# Identification of particles by *mean energy loss* in **the Straw Tracker** at *the SPD*

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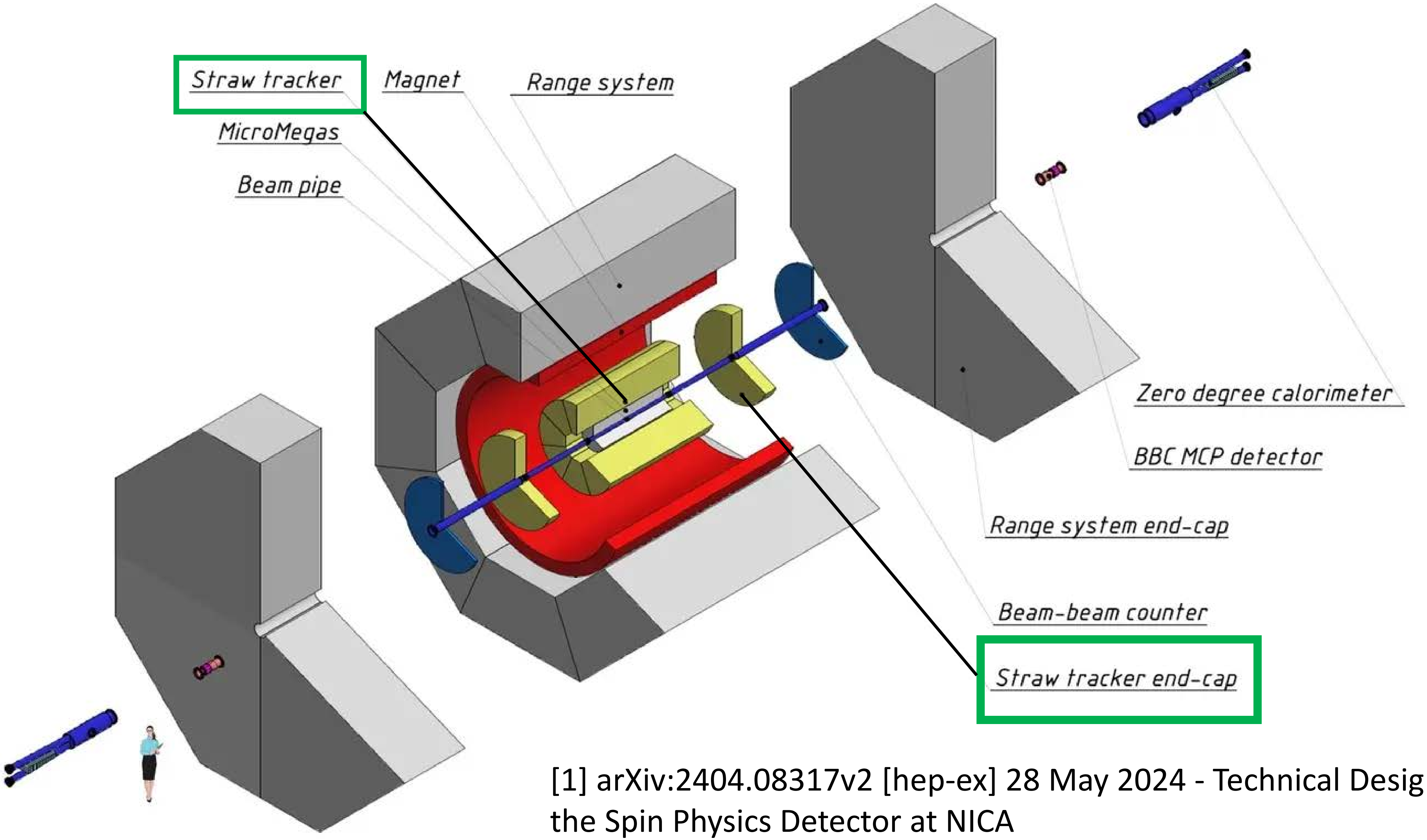
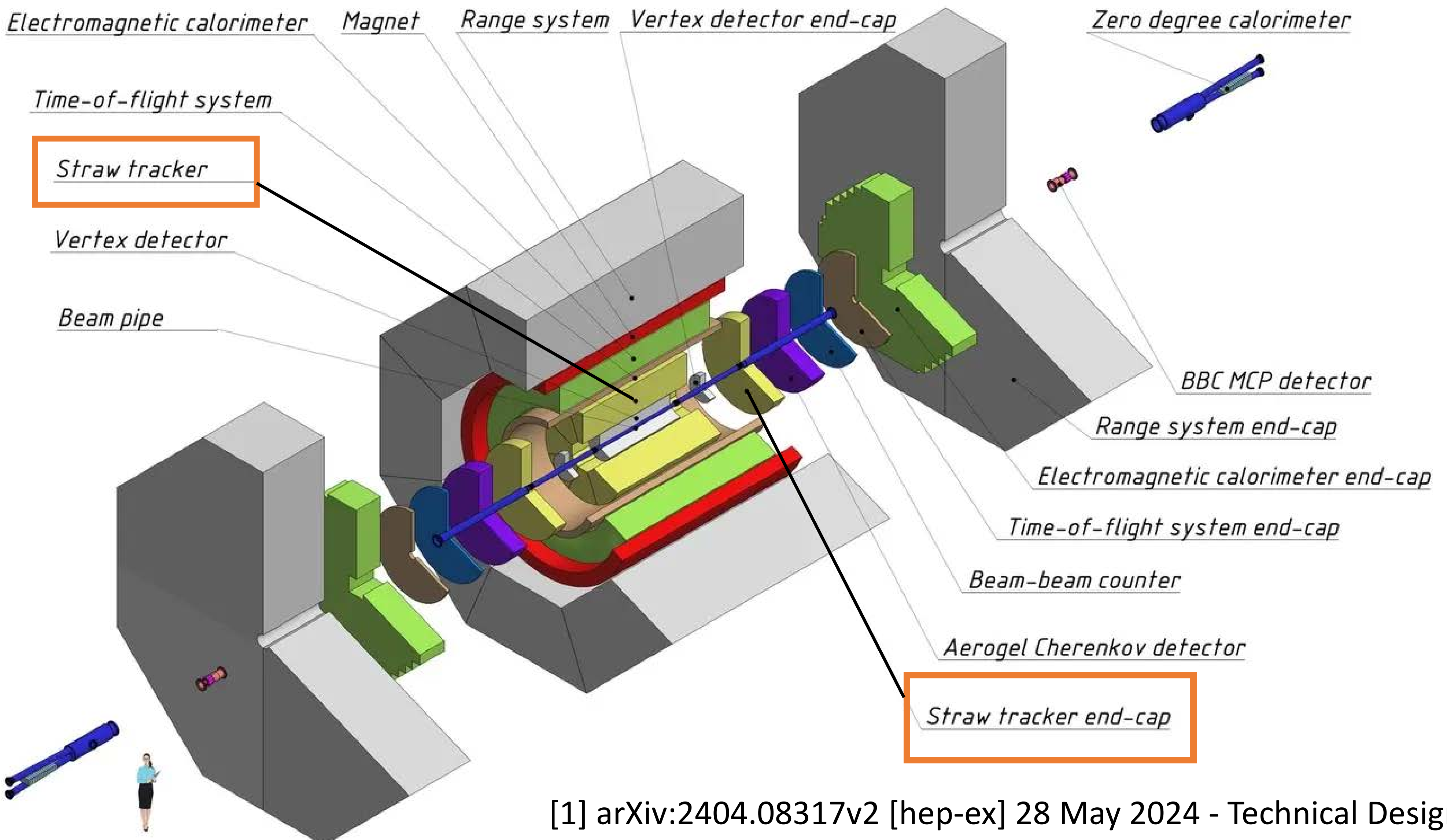
# Spin Physics Detector setup at the first stage [1]




