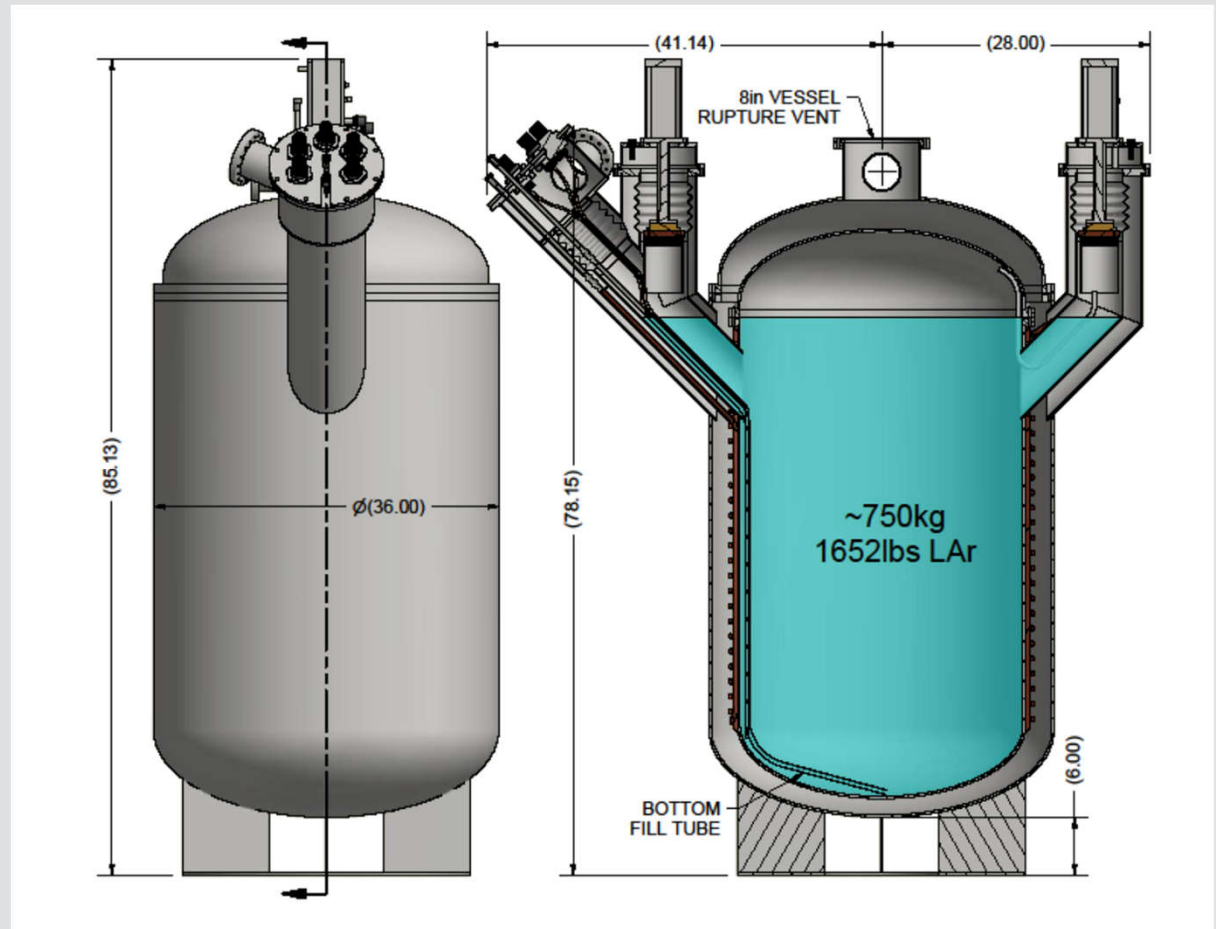


Tonne-scale Liquid Argon Detector for COHERENT

R. Tayloe
Indiana U.

Outline:

- Physics
- CENNS-10 detector
- O(1-ton) detector
- Cost/Schedule



Tonne-scale LAr physics topics

A large LAr detector at SNS neutrino alley will enable a far reaching physics program.

	CsI	Ar	NaI	Ge	Nubes	D ₂ O
Non-standard-interactions/new mediators	✓	✓	✓	✓		
Weak mixing angle measurement	✓	✓	✓	✓		
Neutrino magnetic moment				✓		
Nuclear form factors	✓	✓	✓	✓		
Accelerator-produced DM	✓	✓	✓	✓		
Sterile oscillations	✓	✓	✓	✓		
Inelastic CC/NC xscn for supernova		✓			✓	✓
Inelastic CC/NC xscn for weak coupling parameters		✓	✓		✓	

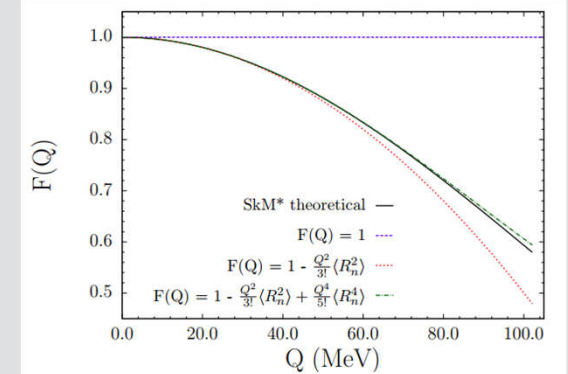
n-radius with O(1-ton) LAr detector

Weak (neutron) radius of nucleus:

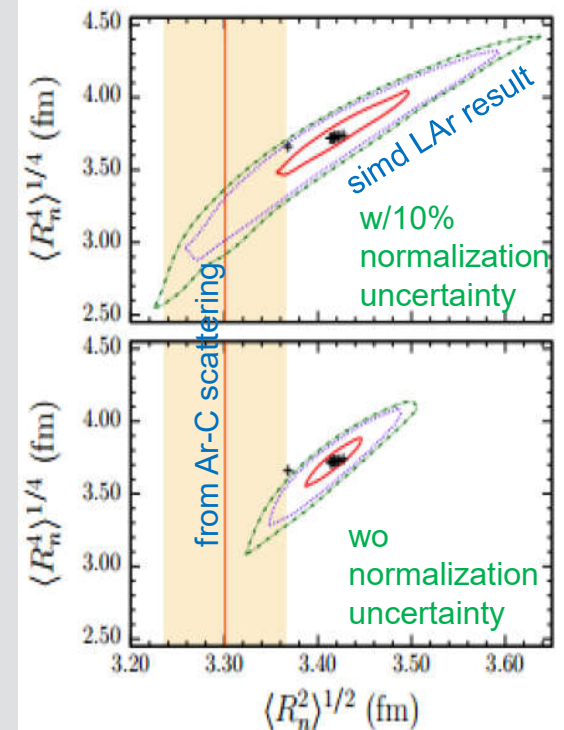
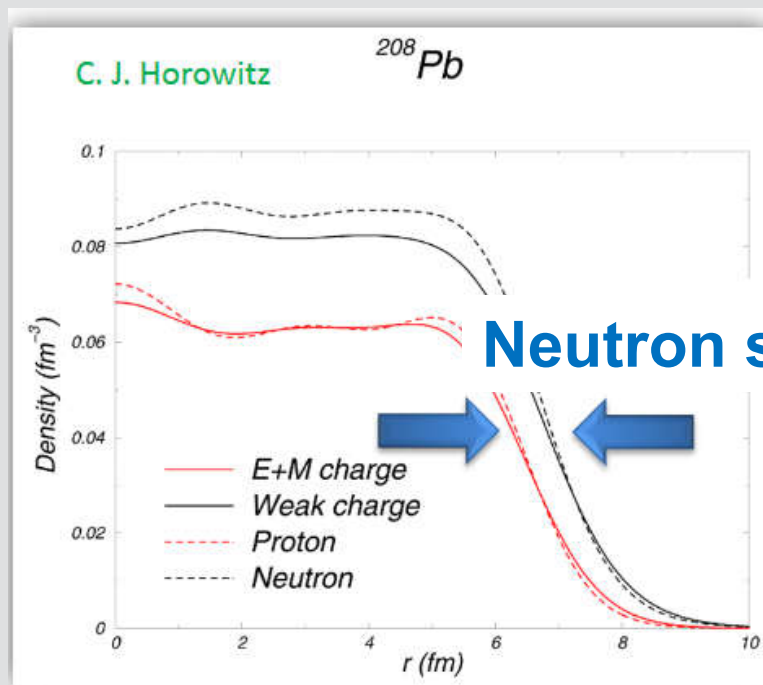
- accessible via Q dependence of nuclear form factors

$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{2\pi} \frac{Q_W^2}{4} F^2(Q) \left(2 - \frac{MT}{E_\nu^2} \right)$$

- Need spectral shape to determine $F(Q)$ moments
- need few % systematics
- complementary to PV e-scattering measurements (eg: PREX/CREX at JLab)

