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

LHCb Collaboration

Georgios Christou

4^{th} 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.

```
        TRandom3* random = new TRandom3();
        random->SetSeed();

        auto dataFramesPi = dataFrame.Define(
                "sPi_C", [random](){
                    return (random->Uniform() < 0.5) ? -1 : 1;
                }
        );
```

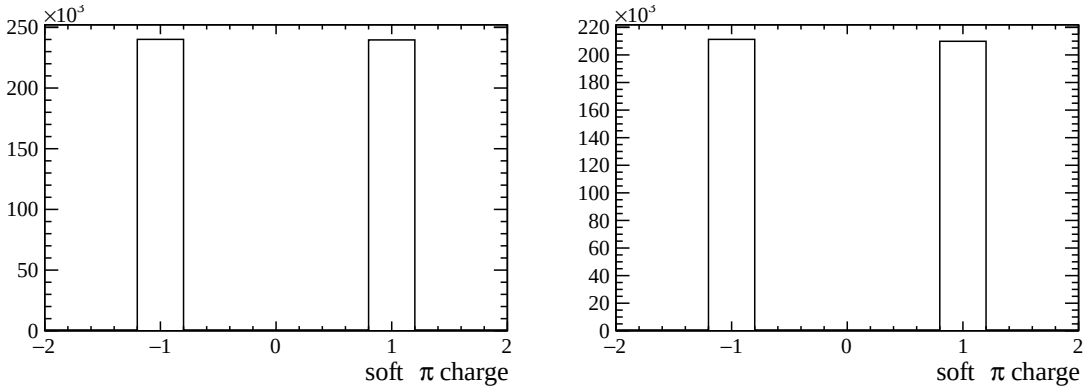

Figure 1: Initial soft π charge distributions for $D^0 \to K^-K^+$(left) and $D^0 \to \pi^-\pi^+$(right).

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:

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

```
        auto dataFrameCP = dataFramesPi.Filter(
                [random, asymmetry](const int& sPi_C){
                        double probability;
                        probability = 1.0 - (1.0 - asymmetry)/(1.0 + asymmetry);

                        if (sPi_C == -1 && random->Uniform() < probability){
                                return false;
                        }
                        return true;
                }, {"sPi_C"}
        );
```

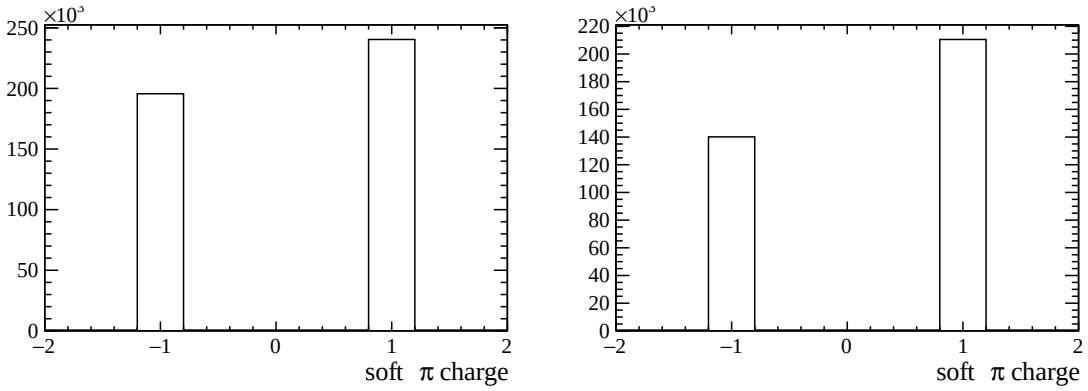

Figure 2: Soft π charge distributions for $D^0 \to K^-K^+$(left) and $D^0 \to \pi^-\pi^+$(right) after inrtoducing a CP asymmetry.

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.

