

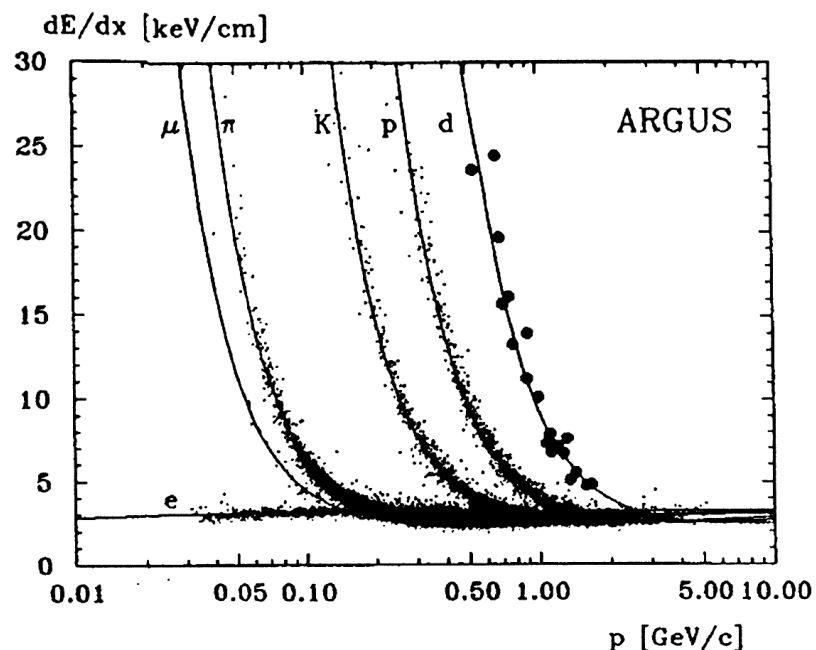
DPG-Frühjahrstagung 2012 in Göttingen

Anti-Nuclei Identification Using TOF at the Belle Experiment

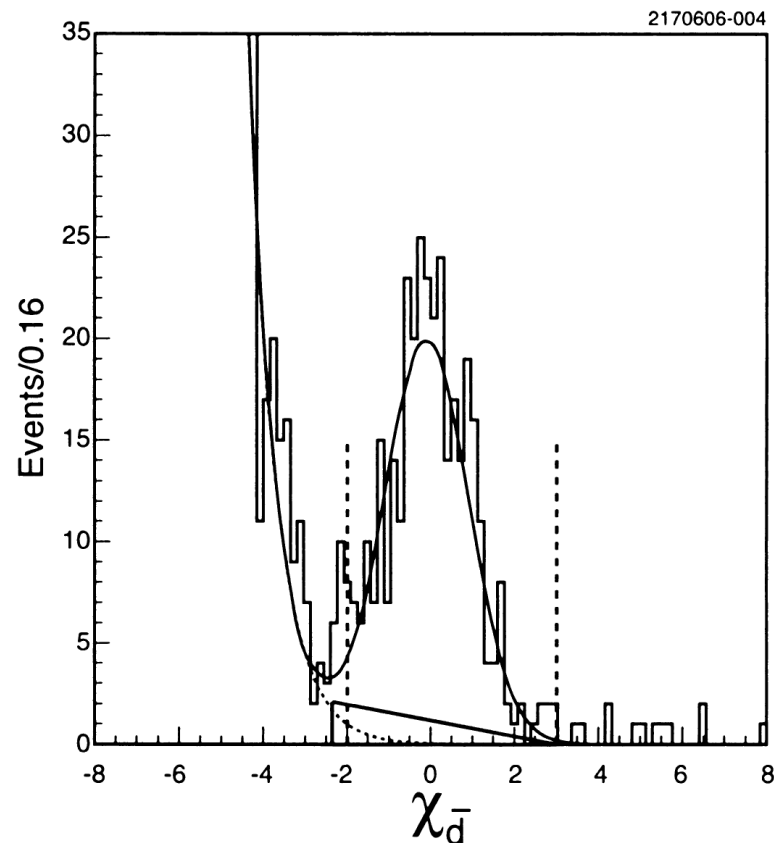
Diego Semmler, Wolfgang Kühn, Sören Lange, Matthias Ullrich, Milan Wagner and Marcel Werner

- Motivation
- The basic idea
- Background suppression
- Results & conclusions

Searches for anti-deuterium in the past



1989: ARGUS found 21 \bar{d} candidates at DESY

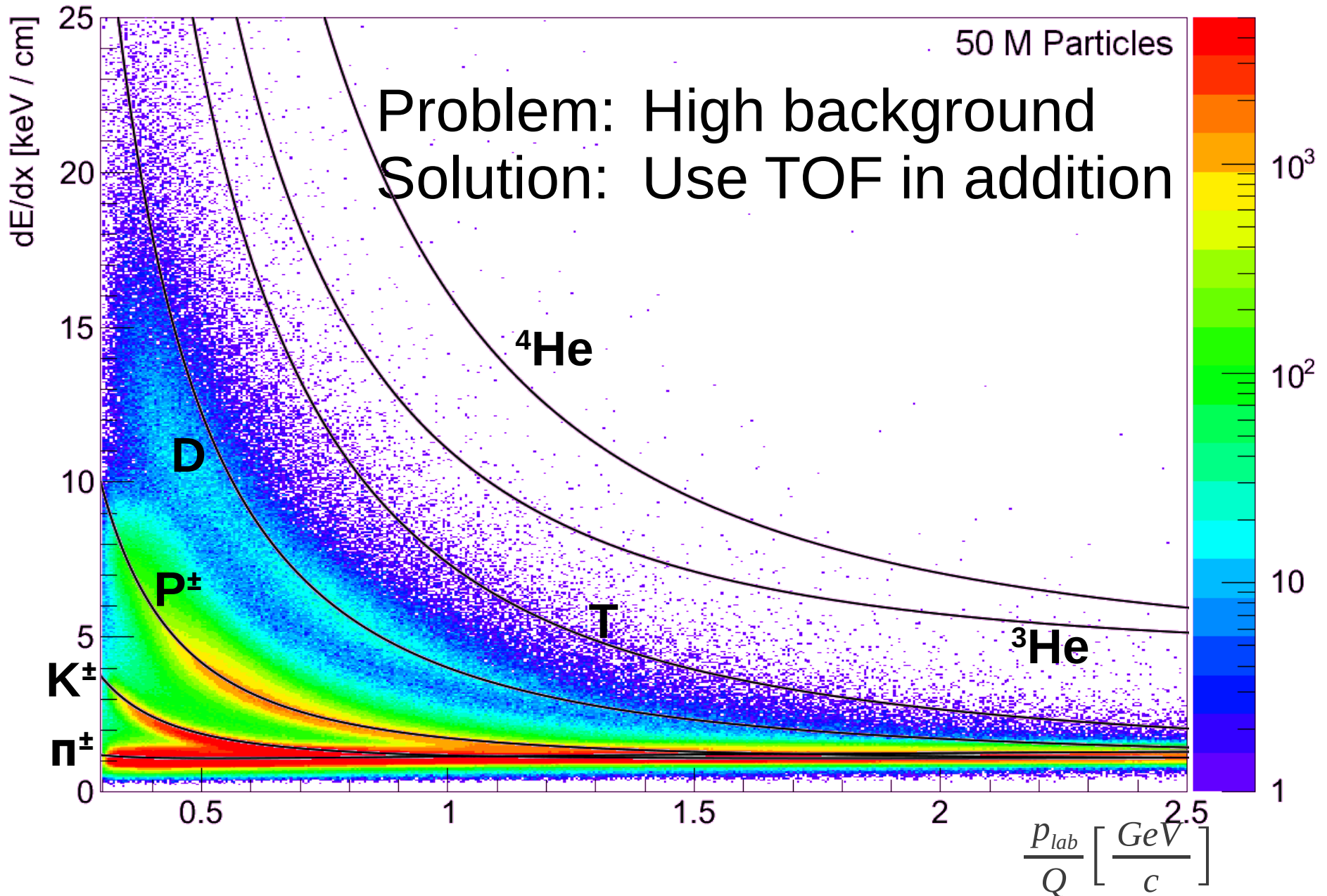


2006: CLEO found 338 \bar{d} candidates at the Cornell Electron Storage Ring

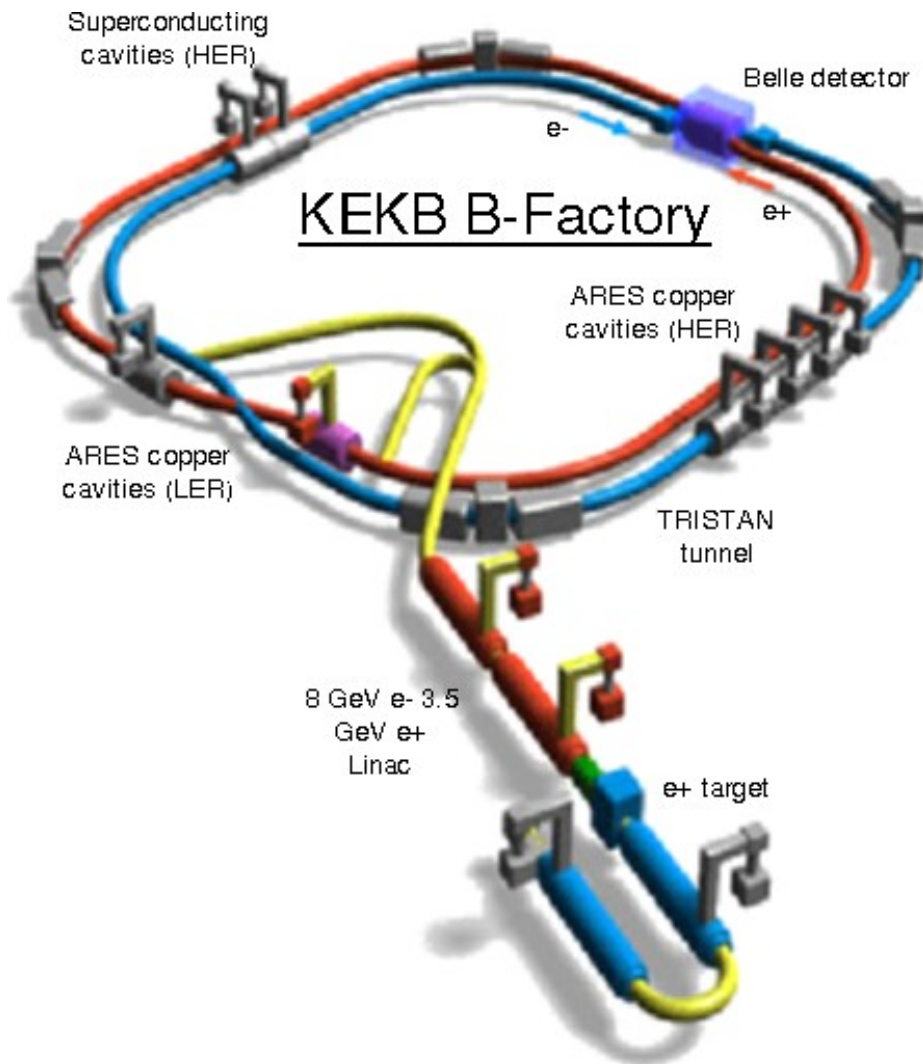
- Studying formation of anti-nuclei in e^+e^- collisions
- Branching fraction can be compared to **coalescence** models (overlap in wave functions)
- Momentum distribution can be compared to **fireball** models
- Clean sample, because antimatter can't be produced by events with the rest gas or the beam pipe
- Primary ansatz for identification: Bethe-Bloch

Motivation

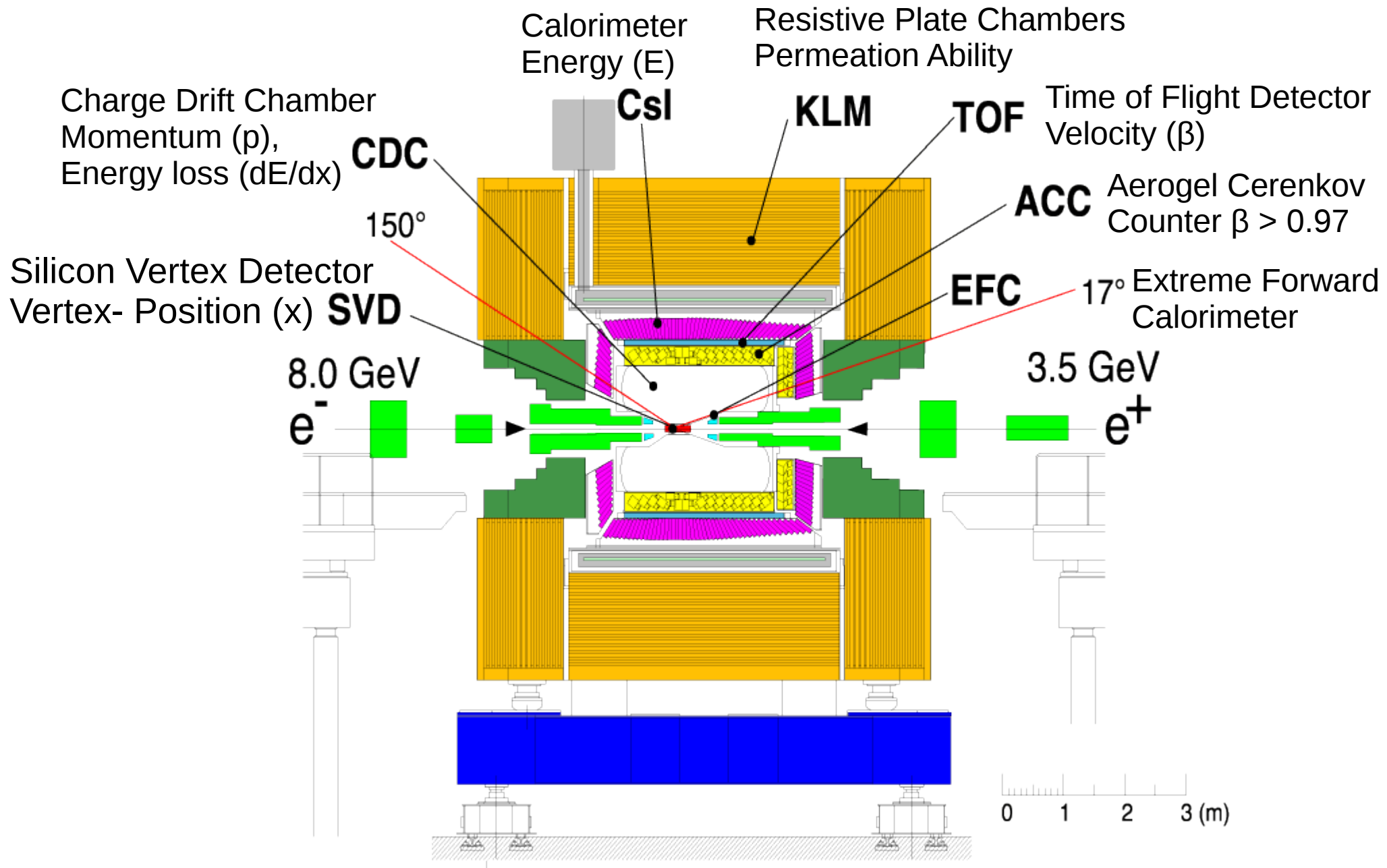
dE/dx vs. p_{lab} ($Q > 0$)



