Towards a Generation-3 Liquid Xenon Experiment

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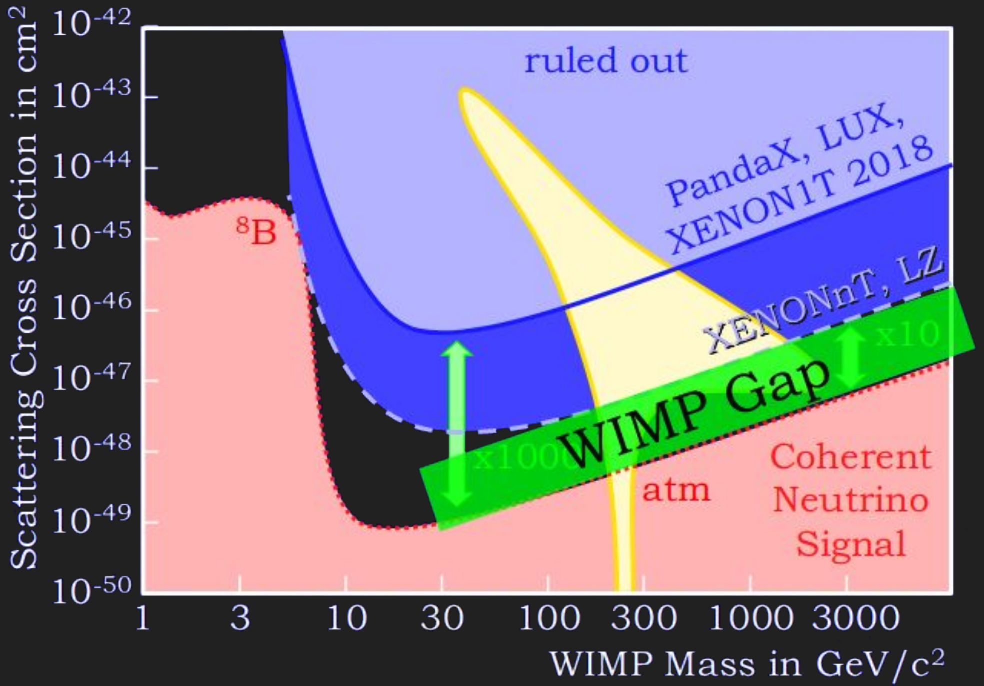
Down to the neutrino floor

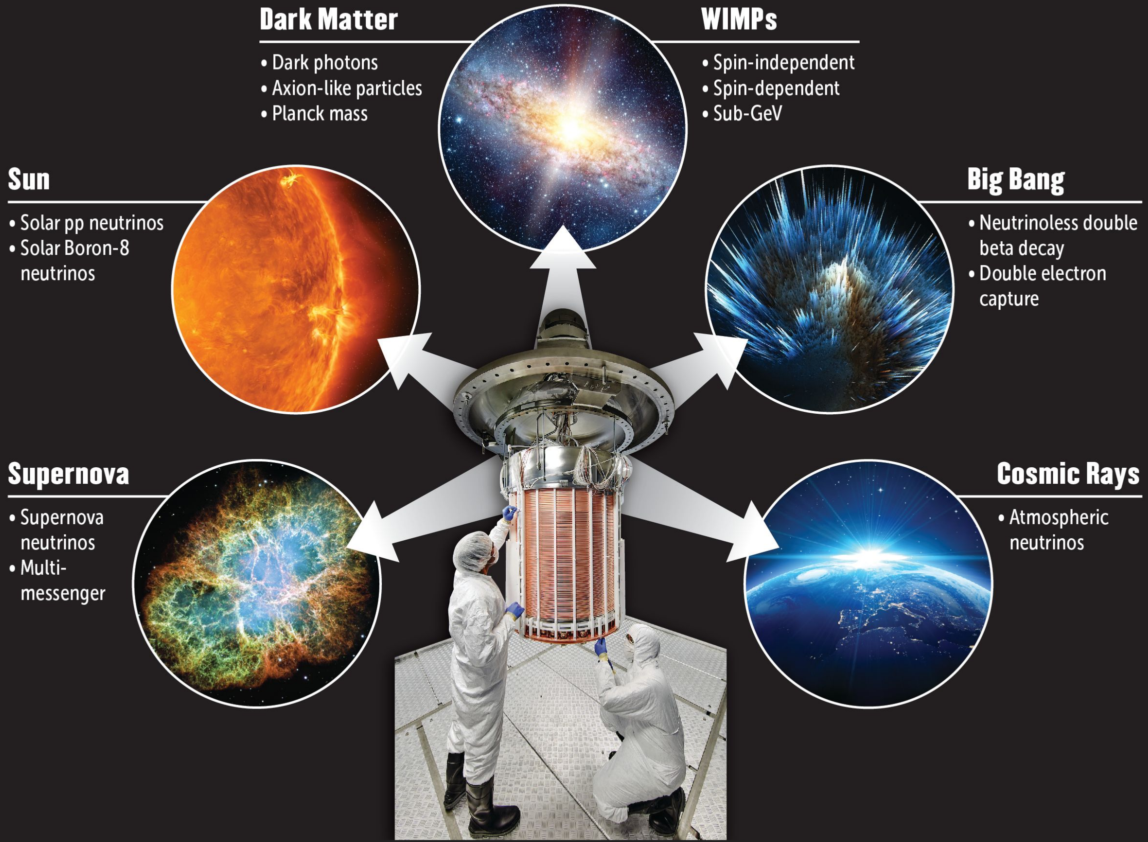
Xenon experiments lead the pack for WIMP detection, and next generation experiments leave parameter space unexplored above the neutrino floor

