VLENF
Experimental Motivation

- As Joachim has just said: Lots of 2 to 3 σ results
  - LSND: $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
  - MiniBooNE: $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
  - MiniBooNE: $\nu_\mu \rightarrow \nu_e$
    - Low E_ν excess
  - Reactor Anomaly
  - MINOS: ν_μ vs. $\bar{\nu}_\mu$
- Cross-section measurements
  - μ storage ring presents only way to measure ν_μ & ν_e (ν and $\bar{\nu}$) x-sections in same experiment

SBNW11

Short-Baseline Neutrino Workshop

- From Richard Van de Water's SBNW summary
  - There are a smorgasbord of experimental hints that point to possible new physics.
    - "Not a single piece of evidence that directly contradicts LSND/MiniBooNE".
    - Much circumstantial experimental evidence that supports LSND/MB from MeV to GeV range. Karmen and ν_μ disappearance provides some restriction.
  - **Need to make smoking gun measurement.**
    - Need to make a >5 sigma measurement at L/E ~1 to convince the community.
    - Need to measure neutrino properties to the ~ 1 percent level.
    - Need sufficient **Rate** = Flux x Cross Section x detector response

Possibilities with μ storage ring

- An experiment that uses a ν_e beam from a muon storage ring can go a long way in ruling out sterile νs
  - Goal:
    - **ν_e disappearance experiment with 1% precision (10^4 events)**
- In addition, the beam opens up opportunities for
  - Detailed study of ν interactions
    - Known ν beam flux and flavor composition
  - Oscillation Physics @ L/E = 1?

ν_e disappearance

- Assume roughly 1kT of detector
  - $\approx$ 100-200T Near
  - $\approx$ 800T Far
- The 10^4 event criterion would then roughly require the equivalent of the MiniBooNE ν exposure
  - MiniBooNE exposure yielded 10^5 events, but the $\mu \rightarrow \nu_\mu + e$ kinematics vs. $\pi \rightarrow \nu_\mu + \mu$ yields less useful νs (hitting the detector)

$L/E \approx 1$ Oscillation physics

- First consider magnetized detector(s)
- Run with μ^-

$$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$$

- Oscillation signal:

$$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$$

  – μ^+ in detector "NF *Golden Channel*"

- Why is this so Powerful?

$\bar{\nu}_\mu$ MiniBooNE *Signal & Background*

5.66 X 10^{20} POT

Process	200 – 475 MeV	475 – 1250 MeV
ν_μ & $\bar{\nu}_\mu$ CCQE	4.3	2.0
NC π^0	41.6	12.6
NC $\Delta \to N\gamma$	12.4	3.4
External Events	6.2	2.6
Other ν_μ & $\bar{\nu}_\mu$	7.1	4.2
ν_e & $\bar{\nu}_e$ from $\mu^\pm$ Decay	13.5	31.4
ν_e & $\bar{\nu}_e$ from $K^\pm$ Decay	8.2	18.6
ν_e & $\bar{\nu}_e$ from K^0_L Decay	5.1	21.2
Other ν_e & $\bar{\nu}_e$	1.3	2.1
Total Background	99.5	98.1
0.26% $\bar{\nu}_\mu \to \bar{\nu}_e$	9.1	29.1

For “Golden”, BKG is essentially 0 – TASD μ charge mis-ID rate < 10^{-4}

Flux will be the issue

MiniBooNE as Far Detector?

- Kinematically ν and ν-bar events are different
  - Muon lifetime due to μ^- capture
  - cosθ distribution
    - ν-bar produce more forward lepton
      - Effect largest around 1 GeV
  - Outgoing nucleon is either a proton or a neutron (QE)
    - Neutron tagging via Gadolinium doping and n absorption
      - 8 MeV γ - Tag ν-bar events
      - Efficiency/mis-ID rate?
- ***I do not think we will have enough flux for this to be viable, however and background level is not clear***

