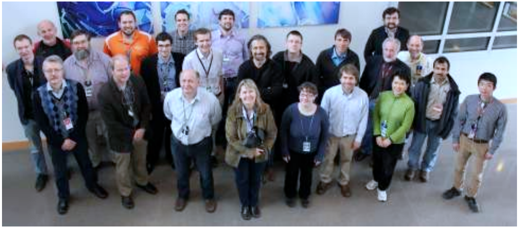
COHERENT AT THE SPALLATION NEUTRON SOURCE

Björn J. Scholz
On behalf of the COHERENT collaboration

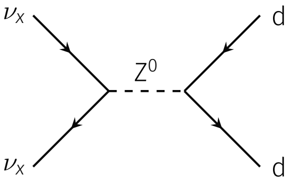
April 17, 2016

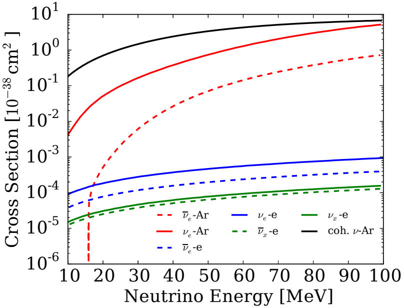
THE COHERENT COLLABORATION



- We are an international collaboration including 17 institutions from the US and Russia
- Our goal is to observe CEνNS at the Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory, Tennessee
- Rich past experience from multiple different areas, including rare event searches such as dark matter, CEνNS, $0\nu\beta\beta$-decay, ...

COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEνNS)





Adapted from S. J. Brice *et al*, PRD89 (2014), 072004

- Predicted standard model cross section is large

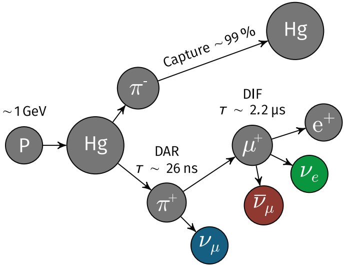
$$\sigma \propto \frac{G^2}{4\pi} E^2 \left[N - \left(1 - 4\sin^2\theta_W \right) Z \right]^2$$

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

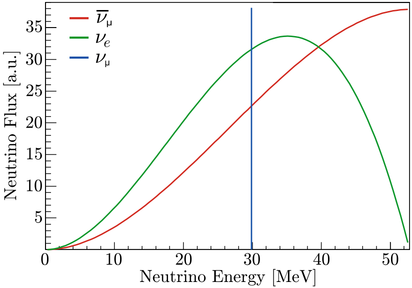
- Coherent interaction requires $Q \lesssim R_A^{-1} \approx 50\,\text{MeV}$
- Maximum recoil energy is small

$$E_{\text{NR,max}} = \frac{2E^2}{M}$$

THE SNS – A STOPPED π NEUTRINO SOURCE



K. Scholberg, PRD73 (2006), 033005

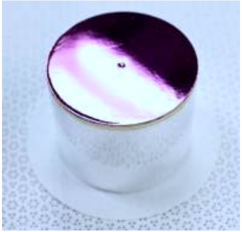


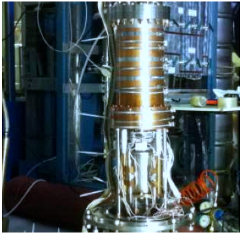
- Pulsed proton beam:
  - $\sim 10^{15}$ protons/s on Hg target
  - Pulse duration $\sim$ 380 ns (FWHM)
  - Repetition rate 60 Hz
  - Total power $\sim$ 1 MW
- Neutrino emission spectrum:
  - Well understood
  - Matching energy range
  - Multiple flavors
  - ν_x flux $\sim 2 \times 10^7 \mathrm{cm}^{-2}\mathrm{s}^{-1}$

