The COBRA Double Beta Decay Experiment

Jaime Dawson

University of Sussex

COBRA - People

D. Dobos, C. Gößling, H. Kiel, D. Münstermann, S. Oehl, T. Villett
University of Dortmund

J. Dawson, C. Reeve, J. Wilson, K. Zuber
University of Sussex

P.F. Harrison, B. Morgan, Y. Ramachers, D. Stewart
University of Warwick

A. Boston, P. Nolan, S. Rigby
University of Liverpool

P. Seller
Rutherford Appleton Laboratory

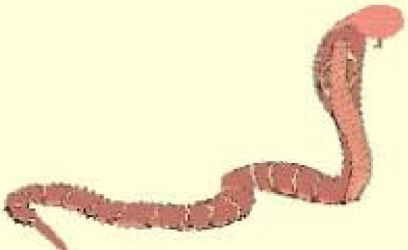
B. Fulton, A. Smith, R. Wadsworth
University of York

T. Bloxham, M. Freer
University of Birmingham

M. Junker
Laboratori Nazionali del Gran Sasso

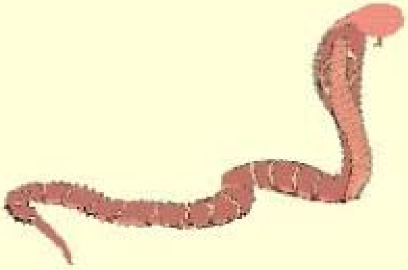
F. Simkovic
University of Bratislava

H. Krawczynski, I. Jung
Washington University in St. Louis



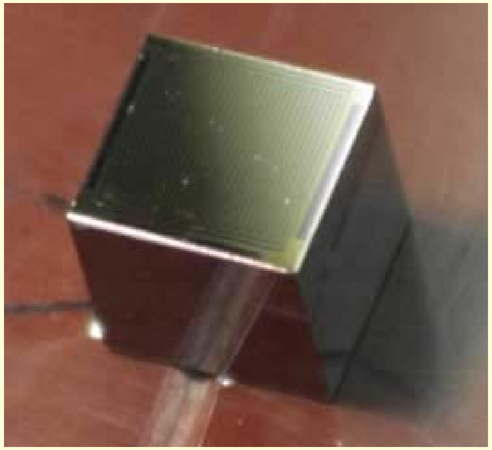
Contents

- What is COBRA?
- Backgrounds
- Current Status (R&D Phase)
- Future plans

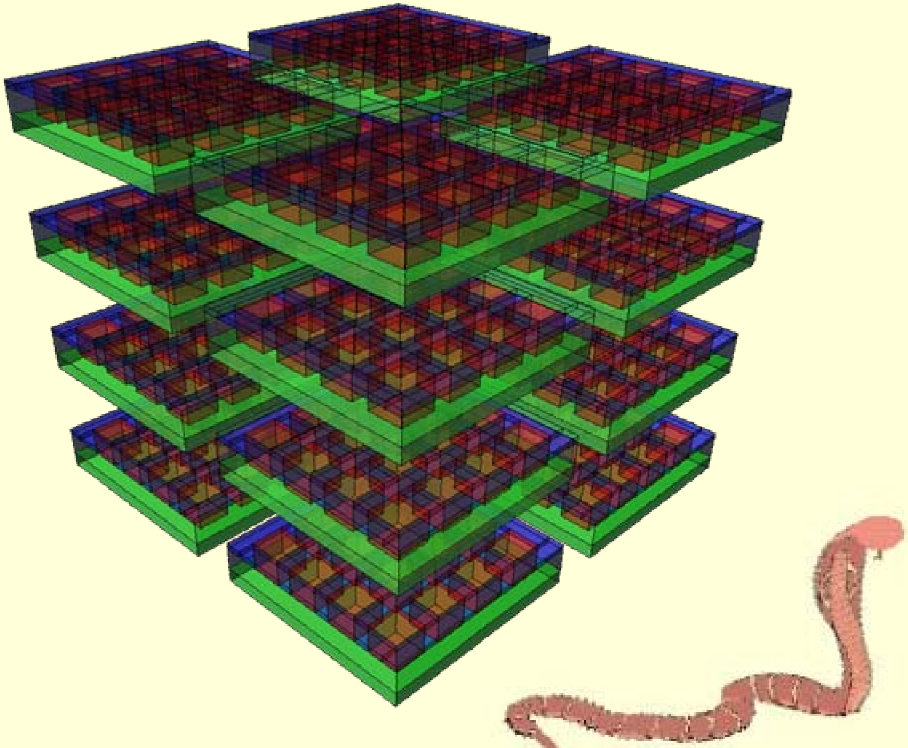


Cadmium-Telluride **O**-neutrino double-**B**eta **R**esearch **A**pparatus

A large array of CdZnTe (CZT) Semiconductor Detectors



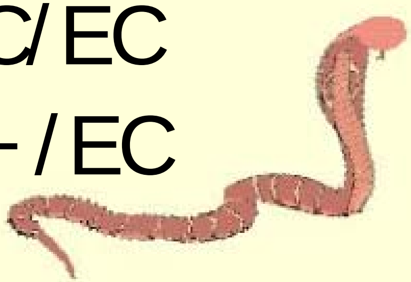
1cm^3 CdZnTe Crystal



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

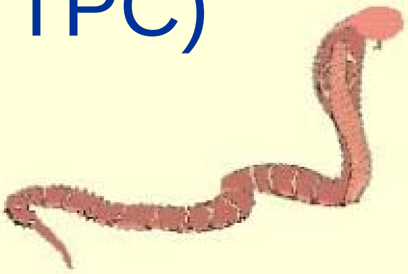
Isotopes

	nat. ab. (%)	Q (keV)	Decay mode
Zn70	0.62	1001	ß-ß-
Cd114	28.7	534	ß-ß-
Cd116	7.5	2805	ß-ß-
Te128	31.7	868	ß-ß-
Te130	33.8	2529	ß-ß-
Zn64	48.6	1096	ß+/EC
Cd106	1.21	2771	ß+ß+
Cd108	0.9	231	EC/EC
Te120	0.1	1722	ß+/EC



