Sub-Thermal Transmission Experiments of Organic Materials at the RPI Gaerttner LINAC Center

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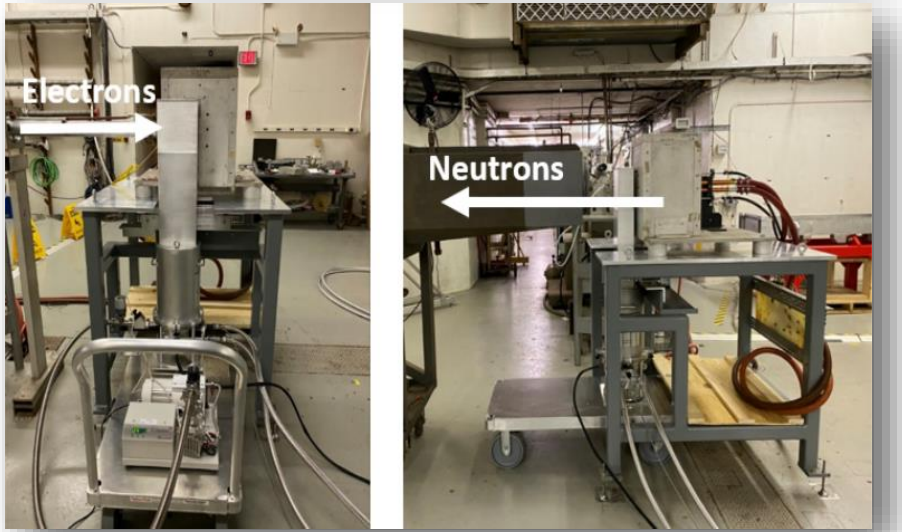
Overview

- RPI LINAC
  - Enhanced Thermal Target with Cold Moderator
  - Sub-thermal Transmission Experiments
- Sample preparation
- Measurement overview
- Preliminary results
- Next steps

RPI LINAC

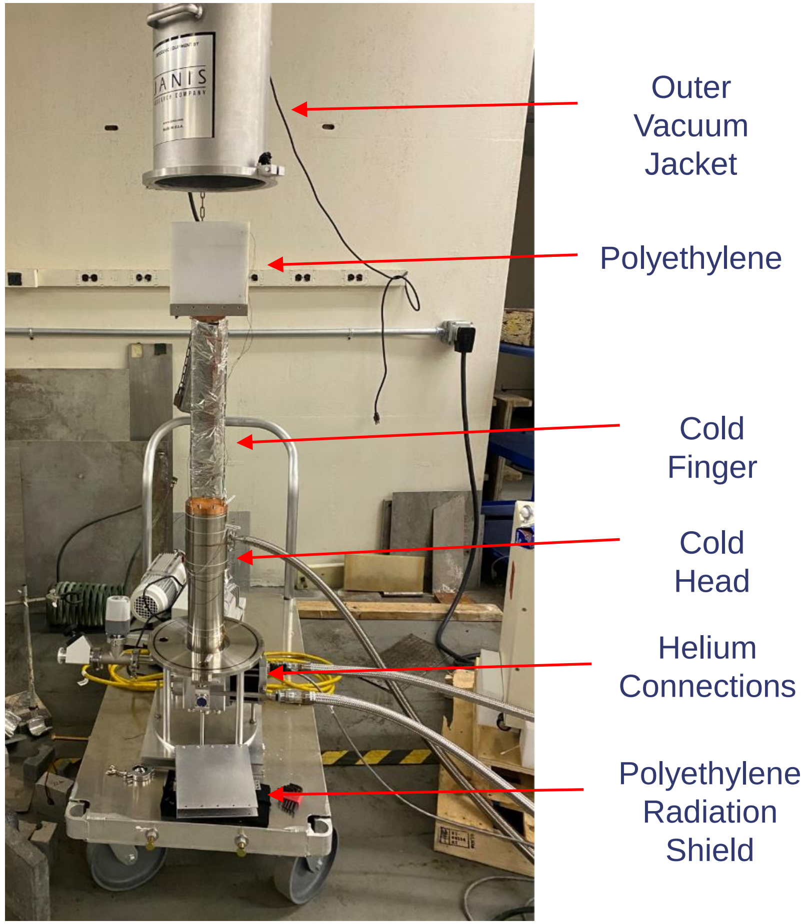
- The RPI LINAC - electron linear accelerator capable of generating short bursts of electrons and accelerating them to energies of 60 MeV
- Electrons impinge on a neutron producing target and generate neutrons via γ,n reaction
- Neutron time-of-flight (TOF) used to calculate incident neutron energy

