dE/dx

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Mean energy loss of charged particles in matter

- Moderately relativistic charged particles lose energy in matter primarily by ionization. The mean rate of energy loss (or stopping power) is given by the Bethe-Bloch equation

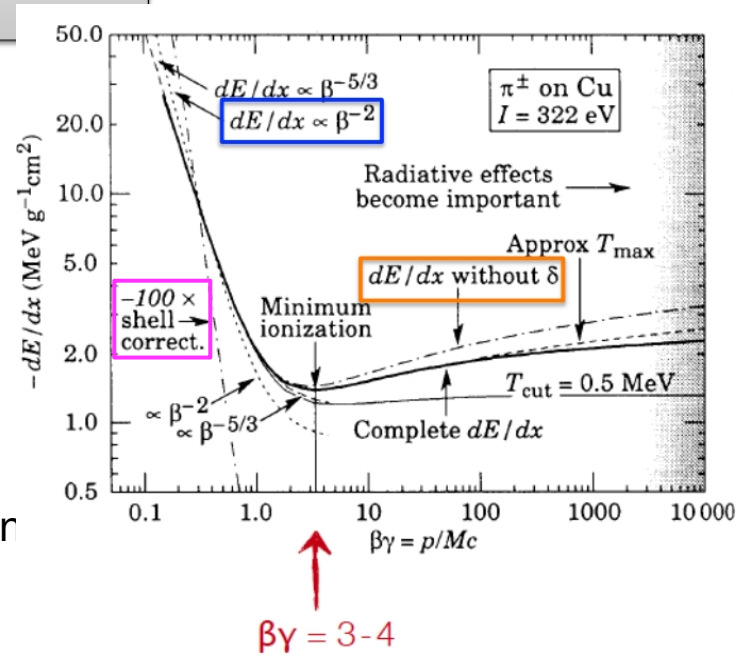
$$-\left\langle \frac{dE}{dx} \right\rangle = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[\ln\left(\frac{2m_e c^2 \beta^2\gamma^2}{I^2} W_{max}\right) - 2\beta^2 - \delta(\beta\gamma) - \frac{C}{Z} \right]$$

$2\pi N_a r_e^2 m_e c^2$ = =0.1535 MeV cm²/g

Fundamental constants
r_e=classical radius of electron
m_e=mass of electron
N_a=Avogadro's number
c =speed of light

Absorber medium
I = mean ionization potential
Z = atomic number of absorber
A = atomic weight of absorber
ρ = density of absorber
δ = density correction
C = shell correction

Incident particle
z = charge of incident particle
β = v/c of incident particle
γ = $(1-\beta^2)^{-1/2}$
W_{max}= max. energy transfer in one collision



Minimum ionizing particles (MIP): βγ = 3-4

dE/dx falls ~ β^{-2}; kinematic factor
[precise dependence: ~ $\beta^{-5/3}$]

dE/dx rises ~ ln(βγ)²; relativistic rise
[rel. extension of transversal E-field]

Saturation at large (βγ) due to density effect (correction δ)
[polarization of medium]

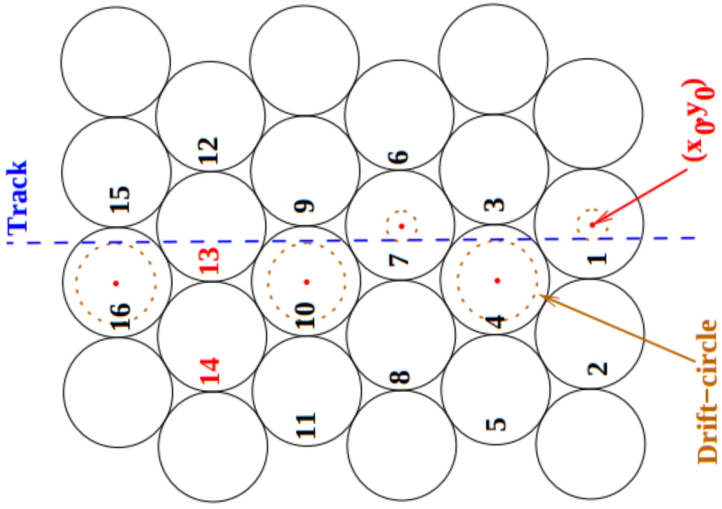
Shell correction: C/Z
Capture process is possible
Units: MeV g^{-1} cm²

MIP looses ~ 13 MeV/cm
[density of copper: 8.94 g/cm³]

- Formula needs to be modified for electrons
- Bethe-Bloch formula is not valid for slow particles βγ<0.02 where dE/dx ∝ β
- Low energies: shell corrections ($\nu_h \sim \nu_{e,orbital}$)
- High energies: density corrections (Polarization along trajectory)

Mean energy loss in the experiment

In a practice, the experimental energy loss is a (semi-) empirical equation.



Mean energy loss in the experiment

In a practice, the experimental energy loss is a semi-empirical equation.

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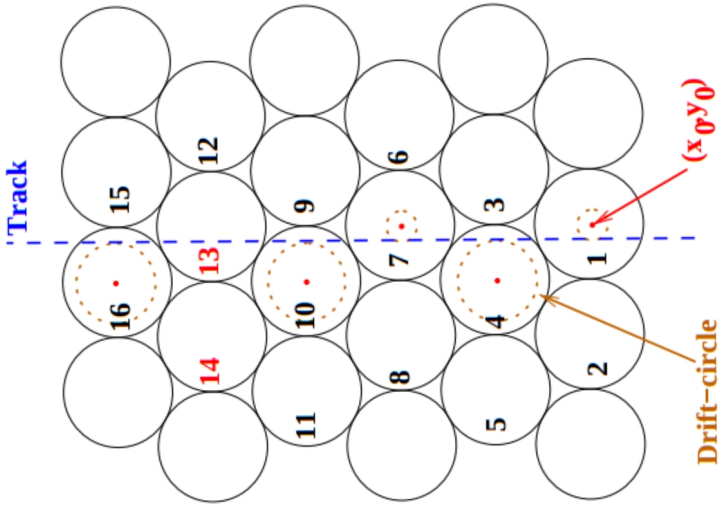

