



COBRA Extended Demonstrator

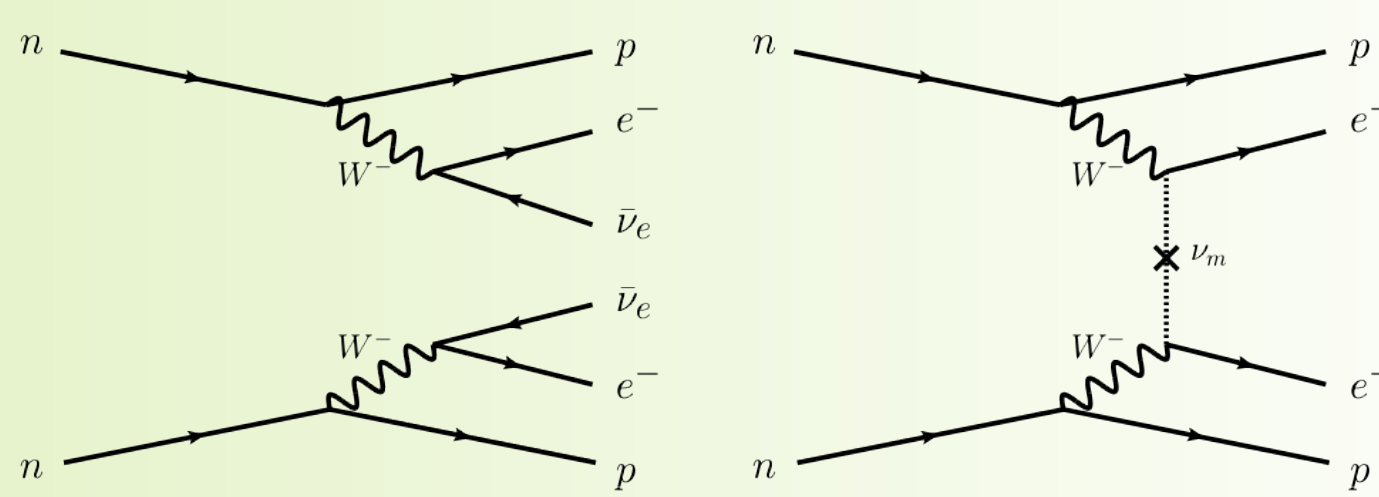
Robert Temminghoff for the COBRA collaboration

Overview

The COBRA collaboration aims to search for $0\nu\beta\beta$ -decay, a lepton-number violating process which could provide information about new physics beyond the current Standard Model using CdZnTe detectors at the LNGS in Italy. The COBRA setup has recently been upgraded (extended demonstrator - XDEM). For XDEM, six times larger detectors with a guard-ring to veto signals from surface contaminations have been installed into the existing setup. Together with some other improvements, XDEM is targeted to reduce the specific backgrounds found in the demonstrator phase. This poster will give a summary of the evaluation of the new detectors in overground laboratories, including the measurement of key parameters like the ideal working point, the efficiency and the energy resolution of each detector. Results from the commissioning of the XDEM into the LNGS setup and the current status of the experiment are also presented.

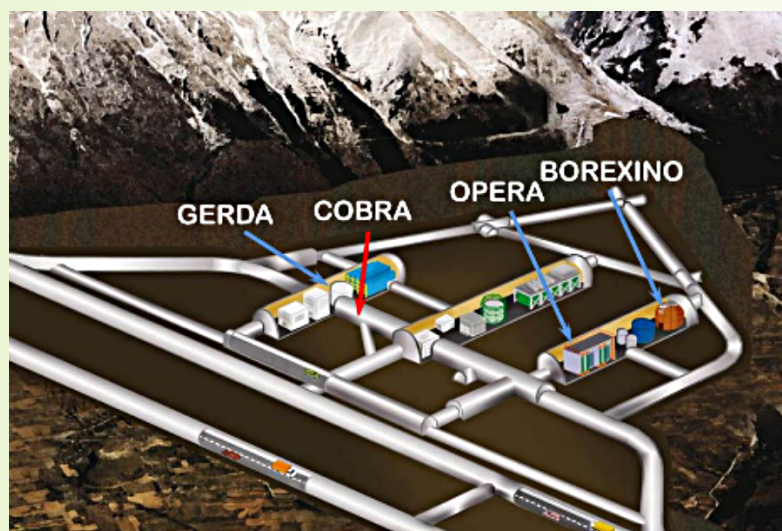
Neutrinoless Double Beta-Decay

- Massive neutrinos could be window to **BSM physics**
- Neutrinoless double beta-decay ($0\nu 2\beta$ -decay) possible with massive neutrinos
- Very rare process, $t_{1/2} > 10^{26}$ yr \rightarrow Not yet detected
- If observed would imply that ν = Majorana particle, reveal information about absolute ν mass-scale and underlying BSM-physics (if observed in >1 isotope) and potentially be the first **Lepton Number violating** process to be observed