1999 - 2010 Belle-detector at KEK



- Asymmetric e^+e^- collider at upsilon 4S resonance
- e^- energy: 8 GeV
- e^+ energy: 3,5 GeV
- CMS-energy: 10,58 GeV
- Range: upsilon(1s) to upsilon(5s)
- Integrated luminosity: 1041 fb^{-1} (980 fb^{-1} used in analysis)



- Calculate $\frac{dE}{dx}$ from the Bethe-Bloch-formula:

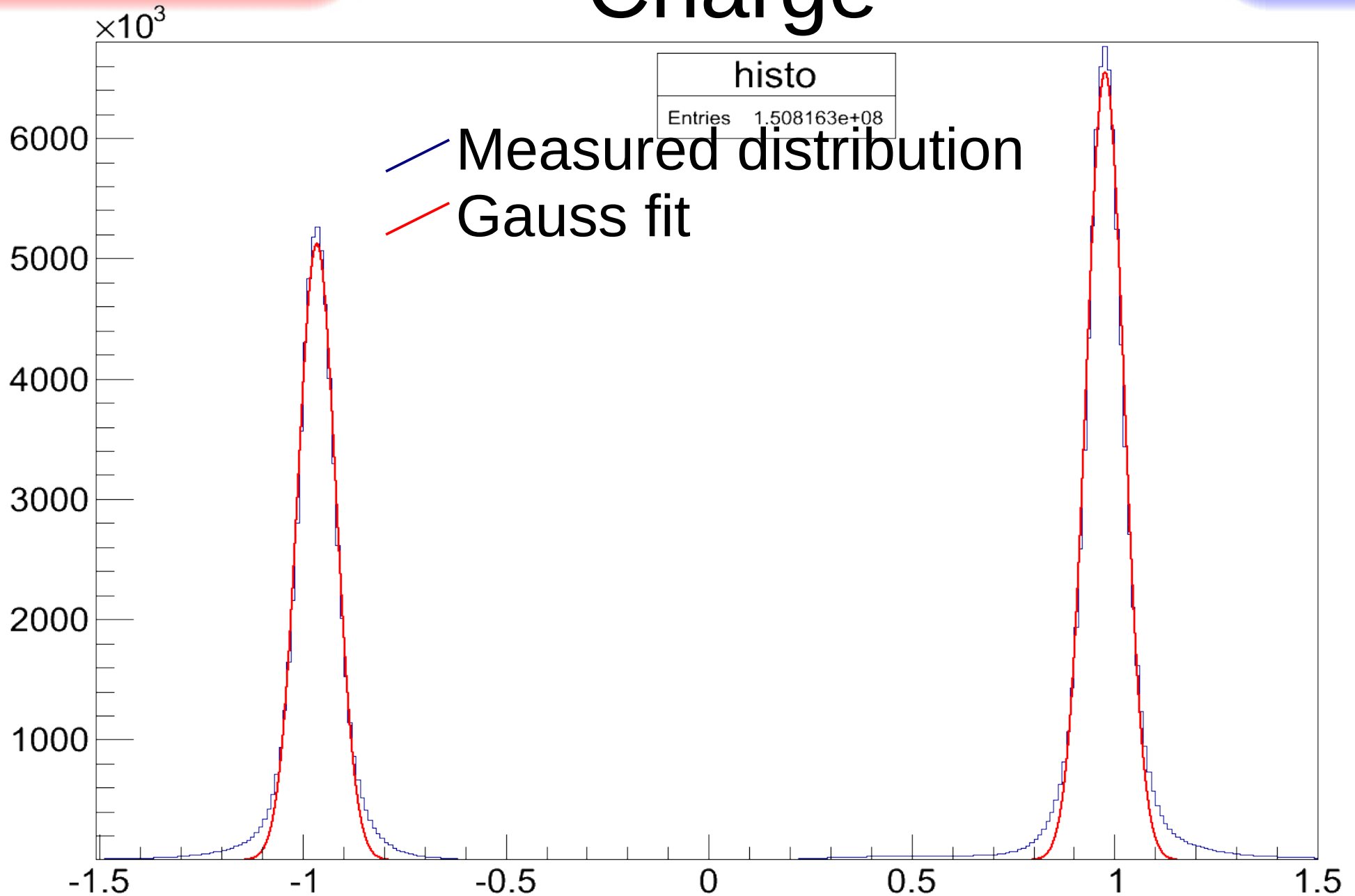
$$\frac{dE}{dx}_{\text{calculated}} = 2\pi N_A r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{Q^2}{\beta^2} \left(\ln \left(2m_e \gamma^2 \beta^2 c^2 \frac{W_{\max}(\beta; m)}{I^2} \right) - 2\beta^2 - \frac{2C(\beta)}{Z} \right) \propto Q^2$$

- Solve for Q:

$$Q = e \cdot \sqrt{\frac{\frac{dE}{dx}_{\text{measured}}}{\frac{dE}{dx}_{\text{calculated}}(\beta; Q=1e)}}$$

$$\Delta Q = \frac{Q}{2} \sqrt{\left(\frac{\Delta \frac{dE}{dx}_{\text{measured}}}{\frac{dE}{dx}_{\text{measured}}} \right)^2 + \left(\frac{\partial \frac{dE}{dx}_{\text{calculated}}}{\partial \beta} \frac{\Delta \beta}{\frac{dE}{dx}_{\text{calculated}}} \right)^2}$$

Charge



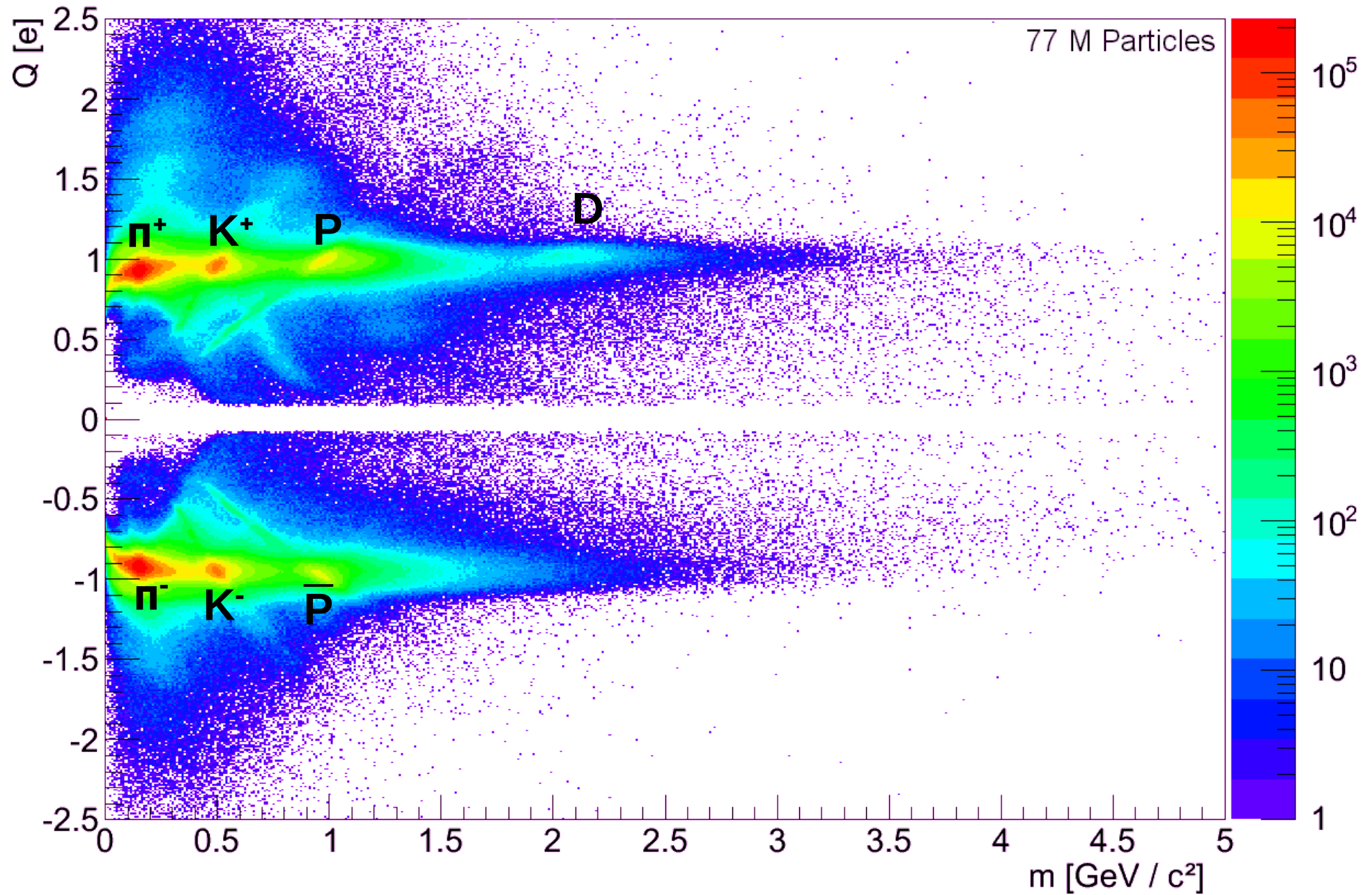
- From special relativity we know:

$$m(p, \beta) = \frac{p}{c} \sqrt{\frac{1}{\beta^2} - 1}$$

- Since we can only measure the ratio $p' \equiv p \cdot \frac{1e}{Q}$:

$$m(p', \beta) = \frac{p'}{c} \cdot \frac{Q}{1e} \cdot \sqrt{\frac{1}{\beta^2} - 1}$$

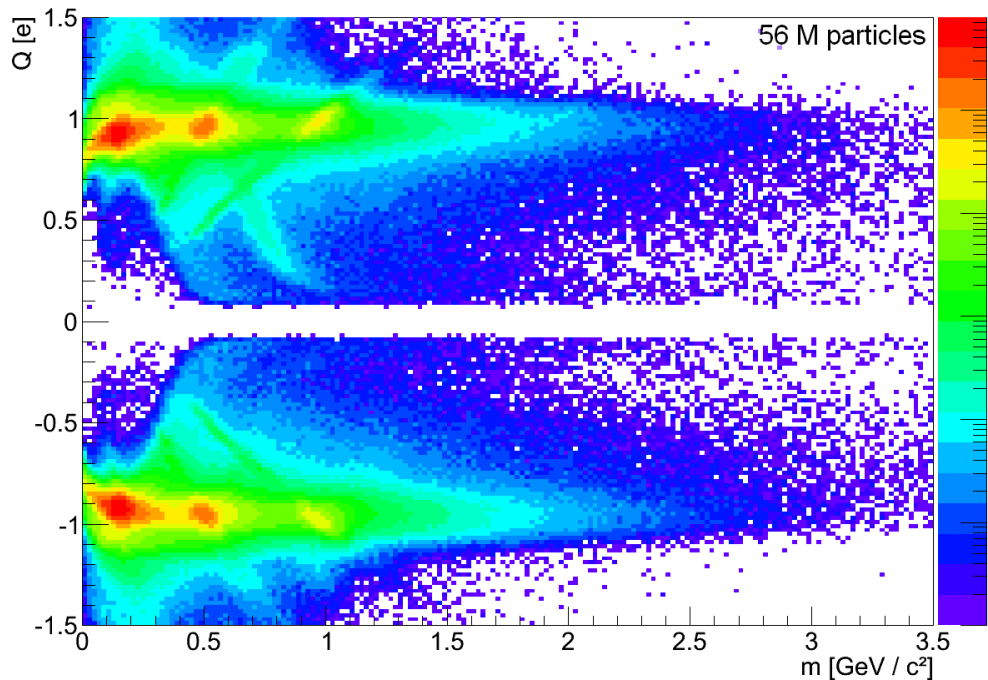
$$\Delta m = m \sqrt{\left(\frac{\Delta p'}{p'}\right)^2 + \left(\frac{\Delta \beta}{\beta} \frac{1}{1-\beta^2}\right)^2 + \left(\frac{\Delta Q}{Q}\right)^2}$$



Vertex Cut

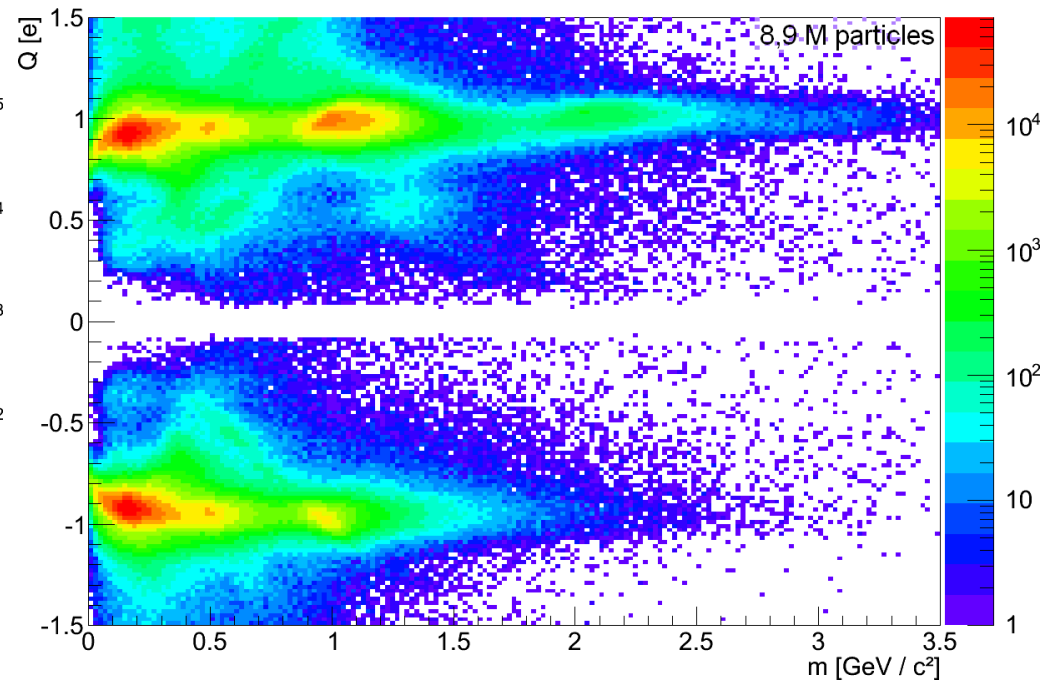
After the cut:

Q vs. m



Ejected:

Q vs. m

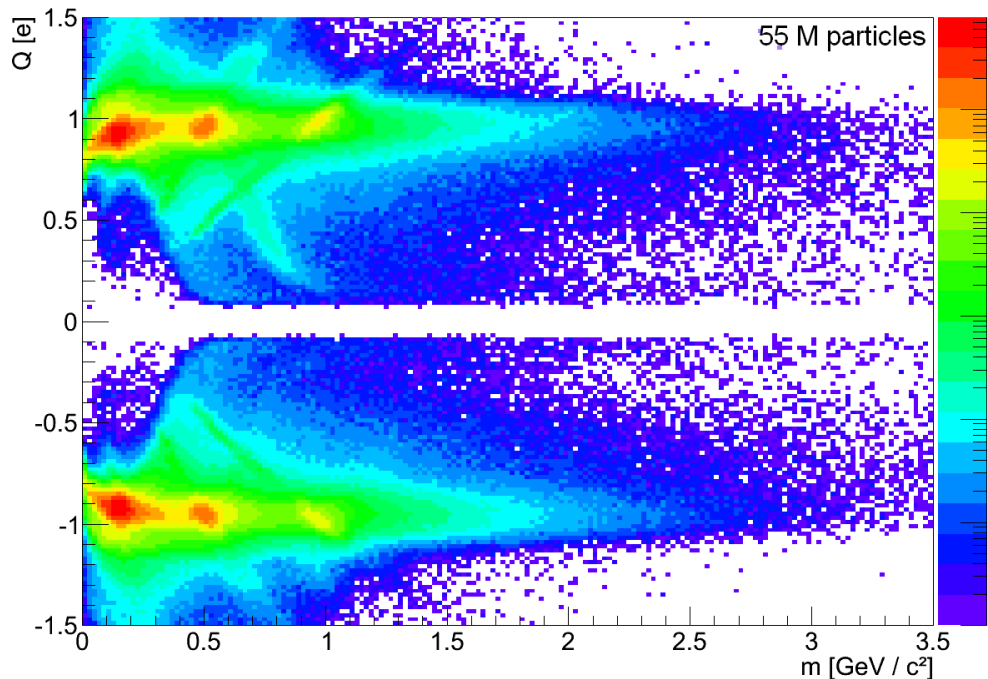


- Reason: Eject particles from beam pipe interaction
- Keeping condition: $dr < 0,15$ mm and $dz < 15$ mm

