dE/dx Studies

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ILD Software & Analysis Online Meeting
21.03.2018 KEK

dE/dx - Compute_dEdxProcessor

- DD4hep geometry issue
- dx calculation strategy
- New processor options:
  - Change truncation values (8%, 30%)
  - Select strategy for dx calculation
  - Generate dE/dx plots for all strategies
  - Weighting each track with sqrt(number of hits) for plots
  - Turn off assining dE/dx to track to only generate plots
- General polishing and documentation
- Pull request to github is currently in review

dE/dx – DD4hep geometry issue

- Gear base unit: mm, DD4hep base unit: cm
- Feature: >> TPCdata.rMinReadout / dd4hep::mm ;
- Problem: without specifying the units min radius was at 37 **mm**

→ Silicon hits were accepted and used for dE/dx calculation

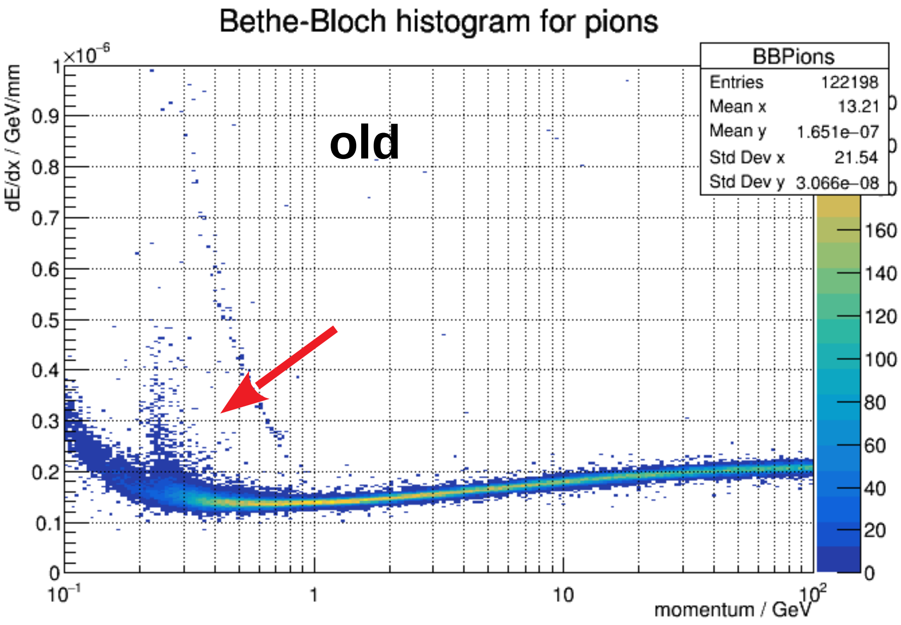
→ usually truncated (lower 8%, upper 30%)

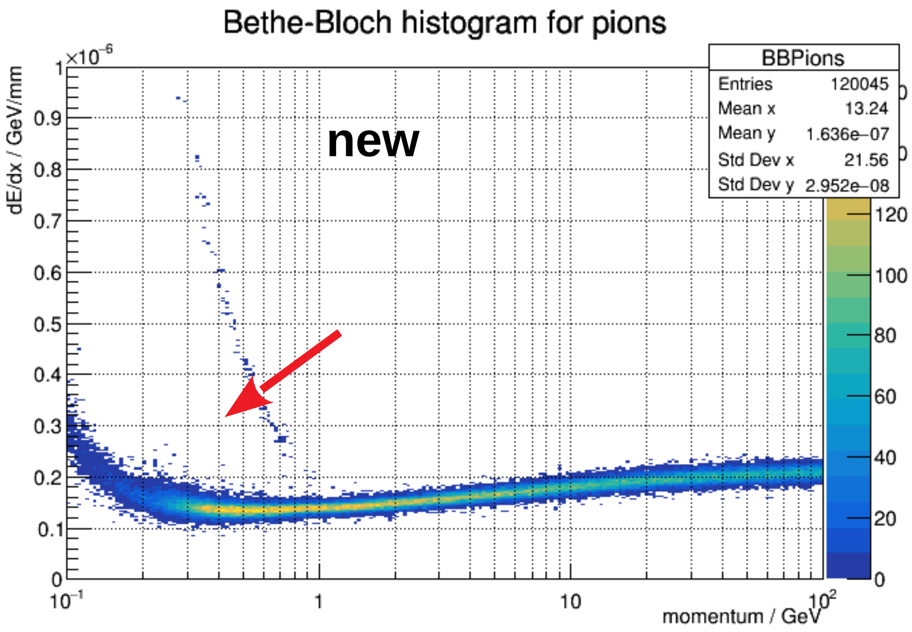
→ only came up when number of hits was low

- Now corrected
- Be aware of DD4hep units!

dE/dx – DD4hep geometry issue

- Now corrected

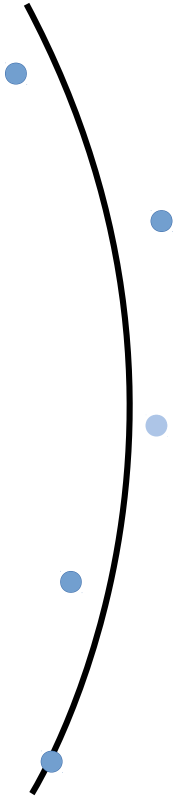




- Be aware of DD4hep units!

dE/dx – dx calculation strategies

- 1 (so far): use real distance between track hit centers
- 2: use helix path length of projected hits (points on the helix closest to the hit position)
  - Gets rid of hit-to-hit position fluctuation
  - Can be acquired from class MarlinUtil::SimpleHelix
  - Performs worse than strategy 1
- 3: use helix path length over the row height of the hit row
  - Gets rid of missing-hits problem, uses all hits
  - Calculate crossing point of helix with cylinder at upper and lower row edge (hit radius +/- half pad height)
  - Get helix path length between those crossing points
  - Performs similar to strategy 1



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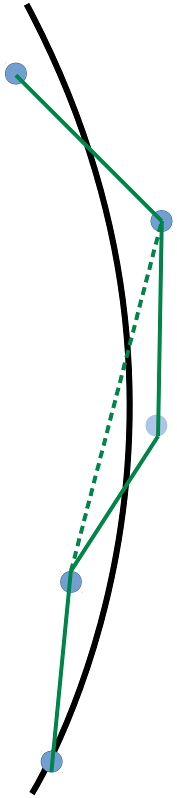

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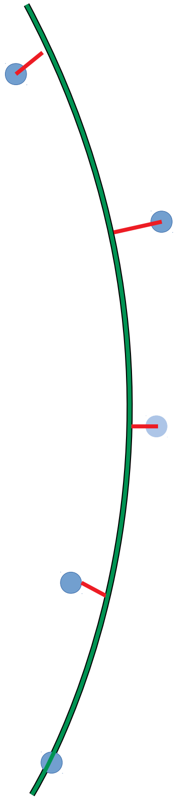

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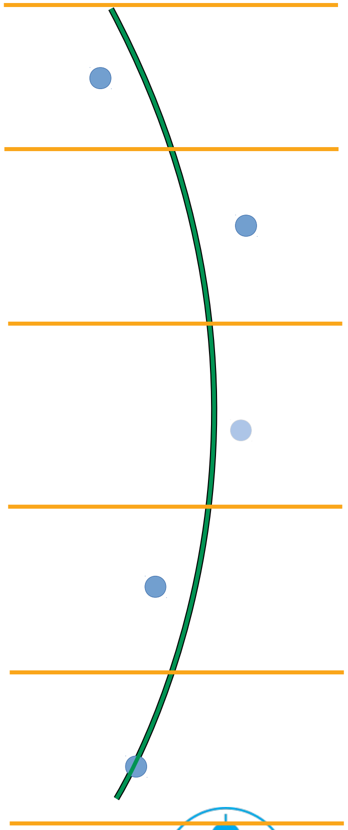
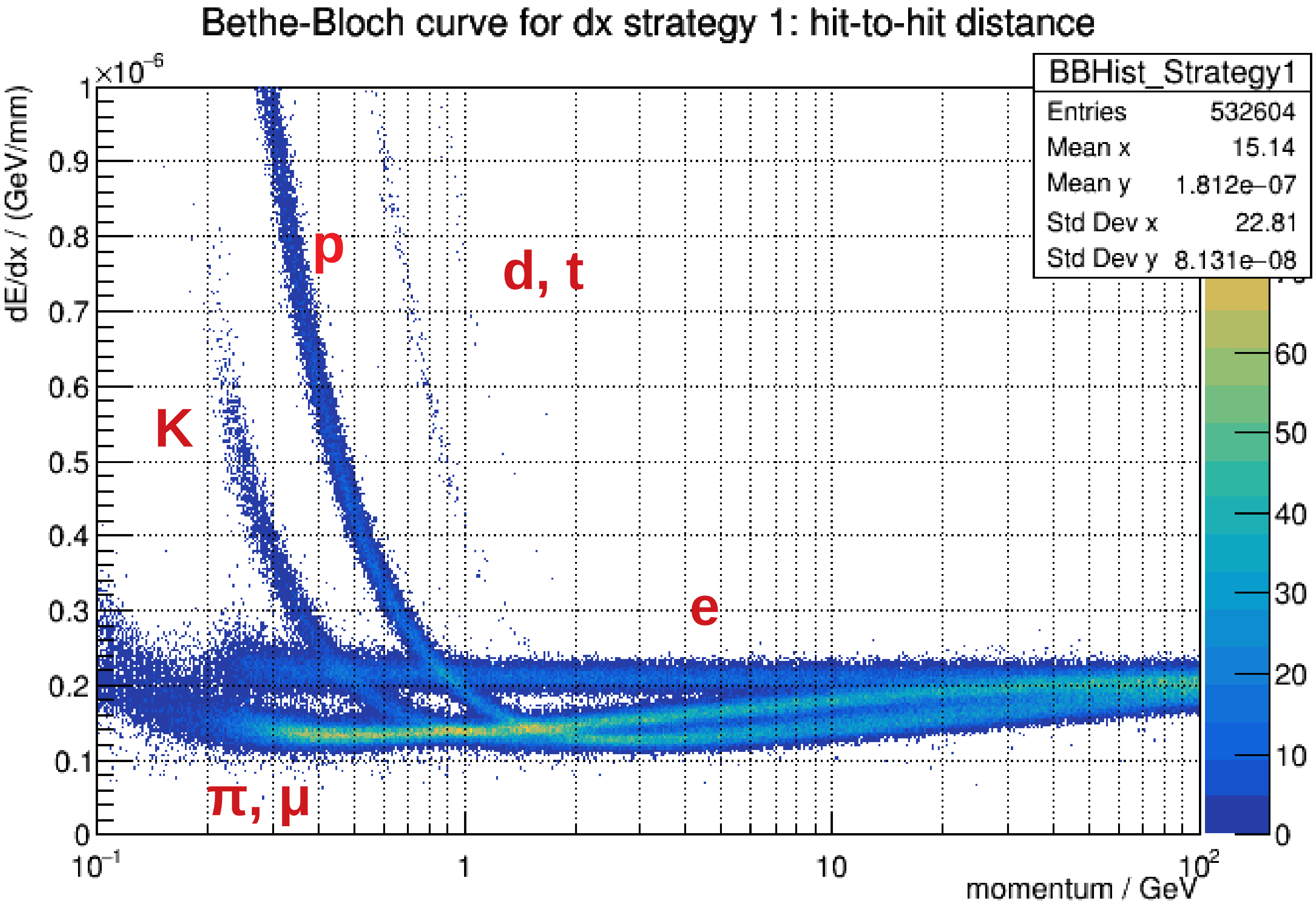


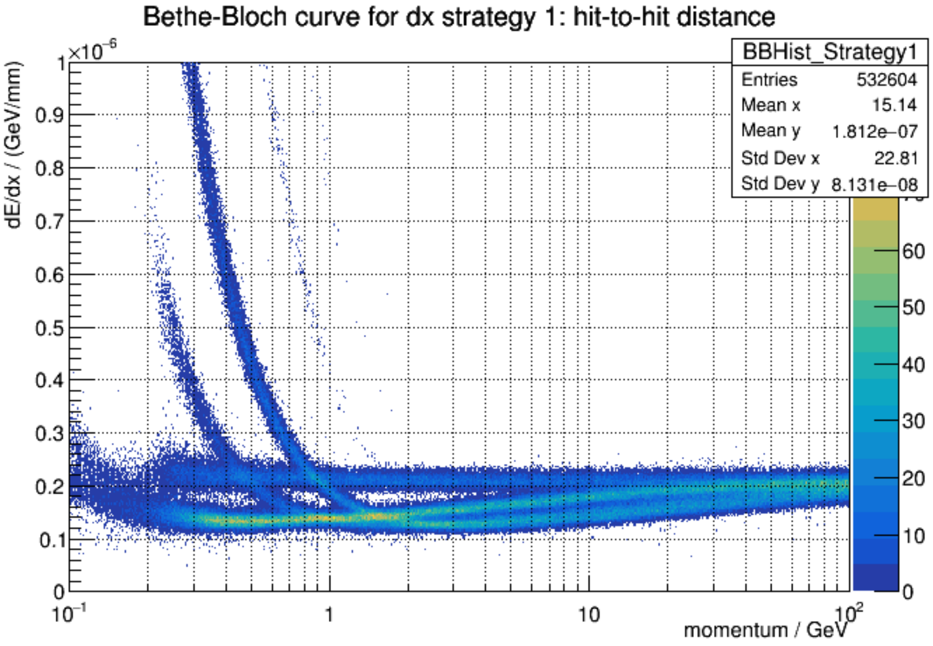
dE/dx – Plots:



