# PID spectra from the TPC

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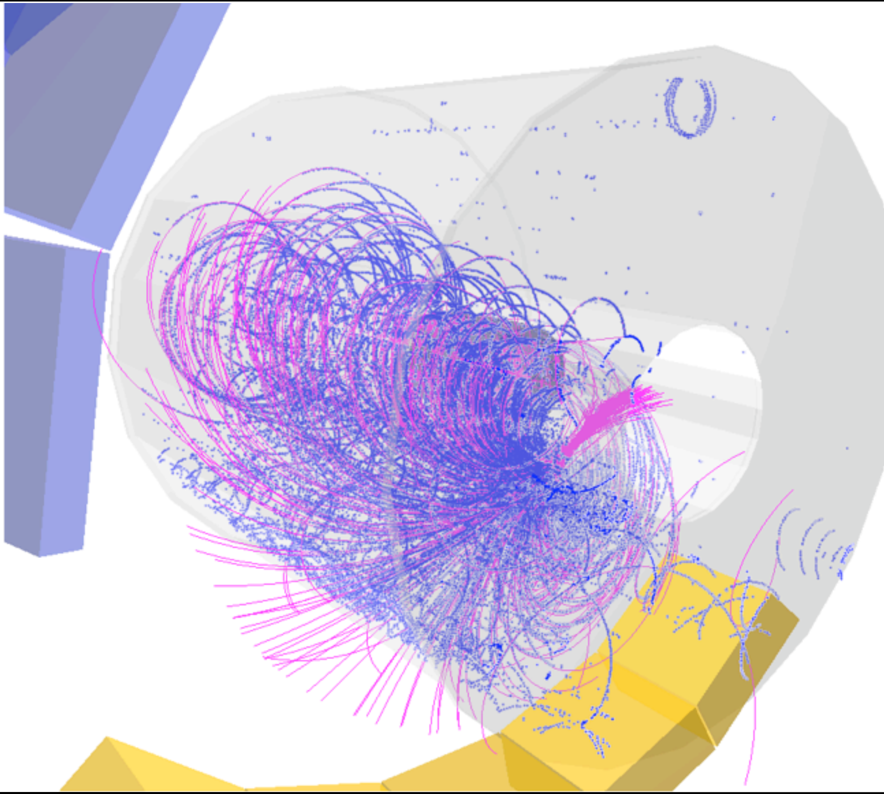
GSI

ALICE

A Large Ion Collider Experiment

CERN

European Organisation for Nuclear Research



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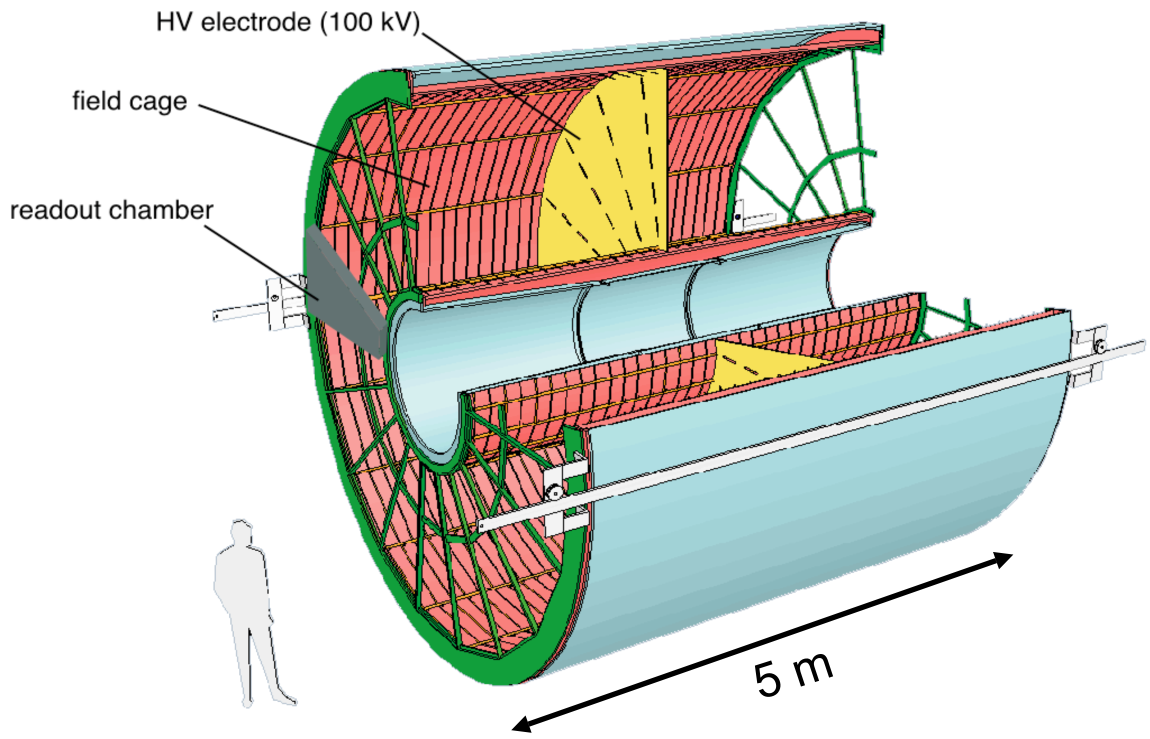
# PID BASICS

# TPC working principle

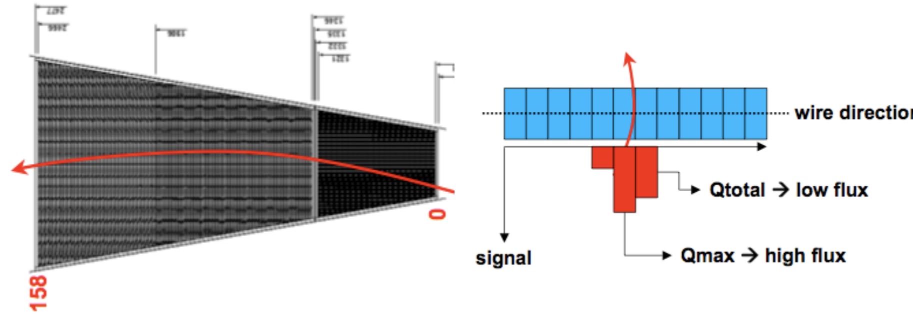
- track position and momentum ($p_T = 0.3 \cdot B \cdot r$)
- particle identification via specific energy loss: dE/dx

radius: 845 - 2466 mm
drift length: 2 x 2500 mm
drift time: 92 µs
gas mixture $Ne\text{-}CO_2\text{-}N_2$
gas volume: 90 $m^3$
557568 readout pads



# The TPC PID

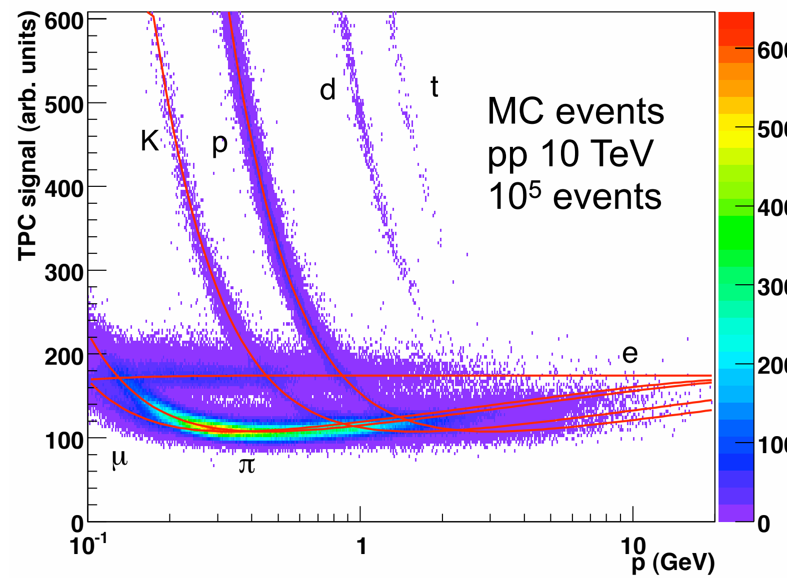
- truncated mean of pad signals (70%) to remove fluctuations of Landau-tails




