Status and Perspectives of the COBRA 0νββ Experiment

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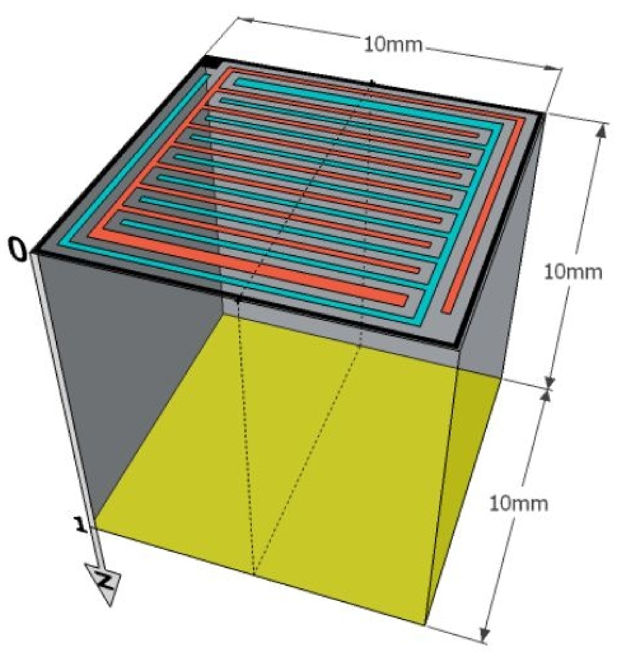
The COBRA Experiment

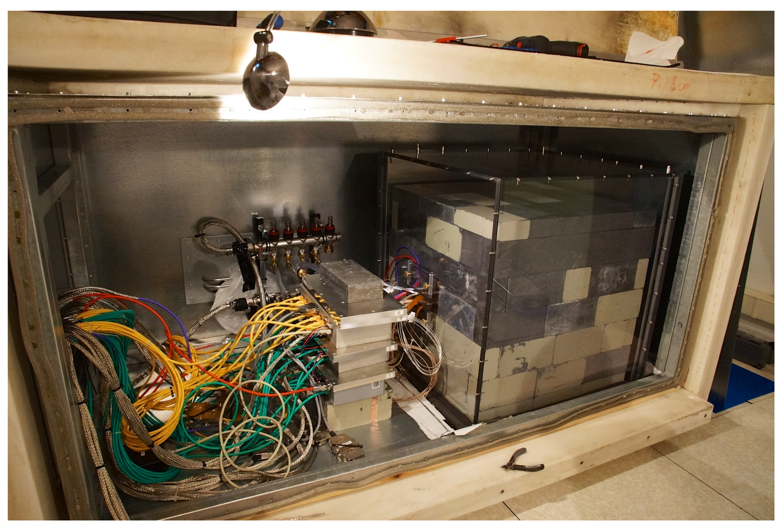
The COBRA experiment [1] is planning to use a large amount of CdZnTe (CZT) room temperature semiconductor detectors for the search of neutrinoless double beta decay (0νββ). CZT contains 9 candidate isotopes for 0νββ, including electron capture and positron decay modes. The isotope with the highest Q-value (2813.5 keV) in the two electron mode is ^{116}Cd. This isotope is the main target of the search, as its Q-value is above the highest relevant naturally occurring gamma line (^{208}Tl at 2614.6 keV).

