# Studies of B→DX decays and prospects for $\gamma$ measurements
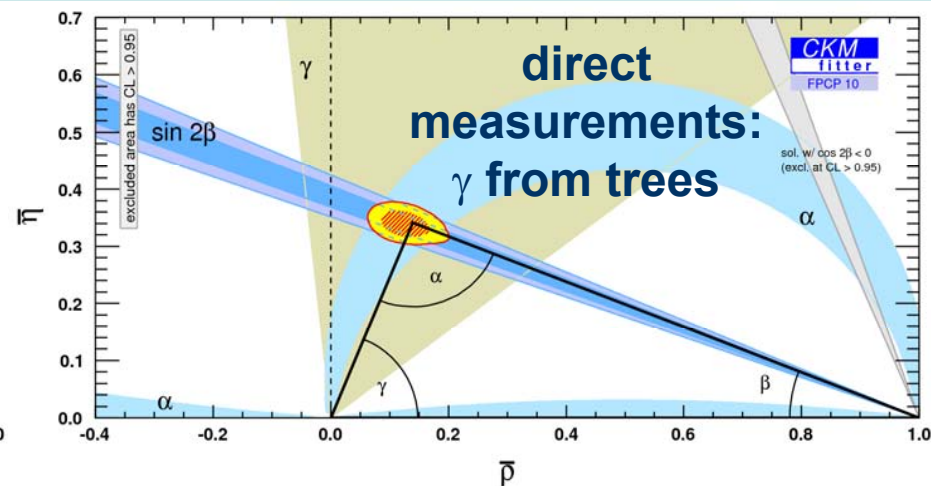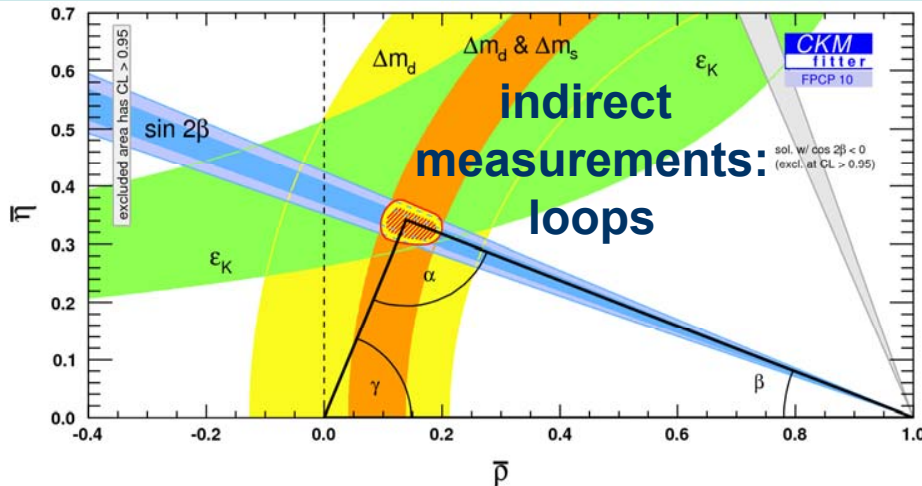
## *The LHCb collaboration*

