Status of the SuperNEMO 0νββ experiment

Cheryl Patrick and Fang Xie

University College London, on behalf of the SuperNEMO collaboration

Neutrinoless double beta decay

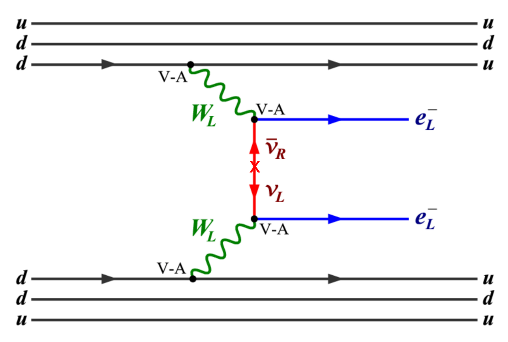

Figure 1: Feynman diagram for neutrinoless double beta decay

Double beta decay, where two neutrons decay simultaneously, has been observed in several isotopes. The final state includes two electrons and two electron antineutrinos (2νββ). If neutrinos are Majorana particles – if they are their own antiparticles – a virtual antineutrino from one decay could be absorbed as a neutrino in the other, with no neutrinos in the final state: neutrinoless double beta decay (0νββ).

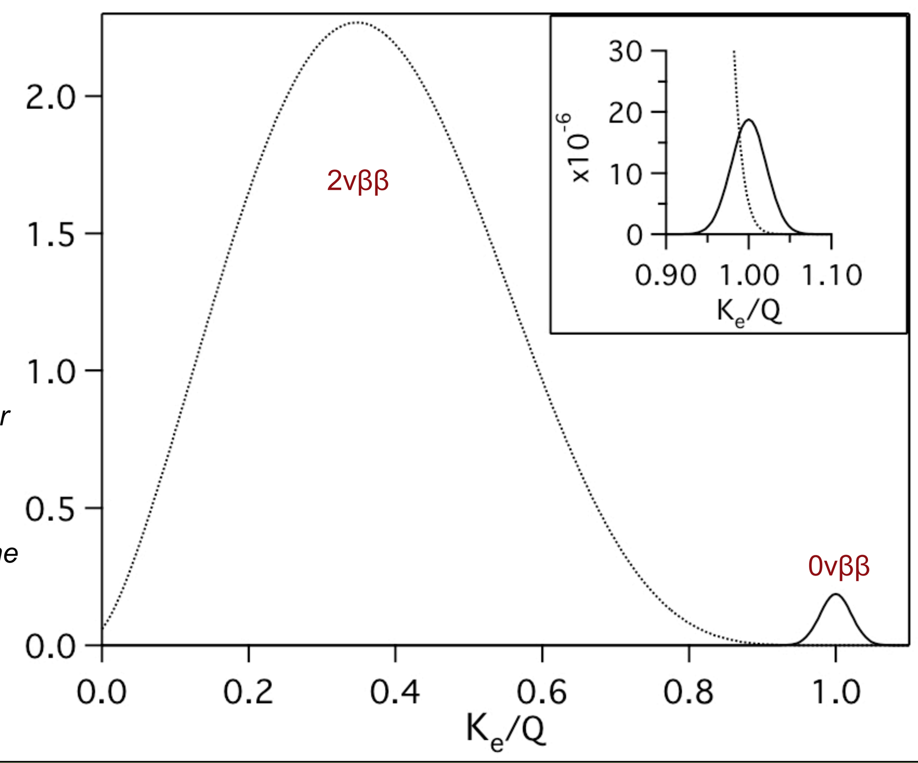

Figure 2: Combined reconstructed energy distribution, in units of interaction energy $Q_{\beta\beta}$, for the two beta electrons if both 2νββ and 0νββ interactions occur. (reconstruction smears the peak).

The SuperNEMO experiment

SuperNEMO is an ultra-low-background tracker-calorimeter experiment designed to look for the 0νββ decay of ^{82}Se. The SuperNEMO Demonstrator Module is currently being assembled at LSM in France, and will begin taking data in 2017.

