Measuring D^0 from D^{*+} Decays at the SPD

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Nov 08, 2024

Vertex Detector Configurations

- Since background for D meson detection is enormous ($\sim 3-4$ orders of magnitude higher), extra handle to tag D mesons are extremely useful
- A subset of D^0 (subsequent discussion holds also for the anti-particle counterpart) comes from decays of excited states (D^{*0}, D^{*+})
- D^{*0} decays to D^0 accompanied by soft photons or π^0 and are not very helpful for tagging due to large background and poor energy resolution for such soft/low-energy photons
- Bulk (67.7%) of the D^{*+} decays via $D^{*+} \longrightarrow D^0\pi^+$ and the charged pions can be used to tag such events
- Suggestion from Igor Denisenko

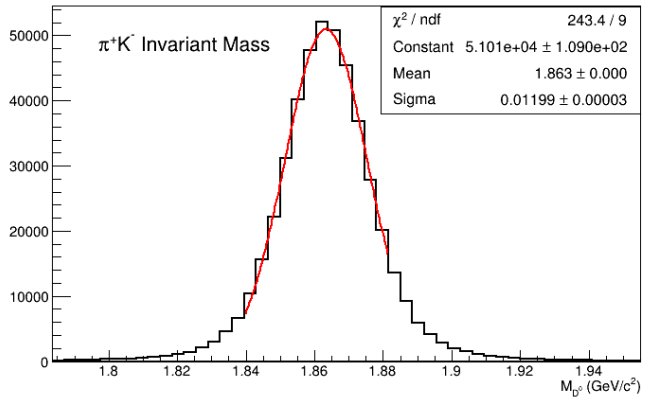
Some Relevant Cross-sections

- NA-27 (European Hybrid Spectrometer) at CERN measured D meson cross-sections with 400 GeV/c proton beam ($\sqrt{s} = 27.4$ GeV)
- Total cross-sections with 15-20 % uncertainty, giving us very decent idea what to expect
- $\sigma(D^0) = 10.5 \pm 1.7$ μb, $\sigma(\bar{D}^0) = 7.9 \pm 1.5$ μb
- $\sigma(D^+) = 5.7 \pm 1.0$ μb, $\sigma(\bar{D}^-) = 6.2 \pm 1.0$ μb
- $\sigma(D^{*+}/D^{*-}) = 9.2 \pm 2.2$ μb. Assuming excited states having same ratio as regular charged versions :
- $\sigma(D^{*+}) \sim 4.4$ μb. BR of $D^{*+} \longrightarrow D^0\pi^+$: 67.7%, leading to :
- $\sigma(D^0$ *from* $D^{*+}) \sim 2.98$ μb, about 28% of all D^0
- Source : Phys. Lett. B, vol. 189, no. 4, p. 476-482

We lose statistics of signal by 72%, but we may be able to reduce background by a larger factor, improving S/B ratio and figure of merit

