The COHERENT Experiment

Kumpan A.V.

On behalf of
COHERENT Collaboration

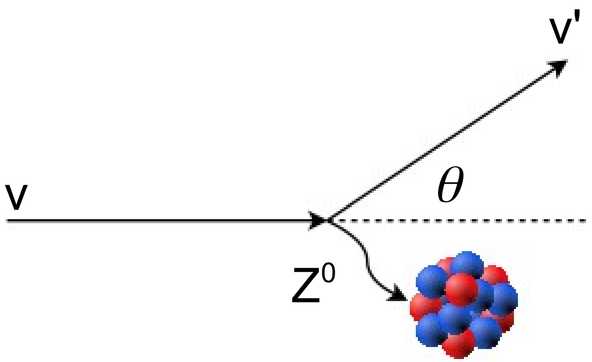
National Research Nuclear University MEPhI

ICPPA, October, 2016

Coherent elastic neutrino-nulcei scattering

CEvNS is a fundamental process predicted by D.Z. Freedman in 1974:

$$\nu + A \rightarrow \nu' + A'$$



Total cross section of the process can be described by the fomula:

$$\sigma_{tot} = \frac{G_F^2 E_\nu^2}{4\pi} [Z(1-\sin^2\theta_W) - N]^2 F^2(Q^2)$$

$F^2(Q^2)$ ground state elastic form factor

θ_W Weinberg angle

A. Drukier & L. Stodolsky, PRD30, 2295 (1984):

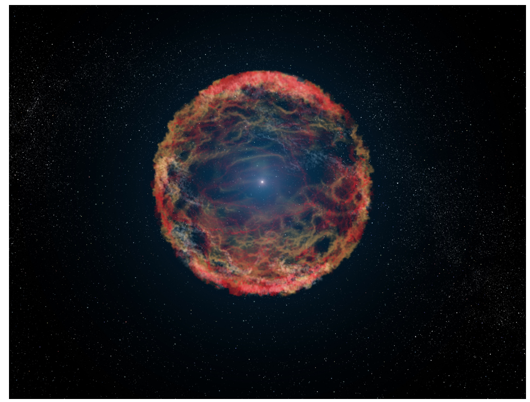
$$\sigma = \frac{G_F^2 N^2}{4\pi} E_\nu^2$$

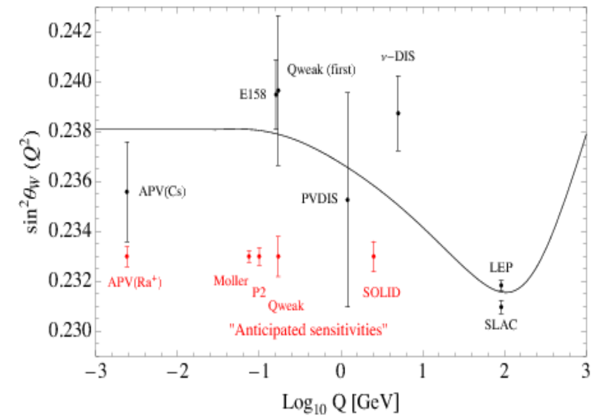
More neutrons — larger cross section.

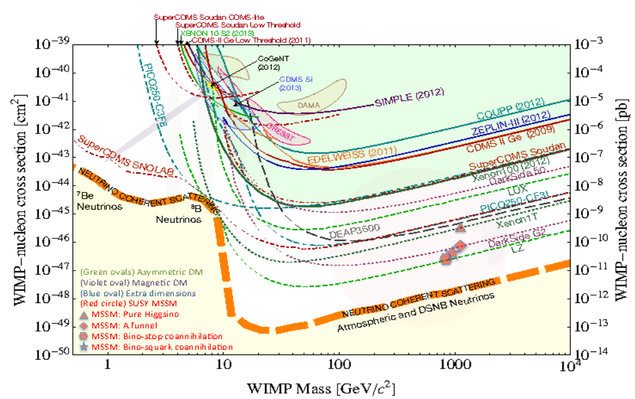
Physics motivation

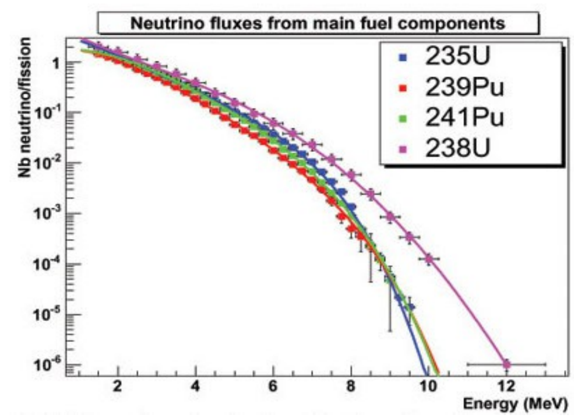
Coherent neutrino nuclei scattering plays a very important role in physics. It could help to improve our understanding of:

- Dark Matter
- Supernova Physics
- Weak Mixing Angle
- Sterile Neutrinos
- Practical applications

