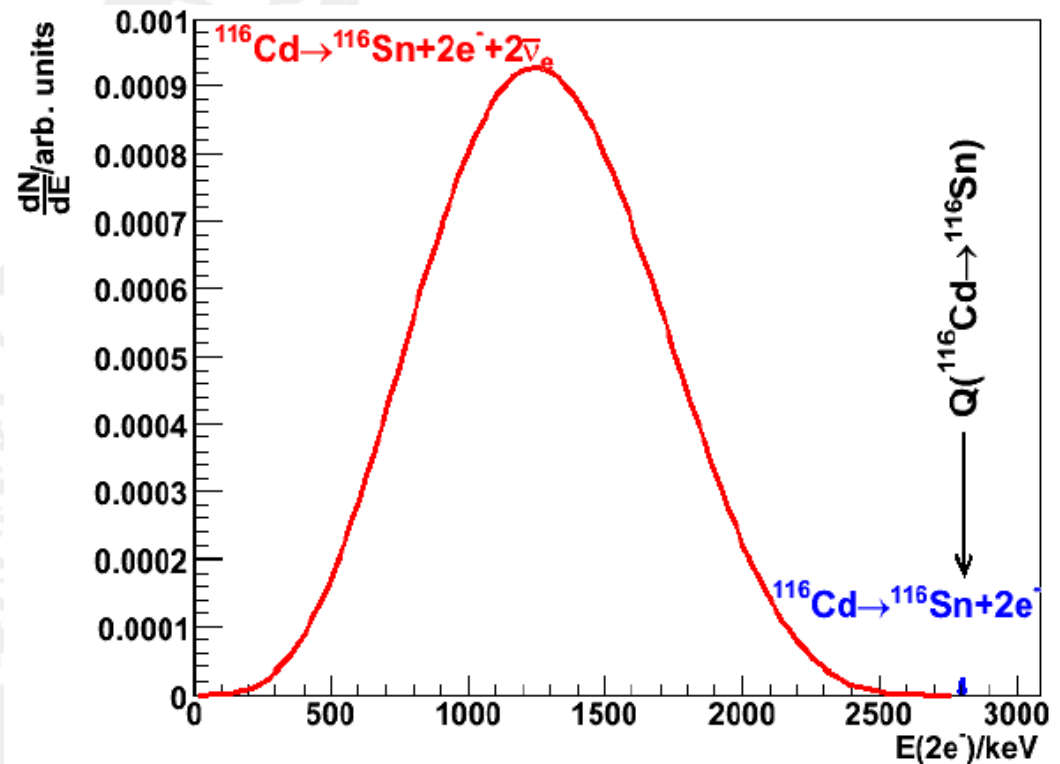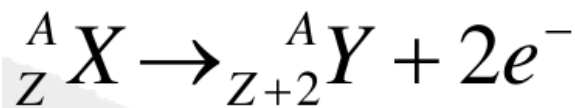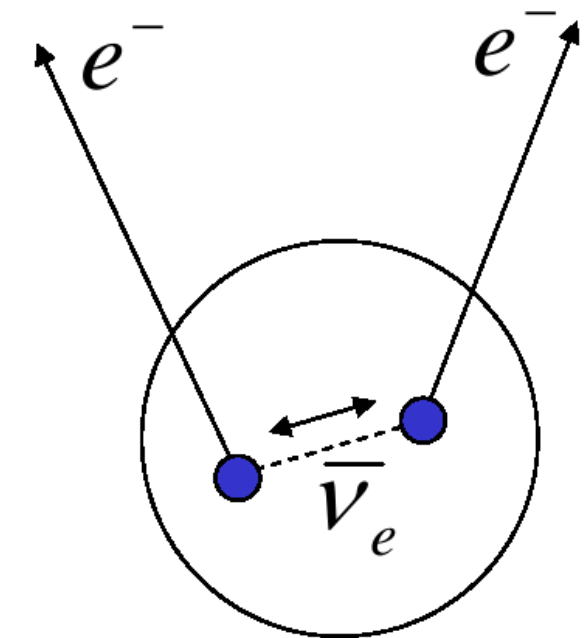# Simulations for COBRA using Geant4

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on behalf of the COBRA collaboration

