COHERENT Experiment: CENNS-10 detector

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On behalf of
COHERENT collaboration

ICPPA, October, 2017

Outline

- Coherent Neutrino Scattering
- Spallation Neutron Source
- The COHERENT Experiment
- Background types
- CENNS-10 detector upgrade

Coherent elastic neutrino-nuclei scattering (CEvNS)

Coherent Neutrino Scattering is a fundamental process predicted within the Standard Model by D.Z. Freedman in 1974:

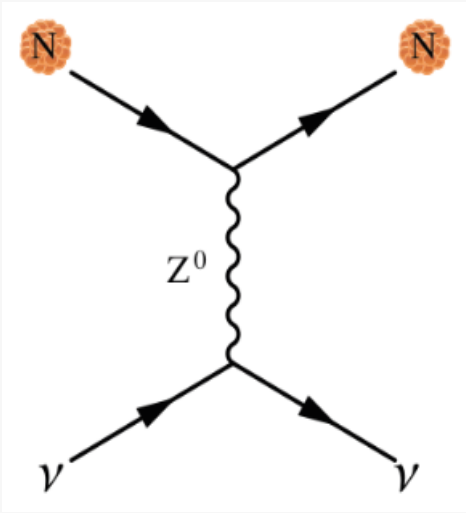
$$\nu + A \rightarrow \nu' + A'$$

Differential and total cross sections of the process are described by the formulas:

$$\frac{d\sigma}{dT_A} = \frac{G_F^2}{4\pi} m_A [Z(1-4\sin^2\theta_w) - N]^2 [1 - \frac{m_A T_A}{2E_\nu^2}] F^2(Q^2)$$

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

m_A - nucleous mass
T_A - kinetic energy of recoil nucleous
E_ν - neutrino energy
Z - nucleous charge
N - number of neutrons in nucleous
F - nucleous form factor



D.Z. Freedman PRD 9 (1974)

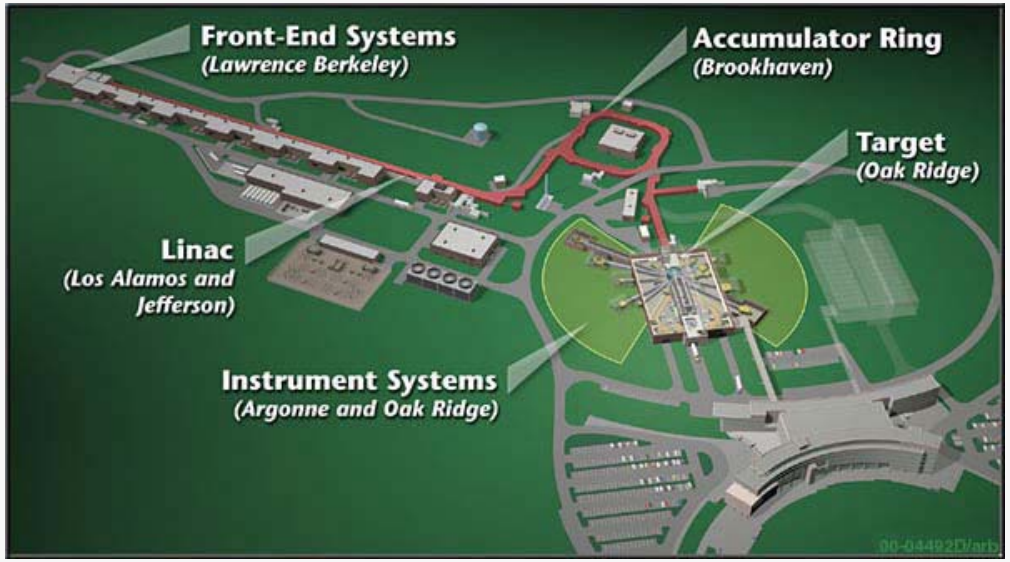
A. Drukier & L. Stodolsky, PRD 30, 2295 (1984)

