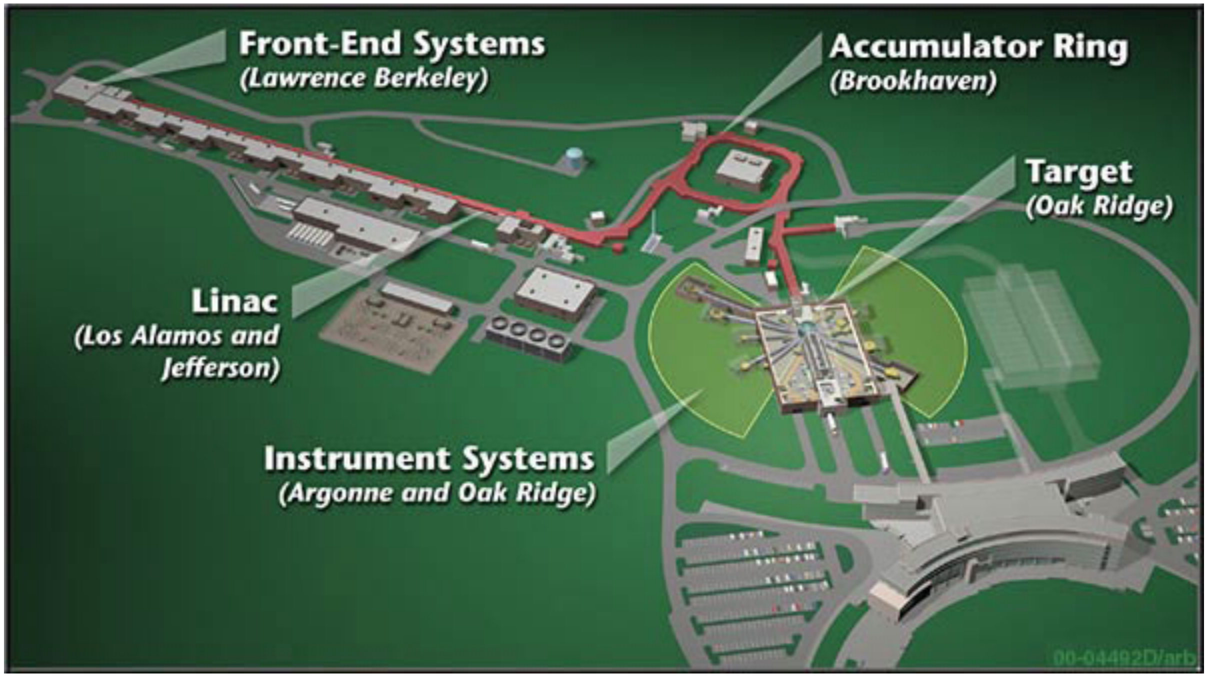
OscSNS: A Definitive Search for Sterile Neutrinos at the Δm^2 ~1 eV^2 Scale

- Introduction & Motivation
- Spallation Neutron(ino) Source
- Physics Potential
- Stopped Pion source at FNAL
- Conclusions

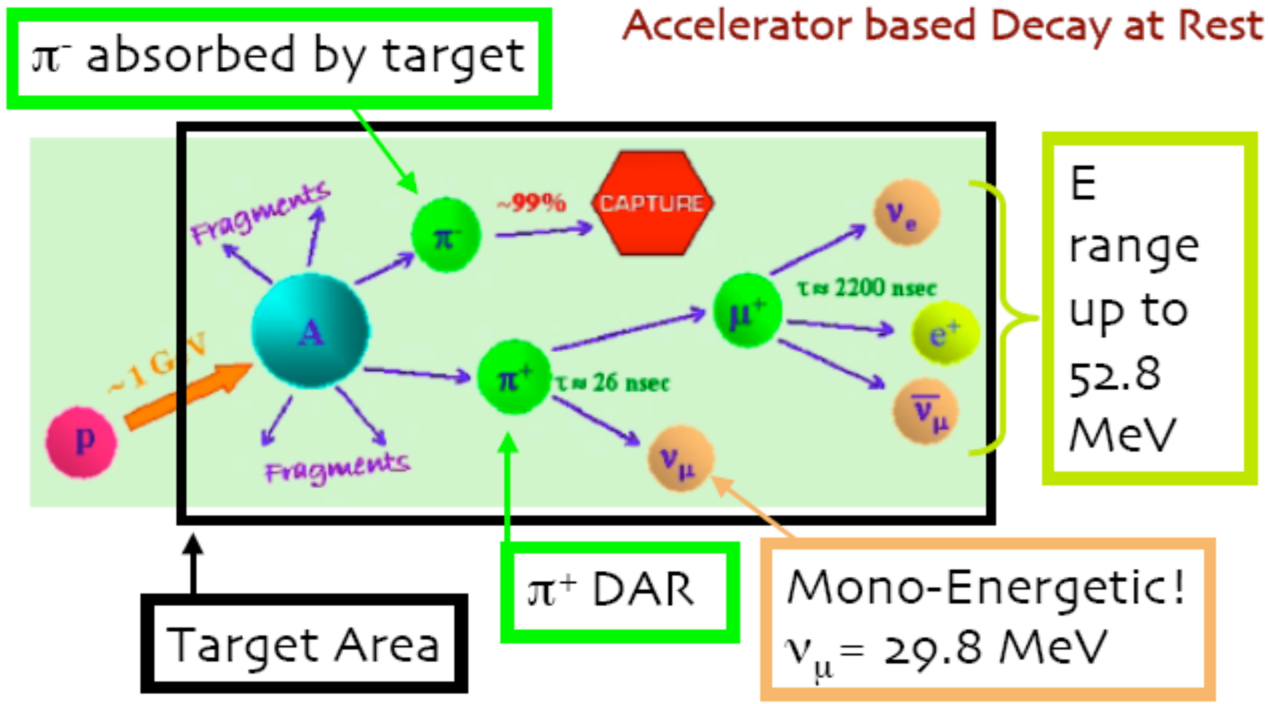


Mercury target

Spallation Neutron Source
Oak Ridge, Tennessee

- 1.3 GeV, 1.2 MWproton beam on Hg target production of spallation neutrons
- 60 Hz with 695 ns pulse length
- Neutrinos are for free!

