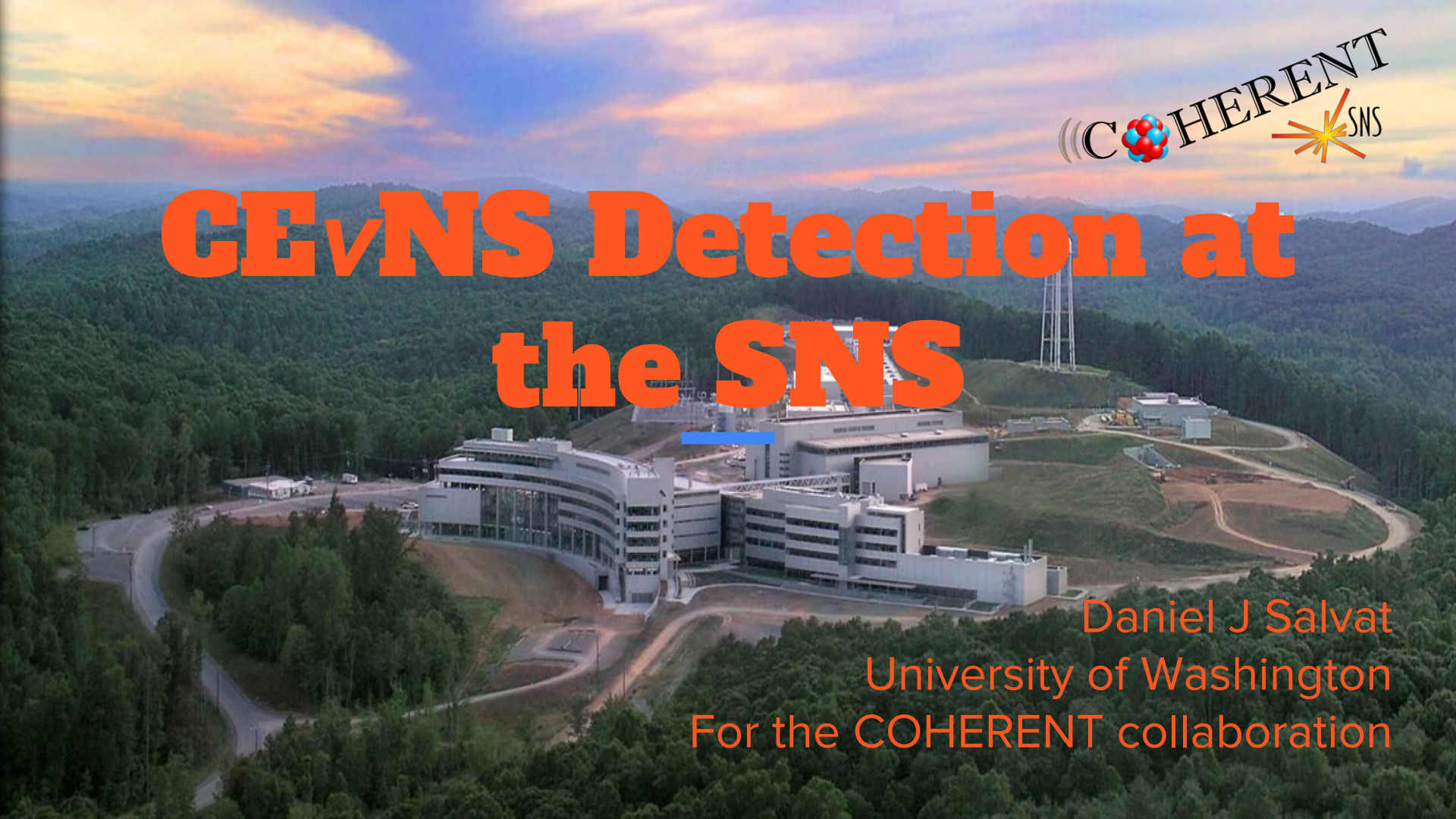


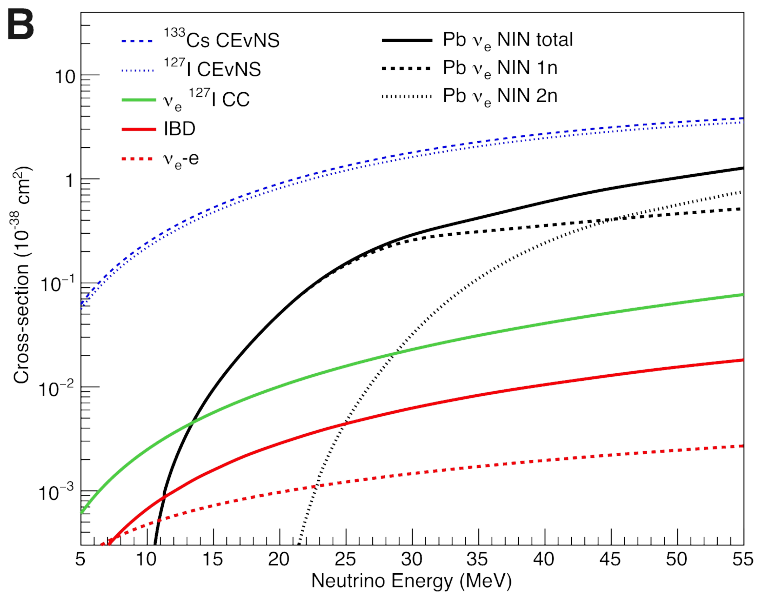
CEνNS Detection at the SNS

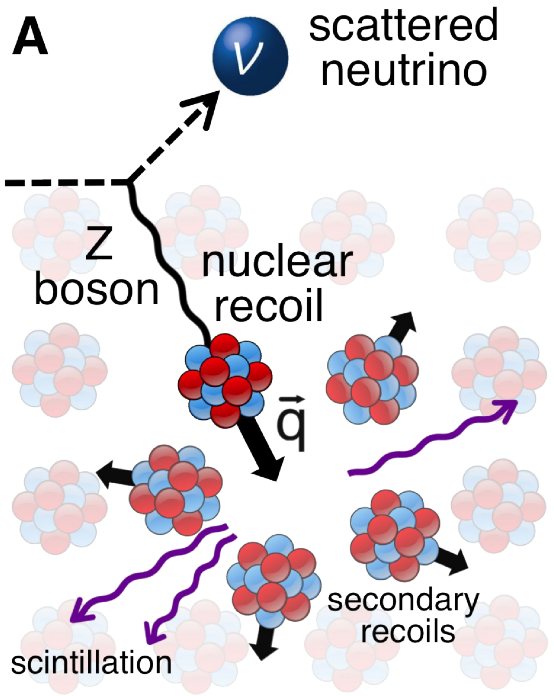
Daniel J Salvat
University of Washington
For the COHERENT collaboration