BEWARE
OF
SNAKES

Geant4 Collaboration Meeting
Hebden Bridge
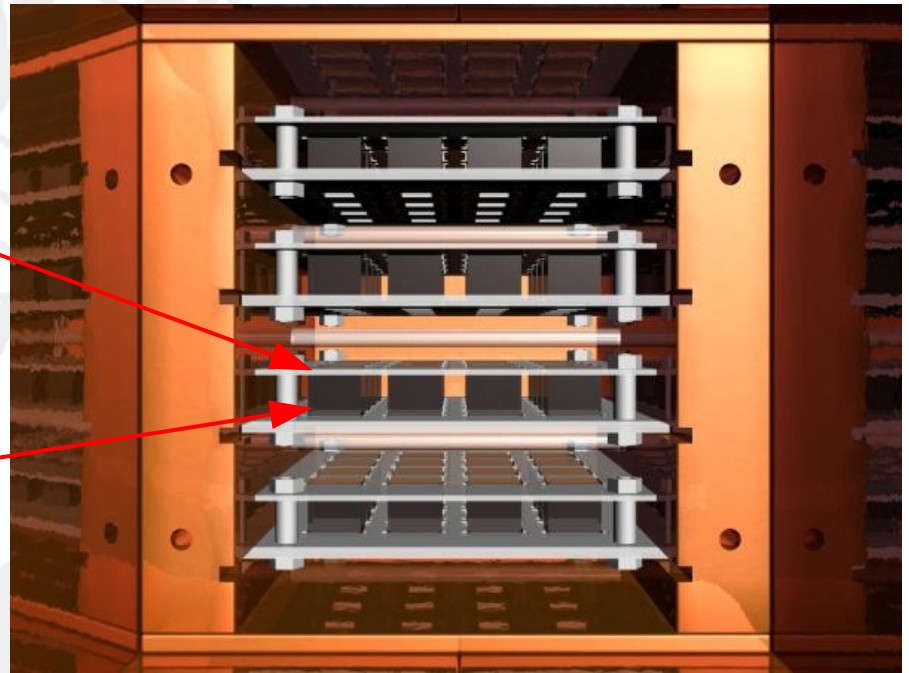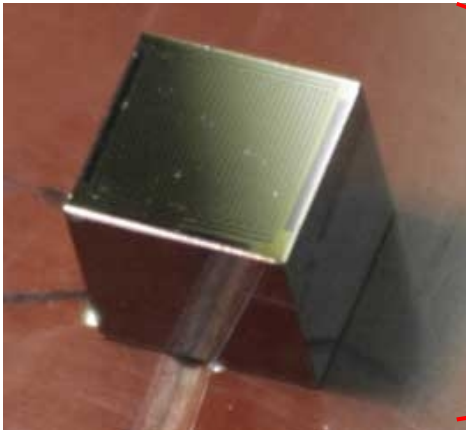13th September 2007

Double Beta Decay

- 0νββ decay: can occur if neutrinos are Majorana particles.

- Detection – determine neutrino nature and mass.

$$_{Z}^{A}X \rightarrow _{Z+2}^{A}Y + 2e^{-}$$

- *A simple signature – peak at decay Q value*

The COBRA Concept

- **C**admium-Telluride **0**-neutrino **B**eta decay **R**esearch **A**pparatus.

- Large array of Cadmium-Zinc-Telluride detectors.

- *Running 64 detectors in Gran Sasso, planning large (64000 crystal) array, pixelated readout.*

Venom Simulation Framework

- Venom is a flexible framework for COBRA simulations built around Geant4.
  - Modelling of signal+background in various geometries.

- Support multiple geometries:
  - Lab setups, 64 array, 64K array, shielding.

- Support EM+Hadronic physics list.
- Support signal and background particle sources:
  - $0/2\nu\beta\beta$ decays, muons, neutrons, radioactive decay.

- Support persistency through ROOT toolkit.

