Search for CP Violation in $B^{\pm}\rightarrow DK^{\pm}$, $D\rightarrow h^{\pm}h^{\mp}\pi^{0}$ Decays at LHCb

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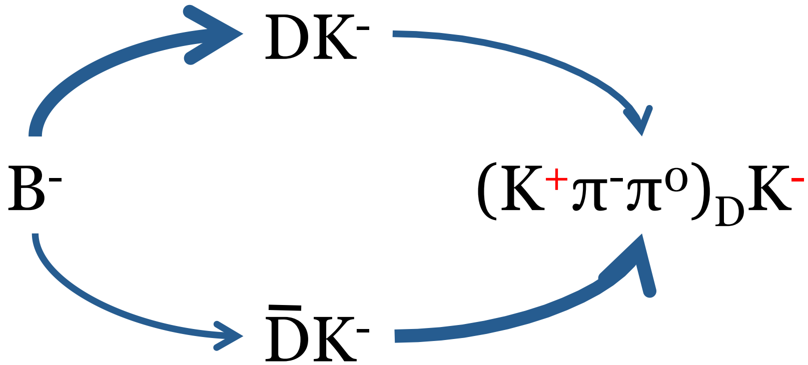
on behalf of the LHCb Collaboration

Introduction

- The CKM angle γ can be measured by studying $B^{\pm}\rightarrow DK^{\pm}$ decays



- ADS method involves the D decaying into a non-CP eigenstate of a kaon and an ensemble of pions (e.g. **$K\pi\pi^0$**)
- Interference between D^0 and $\bar{D}^0$ decays gives sensitivity to γ

- Two prior LHCb analyses have used this method for γ measurement:
  - $B^{\pm}\rightarrow[hh]_D K^{\pm}$ in Phys Lett **B 712** (2012) 203
  - $B^{\pm}\rightarrow[K^{\mp}\pi^{\pm}\pi^{+}\pi^{-}]_D K^{\pm}$ in Phys Lett **B 723** (2013) 44

- Suppressed (principal) channels of interest:
  - **$B^-\rightarrow DK^-$, $D\rightarrow K^+\pi^-\pi^0$** (CP violation)
  - **$B^-\rightarrow D\pi^-$, $D\rightarrow K^+\pi^-\pi^0$** (less CP violation)
- Favoured (control) modes:
  - **$B^-\rightarrow DK^-$, $D\rightarrow K^-\pi^+\pi^0$**
  - **$B^-\rightarrow D\pi^-$, $D\rightarrow K^-\pi^+\pi^0$**

Why $K\pi\pi^0$?

- Statistical perspective

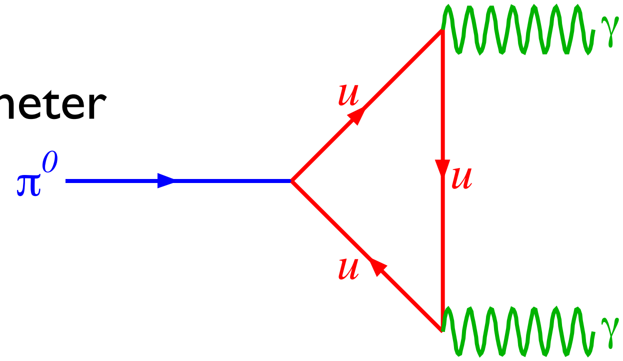
$$\mathcal{B}(D^0 \to K^-\pi^+\pi^0) = (13.9 \pm 0.5)\%$$

