# Thermal Neutron Cross Section Measurements

NDAG Meeting

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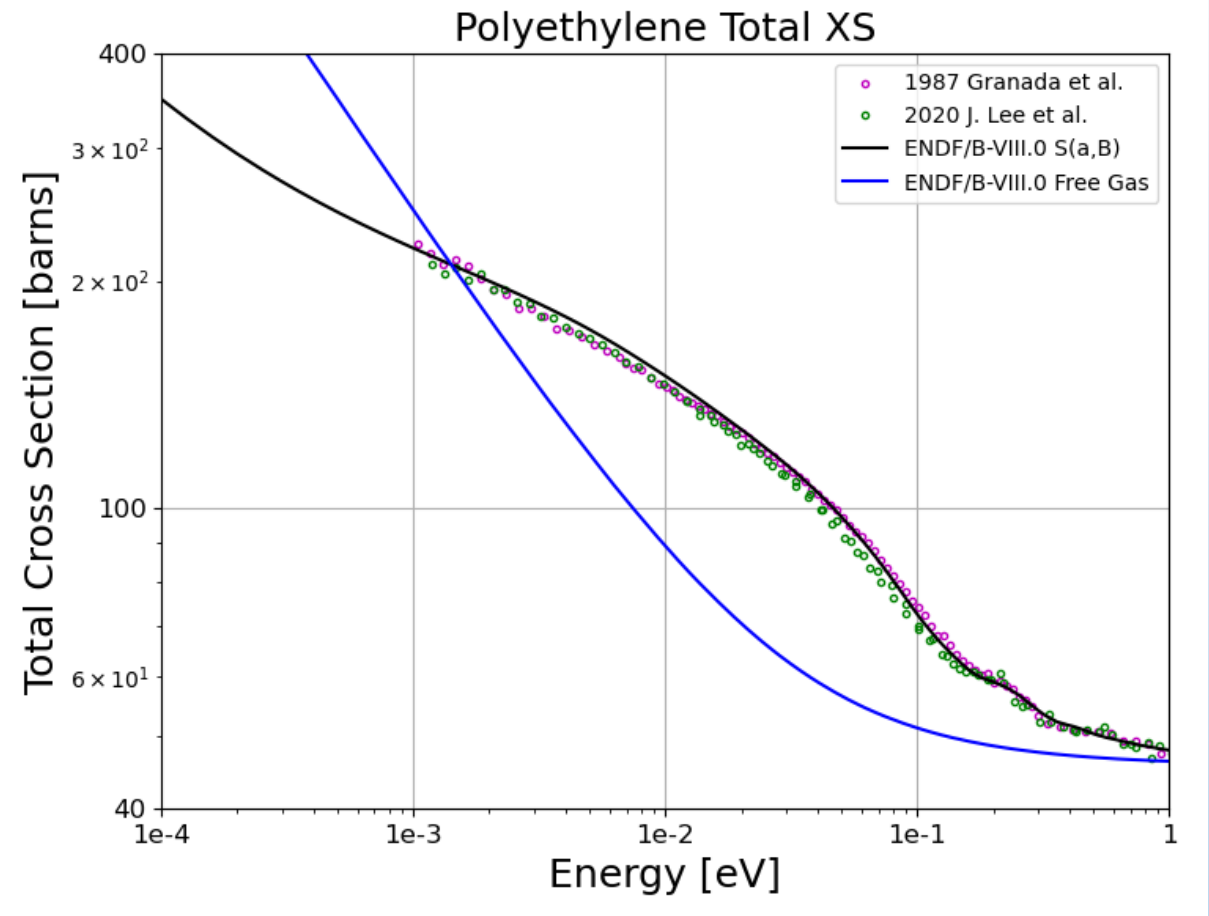
# Overview

- Motivation:
  1. Many materials lack high quality total cross section measurements from 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.**



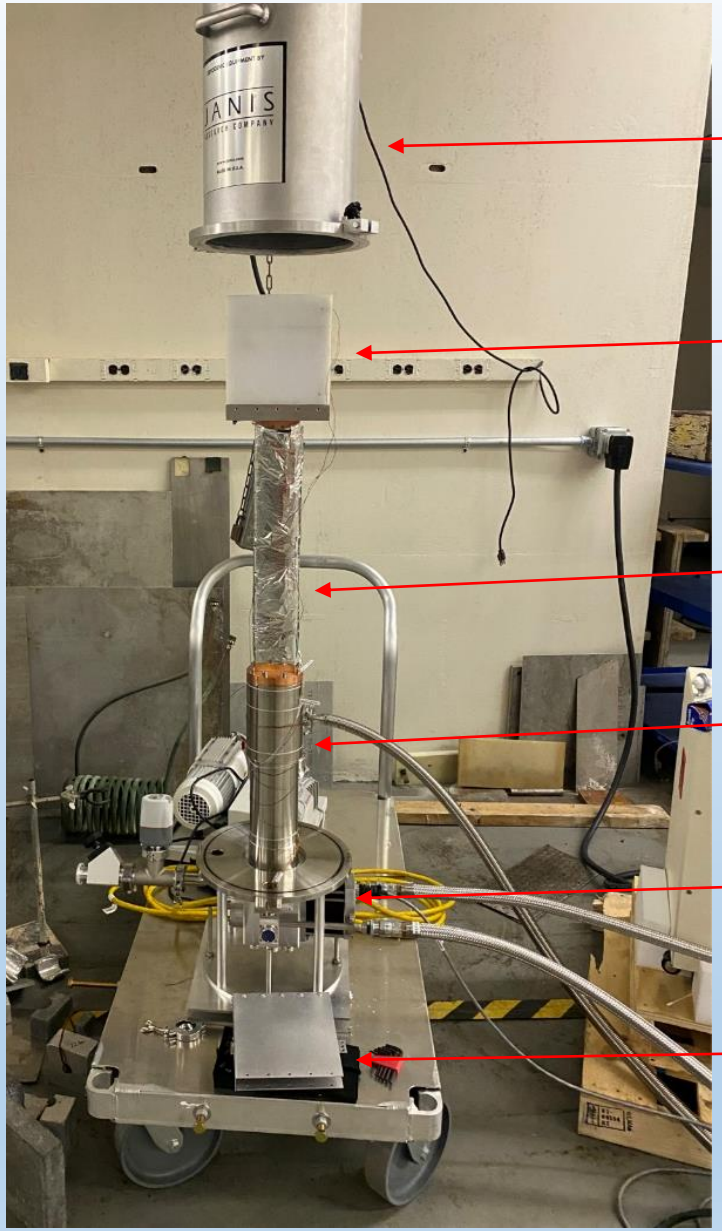

Completed Work:

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 and yttrium hydride.

# Design Specifications

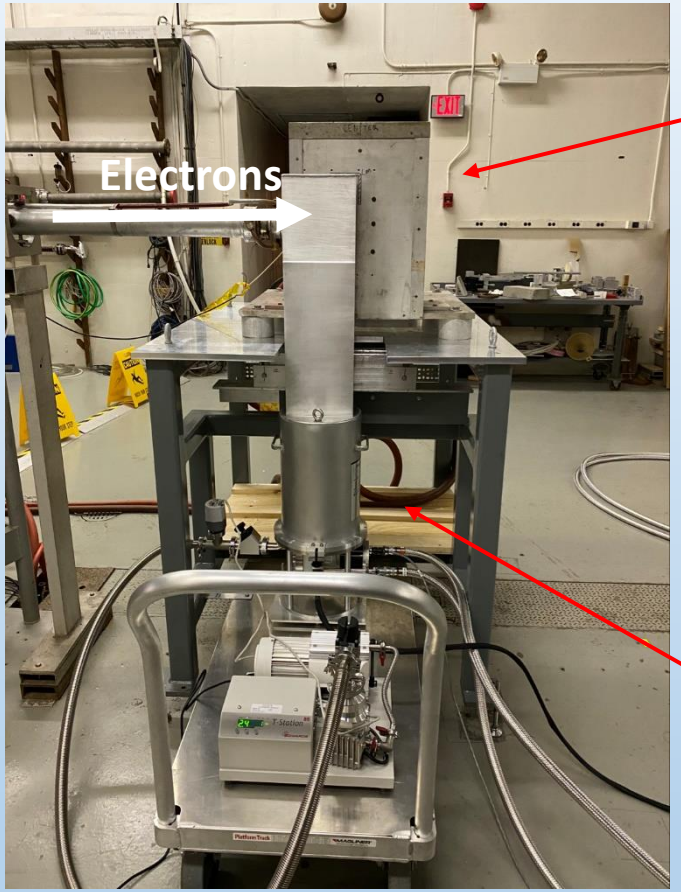
- Neutronics:
  - Polyethylene
    - Large enough to cover collimation
    - As close to source of neutrons as possible
    - As cold as possible in a consistent fashion
  - **Maximize gain over ETT alone (existing target)**
    - Metric: Integral counts in 1 – 5 meV range

