RHUL, May 2011

Results from 2010 data and prospects for γ at LHCb

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Overview

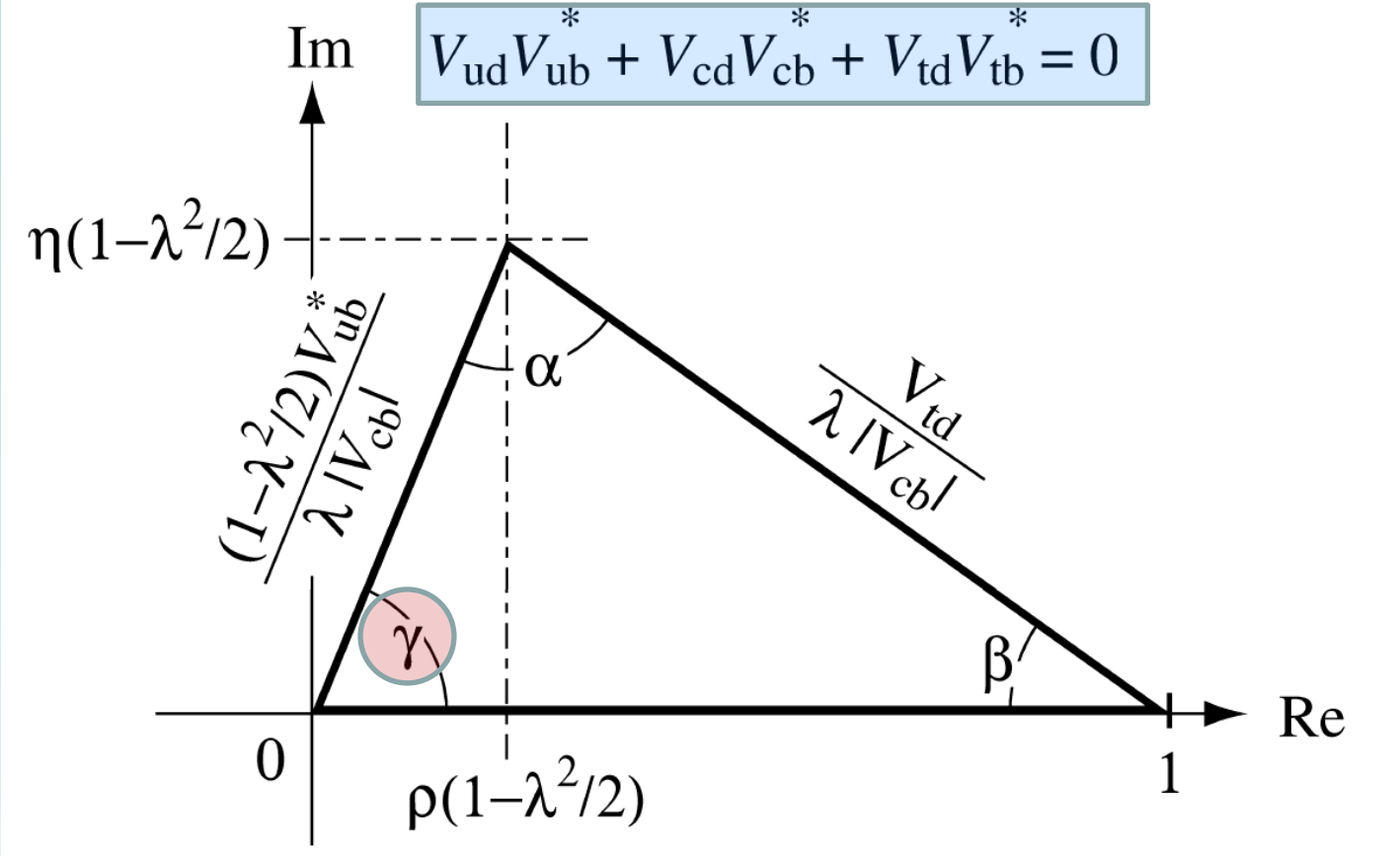
- Introduction: CKM matrix, LHCb
- Detector overview and 2010 performance
- 2010 data and physics results and prospects (CKM angle γ)

Introduction

- SM quark couplings described by CKM matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} = \hat{V}_{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- Unitarity of V_{CKM} can be represented in the complex plane with triangles



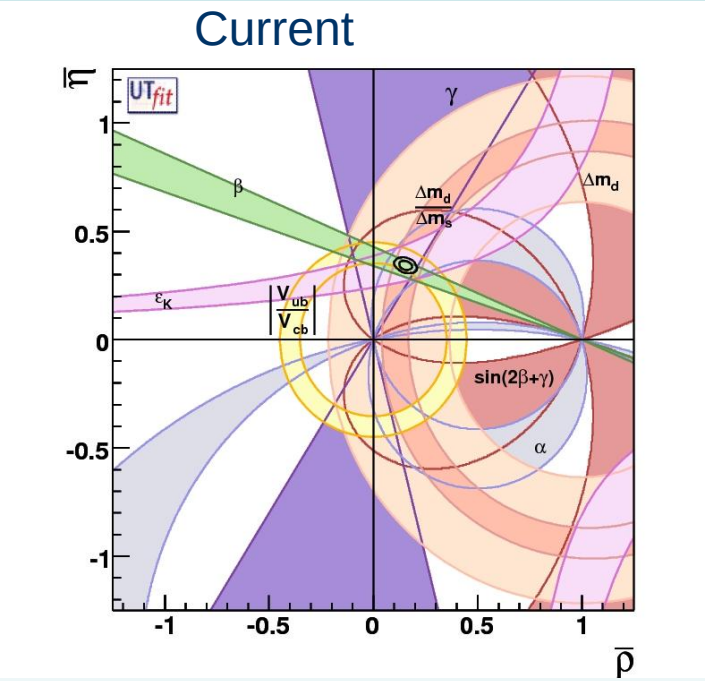
- Make measurements of lengths of sides and angles to place constraints on the position of the apex

Role of LHCb

- Potential extensions to SM could appear at TeV scale – SUSY, extra dimensions etc.
- Complementary approaches at LHC:
  - *Direct searches* – GPDs (ATLAS, CMS)
  - *Indirect searches* – **LHCb**, dedicated B physics experiment

LHCb aims

– Precision measurements of SM CKM parameters → over-constrain the unitarity triangle, "benchmark" SM *e.g. γ from $B^{\pm} \to DK^{\pm}$*



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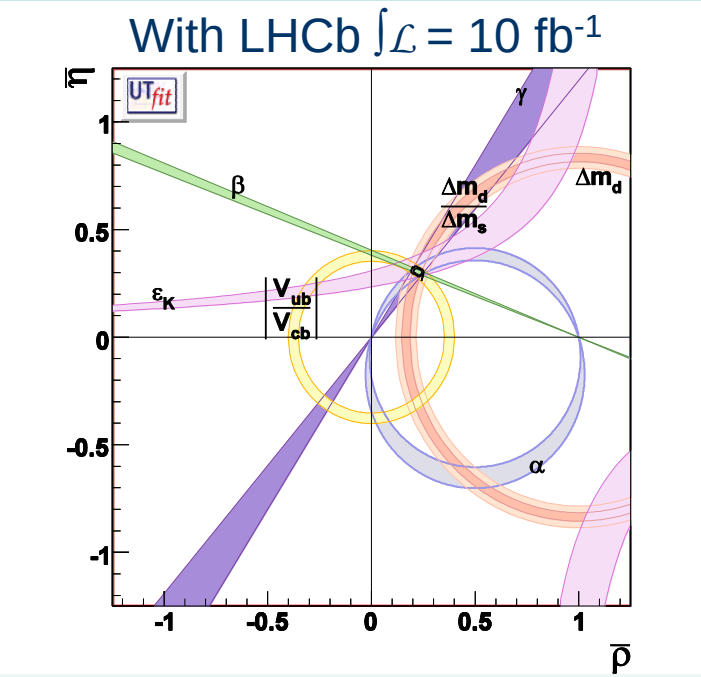


– Need CP-violation beyond SM to explain observed matter anti-matter asymmetry

$\rightarrow$ search for new sources of CP-violation

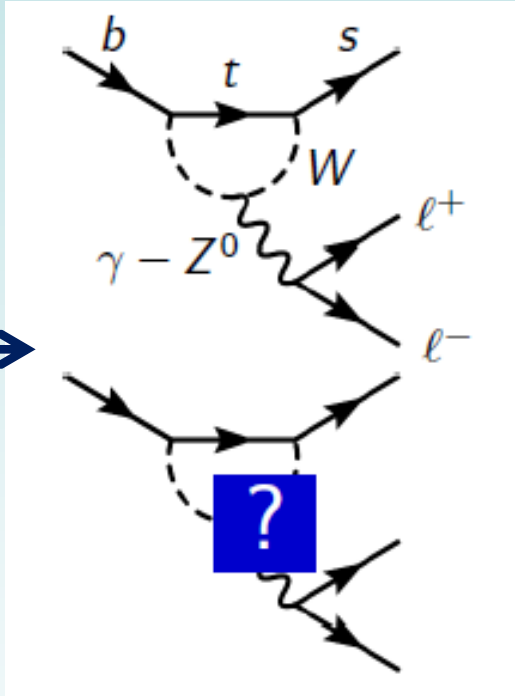
e.g. $B^0 \rightarrow \pi^+ \pi^-$

– Search for new physics

in rare (FCNC)

SM processes

e.g. $B_s \rightarrow \mu^+ \mu^-$, $B^0 \rightarrow K^{*0} \mu^+ \mu^-$

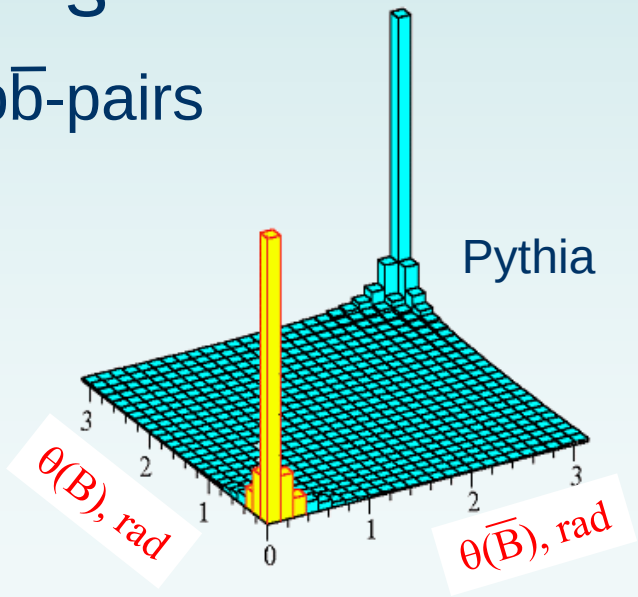


Also charm, EW, spectroscopy...

b-production at LHC

- Forward peaked, correlated $b\bar{b}$-pair production
- Design ($\sqrt{s}$ = 14 TeV): expected

  $\sigma_{b\bar{b}} \approx 500\mu b$, $\mathcal{L} \approx 2\times10^{32}\ cm^{-2}\ s^{-1}$
  - 1 nominal year (10^7 sec) $\Rightarrow$ 10^{12} $b\bar{b}$-pairs
  - ~100 kHz b-production rate
- Single PV per event
  - No ambiguity between B decay vertex and primary vertex