- energy loss per unit path length is described by the Bethe-Bloch formula

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

(depends only on charge and rest mass for a fixed momentum)




- parameterization of is fitted to the data (Aleph-Parameterization)

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

# TPC PID: general comments

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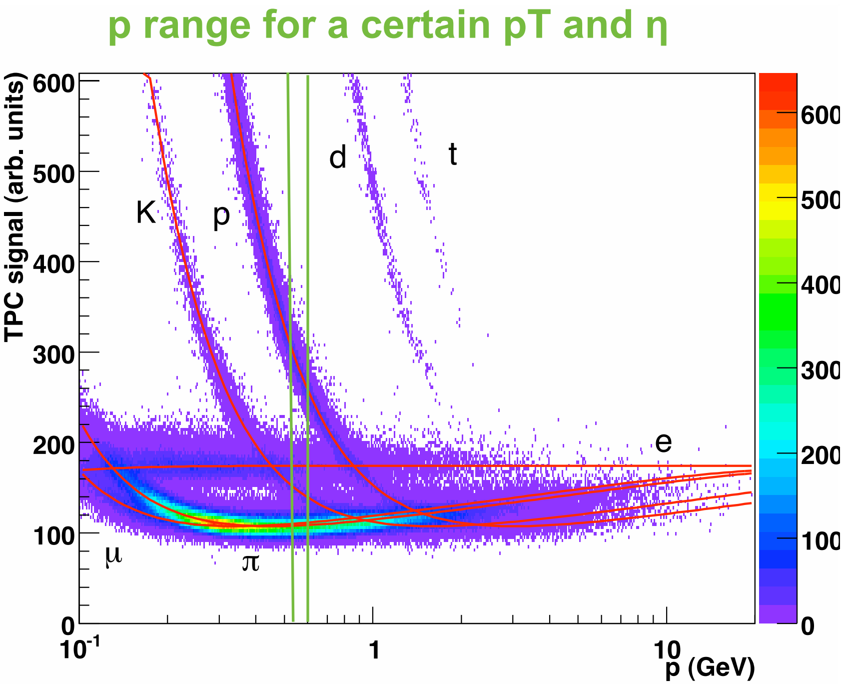
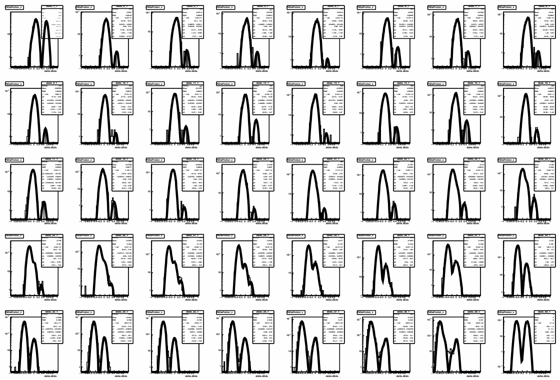
- In a simplistic view:
  - **Method A**: for each $p_T$-bin a histogram with the measured dE/dx minus the expected dE/dx is filled and fitted with a multiple Gauss function (use fit yield or bin counting)
  - **Method B**: select all particles within a 2σ-band (nσ-band) around each Bethe-Bloch curve and the $p_T$-bins are filled directly

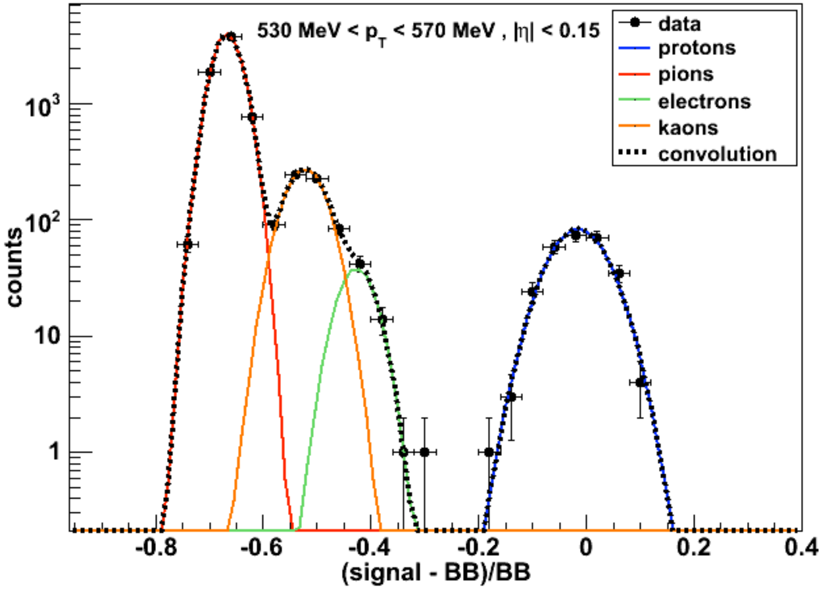
    -> it also allows to look at dca-distributions etc.

    -> this is probably ideal for improving Signal-to-Backgr. ratios for invariant mass analysis

# Extracting pT-spectra ...





# Bayesian PID and the TPC

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- Integral of gaussians would be the priors, gaussian probability density would describe the detector response probability
- tasks for PID calibration: => determine Bethe-Bloch parameters and σ(ncl) .
- Will be done with normal events, cosmics (high-Pt) and maybe V0s (see cosmic results -> possible extraction of a first parameter set).

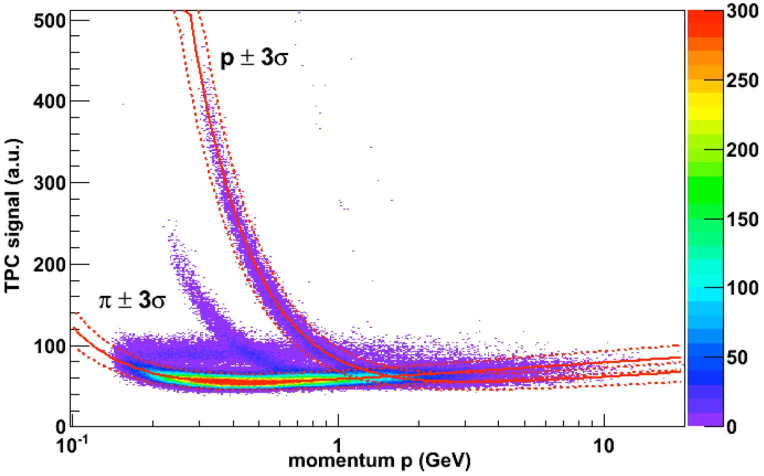
**Detector response probability** → **Bayesian probability**

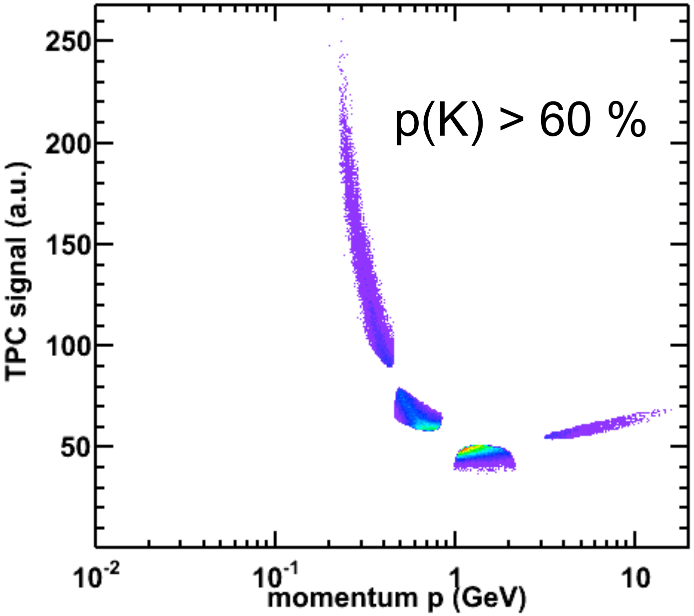
$$P(i) = \frac{1}{\sqrt{2\pi}\sigma_{dE/dx}(n)} \cdot \exp\left(-\frac{\left(\left(\frac{dE}{dx}\right)_{meas.} - \left(\frac{dE}{dx}\right)_{fit}\right)^2}{2\sigma^2_{dE/dx}(n)}\right)$$