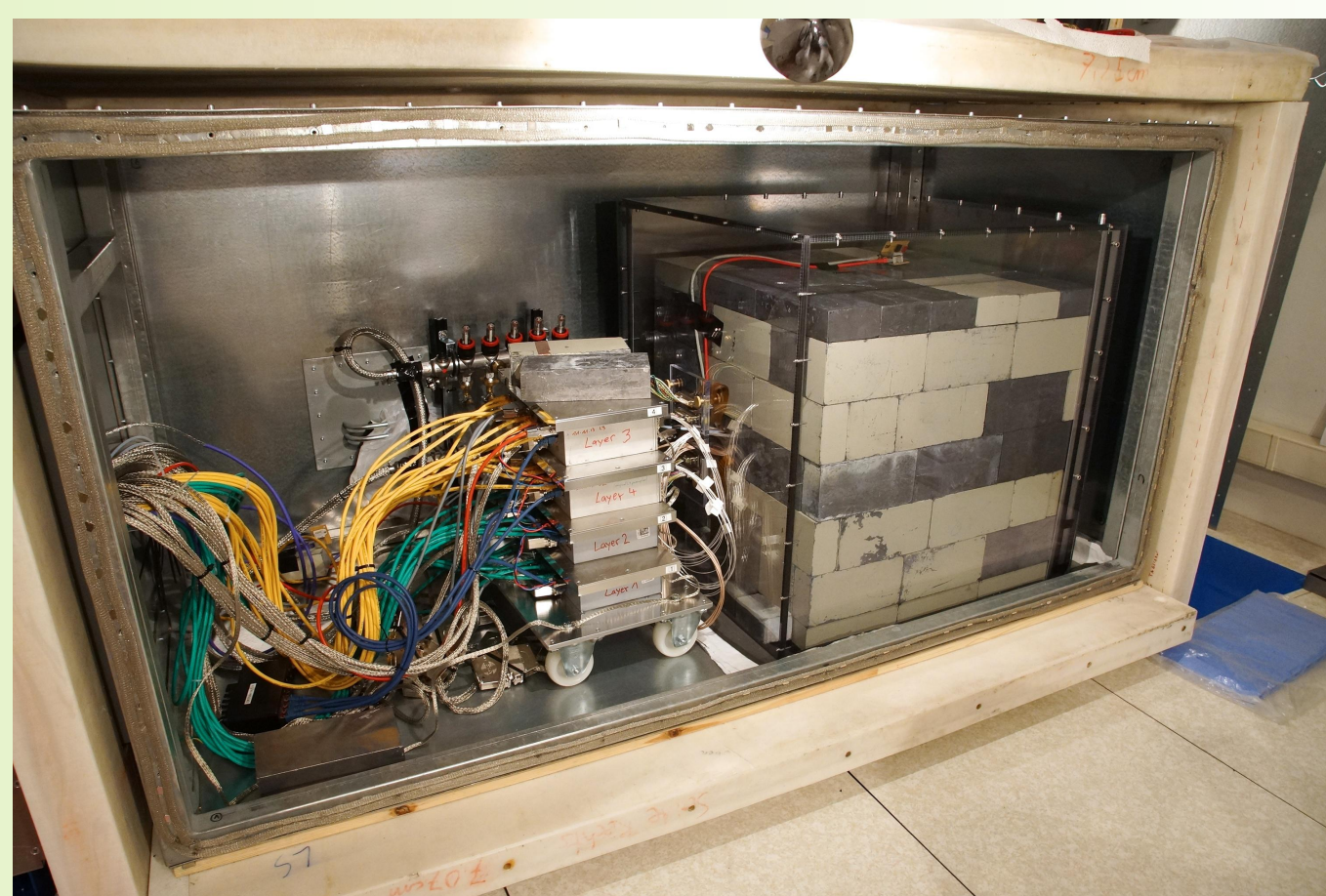


COBRA Experiment

- Cadmium-Zinc-Telluride **o**-Neutrino Double-Beta Research Apparatus [1]
- Low-background experiment at the LNGS in Italy

