Dark Matter Observatories: (X)LZ(D)

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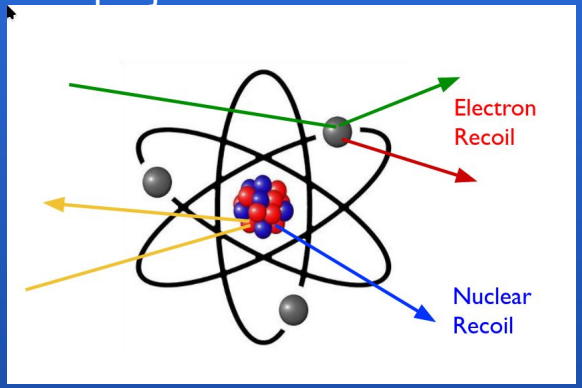
What is dark matter ?

- To our current best knowledge 85% of the matter in the universe is of an unknown form.
- The gravitational effects of dark matter can be seen in astronomical observations:
  - The picture shows the Bullet Cluster where two galaxy clusters have collided head on.
  - Gravitational lensing, the distortion of background images by mass in the cluster, reveals the mass of the cluster is dominated by dark matter (blue).
- Particle properties remain unknown - direct detection would allow us to study these properties.

How are we looking for it ?

- LZ is looking for Weakly Interacting Massive Particles (WIMPs)
- The detector is based on a dual-phase liquid xenon time projection chamber.



Electrons and gammas interact with atomic electrons, producing electron recoils (ER).

WIMPs (and neutrons & solar neutrinos) interact with Xenon nuclei, producing nuclear recoils (NR).

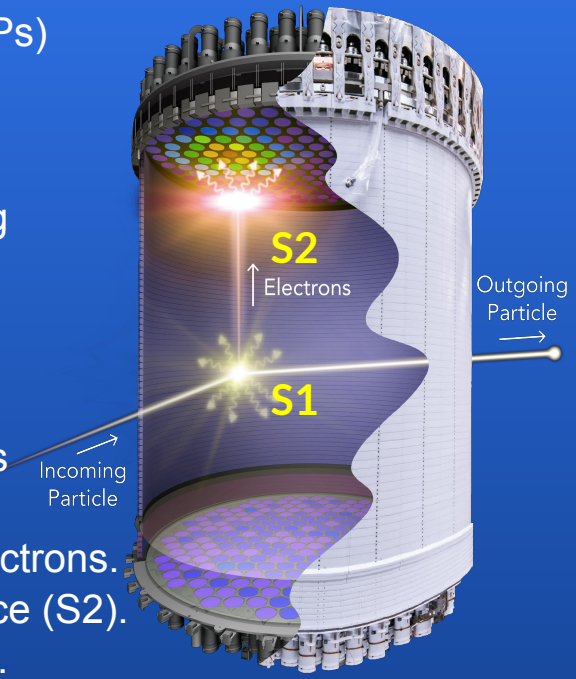


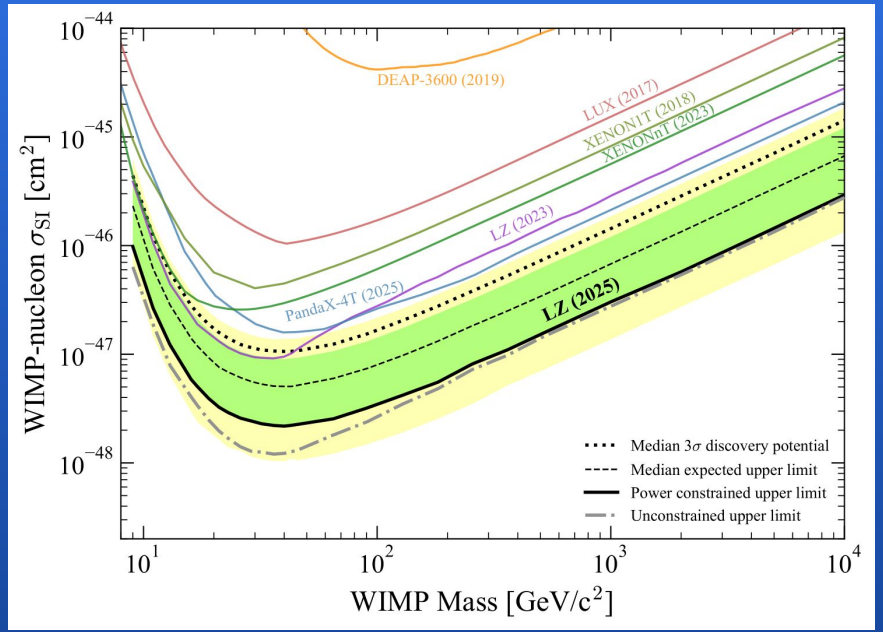
Image credit: G. Blockinger (LZ)