Muon-Veto

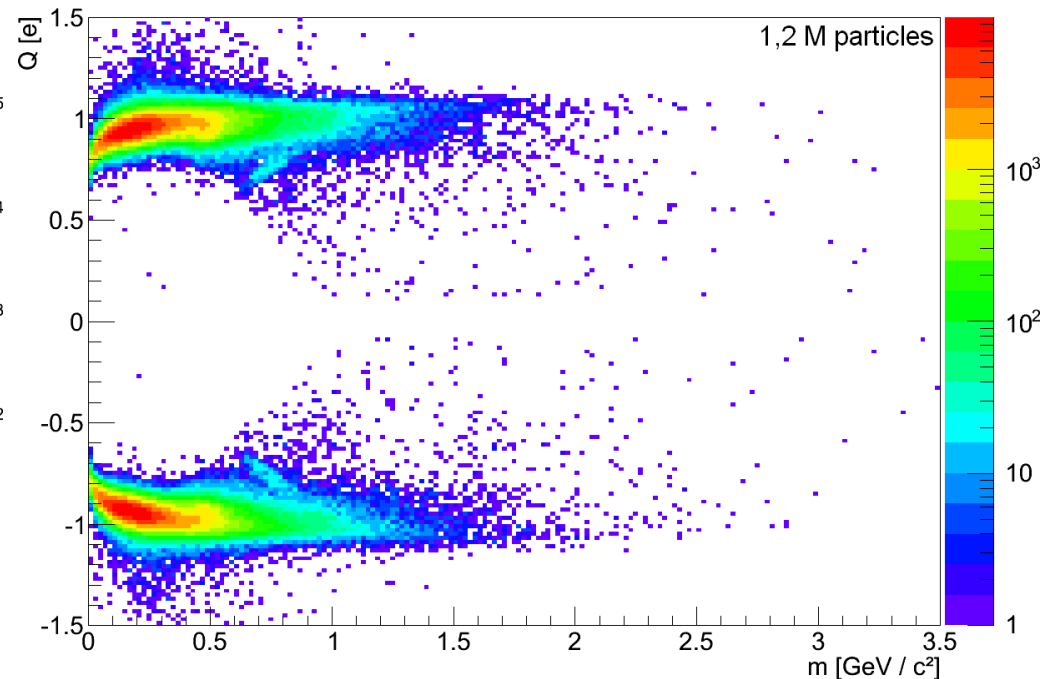
After the cut:

Q vs. m



Ejected:

Q vs. m

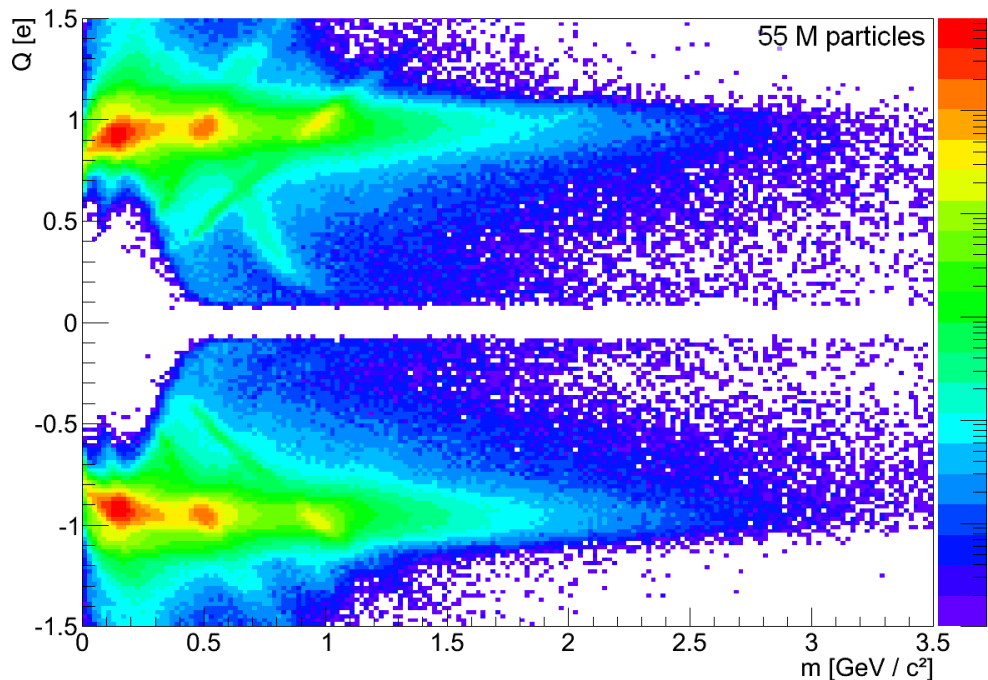


- Reason: Eject muons very cleanly
- Keeping condition: No correlated hit in the KLM-detector

Momentum Cut

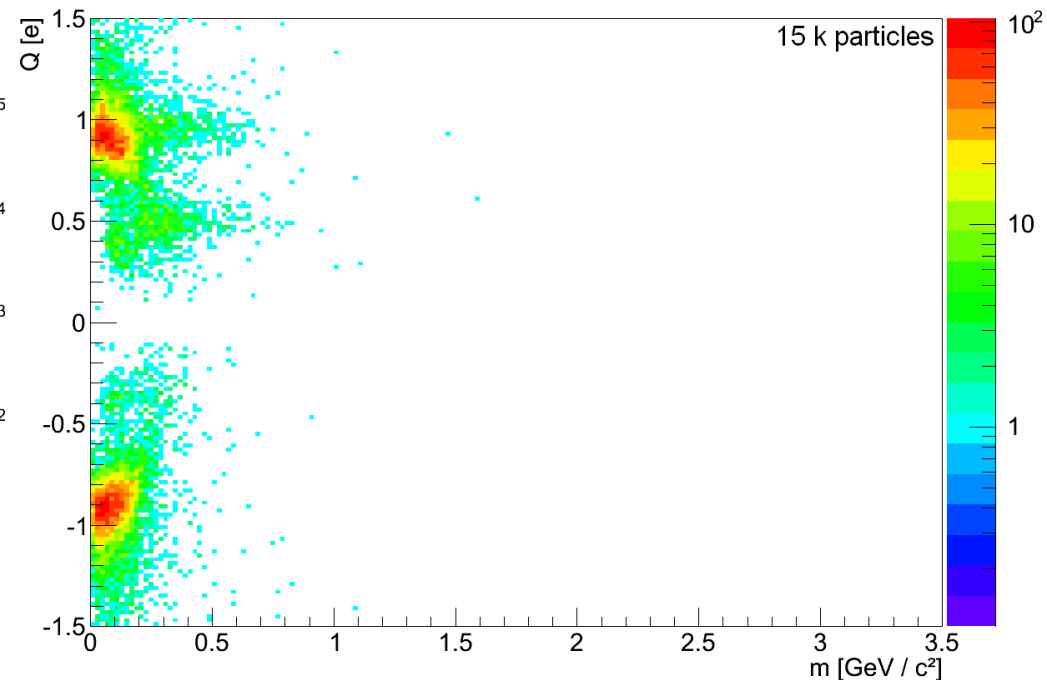
After the cut:

Q vs. m



Ejected:

Q vs. m

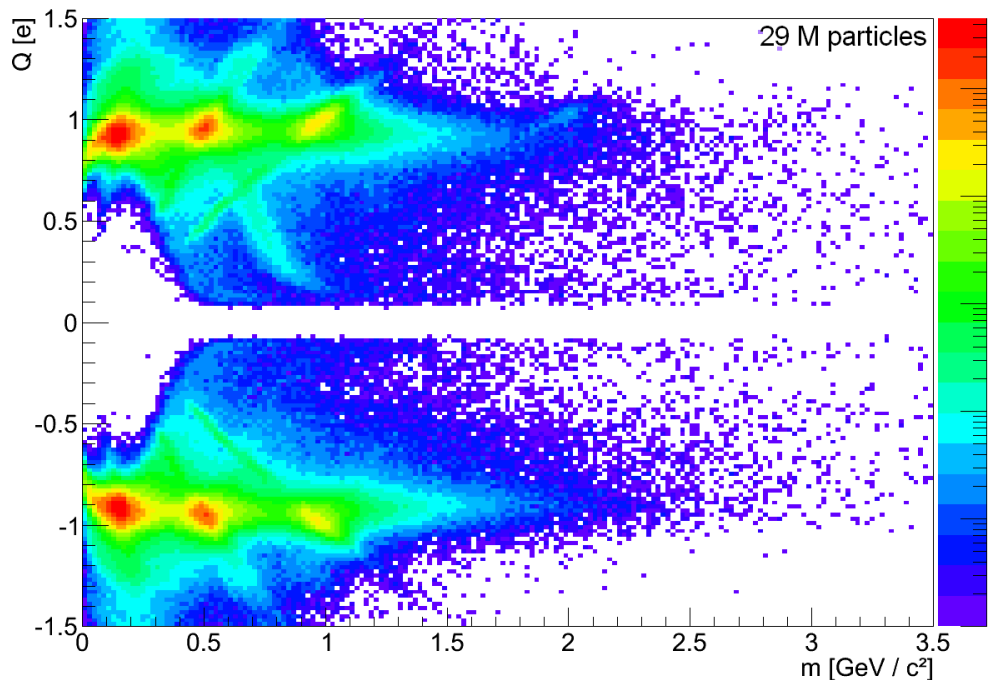


- Reason: Particles with too small p' can't hit the TOF
- Keeping condition: $p_{\text{lab}} > 0,3 \frac{\text{GeV}}{c}$

Cherenkov-Veto

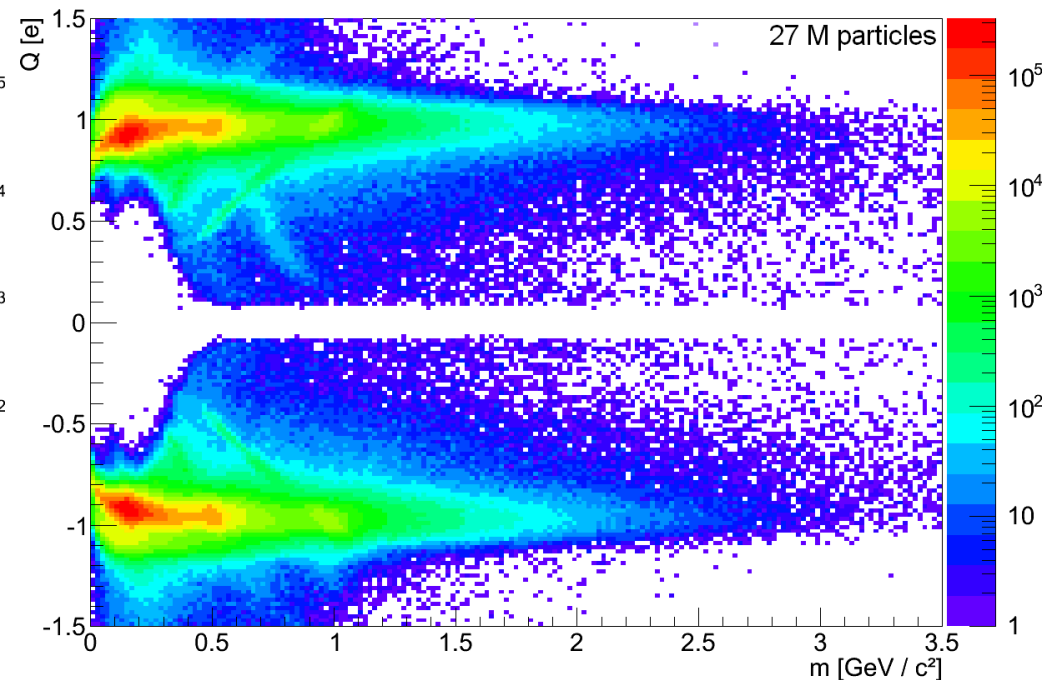
After the cut:

Q vs. m



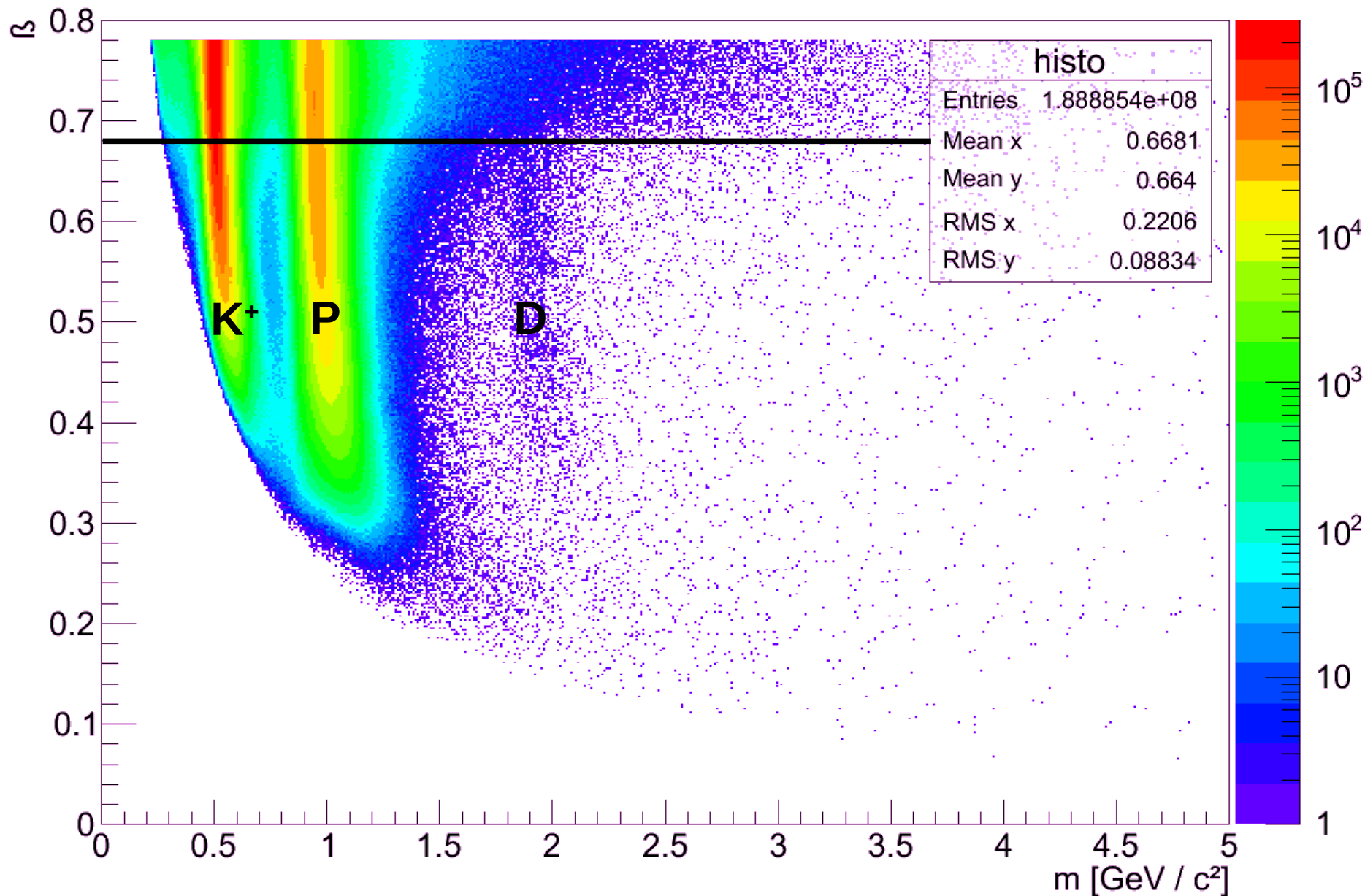
Ejected:

Q vs. m



- Reason: Particles with Cherenkov radiation are too fast
- Keeping condition: No correlated signal in the Cherenkov-detector

β vs. m



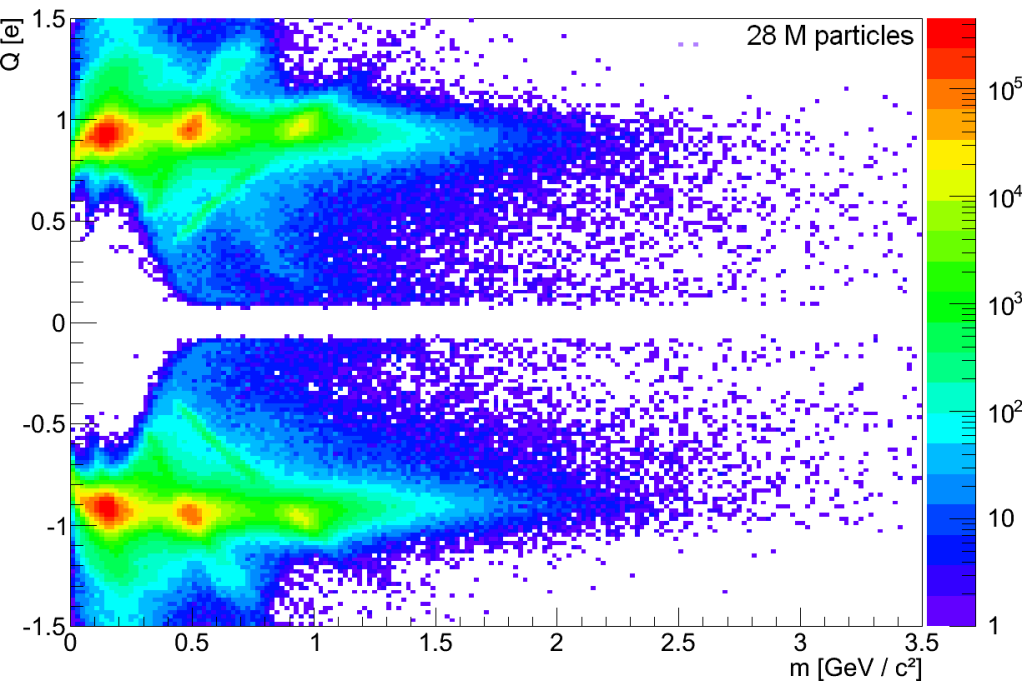
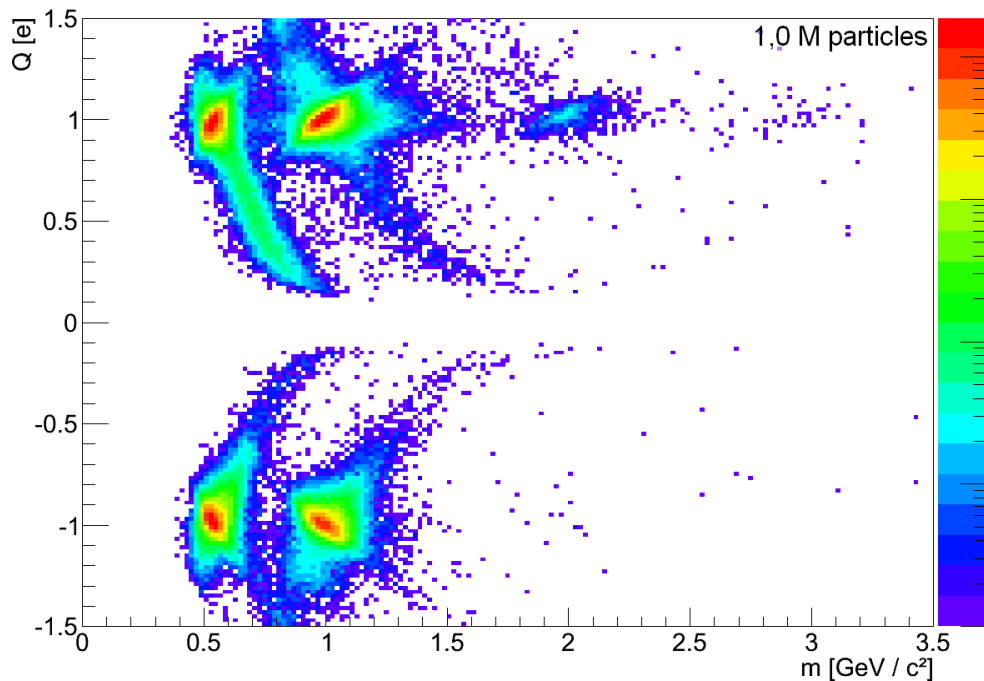
$\frac{dE}{dx} - \beta$ -Cut

After the cut:

Q vs. m

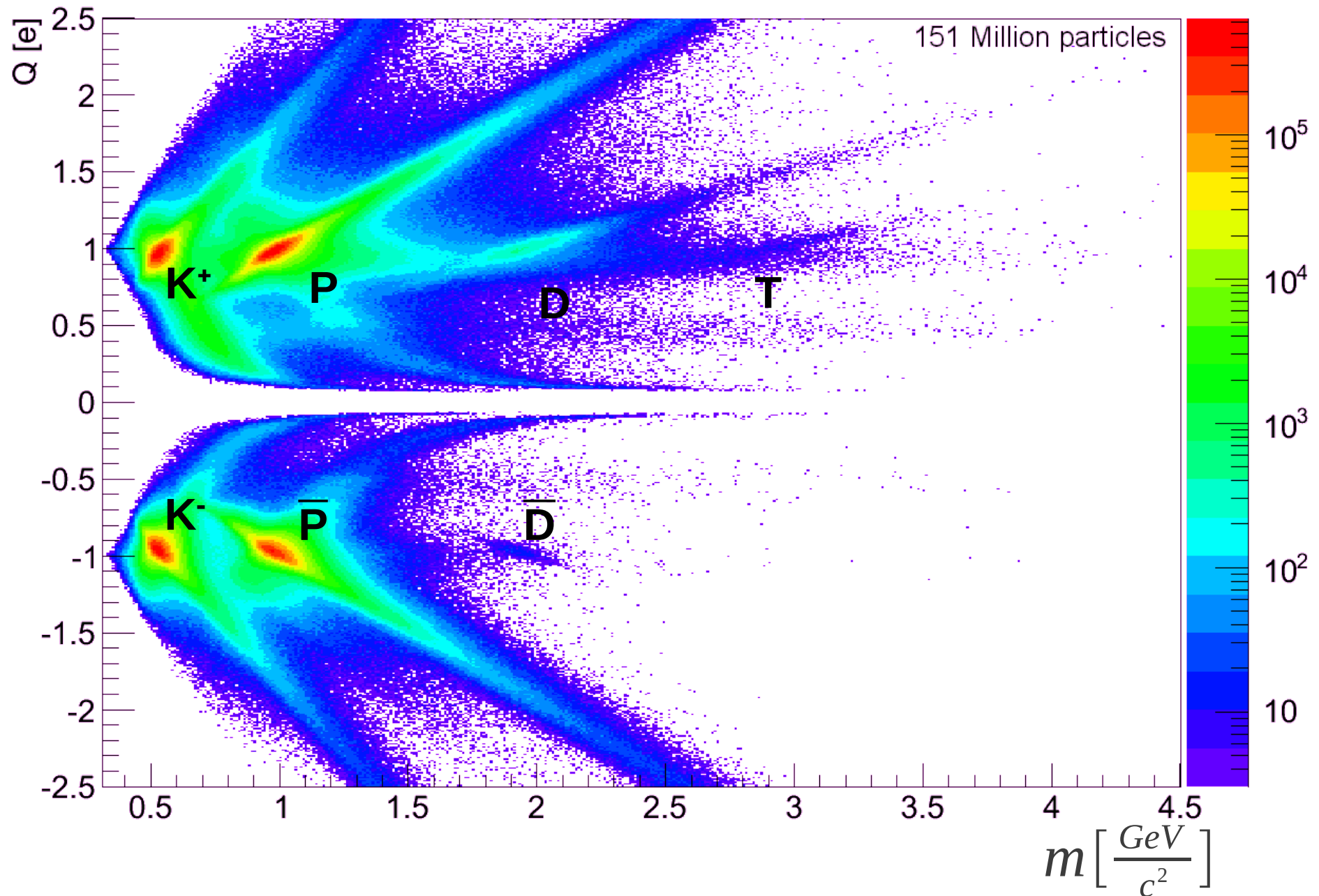
Ejected:

Q vs. m



- Reason: Fast particles have a large error
- Keeping condition: $\beta < 0,68$ and $\frac{dE}{dx} > 1,85 \frac{keV}{cm}$

Q vs. m (All Data)



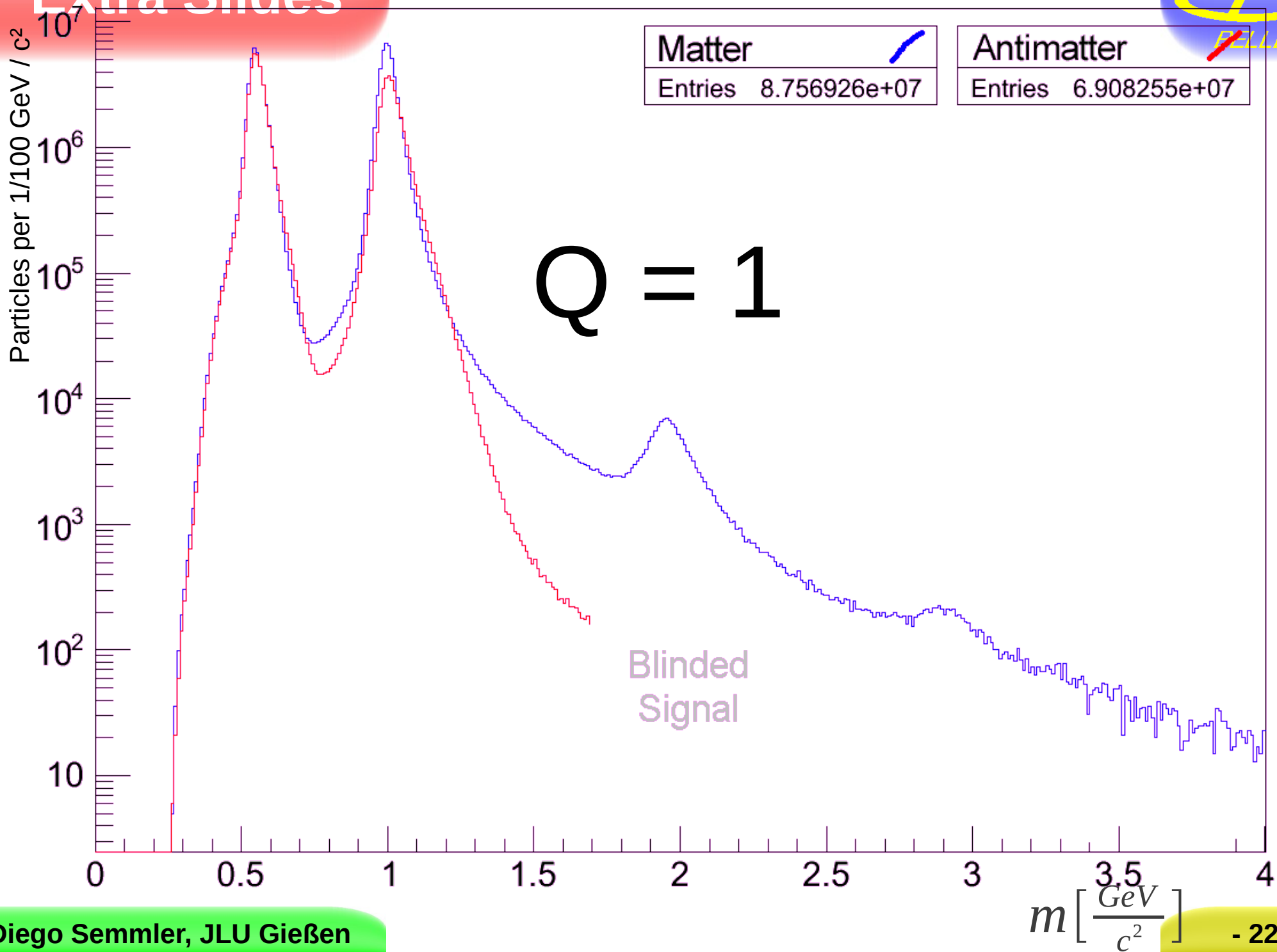
- The basic method works for pions, kaons and protons very well.
- Anti-deuterons are so rare, that additional cuts are necessary.
- These cuts can identify deuterons with low background.
- To be done:
 - Determine branching fractions
 - Momentum distributions
 - Further background reduction for anti-tritium and anti-helium if possible
- Belle II will have a factor 50 higher statistics

