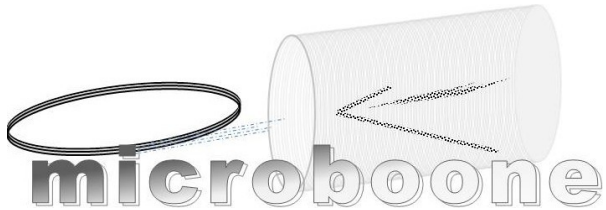
Studies of the Cosmic Ray Flux in MicroBooNE

Katherine Woodruff
with
Vassili Papavassiliou (Prof.) Stephen Pate (Prof.)
Tia Miceli (Postdoc) Alistair McLean (Undergraduate)

for the MicroBooNE Collaboration



APS April Meeting

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MicroBooNE

- MicroBooNE is a liquid Argon time projection chamber (LArTPC) designed to detect neutrino interactions
  - The liquid argon serves as a target for a neutrino beam
  - 87 ton active volume (170 ton total)
  - 2.6 m x 2.3 m x 10.4 m
  - Three wire anode planes on the TPC record the signals

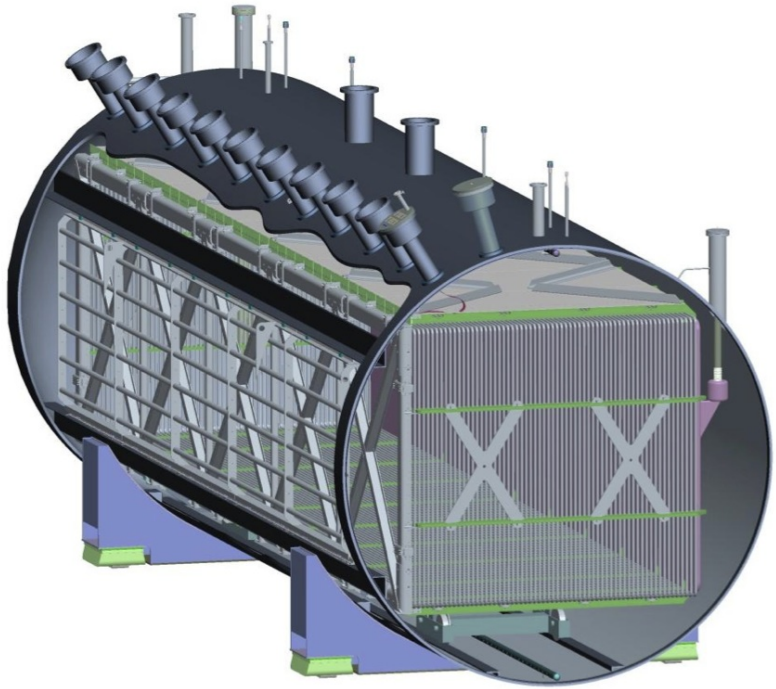
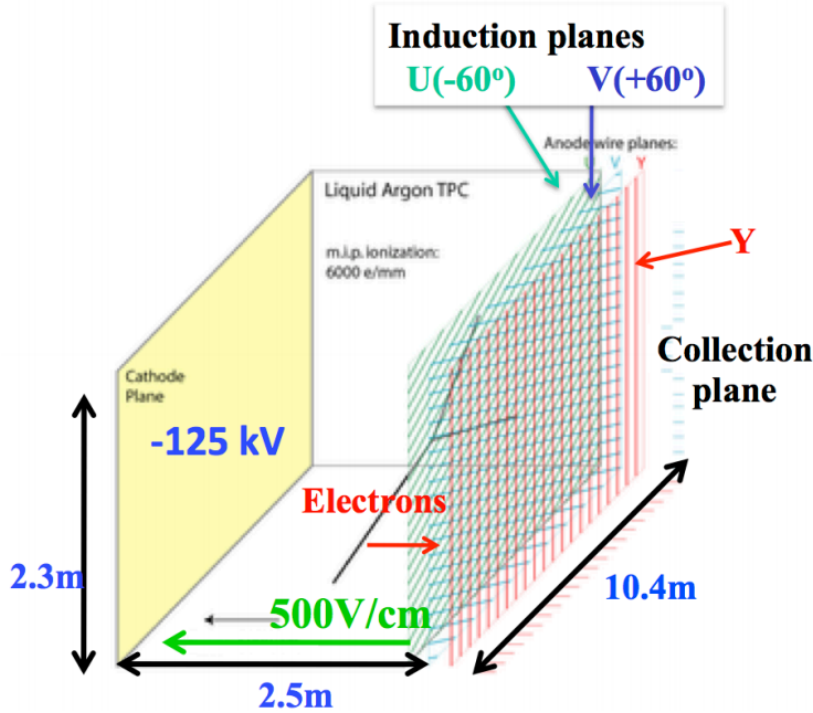


