

NuPRISM Proposal to the J-PARC PAC

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NuPRISM Workshop
March 14th, 2015

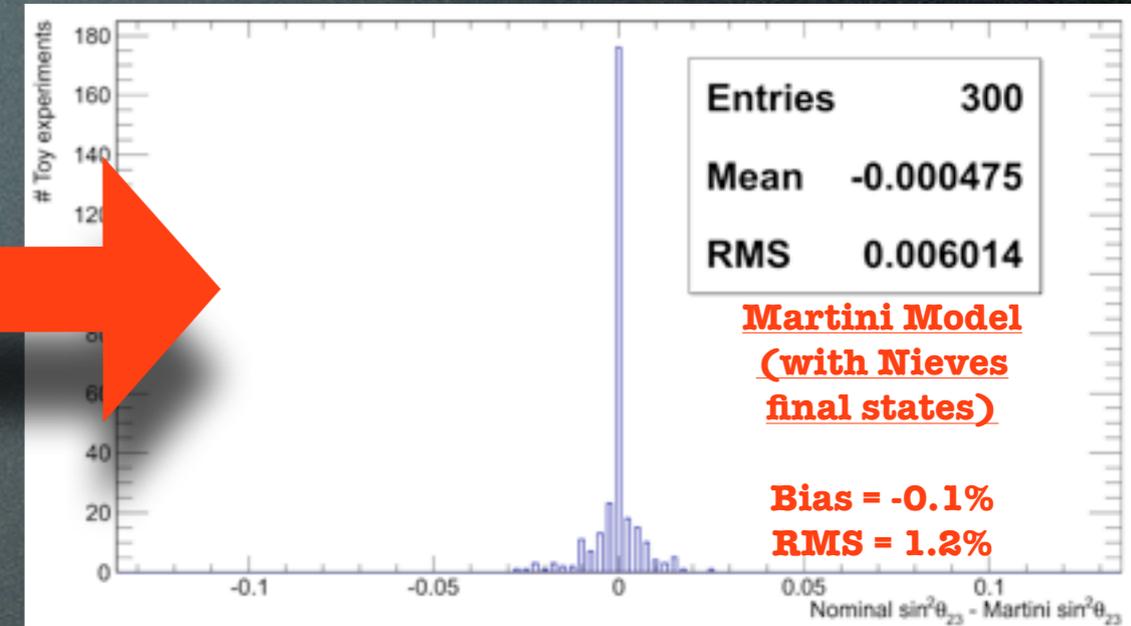
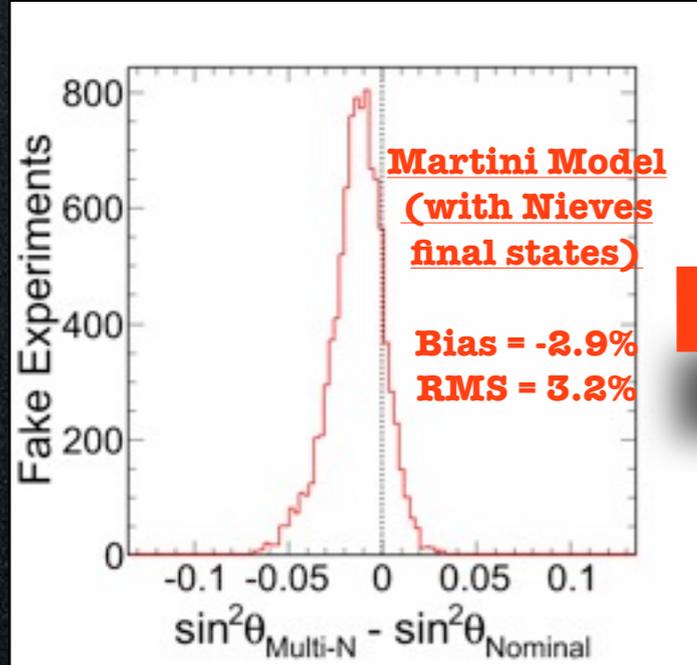
Overview

- We have already submitted an LOI document to the J-PARC PAC
 - This will form the basis of the full proposal
- Full proposal is due on June 15th, 2015
- There are no minimum requirements for additional studies
 - (i.e. we will submit what is available by June)
 - but further progress on existing analyses will help to strengthen our case
- In particular, we need to make the case for:
 - Substantial improvement to the T2K θ_{23} measurement
 - Sterile neutrino sensitivity comparable to the Fermilab short baseline program with reasonable systematic assumptions
 - ν_e and anti- ν_e sensitivity for Hyper-K measurements

