

83Kr Calibration

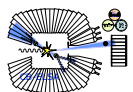
Roman Schmitz

Helmholtz-Institut für Strahlen- und Kernphysik
der Universität Bonn

for the
CBELSA/TAPS-Collaboration
and the
GEM-TPC-Collaboration



Workshop on TPCs at high rate experiments, Bonn
2013-Mar-01



TPC Prototype

Kr-Calibration

Relative
Calibration

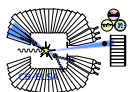
General
Argon
Neon
dE/dx

Stability

Setup
Results

- 1** GEM-TPC Prototype
- 2** Gain calibration using Kr83m
- 3** Relative Calibration Results
 - General
 - Argon
 - Neon
 - dE/dx
- 4** Stability measurements
 - Setup
 - Results

2



Inner tracking upgrade for CBELSA/TAPS and FOPI

TPC Prototype

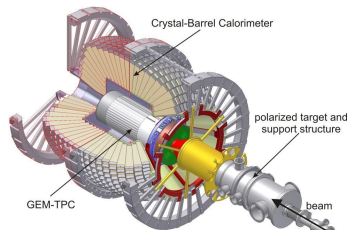
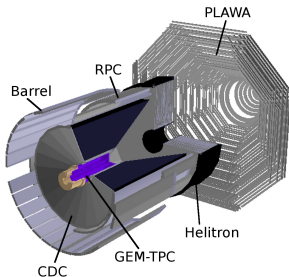
Kr-Calibration

Relative Calibration

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Results



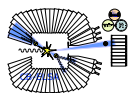
FOPI Spectrometer @GSI

- inside 0.6 T solenoid
- TPC for improved vertexing
- external PID reference (CDC, RPC)
- beam/cosmic tests in 2011/2012

Crystal Barrel Calorimeter @ELSA

- optimized for neutral decay channels
- future inner tracking upgrade
- superconducting solenoid up to 2/2.5 T)
- access to charged decay channels, vertexing

3



GEM-TPC prototype

TPC Prototype

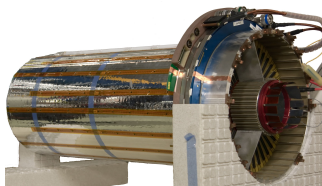
Kr-Calibration

Relative Calibration

General
Argon
Neon
dE/dx

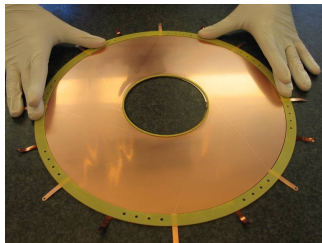
Stability

Setup
Results



GEM-TPC prototype

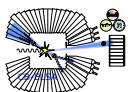
- radius 5/15 cm
- drift length 72.8 cm
- triple GEM (Standard CERN),
8 iris-shaped sectors
- 10254 hexagonal pads (1.5 mm)
- FE: 4x42 T2K-AFTER-Chips



GEM-Foil used for amplification



Padplane with hexagonal pads (1.5 mm)



Energy-Calibration with $^{83\text{m}}\text{Kr}$

TPC Prototype

Kr-Calibration

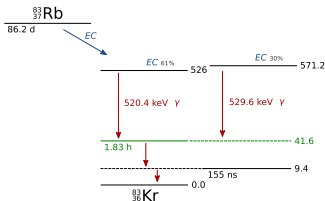
Relative
Calibration

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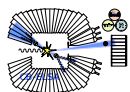
Stability

Setup
Results

- radioactive gas $\rightarrow$ full readout coverage
- GEM gain variations
- local gain variations due to bending, losses at sector borders
- optimize dE/dx-resolution
- study energy resolution performance
- gain stability monitoring



- metastable state with $t_{1/2}=1.83\text{ h}$
- internal conversion factor ~ 2000
- well-known narrow energy levels
- multiple energy lines (K, L, M, Auger, gamma) from 9 to 41 keV
- previously used in TPCs of STAR, ALICE, NA49, ALEPH.



