# Development of a compact & portable muon telescope

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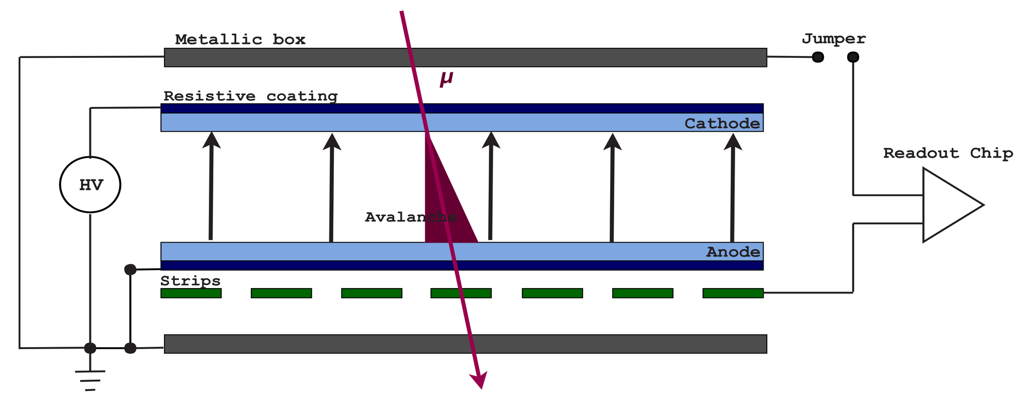
## Motivations

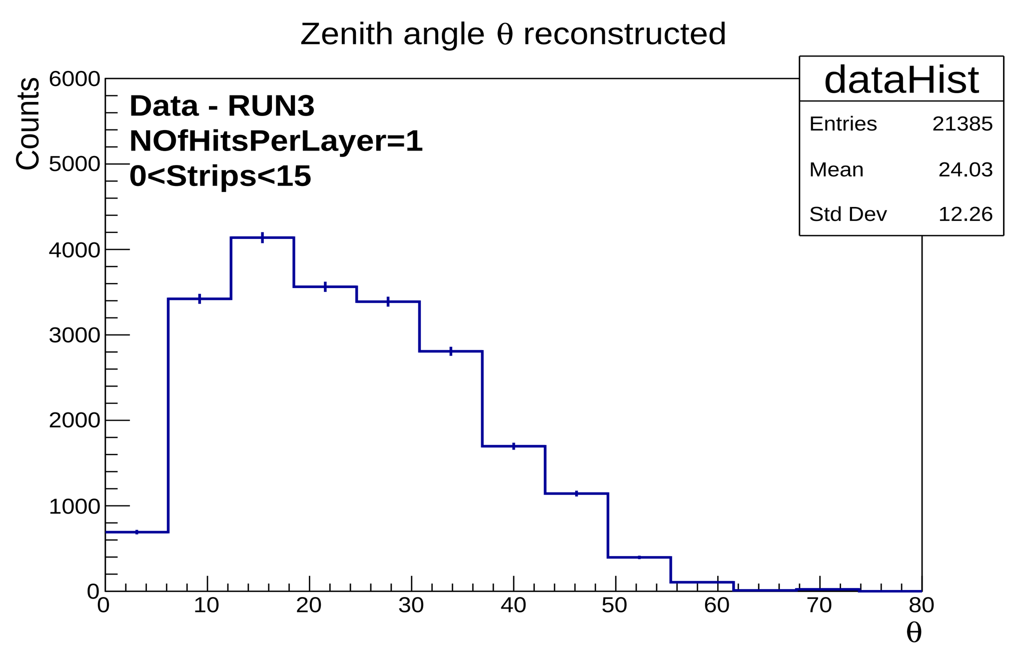
We report on the first steps in the development of a small-size muon telescope based on glass Resistive Plate Chambers with small active area ($16 \times 16\ cm^2$). The long-term goal of this project is to focus on applications of muography where the telescope may have to be operated underground and/or inside confined spaces, and in challenging logistic situations. Driving principles in our design are therefore compact size, low weight, gas tightness, and robustness [1].

