Status of the CENNS-10 LAr detector within the COHERENT experiment

Rudik Dmitry on behalf of COHERENT coll.

Moscow, 26/08/2019, 19 Lomonosov Conference

~ 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
- Summary

This presentation is based on the R. Tayloe's talk @ APS DPF 19

Coherent Elastic Neutrino Nucleus Scattering (CEvNS)

See Alexey Konovalov's talk for more details

PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

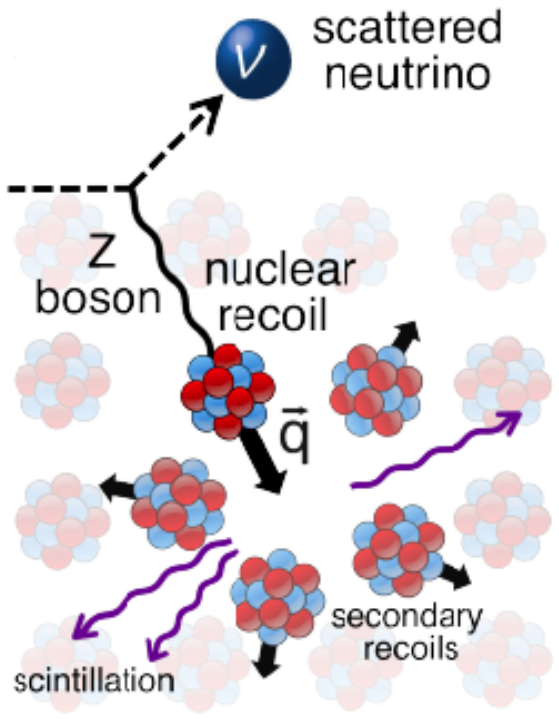
Coherent effects of a weak neutral current

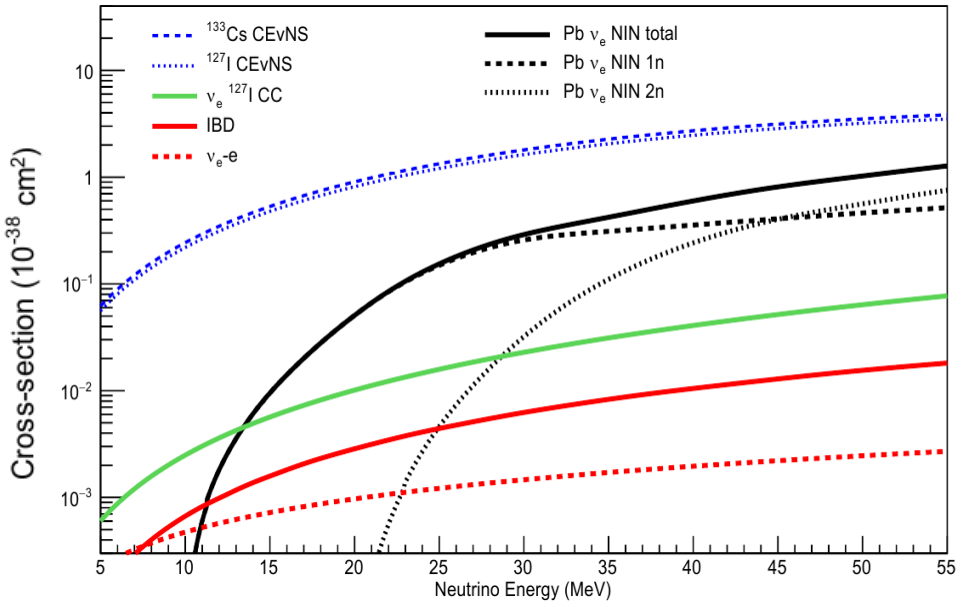
Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790

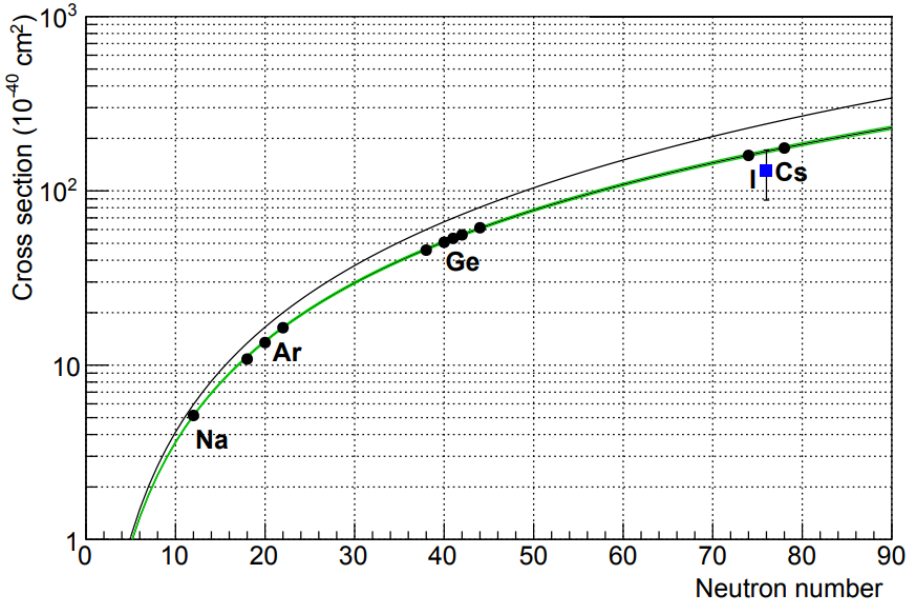
- Predicted by Standard Model
- Cross section:

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

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



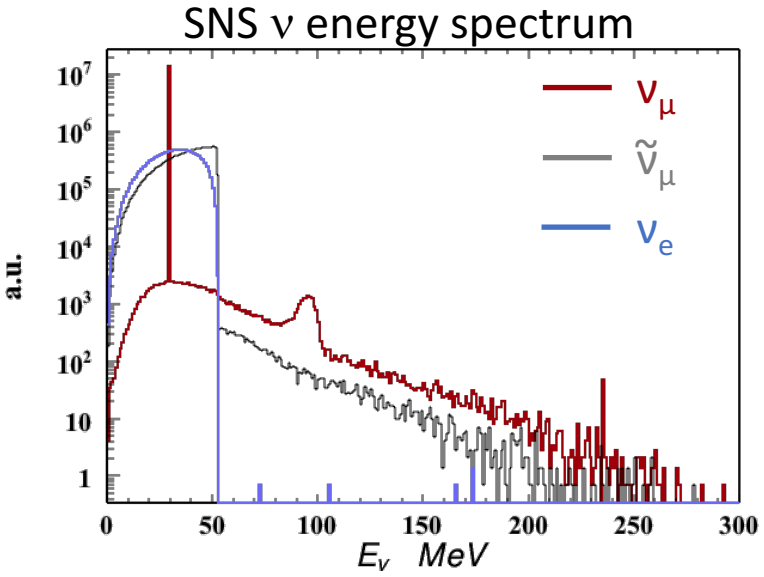


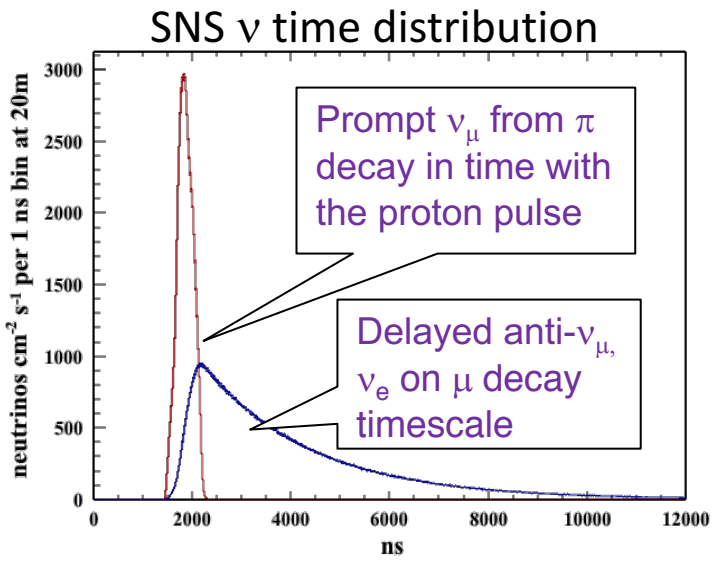


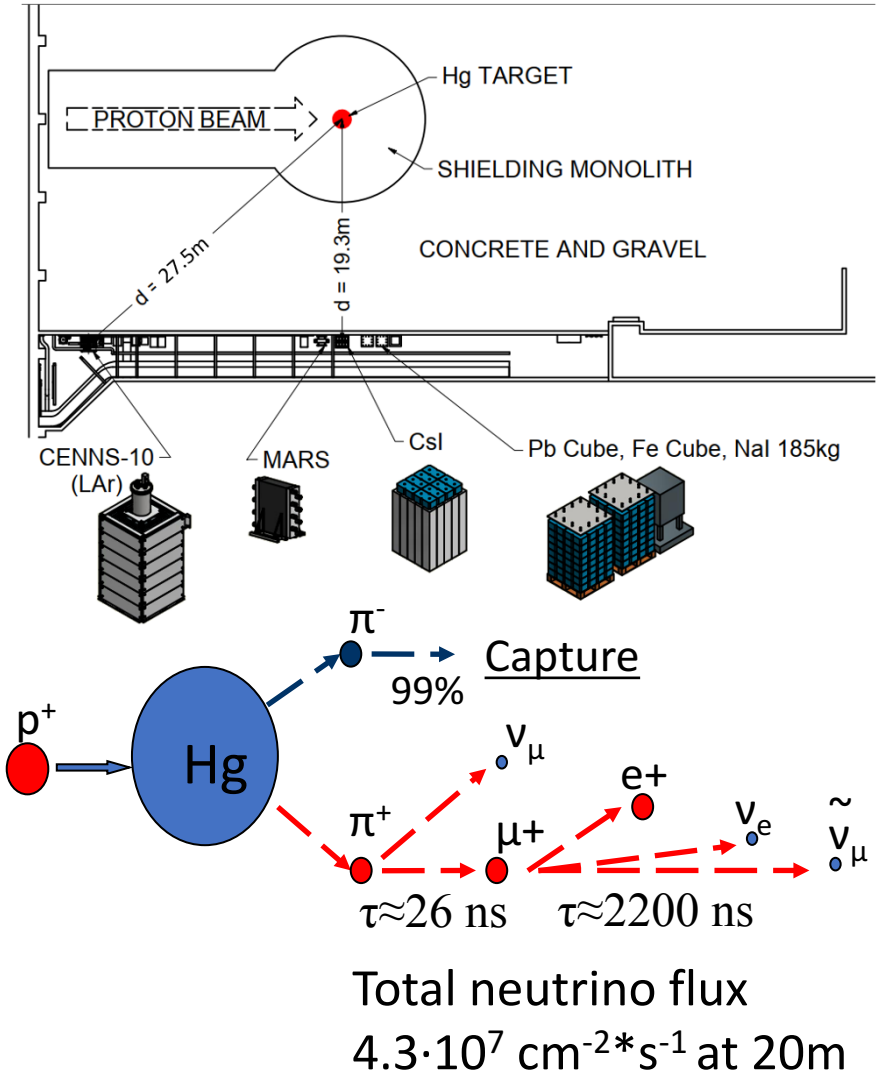
Spallation Neutron Source (SNS)
↳ Neutrino