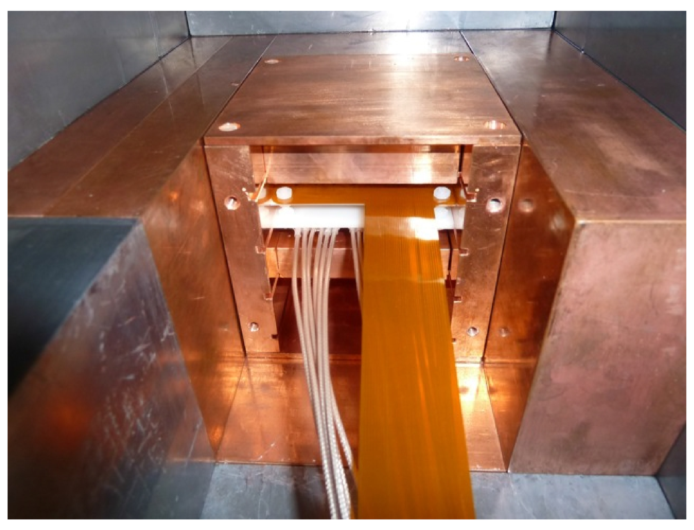
To investigate the experimental challenges of operating CZT detectors in low-background mode and to identify potential background components, a demonstrator setup is operated at the Gran Sasso underground laboratory (LNGS) in Italy, while additional studies are proceeding in surface laboratories. The experiment consists of monolithic, calorimetric **detectors of coplanar grid design** (CPG detectors [2]) operated at room temperature. The ultimate goal is to reach a sensitivity to half-lives of up $2x10^{26}$ years with about 400 kg detector mass.



The Demonstrator Setup

The COBRA R&D low-background test setup is situated in the Italian underground laboratory LNGS. An overburden of 1400 meters of rock coverage (3600 m.w.e.) reduces the cosmic ray flux by about six orders of magnitude.
The **setup** consists of 64 CPG detectors with a volume of 1 cm^3 each arranged in four layers of 4x4 detectors. The layers have been gradually added between November 2011 and the end of 2013, which allowed for constant improvements. They are surrounded by a **shielding** of ultrapure copper and lead, complemented by an additional layer of borated polyethelene and an EMI-shielding. To decrease the background from airborne radon, the setup is continuously flushed with nitrogen.

