Hidden Sector Experimental Challenges

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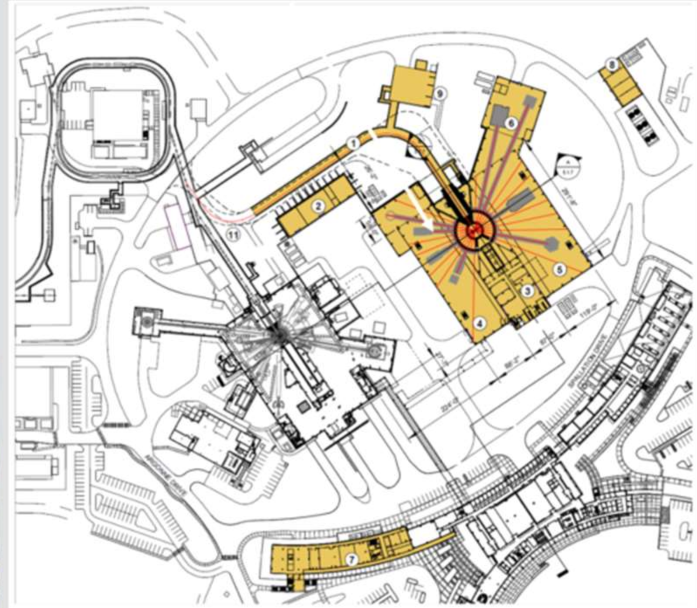
Initial work on low-threshold, high-sensitivity detectors and facilities requirements for accelerator-DM searches and other physics at ORNL-SNS Second Target Station

