The COBRA Experiment

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On behalf of the COBRA Collaboration

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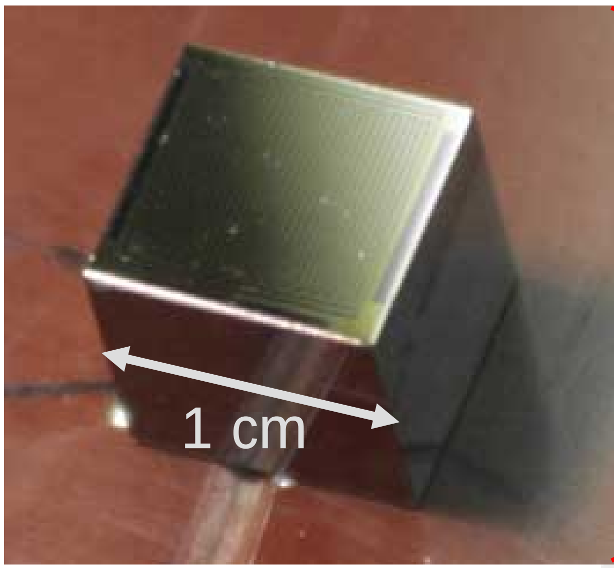
Contents

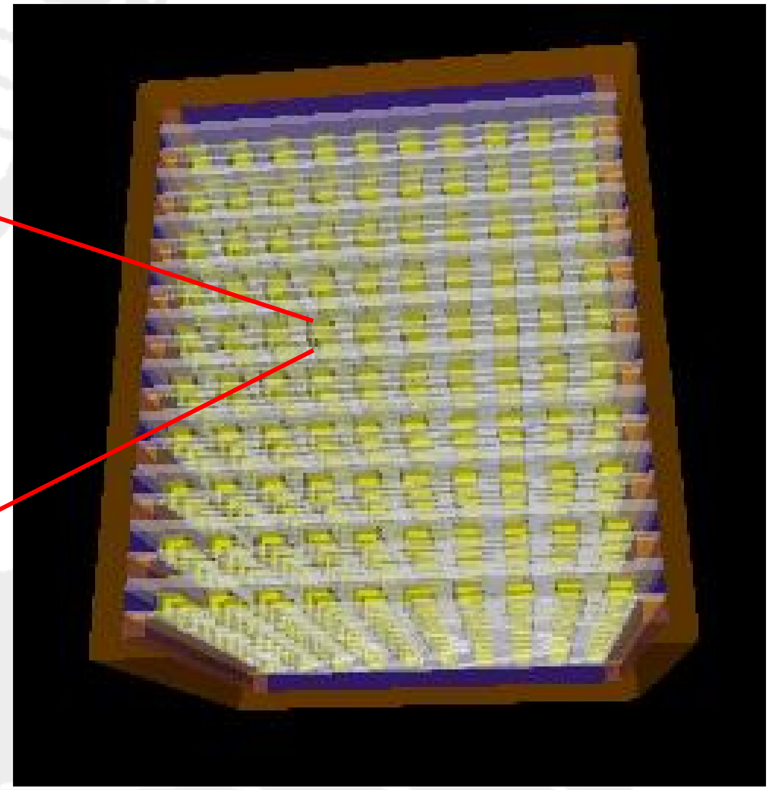
- ★ Concept
- ★ Experimental requirements
  - Energy Resolution
  - Backgrounds
- ★ Experimental status
- ★ Background reduction
  - Coincidences
  - Shielding
  - Pixellisation

COBRA – the Concept

Cadmium **T**elluride **0**-neutrino **B**eta Decay **R**esearch **A**pparatus

★ Build up a large array of CdZnTe semiconductor detectors





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

$0\nu\beta\beta$ Candidate Isotopes

★ CdZnTe contains 9 $\beta\beta$ Isotopes

^{116}Cd, ^{130}Te, ^{114}Cd, ^{70}Zn, ^{128}Te ($\beta^-\beta^-$),

^{64}Zn, ^{106}Cd, ^{108}Cd, ^{120}Te ($\beta^+\beta^+$, β^+EC, EC/EC)

★ Main $0\nu\beta\beta$ candidate: ^{116}Cd

- Endpoint = 2805 keV
- Enrichment to 90%
- Favourable $G_{0\nu}|M_{0\nu}|^2 \rightarrow T_{1/2} \sim 10^{26}$ years for 50meV ν

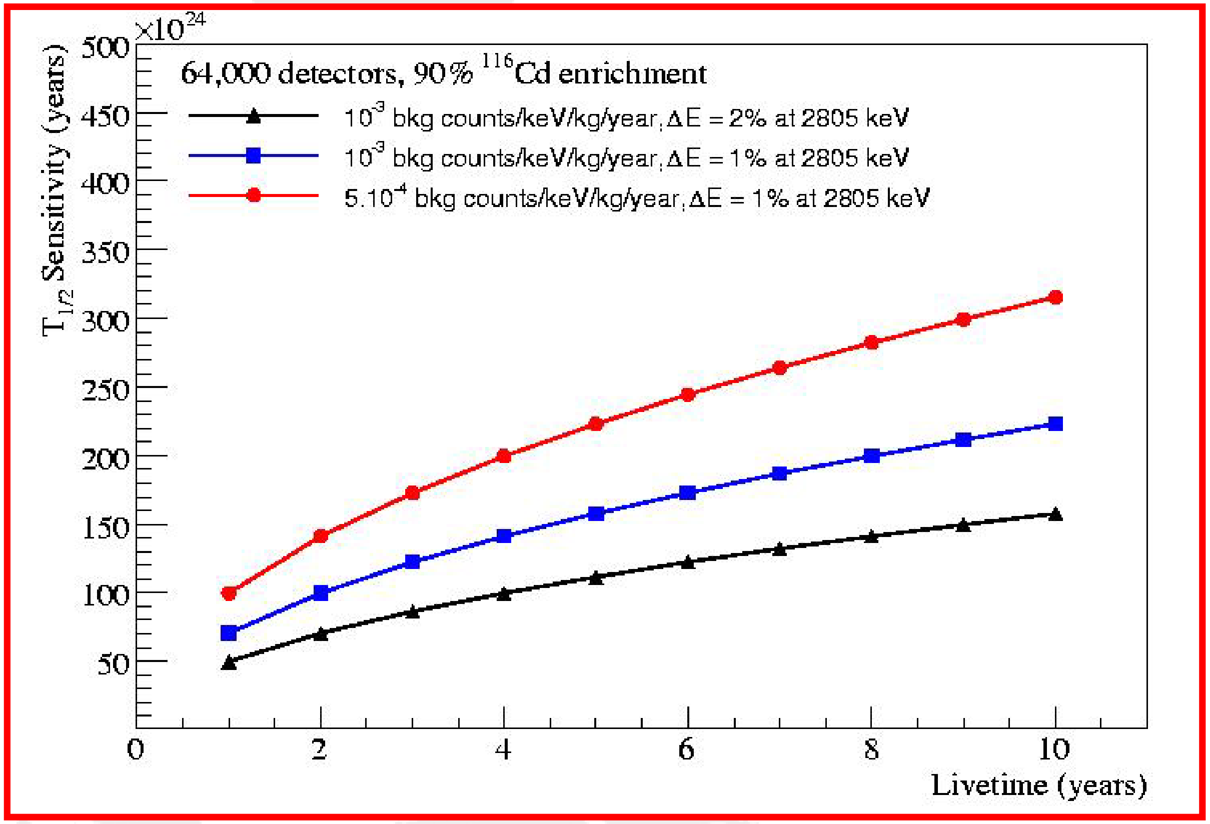
★ Also interesting: ^{106}Cd

- Endpoint = 2771 keV
- EC/EC, β^+/EC and $\beta^+\beta^+$ modes
- β^+/EC - enhanced sensitivity to RH weak currents

