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

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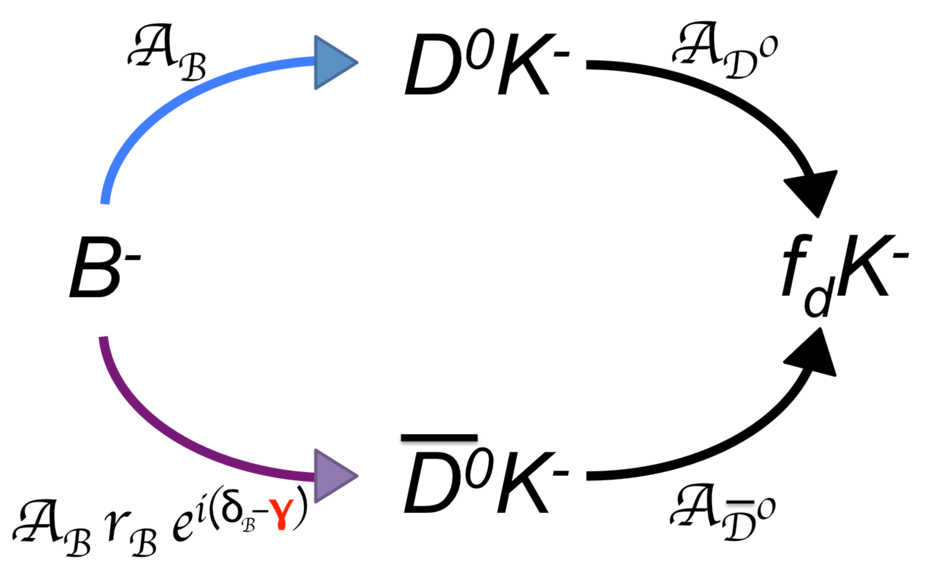
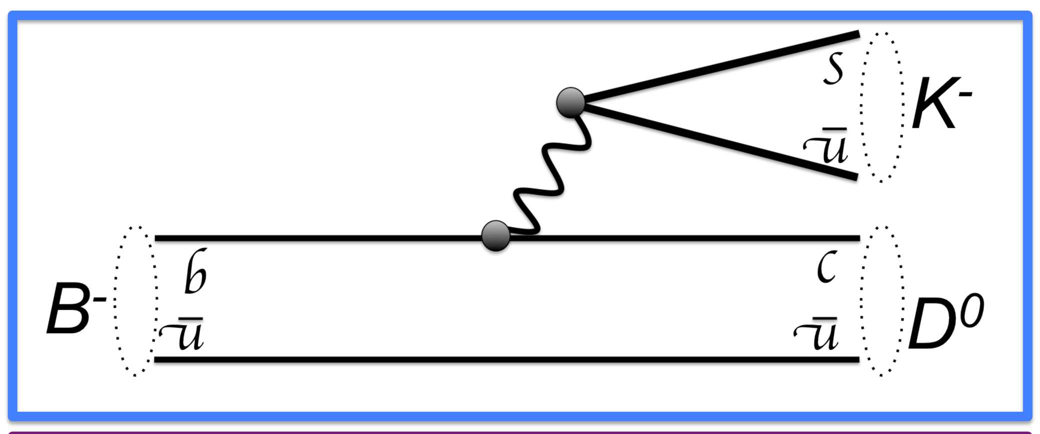
Measurement of CKM angle γ through interference in $B^{\pm}\to D(\to f_D)K^{\pm}$

