Gain Calibration of the ALICE TRD using the Decay of ^{83m}Kr by Internal Conversion

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IRTG Application Seminar

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Outline

1. Motivation
2. The ALICE Experiment
   - The ALICE Transition Radiation Detector
1. The ^{83m}Kr-Decay for Calibration
2. Experimental Setup & Data Taking
3. Analysis
   - The Kr Cluster Finder
   - Fitting the Data
   - Gain Factor Analysis
   - Energy Resolution Measurement
   - Correlations between Gain and High Voltage
1. Summary & Outlook

Motivation

- ALICE studies strongly interacting matter at extreme energy densities in high-energy nuclear collisions
- ALICE Transition Radiation Detector (TRD) provides:
  - Track reconstruction of charged particles
  - e^-/e^+ identification
  - Fast trigger (7 μs)

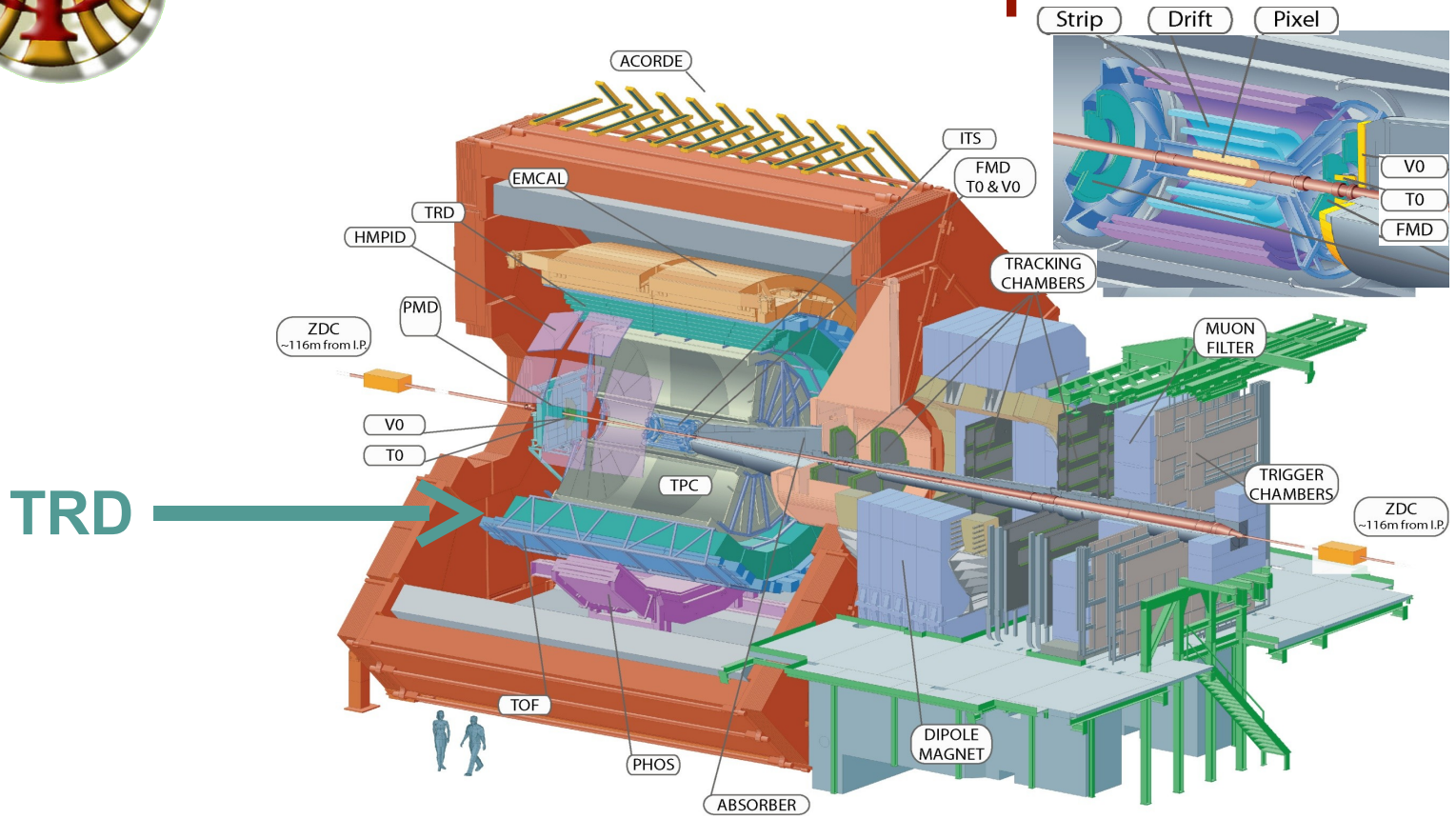
    $\rightarrow$2 μs drift + online tracking and particle identification
- Particle identification demands gain uniformity of

  Δ_{Gain} <1 % (10 % rel. change in Pion suppression)
- Information on mean energy loss of a particle is essential
  - Gain fluctuations with…

    … Chamber geometry

    … Pad-by-pad variations

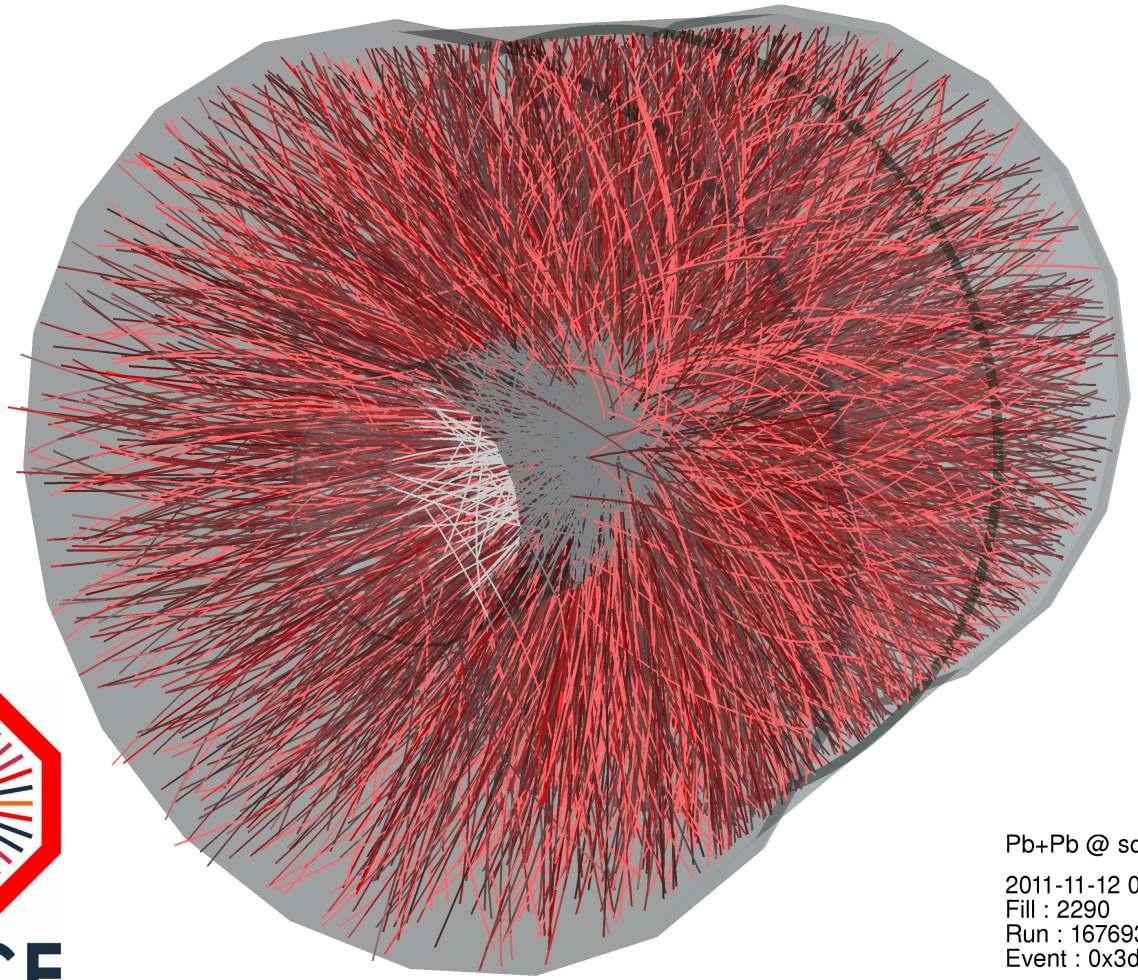
The ALICE Experiment



- 18 subsystems
- 16 x 16 x 26 m
- 10.000 tons

- TPC+ITS+TRD: 645 million pixel
- Readout: 17.5 TB/s
  - PbPb: 1.2 GB/s to tape
  - pp: 100 MB/s to tape

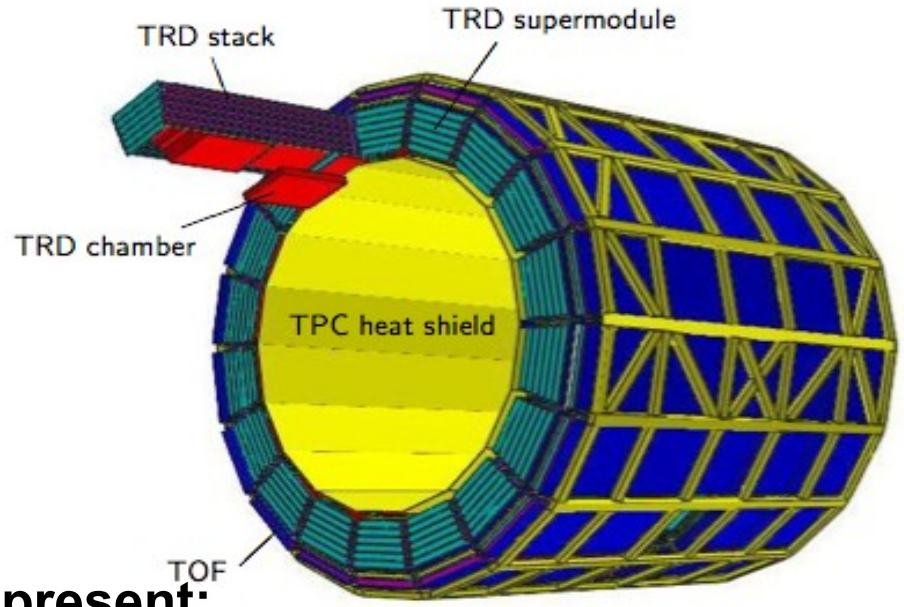
ALICE Event Display



Pb+Pb @ sqrt(s) = 2.76 ATeV

2011-11-12 06:51:12
Fill : 2290
Run : 167693
Event : 0x3d94315a

The ALICE TRD



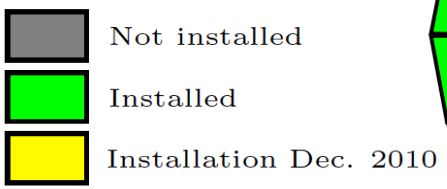
- 18 super modules
- 522 TRD chambers
- 5 stacks along z-axis
- 6 layers covering 2.9 < r < 3.7 m
- -0.9 < η < 0.9 (7 m long)
- 1.15 million readout pads

