



# **Gain calibration of the ALICE TPC**

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# Outline

- calibration strategy:
  - pulser calibration (Jens Wiechula)
  - krypton calibration (Adam Matyja, Stefan Grtner, Marek Kowalski, Jacek Otwinski)
  - time dependence - GOOFIE (Juan Castillo, Martin Siska)
  - gain calibration using tracks (Stefan Grtner)
  - PID calibration (Alexander Kalweit)
- requirements
- status – what is ready for the first collisions?

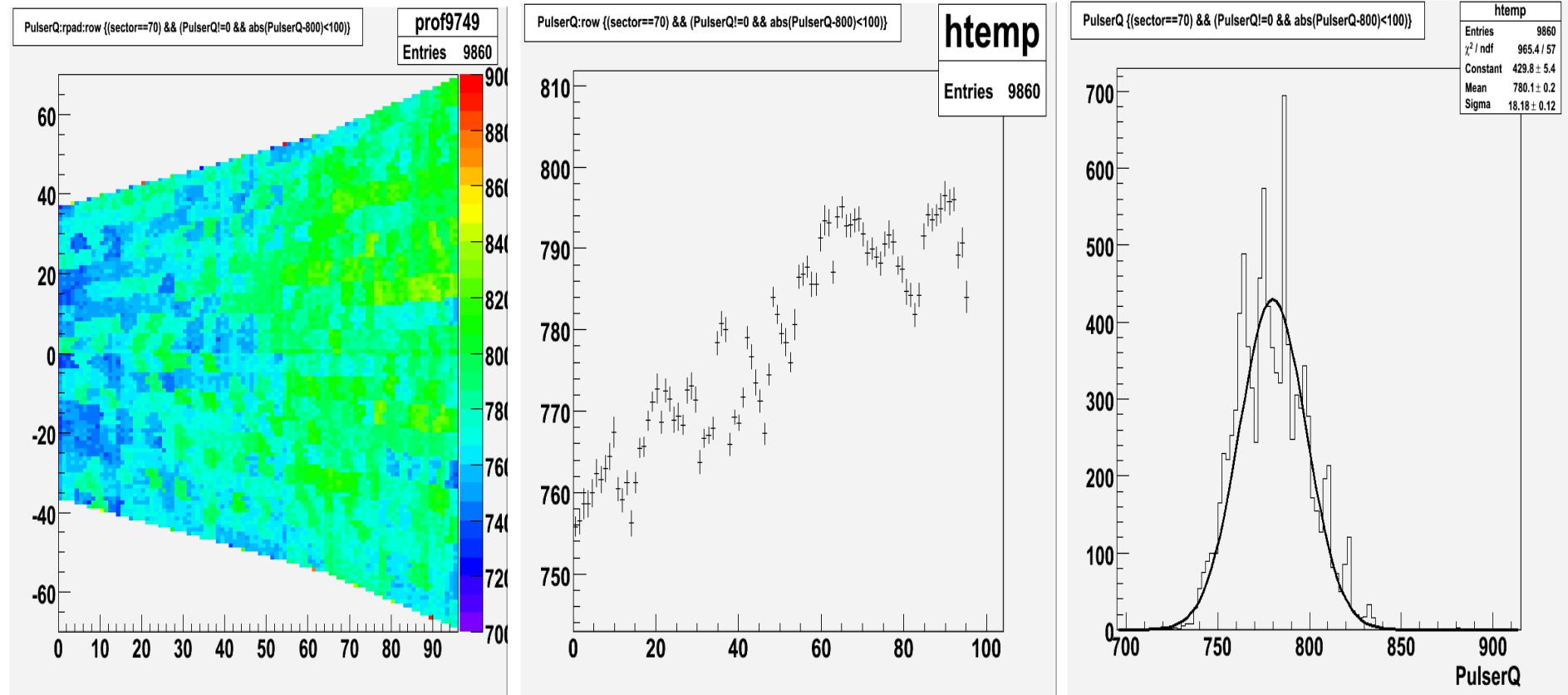
# Requirements and motivation

- our goal: TPC  $dE/dx$  resolution  $\sim 5\%$
- especially the PID information for particles on the relativistic rise depends on the gain calibration
  - systematic shift less than  $\sim 1\%$  (common for all pads)
    - e.g. due to the pressure change
  - pad-by-pad variation less than  $\sim 2\%$ 
    - e.g. chip-by-chip fluctuation

# Pulser calibration

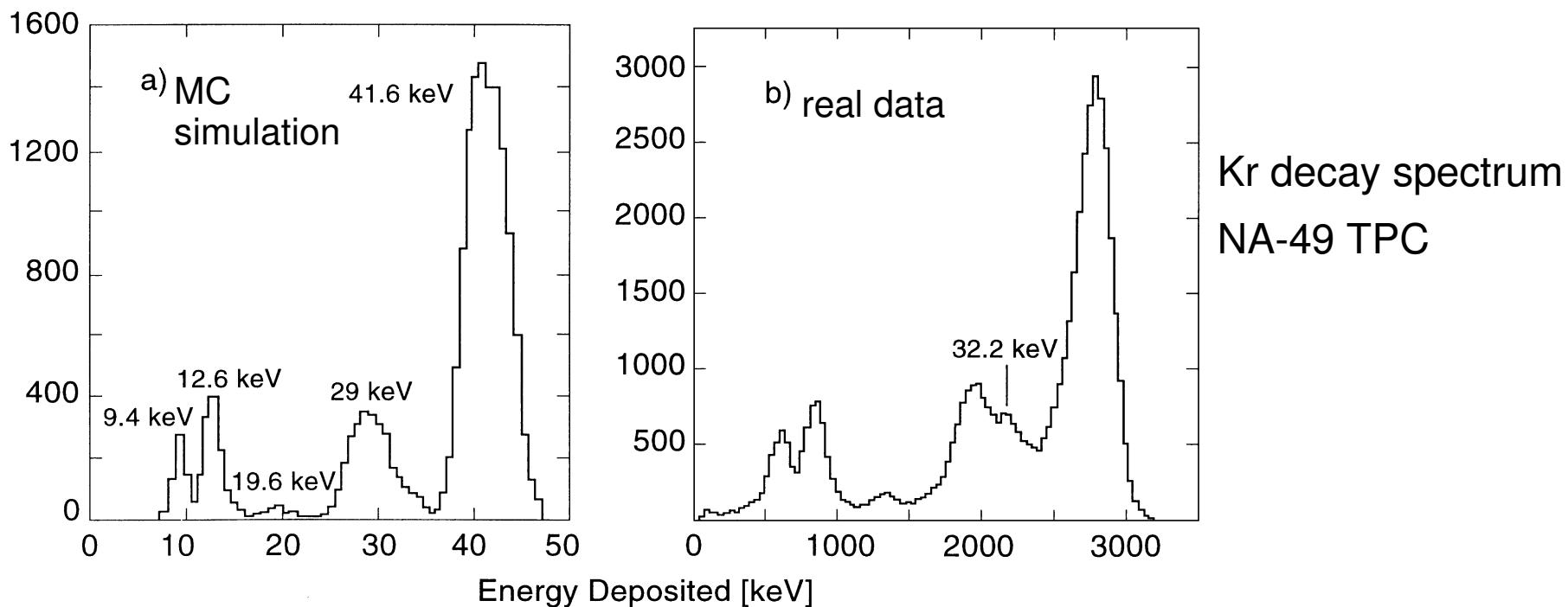
- the calibration pulser is used to scan the **electronic response** of the TPC
- the mean charge of the pulse and its time information for every pad are measured
  - the charge is normalized to the pad size
- 2 tendencies are observed
  - the dependence on the row position – ( $\sim 1\%$ )
  - variation from chip group to chip group ( $\sim 2\%$ )

