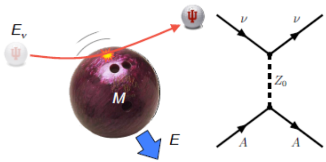
Background Studies at the Spallation Neutron Source for the COHERENT Experiment

M. R. Heath (On behalf of the COHERENT Collaboration)
Indiana University

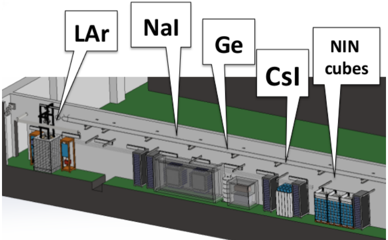
October 15, 2016

Coherent Elastic Neutrino Nucleus Scattering

- Neutrino collides with large nucleus which recoils coherently
  - $E_\nu \lesssim \frac{hc}{R_N} \approx 50\,\text{MeV}$
- Small recoil energy
  - $E_r^{max} \lesssim \frac{2E_\nu^2}{M_N} \simeq 50\,\text{keV}$
  - Difficult to detect



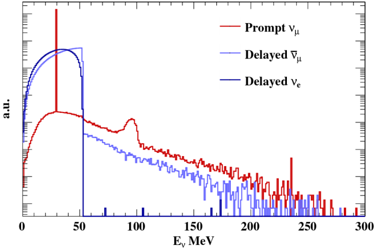
- Background measurements at Spallation Neutron Source (SNS) ID'd "Neutrino Alley"!
  - Low background environment in SNS basement

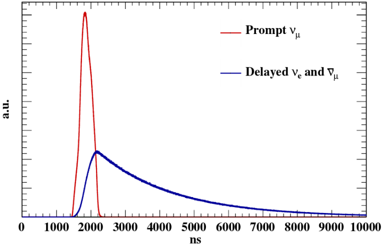


Background Reduction

Pulsed Beam

- SNS neutrino beam flux and timing profile enables background rejection
- Beam duty factor reduces steady state backgrounds by $10^3 - 10^5$
  - Radioactivity and cosmics
  - Can also make use of background subtraction with measurement of beam unrelated backgrounds!

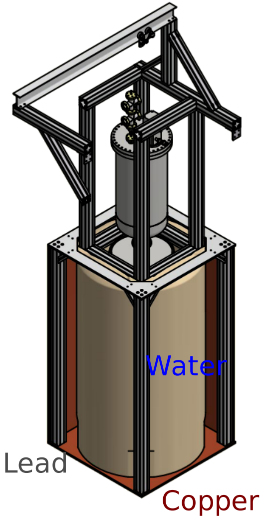




Gamma Backgrounds

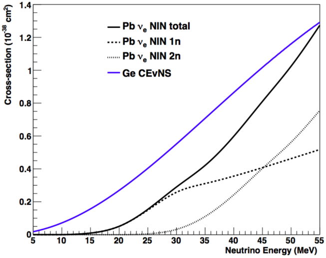
- Main sources:
  - Nearby pipe (511 keV γ's: $(25 \pm 8)\,\gamma/\text{cm}^2/\text{s}$
  - Wall and floor (U/Th/K in concrete): $(2.0 \pm 0.1)\,\gamma/\text{cm}^2/\text{s}$
- Simulations indicate negligible contamination of signal if shielded
- Additionally reduced by beam duty factor and Pulse Shape Discrimination (PSD)
- Expect (1-10) $\times\, 10^{-6}$ events/year

CENNS-10 Shielding

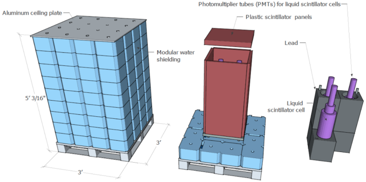


Neutrino Induced Neutrons (NINs)

- Neutron backgrounds in time with expected CEvNS signal!
  - Produced by neutrinos in Pb shielding
- Cross section poorly known
  - Measurement underway
  - Of interest to Helium and Lead Observatory (HALO)
  - Important for nucleosynthesis of heavy elements in supernovae