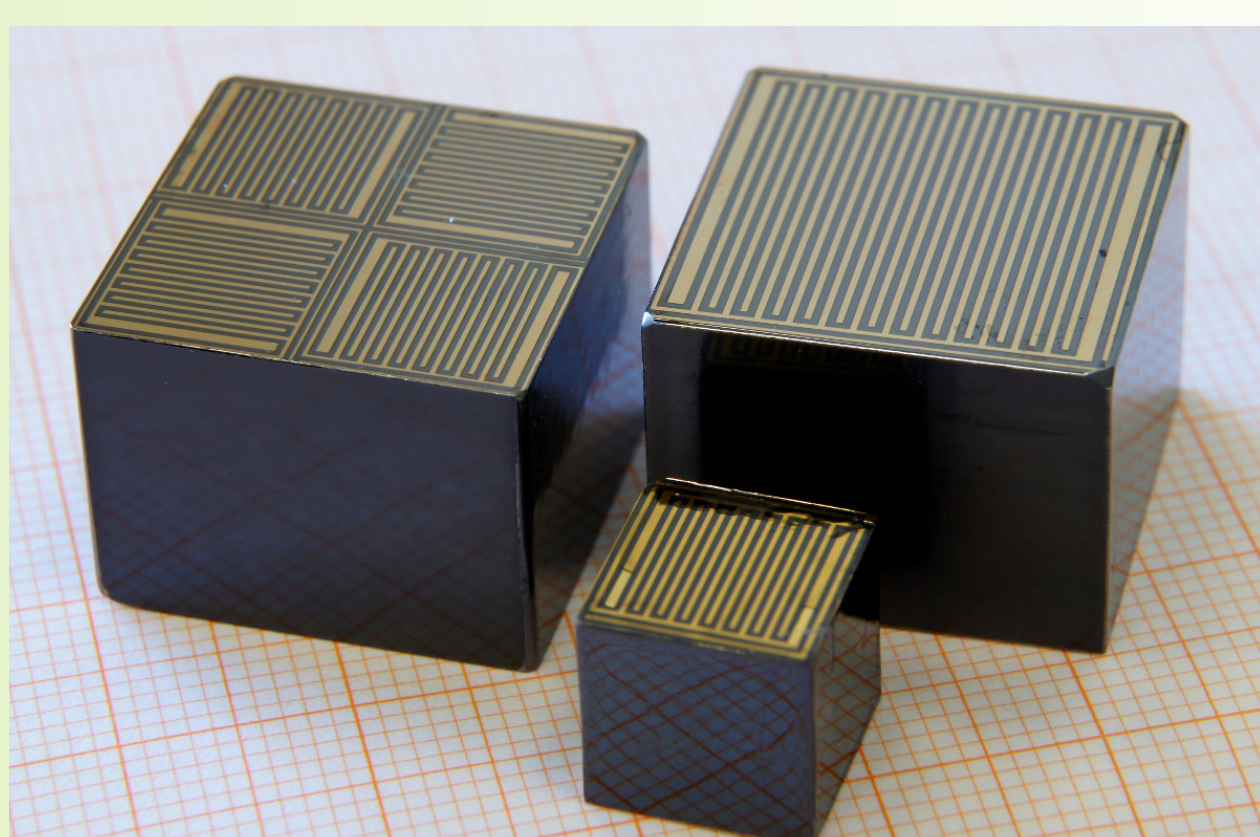


- CdZnTe**: room temperature semiconductor with high density and high average Z
- Good energy resolution using coplanar-grid (CPG) electrodes
- High efficiency, source=detector approach
- Nine $0\nu 2\beta$ -candidates in CdZnTe, most promising ^{116}Cd
- Demonstrator** phase: 64 detectors, volume 1 cm³ each
- Background index at $Q_{\beta\beta}$ of ^{116}Cd is $2.7 \frac{1}{\text{keV kg yr}}$, mostly from surface contaminations [2]
- Extended demonstrator (XDEM)**: 9 additional detectors, volume 6 cm³ each