Coherent elastic *ν*-*N* scattering

largest neutrino-matter cross section

$$\frac{d\sigma}{dT} \propto N^2$$





A grave experimental challenge

PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

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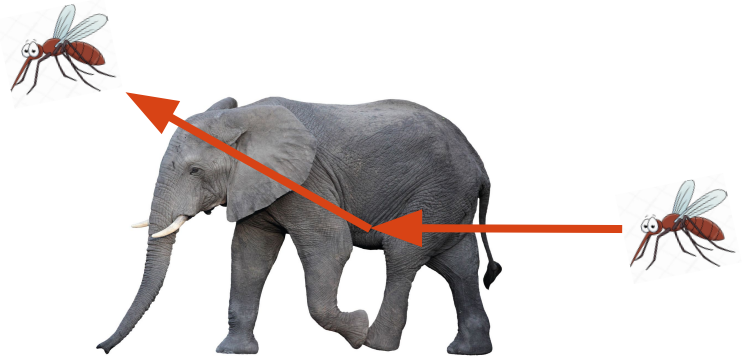
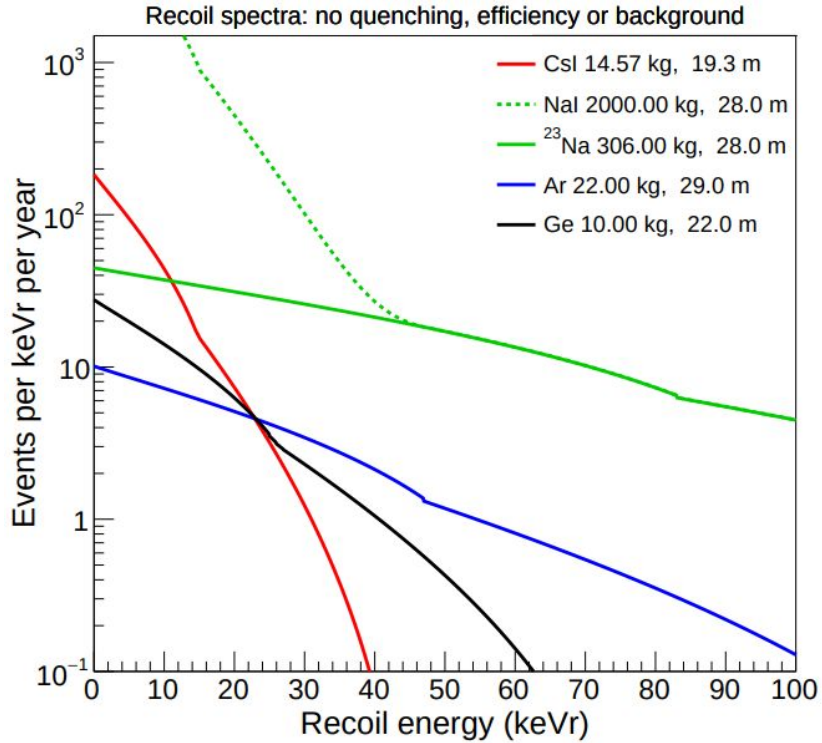
(Received 15 October 1973; revised manuscript received 19 November 1973)

Our suggestion may be an act of hubris, because the inevitable constraints of interaction rate, resolution, and background pose grave experimental difficulties for elastic neutrino-nucleus scattering.





CEvNS in the SM and beyond

$$\frac{d\sigma}{dT}_{coh} = \frac{G_F^2 M}{2\pi}\left[(G_V+G_A)^2+(G_V-G_A)^2\left(1-\frac{T}{E_\nu}\right)^2-(G_V^2-G_A^2)\frac{MT}{E_\nu}\right]$$

$$G_V = (g_V^p Z + g_V^n N) F_{\text{nucl}}^V(Q^2)$$

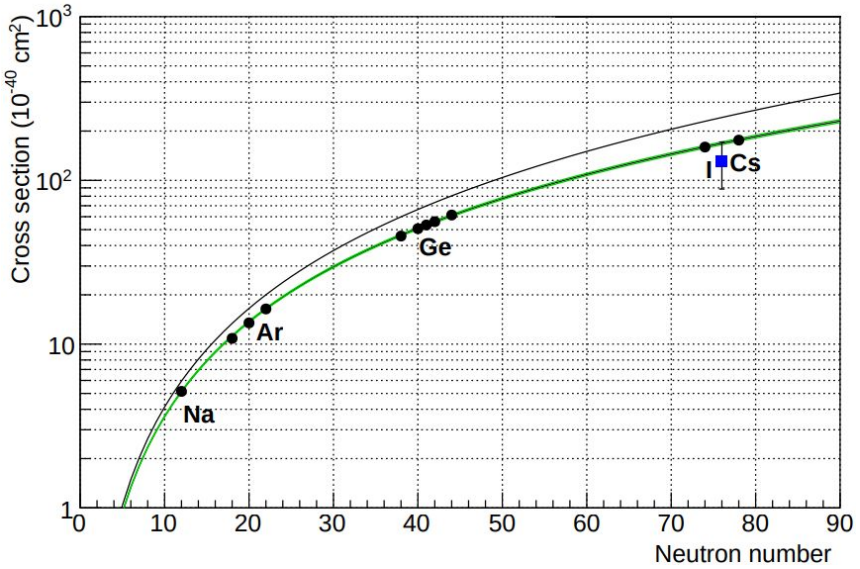
F~1 for low E_ν, ~3% uncty. at E_ν~50 MeV

$$G_A = (g_A^p(Z_+ - Z_-) + g_A^n(N_+ - N_-)) F_{\text{nucl}}^A(Q^2),$$

1/A suppressed

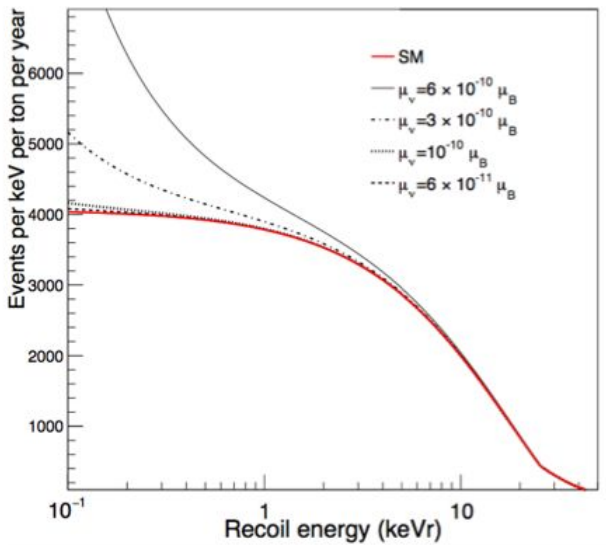
CEvNS probes non-standard interactions (NSI)

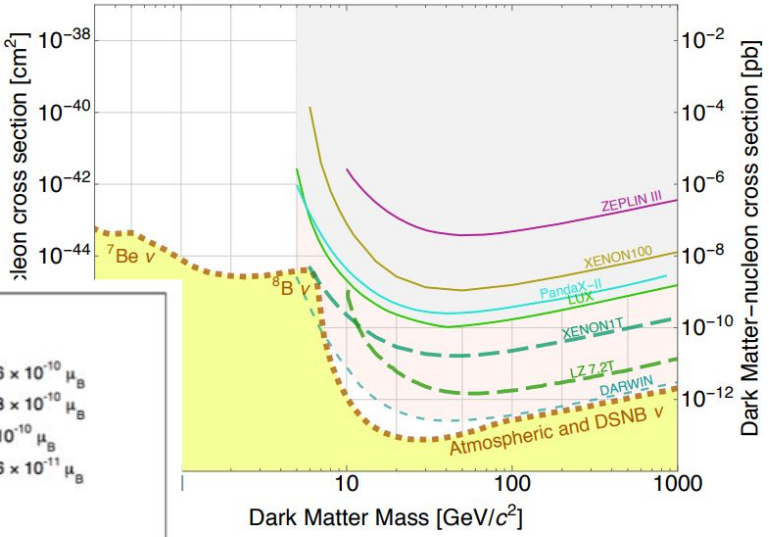
$$g_V^p \to g_V^p + 2\epsilon_{ee}^{uV} + \epsilon_{ee}^{dV}$$
$$g_V^n \to g_V^n + \epsilon_{ee}^{uV} + 2\epsilon_{ee}^{dV}$$



stars, dark matter, nuclear physics...

