PROCEEDINGS OF SCIENCE

High School Students' Muon Underground Shielding Experiment

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Abstract

Students and teachers from high schools near Chicago measured the rate of cosmic ray muons 100 meters underground in the Fermilab MINOS neutrino tunnel. The effect of the overburden was studied as a function of distance away from the access tunnel. A surface detector provided normalization over time and a third detector monitored possible background from the neutrino beam.

1. Aim

Students measured the change in cosmic ray flux in the neutrino tunnel as they move downstream from the access shaft. The change in burden is anticipated to affect the flux.

A measure of the change in flux during descent to the tunnel in the elevator was made.

Angle of acceptance will be factored into the results.

To guide high school students and their teachers in an authentic cosmic ray experiment.

2. Setup and Reasoning

Figure 1 *Moving tunnel arrays from assembly area to tunnel.*

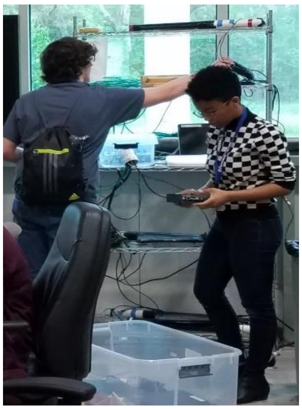


Figure 2 *Surface control detector.*

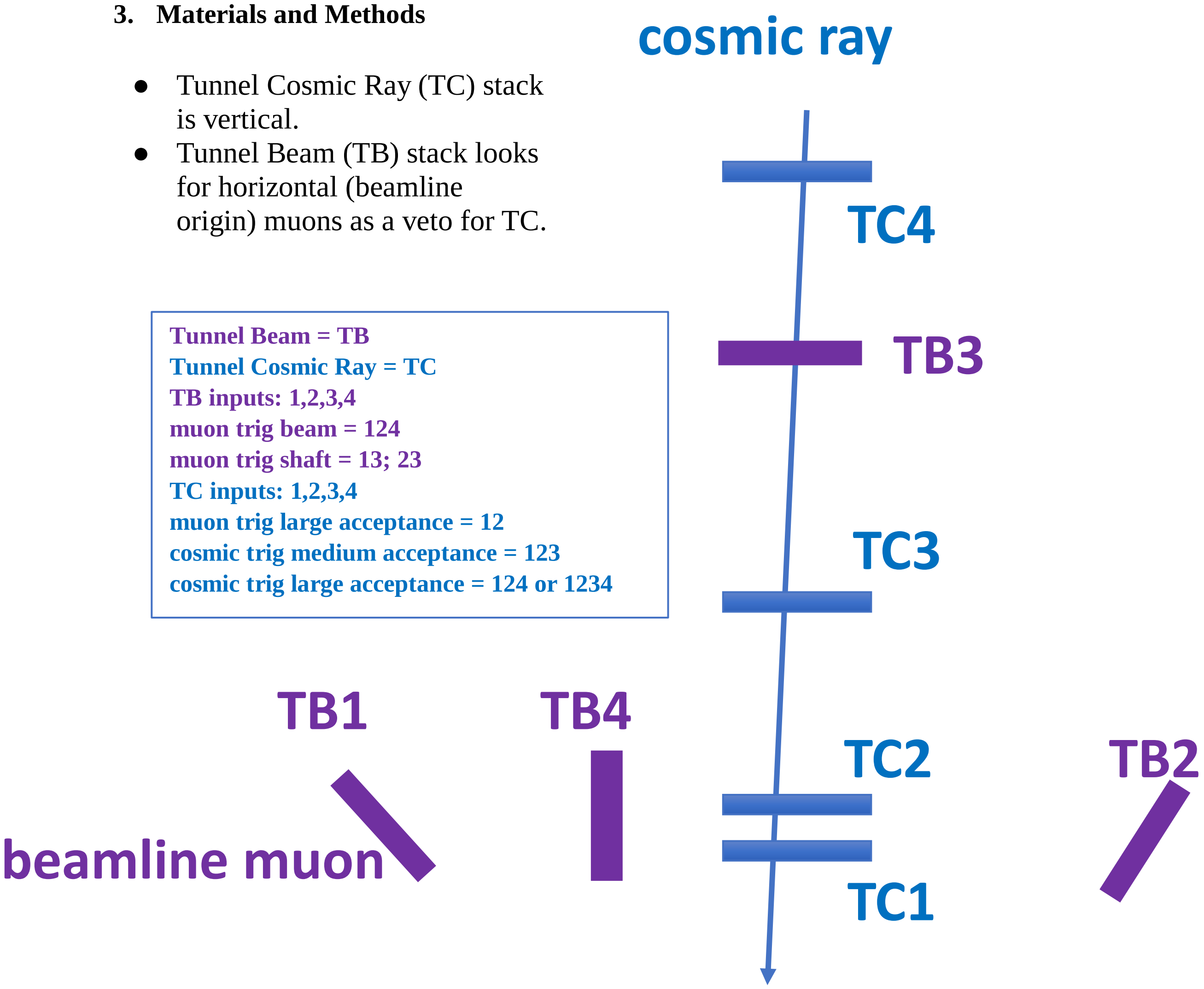
Three Detectors Assembled:

- One to monitor cosmic rays above ground as a control.
- An identical detector (TC) to measure the rate underground.
- A third detector (TB) to measure the muon background in the neutrino beam.

The 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.

3. Materials and Methods

- Tunnel Cosmic Ray (TC) stack is vertical.
- Tunnel Beam (TB) stack looks for horizontal (beamline origin) muons as a veto for TC.



4. Expectations

- As the detector below ground is moved along the tunnel, further away from the vertical access shaft, the ratio of muon flux below ground compared to the rate on the surface will decrease. This is due to the increase in the proportion of burden within the cone of acceptance of the underground detector.

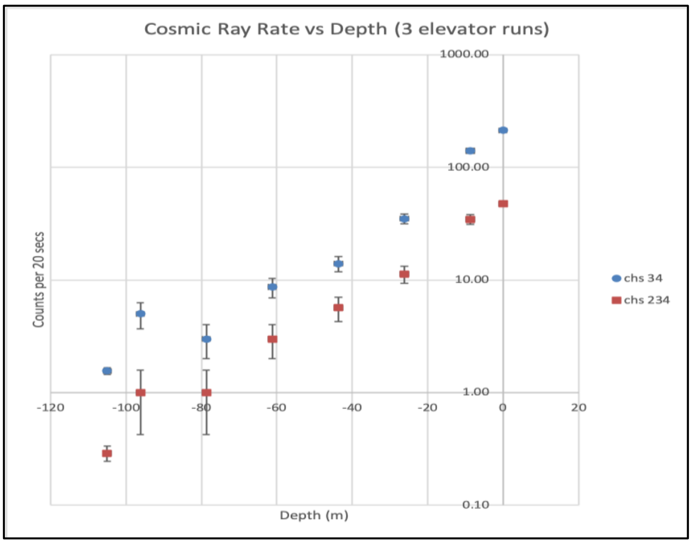
- The muon flux will constantly decrease as the detector descends in the elevator because of the increased burden in the angles of acceptance.

5. Preliminary Results

- A possible decrease of flux was found as the distance from the access shaft. Further analysis is needed to subtract the effect of the neutrino beamline to verify preliminary results.

- Once the effect of the neutrino beamline is subtracted, angles of acceptance, TB1-TB3 and TB2-TB3 will be analyzed for any measureable effects when aimed toward and away from the shaft.

6. Elevator Results



A 200 fold decrease in flux was measured in the elevator while descending into the tunnel. At -95 meters, we notice a bump in the data. We have determined that the neutrino beam was on. Further analysis is being done to eliminate this noise.

7. Conclusion

High school students proposed, designed, built, and analyzed an authentic cosmic ray experience. The teachers also learned how to guide students in developing specific science skills and to shepherd a multi-school collaboration. The level of excitement and learning was a result of the outreach effort of the high energy physics community through QuarkNet.

8. Next Steps

After the analysis is completed, the students plan to submit an article for publication and present at the AAPT Winter Meeting.

9. Acknowledgments

QuarkNet for supplying the teacher training and equipment.

FermiLab for providing the facility, guidance, safety training, and expert support during the experiment.

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