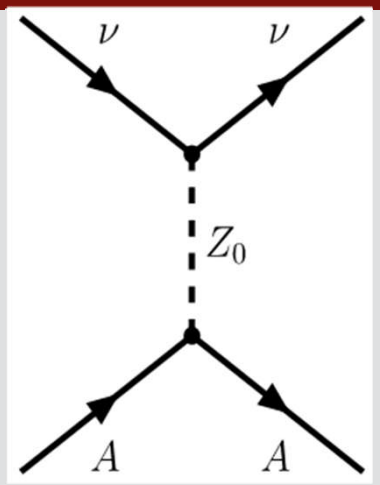
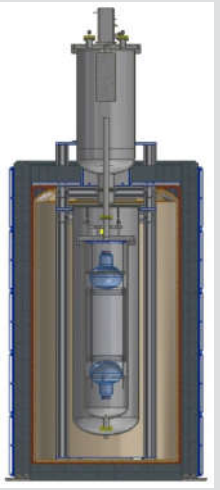
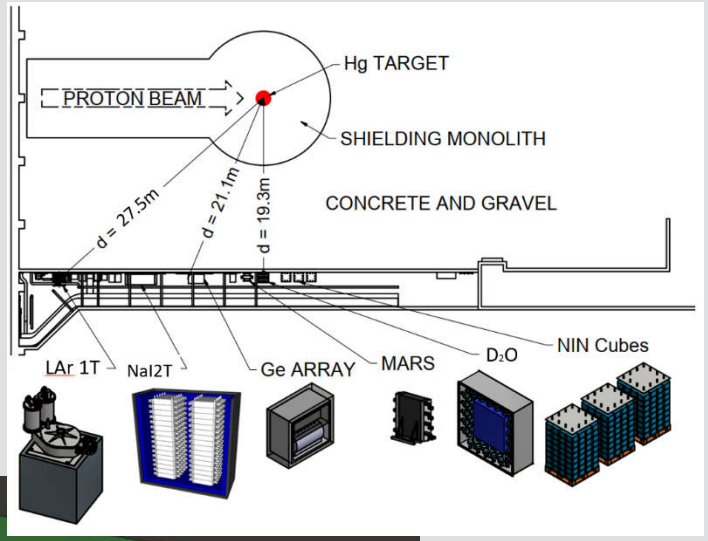
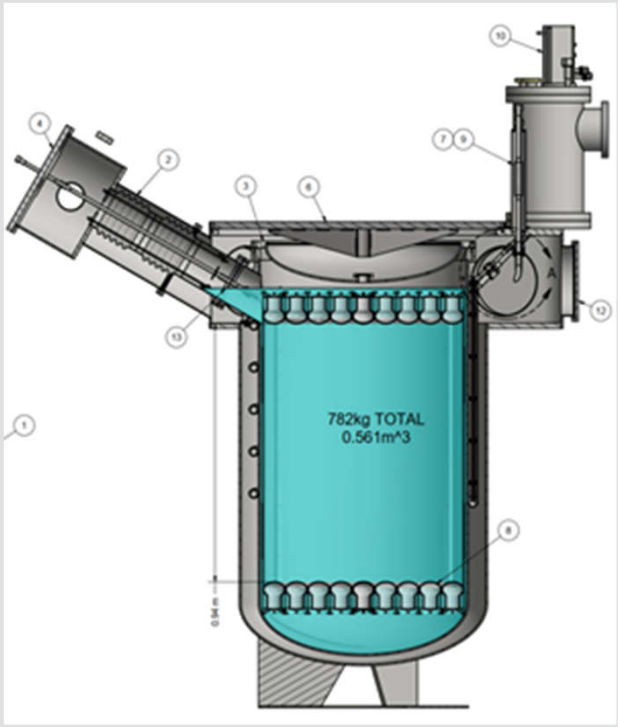
# A future COHERENT program with LAr

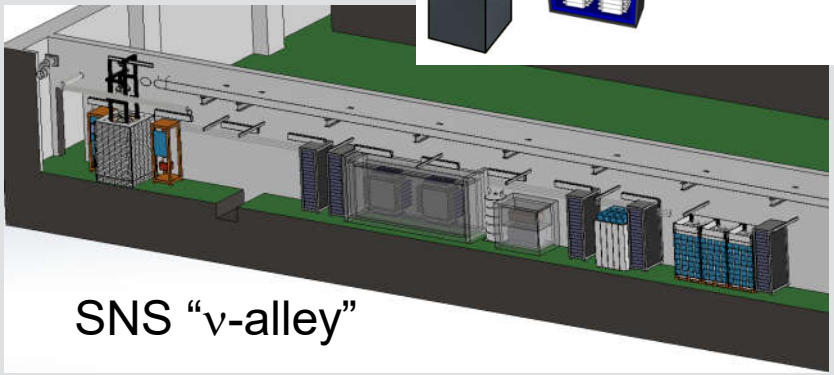
R. Tayloe, Indiana U.
for the COHERENT collaboration

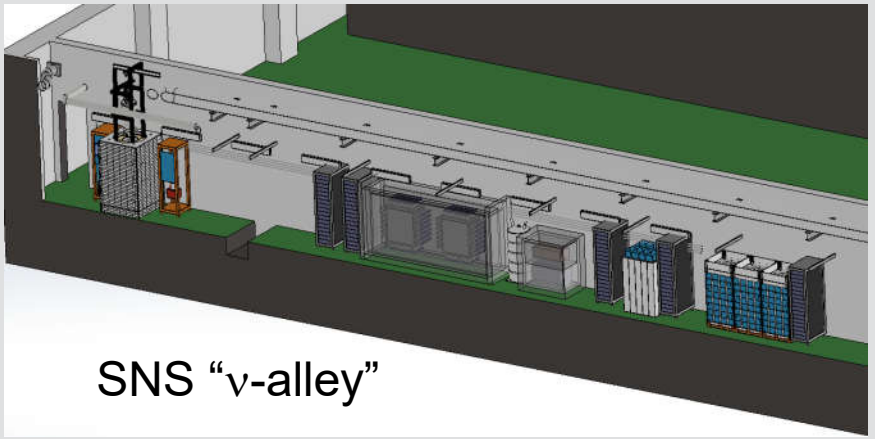


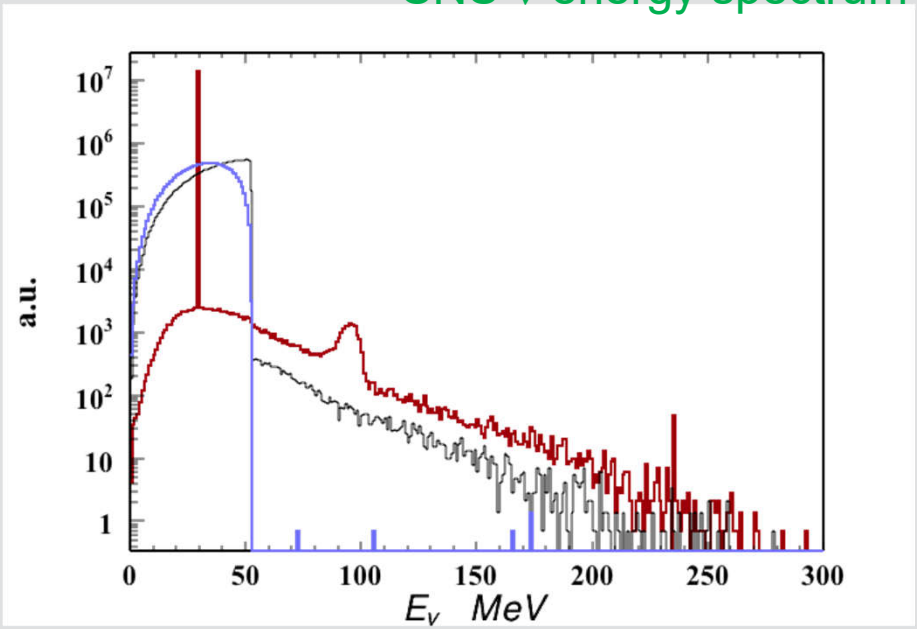


SNS “ν-alley”

## COHERENT experiment in SNS ν-alley

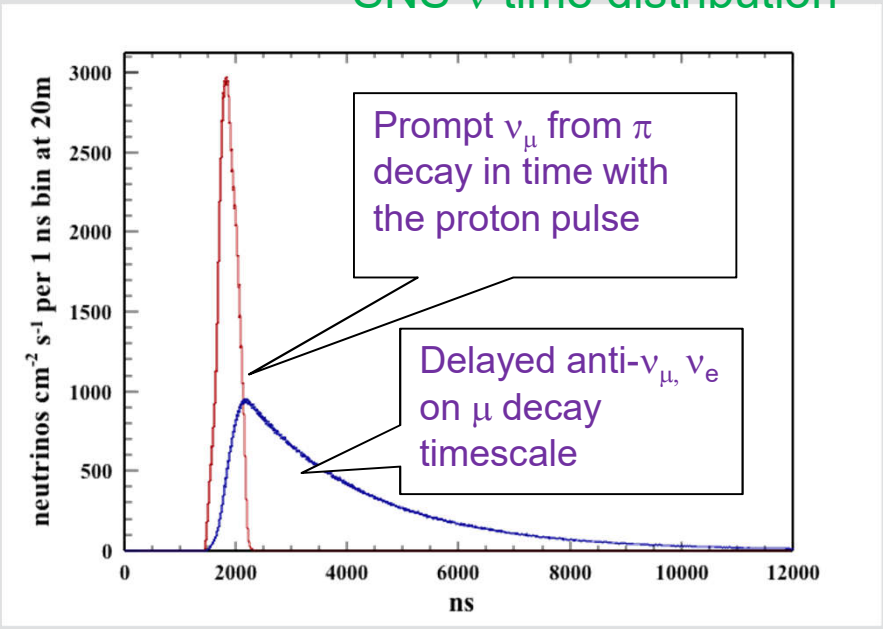
- Low-background area
- near (20-28 m) SNS target with
- 1.4MW, 5000MW/yr, 1.5E23POT/yr,
- pulsed 1GeV proton beam




