TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät für Mathematik und Naturwissenschaften Institut für Kern- und Teilchenphysik

STATUS OF THE COBRA DOUBLE BETA DECAY EXPERIMENT

Benjamin Janutta

NOW 2010, 2010/9/5

What is COBRA?

Cadmium–Zinc–Telluride O-neutrino double-Beta Research Apparatus

- examine usability of CdZnTe–semiconductor detectors to measure the $0\nu2\beta$ decay
- two competing detector concepts:
  - coplanar grid detectors
  - pixelated detectors
- goal: experiment with 400 kg source material (e.g. 64000 CPG–detectors)

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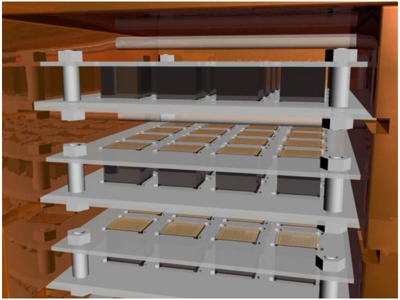

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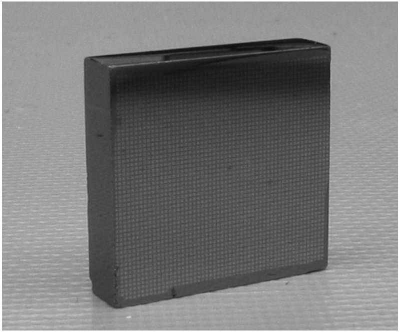

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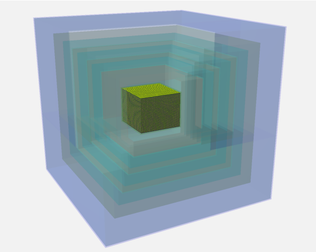
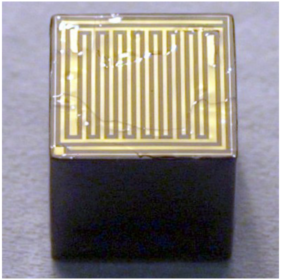


Advantages of CdZnTe–Detectors

- source = detector
- semiconductor (good energy resolution, clean)
- CdZnTe works at room temperature
- coincidence studies possible due to modular design
- industrial production rising in recent years
- tracking possible ("solid state TPC")
- several nuclids can be measured
- highly favorable nuclide: ^{116}Cd with Q–value at 2.8 MeV well above natural γ–background
- enrichement of ^{116}Cd feasable in industrial measures

Coplanar Grid CdZnTe–detectors

- energy resolution better then 2 % at 2,8 MeV
- low costs/channel
- large amounts available at short
- position resolution rather bad (given by dimensions of the detector)
- background reduction via coincidences



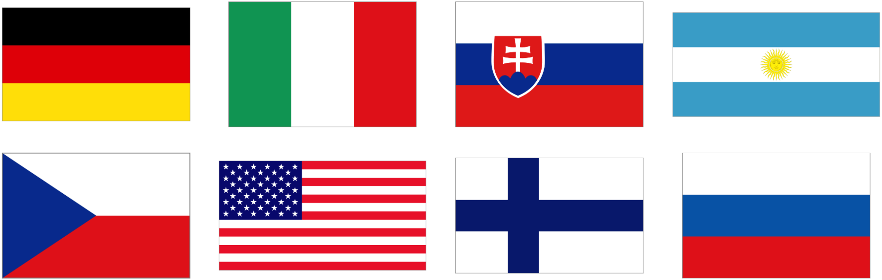
Pixel Detectors

- track reconstruction (depending on pixel size)
- particle identification ($\alpha, \beta, \gamma, \mu$)
- single and double β–decays distinguishable
- expected reduction of background rates by 3 orders of magnitude for γ and α

different pixel systems available:

- Timepix System (minimal pixel size $55{\times}55\,\mu\text{m}^2$)
- Large Volume Polaris System
- working on optimization for different systems (variable pixel size)

COBRA–Collaboration



TU Dortmund, TU Dresden, FMF Freiburg, Universität Hamburg, Technical University Prague

Universität Erlangen–Nürnberg, Washington University St. Louis, JINR Dubna,

University of Bratislava, LNGS, University of Jyvaskyla, University of La Plata,

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COBRA–Collaboration

MORE WELCOME!!!