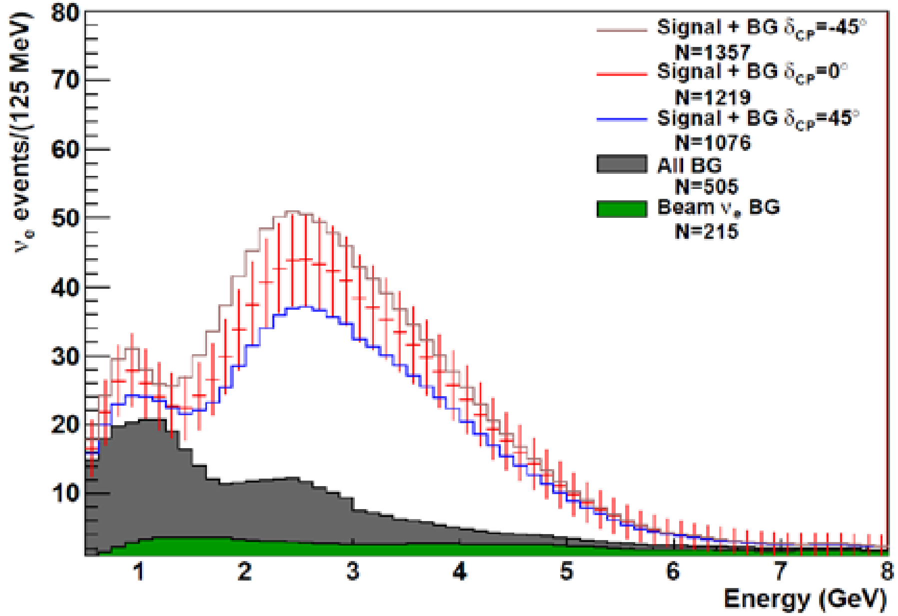
L/E $\approx$ *1* Oscillation physics

Lots of Competition (*3-7 years out)*

- Run uBooNE to test MB low energy anomaly. [$20M]
- Build BooNE (near detector) – decisive (~5 sigma), quick, inexpensive, on Carbon (measure disappearance - appearance). [$8M]
- Build OscSNS/cyclotron experiment (stopping pion source) to retest LSND directly >5 sigma. [$10M]
- Minos+ running to search for sterile nu, NSI, etc. [$5M?]
- Build and run 2 LAr detector experiments at CERN and FNAL to make definitive test of appearance, disappearance, nu decay, LV, etc. [????]
- Katrin results.
- NOvA (2nd near detector) and SciNova. [$5-$30M]
- Develop Muon Storage ring, Reactor (SCRAAM) and Source (LENS,Ga, Borexino) experiments. [????]
  - (MCi source for Borexino is really inexpensive (<$1M), however)

Notes on x-section measurements

- Aligning with LBNE would certainly be an advantage
  - The energy range of interest is 1-3 GeV
- Nuclear effects are important (Short-range correlations, Final-state interactions).
  - Important detector implications
- Measurements on nuclear targets important
  - H_2, D_2, Ar, Fe?



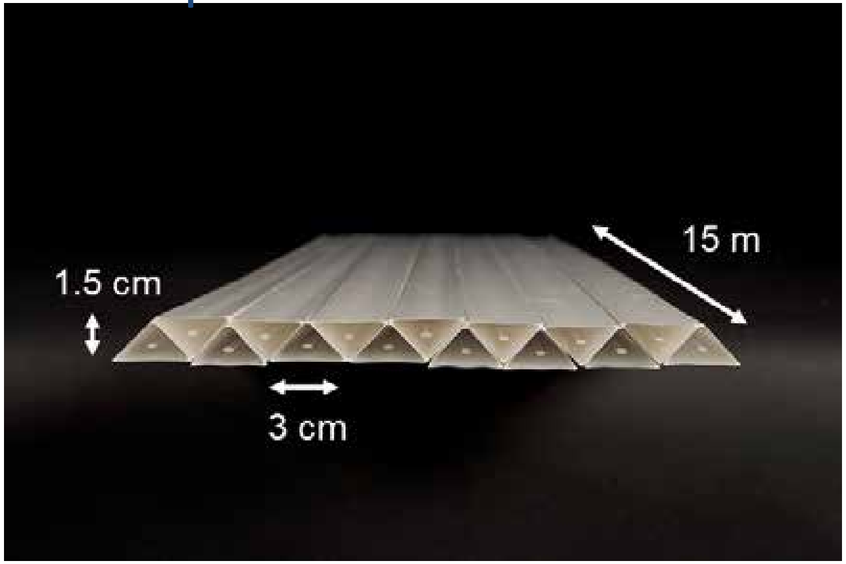
Thoughts on Detectors

- Large Δm^2 oscillation physics – Far detector
  - Magnetized TASD ideal
  - LAr also possible
    - But magnetization raises fundamental problem: PMTs used for trigger (Ar scintillation)
    - Some R&D on alternate approaches to the scintillation light readout being explored
      - WLS bars (might allow for PMTs outside field region?)
  - Near detector
    - More options, but must be totally active
      - TASD (need not be magnetized, but is an advantage)
      - LAr (μBooNE, already has made case for X-section meas. in MB line)

