# ARTIE: Measuring the 57keV neutron cross-section of liquid argon

APS Far West Section

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of the ARTIE Collaboration

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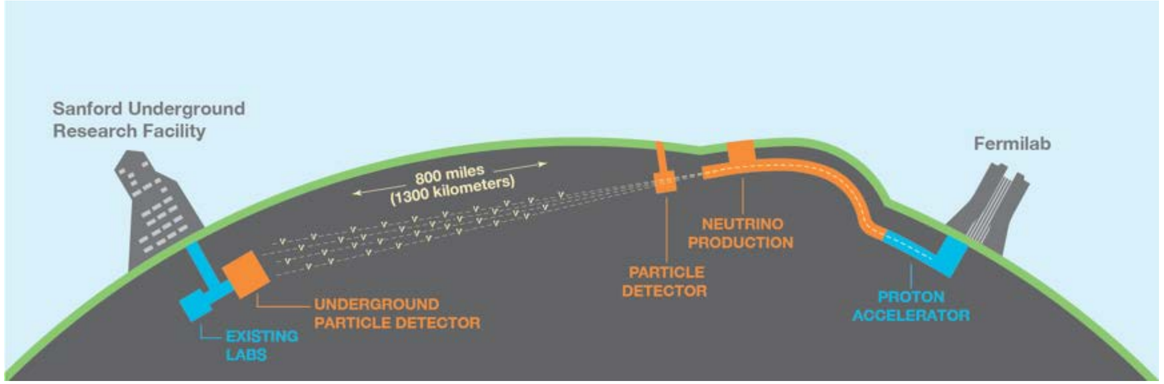
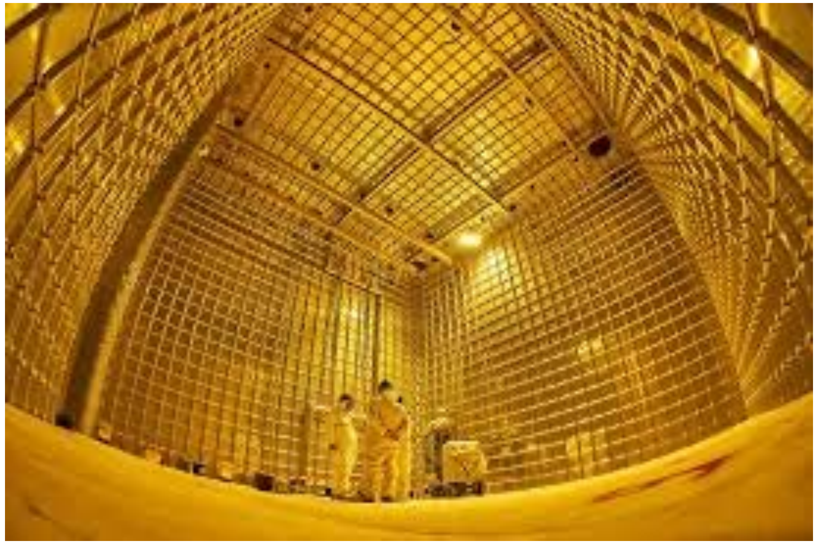
# Understanding Neutrons For DUNE Is Crucial

- DUNE, an upcoming international long-baseline neutrino experiment
  - Utilizes a Liquid Argon (LAr) time-projection chamber (TPC) to explore neutrino physics




- Understanding neutron transport in LAr is important:
  - Neutron Shielding
    - How far will neutrons penetrate the active volume?
  - Calibration
    - Can we inject neutrons into the volume?
  - Neutrino Physics
    - Neutrons can be a product of neutrino interaction events, such as in supernovae