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COBRA–Setup at LNGS

- 3700 m.w.e shielding with Gran Sasso rock
- can hold up to 64 CPG–detectors
- passive shielding with borated polyethylen, lead, copper
- long time measurement with 16er layer at LNGS finished
- at the moment 8 colourless CPG–detectors installed and running
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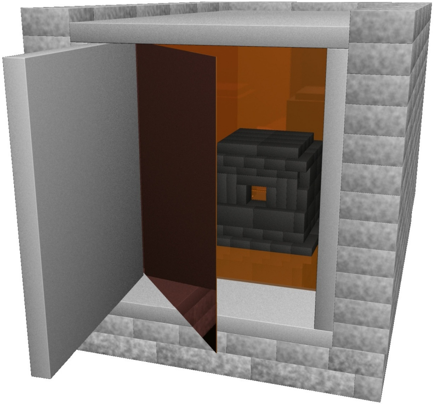

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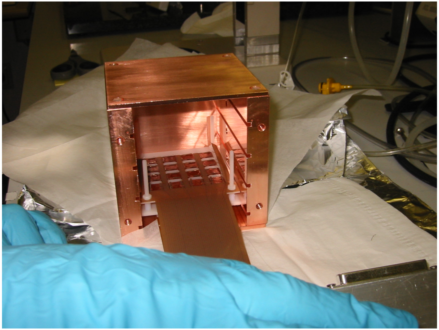

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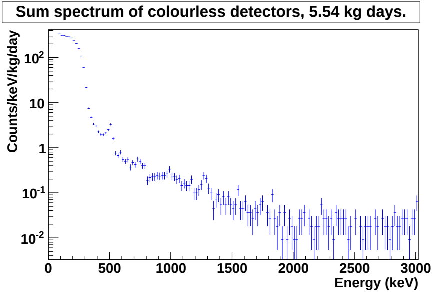

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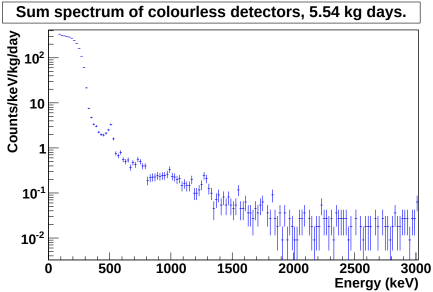
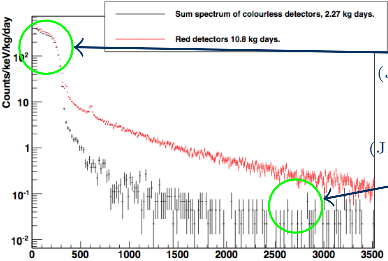


Physics at LNGS

Data taking with 16 red crystals finished, about 18 kg·d
Major background identified: red paint on crystal surface + Radon
Installation of first colourless detectors + nitrogen flushing show promising results:



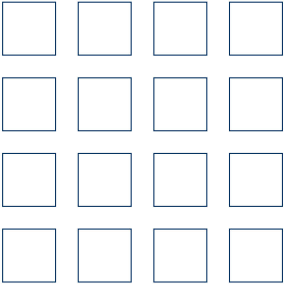
^{113}Cd β decay
(J. V. Dawson et al., Phys. Rev. C 80 (2009) 025502)

^{116}Cd $0\nu2\beta$ decay Q–value at 2.8 MeV
(J. V. Dawson et al.,Nucl. Phys. A 818 (2009) 264-278)

Background around 2.8 MeV: 5 counts/keV/kg/yr!! VERY PROMISING!!