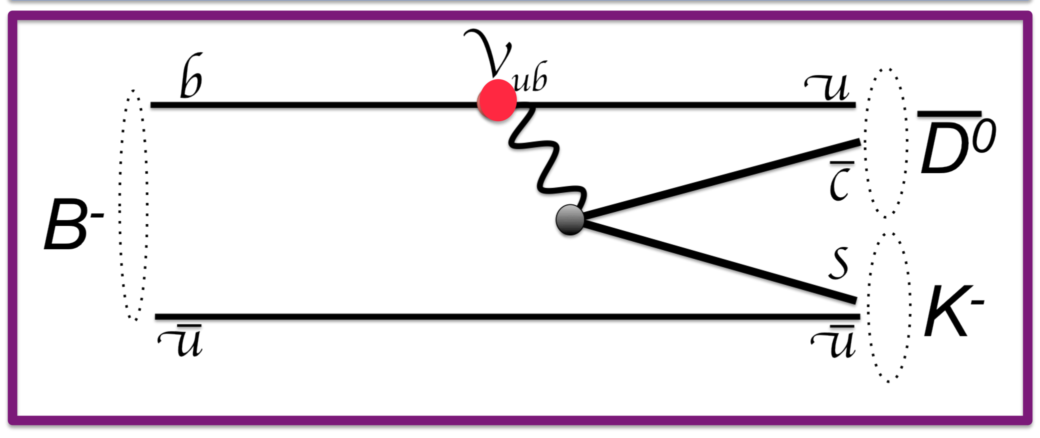


final state accessible to both D^0 and $\overline{D}^0$

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



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



Partial decay width

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

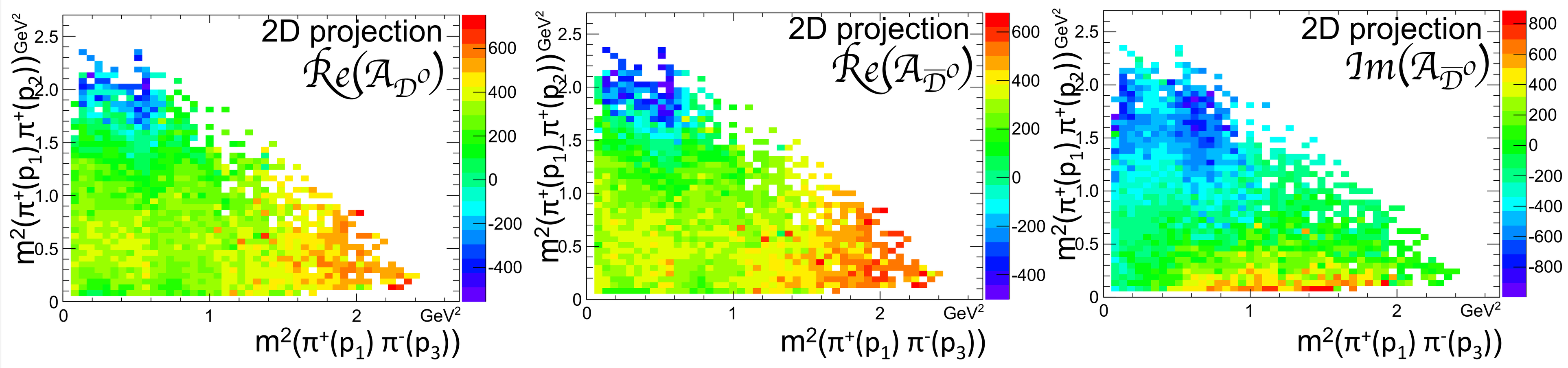
γ becomes an observable in the interference term

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

$$A_{\bar{D}^0}(\pi^+(\vec{p}_1)\pi^+(\vec{p}_2)\pi^-(\vec{p}_3)\pi^-(\vec{p}_4)) \overset{\text{CP-conjugation*}}{=} e^{i\Delta\delta(\vec{p}_1,\vec{p}_2,\vec{p}_3,\vec{p}_4)}A_{D^0}(\pi^+(-\vec{p}_3)\pi^+(-\vec{p}_4)\pi^-(-\vec{p}_1)\pi^-(-\vec{p}_2)) \equiv e^{i\Delta\delta}\,\overline{A_{D^0}}$$

$\Delta\delta$: 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:

$$\frac{d\Gamma}{dp_i+\Delta p}\propto 2r_B\left[c_i\cos(\delta_B-\gamma)+s_i\sin(\delta_B-\gamma)\right]$$