See Alexey Konovalov's talk for more details

- 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





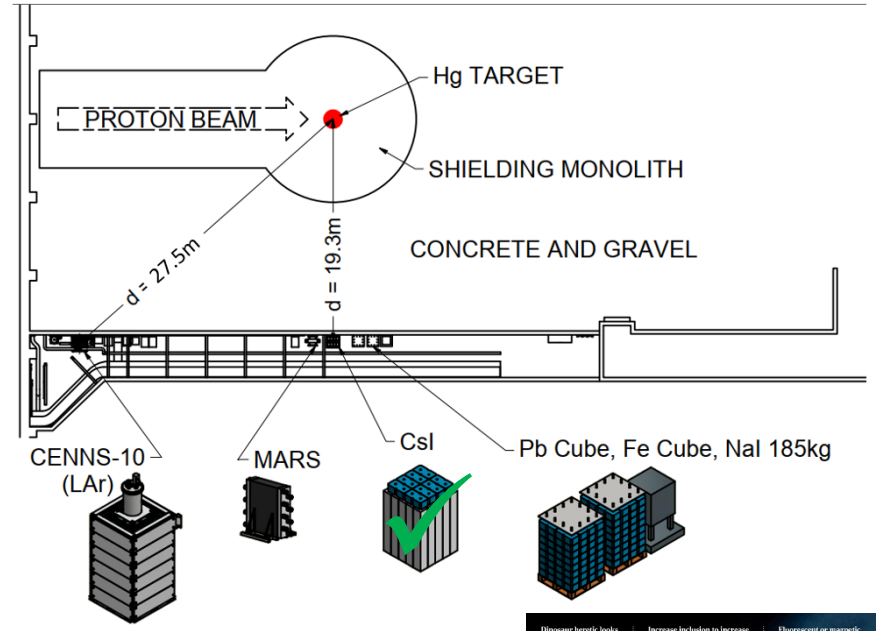


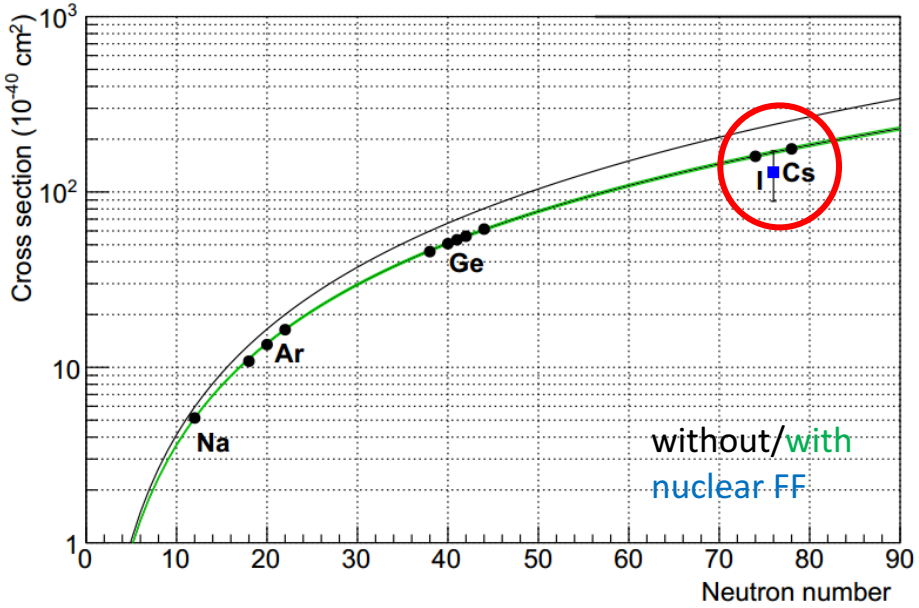
Total neutrino flux
$4.3 \cdot 10^7$ cm^{-2}*s^{-1} at 20m

COHERENT @ SNS

See Alexey Konovalov's talk for more details

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



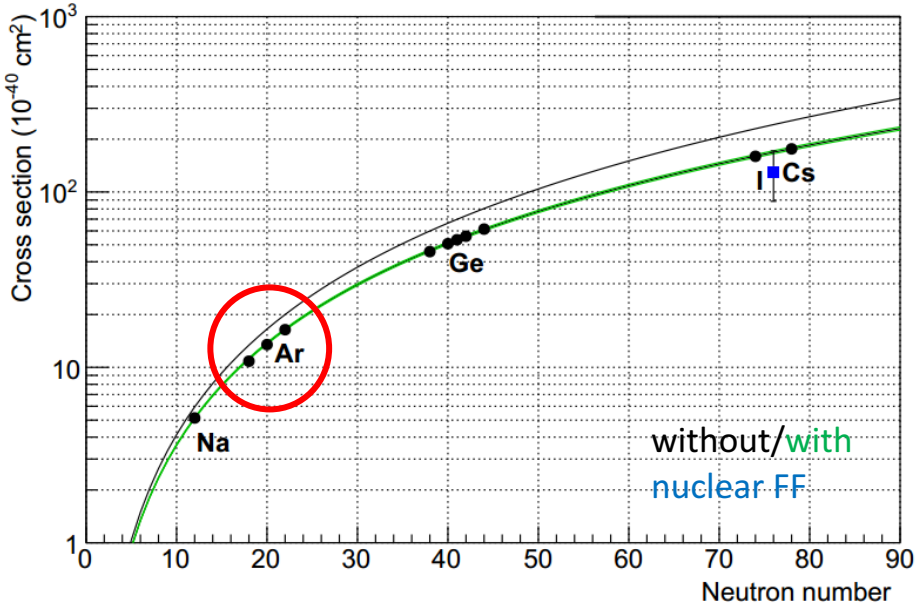


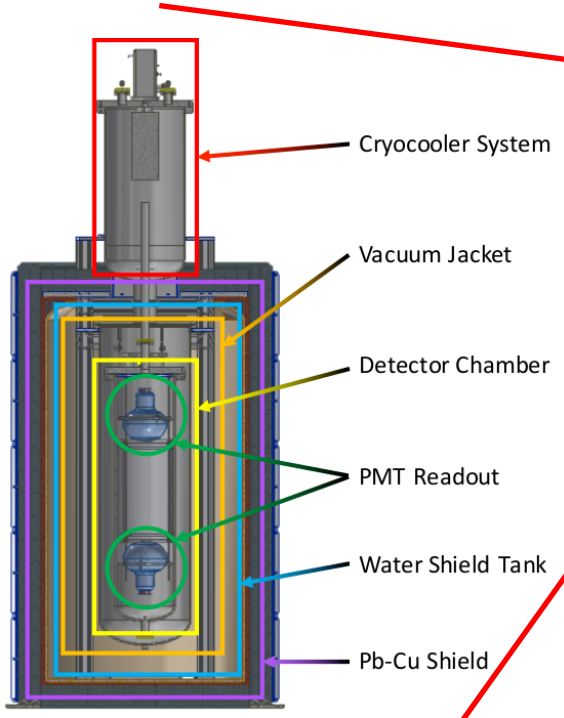
Science, 357 (2017) [arxiv:11708.01294]

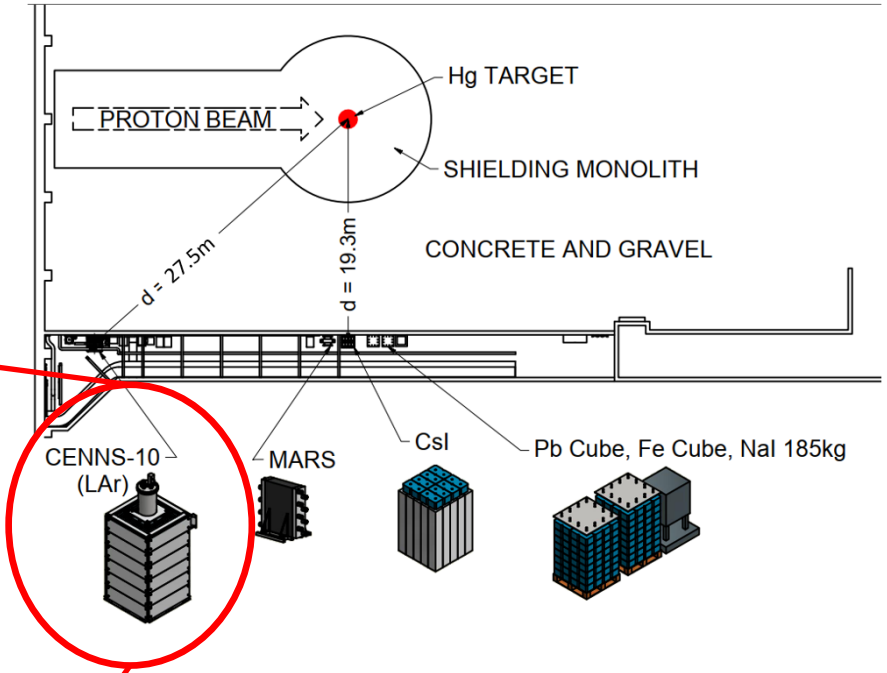
COHERENT 2018 at the Spallation Neutron Source [arXiv:1803.09183v2]