vs

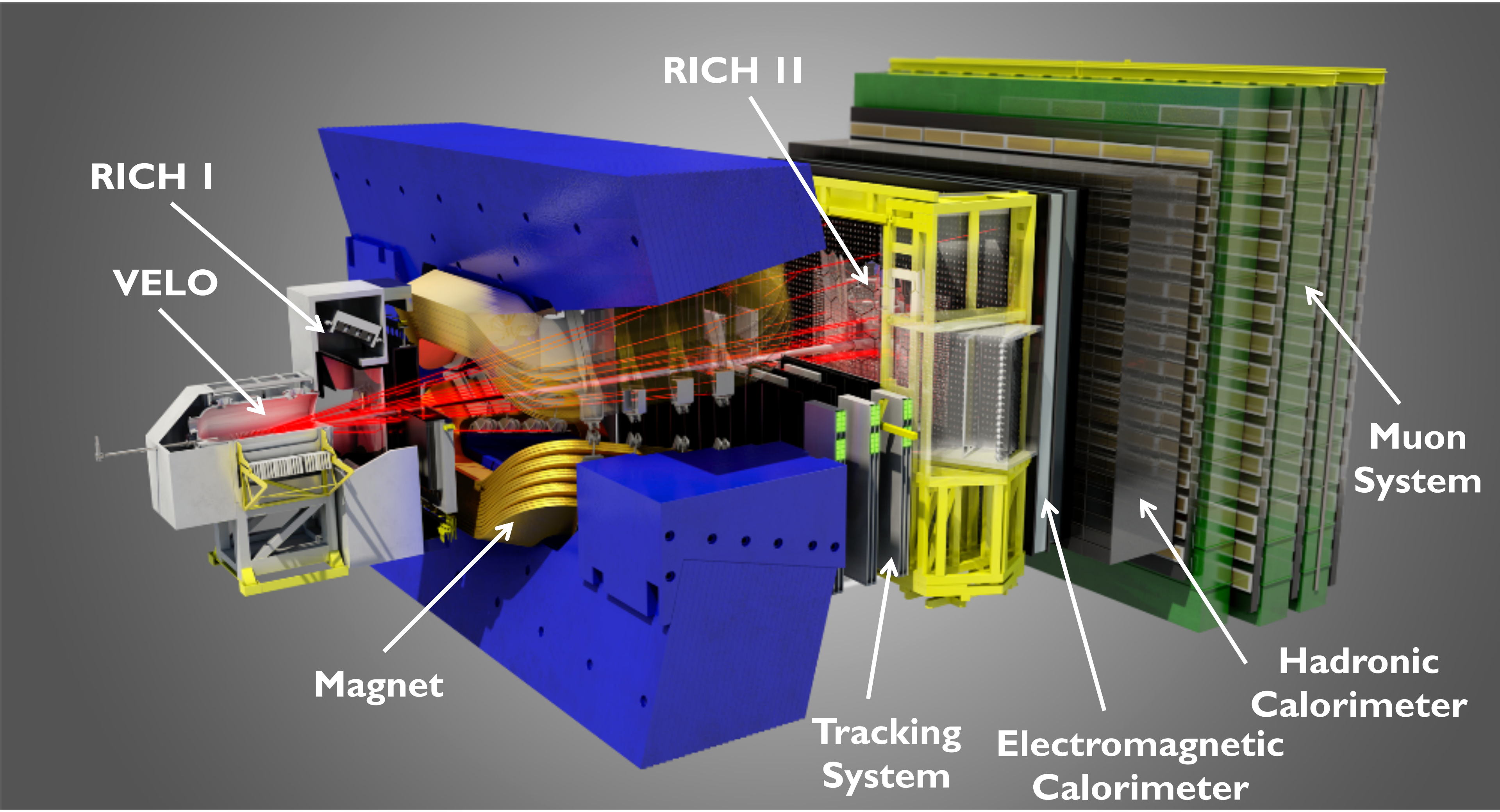
$$\mathcal{B}(D^0 \to K^-\pi^+\pi^-\pi^+) = (8.07 \pm 0.20)\%$$
$$\mathcal{B}(D^0 \to K^-\pi^+) = (3.87 \pm 0.05)\%$$

- In D decays with more than 2 particles in the final state, there are intermediate resonances that must be considered
  - *Coherence factor* parameterises effect of these resonances and affects size of the interference that gives sensitivity to γ
  - Value ranging from 0 to 1: closer to 1, greater the sensitivity to γ
  - Measured to be 0.82 by CLEO [Phys Lett **B 731** (2014) 197]

- Challenge: there's a π^0 in the final state!
  - 20-30 of these in LHCb acceptance per event
  - Some photons convert before reaching calorimeter
  - Modest calorimeter energy resolution