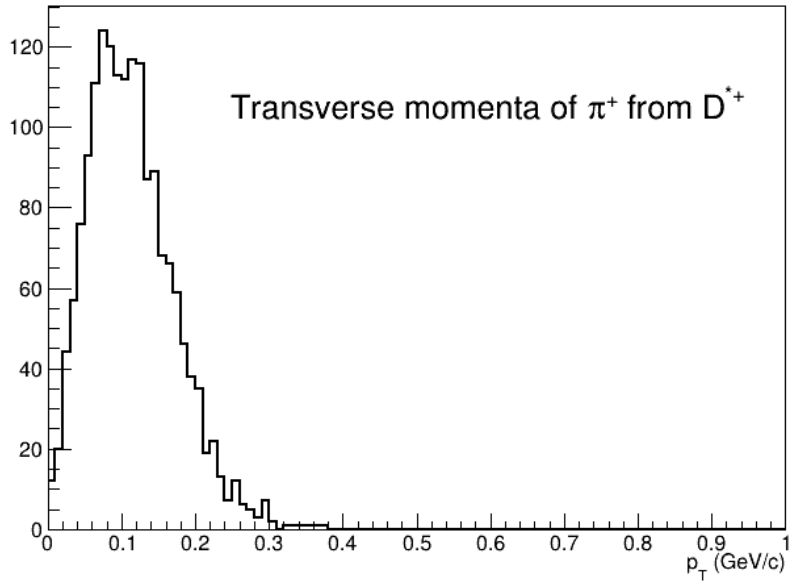
Simulation Setup

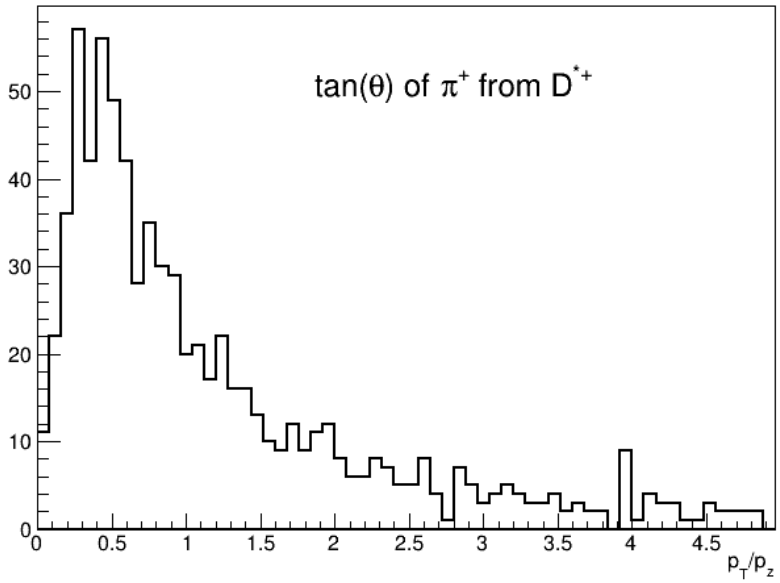
- Pythia8 + SpdRoot, open-charm process for signal and minimum-bias process for backgrounds
- MAPS (barrel only) vertex tracker used
- KFParticle package used to combine π^+, K to reconstruct D^0
- All π^+ (assumed perfect PID) are combined (four vectors) with D^0 candidate to reconstruct D^{*+} (mass = 2.01 GeV/c^2)



Invariant mass distribution of π^+K^- from signal events

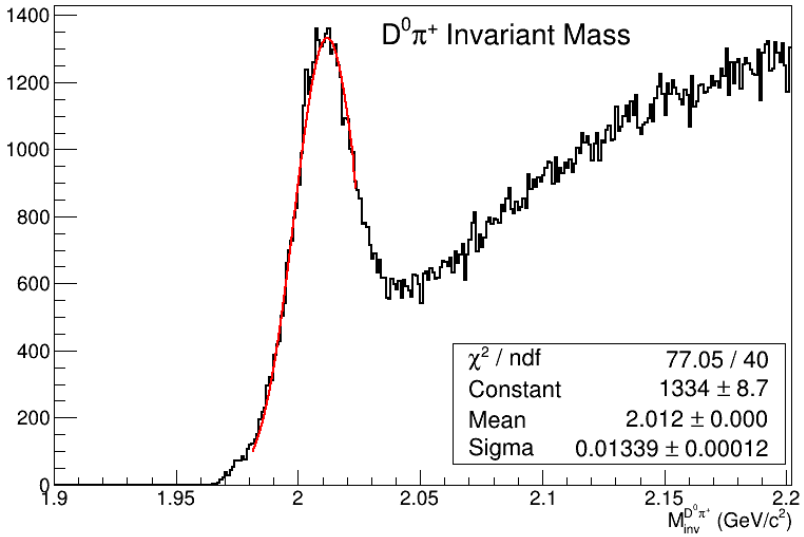
Kinematic Properties of the π^+ from D^{*+} Decay



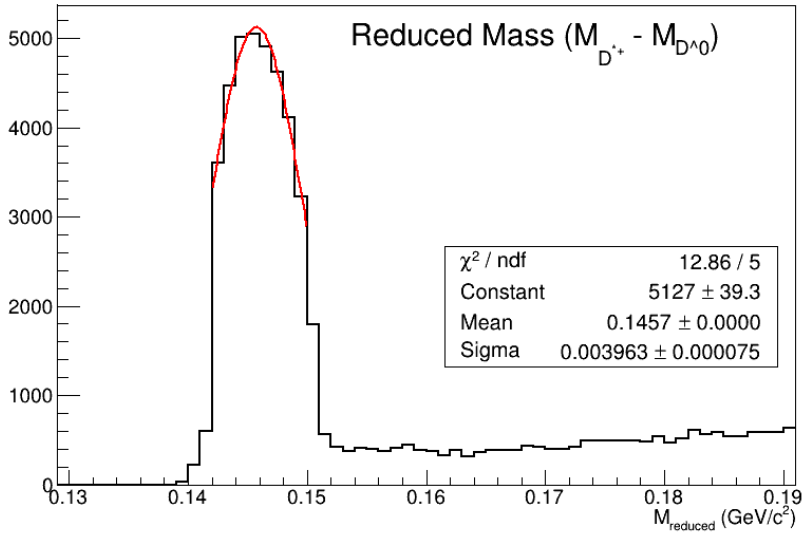


Low p_T charged pions, mostly within $10^0 - 35^0$ polar angle, ending up in the end caps

