Measurement of γ with $B^{\pm} \rightarrow D(K_S^0 \pi^+ \pi^-) K^{\pm}$ at LHCb: technical and systematic challenges

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IOP HEP group meeting
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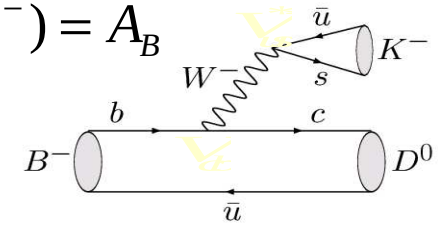
Outline

- Introduction
- Online event selection (trigger)
  - The LHCb trigger strategy
  - Difficulties triggering on the K_S^0

- Extracting γ from $B^{\pm} \rightarrow D(K_S^0 \pi^+ \pi^-) K^{\pm}$
  - I show a model independent method
    - For more details:
    - Giri et al. PRD **68**, 054018 (2003)
    - Bondar and Poluektov, Eur. Phys. J. C47, 347 (2006) and hep-ph/070326
  - Sensitivity study at LHCb

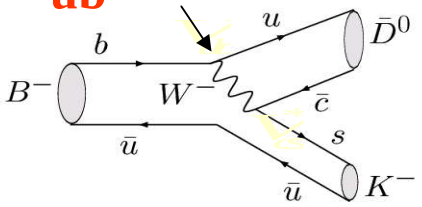
Introduction

$A(B^- \to D^0 K^-) = A_B$



$\mathbf{V_{ub} \propto e^{-i\gamma}}$

$A(B^- \to \overline{D}^0 K^-) = A_B r_B e^{i(\delta-\gamma)}$



- Can utilise the interference between **b→c ū s** and **b→c̄ u s** transitions in $B^{\pm} \to DK^{\pm}$ to extract γ
- No penguins → **Standard candle for γ**
- In $D(K_S^0\pi^+\pi^-)K^{\pm}$ case, γ and $\mathbf{r_B}$ must be extracted from fit to a **Dalitz plot**
  - Rich resonance structure & overlapping resonances