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***ICHEP 2010***

# CKM angle γ "from trees"

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



- Current value of γ from direct measurement

$$\gamma = (70^{+14}_{-21})^\circ \quad \textit{(CKMfitter FPCP 2010)}$$

# Charmed hadronic B decays

- B→DX decays allow extraction of $\gamma$ at tree level

- Essential for benchmarking the SM

- At LHCb, study

  - **time integrated processes**

    $B^-\rightarrow DK^-$ and $\overline{B}^0\rightarrow D\overline{K}^{*0}$

    - 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    Dalitz Analysis, 24-26 Sep. 2002, unpublished]
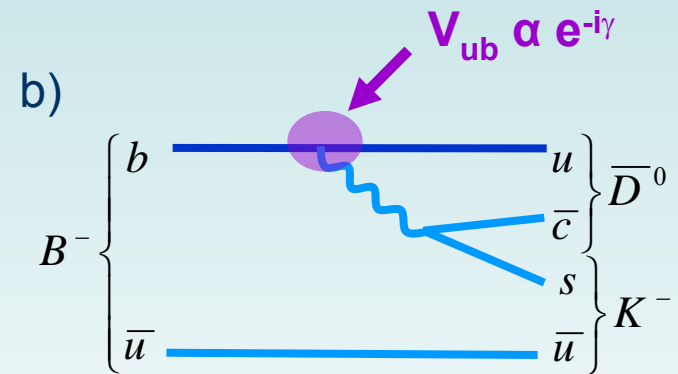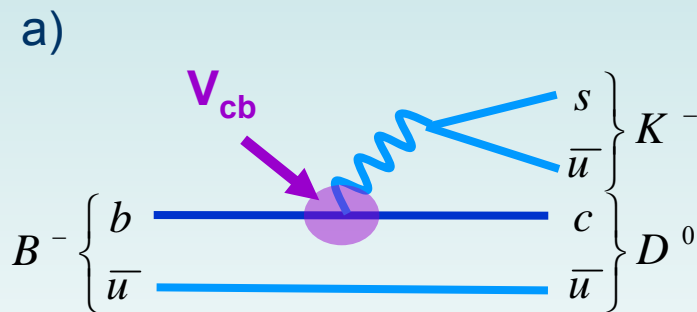
  - **time dependent processes**

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

    [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 $\gamma$ at tree level when $D^0$ or $\bar{D}^0$ decays to same final state, due to interference effects

- e.g. for $B^- \rightarrow DK^-$

a)

$V_{cb}$

$B^-$ $\begin{cases} b \\ \bar{u} \end{cases}$ ... $\left.\begin{matrix} s \\ \bar{u} \end{matrix}\right\} K^-$ ... $\left.\begin{matrix} c \\ \bar{u} \end{matrix}\right\} D^0$

b)

$V_{ub} \; \alpha \; e^{-i\gamma}$

$B^- \begin{cases} b \\ \bar{u} \end{cases}$ ... $\left.\begin{matrix} u \\ \bar{c} \end{matrix}\right\} \bar{D}^0$ ... $\left.\begin{matrix} s \\ \bar{u} \end{matrix}\right\} K^-$

- Similar diagrams for $\bar{B}^0 \rightarrow D\bar{K}^{*0}$

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

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

# GLW/ADS analysis: B→D(hh)K

- **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 $\gamma$, 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**

- **In 1 fb$^{-1}$ at 7 TeV:**

| Channel | Expected event yield |
|---|---|
| $B^-\to D(KK)K^-$ | 2000 |
| $B^-\to D(\pi\pi)K^-$ | 750 |
| $B^-\to D(K\pi)K^-$ favoured | 20000 |
| $B^-\to D(K\pi)K^-$ suppressed | 400 |

| Channel | Expected event yield |
|---|---|
| $B^0\to D(KK)K^{*0}$ | 70 |
| $B^0\to D(\pi\pi)K^{*0}$ | 25 |
| $B^0\to D(K\pi)K^{*0}$ favoured | 800 |
| $B^0\to D(K\pi)K^{*0}$ suppressed | 70 |

Susan Haines

# $B^- \rightarrow D(hhhh)K^-$

- Related analysis of $D^0/\overline{D}^0$ decay to states $K^+K^-\pi^+\pi^-$ and $K^-\pi^+\pi^-\pi^+$ with D from $B^-\rightarrow DK^-$

- D decay to multi-body final state can proceed via several resonant states

- Must account for this in analysis

- In 1 fb$^{-1}$ at 7 TeV:

| Channel | Expected event yield |
|---|---|
| $B^-\rightarrow D(KK\pi\pi)K^-$ | 300 |
| $B^-\rightarrow D(K\pi\pi\pi)K^-$ favoured | 13000 |
| $B^-\rightarrow D(K\pi\pi\pi)K^-$ suppressed | 100 |