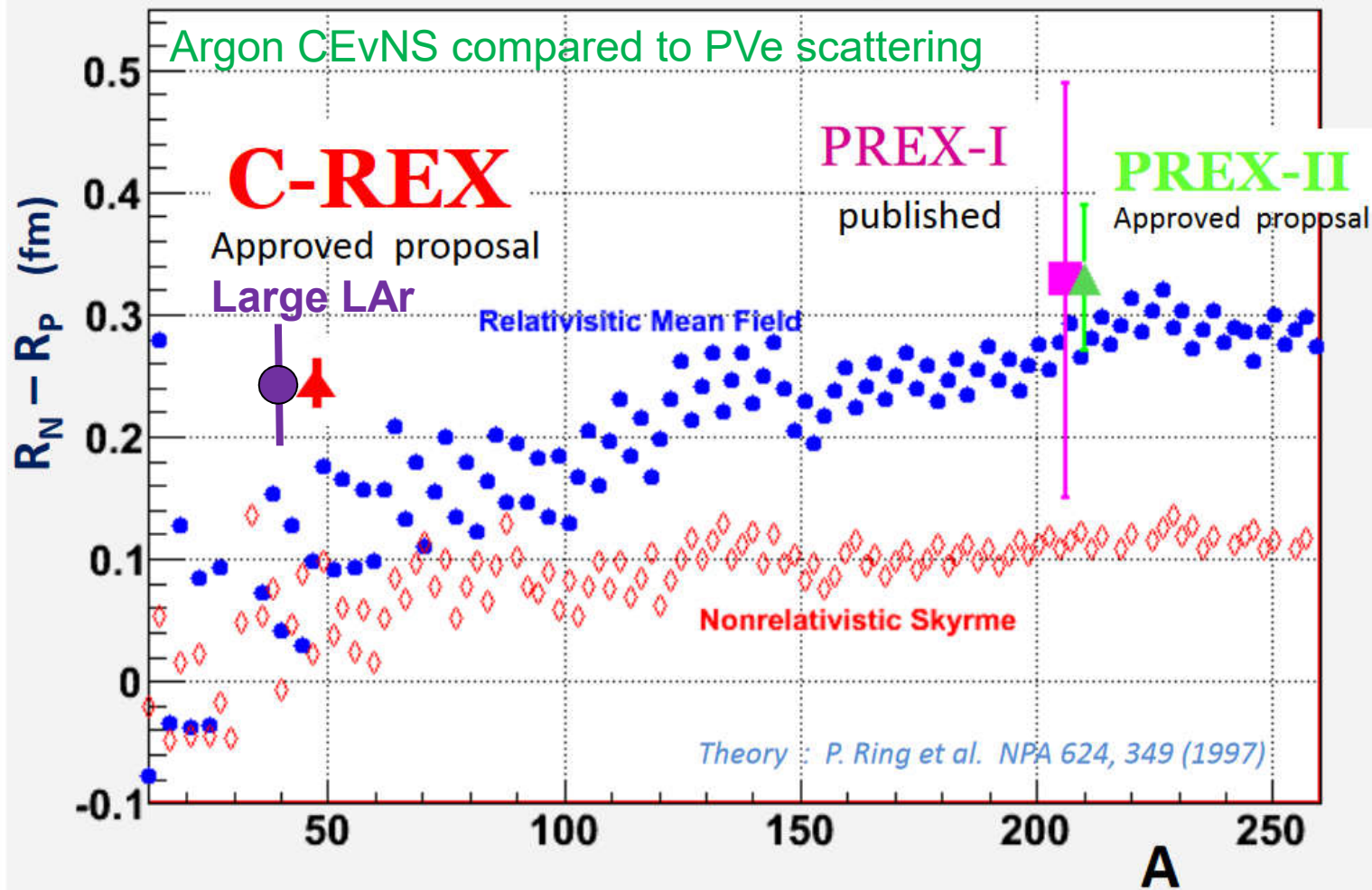


P. S. Amanik and G. C. McLaughlin,
J. Phys. G 36:015105;
K. Patton et al, Phys. Rev. C86, 024612 (2012)



n-radius with O(1-ton) LAr detector

Neutron Skin vs Mass Number A



accelerator-produced DM with O(1-ton) LAr detector

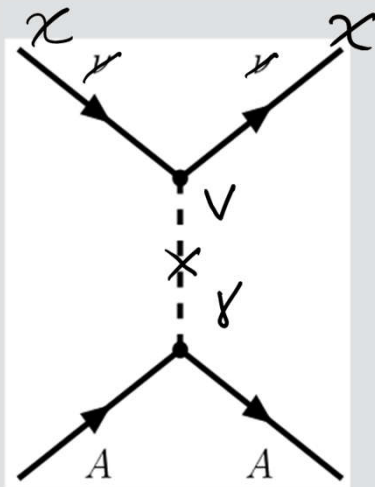
(Not CEvNS, but event signature is same)

Search for accelerator-produced,
low-mass, dark matter

Via:

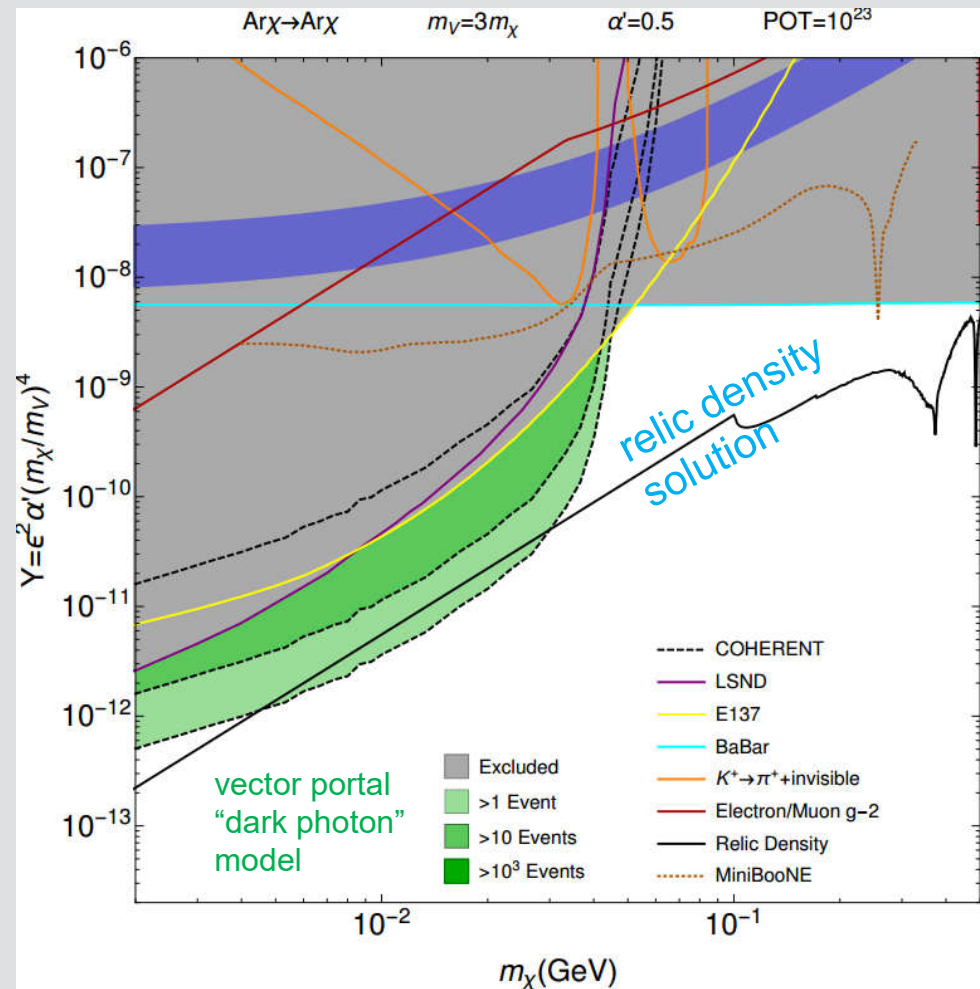
$$p \rightarrow Hg \rightarrow \pi^{0,\pm}$$

$$\pi^0 \rightarrow \gamma + V^{(*)} \rightarrow \gamma + \chi^\dagger + \chi$$



Addresses P5 rec:
Search for DM particles with diversity
of project sizes

1 ton-year LAr
SNS DM sensitivity



CC/NC physics in O(1-ton) LAr detector

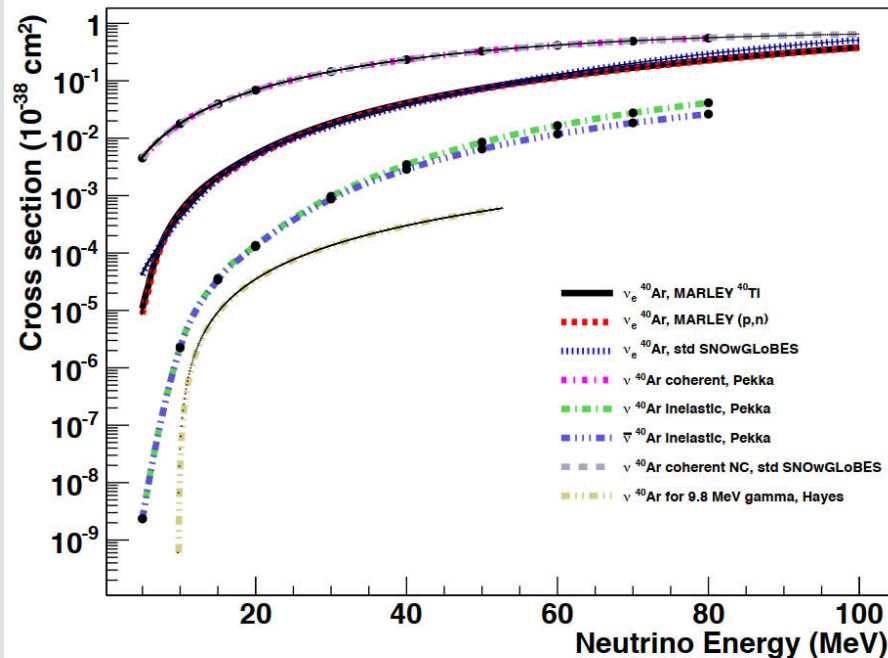
Strong motivation for measuring CC, NC interactions in large LAr detector at SNS:

- supernovae and calibration of DUNE

Challenging:

- event rates are $\sim \times 10$ -100 lower than CEvNS
- containment/reconstruction of CC electrons needs further work

CEvNS/CC/NC cross sections

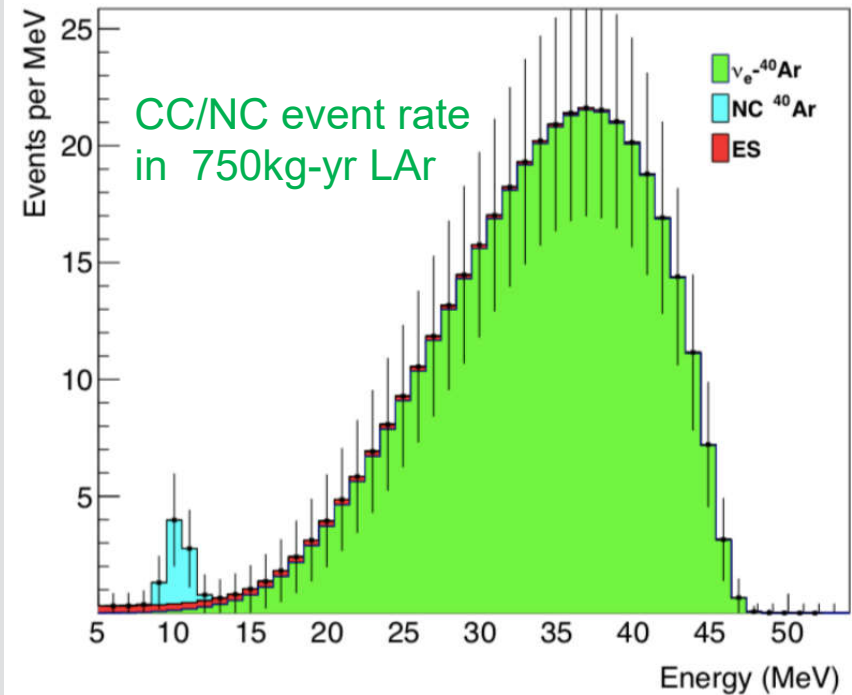
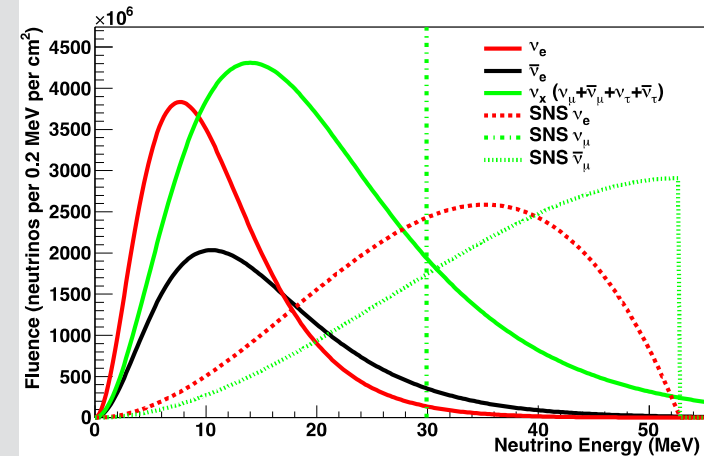


Plot by AJ Roeth

8/15/18

R. Tayloe, COHERENT CAMEL REVIEW

SN/SNS ν fluxes

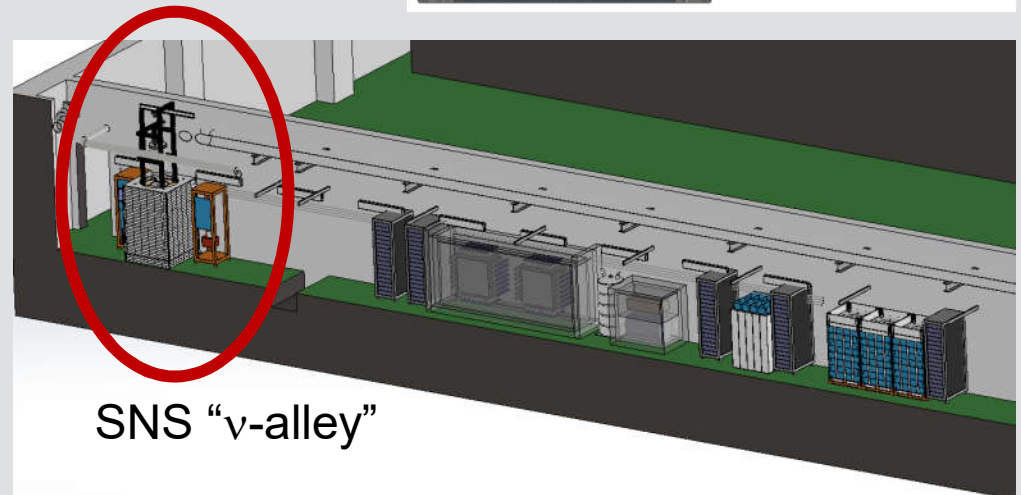
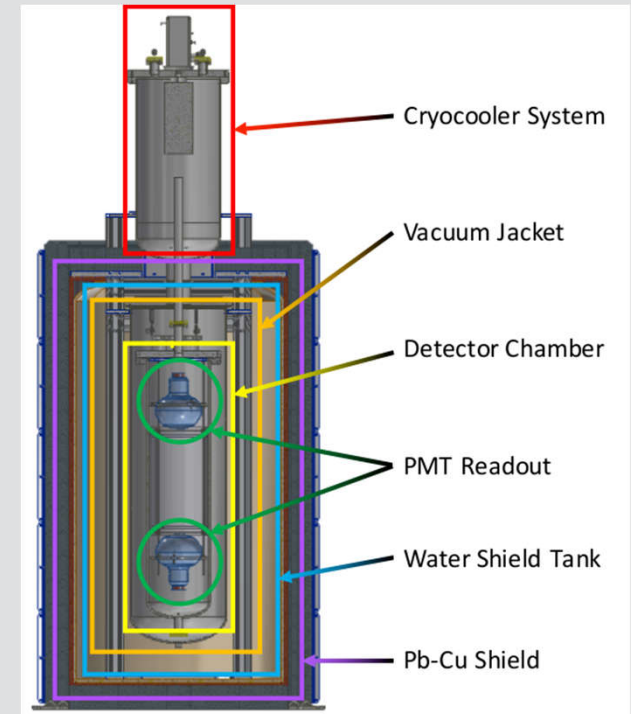


COHERENT LAr: CENNS-10

CENNS-10 detector is currently running at SNS

timeline:

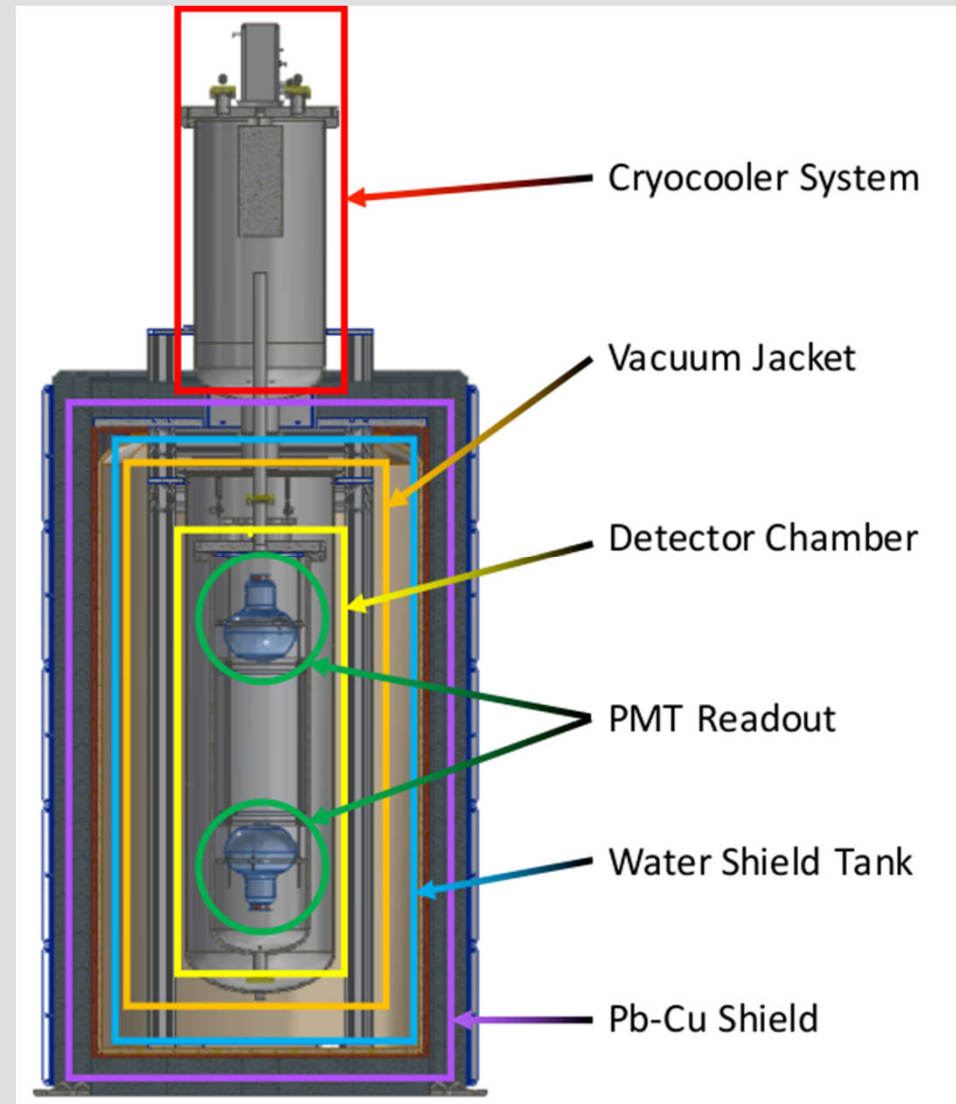
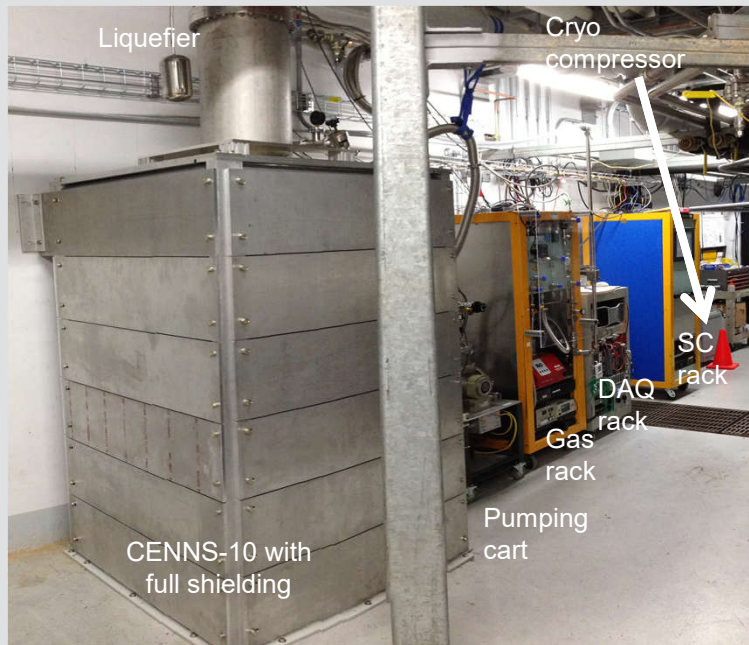
- 2012-15: built at Fermilab for CENNS@Fermilab effort
2015: moved to Indiana U. for commissioning, upgrades, neutron tests
- 10-12/2016: (re)build detector/shielding at SNS
- 12/16, 3-5/17: run with TPB-acrylic parts, $E_{\text{thresh}} \sim 80 \text{ keVnr}$
“Run00” data: 1.7GW hr collected
CEvNS measurement marginal, will constrain beam-related bckgrds
- 6/17: upgrade: TPB-Teflon reflectors, new TPB-coated PMTs, added 4” Pb shielding
- 7/17-12/17: ran in upgraded mode, $E_{\text{thresh}} \sim 20 \text{ keVnr}$
“Run01” data: 2.8GW hr collected
- “Run02” 5/18-12/18, $\sim 3 \text{ GW hr}$



The CENNS-10 (LAr) Detector:

Specs:

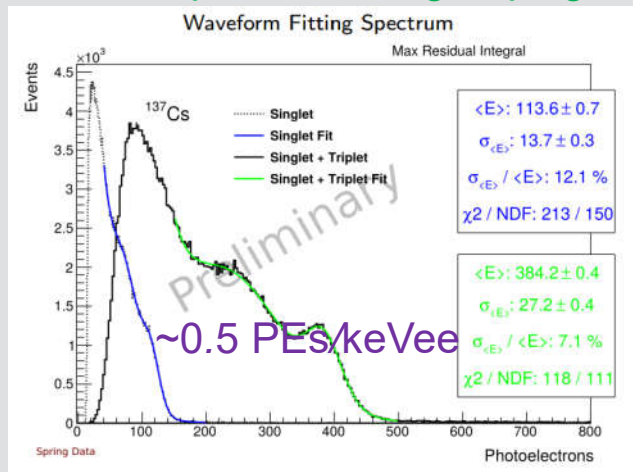
- 22 kg single-phase LAr fiducial volume
- 2 \times Hamamatsu 8" PMTs w/QE=18%@400 nm
- TPB-coated PMTs/teflon side walls
- Energy threshold $\approx 20\text{keVnr}$
- CAEN 1420 (250MHz, 12-bit) digitizer
- 90W single-stage pulse-tube cold head
- SAES MonoTorr gas purifier for ~ 1 ppm purity
- Pb/Cu/H₂O shield
- Expect ~ 140 CEvNS events/SNS-year
- Running in current configuration since July '17



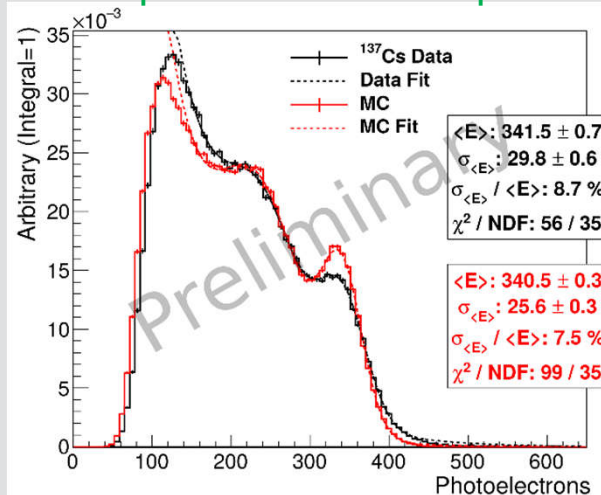
COHERENT LAr: CENNS-10

Preliminary Run00 data

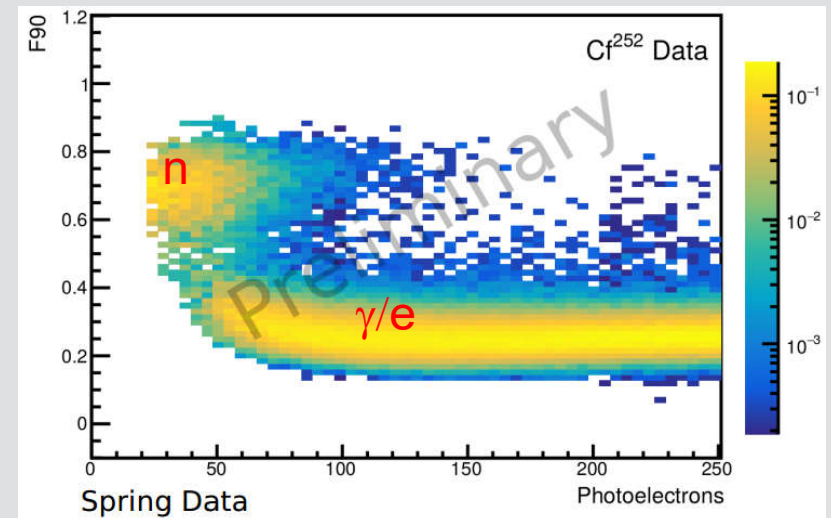
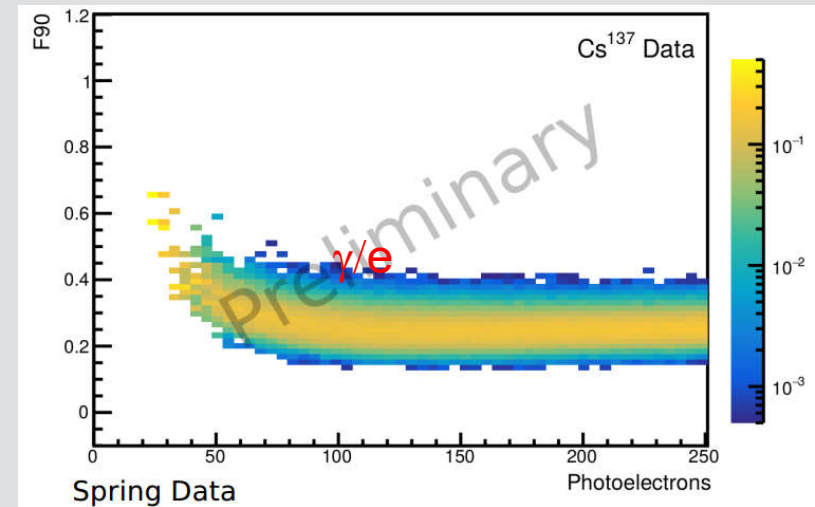
^{137}Cs spectrum: sing+trip light