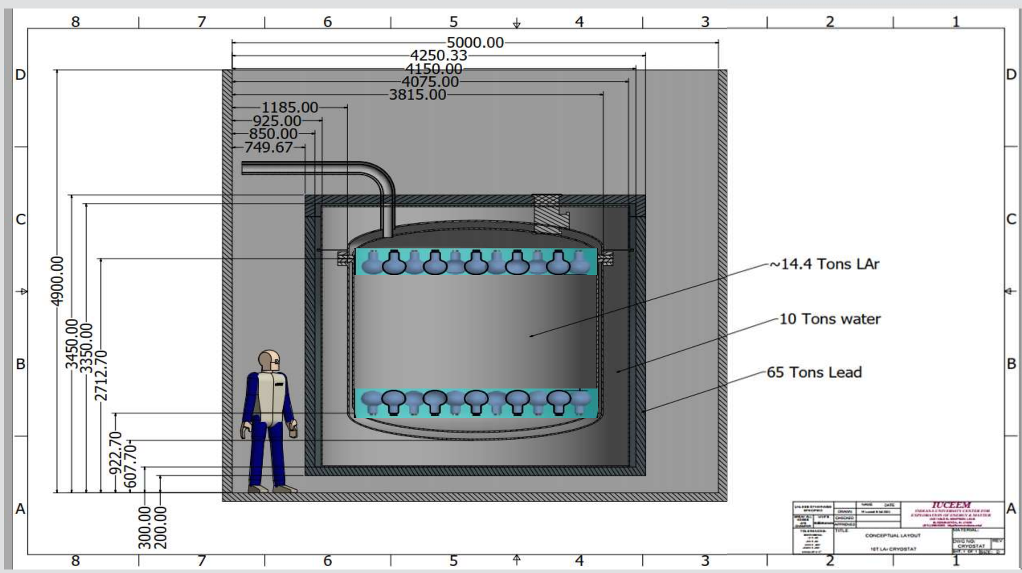
Neutrinos at ORNL Workshop

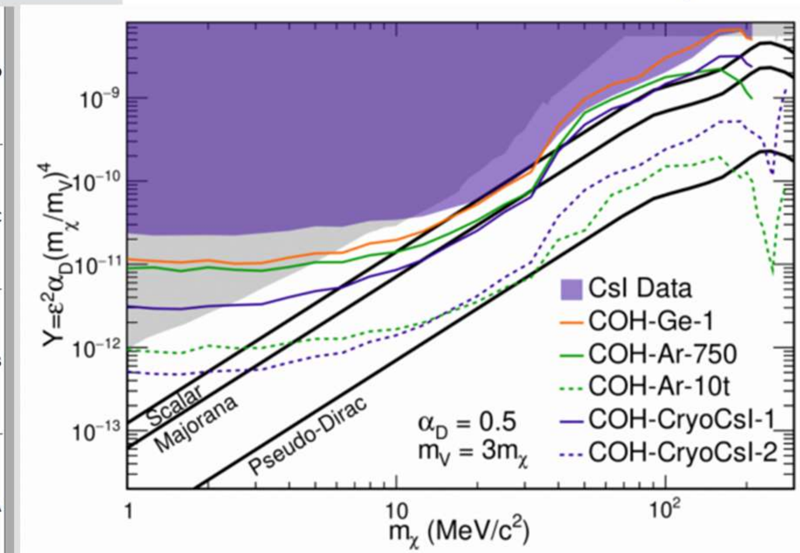
30 November 2021 to 2 December 2021

America/New_York timezone



SNS Site with STS Facility





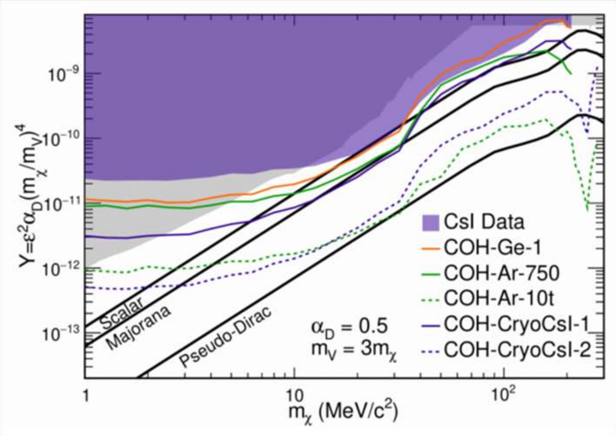
Motivation

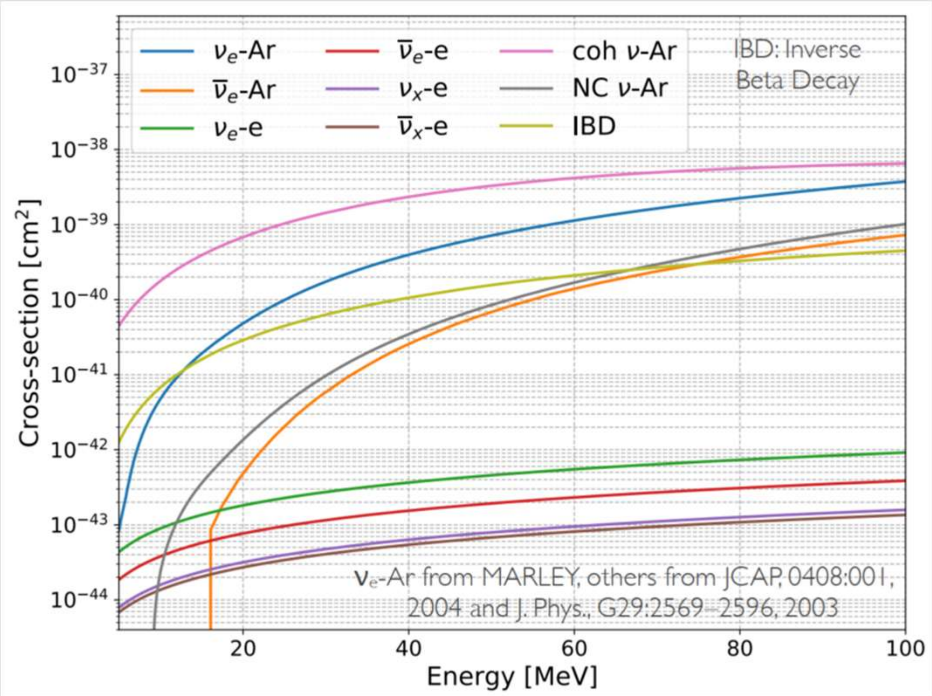
Physics topics:

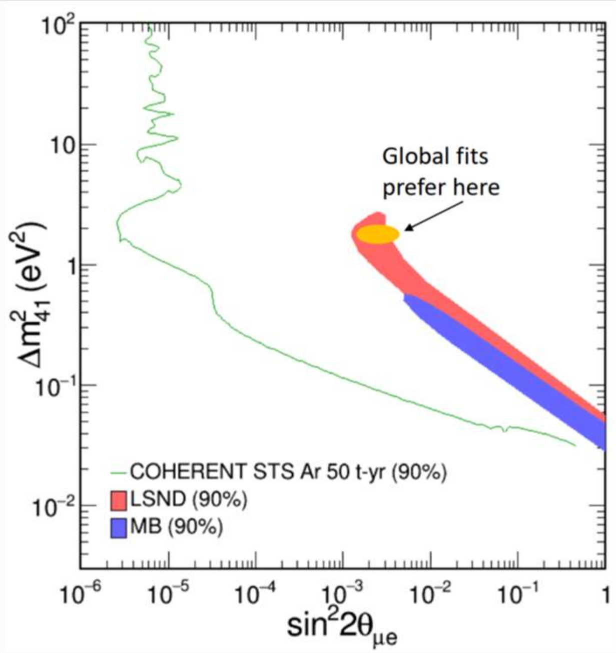
- accelerator-produced dark matter

and…

- further (beyond Neutrino Alley) CEvNS studies of NSI, nuclear form factors, sterile ν searches
- higher-energy inelastic events for SN/DUNE







