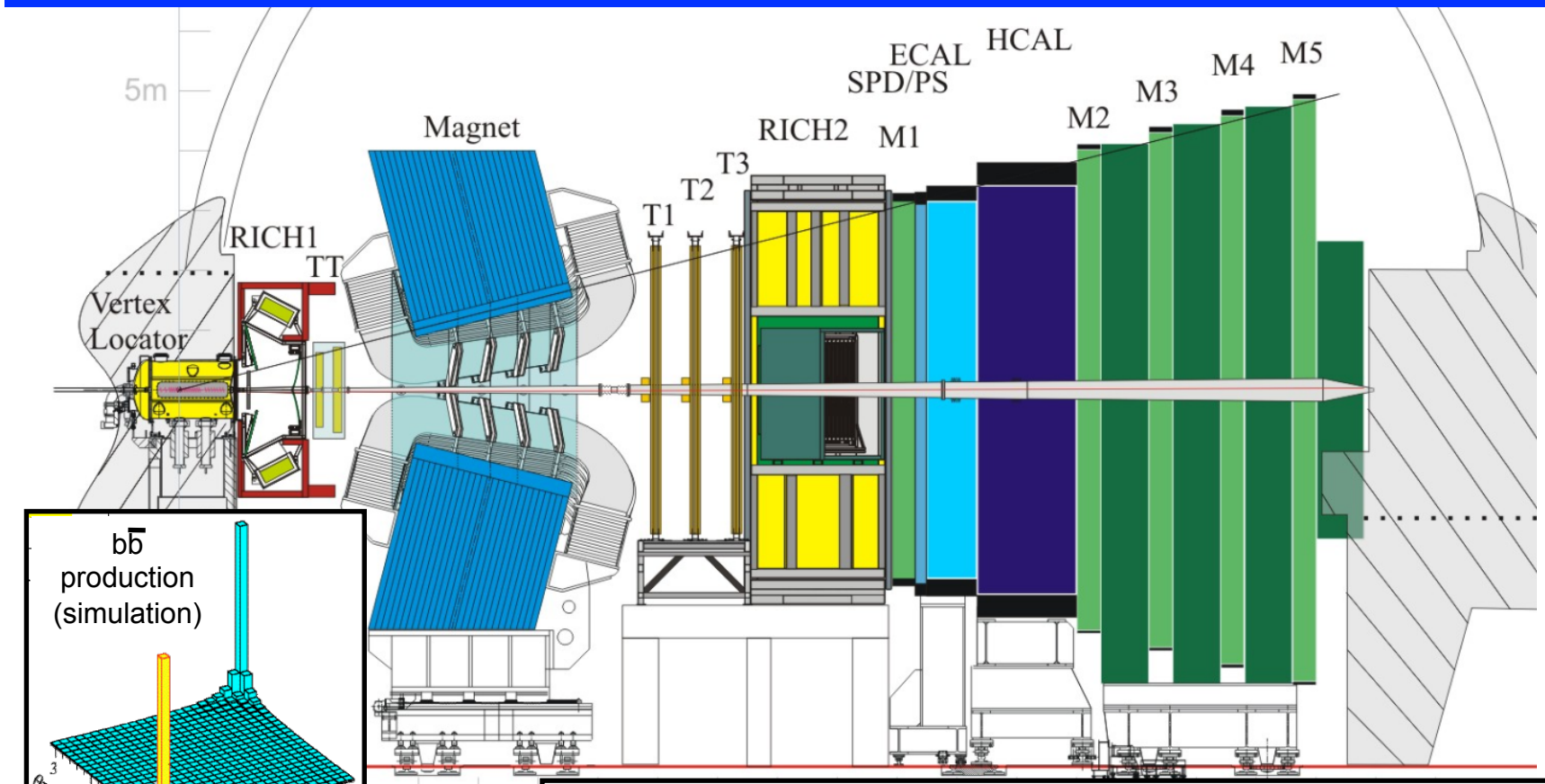
Look for discrepancy with respect to prediction

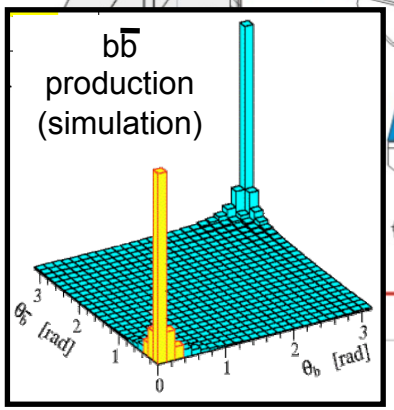
Status of the Art

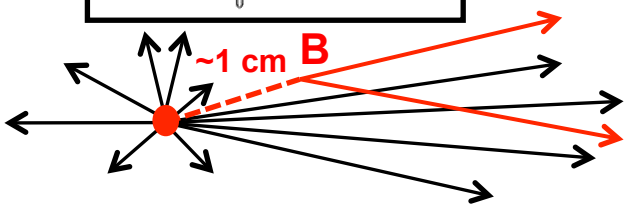


- Good agreement from all measurements
- Still open windows to NP corrections at 10-20%
  - $\sigma(\gamma) \sim 15\text{-}20°$
  - B_s mixing phase
  - Rare decays:
    - $B_s \rightarrow \mu^+\mu^-$: BR not measured (sensitive to NP)
    - $B_d \rightarrow K^*\mu^+\mu^-$: not clear measurements status
  - Charm sector: mixing induced CP-violation needs more precise measurements

LHCb Detector

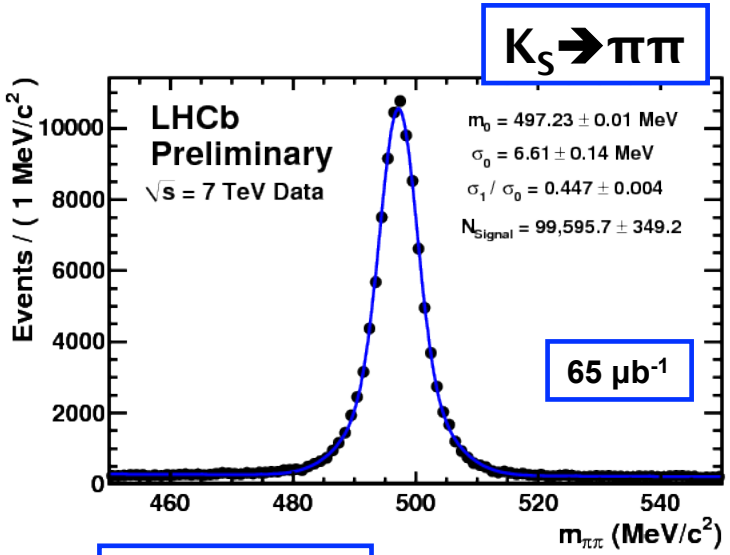


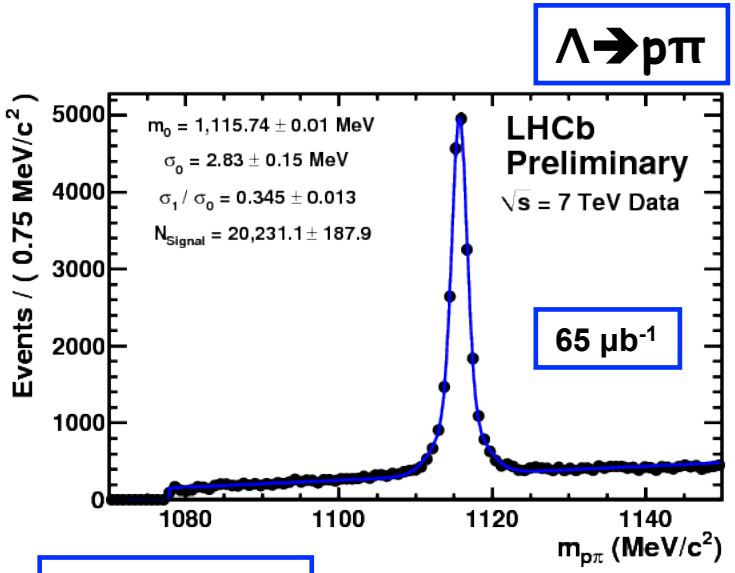


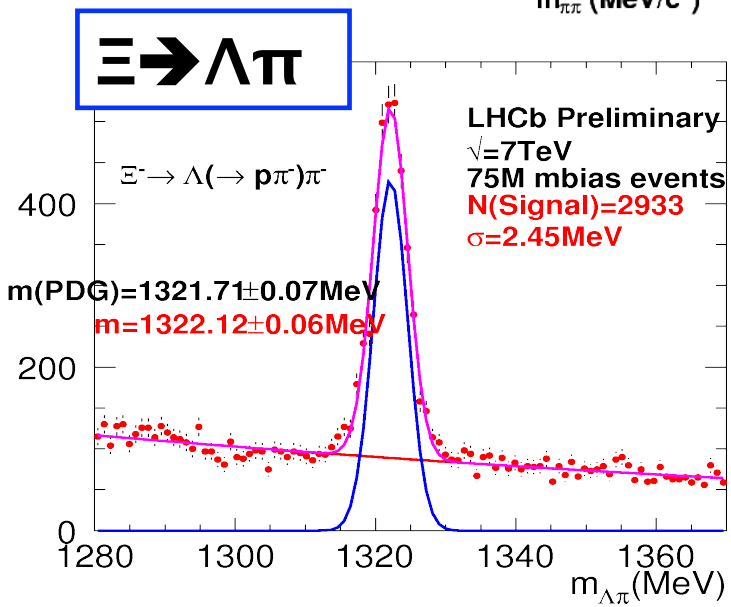


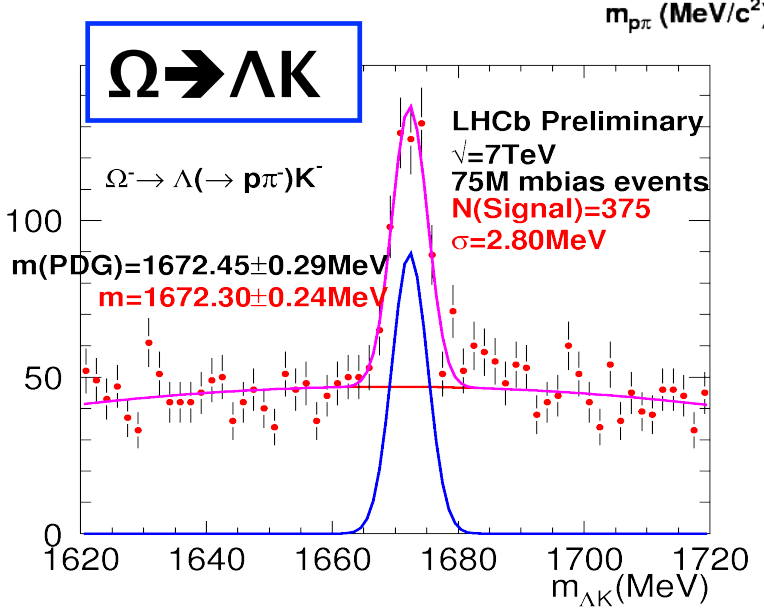
- Excellent vertexing (high proper time resolution)
- Excellent tracking (invariant mass resolution)
- Particle ID (discrimination of various hadrons)
- Trigger on high E_T hadrons and high p_T muons (hints of B presence)

Detector status (I)

