Towards a model-independent measurement of γ through $B^{\pm}\rightarrow D(\rightarrow 4\pi)K^{\pm}$ decays with LHCb and CLEO-c

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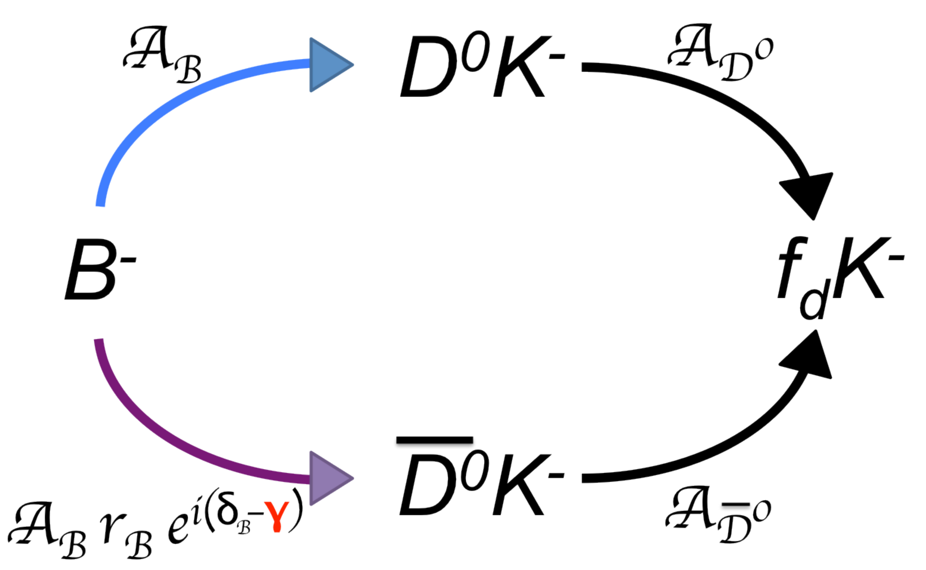
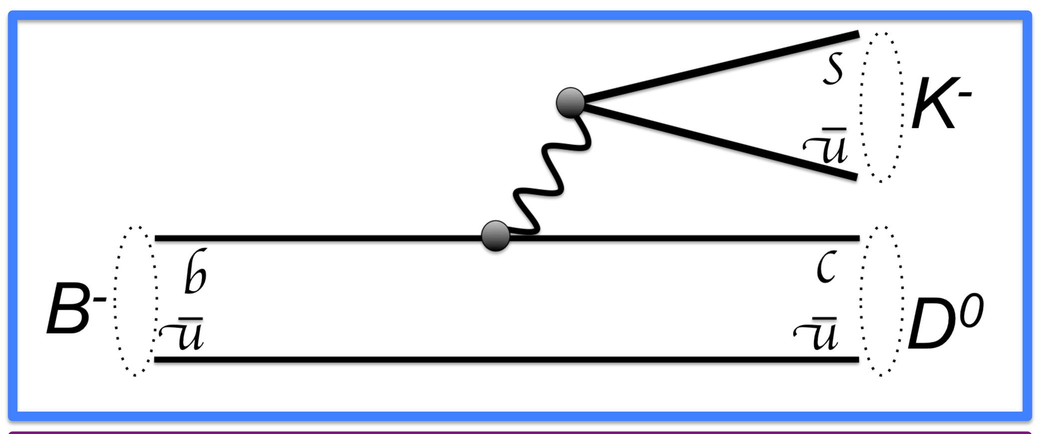
Measurement of CKM angle γ through interference in $B^{\pm}\rightarrow D(\rightarrow f_D)K^{\pm}$

