D meson study with on-the-fly simulations

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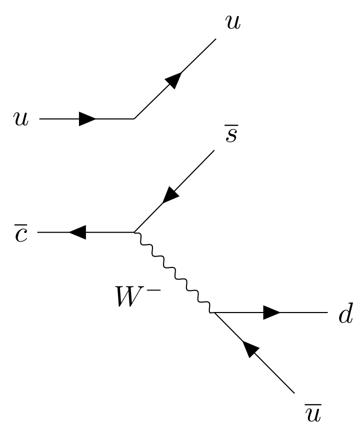
Abstract
The ALICE Collaboration is designing the upgrade for ALICE 3. For this, a new way to simulate many aspects of the detector were developed, the so called "On-the-fly". We tested different designs for the magnetic field of the detector in order to understand how this can affect the measurements of heavy flavour, in particular the D meson, and reconstruct the tracks.

Keywords
CERN report; D meson; On-the-fly; heavy flavour; ALICE 3

1 Introduction

The main interest of this project is studying the influence of different detector configurations of ALICE 3 [Collaboration et al.(2022)] to understand how it influences heavy-flavour analyses. Our test analysis will be a D meson reconstruction analysis using various detector configurations. For this task, we must combine pions and kaons in order to reconstruct the track and separate particles produced at the primary vertex and the particles produced after the decay of the D meson. The decay is $D^0 \to \pi^- K^+$:



To reconstruct the decay channel, a variable of interest is the Distance of Closest Approach to the primary vertex(DCA$_{xy}$) which is an extrapolation of the circular orbits of the pions and kaons. Analysing the distribution of DCA vs $\mathrm{p_T}$ we can fit a function and define a cut to reject a fraction of particles, thus making the reconstruction more efficient.

Furthermore, we want to understand how these configurations can change parameters such as efficiency and mass peak width for the D meson study.

2 Data Analysis and Results

The simulations were done and the output are .root files which contains different histograms to manipulate and extract all the information that we need. The main histograms contains the generated particles and the reconstructed, wich are the indicated in 1.

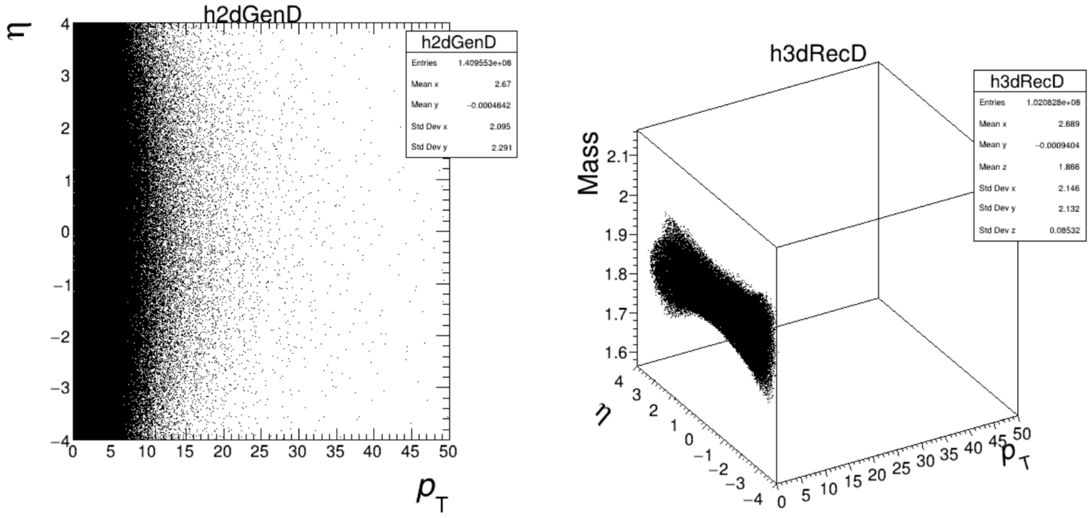


Figure 1: Generated and reconstructed D mesons

Using ROOT [Fuakye(2017)], we can develop a script in C++ language to manipulate these histograms in order to apply some mathematical operations and retrive the informations we need.

5 different configurations of magnetic fields were simulated:

- 0.5T, no dipole;
- 1.0T, no dipole;
- 2.0T, no dipole;
- 1.0T, with dipole;
- 2.0T, with dipole;

2.1 Efficiency

Firstly, the effciency results in 2 tell us that stronger magnetic fields can improve the efficiency for high values of η.