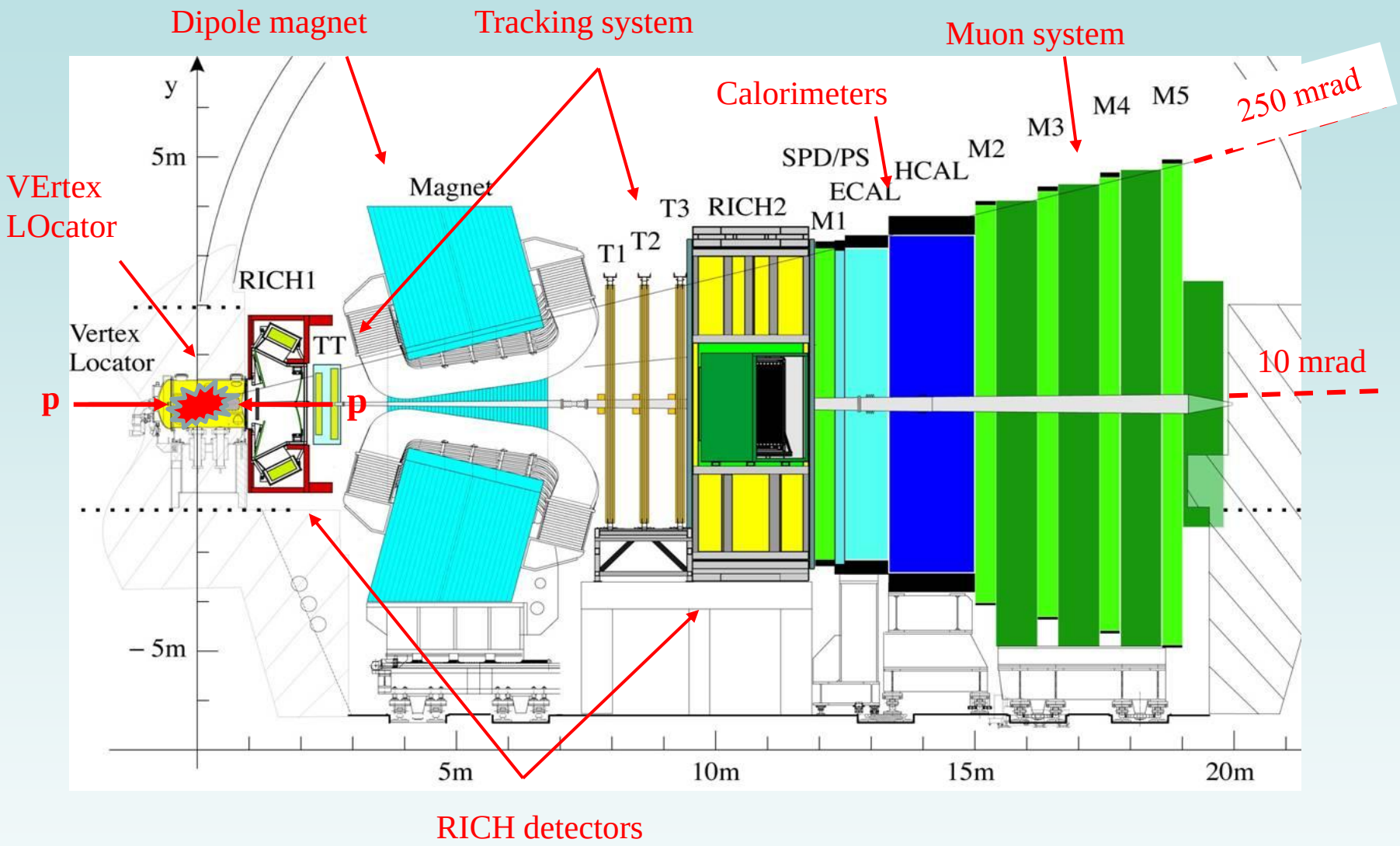


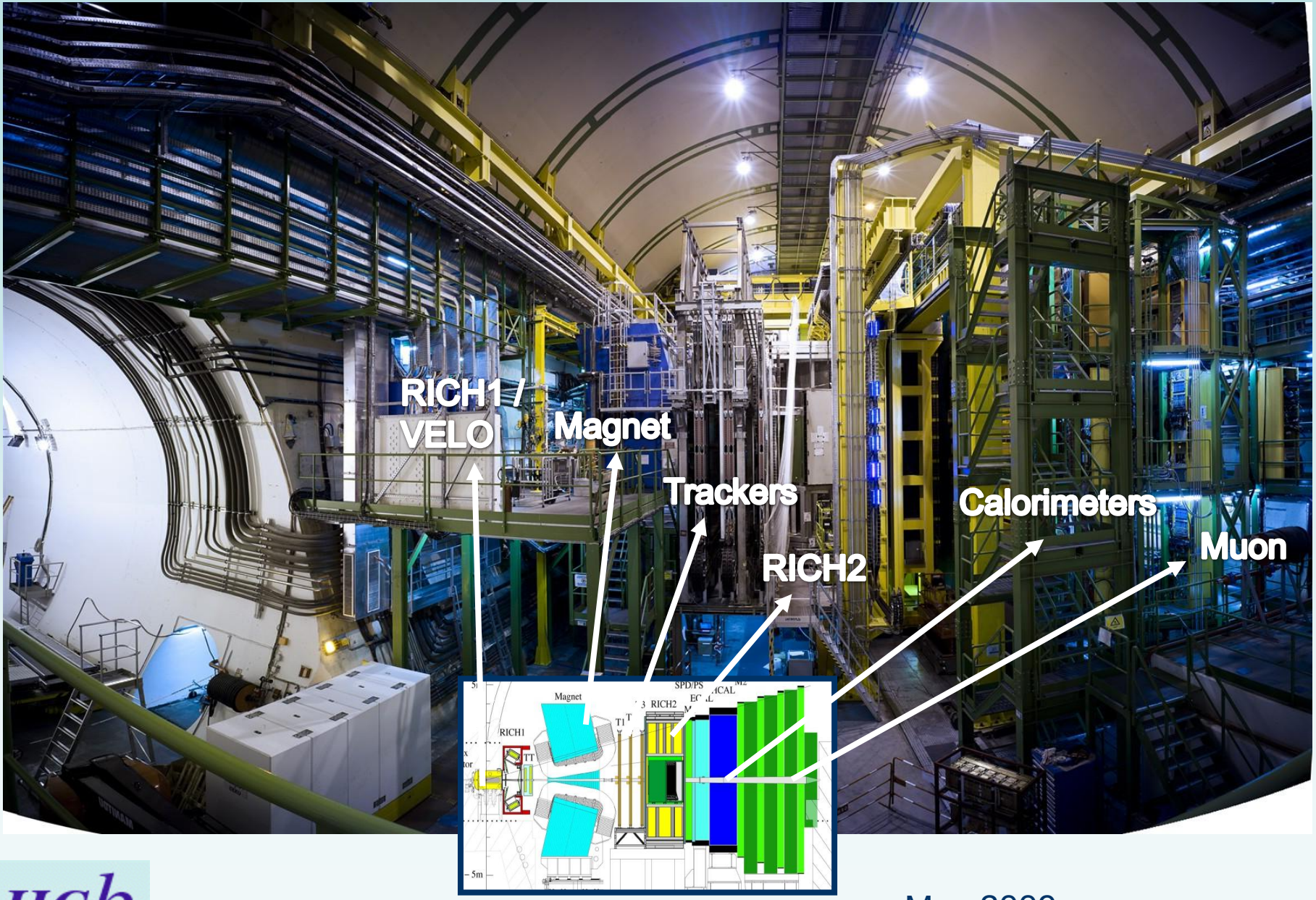
LHCb experiment

Detector overview and 2010 performance

730 authors
54 institutes
15 countries

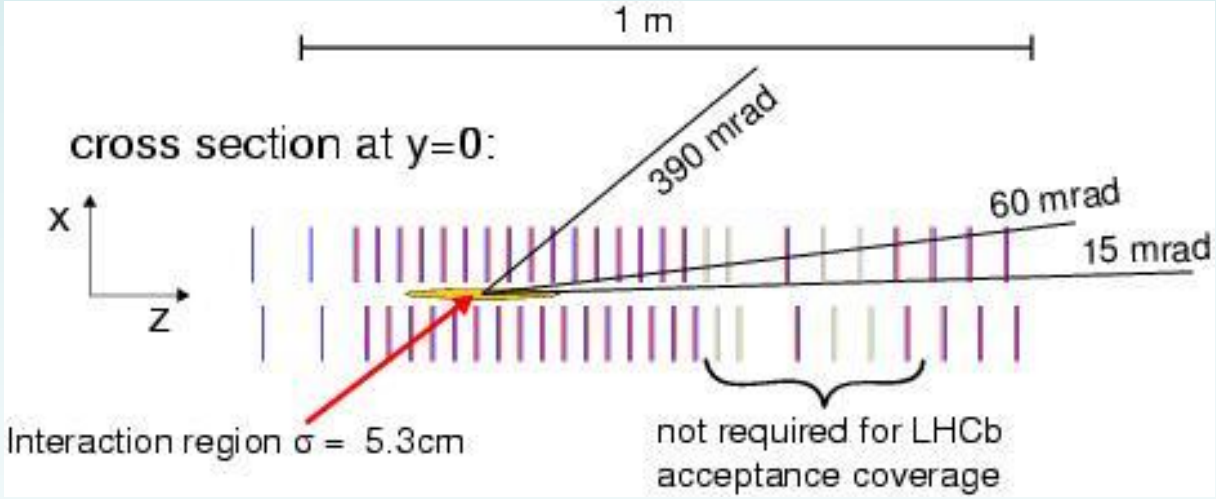
- Peaked B production $\Rightarrow$ LHCb detector is a **forward spectrometer** ($1.9 < \eta < 4.9$)
- Covers ~4% solid angle but captures ~40% of heavy quark production
- Large b-mass $\Rightarrow$ **high p_T tracks**
- Long B-lifetime $\Rightarrow$ B flies ~1 cm in detector $\Rightarrow$ resolve **displaced vertices**

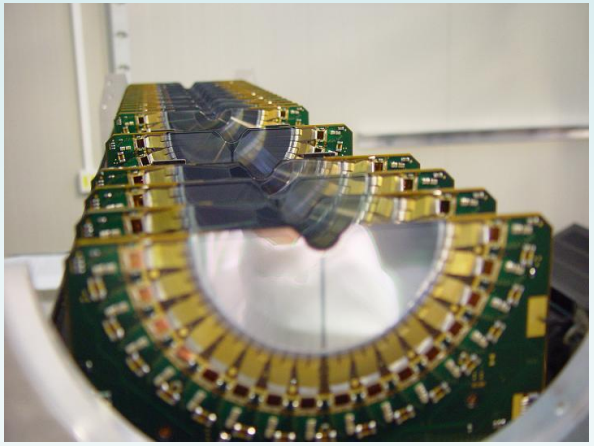

Dipole magnet
Tracking system
Muon system
Calorimeters
VErtex
LOcator
y
5m
– 5m
Magnet
RICH1
Vertex
Locator
TT
p
p
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
250 mrad
10 mrad
5m
10m
15m
20m
RICH detectors


RICH1 /
VELO
Magnet
Trackers
RICH2
Calorimeters
Muon
Magnet
RICH1
RICH2
SPD/PS
TT
-5m

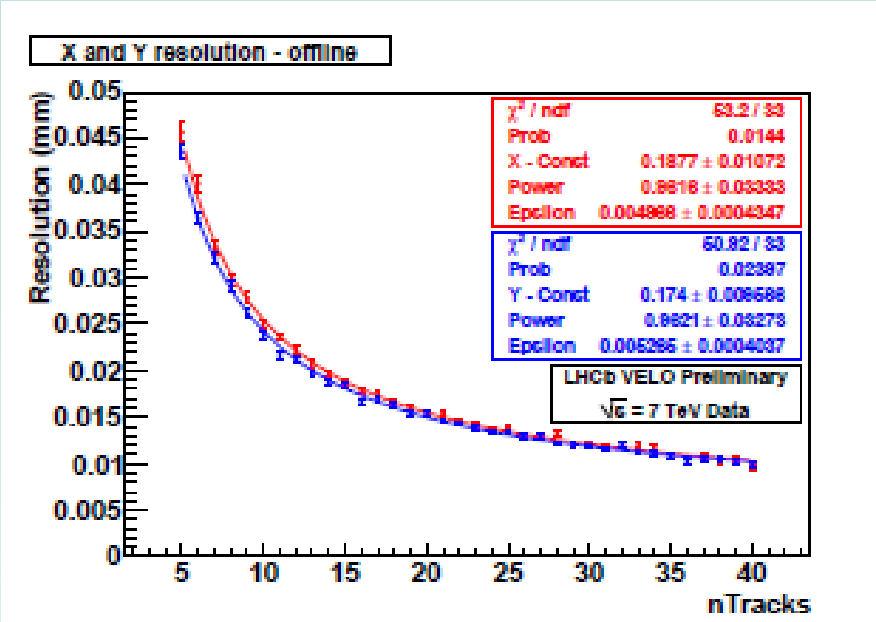
VErtex LOcator

- Need excellent vertex resolution for physics analyses (displaced secondary vertices, high IP tracks) ⇒ silicon R/ϕ strip vertex detector
- 8mm from beam during data-taking; retract to ±3cm during fills

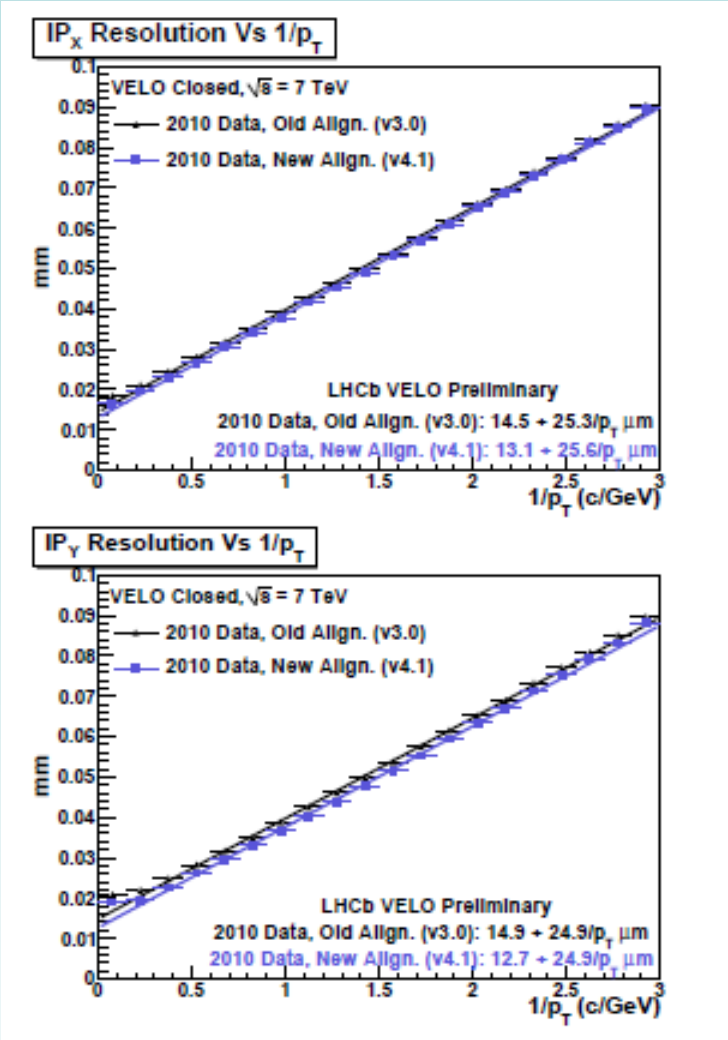




2010 Performance



IP resolution



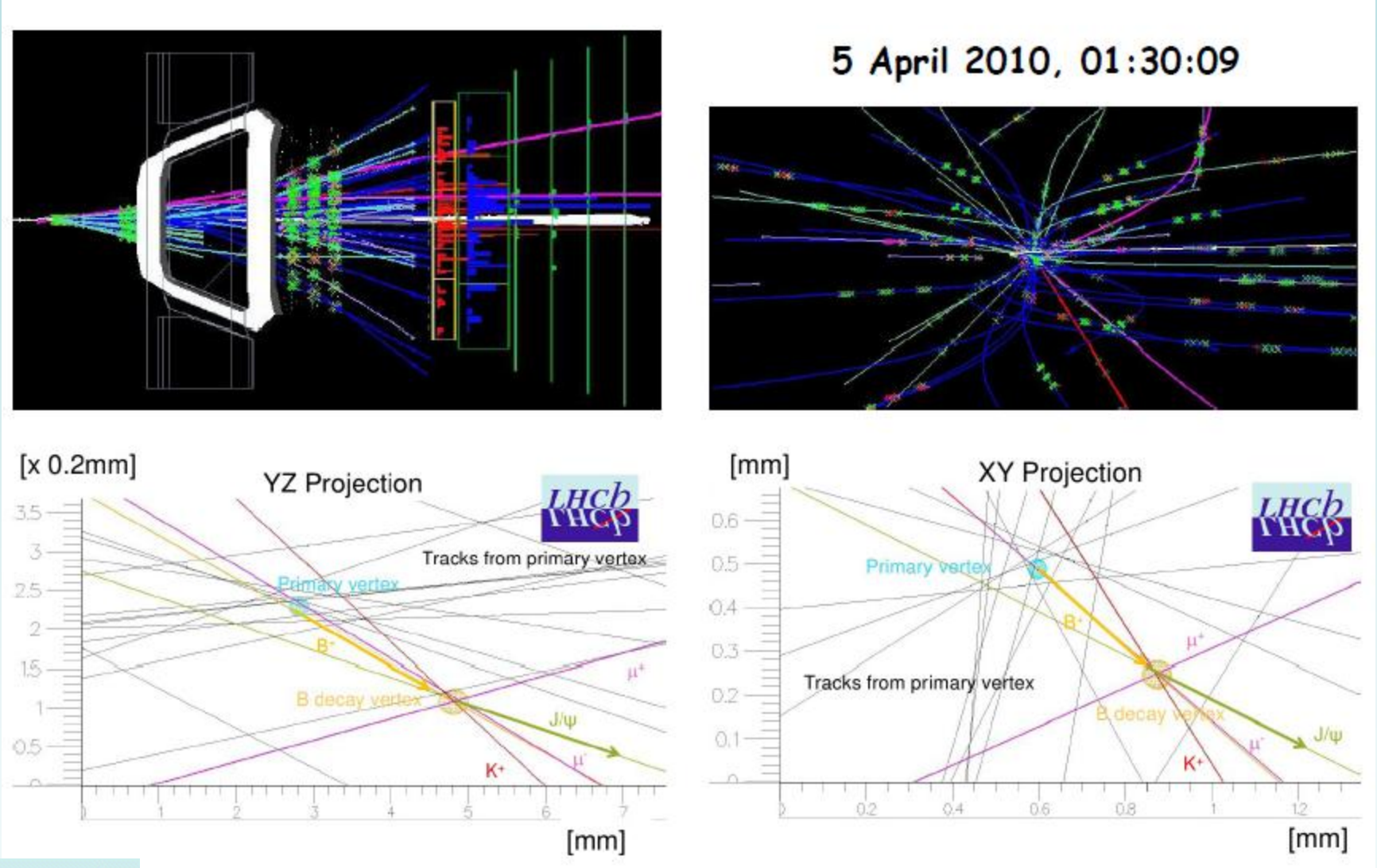
PV resolution

e.g. 25 track PV

- $\sigma_X = 14\ \mu m$
- $\sigma_Y = 13\ \mu m$
- $\sigma_Z = 75\ \mu m$

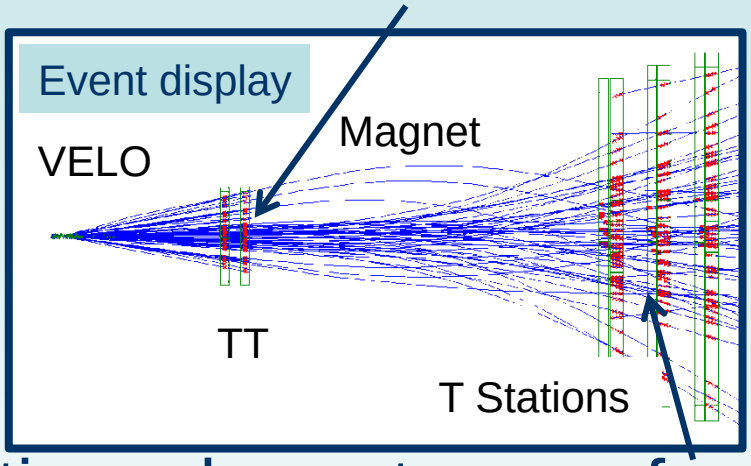
track fit, material description. . . overall improvement with better alignment

