The COBRA double beta decay experiment

Oliver Schulz
on behalf of the COBRA collaboration

technische universität dortmund
Physik E-IV

oliver.schulz@tu-dortmund.de

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COBRA $0\nu\beta\beta$ Experiment
Deutsche Forschungsgemeinschaft DFG
INFN Laboratori Nazionali del Gran Sasso

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- 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 $^{116}\mathrm{Cd}$

Collaboration Members

TU Dortmund

TU Dresden

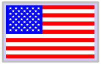
Freiburg Materials Research Center

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

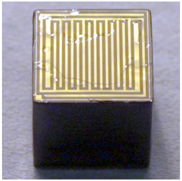
University of La Plata

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: $^{116}\mathrm{Cd}$, $^{106}\mathrm{Cd}$, $^{130}\mathrm{Te}$
- High Q-values ($^{116}\mathrm{Cd}$ above 2615 keV)



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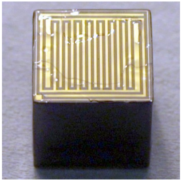
- Semiconductor $\rightarrow$ Good energy resolution, pure material
- Operation at room temperature, easy handling



$0\nu\beta\beta$ 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	$\beta+$/EC
^{106}Cd	1.21	2771	$\beta+\beta+$
^{108}Cd	0.9	231	EC/EC
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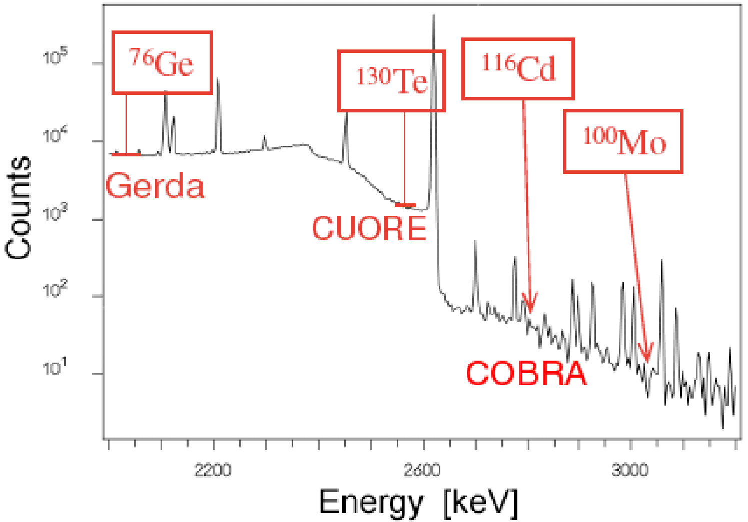
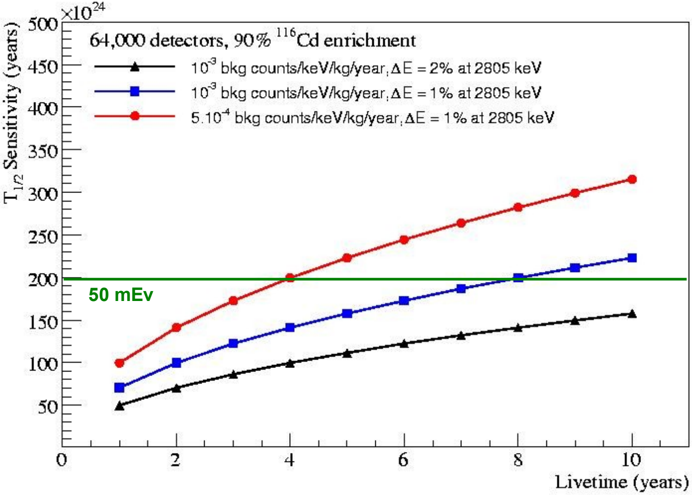
Isotopes and Background



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

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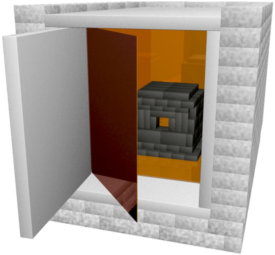
- Past: Ran different setups, installed arrays with up to 64 CdZnTe coplanar-grid detector crystals
- Currently running test array of 8 background improved crystals

Construction and Shielding

- Setup rests on elastic vibration dampeners embedded in sand.
- 70mm Borated PE as Neutron shield