From another point of view, the results in 3 shows that as the magnetic field gets stronger, the efficiency of detector improves for higher values of p_T. Futhermore, the presence of a dipole also makes the efficiency more constant for high p_T.

2.2 Mass Peak Width

These results in 4 shows that the peak width tends to increase for larger values of η when no dipole is present, but tends to be constant if a dipole is present.

Another interesting results comes when we analyse the data accordingly to pT. The dipoles seems to have a more important role to keep the peak width low for higher values of p_T in a bigger range of η.

2.3 DCA distribution

Another variable of interest is the Distance of Closest Approach(DCA) to the primary vertex. The DCA is is an extrapolation of the circular orbits that the particles resulting from the decay perform when they feel the strength of the magnetic field. The DCA is important because is from it that we can select events that probably came from a decay of the D meson and not from the primary vertex, since during a collision, the yield of pions and kaons can be superimposed with the decay of the D meson in pions and kaons either.

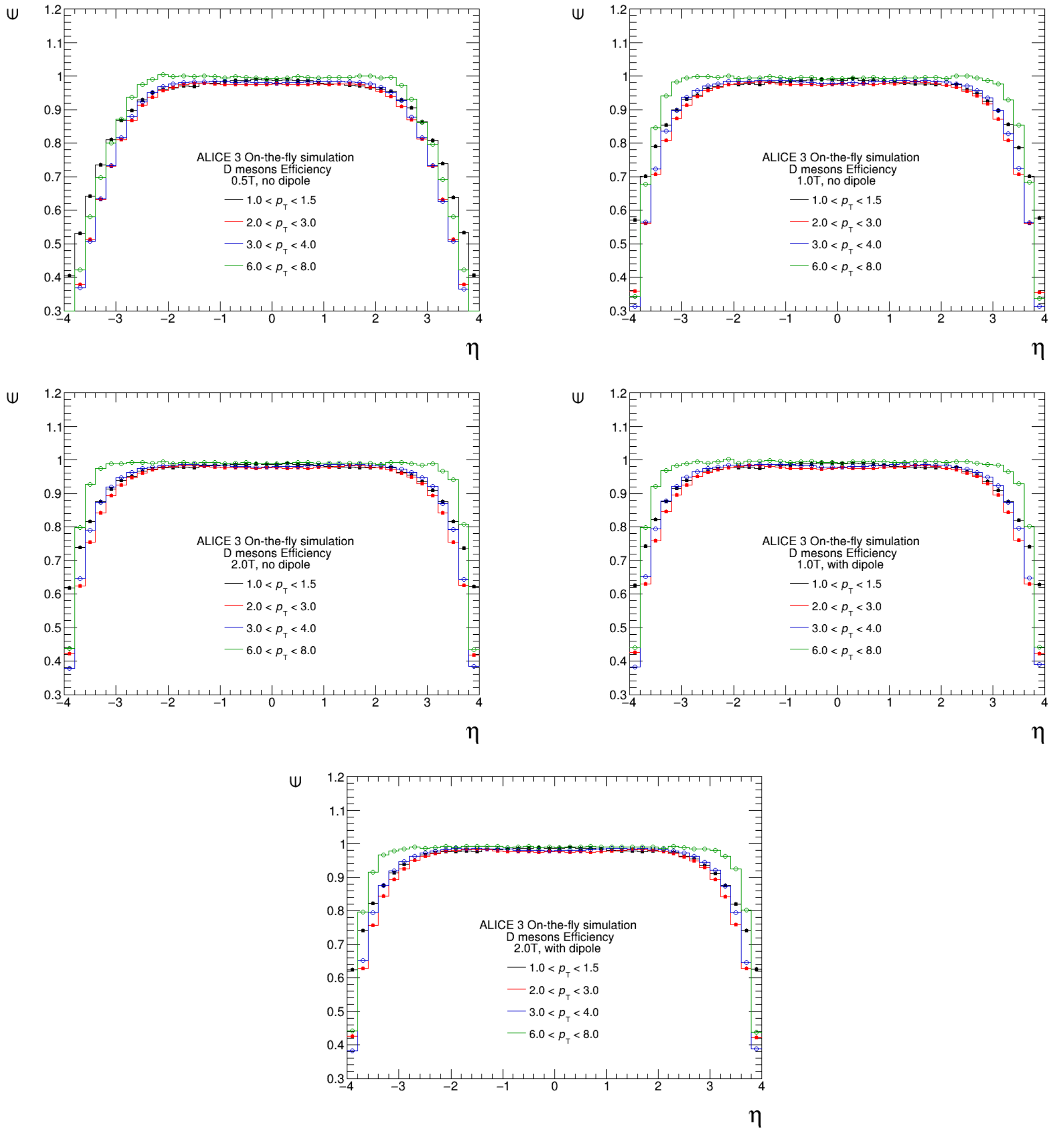


Figure 2: Efficiency vs η in p_{T} ranges

With the distribution shown in 6, we can fit a cut to reject around 60% of the primaries and recalculate the previous parameters to understand the changes.

The efficiency is slightly reduced to reconstruct the tracks, as expected.

2.4 TOF PID

A bonus analysis came from observing the effect of a TOF PID in 8 with DCA selection. In this simulation there is no Monte-Carlo associated so theres background in this data. The TOF contributes to increase the ratio S/B at a factor of 80 90 compared to the previous data

