The COHERENT experiment and status of the CENNS-10 liquid argon detector

Rudik Dmitry on behalf of COHERENT coll.

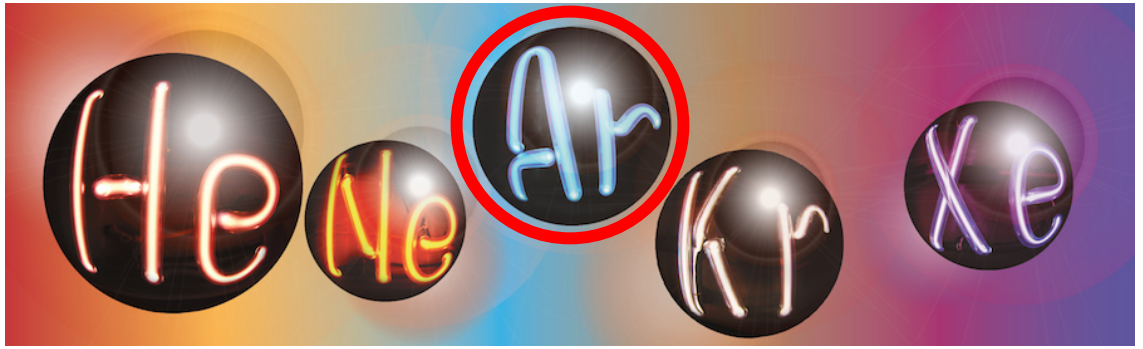
Manchester, 28/08/2019, LIDINE 2019

~ 80 members
~ 20 institutions
4 countries

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

Outline

- Coherent Elastic Neutrino Nucleus Scattering (CEvNS)
- Spallation Neutron Source (SNS)
- COHERENT @ SNS
- Liquid argon (LAr)
- CENNS-10 detector
- Engineering run results
- Production run analysis status
- Future upgrades
- Summary



Based on the Rex Tayloe's talk @ APS DPF

Coherent Elastic Neutrino Nucleus Scattering (CEvNS)

PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

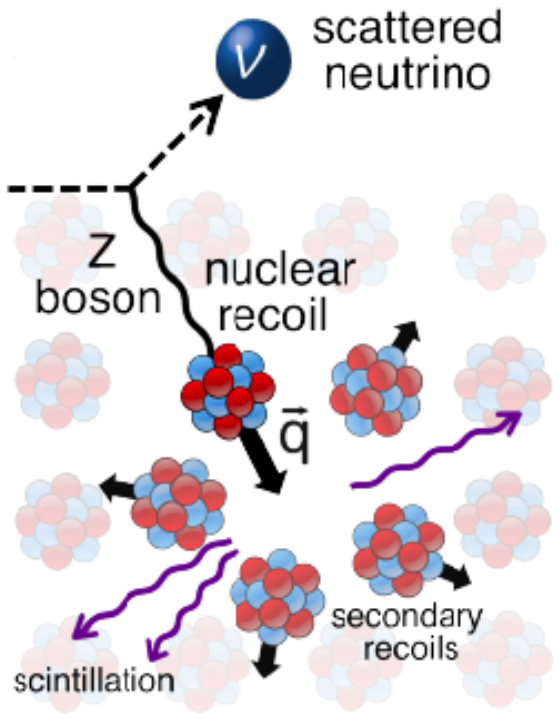
Coherent effects of a weak neutral current

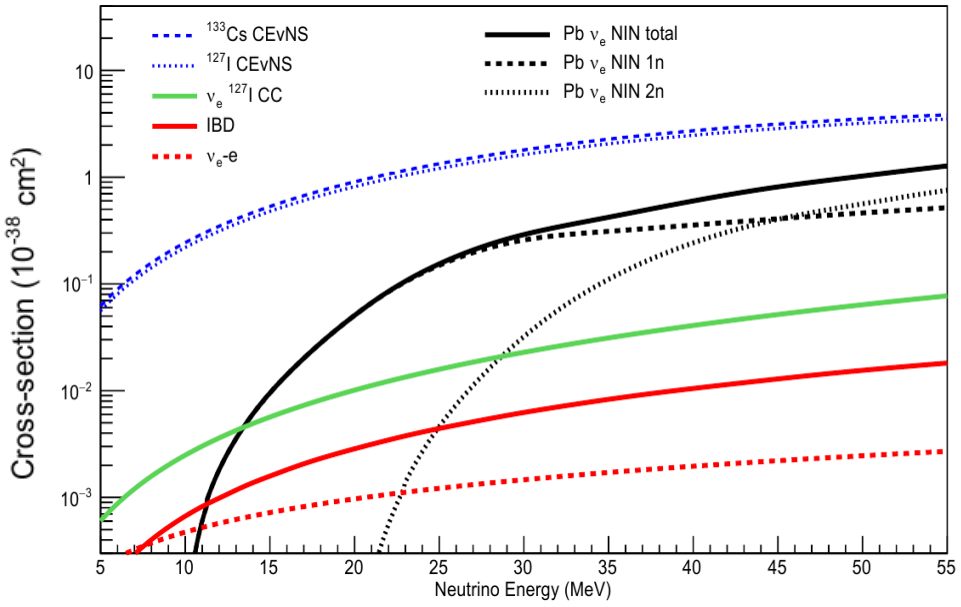
Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790

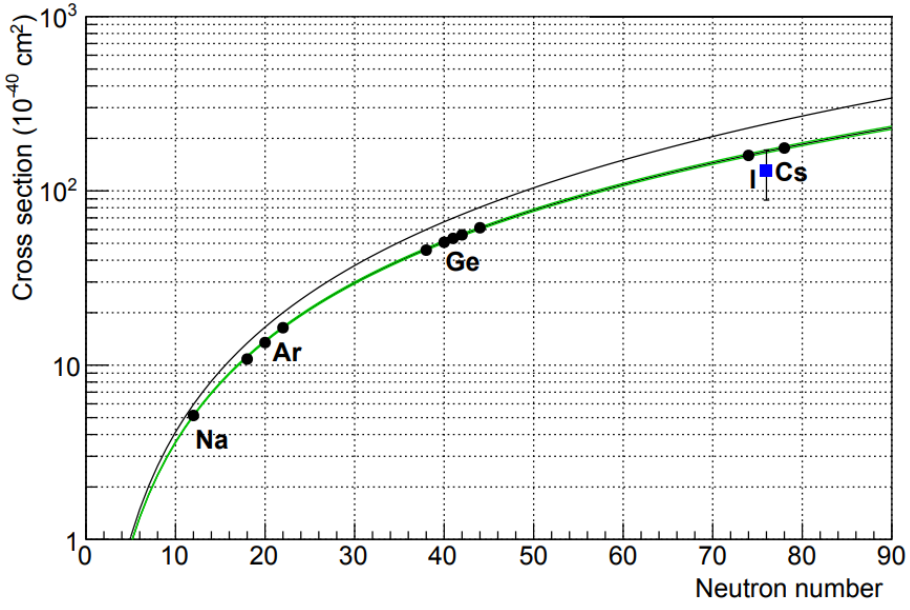
- Predicted by Standard Model
- Cross section:

$$\frac{d\sigma}{d\Omega} = \frac{G^2}{4\pi^2} k^2 (1+\cos\theta) \frac{(N-(1-4\sin^2\theta_W)Z)^2}{4} F^2(Q^2) \propto N^2$$

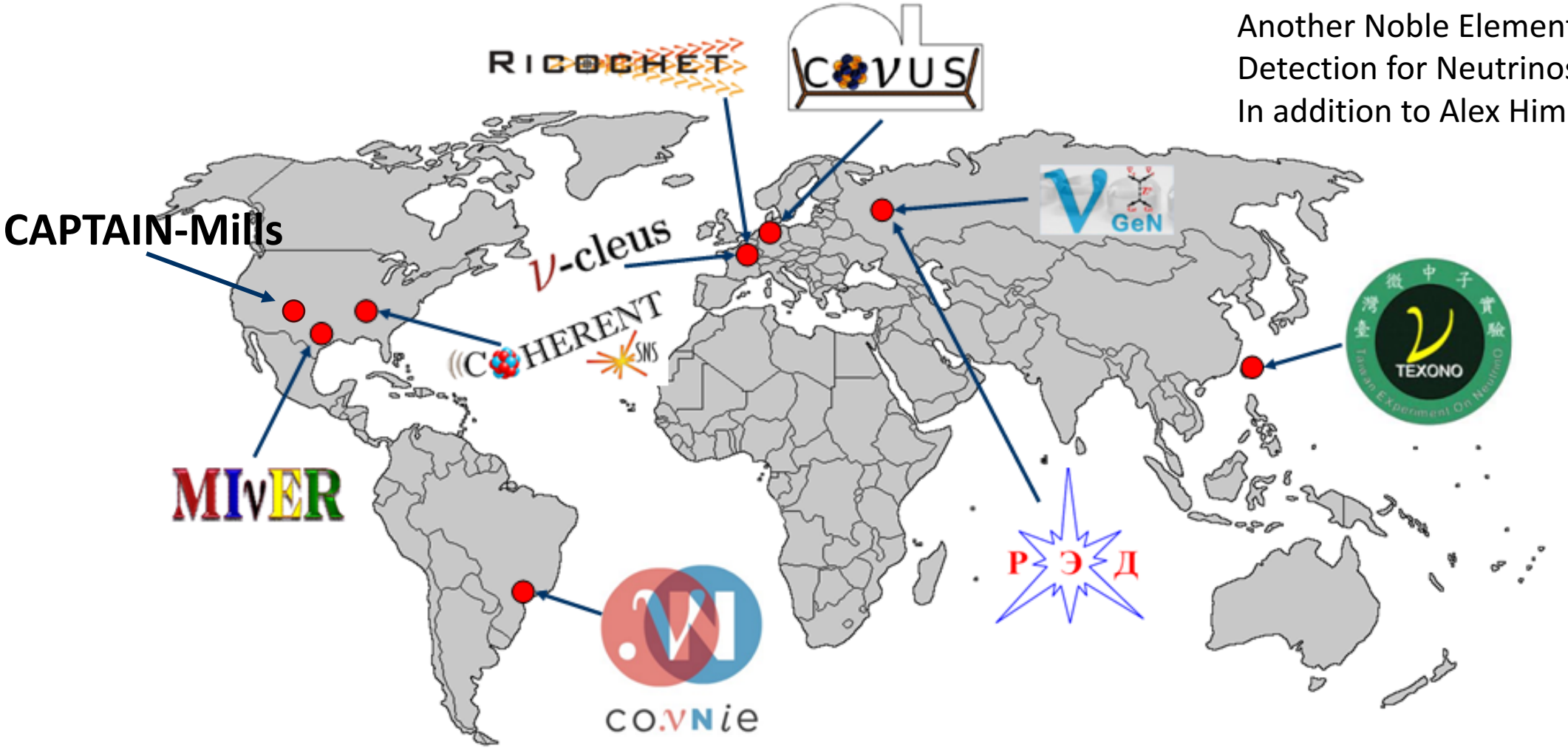
where G – Fermi constant, Z – number of protons, N – number of neutrons, $F(Q^2)$ – nuclear form factor, Q – momentum transfer, k – neutrino energy







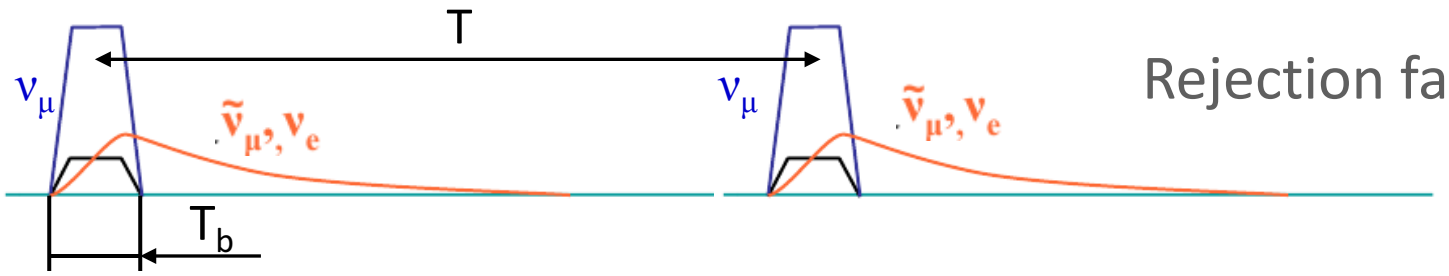
CEvNS searches



Another Noble Elements Light Detection for Neutrinos
In addition to Alex Himmel overview

CEvNS: where to find?

