

The COBRA double beta decay experiment

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on behalf of the COBRA collaboration



2nd LSM Extension Workshop, October 16, 2009



The COBRA Experiment

- ▶ Study of ultra-rare radioactive decays, in particular neutrinoless double-beta ($0\nu\beta\beta$) decays
- ▶ Goal: Array of 64000 enriched CdZnTe Detectors, massing about 400kg, sensitive to decays with half lives exceeding 10^{26} years
- ▶ Primary Focus: $0\nu\beta\beta$ -decay of ^{116}Cd

Collaboration Members



TU Dortmund

TU Dresden

Freiburg Materials
Research Center

University of Hamburg

University of Erlangen



Czech Technical
University in Prague



Laboratori Nazionali
del Gran Sasso



Washington University
at St. Louis



University of Bratislava



University of Jyvaskyla



University of La Plata



JINR Dubna

Supporting Institutes: Jagellonian University(Poland), Los Alamos Nat. Lab. (USA), University of Michigan (USA)

Why use CdZnTe?

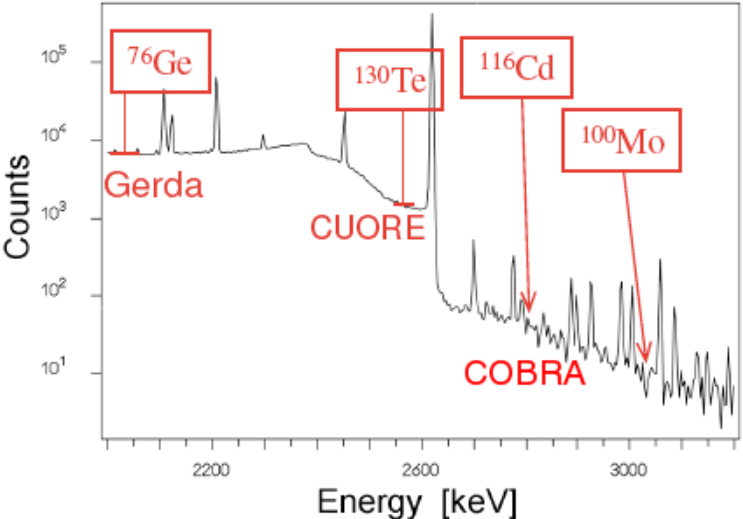
- ▶ Source = Detector
- ▶ Contains 9 $0\nu\beta\beta$ candidate isotopes.
Most interesting: ^{116}Cd , ^{106}Cd , ^{130}Te
- ▶ High Q-values (^{116}Cd above 2615 keV)
- ▶ Semiconductor \rightarrow Good energy resolution, pure material
- ▶ Operation at room temperature, easy handling



$0\nu\beta\beta$ Candidate Isotopes in CdZnTe

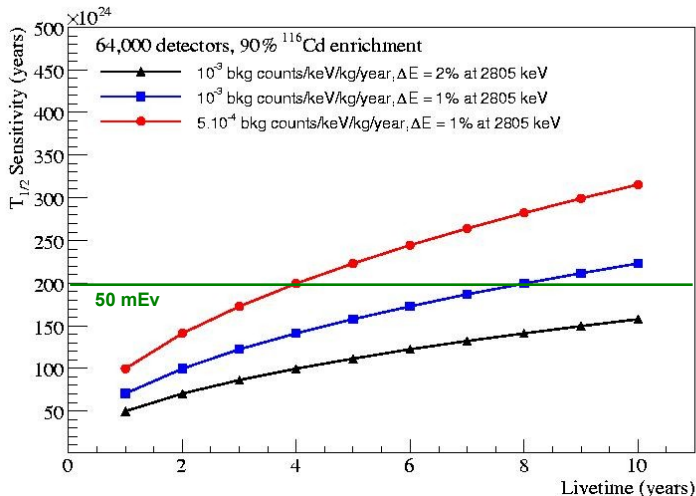
Isotope	nat. ab. (%)	Q (keV)	Decay Mode
^{70}Zn	0.62	1001	$\beta - \beta -$
^{114}Cd	28.7	534	$\beta - \beta -$
^{116}Cd	7.5	2809	$\beta - \beta -$
^{128}Te	31.7	868	$\beta - \beta -$
^{130}Te	33.8	2529	$\beta - \beta -$
^{64}Zn	48.6	1096	$\beta + / \text{EC}$
^{106}Cd	1.21	2771	$\beta + \beta +$
^{108}Cd	0.9	231	EC/EC
^{120}Te	0.1	1722	$\beta + / \text{EC}$

