First results from the ARTIE experiment

Luca Pagani on behalf of the ARTIE collaboration, UC Davis - lpagani@ucdavis.edu

ARTIE Physics Goals

- Argon is widely used for particle detection both as a target or shield material in:
  - low-background dark matter searches (*e.g.* DarkSide)
  - high-energy neutrino experiments (*e.g.* DUNE)
- The theoretical evaluation (ENDF) of the neutron's total cross section (σ) on argon predicts a negative-resonance at 57keV which was not observed by the only previous measurement (Winters et al., 1990)

→ The **A**rgon **R**esonant **T**ransmission **I**nteraction **E**xperiment (ARTIE):

- Measures the depth of the anti-resonance at 57keV using a time-of-flight (TOF) neutron beam
- Data taken during October 10-20th, 2019

How to measure the cross section

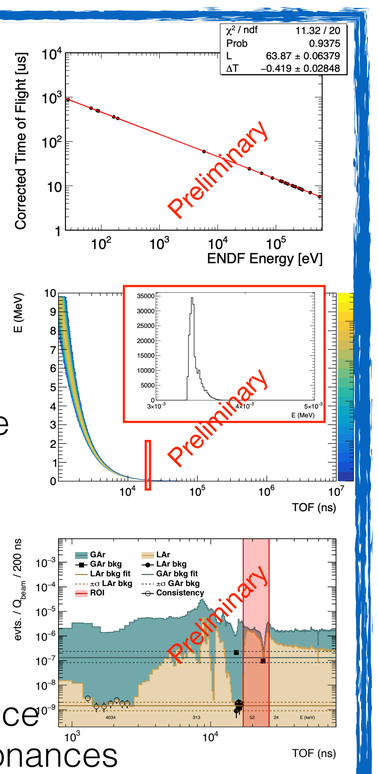
- Consider target in (with liquid argon) and target out (with gaseous argon):

$$\sigma(E) = -\mathbf{\Delta n}^{-1} \ln(\mathbf{N^*}_{in}\mathbf{Q}_{out} / \mathbf{N^*}_{out}\mathbf{Q}_{in})$$

- $\mathbf{\Delta n}=(n_{in}-n_{out})$, where n represents the target column density in atoms/b:
  - $n = d[cm]*N_A[atoms/mol]*\rho[g/cm^3] / m_A[g/mol]*10^{-24}$ cm²/b includes the dimensions (d) and composition (ρ, m_A) of the target
- $\mathbf{N^*}_{in/out}$: background-subtracted neutron count with target in/out
- $\mathbf{Q}_{in/out}$: total number of neutrons produced with target in/out

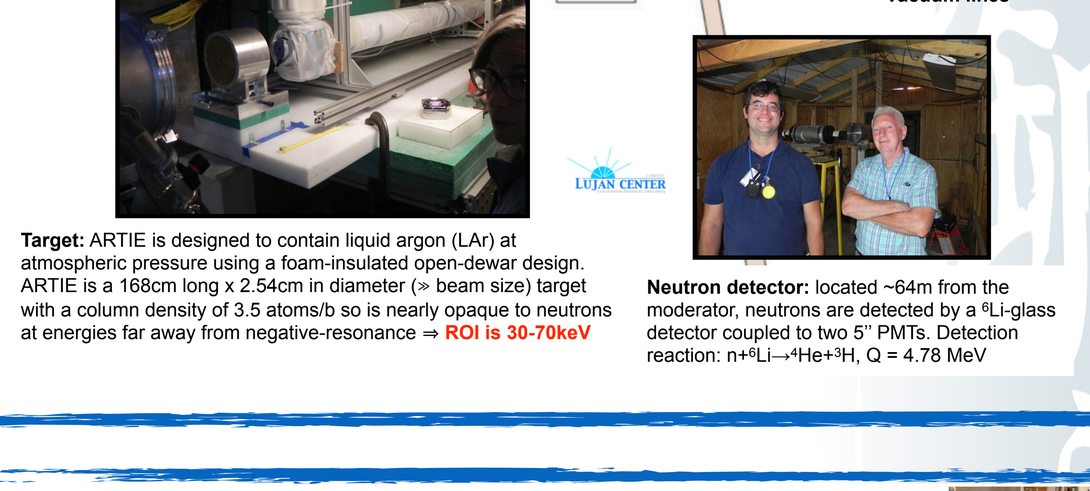
Energy calibration and Background

- TOF technique precisely measures E_n
  - $\mathbf{E = mc^2 (1/\sqrt{1-L^2/c^2t^{*2}} -1)}$ with t*=t-ΔT
  - Calibrated with known resonances (Al and Cd) and $\Delta E/E_{ROI}$=+3.1,-1.3%
- $\mathbf{T(E) = (N_{in}-B_{in})\, Q_{out} / (N_{out}-B_{out})\, Q_{in}}$ where the background B accounts for beam-related and :
  - *Radiogenic, sky shine, or scattering:* ≪1
  - *Late-arriving high-energy multiple scatter neutrons:* "black notch" method assuming B_{in} flat in ROI:
    - **Argon (0.14%):** 100keV (black) resonance
    - **Aluminum (7.1%):** 35,88keV (gray) resonances



Lujan Center at Los Alamos

- ARTIE is located in Flight Path 13 at Lujan Neutron Scattering Center: neutrons produced by protons impinging on W-target (63.5m flight path, 800MeV proton beam at 20Hz and 80μA)