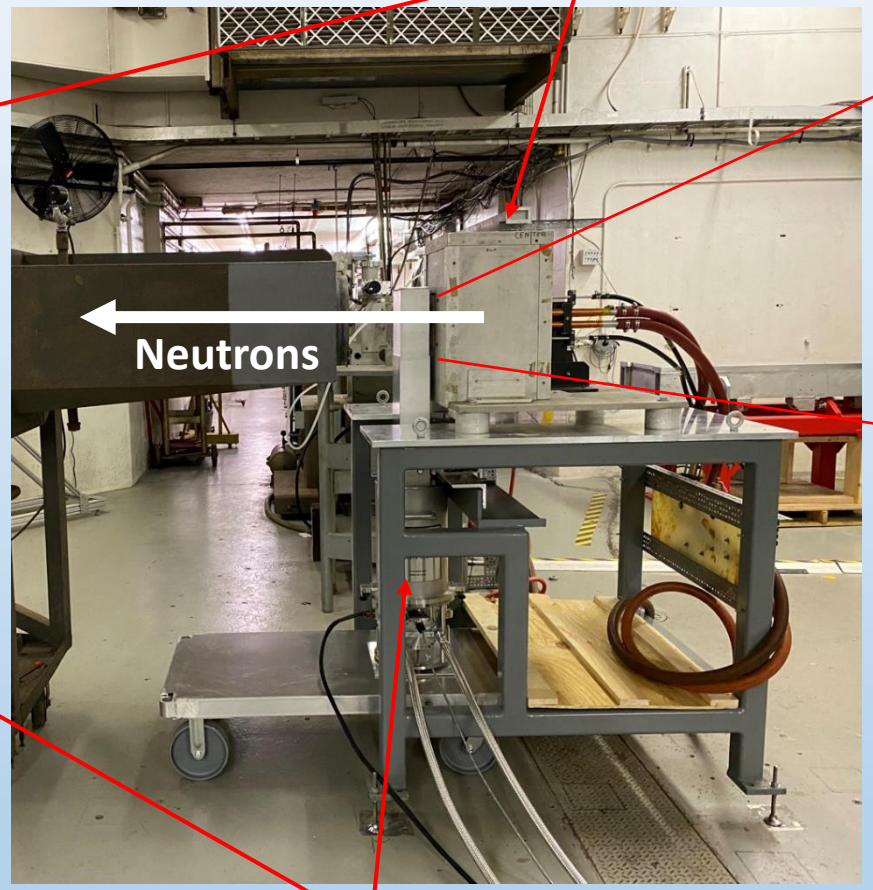
- Thermal/System:
  - HDPE
    - < 30 K w/ 1.5 kW on target
    - Good connection to cryostat
  - System
    - Must couple to ETT target
    - Long cold finger ➔ protect cold head
    - Large cold finger cross-sectional area
    - Portable; Minimal material; Can withstand Hi-Vac
    - Single Stage Cryo-cooler



