SnT 2023
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
HOFBURG PALACE - Vienna and Online
19 TO 23 JUNE

Improving Estimates of Production Rates of ^{37}Ar By Underground Nuclear Explosions in Various Geologies

TEXAS
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INTRODUCTION

^{37}Ar, produced from the neutron activation of ^{40}Ca in sub-surface rock and soil, is an important signature for underground nuclear explosion monitoring.

METHODS/DATA

^{37}Ar sensitivity study to determine how elemental composition of the rock and neutron thermalization affect predicted yield.

Design an experiment using alpha spectroscopy to measure the thermal neutron cross section.

START

RESULTS

Sensitivity Study: trace elements in rocks have the greatest impact on predicted ^{37}Ar yields.

Literature Reevaluation: inaccurate neutron distribution assumptions overestimated cross section measurements.

CONCLUSION

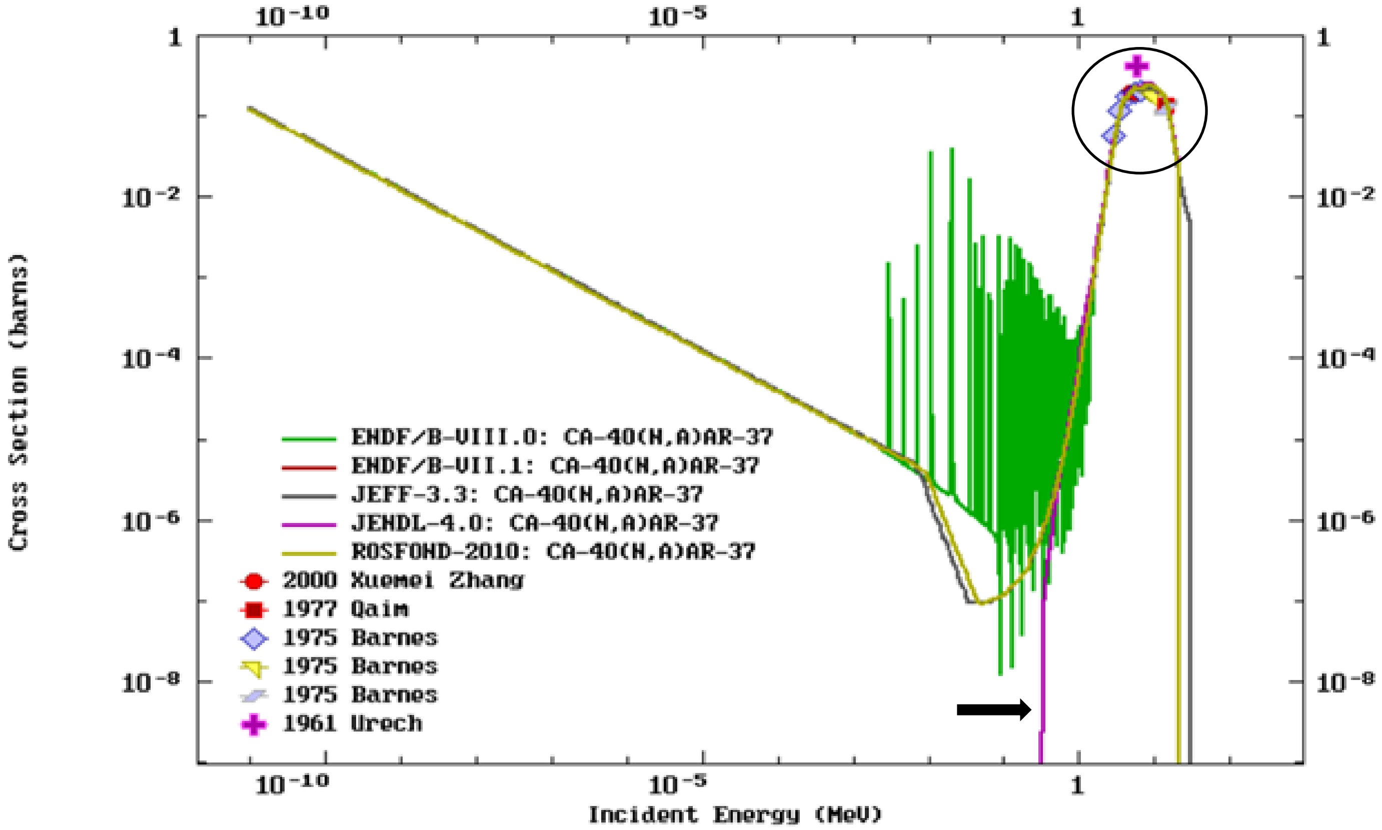
Measuring the thermal neutron cross section for the ^{40}Ca(n,a)^{37}Ar reaction will improve estimates of ^{37}Ar production rates.