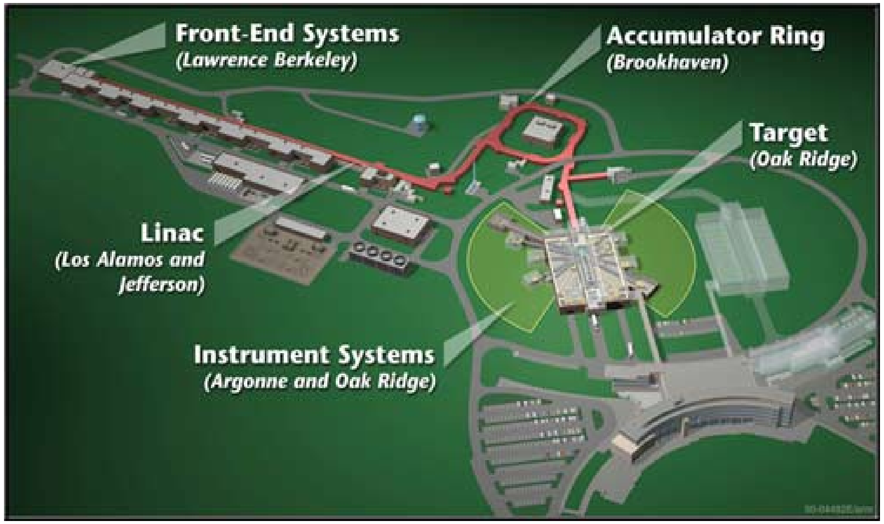


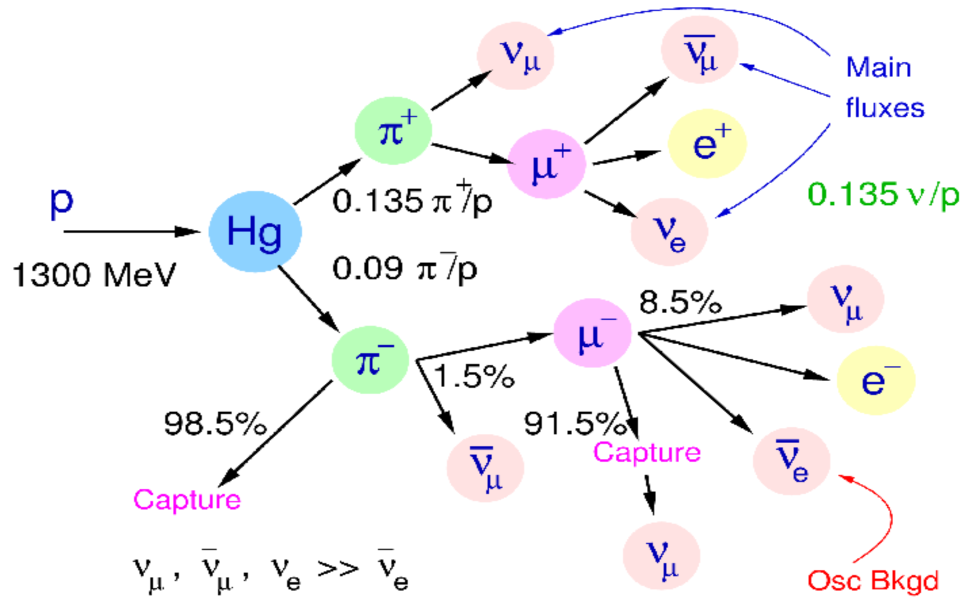




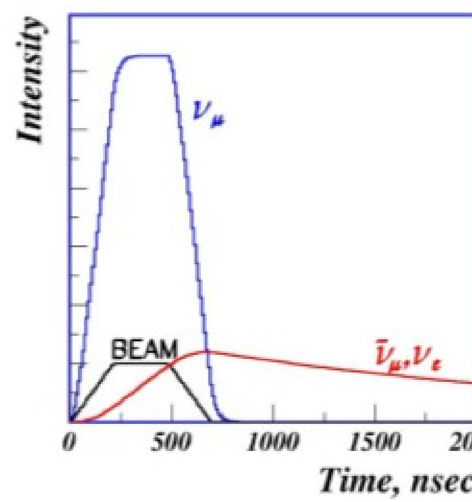


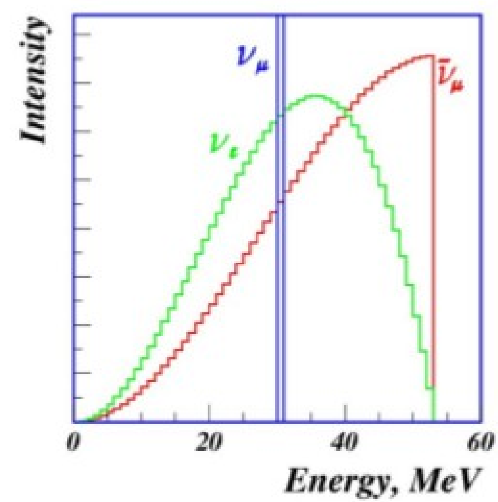
Spallation Neutron Source (SNS), Oak Ridge National Laboratory (ORNL), USA





Proton beam energy — 0.9-1.3 GeV
Intensity — 9.6*10^{15} protons/sec
Pulse duration — 700 ns
Repetition rate — 60 Hz
Liquid Mercury target





1.9*10^{22} year^{-1} neutrinos each of three flavors (ν_e, ν_μ, ν_τ)