Reconstructed D^{*+} : Signal Events



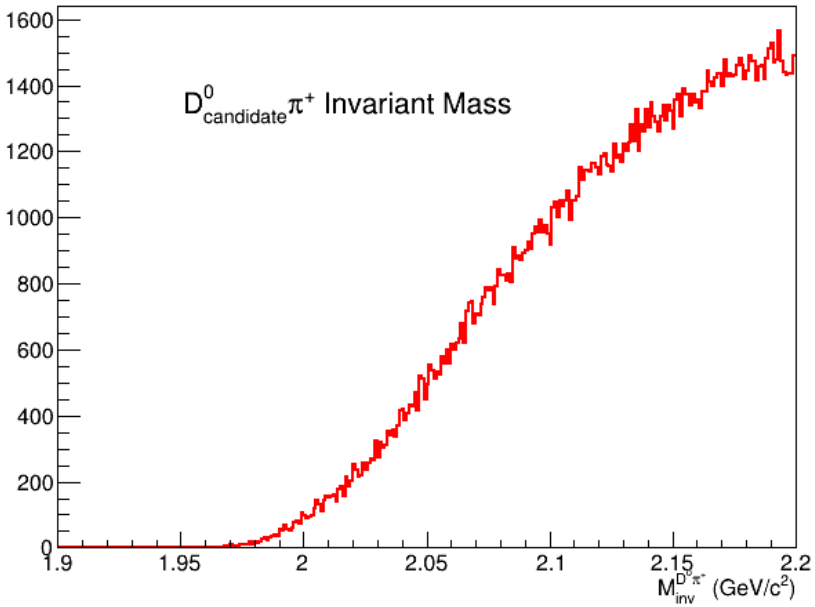
Reconstructed D^{*+} with decent precision ($\sim$ 13 MeV/c^2)



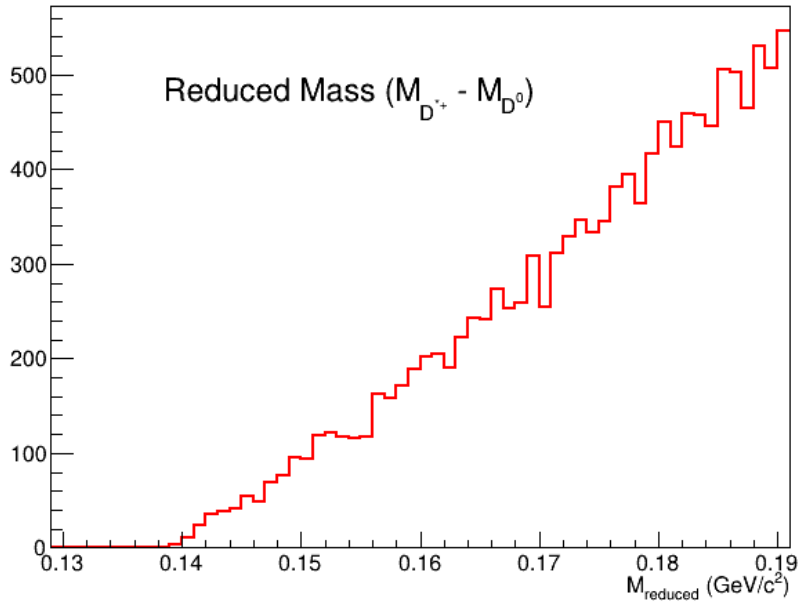
Reduced mass has very high precision ($\sim$ 4 MeV/c^2)