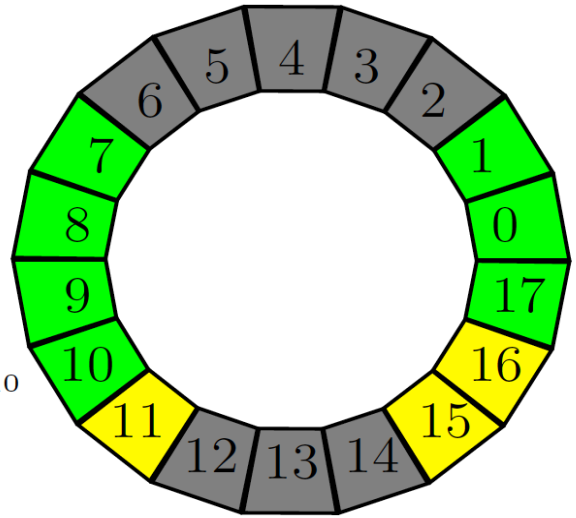
At present:

- 7 super modules installed before 2010
- 3 new super modules installed in December 2010

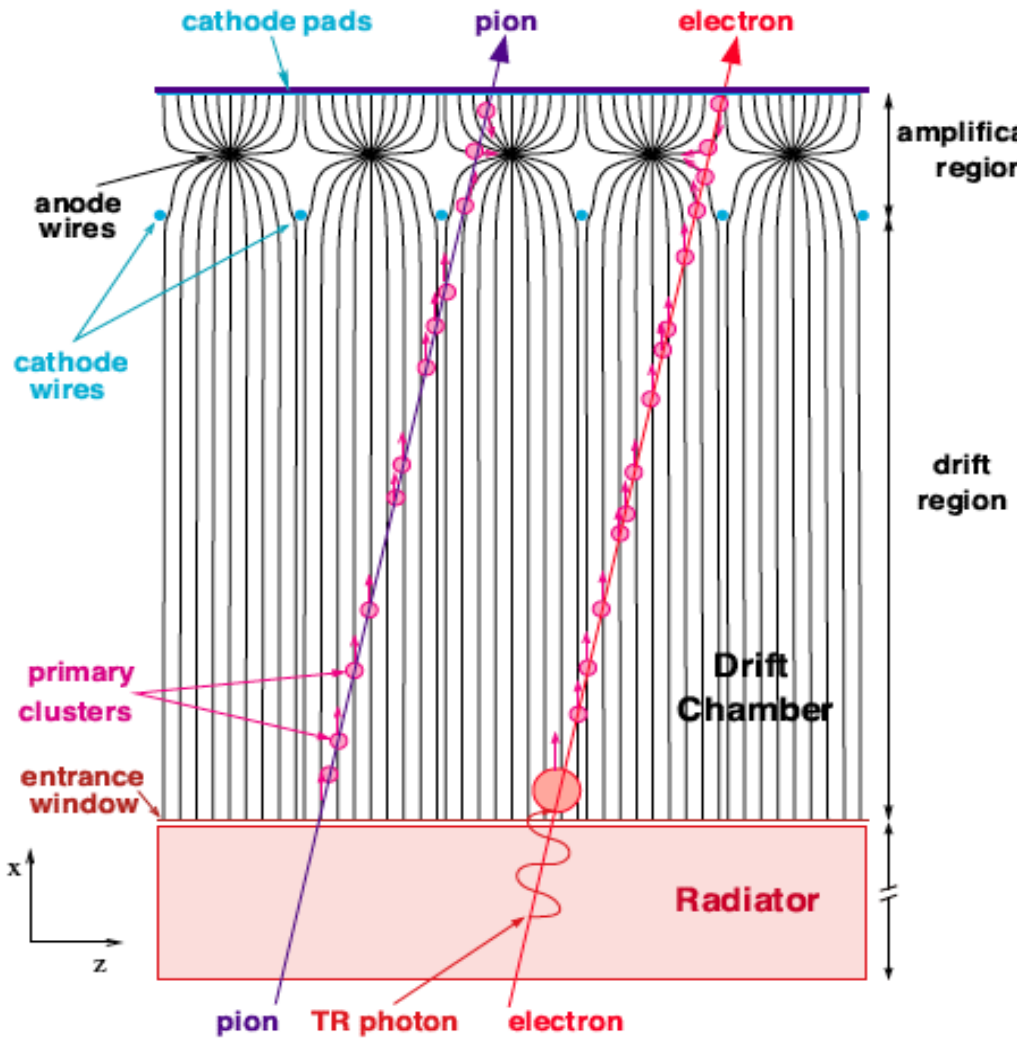
Near Future:

- Installation of 3 more supermodules
- Remaining 5 after end-of-run (end of 2012)

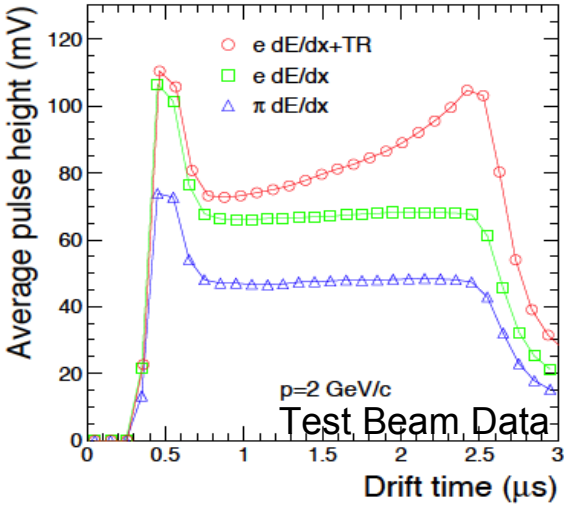




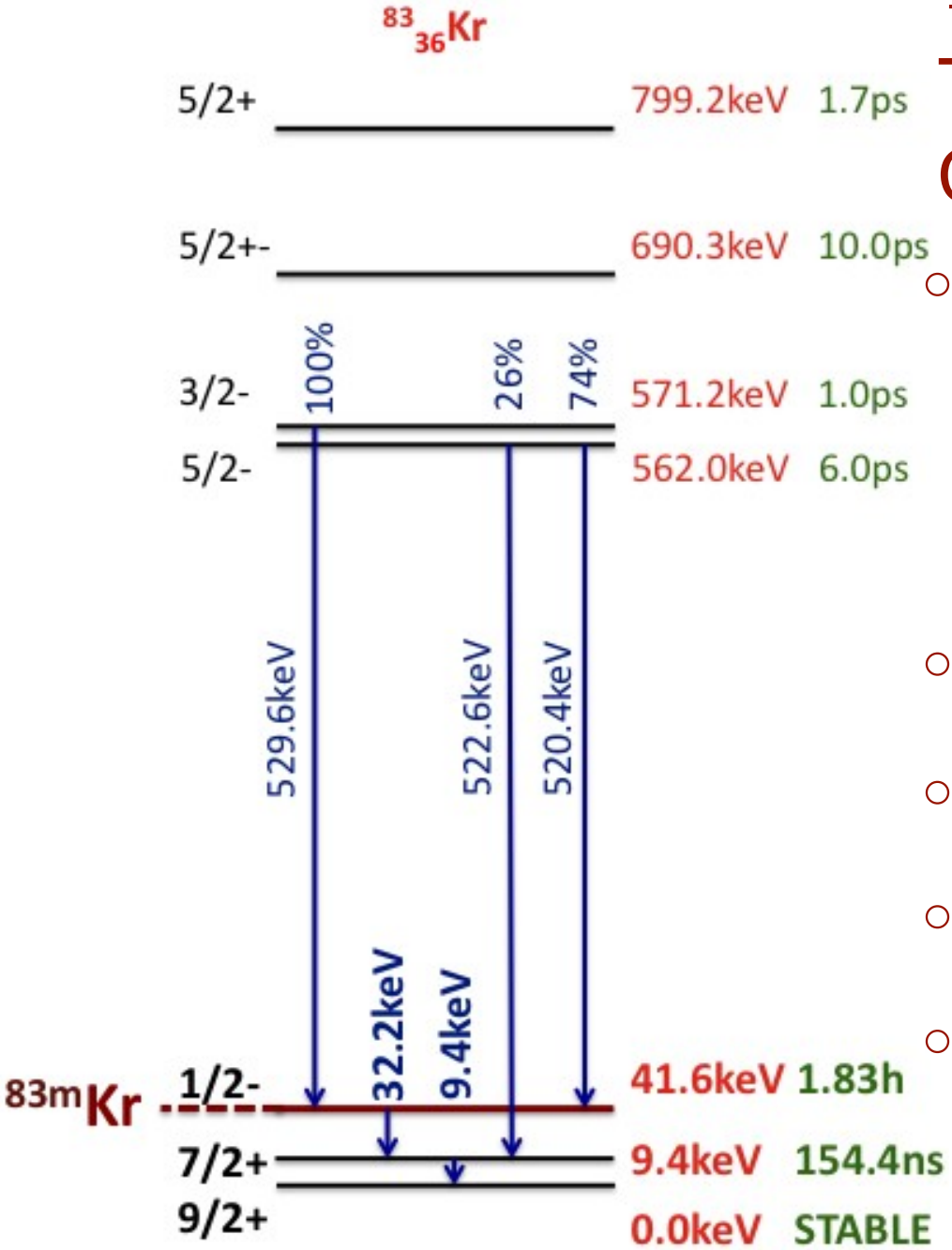
The TRD Chamber



- **Radiator**
  - Rohacell foam + glass fiber
- **Multi-wire proportional chamber + drift region**
  - Operated at 1530 V
  - Gas gain of ~3250
  - Xe-CO_2 [85-15]