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

# PID philosophies in ALICE

- DO NOT CUT ON PROBABILITIES (of a single detector)
- Prior PID is wonderful, but has to be done properly: fractional filling of histograms, correct evaluation of priors (detector-by-detector), ...
  - nσ-bands are a fast and well defined (efficiency) alternative



# CALIBRATION STATUS

# Current status

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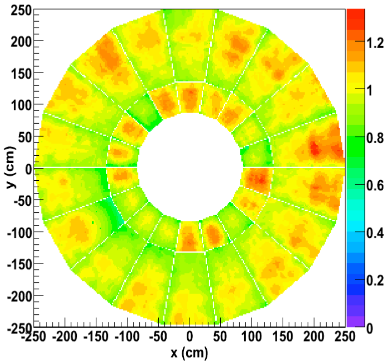
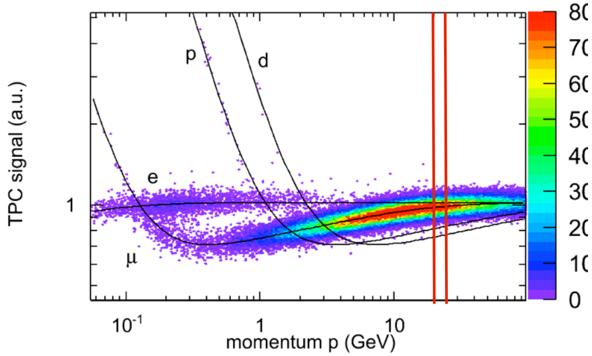
**calibration using Kr**

**performance validation with cosmics**

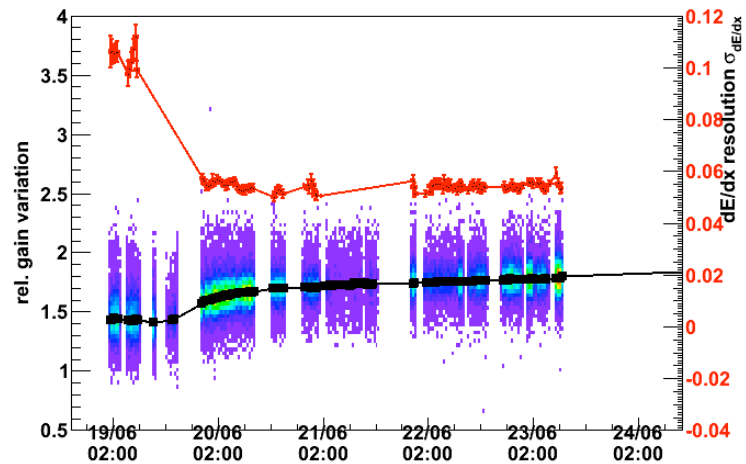
**long-term stability**




Gain Map,
C side




extracted from 7 million cosmics,
red lines -> Aleph param.




evaluation of whole
data-taking in 2008

# Time dependent calibration

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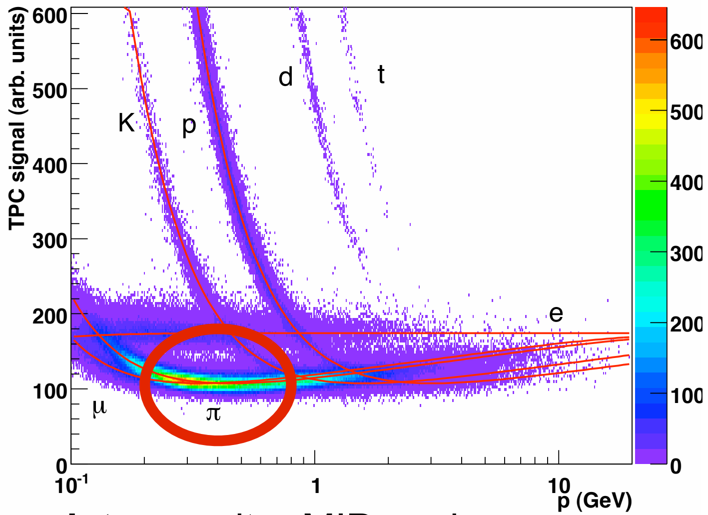
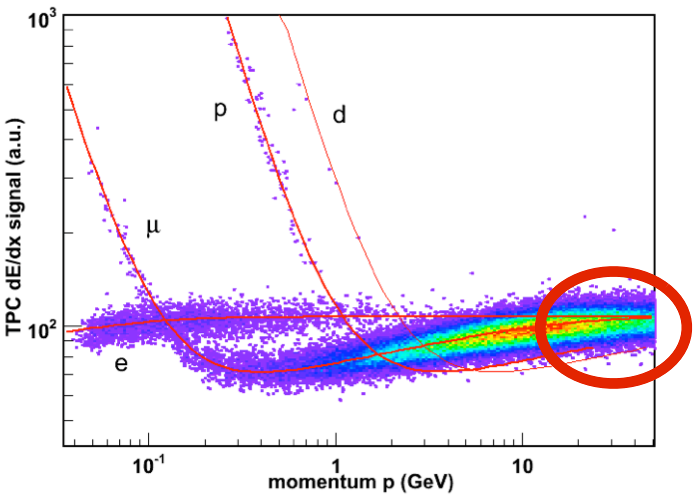
- gain changes due to pressure/temperature changes
- correction factors will be applied in the **tender** of the analysis train (see talk during offline week)
- resolution is also monitored -> QA




