Status of the CENNS-10 Liquid Argon Detector for COHERENT

Jacob Zettlemoyer, for the COHERENT Collaboration
DOE SCGSR Fellow
Indiana University, Bloomington
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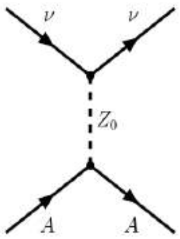
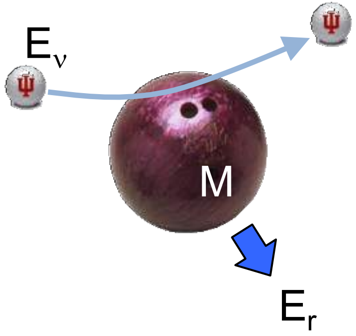
Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)

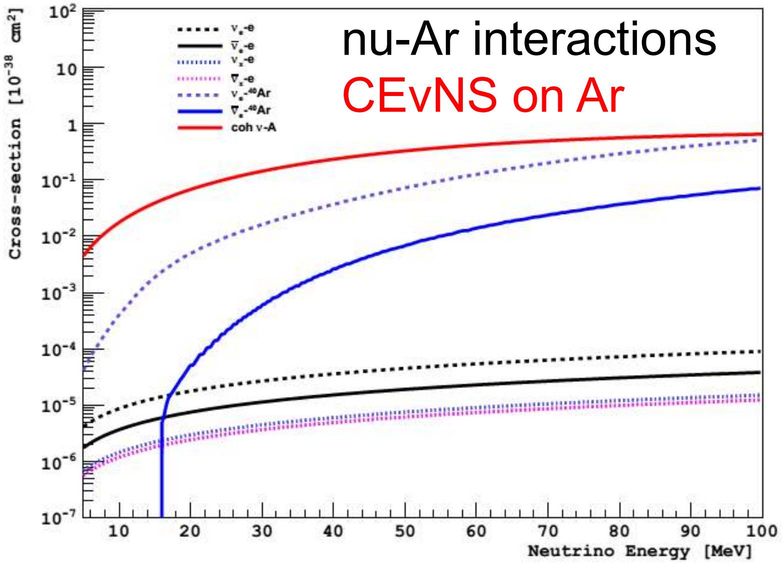
- Process where the neutrino scattering off the nucleus coherently with low momentum transfer
- Large cross section! $E_\nu \lesssim \frac{hc}{R_N} \cong 50 \text{ MeV}$
  - For heavier nuclei at low neutrino energies, the largest channel

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

- Cross section goes as N^2







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

Physics with CEvNS/COHERENT

- Supernova neutrinos
- Dark Matter Backgrounds
- Weak mixing angle
- Neutrino Charged Current Interactions
    - Important in LAr for DUNE
- Accelerator Produced sub-GeV DM

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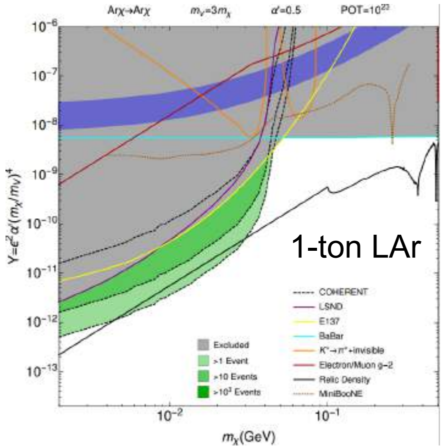
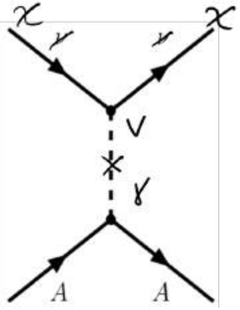
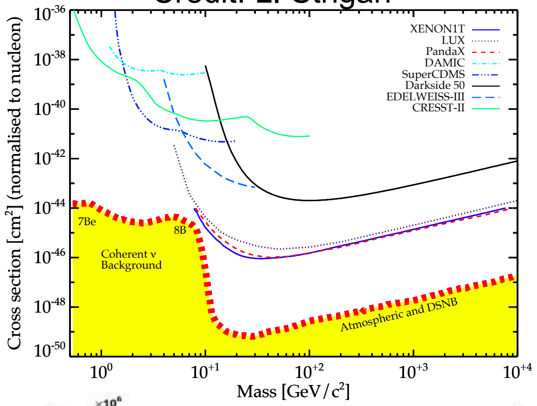
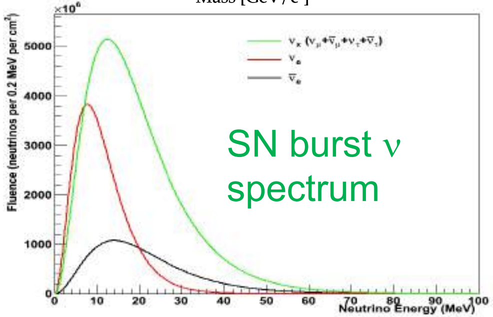
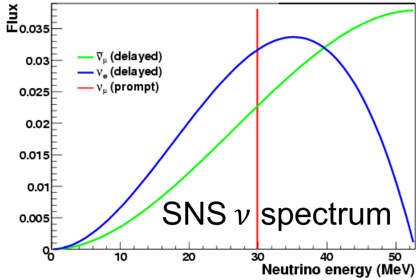