COHERENT collaboration

NC STATE UNIVERSITY

BERKELEY LAB

THE UNIVERSITY of TENNESSEE UT KNOXVILLE

UF UNIVERSITY of FLORIDA

NATIONAL RESEARCH NUCLEAR UNIVERSITY • MOSCOW ENGINEERING PHYSICS INSTITUTE • MEPhI • MEPhI

NM STATE UNIVERSITY

Duke UNIVERSITY

Berkeley UNIVERSITY OF CALIFORNIA

OAK RIDGE National Laboratory

Los Alamos NATIONAL LABORATORY EST. 1943

THE UNIVERSITY OF CHICAGO

Sandia National Laboratories

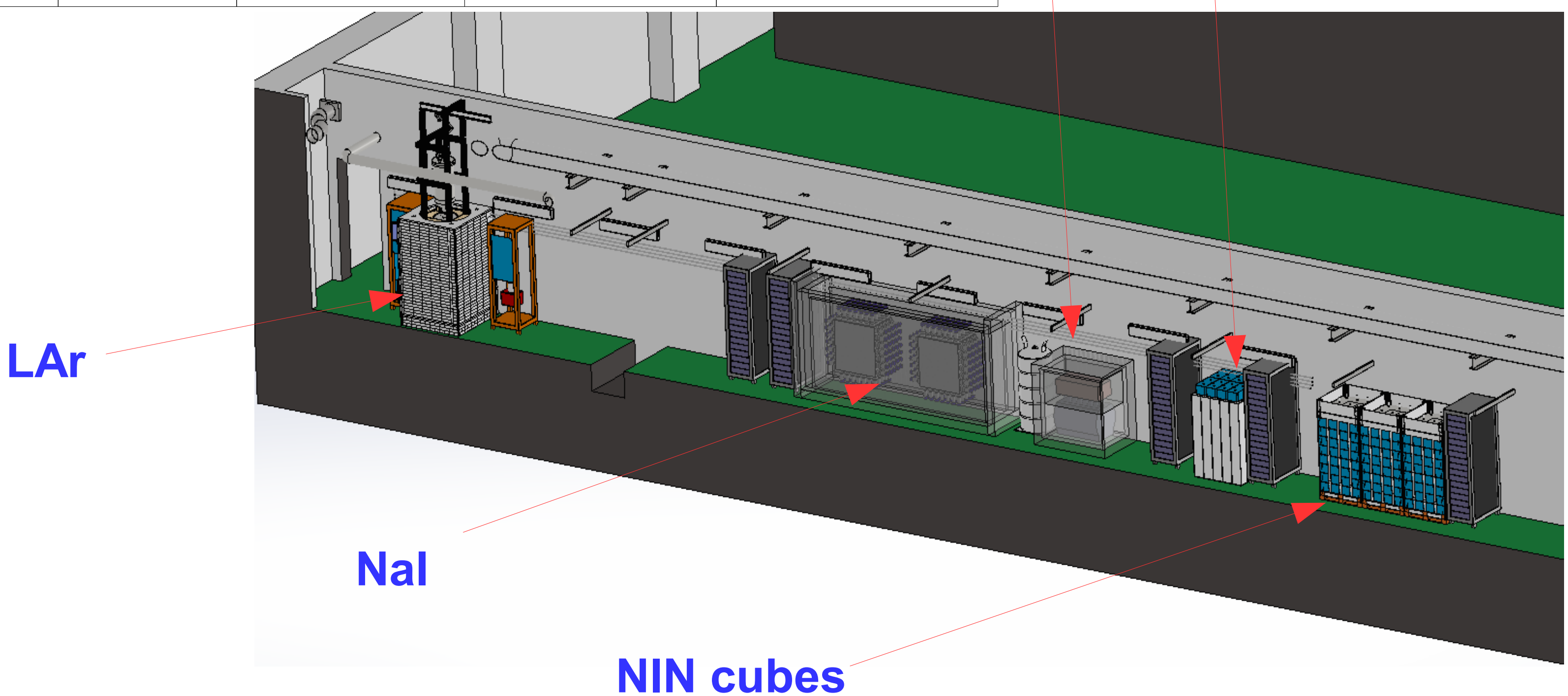
INDIANA UNIVERSITY

W UNIVERSITY of WASHINGTON

NORTH CAROLINA CENTRAL UNIVERSITY FOUNDED 1910

Subdetector Technologies

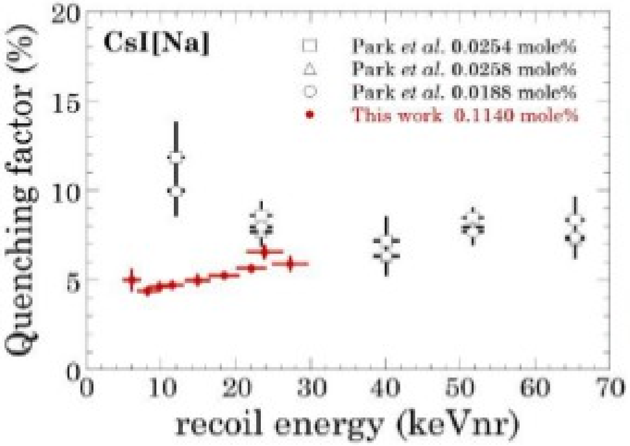
Target	Technology	Mass, kg	Distance from source, m	Recoil threshold, keV	Data-taking start date
CsI[Na]	Scintillaton srystal	14	20	6.5	9/15, 3σ in 2 years
Ge	HPGe PPC	10	22	5	Fall 2016
Ar	Single-phase	35	29	20	Fall 2016
NaI	Scintillation srystal	185*/ 2000	22	13	July 2016



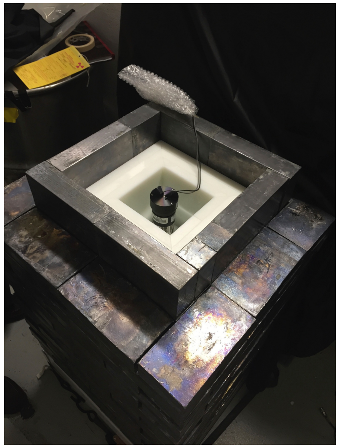
Subdetector technologies
CsI[Na]