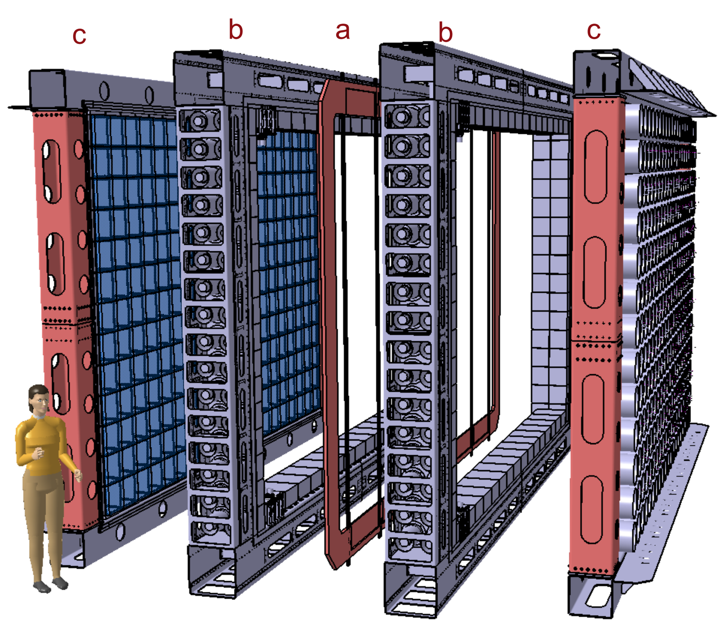

Figure 3: Expanded diagram of the Demonstrator Module showing the a) source foil frame, b) the tracker and c) the calorimeter wall

The source frame (a) will hold 7kg of ^{82}Se foils, with the possibility to switch to other isotopes. The tracker (b) consists of 2034 drift cells. The calorimeter wall (c) consists of 712 optical modules; 8" radiopure PMTs embedded in polystyrene scintillator blocks.

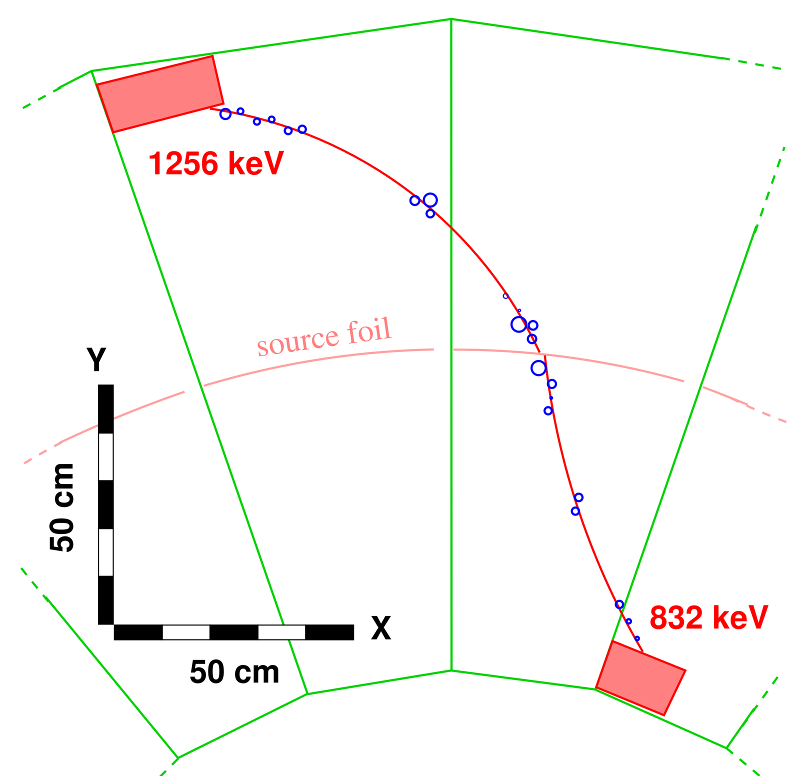

Figure 4: A ββ candidate in SuperNEMO's predecessor, NEMO3, illustrating the curved tracks formed by electrons in the drift chamber, leading to the calorimeters that can reconstruct their energy

Running for 2.5 years, the Demonstrator Module will have a sensitivity to the 0νββ half-life of $T_{1/2}^{0\nu\beta\beta}$ > 6.5 x 10^{24} years ($\langle m_\nu \rangle$ < 0.2 to 0.4 eV).

A proposed 20-module full SuperNEMO detector with an exposure of 500 kg years (5 years, 100 kg of ^{82}Se) improves our sensitivity to $T_{1/2}^{0\nu\beta\beta}$ > 10^{26} years ($\langle m_\nu \rangle$ < 50 - 100 meV).