**beam data**: monitor MIP peak as a function of time -> mean from a gaussian fit




**cosmic data**: monitor muons on Fermi Plateau as a function of time -> mean from a gaussian fit

# Analytical charge correction

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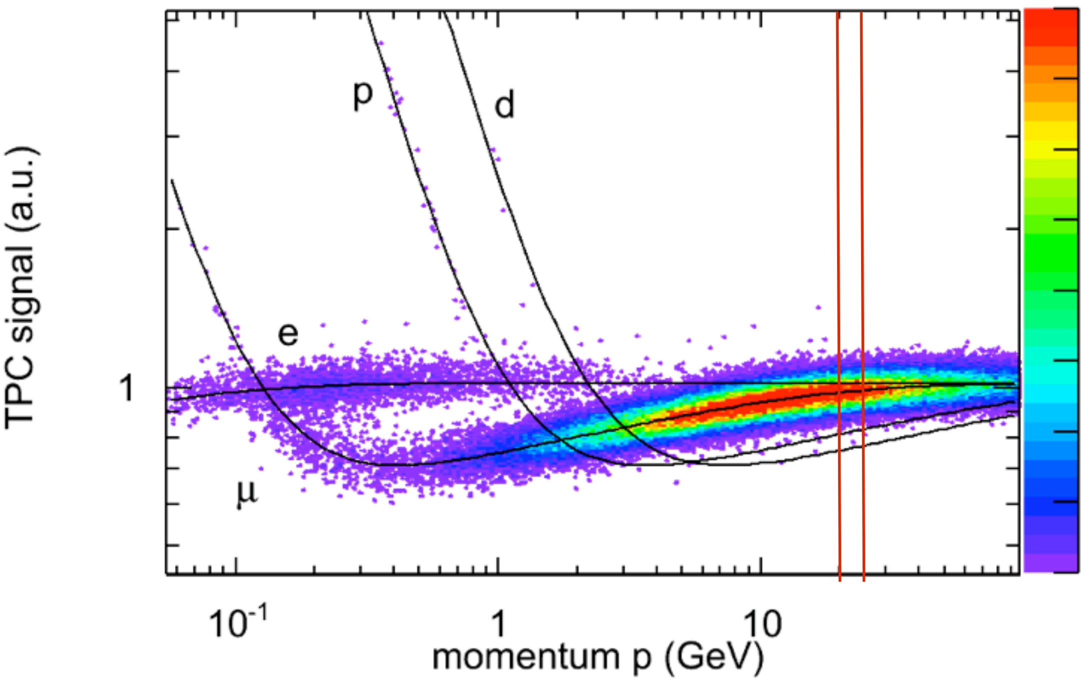
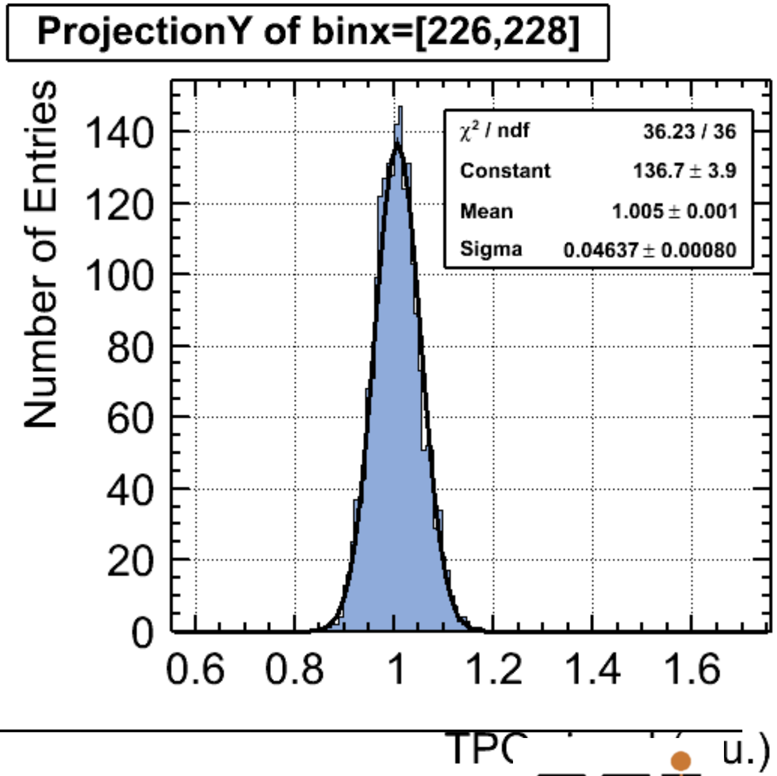
- idea:put a "test charge" at the given cluster position, smeared with the corresponding track angles
- propagate it to the readout pads taking into diffusion
- sample it like a real cluster taking threshold effects into account; extract the corresponding correction factor by comparing the sampled charge with the measured one
- => there seems to be a big improvement due to this (thanks to a huge effort by Marian)

# Recent developments

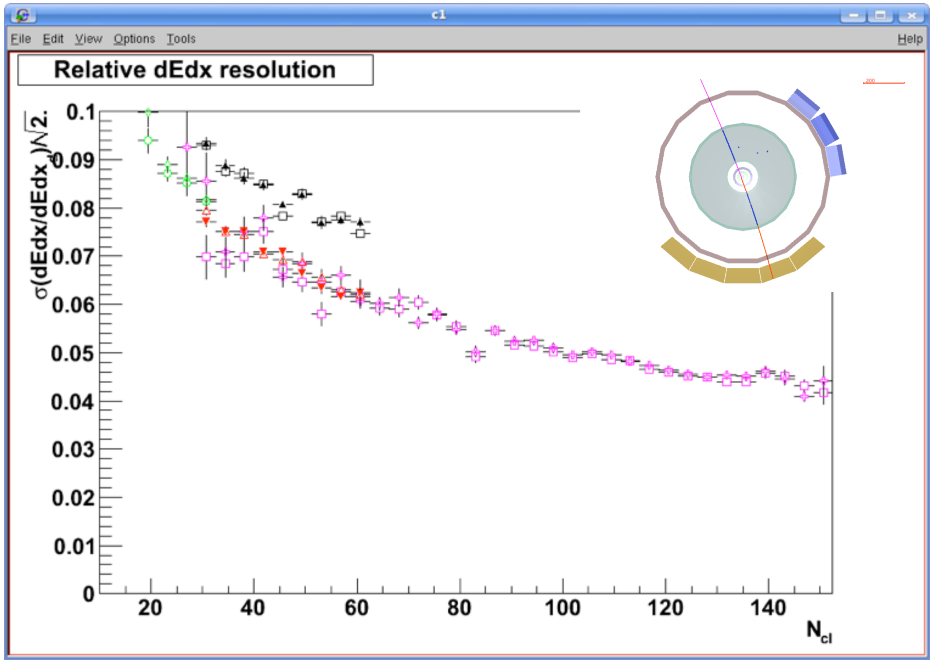
- time dependent calibration and analytical charge corrections were added only recently
- we might be able to reach even better resolutions than TDR

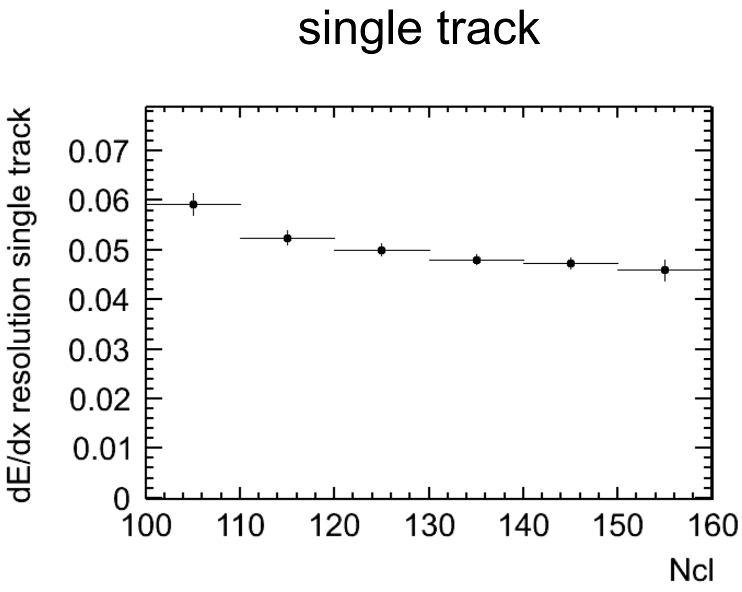


# dE/dx calibration

- almost all necessary studies can/are already be done with cosmics
- e.g.: statistical scaling with track length
- track matching and single track in agreement, σ(ncl) -> OCDB



# dE/dx resolution in MC and real

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- optimizations and tunings are at the moment done on the real data
- the simulation is so general that it also needs to be calibrated
- the analytical charge correction is not yet in the MC reconstruction (will be added soon)
- therefore the obtained resolutions in the currently slightly worse
- now that the calibration seems to converge, the MC will be slowly adapted to the real data (major effort in the next weeks!)

