



Thermal Neutron Cross Section Measurements at the RPI LINAC

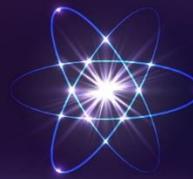
February 15-17, 2022



Presented by:
Dominik Fritz
RPI/NNL Nuclear Data Group, PI Y. Danon, ND2
Rensselaer Polytechnic Institute, Troy, NY, 12180

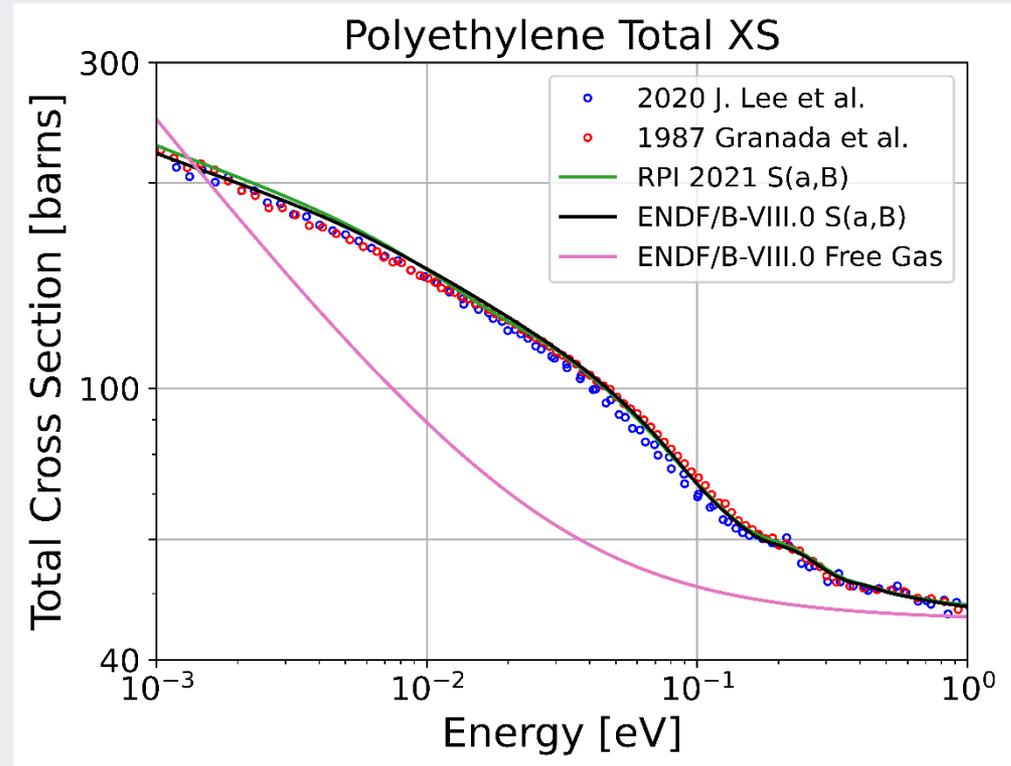
NCSP TPR, February 15-17, 2022 , via webex

Overview



Motivation:

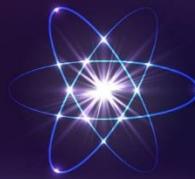
1. Many materials lack high quality total cross section measurements in the 0.5 meV – 1 eV required for validation of thermal scattering library (TSL) evaluations.
2. Evaluations in this region need immediate validation as **thermal scattering can dramatically alter the neutron multiplication factor of a system.**



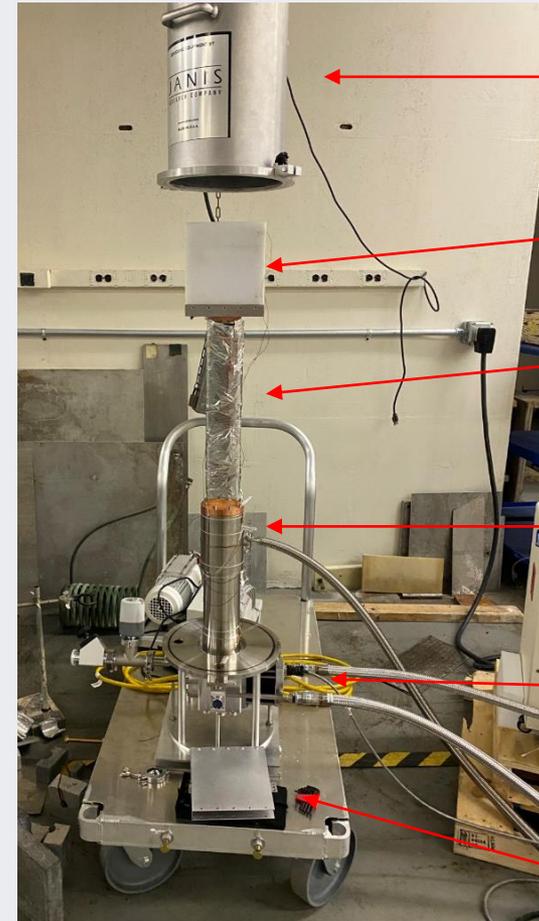
Completed Work:

1. Designed and developed cold moderator capability for use in moderating neutrons to the sub-thermal region (<20 meV).
2. Performed thermal cross section measurements that encompass the entire thermal region (0.5 meV – 1 eV) for polyethylene, polystyrene, Plexiglas G/G-UVT, yttrium hydride and beryllium.