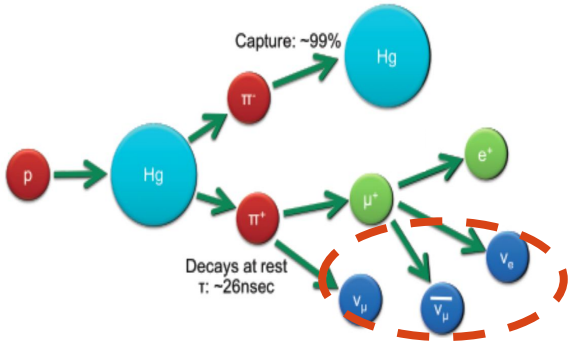
- Irreducible WIMP background
- Critical for heat transport in supernovae
- Independent $sin^2\theta_W$ measurement
- Form factors sensitive to neutron skin
- Future means of reactor monitoring
- Probe BSM physics from ν mag. moment

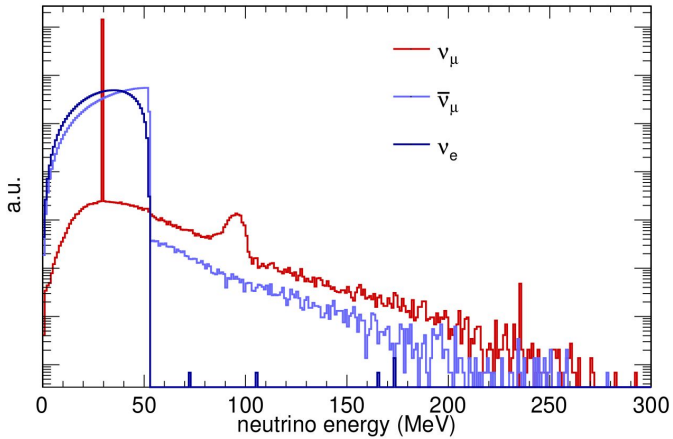


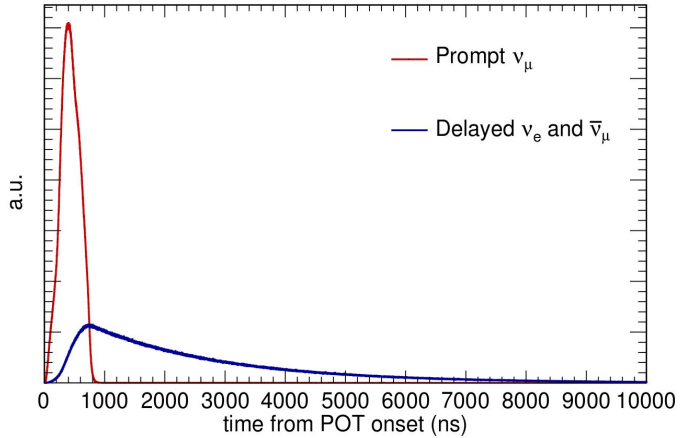


The Spallation ~~neutron~~ neutrino source

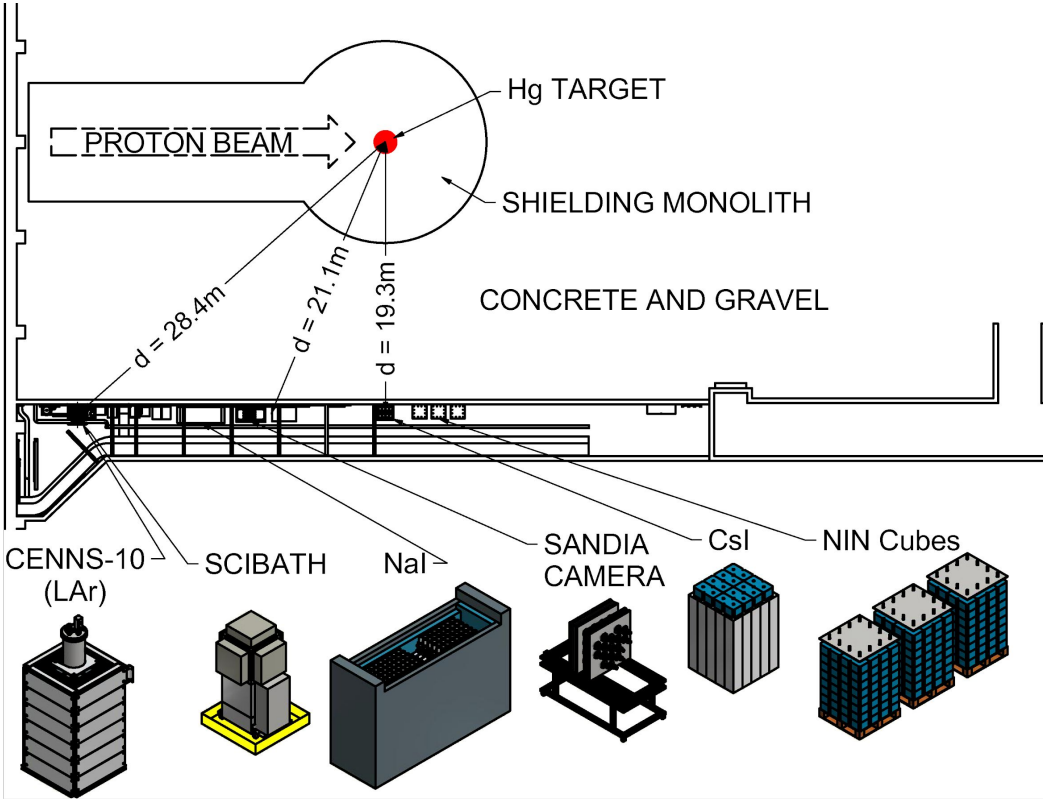
- ~10^7 cm^{-2}s^{-1} per flavor
- *1* MW @ ~*1* GeV
- pulsed @ *60* Hz for ~10^4 bkgd rejection





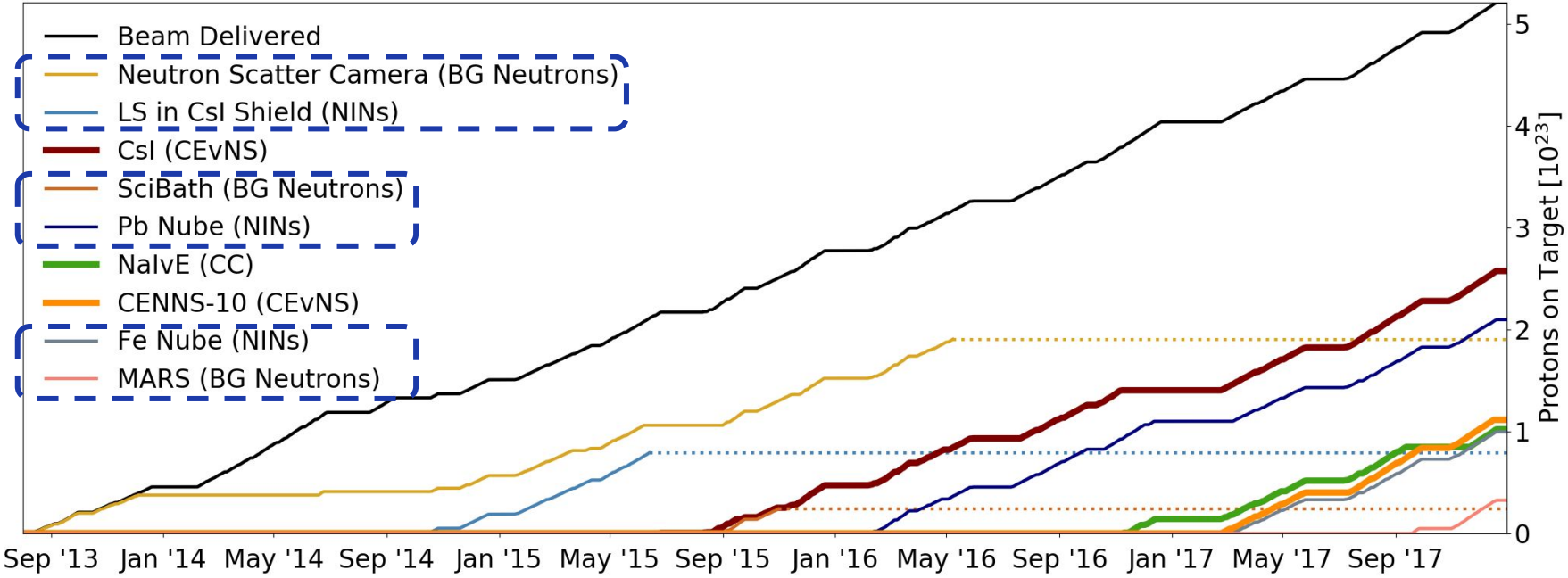


“Neutrino Alley”