# Cold Moderator - ETTC

ETT

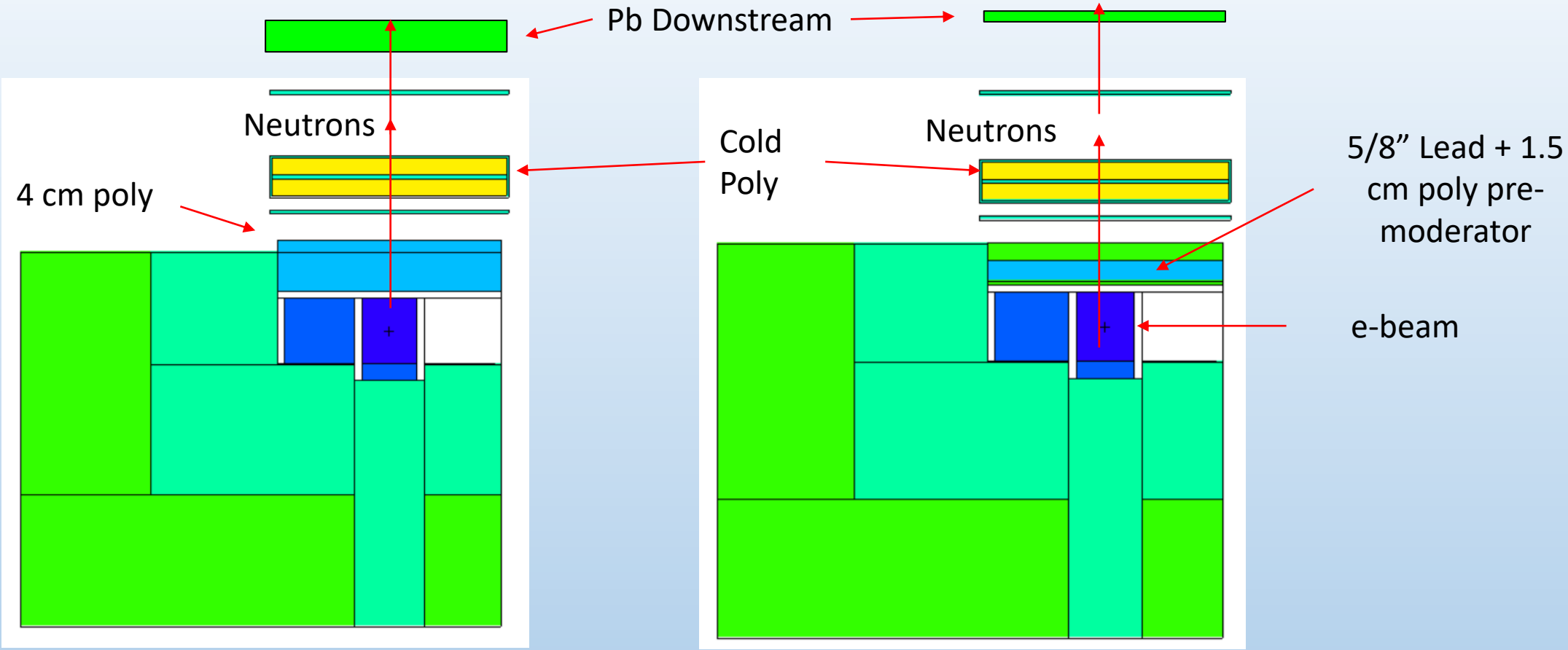



Poly stabilizes at 29 K
with LINAC Power Load

Cryostat rolls in front of ETT

# Design Choice



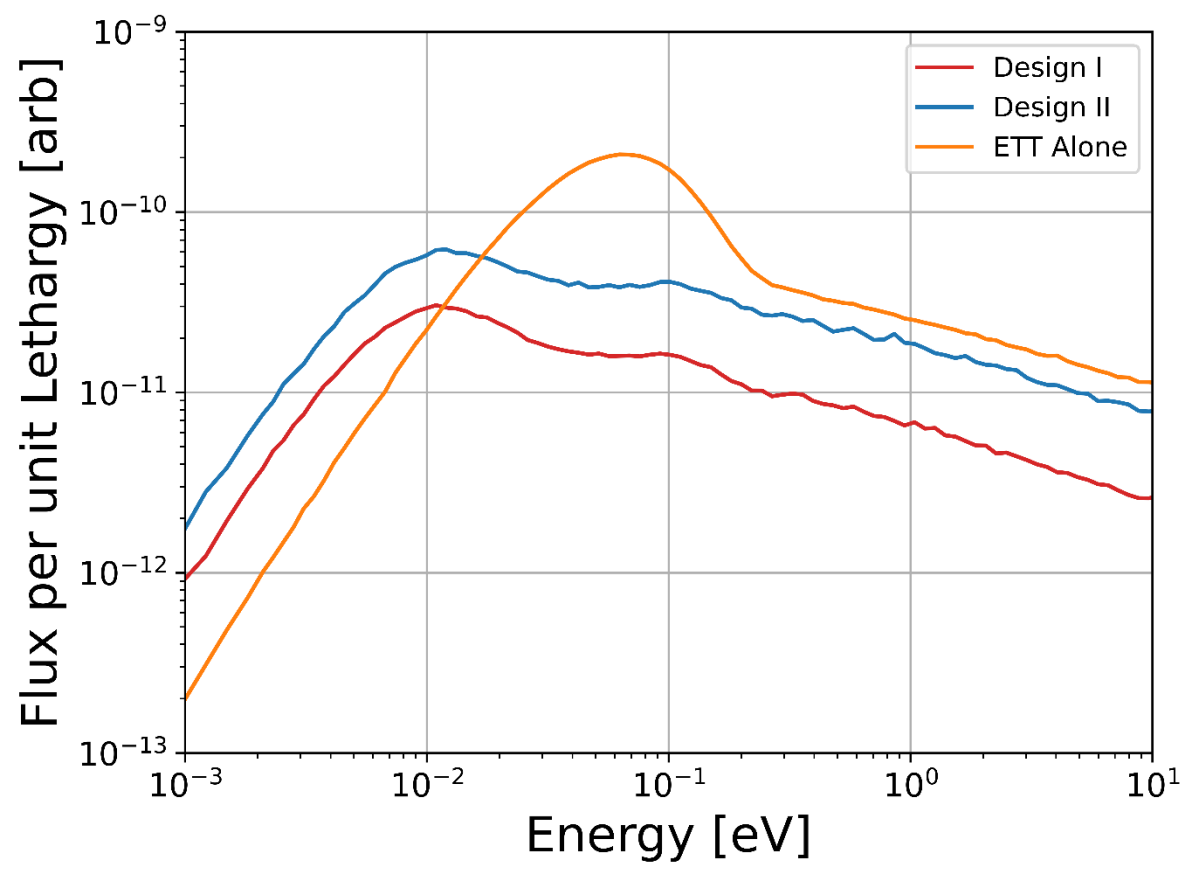

**Design I**

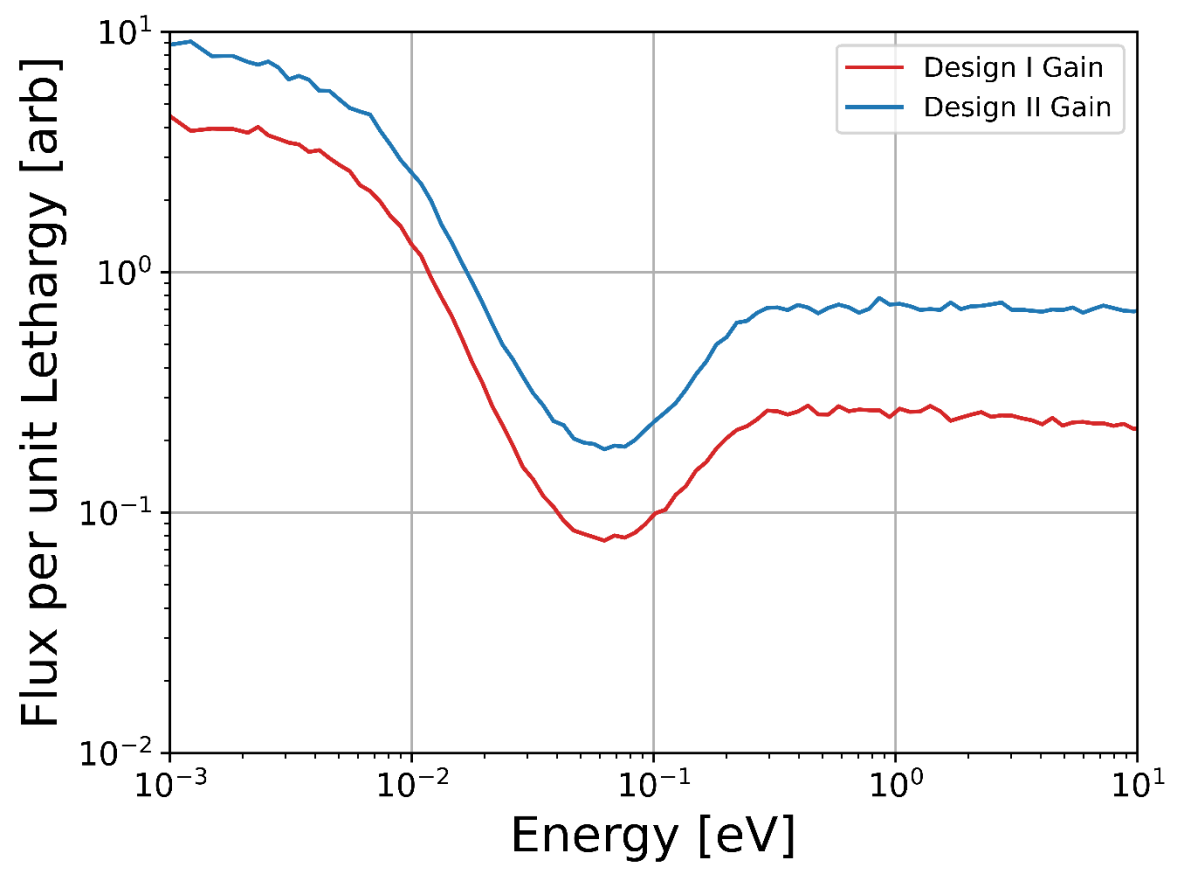
- **Safer** ➔ no changing of pre-moderators after irradiation

**Design II**

- Higher Gain ➔ achieved through moving Pb upstream

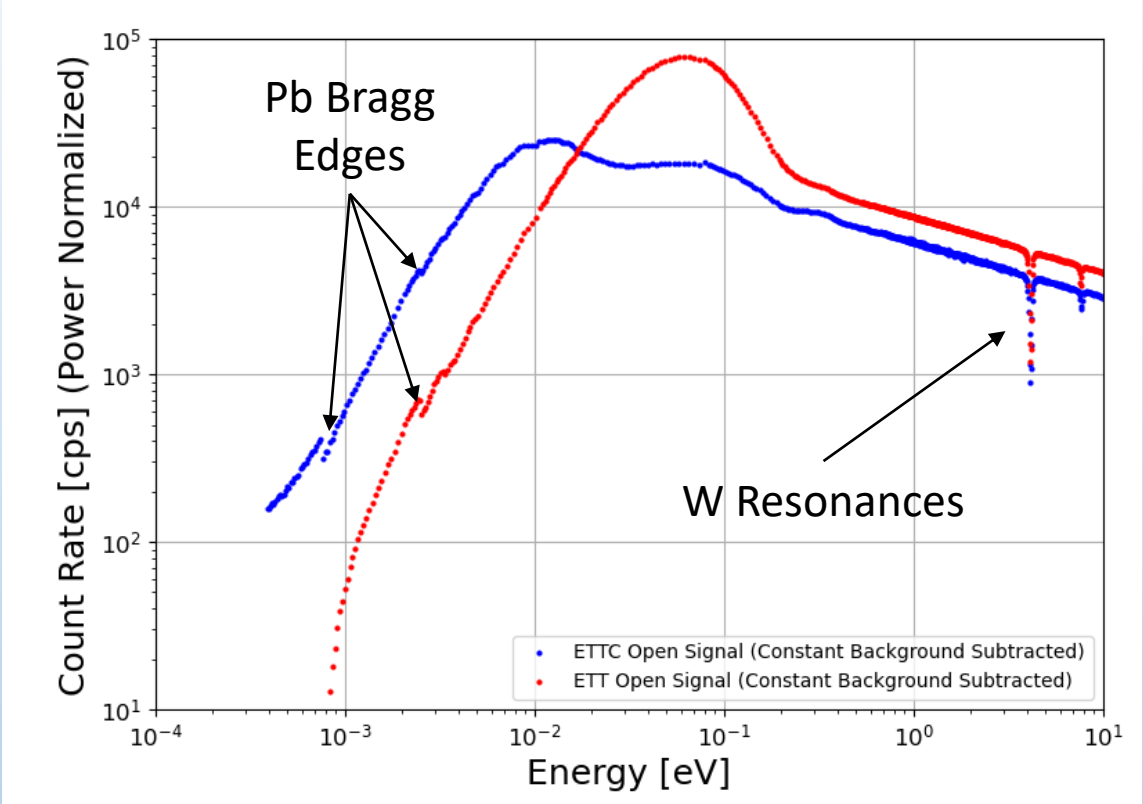
# Design Gain Comparison (Over ETT Alone)

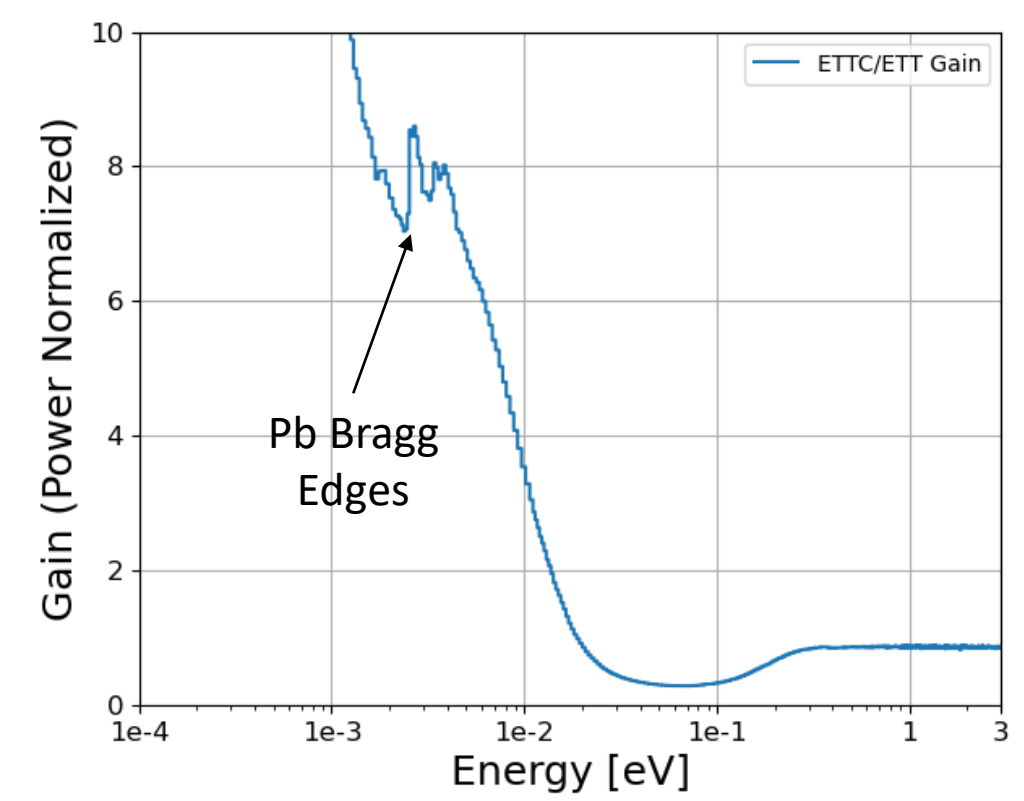



- Both Design I and Design II provide significant gain over the ETT.
- Despite the improvement of Design II over Design I, Design I was proceeded with due to safety considerations.

