Lawrence Livermore National Laboratory

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presents:

MULTI-REACTOR SCIENTIFIC REACH AND APPLICATION MEASUREMENTS WITH

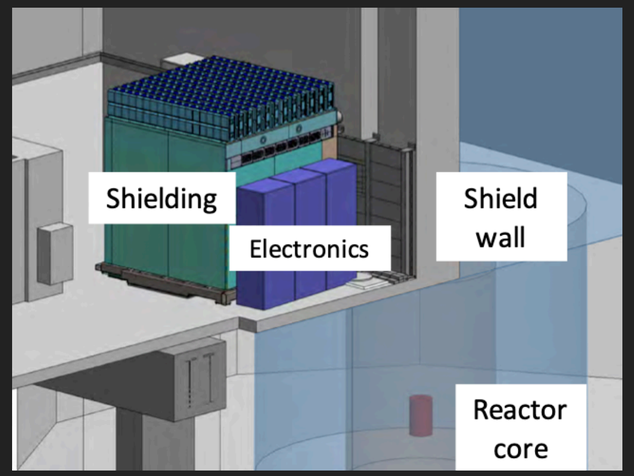
ROADSTR, A MOBILE ANTINEUTRINO DETECTOR

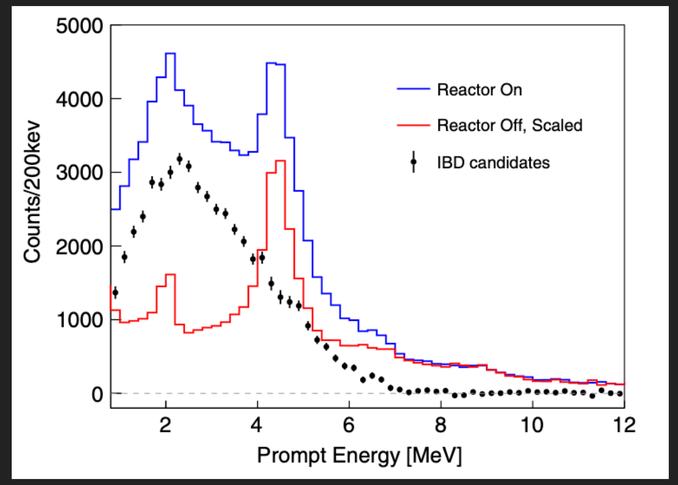
at APS DPF21 - 13.VII.2021

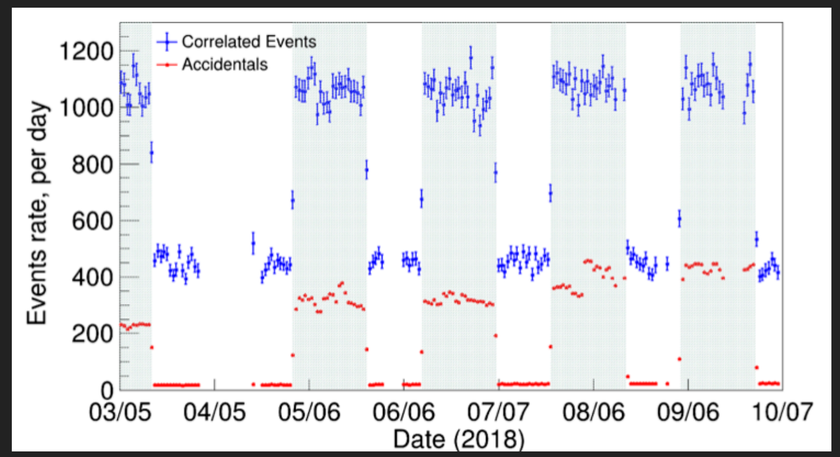
LLNL-PRES-821576
This work has been performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

STATE OF THE ART: ABOVEGROUND REACTOR NEUTRINO DETECTION

PROSPECT has demonstrated first high sensitivity aboveground detection and identified important capabilities.