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

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

c_i : amplitude-weighted average of cos(Δδ)

s_i : 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 pairs from Ψ(3770)→DD

c_i : Reconstruct D→4π as flavour or CP eigenstate by using **opposite side tagging** and 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 between both possible decay paths**

Ψ(3770)

($\pi^+(p'_1)\,\pi^+(p'_2)$ $\pi^-(p'_3)\,\pi^-(p'_4)$) ($\pi^+(p_1)\,\pi^+(p_2)$ $\pi^-(p_3)\,\pi^-(p_4)$)

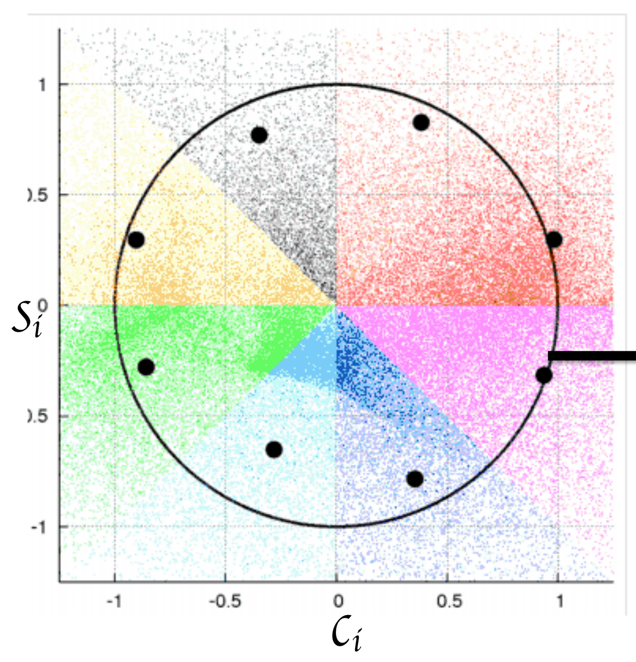
Event rate in i^{th} bin of first and j^{th} bin of second Dalitz plot:

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

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

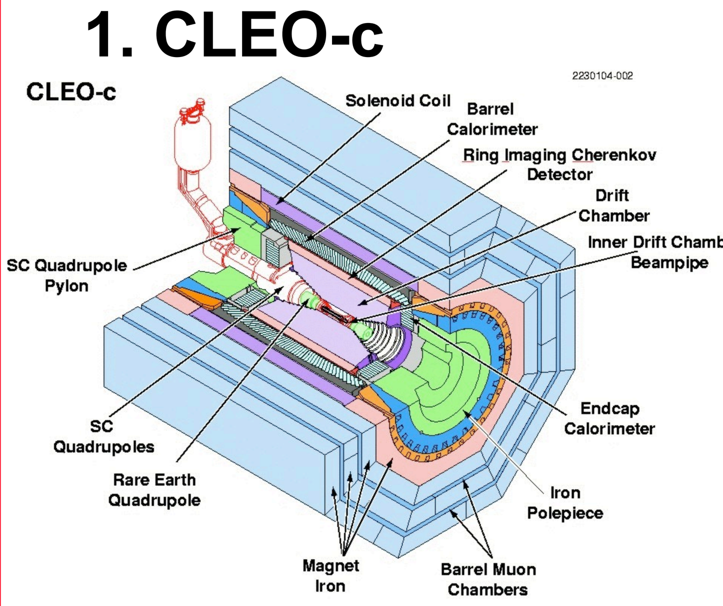
The more Δδ varies over a bin, the smaller $|c_i|$ and $|s_i|$.
$<c_i>$ = 0.04 $<s_i>$ = -0.01

