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Thermal and not so thermal nuclear data measurements capabilities at ORNL

Kemal Ramić, ORNL Nuclear Data Group Team

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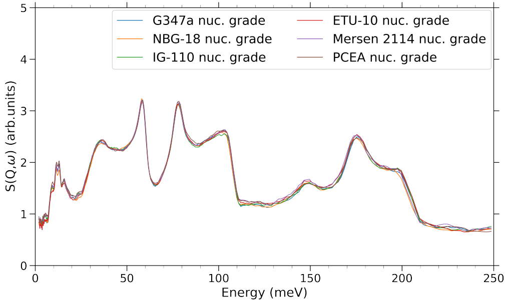
Thermal Scattering Law Data Validation

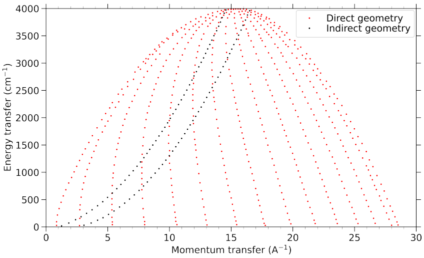
Measurement:	Differential, $S(\alpha, \beta)$	Quasi-integral, Transmission	Integral, PNDA and crit. bench
Dependent on sample characteristics: additives, manufacturing defects, form, porosity, density, grain size	LOW **general shape is consistent**	YES	YES
Complexity:	simple interaction between thermal neutrons and the sample	sample characterization important, additives and impurities affect the total XS	complex, geometrical constraints, sample characterization important, other reactions at higher energies
Priority in TSL validation:	HIGH	HIGH	LOWER

- How do CE Monte Carlo neutronics codes use TSLs for scattering?
  - Sampling the distance to next collision (transmission!)
  - Sampling the reaction ratio probability
  - Sampling the exit energy and angle distributions (TSL!)



Direct (i.e. ARCS) and indirect (i.e. VISION) geometry INS spectrometers:

Trajectory in α and β space:



- For direct-geometry spectrometers: fixed incident neutron energy, energy transfer determined using time-of-flight methods. Measured quantity $S(Q,\omega)$.
- Phonon spectra derivation under the *incoherent* approximation:

$$S(Q,\omega) = e^{-2W(Q)} \frac{Q^2\,\hbar}{2M\,\omega} \left[n(\omega)+1\right] g(\omega) \qquad (1)$$

- In indirect-geometry spectrometers: white “beam” incident energy spectra, graphite analyzer and beryllium filters set the final energy after neutrons scatter of the sample.

+ Measured quantity $S(Q,\omega)$ is directly related to $S(\alpha,\beta)$:

$$S(\alpha,\beta) = \frac{k_B T}{\hbar}\, exp\left(\frac{-\hbar\omega}{2k_B T}\right) S(Q,\omega) \qquad (2)$$

where T is the temperature, and k_B is the Boltzmann constant.

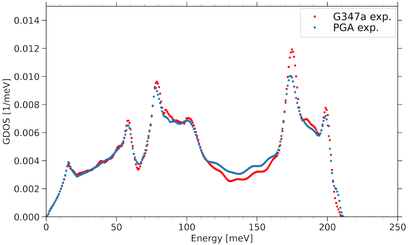
$S(\alpha, \beta)$ and phonon measurements: (Low sample dependence)

Example: Graphite

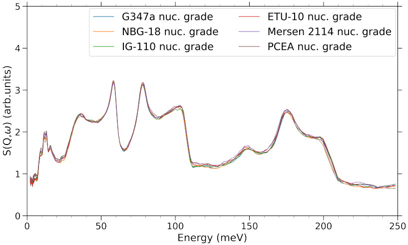
Graphite	Grain size [μm]	Density [g/cm^3]	Porosity [%]
PGA	800	1.70	25
G347a	50	1.85	17.8
IG-110	20	1.77	21.6
NBG-18	1600	1.85	17.8
PCEA	360	1.83	18
Mersen 2114	13	1.81	10
POCO-AXF-5Q	5	1.78	20
POCO-ZXF-5Q	1	1.78	20

Table 1: Properties of different types of graphite.