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

- Analysis of $D^0/\overline{D}^0 \to K_s\pi^+\pi^-$ with D from $B^- \to DK^-$

- Extract $\gamma$ from differences in amplitude of Dalitz plot of D decay from $B^- \to DK^-$ and $B^+ \to DK^+$

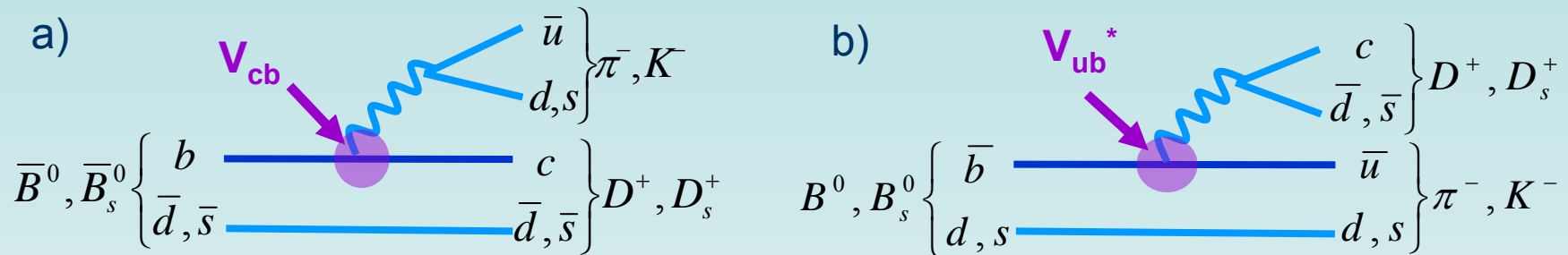Bands centred on invariant mass of 2-body intermediate states