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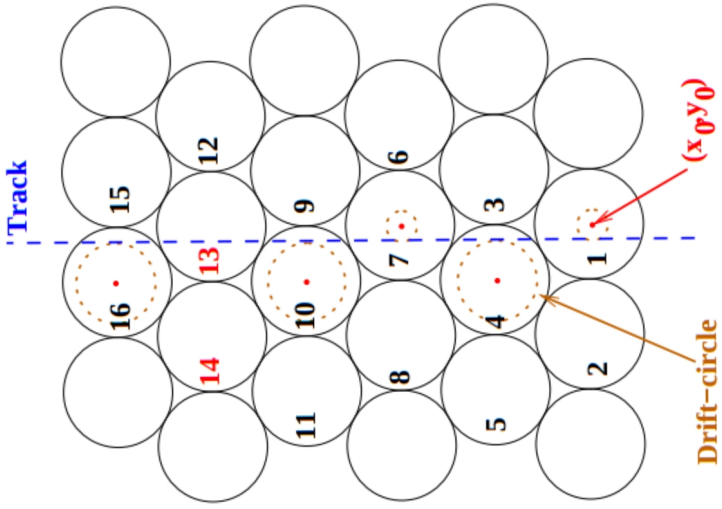

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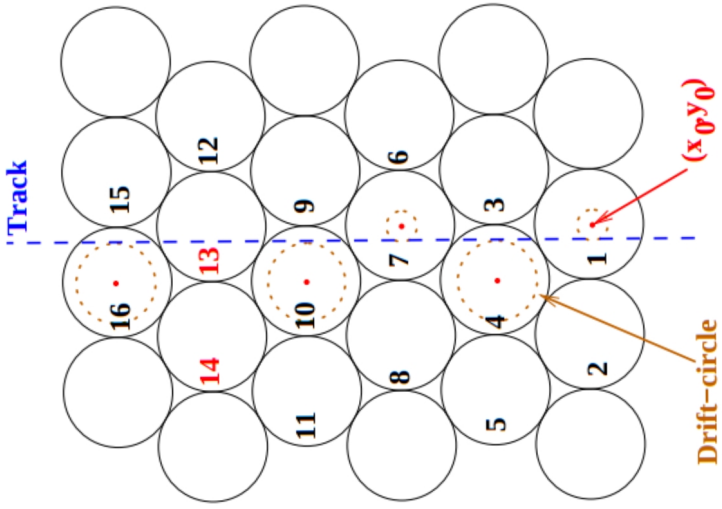

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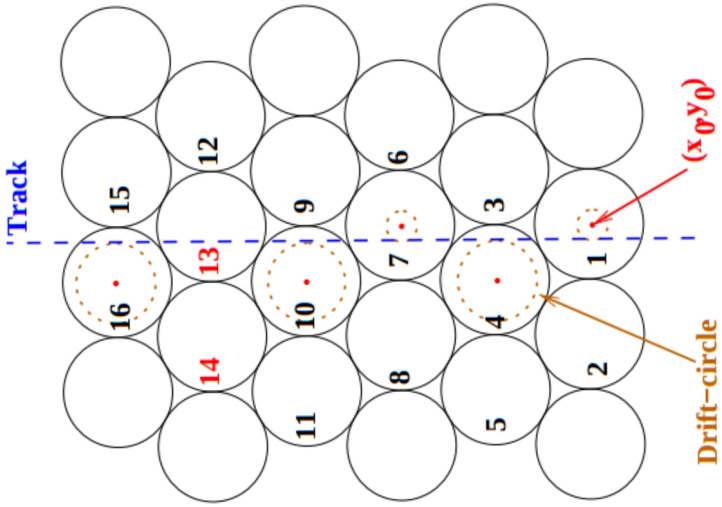

