LZ - The search for Dark Matter

(using simulated LZ data)

LIP Summer Internships

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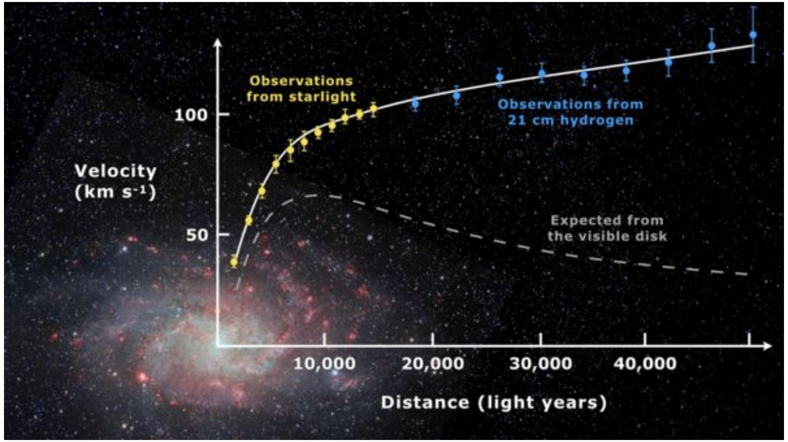
Dark Matter

Constitutes about 85% of the matter in the Universe. **Weakly Interacting Massive Particles** (WIMPs) are hypothetical particles, a proposed candidate for dark matter.

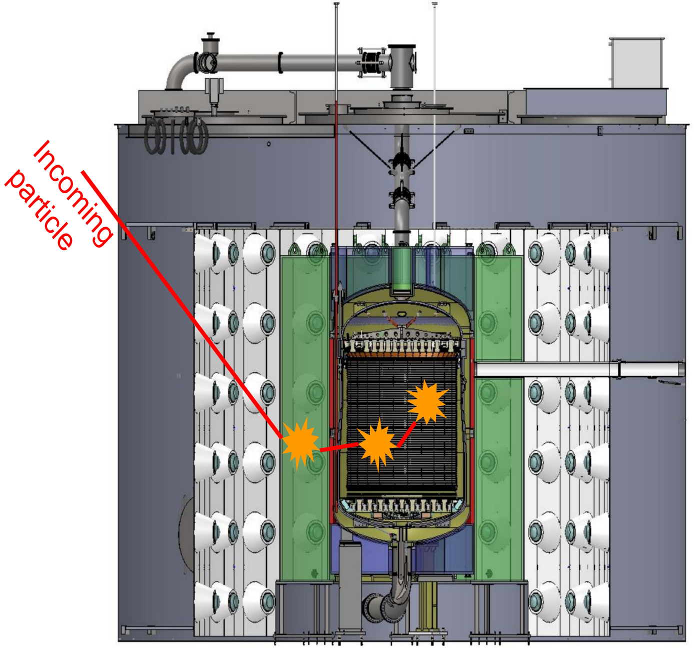
Proofs of existence:

- Galaxy rotation curves
- Cosmic Microwave Background
- Gravitational lensing

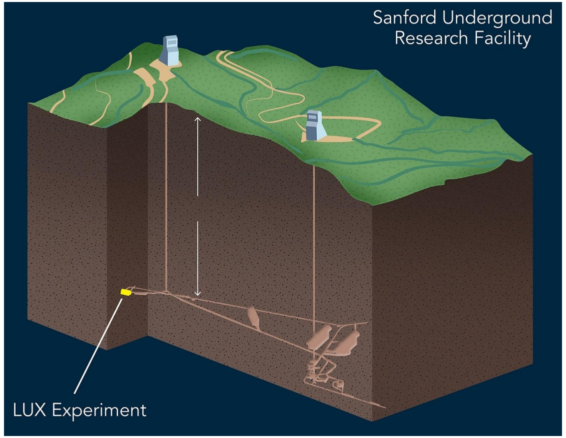


Requirements for Rare Events Search

- Low energy threshold
- Good position resolution
- High amount of target mass
- Ultra low background environment