Geometry
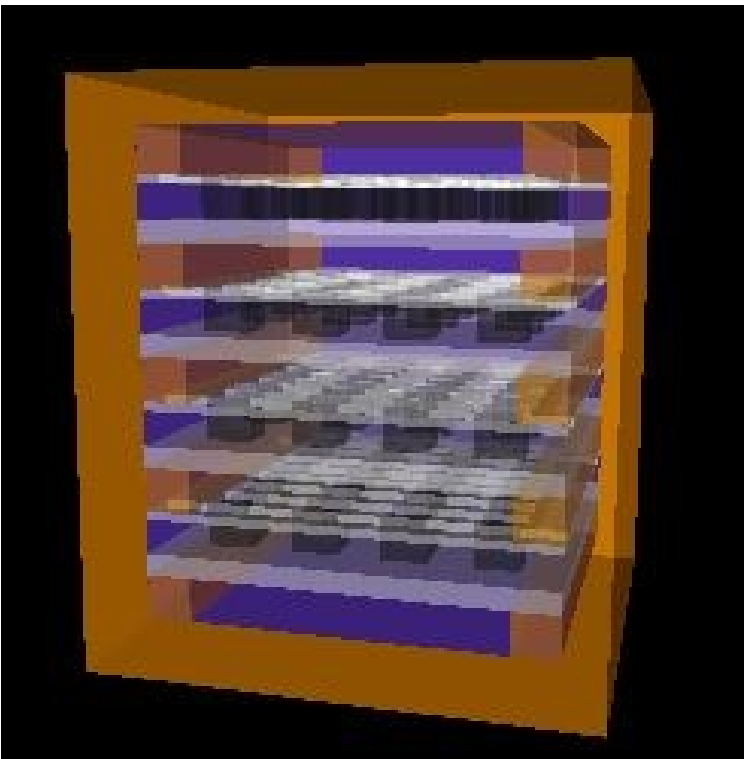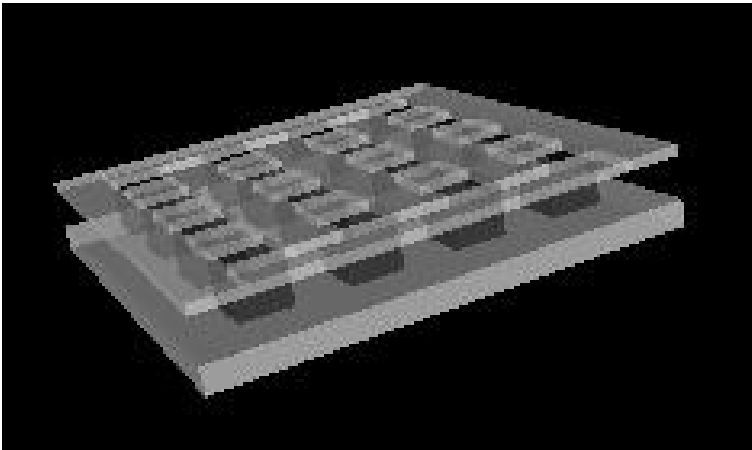
- Divide geometry into reusable 'components'.
  - Well defined physical piece of detector.

- Concrete components through Factory interface

- New components added to Factory at compile time.

- Factory+Messengers allow flexible construction of geometry at runtime.

Physics List

- Adopted physics list from UndergroundPhysics example (LBE list).

- Removed optical physics section for simplicity.

- What about hadronics?

  - Cosmogenic production of isotopes (IDEA)

  - Muon-Induced backgrounds (Pandola et al NIM A570, 149).

- Use these to improve current physics list.

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Event Generators

- GPS used as basic event generator.

- Specialist event generators for:

  - Muon/Neutrons(external to shield).

  - Radioactive decay chains.

  - $2/0\nu\beta\beta$ decays.

- Concrete generators obtained through Factory interface.

- As with geometry components, new generators can be added to Factory at compile time.

- Messenger classes provide runtime interface to give choice of event generator.