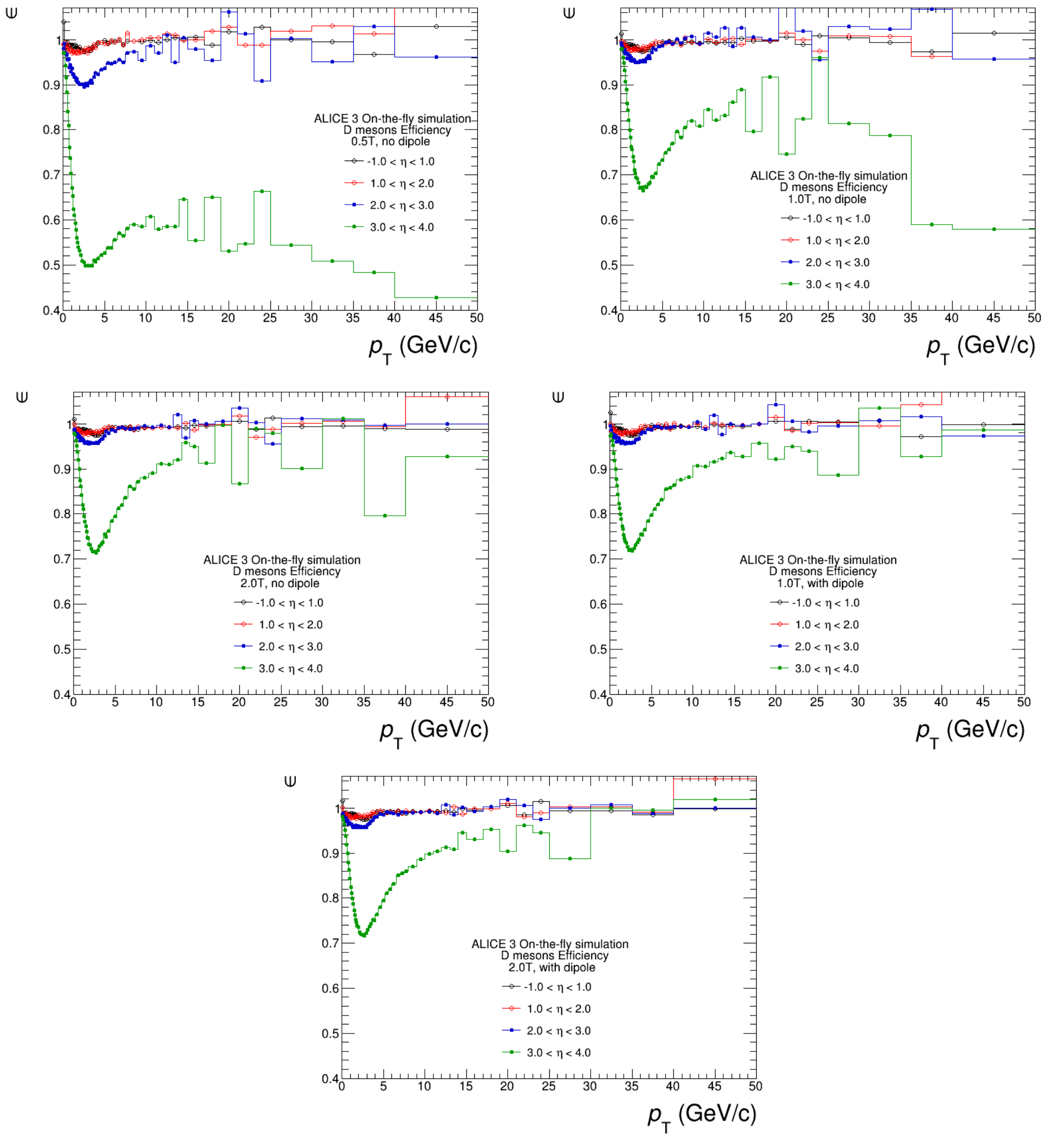


Figure 3: Efficiency vs p_T in η ranges

3 Conclusion

The results shown previously can be summarized below:

1. A predictable broadening for the mass peak width for lower magnetic fields;
2. The presence of dipoles ensure constant performance with η;
3. No dipoles leads to a significant broadening of mass peak width for large values of η;

Actual analysis test done at 2.0T (no dipole):

1. Done with loose DCAxy rejection for now (high efficiency) but we can do a bigger cut;
2. Signal/Background ratio around 5 without any further PID;
3. Signal/Background vs η reaches 70-80 with TOF PID, but worse at large η;
4. Signal/Background vs p$_T$ reaches 90-100 with TOF PID, but theres no effect at large p$_T$.

Further analysis can be done for other parameters of the detector.