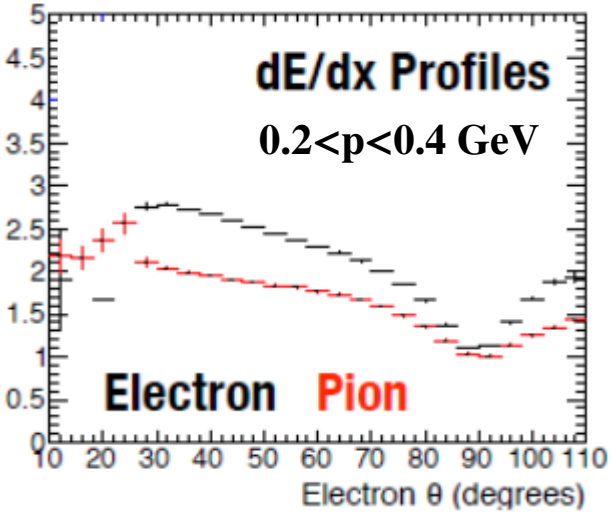

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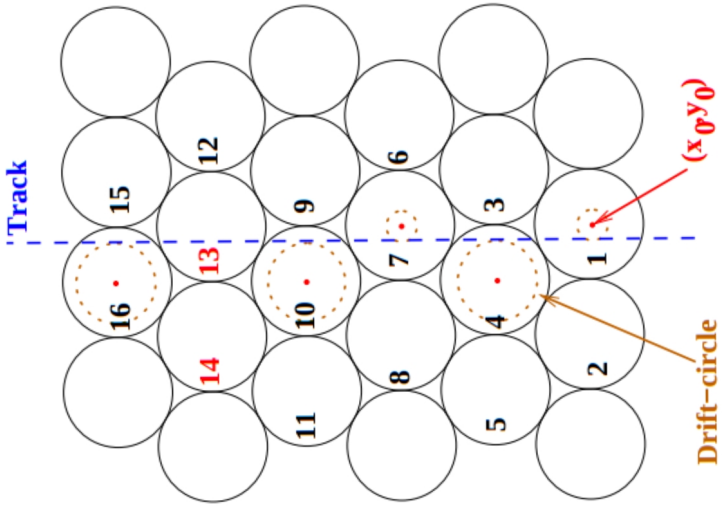
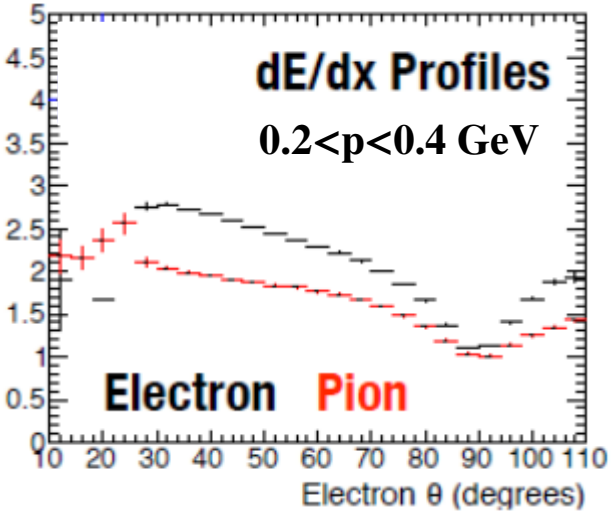
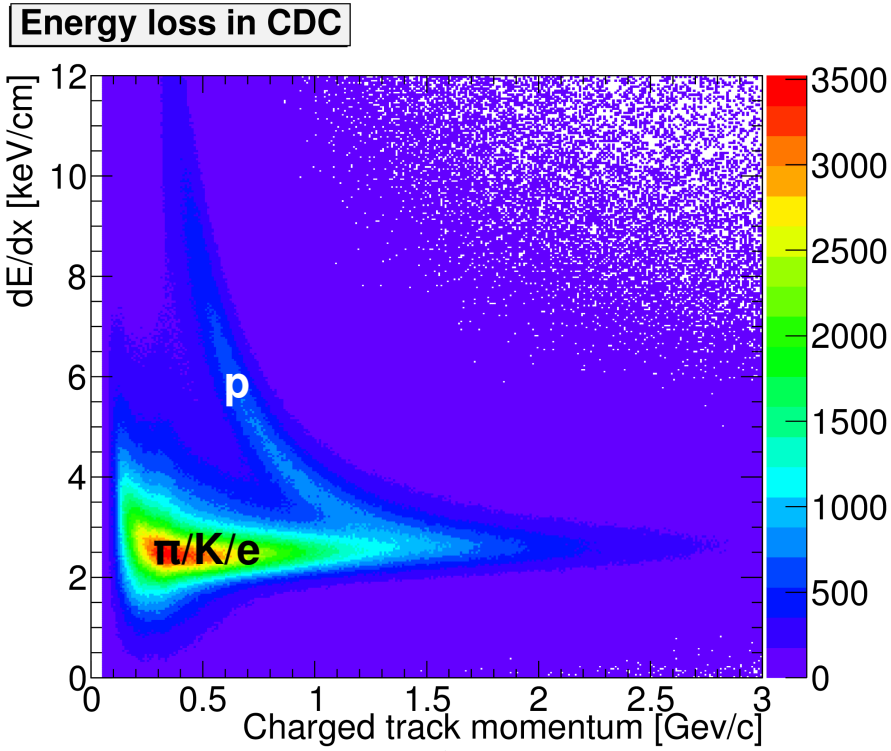
After various calibrations, Estimate the dE/dx for every track by the truncated mean method.



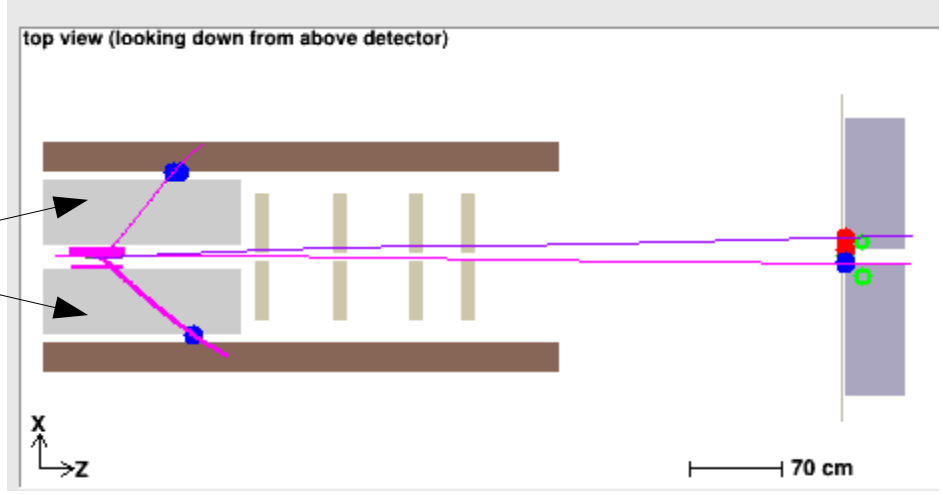


Mean energy loss and PID

- Low Momentum charged particles and most of recoiled protons will not reach outer detectors.
- dE/dx measured in CDC will be the primary source for particle ID in this case



