SNS Directional ν Scattering

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SNS cross-section measurements

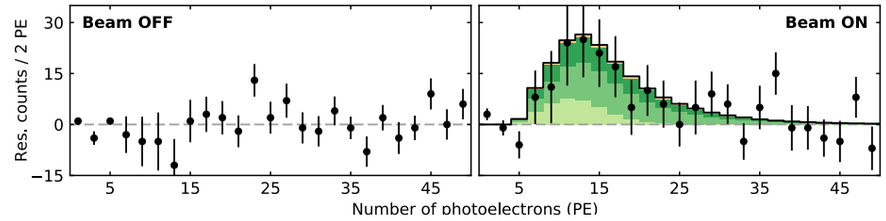
- We are just now beginning to measure neutrino cross-sections at the SNS

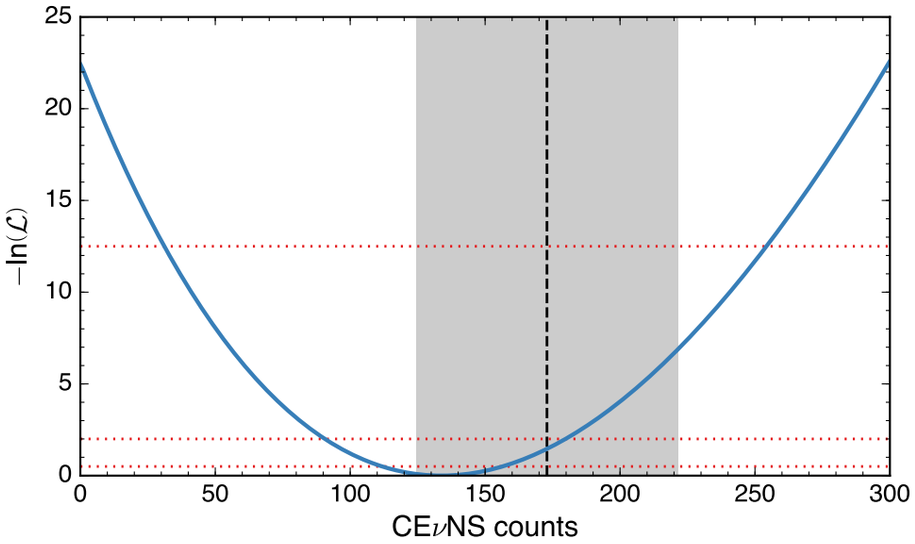
- There is a pretty good list of interesting cross-section measurements that have long been proposed

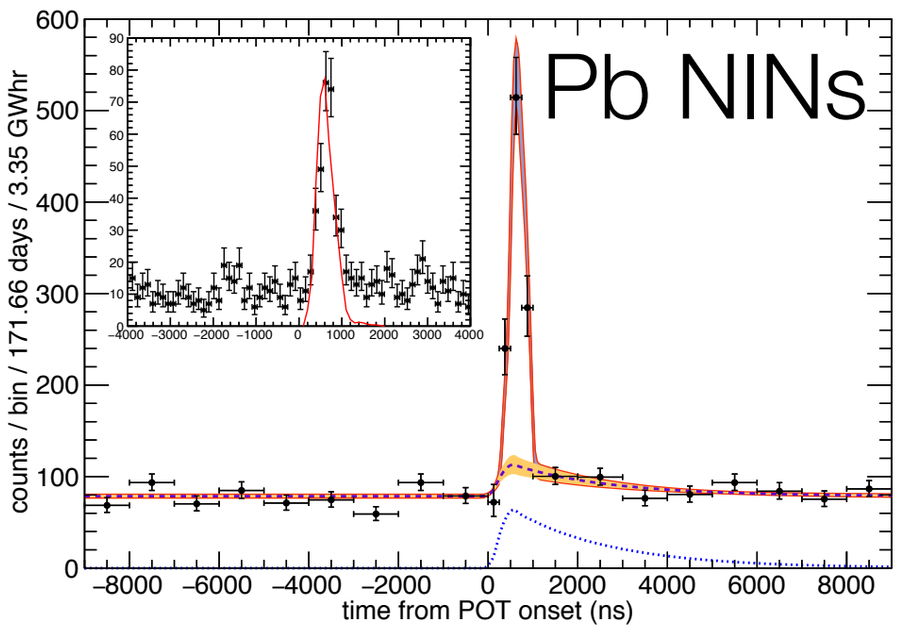
Is following list is good enough to start with?

^{2}d, ^{12}C, ^{16}O, ^{127}I, ^{51}V, ^{27}Al, ^{9}Be, ^{11}B, ^{52}Cr, ^{56}Fe, ^{59}Co, ^{209}Bi, ^{181}Ta