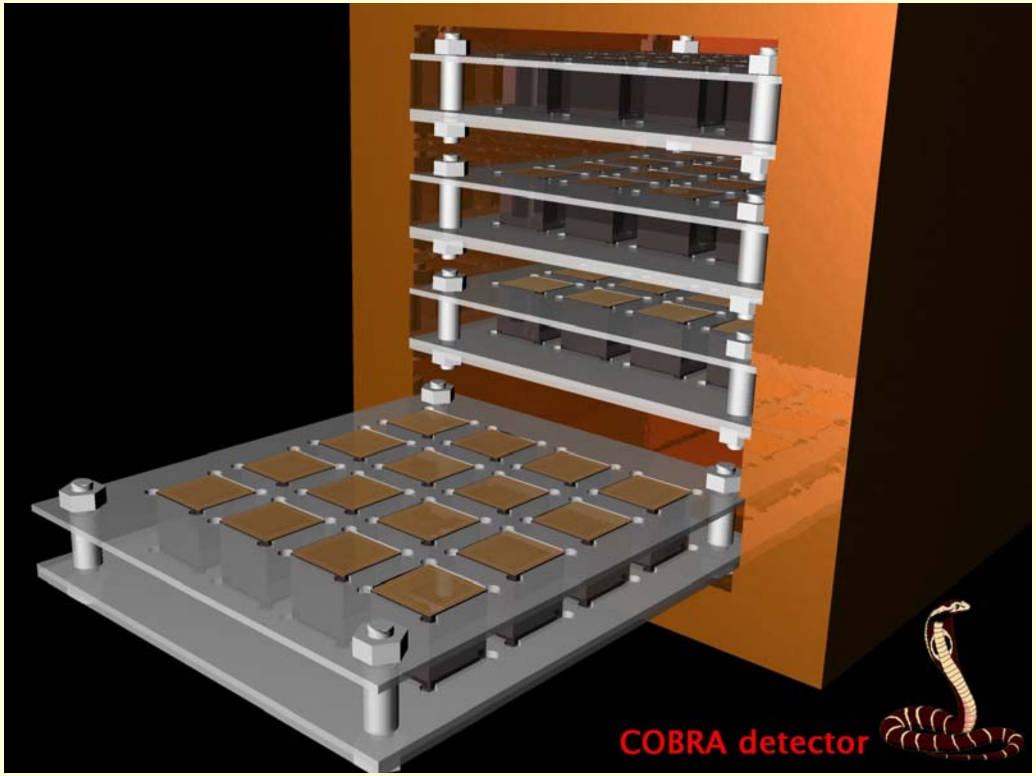
Advantages

- Semiconductor (Good energy resolution, clean)
- Source = Detector
- Room temperature operation
- Modular Design (coincidences)
- Two isotopes at once
- Industrial development of CZT
- ^{116}Cd above 2.614 MeV
- Possibility of Tracking (solid-state TPC)



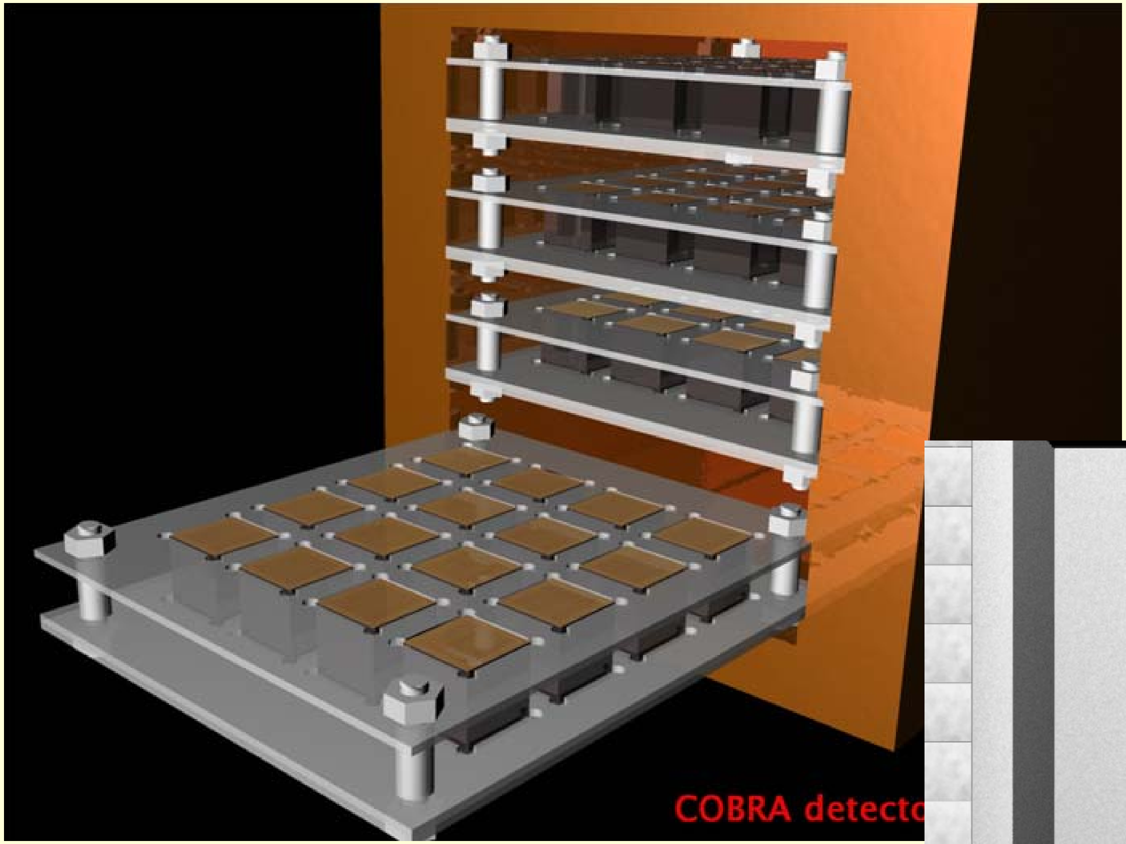
Backgrounds

- High energy Gammas
- Muons
- Alphas and Betas
- Cosmogenics
- Neutrons
- $2\nu\beta\beta$



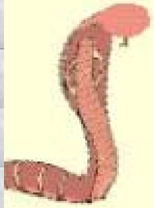
The 64 detector array

Scalable modular design, fine granularity to explore coincidences
Currently only 1 layer installed

