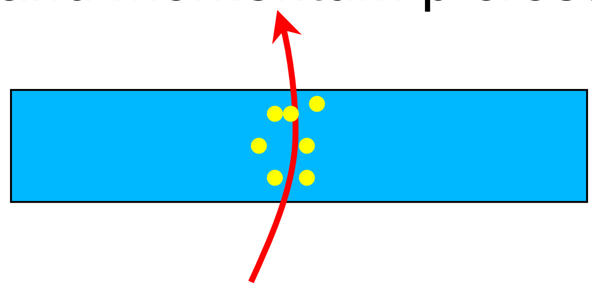
TPC Gain Calibration and Particle Identification

Alexander Kalweit (TU + GSI Darmstadt)
Marian Ivanov (GSI Darmstadt)

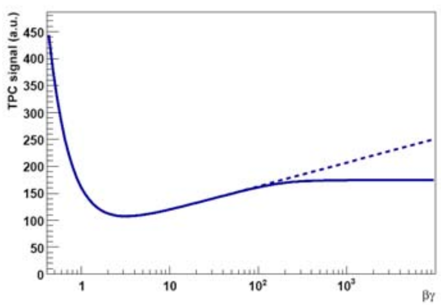
A.Kalweit@gsi.de

Basics I: Bethe-Bloch

- particle with mass m and momentum p crosses a thin gas cell

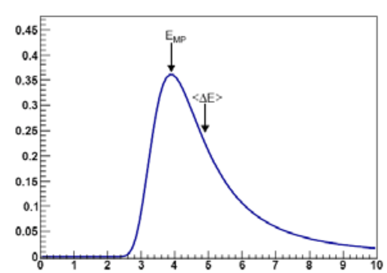


- specific energy loss due to ionisation → primary (cluster) charge



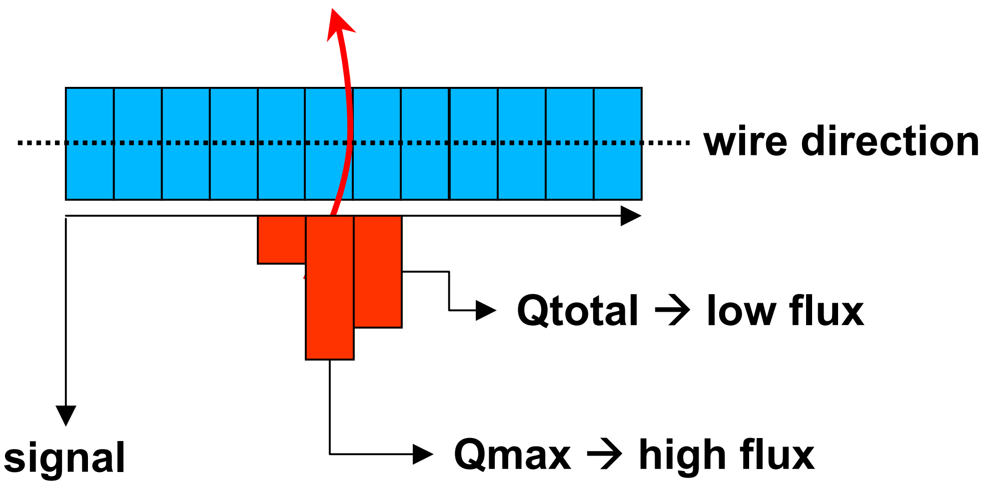
- mean: $$\langle \frac{dE}{dx} \rangle = \frac{4\pi N e^4}{mc^2} \frac{z^2}{\beta^2} \left(\frac{1}{2} \ln \frac{2mc^2 E_{max} \beta^2 \gamma^2}{I^2} - \frac{\beta^2}{2} - \frac{\delta(\beta)}{2} \right)$$

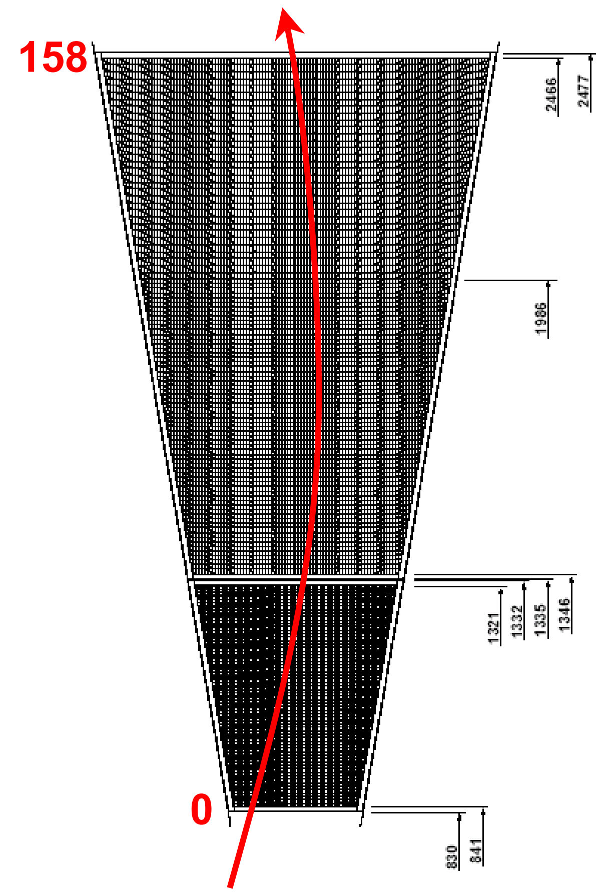
- Landau-like fluctuation:



Basics II: TPC clusters

- charges drift to the amplification region
- each pad row is considered as one gas cell





→159 single dE/dx measurements (cluster charge Q)

Basics III: TPC signal and resolution

- the mean energy loss <dE/dx> is experimentally ill defined because of the tails in the energy loss distribution

  → average over the lowest m = ηn values (truncated mean)

$$< S >_\eta = \frac{1}{m} \sum_{i=0}^{m} Q_i$$

  → it turns out empirically that <S> (TPC signal) follows a Gaussian distribution with the dE/dx resolution σ

- σ depends on the number of clusters n: $\sigma^2_{dE/dx}(n) = \sigma^2_{syst.} + \frac{\sigma^2_{stat.}}{n}$.

- maybe the truncated mean will be replaced by a smooth weighting function

Gain calibration

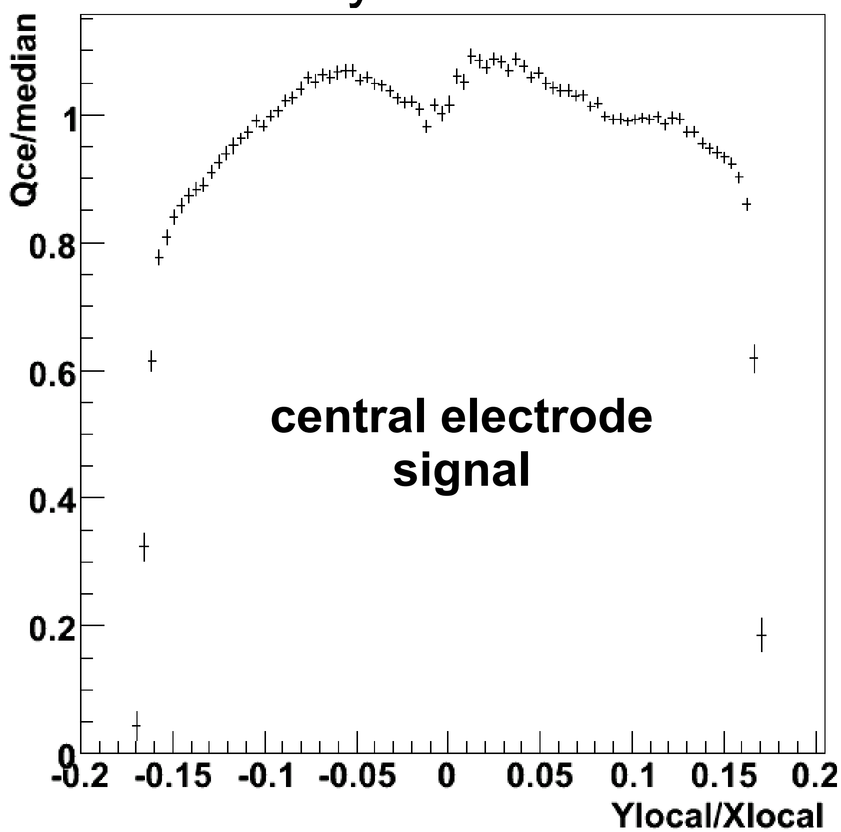
- prerequisite for PID: the gain for each chamber and each pad must be equalized
- 3 different sources: Krypton, laser central electrode, pulser
- general tendencies within a chamber described by parabolic fits

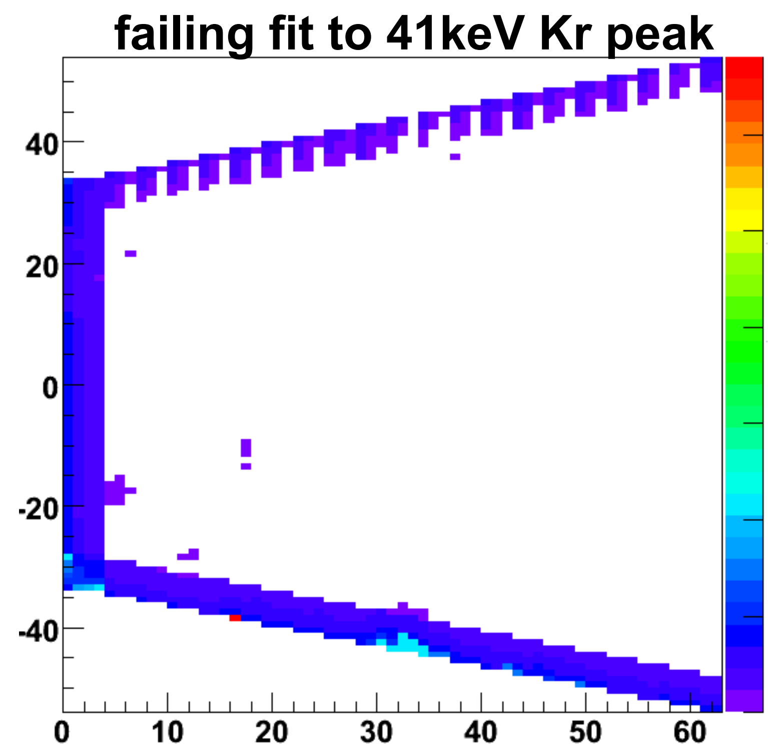
	Amplitude	**Fit**	**Convolution**
Krypton	K_{amp}	K_{fit}	By default
Electrode	E_{amp}	E_{fit}	
Pulser	P_{amp}	P_{fit}	P_{conv}

