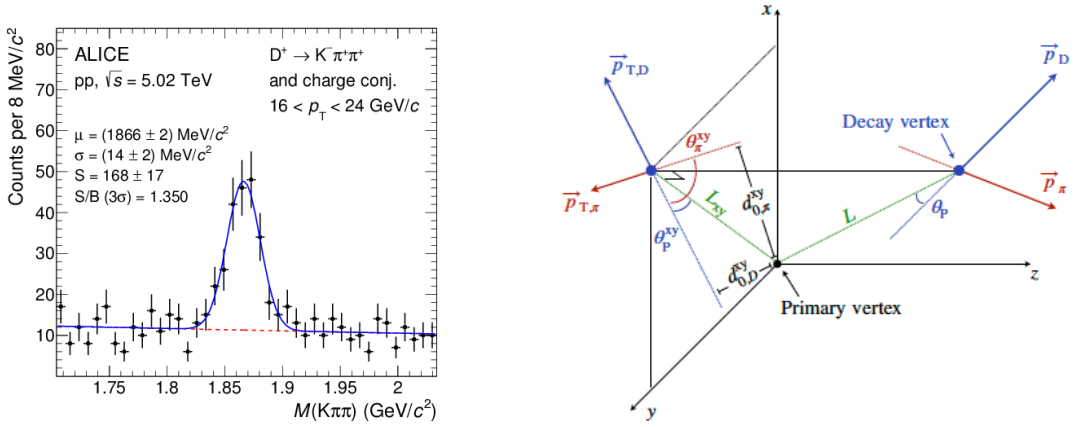
D mesons reconstruction

The challenge

Charm quark is one of the heavy quarks of the Standard Model of particle physics. It's study has important implications in the study of QCD in extreme conditions, as well as in searches for new physics. It is considered an excellent probe for the hot and dense matter produced in heavy-ion collisions, the Quark Gluon Plasma (QGP) [1]. QGP is believed to have been the state of matter that permeated our Early universe a few microseconds after the Big Bang. Due to confinement, in our world we cannot observe a free charm quark, therefore, to study its properties we need to reconstruct particles that contains it. Among others the D^+ meson in a very suitable candidate for charm studies. The D+ meson is reconstructed by means of invariant mass analysis in the decay channel D^+->KKpi (kaon kaon pion). See left panel of the figure.



The detected particles in this case are the 2 kaons and the pions. However, the D^+ meson is rare, we can expect one per few thousands of collisions. On the other side hundreds of pions and kaons are produced in each collision. This fact brings to the problem of having an enormous combinatorial background originating from picking uncorrelated kaons and pions for the invariant mass calculation that effectively makes the signal completely invisible.

To reduce the combinatorial background selections are made in the topology of the decay (See right panel of the figure and find the detailed explanation of the topological variables at [2], section 4.2). Those selections create a 12^{th} dimensional feature space of continuous variables that in addition are partially correlated among each other.

The project

In this project you have the simulated data from the ALICE experiment at CERN LHC. All the topological selections are included both for signal and background in addition to the invariant mass calculation. At a first investigation of the data, you realize that the invariant mass plot contains only an exponential background without any sign of D+ signal. The scope of the project is to build a learning strategy that allows for efficient classification of signal and background. A successful project should end with a fit of the invariant mass with a clear gaussian signal on top of the remaining combinatorial background. Furthermore, students are invited to test two (or more) learning algorithms,

and compare the outcome in terms of performances and reflect on which one is performing better and why. An optimization of the hyperparameters is a plus.

Bibliography

[1] https://www.ncp.edu.pk/assets/docs/slp-2009/mehnaz-hydrodynamics-001.pdf
[2] https://cds.cern.ch/record/2713513/files/CERN-THESIS-2020-017.pdf