

1. Motivation

- Long-lived particles (LLPs)—unstable but with a resolvable decay length—are predicted by many theories of dark matter, baryogenesis, and neutrino masses
- MATHUSLA is a proposed surface detector that would be more sensitive to ultra long-lived particles ($c\tau \gtrsim 200$ m) than the main LHC experiments
- Backgrounds for MATHUSLA include cosmic rays and muons created in LHC collisions

3. Tracking

- Tracks reconstructed by weighted least-squares fit
- Detector noise removed by cuts on hit residuals
- Timing of hits compared to a speed of c , either downward (cosmic ray muon) or upward (LHC muon)
- Figures 3 and 4 show events recorded above ATLAS during proton-proton collisions in October 2018

Figure 3: Candidate cosmic ray muon

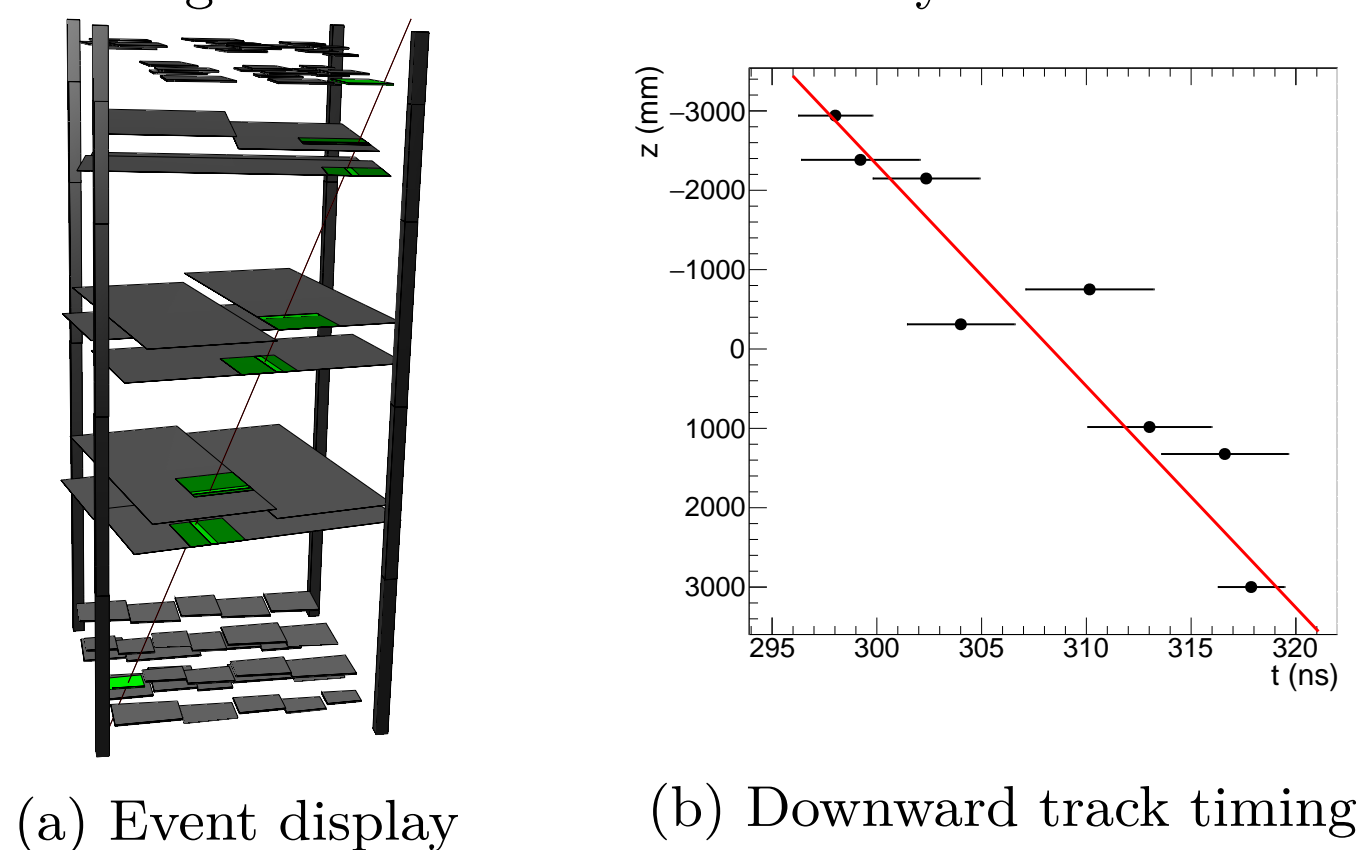
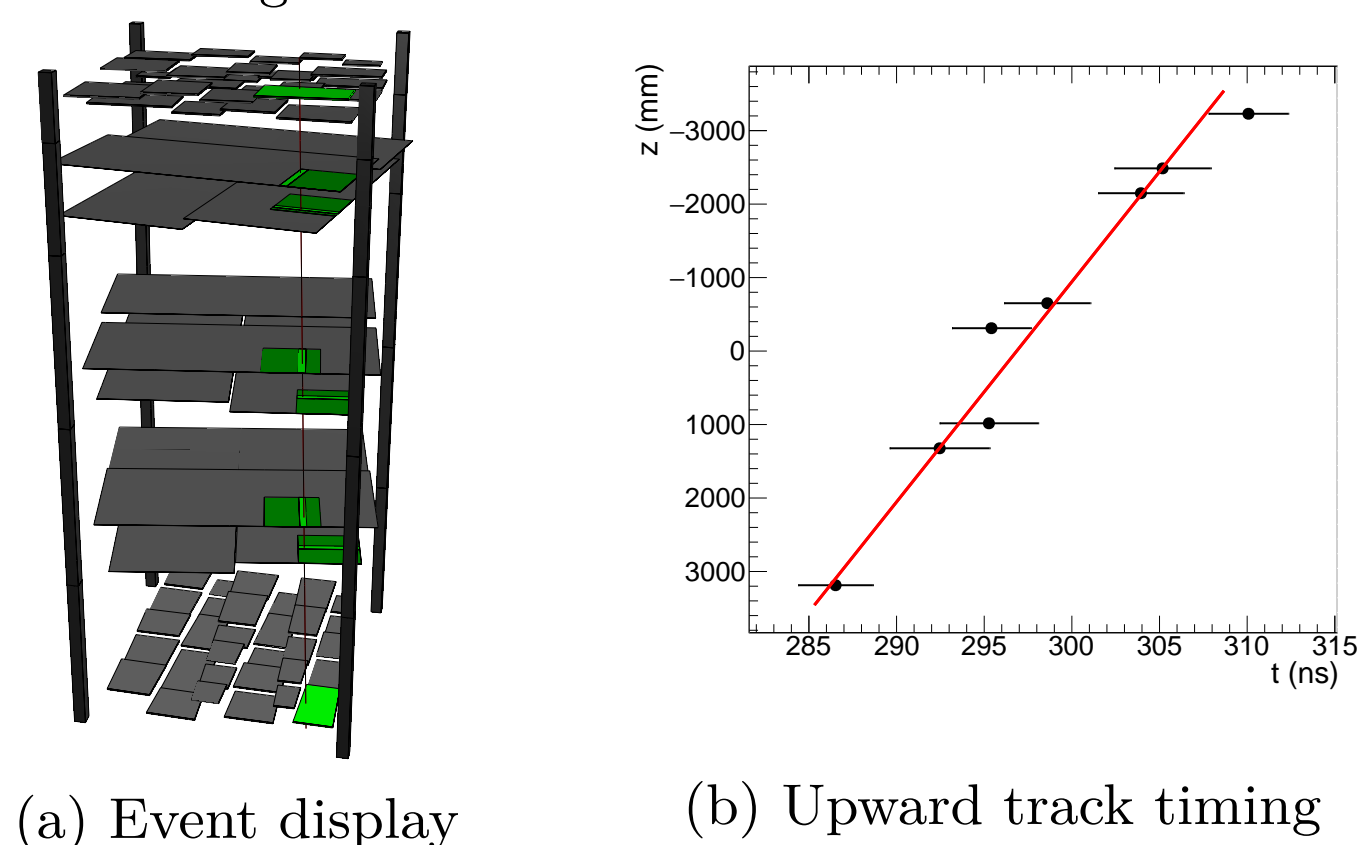