- Krypton K_{amp} can do everything except: edge effect, chip-by-chip fluctuations, regions which were not active during Kr runs

Edge effect

- at the borders of a sector the gain is naturally lower
  → easiest solution: skip these pads, but we want to do better
- Krypton cannot solve this problem, because of the 3cm range of the decay electrons





General strategy for a gain map

- Krypton amplitude for one or several pads not o.k. → use fitted value

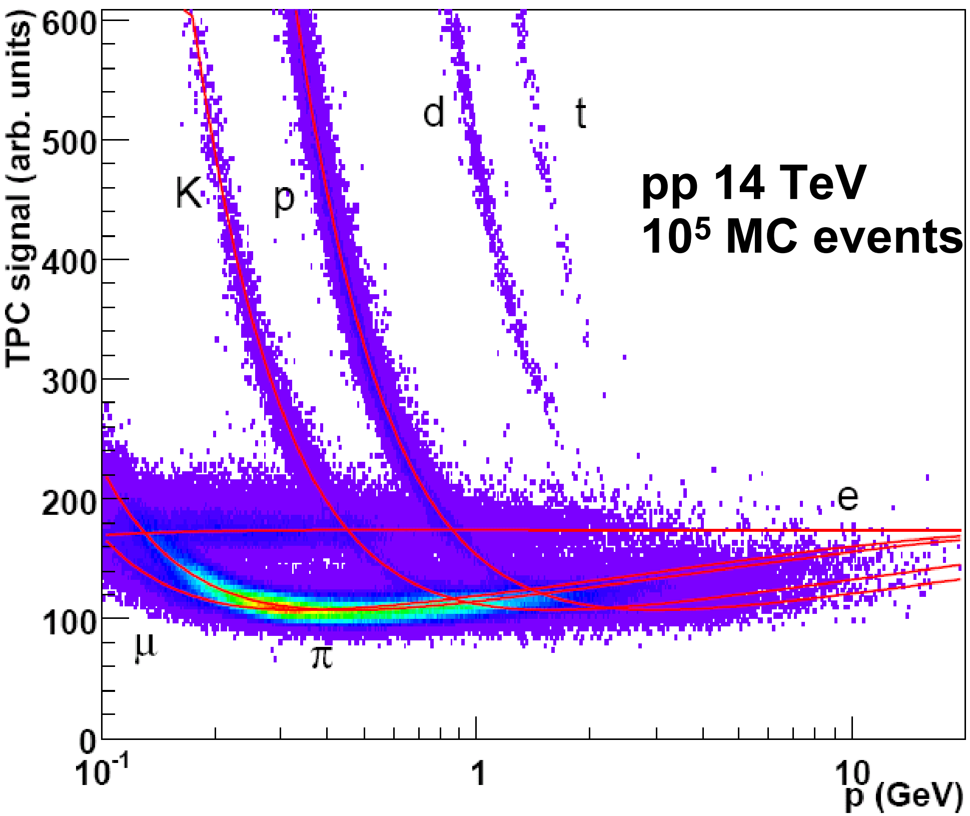
- remove chip-by-chip fluctuation by comparison of Krypton with artificially convoluted pulser data

$$A = K_{amp} \cdot \left(\frac{P_{amp}}{P_{fit}} \right)_{conv}$$

- remove the edge effect with the help of the central electrode

$$A = K_{fit} \cdot \frac{E_{amp}}{E_{fit}}$$

PID calibration



→ Tasks for PID calibration:

- determine the red curves (mean TPC signal)
- determine $\sigma(n_{cluster})$

Detector response probability ⟶ **Bayesian probability**

$$P(i) = \frac{1}{\sqrt{2\pi}\sigma_{dE/dx}(n)} \cdot \exp\left(-\frac{\left(\left(\frac{dE}{dx}\right)_{meas.} - \left(\frac{dE}{dx}\right)_{fit}\right)^2}{2\sigma^2_{dE/dx}(n)}\right)$$

$$w(i) = \frac{C(i) \cdot P(i)}{\sum_{k=e,\pi,\mu,K,p} P(k) \cdot w(k)}$$

The ALEPH parametrisation

Three theoretically possible ways to describe the mean TPC signal

- fit with the ALEPH parametrisation (our solution)

$$f(\beta\gamma) = \frac{P_1}{\beta^{P_4}}\left(P_2 - \beta^{P_4} - \ln\left(P_3 + \frac{1}{(\beta\gamma)^{P_5}}\right)\right)$$