# On the way
# to physiscs ...

# Analysis plans directly after day 0

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- $p_T$-spectra of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$
  focus on low-momenta region (< 5 GeV)
  multiplicity dependence

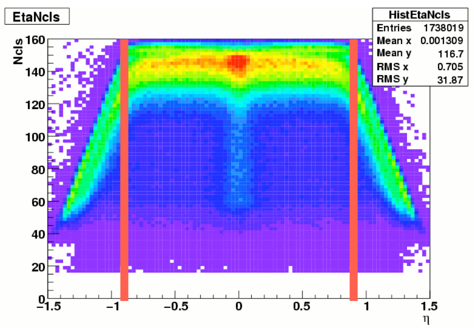
- as well for 900 GeV as for 10 TeV - as soon as possible after the start of data taking

- analysis with the TPC stand-alone possible, but
  - maybe ITS for vertexing and primary/secondary distinction
  - TOF for PID cleaning (crossing points) ??
    -> combination of both detectors would be ideal: for a track matched to TOF the full TPC-PID information is available

- number of events needed 50k - 500k

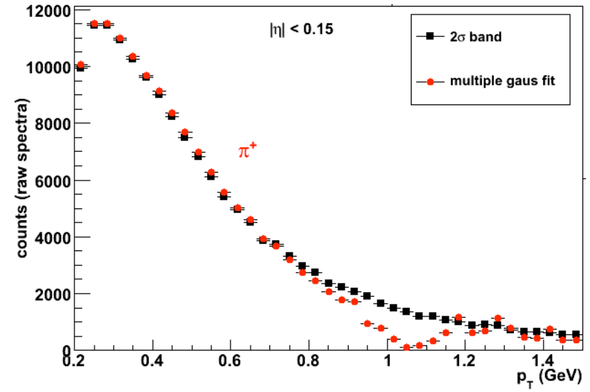
# The analysis chain

1. Event and track selection: with standard track cuts

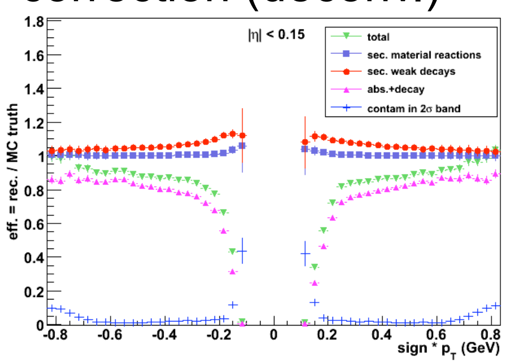



PID with Method A) or Method B)

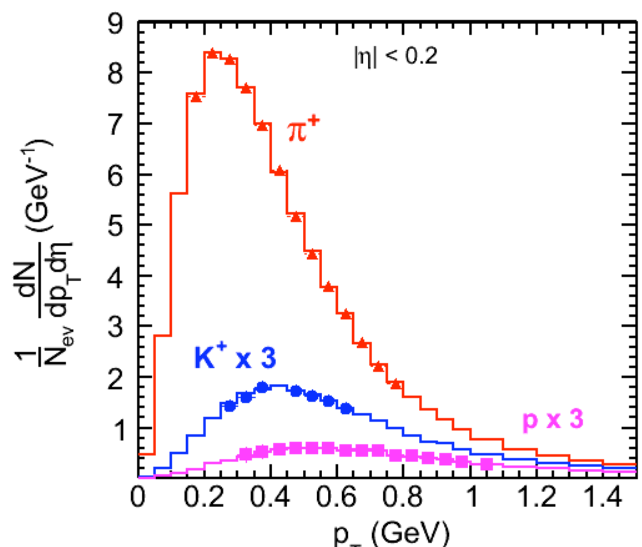
2. raw spectra




3. efficiency correction (deconv.)




4. final spectra



# Results

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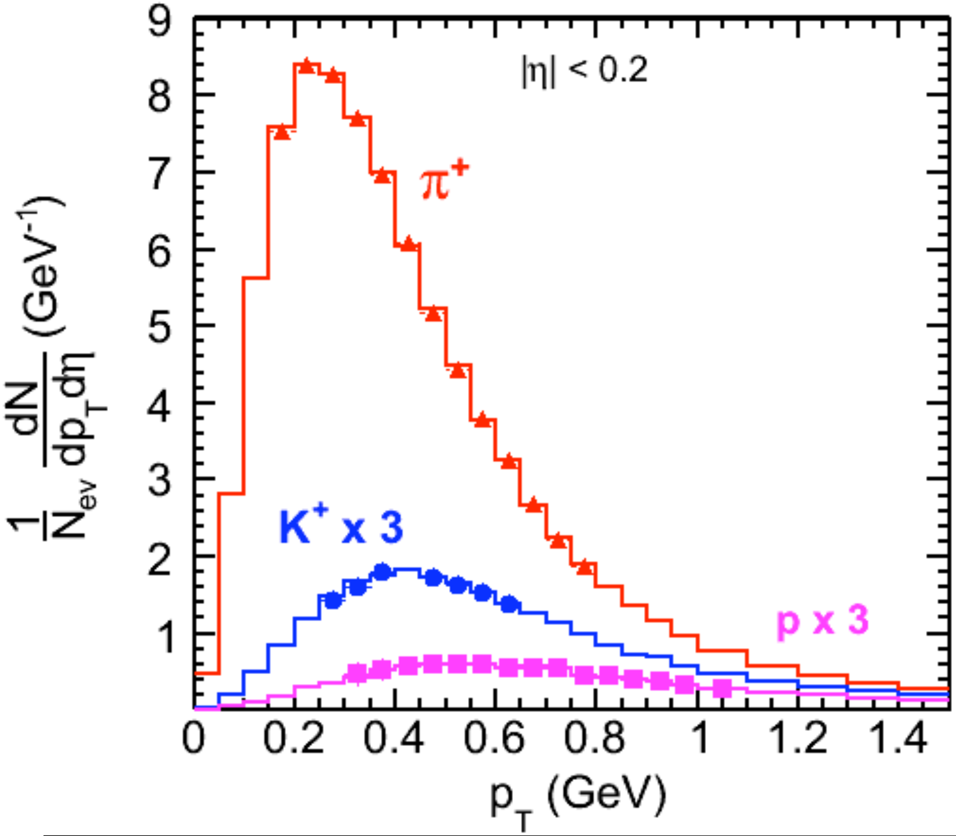
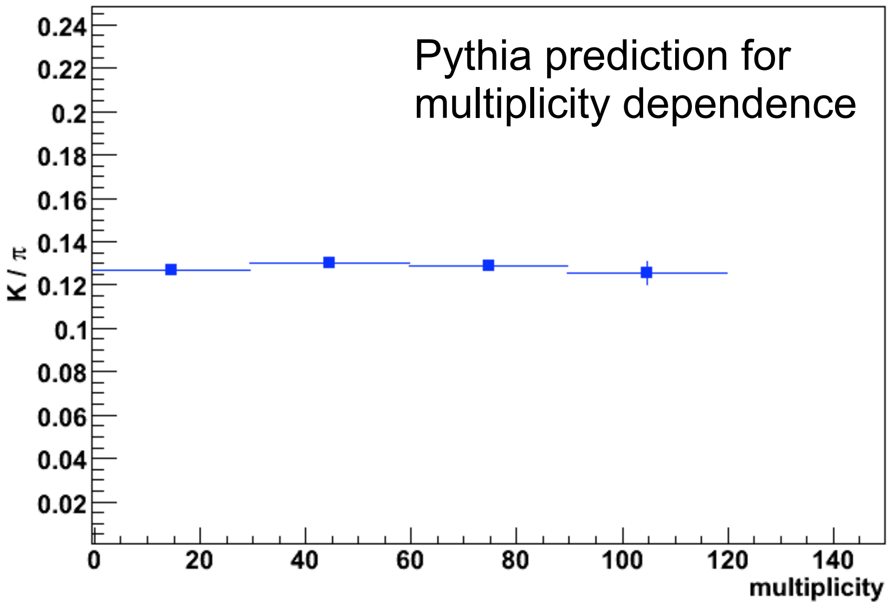
- spectra
- ratios: $K^+/\pi^+$, $K^+/K^-$, $p/\pi^+$ etc., as a **function of pT and multiplicity**