^{137}Cs spectrum: MC comparison



Particle ID

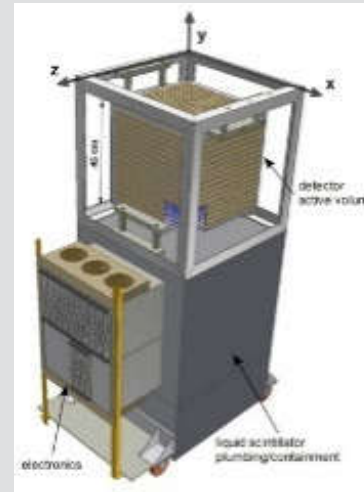


CENNS-10

Run00 data

Run00 data has lower light output (0.5PE/keV), so low sensitivity for CEvNS,
however minimal shielding configs
allow beam-related (BR) neutron measurements

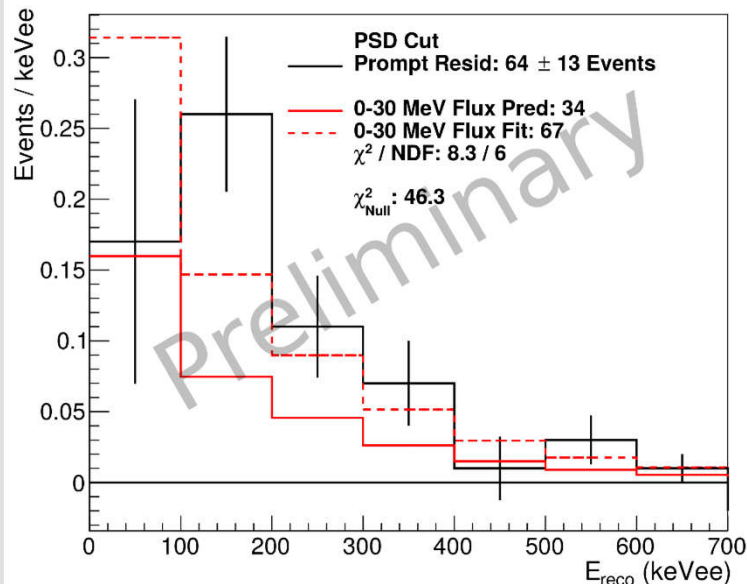
Expect ~10 (10) CENvS (BR-neutron) events in
Run00 data... results soon.



SciBath neutron
meas. @ SNS



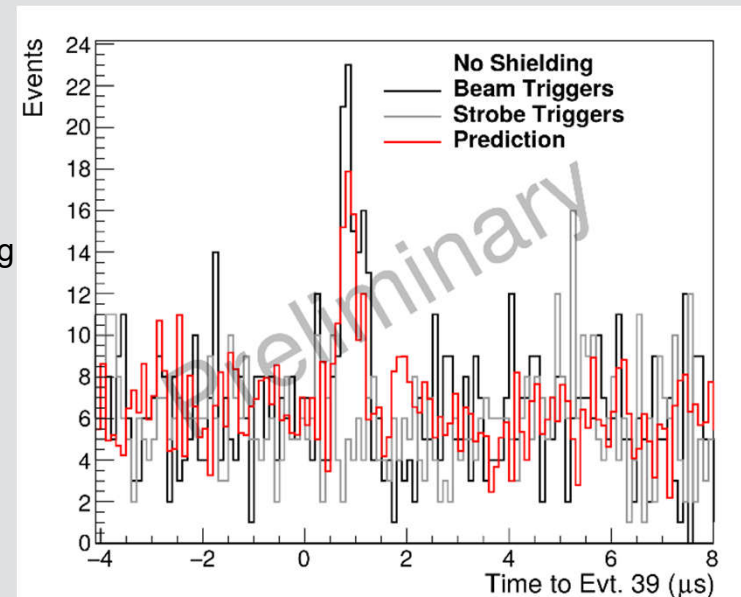
neutron candidate energy



Strobe =
Beam-unrelated
bkgd

Predition = SciBath
Meas + simulation
of CENNS-10 config

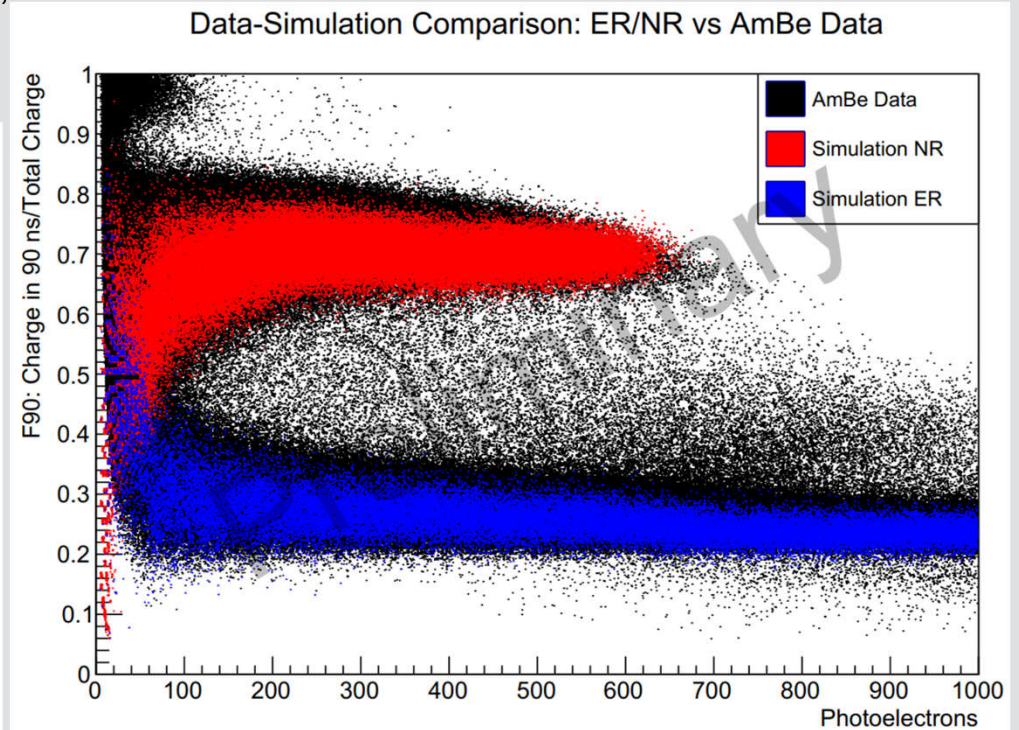
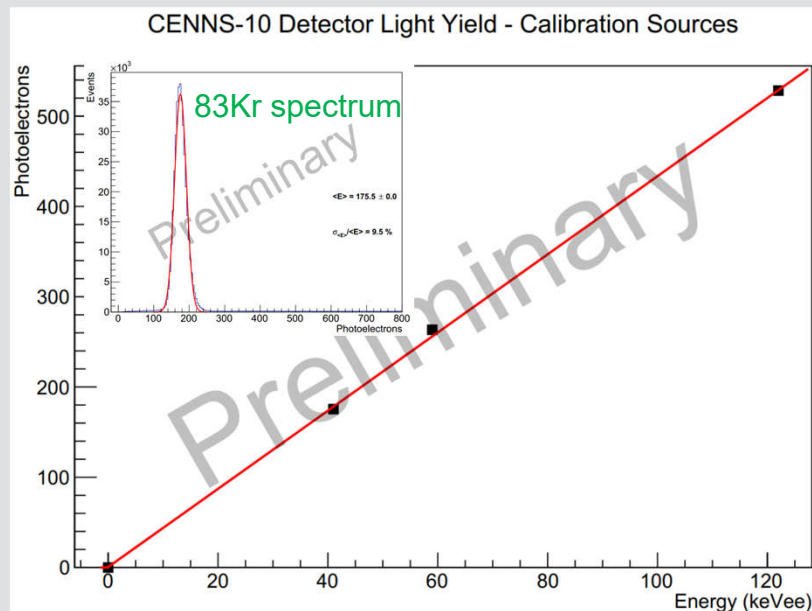
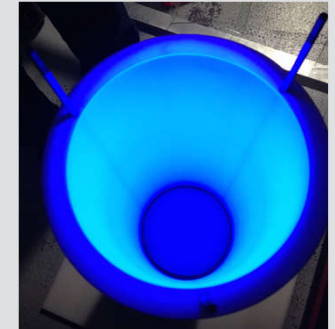
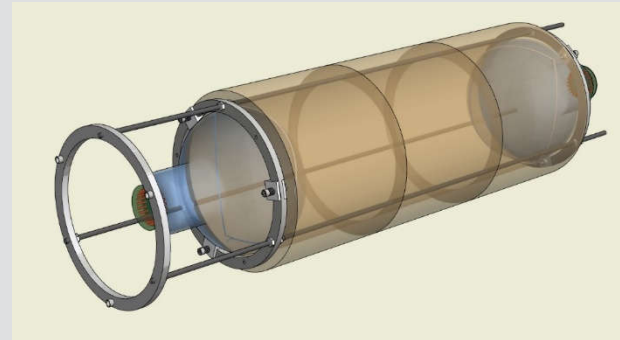
neutron candidate timing



