Constraining ν Flux in NOνA

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Flux Measurement and Determination in the Intensity Frontier Era Neutrino Beams, Pittsburgh, PA

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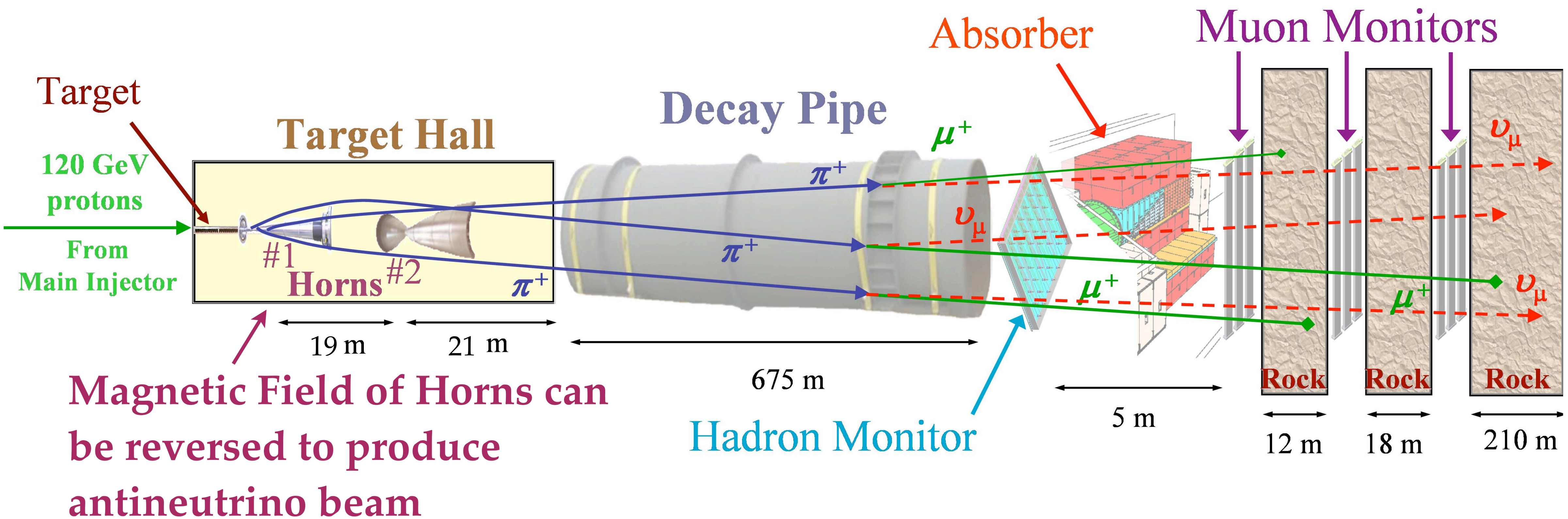
Outline

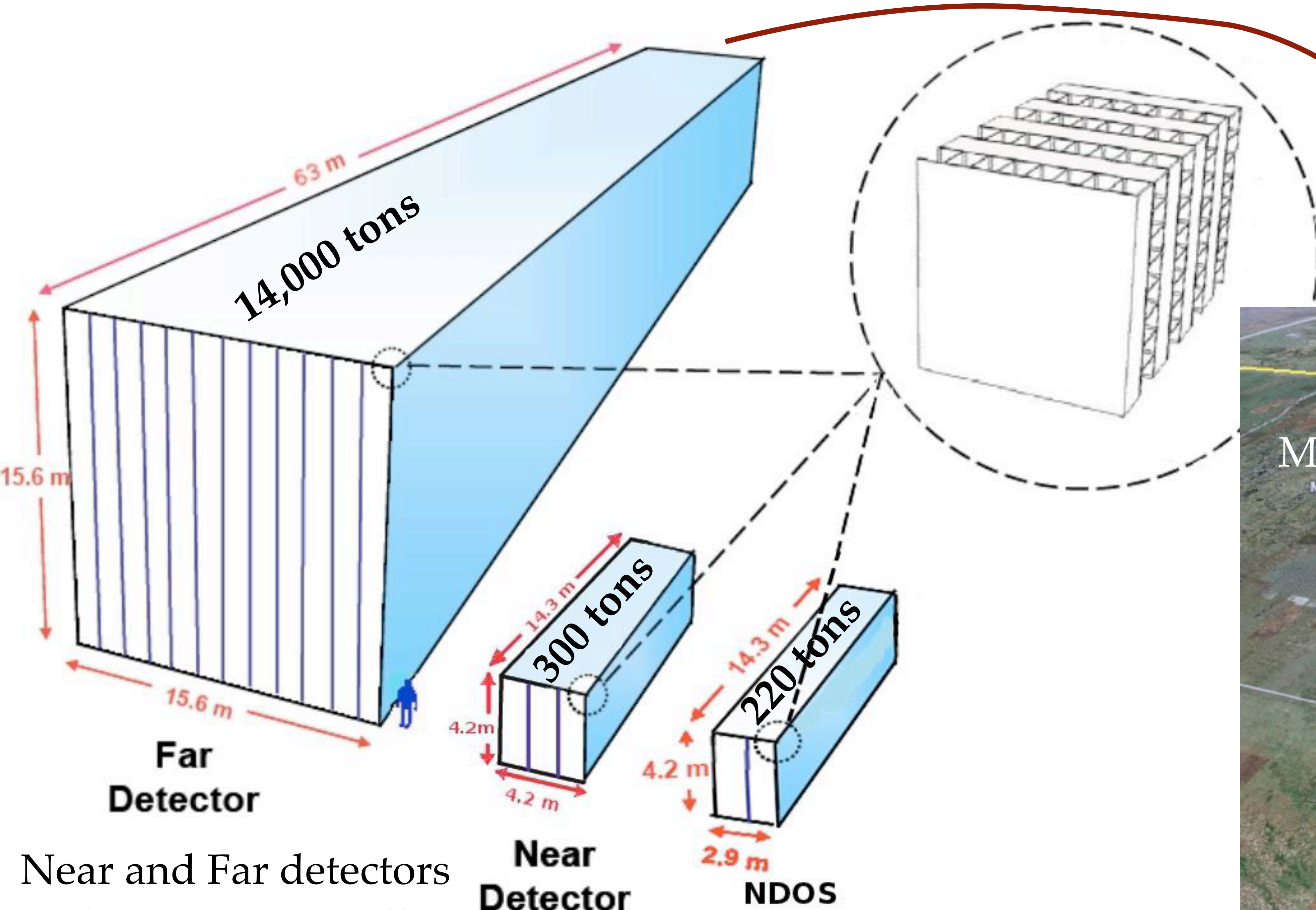
- NOvA Overview and Current Status
- Simulated Neutrino Flux
  - FLUGG
  - Geant4
- Current Flux Constraint Efforts
  - CCQE Analysis at NDOS
  - Fitting NDOS and MINOS Simultaneously
- Flux Constraint Plans

NOvA Overview and Current Status

The NuMI Beam



- Currently being upgraded for NOvA
  - More powerful proton beam (~350 kW → ~700 kW)
  - New target design and location
  - Horn 2 moved to 19m downstream



Near and Far detectors will be 14.6 mrad off-axis

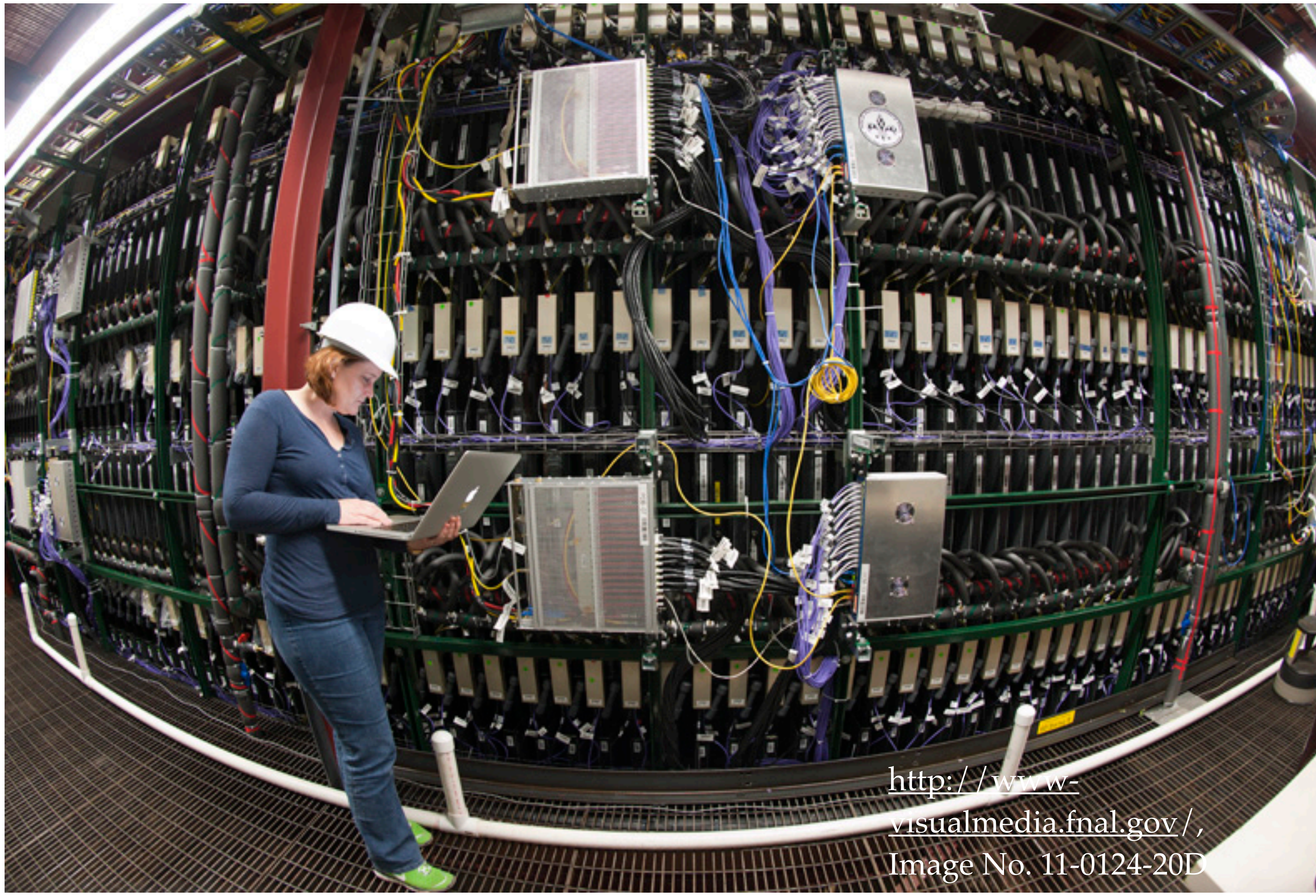
NDOS = Near Detector on the Surface, ~110 mrad off-axis