image: http://www-microboone.fnal.gov/

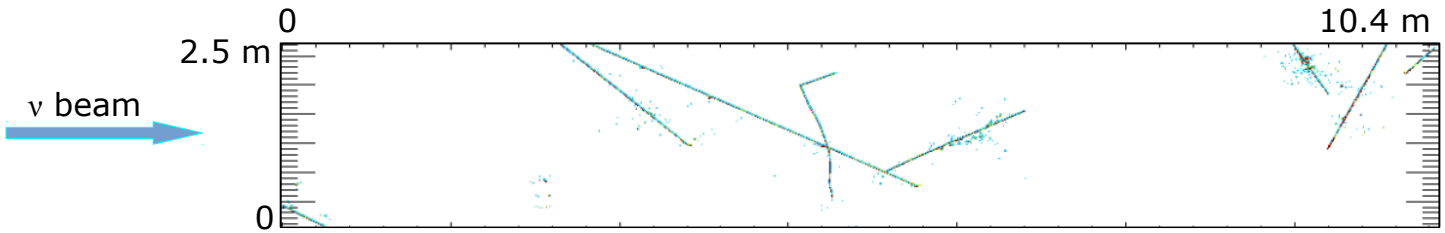
- Will be located in a pit ∼10 m deep with no roof shielding
  - The cosmic ray background needs to be measured at the location

Cosmic Rays in MicroBooNE

- It can take up to 1.6 ms for the electrons to reach the anode and for that information to be processed
- The estimated cosmic ray rate in MicroBooNE is between 4 and 8 kHz



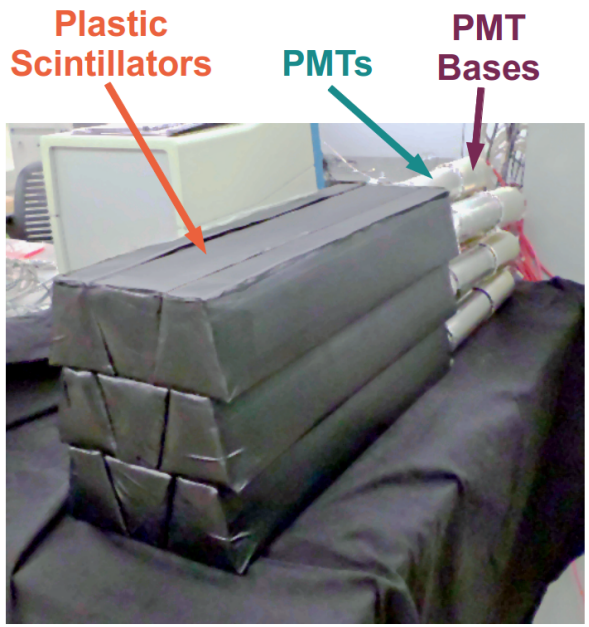
- This gives a rate of ∼6 to 13 muons per 1.6 ms "readout frame"