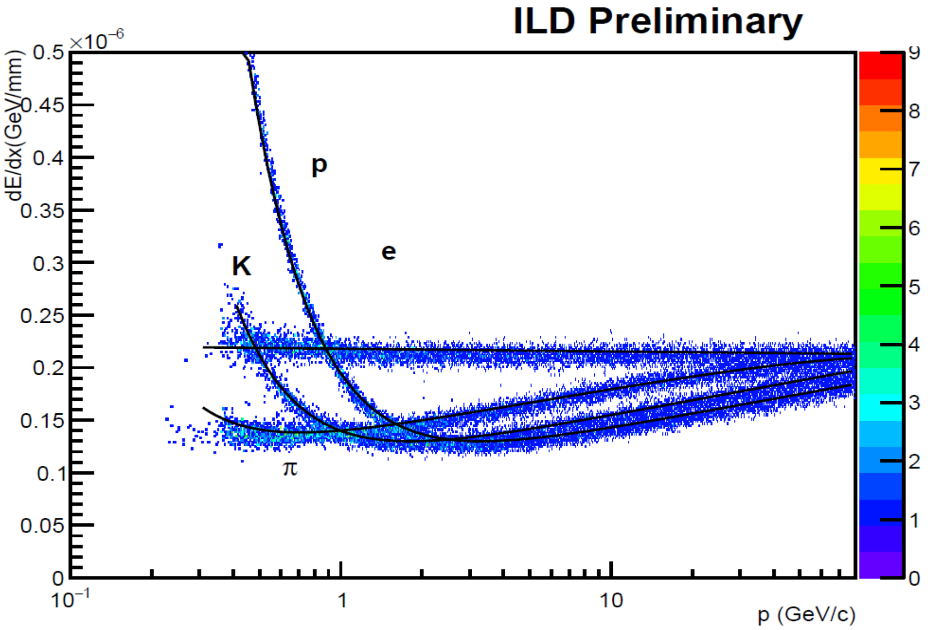
Bethe-Bloch curve for dx strategy 1: hit-to-hit distance
BBHist_Strategy1
Entries 532604
Mean x 15.14
Mean y 1.812e–07
Std Dev x 22.81
Std Dev y 8.131e–08
dE/dx / (GeV/mm)
×10⁻⁶
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10⁻¹
1
10
10²
momentum / GeV
60
50
40
30
20
10
0
p
d, t
K
e
π, μ

dE/dx – Plots: comparing strategies

- Used single particle random momentum rec-files, 100k events for each PDG (electrons, muons, pions, kaons, protons), ILD_l5_o1_v02



Generated with dE/dx processor



Plot by M. Kurata with his tools

Different binning and reconstruction stages!

dE/dx – Plots: comparing strategies

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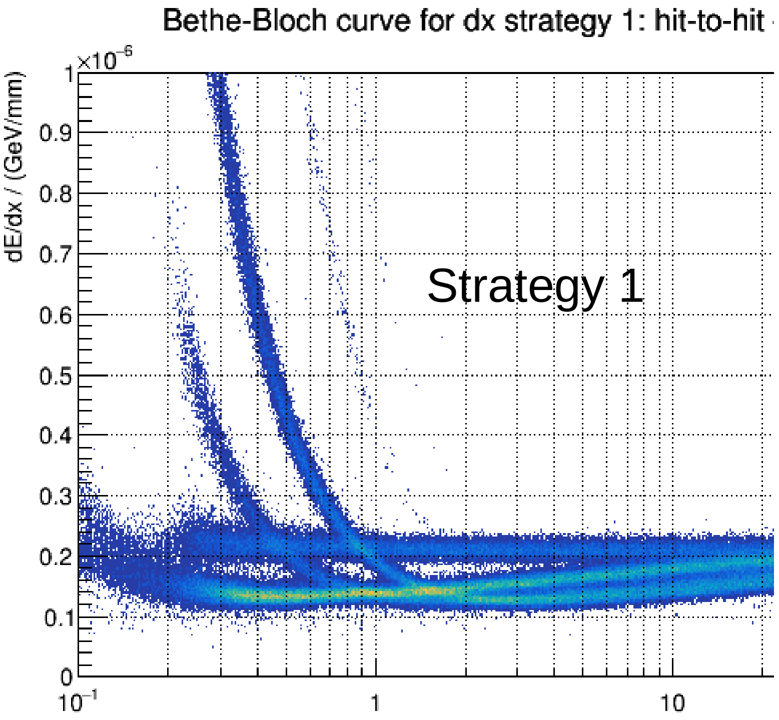
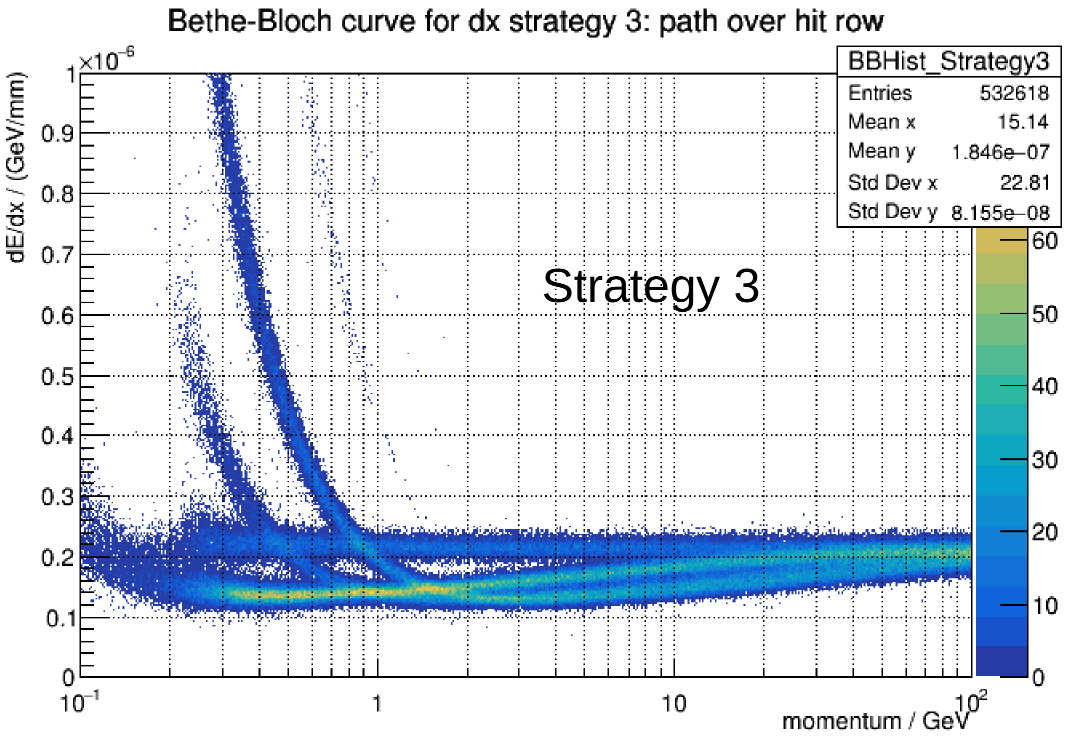
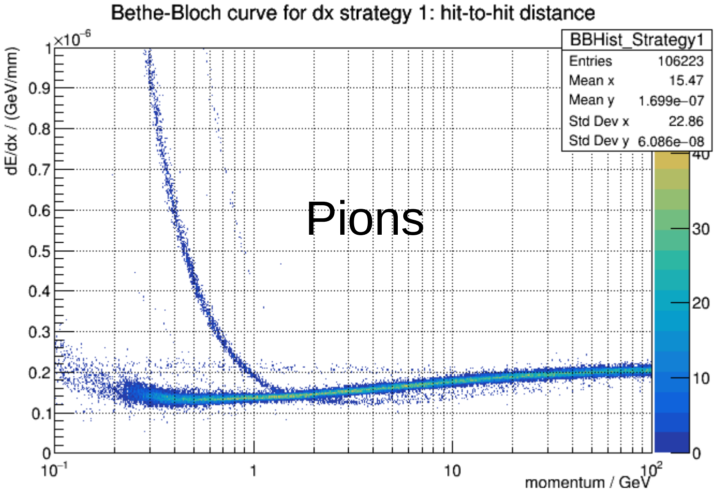




→ Use separation power!

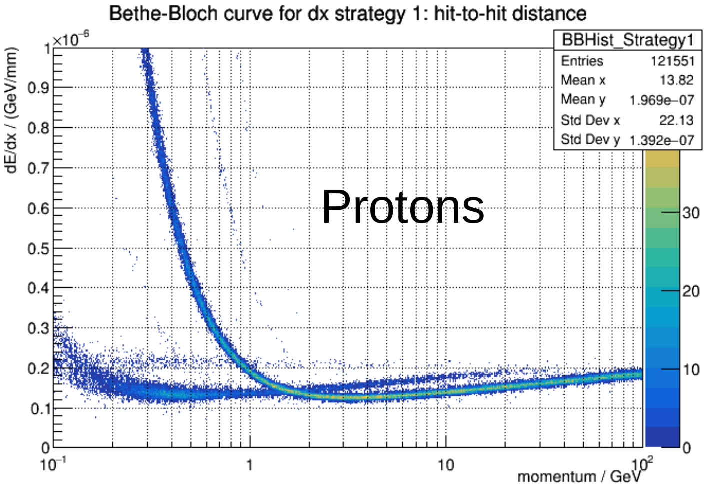
Separate Particle Species

- Base files of single particles had impurities
- Got pdg from Track2MCTruth instead

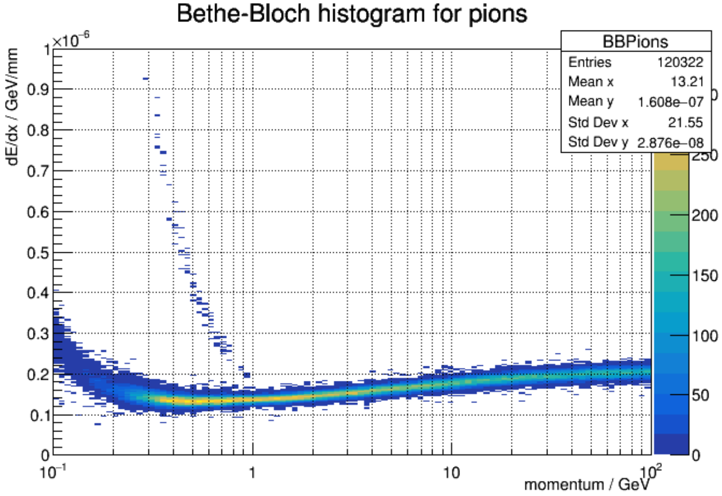


Pions

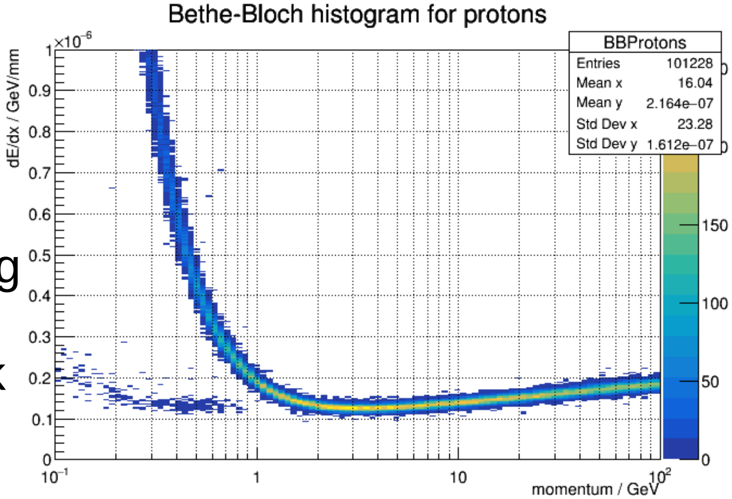
Single particle files



Protons



Track pdg via track truth link



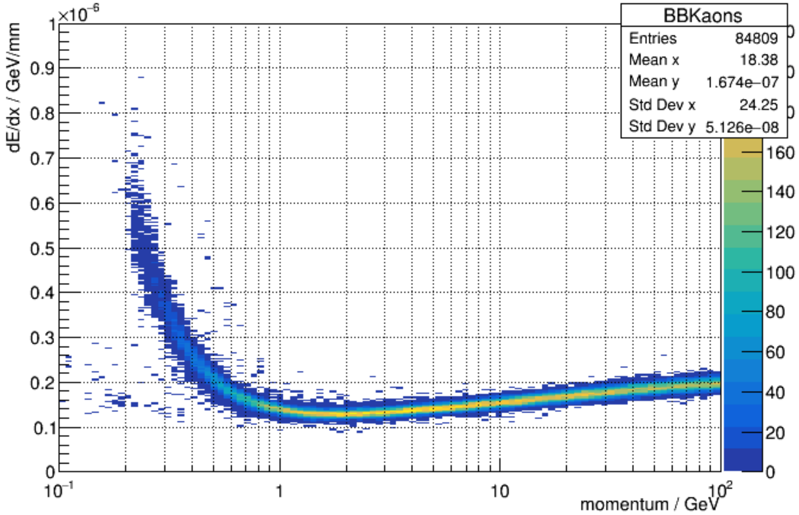
Separation Power

- Use TH2::FitSlicesY
- Goes through every bin in x (momentum) and fits a Gaussian to the distribution in y (dE/dx)
- Reduced (logarithmic) momentum bin number to 100
- Used sliding bins: entries of consecutive 2 bins are added to be fitted, thus bins are correlated
- Used all single particles files (100k per species)