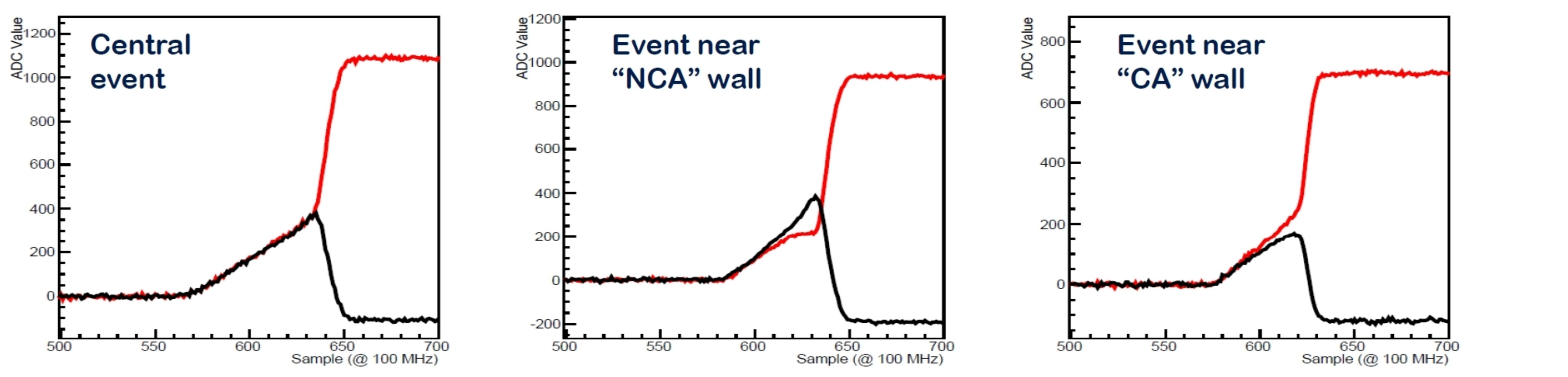




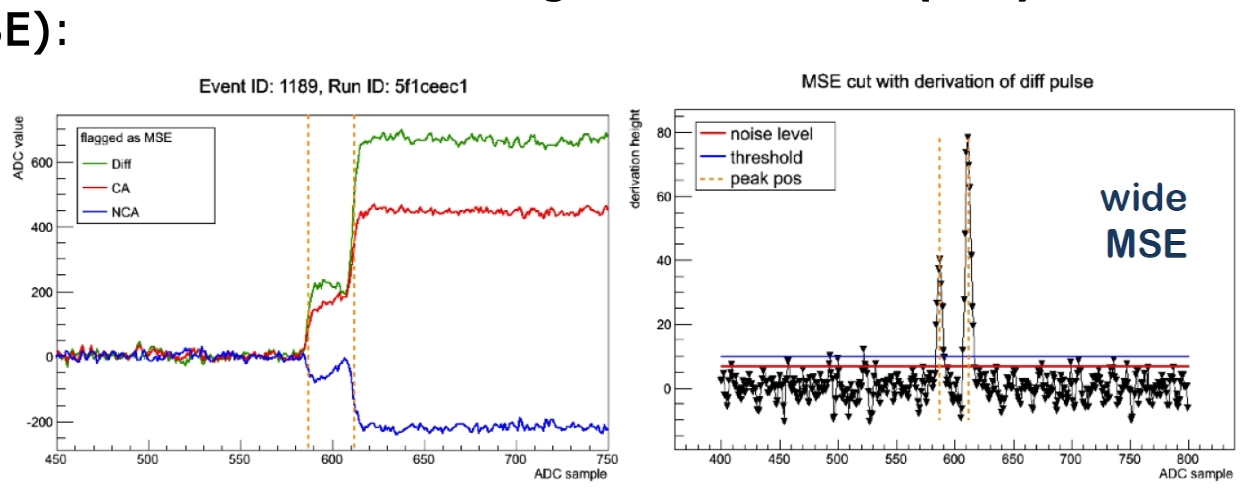
The readout is done by custom-built electronics. The whole signal forms are recorded using fast analogue-to-digital converters (FADCs). This allows for pulse shape analysis, making a major improvement in background reduction. Data taking has been very stable, and currently 10 kg days of data are collected per month. Calibrations using a thorium and a potassium source are performed every few weeks. At the end of 2013, a pulser has been added for synchronisation purposes allowing for coincidence analysis.

Pulse Shape Analysis

Within the collaboration several methods have been developed to extract information from the signal pulses. Beside a refined method to calculate the interaction depth [3] the **identification of lateral surface events** [4] has been studied