2 M signal events

Reconstructed D^{*+} Candidate : Background Events



Reconstructed D^{*+} candidates



Reduced mass distribution for D^{*+} candidates

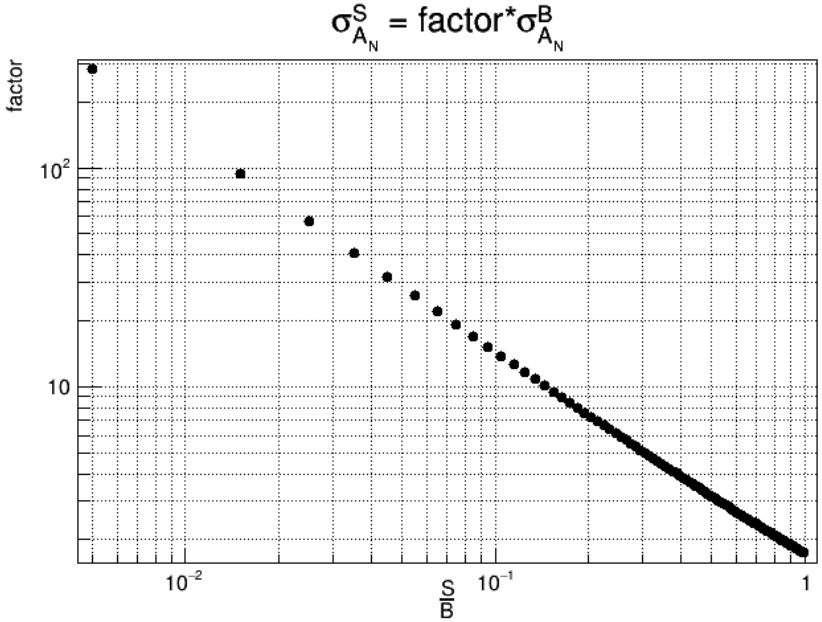
50 M background events

Background (and Signal) Reductions

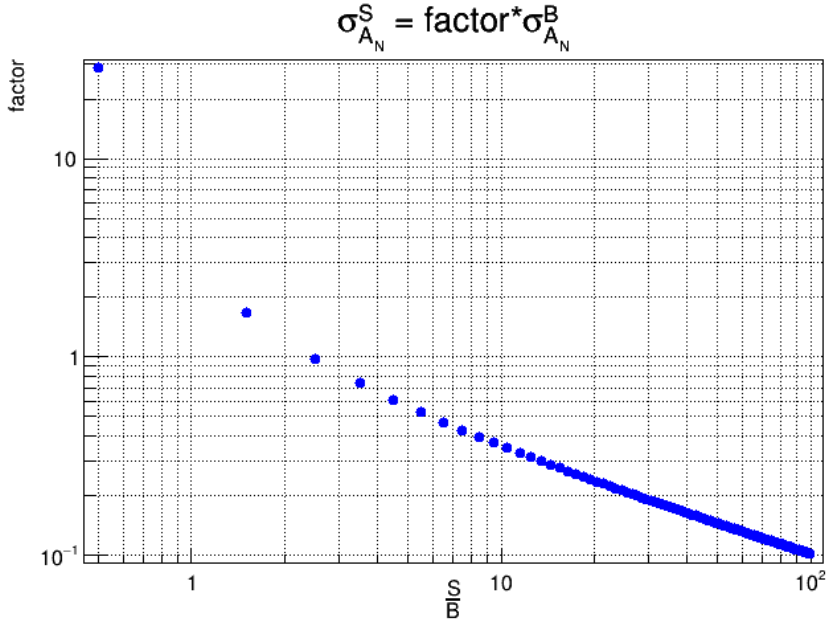
- With cuts on ALL relevant variables (decay length, its uncertainty, opening angle, collinearity angle, DCA of daughter tracks to PV, V0 and each other, DCA of V0 to PV) :
  1. signal suppression : 3.0×10^{-2}
  2. background suppression : 1.1×10^{-4}
- With ONLY reduced mass requirement :
  1. signal suppression : 2.1×10^{-2}
  2. background suppression : 2.9×10^{-5}
- Simulation statistics not enough to make meaningful background reduction estimates and subsequently, uncertainty calculation, however ...

Back of the Envelop Calculations

$$\sigma_{A_N^{Sig}} = \frac{\sqrt{\sigma^2_{A_N^{Raw}} + r^2\sigma^2_{A_N^{Bkg}}}}{1-r} = g(r) * \sigma_{A_N^{Bkg}} = f(\frac{S}{B}) * \sigma_{A_N^{Bkg}}$$



Multiplicative factor up to $S/B = 1$



Multiplicative factor for $S/B > 1$

Uncertainty decreases as S/B increases

Back of the Envelop Calculations

- Uncertainty to the TSSA $\sigma_{A_N^{Sig}} = \frac{\sqrt{\sigma^2_{A_N^{Raw}} + r^2\sigma^2_{A_N^{Bkg}}}}{1-r}$, where $r = \frac{Bkg}{Raw}$
- If we can reduce background by a further factor of 100 (beyond the result of regular cuts) while improving S/B by a factor of 20 ...
- *Both moderate assumptions given that S/B improves by a factor of 4 simply replacing all cuts form our previous studies by this one cut*
- $\sigma_{A_N^{Sig}}$ reduces by $\sim 30\%$