Physics Inputs

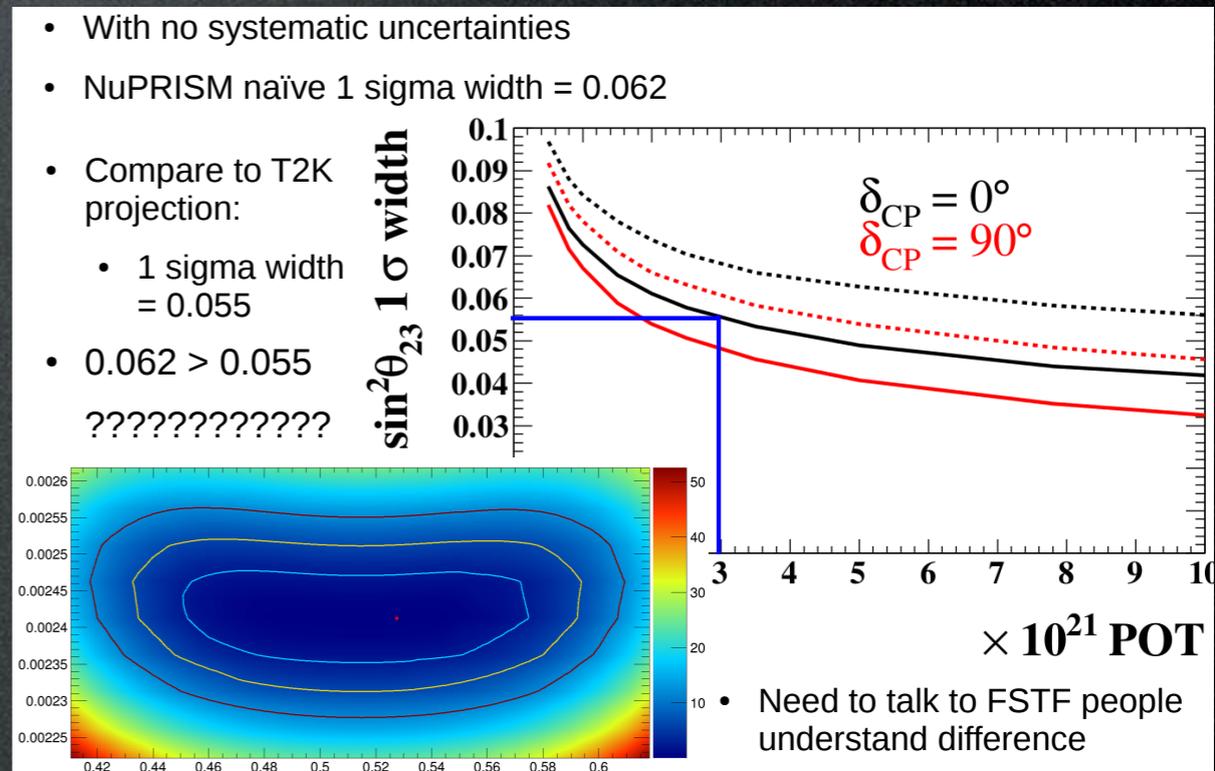
- Accomplished:
 - Reduction of multinucleon uncertainty in ν_μ disappearance to 1% level
 - ν_μ flux fits for ν_e appearance and anti-neutrino analysis
 - Initial (conservative) sterile neutrino sensitivities
- Not yet available:
 - Reduction of overall flux+xsec uncertainty in ν_μ disappearance to $\sim 3\%$ level
 - ν_e appearance constraints
 - Oscillation physics assuming $\sigma(\nu_e)/\sigma(\nu_\mu) = 1$
 - Double differential $\sigma(\nu_e)/\sigma(\nu_\mu)$ measurement
 - Sterile neutrino sensitivities with realistic guesses of systematic error reduction
- In the T2K era, NuPRISM's main impact will be to improve the θ_{23} measurement
 - A more clear explanation of how θ_{23} impacts T2K's sensitivity to δ_{CP} is needed
- Also need to emphasize how cross section modeling affects δ_{CP} sensitivity from ν_e appearance in the Hyper-K era
 - Need to begin understanding NuPRISM now to ensure the success of Hyper-K
- Can also include MH and CP sensitivity from atmospheric neutrinos in the Super-K era
 - This is currently completely absent

ν_μ Disappearance



- Main NuPRISM physics result:
 - Insensitivity to multinucleon effects
- However, it would be useful to demonstrate that other systematics can also be controlled at this level
- So far, sensitivity is not as strong as expected
 - Should be possible, since HK LOI achieves very small uncertainties
 - (depends on assumptions)