# Pulser calibration: sector 70



# Krypton calibration (1)

- krypton calibration is used to scan the **response of the TPC**
  - the creation of krypton clusters is similar to the creation of clusters from real tracks
  - **not only the electronic response**



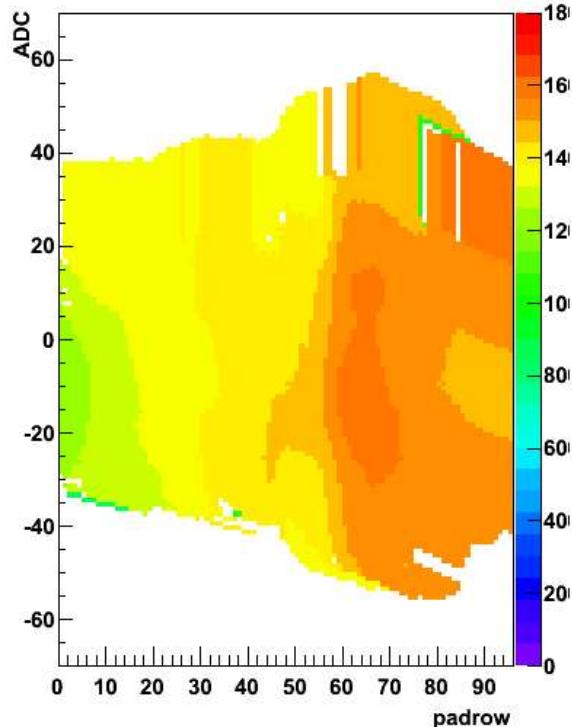
# Algorithm for the krypton calibration

- algorithm is divided into two parts
  - cluster finder
  - analysis – tuning of selection-criteria
- 3D cluster finder (Adam Matyja, Marek Kowalski)
  - accumulates the charge from several pads and time bins
  - the size is given by the range of the krypton electron
- analysis (current status):
  - spectrum is taken for several pads due to low statistics (requirement 1000 in clusters in spectra)
  - Gaussian is fitted to the 41.6 keV peak (fitted mean)
  - mean of the spectrum is also taken (spectrum mean)
- still work in progress
  - enlarge the range (problems with IROC and OROC short pads – charge not fully accumulated because of pad size)

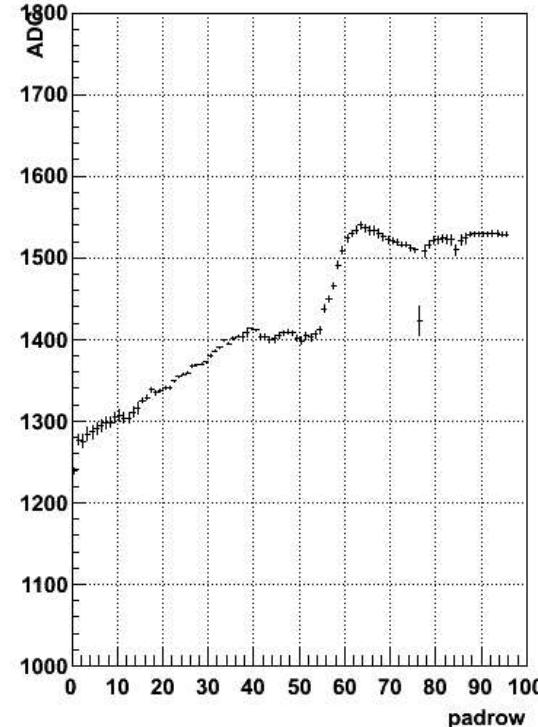
# Krypton calibration: 1<sup>st</sup> results