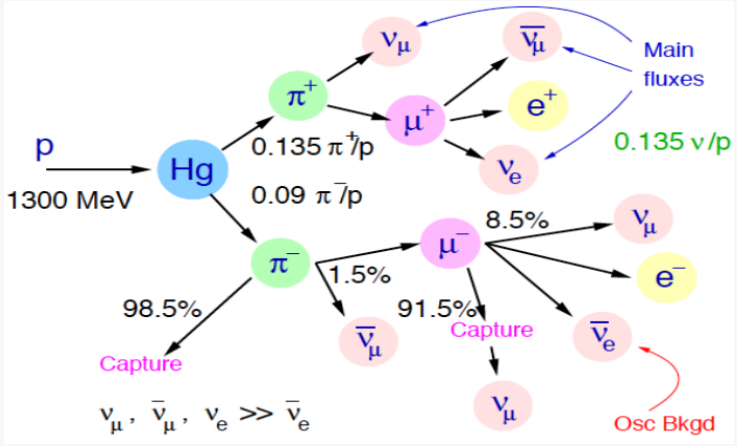
Horowitz et al. astro-ph/0302071

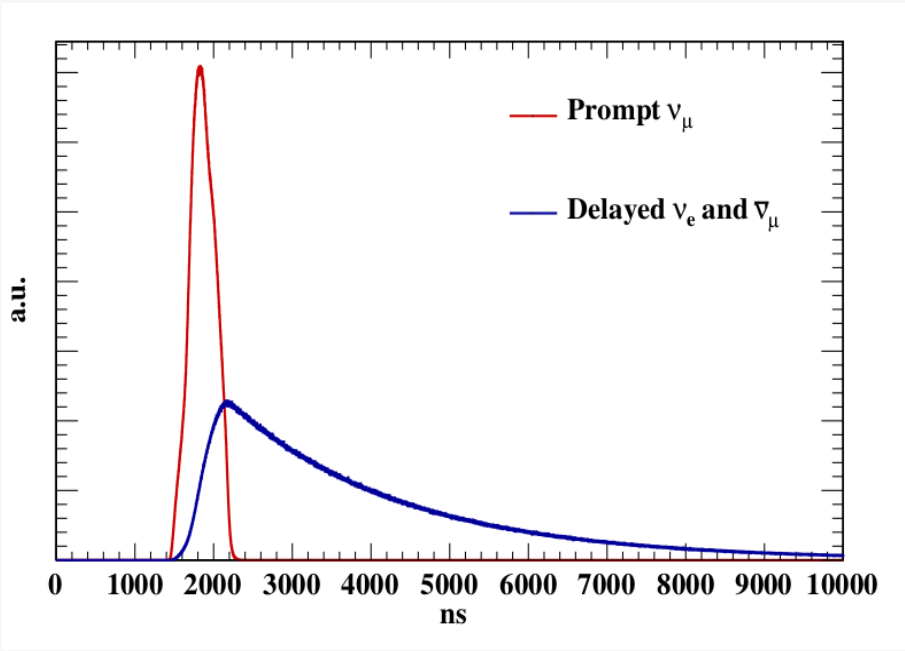
CEvNS was observed for the first time by CsI[Na] detector in terms of scientific program of the COHERENT Collaboration[1].

[1]Observation of coherent elastic neutrino-nucleus scattering.
D. Akimov et al., Science 10.1126/science.aao0990 (2017)