Neutrino production at SNS



Liquid Mercury (Hg+) target

11.6% p produce π^+

$\pi^+ \rightarrow \mu^+ + \nu_\mu$ (100% π^+ decay: 99.3% DAR, 0.7% DIF)

$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$ (~100% μ^+ DAR)

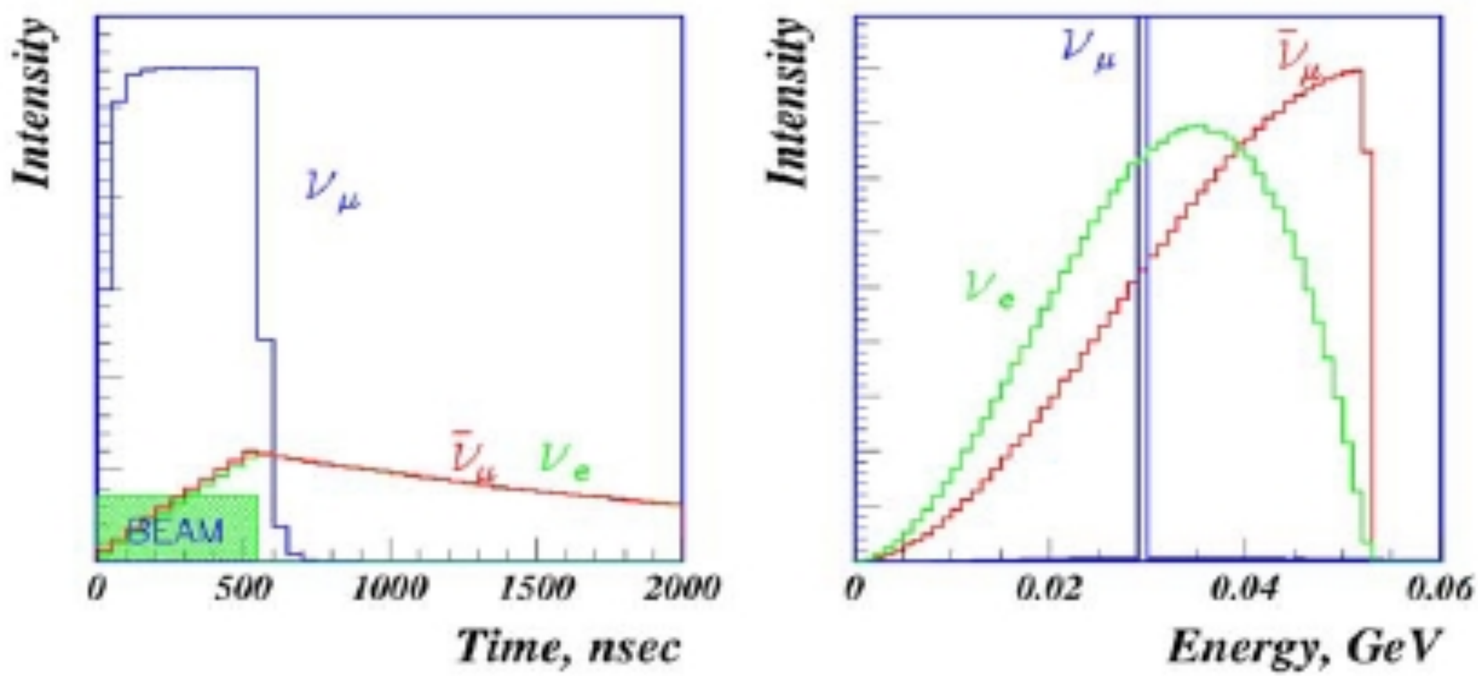
Stopped Pion/Muon Neutrino Source: Beam Time Structure and nu Flux Spectrum

- Neutrino Flux from a Stopped Pion/Muon Source:

$\pi^+ \rightarrow \mu^+ \nu_\mu, \quad \tau = 26 nsec$

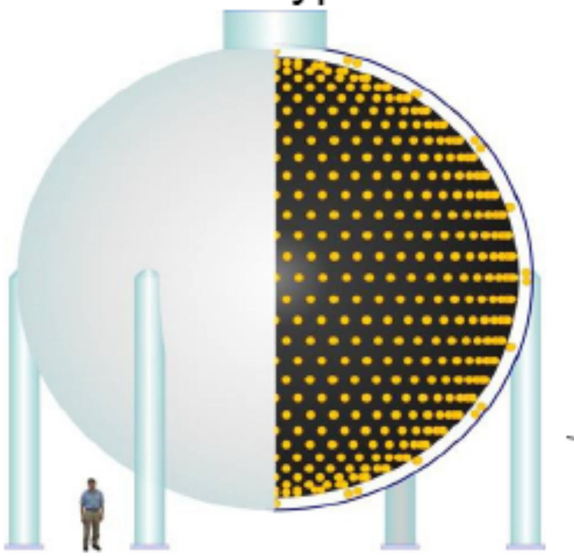
$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e, \quad \tau = 2.2 \mu sec.$

event types	$0 \rightarrow 0.695 \mu$sec	$0.695 \rightarrow 5 \mu$sec	$> 5 \mu$sec
π^+ DAR and $\pi^\pm$ DIF events	96.3%	3.7%	0
μ^+ DAR and oscillation candidates	14.3%	73.6%	12.1%



