Results/Prospects from LZ

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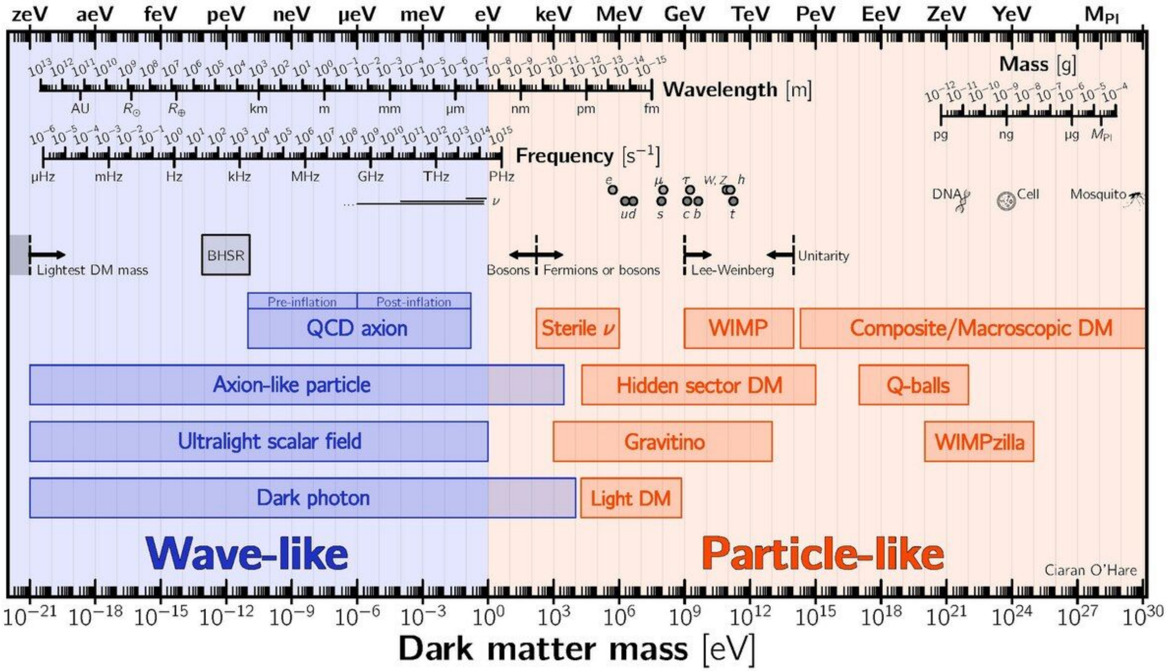
Outline

- Overview of Dark Matter
  - WIMPS
- How WIMPS are detected
- How the LZ Detector works
  - Design/Specifications
  - Particle Collision Scenario
- Results
- Future Prospects

Overview of Dark Matter



- Proof for dark matter exists from mass reconstruction, CMB comparisons, etc.
- Numerous models exist to describe this phenomenon
- Accounts for around 85% of universe matter content

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Dark Matter Interactions

- Can only interact with SM particles via gravity or other weak interactions
  - Must be nearly charge neutral as a result
  - Most can’t be made of baryons
- Density can’t be very large (order of ~0.4 GeV/cm^3) [Queiroz]
- Must be moving non-relativistically (10^{-3} c)
- No strong interactions with itself

WIMPS

- Weakly Interacting Massive Particles
- Mass Range: GeV to TeV
- Scattering Cross Section (low momentum transfer) [Queiroz]:

$$\sigma_{\mathrm{SI}}^{M} = \frac{4\mu_{\chi A}^{2}}{\pi}\left[\lambda_{p}^{M} N_{p} + \lambda_{n}^{M} N_{n}\right]^{2} .$$

- Can annihilate into SM particles
- One particle dark matter model

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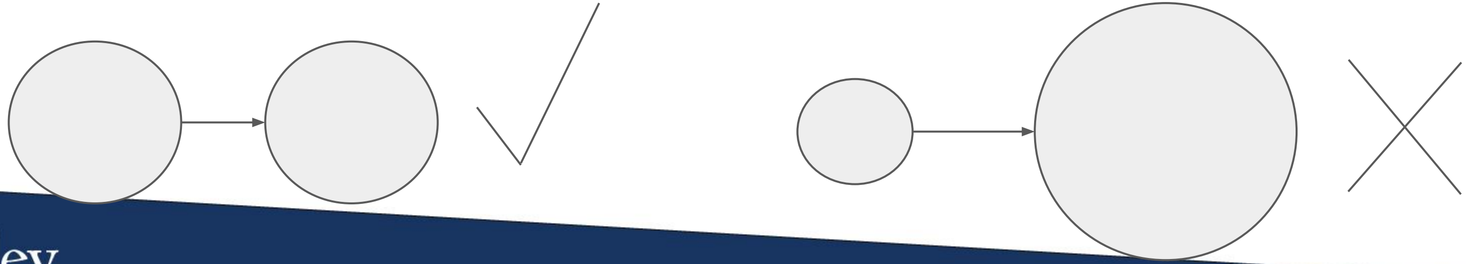
Direct Detection

