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COHERENT SNS ν Scattering

Phil Barbeau, Duke University

Coherent **ν**-Nucleus Scattering

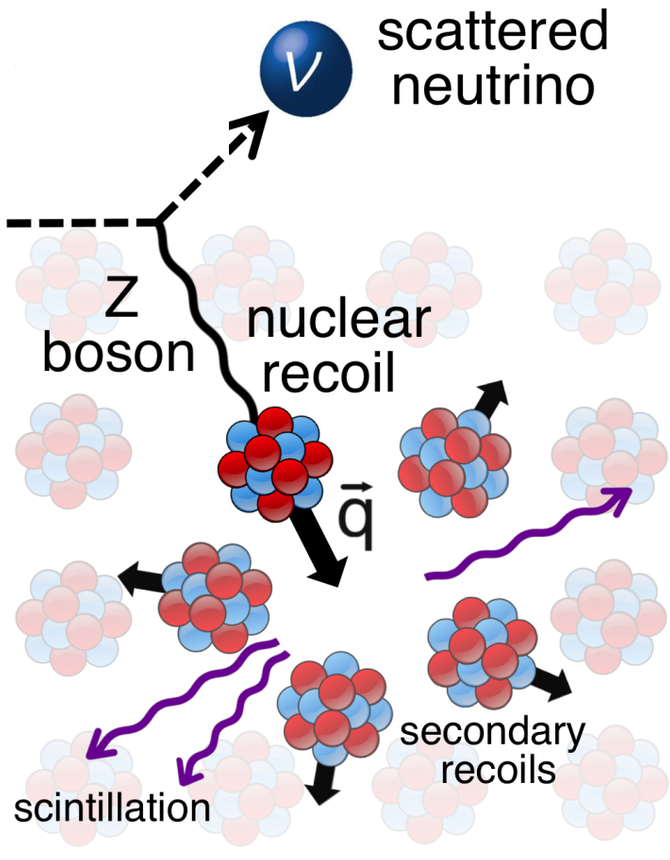
- 43 years ago, Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) was predicted with the realization of the neutral weak current.

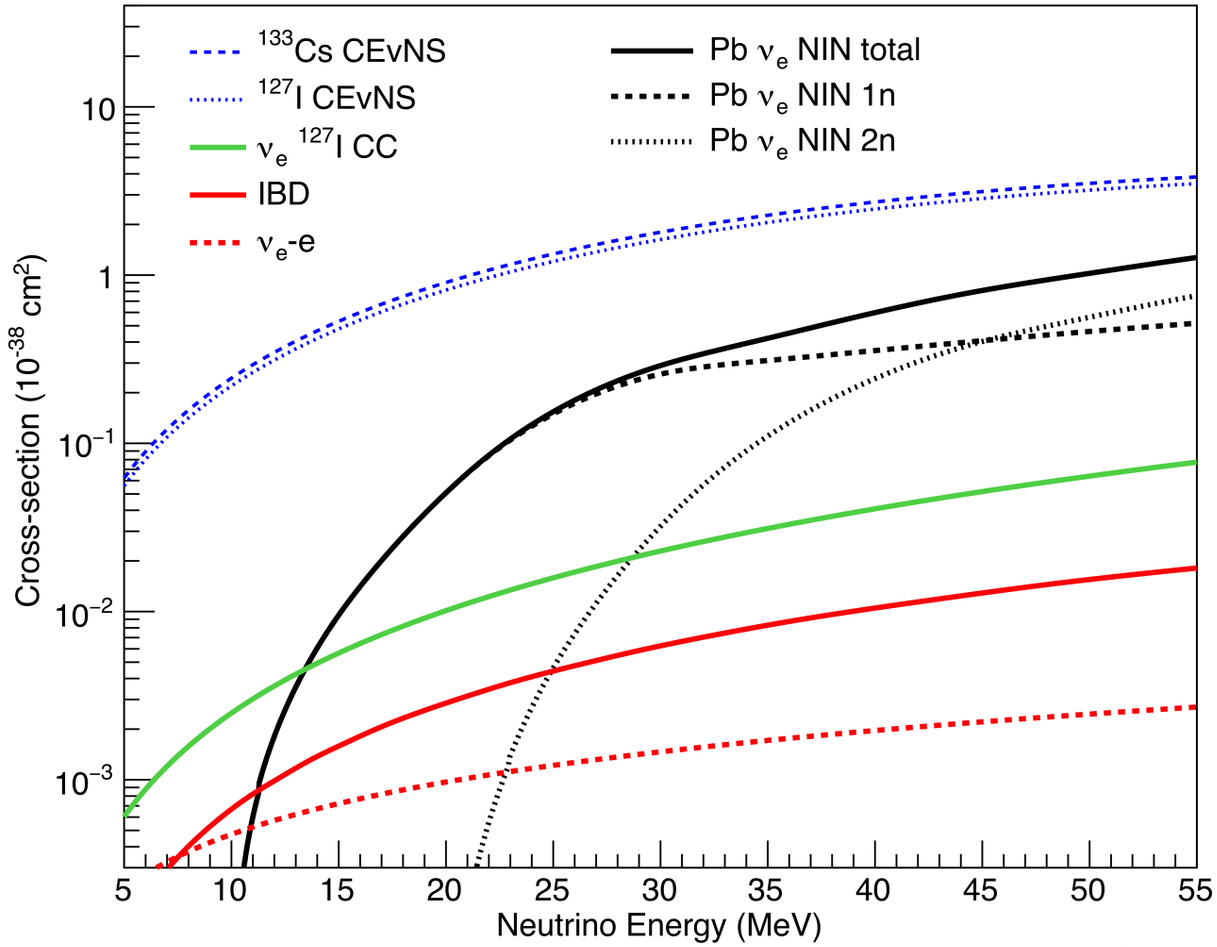
  D. Z. Freedman, PRD 9 (5) 1974

- Neutrino scatters coherently off all Nucleons → cross section enhancement: $\sigma \propto \mathbf{N^2}$

- Initial and final states must be identical: Neutral Current elastic scattering

- Nucleons must recoil in phase →low momentum transfer qR <1 → *very* low energy nuclear recoil





Coherent ν-Nucleus Scattering: a new tool

- Largest σ in Supernovae dynamics.