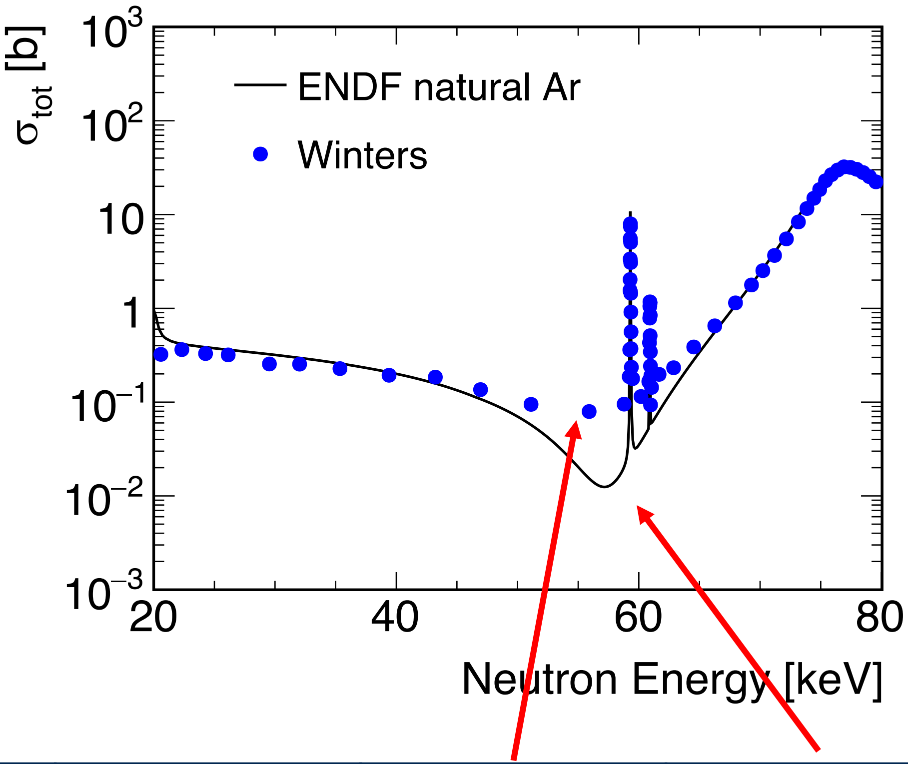


protoDune Cryostat at CERN

# Why ARTIE?

- Current understanding of the total cross section of argon is contested between theory (ENDF) and experiment (Winters *et al*)
  - Winters used gaseous argon (0.2atoms/b) to cover a wide energy range
    - Perhaps not sensitive enough to detect the 57keV anti-resonance!

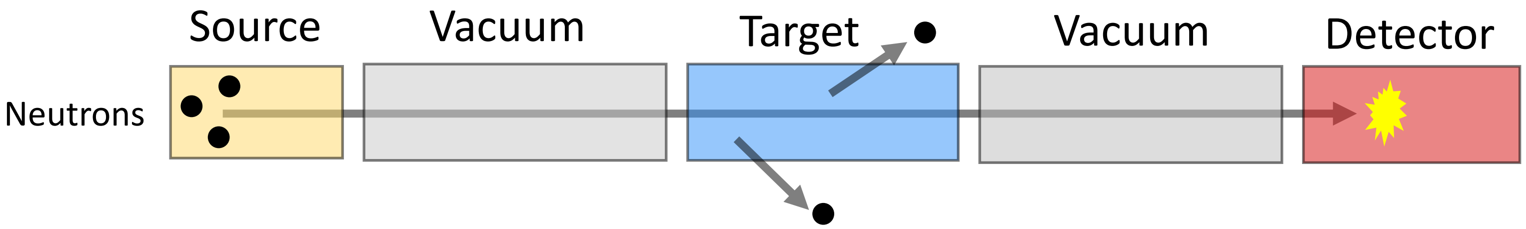
- **A**rgon **R**esonance **T**ransport **I**nteraction **E**xperiment aims to resolve this discrepancy at 57keV
  - At 3.5 atoms/b, we are 15x more sensitive at 57keV!




| | | | |
|---|---|---|---|
| Winters | 0.2 atoms/b | T=0.984 | T=0.998 |
| ARTIE | 3.5 atoms/b | T=0.76 | T=0.97 |

# How do we measure n cross sections?

- Place a target in the beam line and neutrons not scattered will reach the detector
  - We know the flight path length, so then time-of-flight (TOF) determines the energy
  - Turns into a counting experiment, per $i_{th}$ energy bin!