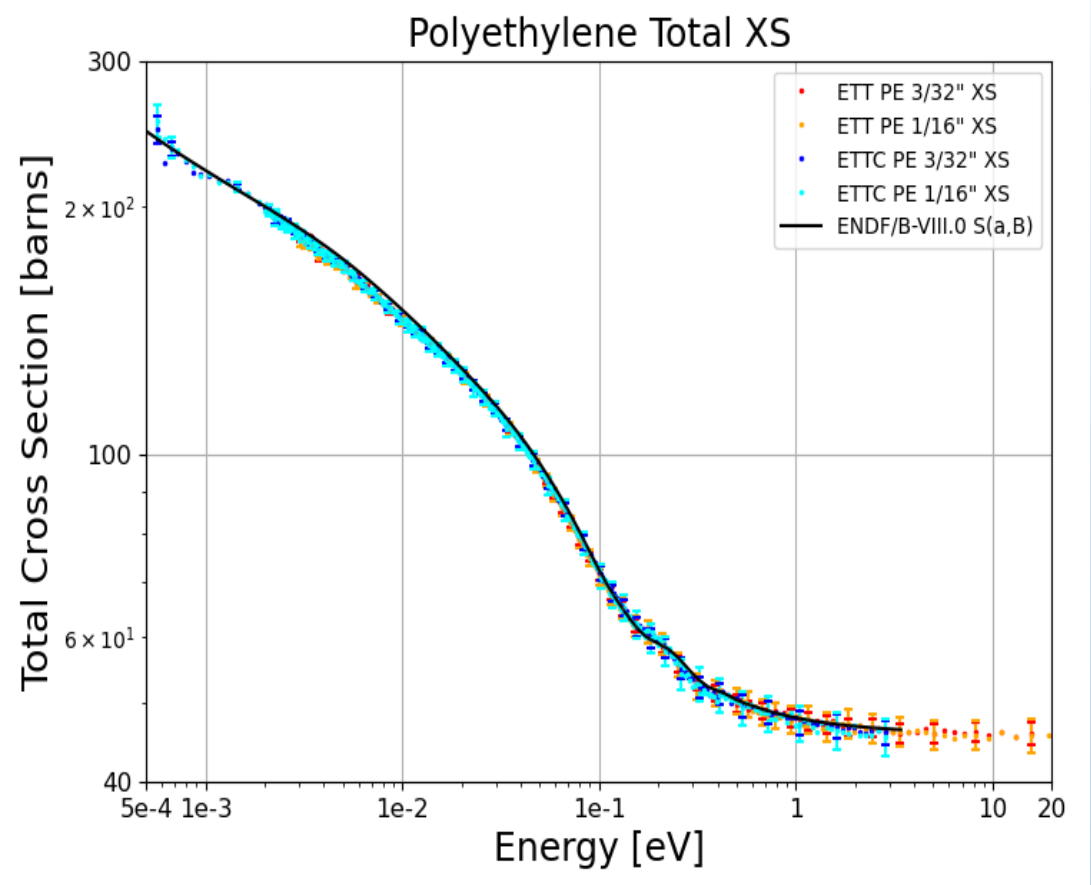
# System Experimental Gain Validation

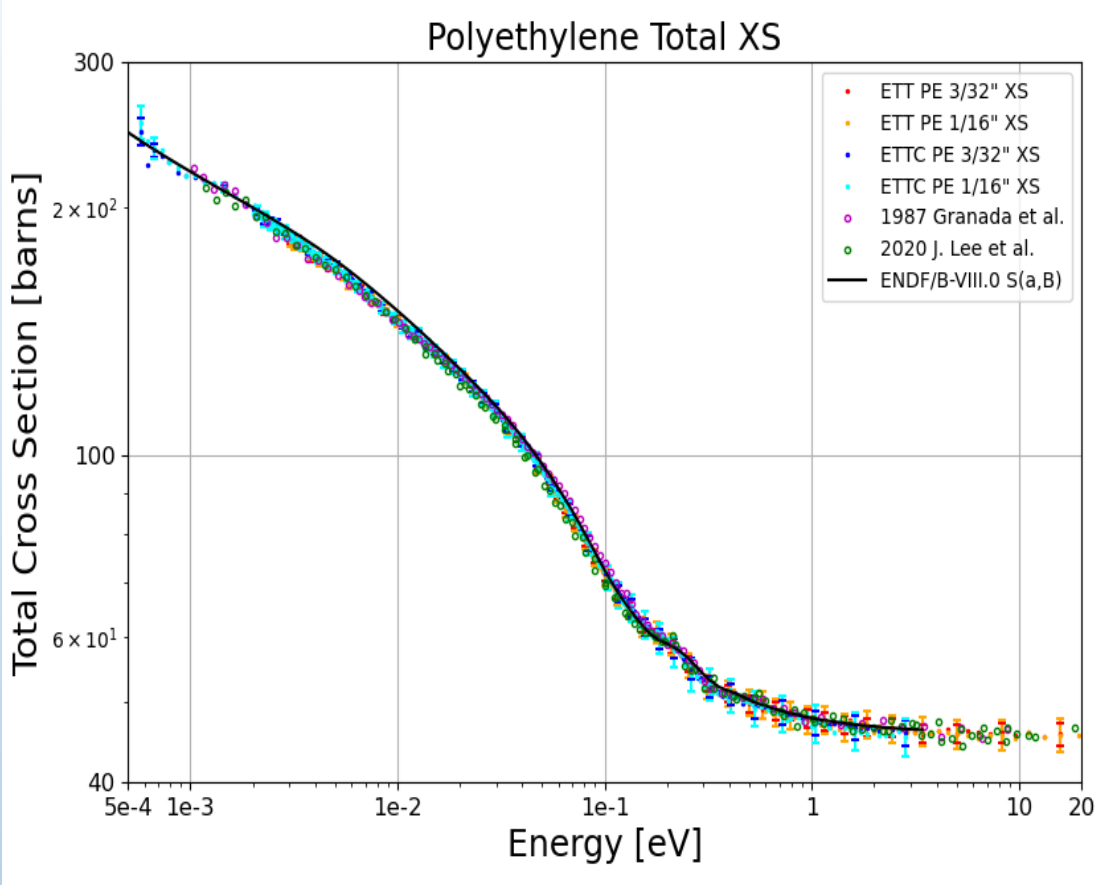



- After LINAC power normalization, the ETTC achieves a gain up to 8 over the ETT.
- ETTC extends flux below 1 meV.

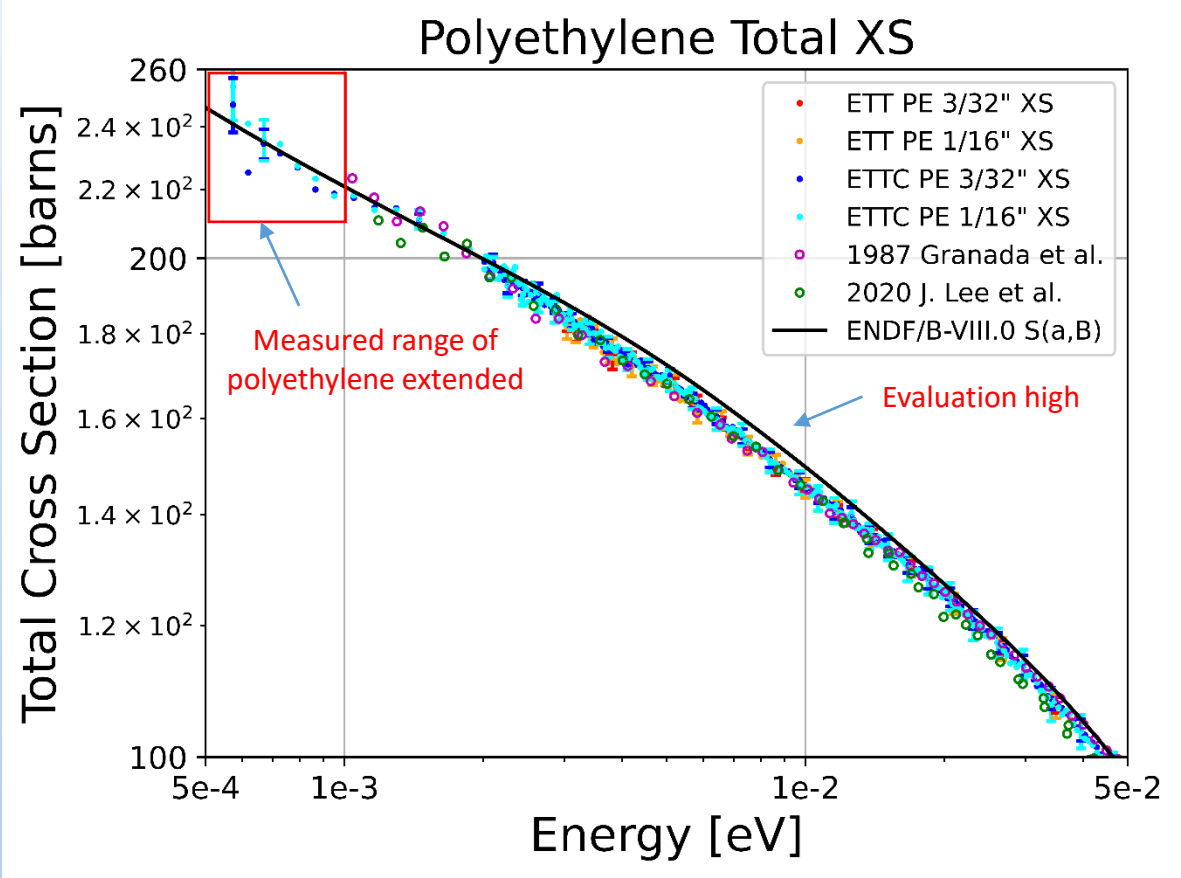
# Thermal Cross Section Validation

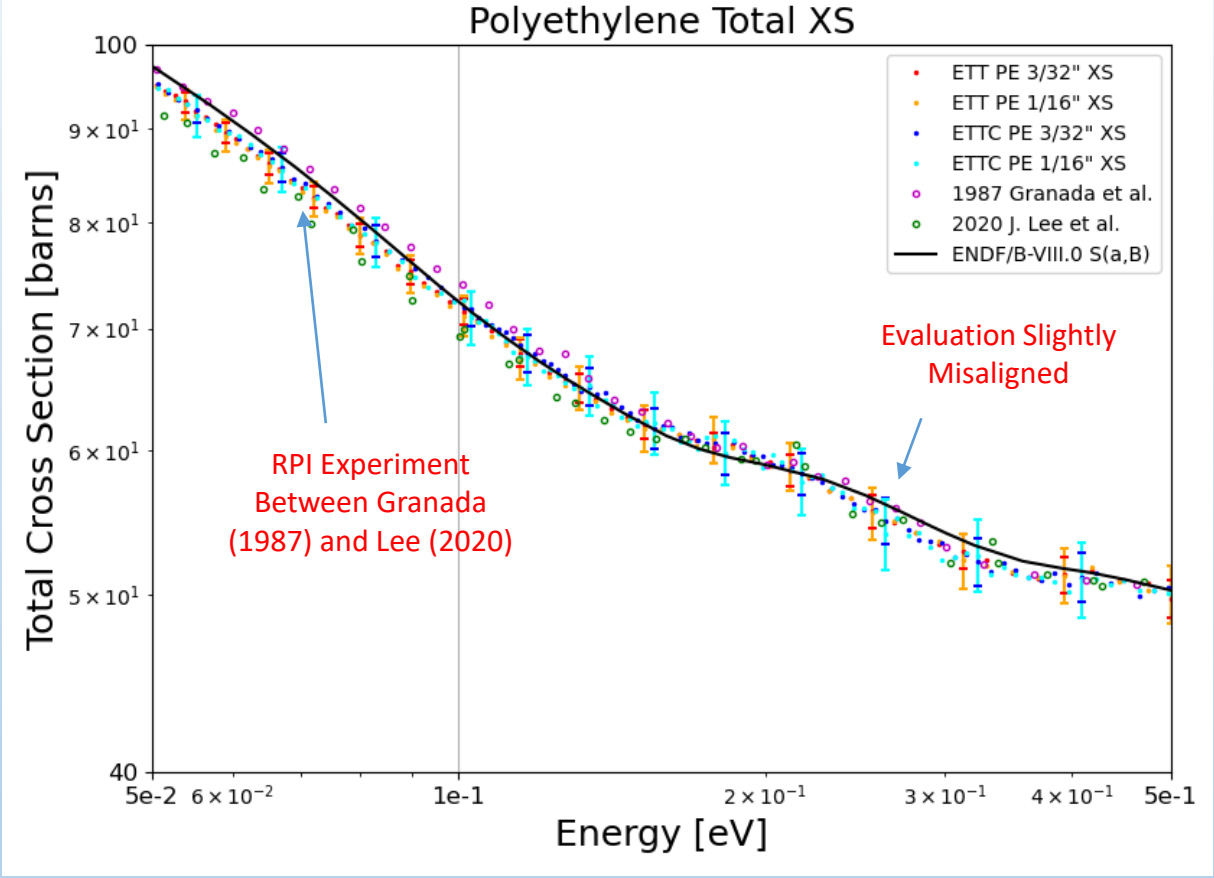



- Excellent agreement between ETT and ETTC cross section for polyethylene (PE).
- Good agreement between all RPI measured cross sections, other measured cross sections, and TSL evaluation.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance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