- ▶ 1<sup>st</sup> Krypton data for the ALICE TPC was taken 3 weeks ago

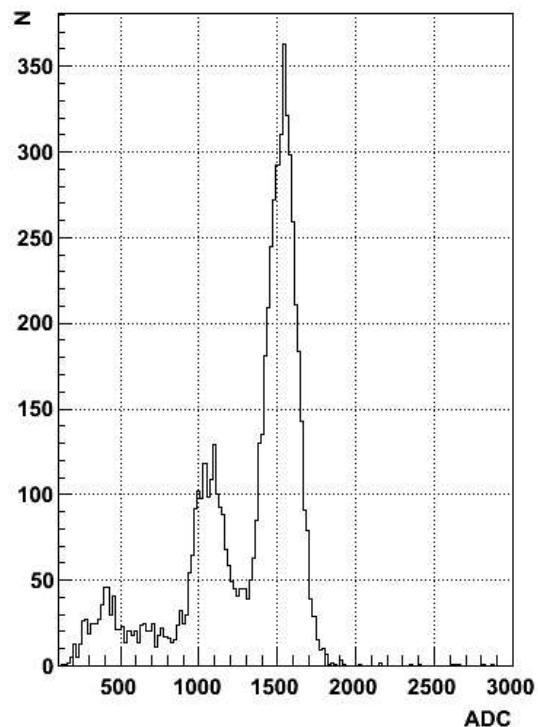
mean of fitted Gaussians for ROC 71



mean of fitted Gaussians vs. padrow for ROC 71

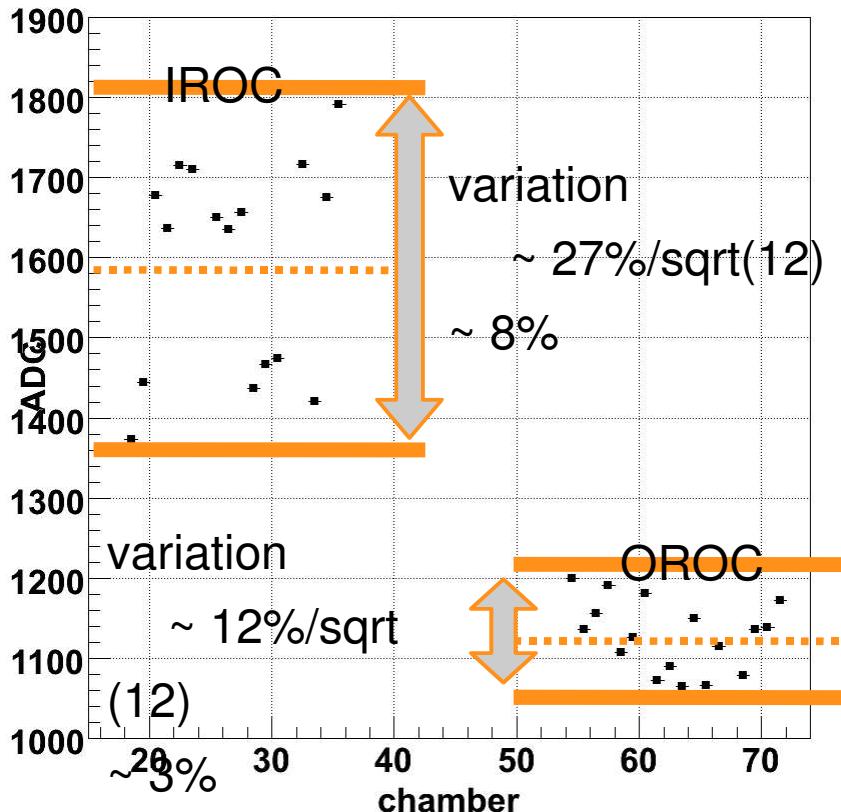


spectrum for rows 75-90, pads 45-85 in ROC 71

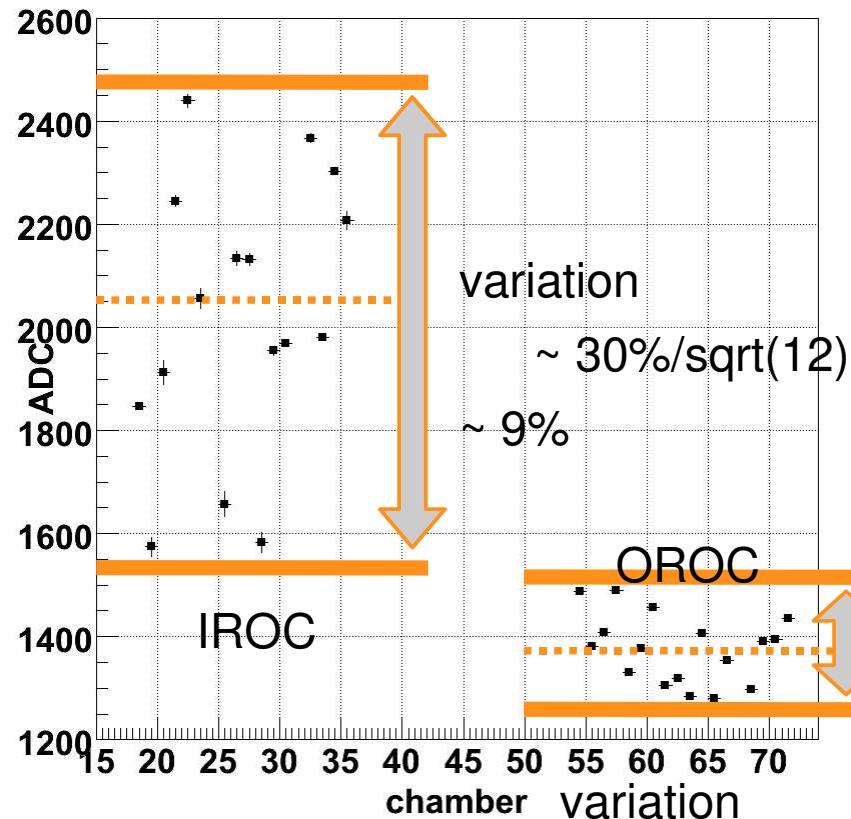


# chamber-by-chamber variations

mean of spectrum vs. chamber



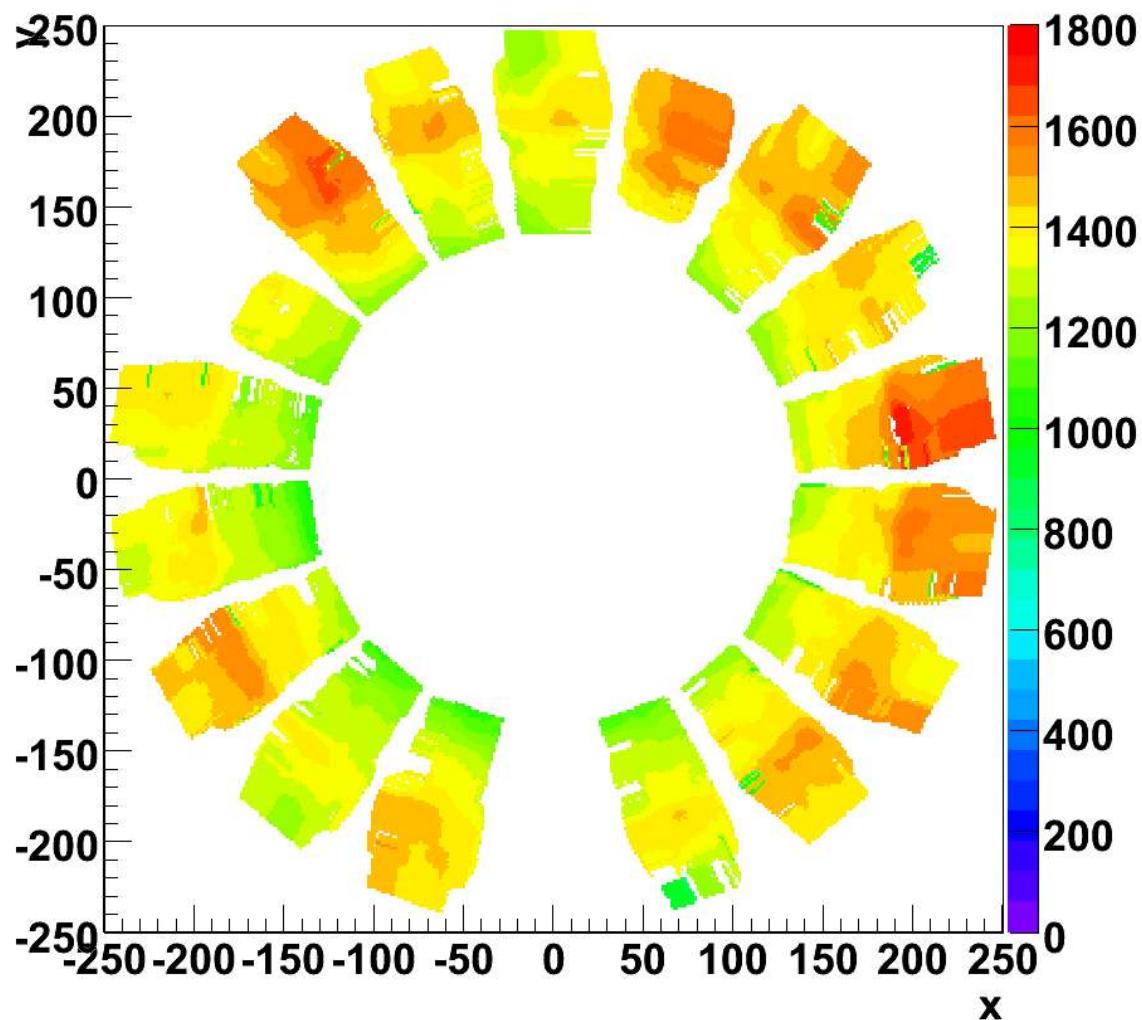
mean of fitted Gaussians vs. chamber



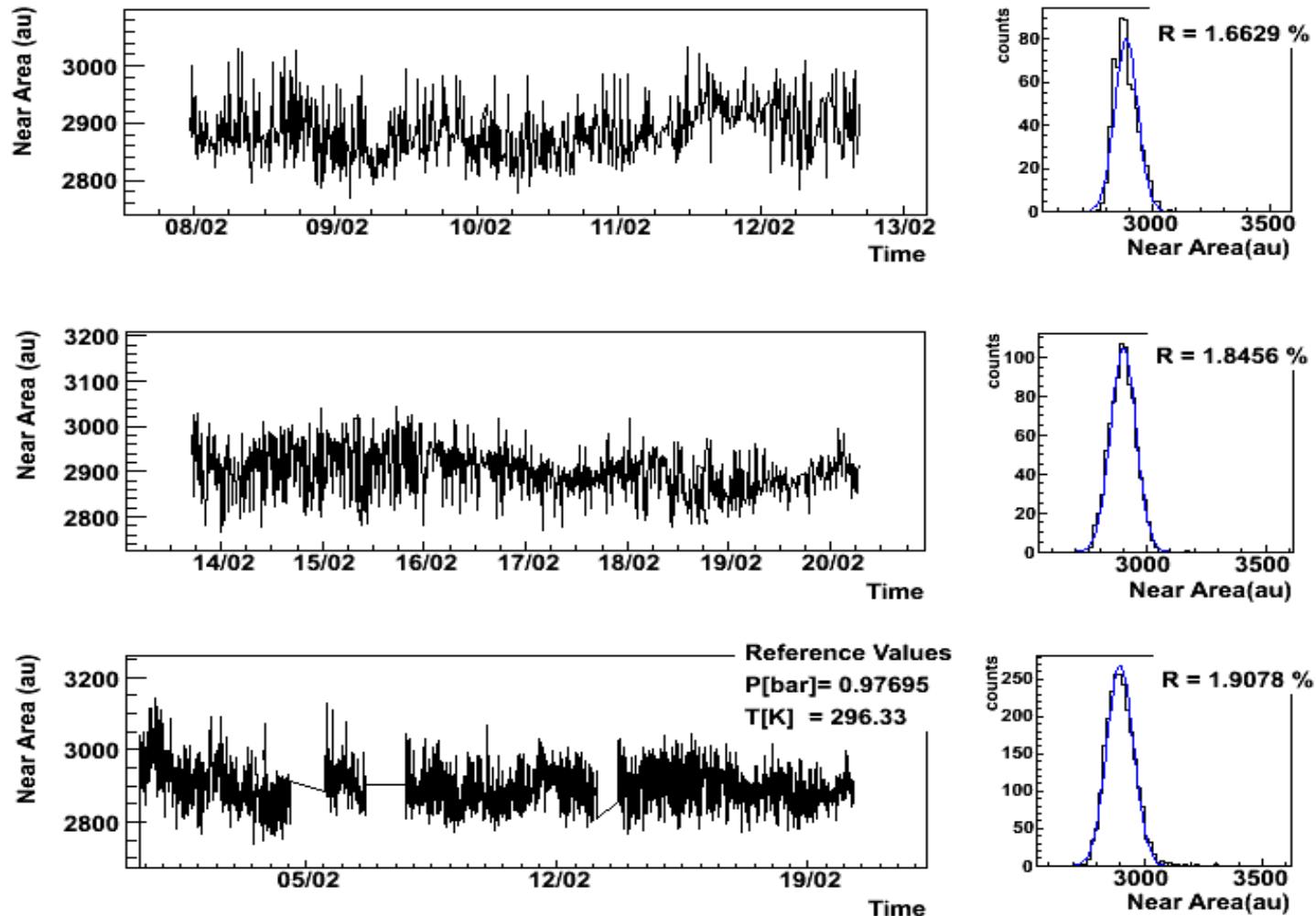
Note: all chambers at the same voltage

~ 15%/sqrt(12)  
~ 4%

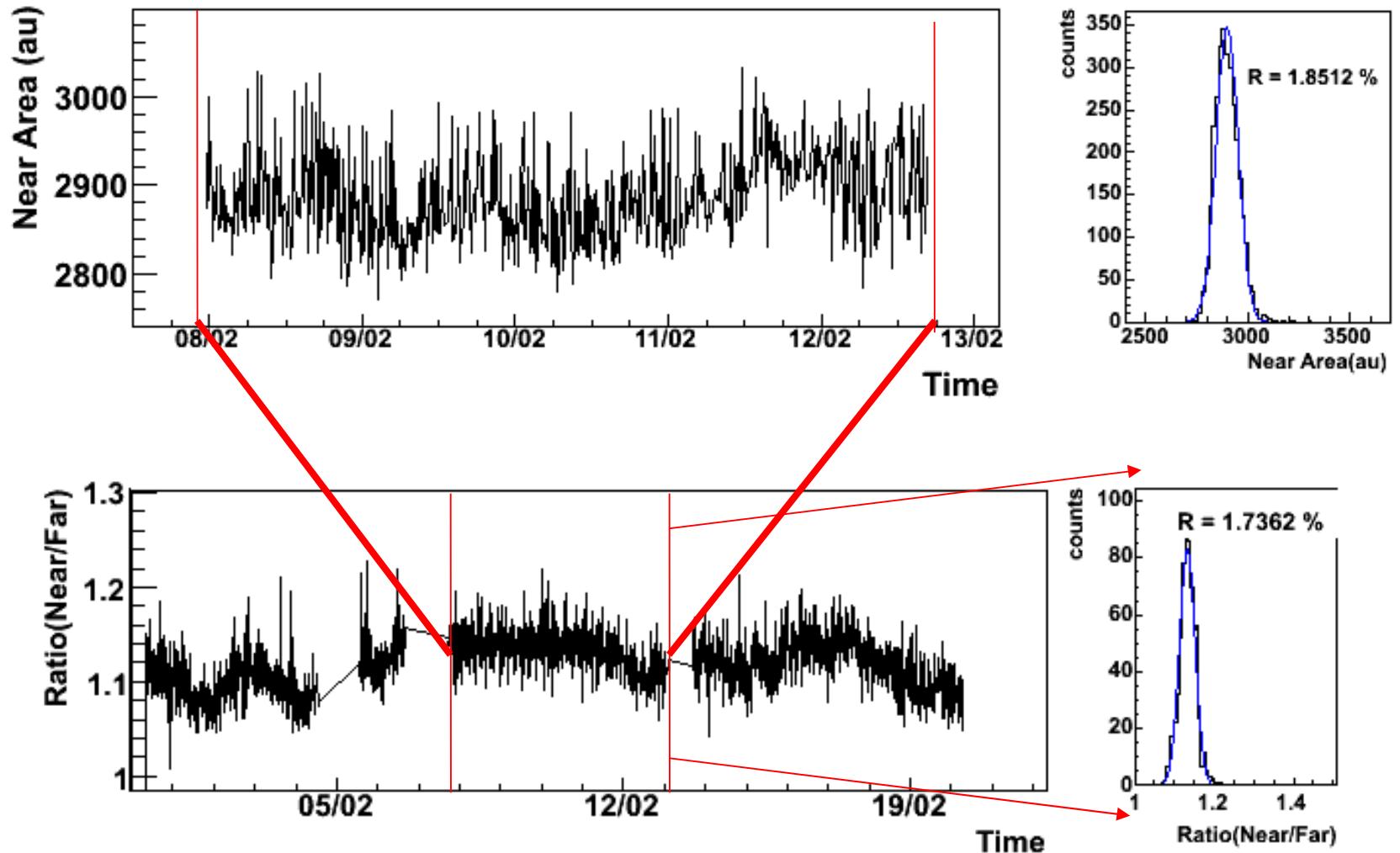
### mean of fitted Gaussians for OROCs



# Time dependence of the gain – gas quality system GOOFIE



# Gain resolution of the GOOFIE

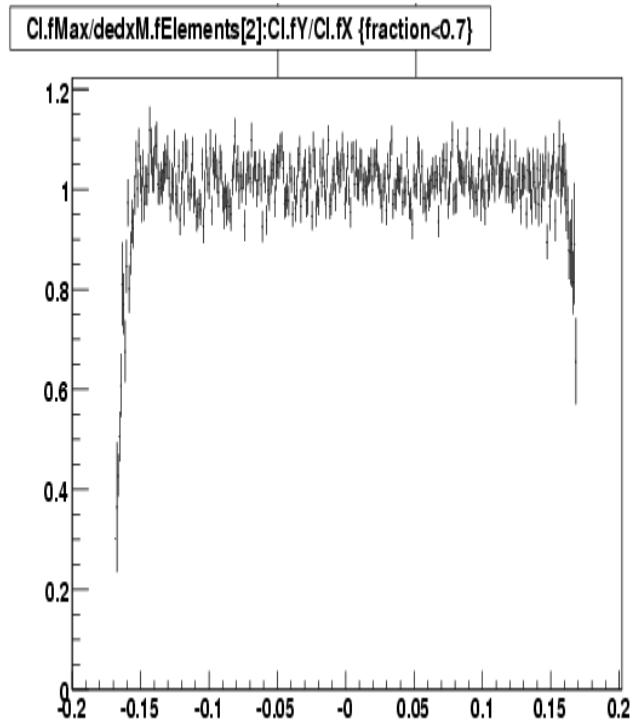


# Gain calibration using tracks (1)

- challenges for a gain calibration with pp or cosmic tracks:
  - mean amplitude at several positions ( $x, y, z$ ) is not only proportional to the gain
$$\overline{A(x,t)} \geq \overline{E_d(x)} > \overline{\langle G(x,t) \rangle}$$
  - the deposited energy  $E_d$  has a big influence
  - $E_d$  is particle (momentum) and angular dependent
- the influence of the energy deposit  $E_d$  can be removed using statistics of the ratios of amplitudes over the mean amplitude for a track; assuming track properties (momentum, angle) are constant along a track
$$\frac{\frac{E_d(x,t)}{\overline{E_d(x,t)}} \geq_{\text{track}} \zeta}{\frac{A(x,t)}{\overline{A(x,t)}} \geq_{\text{track}} \zeta} \cdot \frac{\overline{G(x,t)} \geq_{\text{track}} \zeta}{\overline{\langle G(x,t) \rangle} \geq_{\text{track}} \zeta} = \zeta$$