SNS ν energy spectrum

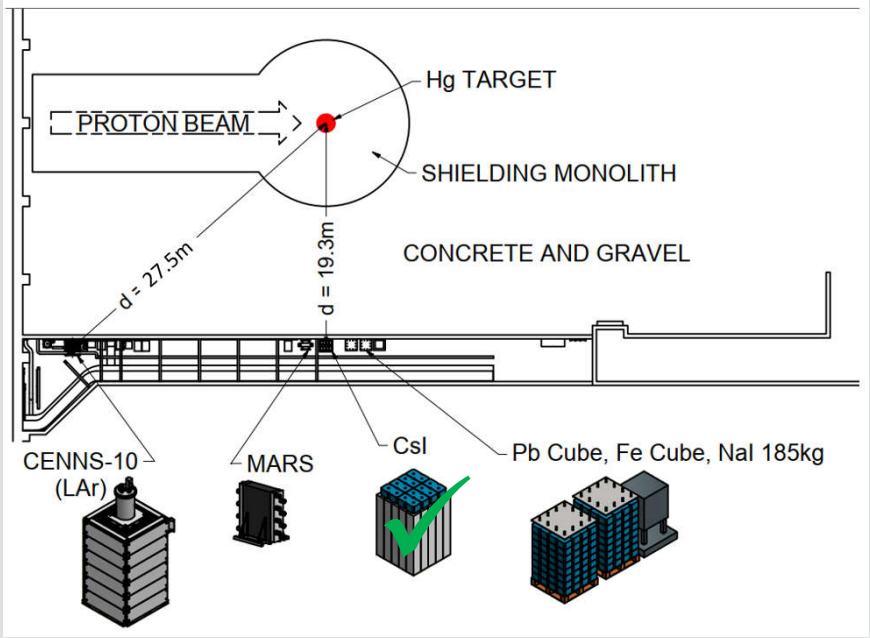


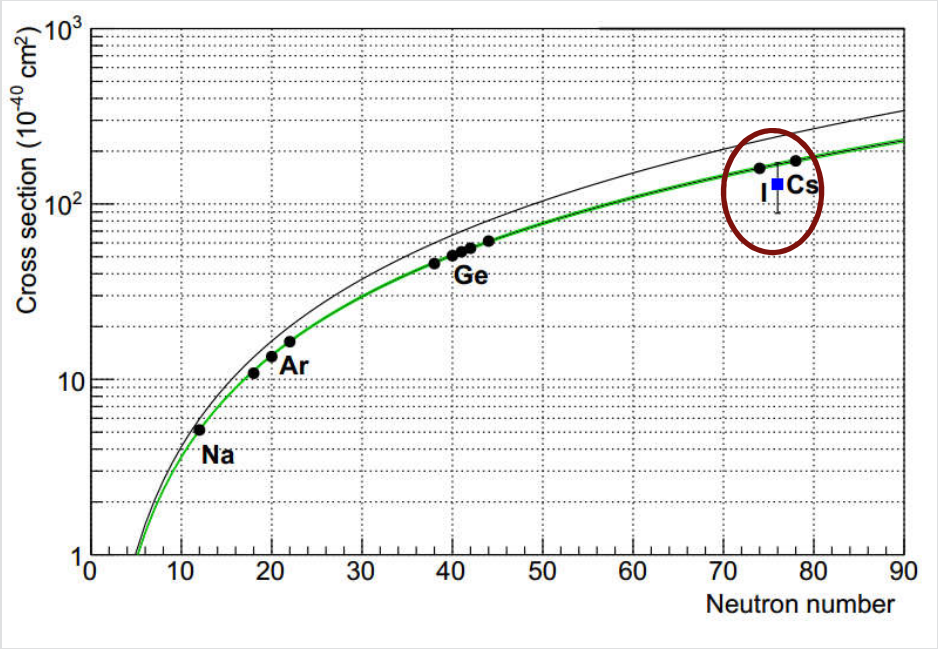

SNS ν time distribution

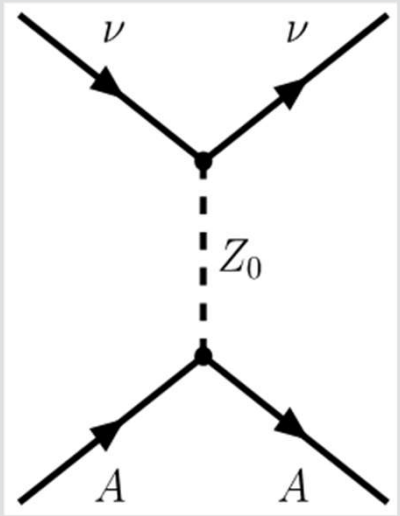


# COHERENT experiment in SNS ν-alley

First detection of CEvNS with CsI ✓

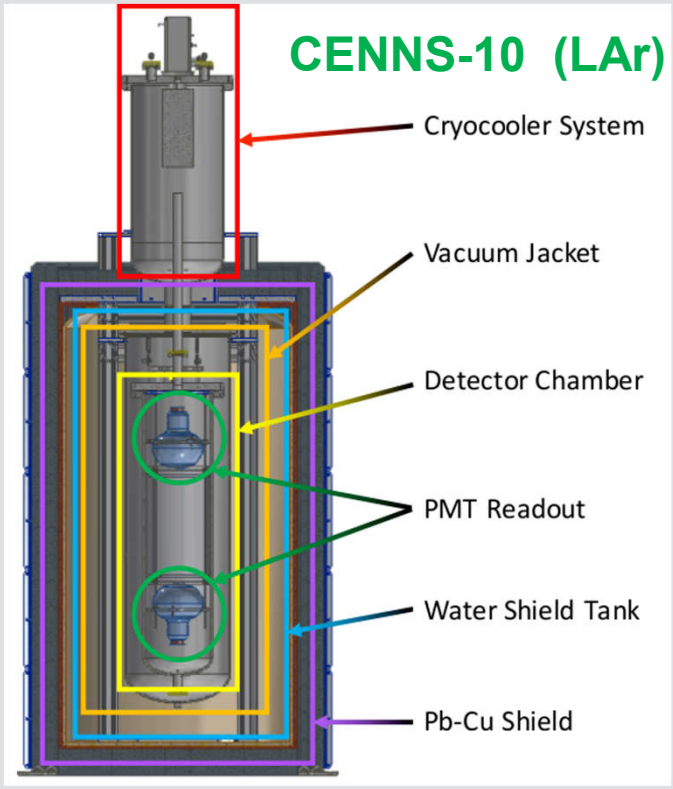


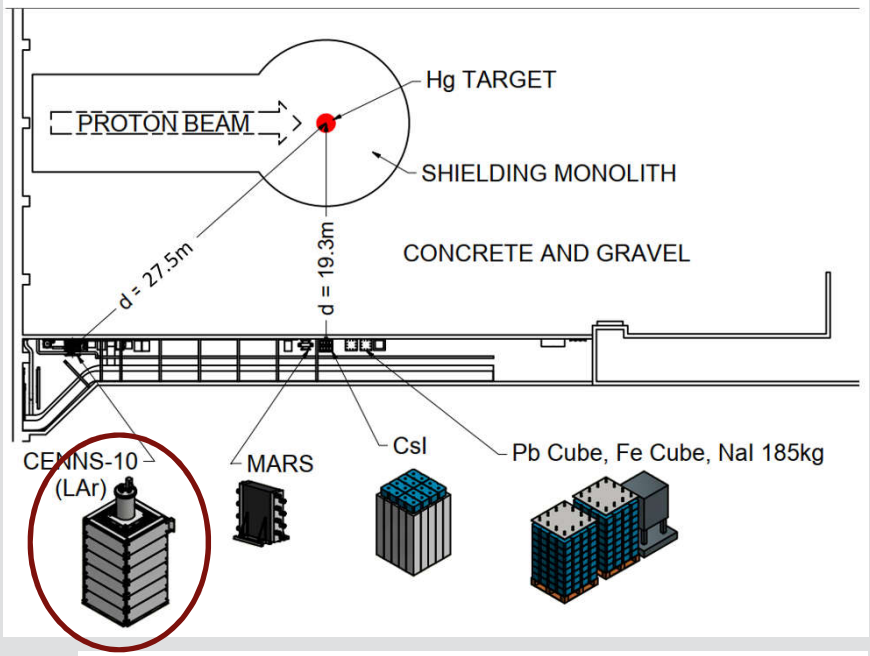



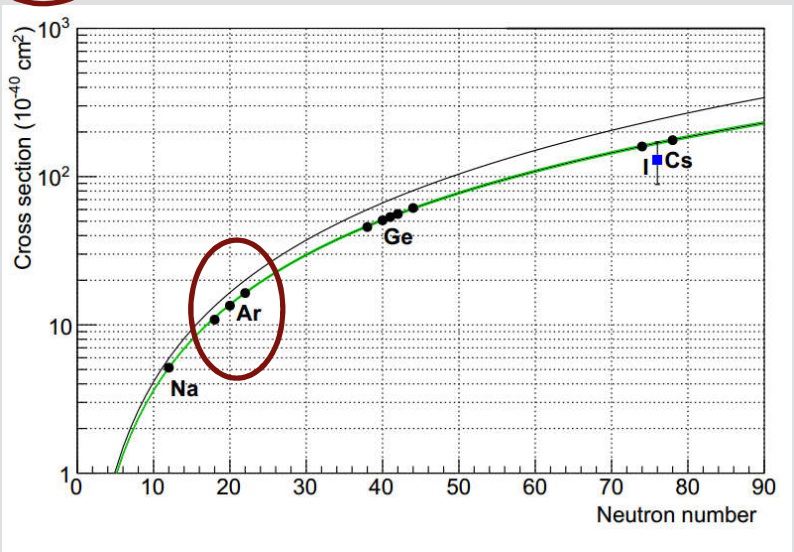




# COHERENT experiment in SNS ν-alley

CENNS-10 (LAr), currently running, to demonstrate $N^2$ dependence of CEvNS



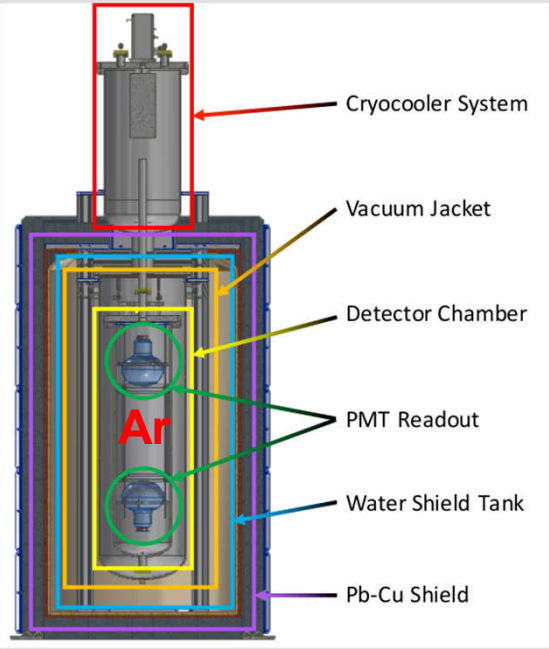



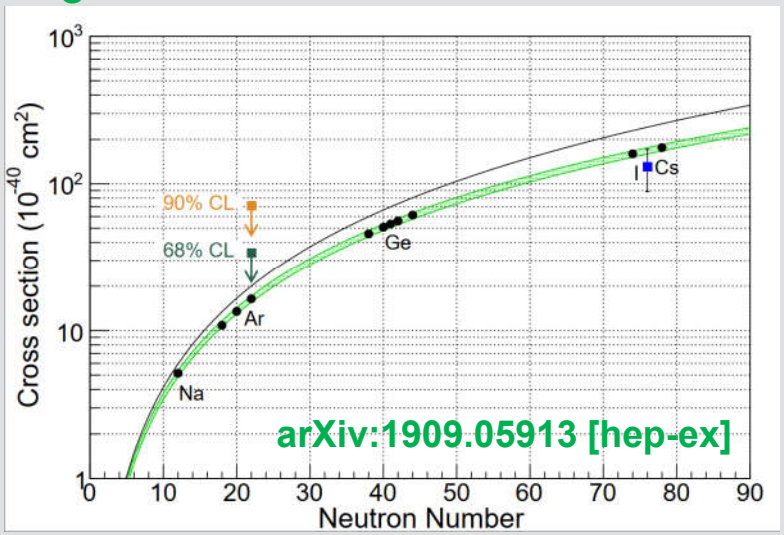
## The CENNS-10 (LAr) Detector:

**Specs:**

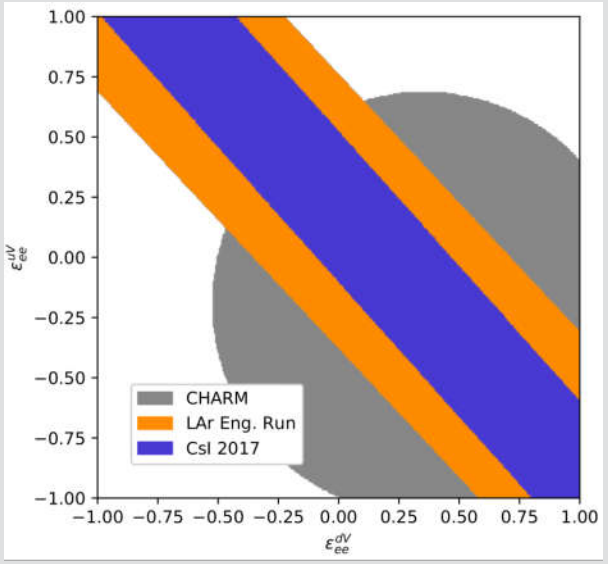
- Built at FNAL, moved to ORNL Fall 16
- 22 kg LAr fiducial volume
- 27.5m from Hg target
- 2 × Hamamatsu 8”PMTs
- TPB-coated PMTs/teflon side walls
- Energy threshold ≈ 20keVnr
- Pb/Cu/H2O shield
- Running in current configuration since 7/17
- Expect ≈140 CEvNS events/SNS-year




## Eng. run CEvNS cross section limits




## corresponding NSI regions

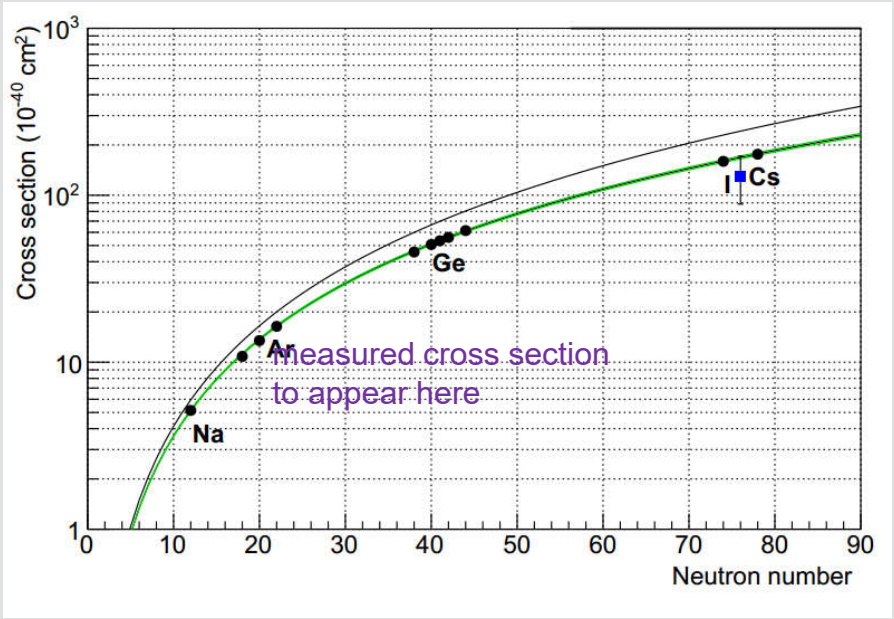