- First $B^+ \rightarrow J/\psi\ K^+$ candidate



Tracking

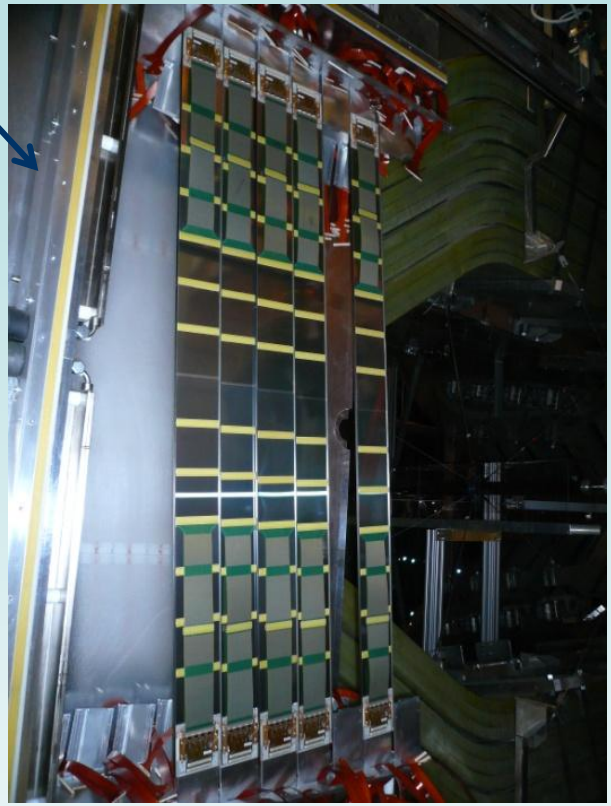
- Want good σ_p for invariant masses
- Rejection of comb. backgrounds
- One station upstream of magnet (TT):
  - Used with VELO for p_T measurement in trigger
  - Low momentum particles swept out by magnet



- Three stations downstream of magnet (T1 – T3):
  - Largely provide tracking in magnet bending plane
  - Also provide position information of tracks in non-bending plane, needed for RICH ring finding

Silicon tracker: TT station and central regions of T1 – T3

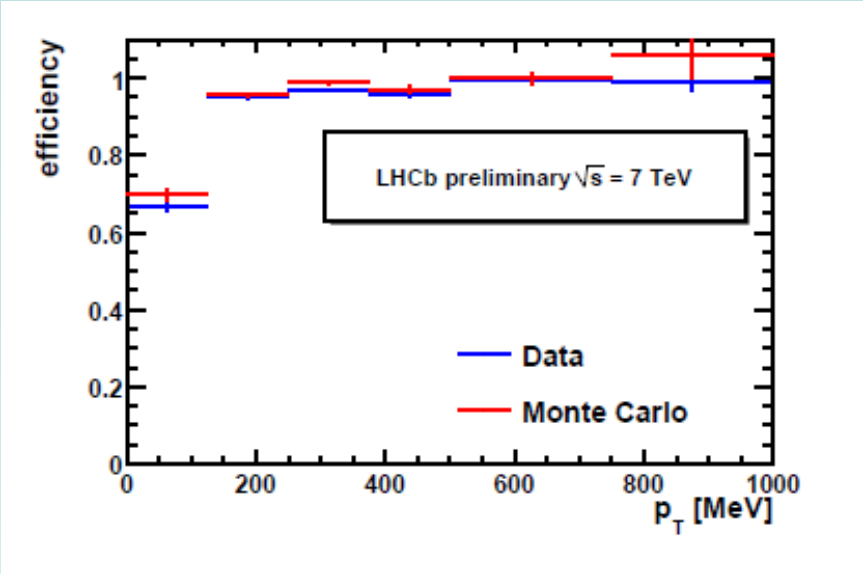
- High occupancy region: 2% of acceptance but 20% of tracks



Outer tracker: outer remainder of T1 – T3

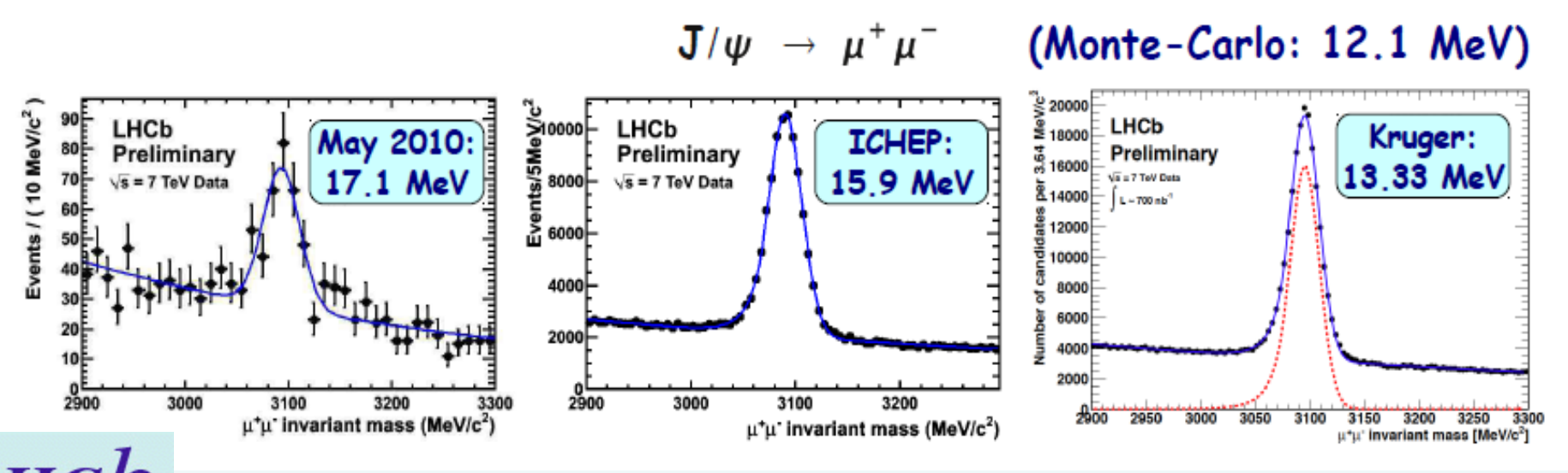
- Straw tube drift cells, filled with Argon, CO_2 and CF_4 mixture

2010 Performance



NB no alignment with cosmics

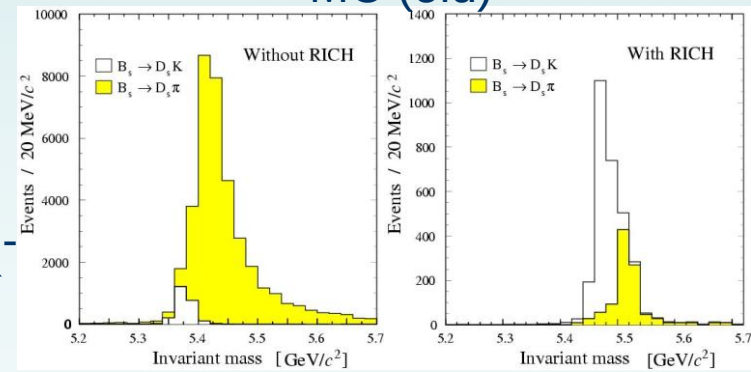
•Reconstruction efficiencies > 90% for tracks above few GeV



Ring **I**maging **CH**erenkov detectors

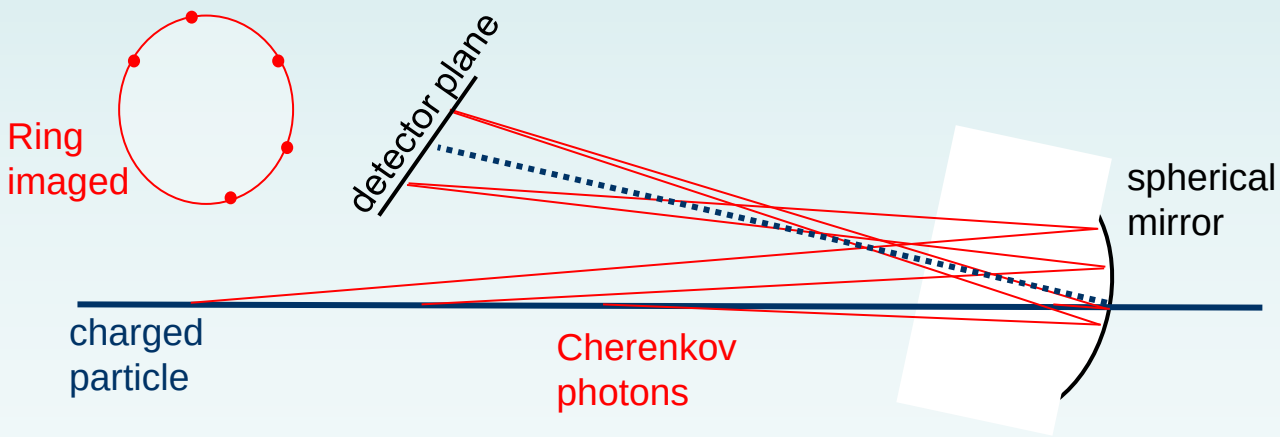
- RICH1 upstream of magnet (reduced size for full angular coverage)
  - π/K separation over low momentum range 2 – 60 GeV
  - Aerogel and C_4F_{10} radiators
- RICH2 downstream of magnet
  - π/K separation over high momentum range 20 – 100 GeV
  - CF_4 radiator
- **PID** crucial for flavour tagging and for separation of B decays with identical topology, e.g. $B^0 \rightarrow \pi^+\pi^- \leftrightarrow B^0 \rightarrow K^+\pi^- \leftrightarrow B_s^0 \rightarrow K^+K^-$

MC (old)

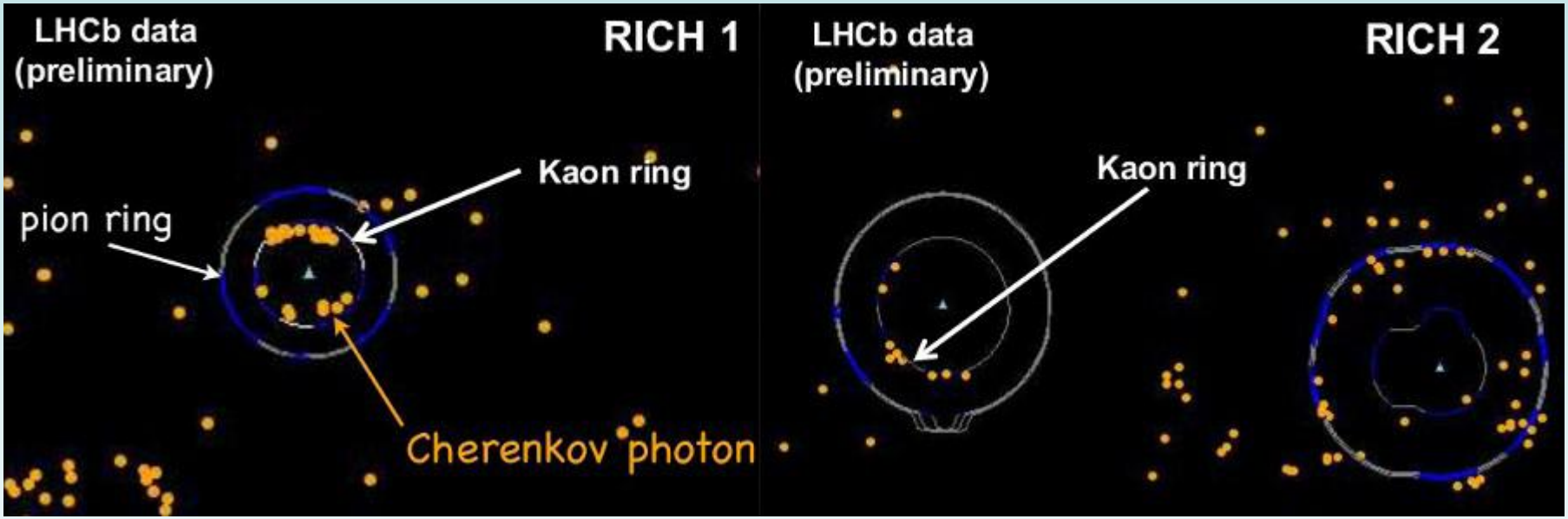


Aside: What is a RICH?

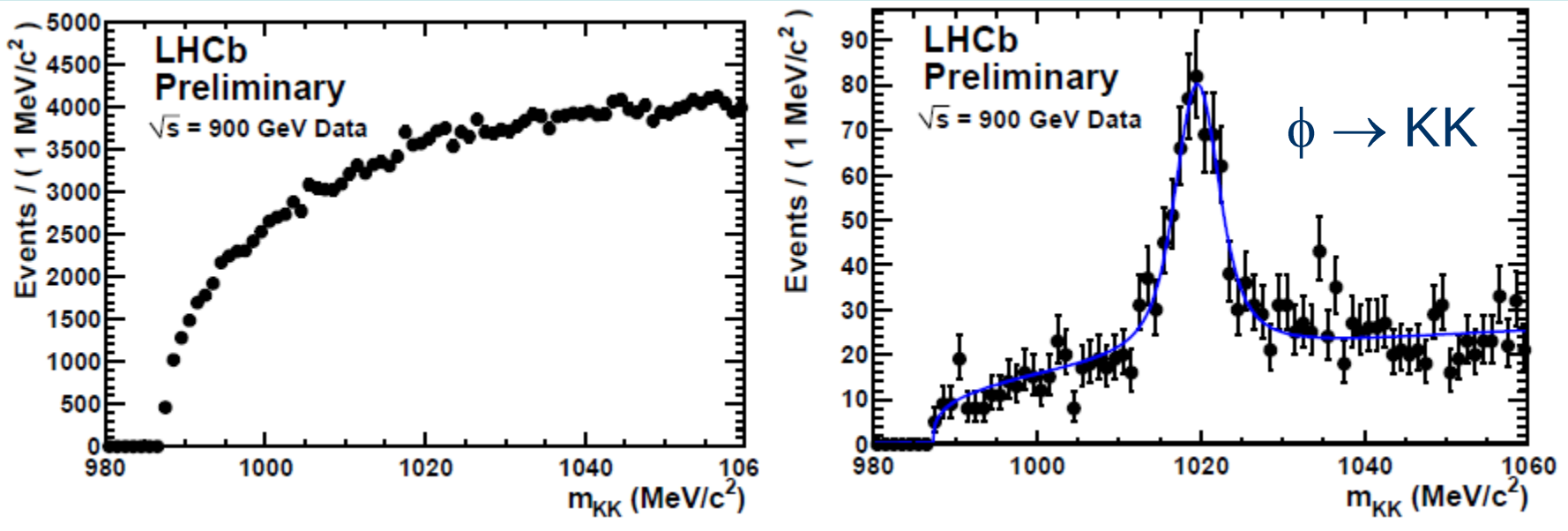
- Cherenkov photons produced in radiator at a fixed angle to particle direction $\cos(\theta_C) = 1 / \beta n$
- Photons produced randomly along radiator length ($\rightarrow$ cone)
  - Direct imaging $\rightarrow$ solid disc
  - Reflection from spherical mirror $\rightarrow$ photons focussed to ring



- Rings!