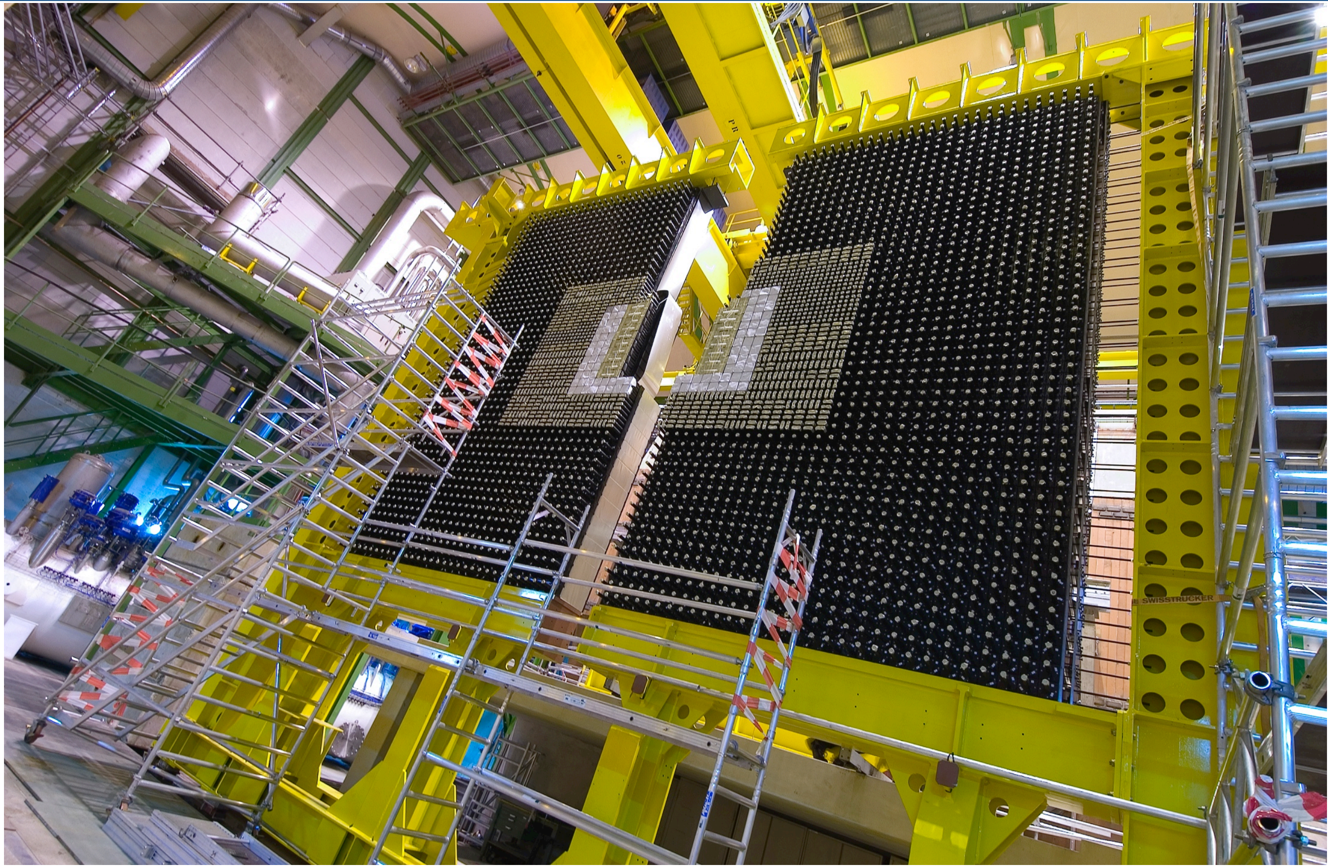
LHCb Detector



Electromagnetic Calorimeter

» Scintillating Pad Detector (SPD) and Pre-Shower Detector (PS) present before ECAL – used for electron/photon distinction