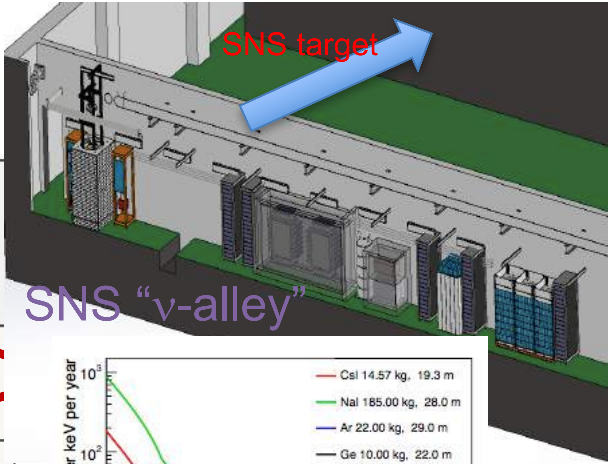
Credit: L. Strigari





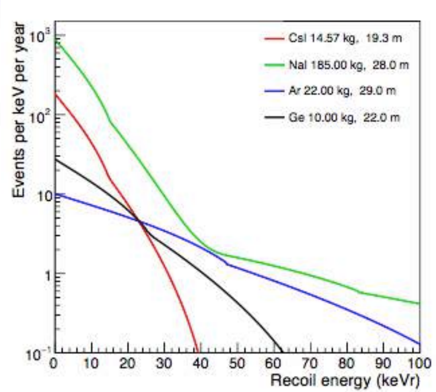


The COHERENT Detector Suite

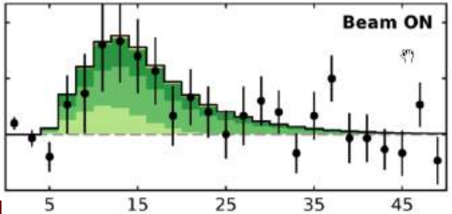


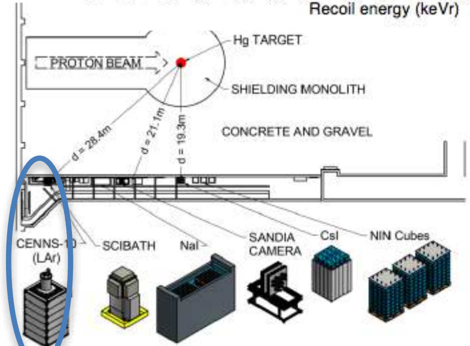
Nuclear Target	Technology	Mass (kg)	Distance from source (m)	Recoil threshold (keVr)
CsI[Na]	Scintillating Crystal	14.6	19.3	6.5
Ge	HPGe PPC	10	22	5
LAr	Single-phase	22	29	20
NaI[Tl]	Scintillating crystal	185*/2000	28	13

Focus of this talk!



First observation of CEvNS!
D. Akimov *et al.*, *Science*
10.1126/science.aao0990 (2017)
134 ± 22 CEvNS events