Gaerttner LINAC Center



ETTC - Enhanced Thermal Target Cold Moderator

- Neutronics
  - Polyethylene
    - Large enough to cover collimation
    - As close to source of neutrons as possible
    - As cold as possible in a consistent fashion
  - Maximize gain over existing source (ETT)
  - Metric: Integral counts in 1 – 5 meV range
- System
  - High density polyethylene (HDPE)
    - < 30 K w/ 1.5 kW on target
    - Good connection to cryostat
  - Long cold finger → protect cold head from radiation
  - Large cold finger cross-sectional area
  - Portable; Minimal material; Can withstand High-Vacuum
  - Single Stage Cryo-cooler



[1]D. Fritz, "Design of a Cold Moderator for Total Cross Section Measurements of Moderator Materials in the meV Energy Range", Rensselaer Polytechnic Institute (Dec. 2022)

Slide adopted from Y. Danon, "Overview of Nuclear Data measurements and analysis at RPI", CSEWG Meeting, Online, November 15-19, 2021

Sub-Thermal Transmission Experiments

- Transmission experiments measure the total cross section, $\sigma_t(E)$
- NE-905 Li-6 glass scintillation detector
  - 76.2 mm diameter
  - Glass perpendicular to neutron beam
- 3/8th inch fixed Pb

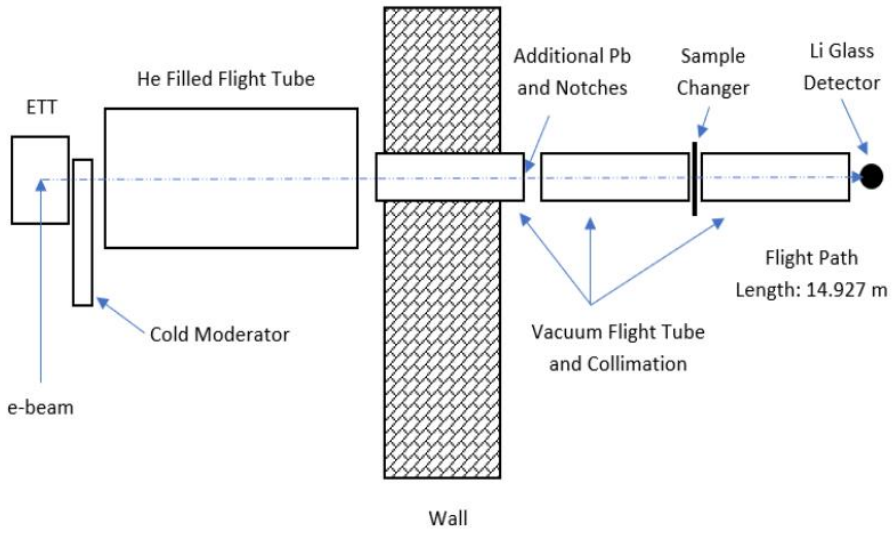


Figure 5.1: Side view of neutron flight path for ETTC.

Monitor Normalize and Sum Counts → Transmission is Calculated → Cross Section is Derived

$$C_s(i) = \frac{M_{opt}}{L_{opt}} \sum_{r=1}^{R} \frac{L_s, r}{M_s, r} C_{s,r}(i)$$

$$T(t_i) = \frac{(C_s(t_i) - K_s B(t_i) - B0_s)}{(C_o(t_i) - K_o B(t_i) - B0_o)}$$

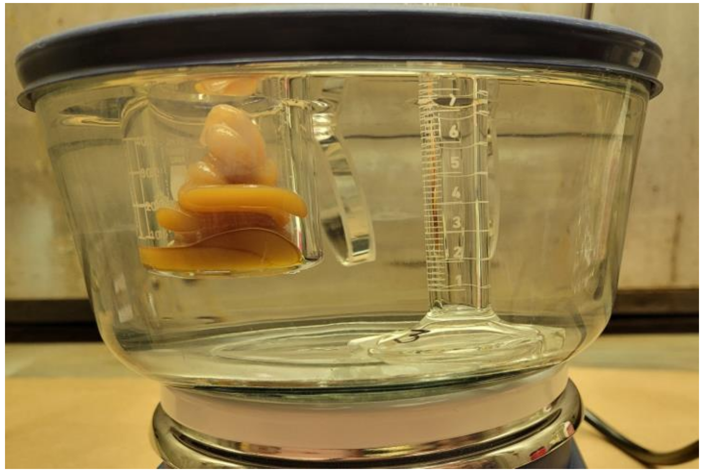
$$\sigma_{t,measured}(t_i) = \frac{-1}{N} * ln(T(t_i)) \; [barns]$$

