Neutrino Physics at the SNS and Understanding Supernova

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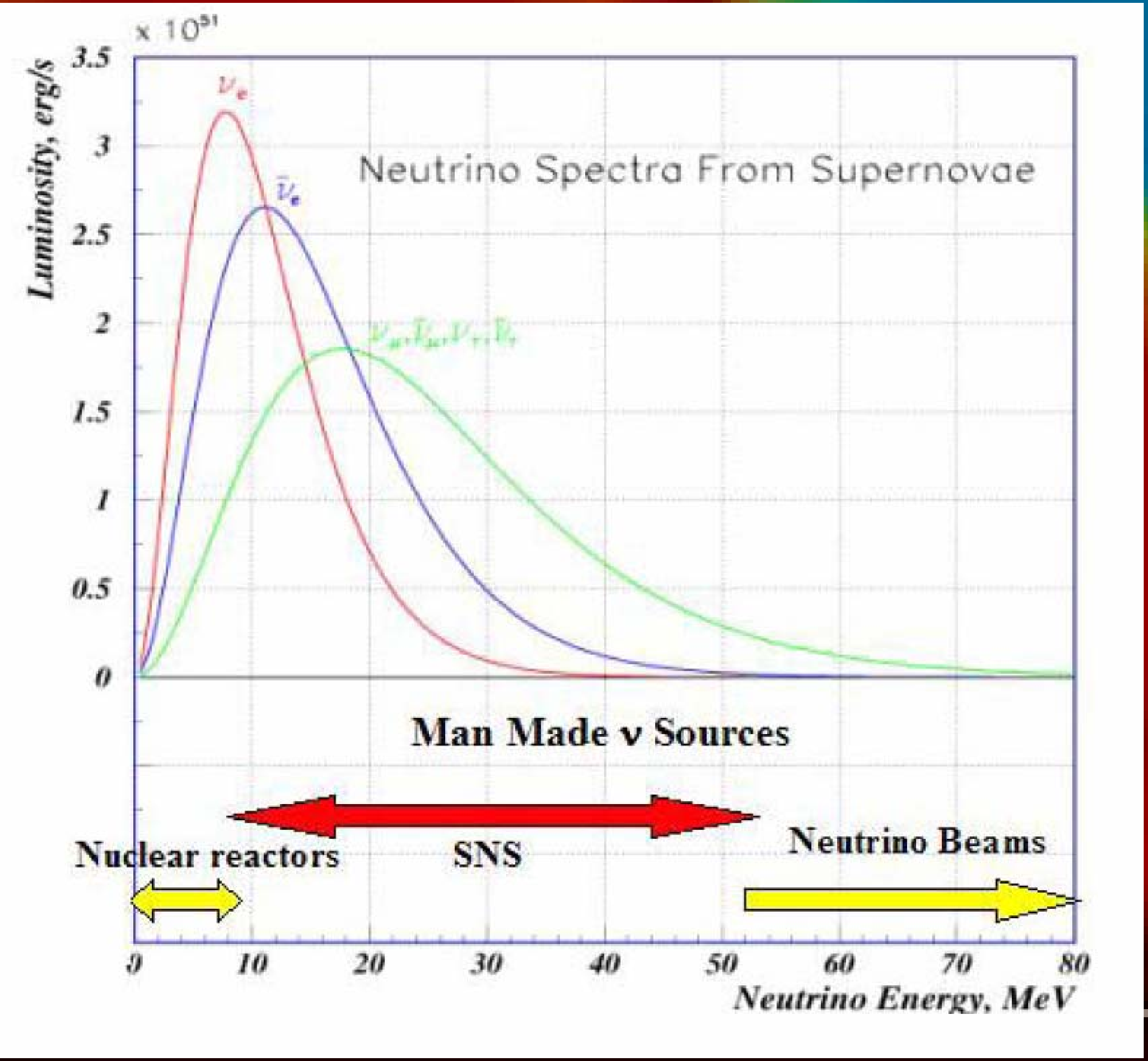
Neutrinos and Supernovae