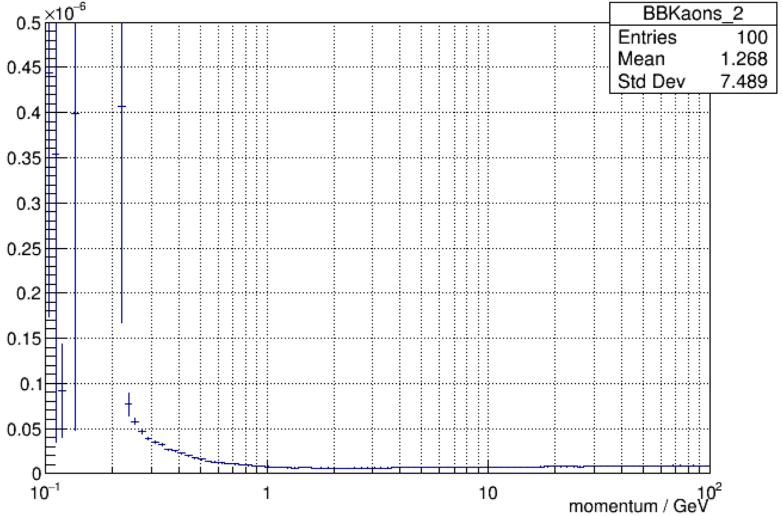
  → got sufficient statistics to have good overall fit results (still some fails)
- Separation power: $\frac{|\mu_\pi - \mu_K|}{\sqrt{\frac{1}{2}(\sigma_\pi^2 + \sigma_K^2)}}$

Separation Power – fit results example

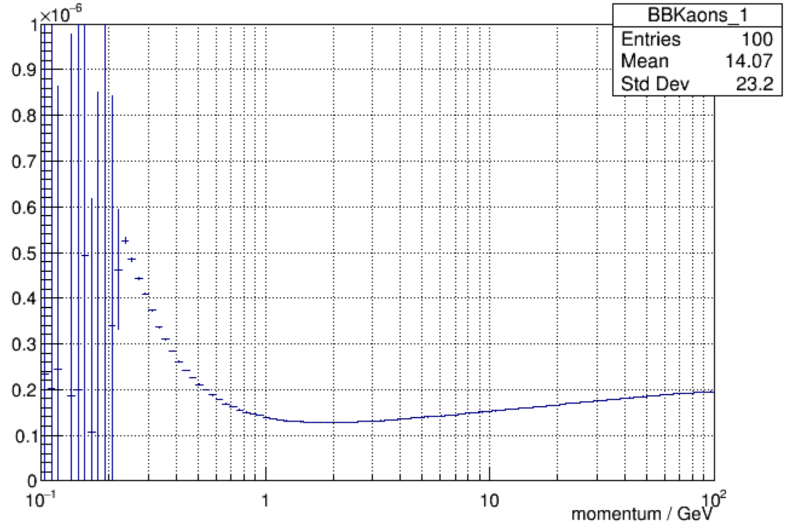
Bethe-Bloch histogram for kaons



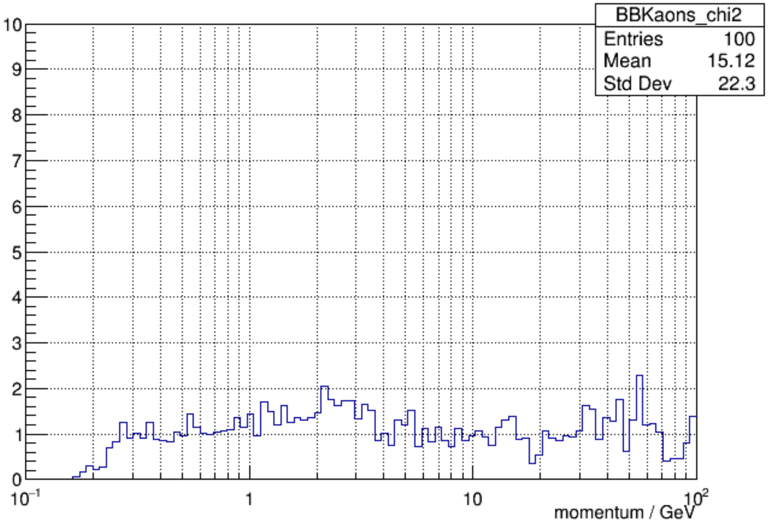
Fitted value of par[2]=Sigma



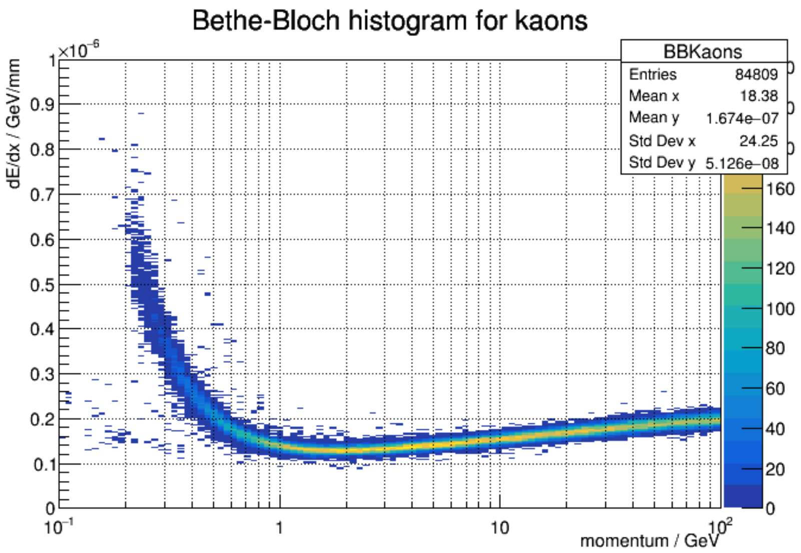
Fitted value of par[1]=Mean

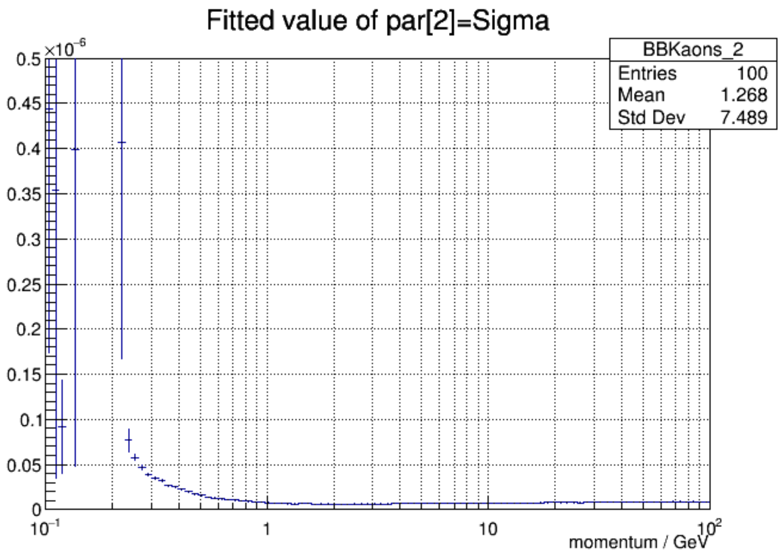


chisquare



Separation Power – fit results example


Bethe-Bloch histogram for kaons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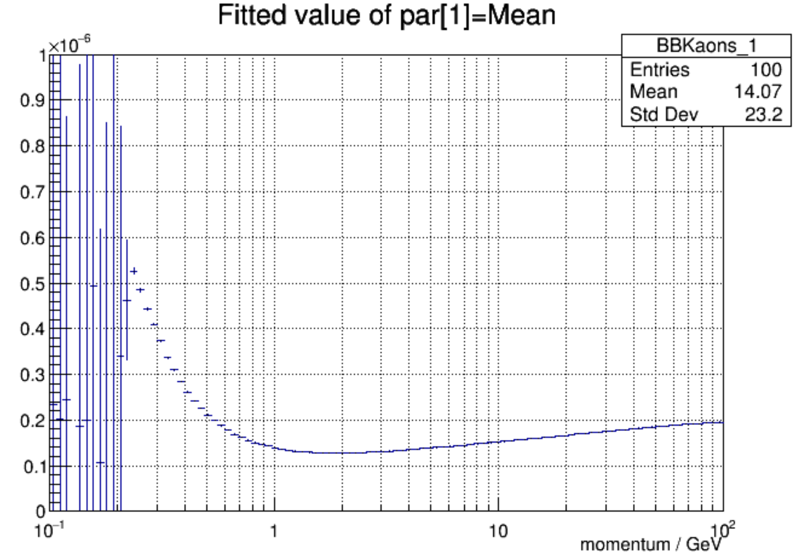
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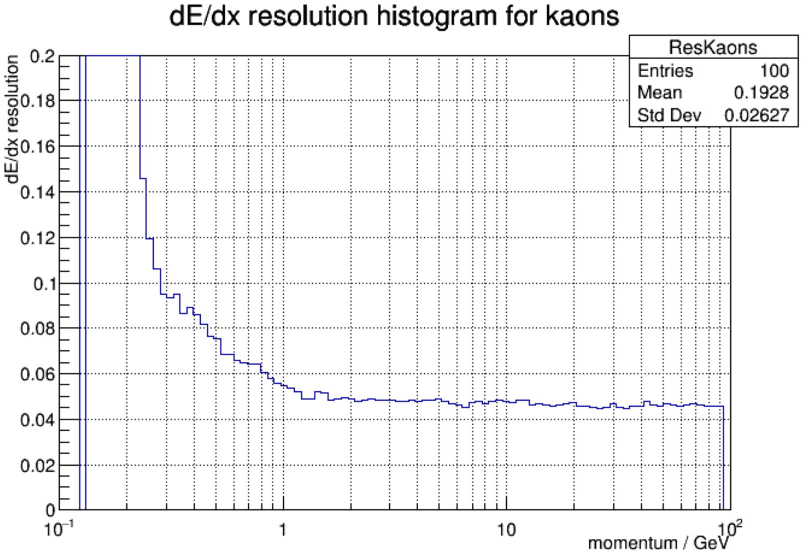
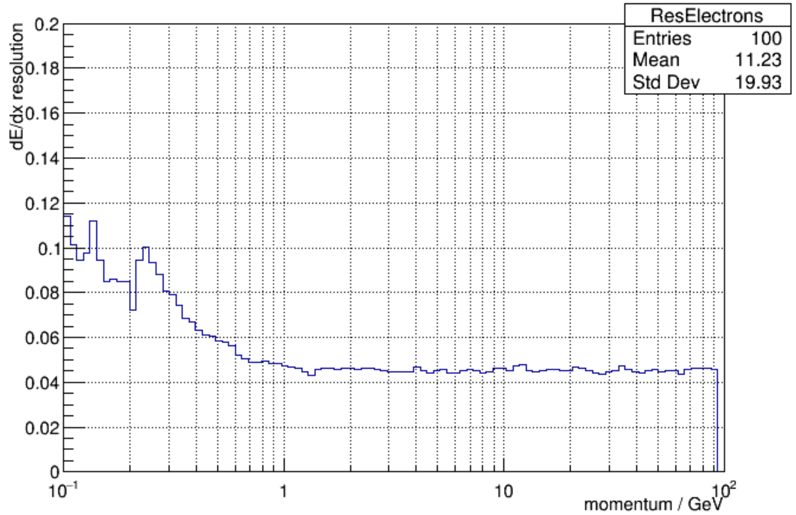
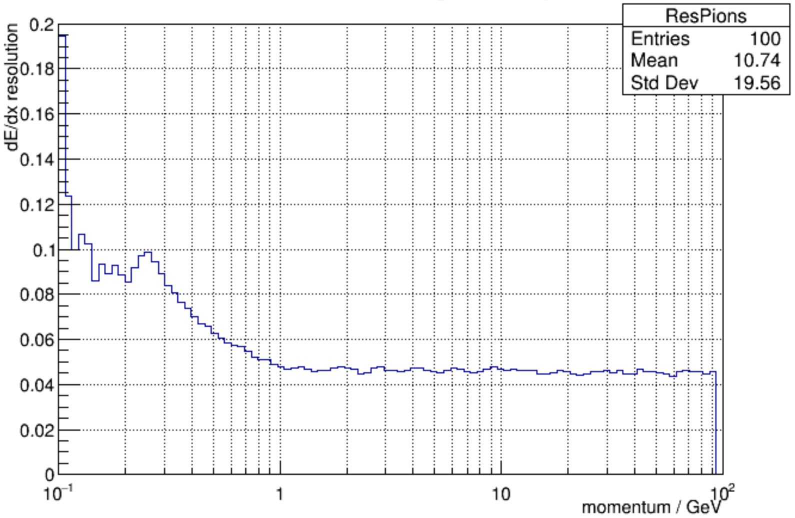
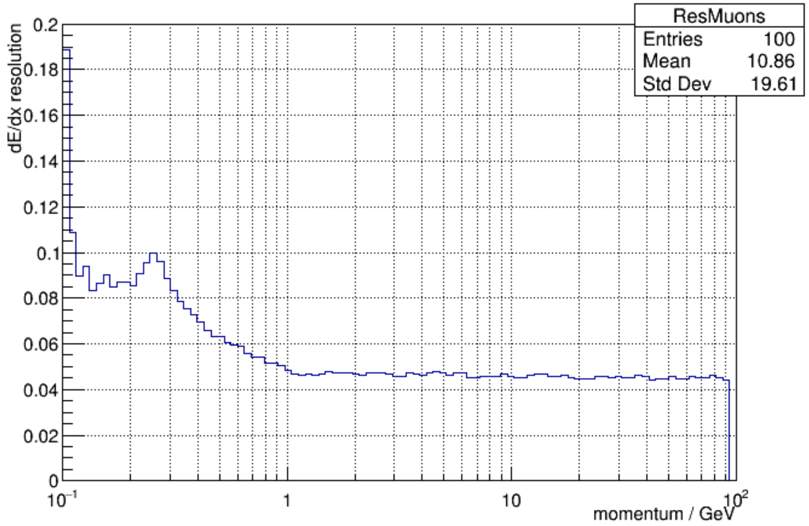
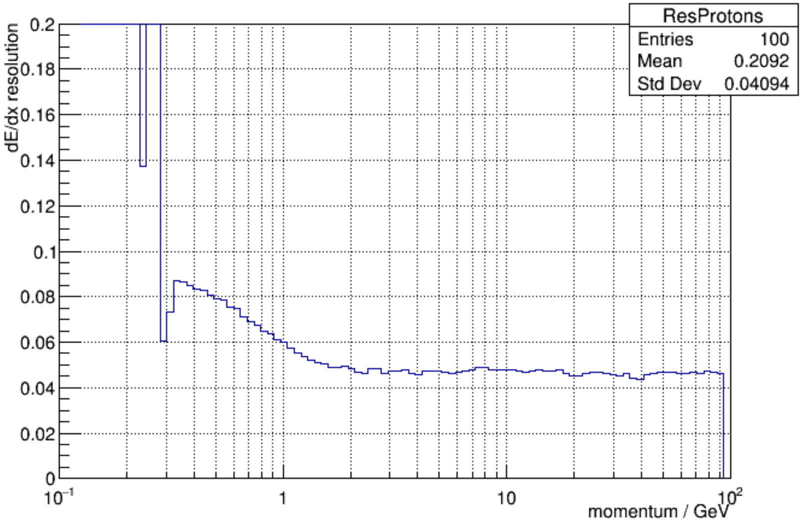

