Discussion of nuPRISM Analysis Tasks Towards the Proposal

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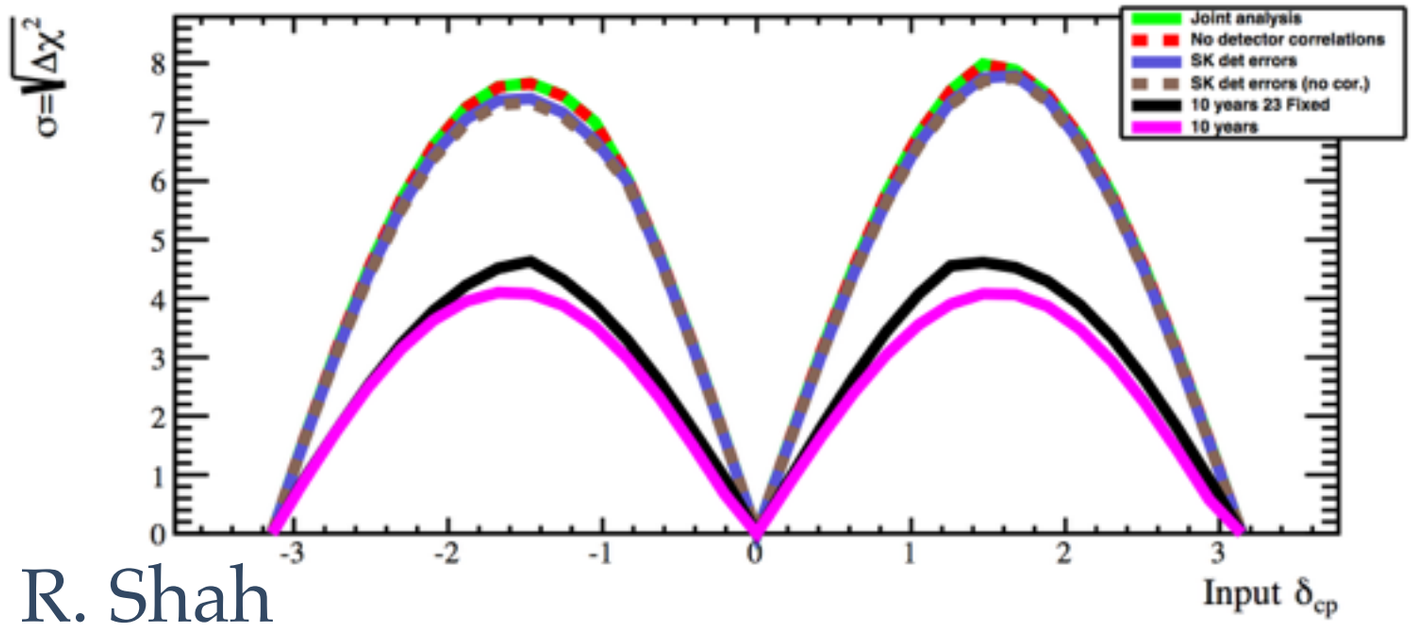
nuPRISM Analyses

