MC21 Testing of the ENDF/B-VIII.1 Graphite TSLs in the ORELA PNSDT Benchmark

Jason Thompson

Background

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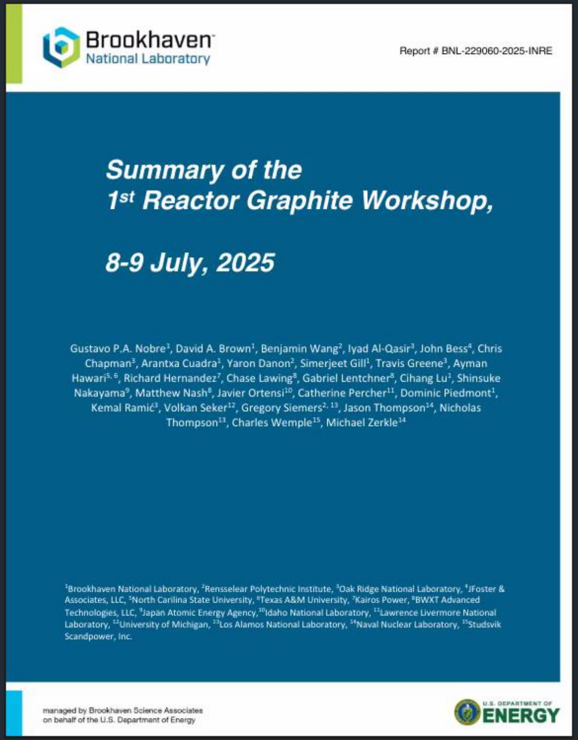

Brookhaven National Laboratory

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Summary of the 1st Reactor Graphite Workshop,

8-9 July, 2025

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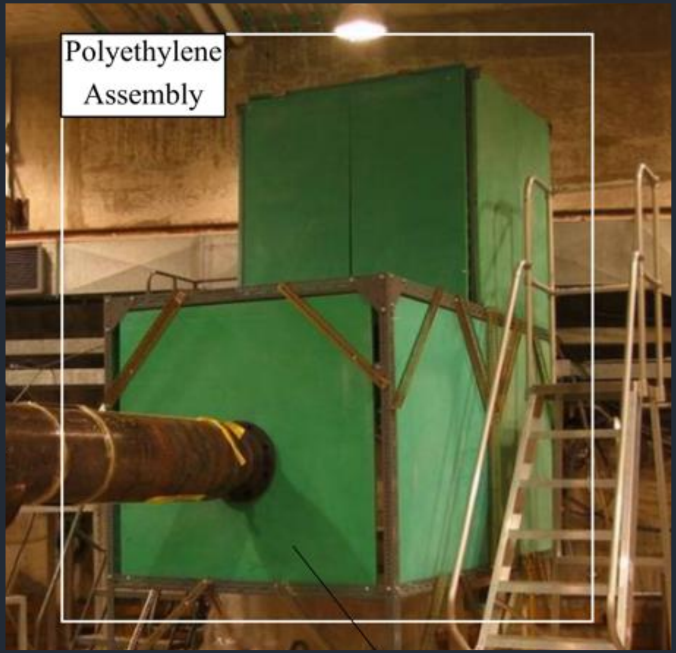
- Concerns over the modeling of reactor-grade graphite have been raised
- For many of us, these concerns are largely been outside of our technical depth
- A special ReGra Workshop was organized as a result
- During ReGra, only a few models were highlighted as potentially useful to assess the impact of different graphite evaluations

Thanks Gustavo and Catherine!