MC

**Particularly sensitive to** $\gamma$

**K*(892)**

**($\to K_s\pi$)**

$\rho$**(770)**

**($\to \pi^+\pi^-$)**
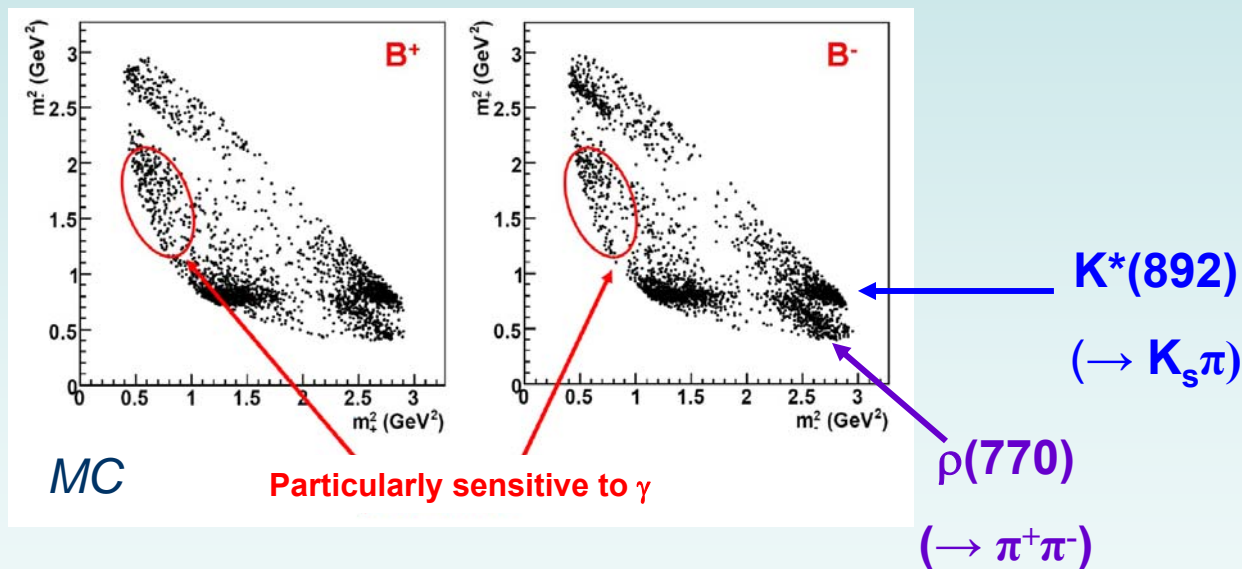
- Expect >1600 events in 1 fb$^{-1}$ at 7 TeV

# Time dependent B→DX measurements

- Tree level $\gamma$ sensitivity from interference between $B^0/\bar{B}^0$ or $B_s^0/\bar{B}_s^0$ decays

a)

$$\bar{B}^0, \bar{B}_s^0 \begin{cases} b \\ \bar{d}, \bar{s} \end{cases} \quad V_{cb} \quad \begin{matrix} \bar{u} \\ d,s \end{matrix} \Big\} \pi^-, K^- \quad \begin{matrix} c \\ \bar{d}, \bar{s} \end{matrix} \Big\} D^+, D_s^+$$

b)

$$B^0, B_s^0 \begin{cases} \bar{b} \\ d,s \end{cases} \quad V_{ub}^* \quad \begin{matrix} c \\ \bar{d}, \bar{s} \end{matrix} \Big\} D^+, D_s^+ \quad \begin{matrix} \bar{u} \\ d,s \end{matrix} \Big\} \pi^-, K^-$$

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

- In 1 fb$^{-1}$ at 7 TeV:

| Channel | Expected event yield |
|---|---|
| $B_s^0 \rightarrow D_s^+ K^-$ | 3500 |
| $B^0 \rightarrow D^+\pi^-$ | 300000 |

# First look at data: $\int \mathcal{L} = 14$ nb$^{-1}$ at 7 TeV

- Challenging to distinguish fully hadronic B decays from background in hadronic environment
- Need to exploit excellent LHCb particle ID, impact parameter and primary vertex resolutions