Cosmic Muons/Neutrons

- Muon and Muon-Induced neutron event generators implemented from Mei &Hime PRD 73,053004.
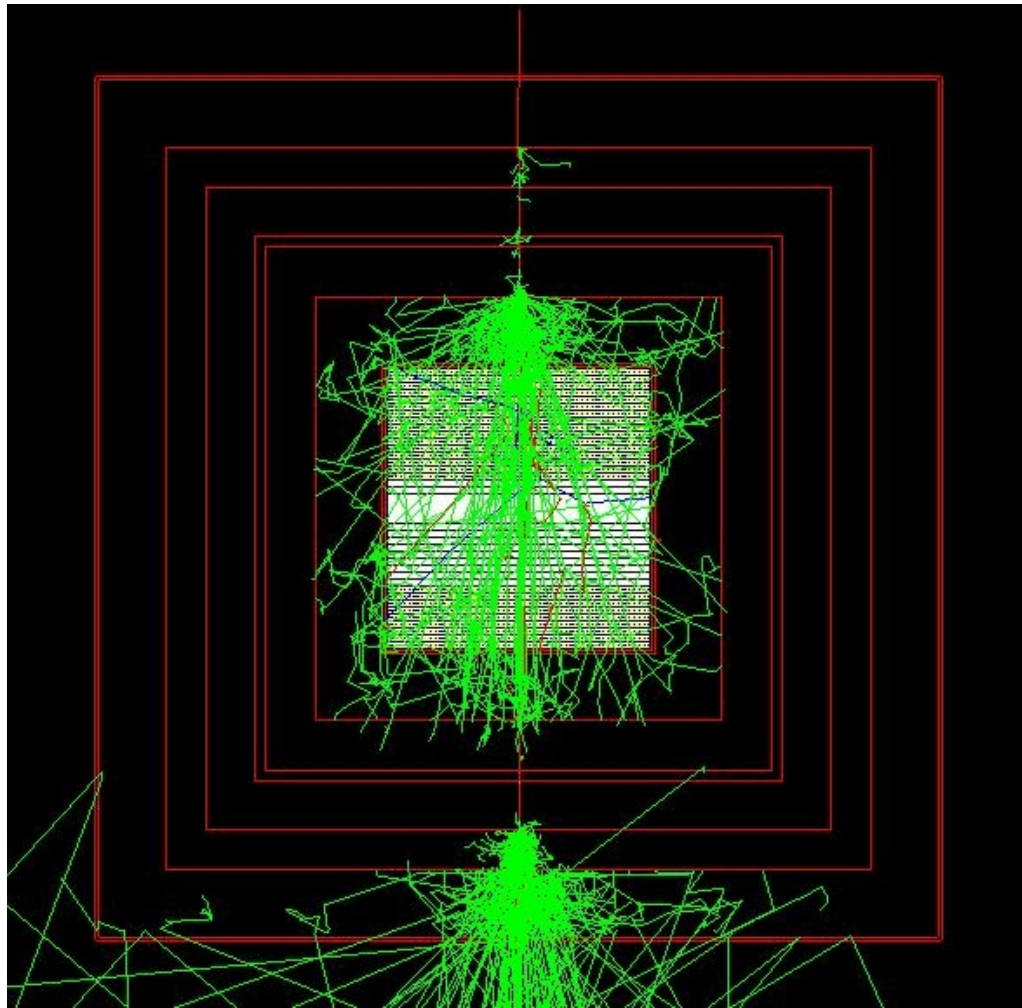