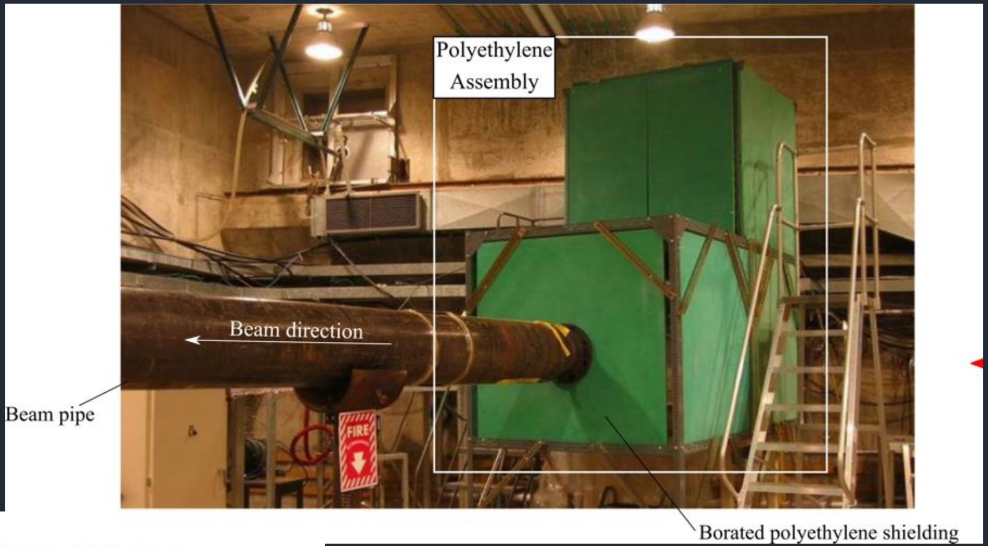
Scope of this presentation

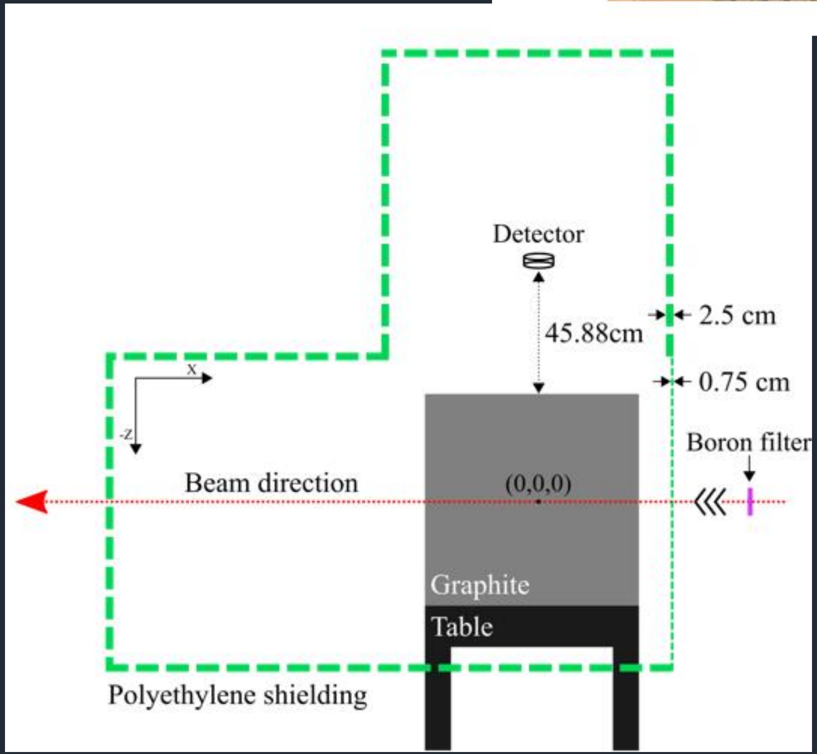


- Analysis of the ORELA model using MC21
  - Taking evaluations as a series of "independent black boxes"
    - Cross sections, energy distributions, angular distributions
    - ~~Phonon density of states, $S(\alpha, \beta)$~~
  - No investigation of sensitivity to contaminants
  - No investigation of optical diffraction SANS
  - No investigation of extinction effects
- Conclusions and recommendations
  - Will not comment on the path forward regarding how to model porous graphite
  - The cross section and scattering energy distribution seem to be the driving factors behind the differences seen in results between the porous and crystalline evaluations
  - More work to be done

OERLA

- Electron-beam driven pulsed neutron source incident on a 70 cm cube of reactor graphite
- Graphite density was reported to be 1.66583 g/cm^3, so 26% porosity
- Li glass scintillator measured counts