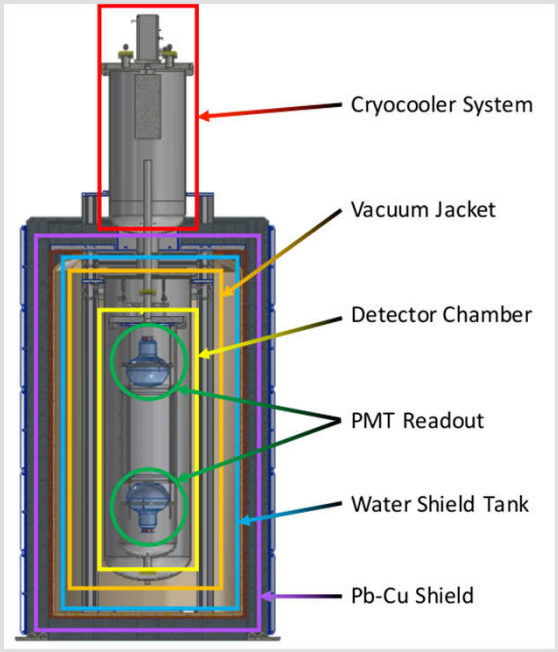

credit: Gleb Sinev, Duke

## CENNS-10 Production run:

## Production runs, 6.1GWhr:

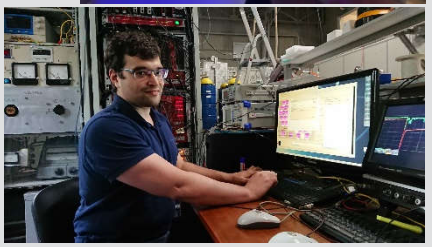
- light yield improved to ~4.5 PE/keV
- Particle ID (PSD), energy resolution/threshold sufficient for observation of CEvNS in $^{40}$Ar
- SM prediction ~150 CEvNS events in this data set
- analyses in end stages, results soon!




Indiana U, Phd Student:
Jacob Zettlemoyer

ITEP/MEPHI (Moscow), Phd Students:
Dmitry Rudik, Alex Kumpan,

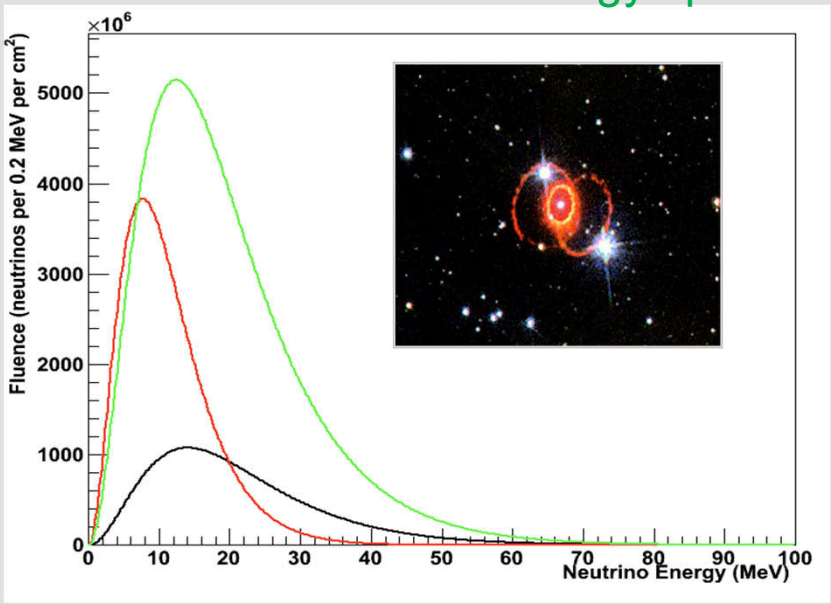


## COHERENT future, next steps

### Physics reach of CEvNS:

- Understanding supernovae (SN):
  - Expected to be important in core-collapse SN and
  - possible SN detection channel.
- Nuclear Physics: nuclear form factors
- Standard Model tests, eg: NSI, $\sin^2\theta_W$, neutrino magnetic moments
- $\nu$ oscillations: Investigation of $\nu_{sterile}$ oscillations
- reactor monitoring (non-proliferation)
- Dark Matter:
  - Important background for O(10-ton) direct searches
  - detectors sensitive for accelerator produced DM.

