Computer Modeling of High-Purity Germanium Detectors in MAJORANA

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MAJORANA

- Located 4850' below ground at Sanford Underground Research Facility
- Array of **high-purity germanium** (HPGe) detectors
- Searching for **neutrinoless double beta decay**

Beta decay

- Type of radioactive decay in which a neutron becomes a proton by emitting an electron and an antineutrino
- Double beta decay occurs when single beta decay is not energetically favorable, but two simultaneous beta decays are
- **Neutrinoless double beta decay** is a variant of double beta decay where the two neutrinos annihilate each other instead of being emitted
- If observed, it would imply that neutrinos are their own antiparticle, i.e. a Majorana particle
- This would conflict with the standard model

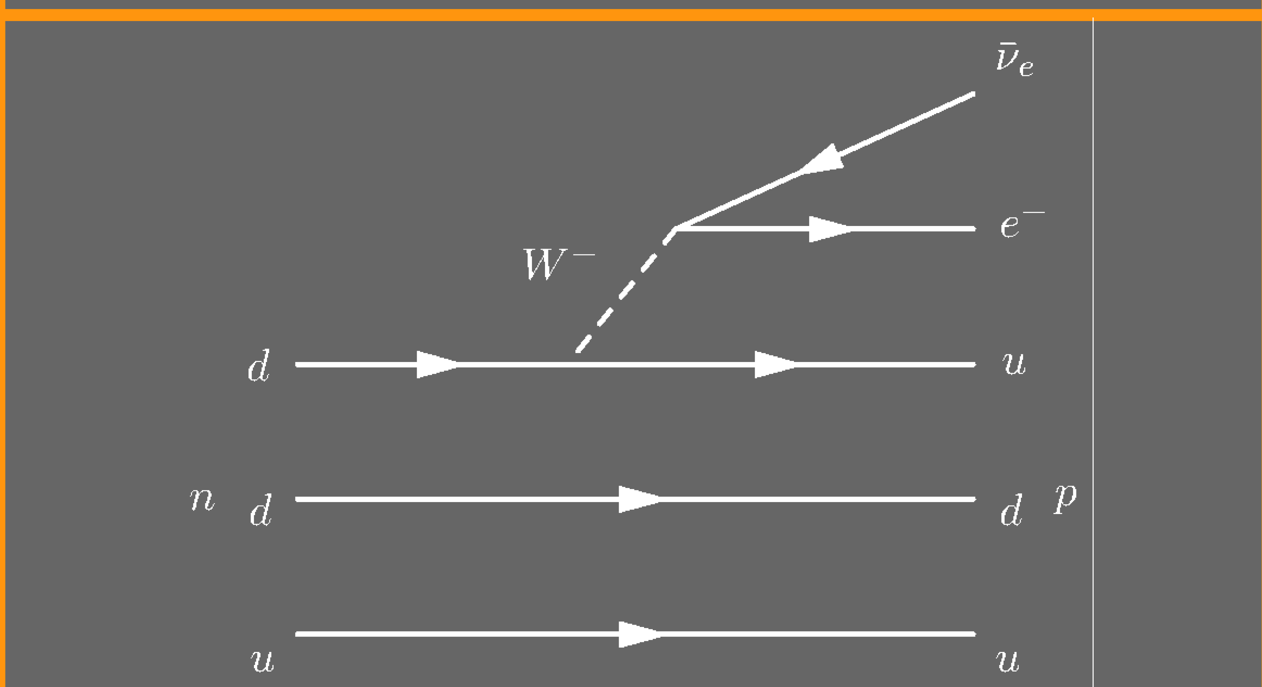

Figure 1: The Feynman diagram for beta decay. The neutron and proton are shown as their component quarks.

Why germanium?

- **Germanium-76** is one of a handful of isotopes that can only decay through double beta decay
- Of those isotopes, it is the second lightest and the most plentiful
- As a semiconductor, germanium is already commonly used in detectors
- Using the same material for both source and detector allows for very simple detector construction
- This is the principle behind MAJORANA

DEMONSTRATOR

- Proof of concept for the MAJORANA project
- Located underground to avoid interference from cosmic rays
- Covered in copper and lead shielding to avoid interference from underground radiation sources, e.g. small amounts of uranium in rock
- All detector materials must be purified as much as possible, and exposed to cosmic rays as little as possible before installation