dE/dx resolution histogram for kaons

Separation Power – resolution: ~ 4.5% above 2 GeV

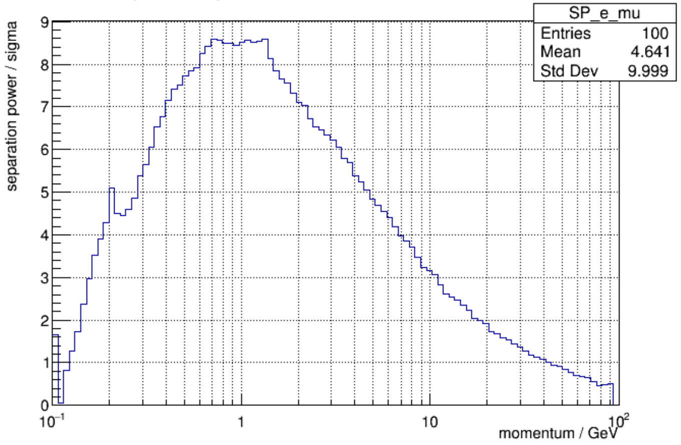

dE/dx resolution histogram for electrons

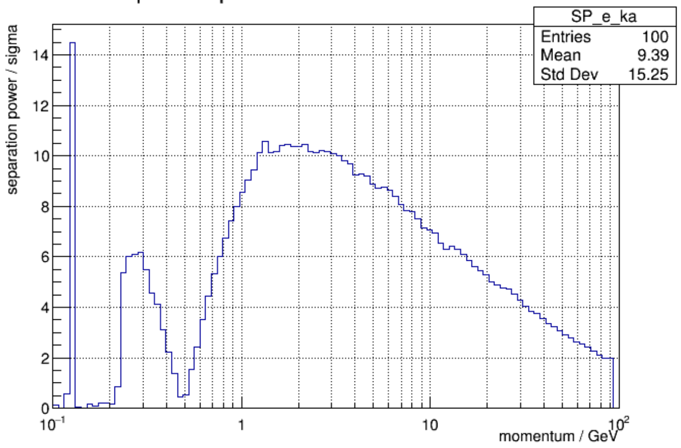

dE/dx resolution histogram for pions

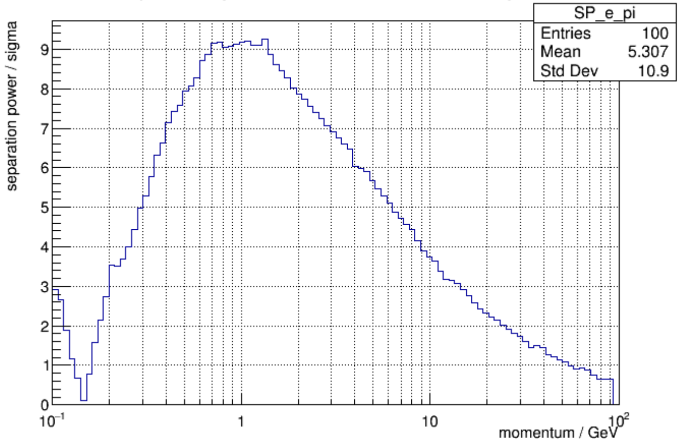

dE/dx resolution histogram for muons


dE/dx resolution histogram for protons

Separation Power - Electrons


Separation power between electrons and muons


Separation power between electrons and kaons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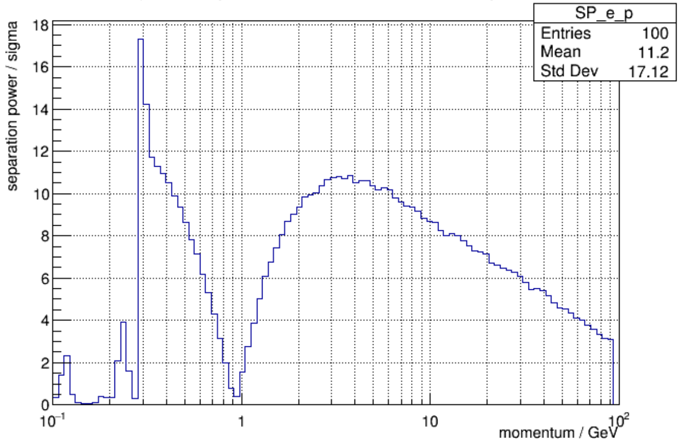
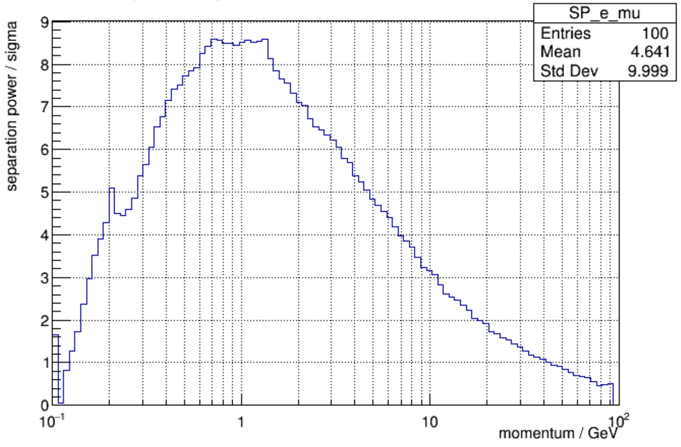
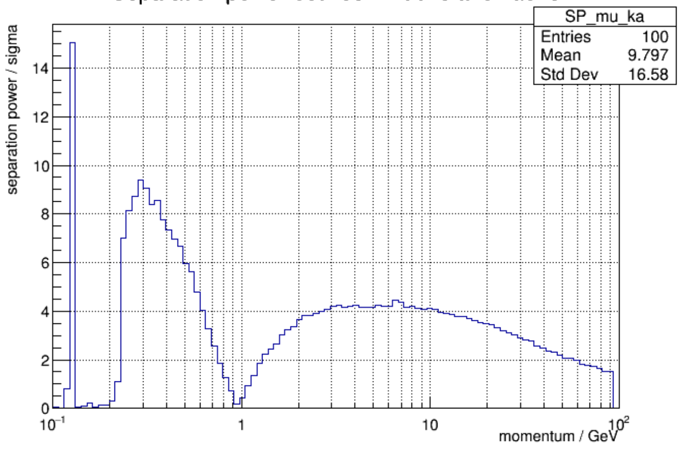

Separation power between electrons and protons

Separation Power - Muons

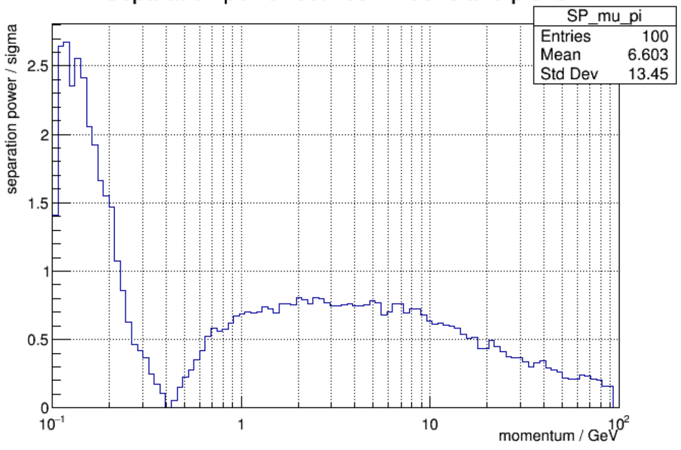
Separation power between electrons and muons



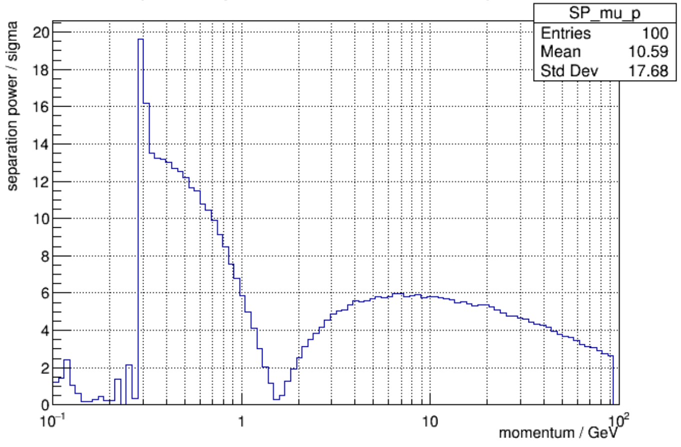
Separation power between muons and kaons



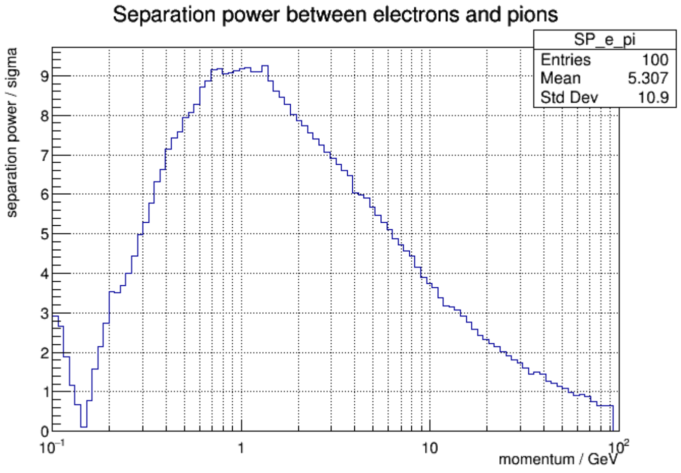
Separation power between muons and pions

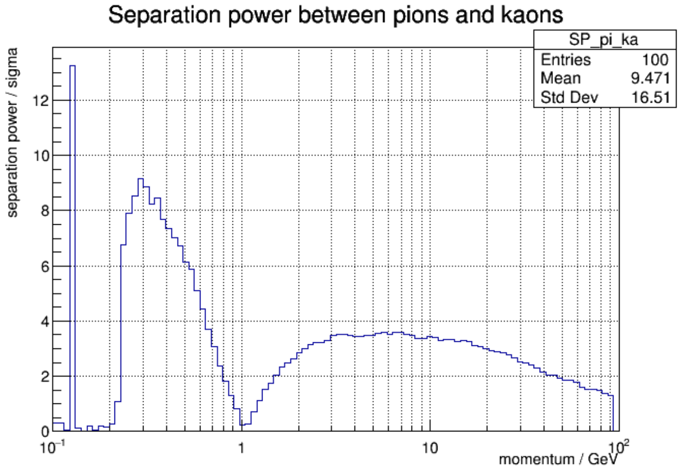


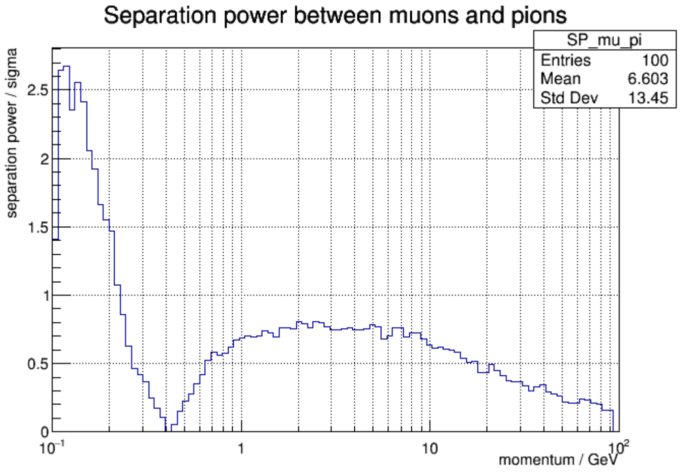
Separation power between muons and protons