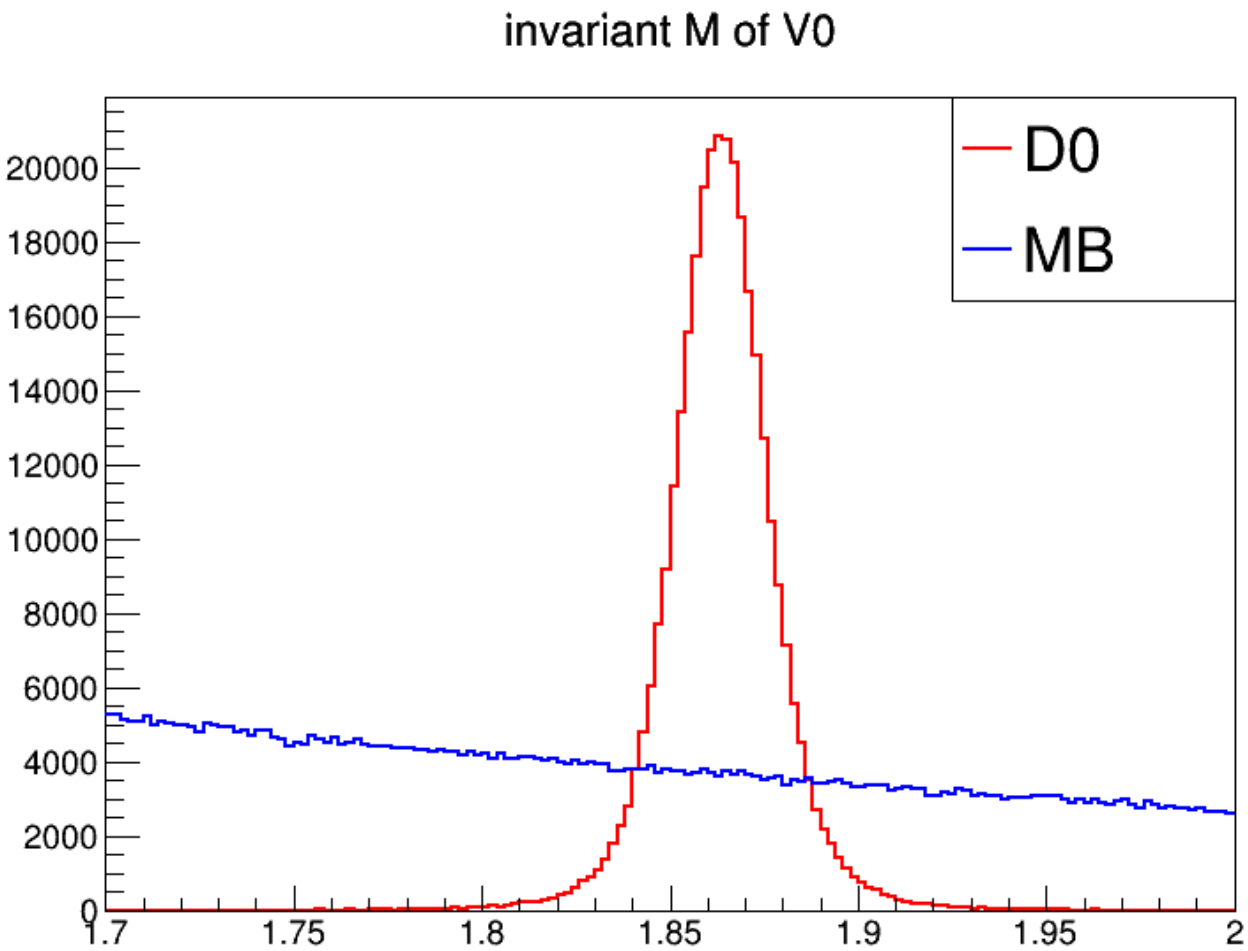
Outlook

- This analysis was done with barrel only MAPS vertex detector
- End Caps for MAPS vertex detector will improve this type of measurement (low p_T charged pions)
- Finally have large scale simulated data production chain working. Test production of 20M min-bias (with DSSD) was finished
- With significant amount of min-bias data (100M - 1B), these studies (of rare processes) can give a more definitive and quantitative answer - for now, we run out of background events
- In general, this low statistics but cleaner channel seems promising