- Phonon measurements at ARCS:



- $S(\alpha, \beta)$ measurements at VISION:



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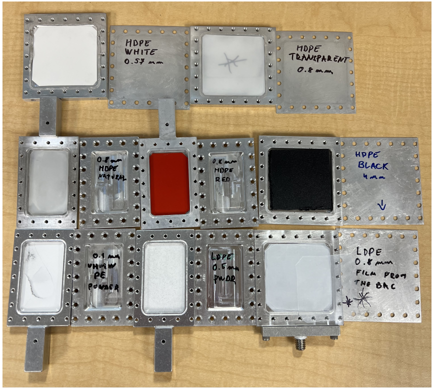
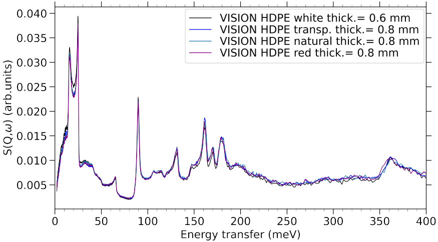
$S(\alpha, \beta)$ measurements: (Low sample dependence)

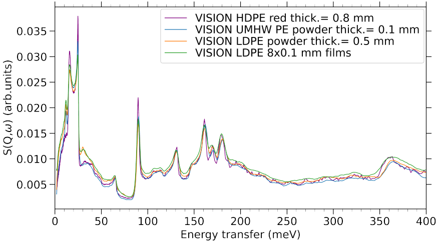
Example: HDPE, LDPE, and UHWMPE



- HDPE comparison:

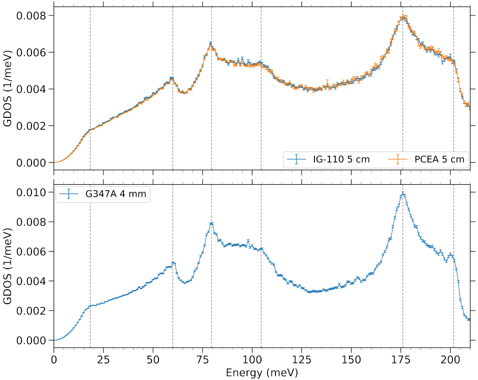


- HDPE vs LDPE vs UHMWPE:

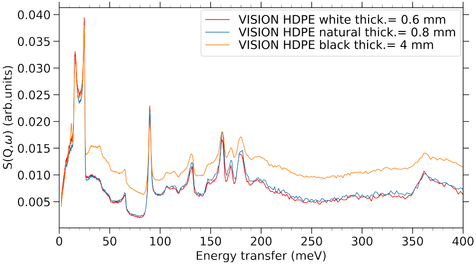


$S(\alpha, \beta)$ and phonon measurements: (Low sample dependence)
Example: Sample thickness

- Graphite comparison:

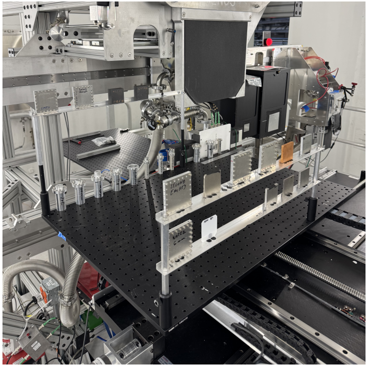


- HDPE comparison:



- Thickness of the sample doesn't play a major role in $S(\alpha, \beta)$ measurements, beyond introducing multiple scattering which smears the features and introduces background.

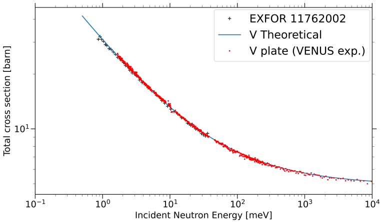
Transmission measurements at VENUS



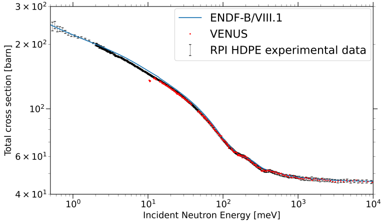
- Sample changer!
- Unprecedented flux enabling measurements on the order of 1 or 2 hours.
- Flexibility with the setups!
- Cryostat and furnaces for temperature dependent measurements from 5 K to 1800 K, same as for INS measurements.