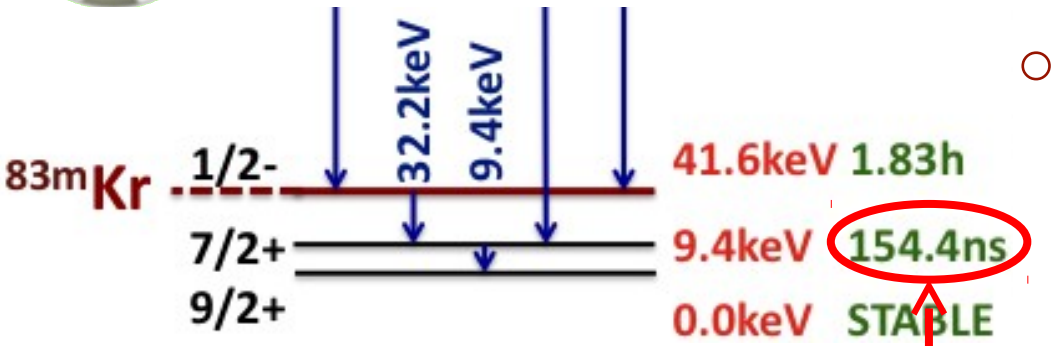


The ^{83m} Kr-Decay for Calibration



- ^{83m} Kr-Decay by internal conversion ideal candidate
  - $t_{1/2}$ =1.83 h
  - Covers same energy range as minimum ionizing particles in Xe-CO_2 [85-15]
- 75.14 %: $^{83}_{37}$Rb decays via electron capture into ^{83m} Kr
- Most prominent: Cascade decay of 41.56 keV and 9.41 keV levels
- ^{83}Rb-source can be simply (dis-)connected to gas flow
- About 3 half-lives after disconnection: Almost no activity left within active gas volume

The 83mKr Decay Spectrum



- Internal Conversion (IC):
  - *Nucleus*-e^- Interaction
  - e^- emitted

  (and X-ray + Auger-e^-)

Most prominent:

41.6 keV: Cascade Decay

1.32.2 keV

IC-e^- from K,L,M,N-shell

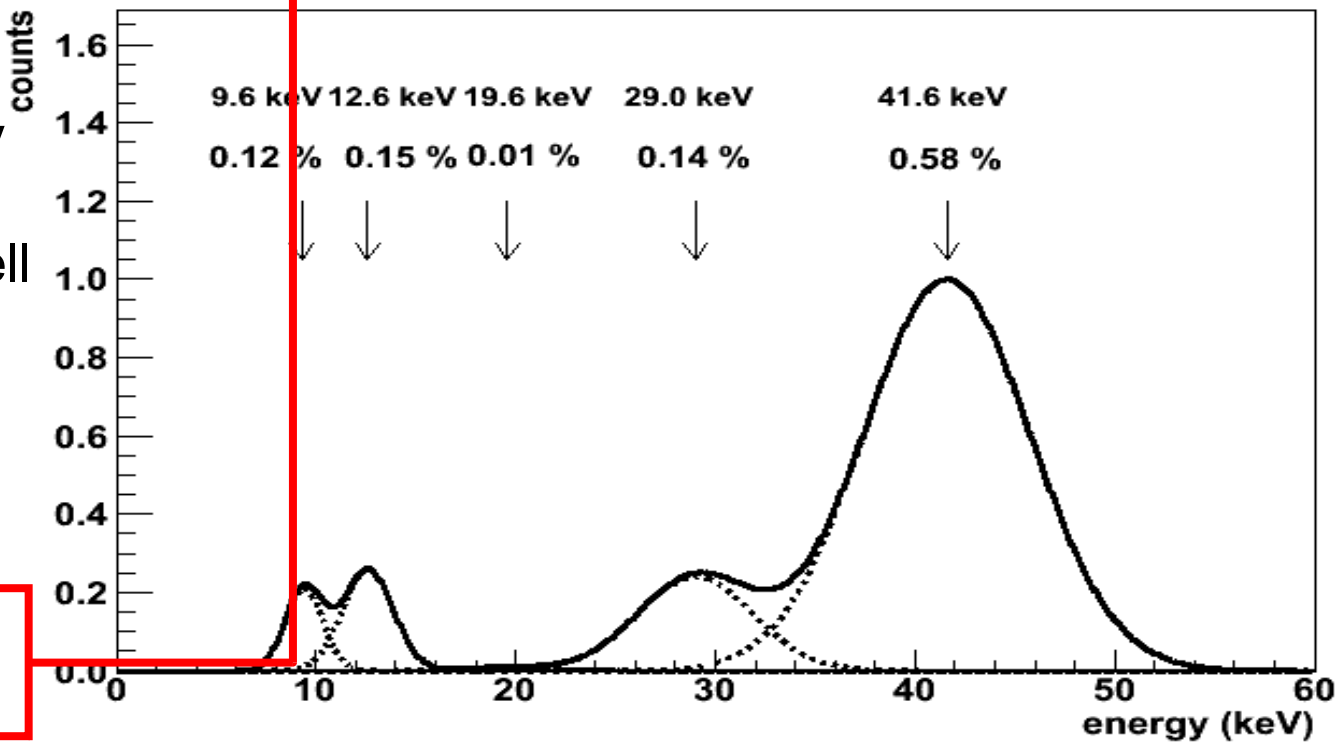
Auger-e^-

1.9.4 keV

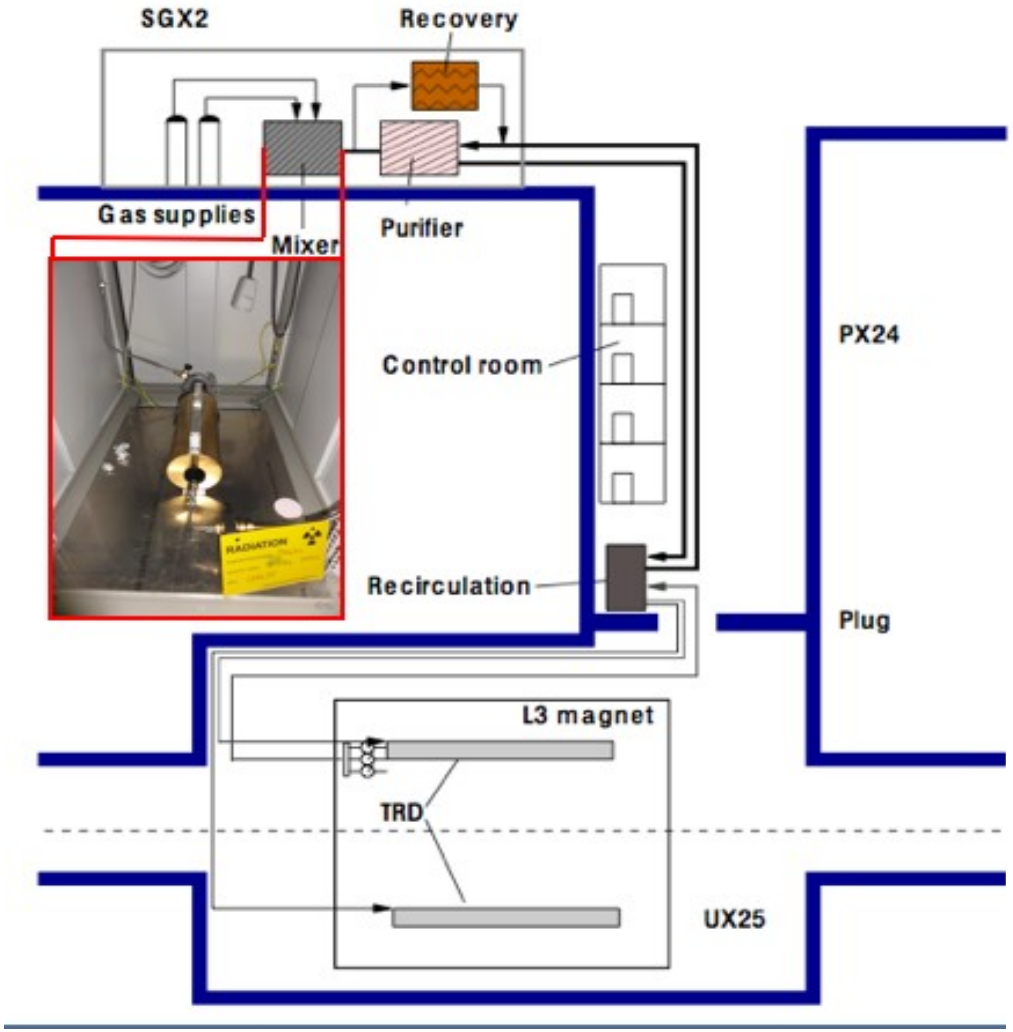
IC-e^- from K-shell<

Auger-e^-

BUT:
Seen as single decay!