Another order of magnitude sensitivity required for a measurement of atmospheric neutrinos



Lang, DPF 2019

Other Science Cases for Generation-3



Lang, DPF 2019

Generation-3 Research Directions

- **Radon Reduction**
  - Radon Distillation/Filtration
  - Surfaces and Coating
  - Hermetic TPC
- **Hermetic TPC**
  - Structural Materials
  - Wavelength Shifting Coatings
- **Xenon Purification**
  - Online liquid purification
  - Hermetic TPC
- **High Voltage**
  - Electrodes, Surface Coatings, Drift Field Uniformity, Feedthroughs
- **Signal Collection**
  - Photon Detection, Localization
- **Data Acquisition**
  - Software Trigger, Data Reduction
- **Single Electron Background Reduction**
  - Identification
  - Mitigation

Radon Reduction

Rn daughters (214Pb) produce the majority of the background in WIMP searches

Online cryogenic distillation and charcoal adsorption removes Rn from the xenon target

Screening materials for low Rn emanation

Mass	1.3 t
$(cS1, cS2_b)$	Full
ER	627 ± 18
neutron	1.43 ± 0.66
CEνNS	0.05 ± 0.01
AC	$0.47^{+0.27}_{-0.00}$
Surface	106 ± 8
Total BG	735 ± 20
$\mathrm{WIMP}_{\text{best-fit}}$	3.56
Data	739

XENON1T, 2018

Additional Radon Reduction Techniques

- Surface treatment of materials to remove diffused Rn
- Coating detector materials to reduce emanation
- Reducing the amount of material in contact with Xe
  - ➔ Hermetic TPC

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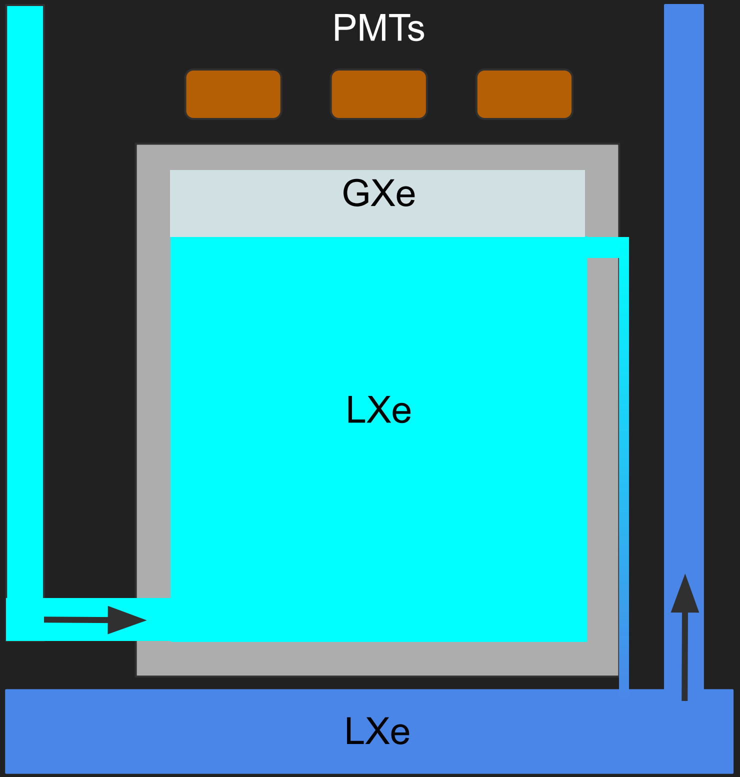
XENON1T, 2018