The total cross section in an $i_{th}$ energy bin is

$$\sigma_i = \frac{-\ln(T_i)}{n}$$

$T_i$ : transmission coefficient
n : target density[atoms/barn]

$$T_i \approx \frac{N_{in}}{N_{out}}$$

$N_{in}$ and $N_{out}$ are the number of observed neutrons with the target in or out

$$n = \frac{d\ N_A}{m_A\ 10^{-24}}\ \rho$$

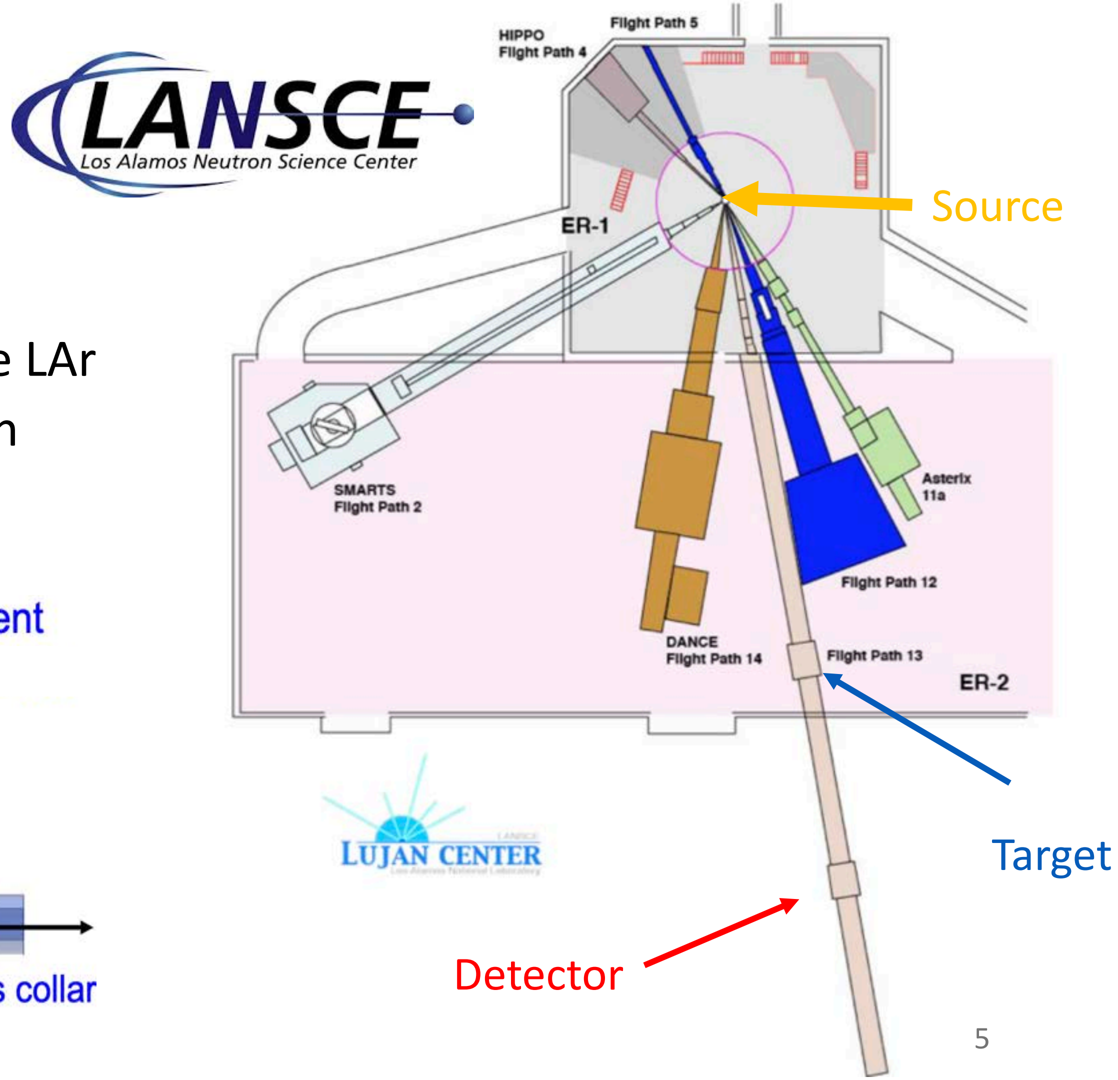
d: length of target
$\rho$: density
$N_A$: Avogadro's number
$m_A$: molar mass