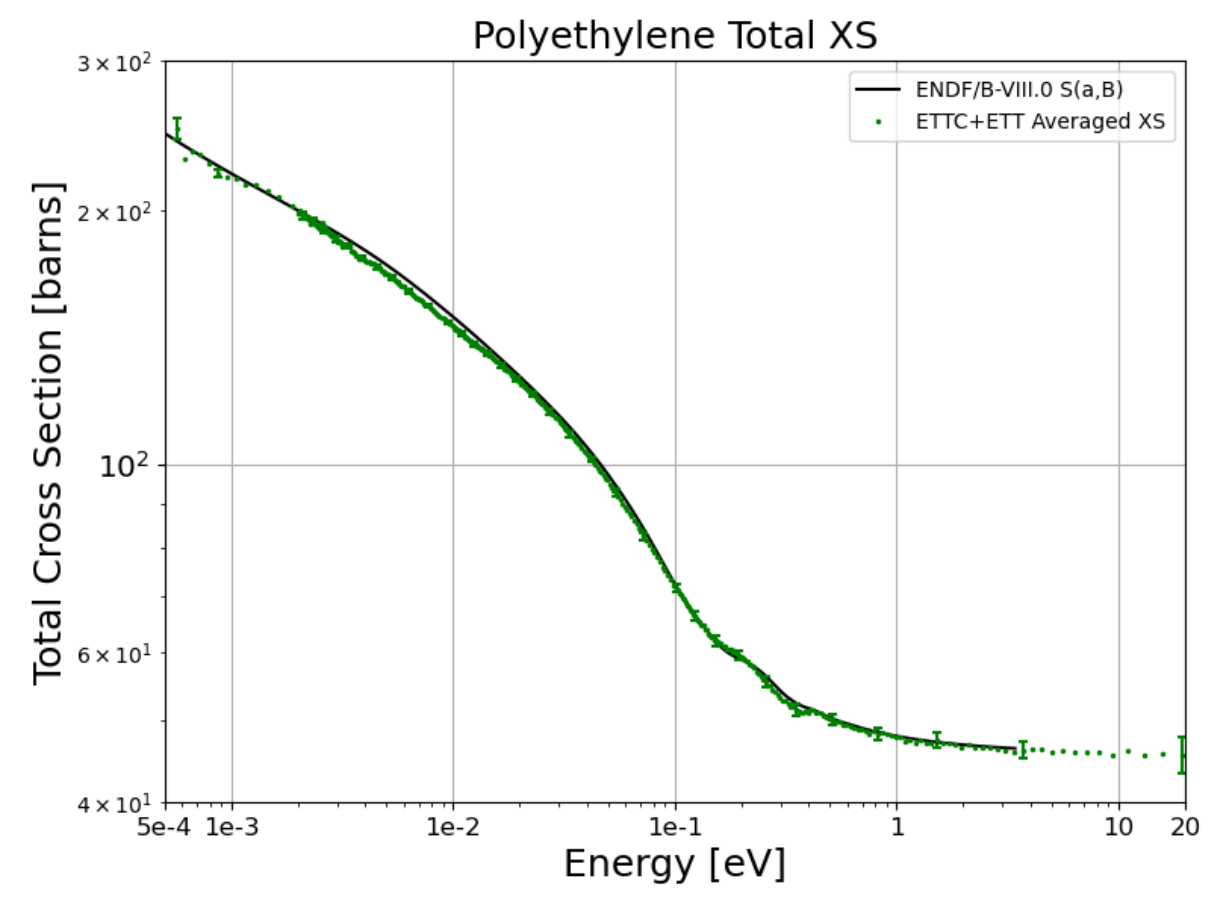
# Polyethylene – Closer Look

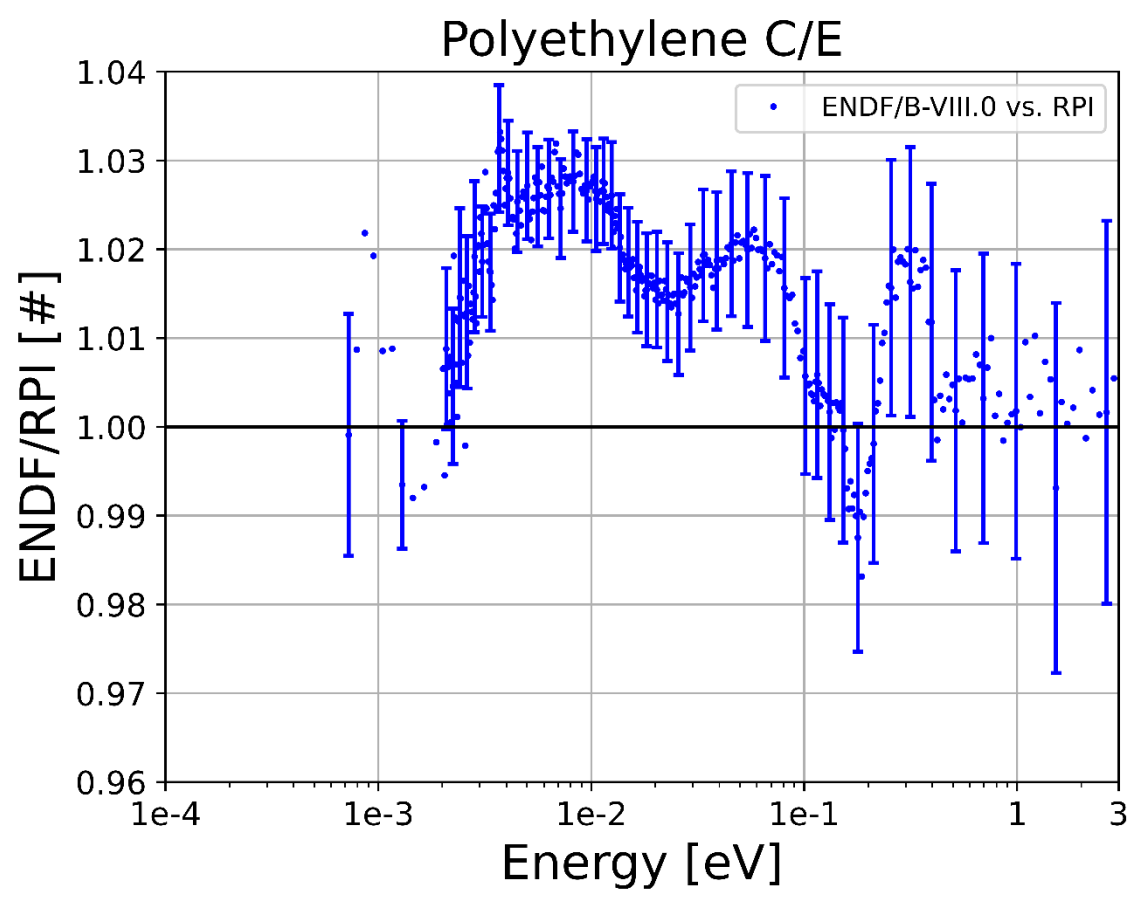



*Excellent agreement between all RPI experiments

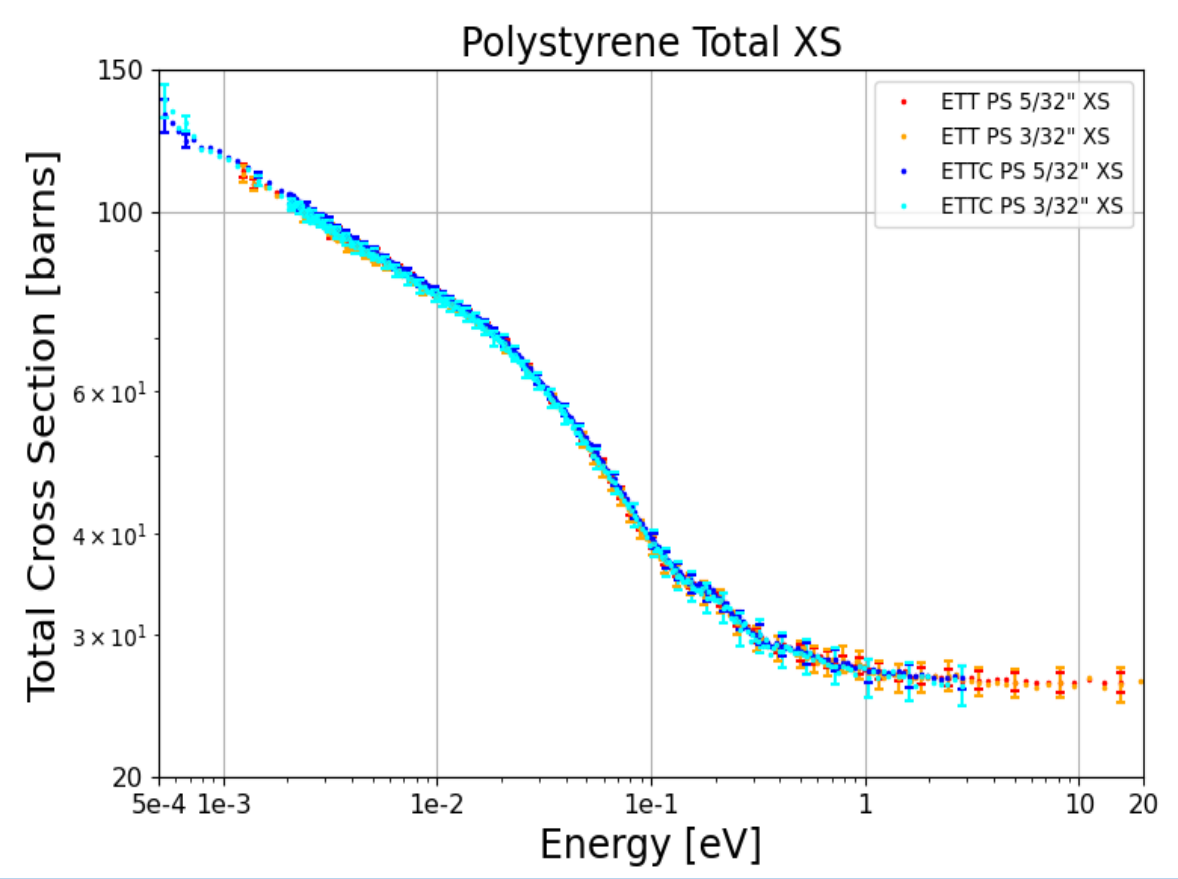
# Polyethylene – Averaged Cross Section

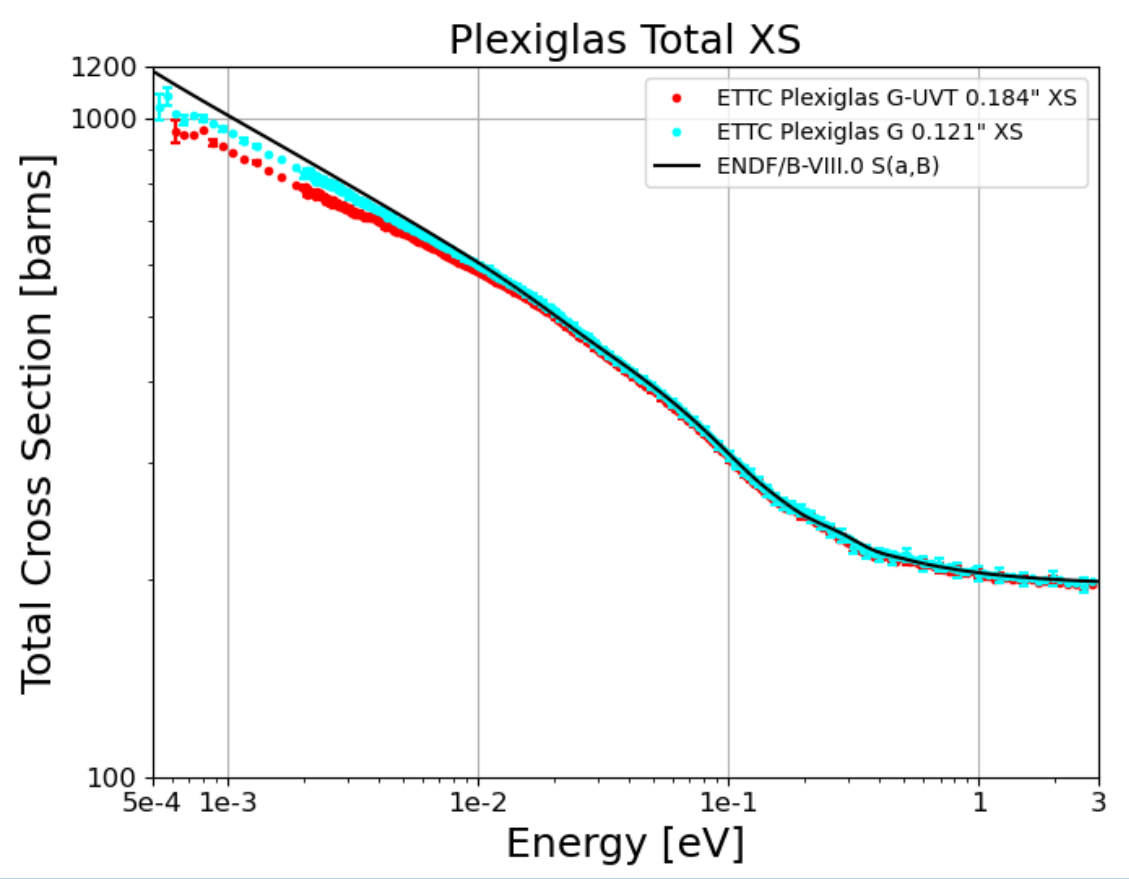



- Weighted average of all polyethylene measurements performed
- ENDF/B-VIII.0 evaluation is higher than measured cross section at most energies