charged current neutrino interaction with cosmics

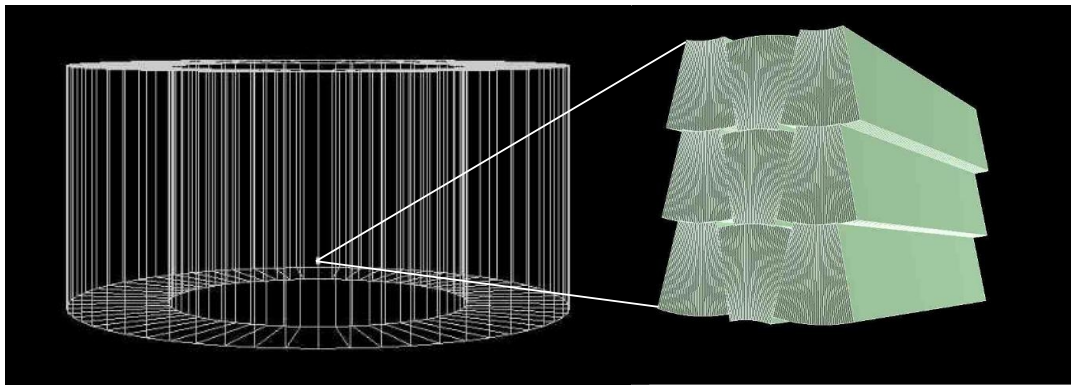
NMSU Cosmic Ray Detector

- NMSU group has built a cosmic ray muon detector to measure the cosmic ray rate and validate Monte Carlo studies
- Taken several measurements of cosmic rays muons in the Liquid Argon Test Facility (LArTF), where MicroBooNE will be located
- Scintillator stack measures 20cm x 24cm x 40cm
- Triggers on any two or more PMTs above a 30 mV (~0.25 MeV) threshold