- Interactions produce scintillation light (S1) and ionization electrons.
- Electrons drift to gas phase and produce electroluminescence (S2).
- ER and NR reactions are distinguished by their S2/S1 ratios.
- Location deep underground (~1.5 km) at the Sanford Underground Research Facility in South Dakota (USA), provides low a background environment.

LZ Results: Best upper limit for WIMP-nucleon cross section

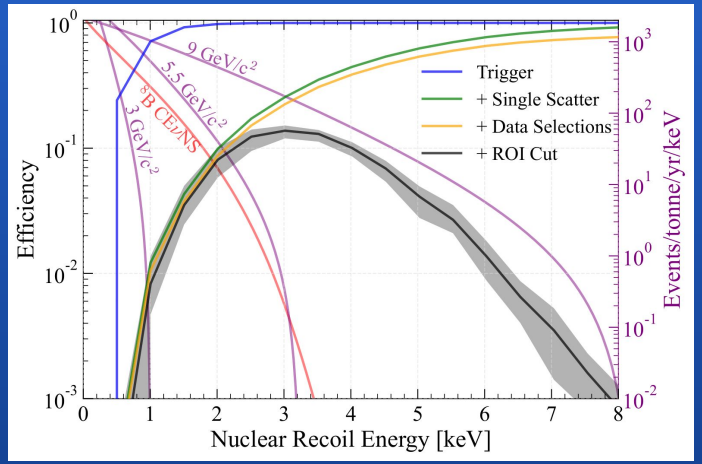
- Result covers WIMP masses between 9 GeV/c^2 and 100 TeV/c^2
- Plot shows upper limits (90% C.L.) on the spin-independent WIMP-nucleon cross section as a function of WIMP mass.
- The *swoosh* shape shape is mainly due to low mass WIMP candidates having lower, and therefore harder to detect NR energies and as the masses get higher, the number density becomes lower (fewer particles for the same fixed dark matter mass).

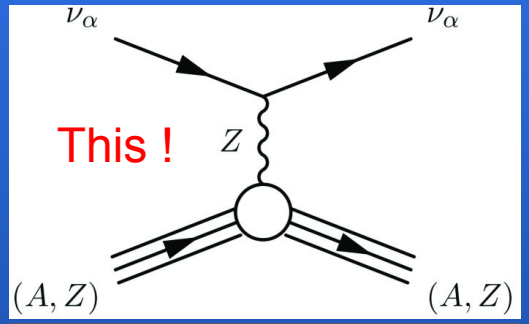
The full result can be found here: PRL, arXiv.

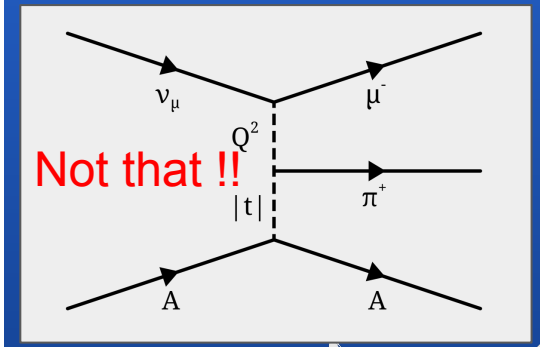


LZ results: Solar (Boron-8) neutrinos (CEνNS)