Calculated decay spectrum

TPC Prototype

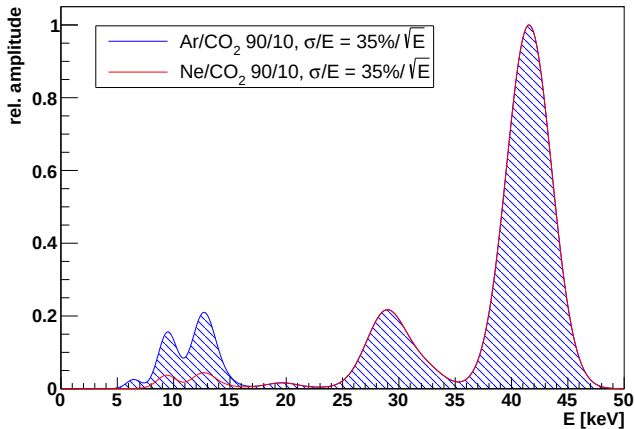
Kr-Calibration

Relative
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dE/dx

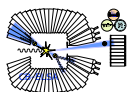
Stability

Setup
Results



Calculated energy spectrum for the drift gases used in our prototype.

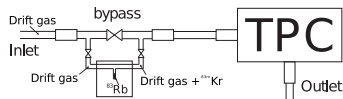
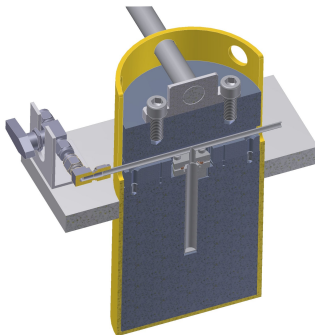
6



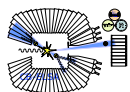
Production and Integration

Rb81 4.576 h 3/2- EC *	Rb82 1.273 m 1+ EC *	Rb83 86.2 d 5/2- EC	Rb84 32.77 d 2- EC, β	Rb85 5/2- 72.165
Kr80 0+ 2.25 Br79	Kr81 2.29E+5 y 7/2+ EC *	Kr82 0+ 11.6 Br81	Kr83 9/2+ 11.5 Br82	Kr84 0+ 57.0 Br83
3/2- 50.69	1+ EC, β *	3/2- 49.31	5- β *	3/2- β

- $^{81}\text{Br}(\alpha, 2n)^{83}\text{Rb}$ with $\sigma=1300\text{ mb}$ at 26 MeV
- production at HISKP Bonn Cyclotron with 54 MeV α -beam (up to 18 MBq possible)
- integration in gas-bypass



Schematic view



Observed Krypton Decays

TPC Prototype

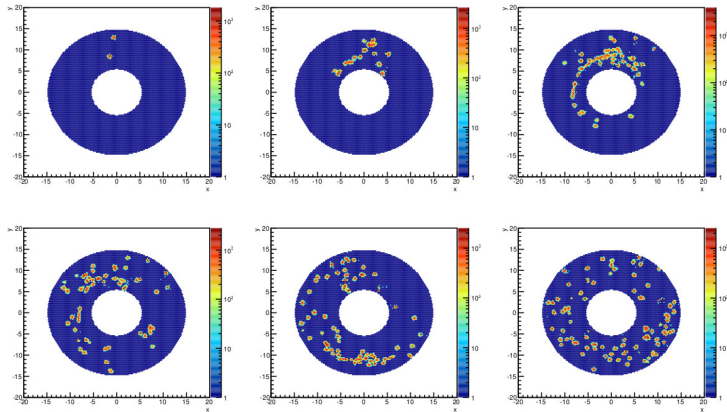
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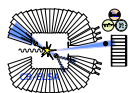
General
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- diffusion of the Krypton inside the chamber, few 10s after injection.
- maximum activity reached after a few minutes



Observed Krypton Decays

TPC Prototype

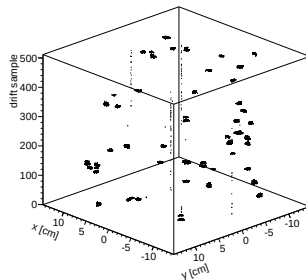
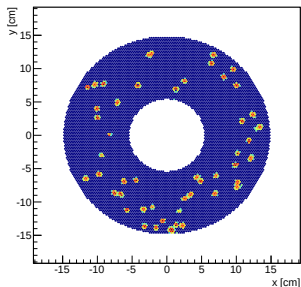
Kr-Calibration