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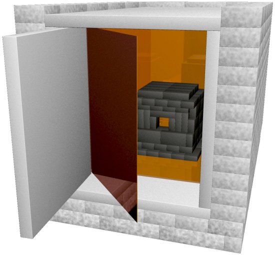

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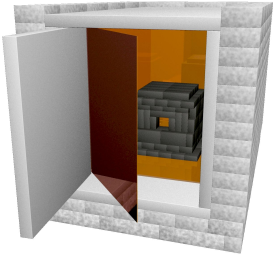

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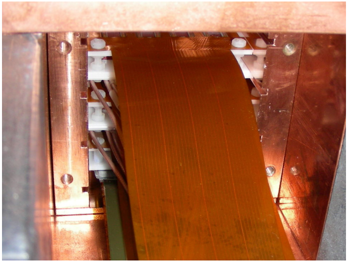

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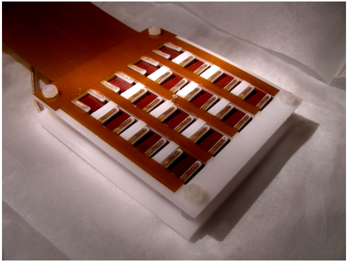

Background issues

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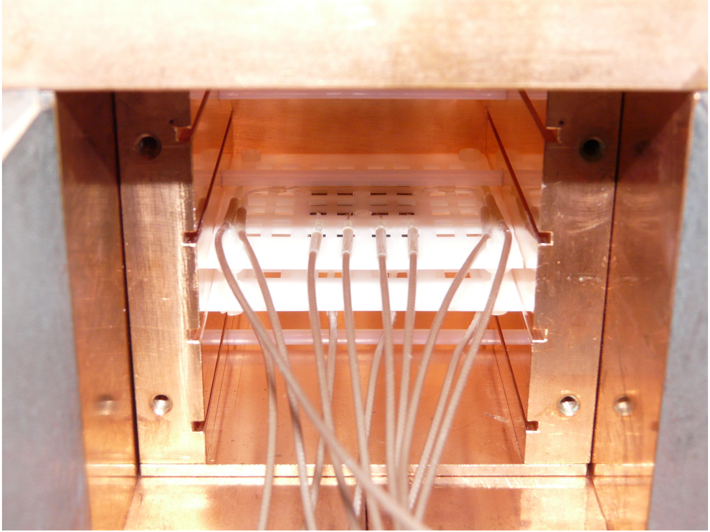
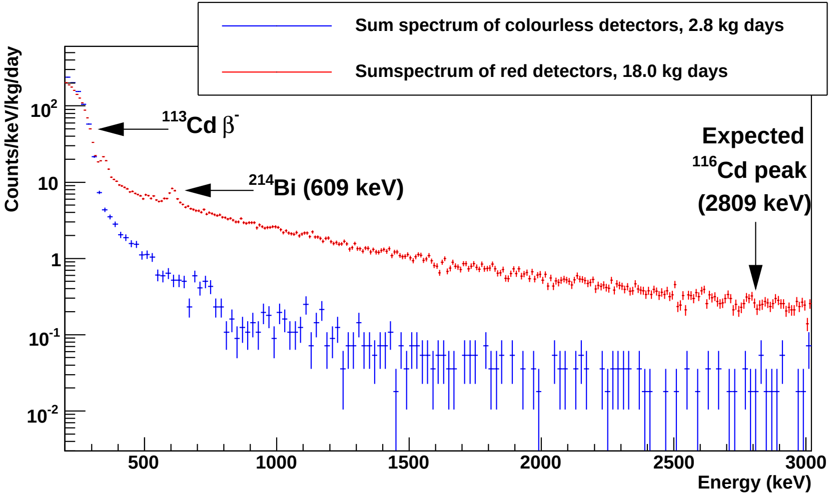
    → Using crystals with new, clear coating now, alternative coating under test
  - Environmental Radon
    → Set up flushing system with filtered Nitrogen
- Also: Had to find clean and reliable system to connect detectors
  → New connecting system, using special conductive glue and thin gold wire