C_s: Monitor normalized and summed counts in sample *s*
M_{opt}: Monitor counts in optimal run
$M_{s,r}$: Monitor counts in run *r* of sample *s*
L_{opt}: LINAC triggers in optimal run
$L_{s,r}$: LINAC triggers in run *r* of sample *s*
$C_{s,r}$: Counts in run *r* of sample *s*

$T(t_i)$: Transmission for time channel (t_i)
K_S, K_O: Background normalization factors for sample, open
B: Time-dependent background fit for time channel (t_i)
$B0_S$, $B0_O$: Constant background for sample, open
$\sigma_{t,measured}(t_i)$: Measured total cross section for time channel (t_i)
N: Atomic areal density of sample.

Sample Preparation

- Sample chemistry obtained for each material
- Two sample thicknesses were needed to cover region-of-interest:
  - 2 mm < 0.3 eV < 5 mm
- Quartz cells (Starna Cells) used
  - Used with other measurements
  - Very tight tolerances
- Petrolatum and Apiezon M-Grease required a water bath ~70-80 C
  - Samples observed to melt between 50 and 60 C
  - High viscosity
  - Active volume of each cell was fully emersed
  - Air bubbles (voids) removed from all samples
  - Controlled heating and cooling



Sub-Thermal Measurement Overview

- Experiment Details
  - Repetition rate – 18 pulse per second
  - Pulse Width – 588 ns
  - Beam Energy ≈ 48 MeV
  - Beam Power ≈ 220 W

- Beam Parameters
  - Profile – Circular
  - Diameter[1] - 44.5 mm

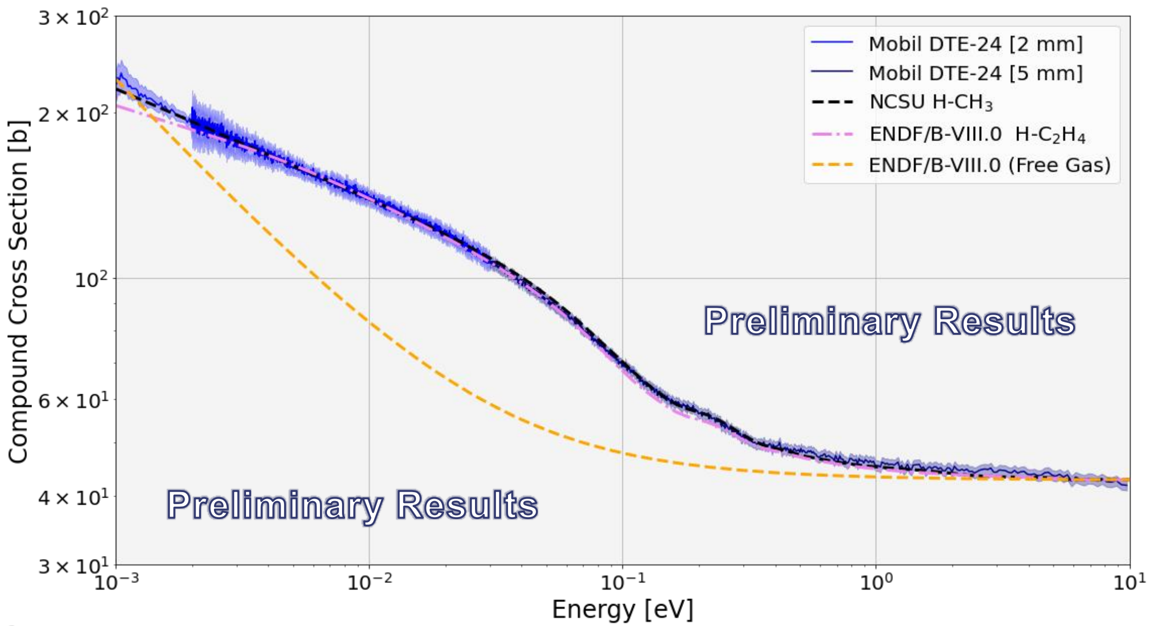
- Sample Information
  - Temperature – 22 C
  - Shape – Cylinder
  - Diameter – 47 mm
  - Thicknesses – 2 mm and 5 mm