SN burst $\nu$ energy spectrum



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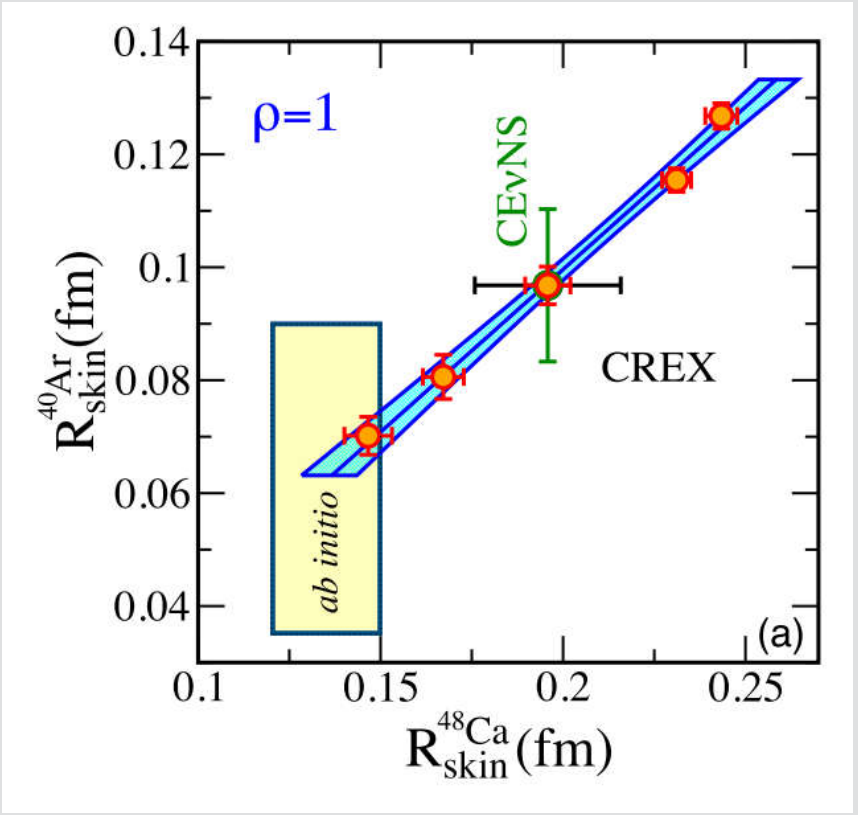

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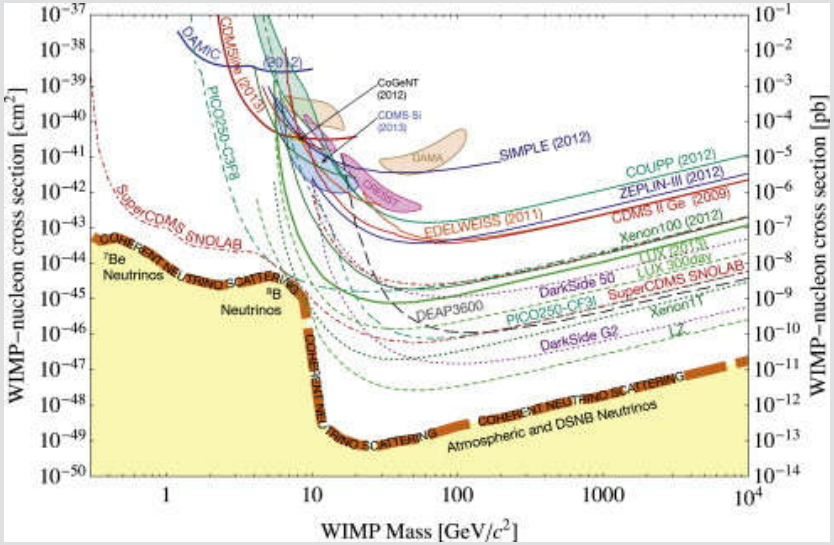


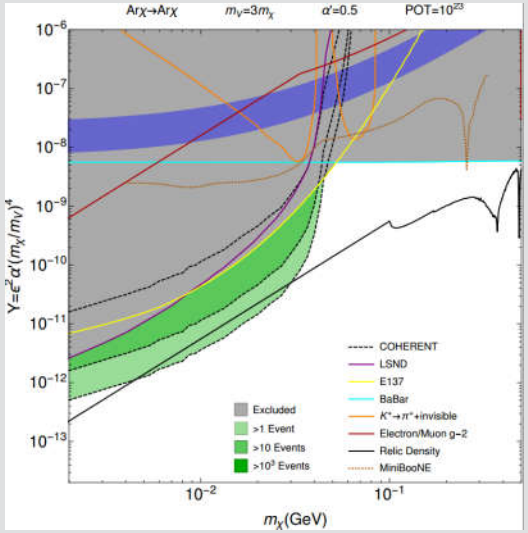


**Light new physics in coherent neutrino-nucleus scattering experiments**


Patrick deNiverville,[1] Maxim Pospelov,[1,2] and Adam Ritz[1]

[1]*Department of Physics and Astronomy, University of Victoria, Victoria, BC V8P 5C2, Canada*
[2]*Perimeter Institute for Theoretical Physics, Waterloo, ON N2J 2W9, Canada*



(Dated: May 2015)

## COHERENT future, next steps

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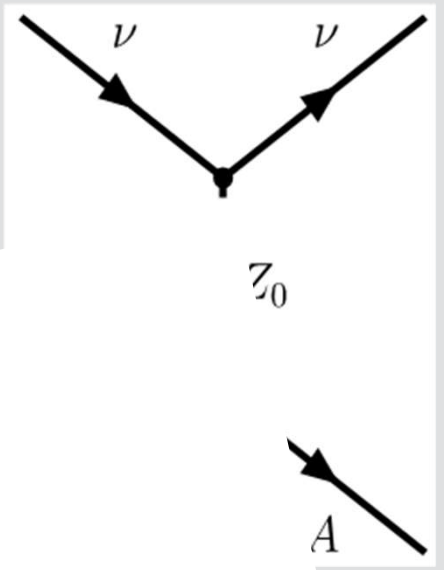
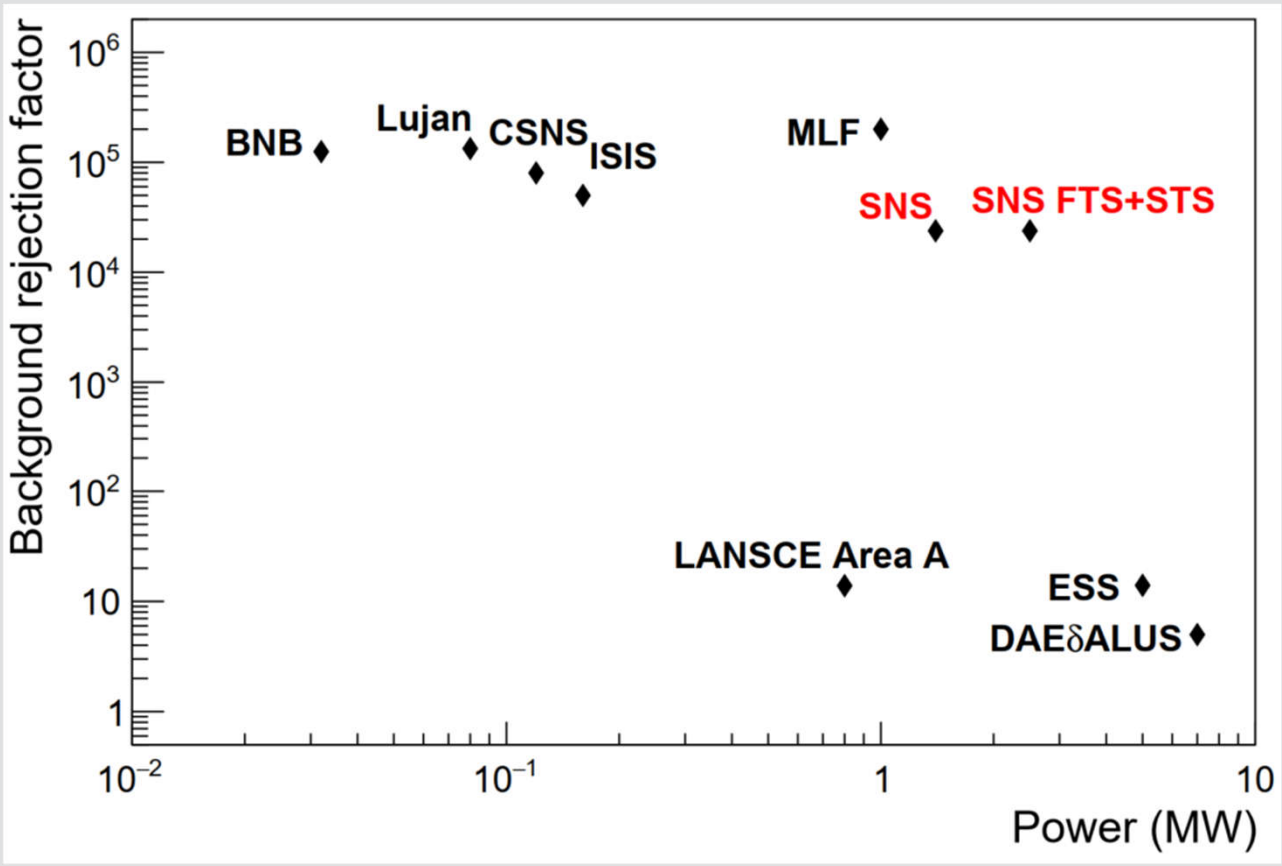



This requires:
- higher event rates via:
  - larger detectors
  - lower thresholds
- reduced errors from backgrounds (both steady-state and beam-related)
- reduced systematics via a measured neutrino flux

for a complete CEvNS physics program.