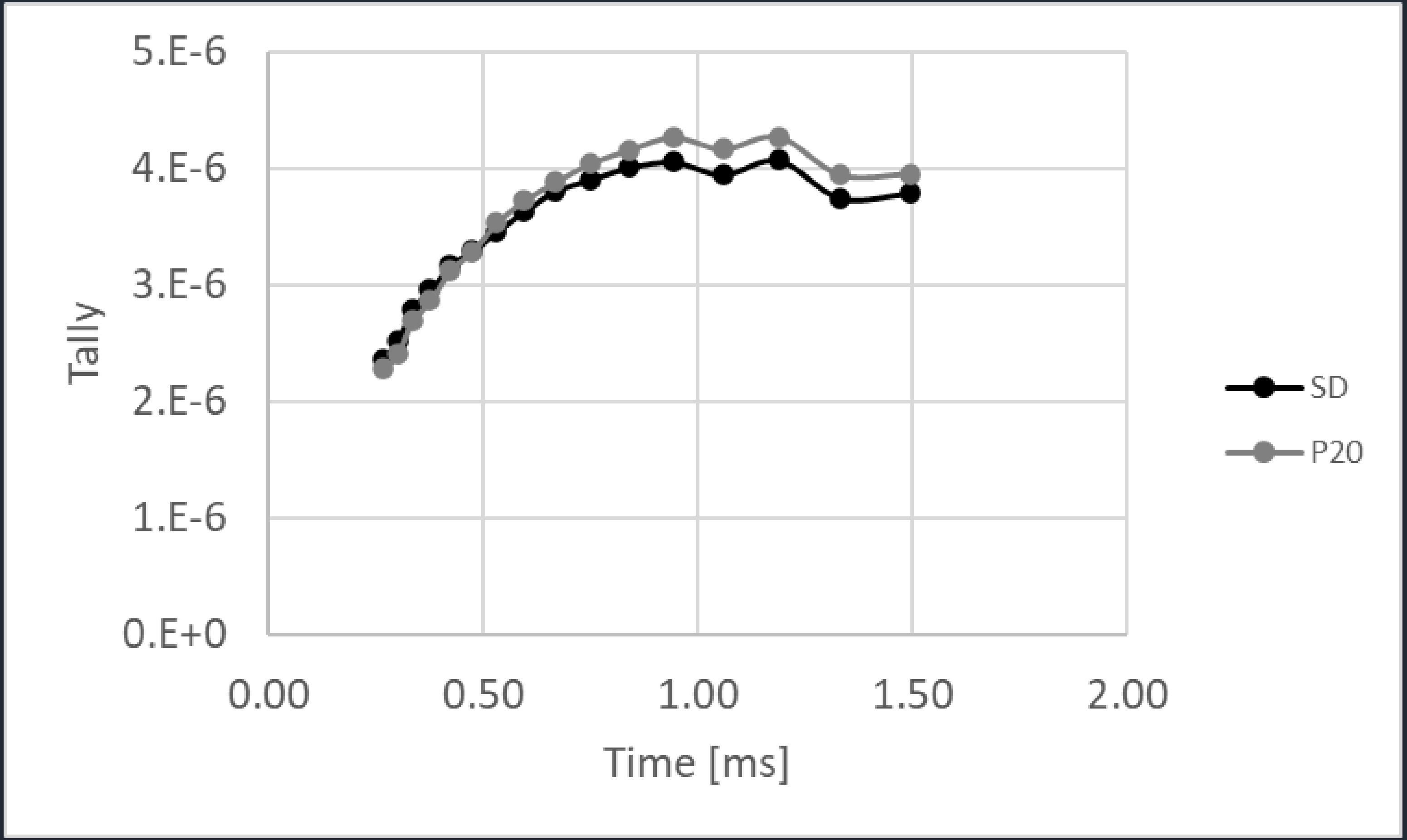
Modeling

- Translated geometry and materials from the FUND-ORELA-ACC-GRAPH-PNDSDT-001 MCNP input to MC21 input
  - Used the crystalline+Sd graphite and 20% porosity graphite evaluations
- Source definition modified for simplicity
  - Energy spectrum modeled as specified in the benchmark
  - Monodirectional "point" source
  - Modeled very slightly closer to the graphite
  - All neutrons born at t=0

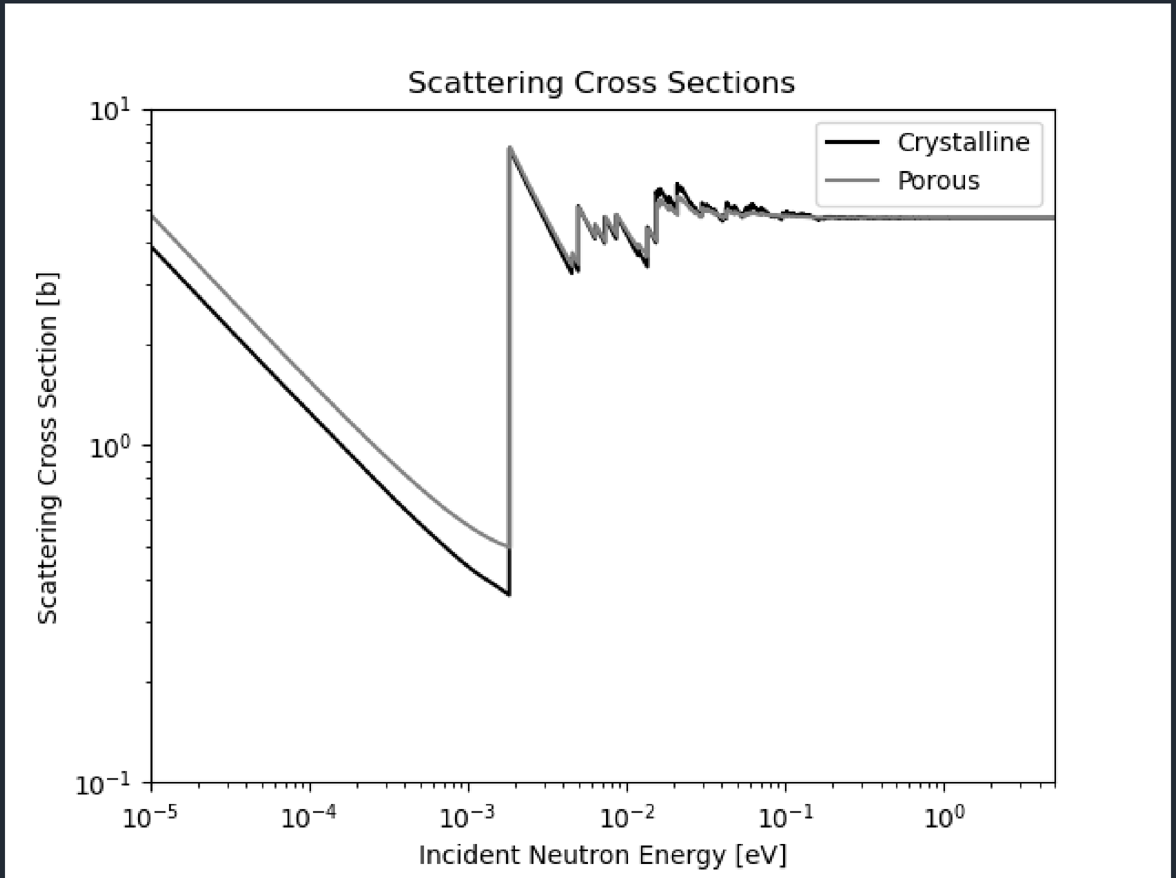
- Used 296 K instead of room temperature
- Tally definition
  - Tallying on $^{6}Li(n,t)$ reactions in the lithium glass scintillator with time bins matching those described in the benchmark
  - Only reporting on the 16 points the benchmark identified as the thermal "region"

