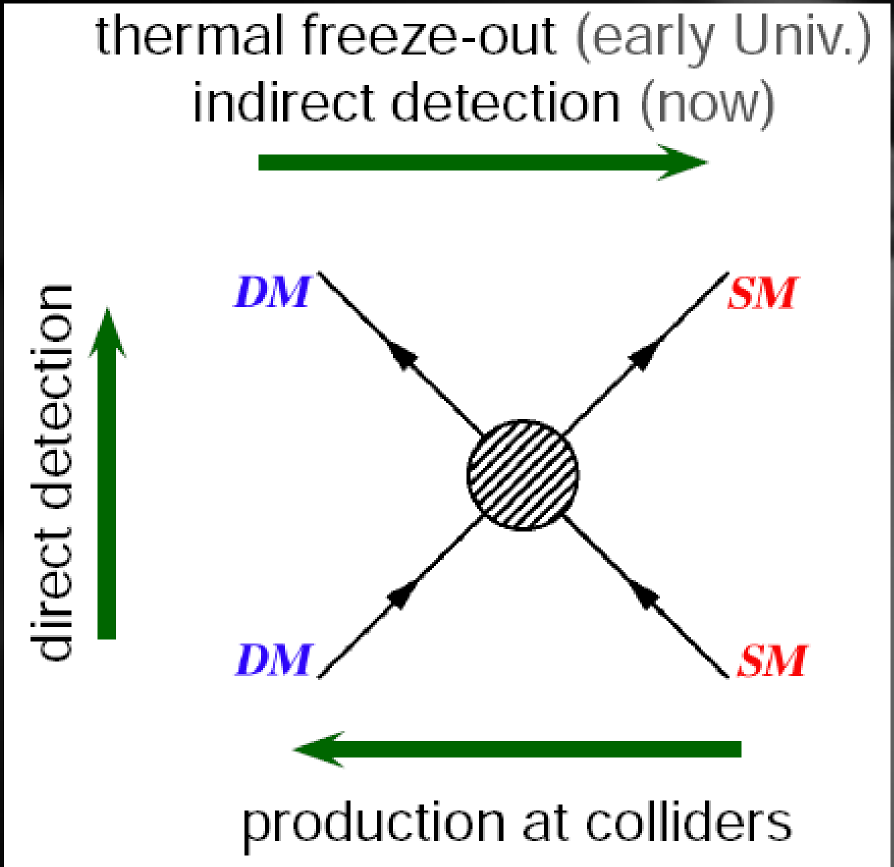
The Large Underground Xenon (LUX) Experiment

An Overview

The Goal: Directly Detect Dark Matter

- We theorize the existence of dark matter based on its gravitational effects. We currently have no other evidence of its existence, or its nature.
- Through direct detection we hope to verify its existence (as opposed to modified gravity theories) as well as learn about its properties (mass, interaction strength, etc).
- Direct detection is when a DM particle scatters off of a normal particle.



The candidate: WIMPs

- The leading candidate for dark matter is a particle called the WIMP.
- WIMP stands for Weakly Interacting Massive Particle, so called because it interacts only via the weak force and via gravity.
- This is because in order to get the correct amount of dark matter out of the big bang in the simplest models requires a particle with a self interaction cross section at the weak scale.
- WIMPS are expected to have mass in the 100GeV range. This makes Xenon an ideal detection medium, having mass ~120GeV.

The Detector: LXe TPC

- Teflon Vessel containing liquid and gaseous Xenon
- PMT arrays at the top and bottom
- Biased wire grids provide electric field