- Reactors
- π production facilities



Rejection factor ≈ T/T_b

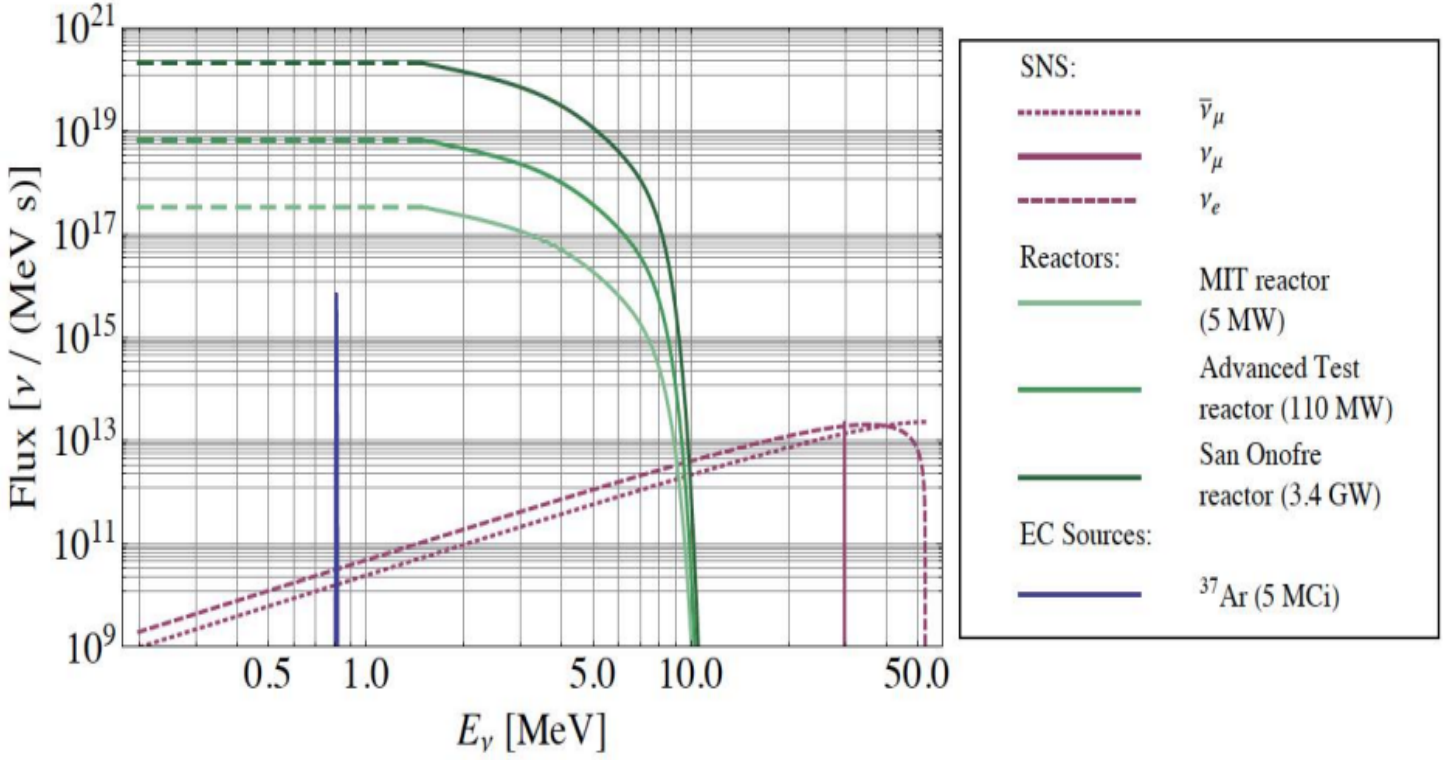
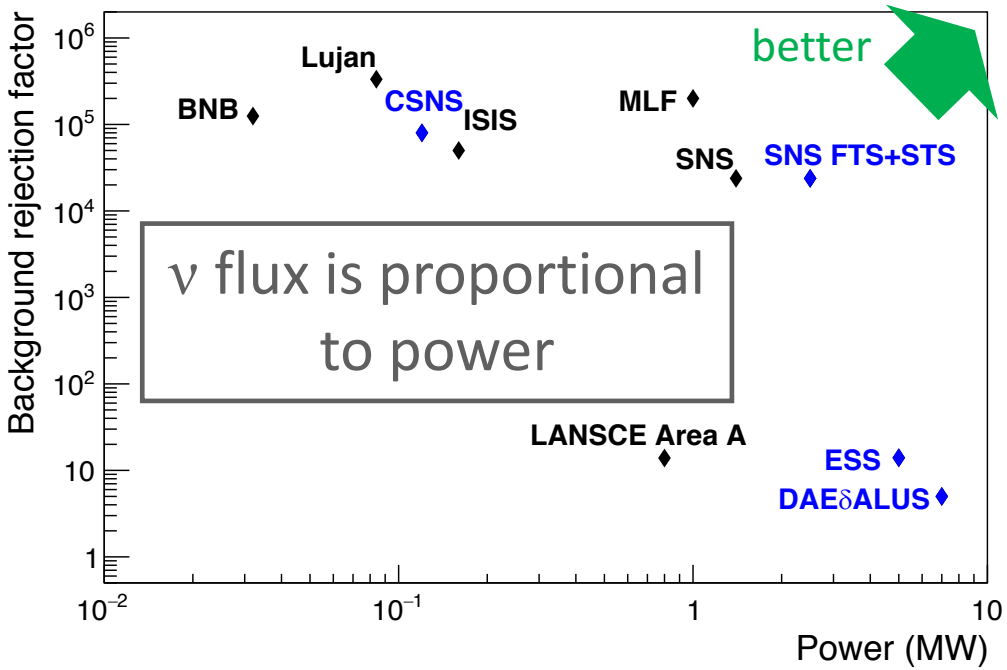
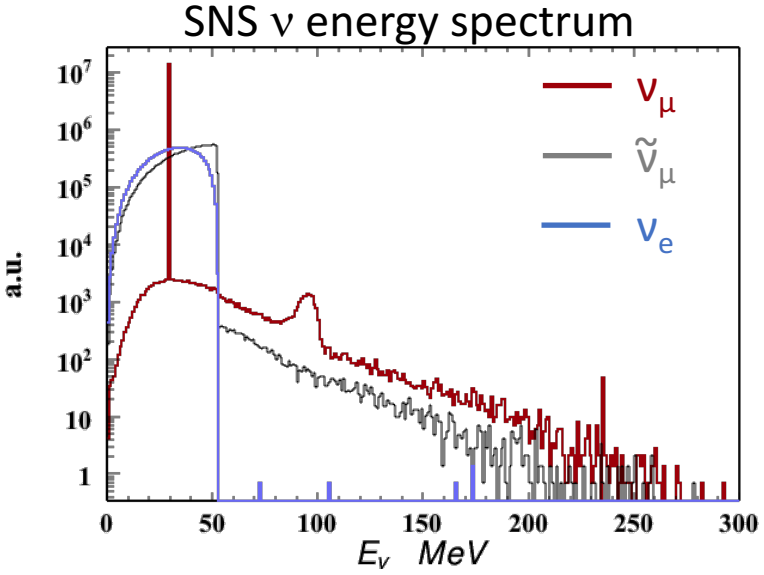


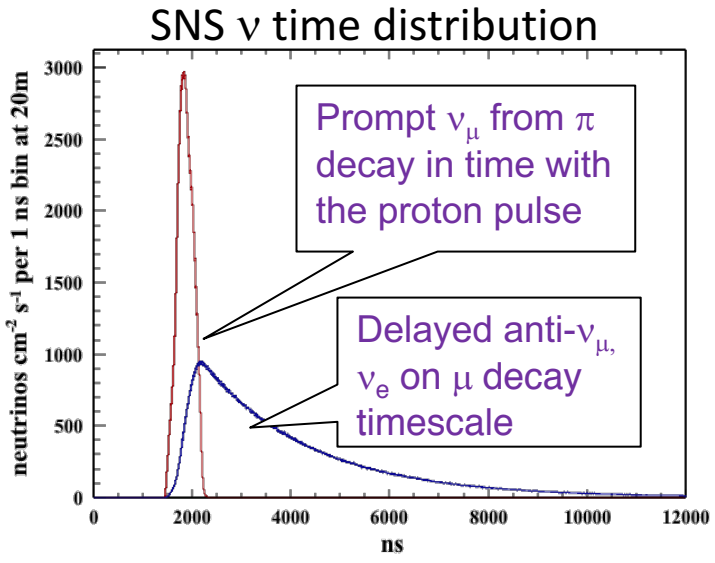
Image by K. Scholberg

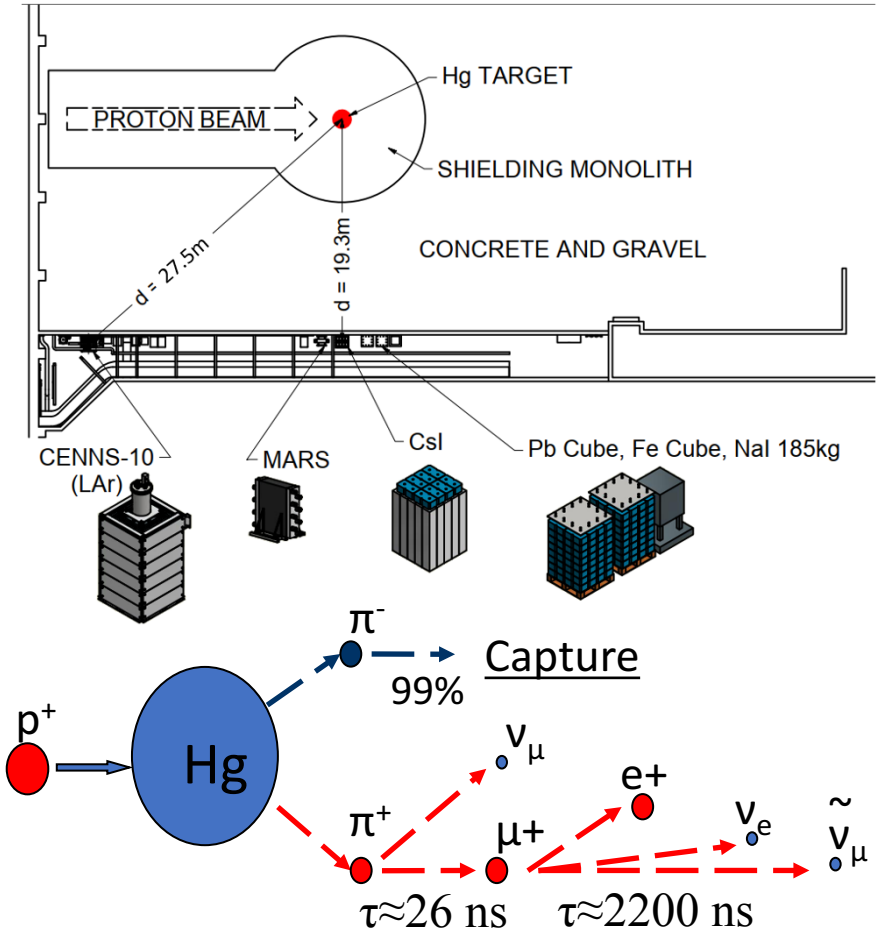


Spallation Neutron Source (SNS)
↳ Neutrino

- 1.4 MWh; ~5000 MWh/yr; $1.5*10^{23}$ POT/yr
- 60 Hz pulsed beam (bunch width is 350 ns FWHM)
- All COHERENT detectors are located in the ~~SNS basement~~ Neutrino alley
- ~ 20 – 28 m from the target