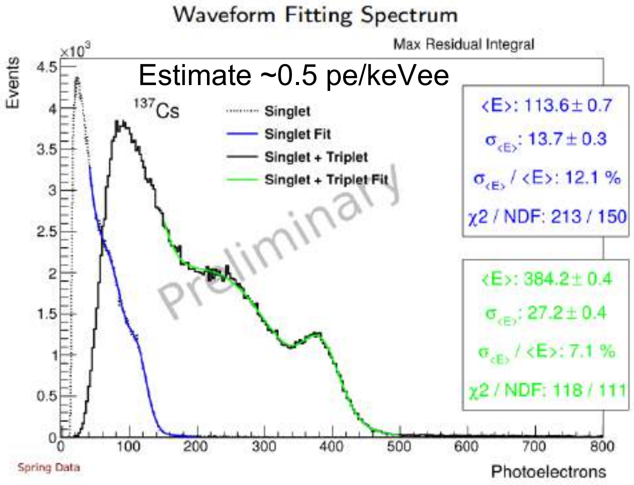


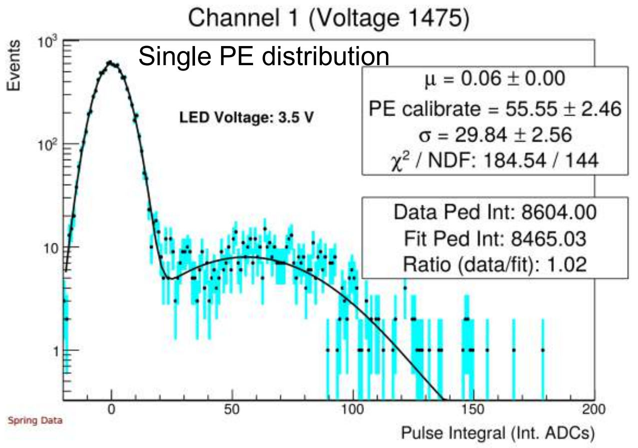
The CENNS-10 Detector

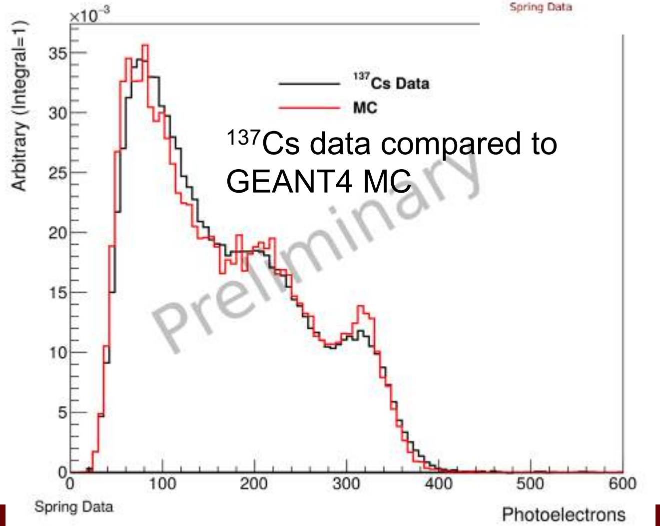
- Built 2012-2015 by team at FNAL for the CENNS effort at FNAL led by J. Yoo, A. Lathrop, R. Davila, and others
- Moved to SNS October 2016
- First run December 2016-May 2017
  - “Spring 2017” Data
  - 35 kg fiducial volume
  - 2x Hamamatsu R5912-MOD02 8” PMT
    - 18% QE at 400 nm
  - CAEN V1720 digitizer based DAQ
  - TPB coated acrylic sides/disks backed by Teflon
    - Expected threshold ~ 100 keVnr
  - H_2O/Cu shielding

First Look at Data – Spring 2017 Data

1. Analysis method is:
   - Fit single PE waveform with template
   - Fit singlet light
   - For triplet contribution, subtract scaled singlet template waveform
   - Integrate triplet light



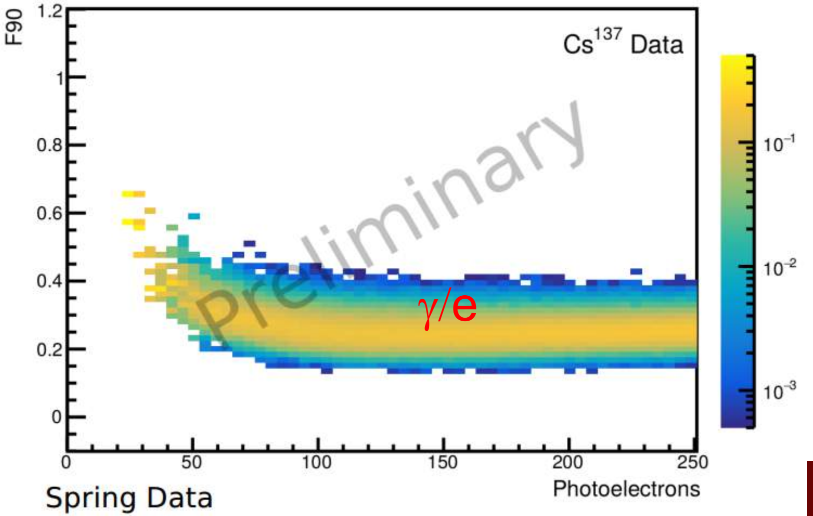


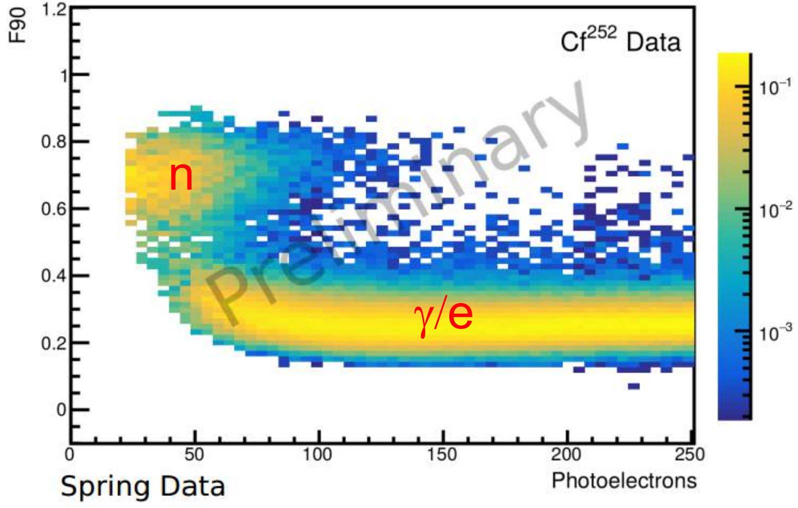


Spring 2017 Data

1. With singlet and triplet time constant sufficiently different and differing triplet decay fractions between neutron and electron recoils, pulse shape discrimination is possible