NOvA Detectors

NDOS is Built and Functioning

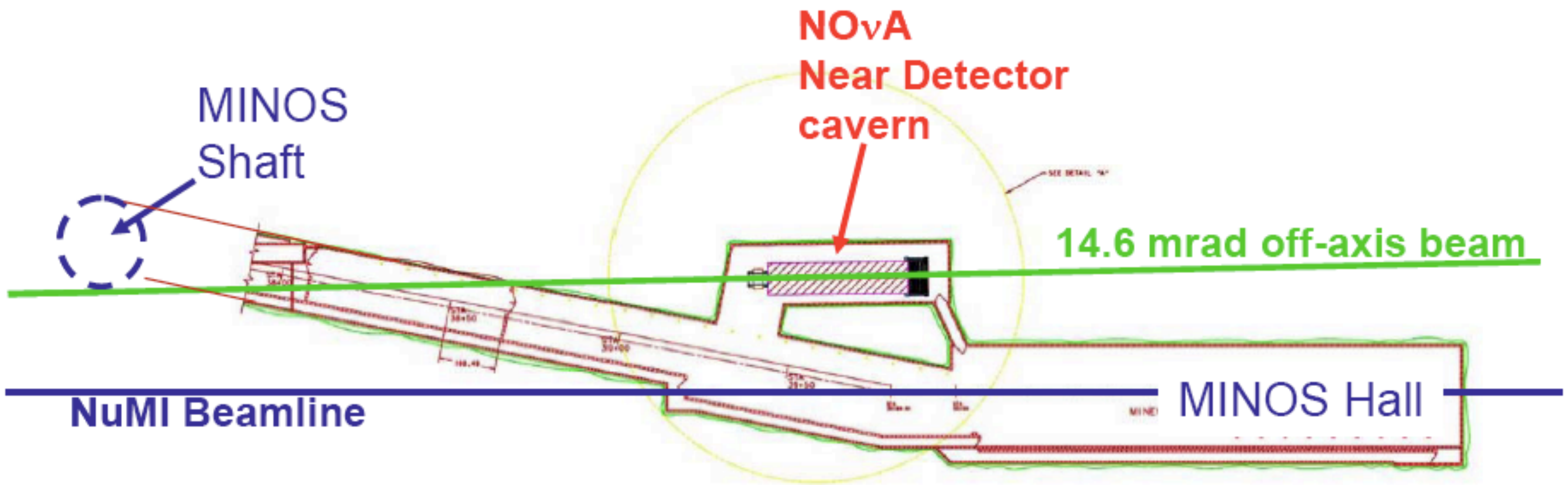
http://www-visualmedia.fnal.gov/, Image No. 11-0124-13D

- Our prototype near detector
- It has taught us many valuable lessons for building NOvA near and far detectors.



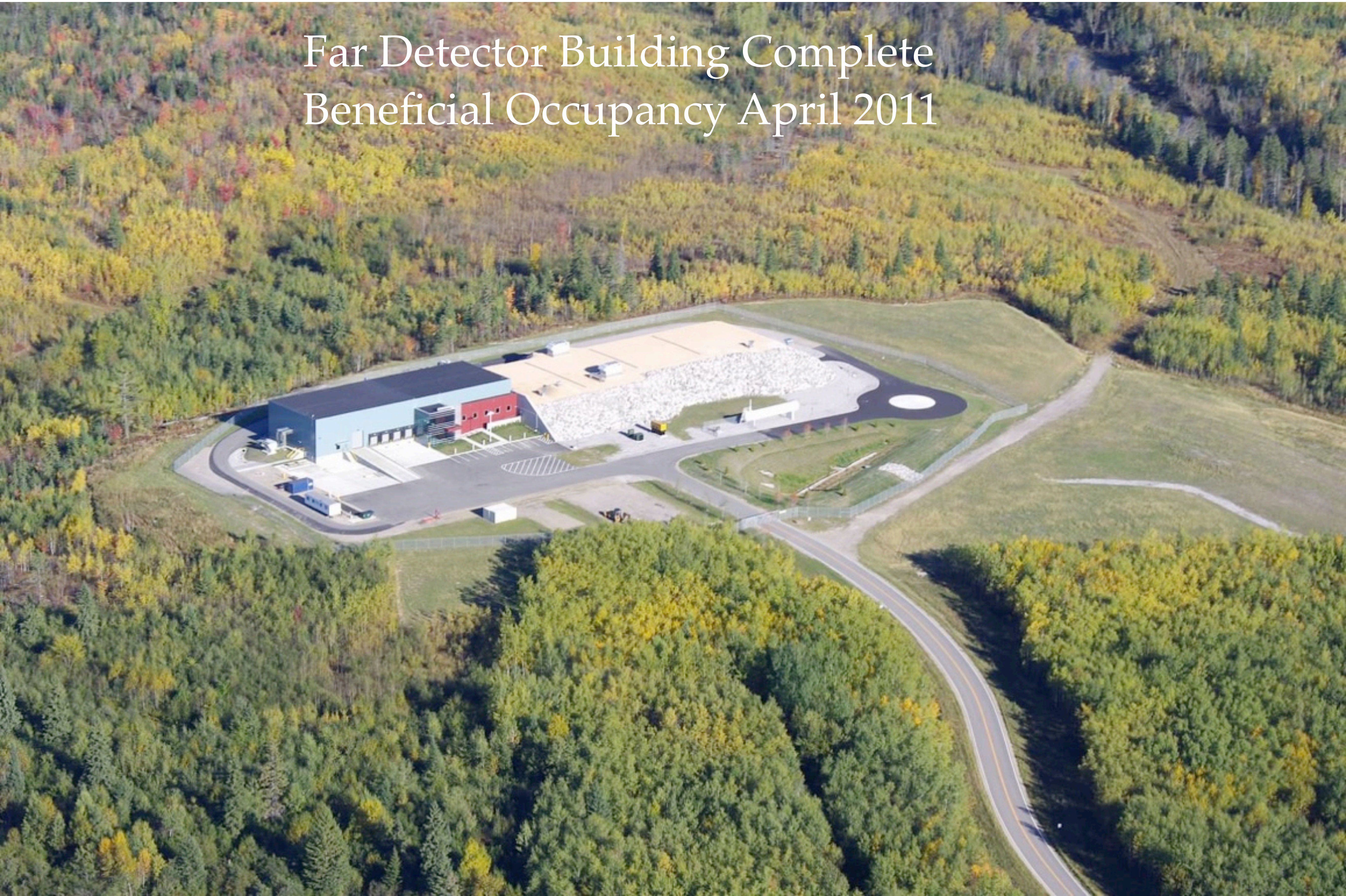
http://www-visualmedia.fnal.gov/, Image No. 11-0124-20D

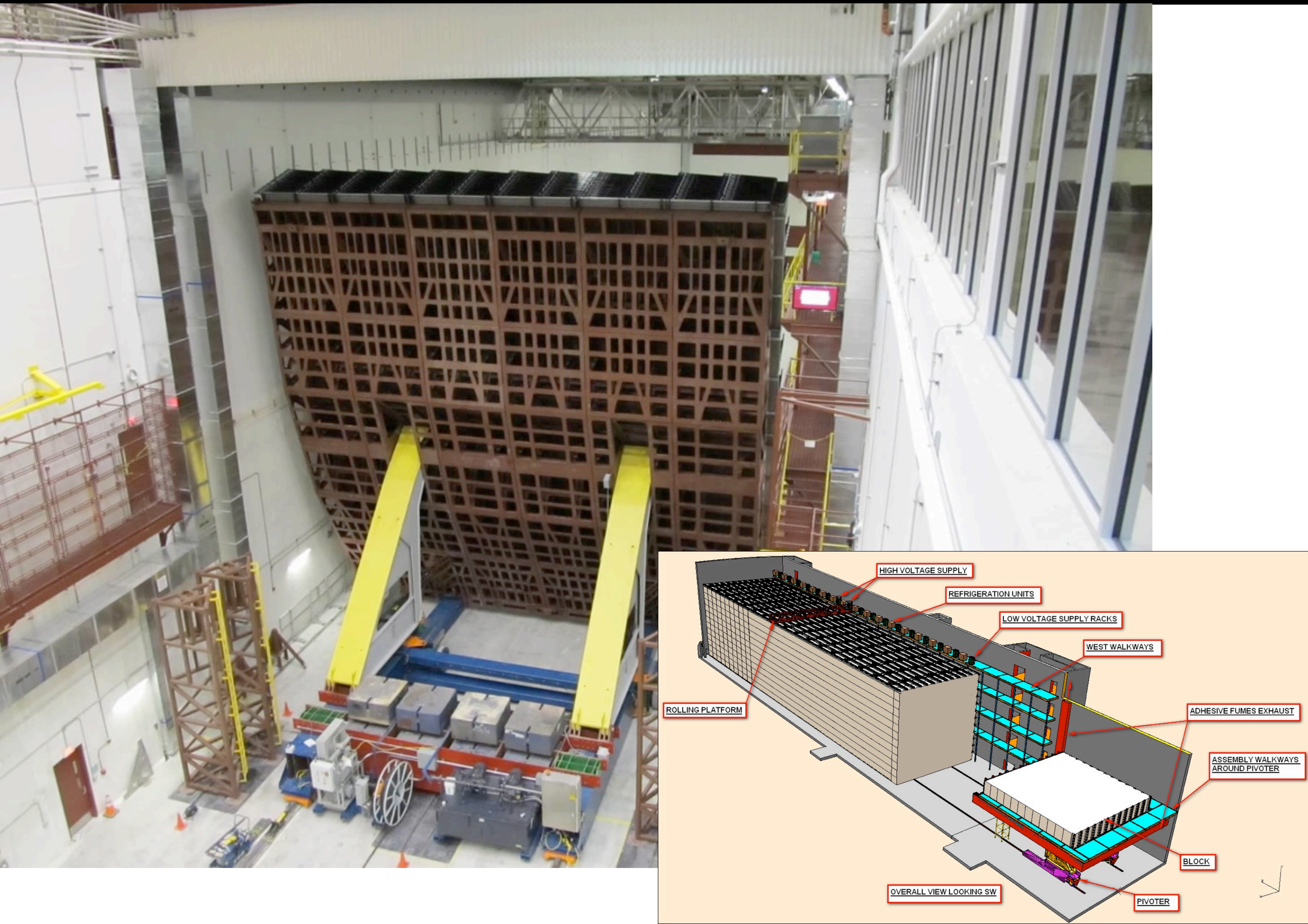
Near Detector Excavation



http://www-visualmedia.fnal.gov/, Image No. 12-0321-03D

Far Detector Building Complete
Beneficial Occupancy April 2011




HIGH VOLTAGE SUPPLY
REFRIGERATION UNITS
LOW VOLTAGE SUPPLY RACKS
WEST WALKWAYS
ROLLING PLATFORM
ADHESIVE FUMES EXHAUST
ASSEMBLY WALKWAYS AROUND PIVOTER
BLOCK
PIVOTER
OVERALL VIEW LOOKING SW

Far Detector

First block in place and freestanding on Sep. 10, 2012

We count blocks starting at 0. Construction on the sixth block (Block 5) will begin soon.