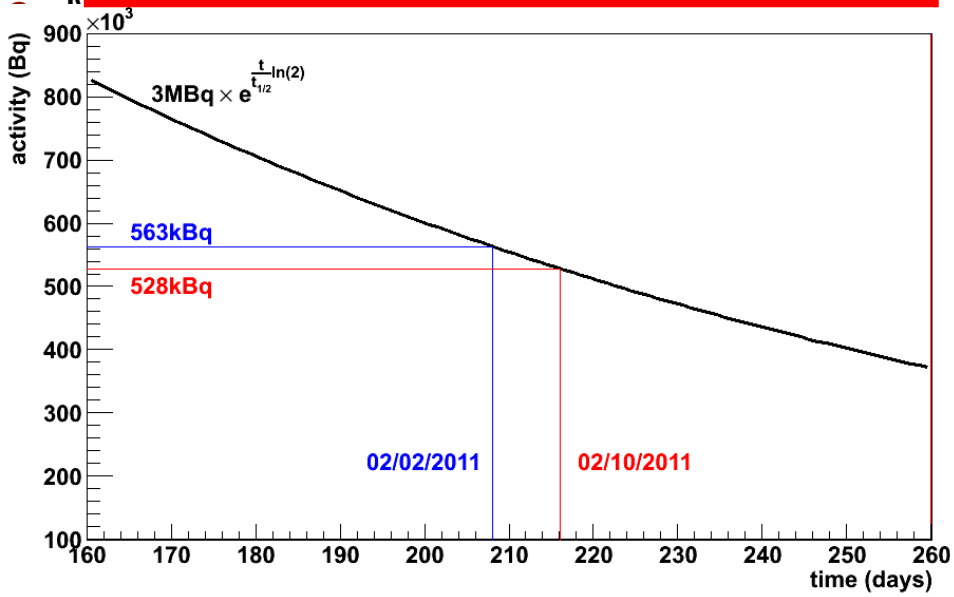


Experimental Setup & Data Taking

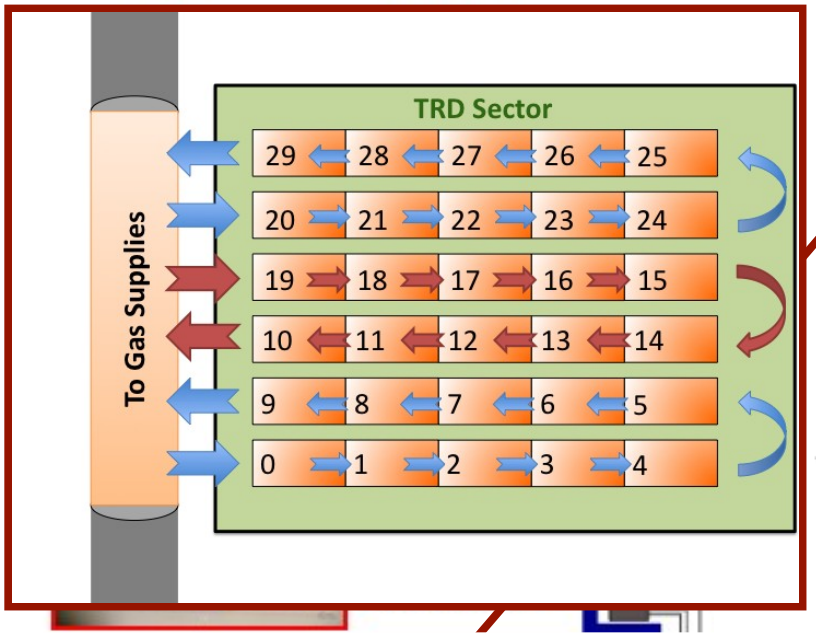


- Data taking between Feb. 2 and 10, 2011
  - 134 runs ≈ 2.3x10^9 Kr decays with HV=+1530V (Gain≈3250)
  - 13 runs with HV=+1490V (Gain≈2260)

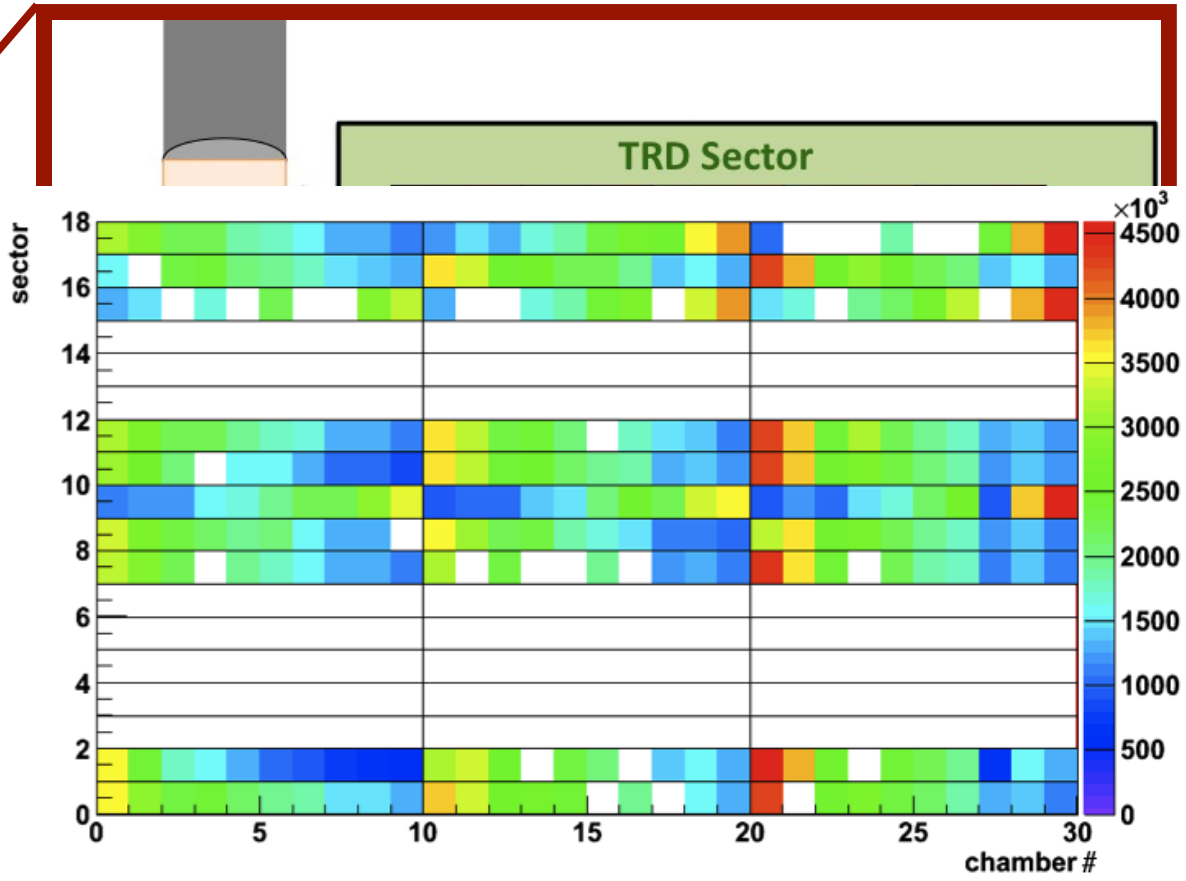
1-2 Krypton decays per recorded event



TRD Gas System

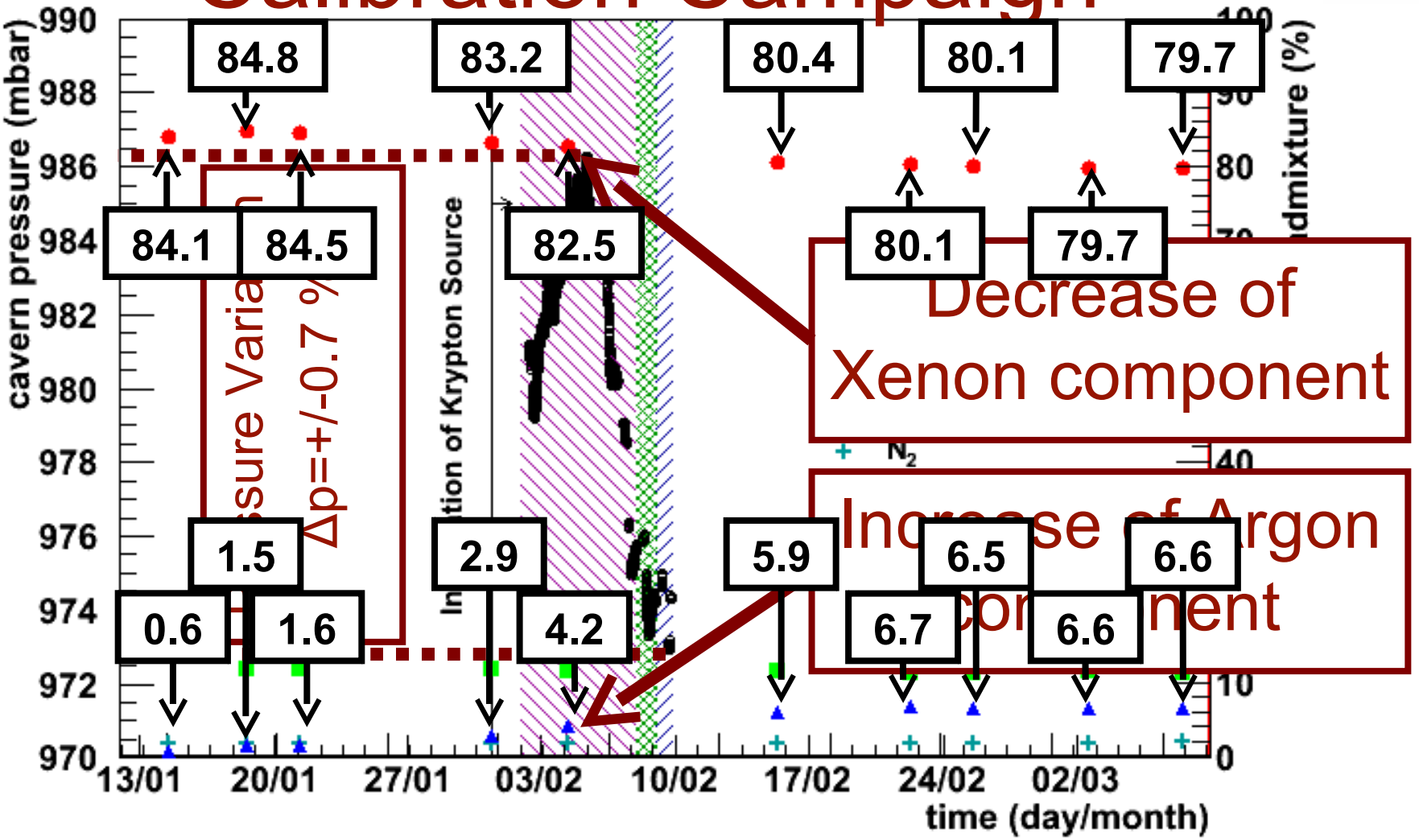


- 3 Gas inlets per sector
- 10 chambers per inlet



- Increase gas flow!
- Collect enough statistics in “last” chambers!!!
  - (>800 decays/pad)