P2.4-352

PNNL-SA-186209

Introduction

The thermal neutron cross section for $^{40}Ca(n,\alpha)^{37}Ar$ is poorly understood, but has great potential utility for nuclear explosion monitoring because ^{37}Ar is a medium-lived isotope that can be detected several hundred days after an explosion occurs.



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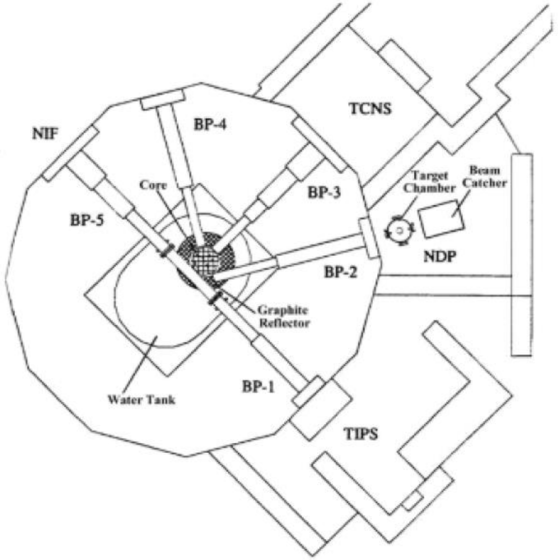
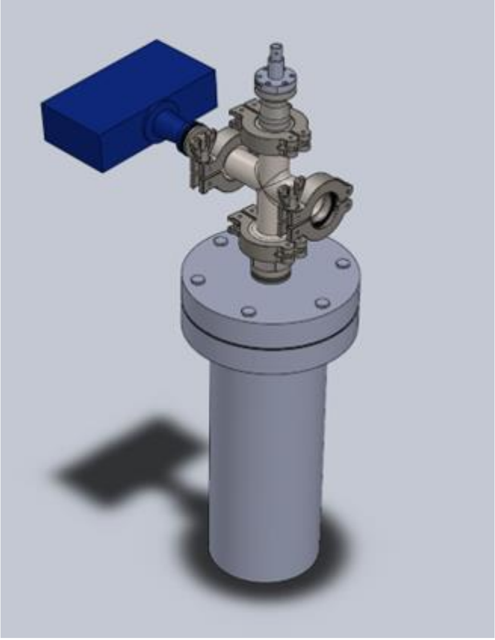
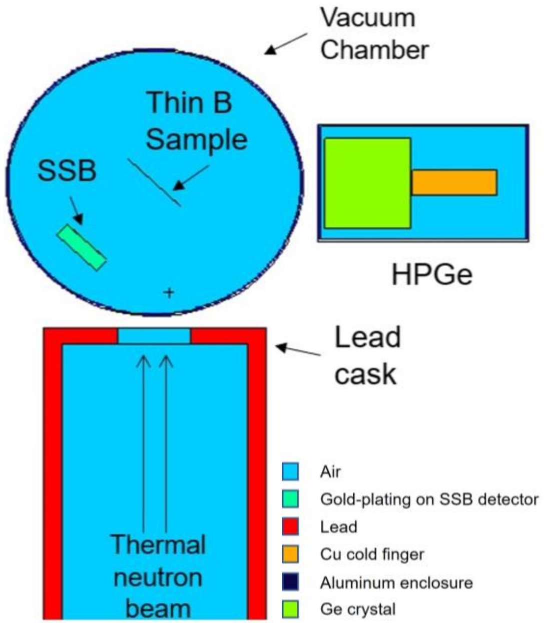
Methods: Experiment Design