CDC



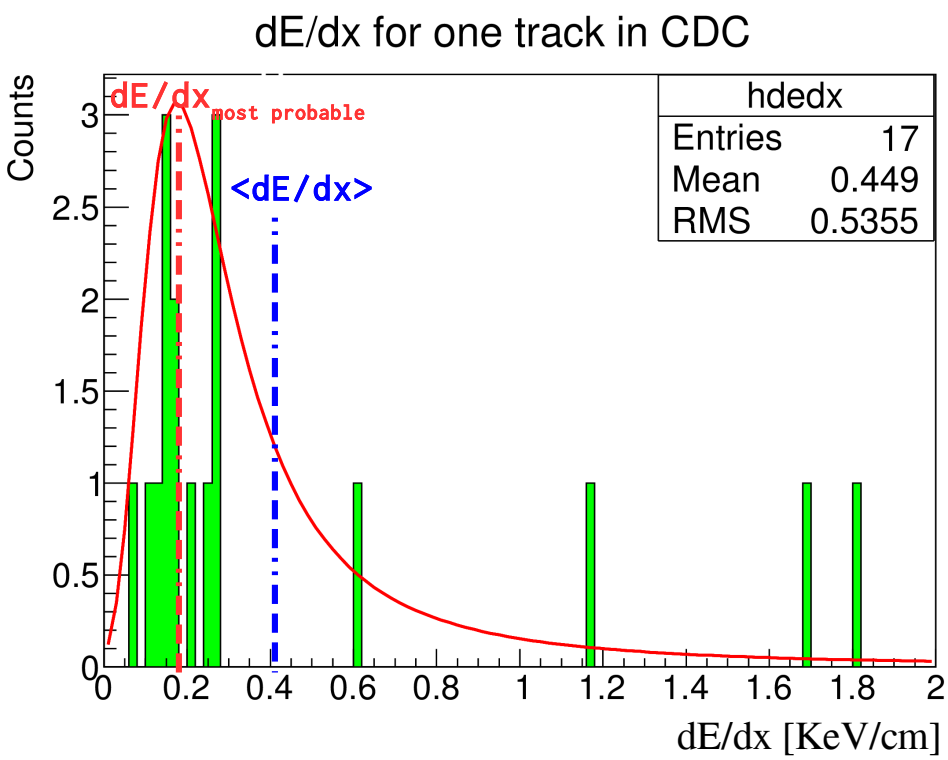
Truncated mean method

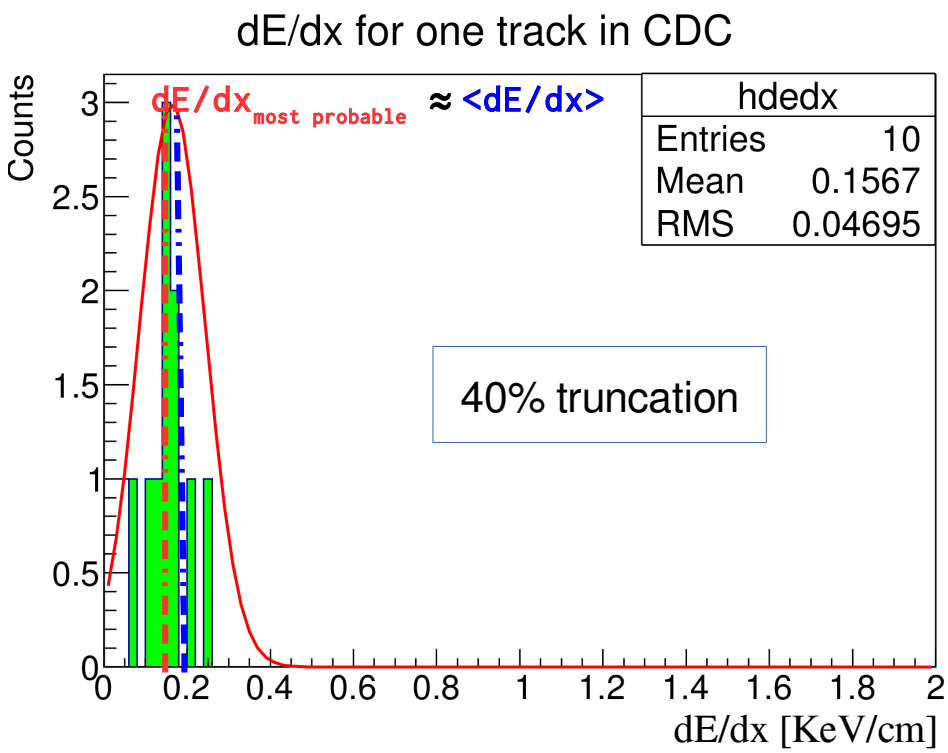
Goal: Achieve the optimal separation of different particle types using dE/dx

- Estimate dE/dx mean value and eventually the width

Method: Truncated mean

- Drop some hits with largest dE/dx values from the track
- Optimize truncation to achieve the Lowest mis-ID.