- WIMPS detected via collisions with ordinary matter
  - Scintillation photons from recoiling track from target nucleus
  - Ionized electrons from track of recoiling nucleus
  - Heat

Scintillator

- Scintillator - type of material that absorbs energy and emits photons
- Liquid xenon used for a variety of reasons
  - Noble gas
  - No long lived radioactive isotopes (Xe124 and Xe136 have low decay rates)
  - Comparable nucleus mass to WIMP mass (120 GeV)
- Two kinds of scintillation light
  - S1 - when particle first comes into contact with xenon nuclei
  - S2 - electrons produced from initial collision traveling through gas near top PMT array



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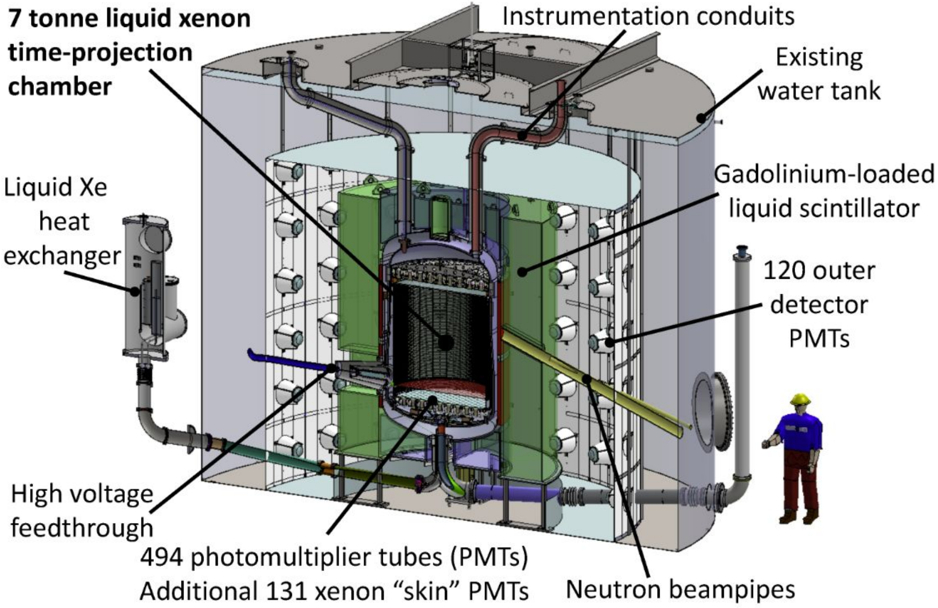
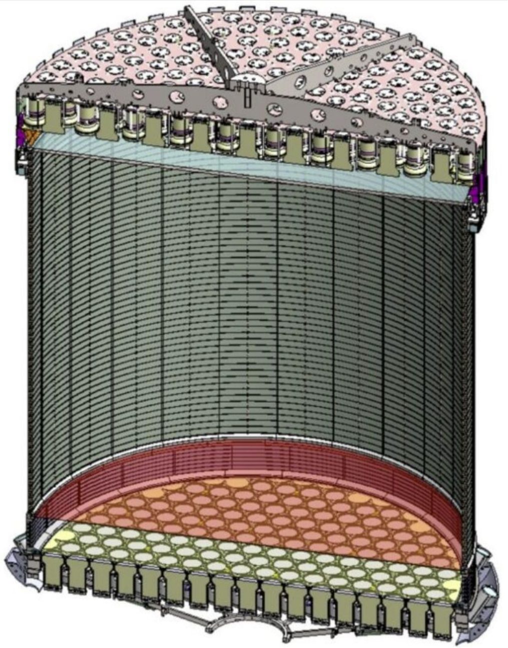
What is LZ?