M. Hirsch et al., Z. Phys. A 347,151 (1994)

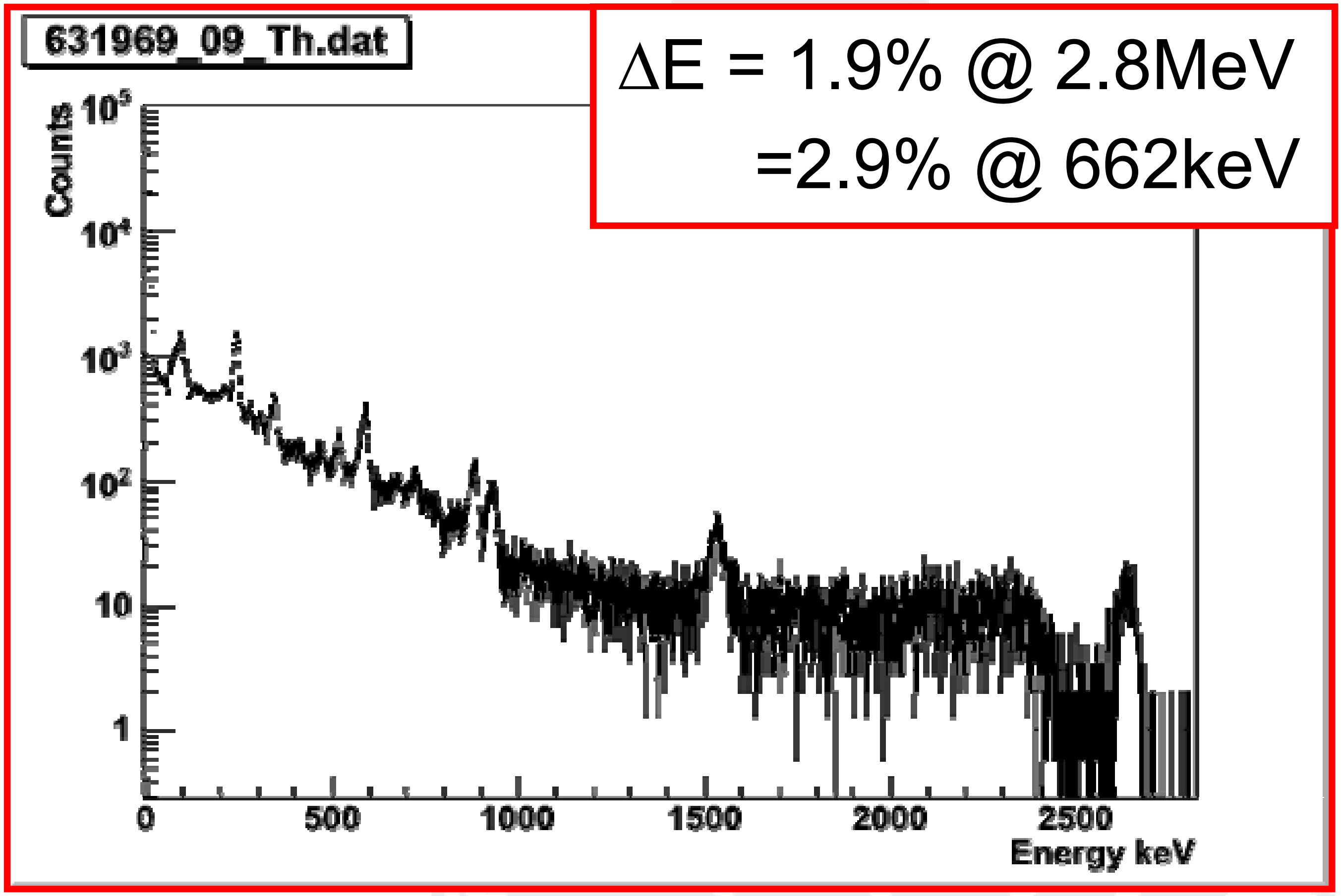
Experimental Requirements

$$T_{1/2}^{0\nu} \propto a\varepsilon\sqrt{\frac{Mt}{\Delta E B}}$$



- ★ 64,000 1cm^3 crystals = 418 kg
- ★ 90% enriched in ^{116}**Cd**
- ★ Backgrounds < 0.001 count keV^{-1}kg^{-1}year^{-1}
- ★ Energy Resolution < 2%

Energy Resolution



★ Only electron signal read out (CPG technology)