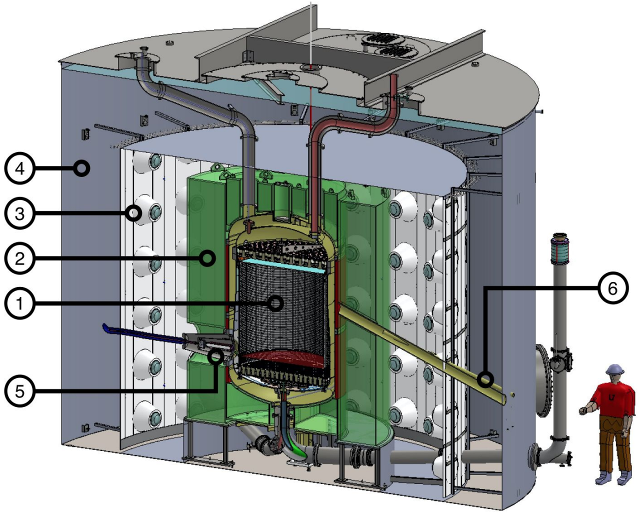
What is the *LUX-ZEPLIN* (LZ) experiment?



- A 10-tonne liquid Xe dark matter detector with ultra-low background.

- It is located at 1478 m underground in a gold mine in Lead, South Dakota.

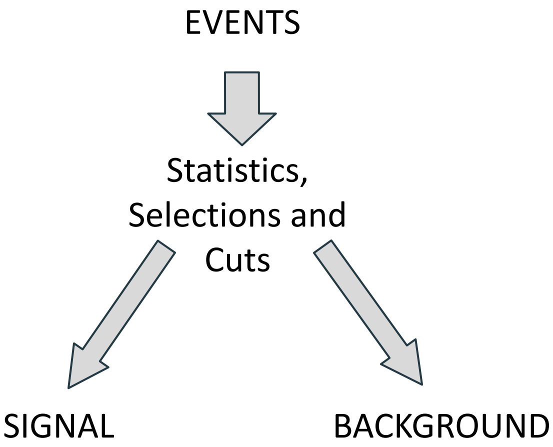
- Its low background makes it extremely sensitive to rare events or decays.

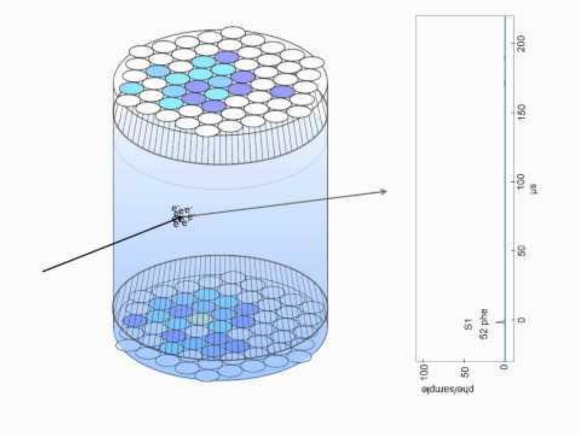


How do we find Dark Matter?