» ECAL has alternating tiles of lead absorber plates and scintillator tiles

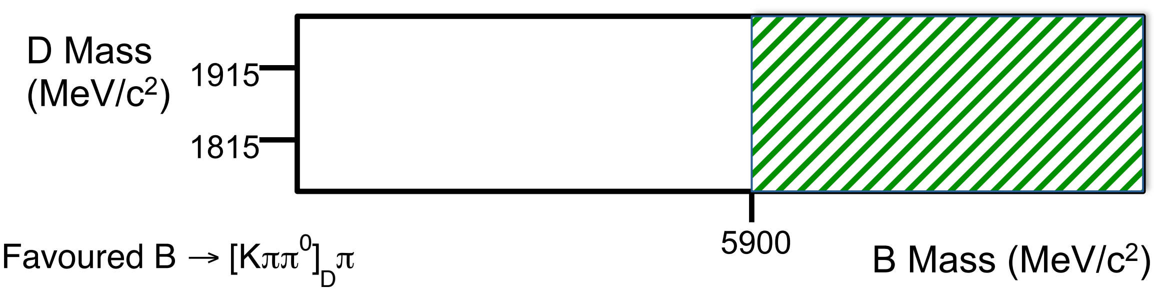


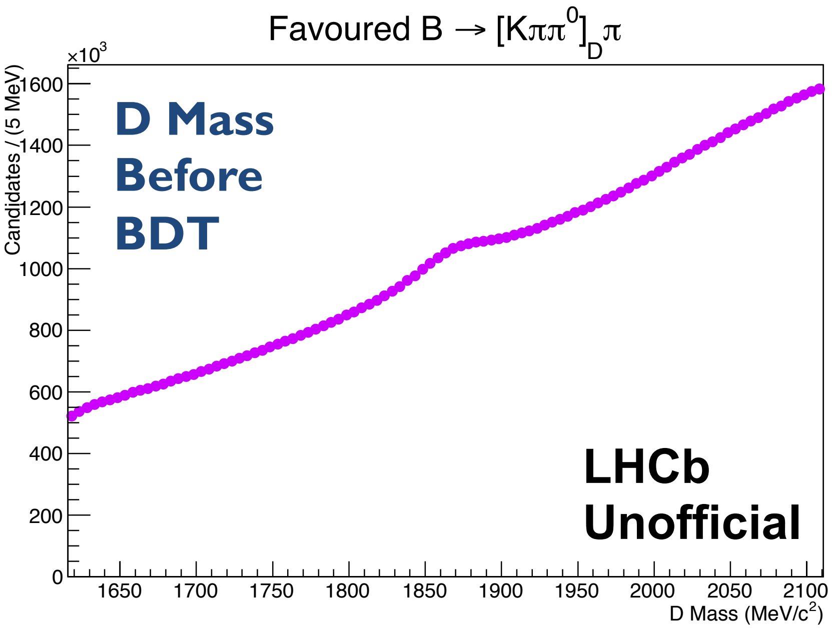
» Cell sizes vary depending on proximity to the beam pipe

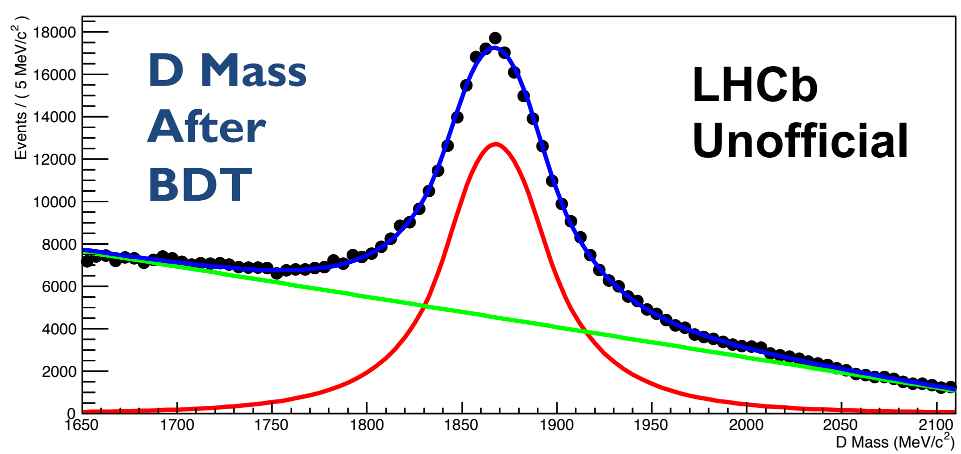
» Energy resolution of $\dfrac{\sigma(E)}{E} = \dfrac{(8-10)\%}{\sqrt{E}} \oplus 0.9\%$