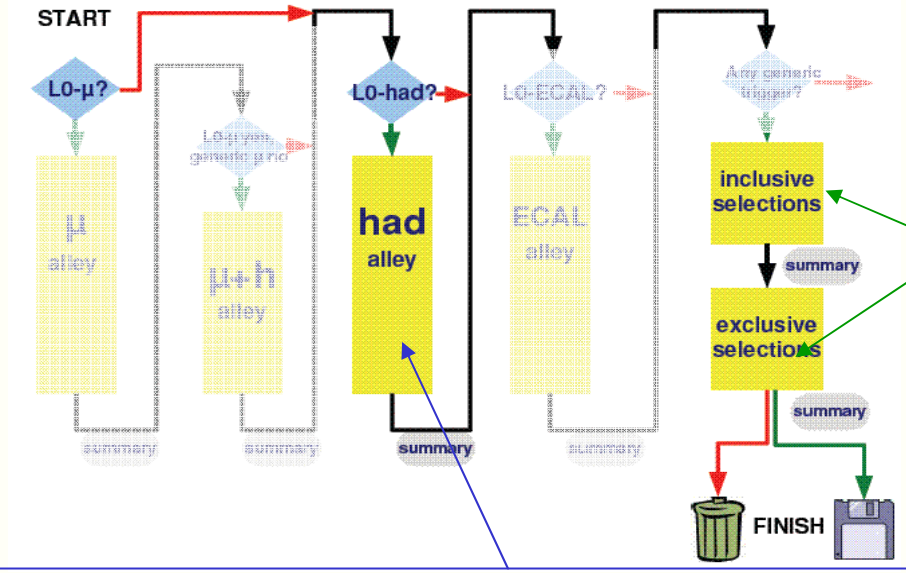
Triggering on K^0_s

The LHCb trigger strategy for hadronic decays

1. 10 MHz visible pp interaction rate

2. Level-0 hardware trigger selects high E_T events and reduces rate to 1 MHz.

   Level-0 has 50 % efficiency for this channel



5. HLT selections reconstruct specific topologies and decays

6. The output rate for all selections is ~2 kHz

   About 2 Hz for each exclusive decay of interest

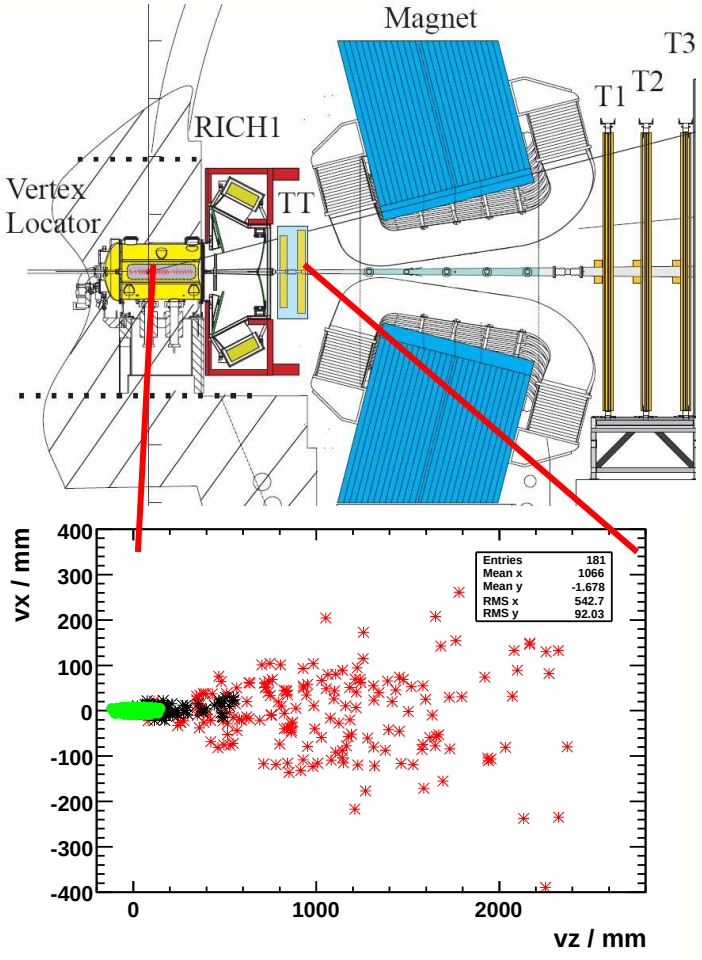
3. The Higher Level Trigger (HLT) runs on a CPU farm.

   Tracks in the vertex locator (VELO) are reconstructed

4. VELO tracks are **extended** to the trigger stations (long tracks).

   Final 30 kHz event rate after the HLT Alleys.