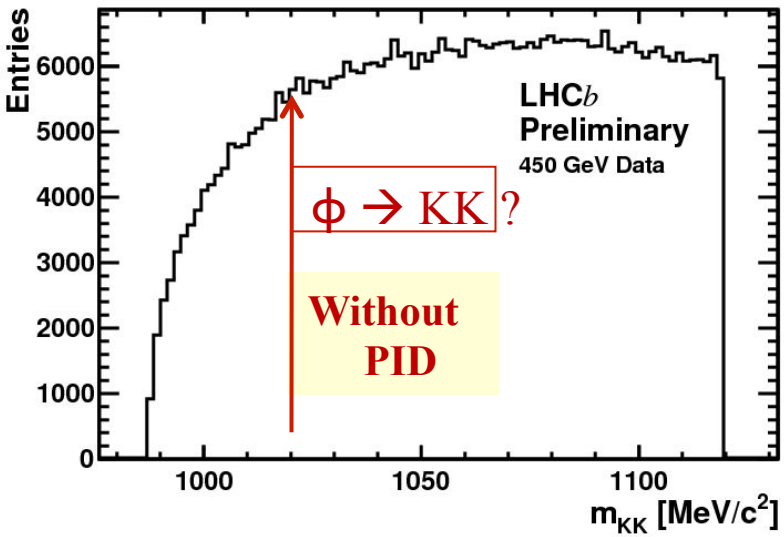


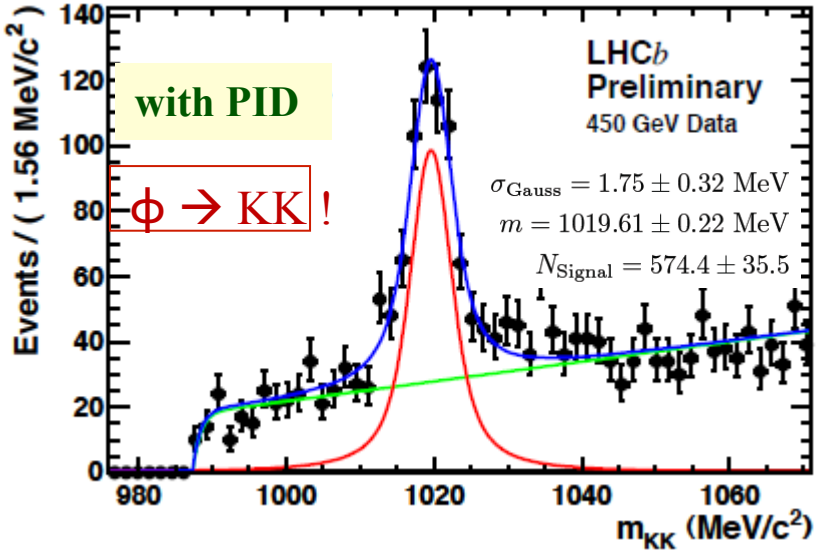


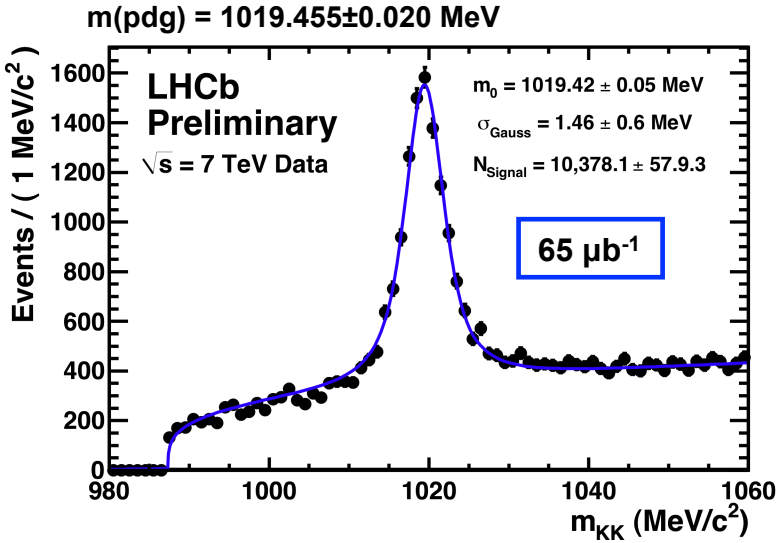




Detector status (II)





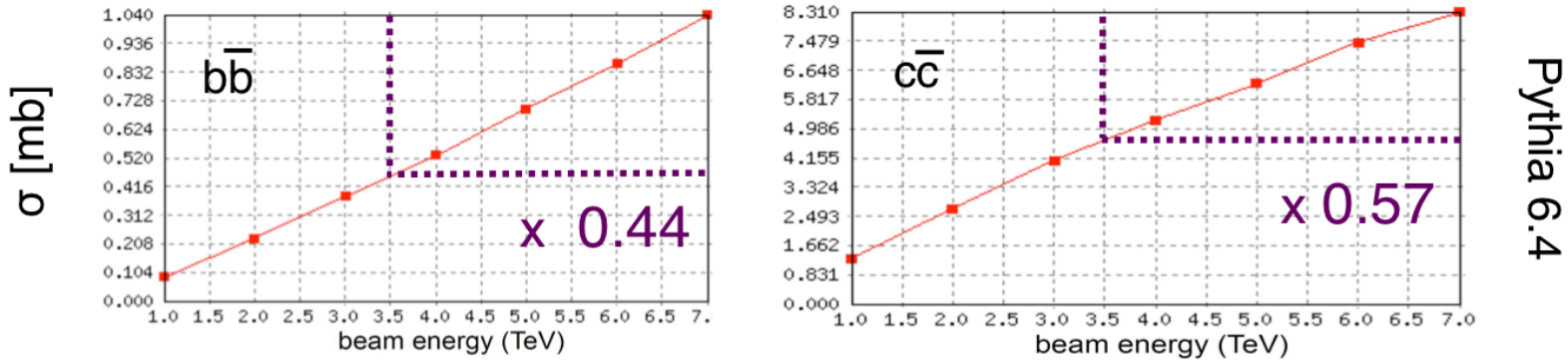


Peak seen cutting only using Particle ID

2010-11 Data Taking

Assumed conditions in MC studies pre-2010			
$\sqrt{s}$	σ_{bb}	$\mathcal{L}$	1 year integrated luminosity
14 TeV	500 μb	2×10^{32} cm^{-2}s^{-1}	2 fb^{-1}

Mainwork about LHCb key measurements **(arXiv:0912.4179v2 [hep-ex])**



2010 expected conditions			
$\sqrt{s}$	σ_{bb}	σ_{cc}	$\mathcal{L}$
7 TeV	500 μb	4.7 mb	< 2×10^{31} cm^{-2}s^{-1}

- Some loss in signal yield due to $\sqrt{s}$=7 TeV
- Release of trigger thresholds
- $\varepsilon_{trig}^{charm}$ ~ 40-50%
- Expected **0.1 fb^{-1}** of integrated luminosity

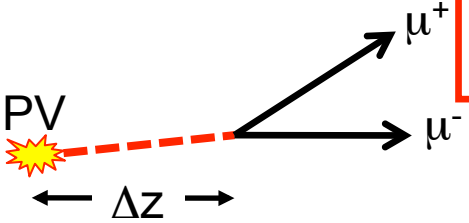
2011 expected conditions			
$\sqrt{s}$	σ_{bb}	σ_{cc}	$\mathcal{L}$
7 TeV	500 μb	4.7 mb	~10^{32} cm^{-2}s^{-1}

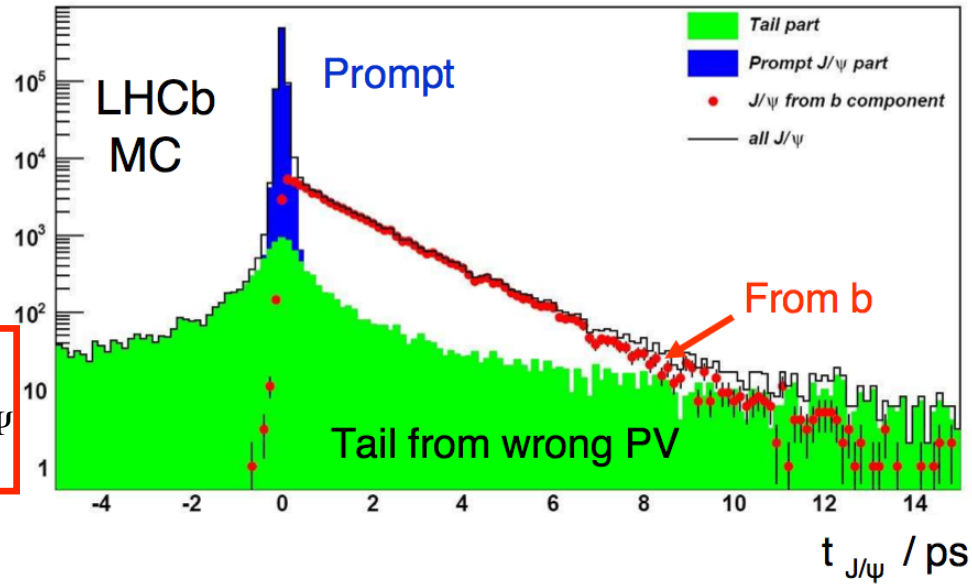
- $\mathcal{L}$ close to design value
- $\varepsilon_{trig}^{charm}$ ~ 10%
- ε_{trig}^{B} ~ 75-80%
- $\varepsilon_{trig}^{B\to\mu X}$ > 90%
- Expected **1 fb^{-1}** of integrated luminosity

$b\bar{b}$ production

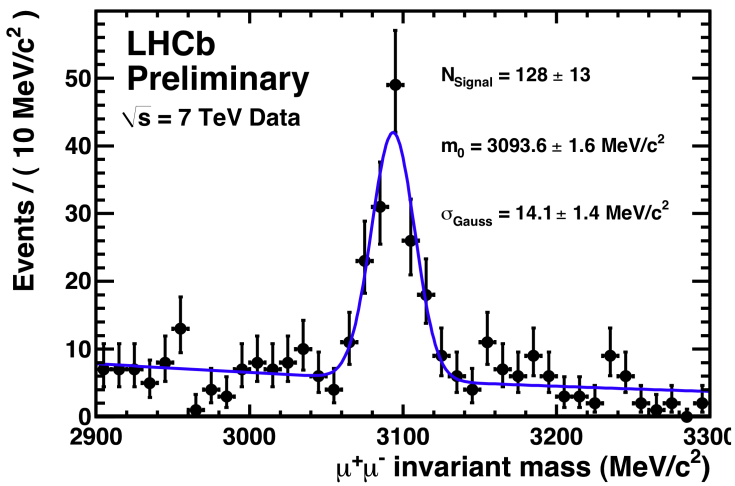
- Evaluation of σ_{bb} from ratio between prompt and displaced J/Ψ
- Combination of invariant mass and pseudo proper-time fits

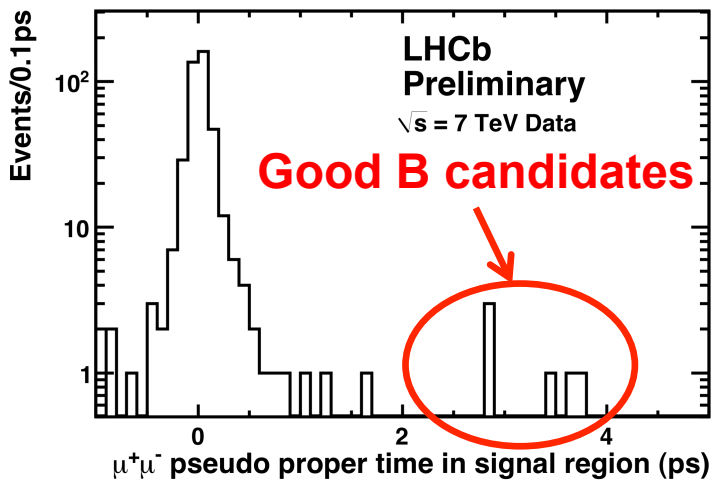
$$t_{J/\Psi} = \frac{\Delta z}{p_z^{J/\Psi}} \cdot m_{J/\Psi}$$