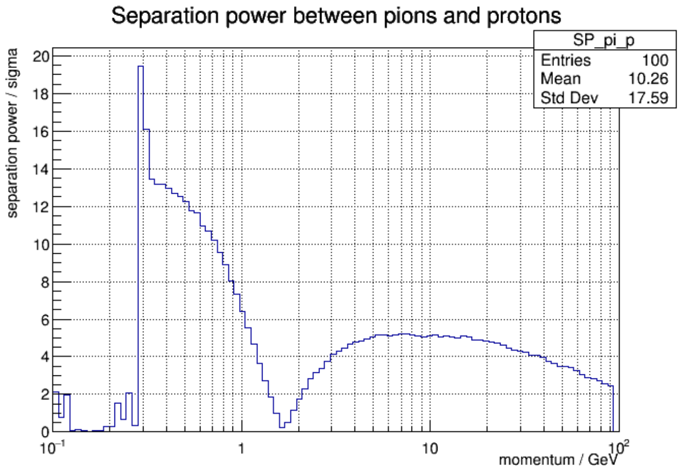


Separation Power - Pions



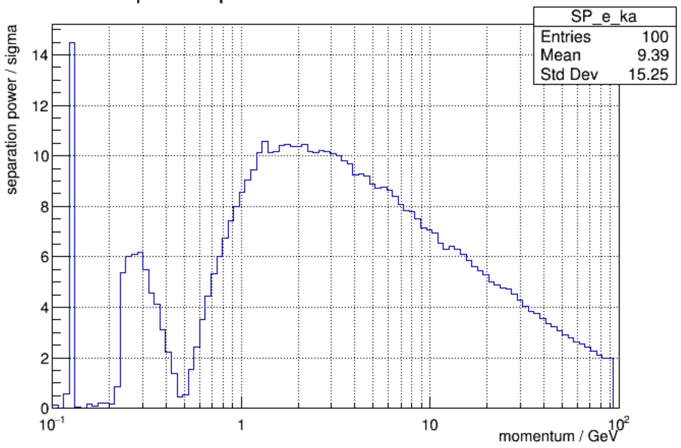




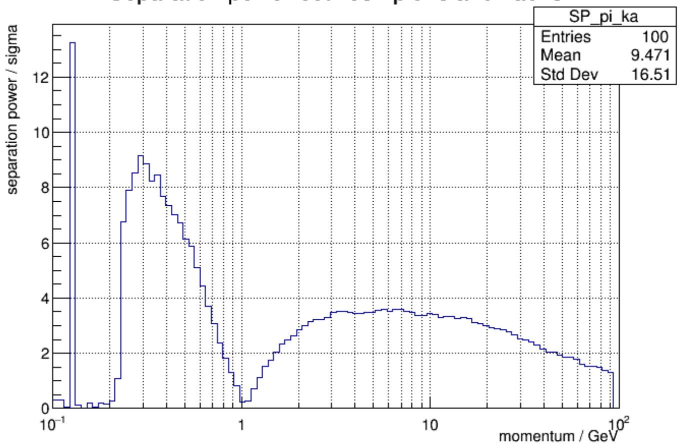


Separation Power - Kaons

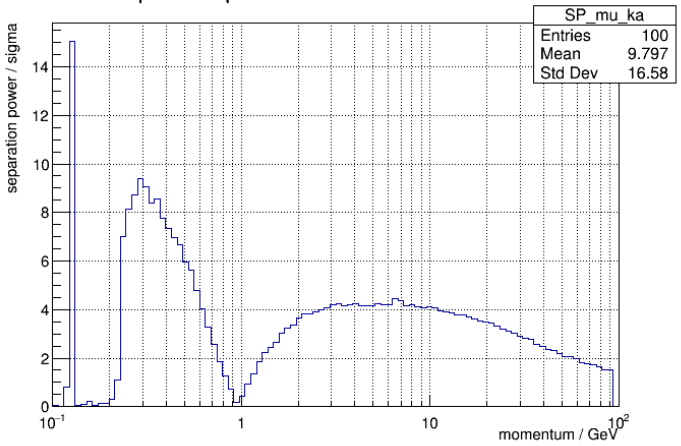
Separation power between electrons and kaons



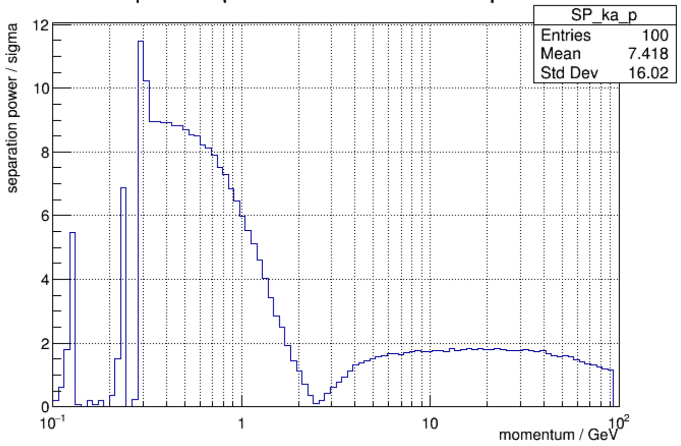
Separation power between pions and kaons



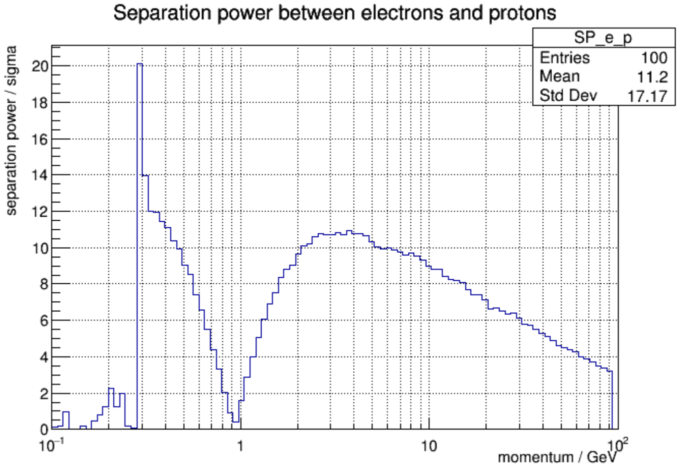
Separation power between muons and kaons

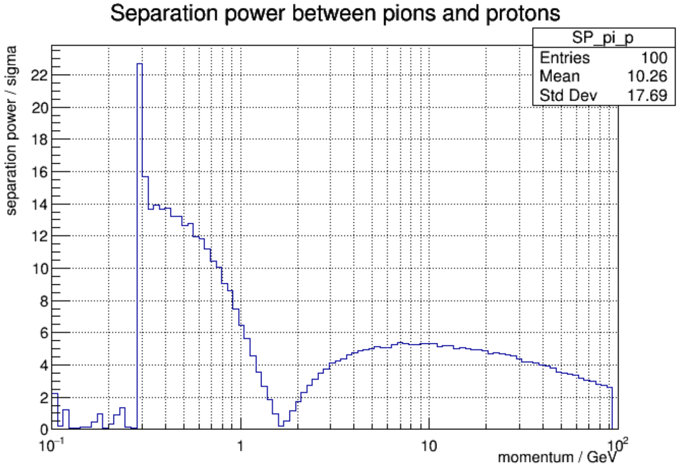


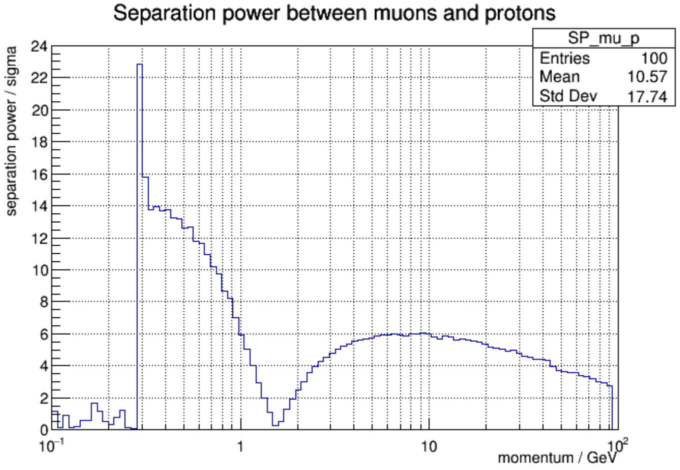
Separation power between kaons and protons