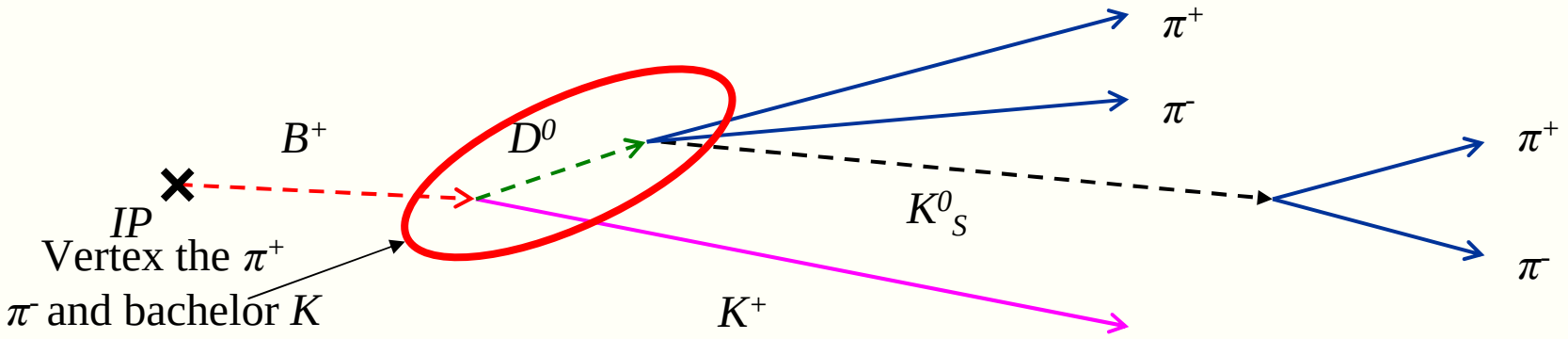
The K_s^0 problem



Decay vertex of downstream K_s^0(red) extended (black) and heavy flavour (green)

- **Tracks** from **D^0** and **$B^{\pm}$** decays originate in vertex locator
  - **Found easily**
  - Extended through magnet
- Most **K_s^0** decays are outside the vertex locator (downstream).
  - Daughters **not reconstructed** in trigger alleys
- A dedicated downstream tracking for K_s^0 :
  - **Too CPU intensive** to be run straight after alleys

Remedy



- Vertex the π^+, π^- and bachelor K^+
- **Topological cuts** on combination
- Preliminary **efficiency 80 -90 %** for offline selected events passing the hadron alley
- Background **rate reduced** by a factor of 15
- Then possible to reconstruct downstream tracks from K_s^0 and combine for exclusive selection

Ongoing work to ensure HLT selection will be in place for first data

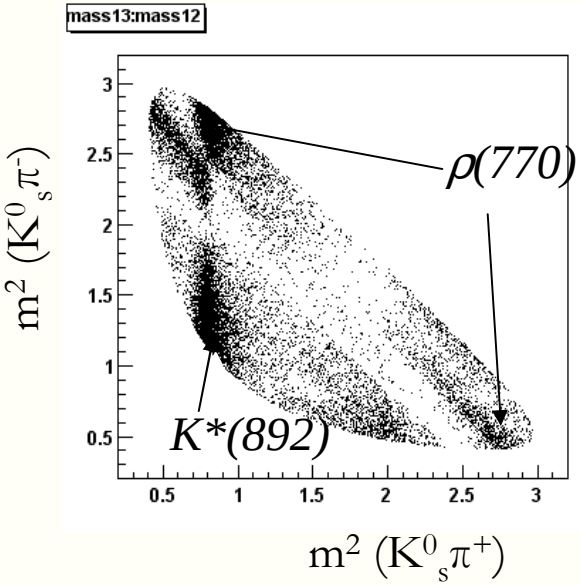
Extracting γ in a model independent way

The need for alternative methods to extract γ

- Determining γ with $\mathbf{B^{\pm} \rightarrow D(\ K_S^0 \pi^+ \pi^-) K^{\pm}}$
- Best measurements of γ dominated by statistical error
  - Un-binned analysis of the Dalitz plot
  - Must **select a model** for un-binned analysis
- **➔ Model dependence ←**

$$\phi_3 = (76^{+12}_{-13}(\text{stat}) \pm 4(\text{syst}) \pm 9(\text{model}))^{\circ}\ [Belle]$$

$$\gamma = (76^{+23}_{-24}(\text{stat+syst}))^{\circ}\ [BaBar] \qquad \text{Moriond 08}$$



- At LHCb, statistical error expected to be **7-12°** with the 2fb^{-1} in a nominal **year**
  - From unbinned maximum likelihood method, see Y. Li's talk
  - Exploits limited statistics well

However, model error likely to dominate within 1 year at LHCb

Binned, model independent method : Formalism

- Decay amplitude of the B

$$A(B^- \to D^0 K^-) = A_B$$
$$A(B^- \to \overline{D}^0 K^-) = A_B r_B e^{i(\delta-\gamma)}$$

- Partial width of the system

$$d\Gamma(B^- \to (K^0_S \pi^+ \pi^-)_D K^- = f^2(m_+^2, m_-^2) + r_B^2 f^2(m_-^2, m_+^2)$$
$$+2 r_B \, \mathrm{Re}[\, f(m_+^2, m_-^2) f^*(m_-^2, m_+^2) e^{-i(\delta_B-\gamma)}]$$