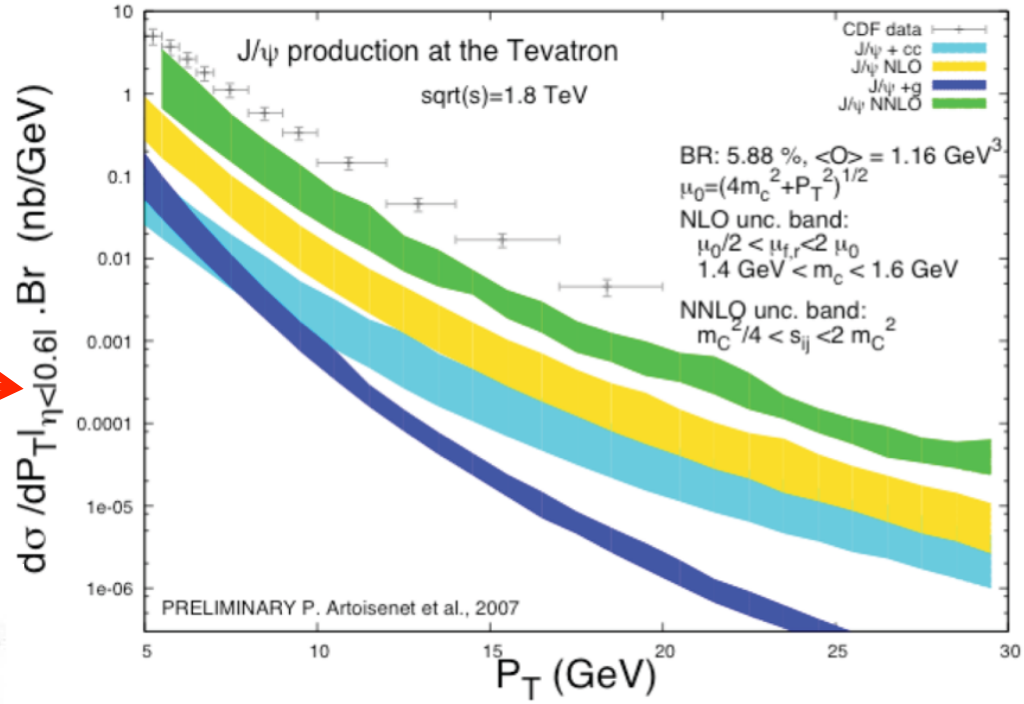
J/Ψ @ 800 μb^{-1}

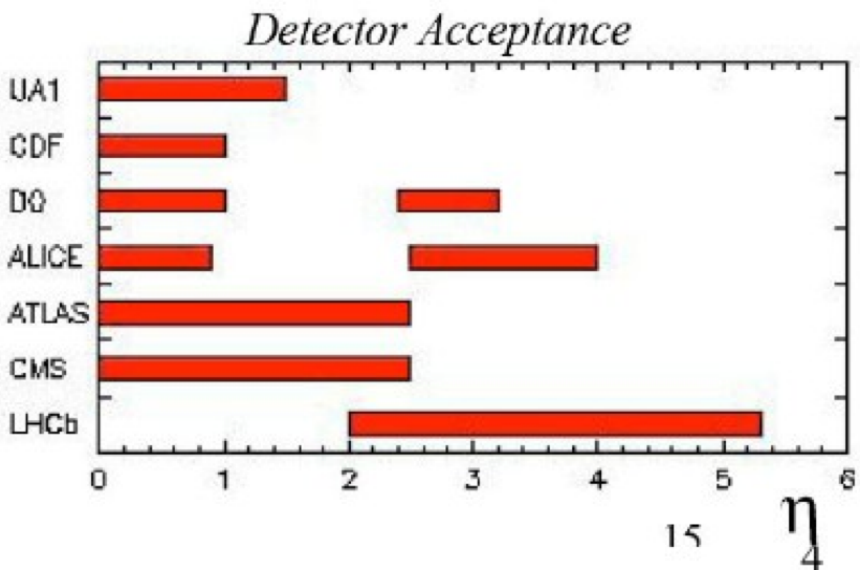




J/Ψ production

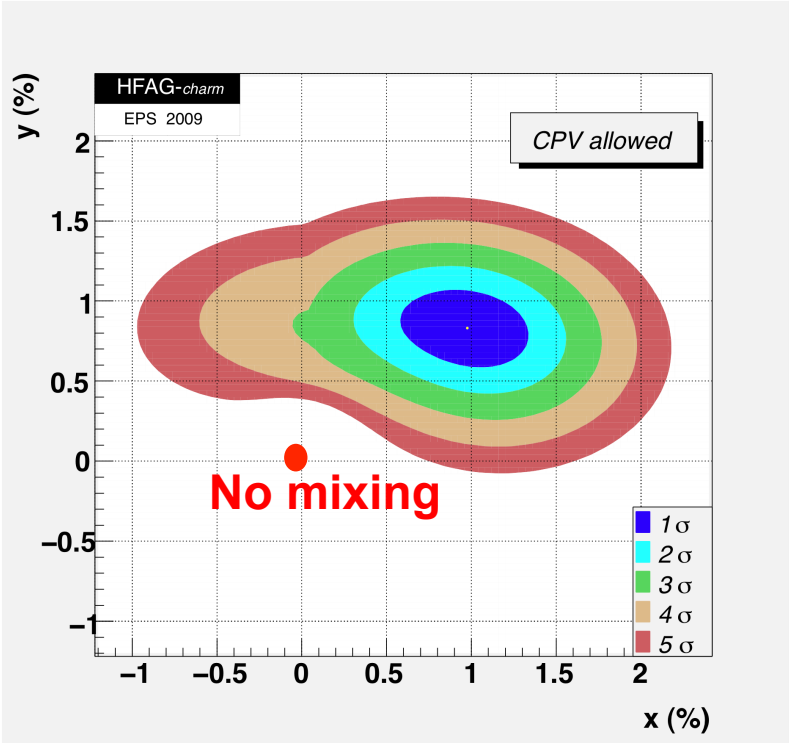
- J/Ψ is also important by itself:
  - All models nowadays fail to incorporate cross section and polarization
- No much data at high pseudorapidity
- J/Ψ also produced in decay of various charmonium states



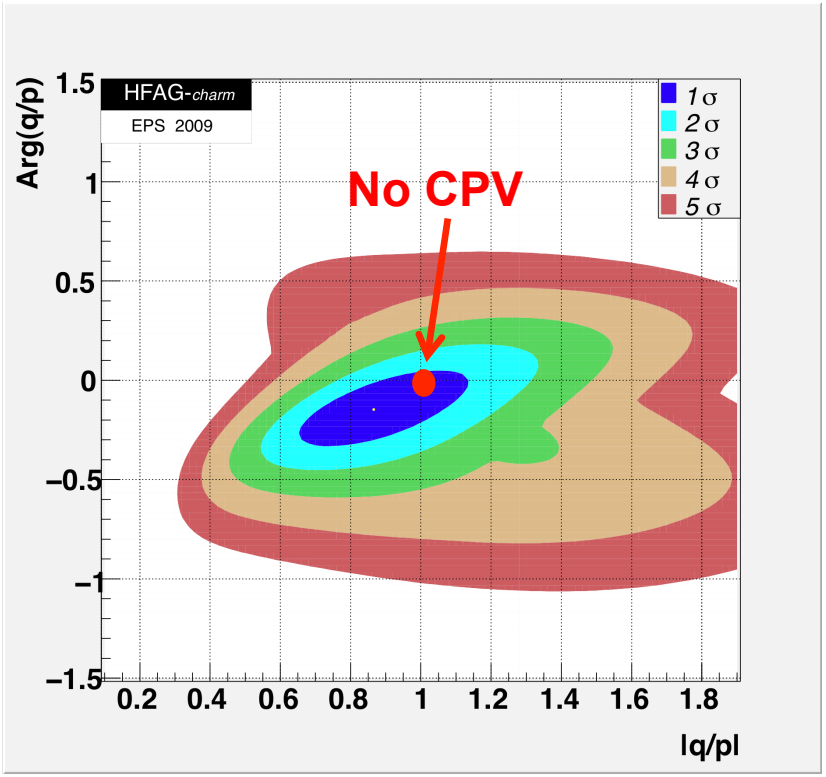


LHCb has great potential to do measurements in uncovered region of pseudorapidity

Mixing and CPV in charm



- Neutral D mixing is nowadays a matter of facts
- More precise measurements needed for CPV programme



- CPV negligible in the SM
  - window for NP discovery
- x and y affect precision on CPV measurements

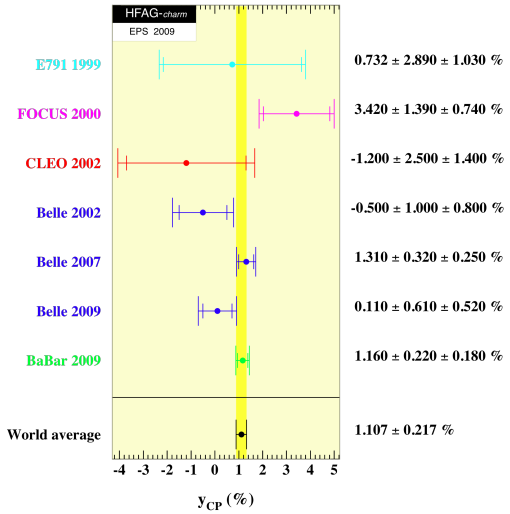
$$A_{CP} \sim A_M y\cos\Phi - x\sin\Phi$$

Mixing and CPV in charm

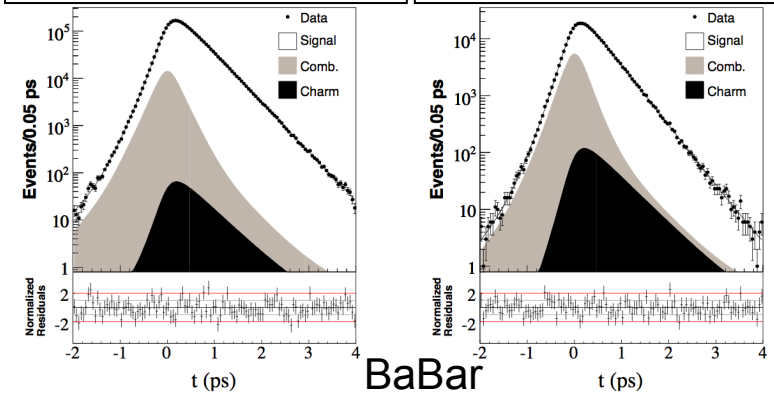
1. Measure "y_{cp}", that means y modified by CPV effects

$$y_{CP} = \frac{\tau\left(D^0 \to K^-\pi^+\right)}{\tau\left(D^0 \to h^+h^-\right)} - 1$$

$$y_{CP} = y\cos\Phi_D - \left(\left|\frac{q}{p}\right|^2 - 1\right) x\sin\Phi_D$$



2.7x10^6 untagged Kπ | 2.6x10^5 untagged KK



BaBar

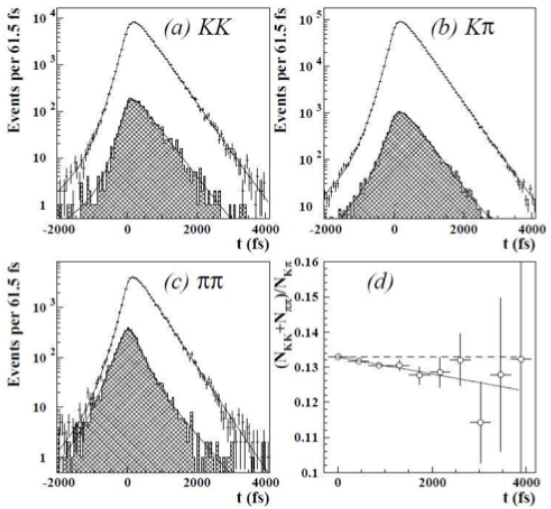
arXiv:0908.0761v1 [hep-ex]