# ARTIE at LANL

- ARTIE utilized neutron flight path 13 at LANSCE, at Los Alamos National Laboratory (LANL)

**ARTIE Target Specifications**

- 168cm long, 1” diam. cylindrical target of 99.99% pure LAr
- Foam jacket insulation, LAr reservoirs, and thin Kapton windows along the beamline

# Problems

- Many corrections during data analysis need to be considered
  - Target density
  - Afterpulsing
  - Deadtime
  - Background subtraction
  - Misalignment
  - Atmospheric effects
- I will primarily discuss:
  - Evaluating the target density
  - Deadtime corrections

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# Systematic: Liquid Argon Density

- As previously seen, the ARTIE target is not pressurized or vacuum sealed
  - Therefore the LAr will constantly boil, this is problematic
- Cross Section given by: $$\sigma_i = \frac{-\ln(T_i)}{n}, \quad n = \frac{d\, N_A}{m_A\, 10^{-24}}\,\rho$$
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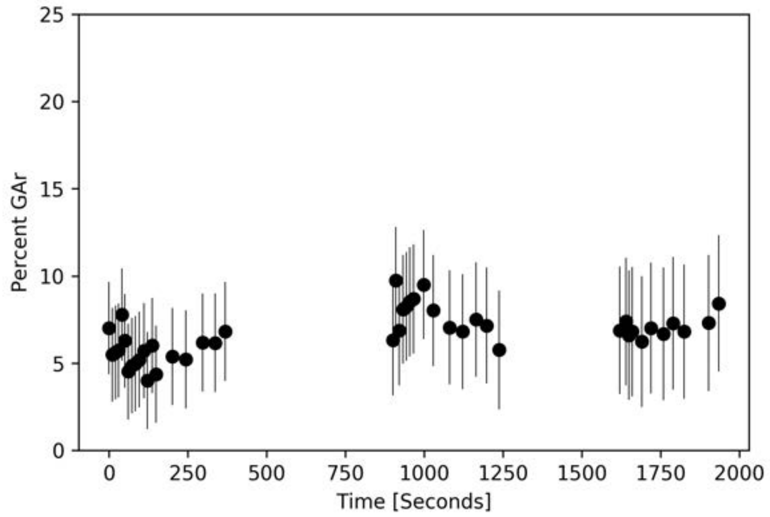
- More gas means lower density, $\rho$ , which will reduce the cross section
  - Need to evaluate this effective density

# Systematics: Target Density

- A side experiment to find the effective density was done back at UCDavis
- Target sits on precision scale, filled with LAr, and is allowed to boil off naturally
  - Mass and liquid level are recorded via camera and then reviewed later
- Given mass of empty target and volume, we can then work out the density