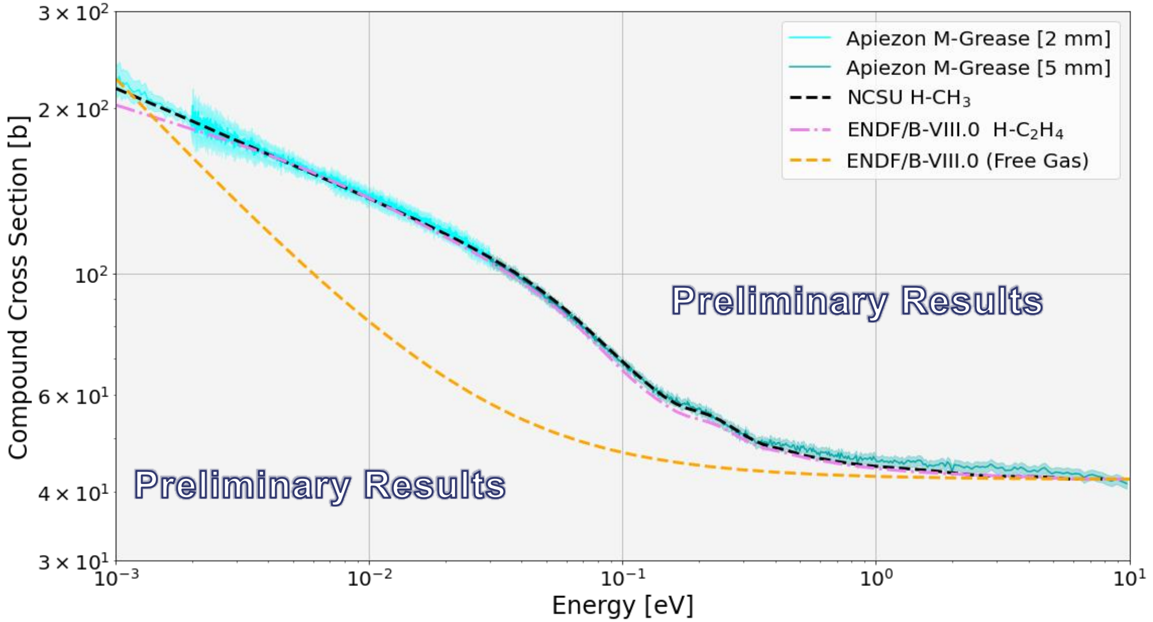
- Two weeks of data collected
  - 160 hours of data
    - 26 hours for each 2 mm sample
    - 21 hours for each 5 mm sample
    - 9 hours for each Open measurement

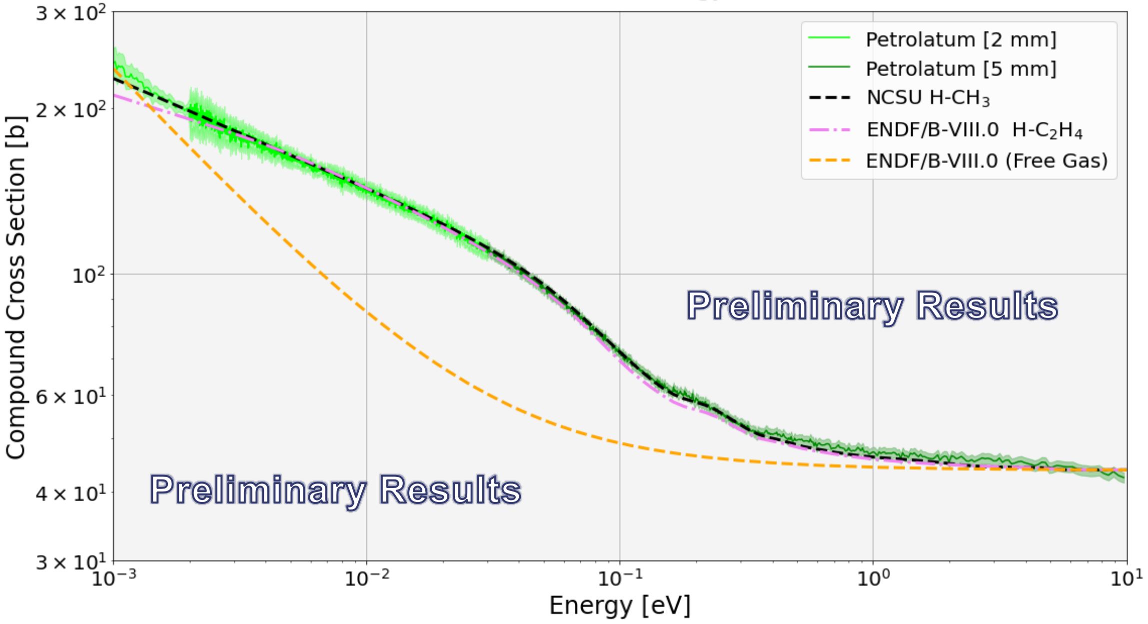
[1] At the sample position

Preliminary Results

- From ~0.001 to 10 eV heavy paraffinic oil[1] TSL (H-CH_3) approximates cross section better than ENDF/B-VIII.0 free gas
- Slight improvement over ENDF/B-VIII.0 H-C_2H_4 at low, ≤ 2 meV, energies



