A Profile of the Muon Flux in Fermilab's MINOS Tunnel

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Motivation

At 103 meters deep the Fermilab MINOS tunnel was built to shield the near detector from cosmic rays and other noise. Since the access shaft to the tunnel removes shielding burden, we wanted to profile the effect of the missing burden of the shaft as it relates to MINOS tunnel experiments. This would benefit the MINOS experiment at Fermilab so they can consider the extra cosmic ray noise due to the access shaft.

Hypothesis

If the distance from the access shaft increases, the cosmic ray muon flux will decrease inversely.

Methods and Equipment

- Feasibility studies were conducted to determine if the detectors were sensitive to changes in the amount of burden by measuring muon flux at various floors (depths) of a school building.
- The studies determined if the detector would still keep accurate GPS time when disconnected from the GPS antenna.
- Three QuakNet Cosmic Ray Muon Detectors were employed:
  - The detector at ground level acted as the control for the experiment.
  - A detector (TC) using a geometry identical to the control measured the muon rate underground.
  - A detector (TB) to measure any muons parallel to the neutrino beam.

• The TC and surface cosmic ray detectors simultaneously record data in large (21 degrees) and small (6 degrees) angular acceptance modes as well as data from the full sky.

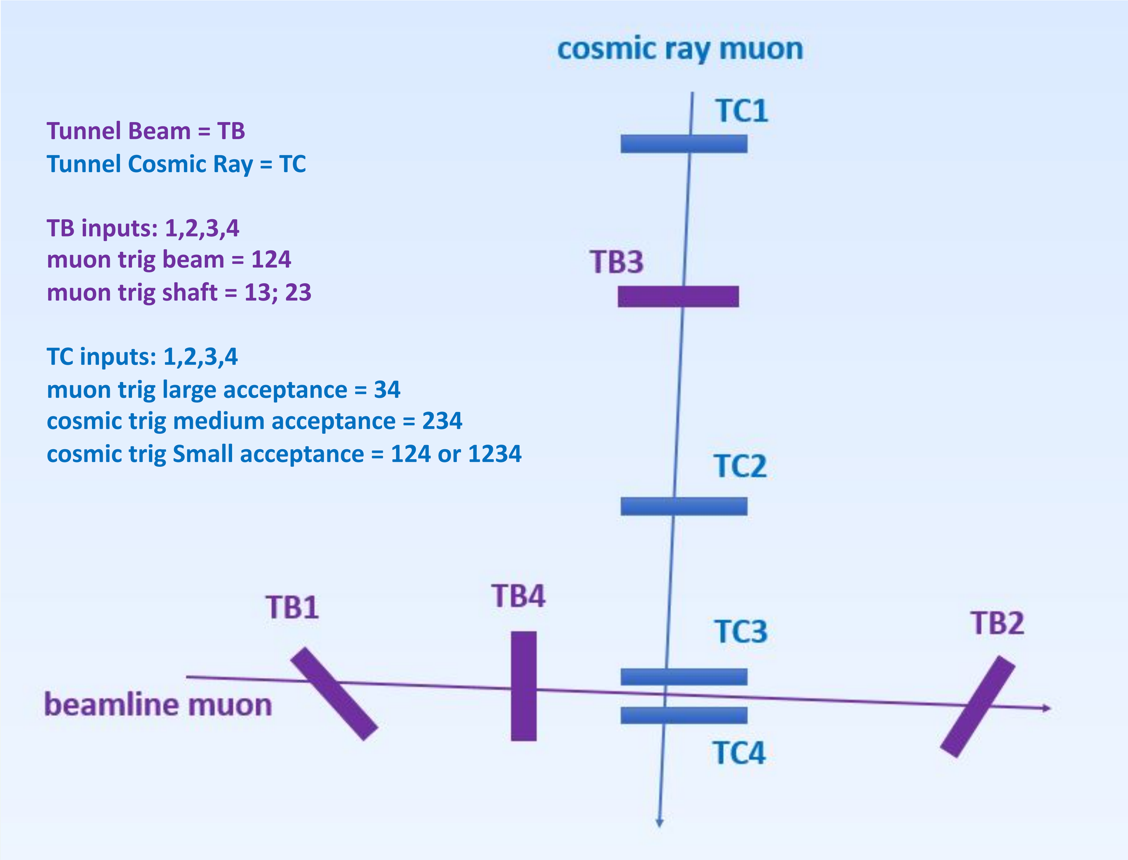

Figure 1. Diagram of underground setup. TC is the vertical cosmic ray muon detector, while TB is the horizontal beamline detector.

Figure 2. Surface Module

Figure 3. Tunnel Module

Figure 4. MUSE students and faculty transfer the detectors from Wilson Hall (the location of the feasibility study) to the MINOS facility for the surface study and the tunnel study.

Results

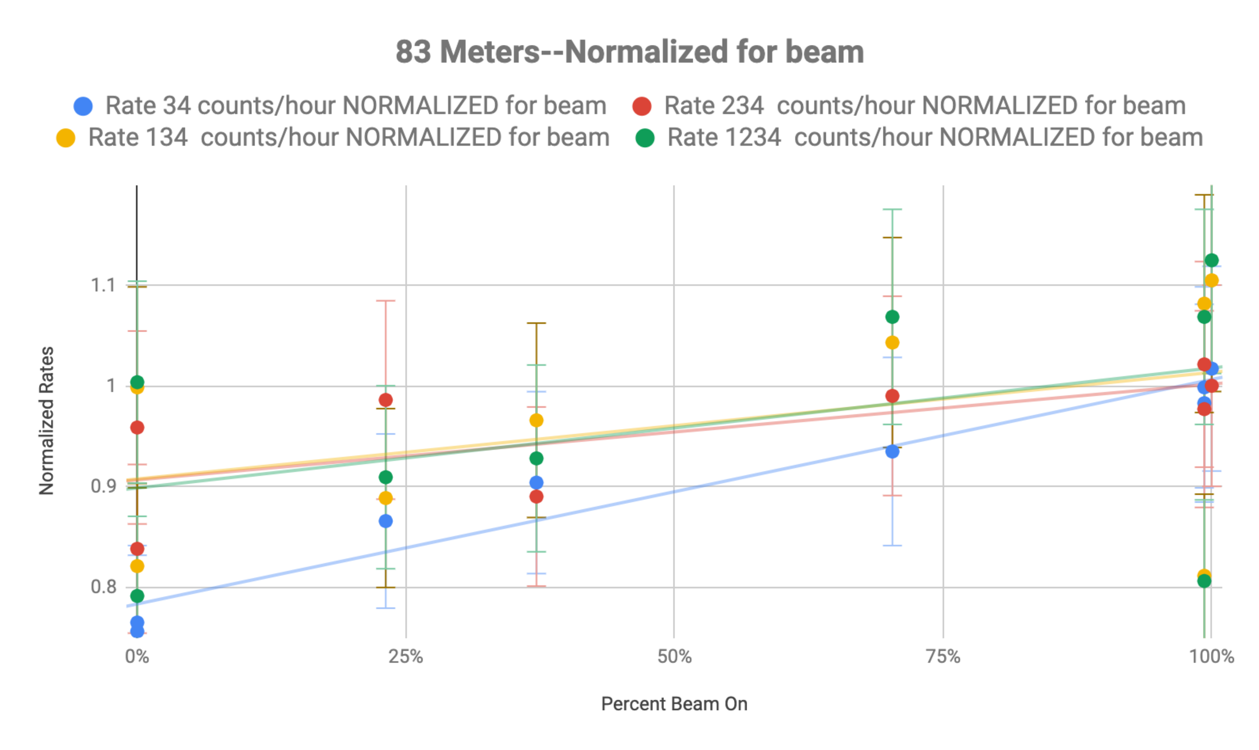

Figure 5. Normalized cosmic ray muon rates as function of percent beamline on; rates increase as percent beam increased, indicating the need for corrections in the rates.