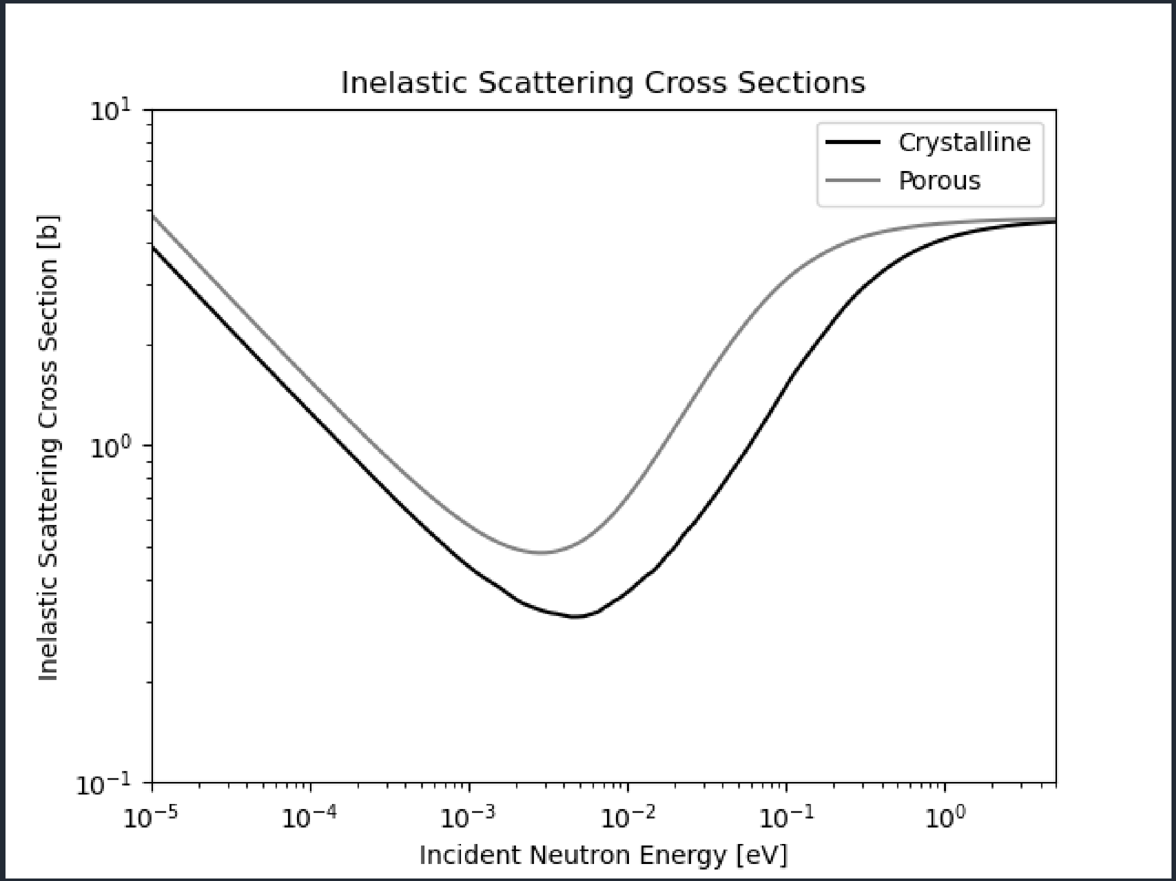
Initial Comparison

- Use of the porous evaluation (P20) causes
  - A slight decrease in detector response at earlier times
  - A larger increase in the detector response at later times