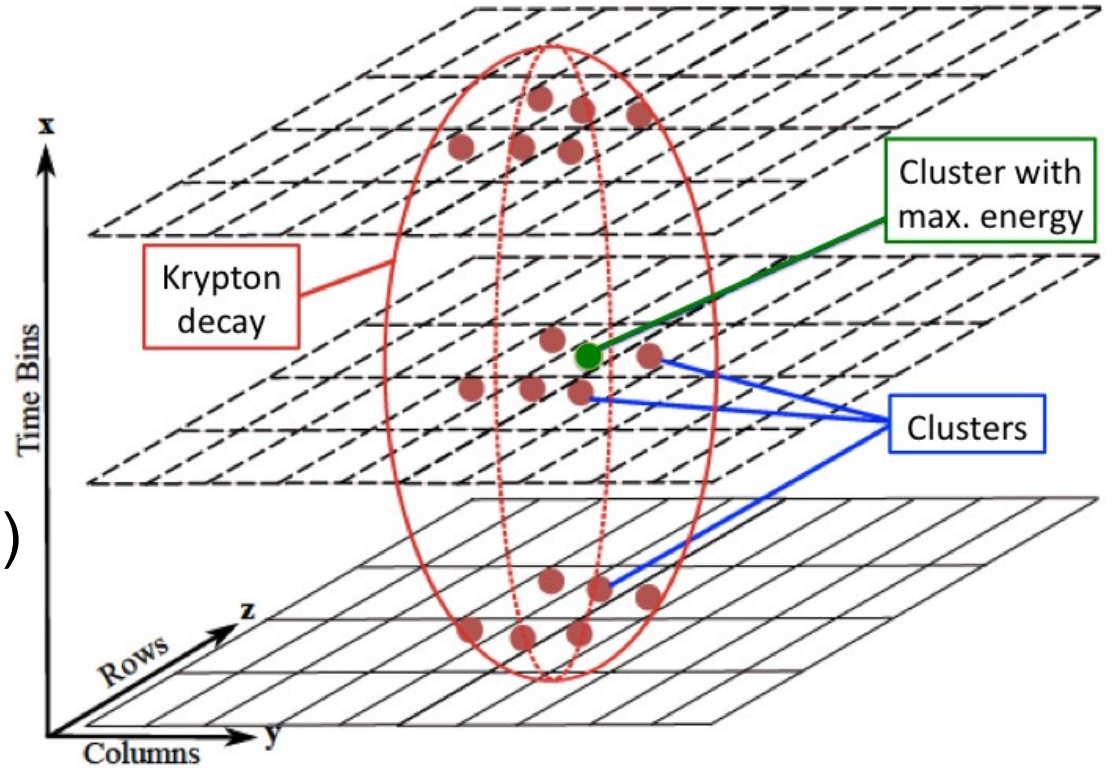
2011 Krypton Calibration Campaign



The Kr Cluster Finder

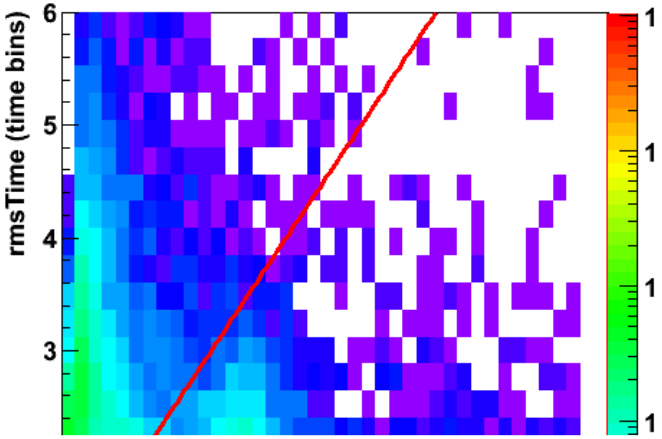
- Tune analysis to Kr decay properties
  - Advanced cluster finder applied after tracking reconstruction

- e^- stopped in Xe-CO_2 within <1 cm (≈1-2 pads)
- Search within 20 time bins (2μs)
- Assign found clusters to single pad (with max. energy)