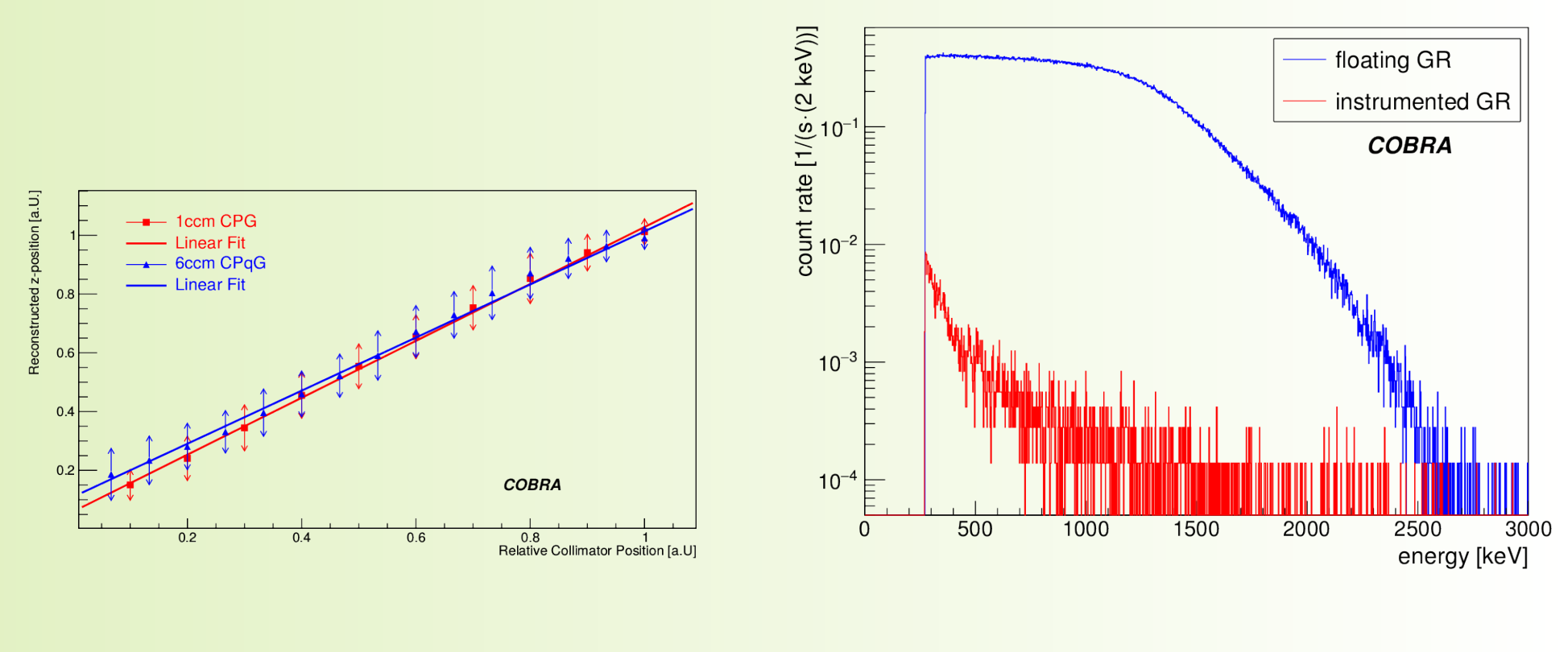
XDEM Idea

- Six times **larger detectors** + guard ring instrumentation
- Aim: Show **reduction of background** level compared to demonstrator
- Improvements in crystal growth allow use of $(20 \times 20 \times 15)$ mm³ detectors
- Increased detection efficiency (62% \rightarrow 72% for e.g. ^{116}Cd)
- Modified read-out electrodes compared to demonstrator
- Guard ring electrode (GR) will be used to veto α -related backgrounds



Pre-Studies

- Two detector designs and two different manufacturers (eV and Redlen)
 - Choose **quad-grid** over single grid for superior energy resolution + coincidence veto [3]
 - Detectors from both manufacturers used for XDEM
- Depth of interaction** can be extracted from pulses in CPGs, important for reducing BG from electrodes [4]
- GR** major tool to minimize surface-related BG: Reduction-factor 5300 for alphas, 85% efficiency for gammas[5]

