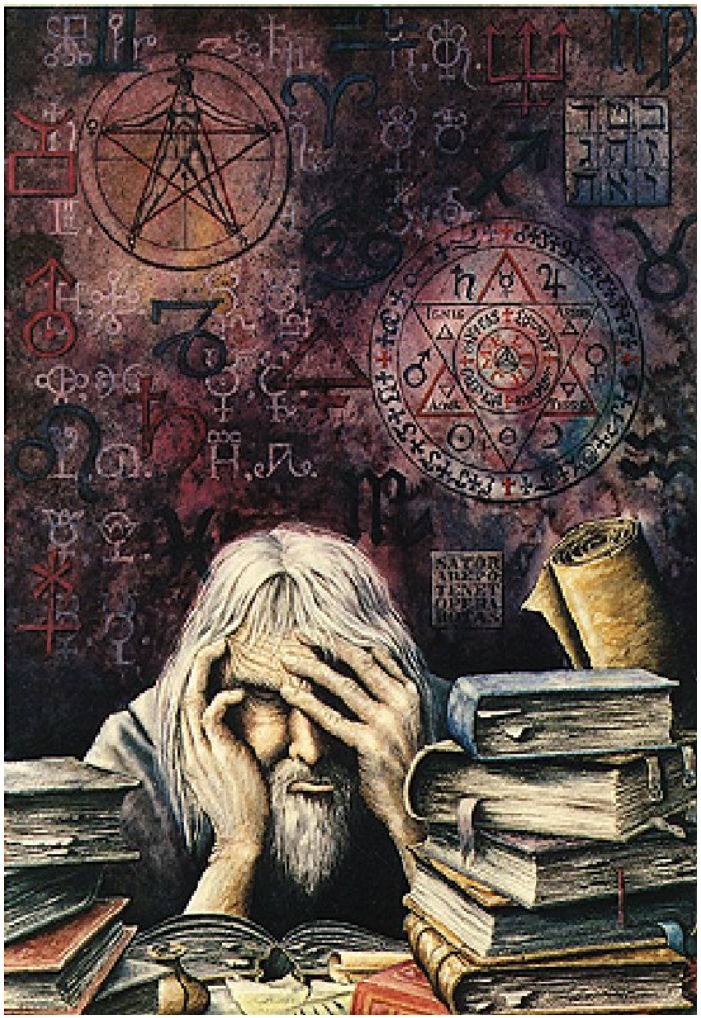
TECHNISCHE UNIVERSITÄT DRESDEN

iktp

A large solid state TPC with COBRA

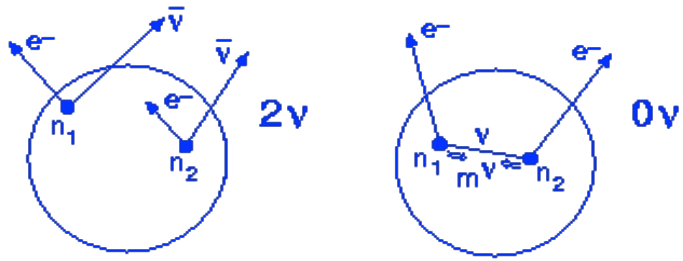
K.Zuber, 25.10.2010



- Double beta decay
- COBRA (CZT detectors)
- The solid state TPC (pixel detectors)
- Outlook
- Summary

Double beta decay

- $(A,Z) \rightarrow (A,Z+2) + 2\,e^- + 2\bar{\nu}_e$ $2\nu\beta\beta$
- $(A,Z) \rightarrow (A,Z+2) + 2\,e^-$ $0\nu\beta\beta$



Unique process to measure the mass of the neutrino

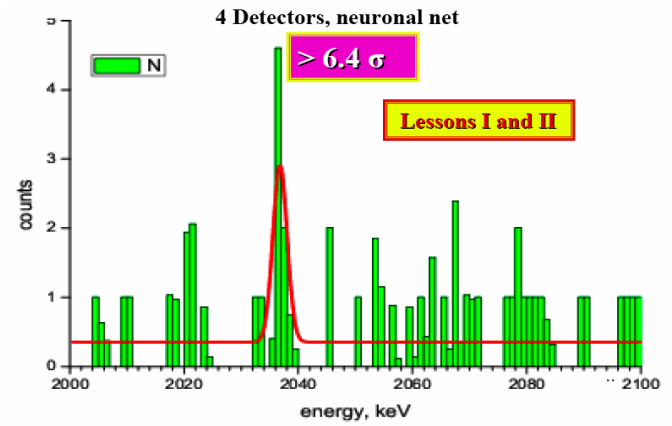
Unque process to measure character of neutrino

Requires half-life measurements well beyond 10^{20} yrs!!!!

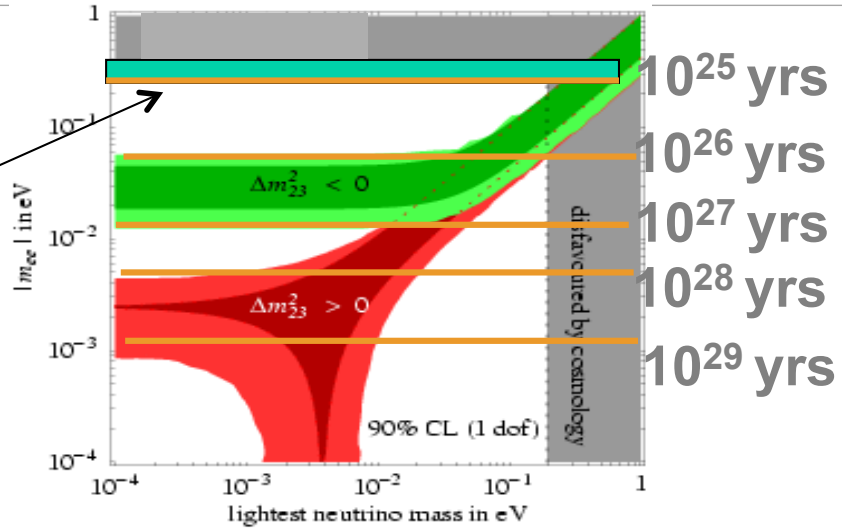
The smaller the neutrino mass the longer the half-life

Double beta decay

claim of evidence



H.V. Klapdor-Kleingrothaus et al. , Mod. Phys. Lett. 2006



$$T_{1/2}^{-1} \propto a\varepsilon Mt$$ (BG free)

$$T_{1/2}^{-1} \propto a\varepsilon\sqrt{\frac{Mt}{\Delta EB}}$$ (BG limited)

$$T_{1/2}^{-1} = PS^{0\nu}\left|M_{GT}^{0\nu} - M_F^{0\nu}\right|^2 \frac{\langle m_\nu \rangle^2}{m_e^2} \longrightarrow m_\nu \propto \sqrt[4]{\frac{\Delta EB}{Mt}}$$

Back of the envelope

This is the 50 meV option, just add 0's to moles and kgs if you want smaller neutrino masses

$T_{1/2} = \ln 2 \cdot a \cdot N_A \cdot M \cdot t / N_{\beta\beta}$ $(\tau_{>>T})$ (Background free)

For half-life measurements of $10^{26\text{-}27}$ yrs

1 event/yr you need $10^{26\text{-}27}$ source atoms

This is about 1000 moles of isotope, implying 100 kg

Now you only can loose: nat. abundance, efficiency, background, ...

Why more than 1 isotope? - I

2012-13:

Imagine GERDA is seeing a clear peak

-> Is it really double beta decay or something Ge-specific?

Imagine GERDA is NOT seeing a peak

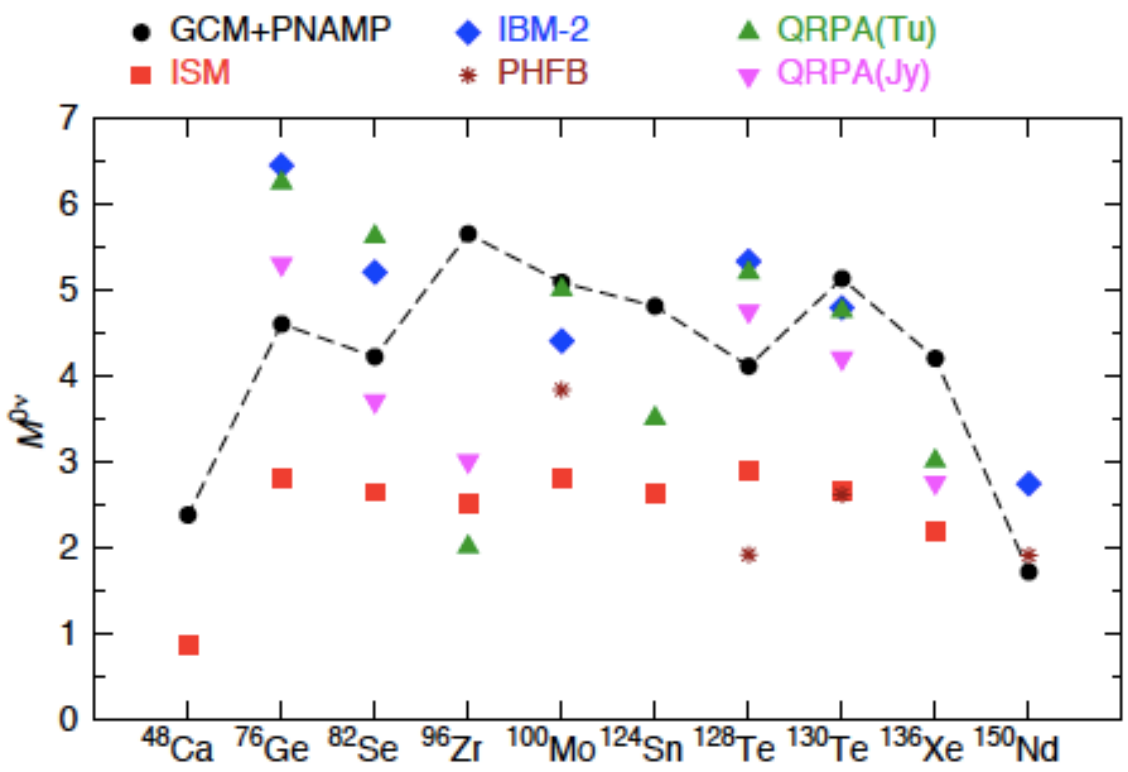
-> talk by B. Majorovits

-> more promising isotopes

(K. Zuber, ECFA workshop „European Strategy for future neutrino physics“, CERN, Okt. 1-3, 2009, arXiv:1002.4313)