[1] arXiv:2404.08317v2 [hep-ex] 28 May 2024 - Technical Design Report of the Spin Physics Detector at NICA

# Spin Physics Detector full setup [1]




[1] arXiv:2404.08317v2 [hep-ex] 28 May 2024 - Technical Design Report of the Spin Physics Detector at NICA

# Straw-Based Tracking system (ST)

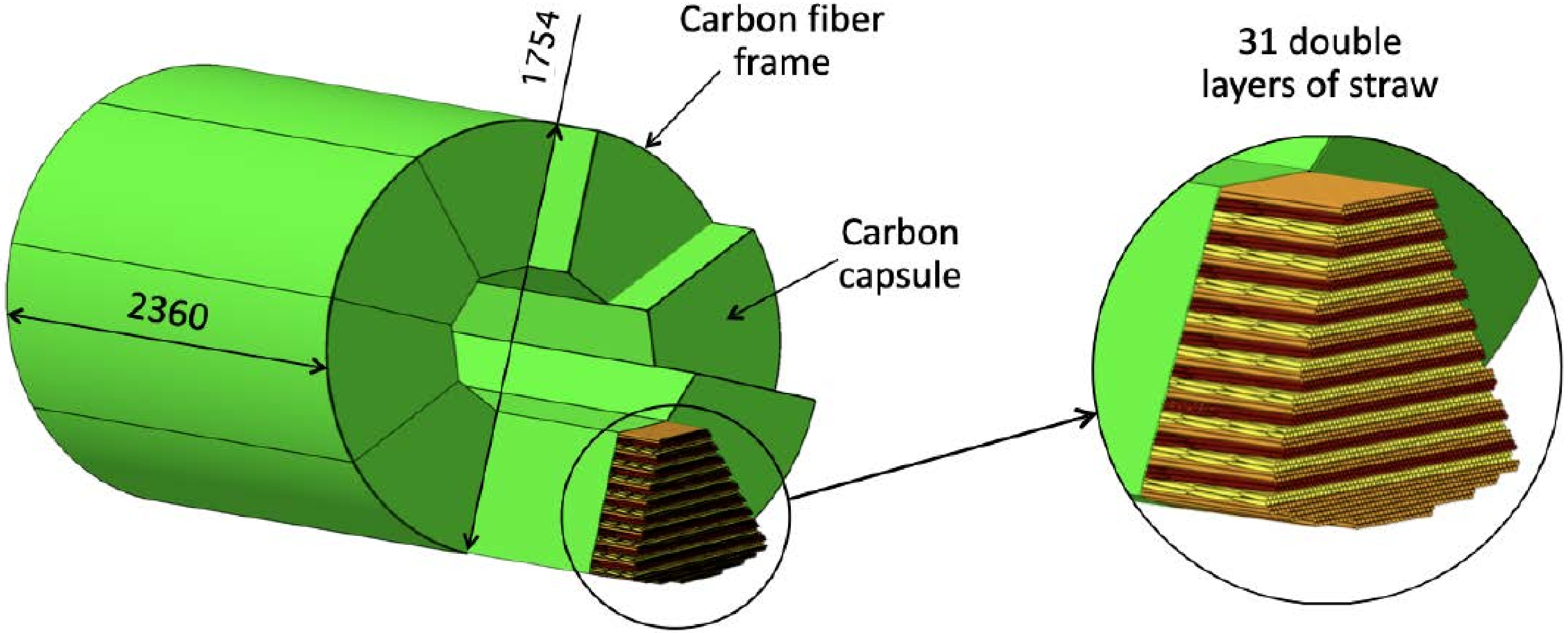
- Main tracking system of SPD
- Spatial resolution ~150 μm
- ~ 26 000 straw tubes
- Three parts: *barrel* and two *end-caps* (different kinds of straw tubes for each part)

The **purposes** of the Straw Tracker:

1. reconstruction of tracks of charged particles
2. measuring particle momenta (based on track curvature in the magnetic field)
3. particle identification via energy deposition (dE/dx) measurements