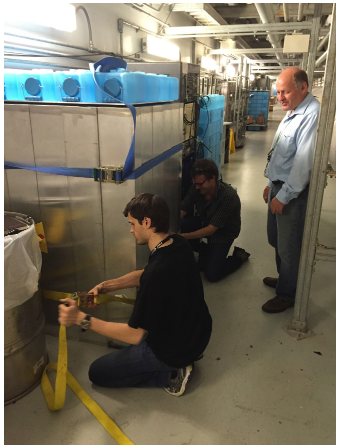
- Mass **14 kg** grown with low level of impurities
- Large CevNNS cross-section of Cs and I provides ~800 recoils per kg per year
- Statistical nuclear/electron recoil discrimination at a level of 1000 accumulated events
- High light yield ~ 45 **photons/keVee**
- Well measured quenching factor

Low background CsI[Na]



J. Collar, (2013), 1302.0796



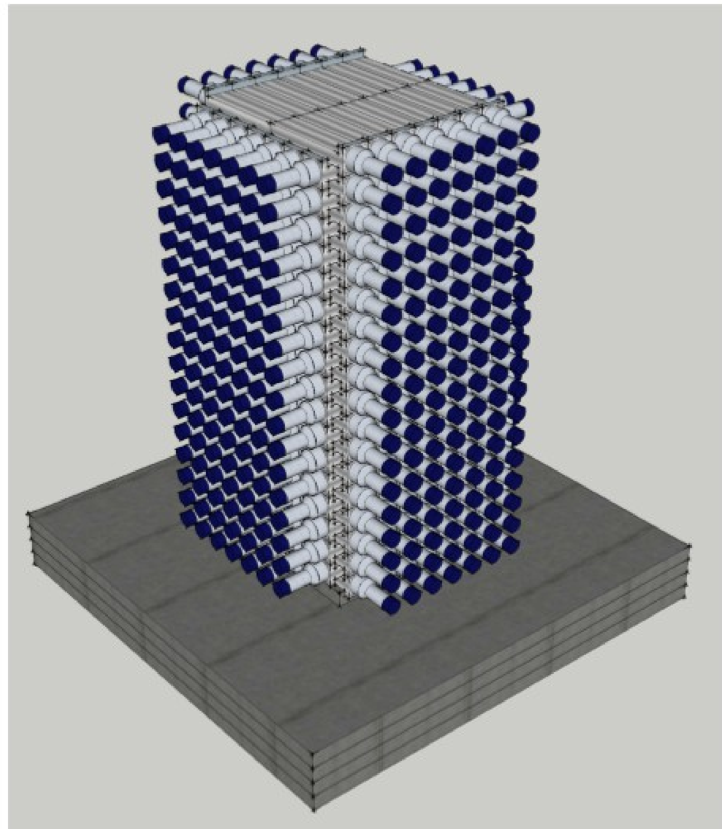


Subdetector technologies
NaI[TI]

- Phase I: 185 detector kg is already deployed but it is not high gain mode sensitive to CevNS yet

- Phase II: 2 ton detector wait for deployment in Fall 2016

Additional goal is to measure neutrino interactions on ^{127}I

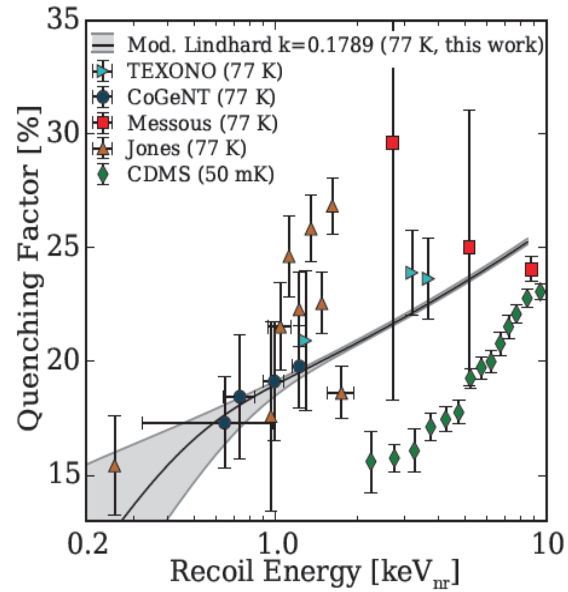


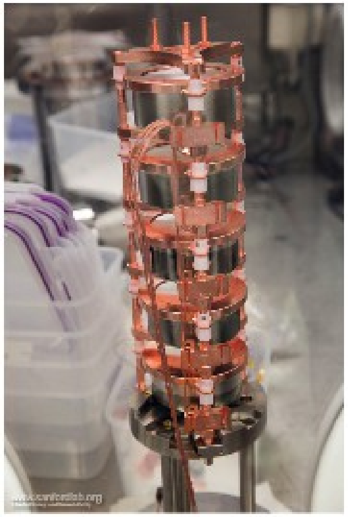
^{127}I	$^{127}\mathrm{I}(\nu_e, e^-)^{127}\mathrm{Xe}$	Stopped π/μ	LSND	$284 \pm 91(\mathrm{stat}) \pm 25(\mathrm{sys})$	210-310 [Quasi-particle] (Engel *et al.*, 1994)

