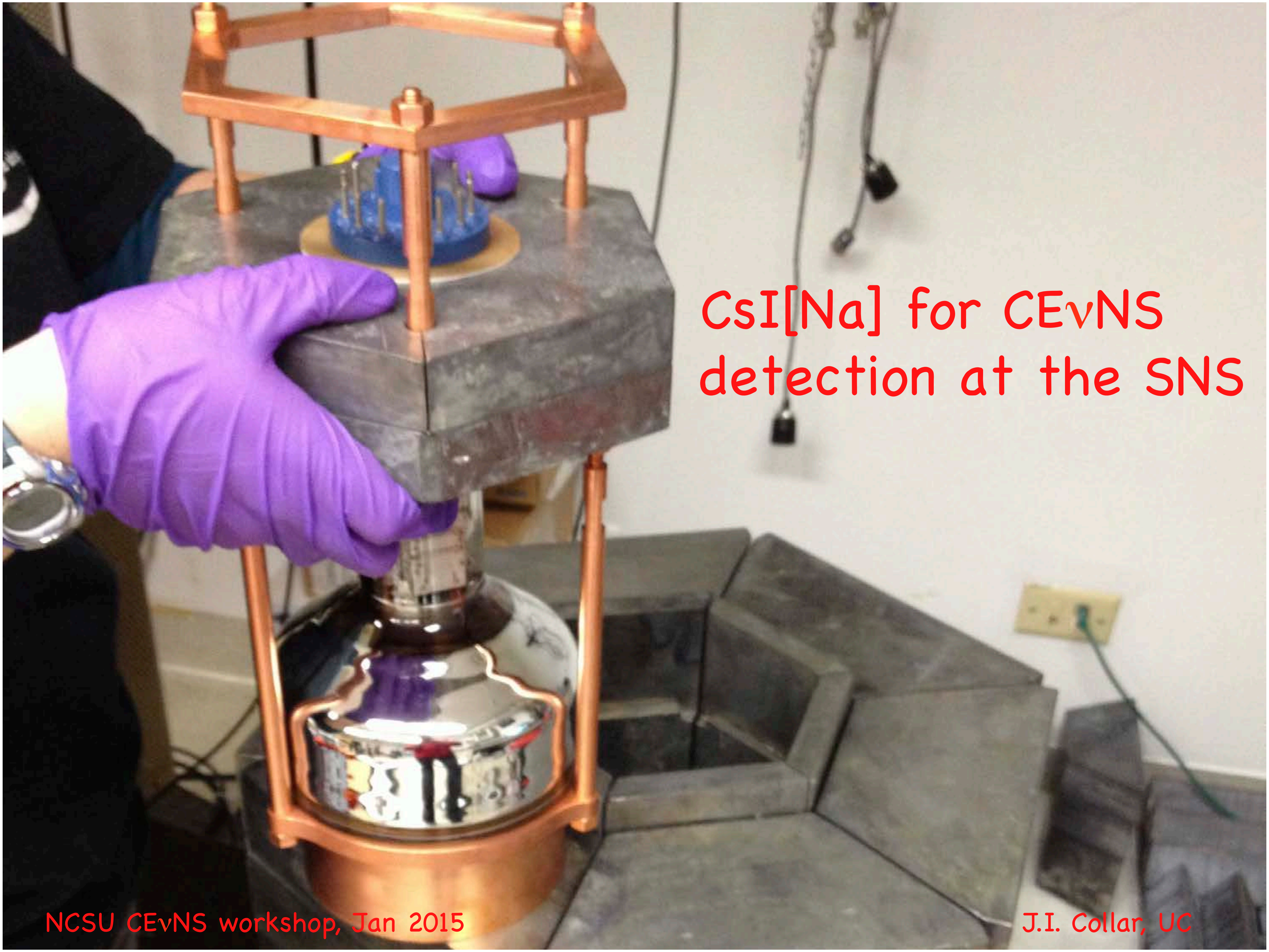
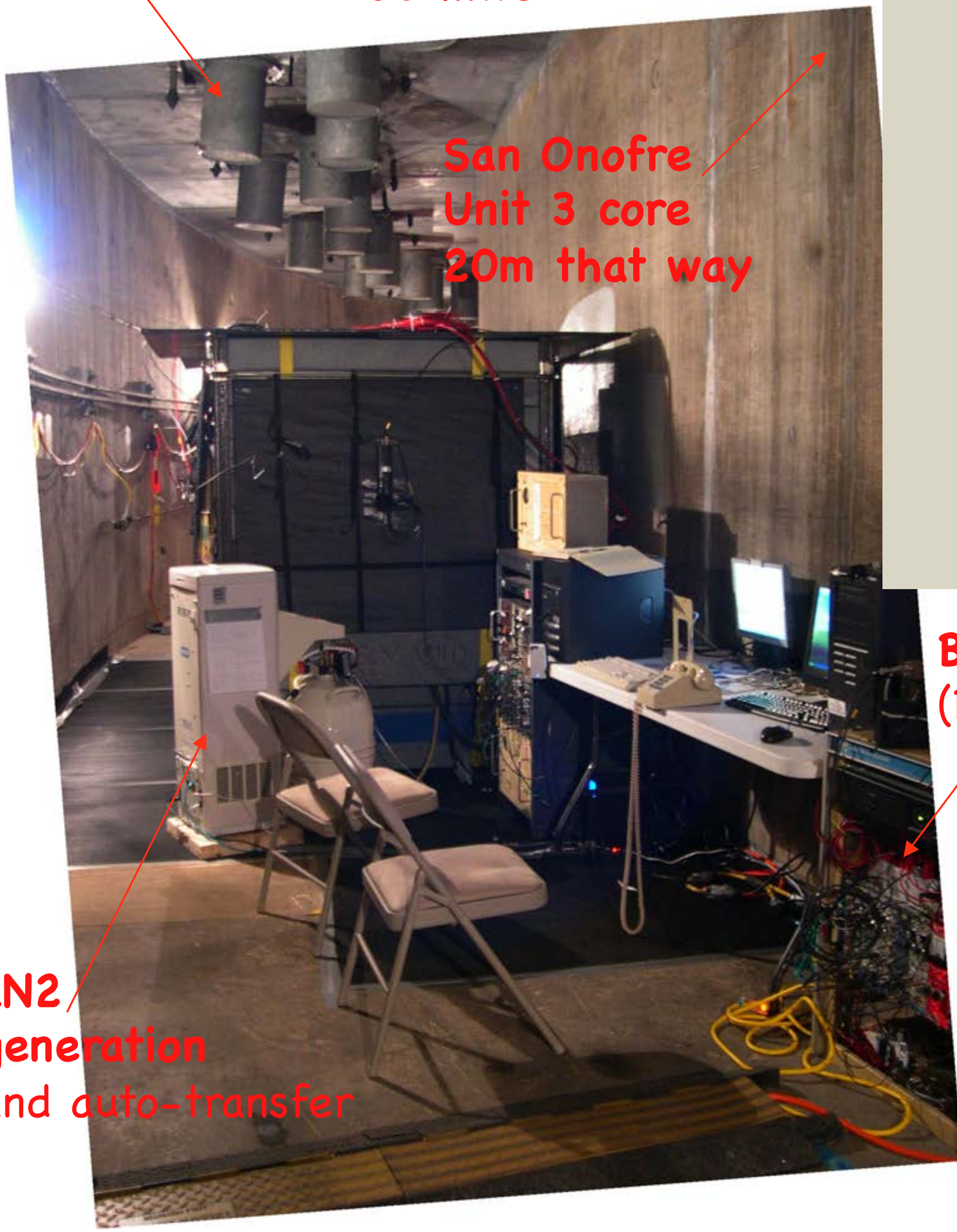

CsI[Na] for CEνNS
detection at the SNS
NCSU CEνNS workshop, Jan 2015
J.I. Collar, UC

