LHCb performance in 2010
First Results on B-Physics
status and plans

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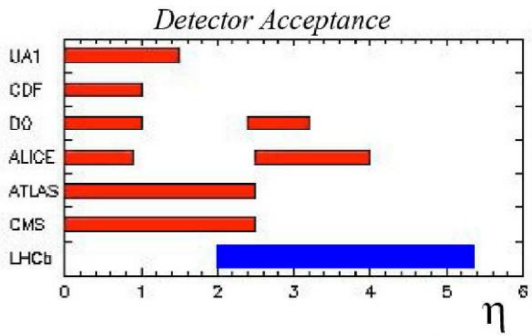
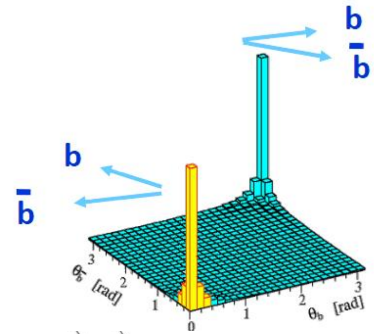
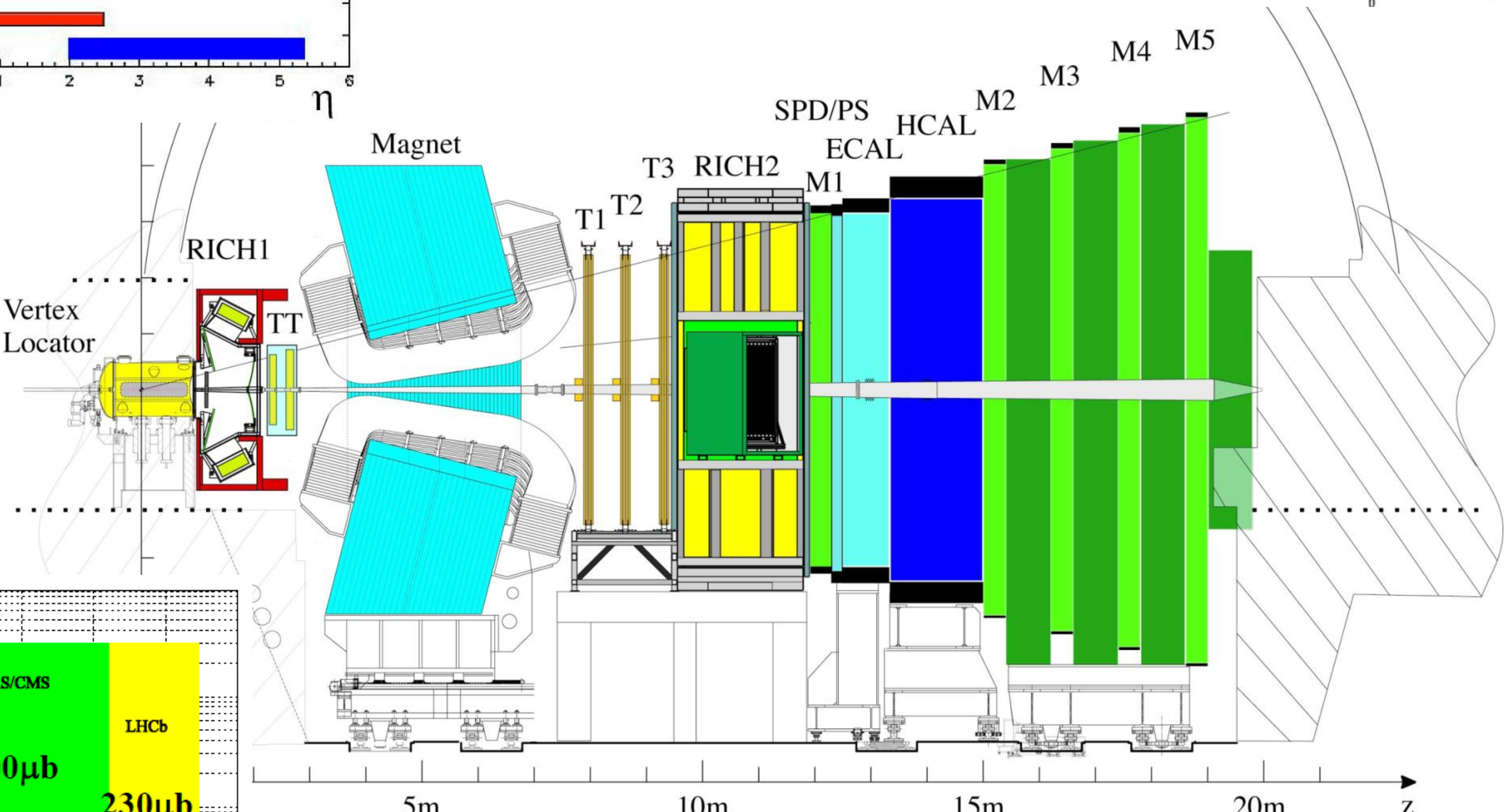
INR, Moscow @ LHCb Collaboration

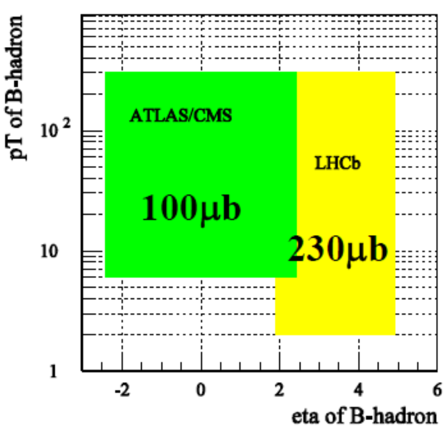
~730 physicists, ~350 students,
54 institutes, 15 countries

LHCb detector





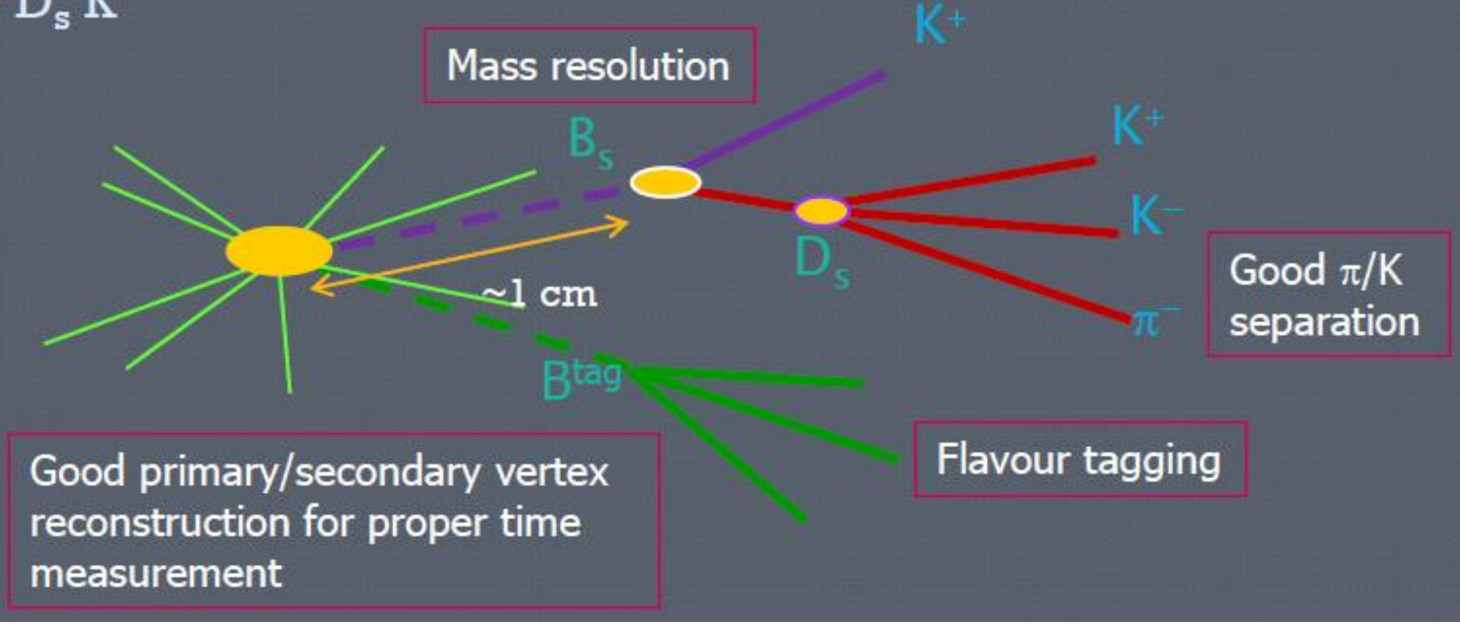




Experimental requirements

- Flexible and efficient trigger for both hadronic and leptonic final states
- Good Particle identification (PID)
- Excellent tracking and vertexing
  - Secondary vertex identification
  - Good momentum, mass and proper time resolutions

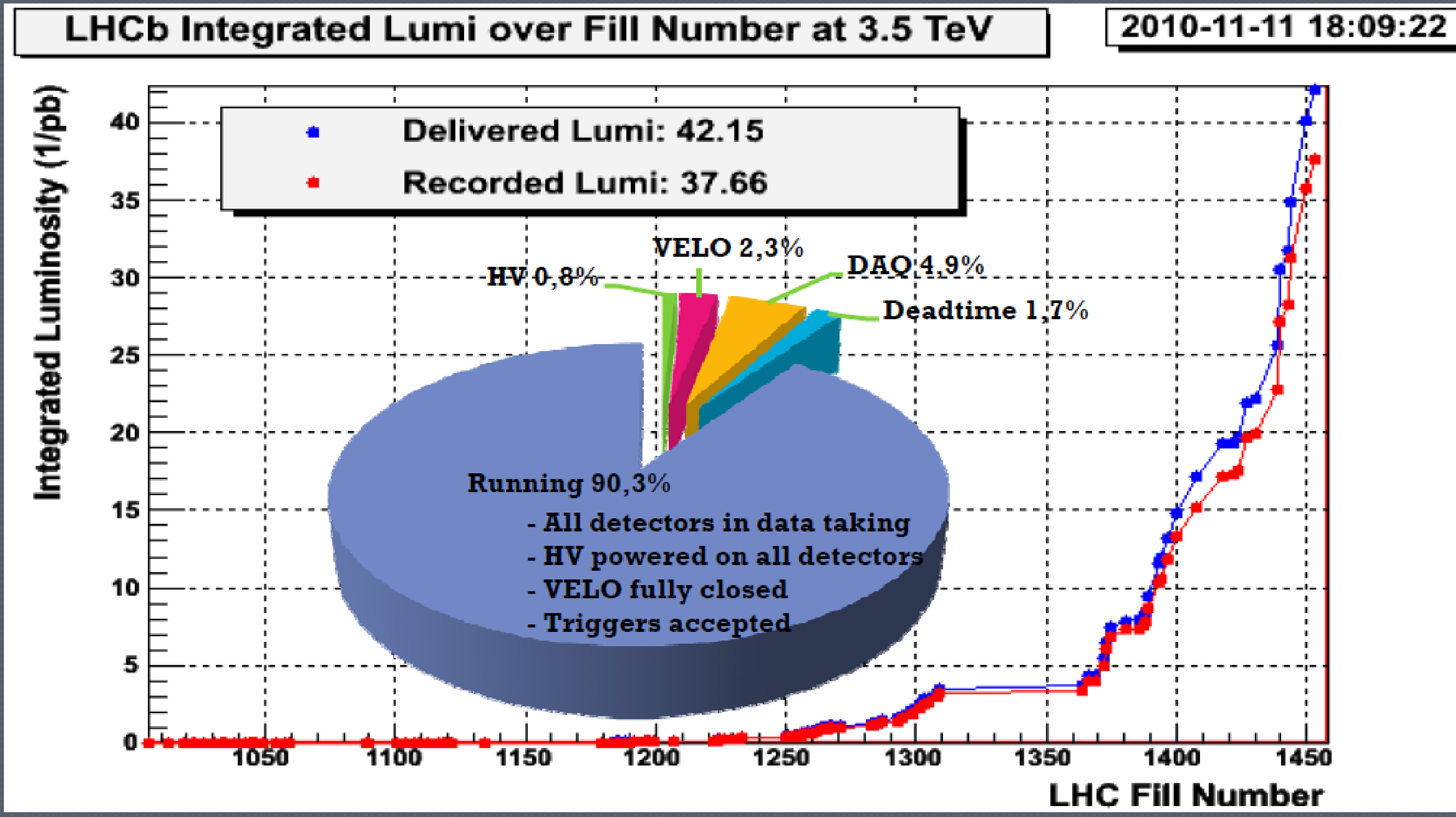
Example: $B_s \rightarrow D_s K$



6.8 μb^{-1} at √s= 0.9 TeV in 2009
0.31 nb^{-1} at √s= 0.9 TeV in 2010
37.7 pb^{-1} at √s= 7 TeV in 2010
(~90% of delivered lumi)

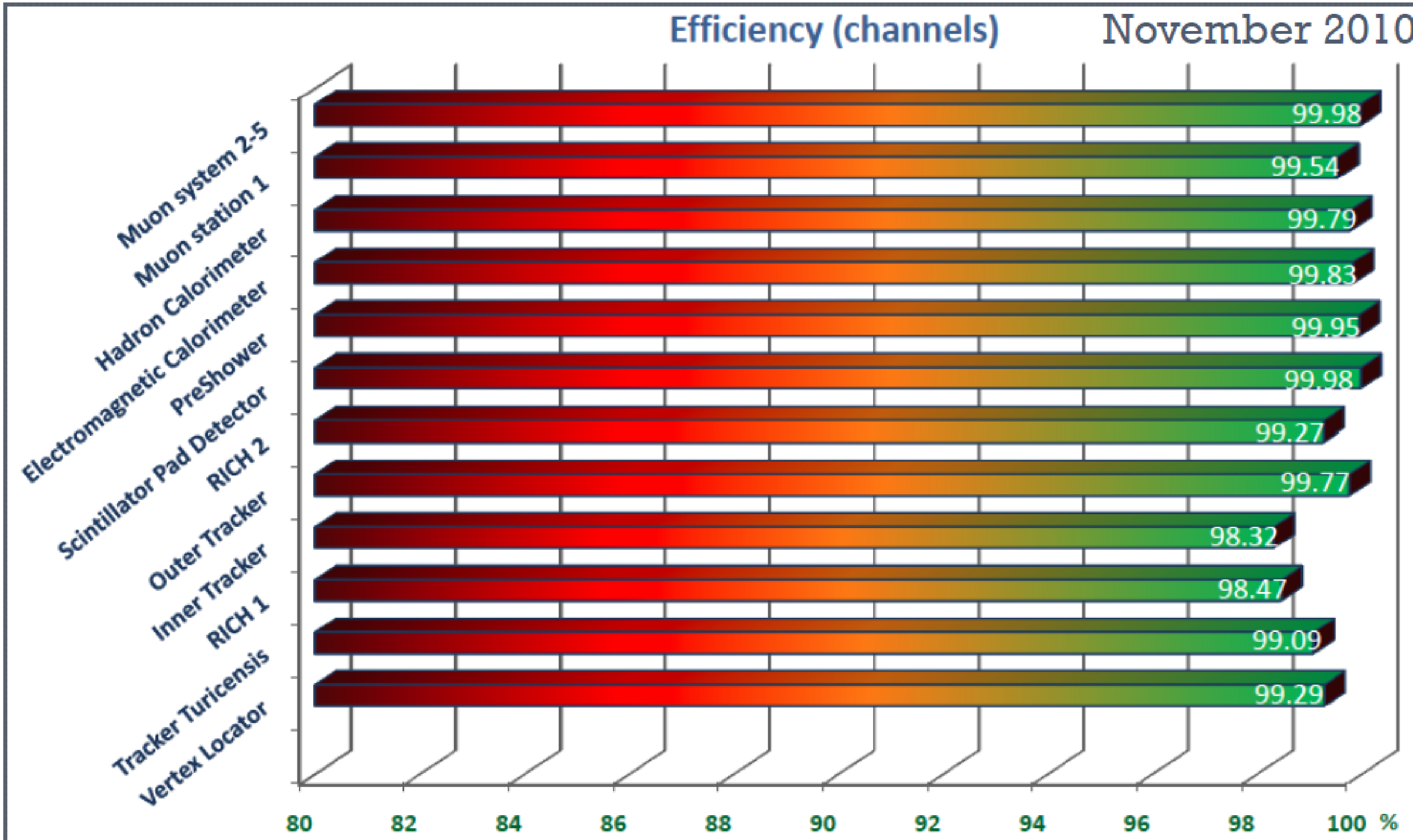
2010 run

From 30th March to 29th October



Last month

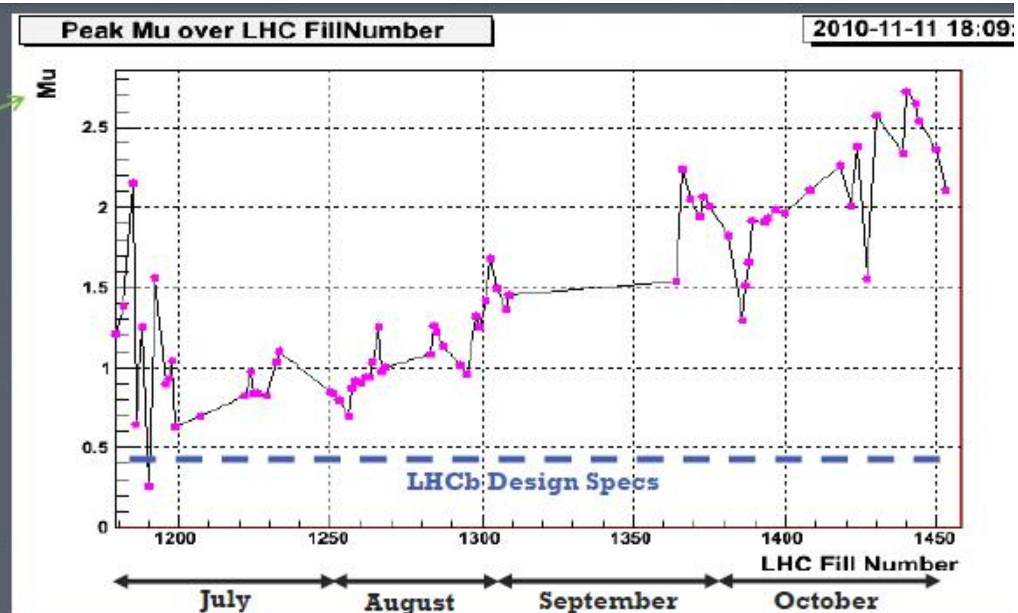
Detector efficiencies

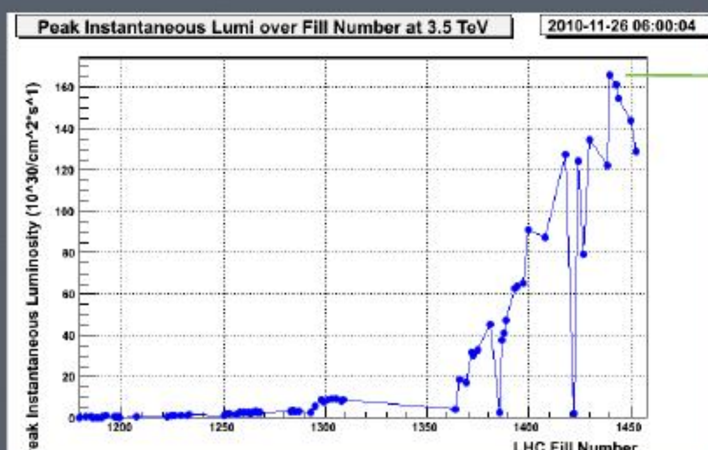


The detector worked extremely well over the entire year!

Luminosity 2010

Average number of visible interactions/crossing in LHCb acceptance (what we call μ)



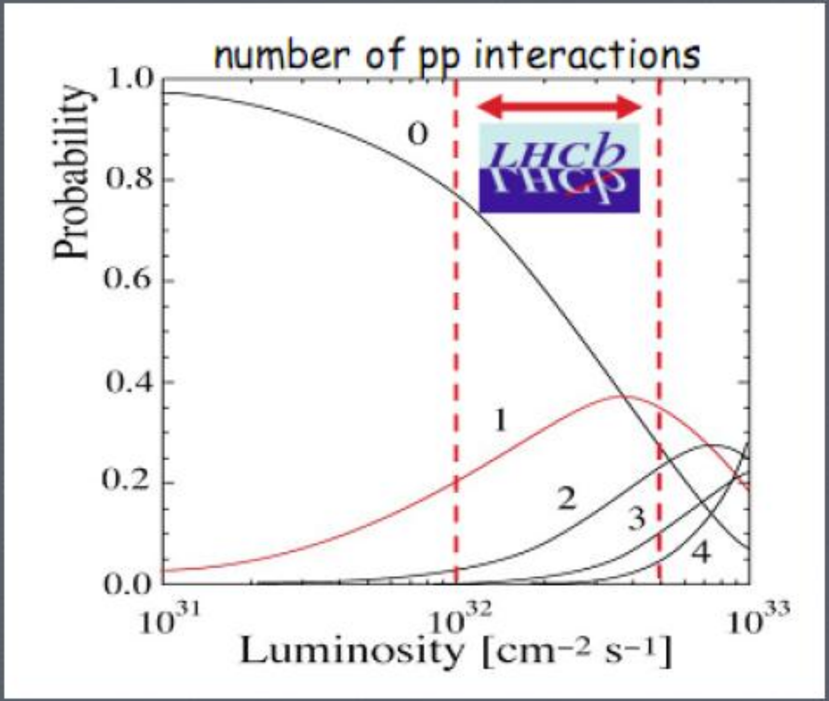


Instantaneous luminosity $1.6 \cdot 10^{32}$ $cm^{-2}s^{-1}$

80% of design luminosity reached with 344 colliding bunches instead of 2622

B physics

- Cross-section predictions (PYTHIA)
  $\sqrt{s}$ = 7, 10, 14 TeV
  σ_{inel} ~ (0.89, 0.95, 1) × 80 mb
  σ_{bb} ~ (0.44, 0.67, 1) × ~500 μb
  ~ 250 μb
- $B^{\pm}$, B^0, B_s, B_c, Λ_b…
  (40%, 40%, 10%, 10% from LEP)
- 10 x larger charm production
- Design $\mathcal{L}$ ~ $2 \cdot 10^{32}$ cm^{-2} s^{-1} (tuned)
  ~ 10^{12} bb events / year (2 fb^{-1})
  10 kHz bb-events in LHCb

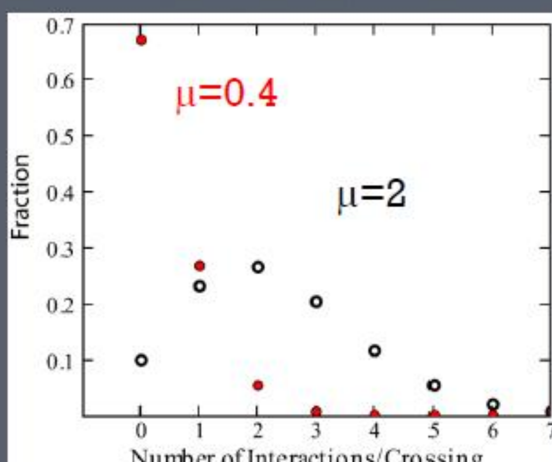


Maximizes fraction of single interaction per bunch crossing

Running conditions 2010

Nominal

- $\sqrt{14}$ TeV
- $L = 2{\cdot}10^{32}\ cm^{-2}\ s^{-1}$
  - Defocus the beams
- 2622 colliding bunches
- $\beta^* = 10$ m
  - Average 0.4 visible interactions/ bunch crossing
- Minimize the pile-up



End of 2010

- $\sqrt{7}$ TeV
- $1.6{\cdot}10^{32}\ cm^{-2}\ s^{-1}$ has been reached
- Small number of bunches (400 max)
- $\beta^* \sim 3.5$ m
  - ~ 2 visible interactions/bunch crossing
- Trigger conditions rapidly evolving to accomodate increasing L

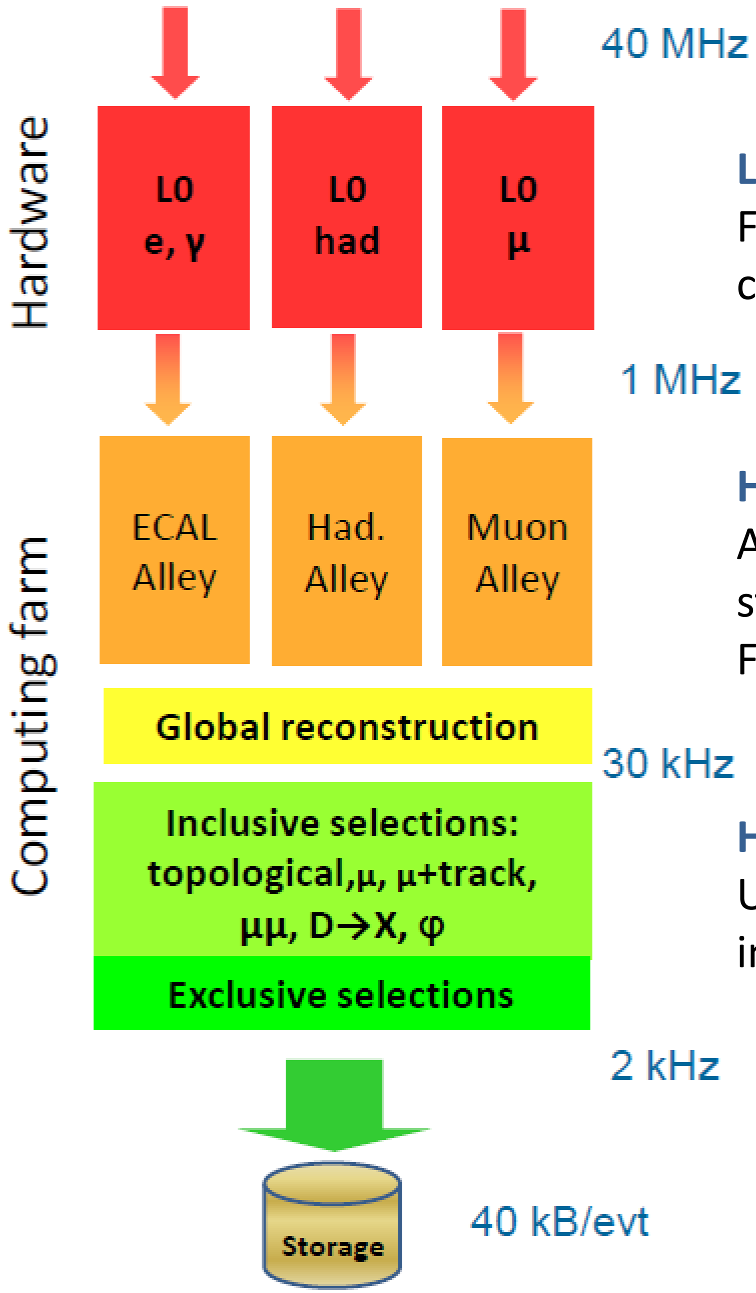
Despite running beyond design conditions, no problem of data quality in 2010

Heavy flavors @LHC

LHC is a B- and D-mesons hyper factory:

- Large $b\bar{b}$ cross section (~300 μb – 500 μb @ $\sqrt{s}$=7 – 14 TeV):
  - LHC @ 50 pb^{-1} [delivered per experiment]
    - ~ 1.5 x 10^{10} B –meson [all species produced, B0,B+,BS,..]
    - ~ 2.5 x10^{11} D mesons
  - B factories @ Y(4S) full statistics [delivered, Babar+Belle]:
    - ~1.5 x10^{9} B+,B0
    - ~2 x 10^{9} D's
- However, there are also challenges:
  - High multiplicity of tracks (~30 tracks per unit of rapidity)
  - High rate of background events (σ_{inel} ~ 60 mb at $\sqrt{s}$ =7 TeV)
    - 1/200 event contains a b quark, typical interesting BR < 10^{-3}
  - An efficient trigger is essential!

