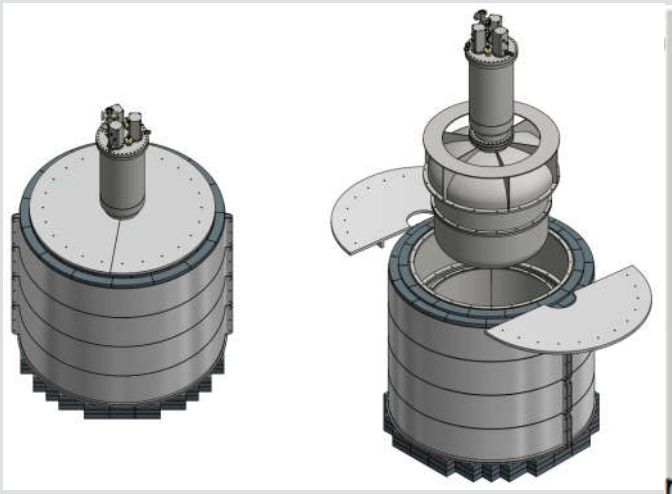
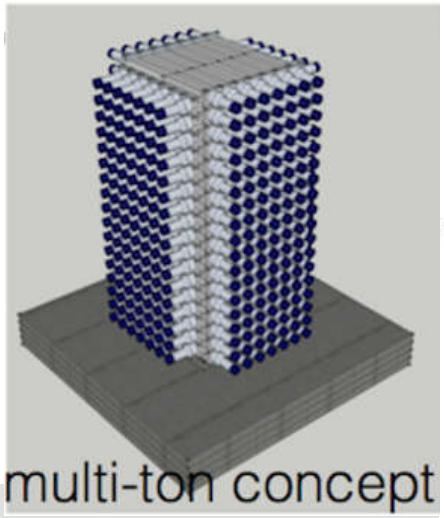
Searching for sub-GeV DM in the COHERENT experiment

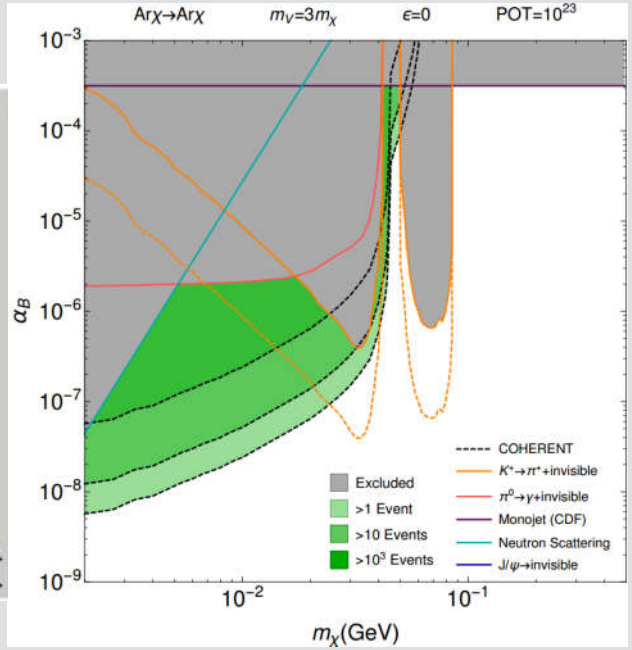
R. Tayloe
Indiana U.

Outline

- CEvNS process and physics
- production/detection of DM
- experimental overview/status
- DM sensitivities



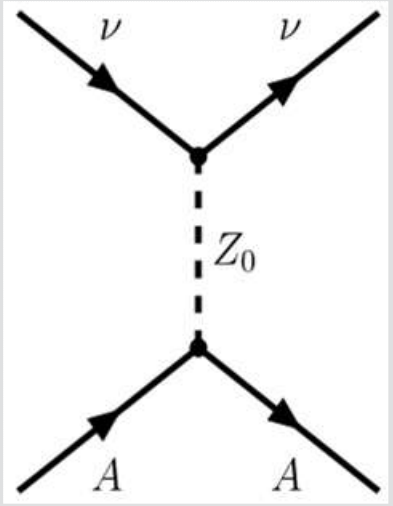




Coherent Elastic ν-Nucleus Scattering:

"CEvNS":

Coherent Elastic ν-Nucleus Scattering: νA→νA

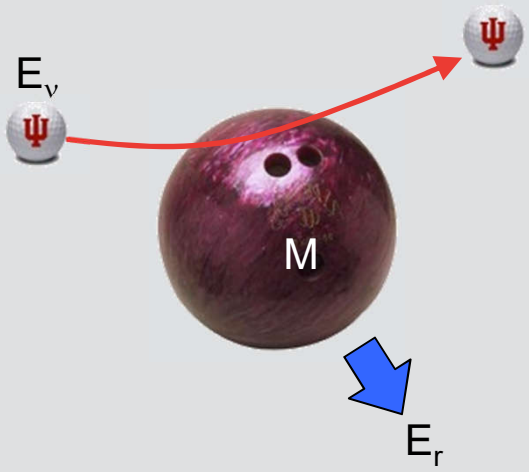


Neutrino scatters with low momentum transfer coherently, elastically from entire nucleus. For large nucleus, R_N~few fm, and:

$$E_\nu \lesssim \frac{hc}{R_N} \cong 50 \text{ MeV}$$

.. but recoil energy is quite small:

$$E_r^{\max} \simeq \frac{2E_\nu^2}{M} \simeq 50 \text{ keV}$$



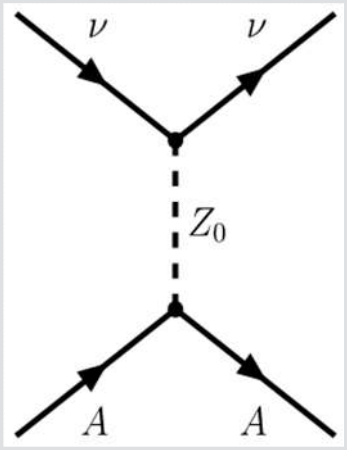
The CEvNS process has yet to be observed…