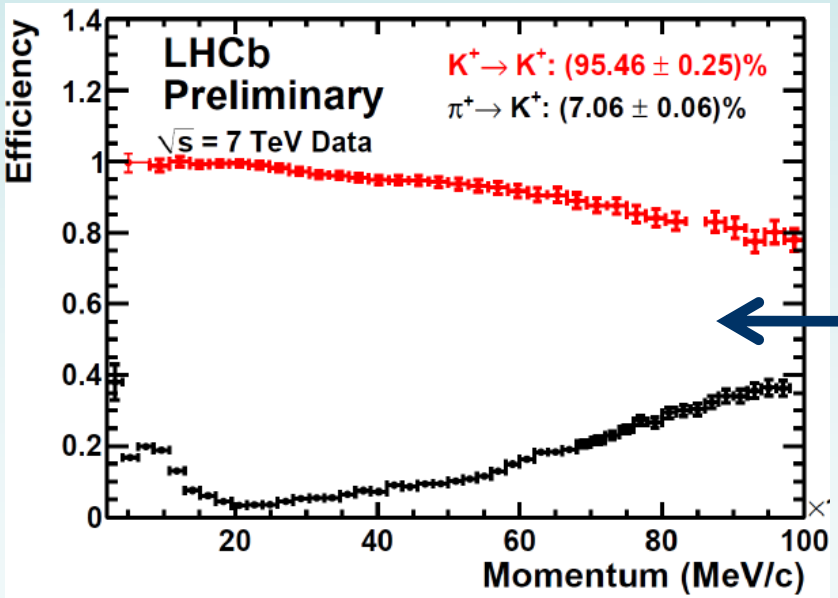

LHCb data
(preliminary)
RICH 1
Kaon ring
pion ring
Cherenkov photon
LHCb data
(preliminary)
RICH 2
Kaon ring

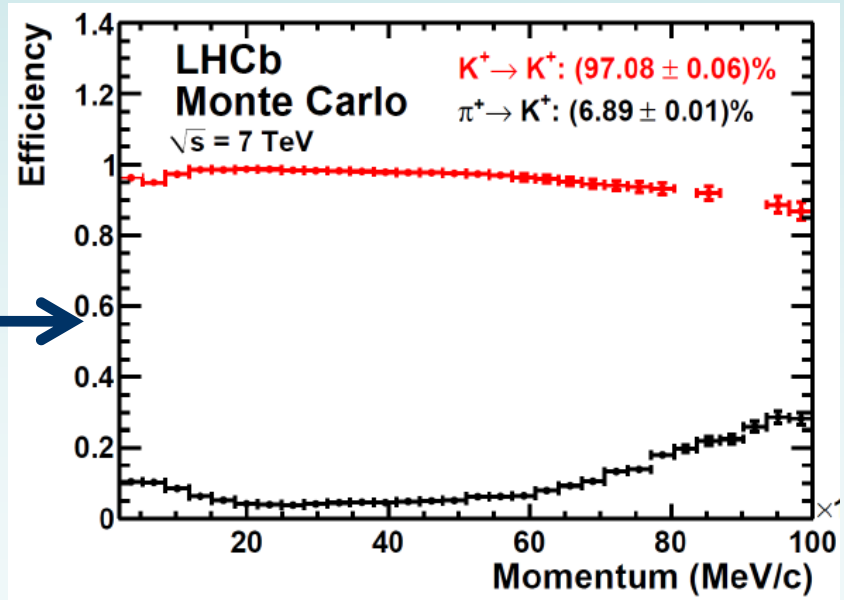
- Example of use of RICH...
- Early data
- Hard cuts on kaon tracks



2010 Performance

- Efficiencies and mis-ID determined from data using $\phi \rightarrow KK$, $K_s \rightarrow \pi\pi$, $\Lambda \rightarrow p\pi$
- Performance found to be close to simulation over full momentum range from few GeV (tagging) to 100 GeV (two-body hadronic decays)





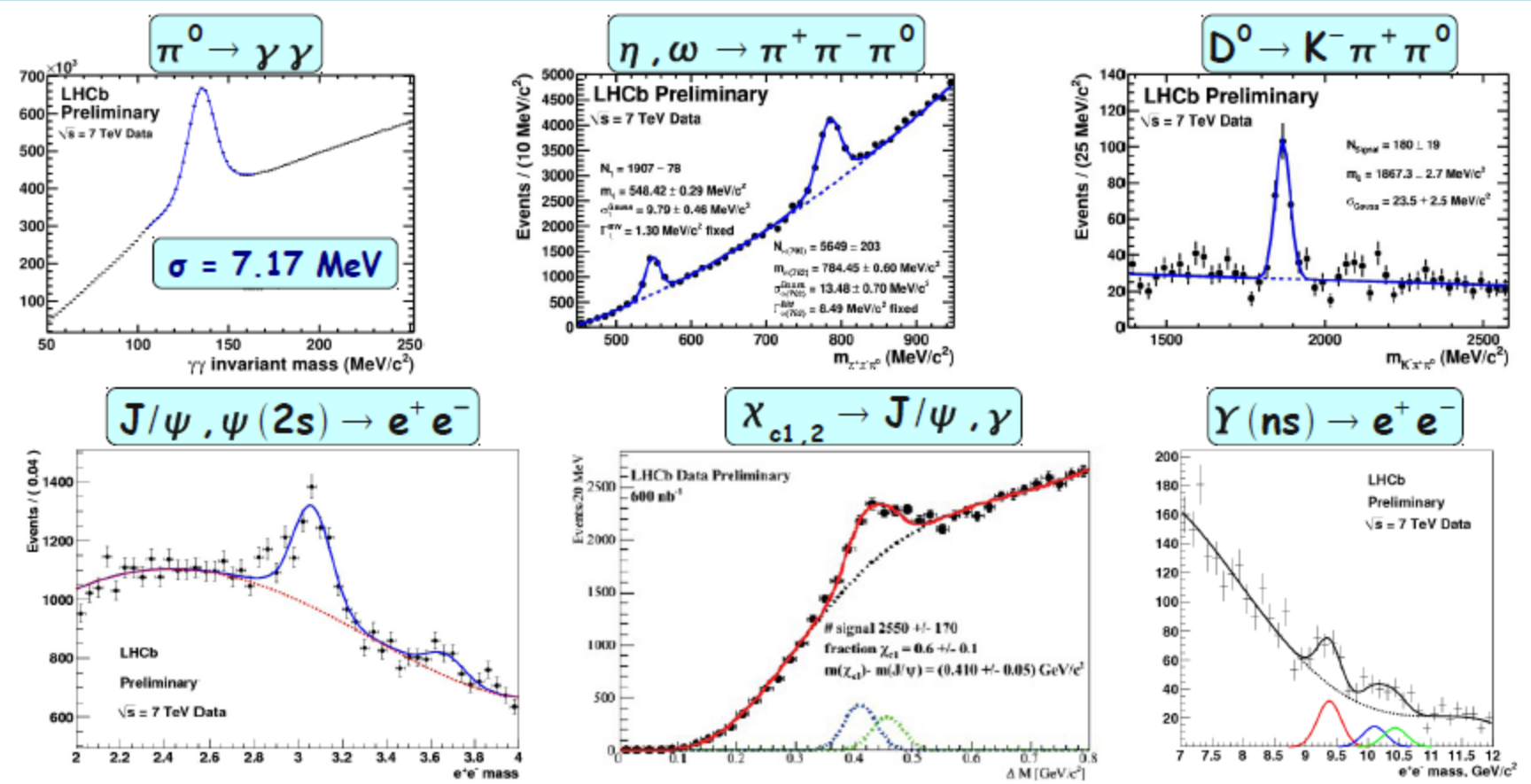
Calorimeters

- Used to provide high E_T information for first level trigger (L0)
- Essential for measurement of final states with e, γ, π^0, e.g. $B^0 \rightarrow K^*\gamma$
- Four sub-systems:

1) Scintillating pad-detector
   - e / γ separation
2) Pre-shower
   - e / π separation
3) ECAL
   - Lead sheets sandwiched with scintillation tiles
4) HCAL
   - Steel sheets interspersed with scintillation tiles

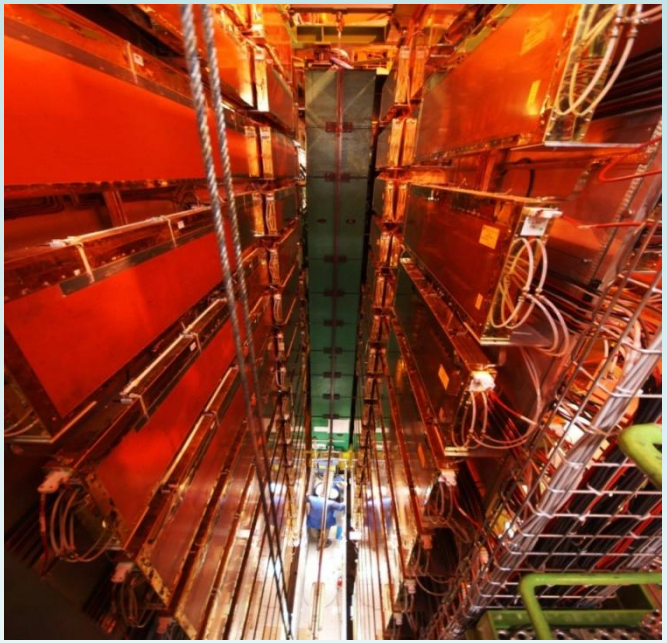
2010 Performance

π^0 resolution in data better than expected from MC



Muon system

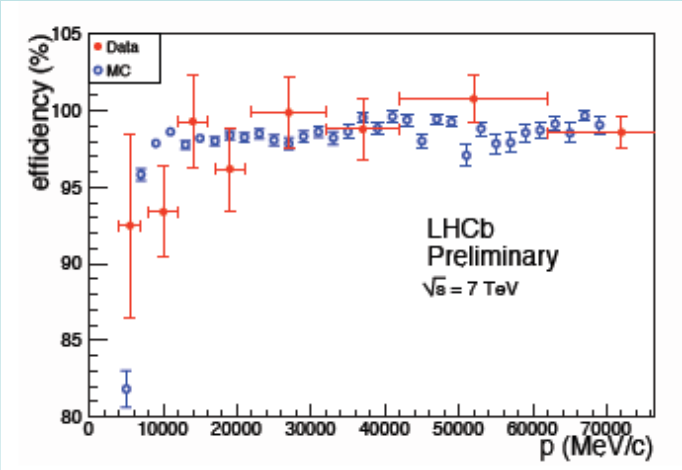
- Muon ID crucial for many physics analyses e.g. $B_s \rightarrow \mu^+\mu^-$, $B^0 \rightarrow K^{*0}\mu^+\mu^-$
- Useful trigger signal
- 5 stations: 1 upstream of ECAL/HCAL (M1), 4 downstream (M2 – M5)
  - Triple-GEM detectors used in inner region of M1
  - Multi-wire proportional chambers used elsewhere

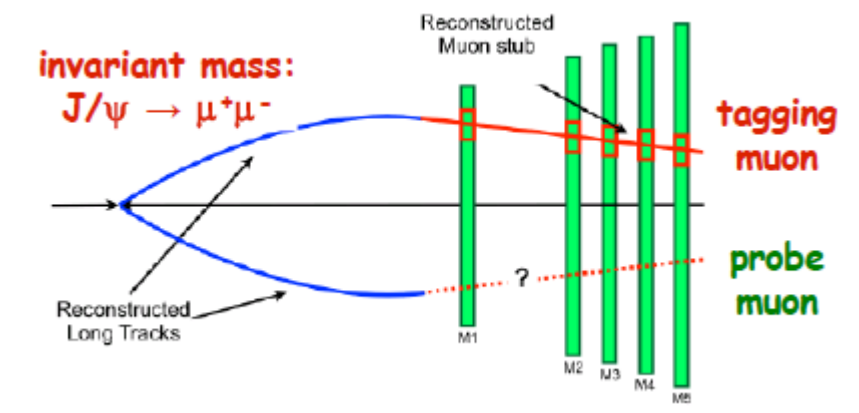


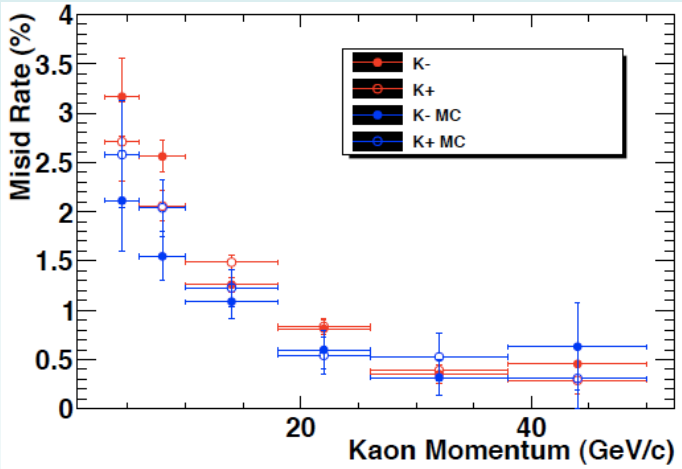
- Chamber size matched to z-distance from PV → constant angular size (trigger coincidence quicker)

2010 Performance

- Efficiency determined from data using tag-and-probe method on $J/\psi \rightarrow \mu^+\mu^-$
- Found to be >90% for p>10 GeV
- Mis-ID probabilities $K\rightarrow\mu$, $\pi\rightarrow\mu$, $p\rightarrow\mu$ determined from data using tag-and-probe method on $\phi\rightarrow KK$, $K_s\rightarrow\pi\pi$, $\Lambda\rightarrow p\pi$







Trigger

- Exploit *generic B decay signature*:
  - decay products with large p_T ("large"= few GeV) and high impact parameter
  - well separated B decay vertex
- Three level trigger:
  - Hardware (L0): high-p_T μ, e, γ, hadron candidates in muon system and calorimeters
  - Software (HLT1 and HLT2):
    - HLT1: cuts on impact parameter and momentum
    - HLT2: global event reconstruction + inclusive b selections

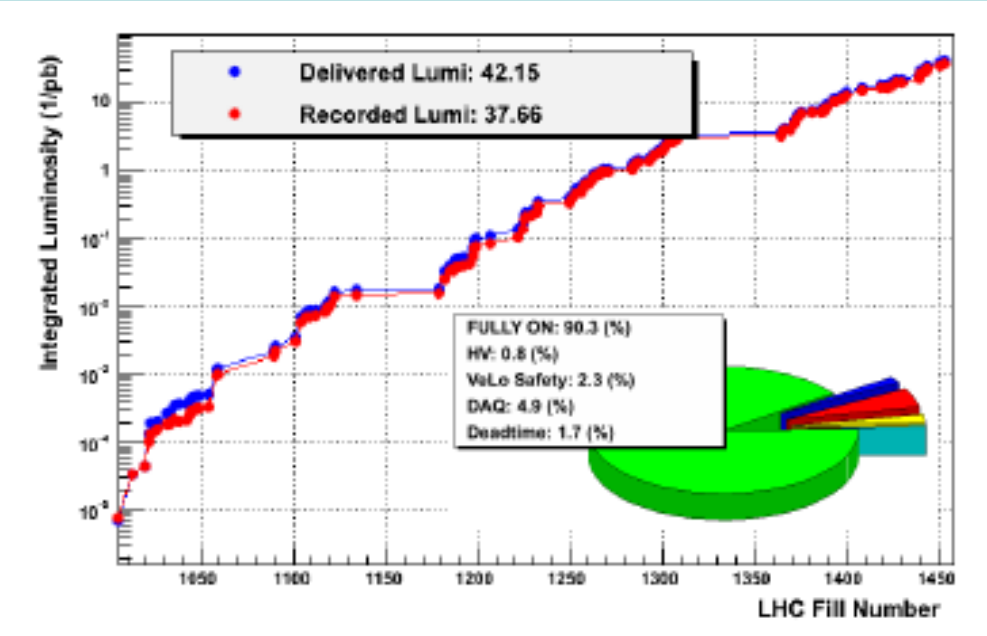
2010 Performance

- In 2010 running, trigger settings continuously changed to deal with rapidly increasing luminosity and changing running conditions
  - early running: low intensity, small number of bunches
    → min bias trigger, require single track in VELO
  - increasing number of bunches and μ:
    → loose pT cut in L0, start to use HLT
  - at highest μ: priority to muon triggers, reduce hadron trigger lines when needed
    → increase cut on transverse momentum / energy
    → "global event cuts" on hit multiplicities to reject very busy events
- Efficiency determined from data using tag-and-probe

	Muon Trigger (J/ψ)	Hadron Trigger (D^0, p_T>2.6 GeV)
Data	(94.9 ± 0.2) %	(60 ± 4) %
Simulation	(93.3 ± 0.2) %	66 %