## Basic Principle of RPCs

RPCs are gaseous detectors that consist of two parallel plates (anode & cathode) of high resistivity separated by a gas volume that acts as a capacitor [2].




## Track reconstruction




Zenith ($0 < \theta < \pi/2$) and azimutal ($0 < \phi < 2\pi$) angles of muon trajectories have been reconstructed thanks to the position information of the hit in each chamber. In this way, four coordinates ($x_0; y_1; x_2; y_3$) obtained from the four chambers directly give the angles of the muon trajectory :

$$\theta = arccos\left(\frac{z}{r}\right), \qquad \phi = atan2\left(\frac{y}{x}\right)$$

where $x = x_2 - x_0$ is the distance between touched strips of x-chambers, $y = y_3 - y_1$ same but between y-chambers, $z$ the fixed distance between x-chambers or y-chambers, $r = \sqrt{x^2 + y^2 + z^2}$ and $atan2$ the C++ function arc tangent in $[-\pi, +\pi]$.

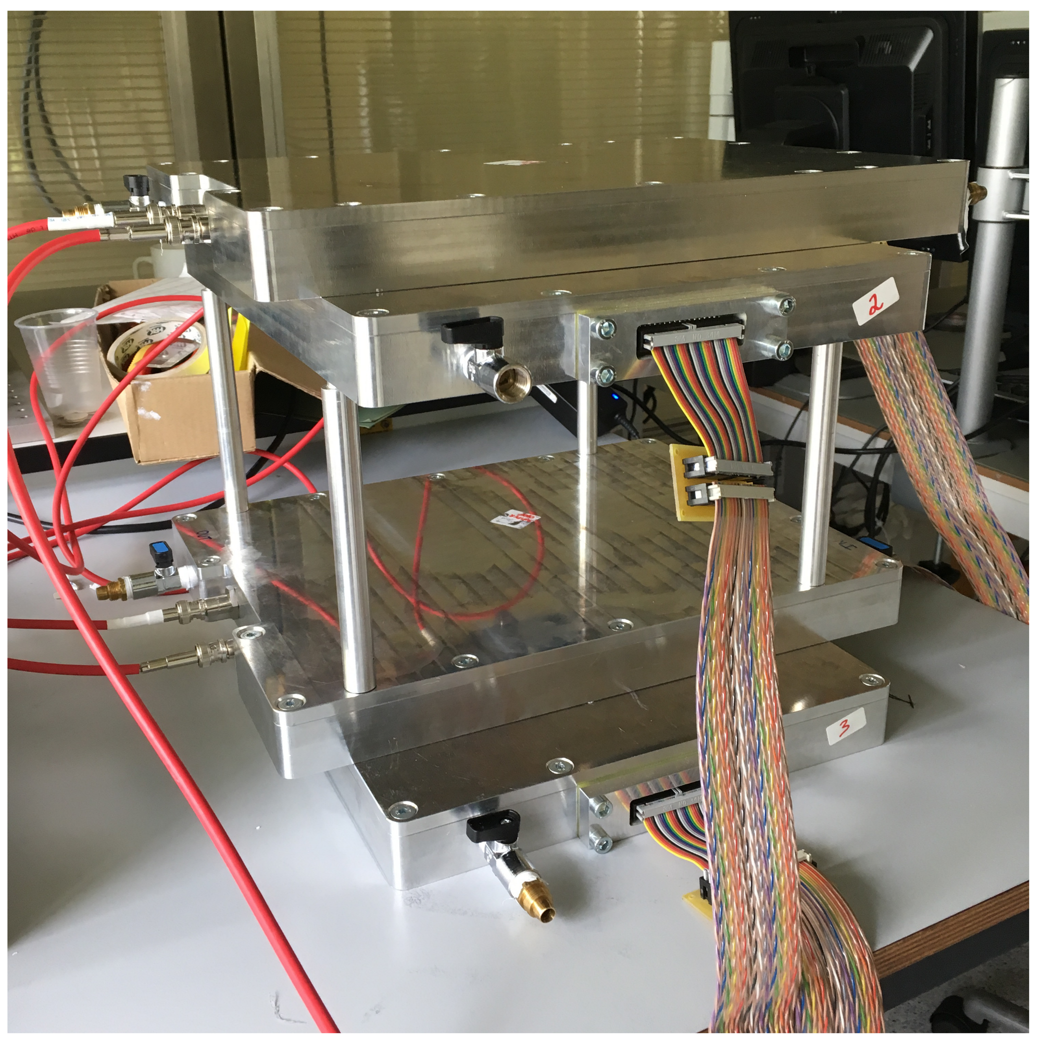
## References

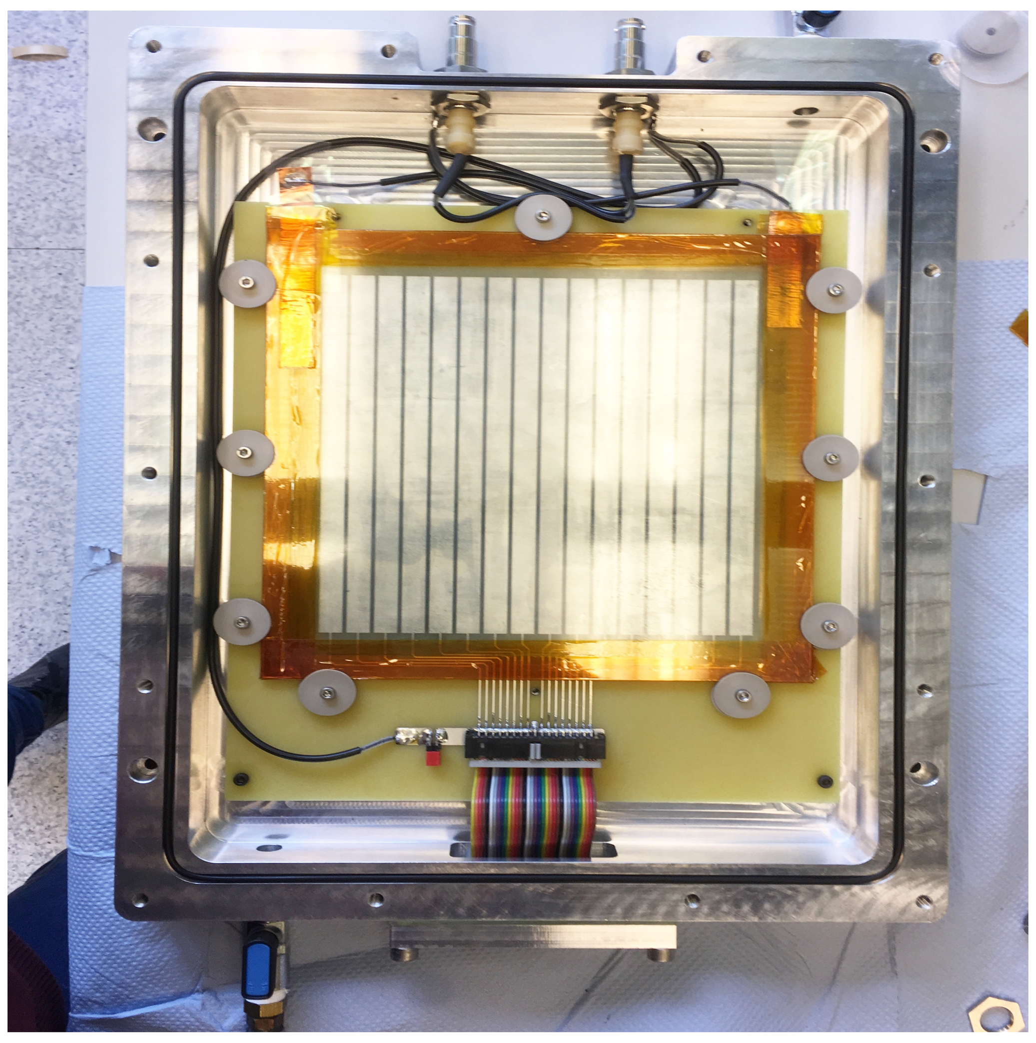
[1] S. Wuyckens, A. Giammanco, E. Cortina Gil, P. Demin. A portable muon telescope based on small and gas-tight resistive plate chambers. Phil.Trans.R.Soc.A 377:20180139, 2018. http://dx.doi.org/10.1098/rsta.2018.0139