—Yuri Efremenko, 2003

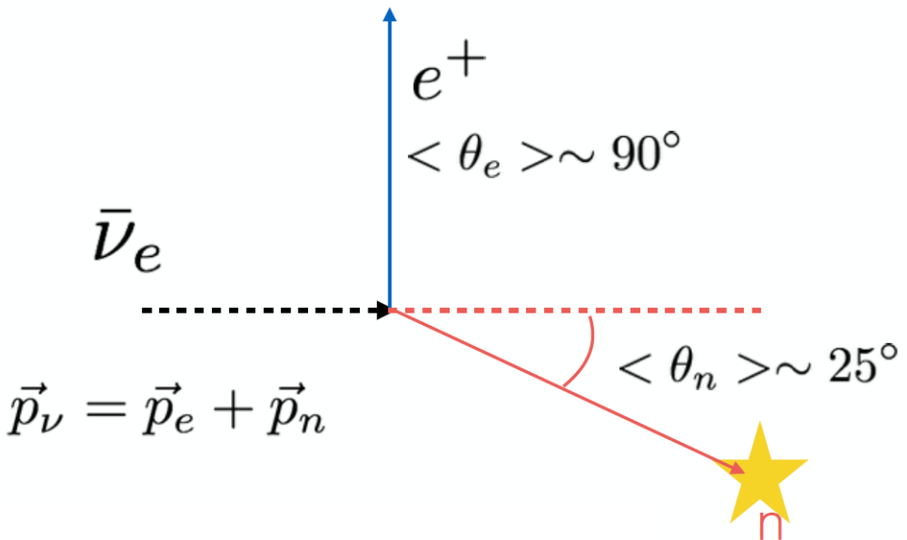


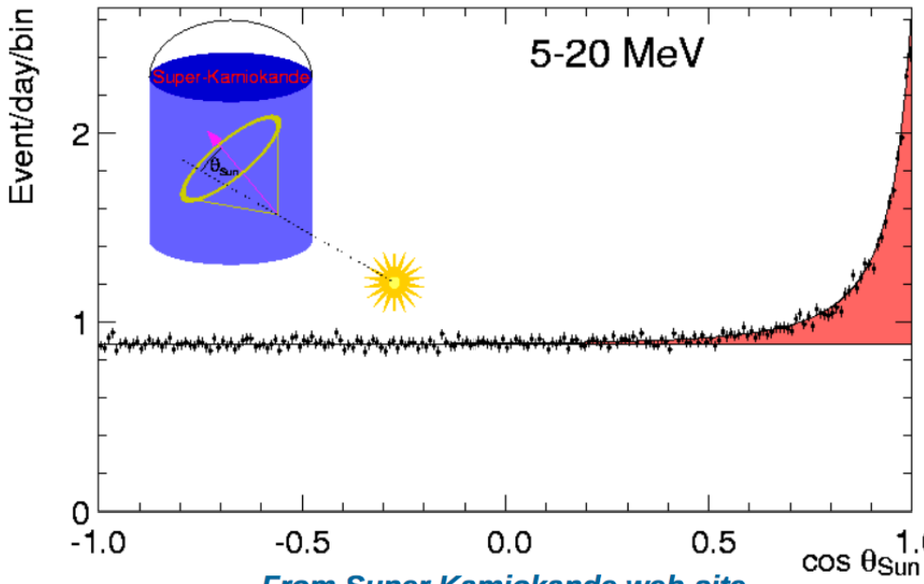




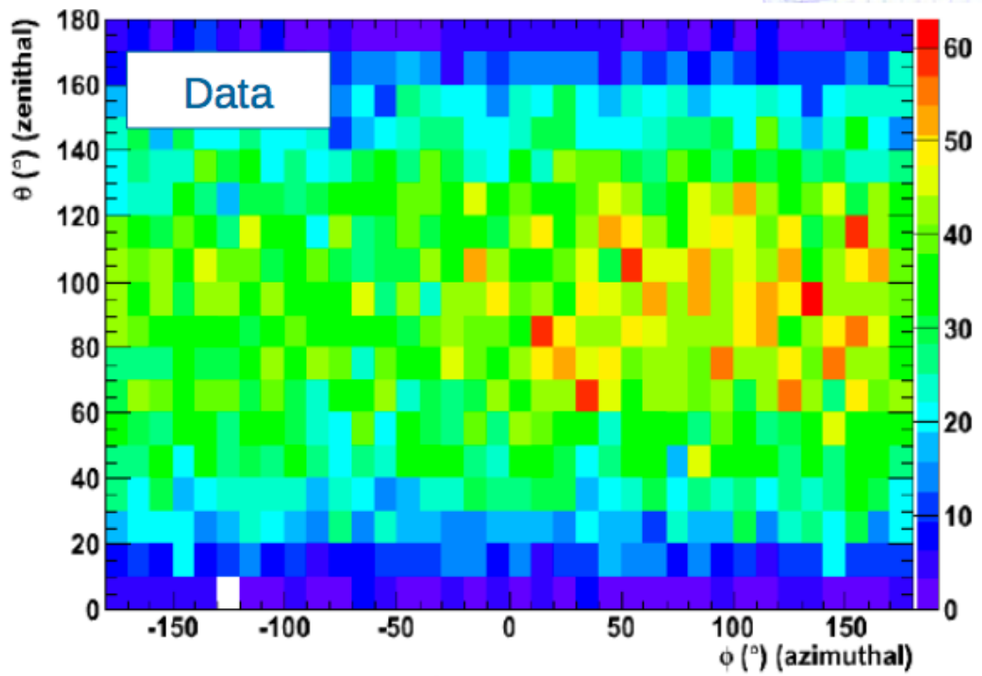
What about Directional Information?

- Neutrino directionality is a common measurement with high energy neutrinos
- But it is not crazy to consider directional detectors with the large flux of low energy neutrinos at the SNS
- Recent discussions on another “holy grail”: reconstruction of the full momentum of the IVBD process (e.g. B. Suerfu, AAP 2015)—talk to C. Awe if you’d like to hear some other ideas we are working on.





From Super Kamiokande web-site



Double Chooz

Why bother with directionality

- The neutrino-induced neutron measurements from the deployed detector measure the cross-section with ~10% efficiency, and can be susceptible to complex systematics

- A detector system that instead measures the lepton would be much more efficient

- Any directional information can help with background reduction.