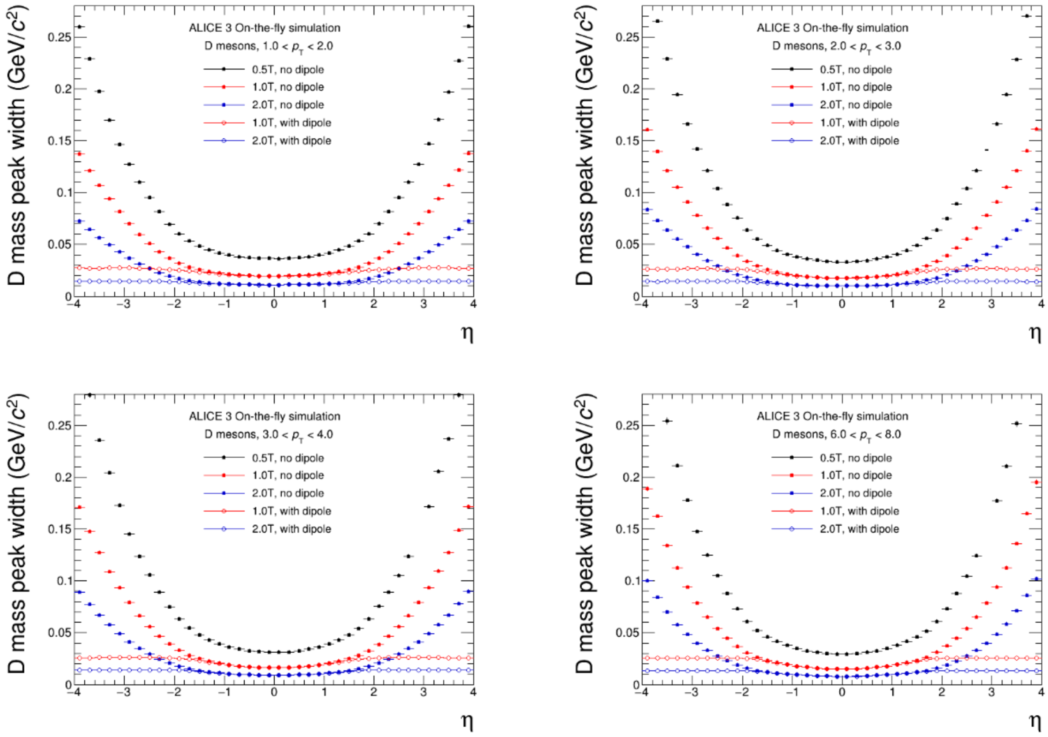


Figure 4: Mass peak width vs η

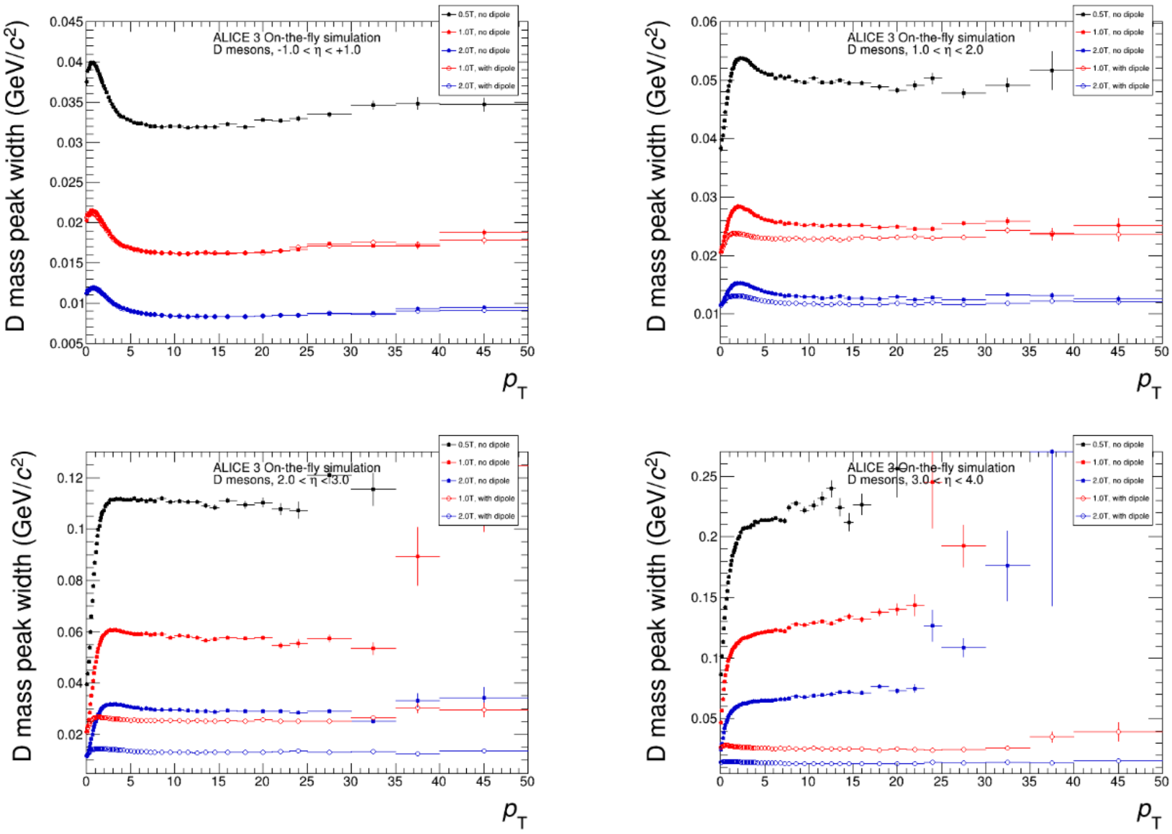


Figure 5: Mass peak width vs p_T