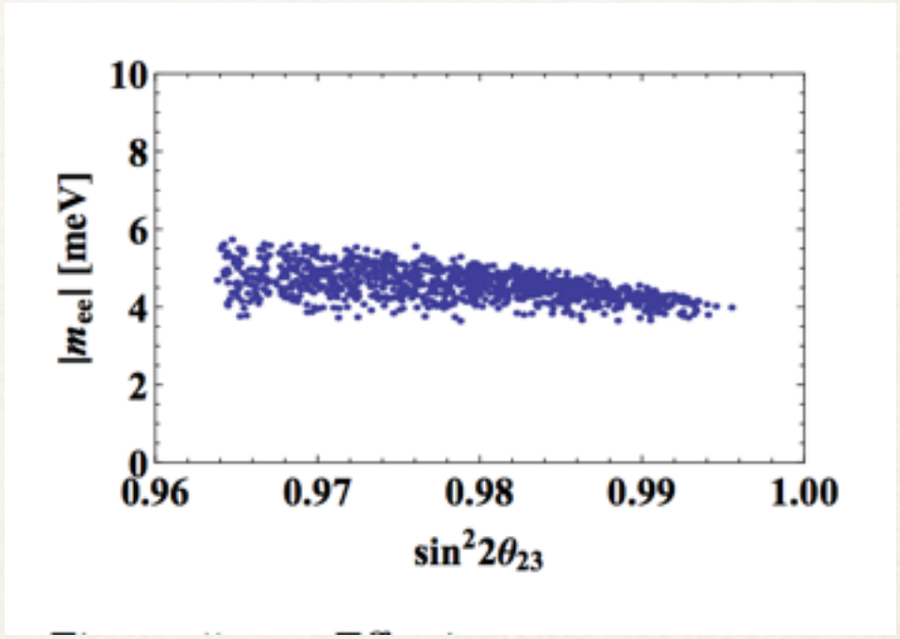
- Muon neutrino disappearance analysis:
  - Optimization of systematic errors for full contours
- Electron neutrino appearance analysis:
  - Development of extrapolation method
  - Optimization of PMT configuration for electron/muon/pi0 particle ID
- Short baseline electron neutrino appearance analysis:
  - Inclusion of the 1 ring mu control sample
  - Optimization of PMT configuration for electron/muon/pi0 particle ID
- Antineutrino analyses
- Cross section measurements
- Measurements for atmospheric analysis and proton decay analysis

Muon Neutrino Disappearance Motivation

- Recent studies by Raj show that the θ_{23} measurement in the disappearance channel is not critical for the CPV measurement
- However the measurement of θ_{23} itself is important
  - Some models for the neutrino mixing matrix predict 45 degrees while others do not
  - We should clearly present this motivation in the proposal, especially since Japan has been a leader in the theory of neutrino masses