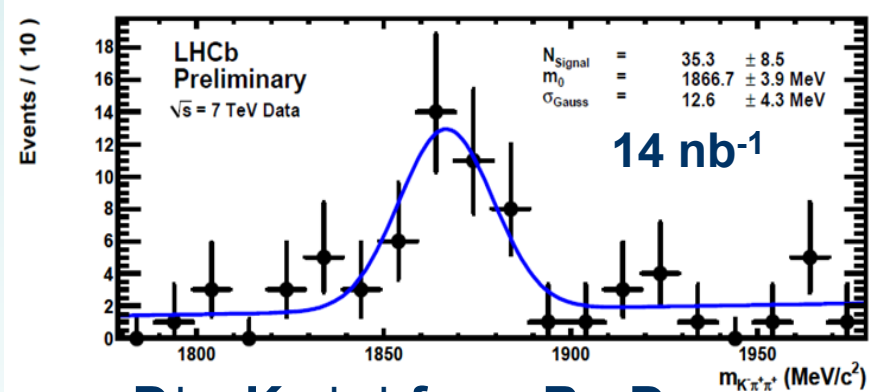PV resolution, x and y



PID K vs $\pi$



IP resolution
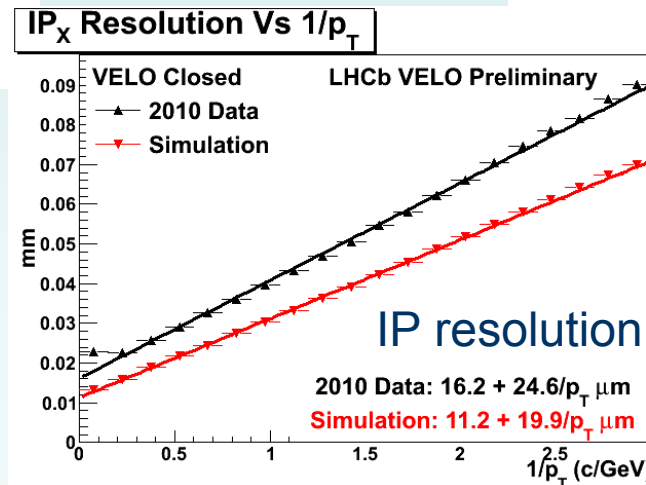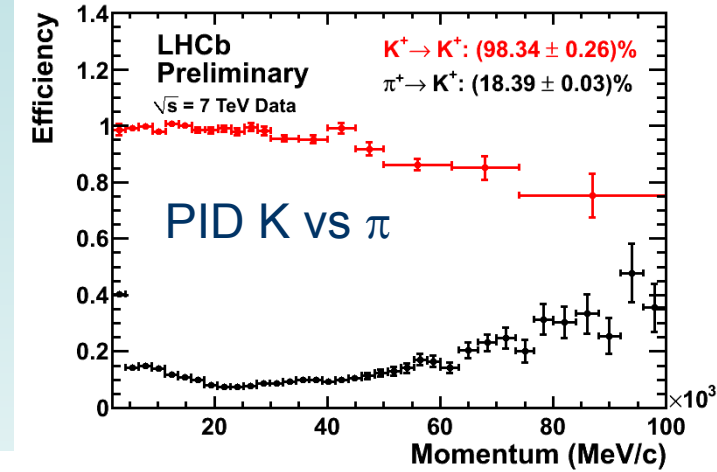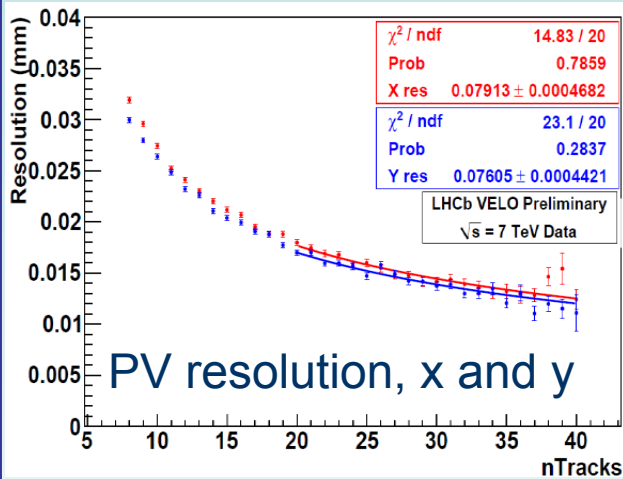