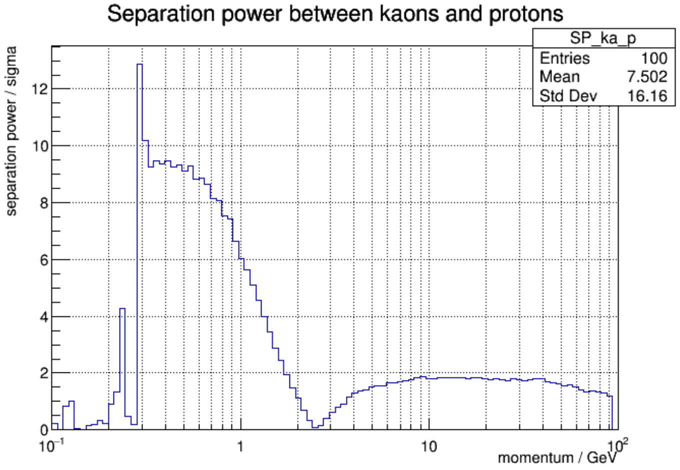


Separation Power - Protons

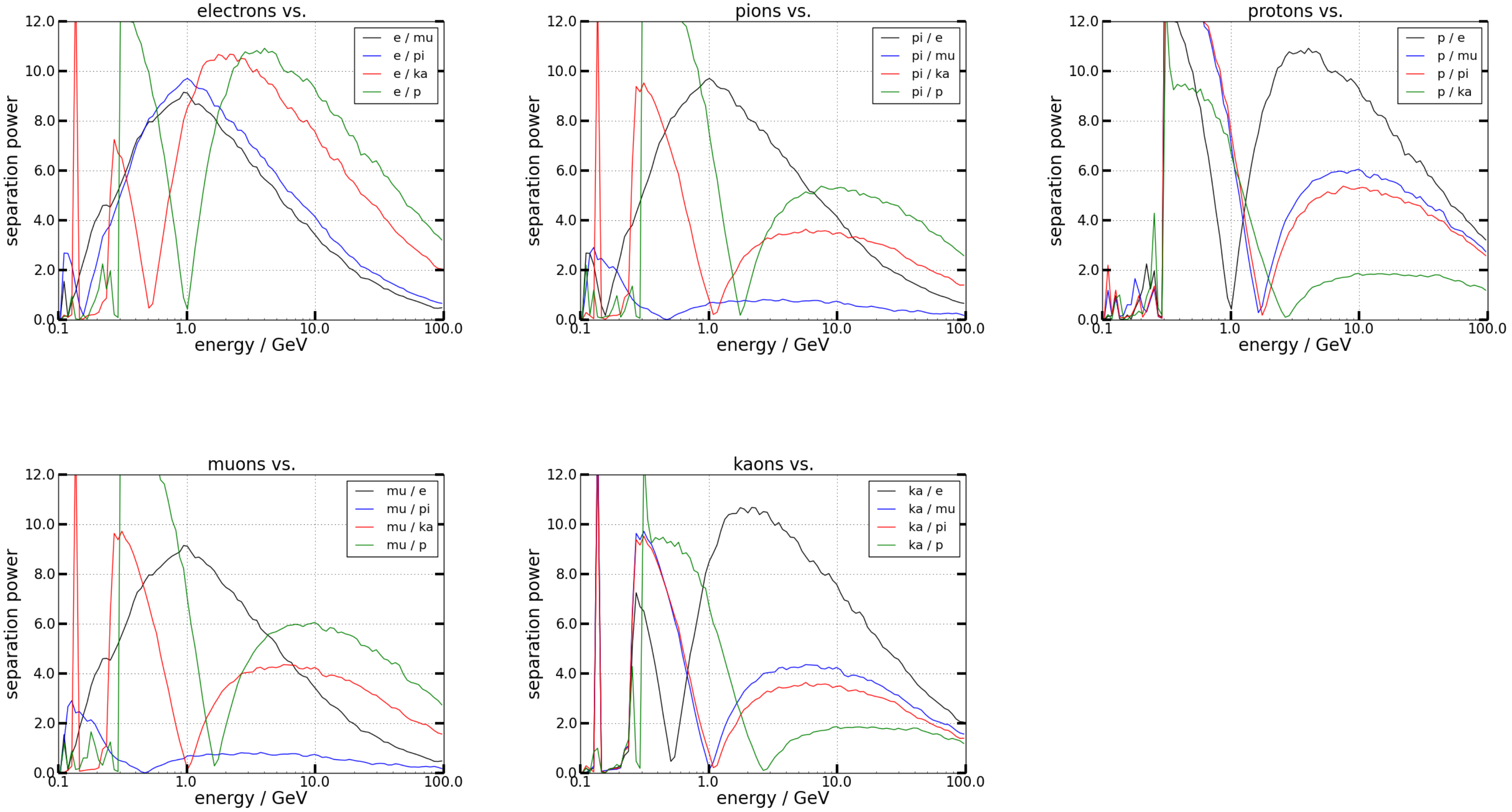

Separation power between electrons and protons


Separation power between pions and protons


Separation power between muons and protons

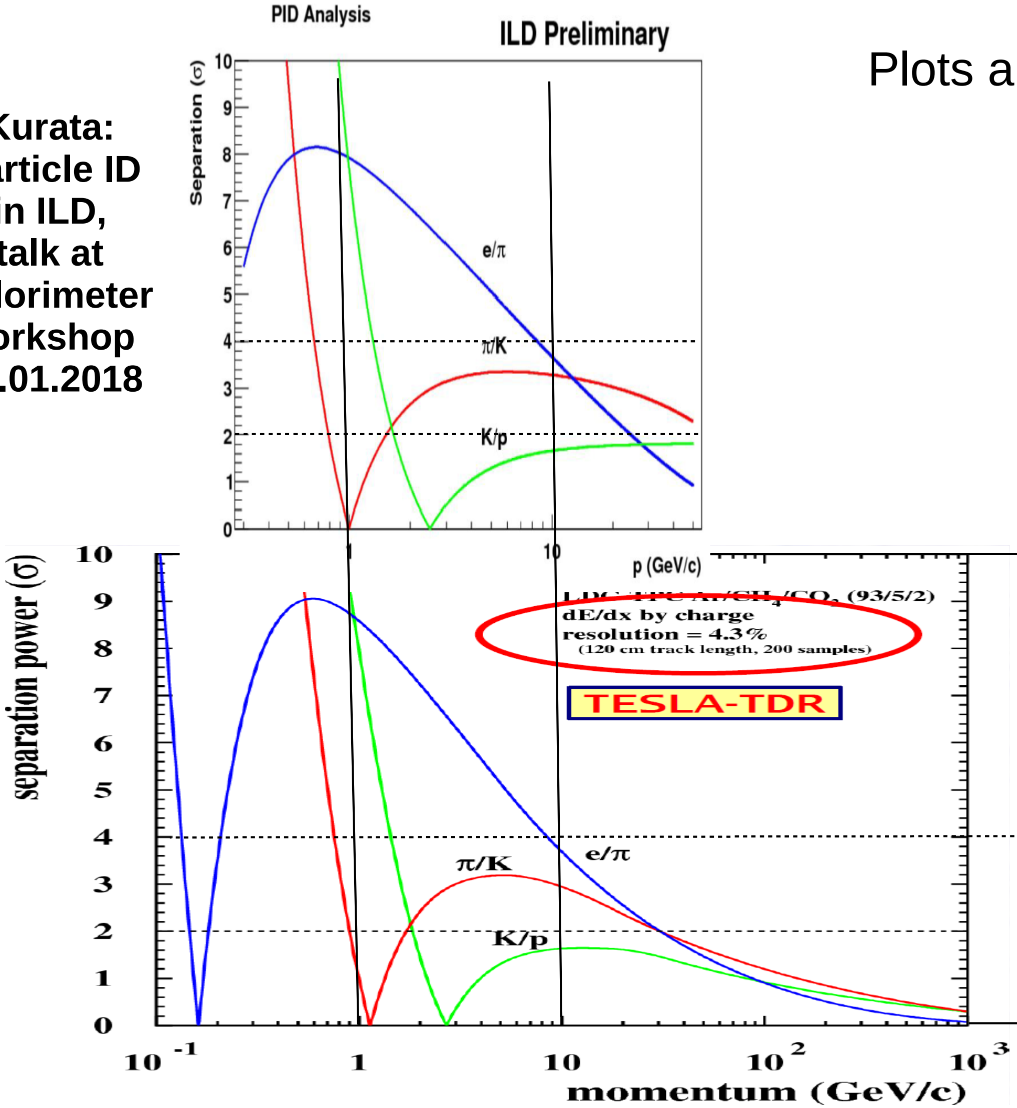

Separation power between kaons and protons

Separation Power – Combined Plots



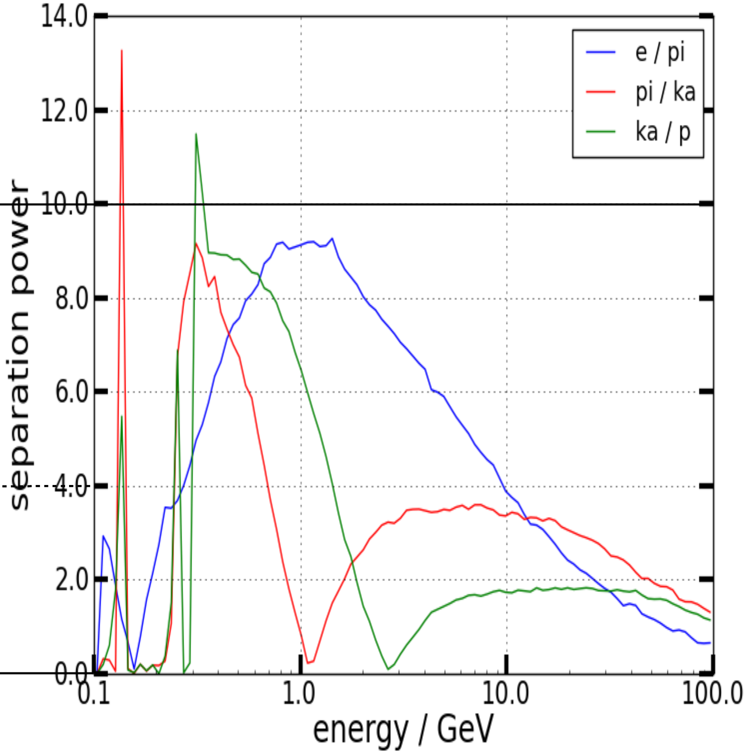
Separation Power - Comparison

Kurata: Particle ID in ILD, talk at Calorimeter Workshop 19.01.2018



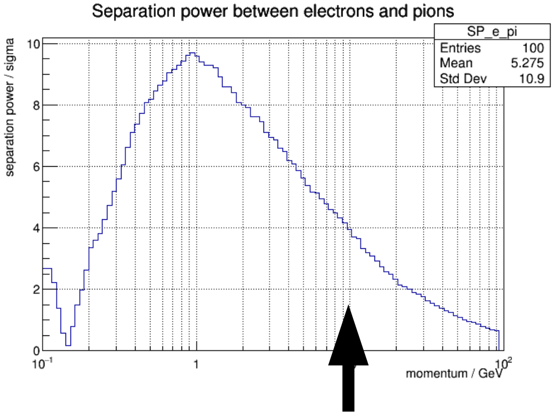
Plots aligned for matching axes

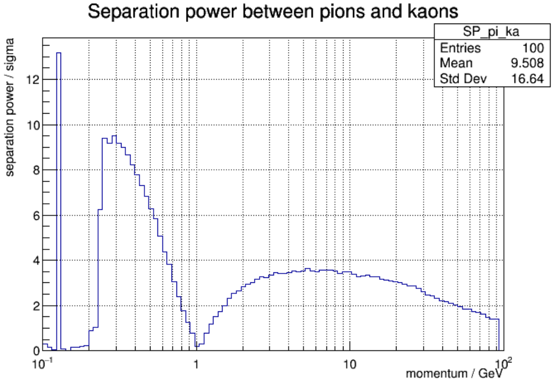
this work

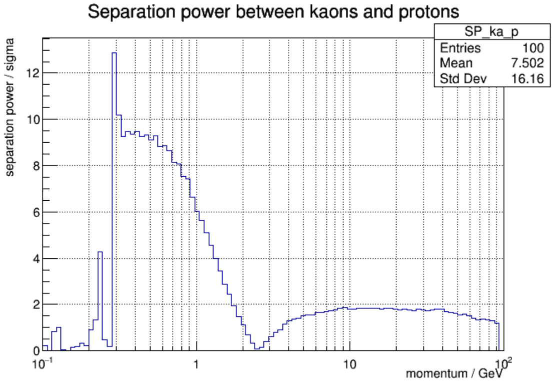


Hauschildt: Gaseous Tracking and dE/dx at Future Colliders, Talk at CERN particle physics seminar, 05.07.2007