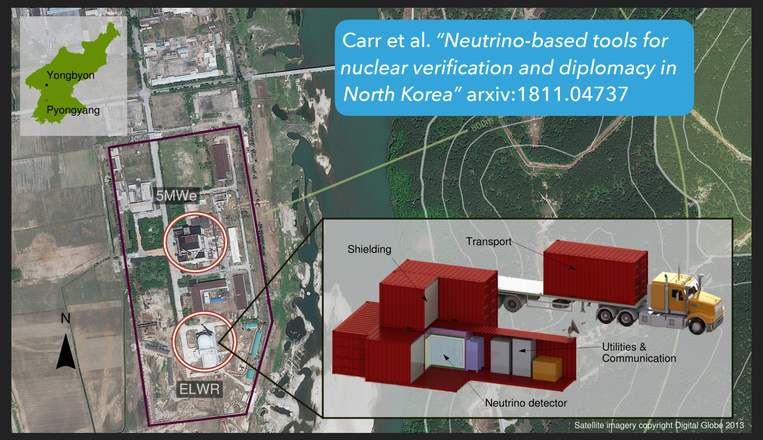






MOTIVATIONS FOR READILY MOBILE ABOVEGROUND DETECTION SYSTEM

Nuclear safeguards and verification applications

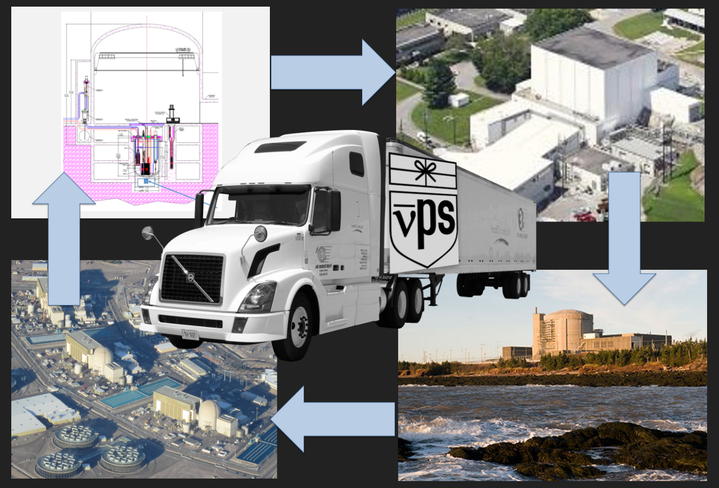


- Potentially useful tool for negotiation and verification of nuclear agreements.
- Advanced reactors may be difficult to safeguard with conventional approaches.

PROSPECT aboveground demonstration has inspired new use cases studies.

Readily mobile systems have several motivations

Multi-reactor measurement campaign with same mobile detector design



- Benchmarks for applications
- Validating flux & spectrum predictions against diverse fuel types.

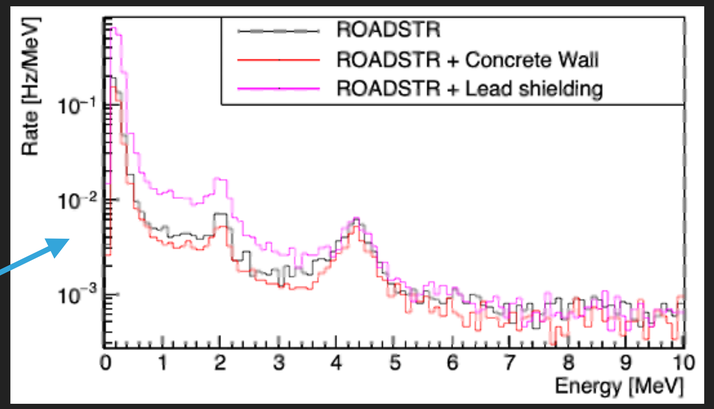
THE ROADSTR PROGRAM AT LLNL

Reactor **O**perations **A**ntineutrino **D**etection **S**urface **T**estbed **R**over