Measure of A_Γ :

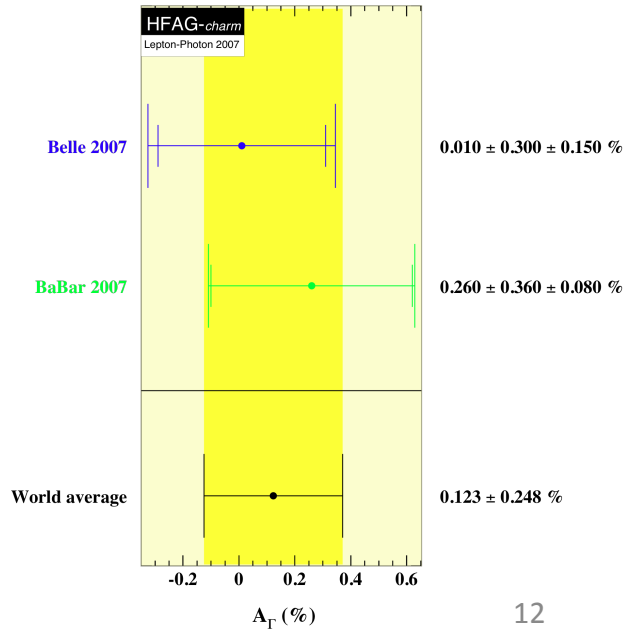
$$A_\Gamma(t) = \frac{\tau\left(\overline{D}^0 \to h^+h^-\right) - \tau\left(D^0 \to h^+h^-\right)}{\tau\left(\overline{D}^0 \to h^+h^-\right) + \tau\left(D^0 \to h^+h^-\right)}$$

$$A_\Gamma = \left(\left|\frac{q}{p}\right|^2 - 1\right) y\cos\Phi_D - x\sin\Phi_D$$

1.1x10^5
tagged D*→D^0(→KK)π

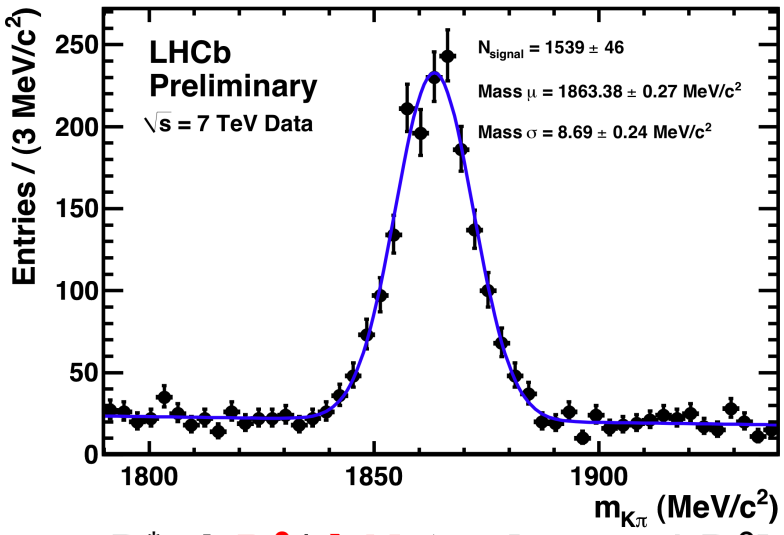


Belle, PRL 98 (2007) 211803

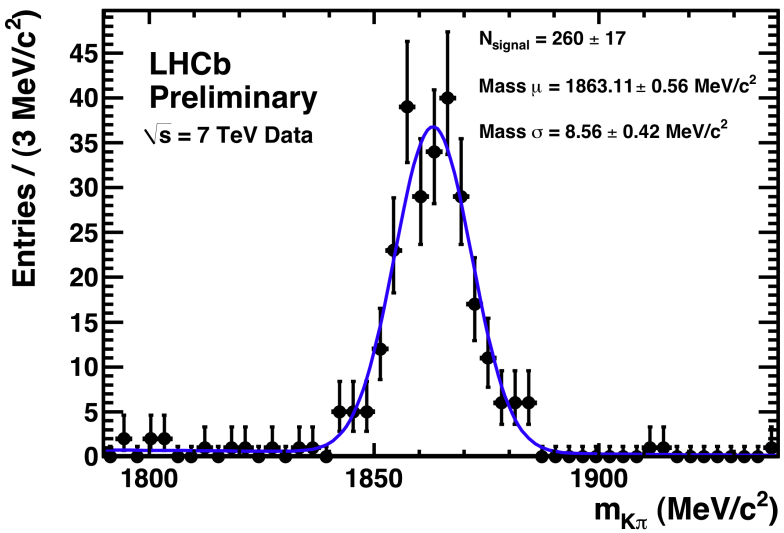


D^0 in LHCb @ 800μb^{-1}

$D^0 \rightarrow K\pi$ untagged

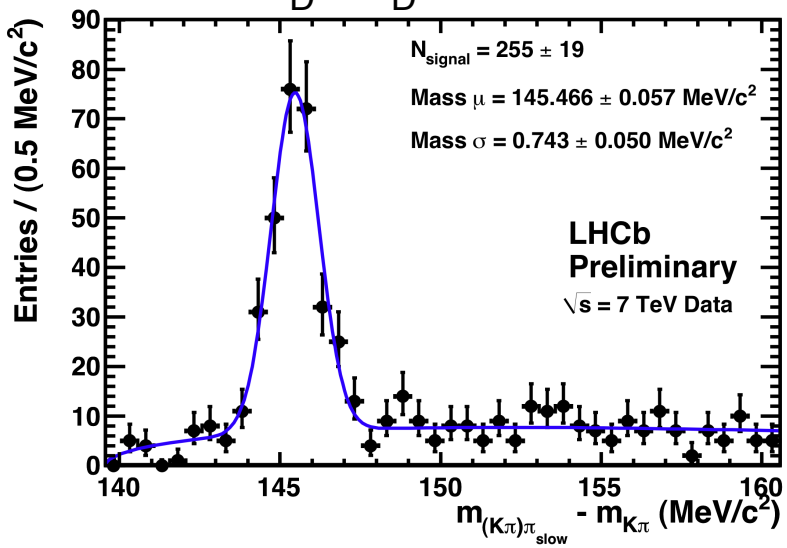


$D^{*+} \rightarrow D^0(\rightarrow K\pi)\pi^+$ [tagged D^0]



Expected several million of untagged and tagged $D^0 \rightarrow K\pi$ @ 0.1 fb^{-1}

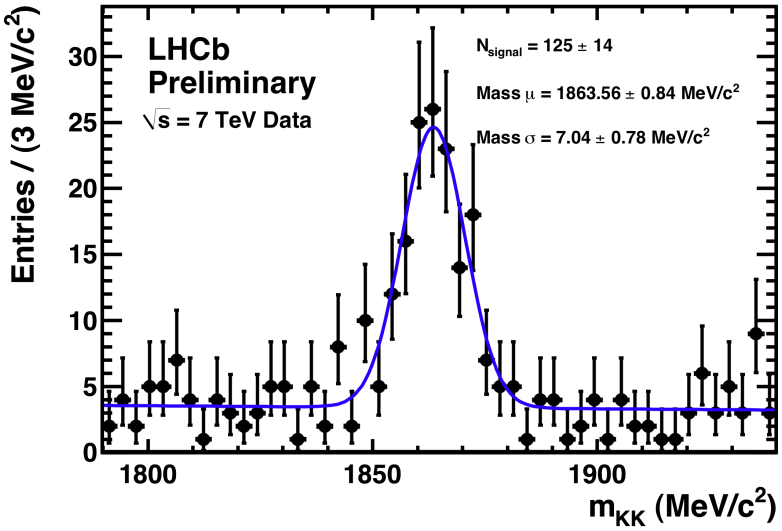
$\Delta m = m_{D^*} - m_D$



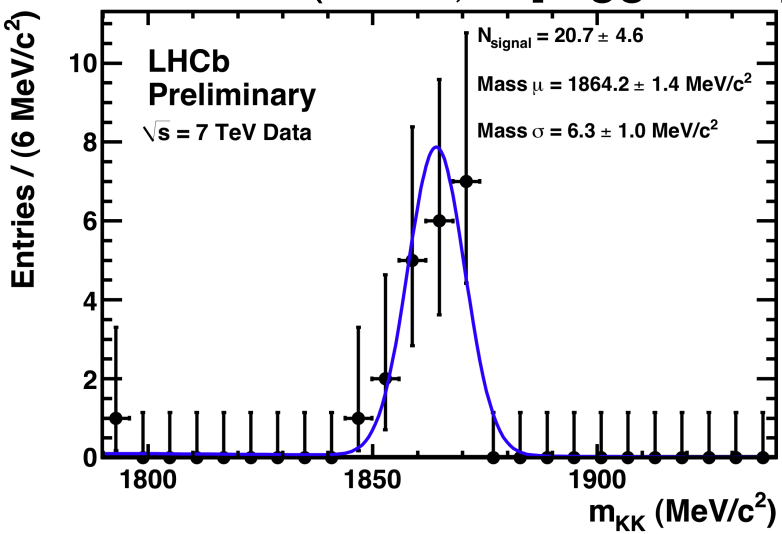
$m_{D^*} - m_D < \mu_{\Delta m} \pm 2\sigma_{\Delta m}$

D^0 in LHCb @ 800μb^{-1}

$D^0 \rightarrow KK$ untagged



$D^{*+} \rightarrow D^0(\rightarrow KK)\pi^+$ [tagged D^0]



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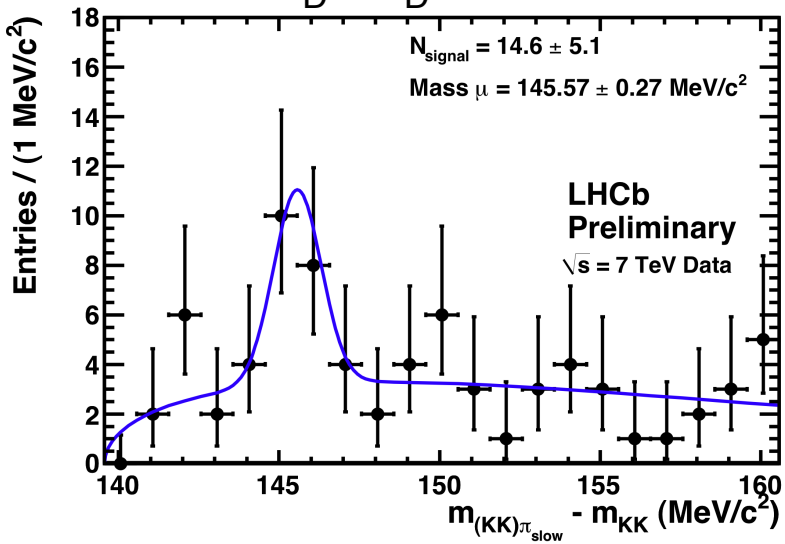
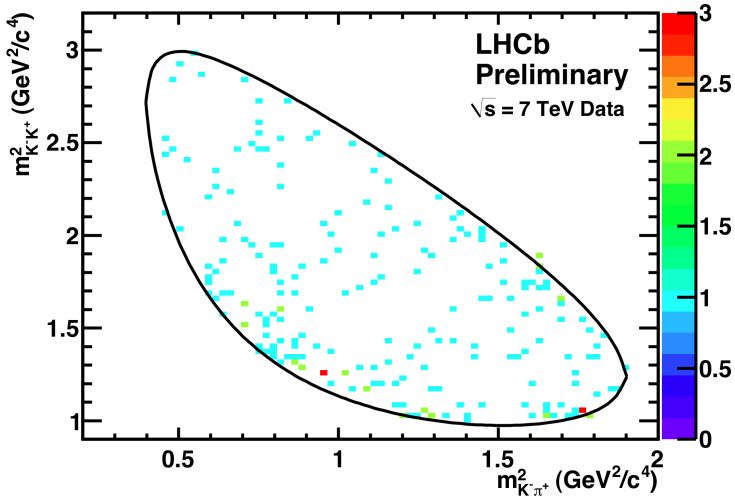
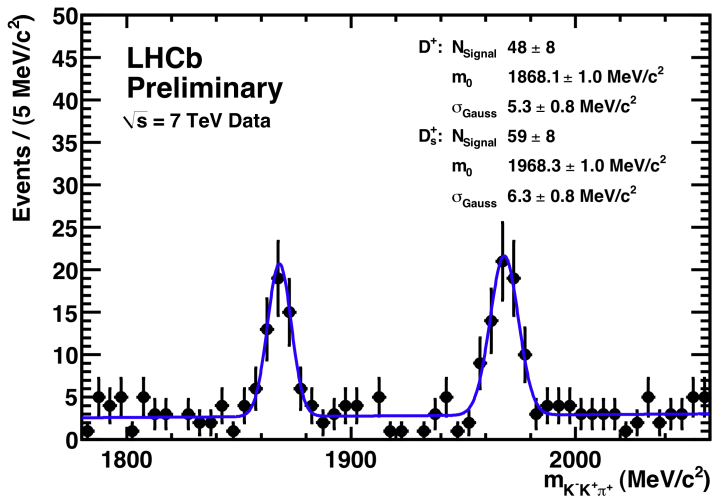