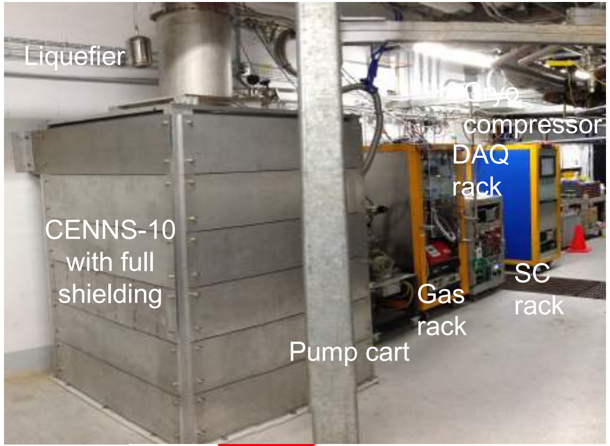
   – Standard parameter is F90 = light in first 90 ns

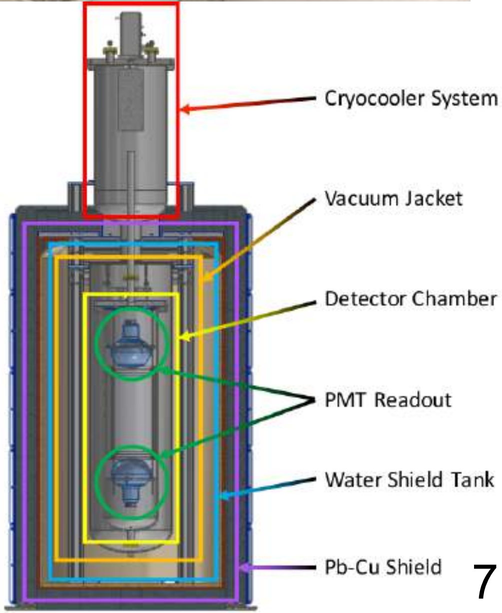


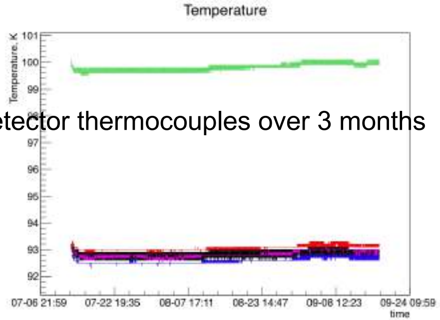


Upgraded CENNS-10 Detector

- Light collection upgrade in June 2017 during SNS shutdown
    - Second run July-December 2017
        - “Summer 2017 Data”
- 22 kg fiducial volume
- TPB coated Teflon side walls, frosted and TPB coated PMT glass
- H_2O/Cu/Pb shielding
- Quenching factor ~25%
    - H. Cao et al. Phys. Rev. D 91, 092007 (2015)
- Expected threshold ~ 20 keVnr
- Expected 140 CEvNS events/yr
- Very stable operation!