COHERENT @ SNS

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





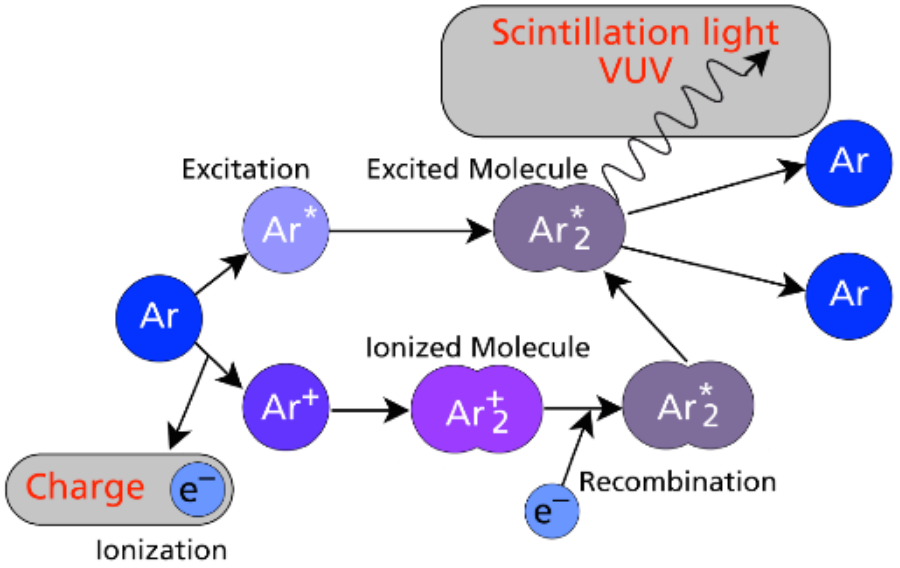


The CENNS-10 Liquid Argon Detector to measure CEvNS at the Spallation Neutron Source [arXiv:1801.00086v2]

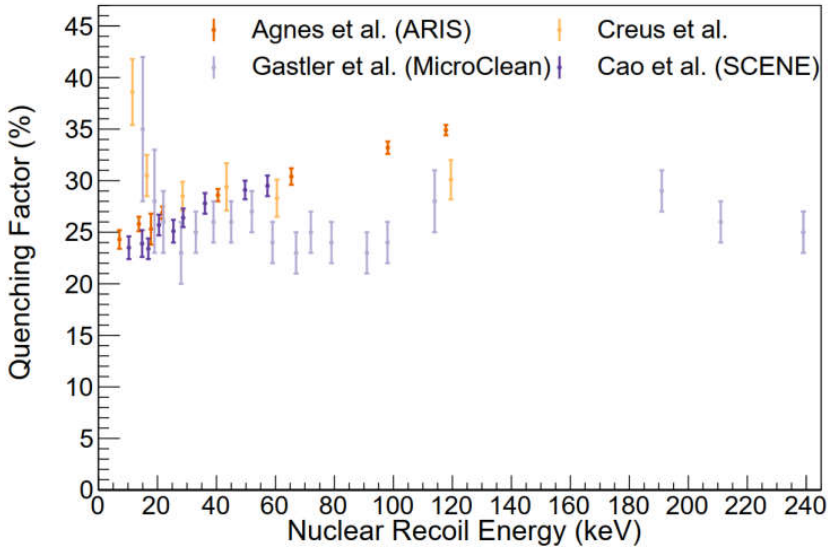
COHERENT 2018 at the Spallation Neutron Source [arXiv:1803.09183v2]