Why more than 1 isotope? - II

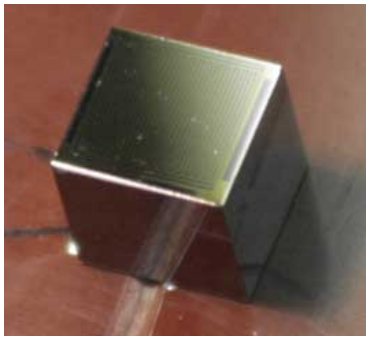
Uncertainties in nuclear matrix elements („conversion factor“)

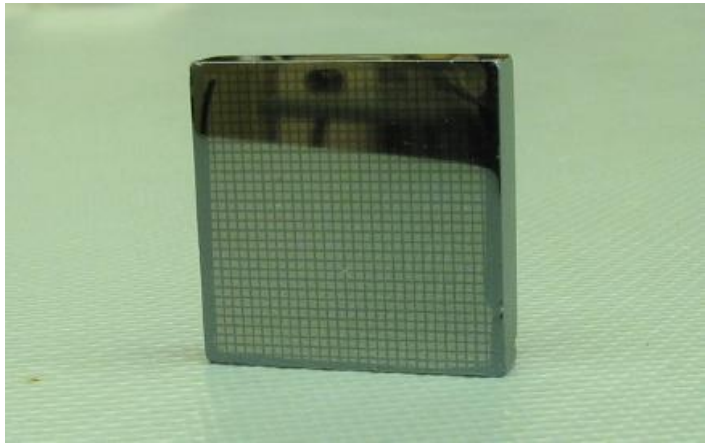


Observation in one isotope results in „predicted ranges“ for others

T.R. Rodriguez, G. Martinez-Pinedo, arXiv:1008:5260

Use large amount of CdZnTe Semiconductor Detectors



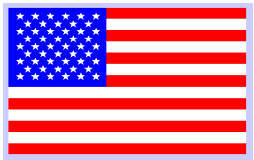


K. Zuber, Phys. Lett. B 519,1 (2001)

COBRA collaboration

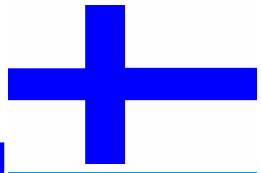
Technical University Dresden
Technical University Dortmund
Material Research Centre Freiburg
University of Erlangen-Nürnberg
University of Hamburg

Laboratori Nazionali del Gran Sasso



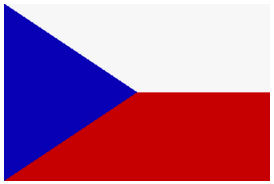
Washington University at St. Louis
Louisiana State University

University of Bratislava

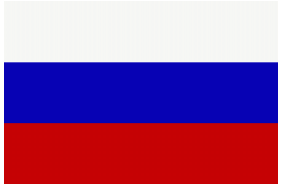


University of Jyvaskyla

University of La Plata



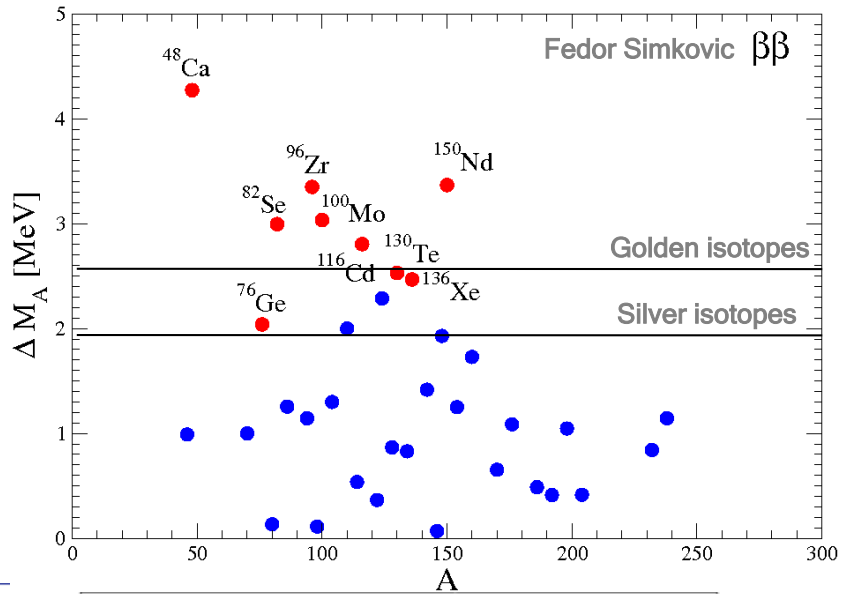
Czech Technical University Prague

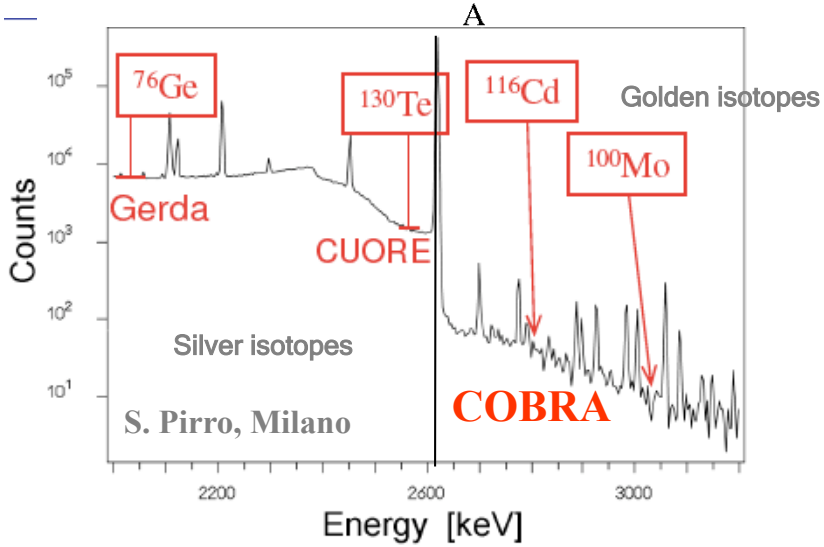


JINR Dubna

Advantages

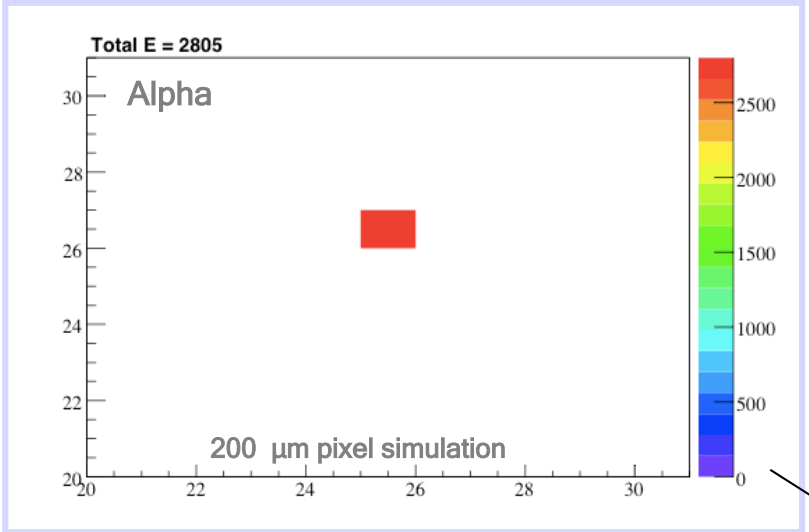
- Source = detector
- Semiconductor (Good energy resolution, clean)
- Room temperature
- Modular design (Coincidences)
- Industrial development of CdTe detectors
- ^{116}Cd above 2.614 MeV
- Tracking („Solid state TPC“)