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

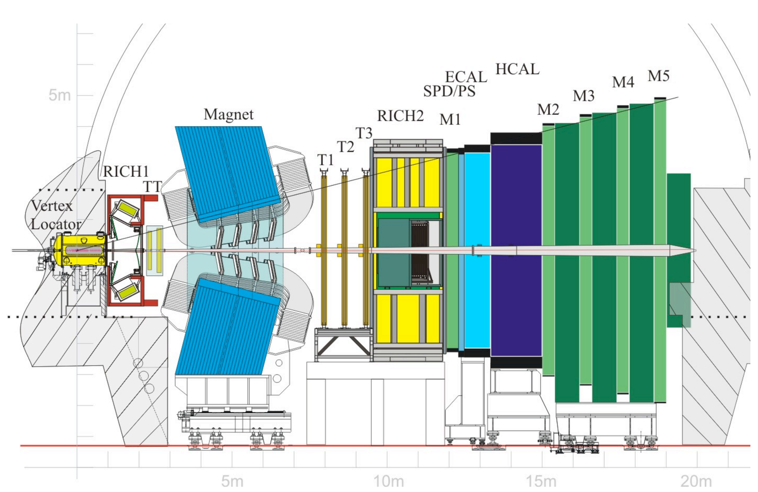


Measurement of c_i and s_i using

~ 9500 flavour tagged
~ 1000 CP tagged $D(\to 4\pi)$ 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 $B^{\pm}\to D(\to 4\pi)K^{\pm}$ events

and the c_i and s_i extracted from CLEO-c.

