MATHUSLA Detector Development

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on behalf of the MATHUSLA collaboration

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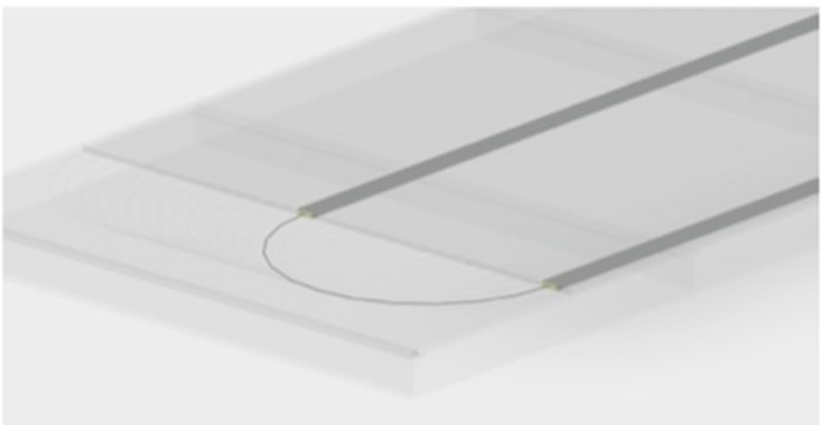
The MATHUSLA collaboration has proposed to construct a large area detector on the surface above the CMS experiment. Such a detector would search for long-lived exotic particles produced in the collisions at the LHC. In order to maximize acceptance and sensitivity, MATHUSLA intends to instrument a large surface area with multiple layers of scintillator bars. The massive scale of the detector requires a high level of modularity and cost efficiency in the design. To achieve these goals, MATHUSLA will use extruded scintillator bars with WaveLength Shifting Fibre (WLSF) threaded through for light collection. This results in a basic detector unit of 2.5m long scintillator bars threaded with a WLSF that terminate at SiPMs on either end. These units are combined into increasingly larger mechanical assemblies to construct the modular MATHUSLA detector layers. At the University of Victoria we are making use of a desktop darkbox as well as MATHUSLA prototype detector made of 4 MATHUSLA-like layers of scintillator to characterize the performance of the various WLSF compounds, SiPMs, and scintillator dimensions.

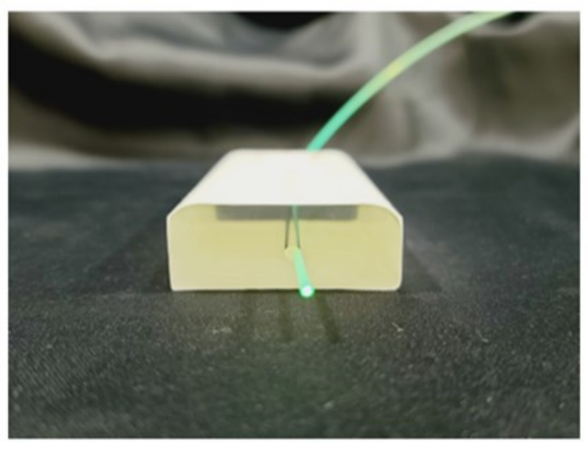
Detector Philosophy

The MATHUSLA detector locates particles:

- Within 5-10 cm along the bars using the time of arrival difference between the fibre ends
- Within 4 cm across the bars by physical constraint
- Within 1 cm vertically by physical constraint

The exact particle path can be reconstructed along with the direction of travel using timing differences between layers