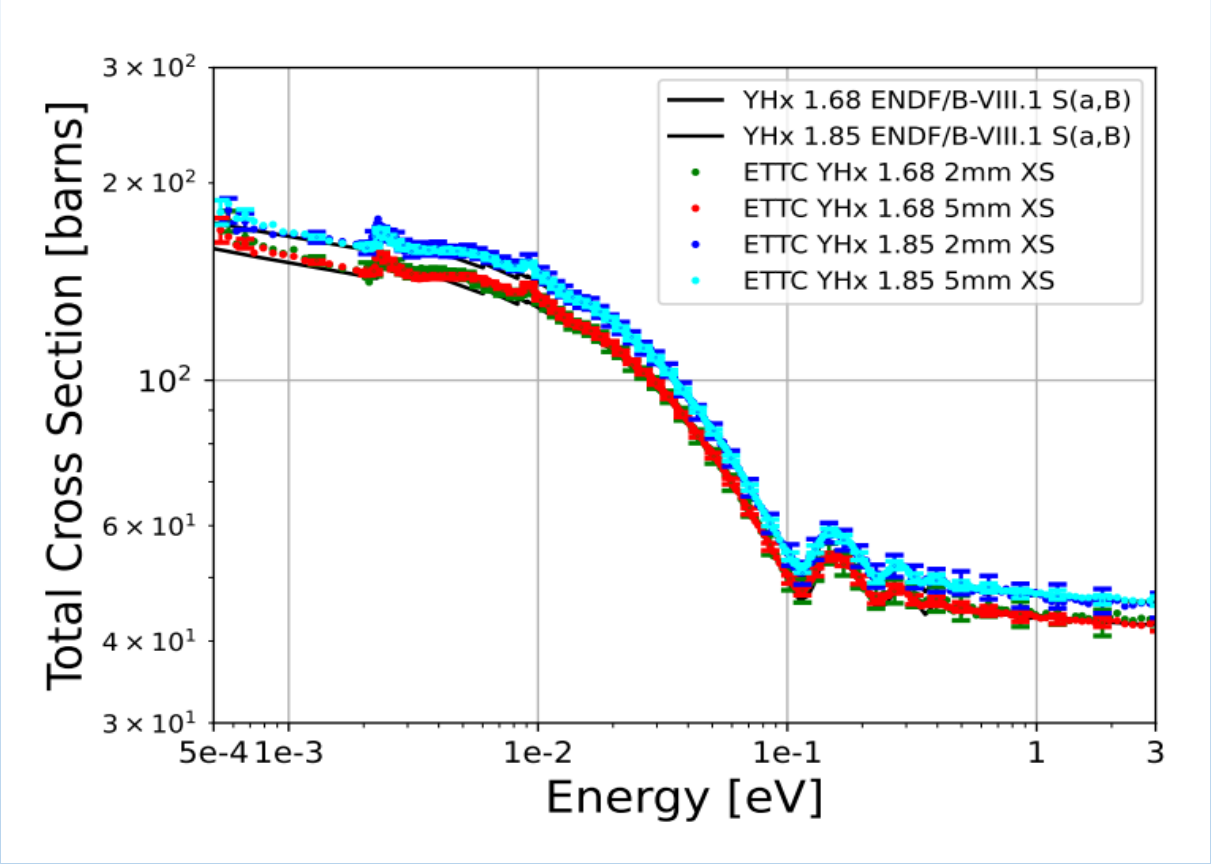
# Thermal Cross Section Measurements: Polymers

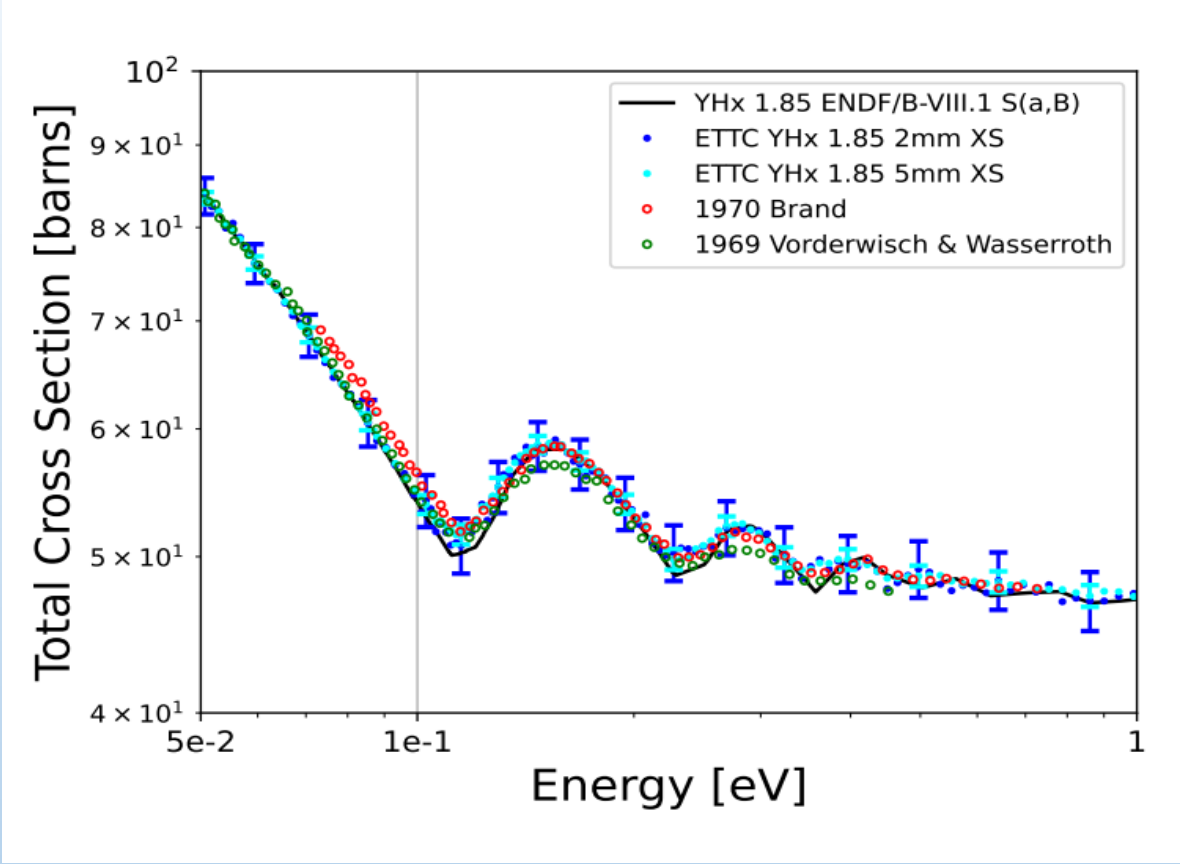



- Generally good agreement between measured cross section and TSL evaluation for polymers.
- Differences in cross section between Plexiglas G and Plexiglas G-UVT.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance matrix.