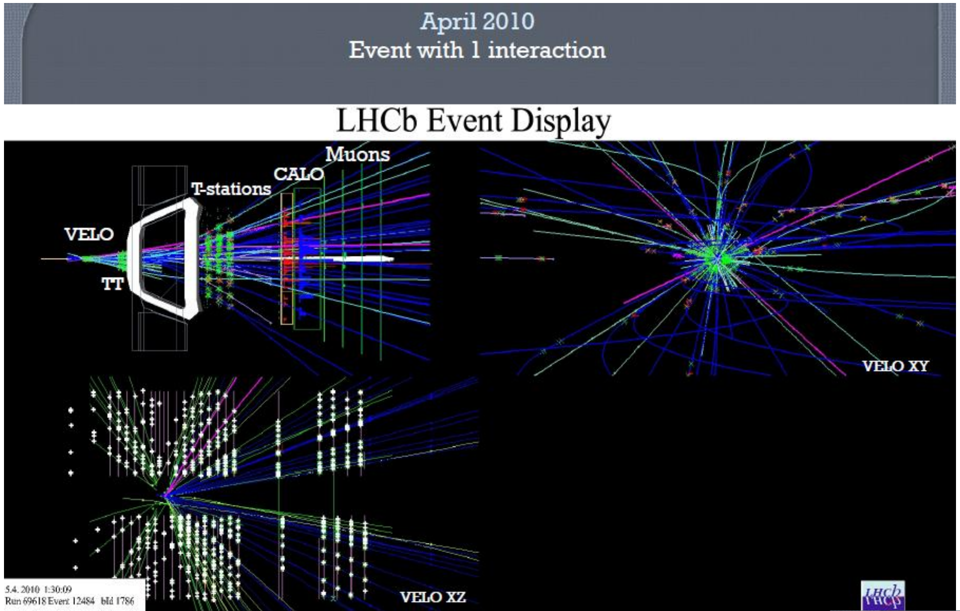
LHCb trigger



Level 0 : Hardware triggers
From Muon system &
calorimeters

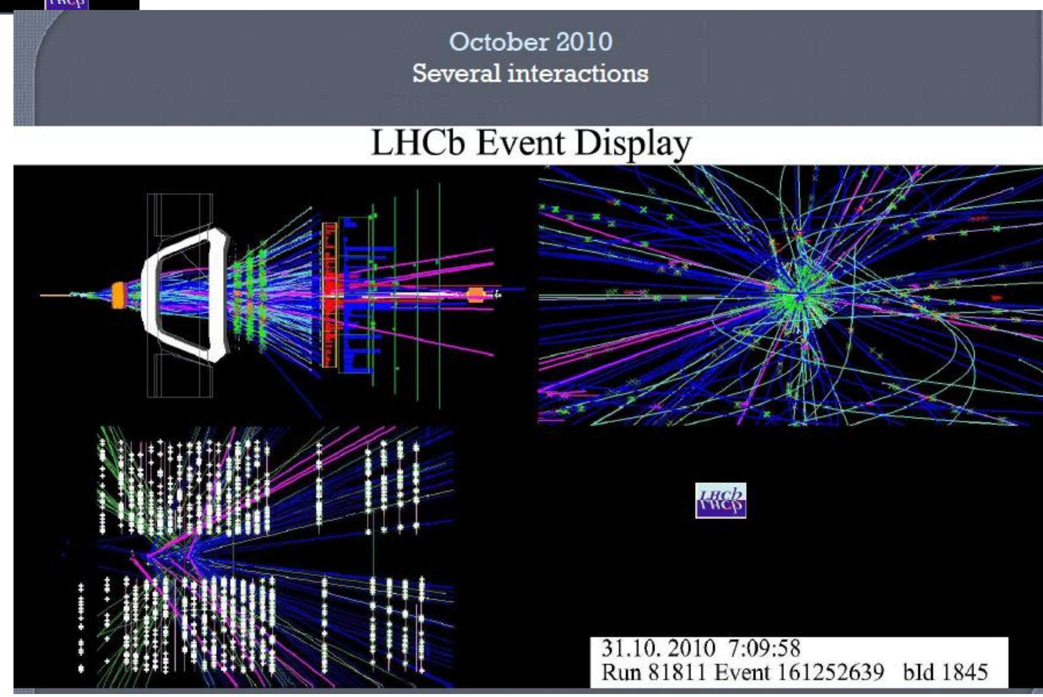
HLT1 : Software triggers
Add information from VELO and tracking stations to Level 0 information
Find proton-proton vertices etc.

HLT2 : Software triggers
Use all of the detector information to make inclusive and exclusive selections



Design:
single event per bunch crossing

2010:
several events per bunch crossing



Detector Performance

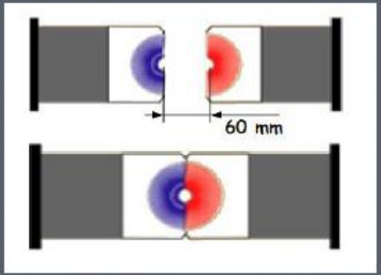
Key aspects for B Physics:

- $\delta p/p$ ~0.45%
  - δM_B ~ 10-40 MeV
- IP resolution
  - ~14μm at high p_T
- Proper time resolution
  - ~50fs
- Particle ID

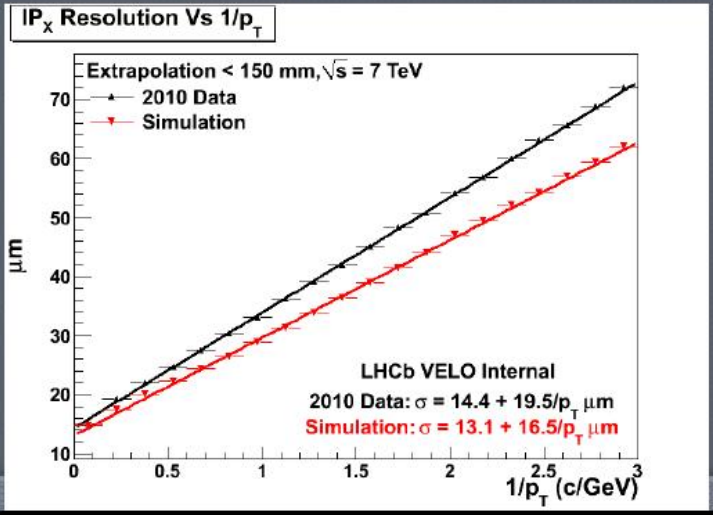
VELO – Vertex Locator

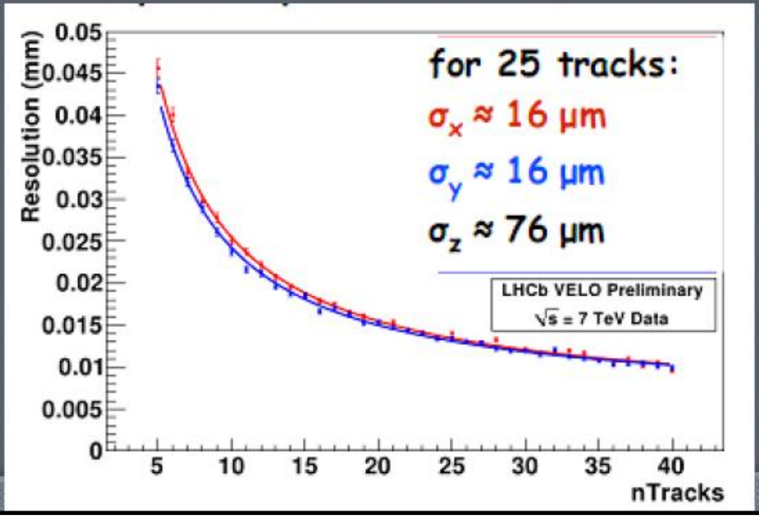
Vertex measurement
σ(z)~ 75 [150] μm for the Primary [Secondary] vertices
σ(IP) ~ 14 + 20/p_T (GeV) μm
σ(τ)~ 60 fs on b-hadrons decay times

Silicon-strip detector
21 stations
Both Velo halves move at every fill



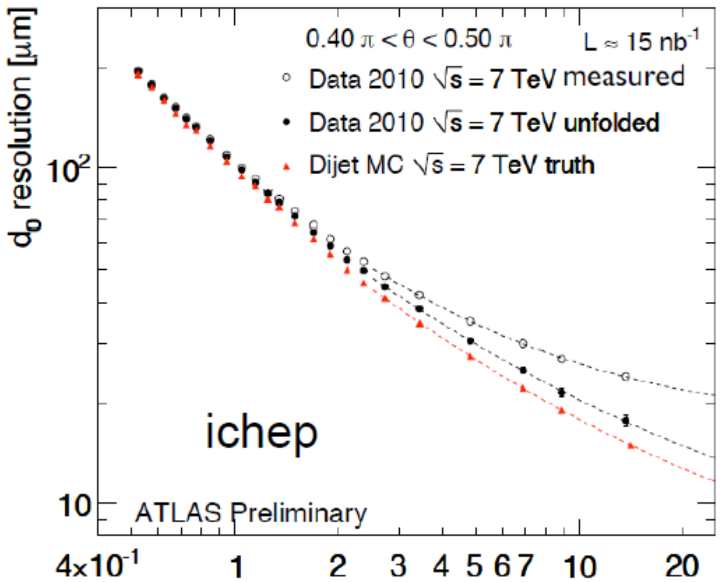
Nominal position of sensor: 8 mm to beam axis
Fill-to-fill variations < 5 μm
Hit resolution 4 μm

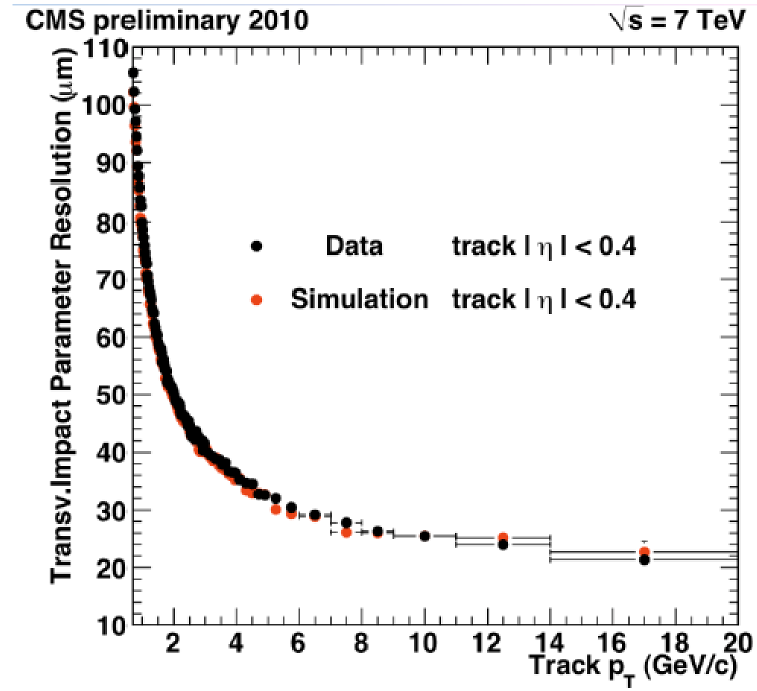




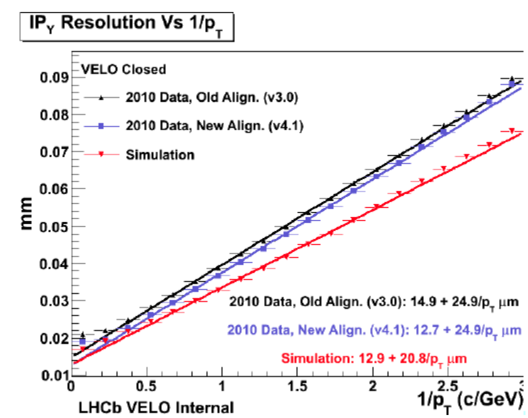
Vertexing

- Tracking performances





@2GeV	ATLAS	CMS	LHCb
σ (IP)	60 μm	50 μm	25 μm



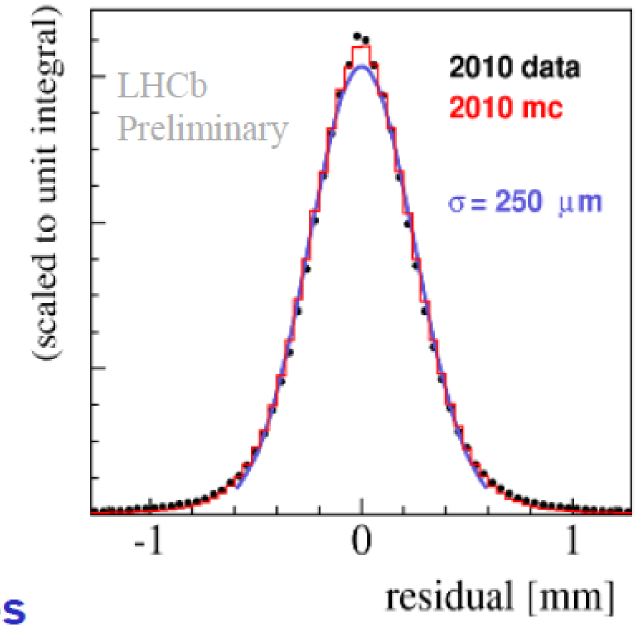
- Better performance expected:
  - Alignment on-going

Tracking

- ❑ High momentum resolution needed to separate topologically similar decay modes

- ❑ Silicon strip and straw-tube detectors for tracking
  - long lever arm ~ 10 m
  - hit resolutions ~ 55 and 250 μm, respectively

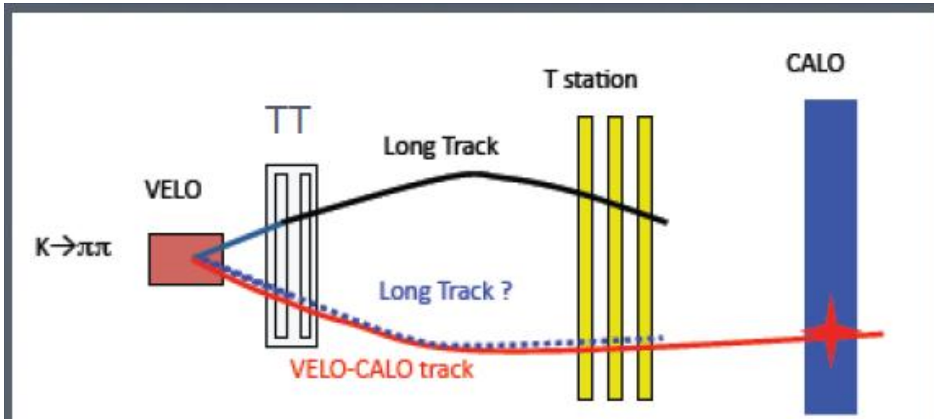
Outer tracker (straw tubes)



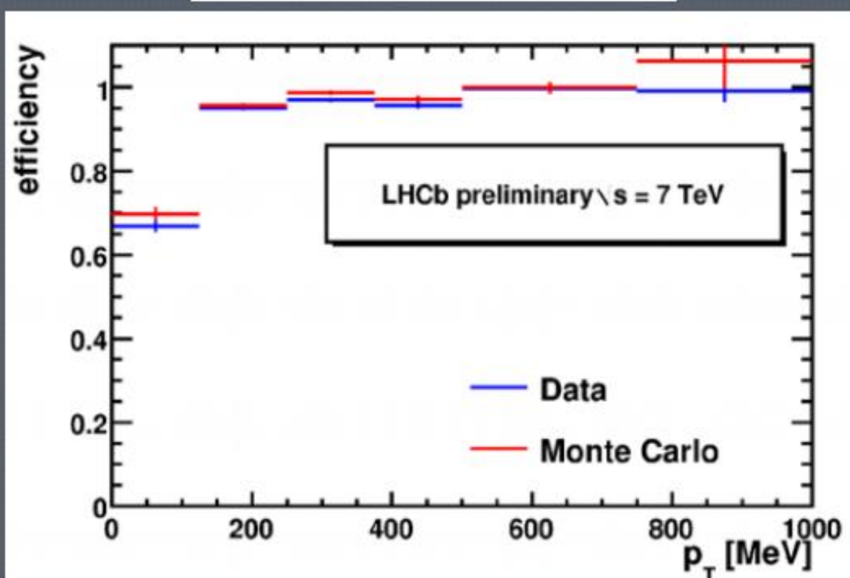
- ❑ Together with precise determination of track slopes provides very good mass resolutions
  - worse by 10-20% compared to MC. But still excellent

- ❑ Provides with high vertex resolutions an excellent propertime resolution

Tracking



$$\varepsilon = \frac{Tracks^{(VELO + IT/OT+CALO)}}{Tracks^{(VELO + CALO)}}$$

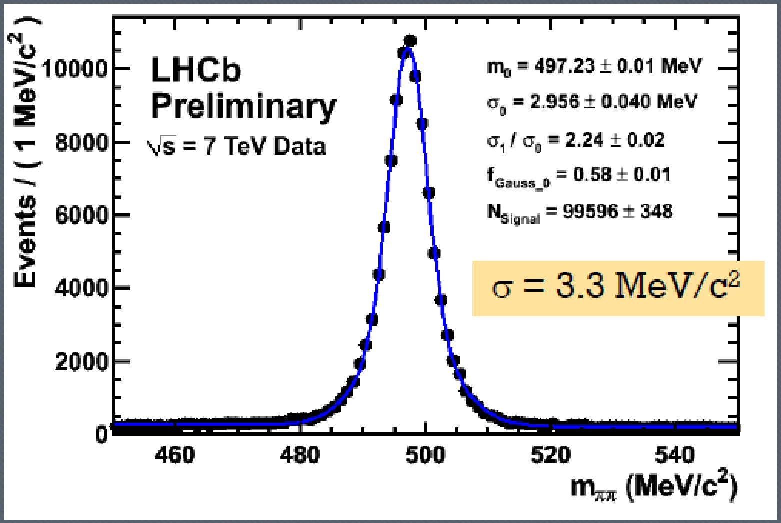


TT + IT (Silicon detectors)
+ OT (Straw Tubes)
4 Tm dipole magnet

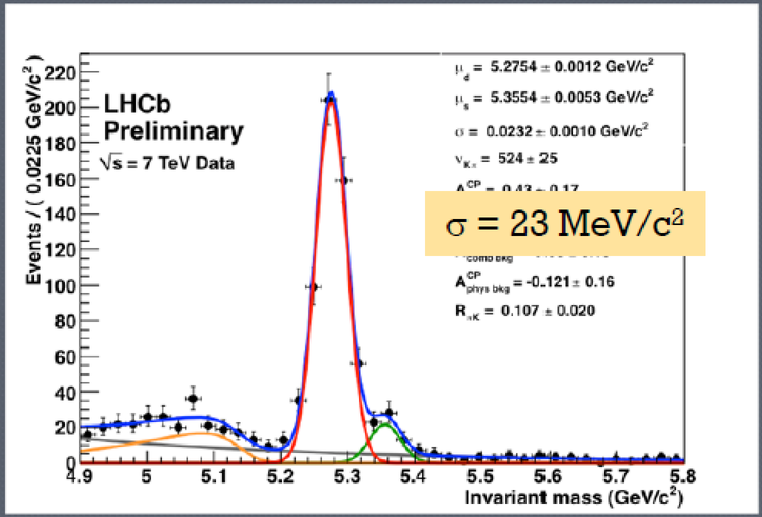
ε = 95% for p> 5 GeV
$\Delta p/p \sim 0.45\%$
σ(b-hadron mass)~11-25 MeV/c^2

Mass resolutions

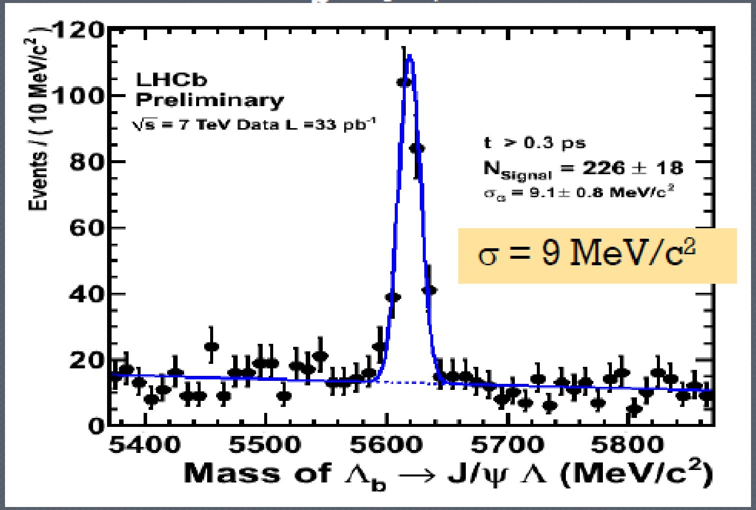
$K_s \to \pi\pi$



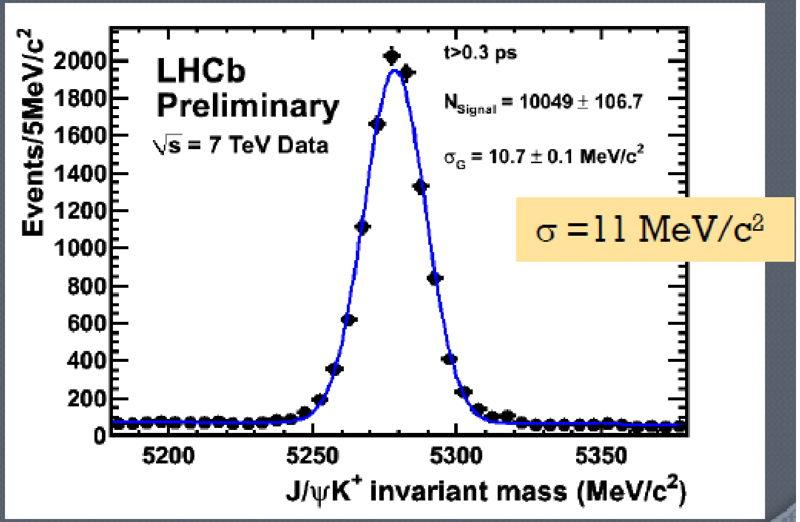
$B^0 \to K\pi$



$\Lambda_b \to J/\psi\Lambda$

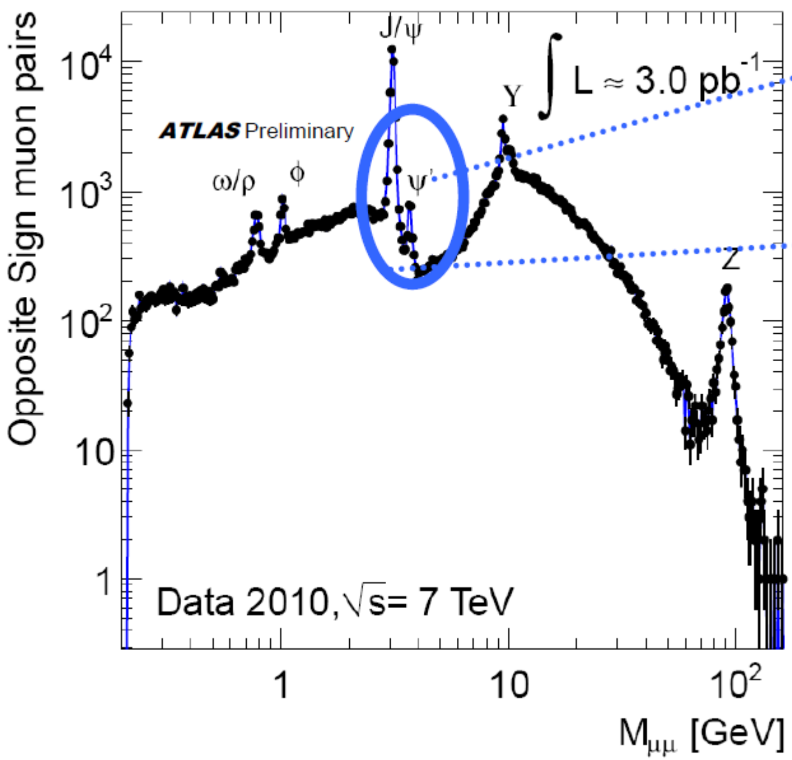


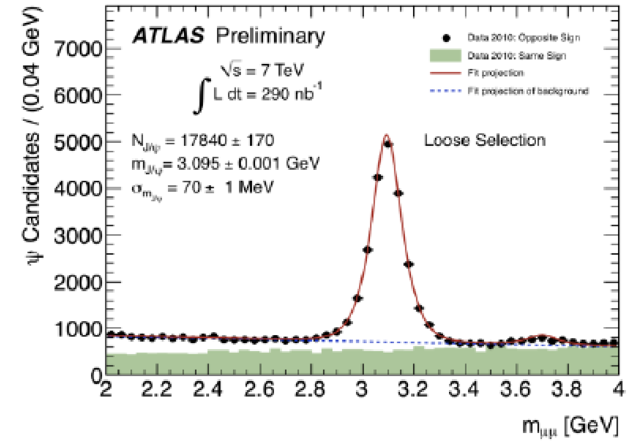
$B^+ \to J/\psi K$

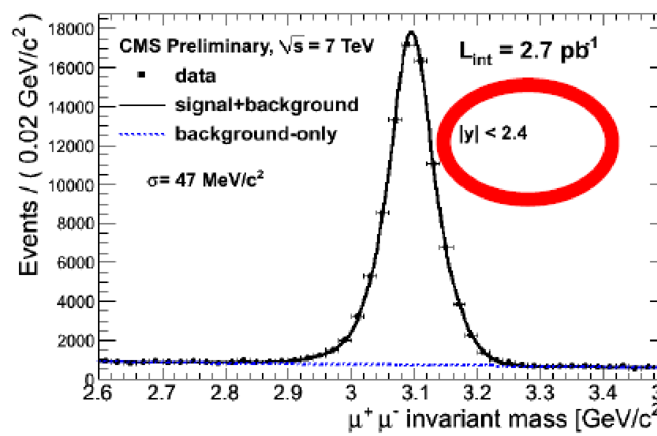


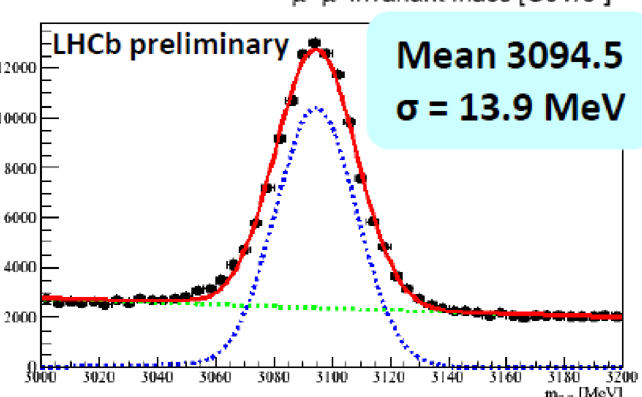
Mass/momentum resolutions: di-muon spectra

