Micro Vertex Detector

Particle Identification

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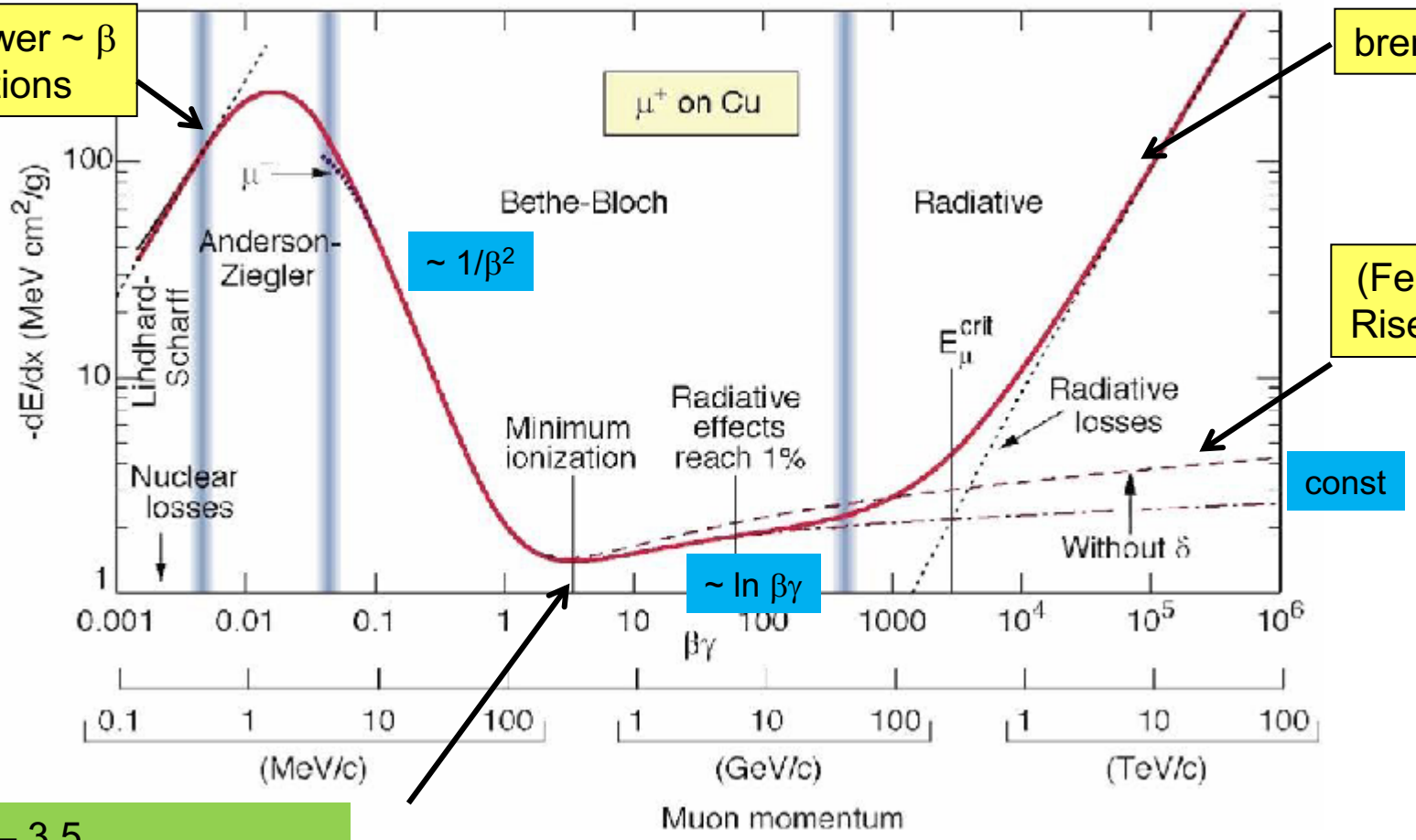
TOBIAS STOCKMANNS

Mean dE/dx

Bethe-Bloch Formula

electronic stopping power ~ β
non-ionizing interactions

bremsstrahlung



(Fermi-)Plateau
Rise: $T_{max} \sim \beta^2\gamma^2$

const

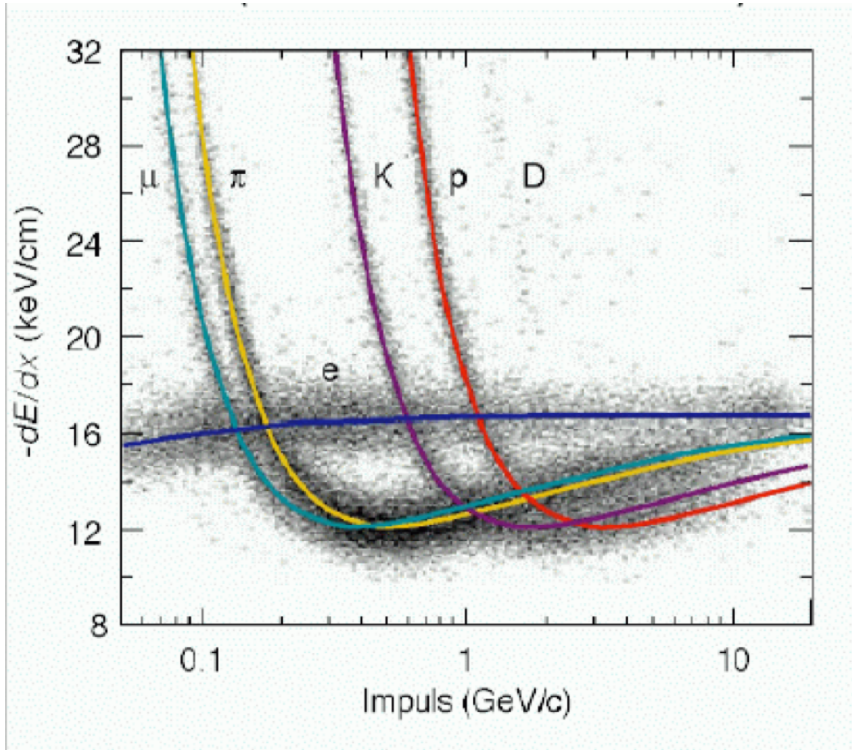
Minimum at $\beta\gamma \approx 3.0 – 3.5$
➔ minimum ionizing particle (MIP)