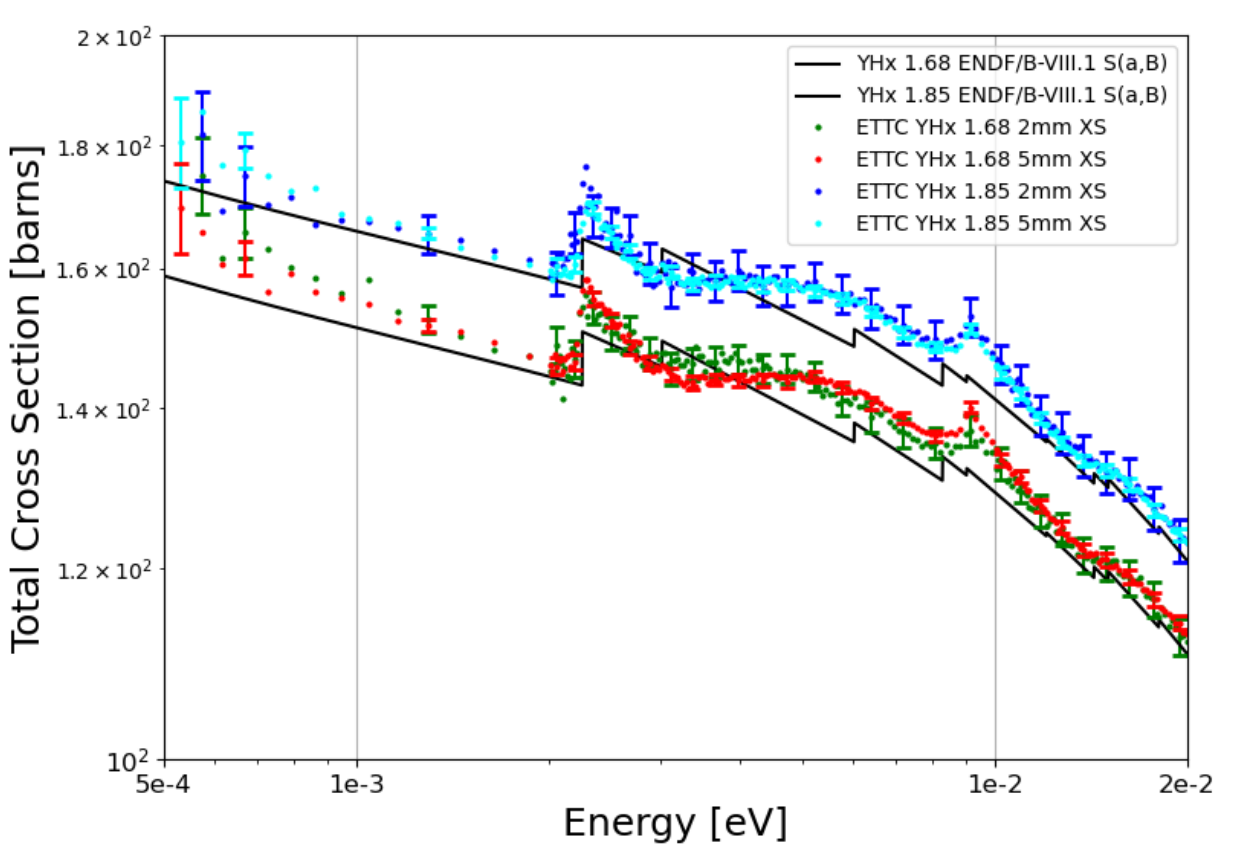
# Thermal Cross Section Measurements: YHx

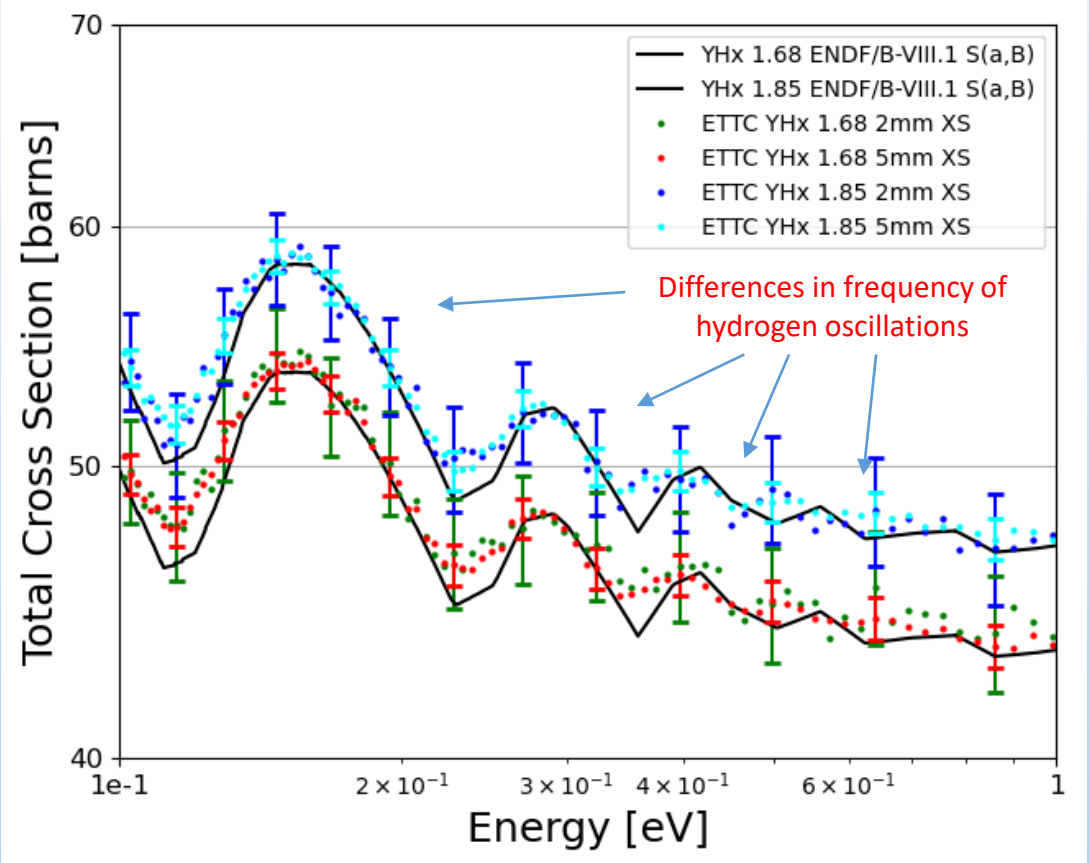



- Generally good agreement between yttrium hydride measured cross section and TSL evaluation for both concentrations.
- Experimental error bars account for all experimental sources of uncertainty and were calculated via a covariance matrix.
- Estimated uncertainty on H/Y ratio from samples not shown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