- Di-muon spectrum ($J/\psi \to \mu^+\mu^-$ candle)





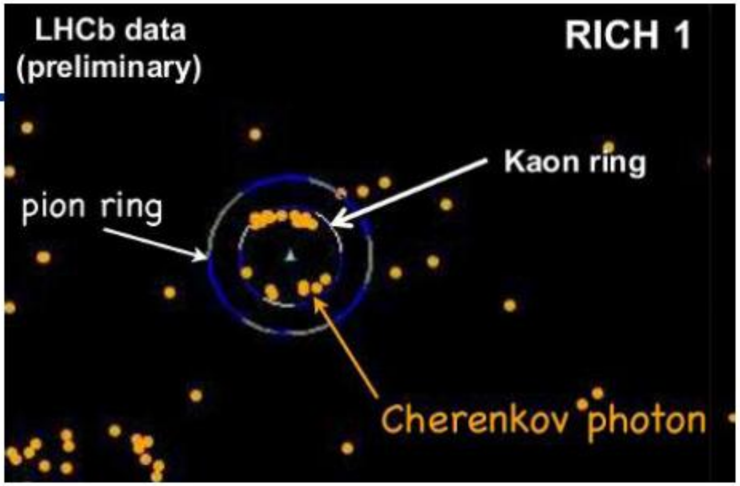


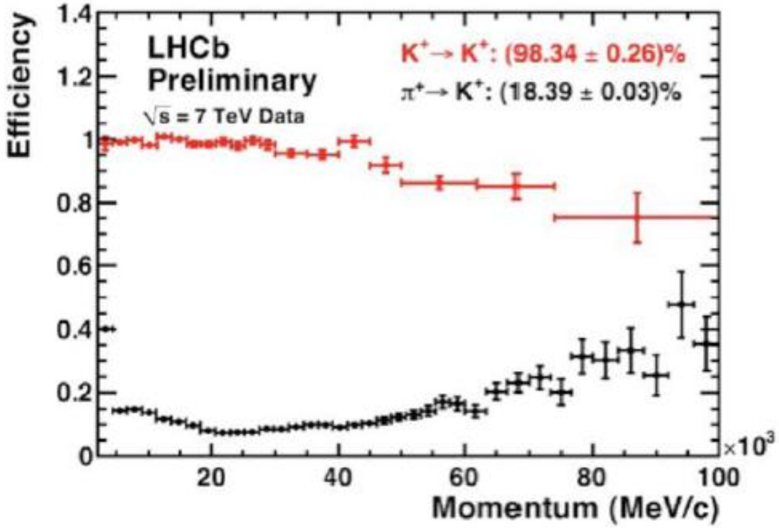


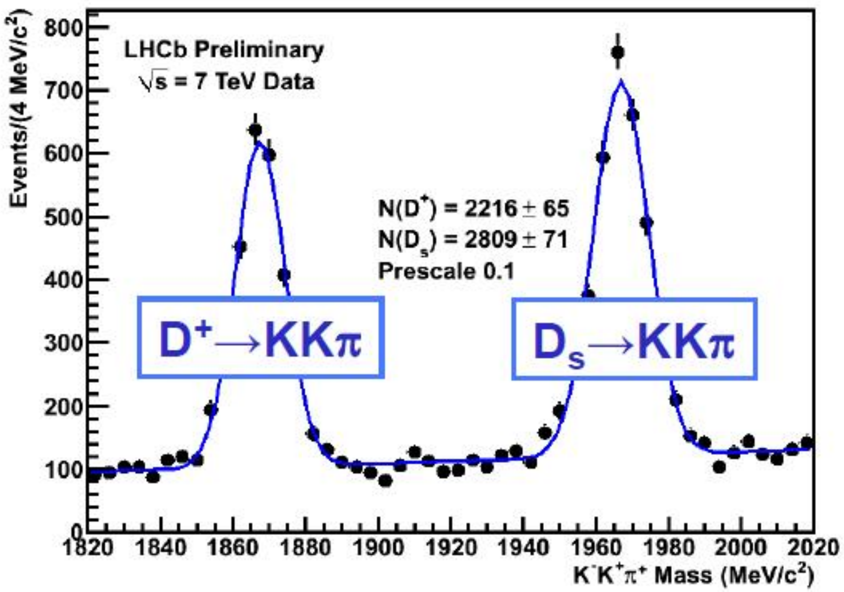
	ATLAS	CMS	LHCb
σ (MJ/ψ)	70 MeV	47 MeV	14 MeV

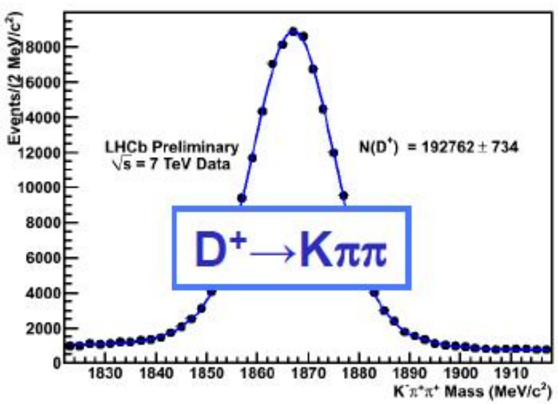
Particle identification

- LHCb has 2 RICH detectors
- Provide excellent π, K and p separation over the large spectrum $p \in [2, 100]$ GeV/c





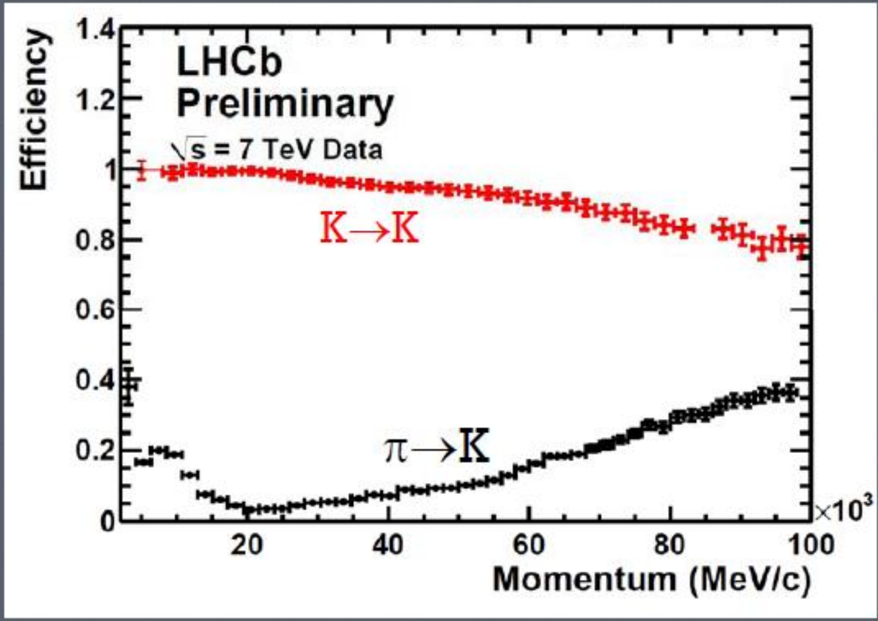


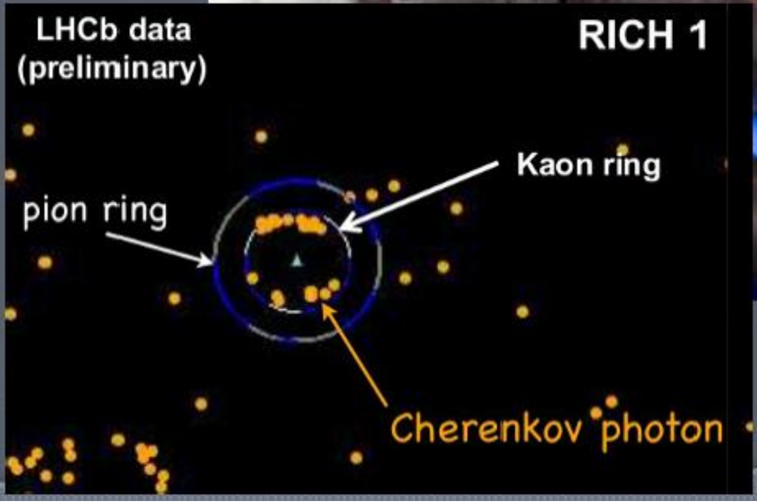


(Only 0.6 pb^{-1})

RICHes

2 Ring Imaging CHerenkov detectors with 3 radiators
Momentum range of 2-100 GeV
Vital for good K/π/p discrimination

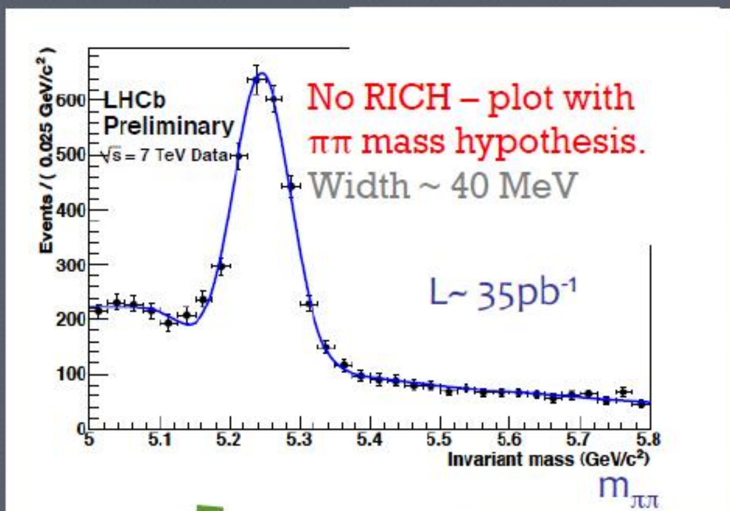




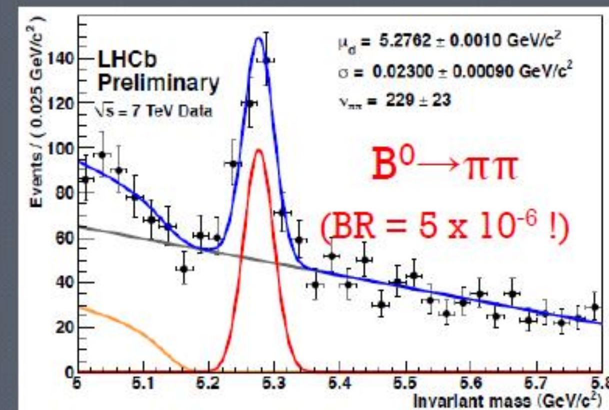
ε(K)~95% at 5% of π/K mis-id

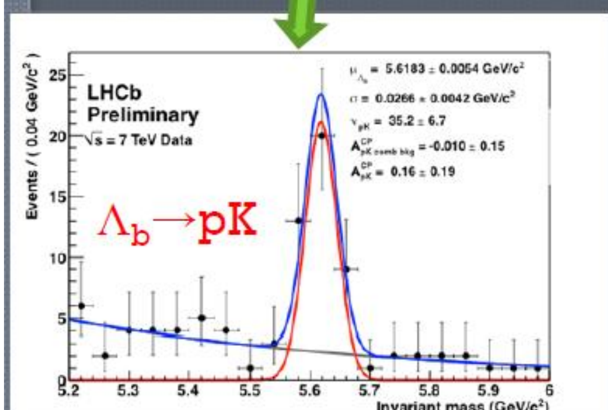
PID allows separation of topologically identical final states

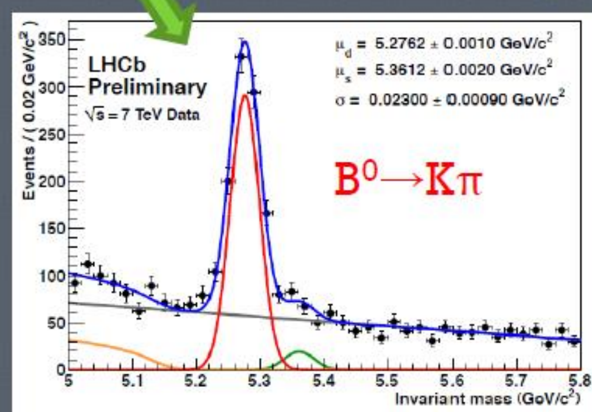
e.g. B→hh

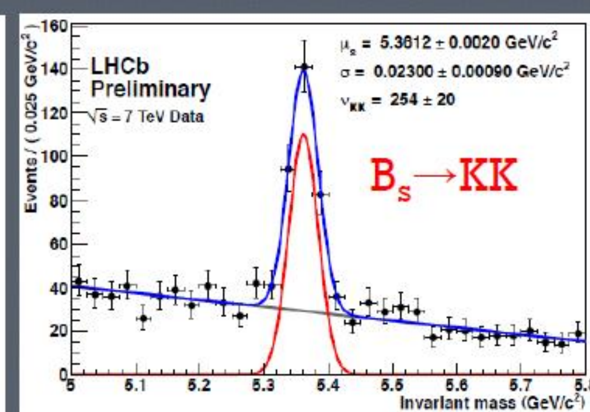


Deploy RICH to isolate each mode





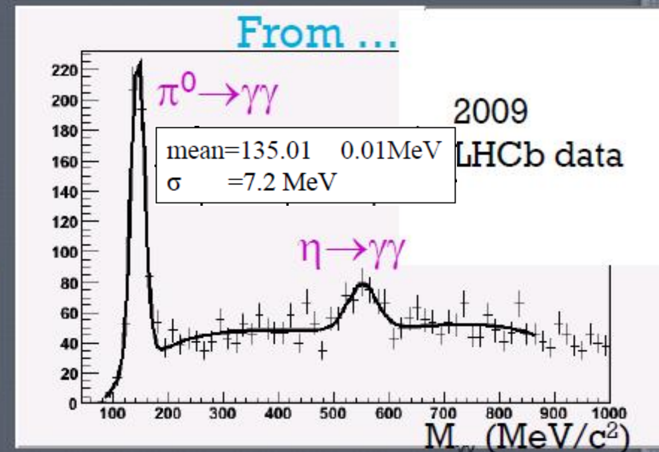


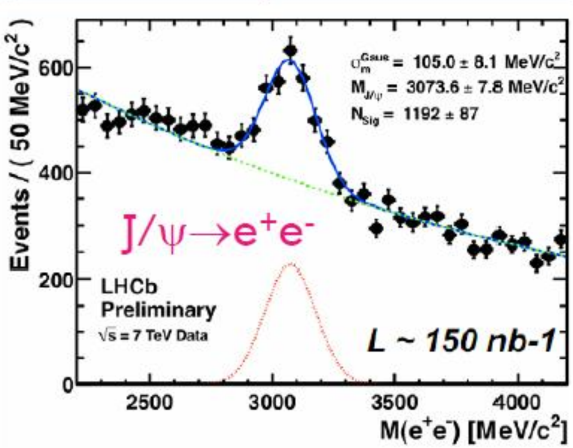


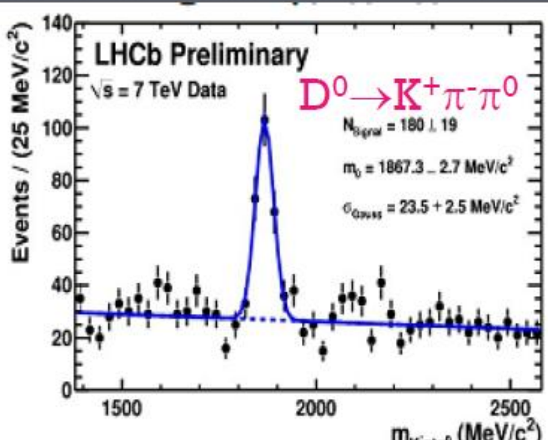
Calorimeters

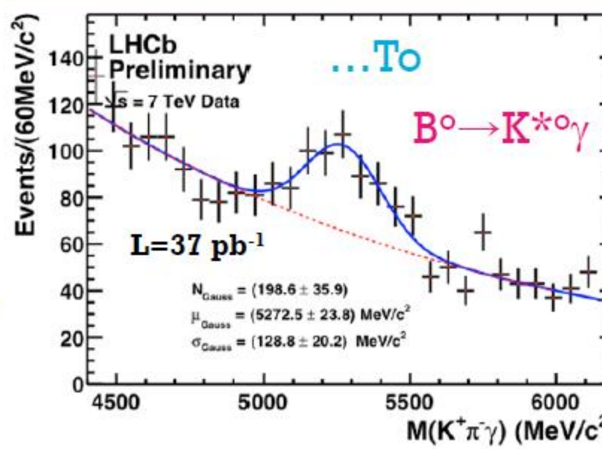
Pre-Shower, ECAL and HCAL
Essential role at L0 trigger
e/γ, h
and PID of e, γ, π^0

$\sigma/E \sim 9\%/\sqrt{E} \oplus 0.8\%$ (ECAL)
$\sigma/E \sim 69\%/\sqrt{E} \oplus 9\%$ (HCAL)



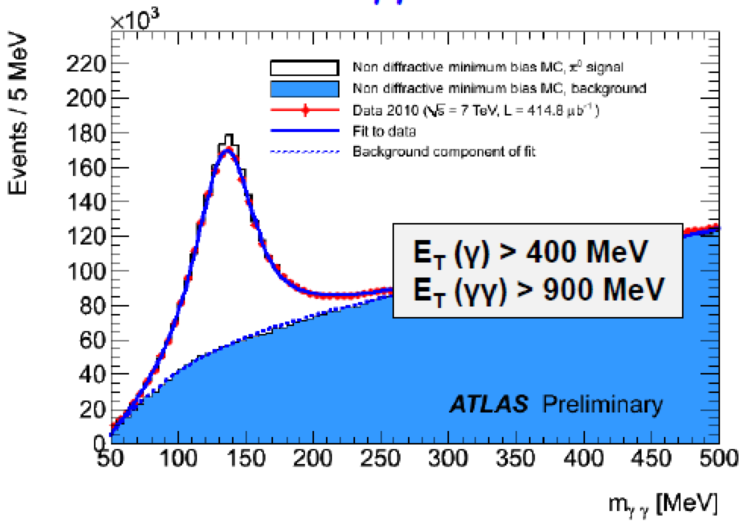


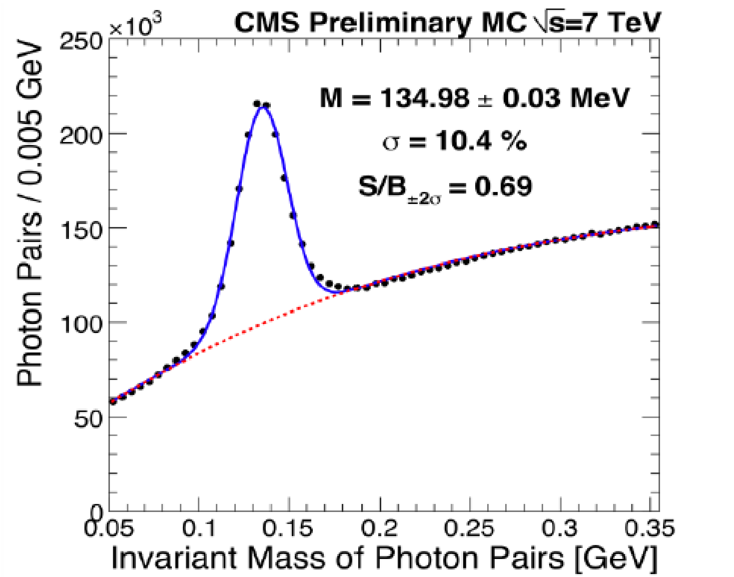




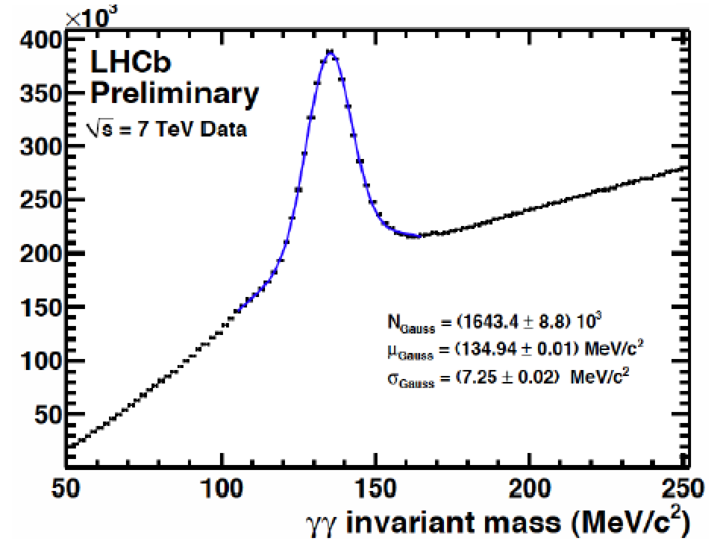
Calorimeters

- Electromagnetic calorimeters:
  - First detectors to be calibrated
  - The $\pi^0 \to \gamma\gamma$ candle:





	ATLAS	CMS	LHCb
$\sigma(M\pi^0)$	20 MeV	14 MeV	7.2 MeV

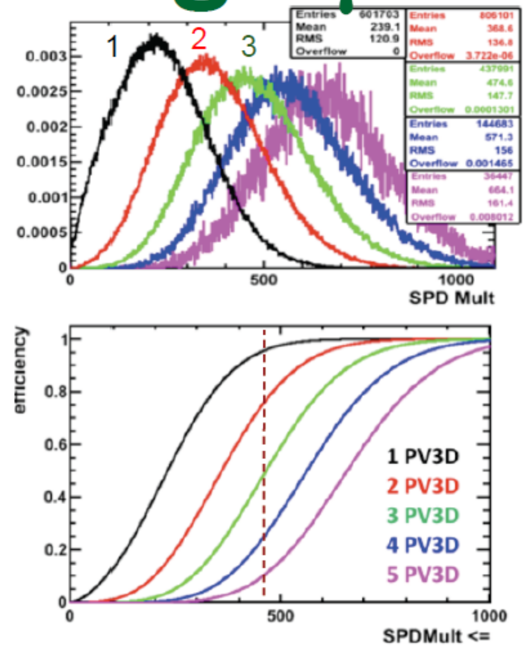


- ECAL calibrated to 1.5 - 2% level
  - π^0 resolution close to expectation
    - Even better for LHCb!

Preshower/SPD

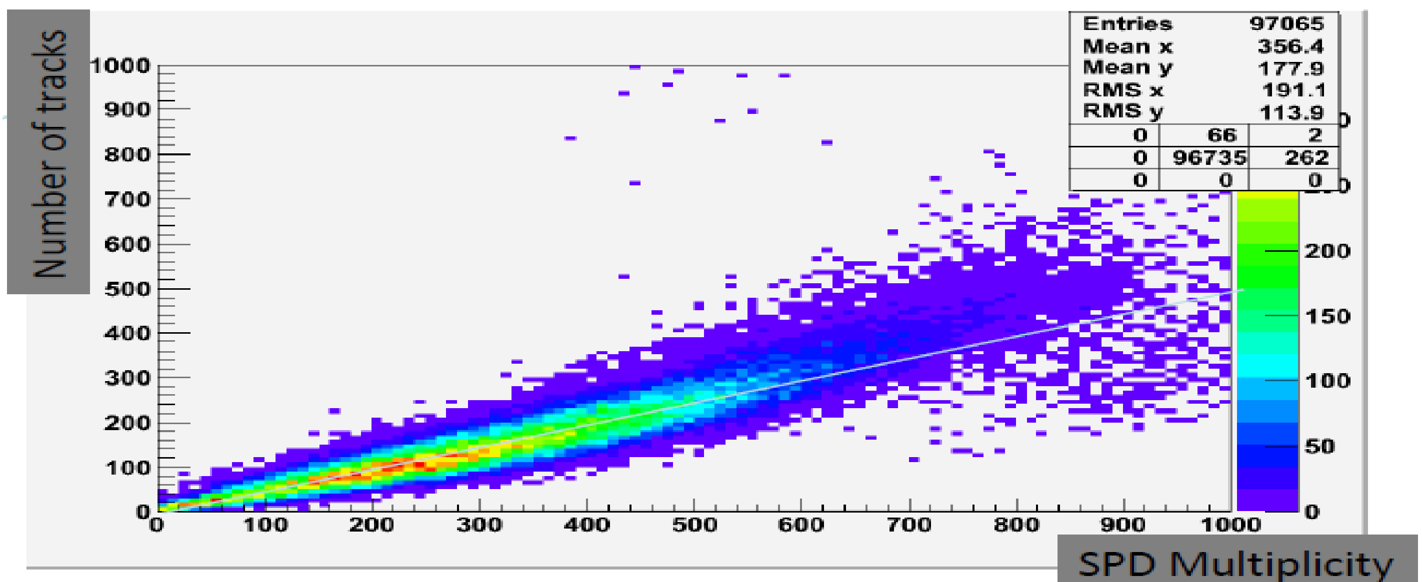
Life at large μ

- For $\mu^+\mu^-$ triggers, take almost everything, SPD<900. Other triggers require rejecting events with large numbers of tracks. Cut on SPD multiplicity as it correlates well & is provided in L0; the cut value changed with L
- This still is a large gain for all modes than the original plan of μ=0.4



SPD multiplicity trigger

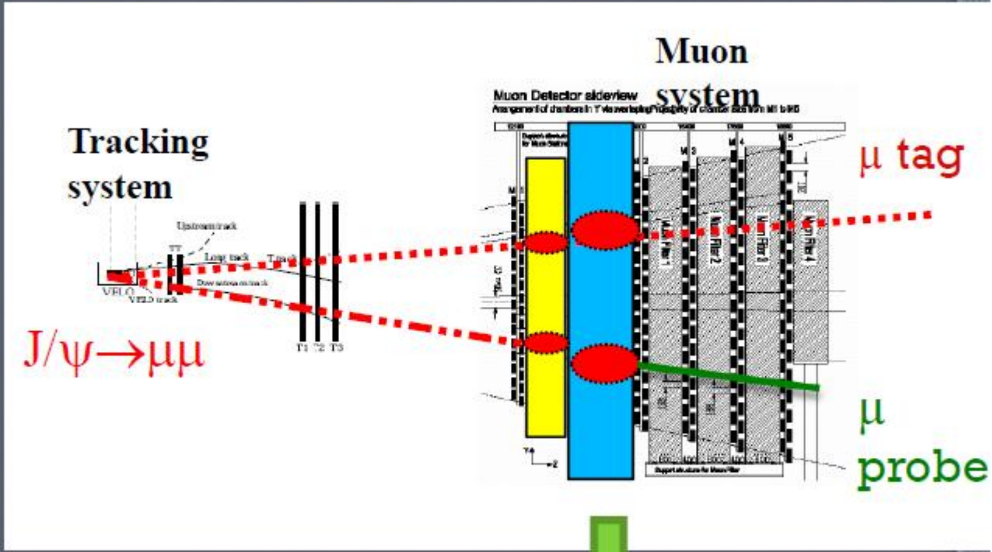
To reduce L0 rate used
SPD cut <450!!!