CHOICE OF TARGET MATERIALS

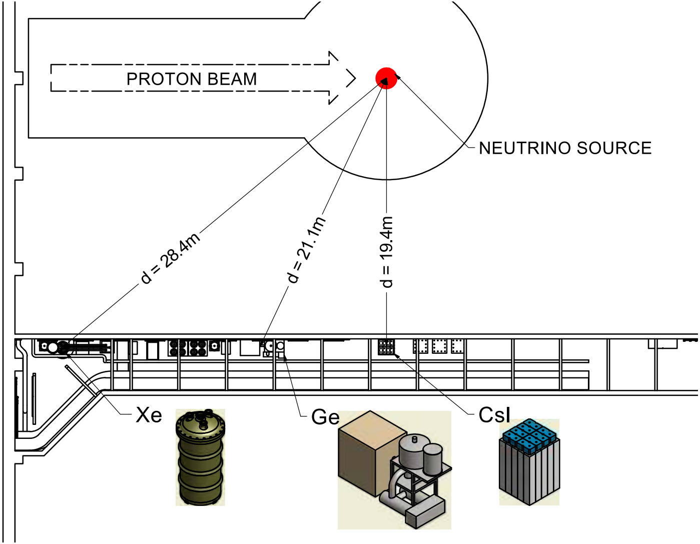
- Multi-target approach favorable to test N^2 dependance
- Various target materials suitable for CEνNS detection, such as NaI, CsI, LXe, LAr, Ge, etc.
  $\rightarrow$ Three of these are planned for deployment in phase I:

CsI[Na] Ge LXe

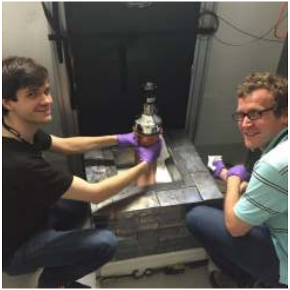


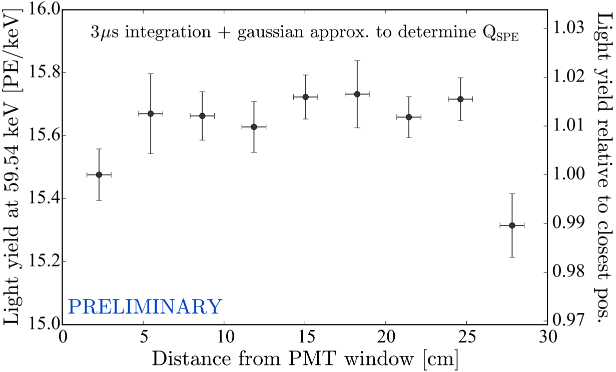


DETECTOR LOCATIONS W.R.T. THE TARGET

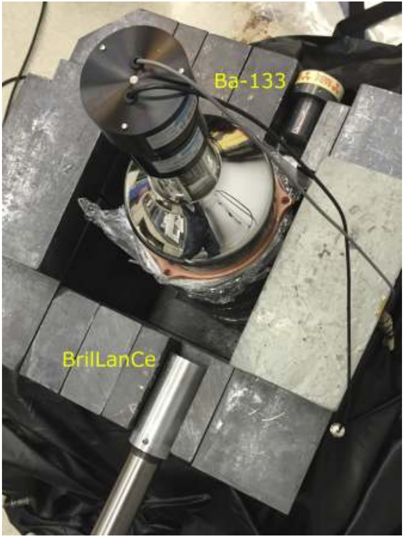


CsI[Na] - Installation in June 2015



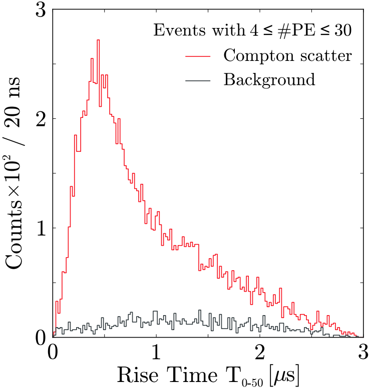



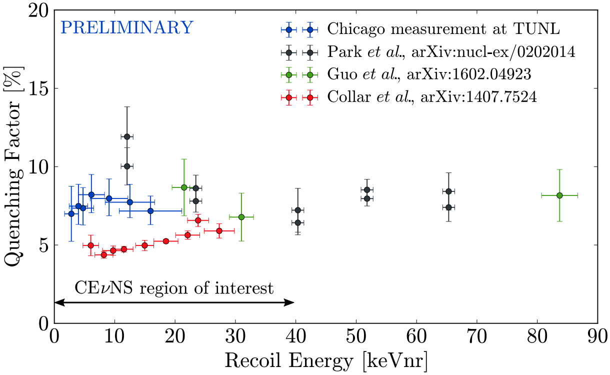
- Light yield calibration using a ^{241}Am $\gamma-$source
- Low energy γ-s interact close to source location making it possible to probe uniformity of CsI[Na] crystal
- Overall variation below 3 %



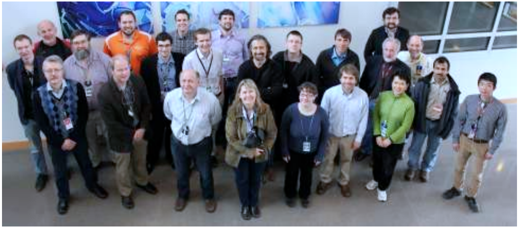
- Built a library of low energy events in CsI[Na] crystal to train future cuts on