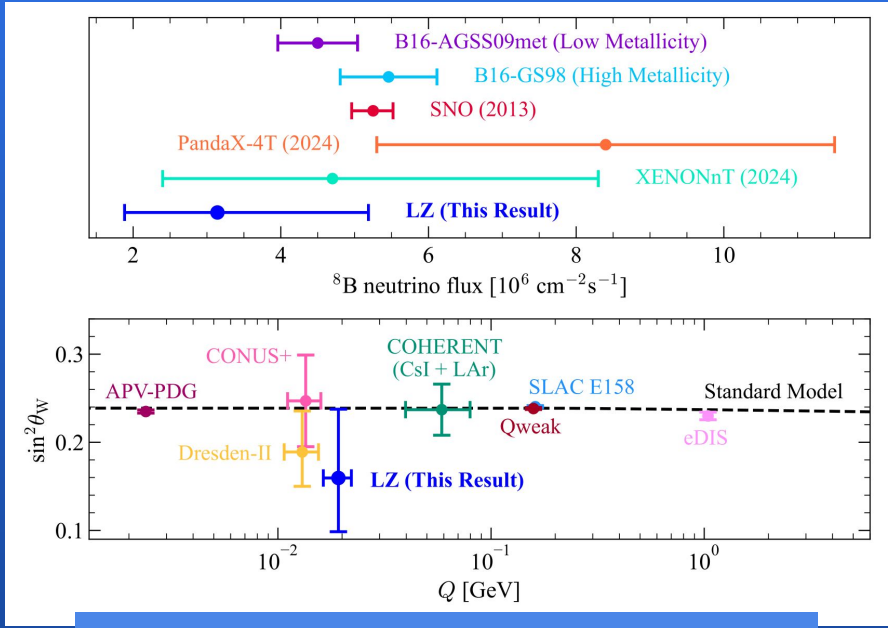
- Solar neutrinos can scatter coherently on atomic nuclei: ***C***oherent ***E***lastic ***N***eutrino ***N***ucleon ***S***cattering
- The difference in detection efficiency between solar neutrinos and WIMP masses < 5.5 GeV/c^2 can best be described as “uh-oh”.
- However:
  Solar neutrinos are interesting in their own right.





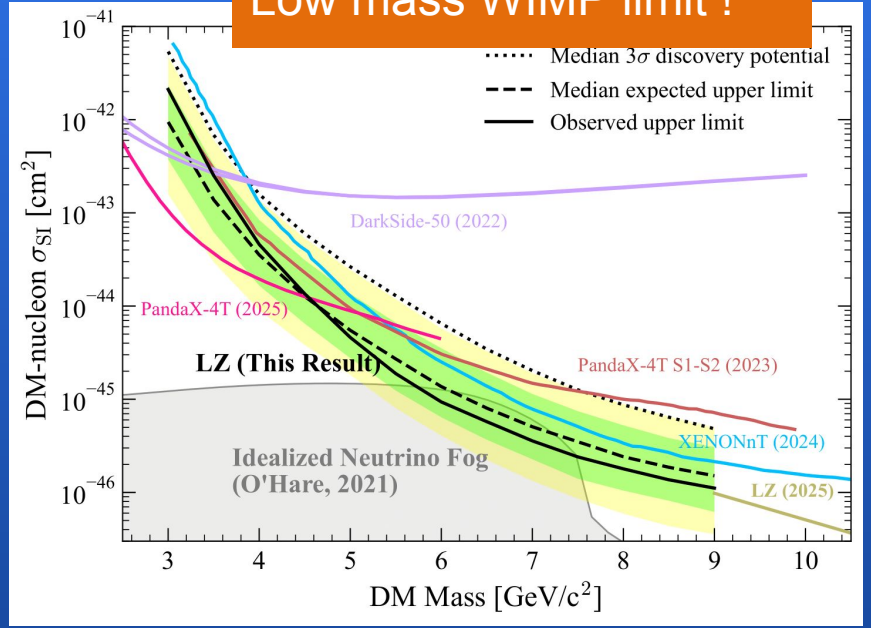


LZ results: Solar neutrinos and low mass WIMPs



Momentum transfer: Q = sqrt($2m_{Xe}E_r$)
θ_W: Weak mixing angle

Low mass WIMP limit !



