Measure of CP violation in $B^{\pm} -> K^{\pm}K^{+}K^{-}$ with *RDataFrame*

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2023
March

In this project we study the CP violation for $B^{\pm}$ decay in three kaons. The Data, which can be downloaded Here, were collected at LHCb in 2011 with a center mass energy of 7 TeV and consist of two `.root` files which differ in the orientation of the magnetic field of the detector. Each file contain a `TTree` filled with 25 variables that describe the candidate events observed for the charged B meson decay. The Data are analyzed mainly using the RDataFrame, and all the code of the project can be found in this github repository, with a brief explanation of the code. Here the main scientific publication used as an inspiration to perform the analysis.

1 Scattering process

The scattering process that we want to analyze in the decay of the charged $B^{\pm}$ in three kaons. In this project we are interested to measure the global asymmetry of the data and later we will look at the dalitz plots to study locally where the asymmetry comes from.
The charged B meson decay is described by the weak interaction where a transition $b \to u$ is observed.

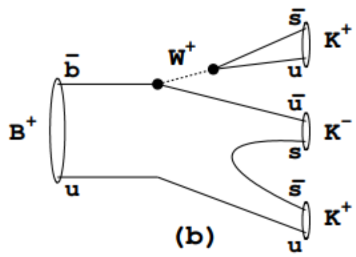

Figure 1: Diagram for $B^{+} \to K^{+}K^{+}K^{-}$

Togheter with this process, other two process are involved, with intermediate states. The first is the $B^{+} \to \phi(1020)K^{+}$ and the other is the resonance with D_0 intermediate state.
The invariant masses of each pair of kaons is needed to study the decay; we will use the following convention for the number of kaons: $B^{\pm} \to K_1^{\pm}K_2^{\pm}K_3^{\mp}$. So m_{12} is the invariant mass of the two kaons with the same charge, always. A relevant quantity that can be measured with this data is the Asymmetry between B^{-} and B^{-}, defined as:

$$A = \frac{N^{+} - N^{-}}{N^{+} + N^{-}}$$

$$\sigma_A = \sqrt{\frac{1 - A^2}{N^{+} + N^{-}}}$$

where $N^{\pm}$ is the number of B meson with $\pm$ charge and the other formula is the statistical error.

2 Cuts and data selection

Some cuts are defined and applied to the data in order to remove the background, or wrong particle identification. The events stored in the two dataset have already passed a preliminary selection : track with low P_T momentum, low IP (impact parameter) χ^2 and high $B^{\pm}$ candidate vertex fit χ^2 are already rejected. In this analysis other cuts are applied, rejecting the particles that are identified as muons, particles with high probability of being

Pions (> 0.5) and low probability of being kaons (< 0.5). The invariant mass of the B cantidated is computed from the momenta of each kaon and a maximum log likelihood fit is perfomed. A Cruijff function (gaussian with asymmetric tails) is used to describe the expected signal, considering also asymmetric effect of radiative emession; an exponential function is used to fit the combinatorial background toghether with the ARGUS distribution to describe the background due to partially reconstructed four-body decays (2). Taking the fit results, we perform an optimization to select a proper interval around the B meson mass peak, in order to reject the background. The interval is defined as ($B_{mass} - x$,$B_{mass} + y$), and we look for the maximum (x_{max}, y_{max}) of the function (9)

$$\frac{S(x,y)}{\sqrt{S(x,y) + B(x,y)}}$$

S is the number of signal expected events, and B are expected background events, that are computed as the integrals of the distributions in (2).

2.1 Global asymmetry

After applying the cuts, a global asymmetry is computed using the formula computed above, the result obtained are:

$4.1\% \pm 1.2\%$	magnetic field UP
$5.6\% \pm 0.9\%$	magnetic field DOWN

The two measure are in agreement, and the difference in the values can be related to the difference in the magnetic field of the detector. The global asymmetry is computed also rejecting the events that come from the D^0 resonance, in this case the global asymmetry are:

$4.6\% \pm 1.2\%$	magnetic field UP
$5.3\% \pm 0.9\%$	magnetic field DOWN

3 Local asymmetry

We computed the two-body invariant masses for each pair of Kaons, and we plot each combination of the invariant masses in three Dalitz plot (5). It's possible to identify two resonances (horizontal/vertical band of points) around $3.5 \cdot 10^6$MeV and $11.5 \cdot 10^6$MeV which are filtered. To study the local asymmetry in the Dalitz plot, it's useful to order the two invariant masses m_{13} and m_{23} that are computed for the two pair of K^+K^-. The new variables are m_{low} and m_{High} and define a new dalitz plot (7). The next step is to divide the new ordered Dalitz plot in different intervals and compute the asymmetry for each interval. The values are displayed using a color map where the bins have different size to account for the difference in statistics for the different areas of the dalitz plot (8). From the plot we identify that the highest contribute to the asymmetry is where $m_{low} \simeq 2\,\text{GeV}$. The significance for each bin is also plotted, and all the bin with a statistical uncertainties $> 10\%$ are not drawn.