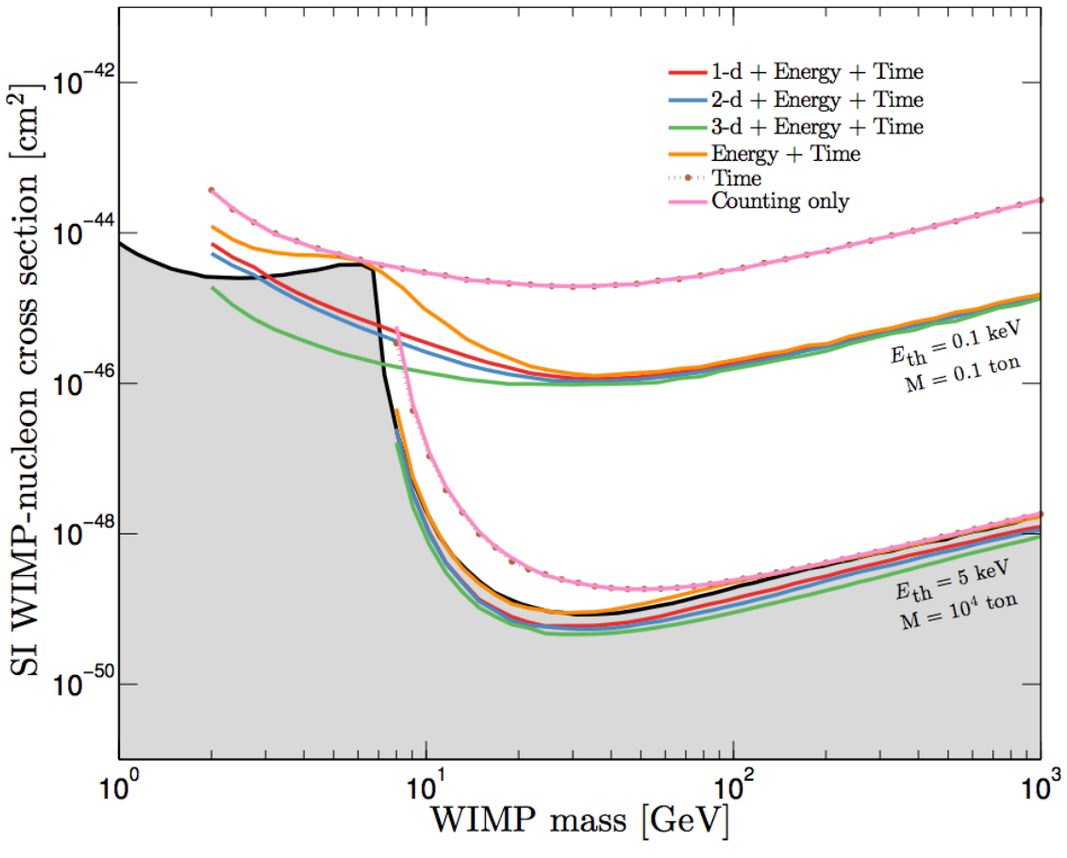
- Can be very interesting for Nuclear Models (See talk by N. Jachowicz)

- Furthermore, studying directionality at the SNS can serve as a technology demonstration for non-SNS applications

