The COBRA Experiment

Status Report

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The COBRA Experiment

Cadmium–Zinc–Telluride **0**–neutrino double–**B**eta **R**esearch **A**pparatus

Concept: Large Array of CdZnTe semiconductor detectors

- Total mass: $\sim 400\,\mathrm{kg}$, 90% enriched in $^{116}\mathrm{Cd}$
- Sensitivity of $T_{1/2}^{0\nu\beta\beta} > 10^{26}\,\mathrm{yr}$ ($m_{\beta\beta} \approx 50\,\mathrm{meV}$)

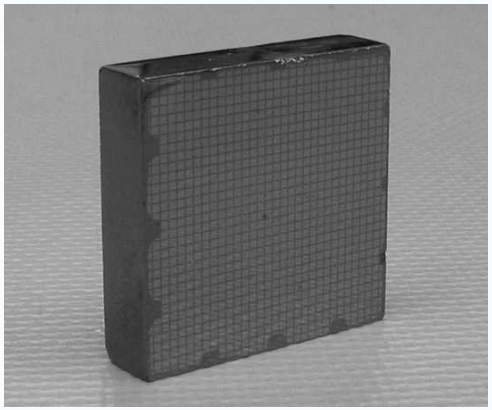
In total 9 $0\nu\beta\beta$ candidates, most important:

- $^{116}\mathrm{Cd}$: Very high Q value of $2813.5\,\mathrm{keV}$ ($\gg 2615\,\mathrm{keV}$)
- $^{130}\mathrm{Te}$: High natural abundance (34.08%)
- $^{106}\mathrm{Cd}$: Q value of $2770\,\mathrm{keV}$, $\beta^+\beta^+$ emitter

The COBRA Experiment

- Source = detector approach
- Room temperatur semiconductor detectors
  - Good energy resolution, intrinsic radiopure
- Granular design
  - Coincidence analysis, background reduction

Investigation of 2 detector concepts:

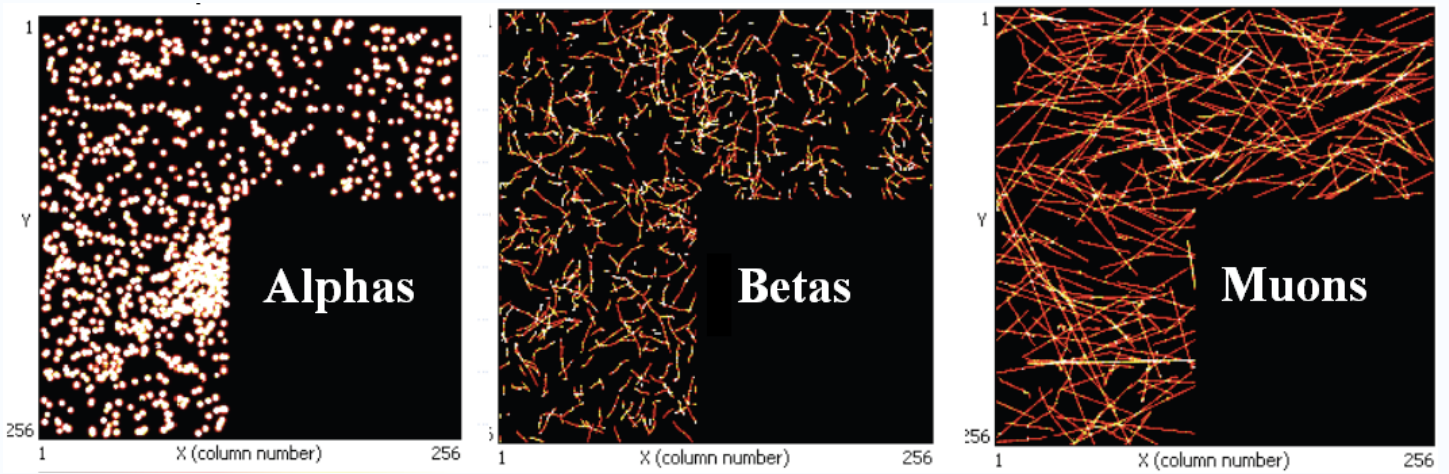


Pixilated detectors

CPG detectors

Thin Pixeleted Detectors

- Timepix detectors of the Medipix2 collaboration
- 55 µm up to 220 µm pixel pitch
- Recording of the particle track
  - Particle identification



- Investigation of a 3D Track reconstruction

Thin Pixeleted Detectors

- Timepix detectors of the Medipix2 collaboration
- 55 µm up to 220 µm pixel pitch
- Recording of the particle track
  - Particle identification

T39.8, Mo 18:30: Thomas Gleixner
Dreidimensionale Spurrekonstruktion in pixelierten CdTe-Detektoren

Coplanar Grid Detectors

Read out of both anode signals via FADCs, pulse shape sampling allows for:

- Energy information
- Determination of the interaction depth
- Discrimination of single/multi-site events
- Classification of lateral surface events
- Removal of electronic disturbance events

Coplanar Grid Detectors

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T18.2, Mo 11:15: Jan Tebrügge
Pulse-shape discrimination of lateral surface events

T18.3, Mo 11:30: Stefan Zatschler
Single-site and Multi-site Event Discrimination

Coplanar Grid Detectors

Read out of both anode signals via FADCs, pulse shape sampling allows for:

- Energy information
- Determination of the interaction depth
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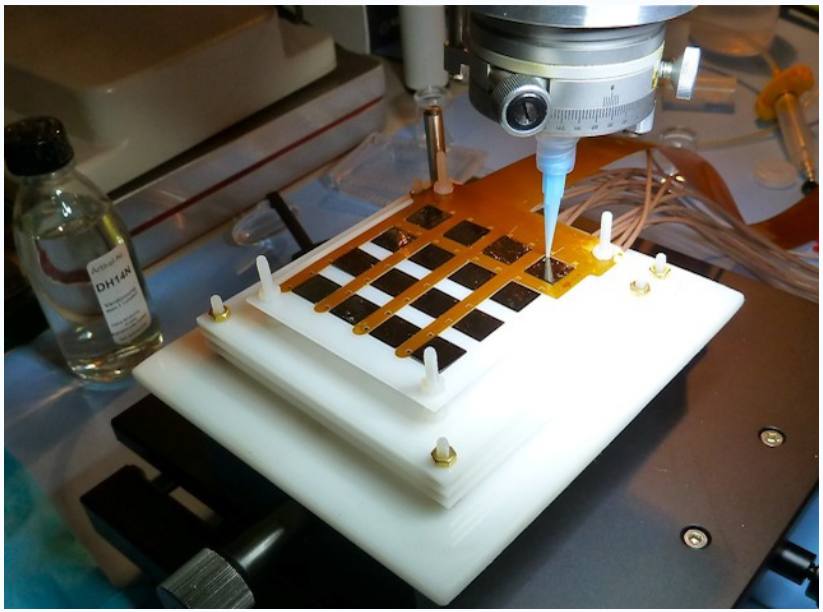
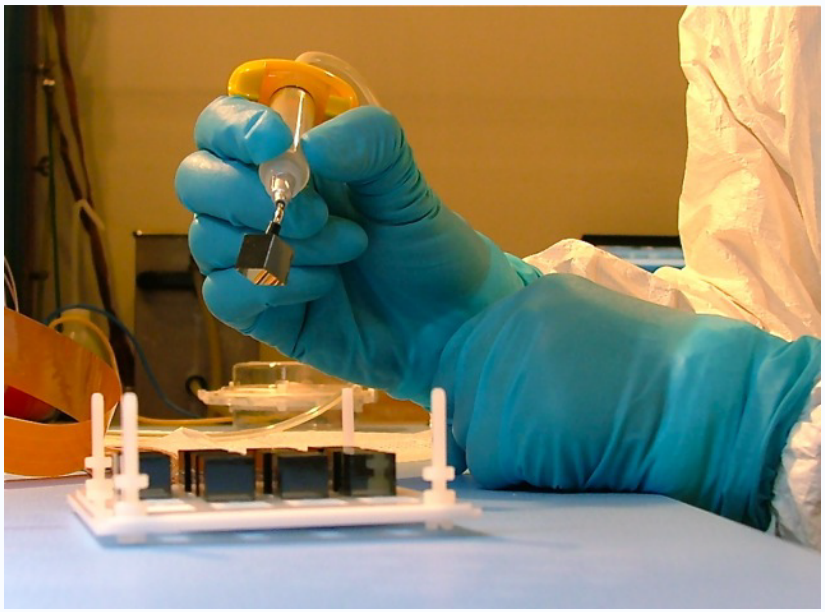
Advantages:

- Small number of read out channels
- No electronics near the detectors

Demonstrator Setup at LNGS

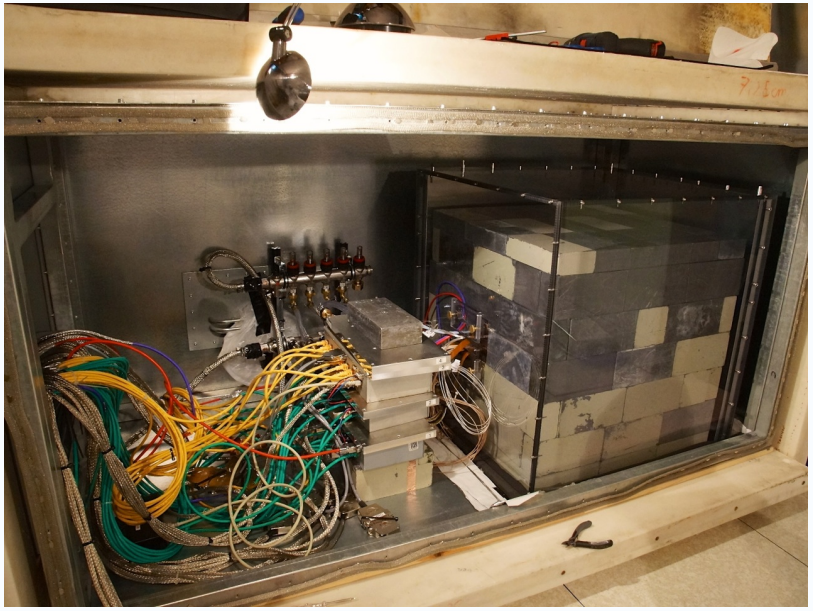
- Onsite layer assembly under clean-room conditions
- 64 CPG detectors are operating
  - Setup completed in November 2013

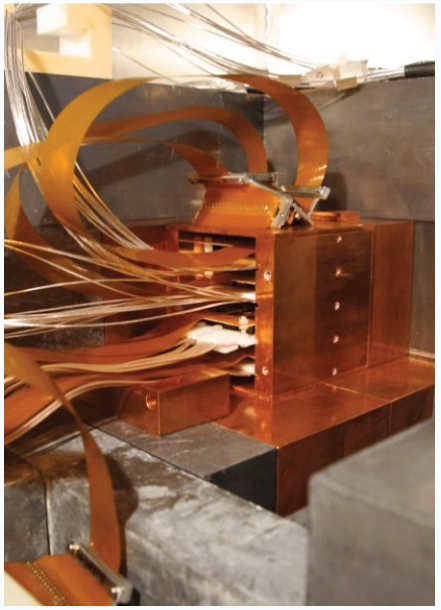




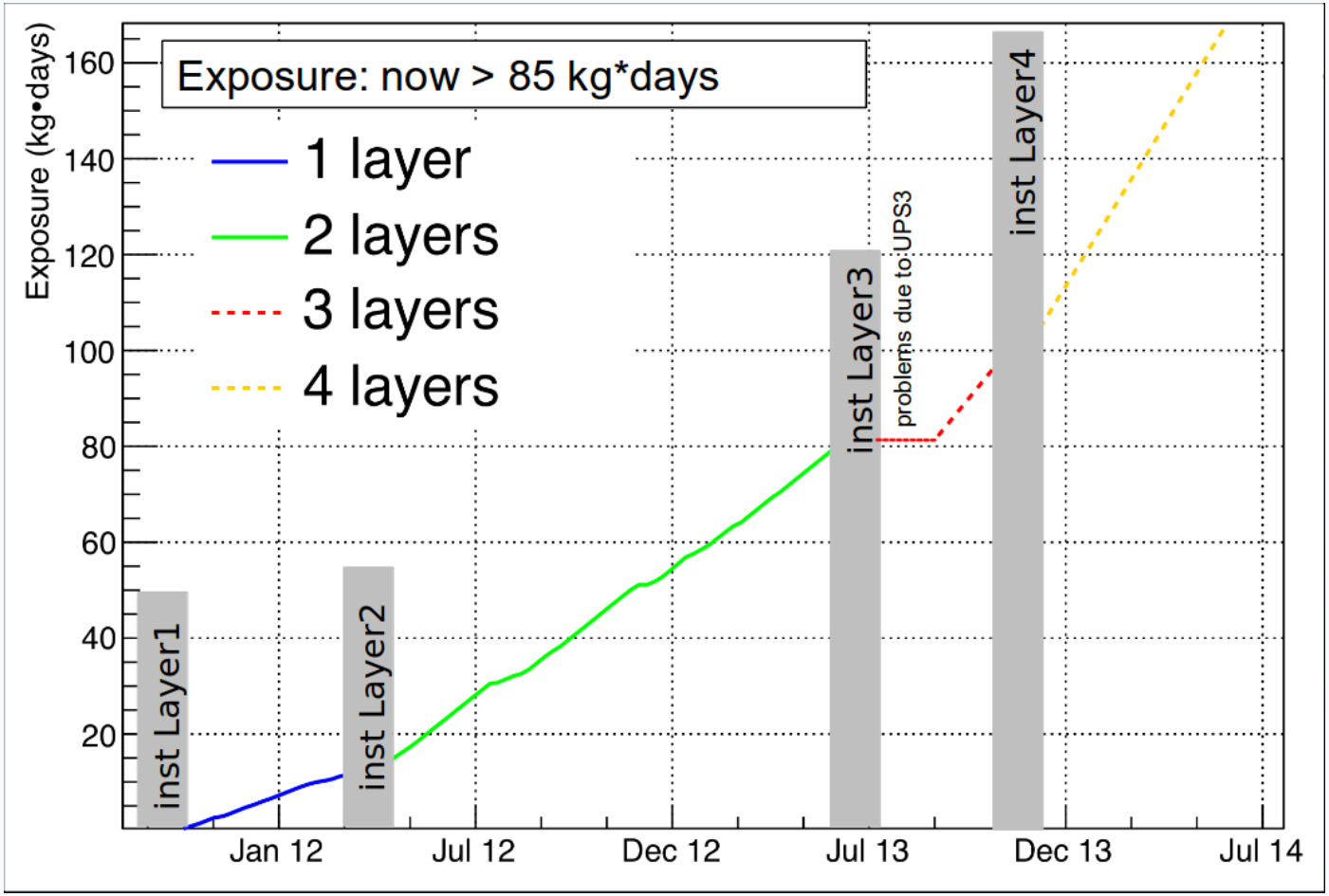
Demonstrator Setup at LNGS

- 7 cm boron-loaded polyethylene
- EMI box against electromagnetic interferences
- Radon shield and nitrogen flushing
- Inner shield: 20 cm low level alpha lead and 5 cm ultra clean copper