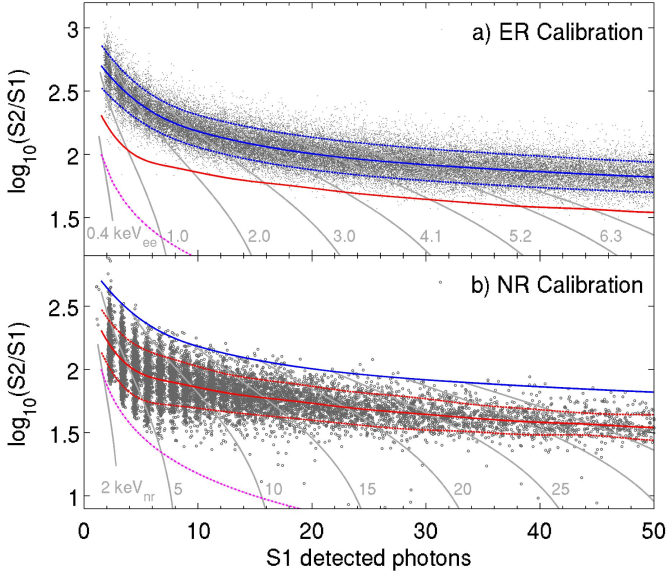
1. An energy deposition in the LXe produces **prompt scintillation light (S1)** and ionization electrons.

2. The electrons that do not recombine are drifted to the liquid-gas interface and extracted into the gas phase, creating **electroluminescence light (S2)**





Electron and Nuclear Recoil Descrimination

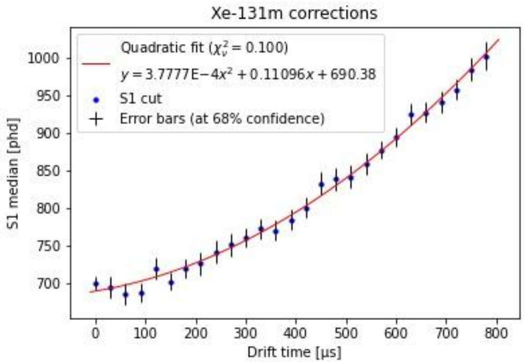


The **ratio of S1 and S2 light** can be used to distinguish between particles interacting with atomic e^- or the nucleus.

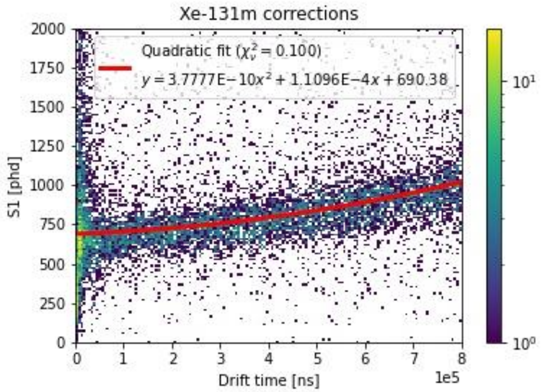
- Electron recoils (ER) are produced by γ-rays, betas and neutrinos.
- Nuclear recoils (NR) are produced by **neutrons**, alphas and hopefully WIMPs.

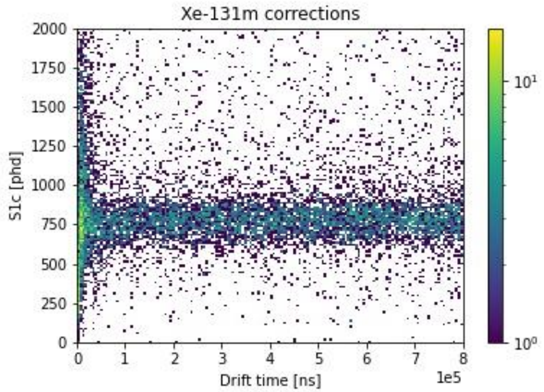
Rejection efficiencies are typically **>99.5%** for ER events under the NR median.