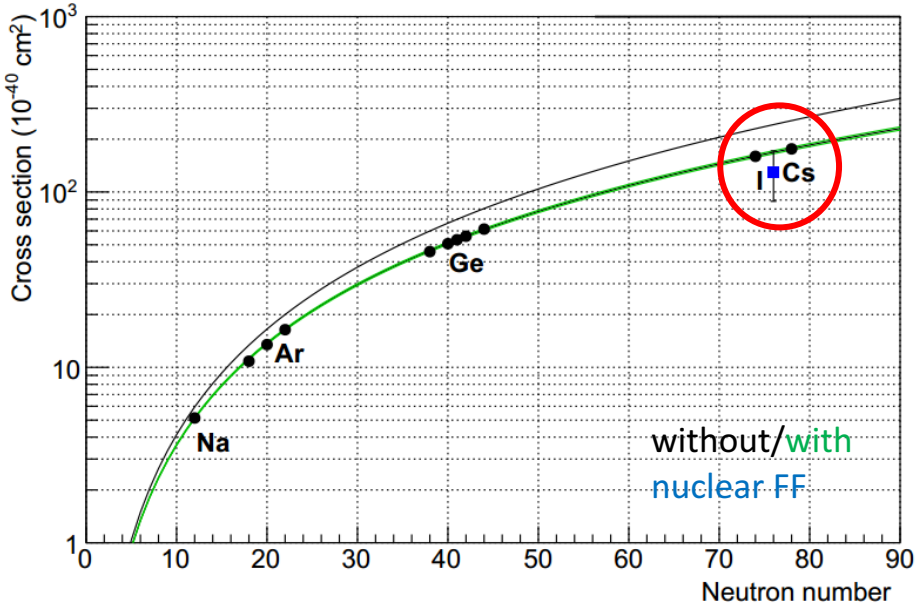


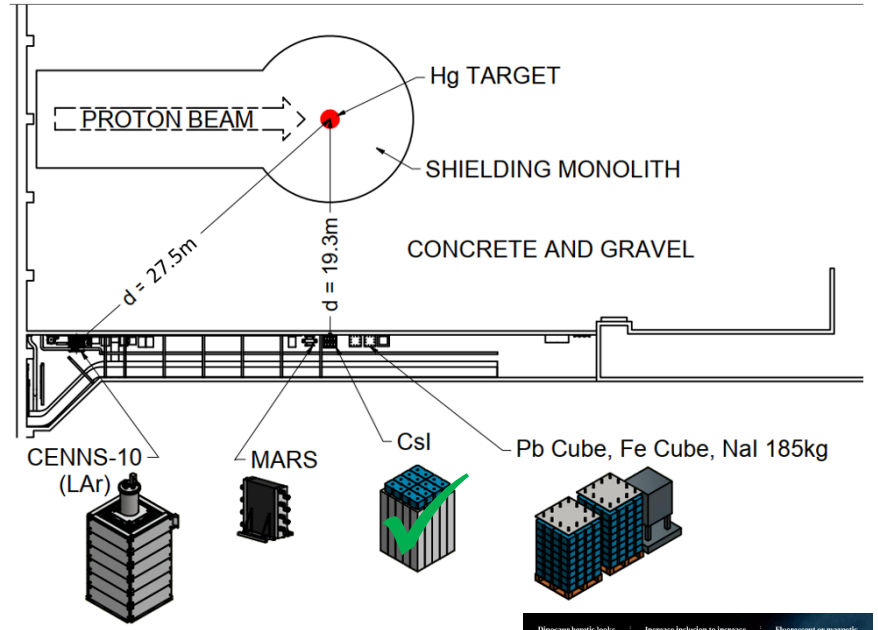


Total neutrino flux
$4.3 \cdot 10^7$ cm^{-2}*s^{-1} at 20m

COHERENT @ SNS

- First CEvNS observation with CsI[Na]
- Multitarget experiment for the $\sigma \sim N^2$ dependence study
- Other physical purposes: NSI, Dark Matter etc





Science, 357 (2017) [arxiv:11708.01294]

COHERENT 2018 at the Spallation Neutron Source [arXiv:1803.09183v2]

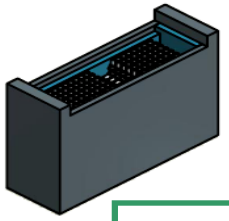
COHERENT @ SNS

Detector subsystems

From the talk of Alexey Konovalov @ Lomonosov 19

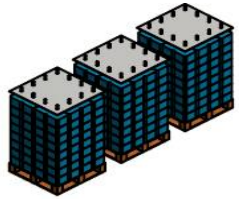
CsI[Na], deployed→decommisioned: 14.5 kg crystal, single PMT readout, LY of 13.4 PE/keV, ~8 keV_{nr} threshold

CENNS-10, deployed: 22 kg liquid argon detector, 2 PMTs readout, LY of 4.5 PE/keV, ~20 keV_{nr} threshold



NaI[Tl]: segmented 185 kg, deployed →2T, ~13 keV_{nr} threshold (Na recoils)

HPGe PPC: 5 kg (cryostat ready, funding secured) →16 kg, ~150 eVee threshold expected (~1keV_{nr})

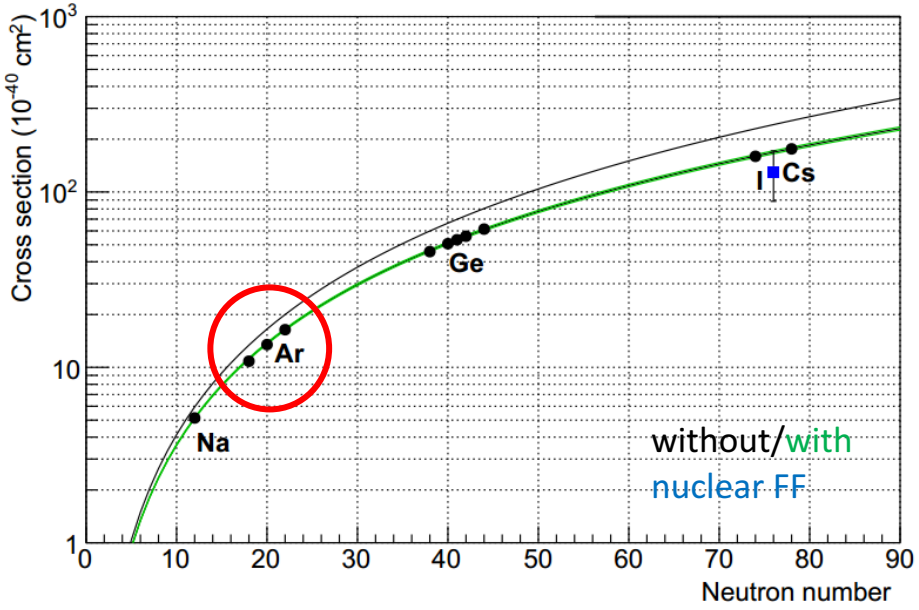


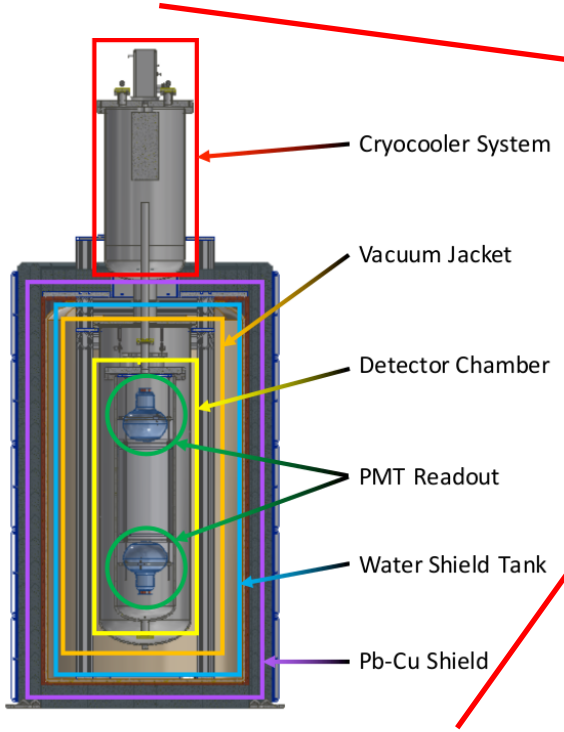
Nubes: 4 LS cells/cube (2*2L+2*1.3L, EJ-301 –PSD capability), surrounded by lead (deployed) / iron (deployed) / copper

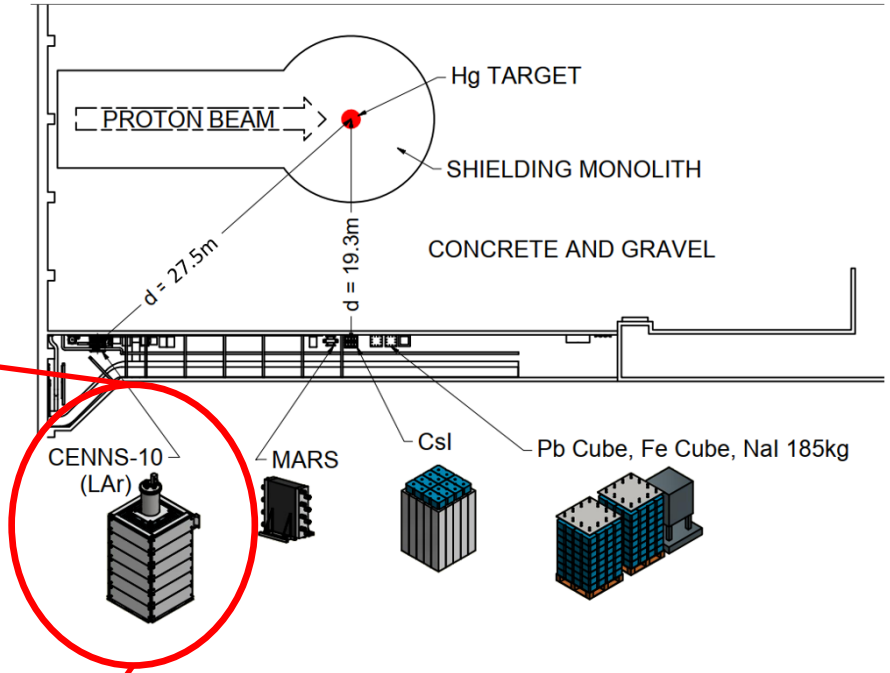
MARS, deployed: BC-408 plastic scintillator interleaved with Gd coated Mylar sheets