Neutrino Detection:

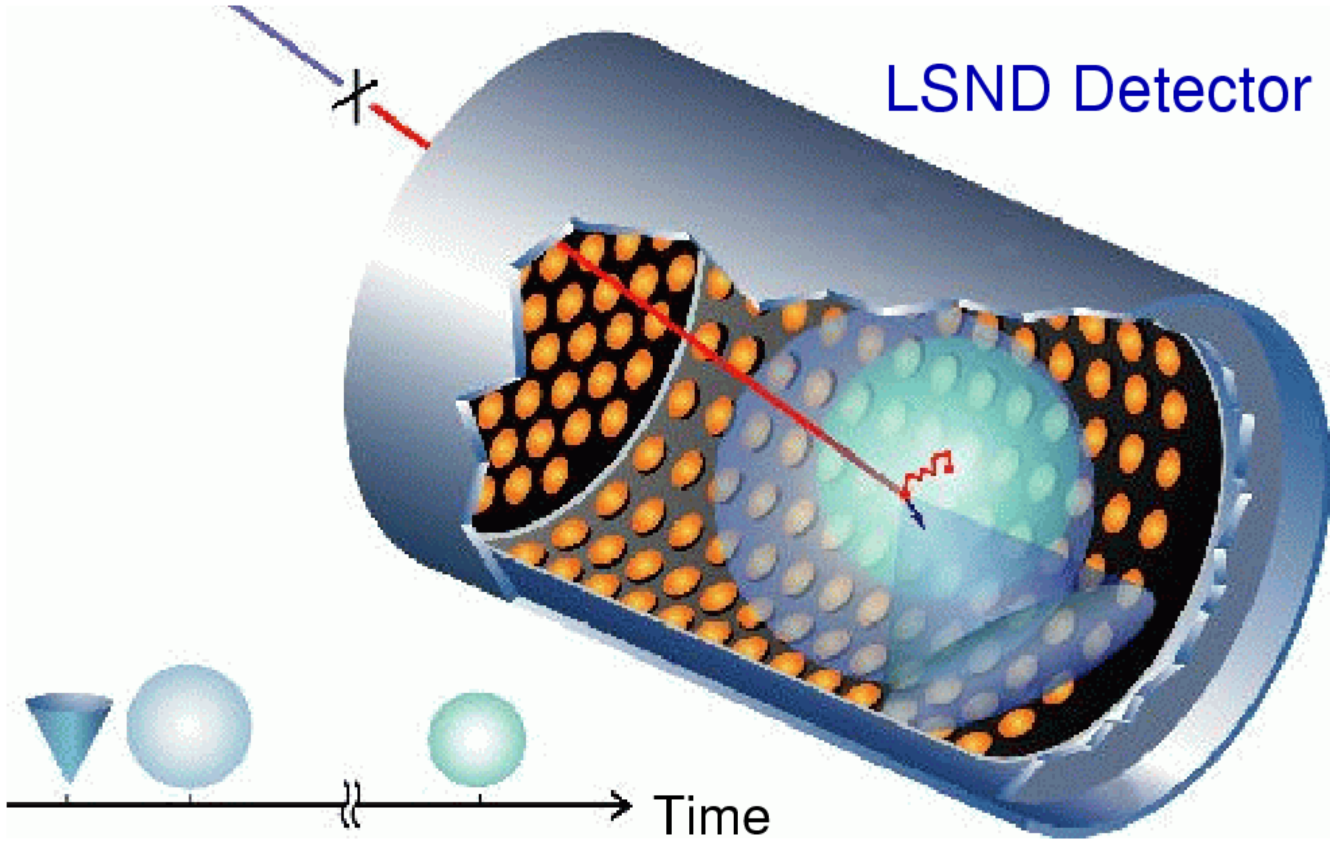
~$8M



- 60 m upstream from the Hg target;
- 12-m diameter sphere (fiducial = 10 m);
- filled with 800 t of mineral oil CH_2(fiducial = 450 t) + ~30 kg of butyl-PBD scintillator;
- 3502 phototubes: 3262 in detector (25% coverage) and 240 in veto region;
- buried under 10 ft of dirt – to suppress cosmic rays and beam-induced neutrons.
- Currently no ideal location for near detector due to space constraints, closest spot is ~20m

The Liquid Scintillator Neutrino Detector Concept

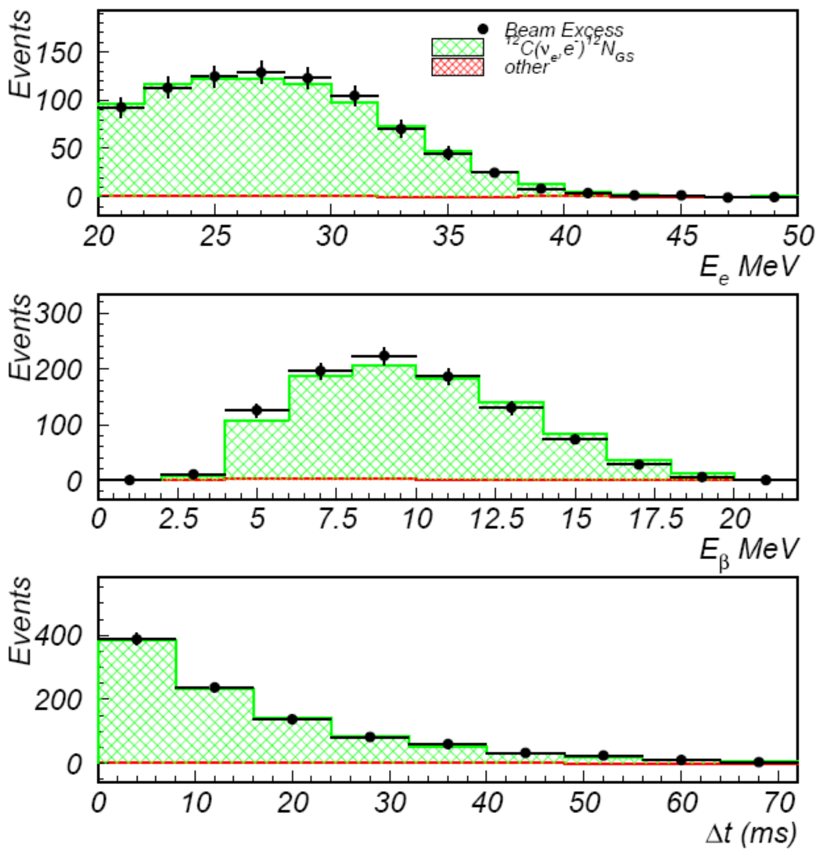
- Prompt Cherenkov light
- Delayed scintillation light
- Good electron ID, event timing, and spatial reconstruction