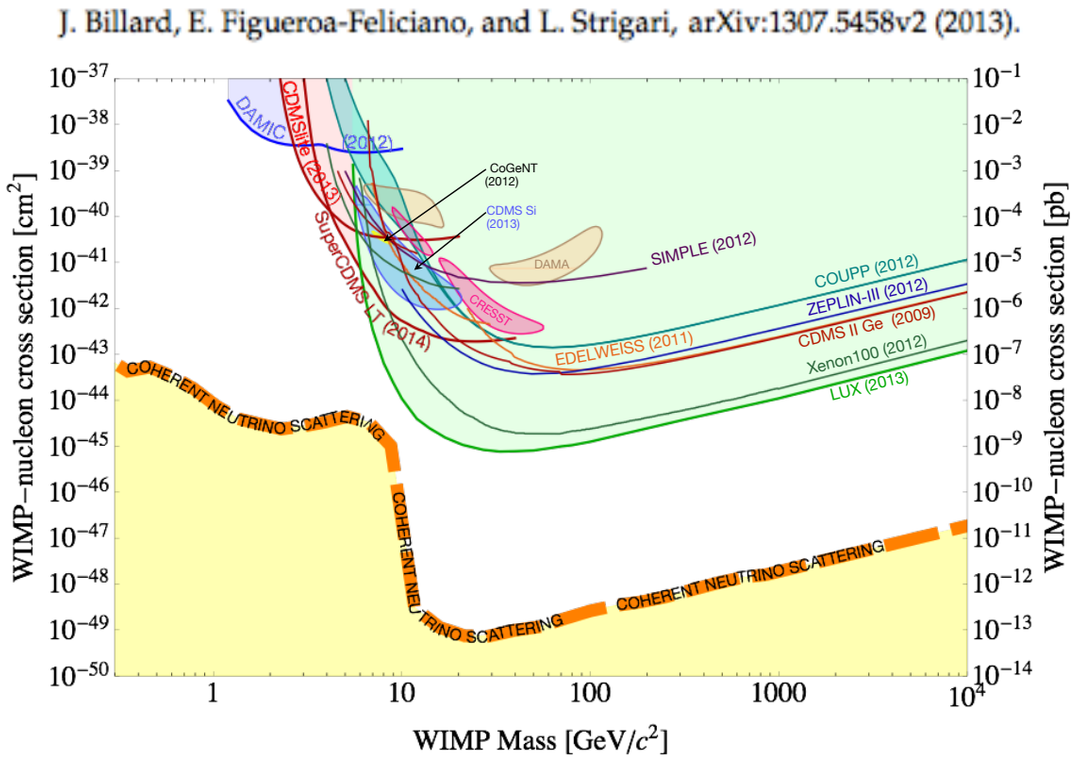
A Neutrino Background

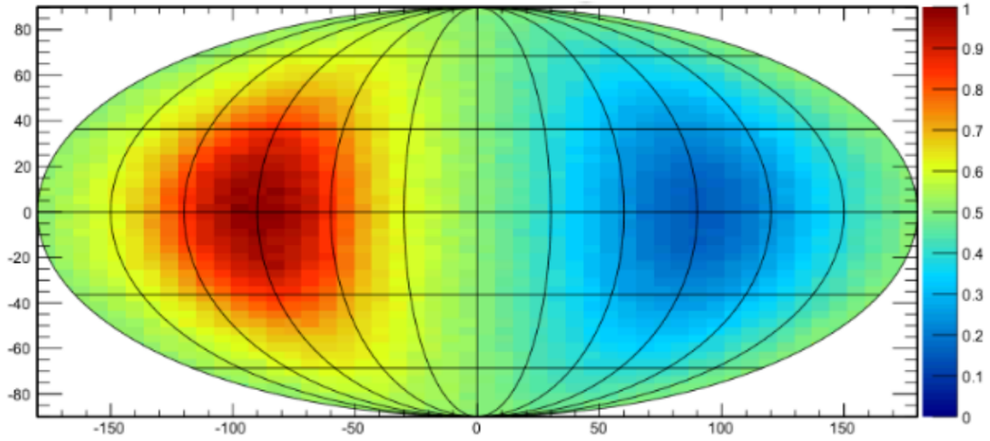
- The next generations of WIMP detectors will begin to be background limited by CEvNS
- In addition to providing an unambiguous discovery signature for WIMPs, a directional detector has the potential to push passed the neutrino floor.

C.A.J. O'Hare, et al., Phys. Rev. D 92, 063518 (2015)



J. Billard, E. Figueroa-Feliciano, and L. Strigari, arXiv:1307.5458v2 (2013).





Sky map in galactic coordinates of recoils from 100 GeV WIMPs on ^{19}F, E>50 keV

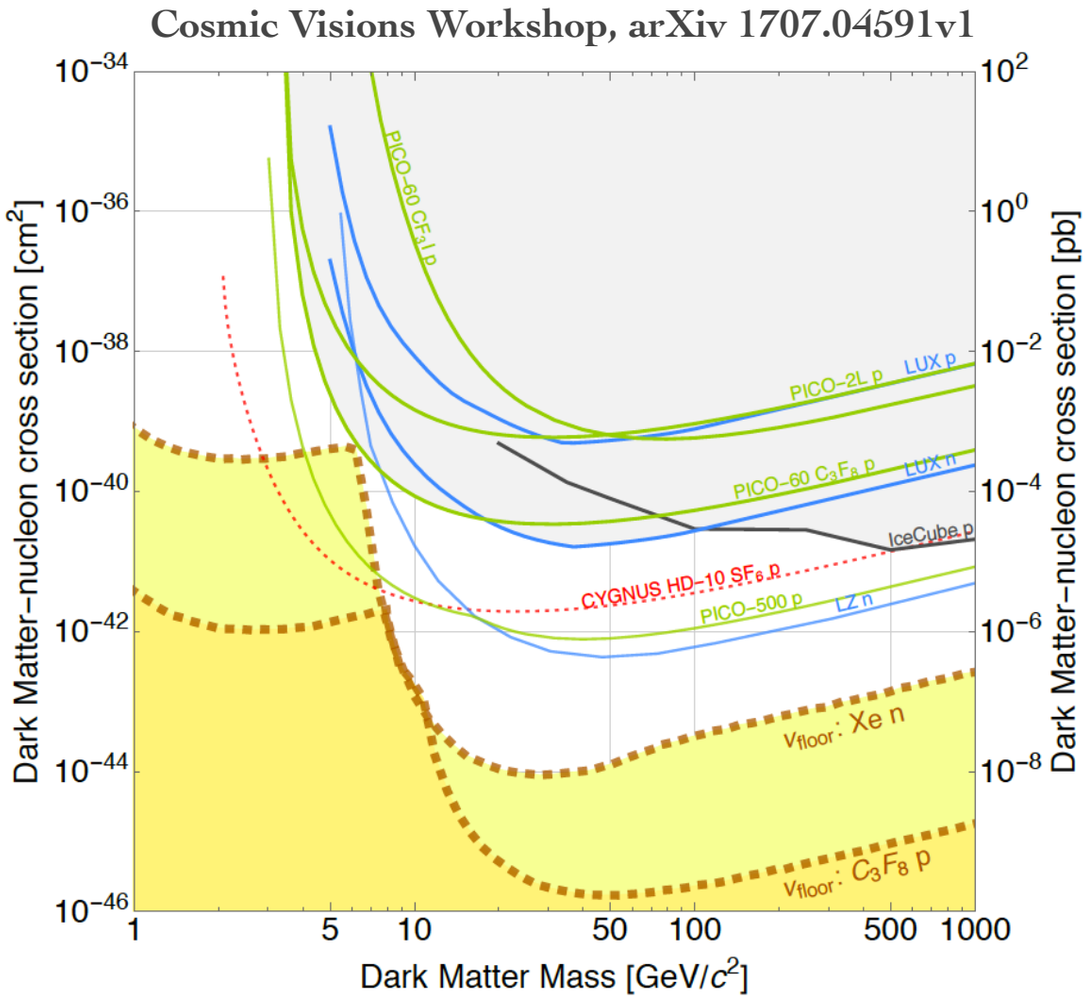
How to Motivate Such a Large Detector

- The CYGNUS collaboration is designing a 10 m^3 detector of He:SF_6, instrumented with MicroMegas.