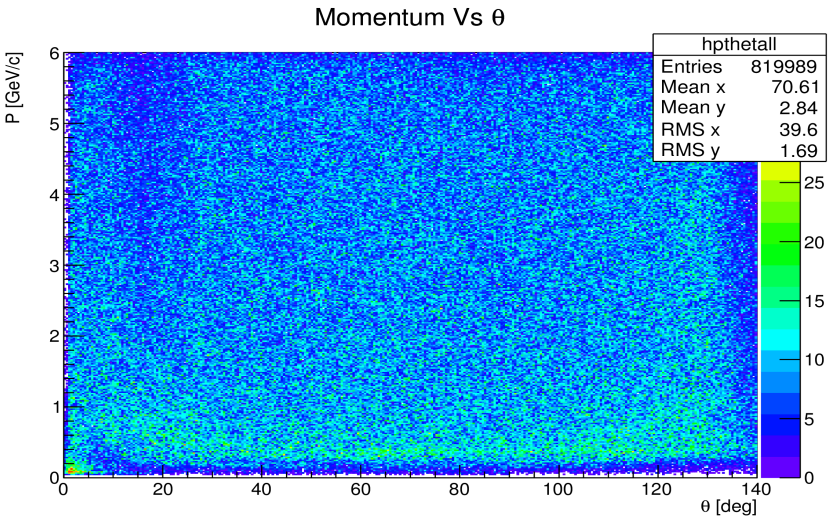


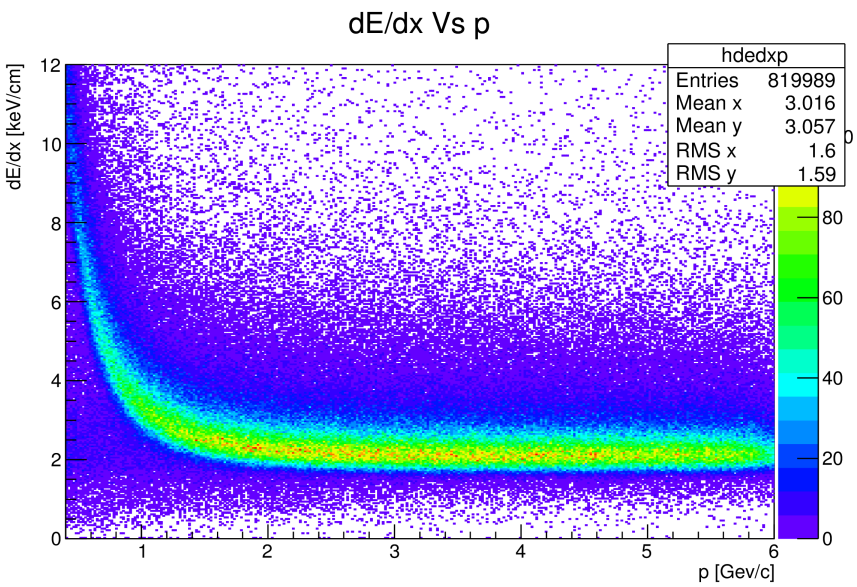


Simulation

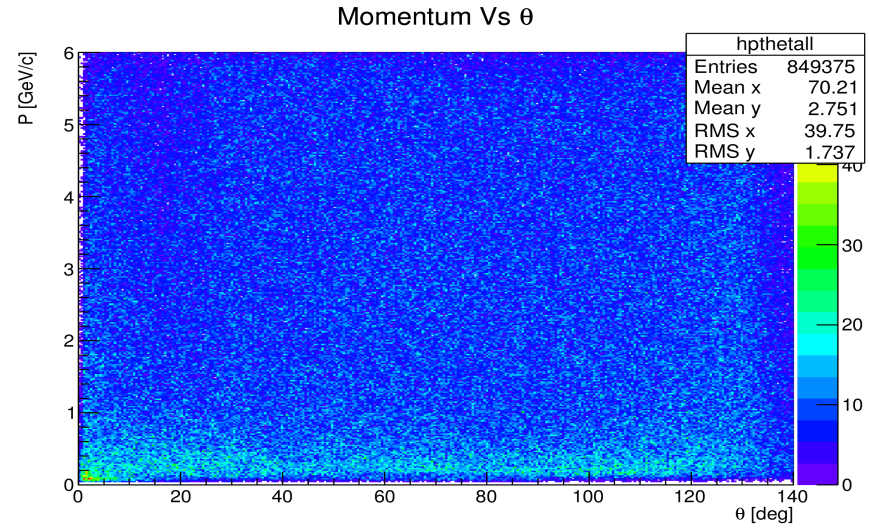
- 1M events Protons (left) & Pions (right) generated and transported through the GlueX detector