Muons

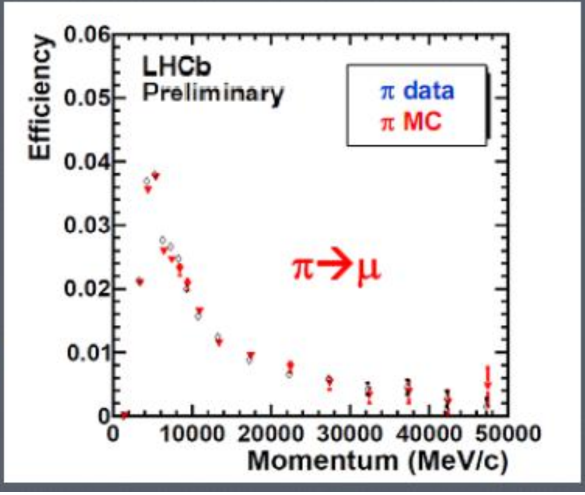
5 muon stations (MWPC)

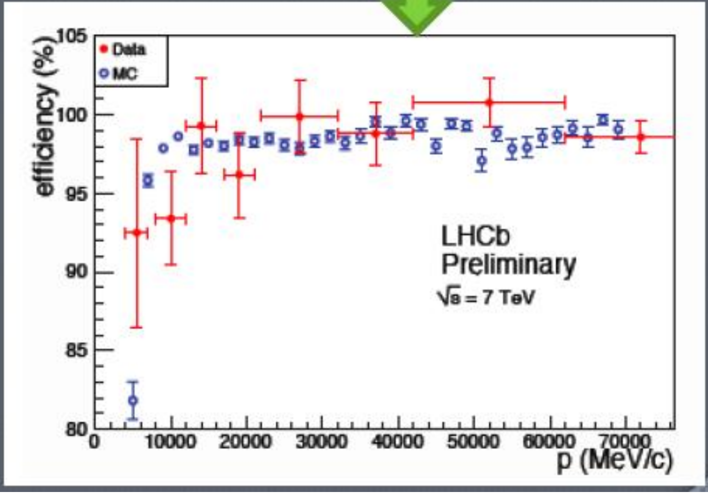
ε(μ)>90% at <2% of π,K/μ mis-id for p>10 GeV/c



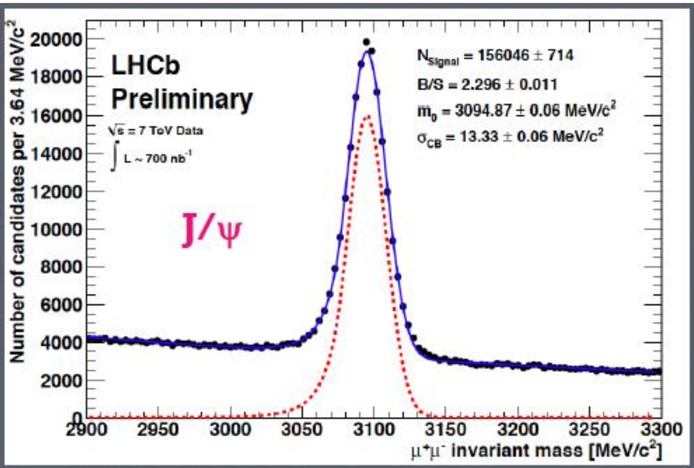
π→μ mis-id from $K_s \to \pi\pi$

(K→μ mis-id from φ)

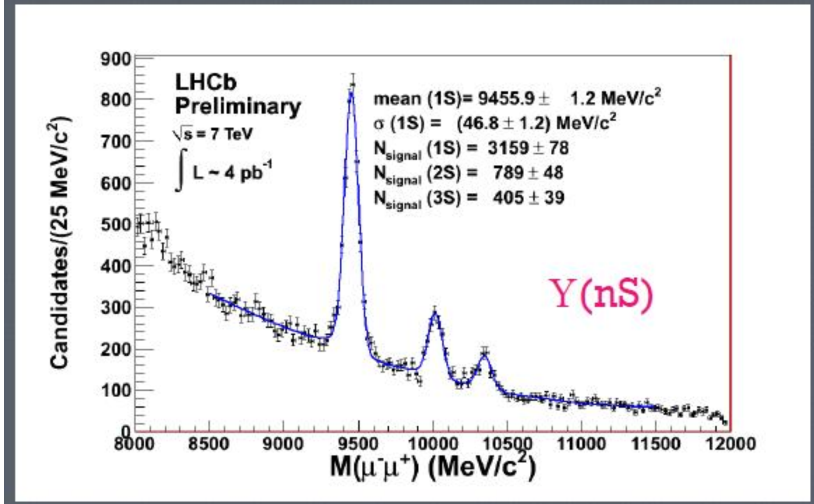




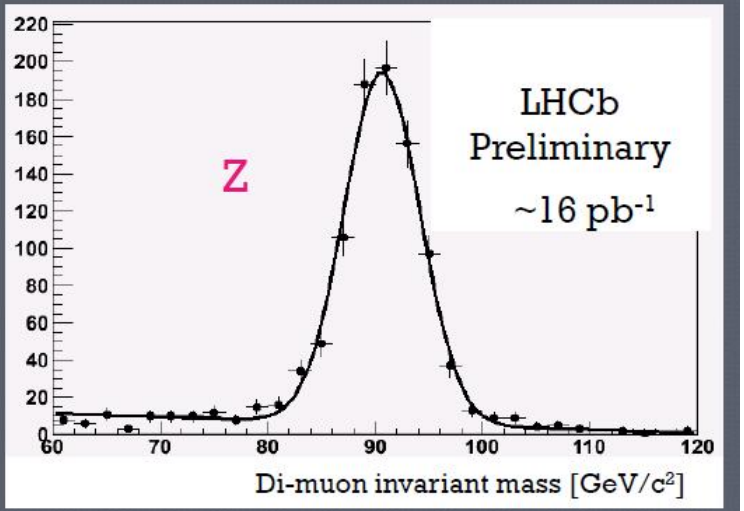
Di-Muons states



$\mathcal{O}$ (1 GeV/c^2)

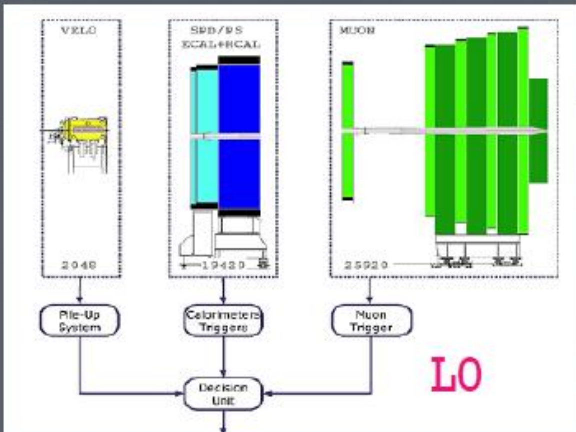


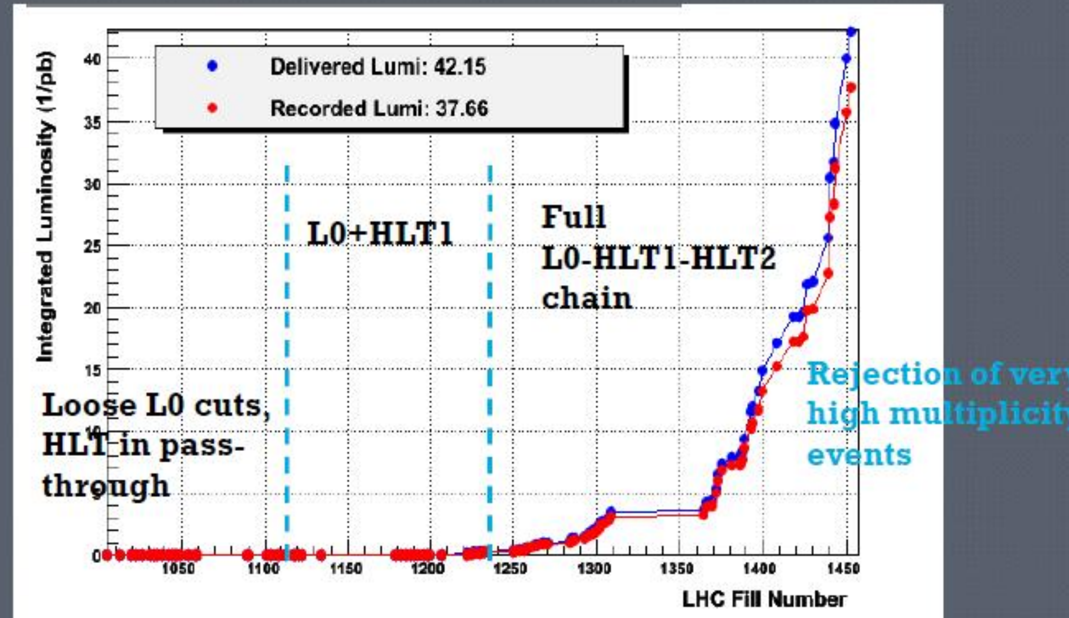
$\mathcal{O}$ (10 GeV/c^2)

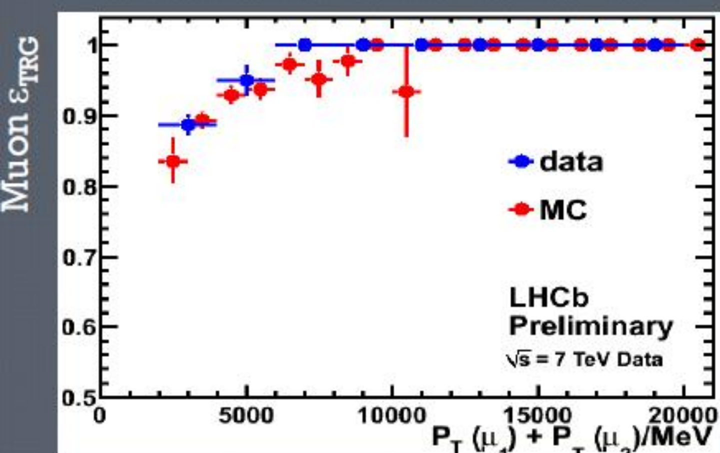


$\mathcal{O}$ (100 GeV/c^2)

Trigger







Trigger efficiencies L0xHLT1 determined on data using the tag-and-probe methods:

	Muon trigger (J/ψ)	Hadron trigger (D^0)
Data	94.9±0.2%	60±4%
MC	93.3±0.2%	66%

LHCb physics program

changes with time :)

CP violation study
Search for new physics
Gamma angle measurements with trees and loops
Rare and radiative decays
+
Electroweak sector (W,Z)
Charm physics
Higgs, Exotica, etc.

Some LHCb key measurements

+ CPV in Charm

CP Violation

Mixing phase φ_s	$B_s \to J/\psi\phi$
CKM angle γ from loops	$B^0 \to \pi\pi$, $B_s \to KK$
CKM angle γ from trees	$B_s \to D_s K$, $B^0 \to D^0 K^{*0}$, $B^+ \to D^0 K^+$

Rare decays

Angular analysis	$B^o \to K^{*o}\mu^+\mu^-$
Observation or BR limits	$B_s \to \mu^+\mu^-$
Radiative penguins in $b \to s\gamma$ transitions	$B_s \to \phi\gamma$, $B^0 \to K^{*0}\gamma$

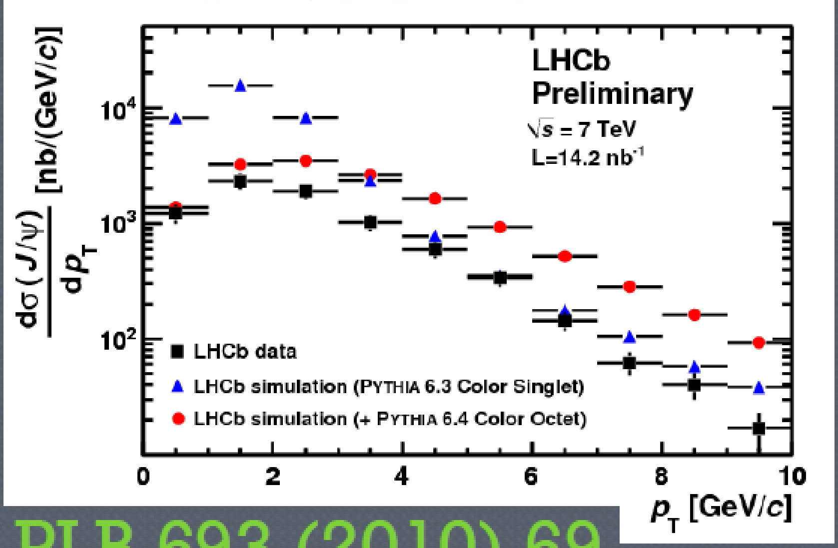
RESULTS 2010

First LHCb results

Physics reaches at LHCb with collected data include so far:

- Inclusive distributions
- Strangeness production
- First Charm results
- Onia (J/ψ, Υ, χ_c, …)
- W, Z production
- Jet studies
- First b results

$J/\psi \rightarrow \mu\mu$ production



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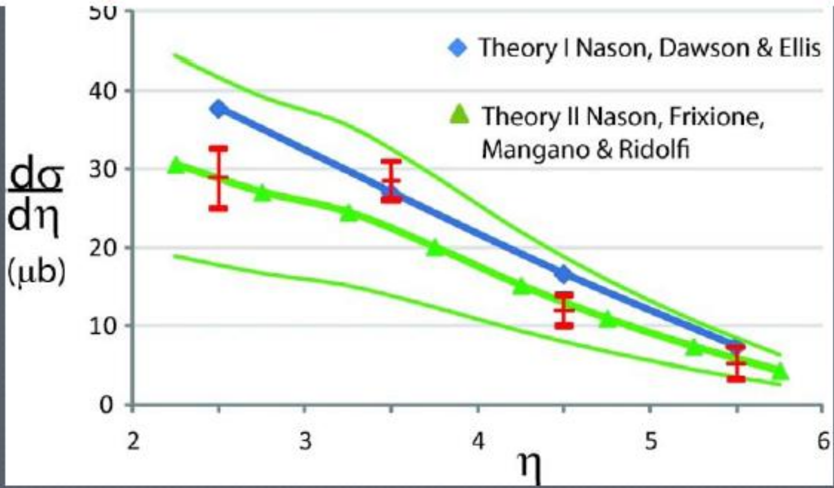
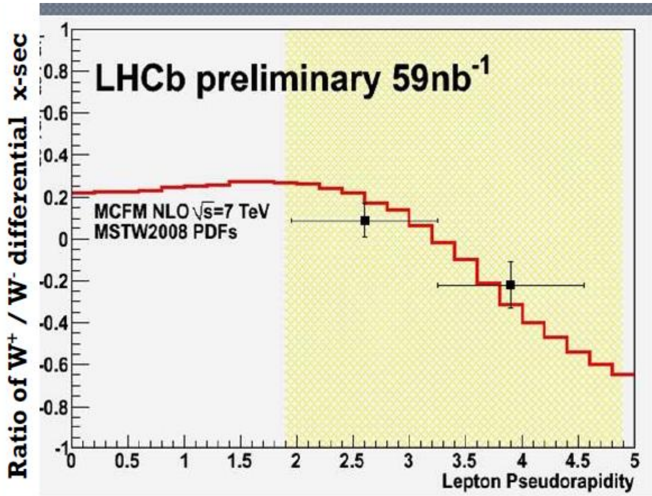
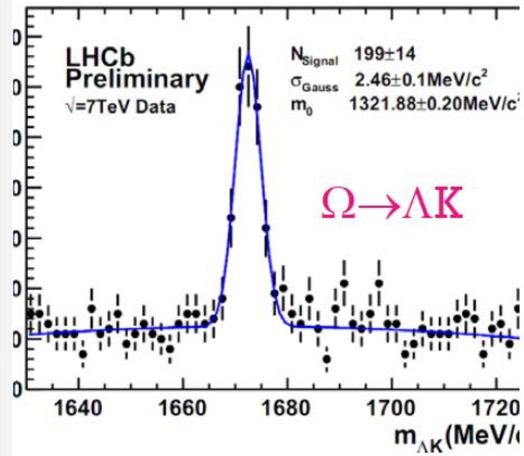
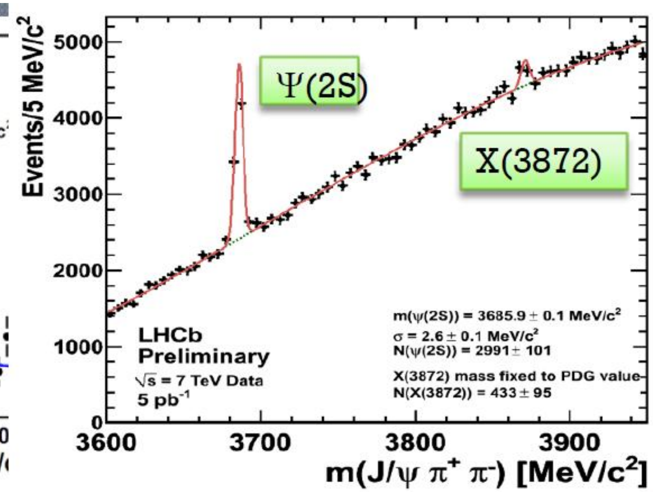
Beauty cross-section with $B \rightarrow D^0 \mu X$

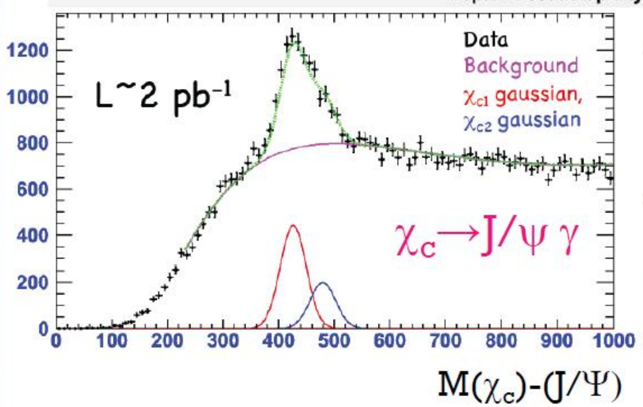


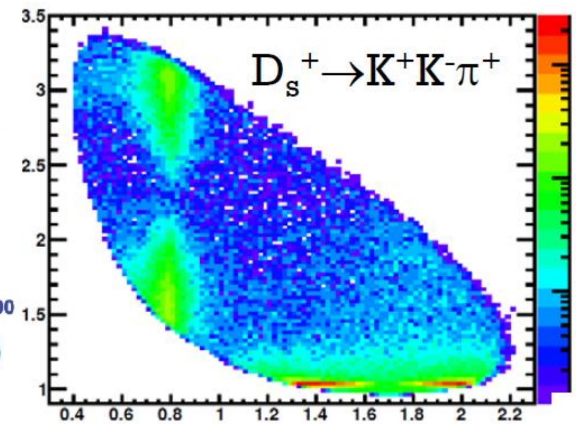
PLB 694 (2010) 209

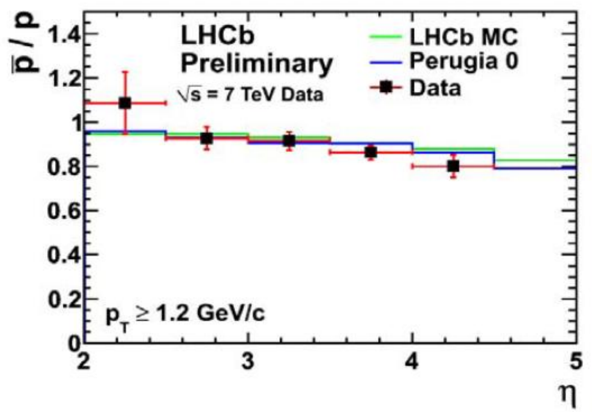




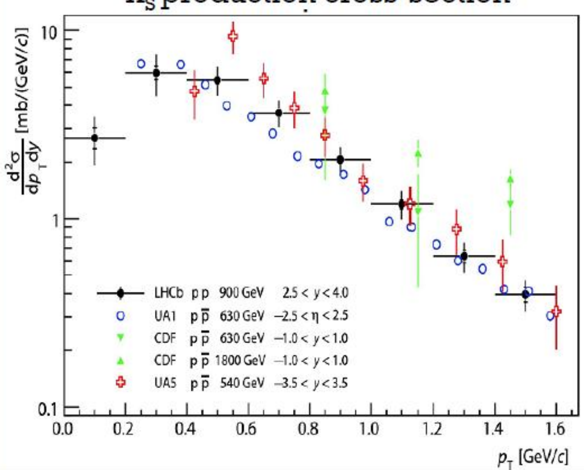


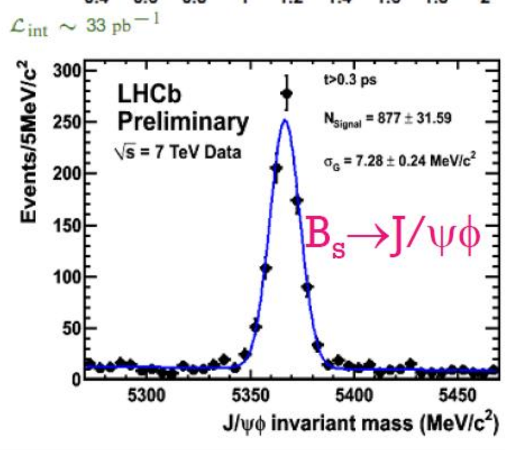


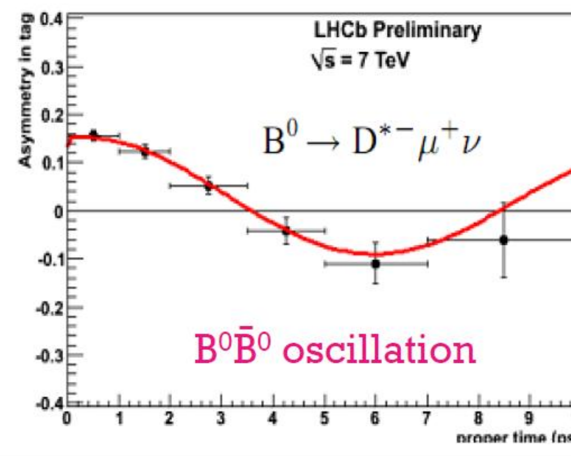




K_S production cross-section







LHCb physics current results

Final results:

"Prompt K^0_S production in pp collisions at $\sqrt{s}$=0.9 TeV", PLB 693 (2010) 69

"Measurement of $\sigma(pp \to b\ \text{anti-}b\ X)$ at $\sqrt{s}$=7 TeV in the forward region", PLB 694 (2010) 209

Preliminary results:

"Prompt charm production in pp collisions in $\sqrt{s}$=7 TeV", LHCb-CONF-2010-013

"Measurements of B^0 mesons production cross-section in pp collisions at $\sqrt{s}$ = 7 TeV using $B^0 \to D^{*-}\mu^+\nu X$ decays", LHCb-CONF-2010-012

"Measurement of prompt Λ-bar/Λ and Λ-bar/K^0_S production ratios in inelastic non-diffractive pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV", LHCb-CONF-2010-011

"Measurement of the J/Ψ production cross section at $\sqrt{s}$ = 7 TeV in LHCb", LHCb-CONF-2010-010

"Measurement of the p-bar/p ratio in LHCb at $\sqrt{s}$=900 GeV and 7 TeV", LHCb-CONF-2010-009

+ more results are coming soon on winter-2011 conferences !!!