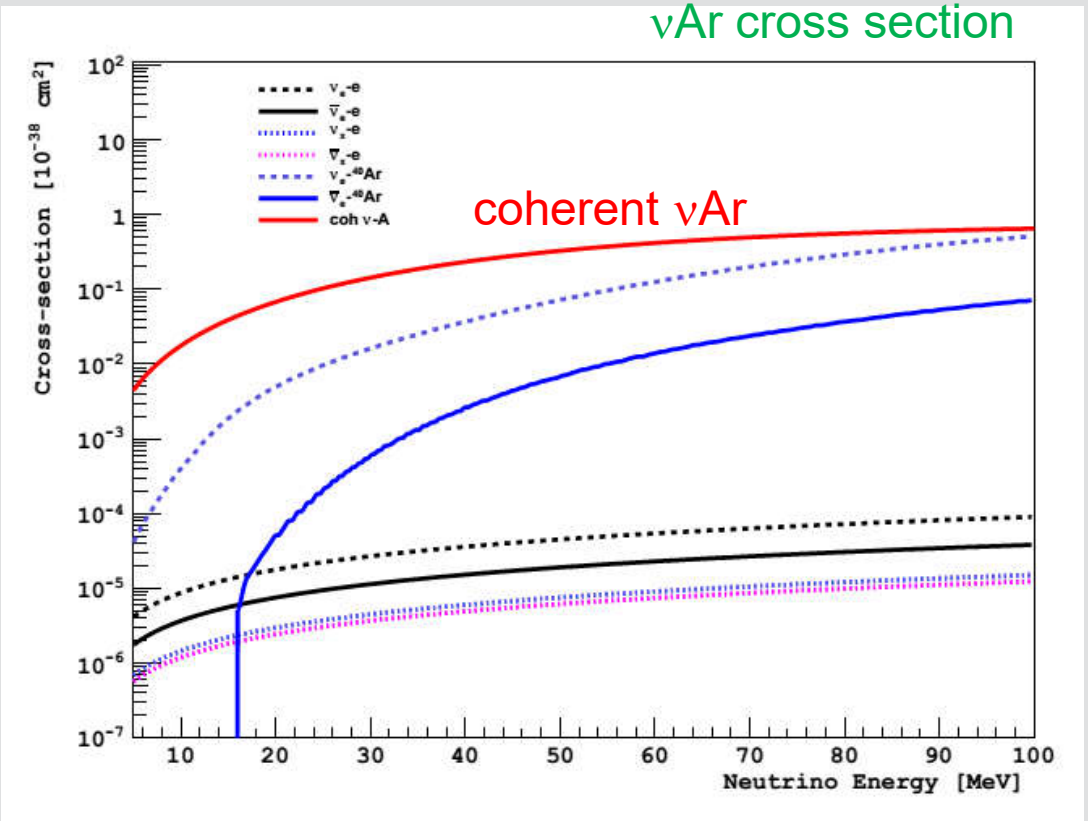
Coherent Elastic ν-Nucleus Scattering:

- Cross section is large…

in fact largest ν channel

at O(10 MeV) on heavier nuclei, eg Ar





- and has distinctive

N^2 dependence

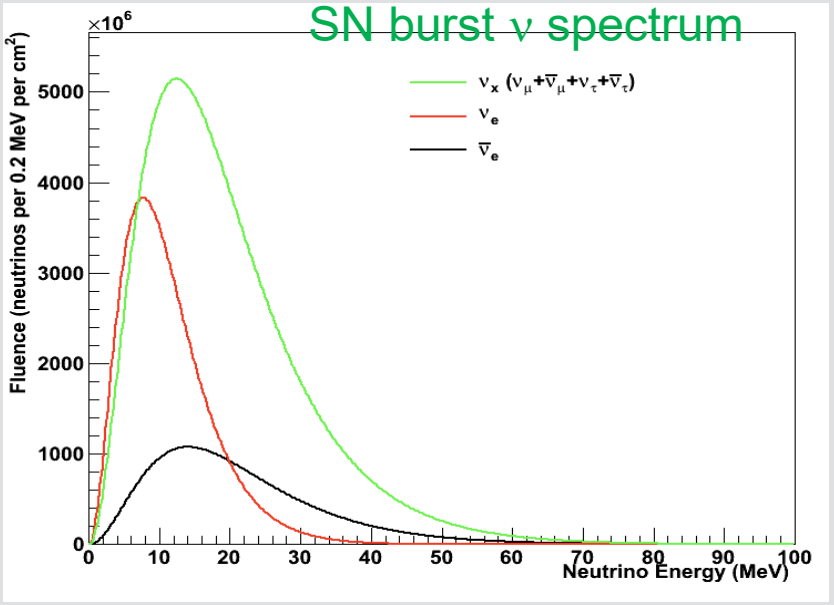
$$\frac{d\sigma}{dE} = \frac{G_F^2}{4\pi}[(1-4\sin^2\theta_w)Z - (A-Z)]^2 M\left(1-\frac{ME}{2E_\nu^2}\right)F(Q^2)^2$$

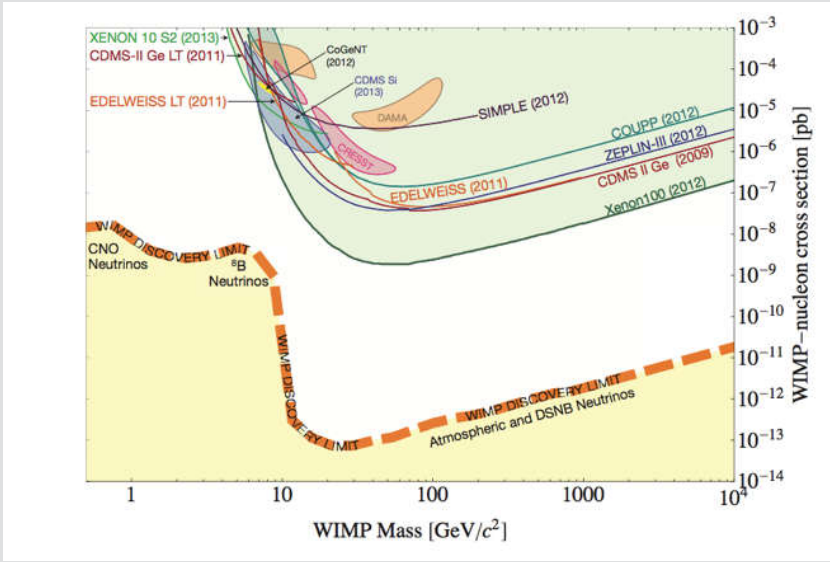
Small N^2

Coherent Elastic ν-Nucleus Scattering:

Physics of CEvNS:

- Supernovae: Expected to be important in core-collapse SN and possible SN detection channel.
- Nuclear Physics: nuclear form factors
- ν oscillations: A possible ν_s detection channel
- Standard Model tests, eg: $\sin^2\theta_w$
- Dark Matter: Important background for 10-ton direct searches

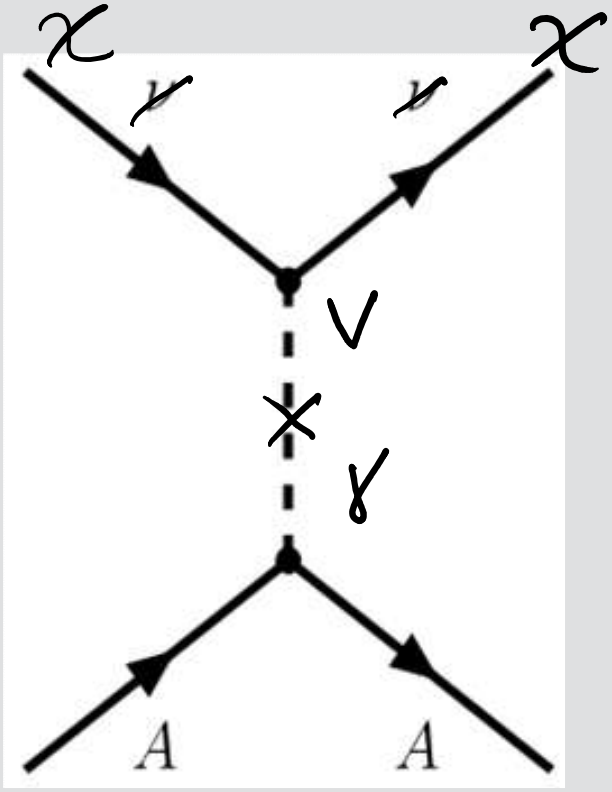




Coherent Elastic ν-Nucleus Scattering:

Physics of CEvNS:

- Supernovae: Expected to be important in core-collapse SN and possible SN detection channel.
- Nuclear Physics: nuclear form factors
- ν oscillations: A possible ν_s detection channel
- Standard Model tests, eg: $\sin^2 \theta_w$
- Dark Matter: Important background for 10-ton searches
- Search for accelerator-produced DM … with "CEDMNS" (or "CExNS" ?)