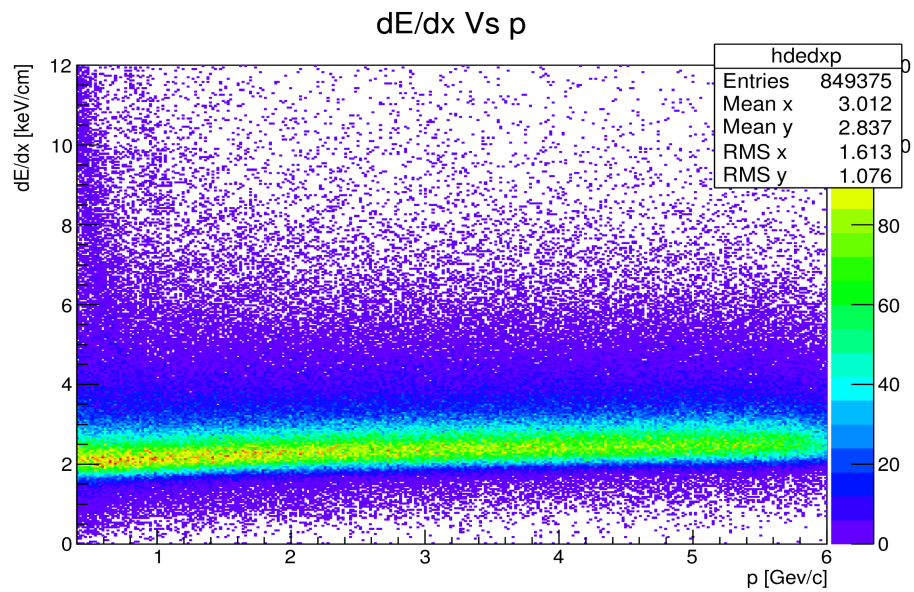
Protons





π^+





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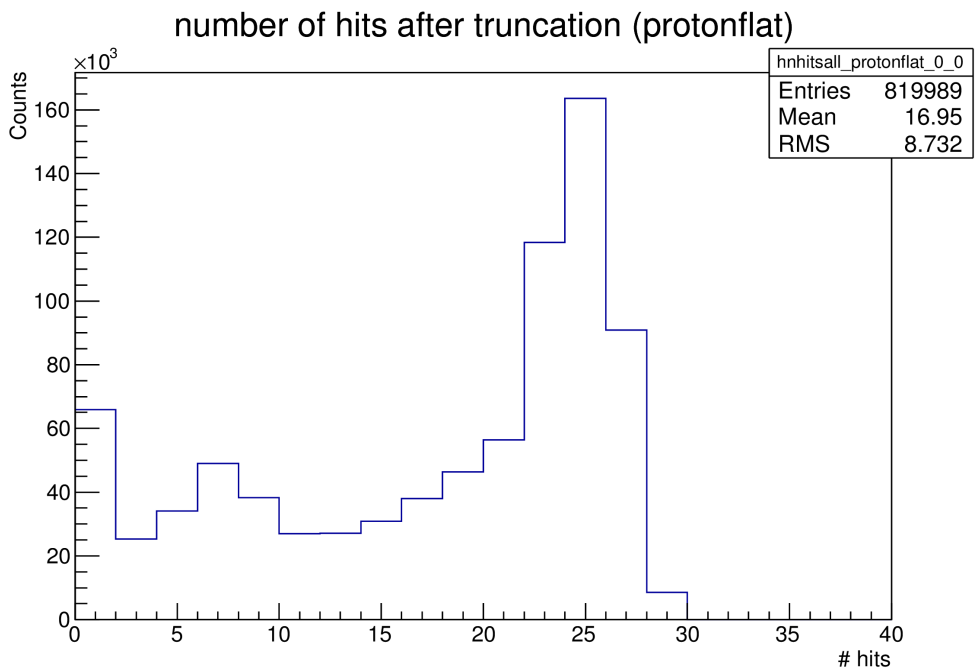
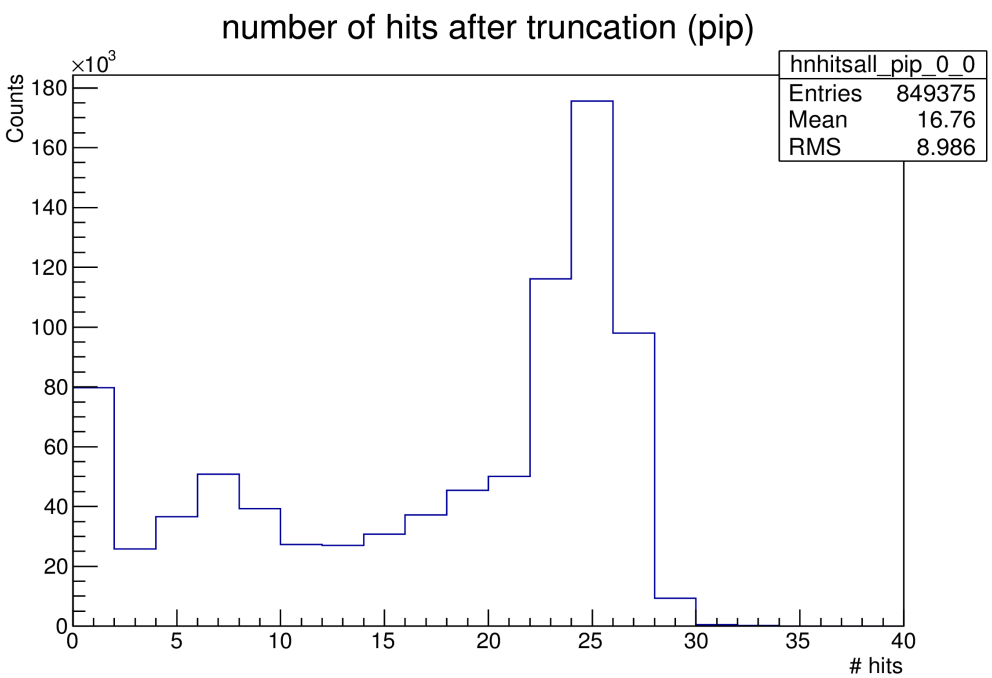
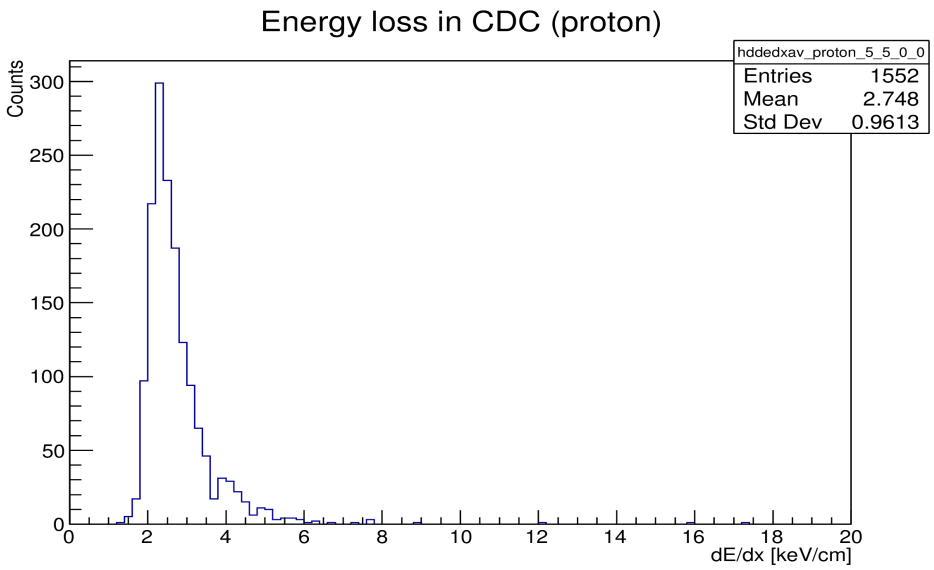
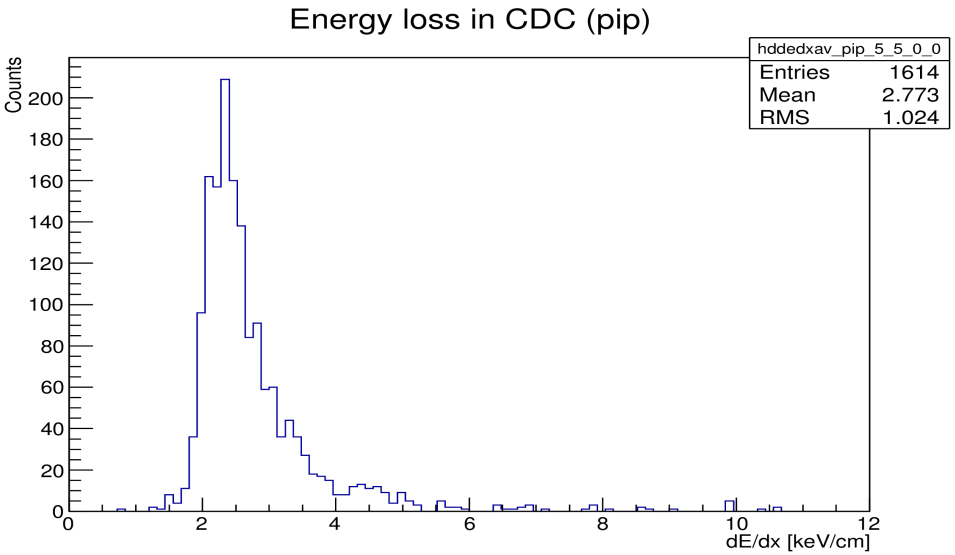