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

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

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

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

$$A_{\text{total}} = \frac{N^+ - N^-}{N^+ + N^-} \tag{3}$$

and the error can be estimated using the standard error propagation

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

However, we can use

$$A_{\text{total}} = \frac{A_{CP} + A_D}{1 + A_{CP}A_D} \tag{5}$$

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

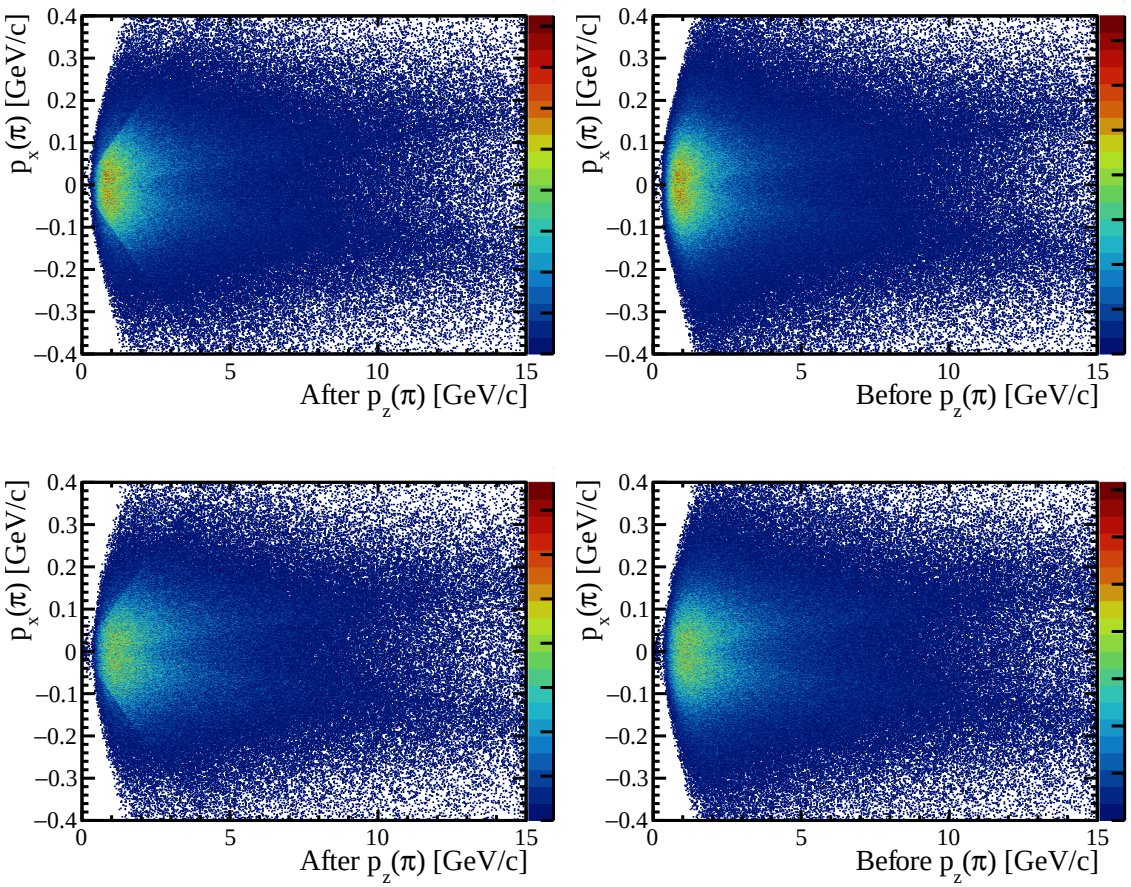

Figure 3: Soft π $p_x - p_z$ plane for $D^0 \to K^-K^+$(top) and $D^0 \to \pi^-\pi^+$(bottom) before and after inrtoducing detection asymmetry.

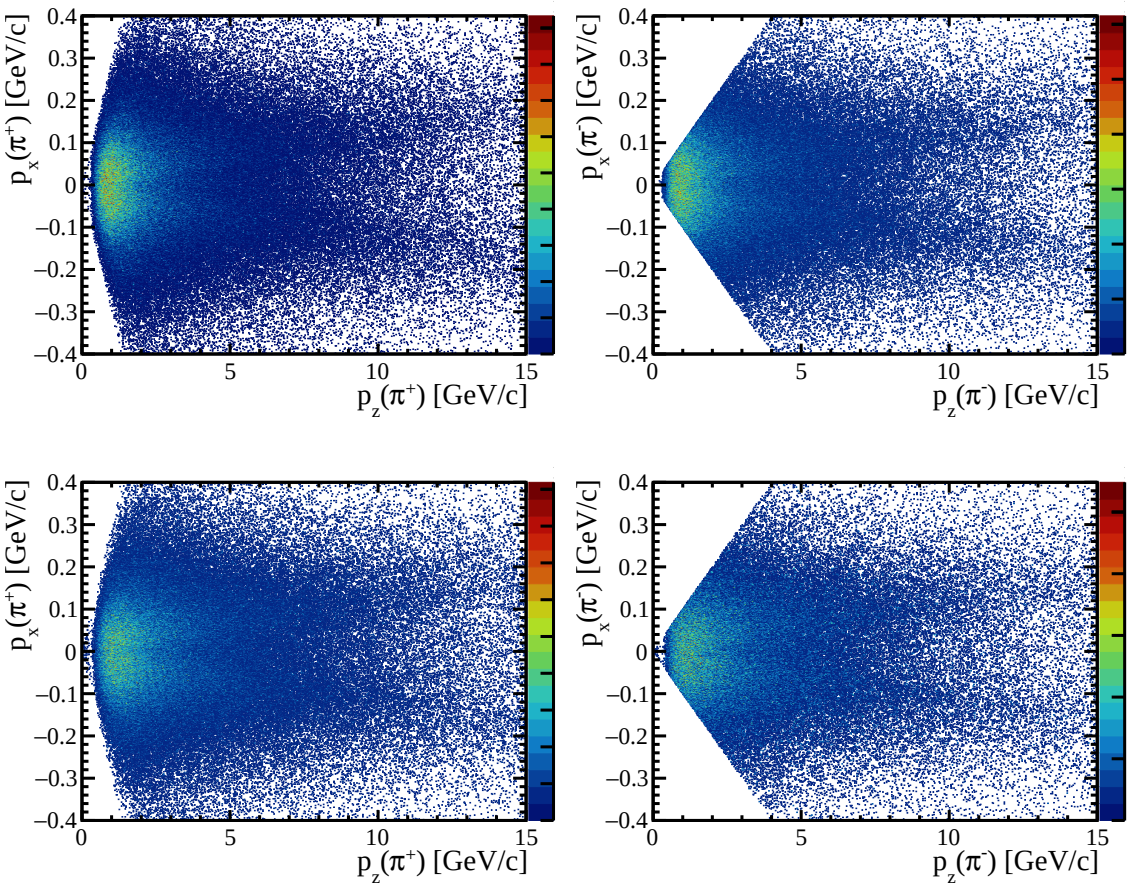

Figure 4: Soft π $p_x - p_z$ plane for $D^0 \to K^-K^+$(top) and $D^0 \to \pi^-\pi^+$(bottom) for π^+ and π^- after inrtoducing detection asymmetry.