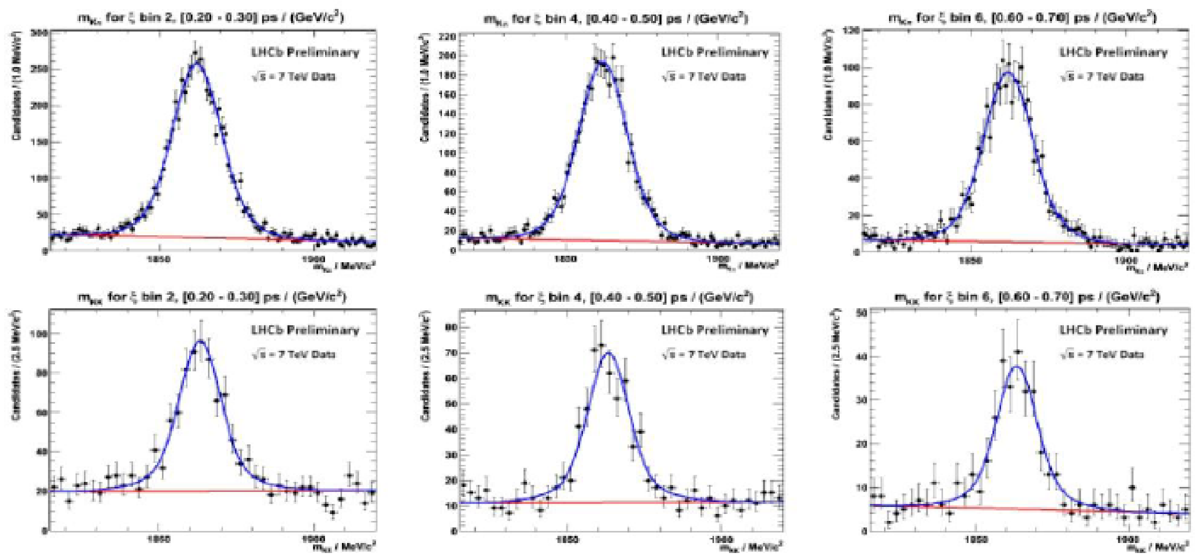
Charm physics at LHCb

- Probe new physics in charm: LHCb
  - CPV from lifetime difference between $D^0 \to KK$ and $D^0 \to K\pi$

Proper lifetime →

$D^0 \to K\pi$

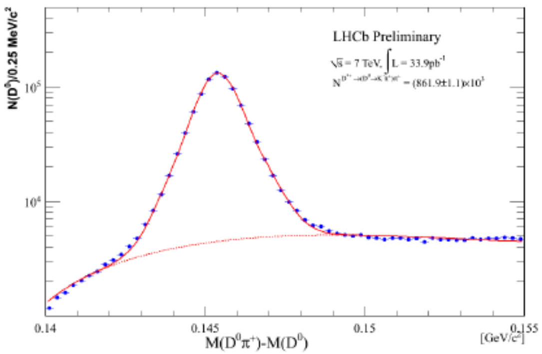
$D^0 \to KK$



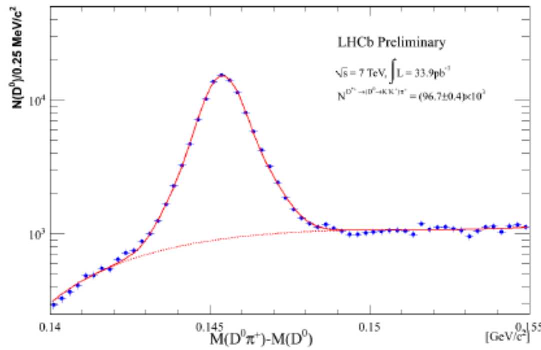
  - Search for mixing and CP-violation in $D^0 \to K_S hh$
  - Search for direct CP-violation in $D^+ \to K^- K^+ \pi^+$
  - Search for rare $D^0 \to \mu^+\mu^-$
    - expected UL 4 10^{-8} @ 90CL for 100 pb^{-1}

Prospects for charm CP violation

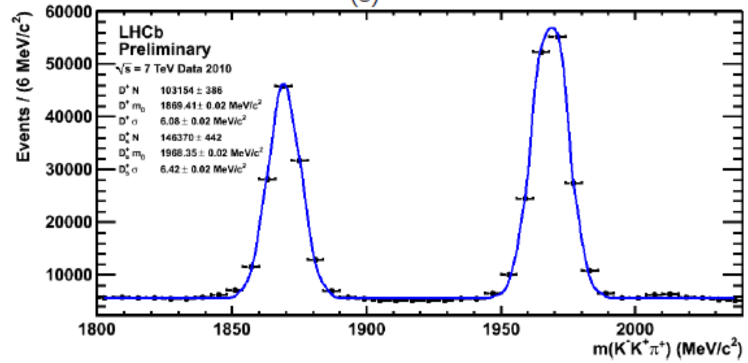
$D^{*\pm} \to D\pi^{\pm}$; $D \to K\pi$



$D^{*\pm} \to D\pi^{\pm}$; $D \to KK$



$D_{(s)}^{\pm} \to KK\pi^{\pm}$



Copious samples of charm already available

- e.g. 10^5 $D^{*\pm} \to D\pi^{\pm}$; $D \to KK$ events in 34/pb
- c.f. Belle: ~3×10^5 in 384/fb

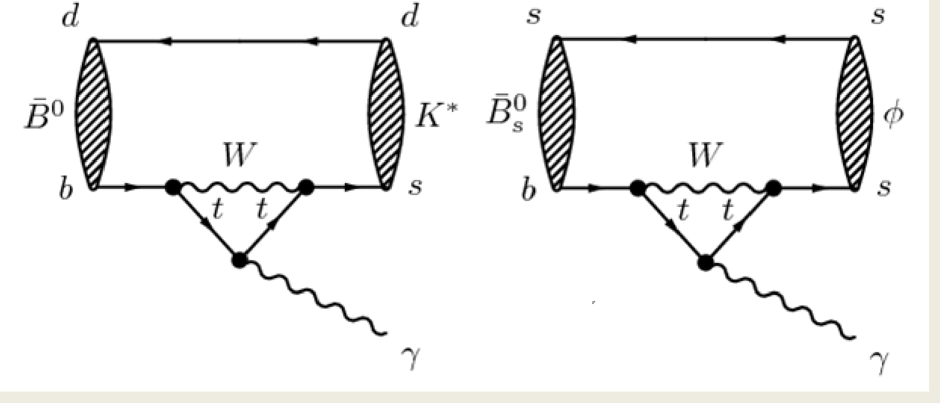
Challenge is to control systematics to necessary level

- work in progress – expect world's best results in 2011

Mass[GeV/c^2]

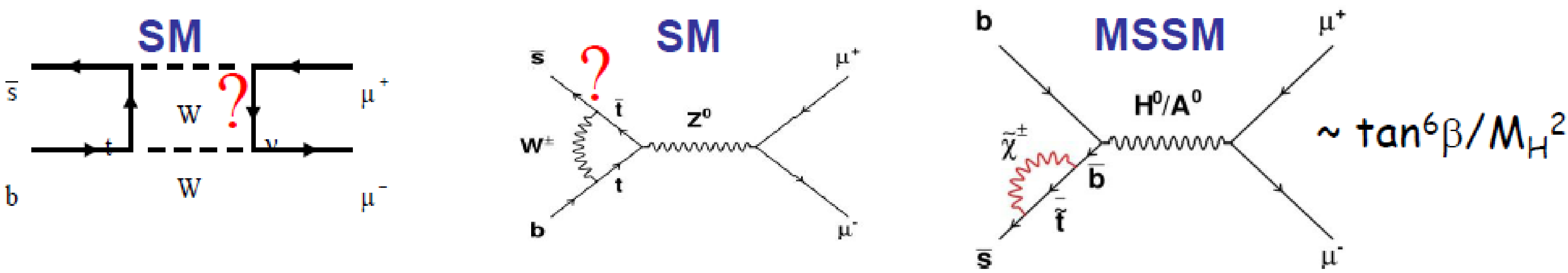
SM & New Physics

- γ from trees
- γ from loops
- CP violation in the B_s system
- Rare B decays
- Radiative B decays
  - *Flavour changing neutral currents*
  - *examples*



Bs->mu mu

New Physics in $B_s \to \mu^+\mu^-$



- Helicity suppressed and in SM: $BR(B_s \to \mu^+\mu^-)=(3.6 \pm 0.3)\times 10^{-9}$
  - sensitive to New Physics; could be strongly enhanced in SUSY
  - Current best limit from CDF: $BR(B_s \to \mu^+\mu^-) < 3.6 \times 10^{-8}$
    - $BR(B_s \to \mu^+\mu^-) < 4.2 \times 10^{-8}$ from D0

$B_s \to \mu^+\mu^-$: ATLAS/CMS

- Expected results (assuming $\sigma(pp \to b\bar{b}X) = 500\ \mu b$) @14TeV:

	N sig	N bkg	90% CL
ATLAS (10 fb^{-1})	5.6	14	---
CMS (1 fb^{-1})	2.4	6.5	$<1.6\ 10^{-8}$

$2.1\ 10^{-8}$ *

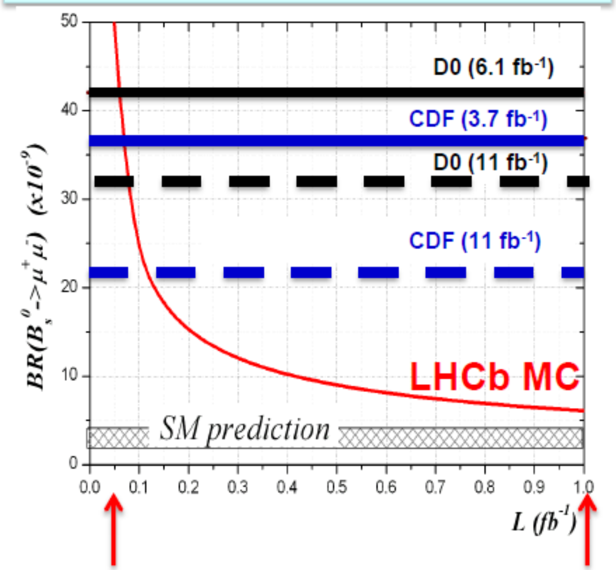
* Scaling quoted result by ratio of LHCb measured x-sec at $\sqrt{s}$ = 7 TeV to 14 TeV value assumed in MC study.

- with 10 – 20 fb^{-1} SM prediction region
- 3σ evidence after 3 years@10^{33}
- 5σ observation after 1 years@10^{34}

$B_s \to \mu^+\mu^-$: LHCb

expected ~ 6 signal events and ~ 30 background events for 1 fb^{-1}

Exclusion limit at 90% CL at $\sqrt{s}$=7TeV



Close to CDF limit possible already end of the year

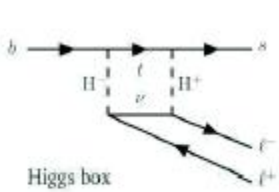
2011?

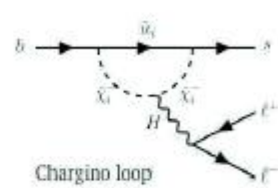
$B_d^0 \to K^* \mu^+ \mu^-$ Potential

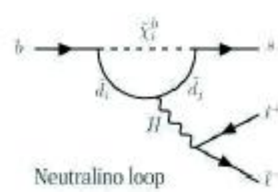
- Another excellent place to look for New Physics!
- $B_d^0 \to K^* \mu^+ \mu^-$ rare but not as rare as $B_s^0 \to \mu^+ \mu^-$.

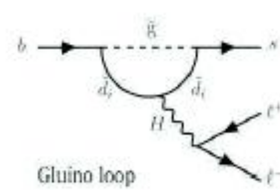
$$\mathrm{BR}(B_d^0 \to K^* \mu^+ \mu^-) = (1.05^{+0.16}_{-0.13}) \cdot 10^{-6}$$ [PDG]

- Decay provides a large variety of observables.
- The aim is measuring angular observables.
- This talk: forward - backward asymmetry.

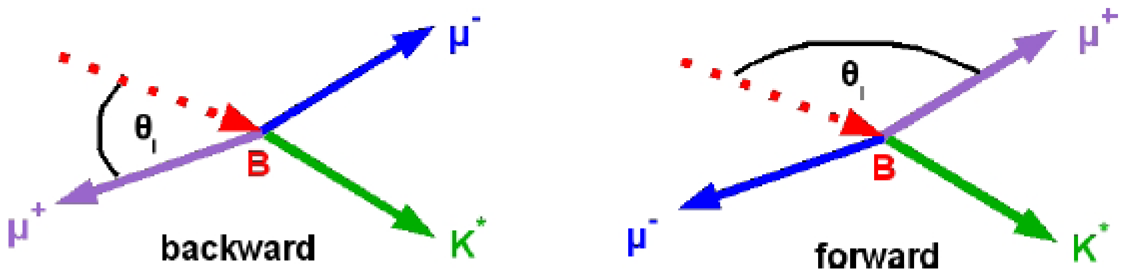

Higgs box


Chargino loop


Neutralino loop


Gluino loop

$B_d^0 \to K^* \mu^+ \mu^-$ Forward-Backward Asymmetry



Definition of the forward - backward asymmetry A_{FB}:

$$A_{FB}(q^2) = \frac{N_F - N_B}{N_F + N_B}$$

with:

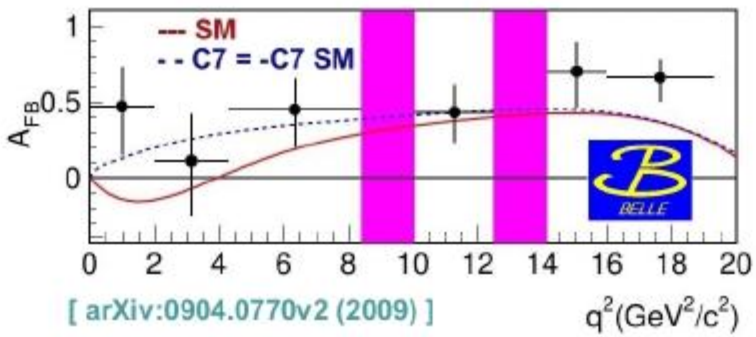
$$N_F = \int_0^1 \frac{\partial^2 \Gamma}{\partial q^2 \partial \cos\theta_l} d\cos\theta_l, \; N_B = \int_{-1}^0 \frac{\partial^2 \Gamma}{\partial q^2 \partial \cos\theta_l} d\cos\theta_l$$

$\theta_l =$ angle between μ^+ and B in the di-muon rest frame

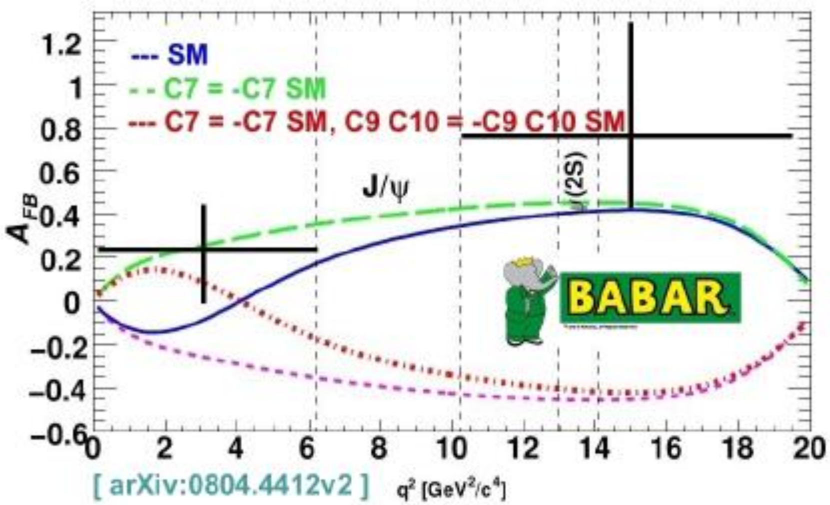
$q^2 = m^2_{\mu^+\mu^-}$ di-muon invariant mass squared

$B_d^0 \to K^* \mu^+ \mu^-$ A_{FB} Measurements

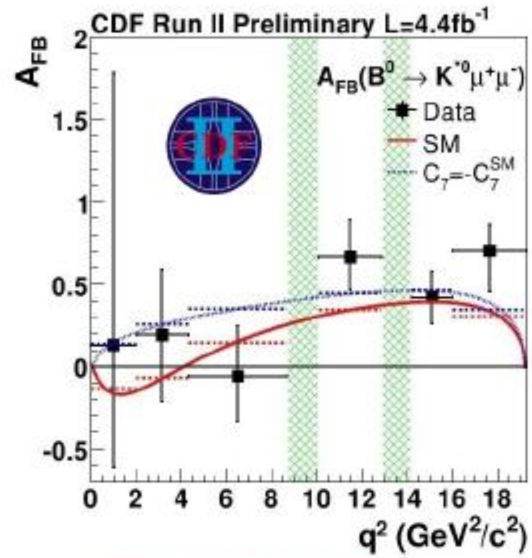
- Data at B-factories and CDF show preference for a non-SM contribution, although not yet significant.



[arXiv:0904.0770v2 (2009)]



[arXiv:0804.4412v2]

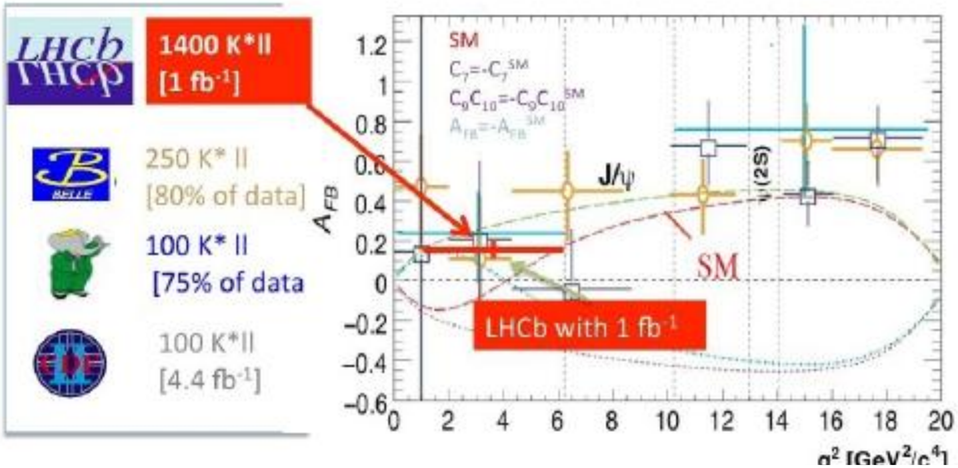


[CDF note 10047 (2010)]

$B_d^0 \to K^*\mu^+\mu^-$ LHCb Perspectives

- With 1 fb^{-1} LHCb expects 1400 signal events.

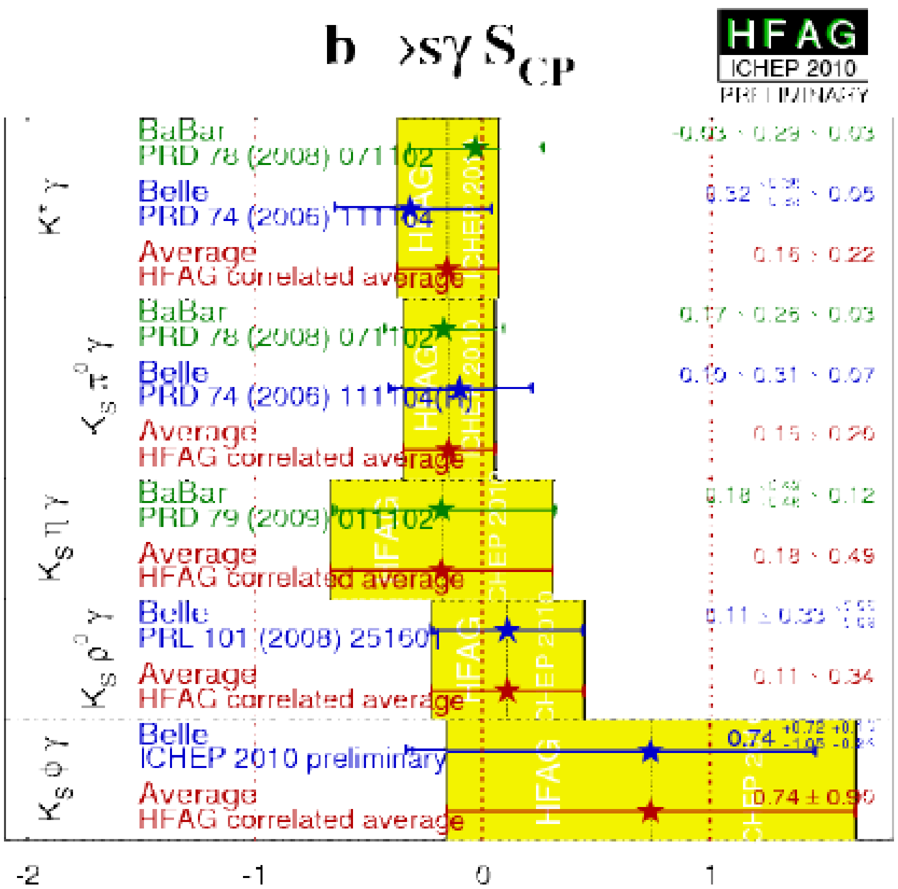
$$\sigma(A_{FB})(1 < q^2 < 6 \quad GeV^2/c^4) = \begin{cases} 0.2 \text{ with } 0.1 \quad fb^{-1} \\ 0.07 \text{ with } 1 \quad fb^{-1} \end{cases}$$



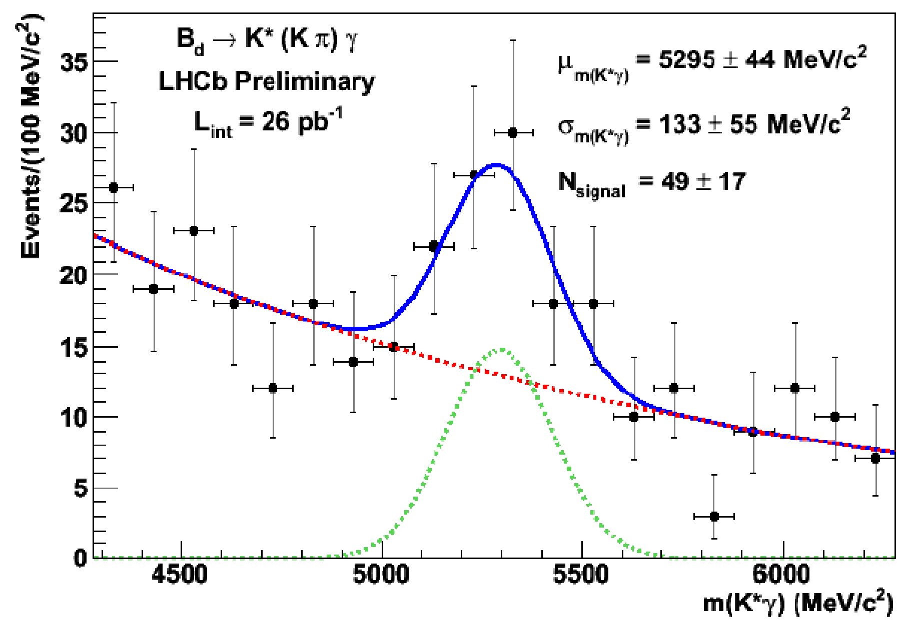
- Forward-backward asymmetry: expect a competitive measurement with 0.1 fb^{-1}.
- Expect to determine $A_{FB} = 0$ with a statistical uncertainty of ± 0.5 GeV^2 with 2 fb^{-1} of data. [LHCb-PUB-2009-029]

Prospects for $B_s \to \varphi\gamma$

- Time-dependent asymmetries in $b \to s\gamma$ transitions act as a photon polarimeter
  - probe the V–A structure of the weak interaction
- B factories have studied several B_d channels
  - but $B_s \to \varphi\gamma$ is the golden mode for this measurement

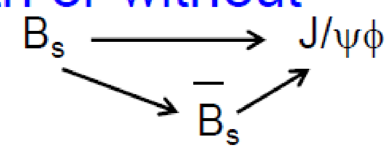


$B_d \to K^*\gamma \to (K^+\pi^-)\gamma$ in 26/pb

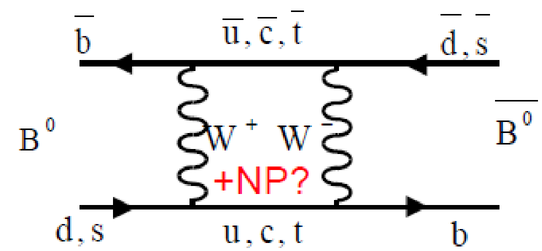


β_s measurements from $B_s \rightarrow J/\psi\ \phi$

- The interference between B_s decay to $J/\psi\phi$ with or without mixing gives rise to a CP violating phase Φ.



  - It is a sensitive probe of New Physics:
    - It is well predicted in the SM: $\Phi=-2\beta_s= -0.0368\pm0.0017$
    - New particles can contribute to the B_s-B_s box diagrams and significantly modify the SM prediction

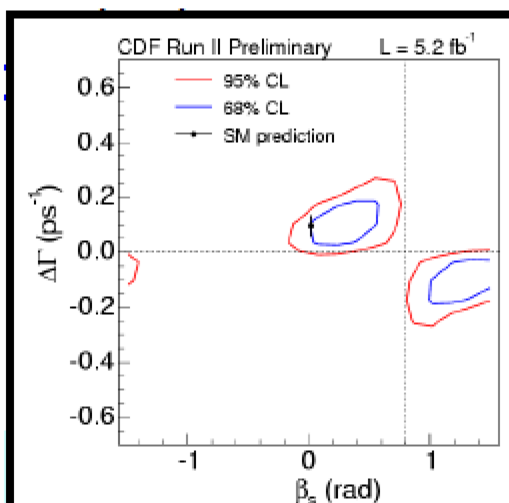


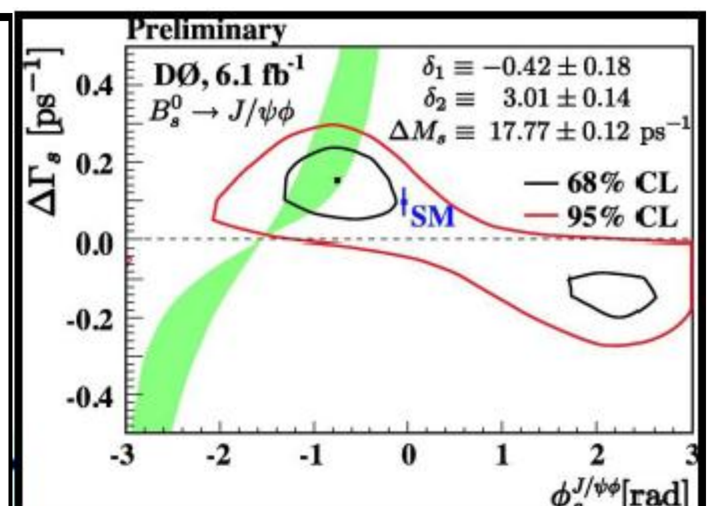
  - It is not a pure CP eigenstate (VV decay)
    - 2 CP even, 1 CP odd amplitude
      - Initial states must be tagged
      - Final states need to be statistically separated through angular analysis
      - Mistag and proper time resolution are crucial…

- TEVATRON:

CDF and D0 set confidence level bounds on

$\Delta\Gamma s$ - ϕs





β_s measurements from $B_s \to J/\psi\ \phi$

Prospects @14TeV assuming $\sigma(pp \to b\bar{b}X)$ = 500 μb

	ATLAS	CMS	LHCb
Integrated lumi (fb^{-1}) (1/4 of nominal year)	2.5	2.5	0.5
$B_s \to J/\psi\phi$ events	23k	27k	30k
Background (B/S)	0.30 Dominated by $J/\psi K^*$, $J/\psi K\pi$	0.33 Dominated by $J/\psi K^*$, $J/\psi K\pi$	2 90% prompt 10% long-lived
Mass resolution (MeV)	16.6*	14*	16.2
Proper time resolution (fs)	83	77	40
Flavour tagging εD^2 (%)	μ,e,Qjet (OS) 3.9	Not yet 0	μ,e,K, Qvtx, OS+SS 6.2
$\sigma(\Delta\Gamma_s/\Gamma_s)$	**0.045**	0.028	**0.023**
$\sigma(2\beta_s)$	**0.16**	No estimated	**0.06**

(*) Jpsi mass constraint, lifetime biased

Standard Model: $2\beta_s=0.0368\pm0.0017$

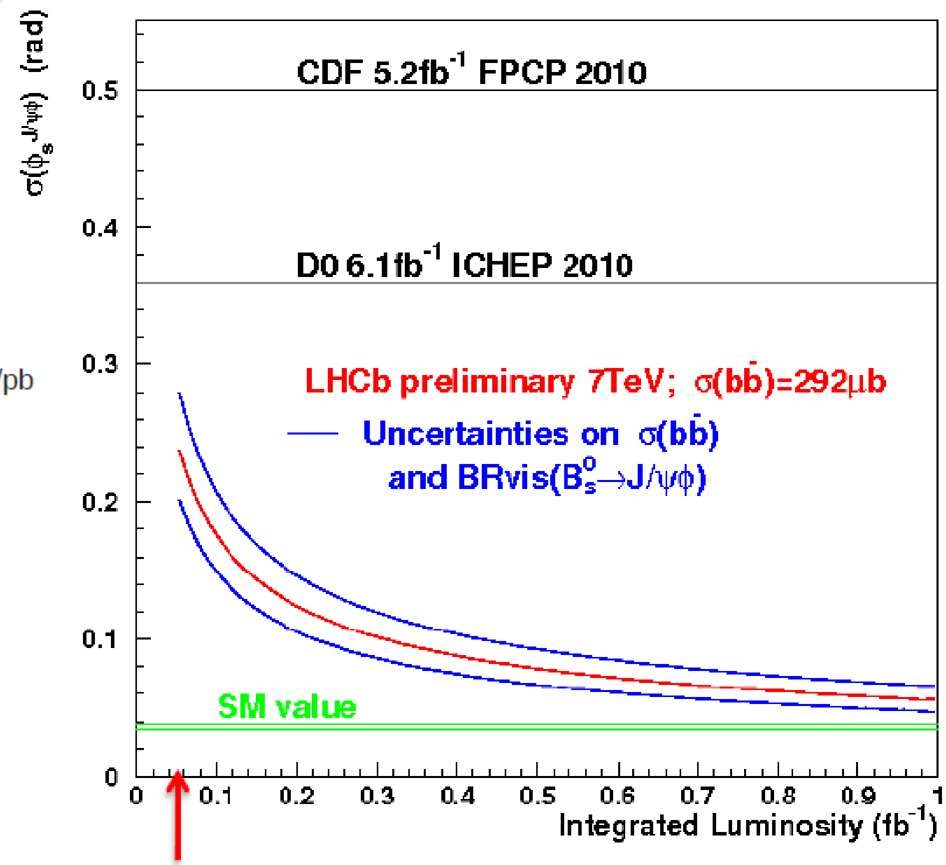
β_s measurements from $B_s \rightarrow J/\psi\ \phi$