Hermetic TPC

Xe target separated from materials such as light detectors, wires, reflectors and cryostat

➔ Reduces the amount of Rn and impurities that can be introduced from these other materials

★ Enclosing materials need to be transparent to Xe scintillation light

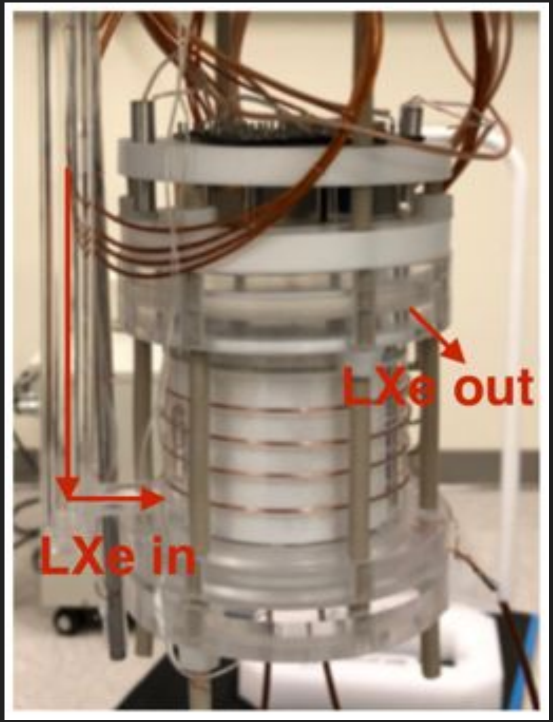


Hermetic TPC

UCSD is testing a hermetic TPC made of fused silica, but this material is not structurally sound at the size needed for Generation-3

Acrylic could be used but would require a wavelength shifter to allow light signals through the material

TPB doesn't behave well with liquid xenon, so other coatings need to be investigated



Sanguino et al., 2016

Ni, TAUP 2019

Liquid Xenon Purification

The volume of xenon involved in a Generation-3 experiment makes gas purification impractical

➔ Liquid purification is required to reach the required flow rates (tens of liters per minute)

XENONnT will use liquid purification, but more study is needed to find the optimum filtration system and materials with low radon emanation and high adsorption of electronegative impurities

High voltage

A large TPC requires higher voltage to sustain the required drift and extraction fields over the full TPC volume

➔ Requires larger HV feedthroughs
➔ Electrodes (meshes, wires) that can sustain high voltages (smooth surface)
➔ Electrodes made of high resistivity coatings

Graphene-coated
Fused silica

Ni, TAUP 2019

Signal Collection

Must cover a large surface area with detector, while maintaining energy resolution, sensitivity, and position reconstruction

Low-background Silicon-PMs could be a good option to increase pixel density and reduce radioactivity

Development of other technologies sensitive to Xe scintillation, or high efficiency wavelength shifting to visible light

Baudis et al., 1808.06827

Data Acquisition and Event Reconstruction

Need to be able to deal with the amount of data coming from the increased number of channels (acquisition, storage, processing)

At the same time, moving away from hardware triggering systems towards software triggering and data compression could allow more information to be kept for later use without veto

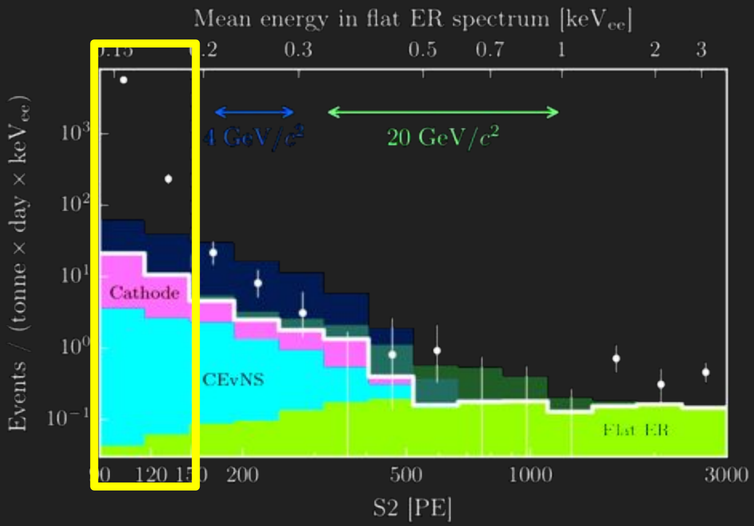
➔ Online analysis of all incoming events to extract the most relevant information from an event, without needing to save all raw data.