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







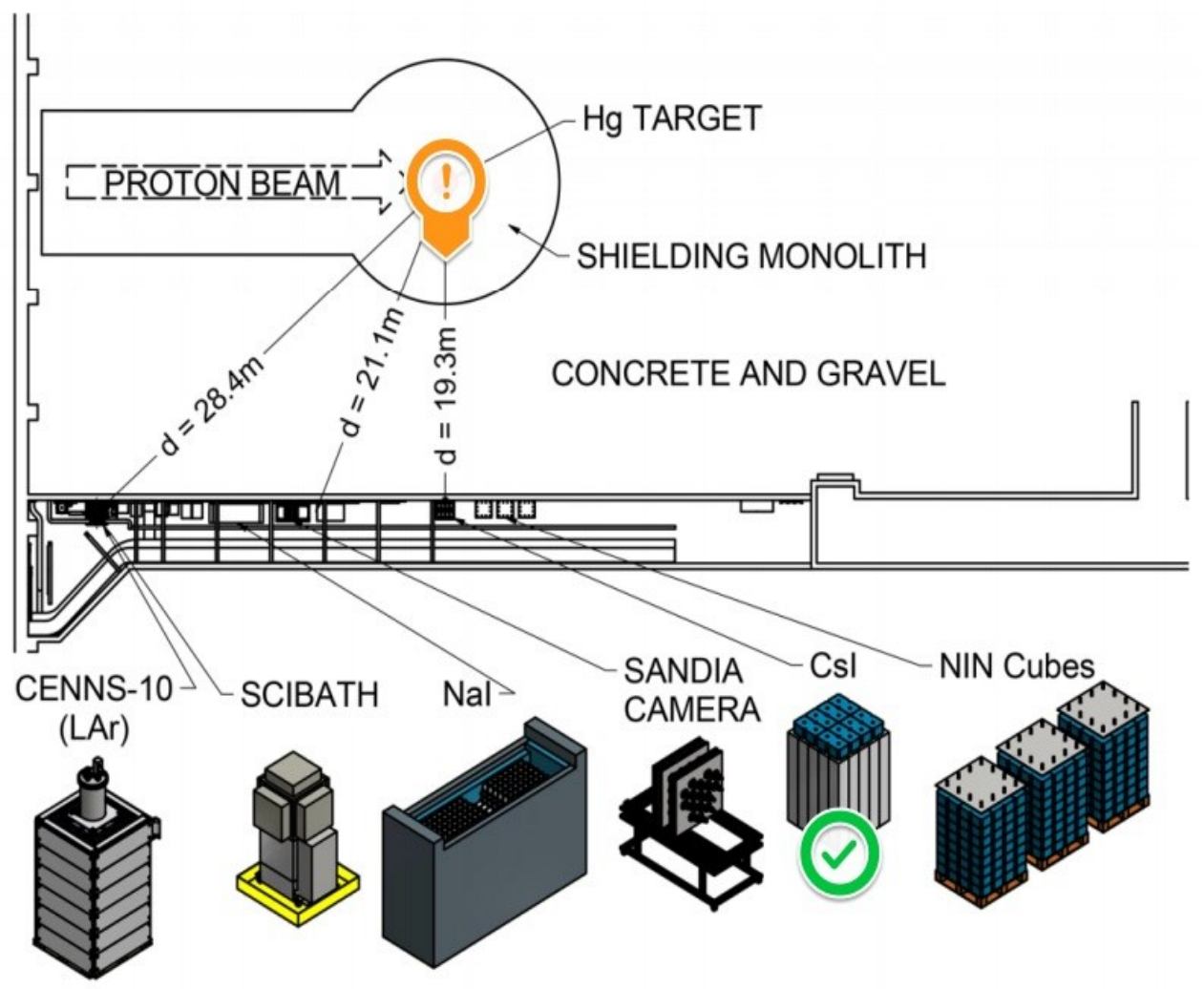
https://arxiv.org/pdf/1509.08702.pdf

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

$1.9 \cdot 10^{22}$ $year^{-1}$ neutrinos each of three flavor (ν_e, ν_μ, ν_μ):
~ $5 \cdot 10^{7}$ $cm^{-2}s^{-1}$ at 20 m from the target

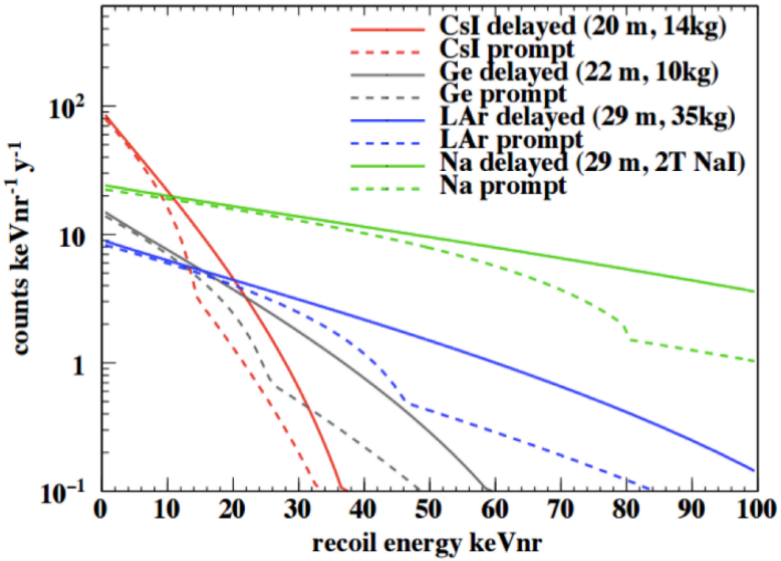
The COHERENT Experiment

The main goal is to study of details of CEvNS with multiple target materials

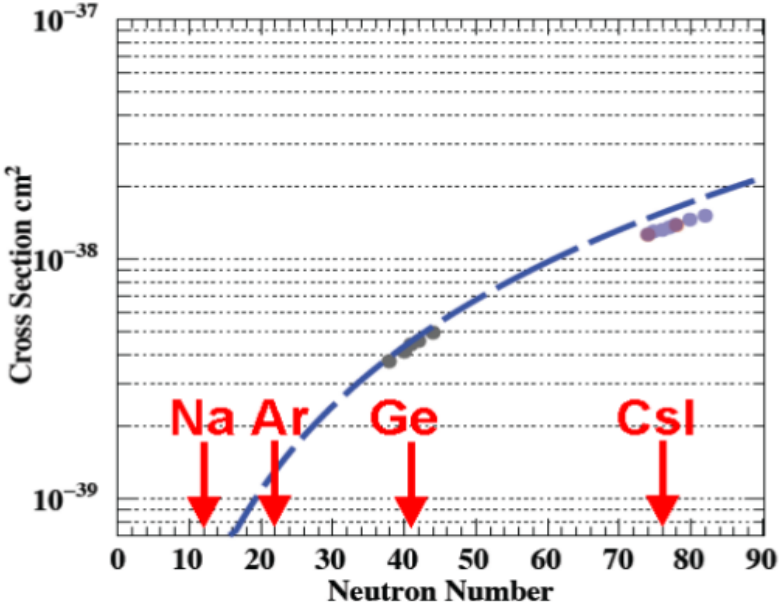


The COHERENT experimental setup.
D. Akimov et al., Science 10.1126/science.aao0990 (2017)