  J.R. Wilson, PRL 32 (74) 849

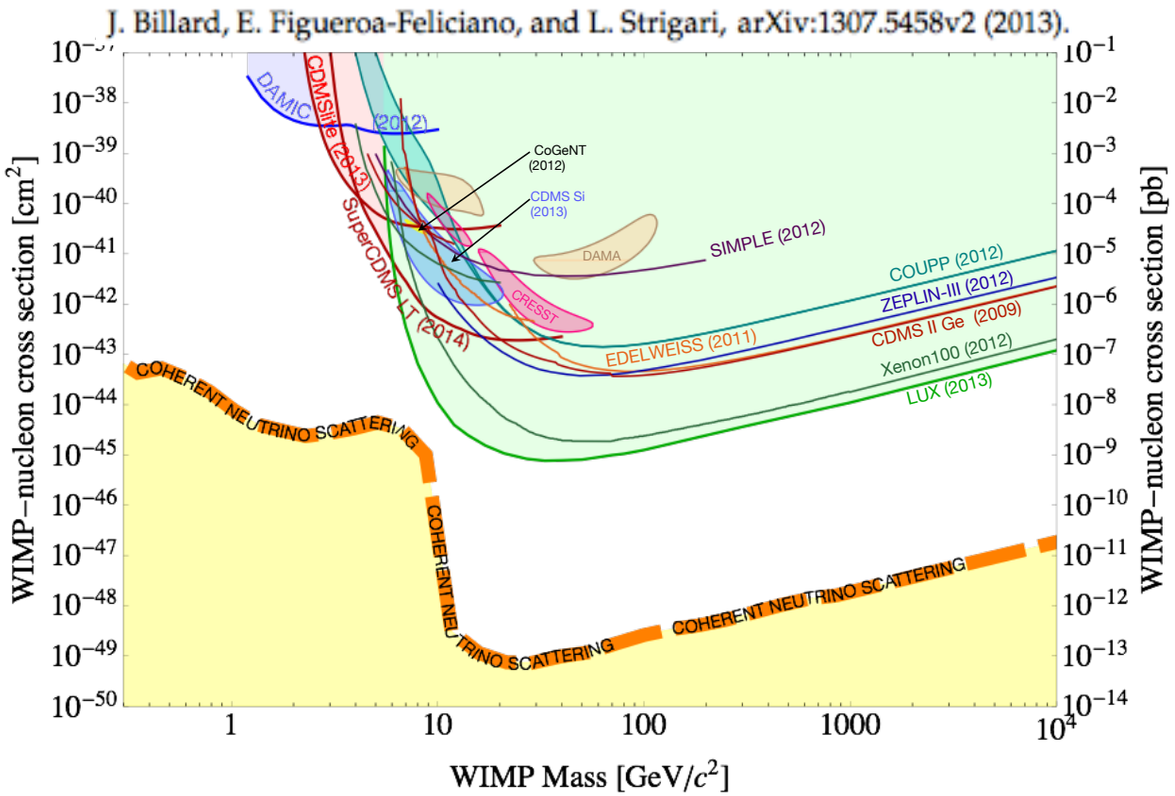
- Non-standard Neutrino Interactions relevant for DUNE & LBL CP violation.

  K. Scholberg, Phys.Rev.D73:033005,2006

  J. Barranco et al., JHEP0512:021,2005

  Mehedi Masud, Poonam, Mehta, arXiv: 1603.01380

- CEvNS is an irreducible background from WIMP searches.



- Sensitive tool for Sterile neutrino searches

  A. J. Anderson et al., PRD 86 013004 (2012)

  A. Drukier & L. Stodolsky, PRD 30 (84) 2295

- A precision test of σ is a sensitive test of new physics above the weak scale.