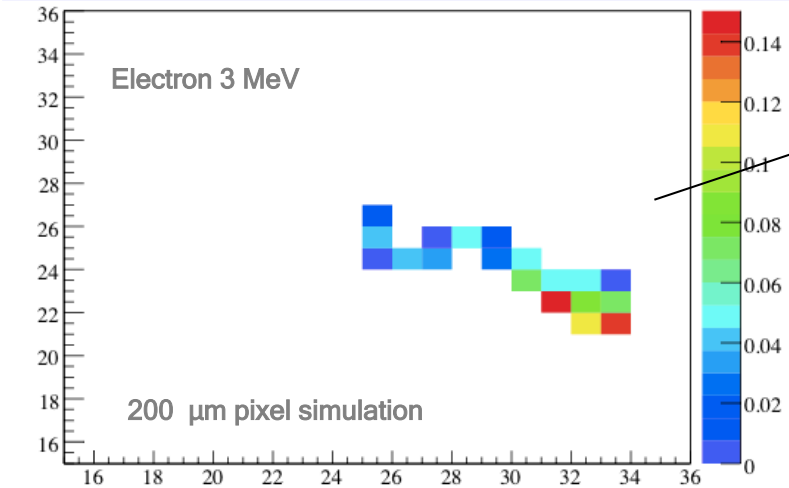


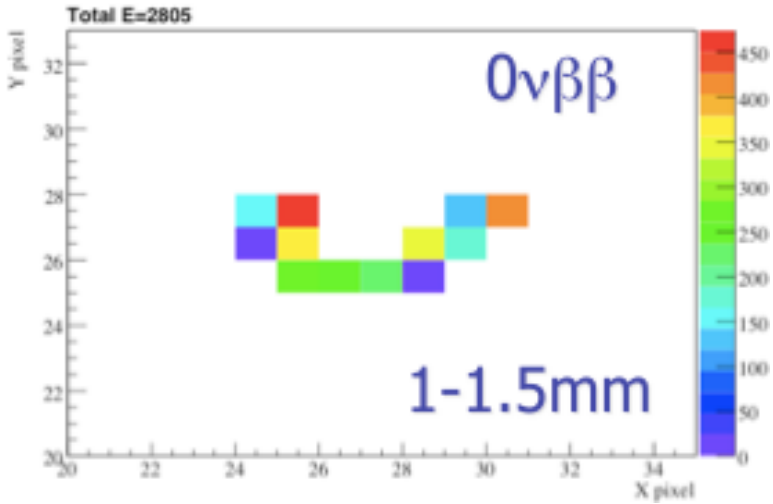


COBRA - Pixel

Idea: Massive background reduction by particle identification



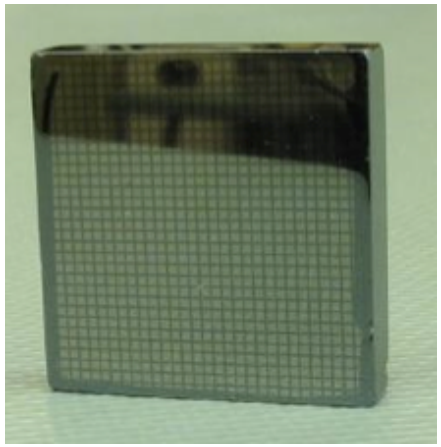




For example Bi-214 :
Time coincidence of both

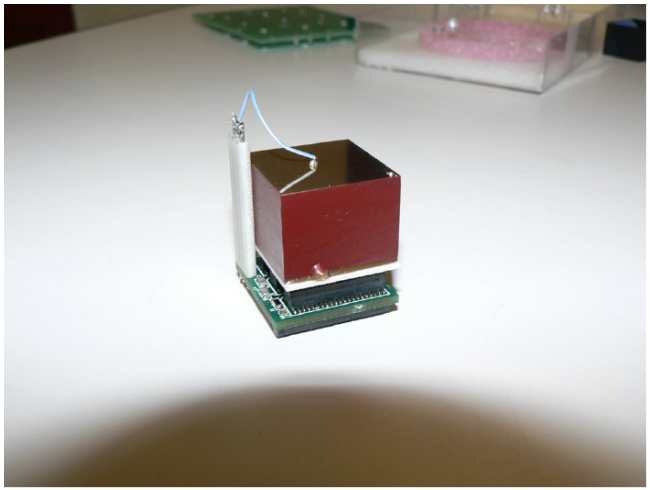
Space and time coincidences possible

COBRA – Pixel CZT



20x20x5 mm^3 systems
8x8 pixels (running at LNGS Jan. -May 2010)
32x32 pixel system
100x100 pixel system

World largest CZT detector = 36 grams
collaboration with Zhong He (Univ. of Michigan)



Timepix system:
14x14x0.3 mm^3 Si (2 systems)
14x14x1 mm^3 CdTe (2 systems)
256x256 systems
128x128 systems

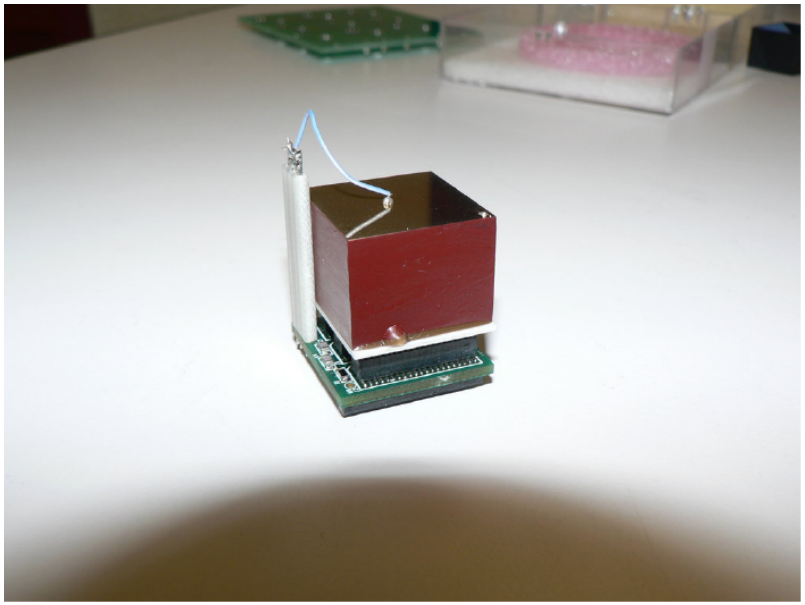
One Si-system running in Felsenkeller Lab since Sep. 2009, one running at LNGS May-Aug 2010, before in Modane

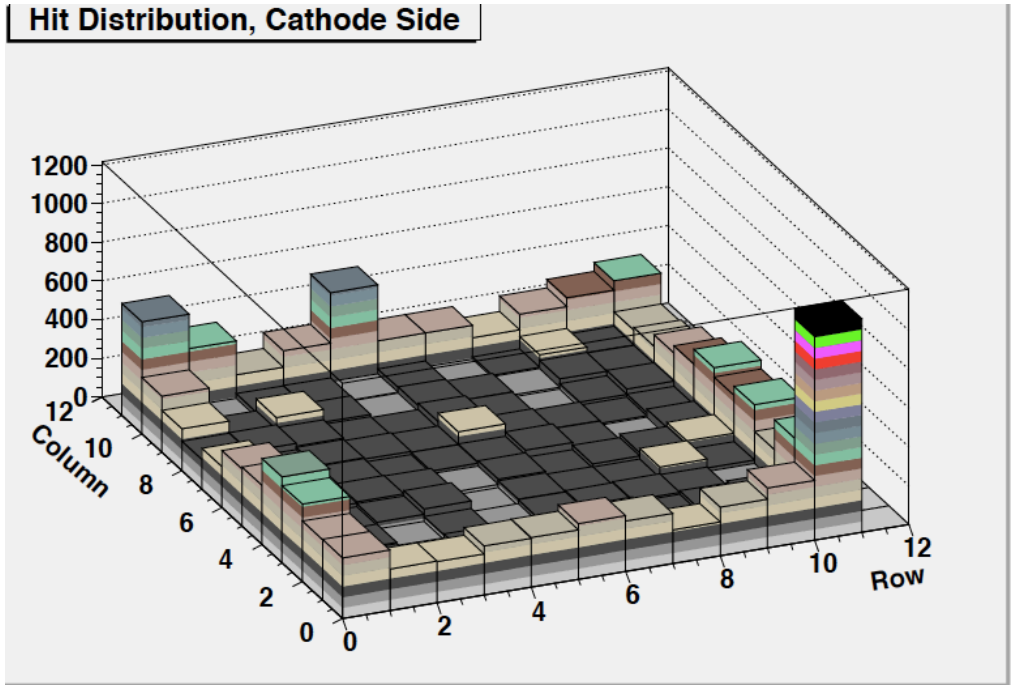
20x20x15 mm^3
11x11 pixel system
Up to 40 slices in z by pulse information
Running at LNGS from Sep. 2009-Jan. 2010

Polaris system

Together with University of Michigan (group Zhong He)

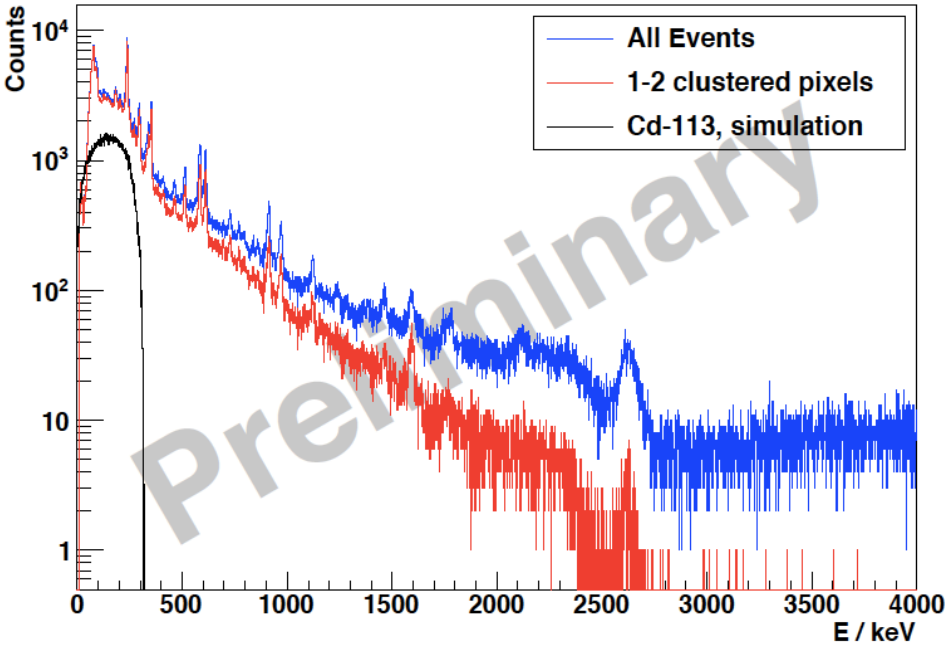
The power of pixels!