Correcting for depth dependence (S1)

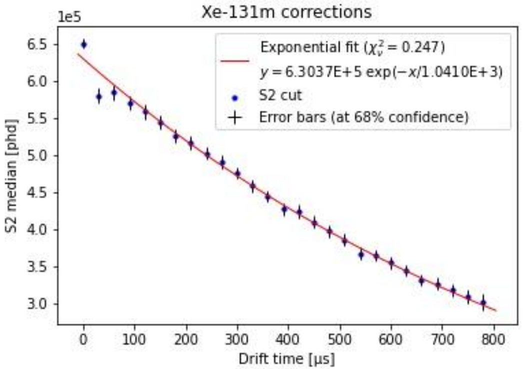


- LZ data is originally depth-dependent (drift time ⇔ depth):
  - in-liquid impurities
  - light-collection efficiency
  - variations in the quantum efficiency of the PMTs
- We want depth-independent (corrected) data that's easier to work with
- How: using a correction function obtained from the median data fits (left), here exemplified with Xe-131m





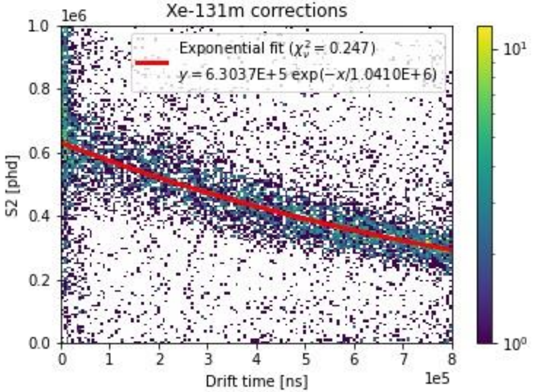
Correcting for depth dependence (S2)

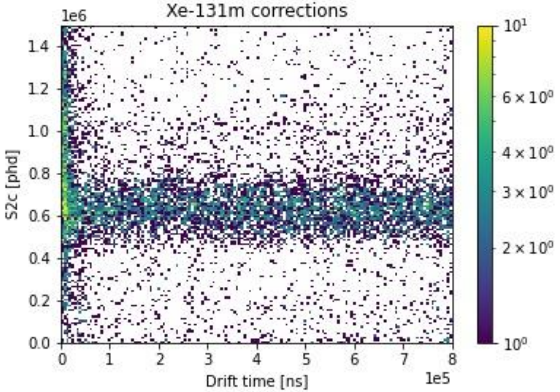


- From the S2 fit, we can also obtain the electron lifetime in the detector:

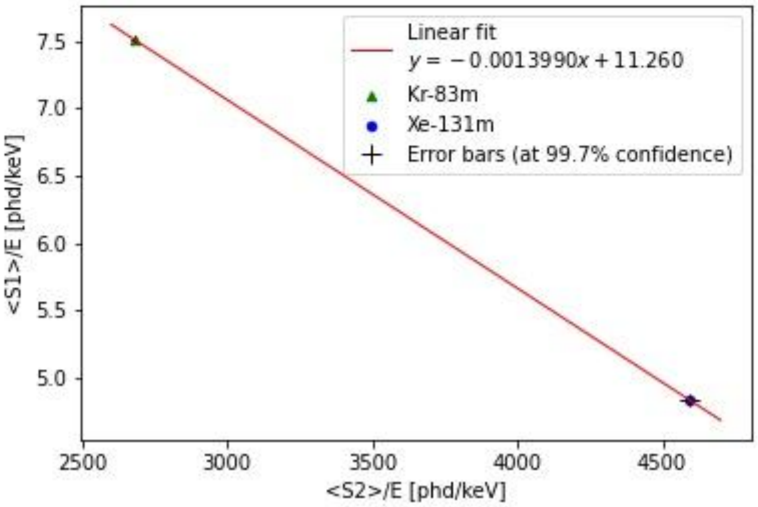
$$f(x; a, b) = a\exp(-x/b)$$

where b is the electron lifetime (b = 1041 μs).





