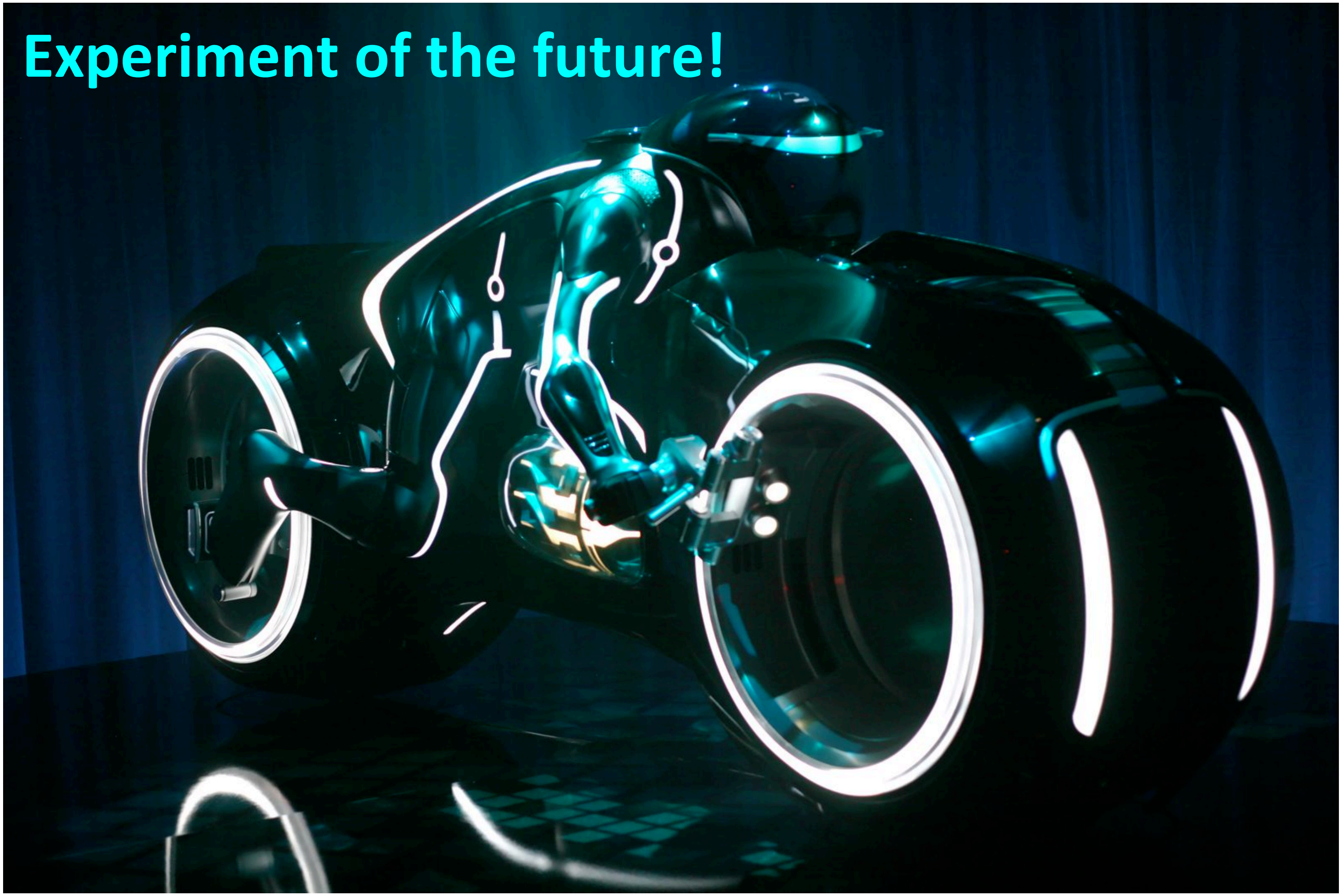
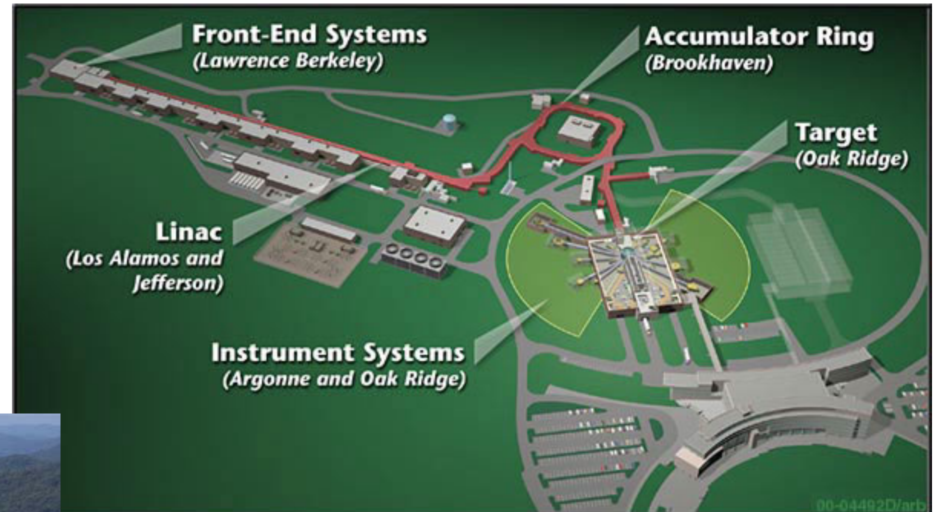
OscSNS



Oak Ridge Laboratory

Spallation Neutron Source

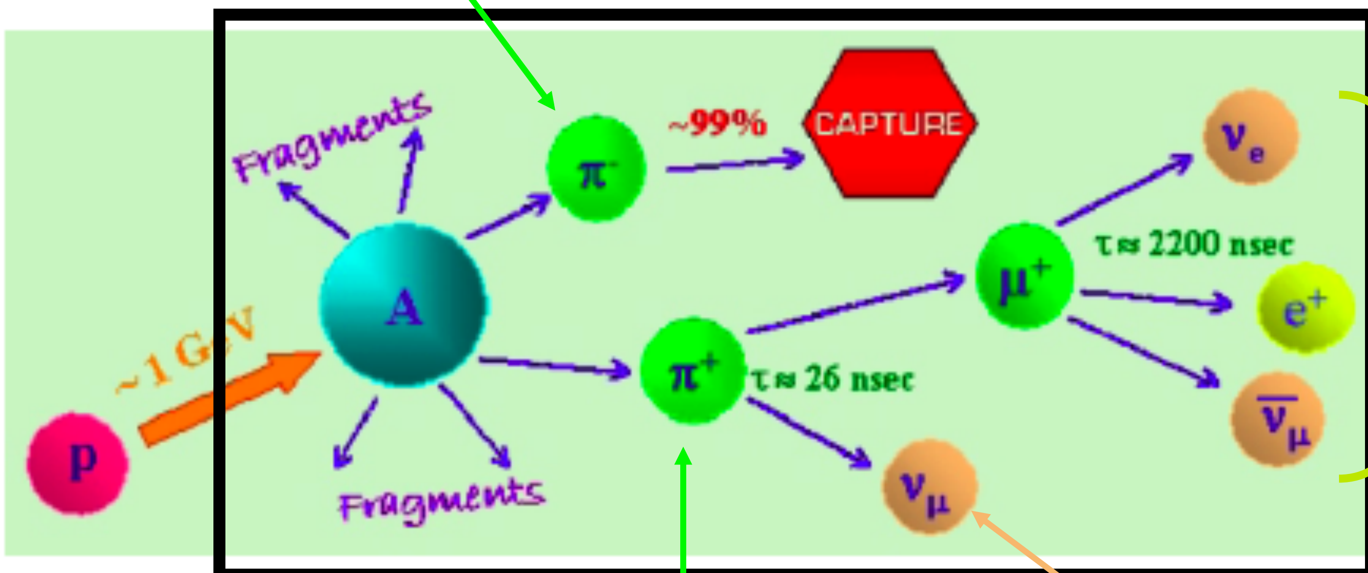


Accelerator based neutron source in Oak Ridge, TN

Spallation Neutron Source

Accelerator based Decay at Rest

π^- absorbed by target



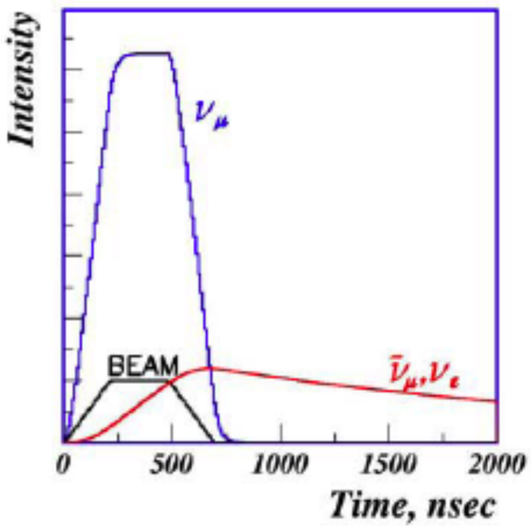
E range up to 52.8 MeV

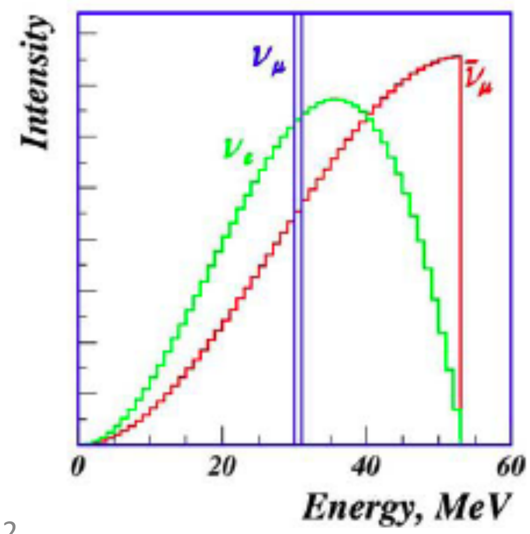
Target Area

π^+ DAR

Mono-Energetic!
ν_μ = 29.8 MeV

Decay At Rest Source





- 700 ns wide pulses
- Frequency of 60 Hz

- Advantage = Know timing of beam, lifetime of particles, use to greatly suppress cosmic ray background, isolate ~pure mono-energetic ν_μ sample