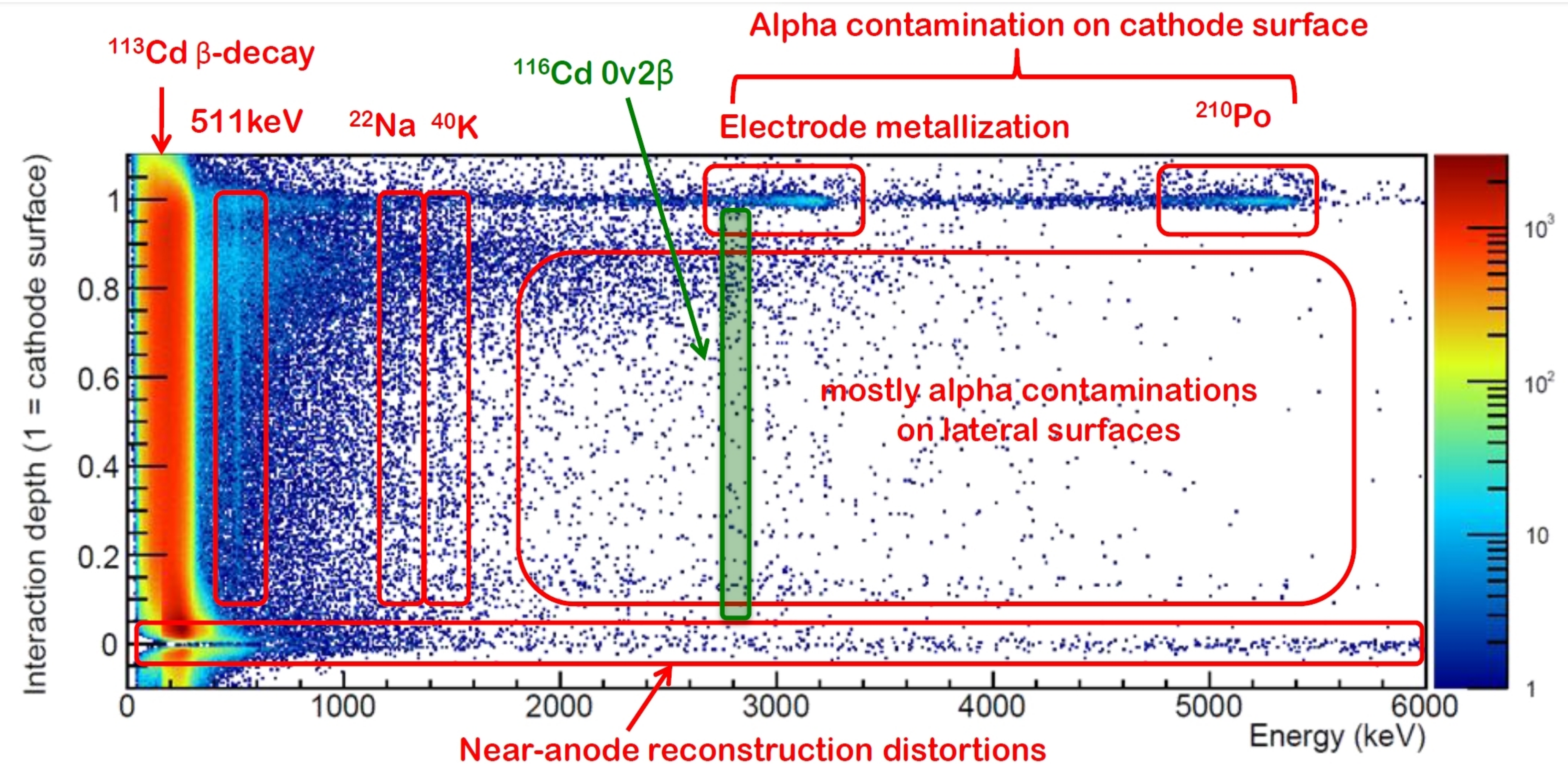
as well as the **discrimination of single-site events (SSE) versus multi-site events (MSE)**:



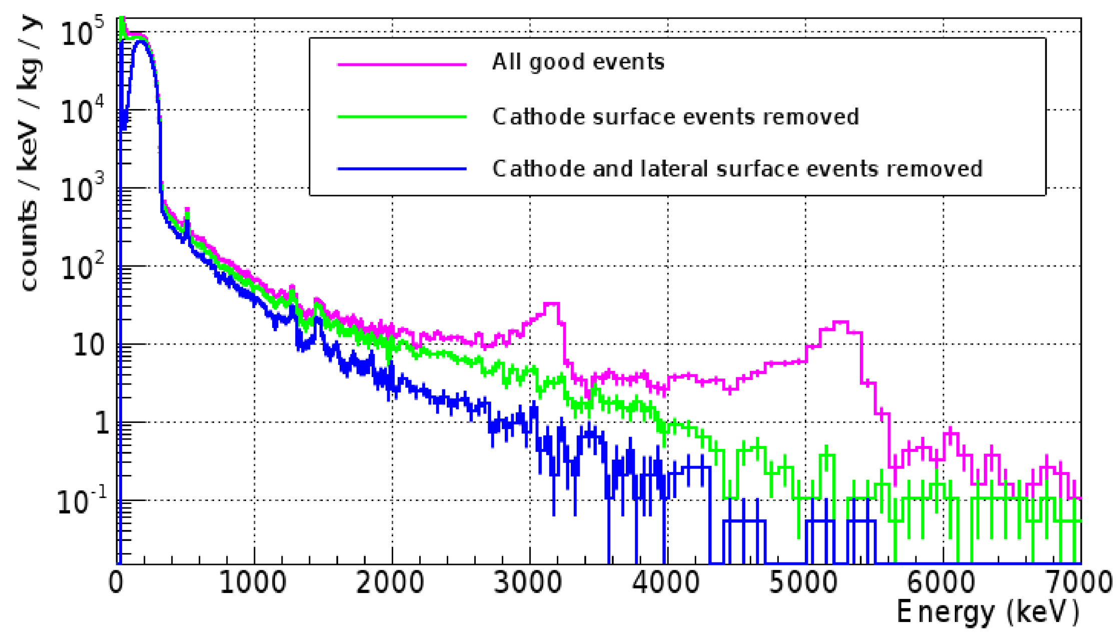
First estimates show that the MSE analysis can reduce the background induced by gammas by 90% in the signal region.