Everyone needs a hobby

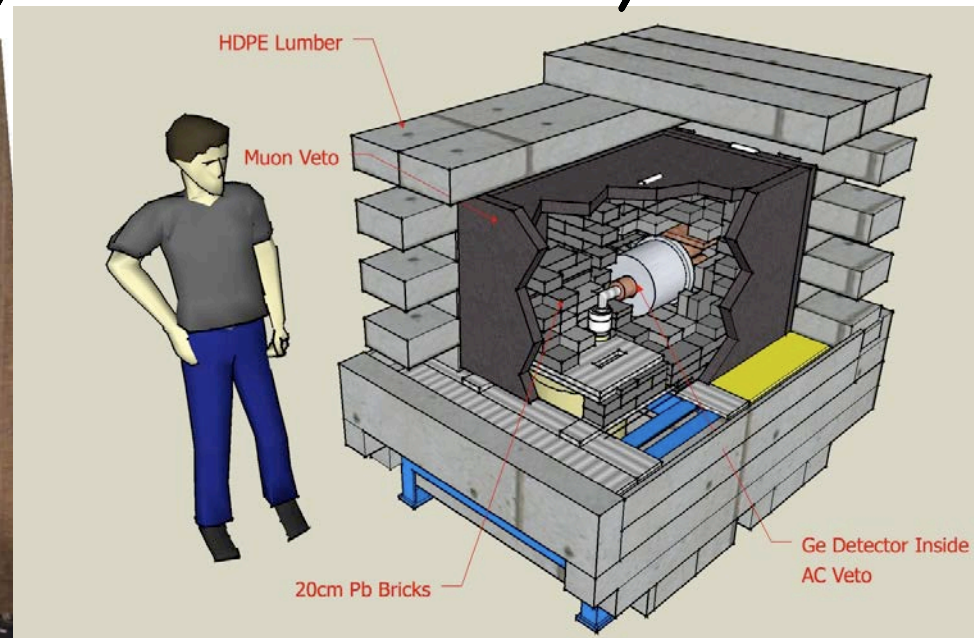
"Tendons"

30 mwe

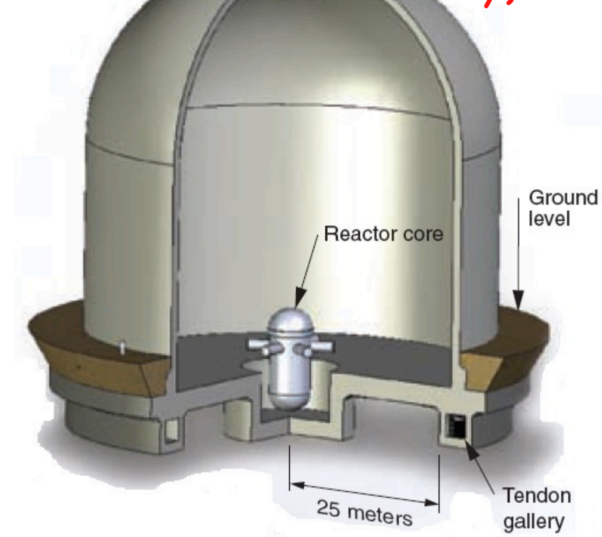
San Onofre
Unit 3 core
20m that way



LN2
generation
and auto-transfer



BaDAss
(Background Detector Assembly)



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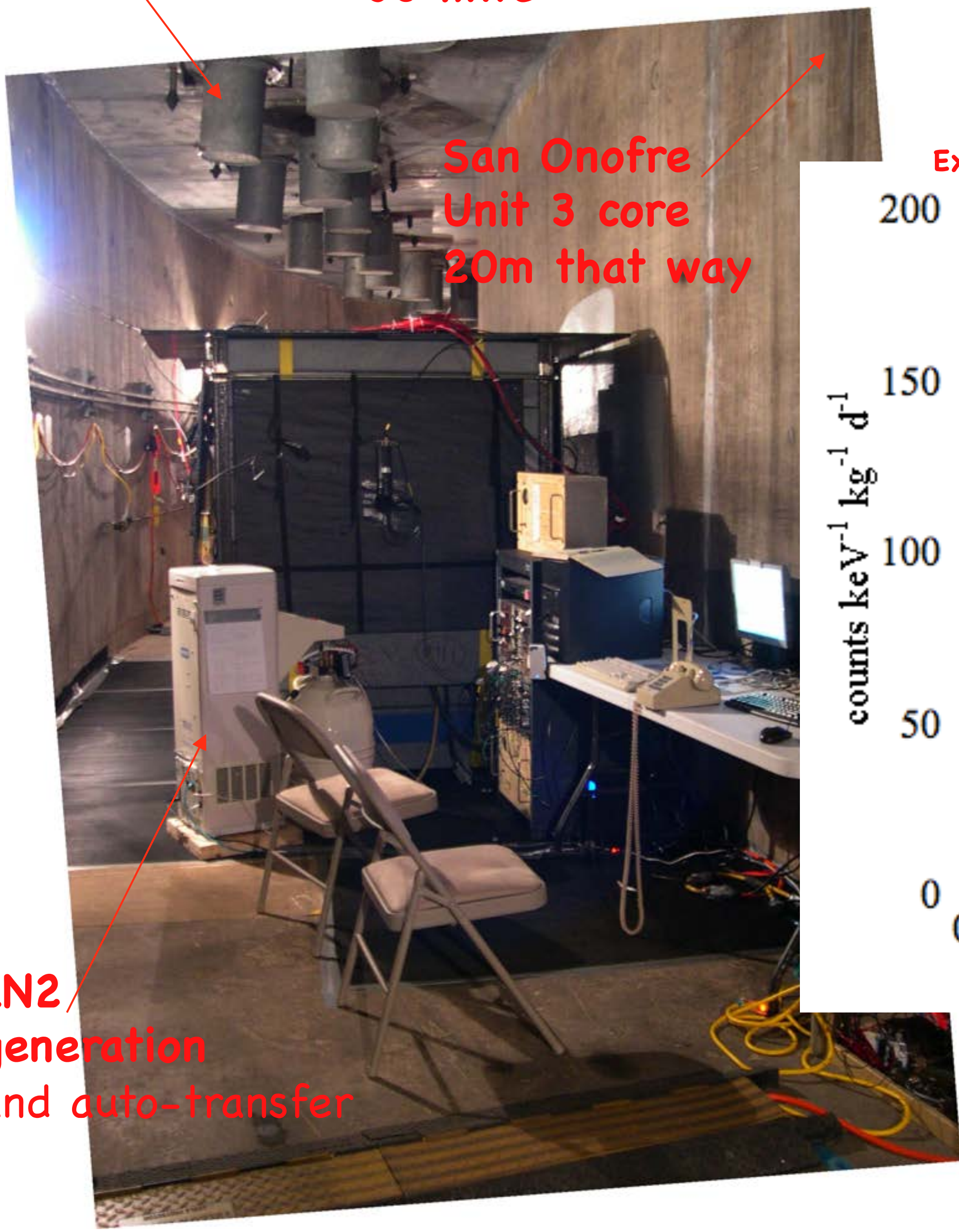
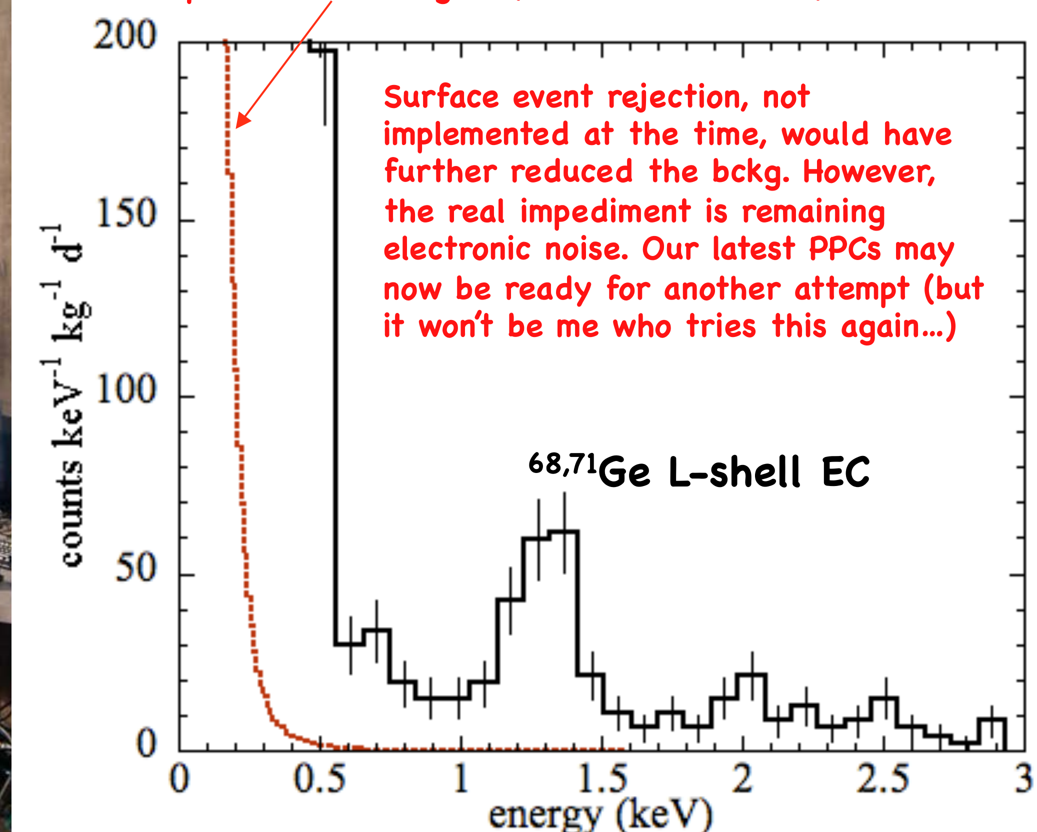