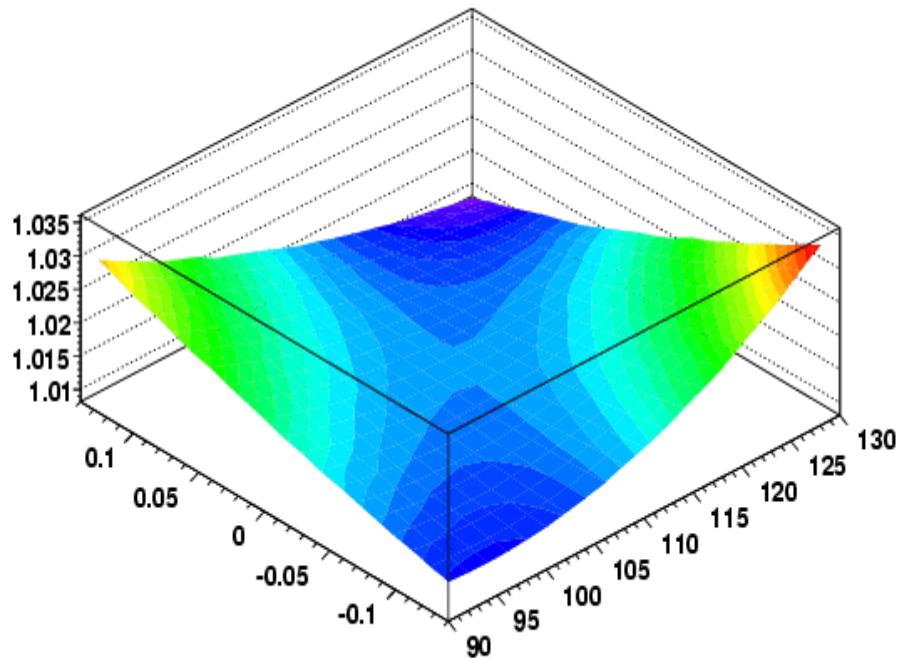
# Gain calibration using tracks (2)

- remove edge effect
- normalize signal to the mean signal over track segment
- perform 3 D parabolic fit

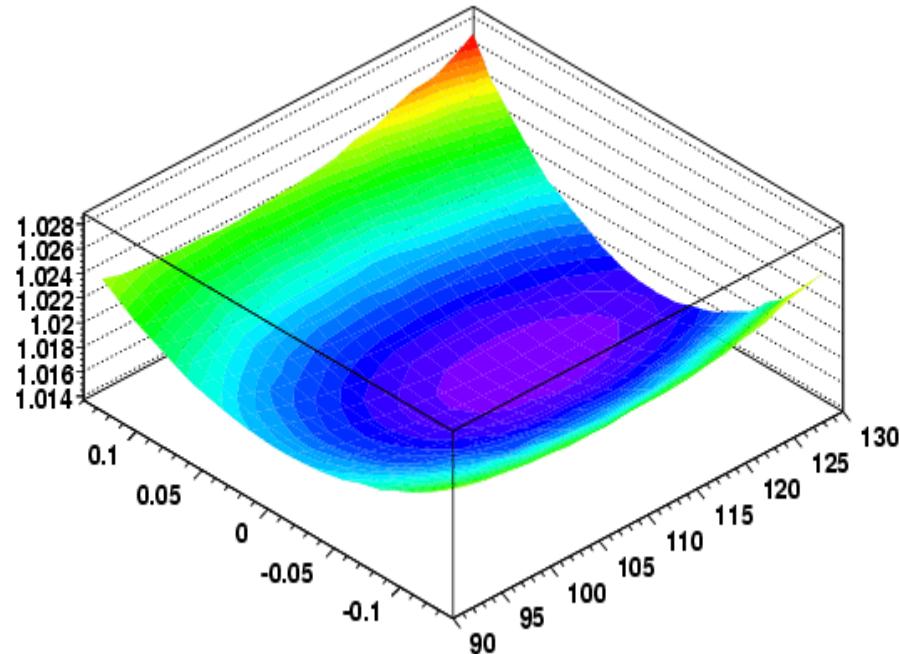


# Gain calibration using tracks (3)

normqt0:Cl.fY/Cl.fX:Cl.fX {IPad==0}



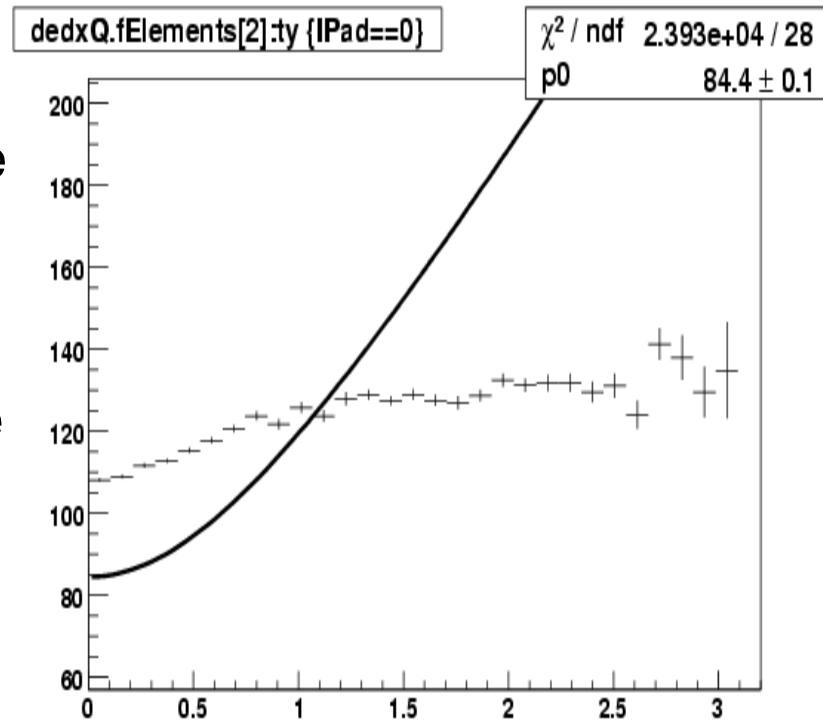
normqt0:Cl.fY/Cl.fX:Cl.fX {IPad==0}



- obtained gain function
  - left side: statistic – ntracks  $\sim 500$  (2 % min-max difference)
  - right side: statistic – ntracks  $\sim 2000$  (1% min-max difference)