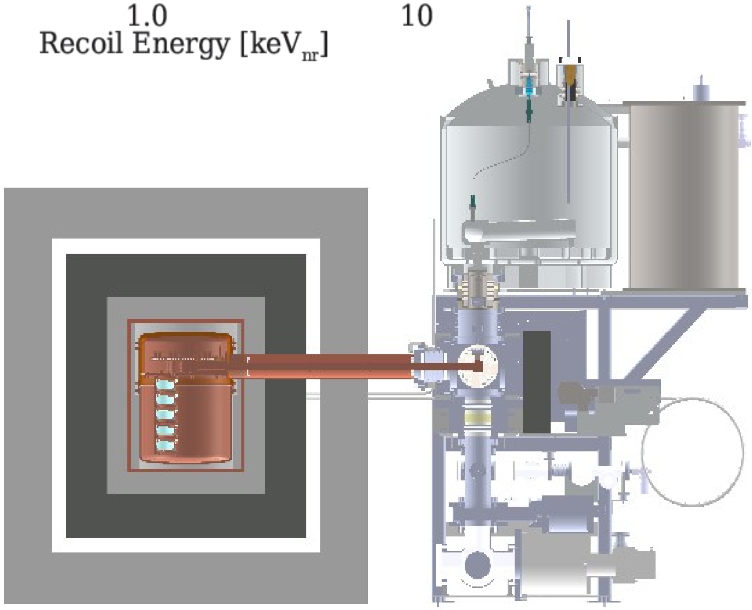
J. A. Formaggio and S. Zeller, Rev. Mod. Phys. 84, 1307 (2012)

Subdetector technologies
High Purity Germanium (HPGe)

- Technology developed for MAJORANA DEMONSRATOR
- 20 m distance from the target
- Resolution at low energy and threshold below 1 keV
- Phase I: 5-10 kg of existing Ge detectors with lead, copper and polyethylene shielding system
- Potential phase II:
  Add additional detector mass with larger detectors



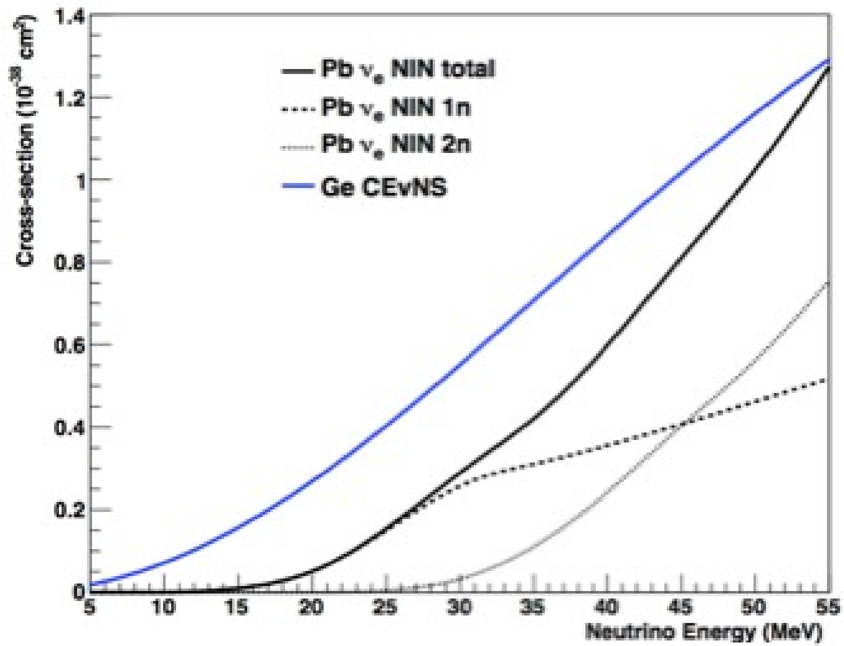




Neutrino Cubes

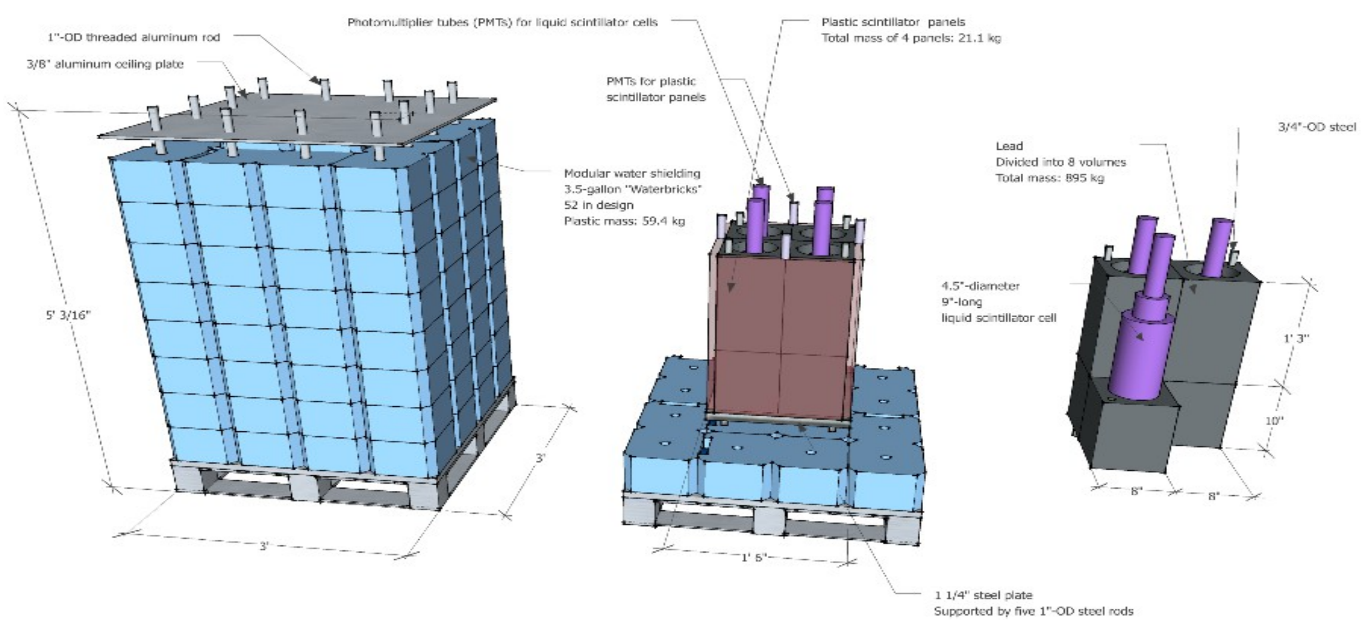
$$\nu_e + {}^{208}Pb \rightarrow {}^{208}Bi^* + e^-$$ ***CC*** process