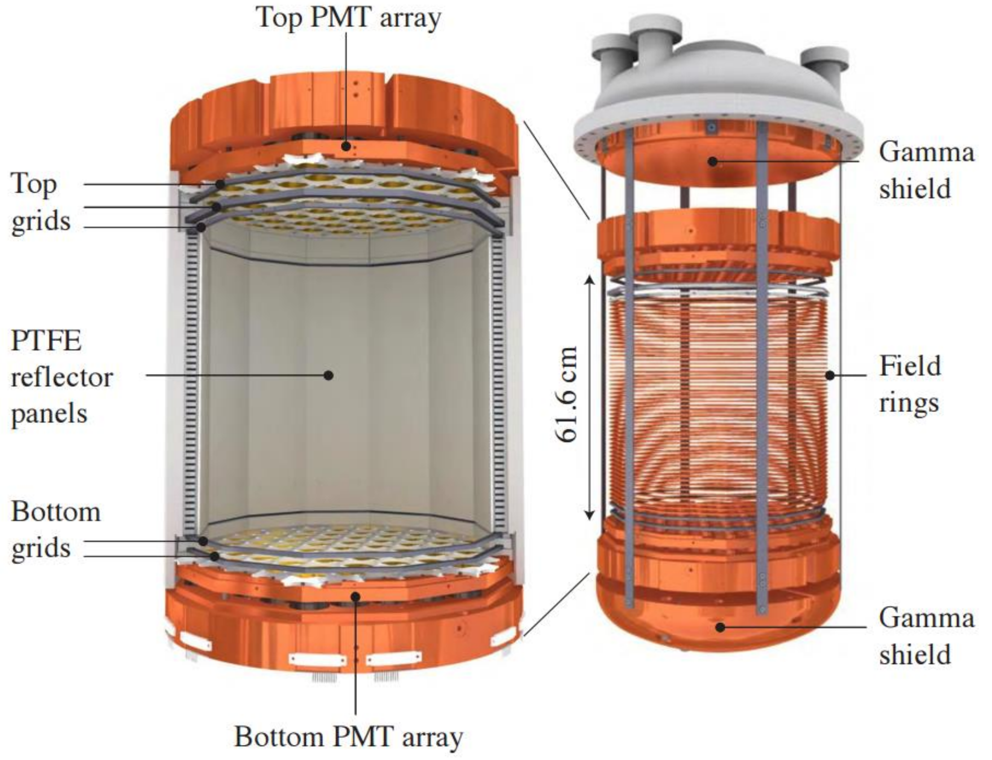
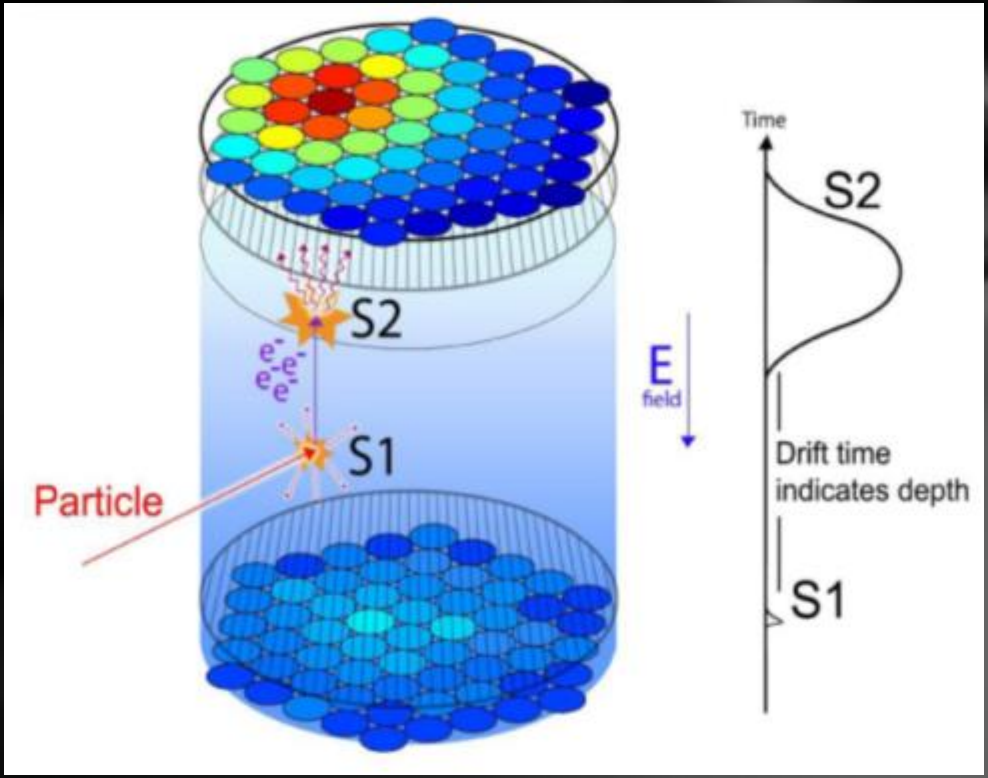


Figure 7: Rendering of the LUX TPC, supported from the top flange of the inner cryostat.