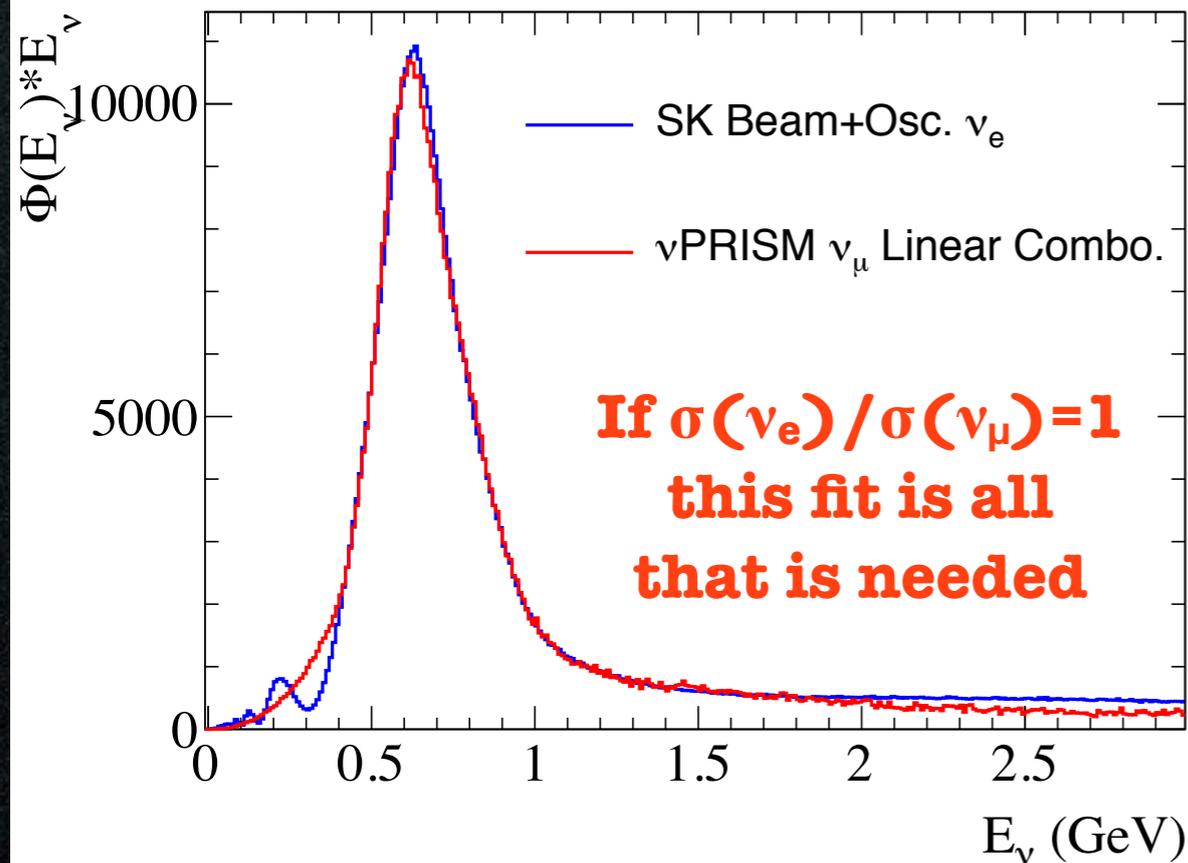
M. Scott, 6th HK Meeting



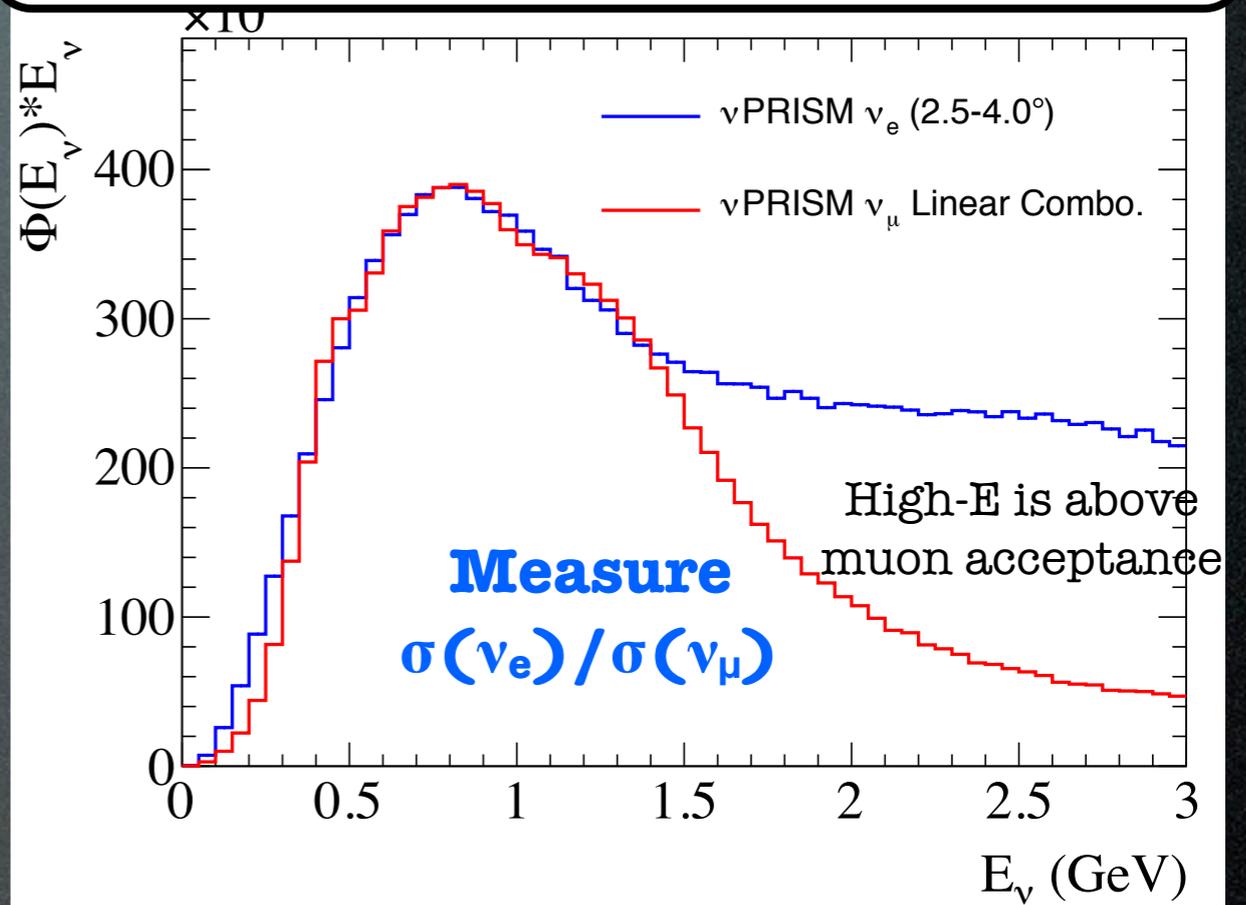
nuPRISM ν_e Appearance

2 step approach:

Step 1: Measure **Super-K** ν_e response with nuPRISM ν_μ



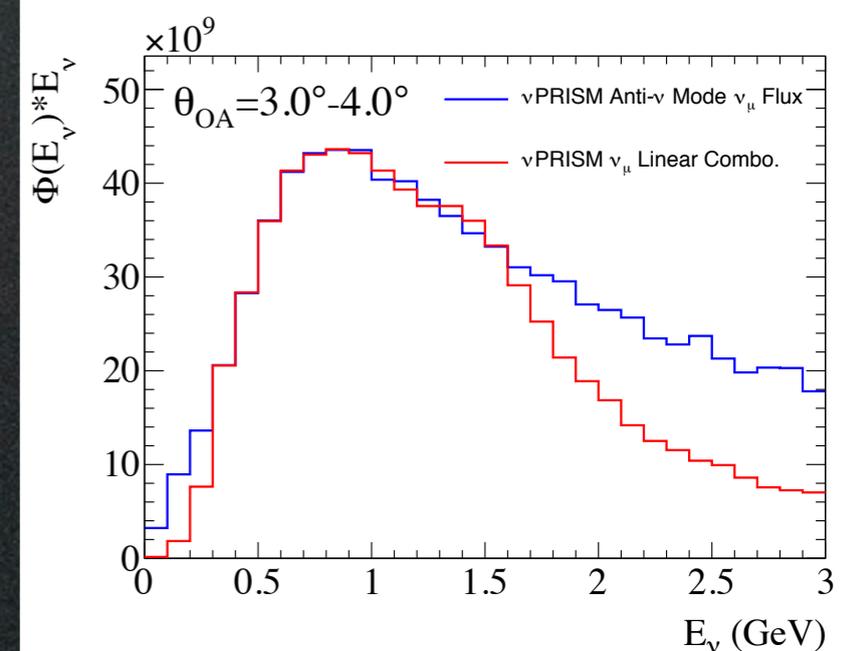
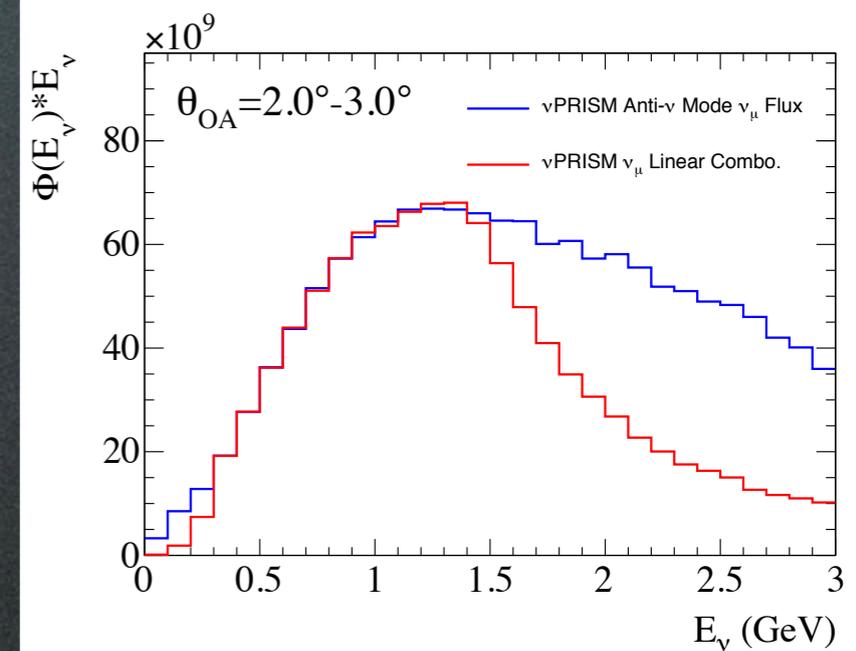
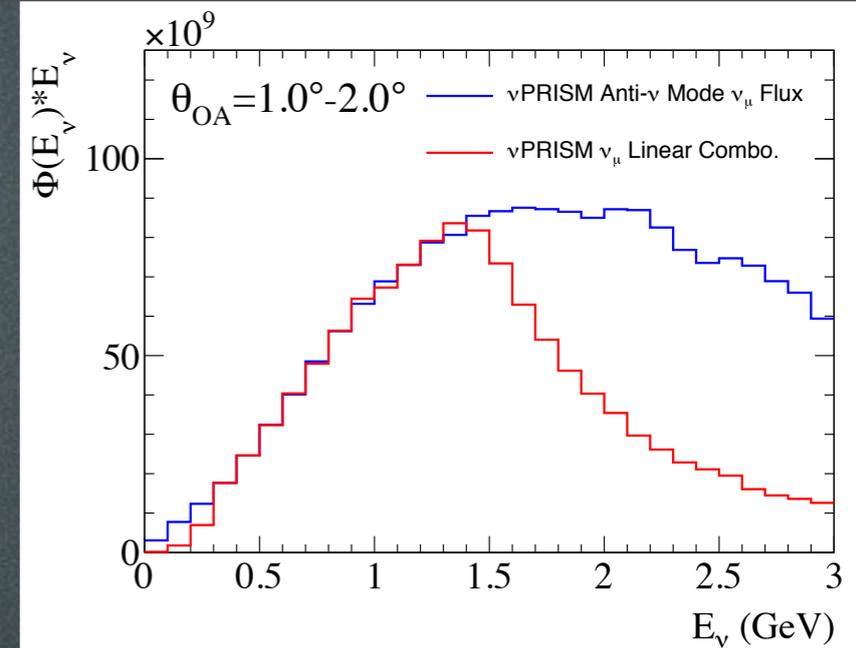
Step 2: Measure **nuPRISM** ν_e response with nuPRISM ν_μ



- For the proposal, we would like to have a preliminary estimate of both steps
- Step 1 should be a straightforward extension of the ν_μ analysis
- Step 2 is being investigated at MSU