COHERENT @ SNS

- The next goal is σ ~ N^2 dependence study
- with CENNS-10 LAr detector





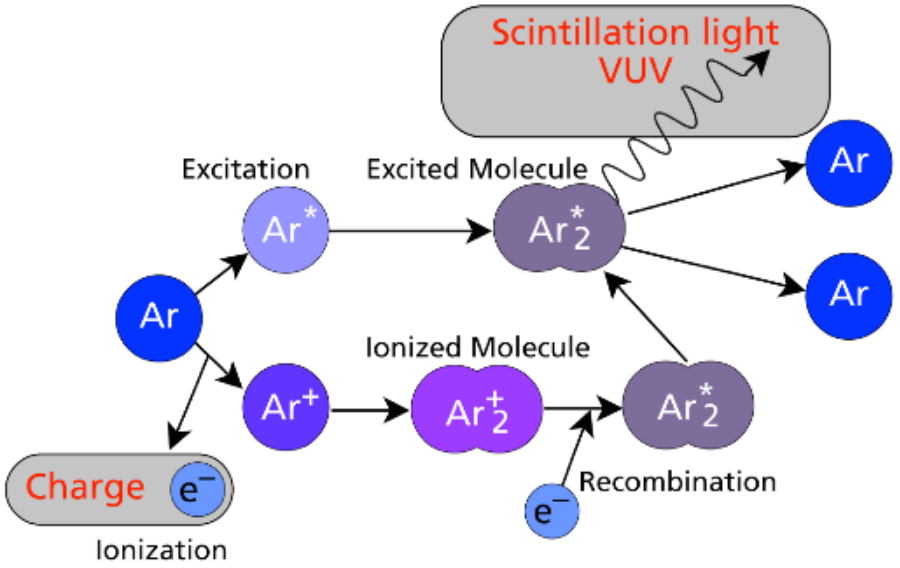


The CENNS-10 Liquid Argon Detector to measure CEvNS at the Spallation Neutron Source [arXiv:1801.00086v2]

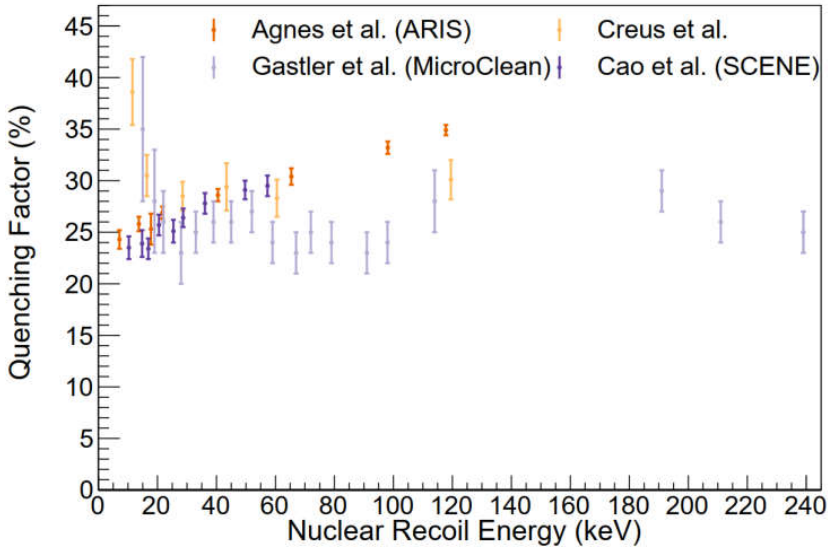
COHERENT 2018 at the Spallation Neutron Source [arXiv:1803.09183v2]

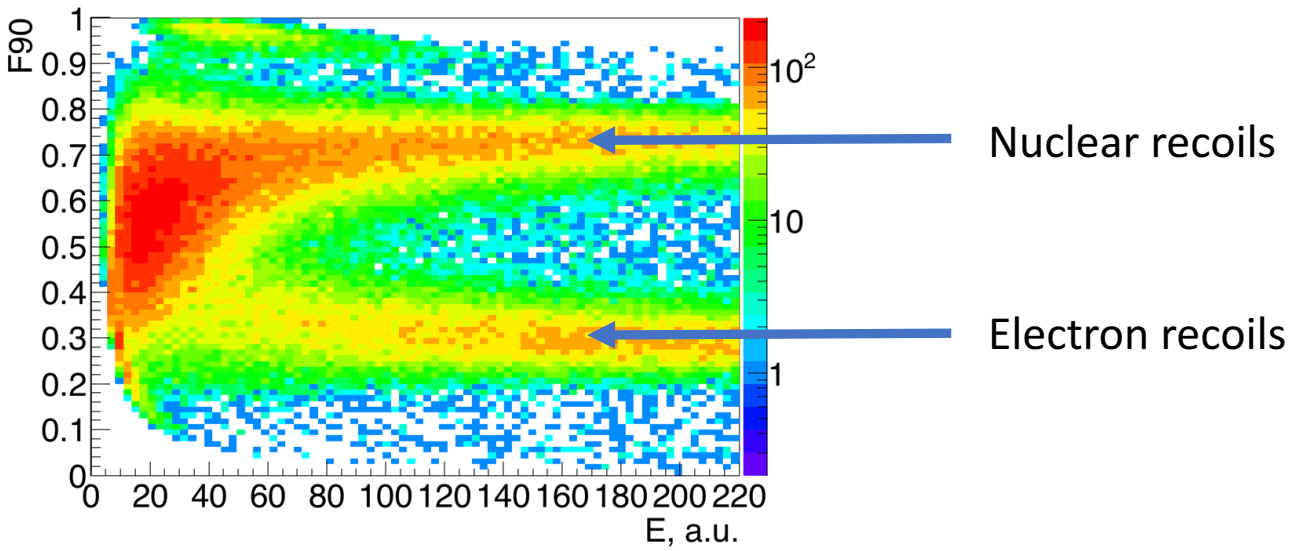
LAr for CEvNS study

- Large scintillation yield ~40 photons/keVee
- Quenching factor is well measured
- Pulse Shape Discrimination is possible
  - There are two scintillation components
    1. Singlet states (~6 ns decay time)
    2. Triplet states (~1.5 μs decay time)
  - Singlet/triplet ratio depends on the recoil type



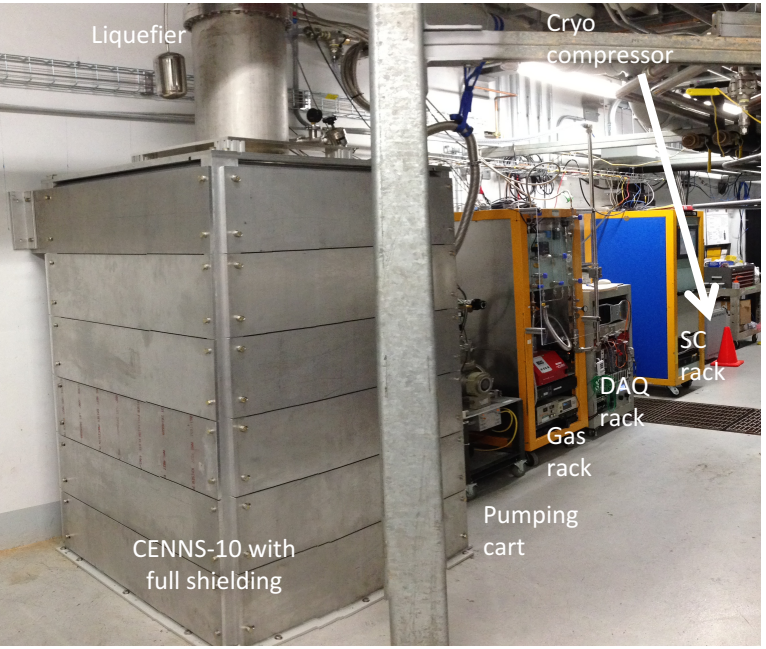
from ArDM

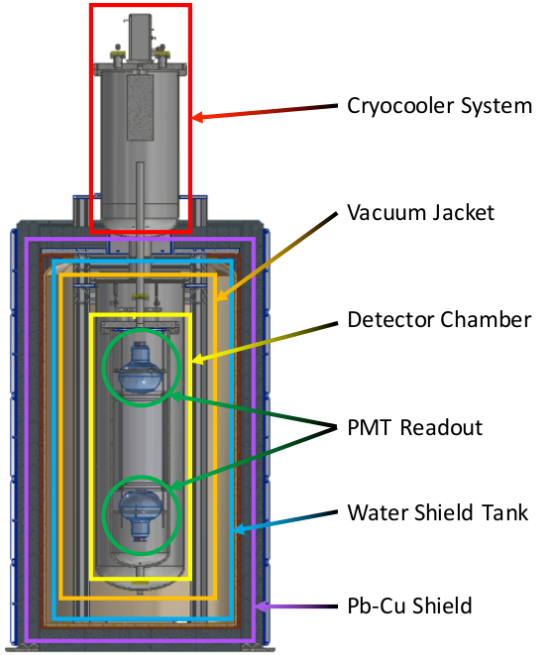


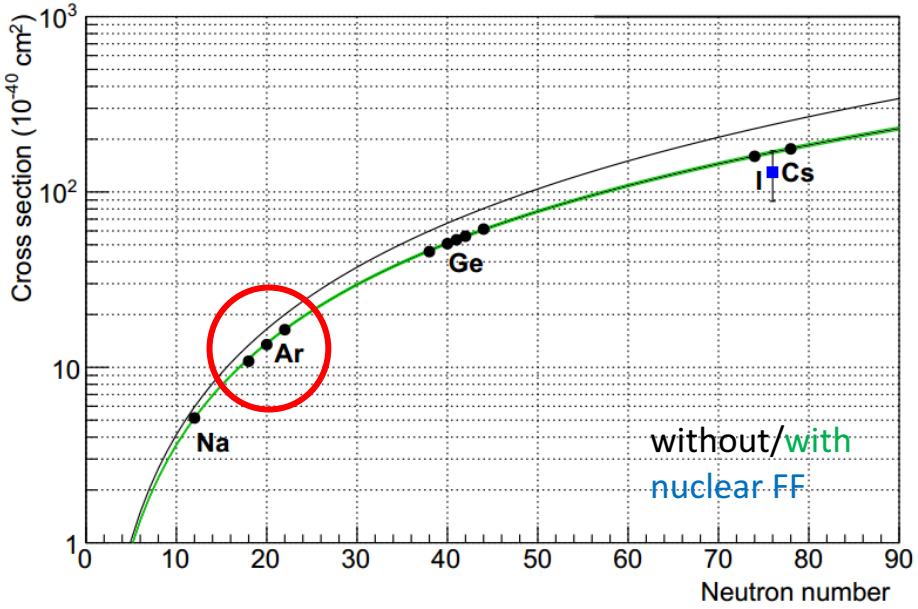


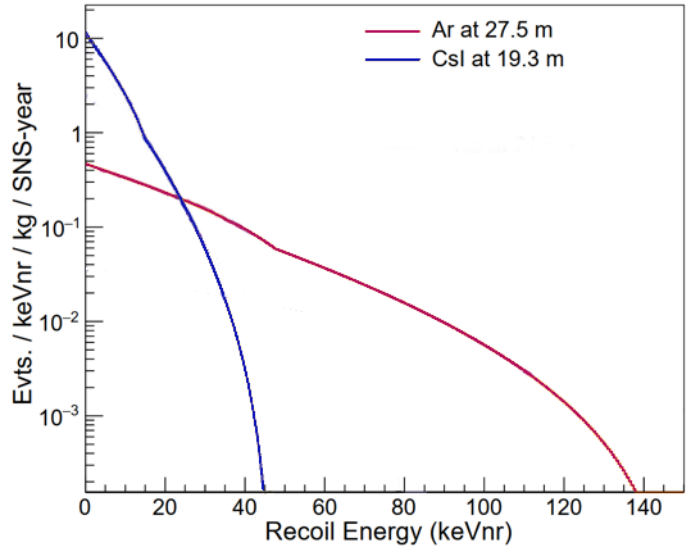
LAr for CEvNS study

- Ar is lighter than Cs and I
- Low region of $\sigma \sim N^2$ dependence
- Lower σ, but more energetic recoils