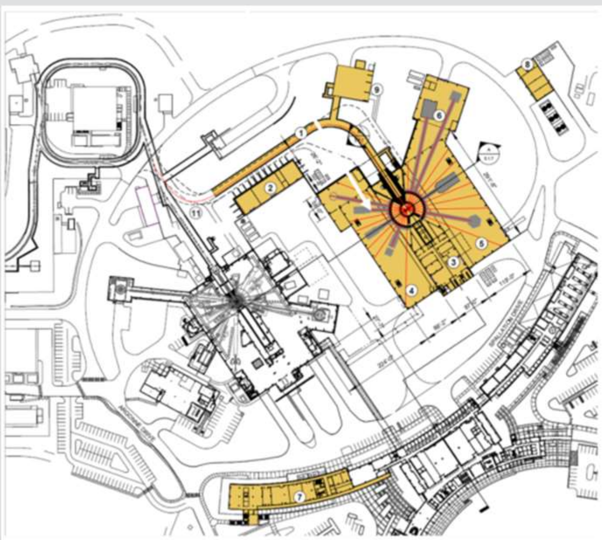
credits: Y-T Tsai, D. Persey, etal

Assumptions

- Considering 10-ton scale detectors, building on ongoing work including ton-scale detectors from COHERENT in Neutrino Alley.
-
- 10-ton scale detectors require larger dedicated halls and therefore the SNS-STS with timescale ~5yrs

COHERENT **CEvNS** Detector Status and **Farther Future**

Nuclear Target	Technology	Mass (kg)	Distance from source (m)	Recoil threshold (keVr)	Data-taking start date	Future
CsI[Na]	Scintillating crystal	14.6	19.3	6.5	9/2015	Decommissioned
Ge	HPGe PPC	18	22	<few	2022	Funded by NSF MRI, in progress
LAr	Single-phase	24	27.5	20	12/2016, upgraded summer 2017	Expansion to **750 kg scale**
NaI[Tl]	Scintillating crystal	185*/ 3388	25	13	2022, high-threshold deployment summer 2016	Expansion to **3.3 tonne**, up to 9 tonnes



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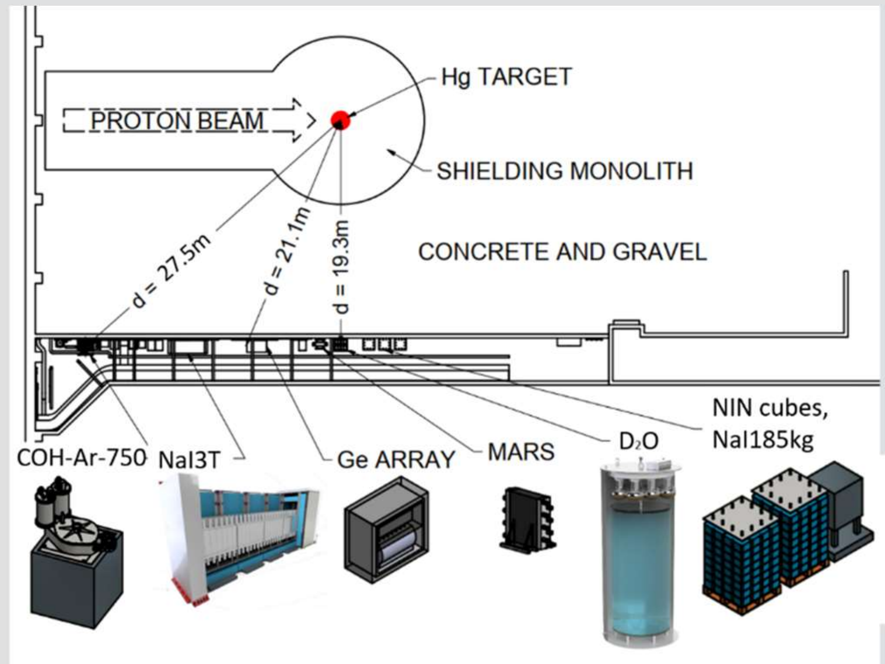
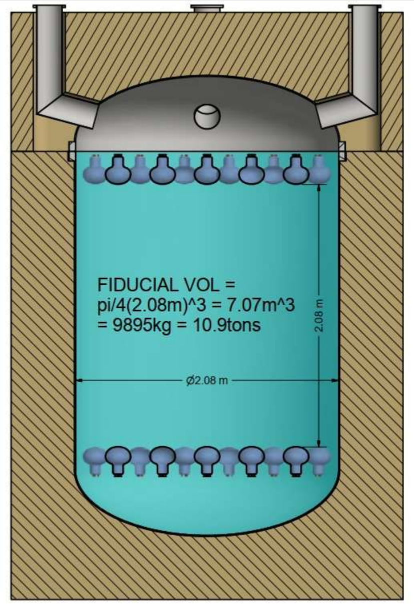