→ Shallow angle Compton scatter events using a pencil beam of ^{133}Ba γ-s



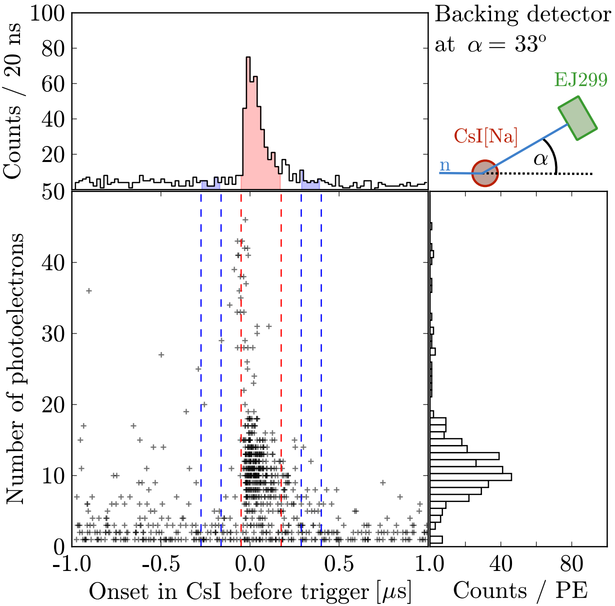


- Some scatter in previous quenching factor measurements
  → Two new, independent q.f. measurements by our Chicago (*included above*) and Duke (*not shown above, being analyzed*) groups at TUNL
- Duke measurements probe both the CEνNS region of interest as well as higher recoil energies



- We are an international collaboration including 17 institutions from the US and Russia determined to observe CEνNS
- The SNS perfectly matches our needs to accomplish our goal
- Three detector sub-systems planned for deployment within phase I. One of which (CsI[Na]) has already been deployed (June 2015)
- Multiple calibration measurements (past and future) to ensure proper understanding of detector response

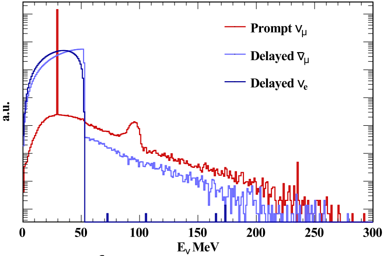
BACKUP



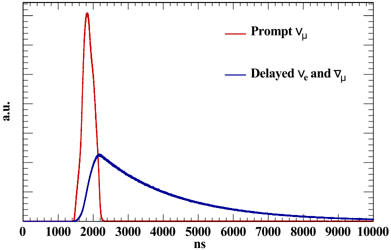
100
80
60
40
20
50
Counts / 20 ns
Backing detector
at $\alpha = 33^o$
EJ299
CsI[Na]
n
α
40
30
20
10
0
Number of photoelectrons
-1.0
-0.5
0.0
0.5
1.0
Onset in CsI before trigger [μs]
40
80
Counts / PE

THE SNS - DETECTOR LOCATIONS - NEUTRON BACKGROUNDS

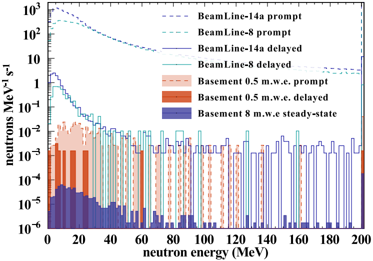
Neutrino Spectrum



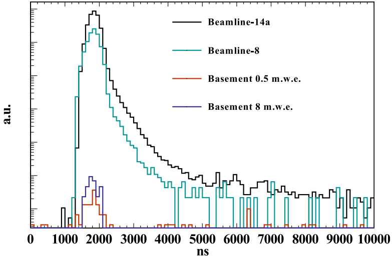
Timing profile



fast neutron spectrum

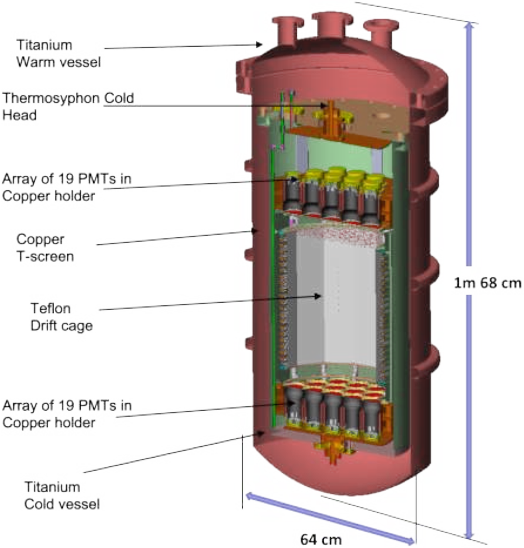


neutron arrival times



DETECTOR TECHNOLOGIES - 2-PHASE XENON (RED 100)