$$\rho_{target} = \rho_{LAr} \frac{V_{tot} - V_{GAr}}{V_{tot}}$$

- $\rho_{target}$ = 1.318 kg/L ± 0.008 (stat) ± 0.015 (sys)
  - Approx 7% GAr

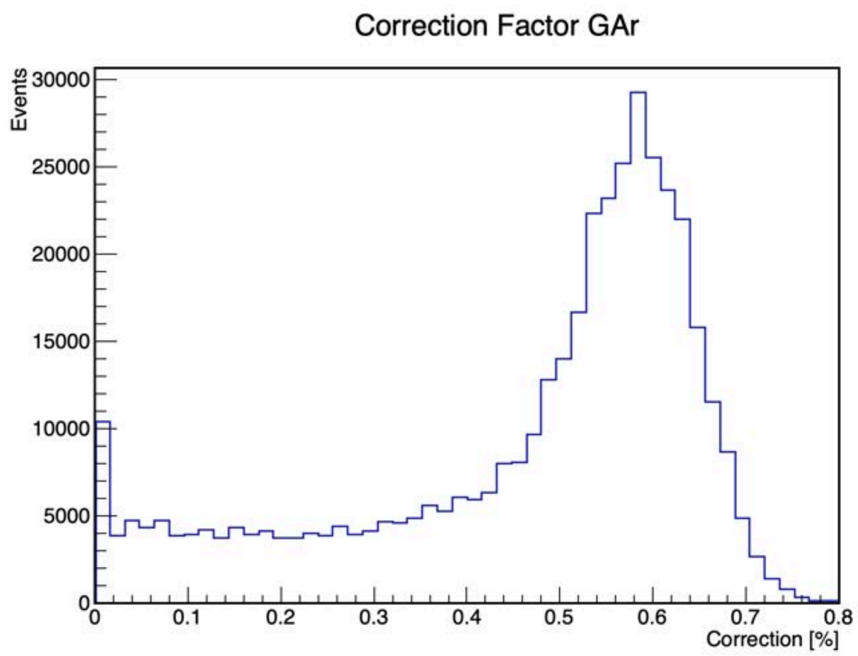



# Systematics: Missed Neutrons

- What happens when neutron events arrive too close together?
  - A problem!
- Our DAQ is insensitive, or dead, for approximately 220ns after it acquires a pulse
  - Our TOF spectra must then be corrected for

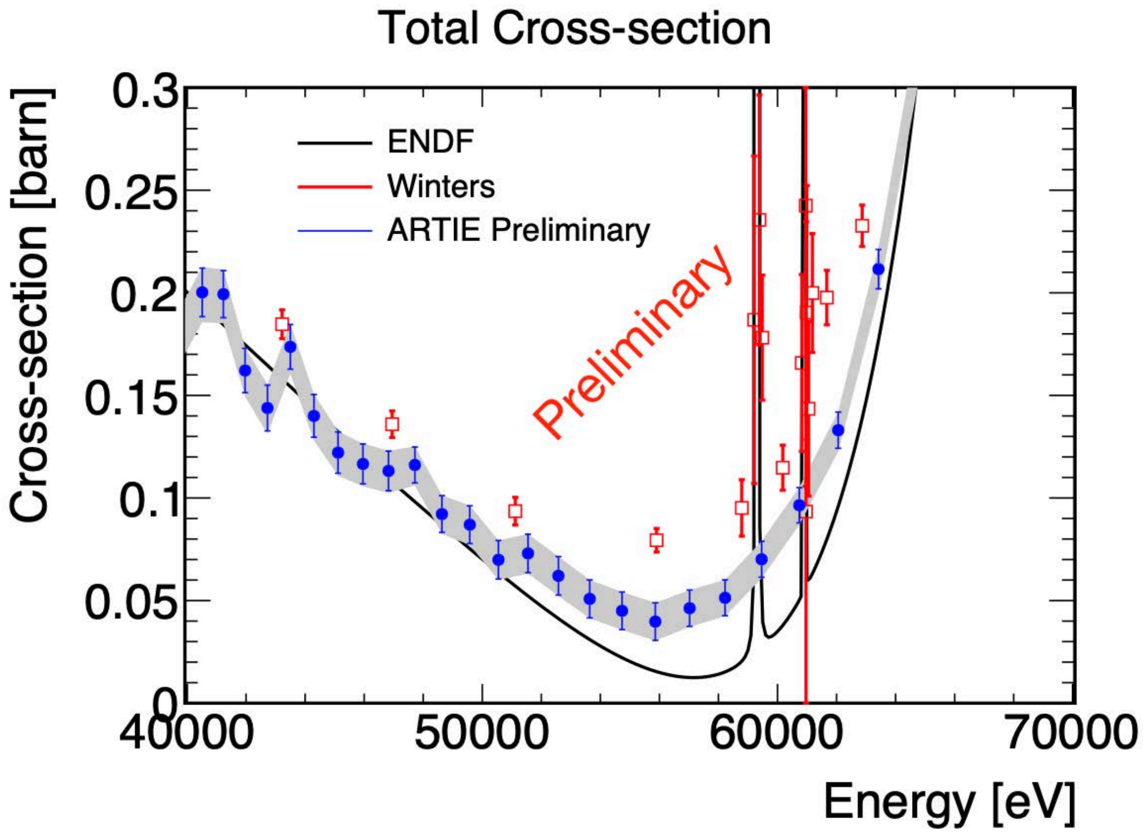
$$N_c(I) = N_b \left\{ -\ln \left( 1 - \frac{N_o(I)/N_b}{\left[ 1 - \sum_{J=I_0}^{I-1} N_o(J)/N_b \right]} \right) \right.$$