Boosted Decision Tree

- Selection is primarily based on use of a Boosted Decision Tree (BDT)
- Trained on a series of kinematic variables including D momentum, π^0 p_T, B vertex quality
- Signal sample from Monte Carlo of favoured $B^{\pm}\to D\pi^{\pm}$, $D\to K^{\pm}\pi^{\mp}\pi^0$
- Background samples from data (attempting to eliminate combinatoric background)



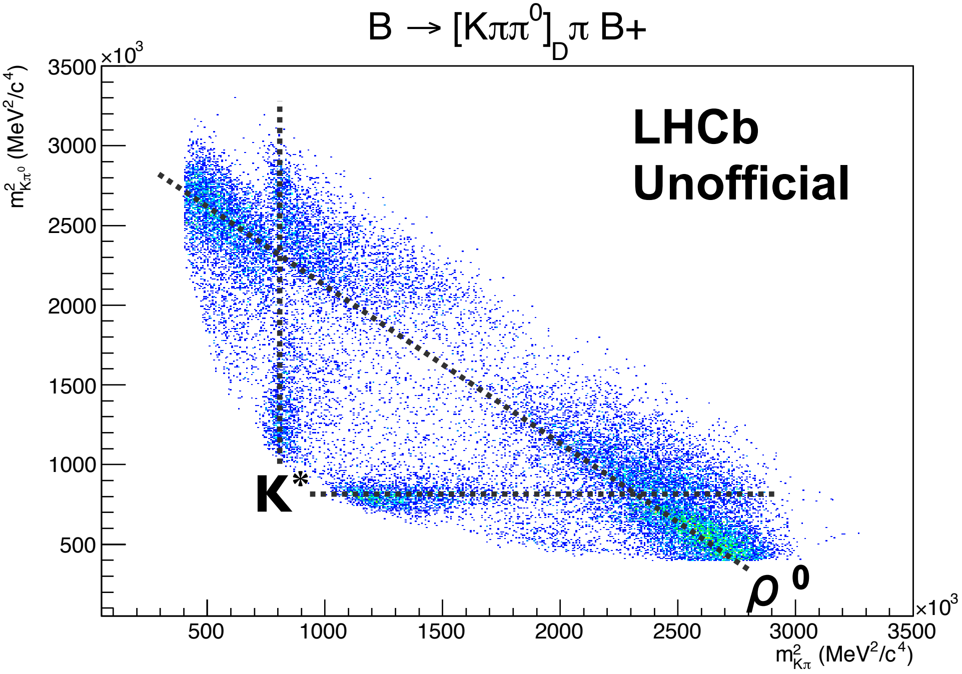


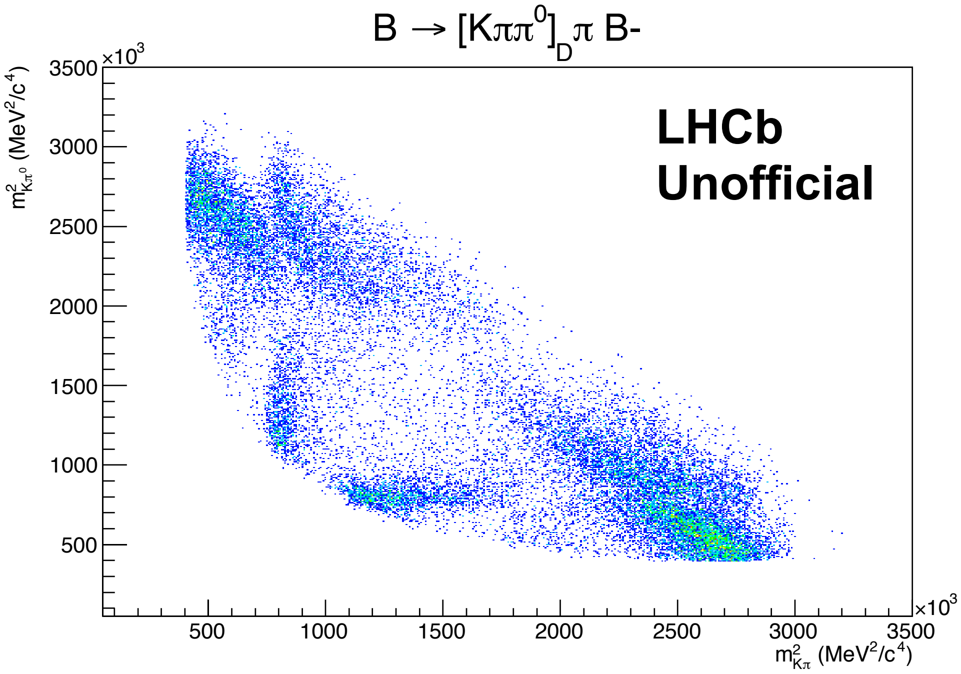


Dalitz Plots

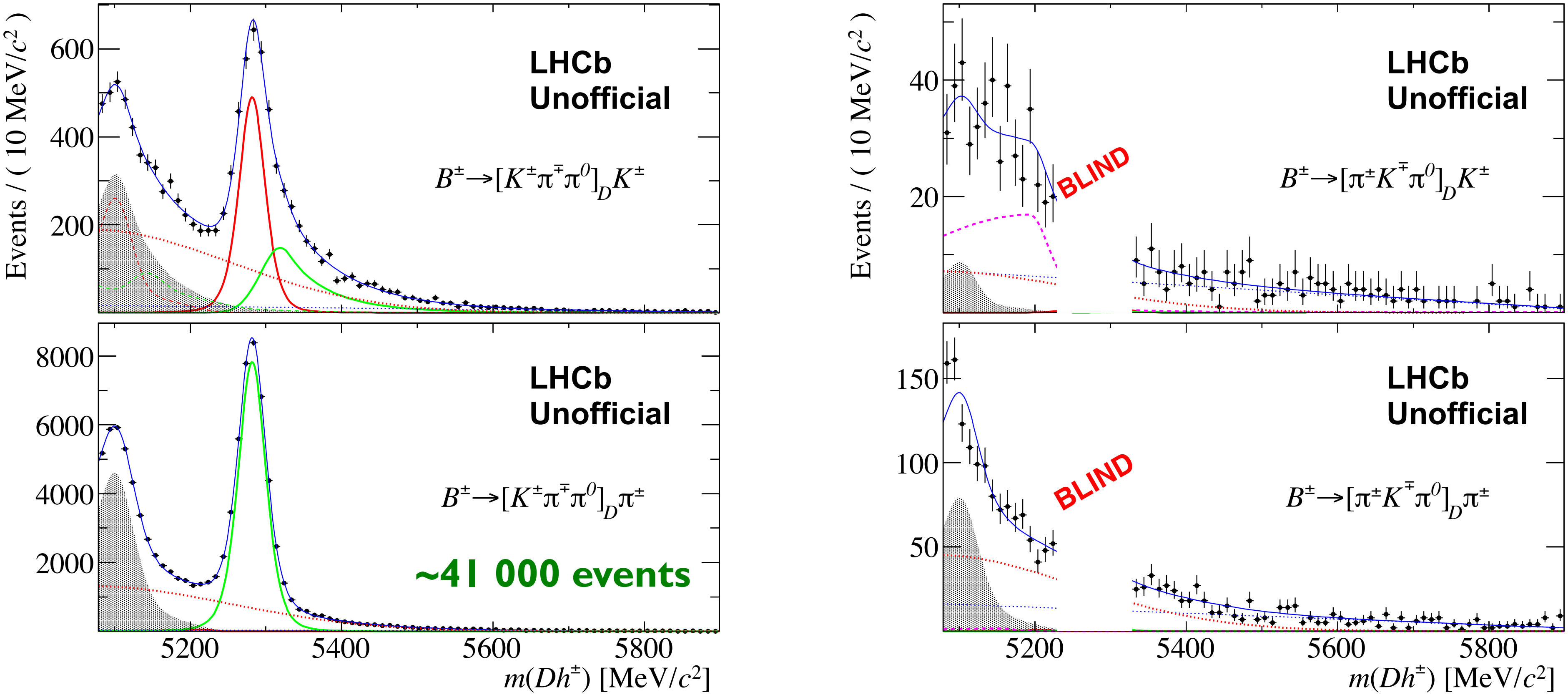
- Since the coherence factor is known, a full Dalitz analysis isn't required for the extraction of CP observables…
  - We can still look at the plots to make sure things look sensible

