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Title: Simulating Active Neutron and Gamma-Ray Spectroscopy for Mars Sample Return

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Los Alamos NATIONAL LABORATORY

Simulating Active Neutron and Gamma-Ray Spectroscopy for Mars Sample Return

CSES Los Alamos

2024 MCNP User Symposium

Los Alamos NATIONAL LABORATORY EST. 1943

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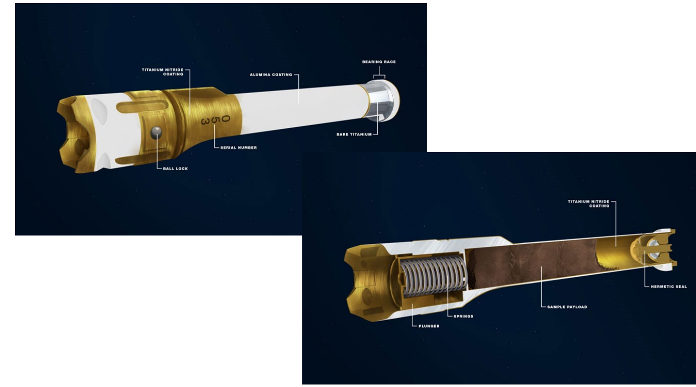
Project Motivation

- Neutron and Gamma-ray Spectroscopy (NS, GRS) have been used at several planetary bodies to measure **bulk** water and elemental abundances.
- Mars Sample Return (MSR) will bring sealed samples of Mars back to Earth in the 2030’s.
- NGRS techniques do not require the sample to be unsealed, which is particularly important for volatiles such as water.
- These elemental abundances provide important clues to martian habitability and crustal evolution.



Images: NASA/JPL-Caltech

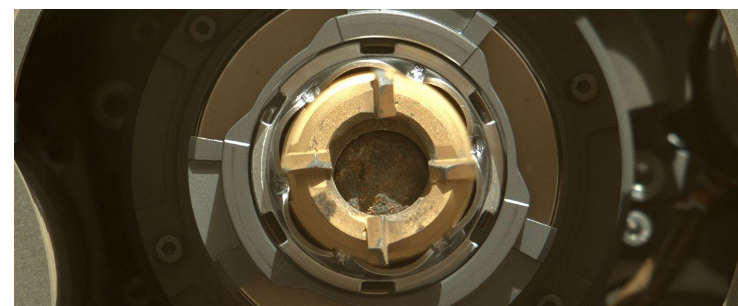


Image: NASA/JPL-Caltech/ASU/MSSS

Project Motivation

LANL is uniquely positioned to develop this technique with institutional expertise in both martian geology and planetary neutron spectroscopy.

Here we use MCNP simulations to accomplish three goals:

1. Demonstrate the viability of NS and GRS for MSR samples
2. Optimize measurement geometry to minimize dose/dose rate
3. Determine measurement requirements to inform future experiments