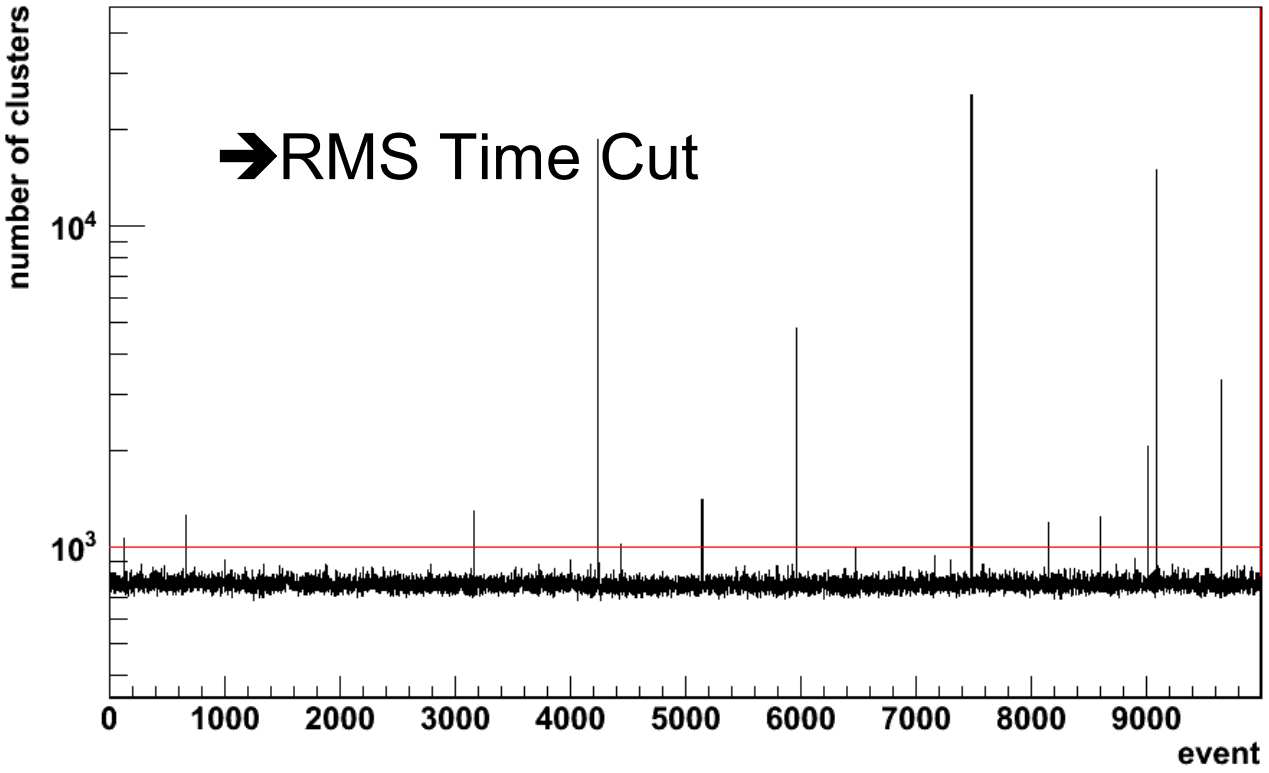


Noise Cuts

- Random fluctua
  - Pedestal Noise



- Many fired pads
  - Many clusters per event
  - Pick up noise

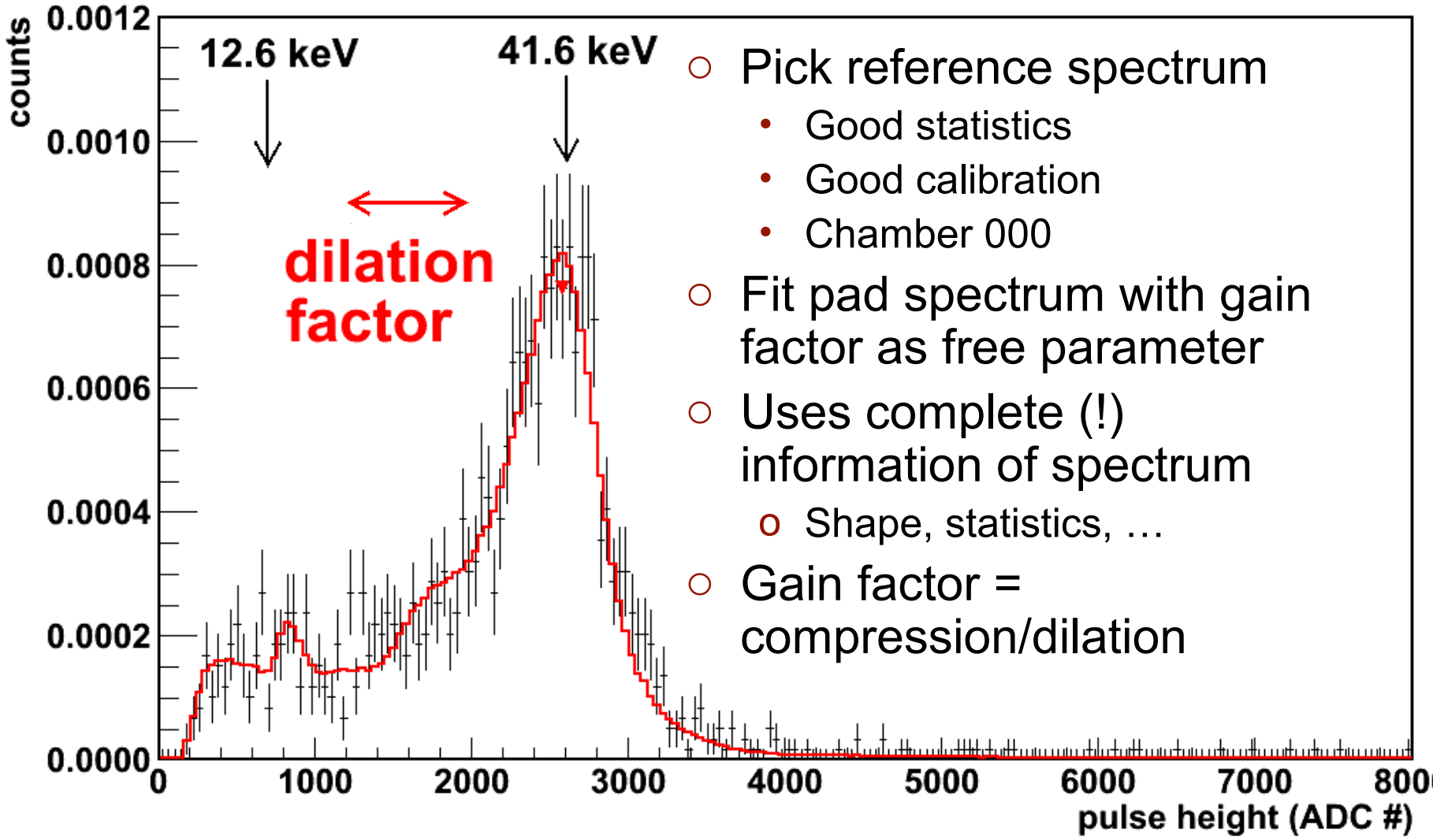


➔RMS Time Cut

➔Threshold Cut at
1000 clusters per event

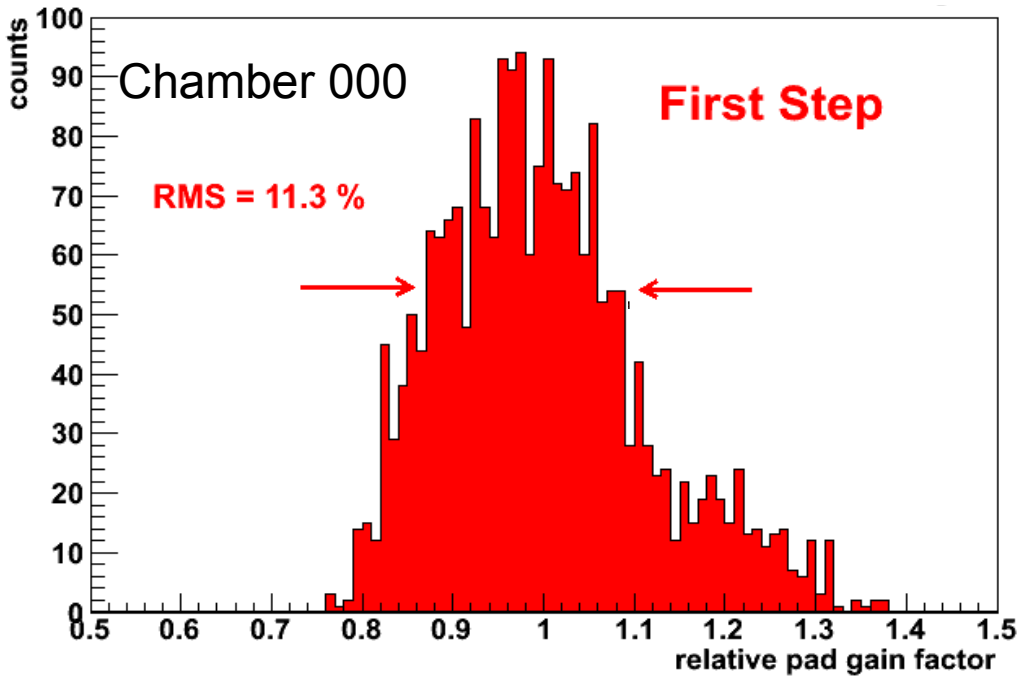
pulse height (ADC counts)

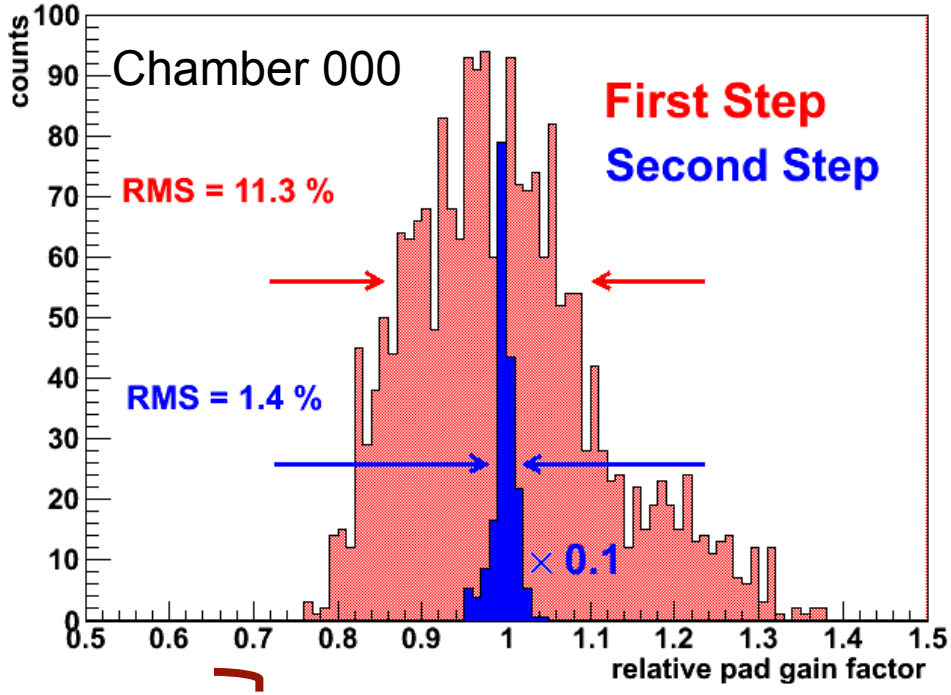
Fit Algorithm



- Pick reference spectrum
  - Good statistics
  - Good calibration
  - Chamber 000
- Fit pad spectrum with gain factor as free parameter
- Uses complete (!) information of spectrum
  - Shape, statistics, …
- Gain factor = compression/dilation

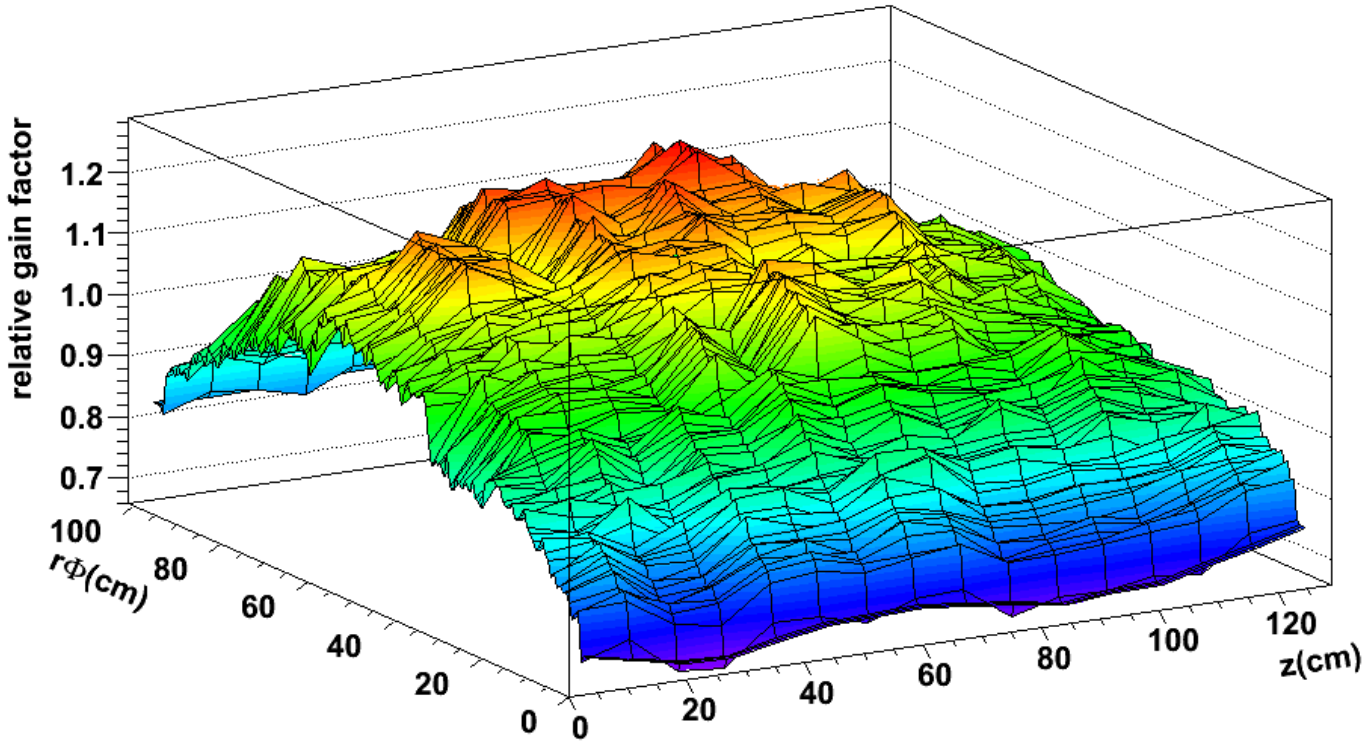
Gain Factor Distribution





- Feed gain factors into database and redo analysis
- "Correction gain factors" converge against optimal value
  - Distribution is significantly narrower
  - Analysis improves gradually until within systematic error (2 %)