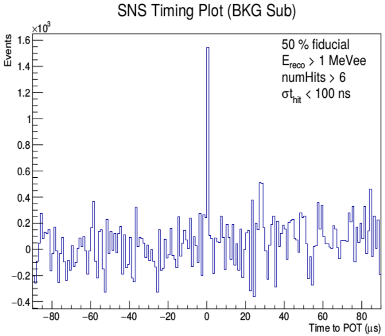
- ~1 % of expected signal



Pb Neutrino Cube (Nube)

Beam Correlated Neutrons

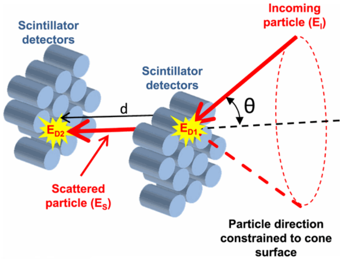
- Largest concern is beam correlated neutrons
  - PSD helps separate nuclear from electronic recoils
  - Fast neutrons difficult to shield
  - Low energy neutrons mimic CEvNS signature!
- Campaign underway since 2013 to measure beam related neutrons



- Very neutron quiet location in the SNS basement ID'd
  - ~10s of neutrons / day

Sandia Neutron Scatter Camera

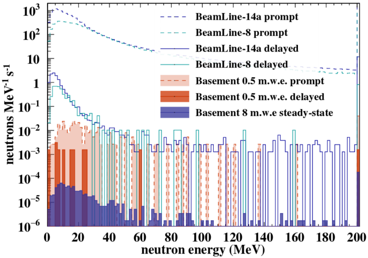
- 2 planes of EJ-309 scintillator cells
  - Good energy resolution and some directionality
- Variable plane separation allows optimization of effective area and resolution
- Neutron/gamma PSD

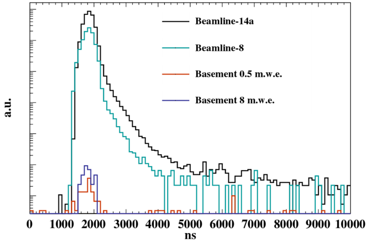


N. Mascarenhas et al., *IEEE Trans. Nucl. Sci.* **56** (2009) 1269.

Sandia Neutron Scatter Camera

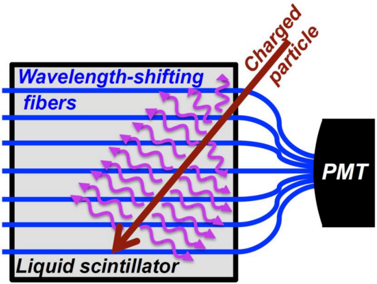
- Map SNS neutrons in 2013
- Fast neutron background easily seen in ~800 ns "prompt" beam window
- Neutron flux down by at least an order of magnitude in the "delayed" beam window
  - ~2.2 μs window after the beam searching for μ decay ($\overline{\nu}_\mu$, ν_e)
  - Neutrons also lower energy
- Results corroborated by IU owned SciBath Detector

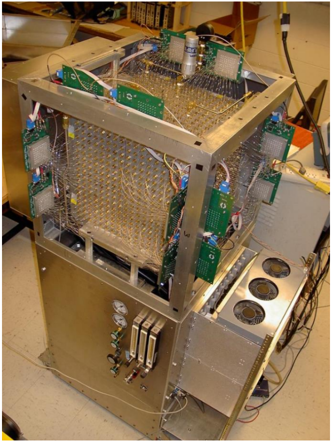




SciBath Detector

- 80 L of liquid scintillator
- 768 fibers in 3D grid for event reconstruction
  - No optical separation
  - High channel density
  - Uniform tracking efficiency



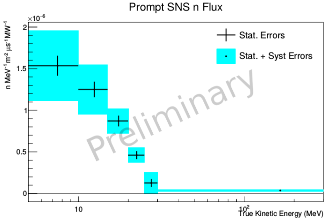


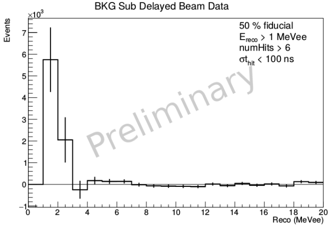
R. Tayloe et al., *Nucl. Instrum. Meth.* **A562** (2006) 198.
S. J. Brice et al., *Phys. Rev. D* **89**, 072004 (2014)