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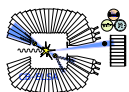
Stability

Setup
Results



- random trigger ~ 500 Hz
- event display with ~ 50 krypton decays inside GEM-TPC
- source activity 5.3 MBq, observed $\sim 1.5 \cdot 10^6$

9



Krypton Spectra in Ar/CO₂ 90/10

TPC Prototype

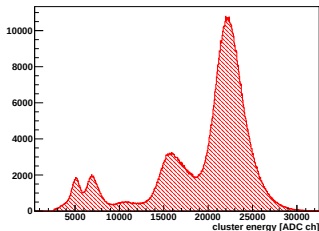
Kr-Calibration

Relative
Calibration

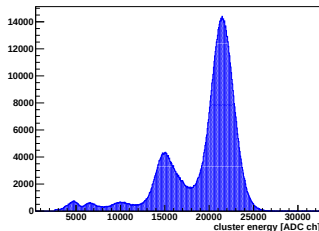
General
Argon
Neon
dE/dx

Stability

Setup
Results



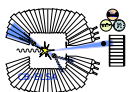
Spectrum for Ar/CO₂ 90/10



Spectrum for Ne/CO₂ 90/10

- uncorrected online spectra for Ar/CO₂ (Ne/CO₂) 90/10
- GEM at gain of ~ 2000 (both gases)
- drift field 360 V/cm

10



Krypton Spectra in Ar/CO₂ 90/10

TPC Prototype

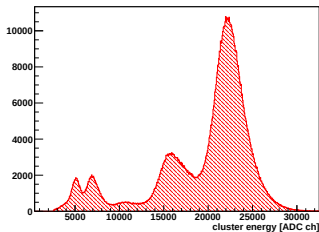
Kr-Calibration

Relative
Calibration

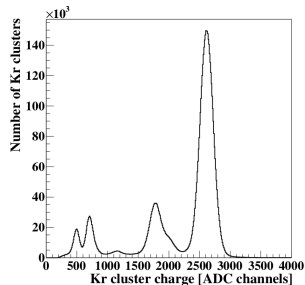
General
Argon
Neon
dE/dx

Stability

Setup
Results



Prototype GEM-TPC (uncorrected)

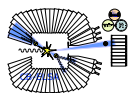


J. Wiechula / Nuclear Physics A 830 (2009) 531c–534c

published result for ALICE TPC

- uncorrected online spectra for Ar/CO₂ (Ne/CO₂) 90/10
- GEM at gain of ~ 2000 (both gases)
- drift field 360 V/cm

10



Relative calibration method

TPC Prototype

Kr-Calibration

Relative
Calibration

General

Argon

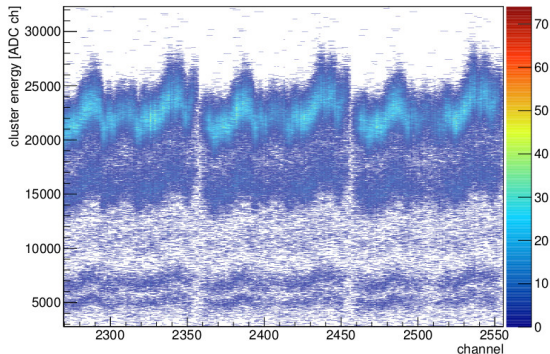
Neon

dE/dx

Stability

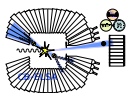
Setup

Results



- channel-wise energy spectra
- losses at sector borders, edges
- normalized to median
- iterative method → relative corrections

11



Gain uniformity and distribution

TPC Prototype

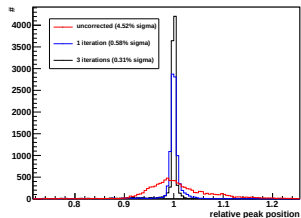
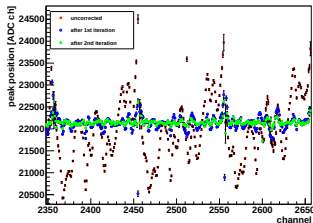
Kr-Calibration