$$\left\langle \frac{-dE}{dX} \right\rangle = K z^2 \frac{1}{\beta^2} \frac{Z}{A} \left[\frac{1}{2} \ln \frac{2c^2 \beta^2 m_e \gamma^2 T_{max}}{I^2} - \beta^2 - \frac{\delta}{2} - \frac{C}{Z} \right]$$

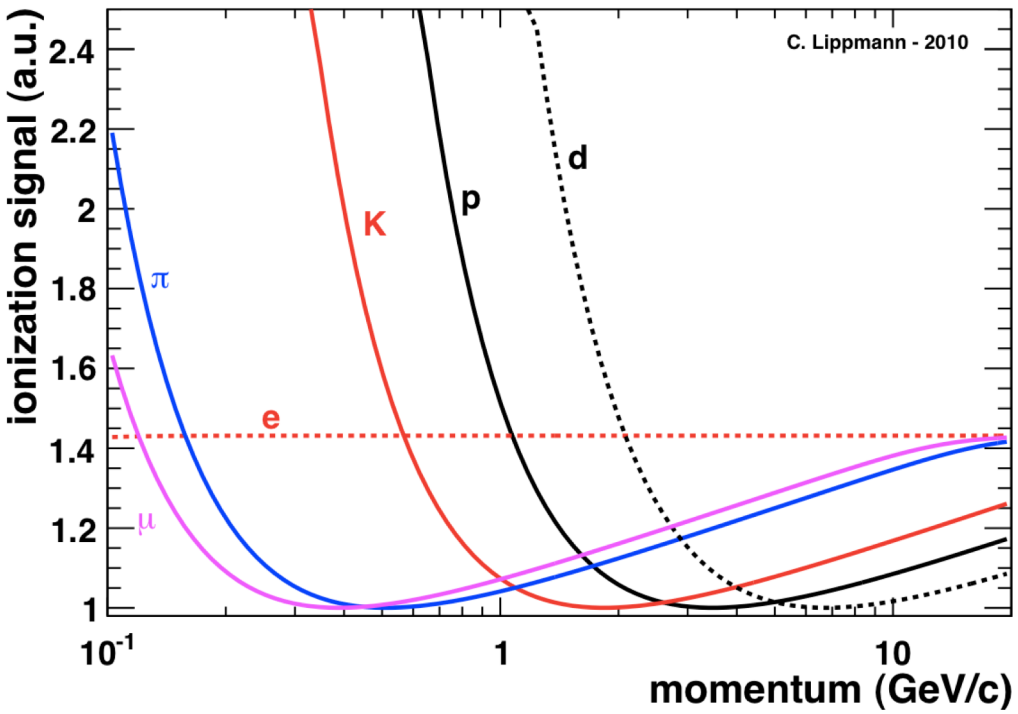
Particle Identification

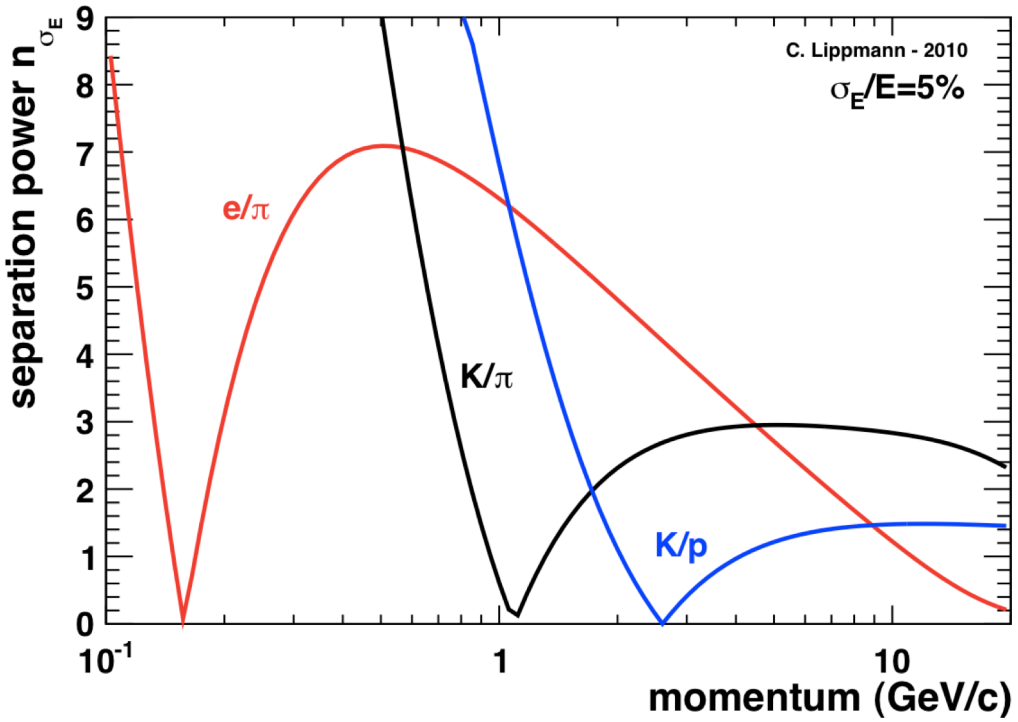
$$\left\langle \frac{-dE}{dX} \right\rangle \approx K z^2 \frac{1}{\beta^2} \frac{Z}{A} \left[\ln \frac{2c^2 \beta^2 m_e \gamma^2}{I^2} - \beta^2 - \frac{\delta}{2} - \frac{C}{Z} \right]$$

