
# Instrumentation Frontier:
## Noble Element Detectors (IF08)

Eric Dahl
Northwestern University

Roxanne Guenette
The University of Manchester

Jen Raaf
Fermilab

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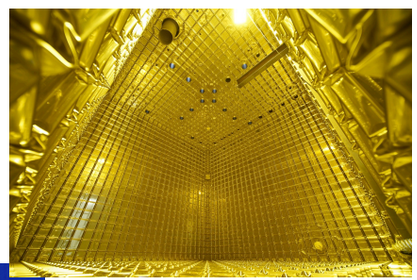
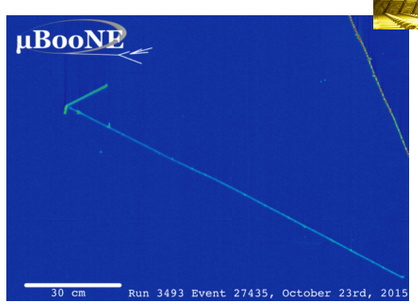
# Noble Element Detectors (main Physics Goals)

## Neutrinos

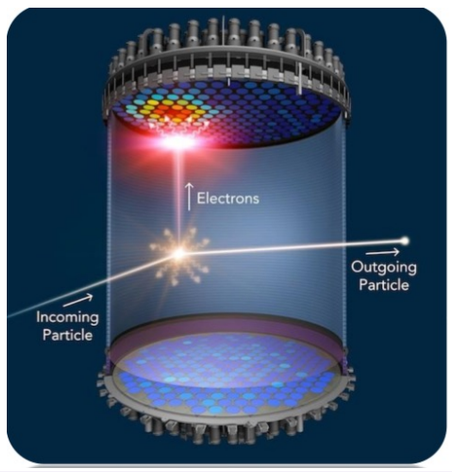
- Precision oscillation measurements ($\delta_{CP}$, mass ordering, $\theta_{23}$ octant, sterile $\nu$s)
- Neutrino interactions (from CEvNS to DIS)
- Astro neutrinos





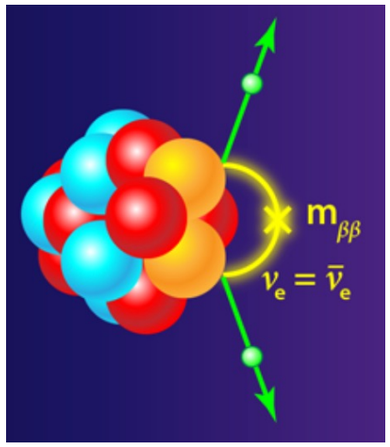

## Dark Matter

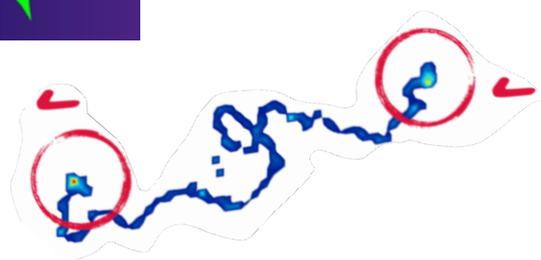
- Direct detection (WIMPs, … )

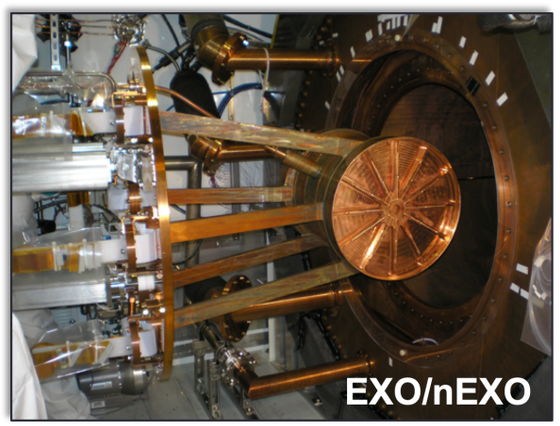



## 0νββ

- Search for Majorana neutrinos



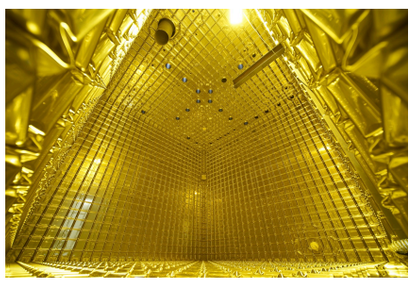



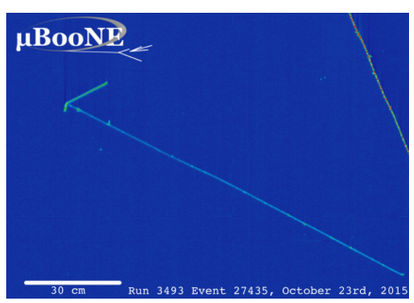


# Noble Element Detectors (technologies)

## Neutrinos

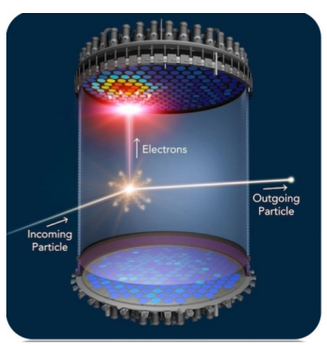
- Single-Phase Liquid Argon TPCs
- Dual-Phase Liquid Argon TPCs
- High-Pressure Argon Gas TPCs
- …