★ Possible improvements: cooling, new grids

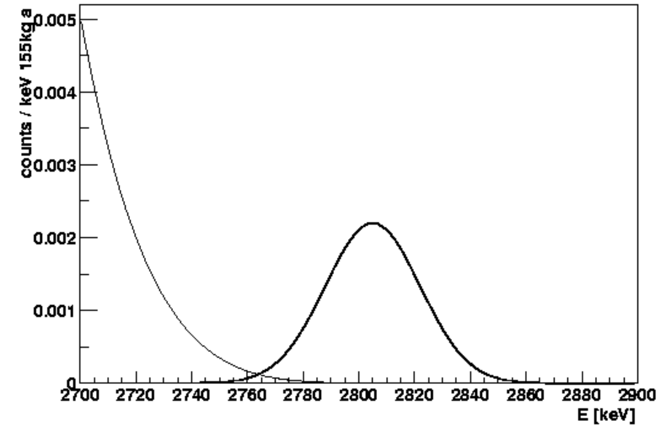
★ Better detectors are available

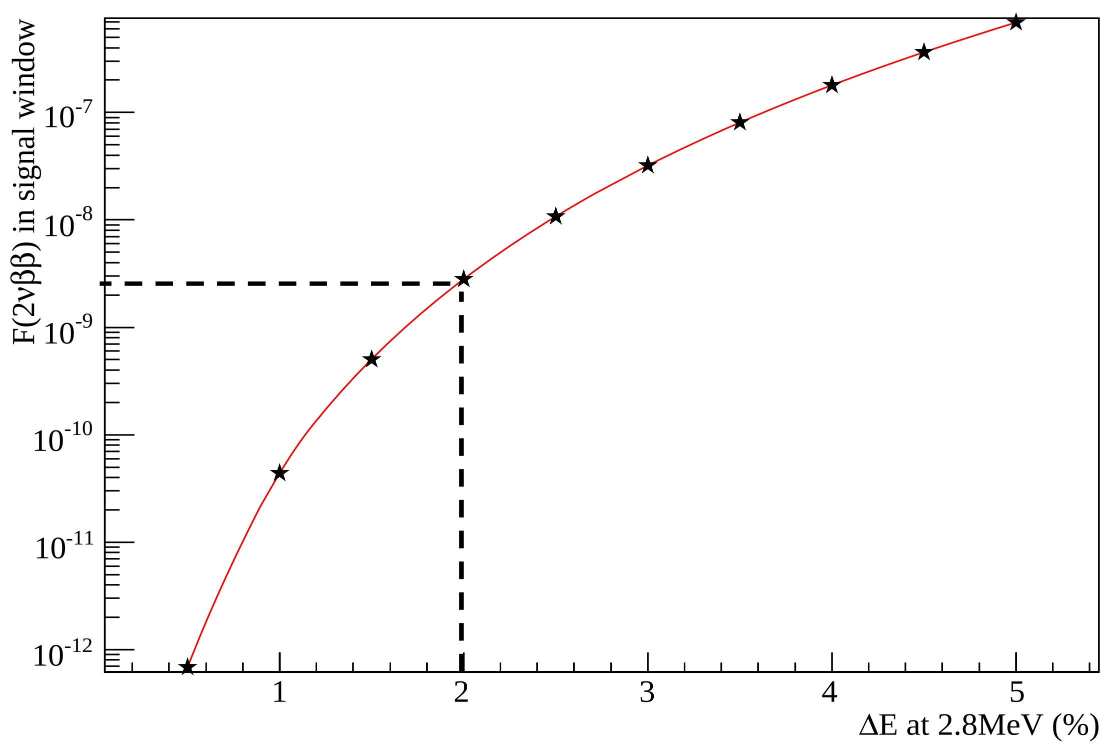
Background Sources - I

★ 2νββ decays

$T_{1/2}(^{116}Cd) = 2.7\times10^{19}$ y

For ΔE = 2%, fraction of 2νββ events in 0νββ window ≈ 3×10^{-9}





$$F = \frac{8Q}{m_e}\left(\frac{\Delta E}{Q}\right)^6$$

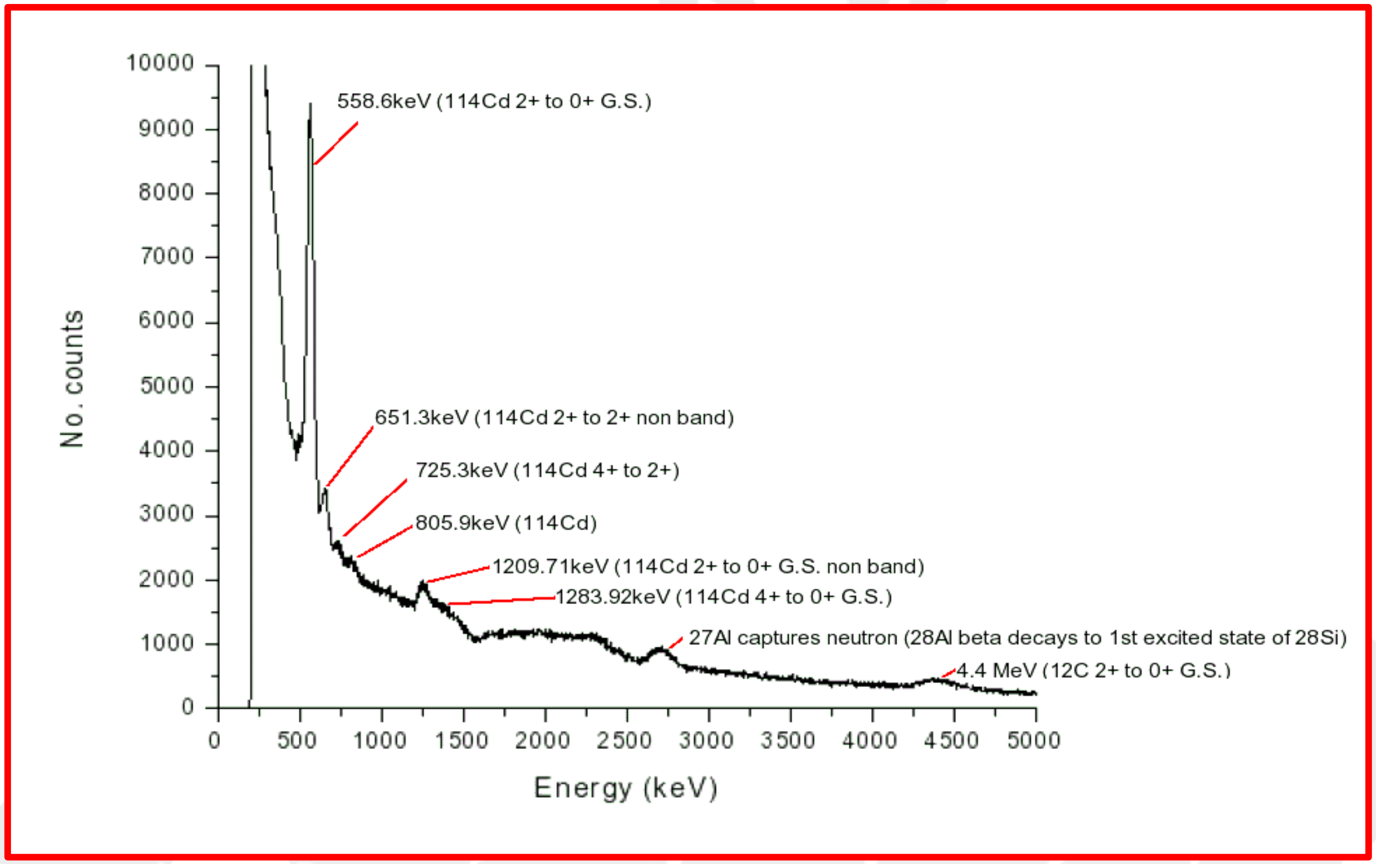
S. Elliott, P. Vogel, Ann. Rev. Nucl. Part. Sci. 2002

Background Sources - II

★ Muons and Neutrons

- ^{113}Cd thermal neutron capture σ = 20,647 barns

Spectrum from activation with 18.5GBq Am/Be source:



★ Detailed MCNP simulations to optimise shielding.