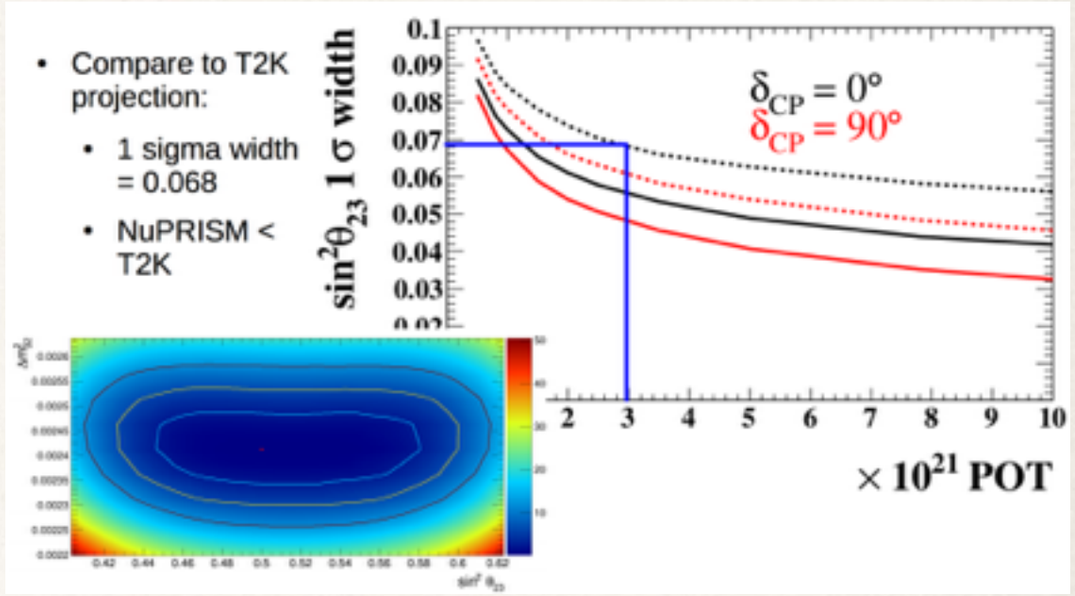
R. Shah

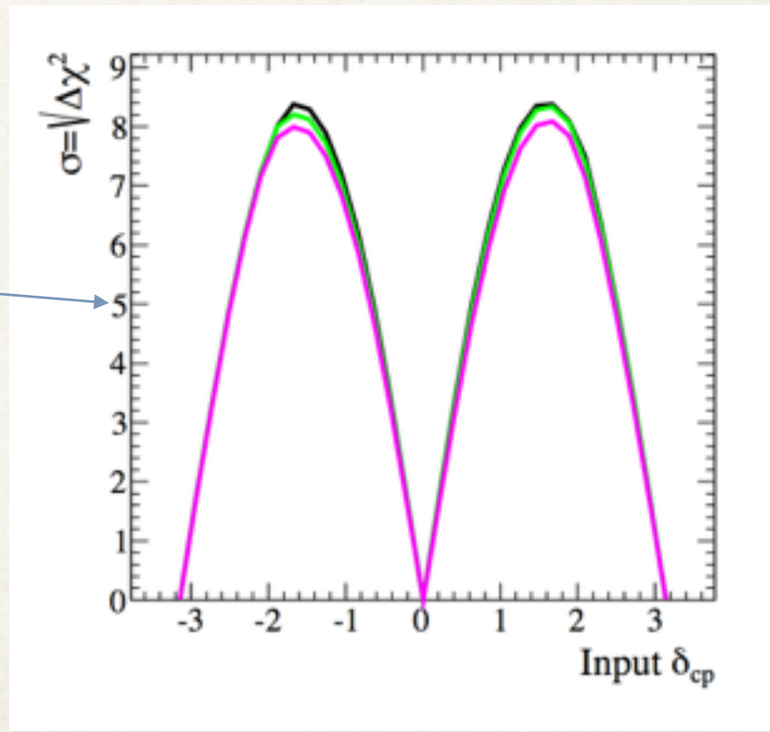


arXiv:1204.2389 - M. Fukugita, et. al.

Muon Neutrino Disappearance Status

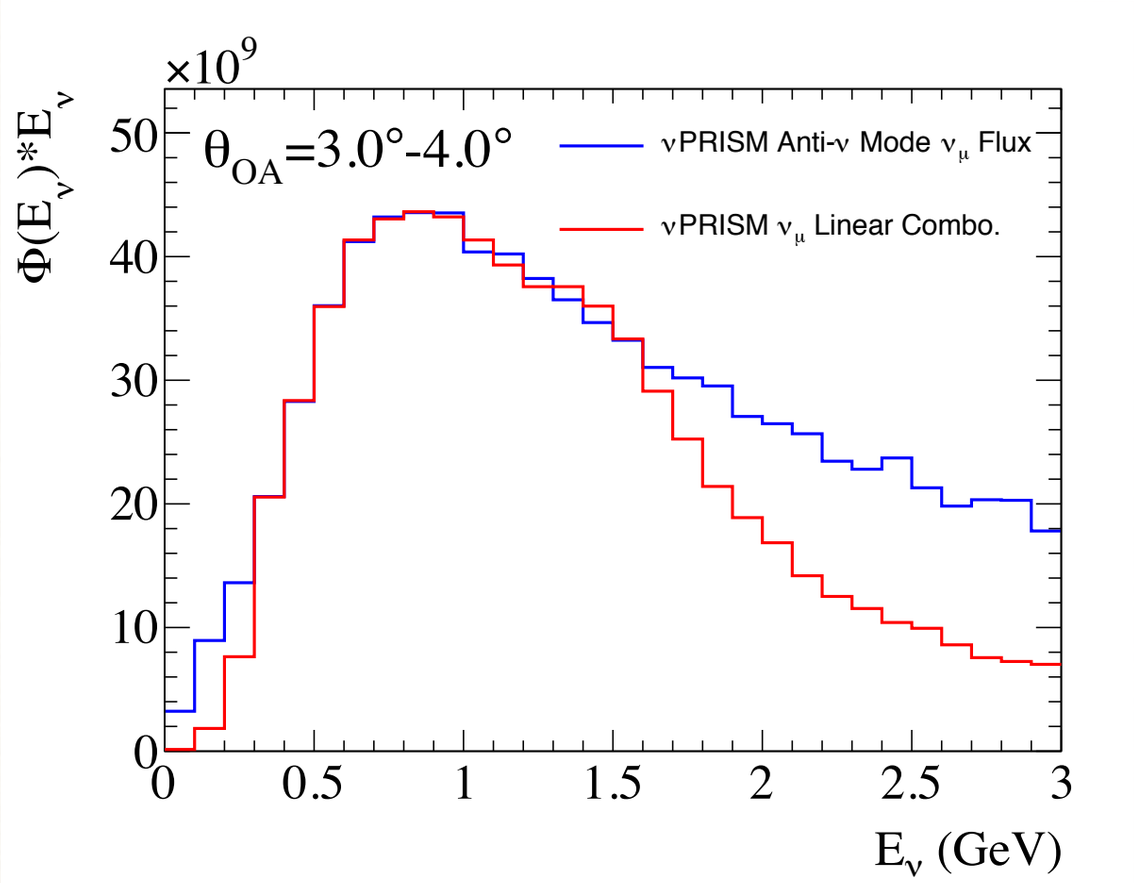
- At the last face-to-face meeting, M. Scott showed full contours with flux and x-sec systematic errors
- We may need some optimization of the coefficient selection to minimize the systematic error size
- Ideally, we should show two types of plots
  - θ_{23} and Δm^2_{32} precision as a function of exposure with and without nuPRISM
  - Sensitivity to a non-45 degree value of θ_{23} as a function of the true value at T2K and HK exposures (similar to the δ_{cp} plots)
- How do we make the without nuPRISM case for these plots?
- Extra man-power?