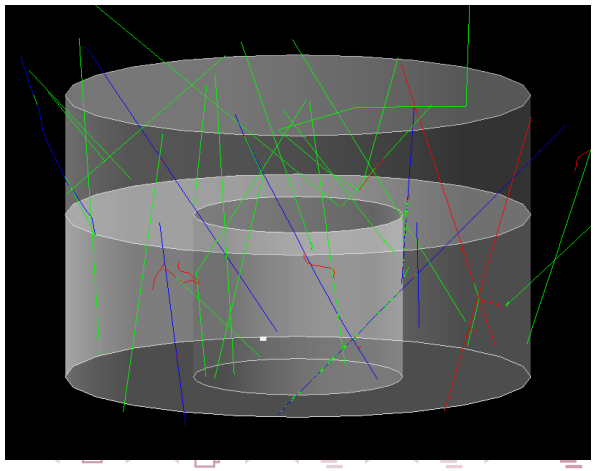
CRY and Geant4 Simulation

- Monte Carlo simulation of our detector in LArTF



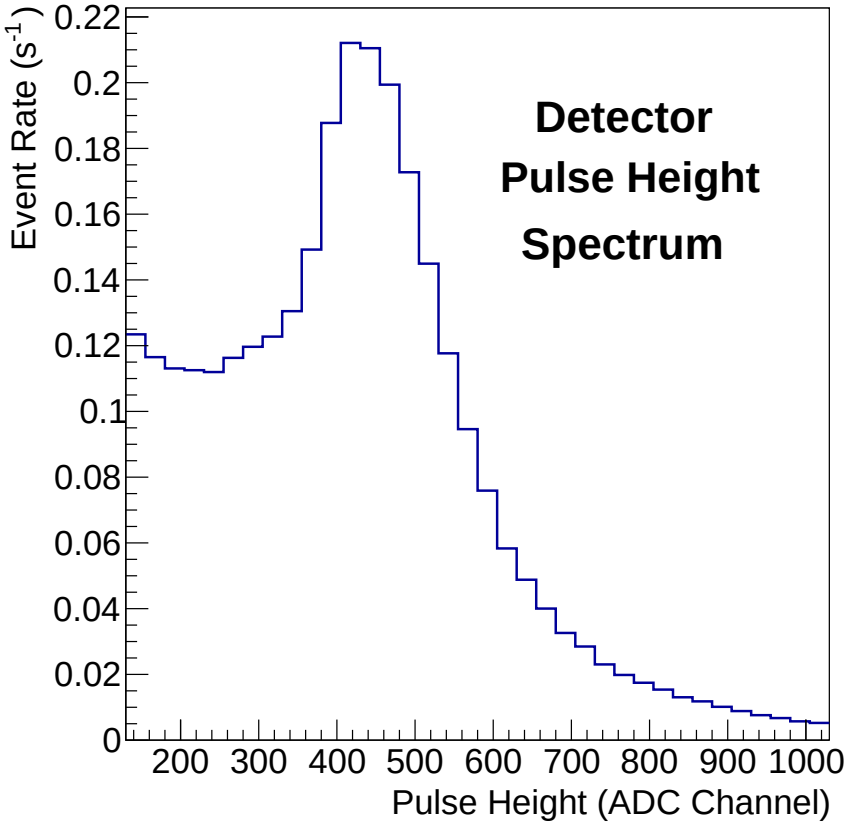
- Geometry and tracking was done using Geant4
  http://geant4.cern.ch/

- Cosmic rays were generated using the Cosmic-Ray Shower Generator (CRY)
  http://nuclear.llnl.gov/simulation/main.html