Neutron Backgrounds

SciBath Detector

- Run in liquid argon location in 2015
- **Prompt flux ((5-30) MeV):**
  $(2.1 \pm 0.4) \times 10^{-5}\ \mathrm{n/m^2/\mu s/MW}$
- Delayed flux:
  - Fast neutron flux consistent with zero
  - Indicative of thermal neutron captures
    - Easily shielded
  - Flux:
    $(1.9 \pm 0.7) \times 10^{-5}\ \mathrm{n/m^2/\mu s/MW}$

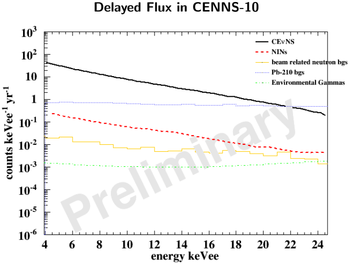


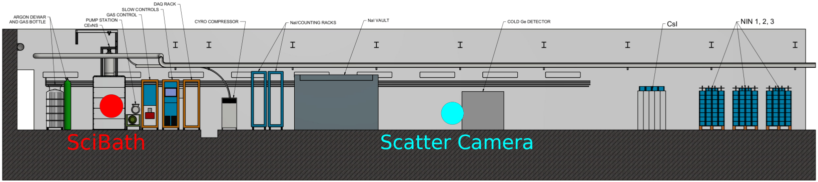


- FLUKA simulations indicate (3.2 ± 0.3) events/year in CEvNS ROI
  - CENNS-10 liquid argon detector
  - Prompt window

Summary

- COHERENT collaboration searching for CEvNS
- Background measurement campaign ID'd EXTREMELY neutron quiet location in SNS basement
- Longer term measurements of real-time neutron flux at detector locations planned





The COHERENT collaboration

arXiv:1509.08702

Institution	Board Member
University of California, Berkeley	Kai Vetter
University of Chicago	Juan Collar
Duke University	Kate Scholberg
University of Florida	Heather Ray
Indiana University	Rex Tayloe
Institute for Theoretical and Experimental Physics, Moscow	Dmitri Akimov
Lawrence Berkeley National Laboratory	Ren Cooper
Los Alamos National Laboratory	Steve Elliott
National Research Nuclear University MEPhI	Alex Bolozdynya
New Mexico State University	Robert Cooper
North Carolina Central University	Diane Markoff
North Carolina State University	Matt Green
Oak Ridge National Laboratory	Jason Newby
Sandia National Laboratories	David Reyna
University of Tennessee, Knoxville	Yuri Efremenko
Triangle Universities Nuclear Laboratory	Phil Barbeau
University of Washington	Jason Detwiler

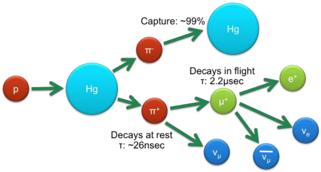
- Collaboration: ~65 members, 16 institutions (USA+ Russia)

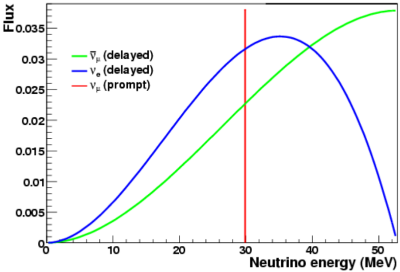
Questions?