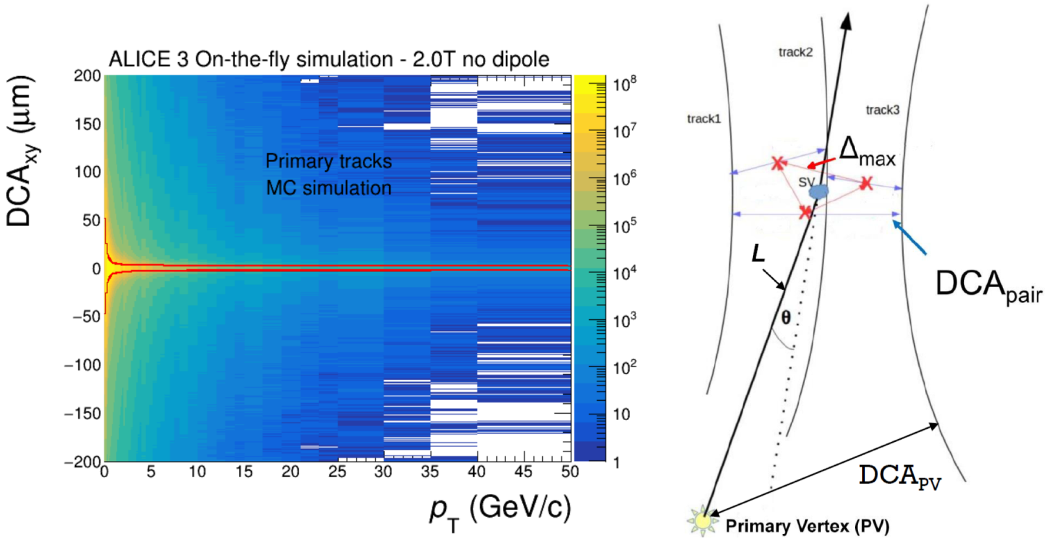


Figure 6: DCA distribution vs p$_T$ [Vanek(2019)]

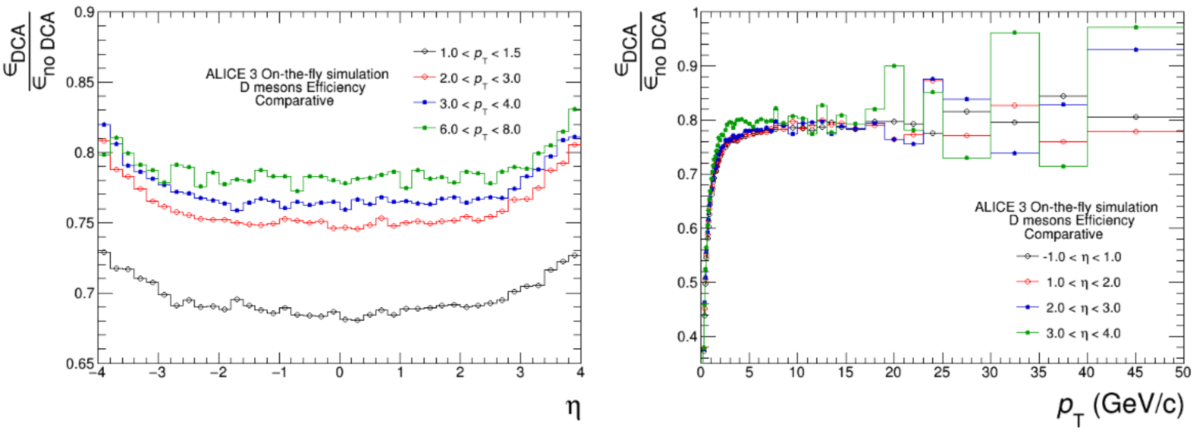


Figure 7: Comparative between effiency