Energy Reconstruction



$$E = \frac{W_q}{L\left(E\right)}\left[\frac{S1}{g_1} + \frac{S2}{g_2}\right]$$

- $W_q \approx 13.7$ eV
- L(E) = 1 (for ER)
- E energy from decay
- S1 photons from scintillation
- S2 free electrons from ionization
- g1, g2 gain factors (what we want)

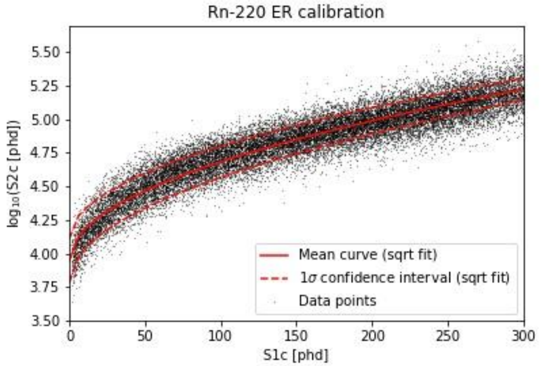
g1= 0.154 (phd/ph) → 15.4% probability of detecting an existing photon
g2= 110.36(phd/e)

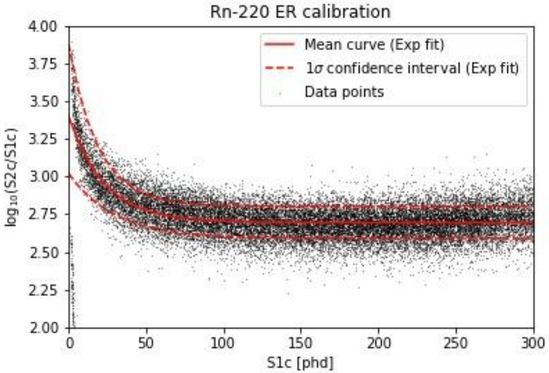
Detector calibration (ER)

- The detector requires calibration in the electronic and nuclear recoil regions (ER and NR, respectively)

- This allows us to discriminate the ER and NR regions in the actual LZ data

- ER calibration using Rn-220 injections (α and β decays)

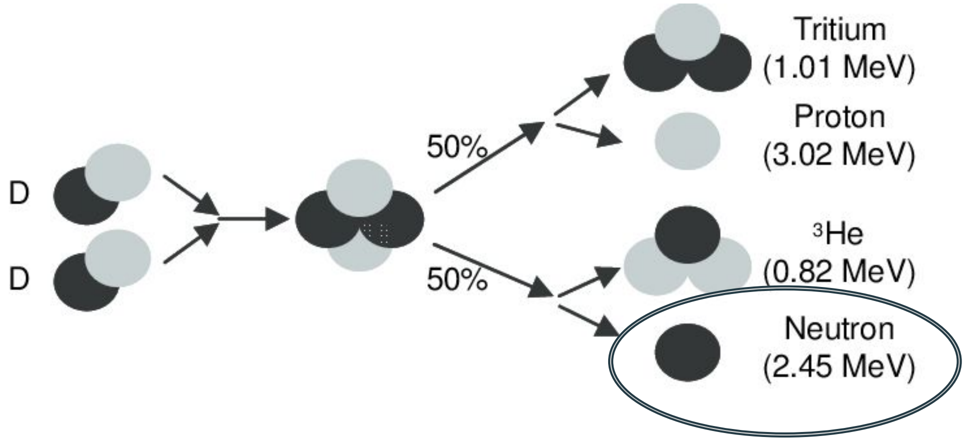




Detector calibration (NR)

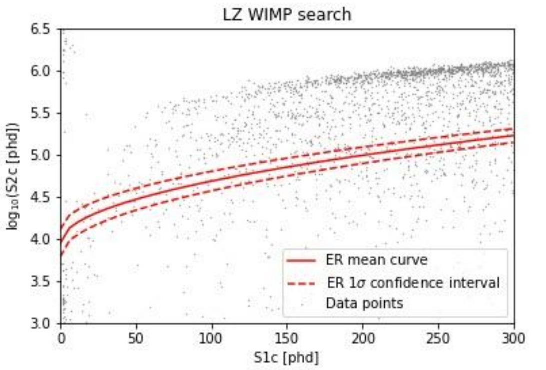
- NR band is obtained using 2.45 MeV neutrons emitted in the D-D fusion reaction