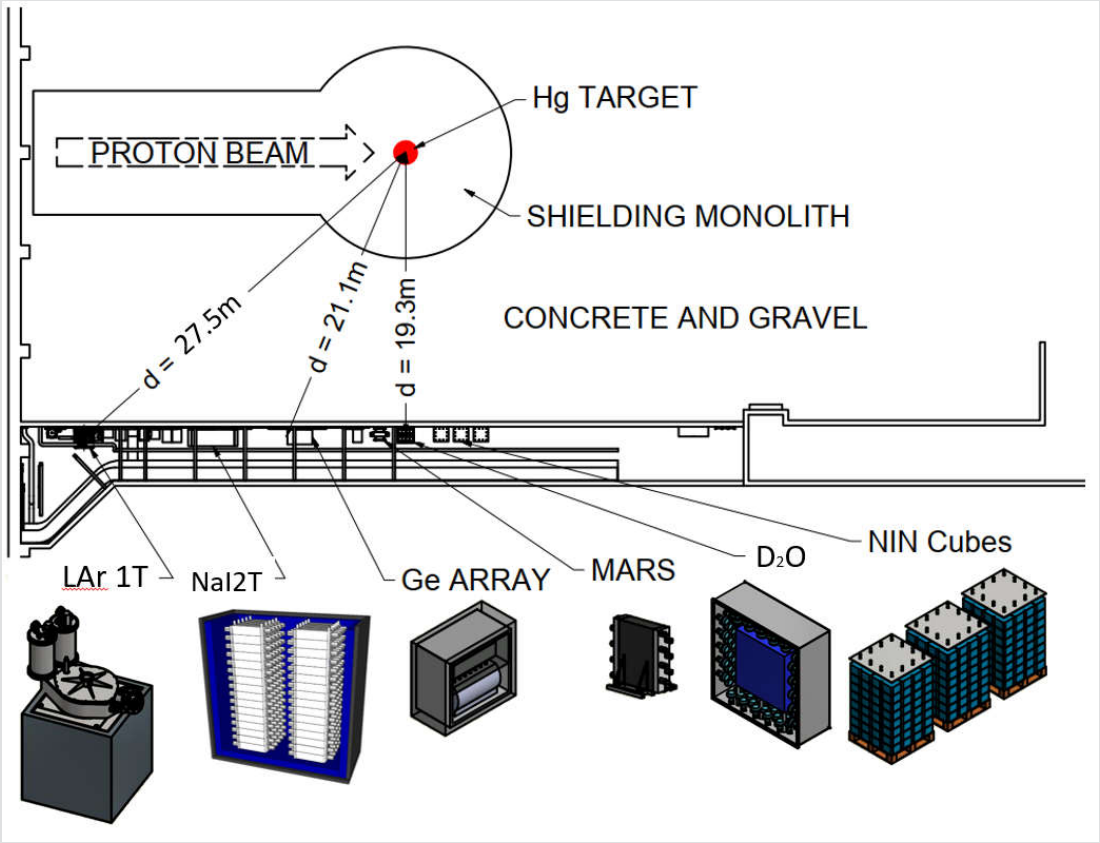
## COHERENT future, next steps

SNS continues to be best existing source for this



## COHERENT future, in $\nu$-alley

- 16kg Ge array
- multi-ton NaI
- $D_2O$ for flux normalization
- also NIN cubes
- neutron background measurements
- ton-scale LAr (CENNS-750)



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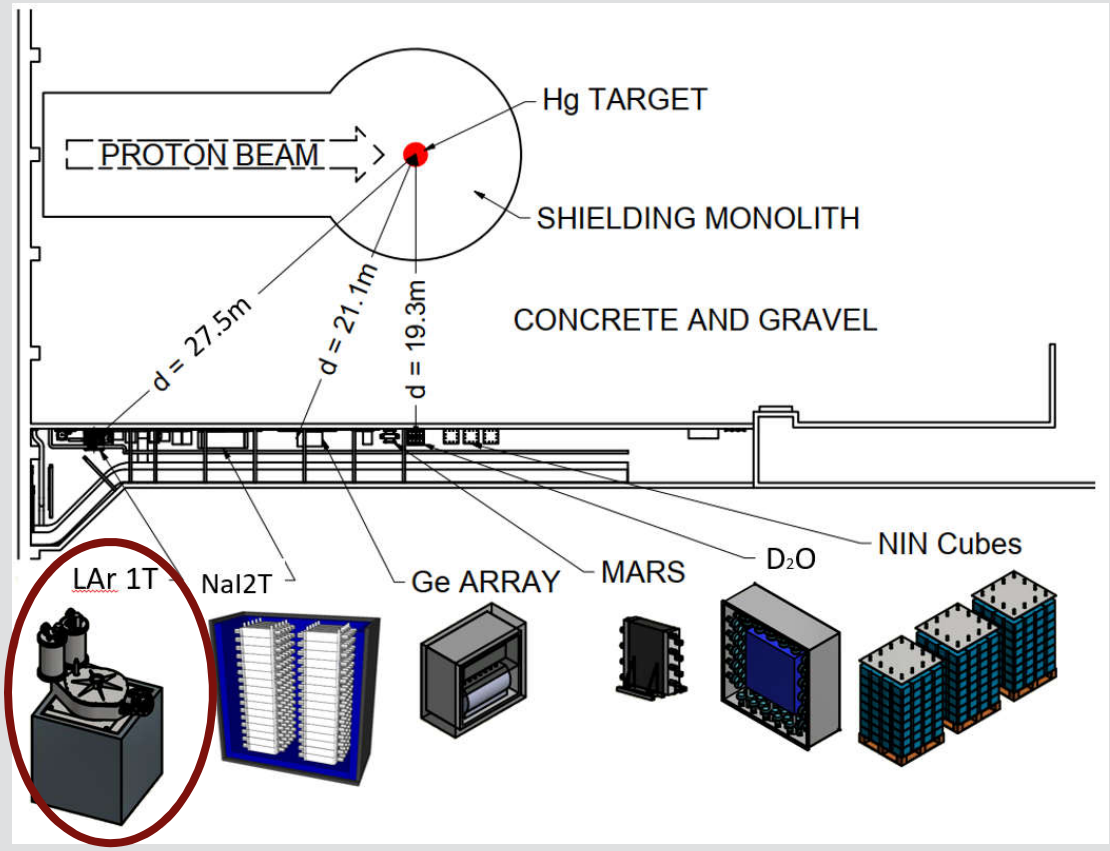
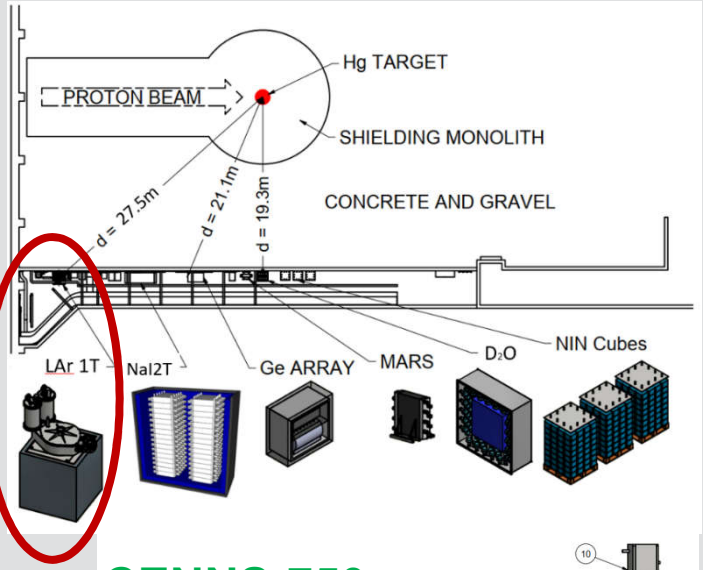


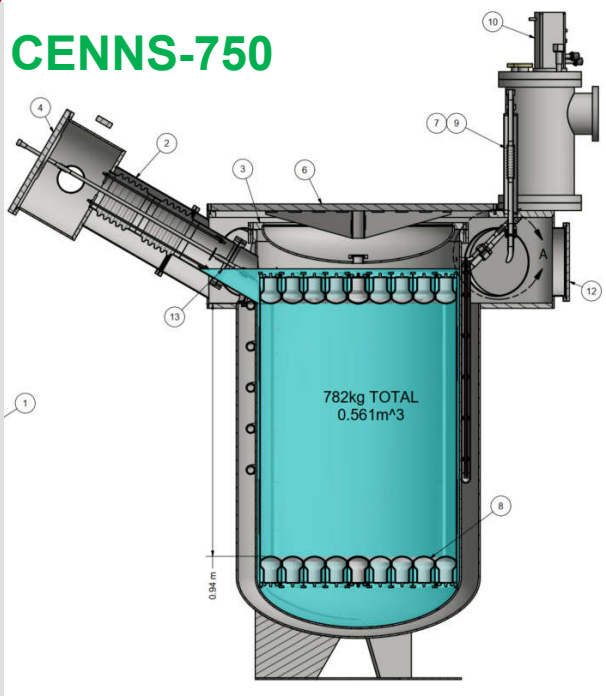
# COHERENT future, large LAr detector

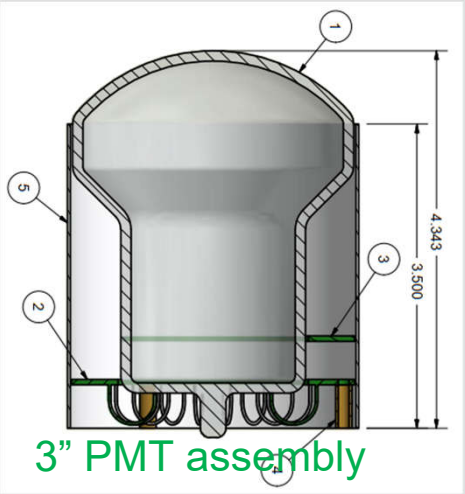
## CENNS-750:

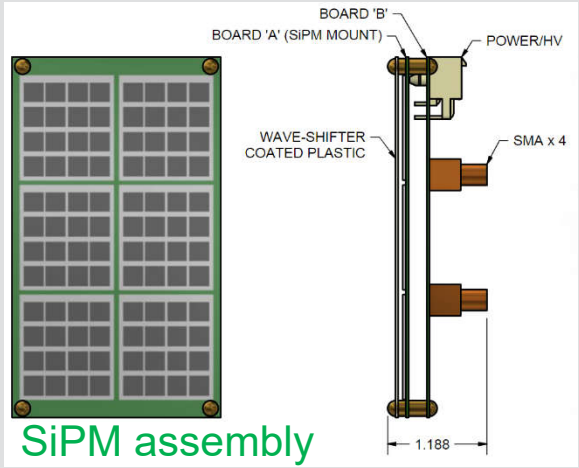
- Based on our experience with CENNS-10 detector, running since 2017.
- Single-phase LAr (scintillation-only) calorimeter, 750/**610kg** total/**fiducial**
- Purpose-designed cryostat w/LN2 precool, and dual cryocooler for liquification/gas purification.
- Light collection: 3”PMTs or VUV/VIS SiPMs w/optimal WLS scheme
- Eventual use of underground (low $^{39}$Ar) argon.

- $\Rightarrow$ 3000 CEvNS, 440 inelastic CC/NC events/yr !

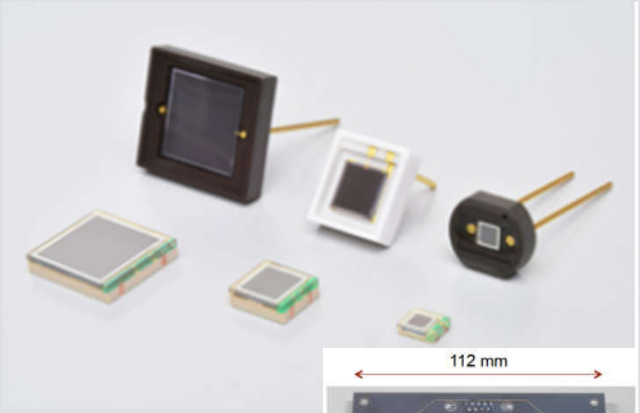


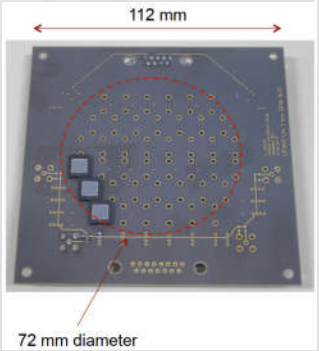



# COHERENT future, large LAr detector

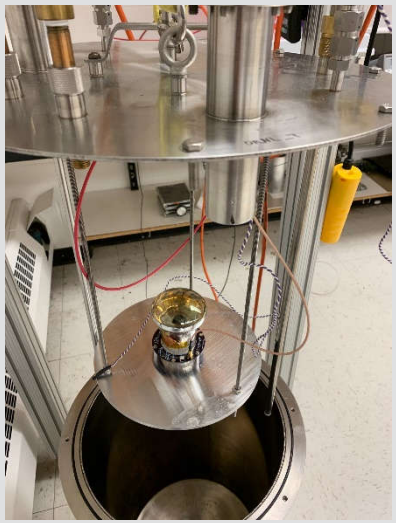


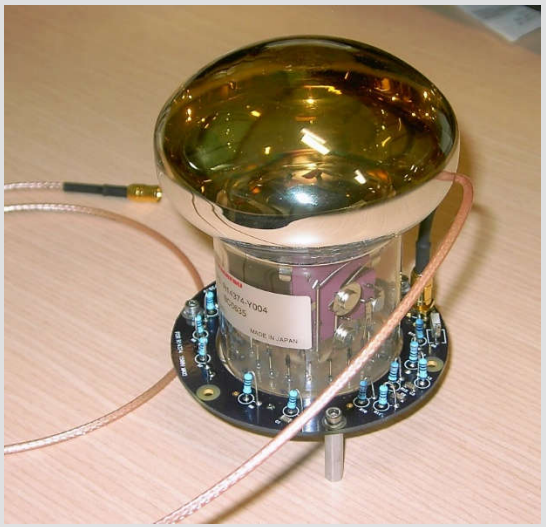



Photodetector/wavelength-shifting optimization:

- require large efficiency×area over ~1.5 $m^2$ for >4PE/keV, E-threshold<20keVnr
- but also need to consider (efficiency×area)/$$
- options under investigation:
  - SiPMs
    - VUV w/direct Ar light detection
    - VIS w/TPB or LXe-doping
    - will allow very low E threshold with enough $$$
    - expensive, investigating other details
  - 3” PMTs
    - VIS with TPB or other WLS
    - E-threshold <~20keVnr
    - economical fast-track solution

