

New kinematic weighting algorithm for CP asymmetries in charm decays

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LHCb Collaboration

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1 Introduction

- Asymmetries at the LHCb

2 Analysis

- RapidSim
- Particle Gun

3 Conclusions



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We study CP asymmetries in the following charm decays

$$D^{*+} \rightarrow D^0 \pi^+ \text{ and } D^{*-} \rightarrow \bar{D}^0 \pi^-,$$
$$D^0 \rightarrow K^- K^+ \text{ and } D^0 \rightarrow \pi^- \pi^+$$

At LHCb we observe:

- CP asymmetry \rightarrow Differences in matter and anti-matter decays
- Production asymmetry \rightarrow Differences in $D^{*\pm}$ production
- Detection asymmetry \rightarrow Differences in π_s^\pm detection

\rightarrow We mainly focus on CP and detection asymmetries throughout this project



→ At an experiment our physical observable is the total asymmetry

$$A_{\text{total}} = \frac{A_{CP} + A_D}{1 + A_{CP}A_D} \approx A_{CP} + A_D + \mathcal{O}(10^{-6}),$$

$$A_D = \frac{\int d\vec{p} N(\vec{p}) A(\vec{p})}{\int d\vec{p} N(\vec{p})} \rightarrow \text{Integrated detection asymmetry}$$

→ We can estimate the total asymmetry through

$$A_{\text{total}} = \frac{N_+ - N_-}{N_+ + N_-}$$

→ We define the total asymmetry difference

$$\Delta A_{\text{total}} = A_{\text{total}}^{KK} - A_{\text{total}}^{\pi\pi} = \Delta A_{CP} + \Delta A_D$$

How can we calculate ΔA_{CP} ?

- We can equalize D^0 kinematic distributions for $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decay modes
- The following weighting function allows us to do that

$$Q(\vec{p}_{D^*}, \vec{p}_{\pi_s}) \simeq \frac{\Gamma_{D^0}^{\pi\pi}(\vec{p}_{D^*} - \vec{p}_{\pi_s}) + \Gamma_{\bar{D}^0}^{\pi\pi}(\vec{p}_{D^*} - \vec{p}_{\pi_s})}{\Gamma_{D^0}^{KK}(\vec{p}_{D^*} - \vec{p}_{\pi_s}) + \Gamma_{\bar{D}^0}^{KK}(\vec{p}_{D^*} - \vec{p}_{\pi_s})}$$

→ The association with π_s includes detection asymmetry to the weighting function \Rightarrow **We introduce bias!**



Asymmetries at the LHCb

→ We introduce a new weighting technique

$$Q(\vec{p}_{D^0}) \simeq \frac{\Gamma_{D^0}^{\pi\pi}(\vec{p}_{D^0}) + \Gamma_{\bar{D}^0}^{\pi\pi}(\vec{p}_{D^0})}{\Gamma_{D^0}^{KK}(\vec{p}_{D^0}) + \Gamma_{\bar{D}^0}^{KK}(\vec{p}_{D^0})} \rightarrow \text{We eliminate the detection asymmetry}$$

→ We effectively equalize the distributions $\Rightarrow \Delta A_D = 0$

→ Now our physical observable can give us useful results!

$$\Delta A_{\text{total}} = \Delta A_{CP}$$

However:

- Such candidates were discarded in Run-2
- We do not have enough statistics from Run-3

→ We resort to MC data to test the new weighting technique



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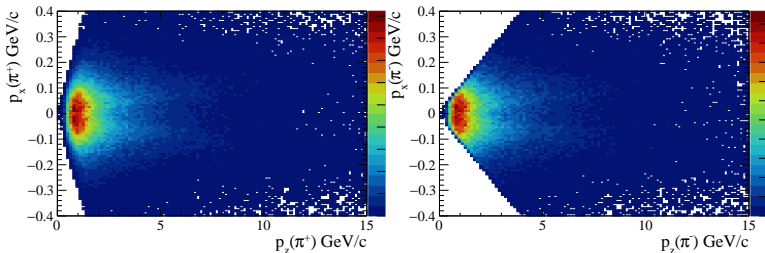
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→ We generate data using RapidSim and introduce:

- Different CP asymmetries for $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decay modes ($A_{CP}^{KK} = 0.1$, $A_{CP}^{\pi\pi} = 0.2$, $\rightarrow \Delta A_{\text{total}} = -0.1$)
- The same momentum-dependent detection asymmetry $A_D(\vec{p})$
→ The integrated detection asymmetries are different for the two samples

→ We exclude negative $\pi_s \Rightarrow$ Large detection asymmetry



→ We calculate the weighting function before and after the introduction of the detection asymmetry

- Before: Not associated with $\pi_s \Rightarrow$ New weighting technique
- After: Associated with $\pi_s \Rightarrow$ We introduce bias

Technique		Weighted	Unweighted
Not associated	ΔA_{total} Deviation (σ)	-0.09845 ± 0.00073 2.12	-0.08303 ± 0.00072 23.6
Associated with π_s	ΔA_{total} Deviation (σ)	-0.09578 ± 0.00073 5.78	

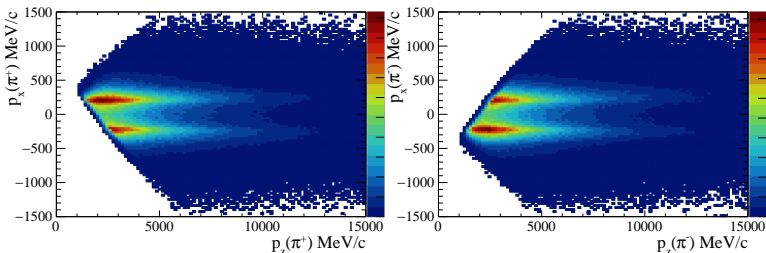
- The unweighted calculation is wrong $\rightarrow \Delta A_D \neq 0$
- The weighting function with π_s association (i.e., with detection asymmetry included) yields a biased result
- The new weighting technique (no detection asymmetry) allows us to keep events associated with large $A_D(\vec{p}) \Rightarrow$ **More statistics!**



Particle Gun

→ We use Particle Gun data for a more realistic scenario.

- We do not introduce CP asymmetry
- There is detection asymmetry due to the magnet polarity



→ The new weighting technique should yield $\Delta A_{\text{total}} = 0$

Technique		Weighted	Unweighted
Not associated	ΔA_{total} Deviation (σ)	-0.000084 ± 0.000262 0.32	-0.000015 ± 0.000262 0.057
Associated with π_s	ΔA_{total} Deviation (σ)	-0.000036 ± 0.000262 0.14	

- The effect of A_D is small
- The asymmetries cancel out after averaging both magnet polarities
- The weighting technique needs to be investigated further

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Thank you for your attention!
Questions?