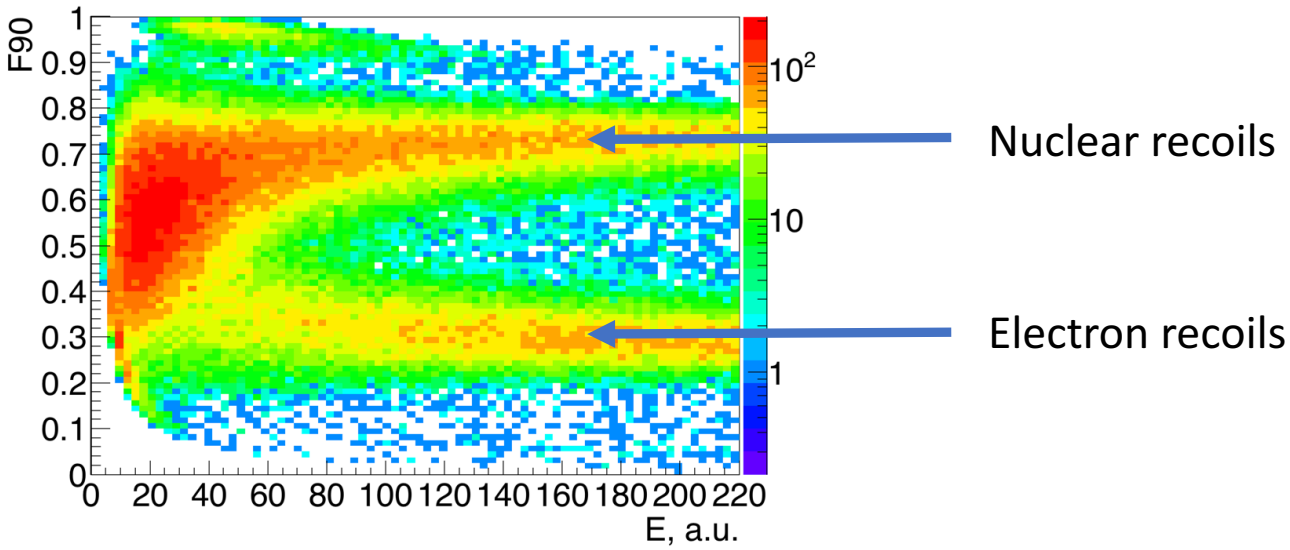
LAr for CEvNS study

- 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



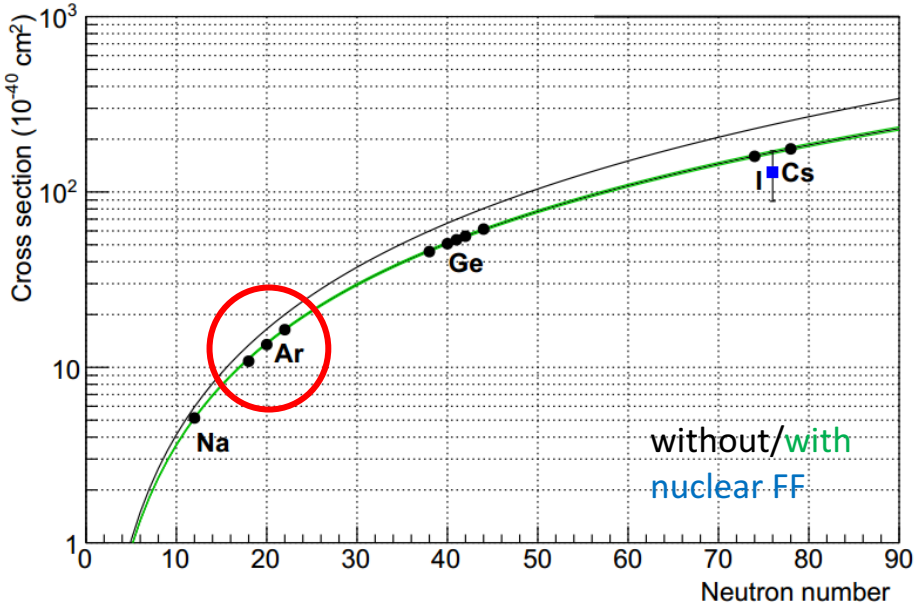
from ArDM

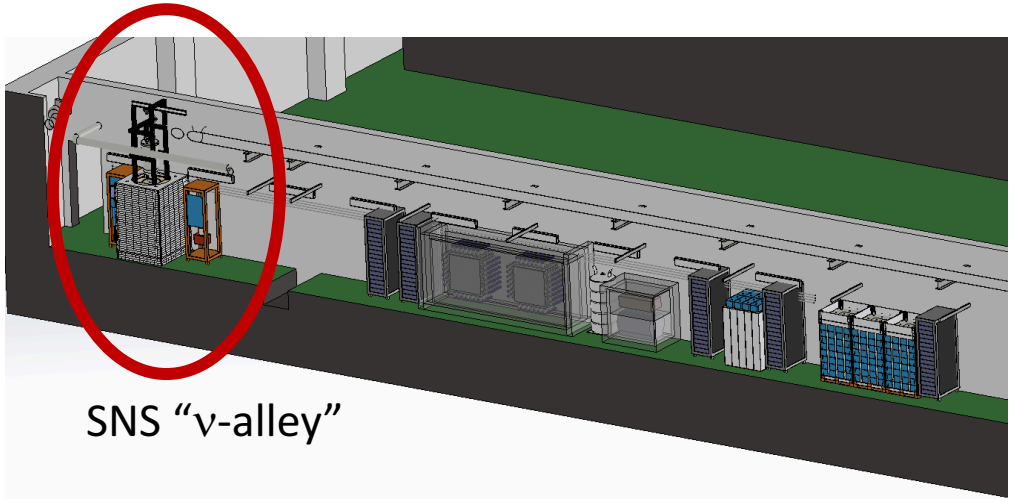


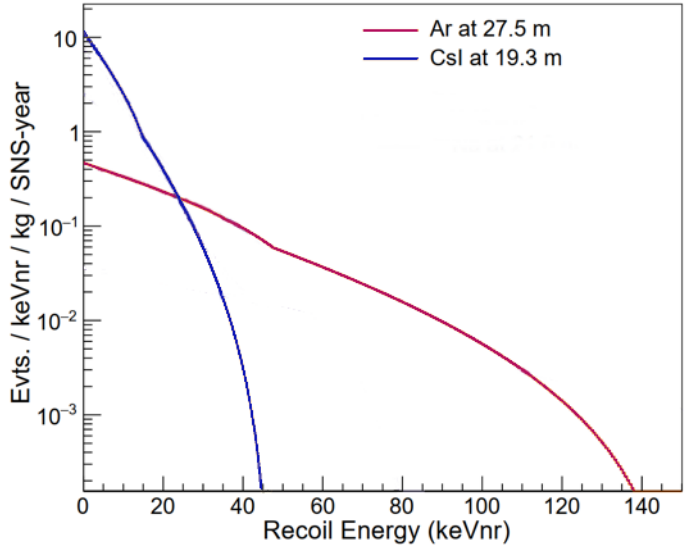


LAr for CEvNS study

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



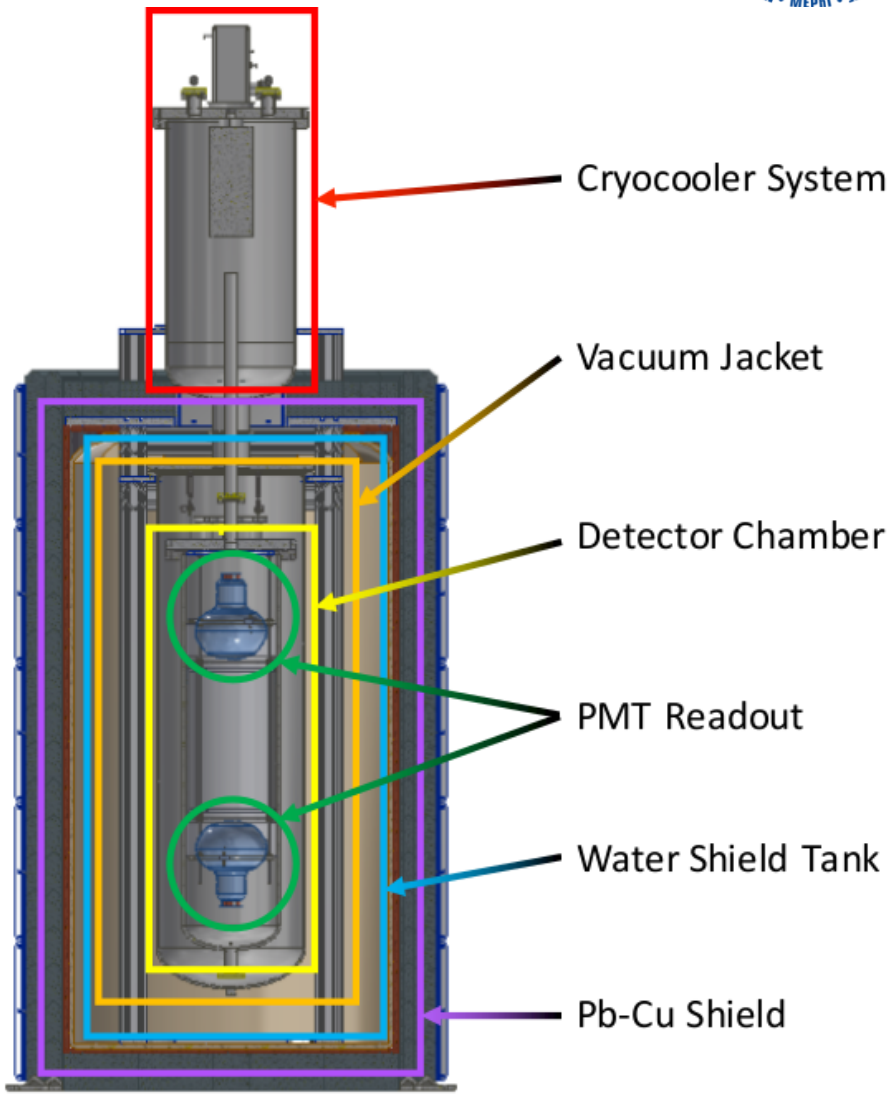




event rates/kg/SNS-yr for COHERENT

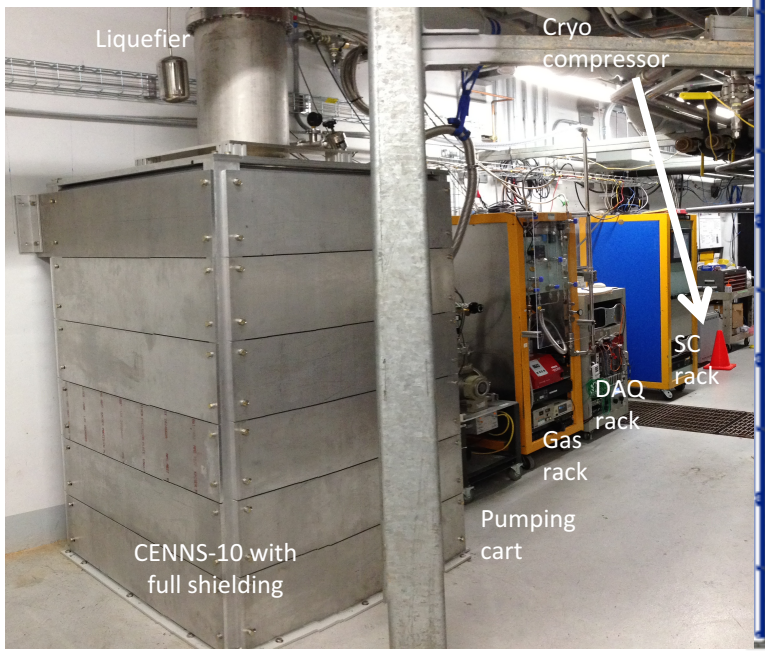
CENNS-10 detector

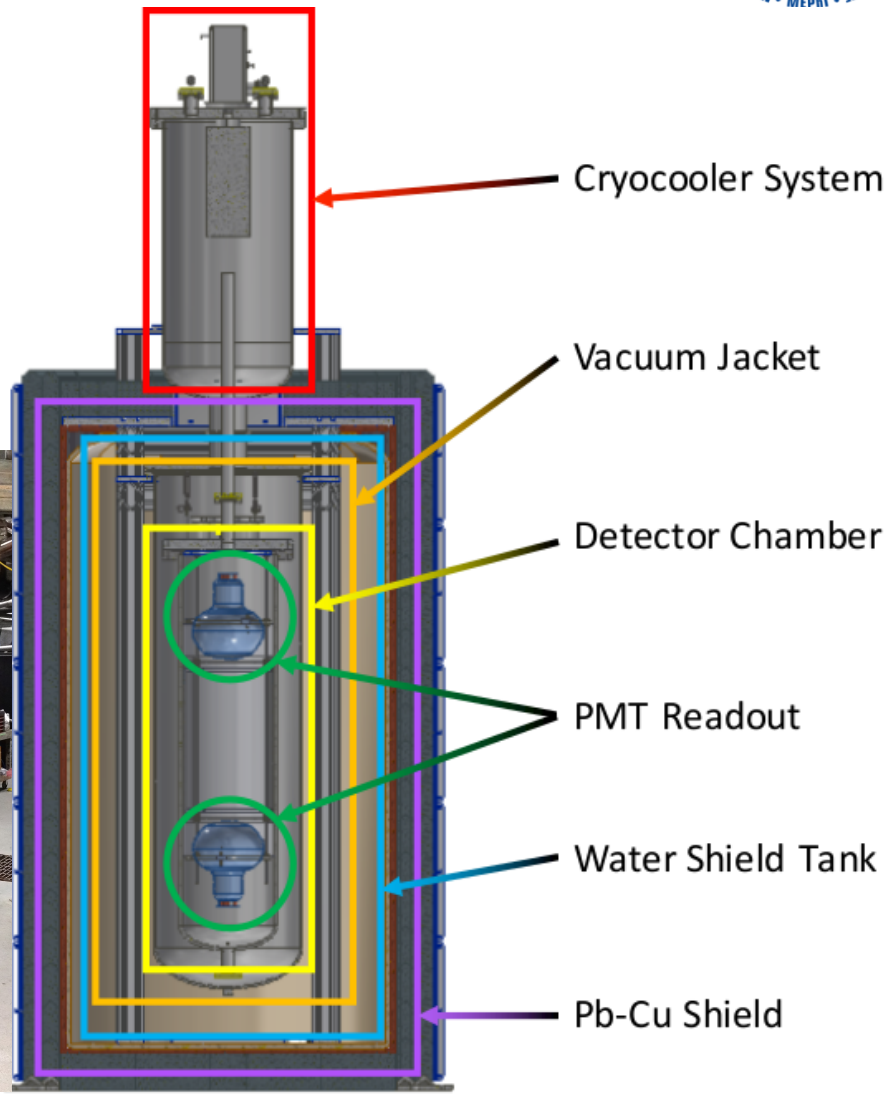
- Timeline:
  - 2012-15: built at Fermilab (J. Yoo etal) for CENNS@Fermilab effort, commissioned/upgraded at Indiana U.