Installation at LSM

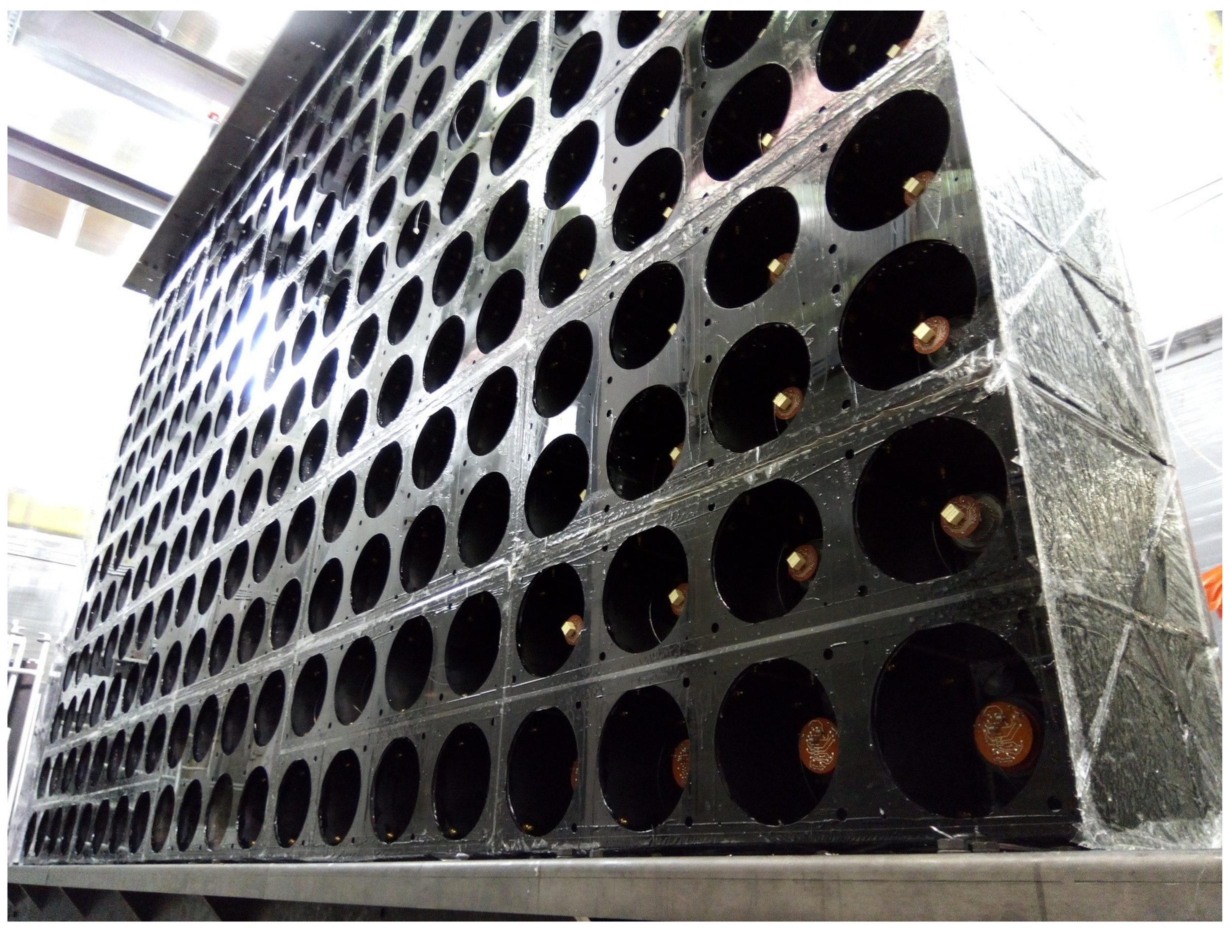

Figure 5: The back side of one of main calorimeter walls

Figure 6: An optical module

The main calorimeter walls consist of 520 optical modules. These are blocks of polystyrene scintillator coupled to 8" PMTs and wrapped in teflon and mylar, with individual iron shielding. The modules have now been assembled into two walls at the Laboratoire Souterrain de Modane (LSM), in the Fréjus road tunnel in France.

All four C-shaped tracker sections have now been shipped from the UK, where they were assembled and commissioned, to LSM.

The first two C-sections have been joined and coupled to the first calorimeter wall, forming half of the Demonstrator Module. *In situ* commissioning of this half detector will be completed in early 2017. The full Demonstrator Module will be assembled by mid-2017.