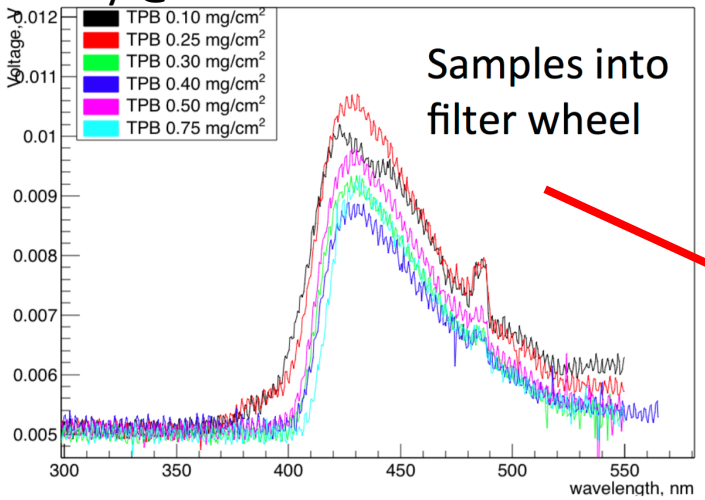
event rates/kg/SNS-yr for COHERENT

CENNS-10 detector

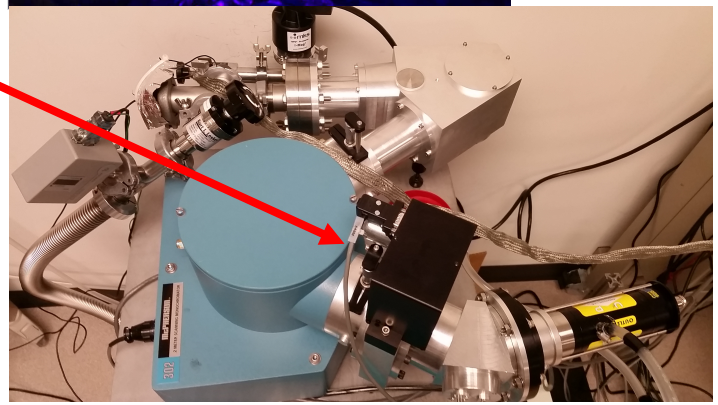
Timeline:

- 2012-15: built at Fermilab (J. Yoo etal) for CENNS@Fermilab effort, commissioned/upgraded at Indiana U.
- late 2016: moved to SNS, installed, shielding built
- early 2017: run with TPB-acrylic parts, E_{thresh}~80keVnr; lots of tests with TPB
  "Engineering Run": 1.8GWhr collected, CEvNS rate low, constrain beam-related bckgrds,
  analysis finished
- mid-17: upgrade: TPB-Teflon reflectors, new TPB-coated PMTs, added 4" Pb shielding
- mid-17-present: run in upgraded mode, E_{thresh}~20keVnr
  "Production Run" : 6.1 GWhr collected,
  blind, 2 parallel, analyses in progress
  in US and Moscow

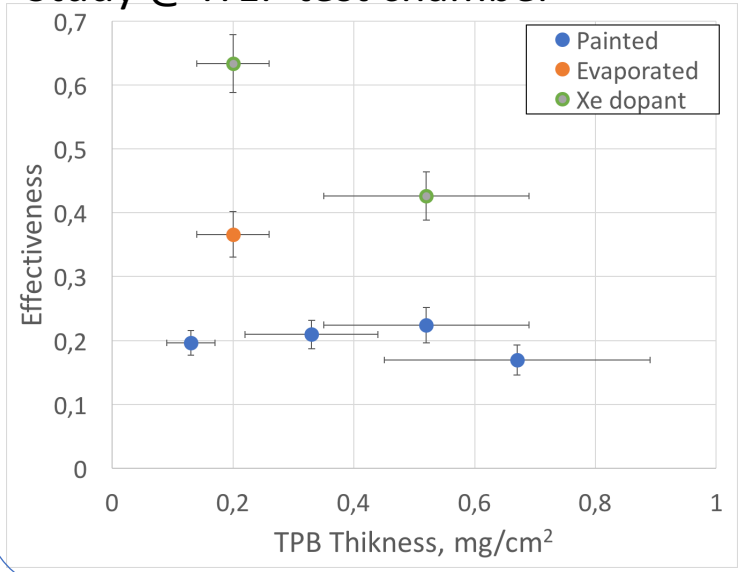
Study @ ORNL VUV monochromator

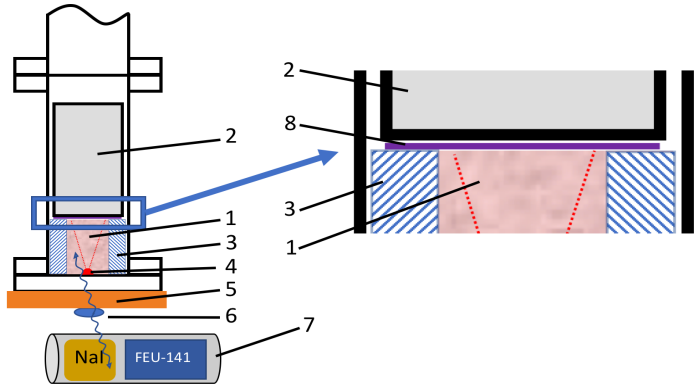


Samples into filter wheel



Study @ ITEP test chamber

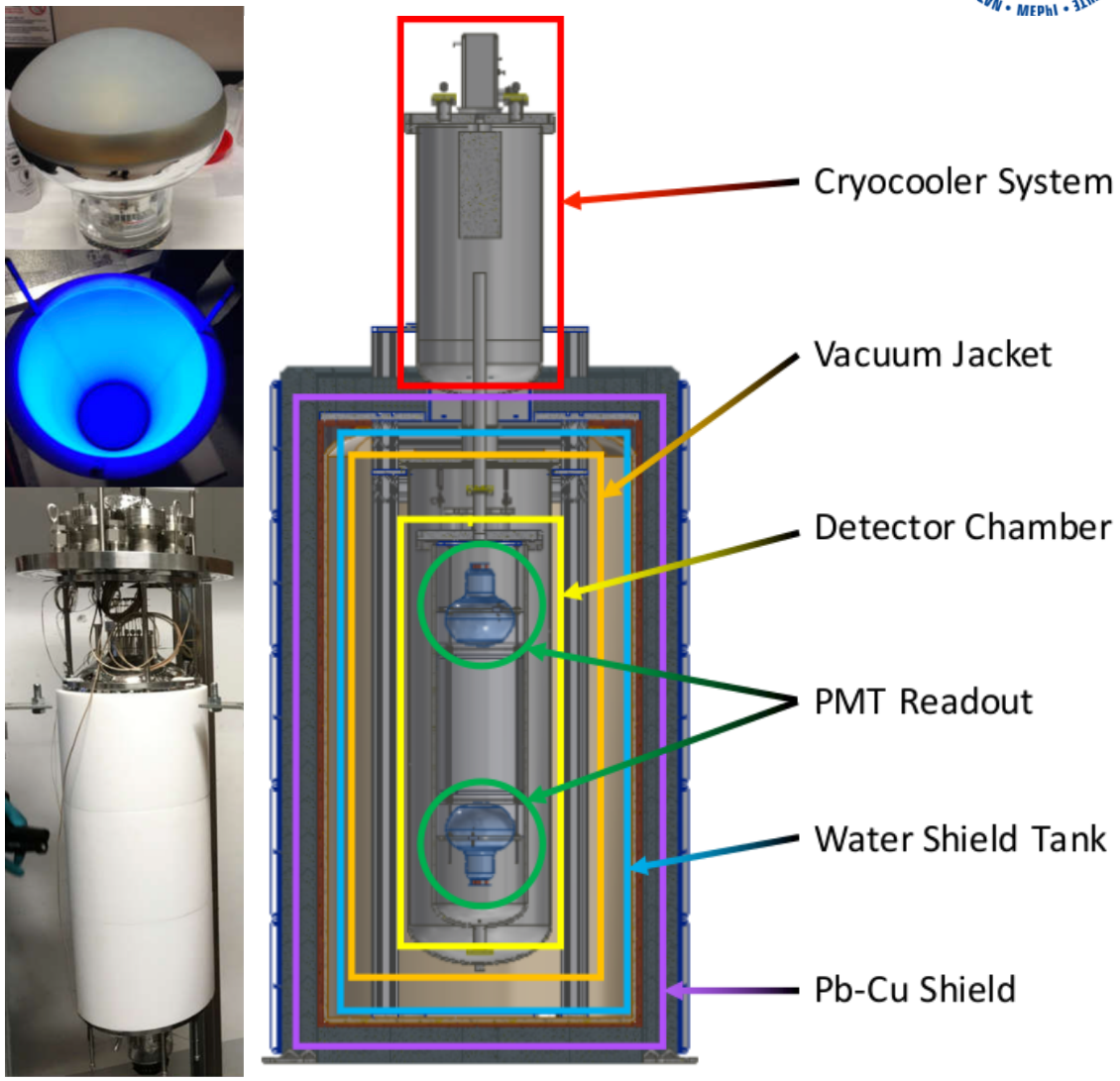




1 – LAr; 2 – PMT; 3 – Teflon insert; 4 – ^{241}Am; 5 – cupper housing; 6 – ^{22}Na; 7 – NaI[Tl]; 8 – sample