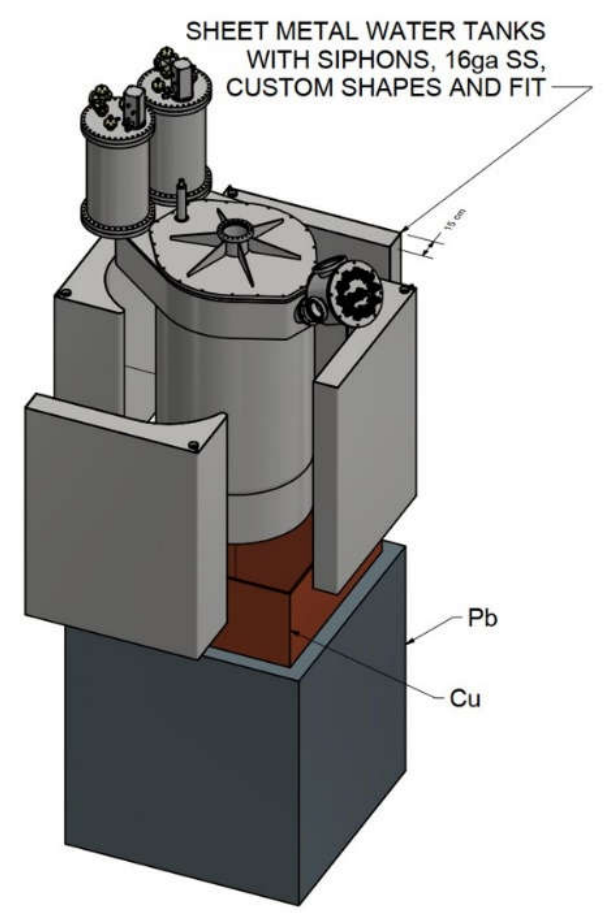
- prototype tests ongoing

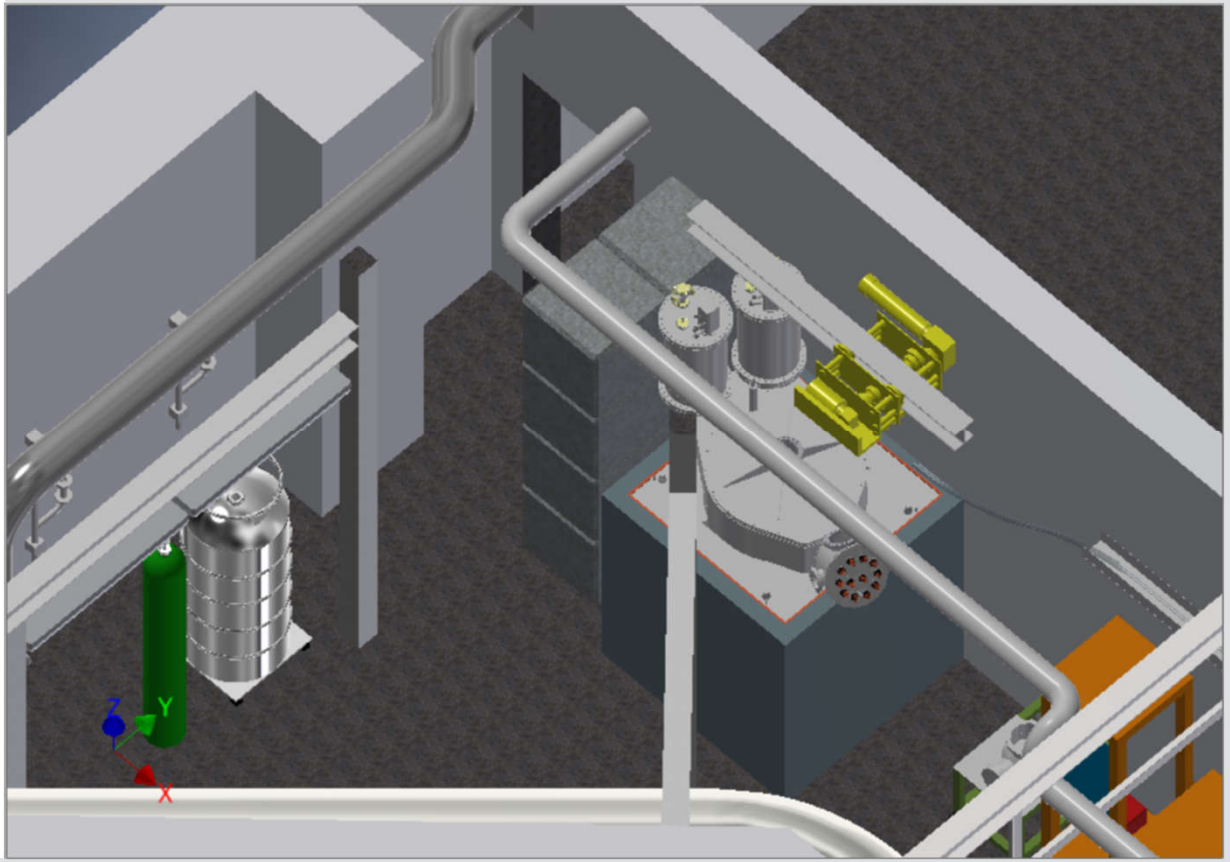




# COHERENT future, large LAr detector

Reduction of beam-related backgrounds (neutrons) via additional shielding

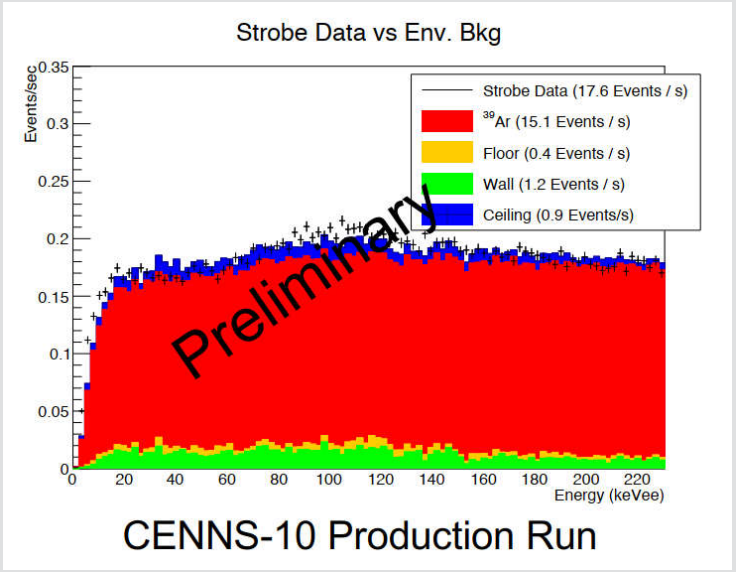


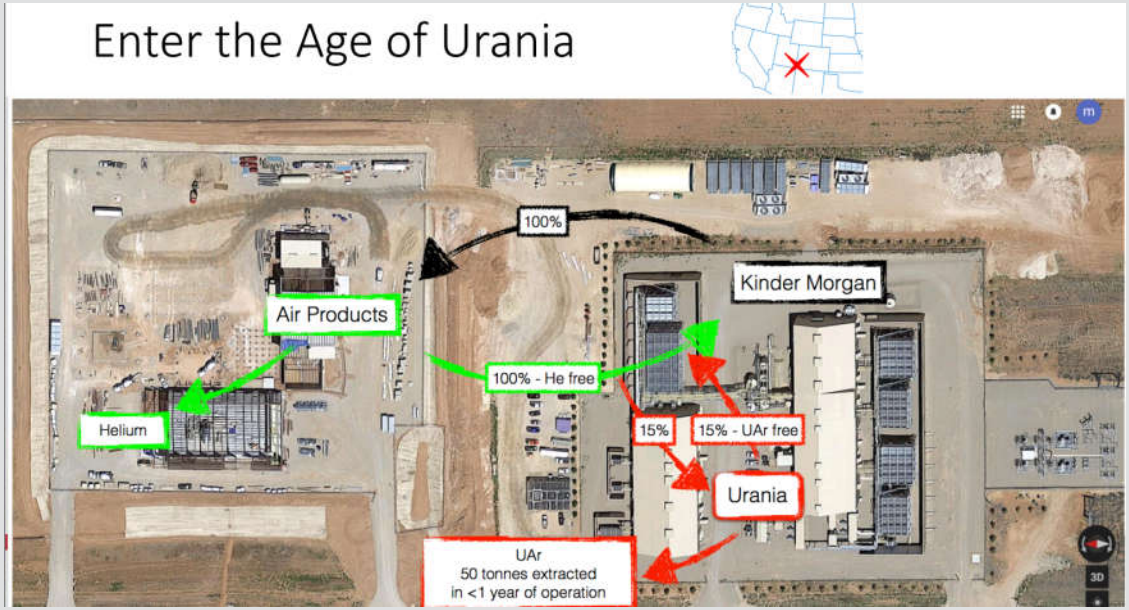



# COHERENT future, large LAr detector

Also desire reduction of beam-unrelated (steady state) backgrounds (mostly Ar-39)

- in current CENNS-10 detector, with "atmospheric" Ar, large beam-unrelated background is from Ar-39
- leads to larger stat errors
- investigating procurement of "underground" Ar, depleted in Ar-39
- EOI in to Urania project about obtaining from Colorado extraction
- estimated reduction of ~100-1000 without further depletion



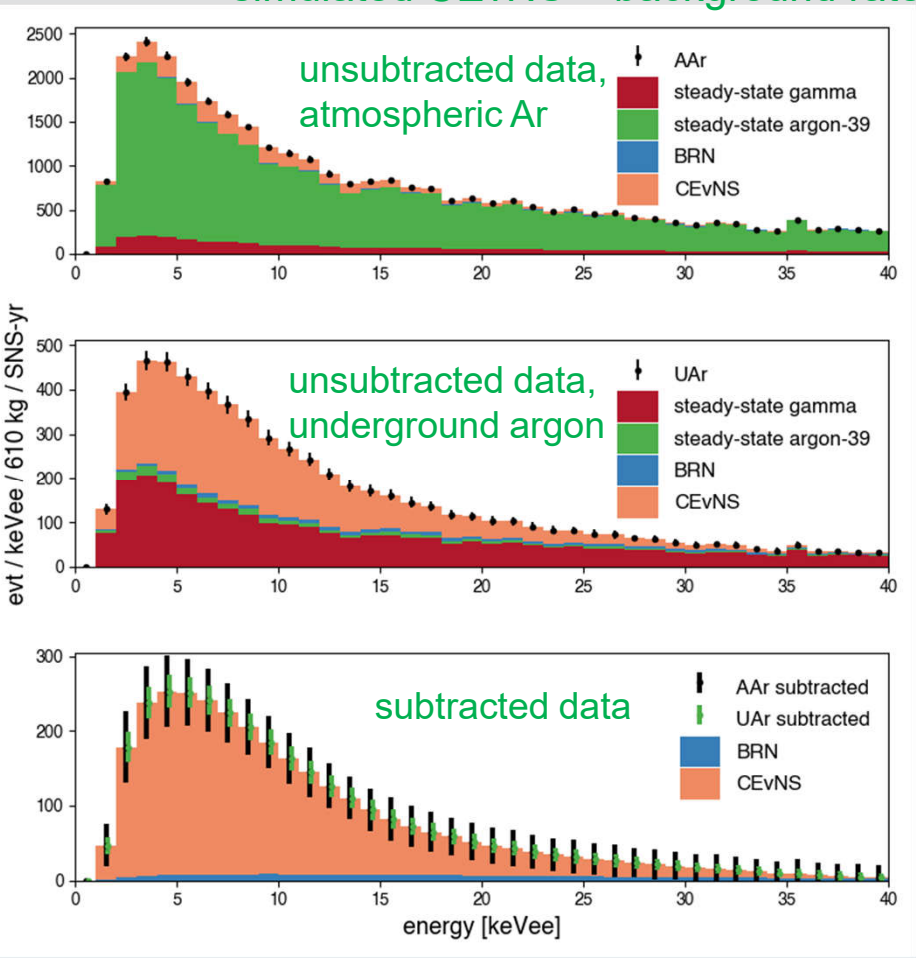

Andrew Renshaw, PNNL

# CENNS-750 LAr detector

event rates in 610kg fiducial LAr detector:

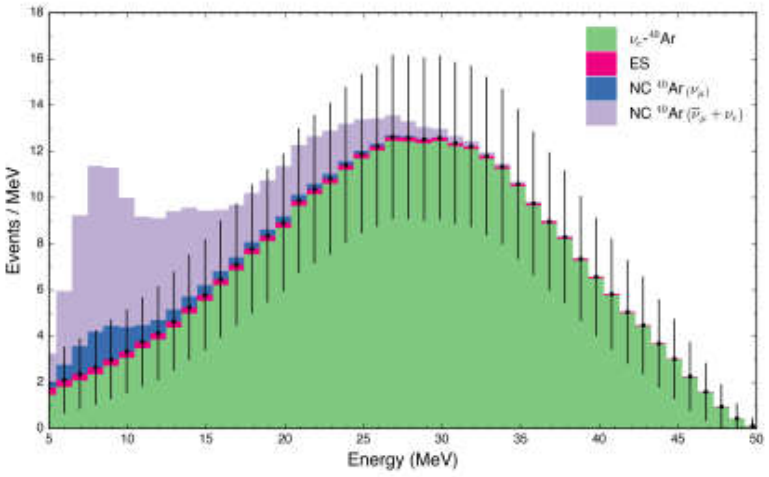
**~3000 CEvNS events/year**

simulated CEvNS + background rates



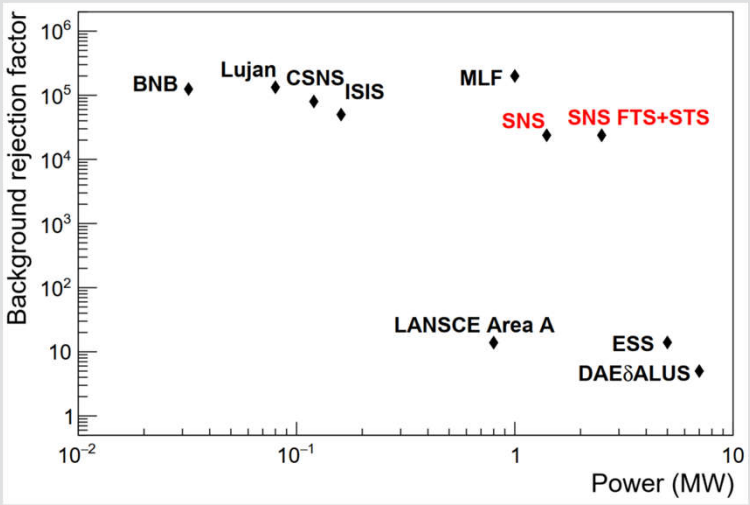

**~440 inelastic CC/NC events/yr**

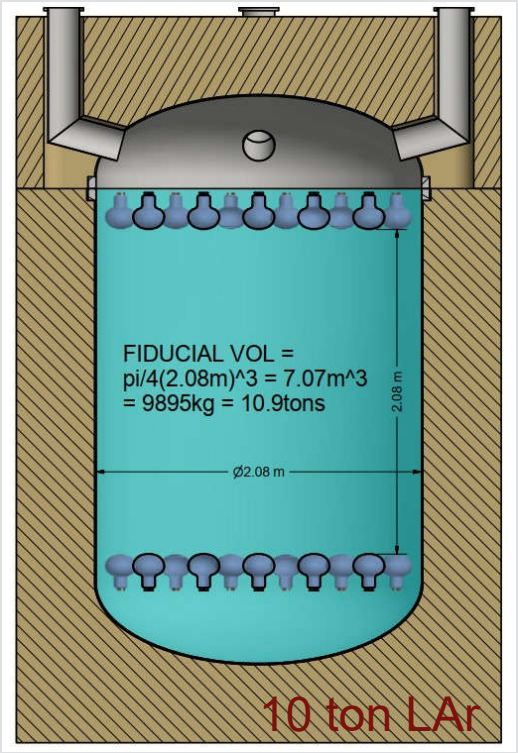
estimated inelastic CC/NC CEvNS rates

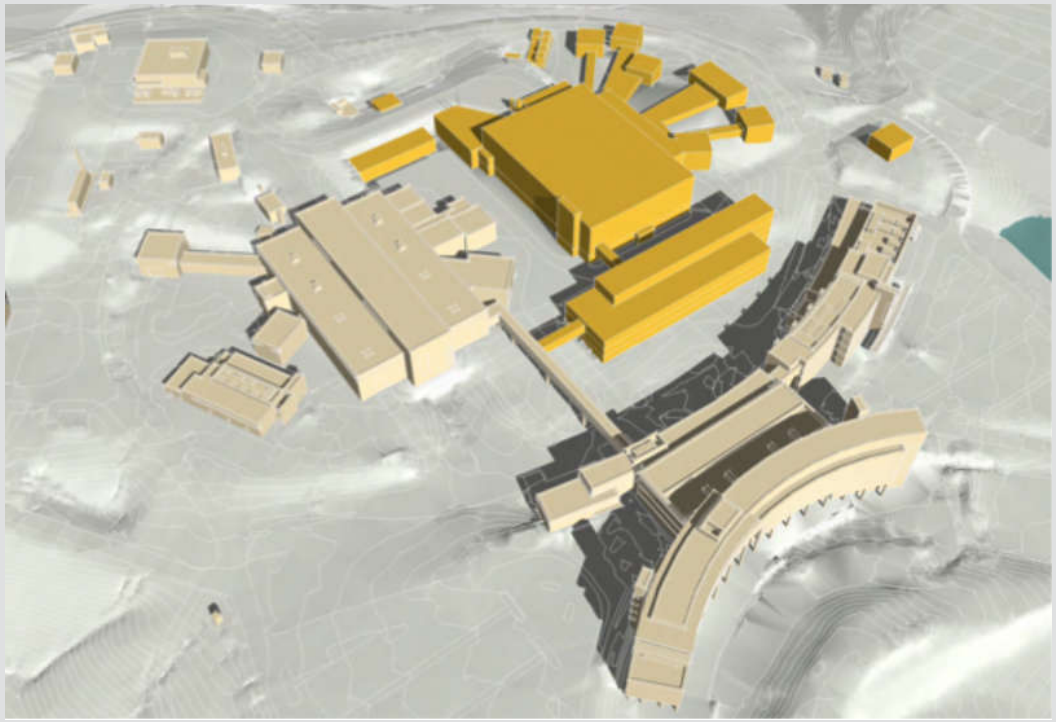


## COHERENT future: LAr beyond ν alley

- SNS second-target station (STS) with dedicated detector hall
  with optimized location and shielding
  would be a world-class ν facility

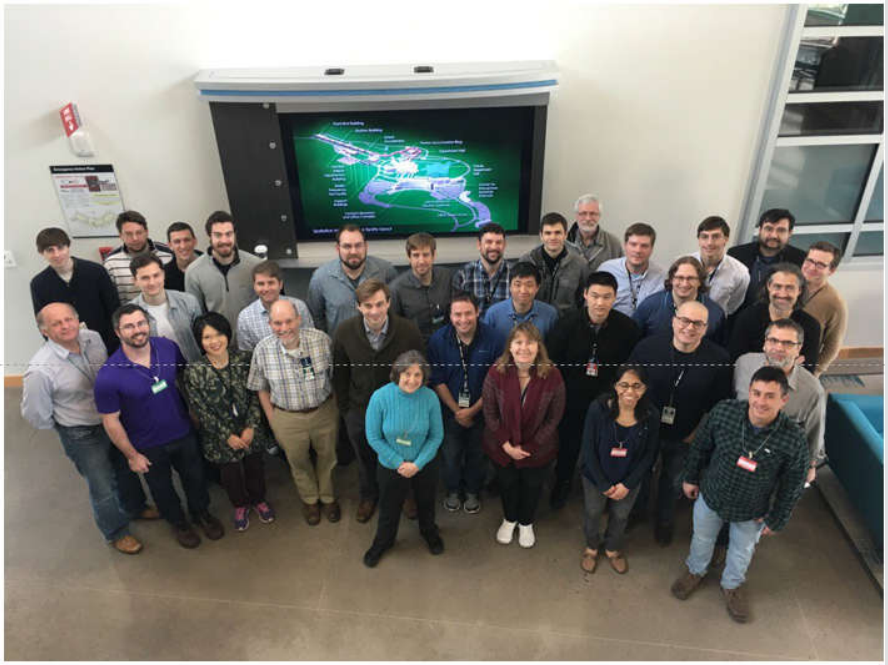


## Summary:

- COHERENT CEvNS program is producing valuable results.
- New results imminent from LAr
- A ton-scale Argon detector will deliver addition important data to field.
- Thanks to COHERENT collaboration!



https://coherent.ornl.gov arXiv:1803.09183v2

CNEC Consortium for Nonproliferation Enabling Capabilities KICP NNSA National Nuclear Security Administration NSF U.S. DEPARTMENT OF ENERGY

COHERENT SNS Spallation Neutron Source

Oak Ridge National Laboratory · Duke University · TUNL · Sandia National Laboratories · The University of Tennessee Knoxville · Los Alamos National Laboratory Est. 1943 · NC State University · University of Washington · The University of Chicago · NM State · MEPhI · UF University of Florida The Foundation for The Gator Nation · KAIST · North Carolina Central University Founded 1910 · Tufts University · VT · Carnegie Mellon University · Laurentian University Université Laurentienne

# backups

# Tonne-scale LAr detector

Quenching factors:

- some spread in data sets, but most recent from ARIS, SCENE have constrained LAr QF fairly well.
- we have fit all data sets simultaneously 0-125keV to linear function, with correlated errors for MicroClean

$$\chi^2(\lambda) = \sum_{i,j=1}^{n} (y_i - \lambda)(V_{ij}^{-1})(y_j - \lambda)$$

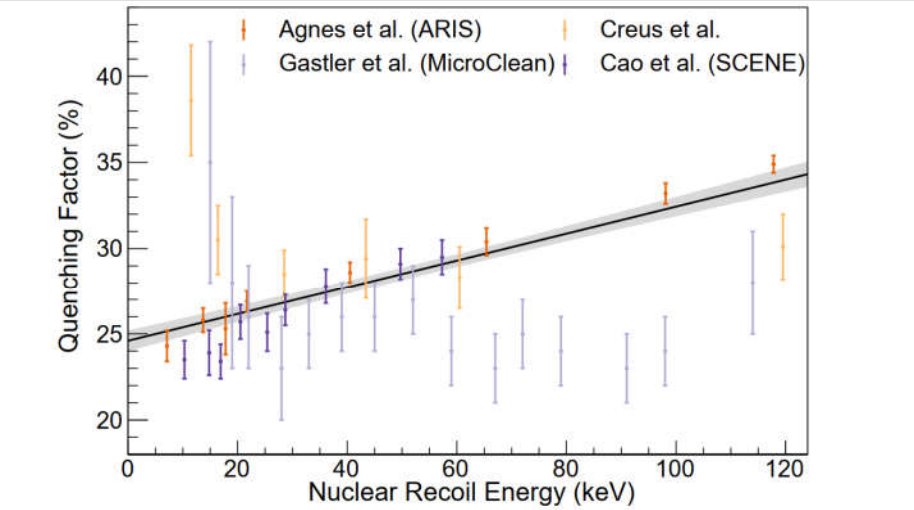



Figure 4: Quenching factor fit resulting from fit#2 in Table 3 with an error band constructed with a overall error scaling to yield $\chi^2/\mathrm{DOF} \approx 1$.

- result:
  - $\chi^2$/dof~4
  - scaled all errors to get $\chi^2$/dof~1 (x 2) as per PDG prescription
  - ~2% error on QF , ~1% error on predicted CEvNS rate (for CENNS-10, with Ethres~20keVnr)
- not anticipated to be limiting error for ton-scale LAr