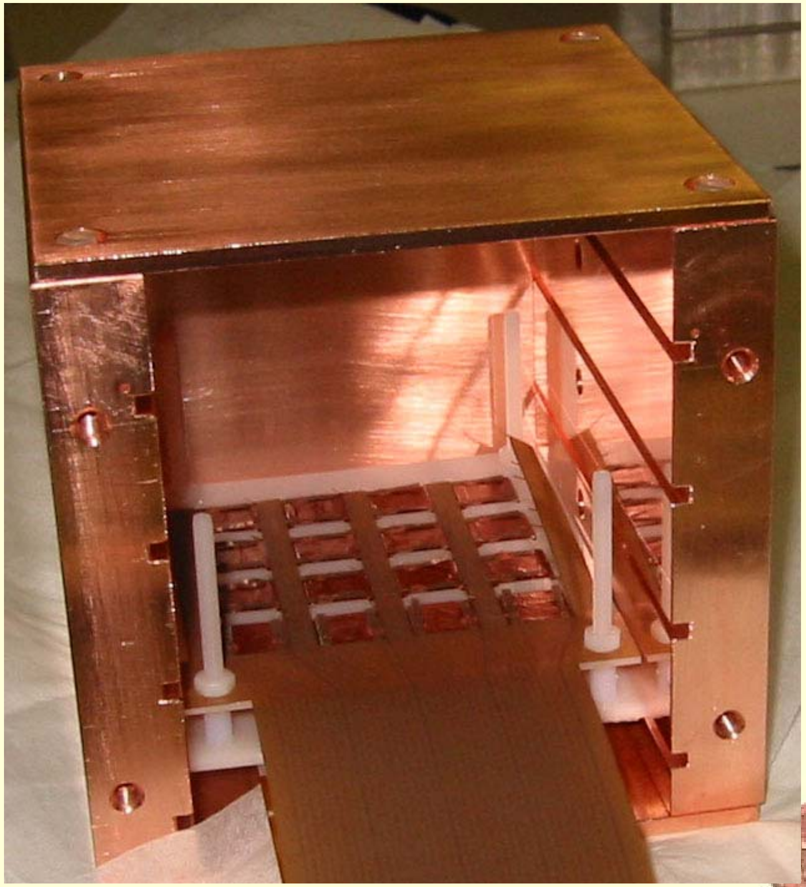


- 0.4 kg CdZnTe
- Nitrogen flushing

Physics
- Access to 2ν2EC
- Precision measurement of ^{113}Cd
- New limits



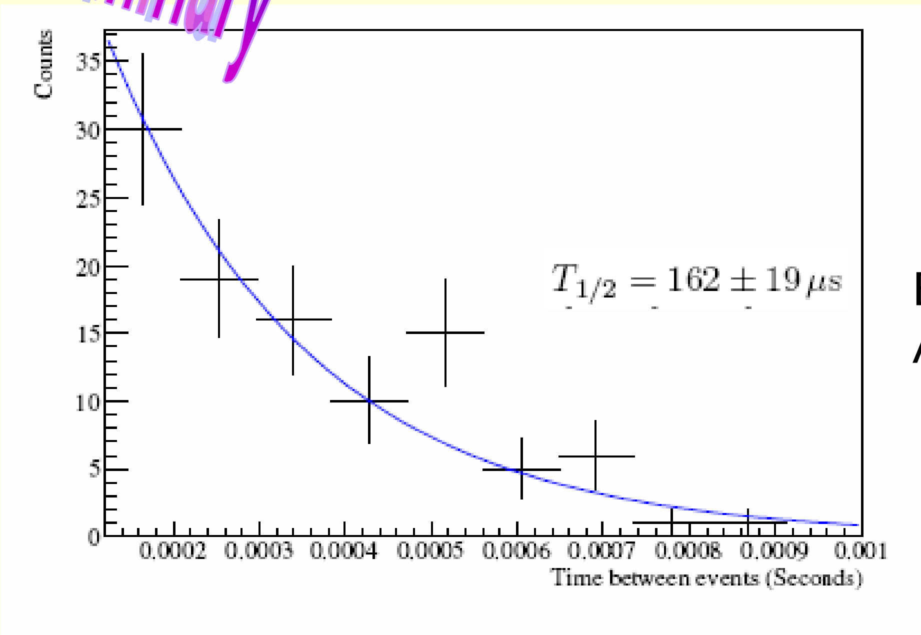
The first layer



Installed at LNGS about three months ago

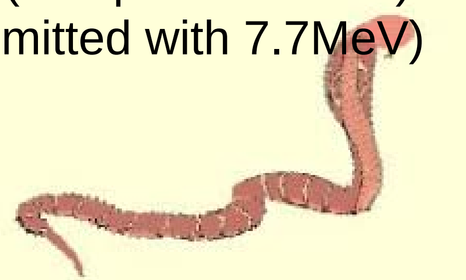
1. Upper limits on activity of ^{214}Bi in crystal material: 5 events in 81.7 days giving activity of < 0.26mBq.kg^{-1} (better than <51mBq.kg^{-1} obtained from LNGS counting facility)
2. Relax alpha energy cut (320 – 8000keV) to give greater sensitivity to events from passivation coating. See 108 event-pairs