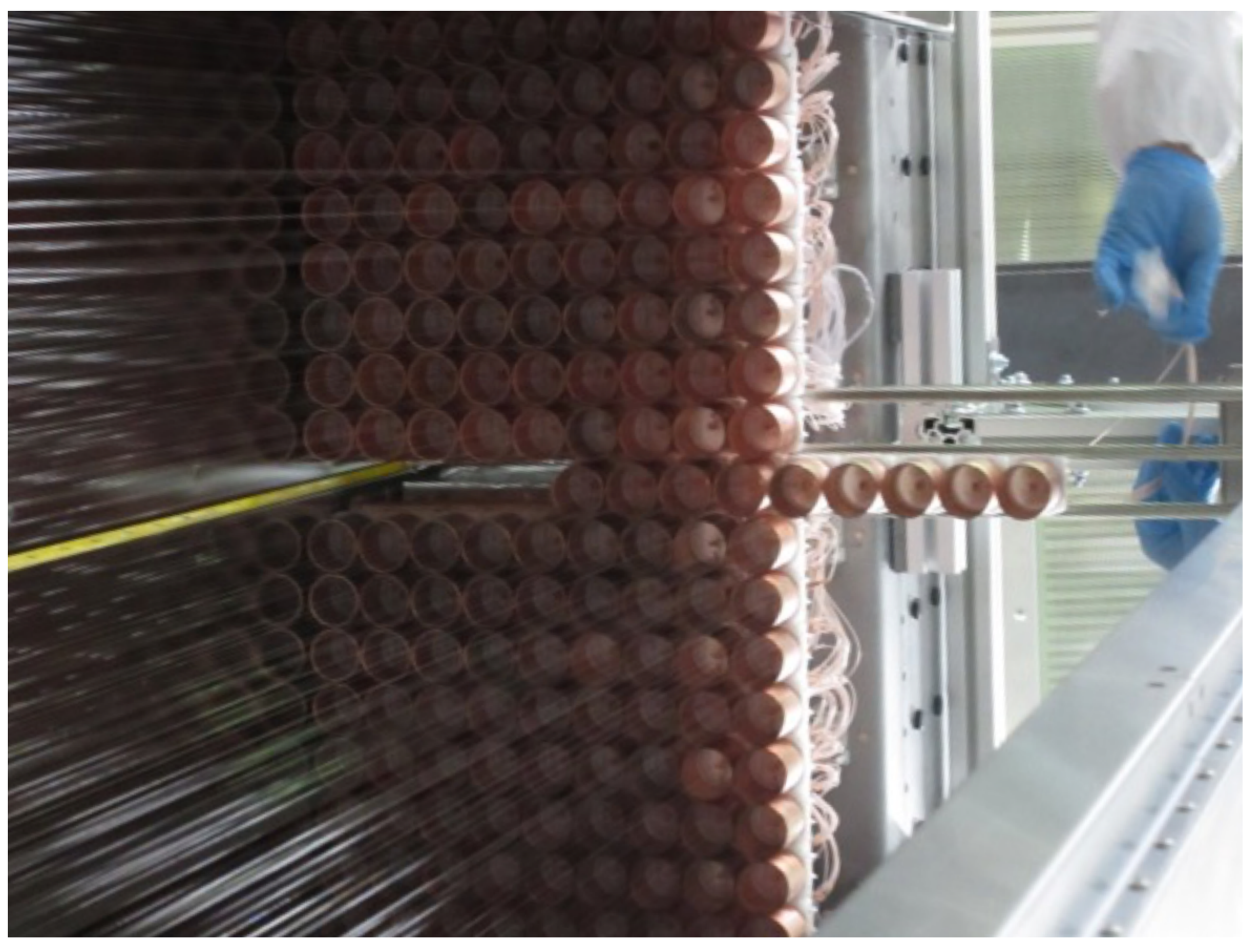

Figure 7: As two C-sections are joined at LSM, a final row of cells is inserted between them

Figure 8: The first pair of joined C-sections are coupled to the calorimeter wall, creating a half detector

Radon mitigation strategy

Our largest background is due to radon, as β decays of its daughter isotope ^{214}Bi can mimic 0νββ. Stringent radiopurity requirements are imposed on both construction materials and gas in the tracking chamber, where we require the radon activity to be below 0.15 mBq/m^3. Our state-of-the-art electrostatic detector is sensitive to ~1 mBq/m^3; adding a Radon Concentration Line (RnCL) enables us to measure to O(10) μBq/m^3 for large gas volumes. Measurements show that with a gas flow rate of 2m^3/hour, we will meet the 0.15 mBq/m^3 requirement.

