Prototype water Cherenkov detector measurements for muon tomography applications

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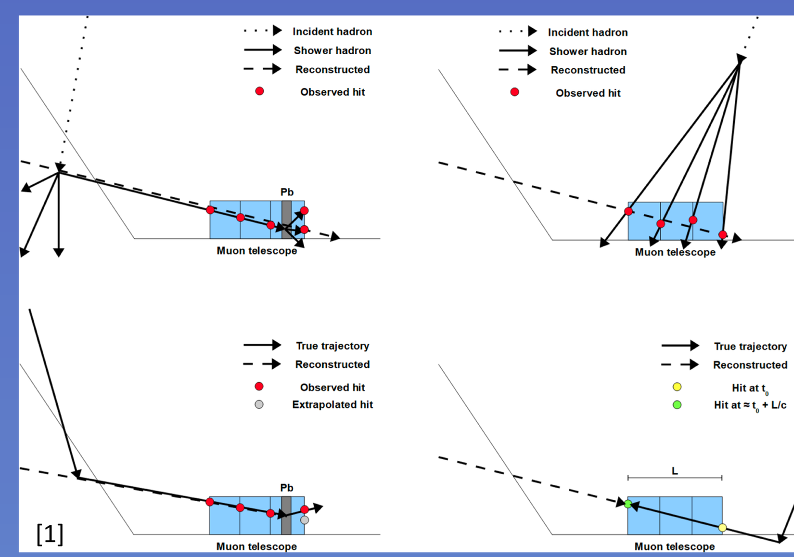
Figure 1

Introduction

Muography is an imaging technique based on the detection of muons produced naturally in the atmosphere with applications in Volcanology, Archaeology, Civil Engineering, Homeland Security etc. Various types of background impact absorption tomography measurements at high zenithal detection angles. Trackers combined with Cherenkov detectors have been proposed as means for better background rejection especially for low energy muons and electrons.

Background Types

- Fake Muons
  Charged hadrons or e±
- Soft Muons
  Low momentum muons


[1]

Prototype Cherenkov Detector

- The prototype (fig. 1) consists of a cylinder of grey PVC with 1 cm thickness and 15.7 cm radius. The internal surface is covered with Tyvek to increase reflectivity and the water level stands at 1 m.
- A Hamamatsu H8804-300 MaPMT is used for the photon detection.
- Optically coupled to 64 optic fibers (Kuraray-Y11) for increased light collection efficiency.

Characterisation Setup

- Hodoscope with two muon trackers on top and below the prototype (fig. 1 - center).
- Energy discrimination for muons above 0.7 GeV with 40 cm of lead bricks in-between the bottom tracker planes.
- 2 DAQ runs performed, with and without lead.

Validation

- Simulation shows similar behaviour for the prototype response at different energy regimes (fig. 2)
- Calculations [2] on the expected Cherenkov light yield from muons & δ-rays shows also an expected drop for the signal (fig. 3), at these energies.

Experimental Results

	No Lead		Lead	
Type	Percent	MPV (p.e.)	Percent	MPV (p.e.)
4-fold	88%	31.29 ± 0.06	70%	31.14 ± 0.05
3-fold	12%	31.10 ± 0.1	30%	27.19 ± 0.15
Tracks:	55191		59566	