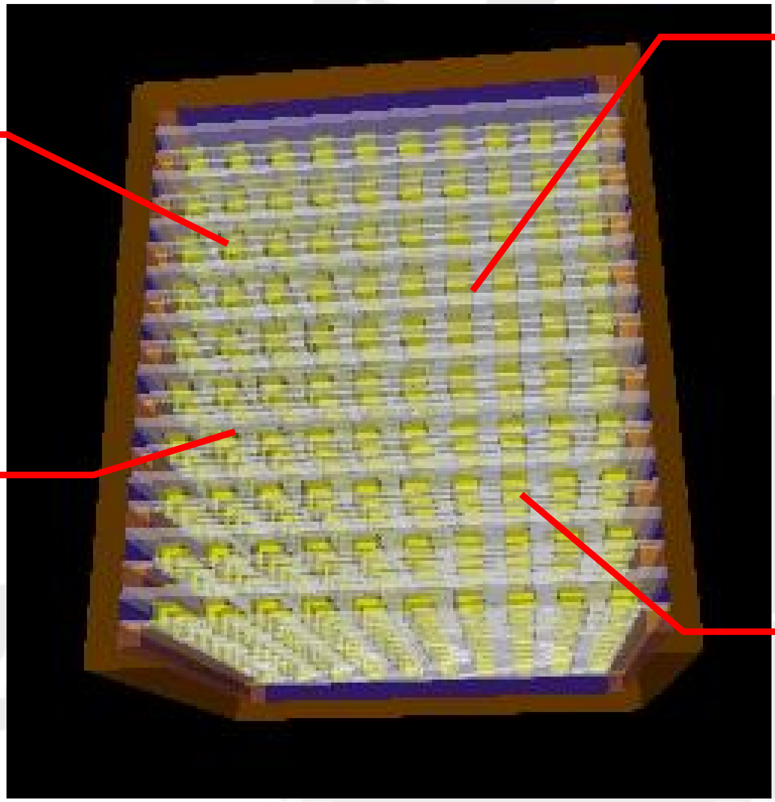
Background Sources - III

★ α, β, γ sources

- Intrinsic and surface contaminants
- Cosmogenics

Gas
^{222}Rn gas

Delrin Holder
^{238}U,^{232}Th decay chain
^{40}K
^{137}Cs



Crystals
^{238}U, ^{232}Th decay chains
^{40}K
^{137}Cs
^{210}Po
^{210}Pb on surface
Cosmogenic isotopes