Accelerator-production and detection of DM with COHERENT experiment:

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)

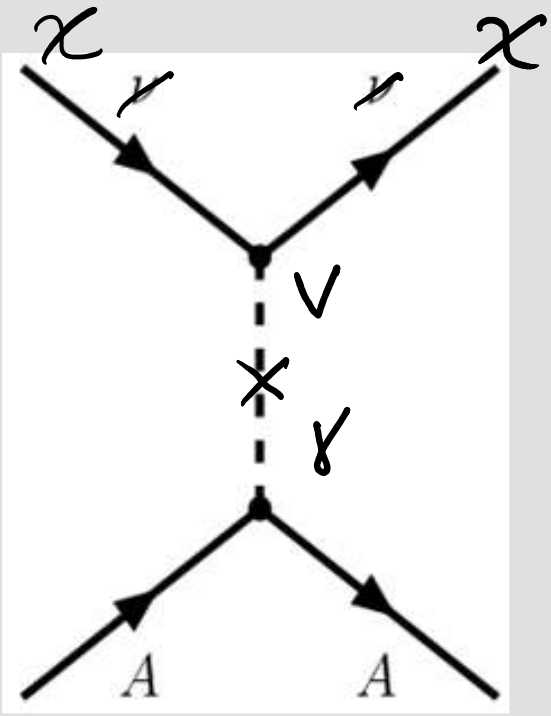
production:

proton → target → $\pi^{0,\pm}$ →

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

$$\pi^- + p \longrightarrow n + V^{(*)} \longrightarrow n + \chi^\dagger + \chi$$

detection:

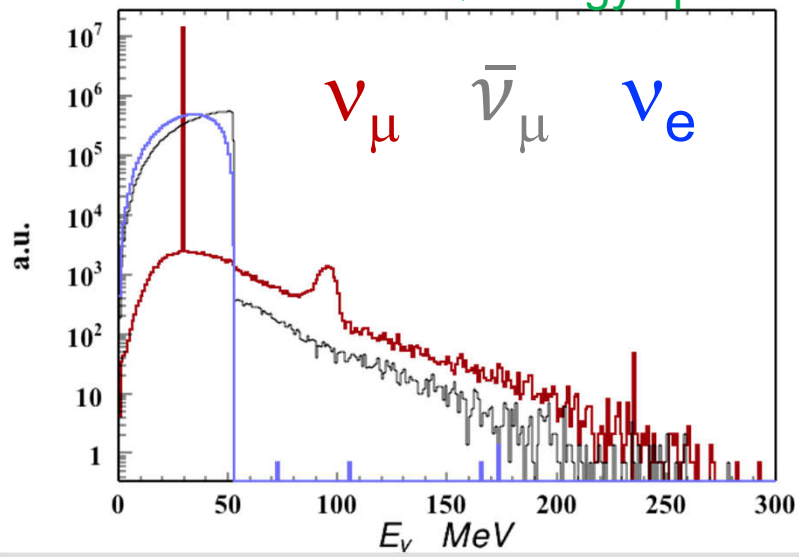


COHERENT experiment at SNS/ORNL

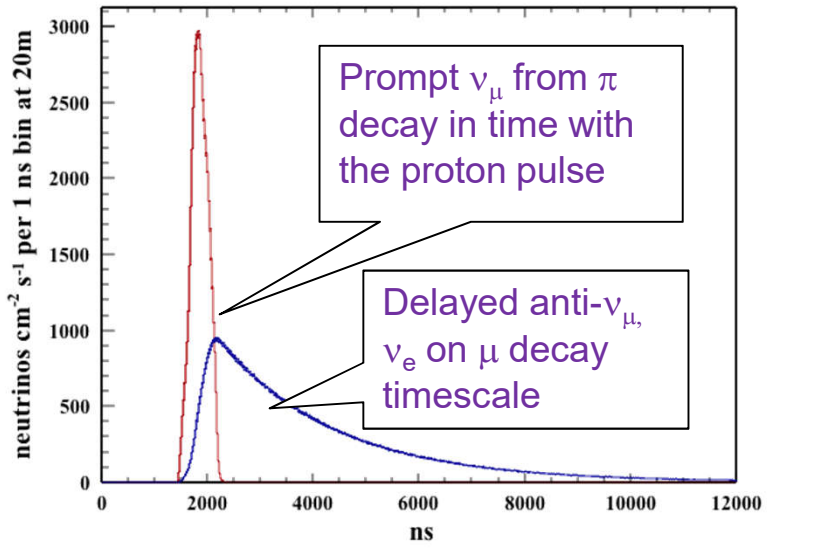
ORNL Spallation Neutron Source (SNS) is also a world-class ν source:

- intense proton beam (~1MW, 1 GeV)
- pulsed (60 Hz, 600ns spill time)…

SNS ν energy spectrum



SNS ν time distribution



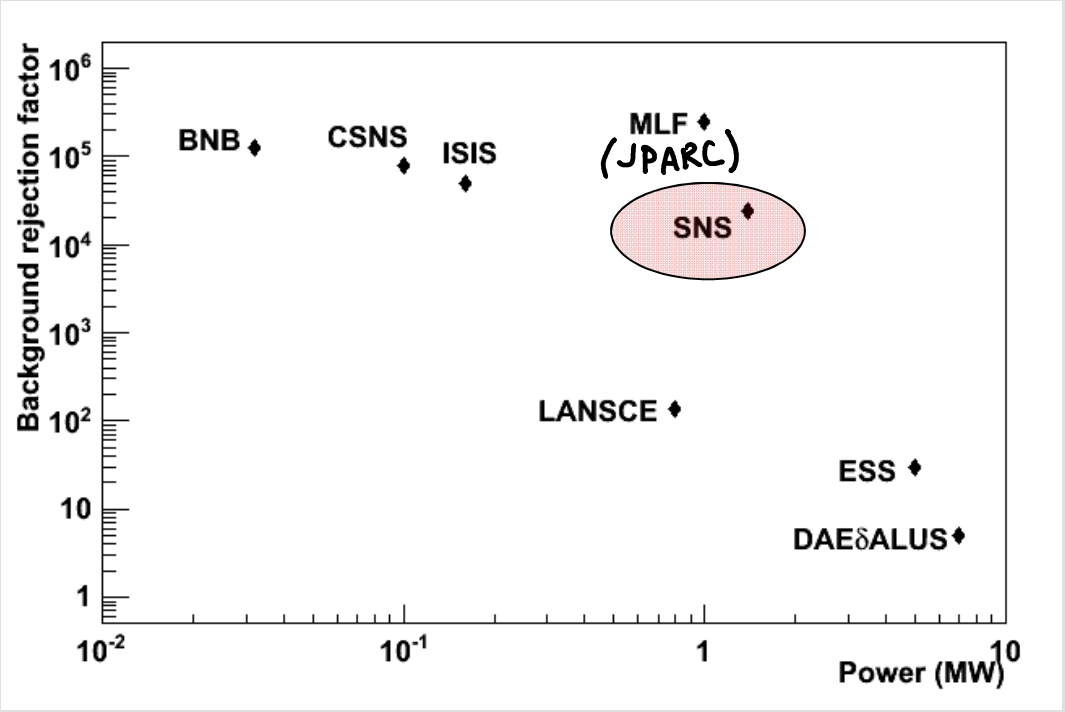
COHERENT experiment at SNS/ORNL

ORNL SNS

… and a possible source of χ

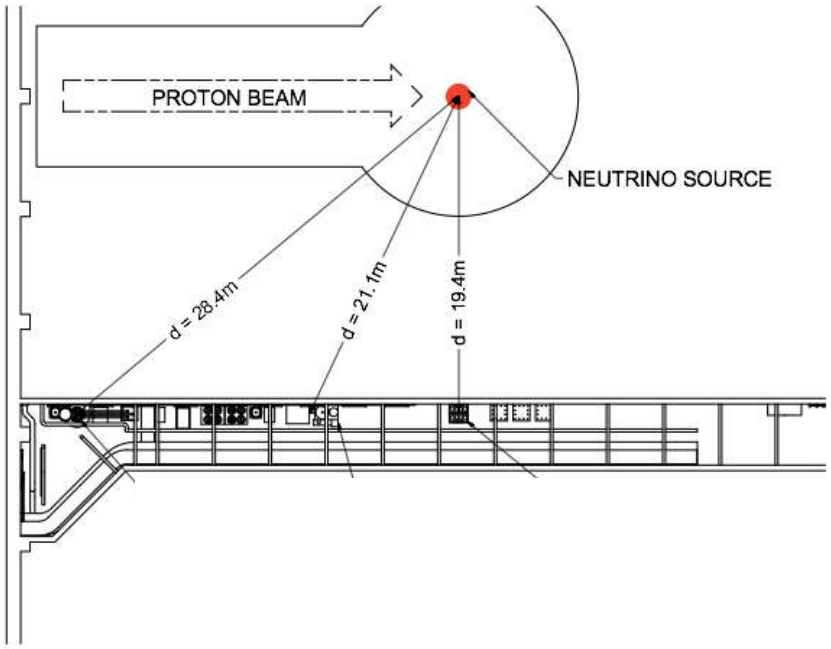
~ 5000MWhr/year

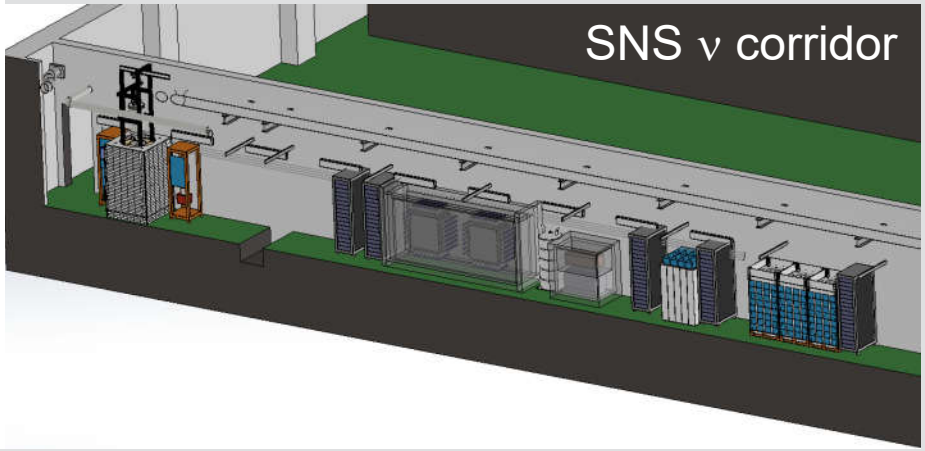
~ 2E23 POT!



COHERENT experiment at SNS/ORNL

- a low-background experimental area has been acquired for COHERENT
- 20-29 m from target





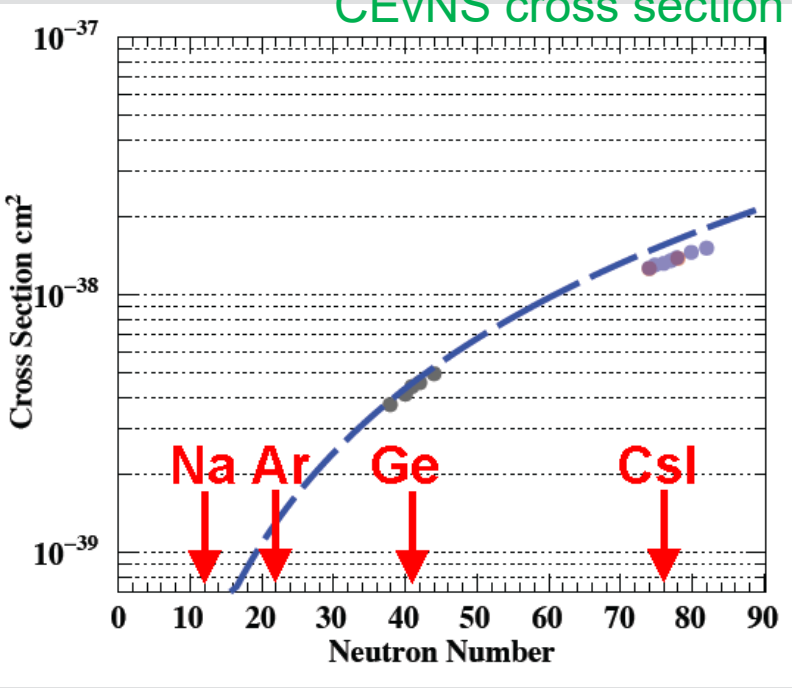
COHERENT experimental strategy at SNS/ORNL

Measure N^2 dependence of CEvNS process

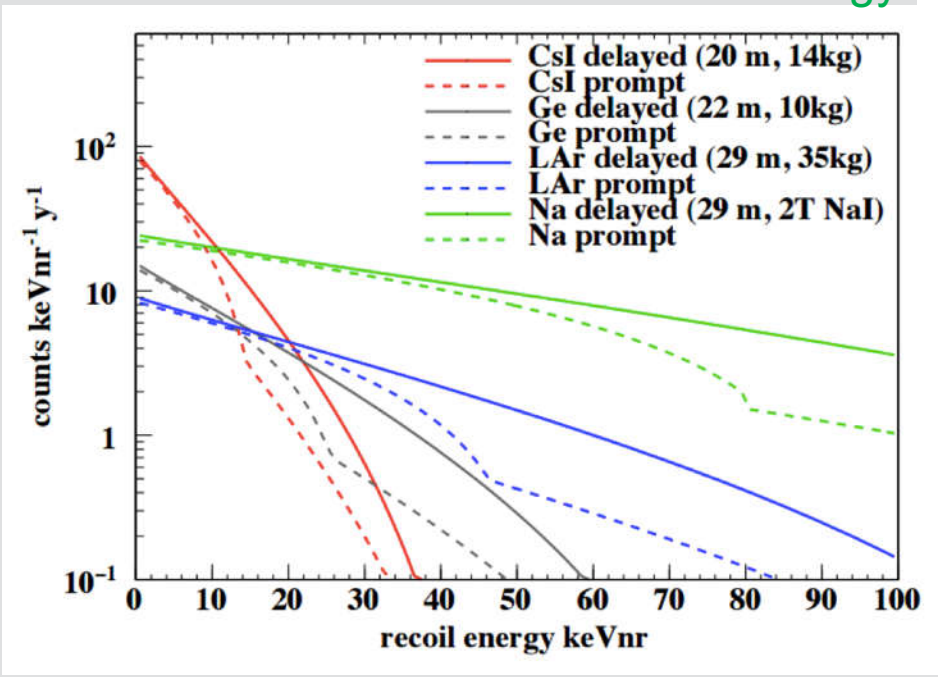
with multiple targets/detector technologies

- (event rate)/kg is high, so relatively small (10-100 kg) detectors sufficient
- radiological background requirements fairly modest, because of pulsed beam
- need low E thresholds !