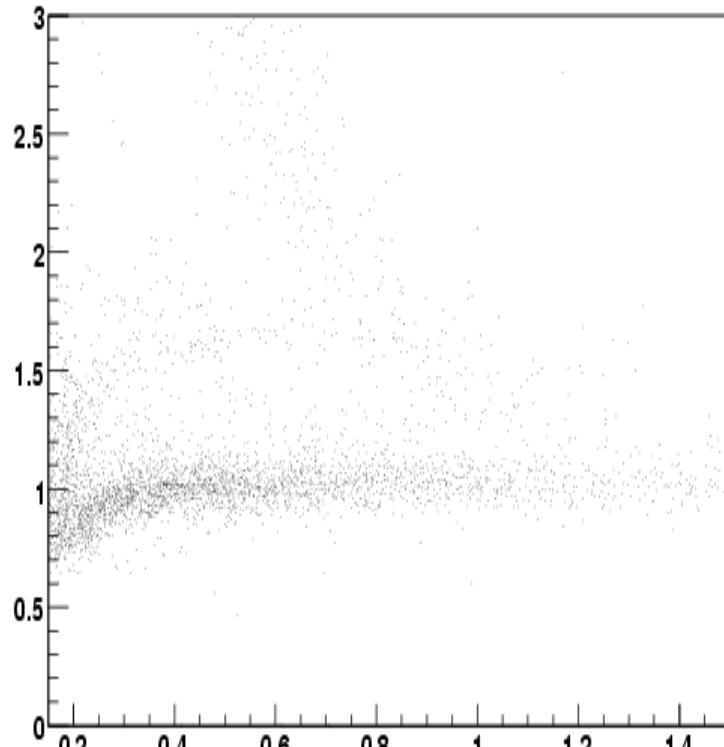
# Calibration of the energy deposit (1)

- for a  $dE/dx$  measurement the energy deposit  $dE$  must be normalized to  $dx$
- the energy deposit ( $Q_{max}$ ) does not scale with the tracklet length
  - $\sqrt{1 + \tan(\text{angle})^2}$
- the charge integration is influenced by the threshold effect
- 2 possible solutions
  - make a 2-dim fit of cluster (needs track angles as input parameters)
  - correct for effect in 3D ( $tany$ ,  $tanz$ ,  $z$ )

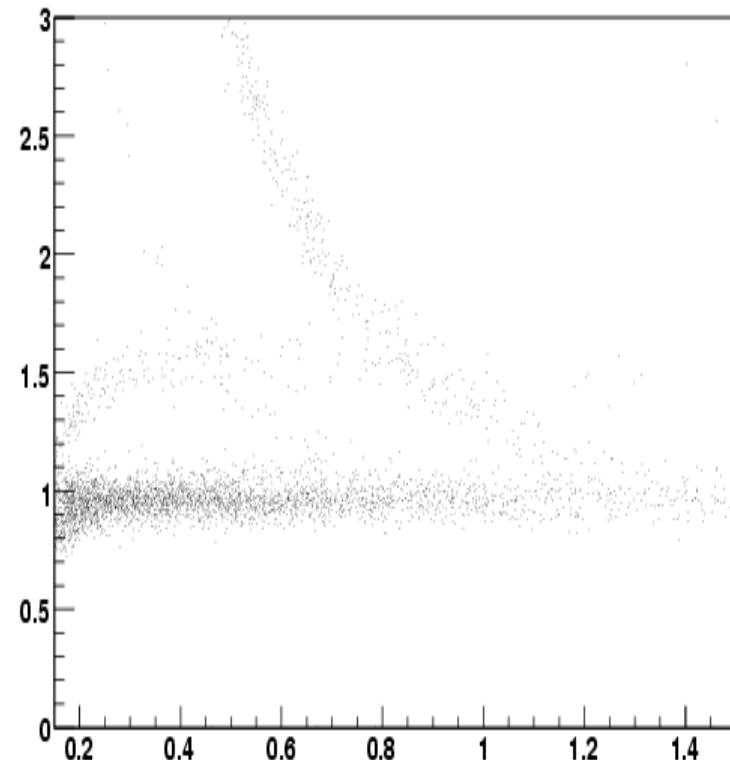


# Calibration of the energy deposit (2)

Track.fEdx/(Track.BetheMass(0.1396)\*47.):Track.P() {Track.tN>100}



Track.CooldEdxNorm(0,0.7,0,0,160)/(Track.BetheMass(0.1396)):Track.P() {Track.tN>100}



- $dEdx / dEdx_{\text{theoretical}} (\pi \text{ mass})$  as a function of the particle momentum
  - left side – using  $\sqrt{1+tan^2 y}$  correction (current aliroot)
  - right side – using fitted correction (to be committed)

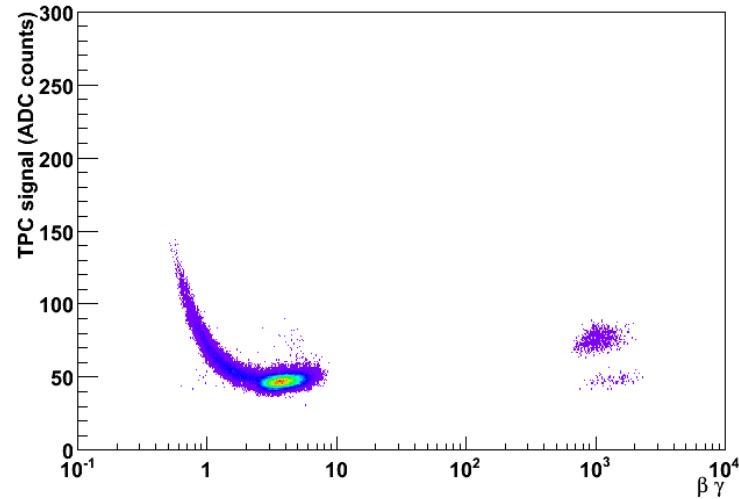
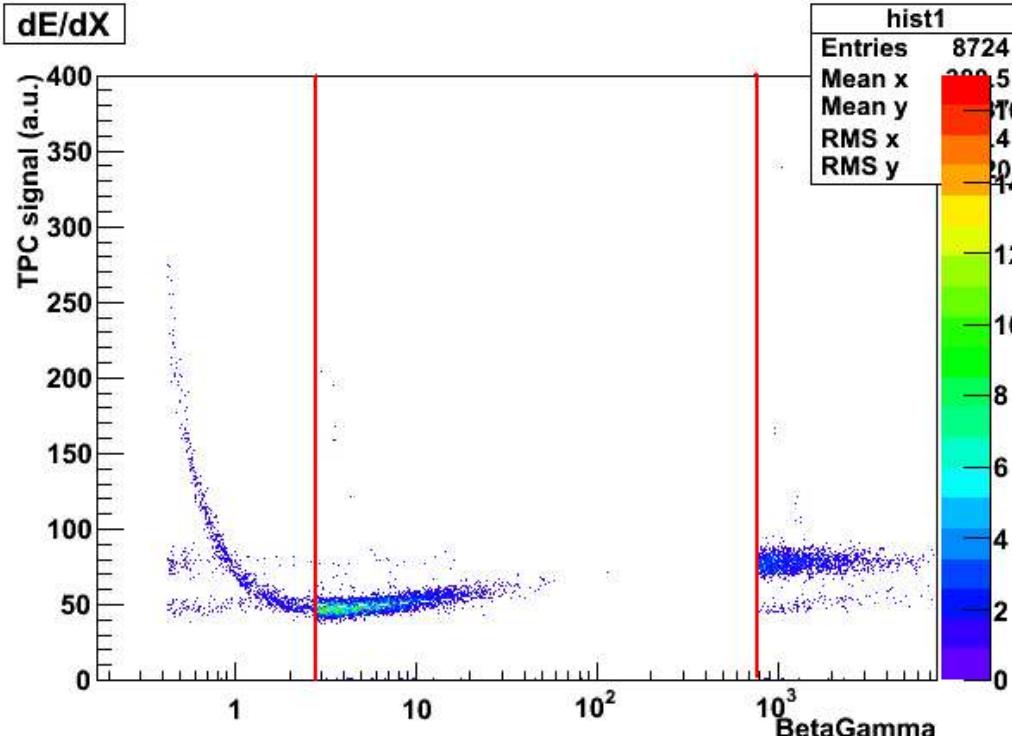
# PID calibration (1)

