Status and Perspectives of the COBRA Experiment

Björn Wonsak
for
the COBRA Collaboration

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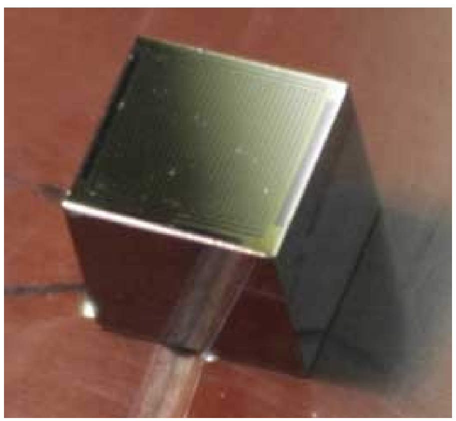
Overview

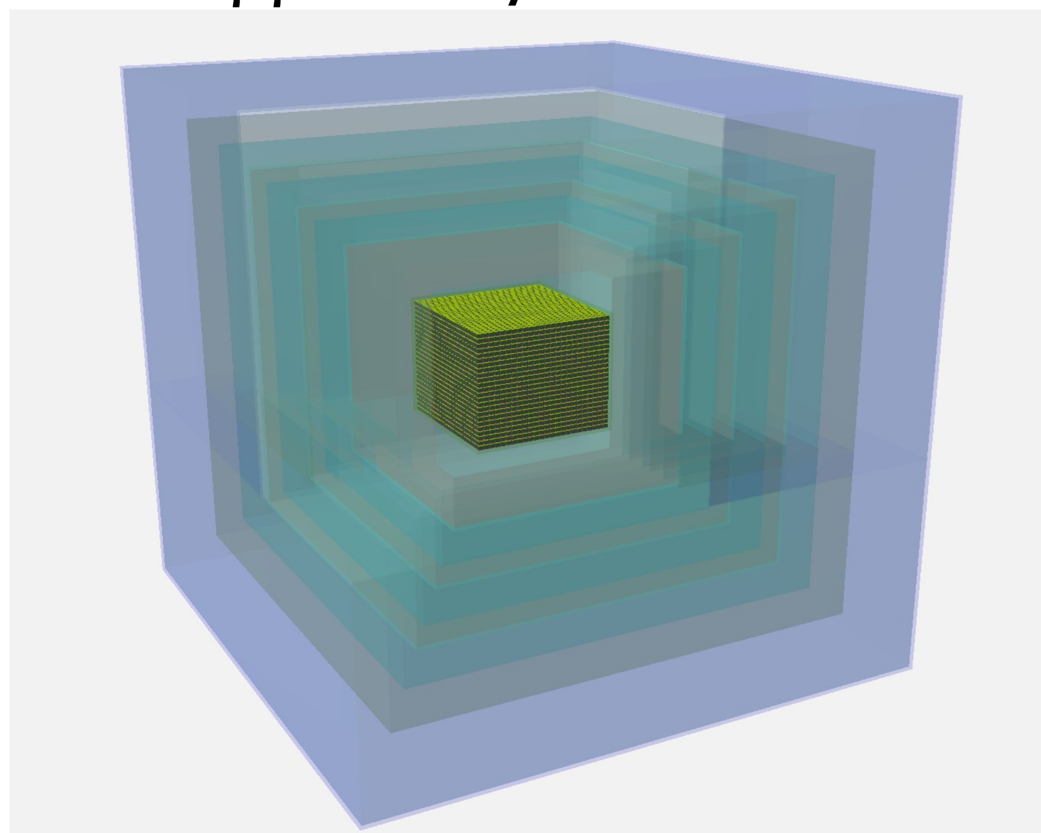
- Introduction
- Prototyp at LNGS
- Results
- Perspectives

COBRA: Basic Concept

Use a large number of
CdZnTe semiconductor detectors
to search for $0\nu\beta\beta$-Decay



'**Cop**lanare **G**rid'-
Detector (CPG)



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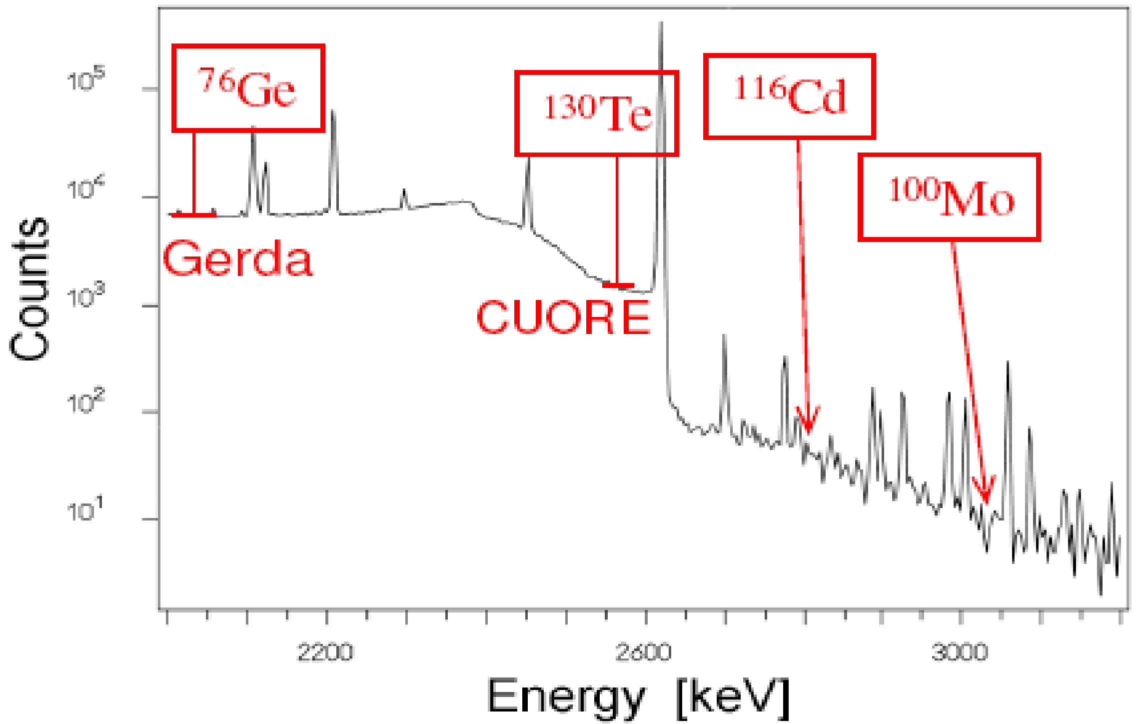
Advantages of CdZnTe

9 isotope undergoing ββ-decay:

- ^{116}Cd: high Q-value (2814 keV)
- ^{130}Te: high natural abundance (33,8%)
- ^{106}Cd: $\beta^+\beta^+$-emitter, high Q-value (2771 keV)



Advantages of CdZnTe

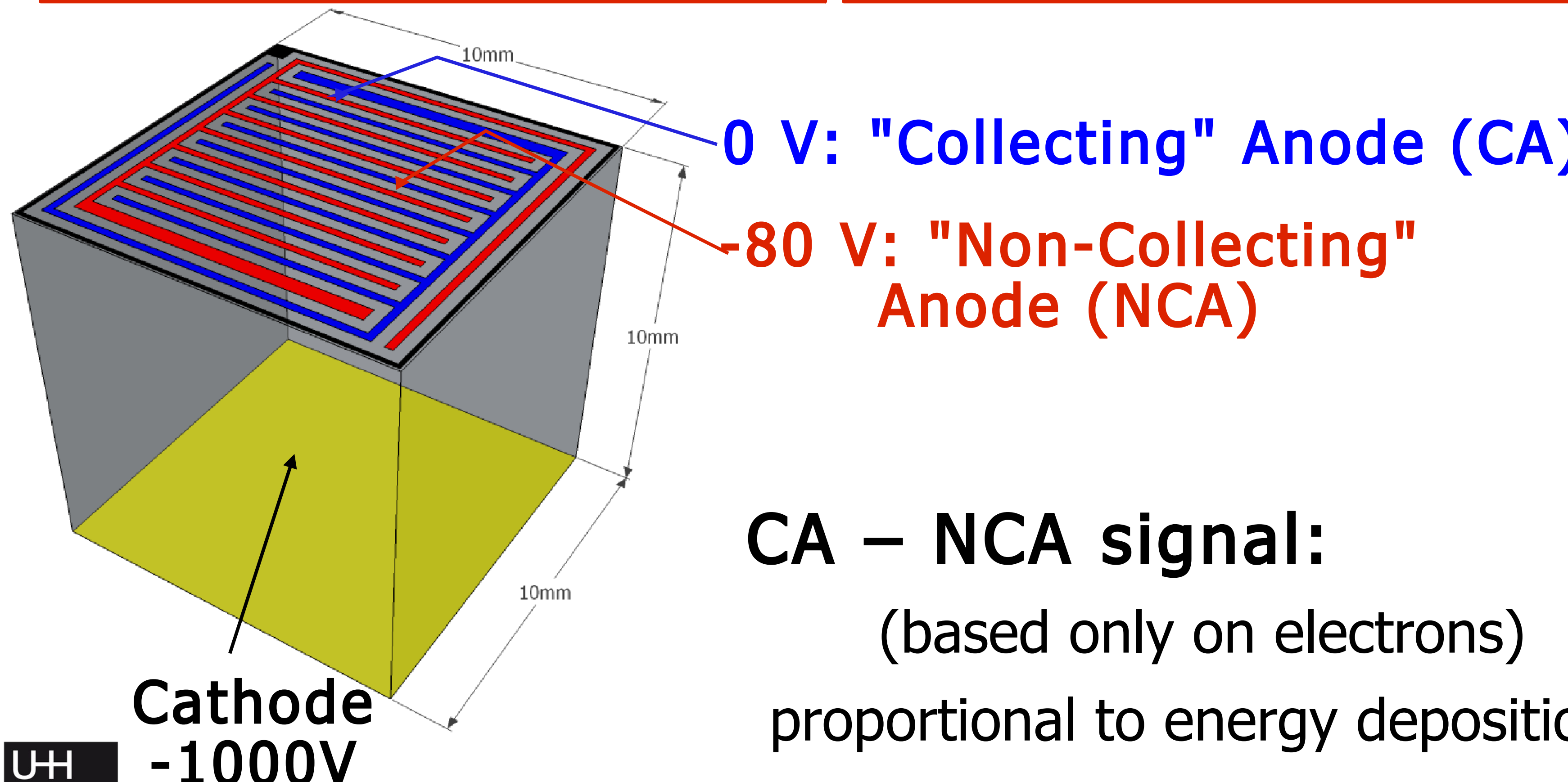
- Source = detector → large mass
- Semiconductor → clean, good energy resolution
- Operation at room temperature → no cooling
- Modular design → coincidence analysis
- Commercially available → easy to get/robust
- Tracking: 'Solid state TPC' (if pixelised)