Thank You

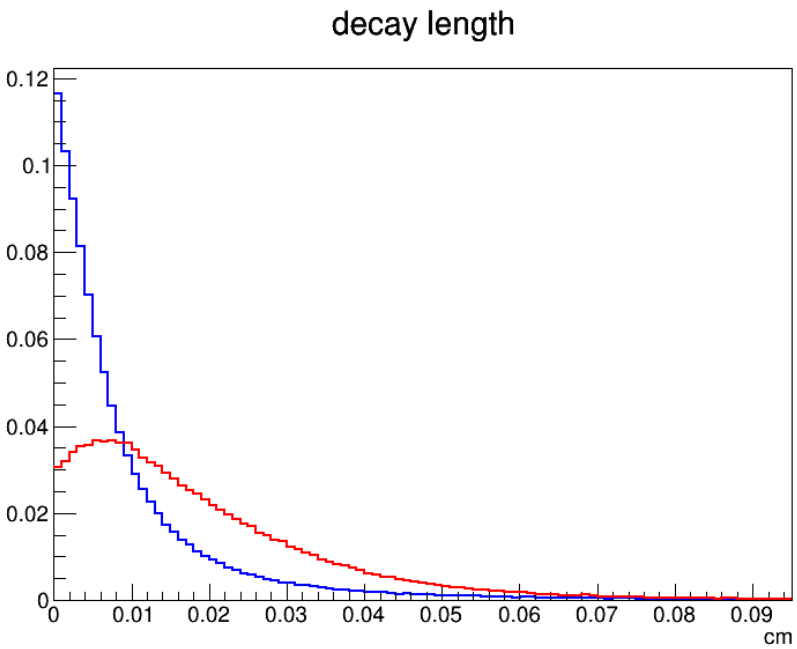
Backup

$\pi^+ K^-$ Invariant Mass



Invariant mass of $\pi^+ K^-$ for signal and background events in simulation

Decay Length



Comparison of decay length

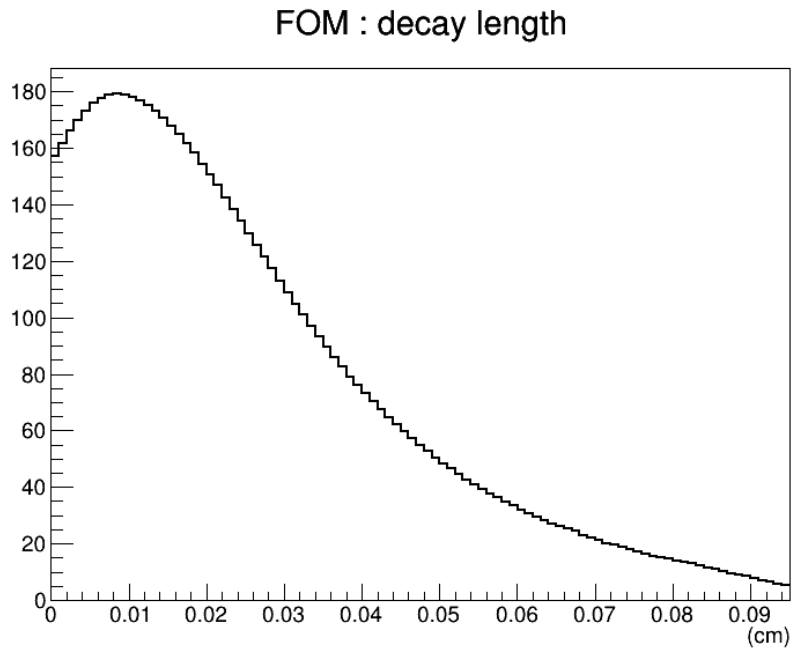
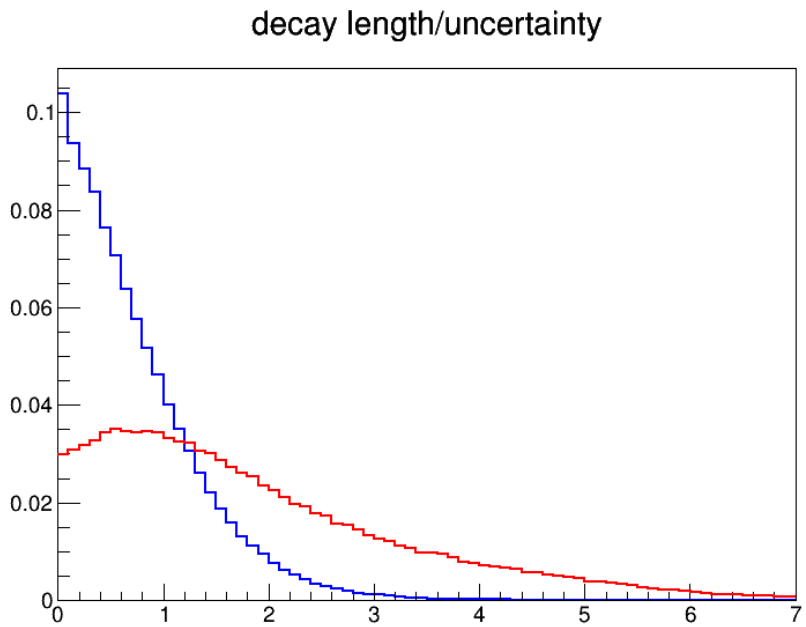


Figure of merit : decay length

Decay Length Divided by Uncertainty



Comparison of decay length divided by uncertainty

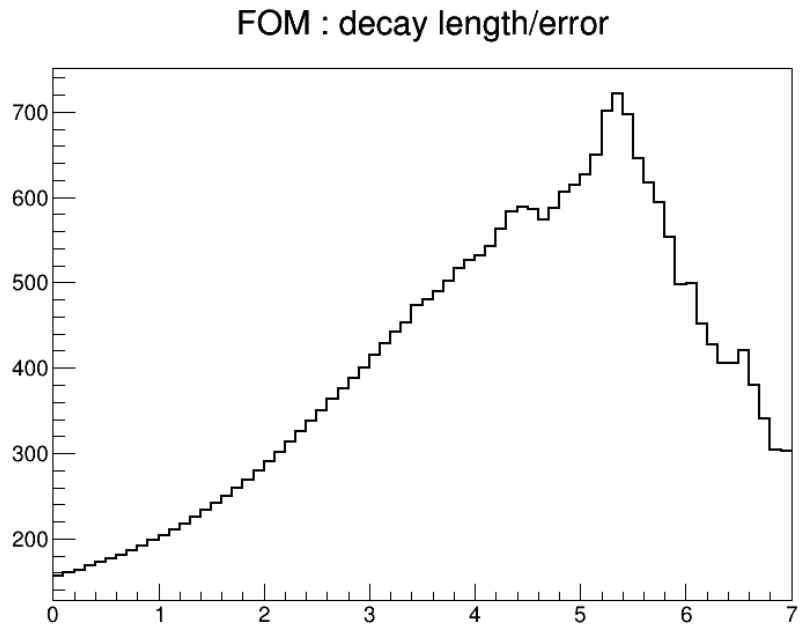
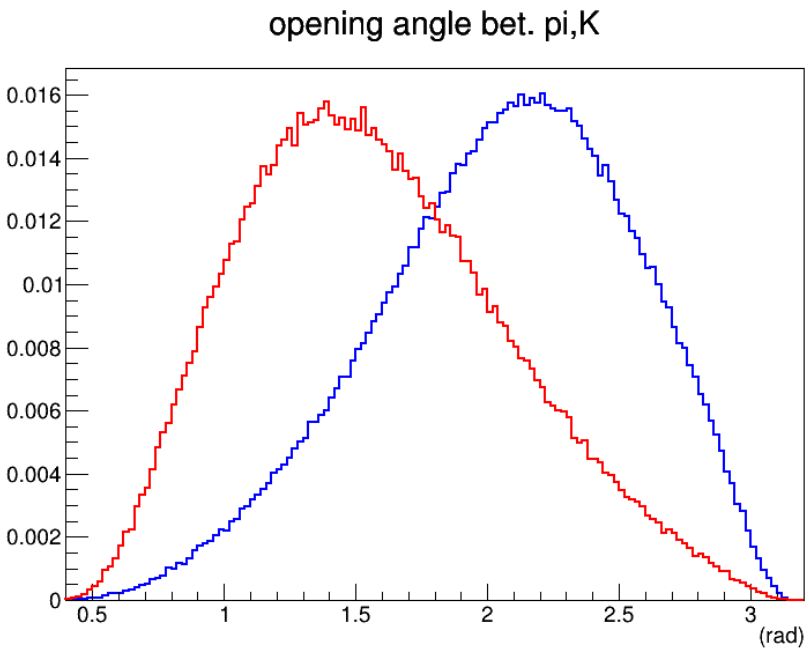