Expected CEνNS signal (resolution folded in)



Giorgio dixit: “first to put CEνNS signal and backgrounds on a lin-lin plot…”

Why CsI[Na]? (NIM A773 (2014) 56)

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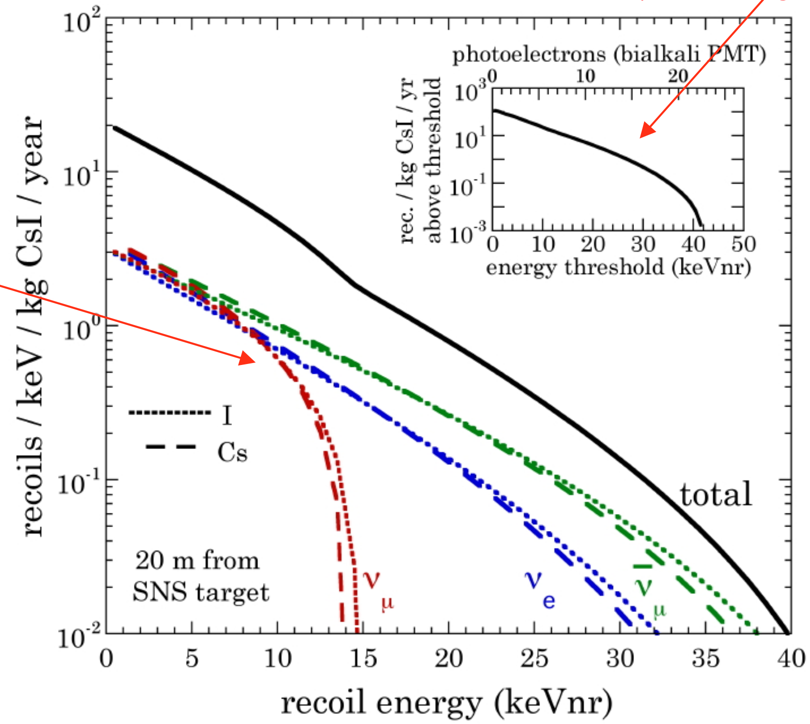
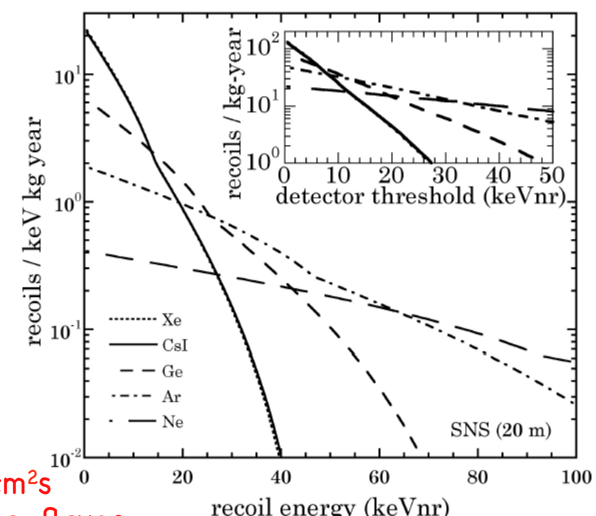
(boule grown at AMCRYS, detector already at UC)

Using **measured** quenching factor





1.7E7 ν/cm²s @20m, e.a. flavor

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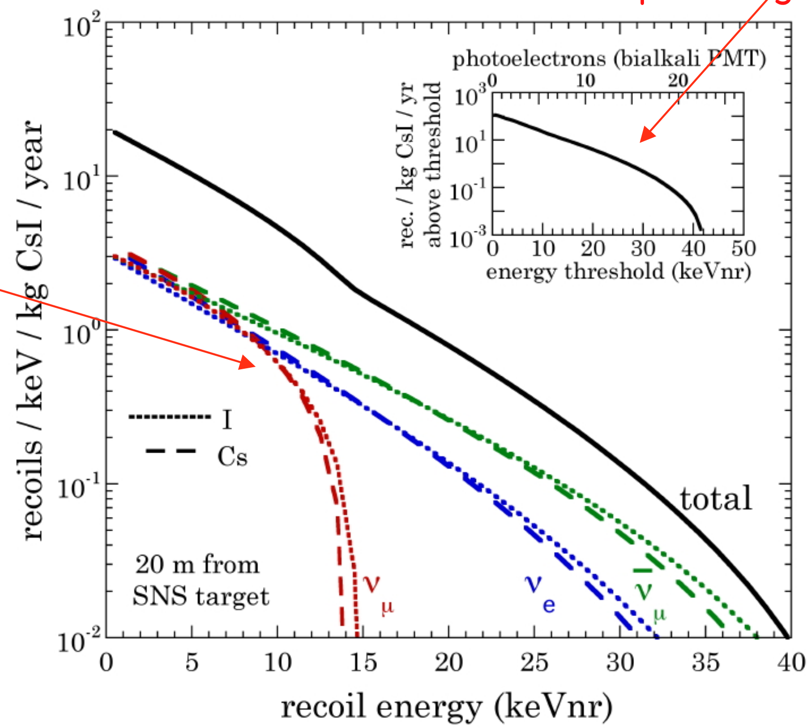