- Disadvantage: Small → large surface

CPG Detectors

- **CdZnTe *problem* :** Poor hole transportation

- ***Solution* :** CPG Same concept as Frisch grid

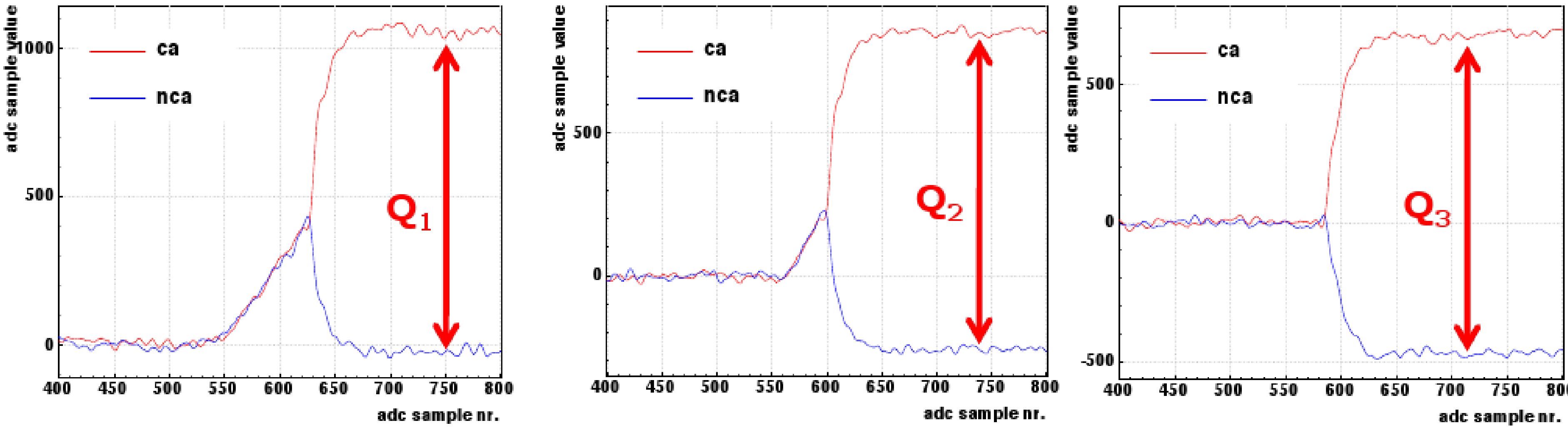


CA – NCA signal:

(based only on electrons)

proportional to energy deposition

Depth Information



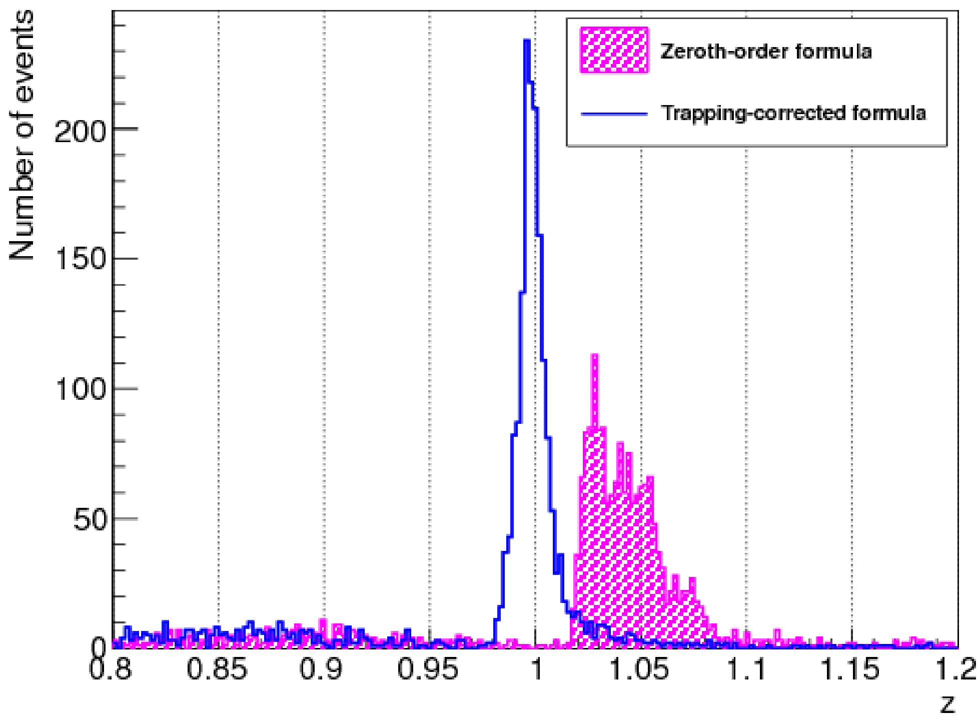
event near cathode — central event — event near anodes

- Contribution of NCA-signal is depth dependent

→ Interaction depth: $$z = \frac{CA + NCA}{CA - NCA}$$ 0th-order formula

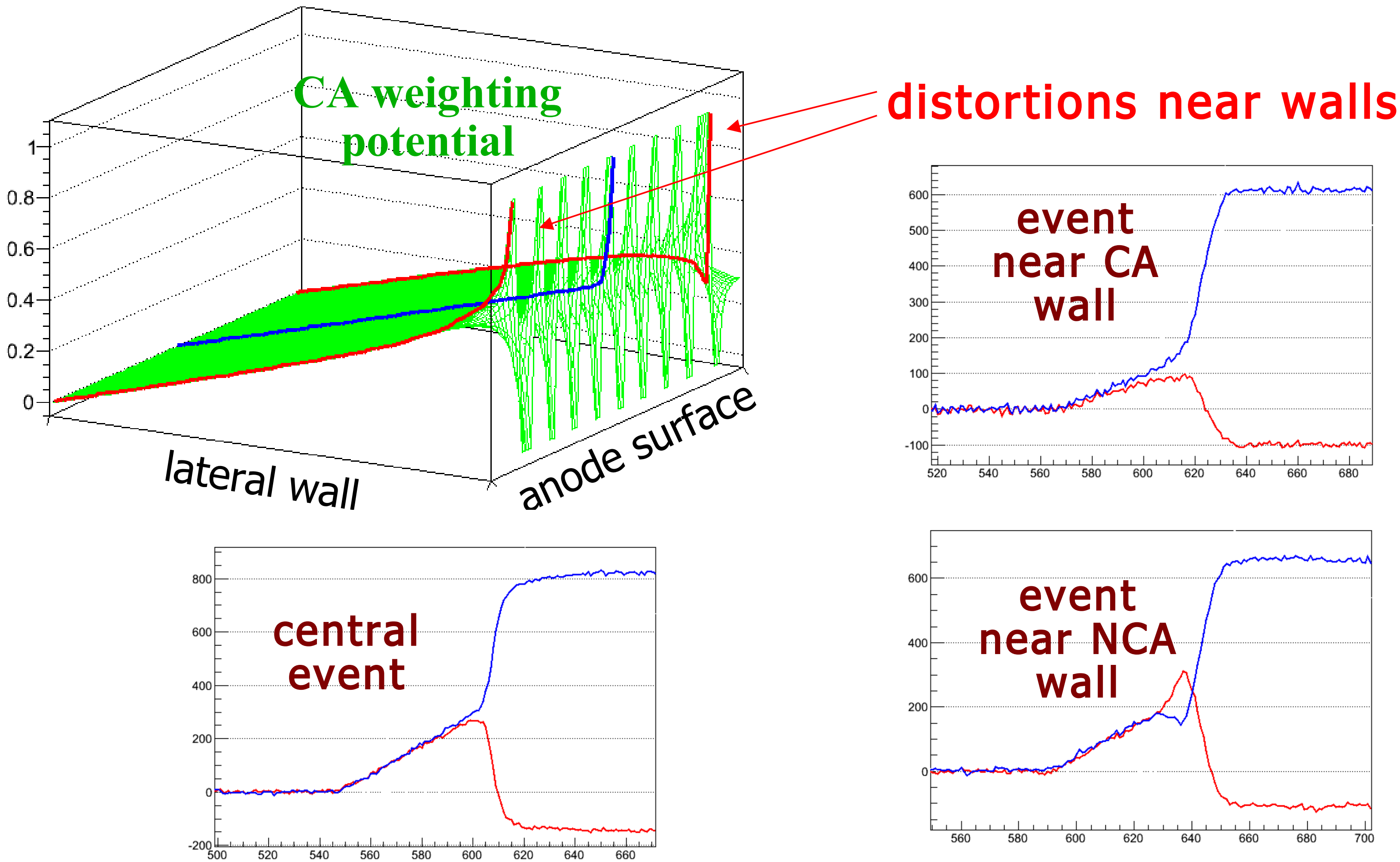
Improved Depth Information

- Electron trapping affects energy & depth information
  → weighting factor for energy
- Improved formulas for depth & energy