- Explosion Dynamics
  - Core collapse cooling yields $10^{57}\nu$/s or 10^{46} $\nu/cm^2/s$
  - Core bounce shock front is believed to stall and νs are partially responsible for shock regeneration
- Heavy element nucleo-synthesis
  - Natural abundances of heavy elements such as Uranium can be explained only by a rapid neutron capture (r-) process
  - Supernova are probably the only possible site for this
  - νs play significant role by both driving the ‘wind’ of heavy elements out of the supernova, but also by interacting and transmuting the nuclei
- Terrestrial detection of supernova νs requires cross section knowledge
  - Cross sections on Pb would be very useful for example
- Neutrino-nucleus cross section knowledge plays a vital role in understanding type II supernova physics

Supernova ν Fluxes

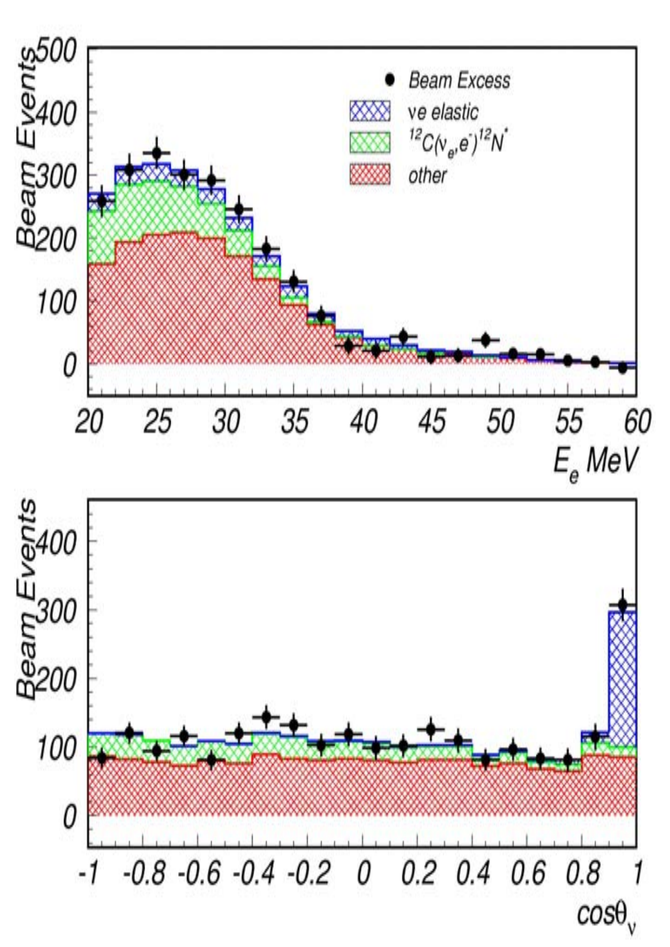
- ν_e 0-35 MeV
- $\bar{\nu}_e$ 0-40 MeV
- ν_μ, ν_τ 0-70 MeV



What has been possible?