2010 running at $\sqrt{s}$ = 7 TeV

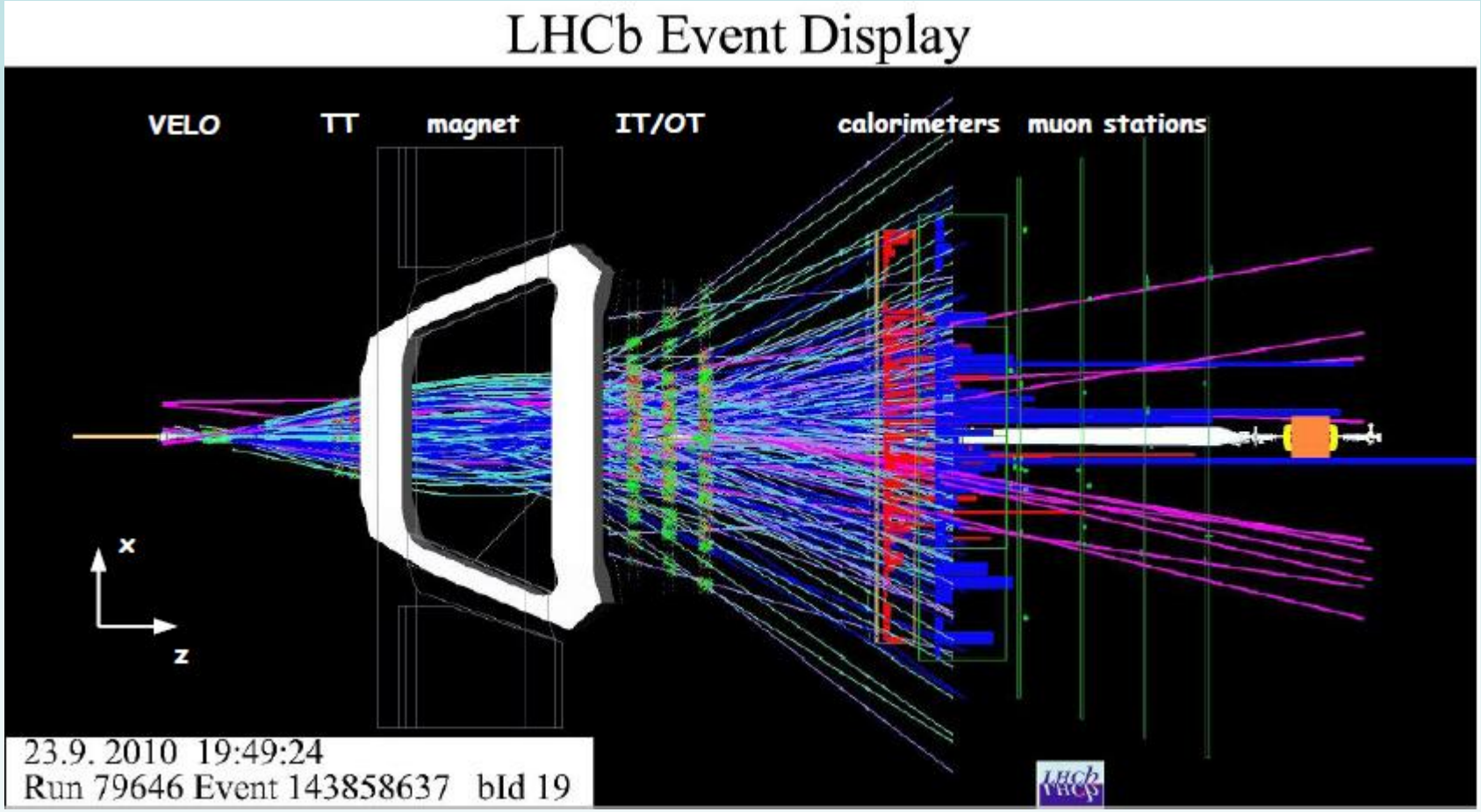
- Recorded $\int \mathcal{L}$ = 37.7 pb^{-1}
  (2.5% of nominal year)



- Peak instantaneous luminosity almost at design ($2x10^{32}$ cm^{-2} s^{-1})

- But only 344 colliding bunches…
- Average # of interactions per bunch crossing >> higher than design (2.5 c.f. 0.4)
  - multiple primary vertices
  - high occupancy, track multiplicities

Typical event, <μ>=2.5



$b\bar{b}$ cross section measurements

- Published result based on ~15 nb^{-1}, using decay modes $B^0 \rightarrow D^0(K^-\pi^+)\mu^-\nu X^+$
- Measured in LHCb acceptance, then used Pythia to extrapolate to full phase space

$$\sigma(pp \rightarrow b\bar{b}X) = (284 \pm 20 \pm 49)\mu b$$

[PLB 694 (2010) 209, arXiv:1009.2731v2 [hep-ex]]

- Further result using inclusive J/ψ production (5 pb^{-1}) consistent

[submitted to Eur. Phys. J. C in early March, arXiv:1103.0423 [hep-ex]]

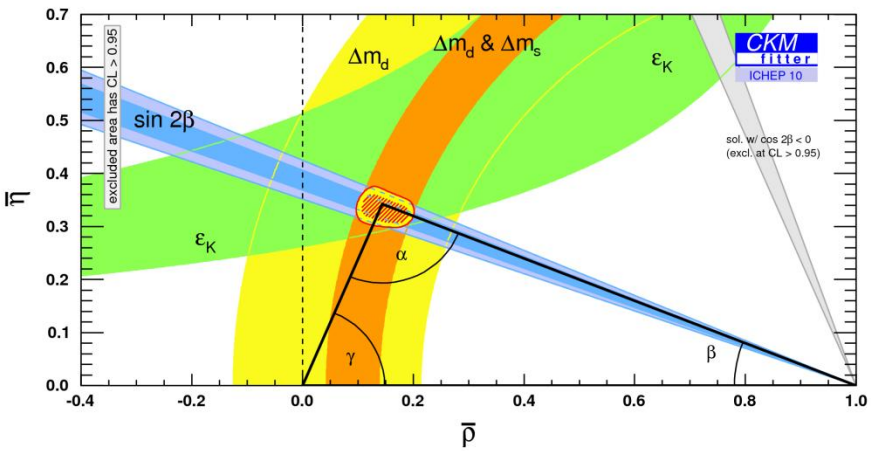
$$\sigma(pp \rightarrow b\bar{b}X) = (288 \pm 4 \pm 48)\mu b$$

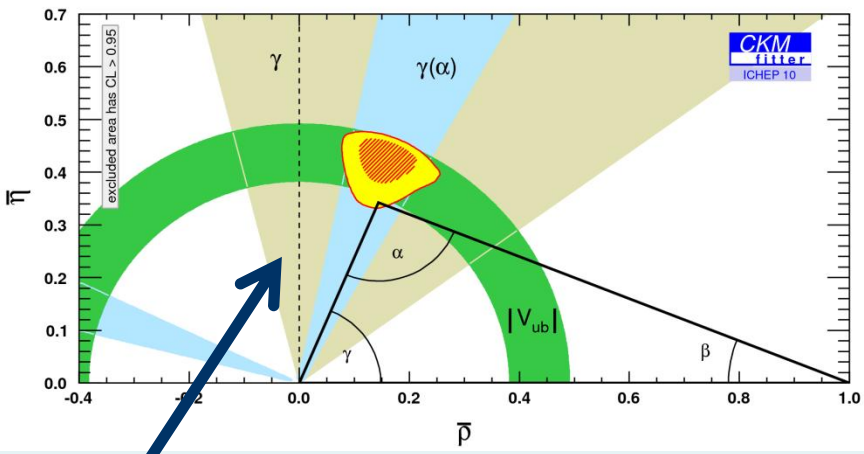
CKM angle γ “from trees”

- Tightest experimental constraints on γ from loop processes, which are sensitive to new physics

Indirect measurements: loops

Direct measurements: γ from trees





- Current value of γ from direct measurement

$$\gamma = (71)^{+21^\circ}_{-25}$$ *(CKMfitter ICHEP 2010)*

Charmed hadronic B decays

- $B \to DX$ decays allow extraction of γ at tree level
- Essential for benchmarking the SM
- At LHCb, study

- time integrated processes

$B^- \to DK^-$, $\overline{B}^0 \to D\overline{K}^{*0}$ and $B^- \to DK\pi\pi$

- GLW/ADS analysis
- Dalitz plot analysis (GGSZ)

[Gronau & London, PLB 253 (1991) 483;
Gronau & Wyler, PLB 265 (1991) 172;
Atwood, Dunietz & Soni, PRL 78 (1997) 3257;
Atwood, Dunietz & Soni, PRD 63 (2001) 036005]

[Giri, Grossman, Soffer & Zupan, PRD 68 (2003) 054018;
Bondar, Proceedings of BINP Special Analysis Meeting on Dalitz Analysis, 24-26 Sep. 2002, unpublished]

- time dependent processes

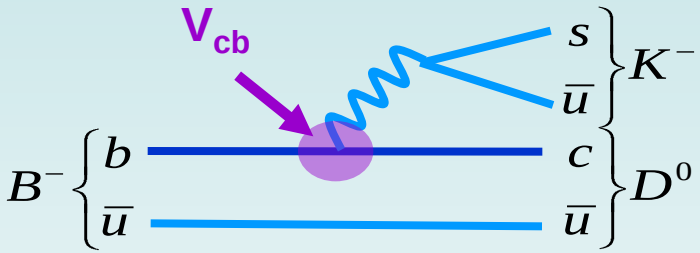
$B_s \to D_s K$, $B^0 \to D\pi$, $B_s \to D_s K\pi\pi$ and $B^0 \to D\pi\pi\pi$

[Aleskan, Dunietz & Kayser, PRC 54 (1992) 653;
Dunietz & Sachs, PRD 37 (1998) 3186; 39 (1989) 3515(E);
Dunietz, PLB 427 (1998) 179]

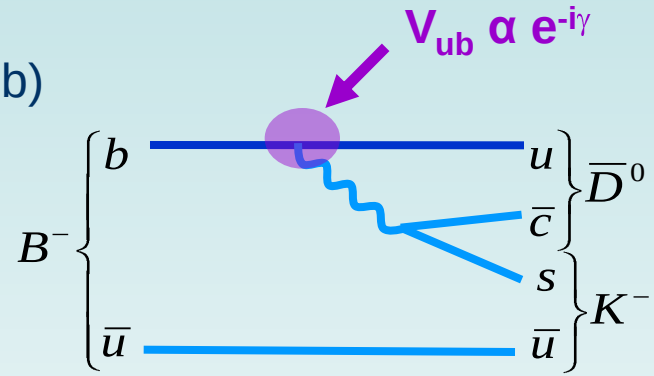
Time integrated B→DX measurements

- Sensitive to γ at tree level when D^0 or $\bar{D}^0$ decays to same final state, due to interference effects
- e.g. for $B^- \to DK^-$

a)



b)



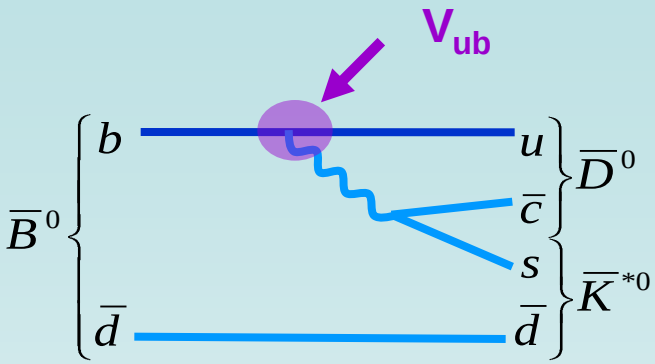
CKM and colour suppressed

- No penguin loop contributions – largest correction is from D^0-$\bar{D}^0$ mixing, giving bias <<1 on γ

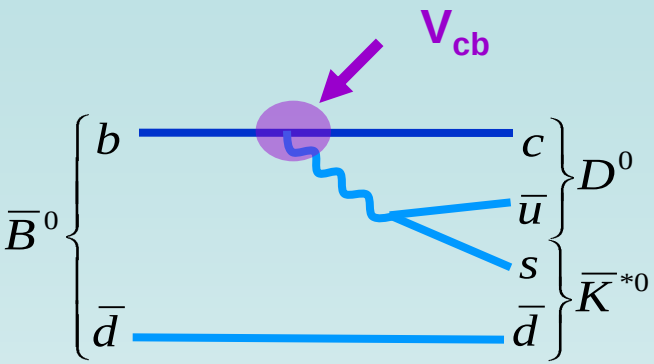
[Grossman, Soffer & Zupan, PRD 72 (2005) 031501]

- Similar diagrams for $\overline{B}^0 \to D\overline{K}^{*0}$

a)



b)



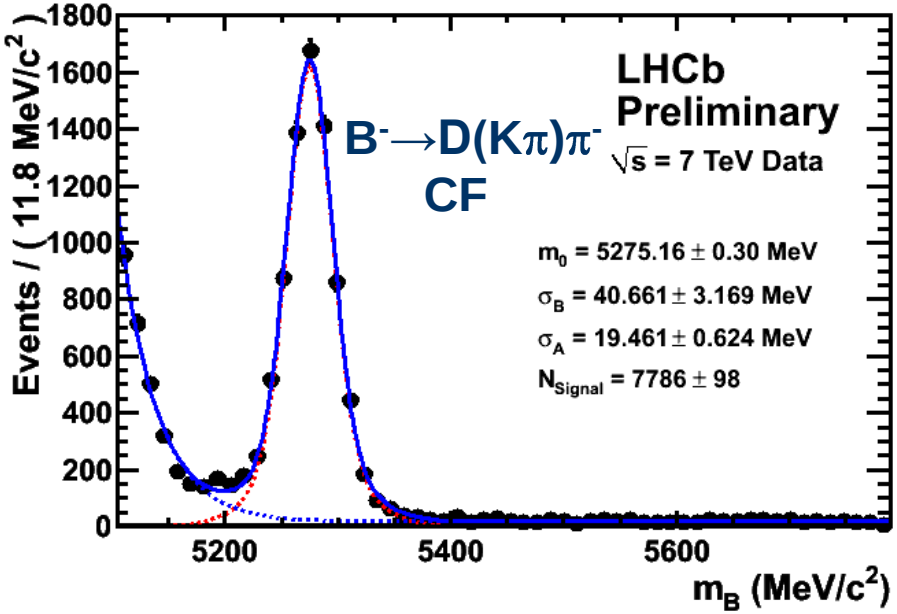
- B^0 decays
  - both diagrams colour suppressed (B^- only has one diagram colour suppressed)
    - get smaller branching fractions than B^-
    - BUT also more interference between the diagrams (which is what gives you sensitivity to γ)
- $\overline{B}^0 \to D\overline{K}^{*0}$ self-tagging
  - charge of K from K* gives flavour of B, i.e. B^0 or $\overline{B}^0$

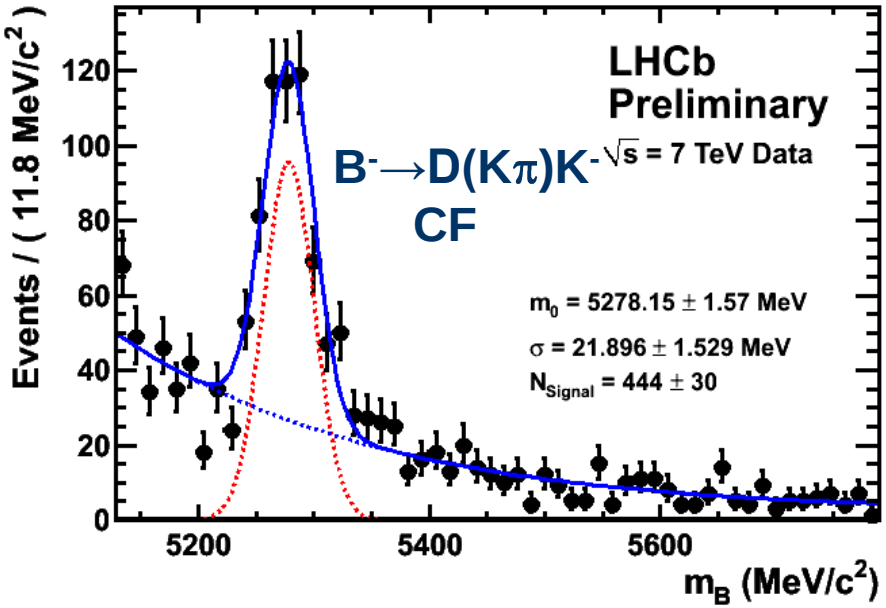
GLW/ADS analysis: B→D(hh)K

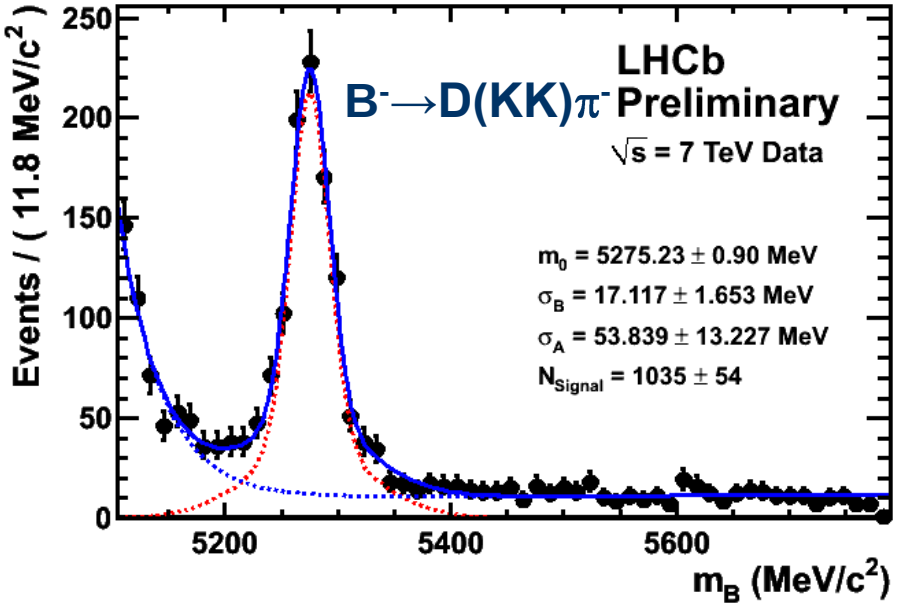
[LHCb-2008-011, LHCb-2009-011, LHCb-2008-0318]