CEvNS recoil energy



CEvNS cross section

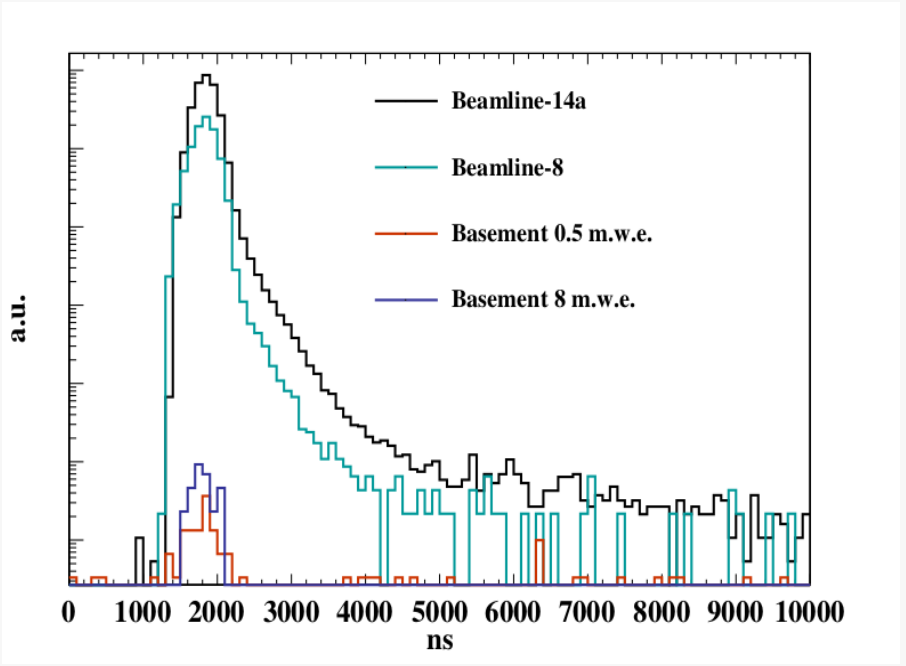


Background sources

Cosmic background:

- Beam duty factor reduces by 10^3-10^5
- Basement provide reduction of cosmic muons as 8 m.w.e

- Neutron flux (SciBath detector):
  - Promt flux ~ (2.1 ± 0.4) × 10^{-5} n/m^2/μs/MW
  - Delayed flux ~ (1.9 ± 0.7) × 10^{-5} n/m^2/μs/MW
- NINs: Neutrino Induced Neutrons