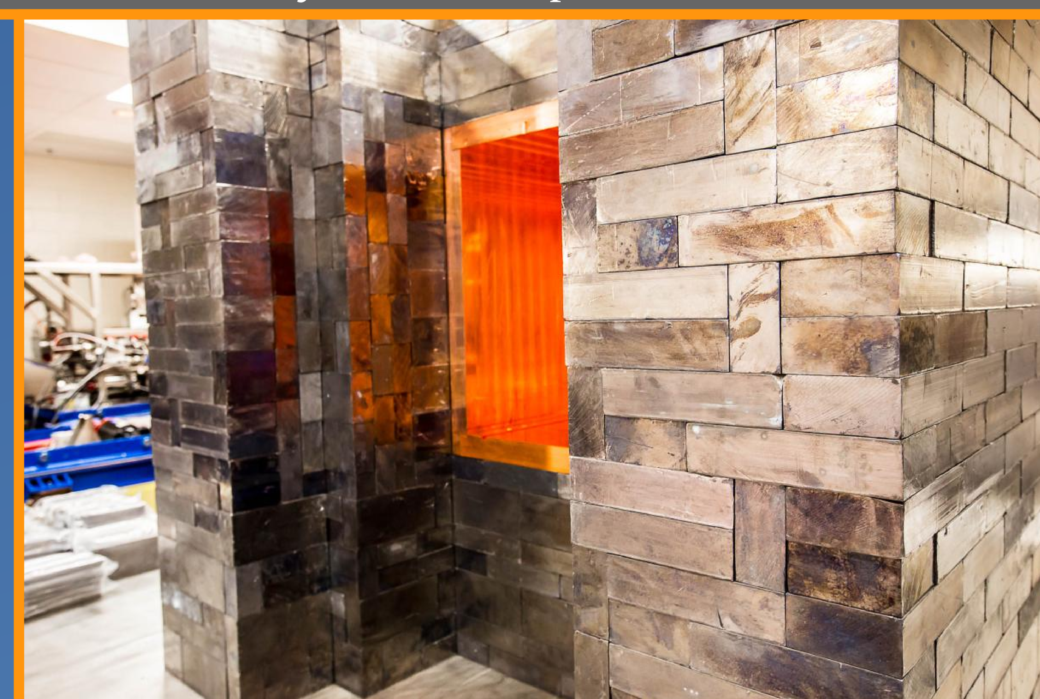

Figure 2: The MAJORANA DEMONSTRATOR.

Geant4

- C++ library developed by CERN
- Used to simulate high-energy physics apparatus such as the DEMONSTRATOR
- Assists with defining:
  - Detector shape and materials
  - Particle types, amounts, and interactions
  - Counting interactions (aka scoring) and data analysis
- Packaged with many example applications
- Large size of source code and dependencies make it time-consuming to compile and install