- select a pure sample of particles **without** using the energy loss information of the TPC
  - V0 decays: K0s, Lambda, Gamma conversions
  - TOF ?
- determine the Bethe-Bloch function (fit) and dE/dx resolution
  - based on ALEPH function
  - sophisticated fit procedure: outliers, complicated function

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

# PID calibration (2)

Algorithm should work stable with roughly 100,000 events

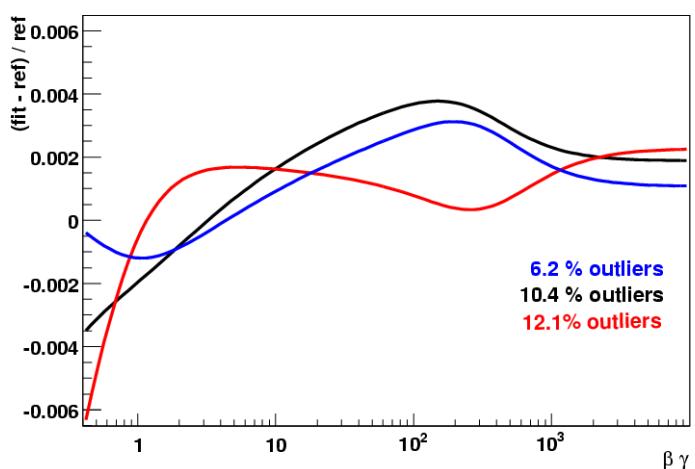
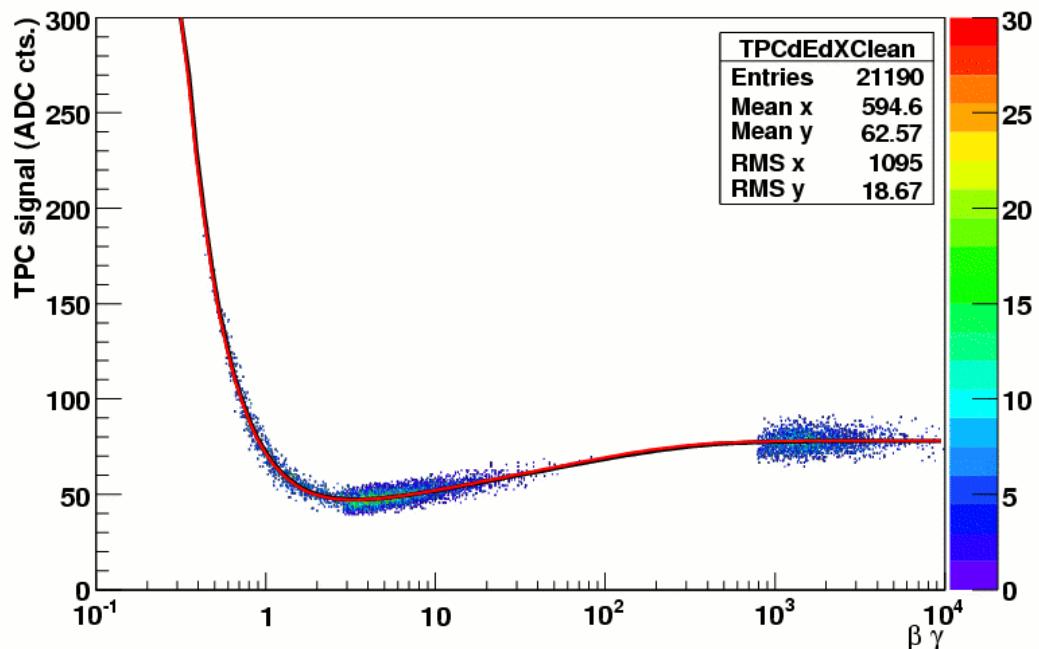


TOF standalone (preliminary):  
smaller acceptance

V0 decays: protons, pions, electrons  
cover different regions (3% outliers)

# PID calibration results

- Spectrum selected with V0s is clean enough for a stable fit (implementation into AliRoot within the next weeks)



# Summary of the calibration strategy

- Krypton calibration once per year
- time dependence of the gain using the GOOFIE, simple multiplication (to be performed on the  $dE/dx$  level)
- verify algorithms for calibration using tracks with the Krypton calibration (until now only verification using MC data)
- calibration using tracks as a quality assurance - in case of mismatch between gains we perform new Krypton calibrations

# Summary table – status for 1<sup>st</sup> physics

	<b>requirement</b>	<b>without calibration</b>	<b>day 0</b>
<b>spatial</b>	2%	4% OROC 9% IROC	2% (chip-by-chip)
<b>time dependence</b>	1%	2.7%	1.2%

# Backup slides

# Gain calibration using tracks (1)

## 1 Alice TPC gain calibration

The detector response ( $A(x,t)$ ) to the particle deposit is a random variable. This variable is position and time dependent. The response can be written as product of the energy deposit ( $E_d$ ) and gain function ( $G(x,t)$ ).

Averaging the detector response over the many particles we can get the mean gain function at given position at some time interval. The systematic uncertainty of such estimate is given by the uncertainty of energy deposit function. The importance of the energy deposit influence can be demonstrated in figure 1.

$$A(x,t) = E_d(x)G(x,t) \quad (1)$$

$$\langle A(x,t) \rangle = \langle E_d(x) \rangle \langle G(x,t) \rangle \quad (2)$$

$$\langle G(x,t) \rangle = \frac{\langle A(x,t) \rangle}{\langle E_d(x) \rangle} \quad (3)$$

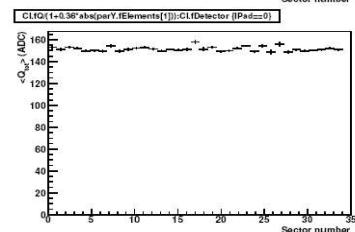
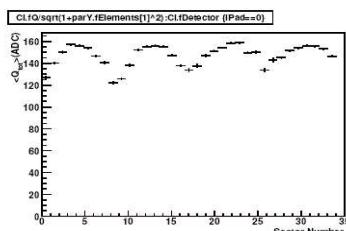
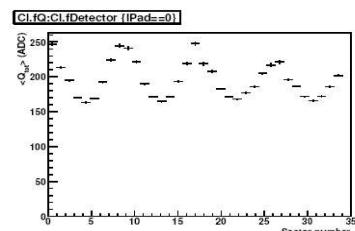


Fig. 1. Cosmic simulation. The mean amplitude at different sectors of the TPC. The gain factor is the same in all sectors. a.) Raw mean amplitude b.) Amplitude normalized to the track length c.) Amplitude normalized to the angle (simple linear parameterization)

The mean amplitude at different x,y,z position is not proportional to the gain

The unknown energy deposit make a big influence

The influence documented on the cosmic MC data

# Gain calibration using tracks (2)

The gain function is product of the gas gain function ( $G_g(x,t)$ ), coupling function (Pad Response function (PRF)), electronic gain ( $G_{chip}$ ) and attenuation

loss ( $A_{att}$ ).

$$G(x, t) = A_{att}(x, t)G_g(x, t)G_{coupling}(x)G_{chip}(x) \quad (4)$$

In the ALICE TPC, the gas gain function  $G_g(x, t)$  and coupling function ( $G_{coupling}$ ) are usually smooth function of the position which are given mainly by distance between the pads and wires. The time dependence of  $G_g(x, t)$  is given mainly by the time variation of the pressure. The other variables will be controlled on the level  $\leq 1\%$ .