- Must integrate over a region of phase space

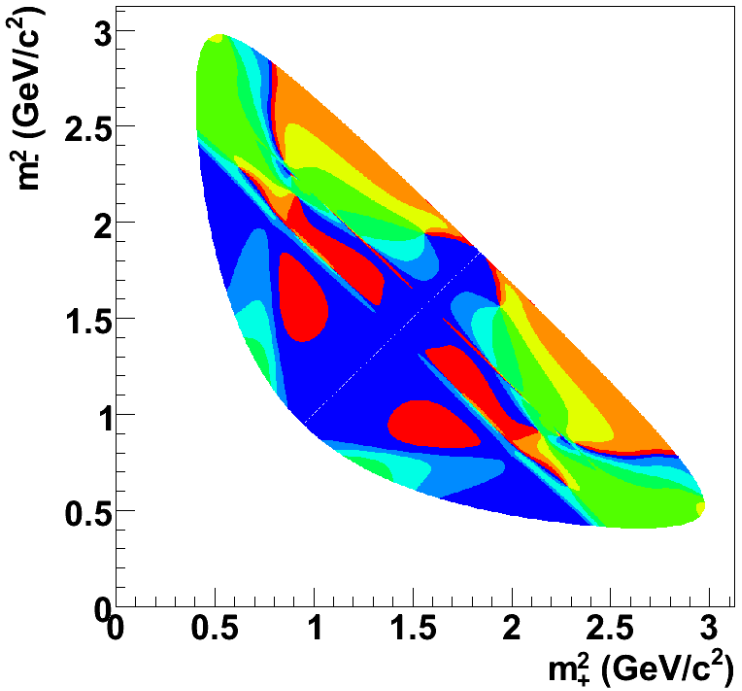
Integral of interference term can be written as :

$$c_i \cos(\delta_B - \gamma) + s_i \sin(\delta_B - \gamma)$$

$$\textit{where} \quad c_i = \int_i [f(m_+^2, m_-^2) f(m_-^2, m_+^2) \cos(\Delta\delta_D)] dp$$

$$s_i = \int_i [f(m_+^2, m_-^2) f(m_-^2, m_+^2) \sin(\Delta\delta_D)] dp$$

Sensitivity to γ is slightly reduced by the binning (80-90 % of unbinned method)

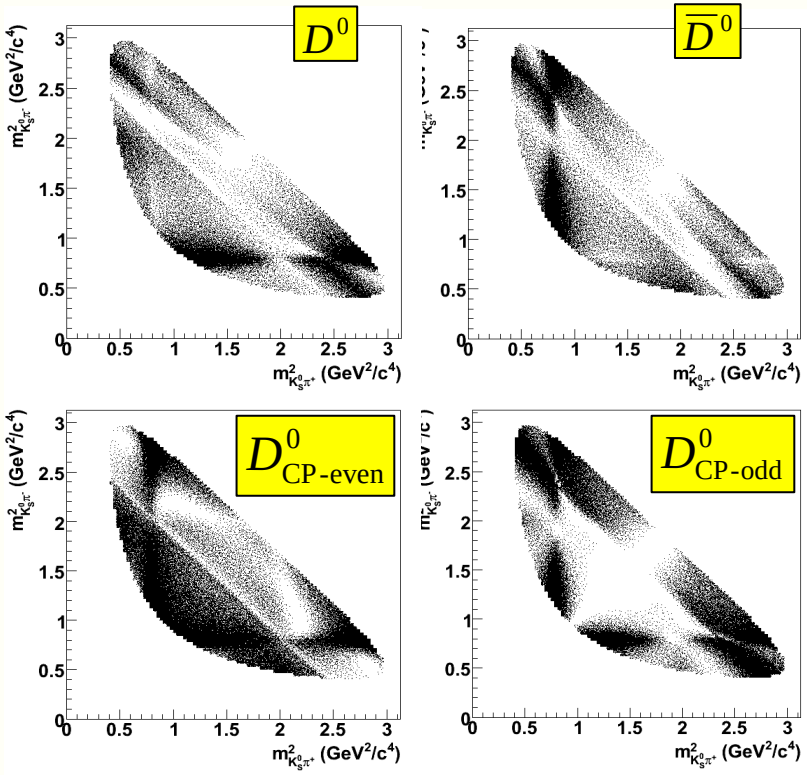


Partition of the Dalitz plot into **bins** defined in terms of the **strong phase difference** between symmetric points in Dalitz space