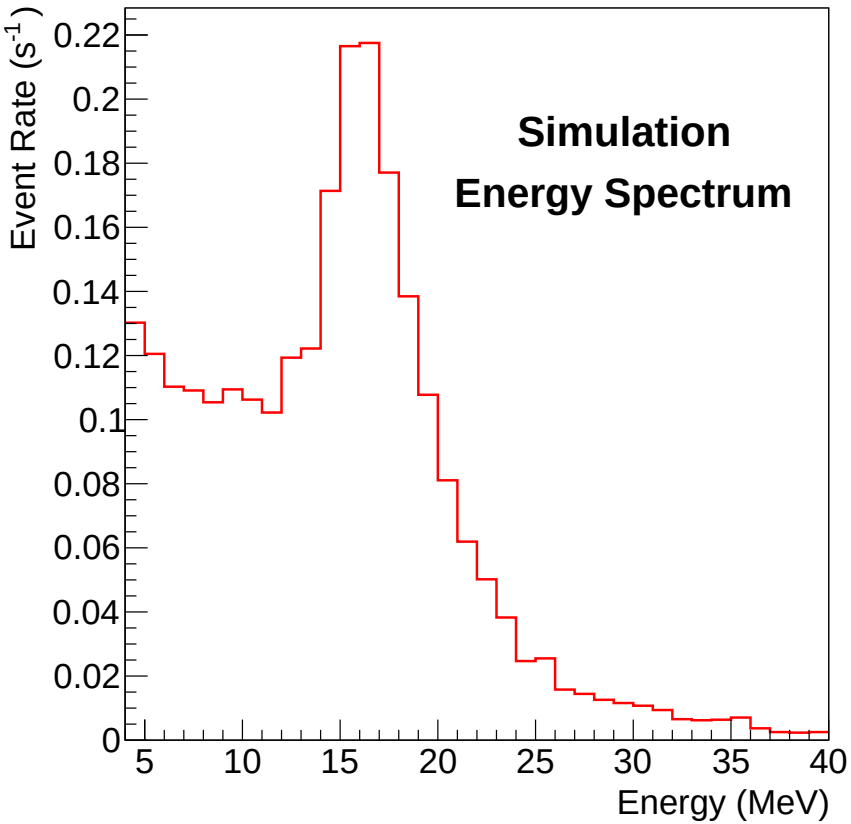


Preliminary Comparison of Simulation and Real Data

Preliminary Detector Data

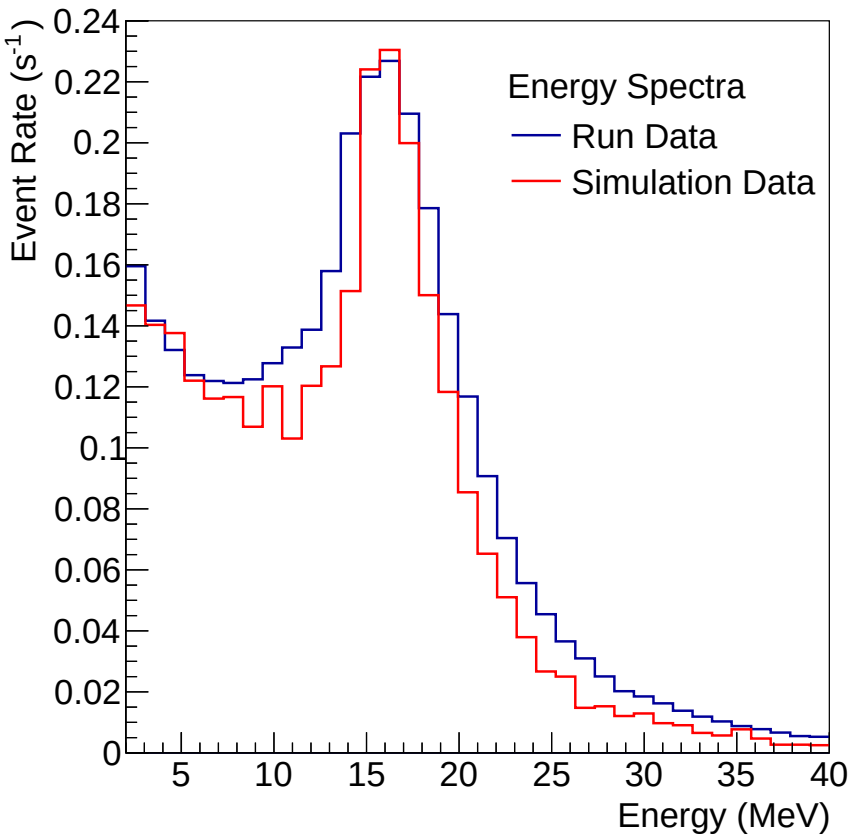


Preliminary Simulation Data



- Peaks correspond to energy deposited by vertical muons
- Can calibrate detector data to units of energy

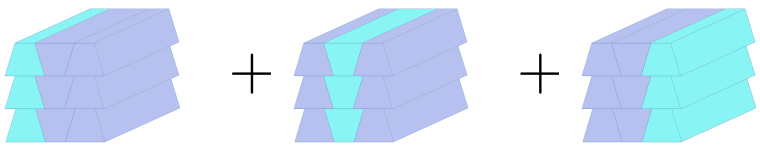
Preliminary Comparison of Simulation and Real Data



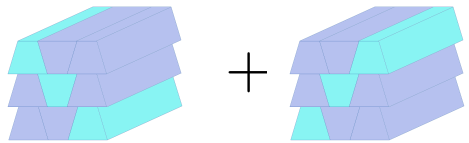
- Can now choose common threshold (4.0 MeV) and compare rates
- Absolute rates compare very well!

	Detector Rate (s^{-1})	Simulation Rate (s^{-1})
Total Rate	10.21 ± 0.01	9.63 ± 0.04
Vertical Rate	2.73 ± 0.01	1.99 ± 0.02
Diagonal Rate	0.717 ± 0.003	0.87 ± 0.01

