



Study of a new kinematic weighting algorithm for the measurement of CP asymmetries in charm decays

LHCb Collaboration

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4th Week
03/06/2023 - 07/07/2023

1 Introduction

We introduce a new TBranch to the TTree which includes randomly distributed values for the soft π charge.

```

1   TRandom3* random = new TRandom3();
2   random->SetSeed();
3
4   auto dataFramesPi = dataFrame.Define(
5       "sPi_C", [random](){
6           return (random->Uniform() < 0.5) ? -1 : 1;
7       }
8   );

```

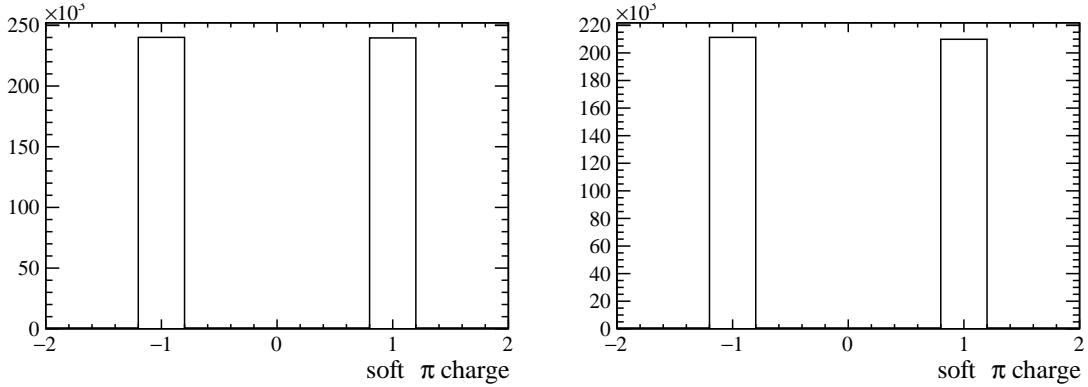


Figure 1: Initial soft π charge distributions for $D^0 \rightarrow K^- K^+$ (left) and $D^0 \rightarrow \pi^- \pi^+$ (right).

Subsequently, CP and detection asymmetries are introduced to filter out events and to emulate what we observe at LHCb. For the CP asymmetry we keep all π^+ events and we filter out π^- events according to the following probability:

$$P(\pi^-) = 1 - \frac{1 - A_{CP}}{1 + A_{CP}} \quad (1)$$

```

1   auto dataFrameCP = dataFramesPi.Filter(
2       [random, asymmetry](const int& sPi_C){
3           double probability;
4           probability = 1.0 - (1.0 - asymmetry)/(1.0 + asymmetry);
5
6           if (sPi_C == -1 && random->Uniform() < probability){
7               return false;
8           }
9           return true;
10      }, {"sPi_C"}
11  );

```

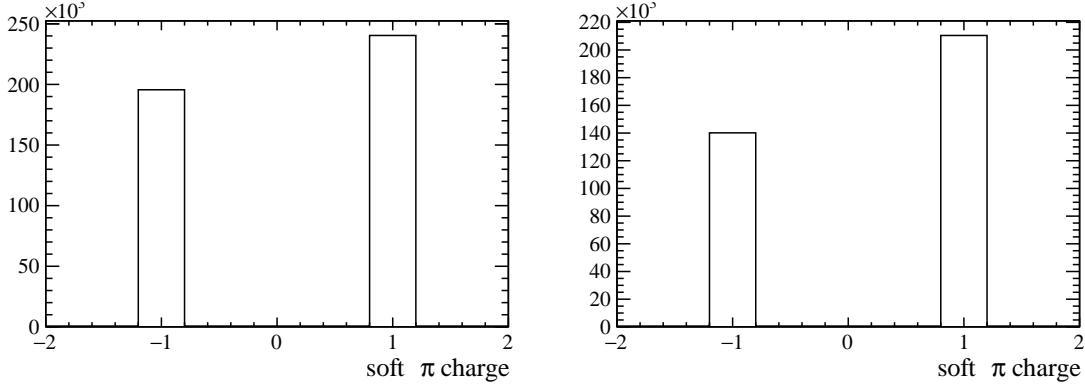


Figure 2: Soft π charge distributions for $D^0 \rightarrow K^- K^+$ (left) and $D^0 \rightarrow \pi^- \pi^+$ (right) after introducing a CP asymmetry.