Thermal neutron transmission validation

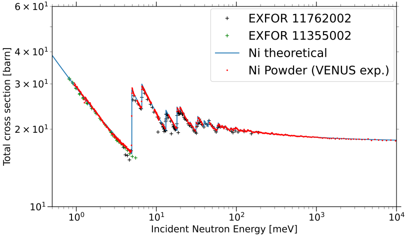
- Vanadium:



- High density polyethylene:



- Nickel:



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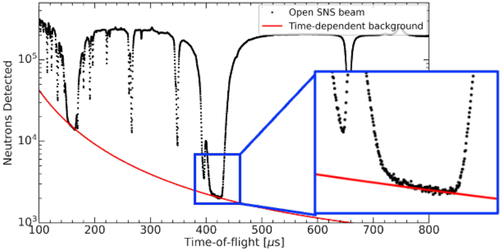
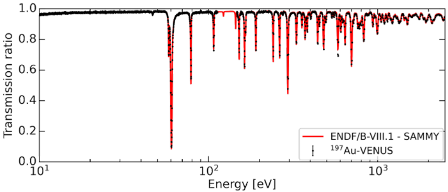
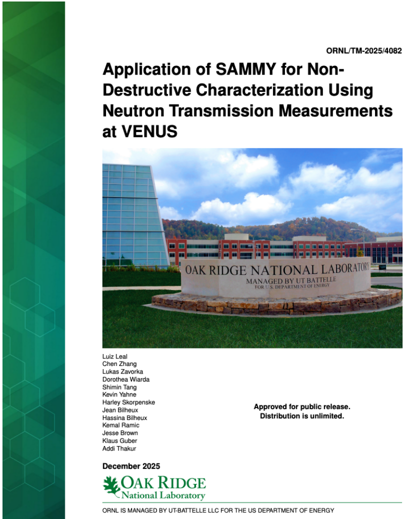
Specific RRR transmission capability





- First-ever time-dependent background measurements at VENUS deliver **100–200:1 S/B**, paving the way to measure cross sections of **short-lived isotopes**, and other small samples.
- Measurements reproduce gold reference cross sections with excellent agreement with the ENDF library.
- Unsurpassed epithermal and fast neutron flux in the US.
- Position sensitive detector.

Non-Destructive Characterization capability



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Application of SAMMY for Non-Destructive Characterization Using Neutron Transmission Measurements at VENUS

Luiz Leal
Chen Zhang
Lukas Zavorka
Dorothea Wiarda
Shimin Tang
Kevin Yahne
Harley Skorpenske
Jean Bilheux
Hassina Bilheux
Kemal Ramic
Jesse Brown
Klaus Guber
Addi Thakur

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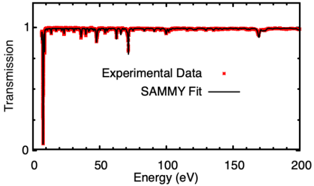
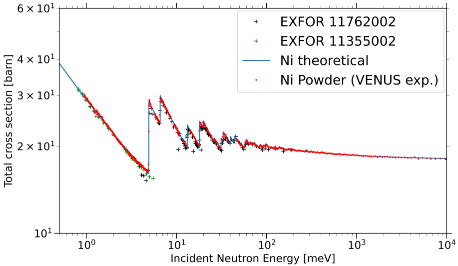


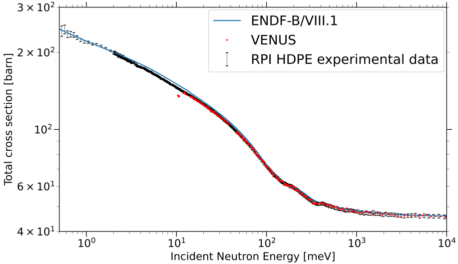
Figure 4. Transmission calculated using ENDF resonance parameters with optimized resolution, density, and temperature parameters. Red points represent the experimental measurements, while the black line shows the SAMMY R-matrix fit.

- Luiz Leal has been leading an effort to utilize transmission measurements at VENUS for NDA analysis.
- The demonstrated ability to extract isotopic compositions from complex, multi-component samples can support applications in nuclear safeguards verification, forensic analysis of nuclear materials, and comprehensive post irradiation examination protocols.

Summary & Conclusions

- ORNL Nuclear Data Group has unmatched evaluation capabilities.
- We have been working on some measurement and validation capabilities.
- We have extensive measurement capabilities in TSL energy region, from differential to transmission measurements, including temperature dependence.
- We have developed a limited resonance transmission capability.
- We can utilize these measurements for NDA analysis.





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