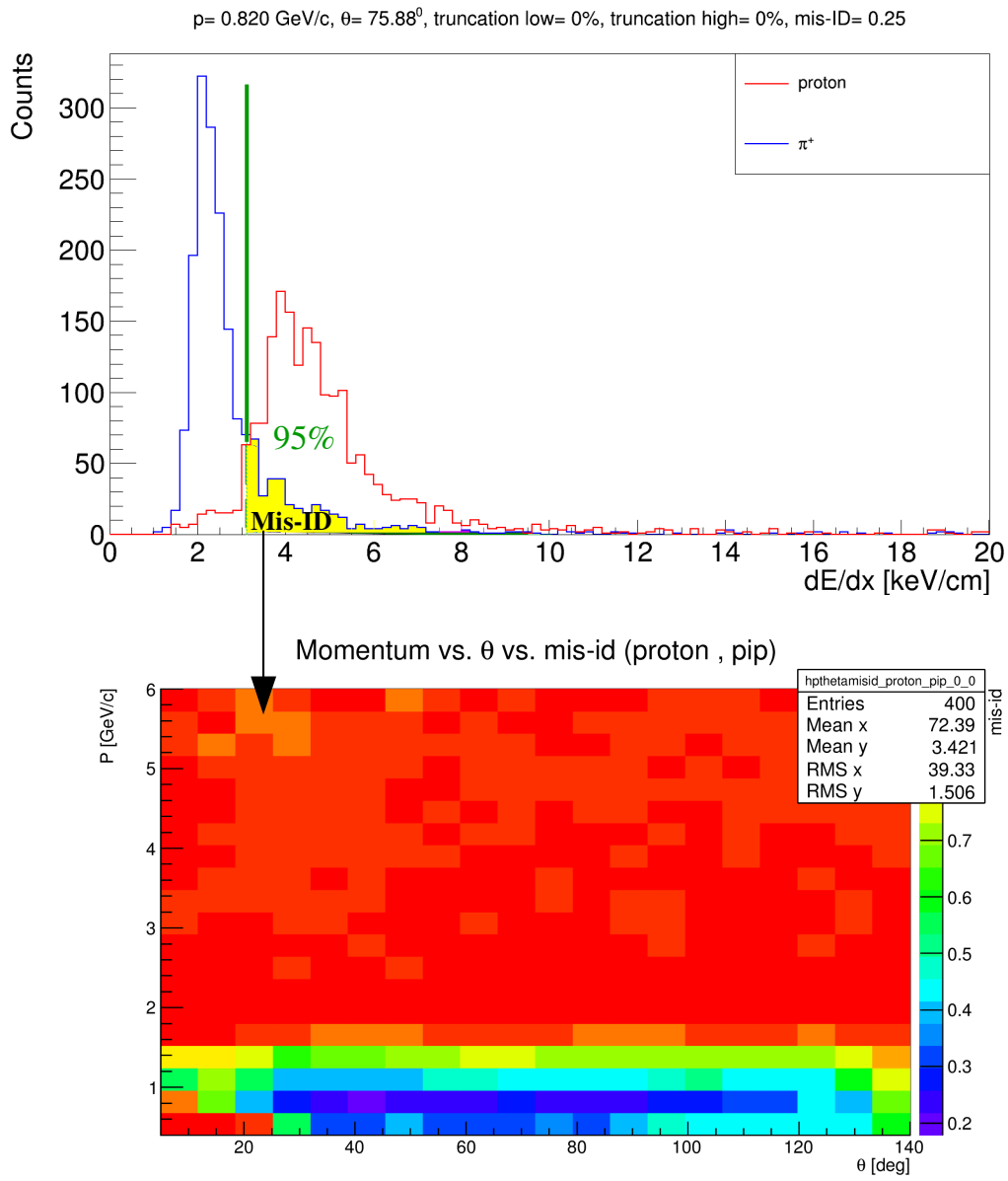






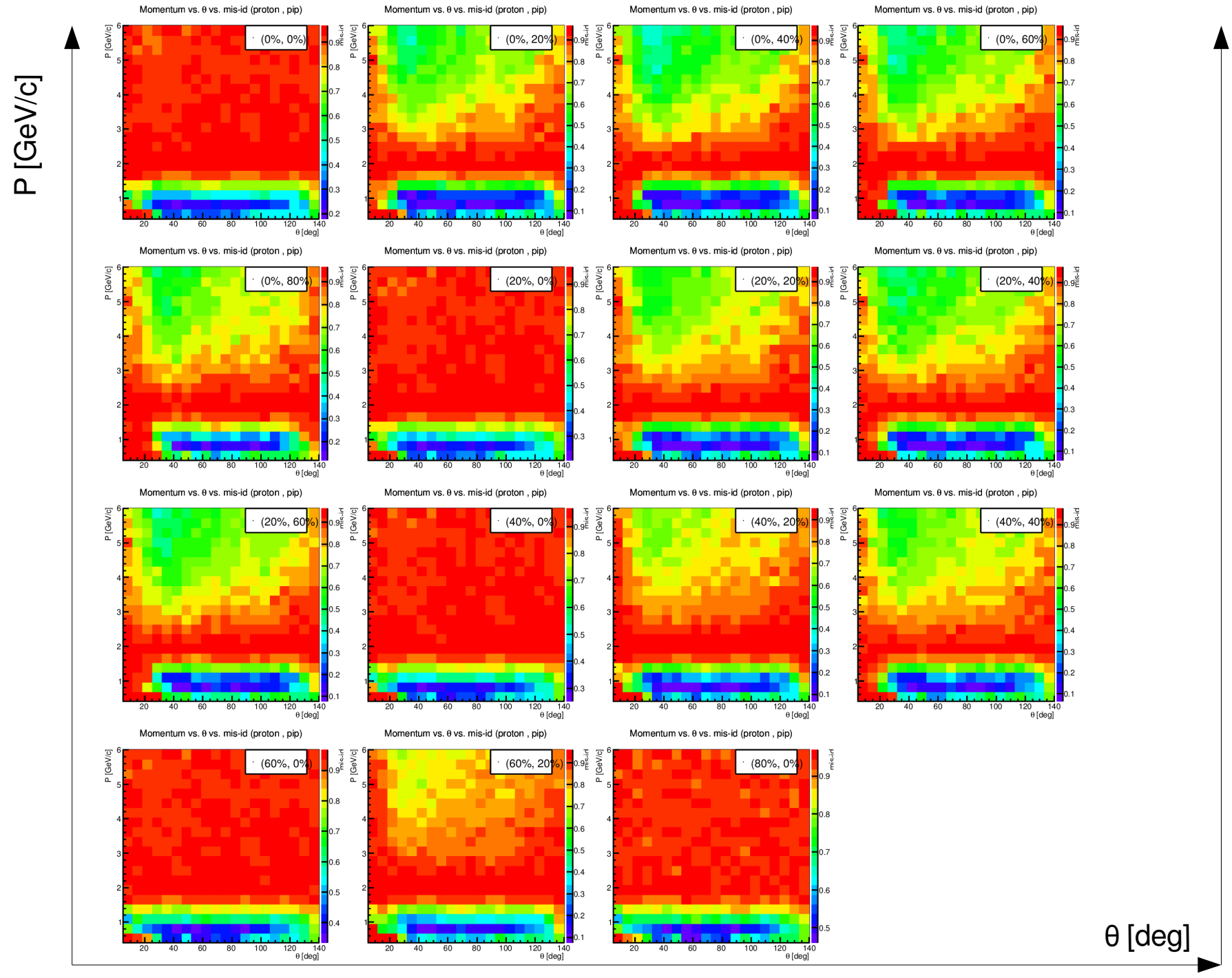
FOM

- Average energy loss in the CDC for protons (red) and π^+ (blue)
- FOM Mis-ID: the optimal truncation correspond to the lowest mis-ID value