- ATLAS/CMS:
  - use Bs lifetime cuts
    - main background is long-lived
    - main systematics: control of acceptance
- LHCb:
  - Does NOT use Bs lifetime cuts
    - main background is prompt
    - Main systematics is mistag and proper-time resolution

877 ± 32 $B_s \rightarrow J/\psi\varphi$ events in 34/pb

- c.f. CDF ~6500 in 5.2/fb
- c.f. D0: ~3500 in 6.1/fb

Expected LHCb sensitivity
10TeV - $\sigma(pp \rightarrow b\bar{b}X)$ = 292 μb



First result possible already with 50 pb^{-1} data

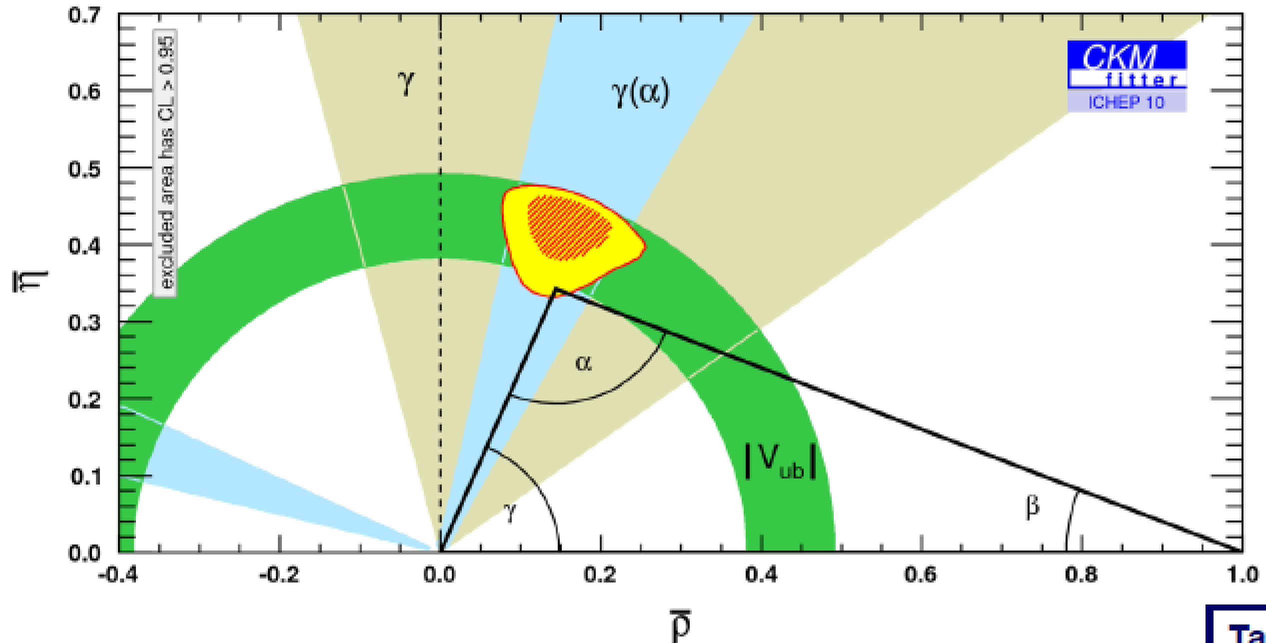
LHCb: yield for 0.2 fb^{-1}: ~ 7 k comparable to CDF @ 5.2 fb^{-1}

Status of γ

Tree-level decays ⇨ **Standard Model benchmark measurement of γ**

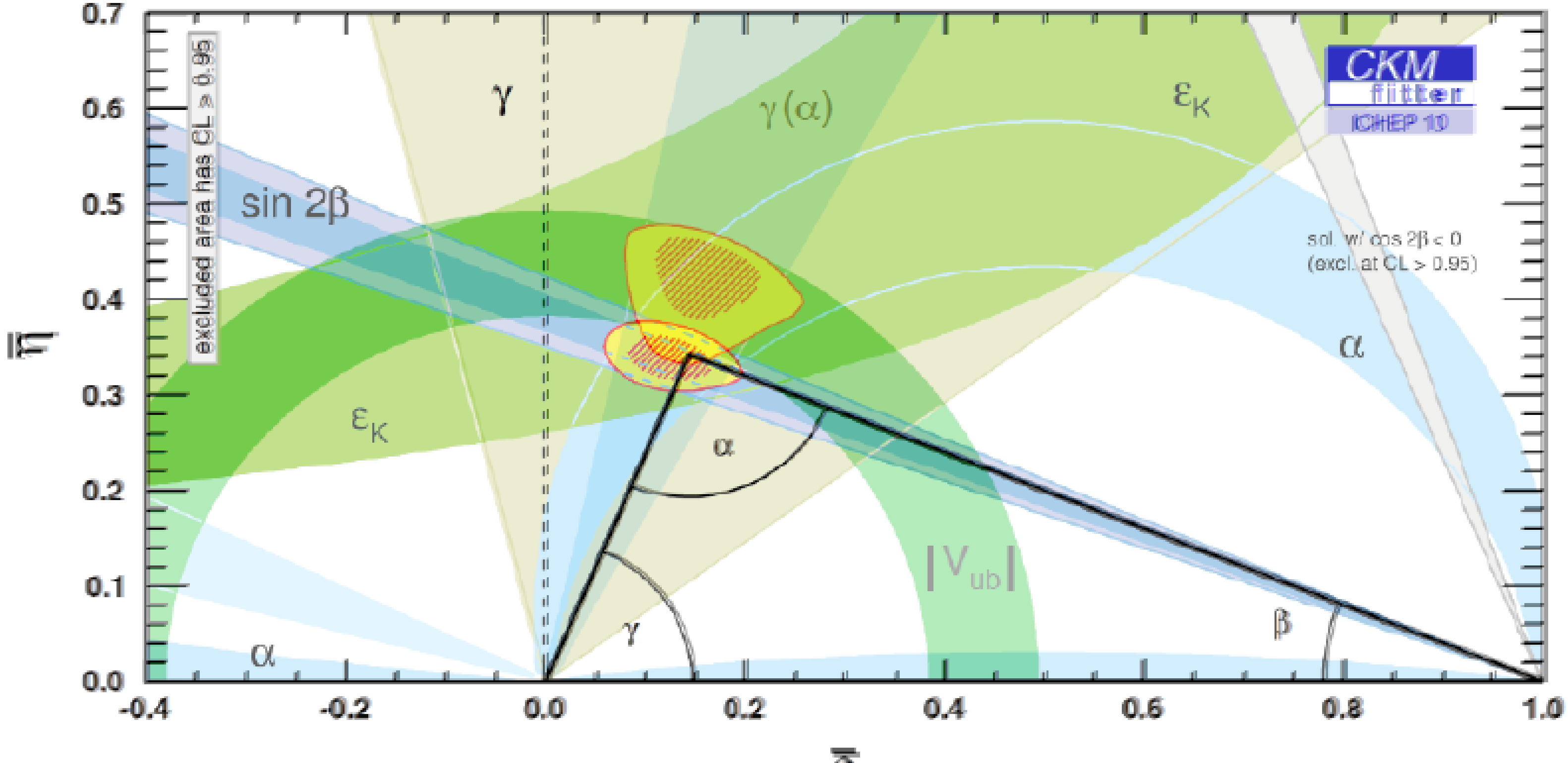
"Loop" decays ⇨ **Measurement of γ sensitive to New Physics**

Fit with "trees" only : γ = (71 ± 21/25)°



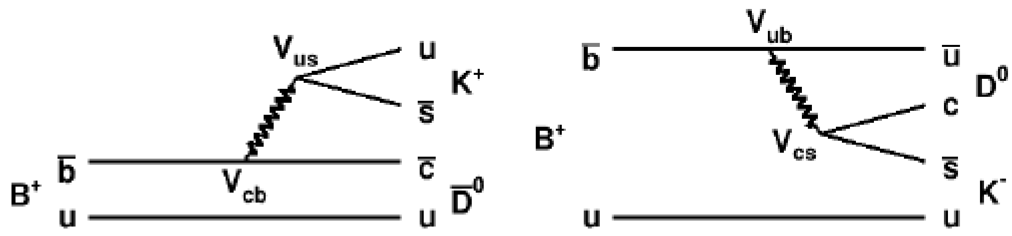
Taken from CKMfitter

Tree vs loops - consistent

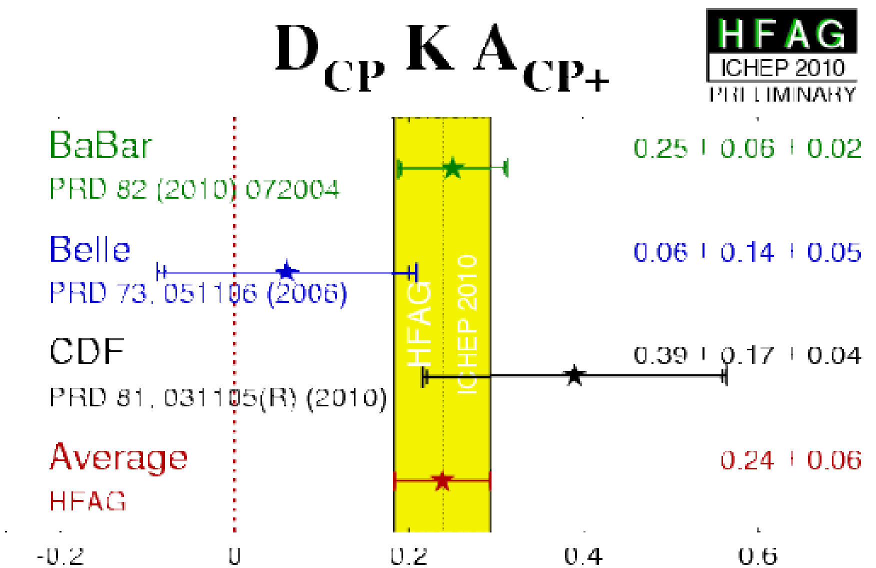


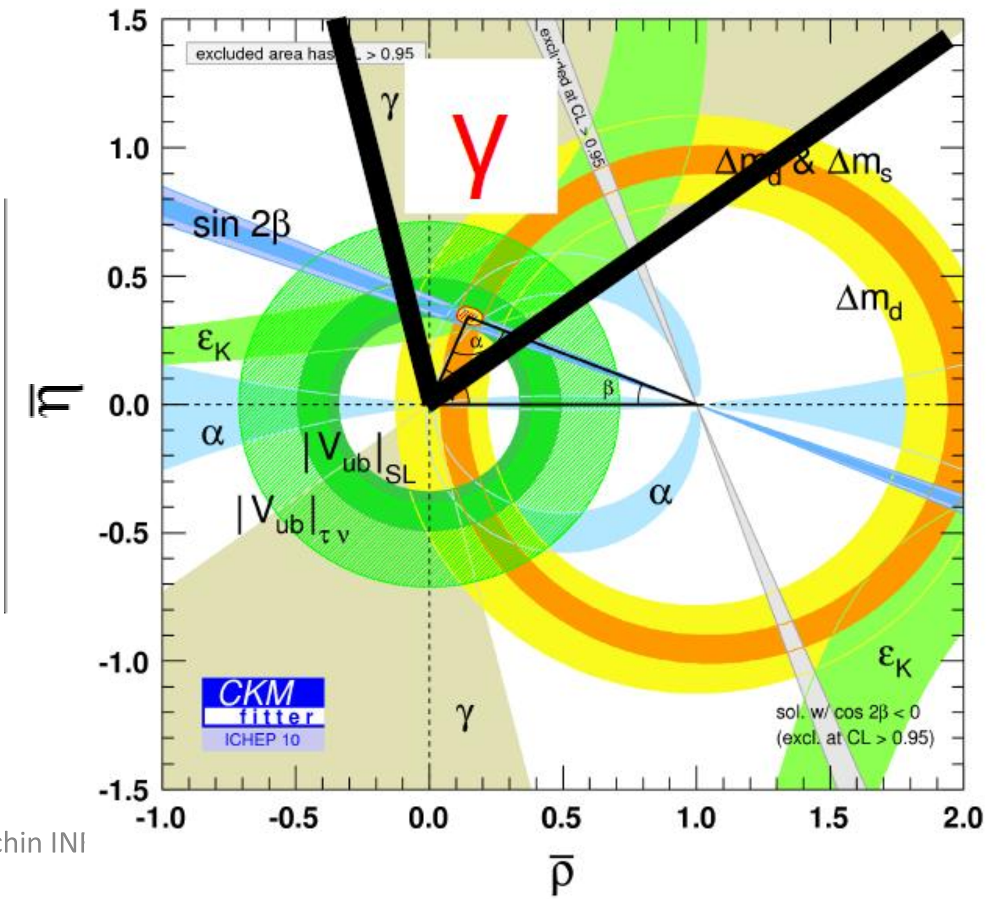
- But consistency is only at the 5% level
- Same for B_s – CP violation in J/ψ ϕ (not including D0 A_{sl}) ⇒limits on NP are not so strong

Measurement of γ from $B^{\pm} \rightarrow DK^{\pm}$



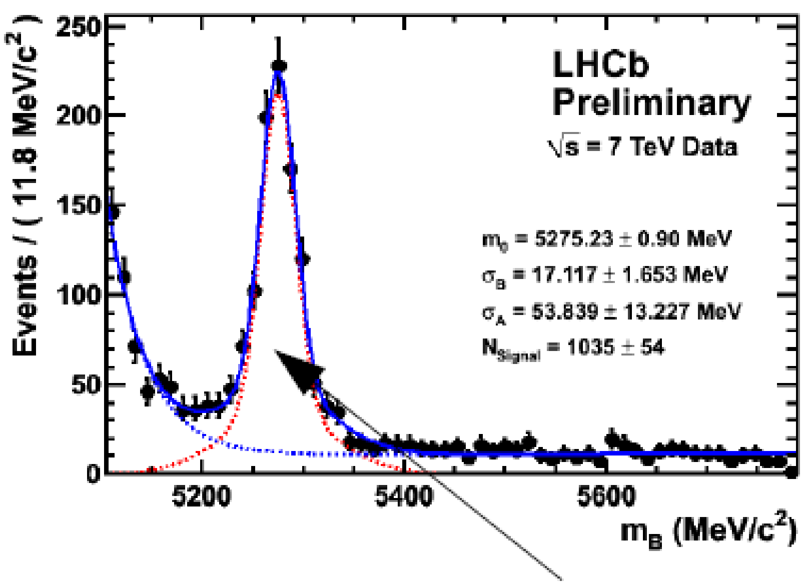
Interference between tree amplitudes gives CP violation effects that depend on their weak phase difference (γ)





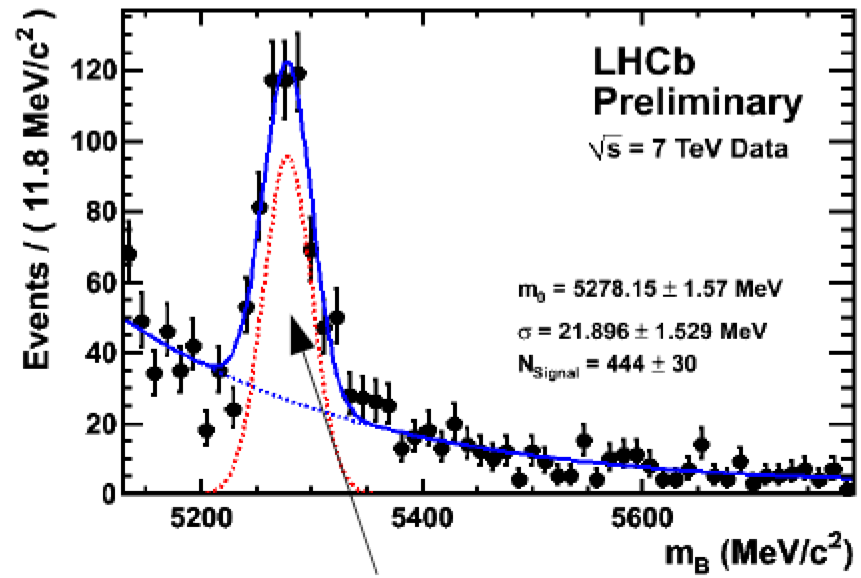
LHCb yields in $B^\pm \to D\pi^\pm$ & $B^\pm \to DK^\pm$

$B^\pm \to D\pi^\pm$ with $D \to KK$



LHCb yield with ~34/pb : 1035 ± 54
c.f. CDF with 1/fb : 780 ± 36

$B^\pm \to DK^\pm$ with $D \to \pi K$

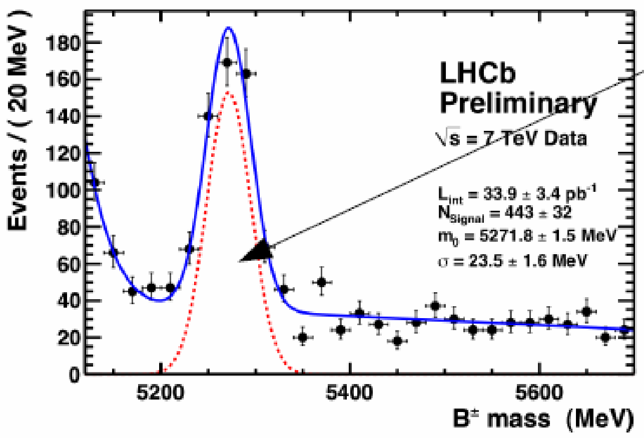


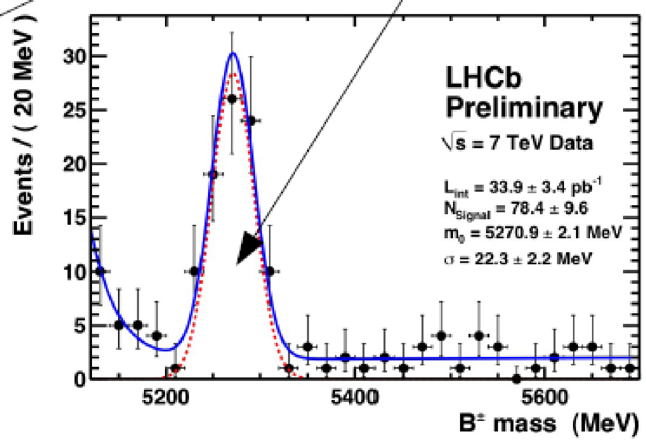
LHCb yield with ~34/pb : 444 ± 30
c.f. CDF with 1/fb : 516 ± 37

Prospects for direct CP violation measurement in charged B decays

- Expect to observe >5σ effect in $B^{\pm} \to D_{CP} K^{\pm}$ with 1/fb
- Excellent prospects also in $B^{\pm} \to D_{sup} K^{\pm}$ (ADS analysis) and $B^{\pm} \to D_{Dalitz} K^{\pm}$

Signals for $(K_s \pi^+ \pi^-)\pi^{\pm}$ and $(K_s K^+ K^-)\pi^{\pm}$ in ~34/pb





- Several other possibilities for the first observation: for example $B^{\pm} \to \rho^0 K^{\pm}$ (in $B^{\pm} \to \pi^+ \pi^- K^{\pm}$ Dalitz plot analysis)

Combined sensitivity to γ from B → DK

- Estimated sensitivity described in LHCb roadmap document arXiv:0912.4179
- Nominal conditions (14 TeV, $\mathscr{L} = 2\ 10^{32}/cm^2/s$)

Table 11: Expected combined sensitivity to γ from $B \to DK$ and time-dependent measurements for data sets corresponding to integrated luminosities of 0.5 and 2 fb^{-1}. The table is taken from Ref. [9]. In these studies the Level-0 and Level-1, a precursor to HLT1, triggers were included. The HLT2 trigger was not included.

δ_{B^0} (°)	0	45	90	135	180
σ_γ for 0.5 fb^{-1} (°)	8.1	10.1	9.3	9.5	7.8
σ_γ for 2 fb^{-1} (°)	4.1	5.1	4.8	5.1	3.9

- At 7 TeV, $\sigma(b\bar{b})$ is lower by a factor of about 2
- Estimated sensitivity of ~7° with 2011 data

Also

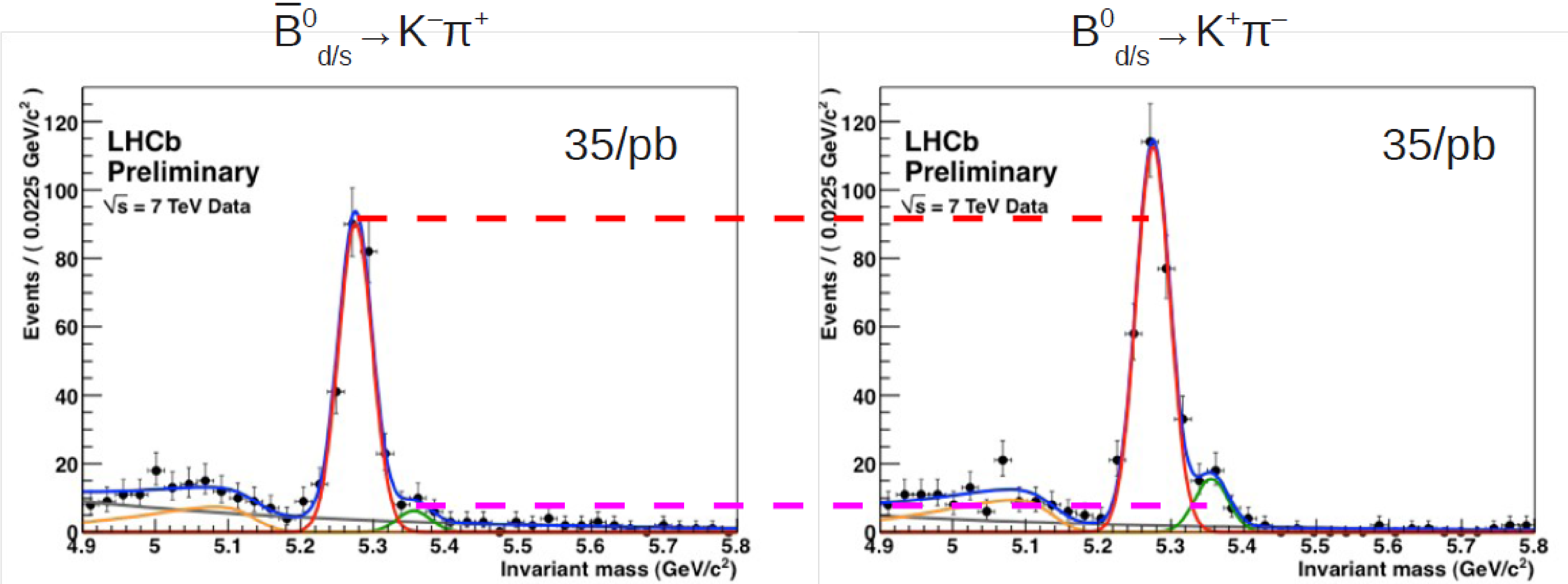
Measurement of γ from $B_s \to K^+K^-$

- LHCb yields in ~35/pb: 254±20 $B_s \to K^+K^-$ & 229±23 $B_d \to \pi^+\pi^-$
  - c.f. CDF in 1/fb: 1307±64 $B_s \to K^+K^-$ & 1121±63 $B_d \to \pi^+\pi^-$
- Expect first time-dependent measurements in 2011
  - (including measurement of B_s lifetime in CP-even K^+K^- final state)

Compilation of *CP* Asymmetries for B_s modes

RPP#	Mode	PDG2010 Avg.	BABAR	Belle	CLEO	CDF	New Avg.
22	$K^+\pi^-$	New				$0.39 \pm 0.15 \pm 0.08$	0.39 ± 0.17

Prospects for direct CP violation in $B_{d/s} \to K^+\pi^-$



- Raw asymmetries clearly visible in existing data
- Central values consistent with expectations & previous measurements
- Calibration and evaluation of systematic uncertainties in progress
- B_s/B^o yield = (10.7±2.0)%
  - evidence for CPV in both
- Using tight cuts $A_{CP}(B_s)$=-0.43±0.17
  - stat error only, no corrections (CDF: 0.39±0.15±0.08 in 1 fb^{-1})

2011 and beyond - expectations

- 2011
  - Ready to have detector, trigger and readout operating at 2-2.5 interations/bunch crossing at a maximum instantaneous luminosity around $3 \cdot 10^{32}$ $cm^{-2}s^{-1}$.
  - Expect to collect an integrated luminosity ~**1 fb^{-1}** and perform full physics programme.
- "1st run"
  - Expect to collect up to **6 fb^{-1}**
- Upgrade
  - Expect to collect **50 fb^{-1}** (5 years at $10fb^{-1}$ /year)
  - Increase nominal luminosity to $L=10^{33}$ $cm^{-2}s^{-1}$
  - Detector read-out at 40 MHz.
    - Allows fully software based trigger.
    - Keep 20 kHz HLT output rate.
  - Phase-I (2016)
    - New FE-electronics for 40 MHz readout
    - Novel Velo pixel detector
    - RICH photon detectors replacement
    - New TT, IT tracking system

Upgraded Sensitivities (50 fb^{-1})	
Observable	Sensitivity
$CPV(B_s \to \phi\phi)$	0.024
$CPV(B_d \to \phi K_s)$	0.027-0.064
$CPV(B_s \to J/\psi\phi)$ $(2\beta_s)$	0.004
$CPV(B_d \to J/\psi K_s)$ (2β)	0.004-0.014
$CPV(B \to DK)$ (γ)	<1.4°
$CPV(B_s \to D_s K)$ (γ)	1.4-2.8°
$\mathcal{B}(B_s \to \mu^+\mu^-)$	~15% of SM
$A_{FB}(B \to K^* \mu^+\mu^-)$	Zero to ±0.1 GeV^2
$\sigma(\sin 2\psi)(B_s \to \phi\gamma)$	0.03
Charm mixing x'^2	$3x10^{-5}$
Charm mixing y'	$4x10^{-4}$
Charm CP y_{CP}	$2x10^{-4}$

Future plans and expectations

2015

LHCb Sensitivities (2 fb^{-1} @14TeV)		
Observable	Sensitivity	SM
$CPV(B_s \to J/\psi\phi)$ $(2\beta_s)$	0.03	0.04
γ tree	5^o	67.2°
$B(B_s \to \mu^+\mu^-)$	Observed at 3σ	3.6×10^{-9}
$A_{FB}(B \to K^*\mu^+\mu^-)$	0.5 GeV^2	4.36 GeV^2
$CPV(B_s \to \phi\gamma)$	0.22	0.10