200GeV Muon
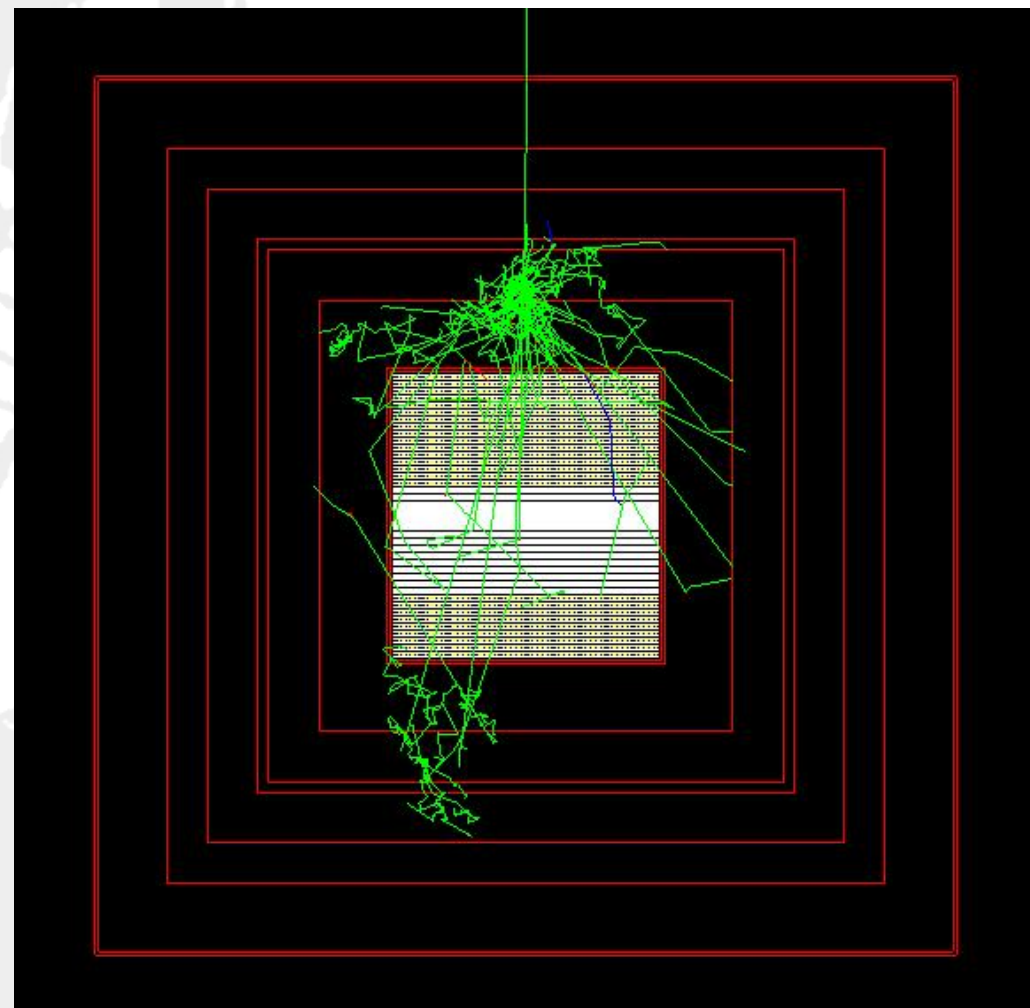
2GeV Neutron

Radioactive Decay

- RDM cascades through decay chain.

  - Not obvious how to separate decays out in data output.

  - For long-lived chains, lose time resolution.

  - How to deal with out-of-equilibrium chains?

- Venom implements special decay chain generator

  - Isotopes selected according to user-specified activity.

  - RDM cascade limited to daughter.

  - Arbitrary chains can be constructed at runtime.

- Interface to DECAY0 output files used to generate double beta decay events.