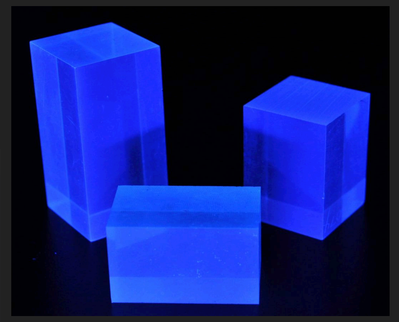
- Building from recent advances, our goals are to develop and demonstrate enabling technologies for mobile antineutrino detectors

Areas of development

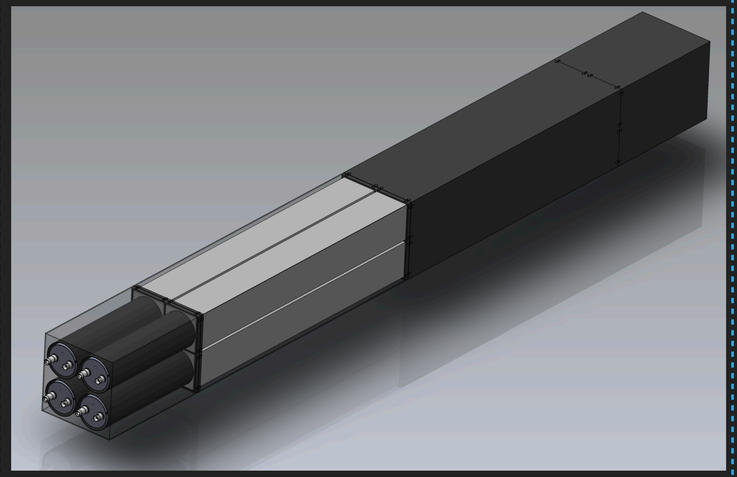
Background prediction



PSD Plastic Scintillators



Segmented geometries

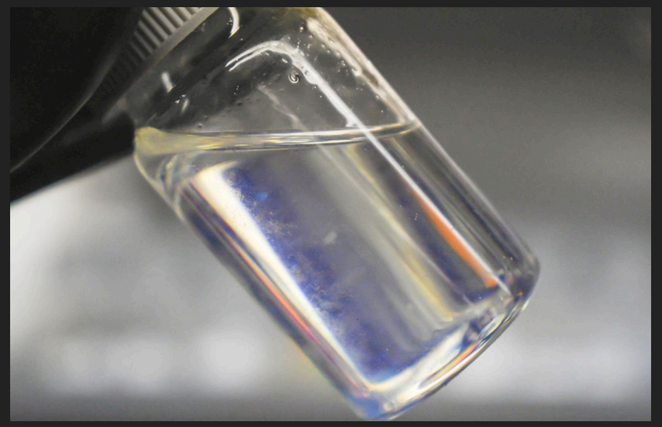


Mobile deployment engineering

PSD PLASTIC MATERIALS: HOMOGENOUS ^{6}LI-DOPING

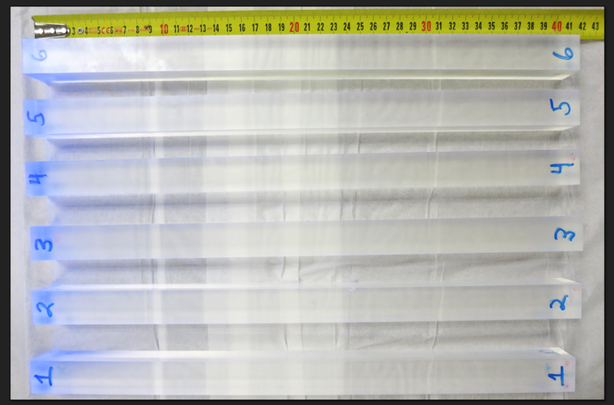
- Building on more than a decade of effort at LLNL by **N. Zaitseva**, **A. Mabe** & **M. Ford**