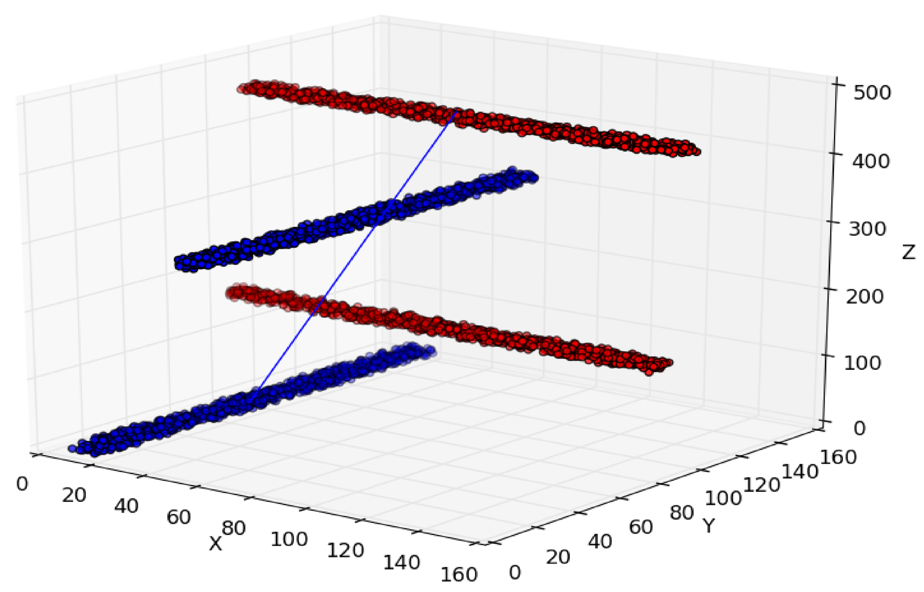
[2] Frederic Van Assche. Development of a resistive plate chamber detector simulation framework. PhD thesis, UGent, 2016

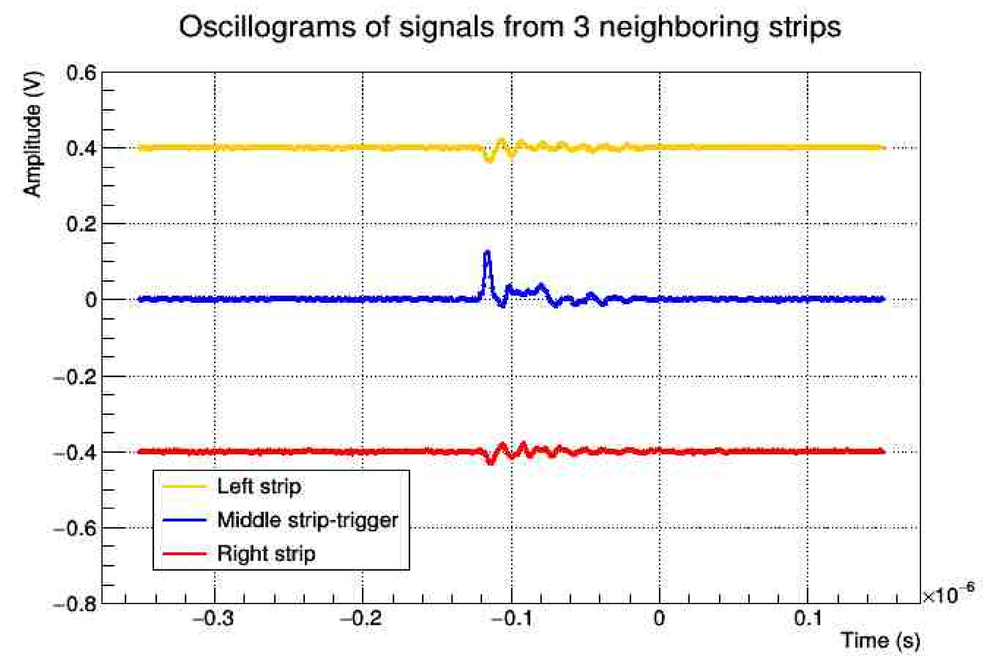
[3] S.Procureur, R.Dupré, S.Aune. Genetic multiplexing and first results with a 50x50 $cm^2$ Micromegas, NIM A, 729:888, 2013.