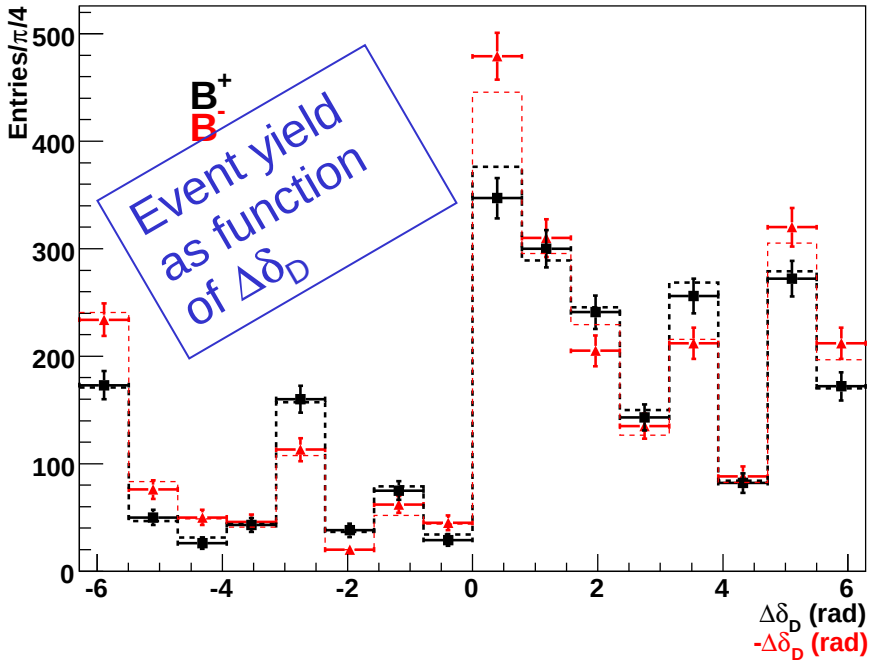
External inputs to fit

- Data from CLEO-c
  $e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0$
- Allows admixtures and gives information on strong phase
  - **Independent measurement of s_i, c_i**
- Dalitz structure determined from flavour specific D decays
- For now use the model described in hep-ex/0607104 (BaBar) to estimate parameters

CLEO-c replaces the model error with a 3°-5° systematic



Sensitivity at LHCb



Generated charge asymmetry (points).

The fit is shown by the dashed lines

The binning is the same as on slide 10 with δ_D offset by $\pi/8$ rad to simplify presentation

- Assume 5000 events per 2 fb^{-1}
  - Y. Li
  - Downstream K_s^0 included
- Toy samples generated with $\gamma = 60°$, $r_B = 0.1$, $\delta_B = 130°$
- Perform simultaneous fit to variables
  - $x = r_B \cos(\delta \pm \gamma)$
  - $y = r_B \sin(\delta \pm \gamma)$
- Plot shown without background or acceptance effects