Current Results

By now, roughly 160 kg days of data have been collected, of which the first 82.3 kg days contain only data from layers 1 and 2 without a pulser. The figure below displays this **early half of the data** in the form of a scatter plot, showing the interaction depth over the energy deposition.



At very low depths, distortions in the energy reconstruction occur as a consequence of the CPG design. At the cathode surface (interaction depth z = 1), the contamination with alpha emitters produces high-energy events at about 3 MeV and 5 MeV. Both the low-depth distortions and the high-depth surface events can be efficiently removed using the interaction depth information. Using the pulse shape analysis from [4] to remove also lateral surface events, the **background rate** can be further reduced.

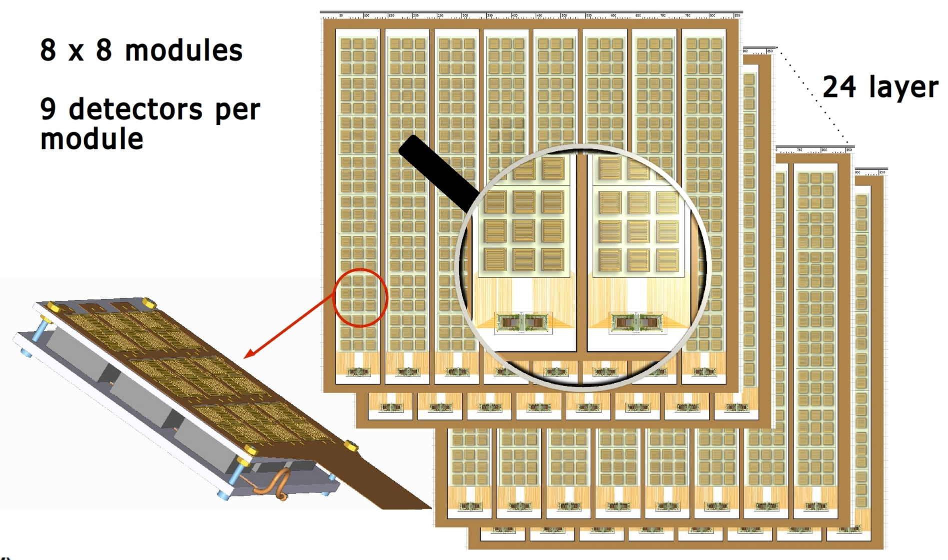


This leads to a background rate of approximately 1 count/keV/kg/y in the region of interest around 2814 keV, given per unit mass of detector material (CdZnTe), and the following **preliminary half-life limits**:

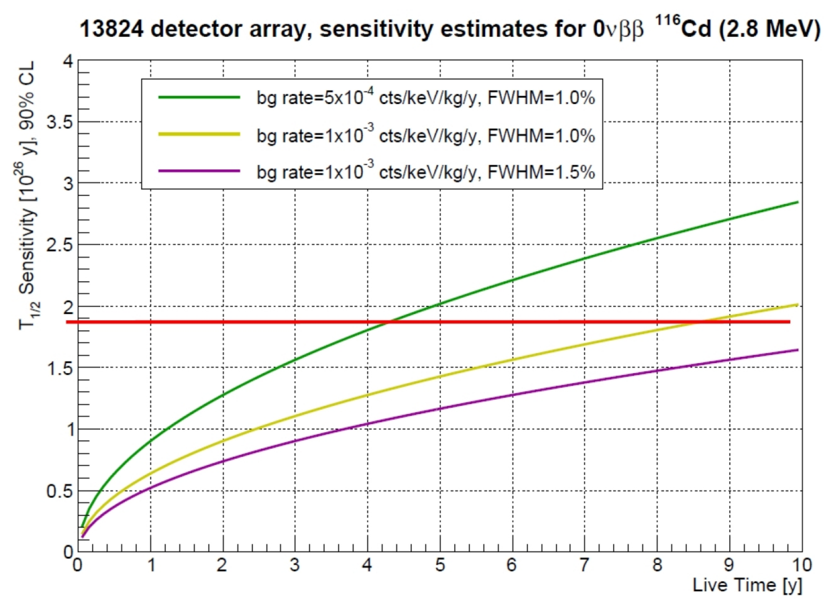
isotope	COBRA'09	COBRA'13 preliminary	worlds best
^{114}Cd	$2.0x10^{20}$	**$1.06x10^{21}$**	$1.1x10^{21}$
^{128}Te	$1.7x10^{20}$	**$1.44x10^{21}$**	$1.1x10^{23}$
^{70}Zn	$2.2x10^{17}$	**$2.57x10^{18}$**	$1.8x10^{19}$
^{130}Te	$5.9x10^{20}$	**$3.88x10^{21}$**	$3.0x10^{24}$
^{116}Cd	$9.4x10^{19}$	**$9.19x10^{20}$**	$1.7x10^{23}$

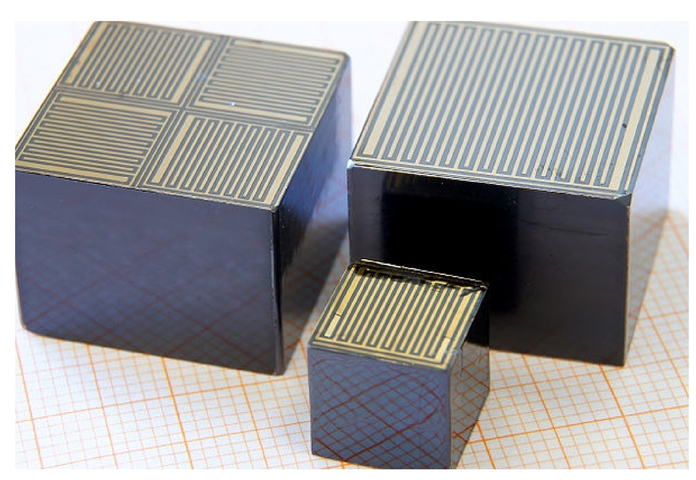
It has to be noted that enough of the events caused by surface contamination (alphas) survive all these cuts so that they still present the dominant background contribution (see [4] and [5]).

Towards a Large Setup



To reduce the surface-to-volume ratio, it has been decided to use **1.5x2x2 cm^3 crystals** for a possible large setup of 400 kg detector mass. Assuming material 90% enriched in ^{116}Cd, the following **sensitivities** can be expected:





To reach the still challenging background rate of $1x10^{-3}$ counts/keV/kg/y, the contribution from surface alphas has to be lowered. Strategies under study for this are: Handling of all materials under clean room conditions to reduce surface contamination with radon decay products, increased thickness of detector lacquer coating to shield alphas, improved pulse shape analysis for alpha discrimination, operation of guard rings to veto lateral surface events.

References:

[1] K. Zuber, Phys. Lett. B 519,1 (2001)
[2] P. N. Luke, IEEE Trans. Nucl. Sci. 42, 207–213 (1995)
[3] M. Fritts et al., NIM A 708 (2013) 1–6
[4] M. Fritts et al., NIM A 749 (2014) 27–34
[5] J. Ebert et al., Adv. HEP 2013 (2013) 703572

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