Following the CP asymmetry, we begin to inject a detection asymmetry with kinematic dependence. Namely, we define a line in the $p_x - p_z$ plane and filter out events according to the p_x value of the soft π .

```

1   double slope = 0.1;
2   auto dataFrameDetection = dataFrameCP.Filter([slope](int& sPi_C, double& sPi_PX, double& sPi_PZ){
3       if (sPi_C == -1 && (std::abs(sPi_PX) > slope*sPi_PZ)){
4           return false;
5       }
6       return true;
7   }, {"sPi_C", "sPi_PX", "sPi_PZ"});
8 }
```

In order to acquire the *integrated detection asymmetry* we have to perform the following integrals

$$A_D = \frac{\int d\vec{p} N(\vec{p}) A_D(\vec{p})}{\int d\vec{p} N(\vec{p})} \quad (2)$$

where each integral is accompanied with an error \sqrt{N} where N is the total number of entries used for the calculation.

The total asymmetry can be measured using

$$A_{\text{total}} = \frac{N^+ - N^-}{N^+ + N^-} \quad (3)$$

and the error can be estimated using the standard error propagation

$$\sigma A_{\text{total}}^2 = \left(\frac{\partial A_{\text{total}}}{\partial N^+} \sigma N^+ \right)^2 + \left(\frac{\partial A_{\text{total}}}{\partial N^-} \sigma N^- \right)^2 \quad (4)$$

However, we can use

$$A_{\text{total}} = \frac{A_{CP} + A_D}{1 + A_{CP} A_D} \quad (5)$$

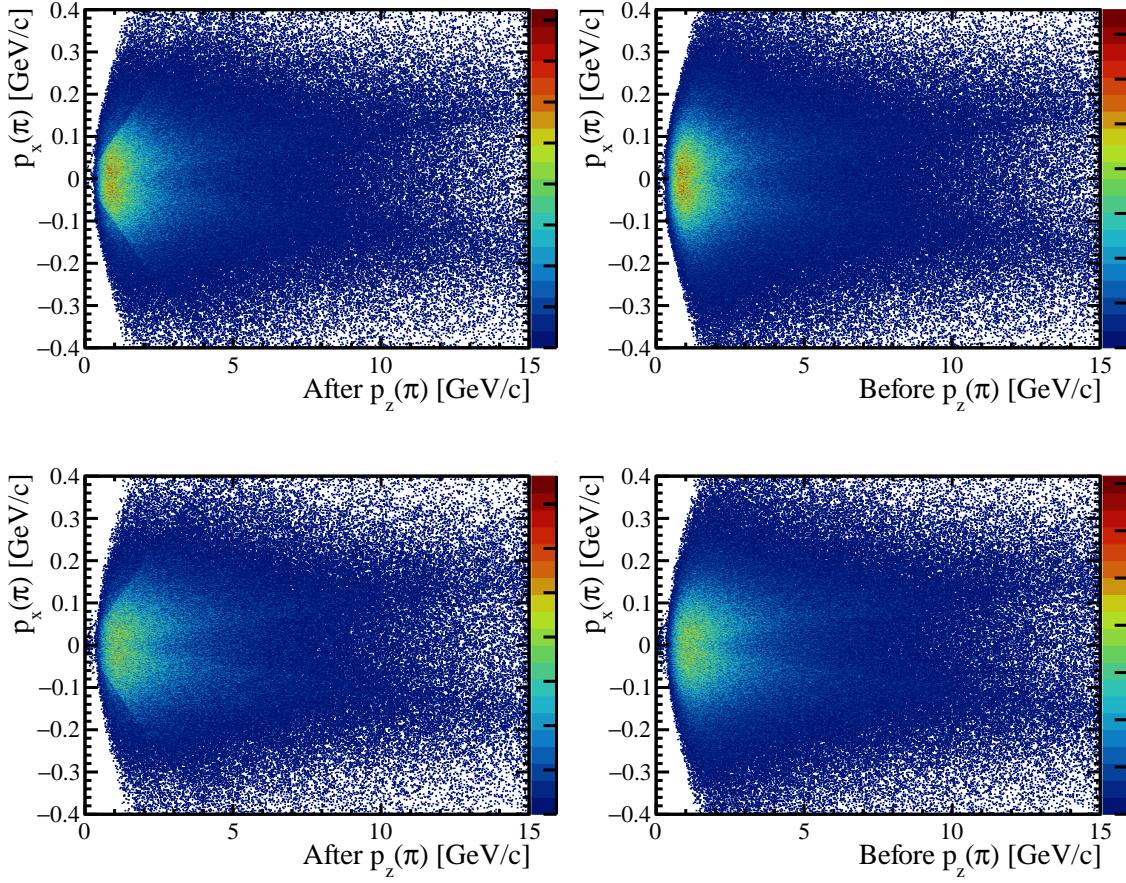


Figure 3: Soft π $p_x - p_z$ plane for $D^0 \rightarrow K^-K^+$ (top) and $D^0 \rightarrow \pi^-\pi^+$ (bottom) before and after introducing detection asymmetry.

to estimate the expected total asymmetry, where A_D is the integrated detection asymmetry.