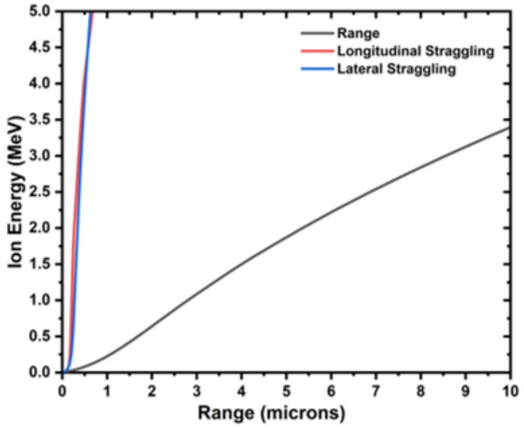
System Requirements:

1. Monoenergetic neutron source with a relatively high flux
2. Vacuum chamber that can be placed in a neutron beam for alpha spectroscopy
3. Ultra-thin Ca sample
4. Counting geometry that maximizes the intrinsic efficiency of the system









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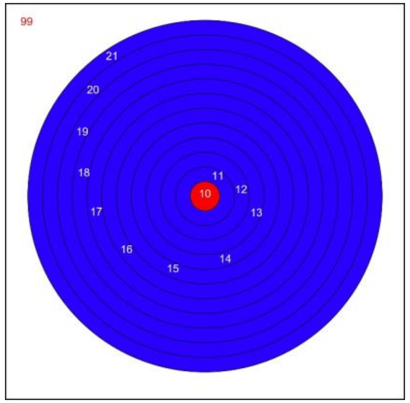
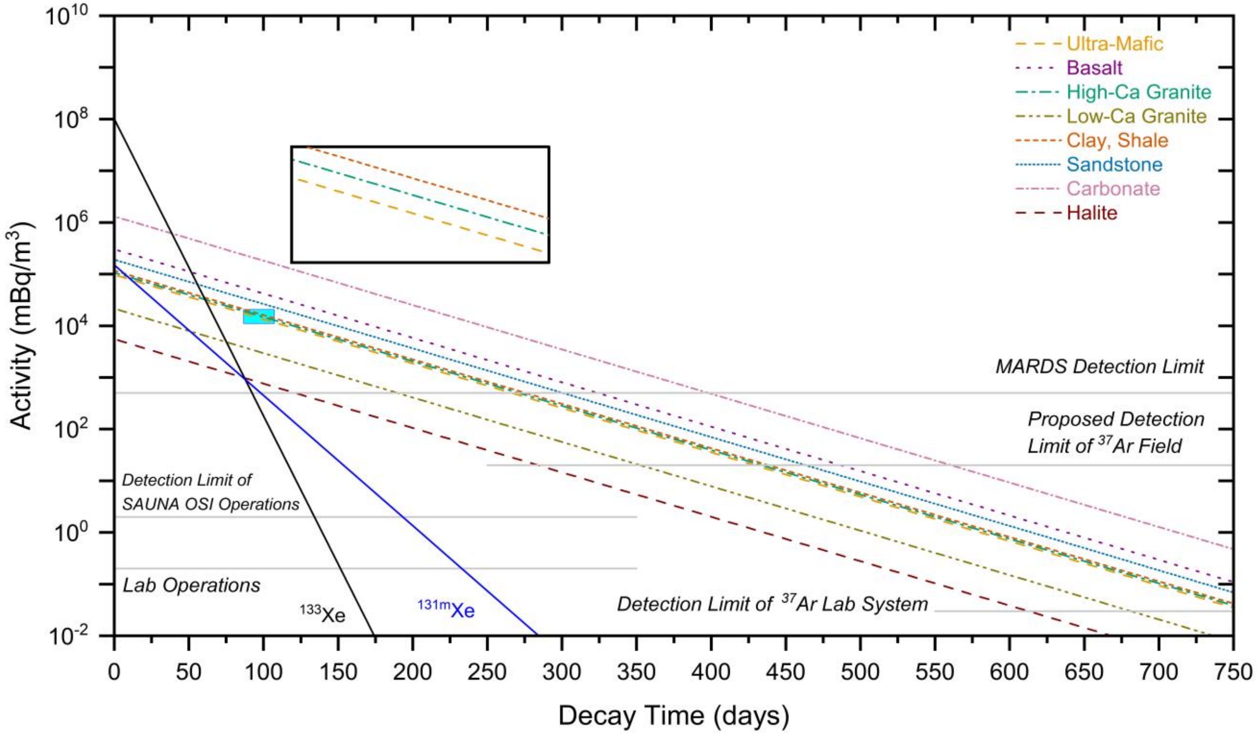
Results: Sensitivity Study and Literature Reevaluation