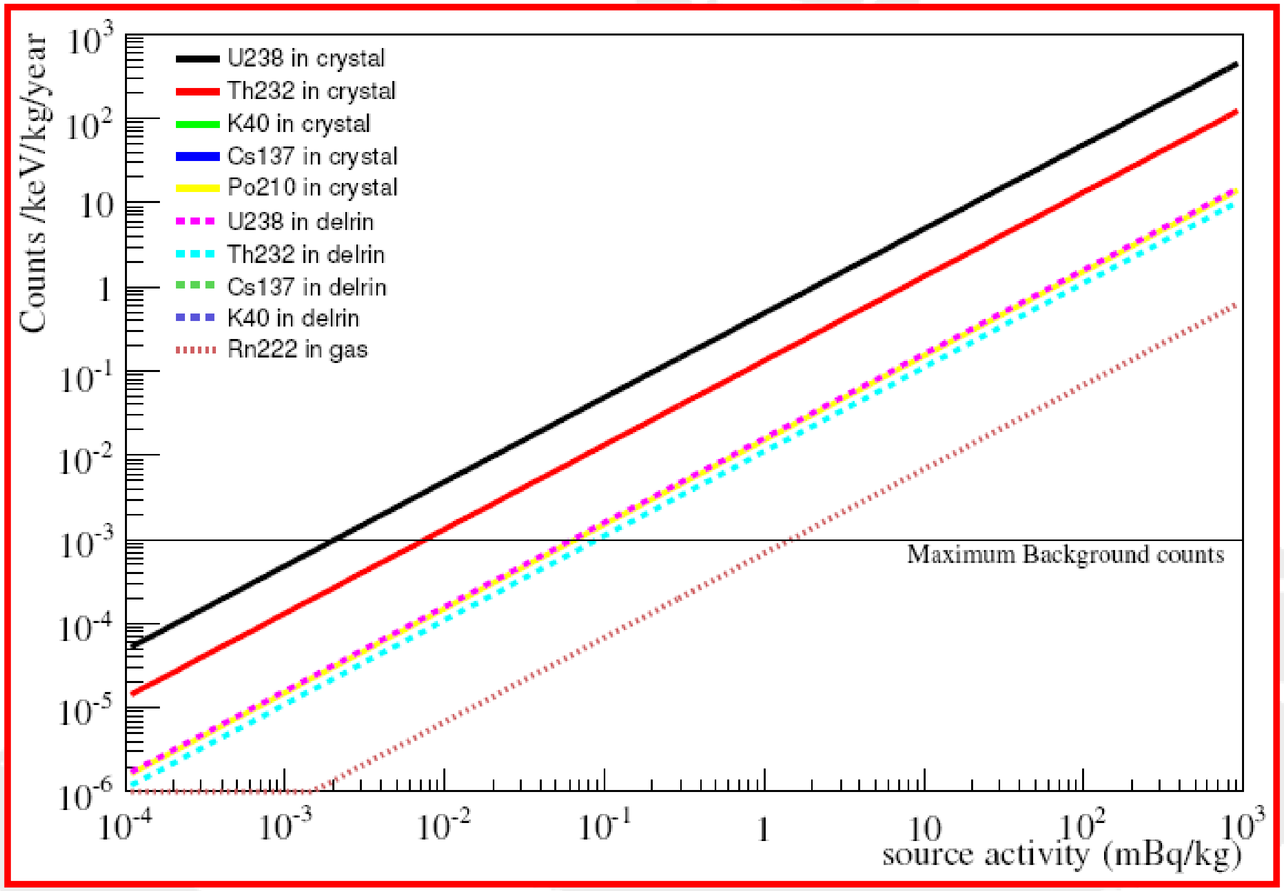
Chamber walls
^{210}Pb on surface

Simulations

★ Determine material requirements through simulation

VENOM – Geant4 based Monte Carlo package

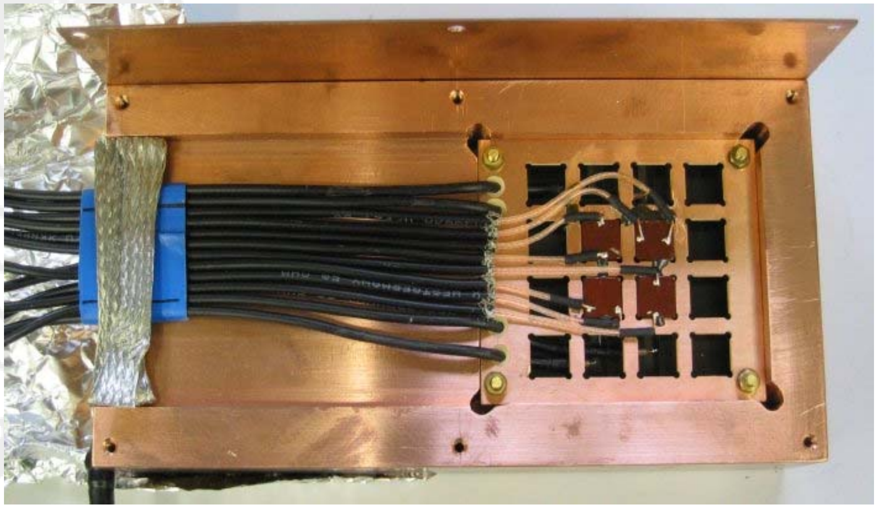
implements the DECAY0 decay generator

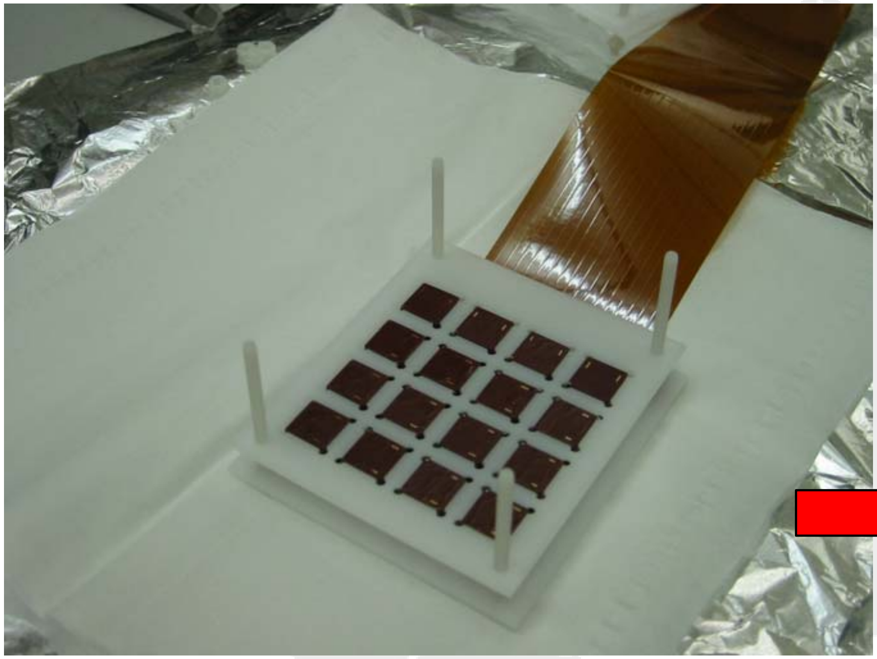


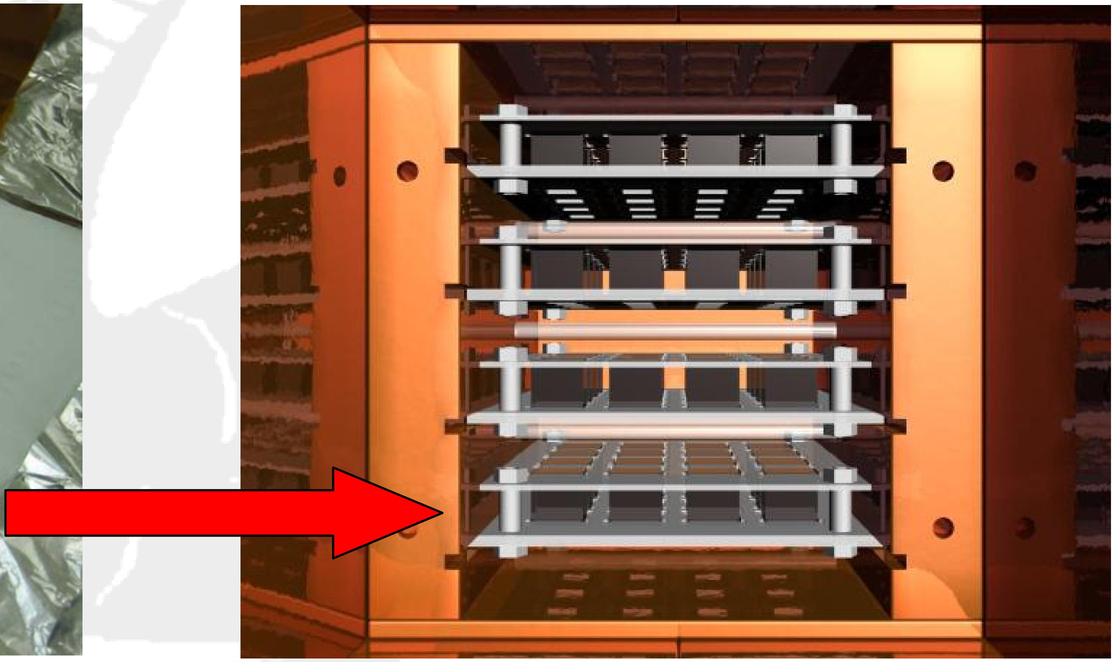
Experimental Status

★ Surface Labs
- Tests of individual crystals

★ LNGS (~3500 mwe)
- 2×2 proto-type
- 4×4×4 array installed



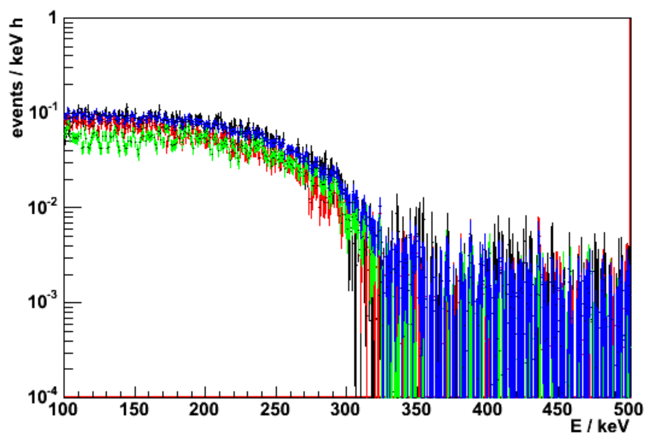




Physics Results

★ 4.34 kg.days of 2×2 proto-type data

★ Measurement of 4-fold forbidden ^{113}Cd β decay

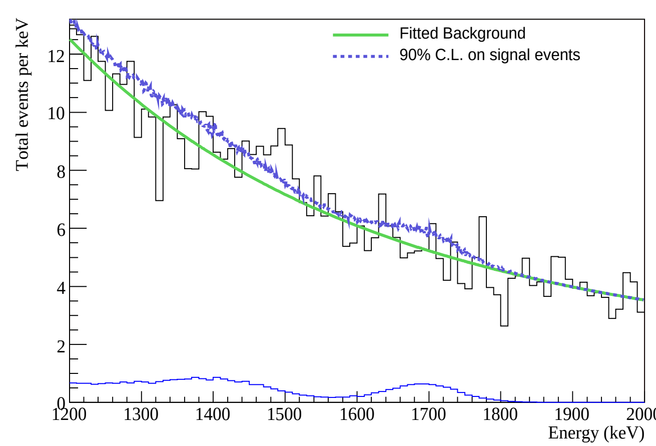


C. Gößling et al. Phys. Rev. C, 2005, 72, 064328

$T_{1/2}$= (8.2 ± 0.2 (stat.) ± 1.0 (sys))10^{15} yrs

★ New $T_{1/2}$ limits on $0\nu\beta^+$/EC and 0νEC/EC modes

- ^{64}Zn 0νEC/EC: $T_{1/2} > 9.7\times10^{16}$
- ^{120}Te 0νEC/EC: $T_{1/2} > 2.2\times10^{15}$
- ^{120}Te $0\nu\beta^+$/EC: $T_{1/2} > 6.4\times10^{16}$