- A small deployment to the SNS can prove the principle that such a detector could identify the direction of the CEvNS recoils

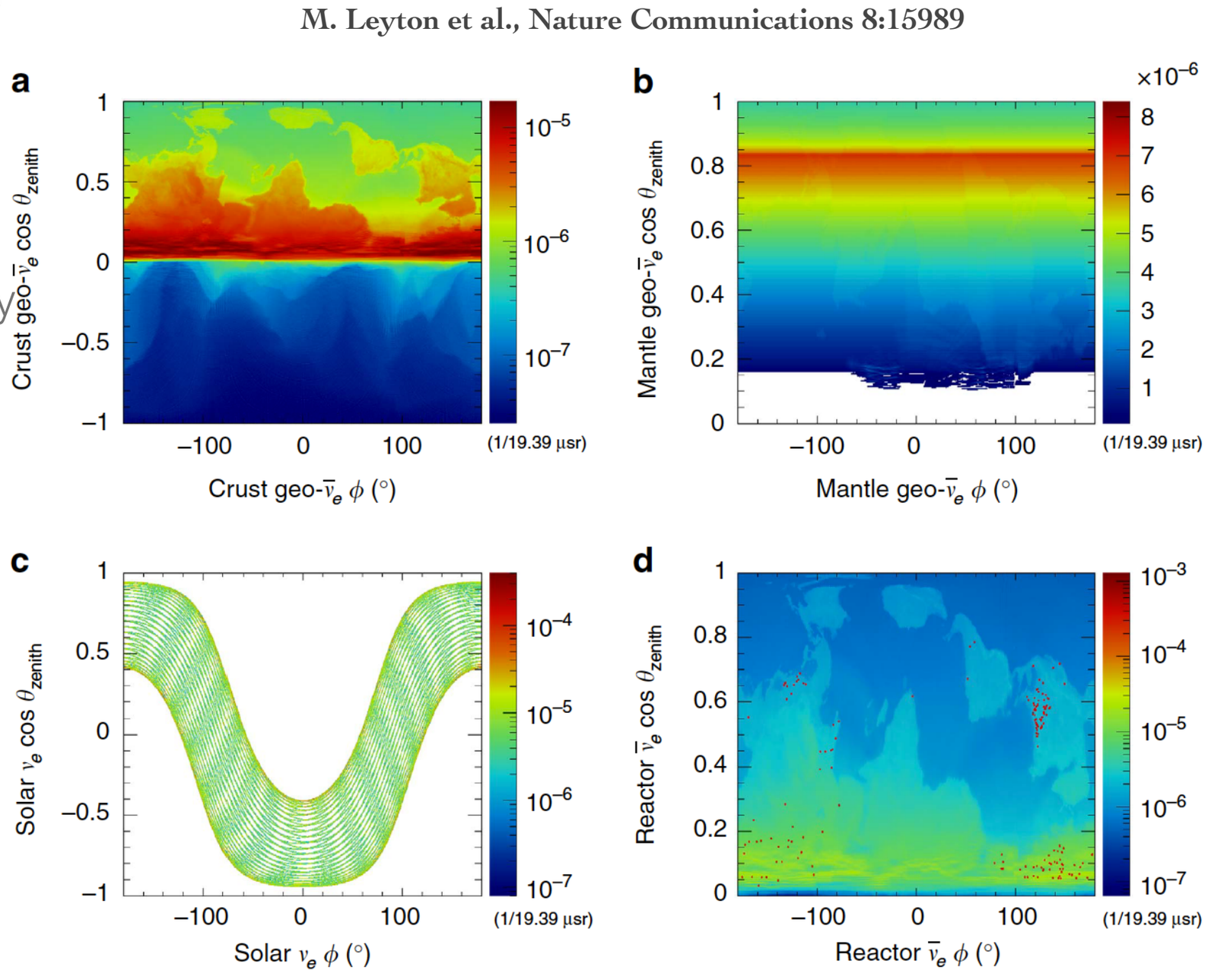
- With F recoils at 20 m from the SNS, we can expect ~ 10 events / kg / yr above 30 keV (proposed threshold for directional detection)

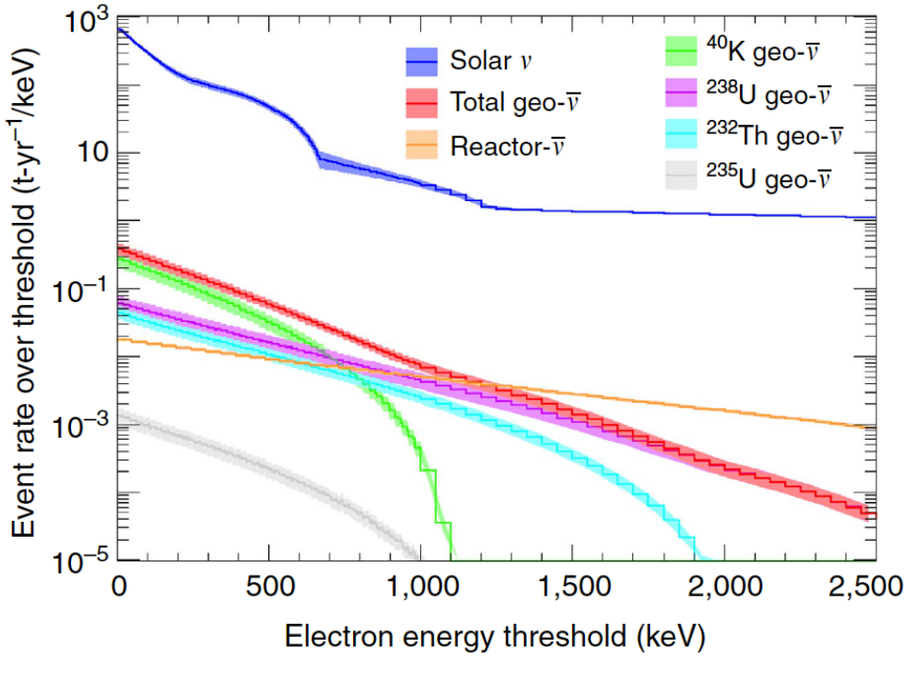
- Such a detector (at 200 torr) would be ~ 6 m^3, and ~ 1 m on a side.