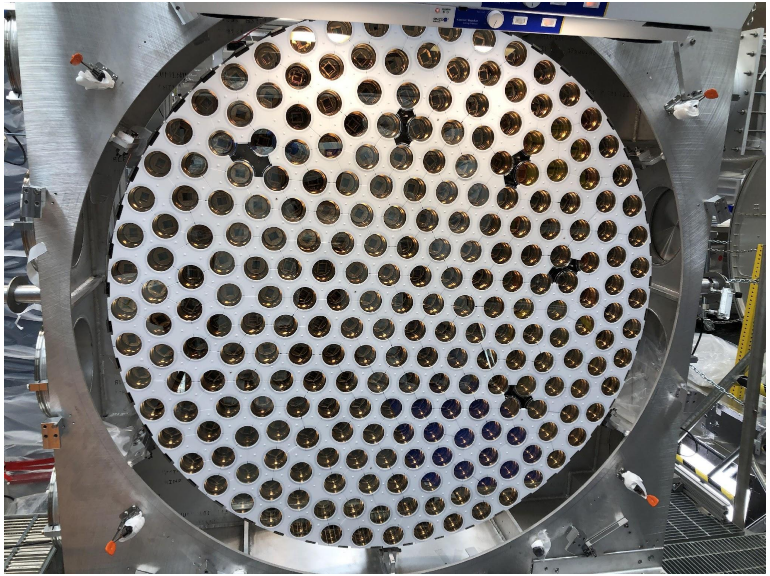
- Dual phase xenon detector
- Built to detect WIMPS
- Utilizes liquid xenon as scintillator
- Records photons produced in scintillator as waveforms via PMT arrays

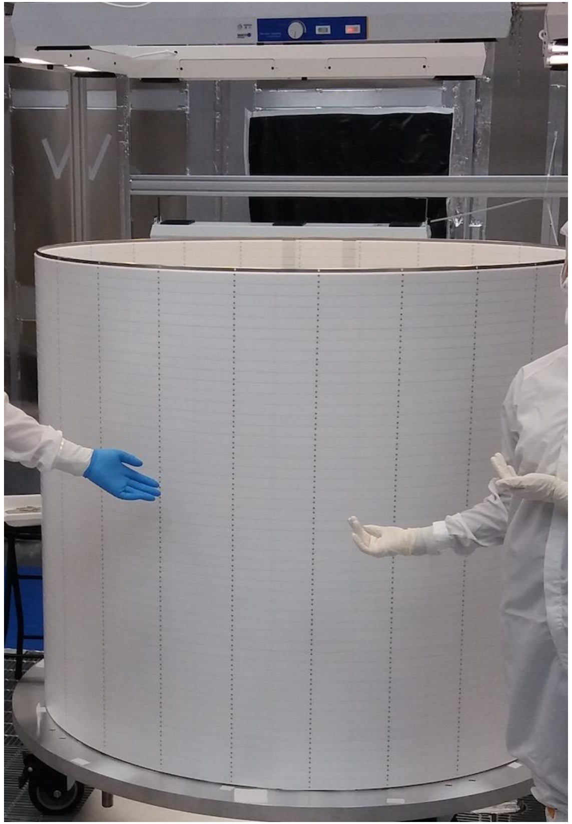
LZ Detector Design





Building LZ





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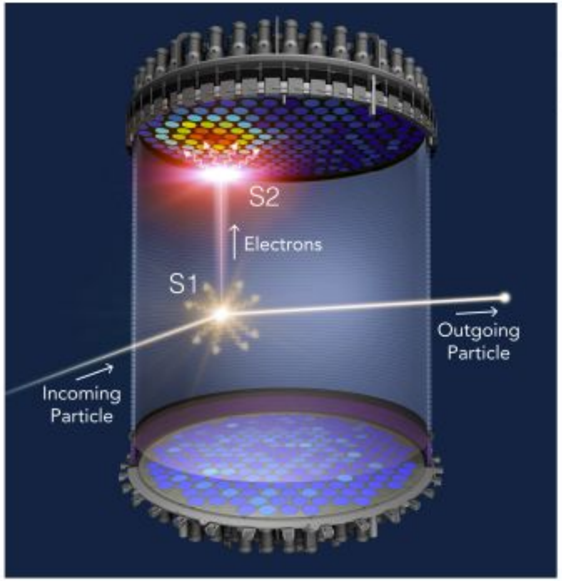
Particle Collision



- Particle coming in hits a xenon nucleus, producing photons (S1) and electrons
- Electrons drift upwards due to external electric field, more photons produced above gas-liquid barrier near top PMT array
- Light pulses recorded via PMTs, producing waveforms