Figure of merit : decay length divided by uncertainty

Opening Angle between Pion and Kaon



Comparison of opening angle

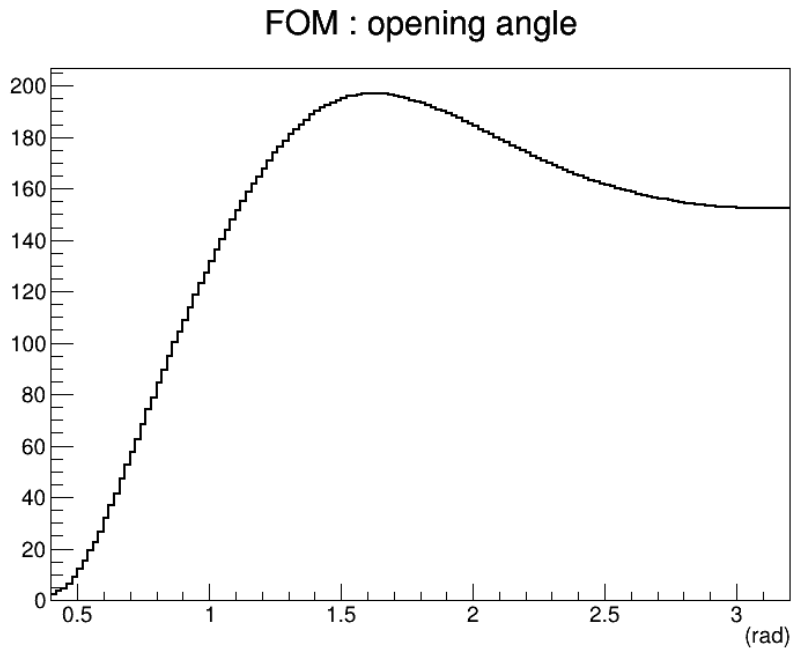
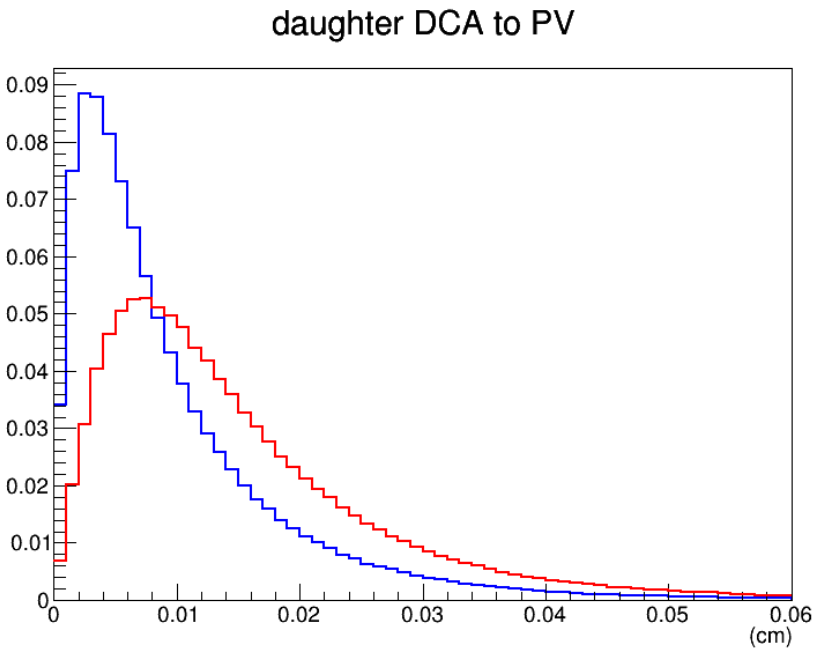