Isotopes and Background



COBRA Sensitivity

$$T_{1/2} \propto \sqrt{\frac{M \times t}{\Delta E \times B}}$$

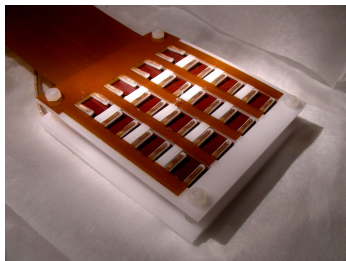


Cobra Setup at LNGS

- ▶ COBRA experimental setup located at Laboratori Nazionali del Gran Sasso (LNGS), Italy
- ▶ Underground location, 1400 m under Gran-Sasso massif, 3700 m water equivalent
- ▶ Past: Ran different setups, installed arrays with up to 64 CdZnTe coplanar-grid detector crystals
- ▶ Currently running test array of 8 background improved crystals

Construction and Shielding

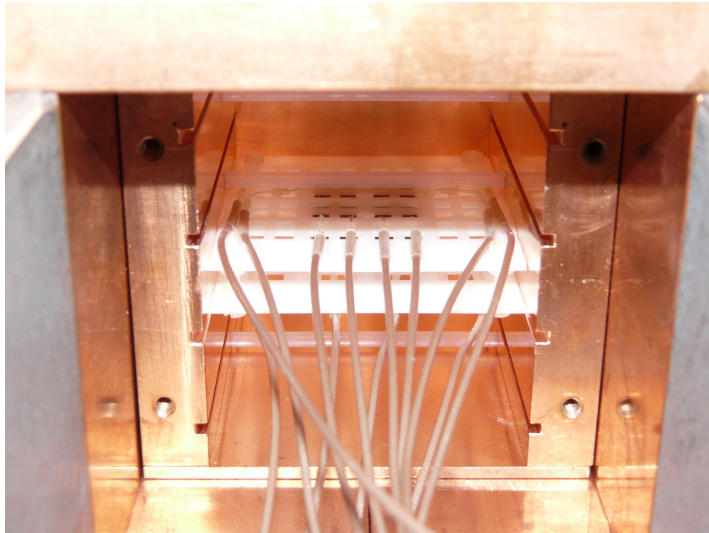
- ▶ Setup rests on elastic vibration dampeners embedded in sand.
- ▶ 70mm Borated PE as Neutron shield
- ▶ Faraday-Cage
- ▶ Lead shielding with clean lead in inner layers and copper core
- ▶ Copper holder for 4 Delrin (POM) crystal layers (16 crystals per layer)



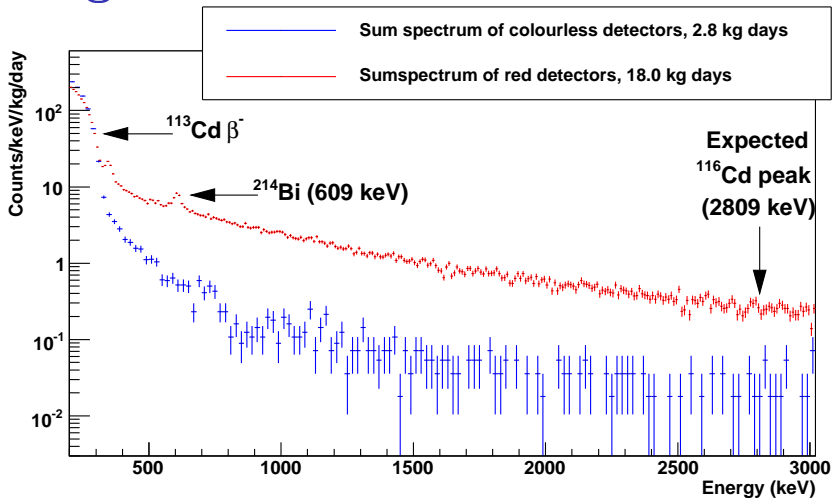
Background issues

- ▶ Major background sources were:
 - ▶ Red passivation coating on CdZnTe crystals
 - Using crystals with new, clear coating now, alternative coating under test
 - ▶ Environmental Radon
 - Set up flushing system with filtered Nitrogen
- ▶ Also: Had to find clean and reliable system to connect detectors
 - New connecting system, using special conductive glue and thin gold wire