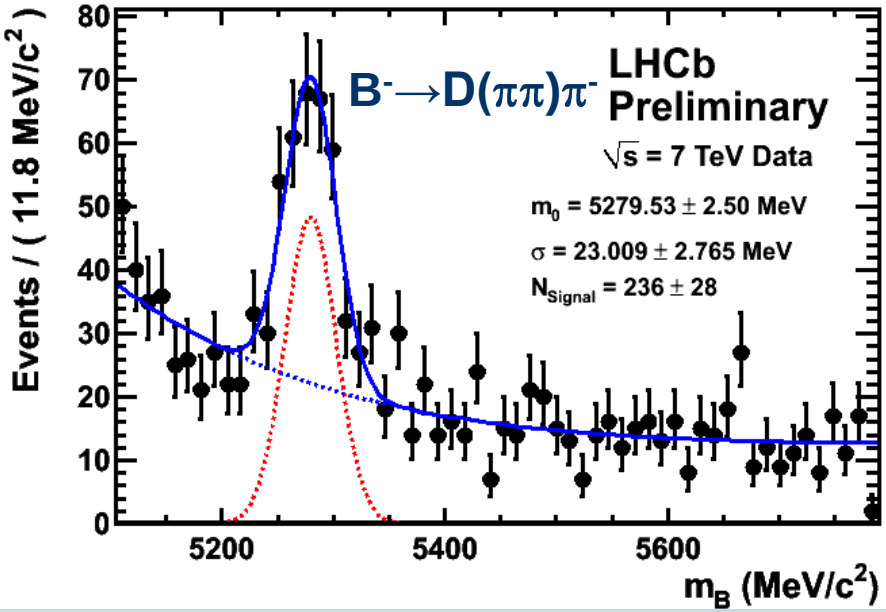
- Analysis of $D^0/\overline{D}^0$ decay to
  - CP even states K^+K^- and $\pi^+\pi^-$ (GLW)
  - flavour specific state $K^+\pi^-$ (ADS)
- To overconstrain the system and extract γ, fit 2 GLW plus 4 ADS rates together
- At LHCb, D from $B^- \to DK^-$ and $\overline{B}^0 \to D\overline{K}^{*0}$ studied

$$
\begin{aligned}
N(B^0 \to D(K^+\pi^-)K^{*0}) &= N_{K\pi}[1 + r_{B^0}^2 r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} + \delta_D + \gamma)], \\
N(B^0 \to D(K^-\pi^+)K^{*0}) &= N_{K\pi}[r_{B^0}^2 + r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} - \delta_D + \gamma)], \\
N(\overline{B^0} \to D(K^-\pi^+)\overline{K^{*0}}) &= N_{K\pi}[1 + r_{B^0}^2 r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} + \delta_D - \gamma)], \\
N(\overline{B^0} \to D(K^+\pi^-)\overline{K^{*0}}) &= N_{K\pi}[r_{B^0}^2 + r_D^2 + 2r_{B^0} r_D \cos(\delta_{B^0} - \delta_D - \gamma)], \\
N(B^0 \to D_{CP}K^{*0}) &= N_{CP}[1 + r_{B^0}^2 + 2r_{B^0} \cos(\delta_{B^0} + \gamma)], \text{and} \\
N(\overline{B^0} \to D_{CP}\overline{K^{*0}}) &= N_{CP}[1 + r_{B^0}^2 + 2r_{B^0} \cos(\delta_{B^0} - \gamma)],
\end{aligned}
$$







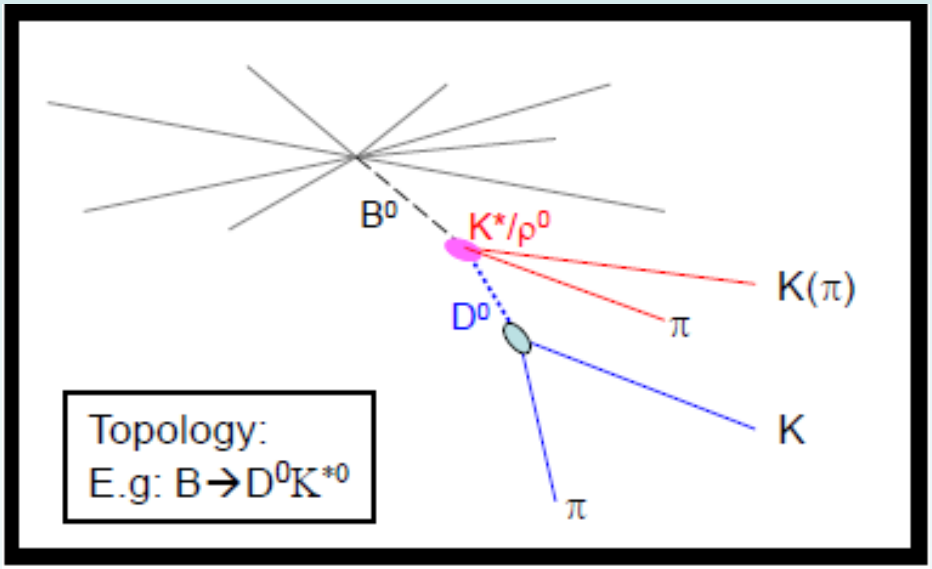


Expect results for summer conferences

[LHCb-CONF-2011-008]

First observation of $B_s \to D^0 K^{*0}$

- Significant background to $B^0 \to DK^{*0}$
- Normalise to $B^0 \to D\rho^0$ (kinematically similar so most systematics cancel)



D^0 Daughters, K (π)
- IP $\chi^2 > 4$
- p_T>400 (250) MeV
- ΔLL(K-π) < 4 (π)
- ΔLL(K-π) > 4 (K)

K*/ρ^0 daughters
- IP $\chi^2 > 4$, p_T>300 MeV
- ΔLL(K-π) < 3 (π)
- ΔLL(K-π) > 3 (K)

D^0
- p_T>1.5 GeV
- Vertex χ^2/dof < 5
- $|m-m_D|$<20 MeV

K* (ρ^0)
- p_T > 1 GeV
- $|\cos\theta_h|$>0.4
- $|m-m_V|$<50 (150) MeV

B
- τ_B > 0.2 ps
- Vertex χ^2/dof < 4
- IP χ^2 to PV < 9

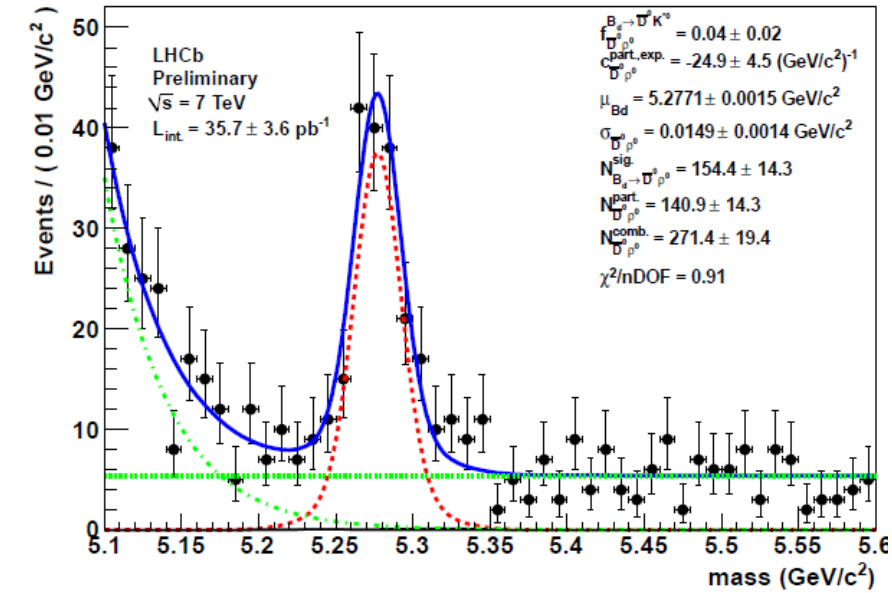
[LHCb-CONF-2011-008]

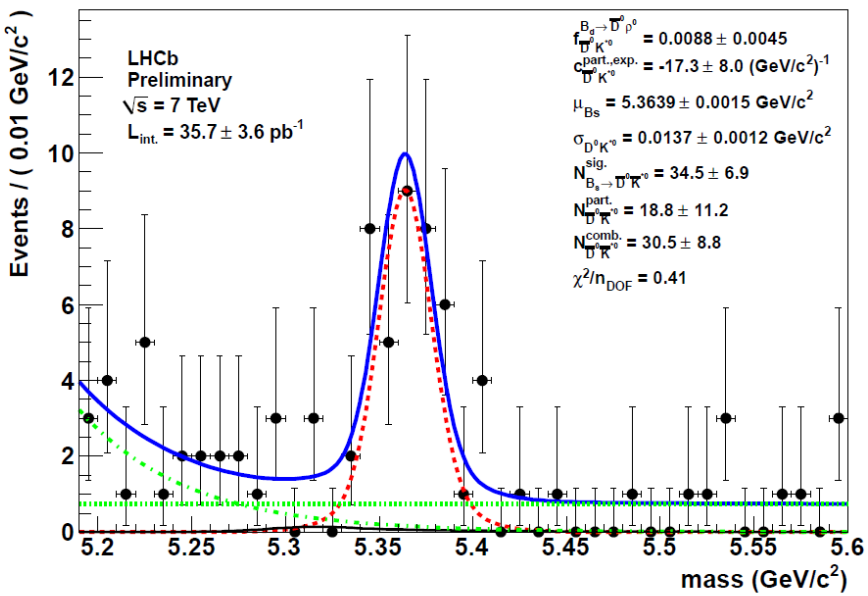
Signals

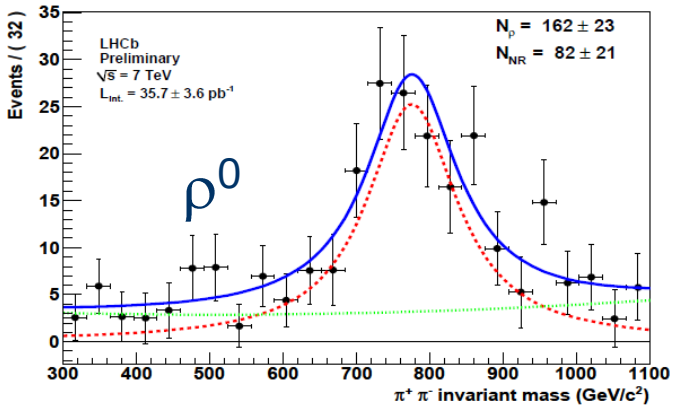
first observation

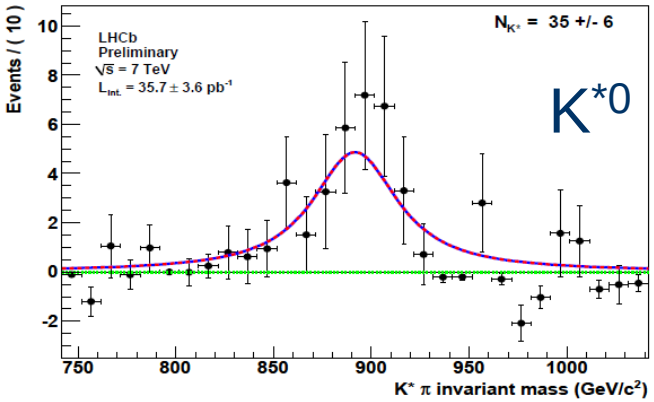
$B^0 \to D\rho^0$ normalisation channel

$B_s \to DK^{*0}$









effs

$$\frac{\mathcal{B}\left(\overline{B}_s^0 \to D^0 K^{*0}\right)}{\mathcal{B}\left(\overline{B}^0 \to D^0 \rho^0\right)} = \frac{N^{\text{sig.}}_{\overline{B}_s^0 \to D^0 K^{*0}}}{N^{\text{sig.}}_{\overline{B}^0 \to D^0 \rho^0}} \frac{\mathcal{B}\left(\rho^0 \to \pi^+\pi^-\right)}{\mathcal{B}\left(K^{*0} \to K^+\pi^-\right)} \frac{f_d}{f_s} \frac{\epsilon_{\overline{B}^0 \to D^0 \rho^0}}{\epsilon_{\overline{B}_s^0 \to D^0 K^{*0}}}$$

#s of events

Result

$$\frac{B(\overline{B}_s^0 \to D^0 K^{*0})}{B(\overline{B}^0 \to D^0 \rho^0)} = \left(1.39 \pm 0.31_{stat} \pm 0.17_{syst} \pm 0.18_{f_d/f_s}\right)$$

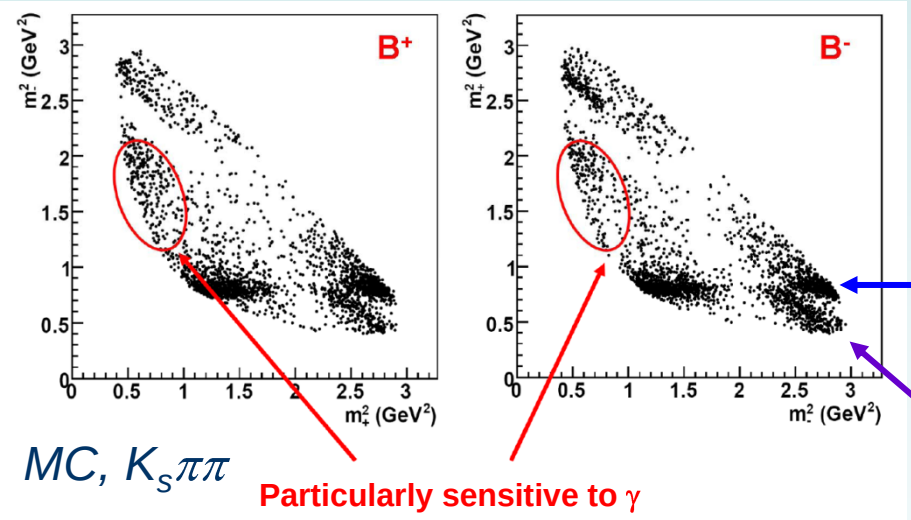
(Using $f_d/f_s = 3.71 \pm 0.47$ from HFAG)

[LHCb-2008-028]

Dalitz (GGSZ) analysis: $B^- \to D(K_s hh)K^-$ (1)

- Analysis of $D^0/\bar{D}^0 \to K_s\pi^+\pi^-$, $K_s KK$ with D from $B^- \to DK^-$
- Extract γ from differences in amplitude of Dalitz plot of D decay from $B^- \to DK^-$ and $B^+ \to DK^+$

Bands centred on invariant mass of 2-body intermediate states



K*(892)