1/16" Cd filter: suppresses thermal neutron flux below 0.5 eV (remove most "overlap" between pulses and and thermal neutrons)

Liquid H moderator: located at ~31m upstream from the W-target, induces a time delay (δT) modeled via Monte Carlo simulation

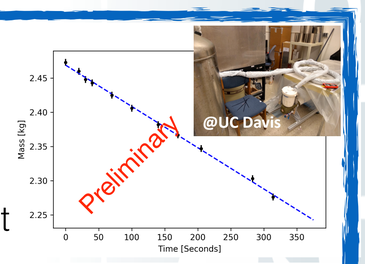
Neutrons travel in **vacuum lines**

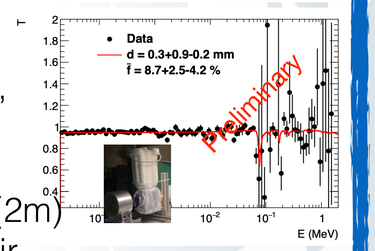
Target: ARTIE is designed to contain liquid argon (LAr) at atmospheric pressure using a foam-insulated open-dewar design. ARTIE is a 168cm long x 2.54cm in diameter (≫ beam size) target with a column density of 3.5 atoms/b so is nearly opaque to neutrons at energies far away from negative-resonance ⇒ **ROI is 30-70keV**

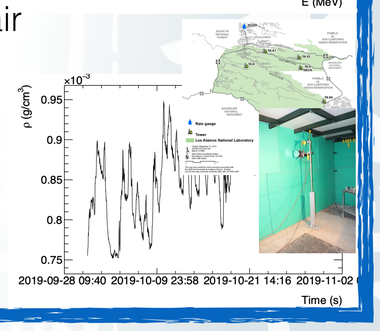
Neutron detector: located ~64m from the moderator, neutrons are detected by a ^{6}Li-glass detector coupled to two 5" PMTs. Detection reaction: n+^{6}Li→^{4}He+^{3}H, Q = 4.78 MeV

Uncertainties

- **Unpressurized vessel:** target is mixture of gaseous and liquid (ρ_{eff}). Separate experiment done to recreate filling/boil off
  - ρ_{eff}=1.32±0.02 kg/L (~6% gas): **±1.3%**
- **Ice build up:** despite flushing with dry gases, a thin layer of ice formed on end caps
  - d=0.3 mm: **-3.1%** max in the ROI
- **Environment air density:** part of flight path (2m) not under vacuum and exposed to ambient air
  - air density variations (±12%): -3.4**±0.4%**
- **Others:**
  - Beam stability (**±3.2%**) and fillings (**-5%**)
  - Nitrogen contamination (0.4ppm): ≪**1**
  - Dead time: **~1%** and **0.2%** correction
  - Other nearby experiments: ≪**1**

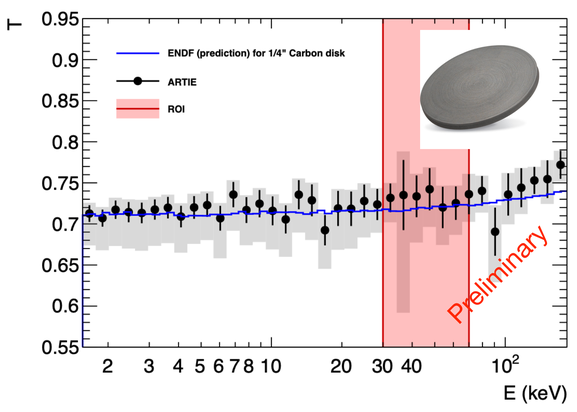


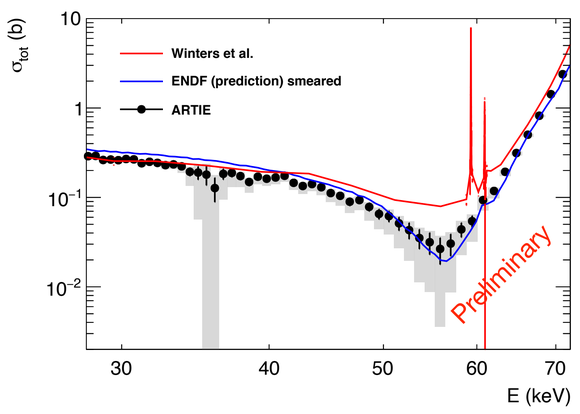




Results

- Analysis strategy tested on a carbon sample of known composition (99.999% purity) and dimensions (x2 0.125±0.010"):
  - Obtained good agreement (χ^2/NDF=43.5/40) in wider energy range than ROI with ENDF ARTIE-smeared carbon σ
- Validated analysis applied to liquid argon data reveals **presence of negative-resonance at 57keV** in agreement with ENDF evaluation
- Manuscript currently pending submission!





Acknowledgements: This material is based upon work supported by the U.S.Department of Energy (DOE) Office of Science under Award. No. DESC0009999, and by DOE National Nuclear Security Administration through the Nuclear Science and Security Consortium under Grant No. DE-NA0003180. Support from LIP was from the Fundação para a Ciência e a Tecnologia, I.P., project CERN/FIS-PAR/0012/2019. A major support was also provided by DOE through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated byTriad National Security, LLC, for the National Nuclear SecurityAdministration of U.S. Department of Energy (Contract No. 89233218CNA000001).