- Advantage = extremely well defined flux

Decay At Rest Source

- Potential disadvantage = Low E limits choices of neutrino interactions
- Potential disadvantage = Beam is isotropic - no directionality
  - Hard to make an intense ν beam
  - Locate detector near source to increase event rates

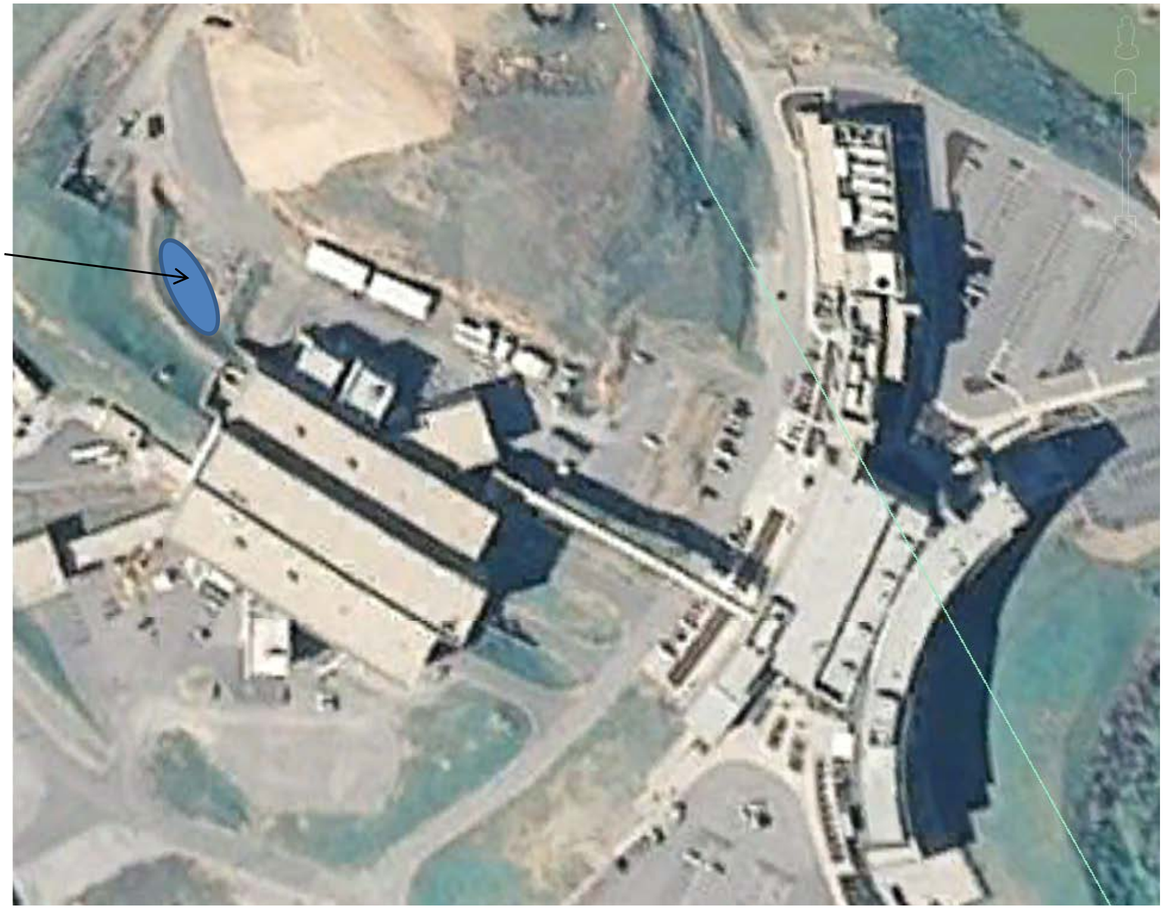
Decay At Rest Source

- Potential disadvantage = Low E limi… choices of neutrino inte… tions
- Potential di…
  di…
  - Hard …
  - … ent rates

Not issues for OscSNS!

OscSNS Location

Assumed detector location



Centered 60m upstream of the beam dump/target - removes DIF bgd

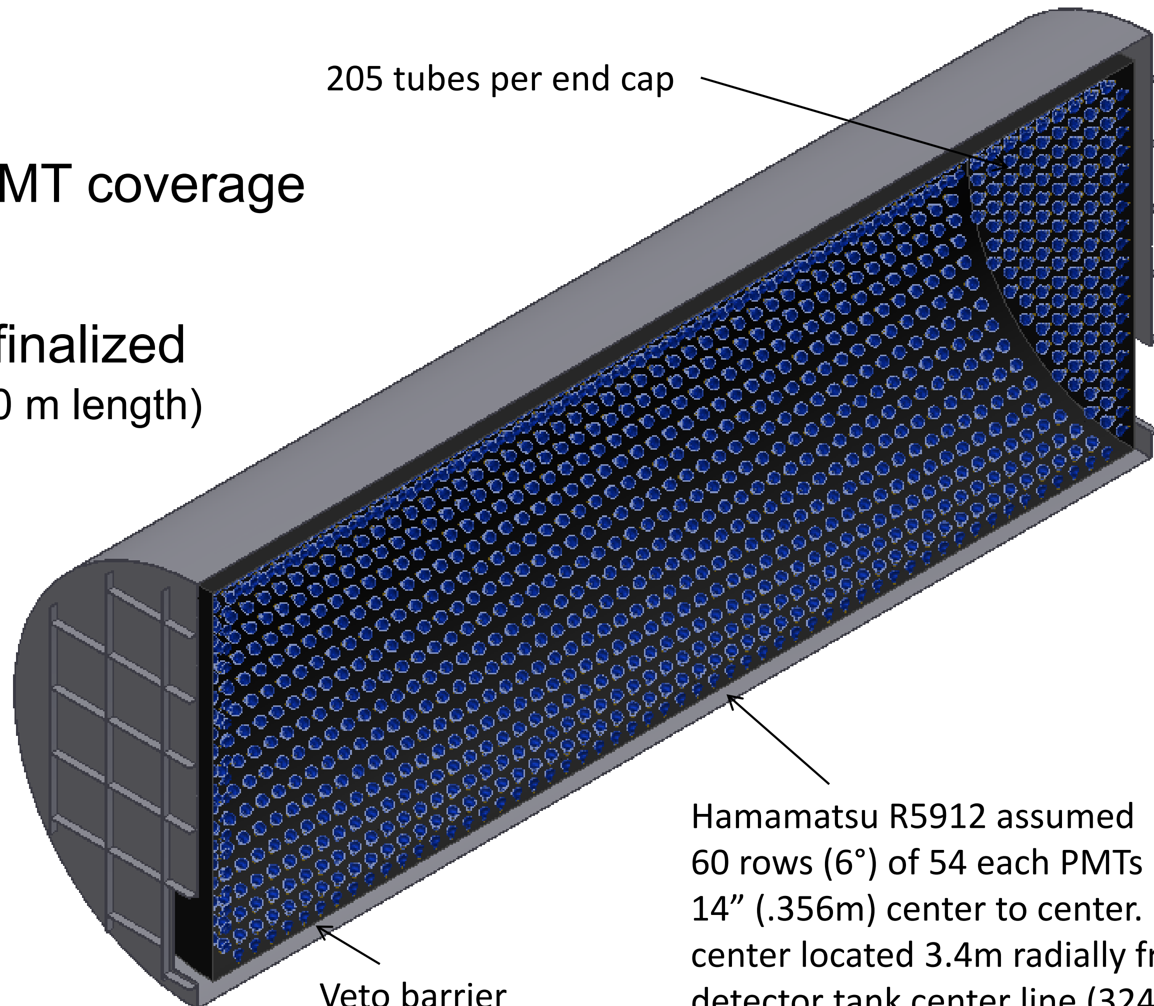
Beam Parameters

- Full beam power: 1.4 MW, 1.3 GeV protons
- 10^{14} protons per pulse
- 700 ns wide pulses
- Frequency of 60 Hz