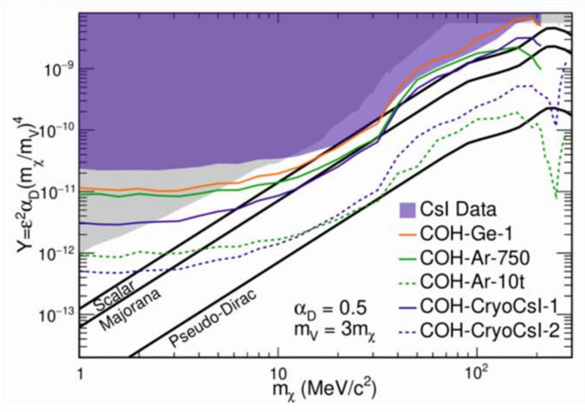
Detectors/Facilities for STS neutrino program

- Detector requirements
  - large mass for sufficient event rates
  - low-energy threshold for DM and CEvNS physics
  - high-spatial resolution for inelastic physics
  - well shielded
- Facility/building/room requirements
  - space
  - utilities for cryogenics, power needs
  - low backgrounds:
    - beam-related neutrons!
    - environmental (concrete etc)
    - cosmics



early concept for 10ton LAr

- Most work, so far, on design and facilities requirements for a ~10ton LAr detectors, since:
  - scales to 10ton naturally
  - overlap with DUNE etal, phyiscs and design experience
  - drives the facility requirements for size and utilities (eg: cryogenics)

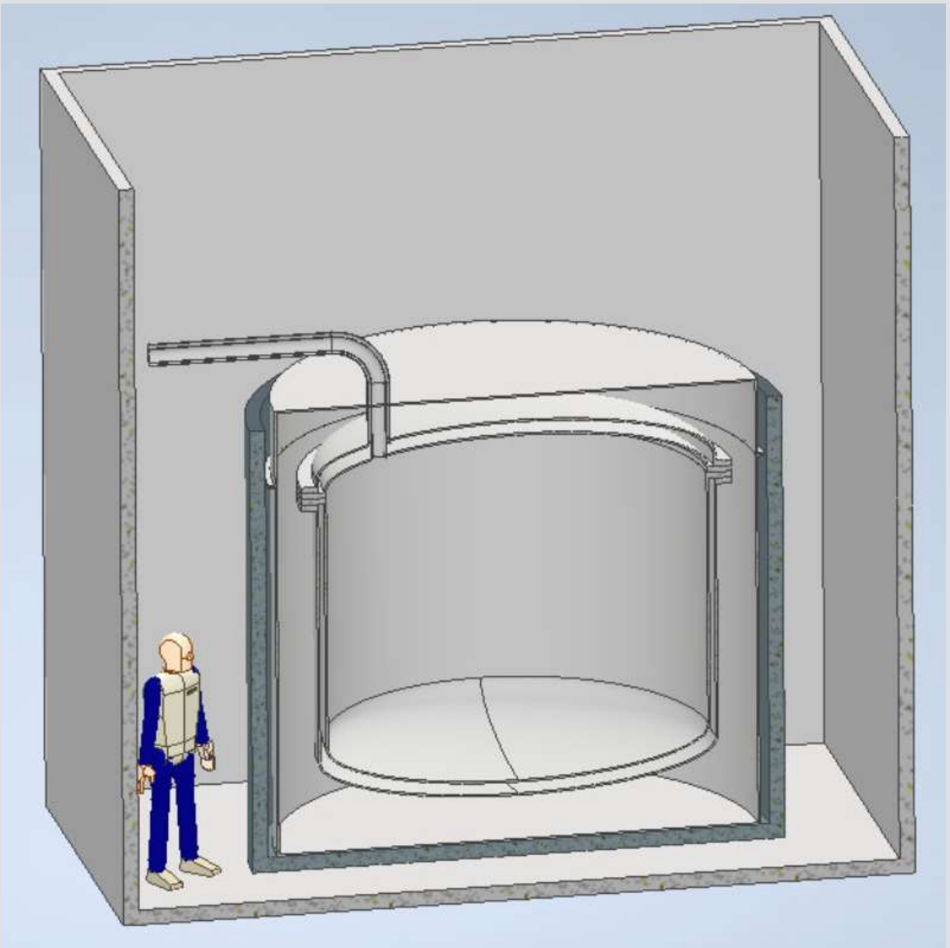


- Other detectors possible in these facilities (eg Cryo-CsI)

Concept for ~10ton LAr detector for scintillation or TPC detector

Cryostat/room specs:

- 4.9m x 5m x 5m room in SNS STS basement
- 2.5m dia x 2m high cryostat, Design from cryofab example from SLAC.
- detector shielding: outside of cryostat, 10" water, 4"Pb.
- For crypgenic plumbing and related, require adjacent 5mx5m room, likely can reduce that.
- Simliar cryostat works for scintillator or TPC detector.
- For best room shielding, suggesting a "shielded cave" approach. Inner detector assembled in high bay, forked into place. Modular H2O tank, Pb assembled in place (eg: no high-bay crane access here)



Shielding

From Neutrino Alley work, we have developed shielding requirements
(for low-energy measurements, reduction of beam-related neutrons most crucial)

General Shielding Requirements

- 20 meters of line of sight shielding between target and neutrino instrument (45-50 interaction lengths, HD concrete reduces distance)
- 3.5 meters of overburden for cosmic ray shielding (could include neutron instrument shielding above)
- 3 meters hermetic shielding around instrument in directions open to beam (learning from FTS BL1 instrument trenches)

This shielding can be comprised of a combination of structural materials, target monolith, etc. and dedicated shielding for neutrinos instruments.

OAK RIDGE National Laboratory | HIGH FLUX ISOTOPE REACTOR | SPALLATION NEUTRON SOURCE

STSnu Working Group 2021-07-13

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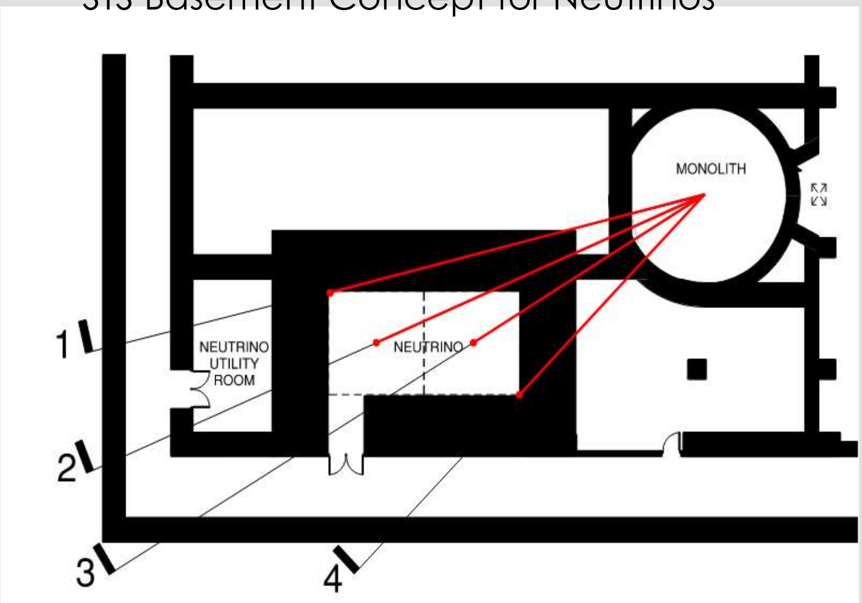
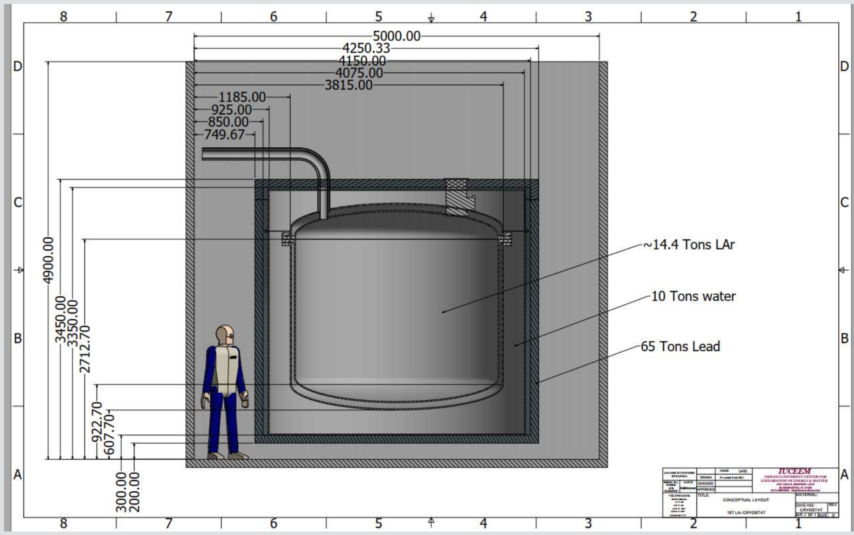
Recent design concept