dE/dX only dependent of velocity and not from mass ➔ particle identification



- Heavy particles:
  - dE/dx well described by Bethe-Bloch-Formula
  - Ionization and excitation of target electrons
- Electrons do not obey the Bethe-Bloch-Formula





$$n_{\sigma_E} = \frac{\Delta_A - \Delta_B}{\langle \sigma_{A,B} \rangle} \, .$$

Energy loss - summary

Bethe-Bloch formula describes the **mean** energy loss -<dE/dX> of (heavy) charged particles in matter:

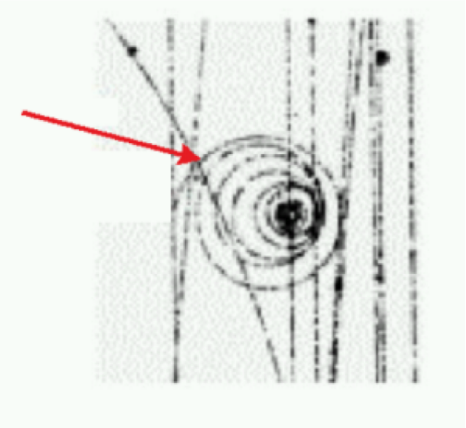
- by ionization and excitation → dominant
- Cerenkov radiation and transition radiation (included in BBF)
- NOT bremsstrahlung (important for electrons and high energy μ or π)

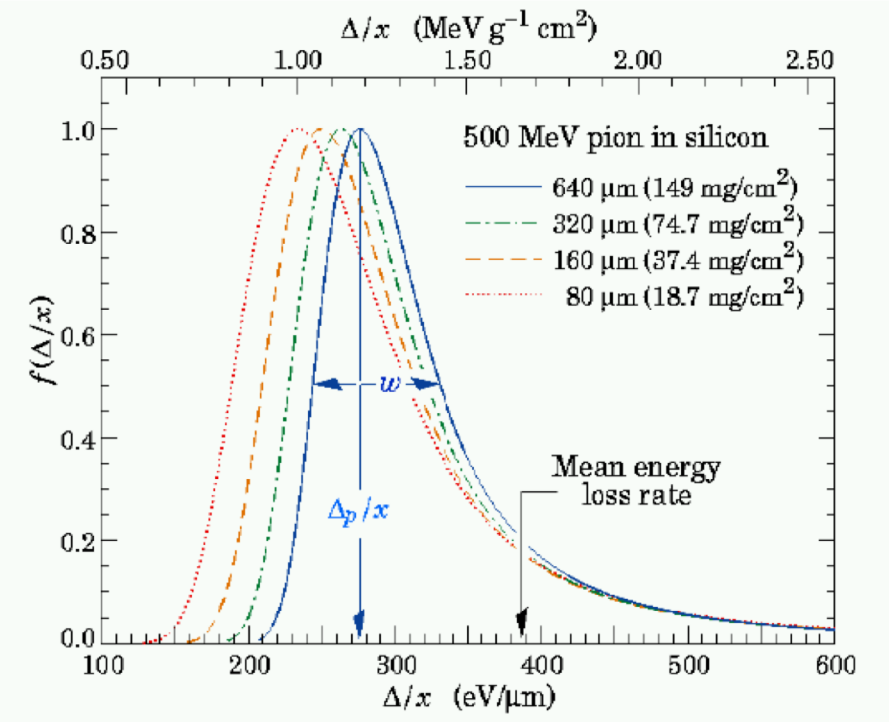
$$\left\langle \frac{-dE}{dX} \right\rangle = K z^2 \frac{1}{\beta^2} \frac{Z}{A} \left[\frac{1}{2} \ln \frac{2c^2 \beta^2 m_e \gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta}{2} - \frac{C}{Z} \right]$$

- at low β: <dE/dX> ~ $1/\beta^2$ down to "Bragg peak"
- minimum at βγ = p/m = 3-3.5 (v=96%c) "MIP"
- relativistic rise ~ ln(βγ) due to relativistic extension of transv. E-field
- density effect → saturation → plateau (polarization effects)
- only weak dependence on medium (Z/A, ln(I))
- height of the plateau~ 1.1 (solid) –1.7 (gas) x minimum
- remember: $\langle dE/dX \rangle_{mip}$~ 1.5 MeV/g cm^2
- plotting against p → possibility to distinguish particles by mass !

Energy loss distribution (straggling)

- Energy loss is a statistical process
- Distribution function is asymmetric for small absorbers
- For thick absorbers the distribution becomes Gaussian
- Collisions with small dE more probable
- large dE rare → electrons with large energy (keV) are called δ-electrons (or –rays)
- δ-electrons have enough energy for their own ionization trace