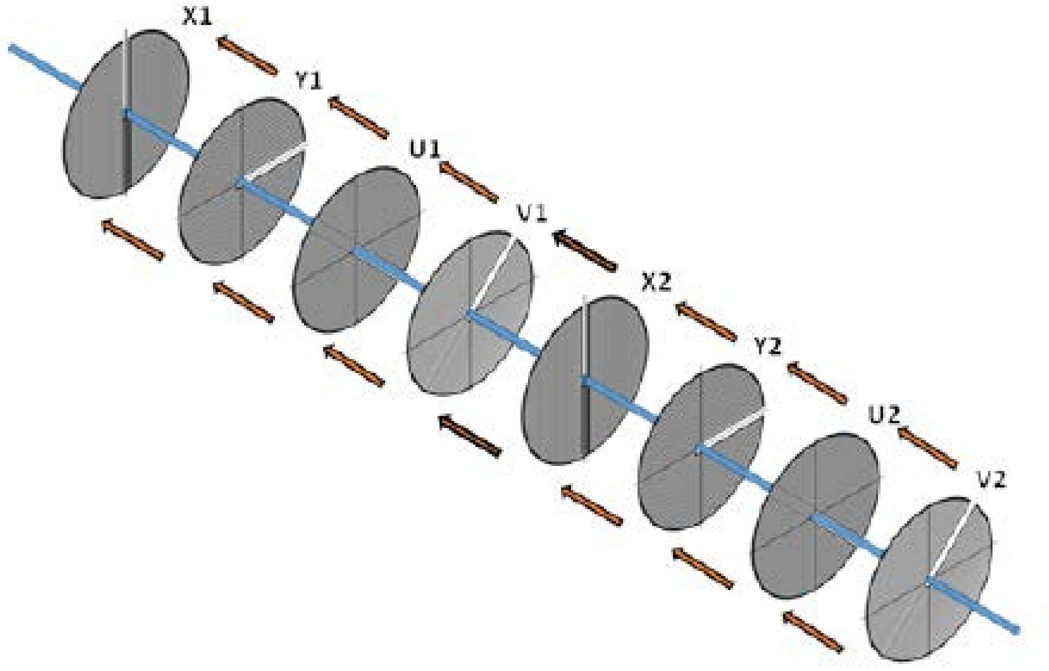
# Straw Tracker *barrel*

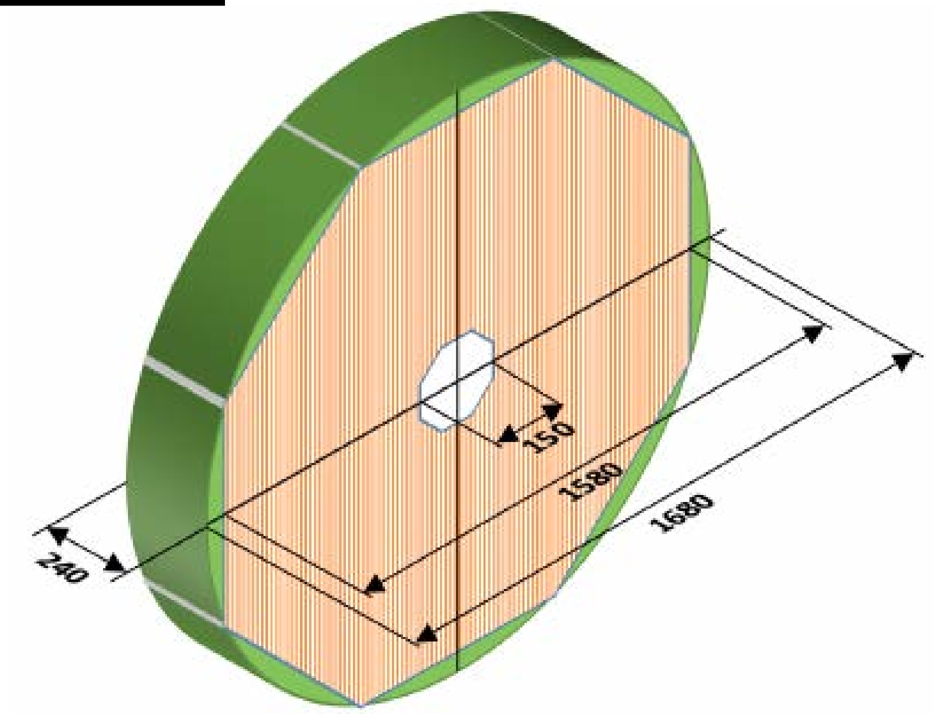
The main axes of the straw directions are Z, U, and V. The Z axis is along the beam axis. The angle between the U, V and Z axes is ±5 degree.




- Barrel part consists of *8 modules* (octants)
- Each module contains *31 double layers of straw tubes* encased in a composite-polymer capsule 400 µm thick

# Straw Tracker *end-caps*




Common view and main dimensions

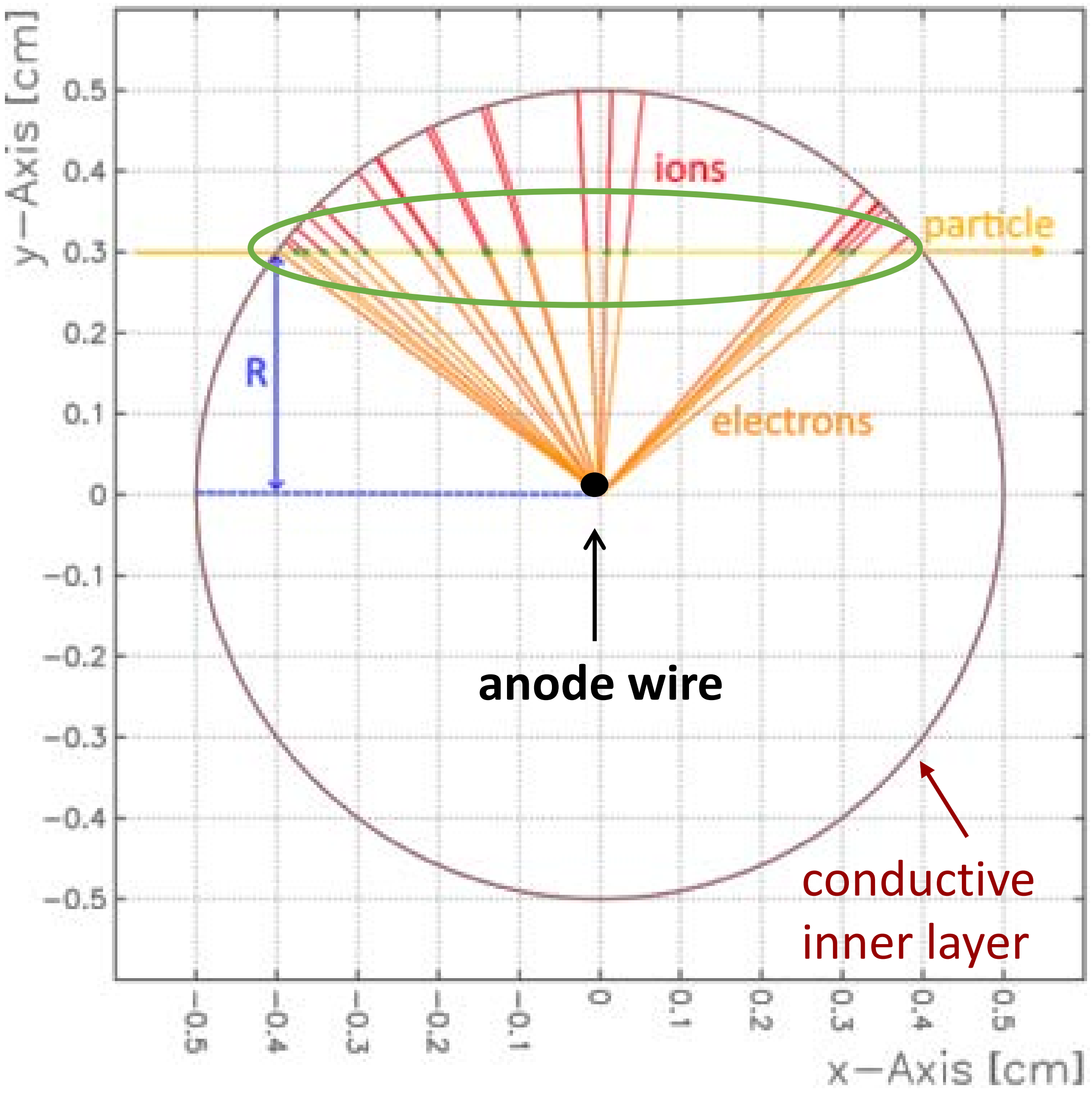
- End-cap is proposed with an octagonal arrangement of *8 drift coordinate planes* at an angle of 45 degrees, which form an X, Y, U, V coordinate system.
- Each coordinate plane consists of two halves of a disk with an interval for installing a vacuum tube.

# Particle detection in straw tubes

Straws are filled with gas. An ionizing particle passes at distance R from anode wire, creates primary ionization clusters along its path. Primary electrons drift toward the anode wire.

The relative coordinate of the primary ionizing particle is reconstructed from the measured electron drift time (which defines distance R)

Straws operate in the proportional mode: total charge of the induced signal is proportional to the ionization energy loss *dE*.