CENNS-10

Run01 data

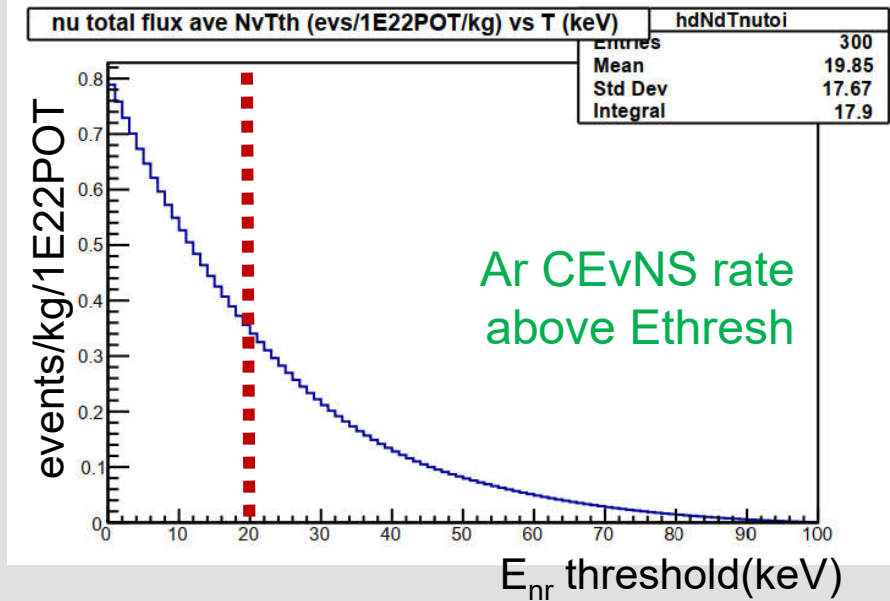
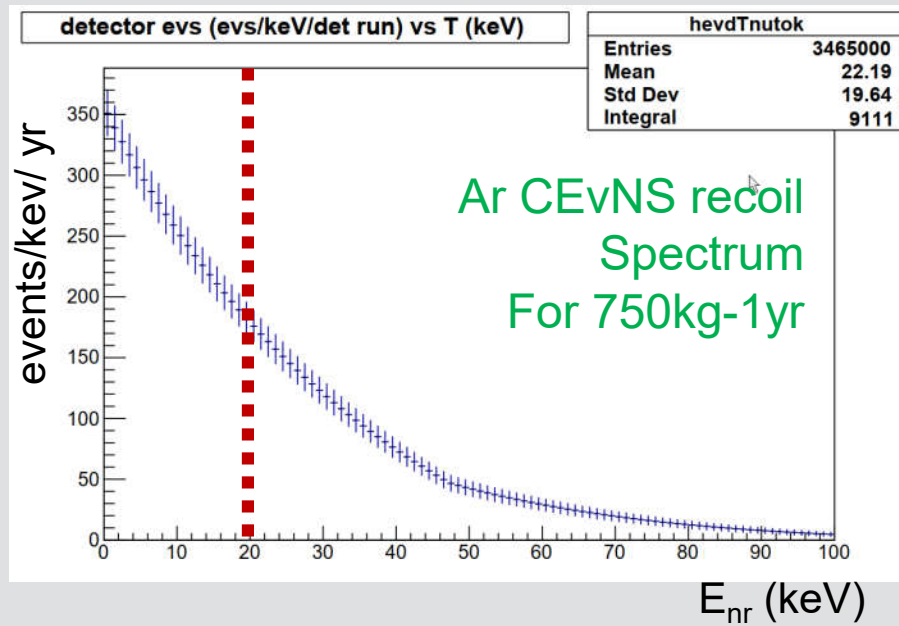
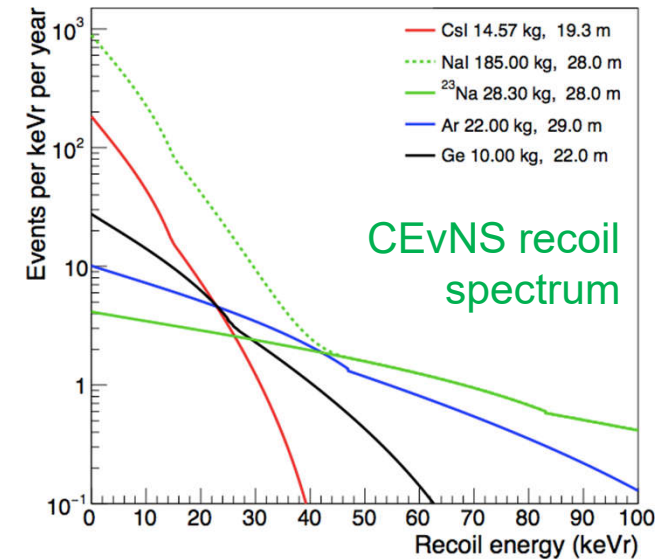
- Upgraded from Run00: new PMTs, new WLS/reflector scheme, full shielding, 83Kr calibration source
- detector calibration shows $\sim 4.5 \text{ PE/keV}$, energy linearity
- Good data/simulation agreement
- Two \sim independent analyses (US-/Moscow based) with blindness scheme, results soon



Tonne-scale LAr detector

CEvNS event rates in LAr:

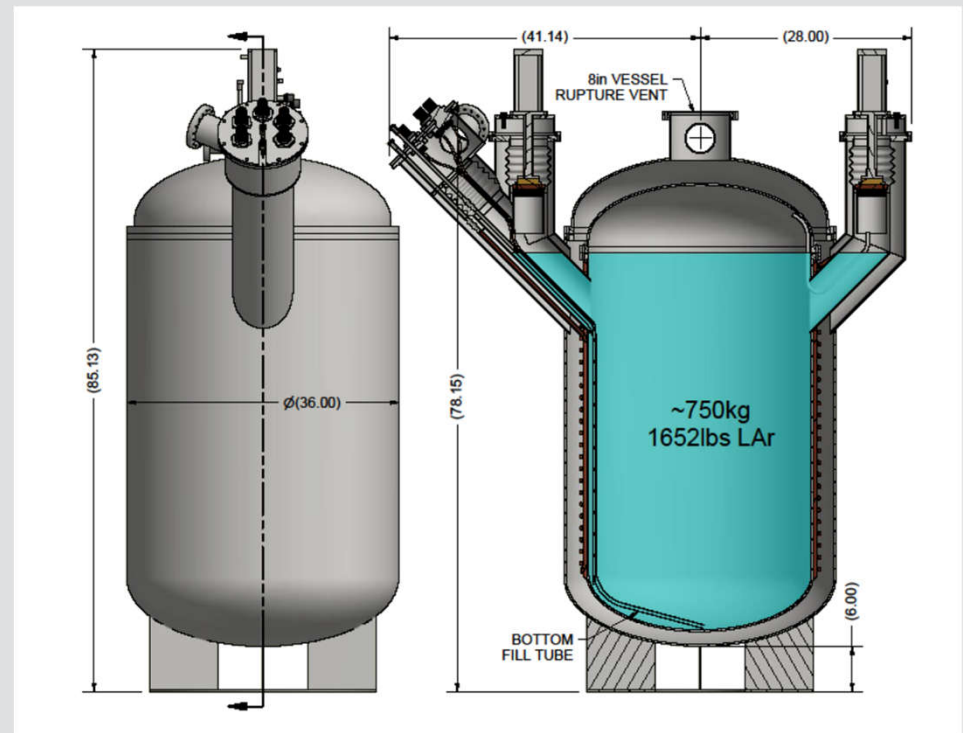
- at CENNS-10 location: 0.09 nu/proton-on-target, 27.5 m
- ~5 evs/kg/yr with 20keV_{nr} threshold, quenching~25%
- So, for 750kg fiducial LAr, ~4000 evs/SNS-yr, with big gains for lower energy threshold



Tonne-scale LAr for COHERENT

Overview:

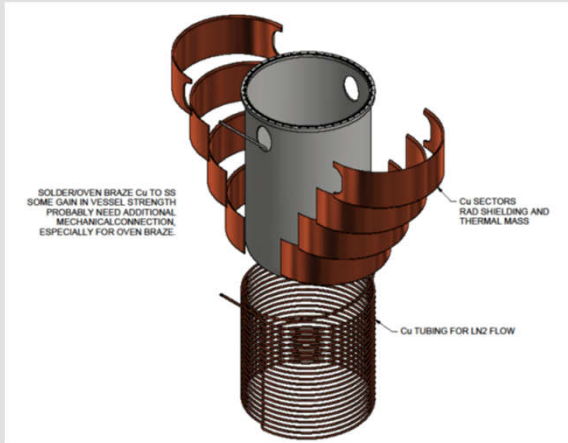
- Single phase LAr (scintillation-only) calorimeter, will easily scale to ~1-ton.
- Underground (low ^{39}Ar) argon
- From CENNS-10 experience, goal of ~1 PE/keVnr (~5PE/keVee) for Ethresh~20keVnr
- Light collection, default: TPB-coated PMTs, TPB-coated Teflon side reflector.
- Options under study:
 - SiPMs, VUV reflectors/ photodetectors
 - Xe-doping of LAr for WLS, shorter excitation time
- Shielding scheme as CENNS-10: Pb, Cu, H_2O . Will optimize.