Developing formulations and production processes



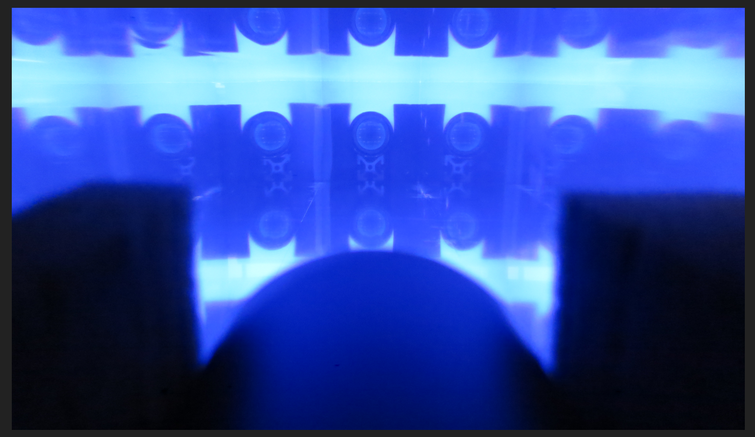
Exploring solubility of multiple Li bearing compounds and their stability

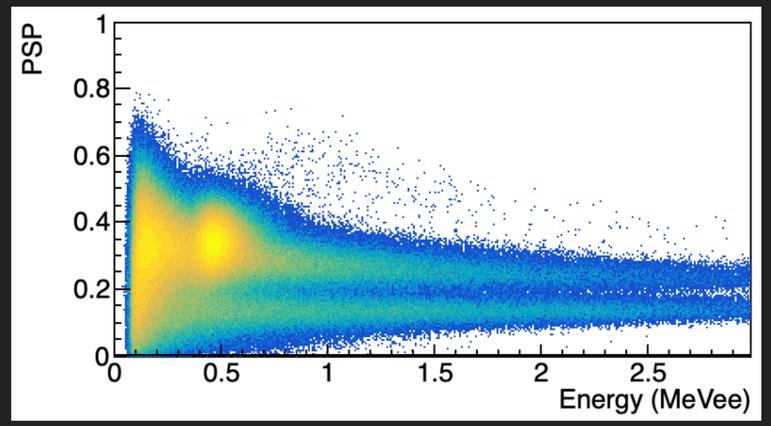
Producing PS bars for testing



Regularly making 2x2x16" elements.

Evaluating light yield, attenuation length, PSD properties

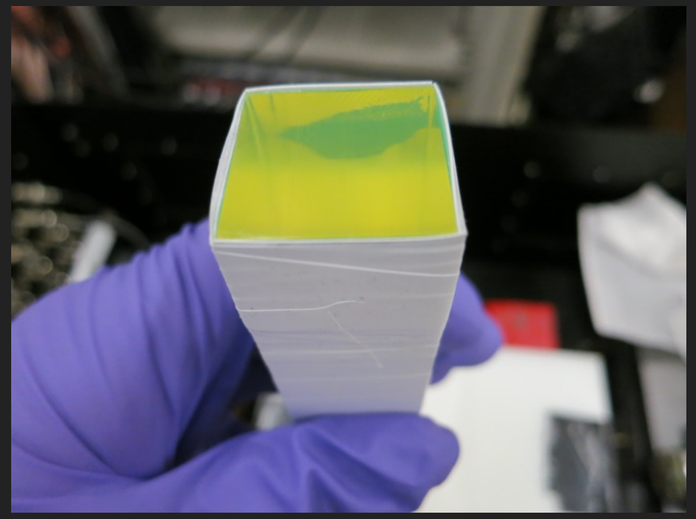




Advancing PSD plastic materials with the goal of matching demonstrated performance of liquids to enable easily mobile systems