$m_{D^*} - m_D < \mu_{\Delta m} \pm 2\sigma_{\Delta m}$

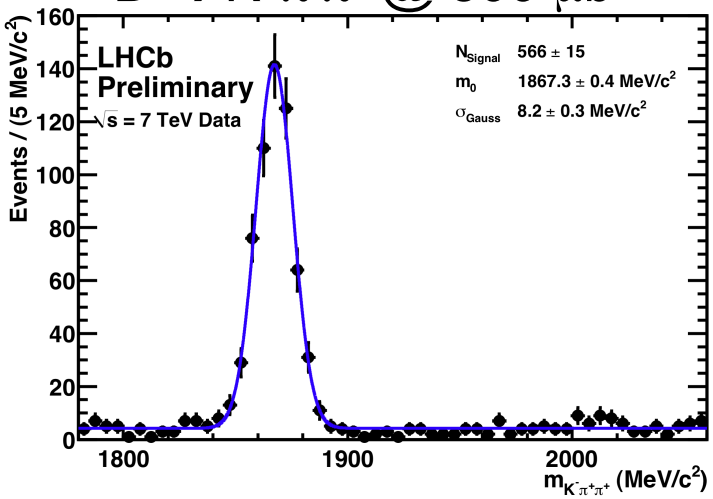
Direct CPV in charm

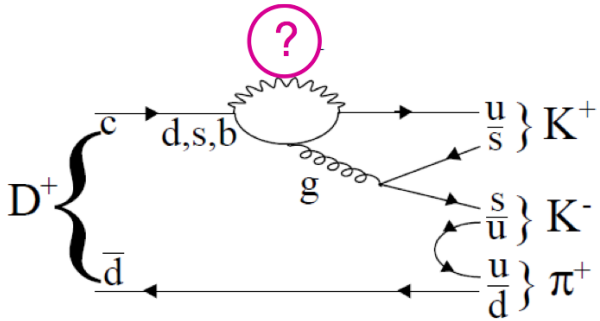




$D_{(s)}^+ \rightarrow K^+K^-\pi^+$ @ 800 μb^{-1}

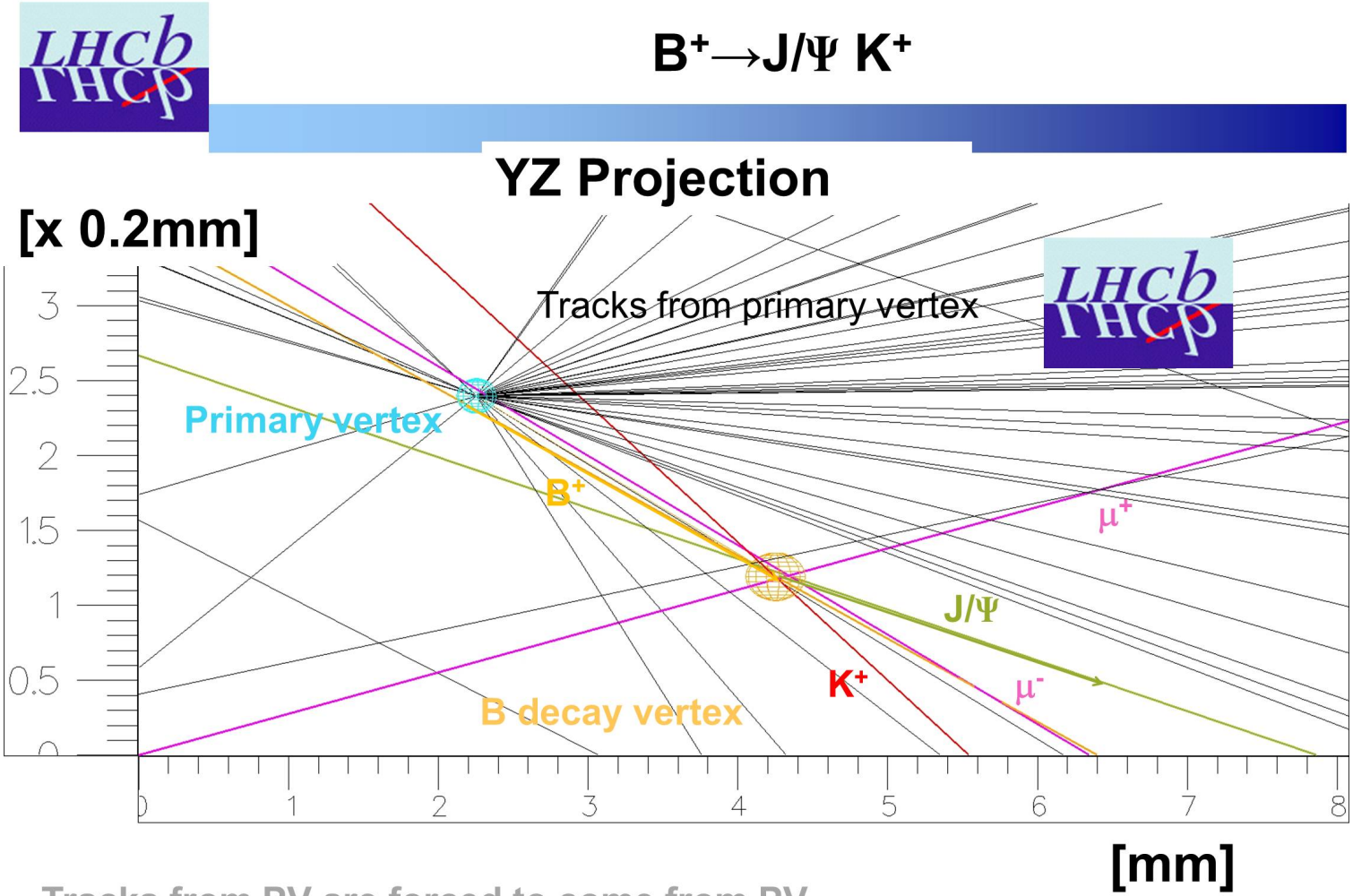
$D^+ \rightarrow K^+\pi^-\pi^+$ @ 800 μb^{-1}





- $D^+ \rightarrow K^+K^-\pi^+$: Cabibbo Suppressed decay
- Penguin loops contributions → possible NP effects
- $D_s^+ \rightarrow K^+K^-\pi^+$ & $D^+ \rightarrow K^+\pi^-\pi^+$: control channels
- Several million @ 0.1 fb^{-1}

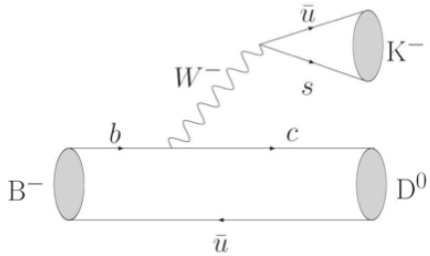
What about B decays?



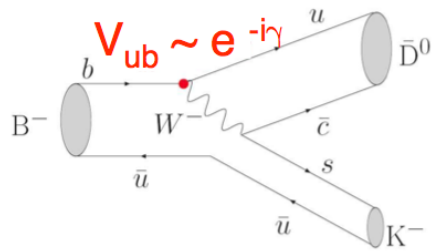
Tracks from PV are forced to come from PV

γ from trees

$B^- \longrightarrow D^0 K^-$



$B^- \longrightarrow \overline{D}^0 K^-$



Many parameters involved can dilute sensibility to γ

$R_{CP} \sim 2r_B\cos(\delta_B)\cos(\gamma)$
$A_{CP} \sim 2r_B\sin(\delta_B)\sin(\gamma) / R_{CP}$

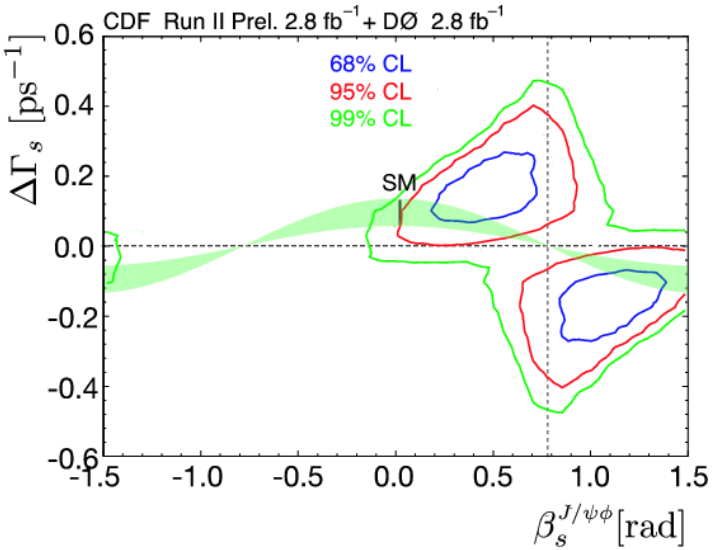
Need to over constrain the system with various channels

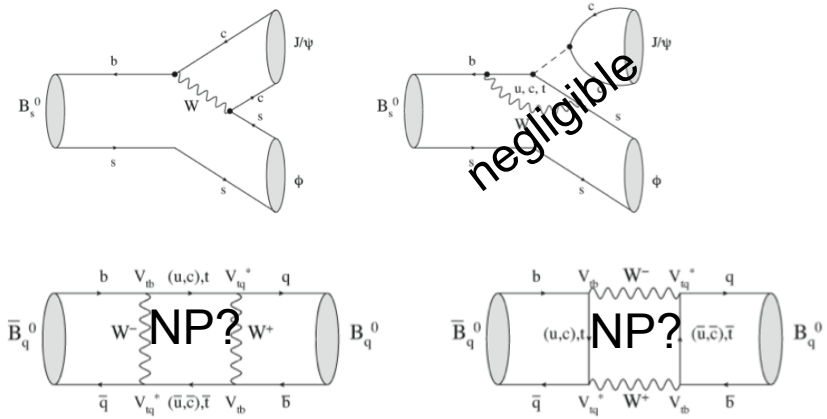
1. GLW (Gronau, London, Wyler):
   - Exploit asymmetries for D^0 decaying to CP-even or CP-odd eigenstates
   - $D^0 \rightarrow KK$, $D^0 \rightarrow \pi\pi$
   - Also $B^0 \rightarrow D^0(\rightarrow hh)K^*$
2. ADS (Atwood, Dunietz, Soni):
   - Exploit asymmetries for D^0 to flavor specific channel ($D^0 \rightarrow K\pi$, $D^0 \rightarrow K\pi\pi\pi$)
3. Dalitz analysis (Giri, Grossman, Soffer and Zupan):
   - Exploit asymmetries in $D^0 \rightarrow K_S^0\pi\pi$ and $D^0 \rightarrow K_S^0 KK$