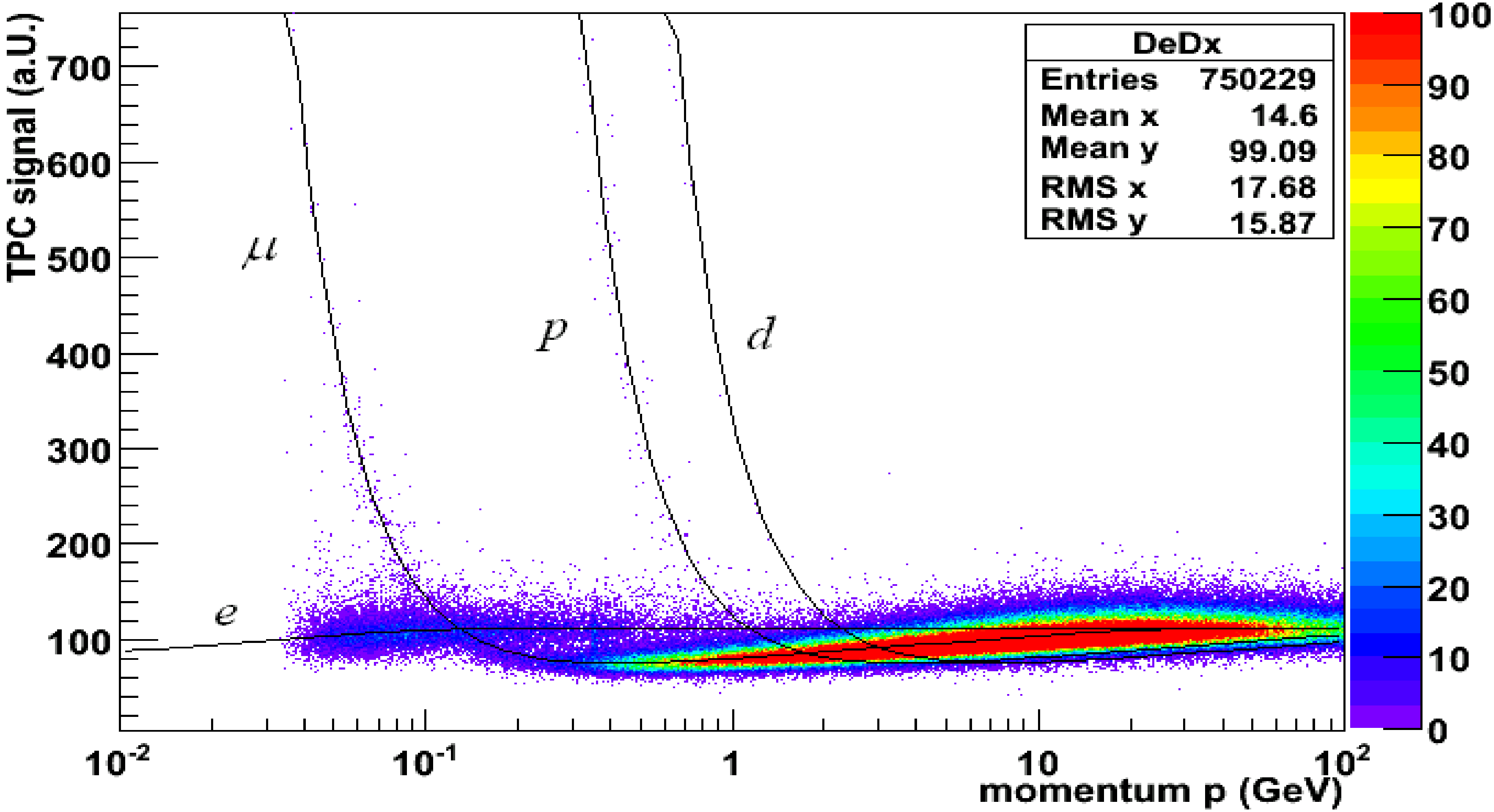
- fit with the Sternheimer parametrisation of the relativistic rise

$$-\langle\frac{dE}{dx}\rangle(\beta\gamma) = \frac{C_1}{\beta^2}\cdot\left(\ln(C_2\beta^2\gamma^2) - \beta^2 - \delta(\beta\gamma)\right) \qquad \delta = \begin{cases} 0, & X < X_0 \\ 4.6052X + C_0 + a(X_1 - X)^m, & X_0 < X < X_1 \\ 4.6052X + C_0, & X > X_1 \end{cases}$$

- don't fit at all, learn sth. about the energy loss of charged particles and use a tuned physics model
  → see talks of P. Christiansen

PID calibration with cosmics data (1)