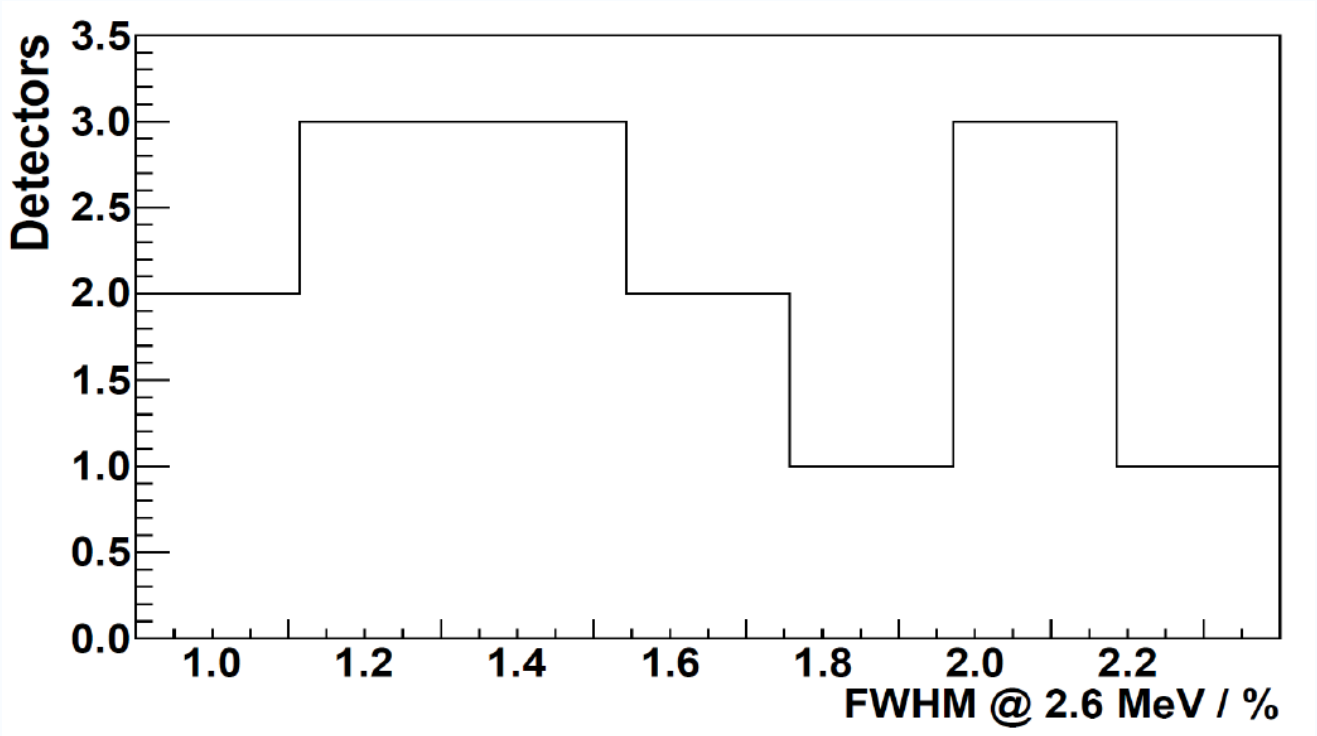


Data Taking

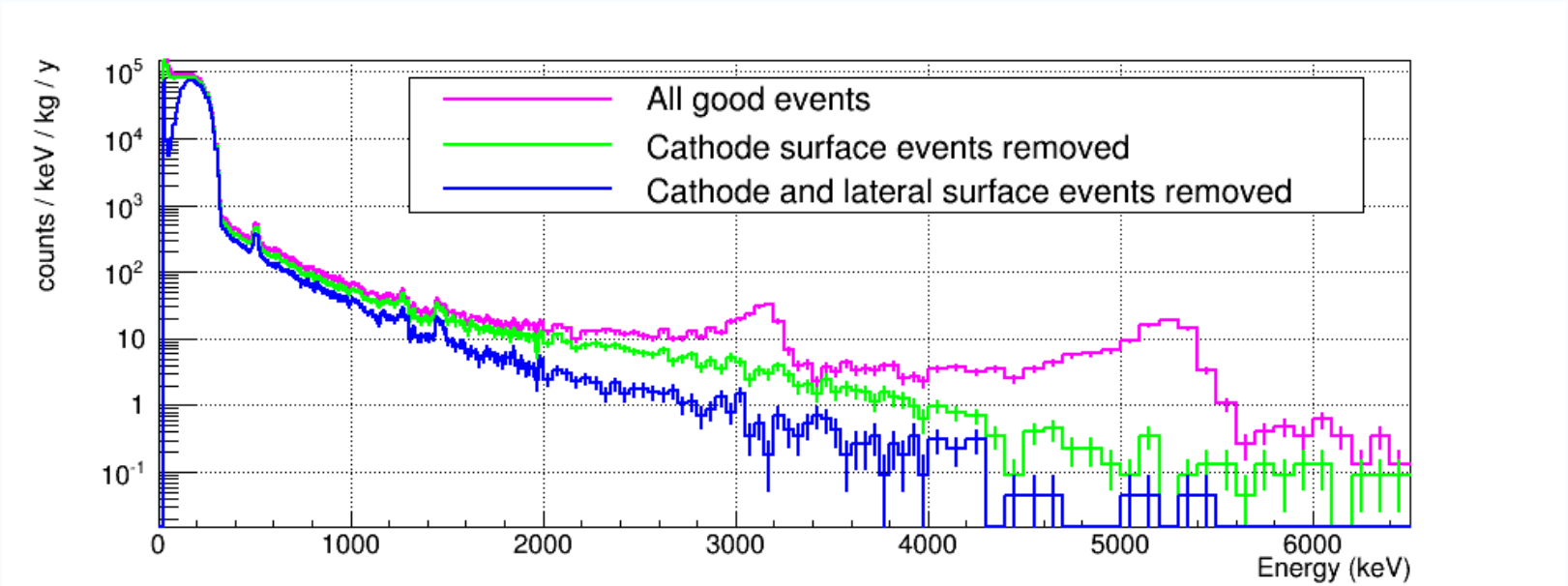

Exposure: now > 85 kg*days
1 layer
2 layers
3 layers
4 layers
Exposure (kg•days)
160
140
120
100
80
60
40
20
inst Layer1
inst Layer2
inst Layer3
problems due to UPS3
inst Layer4
Jan 12
Jul 12
Dec 12
Jul 13
Dec 13
Jul 14