# Variables for calculations

| variable | meaning | type |
|---|---|---|
| Parameters of every track | | |
| nhits_tsb | the sum of hits in Straw Tracker barrel | Int_t |
| nhits_tsec | the sum of hits in Straw Tracker endcaps | Int_t |
| first_mom | momentum in the *first hit* | TVector3 |
| last_mom | momentum in the *last hit* | TVector3 |
| Parameters of every hit | | |
| dE | Energy loses for each hit | vector<Double_t> |
| dx | Segment's length for each hit | vector<Double_t> |

*nhits*

***p*** *(px, py, pz)*

dE/dx [i]

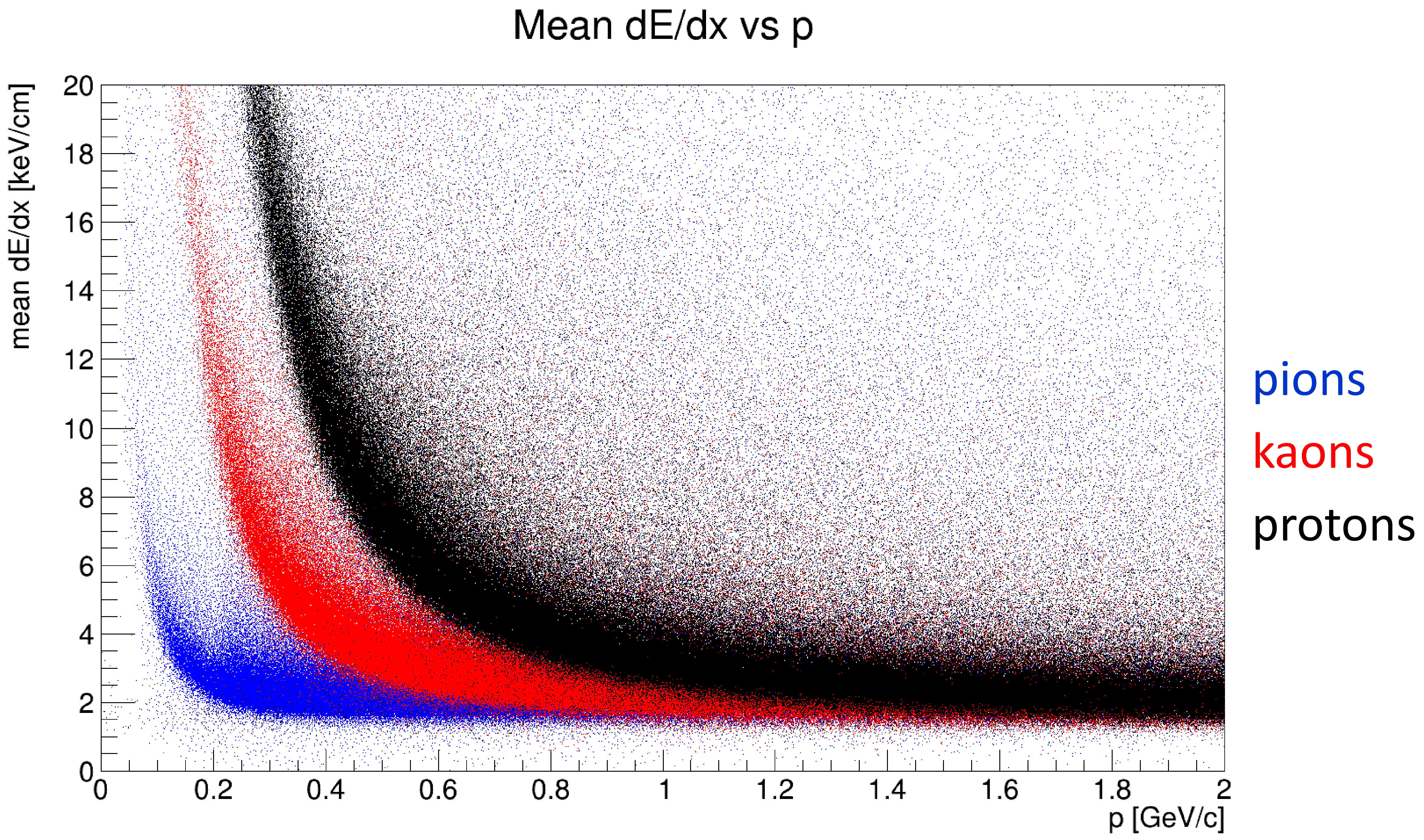
# Obtaining mean energy loses for track

dE, dx → array $\frac{\boldsymbol{dE}}{\boldsymbol{dx}}[\boldsymbol{i}]$ with size ***nhits*** = nhits_tsb + nhits_tsec

$$\left\langle \frac{dE}{dx} \right\rangle_{nhits} = \frac{\sum_{i=1}^{nhits} \frac{dE}{dx}[i]}{nhits}$$

momenta ***p*** = (p_firsthit + p_lasthit)*0.5

Exclude tracks with (*chi2/ndf* > 2)



Mean dE/dx vs p
mean dE/dx [keV/cm]
20
18
16
14
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
p [GeV/c]
pions
kaons
protons