Design Specifications

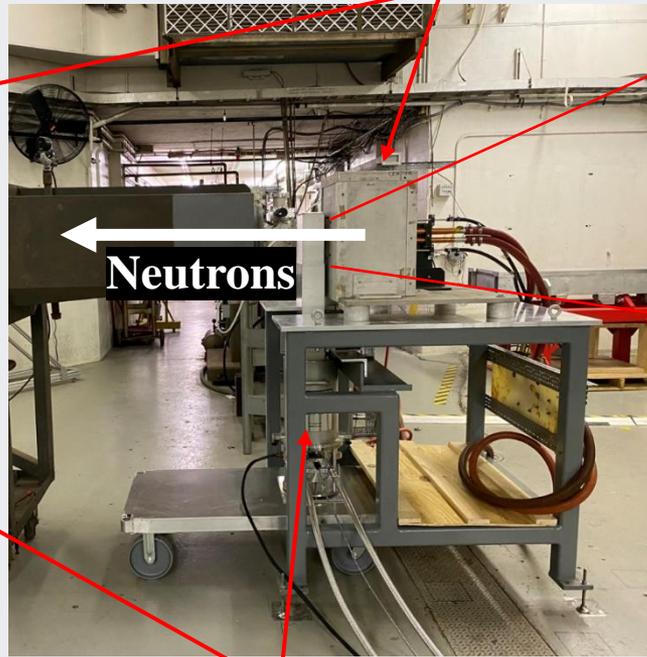
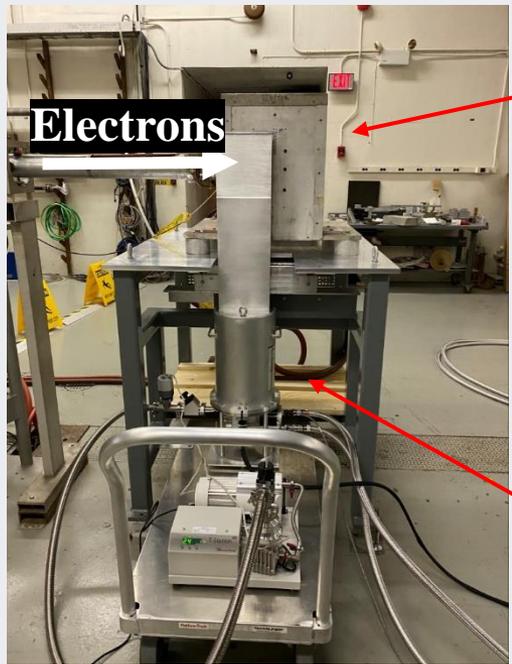
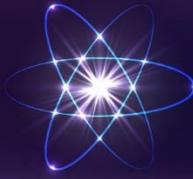


- Neutronics:
 - Polyethylene
 - Large enough to cover collimation
 - As close to source of neutrons as possible
 - As cold as possible in a consistent fashion
 - **Maximize gain over Enhanced Thermal Target (ETT) alone**
 - Metric: Integral counts in 1 – 5 meV range
- Thermal/System:
 - Polyethylene
 - < 30 K w/ 1.5 kW on target
 - Good connection to cryostat
 - System
 - Must couple to ETT target
 - Long cold finger → protect cold head
 - Large cold finger cross-sectional area
 - Portable; Minimal material; Can withstand Hi-Vac
 - Single Stage Cryo-cooler



- Outer Vacuum Jacket
- Polyethylene
- Cold Finger
- Cold Head
- Helium Connections
- Polyethylene Radiation Shield

Cold Moderator - ETTC

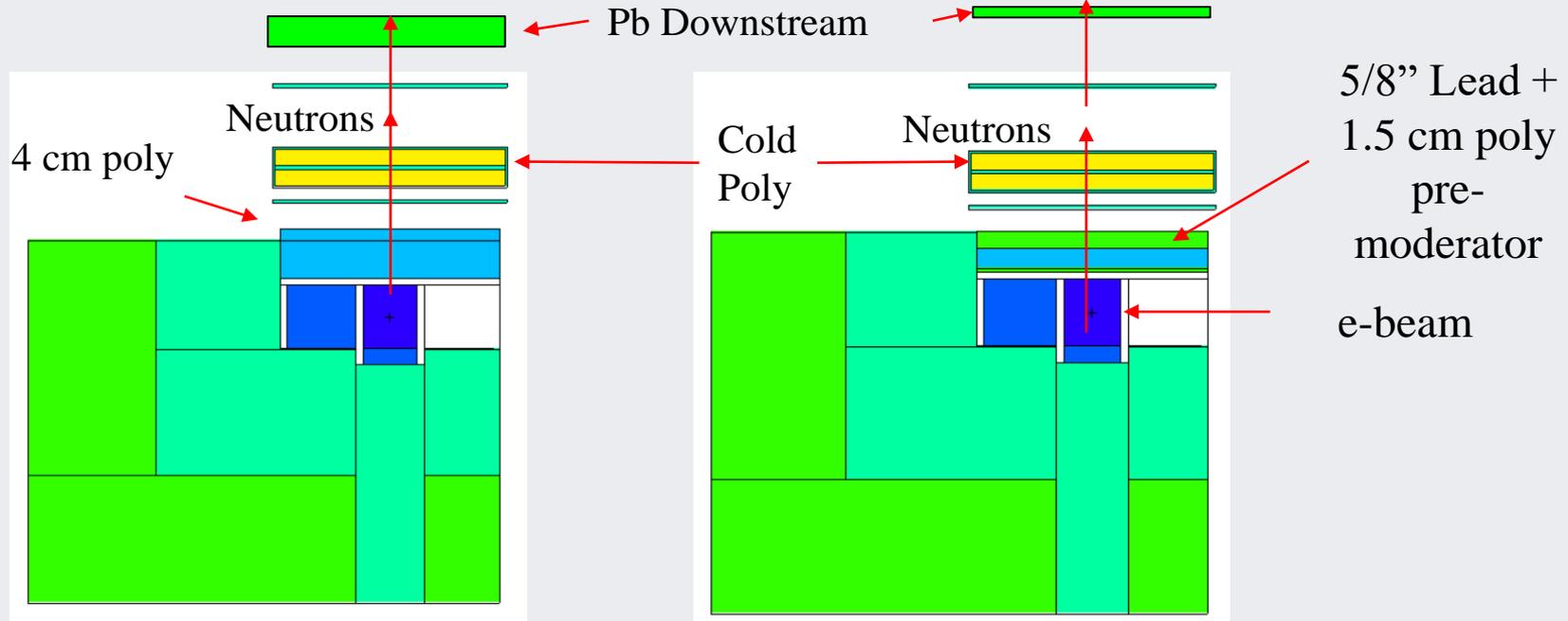
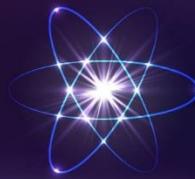