- Parameterized via asymmetric Landau(-Vavilov) distribution

$$L(\lambda) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(\lambda + e^{-\lambda})}$$

$$\lambda = \frac{\frac{dE}{dx} - \left(\frac{dE}{dx}\right)_{mpv}}{k\,\rho\,d}$$

$$k = 4\pi N_A m_e c^2 r_e^2 z^2 \frac{Z}{A}\frac{1}{\beta^2}$$

MVD

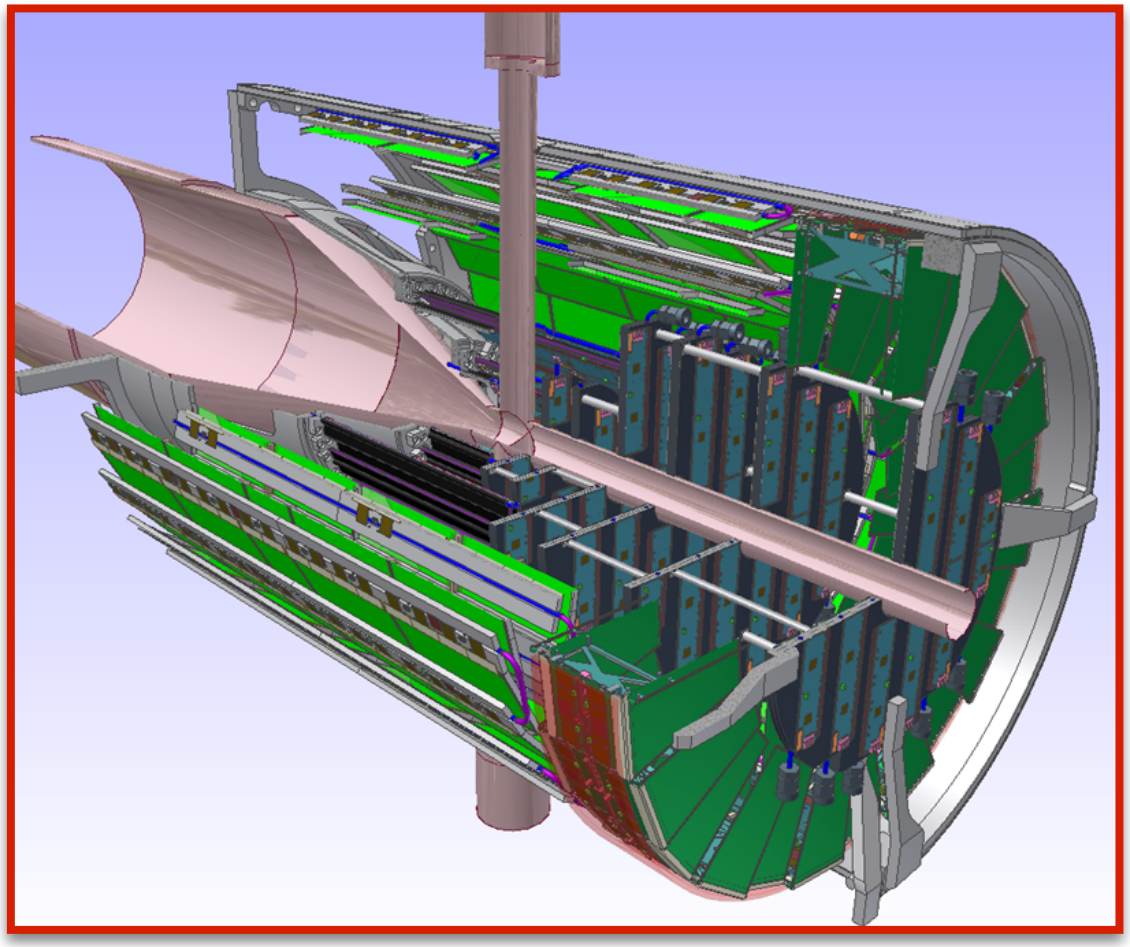
- Barrel:
  - 2 pixel layers
  - 2 strip layers
- Forward:
  - 4 pixel layers
  - 2 mixed layers
- Thickness:
  - 100 µm pixel
  - 280 µm strips

➔ Tracking detector!