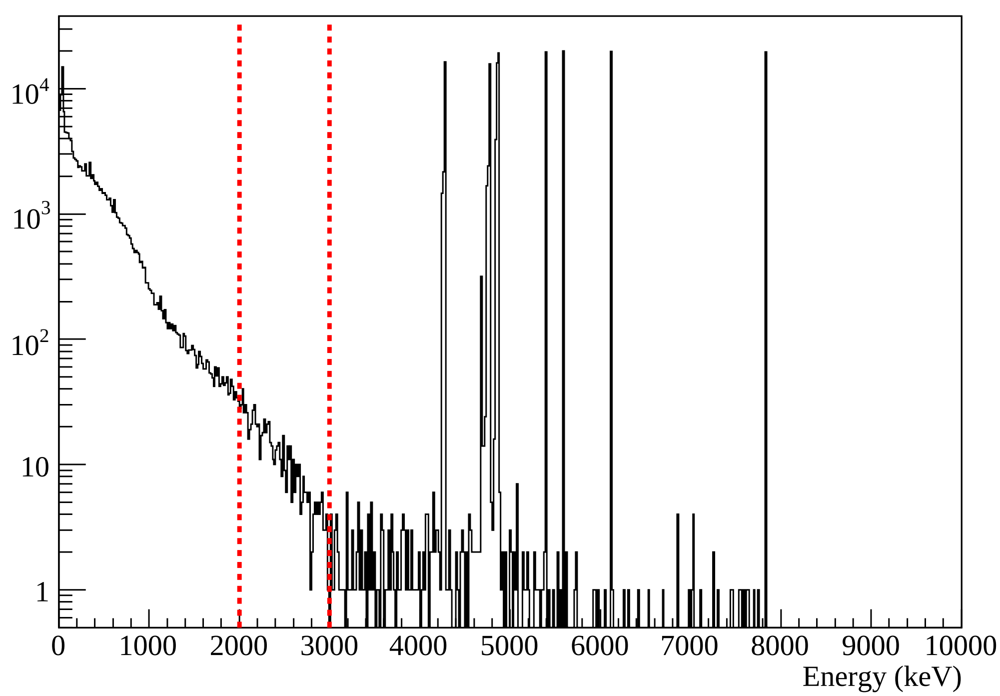


Coincidences

★ Intrinsic ^{238}U and ^{232}Th could be major backgrounds

★ Reject multiple-crystal events

- ββ is normally single crystal event
- Reduce ^{232}Th chain events from crystals by >50%



Simulated ^{238}U chain events inside detectors

No Energy smearing

Timing Coincidences

★ The major contribution to ^{238}U spectrum at 2–3MeV is the fast β–α decay:

$$^{214}\mathrm{Bi} \xrightarrow{\beta} {}^{214}\mathrm{Po} \xrightarrow{\alpha} {}^{210}\mathrm{Pb}$$