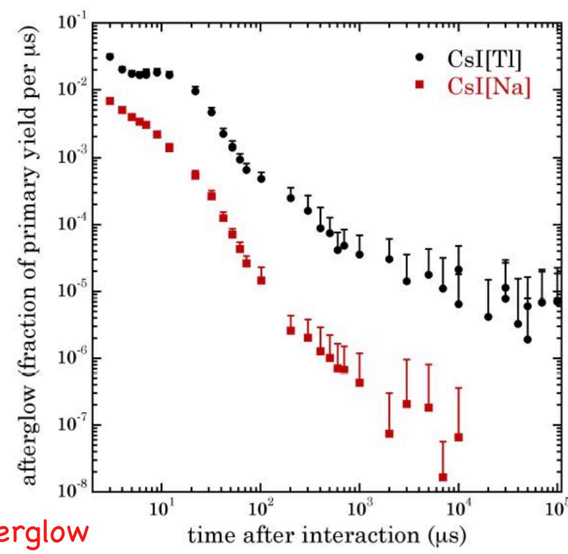

CsI[Tl] not an option due to excessive afterglow

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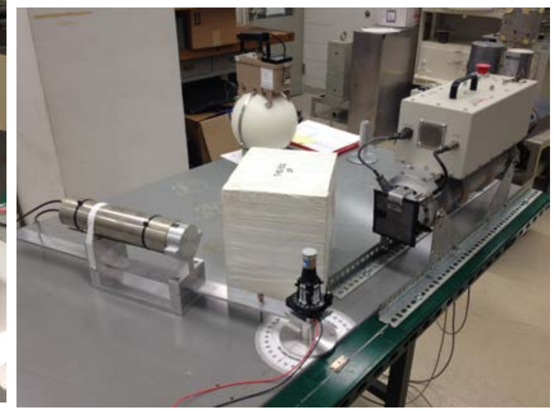
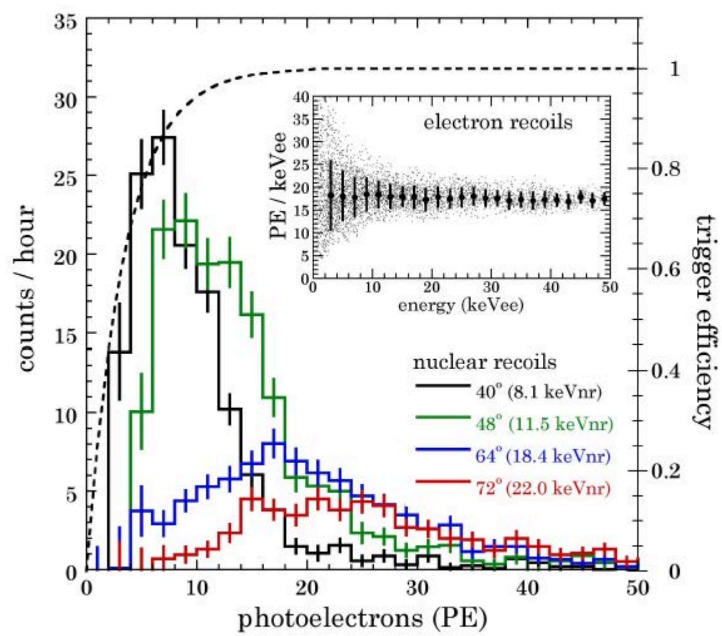
Simultaneous ER and NR low-E response measured via Compton scattering and D-D neutron gun (see PRC 88(2013)035806)





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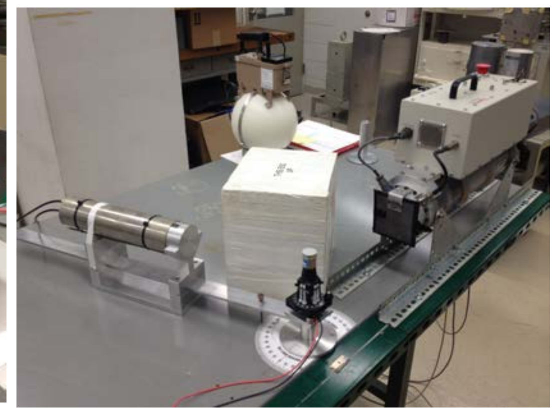

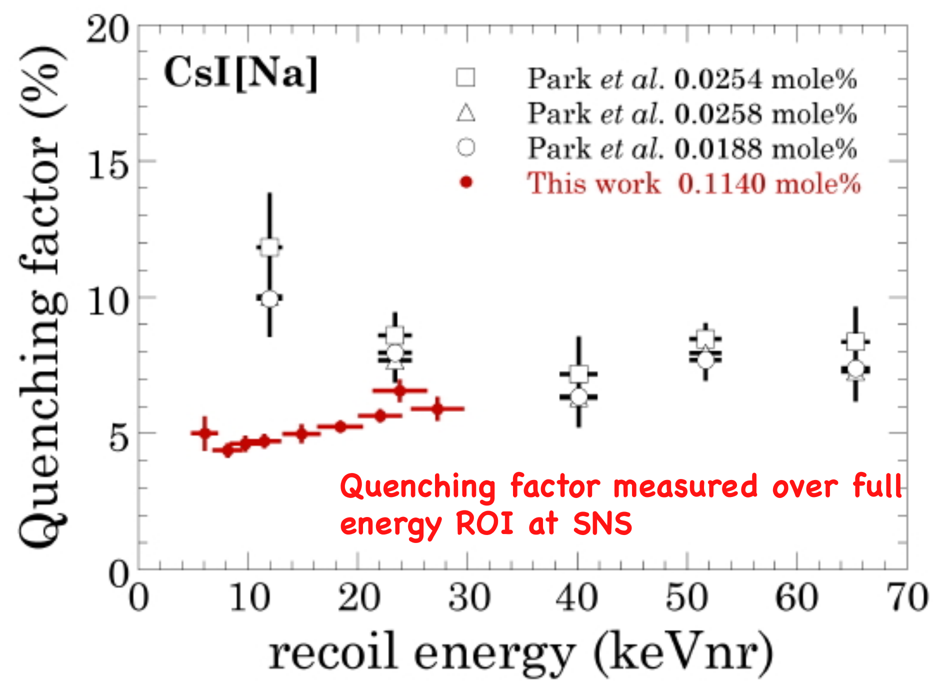

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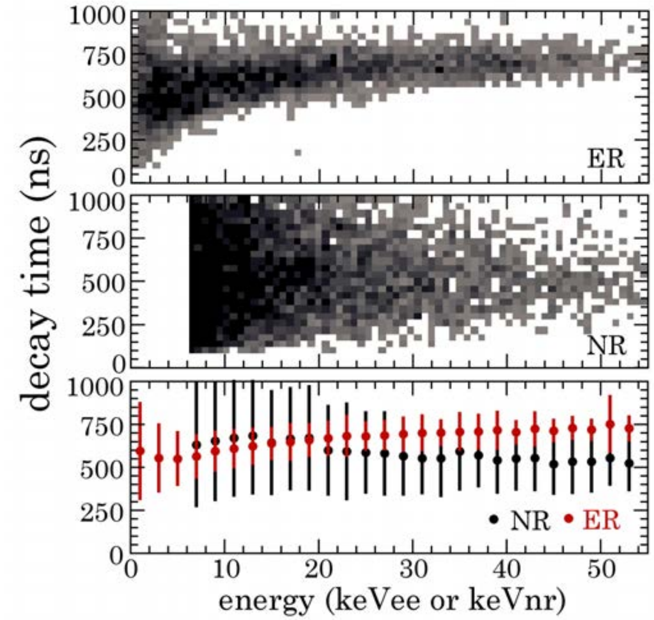
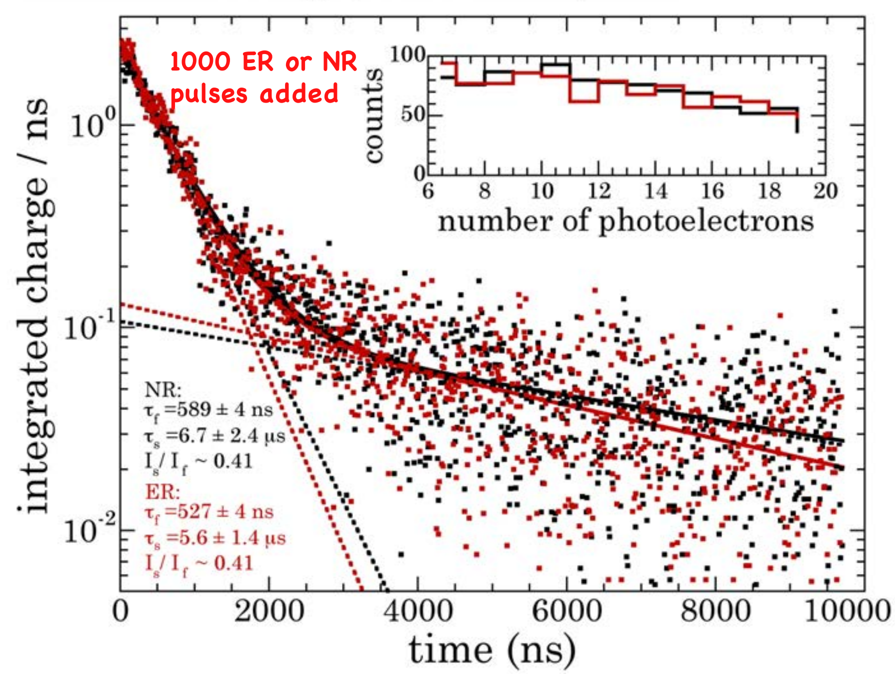


Scintillation response for NRs and ERs studied in relevant low-energy region (~4-20 PEs)