M.Fritts et al, NIM A, Volume 708, 21 April 2013, Pages 1-6, http://dx.doi.org/10.1016/j.nima.2013.01.004

Lateral Surface Effects

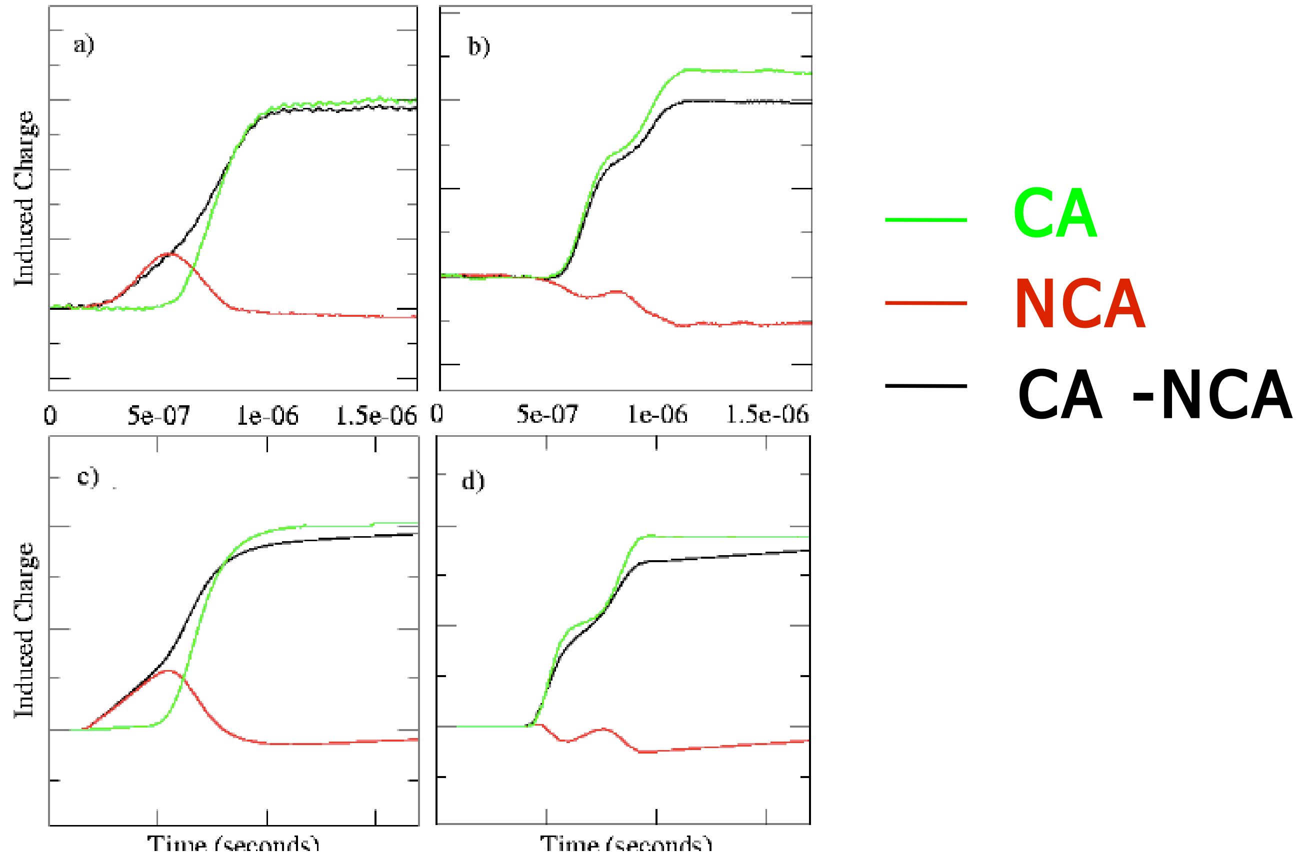


Single-site vs. Multi-site

J. McGrath et al. , NIM A 615,57 (2010)

Experimental signal

Simulated with TCAD software

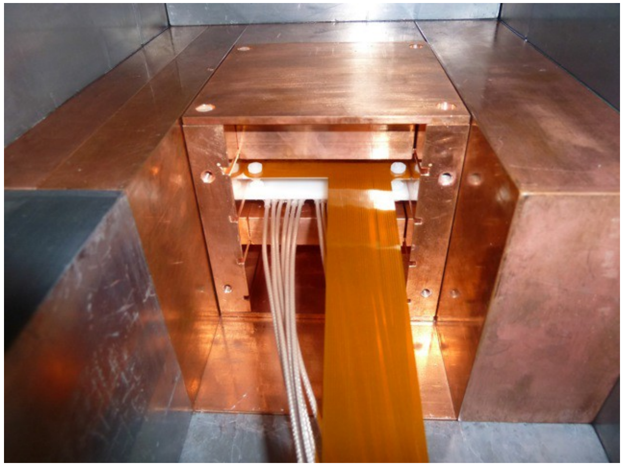


Single-site event (SSE)

Multi-site event (MSE)

Prototyp at LNGS

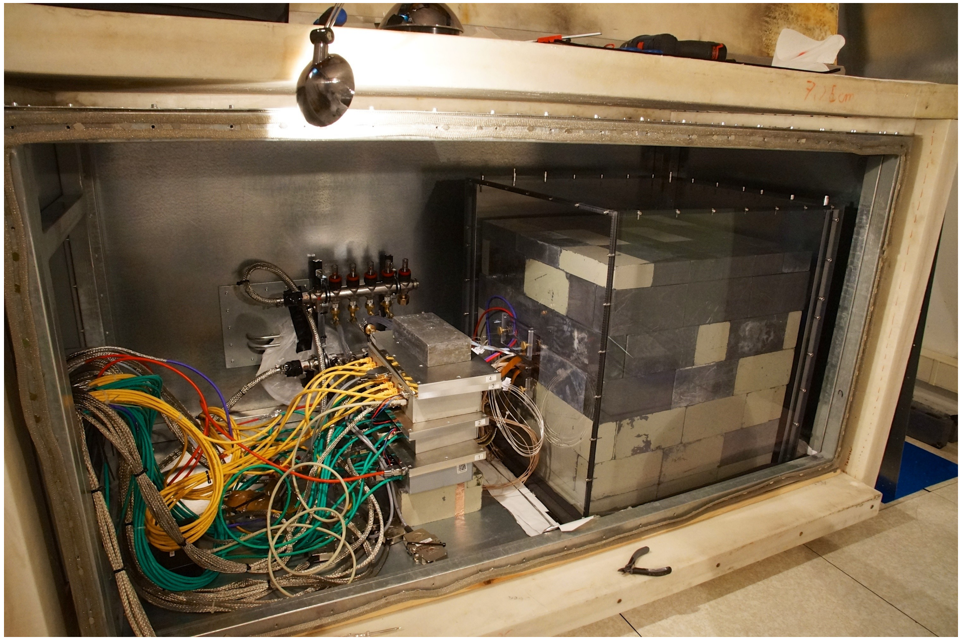
- Room for 64 1x1x1 cm^3 CPGs



- 3 layers installed (Nov. '11, March '12 & June '13)
  → ~ 7.5 kg days/month
- Last layer will follow November '13

The LNGS Prototyp Setup

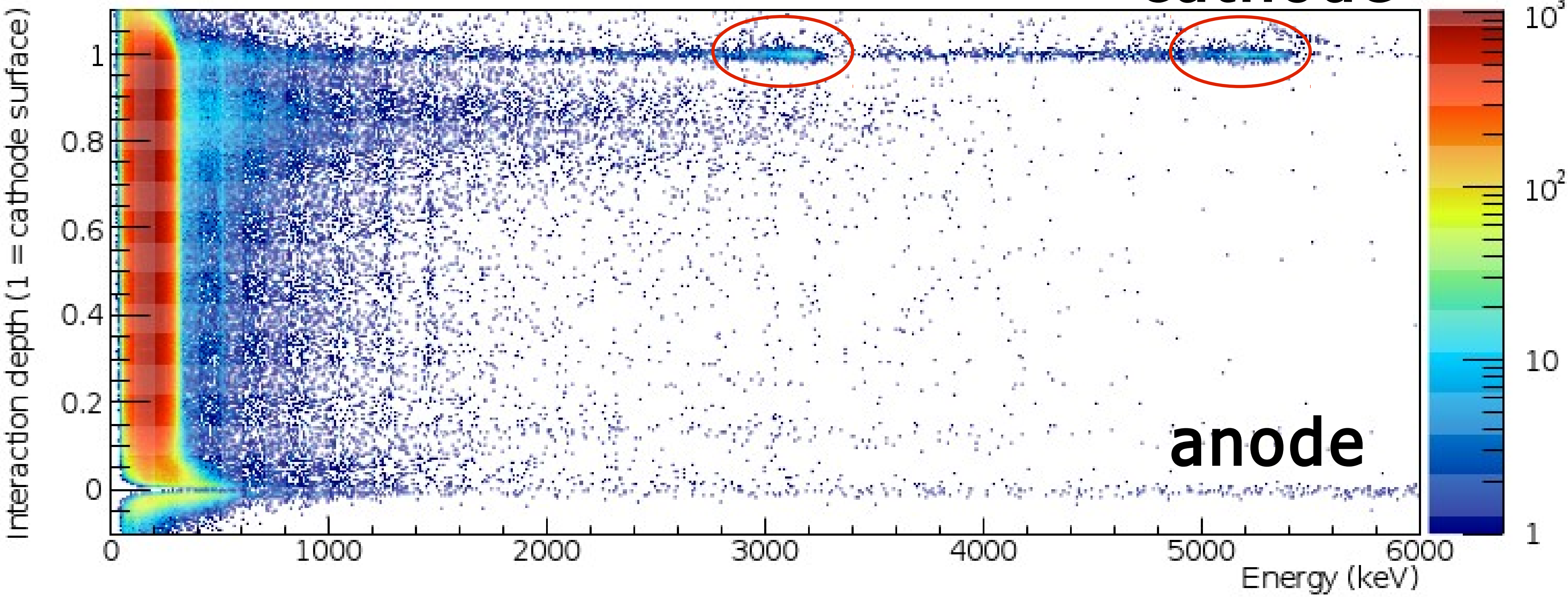
- Pre-characterized CZTs → best working point
  → energy resolution of 1.5 % at 2814 keV
- Readout with FADCs
- Nitrogen flushing