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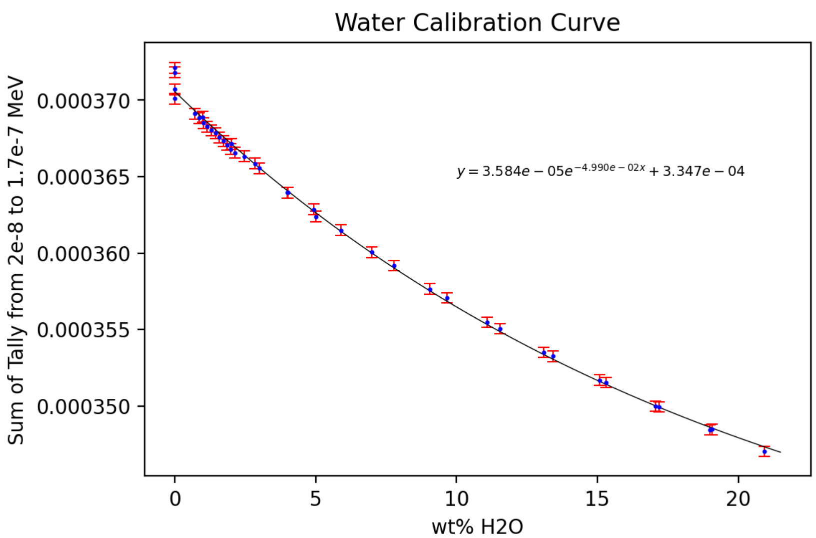
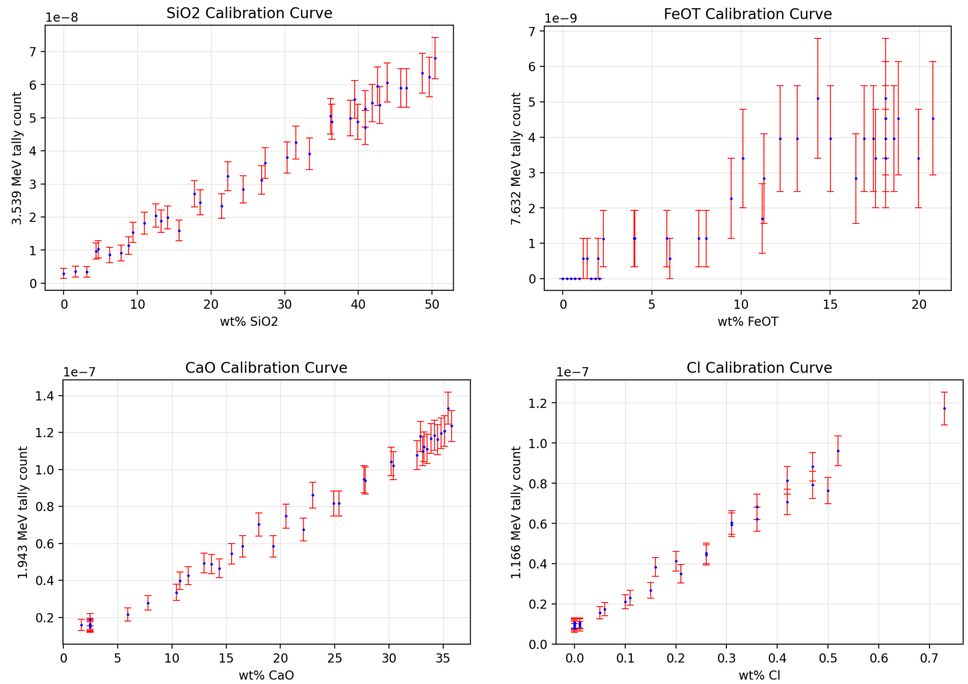
NS	GRS	Goal
✓	✓	1. Demonstrate the viability of NS and GRS for MSR samples
✓	✓	2. Optimize measurement geometry to minimize dose/dose rate
✓	✓	3. Determine measurement requirements to inform future experiments

Previous Results

Previous simulation work in a CSES project led by Chip Legett showed the viability of NS and GRS for small samples in a lab environment. We will extend this work to include MSR compositions, a simulated neutron source, and NS/GRS detectors.

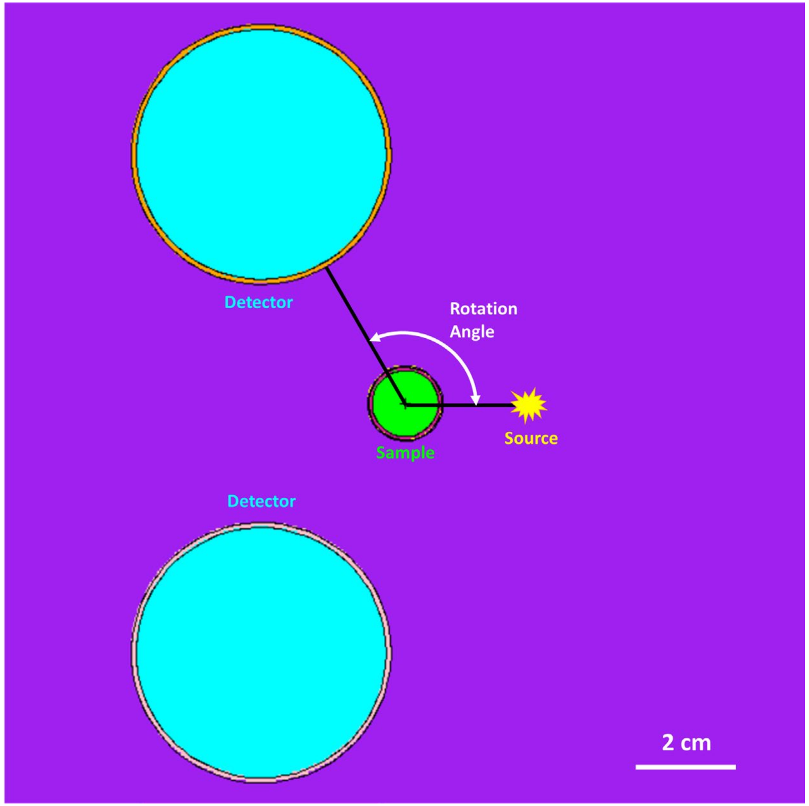




Methods: MCNP Simulations

We simulate neutron particle histories in a 3D environment using the LANL-developed Monte Carlo N-Particle transport code (MCNP), including:

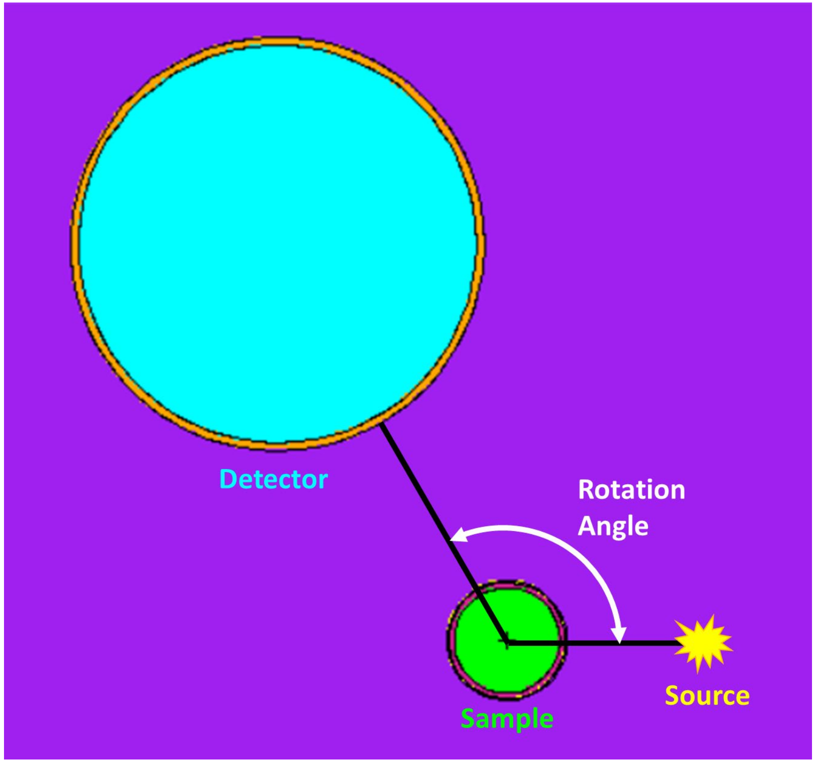
- Neutron point source
- Sample and sample tube
- Neutron detectors, and
- Surrounding atmosphere



Methods: Geometry and Sample Hydration

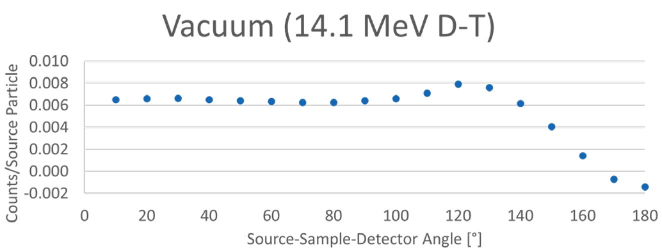
We optimized the simulated experimental geometry by varying the source-sample-detector angle. We ran simulations with angles between 10 – 180° for a variety of source-neutron energies and atmospheric compositions.

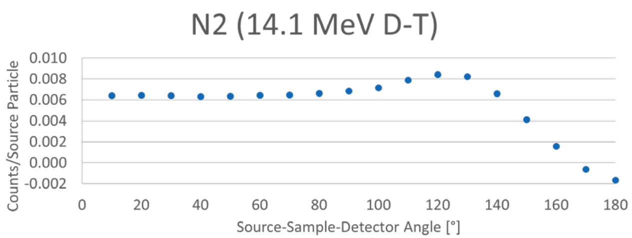
We then ran simulations at the optimum angle (120°) with sample water content varied between 0 – 10 wt.%.