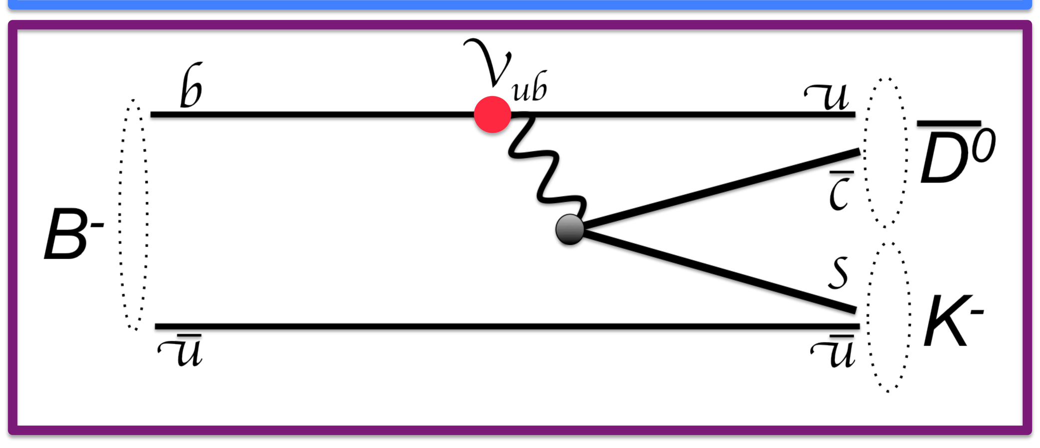


final state accessible to both D^0 and $\overline{D}^0$

$B^-\rightarrow D^0K^-$:



$B^-\rightarrow \overline{D}^0K^-$: colour surpressed



Partial decay width

$$d\Gamma(B\rightarrow D^0(\rightarrow f_D)K^-) \propto A_B^2\cdot\Big(A_{D^0}^2 + r_B^2 A_{\overline{D}^0}^2 + 2r_B\,\mathbb{R}(A_{D^0}A^*_{\overline{D}^0}\, e^{-i(\delta_B-\gamma)})\Big)dp$$

γ **becomes an observable** in the interference term

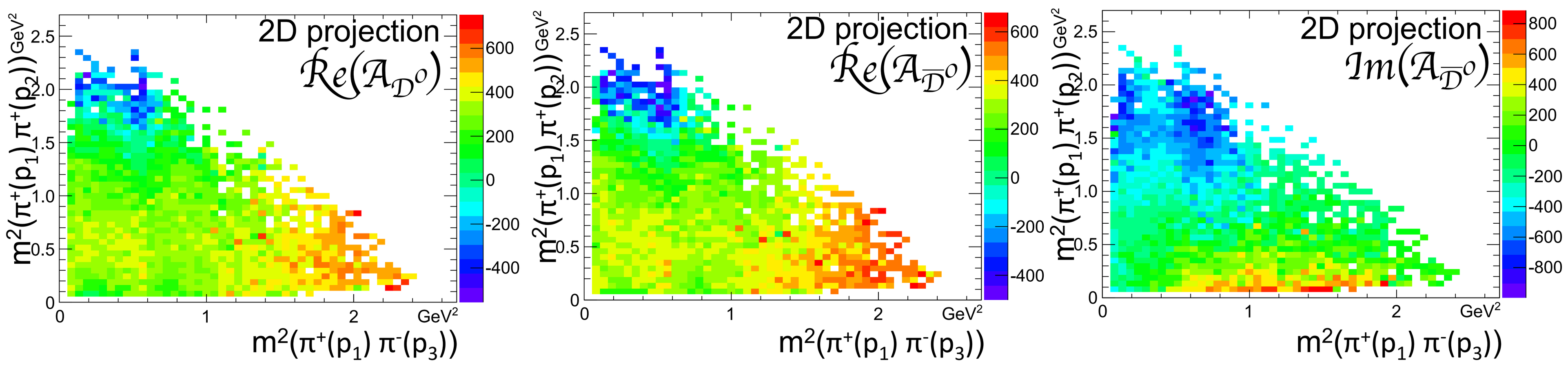
Reconstruction of the D mesons in self- conjugate final state $f_D = \pi^+(p_1)\,\pi^+(p_2)\,\pi^-(p_3)\,\pi^-(p_4)$