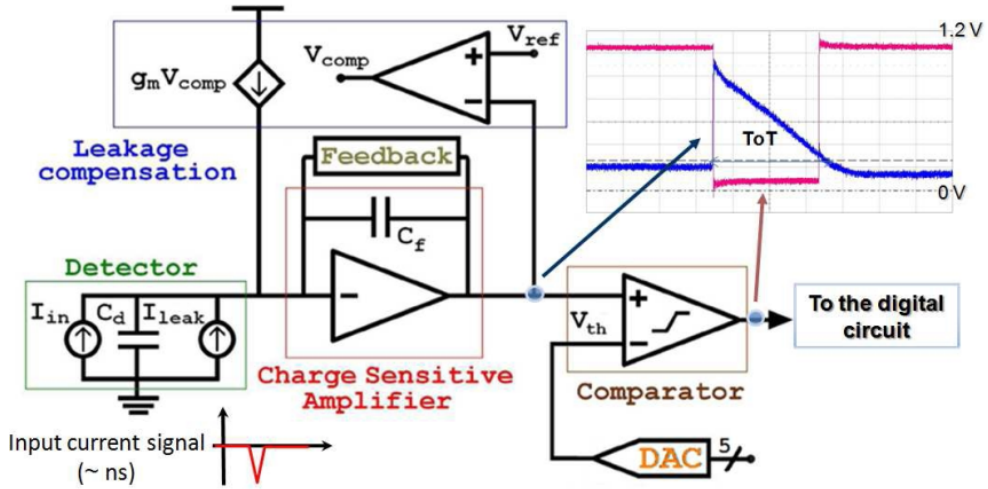
➔ Not an ideal PID detector

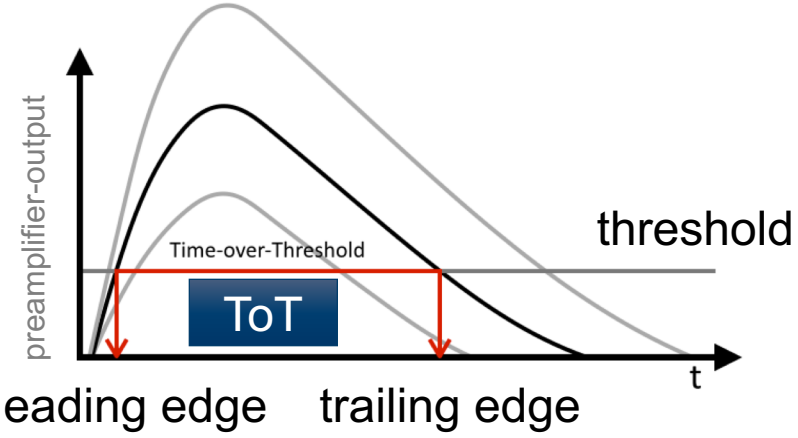
➔ Not enough layers

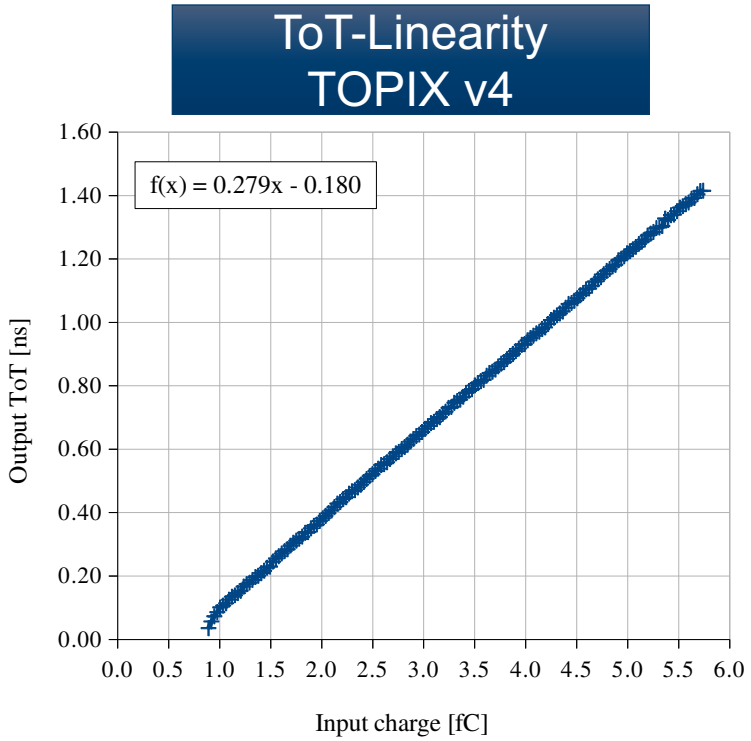
➔ Layers too thin



Charge Measurement