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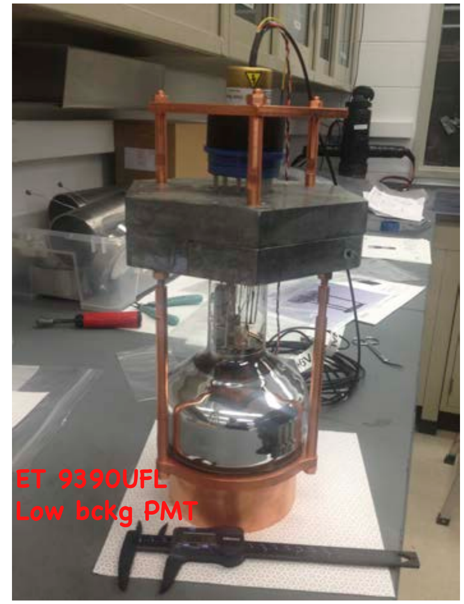

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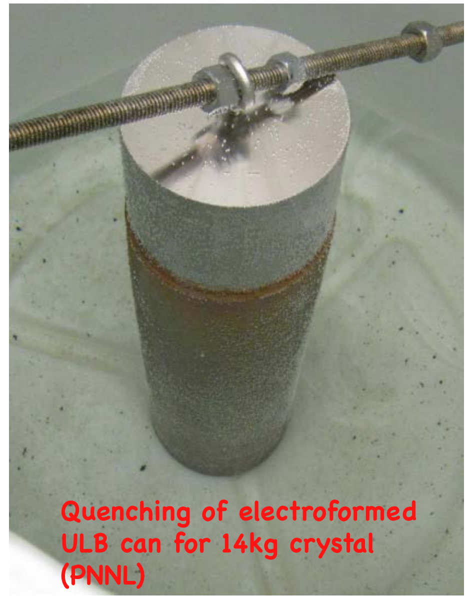
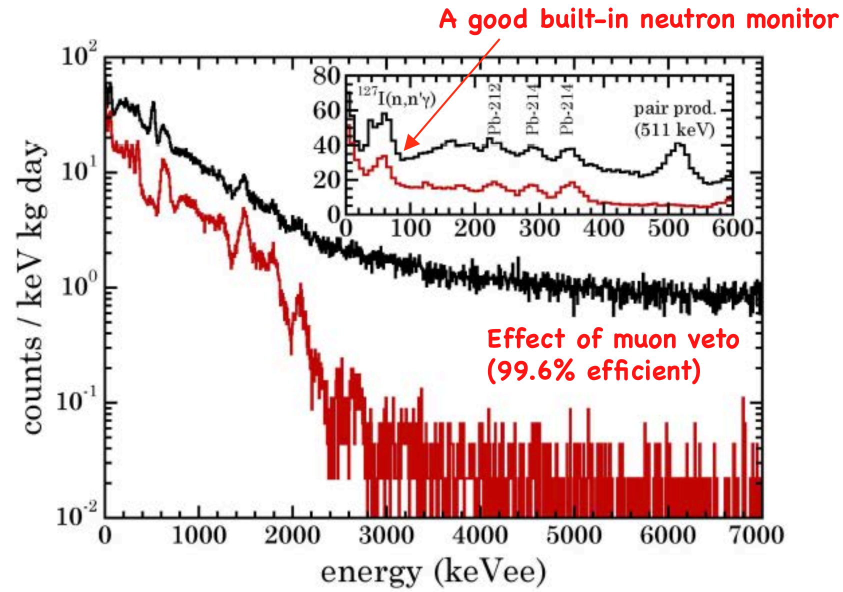
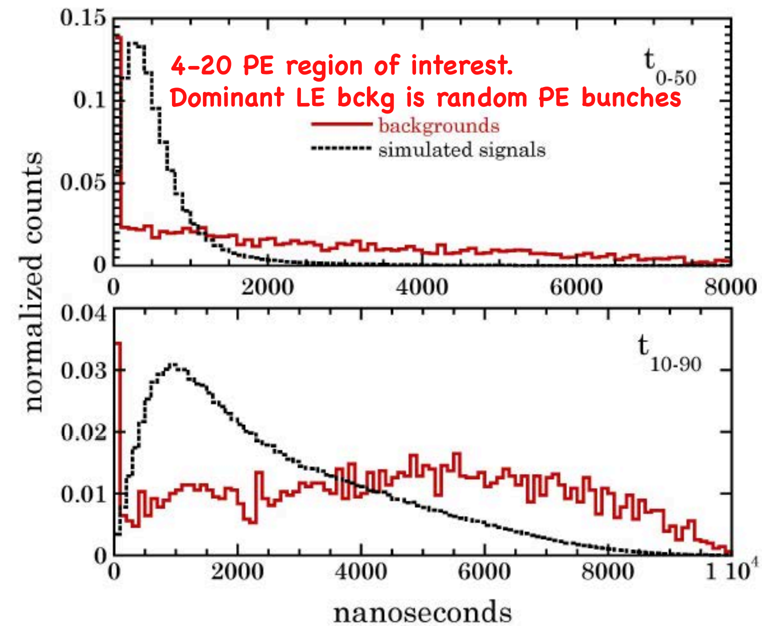


Finished 14 kg detector at UC.
Moved to low-bckg SBA PMT (further ~30% reduction in threshold)
Final characterization ongoing (light yield uniformity)
Installation at SNS ~this spring (once ongoing NIN meas. is over)

Highlights of feasibility study

- Study of backgrounds with 2 kg detector within a full shield (except n moderator) at 6 m.w.e. (~similar to SNS basement).
- Threshold ~7 keVnr (4 PE) demonstrated.
- Clear CENNS excess expected following a 2-3 year run with 14 kg detector. Some ~550 ev/year expected in 4-20 PE region. Measured steady-state backgrounds are sufficiently low (but further improvements seem possible -> neutron moderator, fancier treatment of discrimination against afterglow).
- GEANT simulation (transport of target neutrons to basement) using UC cluster. CPU-intensive! Several sanity checks performed. Confirms that basement location should keep target neutrons at bay.
- ν_e CC reaction in Pb provides largest foreseeable background. Several ways to discriminate CENNS and this reaction.
- Should we measure $^{208}Pb(\nu_e,e)^{208}Bi$ first? Advantages: 1) quick measurement eliminates this unknown, 2) a first ν physics result at the SNS at hand -> useful for HALO, traction with agencies.





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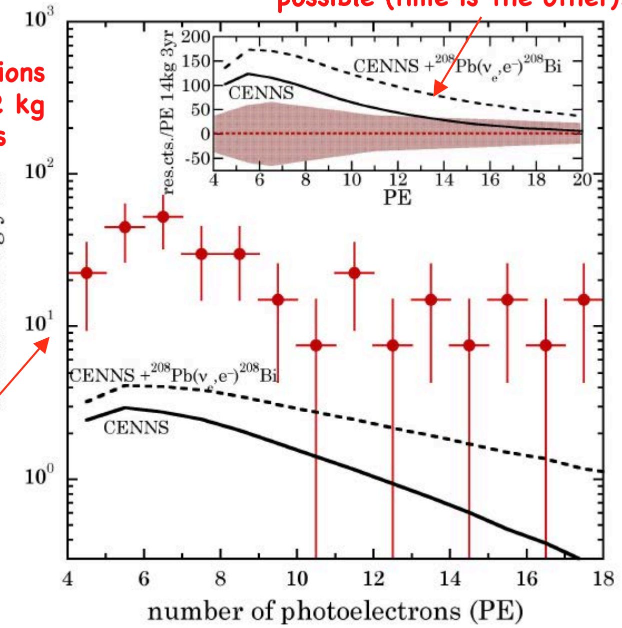
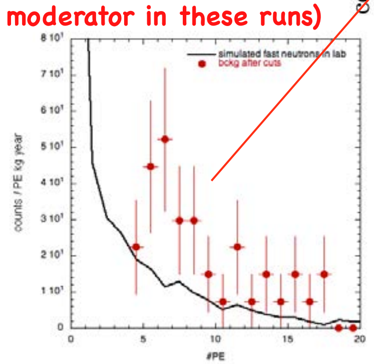
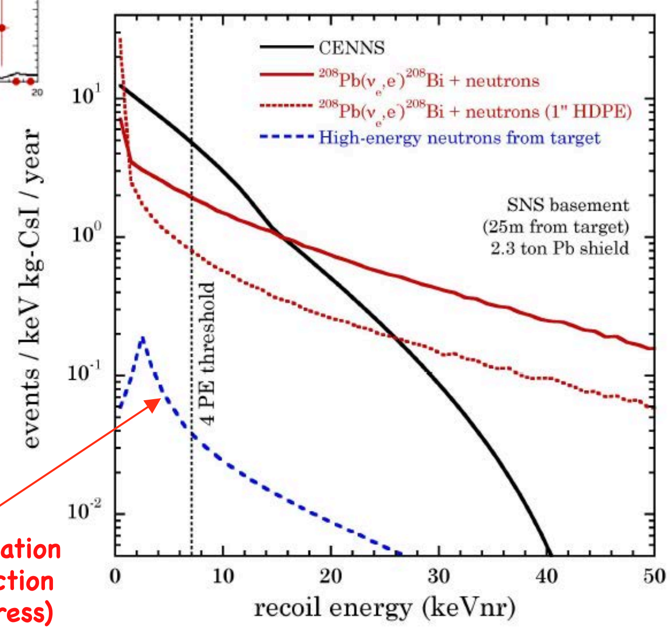
Clear CENNS excess after steady-state bckg subtraction (3 year run shown here). One of two representations possible (time is the other).