$$A_{\overline{D}^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4)) \overset{\text{CP-conjugation}^*}{=} A_{D^0}(\pi^+(-\vec{\mathbf{p}}_3)\pi^+(-\vec{\mathbf{p}}_4)\pi^-(-\vec{\mathbf{p}}_1)\pi^-(-\vec{\mathbf{p}}_2))$$

$$\frac{A_{D^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4))}{A_{\overline{D}^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4))} = \frac{|A_{D^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4))|}{|A_{\overline{D}^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4))|}\, e^{i\Delta\delta(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4))}$$

strong phase difference between A_{D^0} and $A_{\overline{D}^0}$

All amplitudes and phases depend on the point in phase space
→ **Dalitz plot analysis in 5 dimensions**



In order to extract **γ** the analysis has to be performed in bins of phase space.

Binned decay width:

$$d\Gamma_i \propto 2r_B\left[c_i\cos(\delta_B-\gamma)+s_i\sin(\delta_B-\gamma)\right]$$

$$c_i = \frac{1}{N}\int_{p_i}^{p_i+\Delta p} dp\,\frac{d\Phi}{dp}\,A_{D^0}\,\overline{A_{D^0}}\,\cos(\Delta\delta)$$

amplitude-weighted average of cos(Δδ)

$$s_i = \frac{1}{N}\int_{p_i}^{p_i+\Delta p} dp\,\frac{d\Phi}{dp}\,A_{D^0}\,\overline{A_{D^0}}\,\sin(\Delta\delta)$$

amplitude-weighted average of sin(Δδ)

(*) Assuming no CP-V in the D decays and neglecting 2nd order effects from charm mixing.

Model independent determination of c_i and s_i with CLEO-c using correlated D meson pairsfrom Ψ(3770) →DD

c_i : Reconstruct D⟶4π as flavour or CP eigenstate by using **opposite side tagging** ⟶ combine information of **CP ($M^{\pm}_i$)** and **flavour (K_i)** Dalizt plots

Ψ(3770)

Flavour/ CP eigenstate

($\pi^+(p_1)\,\pi^+(p_2)$ $\pi^-(p_3)\,\pi^-(p_4)$)

$$M_i^{\pm} = h_{CP\pm}\left(K_i \pm 2c_i\sqrt{K_iK_{\bar{i}}}+K_{\bar{i}}\right)$$

s_i : Reconstruct Ψ(3770)⟶(DD)⟶(4π)(4π') and use **interference effects between both possible decay paths**

Ψ(3770)

($\pi^+(p'_1)\,\pi^+(p'_2)$ $\pi^-(p'_3)\,\pi^-(p'_4)$)

($\pi^+(p_1)\,\pi^+(p_2)$ $\pi^-(p_3)\,\pi^-(p_4)$)

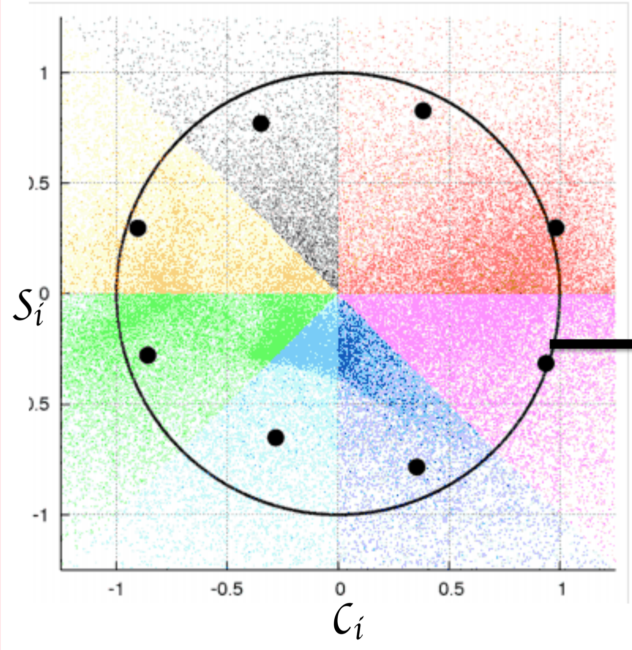
Event rate in i^th bin of first and j^th bin of second Dalitz plot:

$$M_{ij} = h_{corr}\left(K_iK_{\bar{j}}+K_{\bar{i}}K_j - 2\sqrt{K_iK_{\bar{j}}K_{\bar{i}}K_j}\,(c_ic_j+s_is_j)\right)$$

Model inspired binning

The highest sensitivity to γ can be obtained by using **bins with minimal variation of Δδ**.

