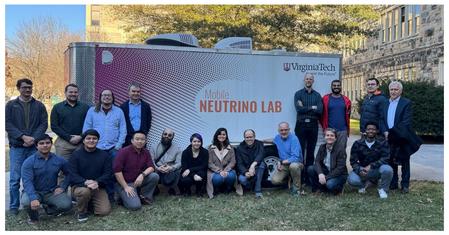
Near-field Antineutrino Application Developments in the U.S.

Nathaniel Bowden *for the CASC-NN and Mobile Antineutrino Demonstrator Projects*

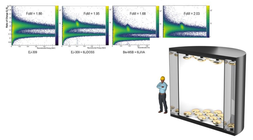
There are several application efforts underway in the U.S. that focus on antineutrino detection in the 'near-field', within 100m of a monitored location. The efforts to be described in this poster are based on technologies that use Inverse Beta Decay and Li-6 as a neutron capture agent since this supports compact systems with high efficiency and excellent background rejection. These include the Mobile Antineutrino Demonstrator, a realistically deployable antineutrino detection system that can operate at essentially any facility with no infrastructure support beyond electrical power and studies to advance high performance Li-6 loaded liquid scintillators and associated detector implementations. Additionally, we will describe studies of uses cases for which these technologies may be applicable and plans for measurement campaigns to advance their technical readiness.



Project Goals

- The "Comprehensive Antineutrino Solutions for Contemporary Nonproliferation Needs" (CASC-NN) Project seeks to advance definition of antineutrino application use cases, the performance and technical readiness of underlying neutrino detection technologies.
- Existing testbeds are being used to provide signal and background models, and conduct technology demonstrations in relevant environments.

Advanced Instrumentation Testbed (AIT) Inputs
- Validate ^{6}Li PSD liquids for space efficient monolithic detector concept



Mobile Antineutrino Demonstrator (MAD) Inputs

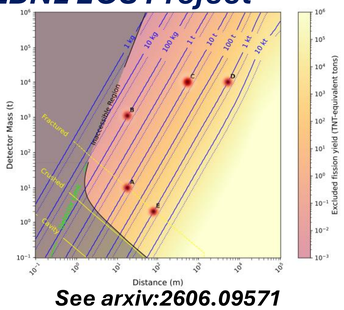
Background studies using MAD prototypes
- Underground (Test Site)
- Shallow overburden (Maritime)

MAD Reactor Demo(s)
- technology suitability in restricted access facilities
- Validation of detector technologies

Use Case Studies – *Joint with LBNL EOS Project*

Test Site Explosion Monitoring

- Absence of neutrino signal can set limit on fission content of chemical explosion
- Few-ton to multi-kiloton detectors can set potentially useful limits on chemical explosions
  - Relevant distances ~10m to 10km
  - Not useful for large-area low-yield monitoring or subcritical experiments

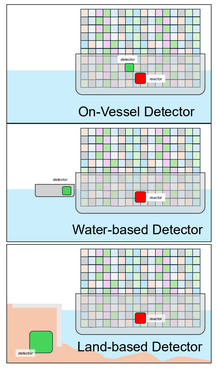


See arxiv:2606.09571

- CASC-NN Implementation Approaches: emphasize practicality through limiting footprint, material, and onsite activity, e.g.:
  - Ton-scale modules: relocatable, reusable, robust, and redundant; using existing drifts; assembled offsite
  - 10-100 ton fixed monitor with high volumetric efficiency emplaced as close as practical to minimize civil works

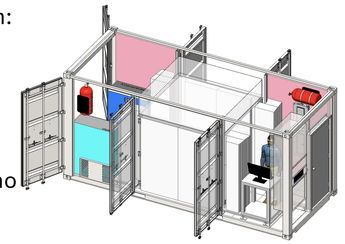
Maritime Reactor Monitoring

- Renewed interest in civilian nuclear propulsion motivated by Advanced Reactor concepts and factors like operational economics
- Non-intrusive neutrino measurements potentially useful for reactor verification
- Challenging use case due to low neutrino flux and/or high background, difficult operational environment
- Multiple 'deployment concepts' identified
- CASC-NN Implementation Approaches: emphasize background rejection to permit near-surface deployment and smaller footprint



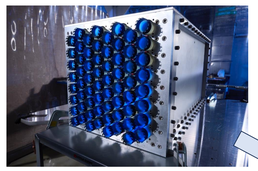
Mobile Antineutrino Demonstrator (MAD)

A readily mobile antineutrino detector system:
- requires no infrastructure beyond power & deployment footprint
- operates aboveground without significant shielding
- incorporates potential end-user input
- advances "Technical Readiness" of neutrino applications by performing capability demonstrations in operationally relevant environments



Advancing Two Solid-State Technologies

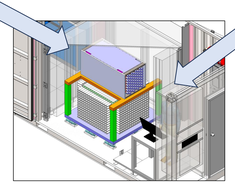
MAD-PSD



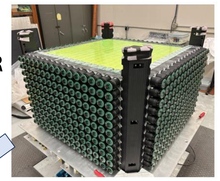
8x8 2D array:
- 6Li-doped PSD plastic scint. bars (1 meter)
- 128 PMTs

See poster 493 S. Ghosh

Robust, segmented detectors with particle ID and ^{6}Li build off PROSPECT and miniCHANDLER surface reactor measurements demonstrations.