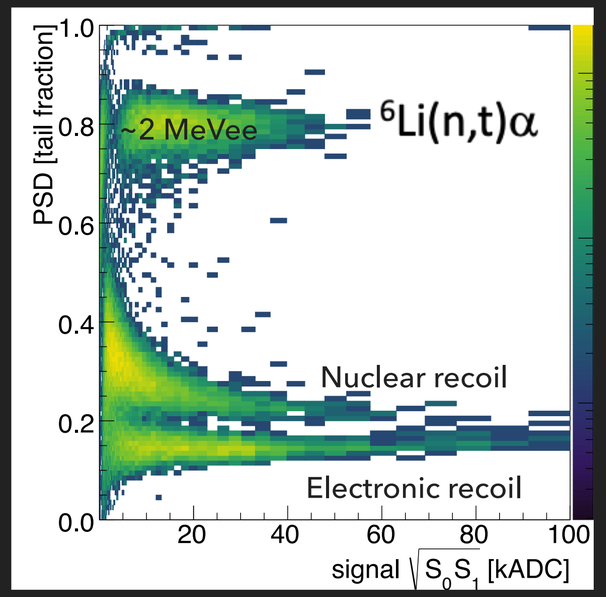
PSD PLASTIC MATERIALS: WAVELENGTH SHIFTING PS FOR LiZnS

- Alternate approach to 6Li inclusion: LiZnS inorganic scintillator sheets around WLS plastic (typically EJ-260)



- Working on direct comparison of EJ-260, WLS PSD, and Li-doped PS materials

Adapt PSD PS technologies to WLS configuration similar to EJ-260:



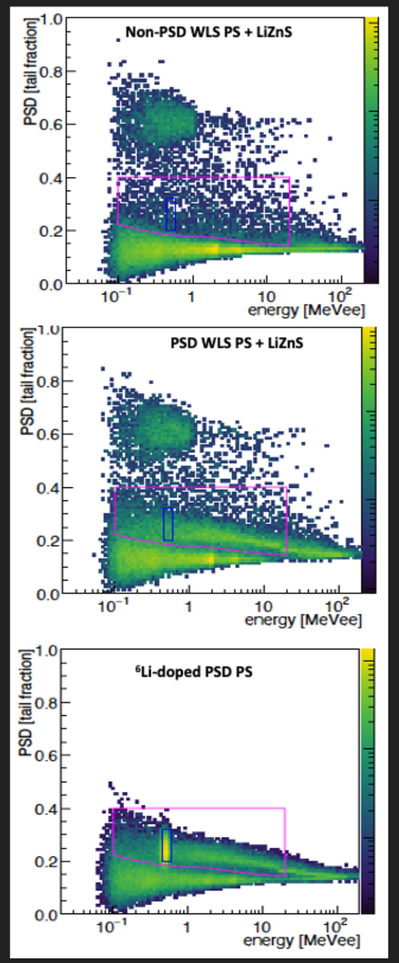
Provides triple PSD with excellent n-capture separation