Other Applications

- A ton-scale detector could also act as a neutrino telescope
- using neutrino-electron scattering (there are few anti-neutrinos at the SNS, but plenty of electron-neutrinos)





What About Existing Detectors at SNS: NaI

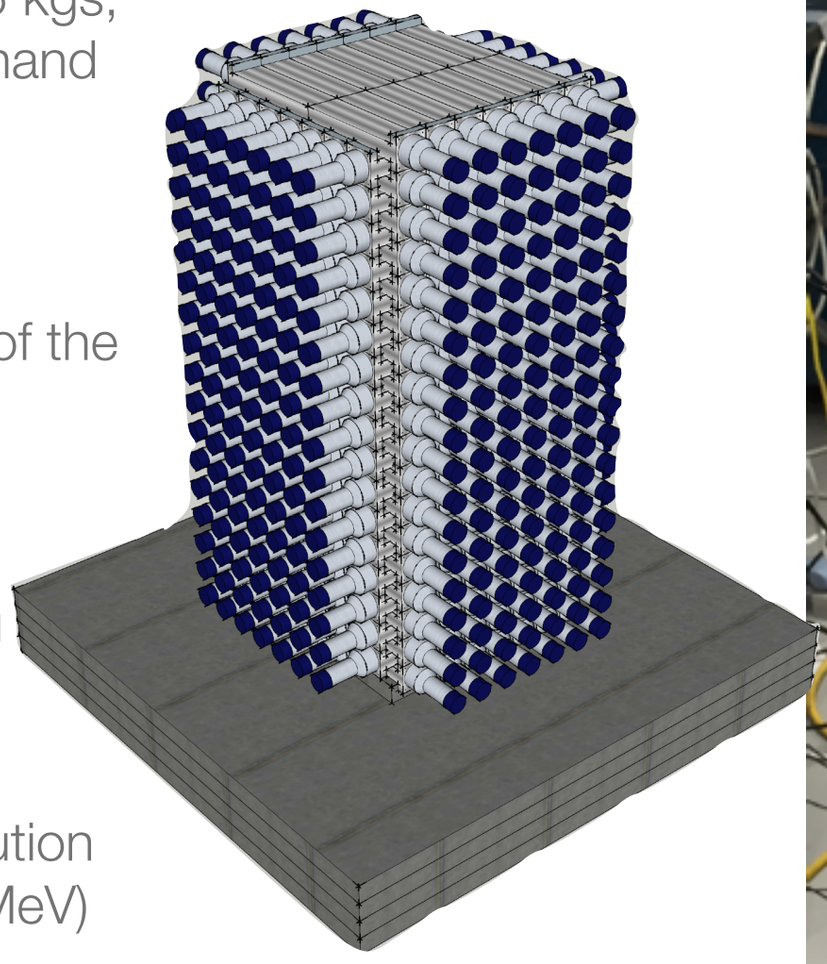
- COHERENT has deployed 185 kgs of NaI[Tl] detectors to investigate the ^{127}I CC reaction

- We expect ~ 70 events per year in 185 kgs, but we have ~ 7 tons of detectors on hand (~2500 /yr)

- As Natalie just told us, there is very interesting information in the direction of the neutrino, corresponding to the excited states.

    - But perhaps Pb is more interesting

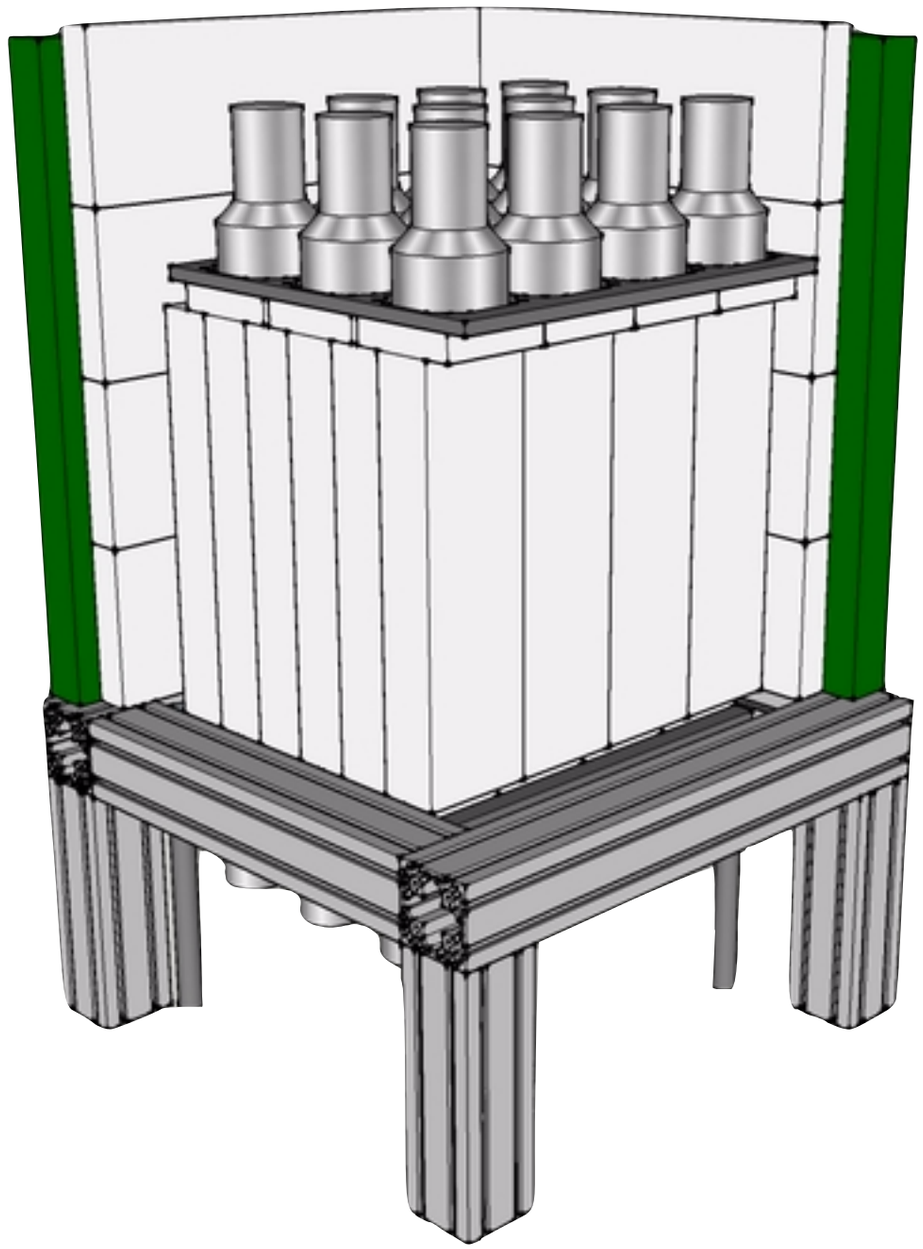
- While the granularity is not great, it is sufficient to provide ~ 30 degree resolution for the highest energy reactions (~50 MeV)