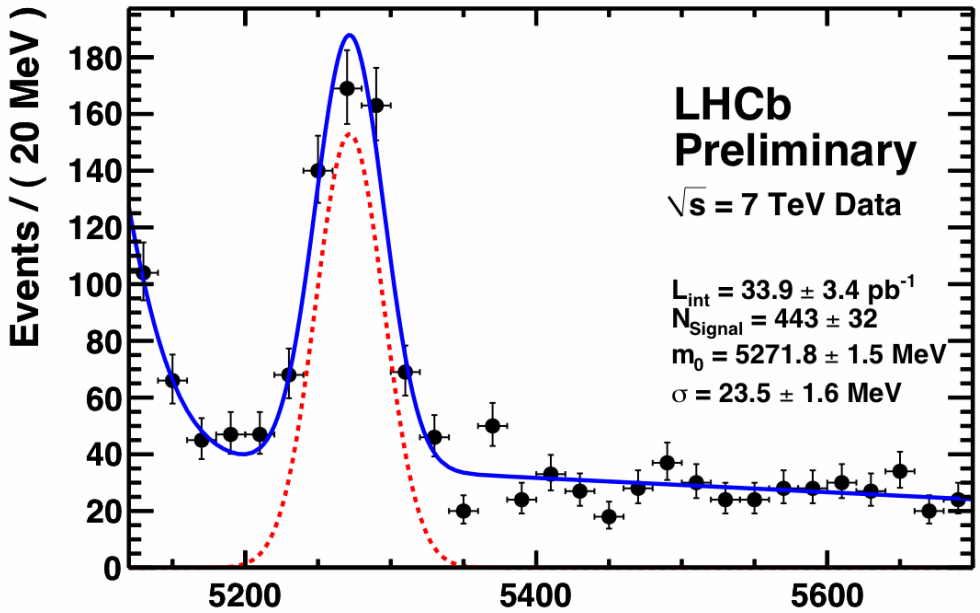
(→ $K_s\pi$)

ρ(770)

(→ $\pi^+\pi^-$)

Dalitz (GGSZ) analysis: $B^- \to D(K_s\pi\pi)K^-$ (2)

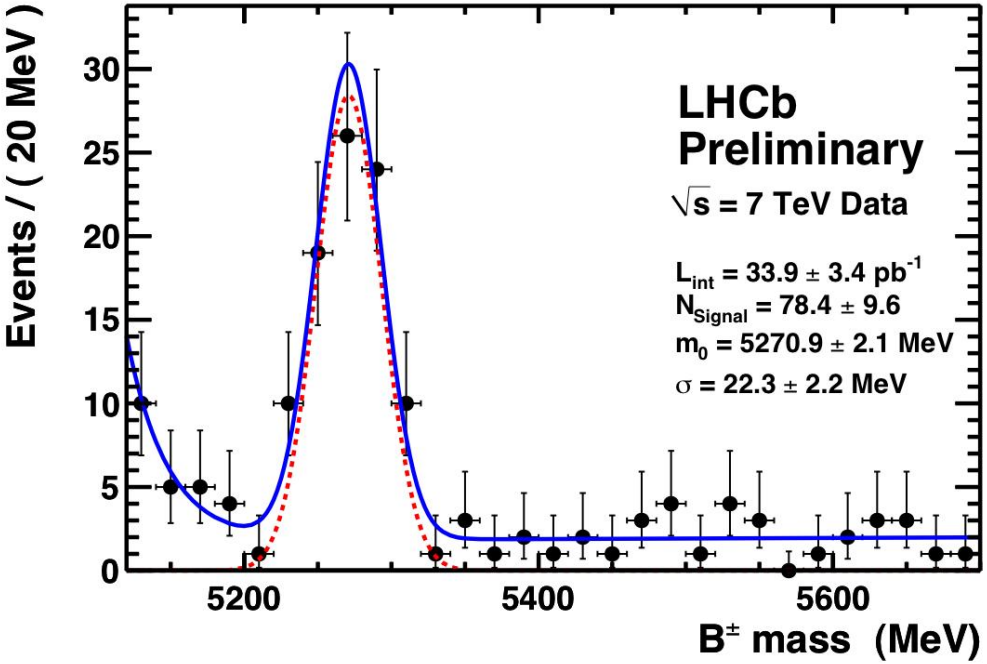
- Two fit methods investigated at LHCb:
  - **Unbinned likelihood fit** uses a model (description of the resonances) across the Dalitz plane. Systematic error from model assumptions (3-9°). Using full statistics.
  - **Binned fit** splits Dalitz plane into bins of similar strong phase. Model independent but lower statistical precision and requires input of CLEO-c measurements (1.7-3.9° error).



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

$B^- \to D(K_s KK)\pi^-$

Expect $K_s\pi\pi$ results later this year

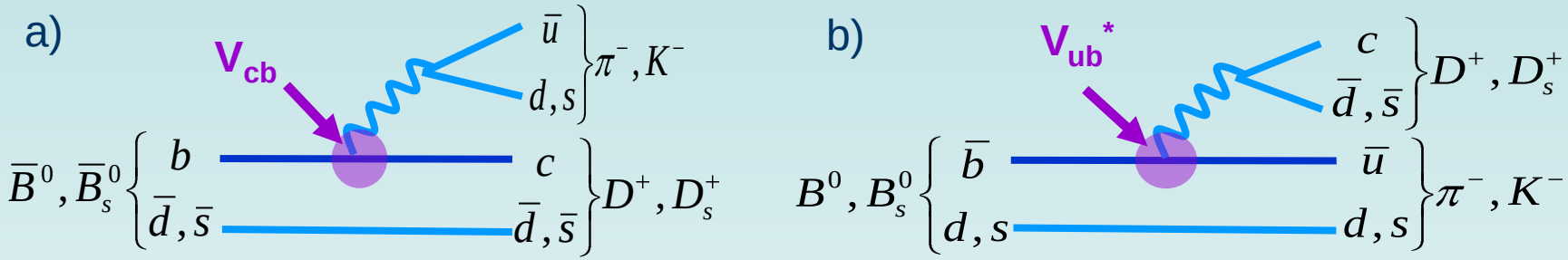


s

[LHCb-2007-041, LHCb-2007-017]

Time dependent B→DX measurements

- Tree level γ sensitivity from interference between $B^0/\bar{B}^0$ or $B_s^0/\bar{B}_s^0$ decays to same final state before and after mixing



- **$B_s \to D_s^+ K^-$** : $\gamma - \phi_M$ determined, where ϕ_M is the B_s mixing phase (will be well constrained from $B_s \to J/\psi\phi$ decays)
- **$B^0 \to D^+ \pi^-$** : $\gamma + 2\beta$ determined
  - Result for γ has ambiguities; use U-spin analysis with $B_s \to D_s^+ K^-$ or measurements from e.g. $B^0 \to D^{*+} \pi^-$ to reduce or remove these

U-spin: SU(2) subgroup of SU(3), like isospin but with (d,s) doublet, so B_s^0 and B^0 identical under U-spin

[LHCb-CONF-2011-013]

Measurement of f_s/f_d and $Br(B^0 \rightarrow D^- K^+)$

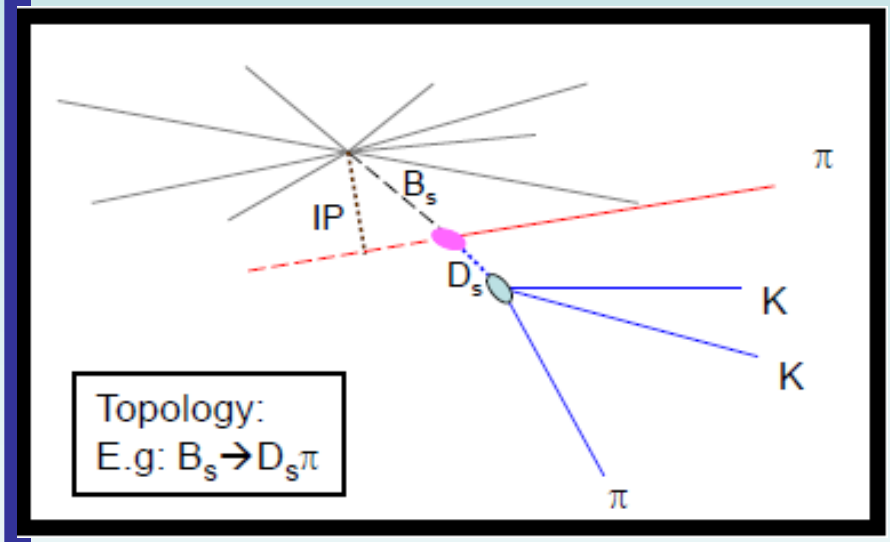
- Preliminary measurements for time-dependent modes:
  - ***f_s/f_d*** important for normalising B_s decay rates at LHCb e.g. $B_s \rightarrow \mu^+\mu^-$
    - Measured in $B_s \rightarrow D_s\pi$ and $B^0 \rightarrow D^-\pi^+$, $B_s \rightarrow D_s\pi$ and $B^0 \rightarrow D^- K^+$
  - ***$Br(B^0 \rightarrow D^- K^+)$*** (was known to ~30%)

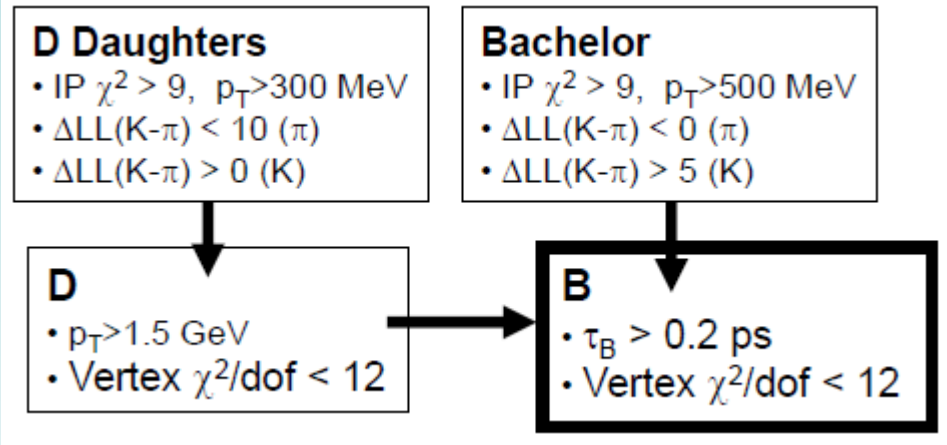
f_q is the probability that a b quark will hadronise to a B_q meson or Λ_b

[LHCb-CONF-2011-013]

Event selection

- Topologically similar decays ⇒one selection

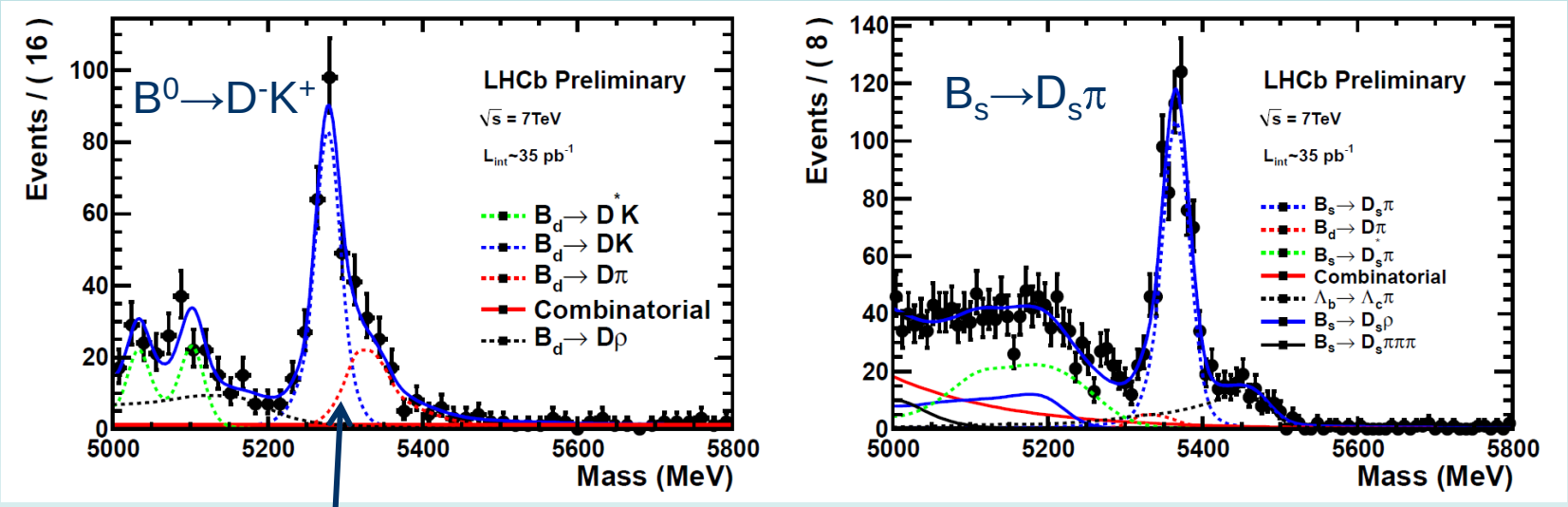


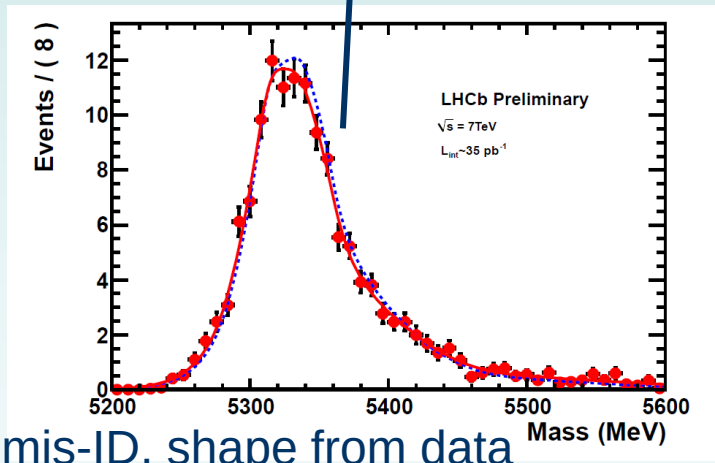


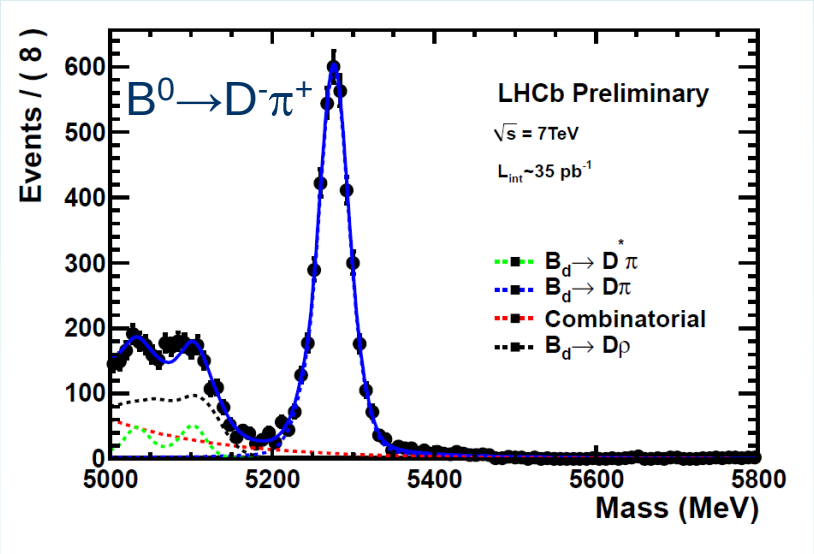
Boosted Decision Tree also used for kinematic variables; trained on signal MC and data sidebands

[LHCb-CONF-2011-013]

Signals







$D\pi$ mis-ID, shape from data

[LHCb-CONF-2011-013]

effs

$$\frac{\mathcal{B}(B_d \to D^{\pm}K^{\mp})}{\mathcal{B}(B_d \to D^{\pm}\pi^{\mp})} = \frac{N_{DK}}{N_{D\pi}} \times \frac{\epsilon_{D\pi}}{\epsilon_{DK}}$$