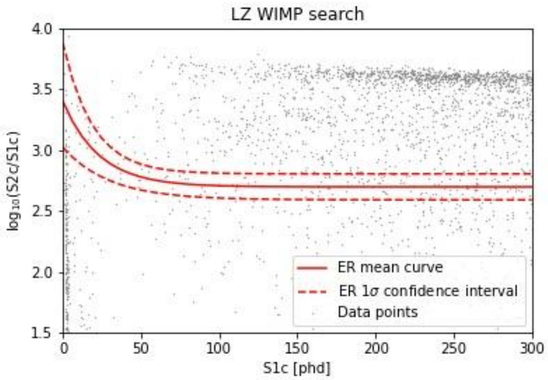
  (still a work in progress)



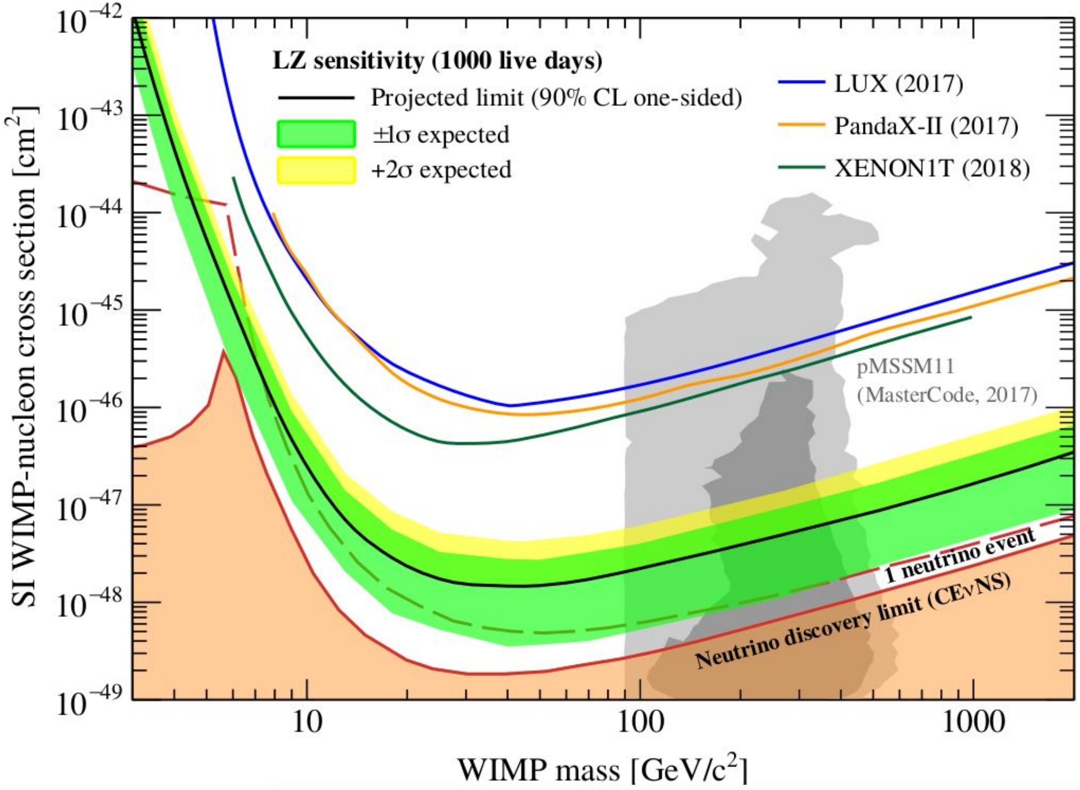
WIMP search data

- The previous ER calibration is overlapped with scatter plots of (uncut) WIMP search data from a 4-day run of the detector





Projected sensitivity of LZ



The End

Questions?