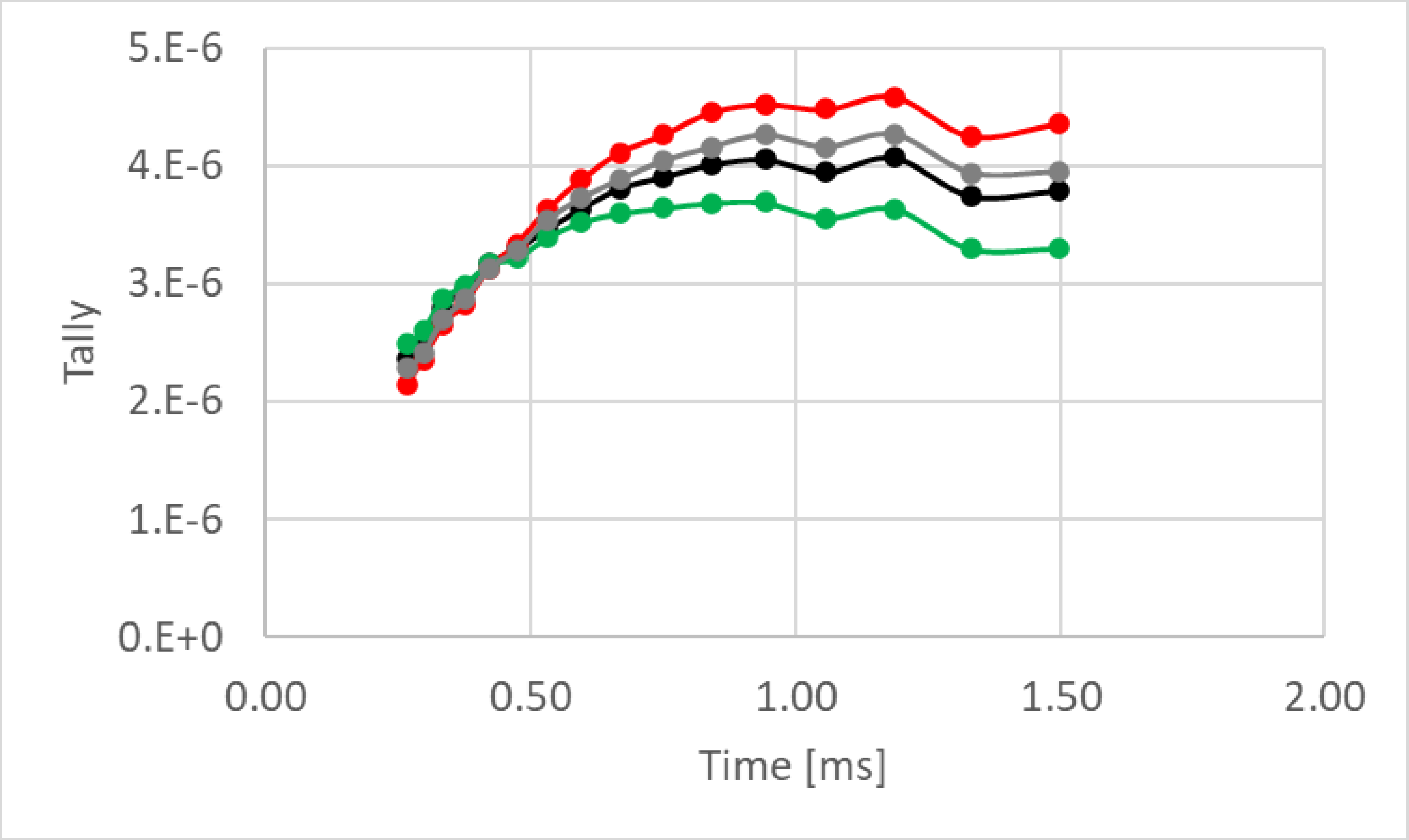
Scattering and Inelastic Scattering Cross Sections