5,000,000 cosmic events from June 2008, simple Kr calibration



very basic cut (> 50 clusters) to not remove statistics at low p

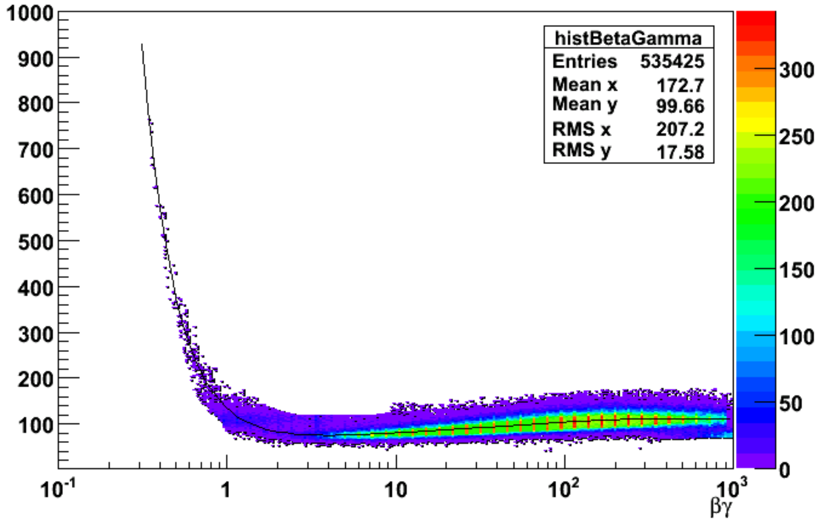
PID calibration with cosmics data (2)

- The lines shown here are all from the ALEPH parametrisation with the same parameter set, only the rest mass of the particle is input

- The fitting procedure is work in progress:

  → start from the Aleph parameters and hand-adjust them slightly

  → use this basic PID to plot it is a function of βγ and refit

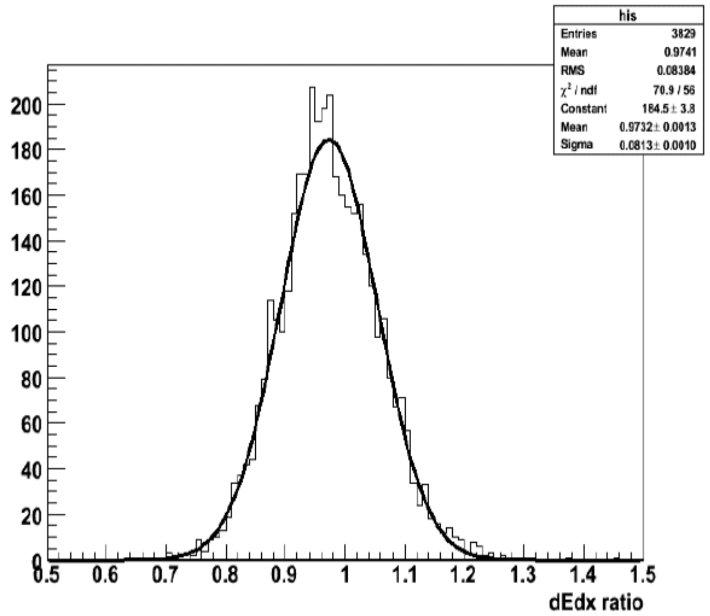


- $1/\beta^2$ part seems to be slightly steeper compared to ALEPH and $I_{plat}/I_0 \approx 1.51$

```
P1 = 3.61; P2 = 16.15; P3 = 1.32e-7; P4 = 2.49; P5 = 2.99
```

dE/dx resolution σ with cosmics data

- cosmic tracks are reconstructed twice (upper and lower half of the TPC)
- by comparing their dE/dx, we can estimate the resolution (see Marian’s talk in the physics forum last week)



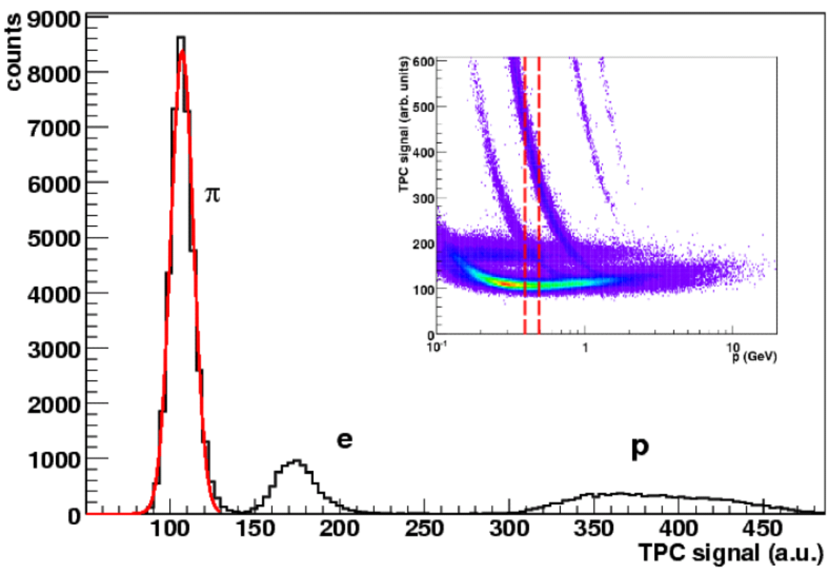
tracks with > 130 clusters:

σ = 5.7 %

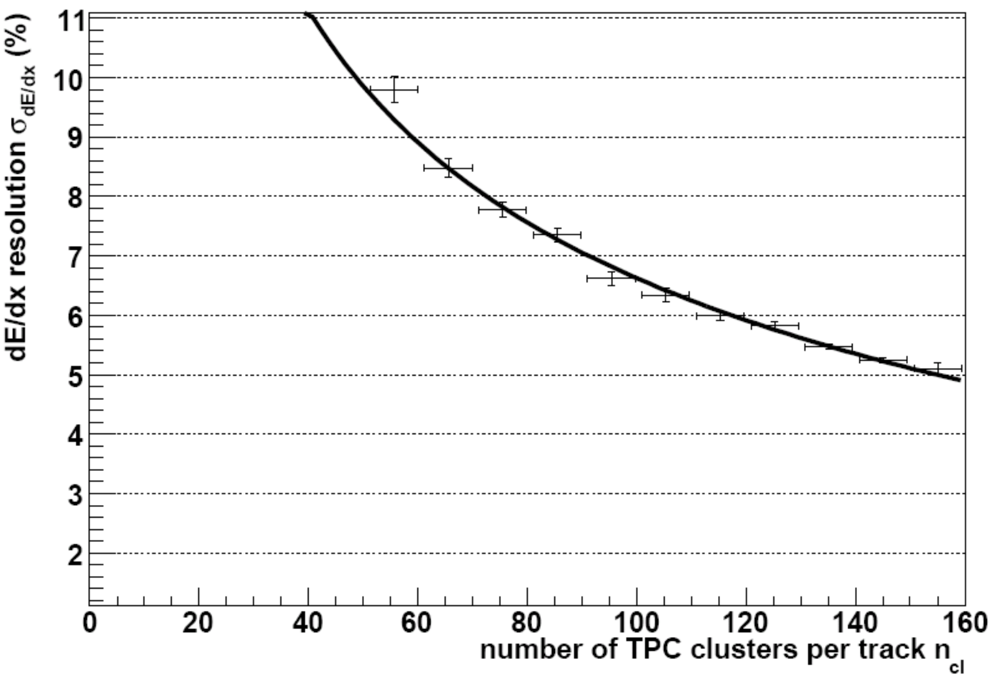
- Please note: angular corrections and for the z-dependence are still done on the basis of MC data; results also hopefully very soon

Dependence of σ on n in MC data

- pions in the MIP region are well separated from other species, so this dependence can be fixed there