CEvNS cross section

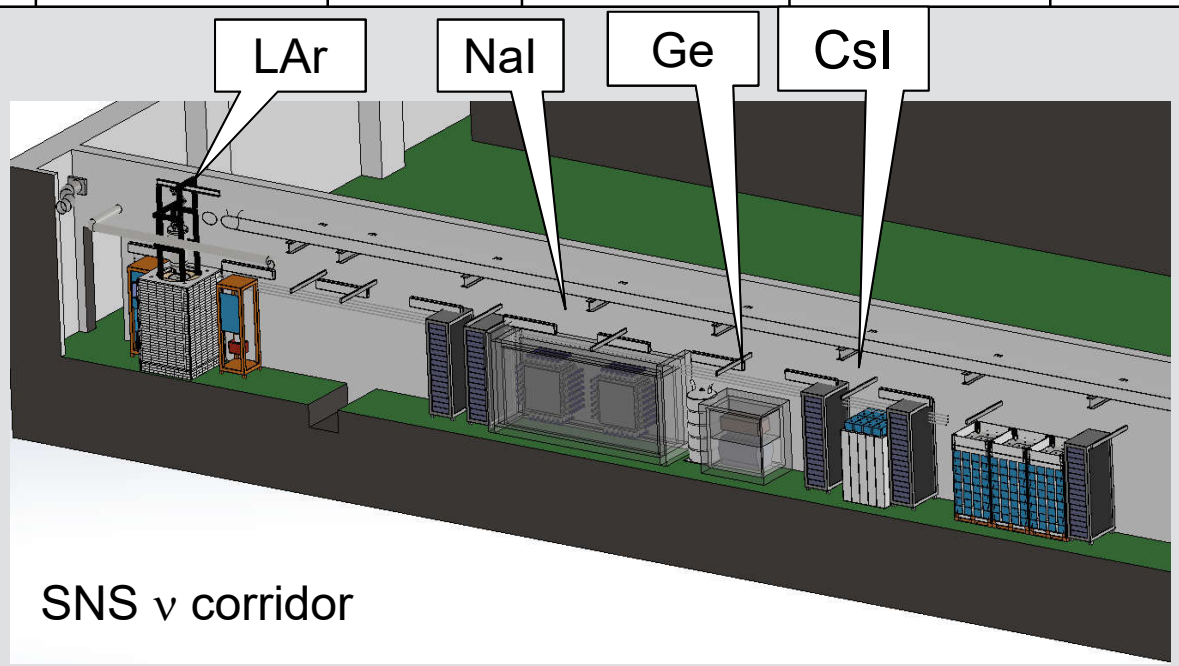


CEvNS recoil energy



COHERENT detectors

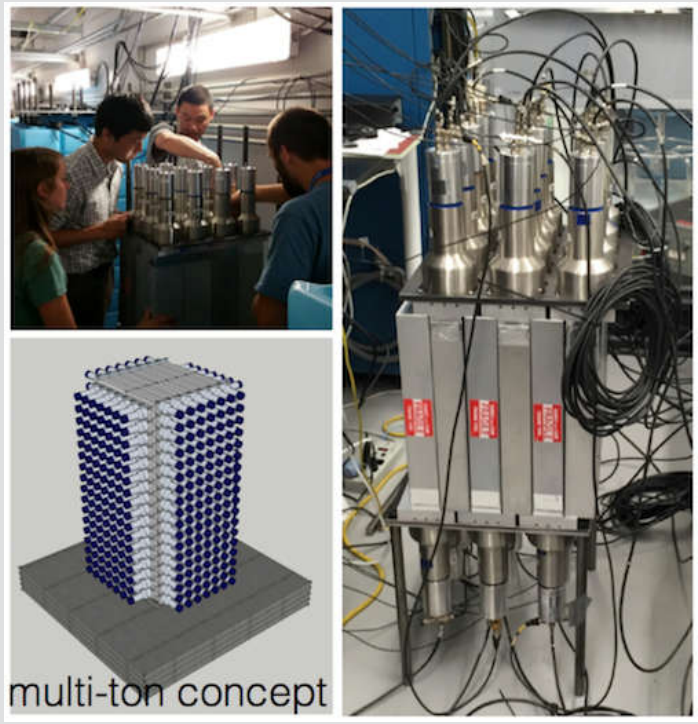
Nuclear Target	Technology	Mass (kg)	source distance (m)	Recoil thresh (keVnr)	Data-taking start date/ status
CsI[Na]	Scint. Crystal	14	20	6.5	9/2015/running
Ge	HPGe PPC	10	22	5	2017/planning
NaI[Tl]	Scintillating crystal	185	28	13	July 2016/running
LAr	Single-phase scintillation	35	29	20	Dec 2016/running



NaI [Tl] for COHERENT

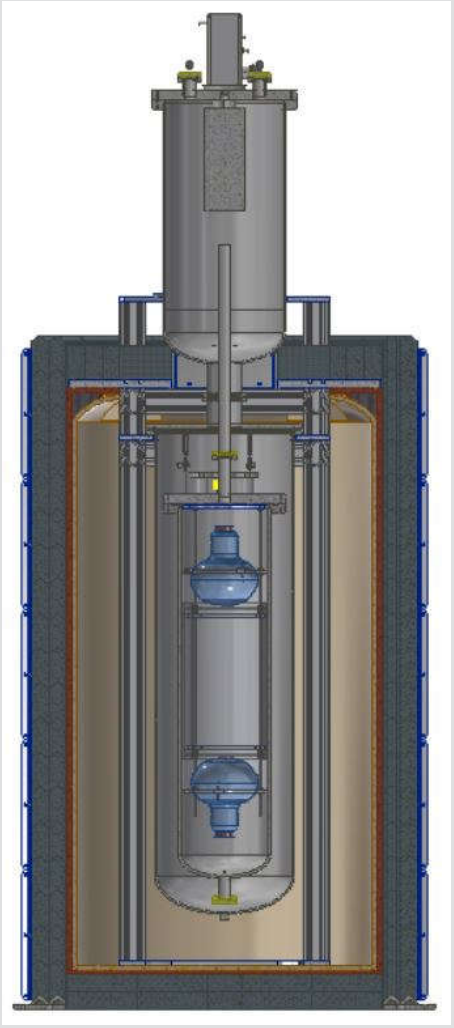
- discontinued DHS program has provided opportunity to use many ~7kg NaI xtals

- 185 kg prototype for initial deployment, currently running
- 2 ton next phase deployment
- Up to 9 tons available