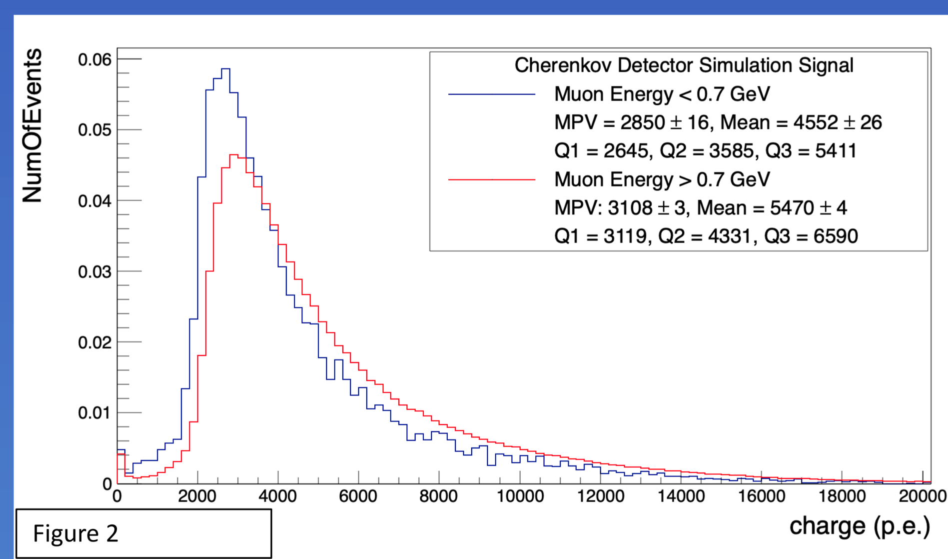


Figure 2

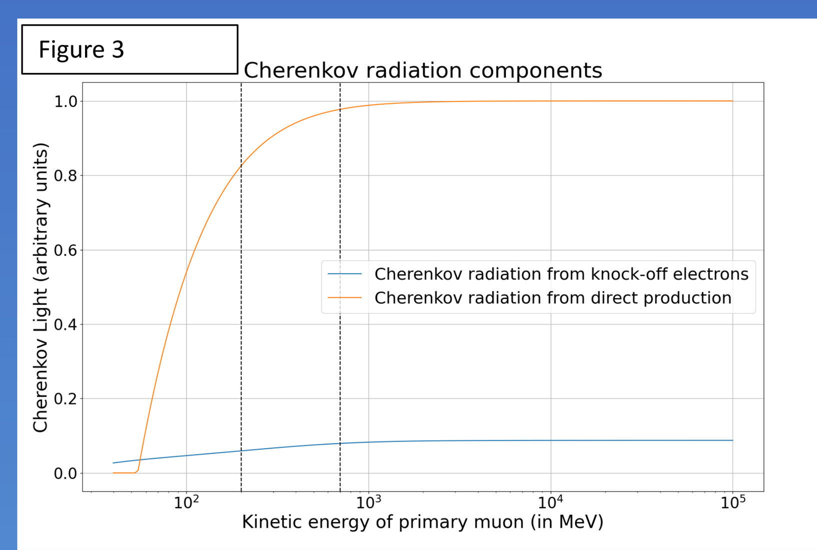


Figure 3

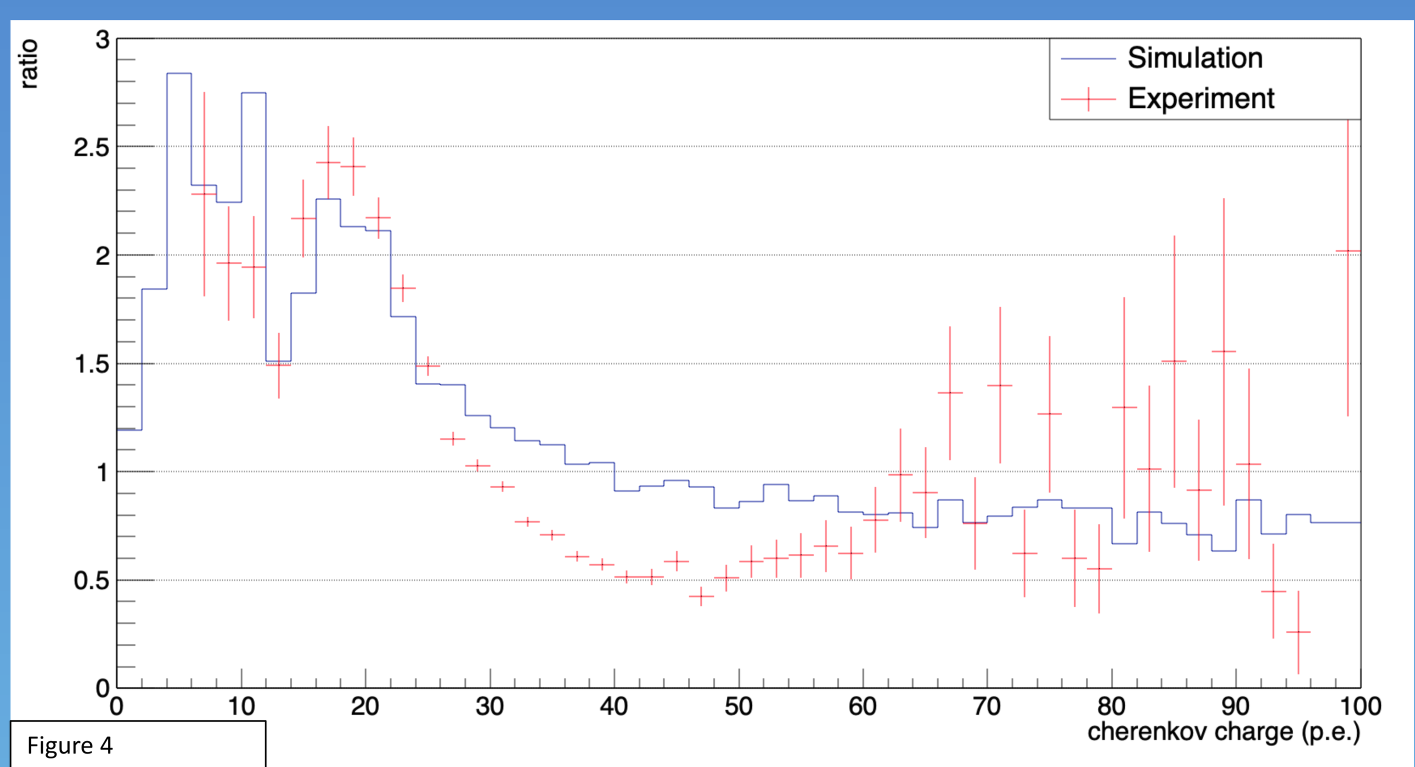


Figure 4

Comparison - Data/MC

- The two orders of magnitude difference between the simulation and the experiment can be explained by the PMT efficiency, the optic fibers collection efficiency and other effects that are not accounted for by the simulation.
- Comparing the Cherenkov response ratio of 3-fold coincidence tracks to 4-fold coincidence tracks shows that the detector differentiates between low energy and high energy muon tracks (fig. 4)
- The probability that the Detector response to low energy tracks is lower than 26 p.e. is 1.5 to 2 times higher than for high energy tracks to give signal in the same region.

Conclusions

- Designed a portable, compact, robust & low power Cherenkov Detector for muography experiments
- Proved that light collection with optical fibers is feasible.
- Operational with the same DAQ chain used for muon telescope elements [3] which means seamless installation to existing telescopes deployed at various sites around the globe.
- Detection of the expected drop in photon yield for low energy tracks is encouraging for future developments on particle energy discrimination.

Outlook

- Propose an optimal fiber layout based on the expected Cherenkov signal (fig. 5)
- Forward/Backward propagating muon discrimination (fig. 6 - Preliminary)
- Develop precise MC for Cherenkov Detector
- Replace the middle plane and the passive particle filter, based on Lead plates, on the existing telescopes with an active Cherenkov detector.