pp 14 TeV
10^5 MC events

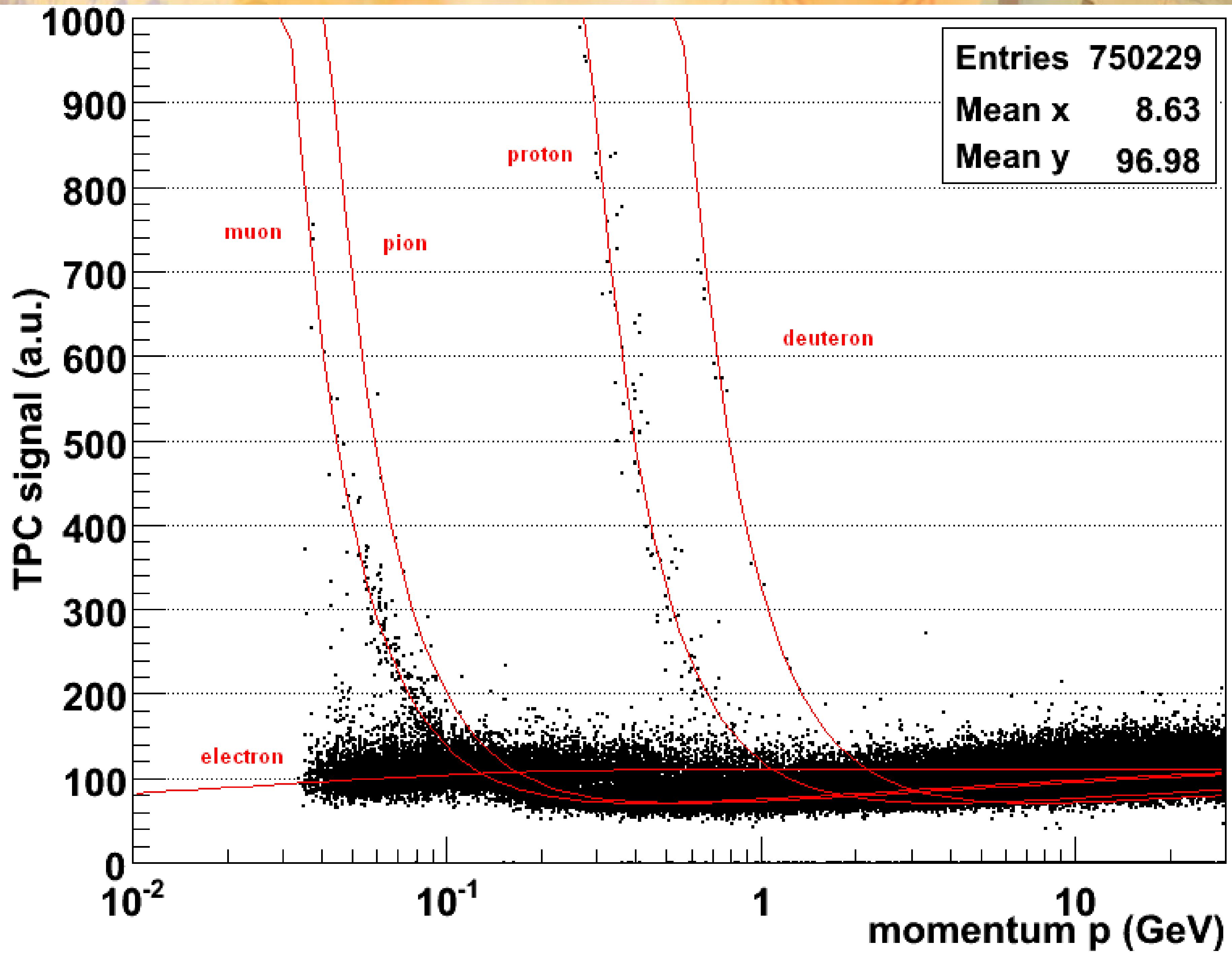


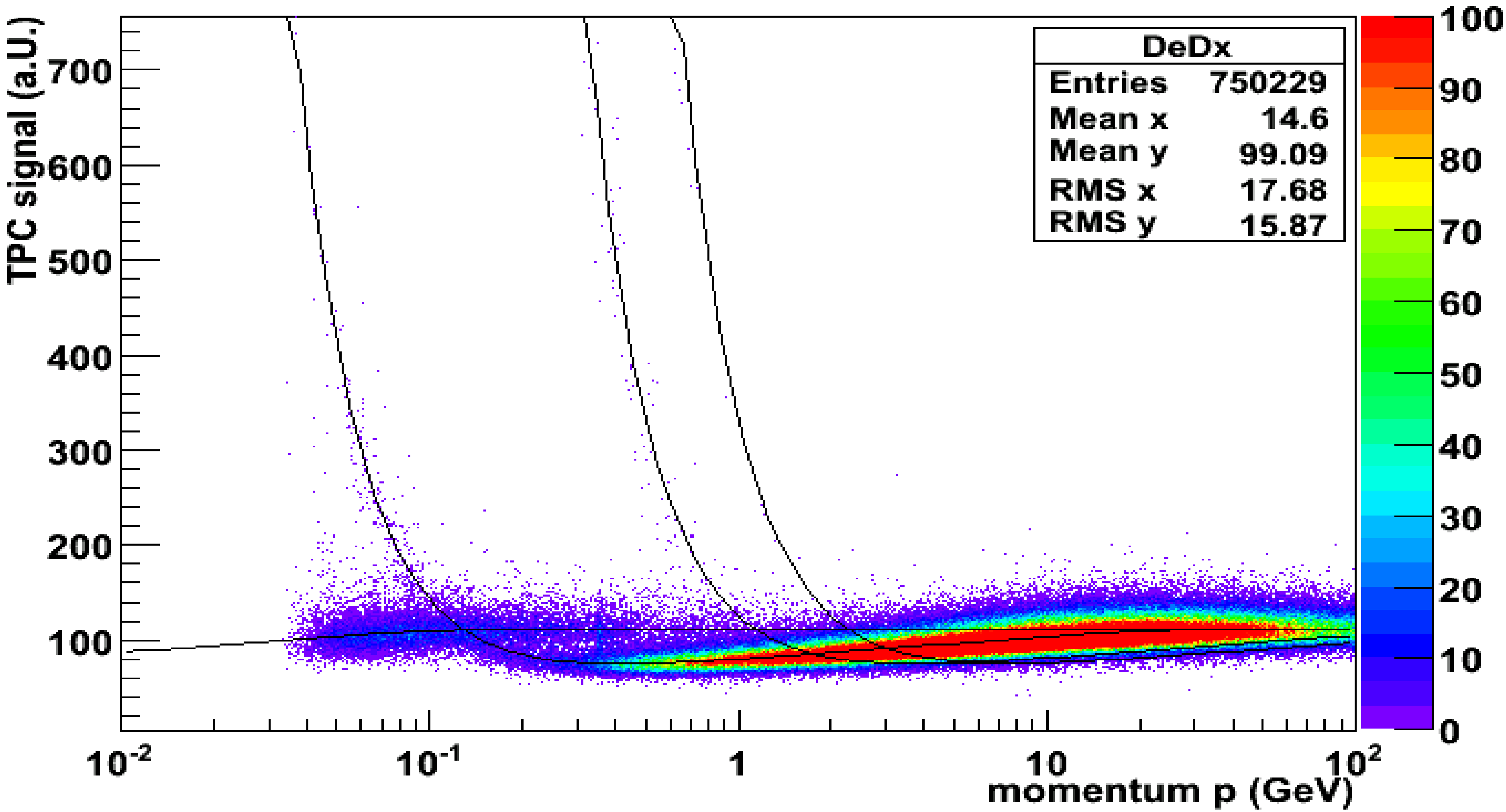
- currently only MC data, but hopefully very soon with cosmcis