MC21 Sensitivity Study – Cross Sections

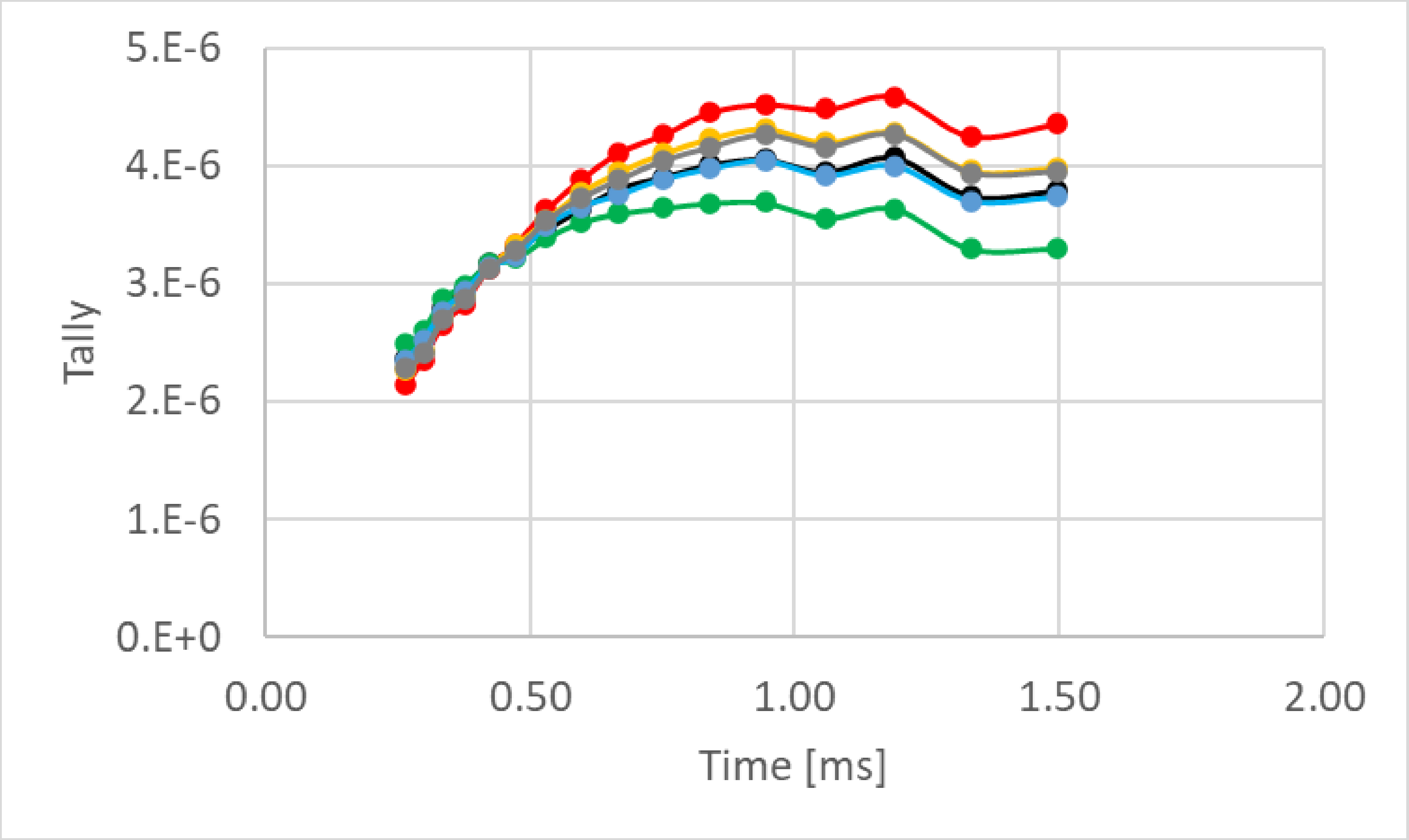
Curve	σ	$p(\beta)$	$p(\alpha)$
Black	+Sd	+Sd	+Sd
Red	20%	+Sd	+Sd
Green	+Sd	20%	20%
Gray	20%	20%	20%



Black = Crystalline
Red = Crystalline with porous σ
Gray = Porous

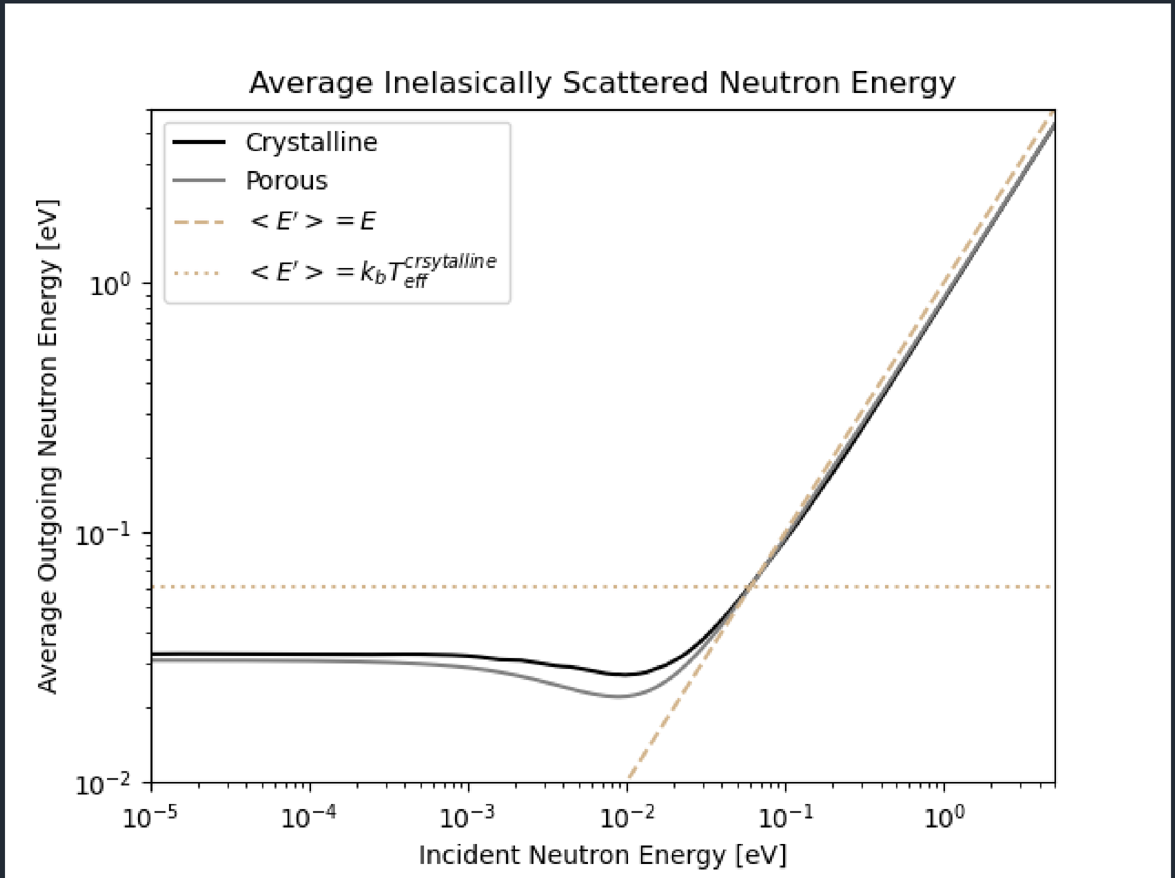
MC21 Sensitivity Study – Energy Distribution