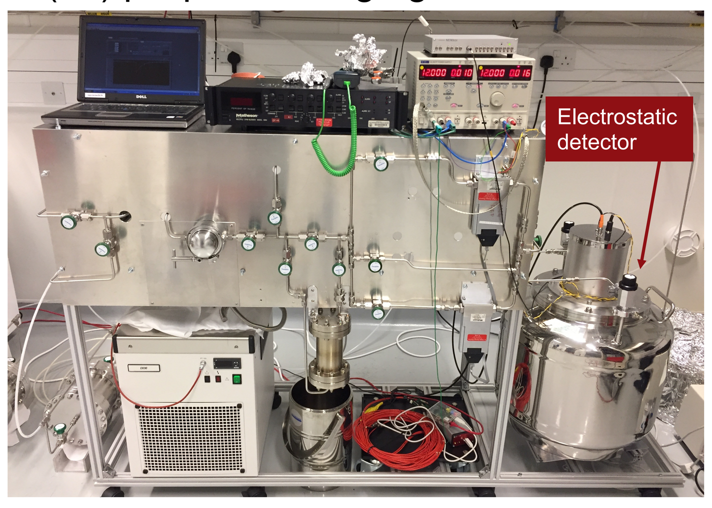

Figure 9: RnCL with the electrostatic detector

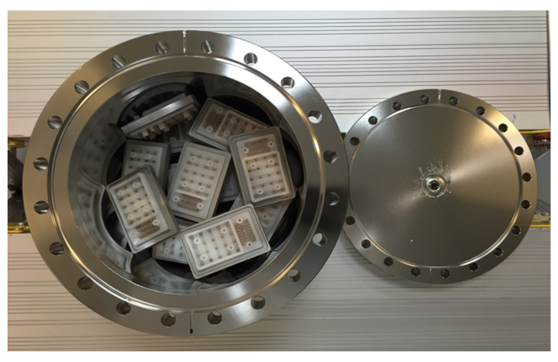

Figure 10: Emanation chamber used to measure the activity of detector components such as these feedthroughs

Figure 11: Sealed C-section inside an anti-radon tent for radon activity measurement

Gas system automation

The tracker gas is 95% He, 4% ethanol, and 1% Ar, with the gas fractions controlled by two bubblers. A Raspberry Pi connected to the slow control system tracks the pressure and temperature in the bubblers, and provides alarms and real-time monitoring via a user interface.

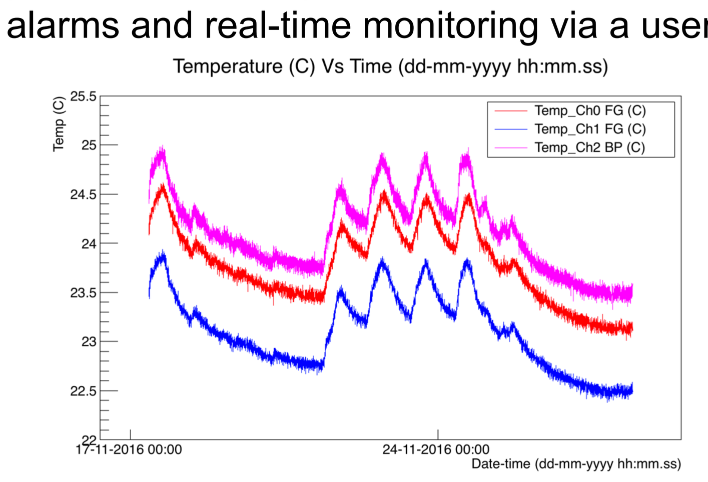

Figure 12: Temperature in the primary (blue) and secondary bubblers (pink, red at different depths), from the user interface