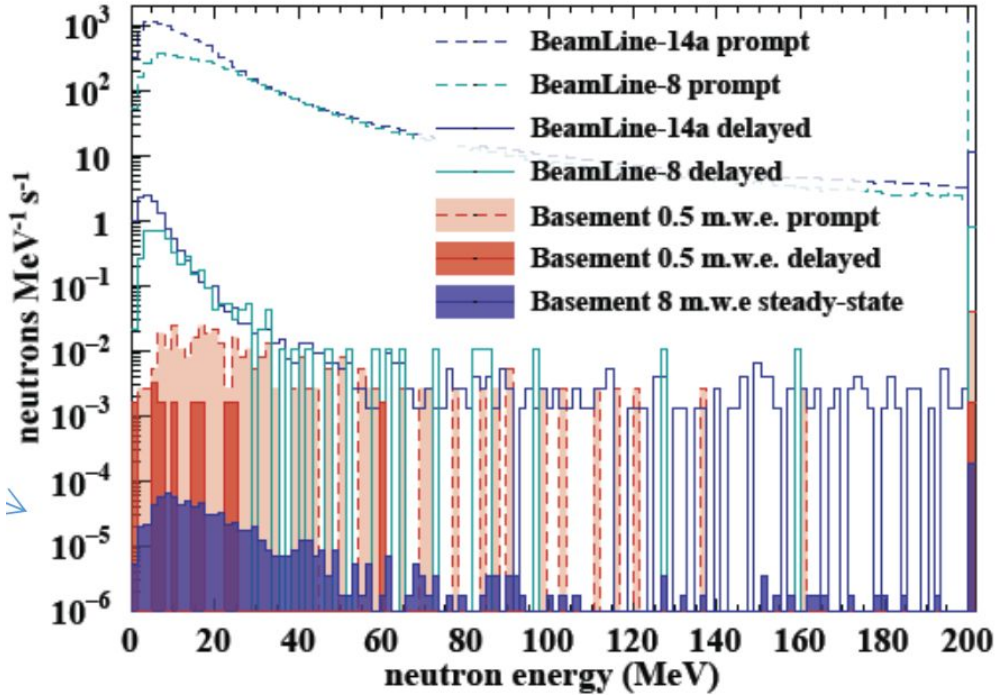
8 m.w.e. overburden

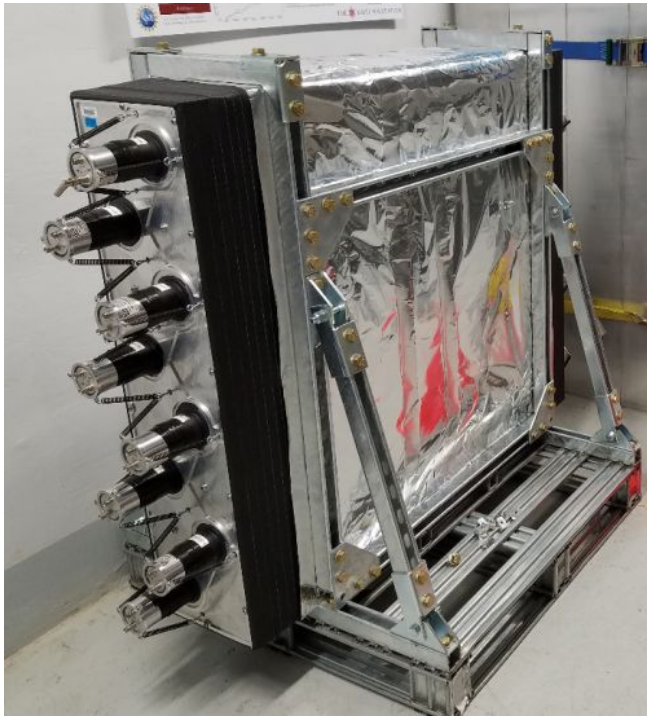
“Neutrino Alley”



Fake *vs*

Dedicated Sandia *n*-scatter camera and SciBath measurements





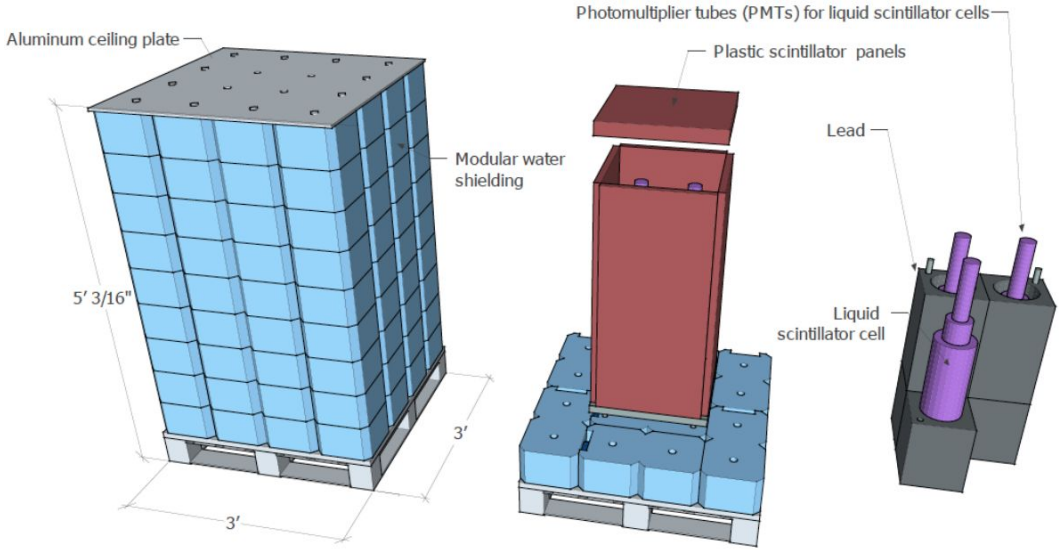
Forthcoming measurements w/ multiplicity and recoil spectrometer (MARS) detector