Relative
Calibration

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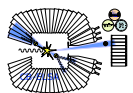
Stability

Setup
Results



- uniformity of 4.52% to 0.31 % after 3 iterations
- stability of distribution (3 datasets) below 1 %
- tested and confirmed with MC simulations extensively
- gainmap with relative factors show sectors/borders

12



Gain uniformity and distribution

TPC Prototype

Kr-Calibration

Relative
Calibration

General

Argon

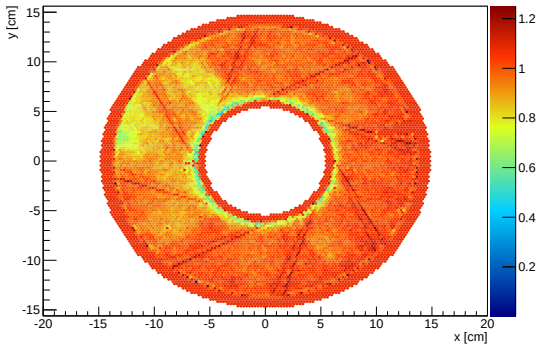
Neon

dE/dx

Stability

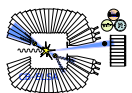
Setup

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Krypton Spectra in Ar/CO₂ 90/10

TPC Prototype

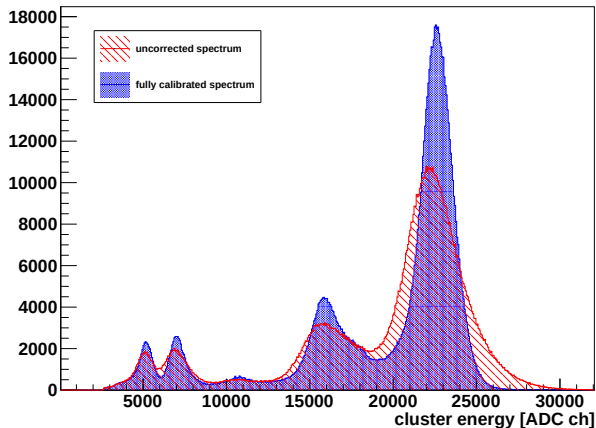
Kr-Calibration

Relative
Calibration

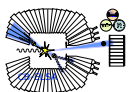
General
Argon
Neon
dE/dx

Stability

Setup
Results



13



Energy Resolution in Ar/CO₂ 90/10

TPC Prototype

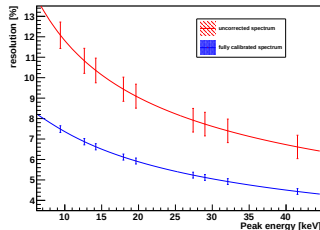
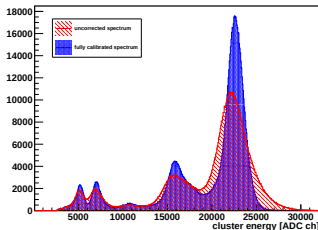
Kr-Calibration

Relative
Calibration

General
Argon
Neon
dE/dx

Stability

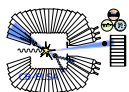
Setup
Results



- GEM HV at 83 % (gain ~ 2000)
- resolution curve from multi-peak-fit to spectrum
- uncalibrated:
 $(47.72 \pm 0.57)\% / \sqrt{E}$,
calibrated:
 $(33.69 \pm 0.14)\% / \sqrt{E}$

peak [keV]	uncorrected	corrected
9.4	12.07 %	7.48 %
12.65	10.82 %	6.86 %
14.2	10.35 %	6.62 %
17.95	9.43 %	6.11 %
19.65	9.09 %	5.92 %
27.4	7.91 %	5.24 %
29.0	7.73 %	5.12 %
32.1	7.40 %	4.92 %
41.55	6.61 %	4.43 %