- Last upgrades:
  - Cooling
  - Pulser

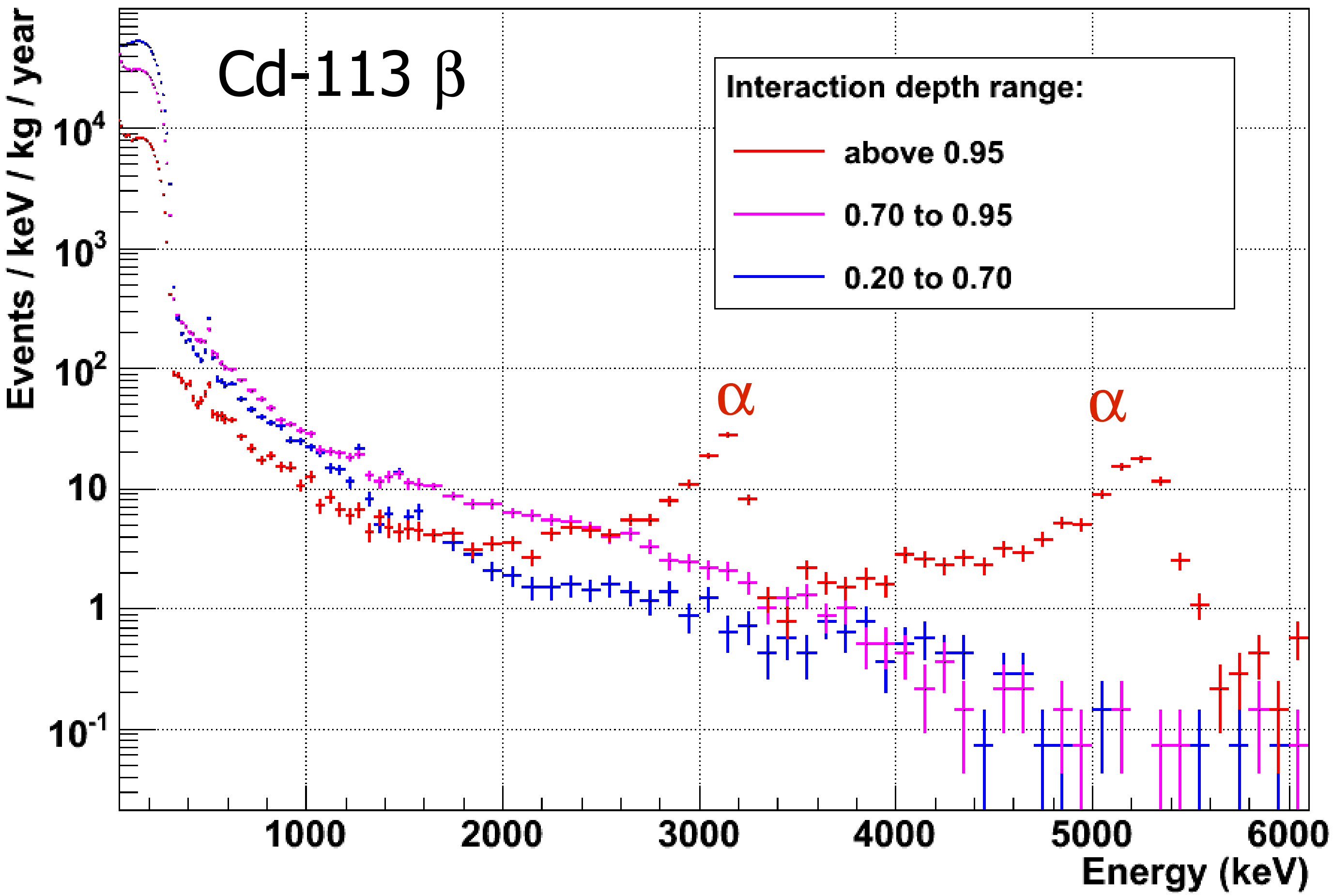
  → synchronisation for coincidence

Prototype: Measured Spectrum

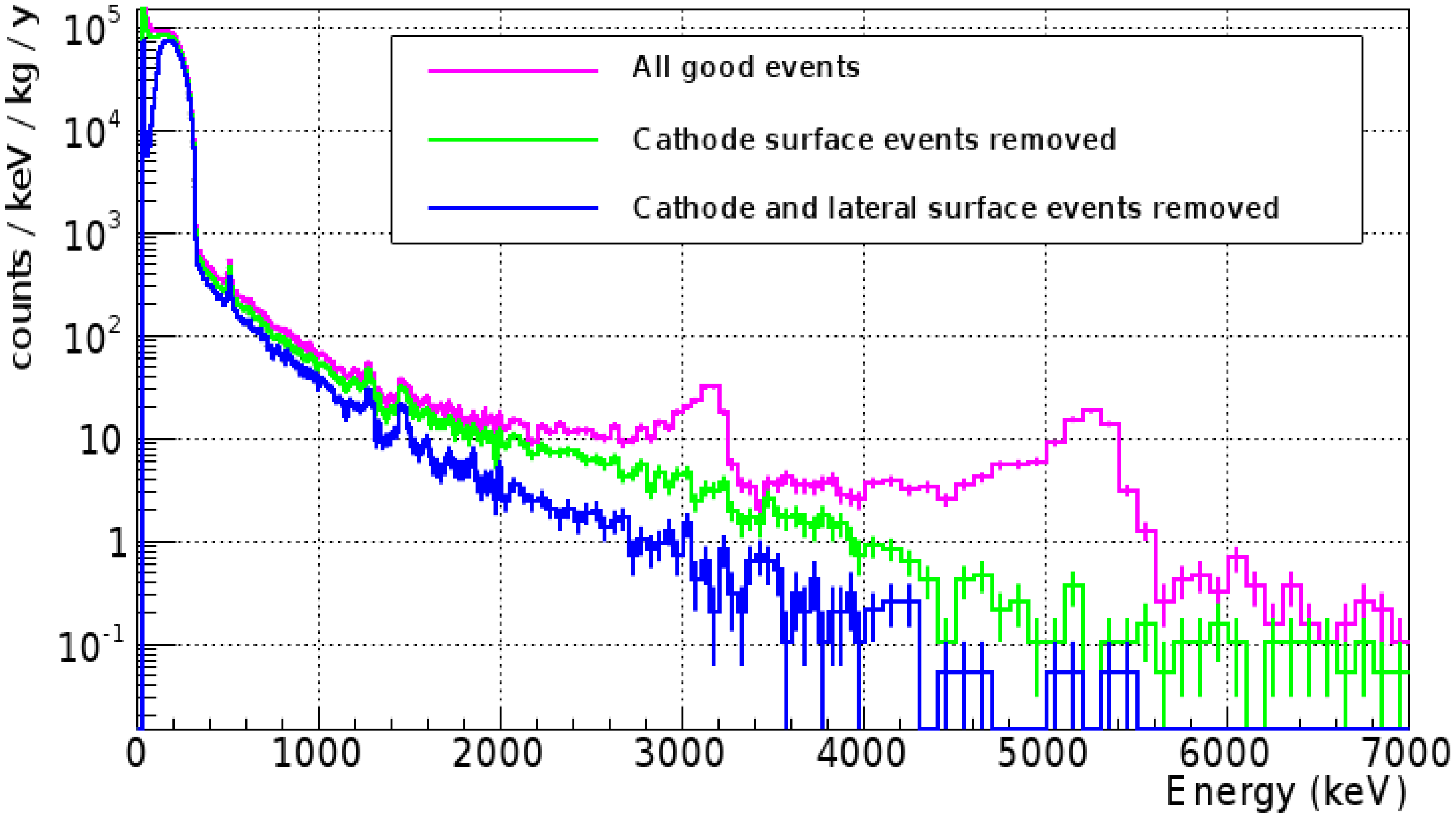


- 69 kg days of data collected until June 2013

Depth Analysis



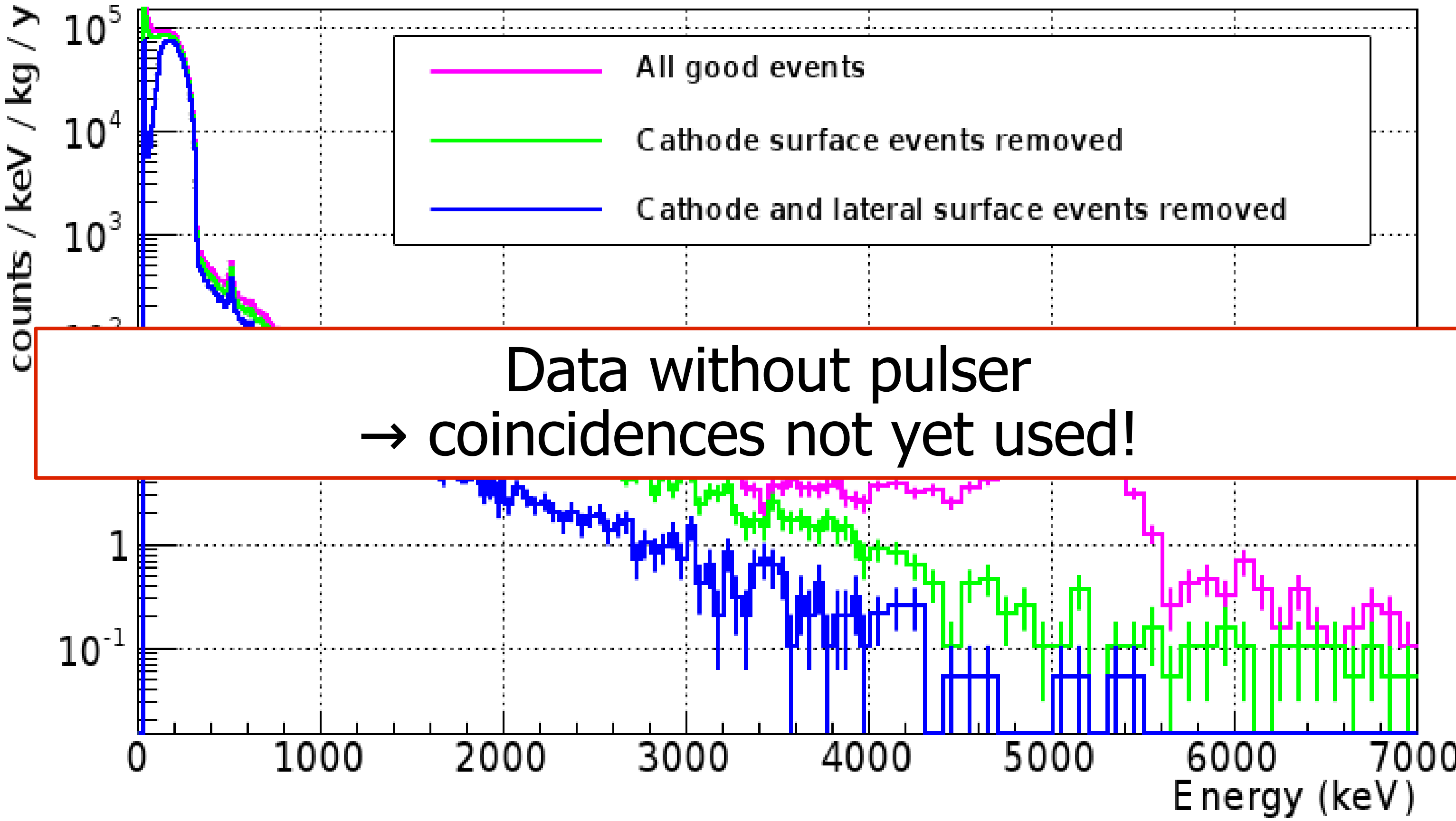
Result



Background after all cuts: ~ 1 cts/keV/kg/y

Cut efficiencies: 95% cathode, 82% lateral

Result