- Visible structure is seen representing K^* and ρ^0 resonances





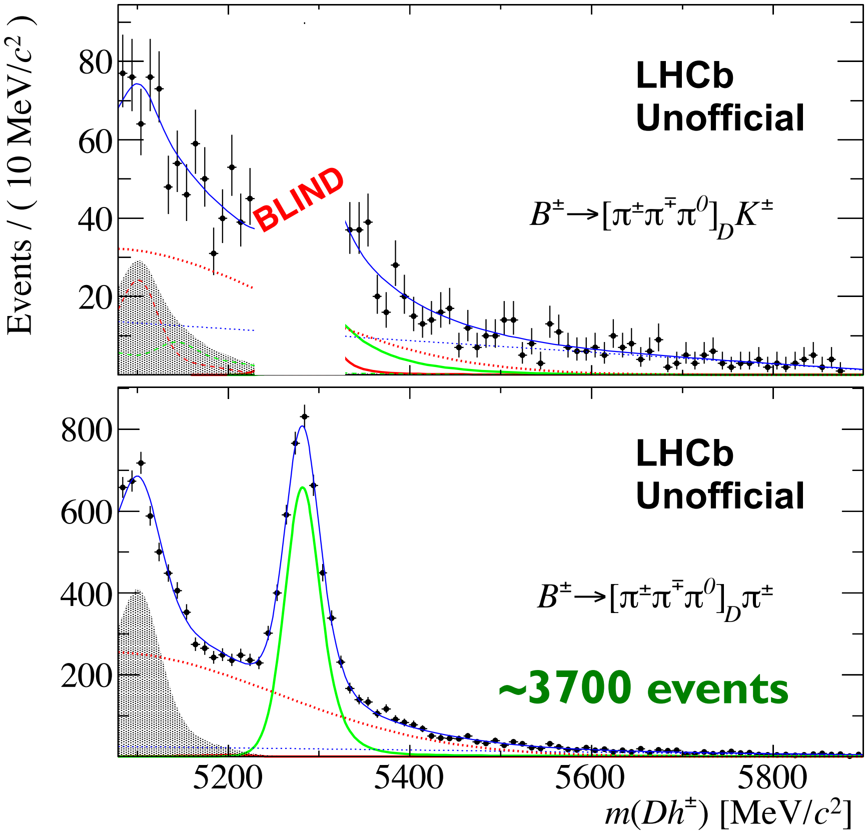
$K\pi\pi^0$



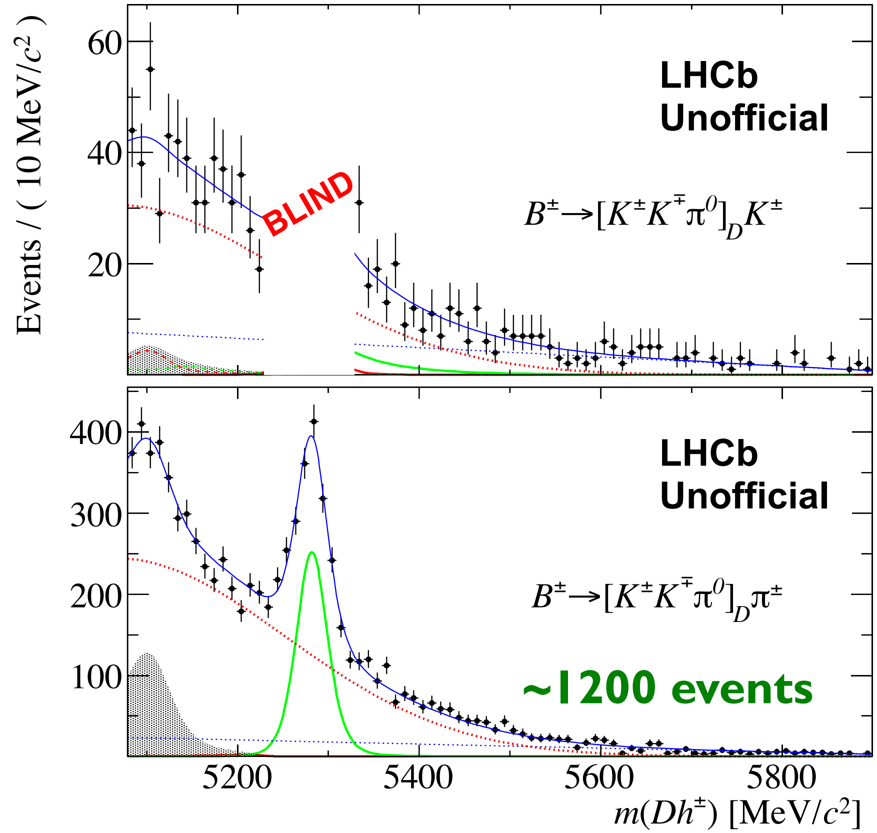
Favoured $K\pi\pi^0$ **Suppressed $K\pi\pi^0$**

- Using full 3 fb^{-1} of LHCb data set
- Prominent peaks are visible!
- Belle has seen evidence of the suppressed DK and Dπ modes (3.2σ level), but neither has been observed

$\pi\pi\pi^0$ & $KK\pi^0$



$\pi\pi\pi^0$



$KK\pi^0$

- Same BDT trained for $K\pi\pi^0$ has been used on these modes
- Potential first observations here as well!

Conclusions

- $B^{\pm} \rightarrow DK^{\pm}$ decays at LHCb offer a rich environment for CP violation measurements
  - Decay modes with a π^0 have yet to be fully exploited in γ measurements