Five Blocks on Dec. 6, 2012

Caveats

- Our efforts at constraining the flux on NOvA are in very early stages
- Our only data is from the NDOS
  - Small detector, farther off-axis than near and far detectors will be
  - It is a prototype, so data is often incomplete from multiple different configurations
- All of the plots, plans, and numbers in this talk are preliminary, early, and in flux.

Simulated Neutrino Flux

FLUGG Simulations

- FLUGG = Fluka + Geant4 Geometry
  - Fluka simulates the hadron production and interactions
  - Geant4 simulates the geometry
- Plots shown today will be for FLUGG 2009.3, Fluka 2008.3d, and Geant 4.9.3
  - Currently upgrading to latest version of Fluka

Pure Geant 4 Simulations

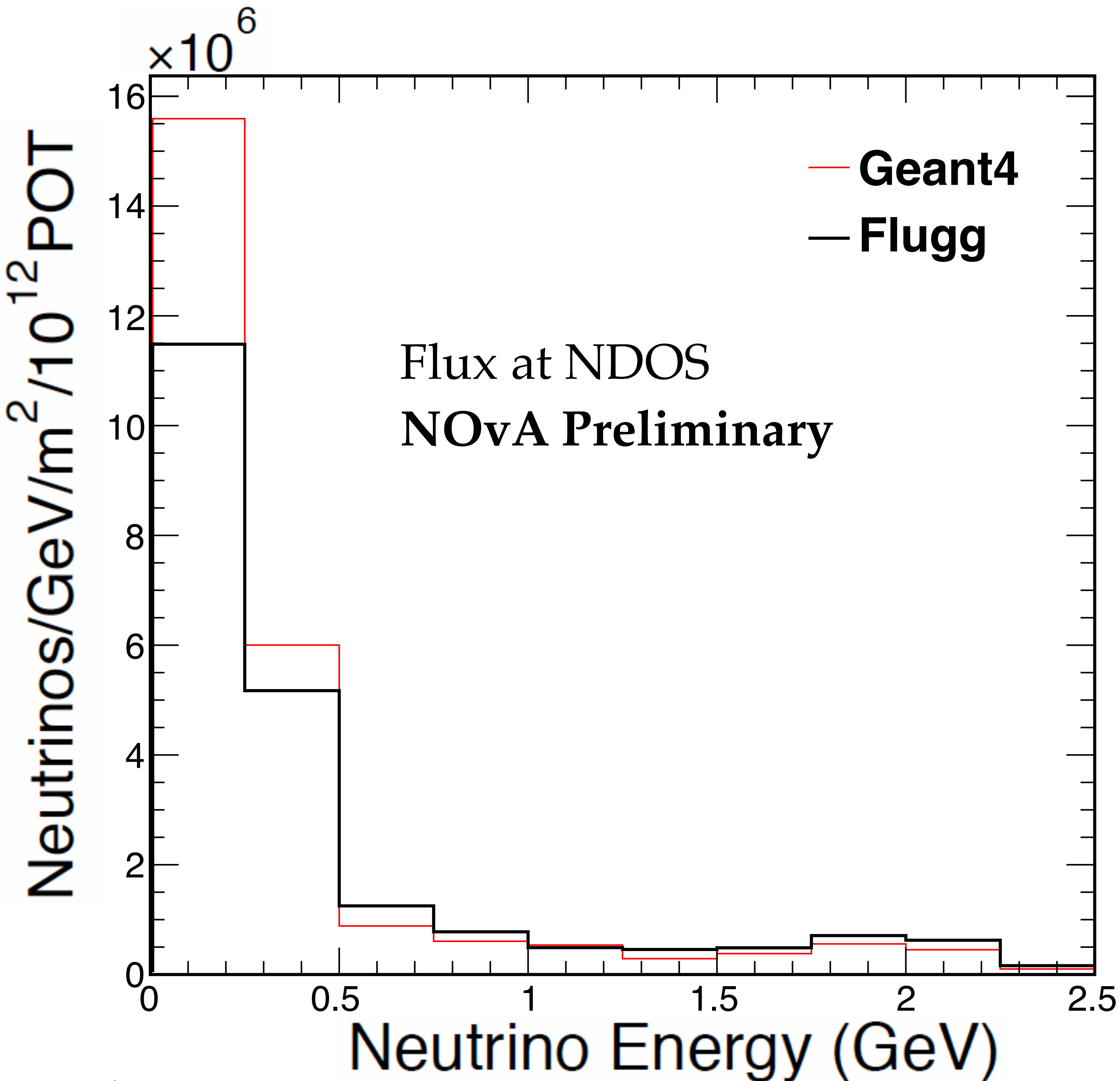
- Using Geant 4 for geometry and hadron production and interaction
- Plots today will have Geant 4 simulations from an implementation used by the LBNE collaboration
    - We are running using NOvA beam geometry (g4numi)
- NOvA implementation ready and being validated
- Will compare Geant 4 to FLUGG with Fluka 2011 when both are validated and running smoothly

Flux Constraints in the NDOS ν_μ CCQE Analysis

Relevance of Flux Constraints

- Minerba Betancourt measuring ν_μ Charged Current Quasi-Elastic (CCQE) cross-section at NDOS
- Uncertainty in the flux is a large systematic.
- Quantify that uncertainty through
  - Variations in the simulations
  - Differences in the FLUGG and Geant4 simulations
- First NOvA analysis to attempt constraints on the flux

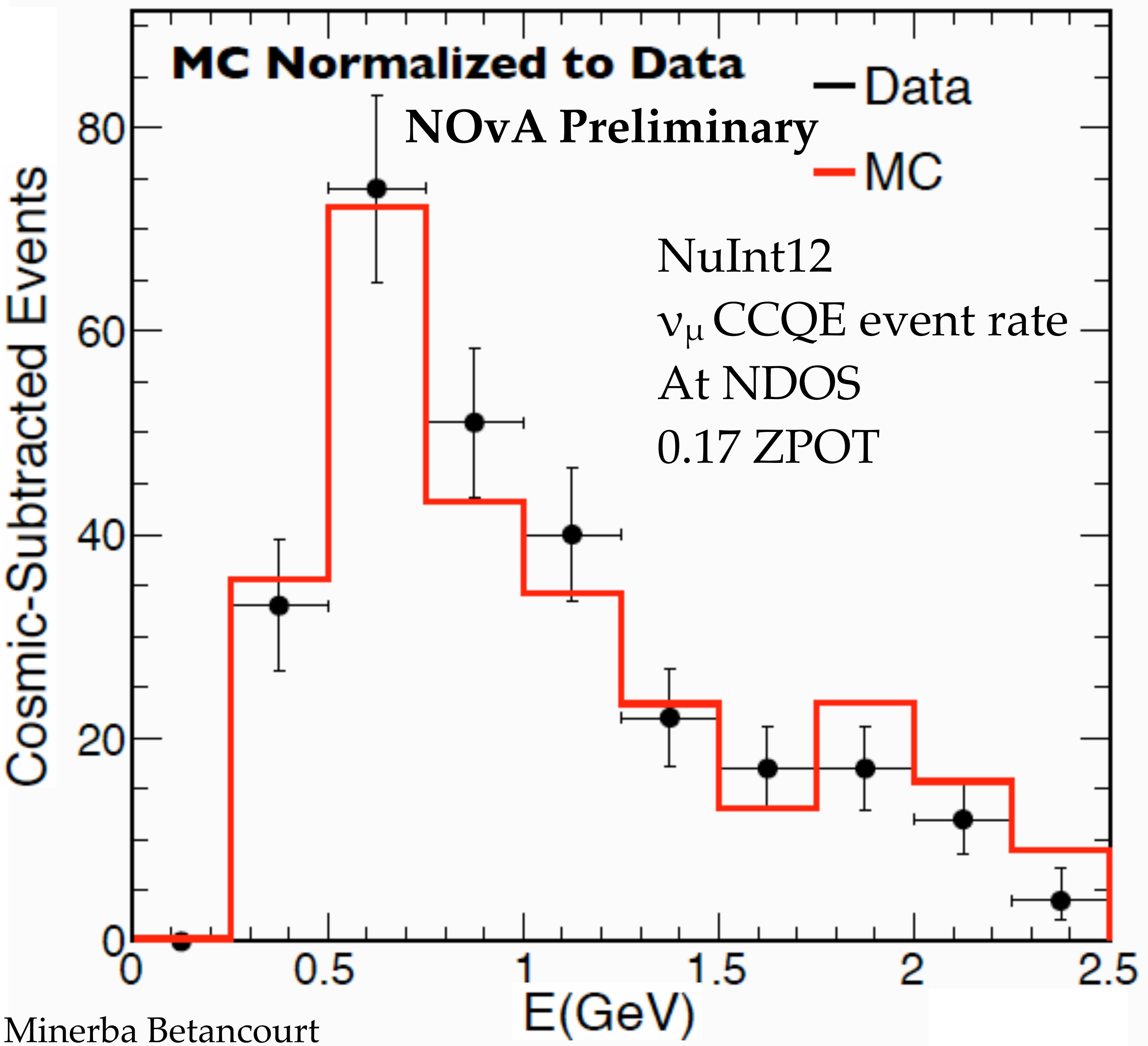
NDOS neutrino flux predictions



Minerba Betancourt

- Comparison of the Neutrino flux at the NDOS for Geant4 and FLUGG simulations.
- Difference is taken as part of systematic uncertainty
- No cross-section or detector effects included