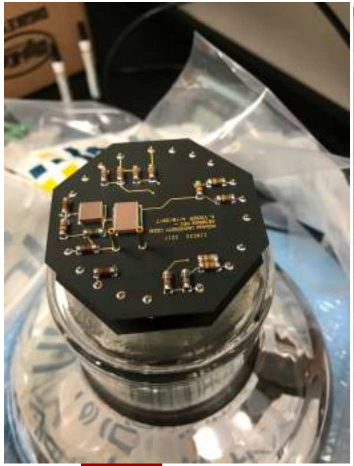


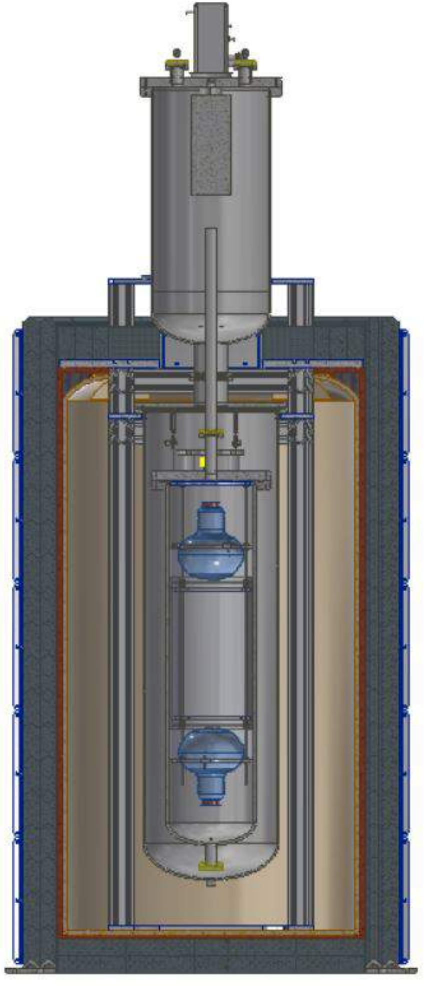


Detector thermocouples over 3 months

Light Collection Upgrade

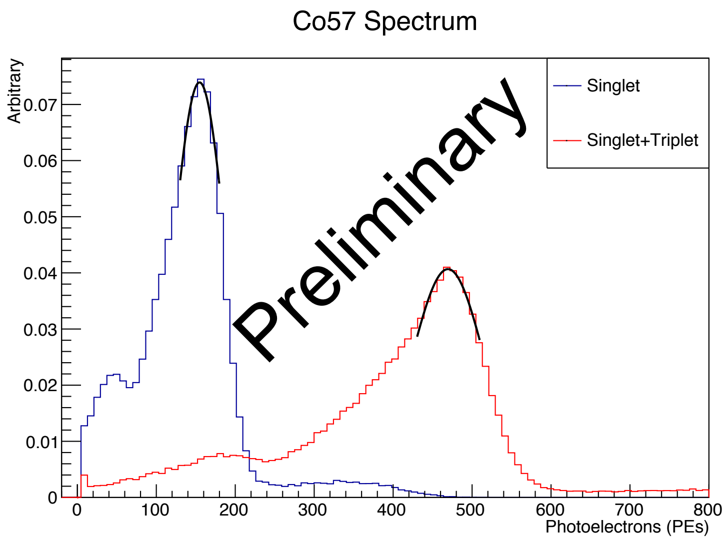
1. TPB coated acrylic parts → TPB coated Teflon/PMTs
2. Electronics Upgrade to clean up PMT signals
3. Expected threshold: 100 keVnr → 20 keVnr

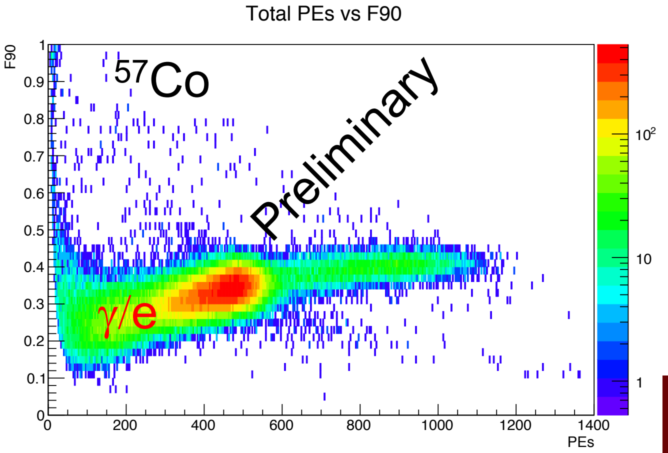


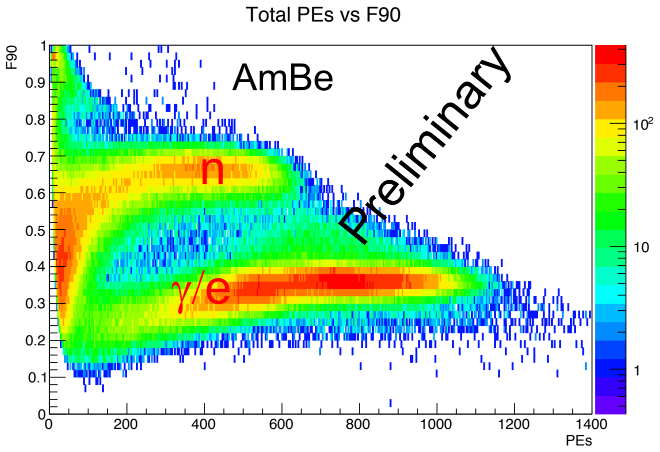


Summer 2017 Data

1. Energy of main ^{57}Co gamma = 122 keV
2. Singlet light yield of detector – Estimate 1.3 pe/keVee
   - Fit mean = 154 PEs
3. For singlet + triplet light yield estimate ~4 pe/keVee currently
   - Fit mean = 470 PEs
   - Still tuning triplet light algorithm but should be similar to this with expected triplet contribution

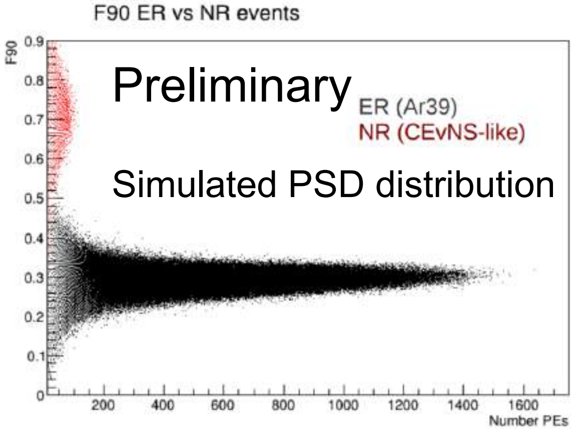






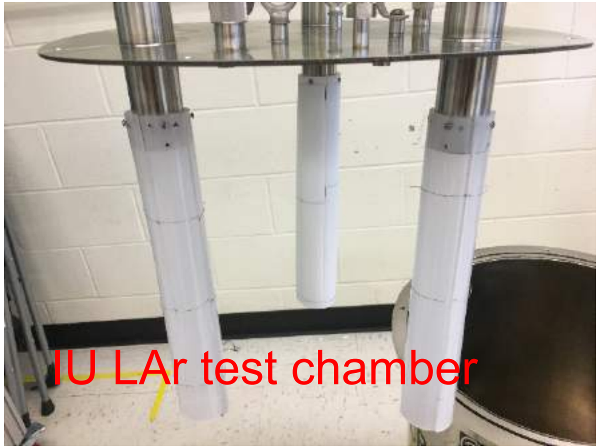
Expected Signal/Background Rate (After Upgrade)