Detector Performance

- Average energy resolution: 1.7% FWHM at 2.6 MeV

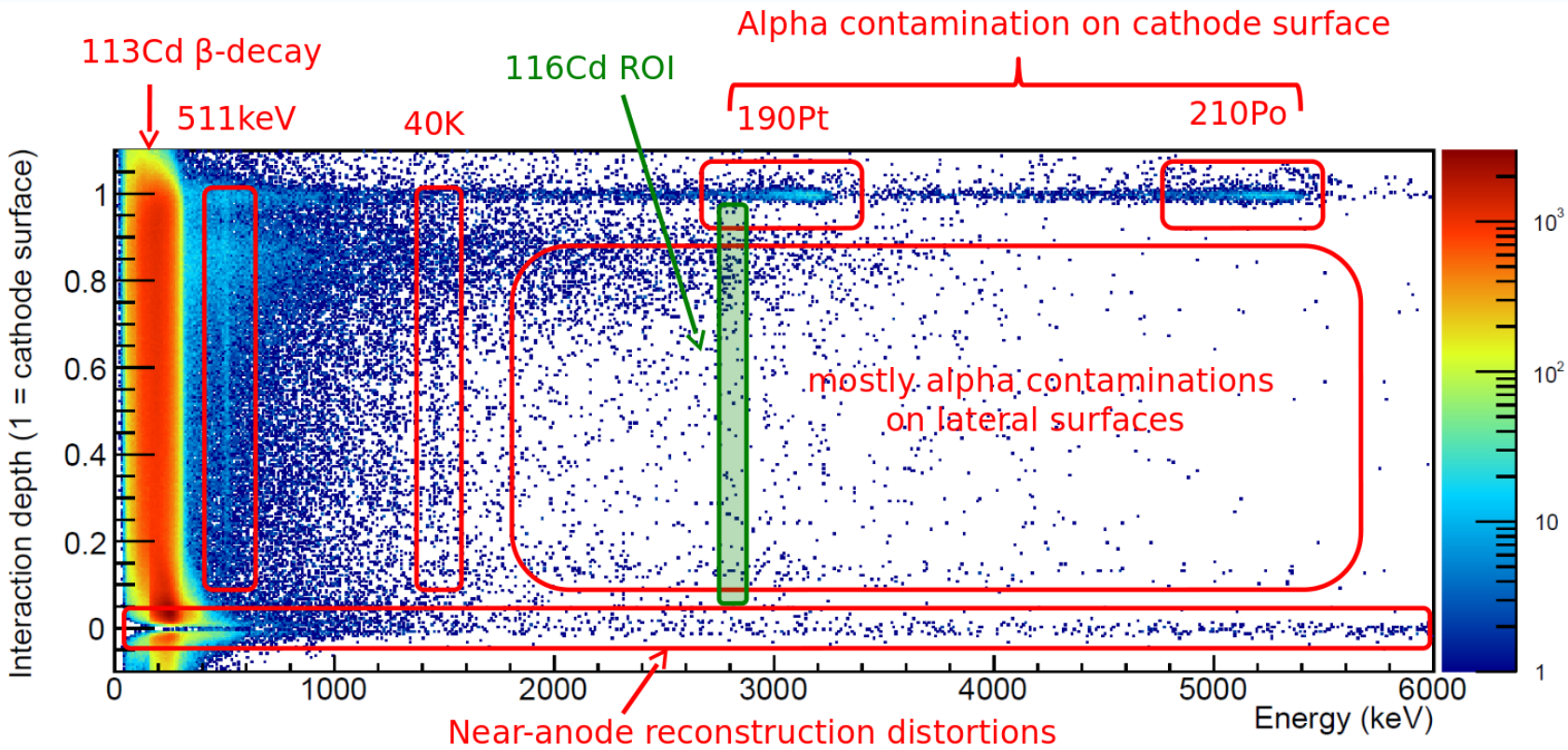


Data Analysis

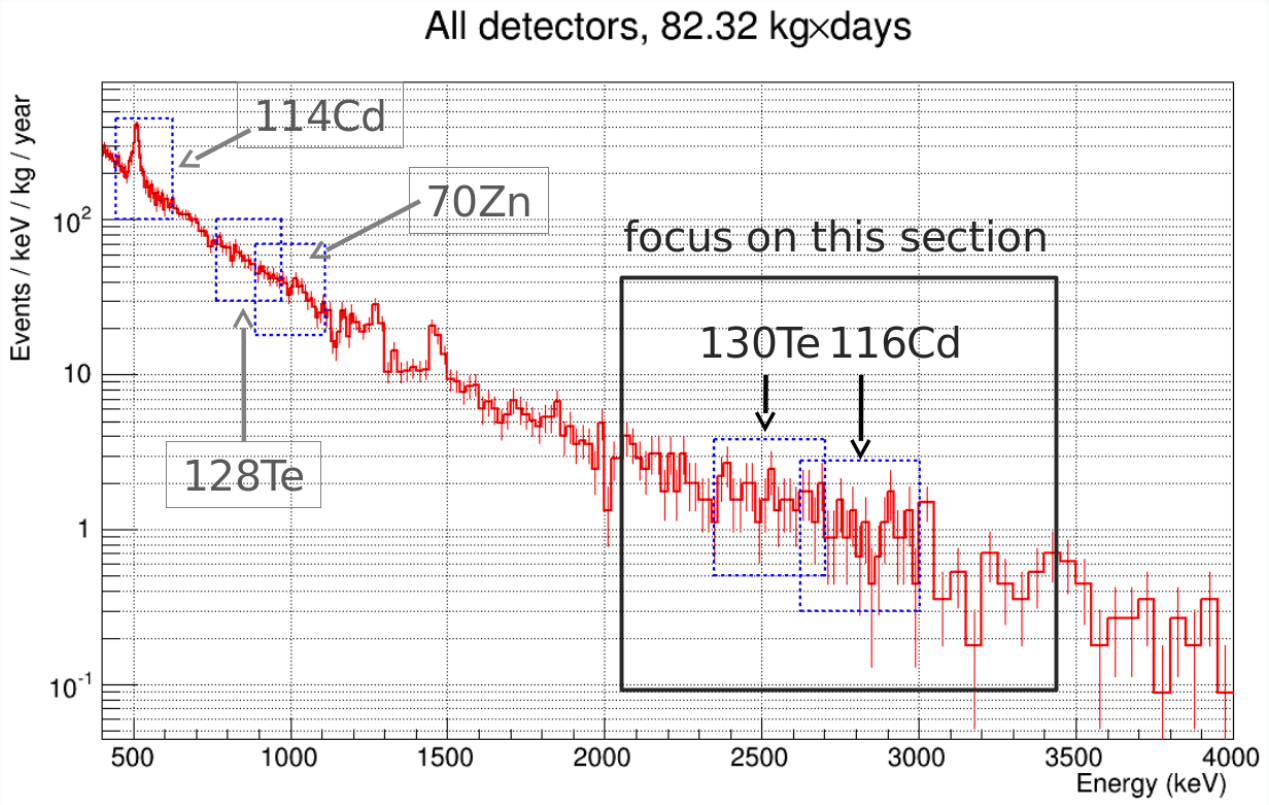


- 82.3 kgd exposure of layer 1 and 2 (32 detectors)
- All events are single detector events (coincidences neglected)
- Discrimination of surface events
- Rejection of multi-site events not applied

Data Analysis



Data Analysis



Background at 2.8 MeV $\cong$ 1 event/keV/kg/yr

Data Analysis

PRELIMINARY!

Isotope	COBRA '09 [yr]	COBRA '13 [yr]	world's best [yr]
^{114}Cd	$2.0 \cdot 10^{20}$	$1.06 \cdot 10^{21}$	$1.1 \cdot 10^{21}$
^{128}Te	$1.7 \cdot 10^{20}$	$1.44 \cdot 10^{21}$	$1.1 \cdot 10^{23}$
^{70}Zn	$2.2 \cdot 10^{17}$	$2.57 \cdot 10^{18}$	$1.8 \cdot 10^{19}$
^{130}Te	$5.9 \cdot 10^{20}$	$3.88 \cdot 10^{21}$	$3.0 \cdot 10^{24}$
^{116}Cd	$9.4 \cdot 10^{19}$	$9.19 \cdot 10^{20}$	$1.7 \cdot 10^{23}$

- based on 82.3 kgd exposure of layer 1 and 2 (32 detectors)
- Main background: alphas
- Improvement expected for continous handling under clean-room conditions for all manufacturing and commissioning steps

Data Analysis

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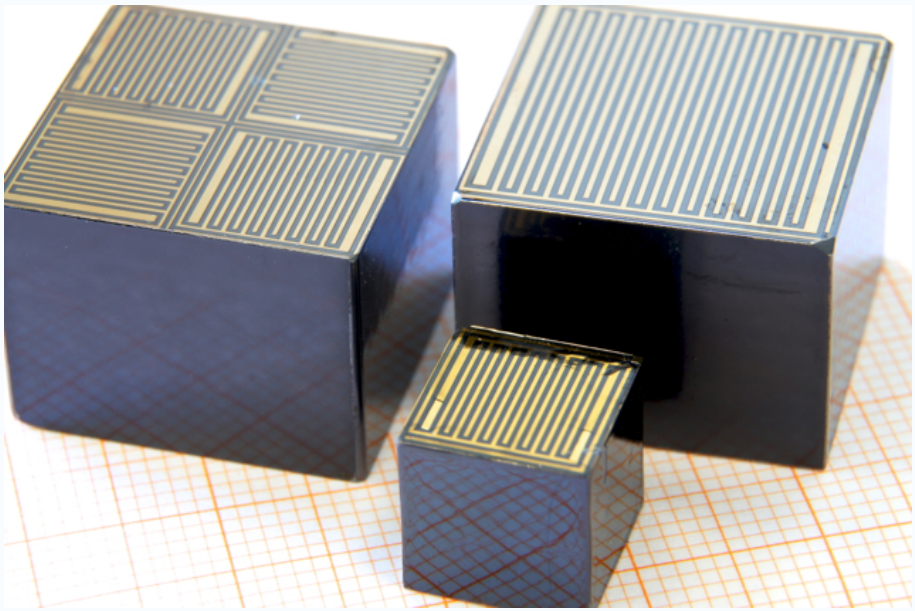
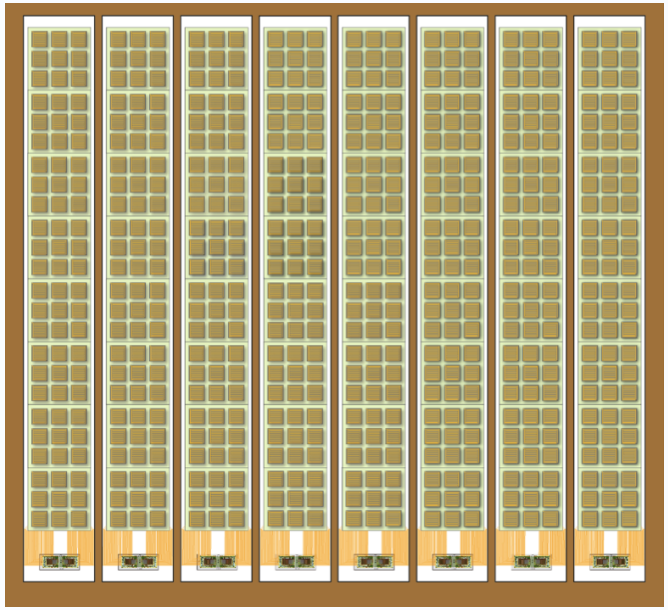
T65.8, Di 18:30: Thomas Quante
Aktuelle Ergebnisse des COBRA Experiments