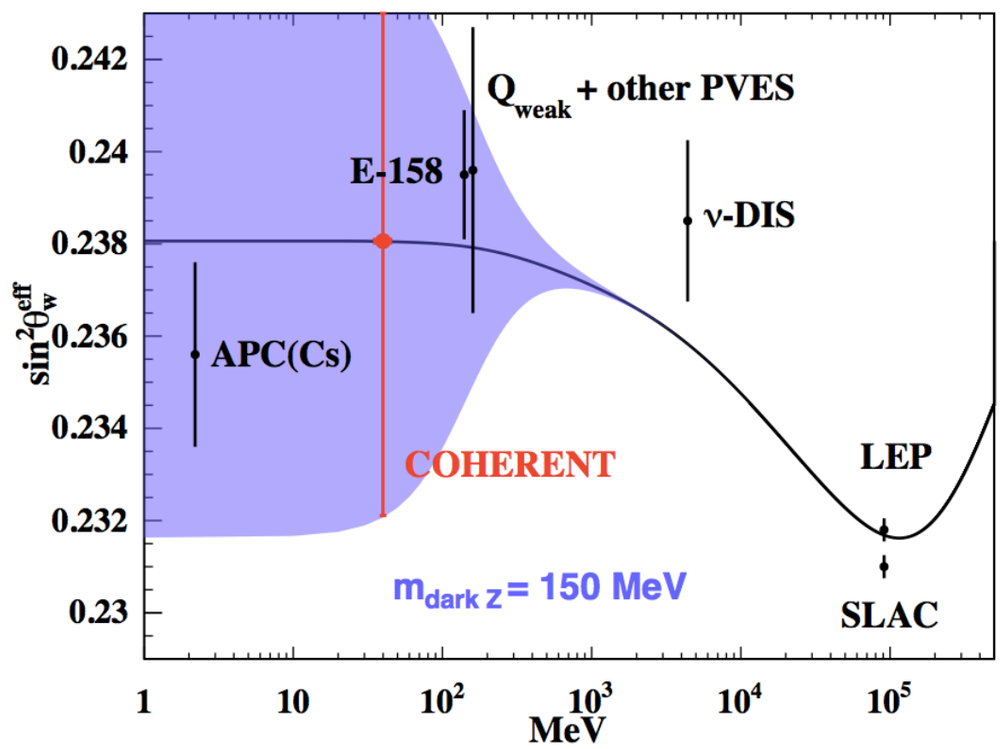
  L. M. Krauss, PLB 269, 407

- Neutrino Magnetic Moments

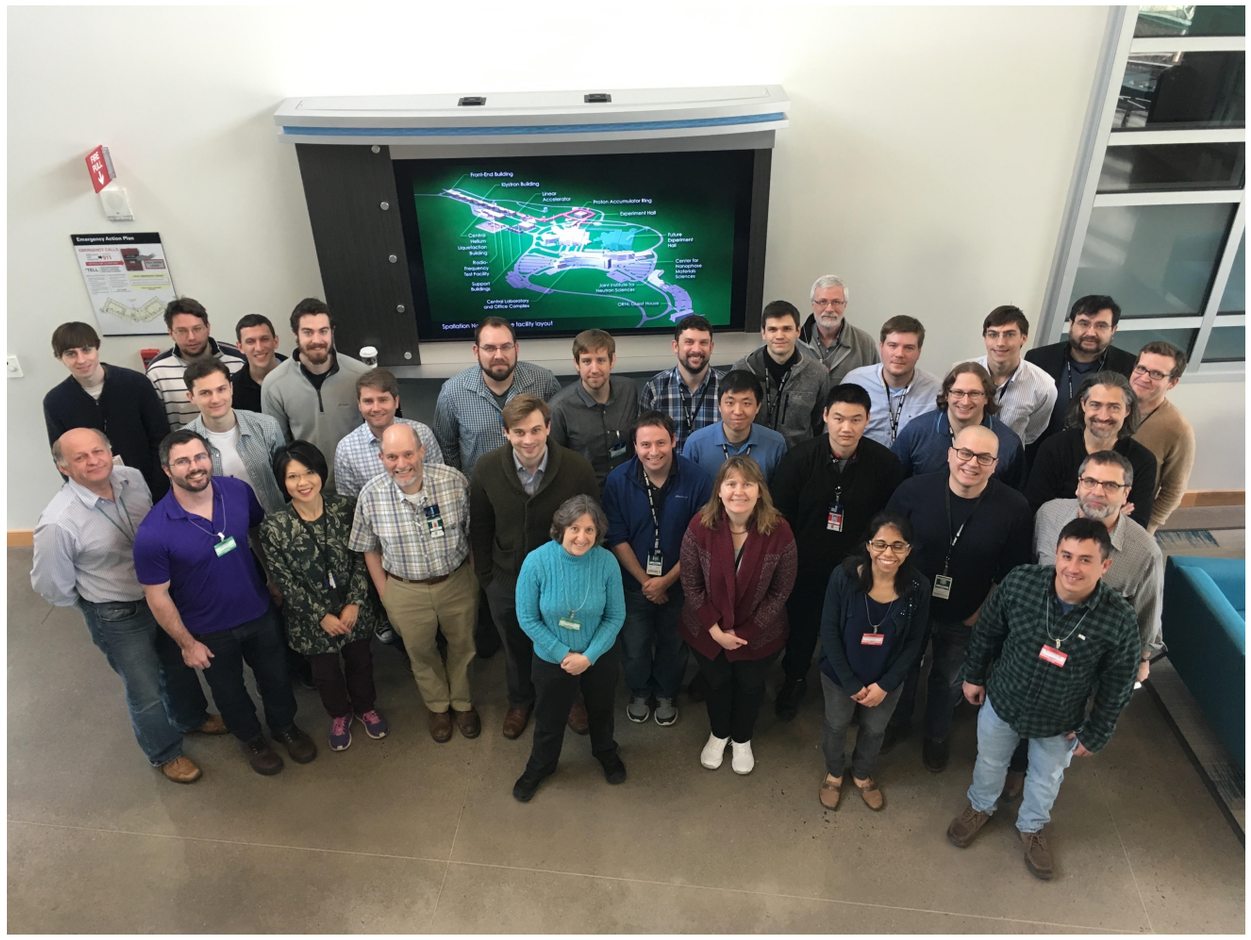
  A. C. Dodd, et al., PLB 266 (91), 434

- Neutron distribution functions

  K. Patton, et al., PRC 86, 024216



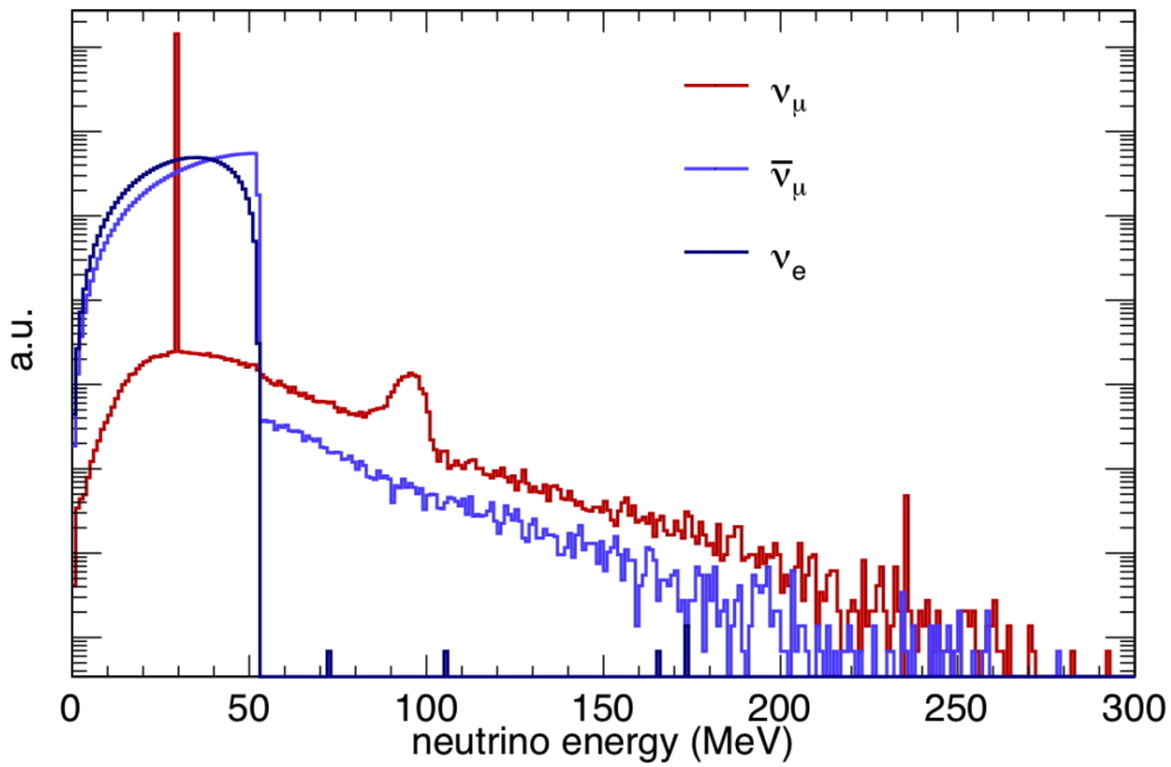
The COHERENT Collaboration



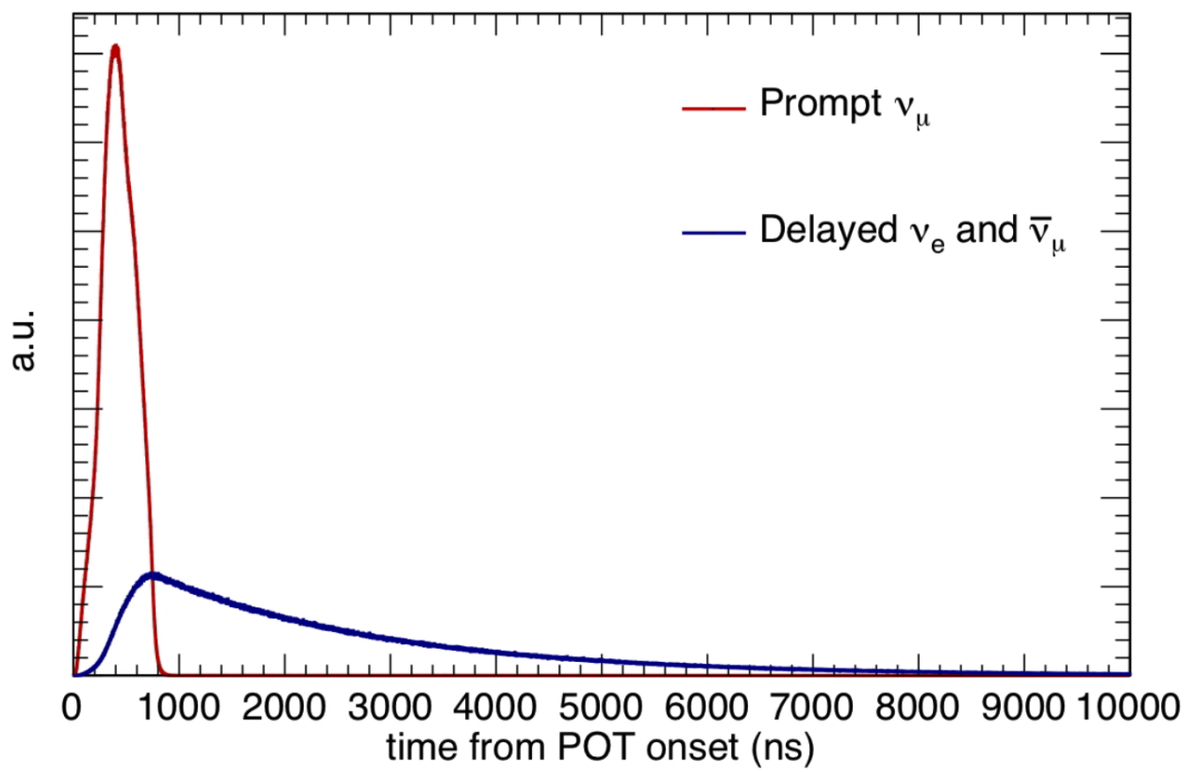
The Spallation Neutron Source

- Pion Decay-at-Rest Neutrino Source
- ν flux 4.3×10^7 ν cm^{-2} s^{-1} at 20 m
- Pulsed: 800 ns full-width at 60 Hz