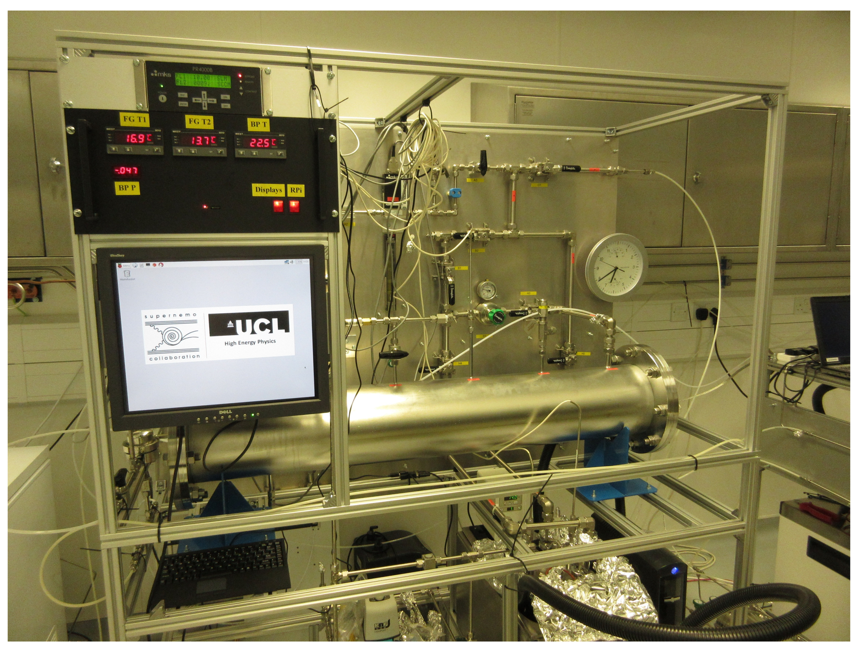

Figure 13: Gas system and accompanying electronics, photographed in the UK before it was transported to LSM

Software and analysis

SuperNEMO's simulation and reconstruction software have been used to perform sensitivity studies, confirming initial predictions, and to evaluate the effects of potential sources of background contamination.

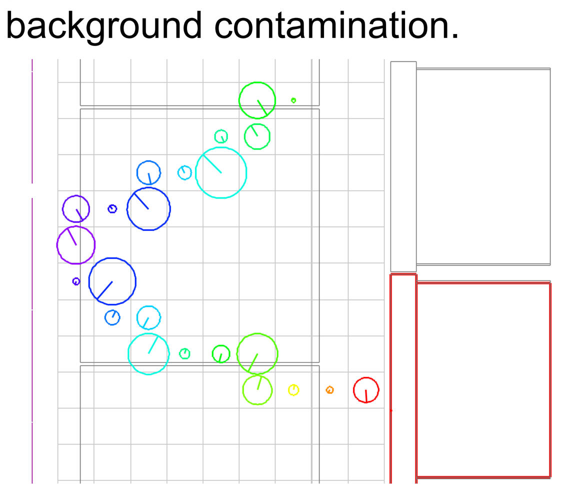

Figure 14: Simulated tracker hits in the SuperNEMO event display show a drift radius in each cell, and use colour to indicate timing, with purple earliest and red latest. A simulated 0νββ event is shown.

The event display, which visualizes and displays information about simulated and reconstructed calorimeter hits, has allowed us to study how signal and background events will present themselves in the detector, enabling us to improve our event selection.

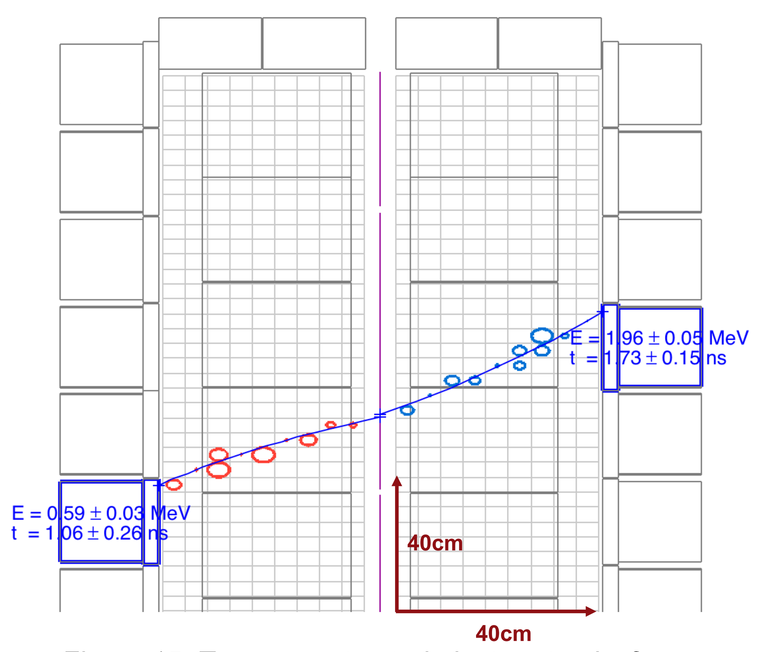

Figure 15: Two reconstructed electron tracks from a simulated 0νββ event in the SuperNEMO event viewer. Circles indicated reconstructed radius in each drift cell. The blue blocks are calorimeters with reconstructed hits. The source foil is highlighted in purple.