# The future: high-pT, jet chemistry

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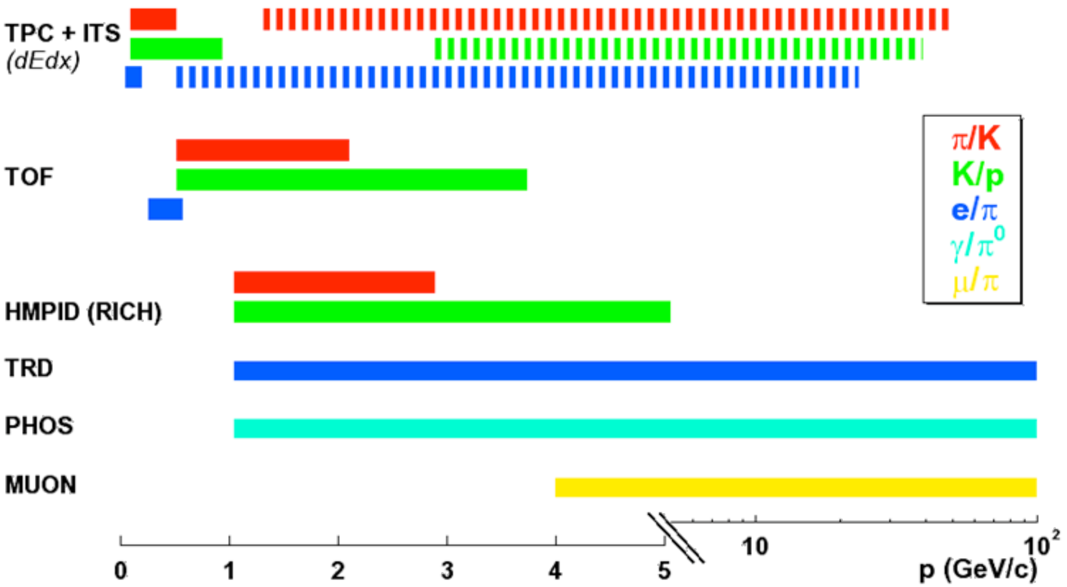
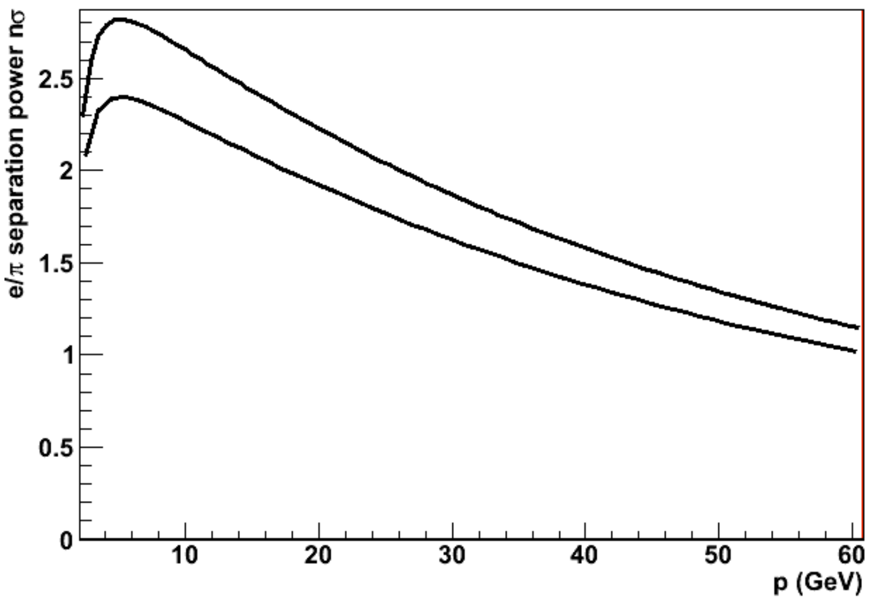
- dE/dx analysis has to be done on the relativistic rise
- include TOF for intermediate pT
- needs much more events
- very careful deconvolution of gauss functions (fix mean and resolution,...)

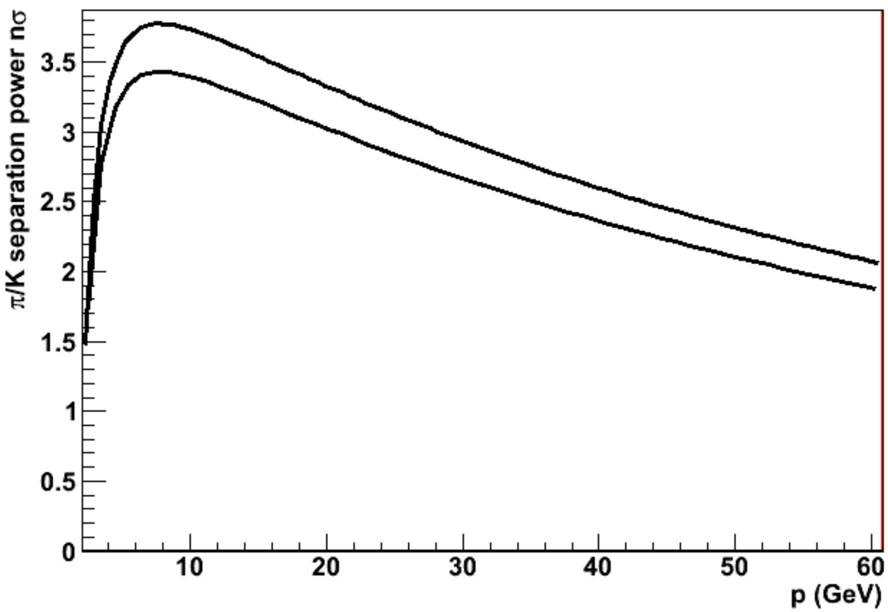


# PID on the relativistic rise



- final answers will probably only be possible with real data
- for the moment: BB and resolution (from cosmics as best scenario + TDR) for tracks > 120 cls.
- for very precise answers a detailed study including all information (proper MC + cosmic) would be needed



# Backup slides

# PID on the relativistic rise

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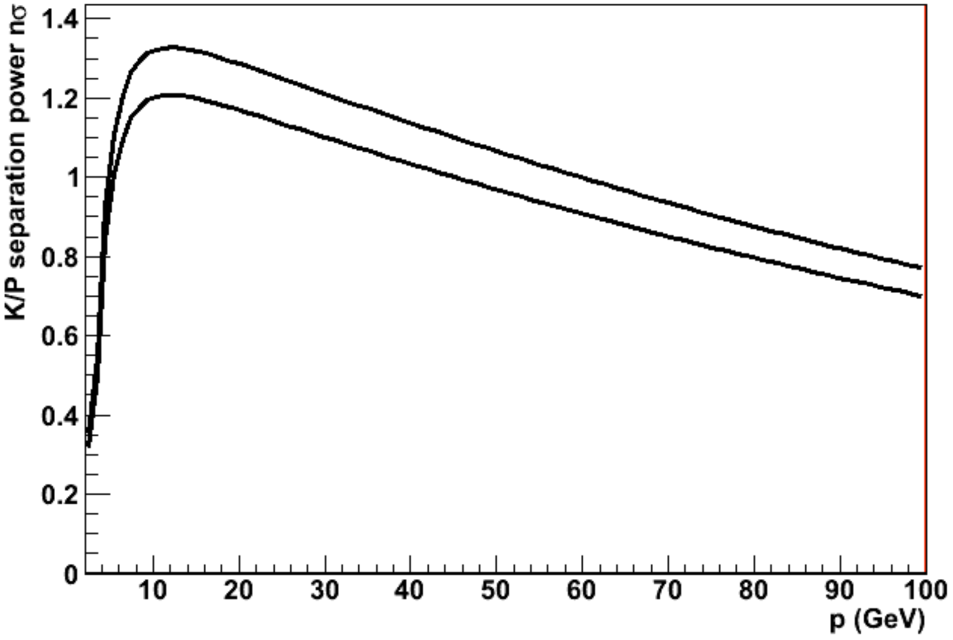
- final answers will probably only be possible with real data
- for the moment: BB and resolution (from cosmics as best scenario + TDR) for tracks > 120 cls.