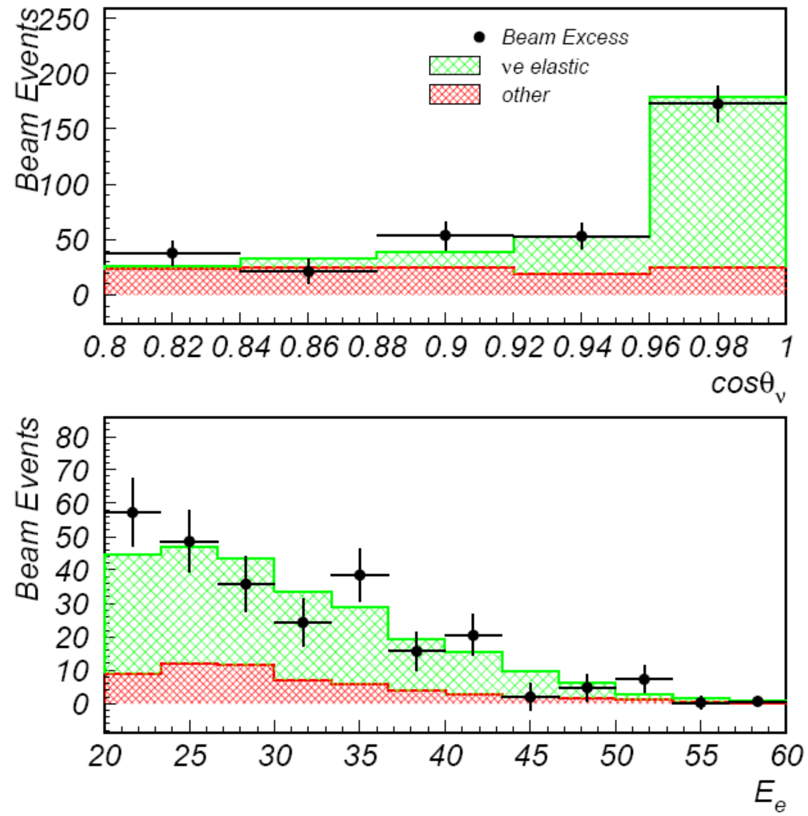
Detector calibration

- Many cosmic ray stopped muon decays
- 16N source: [16O(n, p)16N] producing a -tagged 6.1 MeV gamma-ray.
- 8Li source: electron energy spectrum up to 15 MeV.
- pT source: [3(p,)4He] producing a 19.8 MeV gamma-ray.
- 252Cf source: producing fission neutrons.

LSND Cross Sections



N12 ground state CC electrons



νe elastic electrons

OscSNS can repeat the LSND measurements with much higher precision and lower backgrounds plus additional measurements:

$\nu_\mu \rightarrow \nu_e$ appearance ($\nu_e\ ^{12}C \rightarrow e^-\ ^{12}N_{gs} + \beta$)

$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ appearance ($\bar{\nu}_e\ p \rightarrow e^+\ n + \gamma$)

ν_μ disappearance & search for sterile ν

($\nu_\mu\ ^{12}C \rightarrow \nu_\mu\ C^* + \gamma$) (~1300 events per year)

$\nu e \rightarrow \nu e$ elastic scattering (~1700 ev. per year)

νC cross sections (~4600 events per year)