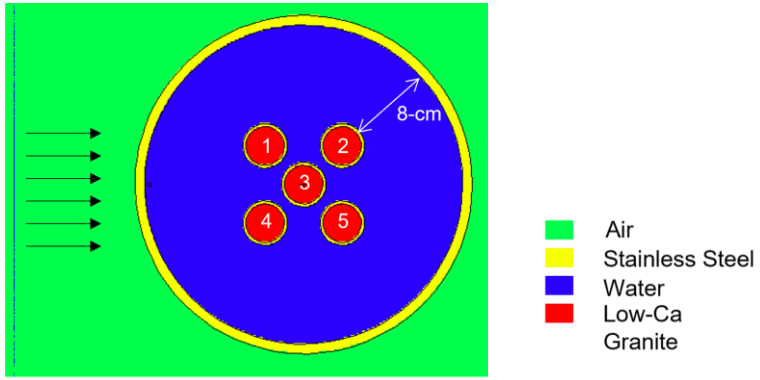
Model: ^{235}U Watt fission spectrum neutron point source surrounded by 11 spheres of rock.

Goal: How much does the elemental composition of rock and the presence of thermal neutrons impact the predicted yield of ^{37}Ar.





The Forster et al. cross section measurement: 4-8 MeV neutron source moderated by 8-cm of water incident upon 5 granite and limestone rock core samples, assuming 95% of the neutrons are thermalized with 8-cm of water.



Rock Sample	Thermal Fraction	Fast Fraction	Fraction < 50 keV
1	9.31%	90.69%	35.01%
2	12.53%	87.47%	39.49%
3	8.21%	91.79%	31.36%
4	9.32%	90.68%	34.97%
5	12.53%	87.47%	39.46%

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Conclusion

Next steps:

1. Flux characterizations of the fast and thermal neutron beams
2. Fast neutron preliminary experiments
3. Final sample curations
4. Thermal neutron experiments

Preliminary experiment setup

Acknowledgments

This Low Yield Nuclear Monitoring (LYNM) research was funded by the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (NNSA DNN R&D). The authors acknowledge important interdisciplinary collaboration with scientists and engineers from LANL, LLNL, NNSS, PNNL, and SNL.

This research was also funded by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1610403. Any opinion, findings, and conclusions or recommendations expressed in these materials are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Related Publications

Shah, K.A., De Luna, B.A., Haas, D.A. Implications of conflicting cross sections for the ^{40}Ca(n,a)^{37}Ar reaction as applied to nuclear explosion monitoring. *J Radioanal Nucl Chem* **331**, 5297-5303 (2022). https://doi.org/10.1007/s10967-022-08522-8

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