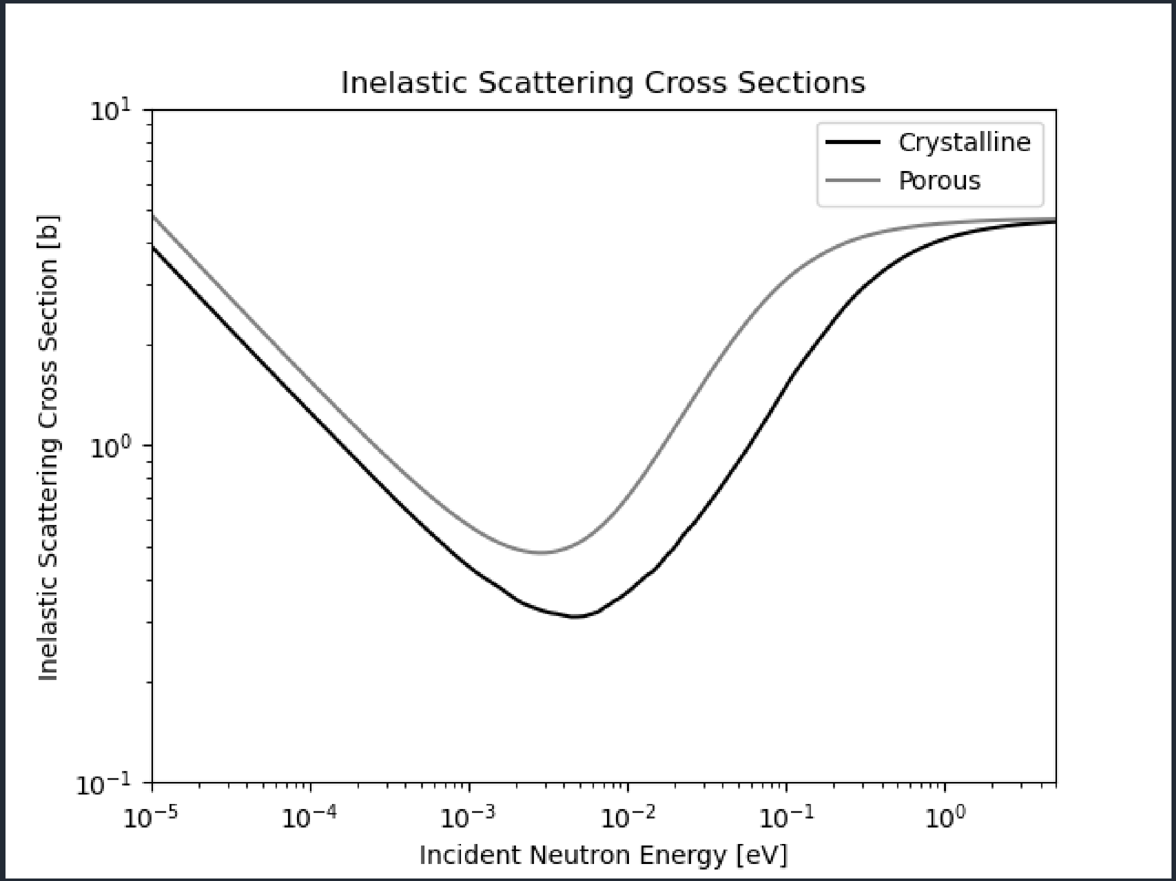
Curve	σ	$p(\beta)$	$p(\alpha)$
Black	+Sd	+Sd	+Sd
Red	20%	+Sd	+Sd
Orange	20%	20%	+Sd
Green	+Sd	20%	20%
Blue	+Sd	+Sd	20%
Gray	20%	20%	20%



Black = Crystalline
Red = Crystalline with porous σ
Orange = Red with porous energy distribution
Gray = Porous