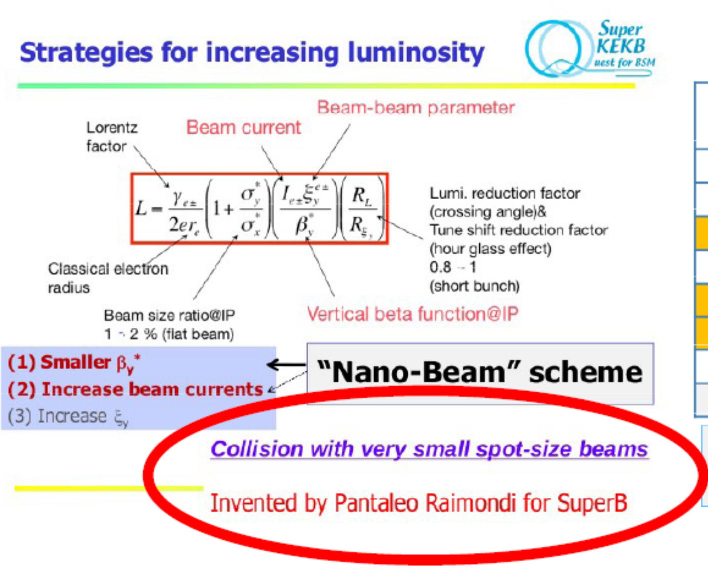
Upgrade

LHCb Sensitivities (100 fb^{-1} @14TeV)		
Observable	Sensitivity	SM
$CPV(B_s \to J/\psi\phi)$ $(2\beta_s)$	0.003	0.04
γ tree	1^o	67.2°
$B(B_s \to \mu^+\mu^-)$	5-10% of SM	3.6×10^{-9}
$A_{FB}(B \to K^*\mu^+\mu^-)$	0.07 GeV^2	4.36 GeV^2
$CPV(B_s \to \phi\gamma)$	0.02	0.10

Back-up slides

Next generation B factories

- LHCb has great potential in many – but not all – sectors
- Two important examples only accessible in e^+e^- collisions
  - $B^+ \to \tau\nu$, $\mu\nu$, $e\nu$ & rare τ decays (except $\tau \to 3\mu$)
- Two next generation experiments proposed
  - Belle2 – upgrade of Belle, approved in Japan, commissioning starts 2014
  - SuperB – new Italy-based project, reusing BaBar/PEP-II hardware, awaiting approval
- The two designs share much in common
  - One difference: potential for beam polarisation in SuperB



Machine design parameters

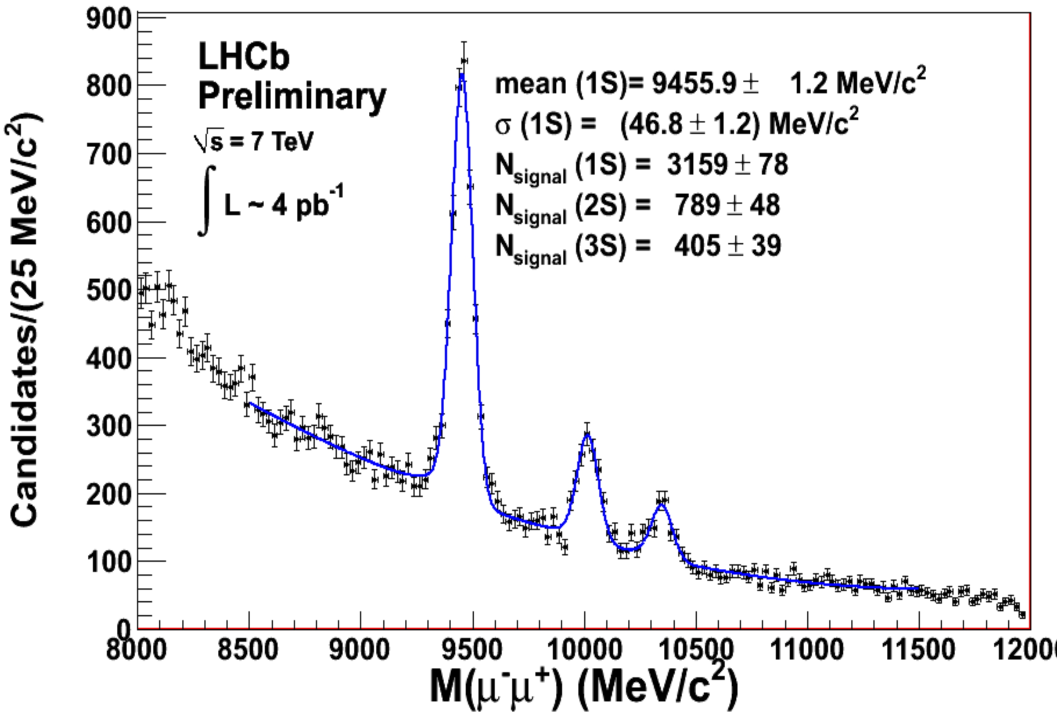
parameters		KEKB LER	KEKB HER	SuperKEKB LER	SuperKEKB HER	units
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	5.0	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

M. Iwasaki, ICHEP2010

B-Basics: Upsilon

- Bound $\bar{b}b$ states
  - $\sigma(1S)$ = 47 MeV

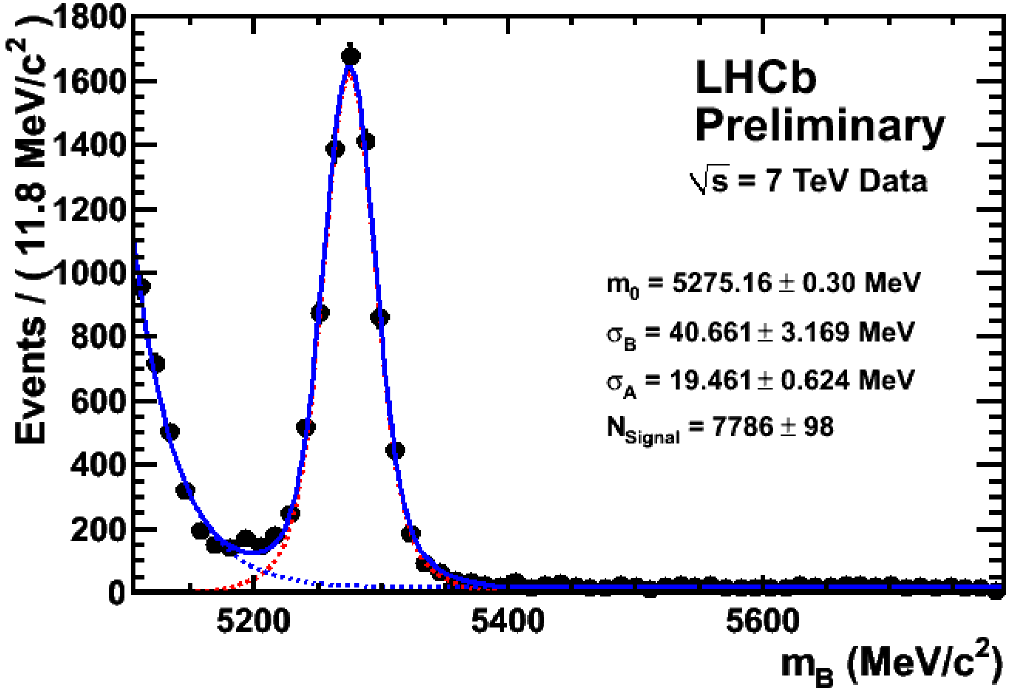


B-Basics: $B^{\pm}$

- Exclusives: e.g. $B^+ \rightarrow D^o \pi^+$

$Br(B \rightarrow D^o \pi^+) \times$
$Br(D^o \rightarrow \pi^+ K^-)$
$= 1.9 \times 10^{-4}$

$\sim 34\ pb^{-1}$



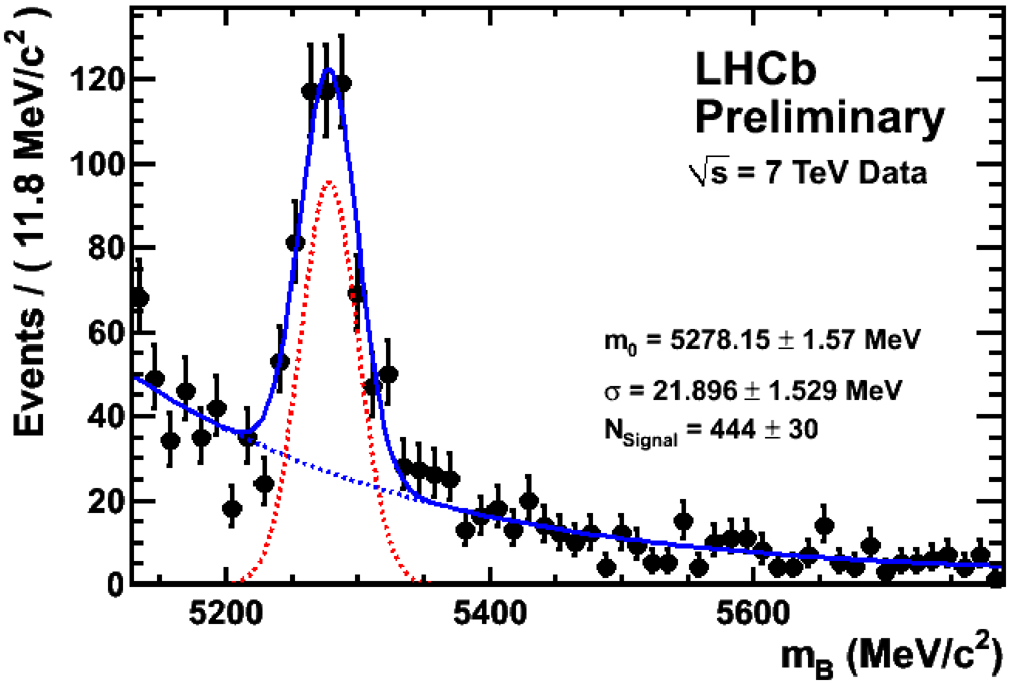
B-Basics: $B^{\pm}$

- Exclusives: e.g. $B^+ \rightarrow D^o K^+$

Huge statistics at LHC

LHCb yield with ~34/pb : 444 ± 30

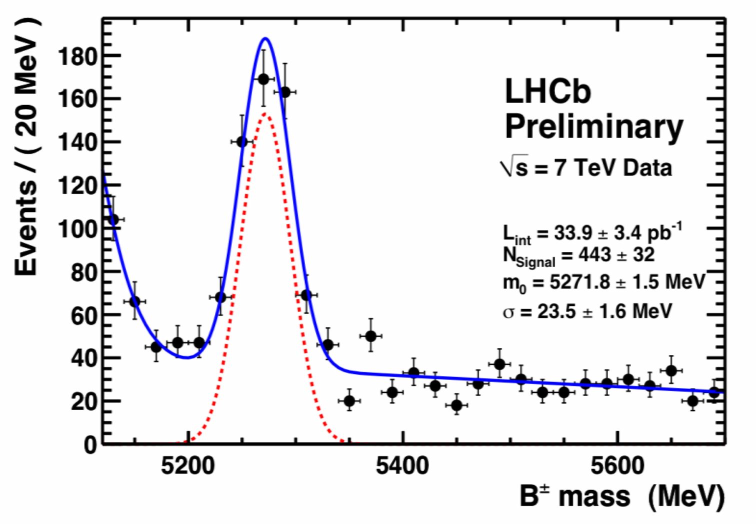
c.f. CDF with 1/fb : 516 ± 37

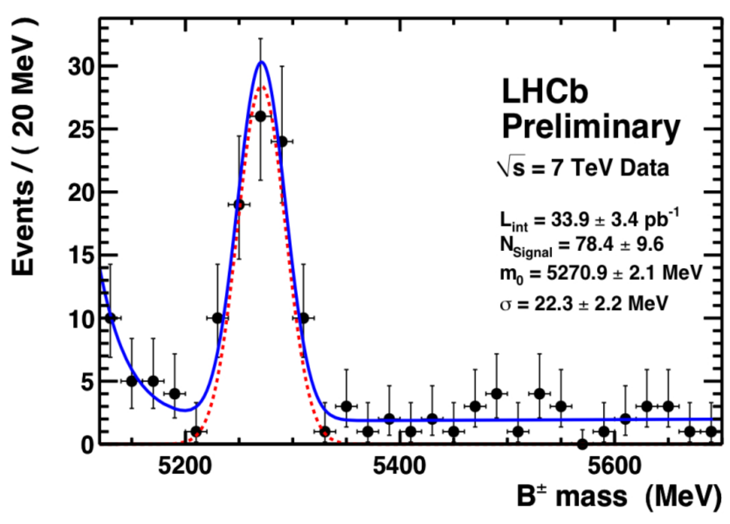


B-Basics: $B^{\pm}$

$B \to D^o(K_s\pi\pi)\pi$

$B \to D^o(K_sKK)\pi$



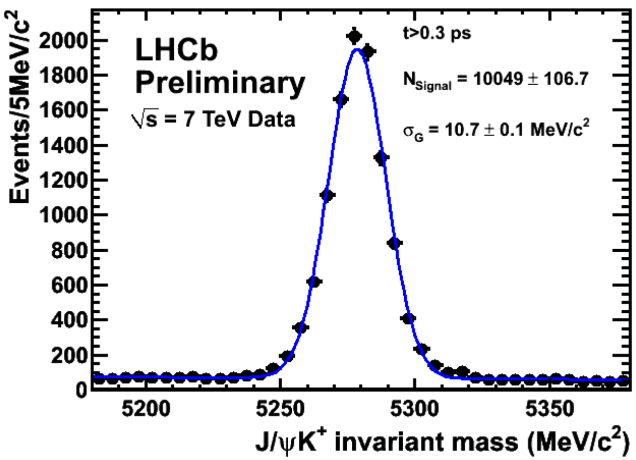


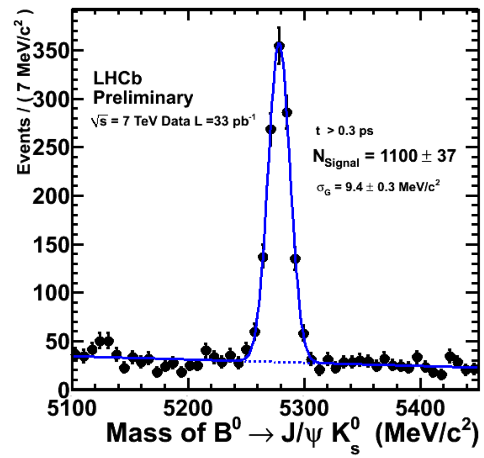
$\sim 34\ pb^{-1}$

Prospects for direct CP violation measurement in charged B decays

B-Basics: $B_s \to J/\psi h$

$J/\psi K^+$





$J/\psi K^{*0}$

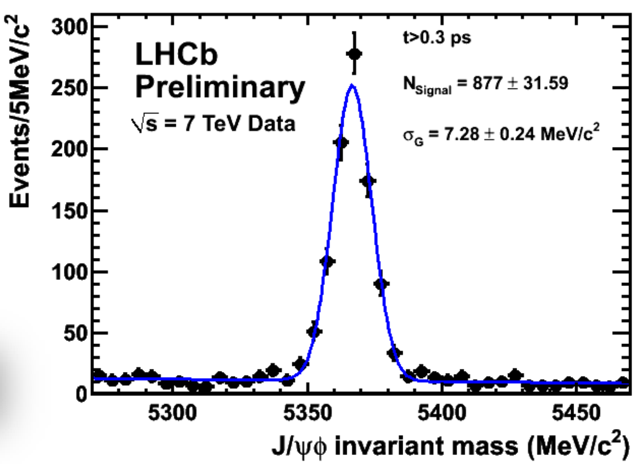
~ 15 pb^{-1}

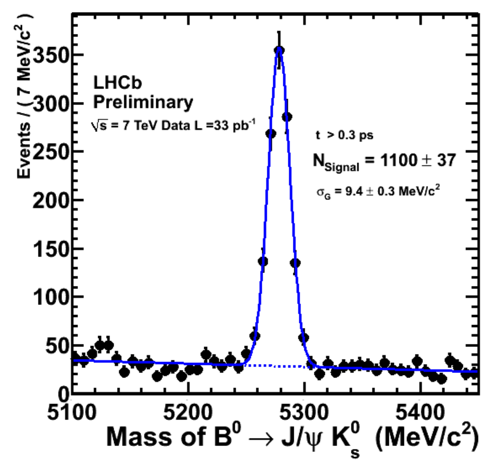
$J/\psi\phi$

CDF ~6500 5.2/fb

- c.f. D0: ~3500 in 6.1/fb

sin2β



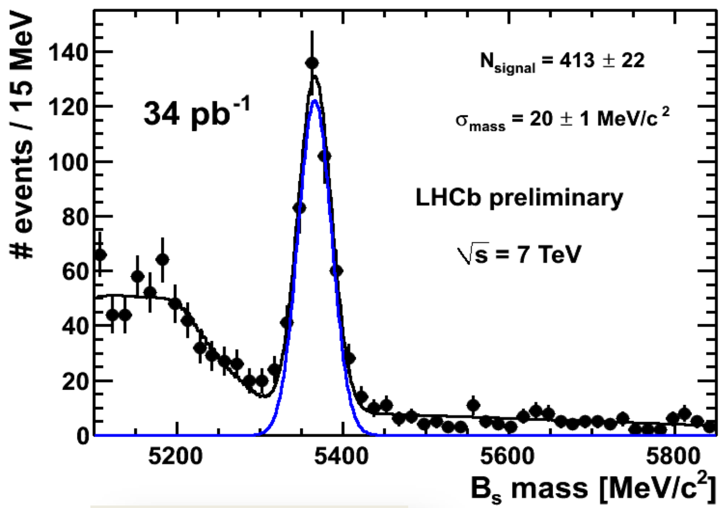


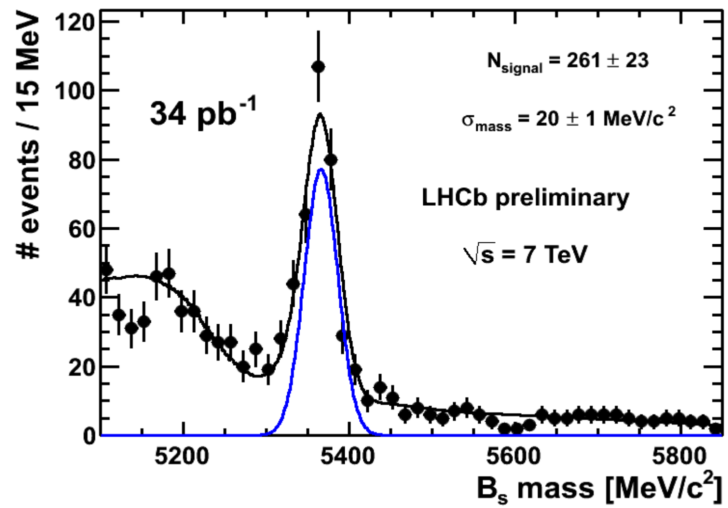
$J/\psi K_s$

B-Basics: B_s

$B_s \to D_s(\phi\pi)\pi$

$B_s \to D_s(K^*K)\pi$





~34 pb^{-1}

Large signals for $B_s \to D_s\pi$ (used for Δm_s measurement)

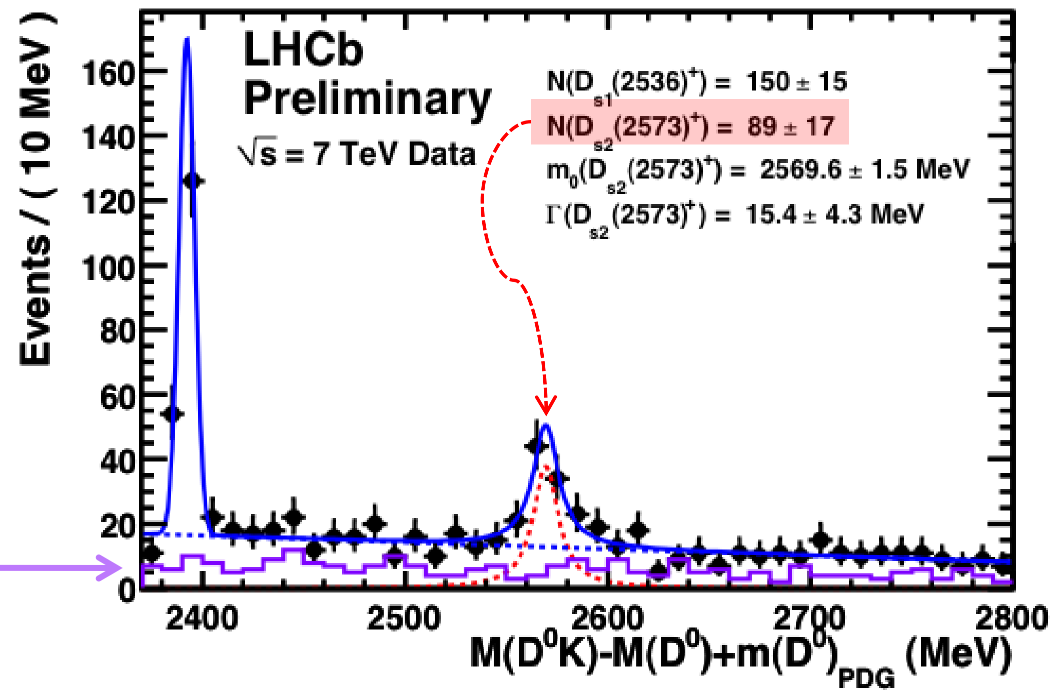
B-Basics: B_s

- Prospects for γ measurement from $B_s \rightarrow D_s K$
  - Final states under study
  - First Time dependent analysis in 2011
- Combined sensitivity to γ from $B \rightarrow DK$
  - Estimated sensitivity of ~7° with 2011 data

B_s: a new decay mode

$B_s \to D_{s2} X \mu \nu$,
$D_{s2} \to D^o K^+$

Wrong sign



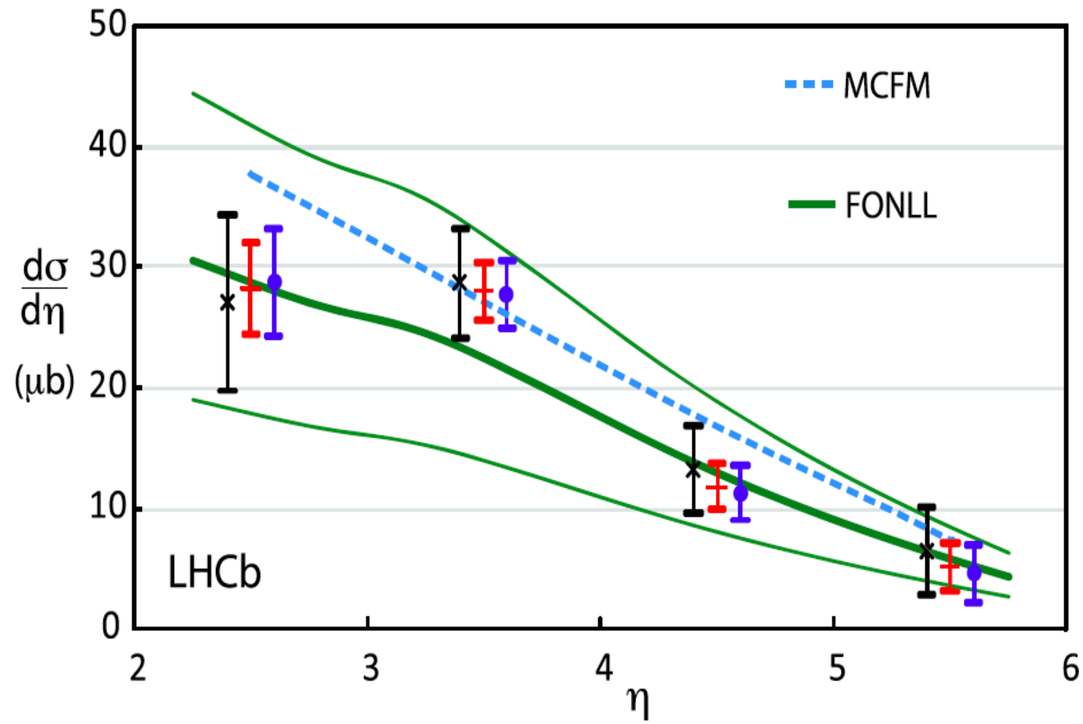
$b\bar{b}$ cross-section

[Physics Letters B 694 (2010) 209.](#)

$\sigma(pp \rightarrow bbX)$ using $b \rightarrow D^0 X \mu^- \nu$, $D^o \rightarrow K^- \pi^+$,
~280 events