# YHx – Closer Look

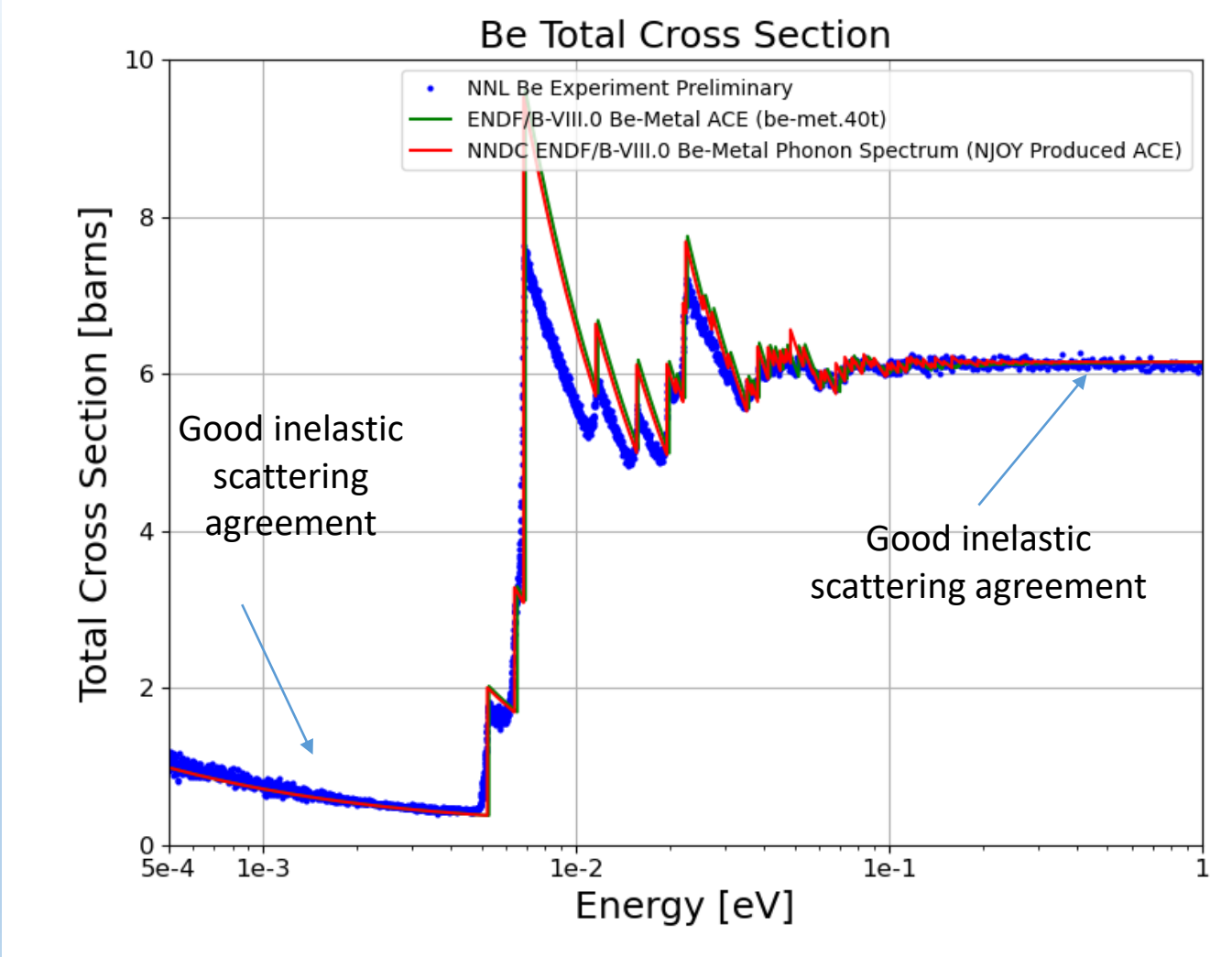



- Misalignment of Bragg edges between experiment and yttrium evaluation
- Cross-over in cross section seen in $YH_{1.68}$ samples

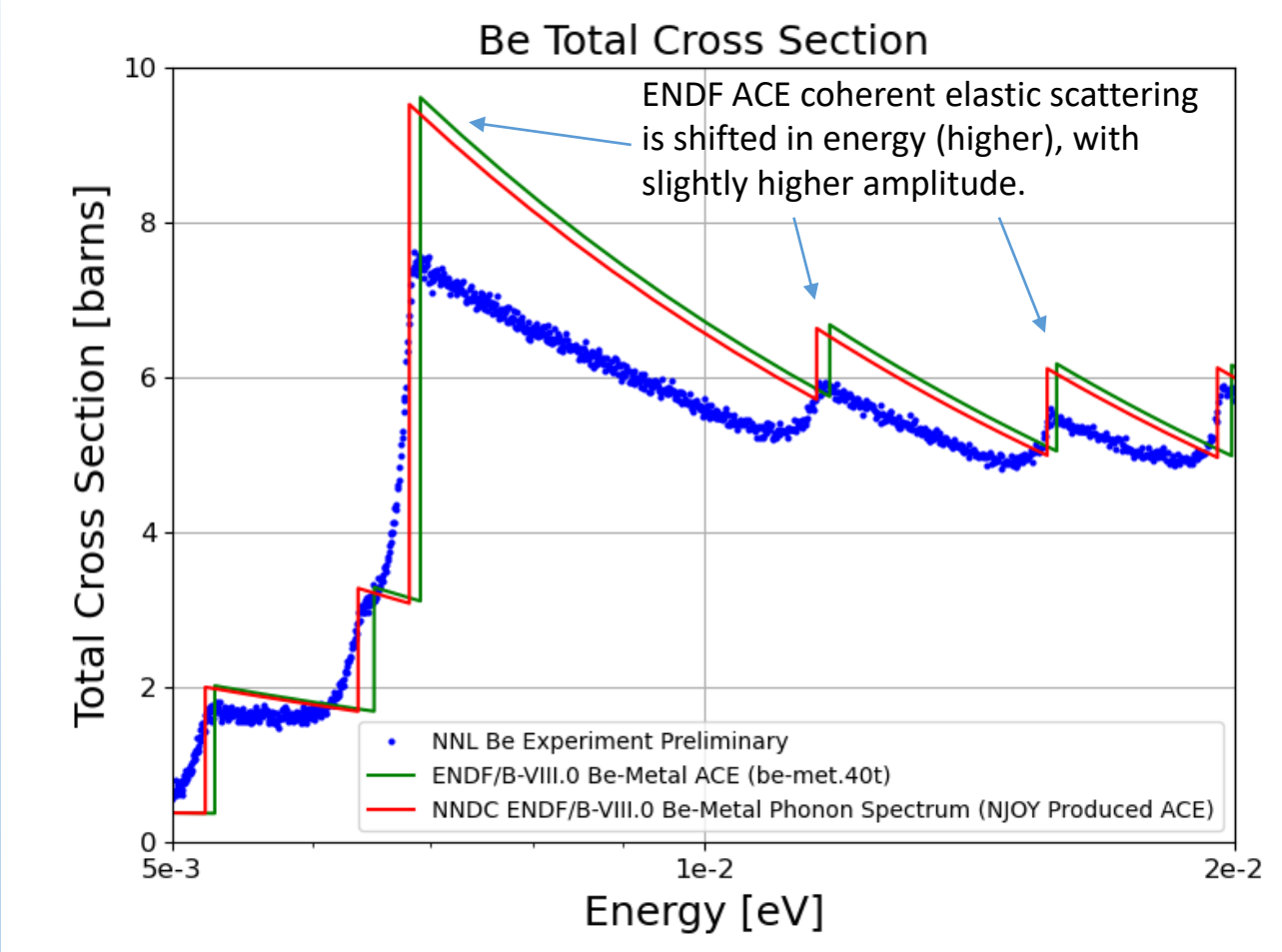
- Potential explanations for differences:
  - Numerical difficulties in NJOY

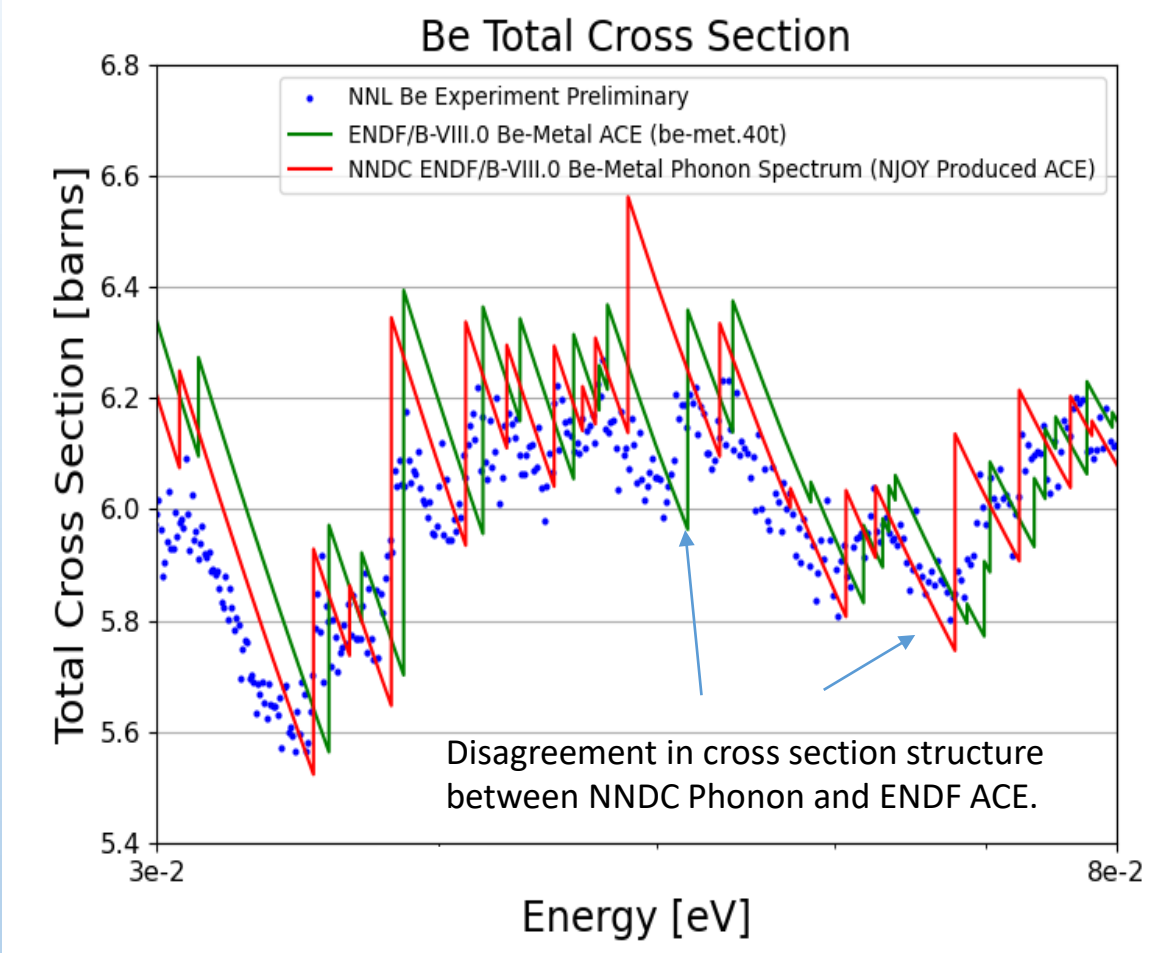
# Be Thermal Cross Section Measurement




- Discrepancies between measured 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 is likely due to the crystalline structure of the Be samples used ➔ evaluations assume no extinction for grain size in Be

# Milestones

- FY19-21 Completed:
  - Successful neutronic/thermal modeling and simulation of cold moderator system.
  - Cryogenic system designed and procured.
  - Tested cryogenic system – steady state temperature of 29K with LINAC Power.
  - Completion of cryogenic system characterization.
  - Completion of total thermal cross section measurements for polyethylene, polystyrene, Plexiglas, yttrium hydride and beryllium.
- FY22:
  - 12/2021: Finalization of all data reduction for all measurements.
  - 2/2022: Completion of necessary journal publications.