  - late 2016: moved to SNS, installed, shielding built
  - early 2017: run with TPB-acrylic parts, E_{thresh}~80keVnr
    "Engineering Run": 1.8GWhr collected, CEvNS rate low, constrain 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



CENNS-10 detector

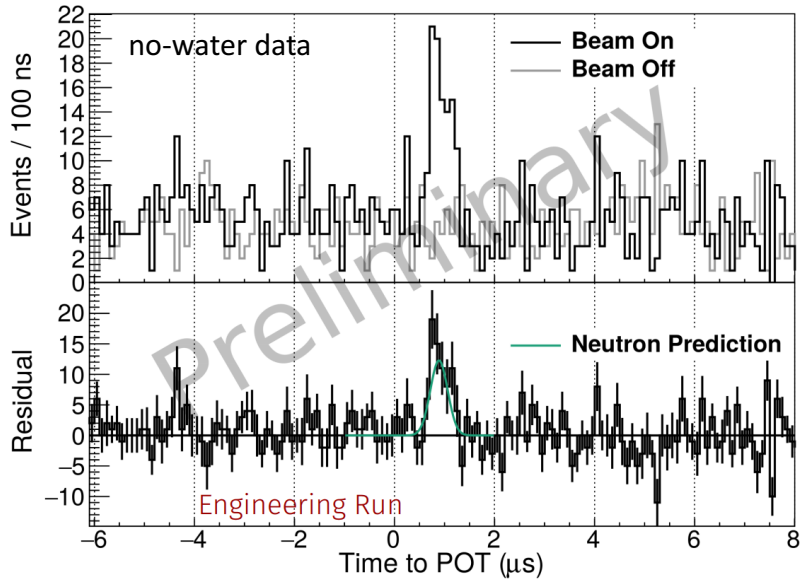
- 22 kg single-phase LAr in fiducial volume
- 2×8”PMTs TPB-coated, w/QE=18%@400 nm
- TPB-coated PMTs/Teflon side walls
- Energy threshold ≈ 20keVnr
- CAEN 1720 (250MHz, 12-bit) digitizer
- 90W single-stage pulse-tube cold head
- SAES MonoTorr gas purifier for ~1 ppm purity
- Pb/Cu/H2O shield
- Expect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