<1% contamination from non-CEvNS scatters

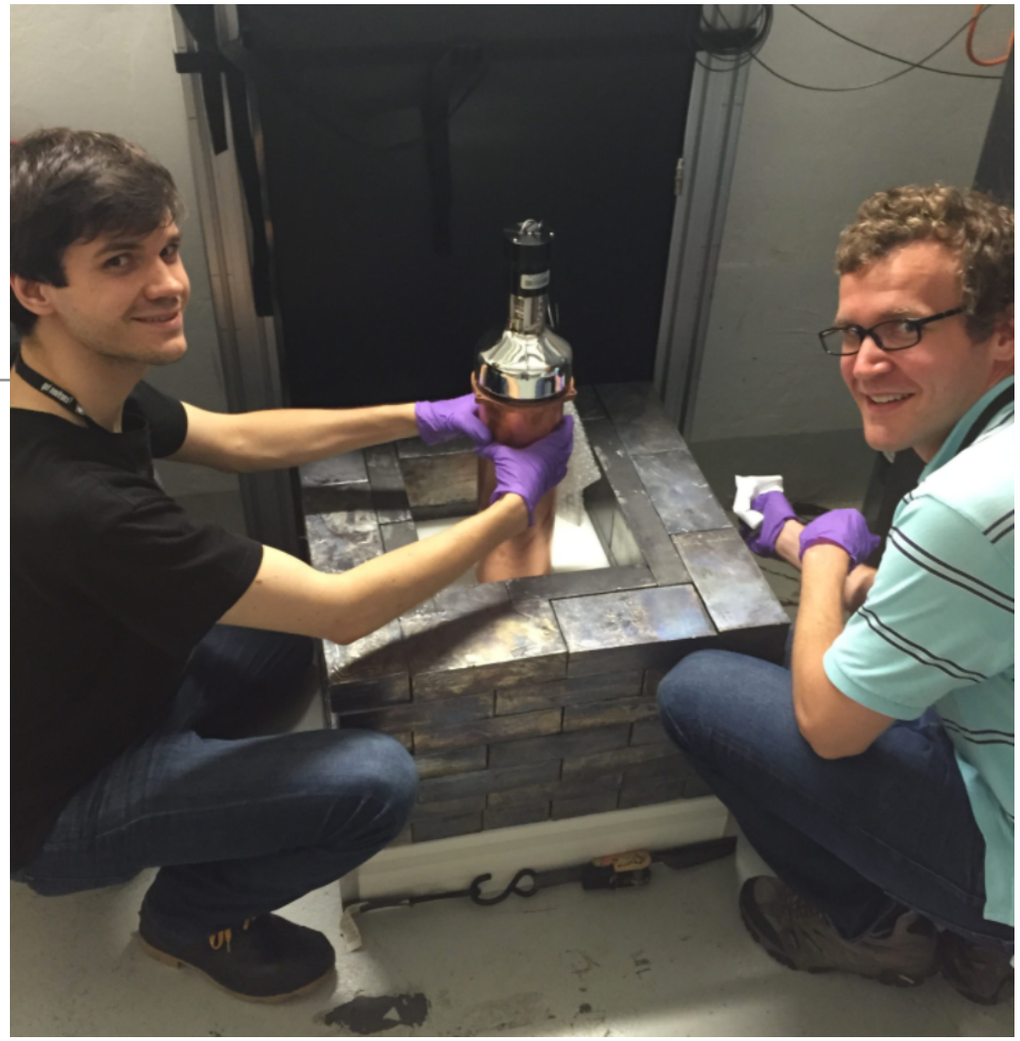


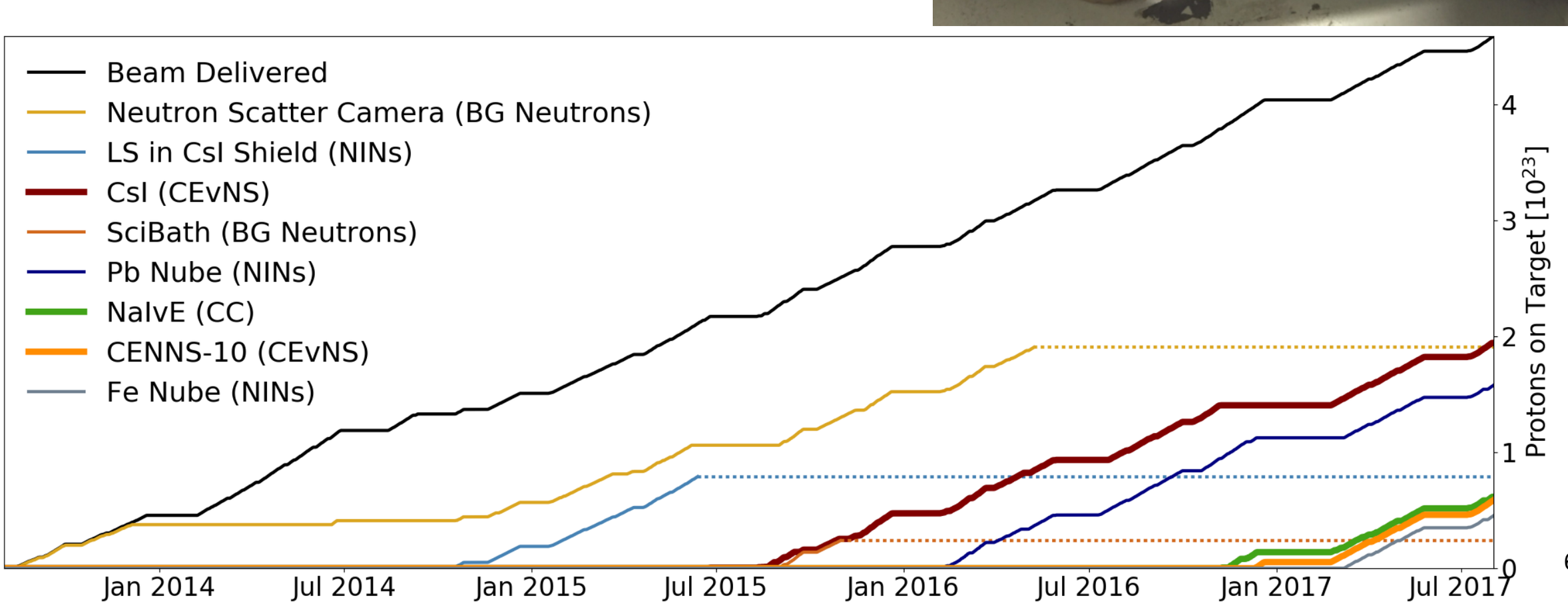
~4×10^{-5} background reduction



A hand-held neutrino detector

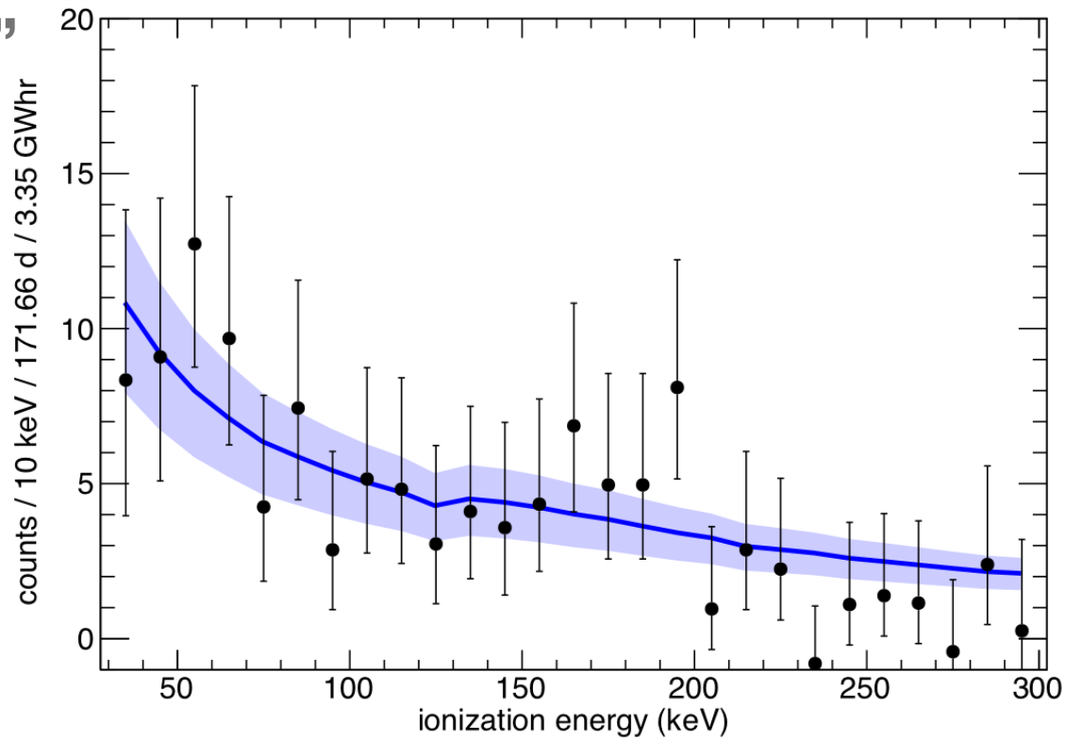