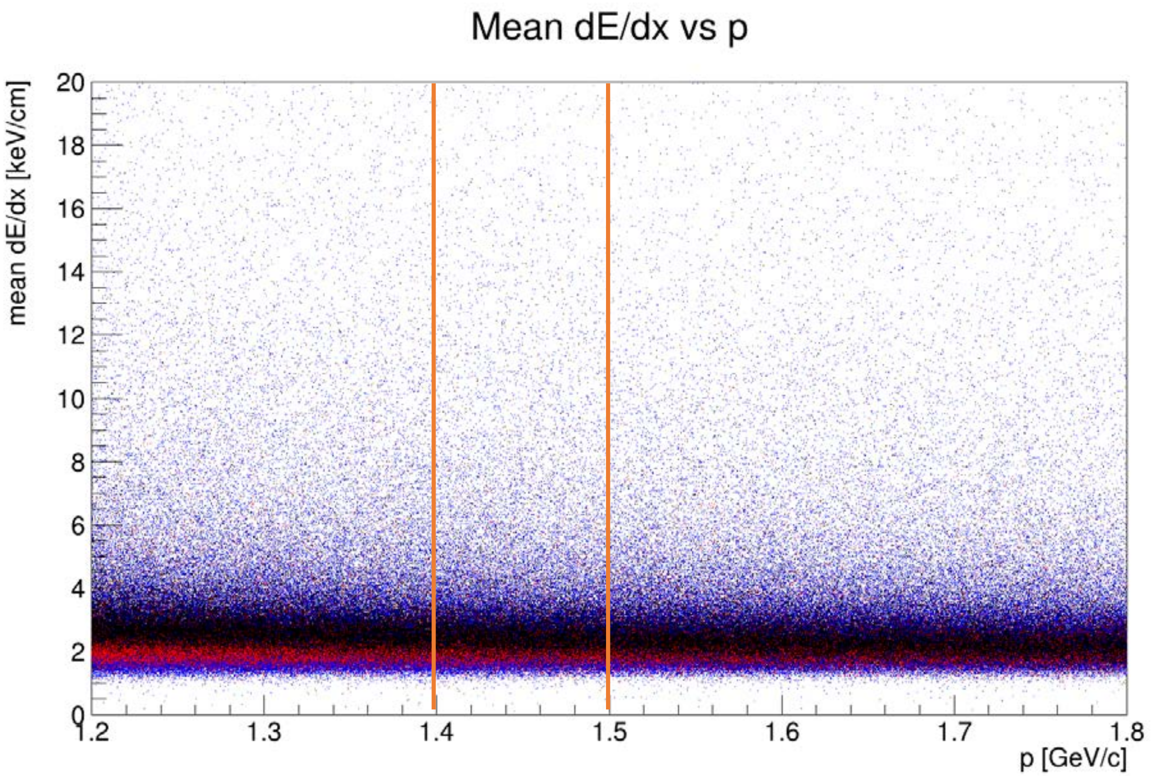
# The truncated mean method

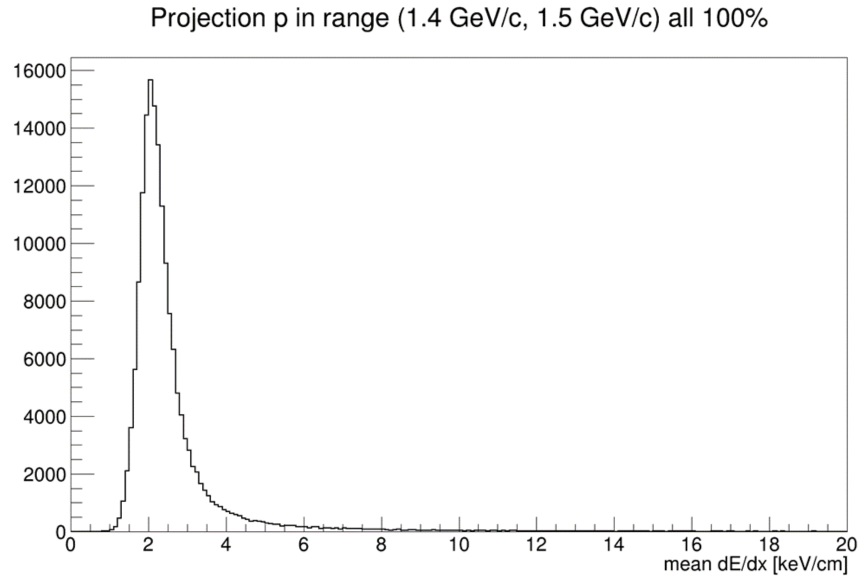
1. Varying ***k*** in range [0; 1] (*k* would be the remaining share of original array after cutting off)
2. Sorting $\frac{dE}{dx}[i]$ in increasing order; i = 1, 2, … , ***nmax*** = *nhits*k*
3. Calculating mean energy loses for every meaning of *nmax* (for remaining part of dE/dx array)

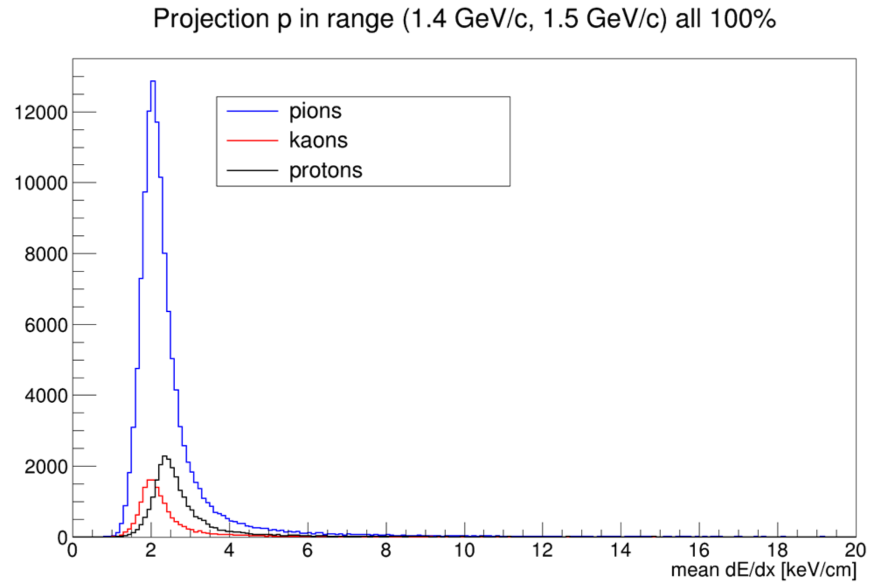
$$\left\langle \frac{dE}{dx} \right\rangle_{nmax} = \frac{\sum_{i=1}^{nmax} \frac{dE}{dx}[i]}{nmax}$$

# Projection along Y

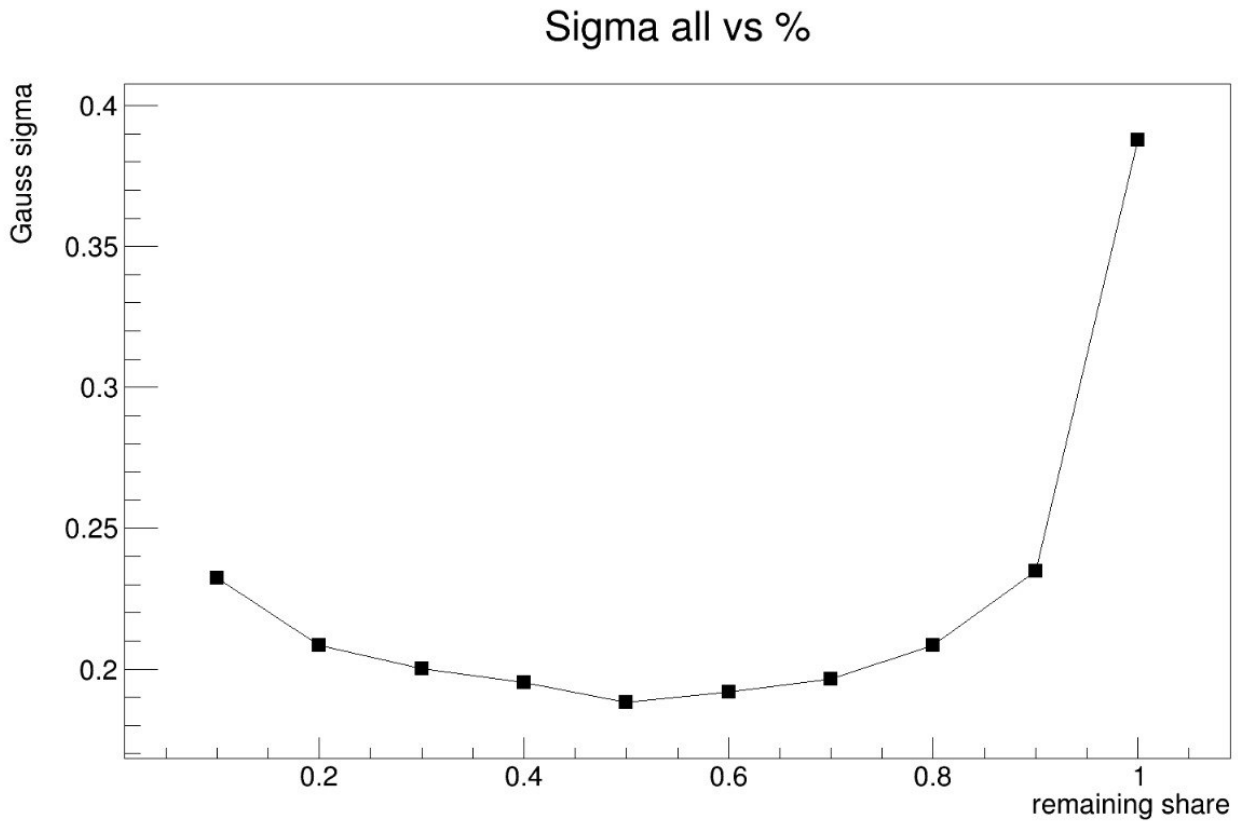
Project a 2D histogram into a 1D histogram along Y (TH1D* ProjectionY in ROOT) for *p* values in range [1.4; 1.5] GeV/c