Errors are statistical only



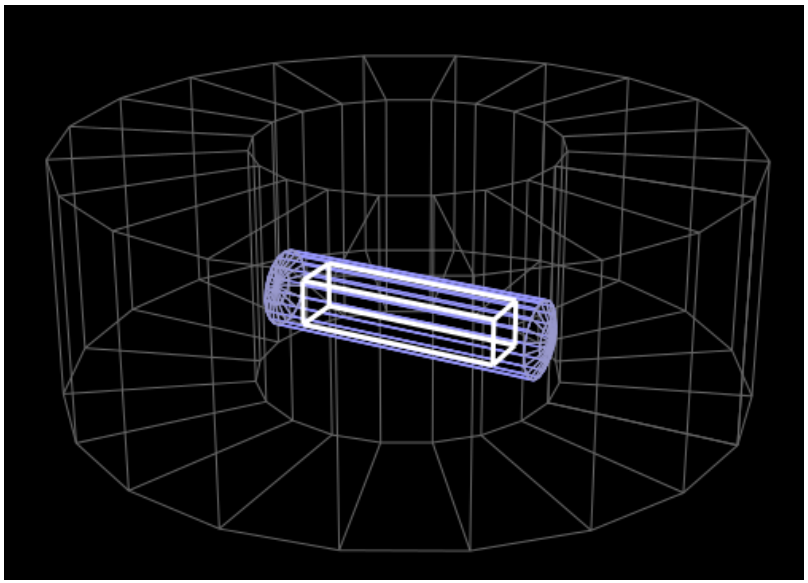
Vertical Rate



Diagonal Rate

TPC Monte Carlo Simulation

- Same simulation was done with MicroBooNE TPC added
- Geometry includes TPC inside steel cryostat filled with liquid Argon

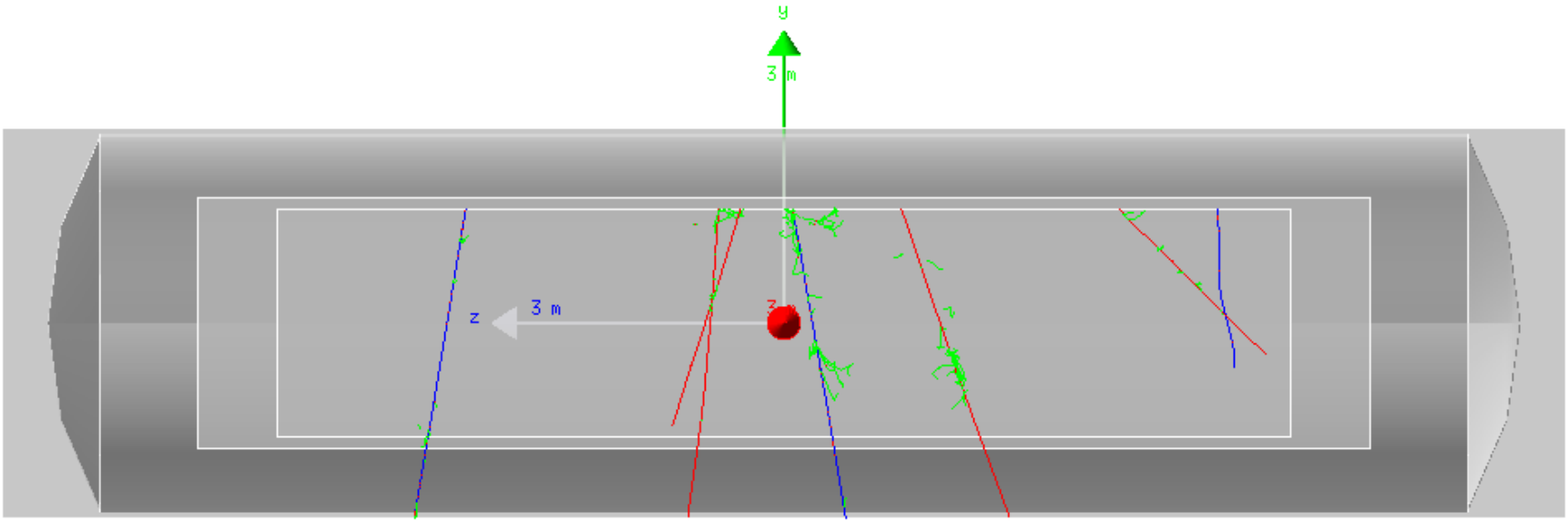


- Generated 60,000,000 cosmic particles
- Corresponds to 41.4 s of simulated time