4 Figures

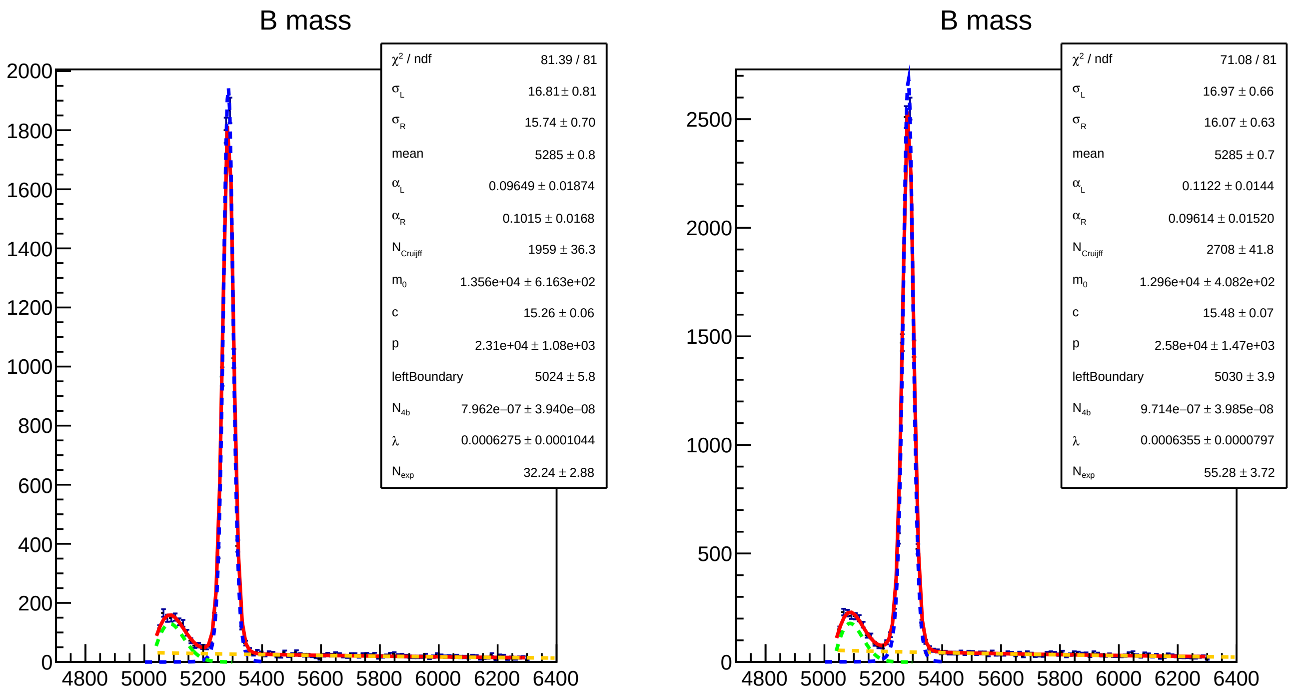

Figure 2: Invariant mass of the B candidates: the green line is the background due to the 4-body decay, in blue the signal, in orange the combinatorial background and the red is the model used to fit the data.

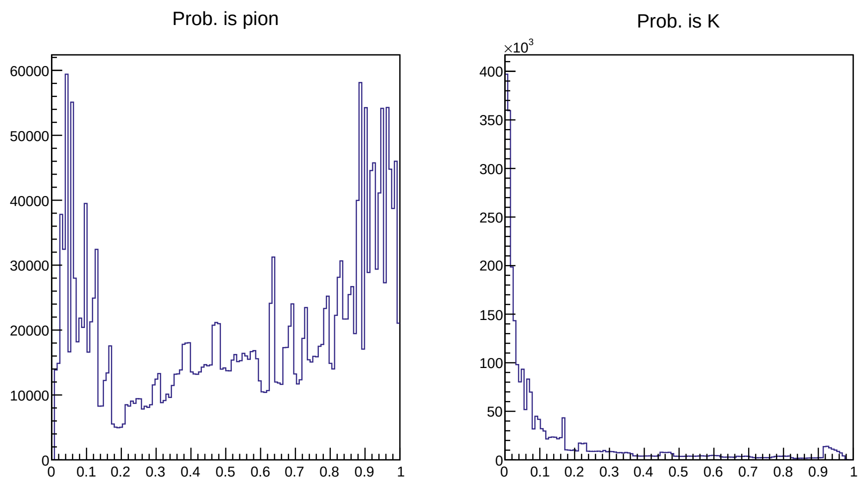

Figure 3: Probability of a particle to be a Pion (left) or a Kaon (right).