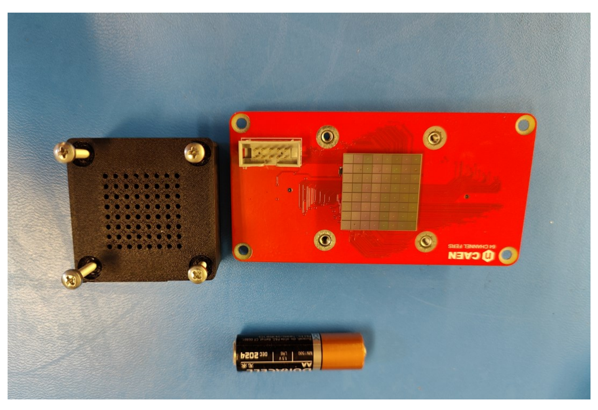


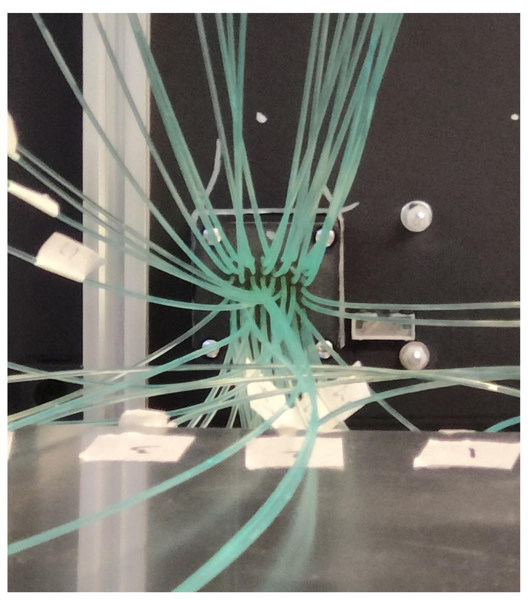


Test stand at the University of Victoria

At UVic we constructed a prototype of the MATHUSLA design

- 4 layers of scintillator spaced ~80 cm apart
- Each layer is ~80x100 cm^2 with alternating orientation
- DAQ is simplified with the use of a 64 channel MPPC SiPM array
- 32 WLSFs spread across the layers

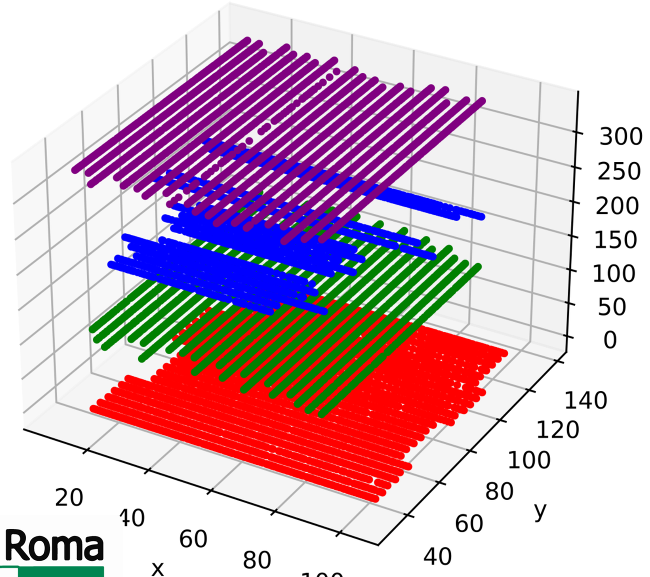


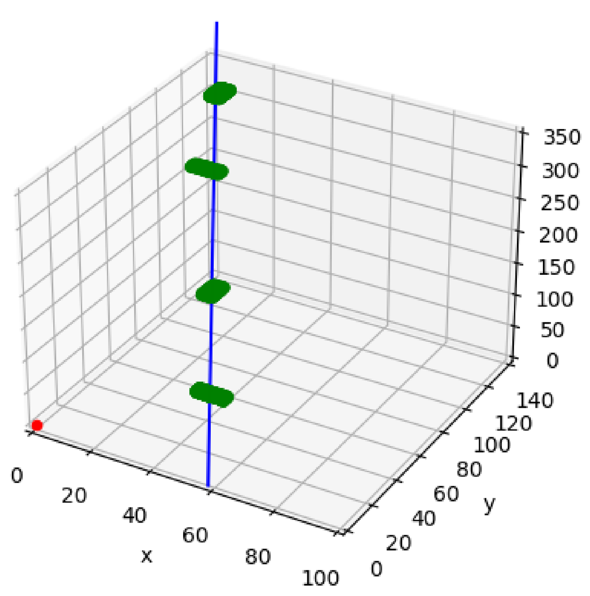


Test stand Operation

The prototype is operated with an OR64 trigger, reading out all SiPMs if any channel exceeds a threshold of 1.5 photoelectrons