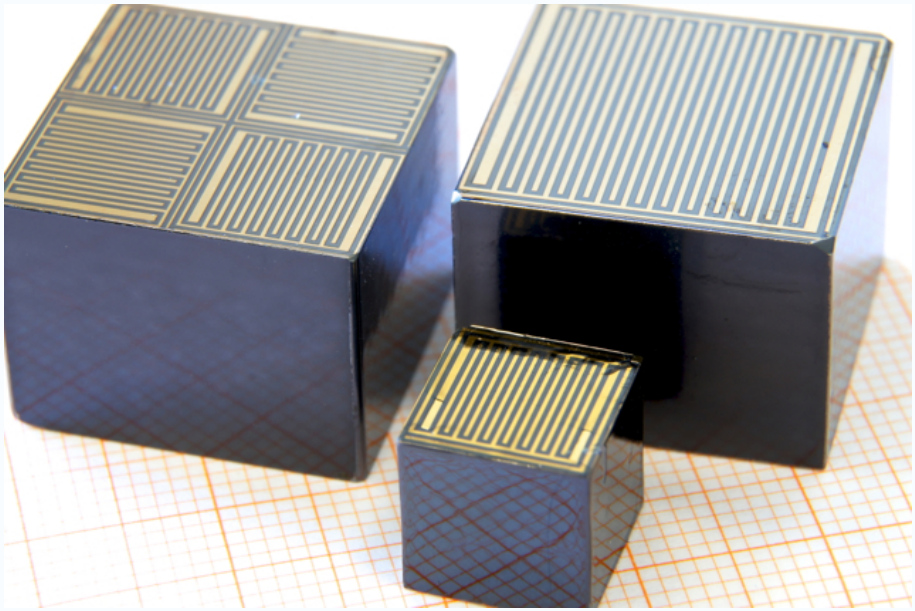
Towards a large scale Setup

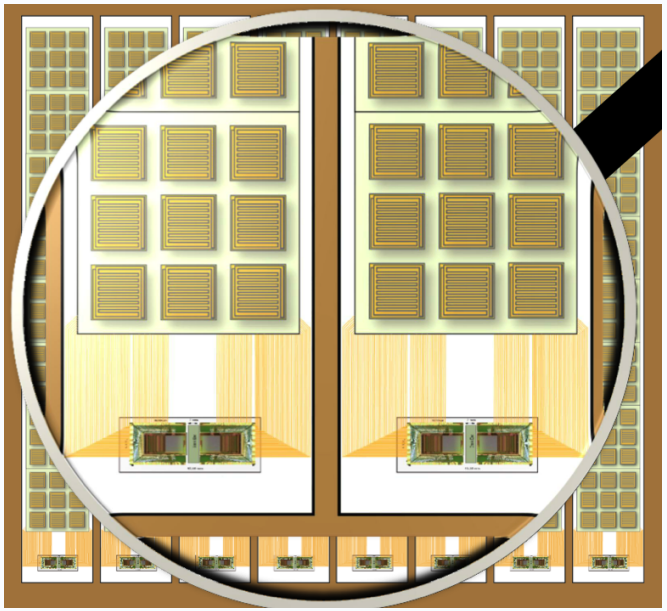




- Switch to larger detectors $2 \times 2 \times 1.5\,\mathrm{cm}^3$
  - Higher detection efficiency
  - Smaller surface to volume ratio