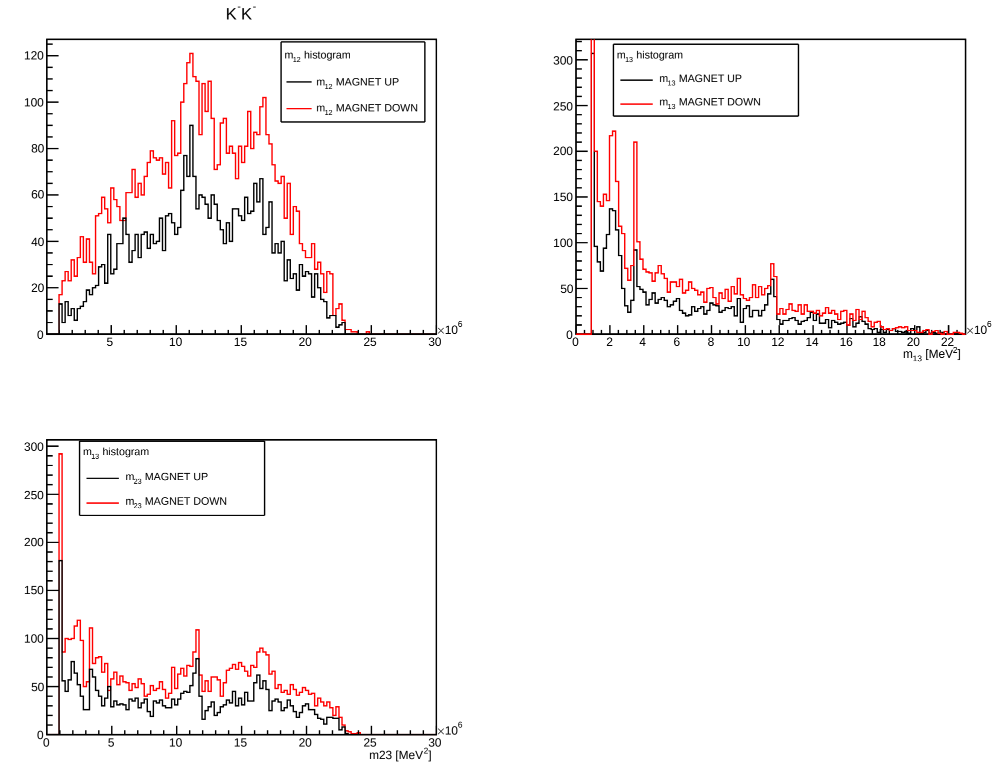

Figure 4: Histogram of the invariant masses, the different color are about the different orientation of the magnetic field