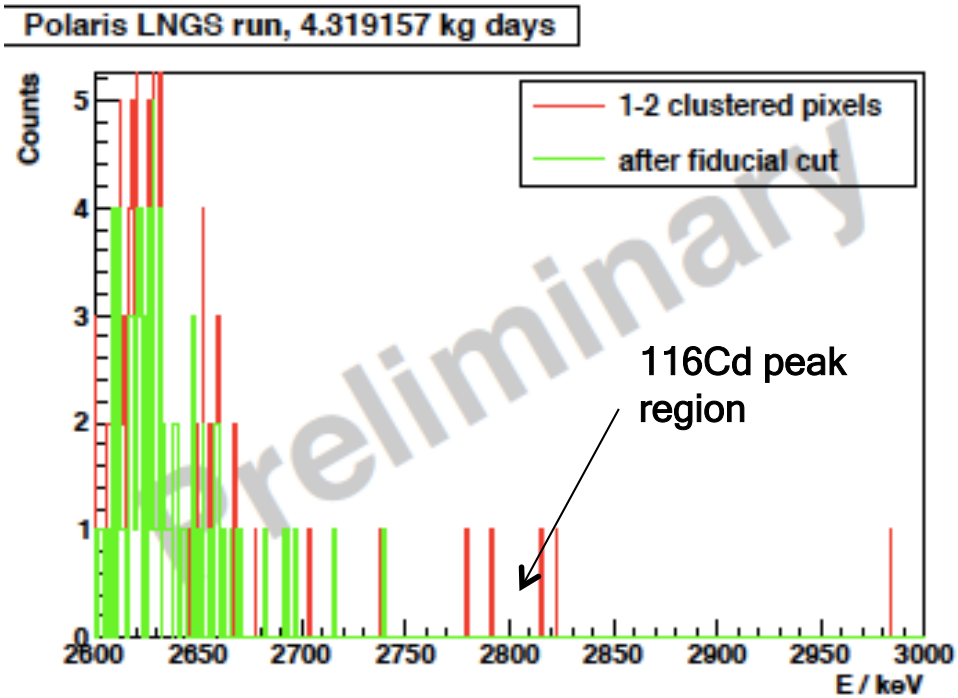




Running at LNGS from Sep. 2009-Jan. 2010

Polaris system





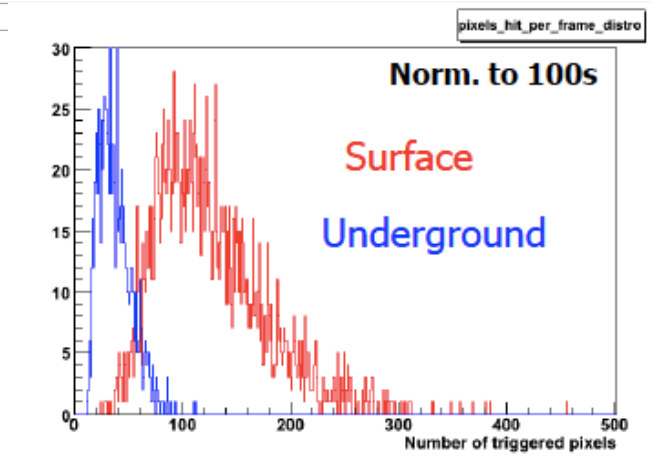
No survivor after 125 days of data taking!!!
Corresponds to a background between 2700-3000 keV of 0.9 counts/keV/kg/yr

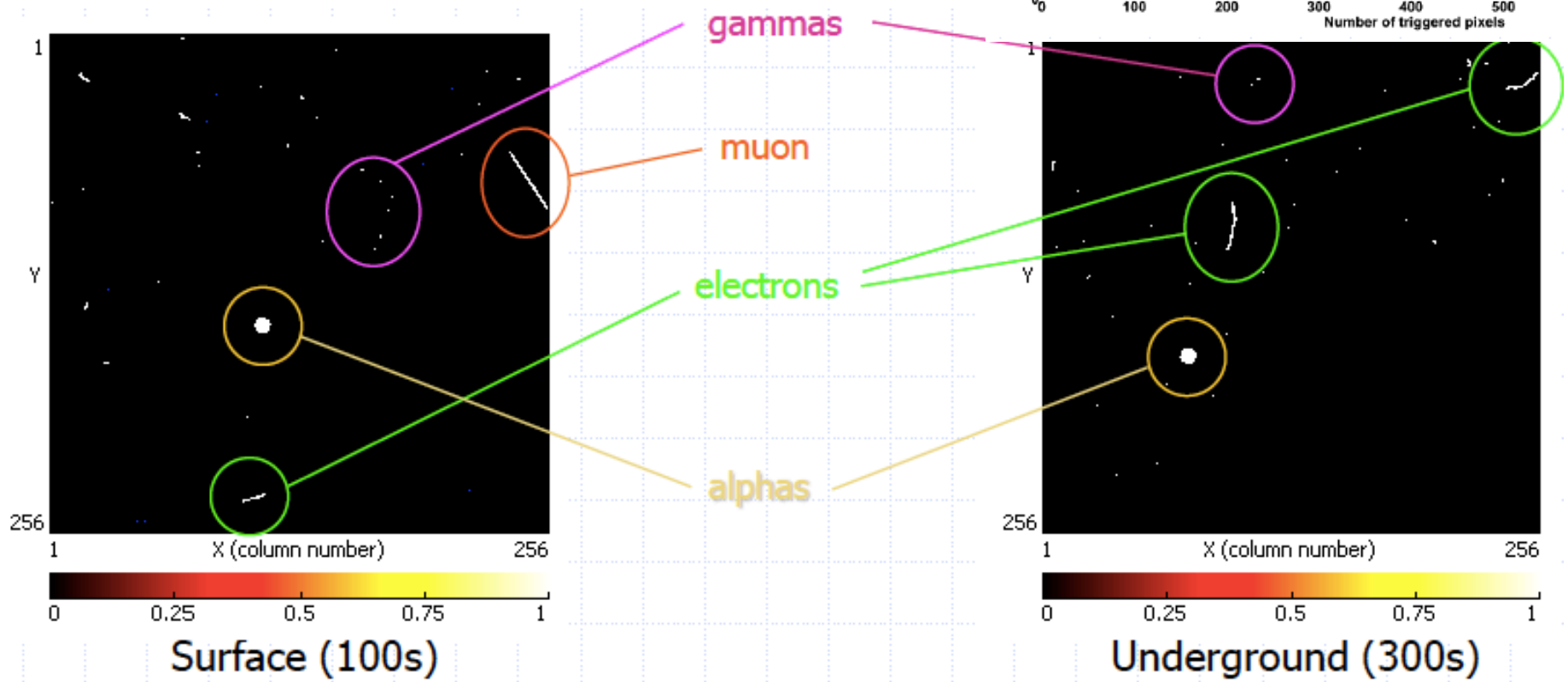
Detector not tuned for low background, no z-analysis

Timepix

55 µm pixel Si Timepix device

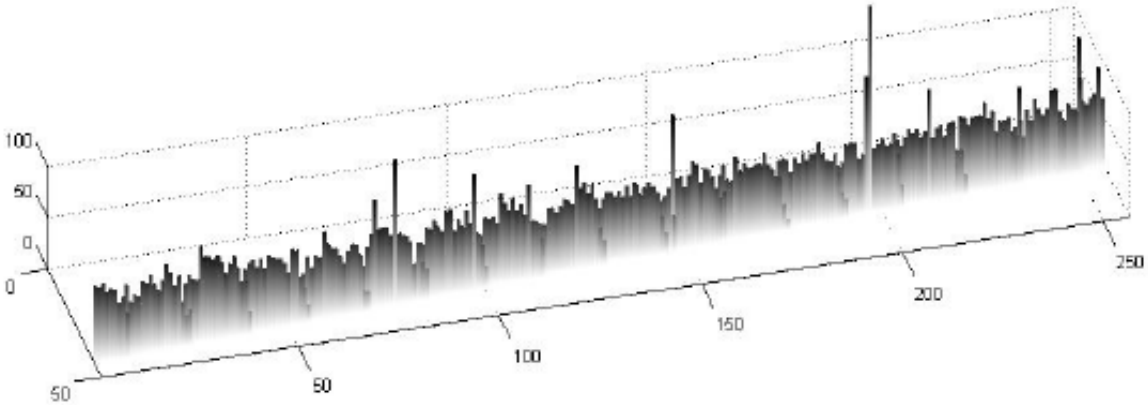
It reacts on environment, ie. not completely dominated by internal background