Conclusions

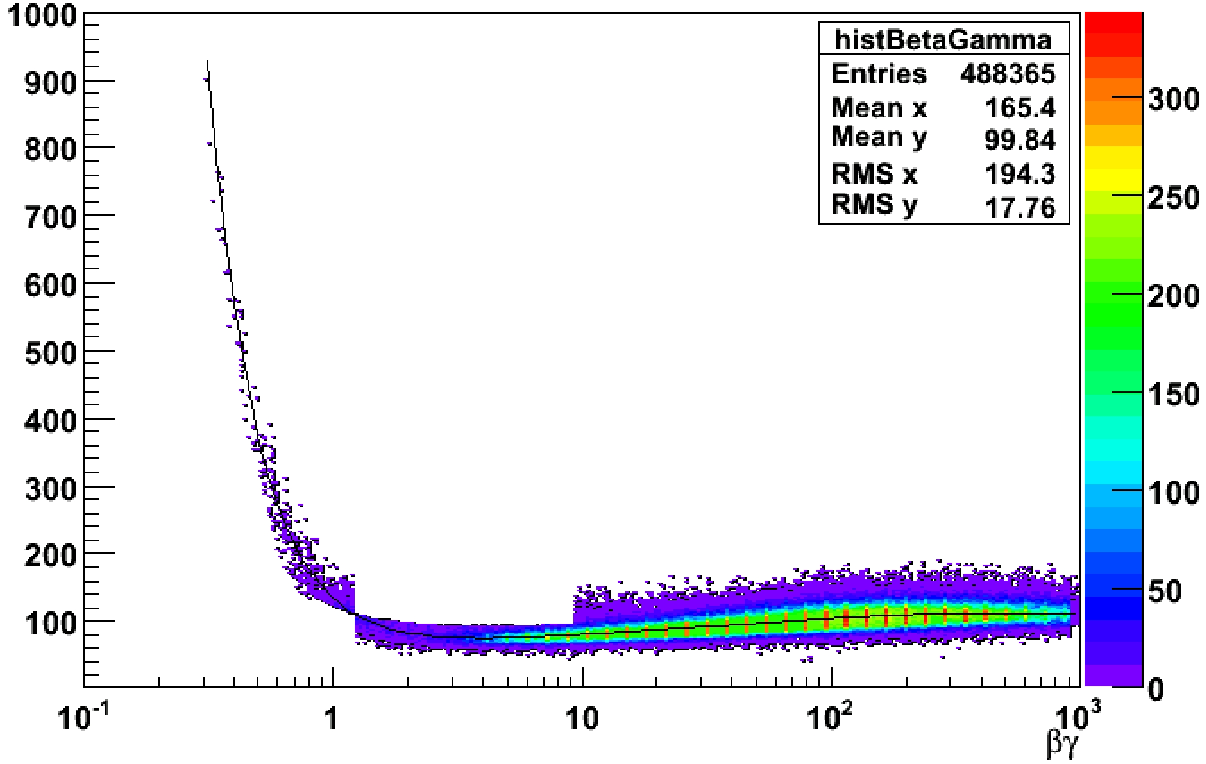
- cosmic data already gives us a very good idea of how the beam data will look like
- a fit with the ALEPH parametrisation seems to be very well suited to describe the energy loss of all particle species
- we can extract a first set parameters which we can then further improve as soon as beam-gas data is available
- we now know which type of particles we can find in our cosmic events…

Backup slides


Entries 750229
Mean x 8.63
Mean y 96.98
muon
pion
proton
deuteron
electron
TPC signal (a.u.)
momentum p (GeV)
0
100
200
300
400
500
600
700
800
900
1000
10^{-2}
10^{-1}
1
10



DeDx
Entries 750229
Mean x 14.6
Mean y 99.09
RMS x 17.68
RMS y 15.87
TPC signal (a.U.)
700
600
500
400
300
200
100
10-2
10-1
1
10
102
momentum p (GeV)
100
90
80
70
60
50
40
30
20
10
0


histBetaGamma
Entries 488365
Mean x 165.4
Mean y 99.84
RMS x 194.3
RMS y 17.76
1000
900
800
700
600
500
400
300
200
100
10^{-1}
1
10
10^{2}
10^{3}
βγ
300
250
200
150
100
50
0