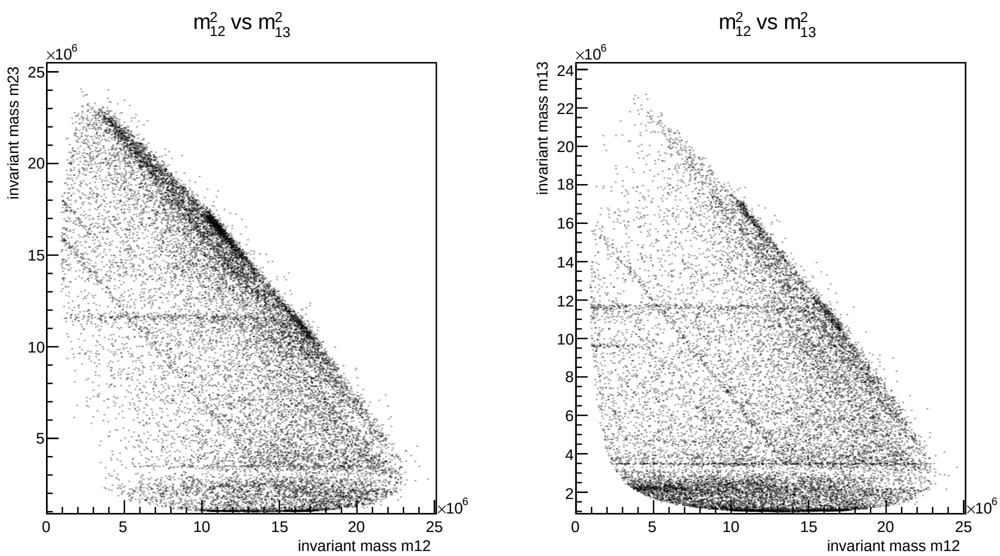

Figure 5: Dalitz plot histograms

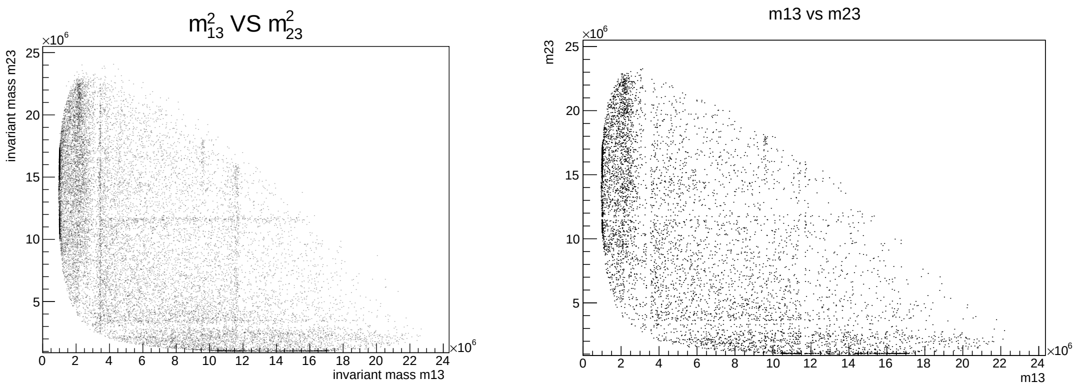

Figure 6: Dalitz plot for m_{13}^2, m_{23}^2, on the right after removing the charm resonance.