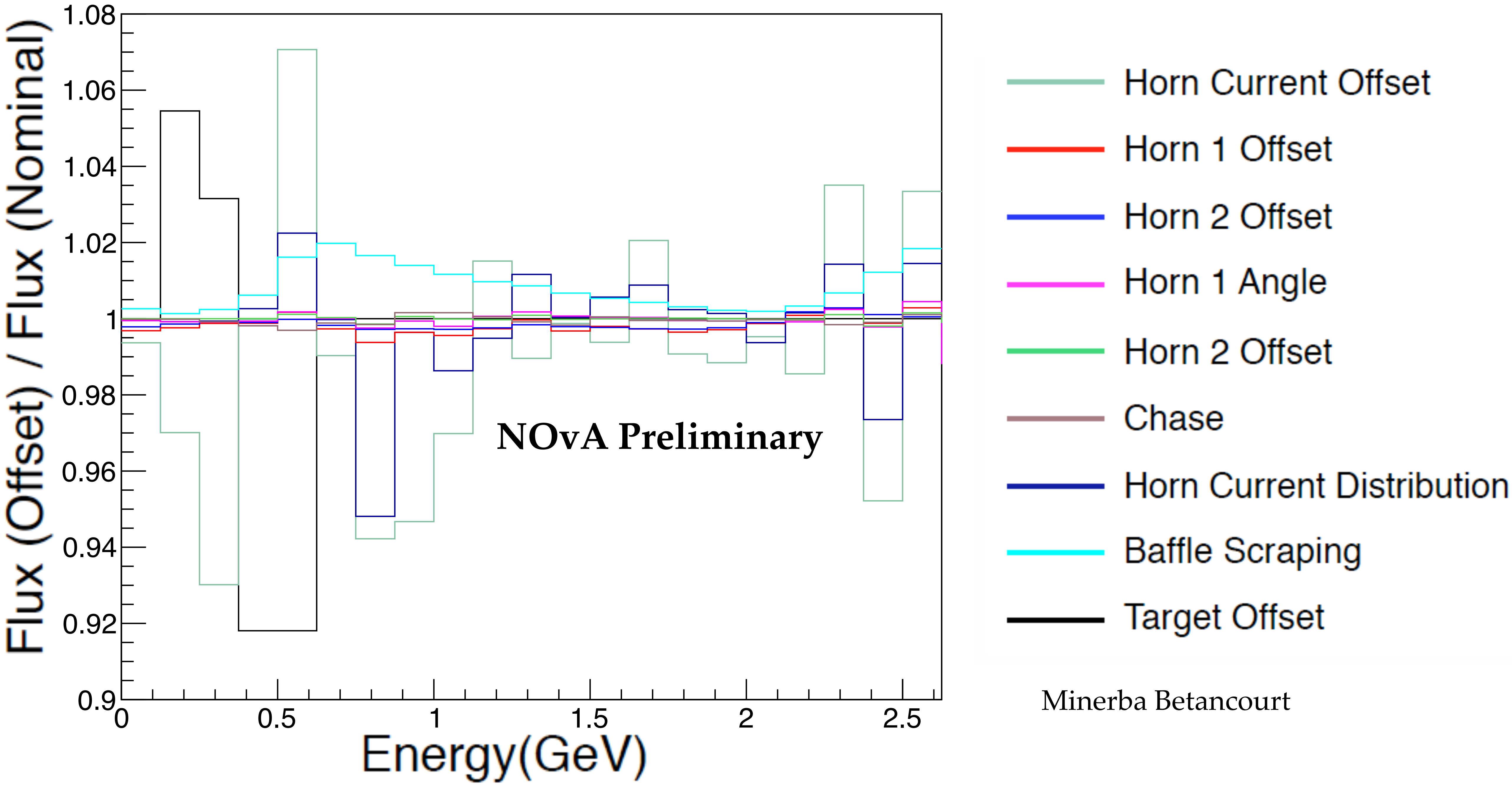
NDOS Data-MC Comparison



Minerba Betancourt

- Predicted ν_μ CCQE event rate at NDOS compared with data
- Area normalized to 1.7×10^{20} protons on target
- MC from FLUGG

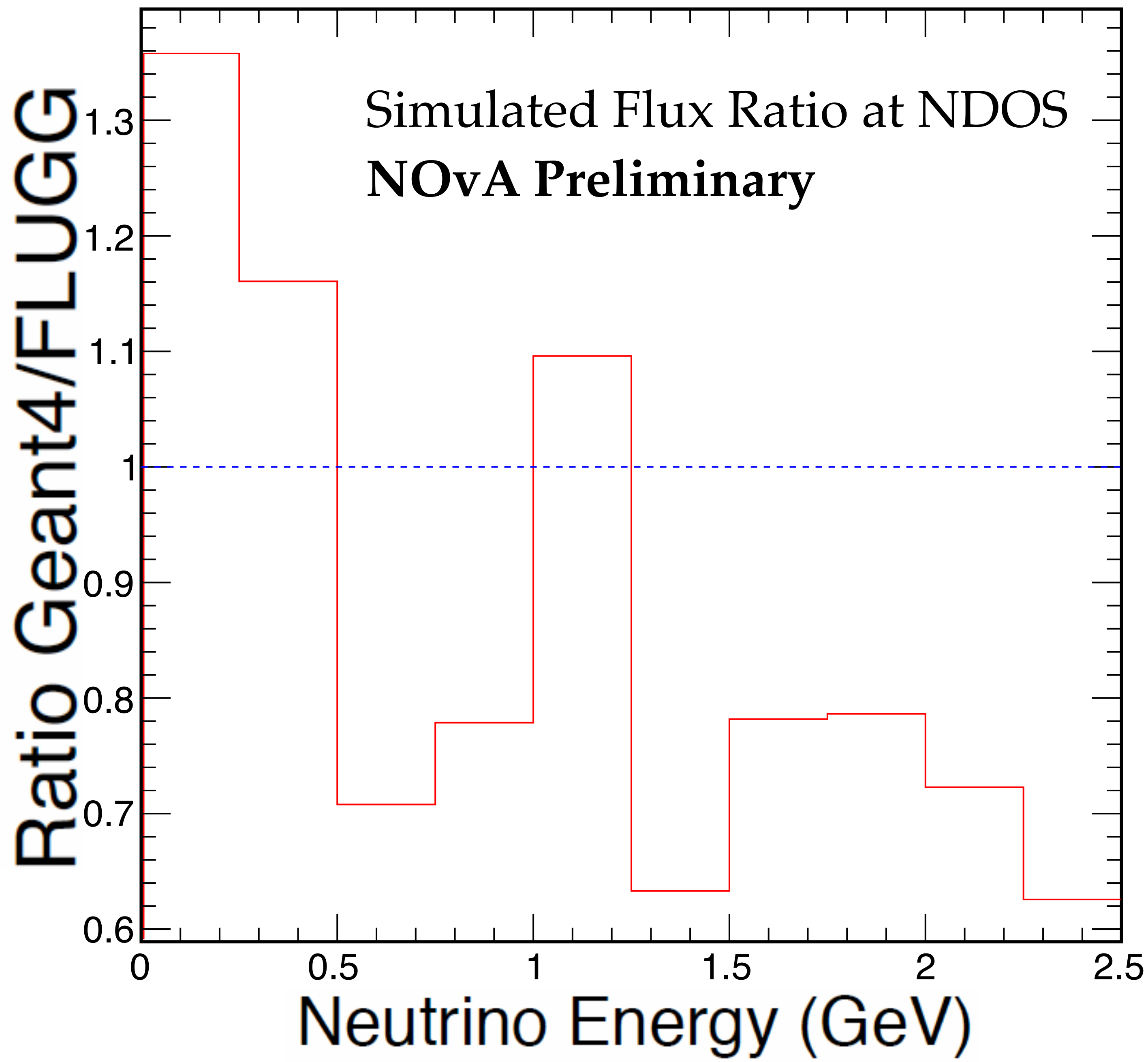
How well do we simulate the flux?



Minerba Betancourt

- Different aspects of simulation are offset from nominal
- Their ratio provides some of the uncertainty

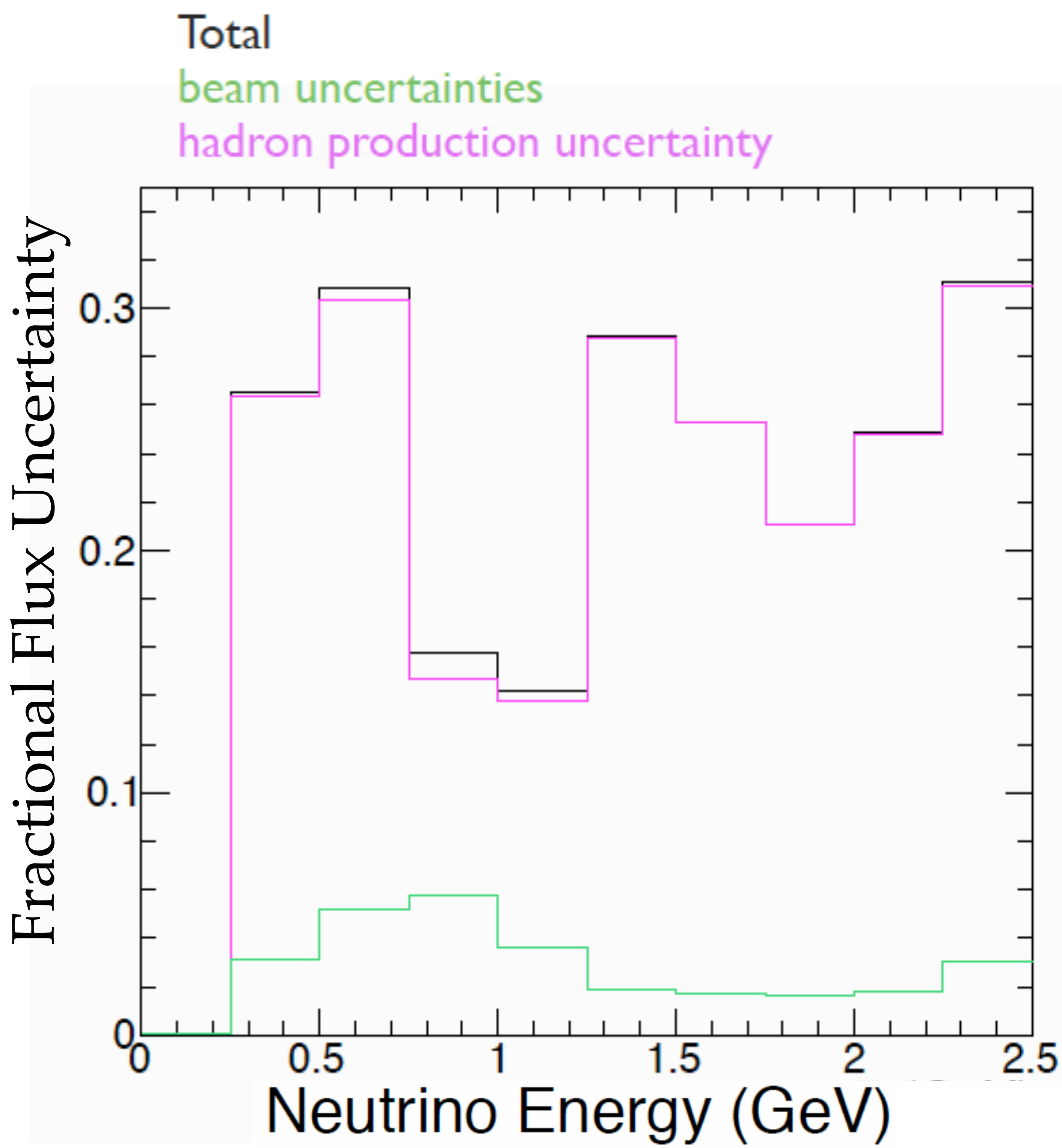
Differences in Simulations



Minerba Betancourt

- Ratio of the Neutrino flux at the NDOS for Geant4 and FLUGG simulations.
- Difference is taken as part of systematic uncertainty
- Statistical Uncertainty ~20%