Preliminary Results

Events per Readout Frame

- Total rate of **all** particles that enter the MicroBooNE TPC in simulation is **4.66 ± 0.01 kHz**
- This gives a rate of **∼7.5** particles per readout frame



Seven randomly selected cosmic events in the MicroBooNE TPC

Preliminary Results

Muon Rates

- Total simulated muon rate in TPC:

$$R_{TPC} = 3.72 \pm 0.01 \text{ kHz}$$

  - Gives rate of 5.95 muons per readout frame

- Simulated rate through top horizontal surface of detector:

$$R_{Top} = 2.67 \pm 0.01 \text{ kHz}$$

  - This gives a horizontal flux in LArTF of

$$\Phi_H = 100.8 \pm 0.4 \text{ m}^{-2}\text{s}^{-1}$$

Other Muon Flux Estimates

- Qing He and Kirk McDonald
  - Calculated muon horizontal flux at ground level
  - $\Phi_H = 172.2\ \mathrm{m}^{-2}\mathrm{s}^{-1}$ (with 0.2 GeV threshold)
  - MicroBooNE Internal Note
- A. Dragic, et al.
  - Measured muon horizontal flux at ground level in Belgrade
  - At elevation of 78 m — closer to Fermilab elevation ($\sim$200 m)
  - $\Phi_H = 137 \pm 6\ \mathrm{m}^{-2}\mathrm{s}^{-1}$
  - Nucl. Instr. and Meth. in Phys. Res. A 591 (2008) 470-475
- Leonidas Kalousis
  - Measured absolute muon horizontal flux at LArTF
  - Bottom of pit: $\Phi_H = 106 \pm 16\ \mathrm{m}^{-2}\mathrm{s}^{-1}$
  - Extrapolated to μB rate: $R_{TPC} = 4.3 \pm 0.7$ kHz (lower bound)
  - MicroBooNE Internal Note