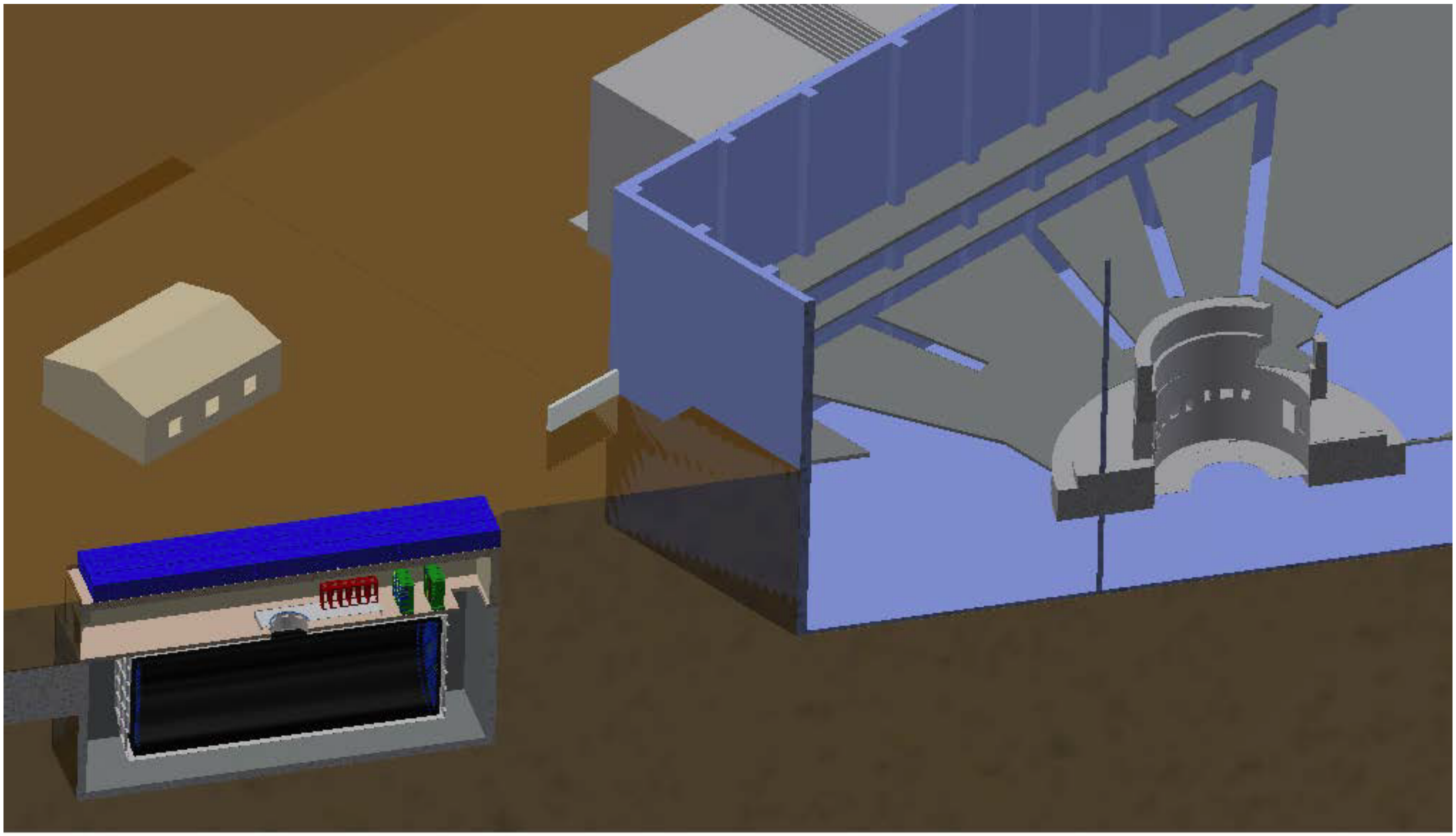
- At 60 meters from the target, expect a total neutrino flux of ~1.6e14 ν/year/cm^2

OscSNS Detector

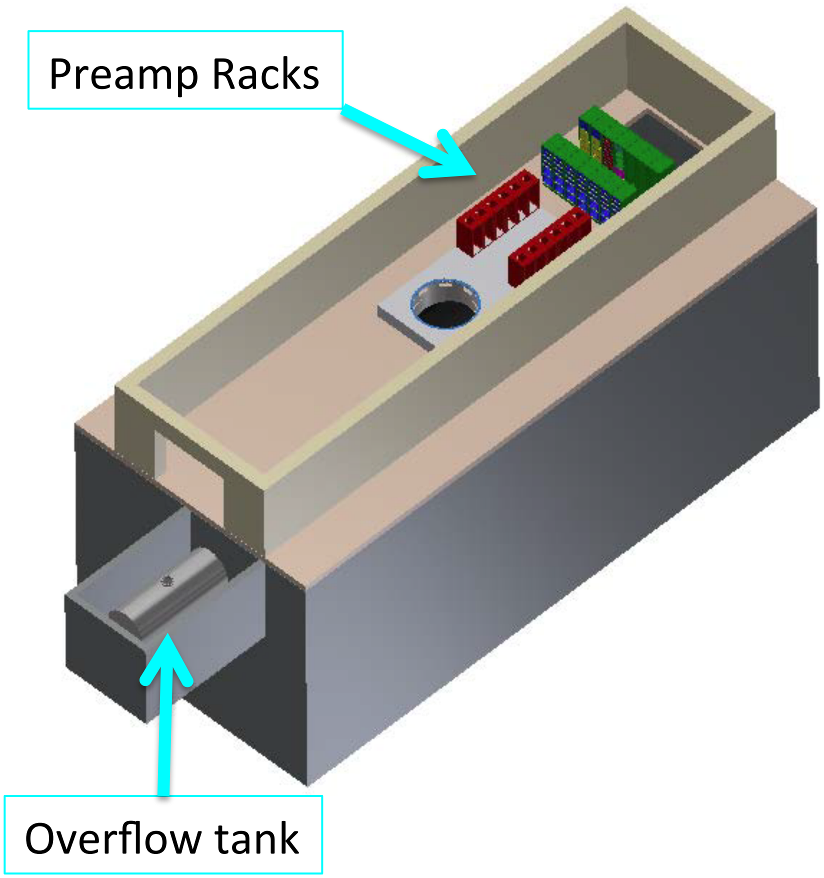
- ~800 tons, 25% PMT coverage
- Design still being finalized
  - 8 m diameter (x 20 m length)
  - LS (+Gd?)
  - +b-PBD?