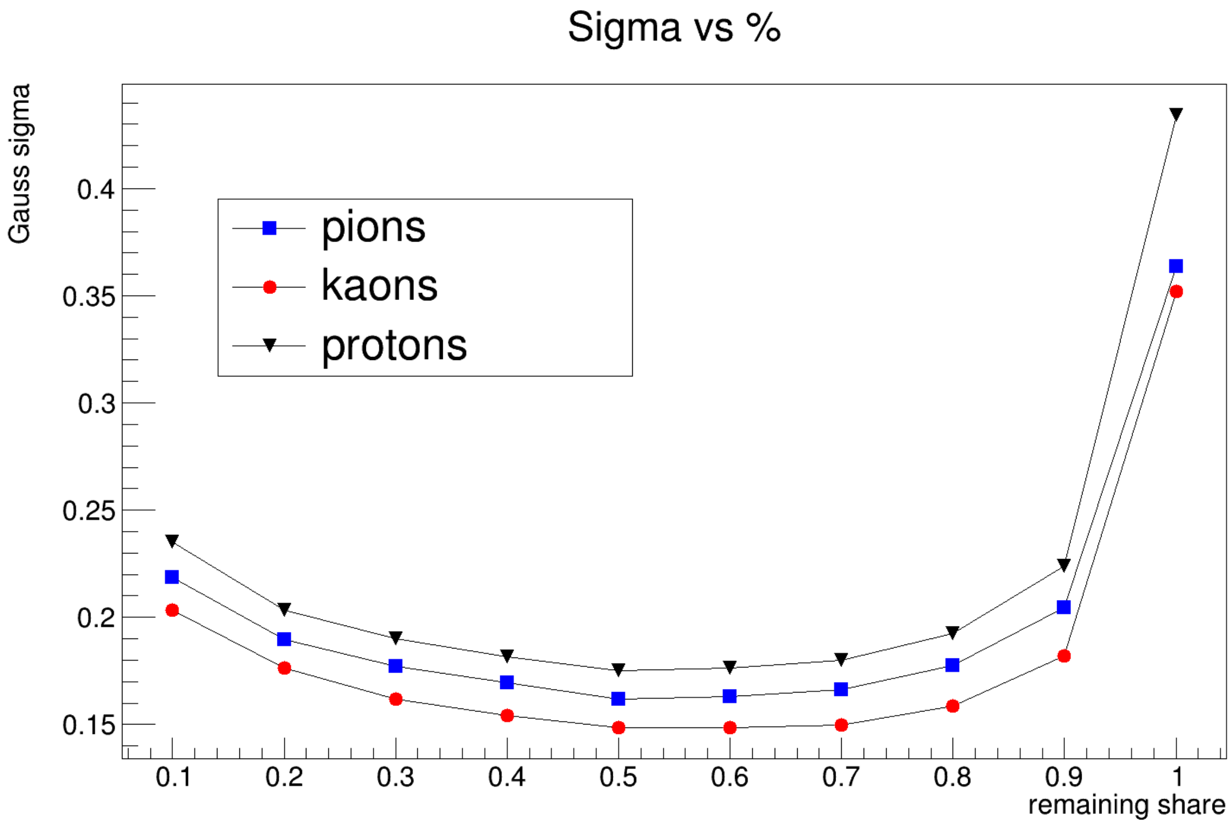


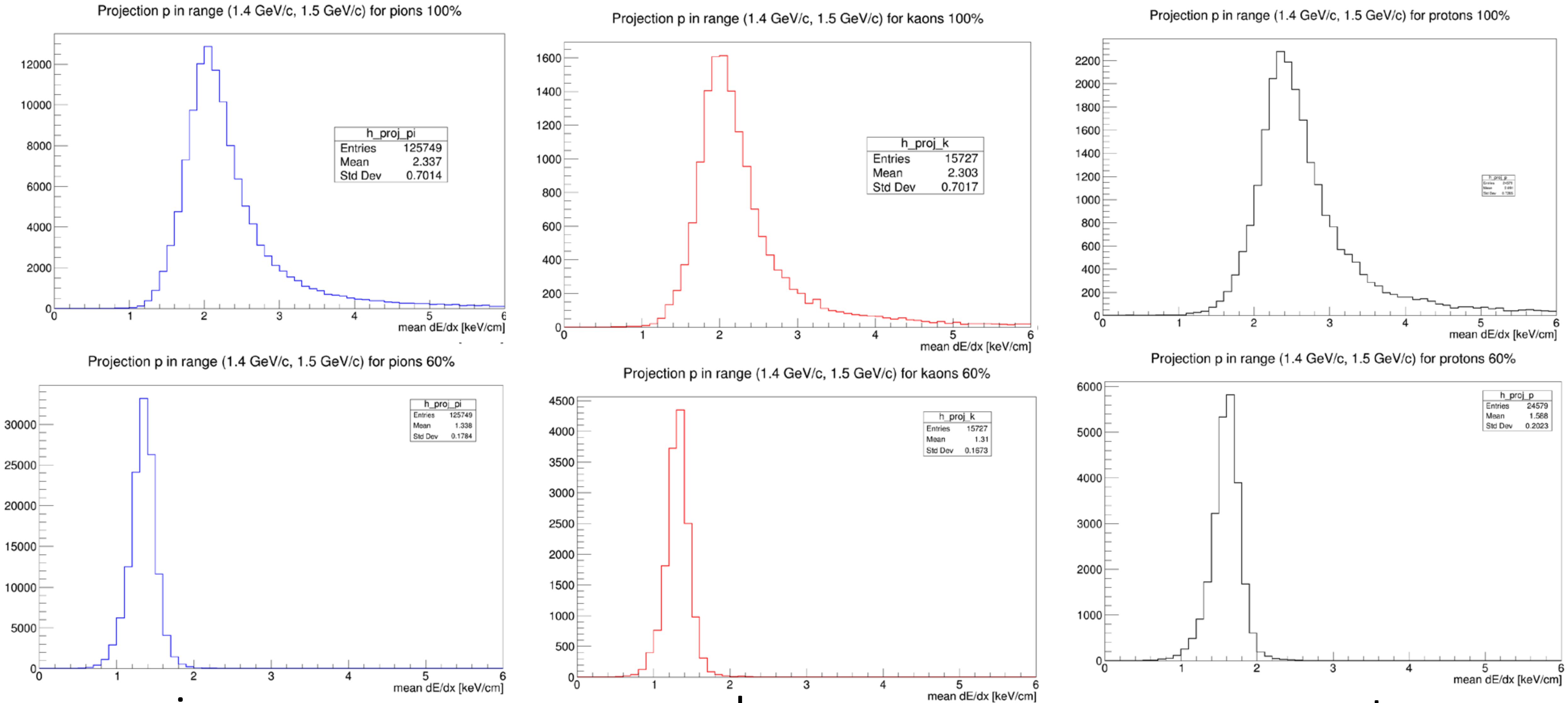
4. TH1D* ProjectionY for remaining part of $\frac{dE}{dx}[i]$ array
5. Fitting 1D histogram with gauss ⟶ $\boldsymbol{\sigma}$ of distribution
6. Choosing $k$ with minimum $\sigma$