What About Existing Detectors at SNS: NaI

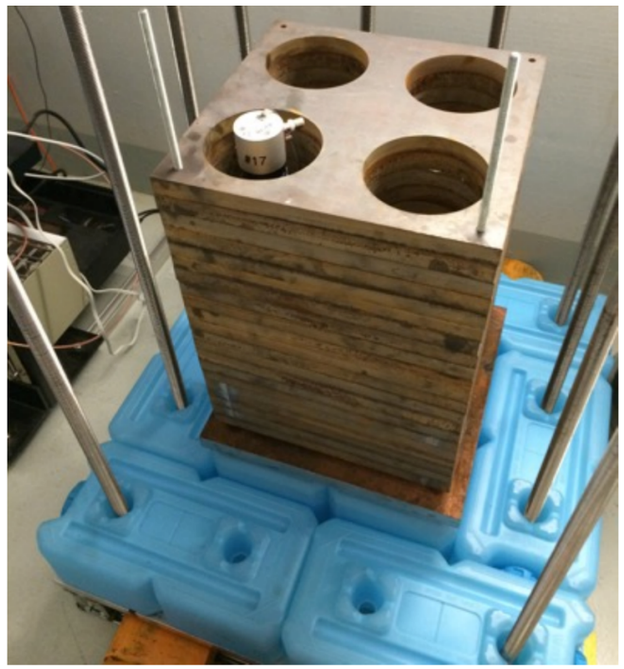
- The detector is being upgraded now, with an Fe shield & muon veto surrounding the crystals.

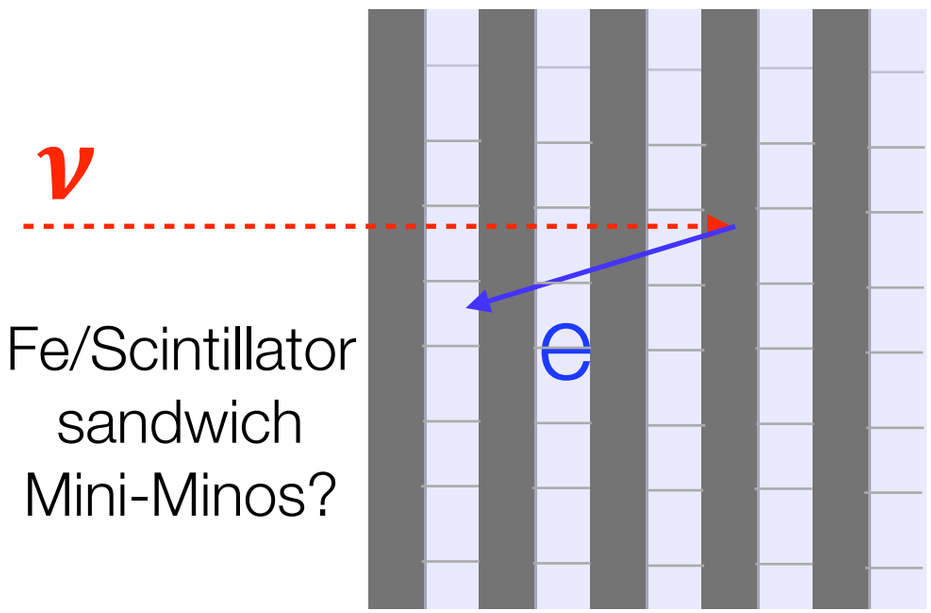
- We can expect ~ 30 events/year from neutrino-Fe CC reactions. We are looking into a forward/backward asymmetry measurement.