ETT

**Cryostat rolls in front of
ETT**

**Poly stabilizes at
29 K with
LINAC Power
Load**

Design Choice



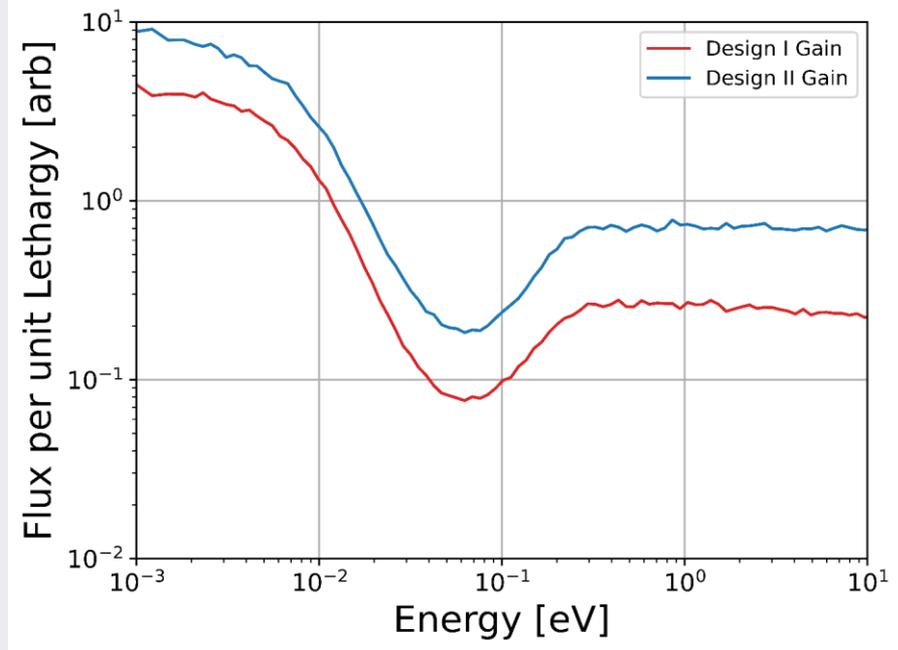
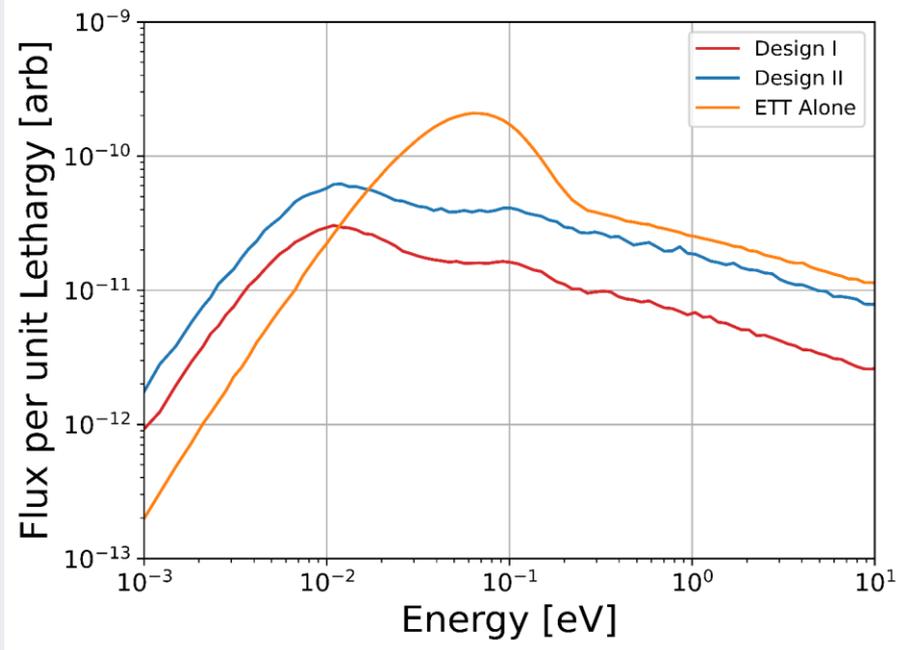
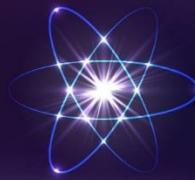
Design I

- **Safer** → no changing of pre-moderators after irradiation

Design II

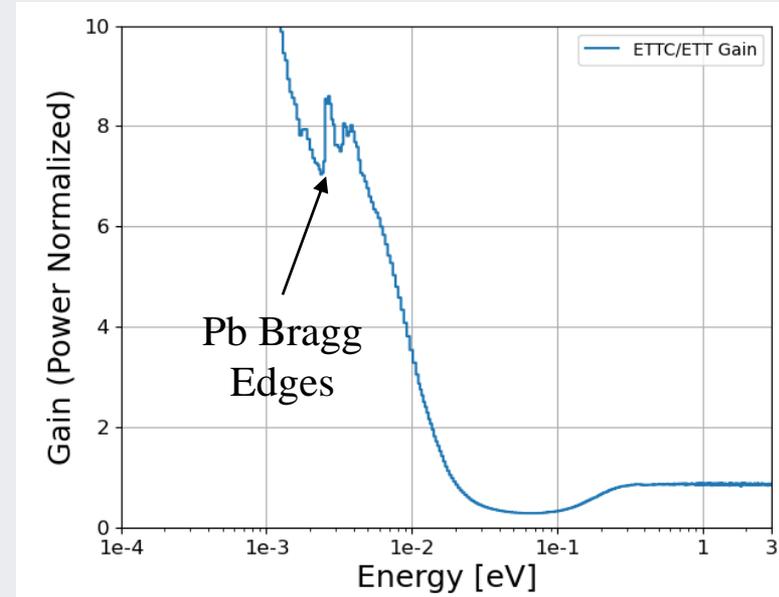
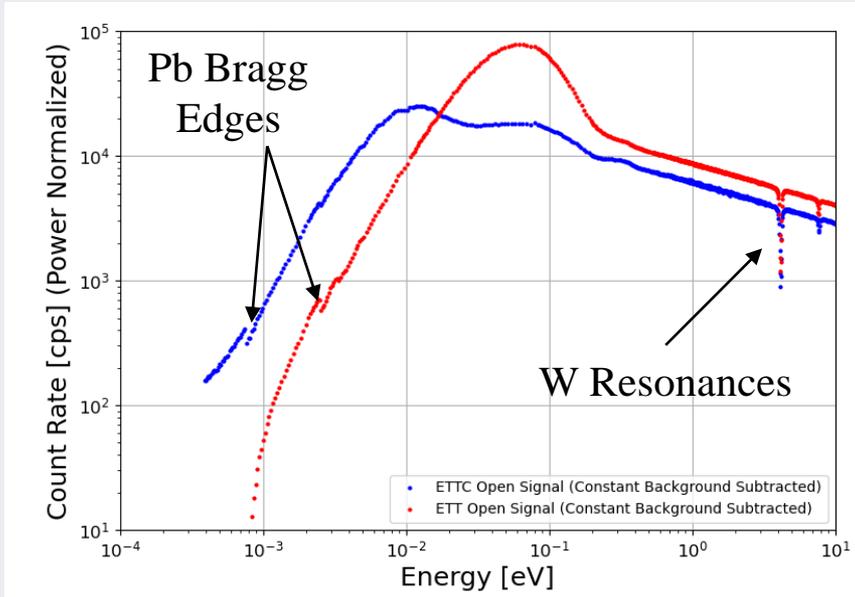
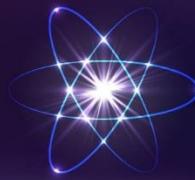
- Higher Gain → achieved through moving Pb upstream