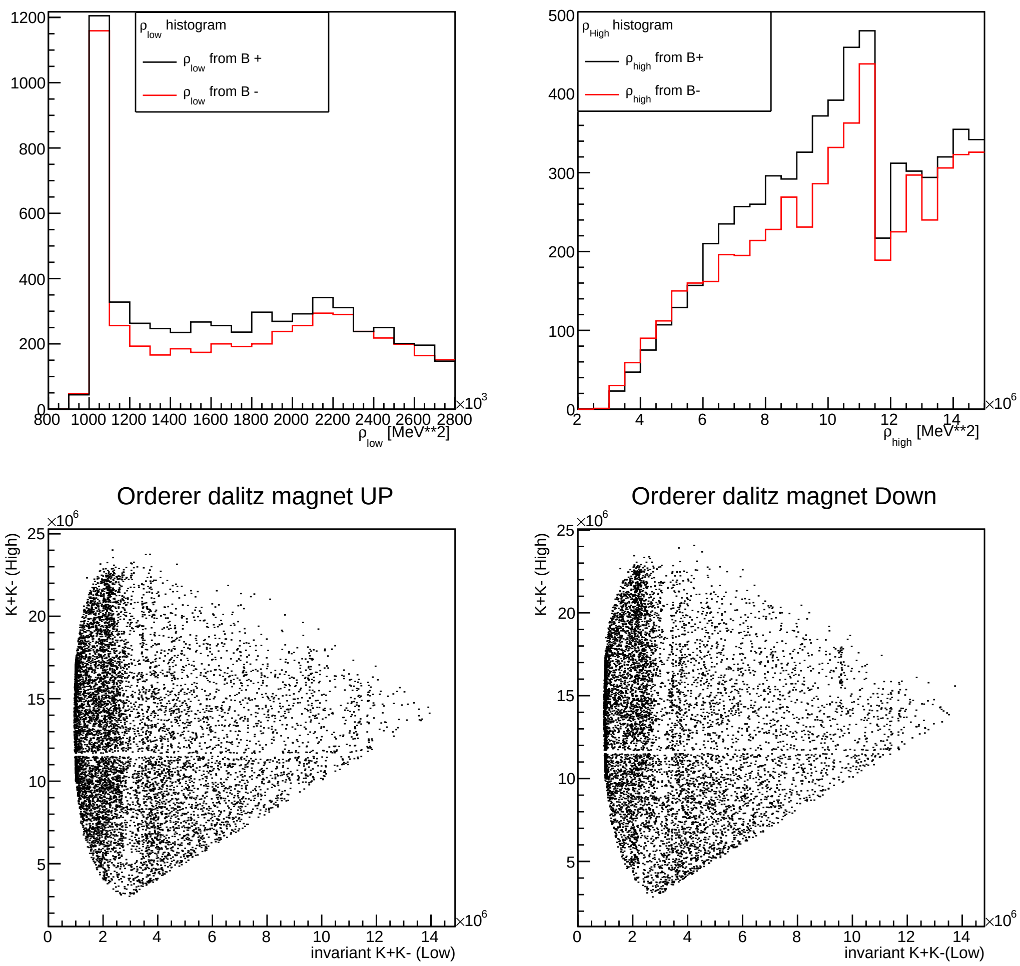

Figure 7: Ordered Dalitz plots, (notice the ϕ resonance in the ρ_{low} histogram)

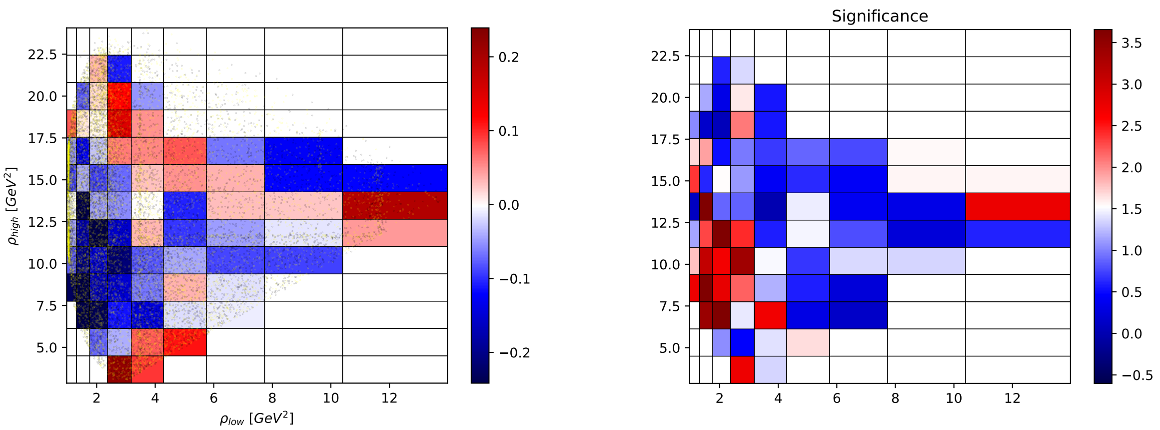

Figure 8: Local asymmetry on the left, significance (asymmetry divided by the error) on the right

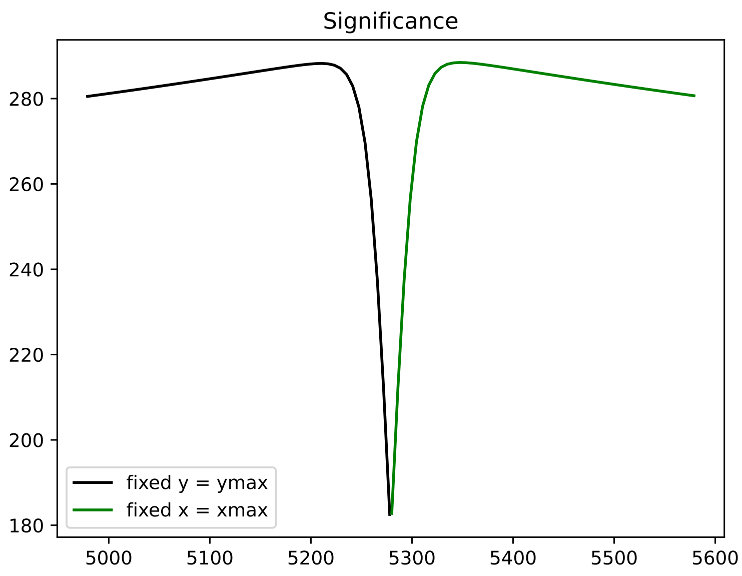

Figure 9: Significance for the B mass interval. The values (x_{max}, y_{max}) are (5223,5347) MeV. They were obtained with searching in the range $(0, 200)$ MeV for both x and y and taking the maximum. Because the Significance is a function with two parameters, we decided to plot the function fixing one value already at the maximum and changing the other.