$$\nu_x + {}^{208}Pb \rightarrow {}^{208}Pb^* + \nu_x$$ ***NC*** process



Pb of shielding interacts with neutrino and interaction result can be source of additional neutrons.

Neutrino Cubes are the detectors used for observing of additional neutron production inside shielding

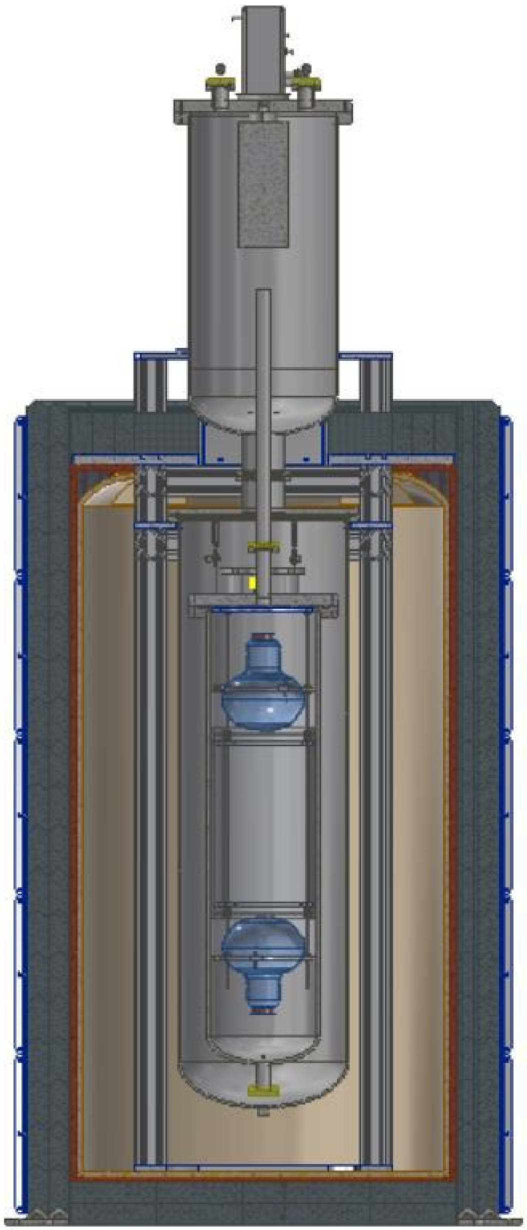


Subdetector technologies
LAr. CENNS-10 detector.

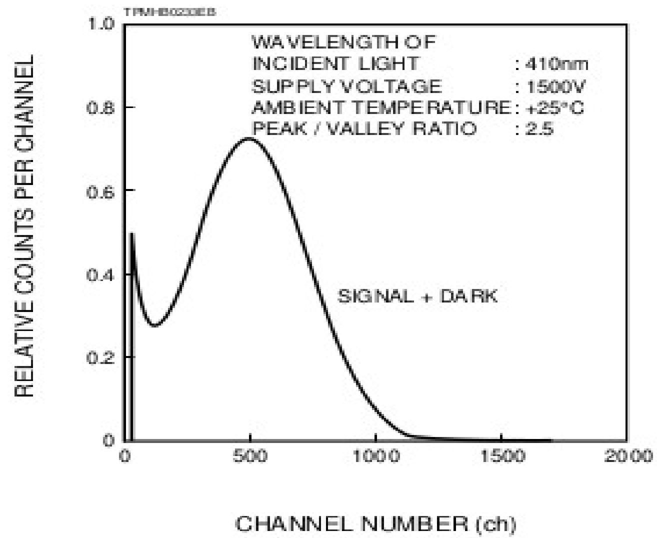
CENNS-10 is one phase liquid argon detector created in FermiLab.