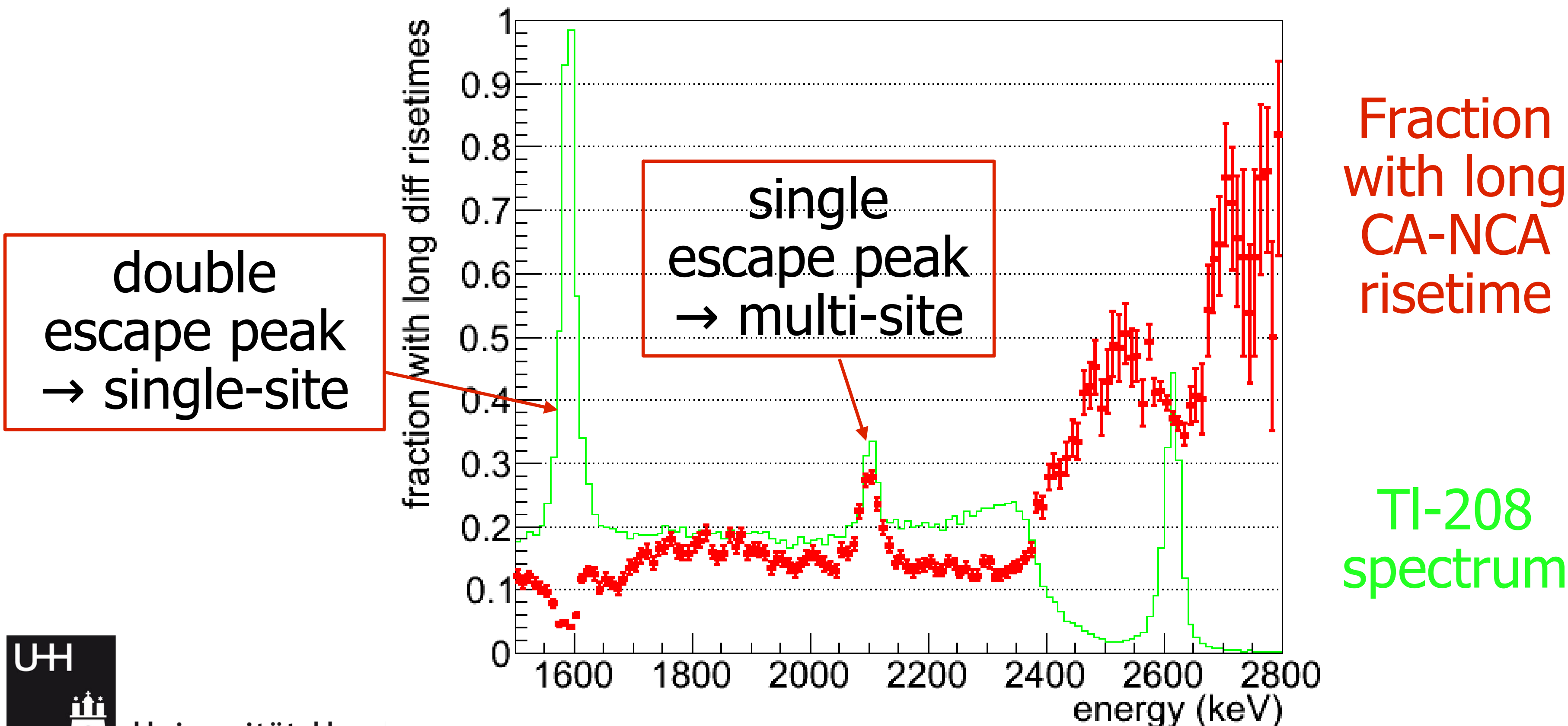
Data without pulser
→ coincidences not yet used!

Background after all cuts: ~ 1 cts/keV/kg/y

Cut efficiencies: 95% cathode, 82% lateral

Single-site vs. Multi-site Events

- Calibration with Th-228 → Tl-208 peak at 2615 keV
- Cut on length of risetime (CA-NCA signal)



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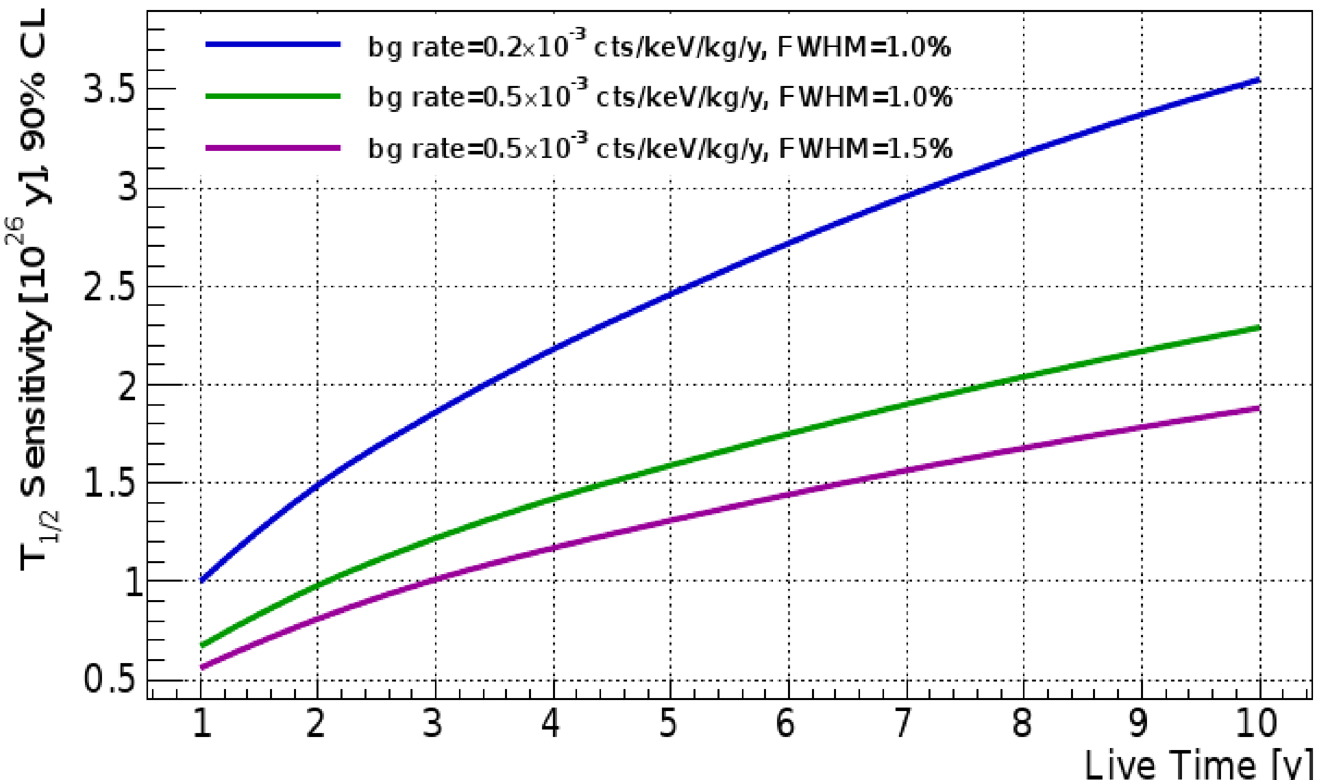
Perspectives