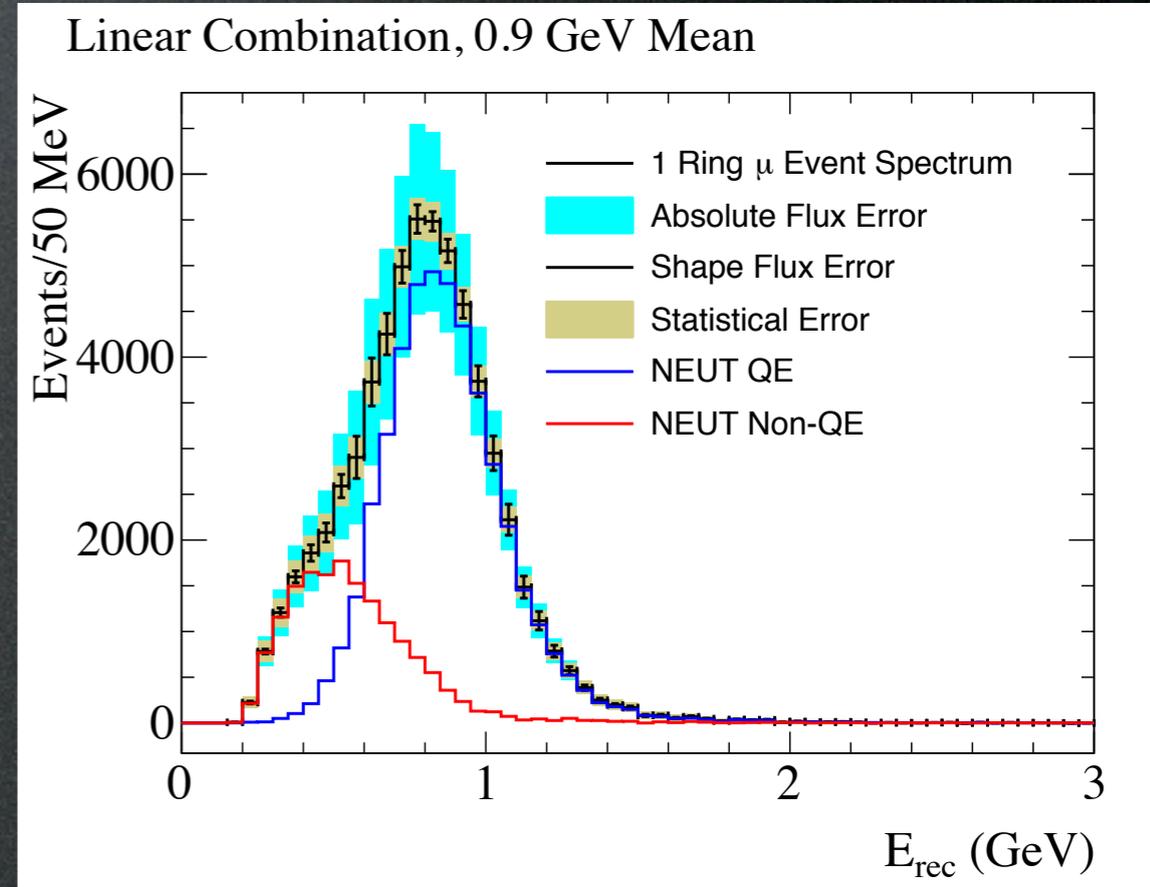
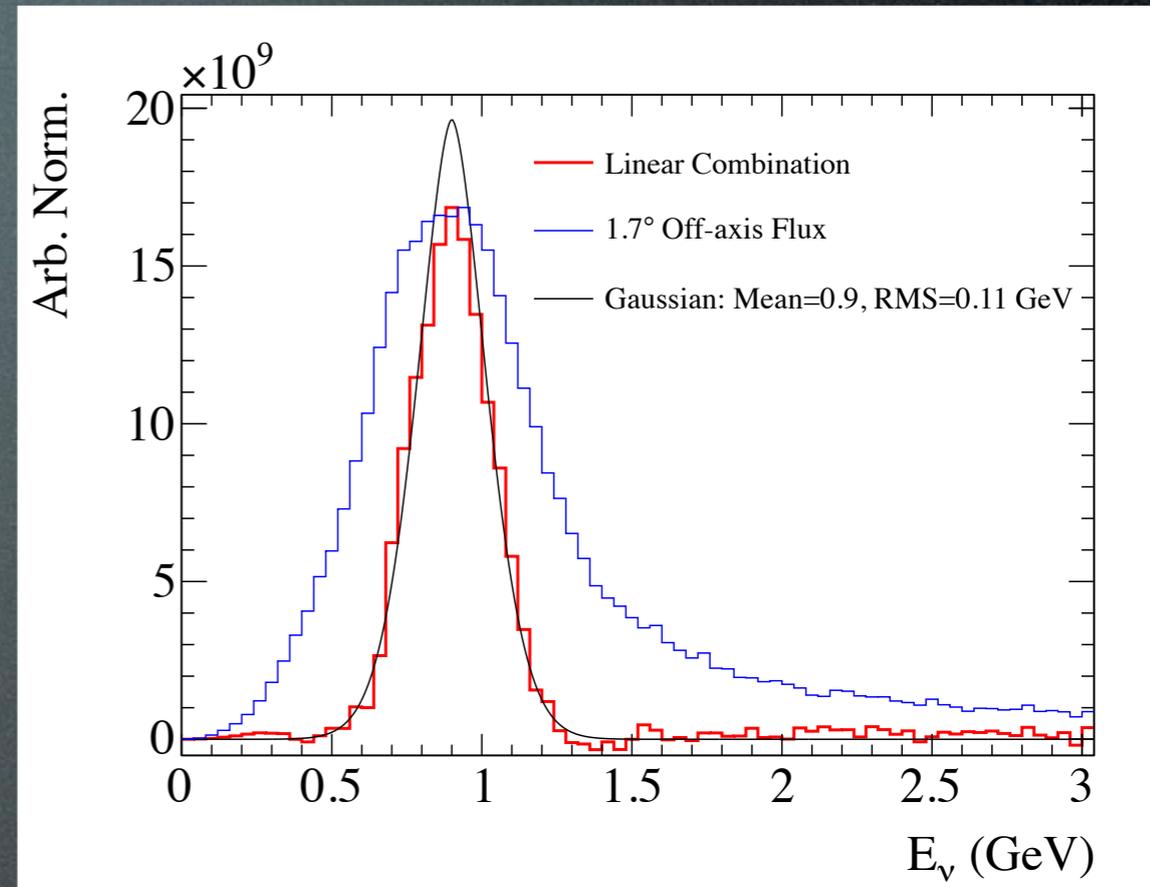
Anti-neutrinos

- The LOI contained only these flux fits of the ν -mode ν_μ to the wrong-sign ν_μ bkg in anti- ν -mode running
 - It would be useful to quantify how well this works
- We will also make the case that ND280 can provide sign selection
 - Demonstrating NuPRISM-only sensitivity to wrong-sign background would be helpful
- Need to discuss this week whether there is sufficient manpower to pursue this



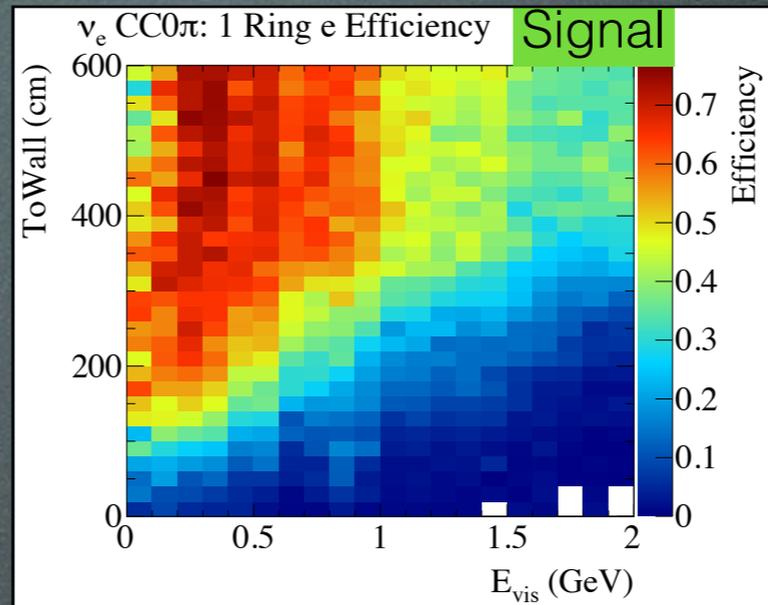
Cross Section Measurements

- Monoenergetic beams are now available for study
 - First ever measurements of NC events with E_ν
 - First ever “correct” measurements of CC events with E_ν
 - Do not rely on final state for E_ν
- How precisely can we measure various final states?
 - e.g. using fitQun μ/π separation
- Of critical importance are the background processes for the ν_e selections
- Lots of room for people to participate!
 - Many processes to study!