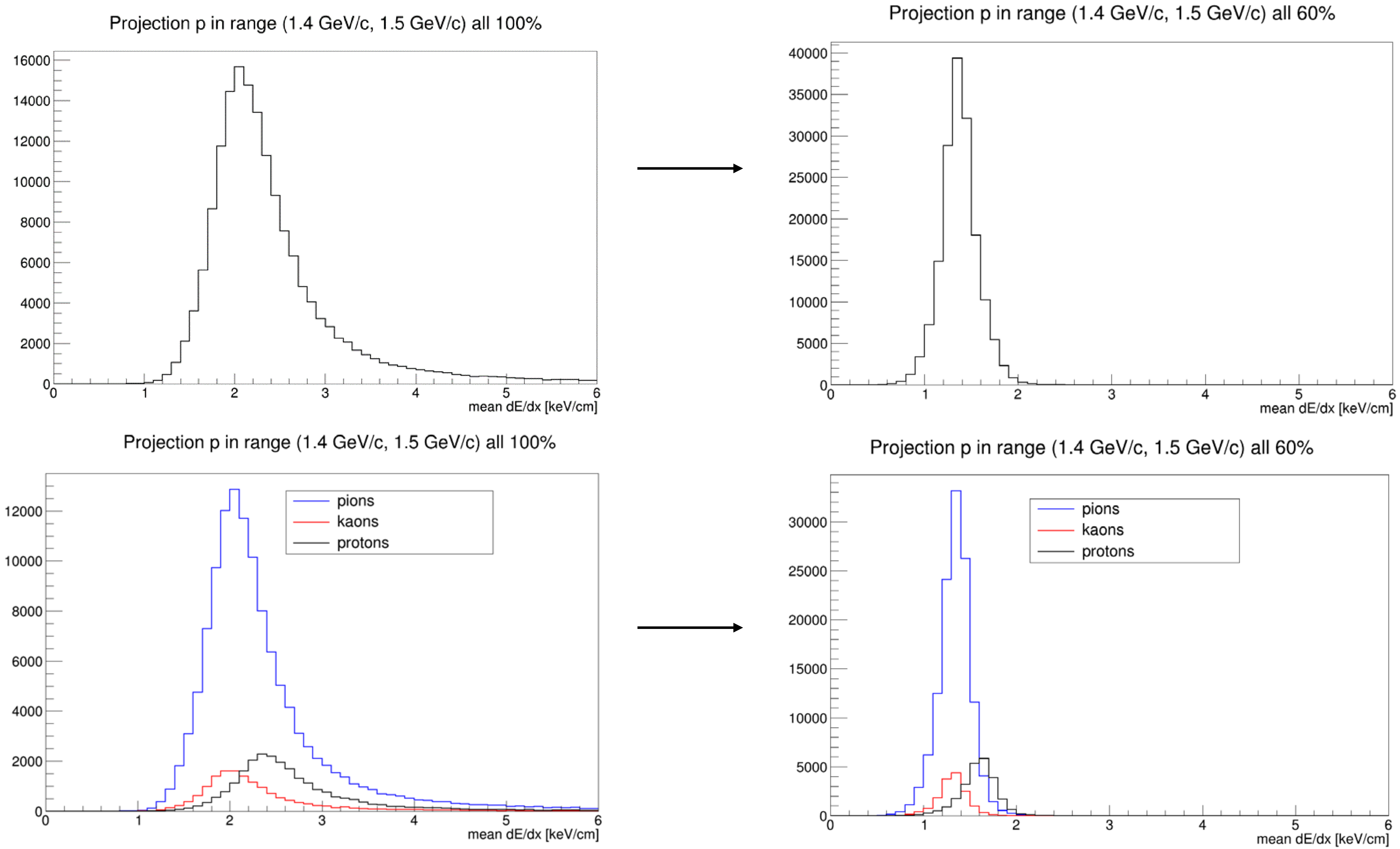




$\sigma$ (k = 0.6) - minimum

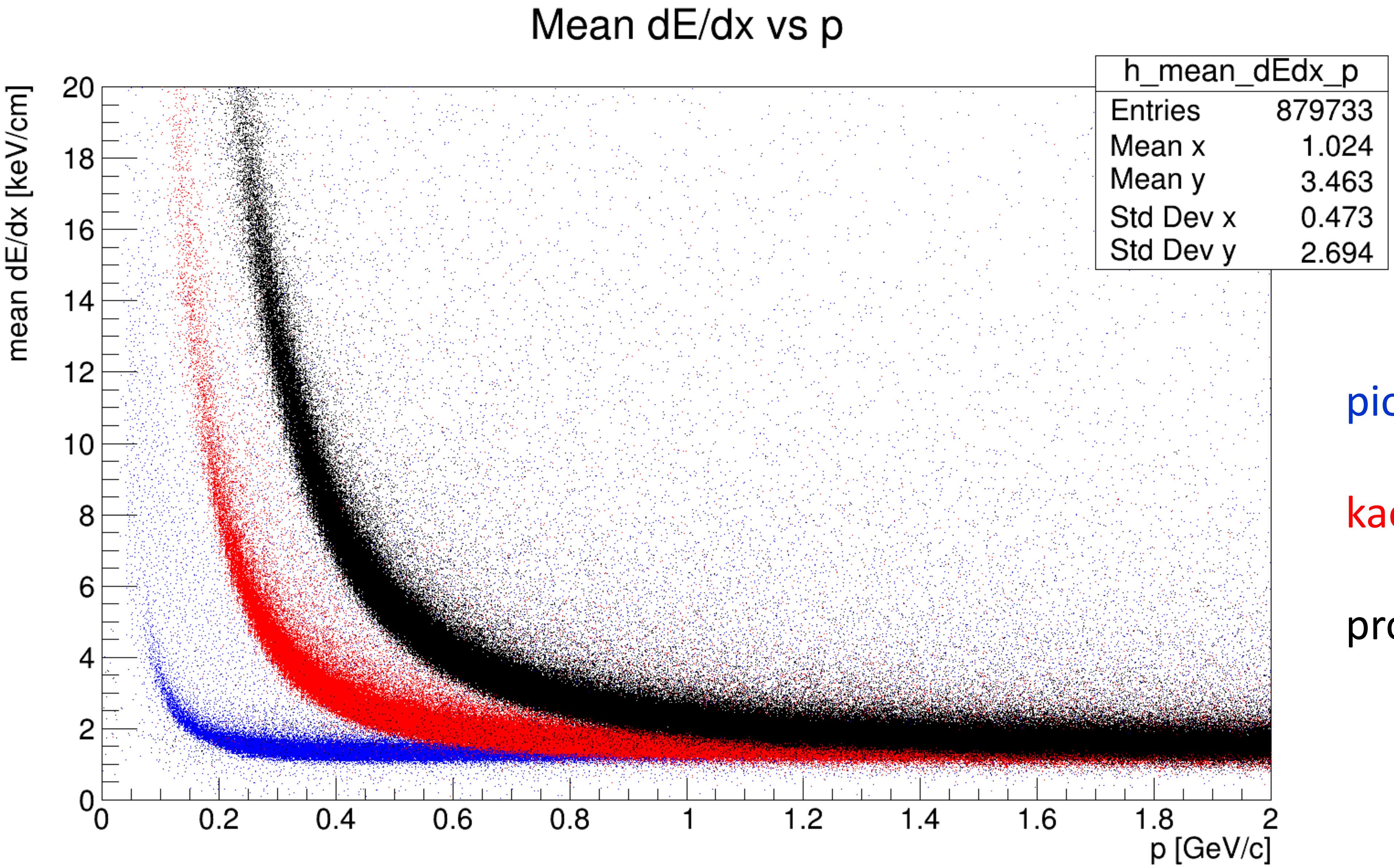
# Comparison original $\left\langle\frac{dE}{dx}\right\rangle$ and cut




pions kaons protons


Projection p in range (1.4 GeV/c, 1.5 GeV/c) all 100%
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
mean dE/dx [keV/cm]
Projection p in range (1.4 GeV/c, 1.5 GeV/c) all 60%
40000
35000
30000
25000
20000
15000
10000
5000
0
0
1
2
3
4
5
6
mean dE/dx [keV/cm]
Projection p in range (1.4 GeV/c, 1.5 GeV/c) all 100%
pions
kaons
protons
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
mean dE/dx [keV/cm]
Projection p in range (1.4 GeV/c, 1.5 GeV/c) all 60%