Figure 4: Candidate LHC muon



2. Apparatus and Operation

- Test stand built to study MATHUSLA backgrounds
- Composed of 59 scintillators and 12 RPCs
- Custom-built trigger and DAQ software
- Operated on surface above ATLAS in 2017 and 2018
- ~500 GB of data collected



Figure 1: Installation of test stand above ATLAS

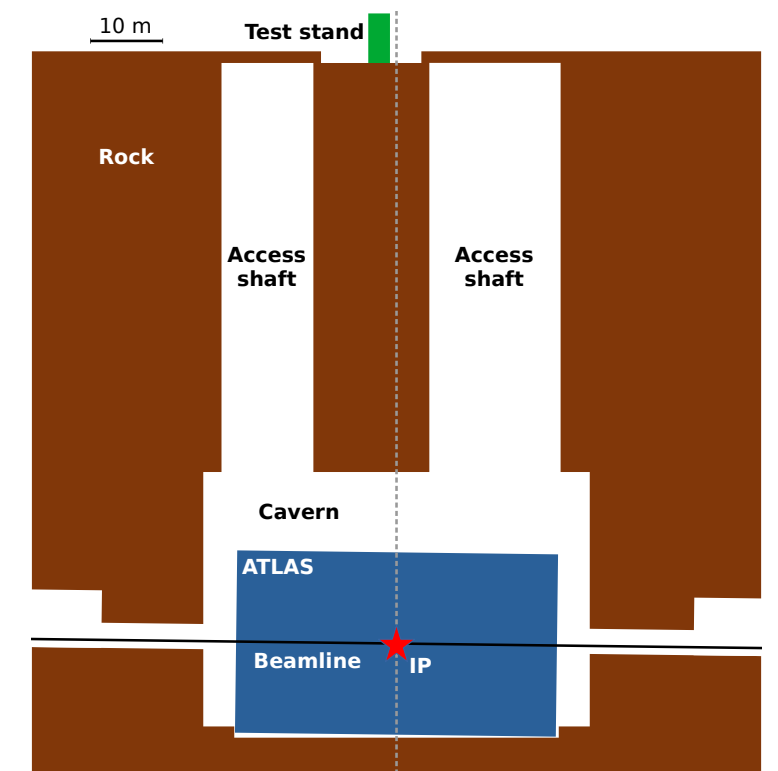


Figure 2: Location relative to interaction point (IP)

4. Results

- Figure 5 shows the angular distribution of downward tracks in data compared to MC-generated tracks from the theoretical cosmic ray muon prediction
- Rate of upward tracks is linearly correlated with the luminosity of collisions within ATLAS (Figure 6)

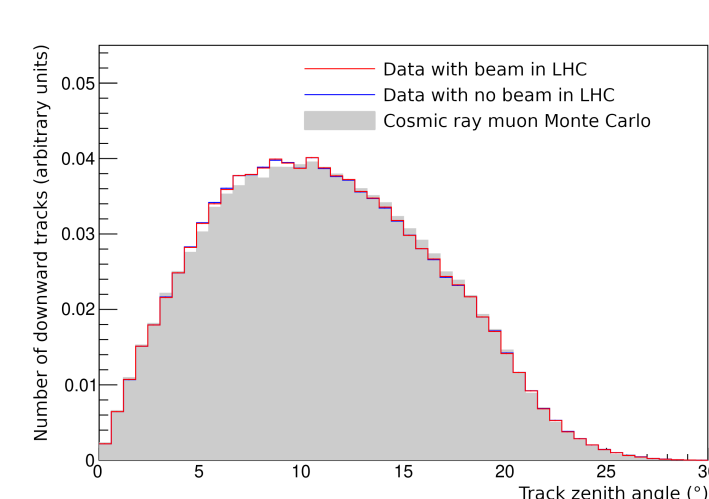


Figure 5

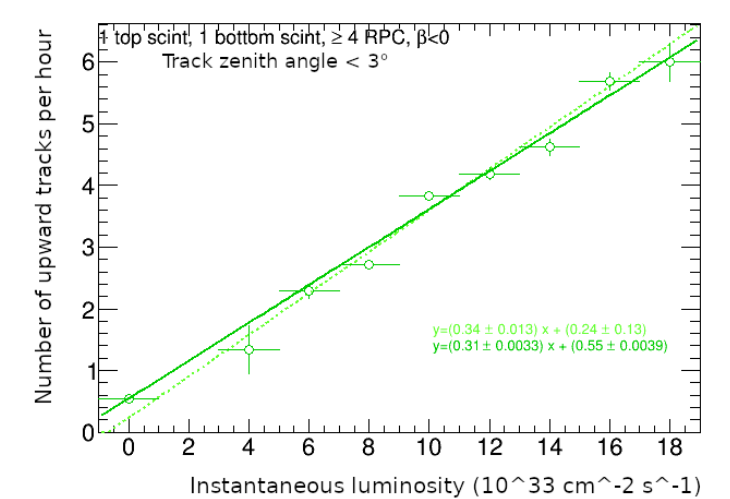


Figure 6

5. Conclusion

- Downward track angle distribution matches that expected from cosmic ray muons
- Data consistent with observation of upward ultrarelativistic particles created in LHC collisions
- Analysis is underway to determine measured rates corrected for acceptance and efficiency

6. References

- [1] J. P. Chou, D. Curtin, and H. J. Lubatti, *New Detectors to Explore the Lifetime Frontier*, Phys. Lett. **B767** (2017) 29-36, arXiv:1606.06298.
- [2] D. Curtin et al., *Long-Lived Particles at the Energy Frontier: The MATHUSLA Physics Case*, arXiv:1806.07396.
- [3] C. Alpigiani et al., *A Letter of Intent for MATHUSLA: a dedicated displaced vertex detector above ATLAS or CMS*, arXiv:1811.00927.