  - *New C++ 0/2νββ generator to be released next month.*

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Example 64K CZT Crystal Spectra
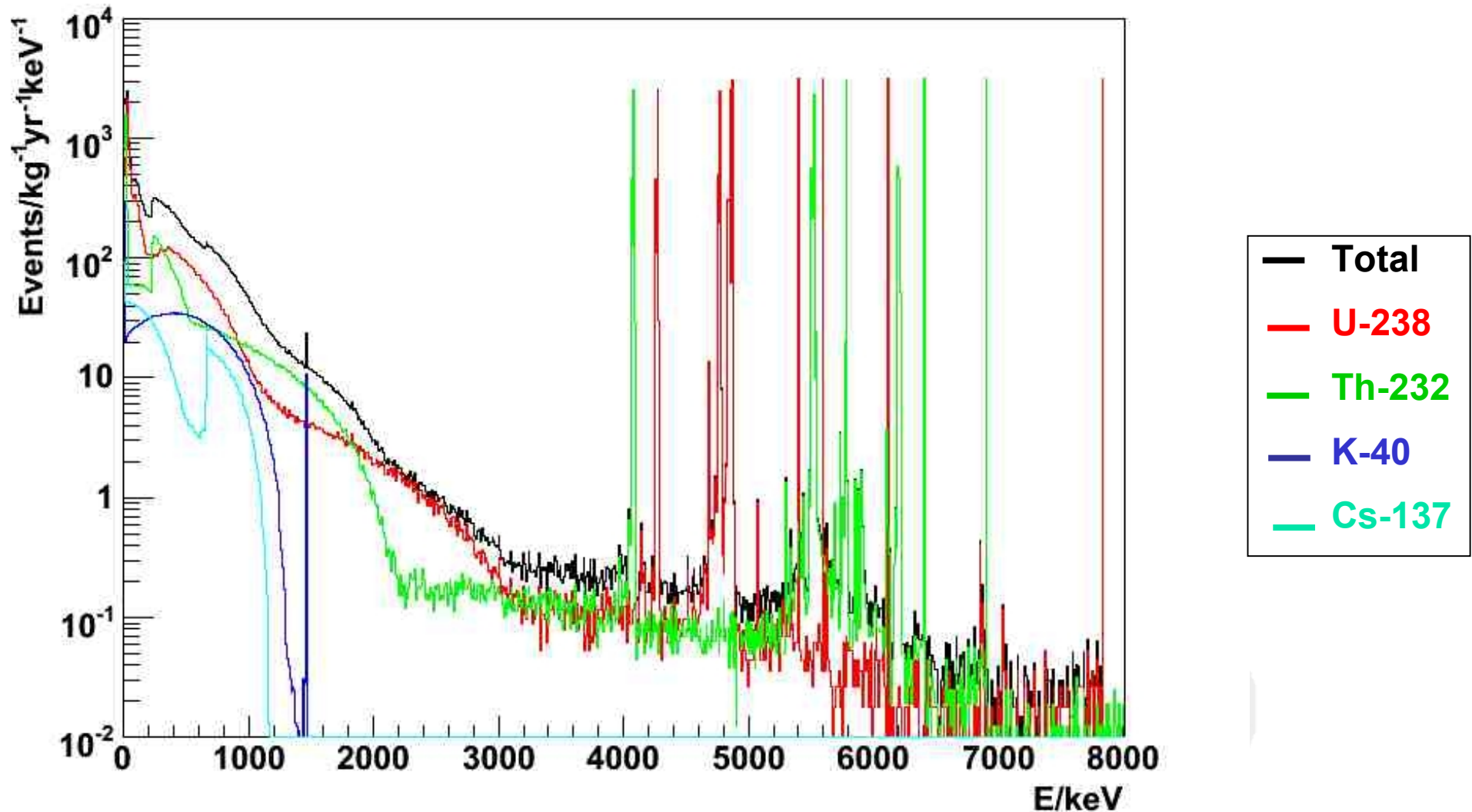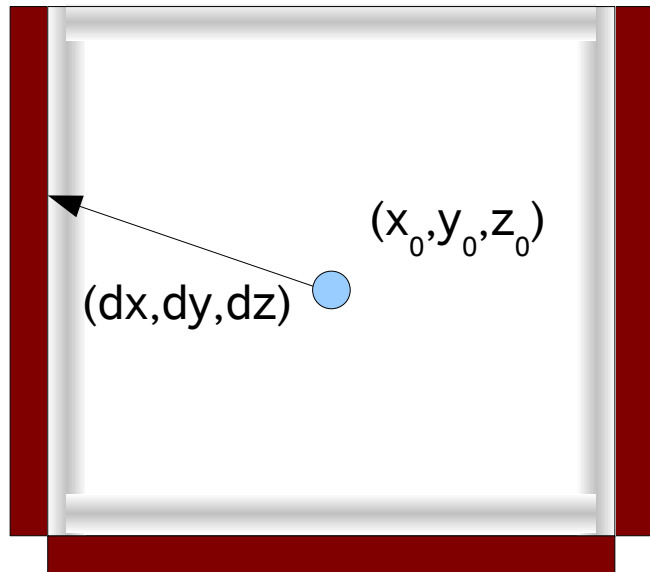

- Decays in CZT crystals, **assumed** 1mBqkg^{-1}.