Design Gain Comparison (Over ETT Alone)



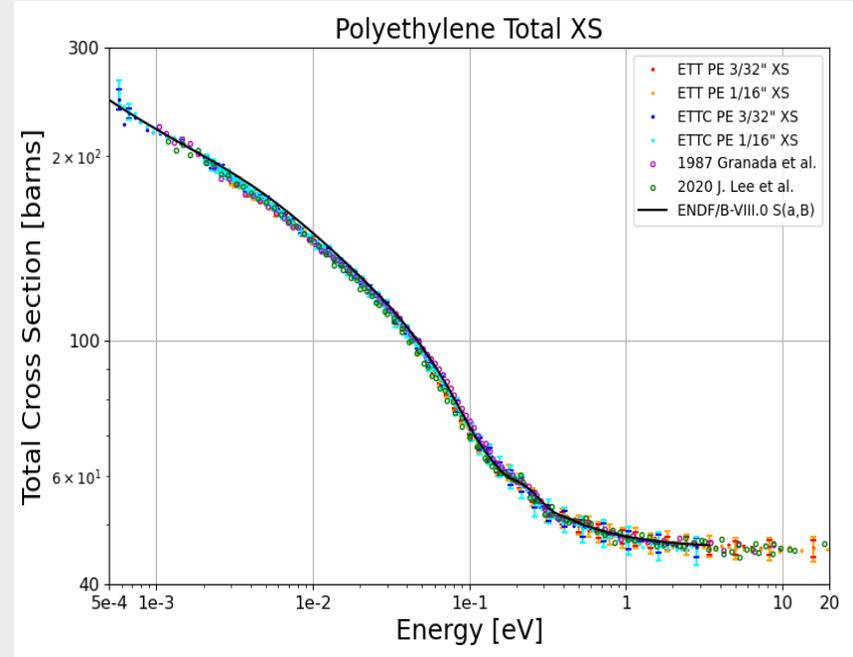
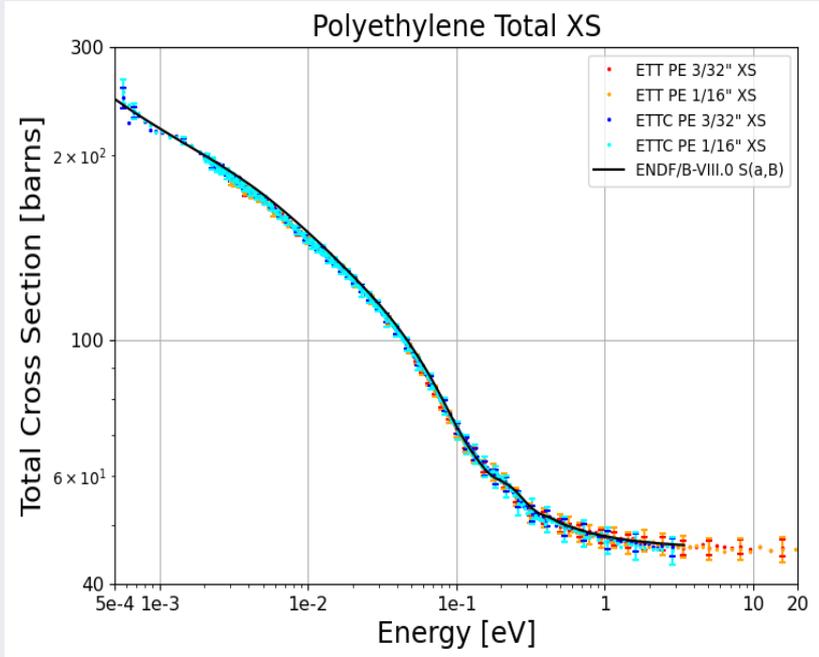
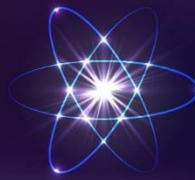
- Both Design I and Design II provide significant gain over the ETT.
- Despite the improvement of Design II over Design I, Design I was proceeded with due to safety considerations.

System Experimental Gain Validation



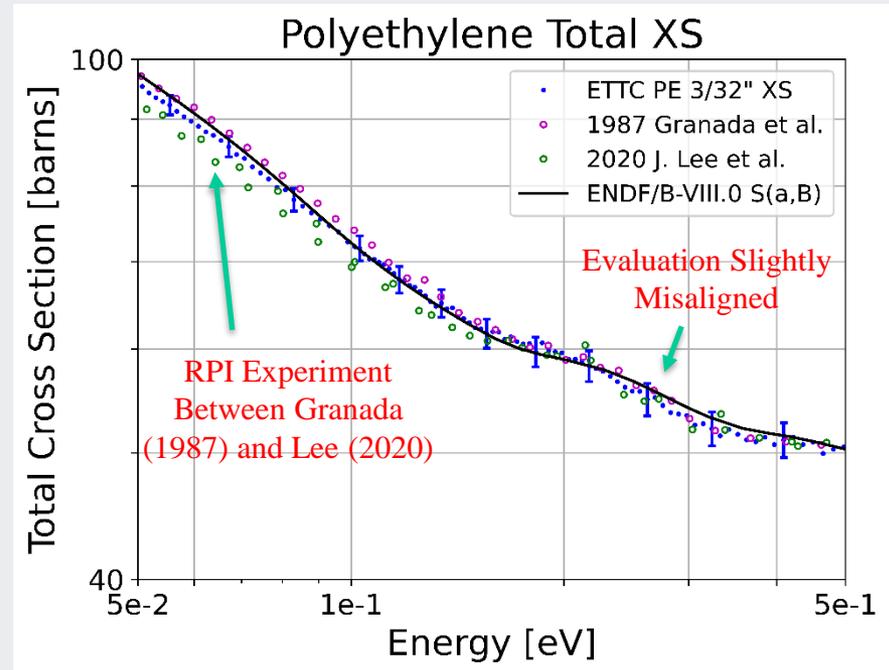
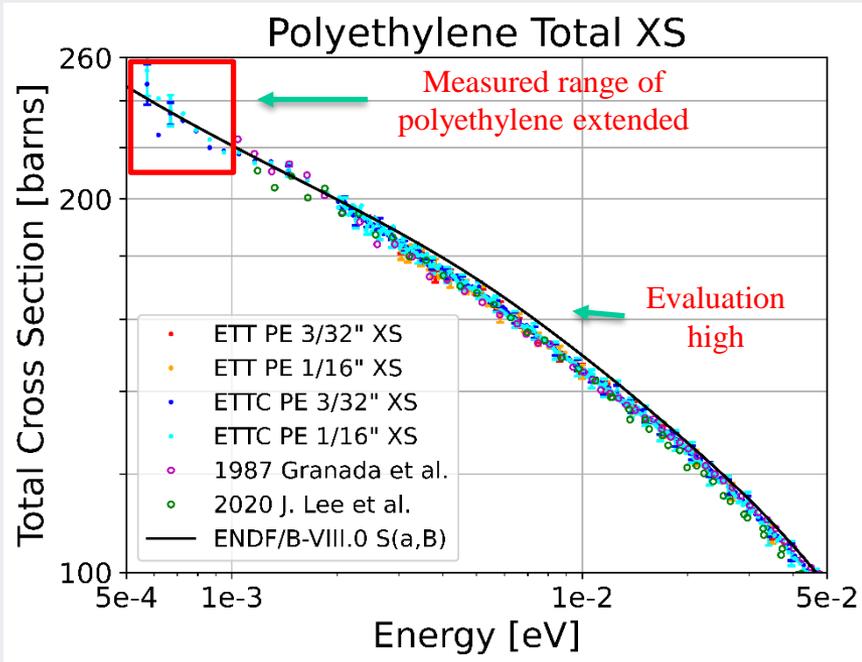
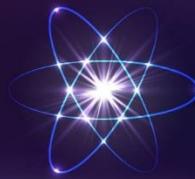
- After LINAC power normalization, the ETTC achieves a gain up to **8** over the ETT.
- ETTC extends flux below 1 meV.