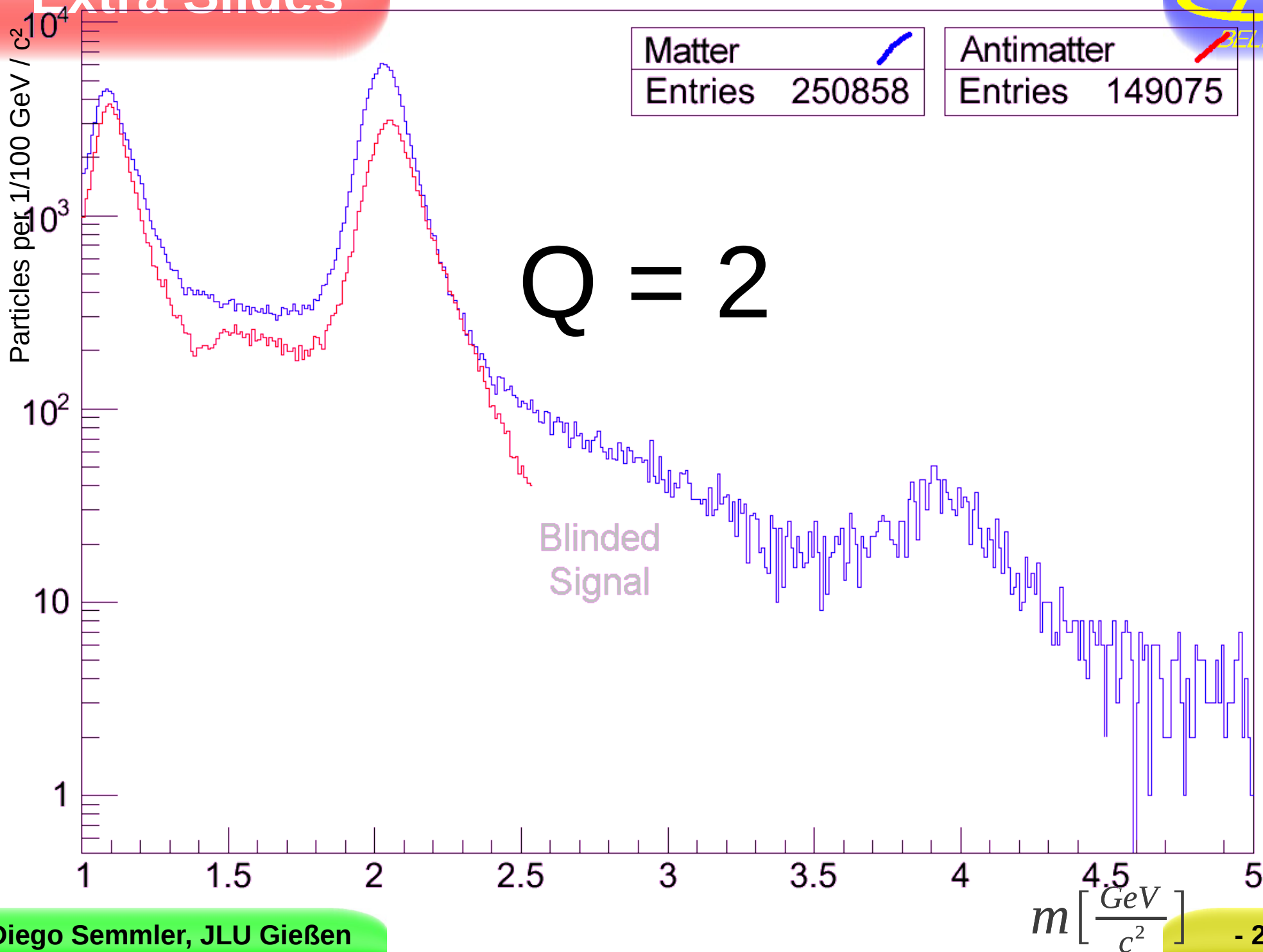
Thanks for your attention

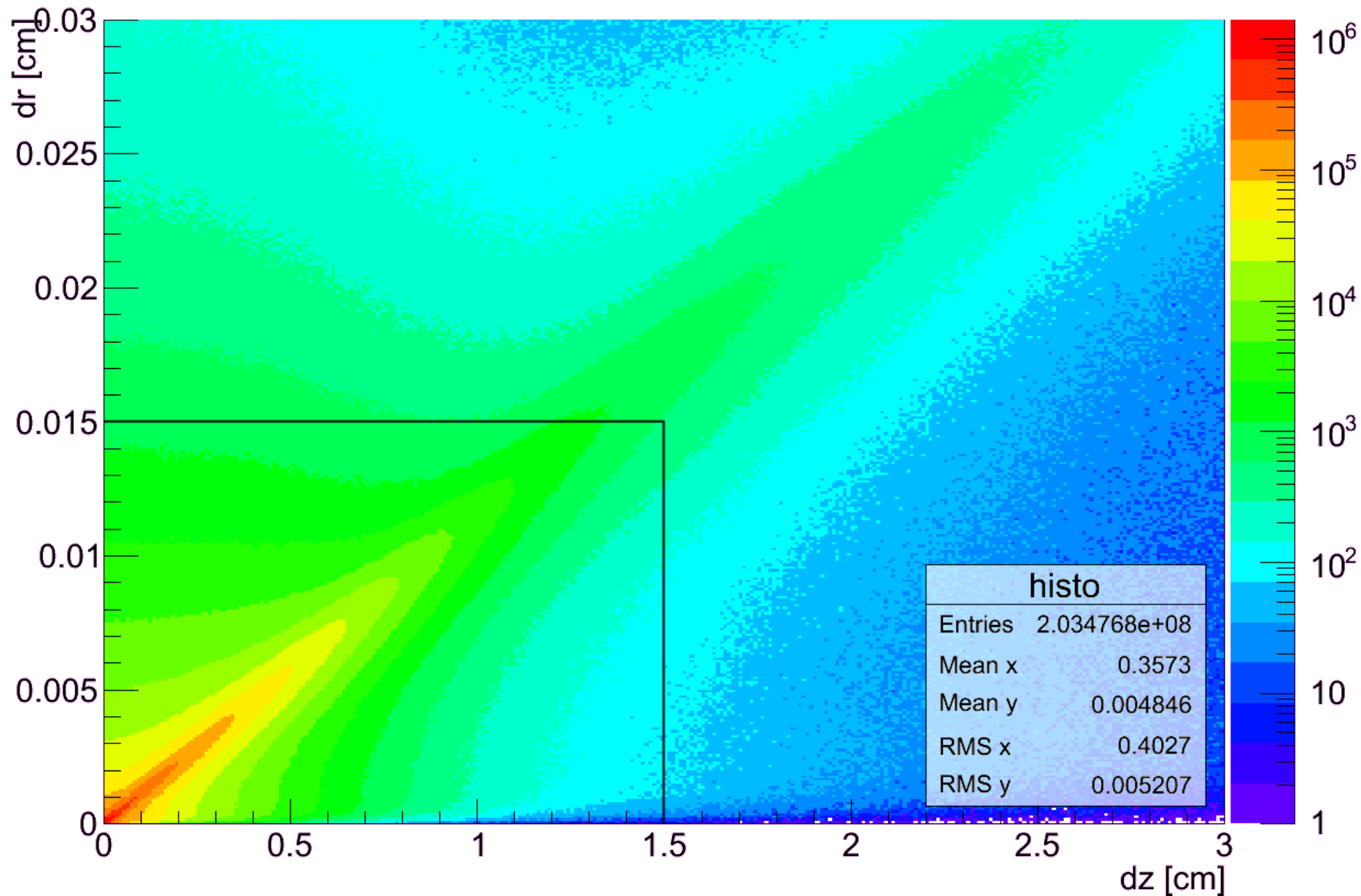
Also thanks to the organizers for giving me a platform to present this talk and to my work group, especially Milan Wagner and Sören Lange for supporting me.



- Formulas: Q M
- General plots: P_{Lab} $-dEdx$ $QMexp7$
- Cuts: Vertex Muon Momentum
Cherenkov β vs. m Beta
- Result plots: QM $Q1$ $Q2$ Loose
- Vertex plots: Vertex β - $dEdx$ Detail
- Energy plots: Gamma1 Gamma2 Energy
Energy vs. m
- More plots: β - $dEdx$ dE/dx vs. m
- Other Cut order: Beta Vertex Momentum
Muon Cherenkov