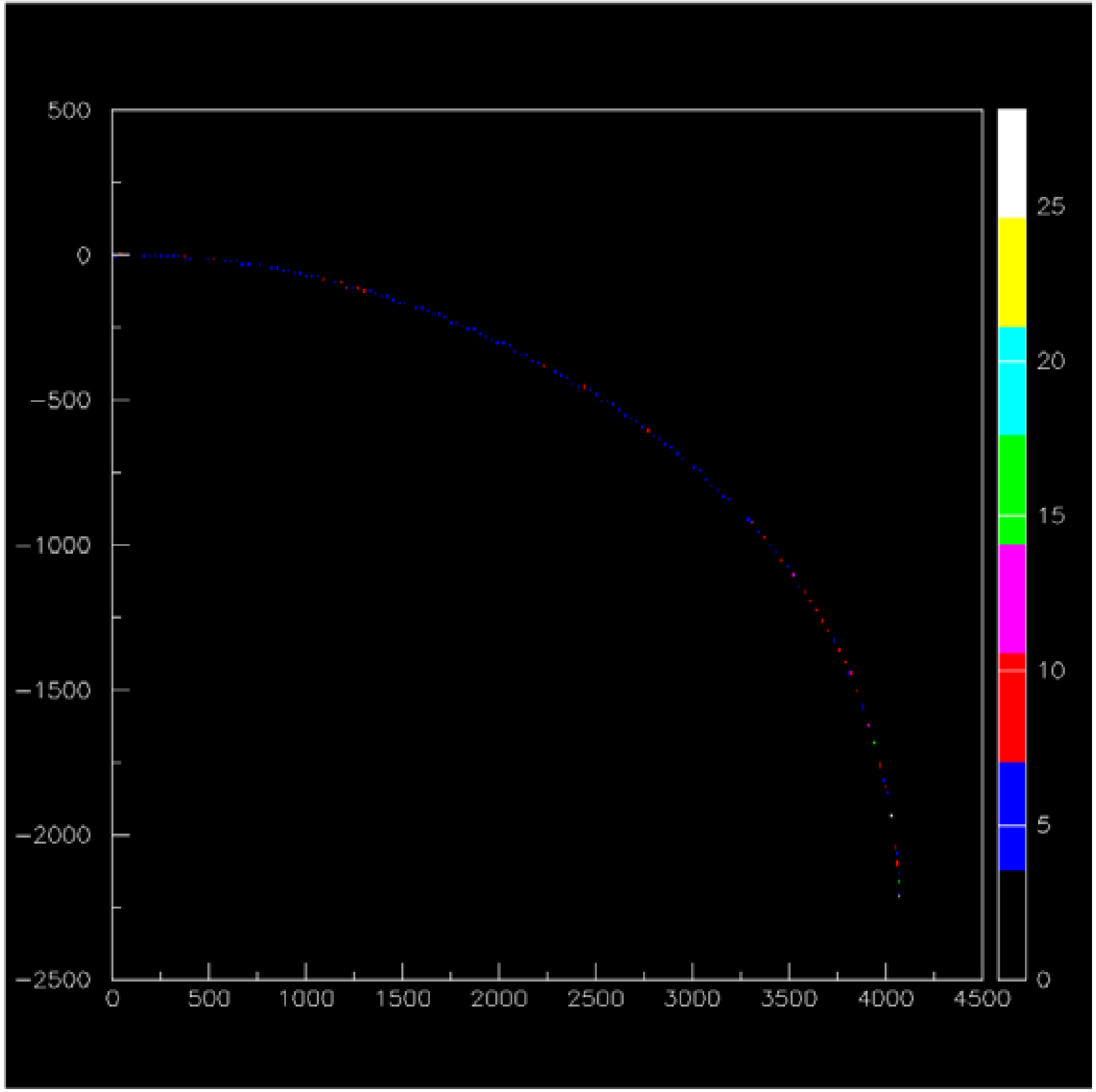
Totally Active Scintillator Detector

Intro – for the uninitiated

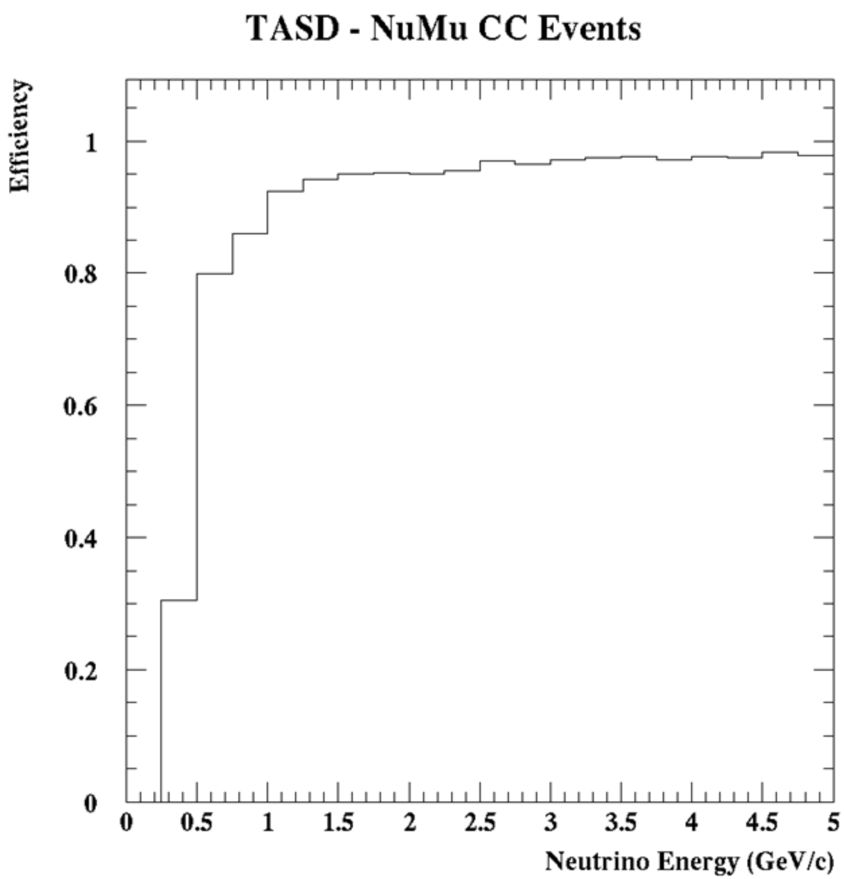
- Simulation of a Totally Active Scintillating Detector (TASD) using Nova and Minerva concepts with Geant4
  - Momenta between 100 MeV/c to 15 GeV/c
  - Magnetic field considered: **0.5 T**
  - Reconstructed position resolution ~ 4.5 mm