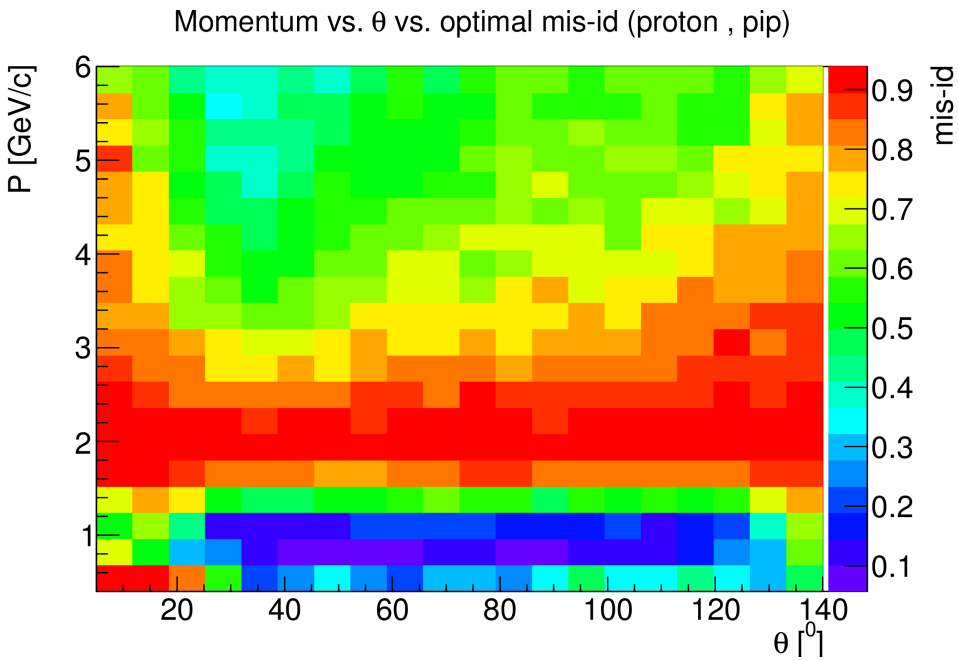
Optimal truncation scan

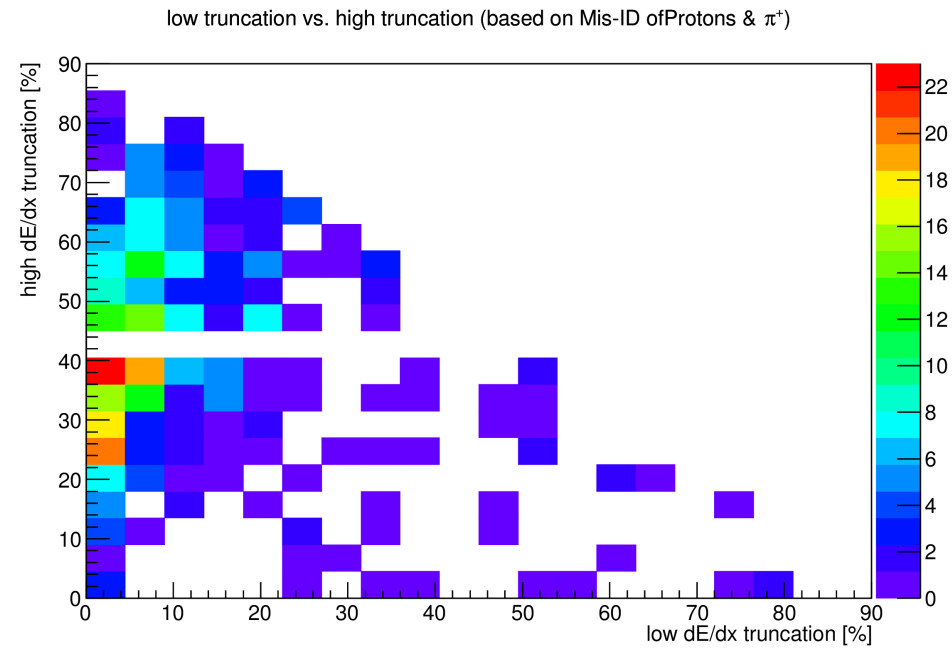
- Scan over all the (p, θ) bins and for all the truncation combinations (low dE/dx, High dE/dx cut)

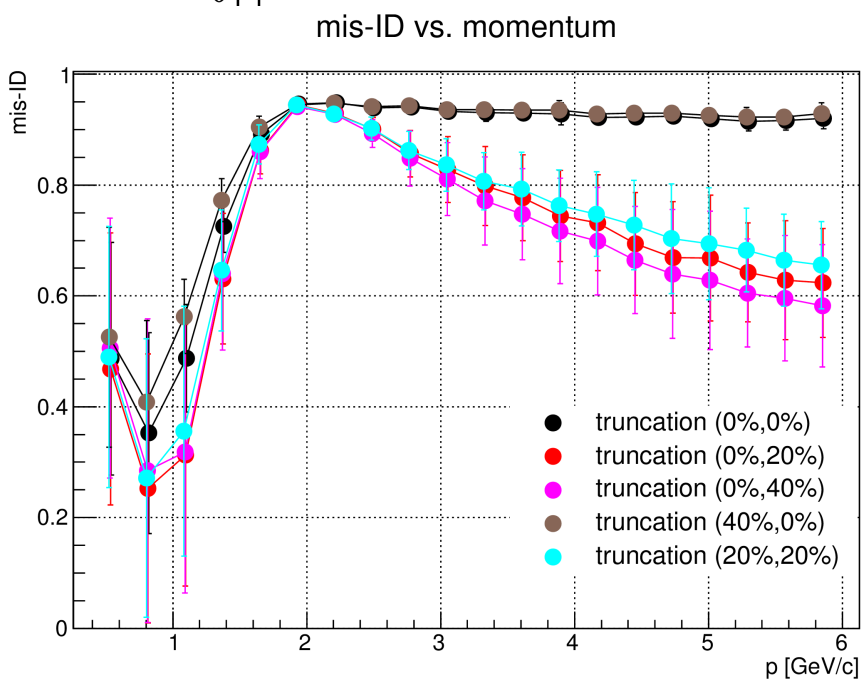


Optimal truncation results

- Optimal truncation based on mis-ID: 20% - 40% cut on the hits with high dE/dx







Thank you for your attention