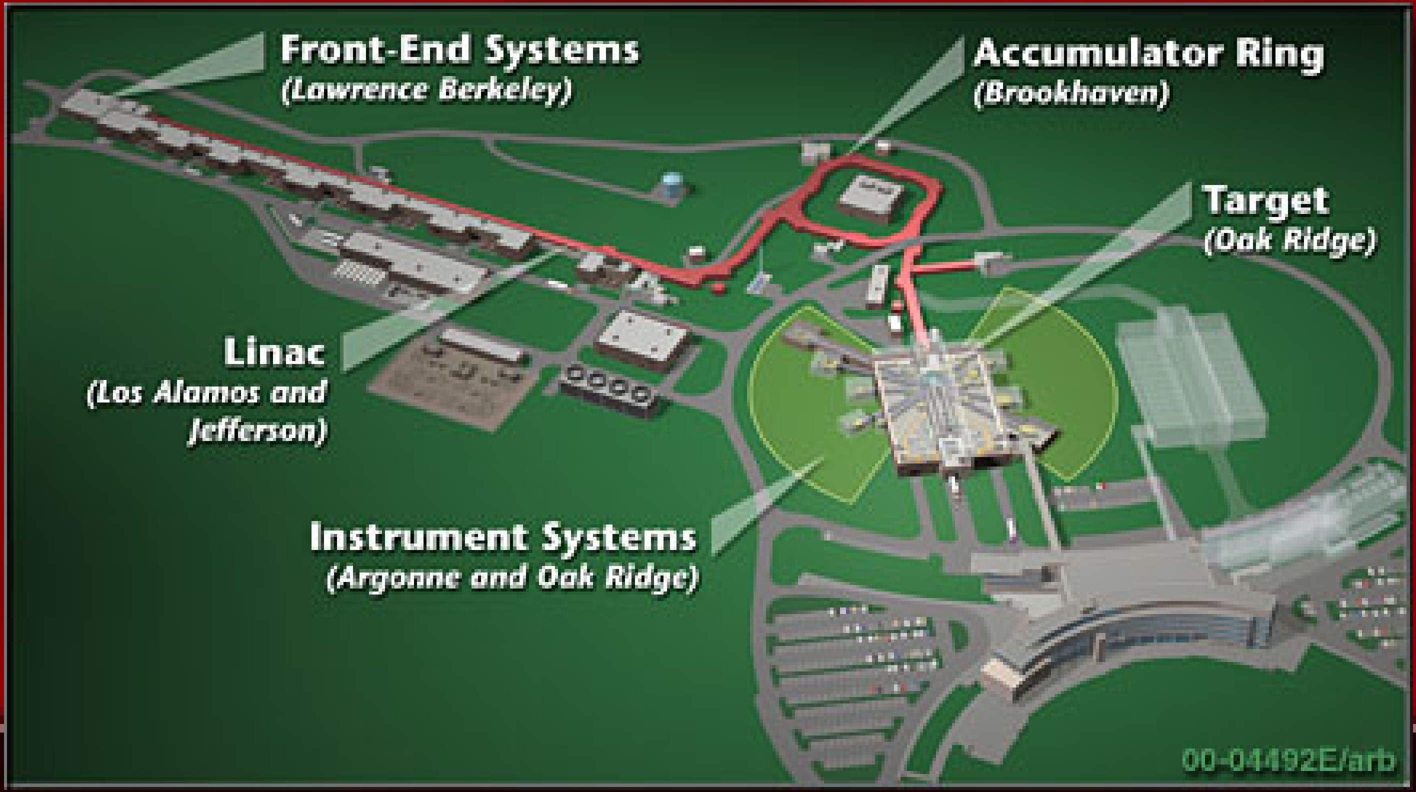
- Neutrino cross sections have been measured (poorly) on only a handful of nuclei: ^{12}C (±10%), H,Fe, I (±40%)
- Supernova calculations would significantly improve with more accurate measurements (±10%) on a wider range of materials