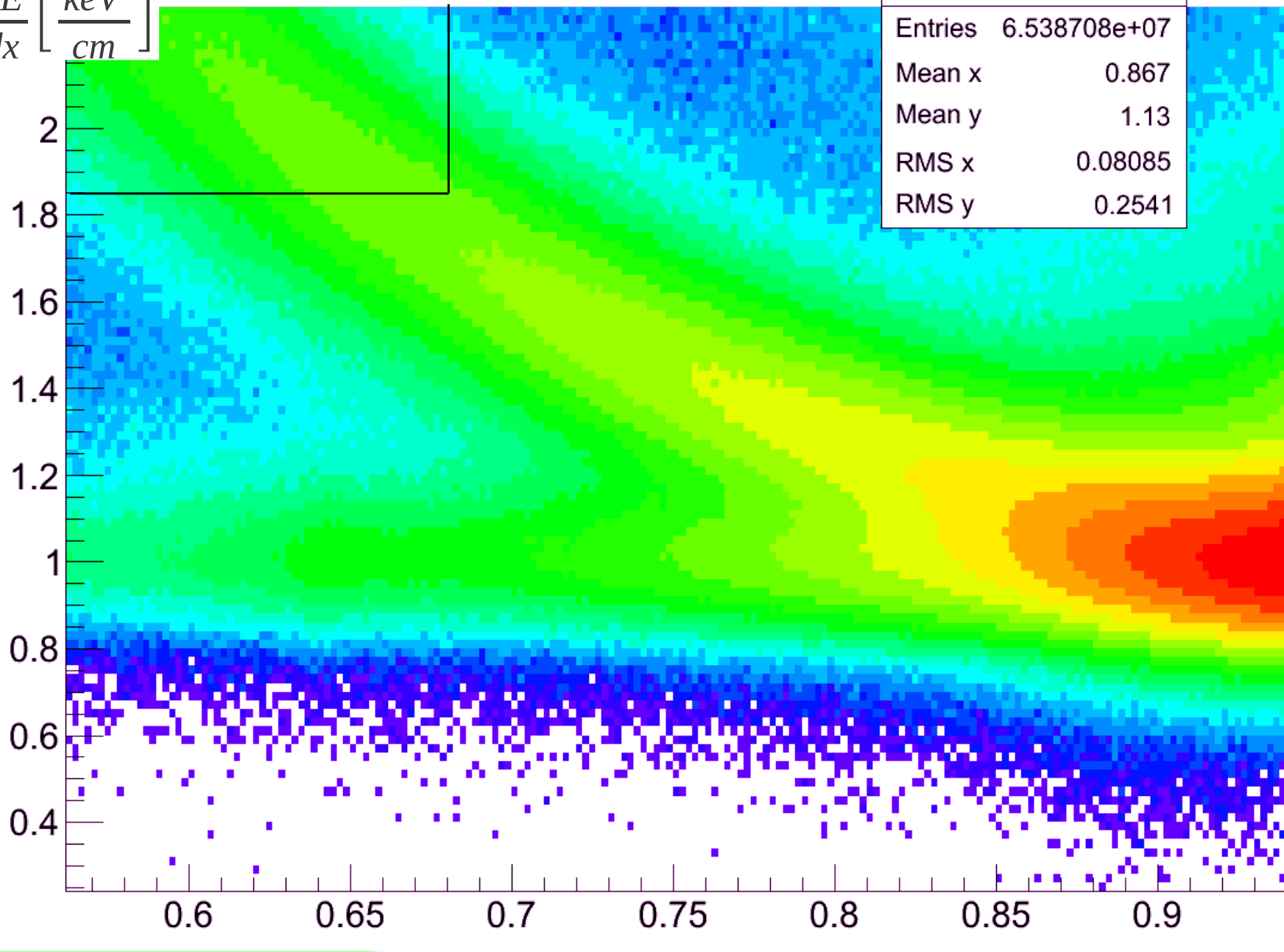






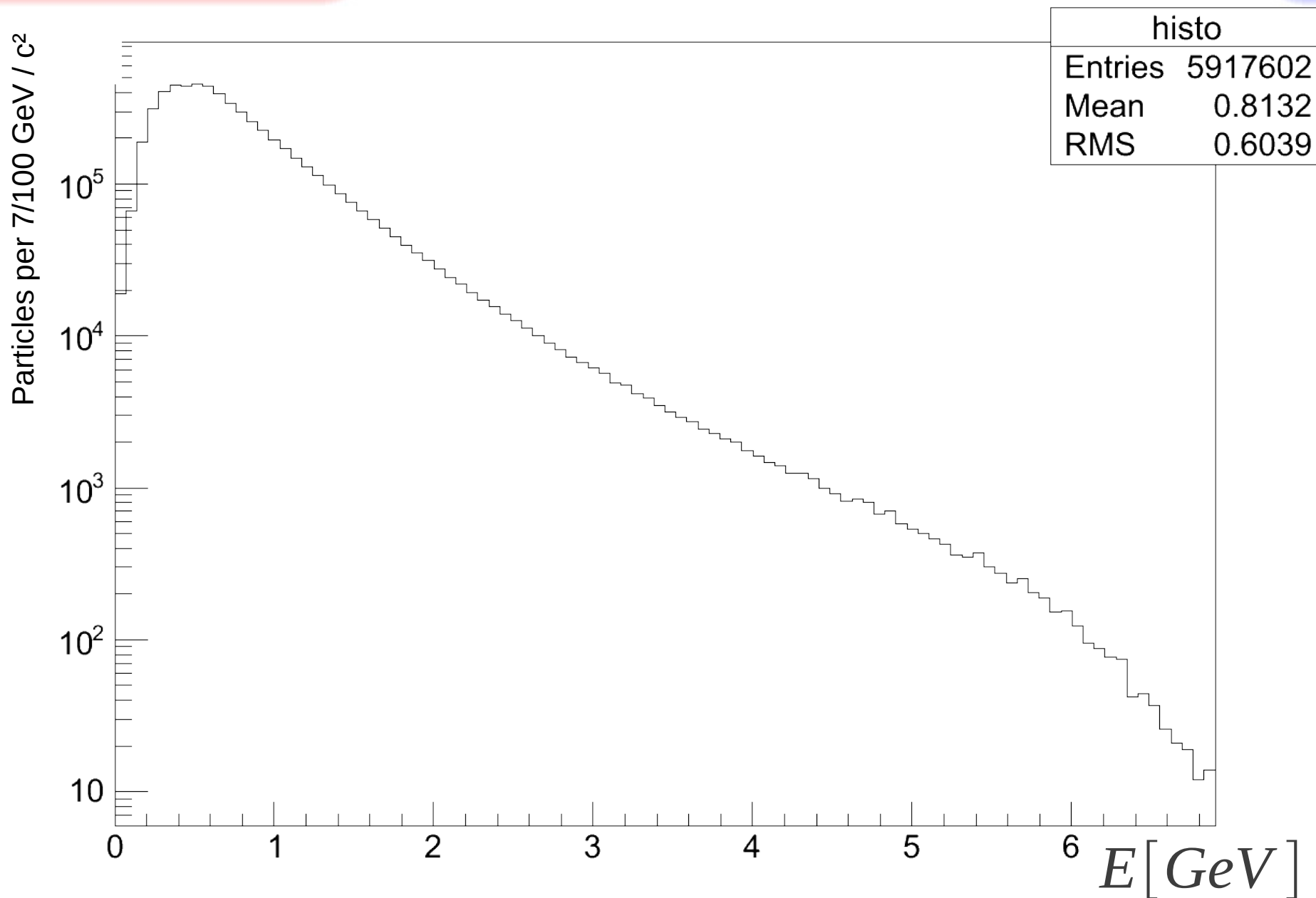
beta vs. dE/dx

$$\frac{dE}{dx} \left[\frac{\text{keV}}{\text{cm}} \right]$$

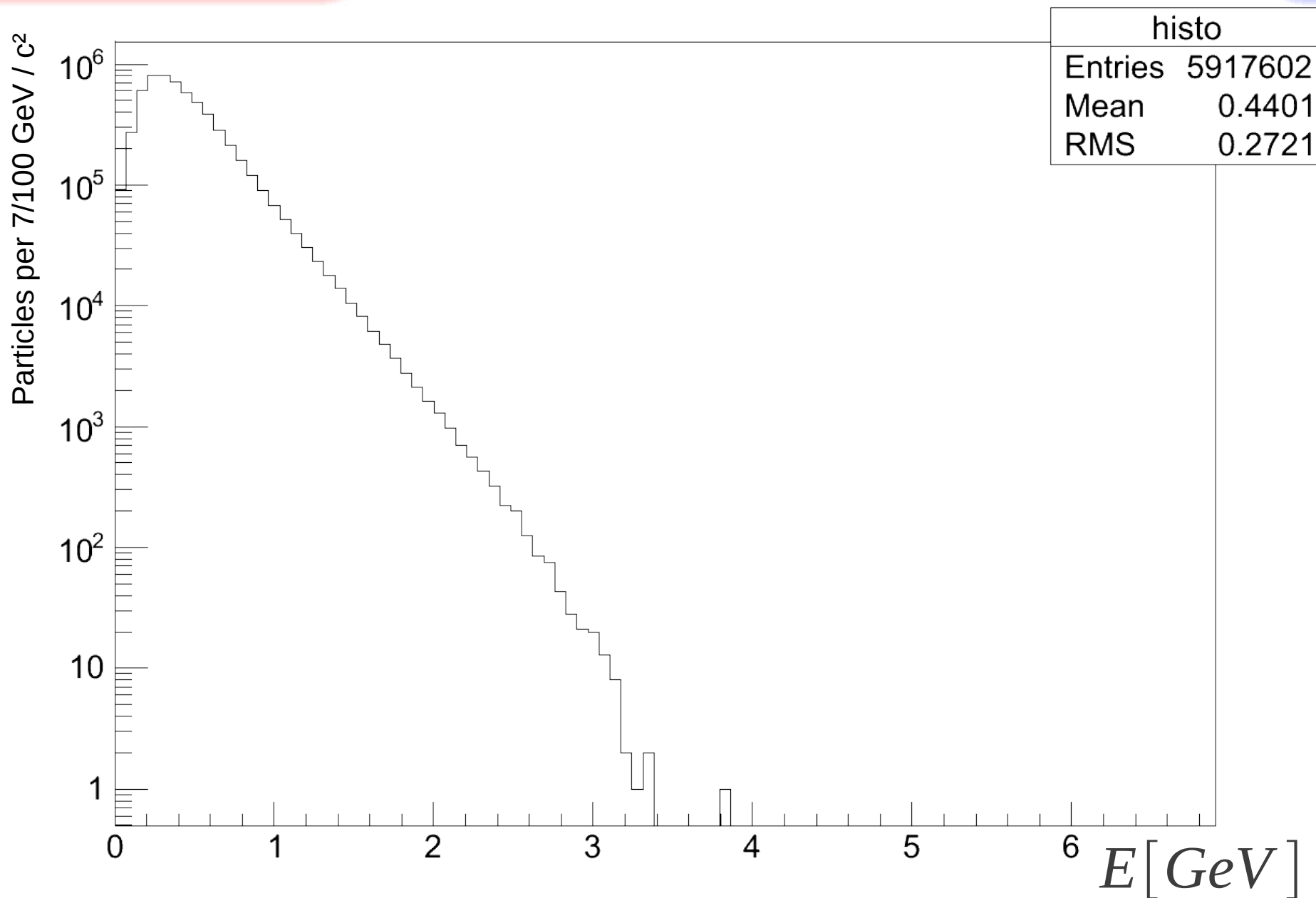


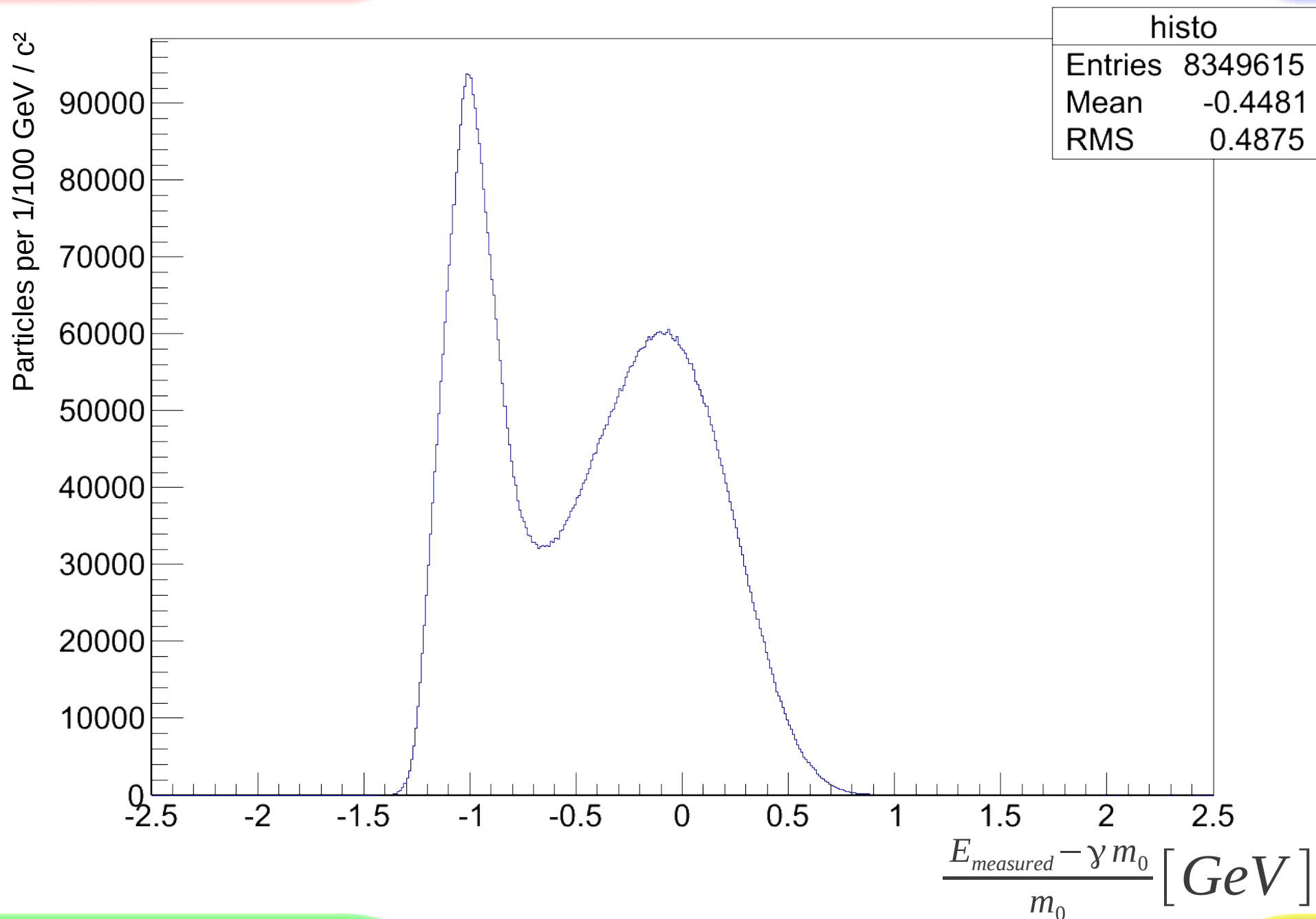
histo	
Entries	6.538708e+07
Mean x	0.867
Mean y	1.13
RMS x	0.08085
RMS y	0.2541

Gamma1 {Q>-1.1 && Q<-0.85 && m>0.9 && m<1.05 && Equality == 2 && Multi == 1}

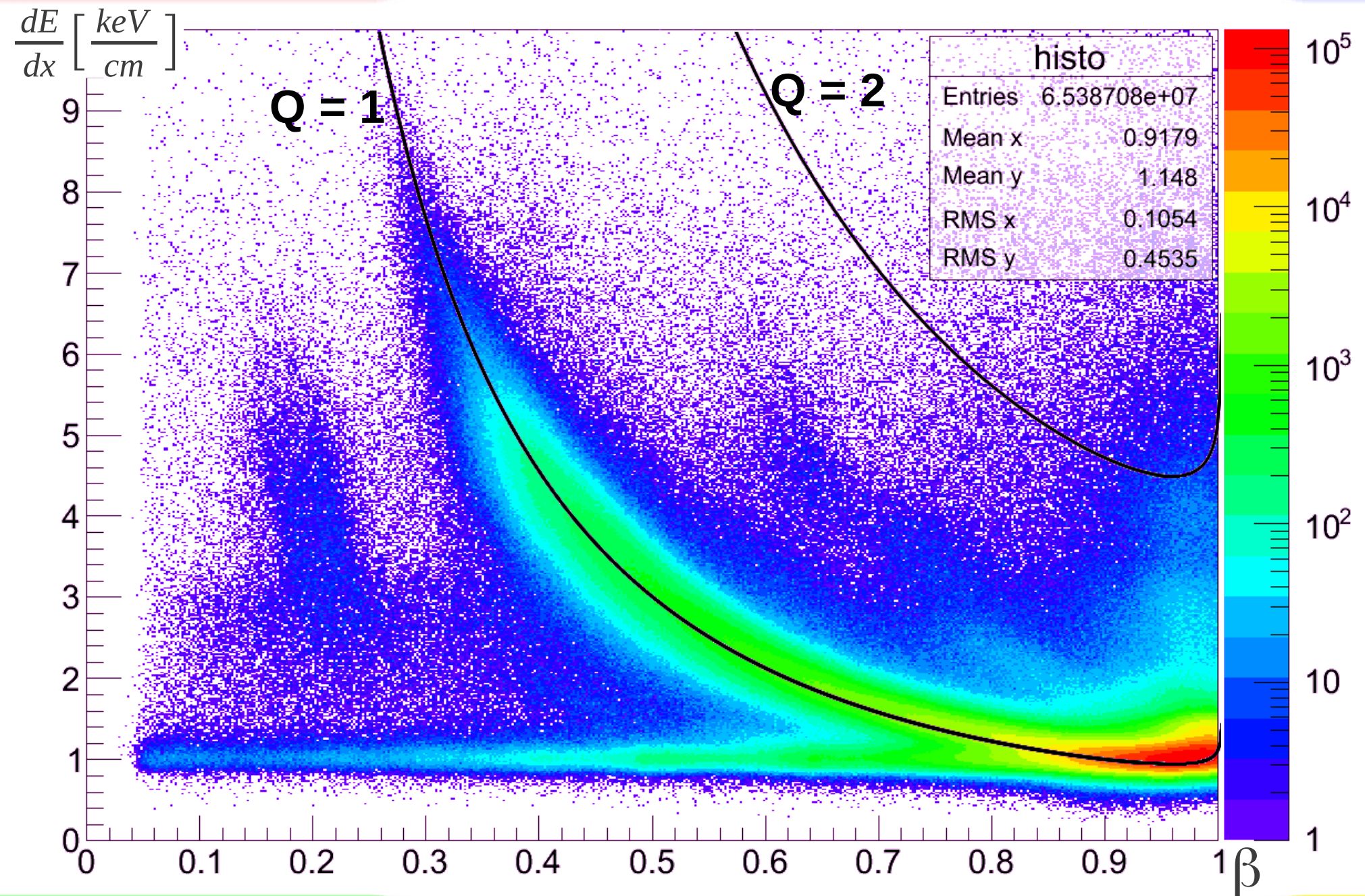


$\text{Gamma2} \{Q > -1.1 \ \&\& \ Q < -0.85 \ \&\& \ m > 0.9 \ \&\& \ m < 1.05 \ \&\& \ \text{Equality} == 2 \ \&\& \ \text{Multi} == 1\}$