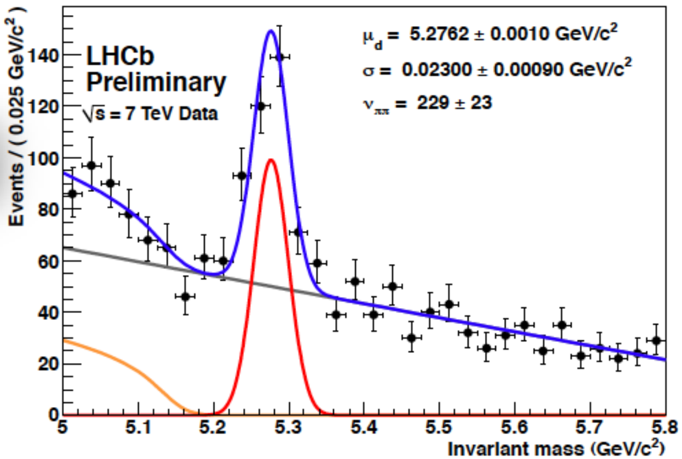
~15 nb^{-1}

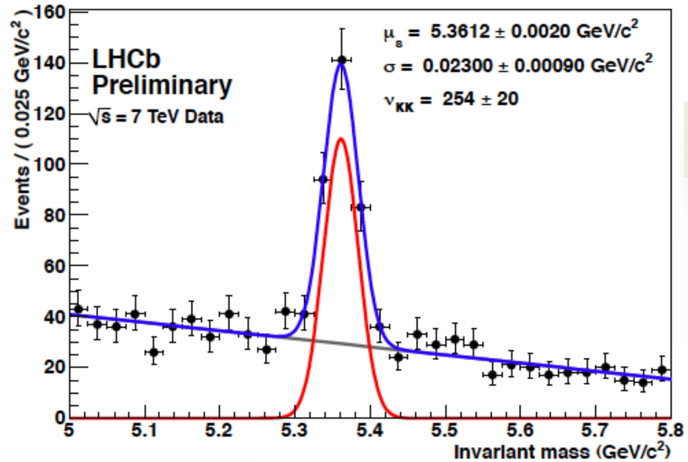
x -Untriggered
• - Single Muon Trigger



Towards γ and CPV

$B^0 \rightarrow \pi\pi$



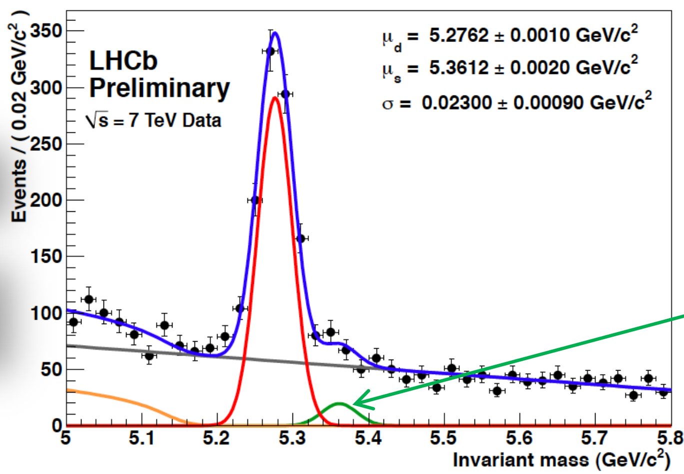


$B_s \rightarrow K^+K^-$

γ

$B^0 \rightarrow K^\pm\pi^\mp$

CPV

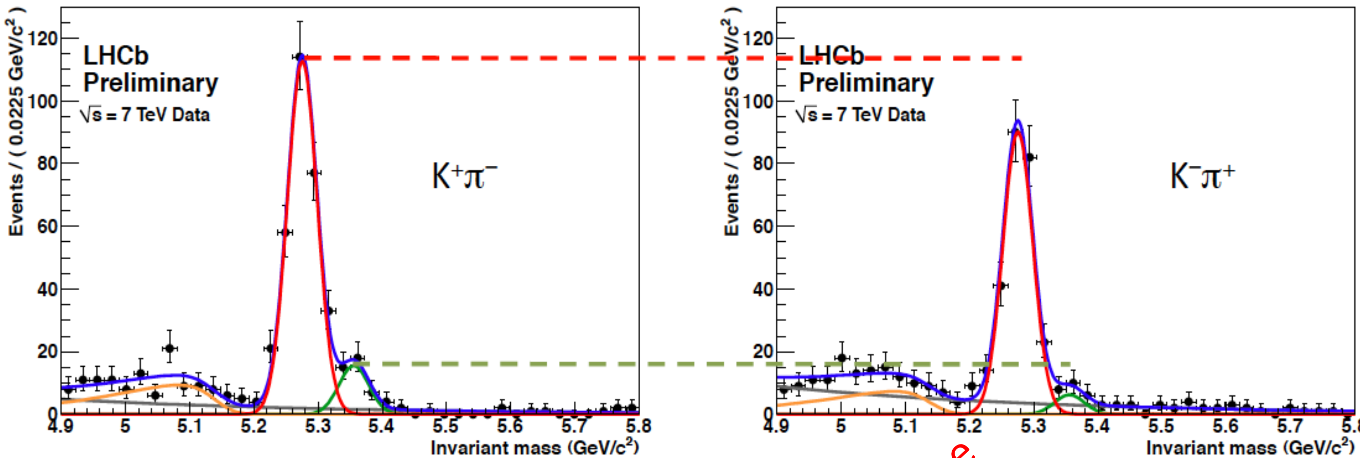


~ 35 pb^{-1}

We will get as many $K\pi$ in 0.5-0.7 fb^{-1} as Belle in 1000 fb^{-1}

$B_s \rightarrow K^\pm\pi^\mp$

CPV: on the horizon



- B_s/B^o yield = (10.7±2.0)%
  - evidence for CPV in both
- Using loose cuts $A_{CP}(B^o)$=-0.134±0.041
  - stat error only, no corrections (HFAG: -0.098±0.012)
- Using tight cuts $A_{CP}(B_s)$=-0.43±0.17
  - stat error only, no corrections (CDF: 0.39±0.15±0.08 in 1 fb^{-1})

I will reference these numbers

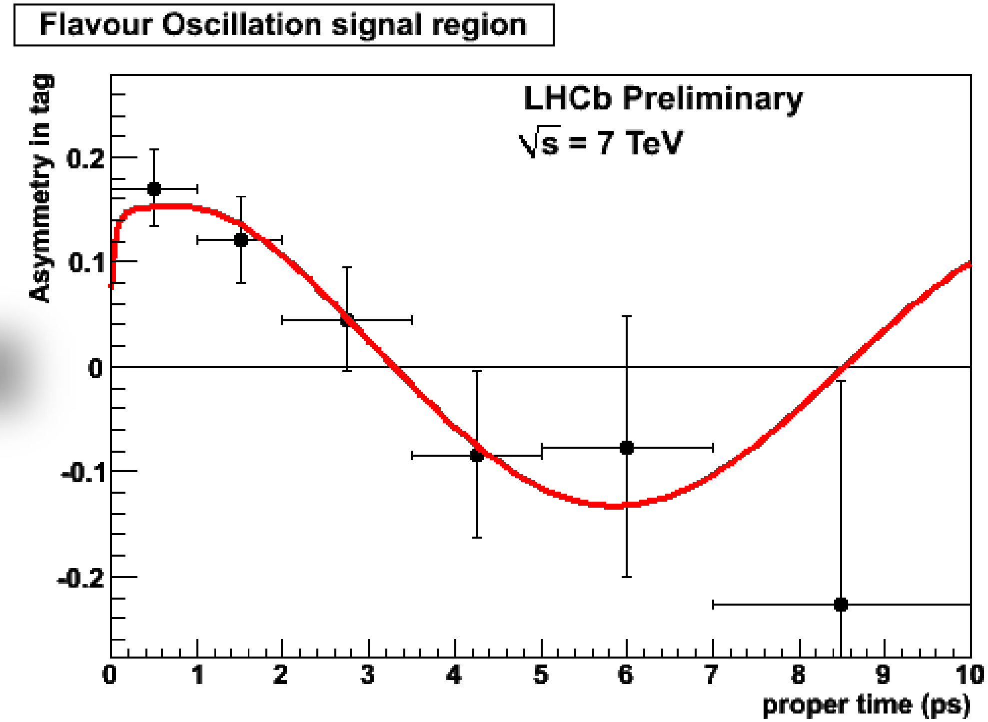
Help on sign!!!

caveat: RAW NUMBERS - no corrections yet applied

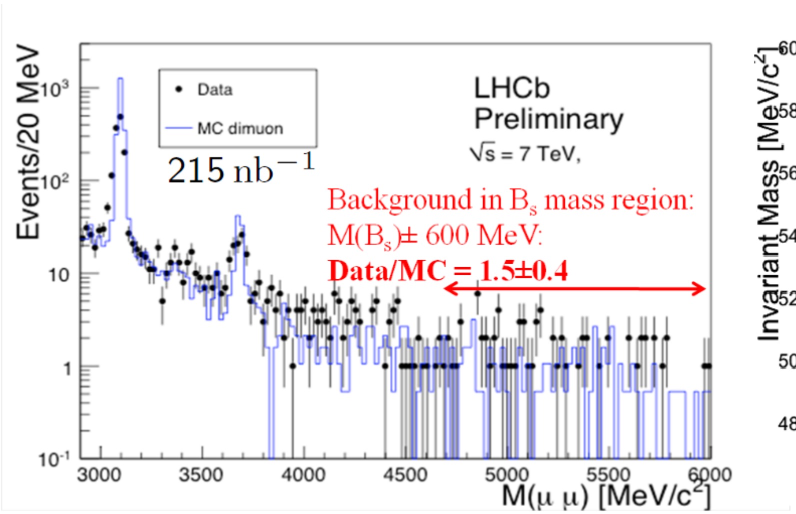
B-oscillations seen

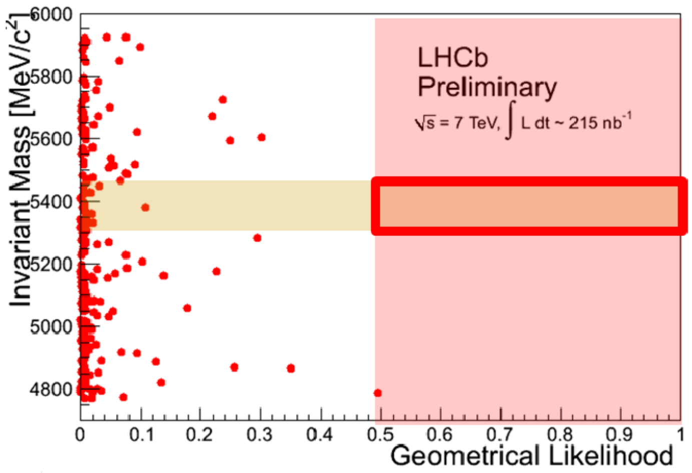
- $B_d \to D^* \mu \nu X$

~ 2 pb^{-1}



Rare B decay: $B_s \to \mu\mu$



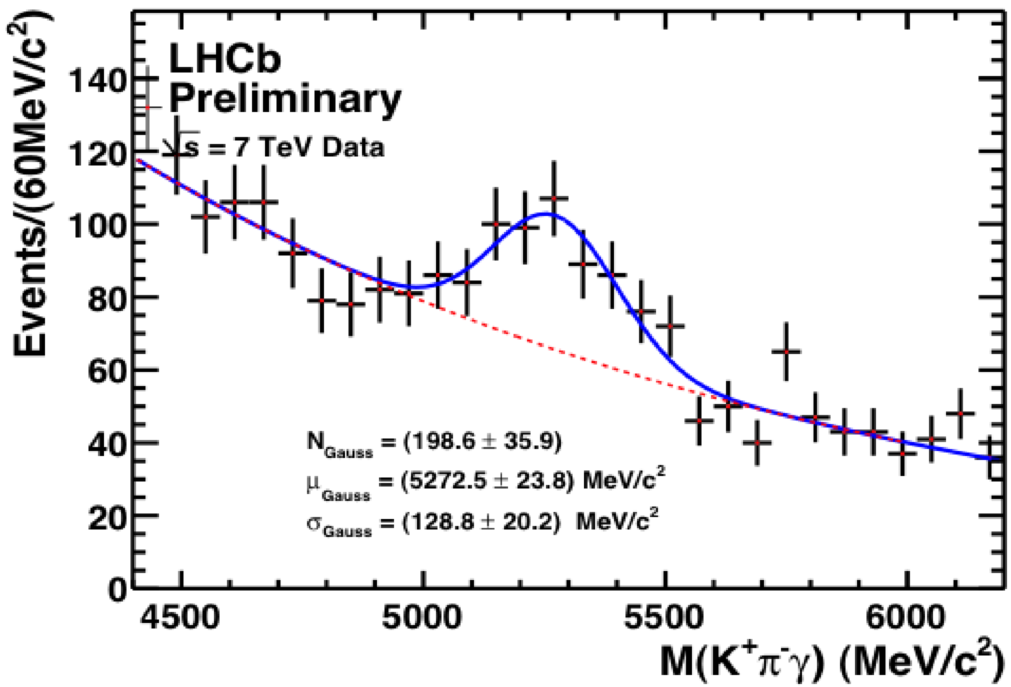


- Good agreement between mass distribution of background events between Data and MC. No evidence for excess of background in data.
- Background events populate the low Geometrical Likelihood region.
- Signal & $B \to \mu\mu$ control channels are at in geometrical likelihood
- Geometrical likelihood depends on based on B kinematics
  - Lifetime, Impact Parameter, Isolation

Radiative Decays: $B^o \rightarrow K^{*o}\gamma$

- NP search

37 pb^{-1}
199 events



b-hadron fractions

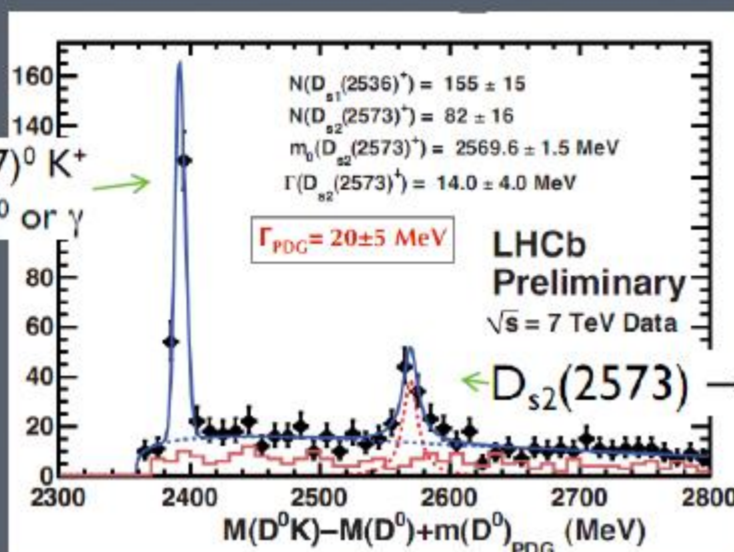
$f_s/(f_u+f_d)$ = 0.130 ± 0.004(stat.) ± 0.013(sys.) [preliminary]

LEP: 0.129 ± 0.012

Tevatron: 0.18 ± 0.03

$B_s \rightarrow D^0K^+X\mu^-\nu$

$D_{s1}(2536) \rightarrow D^*(2007)^0\ K^+$
missed π^0 or γ



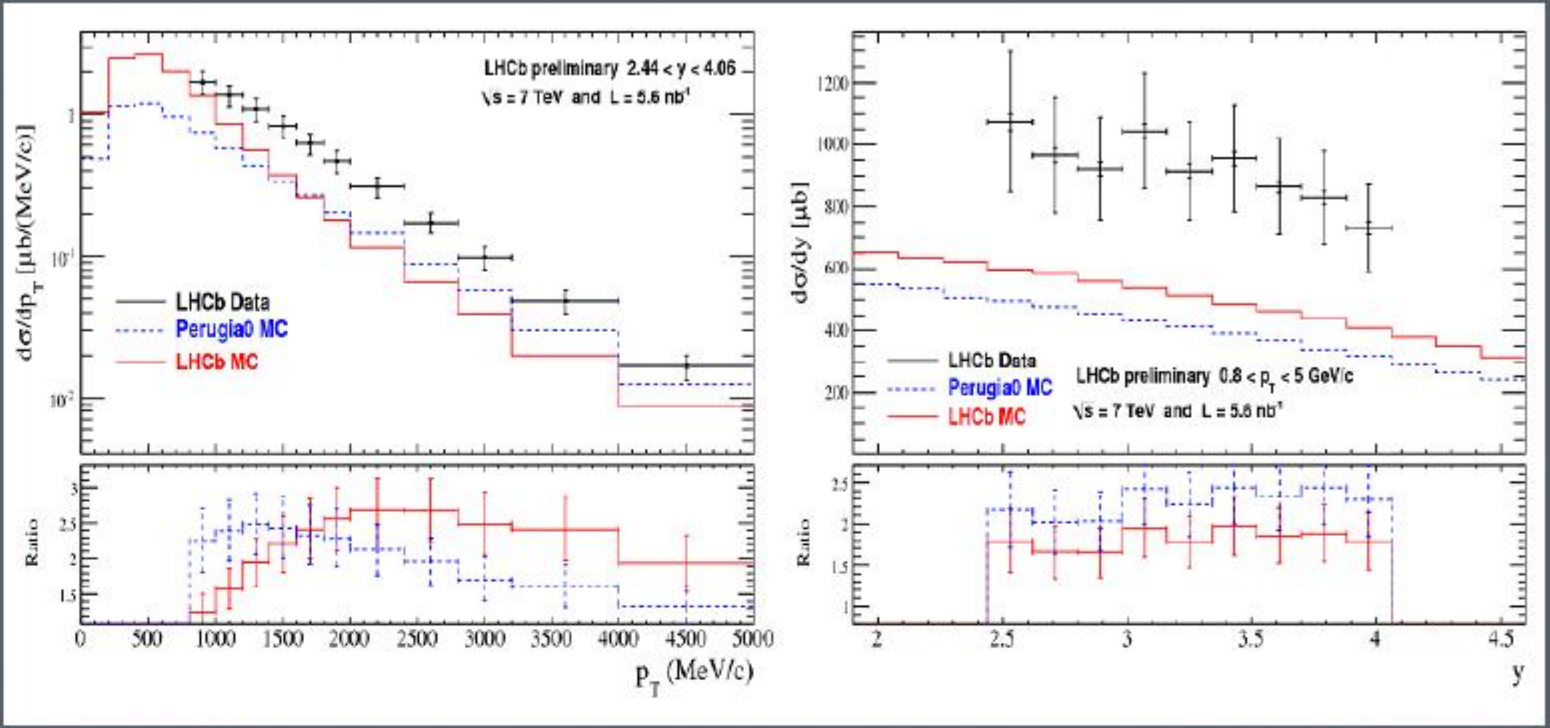
$D_{s2}(2573) \rightarrow D^0\ K^+$

8.3 σ significance for $B_s \rightarrow D_{s2}\mu^-\nu$ mode.

Discovery!

Inclusive Φ cross section

Test QCD fragmentation models

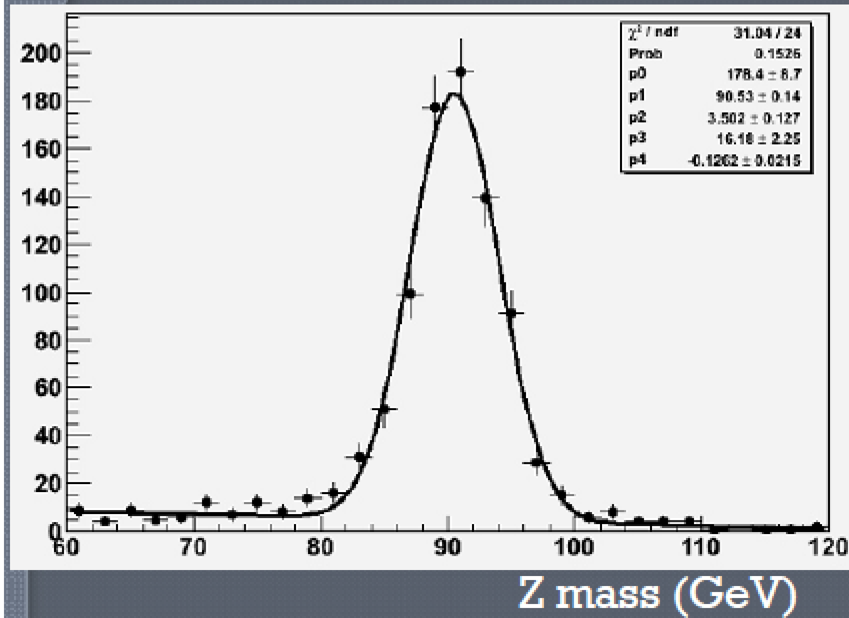


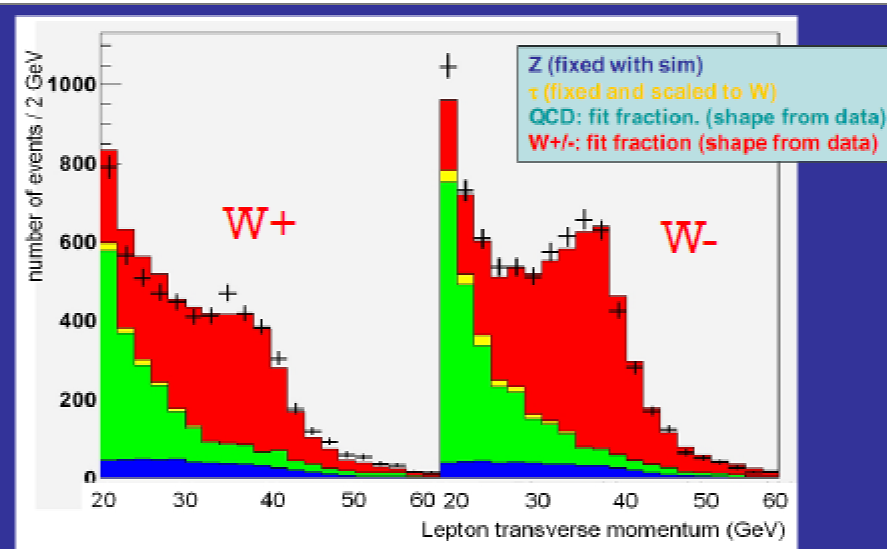
Both tunings underestimate Φ production in the measured kinematic range

$$\sigma(pp \to \phi X) = (1493 \pm 12(\mathrm{stat}) \pm 12(\mathrm{syst}) \pm 209(\mathrm{syst}))\mu\mathrm{b}$$

$$y \in [2.44, 4.06] \qquad p_\mathrm{T} \in [0.8, 5.0]\ \mathrm{GeV/c}$$

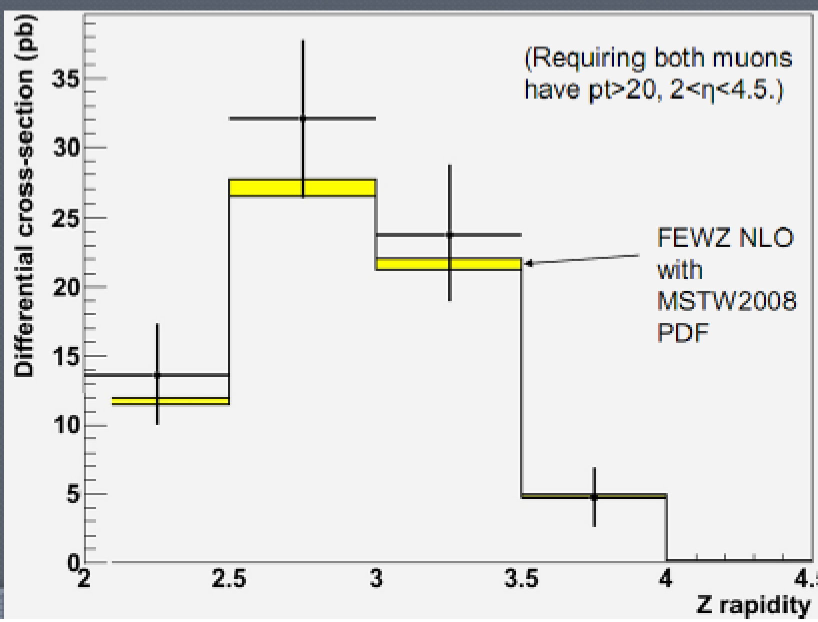
W analysis

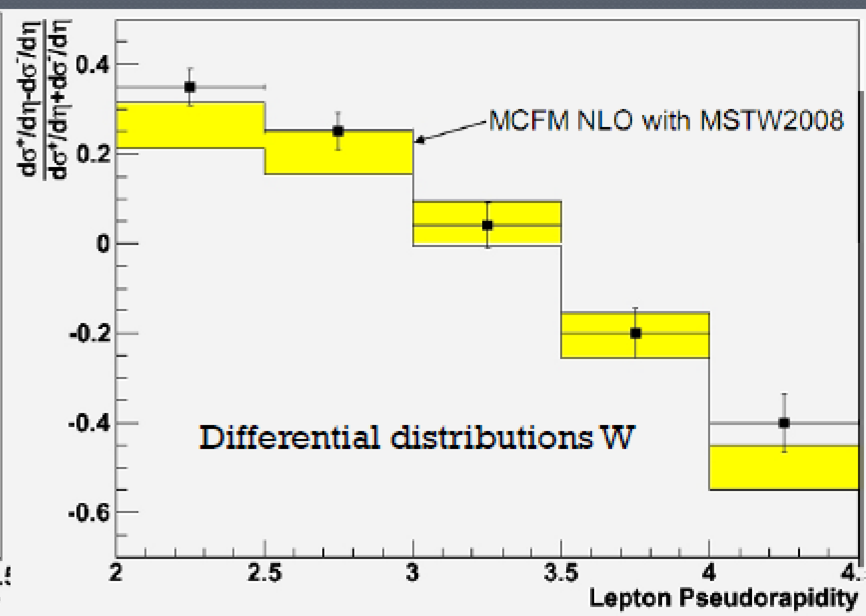




$$\sigma_{W\to\mu\nu}(\Delta\eta) = \frac{N^W_{tot} - N^W_{bkg}}{\epsilon_W L} \rightarrow \frac{N^W_{tot}}{L}\left(\frac{\rho_W}{\epsilon_W}\right)$$

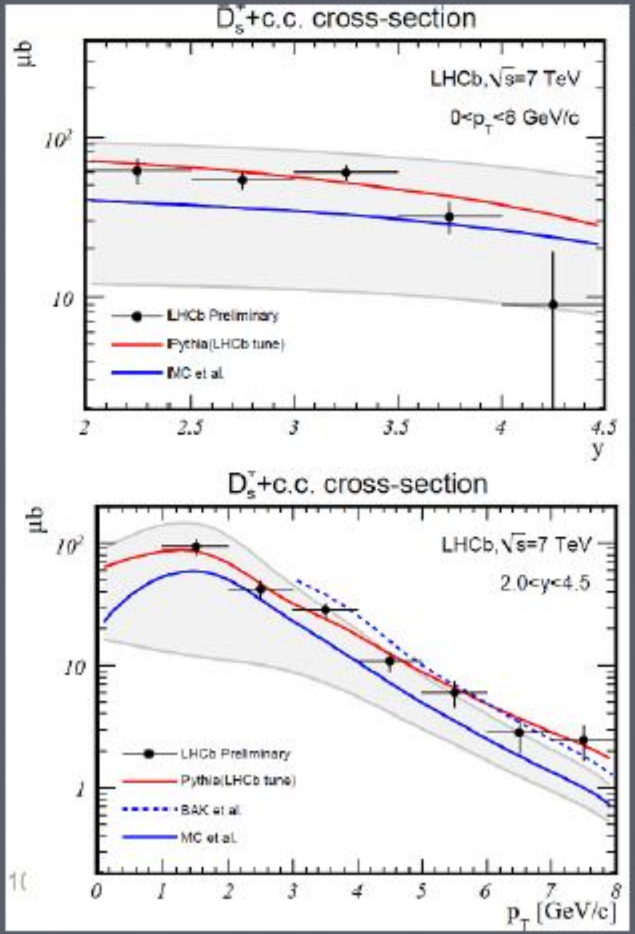
and all found from data.





- prompt K^0_s absolute production cross section at $\sqrt{s}$ = 0.9TeV presented:
  - p_T spectra tend to be "harder" than PYTHIA predictions
  - extended measurement range to lower p_T and new y range
- prompt $\overline{\Lambda}$ / Λ ratio at $\sqrt{s}$ = 0.9TeV
  - tends to be lower than PYTHIA Perugia0 and LHCb tune, lower at larger y
- prompt $\overline{\Lambda}$ / Λ ratio at $\sqrt{s}$ = 7TeV
  - in fair agreement with PYTHIA LHCb tune, quite flat vs. y
- prompt $\overline{p}$ / p ratios at $\sqrt{s}$ = 0.9TeV and $\sqrt{s}$ = 7TeV
  - show similar energy dependence as Λ / Λ
- prompt $\overline{\Lambda}$ / K^0_s ratio at $\sqrt{s}$ = 0.9TeV and $\sqrt{s}$ = 7TeV
  - baryon suppression in hadronization is lower than predicted

Open charm cross-sections (D^*, D^0, D^+, D_s) @ $\sqrt{s}$ = 7 TeV



Combining $D^0/D^+/D^{*+}/D_s^+$

$\sigma(pp \to ccX)$ = 1234 ± 189 μb (pT< 8 GeV/c, 2<y<4.5)

$\sigma(pp \to ccX)$ = 6100 ± 934 μb (full accept.)