Physics at LNGS

Why coincidence analysis??



highly segmented detector give

- possibility to distinguish single-/multisite events
- higher sensitivity to β^+ modes
- higher sensitivity to transitions into excited states

Physics at LNGS

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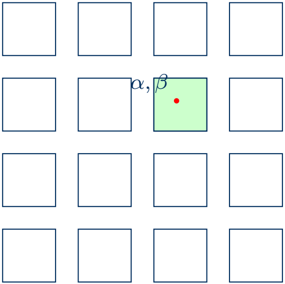

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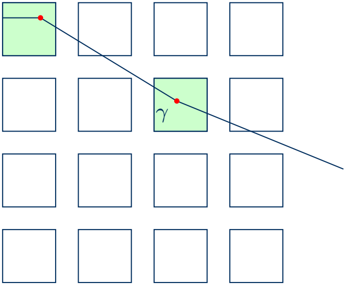

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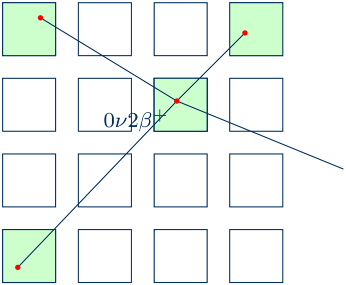

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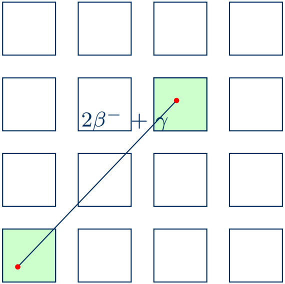

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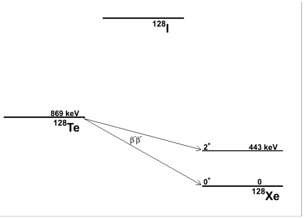
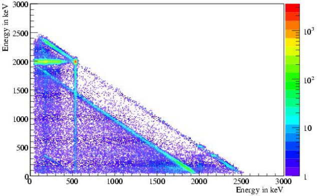
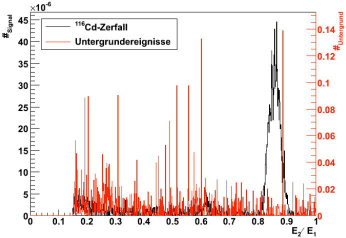


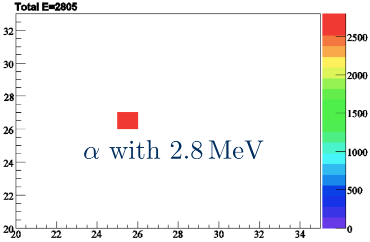


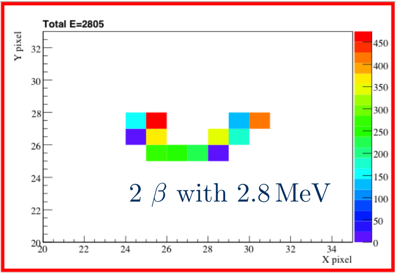


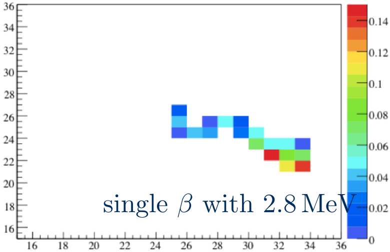
Massive background reduction, but low efficiency.
Limits not yet competitive with single detector results. Planned upgrade should improve this.

Pixel Detectors

Idea: Massive background reduction





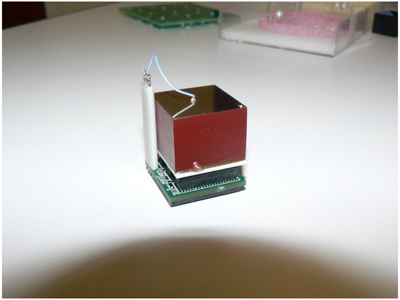


Simulation of 200 μm pixel, J. Wilson

Polaris Installation at LNGS
First low background data taking with a pixelated detector

Prototype provided by Zhong He group, University of Michigan

- biggest CdZnTe detector in the world ($2 \times 2 \times 1.5\,\mathrm{cm}^3$, 36 g)
- 11×11 Pixel + interaction depth sensing via drift time
- energy resolution FWHM better than 2 % at 662 keV
- NO low–background optimization
- lead shielding and nitrogen flushing provided at COBRA setup



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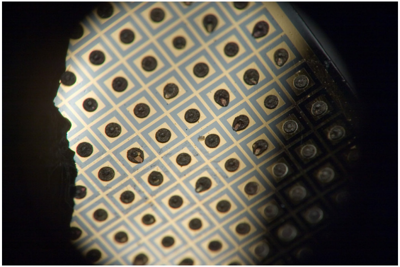