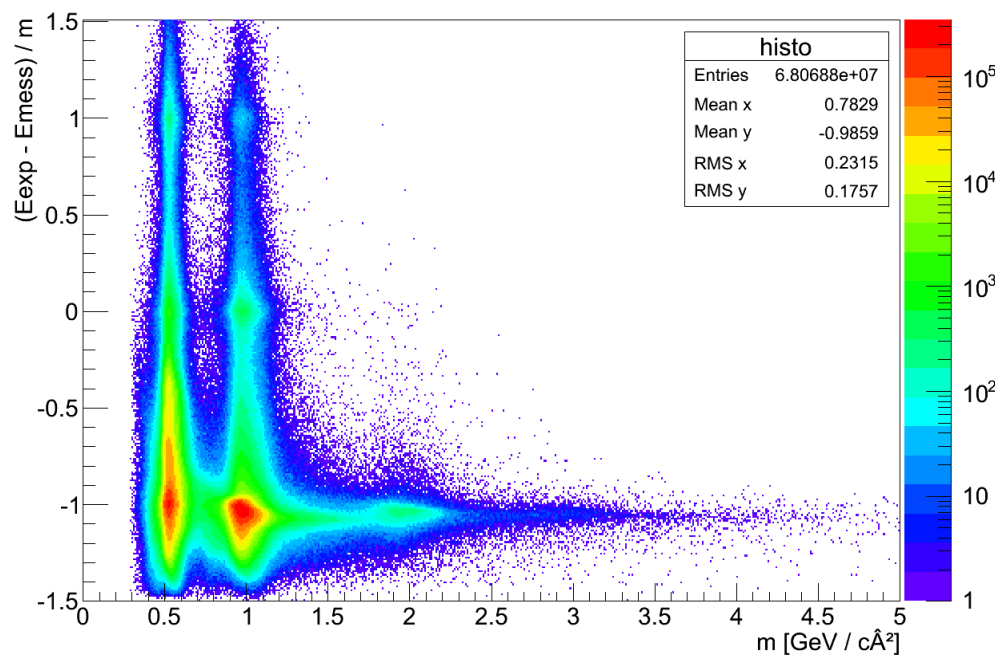


beta vs. dE/dx



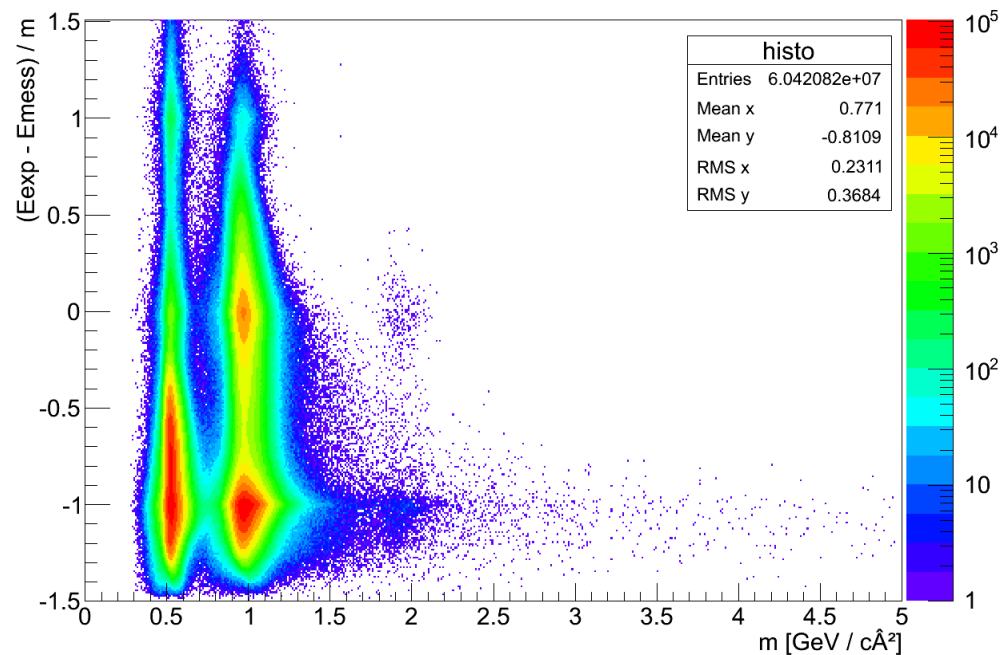
Matter

Expected - Measured Energy vs. Mass



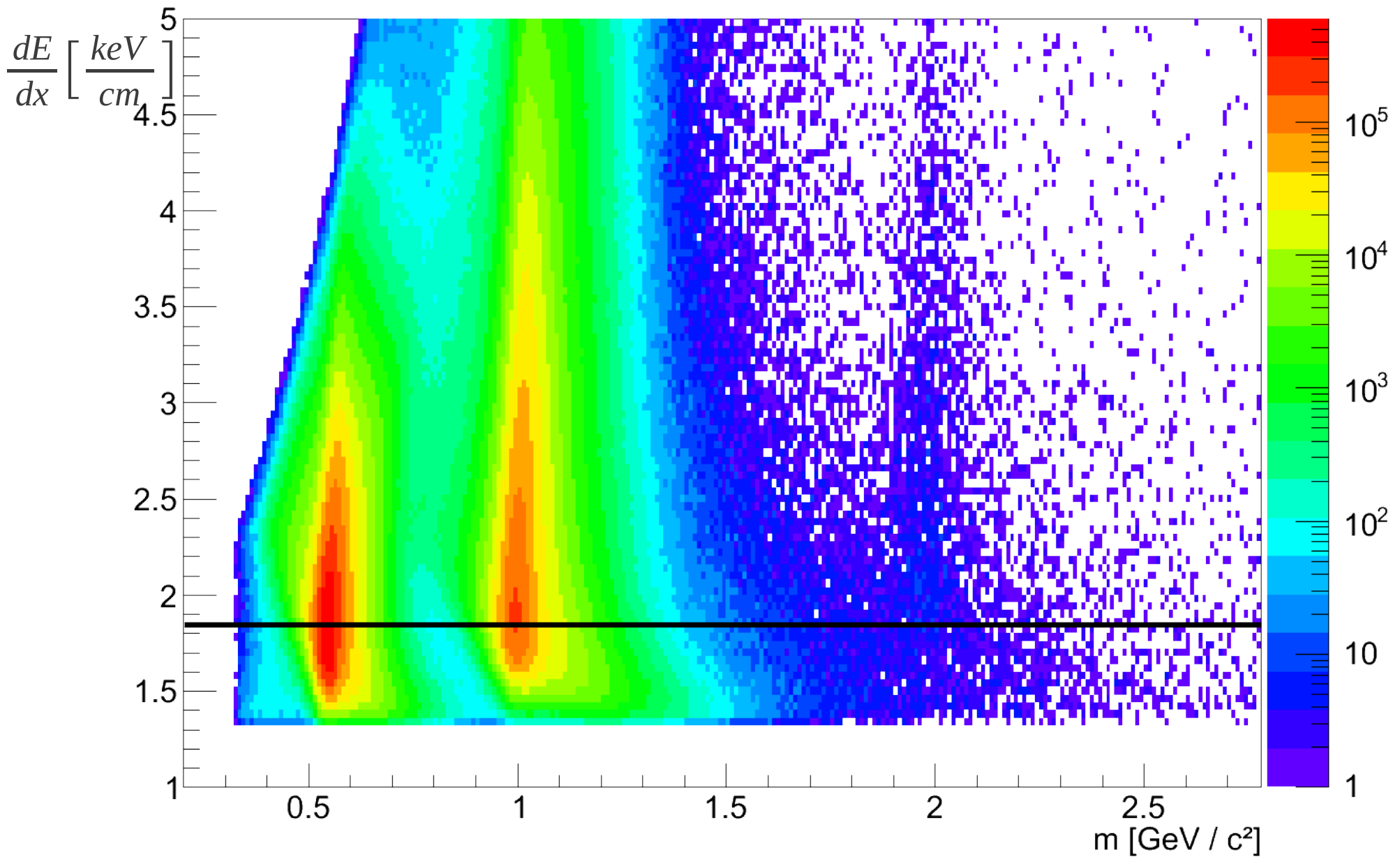
Antimatter

Expected - Measured Energy vs. Mass

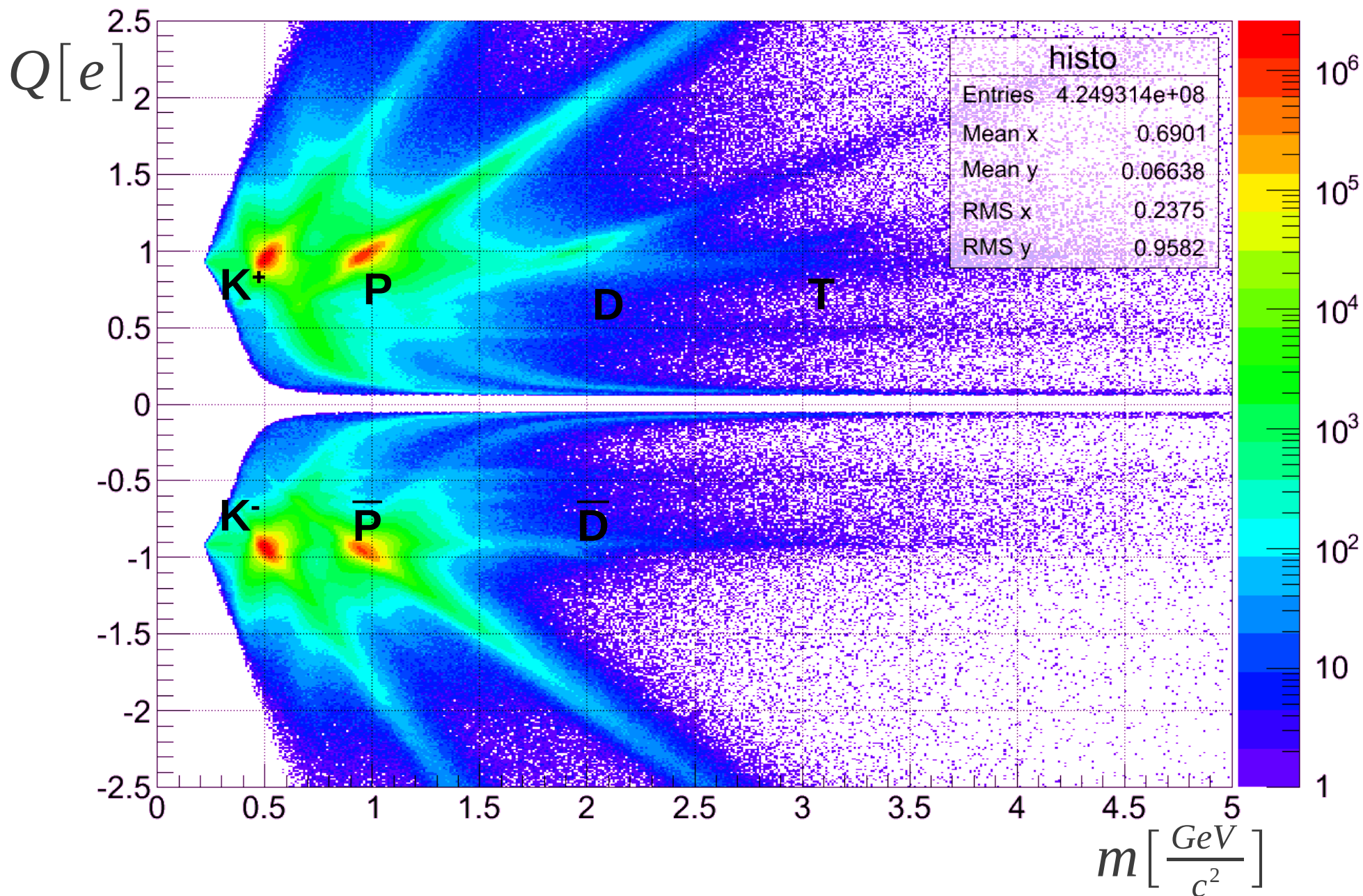


Peaks are artificially generated.

dEdx vs. m



Q vs. M



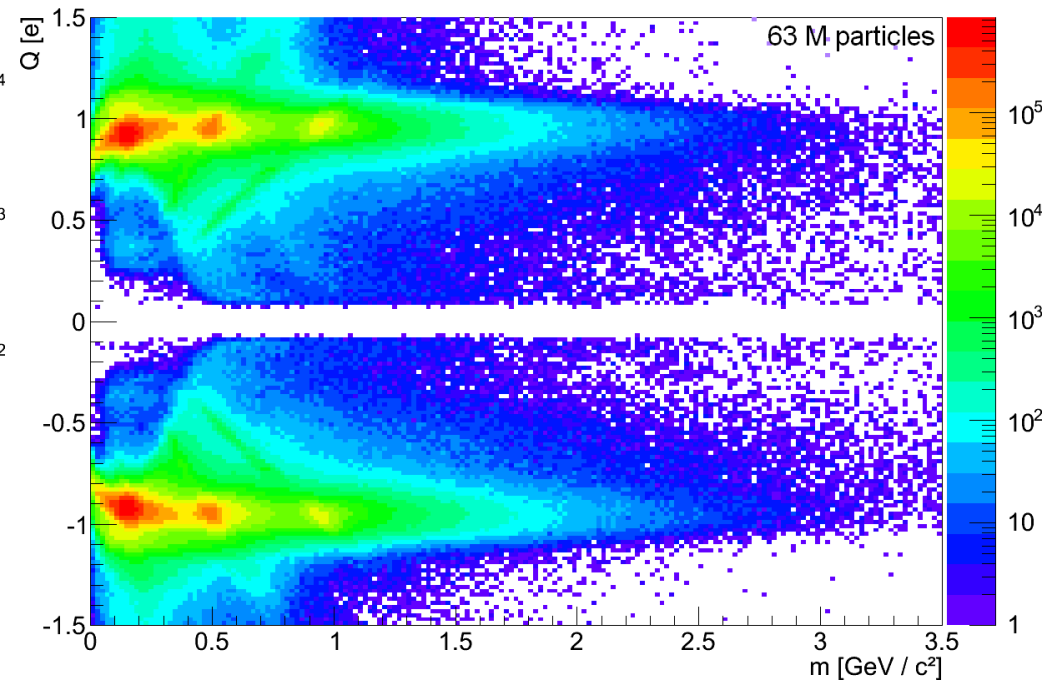
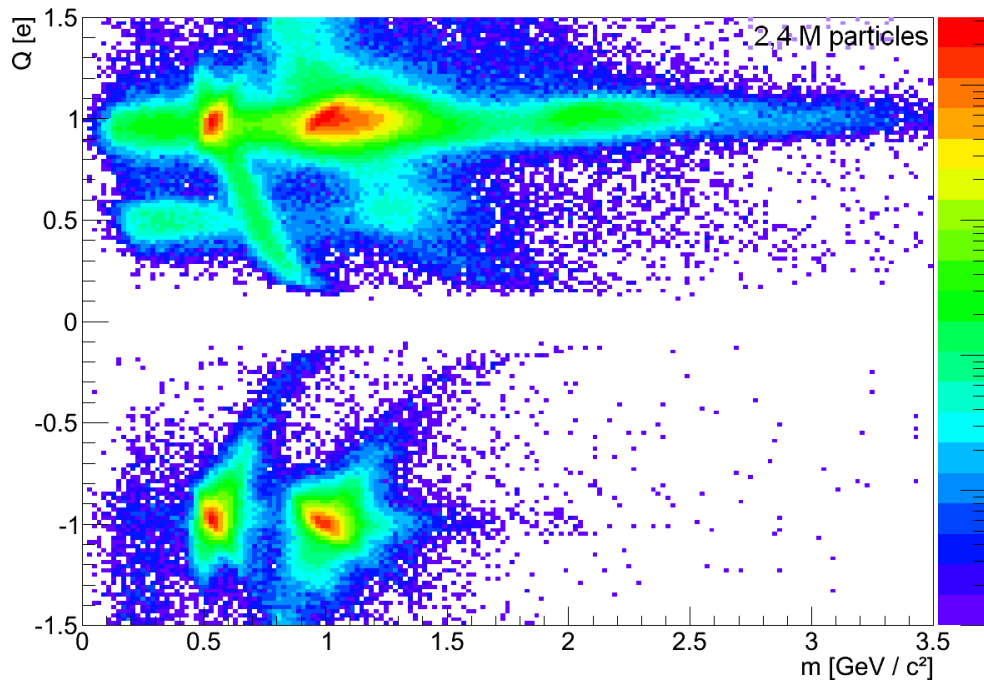
$\frac{dE}{dx} - \beta$ -Cut

After the cut:

Q vs. m

Ejected:

Q vs. m

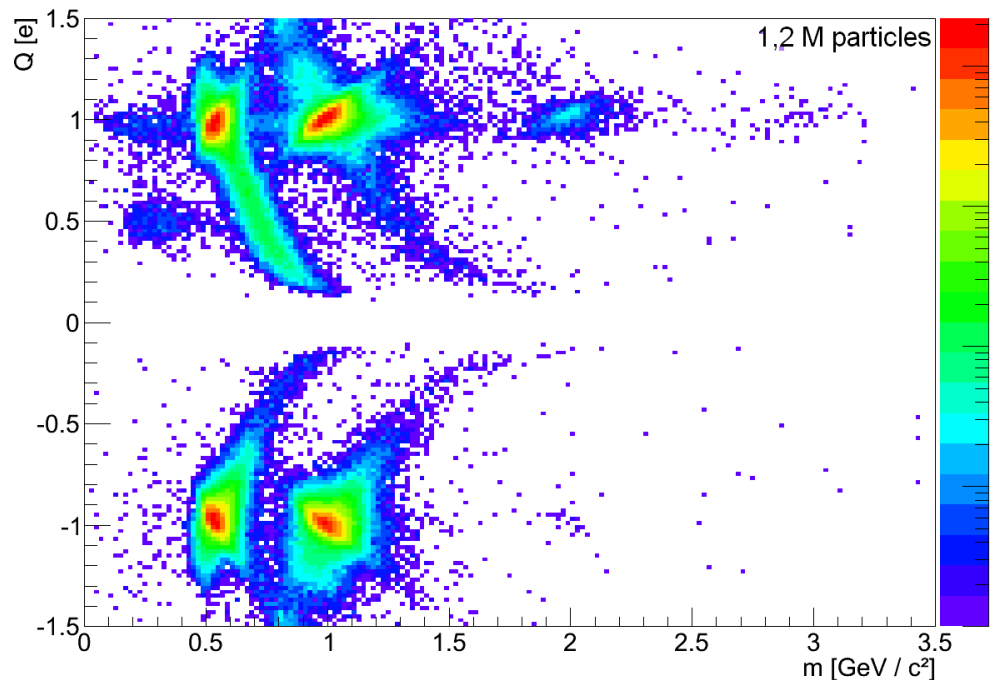


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Vertex Cut

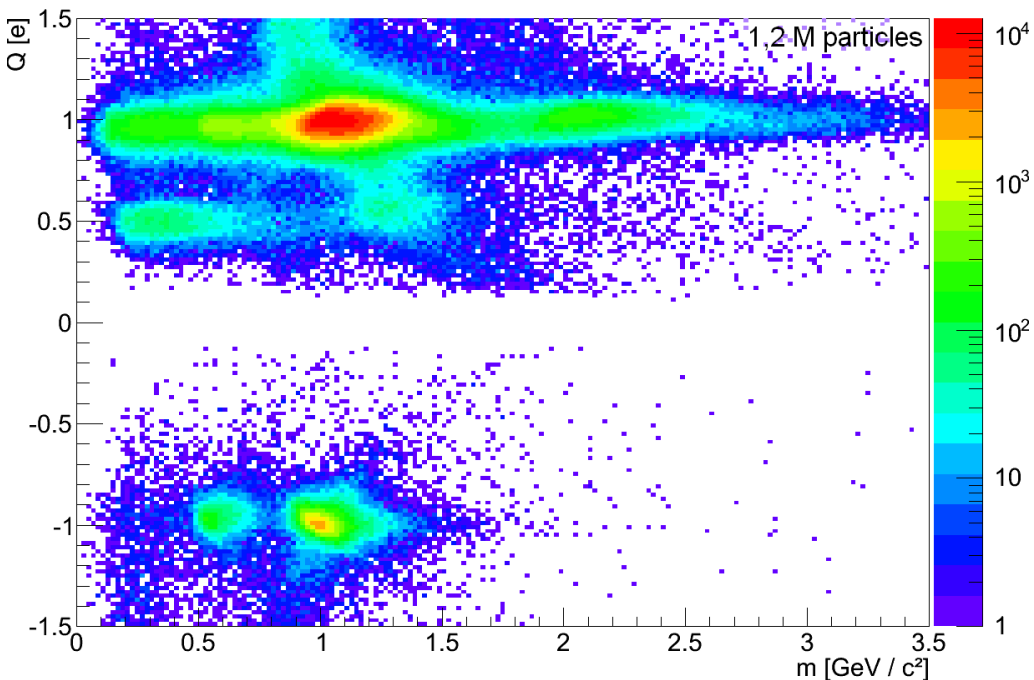
After the cut:

Q vs. m



Ejected:

Q vs. m

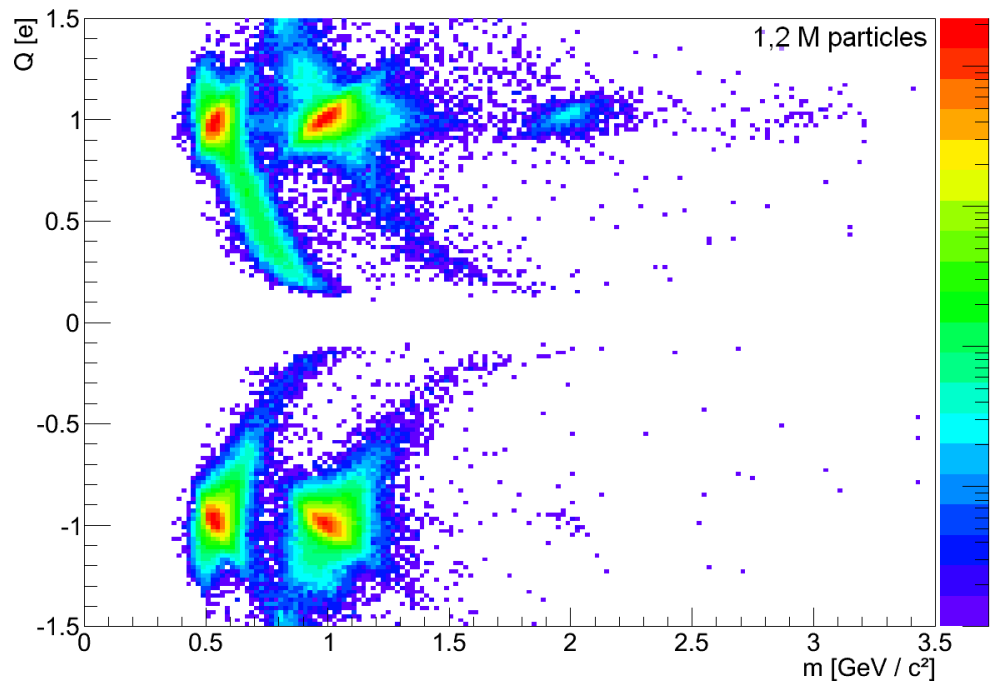


- Reason: Sort out particles from beam pipe interaction
- Keeping Condition: $dr < 0,15$ mm and $dz < 15$ mm

Momentum Cut

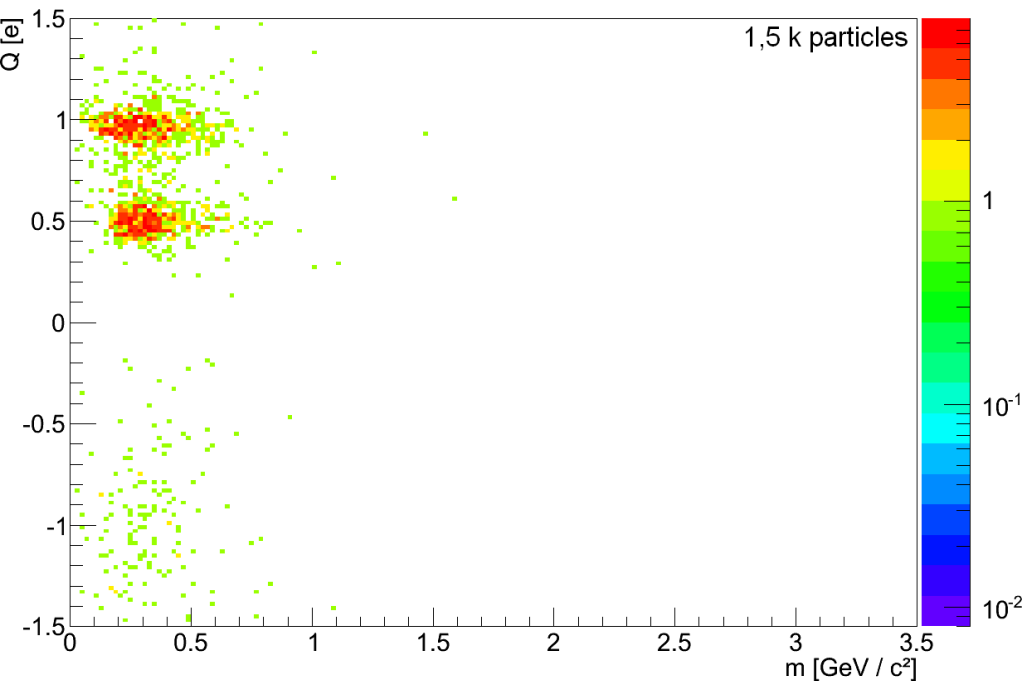
After the cut:

Q vs. m



Ejected:

Q vs. m

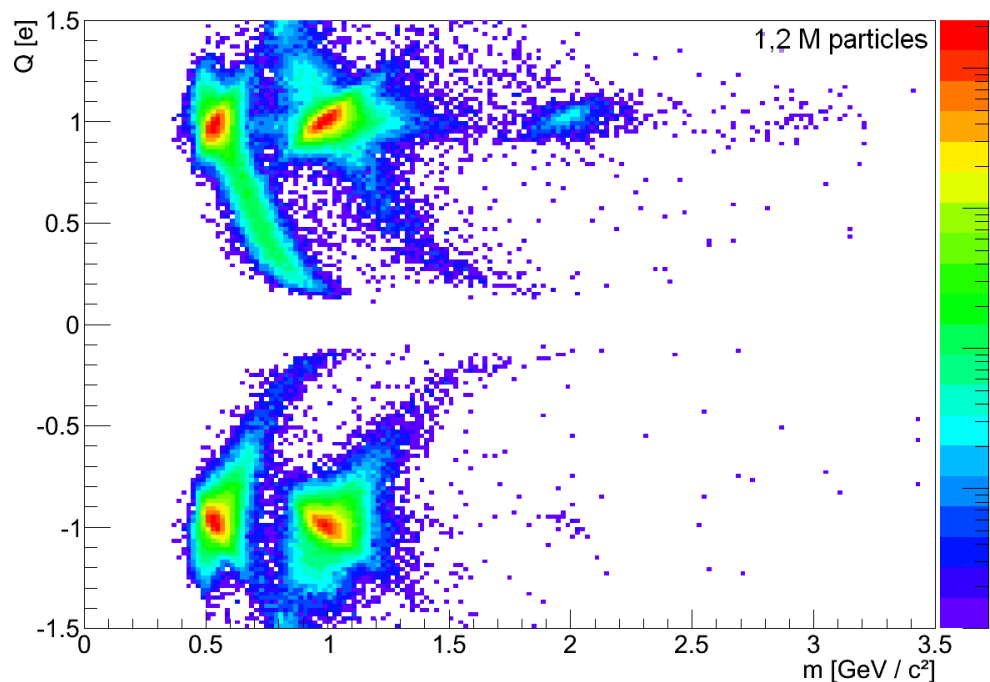


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- Keeping Condition: $p_{\text{lab}} > 0,3 \frac{\text{GeV}}{c}$

Muon-Veto

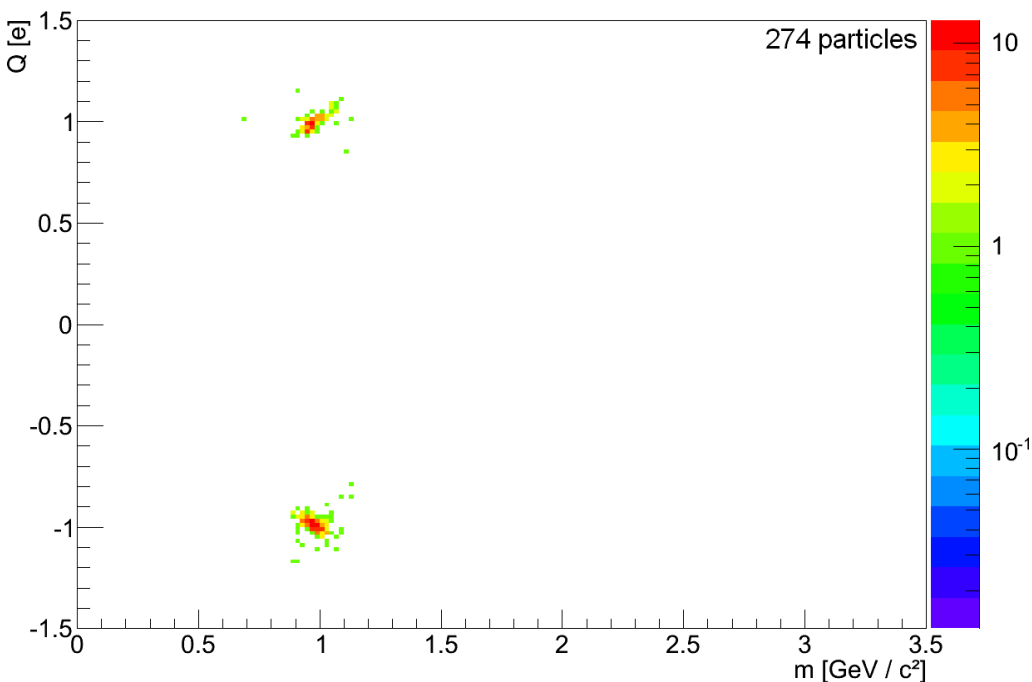
After the cut:

Q vs. m



Ejected:

Q vs. m

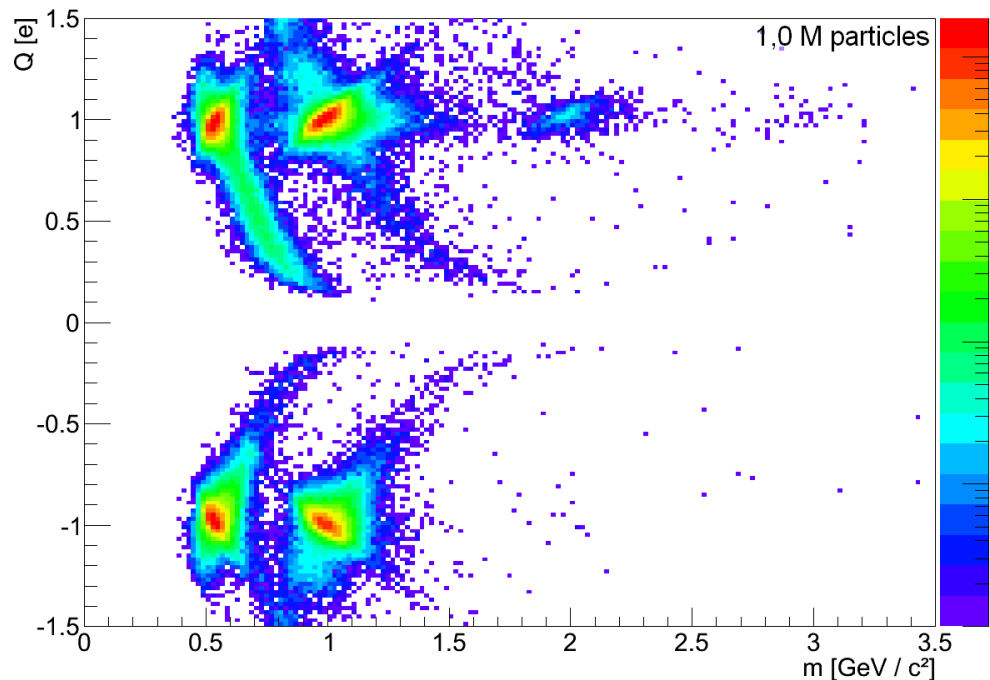


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Cherenkov-Veto

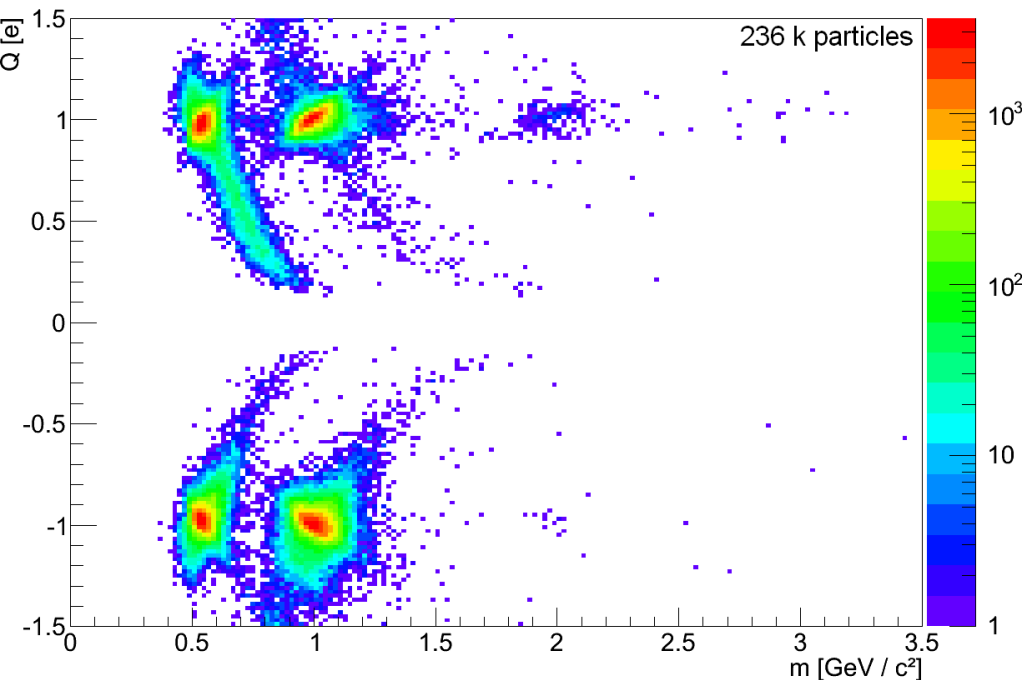
After the cut:

Q vs. m



Ejected:

Q vs. m



- Reason: Particles with Cherenkov radiation are too fast
- Keeping Condition: No signal in the Cherenkov-Detector

End