Hamamatsu R11410-20



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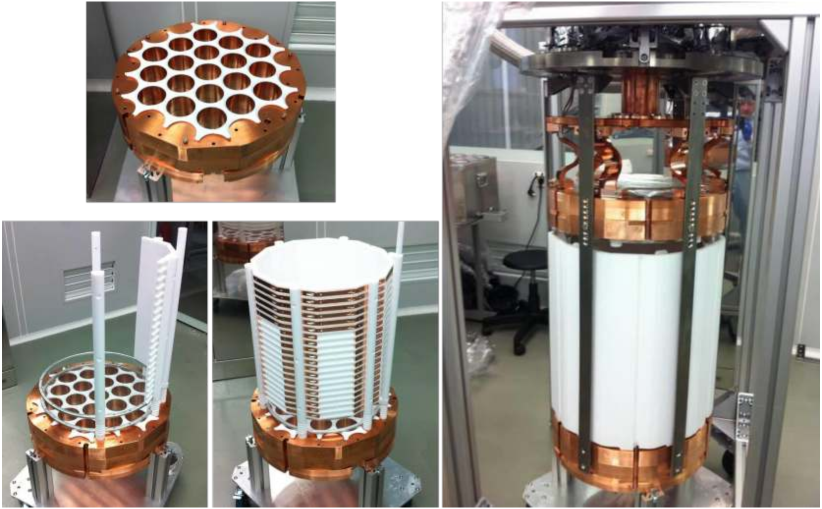
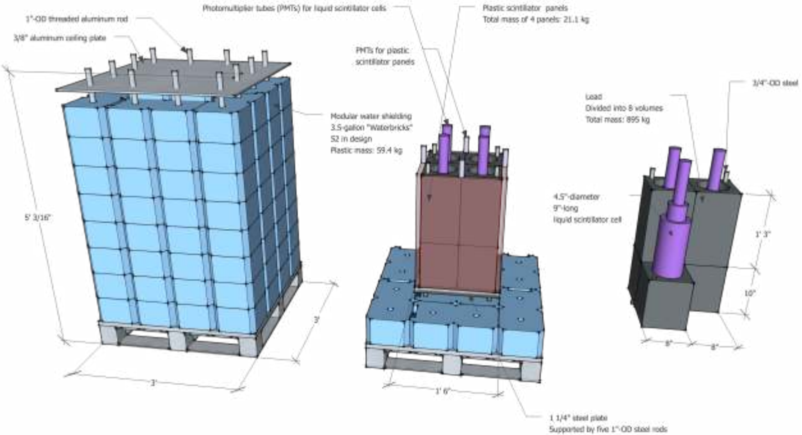


D. Akimov/Xe Working Group

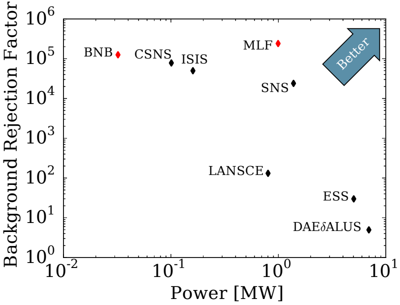
BONUS: NEUTRINO INDUCED NEUTRONS

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

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



COMPARISON OF STOPPED π FACILITIES



From K. Scholberg

Facility	Location	Proton Energy (GeV)	Power (MW)	Bunch Structure	Rate	Target
LANSCE	USA (LANL)	0.8	0.056	600 µs	120 Hz	Various
ISIS	UK (RAL)	0.8	0.16	2 × 200 ns	50 Hz	Water-cooled tantalum
BNB	USA (FNAL)	8	0.032	1.6 µs	5-11 Hz	Beryllium
SNS	USA (ORNL)	1.3	1	700 ns	60 Hz	Mercury
MLF	Japan (J-PARC)	3	1	2 × 60-100 ns	25 Hz	Mercury
ESS	Sweden (planned)	1.3	5	2 ms	17 Hz	Mercury
DAEδALUS	TBD (planned)	0.7	$\sim 7 \times 1$	100 ms	2 Hz	Mercury