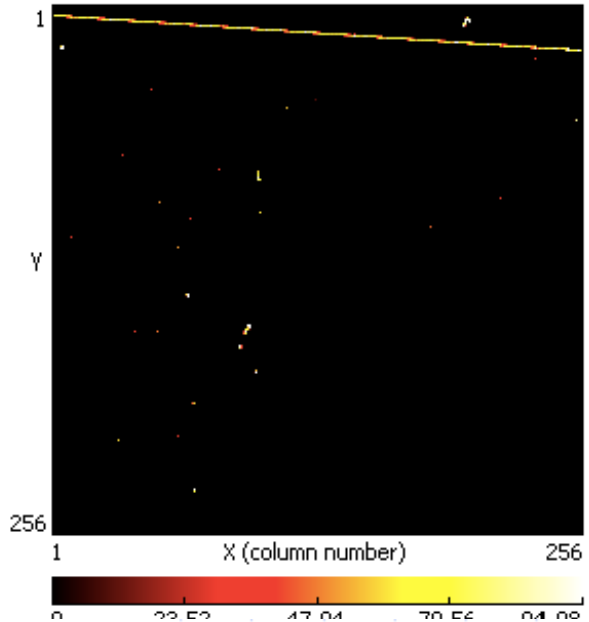




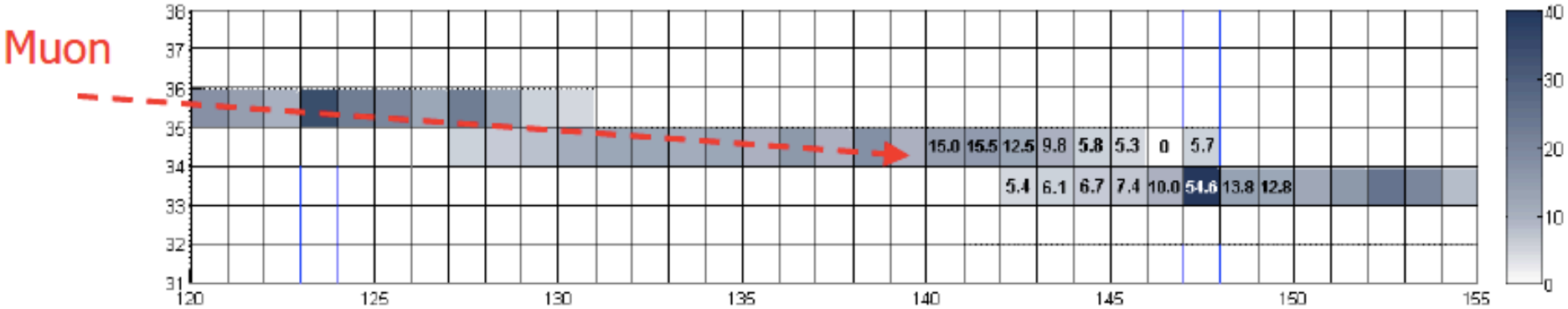
A nice muon

- Track crossing whole detector



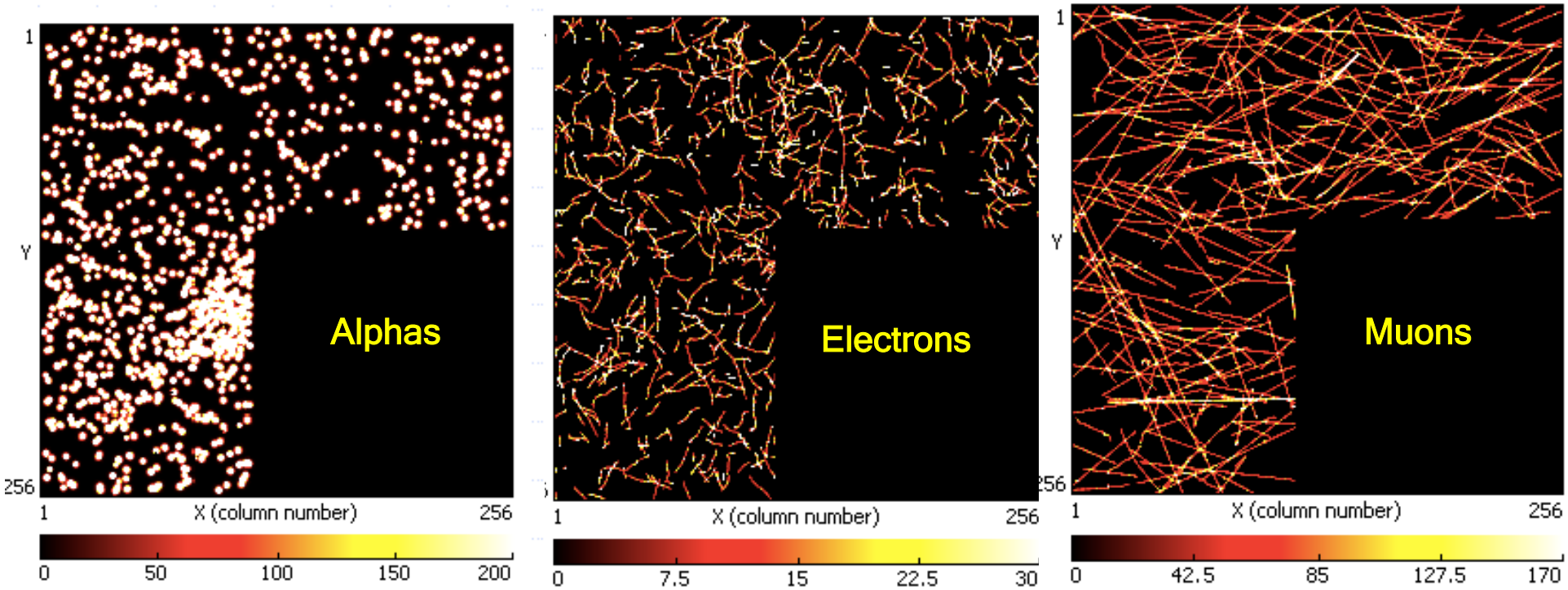


- Top view + deposited energy, charge sharing effect



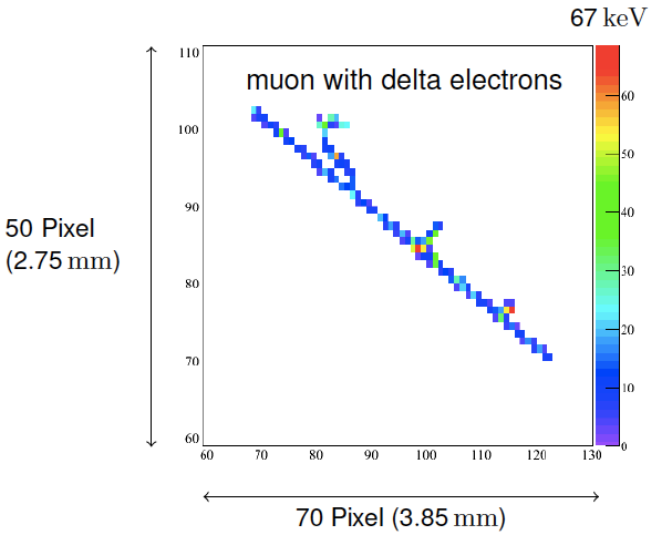
Timepix

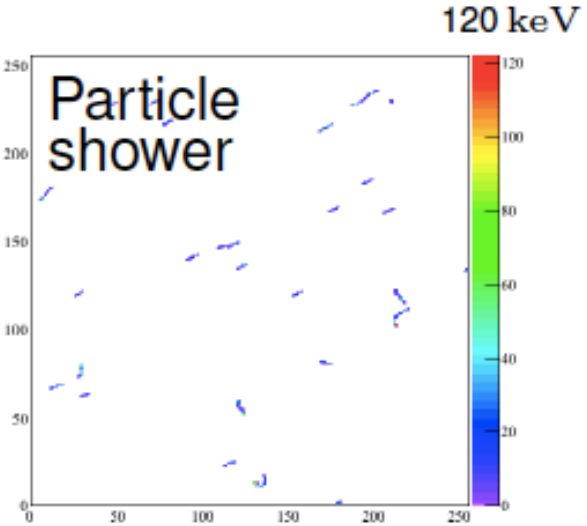
256x256 pixels, 55µm

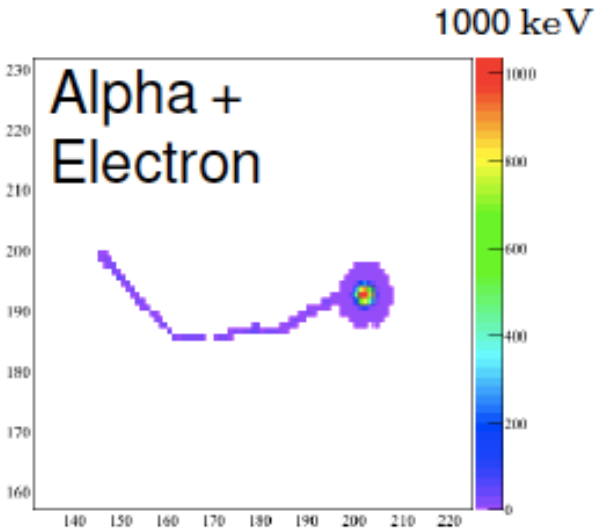


Particle identification as background reduction tool works!

Picture show



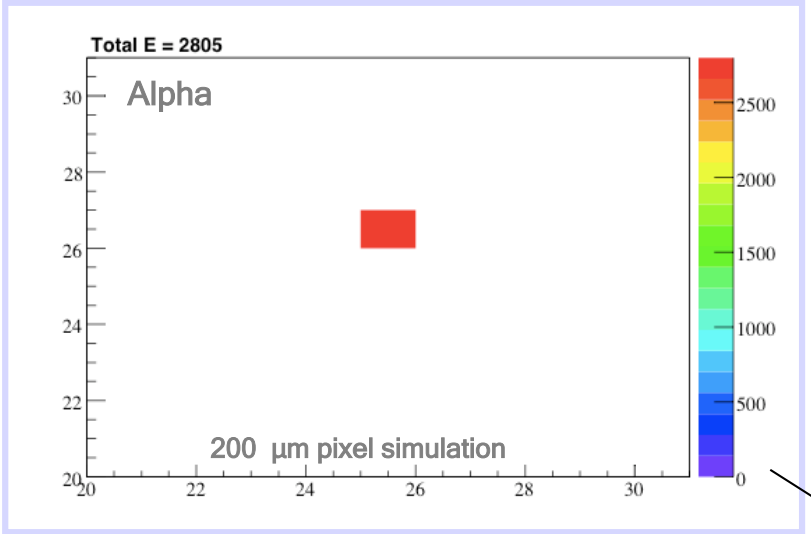


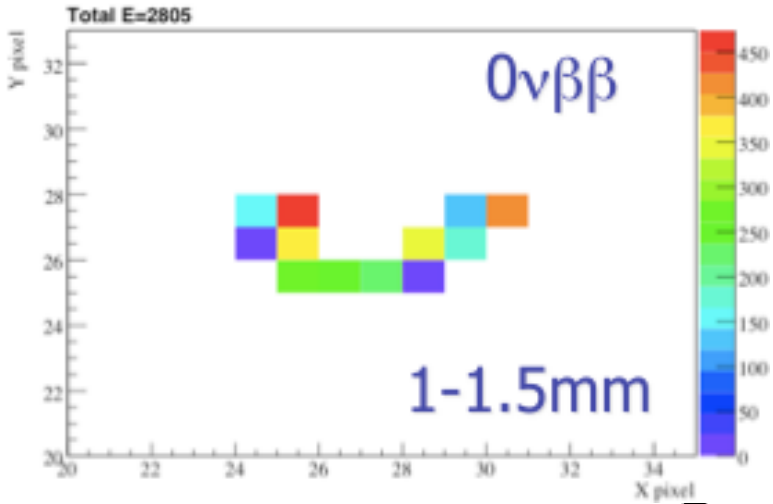


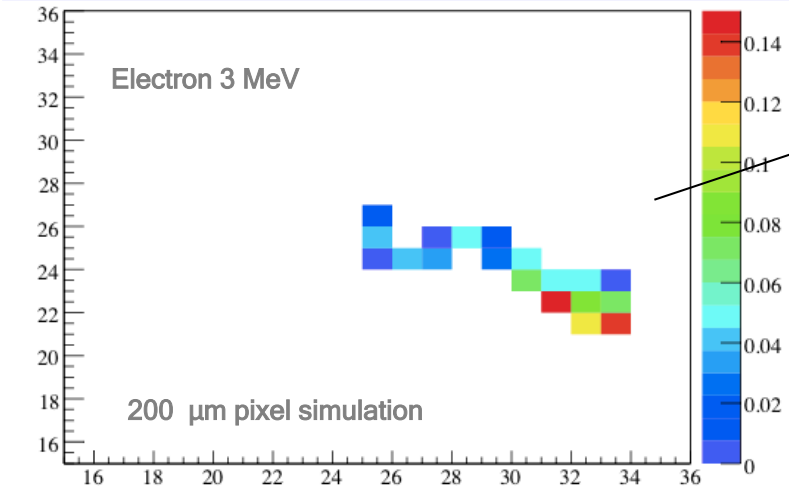
NO event in 117.5 days in energy range between 2.7 and 3 MeV which looks like 1(2) electrons