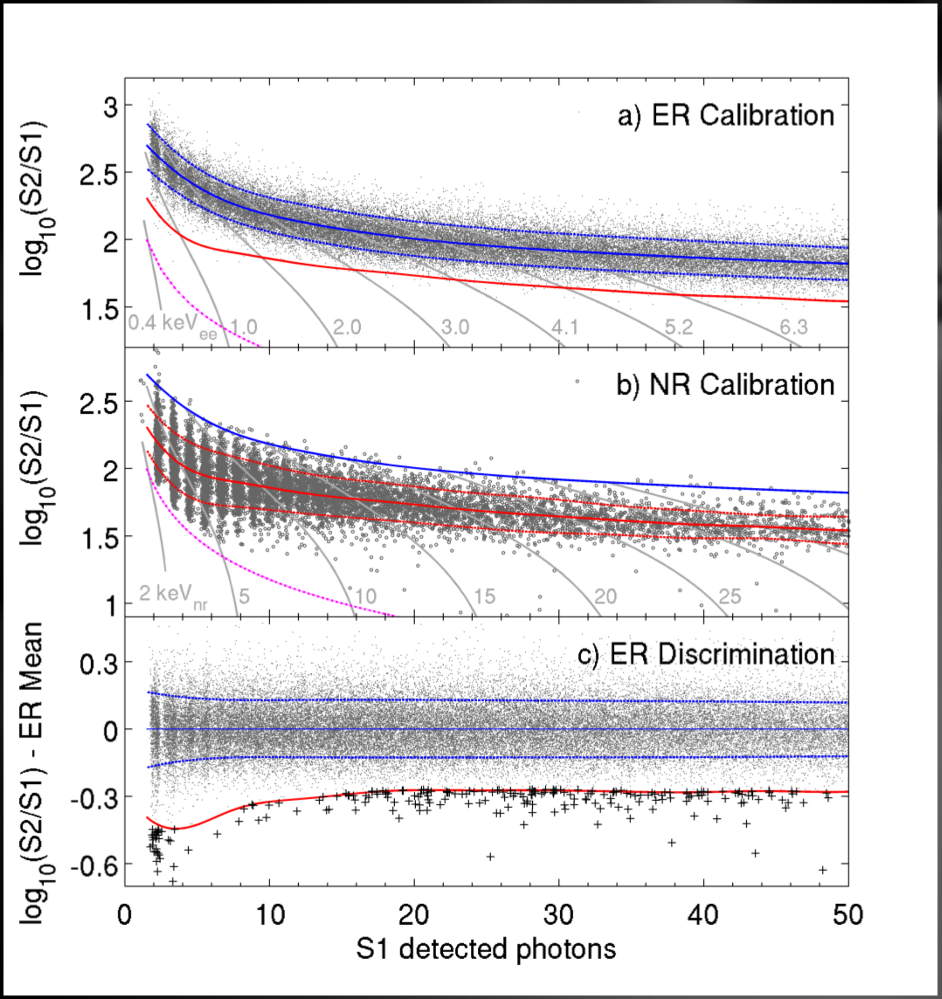
The Signal: Scintillation and Electroluminescence

- Interactions produce both excited Xe molecules (Xe_2^*), and Xe ions (Xe^+).
  - Xe_2^* relaxes to produce scintillation (S1) (175 nm photons).
  - e^- from ionization can do two things:
    - recombine to form Xe_2^*, then scintillate
    - or drift to the surface and cause electroluminescence (S2) in the gas (the e^- further excite Xe gas and that scintillates)
- The pattern of light on the PMT arrays along with the delay between the S1 and S2 signals tell us where the event took place.



Signal Types: Electron vs Nuclear recoils

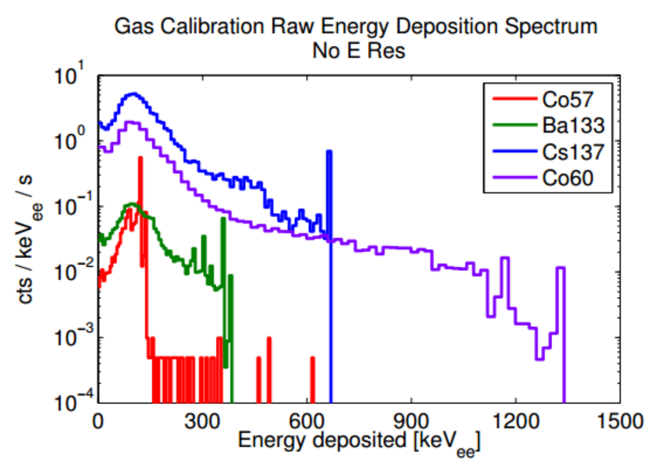
- Charged particles and photons produce electron recoils.
- Non-charged particles (like WIMPS and neutrons) produce nuclear recoils.
- Electron recoils result in more ionization than nuclear.
- Because of this, their S2/S1 ratio is higher which can be used to distinguish between them.



