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Portable Muon Telescope for multidisciplinary applications

Muon tomography or "Muography"is an emerging imaging technique that uses cosmogenic muons as the radiation source. Due to its diverse range of applications and the use of natural radiation, muography is being applied across many fields such as geology, archaeology, civil engineering, nuclear reactor monitoring, nuclear waste characterization, underground surveys, etc. [1]. Muons can be detected using various detector technologies, among which, resistive plate chambers (RPC) are a very cost effective choice [2]. RPCs are planar detectors which use ionization in a thin gas gap to detect cosmic muons, already used since years in major particle accelerator experiments.

In this project, we have developed a muon telescope (or "muoscope") composed of small scale RPCs. The design goal for our muoscope is to be portable and autonomous, in order to take data in places that are not easily accessible. The whole setup is light and compact, such to be easily packed in a car trunk. Individual RPCs are hosted in aluminium that are gas tight. There is no need for gas bottles, once the chambers are filled. The muoscope can be controlled from a reasonable distance using wireless connection. The usage goals of our device are very broad and include, for example, 3D imaging of cultural heritage, such as monumental statues and building decorations. For this kind of application, more established methods based on other forms of radiation (X rays, neutrons) are often infeasible as these objects are very large and in many cases they can not be transported to a properly equipped laboratory.

The current muoscope prototype consists of four identical RPCs and the data acquisition system (DAQ) comprising a computer integrated with high voltage supply to the RPCs. The first and third RPCs are oriented orthogonally to the second and fourth, in order to provide a bi-dimensional information (x and y orientation). Each RPC consists of 2 glass plates with the size of 20 cm x 20 cm, with semi-resistive coating of 18 cm x 18 cm active area, separated with spacers to create a gap of 1.1 mm between them, and a readout board with 16 copper strips. Each strip is 16 cm long and 0.9 cm wide, with a 0.1 cm distance between strip edges. Our RPCs are filled with a specific mixture of 3 gases: Freon (95.2%), ISO-Butane (4.5%) and SF6 (0.3%). The DAQ has two front end PRC boards from the CMS experiment, and each board can handle 32 analog inputs. Each channel is connected to the System on Chip (SoC) module, which is installed in a carrier board with wireless connection. We are using different simulation frameworks like Geant4, COMSOL/Elmer (to calculate the electric field), Garfield++ (to simulate the signal formation) to compare with actual data.

At iWoRID 2021, we are going to present recent development of the current prototype with respect to [3] and [4] and the development that we are planning to do in the near future. We introduced an external trigger system, and the RPCs are upgraded with new semi-resistive glass plates and gas mixture. The resistive coating of these glass plates is laid with a serigraphy method, achieving a much better uniformity with respect to the manual procedure described in [3]. We report on performance and simulation studies and on the resistivity variation of these plates with time.

[1] Atmospheric muons as an imaging tool / L. Bonechi, R. D'Alessandro, A. Giammanco; arXiv:1906.03934 [physics.ins-det]; Reviews in Physics 5 (2020) 100038.
[2] Resistive Plate Chambers in Muography, S. Andringa, E. Cortina Gil, A. Giammanco, M. Tytgat. 22 pages. Peer-reviewed contribution (status: accepted) to the book "Muography: Exploring Earth's Subsurface with Elementary Particles", edited by L. Olah, H. Tanaka and D. Varga. To be published in 2021 by the American Geophysical Union / Wiley.
[3] Towards portable muography with small-area, gas-tight glass Resistive Plate Chambers / S. Basnet, E. Cortina Gil, P. Demin, R.M.I.D. Gamage, A. Giammanco, M. Moussawi, M. Tytgat, S. Wuyckens; arXiv:2005.09589 [physics.ins-det]; JINST 15 (2020) C10032

[4] A portable muon telescope based on small and gas-tight Resistive Plate Chambers / S. Wuyckens, A. Giammanco, P. Demin, E. Cortina Gil; arXiv:1806.06602 [physics.ins-det], Phil. Trans. R. Soc. A 377 (2018) 20180139

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