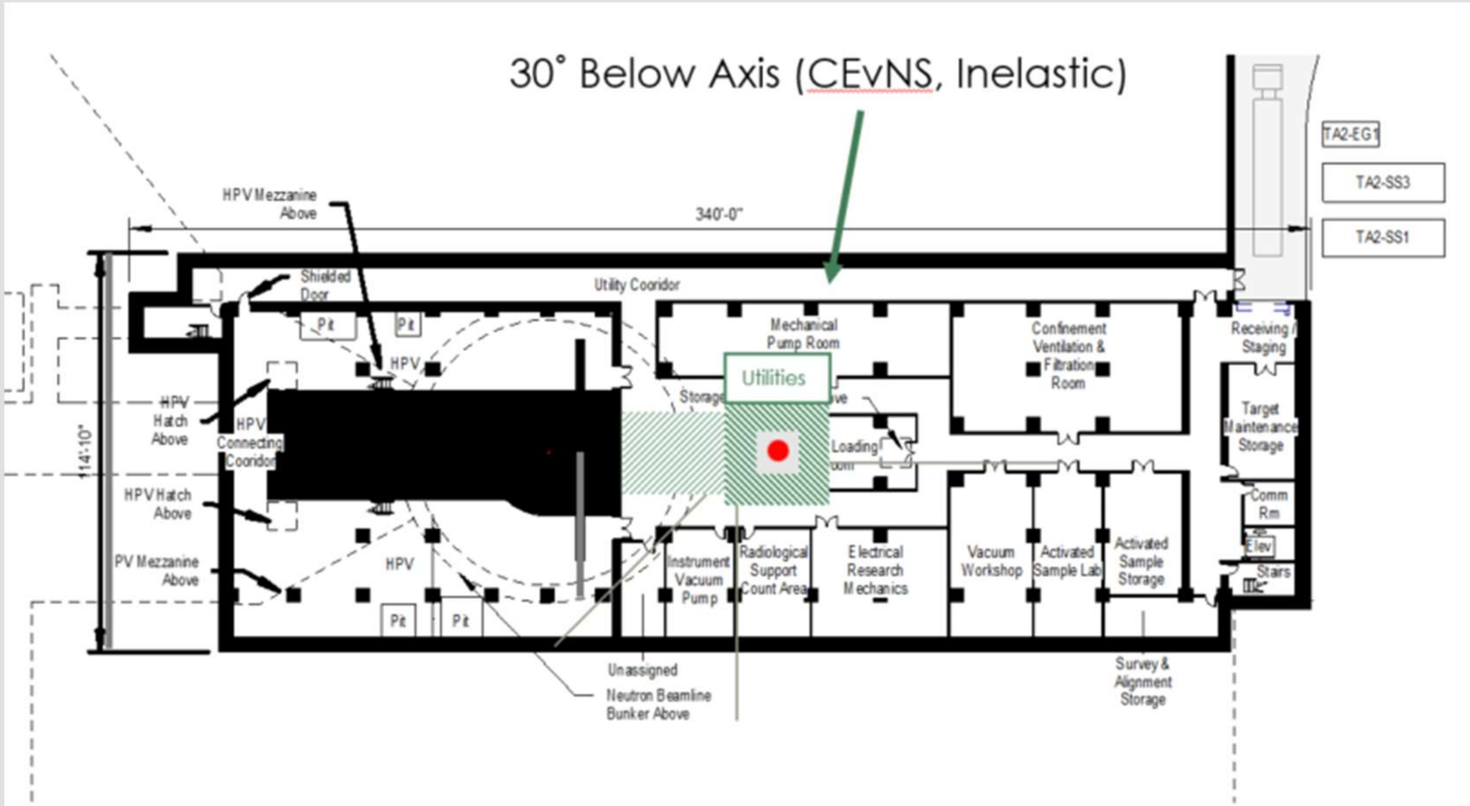
STS Basement Concept for Neutrinos





STS Basement concept:

Recall that forward production of heavier DM suggests a small-angle hall.
A more challenging specification…. work in progress.