LAr for COHERENT

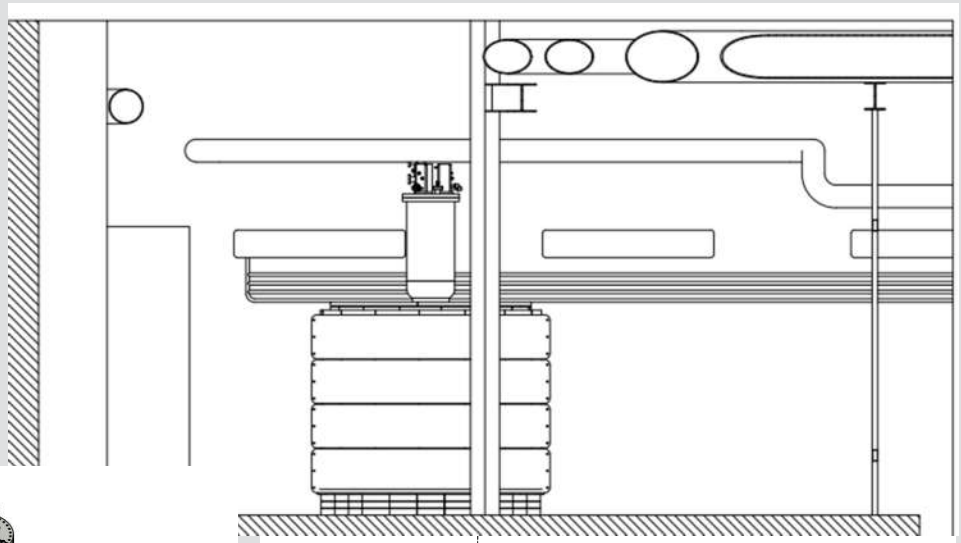
- Single-phase scintillation-only detector
- built by J. Yoo, etal at Fermilab for CEvNS effort
- ~35-kg fiducial volume
- Readout: 2 × Hamamatsu R5912-02MOD PMT (8” cryogenic)
- Excellent nuclear-/electron-recoil PSD demonstrated by miniCLEAN, etal.
- SCENE has measured quenching factors[1]
- ^{39}Ar controllable with PSD and duty factor
- Pb, Cu, H2O shielding structure
- Currently running at SNS through 2017

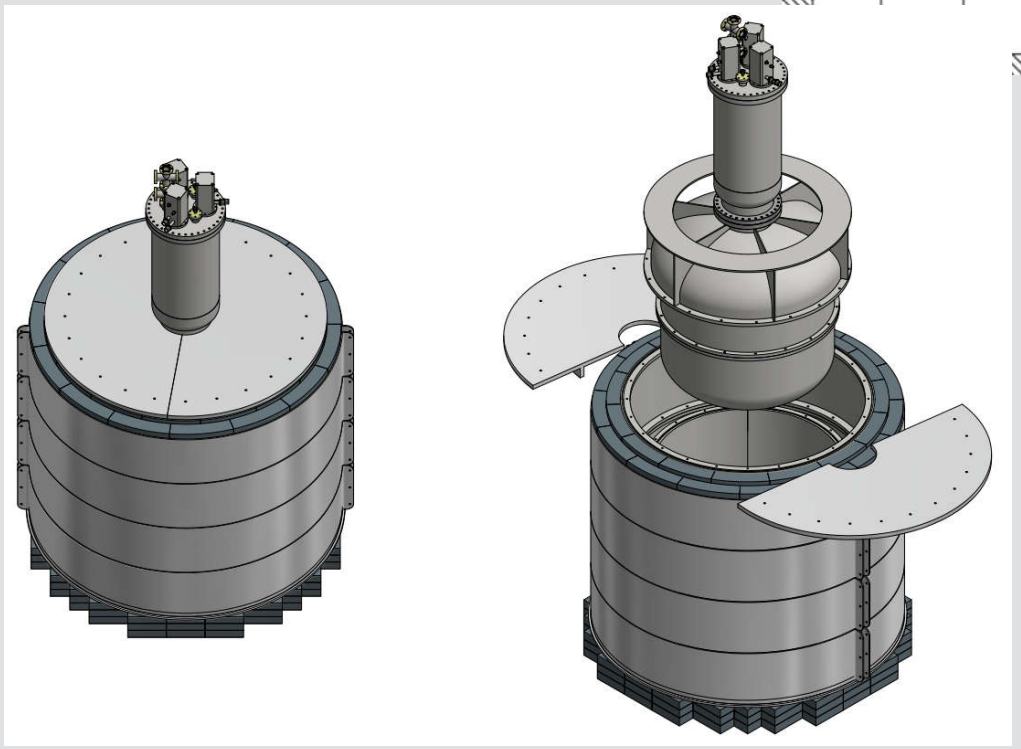


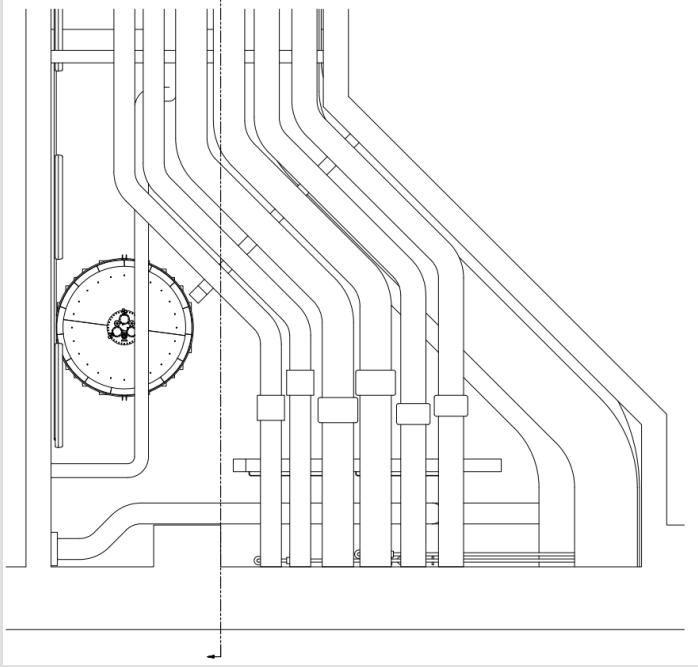
[1]H. Cao et al., SCENE Collaboration, *Phys. Rev.* **D91** (2015) 092007. arXiv:1406.4825 [physics.ins-det].

LAr for COHERENT

- ~1 ton LAr detector is possible future option
- fits in SNS ν corridor
- scintillation-only detector
- modest cost