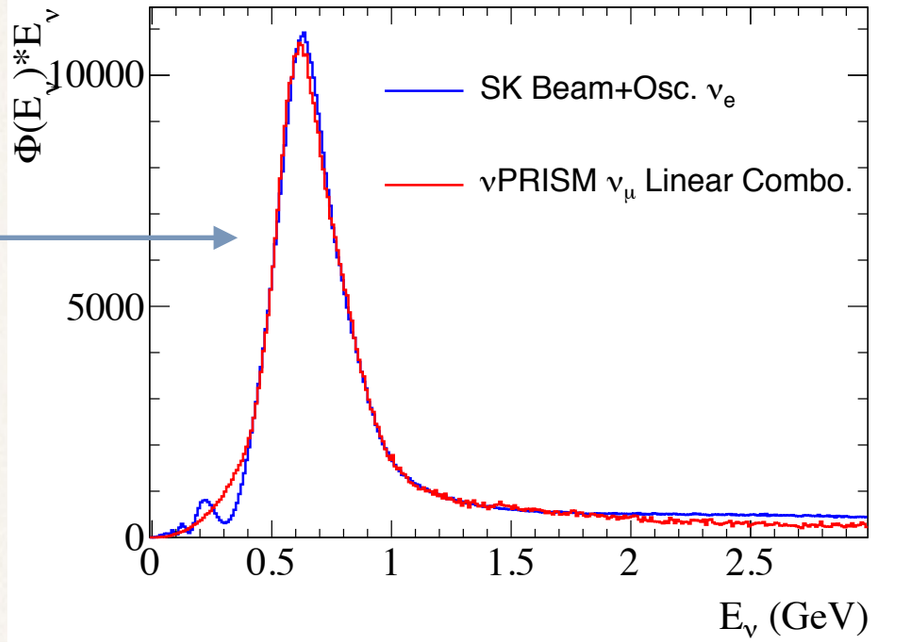
Antineutrino Treatment

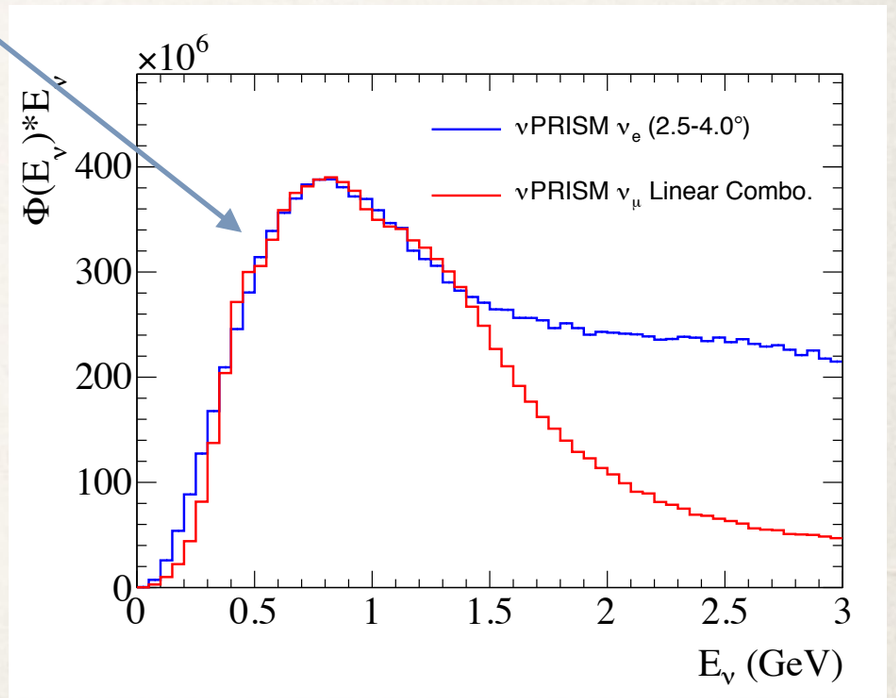
- We should extend the disappearance analysis (and all analyses) to antineutrinos
- Requires the additional step of modeling the wrong sign background with linear combinations of the right sign neutrino flux
- L. Haegel is working on this, but could use help



nuPRISM for CPV Measurement

- This analysis requires a two step approach
  - Use the usual linear combination method to reproduce the intrinsic nue+oscillated nue flux at the far detector using the numu flux at nuPRISM
    - If electron and muon had the same mass, this would be sufficient
  - Use the linear combination method to reproduce the intrinsic nue flux at nuPRISM using the numu flux at nuPRISM
    - Can measure the double differential nue/numu cross section ratio with the same flux
    - Use this measurement to correct the prediction from the first step
    - Can also use nuPRISM to constrain the CC numu and NCpi0 backgrounds from the nuPRISM nue measurement





nuPRISM for CPV Measurement, Cont.

- Kendall and the MSU group are starting on the analysis steps for CPV
  - Using the disappearance analysis code as a starting point for extrapolating the appearance+intrinsic background
  - Development of the cross-section ratio measurement and evaluation of the flux systematic uncertainties
  - Development of the nu_mu to nu_e “extrapolation”
    - What are the best variables to use
    - Additive, multiplicative or migration type correction?
- Tomoyo Yoshida will work on the optimization of the PMT configuration to improve the electron selection efficiency and purity
  - Requires running WCSim+fiTQun for new PMT size/spacing
  - When results are available, can plug into the analysis framework from the MSU group