- 14.6 kg low-background CsI[Na] detector deployed to a basement location of the SNS in the summer of 2015
- ~ $2x10^{23}$ POT delivered and recorded since CsI began taking data

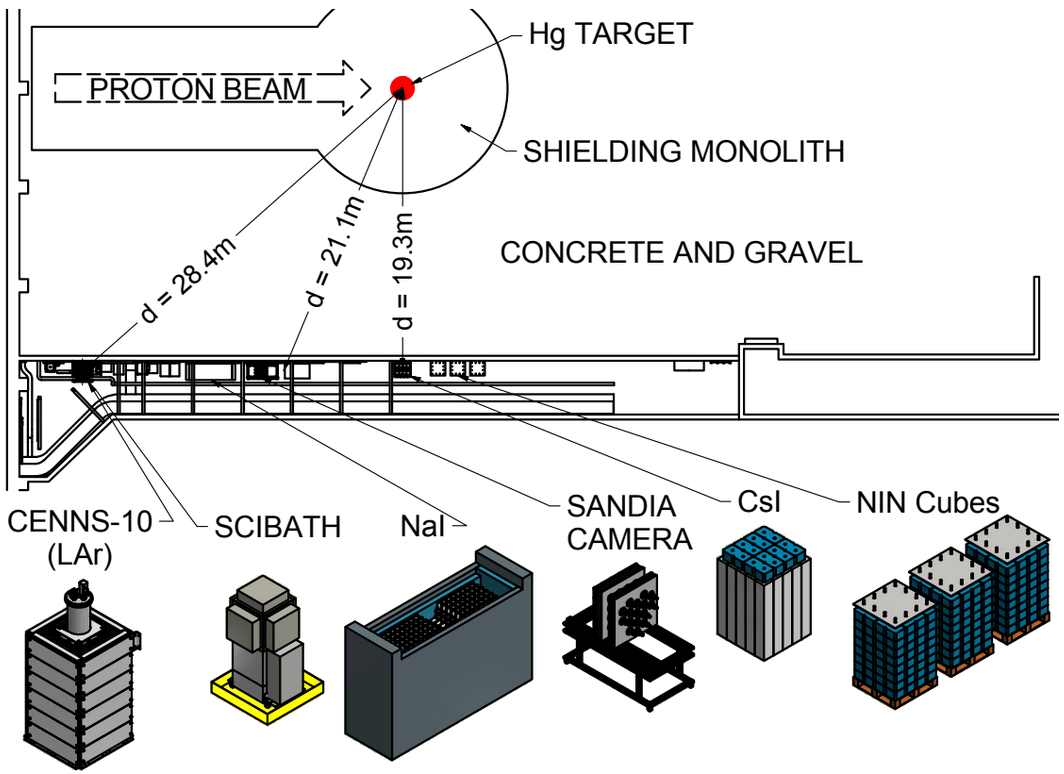


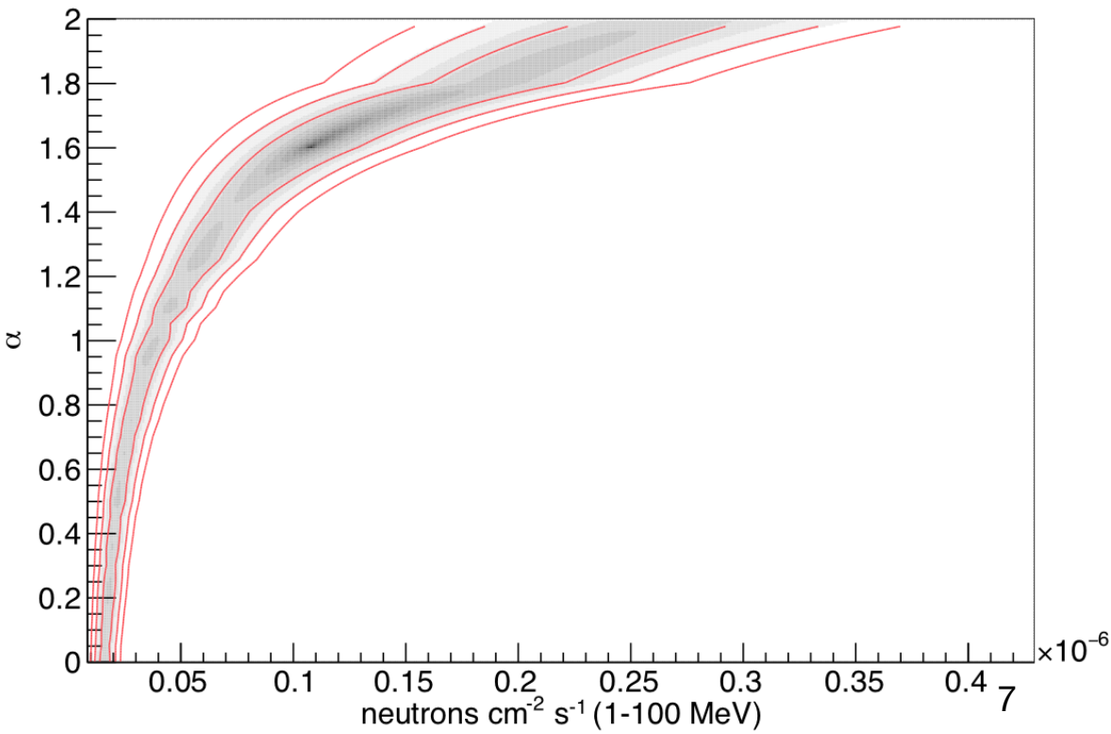


What about neutron backgrounds?