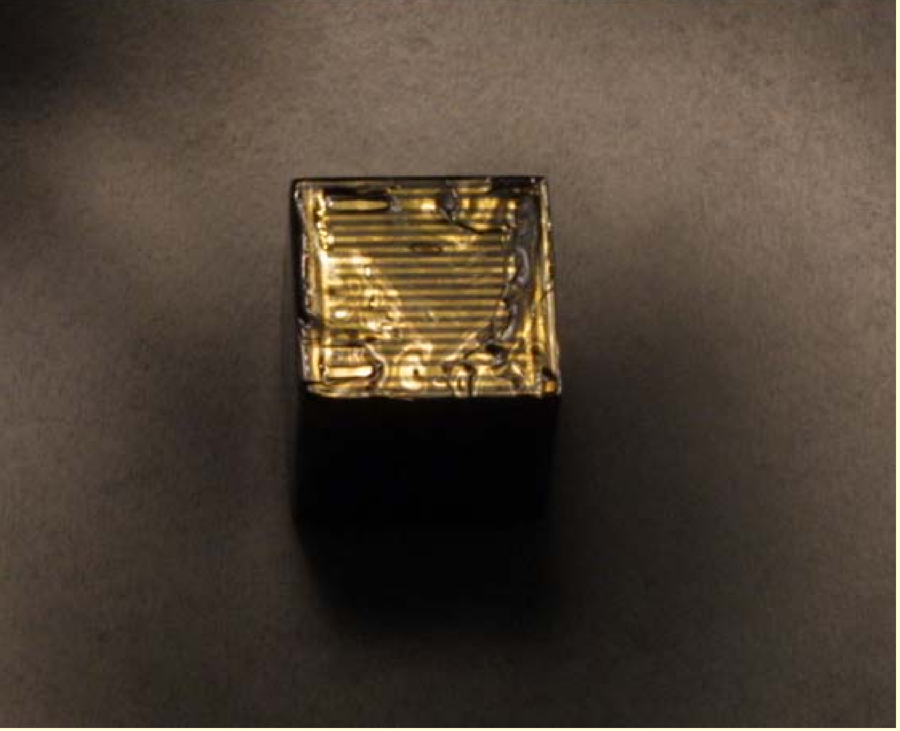
Preliminary



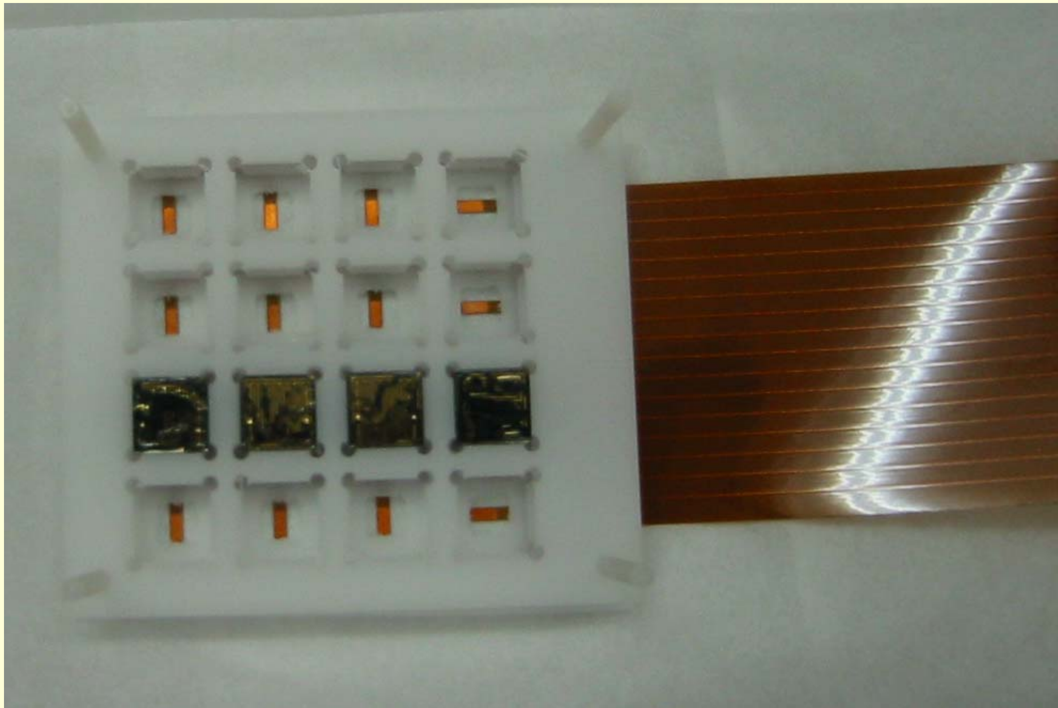
$$^{214}_{83}\mathrm{Bi} \xrightarrow{\beta} {}^{214}_{84}\mathrm{Po} \xrightarrow{\alpha} {}^{210}_{82}\mathrm{Pb}$$

Beta cut 320-3500 keV (end point 3.3MeV)
Alpha cut 7000-8000 (emitted with 7.7MeV)