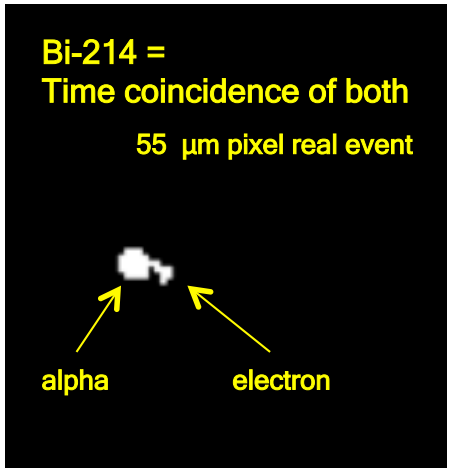
COBRA - Pixel

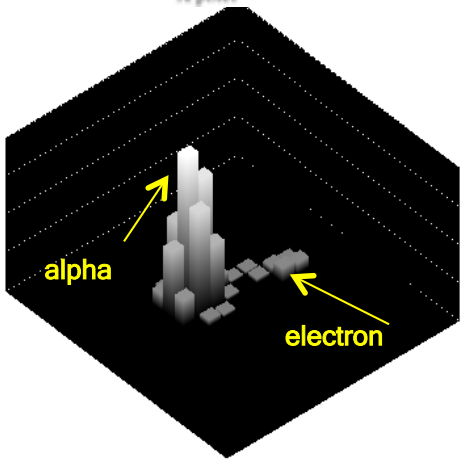
Idea: Massive background reduction by particle identification







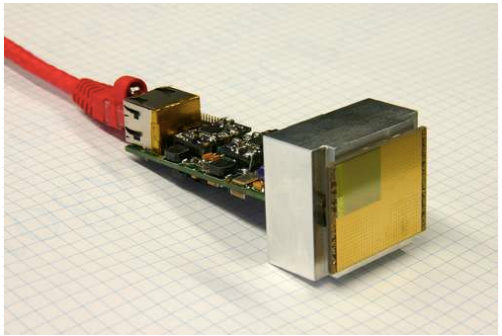


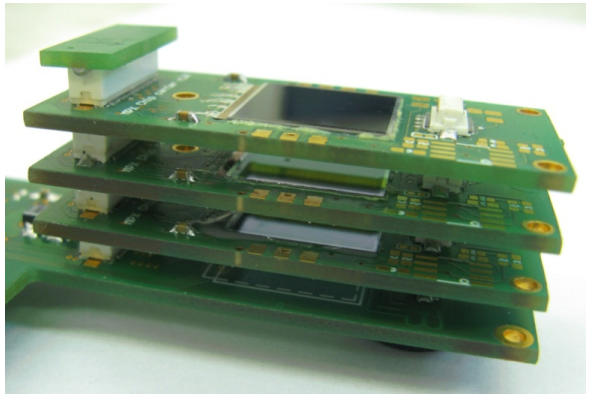


COBRA Upgrade 2010/11

Upgrade to 64 CZT 1 cm^3 detectors, about 0.42 kg (all detectors at hand)
Single grid readout , i.e. pulse shaping (done end of Aug. 2010)
Improved shielding , readout (new DAQ) , material selection
Active veto (CsI), strongly enhances physics potential
Aim : Background below 1 count/keV/kg/yr for CPGs
Good news: Got a new location at LNGS (former HdM building)

Running CZT in LSci
Produce enriched CZT detectors
Running larger scale Polaris and pixel systems



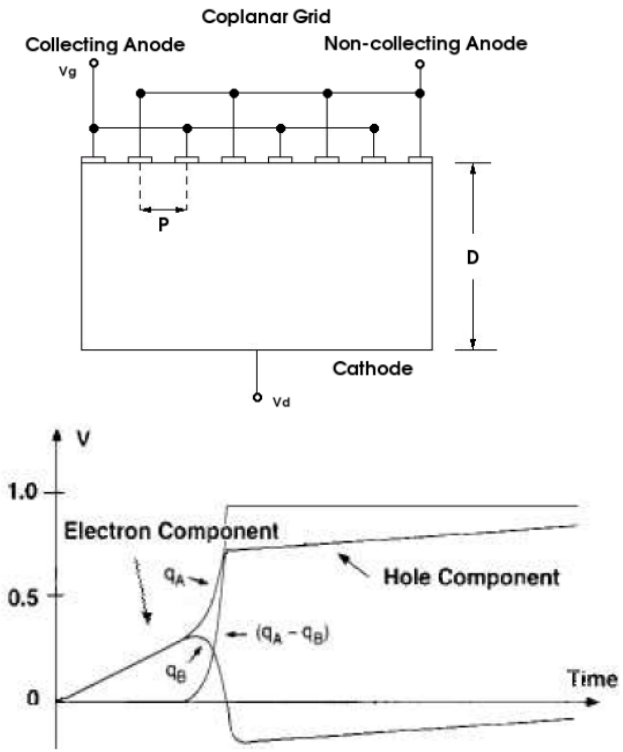


Pulse shape

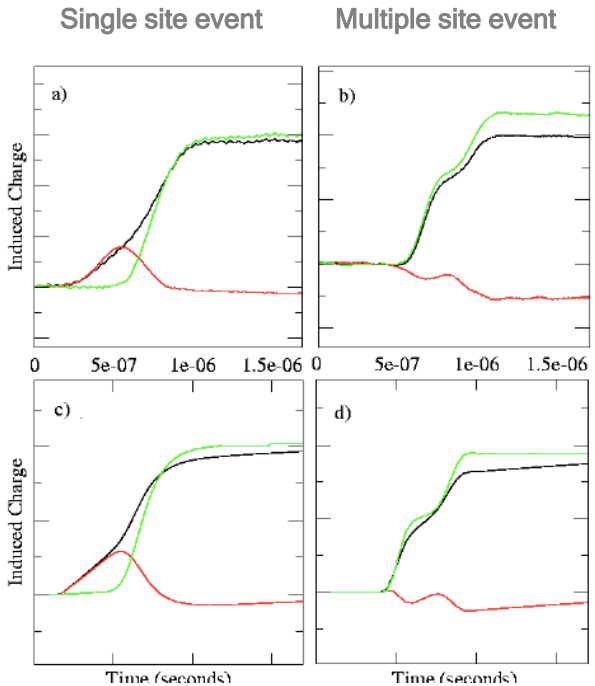
J. McGrath et al. , NIM A 615,57 (2010)

Much more information in pulse shape

CPG detector works like a Frisch grid in wire chambers
P. Luke , IEEE Trans. NS 42, 207 (1995)



^{60}Co pulse



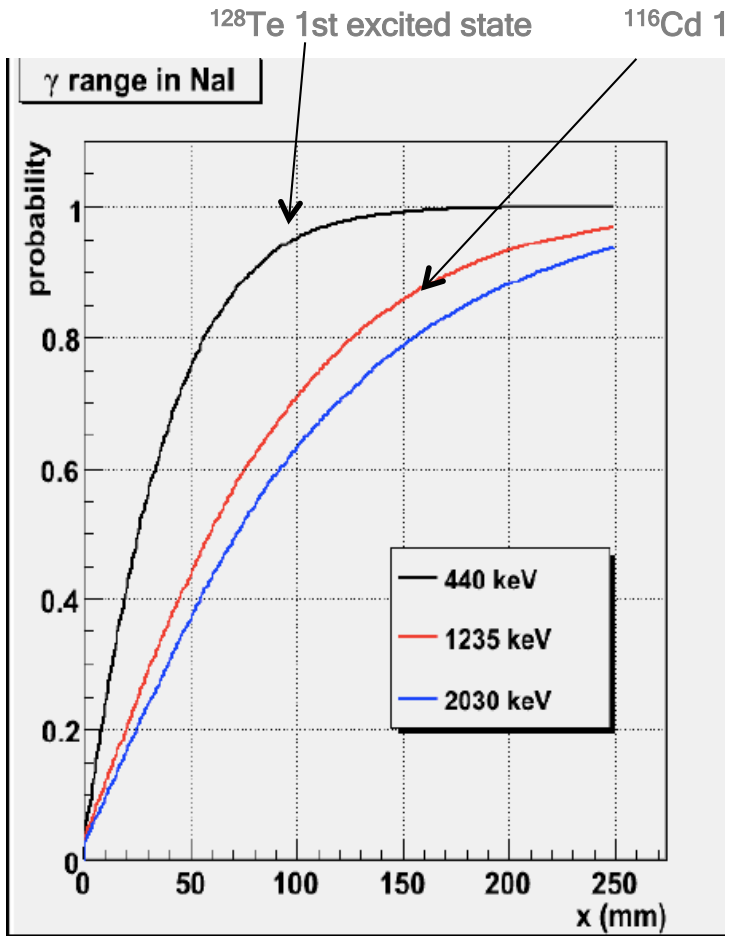
Experiment

TCAD simulation

Modification of preamps necessary... Done
First new preamps and two FADCs installed at LNGS this week