14



Krypton Spectra in Ne/CO₂ 90/10

TPC Prototype

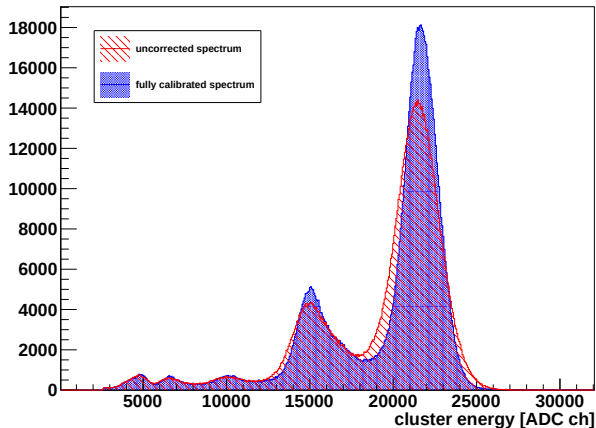
Kr-Calibration

Relative
Calibration

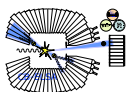
General
Argon
Neon
dE/dx

Stability

Setup
Results



15



Energy Resolution in Ne/CO₂ 90/10

TPC Prototype

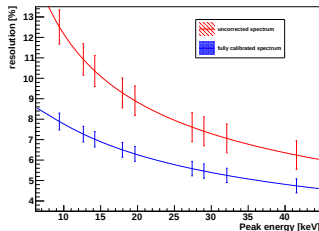
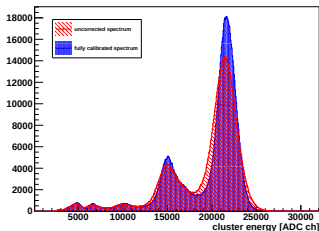
Kr-Calibration

Relative
Calibration

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dE/dx

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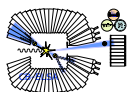
Setup
Results



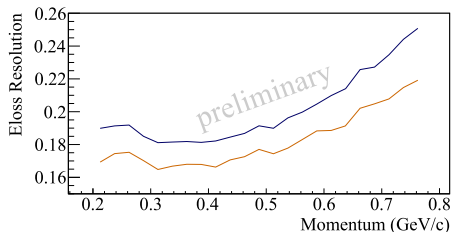
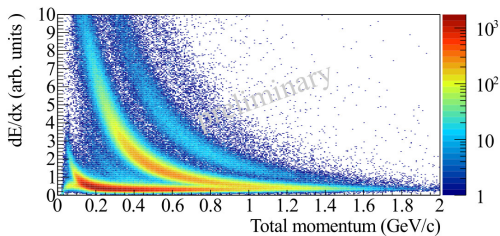
- GEM HV at 72 % (gain ~ 2000)
- low statistics in photon peaks (conversion in Neon)
- resolution curve from multi-peak-fit to spectrum
- uncalibrated:
 $(41.96 \pm 0.69)\% / \sqrt{E}$,
calibrated:
 $(36.34 \pm 0.34)\% / \sqrt{E}$

peak [keV]	uncorrected	corrected
9.4	12.51 %	7.89 %
12.65	10.92 %	7.27 %
14.2	10.35 %	7.02 %
17.95	9.29 %	6.50 %
19.65	8.90 %	6.30 %
27.4	7.61 %	5.58 %
29.0	7.41 %	5.46 %
32.1	7.06 %	5.25 %
41.55	6.24 %	4.73 %

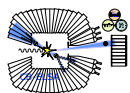
16



Effects on dE/dx resolution



17



- Full FOPI reconstruction, TPC dE/dx
- resolution improvement: 10-15%
- work in progress (Plots by F.V. Böhmer)

Small TPC prototype with monitoring

TPC Prototype

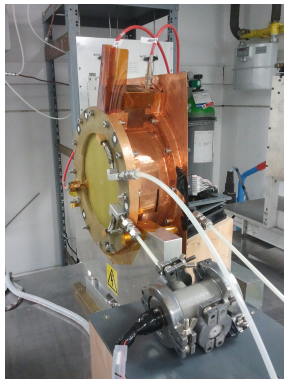
Kr-Calibration

Relative
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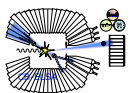
Stability