- A basement location dubbed **“Neutrino Alley”** shields us from the copious flux of neutrons produced at the SNS
- Location identified after a detailed hunt with neutron detectors (Scatter-Camera and SciBath)
- In situ measurement of the neutrons within the CsI shield prior to installation of CsI[Na] detector







Another background: neutrino-induced neutrons

- In-situ measurement also provides a constraint on a neutron-producing background in the lead shield of the detector

- First indications of neutrino-induced neutrons in Pb (a factor of 1.7 below theory prediction)

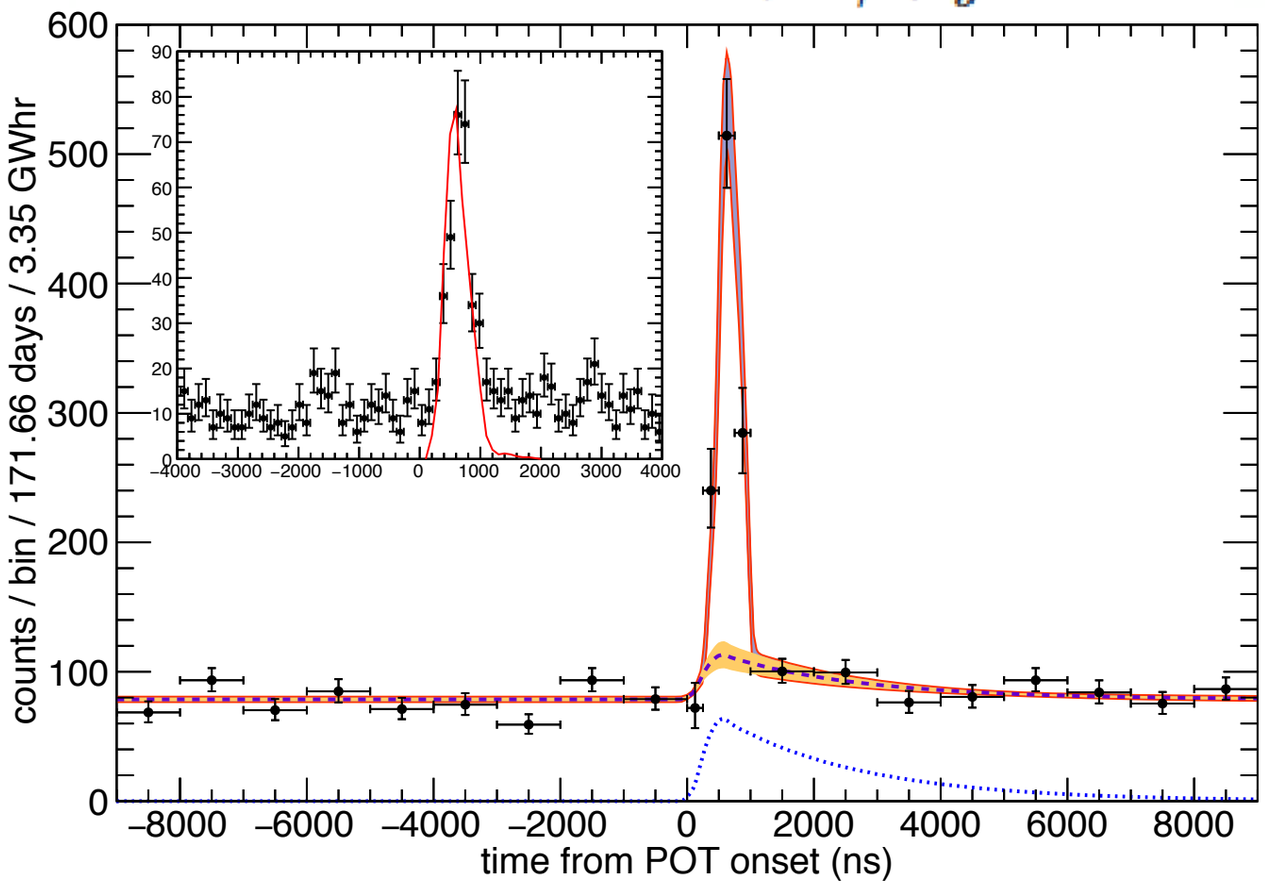
- Can be important process in many stellar environments

  C.A. Duba *et al.* J.Phys.Conf.Series 136 (2008)
  Y-Z. Qian *et al.*, Phys. Rev. C 55 (1997)
  M. Athar, S. Ahmad and S. K. Singh., Nucl. Phys. A 764 (2006) 551-568

- Both neutron measurements provide constraints that are used in the final analysis

$$\nu_e + {}^{208}Pb \Rightarrow {}^{208}Bi^* + e^- \quad (CC)$$
$$\Downarrow$$
$${}^{208-y}Bi + x\gamma + yn$$

$$\nu_x + {}^{208}Pb \Rightarrow {}^{208}Pb^* + \nu_x' \quad (NC)$$
$$\Downarrow$$
$${}^{208-y}Pb + x\gamma + yn.$$