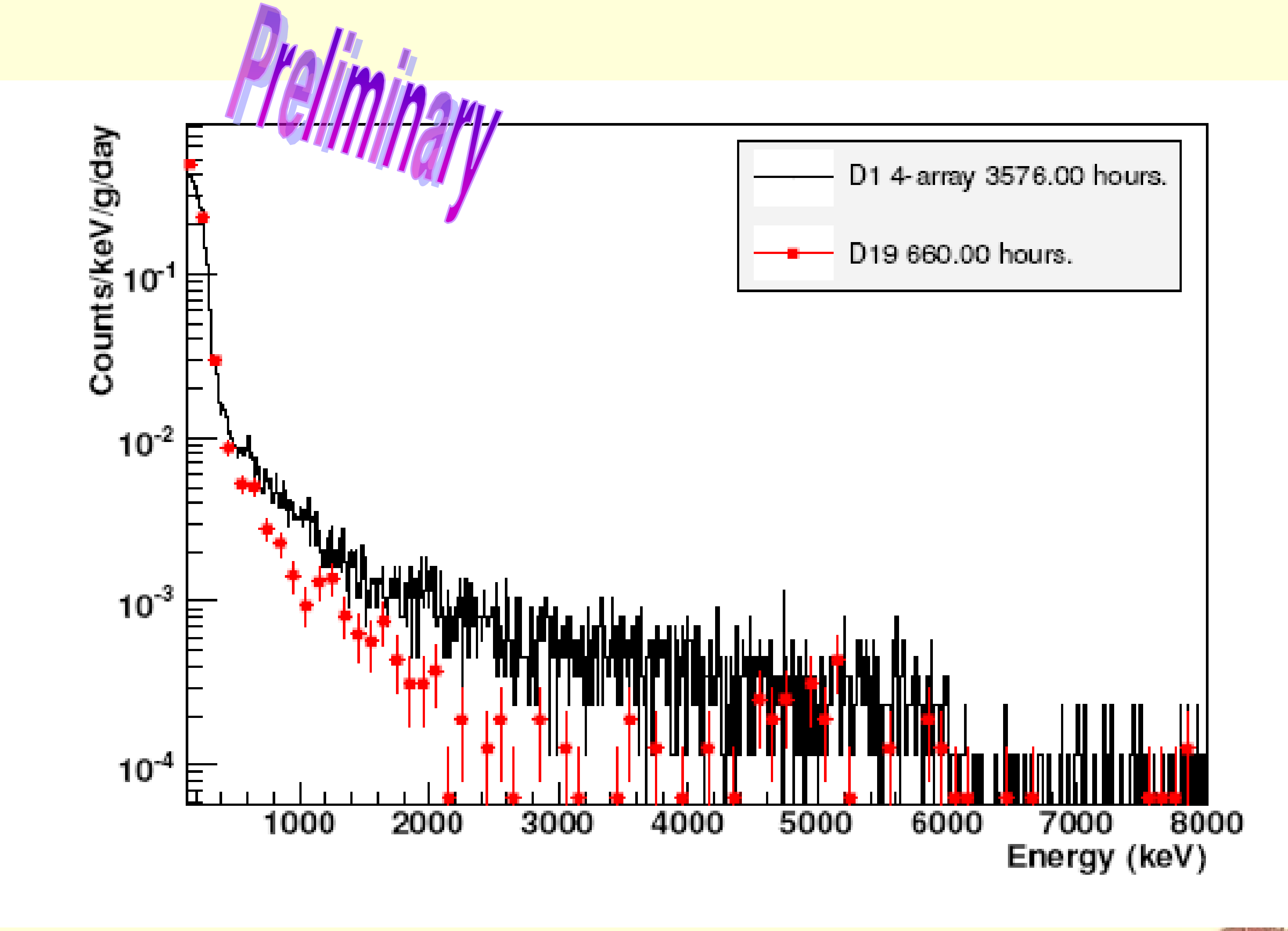


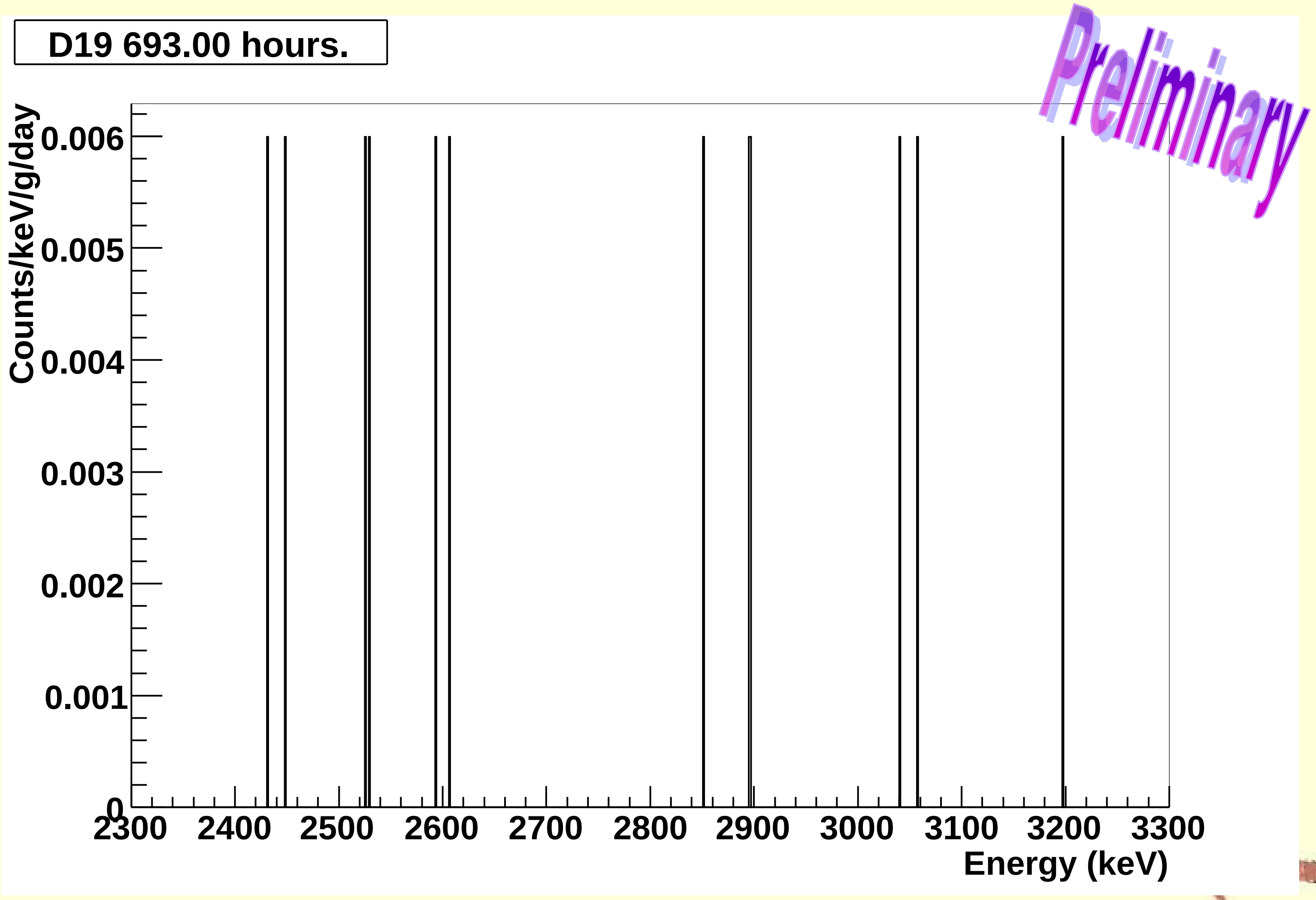


New Passivation Coating



Improved Background





D19 693.00 hours.
Preliminary
Counts/keV/g/day
0.006
0.005
0.004
0.003
0.002
0.001
0
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
Energy (keV)

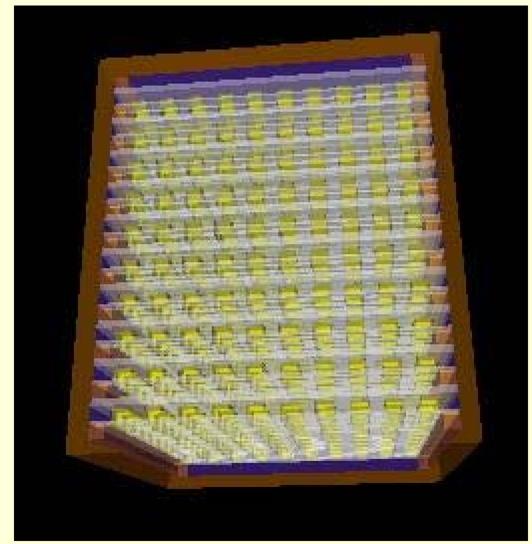
The 64k Array Feasibility Study

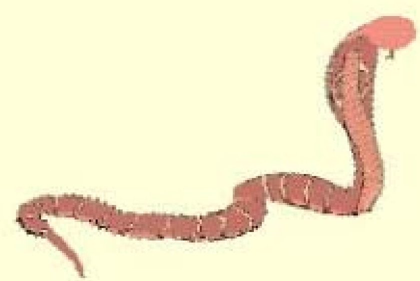
Extensive GEANT 4 simulations to specify