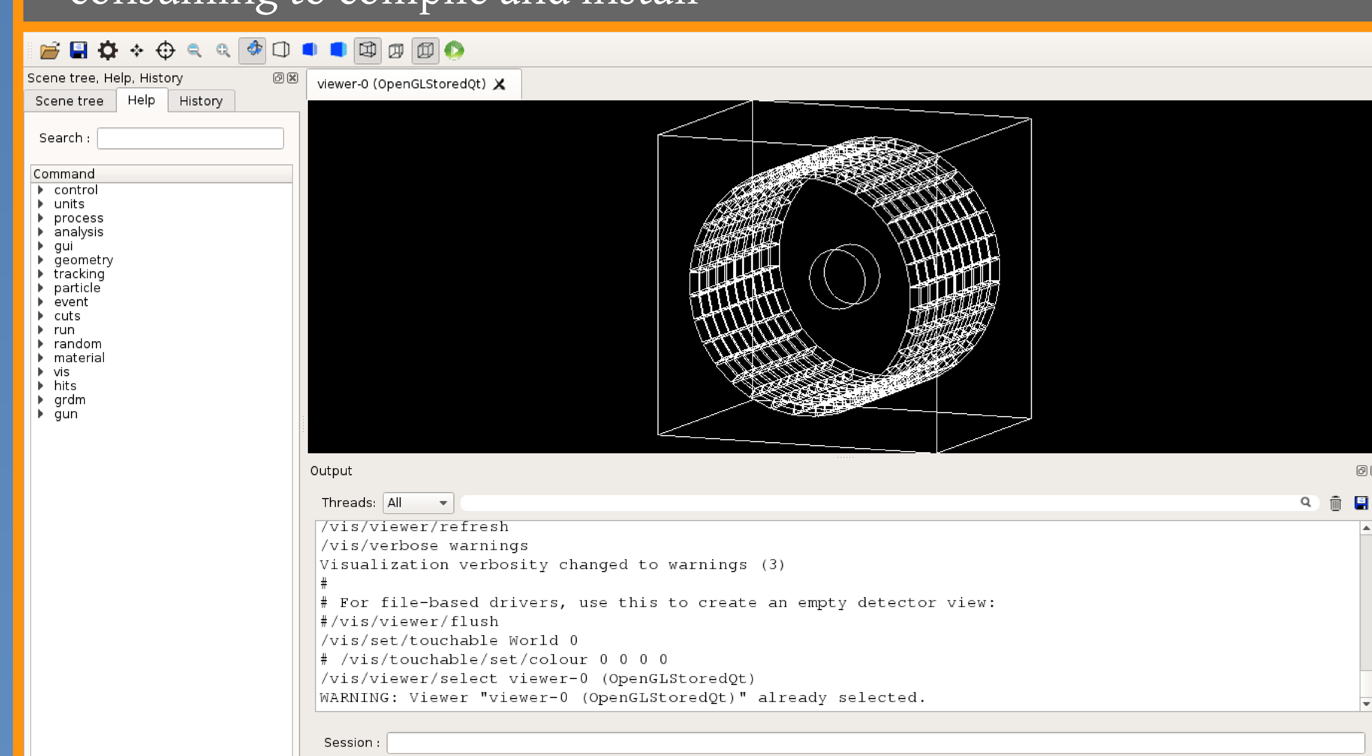

Figure 3: A Geant4 example application using the Qt graphics framework to display a detector.

Materials and geometry

- Detector material is ~87% Ge-76, 13% normal isotope distribution
- Detectors are pucks of germanium strung vertically
- They are surrounded by the lead and copper shielding "castle" shown in Figure 2

GMajor

- I created a Geant4 application called "GMajor" which simulates the DEMONSTRATOR
- **Current features:**
  - Simulates a single string of germanium pucks
  - Exact specification of high-purity germanium
  - Very simplified implementation of beta decay
- **Planned features**:
  - Improve implementation of double beta decay
  - Create scripts to automate data gathering
  - Implement configuration files instead of hard-coding parameters

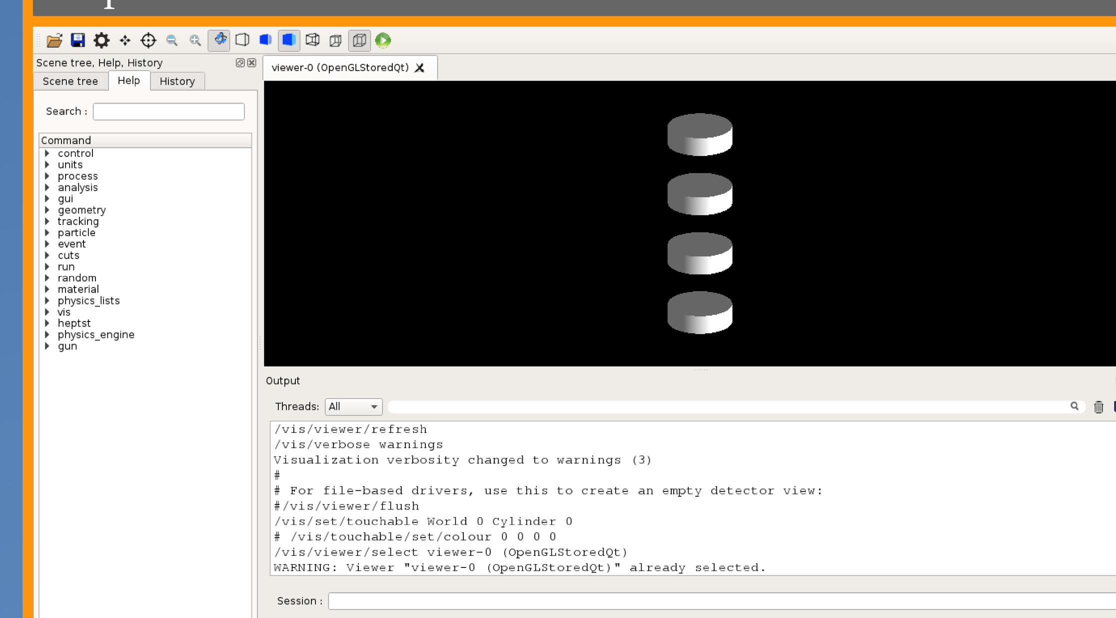

Figure 4: Part of the DEMONSTRATOR being simulated within GMajor.

Acknowledgements

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References

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