Background

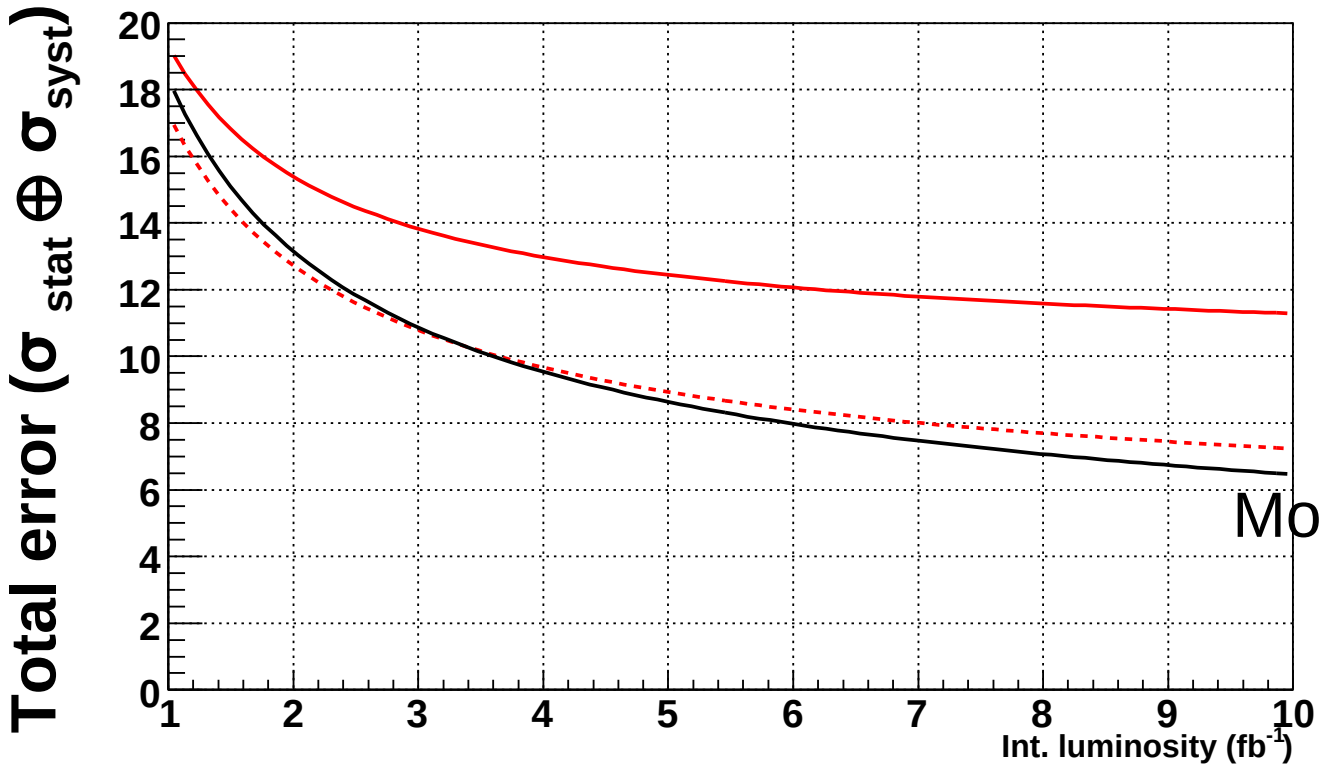
Backgrounds estimated from GEANT4 simulation

- $D^0(K_S^0\pi^+\pi^-)\pi^\pm$ (π mis-ID as K)
- Worst case combinatoric B/S<0.7

- $K^\pm$ mis-id rate can be determined from $D^{+*} \rightarrow D^0(K\pi)\pi^\pm$ to better than 1%
- Absolute combinatoric B/S will be determined from B and D mass sidebands

Scenario	$2\ fb^{-1}$ Mod. Independent σ_{stat}	$2\ fb^{-1}$ Mod. Dep. (LHCb-048-2007) σ_{stat}
No background	**8°**	6°
With background	**9-13°**	7-12°

Comparison with model dependent study



σ(model)=10°

σ(model)=5°

Model independent

Currently expected model error at LHCb is 10-15° (scales with $1/r_B$)

A model error on gamma of 5° is shown for comparison , may be possible with an improved model of the D Dalitz distribution

Conclusions

- Development of robust HLT for $B^{\pm} \rightarrow D(K_S^0 \pi^+ \pi^-) K^{\pm}$ is well advanced
  - K_S^0 decaying outside vertex detector requires novel strategies
- Complementary model independent analysis useful at high statistics
  - Binning definition consistent with CLEO-C
  - Error on γ in 1 nominal year 8-13°
- Statistical sensitivity of this mode to γ in LHCb lifetime 4-6°, dependent on background