nu_e Appearance Sterile Analysis

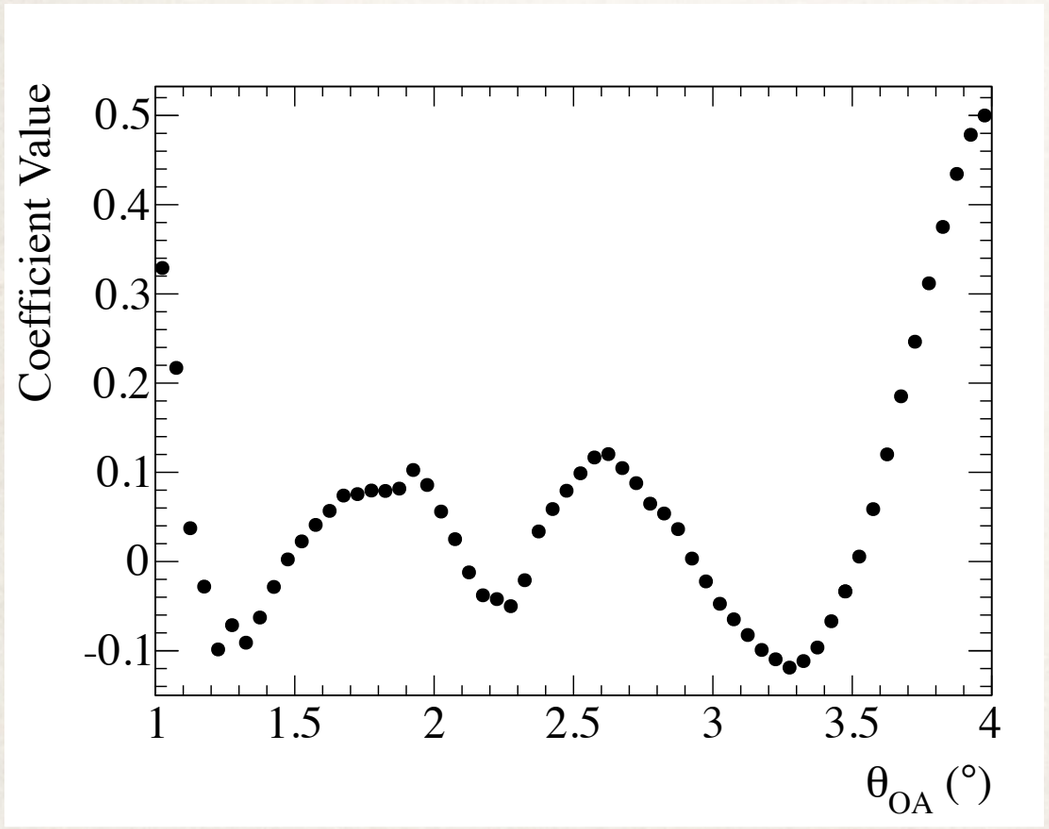
- Areas for improvement
  - Combined nu_e-nu_mu candidate fit
  - Using the WCSim+fiTQun MC with better nue efficiency and purity
  - Combination with ND280 data
- Additionally, we can study the insensitivity to false positives that could be consistent with the excess observed at MiniBooNE
  - For example, an increased NC-gamma background, more feed-down from CC interactions or mis-modeling of the NCpi0 efficiency
- Should also include a nuPRISM detector systematic error model
- S. Bordoni and J. Vo (at the workshop) will work on the sterile analysis