The attenuation function is given mainly by electron attachment, it is drift length dependent - exponential decay. The decay length depends on the admixture of the electronegative molecules in the gas. The concentration of these admixtures is time dependent, therefore its decay length should be regularly controlled.

The electronic gain ( $G_{chip}$ ) is determined by the tolerance (...). In ALICE TPC the variation is on the level of  $\sigma \approx 1\%$ . The grouping on the chip level is observed. (need picture 1D and 2D).

The energy deposit ( $E_d$ ) is given by the type of the particle (mass), their local properties (momenta, pad length, tracklet orientation ( $\phi$  and  $\theta$ )).

$$E_d(x) = E_d(m, p(x), l(x)) \approx k \frac{dE}{dx}(\beta\gamma)L(\text{padlength}, \phi, \theta) \quad (5)$$

The mean energy deposit  $\langle E_d(x) \rangle$  can strongly differ for different physical cases (cosmic, beam-beam interaction).

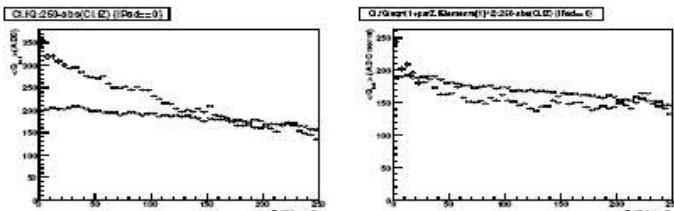


Fig. 2. Mean total charge as function of z for cosmic topology and for pp events. Before and after normalization to the local inclination angle.

The energy deposit is particle and angular dependent

Example, mean amplitude as function of z - comparison of the pp event and cosmic (MC) data

# Gain calibration using tracks (3)

The gainfunction is given as ratio of the mean detector response ( $A(x,t)$ ) and mean energy deposit  $E_d(x)$ . The  $E_d(x)$  can be eliminated, under assumption

that the track properties (momenta, angle) are constant along the track.

$$\frac{A(x,t)}{\langle A(x,t) \rangle_{track}} = \frac{E_d(x)}{\langle E_d(x) \rangle_{track}} \frac{G(x,t)}{\langle G(x,t) \rangle_{track}} \quad (6)$$

Having the analytical model of the gain as function of position the mean gain along the track trajectory can be calculated. In case of the Alice TPC we will assume that the gain can be approximated by parabola (x,y,z coordinates). The mean gain than can be calculated integrating the parabola over track trajectory.

The influence on the energy deposit  $E_d$ , can be removed using statistic of the ratios of amplitudes over the mean amplitude for track

# Gain calibration using tracks (4)

- Cluster - Gaussian shape

$$f(t, p) = K_{Max} \cdot \exp \left( -\frac{(t - t_0)^2}{2\sigma_t^2} - \frac{(p - p_0)^2}{2\sigma_p^2} \right) \quad (7)$$

$K_{Max}$  - normalization factor and maximal value of cluster charge

$t, p$  - time and pad bins

$t_0, p_0$  - center of cluster

$\sigma_t, \sigma_p$  - sigma of time and pad cluster distribution

- Total charge  $N_{ch}$  in cluster :

$$N_{ch} = \int_{-\infty}^{\infty} f(t, p) dt dp = K 2\pi \sigma_t \sigma_p \quad (8)$$

$$K_{Max} = \frac{N_{ch}}{2\pi \sigma_t \sigma_p} \quad (9)$$

- Effective area  $s_{eff}$  of cluster : area of elipsa given by threshold th

$$s_{eff} = 2\pi \sigma_t \sigma_p \ln \left( \frac{K_{Max}}{th} \right) \quad (10)$$

The dependence of the mean total amplitude of the cluster and mean maximal charge amplitude depends on the cluster shape

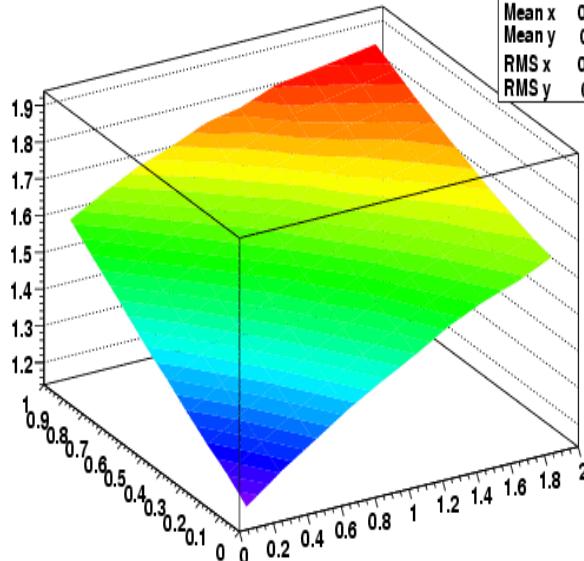
The shape is determined by the cluster z position and

2 track inclination angles



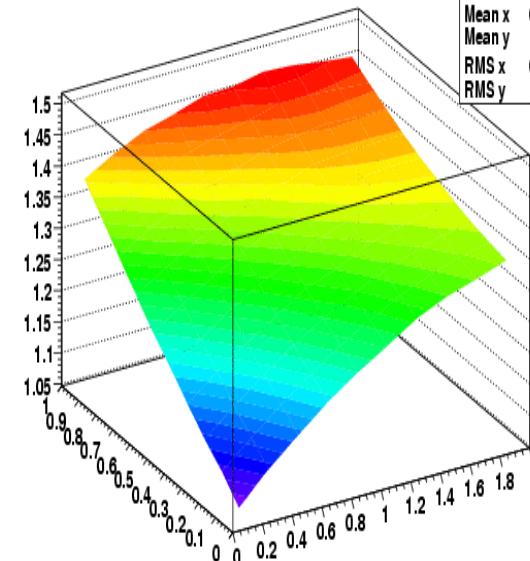
# Calibration of the energy deposit (2)

AliTPCClusterParam::SQnorm(0,1,0,ty,tz)/64:tz:ty



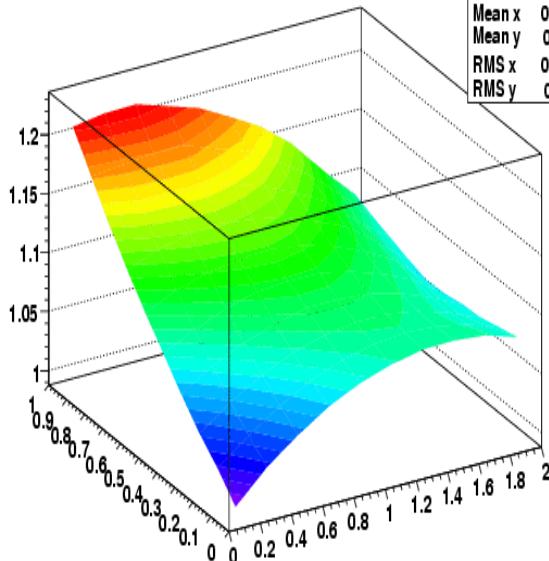
his  
Entries 10000  
Mean x 0.5662  
Mean y 0.3191  
RMS x 0.4872  
RMS y 0.2411

AliTPCClusterParam::SQnorm(0,1,0.5,ty,tz)/64:tz:ty



his  
Entries 10000  
Mean x 0.5662  
Mean y 0.3191  
RMS x 0.4872  
RMS y 0.2411

AliTPCClusterParam::SQnorm(0,1,1,ty,tz)/64:tz:ty



his  
Entries 10000  
Mean x 0.5662  
Mean y 0.3191  
RMS x 0.4872  
RMS y 0.2411

- the energy deposit as function of the inclination angle at 3 different z position