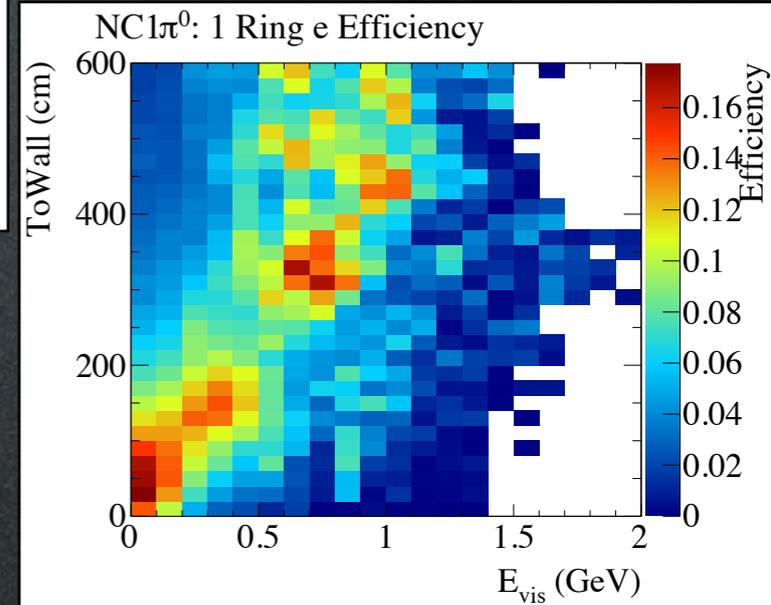
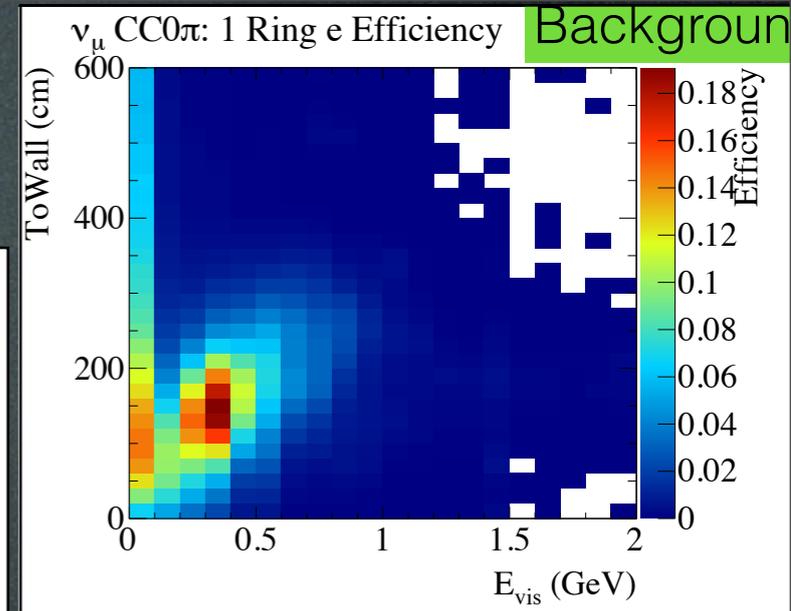
ν_e Event Selection

- Current PID assumes Super-K efficiencies
- Improvement would be very helpful for NuPRISM
- Low purity
 - Too much NC background
- Need to understand performance with realistic reconstruction