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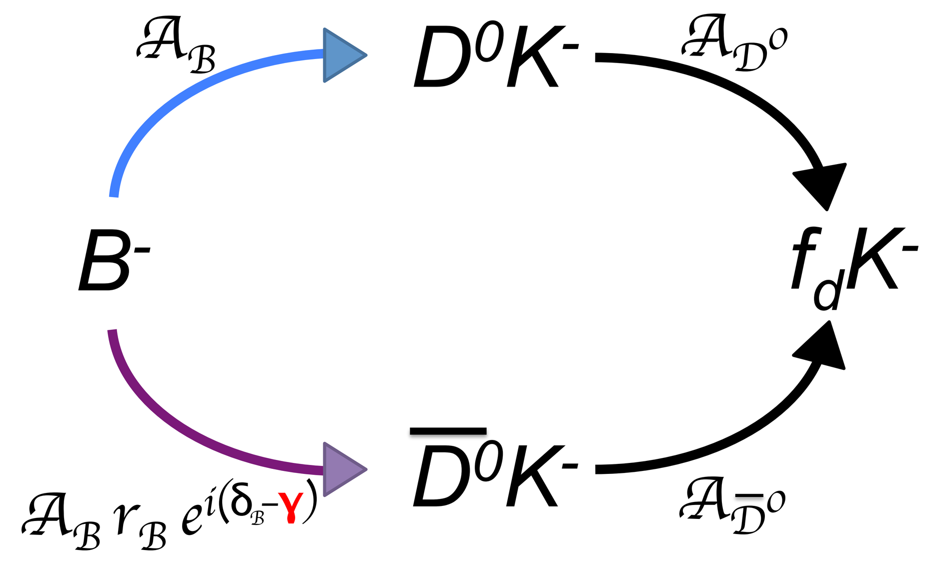
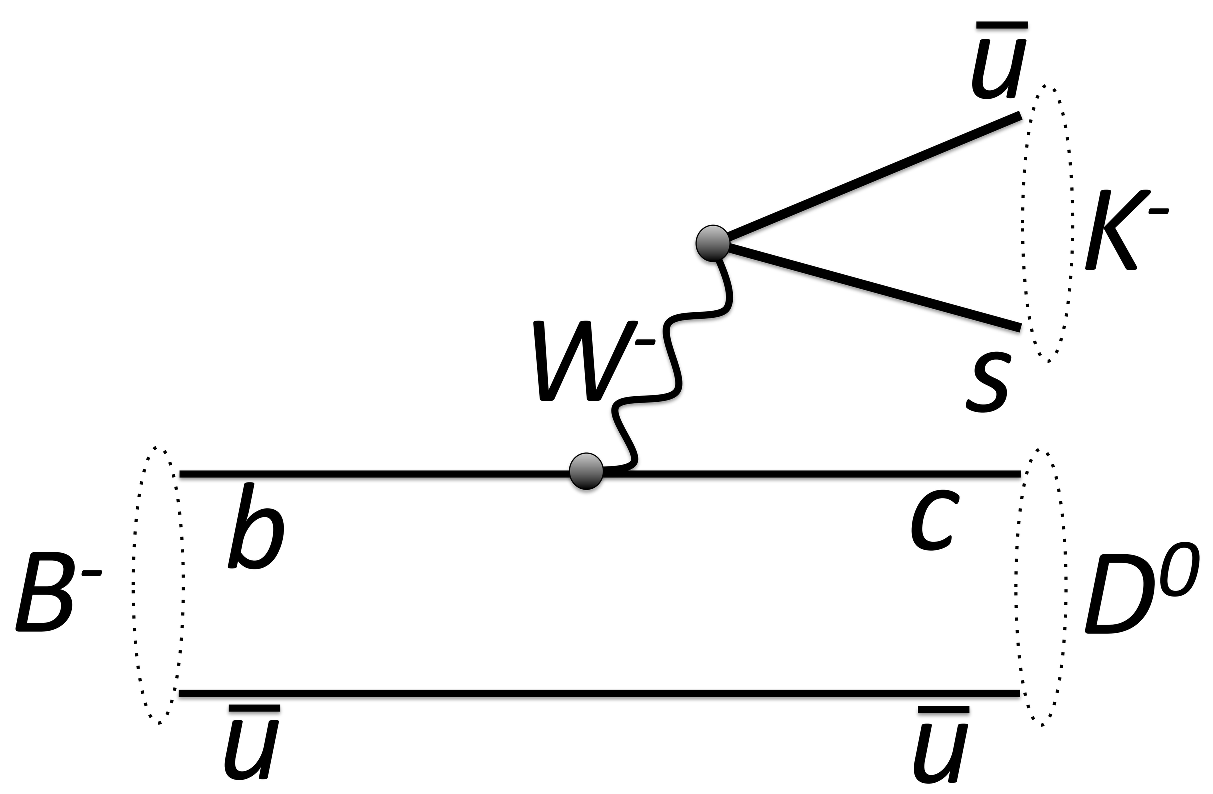
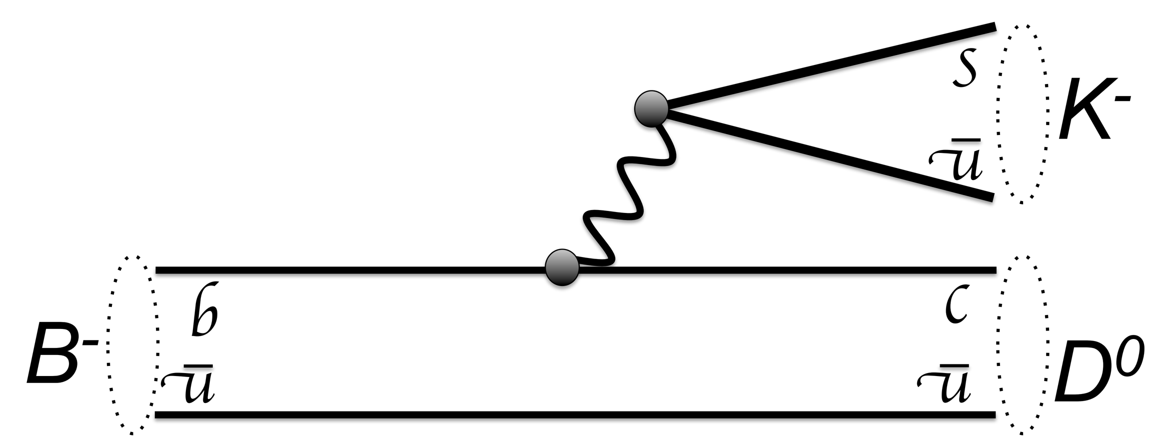
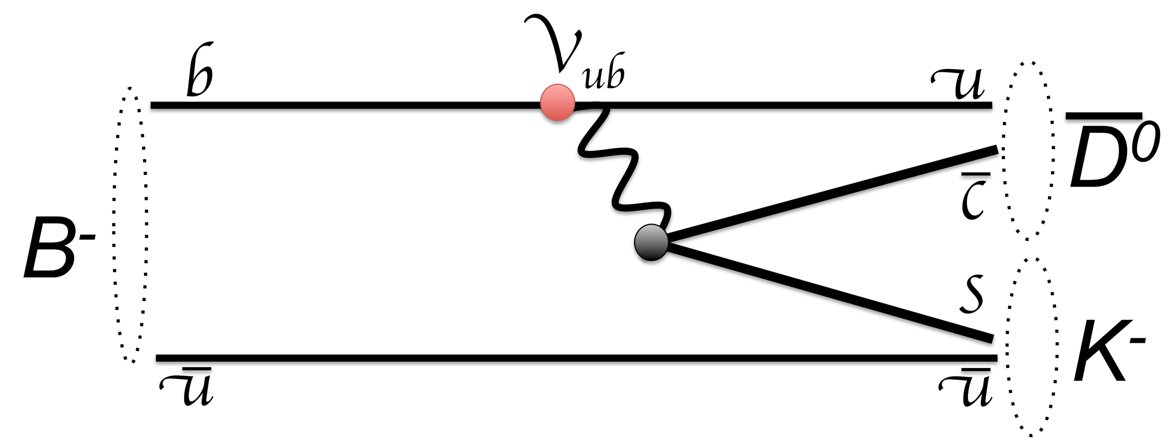
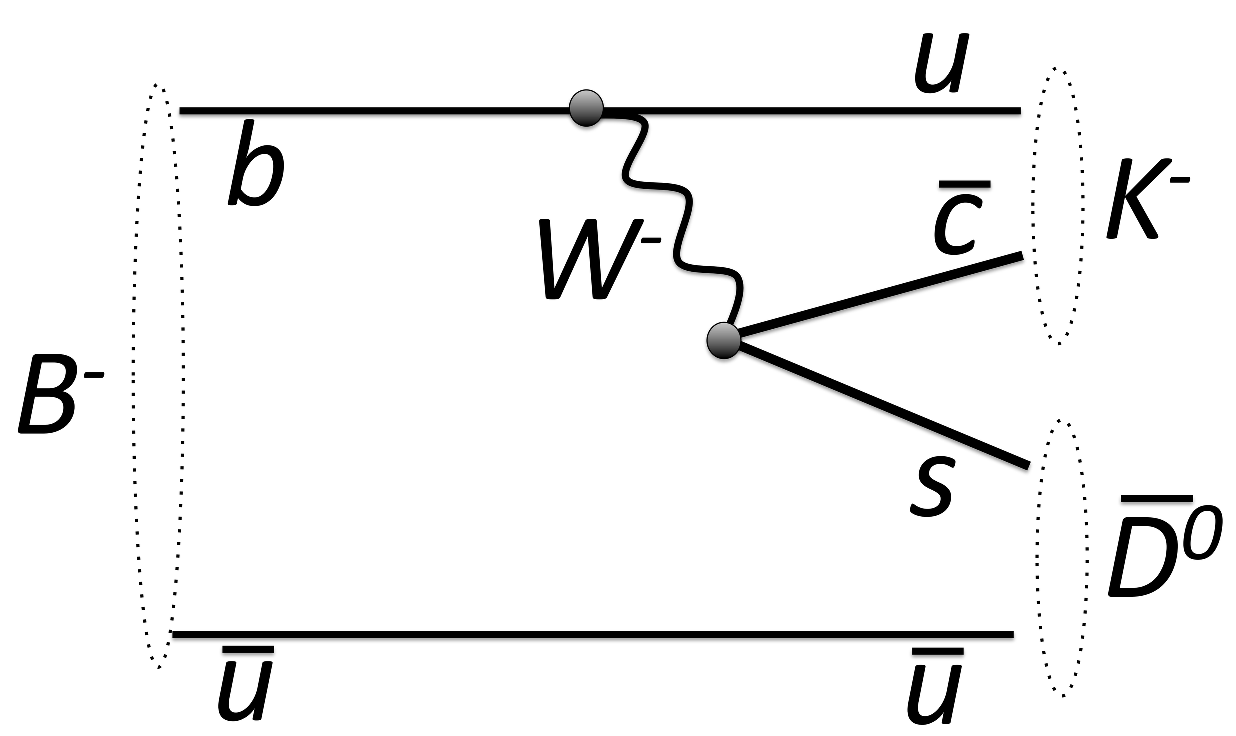