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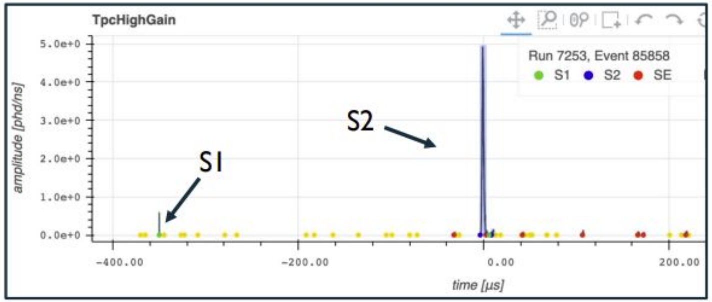
Sample Waveform



- Typical S1 signal will be smaller than S2 as the S2 signal is multiplied
- Time delay between S1 and S2 gives a sense of the event's depth
- S2 signal location gives x and y coordinates

First Results

First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment

J. Aalbers,[1,2] D.S. Akerib,[1,2] C.W. Akerlof,[3] A.K. Al Musalhi,[4] F. Alder,[5] A. Alqahtani,[6] S.K. Alsum,[7]
C.S. Amarasinghe,[3] A. Ames,[1,2] T.J. Anderson,[1,2] N. Angelides,[5,8] H.M. Araújo,[8] J.E. Armstrong,[9] M. Arthurs,[3]
S. Azadi,[10] A.J. Bailey,[8] A. Baker,[8] J. Balajthy,[11] S. Balashov,[12] J. Bang,[6] J.W. Bargemann,[10] M.J. Barry,[13]
J. Barthel,[14] D. Bauer,[8] A. Baxter,[15] K. Beattie,[13] J. Belle,[16] P. Beltrame,[5,17] J. Bensinger,[18] T. Benson,[7]
E.P. Bernard,[13,19] A. Bhatti,[9] A. Biekert,[13,19] T.P. Biesiadzinski,[1,2] H.J. Birch,[3,15] B. Birrittella,[7]
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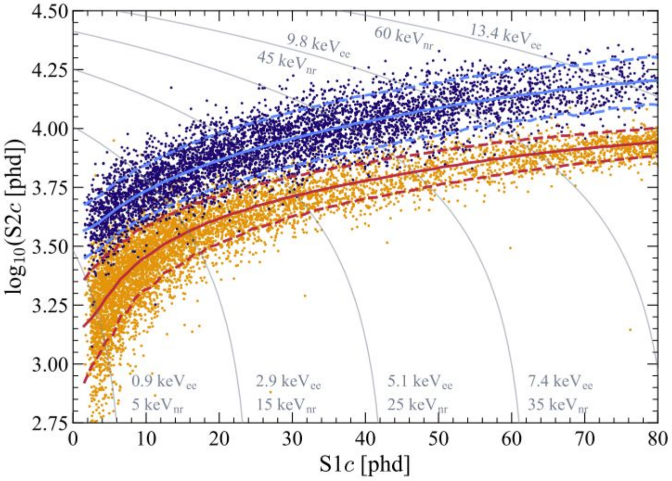
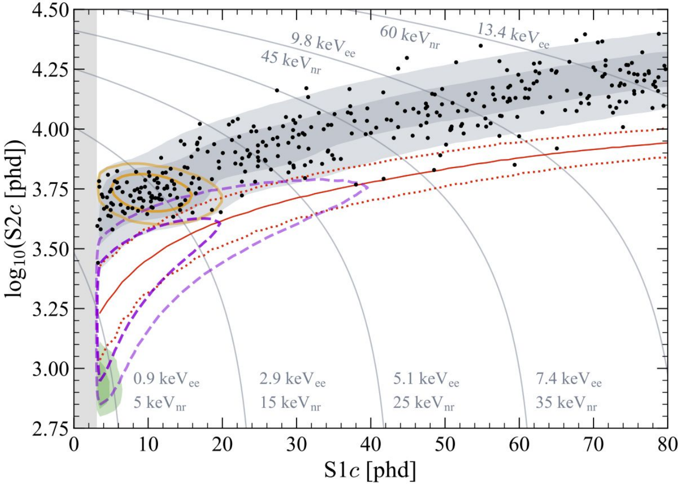
- First results published in 2023
- Nuclear-recoil calibration done via DD, AmLi, and YBe neutron sources
- Electron-recoil calibration done via sources such as tritium (beta decay)

First Results





- Left: Overlay of calibration data (tritium in blue, DD in orange)
- Right: Observed WIMP-search data (60 out of 1000 live planned days)