Backups

Beam Signal

- 60 Hz pulsing of protons on target produces sharply pulsed timing structure
- Prompt ν_μ with delayed $\overline{\nu}_\mu$ and ν_e



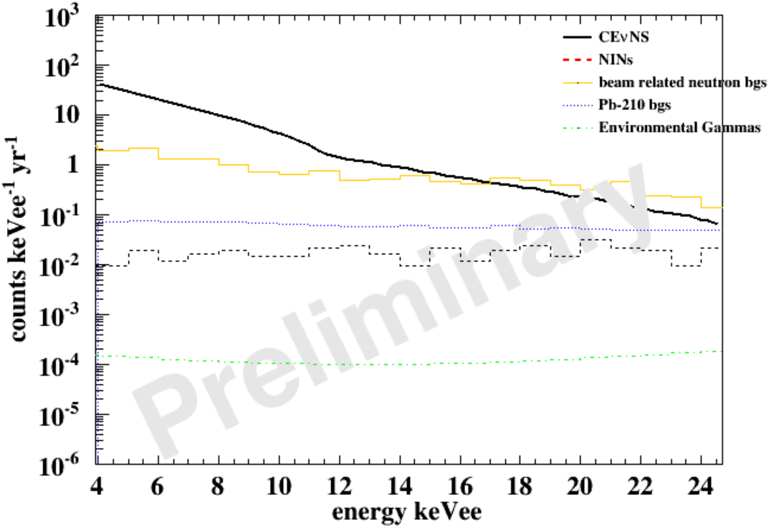


$\pi^+ \rightarrow \mu^+ + \nu_\mu$ *Prompt 29.9 MeV*

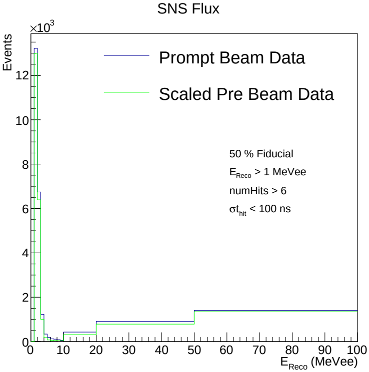
$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$ *Delayed, spectrum from 3-body decay*

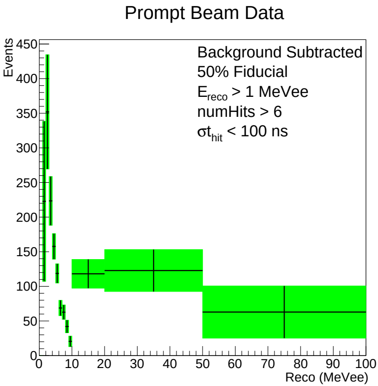
Avignone & Efremenko, J Phys G 29 (2003), 2615-2628