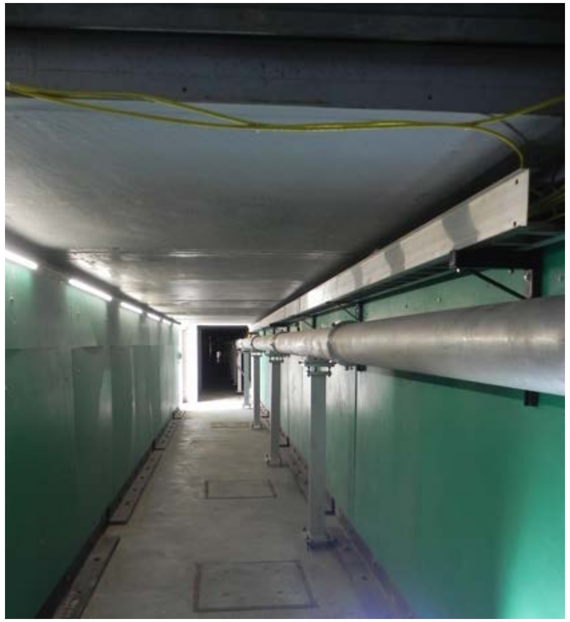
- Using an analytical "Bowman" correction, we can move through bin-by-bin and correct for the deadtime losses
  - For the worst-case scenario, GAr, it never exceeded 1%
- To verify, a Monte Carlo was constructed and agreed w/n 0.5%



# Preliminary Results

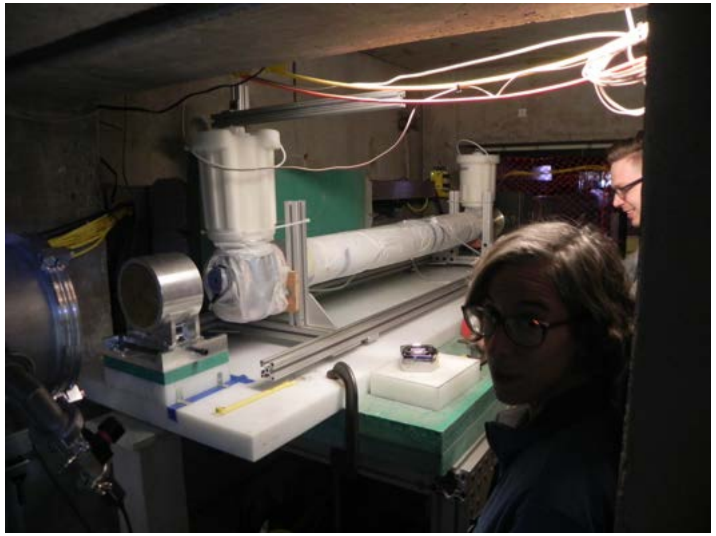
- The ARTIE experiment is coming to a close
- Systematics are being finalized and validated
  - Barring a few corrections, *preliminary* results are presented here
- Paper under preparation, expect an arXiV submission in about 4 weeks!





FP13 Beam line, downstream

ARTIE target installed:
Leon Pickard (right)



# Questions?

Prof. Mike Mulhearn (left), Prof. Bob. Svoboda (right) with the Li6 detector (behind)

Part of the ARTIE Crew at LANL:
me(left), Prof. Bob Svoboda (right), Prof. Sofia Andriga (top)

# Backup: Missed Neutrons

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  - Thus we miss some neutron events