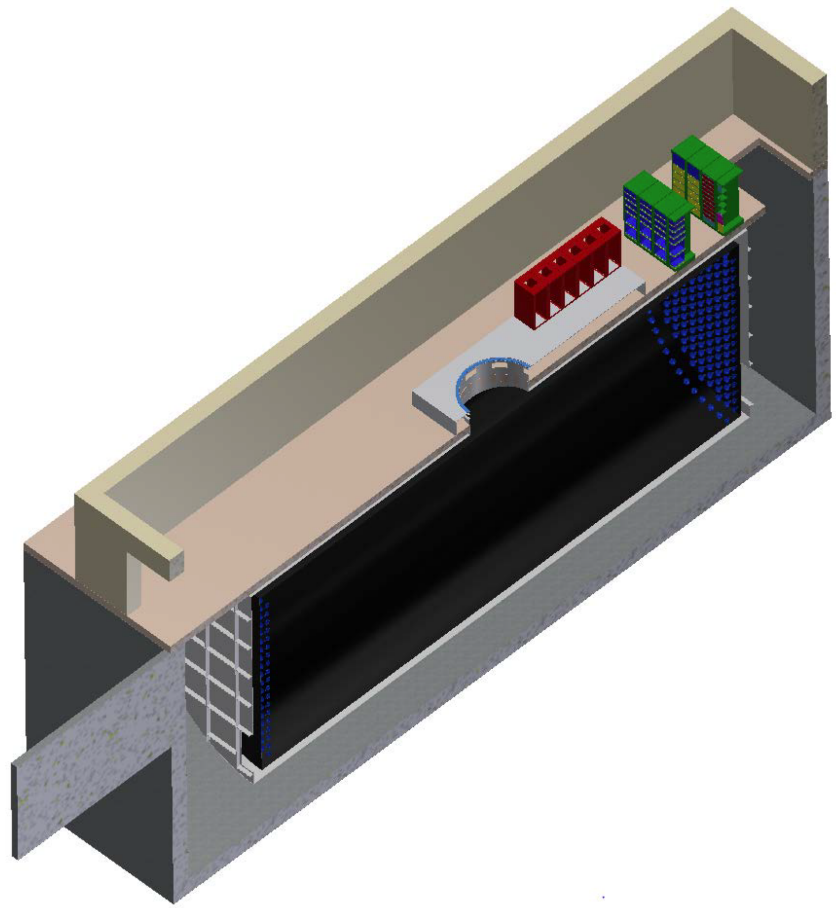


OscSNS Detector



OscSNS Detector



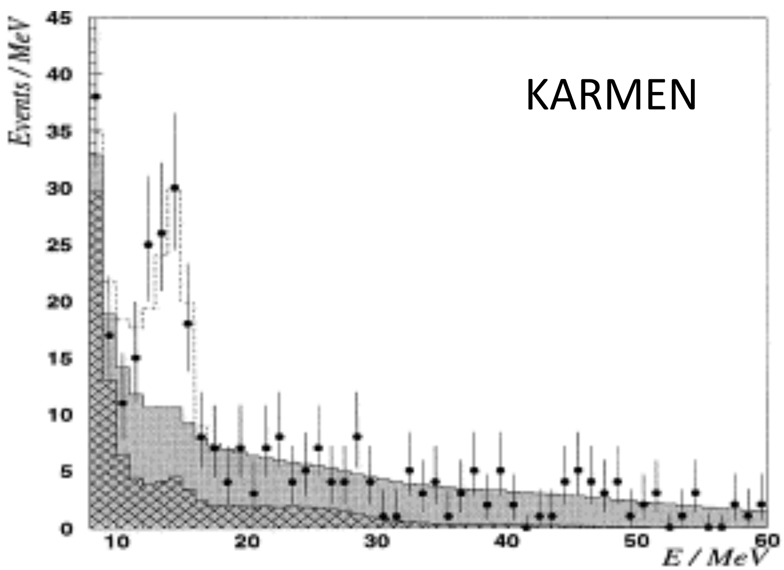


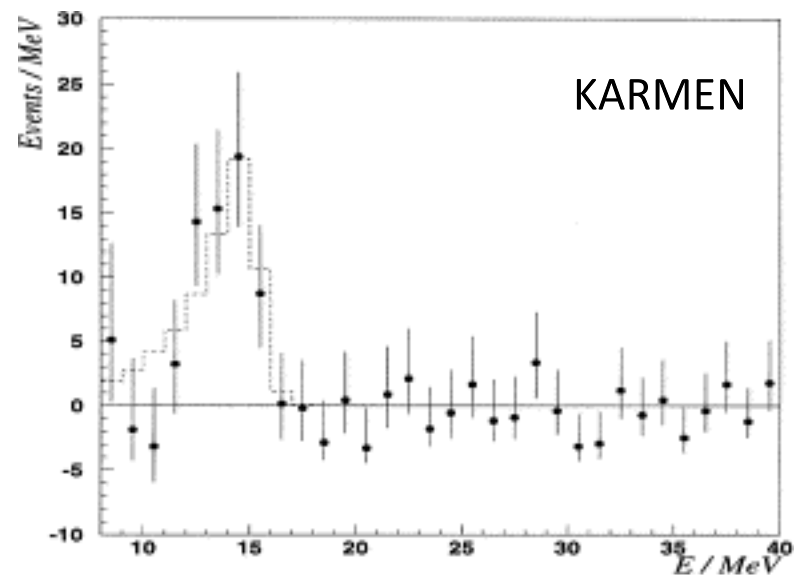
OscSNS Physics Plan

- Expect ~4e19 ν/year/species for a 8 m diameter cylinder, front face located 50 m from source
- Measure scattering cross sections
- Several channels to search for oscillations, sterile neutrinos
  - 2 NC disappearance (ν_μ, ν_x ^{12}C to $^{12}C^*$)
  - 1 CC disappearance (ν_e ^{12}C -> e^- $^{12}N_{gs}$)
  - 2 CC appearance (ν_e, anti-ν_e)
- MiniBooNE low E excess (?) -> LSND check

Cross Sections: I

NC: $\nu_\mu\ ^{12}C \rightarrow \nu_\mu\ ^{12}C^*$ (15.11)



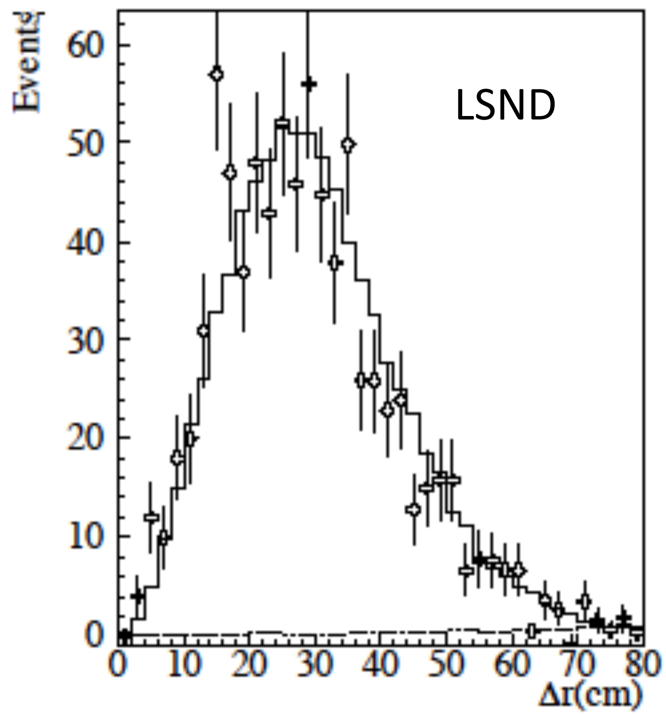


$\boldsymbol{\sigma}_{NC} = (3.2 \pm 0.5 \pm 0.4) \times 10^{-42}\ cm^2$ (B. Armbruster et al., Phys. Lett. B423 (1998) 15)

KARMEN, 86 events, 20% total error (half due to stats)

Cross Sections: II

CC: ν_e C -> e^- N_{gs}



σ_{CC} = (8.9 ± 0.3 ± 0.9) x 10^{-42} cm^2 (L. B. Auerbach et al., Phys. Rev. C64, 065501 (2001))

LSND, 191 events, 17% total error

Event Rates per Year

All estimates include 50% detector efficiency

Channel	Event Rate
NC $\nu_e e^- \rightarrow \nu_e e^-$	$1{,}353 \pm 77$
NC $\nu_\mu\ {}^{12}C \rightarrow \nu_\mu\ {}^{12}C^*$	1490 ± 84
CC $\nu_e\ {}^{12}C \rightarrow e^-\ {}^{12}N_{gs}$	4705 ± 245

KARMEN, 86 events, 20% total error (half due to stats)	
LSND, 191 events, 17% total error	

Flavor Oscillations: I

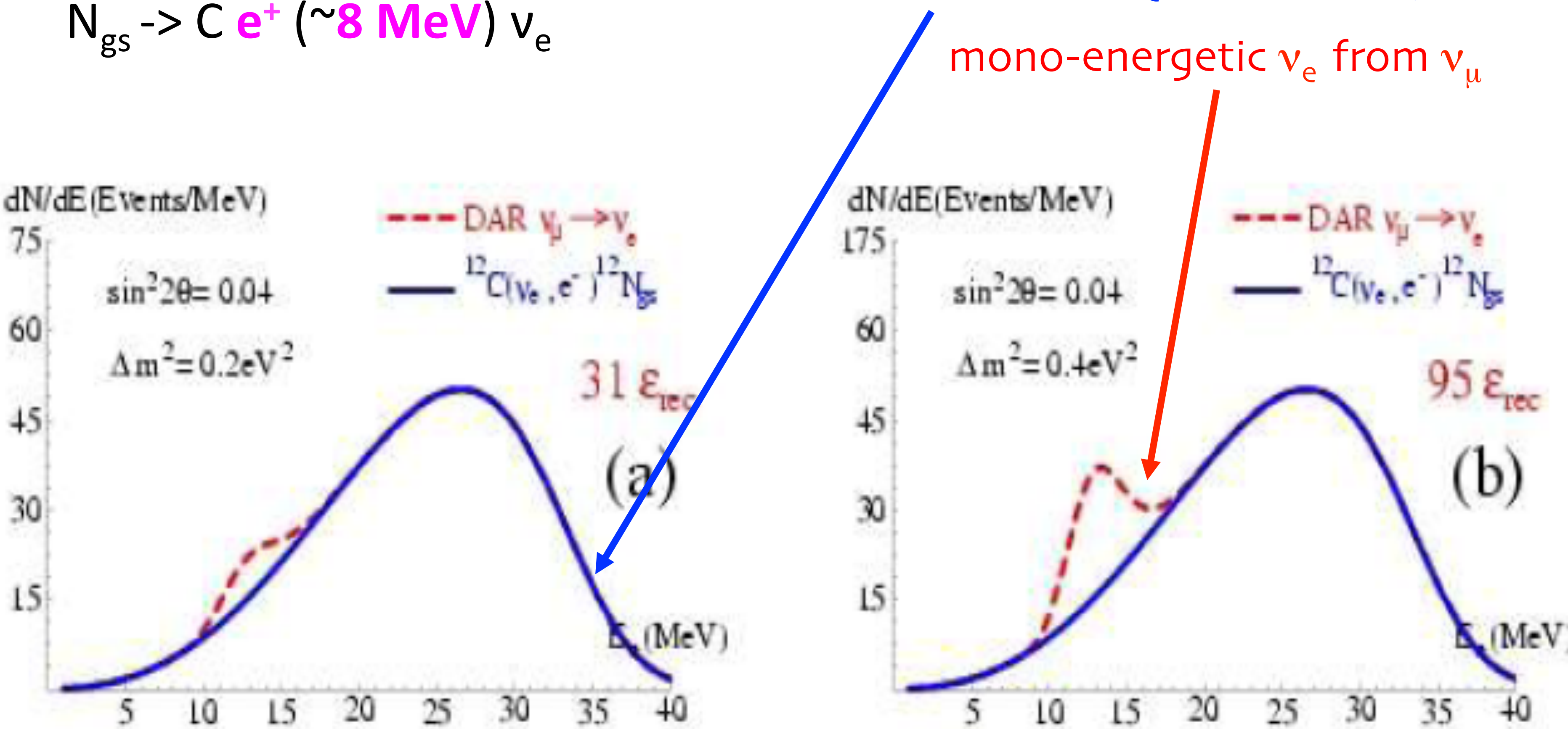
CC Appearance: mono-energetic ν_μ -> ν_e

