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

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Outline

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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 $\mu$s)
    $\rightarrow$ 2 $\mu$s drift + online tracking and particle identification
- Particle identification demands gain uniformity of
  $\Delta_{\text{Gain}} < 1\%$ (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
The ALICE TRD

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)

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

**Test Beam Data**
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 %: $^{83}$ 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 ≈ $2.3 \times 10^9$ Kr decays with HV=+1530V (Gain≈3250)
  - 13 runs with HV=+1490V (Gain≈2260)
  - 6 runs with HV=+1450V (Gain≈1570)

- Monitor:
  - Gas flow (statistics)
  - Change of atmospheric pressure (gain)
  - HV stability (gain)
  - Gas composition (gain)

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

Increase of Argon component

Decrease of Xenon component

Δp = +/−0.7 %
The Kr Cluster Finder

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

- e⁻ stopped in Xe-CO₂ within <1 cm (≈1-2 pads)

- Search within 20 time bins (2µs)

- Assign found clusters to single pad (with max. energy)
Noise Cuts

- Random fluctuations
  - Pedestal Noise
- Many fired pads
  - Many clusters per event
  - Pick up noise

→ RMS Time Cut

→ Threshold Cut at 1000 clusters per event
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 %)
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

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

**Kr Calibration: Chamber 15-0-3**

**Standard TRD Chamber Testing: Chamber 15-0-3**
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:
  \[ \Delta E_{\text{res}} = \frac{\text{Sigma}_{\text{Gauss}}}{\text{Mean}_{\text{Gauss}}} \]

- \( \Delta E_{\text{res}} \) dependent on pad position within chamber

- Compares well to TRD design energy resolution of \( \Delta E_{\text{res}} < 10\% \)
Systematic Uncertainty

- Gauss Fit on summed spectra of three pads
- Statistics

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

Both methods agree within +/-2%
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 $^{83}_{\text{m}}$ Kr-decay as important tool for particle identification
- Effective fitting procedure developed
  - 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
  \( \frac{dG}{G} = -6.03 \frac{dp}{p} \)
- Predict: \( \frac{dG}{G} = 4.2\% \)