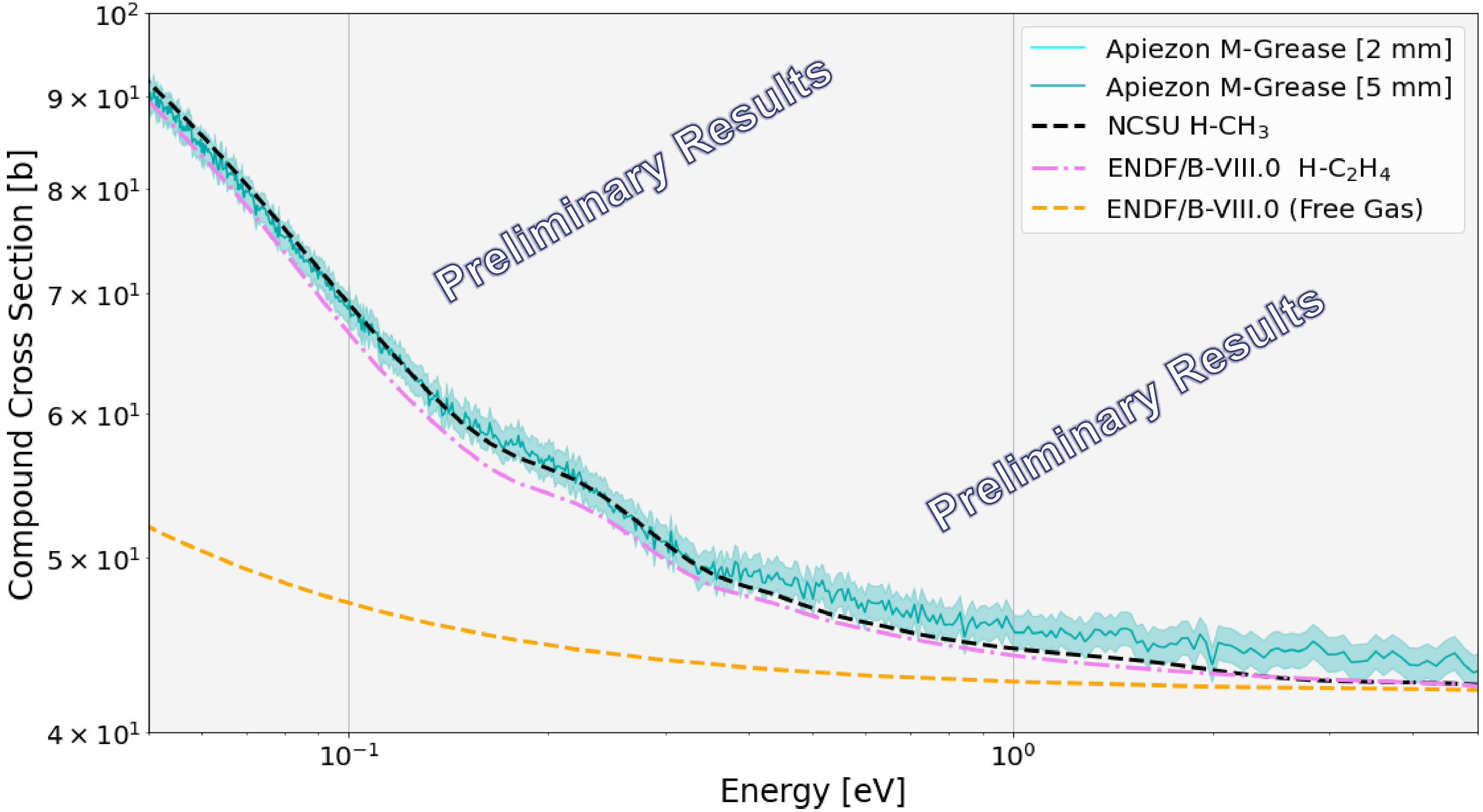




[1] C.A. Manring, A.I. Hawari, "Assessment of Thermal Neutron Scattering in a heavy Paraffinic Molecular Material", PHYSOR 2018, Cancun, Mexico, April 22-26, 2018

Preliminary Results

- Both H–CH_3 and H–C_2H_2 seem to underpredict the cross section above 0.4 eV.



Next Steps

- Calculate experiment systematic uncertainty
- Complete background analysis
  - Time-dependent
  - Time-independent
- Complete sample characterization
  - Impurities, densities, uncertainties, etc.
- Document results