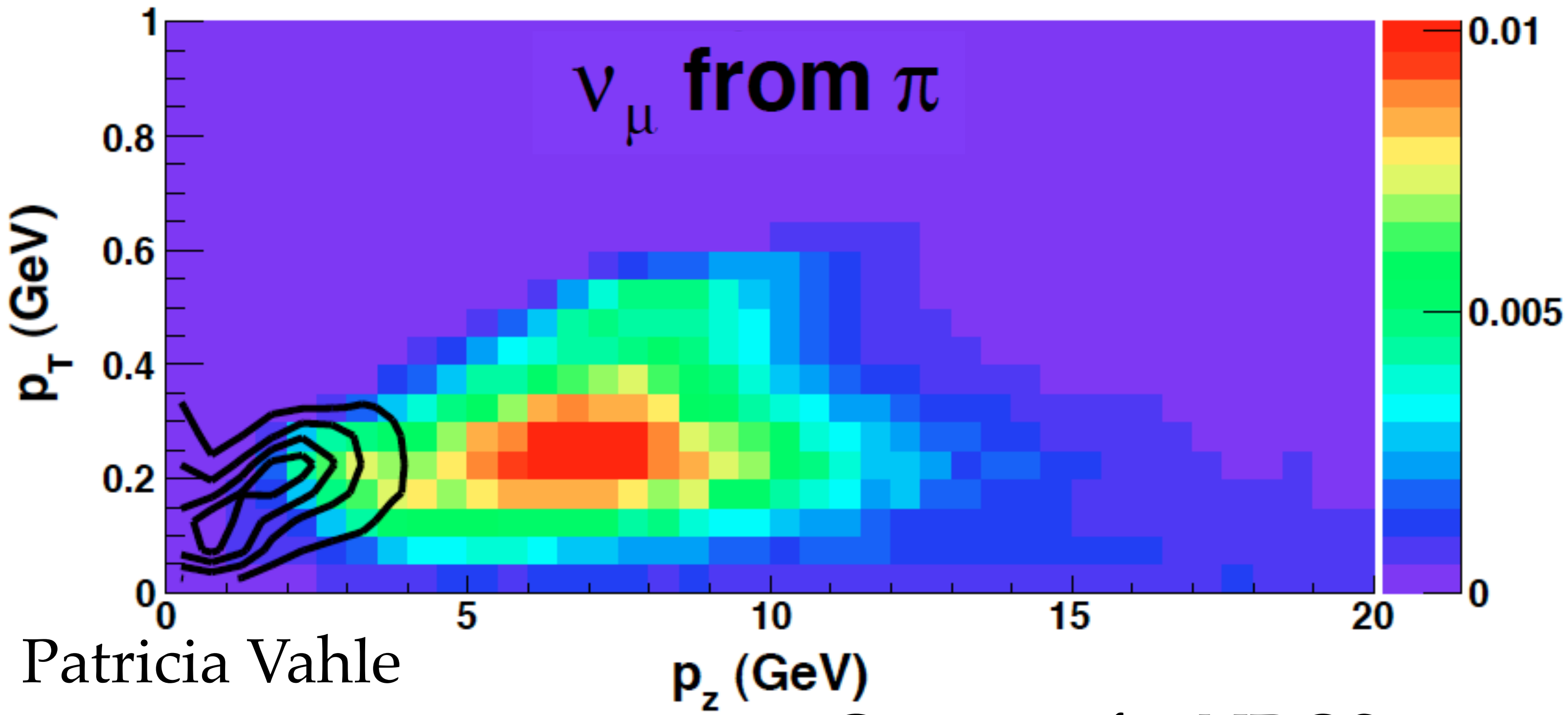
Total Flux Uncertainty



- Difference between simulations is the bulk of the flux uncertainty
- Studies ongoing to resolve these differences
- Similar analysis underway to measure inclusive ν_μ cross section above 1.5 GeV

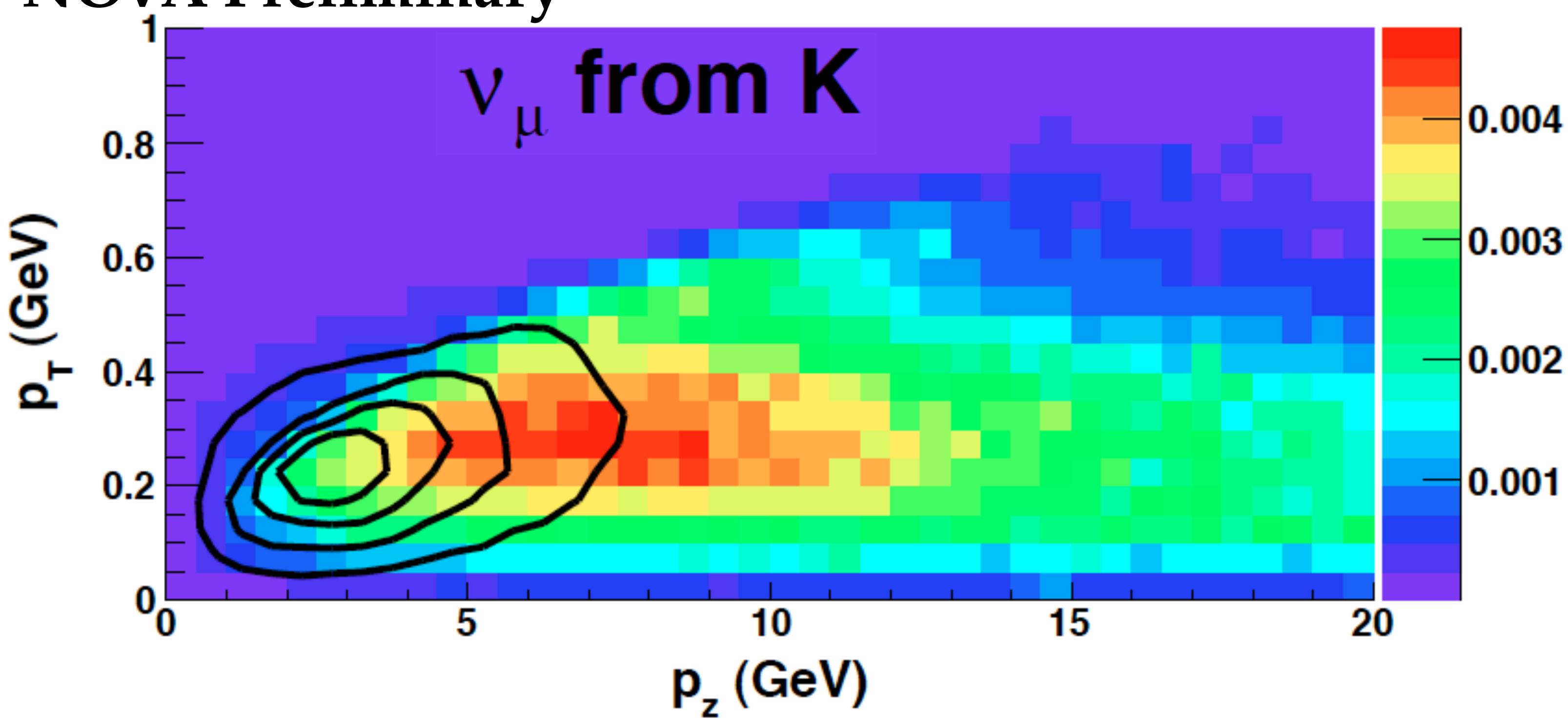
Fitting NDOS and MINOS Simultaneously

NDOS + MINOS ND



Patricia Vahle
Anna Holin
NOvA Preliminary

Contents for NDOS
Color for MINOS ND



- Simulated flux from MINOS beam
- NDOS and MINOS ND peak in different areas of phase space
- Would like to exploit this to constrain the flux

Using NOvA and MINOS Together

- In MINOS, flux is constrained in part various beam configurations from different target positions and horn currents
    - Data is analyzed in a multi-parameter fit
- NOvA target is fixed; we lose these degrees of freedom
    - Can still vary horn current
- Studying if we can use the different NOvA detector positions in concert with the MINOS detectors to obtain similar constraints

Future Flux Constraints Near Term

- Early Stages
  - Simulations
  - MINOS ND
  - NDOS
  - Possibly Muon Monitors
- We will not have a Near Detector for the first oscillation analysis and a partial Far Detector