Preliminary Results

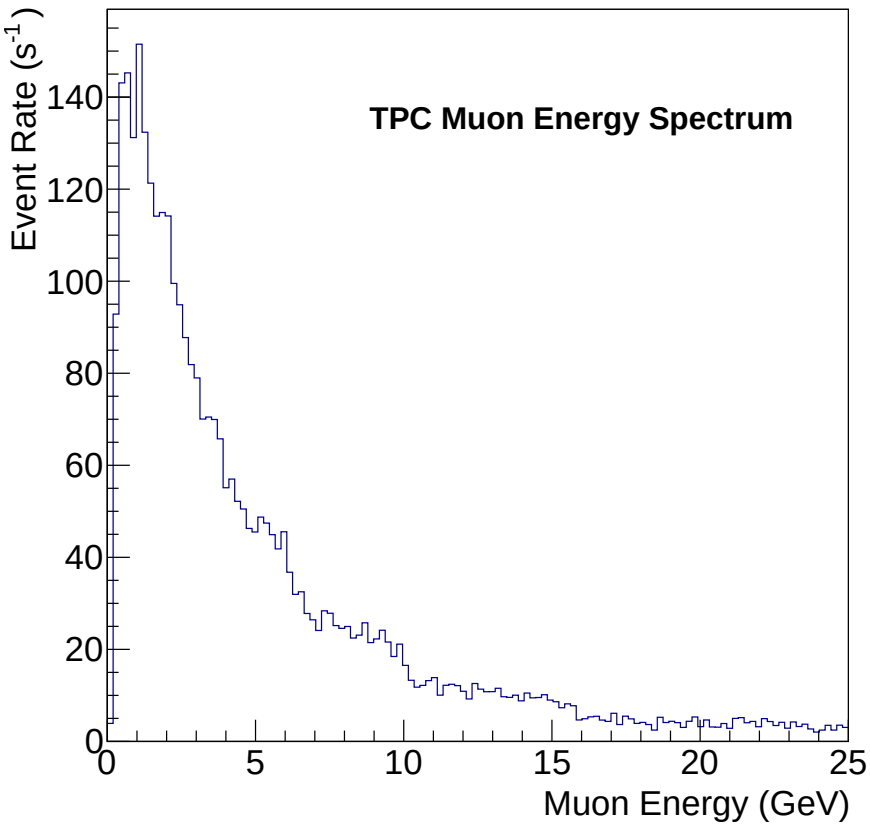
Comparison to Predictions

	Validated Simulation Rate	Kalousis Measured Rate
muon flux at LArTF ($m^{-2}s^{-1}$)	100.8 ± 0.4	106 ± 16
muon rate in μBooNE (kHz)	3.72 ± 0.01	4.3 ± 0.7

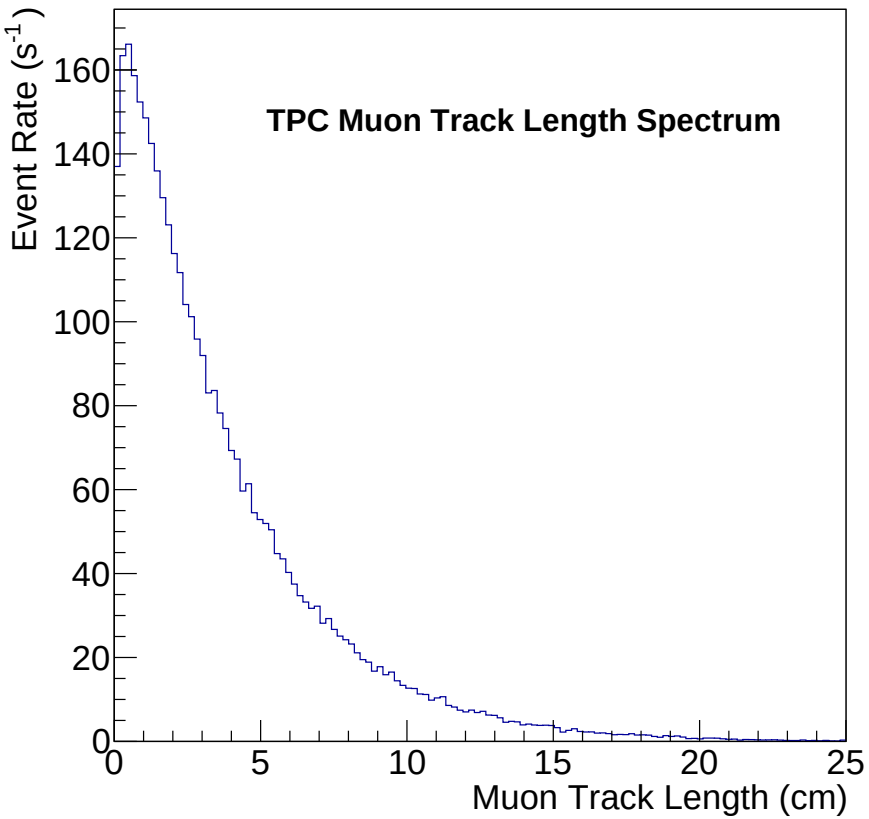
Errors are statistical only

Preliminary Plots

Preliminary



Preliminary



Summary and Conclusions

- Cosmic rays are an important background in MicroBooNE
- Monte Carlo Simulations need to be validated with measurements
- NMSU Cosmic Ray Detector has measured the cosmic rays in LArTF
- We are studying the performance of our detector and simulation
- Validated Monte Carlo simulation of muon detector in LArTF
- Estimated MicroBooNE flux to within 10%
- Thank you!