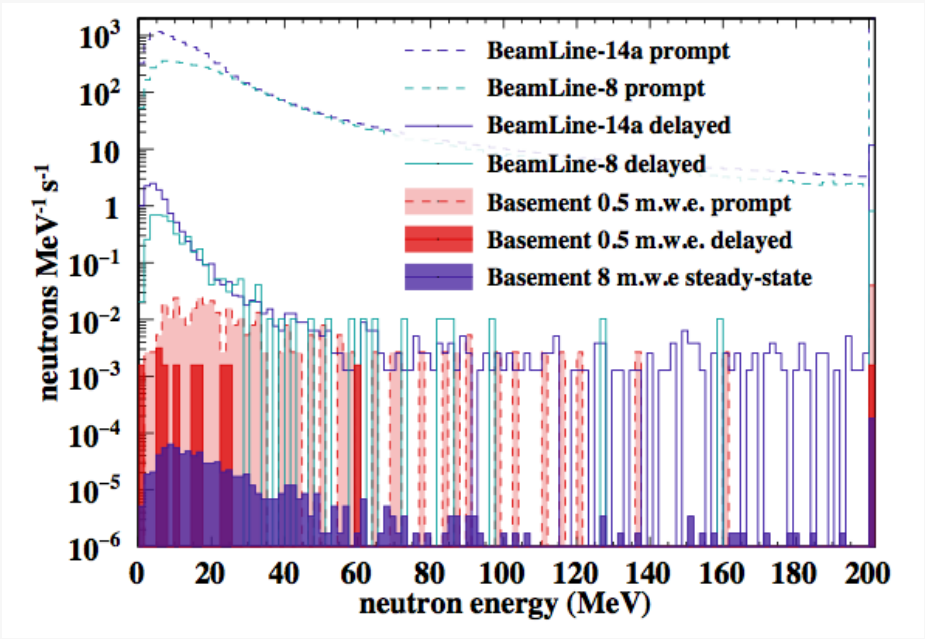


$$\nu_e + {}^{208}Pb \rightarrow {}^{208}Bi^* + e^-$$

1 n, 2n emission

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

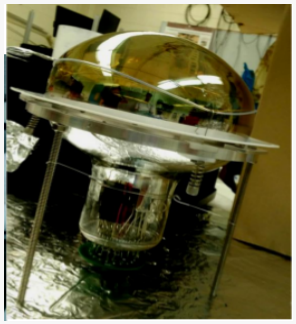
1 n, 2n, γ emission

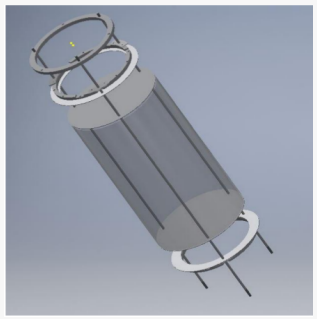


See talk of Alexey Konovalov

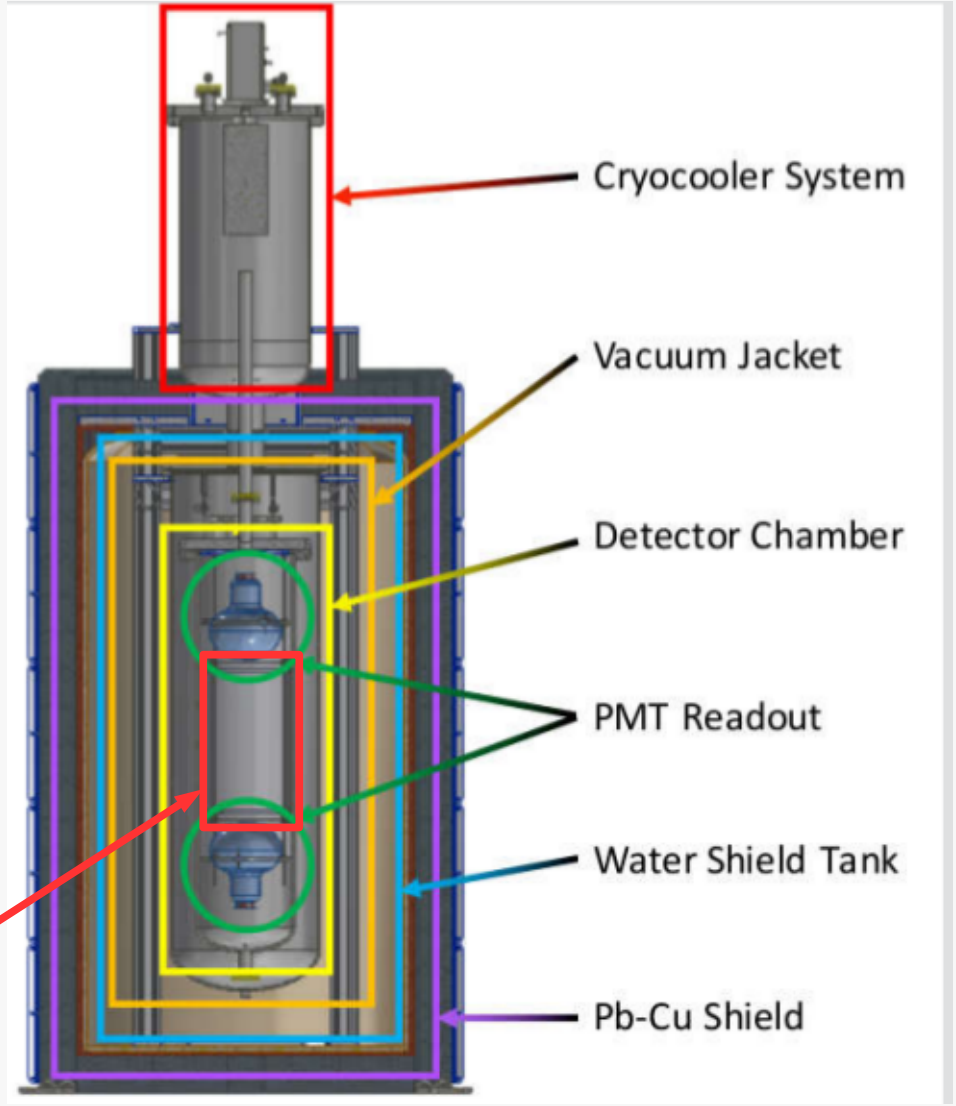
LAr option: Detector CENNS-10

- Single-phase liquid Ar scintillation detector built by J. Yoo, etal at Fermilab;
- ~ 28 kg fiducial volume;
- 2 x PMT Hamamatsu R5912-02MOD PMT (8” cryogenic);
- Max recoil energy ~ 48 keV;
- ~ 250 events/year;
- Threshold ~ 10 $keV_{nr;}$
- Cu, H_2O shielding structure;
- Calibration with ^{137}Cs, ^{57}Co and ^{252}Cf sources;
- In this configuration took data during spring 2017