NINS

Neutrino-induced-neutrons
correlated with beam

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

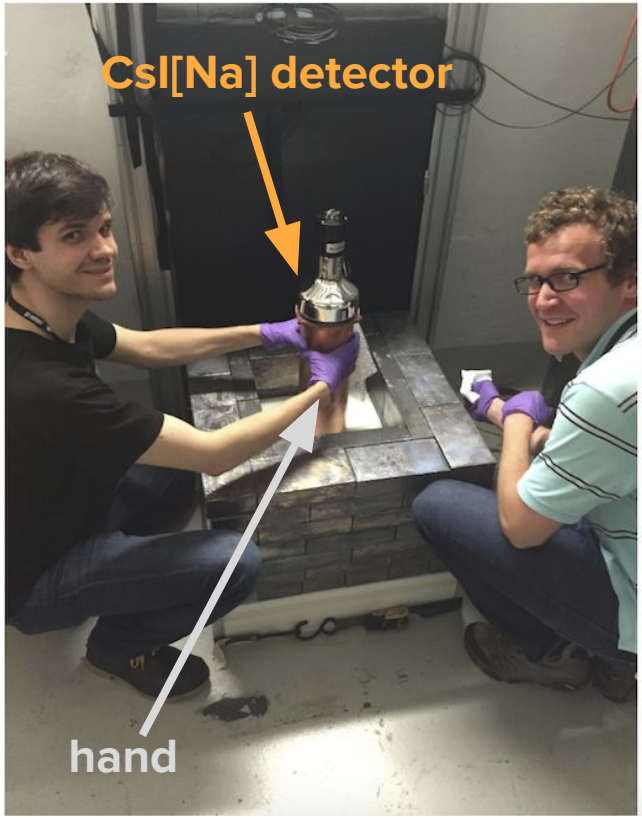
$$\nu_x + {}^{208}Pb \Rightarrow {}^{208}Pb^* + \nu_x' \quad (NC)$$
$$\Downarrow$$
$${}^{208-y}Pb + x\gamma + yn.$$



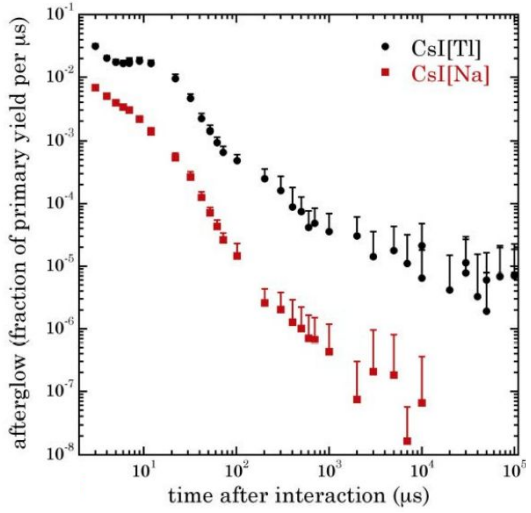
Not just a “nu”-isance -- cross section is of astrophysical interest, e.g. SN*ν* detection in HALO expt

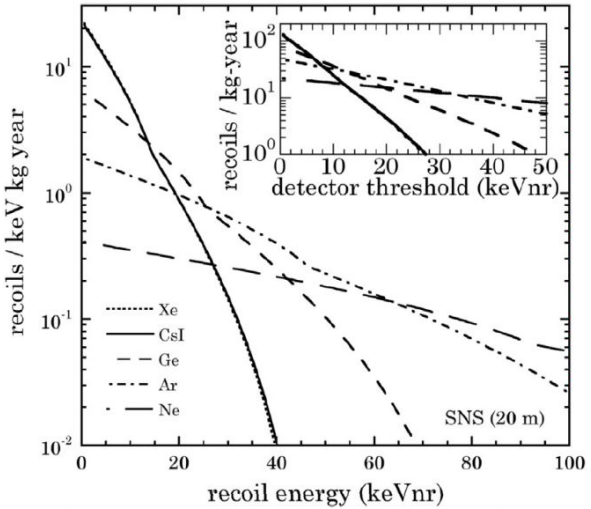
We are measuring this

A hand-held neutrino detector

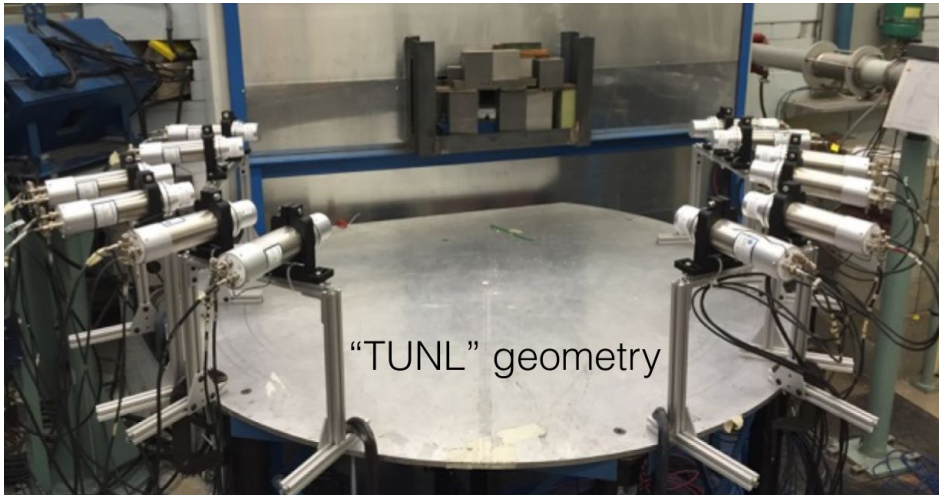


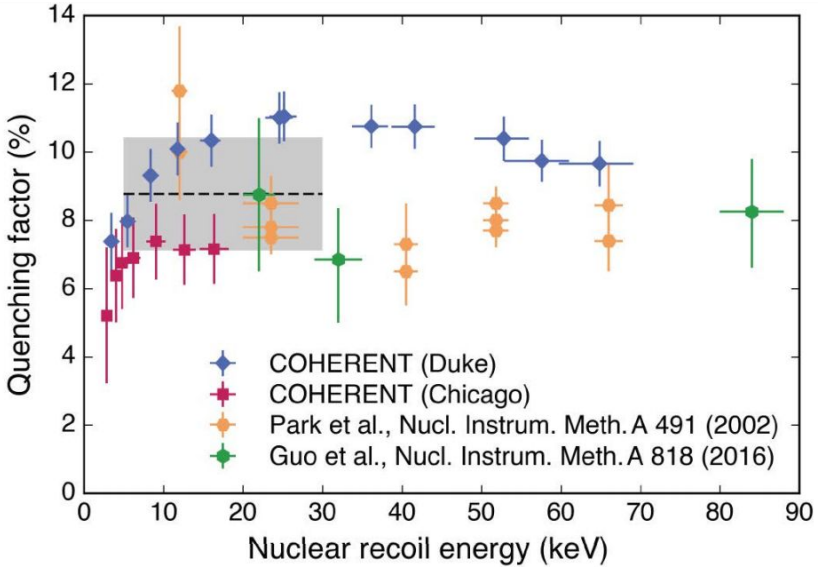
- ***14.6*** **kg low bkgd crystal in e-formed Cu, PTFE reflector, super-bialkali PMT**
- **Na doping for lower afterglow**
- **shielded w/ HDPE, Pb, water + *μ*-veto**