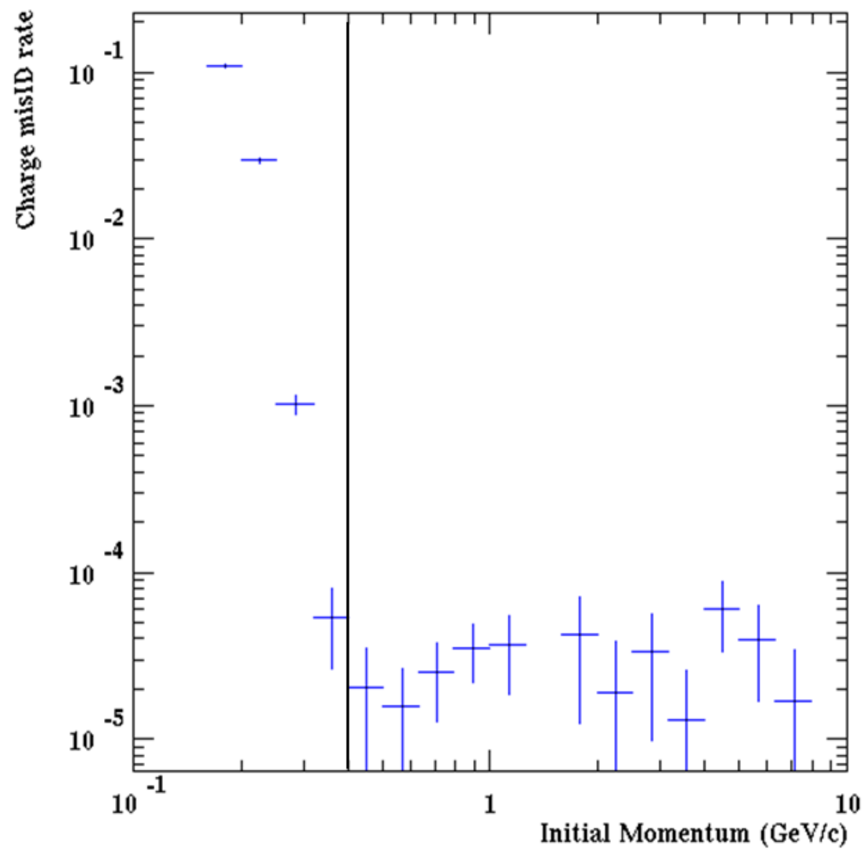
1 GeV μ track in TASD



TASD Performance

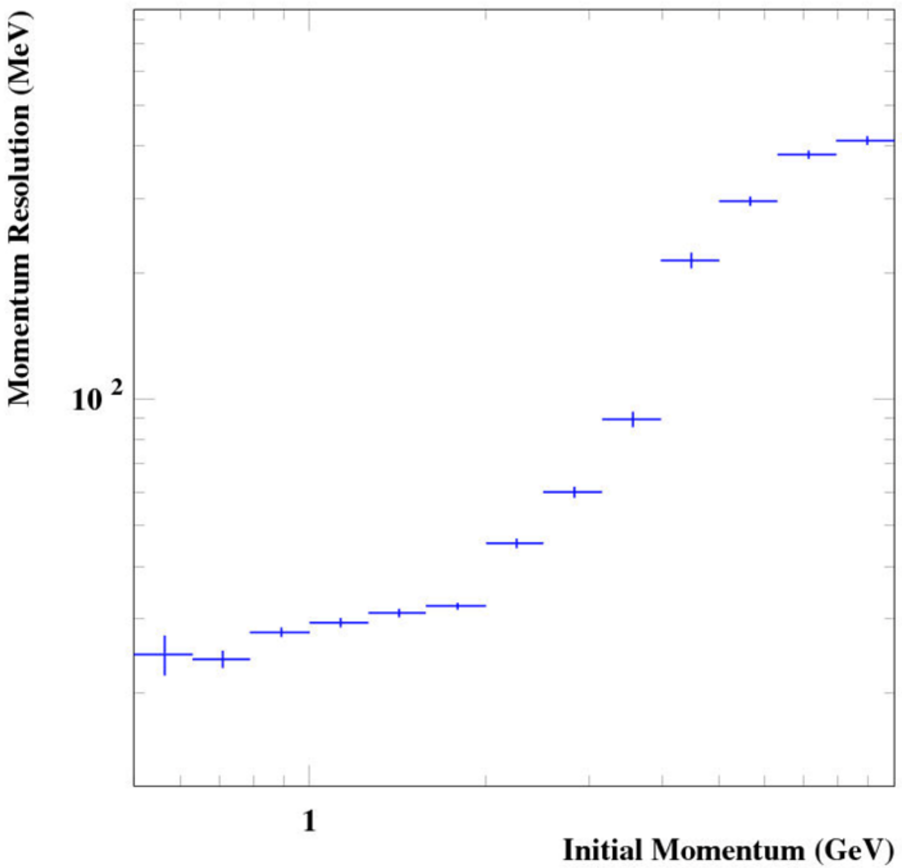


ν Event Reconstruction Efficiency



Muon charge mis-ID rate

TASD Performance II



Momentum resolution excellent

- Neutrino Event energy reconstruction from tracking
- EM component from hit counting - possibly

Simplifies electronics

- No calibration needed
- Hit efficiency is only consideration

Conclusions

- With sufficient flux an $L/E \approx 1$ oscillation experiment using a muon storage ring can "easily" reach a 5σ+ benchmark, *it is just the "Golden Channel" after all*
  – Need to know our flux (Tom will elaborate in a bit)
  – Should do a Globes analysis using known TASD performance parameters once defendable flux estimate is known
  – Lots of competition, however
- Cross section measurements at a 100-200T near detector offer a unique opportunity
  – The detector design is crucial (need not be magnetized)
    - TASD
    - LAr
  – μBooNE would present an interesting option (100T)