Thermal Cross Section Validation



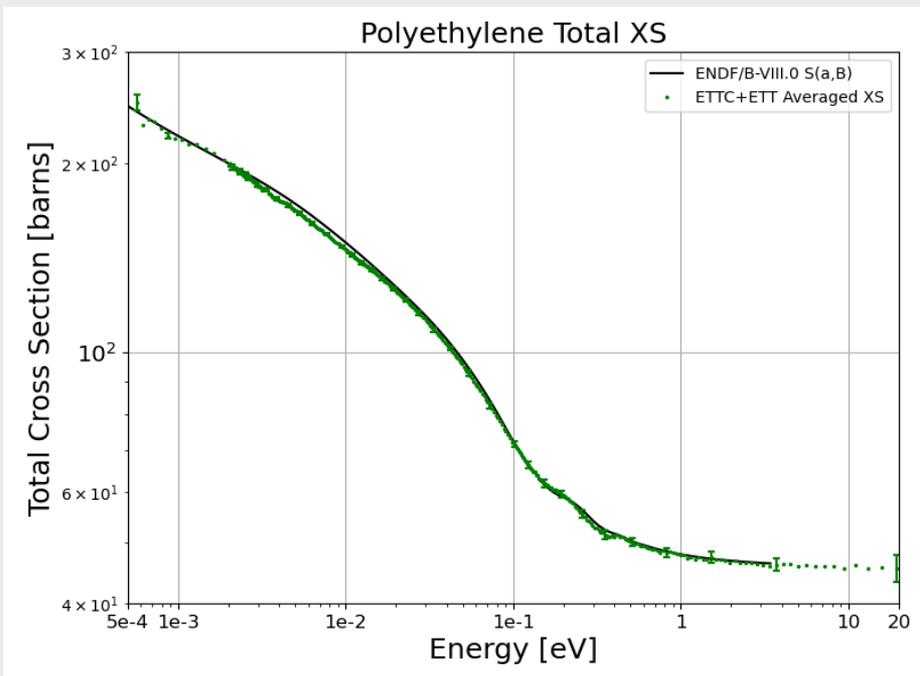
- Excellent agreement between ETT and ETTC cross section for polyethylene (PE).
- Good agreement between all RPI measured cross sections, other measured cross sections, and TSL evaluation.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance matrix.

Polyethylene (Closer Look)

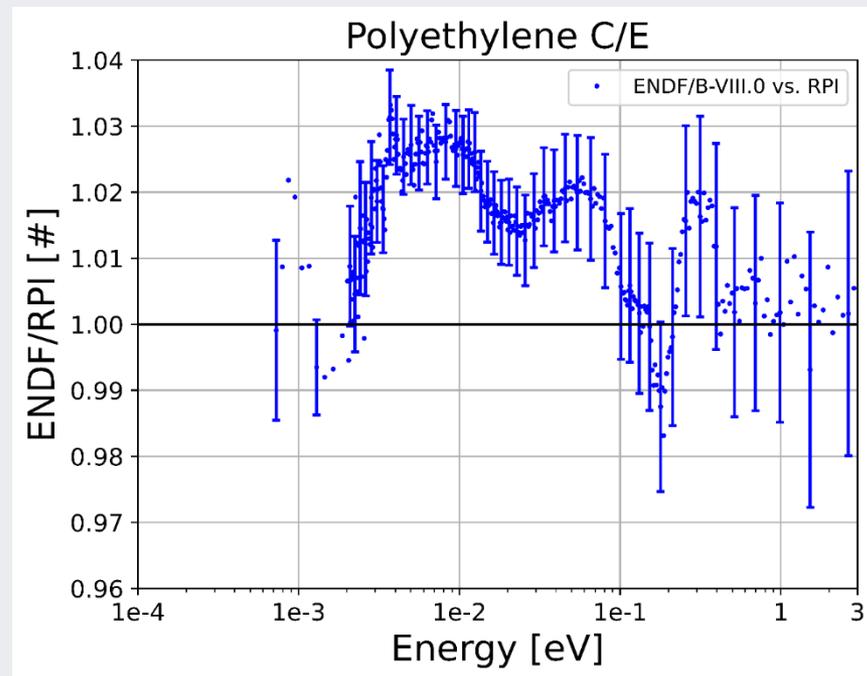


*Excellent agreement between all RPI experiments

Polyethylene (Averaged Cross Section)