## Experimental set-up and muon signal



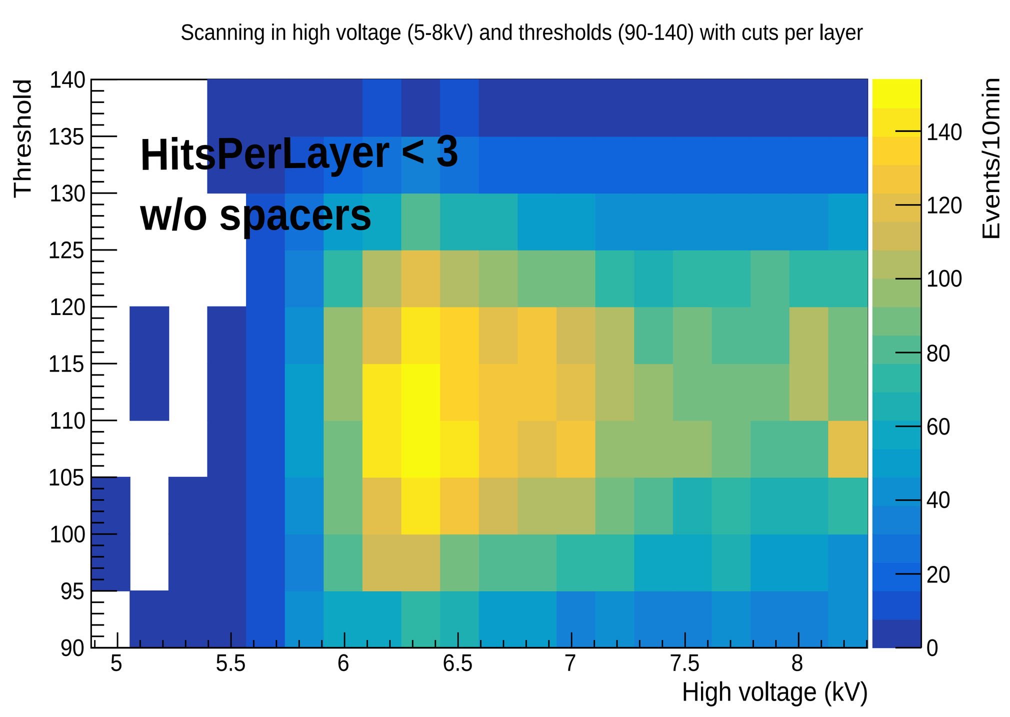


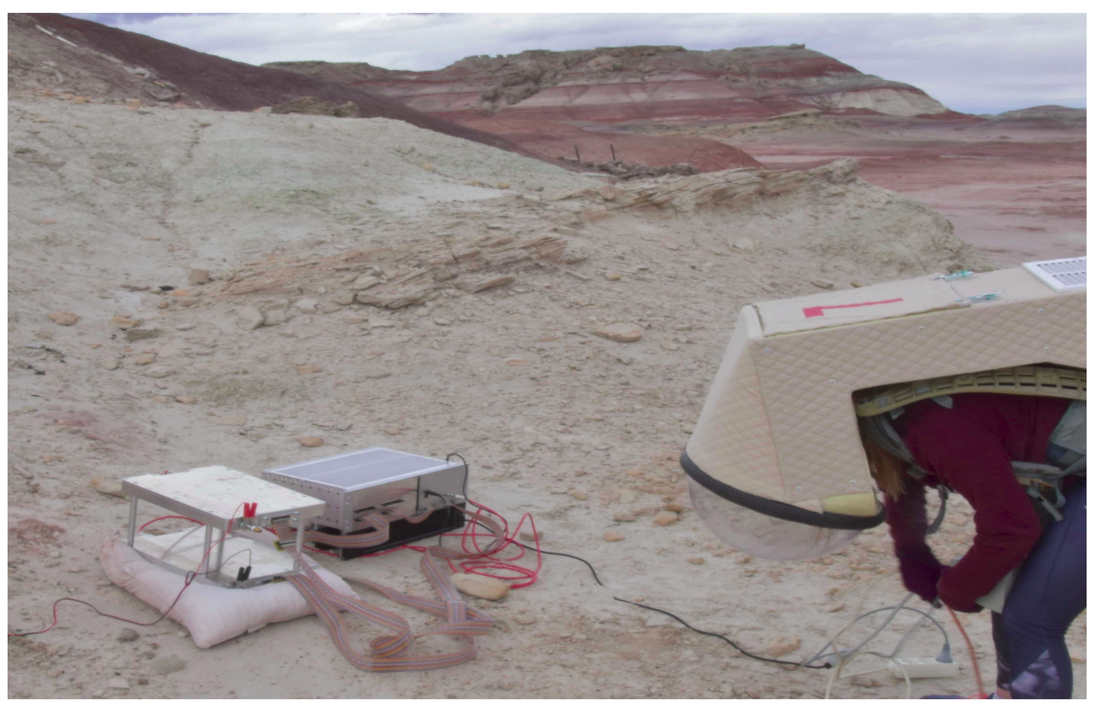



## Operation

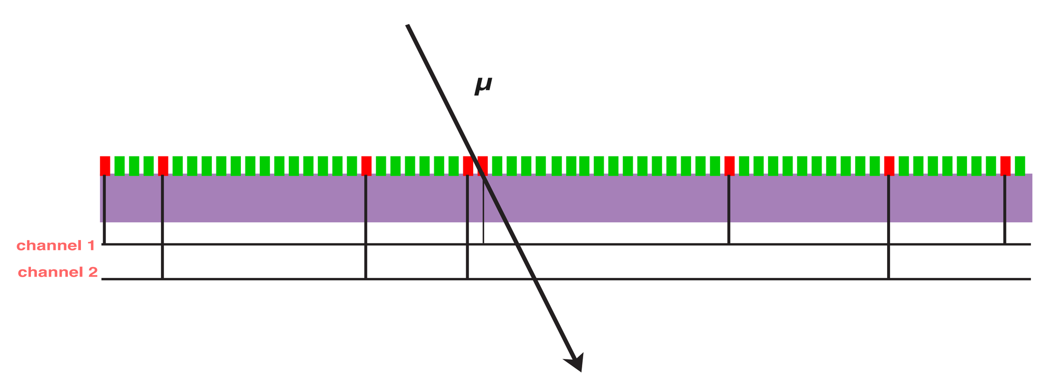
Taking advantage of the participation to UCL to Mars 2018 (`http://ucltomars.org/`), a life on Mars simulation at the Mars Desert Research Station, a first campaign has been conducted during 15 days in the Utah Desert (USA). It was a useful test of portability, and we verified that this set-up is sufficiently robust and gas-tight, in spite of its lightness, to survive a trip to the US and back. The data obtained were not as satisfactory as expected due to bad gas mixture filling and wrong polarity voltage. New data have been collected at UCL to find the optimal values for operating voltage and threshold as well as getting zenith and azimuths angle distributions of muons.



## Next Steps

- Long-term stability tests for sealed chambers
- Optimization of chamber construction: new coating procedures for the glass electrodes
- Optimization and simplification of gas parameters (with University of Ghent)
- Improvement of spatial resolution:
  1. Thinner strips: up to a factor 10 is potentially achievable
  2. High-granularity, low power consumption electronics with the MAROC3 64-channel ASIC (with LIP, Portugal)
  3. Codification / grouping of readout structures to reduce by factor 10 the number of front-end electronic channels




Genetic multiplexing principle [3]

## Acknowledgements

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