CENNS-10:

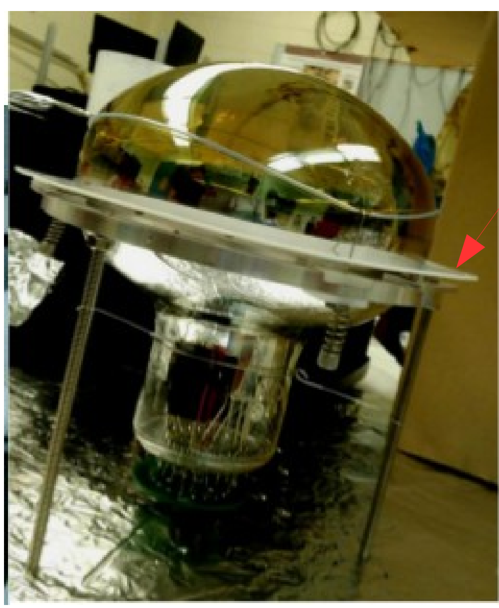
- filled with 35 **kg** of liquid Argon (N = 40)
- ~ 28 meters from the target
- Has 2 low background **PMT R5912-02MOD** for cryogenics
- TPB (tetraphenyl butadiene) covered acrylic plates and cylinder inside surface for wavelength shifting
- Placed in lead and copper shielding and water tank
  Is under deployment at SNS Basement now



Subdetector technologies: LAr. Inner structure.

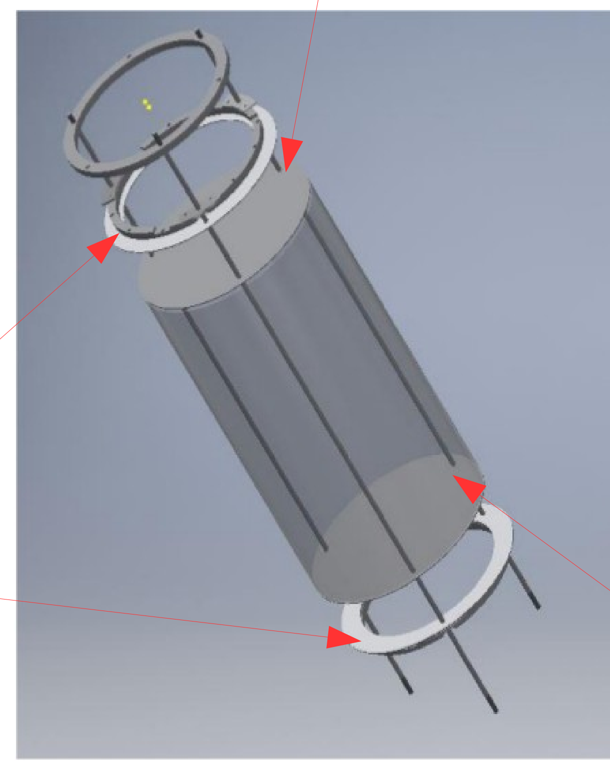


PMT R5912



PMT mounting rings

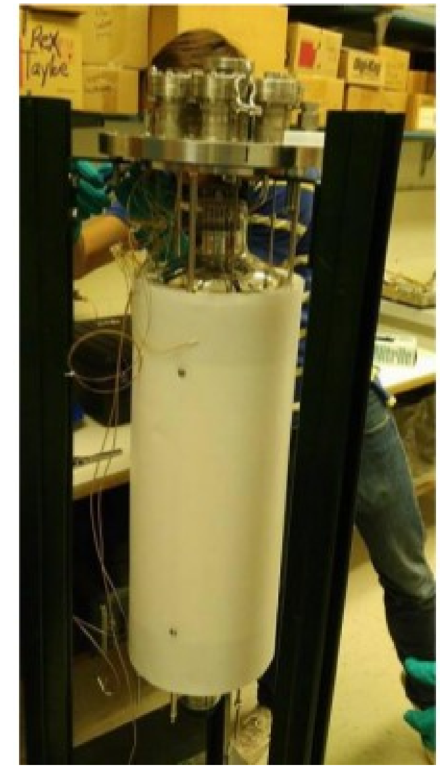
Top acrylic disk. There is the same disk on the bottom.



CENNS-10 inner frame

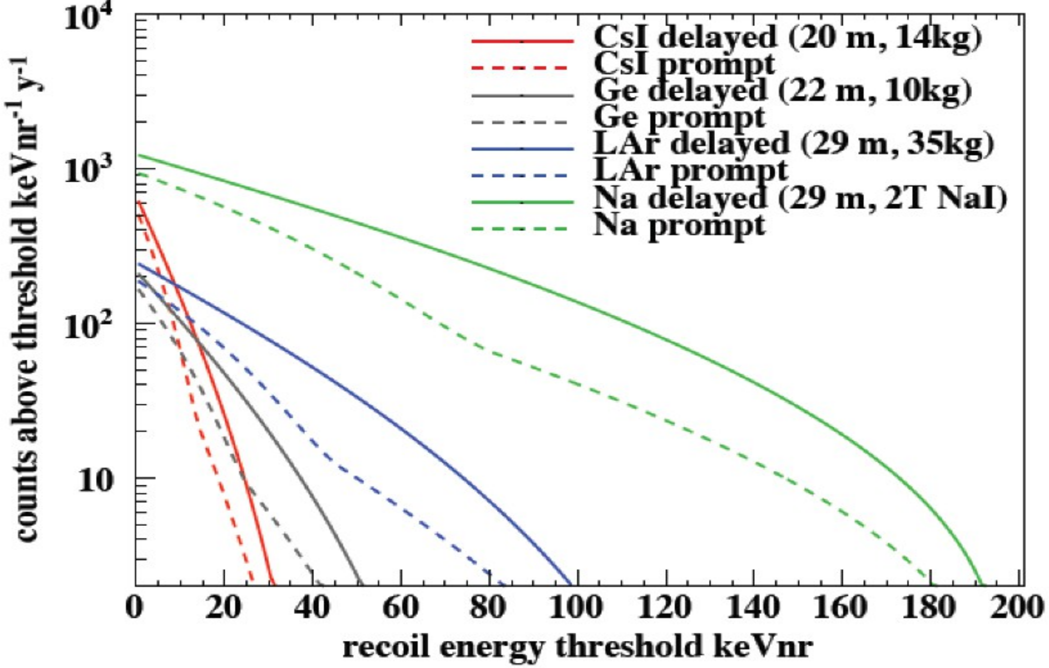
Acrylic cylinder and disks covered with TPB