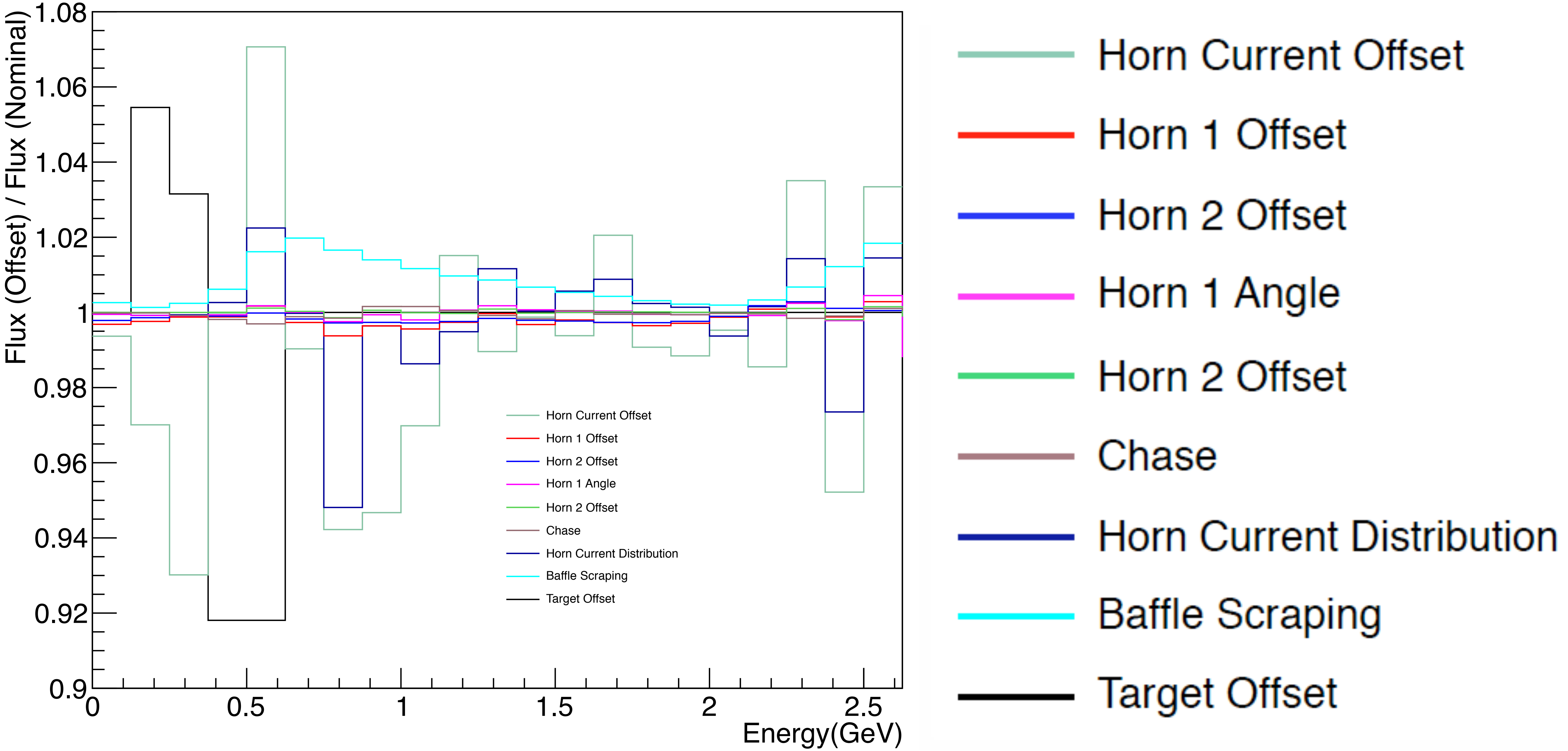
Future Flux Constraints Long Term

- Once we have a Near Detector
  - Primarily use the NOvA ND to constrain flux
  - MINOS ND
  - Muon Monitors
- We will also make use of hadron production data from US-NA61.

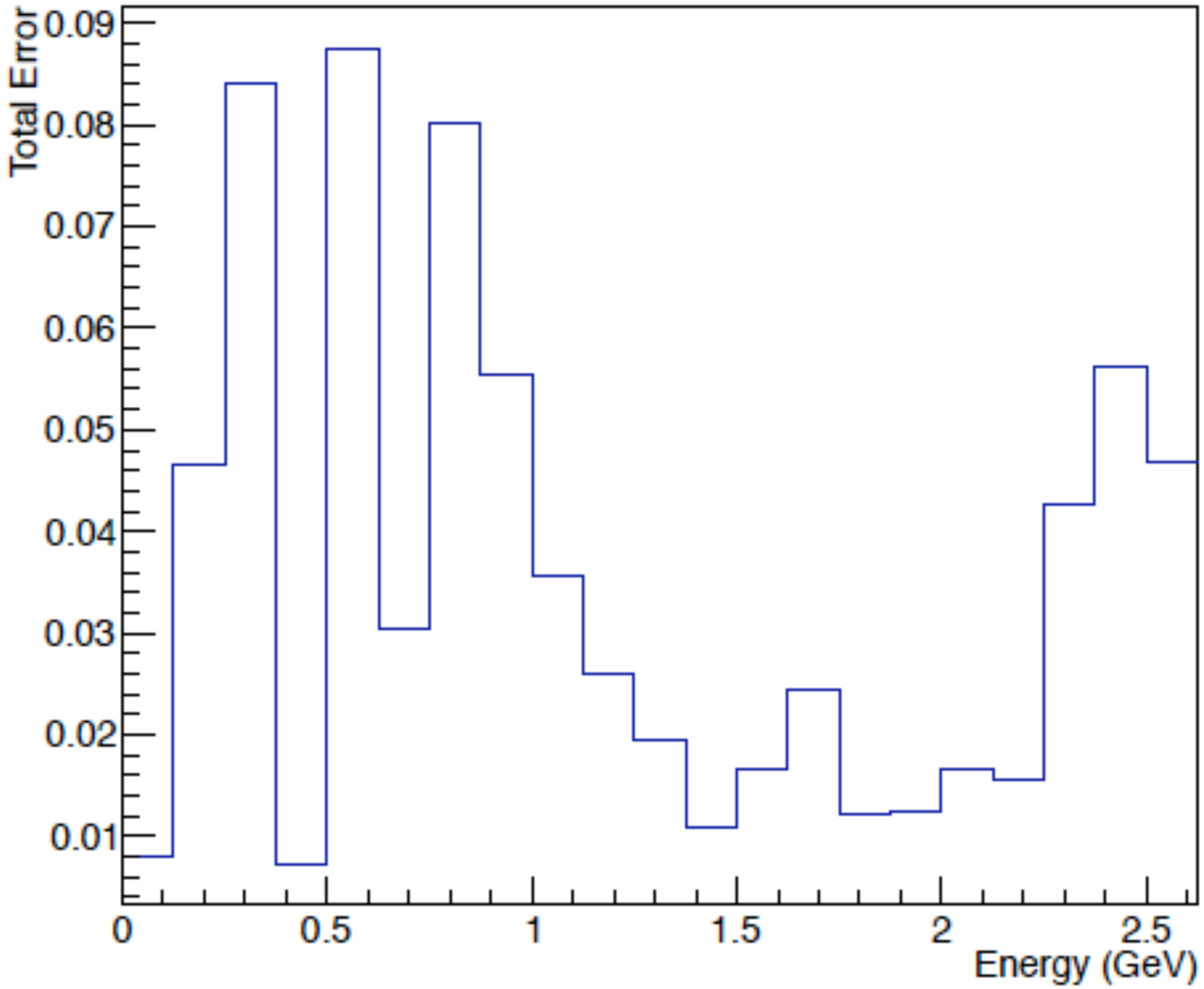
Conclusion

- Neutrino flux constraints on NOvA in early stages but well under way
- 1st analysis using flux constraints is ν_μ CCQE
- Future plans for NOvA and combined MINOS-NOvA constraints are being developed
  - NDOS and simulations
  - Multi-detector fit
  - Rely primarily on ND when it its ready
- Thanks to M. Betancourt and A. Holin for their help.
- Thank you for your attention