Array of 4 Crystals, Clear Coating

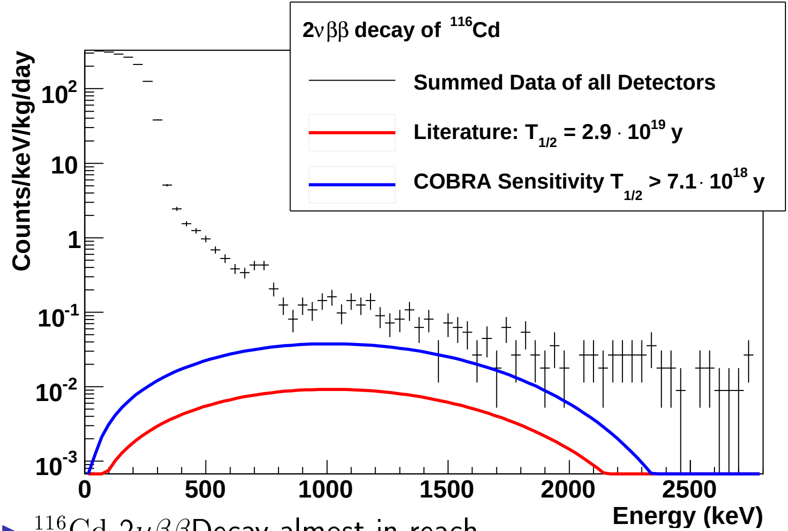


Background Reduction So Far



- 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

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- Further reduce background
- Improve energy resolution
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- Expect new test detectors this month
- Applied to DFG for procurement of 90% enriched Cd.

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- 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
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- Accelerate materials screening process
  - Built new facility at TU Dortmund for material pre-screening
  - Additional facility planned at TU Dresden

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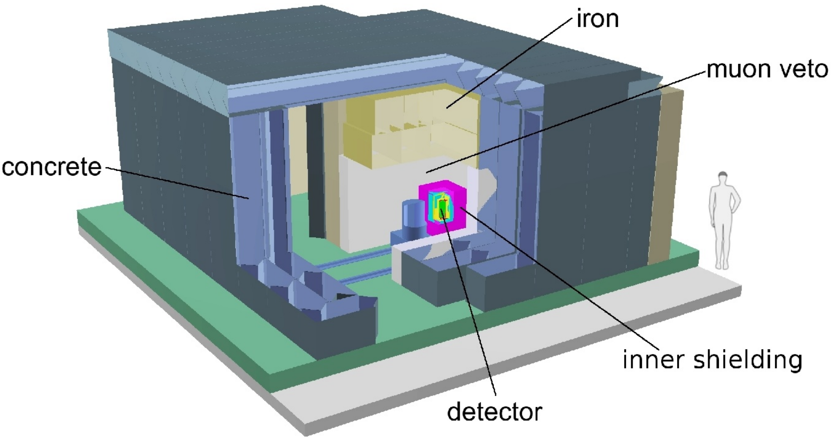
- Currently reached 4.25 counts/kg/min (integrated, 40 - 2700 keV)
- Still room for improvement

DLB Schematic Drawing



DLB, Detector and Muon Veto

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  - Coplanar Grid detectors
  - Pixelized detectors

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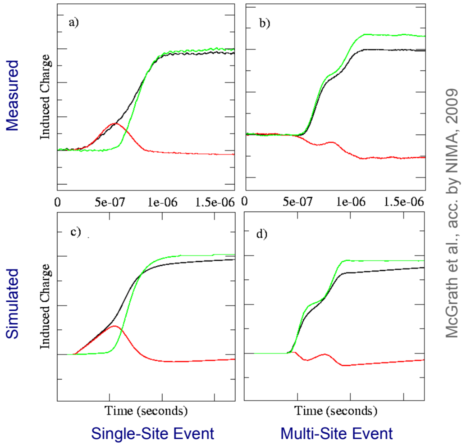
CPG Pulse shape analysis