We present the asymmetry results for both decays in the following tables:

Asymmetry	Expected	Calculated
A_{CP}	0.1	0.0998 ± 0.0012
A_D	0.0633 ± 0.0019	0.0688 ± 0.0016
A_{total}	0.1677 ± 0.0016	$0.1621 + / - 0.0014$

Table 1: Asymmetries for $D^0 \rightarrow K^-K^+$ TTree.

Asymmetry	Expected	Calculated
A_{CP}	0.2	0.2005 ± 0.0016
A_D	0.04711 ± 0.0024	0.0561 ± 0.0018
A_{total}	0.2533 ± 0.0017	0.2453 ± 0.0017

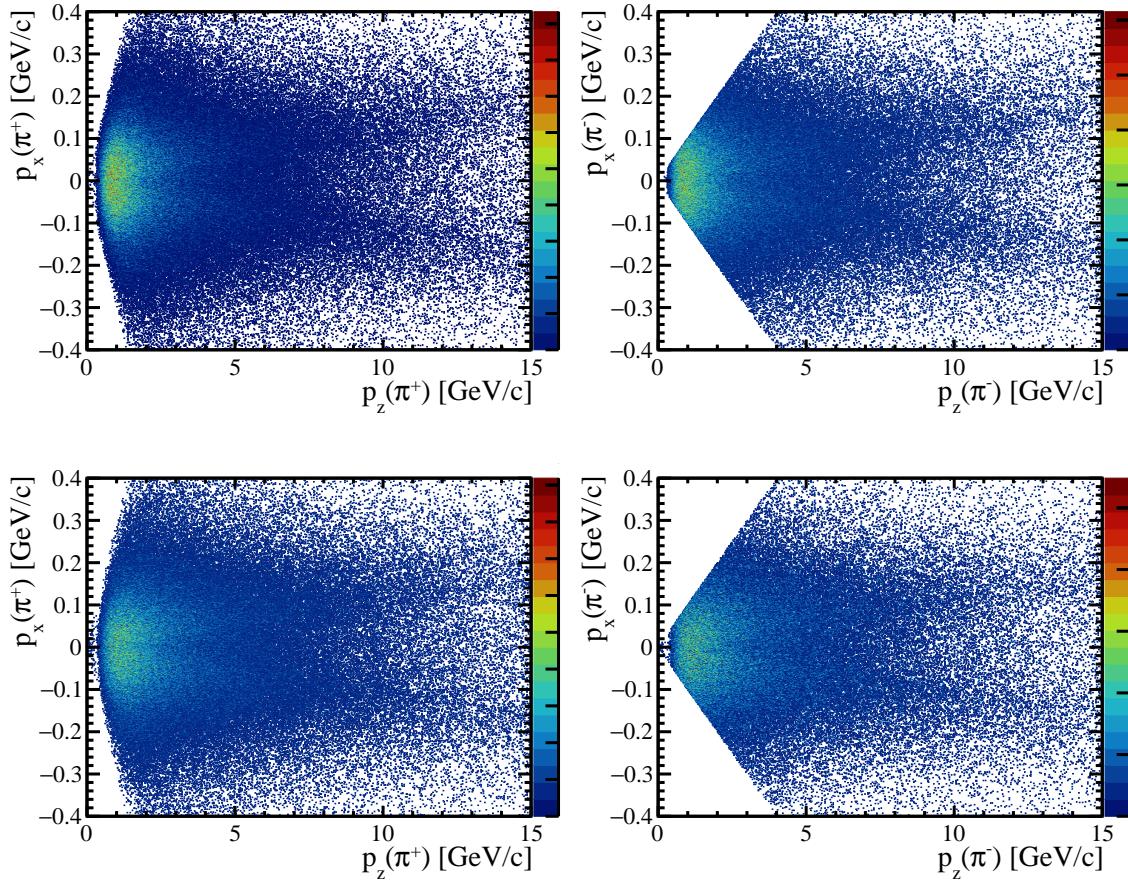


Figure 4: Soft π $p_x - p_z$ plane for $D^0 \rightarrow K^- K^+$ (top) and $D^0 \rightarrow \pi^- \pi^+$ (bottom) for π^+ and π^- after introducing detection asymmetry.

Table 2: Asymmetries for $D^0 \rightarrow pi^- \pi^+$ TTree.