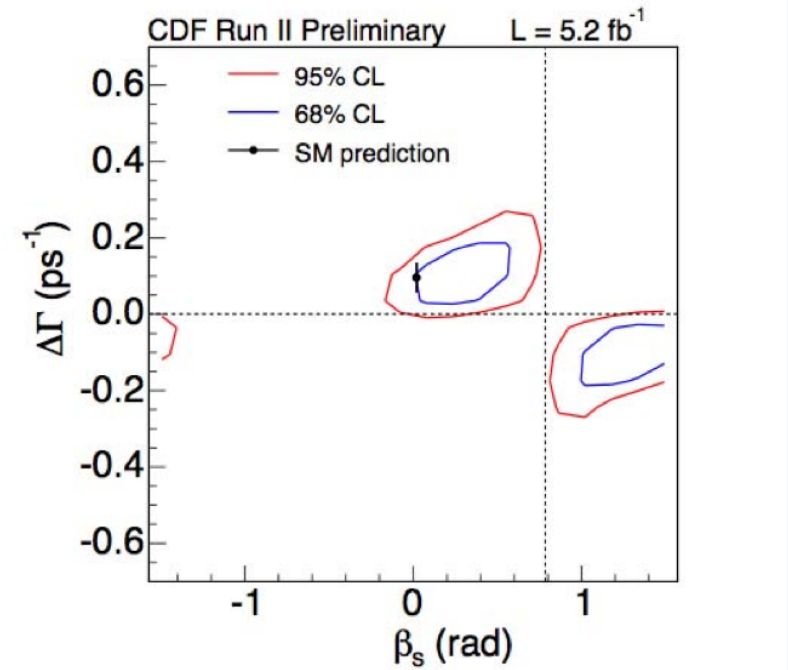
- **$\sigma_{LHCb} \sim 7°$ @ $1fb^{-1}$**

B_s mixing phase

- Very precisely predicted in SM → $\beta_s = 0.02$
- Tevatron measurements give us a hint for NP
- Golden channel: $B_s \rightarrow J/\Psi\ \Phi$
  - Penguin pollution negligible
  - $J/\Psi \rightarrow \mu\mu$: very clean signal for LHCb







History:

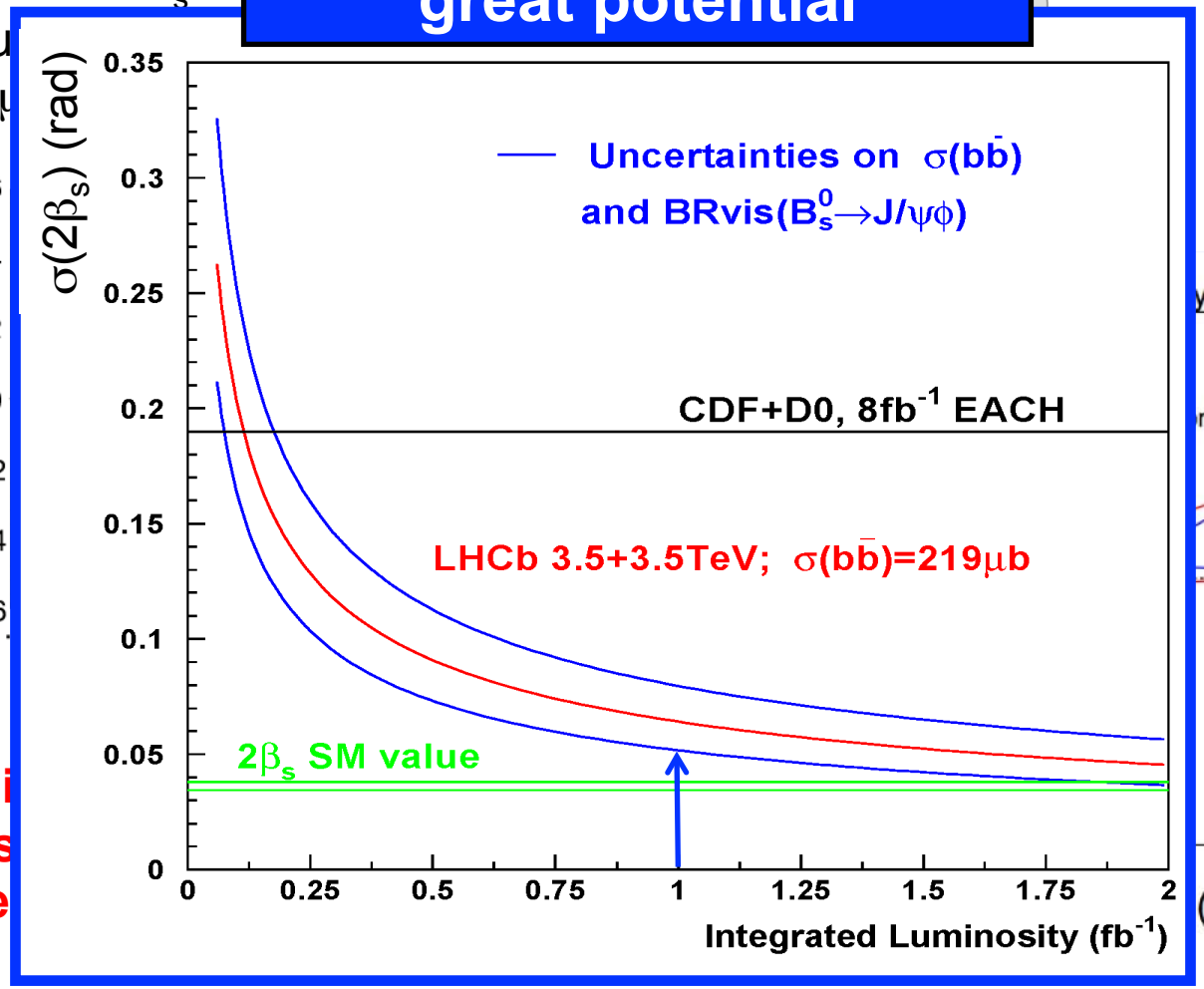
Old result: β_s = [0.10, 1.42] @ 95% C.L.

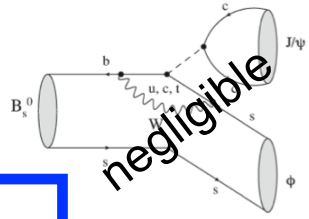
New result: β_s = [-0.1, 0.7] @ 95% C.L.

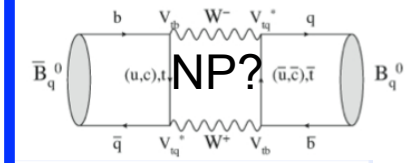
B_s mixing phase

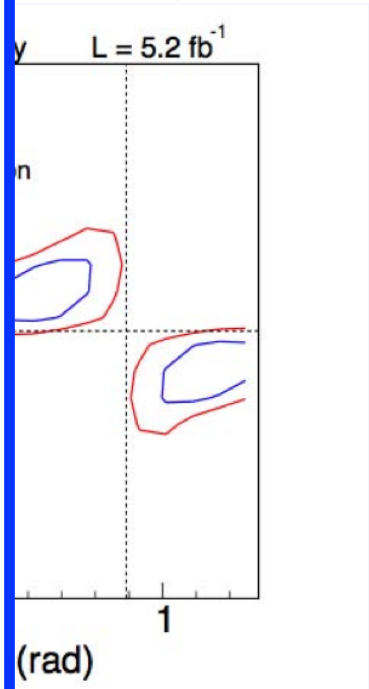
- Very precisely predicted in SM → β_s = 0.02
- Tevatron measuremen
- Golden channel: B_s→
  - Pengu
  - J/Ψ→μ

LHCb has in any case a great potential





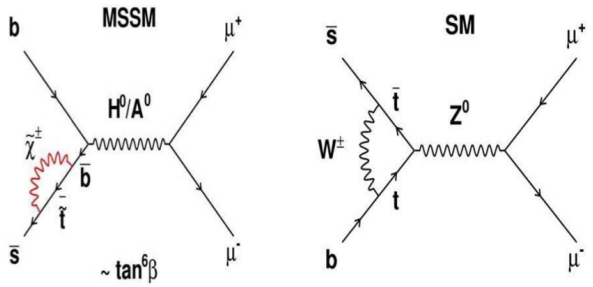




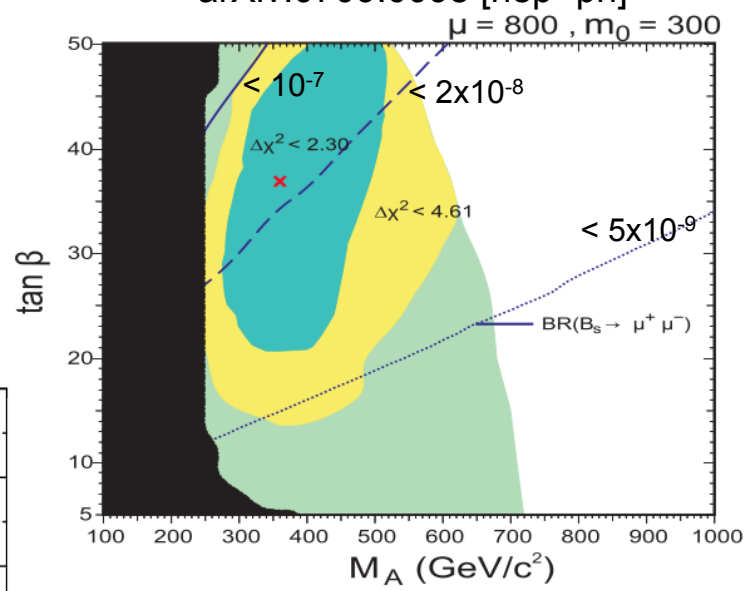
Intrigui
Old res
New re

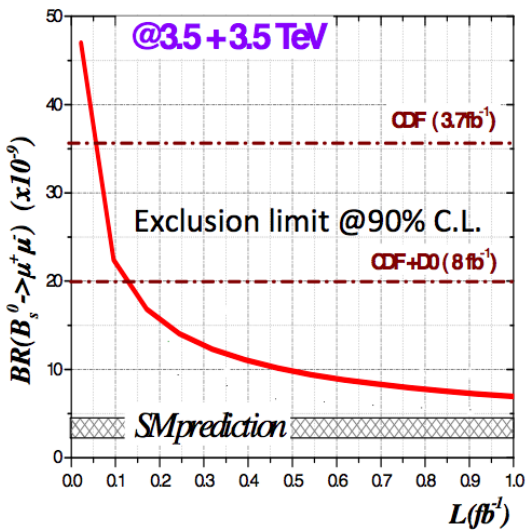
$B_s \rightarrow \mu\mu$ (I)