Setup
Results



- small GEM-TPC with 1500 channels, 10x10cm active area and 7.7 cm drift
- monitoring chamber parallel to TPC
- high-precision altimeter module (accuracy 15-20 cm, sea level $\approx 8\text{m/1hPa}$)
- constantly averaging p,T (up to 45 cycles/sec)
- > 1 month of data taking, $T \approx 12\text{-}25^\circ\text{C}$ (stabilized), $p \approx 980\text{-}1030\text{ hPa}$

18



Temperature dependence

TPC Prototype

Kr-Calibration

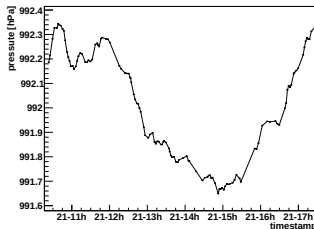
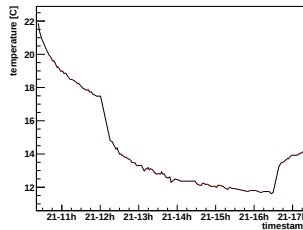
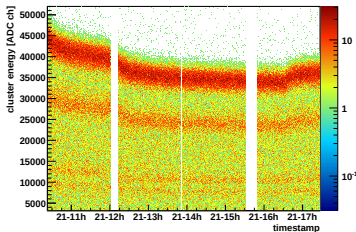
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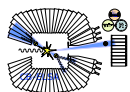
Setup

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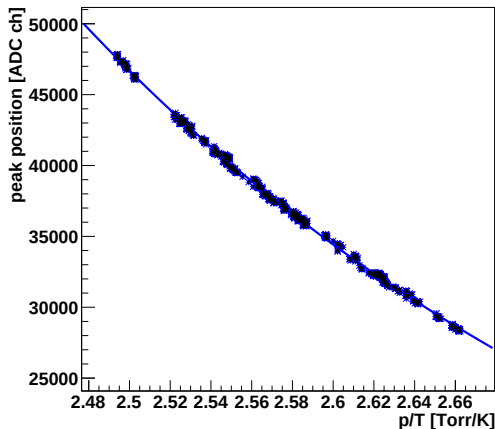


- strong T-dependence of gain (about 1 %/ per °C)
- fast ramping due to cooling of whole room
- pressure stable by less than 1 hPa

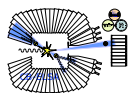
19



p/T dependence of gain



- exponential dependence on p/T (gas density, λ) expected
- $G = G_0 \cdot \exp(-\mu(p/T))$ with $\mu = 3.0456 \pm 0.0022$, G_0 for 20 °C, 760 Torr
- values consistent for different bins in p and T



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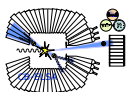
Summary

- Kr-83m successfully used for calibration (decay-rate $1.5 \cdot 10^6$ 1/s in TPC)
- calibration method developed, tested, confirmed (MC)
- excellent energy resolution (4.4%/4.7% for Argon/Neon in 41.55 keV peak)
- improvement of 10-15% in energy resolution and dE/dx
- global gain calibration/monitoring very important

TODO

- optimize calibration w.r.t. dE/dx resolution
- test rate-stability of gain (charge-up)

21



TPC Prototype

Kr-Calibration

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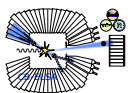
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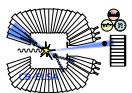
Thank you for your attention !

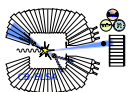
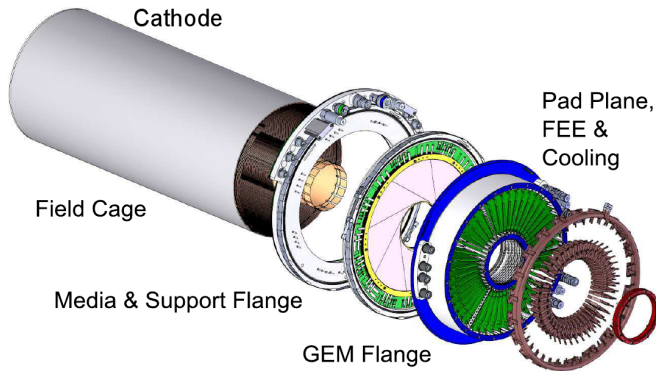
22