See A. Powell, 22nd July for details of LHCb PID and S. Borghi, 22nd July for details of tracking
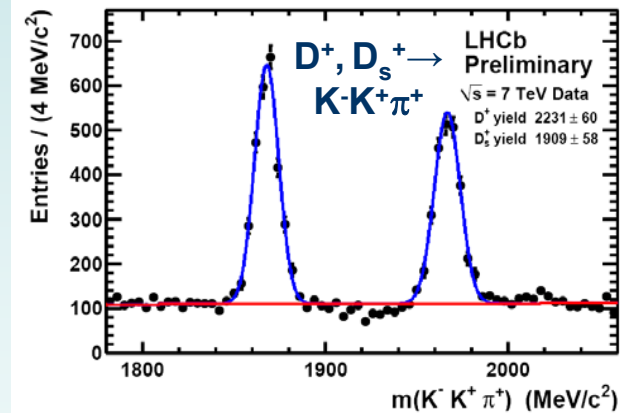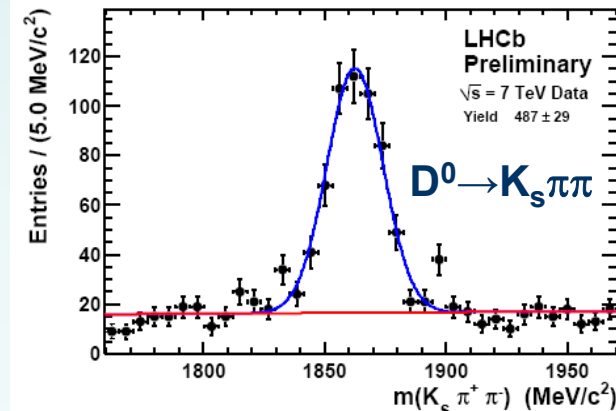
- Have now accumulated some B candidates:



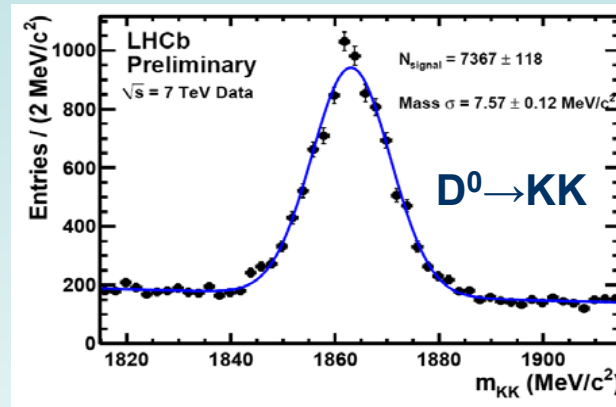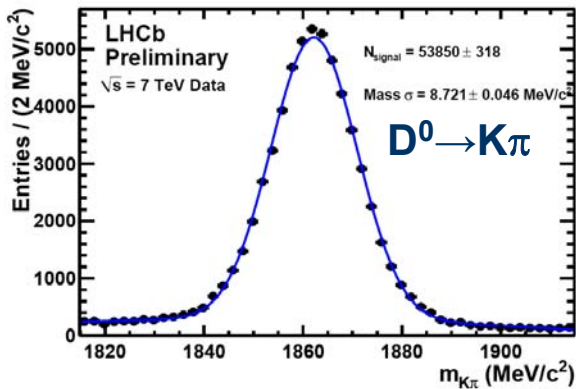$B^0 \rightarrow D^+\pi^-$ and
$B^- \rightarrow D^0\pi^-$, 14 nb$^{-1}$
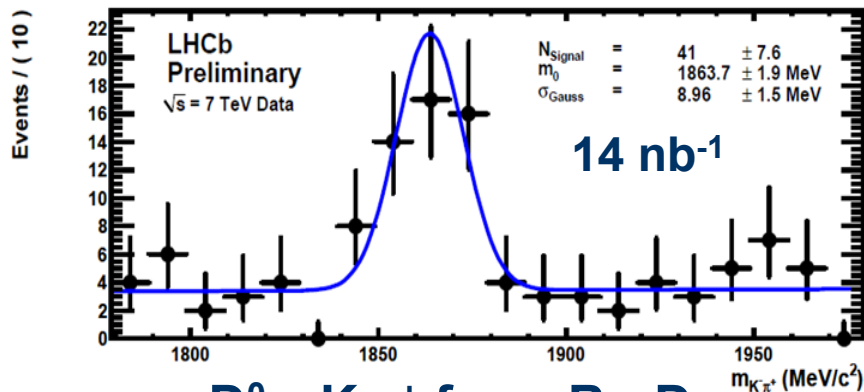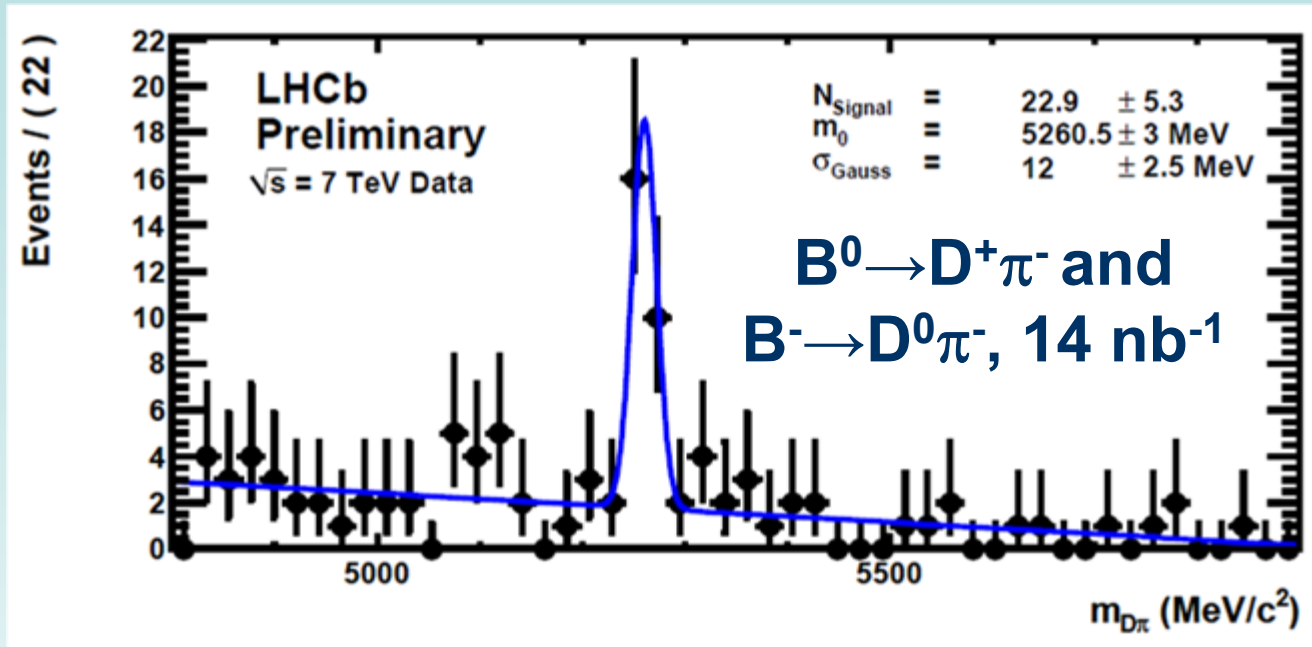
$D^0 \rightarrow K^-\pi^+$ from $B \rightarrow D\pi$

