Measurement of the Neutron Total Cross section on Argon in Energy Range of 30-70 keV

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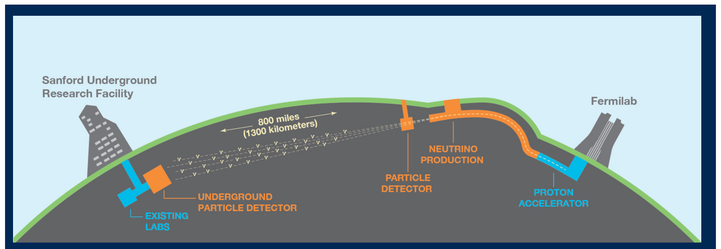
Abstract

The **A**rgon **R**esonant **T**ransport **I**nteraction **E**xperiment (**ARTIE**) was recently performed at the Time-of-Flight neutron beam at Los Alamos National Laboratory (LANL). ARTIE makes a new measurement of the total cross-section of neutrons on natural argon between 30-70 keV. This measurement is crucial for the Deep Underground Neutrino Experiment (DUNE) as it determines the feasibility of the neutron-based detector calibration technique and provides a deeper understanding of signals and backgrounds for the low energy physics programs.

Motivation

The Deep Underground Neutrino Experiment (DUNE) is an upcoming US-based international long-baseline experiment for neutrino science.



DUNE is the future flagship experiment of the Department of Energy. It will send a neutrino beam from Fermilab in Illinois to Sanford Underground Research Facility in South Dakota [1]

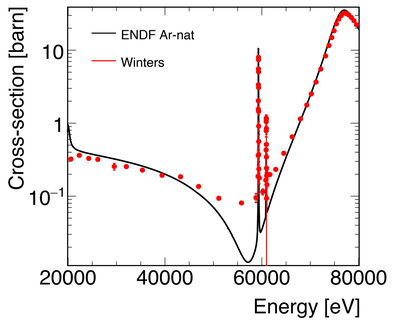
The neutron transport in liquid argon is important:

1. **Detector calibration:** Can we use an external pulsed neutron source to calibrate the far detector? Neutron capture signal could be used as a standard candle energy.
2. **Neutron shielding:** How much shielding material is needed for suppressing the neutron backgrounds in supernova and solar neutrino programs.
3. **Neutrino Physics:** Are nearby neutrons useful to achieve better energy resolution during the reconstruction of the supernova neutrinos?

Need good understanding of neutron total cross section in the range of 30-70 keV

ENDF vs Previous Measurement

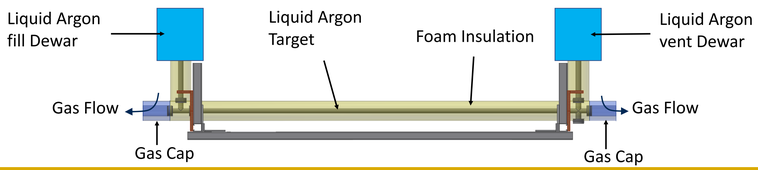
- The ENDF prediction of the neutron total cross section on natural argon is ~0.01 barn at 57 keV, which disagrees with a previous measurement of ~0.1 barn [2].
- **Previous Measurement by Winters:**
  - Neutron Transmission Measurement 2.216-meter long gaseous target with a density of 0.211 atoms/barn
  - Not sensitive to low cross section at energy range of 30-70 keV



Design of Liquid Argon Target

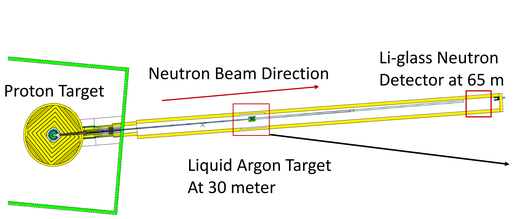
ARTIE's target density is 3.5 atoms/barn: blind to high cross sections but sensitive to low-cross sections at 30-70 keV

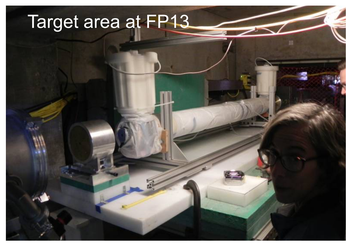
- 168 cm long, 1" OD stainless steel tube
- Sealed by Kapton foil windows allowing neutrons to go through
- Dry-nitrogen gas-flow-caps used to prevent ice formation on Kapton windows
- Liquid level monitored by video cameras and temperature sensors
- Thermal insulation provided by Polyurethane foam



Experimental Setup at LANL

- Neutron beam: Flight Path 13 at Lujan Center at the Los Alamos Neutron Science Center (LANSCE) [3]





Measurement Strategy

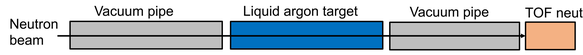
Transmission Measurements:
- "Target-out" run with the target tube flushed by gaseous argon
- "Target-in" run with the target tube filled with liquid argon

Background Measurements:
- Beam-off data: Constant-in-Time background
- Beam-on, neutron shutter closed: sky shine neutron background, gamma ray background
- Liquid argon filled in target with Aluminum filter: multiple scattering background

Reference Material:
- 0.125"and 0.250" thick carbon targets with well-known cross sections were measured as a reference to correct the overall systematics.

Neutron Total Cross Section

- Neutron energy determined using the Time-of-Flight technique
- **The total cross section is measured through neutron transmission**



$$\sigma_i = -\frac{1}{n^*}\ln(T_i) = -\frac{1}{n^*}\ln\left(\frac{C_{in}-B_{in}}{C_{out}-B_{out}}\right)$$

$$n^* = n_{liquid} - n_{gas}$$

σ_i: total cross section at energy bin i
n^*: effective column density of the target
T_i: transmission coefficient at energy bin i
C_{in}: *Total neutron count for target-in run*
B_{in}: *Background count for target-in run*
C_{out}: *Total neutron count for target-out run*
B_{out}: *Background count for target-out run*

Summary

- The ARTIE experiment was performed recently using a Time-of-Flight neutron beam at LANL
- The data analysis is underway to resolve the disagreement between the ENDF library and the only previous measurement.
- The result of ARTIE is important to DUNE and other liquid argon-based experiments that care about neutron transport.

References

[1] http://www.dunescience.org
[2] R.R Winters, et al., Phys. Rev. C 43 492 (1991)
[3] https://lansce.lanl.gov

Acknowledgements

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