ν_e C -> **e⁻** N_{gs}

N_{gs} -> C **e⁺** (~**8 MeV**) ν_e

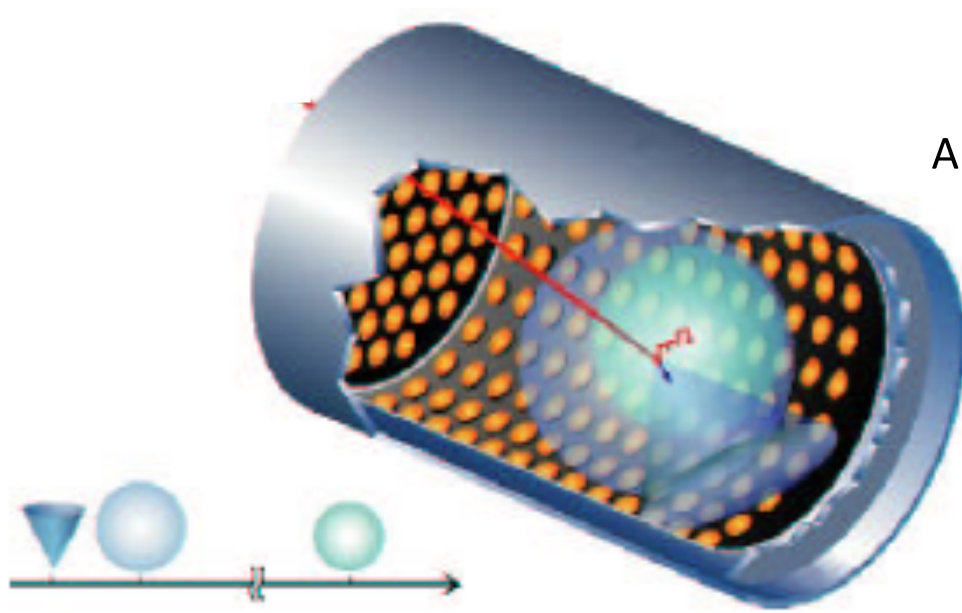
Intrinsic ν_e from μ decay

mono-energetic ν_e from ν_μ



Flavor Oscillations: II

CC Appearance: anti-ν_μ -> anti-ν_e
anti-ν_e p -> **e^+** n
n p -> d **Y** (**2.2 MeV**)

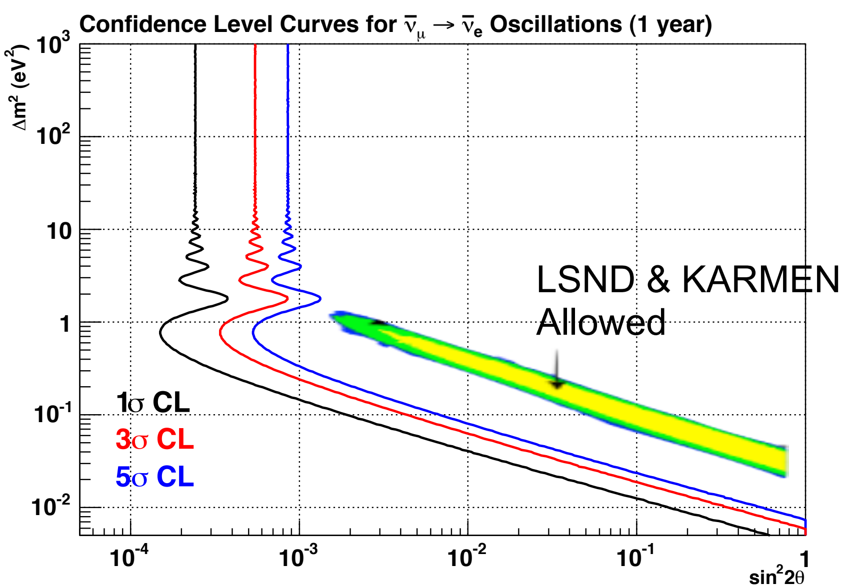


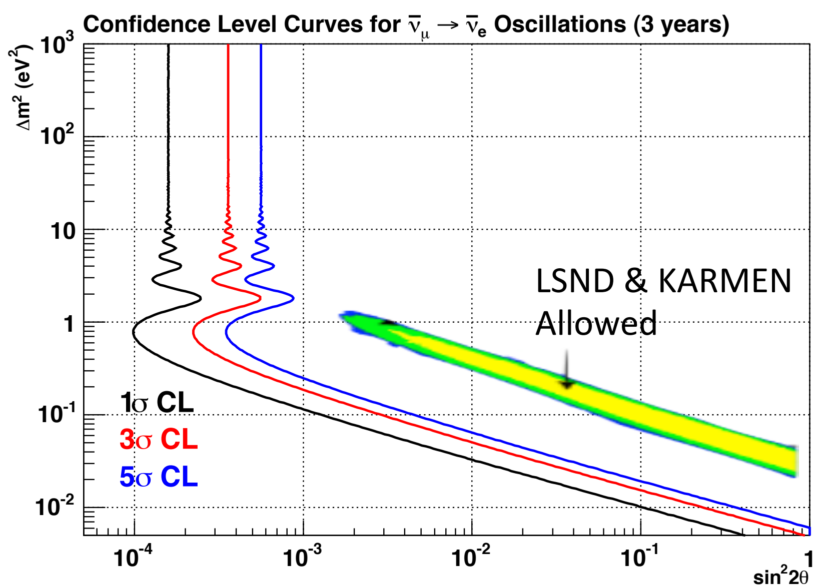
Aka the LSND Effect

Appearance Sensitivity

- $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ appearance sensitivity for 1 & 3 years of running:

$\bar{\nu}_e\, p \rightarrow e^+ n$; $n\, p \rightarrow d\, \gamma$ (2.2 MeV)