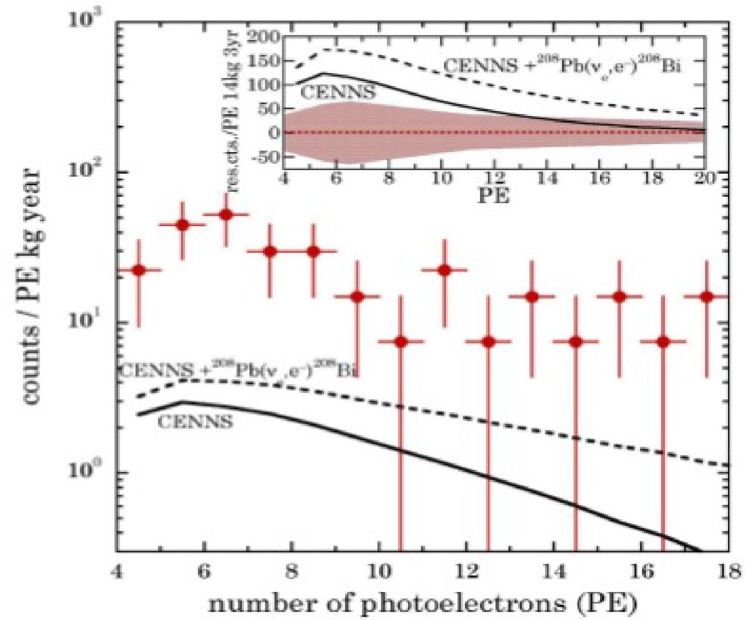
Teflon covered inner frame

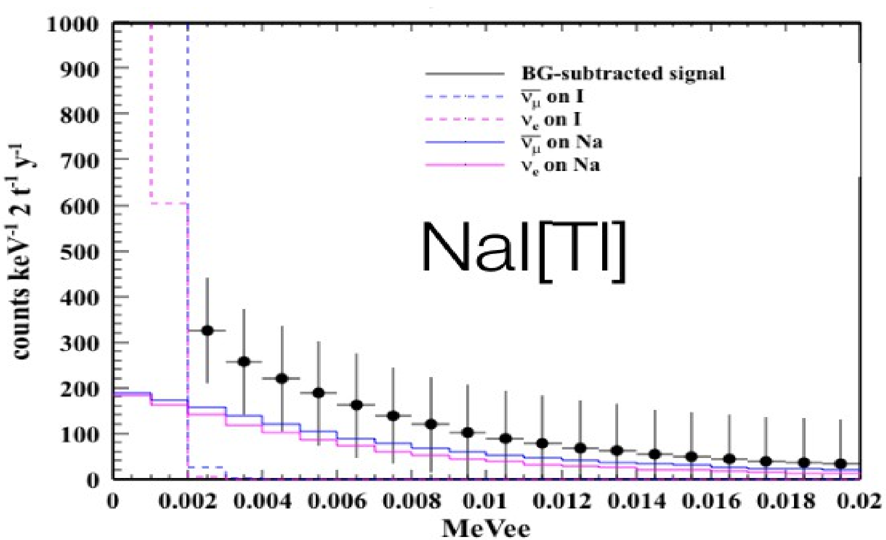


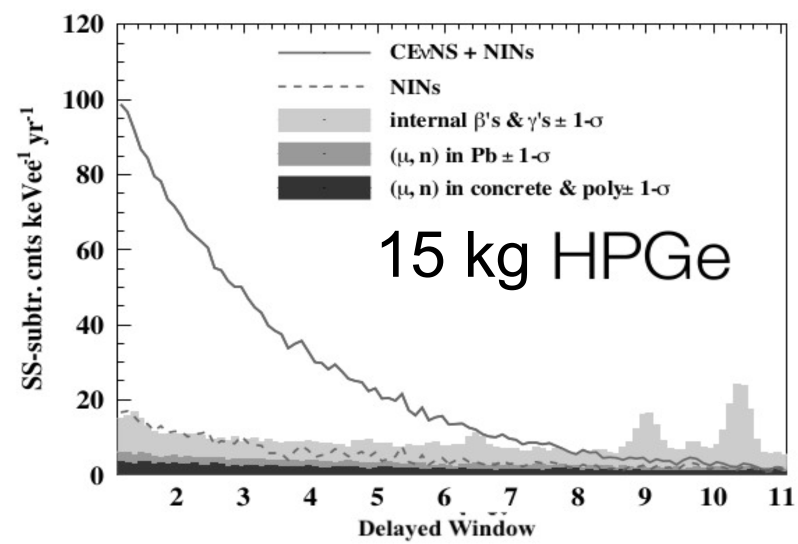
Acrylic Cylinder

Expected signals and detector backgrounds









Summary

COHERENT:

- Proposed to use a few detector technologies to register CevNS
- Deployed first order of detectors in SNS Basement
- Uses additional detectors to measure Neutrino Induced Neutron background
- Main goal for first order of detectors is testing of N^2 dependence