Detector details for STS neutrino program

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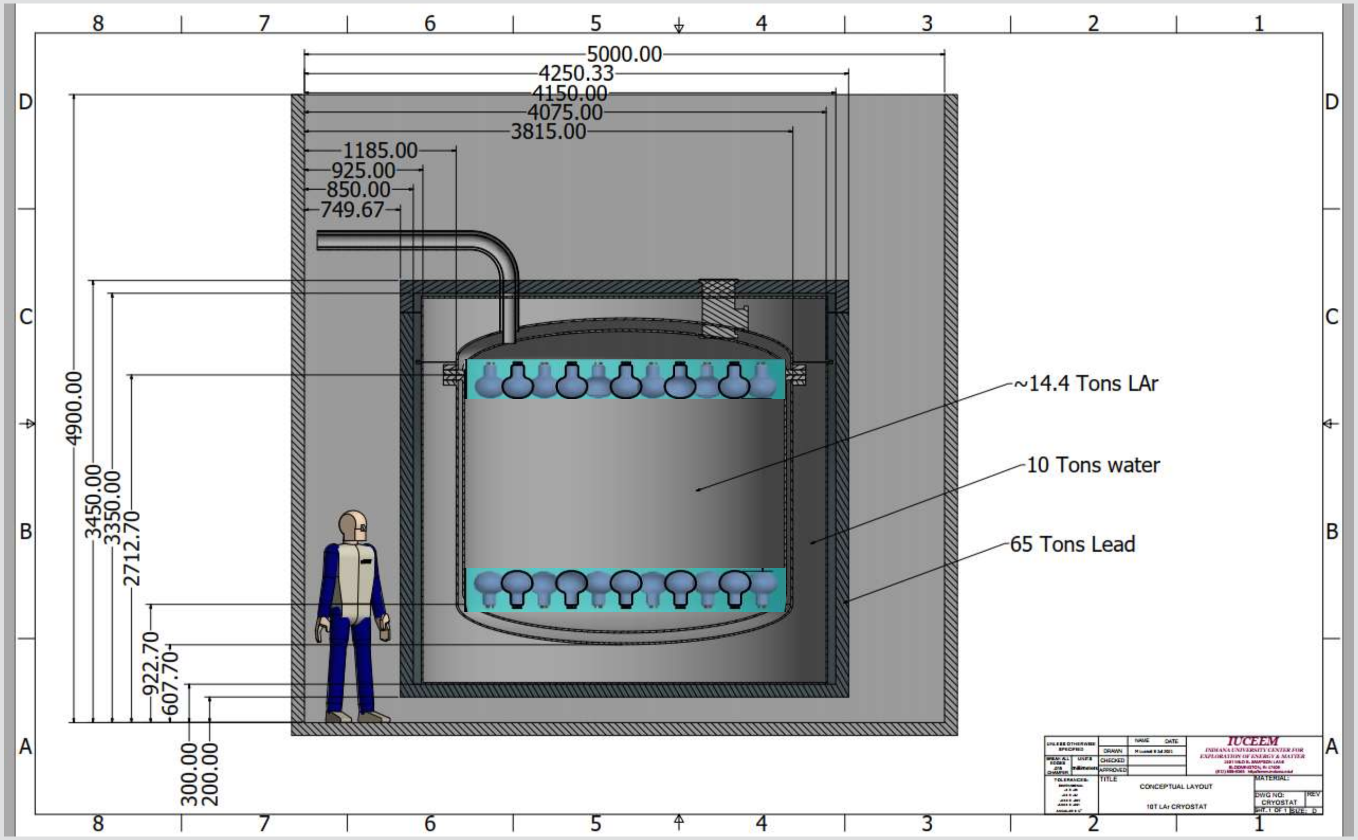
Concept for a ~10ton LAr **scintillation** detector