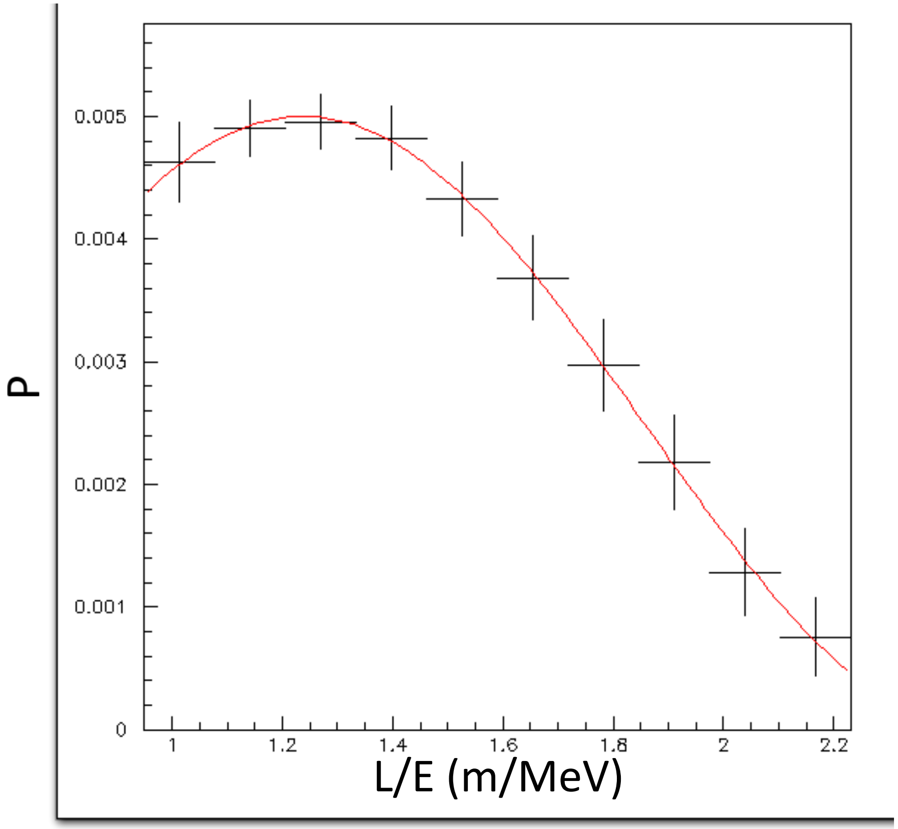




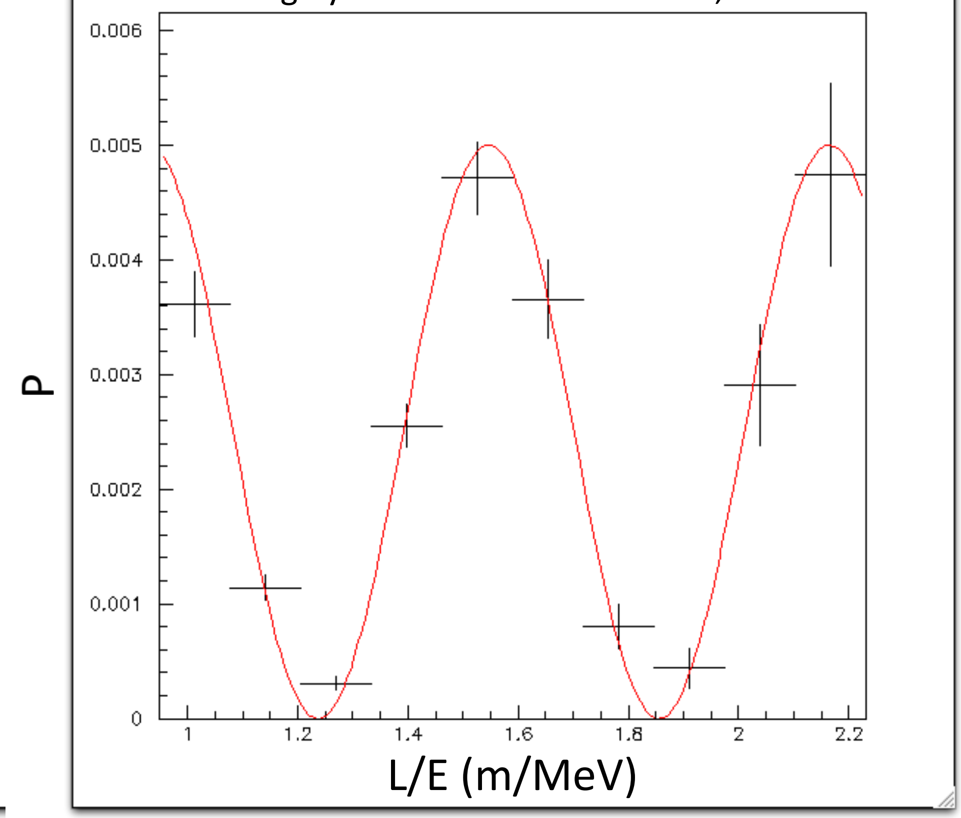
Appearance Sensitivity

Statistical errors, account for 20% bgd

Assuming 5y of data & $\sin^2 2\theta = 0.005$, $\Delta m^2 = 1\ eV^2$



Assuming 5y of data & $\sin^2 2\theta = 0.005$, $\Delta m^2 = 4\ eV^2$



Sterile Oscillations

- 3 neutrinos in the SM, left-handed, engage via the weak interaction with other matter, “flavor” states

- Variety of experimental anomalies can be reconciled through the introduction of a right-handed, or sterile, neutrino(s)

Experimental Anomalies

- LSND! (anti-ν_μ -> anti-ν_e, $\Delta m^2_{sterile} \sim 1$ eV^2), MiniBooNE (low E excesses in both samples)
- Re-evalulation of reactor neutrino flux (~6% deficit of anti-ν_e, $\Delta m^2_{sterile} > 1$ eV^2)
- Gallium anomaly (5-20% deficit of ν_e, $\Delta m^2_{sterile} > 1$ eV^2)
- Cosmological data (CMB, BBN) favor a 4th light DOF, could be a sterile neutrino (mass ~< 1 eV)
- Anomalies only in count rates; no energy and distance dependent signal observed

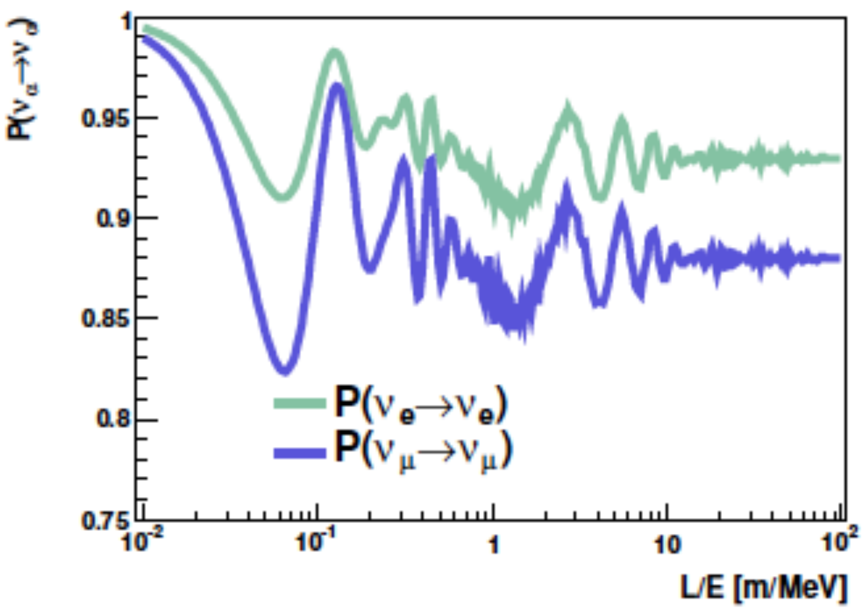
http://cnp.phys.vt.edu/white_paper/

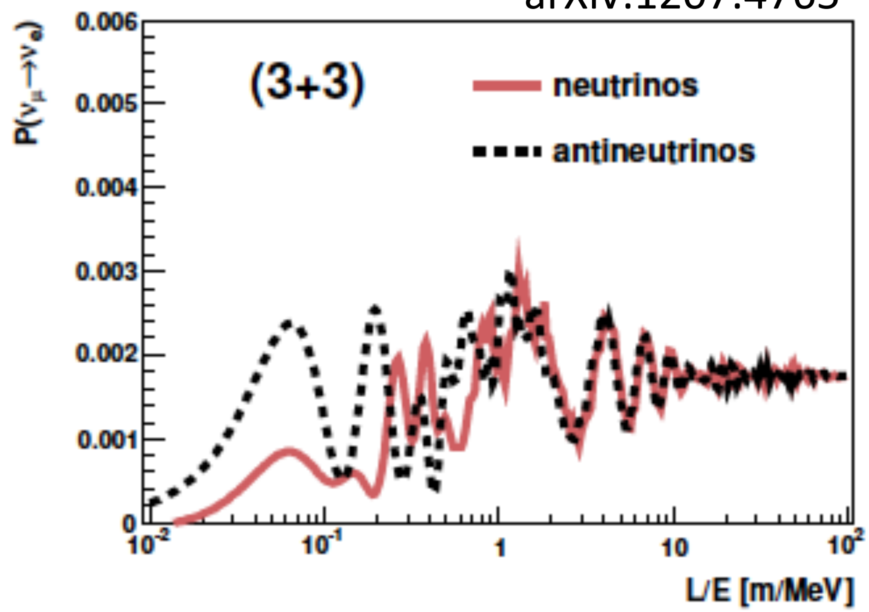
Global 3+N Fits

• The world neutrino & antineutrino data can be fit fairly well to a 3+N oscillation model with large ν_μ disappearance (>5%)

• 3+3 fit finds 67% goodness of fit, 90% compatibility with all data sets (still tension between appearance, disappearance)