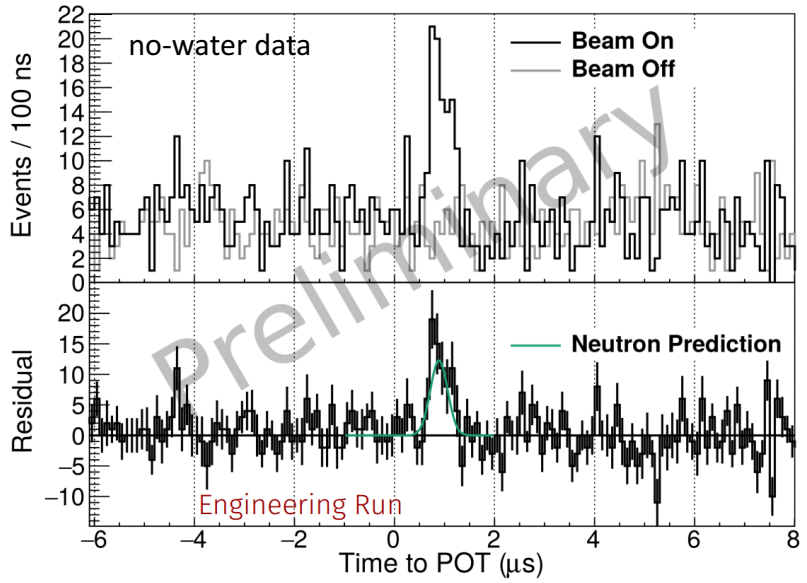
CENNS-10 detector

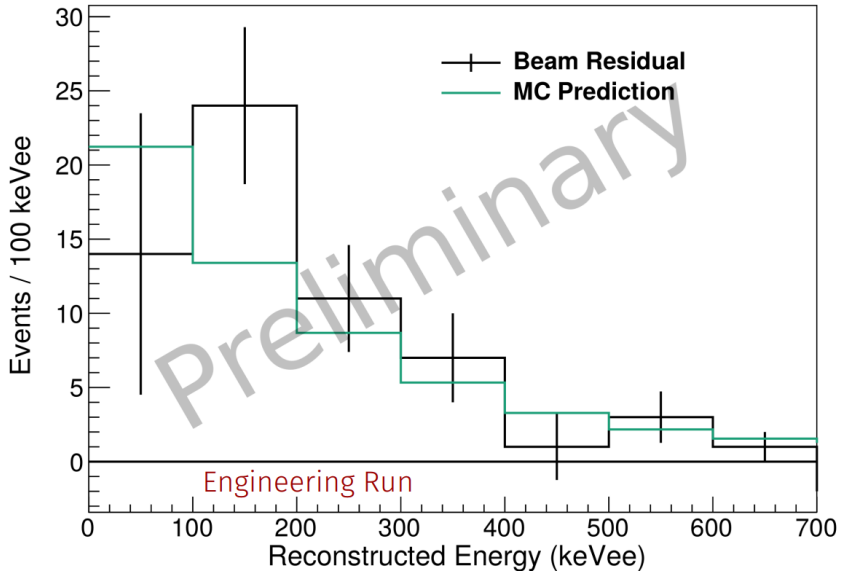
- 22 kg single-phase LAr in fiducial volume
- 2×8”PMTs Hamamatsu R5912-02MOD TPB-coated, w/QE=18%@400 nm
- TPB-coated PMTs/Teflon side walls
- Energy threshold ≈ 20keVnr
- CAEN 1720 (250MHz, 12-bit) digitizer
- 90W single-stage pulse-tube cold head
- SAES MonoTorr gas purifier for ~1 ppm purity
- Pb/Cu/H2O shield
- Expect ≈140 CEvNS events/SNS-year
- Running in current configuration since July ‘17



CENNS-10 detector

- Analysis overview
  - Calibration
    - SPE
    - Different sources
  - Background study
    - Steady-state (beam off) background
    - Beam related neutrons (BRN) without water shielding and other neutron detectors
  - MC & Cuts optimization
  - Double check and verify everything
  - “Open the box”
    - Counting experiment
    - Full likelihood analysis

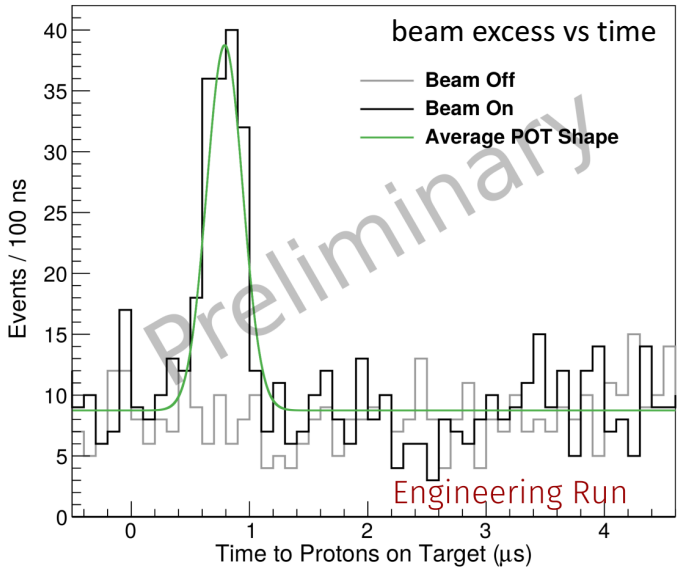


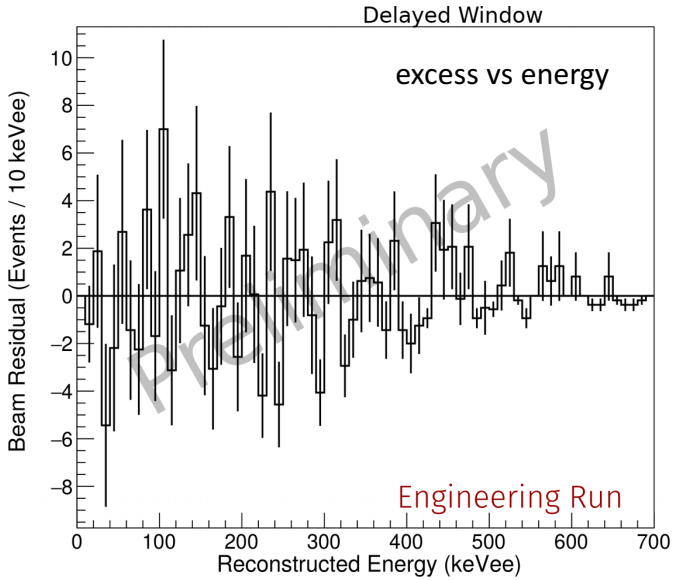


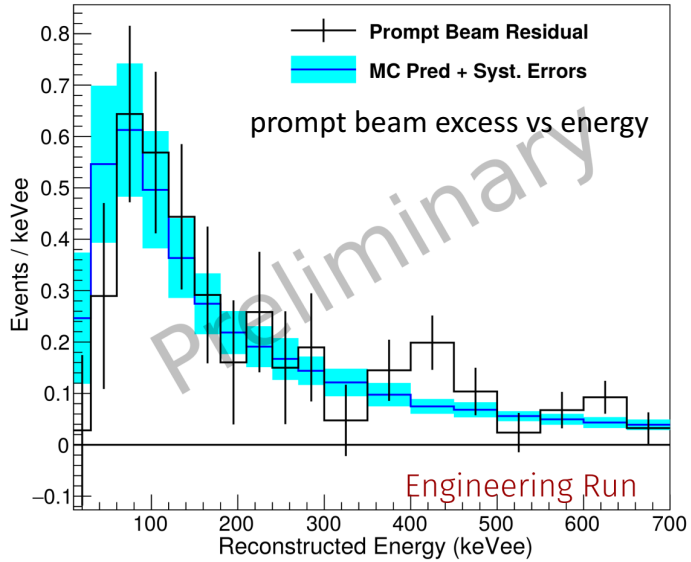
Engineering run results

- Event excess in the prompt region is consistent with BRN prediction
- No event excess observed in the delayed window (0.5 CEvNS expected)
  - Limit on the delayed neutron background
  - Limit on the CEvNS cross section

work of
IU PhD Student:
Matthew Heath

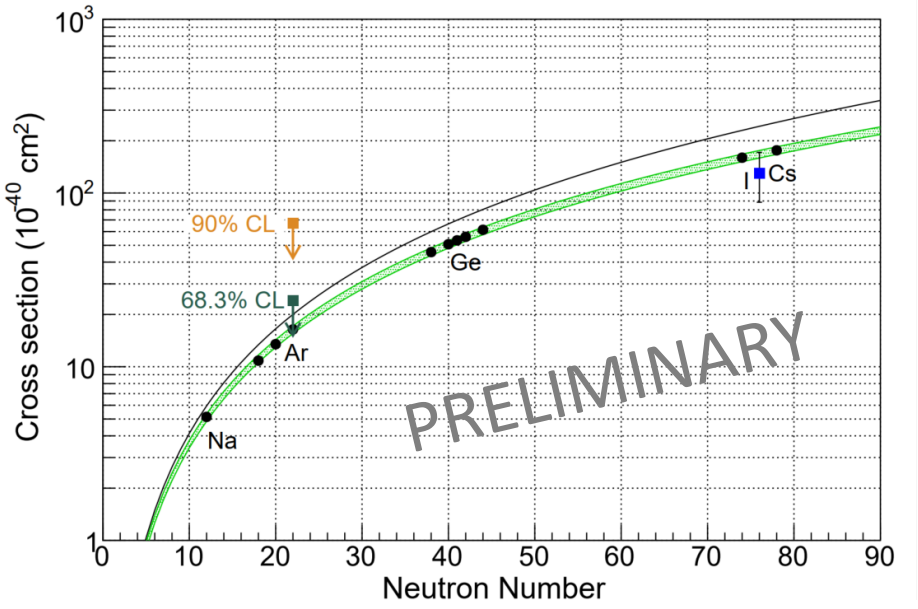


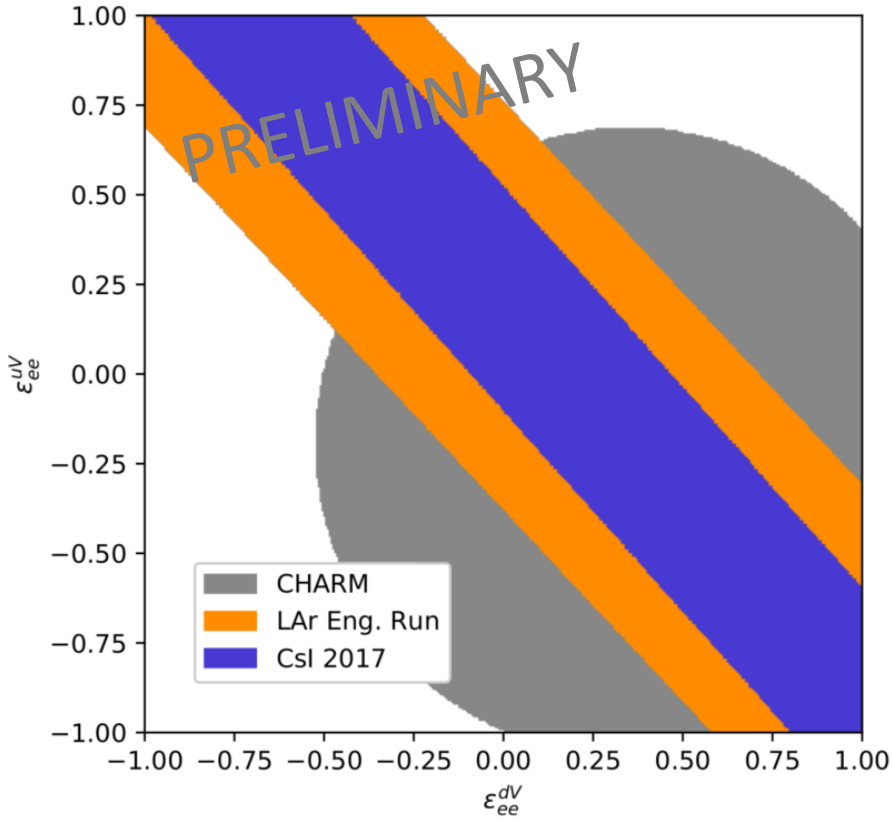




Engineering run results

- Full likelihood analysis results
  - Cross section limits
  - Non-standard interaction constraints