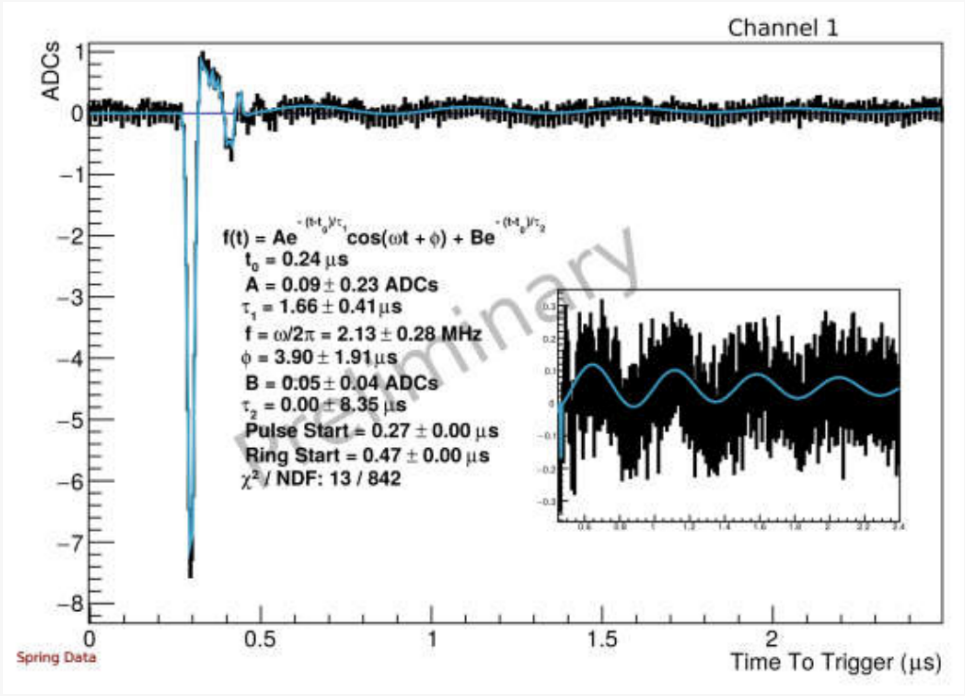


Acrylic cylinder and disks

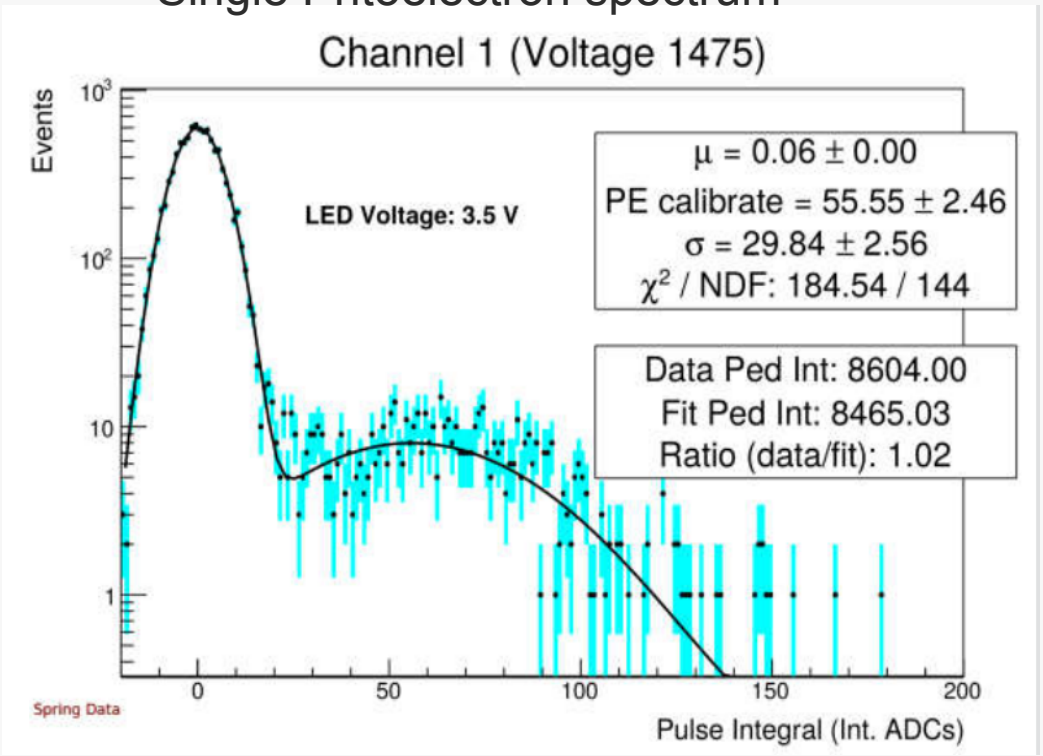


Detector CENNS-10: Preliminary data analysis. SPE analysis.