OscSNS Advantages Over Other Neutrino Oscillation Experiments

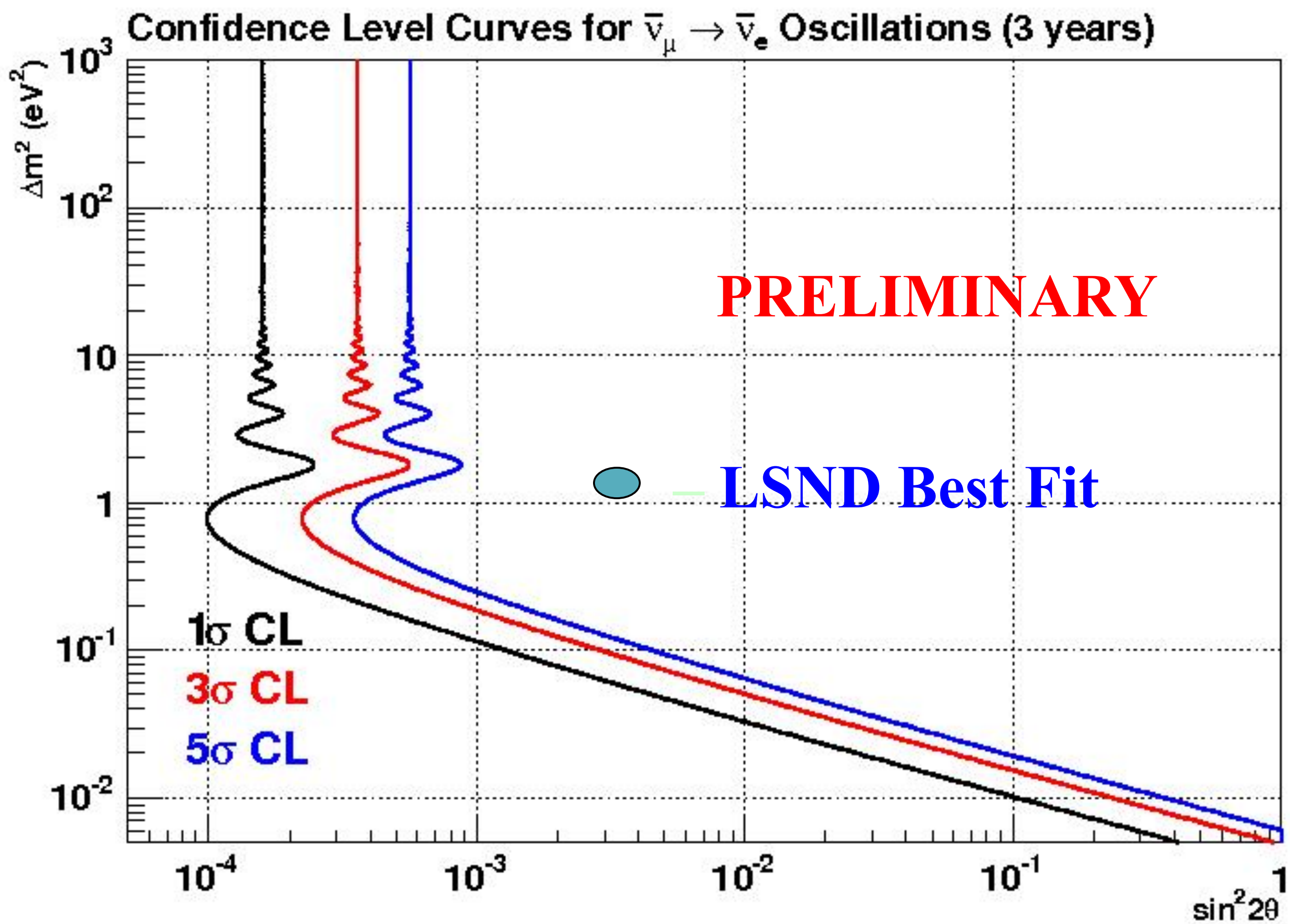
- Well understood ν flux (~7%, maybe better)
- Well understood ν flux spectrum
- Well understood ν cross sections (1-2%)
- Low duty factor and good timing
- Absence of nuclear effects that can affect energy reconstruction
- Very low backgrounds (< 0.1%)
- Beam comes for free from the SNS
- SNS runs more than ½ the year

OscSNS $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ Experiment vs LSND

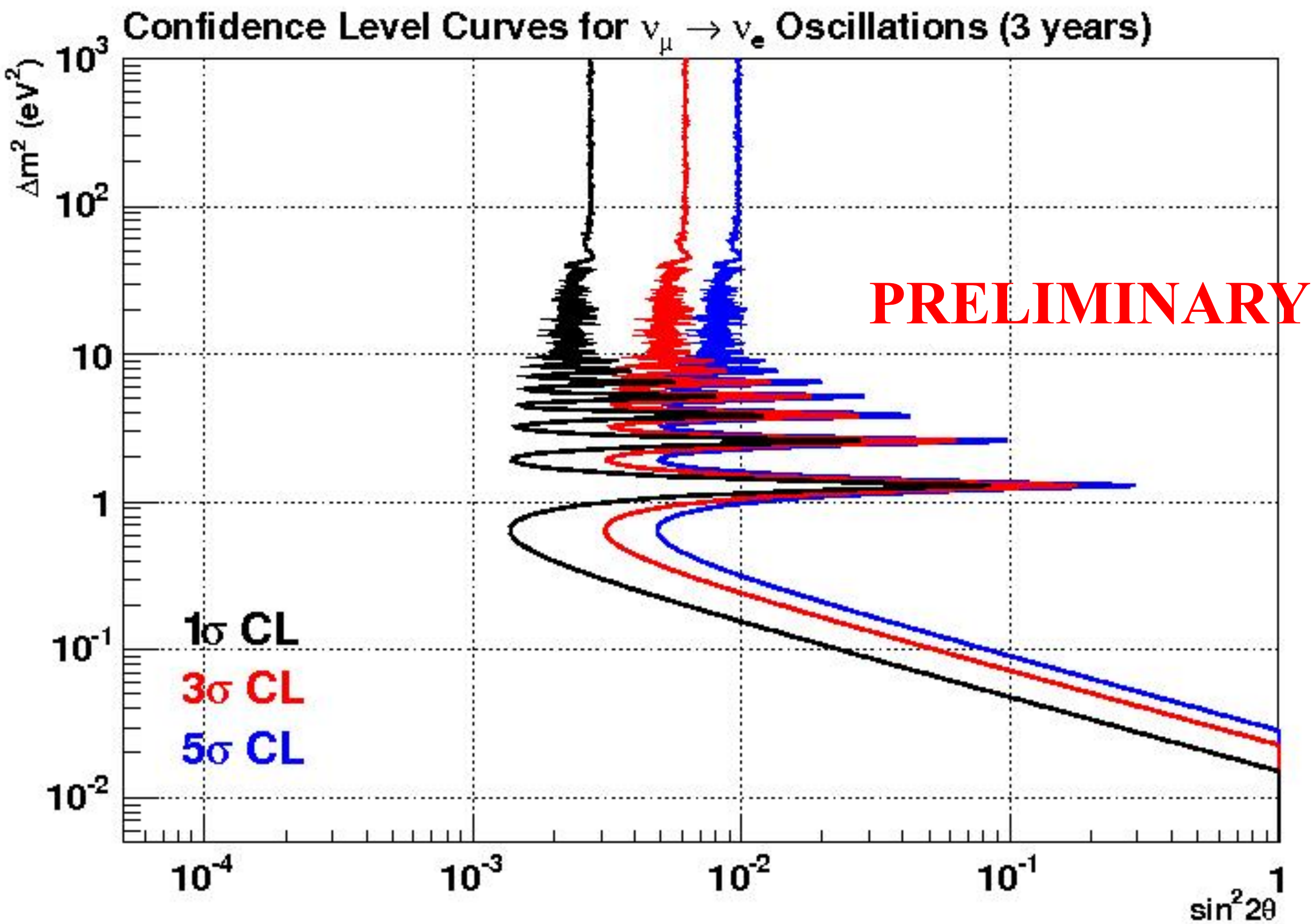
(assuming $\Delta m^2 < 1$ eV^2)