Proof that LZ can see NR signals of astrophysical origins.

Full results can be found here: Preprint

LZ Computing

LZ has used GridPP/IRIS resources for **large scale processing campaigns.**

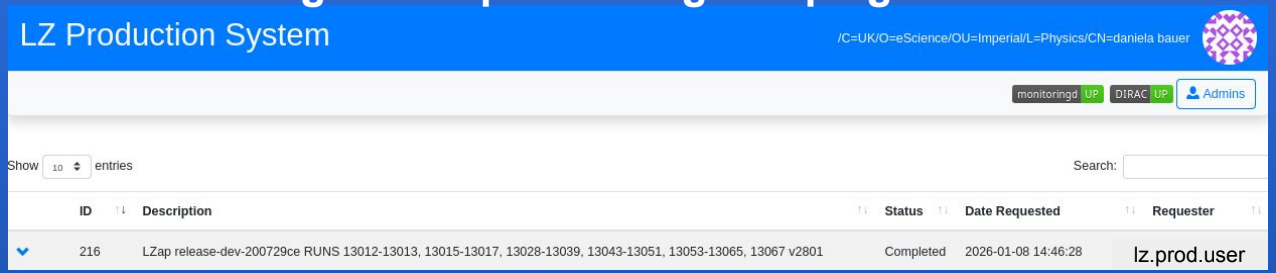
Facilitated by a web based custom workflow system.

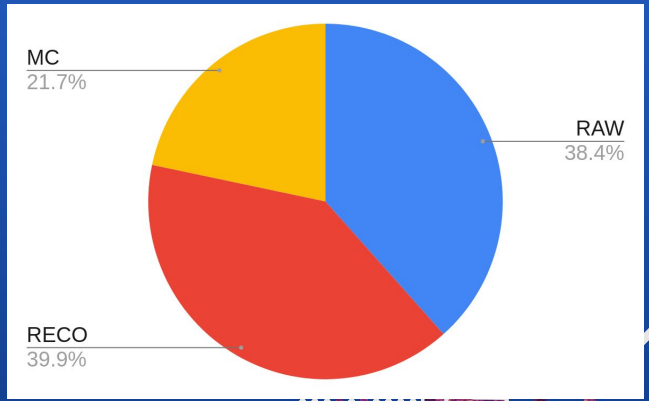
DIRAC used as a unified interface to grid & cloud resources: https://diracgrid.org/

IRIS currently hosts ~7.5 PB of LZ data.

The final data set is expected to comprise up to 12 PB.

User analysis has been performed at NERSC because users really like to share :-)