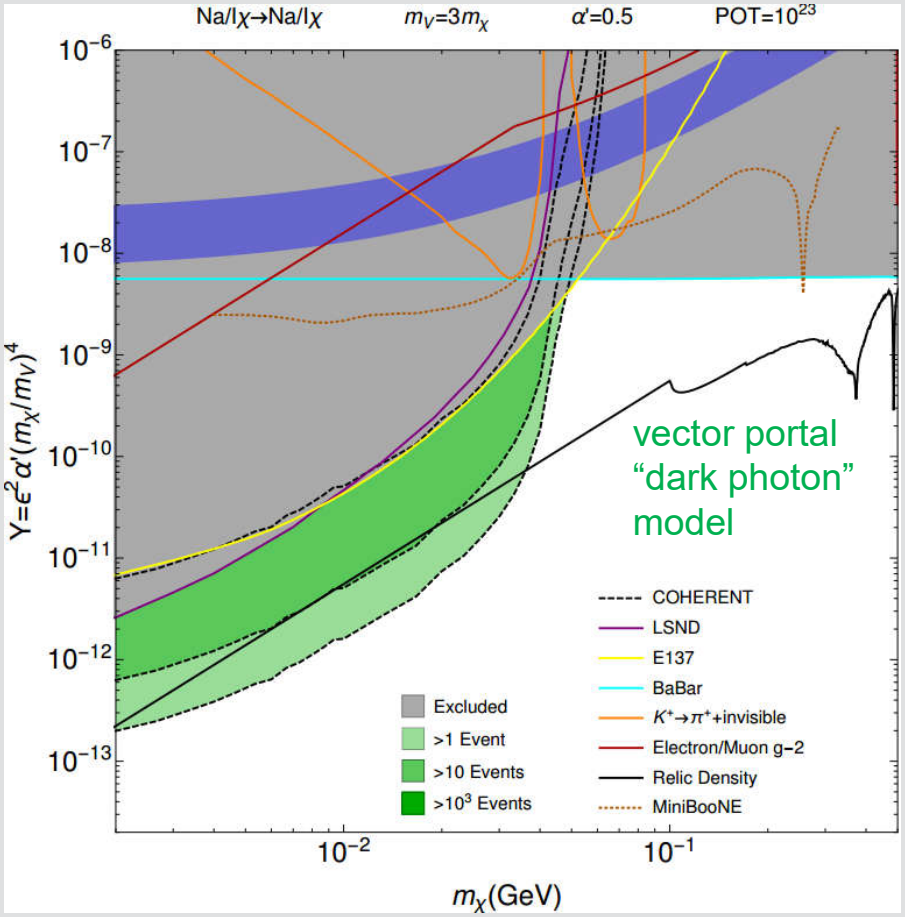


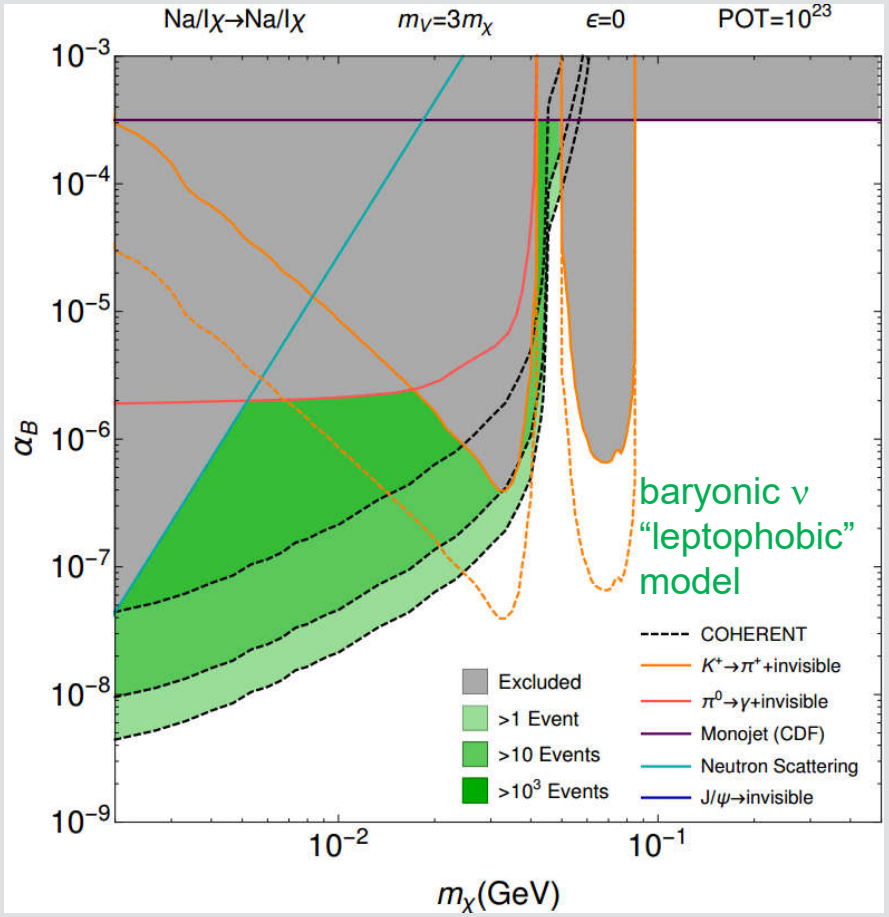


DM sensitivities with NaI in COHERENT

- 5 ton NaI, E> 20keVnr, 1E23POT
- 1-1000 event sensitivity plots
- predicted experimental sensitivities – work in progress