- More Detector Mass (x5)
- Higher Intensity Neutrino Source (x2)
- Lower Duty Factor (x100) (less cosmic background)
- No DIF Background (backward direction)
- Lower Neutrino Background (x4) (60m vs 30m)
- Better Signal/Background (x4)
- For LSND parameters, expect ~350 ν_e oscillation events & <50 background events per year!

OscSNS Oscillation Sensitivities



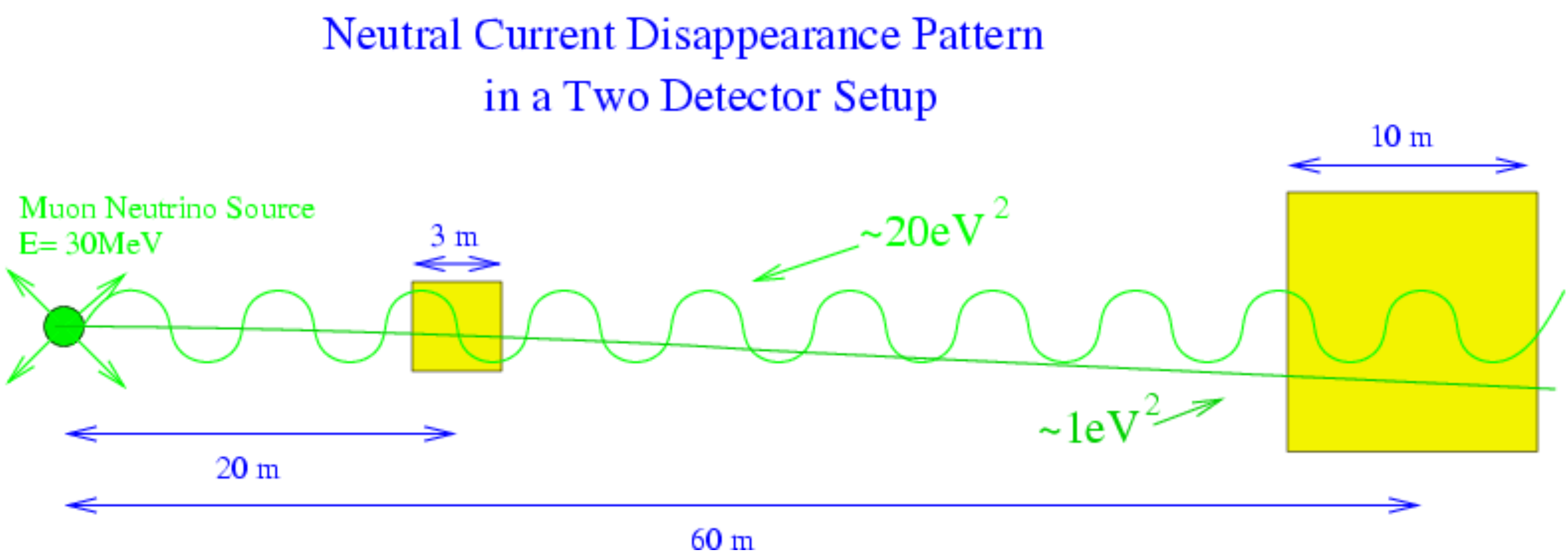
OscSNS Oscillation Sensitivities



A Smoking Gun Search for Sterile Neutrinos Via Measurement of NC Reaction:

ν_μ C -> ν_μ C*(15.11)

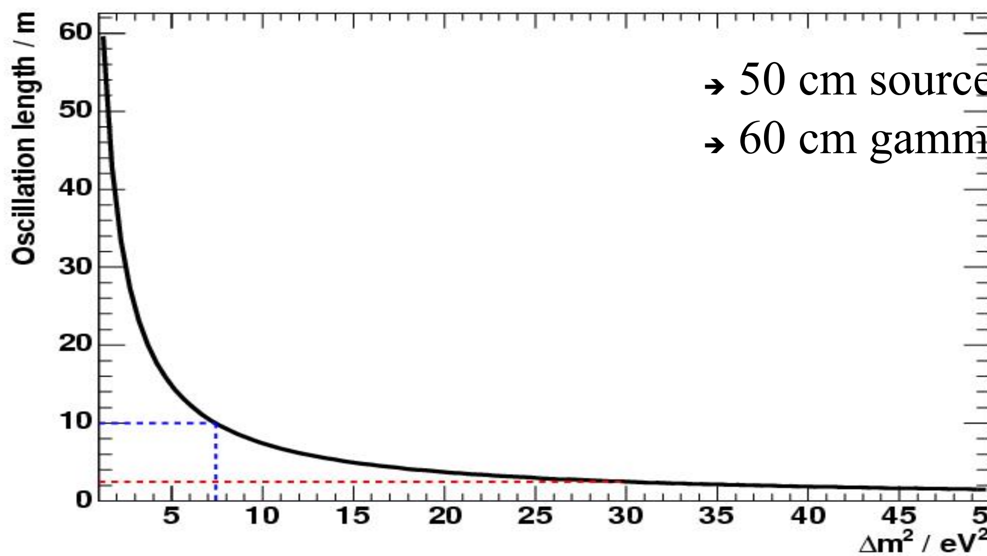
Garvey et al., Phys. Rev. D72 (2005) 092001