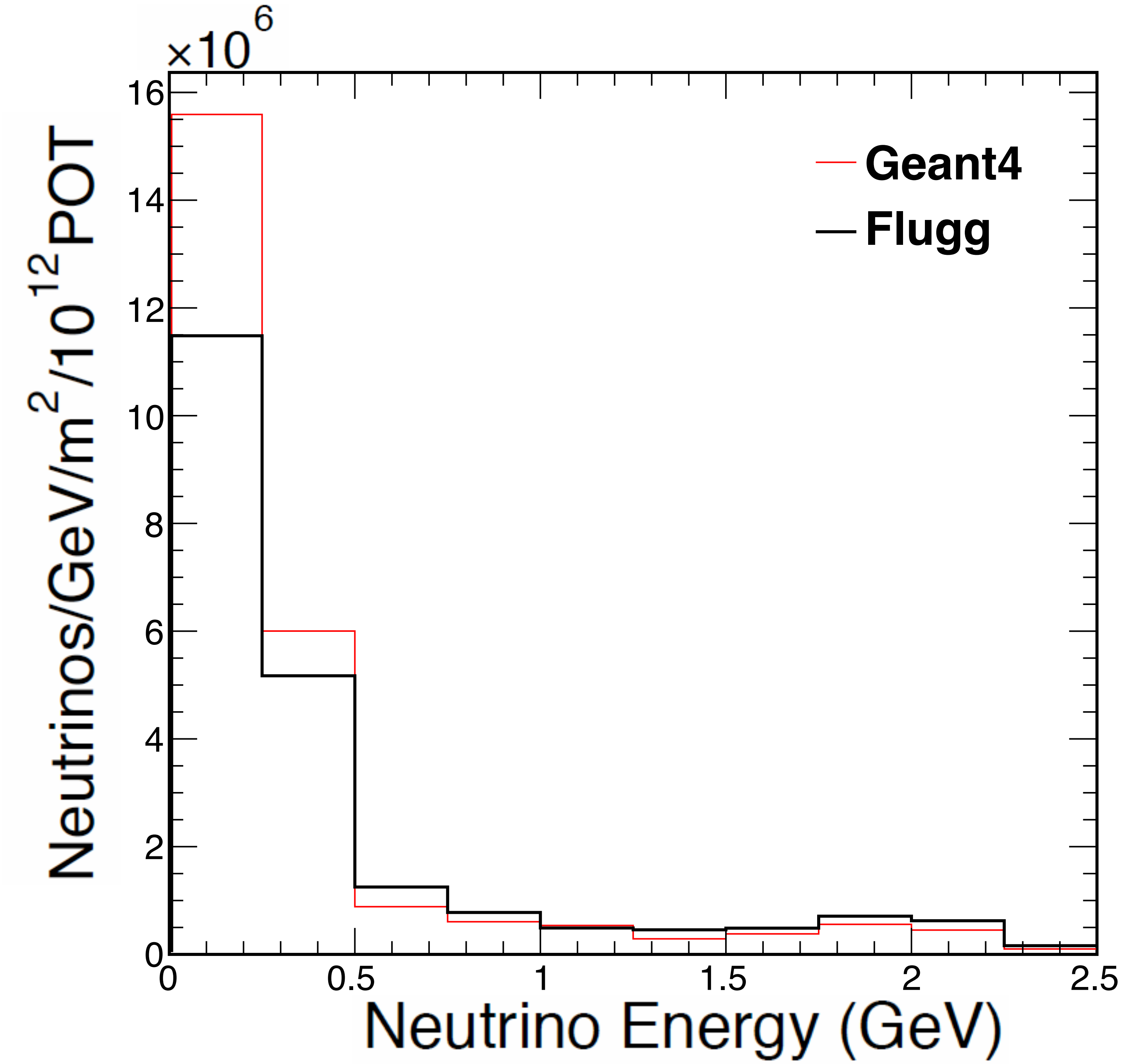
Backup Slides



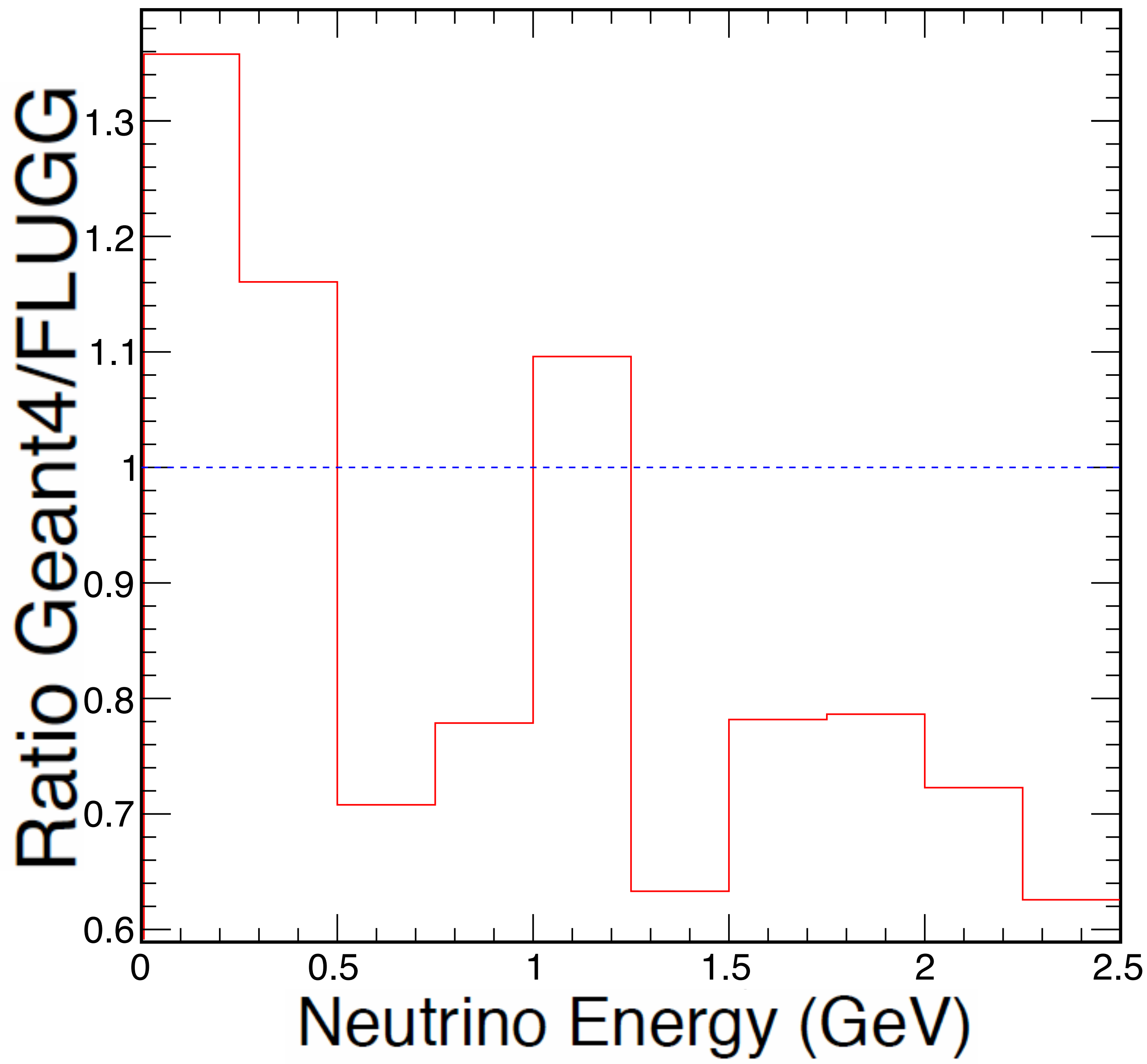
The systematic uncertainties on the neutrino flux from NOvA beam simulations. The ratio of the flux with a given systematic variable shifted to the nominal flux is shown in each histogram. The exact offsets are shown in NOvA-doc-7786, slide 3.



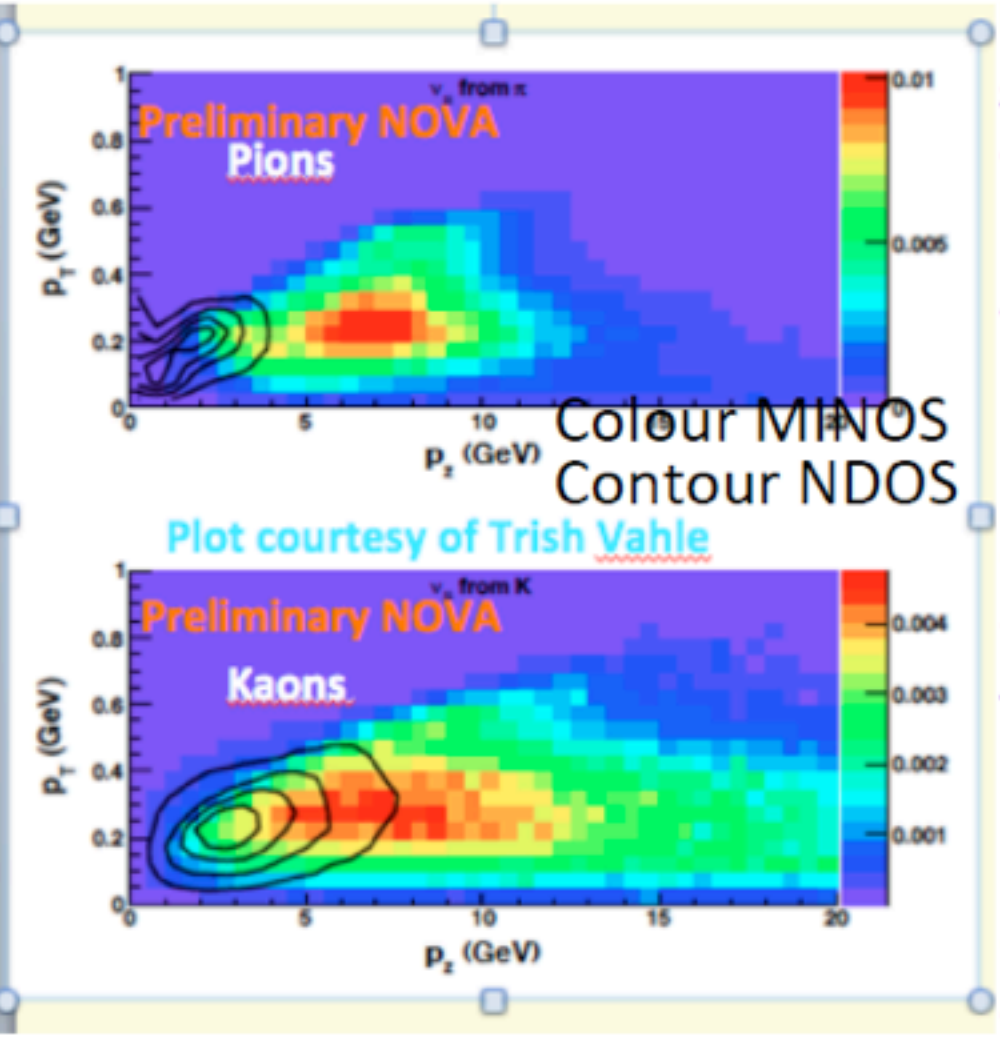
The total fractional uncertainty on the neutrino flux as a function of neutrino energy from the NOvA beam simulation.



The simulated neutrino flux at the NOvA prototype near detector on the surface (NDOS) from Geant4 and FLUGG (using Fluka 2008) simulations.



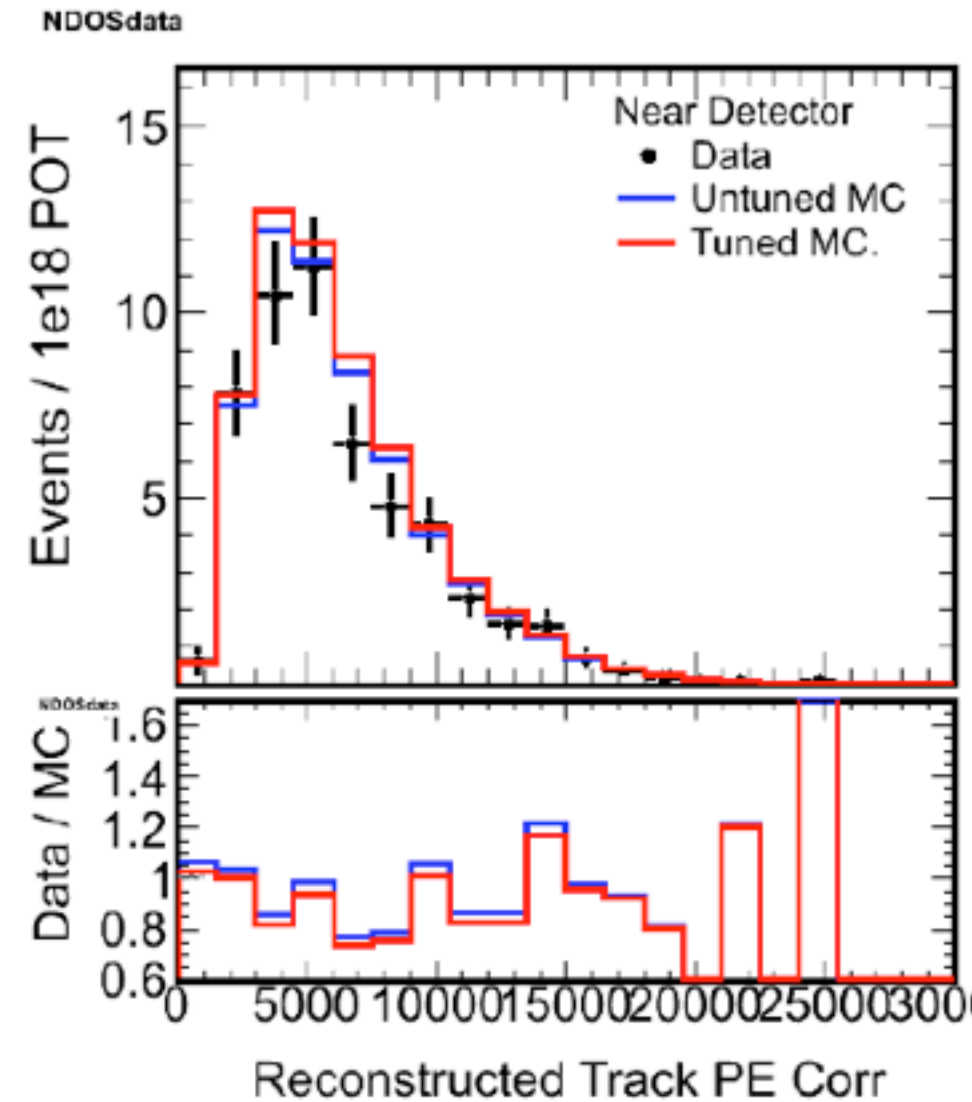
The ratio of the Geant4 and FLUGG (using Fluka 2008) simulations of the neutrino flux at the NOvA prototype near detector on the surface (NDOS).