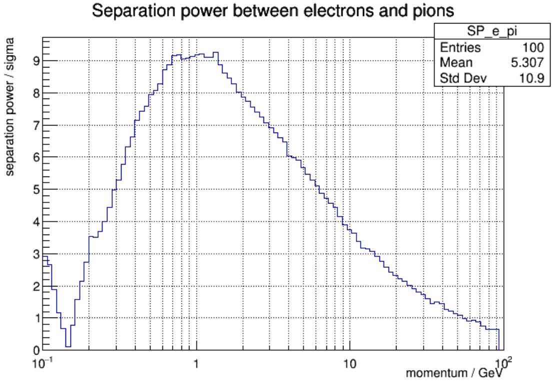
dx Strategy Comparison

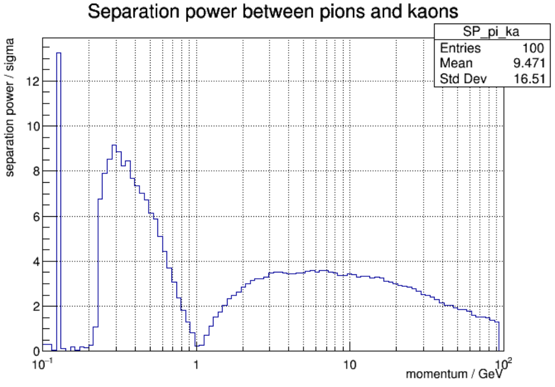

Separation power between electrons and pions

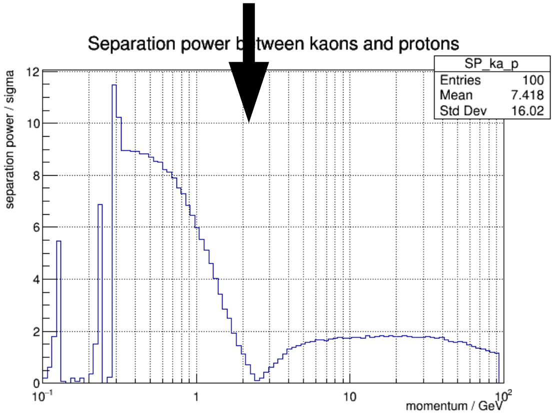

Separation power between pions and kaons


Separation power between kaons and protons

Strategy 1 is very similar, maybe slightly better than strategy 3

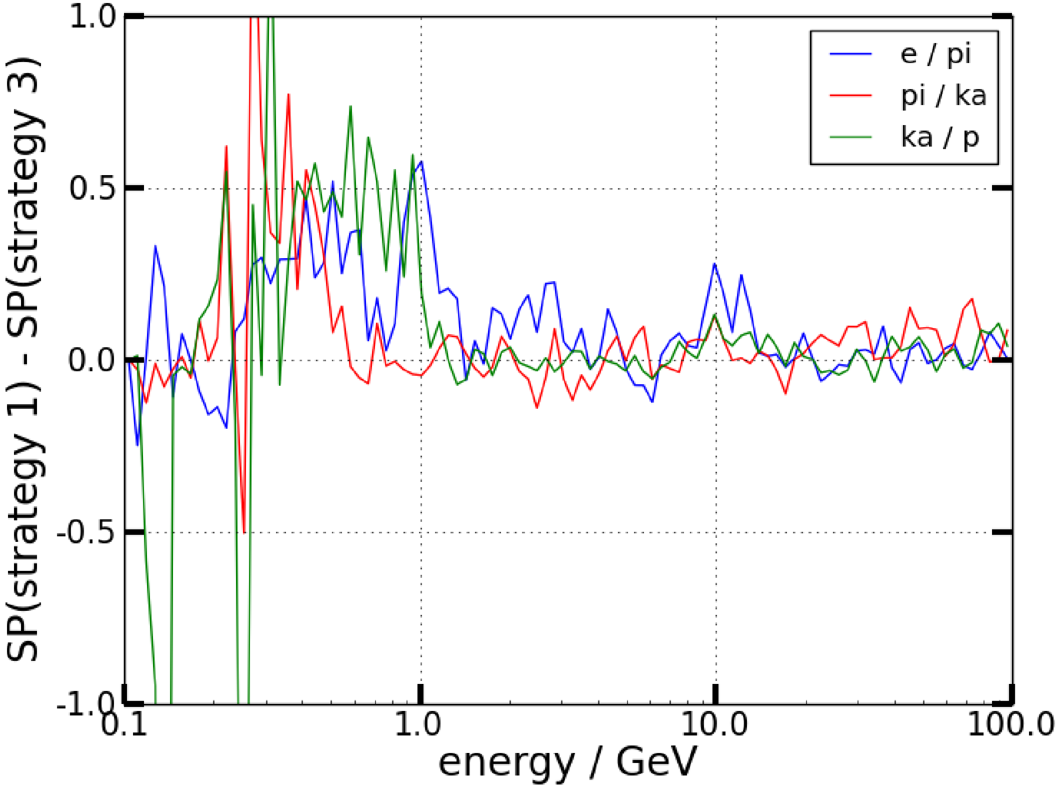

Separation power between electrons and pions


Separation power between pions and kaons


Separation power between kaons and protons

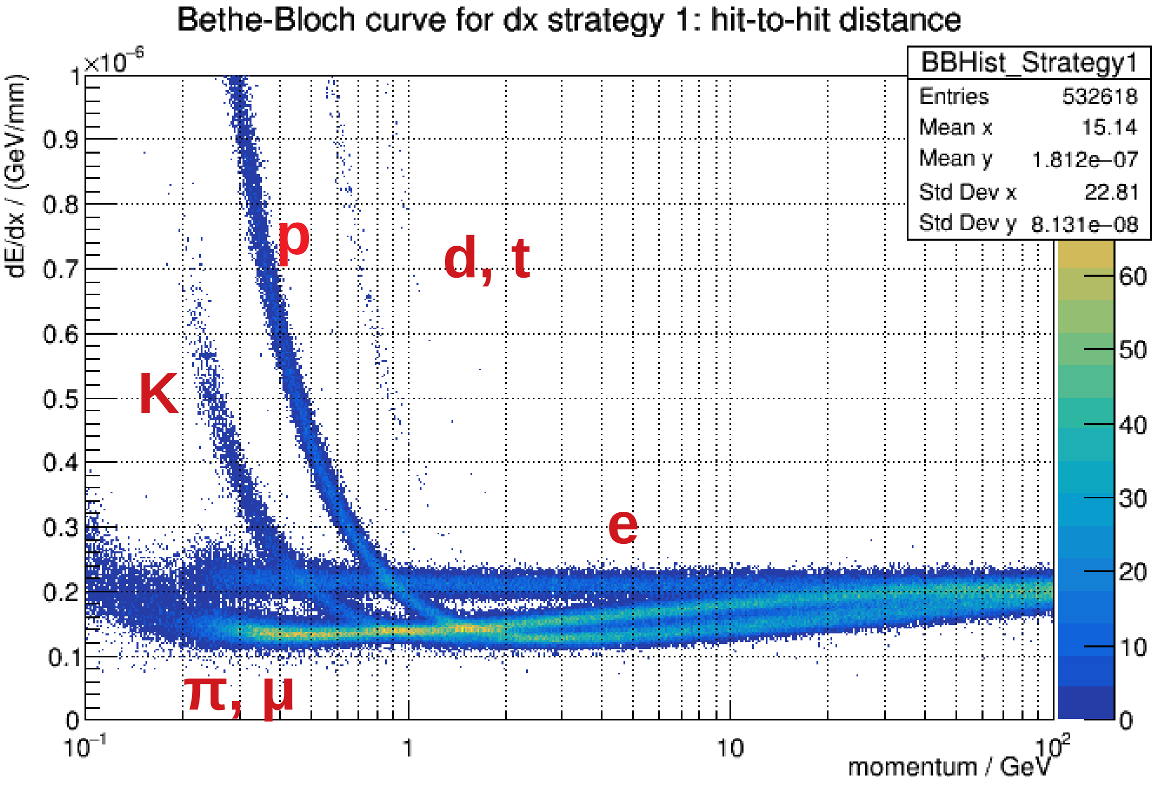
dx Strategy Comparison

- Strategy 1 is very similar to, maybe slightly better than strategy 3
- Difference plot:



To Do

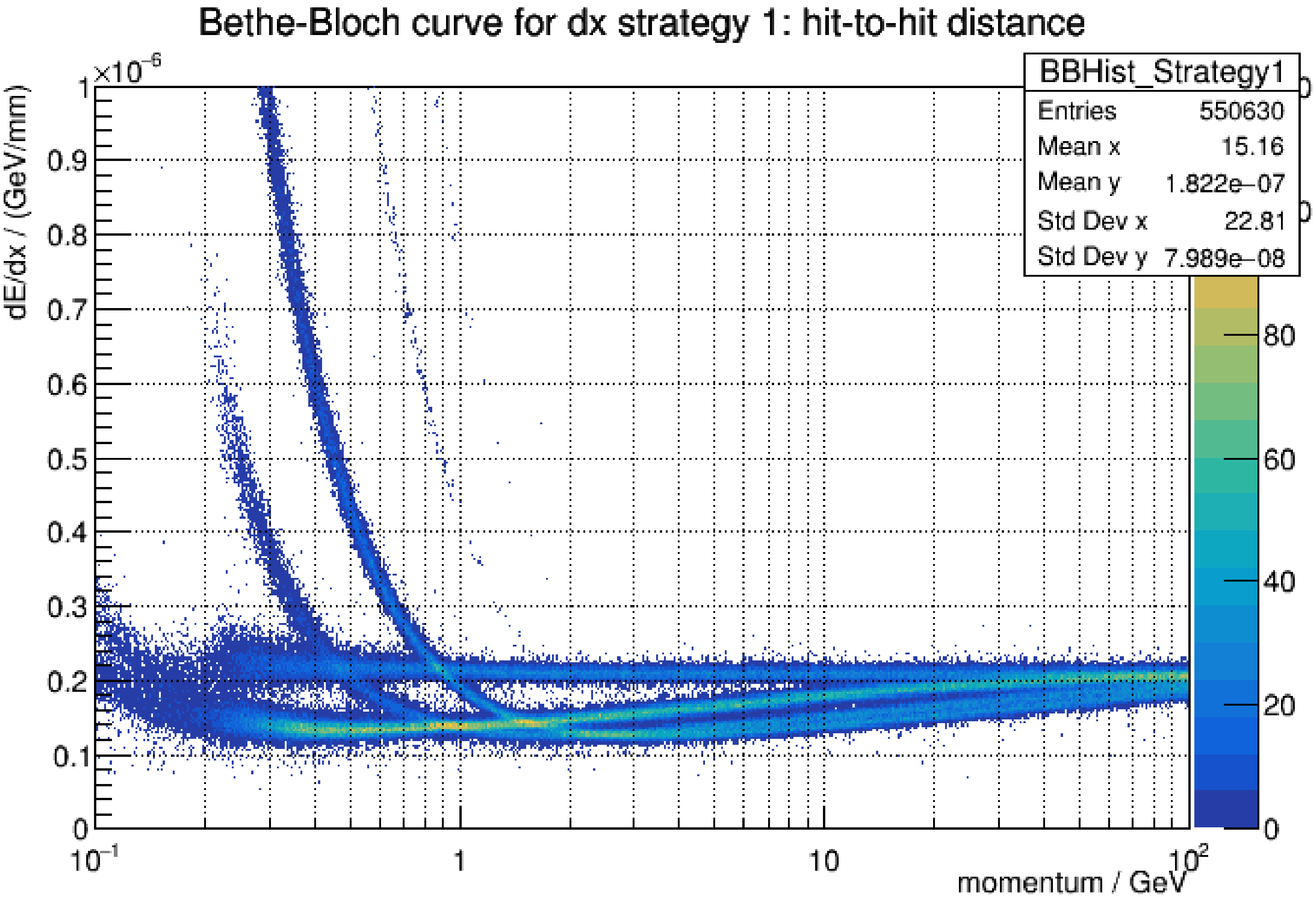
- Add analysis code to github (?)
- Comparisons based on separation power:
  - dx strategies
  - Detector models and technologies
  - Improved dE/dx resolution (high granularity TPC)
  - Added weighting or other refined algorithms
- But: re-run (nearly) full reconstruction chain each time
- Interesting: Combine with potential TOF


Bethe-Bloch curve for dx strategy 1: hit-to-hit distance
BBHist_Strategy1
Entries 532618
Mean x 15.14
Mean y 1.812e−07
Std Dev x 22.81
Std Dev y 8.131e−08
dE/dx / (GeV/mm)
×10⁻⁶
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10⁻¹
1
10
10²
momentum / GeV
60
50
40
30
20
10
0
p
d, t
K
e
π, μ

Thanks!