Array of 4 Crystals, Clear Coating

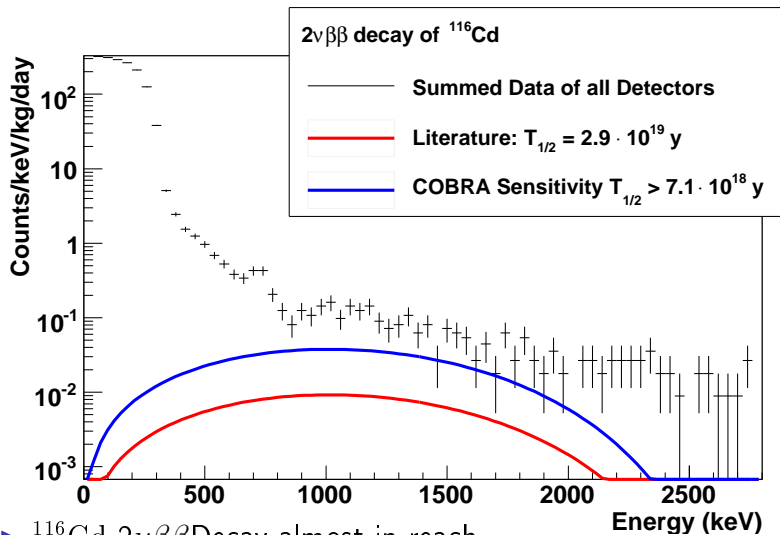


Background Reduction So Far



- ▶ Background in ROI around 2809 keV:
< 8 counts/keV/kg/year

Sensitivity to the ^{116}Cd $2\nu\beta\beta$ Decay



► ^{116}Cd $2\nu\beta\beta$ Decay almost in reach

Challenges

- ▶ Scale up isotope mass
→ produce detectors enriched to 90% ^{116}Cd content.
- ▶ Further reduce background
- ▶ Improve energy resolution
- ▶ Veto background events

Detector production

- ▶ Collaboration member FMF Freiburg is researching CdZnTe crystal growth
- ▶ Expect new test detectors this month
- ▶ Applied to DFG for procurement of 90% enriched Cd.

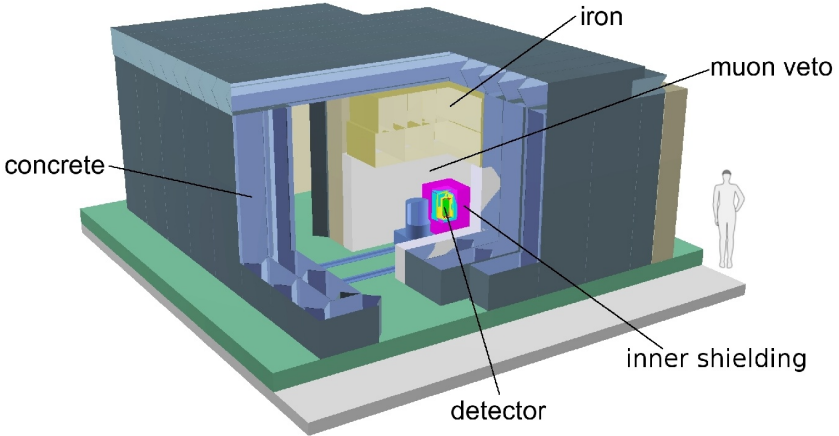
Further background reduction

- ▶ Major upgrade of LNGS setup planned for summer 2010
 - ▶ Surround detectors by scintillators
 - ▶ Cleaner cables and materials
 - ▶ Improved EM-radiation shielding
 - ▶ Installed detector mass of about 400g CdZnTe
 - ▶ Aim for $2\nu\beta\beta^{116}\text{Cd}$ decay.
- ▶ Accelerate materials screening process
 - ▶ Built new facility at TU Dortmund for material pre-screening
 - ▶ Additional facility planned at TU Dresden

Dortmund Low-Background facility (DLB)

- ▶ New HPGe Spectrometry Facility at TU Dortmund, purpose built for COBRA
- ▶ Detector: Ultra-LB HPGe Detector, 60% eff.
- ▶ Surface location, but shallow-underground performance due to massive layered shielding
 - ▶ 325 t baryte concrete, 43 t cast iron above detector
→ 10 m water-equivalent
 - ▶ active muon veto
 - ▶ layered inner shielding with neutron absorber
- ▶ Currently reached 4.25 counts/kg/min (integrated, 40 - 2700 keV)
- ▶ Still room for improvement