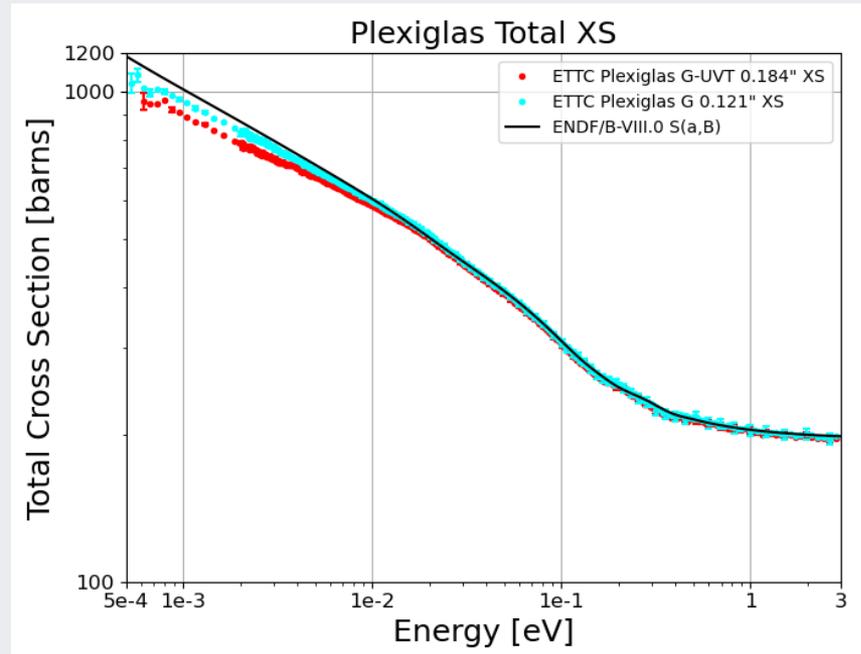
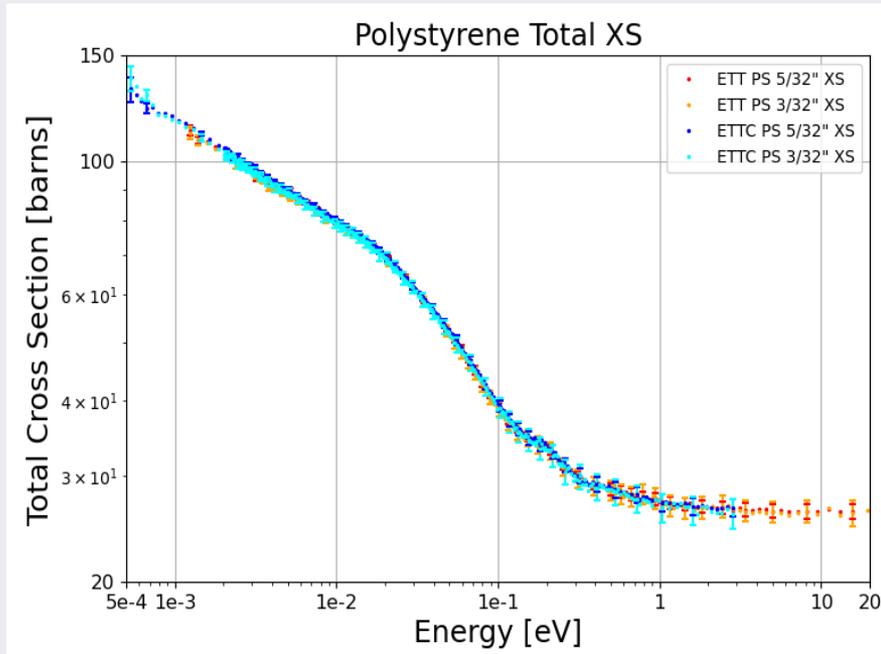
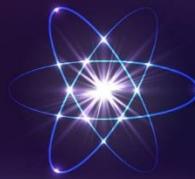


- Weighted average of all polyethylene measurements performed



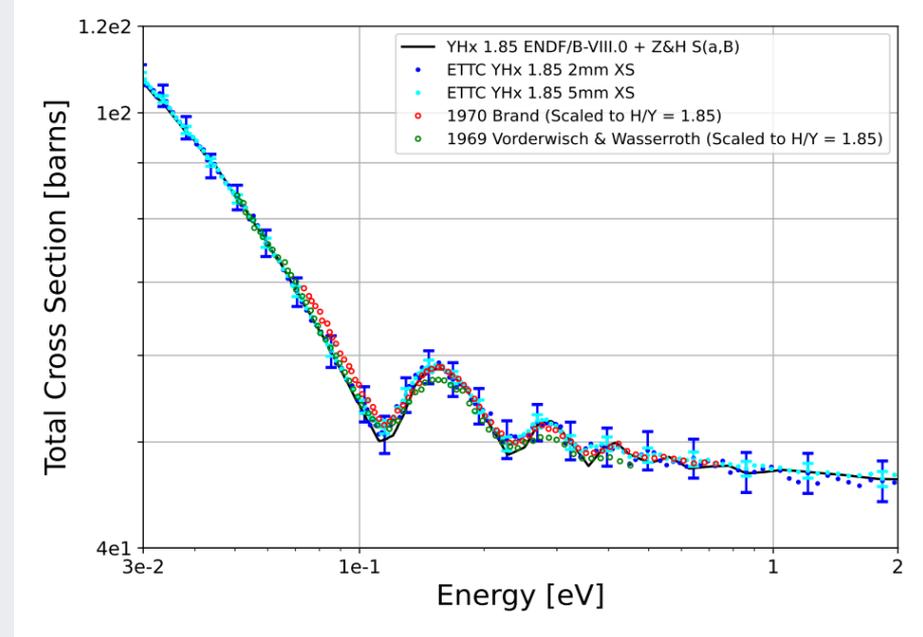
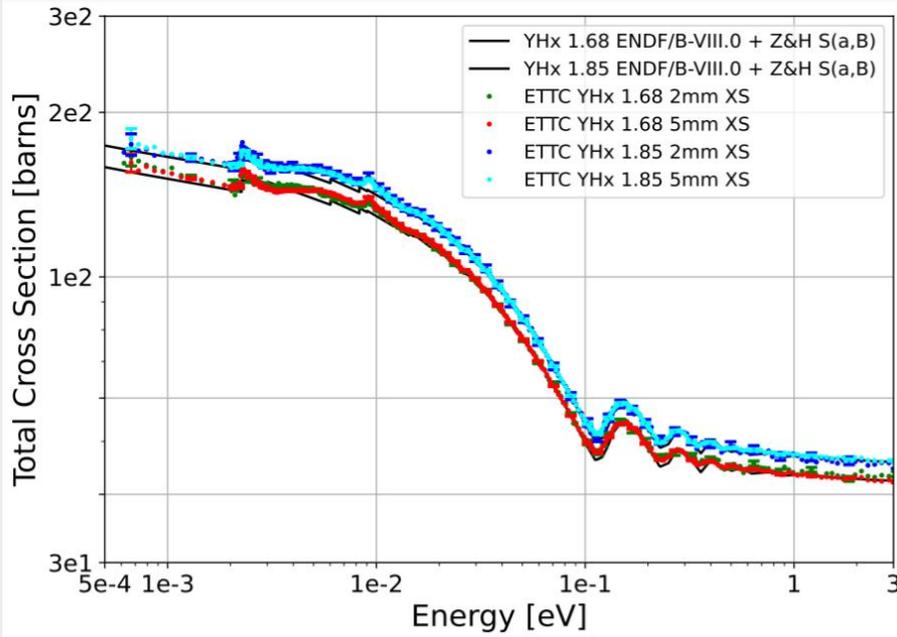
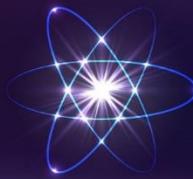
- ENDF/B-VIII.0 evaluation is higher than measured cross section at most energies