endpoint 3.3MeV, accounts for >70% events in 2-3MeV region from ^{238}U chain

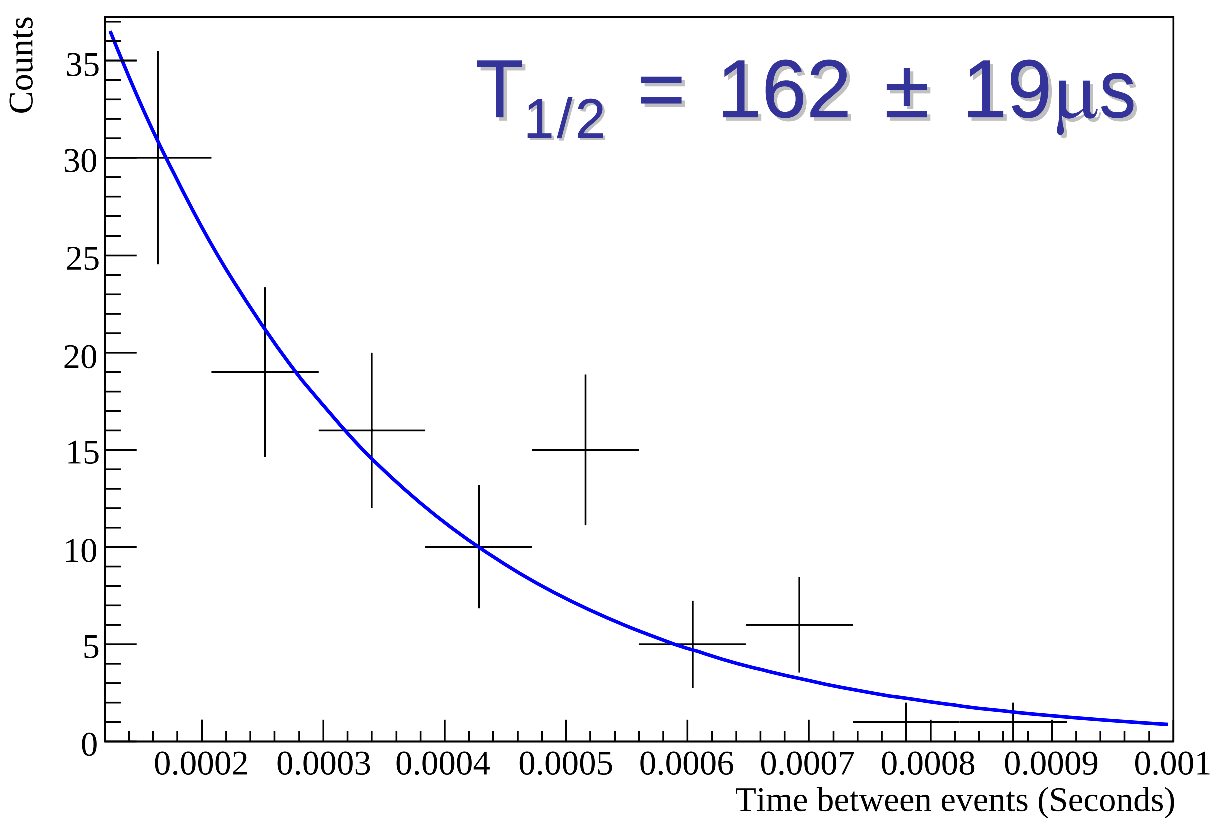
7.7MeV alpha
half-life = 164.3μs

★ >40% efficiency for tagging ^{214}Bi events originating inside the crystals

Observation of ^{214}Bi events

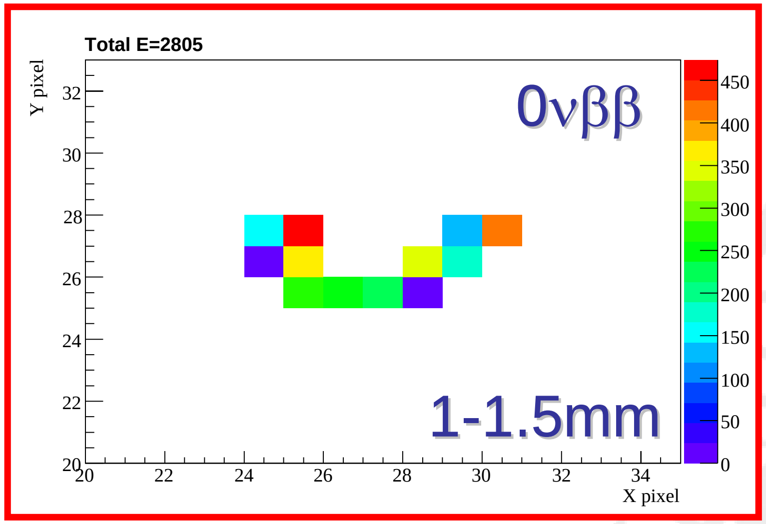
★ Surface coating → self calibrating device!

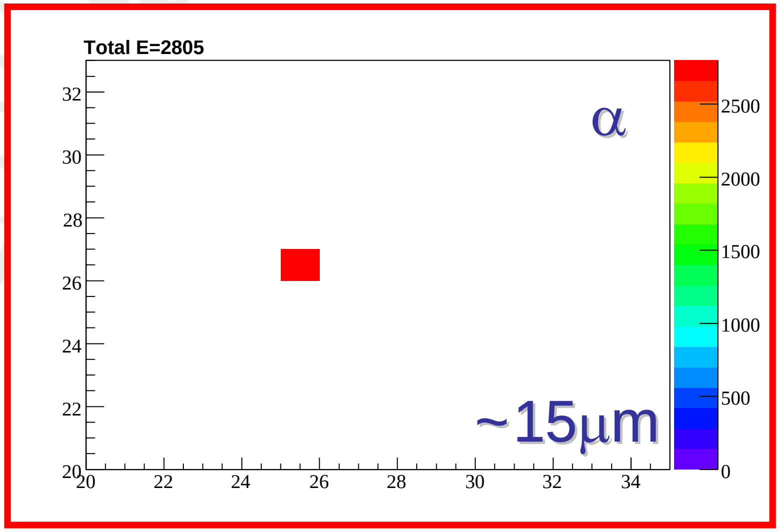
- small dead volume
- Measure of "paint" activity



Pixellisation - I

★ Extra information on events with signal energy.
200μm pixels (example simulations):

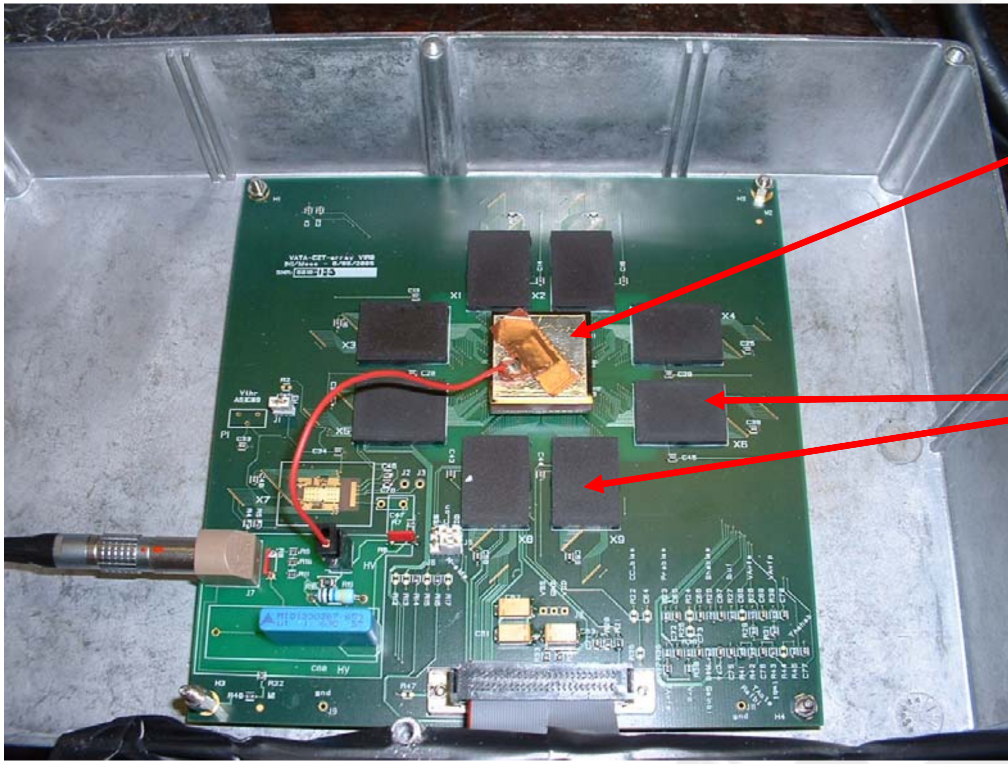




★ eg. Could achieve nearly 100% identification of ^{214}Bi events.