DLB Schematic Drawing



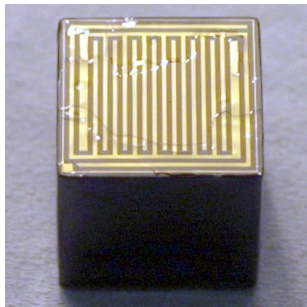
DLB, Detector and Muon Veto



CdZnTe Detector Types

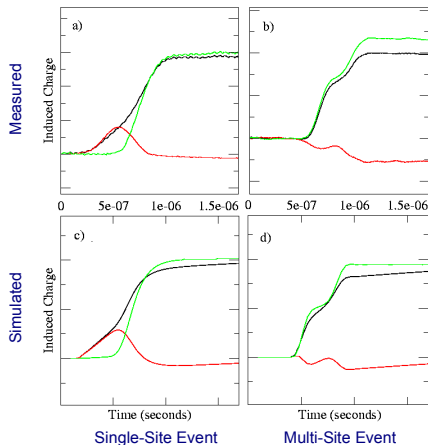
- ▶ Energy resolution and identification of BG-Events depends on choice of detector type.
- ▶ Two options for CdZnTe:
 - ▶ Coplanar Grid detectors
 - ▶ Pixelized detectors

CdZnTe Crystal with Coplanar Grid



- ▶ CPG: Two comb-shaped, differently biased anode grids create virtual "small pixel effect".
- ▶ Advantages: Simple, low background compatible.
- ▶ Disadvantages: Less detailed information about events.
- ▶ Currently used for the LNGS Setup, energy-only output

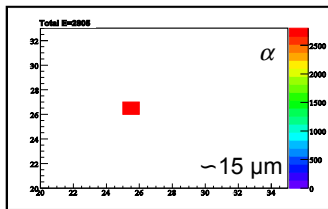
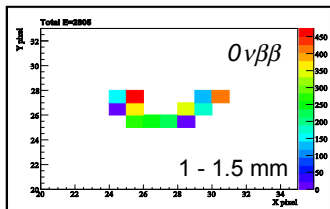
CPG Pulse shape analysis



McGrath et al., acc. by NIMA, 2009

- ▶ Pulse shape analysis will enable us to reject certain background types
- ▶ Planned for LNGS upgrade in summer 2010.

CdZnTe Pixel detectors



- ▶ Better energy resolution than CPG
- ▶ Very detailed information about events \rightarrow TPC-like
- ▶ Massive background reduction due to particle identification: Potentially 3 orders of magnitude for α and γ
- ▶ But: Low-Background compatibility of frontend electronics still unknown
- ▶ Currently testing two systems at LNGS and Modane

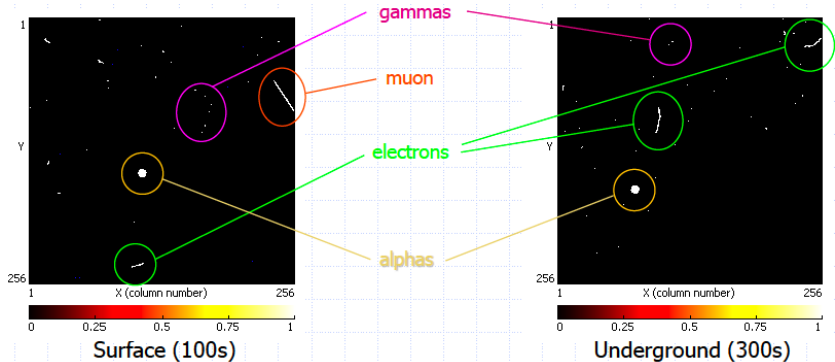
Pixel Pitch

- ▶ Tracking and energy resolution depends on pixel size
- ▶ Small pixels: Detailed tracking but reduced energy resolution
- ▶ Big pixels: Excellent energy resolution but reduced tracking
- ▶ Simulation of charge deposition and transport necessary to determine optimum pixel size → ongoing

Pixel Detector Frontend Electronics

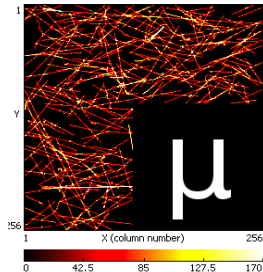
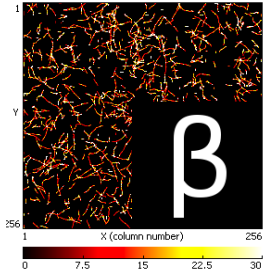
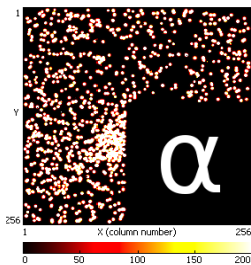
- ▶ Frontend ASIC development very expensive
→ currently evaluating three existing systems:
- ▶ Medipix/Timepix (currently at Modane)
 - ▶ Small (55 micron) pixels
 - ▶ Not low-background optimized yet
- ▶ Polaris System, Univ. Michigan (currently at LNGS)
 - ▶ Large (2000 micron) pixels
 - ▶ Not low-background optimized yet
- ▶ CZT Pixel, Univ. St. Louis
 - ▶ Different pixel sizes available
 - ▶ First test with LB-optimized system in Winter 2009 at LNGS.