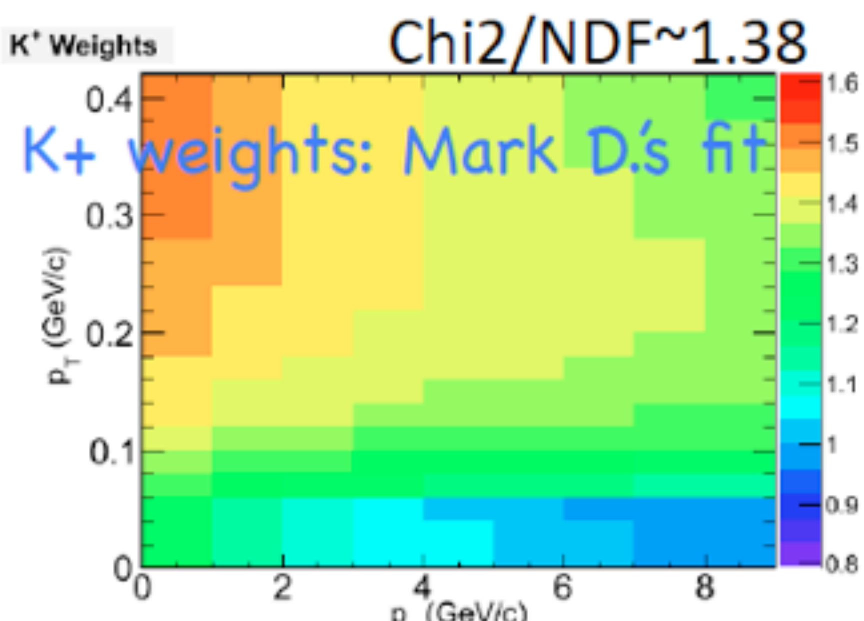


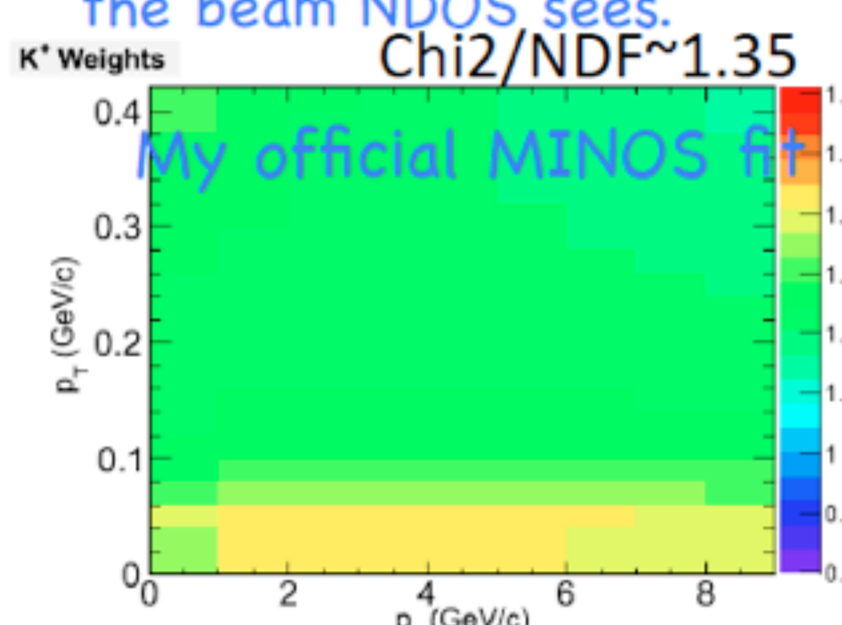
Left is a plot from Trish showing the phase-space where the neutrino parents come from.

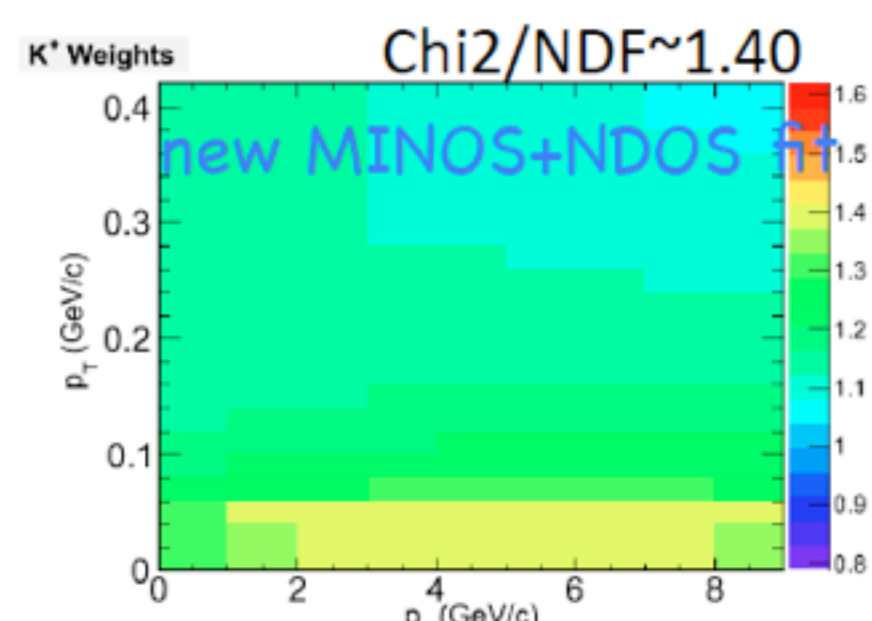
Right is my plot of NDOS track PE (NDOS variable I actually fitted) before and after the NDOS +MINOS fit

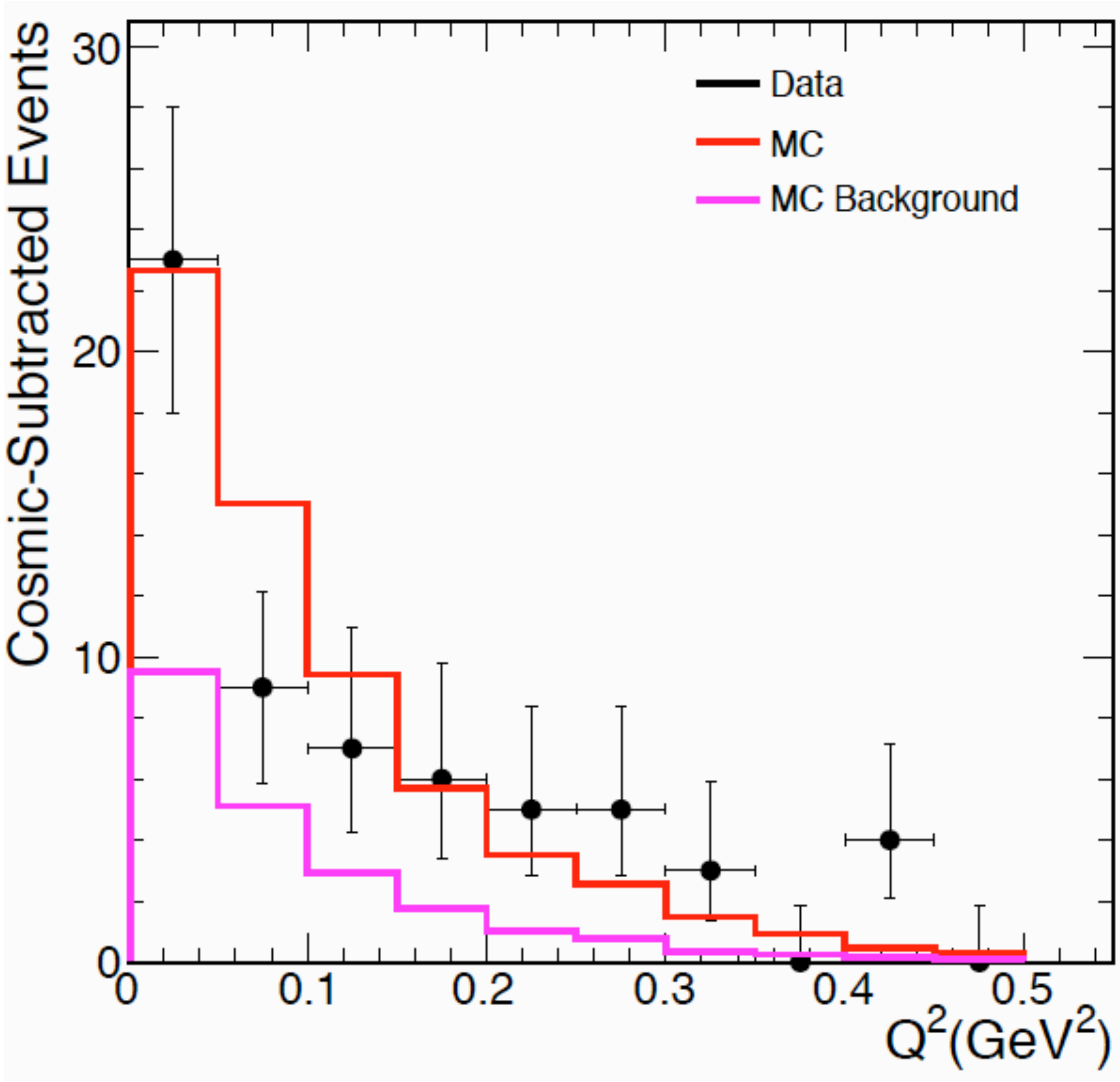
The fit hardly changes the pion weights, but the kaon weights are affected as would be expected since there is a large kaon component in the beam NDOS sees.











A comparison of beam data to simulation for the NDOS as a function of momentum transfer (Q^2). The are of the red histogram is normalized to match the data, which consists of 9.6×10^{18} protons on target (POT) taken from April through May of 2011.