Measuring the quenching factor

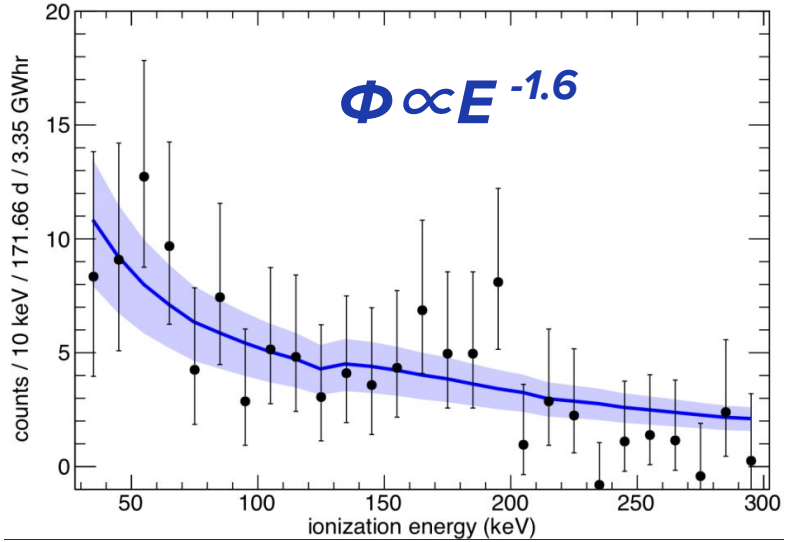


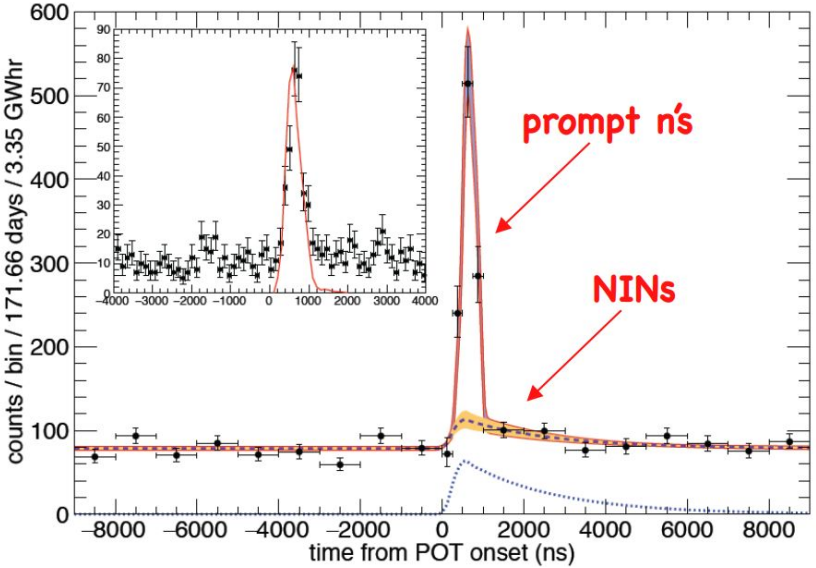


- detect fast-*n* scatters with known kinematics
- Dominant systematic for CsI[Na] result
- Improved analysis within COHERENT forthcoming

In situ background measurements

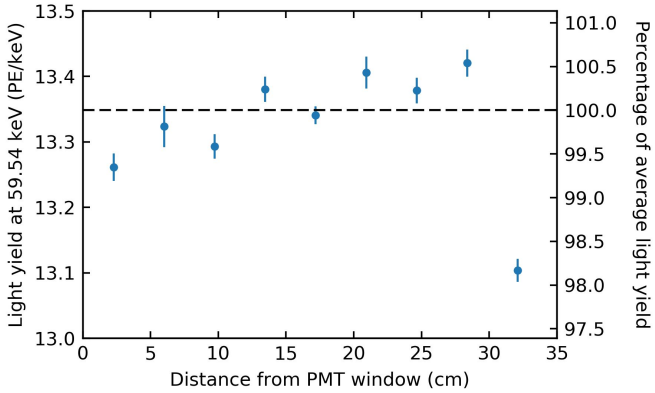
- EJ301 fast-*n* detectors in similar shielding package
- systematic MCNP-PoliMi comparison

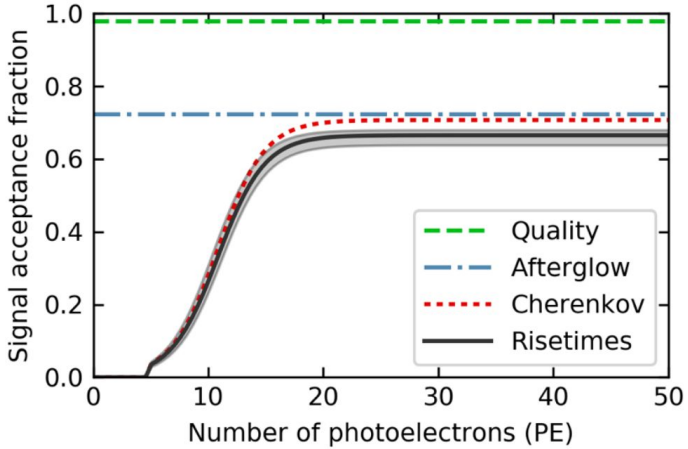


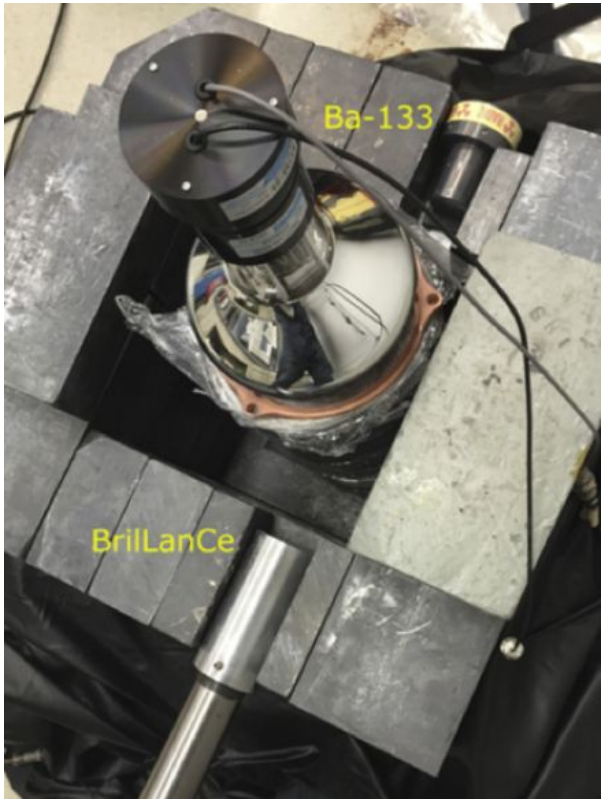


$\sim 10^{-7}$ cm^{-2}s^{-1} → more than order of magnitude smaller than CEvNS signal!