14 kg predictions scaled from 2 kg measurements



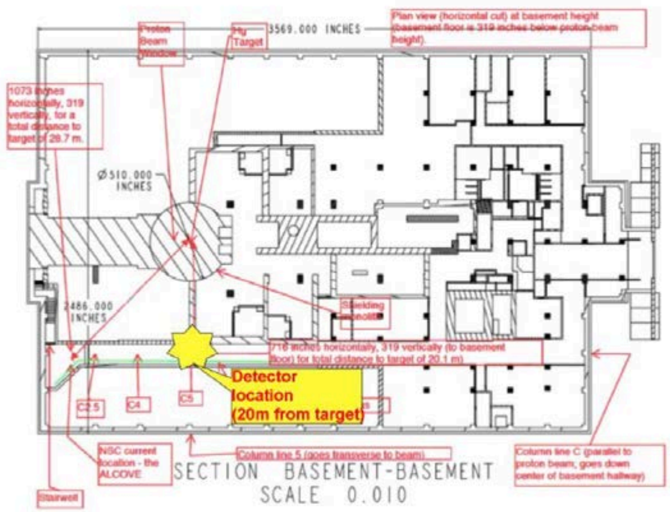
Residual background may be dominated by environmental n (no moderator in these runs)

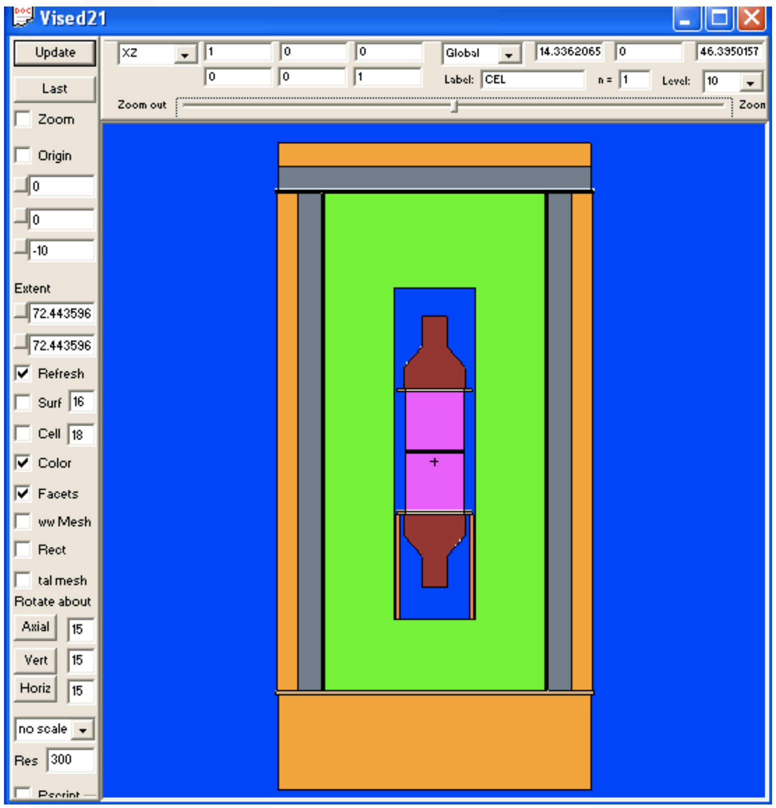




Very conservative (dominated by γ, shielding not in simulation yet. HP GEANT prediction is x10 lower. In progress)

Preliminaries: *in situ* NIN measurement





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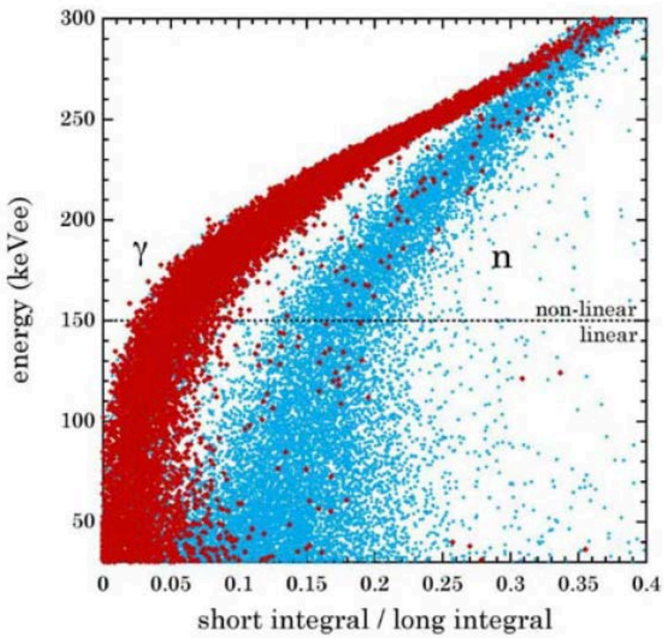
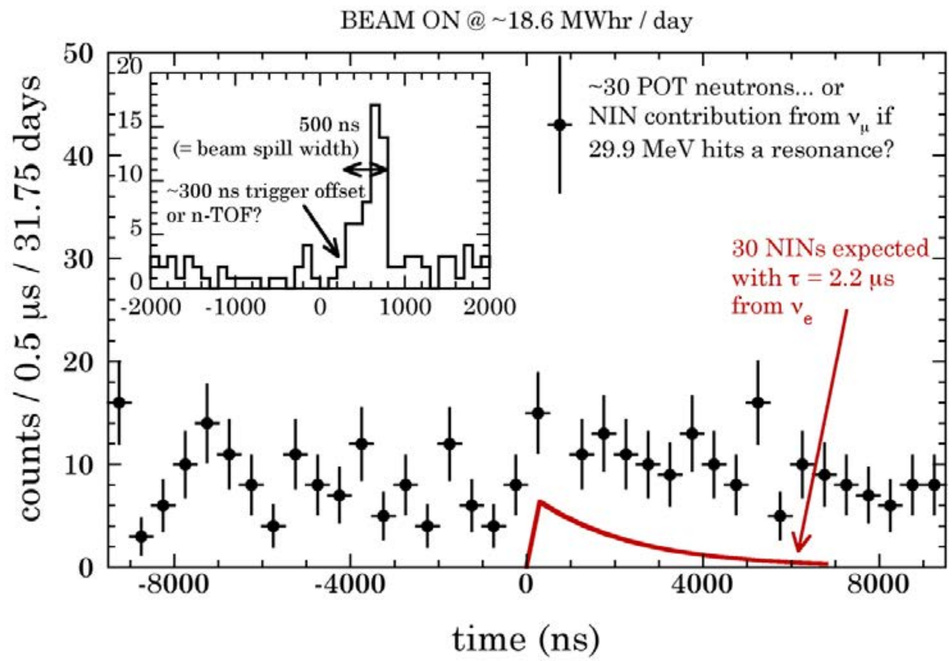
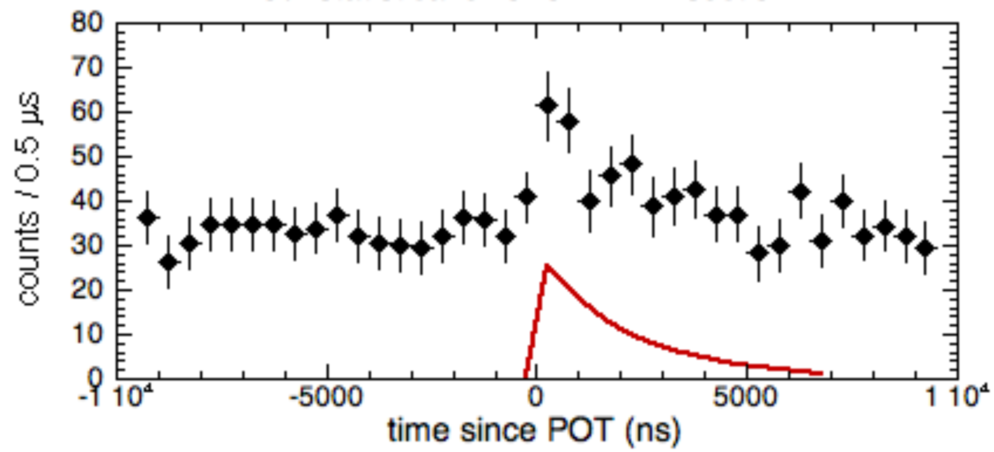