- Plan for large array setup:
  - 2x2x1.5 cm^3 CPG detectors
  - 400 kg total mass → ~11000 CPGs
  - 90% enriched in Cd-116



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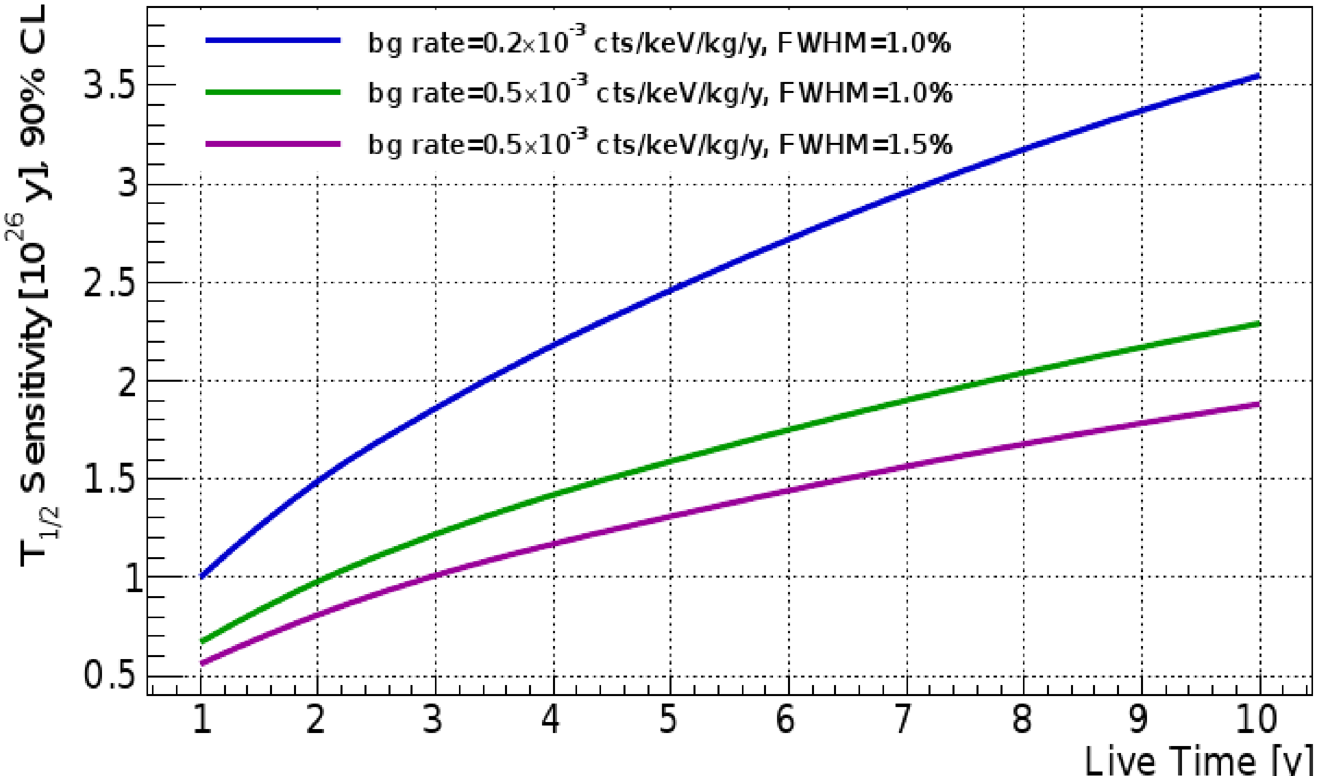
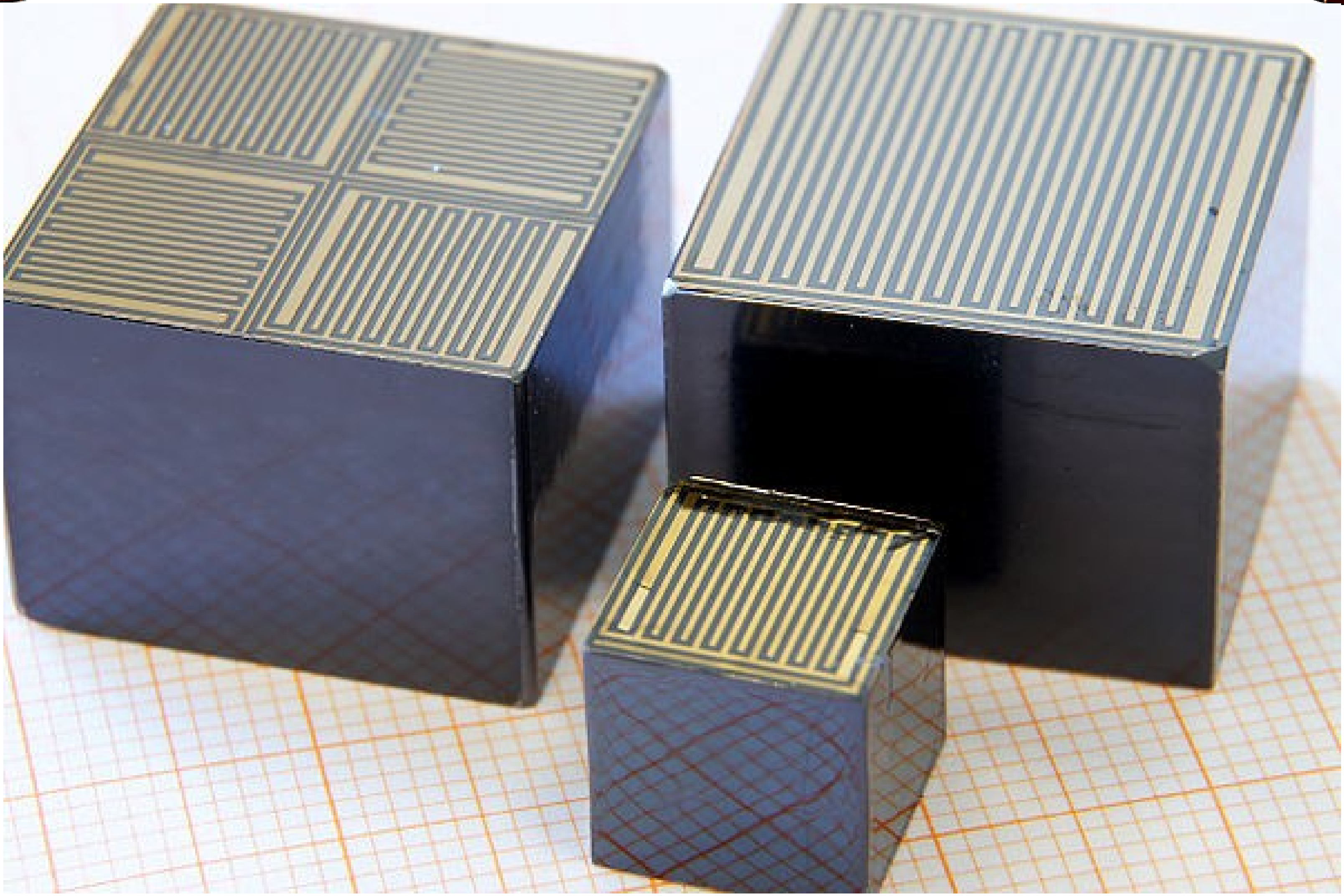