Particle Identification



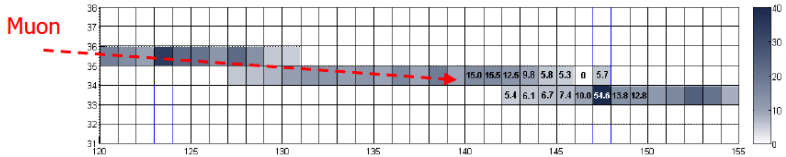
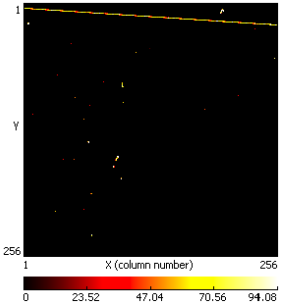
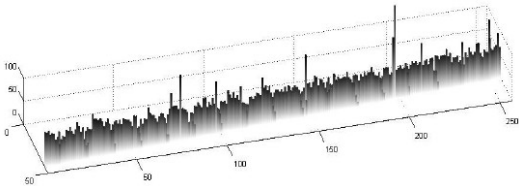
- ▶ Particle tracks in a 55 micron timepix detector
- ▶ Easy particle identification

Particle Identification



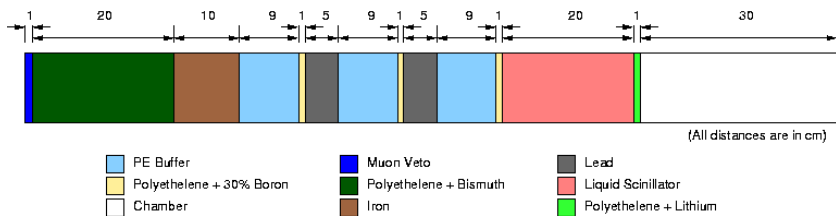
- ▶ Separation of events by type

Muon Track across whole detector



Enhanced shielding

- ▶ Currently starting monte-carlo campaign to identify best shielding strategy.
- ▶ Possible candidate:

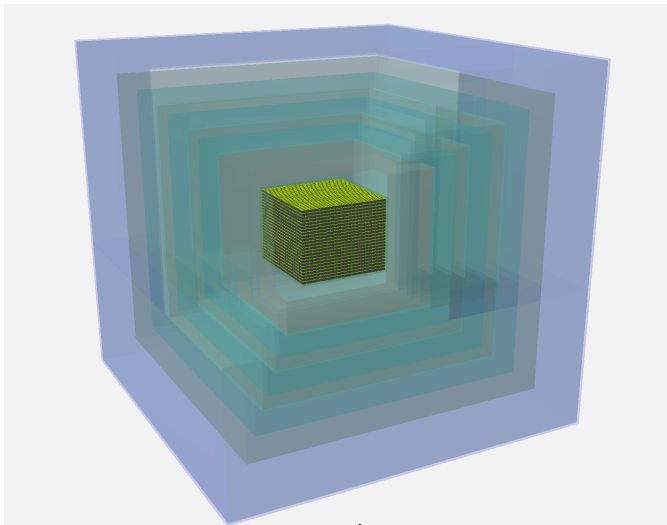


- ▶ Interesting shielding option:
Suspend detectors directly in liquid scintillator
→ preparing for tests at Uni Hamburg

Long-Term COBRA Roadmap

- ▶ Summer 2010: LNGS Test setup upgrade
- ▶ End of 2012: COBRA Technical Design Report
- ▶ (Hopefully) 2013: Funding and location decision
- ▶ COBRA perspective for Modane:
After LSM extension in 2013, install full-size shielding
with first prototype detector modules

Possible Large Scale COBRA Setup



- ▶ Size: About 2m x 2m x 2 m (detectors and shielding only)

Conclusion

- ▶ COBRA: A new innovative approach for the $0\nu\beta\beta$ -decay search, especially in ^{116}Cd .
- ▶ Despite small mass already some interesting results.
- ▶ Major upgrade of current setup in 2010.
- ▶ Compact sized full-scale setup.
- ▶ Would be well suited for installation at Modane.