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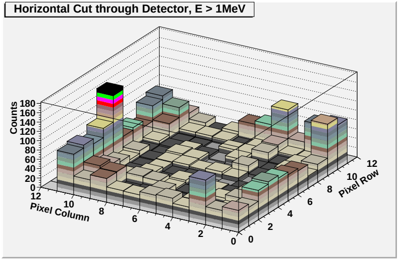
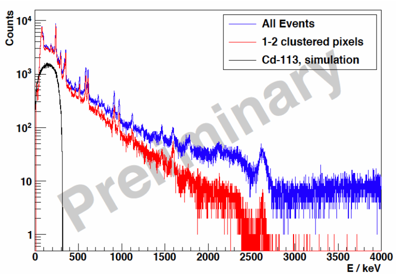
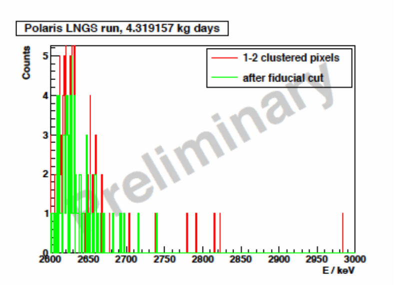


Polaris results





No survivor after 125 days of data taking
0.9 counts/keV/kg/yr between 2.7 and 3.0 MeV

Measurements with Si–Timepix detector
at Niederniveau Messlabor Felsenkeller

- Pixeldetector provided by the Medipix 2 Collaboration
- installation in september 2009
- laboratory with about 120 m.w.e. in Dresden
- 300 μm Si detector with 65536 pixels ($55 \times 55\,\mu\text{m}^2$)
- Goal: development of algorithms to identify α, β, γ und μ
- analysis ongoing

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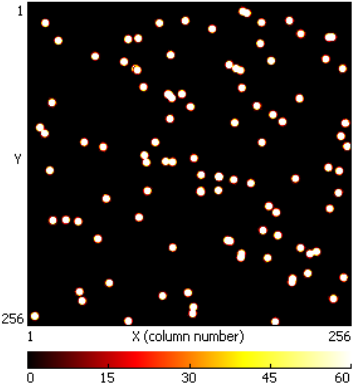

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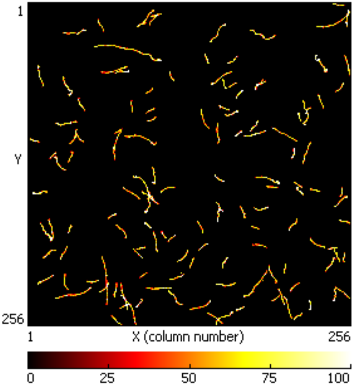

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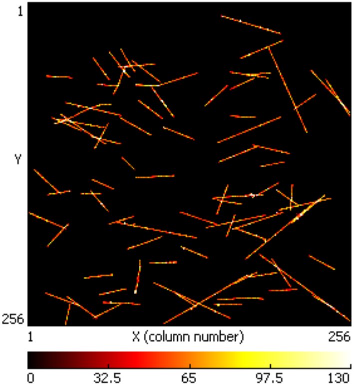


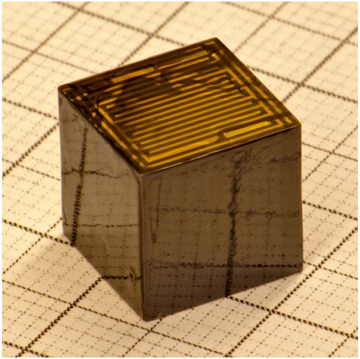
Outlook

LNGS Upgrade

- Upgrade to 64 colorless CZT $1\,cm^3$ detectors, about 0.42 kg (all detectors at hand)
- Single grid readout , i.e. pulse shaping
- Improved shielding , readout (new DAQ) , material selection
- new HV power supply, new amplifier electronics