- If x-sections are what is expected, we should have a measurement of CC (+ perhaps NC) NIN production in Pb within the next few months.
- Main purpose of ongoing measurement is to educate CsI[Na] shield design. We plan a much higher statistics measurement with dedicated NIN detectors ("NIN-cubes"), also using other targets (G. Rich talk tomorrow)
- We need theory help <u>already</u>!

simulated CC NIN signal by mid-April 2015
~4σ evidence (likelihood ratio)
~20% statistical error on NIN x-section



Dangling ends desperately needing theory input:

1) A best effort at calculating CC NIN x-section specifically for SNS ν energies. We should be able to distinguish between predictions from different nuclear models.

J. Phys. G: Nucl. Part. Phys. 37 (2010) 125101 (10pp) doi:10.1088/0954-3899/37/12/125101

Low-energy neutrino scattering measurements at future spallation source facilities

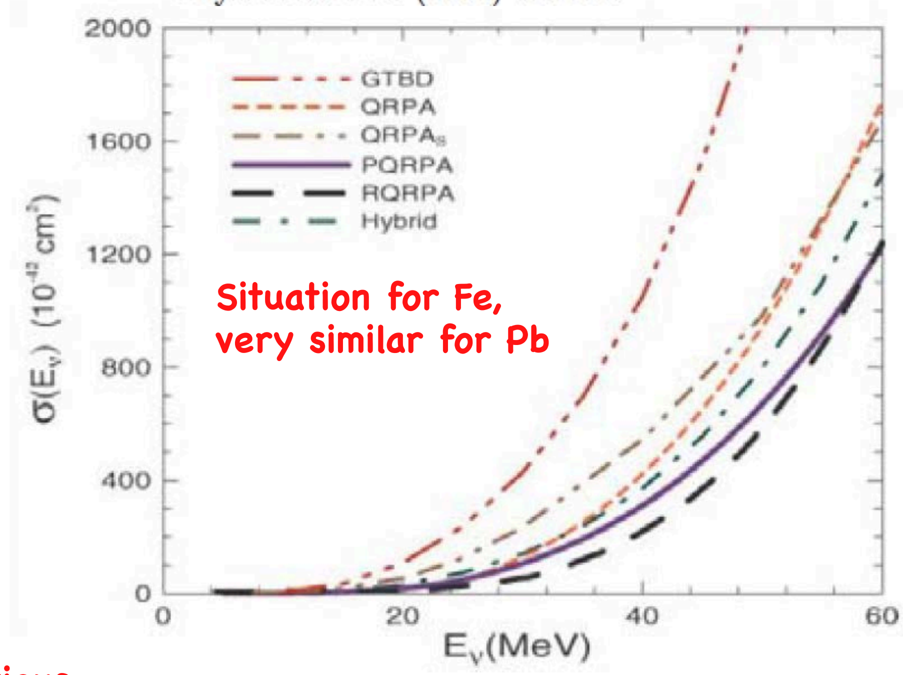
R Lazauskas[1] and C Volpe[2]

CC QRPAs calculation

Table 2. Results on the number of events at a neutrino experiment based at a spallation source facility. The events are calculated assuming 10^{15} ν_e s^{-1}, in 1 year (3×10^7 s), with a fully efficient 1 ton cubic detector. The columns correspond to the considered targets (first column), the rates at different distances d (meters) from the source, the material density (fourth column) and the flux-averaged cross sections in the unit 10^{-40} cm^2 (last column).

	10	20	50	ρ ($g\,cm^{-3}$)	$\langle\sigma\rangle_{DAR}$
^{12}C (in $C_{16}H_{18}$)	1 470	384	63	0.992	≈0.14 [10, 13]
^{16}O (in water)	998	261	43	1.	0.131 [56]
^{40}Ar	8 860	2310	380	1.43	2.56 [44]
^{56}Fe	9 100	2330	377	7.87	3.53 [56]
^{100}Mo	17 300	4420	716	10.28	11.95 [56]
^{208}Pb	34 500	8820	1430	11.34	49.6 [56]
^{208}Pb + 1n	~~1 630~~ 16350	4180	677		23.5 [28]
^{208}Pb + 2n	9 420	~~1140~~ 2400	390		13.5 [28]

Phys. Rev. C78 (2008) 024312.



(this is what is used for the expectations in previous transparency, post corrections <- checked with authors)

Dangling ends desperately needing theory input:

PHYSICAL REVIEW C **63** 025802

2) Best effort at calculating spectrum of neutron emission energies. Presently using a simple spallation spectrum in Pb as a place holder (NIMA 354 (1995) 553). We should be able to eventually deconvolve this emission spectrum with data from a high-statistics run using the NIN-cubes (G. Rich talk tomorrow).

3) Is the assumption of isotropic neutron emission correct?

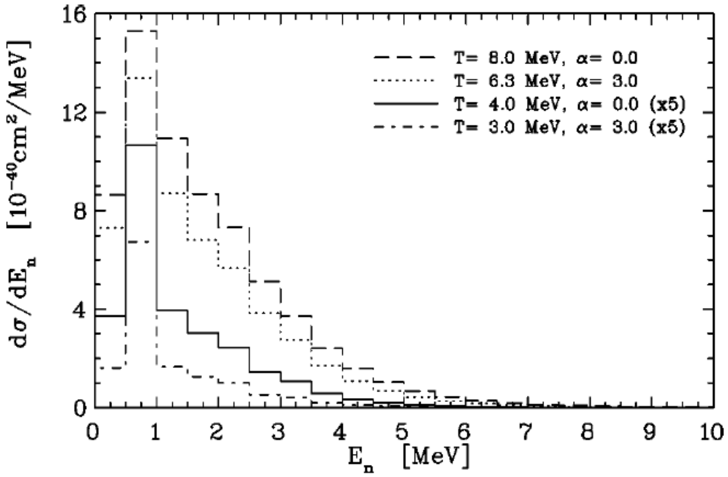
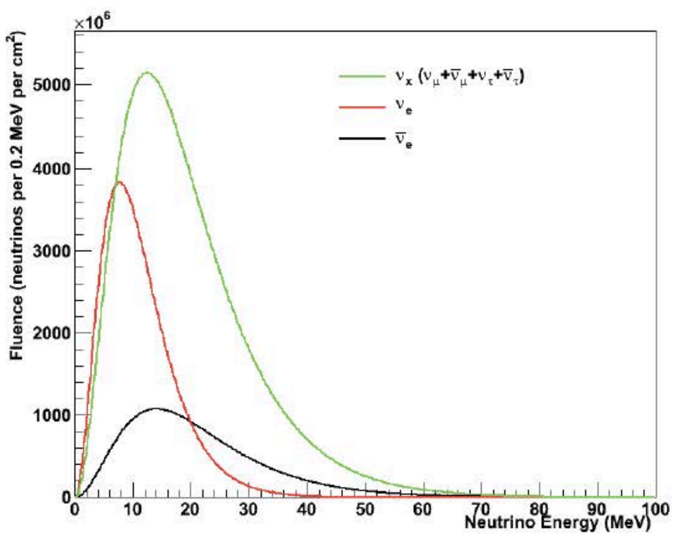
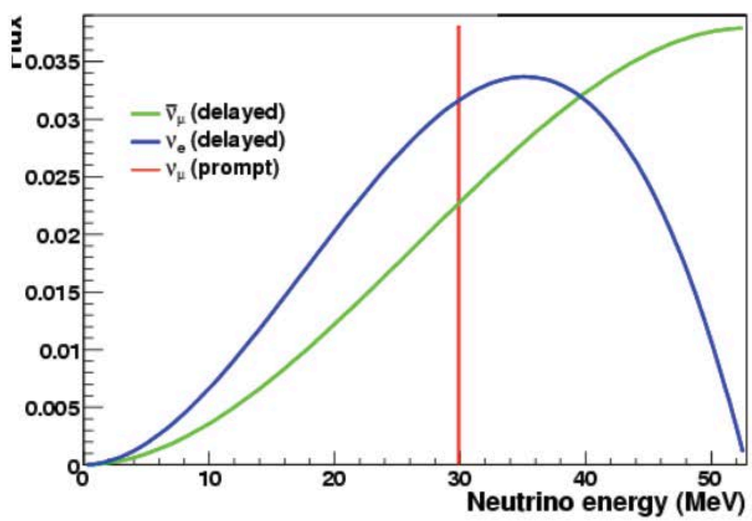