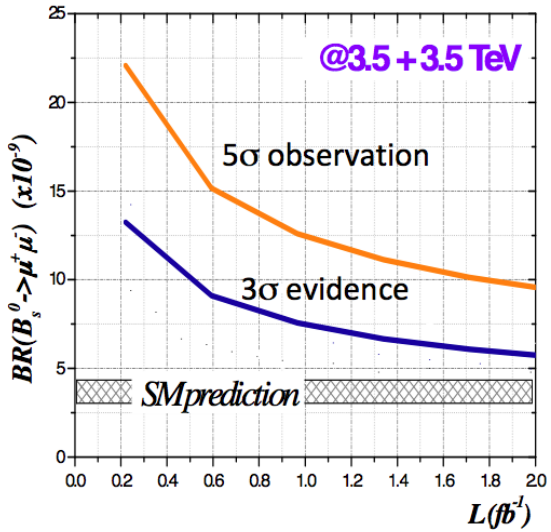
- Flavor Changing Neutral Current process
- $BR(B_s \rightarrow \mu\mu) = (3.35 \pm 0.32) \times 10^{-9}$ [Blanke et al., JHEP 0610:003,2006]
- Very sensible to NP → BR altered from SM prediction



arXiv:0709.0098 [hep- ph]

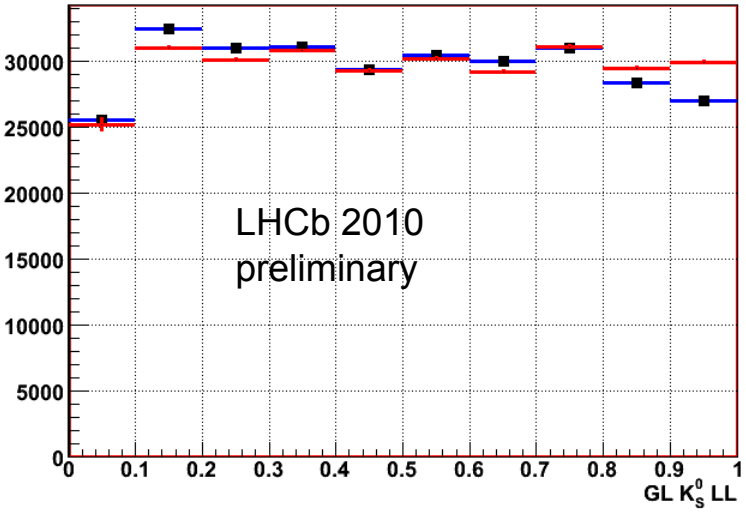






Already at 0.1 fb^{-1} LHCb can give competitive results

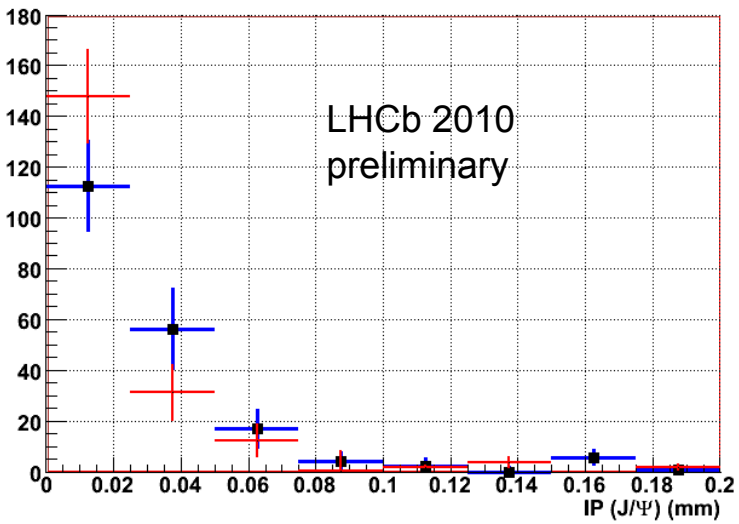
$B_s \rightarrow \mu\mu$ (II)

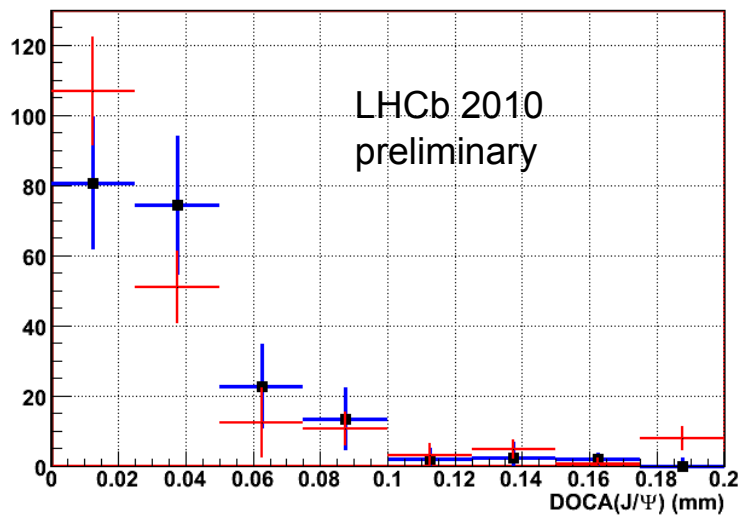


- Strategy (as at Tevatron):
  - Very loose selection
  - Loooking for signal using a global likelihood method
- Calibration already started using **$K_S^0 \rightarrow \pi^+\pi^-$** and **$J/\Psi \rightarrow \mu^+\mu^-$**

data

MC



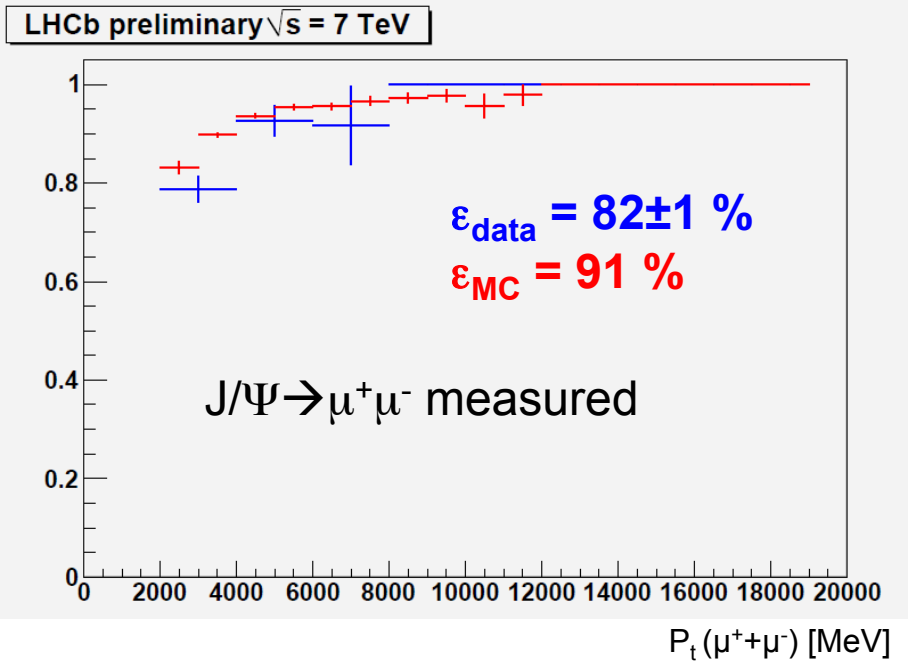


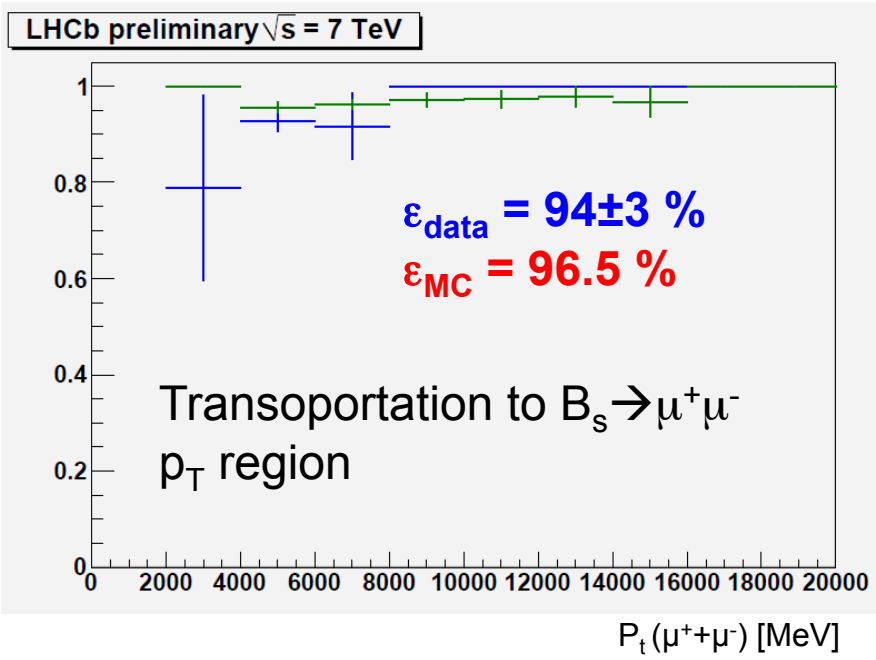
$B_s \rightarrow \mu\mu$ (II)

- Trigger must to be as efficient as possible:
  - Calibration with $J/\Psi \rightarrow \mu^+\mu^-$