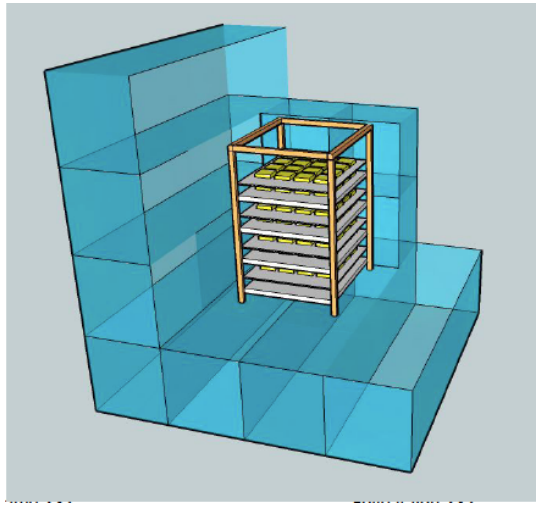
COBRA Upgrade

Aim : Improve excited state and positron decay sensitivity by factor 10-30

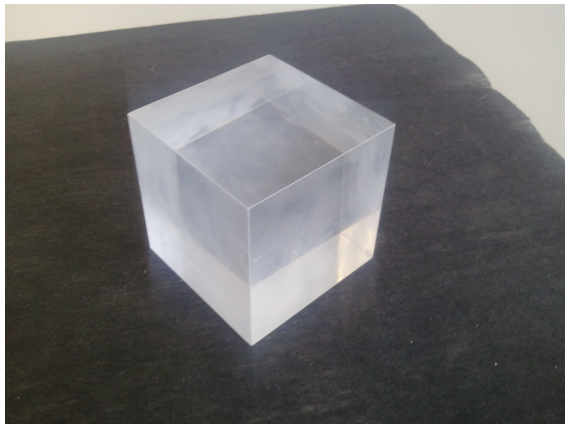


Done for :
NaI, CsI , BGO, $CdWO_4$

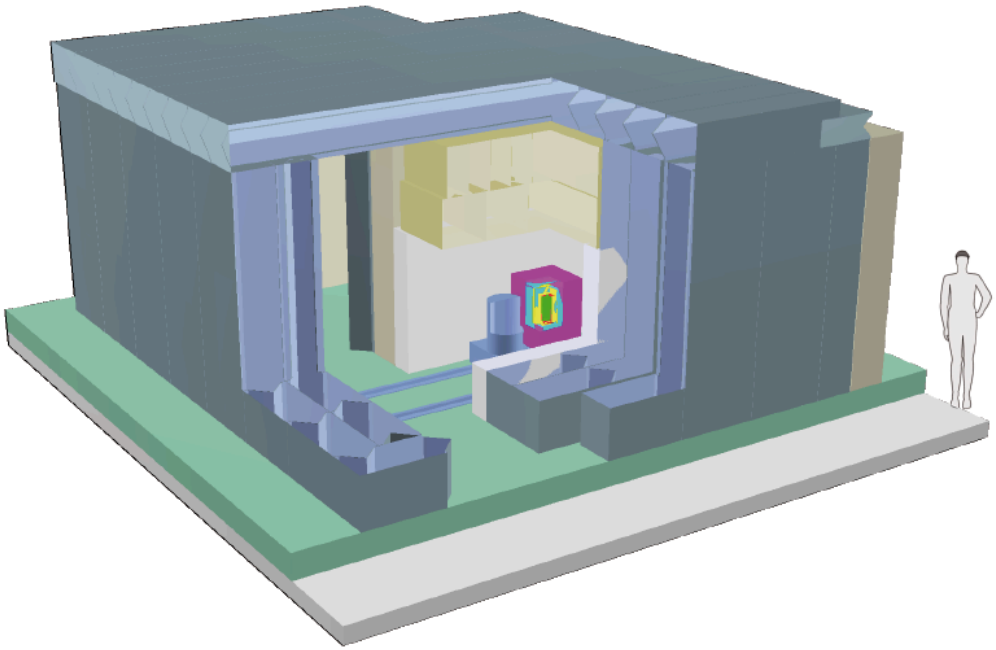
Exploring various readout concepts

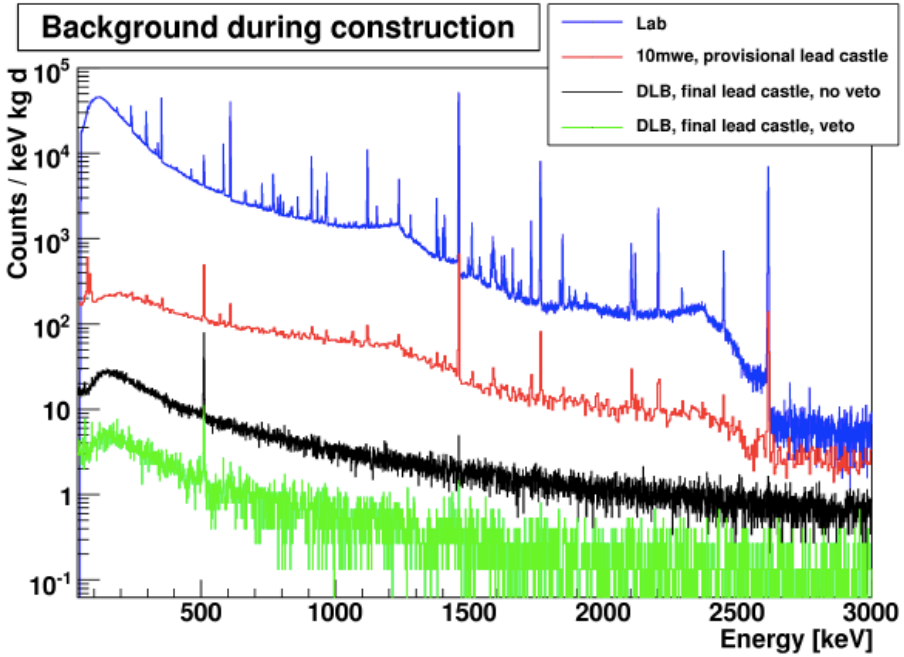


Note:
Can tolerate some impurities because of coincidence requirement



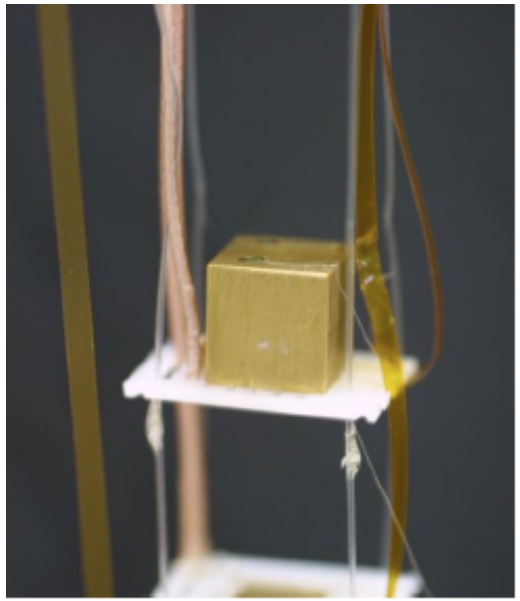
Material screening (DLB)

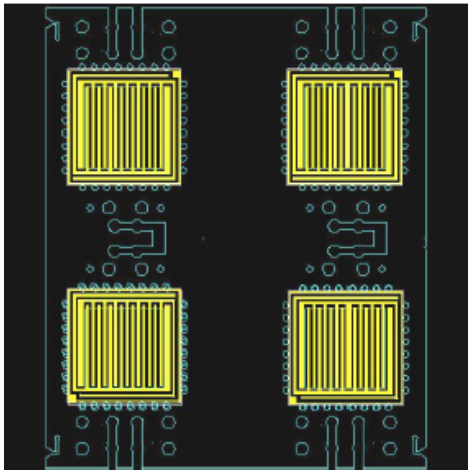


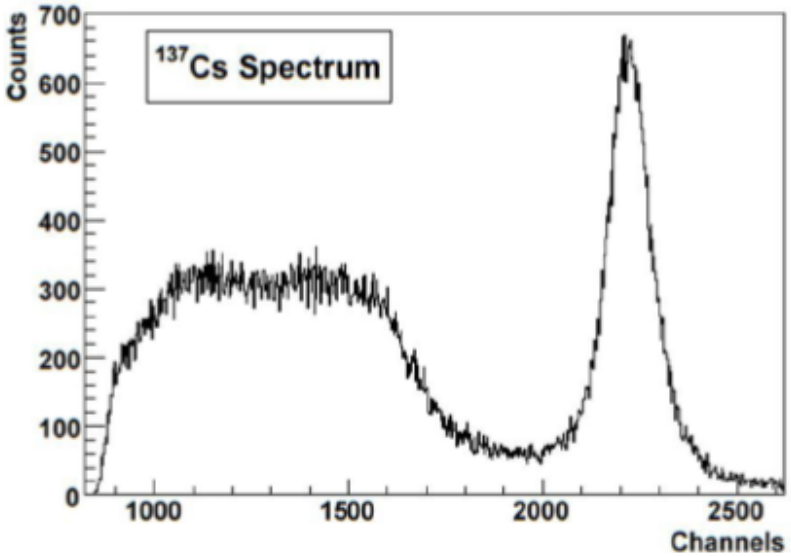


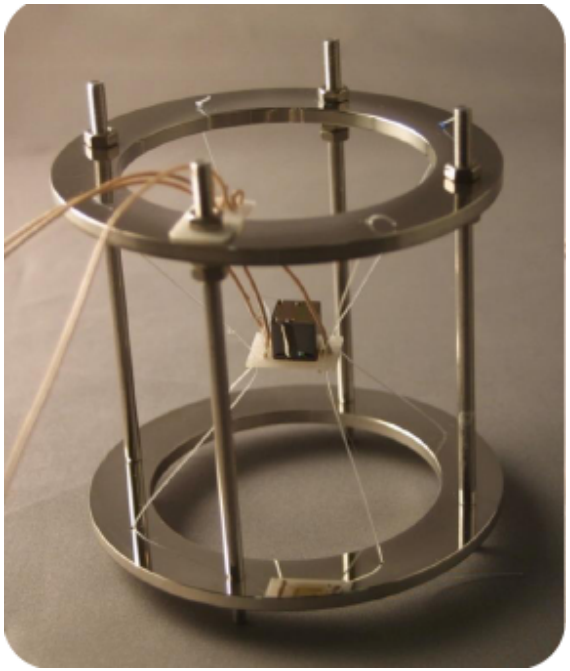
Factor of 1000 reduction with respect to unshielded