Single Phtoelectron waveform



Single Phtoelectron spectrum

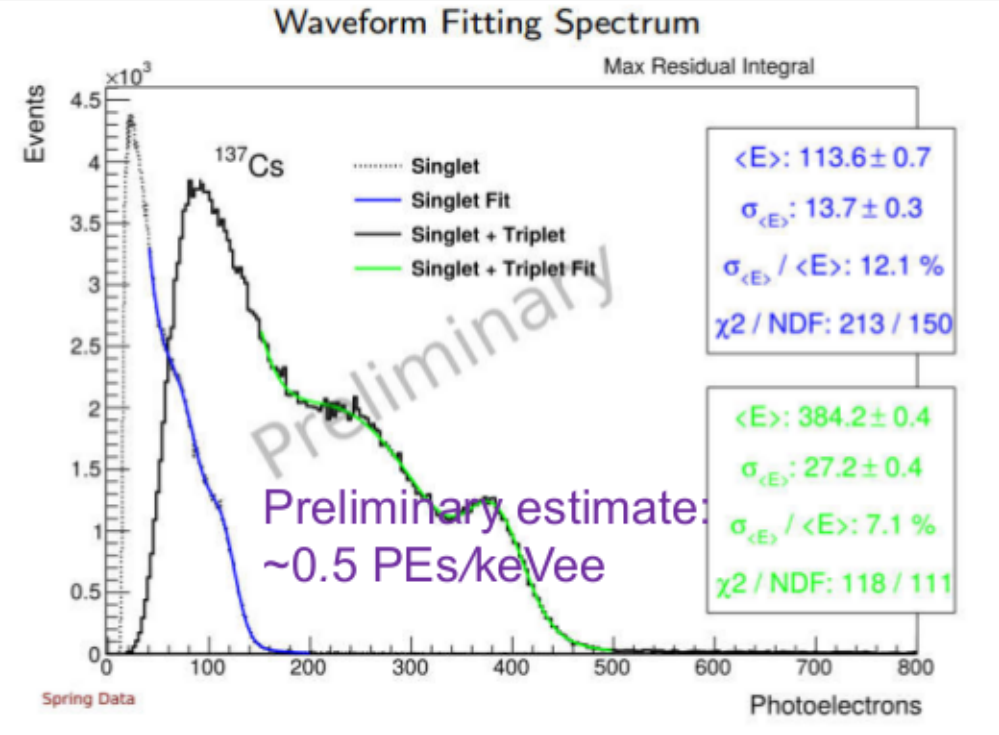


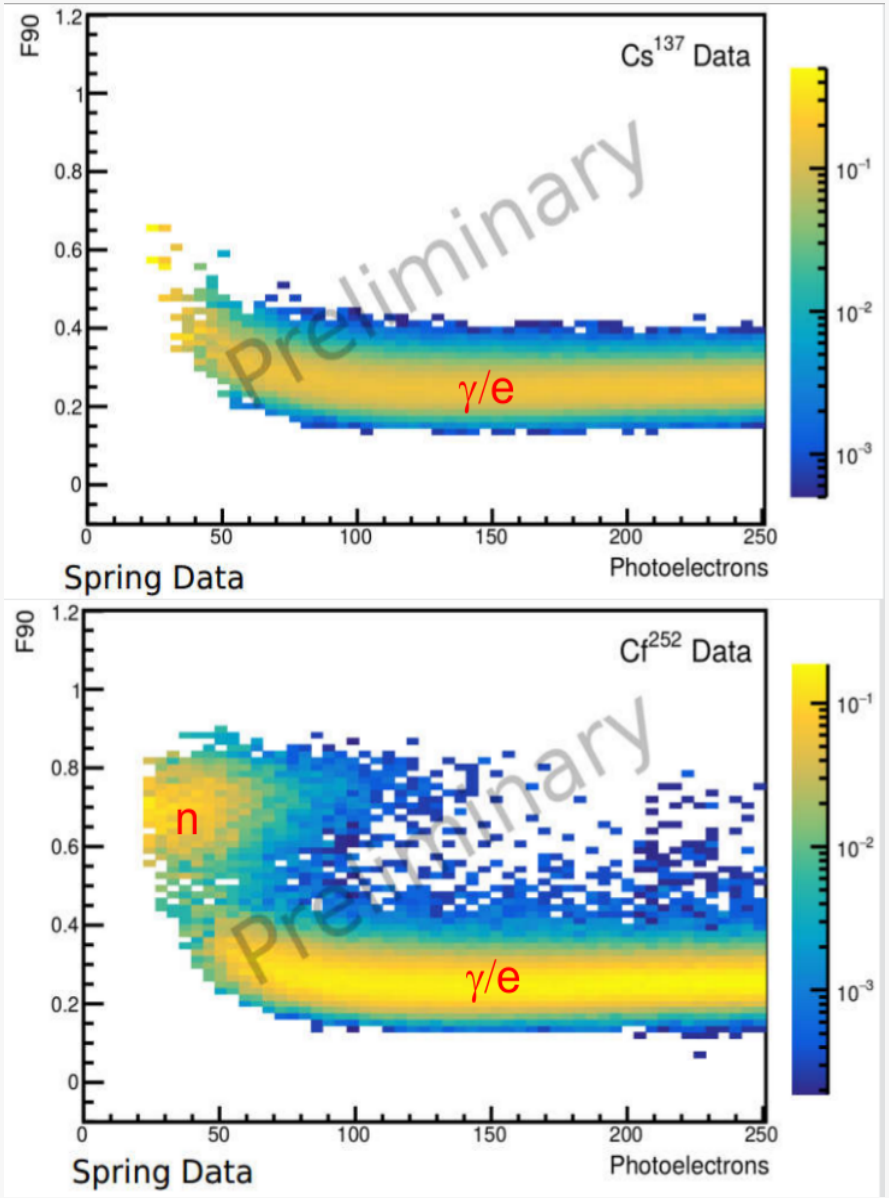
Plots from M. Heath, Indiana University

Detector CENNS-10: Preliminary analysis. Calibration data.