New Large CPGs

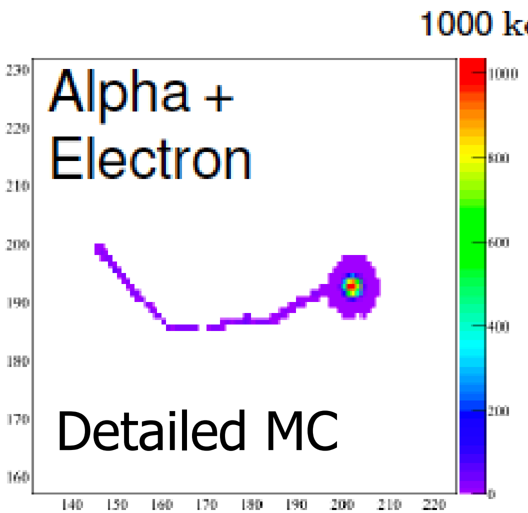


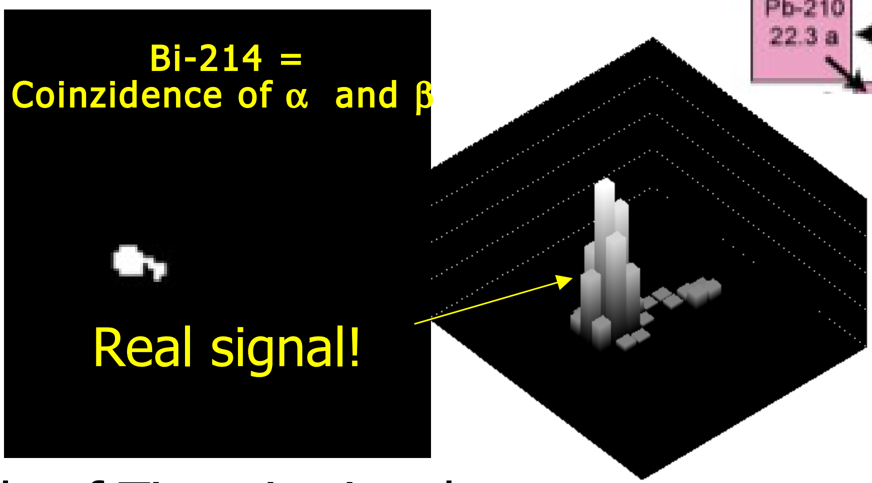
Pixelised Detectors

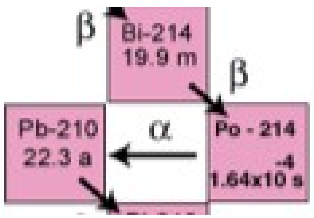
- Three different systems under investigation
- Large and small pixels (2 mm – 50 μm)

  → surface & SSE vs. MSE identification
- Small pixels → topological information

  → particle identification







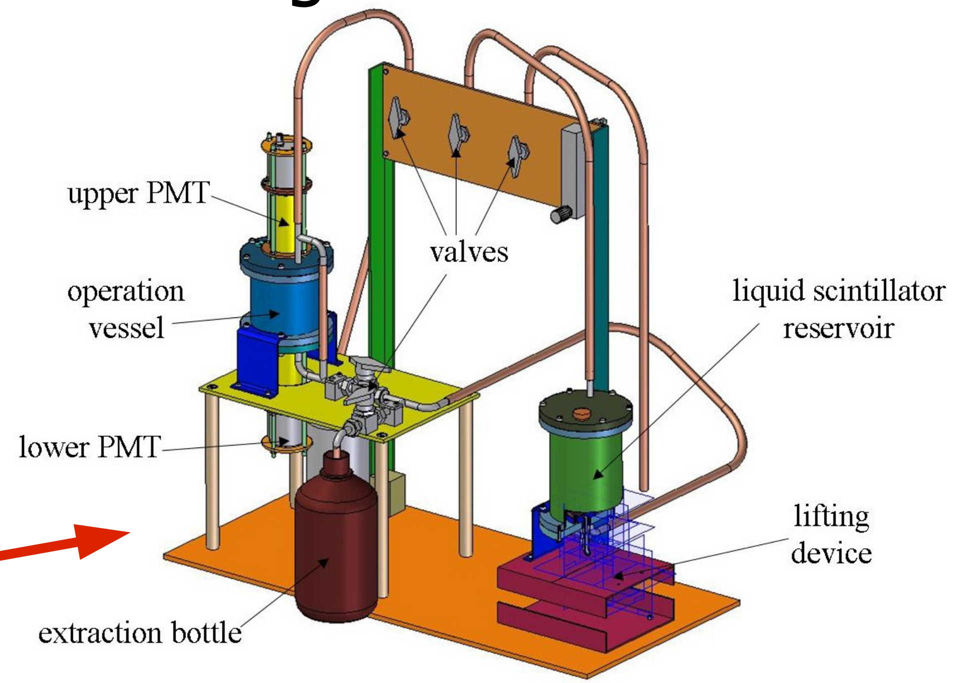
example of Timepix signals

CZT in Liquid Scintillator

- Can be used instead of passivation
  → no contamination from lacquer
- Is very clean
- Can act as veto and shielding
- No air → no radon

D.Y. Stewart and Y.A. Ramachers, JINST 3 (2008) P01007

Test setup at University of Hamburg



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Summary

- Improved Prototype:
  - Data taking since November 2011
  - Fully instrumented by the end of 2013
  - 69 kg days of data collected until June 2013
- Pulse shape analysis used for discrimination against surface events → ~1cts/keV/kg/y
- Main background: α from surface contamination
  - Guard ring not used yet → could help
- Coincidence analysis now possible
- SSE vs. MSE-discrimination under investigation
- Technical Design Report in preparation

The COBRA Collaboration

Technical University Dresden
Technical University Dortmund
Material Research Centre Freiburg
University of Erlangen-Nürnberg
University of Hamburg