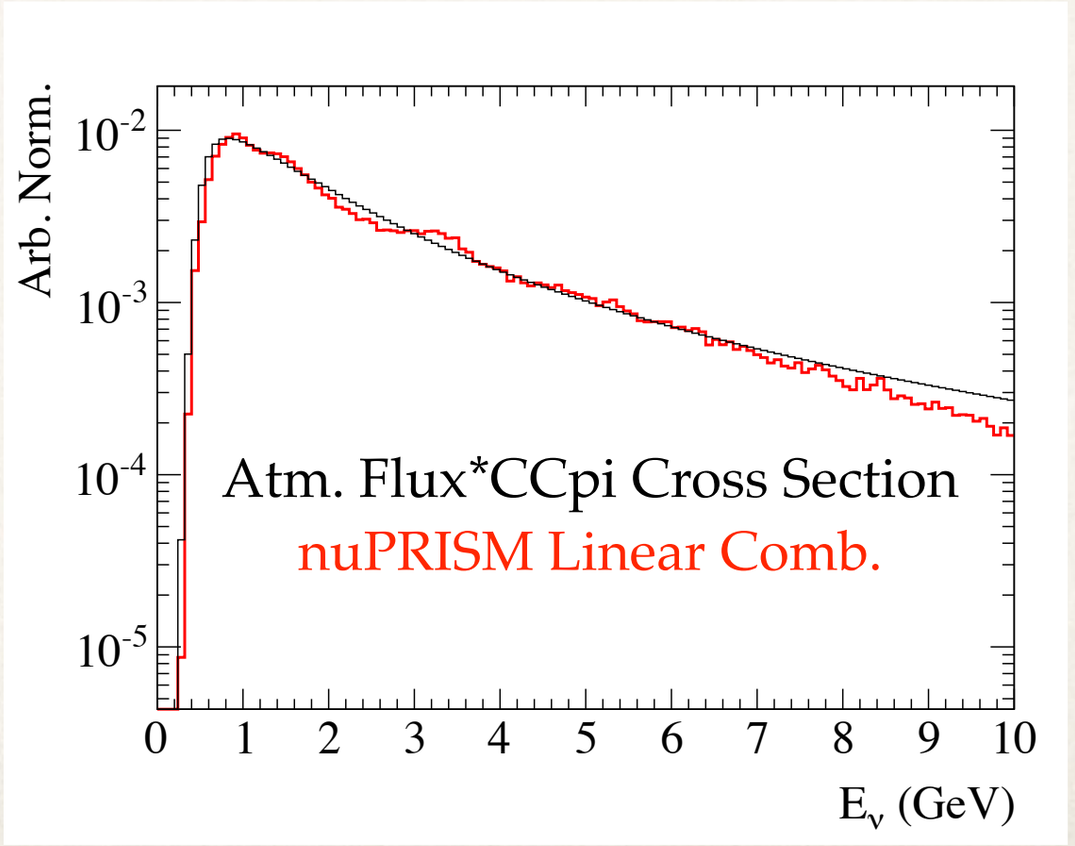
Other physics capability studies

- Single lepton ring cross section measurements (mono-chromatic beams)
  - Mono-chromatic analysis appears to be working
- The study of cross-sections with multi-ring candidates and background measurements (NCpi0, CC1pi+, NCpi+, CC multi-pi, etc.)
  - These require the full reconstruction to produce samples with multi-ring final states
- Constraints for atmospheric neutrino measurements:
  - Angular distribution of 400-1000 MeV single ring events for CP violation (see Akira's talk at the HK Meeting) can be done with mono-chromatic beams
  - Measurements of 2-10 GeV multi-ring events for the mass hierarchy measurements (more on next slide)
  - Calibration of neutrino/antineutrino separation using neutron tagging with Gd in nuPRISM
- Proton decay backgrounds
  - Measurement of e-pi0 or kaon backgrounds with the atmospheric flux

Measurements for Atmospheric Samples

- nuPRISM can also be used to constrain systematic uncertainties for atmospheric samples
- In the atmospheric data, events around 3-10 GeV are sensitive to the mass hierarchy
- In multi-ring events, the number of Michel electrons or non-leptonic part of the event are used to make a statistical separation of neutrinos and antineutrinos
  - These properties of the events can be constrained with nuPRISM
- The atmospheric flux*CCpi cross section can be reproduced at nuPRISM:





Analysis Tools

- WCSim for nuPRISM is now working
  - Will start generating large MC samples with baseline PMT configurations this week
  - May start with particle guns for the PID studies
- fiTQun for nuPRISM is almost working
  - Will focus on this today and tomorrow
- Analysis tools need to be adapted to the fiTQun outputs?
  - Or do we use the old analysis tools and just implement new efficiency tables
- Should work on a better interface for applying flux and cross section systematic errors

Goals for this week

- Fully functioning WCSim+fiTQun for nuPRISM with tuning
  - Procedure for implementing new PMT configurations
  - Plan for detector configuration studies
- Develop a plan to finish the muon neutrino disappearance analysis
  - Optimization of the coefficients/systematic errors?
  - Improved assumptions about the systematic errors in the correction step of the analysis
- Develop the plan for the nu_e appearance analysis
  - Two step approach with existing tools
  - PMT configuration optimization -> improving PID
    - Update analysis with new efficiency tables?
- For the sterile analysis, what improvements can we achieve by the proposal?