- Dark noise is rejected in offline processing by requiring a coincident detection on the channel sharing the WLSF
- Mapping the location of hits from the timing differences allows for the detector to be mapped and tracks to be identified





Scintillator Bars

MATHUSLA requires about 100 tons of extruded polystyrene scintillator, in the shape of 250-cm long bars, with a 1x4 cm^2 cross-section

- Fermilab has produced a significant sample of scintillator for lab studies
- In discussion with Fermilab for large-scale production

Features under study:

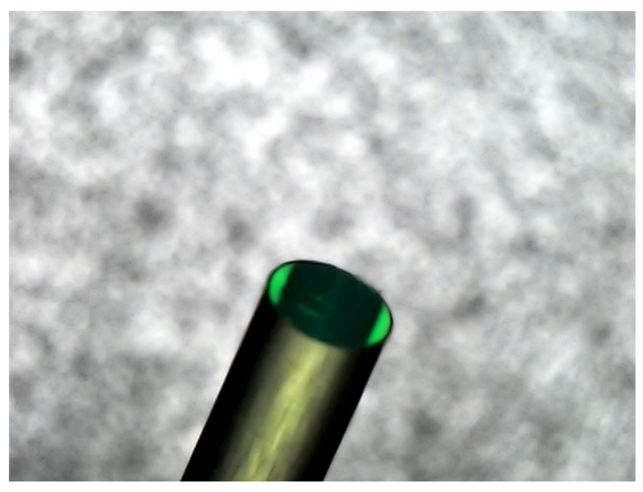
- Production variability in quality
- Expected light yield per muon crossing
- Inherent timing resolution

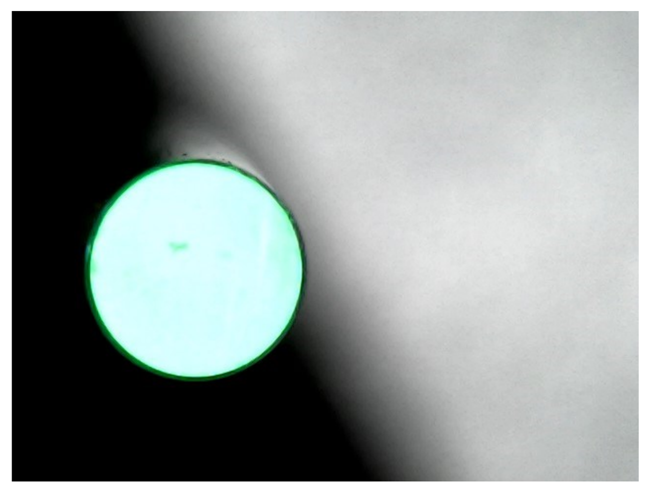
Wavelength Shifting Fibres

WLSFs transport the light from the scintillator to the SiPMs, important features include:

- Attenuation length
- Photon capture/re-emission efficiency
- Timing resolution

Currently under study are various Saint-Gobain and Kuraray fibres





Future Prospects

The test stand enables a number of studies preparing for the MATHUSLA full scale detector

- Study the inherent timing resolutions possible and the resulting track reconstruction constraints
- Develop software for reconstruction, quality assurance, tracking, directionality, and light leak detection
- Identify performance differences between various material choices
- Determine optimal layer spacings
- Measure the detection efficiency from expected cosmic muon flux

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