Aim: Background < 1 count/keV/kg/yr

colorless CPG detector



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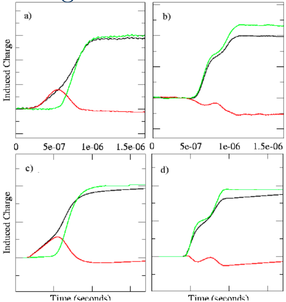
single site multi site



experiment

simulation

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

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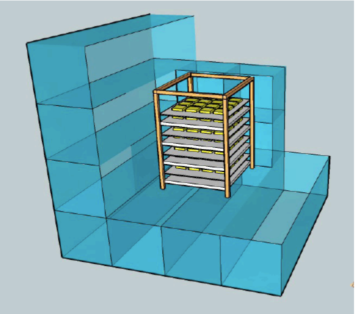

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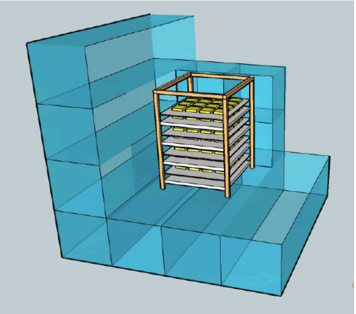


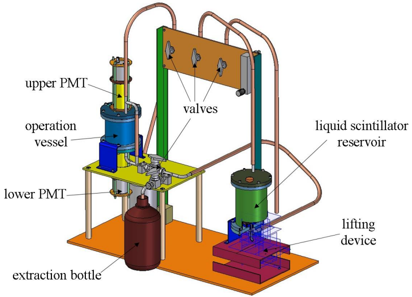
Summary

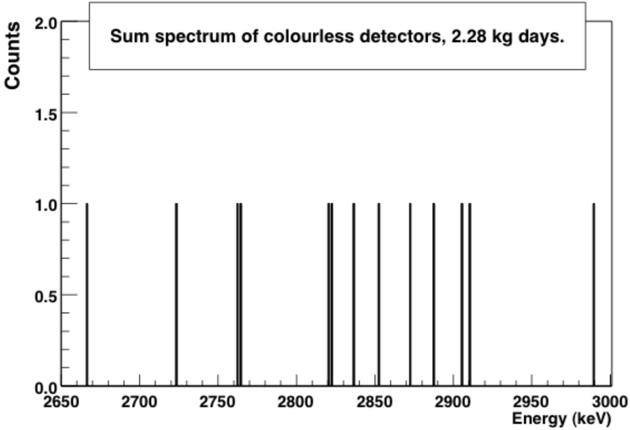
- COBRA investigates the applicability of CdZnTe–detectors for searches of rare weak decay processes
- successful operation of different setups in low–background environment
- first time ever operation of pixelated detectors in low–background environment
- despite low detector mass world best limit published
- major upgrade planned for end of 2010, begining 2011
- Goal: have a proposal for a large scale experiment (400 kg) by end of 2012

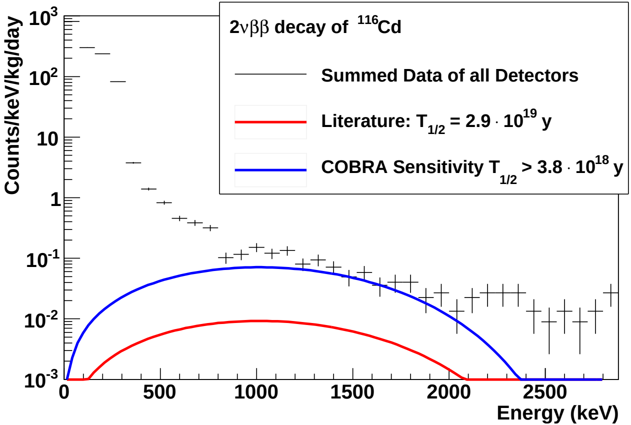
CdZnTe detectors in liquid scintillator

Liquid scintillator as active veto

- setup running
- Monte Carlo simulation available
- detailed studies of longtime stability, pulse shape and chemical stability




Sum spectrum of colourless detectors, 2.28 kg days.
Counts
2.0
1.5
1.0
0.5
0.0
2650
2700
2750
2800
2850
2900
2950
3000
Energy (keV)


2νββ decay of 116Cd
Summed Data of all Detectors
Literature: T1/2 = 2.9 · 10^19 y
COBRA Sensitivity T1/2 > 3.8 · 10^18 y
Counts/keV/kg/day
Energy (keV)
10^3
10^2
10
1
10^-1
10^-2
10^-3
0
500
1000
1500
2000
2500