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



colours correspond to bins of Δδ

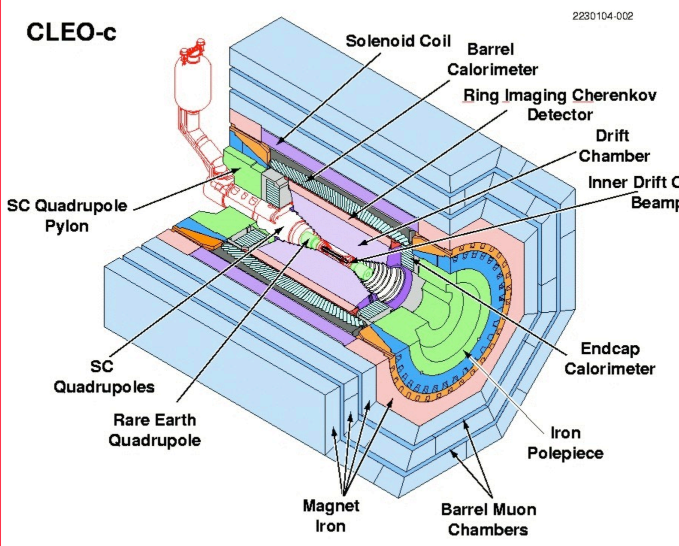
The more Δδ varies over a bin, the smaller $|c_i|$ and $|s_i|$.
$\langle c_i\rangle = 0.04$ $\langle s_i\rangle = -0.01$

Obtain Δδ by applying a model for $\mathcal{A}_{D^0}$ obtained from CLEO-c.

Note: The binning only influences **the sensitivity** of the γ measurement but **not the γ value itself**.

Analysis procedure for the future:

1. CLEO-c

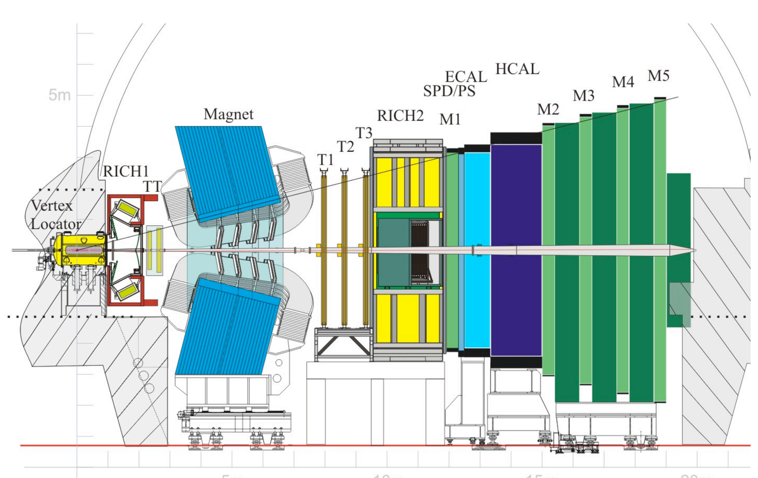


Measurement of c_i and s_i using

~ 9500 flavour tagged
~ 1000 CP tagged $D(\rightarrow 4\pi)$ events

and performing a 5 dimensional fit for each bin in phase space.

2. LHCb



Simultaneous fit of r_B, δ_B and γ in all bins of phase space using

a few 10^3 $B^{\pm}\rightarrow D(\rightarrow 4\pi)K^{\pm}$ events

and the c_i and s_i extracted from CLEO-c.

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