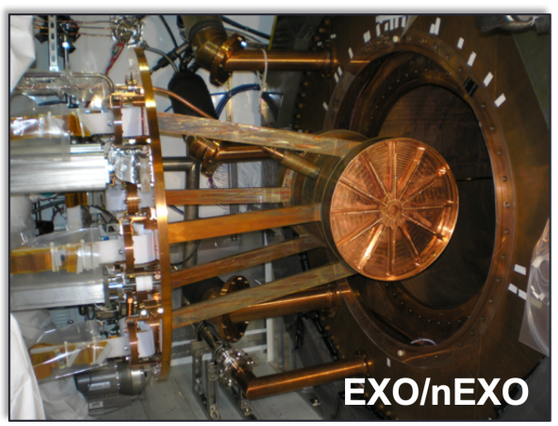

## Dark Matter

- Dual-phase Liquid Xenon TPCs
- Dual-phase LAr TPCs
- Single-phase LAr
- Liquid Helium
- Liquid Argon / Xenon Scintillating Bubble Chambers
- …




## 0νββ

- Single-phase Liquid Xenon TPCs
- High-Pressure Xenon Gas TPCs
- …



# Noble Element Detectors (experiments)

## Neutrinos

- Current generation:
  - ✓ ArgoNeuT
  - ✓ MicroBooNE
  - ✓ LArIAT
  - ✓ 35 ton
  - ✓ protoDUNEs
  - ✓ CAPTAIN
  - ✓ ICARUS
  - ✓ SBND
  - ✓ COHERENT
- Future generation:
  - ✓ DUNE modules 1 & 2
  - ✓ DUNE near detectors
  - ✓ DUNE modules 3 & 4

## Dark Matter

- Current generation:
  - ✓ LUX / LZ
  - ✓ XENON 10/100/1T/nT
  - ✓ Dark Side 50/20k
  - ✓ DEAP-3600
  - ✓ Panda-X
- Future generation:
  - ✓ DARWIN / G3 LXe
  - ✓ GADMC/Argo
  - ✓ HeRALD
  - ✓ SBC

## $0\nu\beta\beta$

- Current generation:
  - ✓ EXO-200
  - ✓ NEXT-White
  - ✓ KamLand-Zen
- Future generation:
  - ✓ nEXO
  - ✓ NEXT-100/tonne
  - ✓ KL-Z+

# Future Physics Needs

## Neutrinos

- **Push Energy thresholds** down to ~1MeV to enhance oscillation physics, study supernovae νs, to enable solar νs …
- **Scalability**
- **Unambiguous readout**
- **…**

## Dark Matter

- **Push Energy thresholds** down to 1 meV/10 eV/1 keV to enable low mass DM/1 GeV DM/WIMPs.
- **Reduce background rates**
- **Scalability**
- **…**

## 0νββ

- **Improve Energy Resolution** to sub-% FWHM
- **Reduce background rates**
- **Scalability**
- **…**

# IF08 activities

- IF08 (Noble Elements) includes technology with Ar, Xe, He in any phases.

- We received 53 LOIs that we organized into 4 main *Priority Research Directions* (PRDs):
    1. Enhance and combine modalities to increase signal-to-noise and reconstruction fidelity
    2. Develop new modalities for signal detection
    3. Challenges in scaling technologies
    4. Improve the understanding of detector microphysics and characterization

- We have closely followed the BRN (link) inputs (and ensured for additional inputs)