MAD-CHANDLER-650



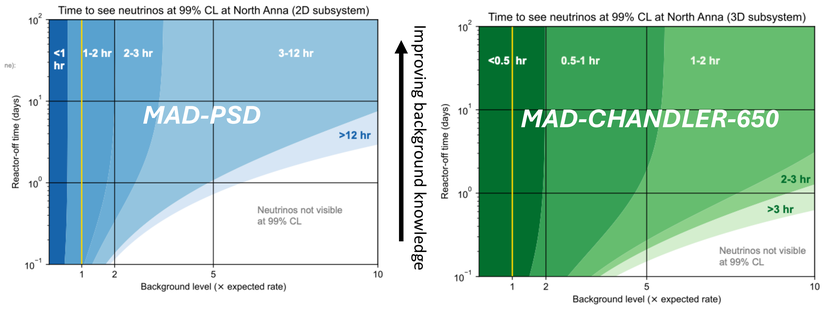
Raghavan Optical Lattice:
- 832 PMTs
- 6,400 plastic scint. cubes
- ^{6}LiZnS sheets

A. Haghighat Phys.Rev.Applied 13 (2020) 3, 034028

See poster 381 I. Olusola

Example MAD Performance Prediction

- During an aboveground deployment 25m from a 3GW reactor, On-Off observation expected within hours even if backgrounds higher than predicted



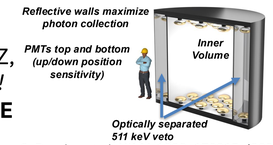
- Both subsystems will be able to reactor antineutrino detection capability demonstrations and advance the technology concepts

^{6}Li-doped PSD liquid scintillator studies

Concept for high volumetric efficiency & background rejection
- 10m^3 achieves similar sensitivity to Double CHOOZ, *with 7x less depth and 13x less non-target volume !*

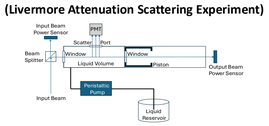
Qualifying new PSD (6Li) liquid scintillators w/ LASE
- Modern reference - EJ-309: Attenuation – 1.2 m (blue) to ~4 m (green)
- 6Li PSD Liquid Results: Attenuation - 50% - 70% of EJ-309

Insufficient for multi-meter systems at present time
Investigating purification and alternate formulations



S. Dazeley et al. NIMA 1082, 170915, (2025)

LASE (Livermore Attenuation Scattering Experiment)



J. Hecla, et al, Phys.Rev.D 111 (2025) 5, 052005

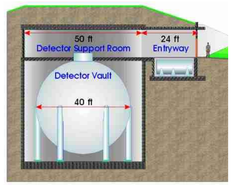
Use Case Relevant Background Measurements

ROADSTR PSD Plastic Prototype packaged for multi-site measurements
- Test Site Use Case - deep overburden: Environmental backgrounds, facility characteristics
- Maritime Use Case - shallow overburden: Map background transition

Results to inform background modelling for use case development

ROADSTR at NNSS P-Tunnel

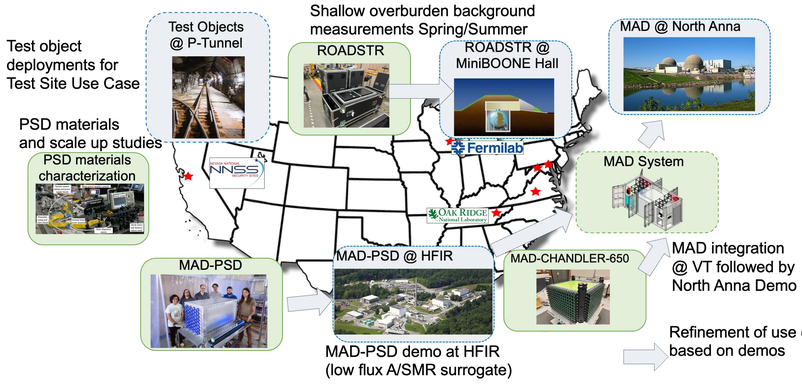
FNAL MiniBOONE Hall



O. Benevides Rodrigues, et al, Phys.Rev.Applied 24 (2025) 5, 054023

See poster 494 - O. Benevides Rodrigues

Planned Measurement and Deployments



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