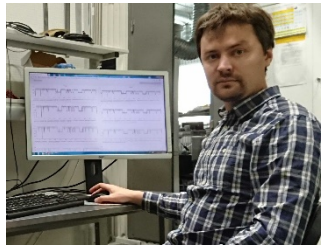


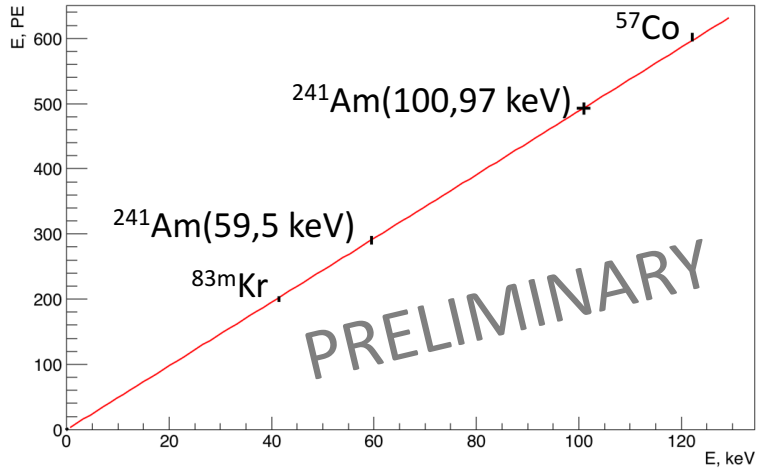
Production run analysis status

- Light Yield (LY) was improved to ~4.5 PE/keVee
- PSD, energy resolution/threshold sufficient for CEvNS observation
- ^{83m}Kr study: LY is linear down to ~9 keV
- SM prediction: 130 CEvNS in this data set
- Blind dual analysis scheme
- Both groups are in the end stage of analyses
- Results soon!

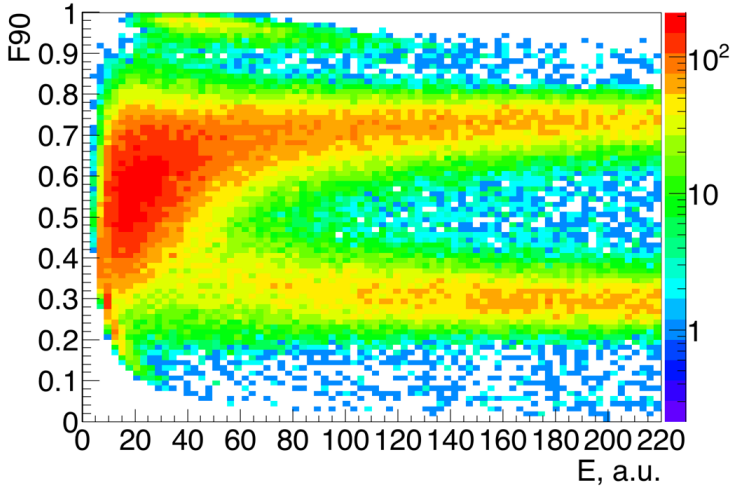
US group: Indiana U:
Jacob Zettlemoyer

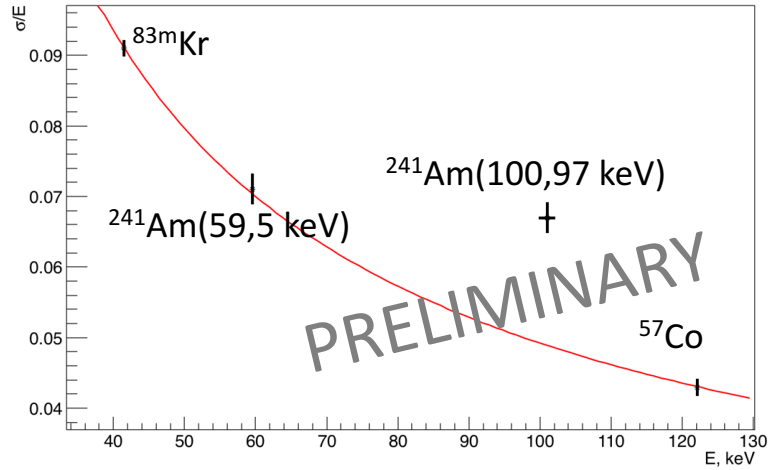
Russian group: ITEP/MEPHI (Moscow):
Dmitry Rudik, Alex Kumpan,





AmBe data, particle ID





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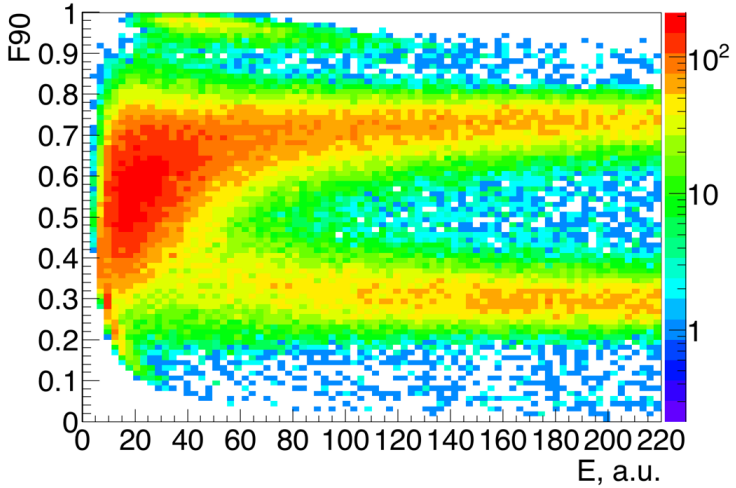
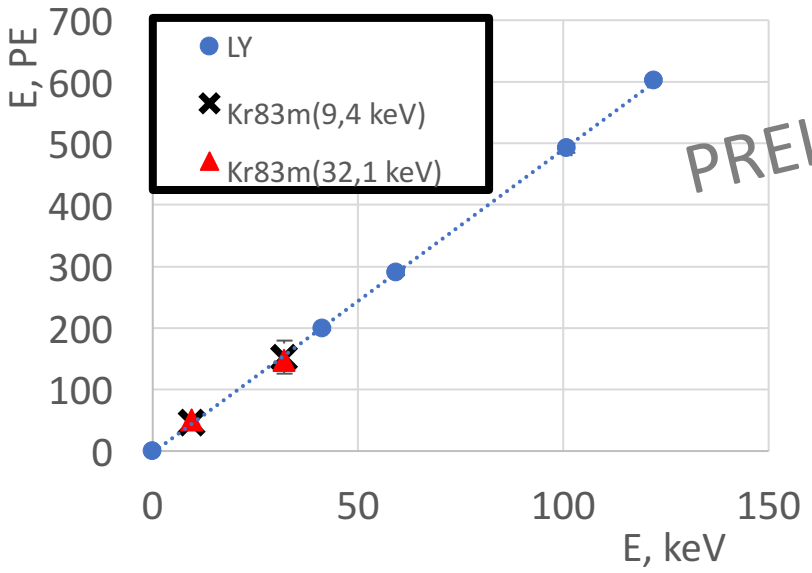
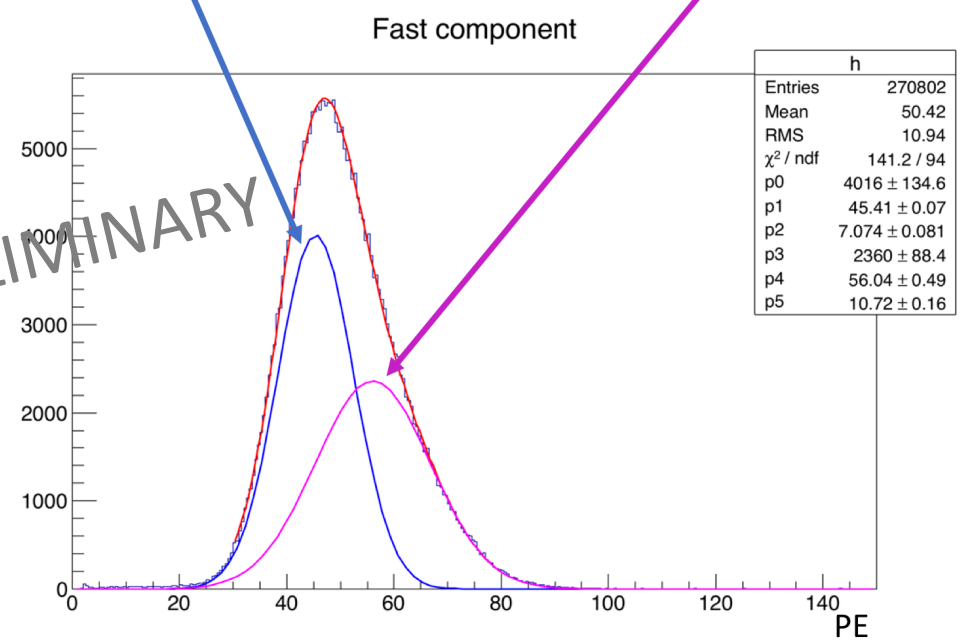