Active-Sterile Neutrino Oscillations with Stopped Pions (hep-hp/0501013)

- If LSND oscillations is $\nu_\mu \rightarrow \nu_s \rightarrow \nu_e$, then we expect $P(\nu_\mu \rightarrow \nu_s) > 0.10$
- Can detect all neutrinos via NC reaction, $\nu_x\,^{12}C \rightarrow \nu_x\,^{12}C^*(15.11 MeV)$.
- Since we have monoenergetic ν_μ source, then look for NC rate distortion as a function of L.

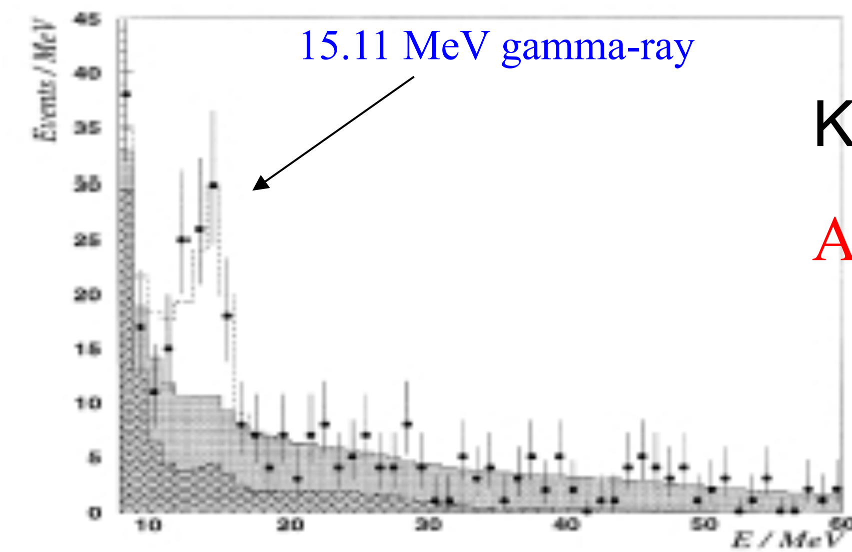
$$P(\nu_\mu \rightarrow \nu_\mu) = 1 - sin^2(2\theta)\sin^2(\frac{1.27}{30}\delta m^2 L)$$



- 50 cm source size
- 60 cm gamma Compton scattering.

Sterile Neutrino Oscillations with $\nu_\mu\,^{12}C \rightarrow \nu_\mu\,^{12}C^*(15.11 MeV)$

- KARMEN measures $\sigma = (3.2 \pm 0.6) \times 10^{-42}\ cm^2$



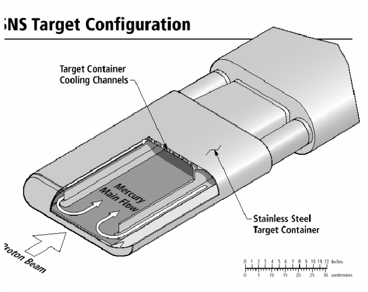
KARMEN gamma $\sigma(E) \sim 2\%$

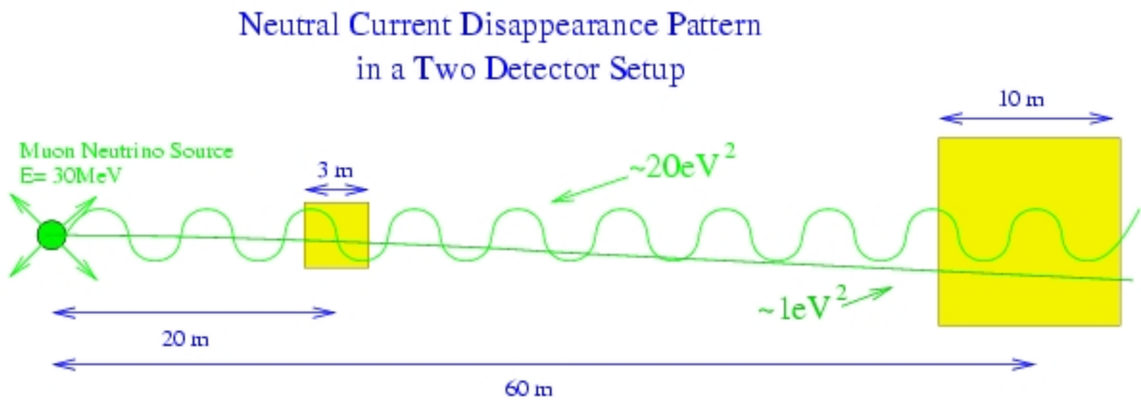
At SNS design for $\sigma(E) \sim 4$ to 7%

- Expected Backgrounds from NC $\bar{\nu}_\mu$ and CC ν_e, can be measured from beam off/out of time.