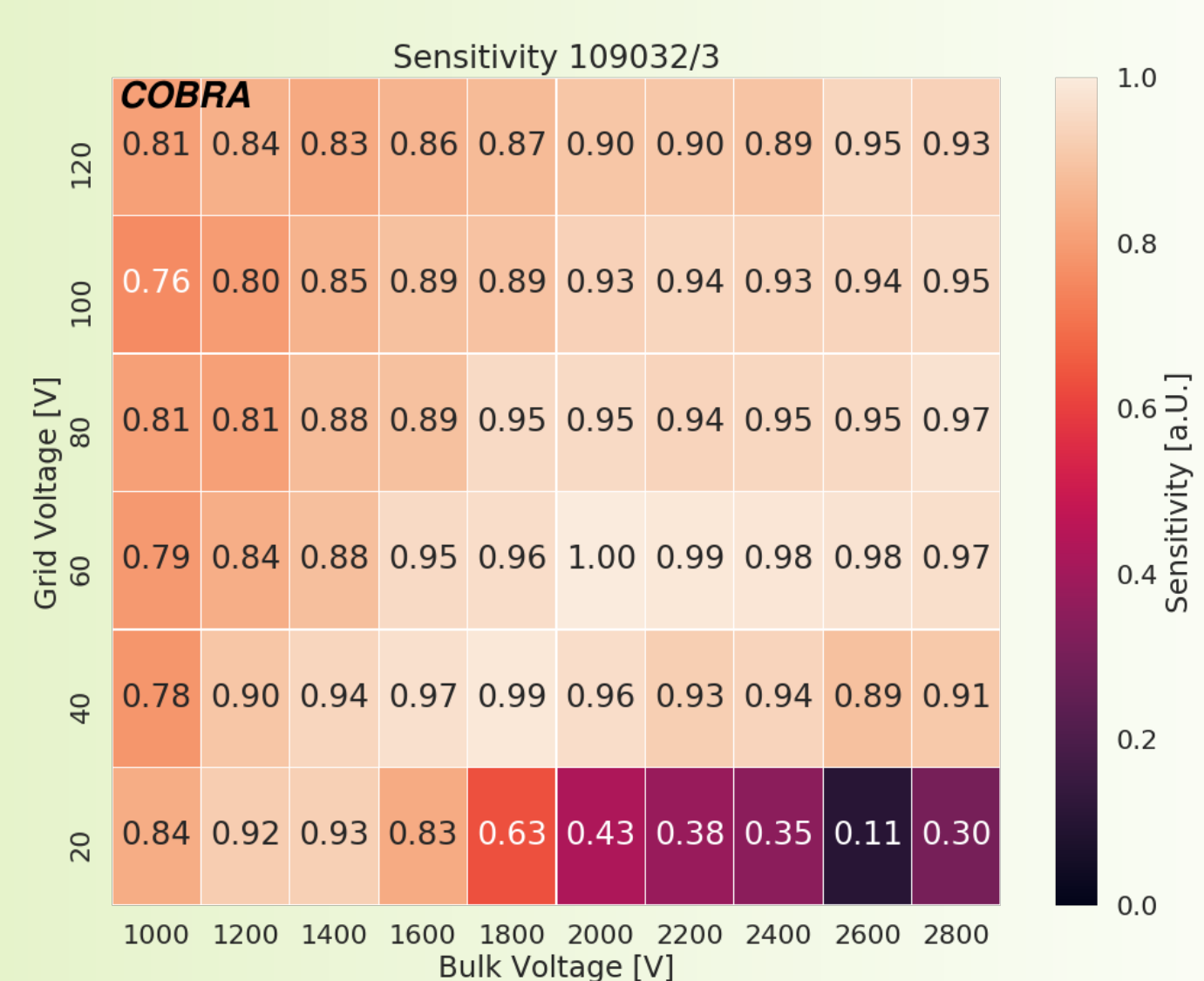


Background Improvements

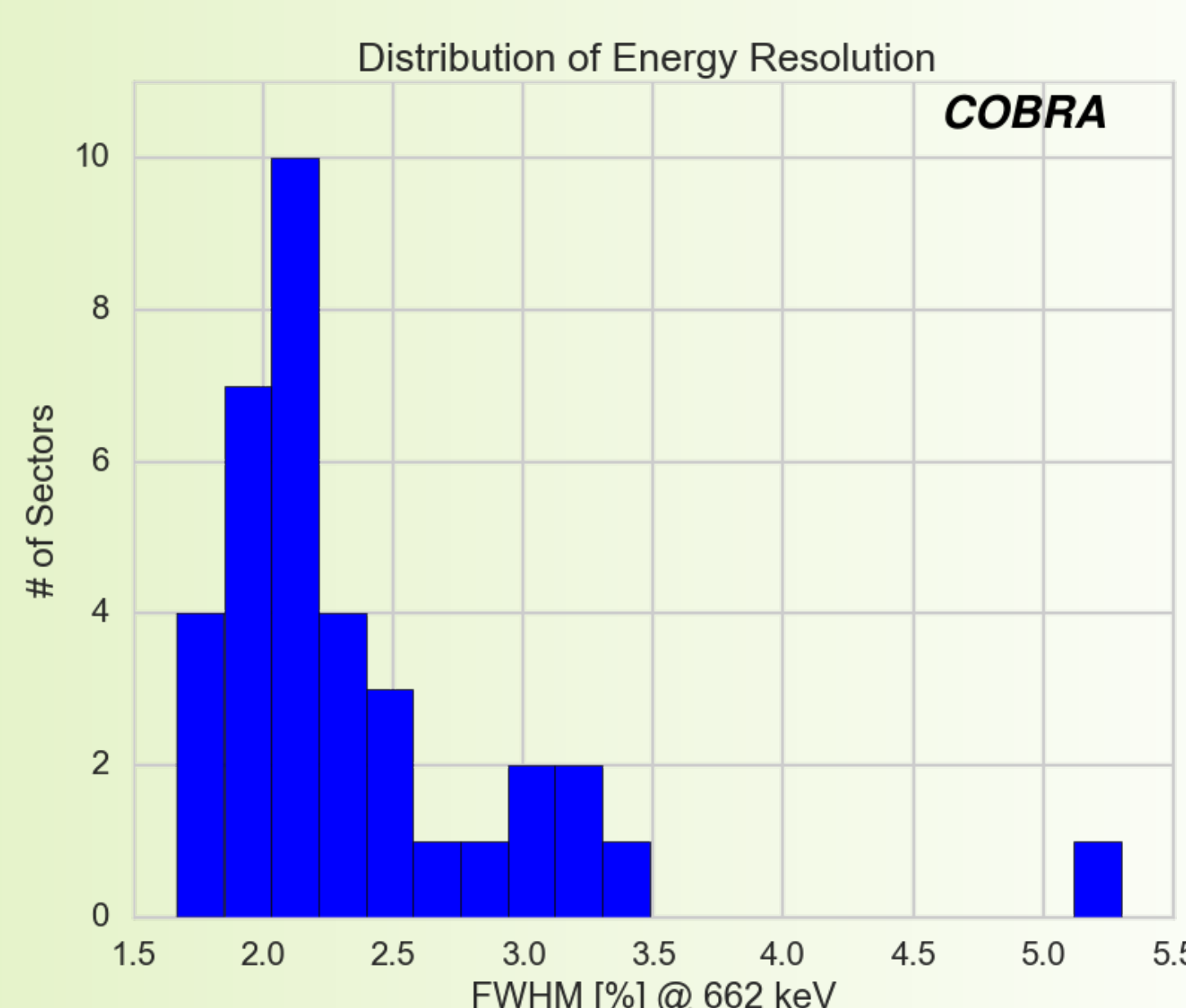
- Based on **experience** from demonstrator phase
- GR + interaction depth** give 4π veto for surface events
- Larger detectors reduce **surface-to-volume** ratio and inactive mass
- New coating with highly reduced ^{40}K content and Pt-less electrode for *Redlen* detectors
- Continuous N_2 flushing during characterization and storage
- Electro-polishing of cooper parts for detector housing
- Reduced number of materials for easier control of radio-purity

Characterization

- Extensive campaign to characterize new detectors in 2017/18
- Determination of **working point**, **energy resolution**, efficiency and leakage currents, about 2500 individual measurements in total
- Figure of merit for working point: Sensitivity = $\epsilon/\sqrt{\text{FWHM}}$