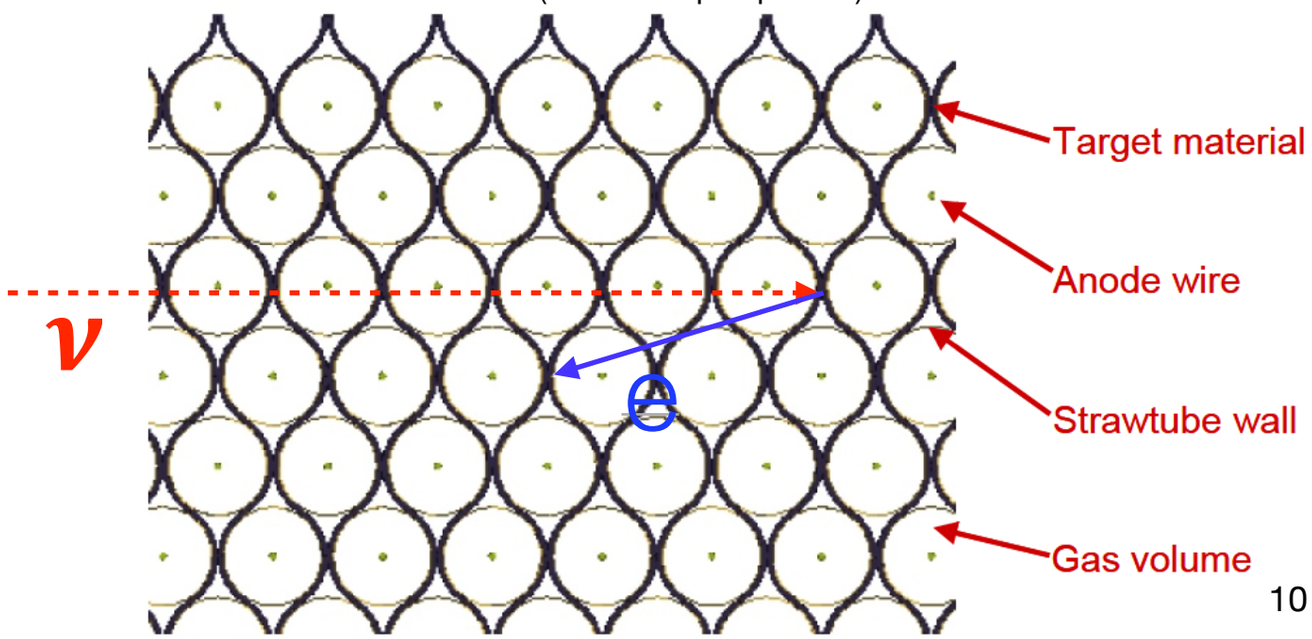
What About Existing Detectors at SNS: Pb & Fe Nubes

- Can we make the Nubes sensitive to the lepton, instead of just the emitted neutrino (answer = yes)
- But: due to the geometry of the Neutrino-cubes, we won't get directional information from any interactions
- With a better geometry, a 2 degree angular resolution could be the ultimate goal—however, there is a bit of a tradeoff between angular and energy measurement.





Straw tubes (NuSNS proposal)



The next life for the Neutrino-cubes?

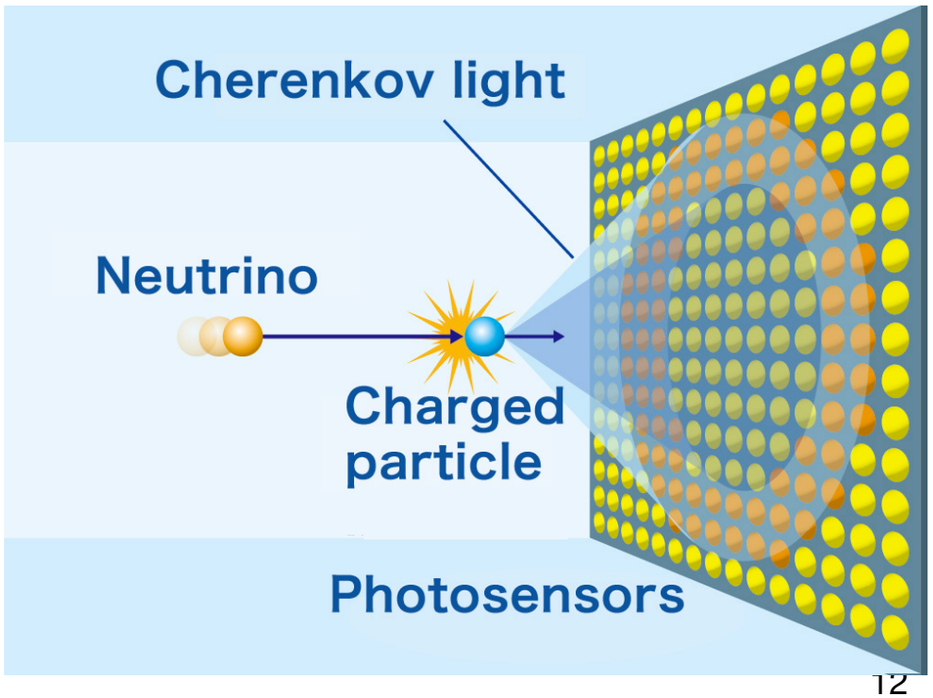
- In principle, the target (either the plates, or the metal of the straw tubes) can be interchanged…in approximate order of difficulty

Target	Expected rate in Nube-sized detector (c / T/ yr)
^{56}Fe	1000
^{208}Pb	2800
^{40}Ca	60
^{12}C	40
^{2}H	70
^{238}U	10,000

* note that contamination for other stable isotopes has to be considered

What about neutrino-electron scattering?

- Yuri talked about this on Sunday ~26 counts / T / yr @ 20m
- It's not just possible with a Cygnus style detector — what about a Ring Imaging Cherenkov Detector?
- TUNL has ~ 1T of Pb-glass that has been sitting in storage.
- But! The ^{208}Pb CC electron-producing process will be a background, though energy and directionality may be able to separate these two processes.
- Could calibrate the ^{208}Pb CC interaction w.r.t to the neutrino-electron scattering cross-section —beat current neutrino flux uncertainties.



How Much of This Can Actually Happen?

- We have now demonstrated that the SNS is actually a neutrino facility

- Moreover, some very difficult and long-awaited measurements have already been made

- Perhaps it's time to turn the volume up to 11, and try in earnest to see what kind of measurements, and how many, we can make in the next few years

"Our suggestion may be an act of hubris…" — D.Z. Freedman

"Maybe not" — P. S. Barbeau

Nigel Tufnel: What we do is, if we need that extra push over the cliff, you know what we do?
Marty DiBergi: Put [the volume] up to eleven.
Nigel Tufnel: Eleven. Exactly. One louder.
— *This Is Spinal Tap*