arXiv:1207.4765



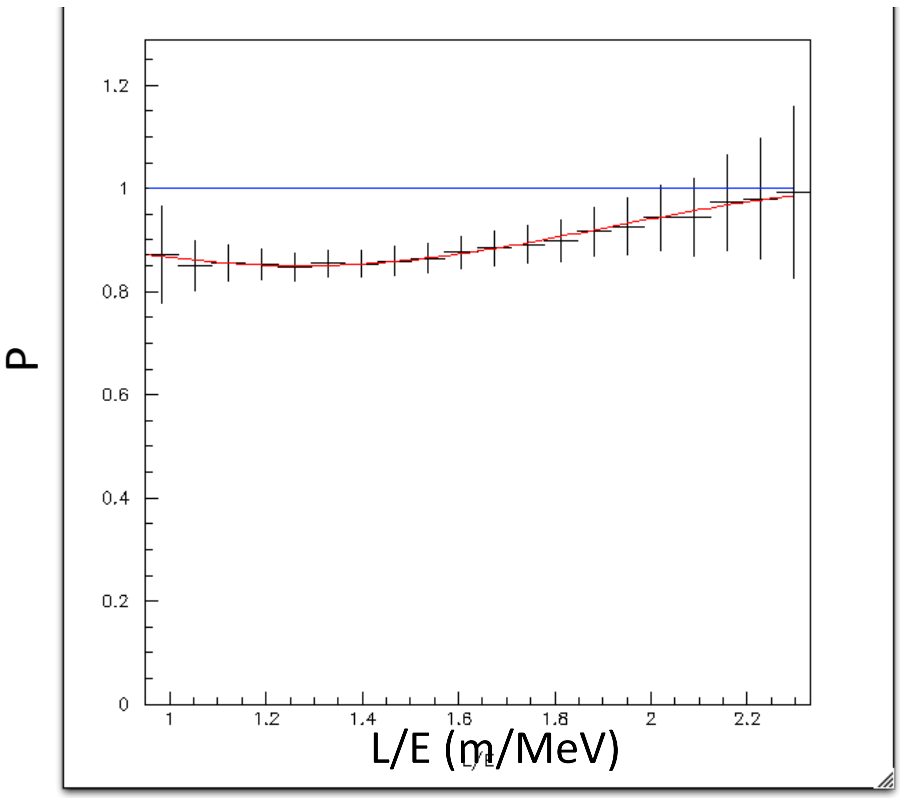


Disappearance Sensitivity

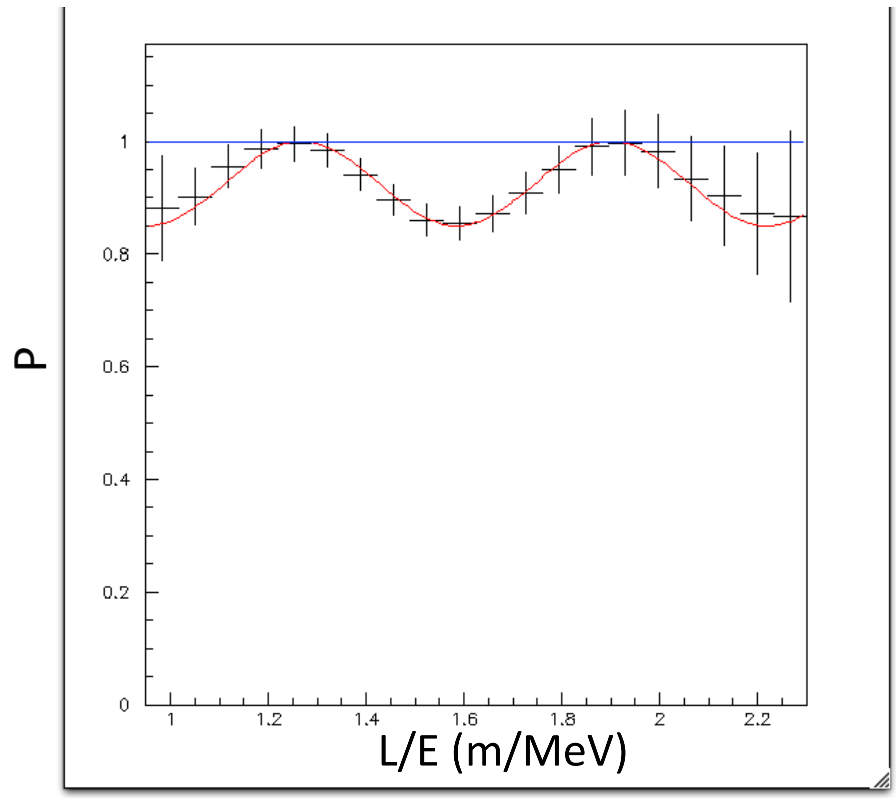
Statistical errors, account for 1% bgd

ν_e C -> e^- N_{gs} , N_{gs} -> C_{gs} e^+ ν_e

Assuming 5y of data & $\sin^2 2\theta = 0.15$, $\Delta m^2 = 1\ eV^2$



Assuming 5y of data & $\sin^2 2\theta = 0.15$, $\Delta m^2 = 4\ eV^2$

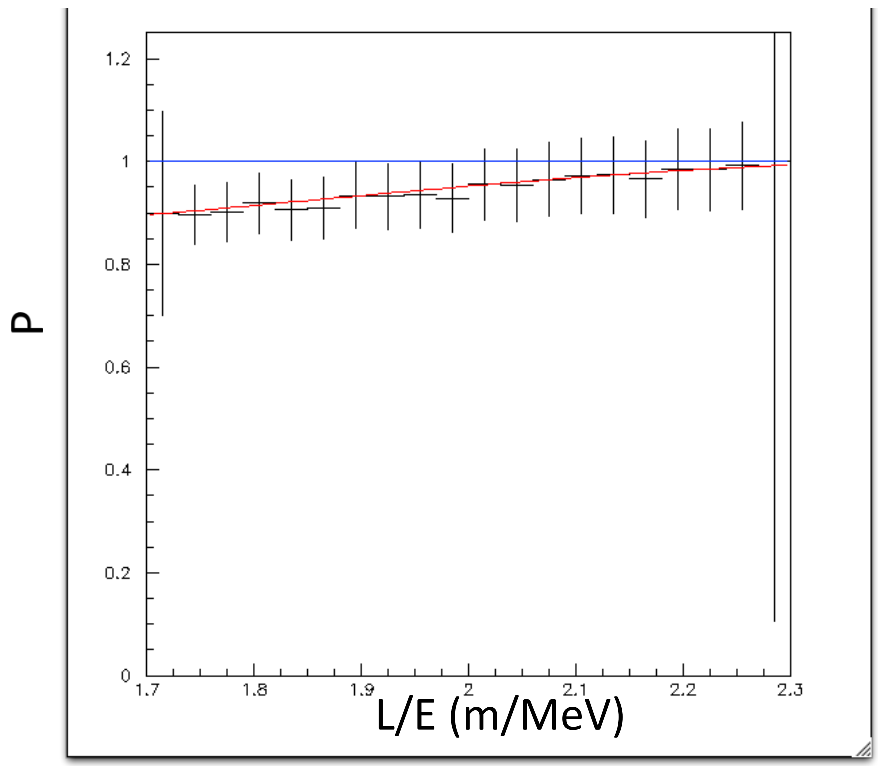


Disappearance Sensitivity

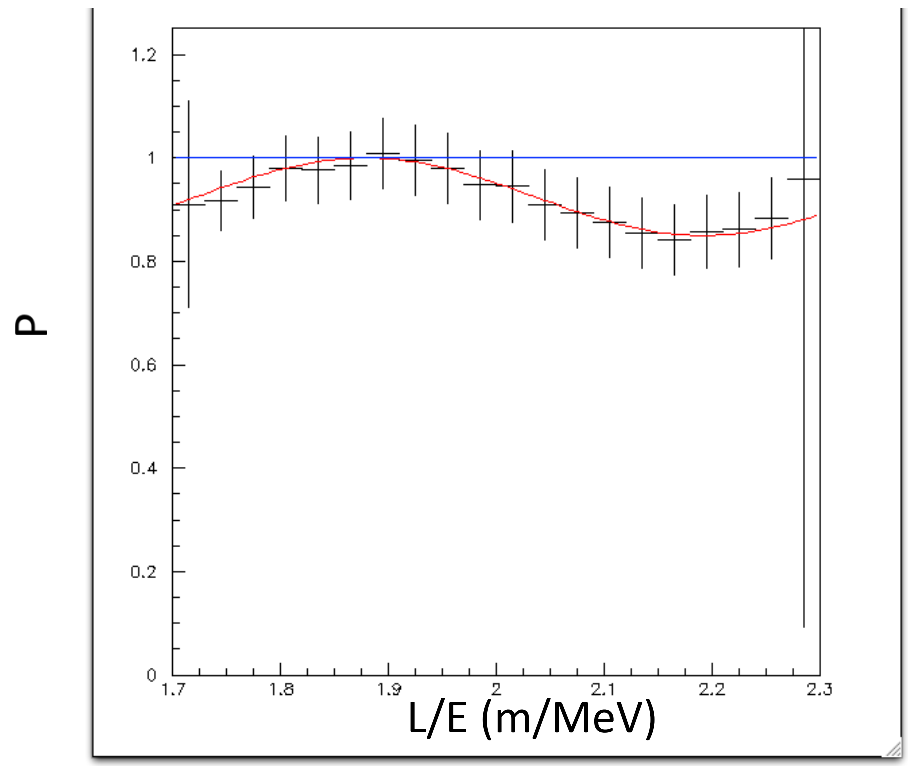
Statistical errors, account for 30% bgd

ν_μ C -> ν_μ C*(15.11)

Assuming 5y of data & $\sin^2 2\theta = 0.15$, $\Delta m^2 = 1\ eV^2$



Assuming 5y of data & $\sin^2 2\theta = 0.15$, $\Delta m^2 = 4\ eV^2$



Event Rates per Year

All estimates include 50% detector efficiency

Channel	Background	Signal	S/B	Efficiencies Applied
Disappearance Search				
$\nu_\mu\ {}^{12}C \to \nu_\mu\ {}^{12}C^*$ $\nu_e\ {}^{12}C \to \nu_e\ {}^{12}C^*$ $\bar{\nu}_\mu\ {}^{12}C \to \bar{\nu}_\mu\ {}^{12}C^*$	2121 ± 71	7070 ± 363	~3	30% bgd from Karmen measurement, under 15.11 MeV peak
$\nu_\mu\ {}^{12}C \to \nu_\mu\ {}^{12}C^*$	447 ± 149	1490 ± 84	~3	(same as above)
$\nu_e\ {}^{12}C \to e^-\ {}^{12}N_{gs}$	47 ± 25	4705 ± 245	~10	1% bgd from LSND
Appearance Search				
$\bar{\nu}_\mu \to \bar{\nu}_e$: $\bar{\nu}_e\ {}^{12}C \to e^+\ {}^{11}B\ n$ $\bar{\nu}_\mu \to \bar{\nu}_e$: $\bar{\nu}_e\ p \to e^+\ n$	83 ± 10	240 ± 20	~3	20 MeV e selection cut eff applied to S, B, 0.26% osc
$\nu_\mu \to \nu_e$: $\nu_e\ {}^{12}C \to e^-\ {}^{12}N_{gs}$	16 ± 4	7 ± 3	~0.4	12.5 MeV e plus e+ cut, beam timing cut, 0.26% osc

SNS vs Other Beamlines

	LAMPF	Booster	SNS
Energy	800 MeV	8000 MeV	1300 MeV
Current	1 mA		1.1 mA
Power	0.8 MW	42 kW	1.4 MW
Pulse Length	600 µs	1600 ns	695 ns
Rep Rate	120 Hz	6.5 Hz	60 Hz
Duty Factor	7.2%	43%	0.0042%

Max delivery rate, from T. Kobilarcik

OscSNS: Pros

- Well understood ν fluxes: ν_μ, ν_e, ν_μ
- Low duty factor
- Very low backgrounds (~0.1%)
- Beam comes for free from the SNS, runs >1/2 the year

- Search for both appearance & disappearance oscillations
- Possibility of observing oscillations in the detector for $\Delta m^2 > 1\ eV^2$!
- The OscSNS experiment can measure neutrino oscillations with high significance (>5σ) and prove that sterile neutrinos exist!