Backup slides

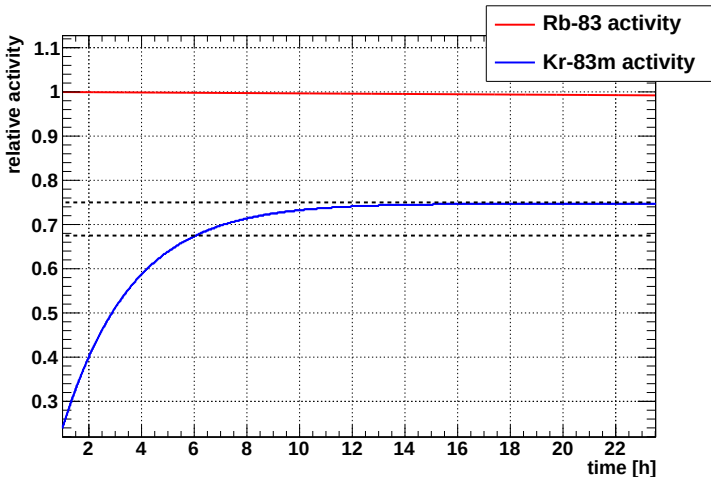
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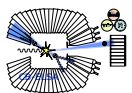


Accumulation of Krypton activity

Backup slides

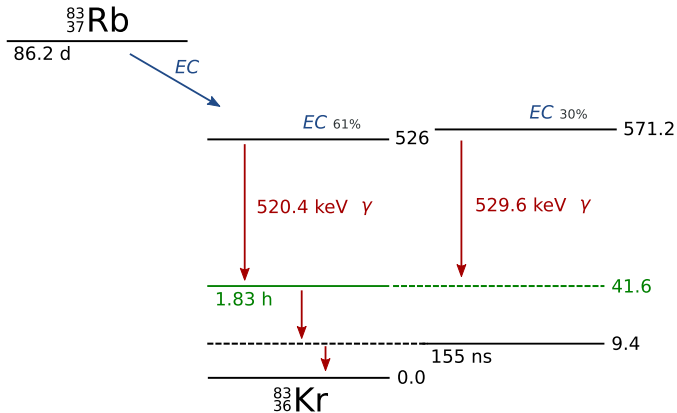


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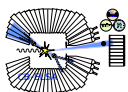


Simplified Rb Scheme

Backup slides

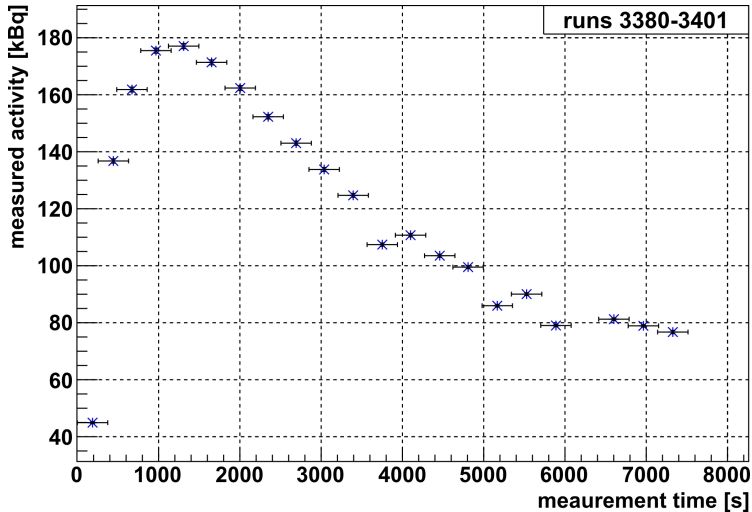


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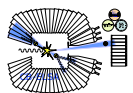