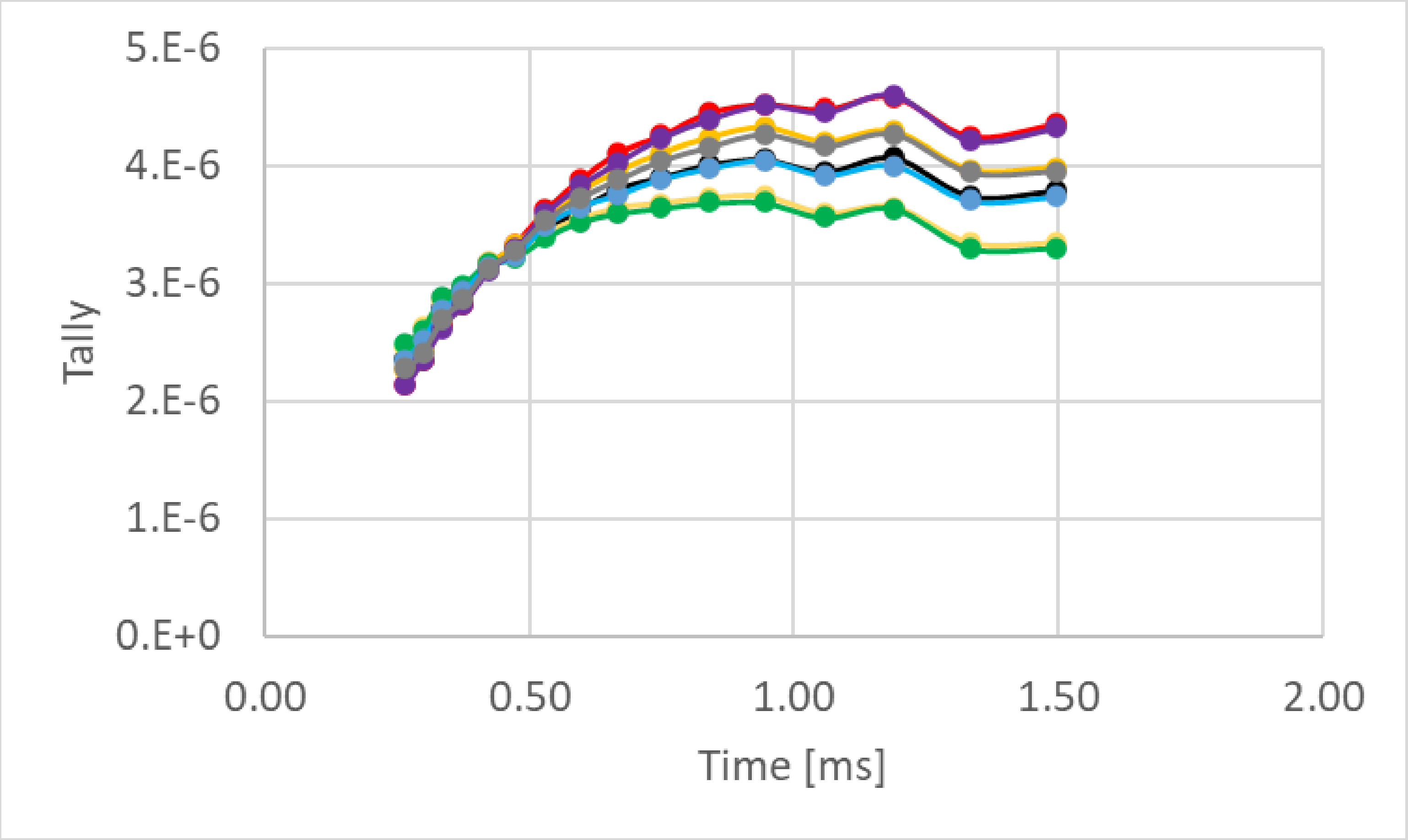
Average Inelastically Scattered Neutron Energy





MC21 Sensitivity Study – Angular Distribution

Curve	σ	$p(\beta)$	$p(\alpha)$
Black	+Sd	+Sd	+Sd
Red	20%	+Sd	+Sd
Orange	20%	20%	+Sd
Yellow	+Sd	20%	+Sd
Green	+Sd	20%	20%
Blue	+Sd	+Sd	20%
Purple	20%	+Sd	20%
Gray	20%	20%	20%



Conclusions

- Results are inline with the benchmark enough that no errors in the benchmark have been noticed
- Scattering cross sections and outgoing energy distributions are the data driving the difference in results between crystalline and porous graphite evaluations in the ORELA benchmark
  - Cross sections and energy distributions seem to have opposite effects

Future Work

- Improve the tallies
  - Extend the time binning of the detector tally
  - Implement additional tallies within the graphite to determine if neutrons are leaking early or being held within the graphite longer
- Model optical diffraction of neutrons (SANS)
  - This is another proposed mechanism which has been suggested as the cause of the discrepancy between experiment and simulation using the crystalline evaluation
- Assess sensitivity of hydrogen (water) impurity
  - RPI bakes their graphite prior to performing measurements and sees a reduction in sample mass
- Assess sensitivity to extinction effects
  - Models with crystalline graphite may be more sensitive to extinction because more of the total cross section comes from coherent elastic scattering