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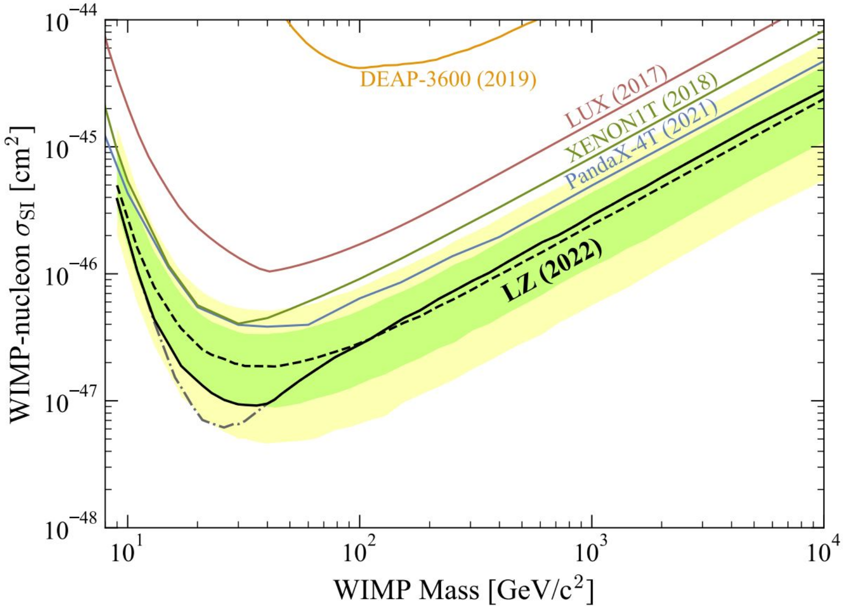
First Results



- Sensitivity lost for extremely large/small WIMP masses
- WIMP mass tested from 9 GeV to 10 TeV
- Most sensitive WIMP search to date
- Still currently collecting more data

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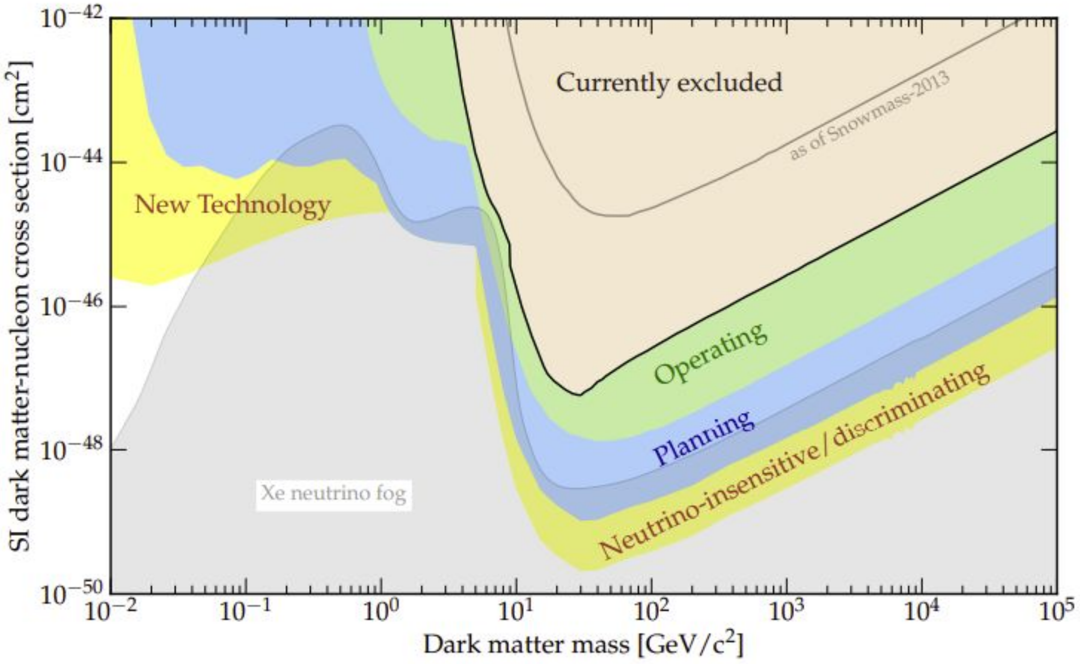
Prospects



- Planning to increase the exclusion space [Chou, Soares]
- Extend space to around green region
- Increase sensitivity to approach neutrino fog region
- Unique detectors utilizing liquid helium can fill in new technology band

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Sources

- Queiroz, F. S. (2017). WIMP Theory Review. *arXiv [Hep-Ph]*. Retrieved from http://arxiv.org/abs/1711.02463
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- Chou, A. S., Soares-Santos, M., Tait, T. M. P., Adhikari, R. X., Anchordoqui, L. A., Annis, J., … Tanedo, P. (2022). Snowmass Cosmic Frontier Report. *arXiv [Hep-Ex]*. Retrieved from http://arxiv.org/abs/2211.09978

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