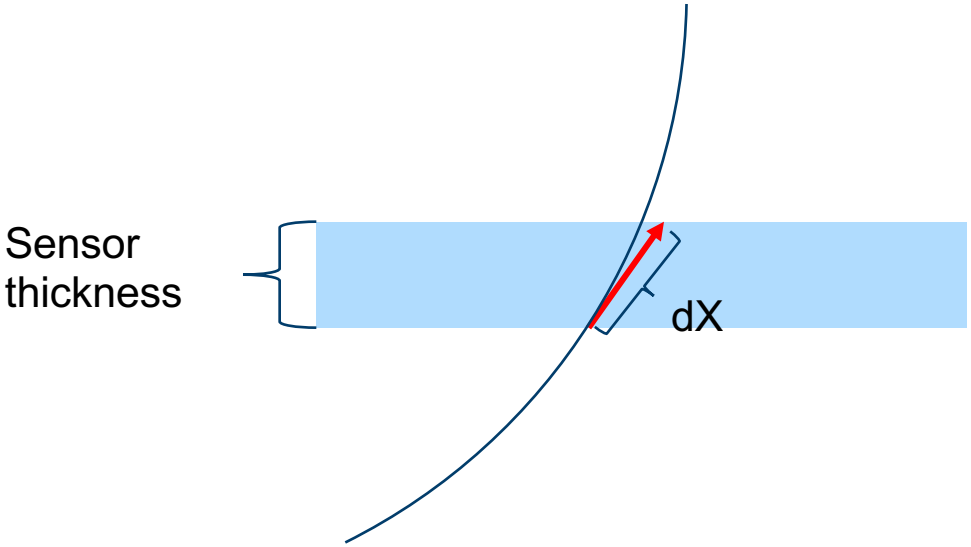




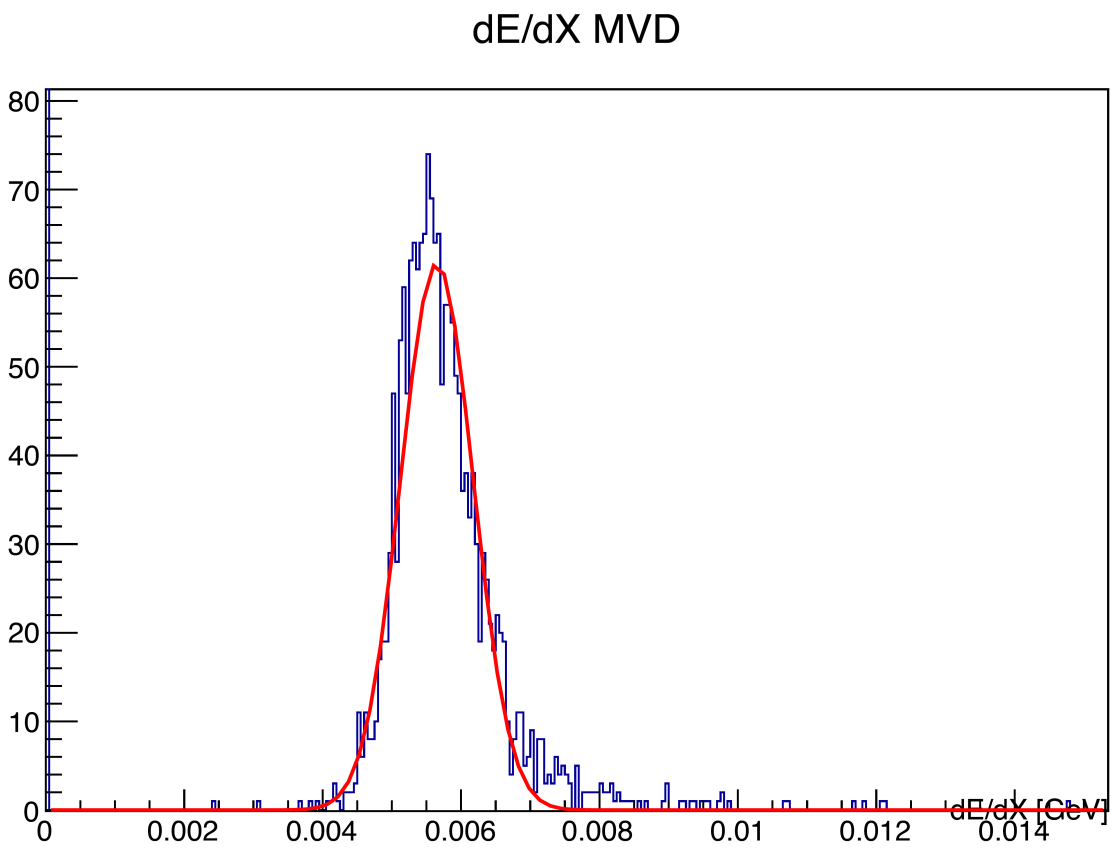
- Charge is measured as ToT
- ToT ∝ dep. Charge
- SNR (MIP):
  - 60 Pixel
  - 20 Strip

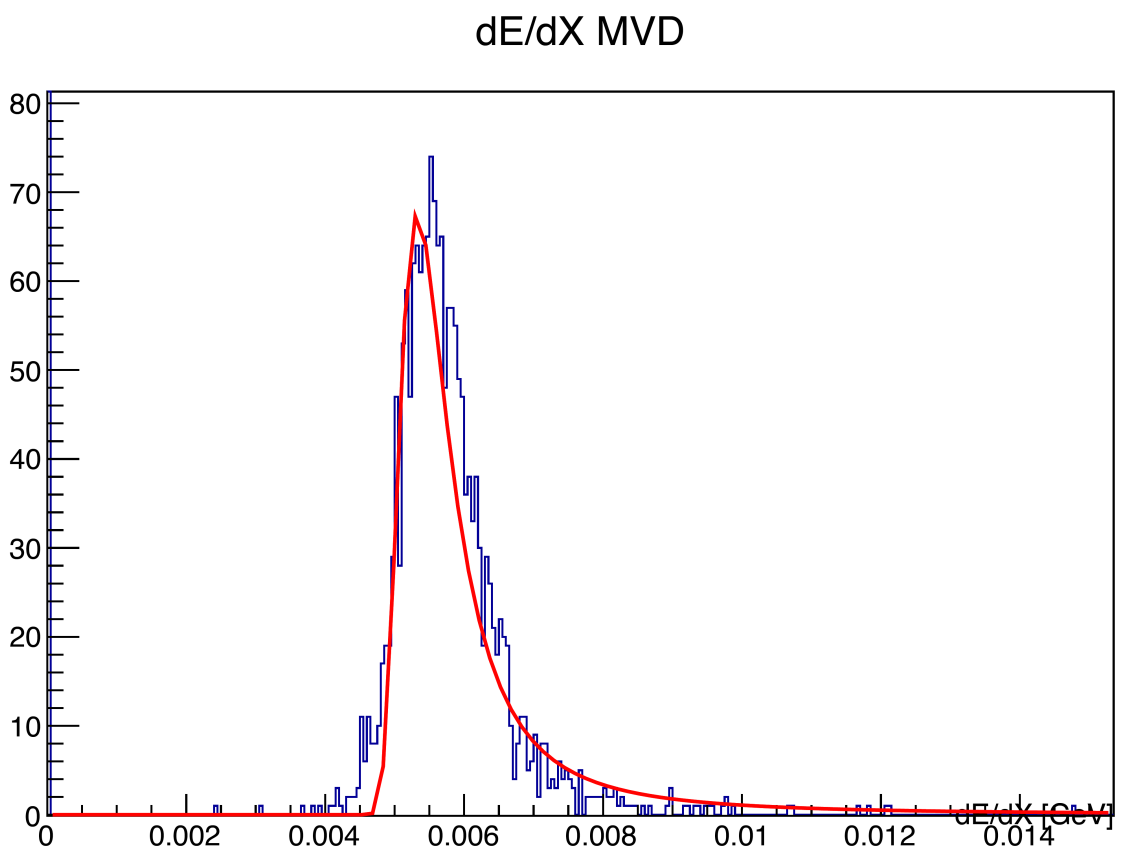
How to get dX?