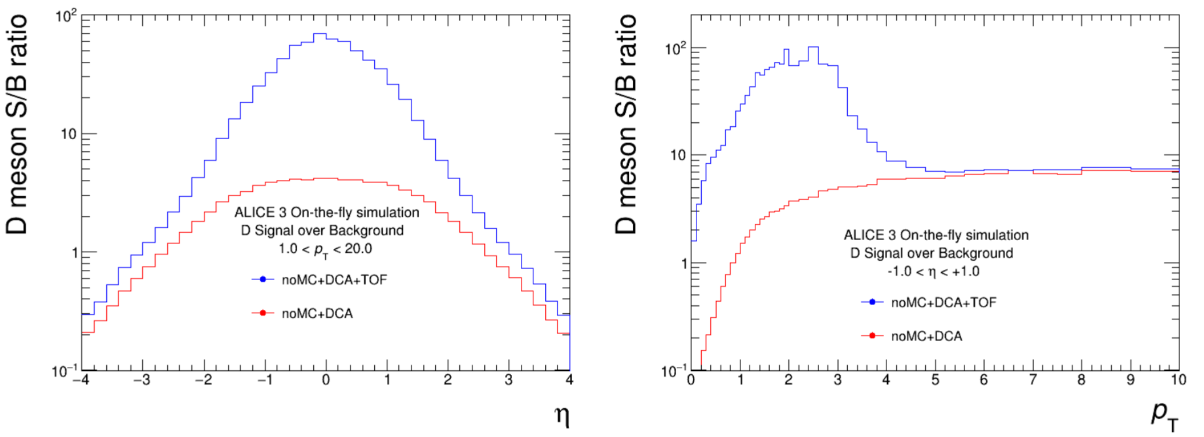


Figure 8: Signal/Background Ratio with TOF PID

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