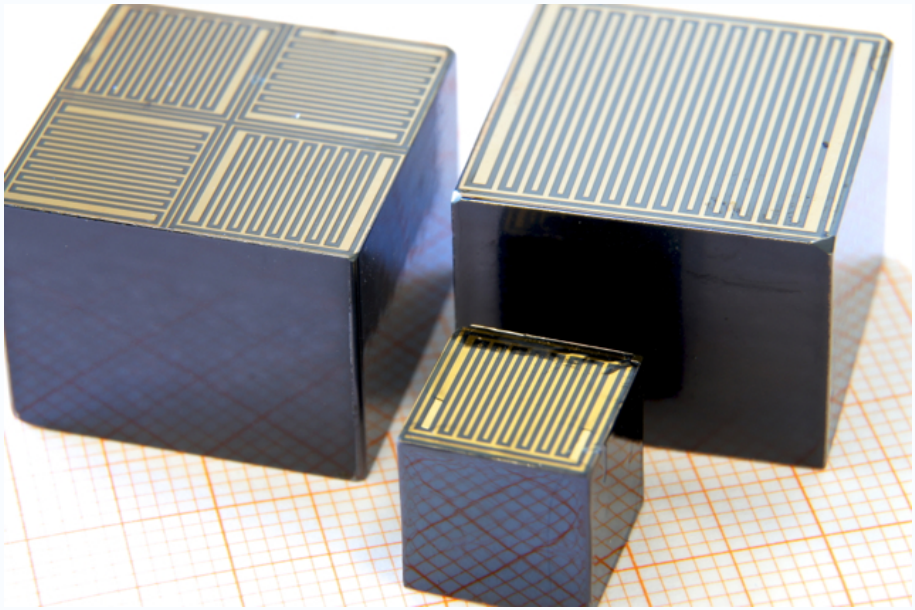
Towards a large scale Setup

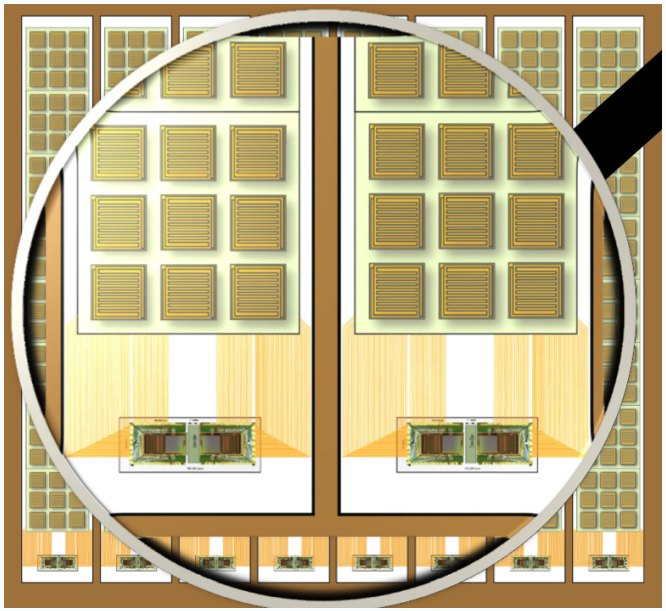




- Use of highly integrated DAQ electronics
  - ASIC/FPGA
  - Development ongoing

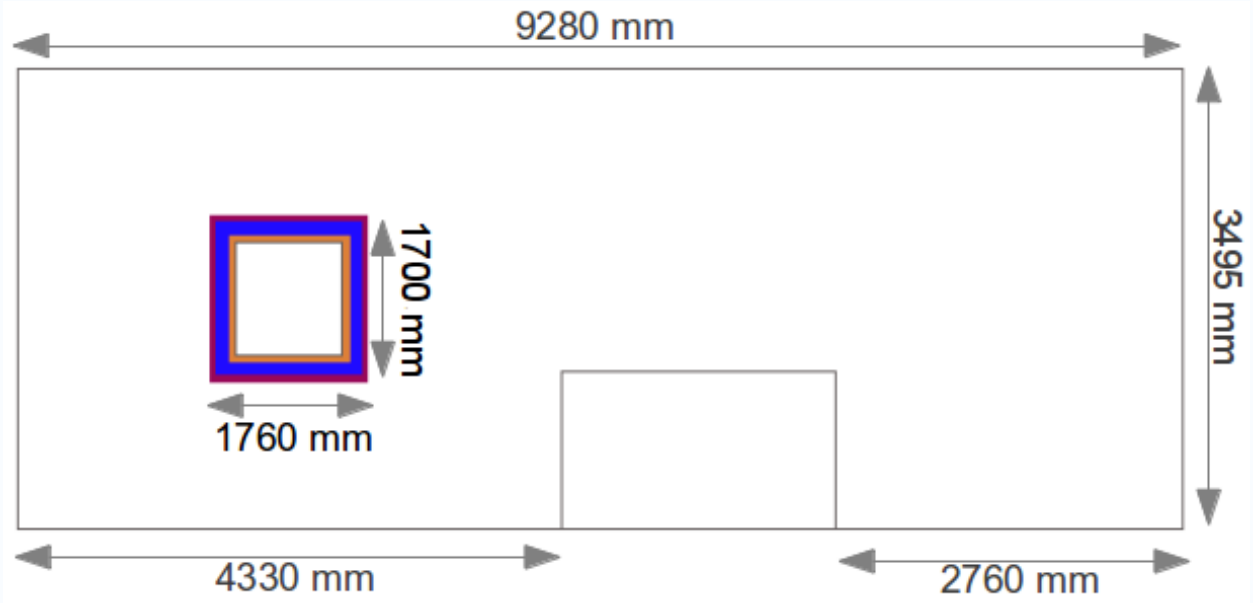
Towards a large scale Setup





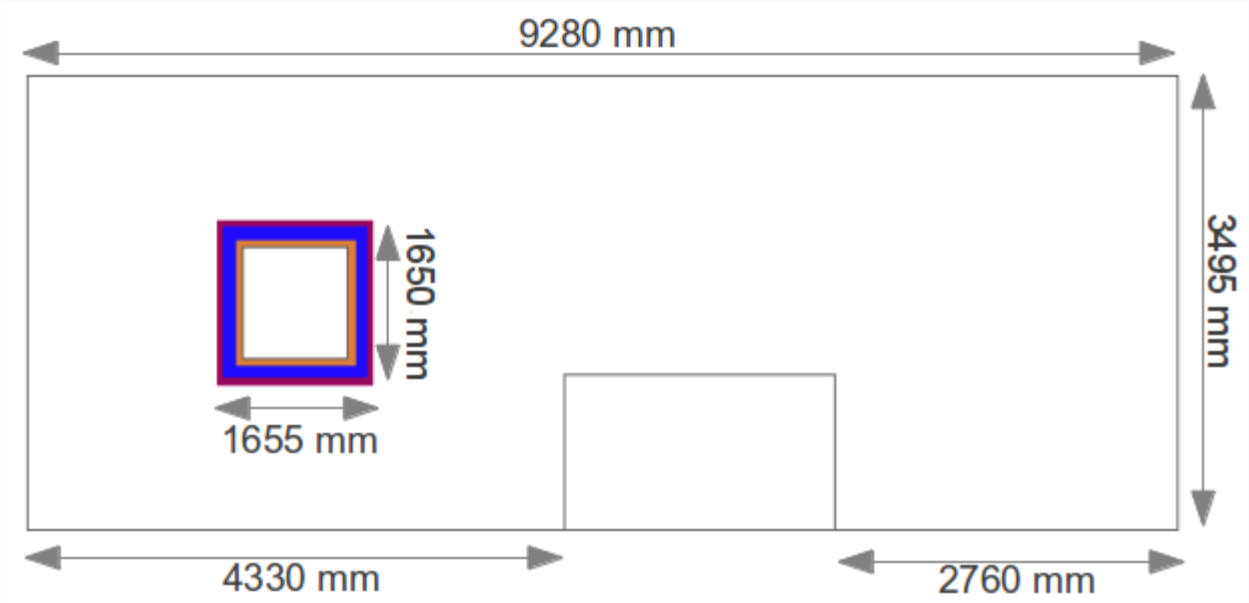
T23.4, Mo 11:45: Oliver Schulz
ASIC-Based Readout for a Large-Scale COBRA Experiment

Towards a large scale Setup



- MC compaign to determine the contribution of all possible background sources to the background rate on going
- Developed shield: B5%PE (10 cm) – Lead (20 cm) – Copper (10 cm)
- $95.5 \times 90 \times 85\,\mathrm{cm}^3$ are reserved for detectors

Towards a large scale Setup



T18.4, Mo 11:45: Nadine Heidrich
Background Estimation for a large scale COBRA Experiment

Summary

- COBRA is a $0\nu\beta\beta$ decay experiment with CdZnTe detectors
- Pixelated detectors offer the possibility of particle identification and effective background reduction
- 64 Coplanar Grid detectors installed and running at LNGS
- Background at 2.8 MeV $\cong$ 1 event/kev/kg/yr
- Goal: Sensitivity for the large-scale setup $> 10^{26}$ yr

Thank you for your attention!

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Pulse-shape discrimination of lateral surface events for the COBRA experiment

T18.3, Mo 11:30: Stefan Zatschler
Single-site and Multi-site Event Discrimination for the COBRA Experiment

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Background Estimation for a large scale COBRA Experiment

T23.4, Mo 11:45: Oliver Schulz
ASIC-Based Readout for a Large-Scale COBRA Experiment

T18.5, Mo 12:00: Jan Timm
COBRA als Neutronenspektrometer?