- After upgrades, threshold ~ 20 keVnr
- beam-unrelated backgrounds
  - ^{39}Ar (1 Bq/kg), environmental γ assumed negligible with shielding, PSD, and background subtraction
- beam-related backgrounds:
  - Neutrons in time with beam measured – 60 events/yr
- CEvNS signal
  - estimate 60 prompt/80 delayed events/yr
    - Prompt – within 1 μs after SNS beam spill
    - Delayed – 1-10 μs after SNS beam spill

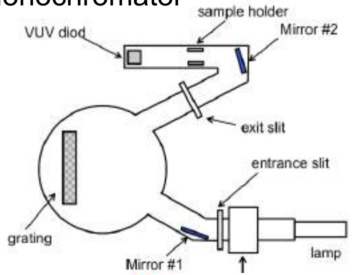


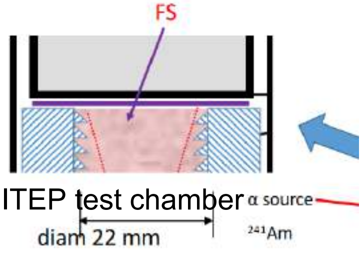
Future Liquid Argon Program

1. Test chambers for future LAr ton-scale detector R&D work under construction at IU/ORNL
   - Readout electronics, other WLS methods
2. WLS tests underway at IU/ORNL/ITEP(Moscow, Russia) for optimization of techniques for future LAr

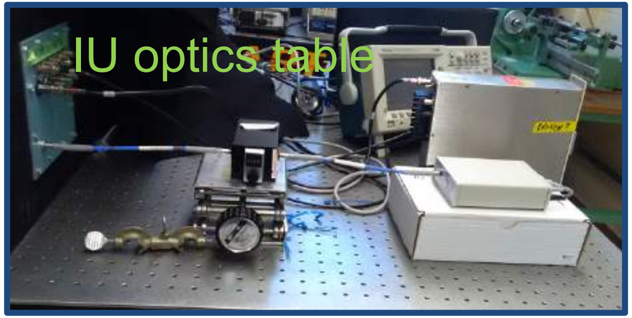


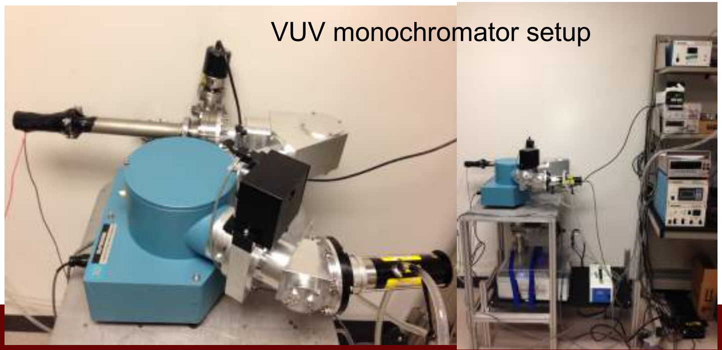
VUV Monochromator





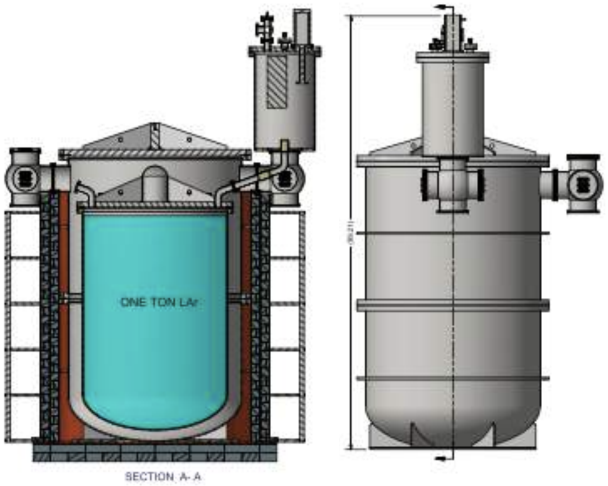
ITEP test chamber

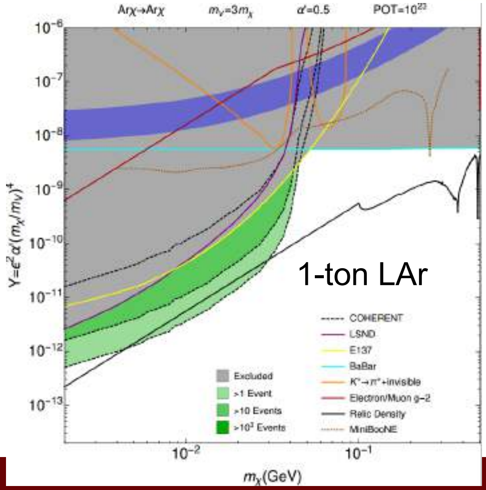


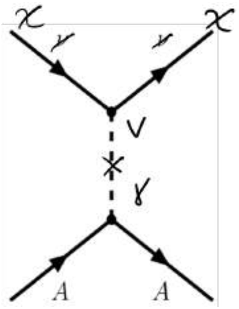


Future Liquid Argon Program

1. Current CENNS-10 detector
   - More upgrades during 5 month SNS shutdown 1/18-6/18, options include
     - Improved WLS from studies
     - depleted Ar (~1 mBq/kg ^{39}Ar)
     - more electronics upgrades
     - LXe doped LAr
2. Long term
   - Ton scale LAr detector
     - Good charged current interaction measurement
     - Better CEvNS measurement
   - LXe, LNe