LSND

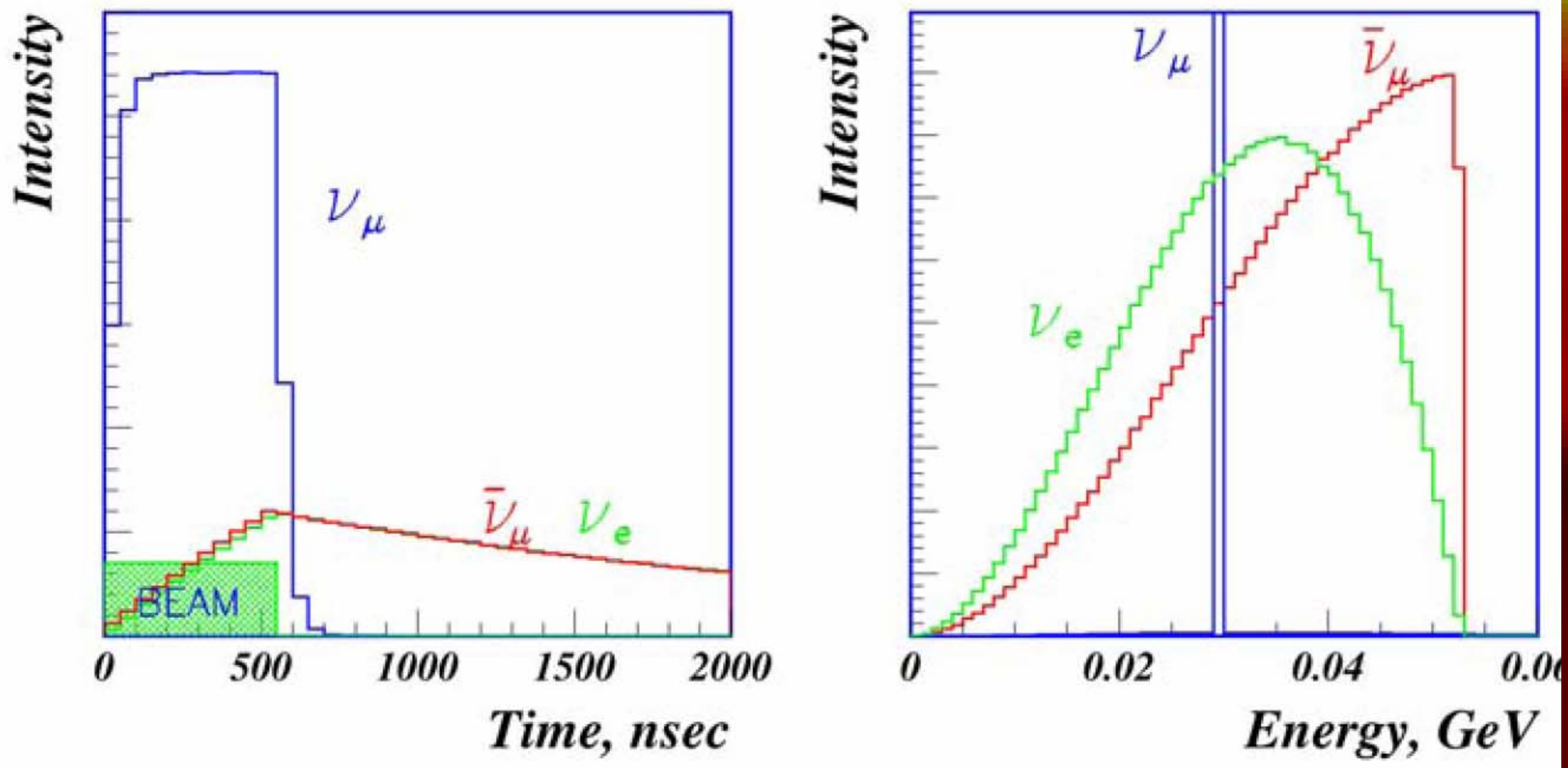


Spallation Neutron Source

- Powerful pulsed proton source
  - 1 MW proton beam power (1 mA at 1 GeV)
- Short time structure which minimizes cosmic ray background
  - 700 ns at a 60 hertz repetition rate
- Tremendous source of neutrinos (~3×10^{14} $\nu/cm^2/year$) at no cost



SNS ν Fluxes

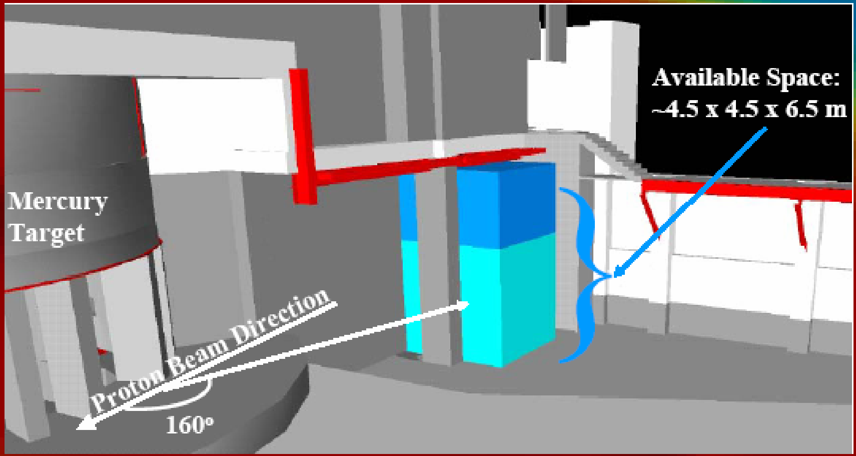


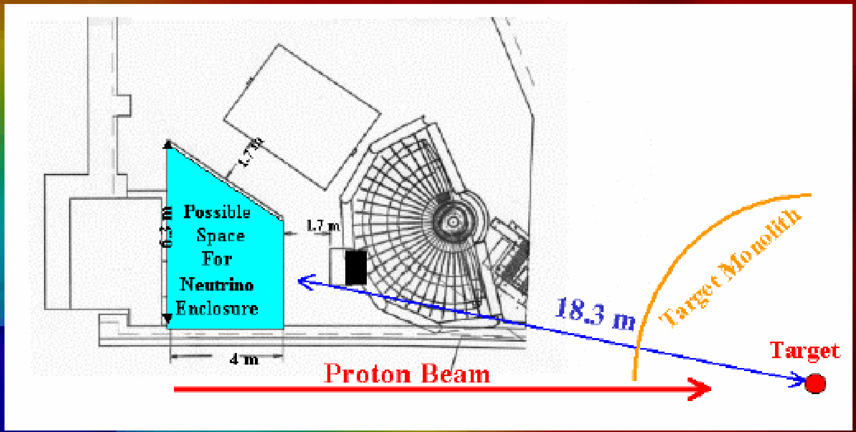
Intensity
ν_μ
ν̄_μ ν_e
BEAM
0
500
1000
1500
2000
Time, nsec
Intensity
ν_μ
ν̄_μ
ν_e
0
0.02
0.04
Energy, GeV