CsI calibration and cuts



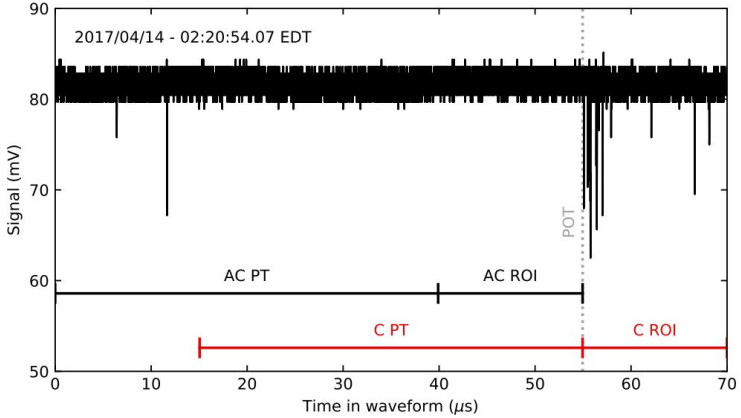




Careful tuning of cuts, measured light yield and uniformity

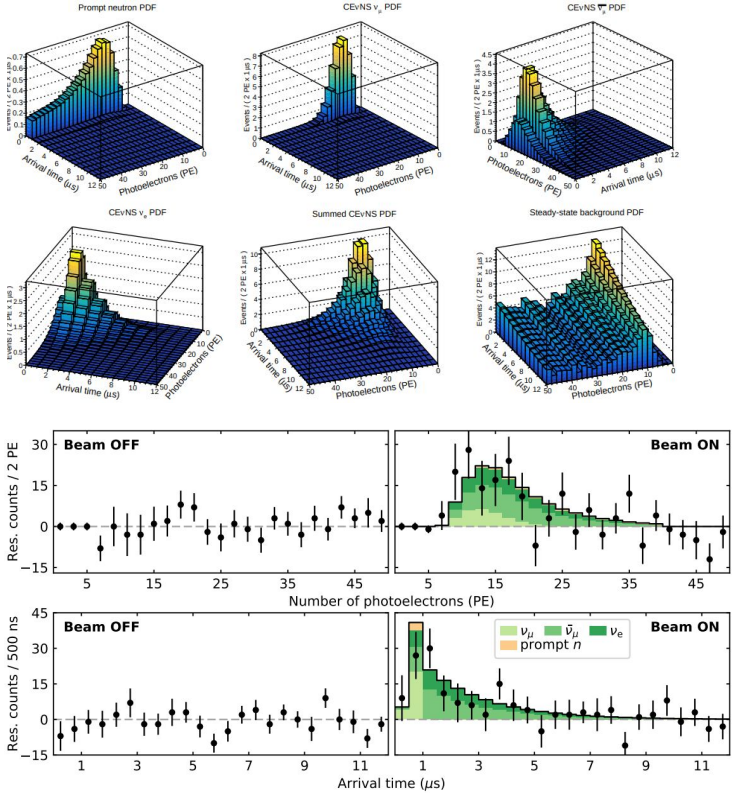
Extracting the CE*v*NS signal

Acquire beam *coincident* and *anti-coincident* data



Construct expected signal from known light yield, Q.F., flux, timing, form factor information

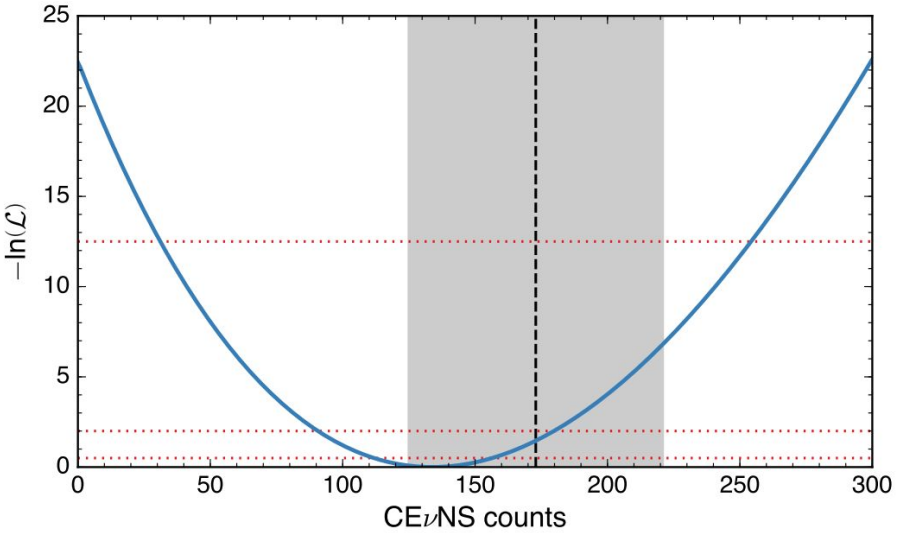
construct measured signal vs time and p.e.