$D^+ \rightarrow K^-\pi^+\pi^+$ from $B \rightarrow D\pi$

- Still waiting to see B candidates in other channels
- Currently studying detector, trigger, backgrounds
- However, D decays have been reconstructed – as $\int \mathcal{L}$ increases, will be able to reconstruct B candidates
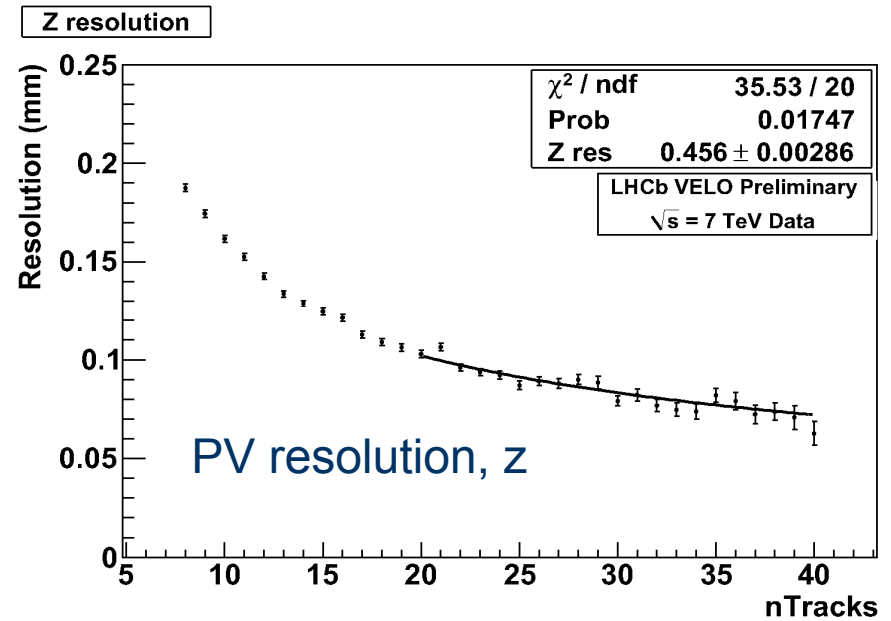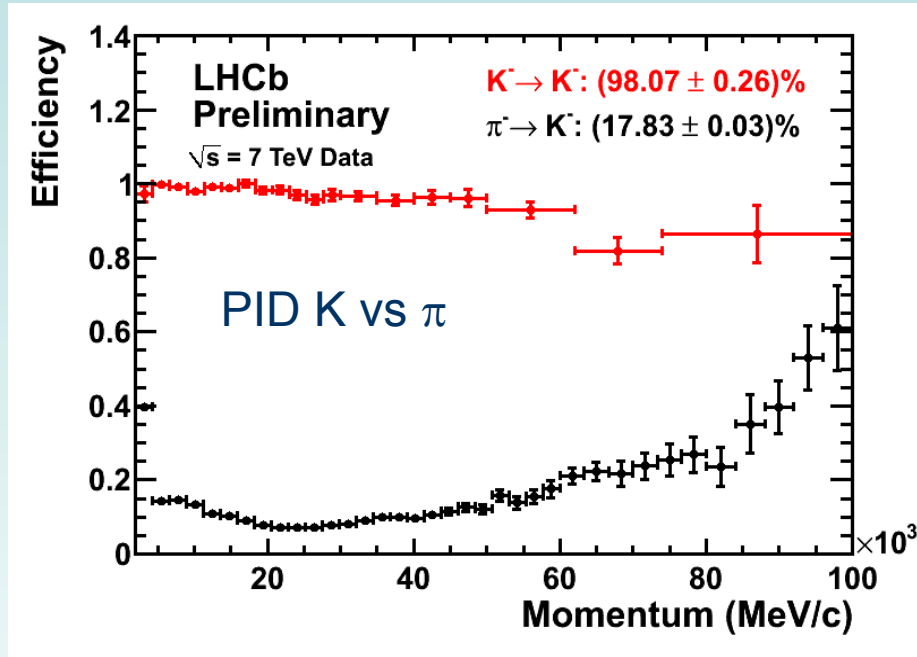


**See E. Van Herwijnen, 22nd July for details of LHCb trigger and I. Belyaev talk, 23rd July for LHCb Charm results**

# Current status and prospects

- **Current status:** ~14 nb$^{-1}$ of 7 TeV data analysed
    - first B signal candidates seen
    - studying backgrounds, detector and trigger
- **Expectations:**
    - **Early data:** ~0.2 fb$^{-1}$ of data at 7 TeV   [LHCb-2008-031]
        - expected overall combined sensitivity comparable to B factories **σ(γ) ~ 12-15°**
    - **2011:** ~1 fb$^{-1}$ of data at 7 TeV
        - expected overall combined sensitivity **σ(γ) ~ 6-8°**
    - **Total LHCb dataset:** 10 fb$^{-1}$ at 14 TeV
        - expected overall combined sensitivity **σ(γ) ~ 1.9-2.7°**

# Backup



PID K vs $\pi$

LHCb
Preliminary
$\sqrt{s}$ = 7 TeV Data

$K^- \rightarrow K^-$: (98.07 $\pm$ 0.26)%
$\pi^- \rightarrow K^-$: (17.83 $\pm$ 0.03)%



PV resolution, z

Z resolution

| | |
|---|---|
| $\chi^2$ / ndf | 35.53 / 20 |
| Prob | 0.01747 |
| Z res | 0.456 $\pm$ 0.00286 |

LHCb VELO Preliminary
$\sqrt{s}$ = 7 TeV Data

# $B_s^0 \rightarrow D_s^+ K^-$ lifetime



**LHCb MC**

Double Gaussian fit

$\sigma_1 = 33 \pm 1$ fs
$\sigma_2 = 67 \pm 3$ fs (31%)

Decay time resolution (MC) 40 fs

$t_{rec} - t_{true}$ [fs]