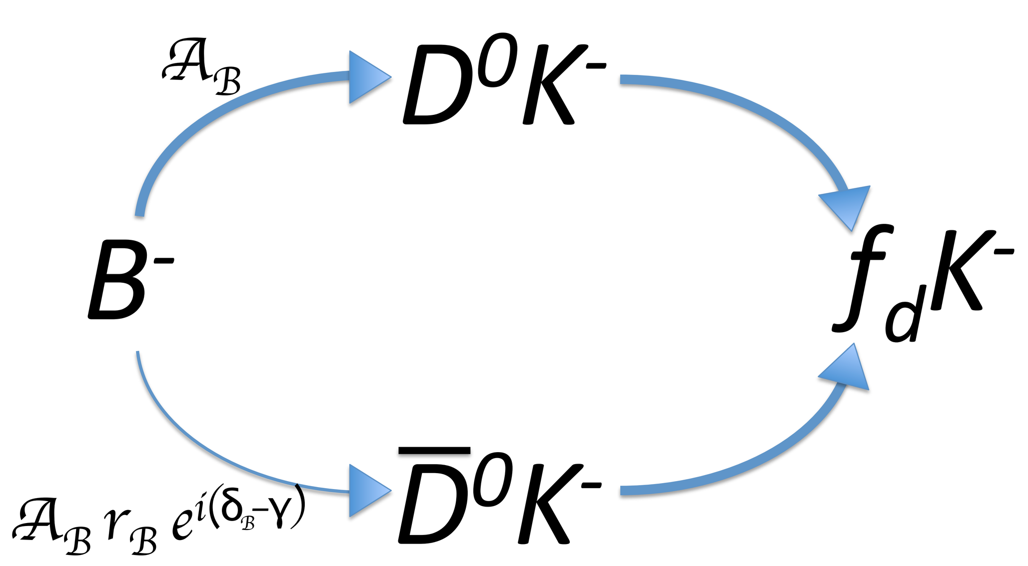

$\mathcal{A}_B$
D^0K^-
$\mathcal{A}_{D^0}$
B^-
f_dK^-
$\mathcal{A}_B\, r_B\, e^{i(\delta_B-\gamma)}$
$\bar{D}^0K^-$
$\mathcal{A}_{\bar{D}^0}$


$\bar{u}$
K^-
W^-
s
B^-
b
c
D^0
$\bar{u}$
$\bar{u}$


s
K^-
$\bar{u}$
B^-
b
c
D^0
$\bar{u}$
$\bar{u}$


b
V_{ub}
u
$\bar{D}^0$
$\bar{c}$
B^-
s
K^-
$\bar{u}$
$\bar{u}$


b
u
W^-
$\bar{c}$
K^-
B^-
s
$\bar{D}^0$
$\bar{u}$
$\bar{u}$


$\mathcal{A}_B$
D^0K^-
B^-
f_dK^-
$\mathcal{A}_B\, r_B\, e^{i(\delta_B-\gamma)}$
$\bar{D}^0K^-$