- Acceptable contamination levels including cosmogenics

Material	Mass (kg)	Background Contributions
CdZnTe volume	417.92	natural radioactivity ^{238}U, ^{232}Th, ^{40}K, ^{137}Cs, ^{210}Po
CdZnTe volume	417.92	cosmogenic backgrounds ^{124}Sb, ^{126}Sb, ^{110m}Ag, ^{88}Y, ^{56}Co, ^{58}Co, ^{60}Co, ^{114m}In, ^{105}Ag, ^{99}Rh, ^{88}Zr, ^{102m}Rh
CdZnTe volume	417.92	$2\nu\beta\beta$ of ^{116}Cd
Delrin volume	62.69	natural radioactivity ^{238}U, ^{232}Th, ^{40}K, ^{137}Cs
Air/Gas volume	0.49	^{222}Rn

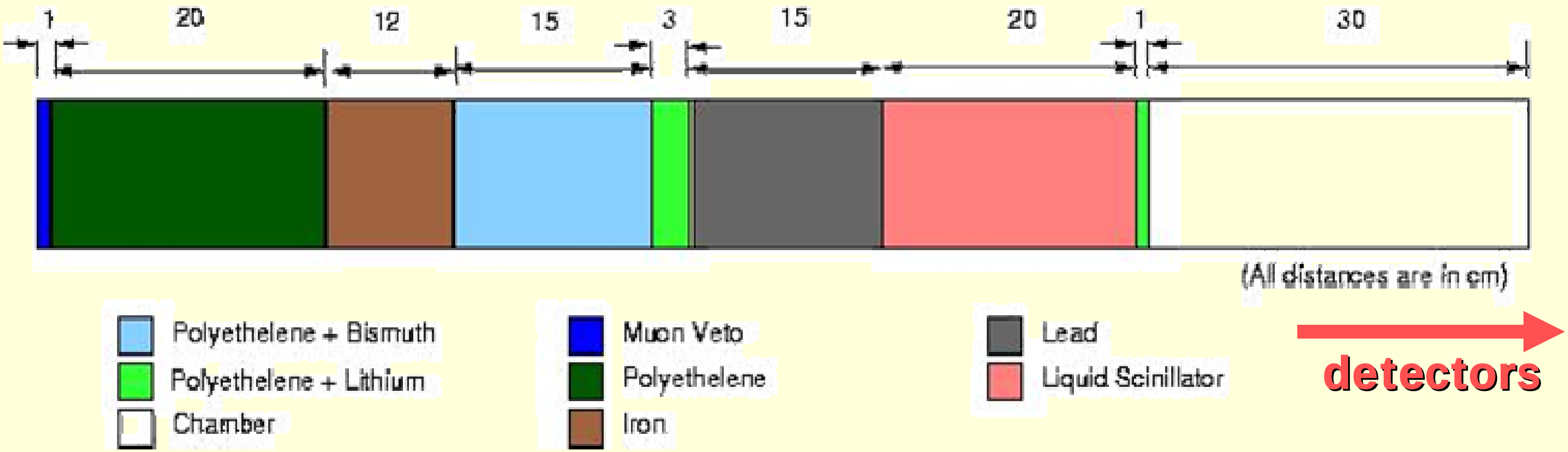
Material	Area (m^2)	Background Contributions
CdZnTe surface	41.65	^{210}Pb
Chamber surface	3.77	^{210}Pb





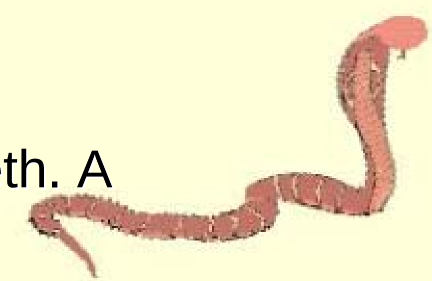
Shielding and Veto

- Simulated LNGS neutron flux
- ~3x10^{-7} counts/year/kg/keV in the crystals.
- <1 neutron per year! (in 64000 detectors)