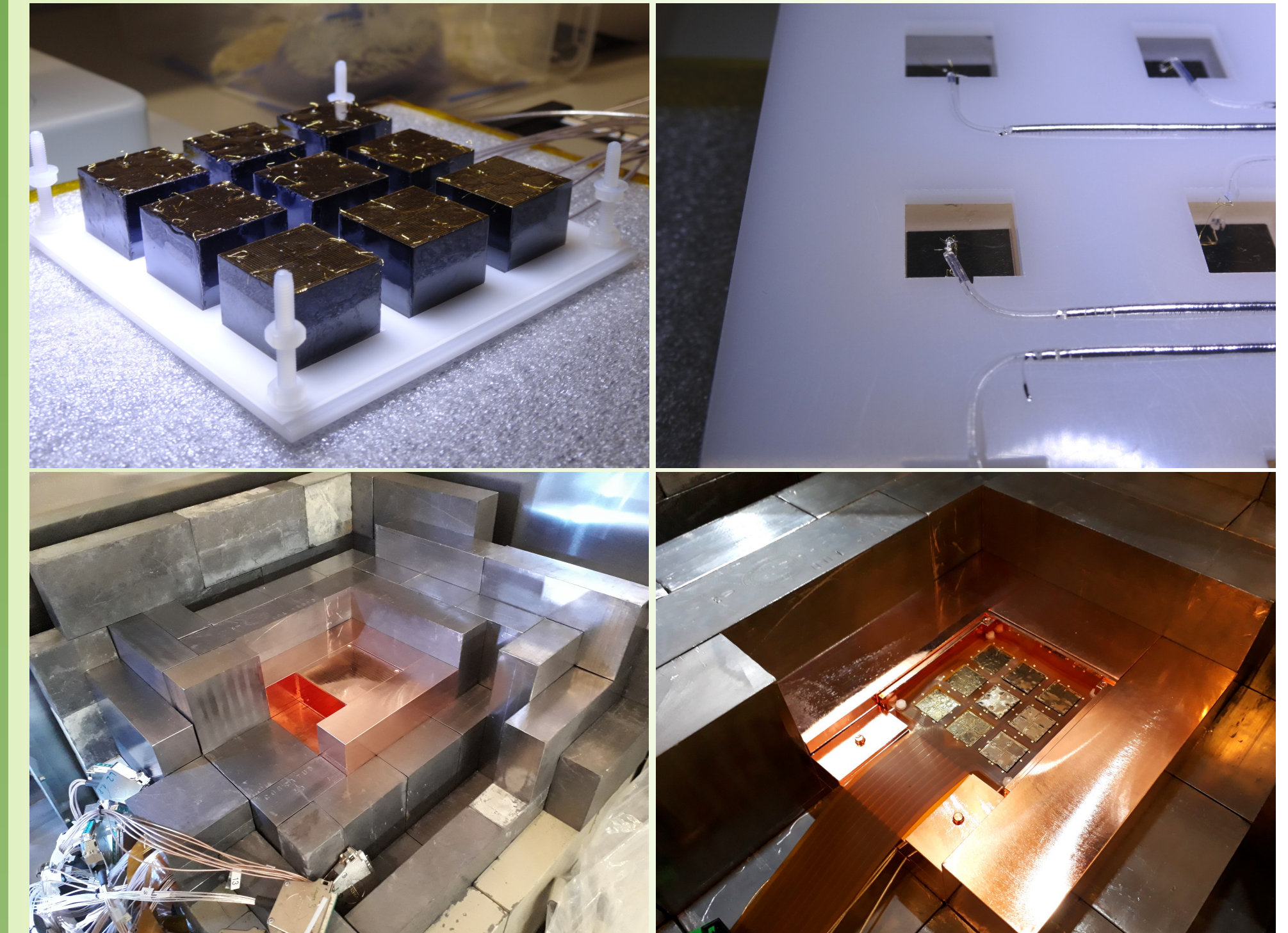


- Mean FWHM** at 662 keV of installed detectors during evaluation for XDEM 2.4% compared to 2.8% for demonstrator phase, corresponding to about 1.3% FWHM at $Q_{\beta\beta}$ of ^{116}Cd