# TPC Particle Identification

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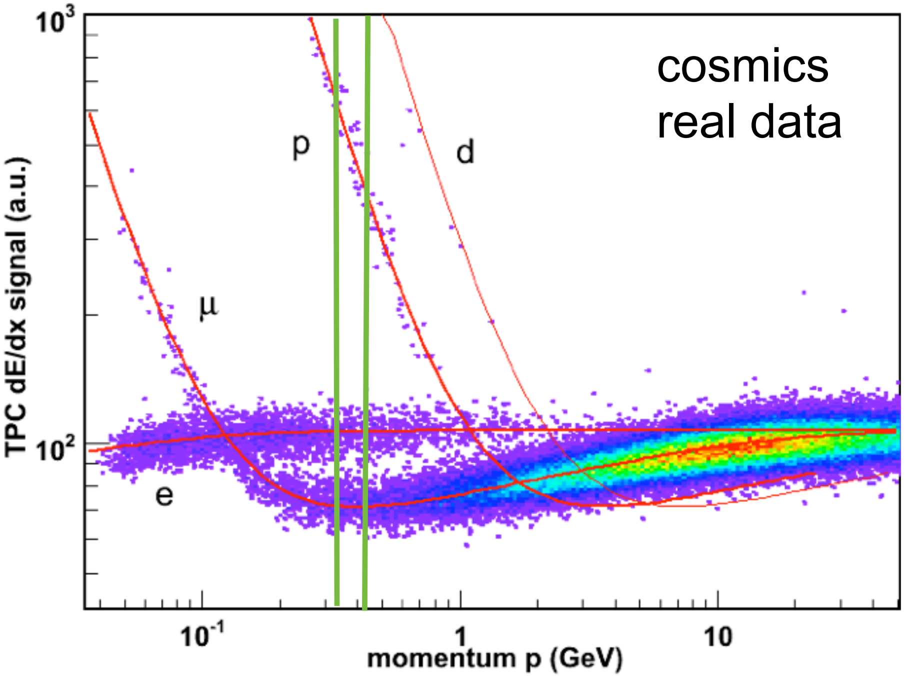
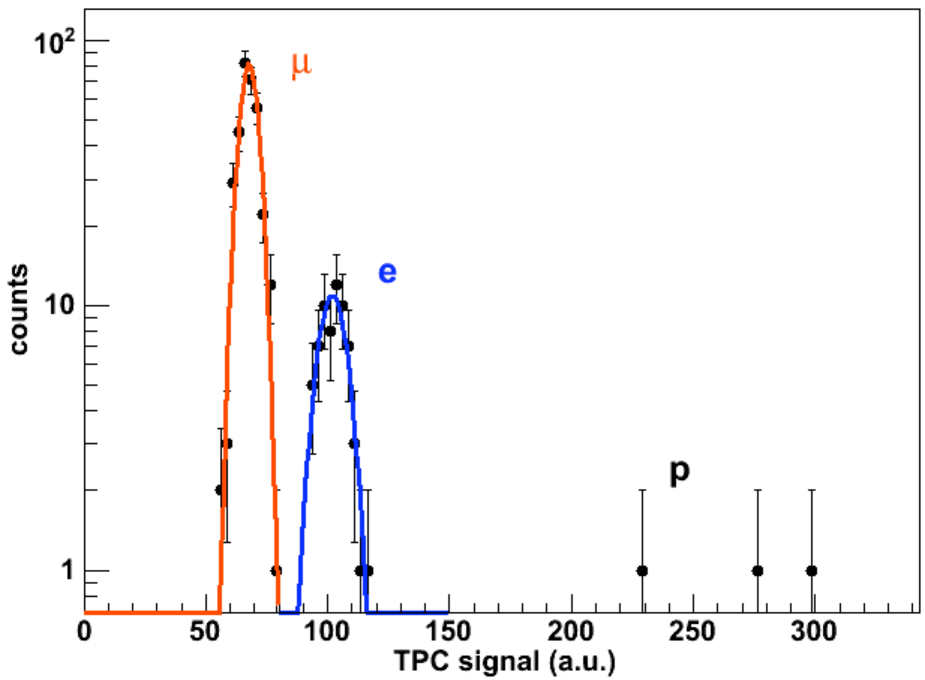
- commissioning of the TPC particle identification is well progressing; resolutions are sufficient for physics (≈ 5.7 %)



# Outline

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- The ALICE TPC and particle identification via dE/dx (detector status)
- some general comments on PID with the TPC
- measurement of identified charged kaon (hadron) spectra

- more technical details of the analysis in the last PWG2s presentations:

  http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=24911
  http://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=54794
- more technical details on the cosmic ray data analysis in Technical Forum presentations
  http://indico.cern.ch/getFile.py/access?subContId=0&contribId=3&resId=3&materialId=slides&confId=54444

# Systematic uncertainties

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- systematic uncertainties are different for each particle type! -> e.g.: the number of secondary Kaons is negligible whereas the number of secondary protons is huge (material interactions and feed-down from Lambda)

- List of systematic uncertainties which we investigate:
  - secondaries from material
  - secondaries from weak decay
  - energy loss and absorption in material
  - decay (Kinks for Kaons)
  - non-gaussianity of dE/dx signal
  - beam-gas interactions
  - multiple interactions per bunch -> Multiplicity!

# Conclusions

- Particle identification via dE/dx is a powerful tool for the direct measurement of charged hadron spectra and for reducing the background
- We are optimistic that it is usable from day 0 on
- Already with the TPC stand-alone and limited statistics a measurement of charged hadron spectra should be possible

# Kaon kinks

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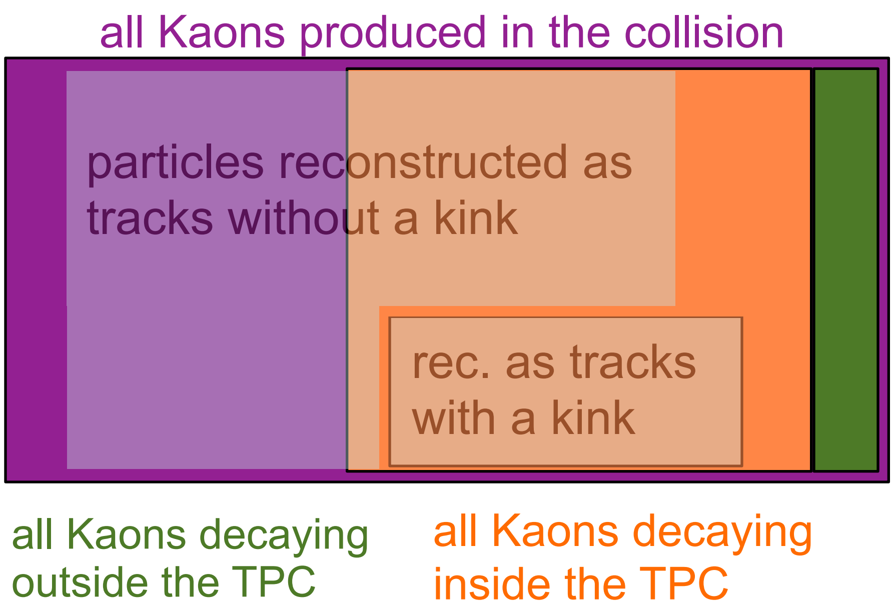
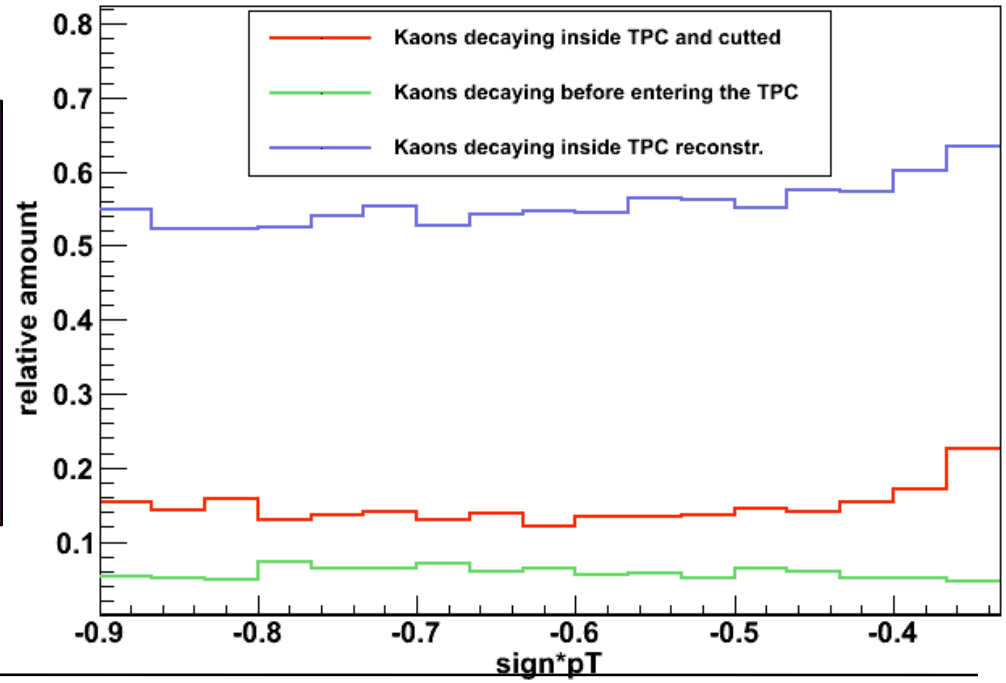
- Kaons decay with a cτ = 3.71 m, this has to be corrected based on efficiencies from simulation
- the cut on the number of TPC clusters is most relevant (how short the mother track is allowed to be) -> *the correctness can be checked by repeating analysis with different cuts on nTPCcls*