Thermal Cross Section Measurements: Polymers



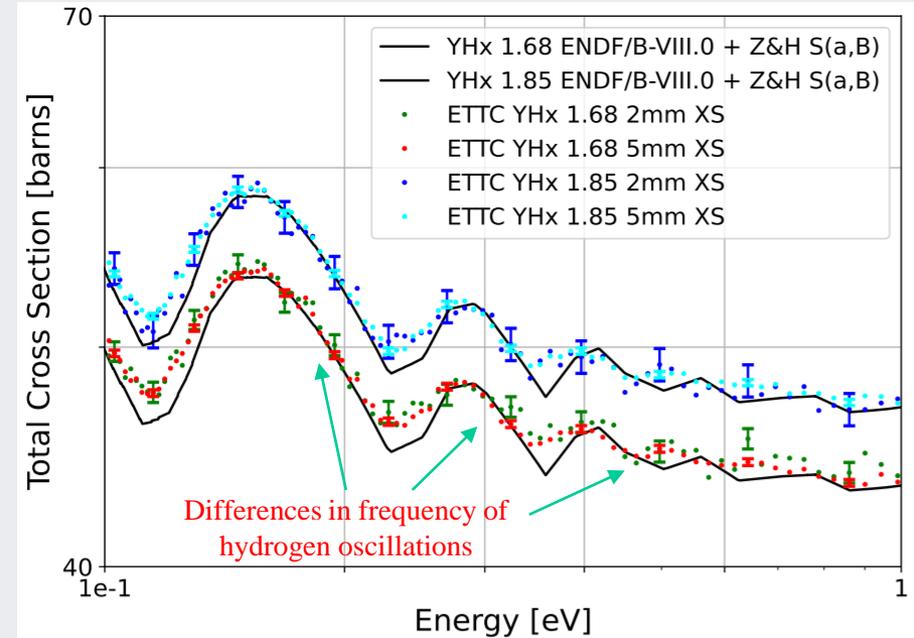
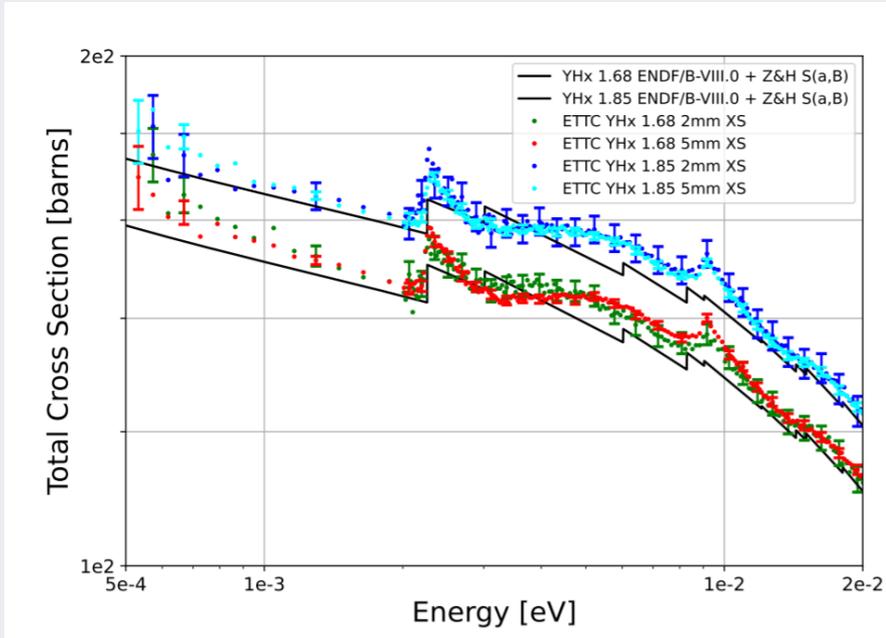
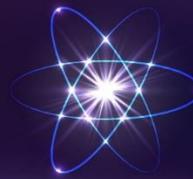
- Generally good agreement between measured cross section and TSL evaluation for polymers.
- Differences in cross section between Plexiglas G and Plexiglas G-UVT.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance matrix.

Thermal Cross Section Measurements: YHx



- Generally good agreement between yttrium hydride measured cross section and TSL evaluation for both concentrations.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance matrix.
- Estimated uncertainty on H/Y ratio from samples not shown here.

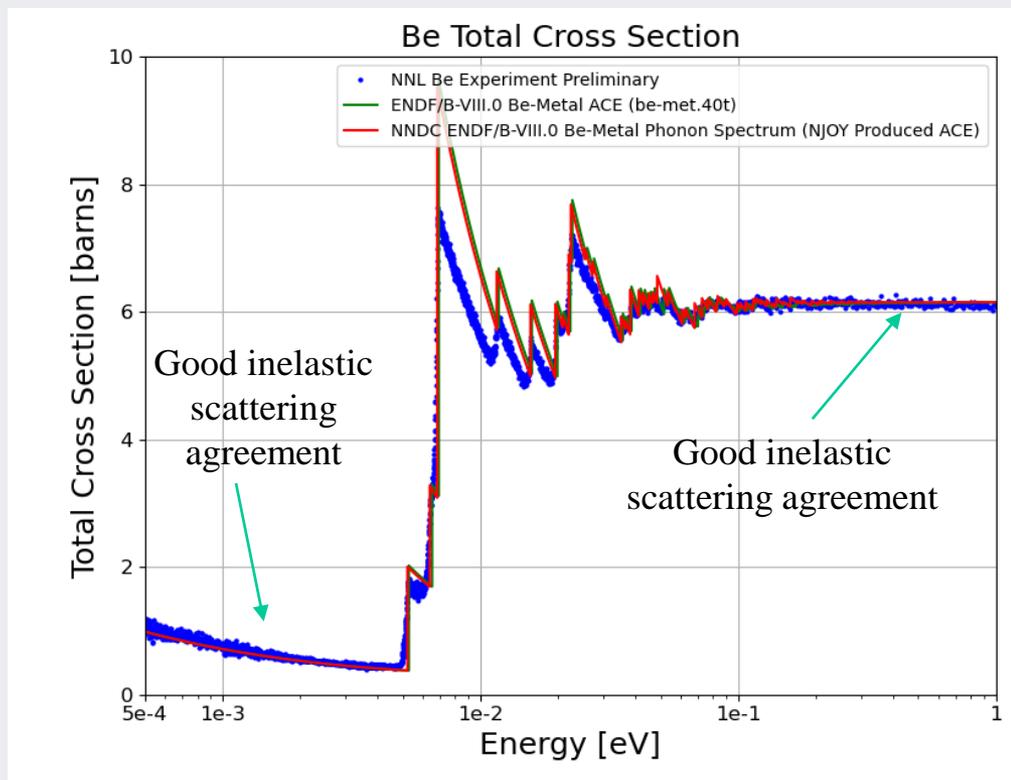
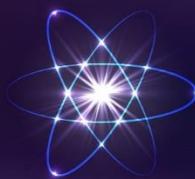
YHx (Closer Look)