- Comes from tracking
  - Sensor thickness from TGeoManager
  - Track angle from track parameters
  - Propagation to sensor plane via GEANE
  - Does not take magnetic field into account
    - Sensor thickness O(100 µm),, r_{min} 7 cm
    - Neglectable



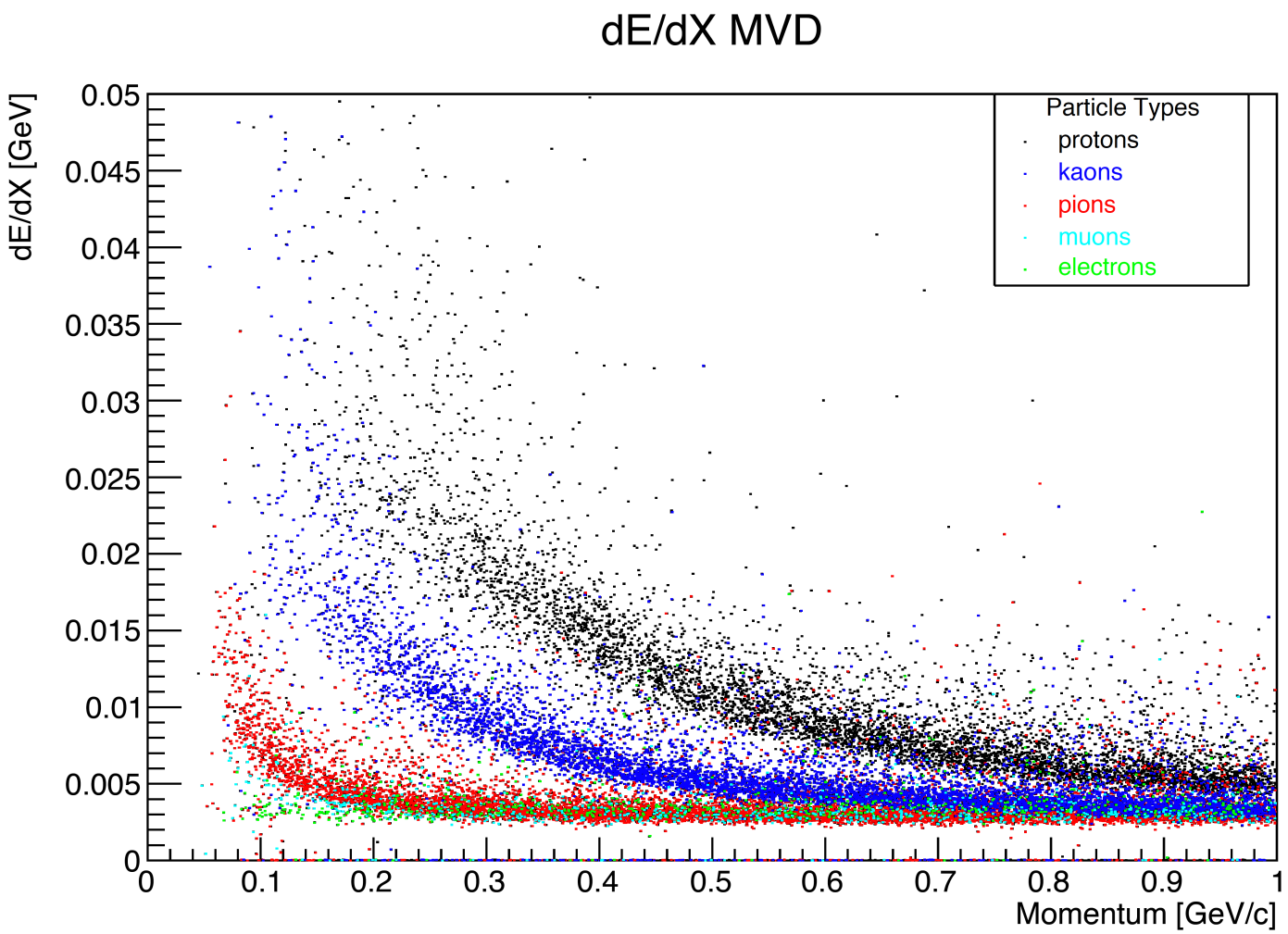
Trunkated Mean for MVD





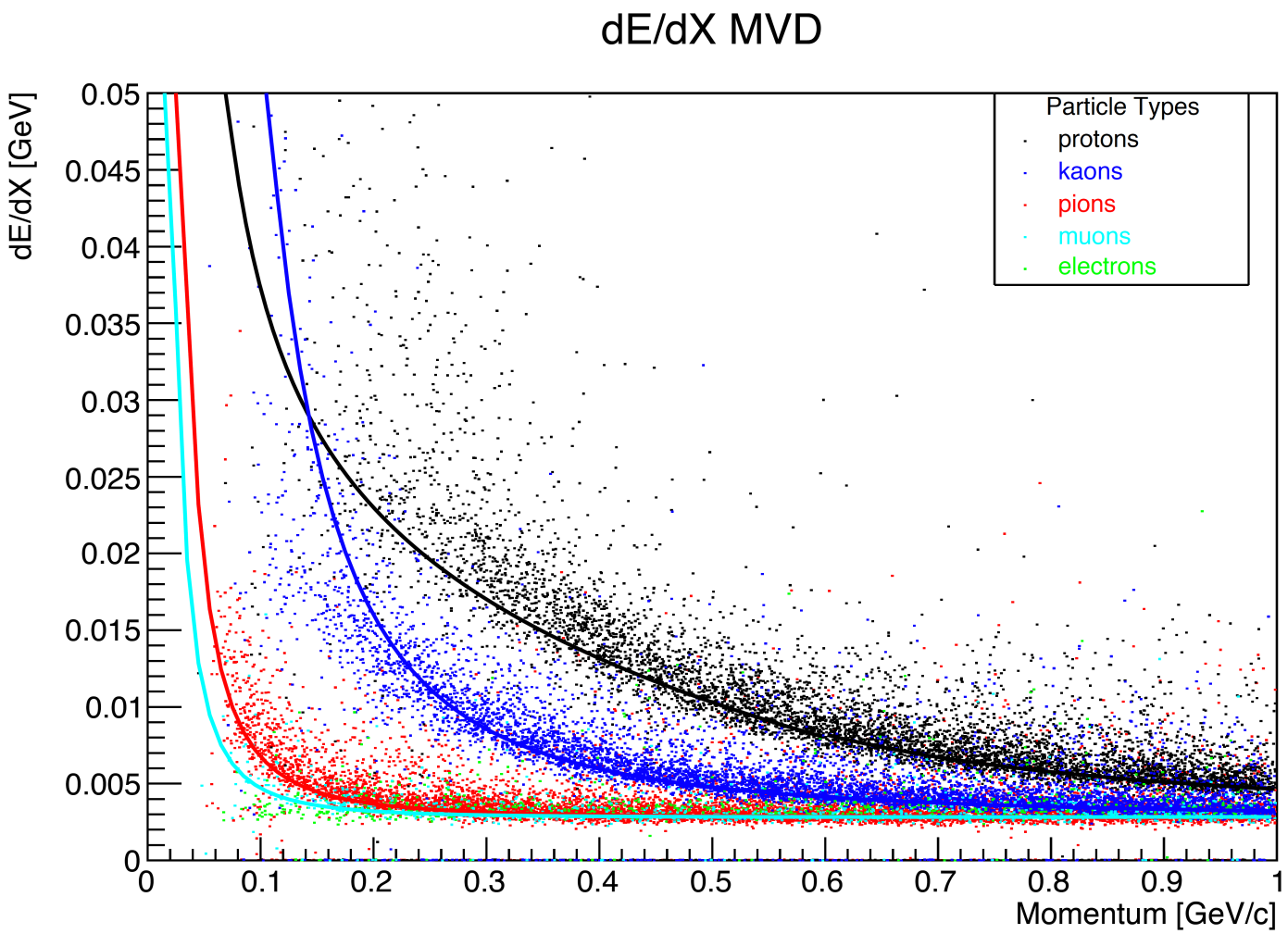
Simulated dE/dx

- MVD dE/dx from PidCandidate
- Trunkated mean of all MVD points per track

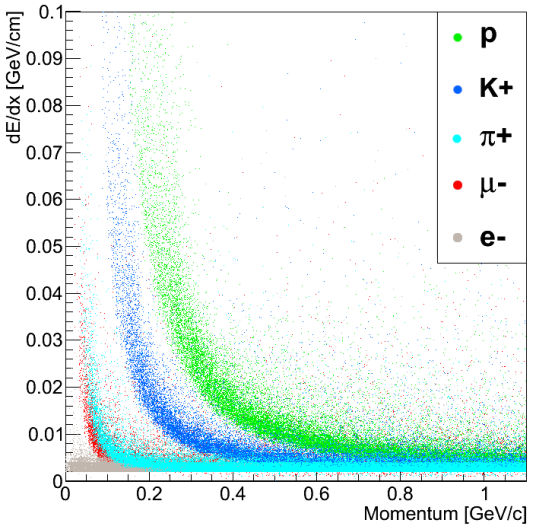