1 Ring e selection:

$E_{vis} > 200$ MeV
 $D_{Wall} > 200$ cm
 $ToWall > 320$ cm

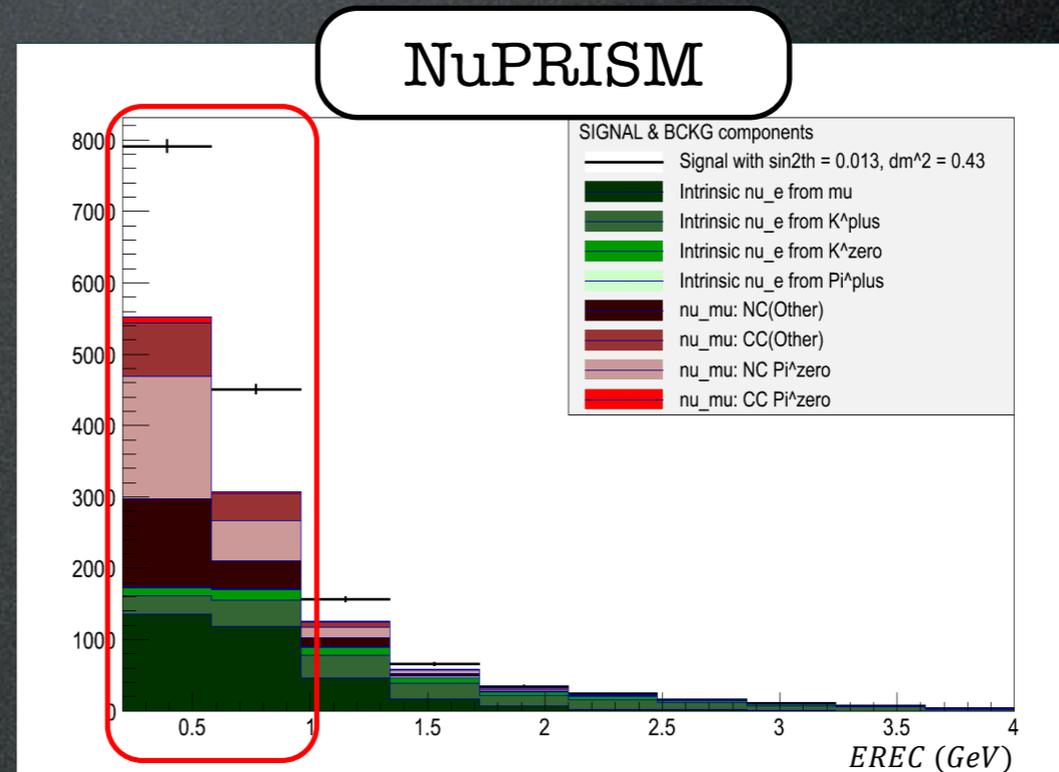
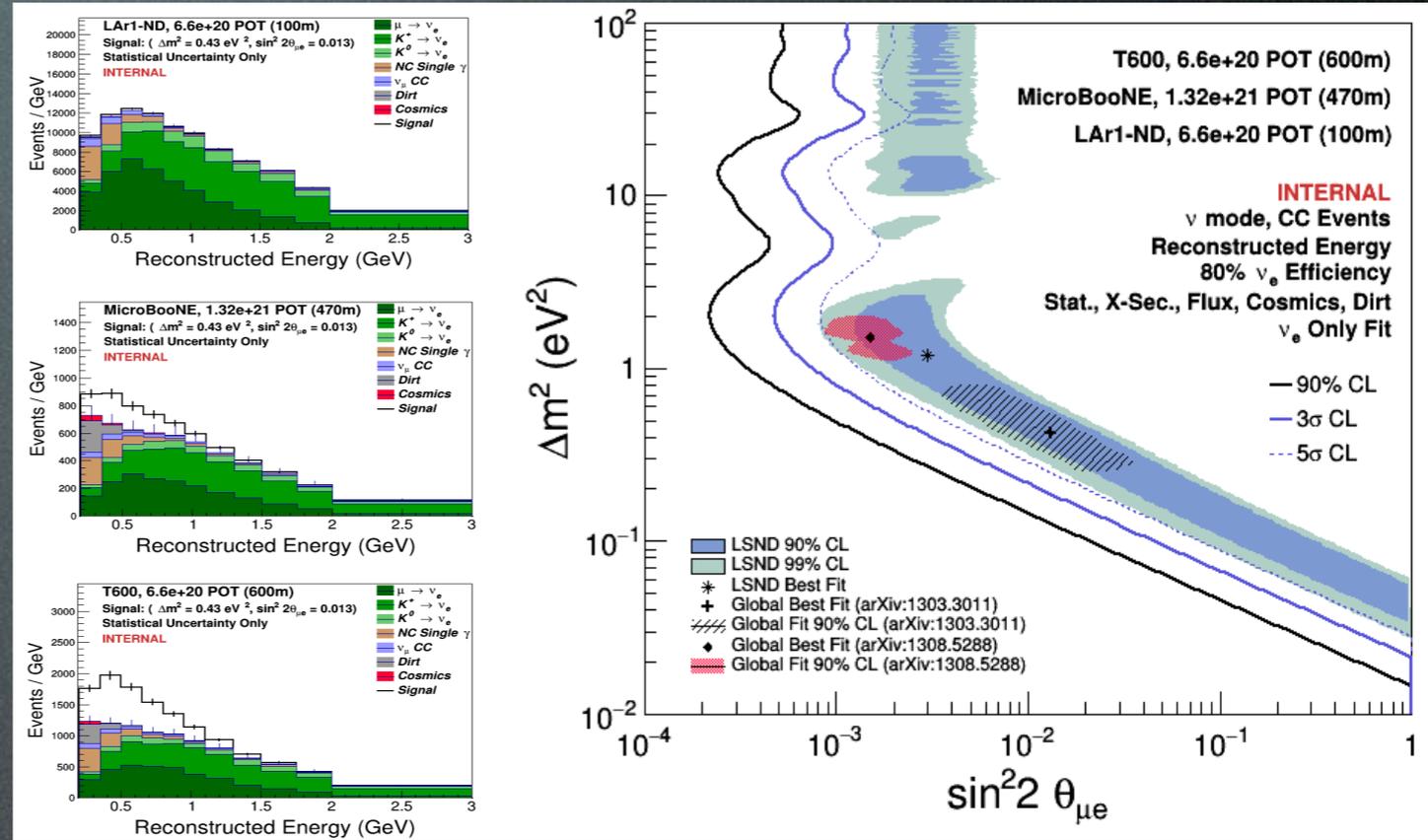


| nuPRISM-lite Position | Purity |
|-----------------------|--------|
| 1.0-1.6° | 30.6% |
| 2.0-2.6° | 47.8% |
| 3.0-3.6° | 68.6% |

Sterile Analysis

Fermilab LAr SB Sensitivity

- Goal is to properly compare NuPRISM with other sterile neutrino sensitivities
- Fermilab SBN
- J-PARC MLF experiment
- Reproducing these plots for NuPRISM will be important to contextualize our sensitivities
- Some short term studies are planned
- Investigate uncertainties on each bkgd
- Explore how reducing particular bkgds with NuPRISM control samples can improve sensitivity