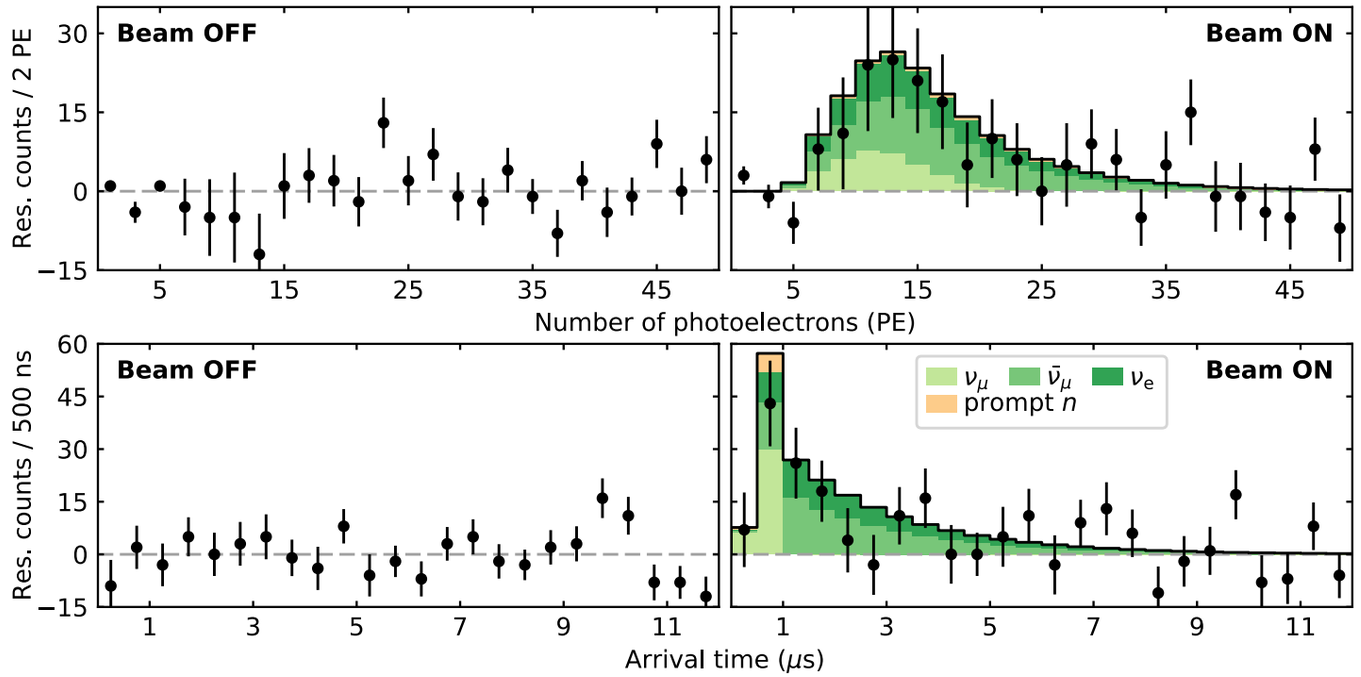


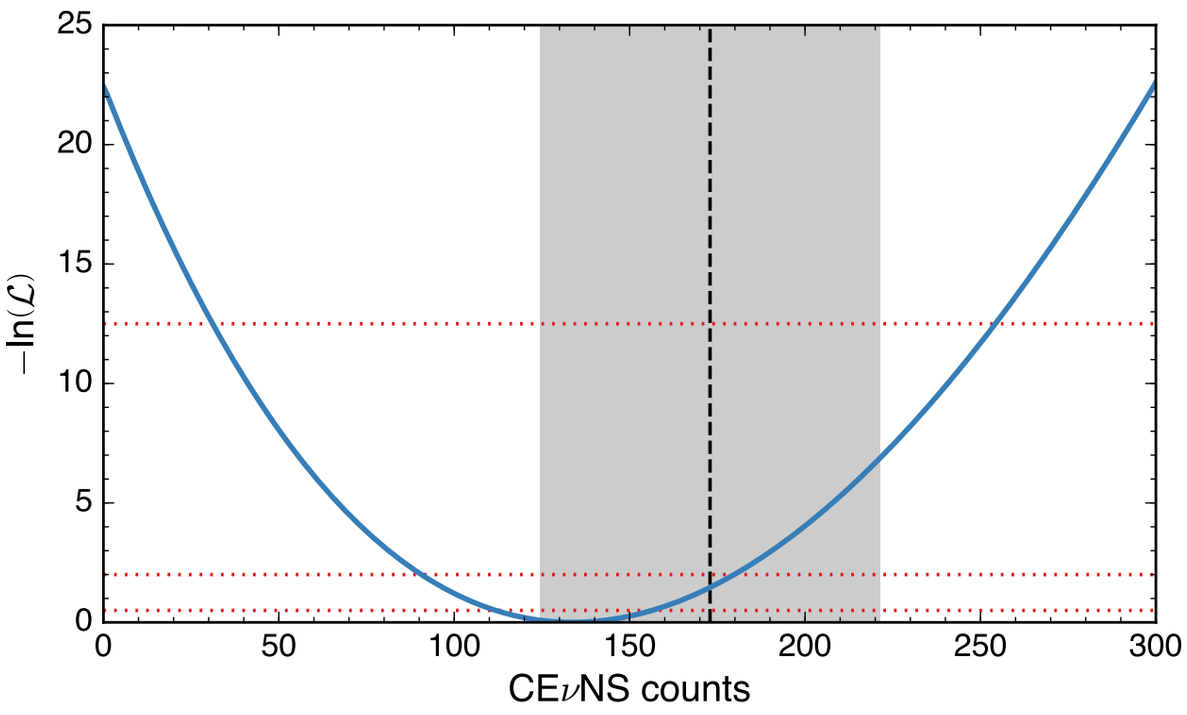
The Result

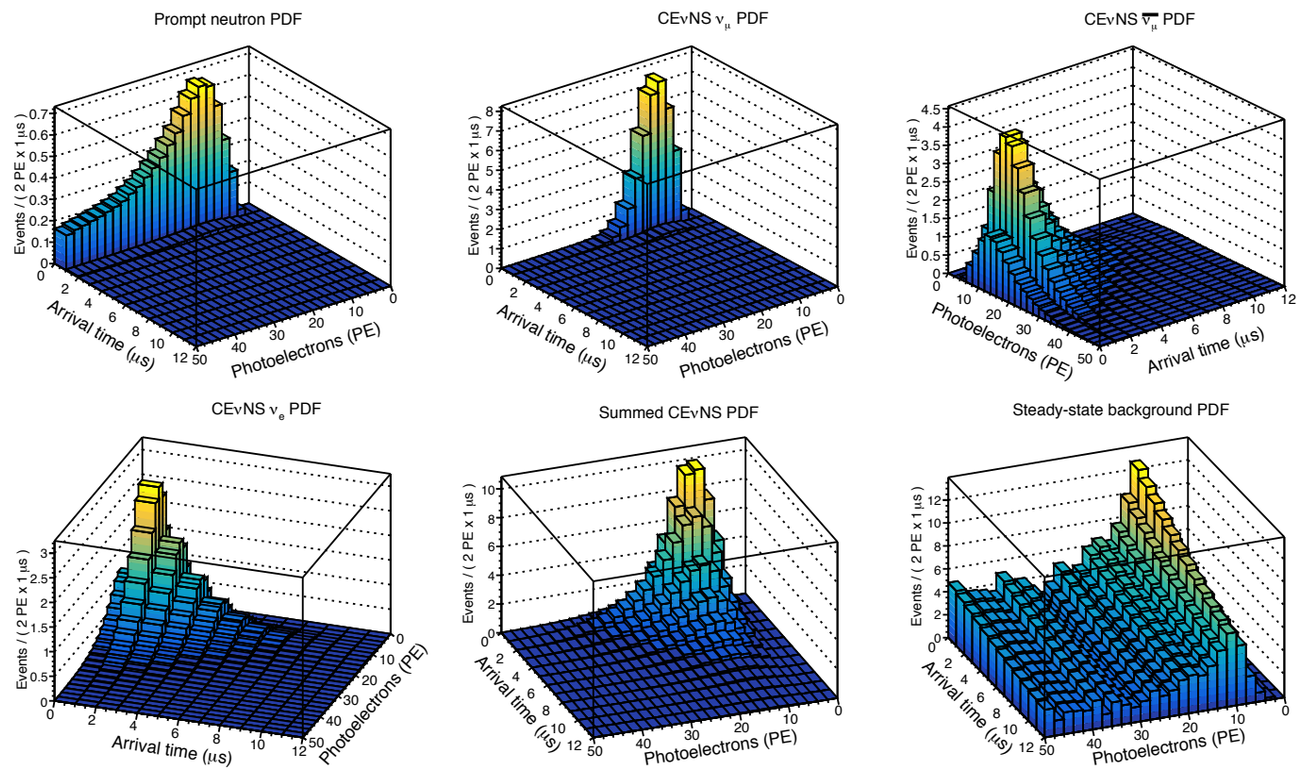
D. Akimov et al., Science 10.1126/science.aao0990 (2017).