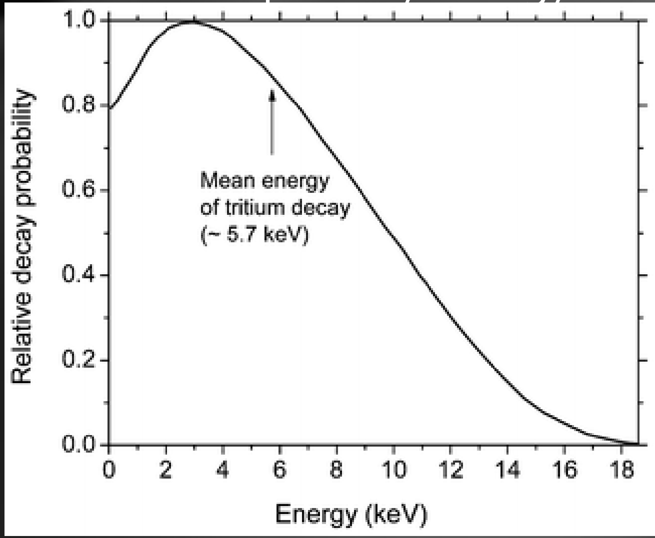
Calibration: Electron Recoil

- We use a range of γ-ray sources to determine the shape of the ER band. Most of these are deployed externally and only penetrate the outer edge of the detector.
- Two sources are injected directly:
  - Tritium (^3H) in the form of CH_3T - a β source at < 18.6 keV (mean e^- energy of 5.7 keV)
  - ^{83m}Kr - A metastable excited state of Krypton which emits two γs at 41.6 keV and 9.4 keV.