- Misalignment of Bragg edges between experiment and yttrium evaluation
- Cross-over in cross section seen in YH_{1.68} samples

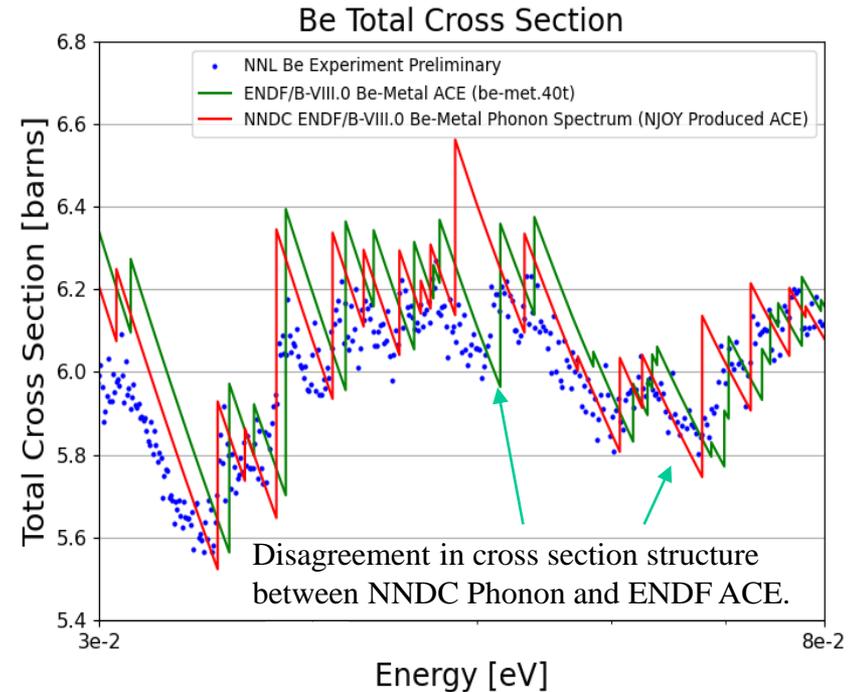
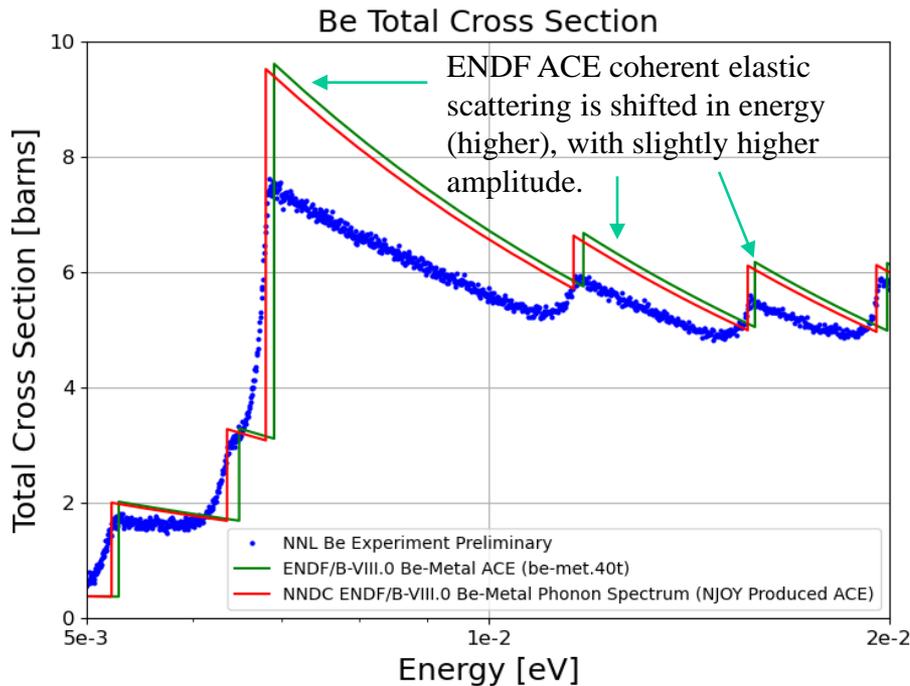
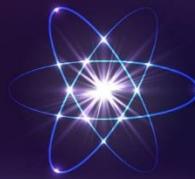
- Potential explanations for differences:
 - Numerical difficulties in NJOY?

Be Thermal Cross Section Measurement



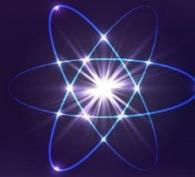
- Discrepancies between measured (preliminary) Be cross section and evaluated data
- Discrepancies between NNDC ENDF/B-VIII.0 Phonon Spectrum and ENDF/B-VIII.0 ACE file
- Both NNDC and ENDF ACE had ENDF/B-VIII.0 Be capture data added.

Be (Closer Look)



- Large differences in amplitude between evaluations and measurement (preliminary) could be due to the crystalline structure of the Be samples.
- Differences in lattice parameters result in the discrepancy seen between the NNDC phonon spectrum (processed through NJOY) and the ENDF/B-VIII.0 ACE file.

Conclusions and Future Work



- Cold polyethylene shows adequate capacity for enhancing sub-thermal neutron flux.
 - Steady state temperature of 29K with LINAC power.
 - Achieved gain up to 8 over current ETT configuration.
 - Extended thermal cross section measurement capability down to 0.5 meV.
- Cold moderator system produced high quality thermal cross section measurements.
 - Measurements performed for polyethylene, polystyrene, Plexiglas, yttrium hydride and beryllium and compared with ENDF/B-VIII.0 TSL evaluations.
 - Finalized all data reduction for all measurements.
- Future Work:
 - Completion of necessary journal publications.