# Pile-up within one bunch

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- until now no work on this within the framework of this analysis (but close contact to 1st physics WG $p_T$ spectra)
- different strategies depending on the situation:

| probability for multiple interactions per bunch | pile-up corrections | possible physics |
|---|---|---|
| negl. | not needed | particle ratios, spectra, full multipli. depend. |
| low | none | ratios |
| | poissonian stat. | spectra, limit. multipl. |
| | multi vtx. rec. | spectra, full multipl. |
| high | none | ratios |
| | poissonian stat. | spectra |
| | multi vtx. rec. | spectra, mult |

# Pile-up from different bunches

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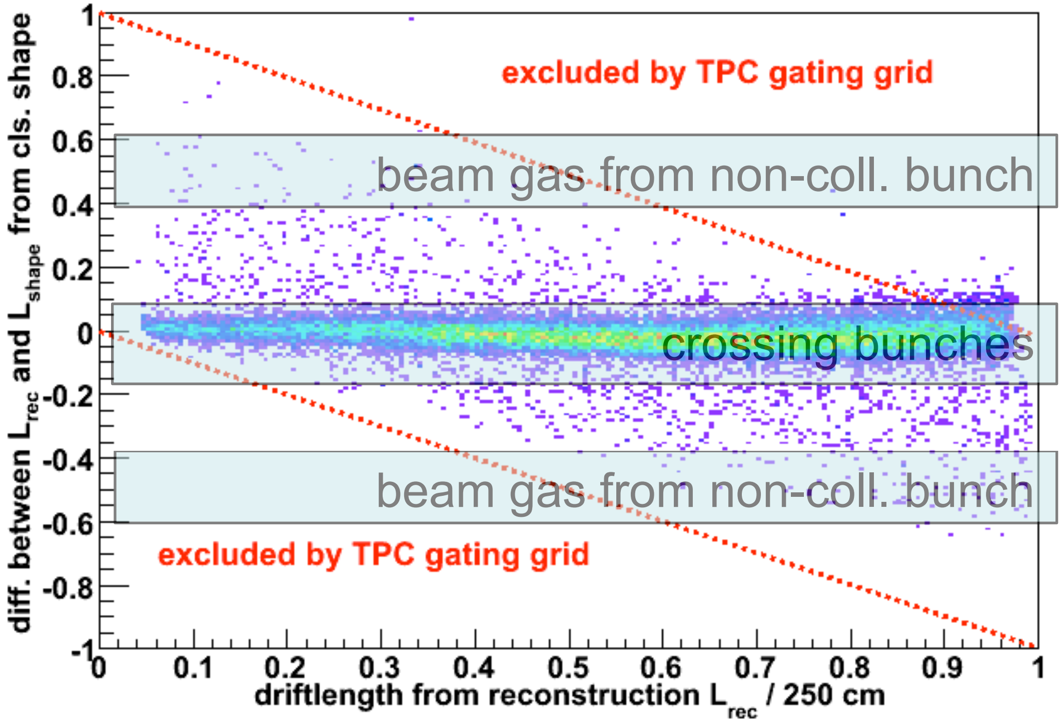
- estimate time difference from cluster shape alone with the TPC (5-7% time resolution)
- still a little experimental, but works with the cosmics
- also rejects background from beam gas
- together with dca-to-vtx. cut in z a rather clean situation can be expected

schematic example: 4 Bunches in LHC



# Secondary protons

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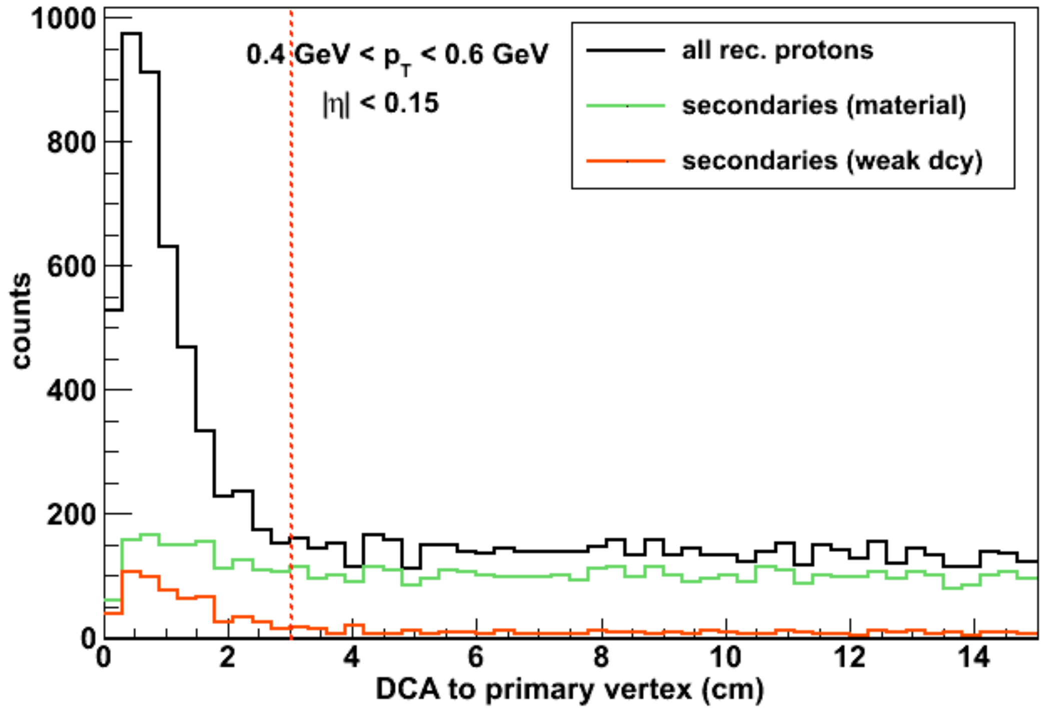
- in a lower $p_T$-region secondaries from material interactions are the main source of background for protons, but there protons are very well separated from other species
- the good separation allows to use Method B and therefore to take dca into account
- the best strategy: $2\sigma$+dca at lower $p_T$, multiple gauss for higher $p_T$




- different possible definitions for prim./sec. can be used