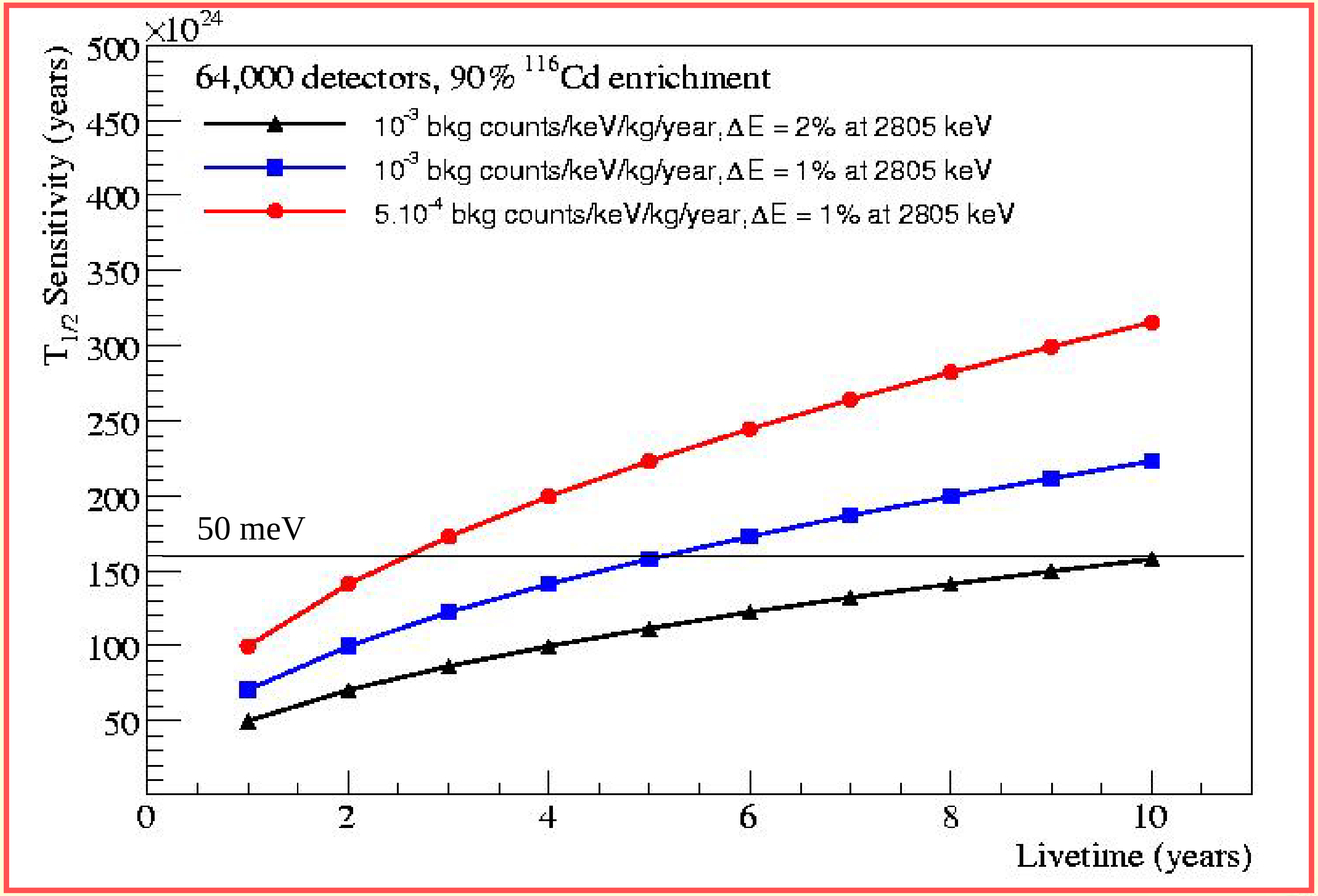


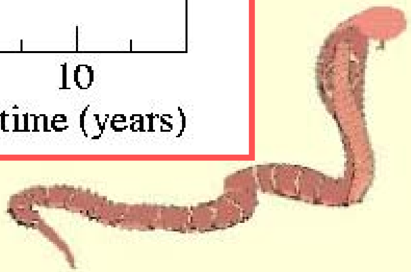
Mass = 64964 kg

D. Stewart et al., submitted to Nucl. Inst. Meth. A



Sensitivity

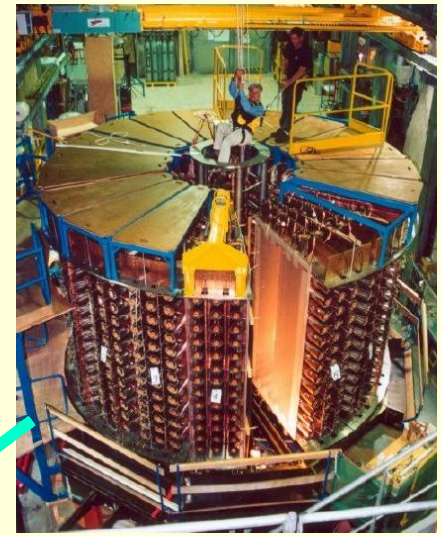




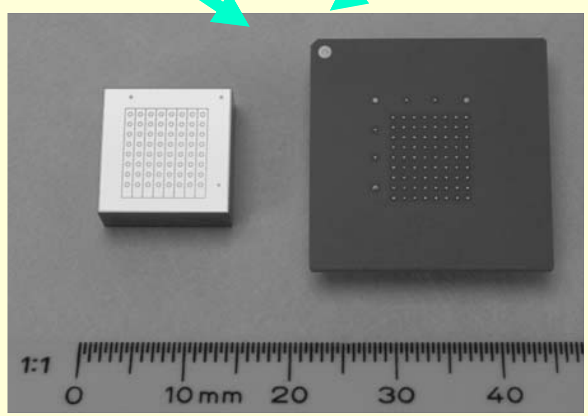
The solid state TPC

Energy resolution

Tracking



- Massive background reduction
- Positive signal information

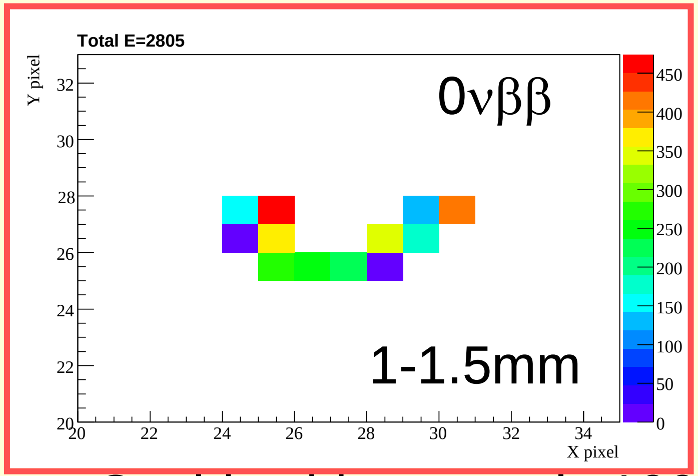


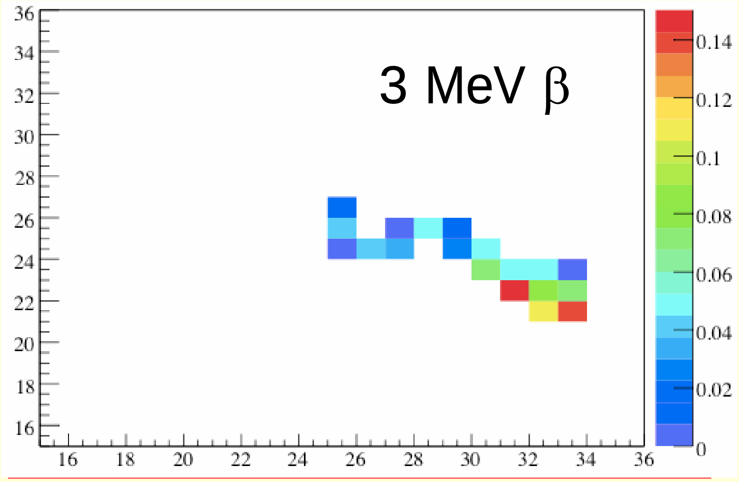
Pixellated CdZnTe detectors

Pixellisation - I

- Massive BG reduction by particle ID , 200μm pixels (example simulations):

α= 1 pixel, β and ββ= several connected pixel, γ= some disconnected p.