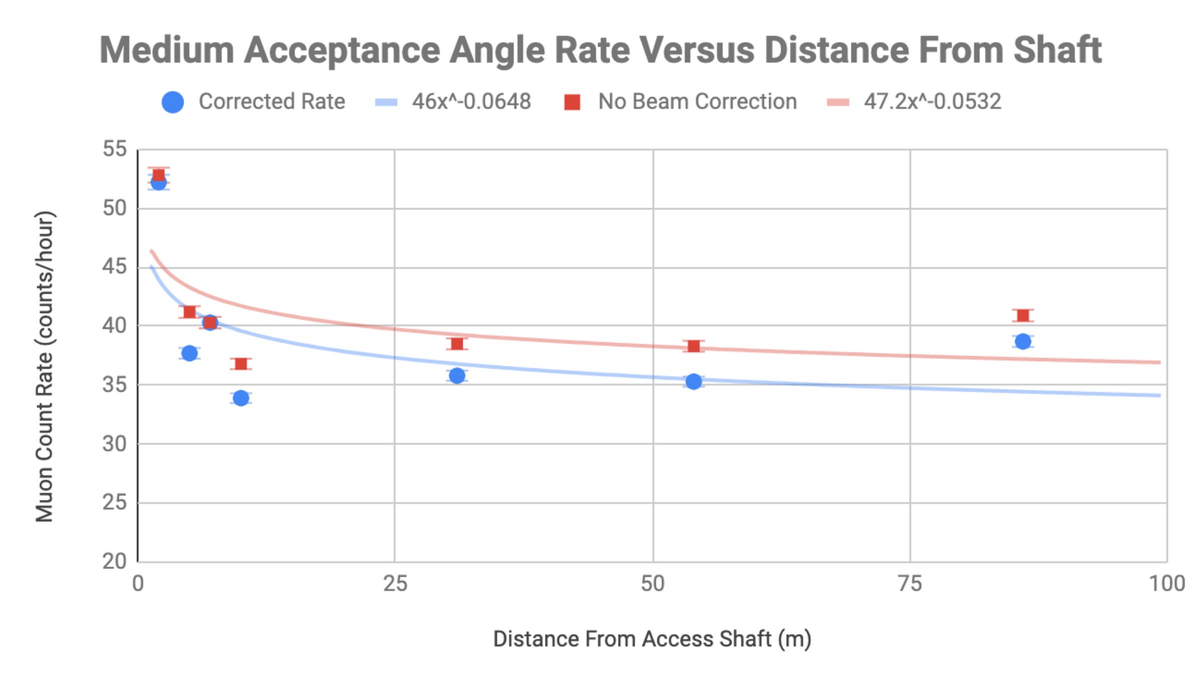

Figure 6. Muon rates as function of distance from shaft for both uncorrected and corrected rates.

- Muon rate without beam correction: $F = 47.2x^{-0.053}$
- Muon rate with beam correction: $F = 46x^{-0.065}$
- F = muon rates and x = horizontal distance from shaft
- Muon rates drop rapidly at first as detector is moved away from access shaft, but the rates become asymptotic as distance from shaft increases.
- Figure 5 shows that the cosmic ray detector is detecting muons from the beamline instead of from cosmic rays. This is a source of error.
- Results are similar after corrections from beamline muons despite slight drop in rates indicating that the beamline only slightly affects cosmic ray muon counts.

Conclusion

- Muon rates do increase near the access shaft.
- There is an inverse relationship between the muon rates and distance from the access shaft.
- The cosmic ray rates need to be corrected for the muons detected from the beamline.
- The number of data points was limited by the constraint of measuring in weekly intervals for six weeks.
- Our intent was to benefit the MINOS experiment at Fermilab so they can consider the extra cosmic ray noise due to the access shaft.
- A possible follow-up experiment might be to measure how the extra noise due to the access shaft actually affects the MINOS experiment.

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