Analysis procedure:

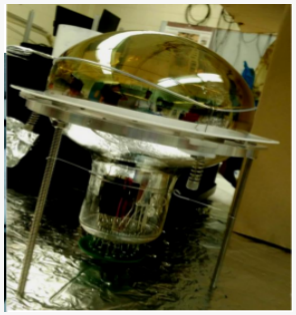
- Fit prompt (singlet) light;
- subtract scaled singlet waveform;
- integrate delayed (triplet) light;
- form F90 ratio (fract of light in 1 st 90ns) for PSD (pulse-shape discrimination)





Detector CENNS-10: Summer 2017 upgrade

- Acrylic cylinder and disks were replaced by teflon reflectors coated by TPB;
- PMT windows were also covered by evaporated TPB (2 mg/cm2);
- 22 kg fiducial volume;
- Full CENNS-10 shielding structure has been assembled.

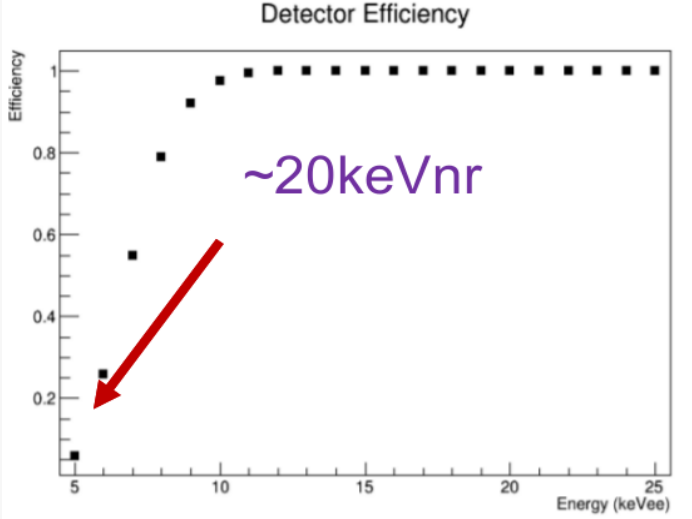


CENNS-10 detector improvement:

- Light Yield: increased at least up to the 2 SPE/keV;
- Background rate decreased by a factor of 5 (~ 180 Hz) with a full shielding structure (1.2 MW beam)

Detector CENNS-10: Predictions for upgraded detector

Estimated CEvNS threshold E_{thresh} ~ 20 keV_{nr}



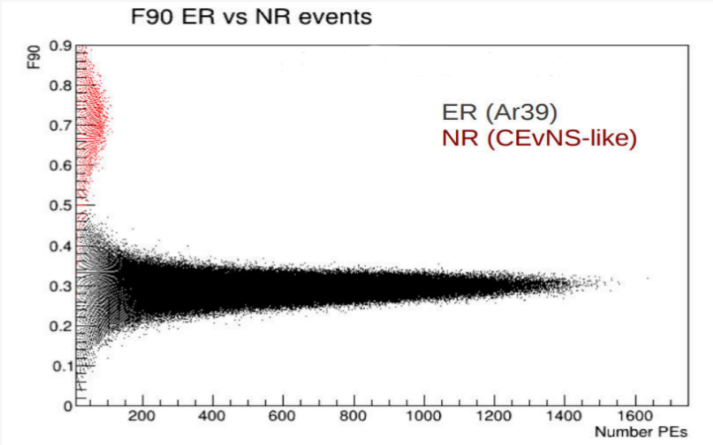
Backgrounds

Beam-unrelated:
^{39}Ar and environmental γ reduced with PSD estimated to be negligible

Beam-related:
Neutrons measured at CENNS-10 location
Expected rate ~ 60 events per year

Nuclear-/electron- recoils quenching factor has been measured by SCENE Collaboration.
H. Cao et al., SCENE Collaboration,Phys. Rev. D91 (2015) 092007

Expected ~ 60 promt and ~ 80 delayed CEvNS events per year



Simulation plots from J.Zettlemoyer Indiana University

Simulated PSD distribution

Summary

The COHERENT Collaboration:

- Use a few detector technologies to register CEvNS
- Main goal is to study of details of CEvNS with multiple target materials
- First success: CEvNS effect was observed with CsI[Na] detector first time ever
- COHERENT scientific program gains its momentum.

CENNS-10 detector:

- Has been upgraded in summer 2017
- Significant increase of scintillation light yield and background rate reduction have been achieved
- New results are coming soon...