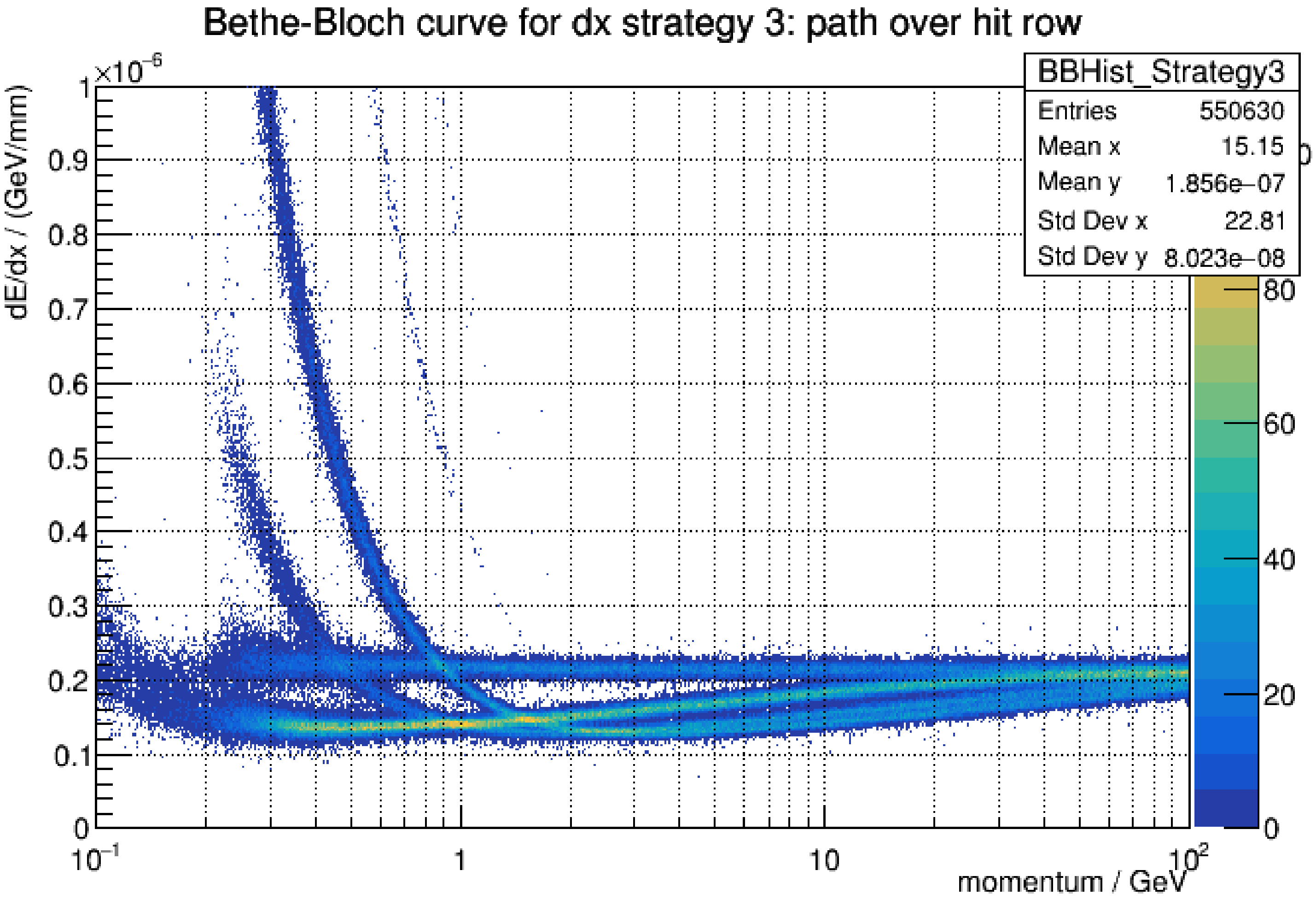
Backup

dE/dx – Plots: comparing strategies



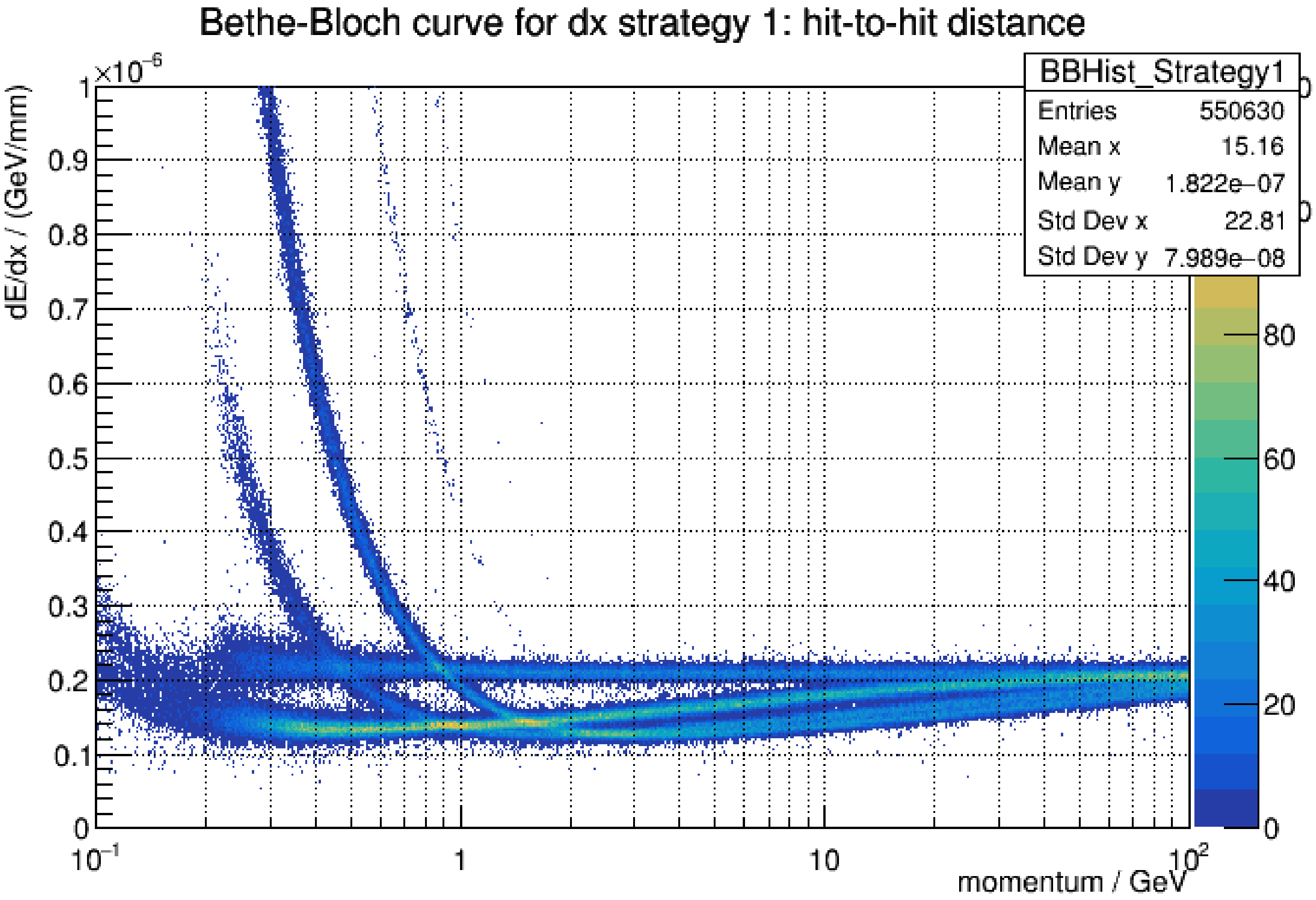
Strategy 1

dE/dx – Plots: comparing strategies



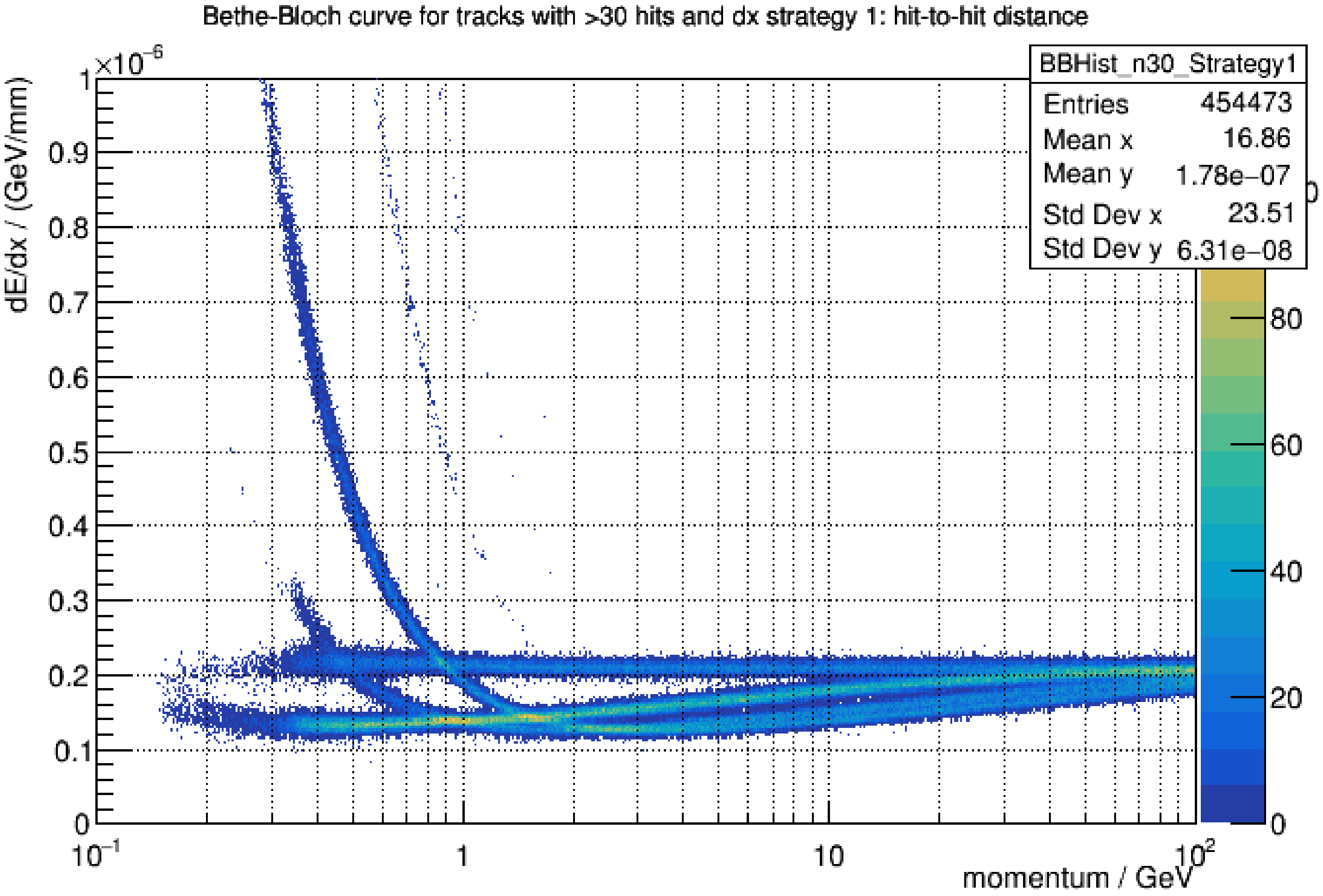
Strategy 3

dE/dx – Plots: comparing cut >=30 hits



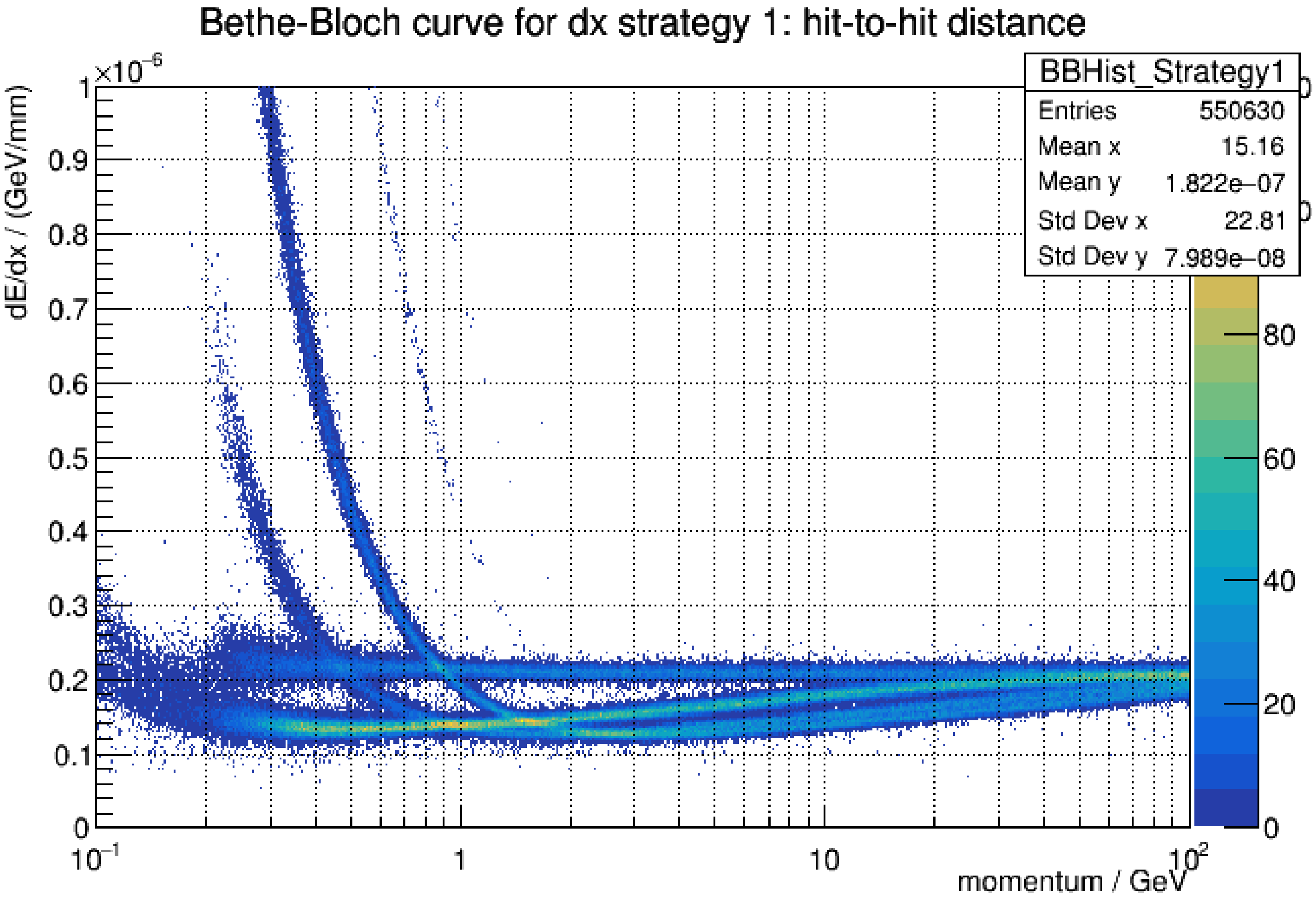
All tracks

dE/dx – Plots: comparing cut >=30 hits



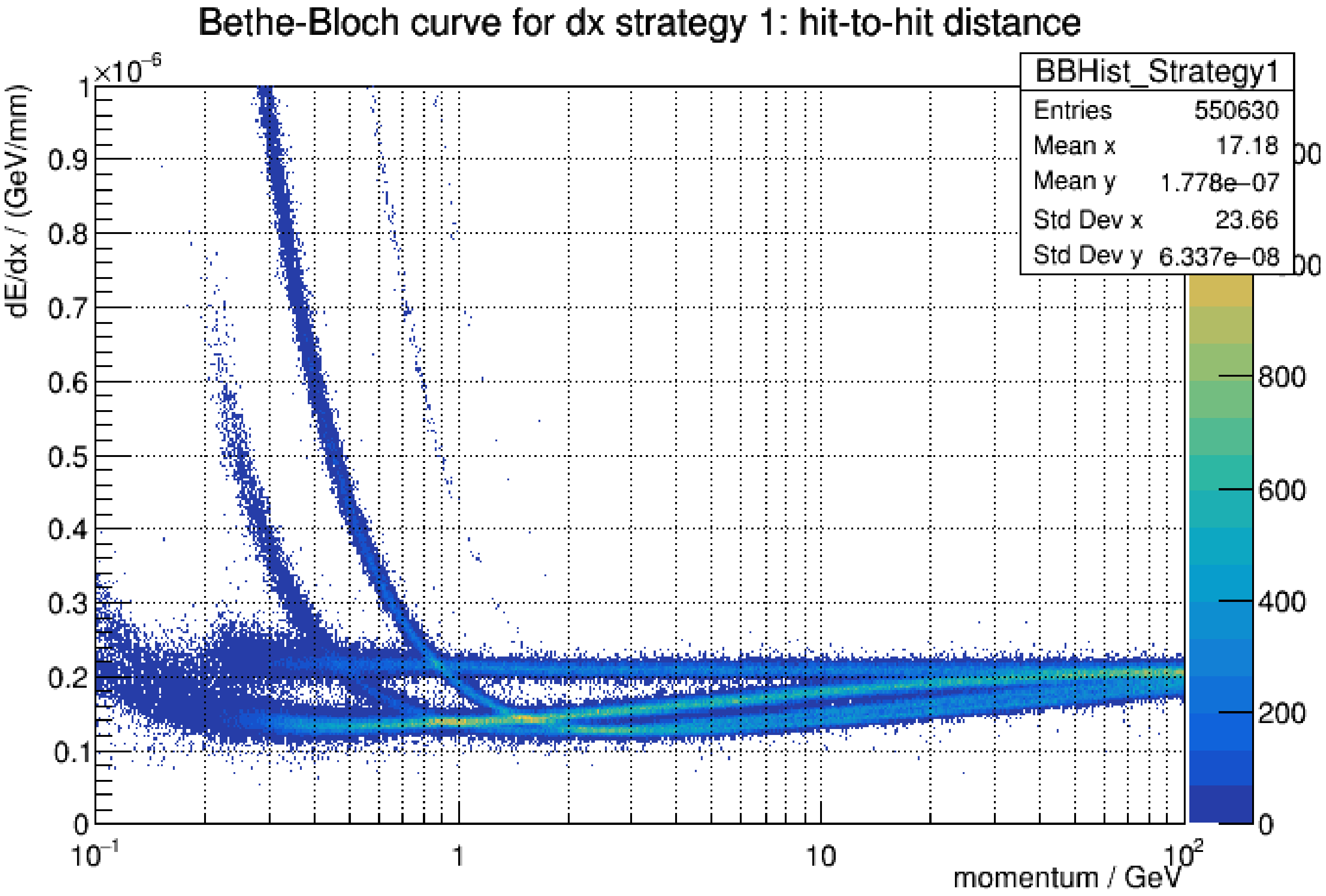
Only tracks with >= 30 hits

dE/dx – Plots: comparing weighting



Without weighting

dE/dx – Plots: comparing weighting



With sqrt(nHits) weighting