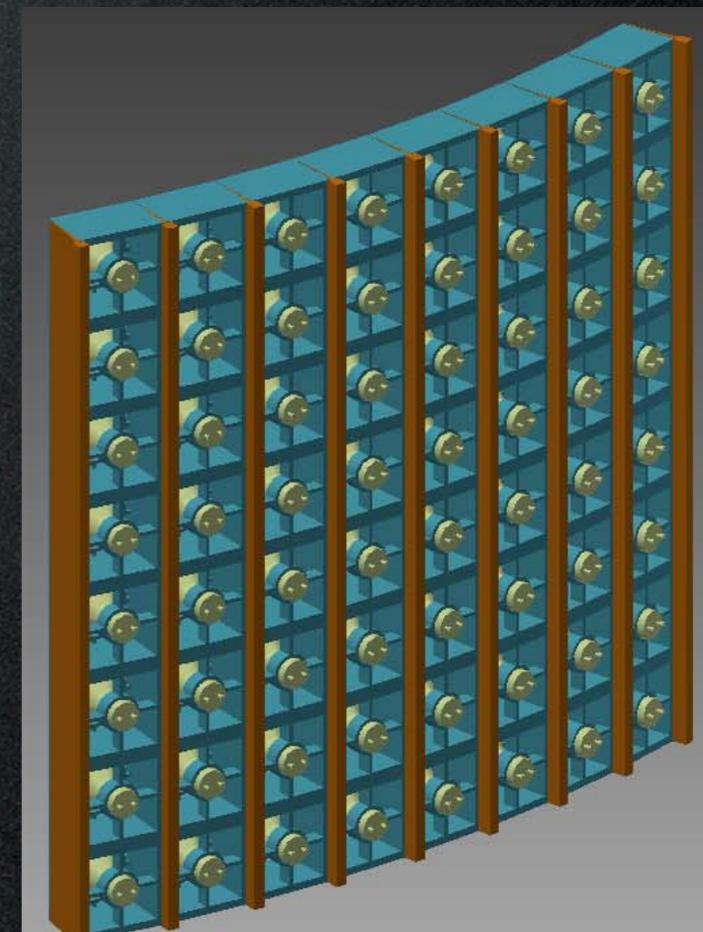
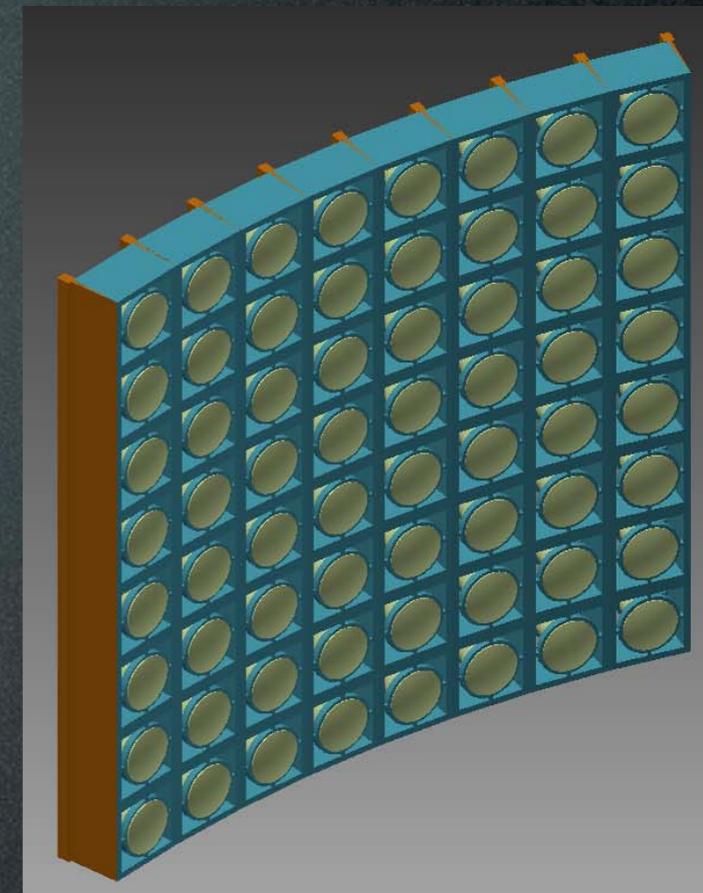
NC backgrounds are dominant (need to check with realistic simulation & reconstruction)

Simulation and Reconstruction

- **One of the main goals of this meeting is to incorporate WCSim+FitQun in the analyses**
- Currently, the NuPRISM geometry is using the default WCSim 8" PMT (more from M. Scott)
 - In WCSim, 8" PMT = 20" PMT with one parameter modified (time resolution constant)
- FitQun tuning requires several code modifications that exist in a separate copy of WCSim
 - Currently attempting to replicated official NuPRISM geometry in this version of the code
 - We should merge all needed WCSim code this week
- All tuning MC and analysis scripts have been produced
 - PMT charge response inputs are ready
 - Scattering table files are generated
 - PMT angular distribution MC has been generated
 - All the time pdf MC has been generated, and the analysis scripts have been adapted to WCSim
 - Need to finish assembling these pieces this week
- In the future we should explore other options
 - HPDs & HQE PMTS
 - Different sizes: 8", 5", etc.
- For the proposal, we likely only have time to stick with the existing 8" PMTs

Detector Design

- Building a very large PMT structure that can move vertically is a very challenging engineering problem
 - Very large volume filled with water that must maintain structural integrity while being pulled through the pit
 - Must use materials that can withstand ultrapure water (expensive!)
 - Also must ensure that PMTs are not damaged while moving the structure
- Currently working with an engineer at Stony Brook to put together some strawman designs of the tank and PMT array
 - Plastic housing around PMTs to act as a shock absorber, and allow for individual removal and maintenance
 - A series of I-beams (not pictured) to provide structural support for the structure
- We may try to have somewhat regular meetings if others are interested in discussing plausible designs that can be included in the proposal



Cost Estimates

- LOI had a very crude cost estimate of the entire project
- Cost drivers (PMTs and civil construction) were based on real numbers from companies
 - Although the civil construction depends on a geological survey of the eventual site
- Most of the remaining costs were taken from the T2K 2 km proposal
 - Exchange rate of 107 yen / \$
 - 2005 prices assumed (i.e. flat Japanese inflation rate)
- We must decide which items need more precise cost estimates for the proposal
 - PMT support structure cost may be underestimated

TABLE IV. Summary of nuPRISM project costs, excluding any contingency. Costs taken directly from the T2K 2 km proposal are labeled with *

| Item | Cost (US M\$) |
|---|---------------|
| Cavity Construction, Including HDPE Liner | 6.00 |
| *Surface Buildings | 0.77 |
| *Air-Conditioning, Water, and Services | 0.50 |
| *Power Facilities | 0.68 |
| *Cranes and Elevator | 0.31 |
| *PMT Support Structure | 1.27 |
| 3,215 8-inch PMTs | 4.30 |
| PMT Electronics | 1.45 |
| *PMT Cables and Connectors | 0.13 |
| Scintillator Panels | 0.36 |
| Water System | 0.35 |
| Gd Water Option | 0.15 |
| *GPS System | 0.04 |
| Total | 16.31 |

Summary

- The NuPRISM proposal will be submitted in just under 3 months
 - Time is short to make significant analysis upgrades
- Implementing simulation & reconstruction this week should enhance several analyses
 - Particularly the sterile and long-baseline ν_e analyses
- For the proposal, we should be sure to explain what NuPRISM might reasonably achieve (not just what we can already prove today)
- Let's try to strengthen our physics case over the next three months!