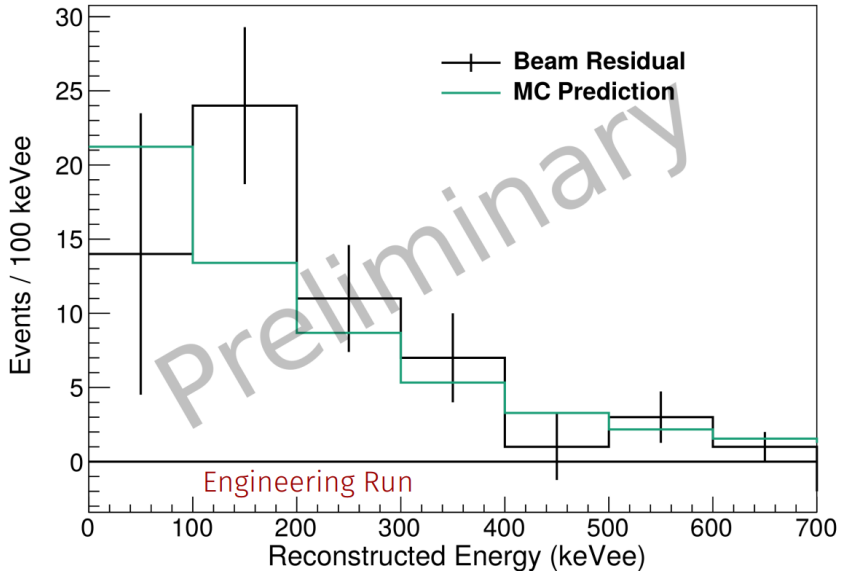




CENNS-10 detector

- 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

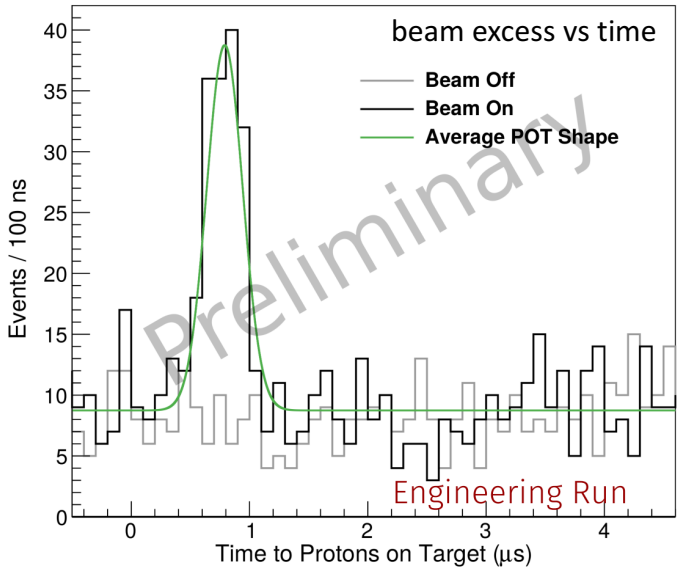


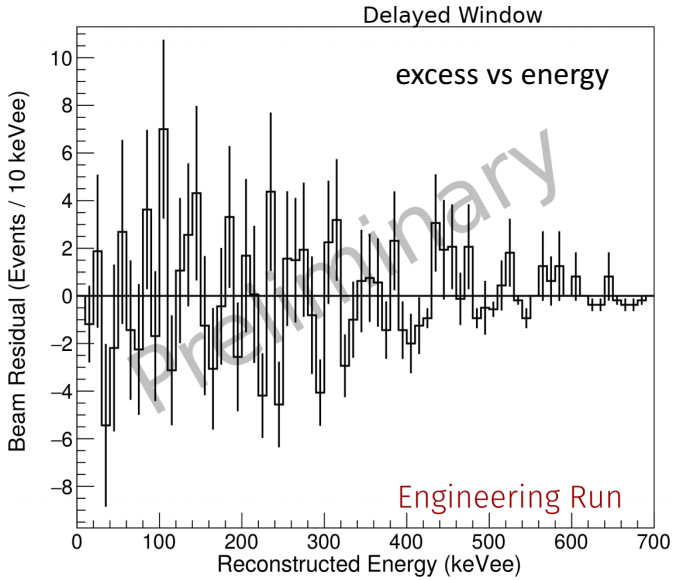


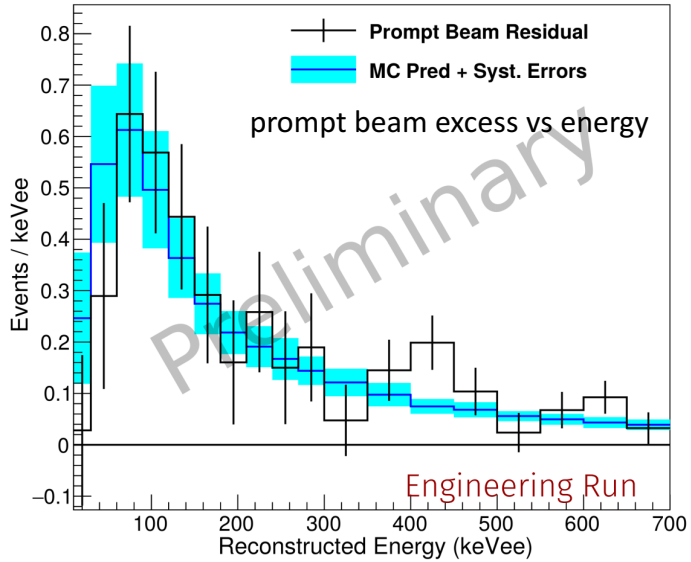
Engineering run results

- 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

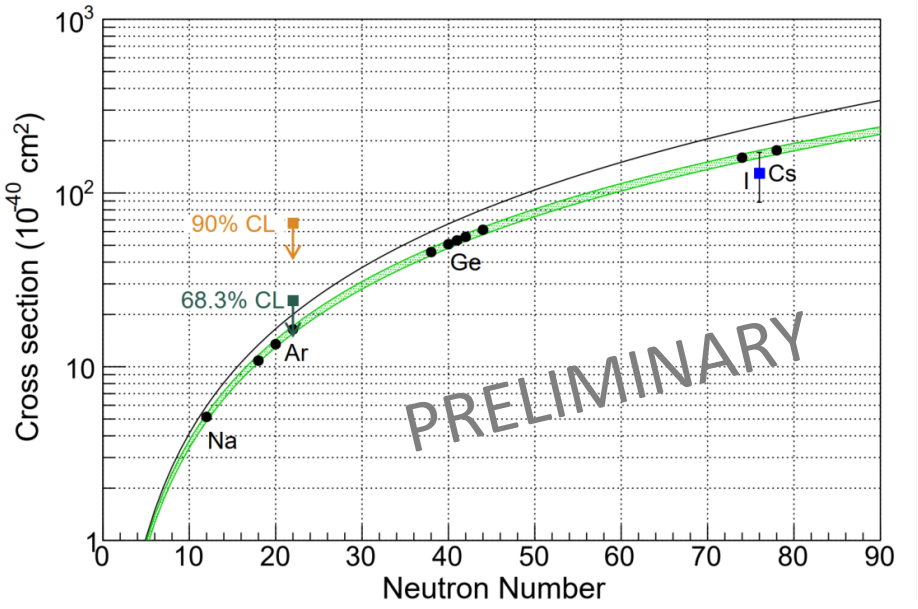


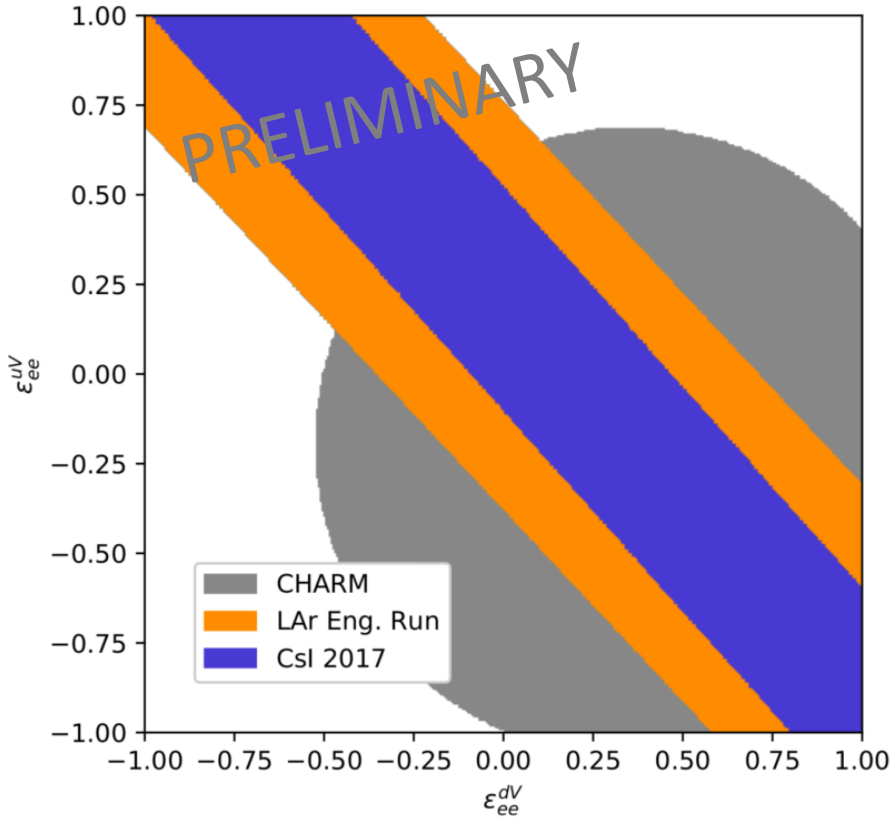




Engineering run results

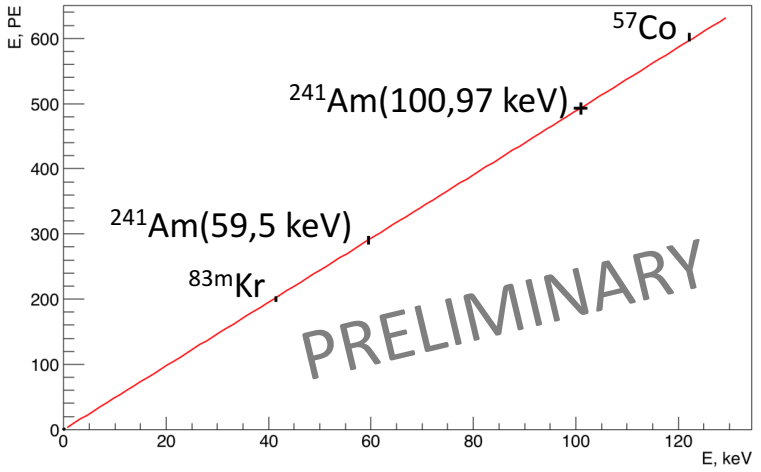
- Full likelihood analysis results
  - Cross section limits
  - Non-standard interaction constraints





