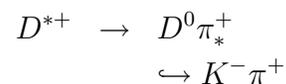## Computerpraktikum zur Vorlesung
Teilchenphysik für Fortgeschrittene

Reconstruction of D^0 Mesons from D^* Decay

We are interested in studying D^0 mesons from the D^* decay. The considered channel is:

$$D^{*+} \rightarrow D^0 \pi_*^+$$
$$\hookrightarrow K^- \pi^+$$

We will first have a look at all D^0 mesons and will select in a second step the D^0 mesons from D^* decay.

Setting up

- Have a look at the directory `/home/stat/wagner/DmesonDaten`. In the D meson project we will analyze data contained in the files

  - `praktikum1_dat.root`
    which contains real DELPHI data

  - `praktikum1_mc.root`
    containing D^* Monte Carlo events subjected to a full DELPHI detector simulation.

  You do not need to copy these files to your own area, rather access them from where they are.

- Copy the file `dmeson.tar` from the web page of this course into your working directory and unpack it with the command `tar xf dmeson.tar`. You will find five files in this package: `DMesonAna.cc`, `DMesonAna.hh`, `driveAna.cc`, `Makefile` and `plotDmeson.cc`. These files serve as templates for your analysis.

- In the files `DMesonAna.cc` and `DMesonAna.hh` you can implement your analysis code to select D meson candidates and fill histograms. The file `driveAna.cc` contains the `main` function from which methods of the analysis class are called. The executable is called `driveAna`. The histograms will be stored in a ROOT file named `Dhistos.root`

Variable Name	Definition
'D^0 variables'	
Qka	Charge of the Kaon in the D^0 candidate
Dpx	p_x momentum component of the D^0 candidate
Dpy	p_y momentum component of the D^0 candidate
Dpz	p_z momentum component of the D^0 candidate
De	Energy of the D^0 candidate
Dmas	Invariant mass of the D^0 candidate
'slow pion variables'	
Npi	Total number of charged particles (other than the Kaon and pion of the D^0 candidate)
Pipx(I)	p_x momentum component of charged particle I
Pipy(I)	p_y momentum component of charged particle I
Pipz(I)	p_z momentum component of charged particle I
Pie(I)	Energy of charged particle I
Qpi(I)	Charge of particle I
'truth variables'	
Flag1(I)	=1 if particle I actually comes from a D^0 (for the case of $D^0 \rightarrow K^-\pi^+$)
Flag2(I)	=1 if particle I actually comes from a D^* (i.e. the slow pion, when $D^0 \rightarrow K^-\pi^+$)

which can be read by the root script `plotDmeson.cc`. In this script you can add code to draw and fit the histograms.

The ROOT Trees contain data in which D^0 candidate 4-vectors have already been reconstructed by combining kaon and pion candidates. The full Tree description is given below: Note that the 'truth variables' will always be zero for real data. Ignore the variable `Flag1`.

Exercises

1.1 Add code to `DMesonAna.cc` to make some histograms of the D^0 variables in the **real data** Tree. Do not look at the individual momentum components but compute the absolute value of the D^0 momentum. What do you conclude from plotting the D^0 mass spectrum?

1.2 Can you qualitatively improve the significance of the D^0 peak by cutting on the D^0 momentum? Play a bit with this cut. However, disregard the momentum cut for the following exercises 1.3 to 1.8.

1.3 The purity of our D^0 sample[1] can be significantly improved by selecting D^0 mesons

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[1]Charge conjugate states are always implied.

which originate from a D^{*+} decay. To find these mesons we need to search for the *slow pion* from the D^* decay and combine it with the D^0 candidate to reconstruct the invariant mass of the D^{*+}.

In `DMesonAna.cc` you find a loop over all the charged particles in the event other than the kaon and pion that form the D^0 candidate. Consider every particle with a charge opposite to that of the kaon candidate to be a slow pion candidate. Form the invariant mass of the D^{*+} candidates i.e. of slow pion/D^0 combinations. For the 4-vector computation you can use the ROOT class `TLorentzVector`. The vector is instantiated and initialized by:

`TLorentzVector v(Px, Py, Pz, E);`

Make a histogram of the D^* mass and of $Q = M(D^0 \pi^+) - M(D^0)$. How do you interpret the result?

1.4 Repeat your analysis with the Monte Carlo events. Produce in addition a histogram of Q for true slow pion candidates by using the Monte Carlo truth flag `Flag2` which indicates whether a charged particle is a slow pion or not. Deduce a cut on Q from the Monte Carlo distribution.

1.5 Switch back to real data. Apply the Q cut you found in exercise 1.4 and redo the D^0 mass distribution for the surviving candidates.

1.6 Fit the $M(D^0)$ distribution using the function `BreitWig` predefined in `plotDmeson.cc.` to find the central value and width of the D^0 peak. You can switch between different background parametrizations.

1.7 Choose an interval in $M(D^0)$ that defines the signal peak and, estimate from the fit result the number of entries from signal and the number from background. Hence form the *Signal/Noise* or S/N ratio for your data.

1.8 Using the fitted width of your signal, determine the lifetime of the resonance. How well does this agree with the known lifetime of the D^0 ($\tau(D^0) = 0.413$ ps)? What defines the *measured* width of a resonance?

1.9 Investigate how you could improve the S/N ratio of the D^0 signal by adding the cut on the D^0 momentum again.

Make a 2-D histogram of $M(D^0 \pi^+) - M(D^0)$ against $p(D^0)$. You should be able to clearly distinguish the signal from the combinatorial background. Make the same plot for Monte Carlo events demanding the truth flag to be set for the slow pion candidate. Decide on a reasonable cut you could make to reduce the combinatorial background and re-make the $Q-$value histogram with this cut in place.

1.10 Redo the D^0 mass plot with all cuts applied. Compute the S/N ratio. Did you reach an improvement? Calculate the efficiency drop with respect to the signal found in Exercise 1.7.