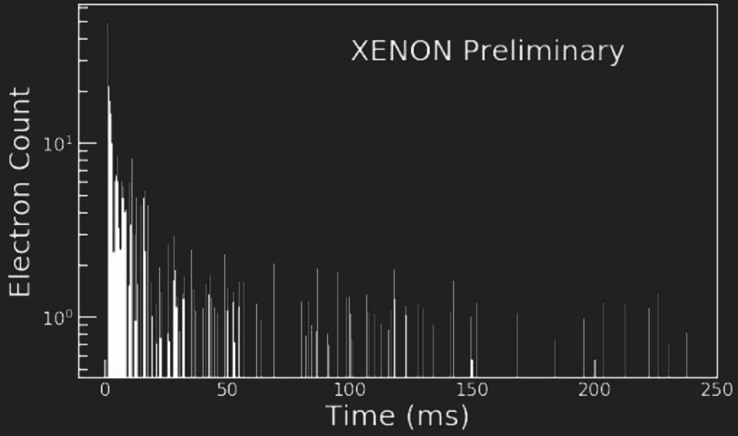
Low Energy Backgrounds

Low-energy backgrounds need to be well understood to reduce the energy threshold

Single-electron backgrounds are observed many milliseconds after large energy deposits

Long time-scales means we must reduce this background through hardware





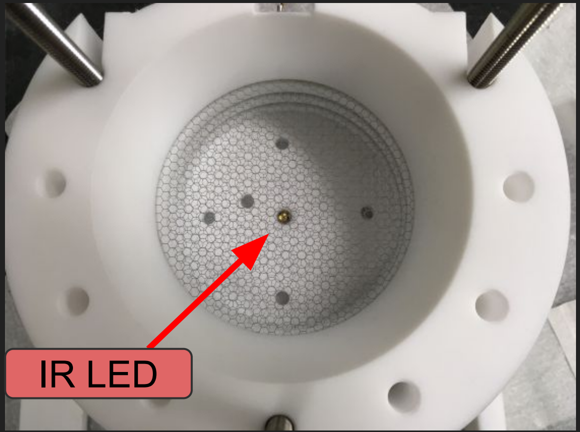
XENON1T, 2018

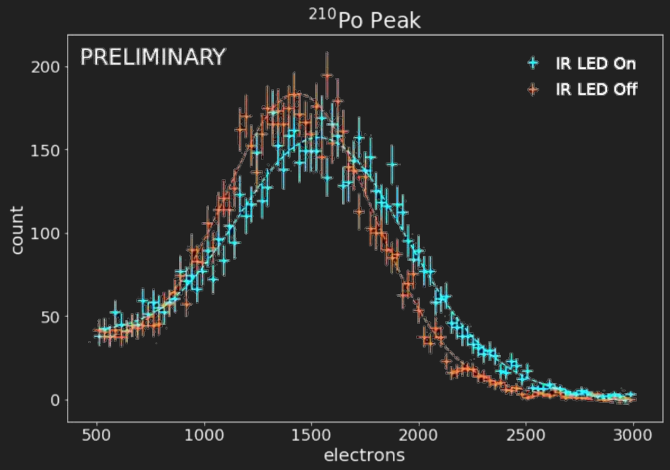
Quenching with IR light

At Purdue - Seeking to understand and mitigate these single-electron events as part of the LBECA collaboration

Investigating hypothesis that electrons from high energy events are trapped by impurities or at the liquid-gas interface

Low-purity data shows that IR LED increases extracted electrons, but the effect is small, recent improvements to increase light flux





Conclusion

Generation-3 liquid xenon promises great performance in the future of astroparticle physics

R&D is still needed to iron out the technical aspects of design and background reduction