pions
kaons
protons
30000
25000
20000
15000
10000
5000
0
0
1
2
3
4
5
6
mean dE/dx [keV/cm]

# Energy loses with truncated mean method (60% remain)

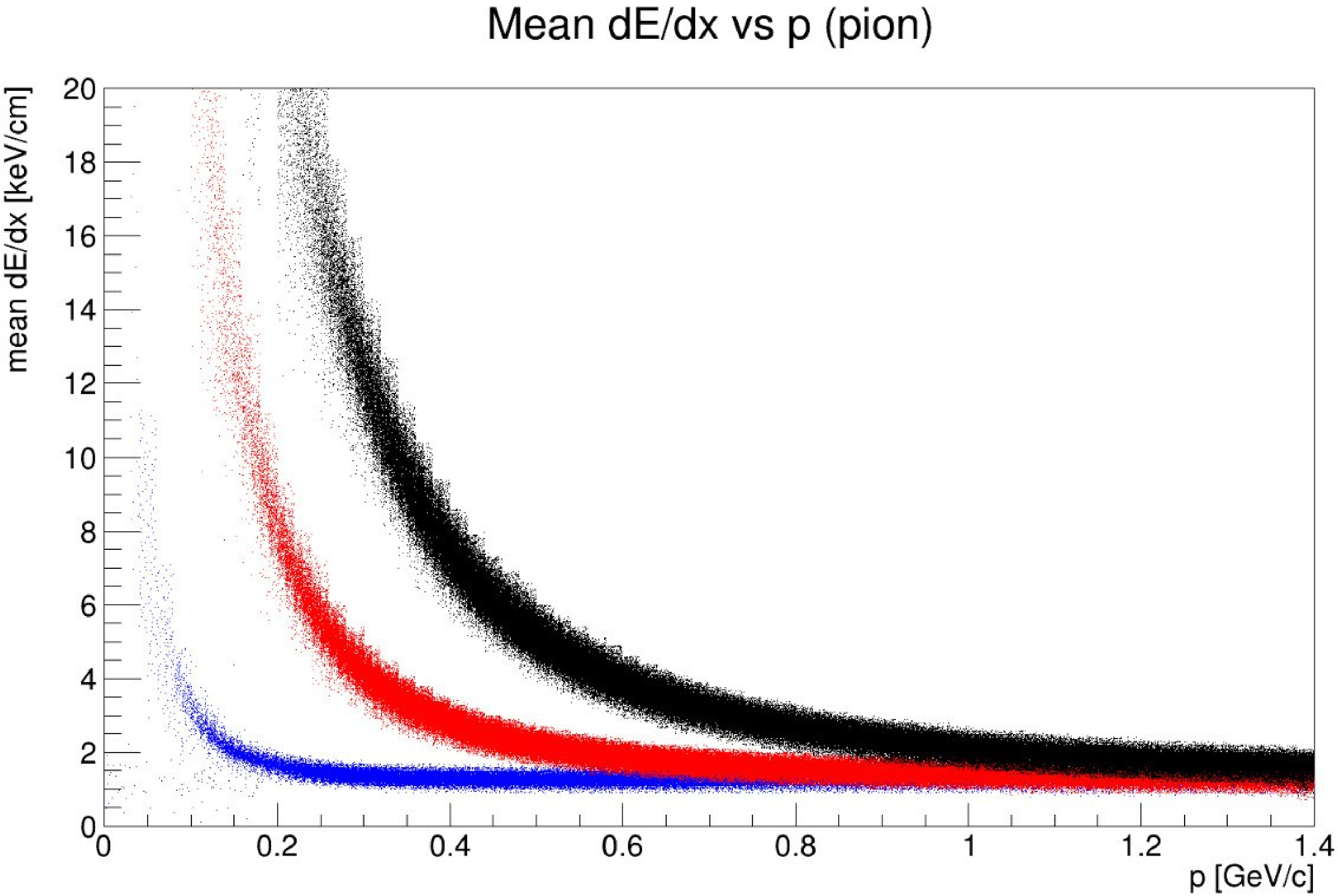



pions

kaons

protons

# Mean energy loss in the interval of $\pm 3\sigma$




pions

kaons

protons

# Summary

- In Straw Tracker system PID via dE/dx loses measurements is possible
- Truncated mean method allows to separate areas of mean energy depositions for different types of particles
- $\left\langle \frac{dE}{dx} \right\rangle (p)$ resolutions at maximum *p* values

for pions and kaons ~ **0.5** GeV/c

for kaons and protons ~ **0.8** GeV/c