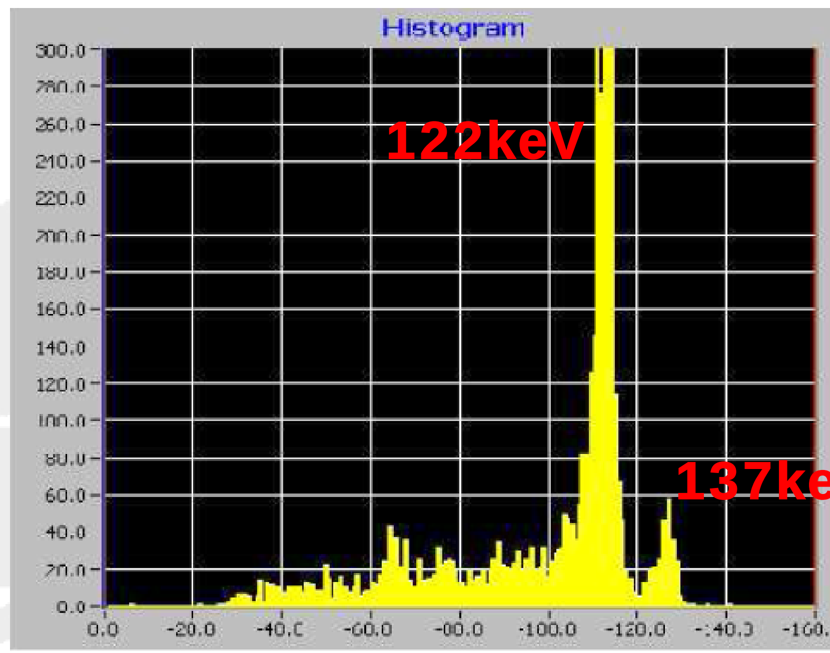
Pixellisation - II

★ Tests of 16×16 1.6mm pixel detectors



crystal

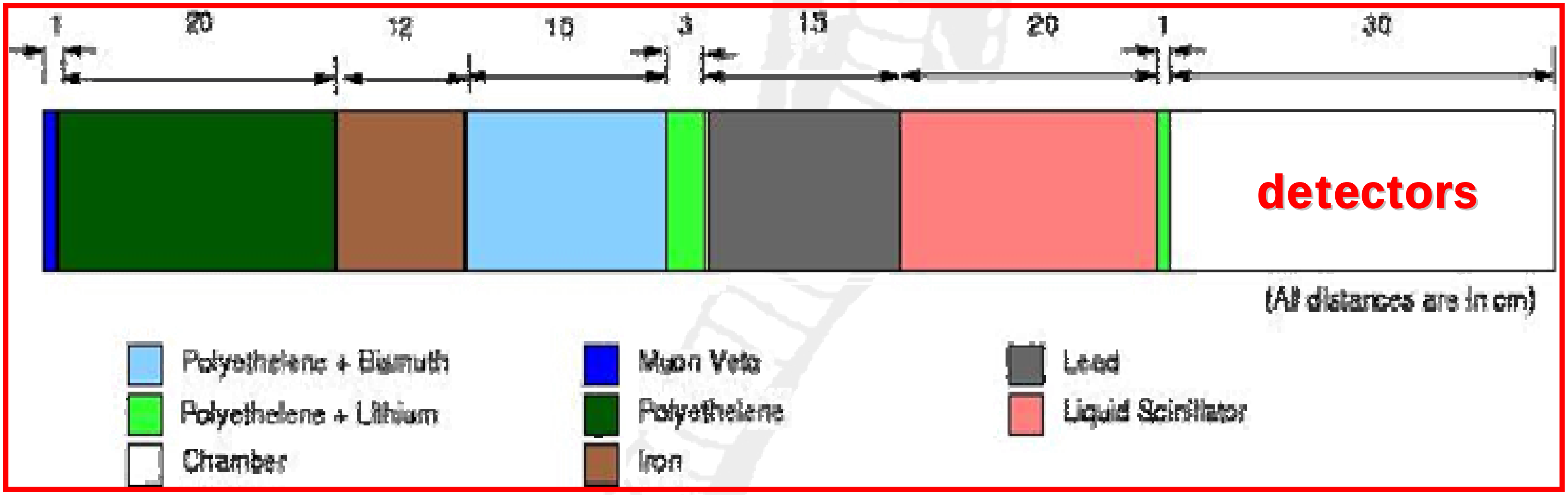
ASIC readout



Single Pixel ^{57}Co spectrum

Shielding and Veto

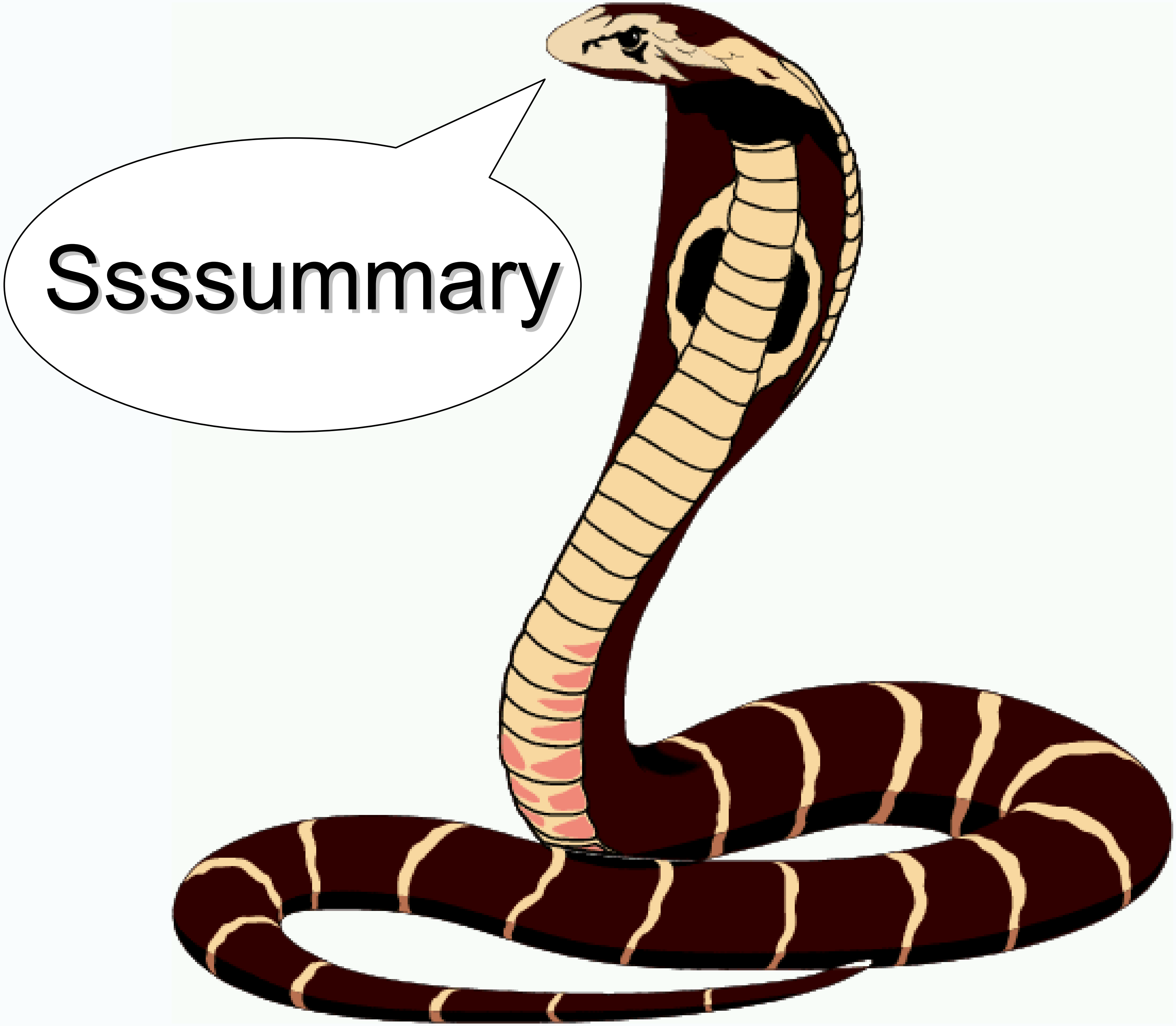
★ Optimise shielding design for neutrons



Size = 18.4 m^3, Mass = 64964 kg

★ Active scintillator component for inner layer

- Veto any residual external background components
- Veto γs from internal backgrounds
- Enhance sensitivity to $\beta\beta$ decays with high energy γs


Ssssummary

Join the party!

★ New collaborators would be welcomed!