Laboratori Nazionali del Gran Sasso

Washington University at St. Louis

University of Bratislava

University of Jyvaskyla

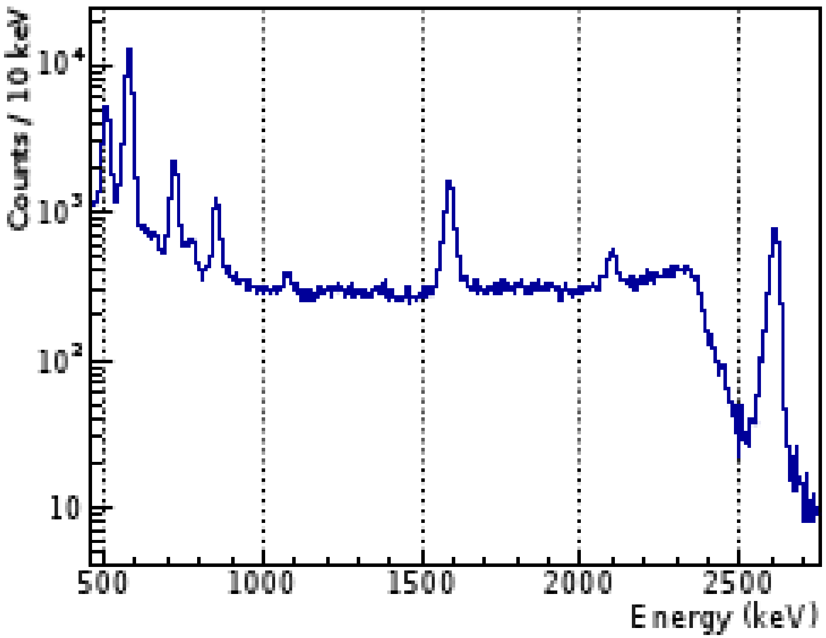
University of La Plata

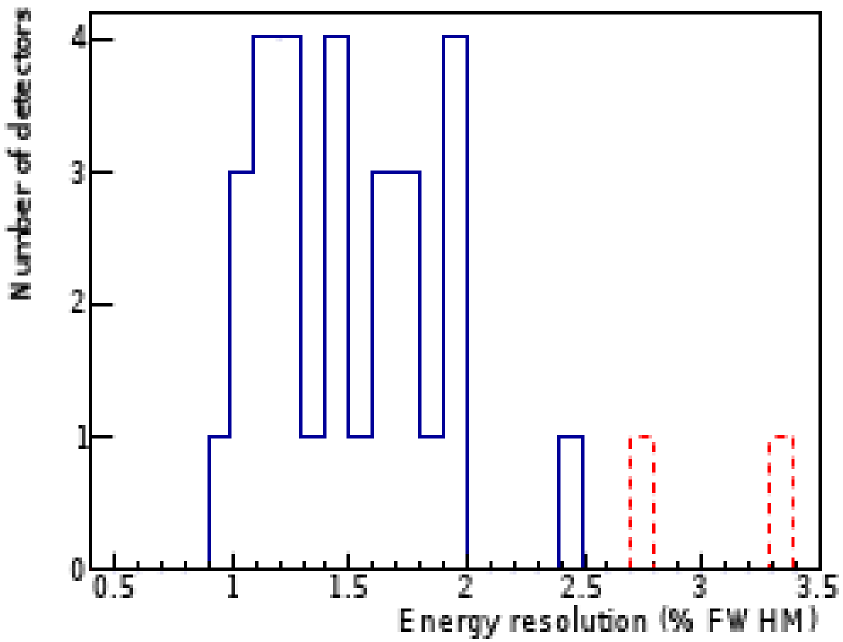
Czech Technical University Prague

JINR Dubna

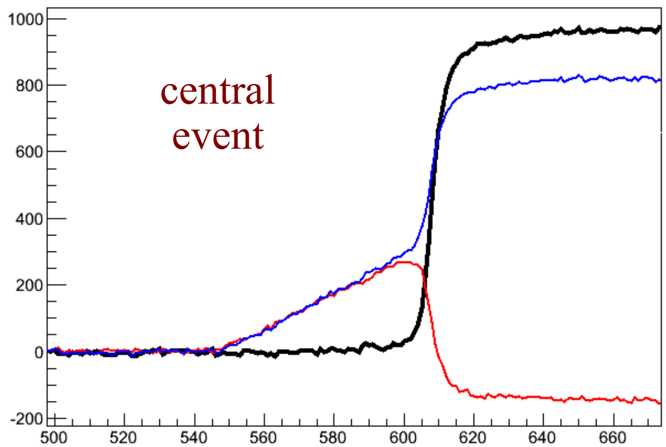
Backup

Energy Resolution



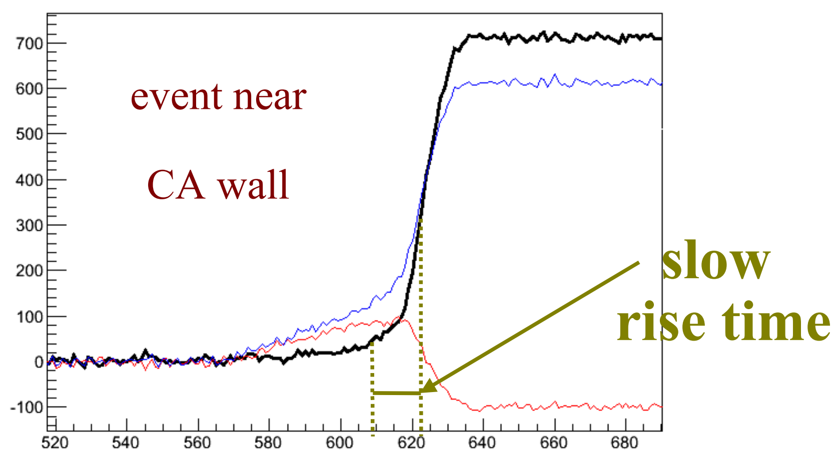


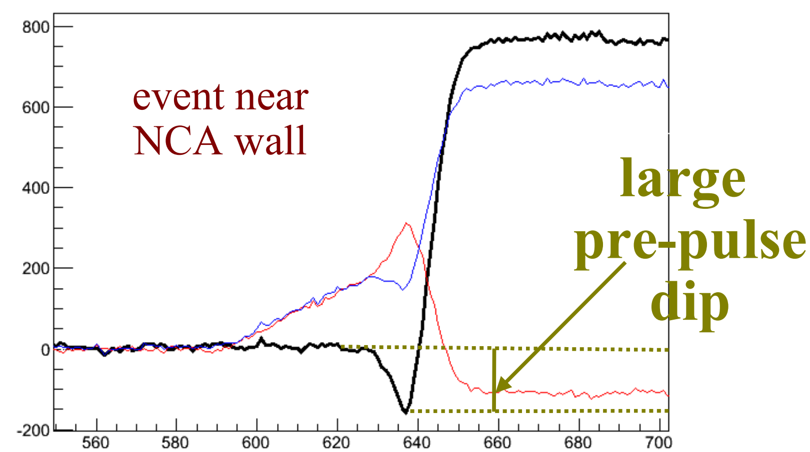
Quantifying near-wall distortions



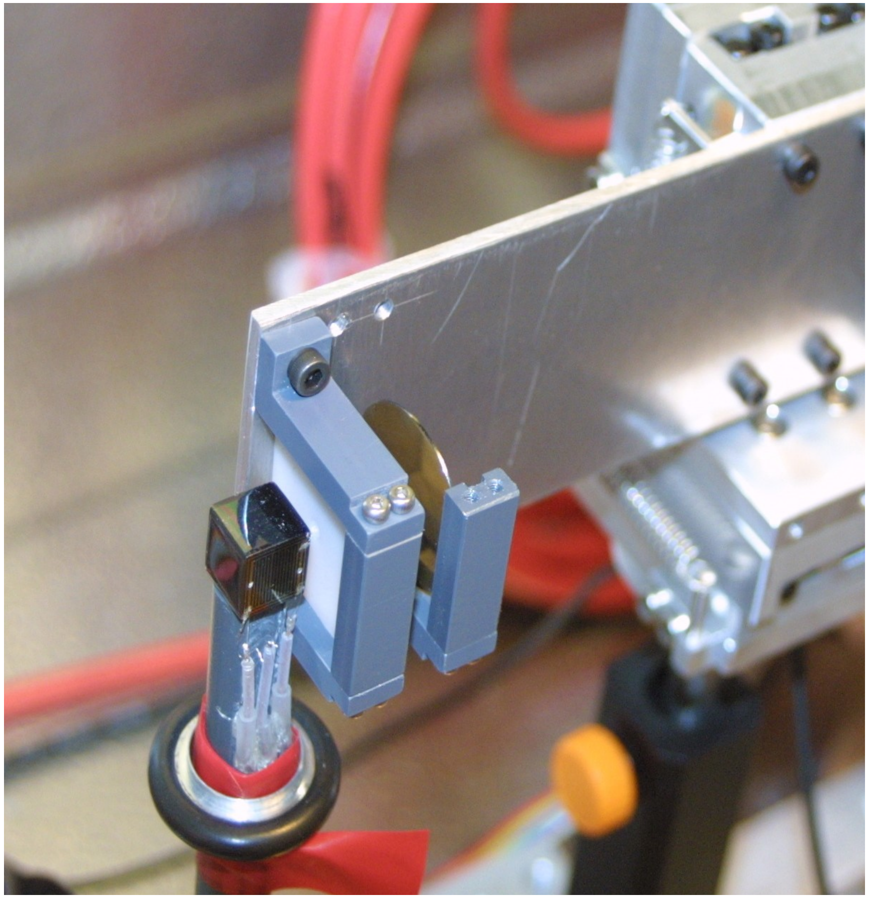
CA – NCA difference pulse

- normally a step function, approximately
- sensitive to distortions





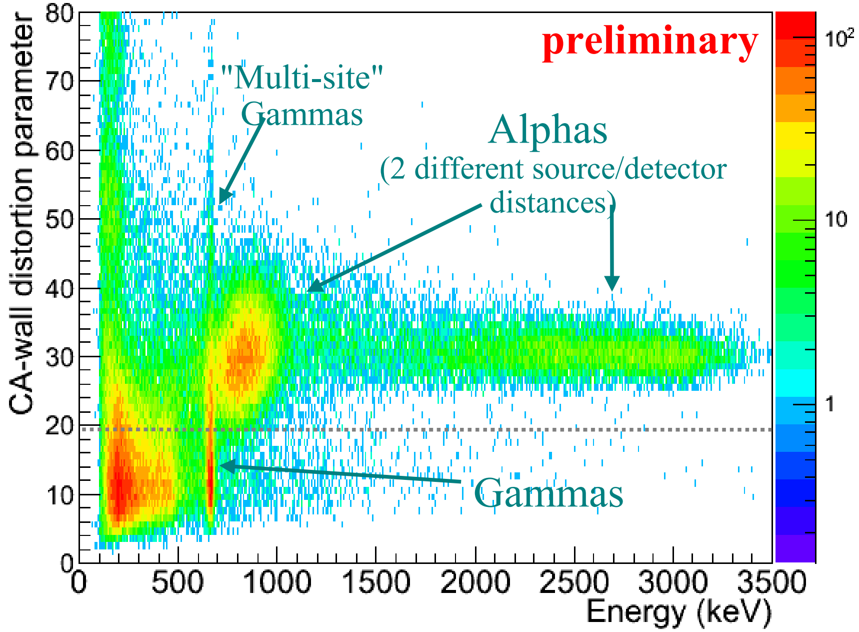
Verification at TU-Dortmund



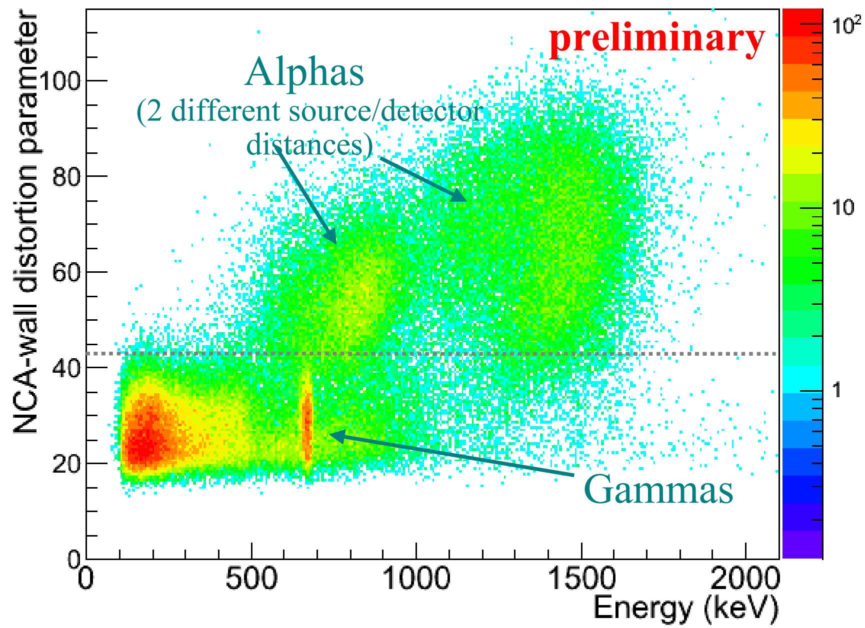
- Collimated ^{241}Am alpha source aimed at detector walls
  - lateral surface events
  - thin passivation layer, little energy loss
- ^{137}Cs gamma source
  - central events, mostly

Alpha test results

Alpha source aimed at CA wall



Alpha source aimed at NCA wall



dashed lines are sample LSE discrimination thresholds
(3-sigma above gamma center)

$$T_{1/2}^{0\nu} \propto \alpha \cdot \epsilon \cdot \sqrt{\frac{M \cdot t}{\Delta E \cdot B}}$$