External Source Spectra



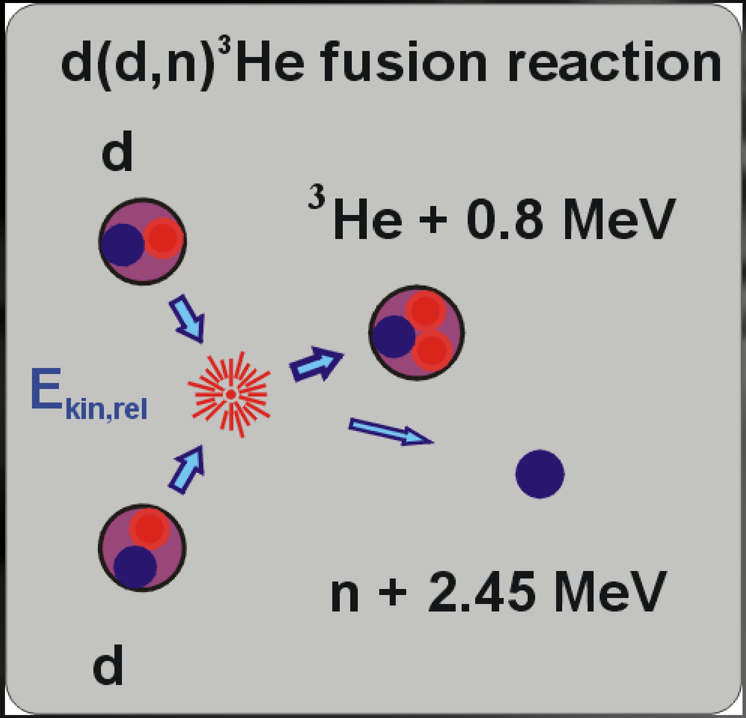
Tritium β Decay Energy



http://i1.wp.com/physicsopenlab.org/wp-content/uploads/2016/02/trizio.gif

Calibration: Nuclear Recoil

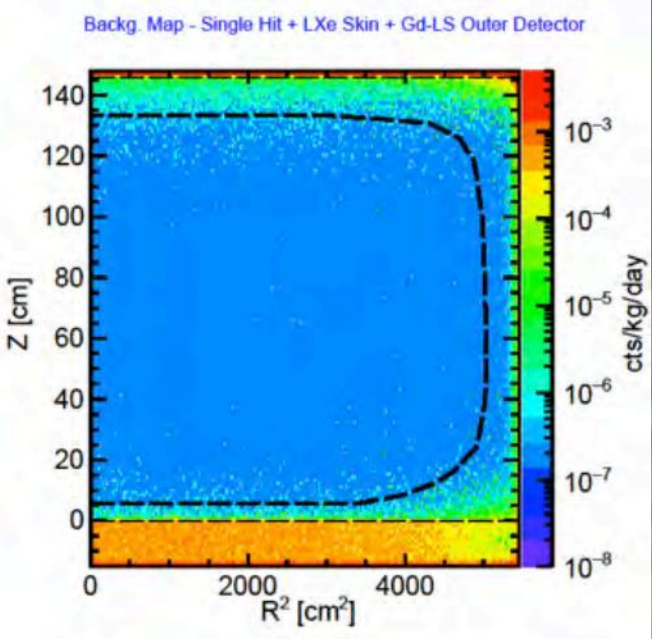
- We use a Deuterium-Deuterium (DD) neutron generator to map out the NR band.
- The neutrons are monoenergetic with 2.45 MeV kinetic energy.
- This creates a energy deposition spectrum out to ~74 keV, covering the expected WIMP region.

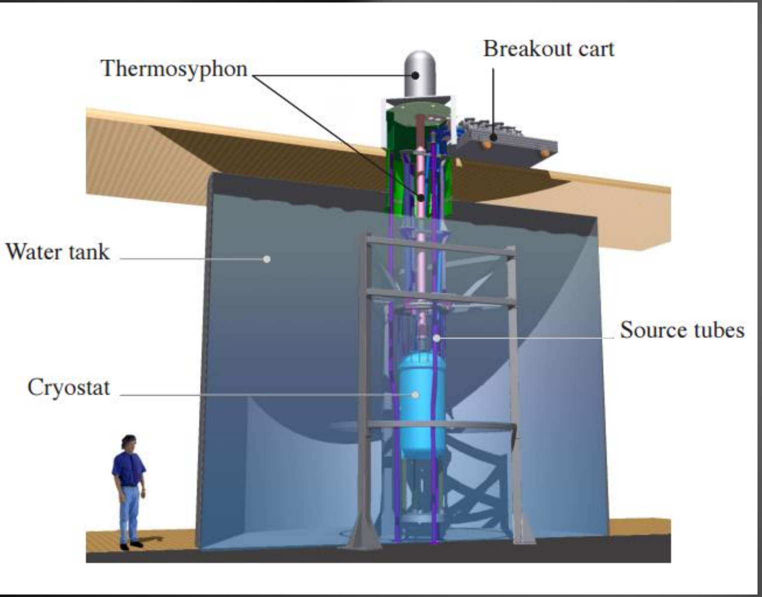


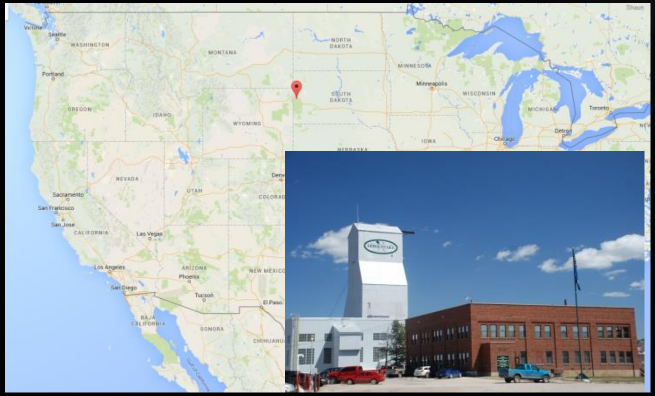
http://www2.mpq.mpg.de/lpg/research/neutrons/neutrons.html

Backgrounds:

- We mitigate the background from cosmic rays by retreating underground to the 4850’ level at the Sanford Underground Research Facility in Lead, SD.
- The ground is also radioactive, however, so we need a water tank to shield against radiation from the cavern walls.
- The detector components themselves also emit radiation so we only use the innermost portion of the Xe to look for WIMPs.







Results & Progress

- Our first real search was a 90 day run (called run03). Which produced the best spin independent limit at that time.
- After the fact, we refined calibrations and analysis techniques and produced a new limit with the same data from Run03 which we call the "Run03 Reanalysis" which is the current leading spin independent limit.
- Run04 is an additional 210 live-day run that just finished earlier this month.
- We are in the process of final calibrations and analysis of this data.