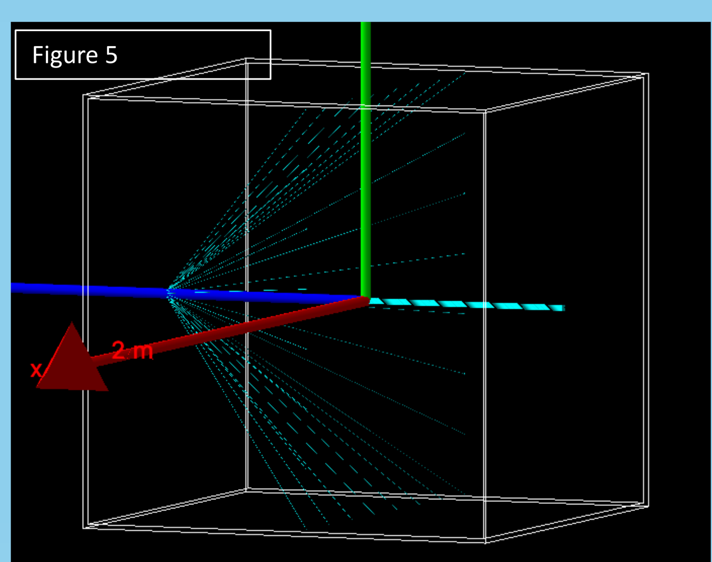
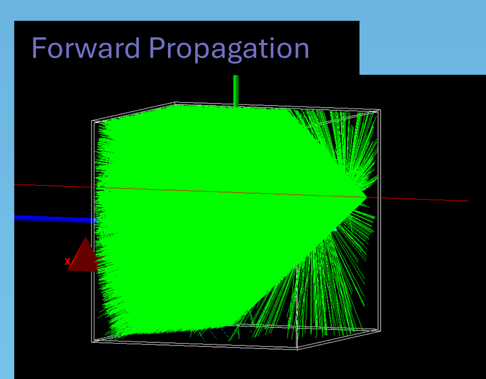
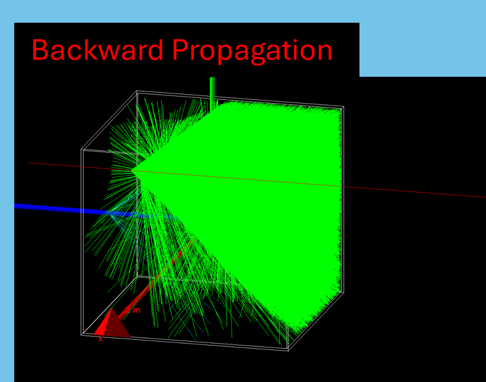


Figure 5





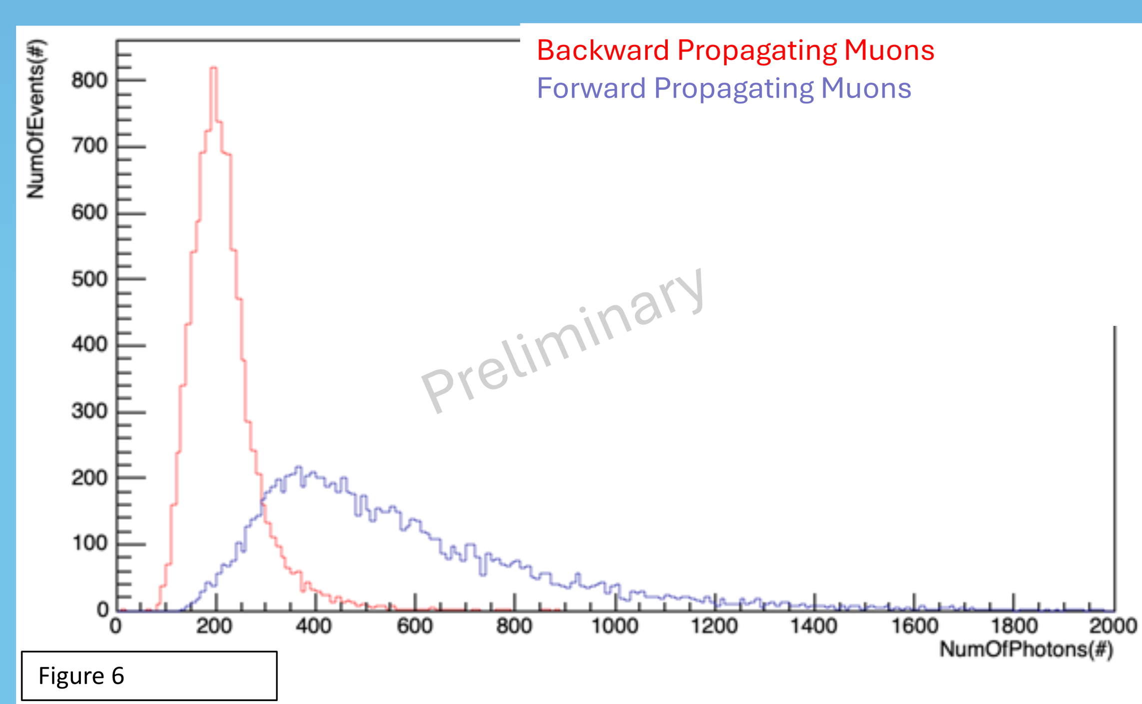


Figure 6

Acknowledgements

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