FIG. 6. Neutron energy spectrum produced by the charged-current (ν_e, e^-) reaction on ^{208}Pb. The calculation has been performed for different supernova neutrino spectra characterized by the parameters (T,α). Note that the cross sections for $(T,\alpha)=(4,0)$ and (3,3) neutrinos have been scaled by a factor of 5.

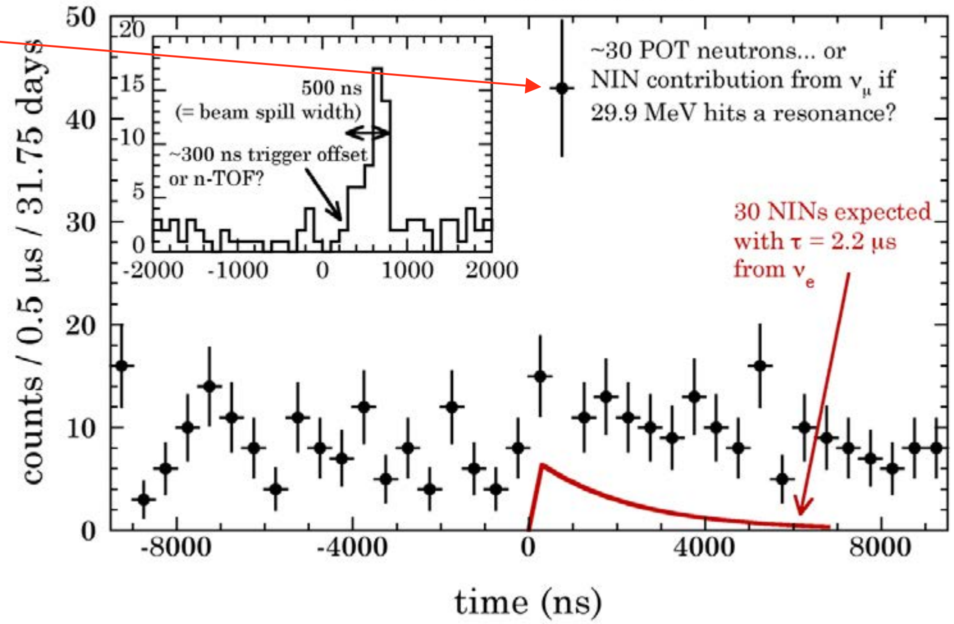




Dangling ends desperately needing theory input:

4) NC NINs are prompt, but in principle only a ~10% fraction of CC NINs. We may be able to measure these too, or to at least place an upper limit to the x-section. Best effort needed to calculate ν_μ NIN x-section at *exactly* 29.9 MeV (resonances could make a significant difference). We plan to run with detectors outside Pb, to help disentangle NC NINs from POT neutrons.

BEAM ON @ ~18.6 MWhr / day



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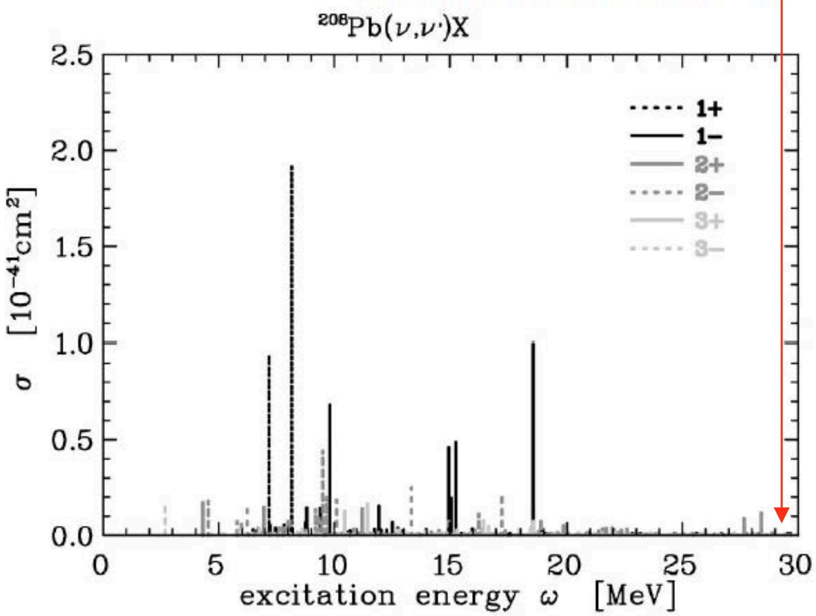

FIG. 3. Excitation spectrum of the ^{208}Pb nucleus for photoabsorption (upper part) in comparison to the spectrum excited by neutral current neutrino scattering (lower part), which is decomposed into the dominant multipole contributions.

WHAT CAN BE LEARNED WITH A LEAD-BASED . . . PHYSICAL REVIEW D **67**, 013005 (2003)

TABLE I. Neutrino cross sections in units of 10^{-40} cm^2 as a function of energy (MeV) for emission of one and two neutrons, and summed over all decay channels, obtained with the Skyrme force SIII. We include the charged-current channel for neutrinos, and the neutral-current channel for both neutrinos and antineutrinos.

	$\nu_e \to e$			$\nu \to \nu$			$\bar{\nu} \to \bar{\nu}$		
E_ν	1n	2n	total	1n	2n	total	1n	2n	total
5			0.39×10^{-7}			0.67×10^{-11}			0.66×10^{-11}
10	0.29×10^{-11}		0.09	0.002		0.007	0.002		0.007
15	0.91		1.54	0.06		0.08	0.05		0.08
20	4.96		6.51	0.20		0.27	0.18		0.24
25	14.66	0.45	17.63	0.46	0.03	0.62	0.40	0.03	0.54
30	25.05	3.15	32.22	0.87	0.15	1.22	0.73	0.13	1.04
35	29.27	10.85	45.37	1.44	0.42	2.15	1.18	0.36	1.79
40	33.56	23.68	64.10	2.15	0.93	3.48	1.73	0.76	2.82
45	37.91	38.97	85.33	2.97	1.74	5.25	2.34	1.39	4.17
50	42.54	53.79	106.16	3.86	2.93	7.50	2.99	2.26	5.82
55	47.17	71.63	130.09	4.79	4.56	10.24	3.65	3.42	7.78
60	52.02	90.05	154.64	5.74	6.63	13.50	4.31	4.85	10.04
65	56.31	108.73	178.75	6.71	9.17	17.25	4.97	6.54	12.57
70	60.39	129.14	204.17	7.69	12.17	21.49	5.62	8.47	15.34
75	64.03	150.40	229.88	8.67	15.59	26.14	6.25	10.62	18.31
80	67.04	170.75	253.92	9.65	19.39	31.16	6.86	12.94	21.42
85	69.69	191.16	277.58	10.58	23.51	36.43	7.44	15.39	24.61
90	71.95	211.73	300.95	11.45	27.90	41.88	7.97	17.93	27.82
95	73.91	231.25	323.03	12.23	32.47	47.39	8.45	20.51	31.00