data

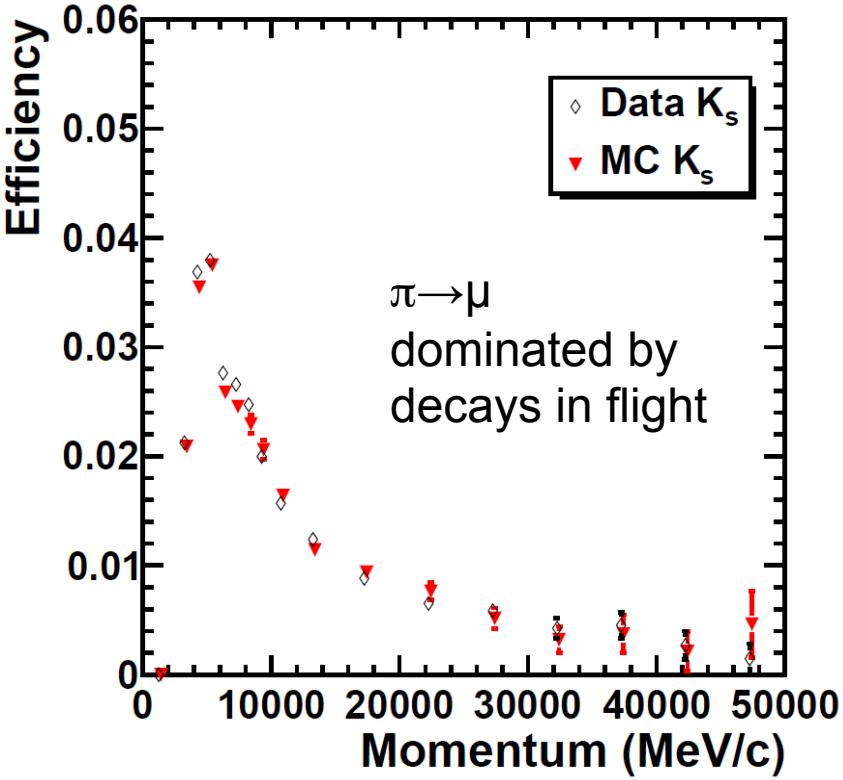
MC

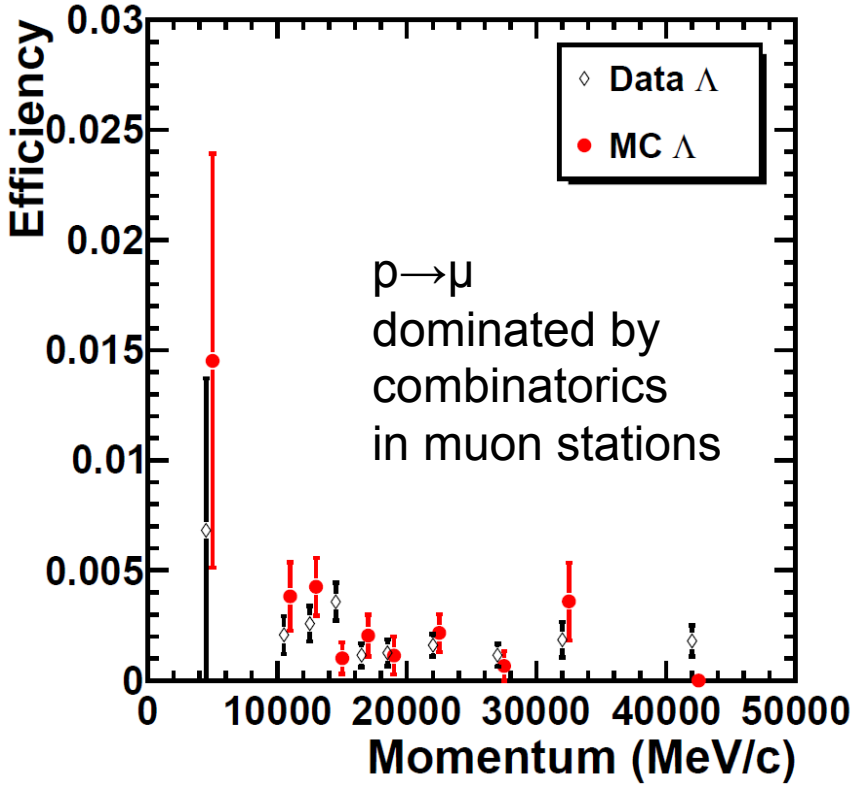




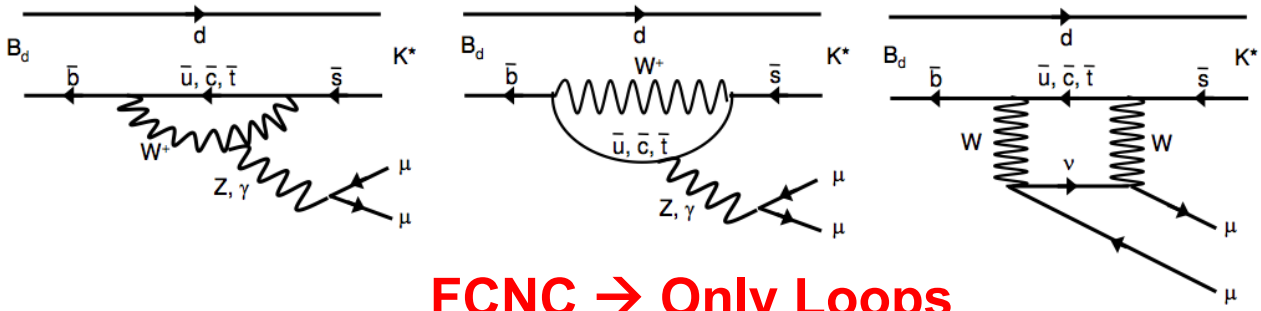
$B_s \rightarrow \mu\mu$ (III)

- Importance of MuonID:
  - Mis-ID: using K_S^0 and Λ as source of π and p
  - MuonID: using $J/\Psi \rightarrow \mu^+\mu^-$





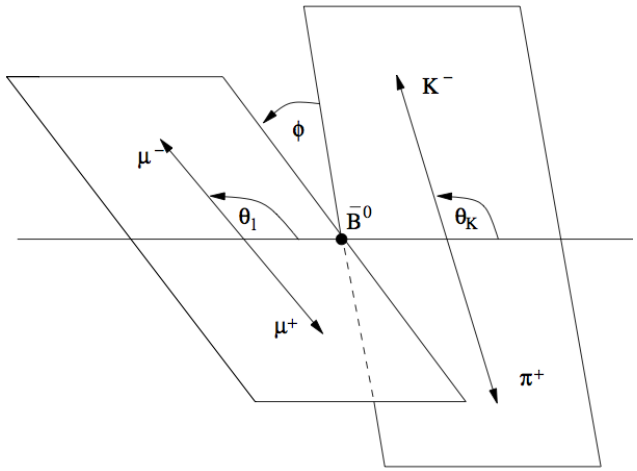
$B^0 \rightarrow K^* \mu^+ \mu^-$ (I)

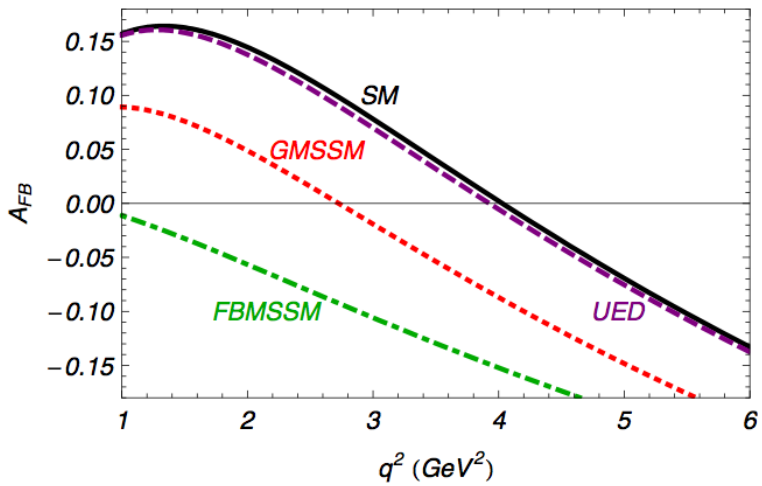


FCNC → Only Loops

NP

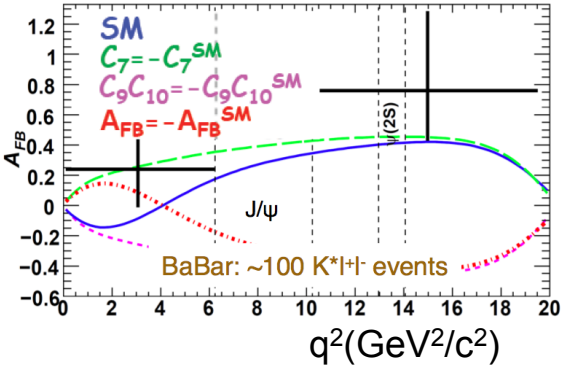
Decay totally described via geometrical observables



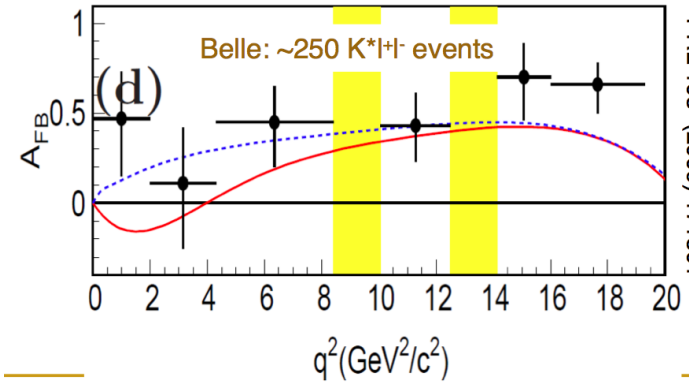


The point at A_{FB} = 0 can probe various NP models

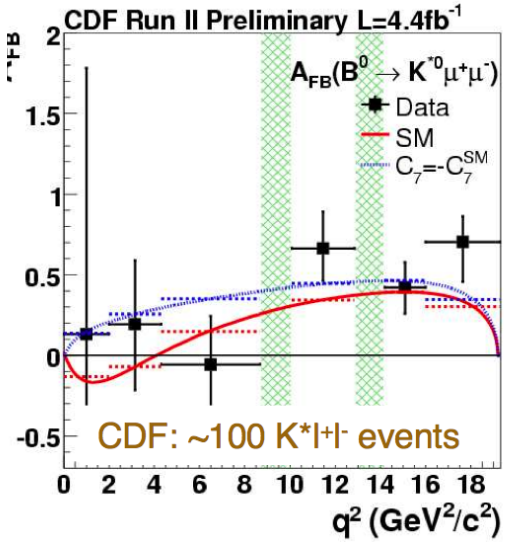
$B^0 \rightarrow K^* \mu^+ \mu^-$ (II)



PRD 79 (2009) 031102



PRL 103 (2009) 171801

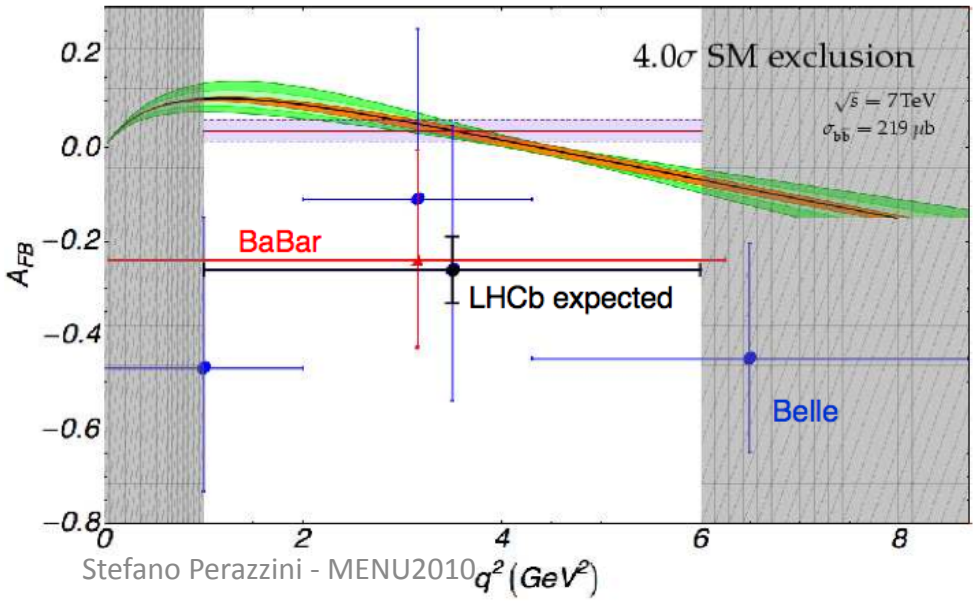


CDF note 10047

Experimental status not so clear

LHCb @ 1 fb^{-1}
~1200 events

If NP signal not so large will be necessary to more bins in q^2
$\sigma(q^2) \sim 0.8$ GeV^2 @ 1fb^{-1}



Flipped sign in asymmetry definition compared with slide on existing results

No time to mention

- V^0 analysis:
  - Λ, anti-Λ and K_s^0 production
  - (Λ and anti-Λ)/K_s^0 ratio
- CP asymmetries in gluonic $b \to s$ penguin decays
  - $B_s \to \phi\phi$, K^*K^*
- Charmless hadronic 2-body and 3-body B Decays
- Radiative penguin decays
  - $B_s \to \phi\gamma$, $B \to K^*\gamma$
- More CKM metrology
  - $\sin 2\beta$ ($B_d \to J/\psi K_S$)
  - α ($B \to \rho\pi$)

Conclusions

1. LHC has started:
   a) The lower centre-of-mass energy of LHC loss will not affect dramatically LHCb performances → wait for a measurement of σ_{bb}
   b) Luminosity conditions opened a very promising window on charm and is expected to approach the LHCb design luminosity in 2011

2. LHCb status is good:
   a) Already seen a lot of well known strange and charm peaks
   b) Calibration well underway (alignment and PID)
   c) First B candidates observed

3. Physics programme:
   a) Charm analysis will exploit several million of D meson decays
   b) B physics core analyses can lead to competitive measurements already with 0.1 fb^{-1}
   c) 1 fb^{-1} should lead to quite exciting results and New Physics