Observed Krypton activity

Backup slides

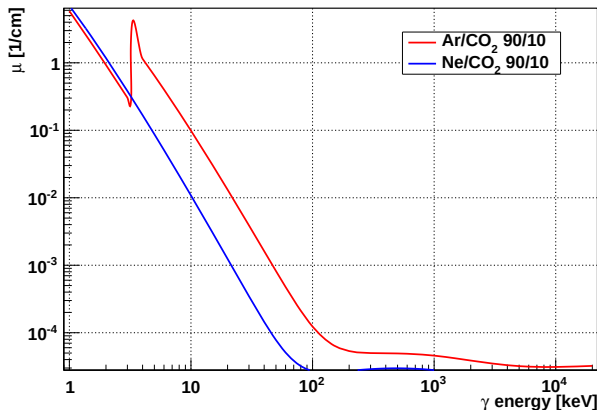


5



Energy absorption coefficients

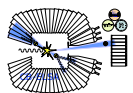
Backup slides



Berger, M.J., Hubbell, J.H., Seltzer, S.M., Chang, J., Coursey, J.S., Sukumar, R., Zucker, D.S., and Olsen, K. (2010),

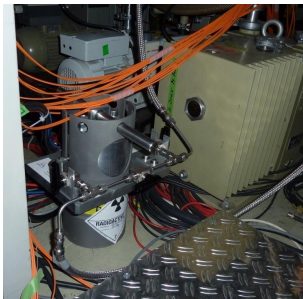
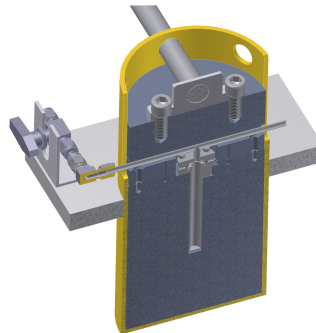
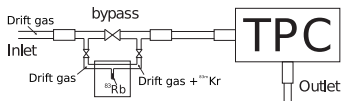
XCOM: Photon Cross Section Database (version 1.5). [Online] Available: <http://physics.nist.gov/xcom> [Wednesday,

27-Feb-2013 09:27:08 EST]. National Institute of Standards and Technology, Gaithersburg, MD.

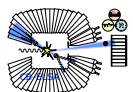


Integration into gas system

Backup slides

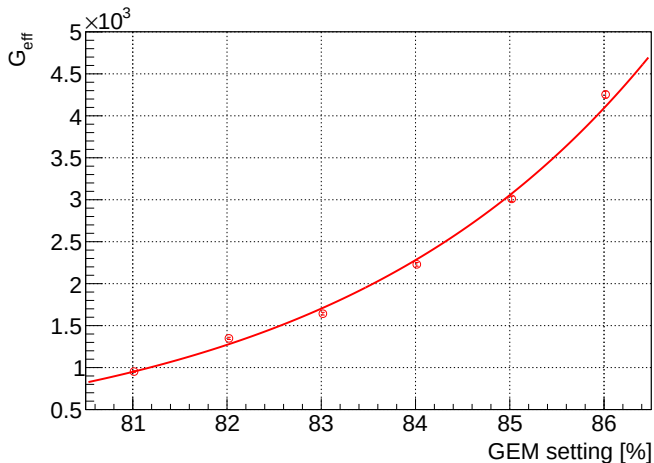


- lead shielding for γ radiation
- gas tight container for source
- connection to gas system via bypass valve
- typical gas flow $\approx 40\text{-}60\text{ ltr/h}$

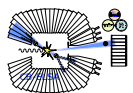


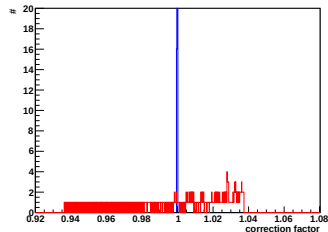
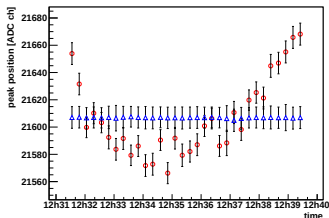
Gain estimation from cosmic muons

Backup slides



8





- gain-fluctuations of %-order
- no usable p/T data available ($\rightarrow$ further studies)
- correction of fluctuations over measurement time
- short time-scale with linear interpolation
- fluctuations before: 2.9 %, after: 0.01 %
- effect on main peak resolution $\approx 0.2\%$