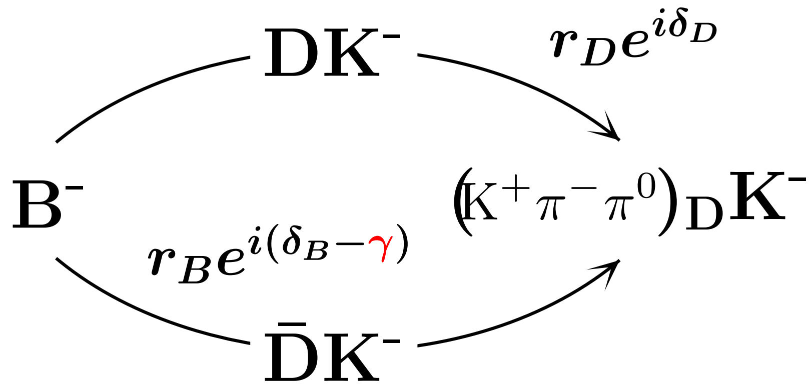
- Multivariate selection technique (BDT) has been effective at reducing backgrounds for these modes with a π^0

- Visible signals in the control modes for **$K\pi\pi^0$**, **$\pi\pi\pi^0$** and **$KK\pi^0$**
  - Potential for several first observations
  - After unblinding and measurement of CP observables, results will be incorporated into LHCb γ combination measurement

- CP violation analysis with a neutral pion being performed at a hadron collider experiment: exciting proof of principle!

Backup

Coherence Factor



$$\Gamma(B^\pm \to (K^\mp\pi^\pm\pi^0)_D K^\pm) \propto 1 + (r_B r_D^{K\pi\pi^0})^2 + 2R_{K\pi\pi^0} r_B r_D^{K\pi\pi^0} \cos(\delta_B - \delta_D^{K\pi\pi^0} \pm \gamma)$$