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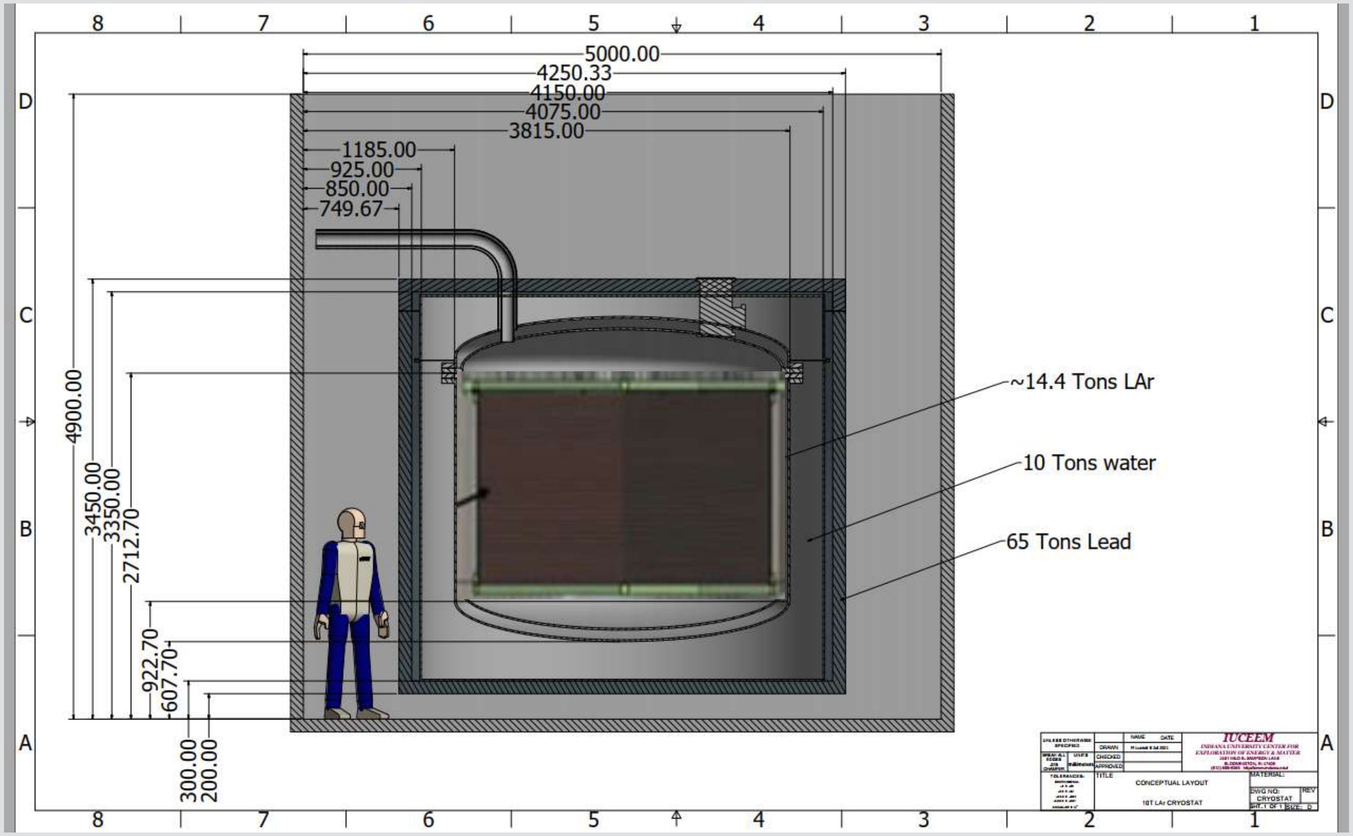
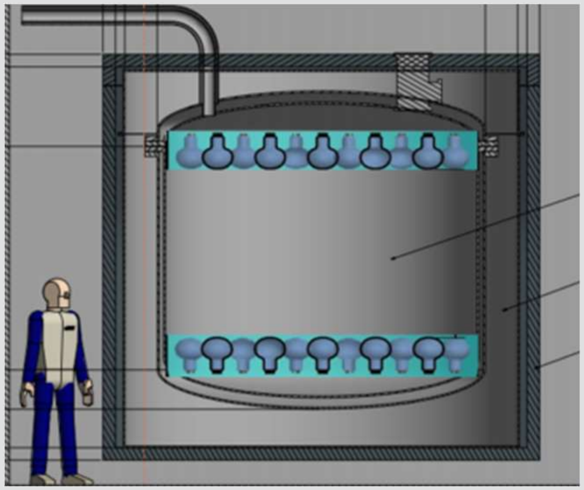
Concept for a ~10ton LAr **TPC** detector



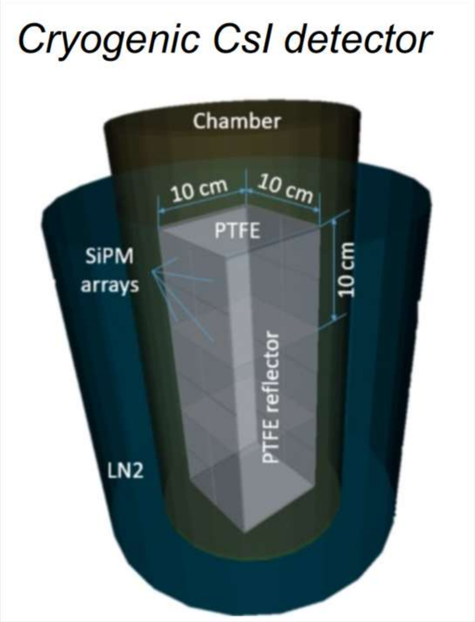
more on TPC design
from Y-T Tsai talk

Detector details for STS neutrino program



Detector technology, possible R&D, and further work

- Underground argon: All cryostats wait for UAr from Urania(Kinder-Morgan) in Colorado. Other avenues? (2018 Workshop writeup arXiv:1901.10108)
- Xe-doping: May eliminate need WLS-coatings while maintaining ER/NR PID (eg: inspirehep.net/literature/1737812)
- SiPM implementation: optimize channel count/segmentation for position reconstruction in CEvNS and hi-energy detectors, heat load a concern in cryogenic detectors, onboard digitization.
- In-situ sources such as ^{83m}Kr for calibration (eg: https://inspirehep.net/literature/1824411) .
- In-situ nuclear recoil calibration (eg: https://inspirehep.net/literature/1811232)
- cryogenic CsI (eg: https://doi.org/10.1140/epjc/s10052-020-8111-7)
- dual-phase and/or other noble gases should be considered (see J. Daughhetee talk tomorrow)



Summary

- Opportunities for neutrino and DM physics at SNS-STS exist
- program will yield high-impact physics for modest investment
- Facilities and detector planning underway
- More participation and ideas welcomed