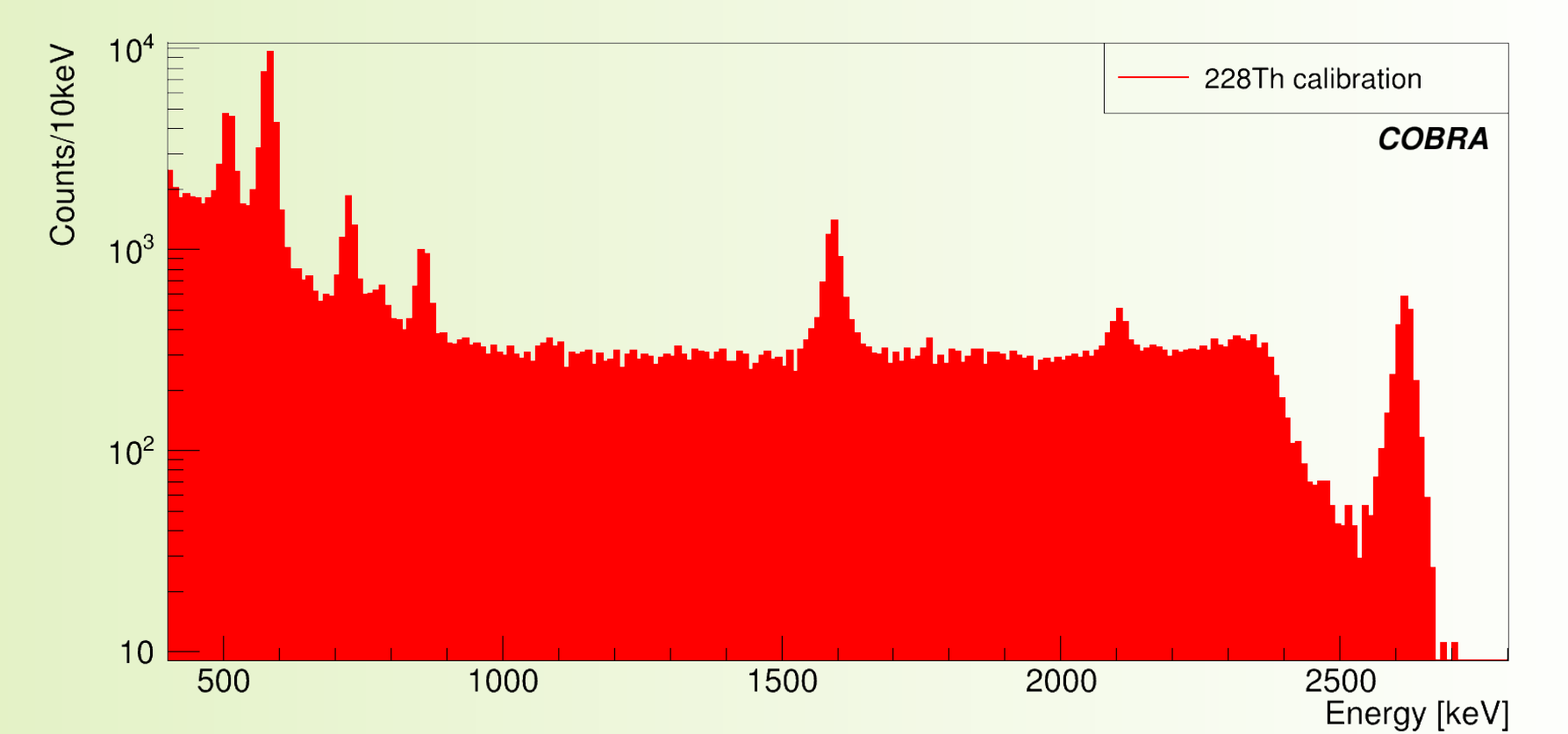


Commissioning

- Two week shift to install new detectors and electronics into setup in March 2018
- Dismantling of large parts of existing setup
- Major extensions** of nearly all parts of experiment



- Successful installation of detectors, working electrical contact for all channels, calibration with ^{22}Na and ^{228}Th



Status

- Stable** data taking since April
- Due to high voltage and routing problems, only 15/36 sectors are working at the moment
- Preliminary results indicate performance comparable to results from characterization
- First analysis** of 2.3 kg d of data - with only data-quality cuts applied - shows just two near-electrode events above 2 MeV
- Manufacturing of improved HV filter and new signal PCB
- Exchange in July to achieve full potential of XDEM

Summary

- COBRA XDEM major upgrade of existing demonstrator
- Characterization campaign demonstrated good performance of new detectors
- Preliminary data taking with partly working setup ongoing
- Expect fully working setup end of July

References

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- [2] J. Ebert et al., "Results of a search for neutrinoless double- β decay using the cobra demonstrator," *Phys. Rev. C*, vol. 94, p. 024603, Aug 2016.
- [3] J. Ebert et al., "Characterization of a large CdZnTe coplanar quad-grid semiconductor detector," *Nucl. Instruments Methods Phys. Res. Sect. A: Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 806, pp. 159-168, 2016.
- [4] R. Temminghoff, "Investigation of the Depth Reconstruction and Search for Local Performance Variations With a Large Coplanar-Quad-Grid CdZnTe Detector," *IEEE Transactions on Nuclear Science*, vol. 64, pp. 1934-1941, July 2017.
- [5] J.-H. Arling et al., "Suppression of alpha-induced lateral surface events in the COBRA experiment using CdZnTe detectors with an instrumented guard-ring electrode," *J. Instrumentation*, vol. 12, no. 11, p. P11025, 2017.

Acknowledgement & Contact

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