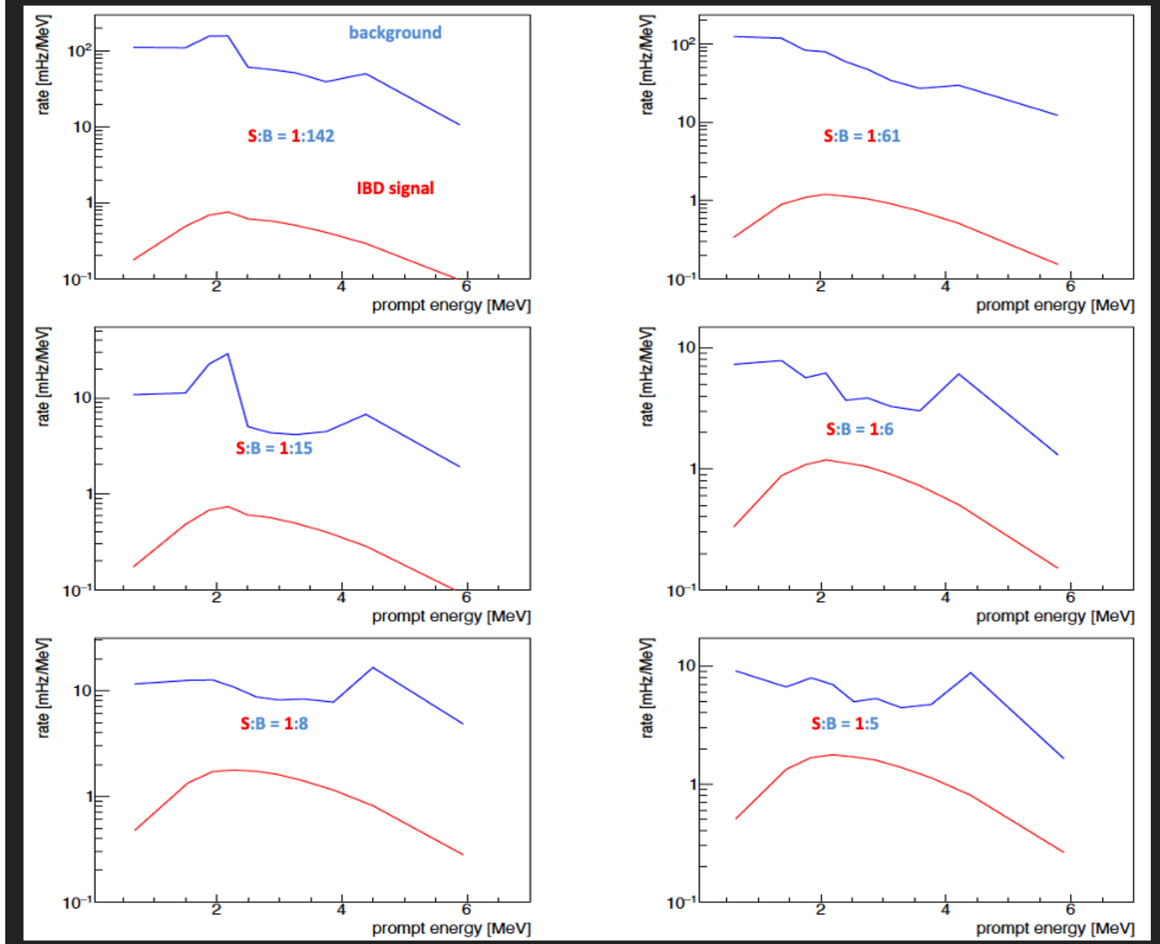
Drawback is lower n-capture efficiency and PE Yield.

Pursuing multiple material approaches to high performance aboveground detection

DETECTOR CONFIGURATION STUDIES

- **Simulations** have been produced for 1 m^3 scale rectangular bar arrays, varying:
  - Segment size
  - Fast neutron capabilities
  - Homogeneous 6Li-doping vs 6LiZnS
- **Event selection** similar to **PROSPECT**, with additional topological information
- Preliminary analysis shows **good performance** for **PSD** materials and some benefit from **smaller segment** size.



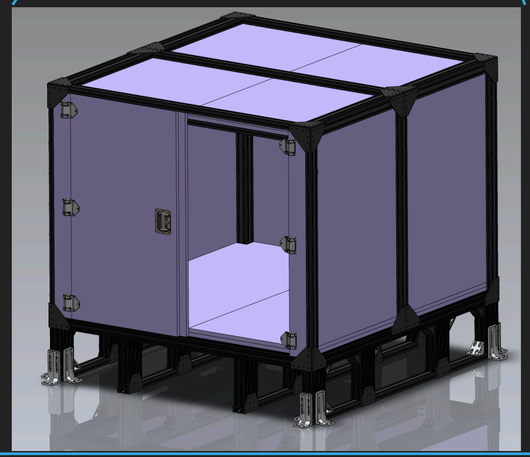


Studies to date validate emphasis on having both fast-neutron recoil and ^{6}Li (n, t) α identification

THE ROADSTR PLATFORM

- Mobile deployment platform for prototype detector testing
- Validate mobility and detector array performance
- Planning ~0.25-0.5m3 segmented plastic detector prototype within this project

- Moderated shielding: ~1m3 borated polyethylene enclosure and electronics to support multiple prototypes and technologies