Sterile Neutrino Oscillations with $\nu_\mu\,^{12}C \rightarrow \nu_\nu\,^{12}C^*(15.11 MeV)$

SNS source L=50 cm

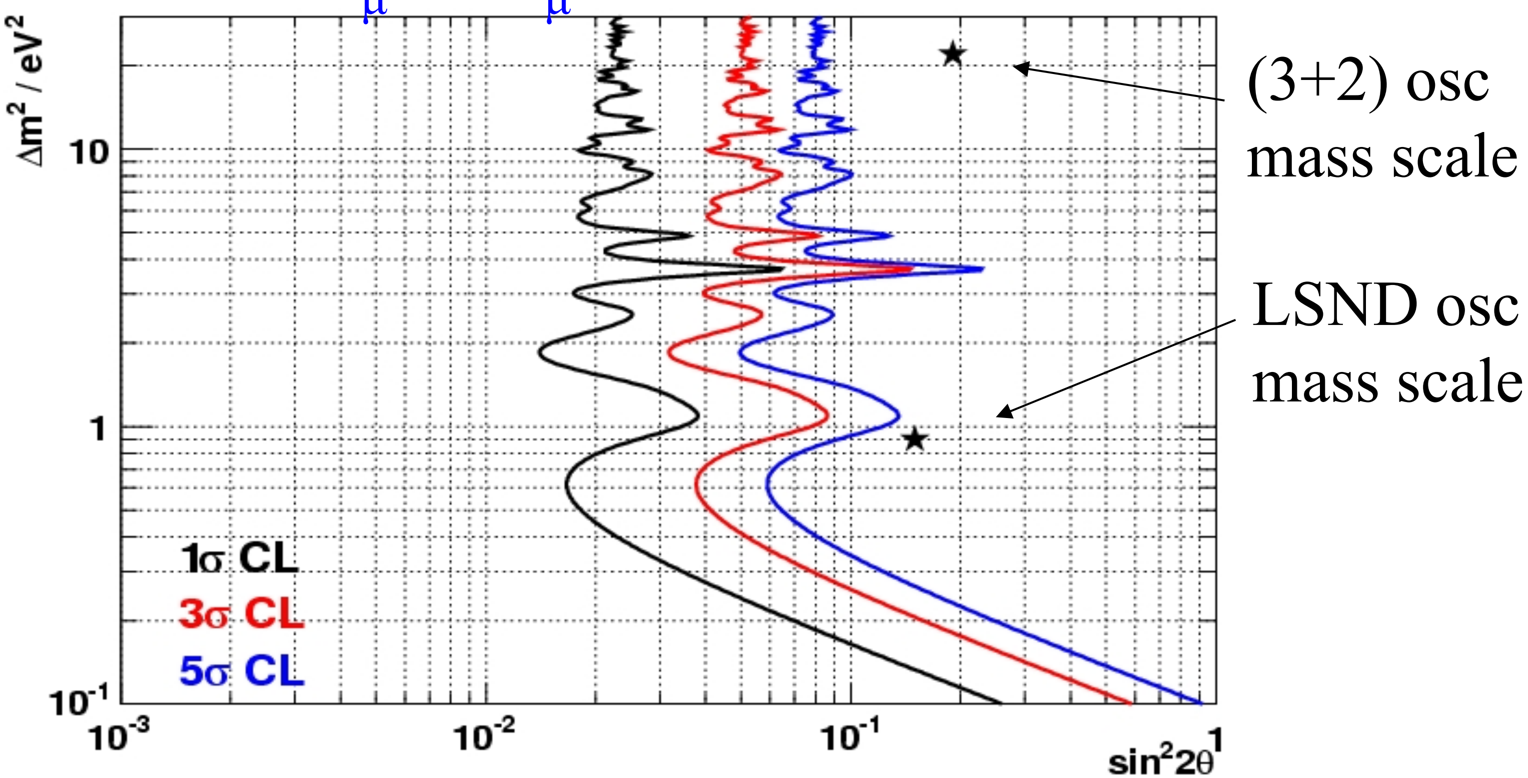




Detector	Source Dist. (m)	FD Size (tons)	FD Length (m)	$\nu_x\,^{12}C \rightarrow \nu_x\,^{12}C^*$ events/year
SNS Near	18	25	3	2056
SNS Far	60	500	10	3702

Sterile Neutrino Oscillations Sensitivity with SNS Source and Two Detectors (3 years), 5% flux+xsec systematic error.

$\nu_\mu \rightarrow \nu_\mu$ Oscillations



Stopped Pion Source at FNAL

- MiniBooNE target are is a source of stopped pions! Calculated ν_μ fluxes (Steve Brice):
  - LSND at 30m: 1.2×10^6 $\nu/cm^2/s$ (detector 167 tons)
  - KARMEN at 17m: 1.6×10^6 $\nu/cm^2/s$ (detector 56 tons)
  - OscSNS at 60m: 1.2×10^6 $\nu/cm^2/s$ (proposed detector 1kton)
  - BNB at 15m: 0.7×10^6 $\nu/cm^2/s$
- However, MiniBooNE source very extended ~5m, and at higher energy there are Kaons (background or source?)
- Can build a dedicated target Hall on the BNB, take advantage of higher POT with Project X.

Conclusions

- A stopped pion beam provides a source of neutrinos with a well characterized flux (flavor, magnitude, and energy) and interaction cross sections.
- Using the stopped pion source at SNS could provide definitive (>5sigma) evidence that LSND observed an excess of $\bar{\nu}_e$ events in a $\bar{\nu}_\mu$ beam which could be interpreted as oscillations at the ~1eV2.
  - Two detector would prove if this was oscillations.
- A stopped pion source (SNS/BNB) with short duty cycle and two detectors could provide definitive evidence of sterile neutrino oscillations at the ~1eV^2 scale.