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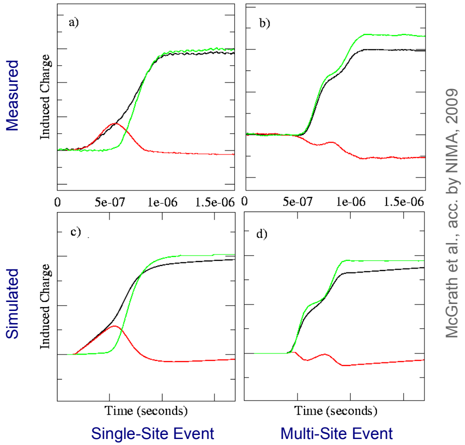
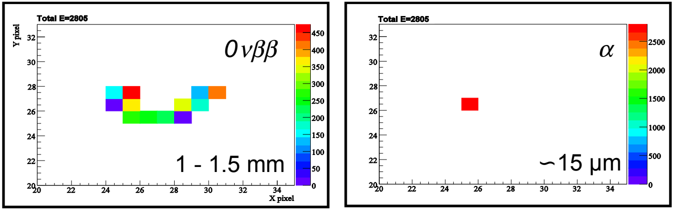


- Pulse shape analysis will enable us to reject certain background types
- Planned for LNGS upgrade in summer 2010.

CdZnTe Pixel detectors

- Better energy resolution than CPG

CdZnTe Pixel detectors



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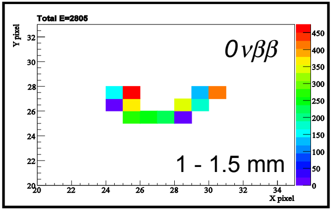

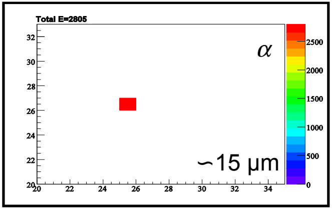

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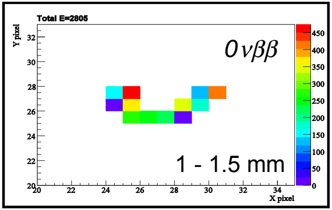

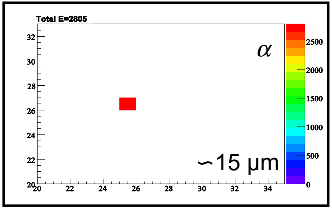

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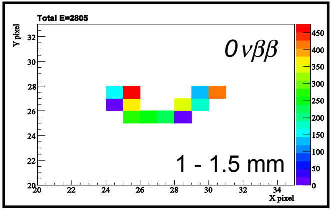

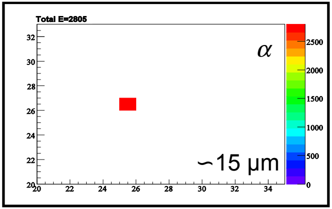

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- Currently testing two systems at LNGS and Modane

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- Simulation of charge deposition and transport necessary to determine optimum pixel size $\longrightarrow$ ongoing

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  - Large (2000 micron) pixels
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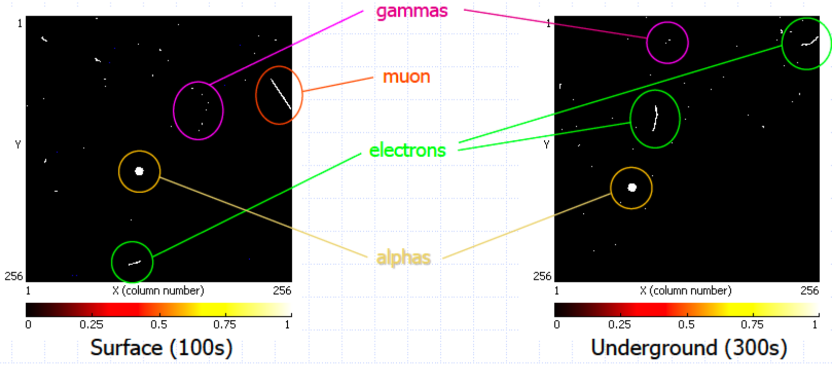
- CZT Pixel, Univ. St. Louis
  - Different pixel sizes available
  - First test with LB-optimized system
    in Winter 2009 at LNGS.