Example 64K CZT Crystal Spectra
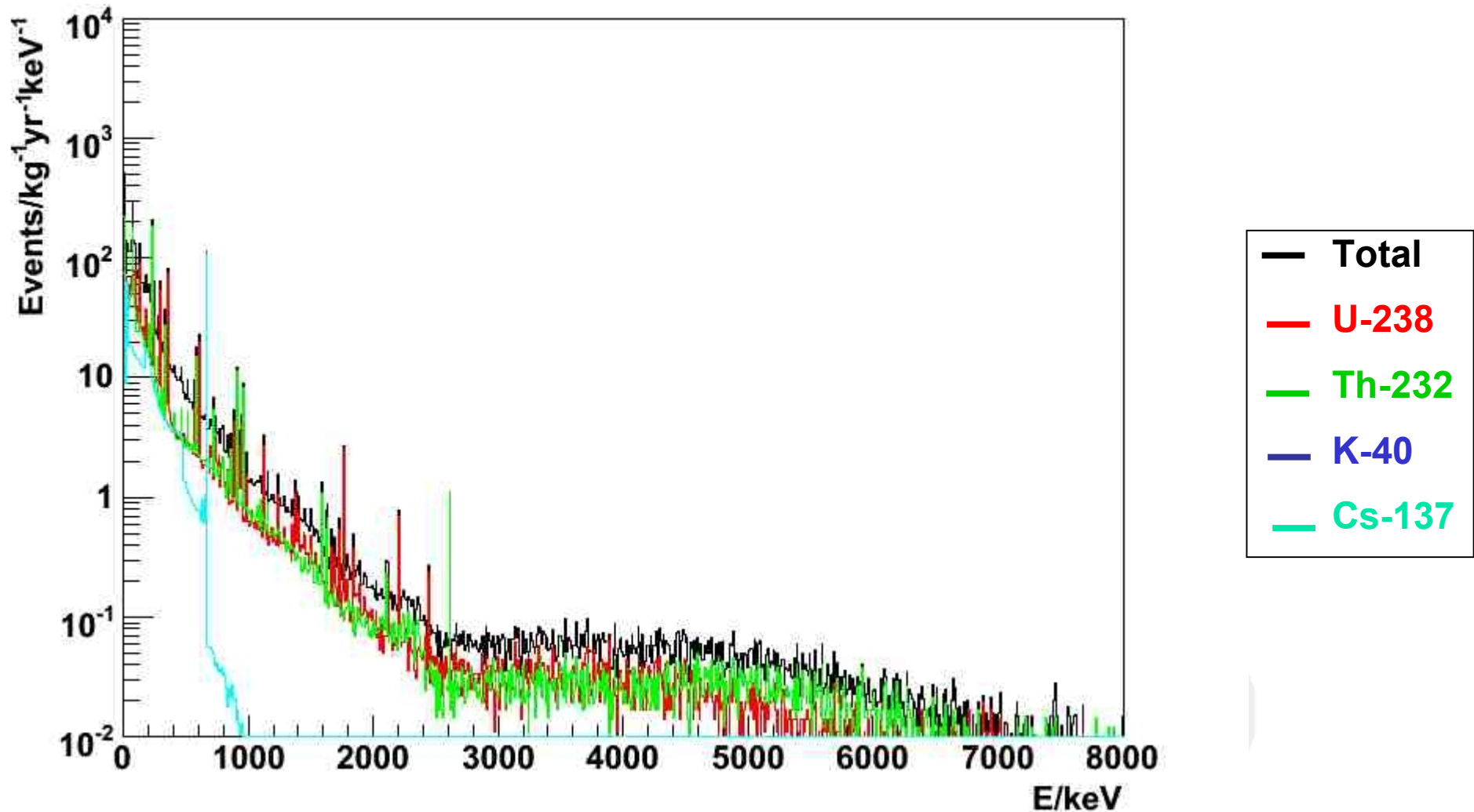
- Decays in crystal holders, *assumed* $1\,mBqkg^{-1}$.

Volume/Surface Sources

Containing Volume V_c

(x_0, y_0, z_0)

(dx, dy, dz)

Vertex Volume V_v

$V_v / V_c << 1$

- GPS techniques used to generate event vertices in specific volumes.

- Two problems:
  – Crystal passivation
  – Radon plate out sources

- Selecting point in small volume is inefficient.

- Plate out sources have distribution in space.

- Select main volume, then offset to get vertex

- *Are there better techniques though?*

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Persistency

- Decision taken to use ROOT for persistency.

- Output from each sensitive detector recorded:

  - Muon and liquid scintillator vetos, crystals.

- Each sensitive detector creates a TDirectory where its data structures are stored.

- Observer Pattern used to trigger writing of data at end of each event.

- Not an ideal system – now looking at use of G4PersistencyManager.

Further Development/Questions

- Investigate GDML for geometry.

- Factories with loadable shared libraries?

- Use of XML to define physics list?

- Integrate new C++ $0/2\nu\beta\beta$ event generator.

- Better design for persistency.

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