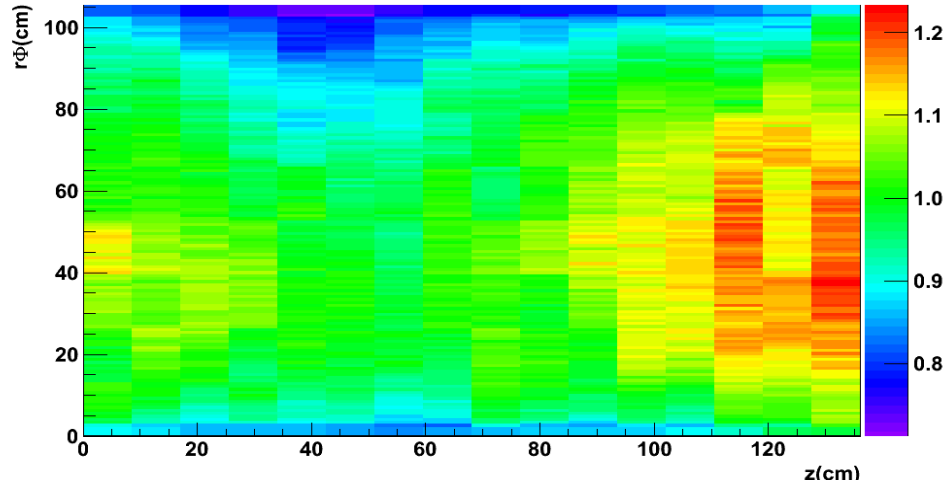
Gain Map



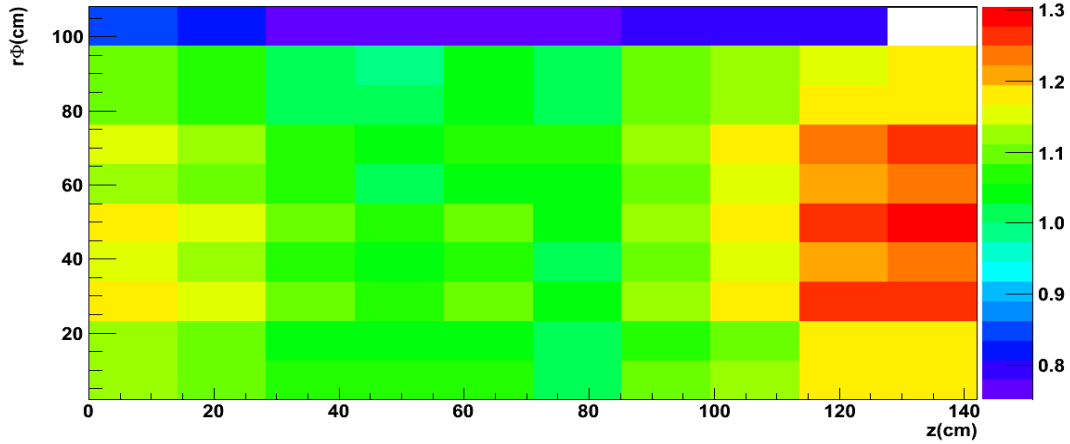
- Geometrical distortions (i.e. outward bending because of overpressure) on pad-by-pad resolution clearly visible
- Various shapes observed, mostly dependent on chamber type (size & position)

Gain Factor Map Comparison

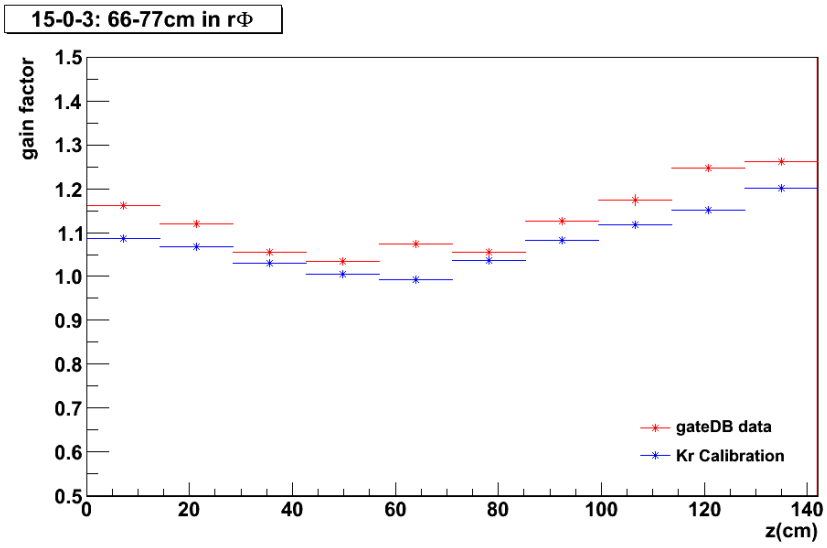
Kr Calibration: Chamber 15-0-3



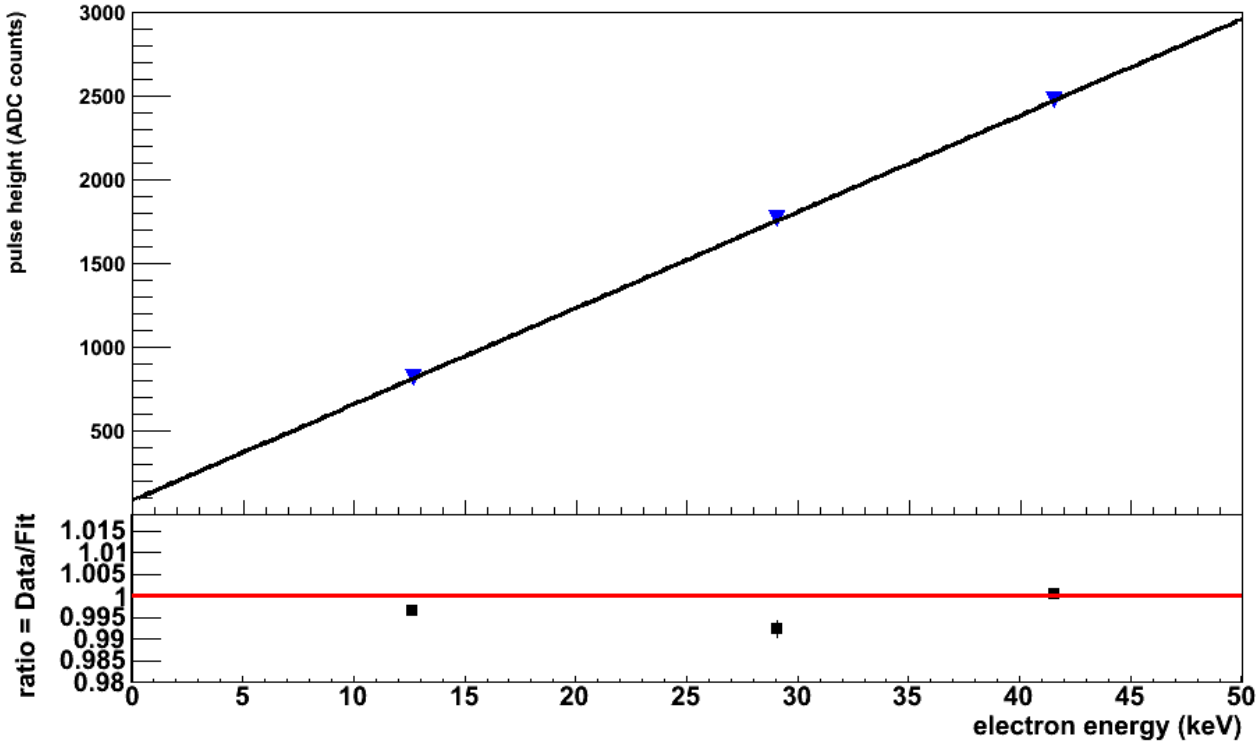
Standard TRD Chamber Testing: Chamber 15-0-3



- Compare to TRD chamber testing during construction
  - Scan 10x10 mesh with radioactive source
  - Measure anode current
- Mostly good agreement with available data



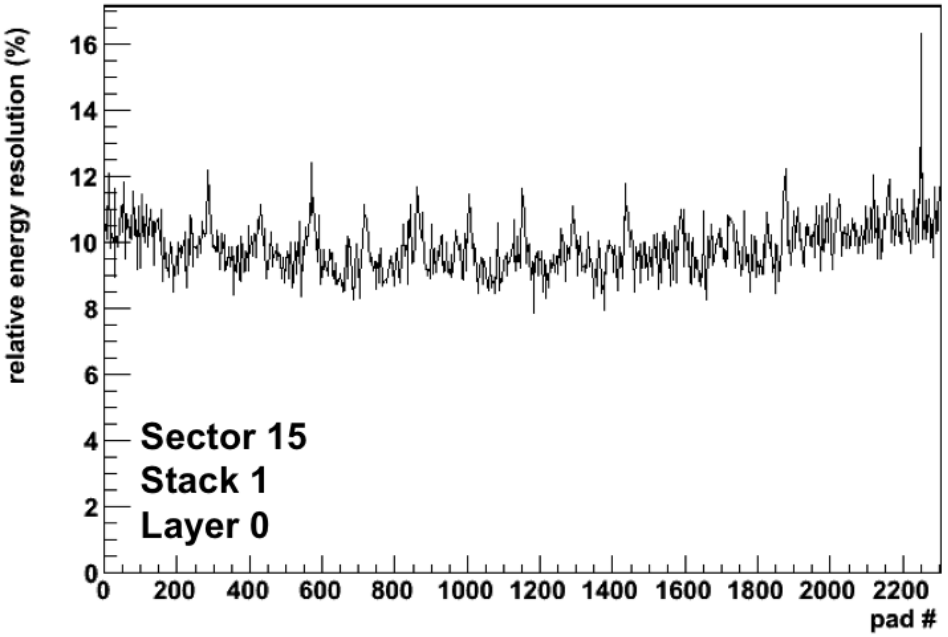
Electronics Linearity

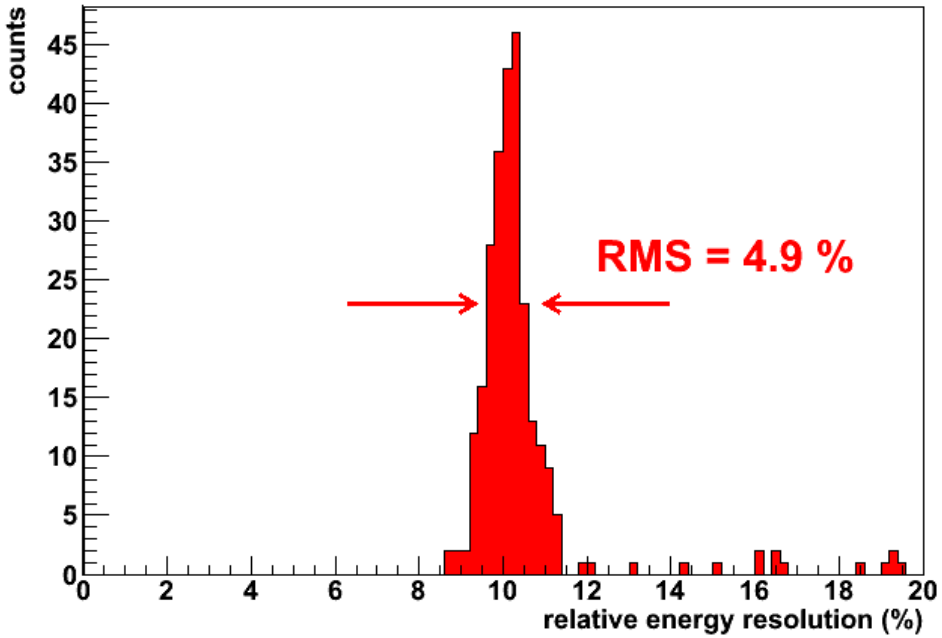


- Electronics designed for linear signal processing
- Gauss Fit to three decay peaks in the chamber spectra
- Linear Fit confirms linearity within six per mill