# Topics

| Key Concern / PRD | Subtopic | LOI | Title |
|---|---|---|---|
| **Enhance and combine existing modalities to increase signal-to-noise and reconstruction fidelity** | | | |
| | **Pixels** | | |
| | | IF2_IF8-I | Multi-modal pixels for noble element time projection chambers |
| | | IF7_IF8-I | Q-Pix: kiloton-scale pixelated liquid noble TPCs |
| | | IF7_IF8-I | An R&D collaboration for scalable pixelated detector systems |
| | **Charge Gain** | | |
| | | CF1_CF | Search for low mass WIMPs with spherical proportional counters |
| | | IF8_IF0-I | Electron multiplication in liquid argon TPC detectors for low energy rare event physics |
| | | IF8_IF5-I | Scintillating and quenched gas mixtures for HPGTPCs |
| | **Low-threshold TPCs (electron counting)** | | |
| | | IF8_IF0_ | R&D for low-threshold noble liquid detectors |
| | | NF7_NF | Noble liquids for the detection of CEvNS from artificial neutrino sources |
| | **Increasing Light Collection** | | |
| | | IF8_IF2_ | Cost-effective solution for increased light collection in noble-element detectors with meta |
| | | IF8_IF2_ | Wavelength-shifting relfector foils in liquid Argon neutrino detectors |
| | | IF3_IF8-I | COHERENT: Instrumentation development |
| | | NF10_NI | Improving large LArTPC performance through the use of photo-ionizing dopants |
| **Develop new modalities for signal detection** | | | |
| | ~~**Ultra-low-threshold (cryogenic) detectors w/ quasi-particle sensing**~~ | | |
| | | IF1_IF8-I | ~~Calorimetric readout of a superfluid 4He target mass~~ |
| | | CF1_CF | ~~The TESSERACT dark matter project~~ |
| | | IF8_IF0-I | A crystalline future for dual phase xenon direct detection instruments |
| | **Barium Tagging** | | |
| | | NF5_NF | Barium tagging for a nEXO upgrade and future 136Xe 0vbb detectors |
| | | NF5_NF | Barium tagging in Xenon gas for neutrinoless double beta decay |
| | **Metastable fluids** | | |
| | | IF8_IF0_ | Enabling the next generation of bubble-chamber experiments for dark matter. and neutri |
| | | CF1_CF | Metastable water: breakthrough technology for dark matter & neutrinos |
| | **Directionality / micron-precision spatial reconstruction** | | |
| | | IF9_IF8-I | Dual-readout time projection chamber: exploring sub-millimeter pitch for directional dark |
| | | IF8_IF0-I | Towards directional nuclear recoil detectors: tracking of nuclear recoils in gas Argon TP |
| | | IF8_IF1_ | Instrumentation and R&D for the Global Argon Dark Matter collaboration |

New Modalities in Existing Infrastructure

Better fit in IF-01

+ HydroX

# Topics

| | | | |
|---|---|---|---|
| **Challenges in scaling technologies** | | | |
| | **High Voltage** | | |
| | | IF8_IF0-( | High voltage cable feed-through |
| | | NF10_NI | Development of LArTPC vertical drift solutions with PCB anode readouts for DUNE |
| | **Sourcing / purifying noble gasses** | | |
| | | NF5_NF: | Kilotonne-scale Xe TPCs for 0vbb searches at 10^30 yr half-life sensitivity |
| | | NF5_NF | DUNE-Beta: searching for neutrinoless double beta decay with a large LArTPC |
| | | IF8_IF0-( | Charcoal-based radon reduction systems for ultra-clean rare-event detectors |
| | | IF8_IF0-I | Using metal organic frameworks for Krypton and Radon removal in low-background Xer |
| | | IF8_IF9_ | Applications for underground Argon |
| | **TPC with magnetic field** | | |
| | | IF8_IF9-: | Magnetizing the liquid Argon TPC |
| | | NF2_NF( | ICARUS in the next decade |
| | **Next-generation large scale detectors** | | |
| | | CF1_CF: | The exploitation of Xe large scale detector technology for a range of future rare event ph |
| | | IF8_IF0-I | High-pressure xenon gas time-projection chambers for neutrinoless double-beta decay s |
| | | IF8_IF9_ | Instrumentation and R&D for the Global Argon Dark Matter collaboration |
| | | NF10_NI | DUNE near detector |
| | | NF10_NI | Low background kTon-scale liquid Argon time projection chambers |
| **Improve the understanding of detector microphysics and characterization** | | | |
| | **Calibration** | | |
| | | IF8_IF6_ | Precision calibration of large LArTPC detectors |
| | | IF8_IF0-I | NEST, The Noble Element Simulation Technique: a multi-disciplinary monte carlo tool ar |
| | | IF6_IF8-I | Nuclear recoil calibration techniques for dark matter and neutrino experiments |
| | | IF8_IF9-( | Investigations of fundamental parameters of liquid argon for particle detection |

# Status

- IF08 decided to produce Executive Summaries for each sub-group of the PRDs (White Papers allowed, but not required)
  - Executive Summaries presented at a series of mini-workshops held bi-weekly since October 2021 (final one is 7 March 2022)

- Deadline for the Executive Summaries is end of March

- **In May (TBA), the IF08 conveners will present the overall coherent picture directly from the Executive Summaries (important to attend!)**

- Based on the feedback from the May meeting, we will produce a written draft that we will share with IF08 before heading out to Seattle

**Email subscription: snowmass-if-08-noble-elements@listserv.fnal.gov**