Studies of the Cosmic Ray Flux in MicroBooNE

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with
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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

- 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 \( \sim 6 \) to 13 muons per 1.6 ms “readout frame”.
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
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!

<table>
<thead>
<tr>
<th></th>
<th>Detector Rate ($s^{-1}$)</th>
<th>Simulation Rate ($s^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>10.21 ± 0.01</td>
<td>9.63 ± 0.04</td>
</tr>
<tr>
<td>Vertical Rate</td>
<td>2.73 ± 0.01</td>
<td>1.99 ± 0.02</td>
</tr>
<tr>
<td>Diagonal Rate</td>
<td>0.717 ± 0.003</td>
<td>0.87 ± 0.01</td>
</tr>
</tbody>
</table>

Errors are statistical only

- Vertical Rate
- Diagonal Rate

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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 $4.66 \pm 0.01$ kHz
- This gives a rate of $\sim 7.5$ 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
  - $\Phi_H = 172.2 \text{ m}^{-2}\text{s}^{-1}$ (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 (∼200 m)
  - $\Phi_H = 137 \pm 6 \text{ m}^{-2}\text{s}^{-1}$

- Leonidas Kalousis
  - Measured absolute muon horizontal flux at LArTF
  - Bottom of pit: $\Phi_H = 106 \pm 16 \text{ m}^{-2}\text{s}^{-1}$
  - Extrapolated to $\mu$B rate: $R_{TPC} = 4.3 \pm 0.7 \text{ kHz}$ (lower bound)
  - MicroBooNE Internal Note
## Preliminary Results

Comparison to Predictions

<table>
<thead>
<tr>
<th></th>
<th>Validated Simulation Rate</th>
<th>Kalousis Measured Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>muon flux at LArTF (m^{-2}s^{-1})</td>
<td>100.8 ± 0.4</td>
<td>106 ± 16</td>
</tr>
<tr>
<td>muon rate in $\mu$BooNE (kHz)</td>
<td>3.72 ± 0.01</td>
<td>4.3 ± 0.7</td>
</tr>
</tbody>
</table>

Errors are statistical only
Preliminary Plots

Preliminary

TPC Muon Energy Spectrum

Event Rate (s⁻¹)

Muon Energy (GeV)

0 5 10 15 20 25

TPC Muon Track Length Spectrum

Event Rate (s⁻¹)

Muon Track Length (cm)

0 5 10 15 20 25

Katherine Woodruff, et al.
New Mexico State University
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!