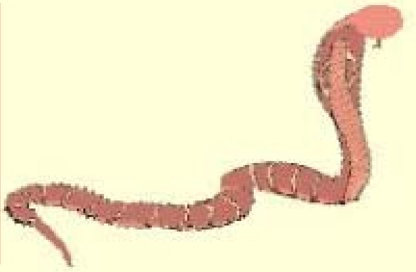


- eg. Could achieve nearly 100% identification of ^{214}Bi events (^{214}Bi → ^{214}Po → ^{210}Pb)

.

Beta with endpoint 3.3MeV

7.7MeV α life-time = 164.3μs

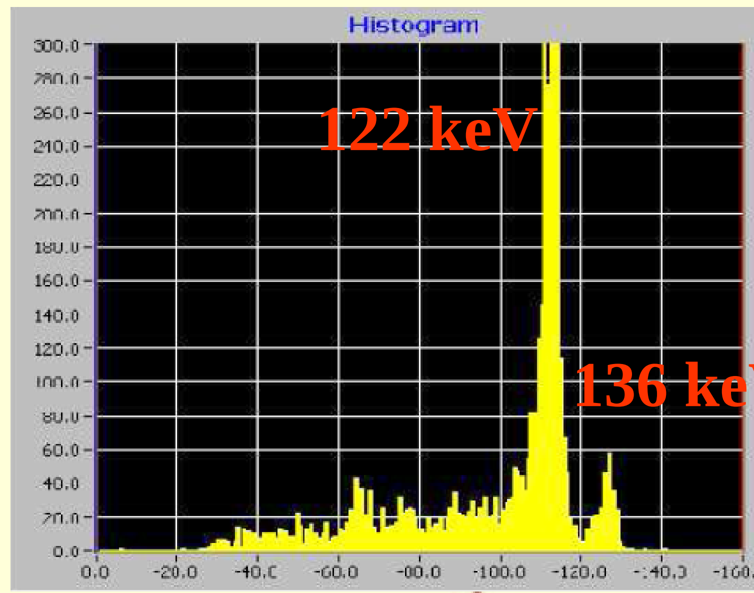


Pixellisation - II

Tests of 16×16 1.6mm pixel detectors

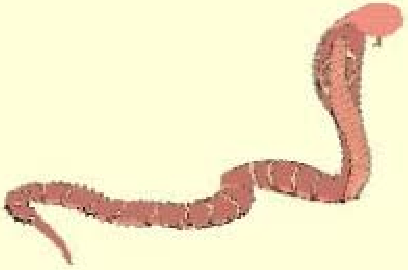
crystal

ASIC readout

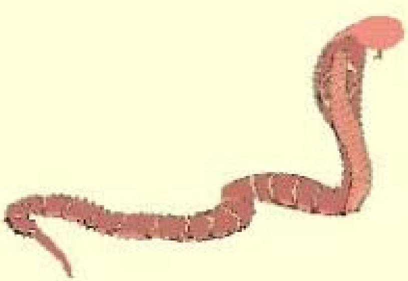


Summary

- COBRA plans to use a large amount of CdZnTe semiconductors for double beta searches
- Collaboration of about 25 people established
- Currently preparing a 64 detector array (about 0.5 kg), installation at LNGS started spring 2006
- Design changed to allow easy upgrade to larger scales
- Exploring pixellated detectors for background reduction.



Join the Party!



Published Results

- Existing limits from CZT under rough background conditions (532gd):

Kiel et al, Nuclear Physics A 723 499 (2003) [nucl-ex/0301007]

$0\nu\beta\beta$ ^{64}Zn $T_{1/2}>1.3*10^{16}$y

$0\nu\beta$+EC ^{120}Te $T_{1/2}>2.2*10^{16}$y

2νECEC ^{120}Te $T_{1/2}>9.4*10^{15}$y

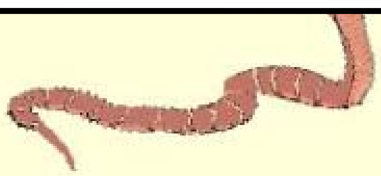
2νECEC limits for ^{106}Cd, ^{108}Cd, ^{64}Zn

Muenstermann & Zuber [nucl-ex/0204006]

2^{nd} forbidden EC of ^{123}Te $T_{1/2}> 3.2*10^{16}$y

Preliminary

	Half Life $T_{1/2}$ (years)		
Isotope	COBRA	CZT 2003*	World Best
^{70}Zn	> 2.8 . 10^{17}	> 1.3 . 10^{16}	> 0.7 . 10^{18}
^{128}Te	> 4.6 . 10^{19}	> 8.8 . 10^{18}	> 1.1 . 10^{23}
^{130}Te	> 8.1 . 10^{19}	> 3.3 . 10^{19}	> 1.8 . 10^{24}
^{114}Cd	> 4.8 . 10^{19}	> 6.4 . 10^{18}	> 2.5 . 10^{20}
^{116}Cd	> 1.0 . 10^{19}	> 8.0 . 10^{18}	> 1.7 . 10^{23}



*Kiel et al, Nuclear Physics A 723 499 (2003) [nucl-ex/0301007]

Preliminary

	Half Life $T_{1/2}$ (years)		
Isotope	COBRA	CZT 2003*	World Best
^{106}Cd $0\nu\beta^+\beta^+$	> 7.0 . 10^{17}	> 1.5 . 10^{17}	> 2.2 . 10^{19}
^{106}Cd $0\nu\beta^+$EC	> 1.6 . 10^{18}	> 3.8 . 10^{17}	> 3.7 . 10^{20}
^{120}Te $0\nu\beta^+$EC	> 9.3 . 10^{16}	> 2.2 . 10^{16}	> 2.2 . 10^{16} *
^{64}Zn $0\nu\beta^+$EC	> 2.6 . 10^{17}	> 2.8 . 10^{16}	> 2.3 . 10^{18} (68%)

*Kiel et al, Nuclear Physics A 723 499 (2003) [nucl-ex/0301007]

Natural Thorium Spectrum