CENNS-10 Promp Signal + BKG

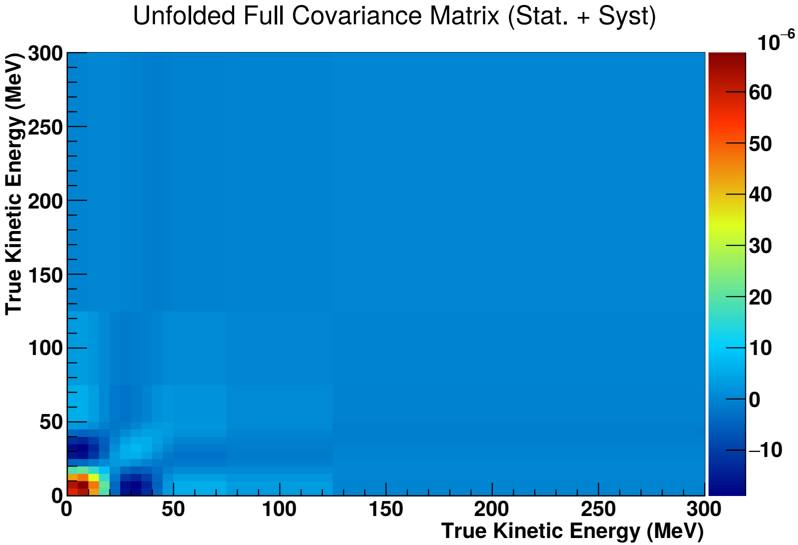


SciBath Prompt Reco Distribution

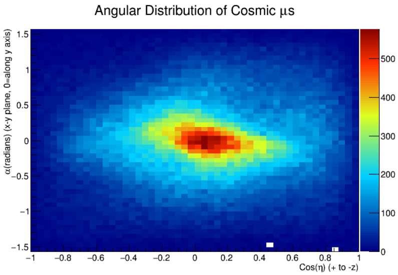


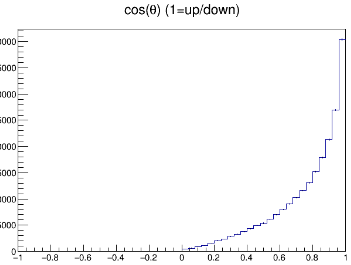


Full Covariance Matrix

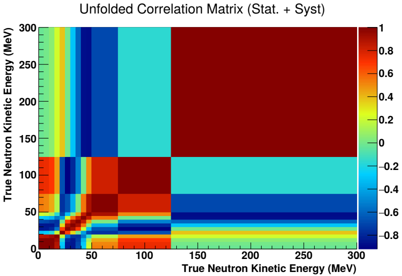


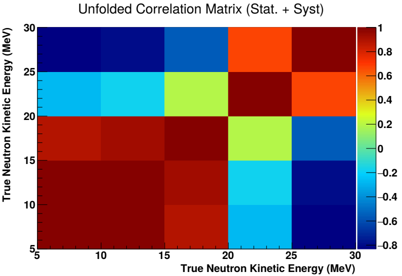
Muon Results



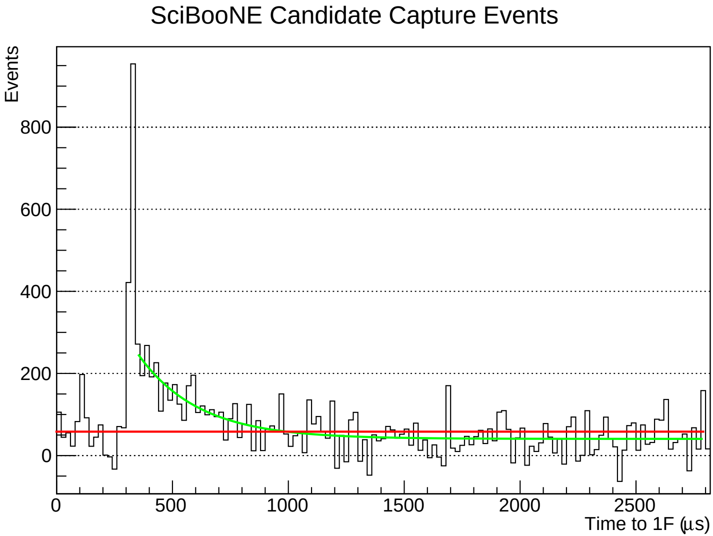


Correlation Matrix

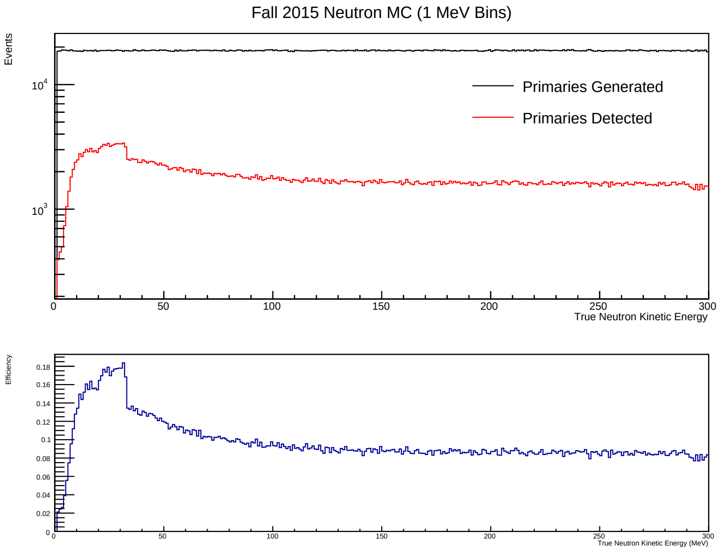




Neutron Captures



Neutron Scatter Efficiency



Cross Section Issues