ν-SNS Conceptual Design

- Initially two detectors
  - Segmented detector
  - Homogenious detector

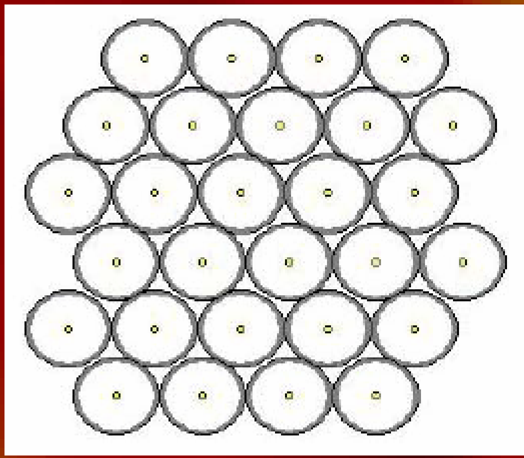
- Occupy a small alcove in the neutron target hall
  - At 18.3 meters from proton target





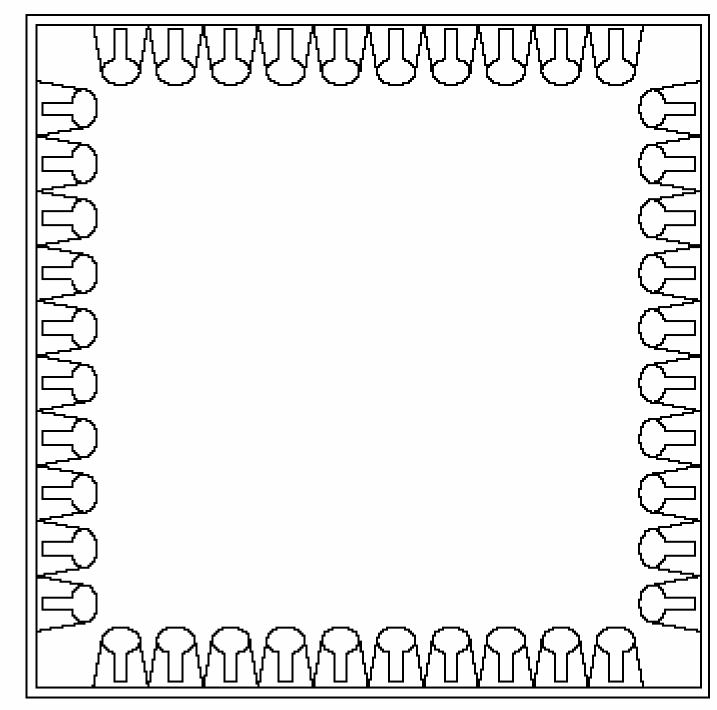
Detector I

- Highly segmented detector
  - Lead, aluminum, iron tubes easily available
  - Target material formed into tubes of ~15mm diameter and 0.75 mm wall thickness
  - Thin-walled gas proportional tubes inserted inside target material tubes for particle detection
  - A 10 ton detector of Fe (2m x 2m x 2.2m) volume with 21,000 tubes with a 40% efficiency yields ~2000 events/day