updated plots from Patrick DeNiverville

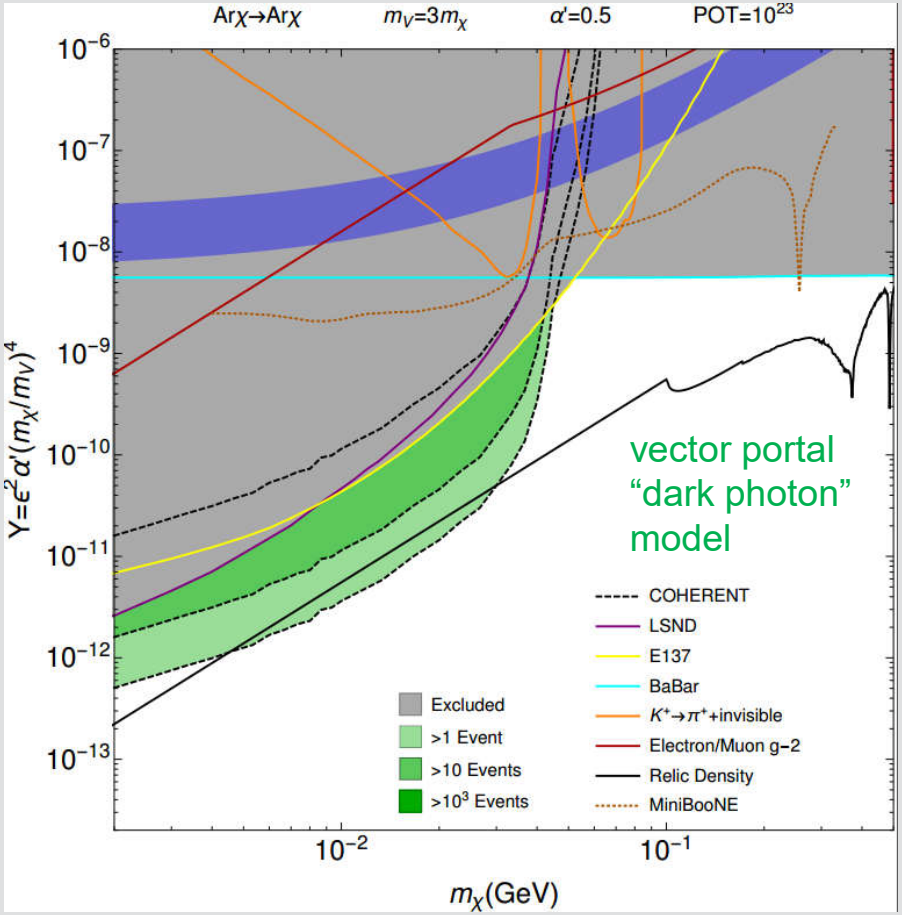


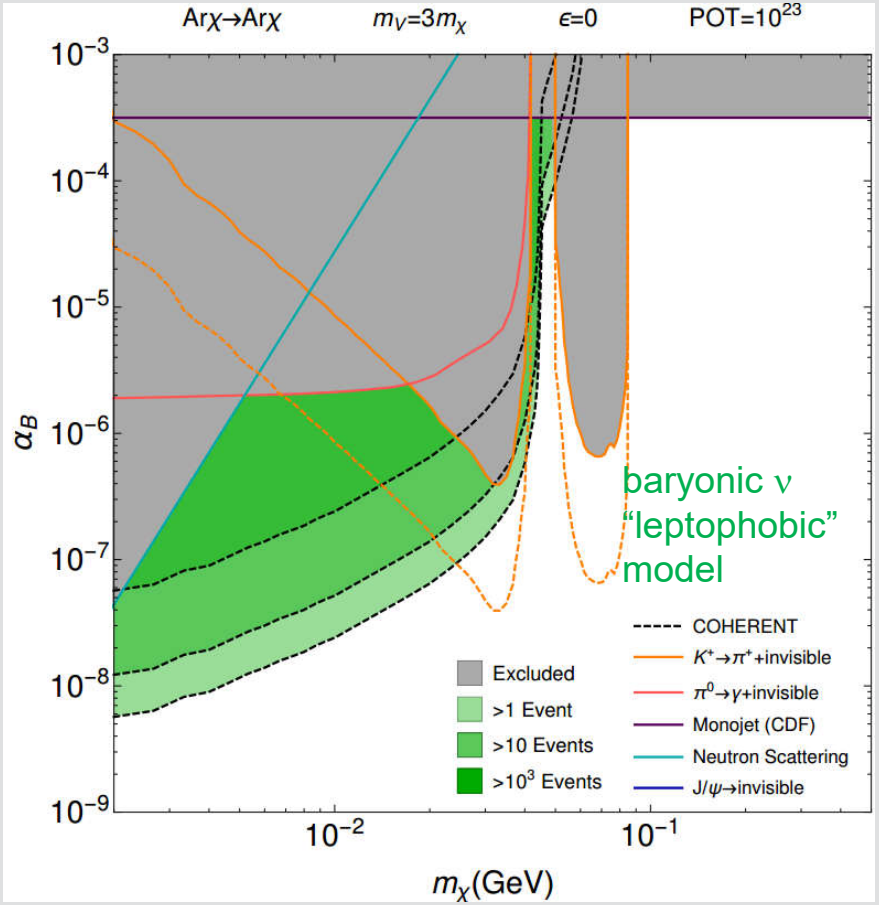


DM sensitivities with LAr in COHERENT

- 1 ton LAr, E>20keVnr, 1E23POT
- 1-1000 event sensitivity plots
- predicted experimental sensitivities – work in progress

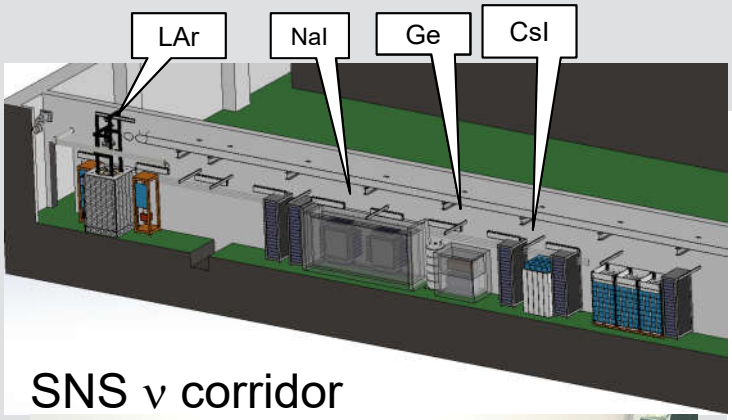
updated plots from Patrick DeNiverville



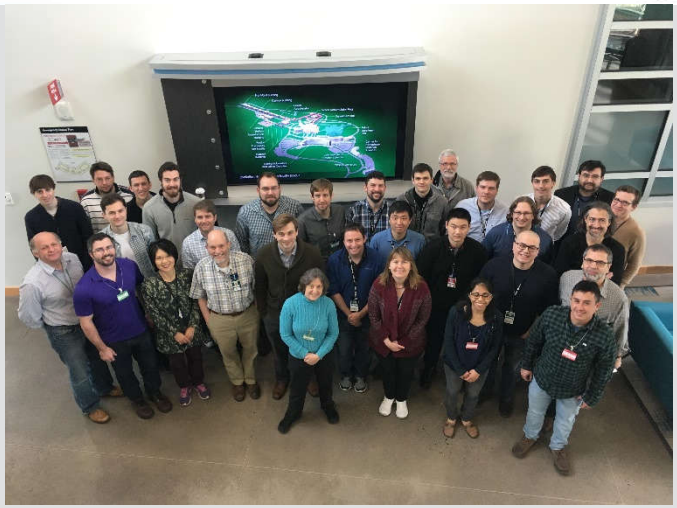


Summary

- DM searches possible in near future with ~1 ton detectors at (intense!) SNS
- Thanks for DOE, NSF, ORNL support so far!



SNS ν corridor



COHERENT SNS SPALLATION NEUTRON SOURCE

The COHERENT Experiment at the Spallation Neutron Source

D. Akimov,[1,2] P. An,[3] C. Awe,[4,3] P.S. Barbeau,[4,3] P. Barton,[5] B. Becker,[6] V. Belov,[1,2] A. Bolozdynya,[2] A. Burenkov,[1,2] B. Cabrera-Palmer,[7] J.I. Collar,[8] R.J. Cooper,[5] R.L. Cooper,[9] C. Cuesta,[10] D. Dean,[11] J. Detwiler,[10] A.G. Dolgolenko,[1] Y. Efremenko,[2,6] S.R. Elliott,[12] A. Etenko,[13,2] N. Fields,[8] W. Fox,[14] A. Galindo-Uribarri,[11,6] M. Green,[15] M. Heath,[14] S. Hedges,[4,3] D. Hornback,[11] E.B. Iverson,[11] L. Kaufman,[14] S.R. Klein,[5] A. Khromov,[2] A. Konovalov,[1,2] A. Kovalenko,[1,2] A. Kumpan,[2] C. Leadbetter,[3] L. Li,[4,3] W. Lu,[11] Y. Melikyan,[2] D. Markoff,[16,3] K. Miller,[4,3] M. Middlebrook,[11] P. Mueller,[11] P. Naumov,[2] J. Newby,[11] D. Parno,[10] S. Penttila,[11] G. Perumpilly,[8] D. Radford,[11] H. Ray,[17] J. Raybern,[4,3] D. Reyna,[7] G.C. Rich*,[3] D. Rimal,[17] D. Rudik,[1,2] K. Scholberg†,[4,‡] B. Scholz,[8] W.M. Snow,[14] V. Sosnovtsev,[2] A. Shakirov,[2] S. Suchyta,[18] B. Suh,[4,3] R. Tayloe,[14] R.T. Thornton,[14] I. Tolstukhin,[2] K. Vetter,[18,5] and C.H. Yu[11]

[1] *SSC RF Institute for Theoretical and Experimental Physics of National Research Centre "Kurchatov Institute", Moscow, 117218, Russian Federation*
[2] *National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, 115409, Russian Federation*
[3] *Triangle Universities Nuclear Laboratory, Durham, North Carolina, 27708, USA*
[4] *Department of Physics, Duke University, Durham, NC 27708, USA*
[5] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA*
[6] *Department of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA*
[7] *Sandia National Laboratories, Livermore, CA 94550, USA*
[8] *Enrico Fermi Institute, Kavli Institute for Cosmological Physics and Department of Physics, University of Chicago, Chicago, IL 60637, USA*
[9] *Department of Physics, New Mexico State University, Las Cruces, NM 88003, USA*
[10] *Department of Physics, University of Washington, Seattle, WA 98195, USA*
[11] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[12] *Los Alamos National Laboratory, Los Alamos, NM, USA, 87545, USA*
[13] *National Research Centre "Kurchatov Institute", Moscow, 117218, Russian Federation*
[14] *Department of Physics, Indiana University, Bloomington, IN, 47405, USA*
[15] *Physics Department, North Carolina State University, Raleigh, NC 27695, USA*
[16] *Physics Department, North Carolina Central University, Durham, North Carolina 27707, USA*
[17] *Department of Physics, University of Florida, Gainesville, FL 32611, USA*
[18] *Department of Nuclear Engineering, University of California, Berkeley, CA, 94720, USA*

arXiv:1509.08702