Figure of merit : opening angle

Distance of Pion, Kaon from Primary Vertex



Comparison of daughter DCA to PV

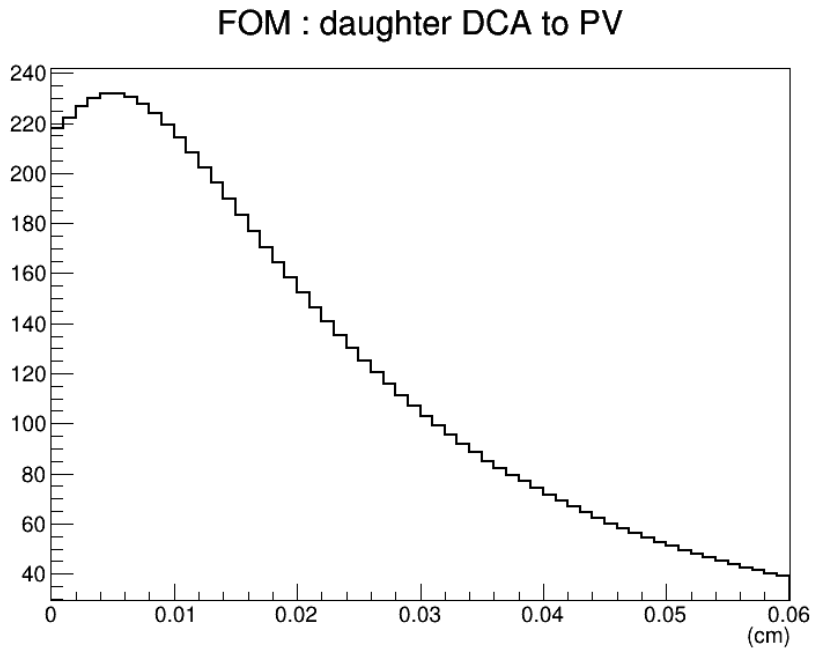
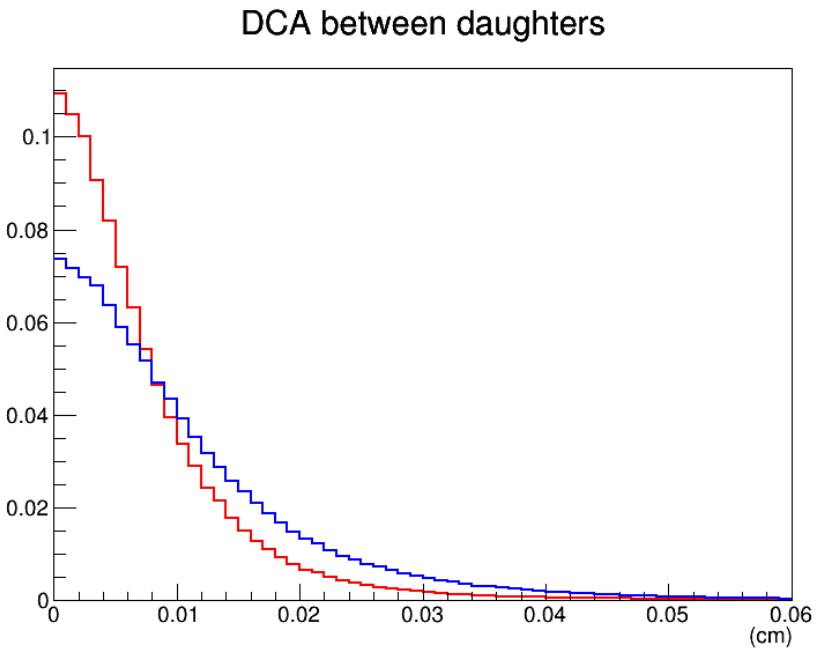


Figure of merit : daughter DCA to PV

Distance between Pion and Kaon



Comparison of DCA between daughters

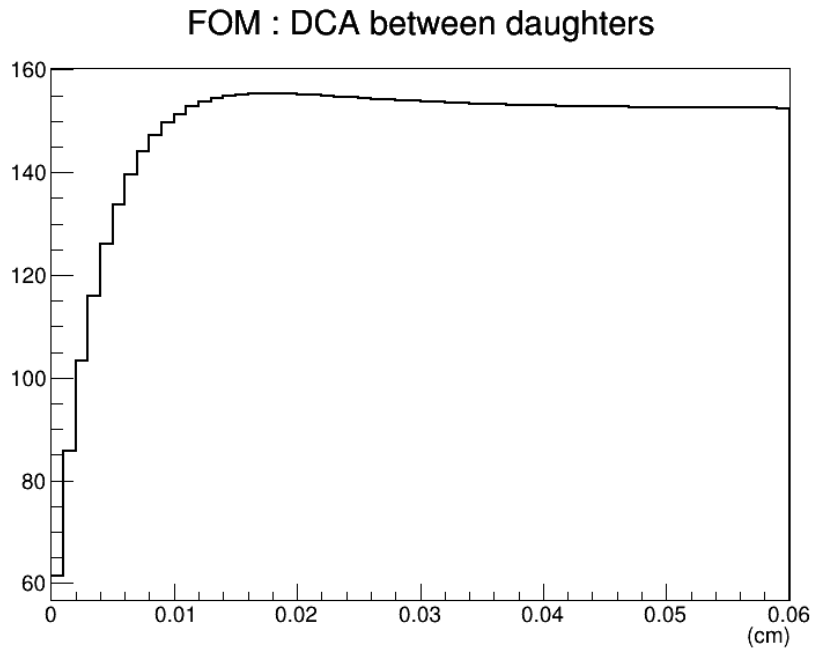


Figure of merit : DCA between daughters