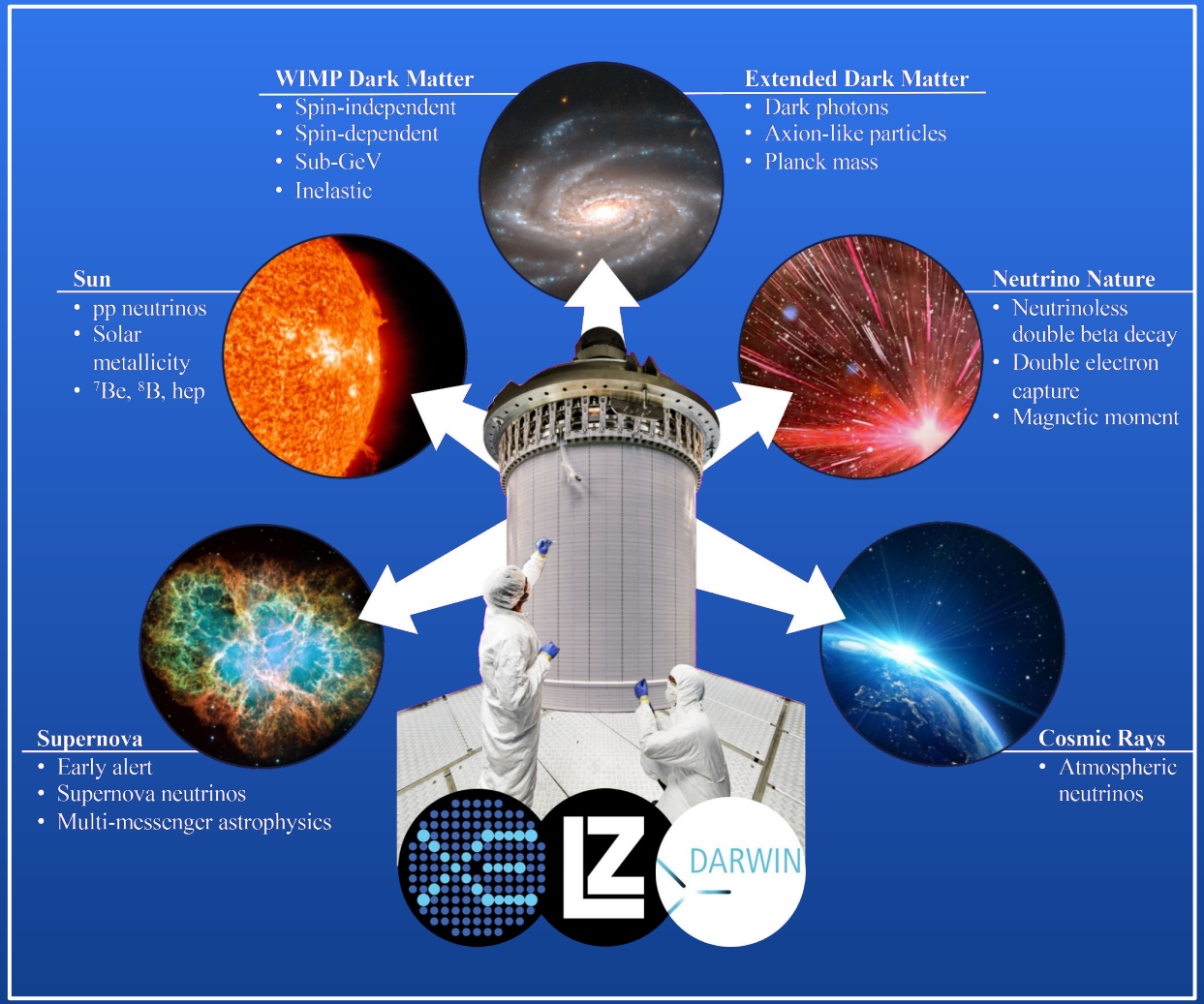


XLZD: A low background observatory for rare events

- XLZD is bringing together experts from the LZ and XENON experiments and the DARWIN R&D project
- The goal is to design a 60-80 tonne liquid xenon detector that forms the basis of a world leading low background rare event observatory.

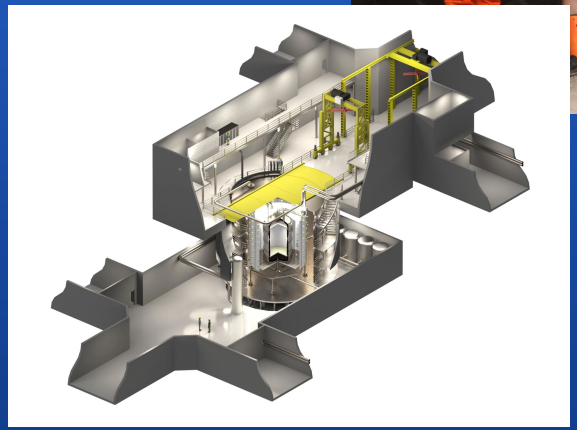

XLZD Collaboration, LNGS, Summer 2025

The XLZD physics programme



Possibly soon coming to the UK ?

- The UK is applying to host XLZD at the Boulby Underground Laboratory
- The Boulby Development Project aims to extend the current laboratory and would include a custom made hall for XLZD at 1300m underground
- XLZD@Boulby is already an IRIS Science Partner !
- Using IRIS' shared infrastructure decreases the risk of experimental delays impacting computing provisions



Conclusion

- Using IRIS resources LZ has achieved world leading WIMP-nucleon cross section limits.
- LZ is currently approved to run until the end of 2028; more results expected.

- Great chance for UK to host XLZD - and IRIS forms a core part of the UK bid.

Backup

LZ detector

[How it works]