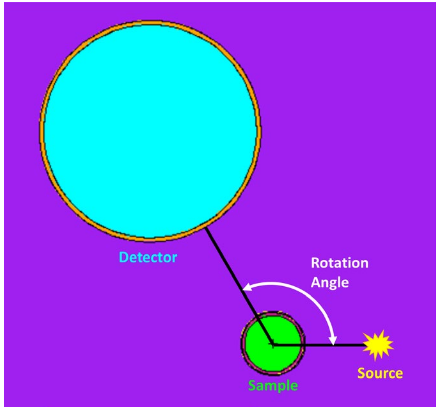


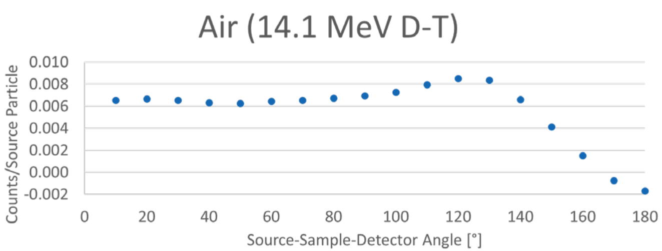
Results: Optimized Experimental Geometry

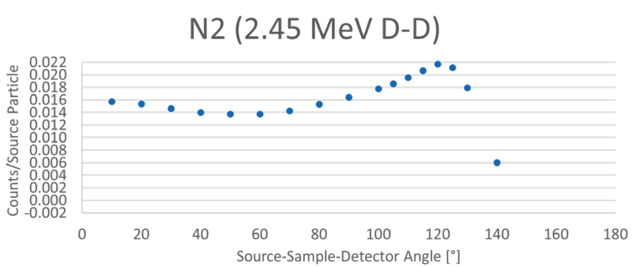
We found that the optimal source-sample-detector angle for either neutron source (2.45 or 14.1 MeV), and all atmospheric compositions (vacuum, air, or N_2), is 120°. This angle gave the maximum neutron signal in each set of simulations.





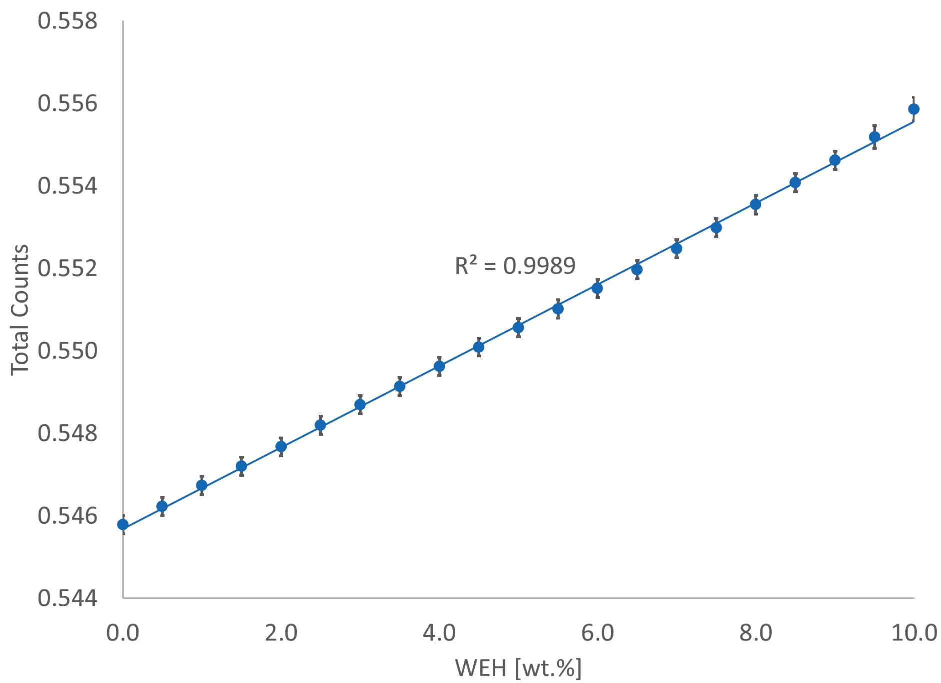






Results: Variable Hydration

We found a near-perfect correlation between total neutron counts and sample hydration measured in WEH (water-equivalent hydrogen).



Conclusions

Our results so far show that:

1. **A source-sample-detector angle of 120° maximizes neutron signal. In future experiments, we can use this simulation result to minimize the needed radiation dose to samples.**

2. **Sample hydration can be precisely measured using laboratory neutron spectroscopy.**