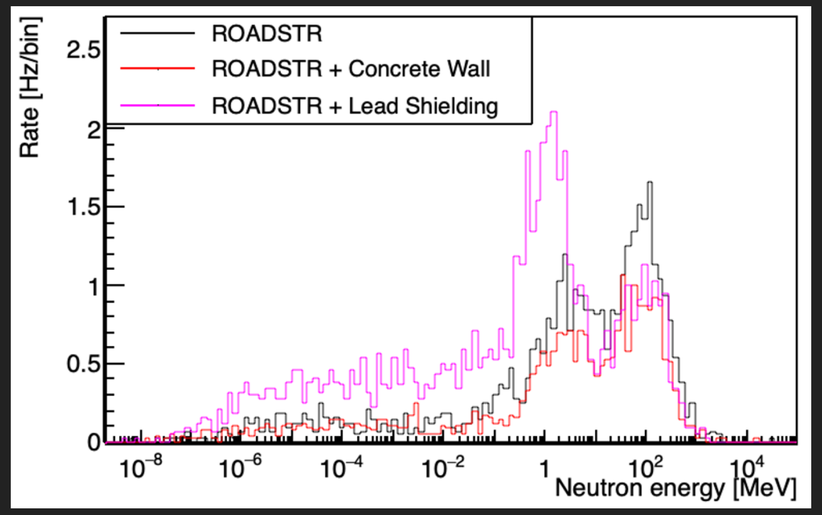


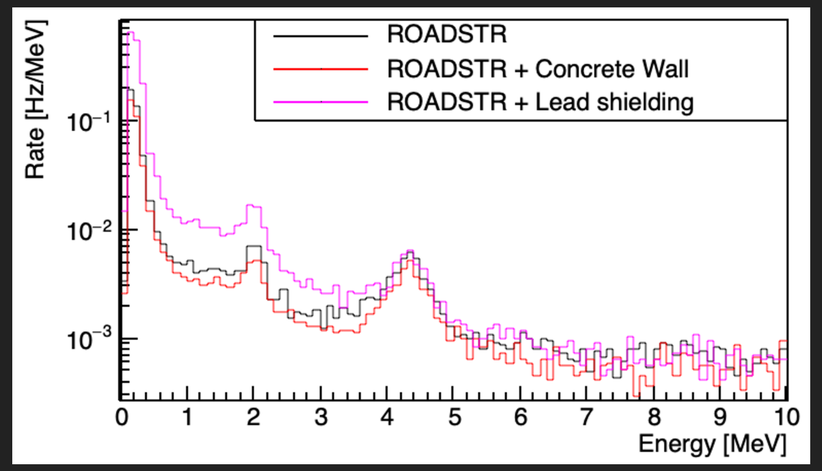
Flexible platform to support technology testing, plus collect data and gain experience at wide variety of sites

MULTI-SITE BACKGROUND STUDIES

IBD signal acceptance can be predicted quite well, but IBD-like background estimates are more challenging.

- For applications, well validated ability to predict background based on site conditions would be advantageous.
  - Reactor off periods are limited for commercial reactors
  - Backgrounds may vary between reactor on and off periods due to changes in atmospheric conditions, site activities, etc.





- Preliminary simulations show important effect of different on-site materials surrounding the detector
- Planning multi-condition background measurement campaign using the ROADSTR platform to tune and validate our background simulation

Goal is to support rapid deployment of mobile systems by not requiring a full characterization of backgrounds for every site

CONCLUSIONS

- The **PROSPECT aboveground** detection is an important capability **demonstration** for reactor **monitoring applications** and other **reactor neutrino** studies
- **Mobile** aboveground systems that maintain **high sensitivity** are a clear **next step** along the technology development path

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- The **ROADSTR** program is **advancing** several **technology** options towards this **goal** and developing supporting capabilities:
  - ➡ **PSD Plastic Scintillators**
  - ➡ **Segmented Detector Geometries**
  - ➡ **Mobile Deployment Engineering**
  - ➡ **Background Prediction**