#s of events

$$\frac{f_s}{f_d} = 0.0743 \times \frac{\tau_{B_d}}{\tau_{B_s}} \times \left[\frac{1}{\mathcal{N}_a \mathcal{N}_F} \frac{\epsilon_{DK}}{\epsilon_{D_s\pi}} \frac{N_{D_s\pi}}{N_{DK}}\right]$$

$B_s \to D_s\pi$ and $B^0 \to D^-K^+$

Lifetimes

Theoretical factors

effs

#s of events

$$\frac{f_s}{f_d} = 0.982 \times \frac{\tau_{B_d}}{\tau_{B_s}} \times \left[\frac{1}{\mathcal{N}_{\mathcal{A}} \mathcal{N}_{\mathcal{F}} \mathcal{N}_{\mathcal{E}}} \frac{\epsilon_{D\pi}}{\epsilon_{D_s\pi}} \frac{N_{D_s\pi}}{N_{D\pi}}\right]$$

$B_s \to D_s\pi$ and $B^0 \to D^-\pi^+$

[LHCb-CONF-2011-013]

Results

$$\frac{B\left(B_d \to D^{\pm}K^{\mp}\right)}{B\left(B_d \to D^{\pm}\pi^{\mp}\right)} = 0.0752 \pm 0.0064 \pm 0.0026,$$

Most precise measurement of this BF

$$\frac{f_s}{f_d} = 0.242 \pm 0.024^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.016^{\text{theor}}$$

$B_s \to D_s\pi$ and $B^0 \to D^-K^+$

$$\frac{f_s}{f_d} = 0.249 \pm 0.013^{\text{stat}} \pm 0.020^{\text{syst}} \pm 0.025^{\text{theor}}$$

$B_s \to D_s\pi$ and $B^0 \to D^-\pi^+$

$$\frac{f_s}{f_d} = 0.245 \pm 0.025^{\text{stat}\oplus\text{syst}\oplus\mathcal{N}_E} \pm 0.016^{\mathcal{N}_F}$$

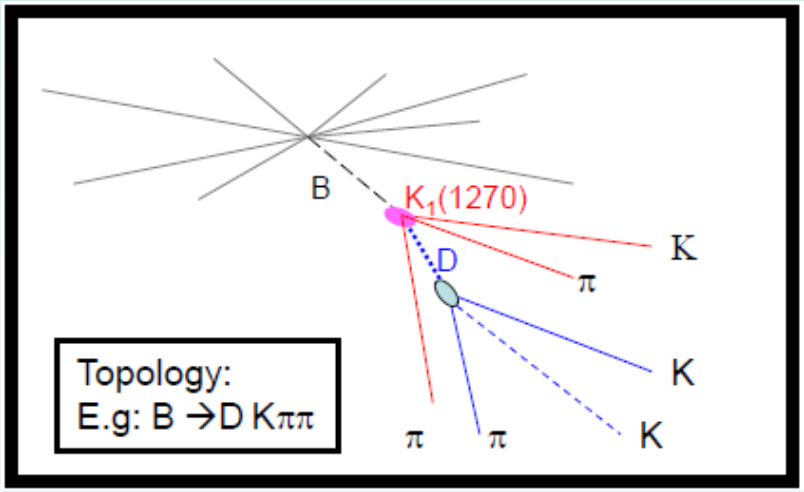
combined

[LHCb-CONF-2011-007, LHCb-CONF-2011-018]

$X_b \to X_c \pi\pi\pi$ and $X_b \to X_c K\pi\pi$

- $X_b = B_{(s)} / \Lambda_b$, $X_c = D_{(s)} / \Lambda_c$
- Current measurements low precision (>30%) or unknown

PDG



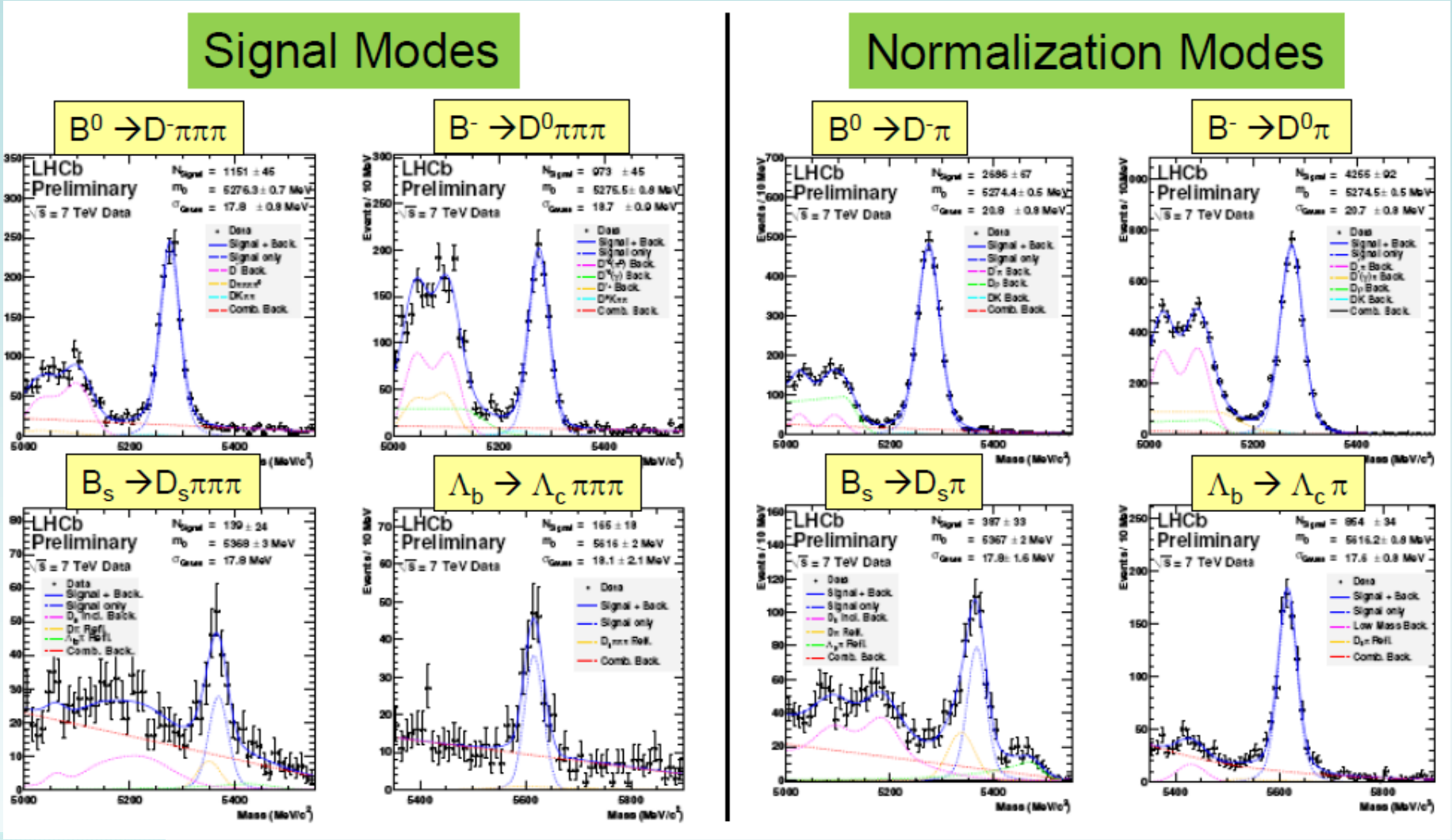
Decay	$\mathcal{B}$ (10^{-3})	$\frac{\mathcal{B}(B\to D+3h)}{\mathcal{B}(B\to Dh)}$
$\bar{B}^0 \to D^+\pi^-\pi^+\pi^-$	8.0 ± 2.5	3.0 ± 0.9
$B^- \to D^0\pi^-\pi^+\pi^-$	11 ± 4	2.3 ± 0.8
$B_s^0 \to D_s^+\pi^-\pi^+\pi^-$	8.4 ± 3.3	2.6 ± 1.1
$\Lambda_b^0 \to \Lambda_c^+\pi^-\pi^+\pi^-$	-	-
$\bar{B}^0 \to D^+\pi^-$	2.68 ± 0.13	-
$B^- \to D^0\pi^-$	4.84 ± 0.15	-
$\bar{B}_s^0 \to D_s^+\pi^-$	3.2 ± 0.5	-
$\Lambda_b^0 \to \Lambda_c^+\pi^-$	8.8 ± 3.2	-

[LHCb-CONF-2011-007, LHCb-CONF-2011-018]

- These multi-body decays are of interest:
  - $\mathbf{B_s \to D_s \pi\pi\pi}$ for Δm_s and mistag calibration for $B_s \to D_s K\pi\pi$
  - $\mathbf{B^0 \to D^- \pi\pi\pi}$ for time-dependent γ (like $B^0 \to D^- \pi^+$)
  - $\mathbf{B_s \to D_s K\pi\pi}$ for time-dependent γ (like $B_s \to D_s K$)
  - $\mathbf{B^- \to D^0 K\pi\pi}$ for time-independent γ (like $B^- \to D^0 K^-$)
- If multi-body part dominated by single resonance, can treat them like corresponding $B \to DX$ modes to extract γ
- If not, model resonances or fit additional strong phase parameter

[LHCb-CONF-2011-007]

Signals (CF modes)



[LHCb-CONF-2011-007]

Results (CF modes)

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+\pi^-\pi^+\pi^-)}{\mathcal{B}(\bar{B}^0 \to D^+\pi^-)} = 2.35 \pm 0.11(\text{stat}) \pm 0.24(\text{syst})$$

$$\frac{\mathcal{B}(B^- \to D^0\pi^-\pi^+\pi^-)}{\mathcal{B}(B^- \to D^0\pi^-)} = 1.26 \pm 0.07(\text{stat}) \pm 0.12(\text{syst})$$

$$\frac{\mathcal{B}(\bar{B}_s^0 \to D_s^+\pi^-\pi^+\pi^-)}{\mathcal{B}(\bar{B}_s^0 \to D_s^+\pi^-)} = 2.22 \pm 0.41(\text{stat}) \pm 0.25(\text{syst})$$

$$\frac{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-\pi^+\pi^-)}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-)} = 1.32 \pm 0.15(\text{stat}) \pm 0.14(\text{syst})$$

$$\mathcal{B}(\bar{B}^0 \to D^+\pi^-\pi^+\pi^-) = (6.16 \pm 0.26(\text{stat}) \pm 0.69(\text{syst})) \times 10^{-3}$$

$$\mathcal{B}(B^- \to D^0\pi^-\pi^+\pi^-) = (5.96 \pm 0.29(\text{stat}) \pm 0.61(\text{syst})) \times 10^{-3}$$

$$\mathcal{B}(\bar{B}_s^0 \to D_s^+\pi^-\pi^+\pi^-) = (6.28 \pm 1.10(\text{stat}) \pm 1.21(\text{syst})) \times 10^{-3}$$

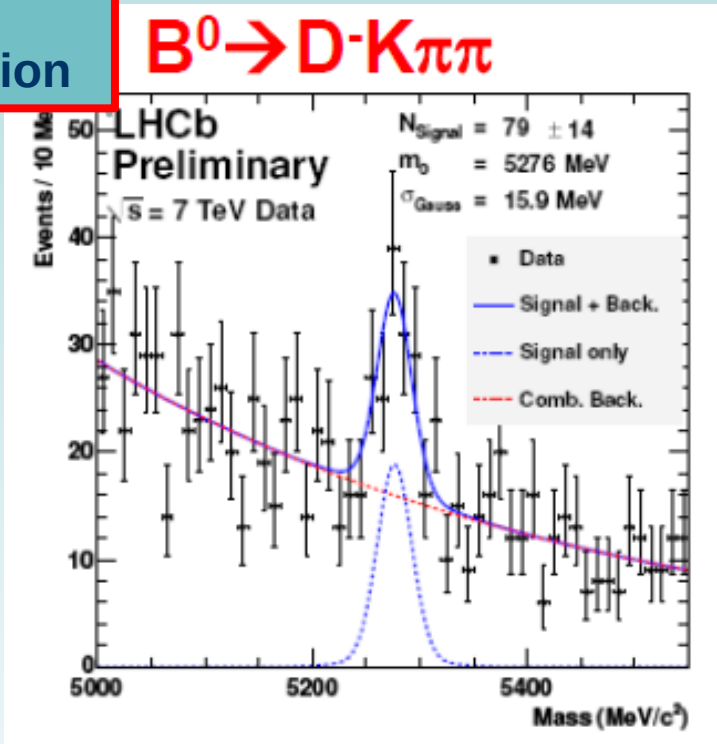
$$\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-\pi^+\pi^-) = (12.2 \pm 1.4(\text{stat}) \pm 4.6(\text{syst})) \times 10^{-3}$$

Significant improvement in knowledge of these decays

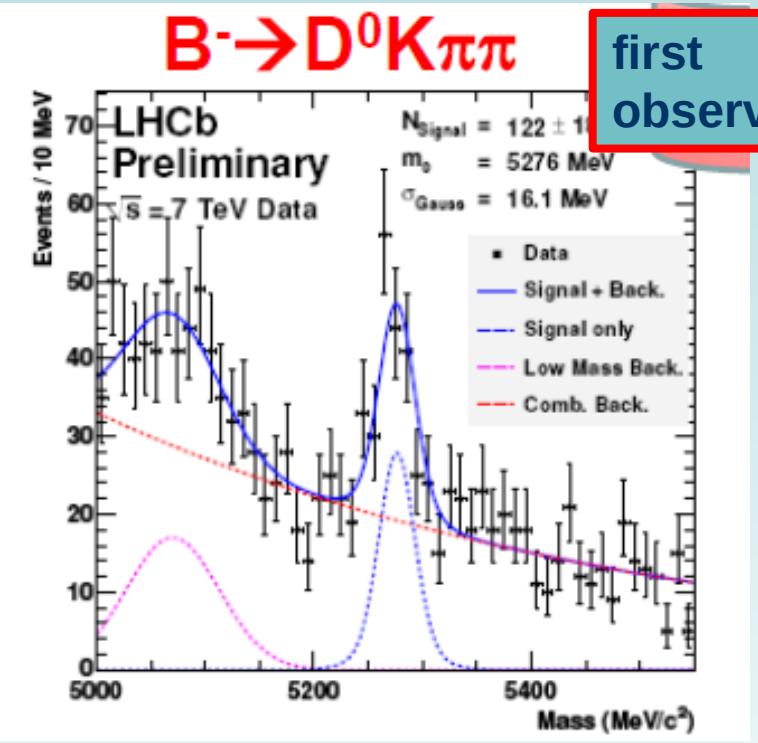
[LHCb-CONF-2011-018]

Signals (CS modes)

first observation



6.6σ significance



first observation

8.0σ significance

[LHCb-CONF-2011-018]

Results (CS modes)

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+K^-\pi^+\pi^-)}{\mathcal{B}(\bar{B}^0 \to D^+\pi^-\pi^+\pi^-)} = (5.2 \pm 0.9(\text{stat}) \pm 0.5(\text{syst})) \times 10^{-2}$$

$$\frac{\mathcal{B}(B^- \to D^0K^-\pi^+\pi^-)}{\mathcal{B}(B^- \to D^0\pi^-\pi^+\pi^-)} = (9.6 \pm 1.5(\text{stat}) \pm 0.8(\text{syst})) \times 10^{-2}.$$

For comparison, B→DK modes:

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+K^-)}{\mathcal{B}(\bar{B}^0 \to D^+\pi^-)} = (7.52 \pm 0.66) \times 10^{-2}$$

$$\frac{\mathcal{B}(B^- \to D^0K^-)}{\mathcal{B}(B^- \to D^0\pi^-)} = (7.6 \pm 0.7) \times 10^{-2}.$$

2011 prospects for γ

- Further results on the road to γ will be released during this year
- Expect combined measurement with

$\sigma_\gamma \sim 5 - 7°$ from $\sim 1 fb^{-1}$ dataset (2011/2012)

Conclusions

- 2010 data taking at LHCb successful in challenging environment
- Detector performing well
- Results in many areas
- “from trees” γ measurements expected to give $\sigma_\gamma \sim 5 - 7°$ from $\sim 1 fb^{-1}$ 2011/2012 dataset