Search for accelerator produced low mass dark matter

Summary/Acknowledgements

1. The CENNS-10 detector is a 22 kg liquid argon detector built at Fermilab currently running at the SNS at ORNL
   - Upgraded for better light collection in June 2017 during SNS shutdown after completion of first run in May 2017
   - Should provide the first CEvNS measurement on liquid argon with current data run of upgraded detector
2. There are current plans for studies and tests for a future large scale detector and a long term liquid argon program at the SNS
3. Ideas/Interest welcome!
4. Thank you to DOE Office of Science, Oak Ridge National Laboratory, and the NSF for sponsoring this work!
   - *This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists, Office of Science Graduate Student Research (SCGSR) program. The SCGSR program is administered by the Oak Ridge Institute for Science and Education (ORISE) for the DOE. ORISE is managed by ORAU under contract number DE-SC0014664*

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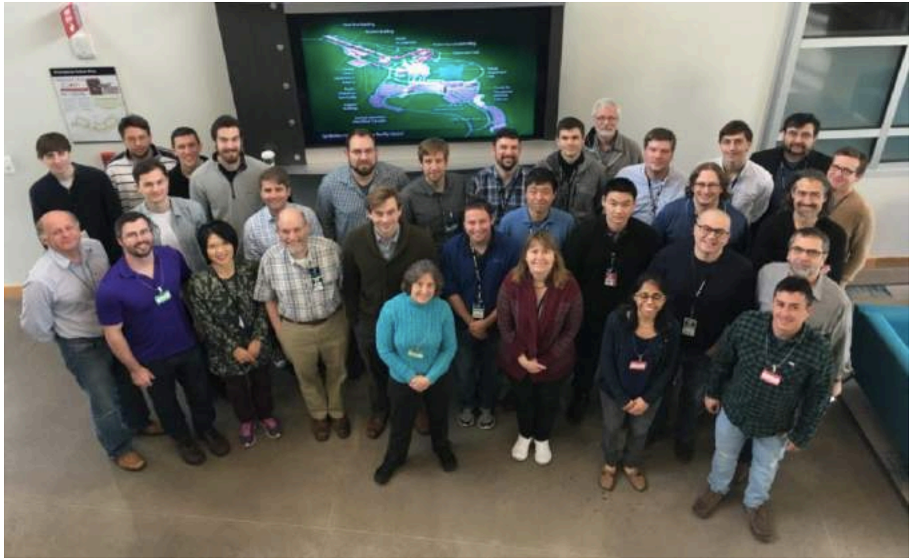
The COHERENT Collaboration



http://sites.duke.edu/coherent

arXiv:1509.08702

COHERENT

SNS SPALLATION NEUTRON SOURCE

THE UNIVERSITY OF CHICAGO · Duke UNIVERSITY · UF UNIVERSITY of FLORIDA · KAIST · Laurentian University Université Laurentienne · Los Alamos NATIONAL LABORATORY EST. 1943 · BERKELEY LAB · NORTH CAROLINA CENTRAL UNIVERSITY · NC STATE UNIVERSITY · NM STATE UNIVERSITY · OAK RIDGE National Laboratory · Carnegie Mellon University · Sandia National Laboratories · THE UNIVERSITY of TENNESSEE KNOXVILLE · TUNL · UNIVERSITY of WASHINGTON

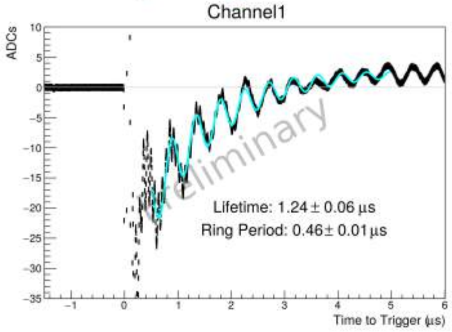
NNSA National Nuclear Security Administration · KICP · NSF · U.S. DEPARTMENT OF ENERGY Office of Science · CNEC