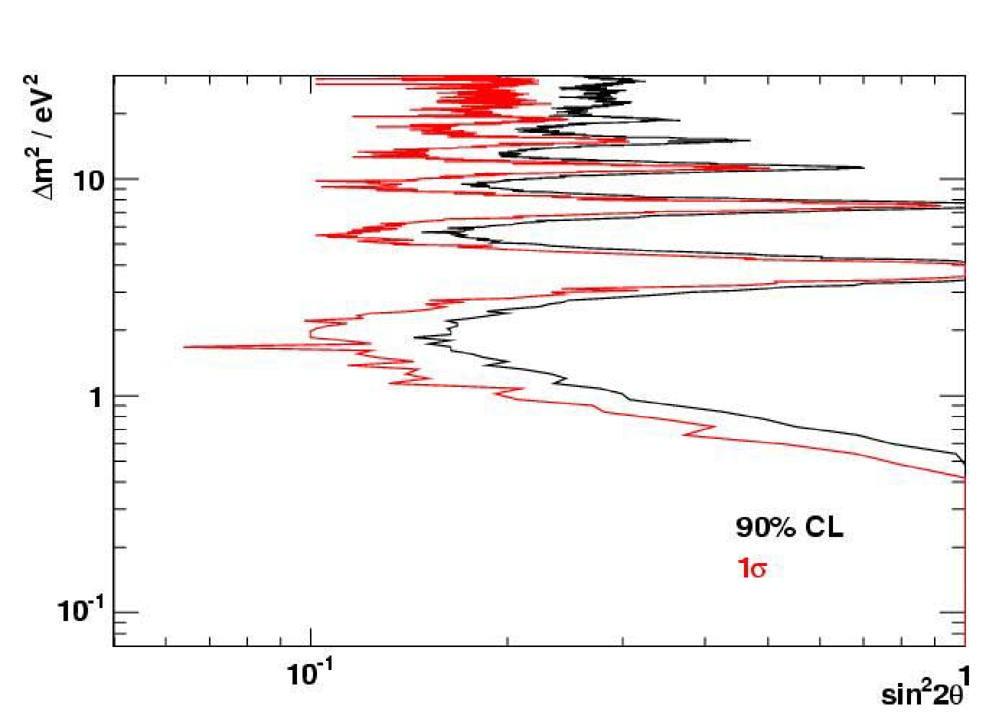
Detector II

- Liquid target detector
  - Target is liquid or in solution, e.g. ^{2}H, ^{12}C, ^{16}O, ^{127}I
  - 27 m^3 steel tank instrumented with about 300 PMT's
  - Start with liquid scintillator liquid, like LSND, since improved ^{12}C cross sections are desired
  - ν event rate ~3500 events/year (5x that of Karmen)



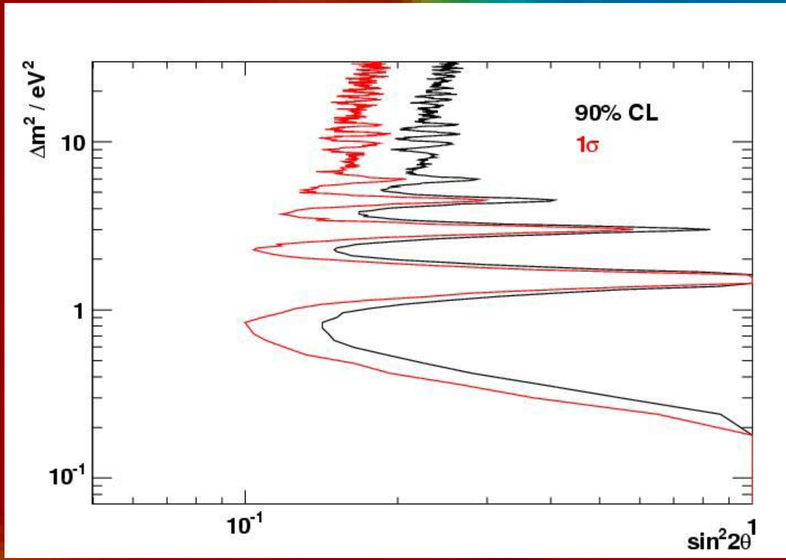
Additional Physics Goals

- Search for light sterile neutrino oscillation effects
  - Neutral current reaction:
    $^{12}C(\nu, \nu') \, ^{12}C^{*}(15.11)$
    vs charged current
    $^{12}C(\nu_e, e) \, ^{12}N(GS)$
    is sensitive to sterile neutrino oscillations



Future Extensions

- Build a larger detector 100m from source where there is space available
- Cross check on LSND result if no oscillations observed at MiniBooNE (e.g. anomolous muon decay or Lorentz/CPT violating models of neutrino oscillations



Conclusions

- SNS is a world class source of neutrinos and they are free!
- A neutrino program at the SNS would provide measurements vital to understanding supernova dynamics, nucleo-synthesis in supernovae, and future supernova neutrino detectors
- It would also provide a unique opportunity to investigate sterile neutrino oscillation effects in the 0.2-30eV^2 range.