Tonne-scale LAr for COHERENT

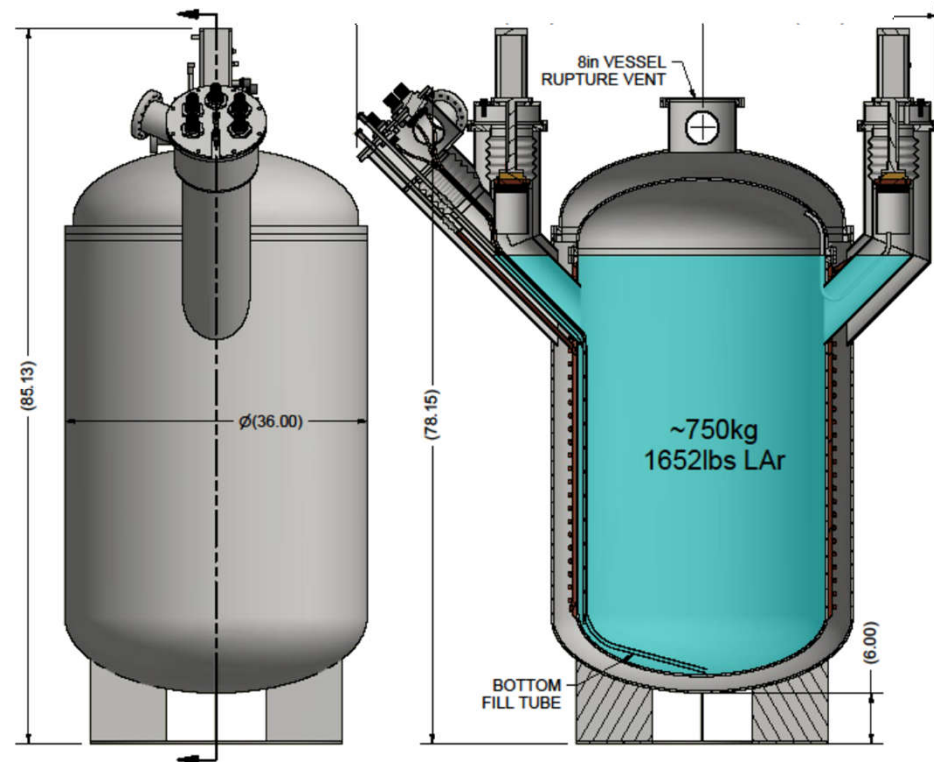
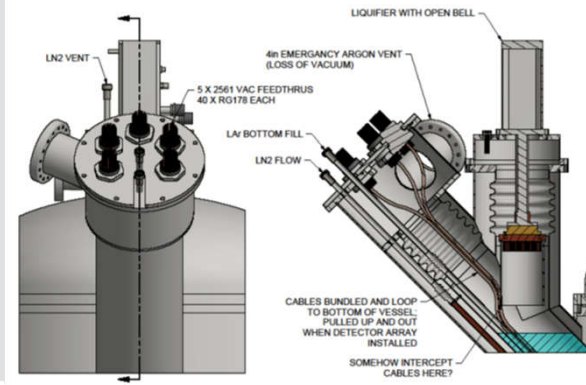
Cryogenics design study in progress
(Funded by IU proposal development grant.)

- preassembled cryostat with single-wall feedthrough system
- liquid fill with underground Ar
- liquid/gas purification for ~ppm purity
- assuming PT cryocoolers for O(20W) cooling, considering LN2-only option



Design Intent & Restrictions

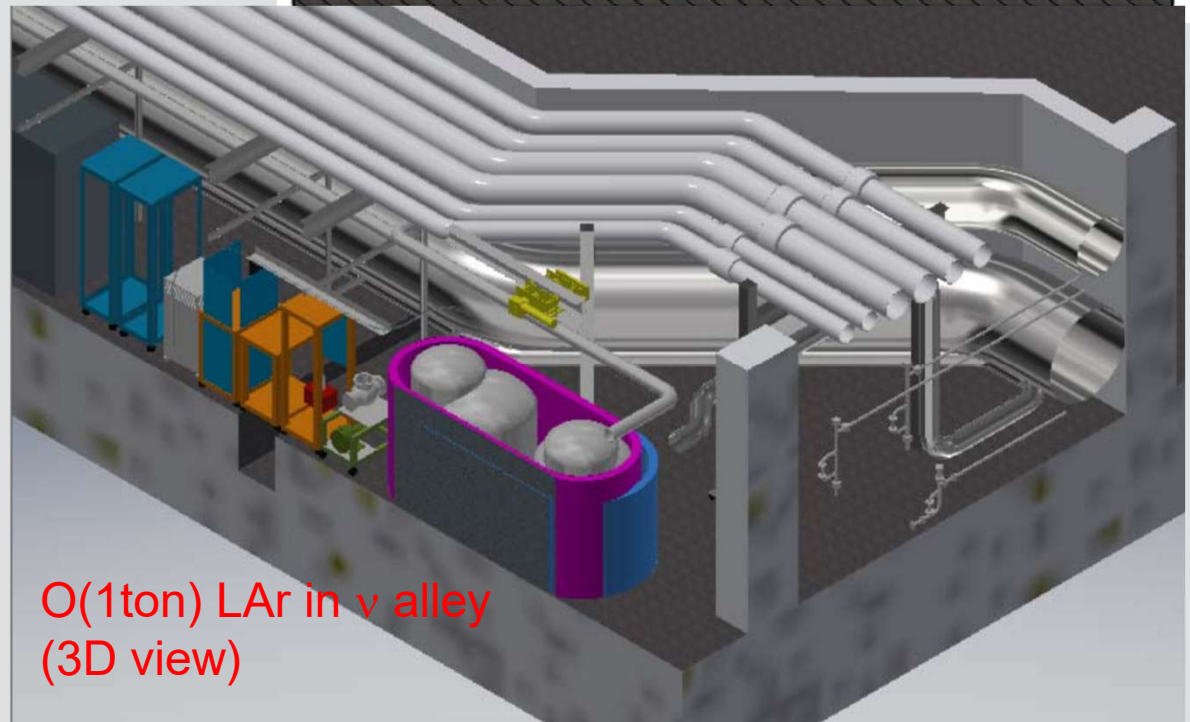
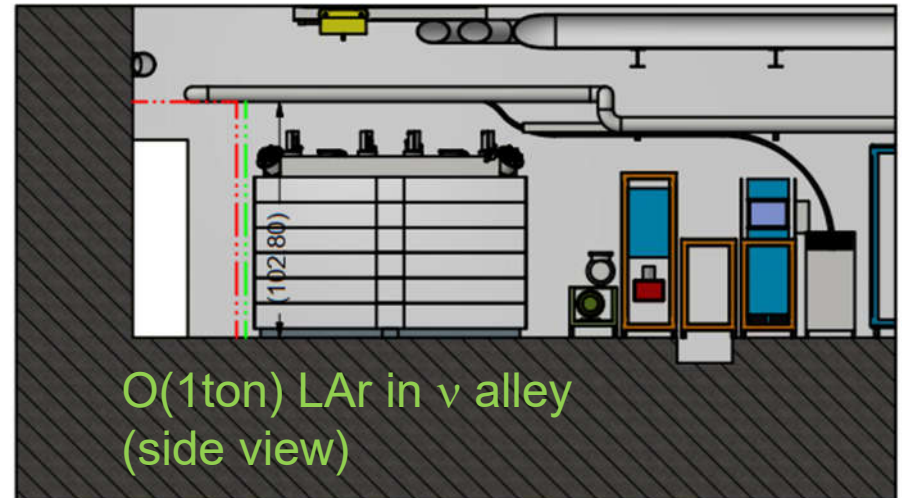
- Cryogenic Vessel to Hold and Maintain Approx. One Ton of High Purity, Fossil Depleted Argon, Would Like to Keep Steady State Heat Load < 10W
- Adapt to EXTREME Space, Utility and Safety Restrictions in SNS basement Hall.
- Allow Cooling, Liquefaction and Maintenance by Cryo Refrigerators and/or LN2
- Develop Safe and Clear Procedures for Operation, Filling and Emergency Response



Tonne-scale LAr for COHERENT

More details:

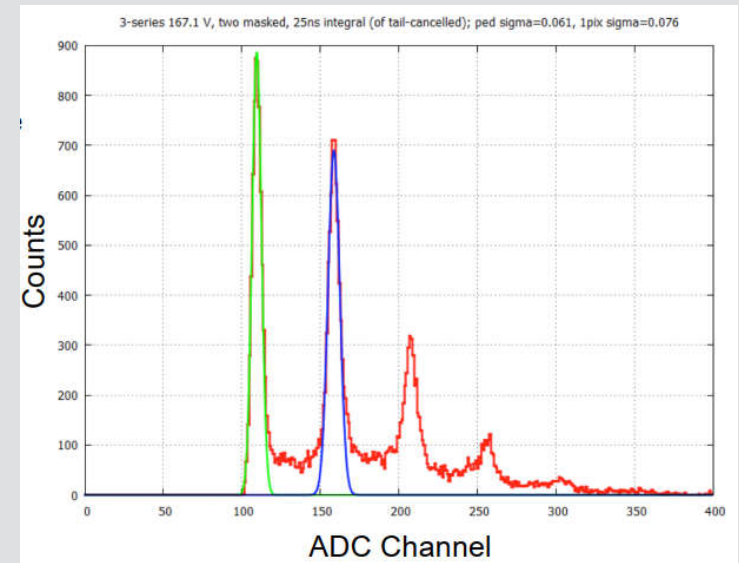
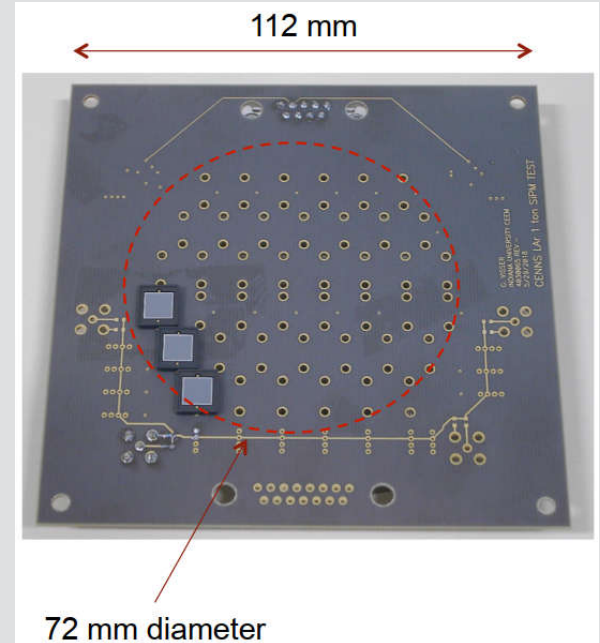
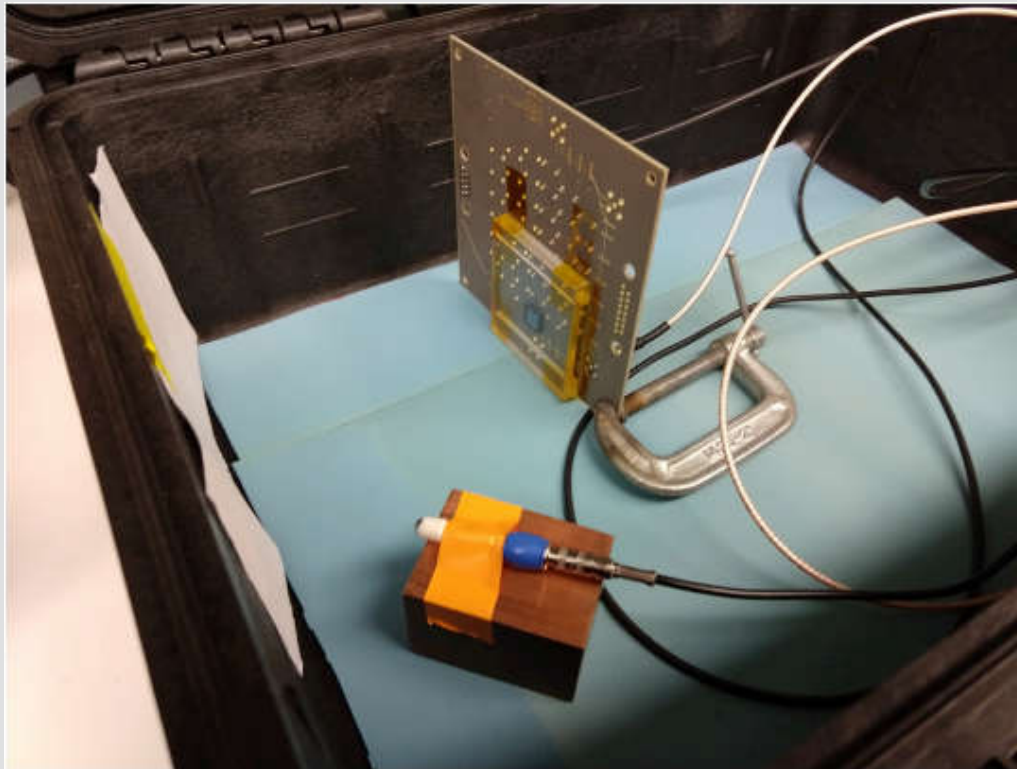
- adequate space for detector, shielding in neutrino-alley (current CENNS-10 location)
- for higher-energy CC processes, additional components may be needed, eg: cosmic ray trackers, active water shielding



Tonne-scale LAr for COHERENT

Readout:

- Currently considering/evaluating options: 8"-2" PMTs, SiPMs for cost/performance, require large area for 20PEs/keV
- Plots from ongoing SiPM tests to determine noise, dark rate, etc from 42 6x6mm² array



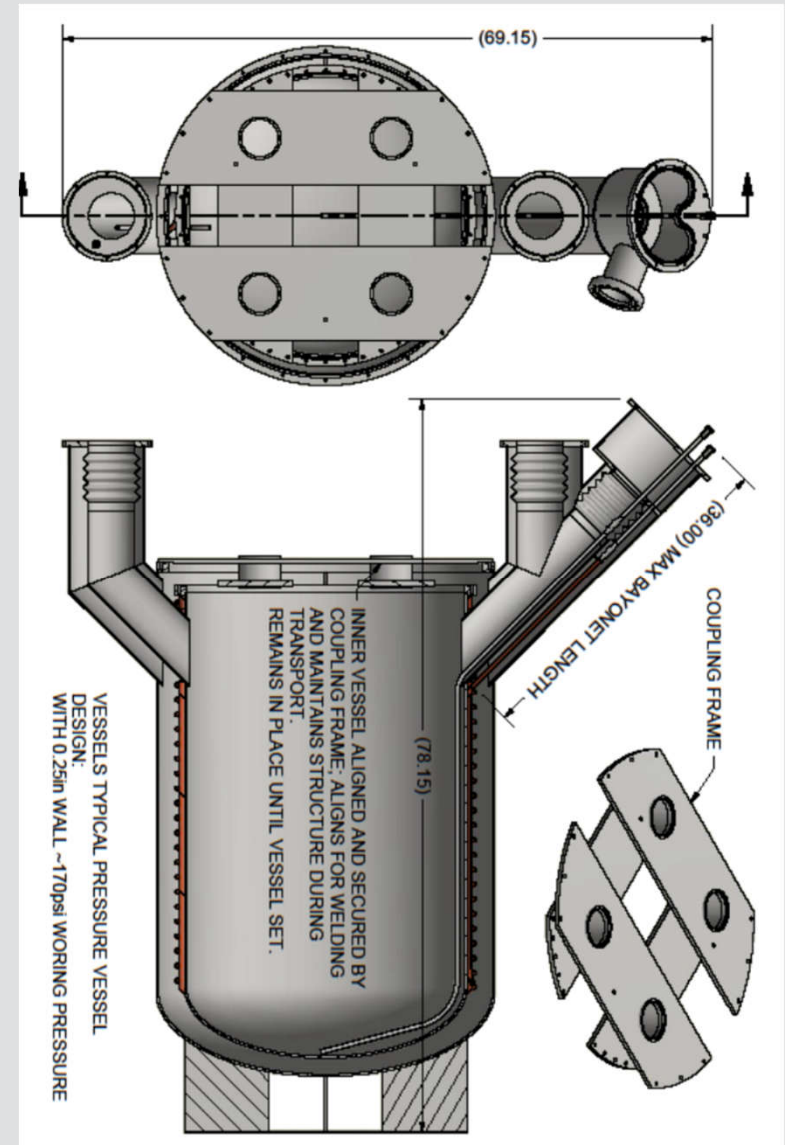
Tonne-scale LAr for COHERENT: cost/schedule

Component costs estimate

- cryostat: \$150k
- shielding: \$100k
- cryo/pumps/gas systems: \$200k
- recovery system: \$100k
- Calibration system(s): \$100k
- readout: \$200k-\$600k (8" PMT – SiPMs).
- underground Argon (?)

schedule:

- proposals: 2018-19,
- construction: 19-20,
- data collection: 2021-25



Summary

- A large LAr detector at SNS neutrino alley will enable a far reaching physics program.
- Existing LAr work at SNS enables a straightforward scale-up to O(1ton) with modest cost/schedule.
- Work on design, physics studies ongoing.