Particle Identification



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

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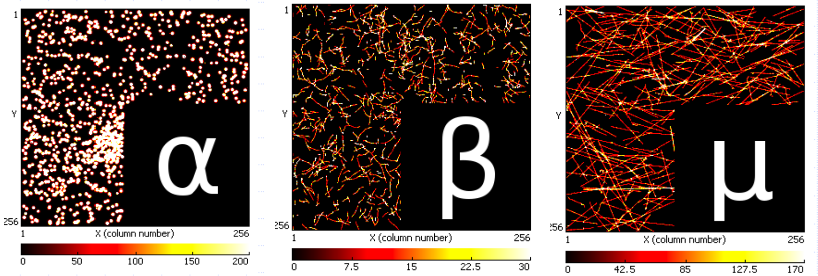
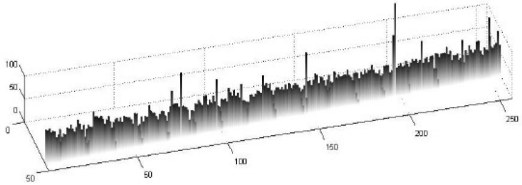
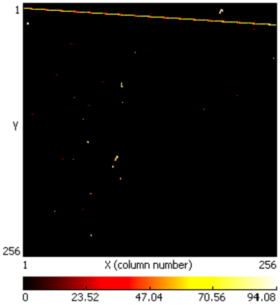
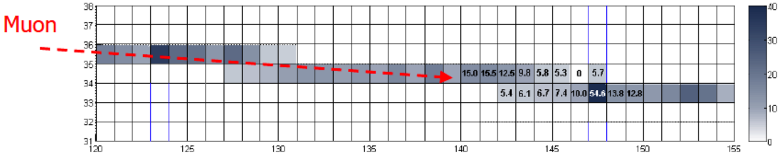


- Separation of events by type

Muon Track across whole detector







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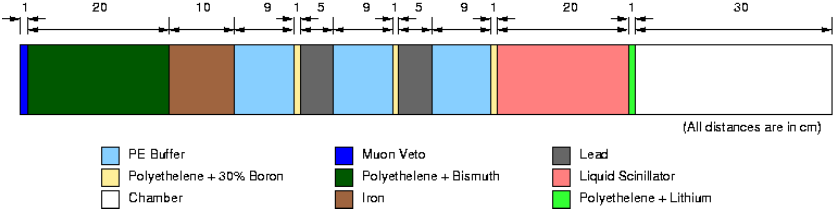

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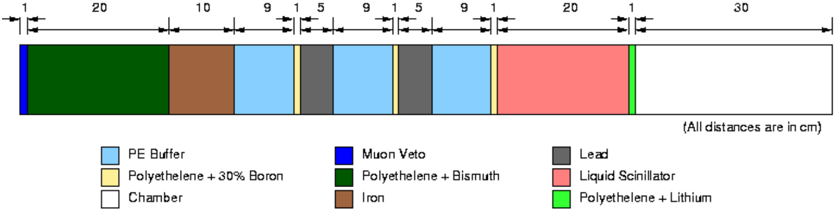

- Interesting shielding option:
  Suspend detectors directly in liquid scintillator
  $\longrightarrow$ preparing for tests at Uni Hamburg

Long-Term COBRA Roadmap

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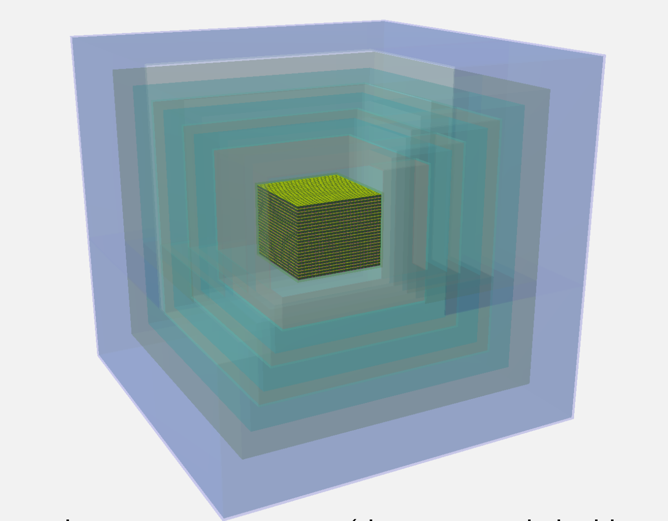
- COBRA perspective for Modane:
  After LSM extension in 2013, install full-size shielding
  with first prototype detector modules

Possible Large Scale COBRA Setup



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

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- Major upgrade of current setup in 2010.
- Compact sized full-scale setup.
- Would be well suited for installation at Modane.