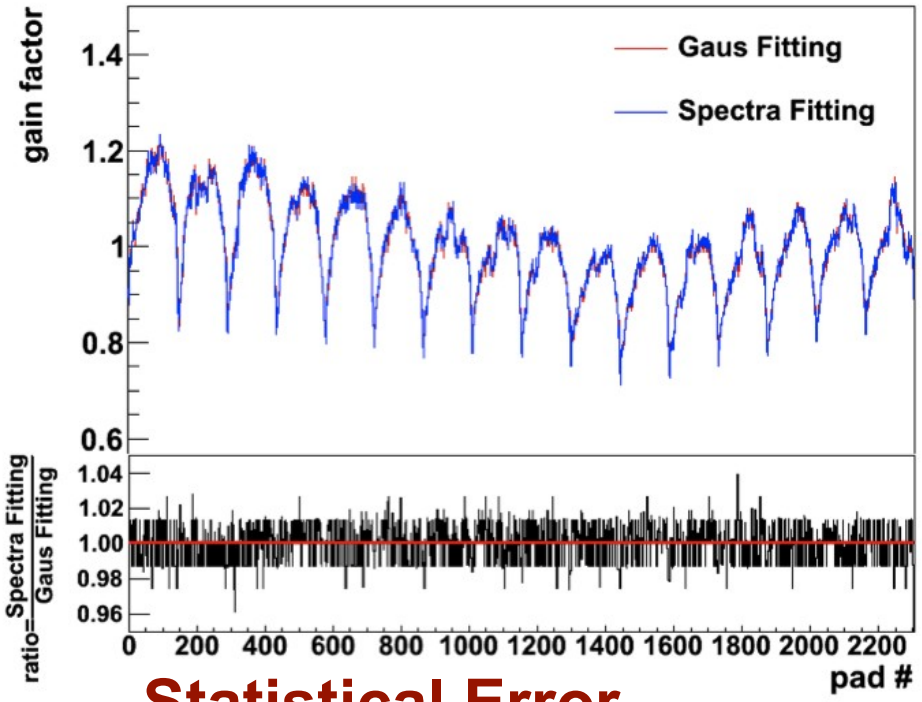
Energy Resolution Measurement

- Gaussian fit on main decay peak → Relative energy resolution:
  $\Delta E_{res} = Sigma_{Gauss}/Mean_{Gauss}$
- ΔE_{res} dependent on pad position within chamber
- Compares well to TRD design energy resolution of ΔE_{res}<10%





Systematic Uncertainty

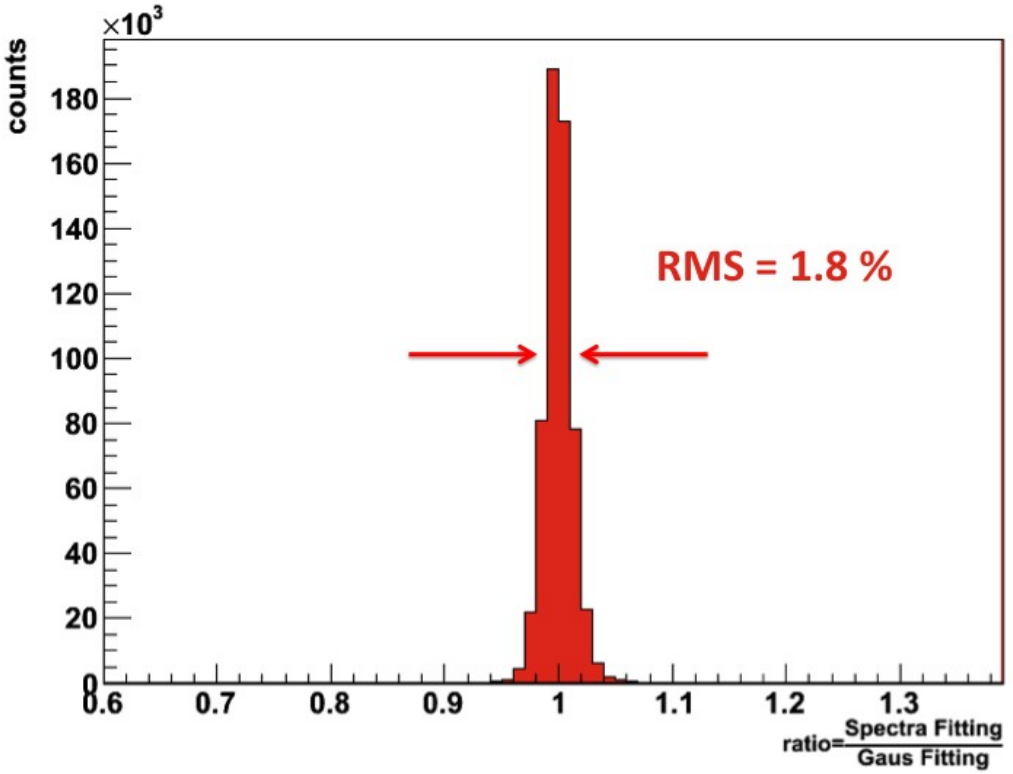


Statistical Error

- Gauss Fit: ~1 %
- Spectra Fit: <1 %

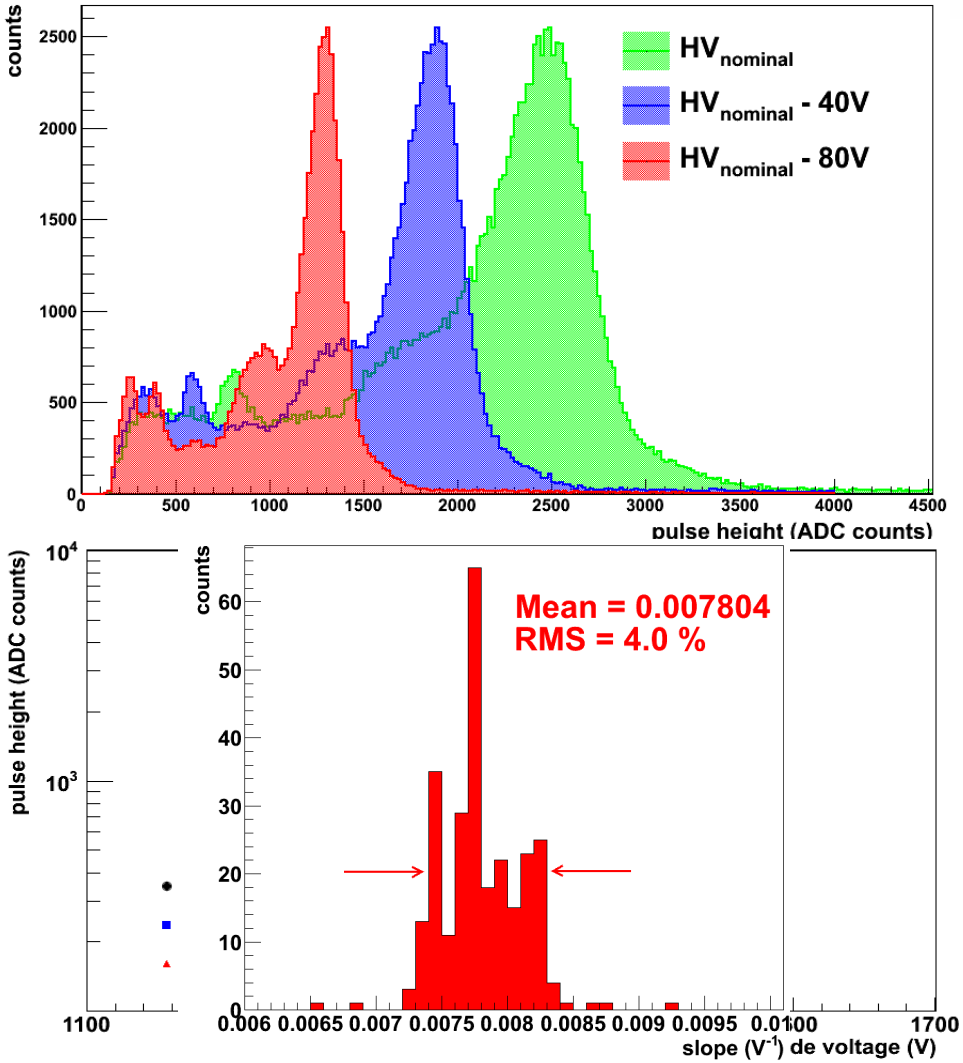
Both methods agree within +/-2%

- Gauss Fit on summed spectra of three pads
- Statistics



Gain vs. High Voltage

- Study on correlation between high voltage and gain to compensate gain variations
  1) Fit exponential to the three data points at HV_{nom} =1530 V, HV_1=1490 V & HV_2=1450 V
  2) Find mean slope for all chambers and calculate three data points
- Allows online HV adjustment of gain variations due to pressure changes for individual chambers



Summary

- Gain calibration with ^{83m}Kr-decay as important tool for particle identification
- Effective fitting procedure developed
  $\rightarrow$Uses complete information of spectra!
- Results compare very well to TRD construction testing procedure
- Kr calibration as useful tool to study TRD performance
  - Identifies problematic channels!
- Newly acquired gain factors used:
  - Offline: Data analysis
  - Online: Download to TRD Front-End Electronics
- Iterative process to optimal values

Outlook

- Next Time: Use source with higher activity
- Repeat Analysis after new supermodules are installed

Outlook – As PhD student at IRTG…

Road map (very preliminary):

- Join ITS Upgrade Working Group
  - Monte Carlo Studies (?)…
- D*+ Production in p+Pb collisions

BACKUP
Slides

ALICE TRD as Barometer

- TRD is a closed gas system
- Atmospheric pressure fluctuates
- ➢ Gas density fluctuates

  dG/G = -6.03 dp/p
- ➢ Predict: dG/G = 4.2 %