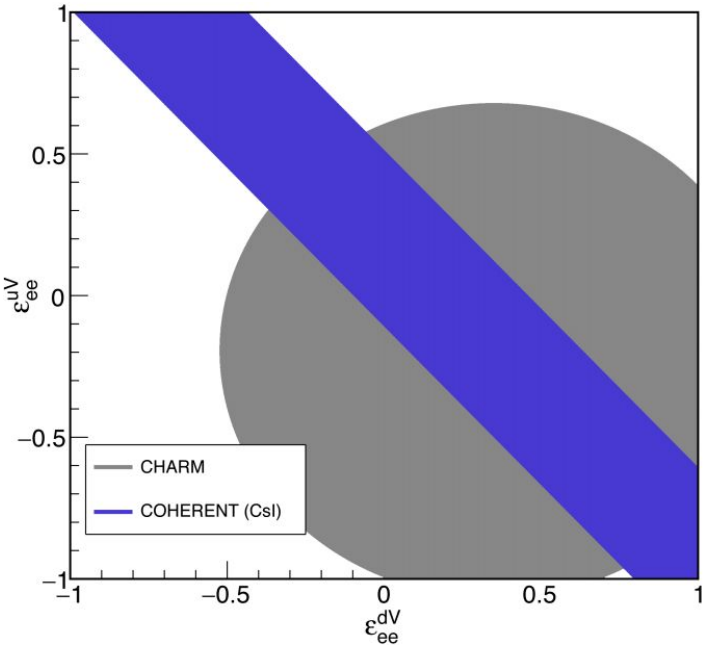


First results and impact

CEνNS signal at *6.7 σ*

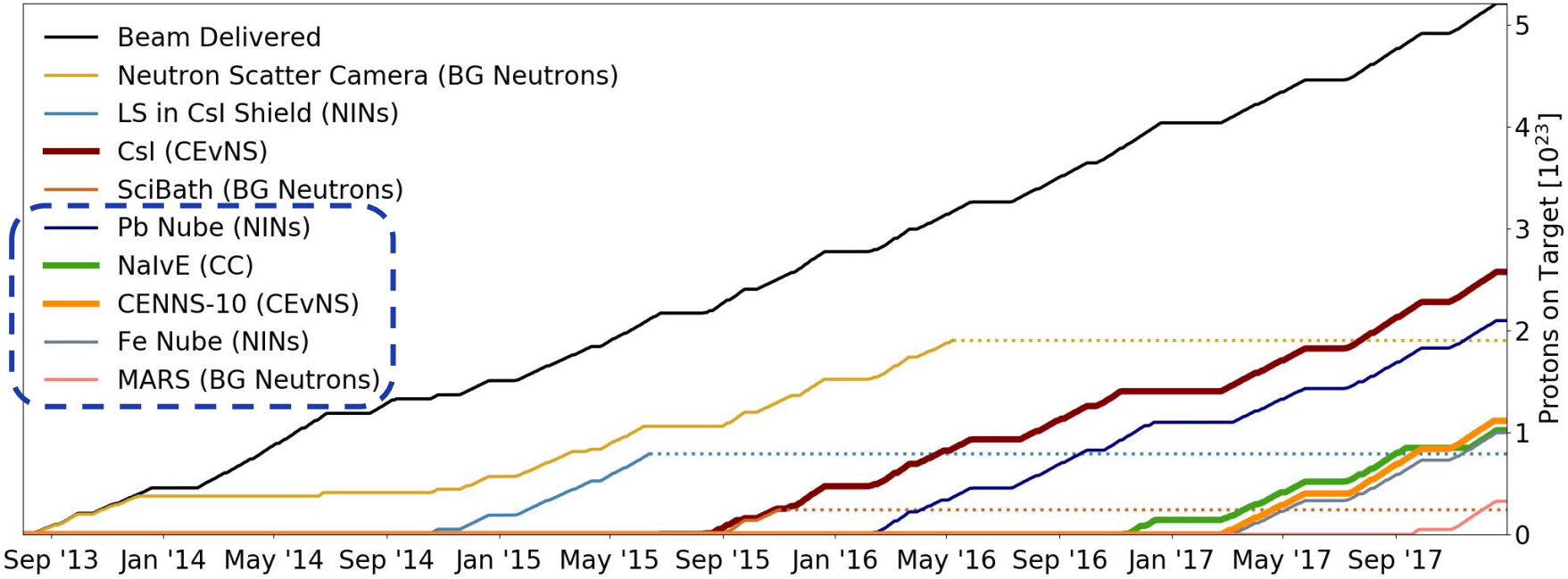
SM agreement at *~1 σ*





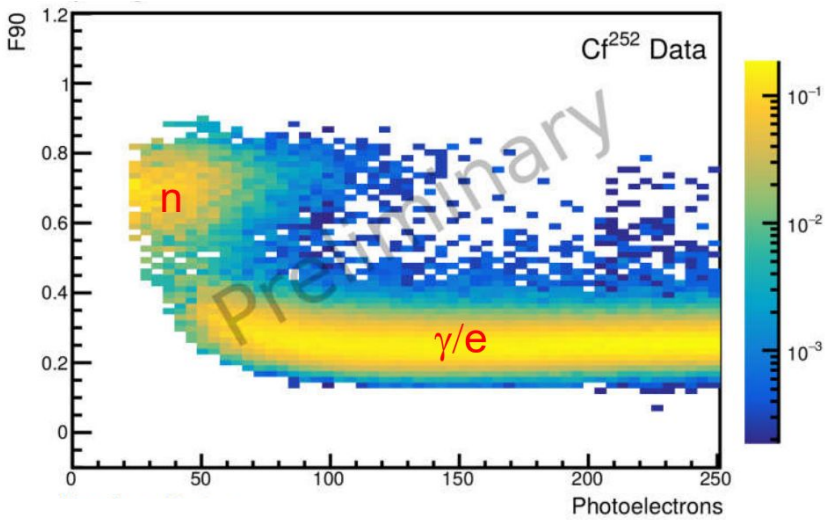
new constraints on NSIs for *M≳10* MeV

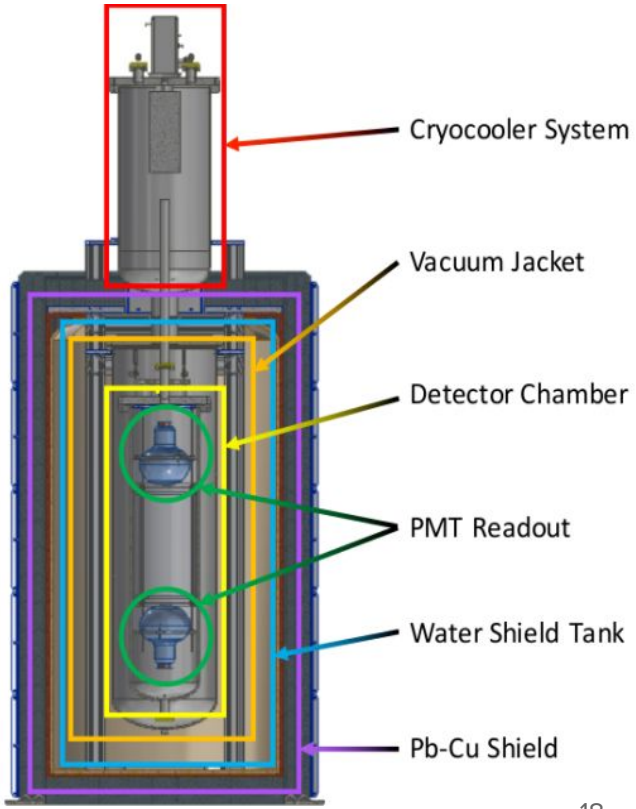
Meanwhile in neutrino alley…



22 kg single-phase LAr scintillator

- Built by FNAL, commissioned at IU
- heated getter for ~1ppm purity
- E_{th}~20 keV, ~3 p.e./keVee
- expect first CEνNS result in ~1 y



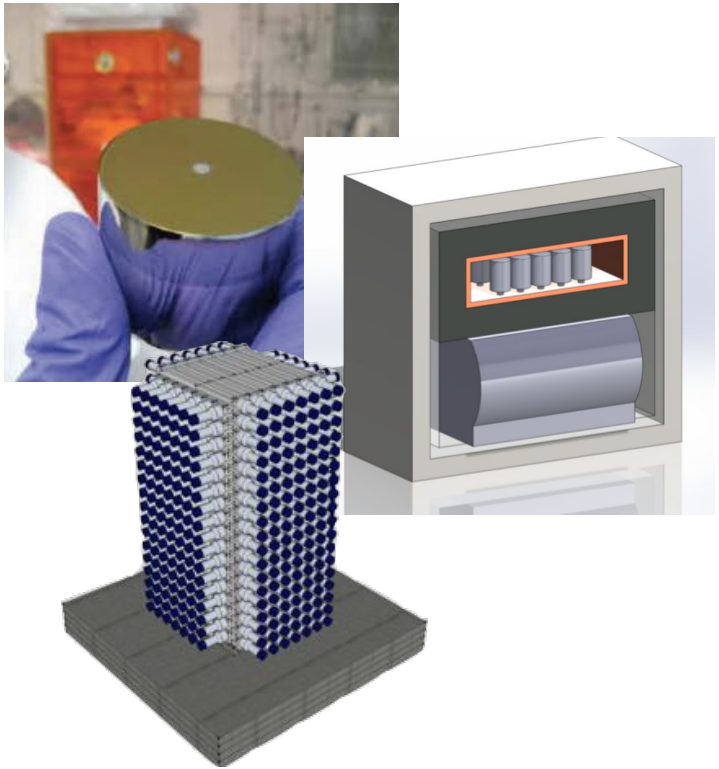


NaIvE

- 185 kg compact NaI[Tl] array
- Measure inclusive $^{127}I(\nu_e,e^-)Xe^*$ cross section -- nuclear modeling/address g_A quenching
- Expect *O(5-10)* evt. per month
- μ-veto upgrade in Nov 2017
- Bkgd characterization for ton-scale upgrade

	$^{12}C(\nu_\mu,\mu^-)X$	Decay in Flight	LSND	$1060 \pm 30(\text{stat}) \pm 180(\text{sys})$	1750-1780 [CRPA] (Kolbe *et al.*, 1999b) 1380 [Shell] (Hayes and S, 2000) 1115 [Green's Function] (Meucci *et al.*, 2004)
	$^{12}C(\nu_\mu,\mu^-)^{12}N_{g.s.}$	Decay in Flight	LSND	$56 \pm 8(\text{stat}) \pm 10(\text{sys})$	68-73 [CRPA] (Kolbe *et al.*, 1999b) 56 [Shell] (Hayes and S, 2000)
^{56}Fe	$^{56}Fe(\nu_e,e^-)^{56}Co$	Stopped π/μ	KARMEN	$256 \pm 108(\text{stat}) \pm 43(\text{sys})$	264 [Shell] (Kolbe *et al.*, 1999a)
^{71}Ga	$^{71}Ga(\nu_e,e^-)^{71}Ge$	^{51}Cr source	GALLEX, ave.	$0.0054 \pm 0.0009(\text{tot})$	0.0058 [Shell] (Haxton, 1998)
		^{51}Cr	SAGE	$0.0055 \pm 0.0007(\text{tot})$	
		^{37}Ar source	SAGE	$0.0055 \pm 0.0006(\text{tot})$	0.0070 [Shell] (Bahcall, 1997)
^{127}I	$^{127}I(\nu_e,e^-)^{127}Xe$	Stopped π/μ	LSND	$284 \pm 91(\text{stat}) \pm 25(\text{sys})$	210-310 [Quasi-particle] (Engel *et al.*, 1994)

A look ahead



- We have detected CE*v*NS at *6.7 σ*, with good SM agreement -- CsI[Na] data-taking continues
- Improved background studies with Nubes/MARS
- 10 kg PPC Ge, w/ future upgrade to state-of-the-art tech -- study e.m. properties
- NaI: 2-ton CE*v*NS sensitive upgrade
- Further NIN studies, several prospects for additional target nuclei for improved nuclear-, astro-, and particle-physics reach

The COHERENT Collaboration