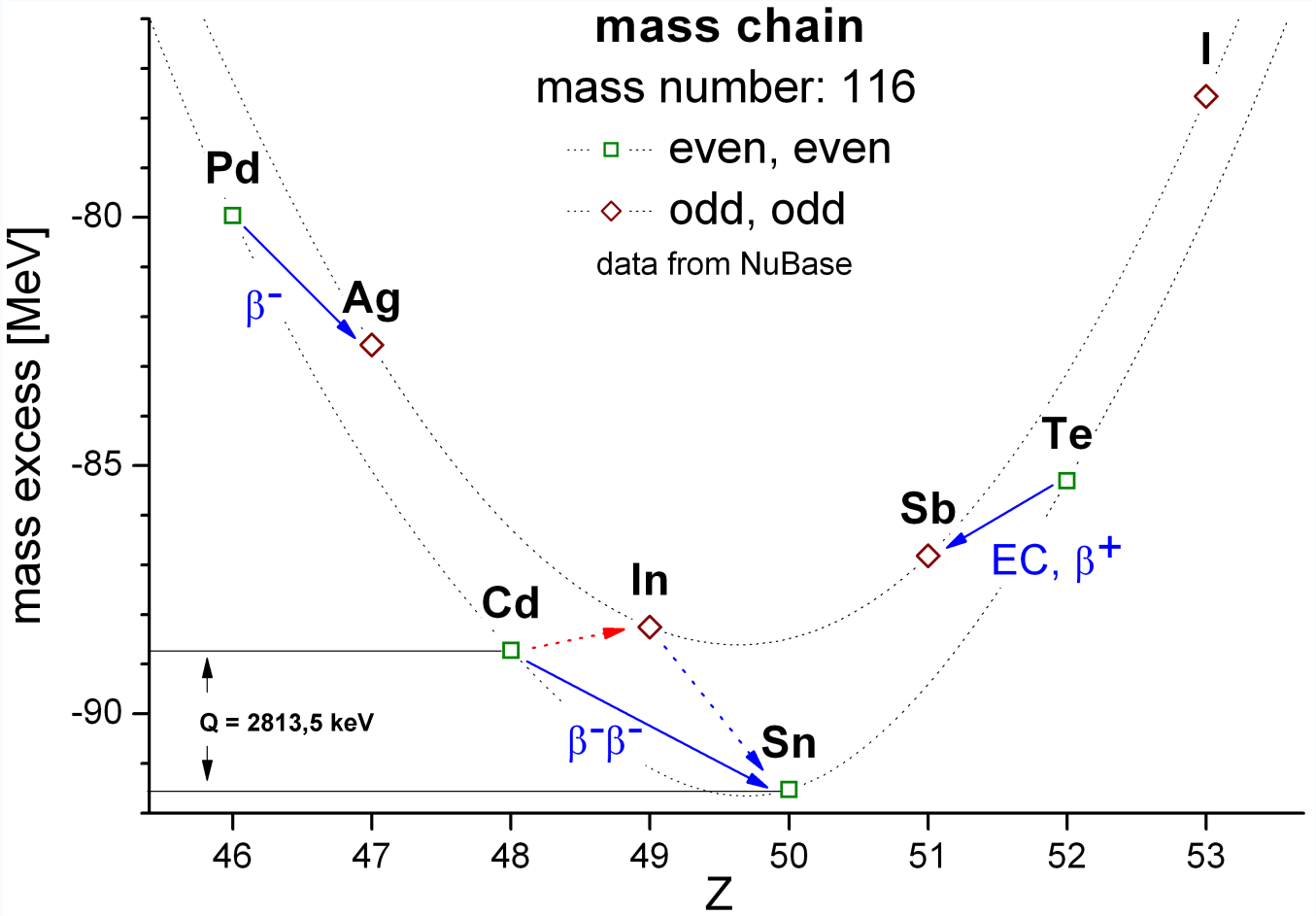
T39.8, Mo 18:30: Thomas Gleixner
Dreidimensionale Spurrekonstruktion in pixelierten CdTe-Detektoren

T65.8, Di 18:30: Thomas Quante

Aktuelle Ergebnisse des COBRA Experiments

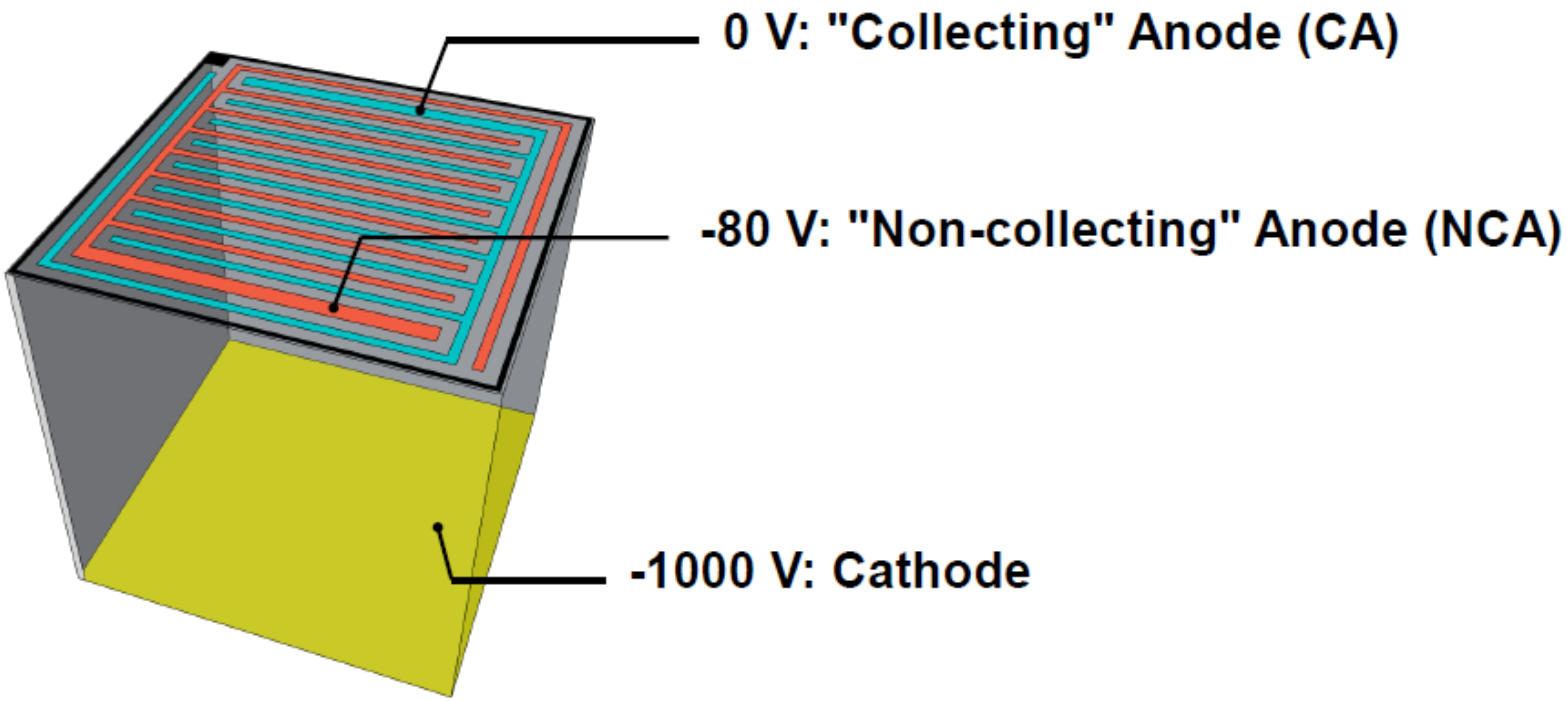

Backup–Slides

$0\nu\beta\beta$ decay of ^{116}Cd

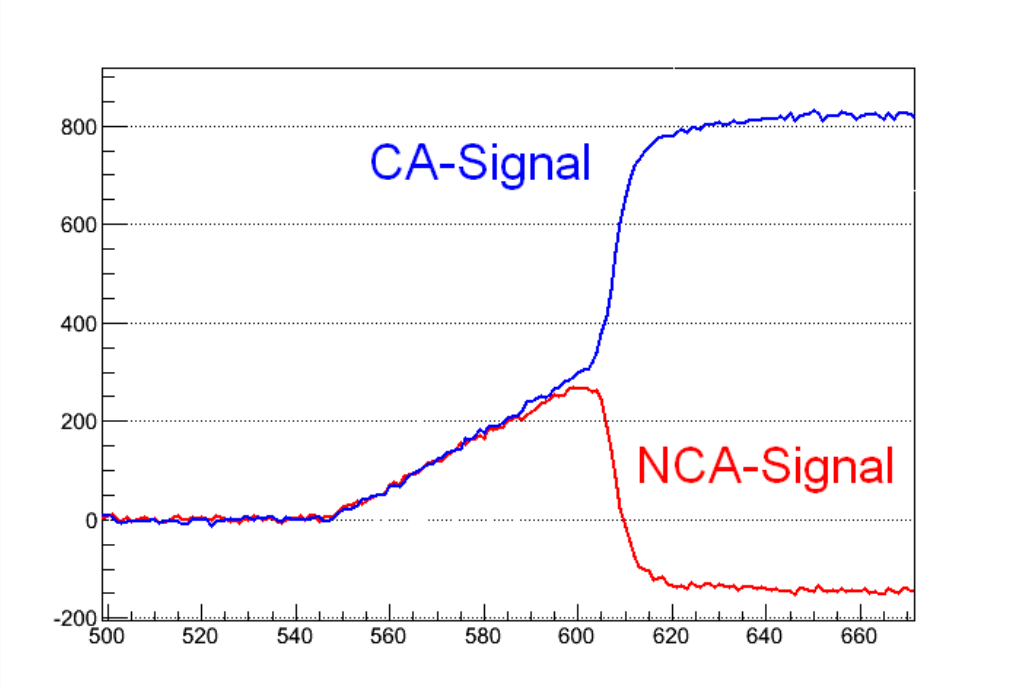


CPG

- Low mobility lifetime product for holes in CdZnTe
  - Read out of two anodes (CPG approach)