Simulated dE/dx

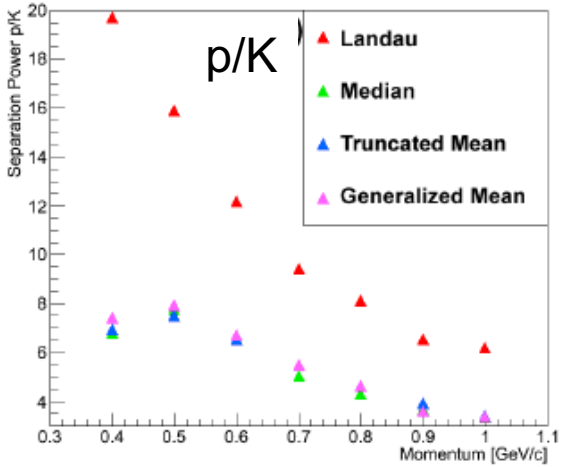
- Curves for MPV and Sigma stored in PandaRoot
- Curves generated from Gaussian fit to data
- Probability calculated based on measured dE/dx and fitted curves
- Uses Root LandauPDF function

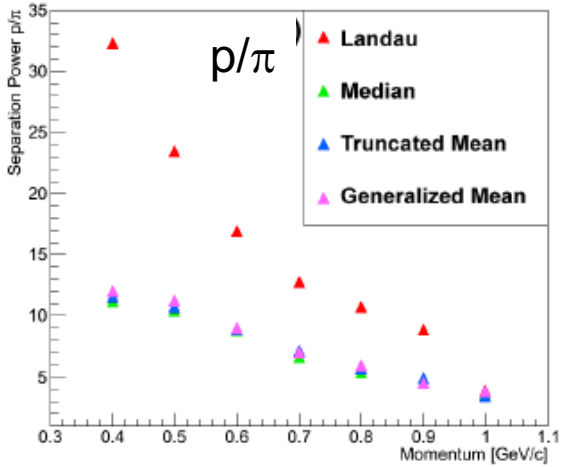


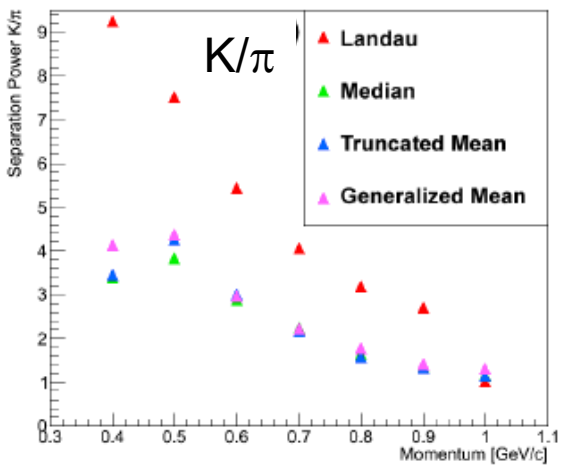
dE/dx



Separation Power







Summary

- MVD is a tracking detector
- Limited PID possible via dE/dx
  - Proton and kaon identification < 1 GeV/c particle momentum