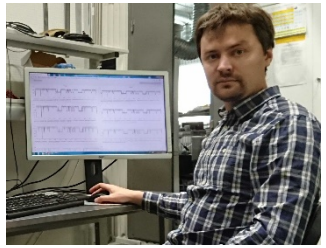
Production run analysis status

- Light Yield (LY) was improved to ~4.5 PE/keVee
- PSD, energy resolution/threshold sufficient for CEvNS observation
- SM prediction: 130 CEvNS in this data set
- Blind dual analysis scheme
- Both groups are in the end stage of analyses
- Results soon!

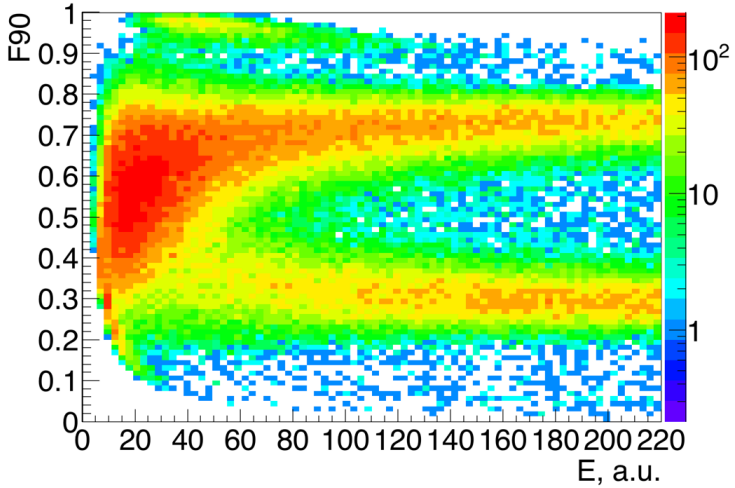


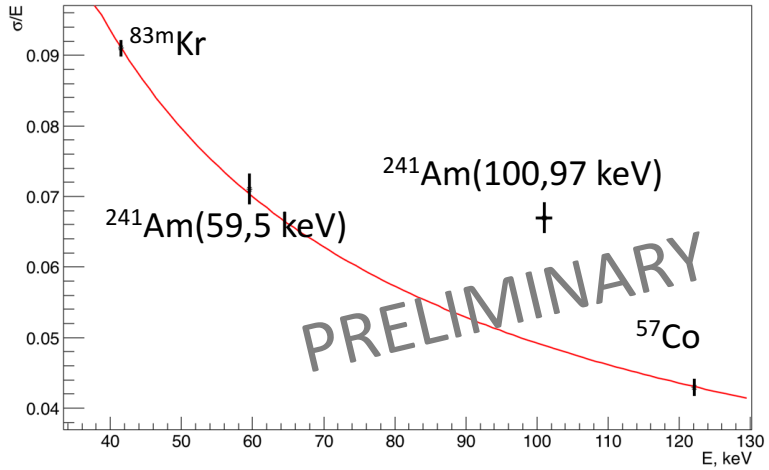
US group: Indiana U:
Jacob Zettlemoyer

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



AmBe data, particle ID





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