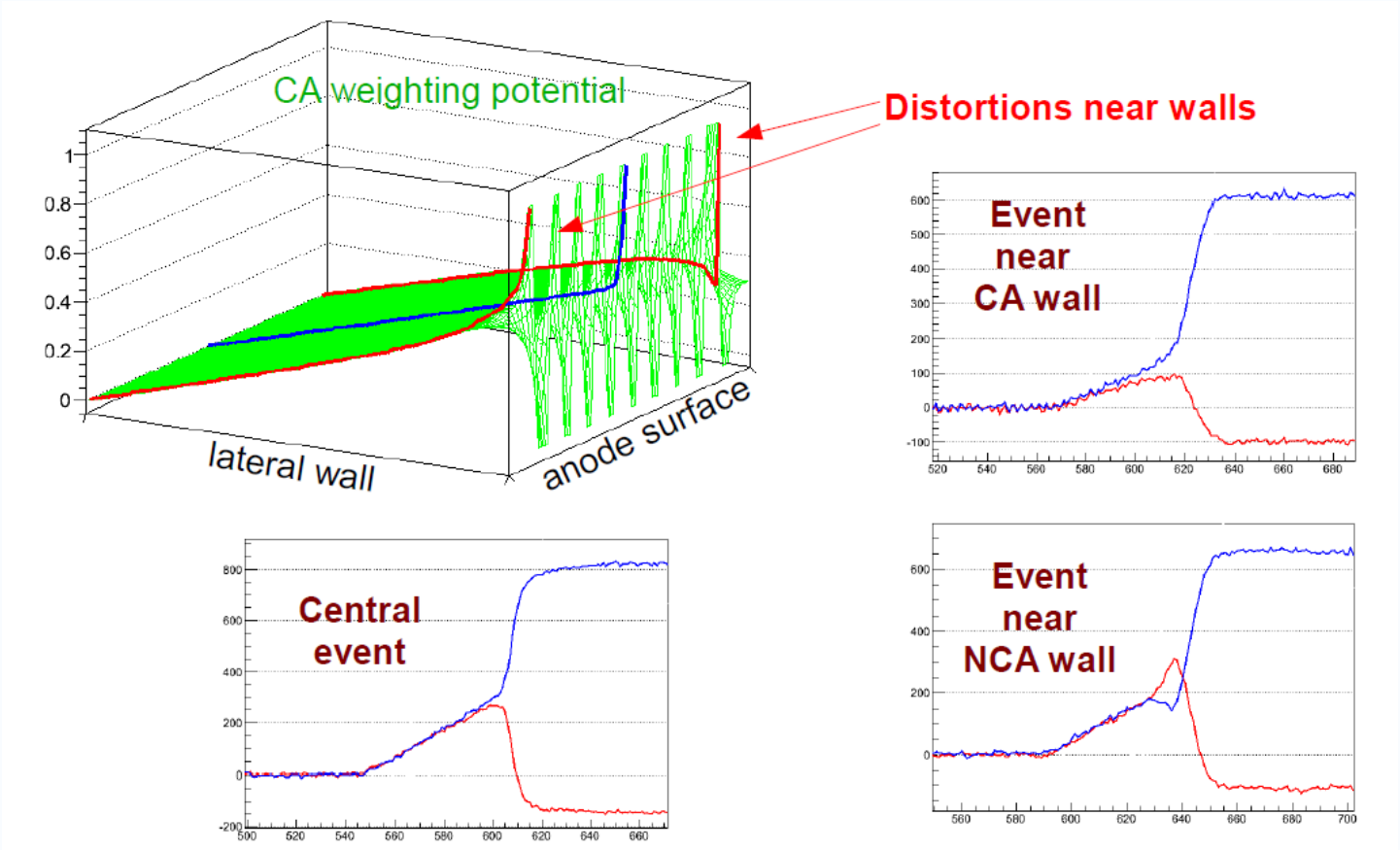


Energy & Interaction depth

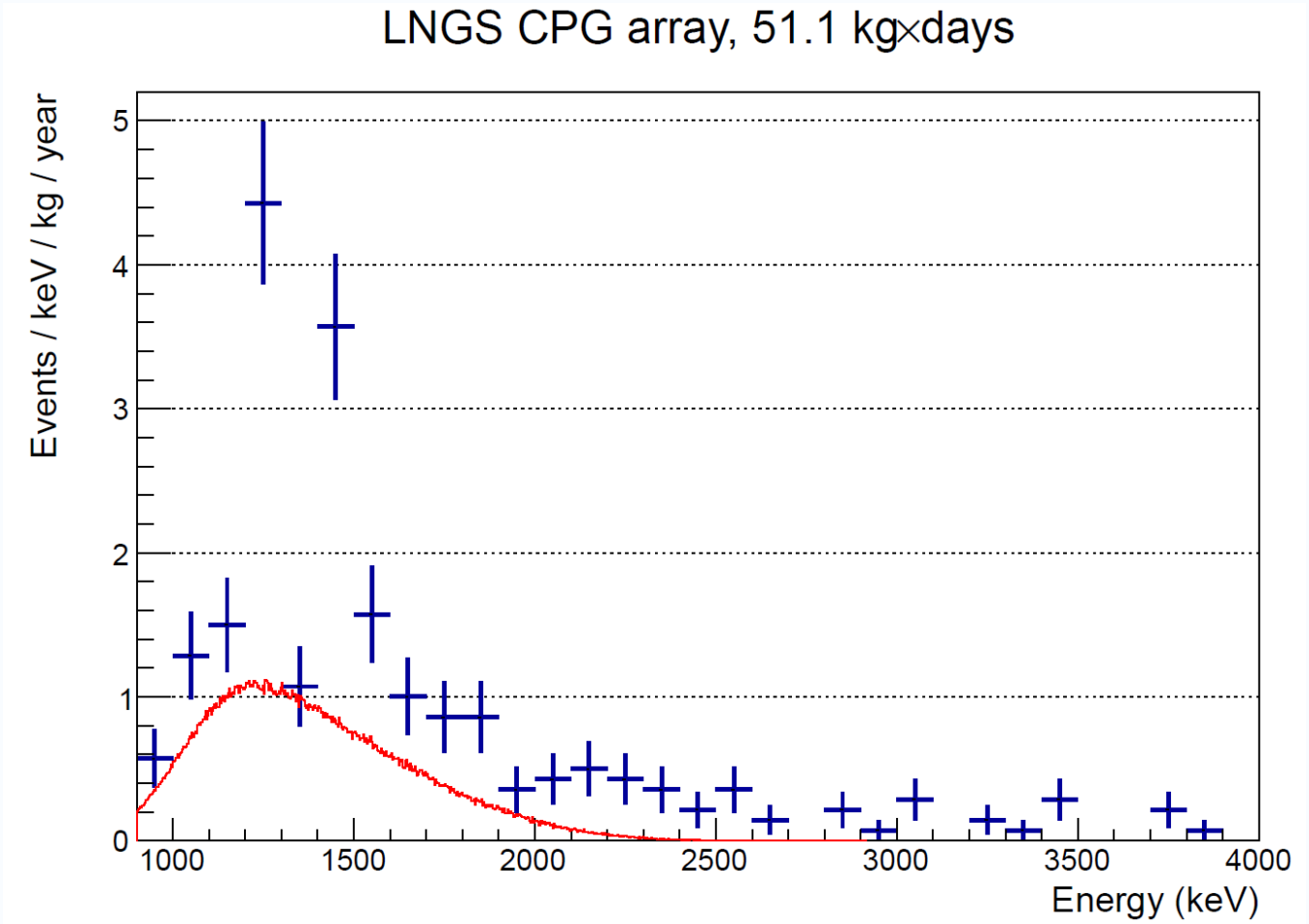


- Energy deposition: $E \propto CA - NCA$
- Interaction depth: $z \propto \frac{CA+NCA}{CA-NCA}$

Lateral Surface Events



$2\nu\beta\beta$ decay of ^{116}Cd



Read Out LNGS