~80 members,
18 institutions
4 countries

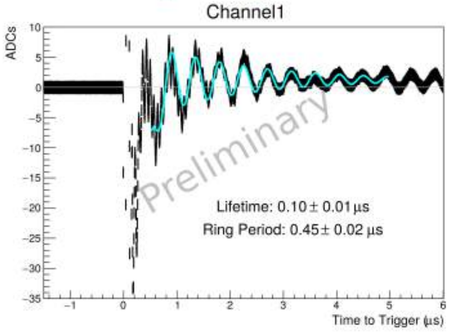
Backups/ Extras

Triplet Lifetime

Pre-Doping



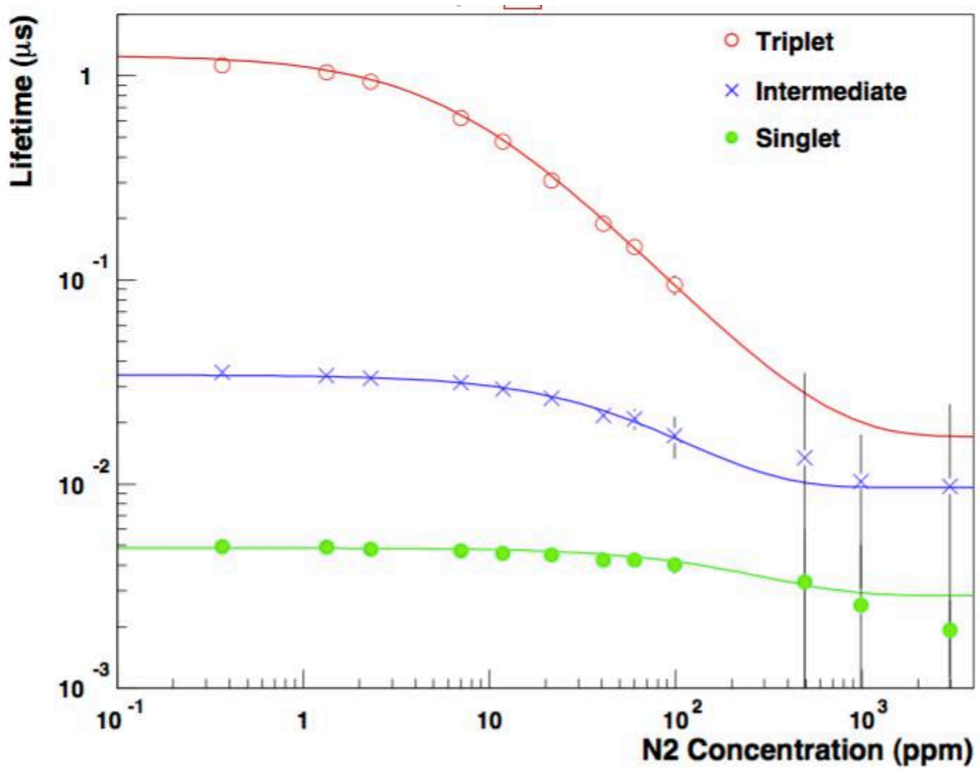
Post-Doping



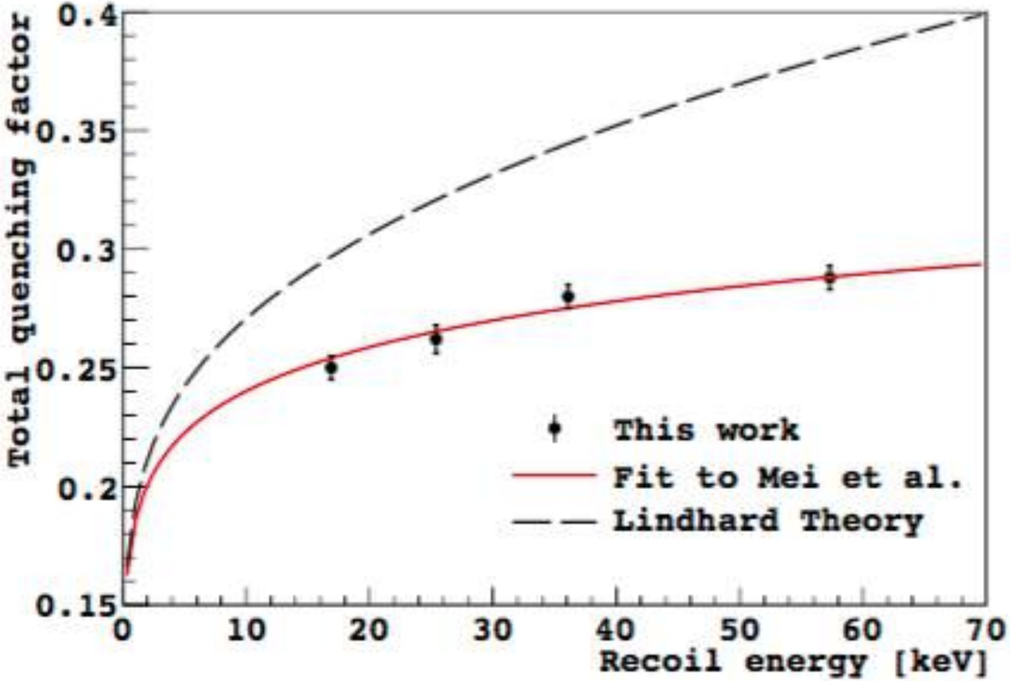
- As data quality check introduce N_2 after spring run
- Introduce ~25 ppm N_2
- Triplet lifetime changed from ~1.2 µs to 0.20 µs
  - Correspond to 1 ppm and 20 ppm respectively[2]
- Verified with LDetek8000 N_2 monitor readings

[2] R. Acciarri et al. Effects of Nitrogen Contamination in Liquid Argon. JINST, 5:P06003, June 2010.

Importance of Purity



LAr Quenching Factor



H. Cao et al. Phys. Rev. D 91, 092007 (2015)