Bare crystals in LScintillator II



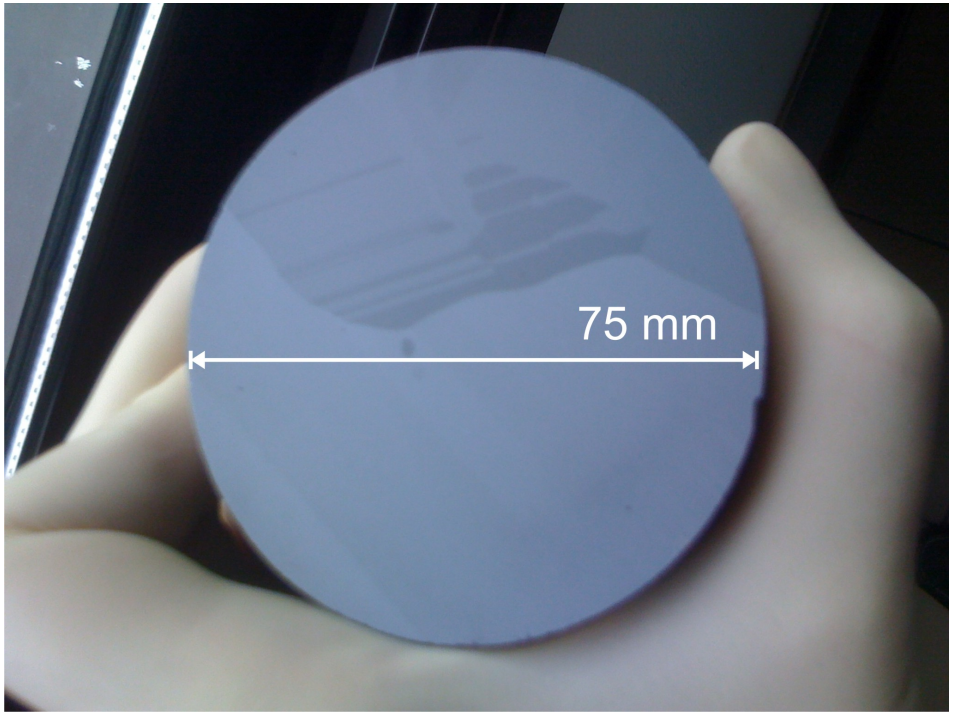


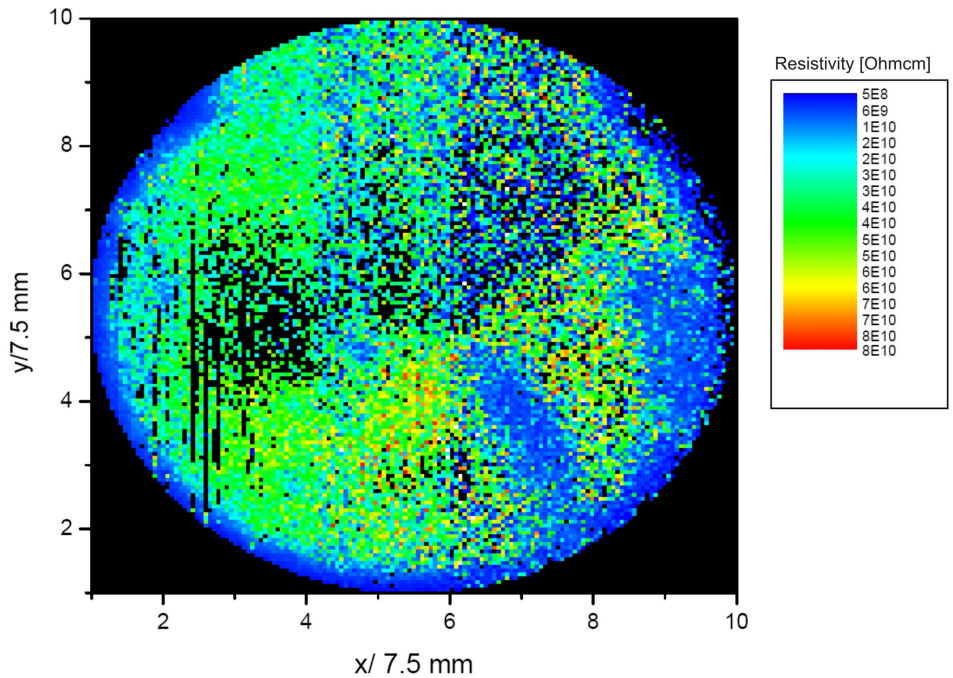




Crystal growing

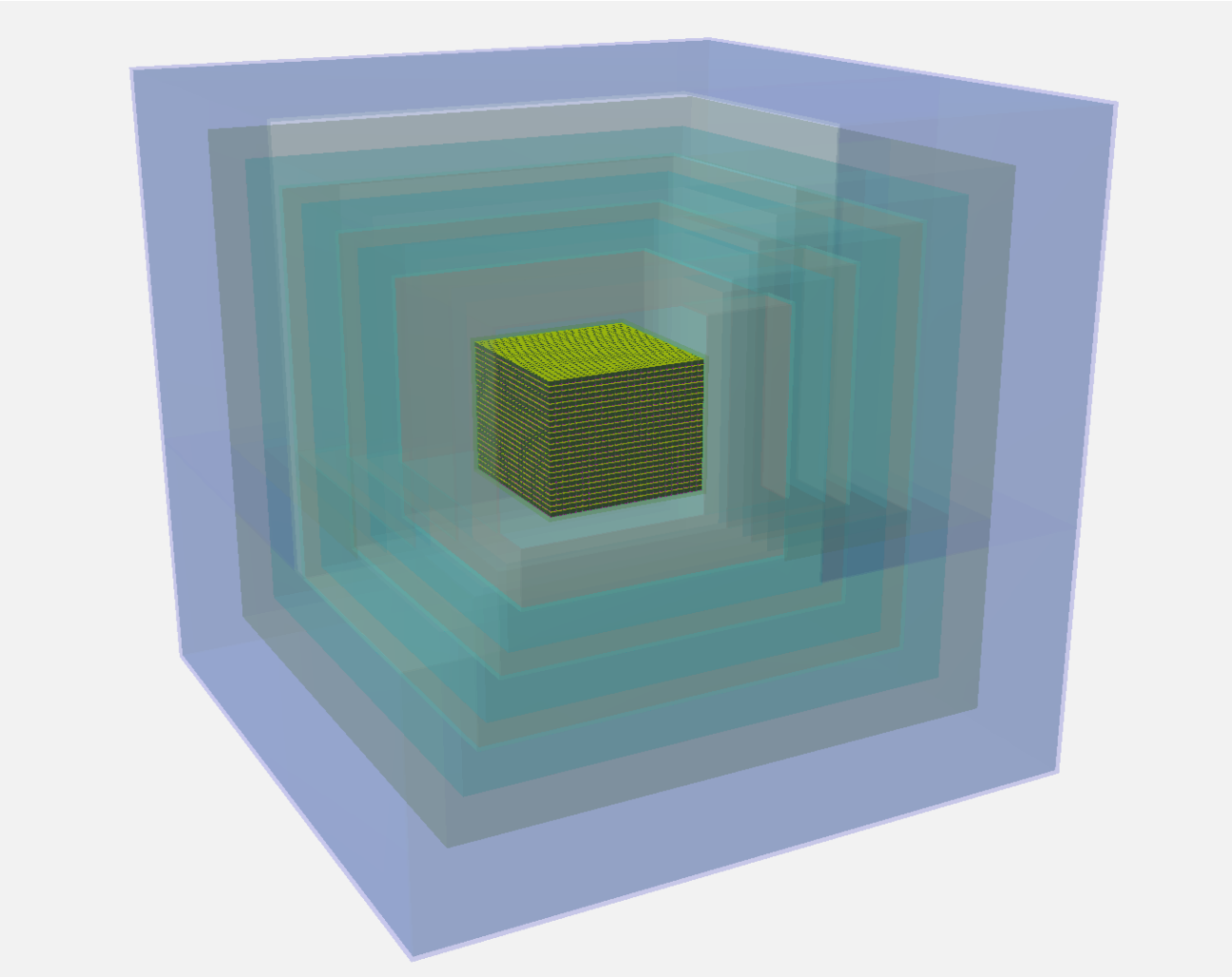
Crystal growing done within the collaboration





Preparation for growing enriched crystal/detector

King Cobra



Measurement of 50 meV neutrino mass would require about 420 kg of CZT, isotopically enriched in Cd-116

Shielding must be able to reduce background to less than 10^{-3} events /kg/ keV/yr

Plan is to have TDR by end of 2012

Conclusion

- **COBRA is a promising next generation experiment to explore double beta decay of Cd-116. First scientific results have been obtained , major upgrades planned in the next year**

- **Unique option would be the semiconductor tracker (solid-state TPC) in form of a pixel CZT, first measurements are very promising**

- **The plan is to have a proposal for the large scale experiment ready by end of 2012**

Solar neutrinos, reactor neutrinos, geoneutrinos, supernova neutrinos, double beta decay