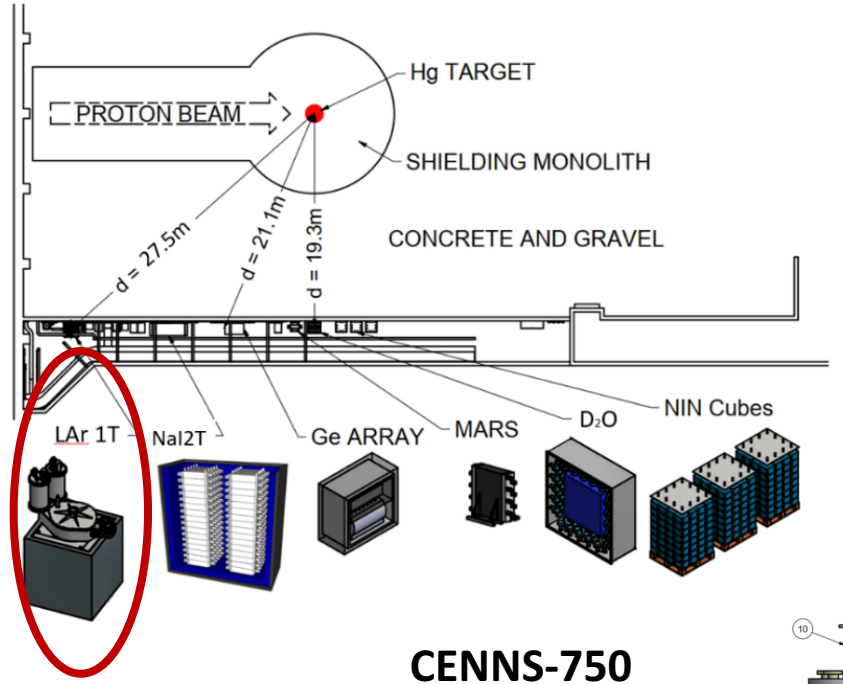




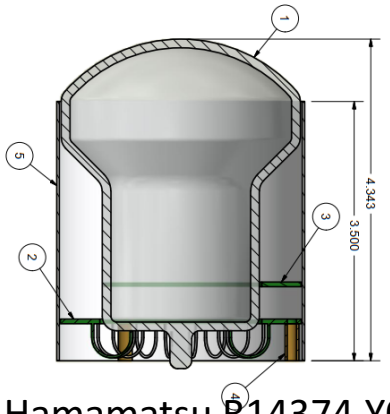
Future

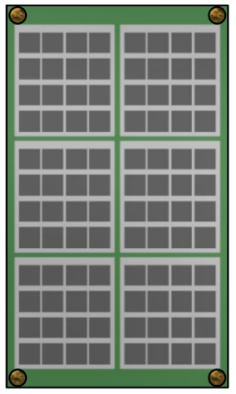
CENNS-750

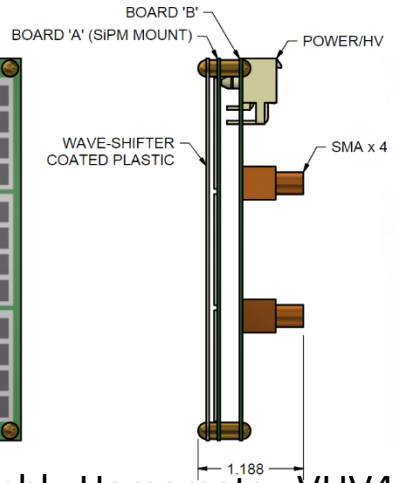
- Based on our experience with CENNS-10
- Single-phase LAr, 750/610 kg total/fiducial
- Purpose-designed cryostat w/LN2 precool, and dual cryocooler for liquification/gas purification.
- **Light collection**:
  - TPB (?)
  - Xe-dopant (?)
  - combined with 3”PMTs/SiPMs
- Eventual use of underground (low ^{39}Ar) argon
- $\Rightarrow$ 3000 CEvNS, 440 inelastic CC/NC events/yr !



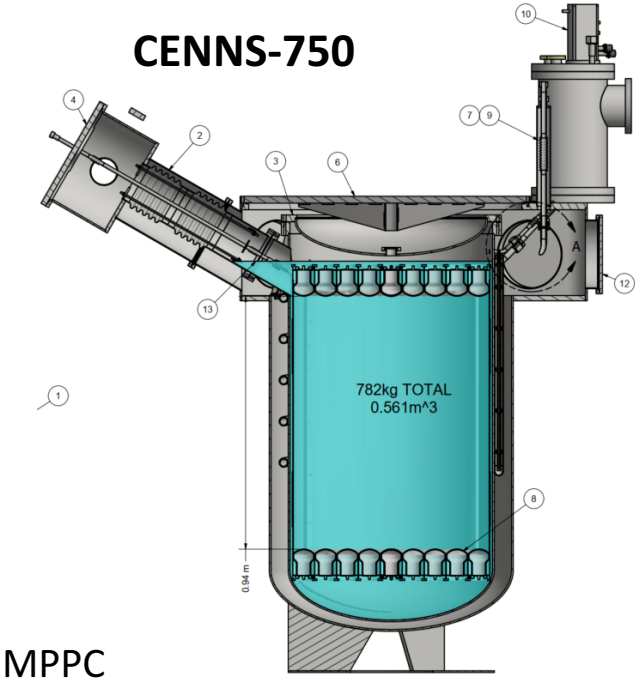
Now under investigation →
We also look for another options







CENNS-750

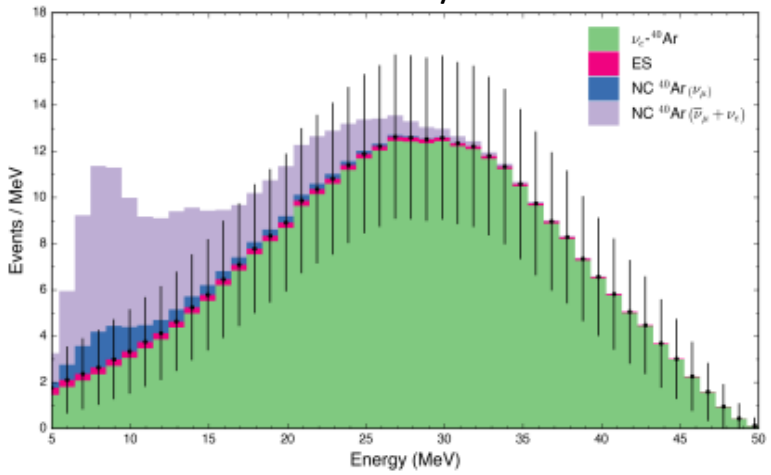


3” PMT assembly Hamamatsu R14374-Y004 SiPM assembly Hamamatsu VUV4 MPPC

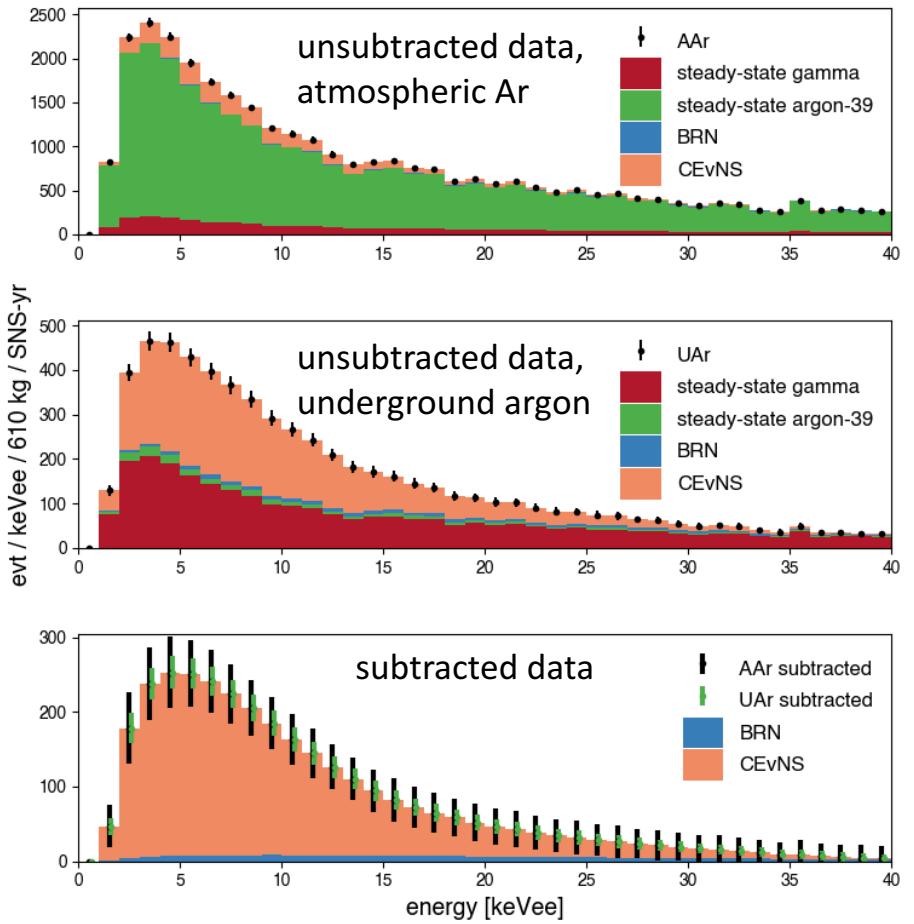
Future

- Preliminary MC predictions
- ~3000 CEvNS events/year
- ~440 inelastic CC/NC events/year

estimated inelastic CC/NC CEvNS rates

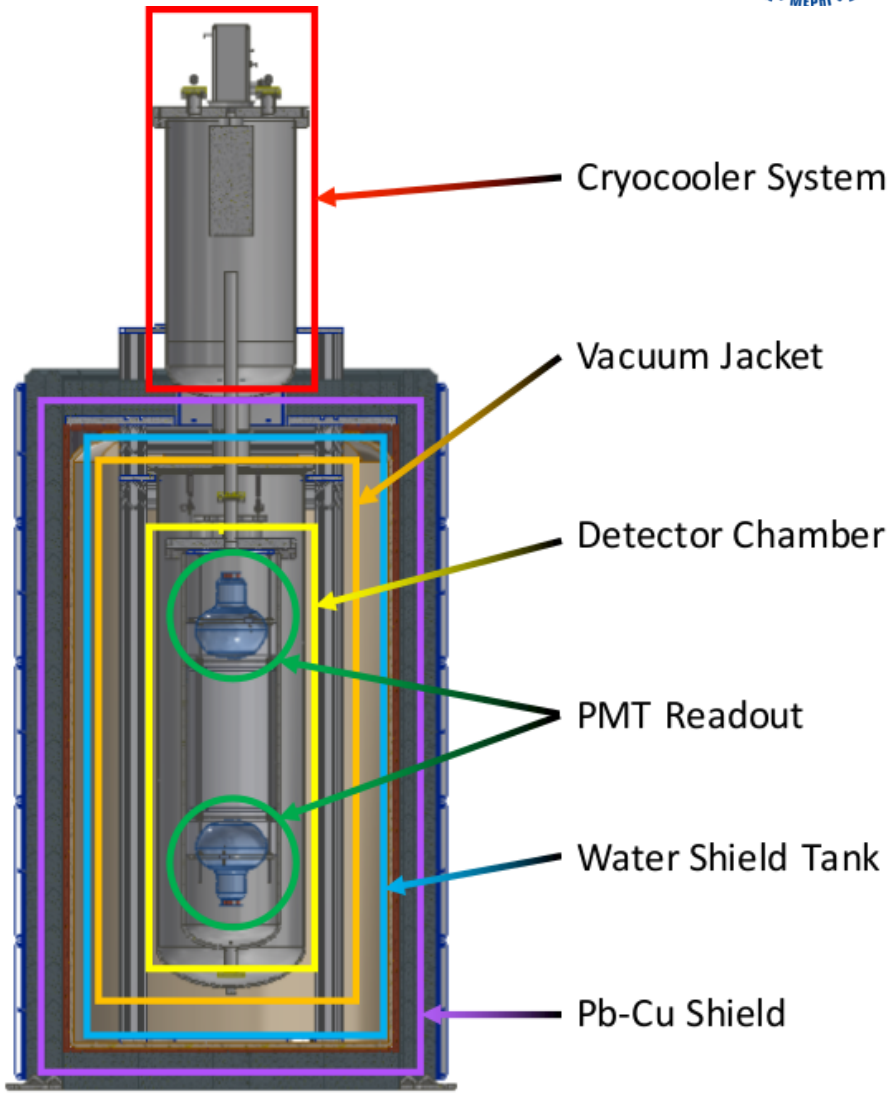


simulated CEvNS + background rates



Nearest future program with CENNS-10

- Increase statistic in current configuration
- BRN investigation
- Light readout tests for CENNS-750
  - 3” PMTs
  - SiPM
  - Xe-doping of high concentration
    - With TPB
    - Without TPB



Summary

- First CEvNS observation with CsI[Na] within COHERENT experiment
- CENNS-10 LAr detector for the N^2 dependence study is running
- First results from the engineering run of CENNS-10 LAr detector
  - Constraints on the CEvNS cross section
  - Constraints on the NSI parameters
- More results from the production run of CENNS-10 will coming soon
- Upcoming big program of light collection investigation with CENNS-10
- CENNS-750 in a future