- We perform a binned ML fit for the CEvNS signal, including the constraints on the neutron backgrounds, and taking steady-state backgrounds from an anti-coincident window

- We report a **6.7 sigma** significance for an excess of events, that agrees with the standard model prediction to within **1 sigma**

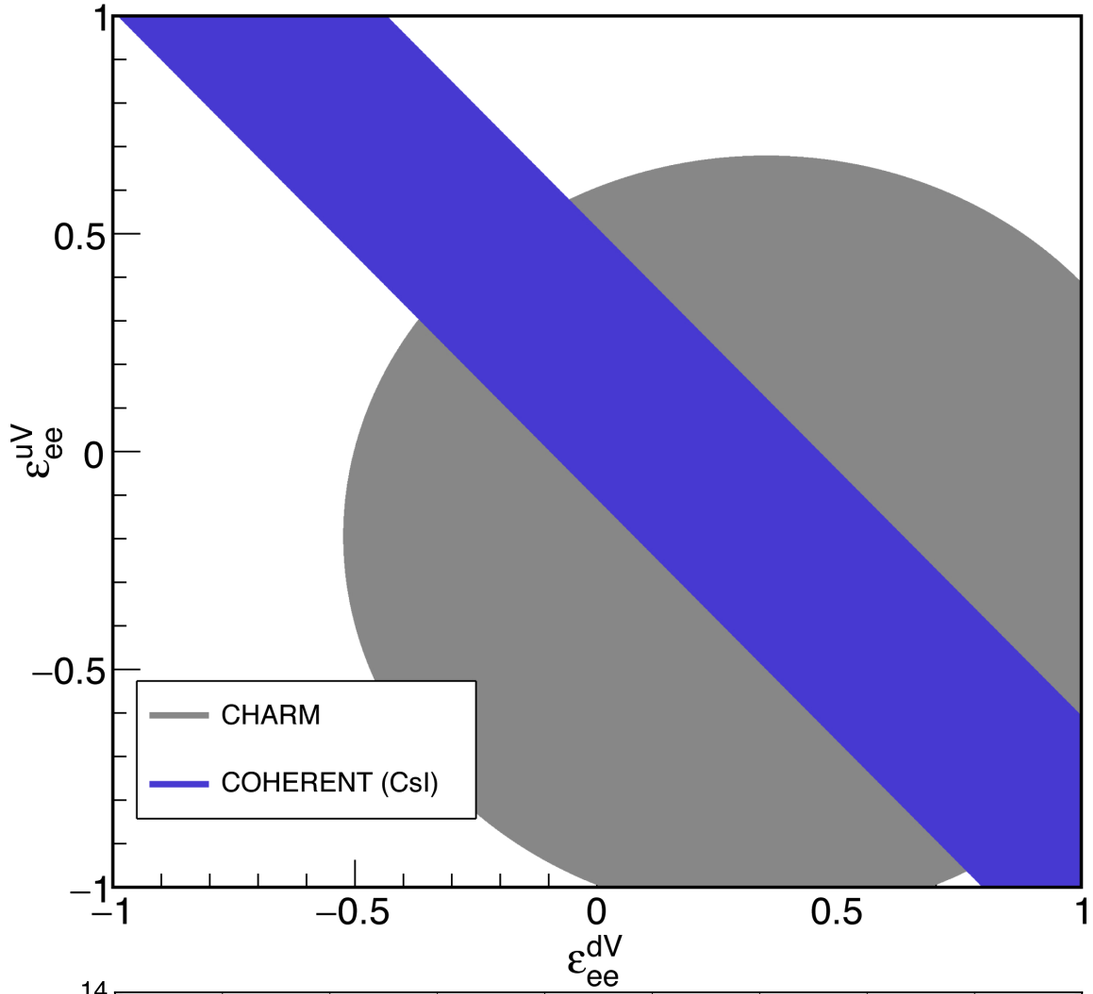


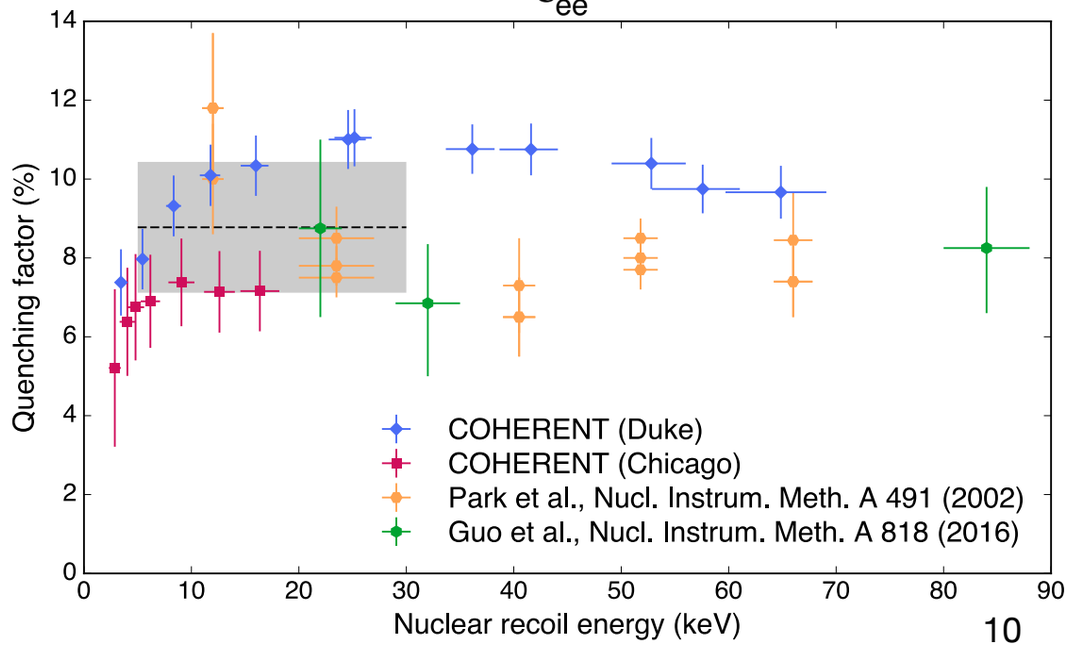




Implications for Non-Standard Neutrino Interactions

- First result improves constraints on non-universal NSI
- Low hanging fruit. We can expect significant improvement with more data, and when more COHERENT detectors report their results
- Uncertainty currently dominated by our knowledge of the quenching factor in CsI[Na] (~25%)
- Can factor out the ~10% neutrino flux uncertainty by measuring the ratio of interaction rates when the other COHERENT detectors report their results





Where do we go from here

- More exposure for CsI[Na] detector & better understanding of QF
- A number of COHERENT detectors are now online (LAr, NaI[Tl]-185 kg, MARs neutron detector) with PPC HPGe coming soon and ton-scale NaI being designed!
- Rich neutrino physics program for non-CEvNS cross-sections including CC cross-sections on ^{127}I, ^{56}Fe and ^{208}Pb
- We also look forward to a new era of miniaturized neutrino detector technology with several other collaborations coming on line soon.