Current Status & Conclusions

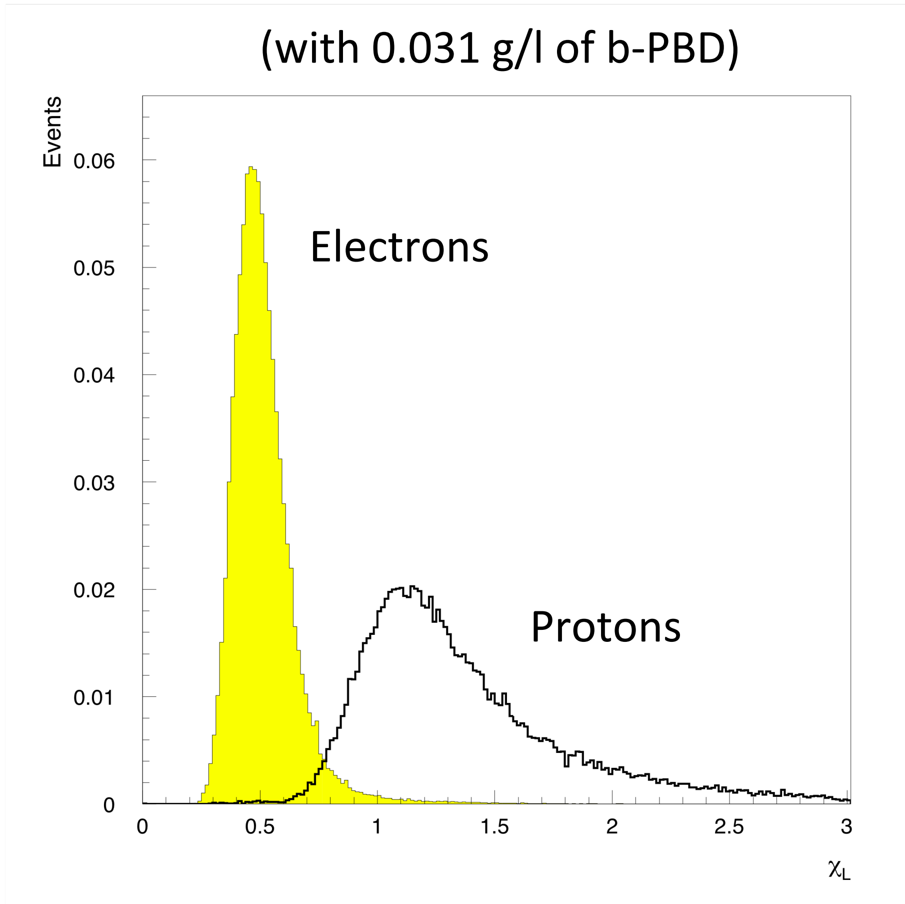
- Step 1: Tackle biggest issue: construction feasibility with civil engineering survey

- Step 2: collaborate with neutron detector people, perform in-situ measurement of neutron bgd in time with beam

- Step 3:

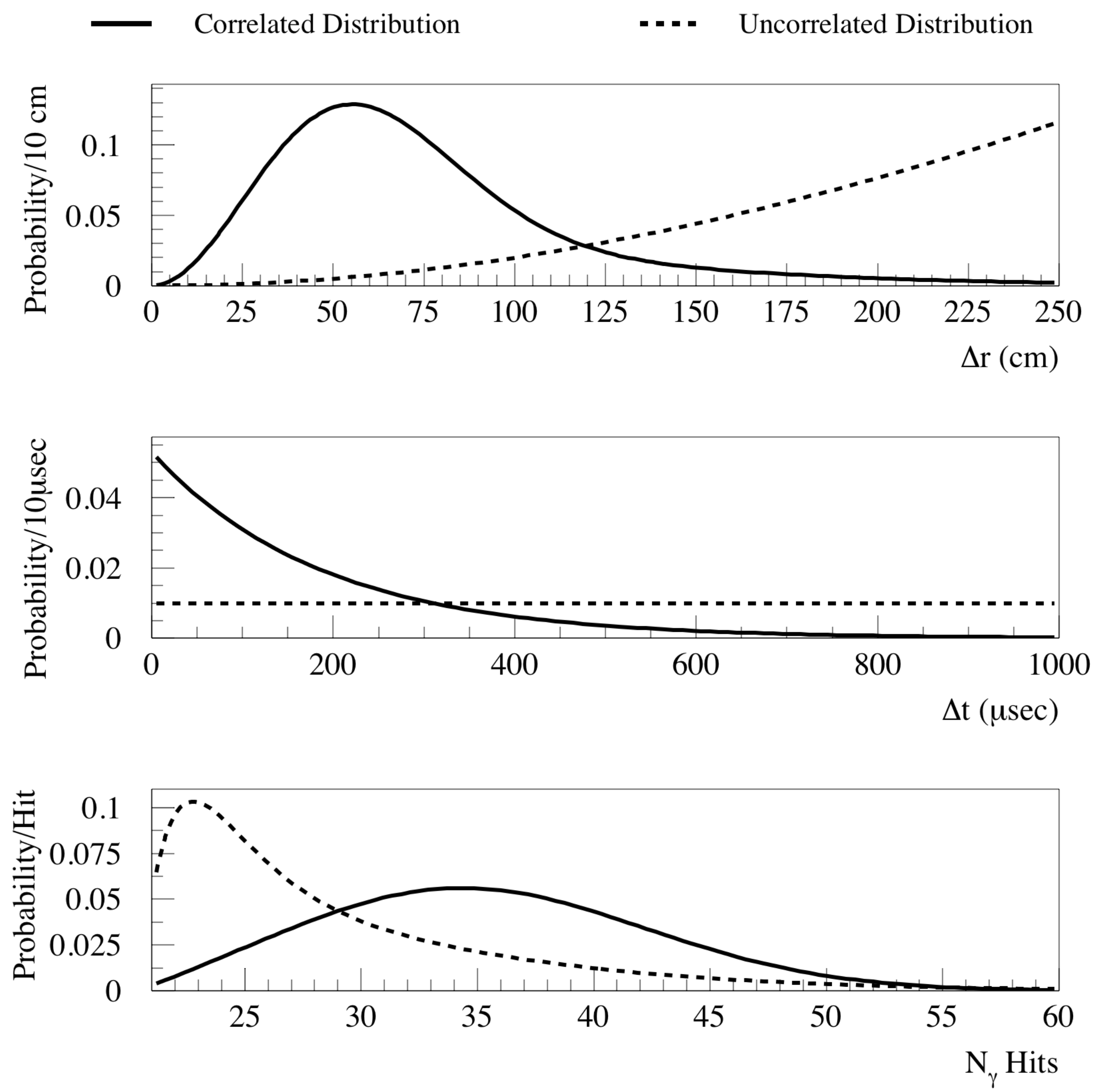
Backup

Particle Identification



Particle Identification depends on Cherenkov cone fit, position fit, and fraction of late light

Particle Identification



2.2 MeV γ

Global 3+N Fits

arXiv:1207.4765

Tag	Section	Process	ν vs. $\bar{\nu}$	App vs. Dis
LSND	3.2.1	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}$	App
KARMEN	3.2.1	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}$	App
KARMEN/LSND(xsec)	3.2.1	$\nu_e \to \nu_e$	ν	Dis
BNB-MB(νapp)	3.2.2	$\nu_\mu \to \nu_e$	ν	App
BNB-MB($\bar{\nu}$app)	3.2.2	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}$	App
NuMI-MB(νapp)	3.2.2	$\nu_\mu \to \nu_e$	ν	App
BNB-MB(νdis)	3.2.2	$\nu_\mu \to \nu_\mu$	ν	Dis
NOMAD	3.2.3	$\nu_\mu \to \nu_e$	ν	App
CCFR84	3.2.3	$\nu_\mu \to \nu_\mu$	ν	Dis
CDHS	3.2.3	$\nu_\mu \to \nu_\mu$	ν	Dis
Bugey	3.2.4	$\bar{\nu}_e \to \bar{\nu}_e$	$\bar{\nu}$	Dis
Gallium	3.2.4	$\nu_e \to \nu_e$	ν	Dis
MINOS-CC	3.2.5	$\bar{\nu}_\mu \to \bar{\nu}_\mu$	$\bar{\nu}$	Dis
ATM	3.2.5	$\nu_\mu \to \nu_\mu$	ν	Dis