

First results of the cosmic ray muon variation study by means of the scintillation muon hodoscope

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Abstract. The new scintillation muon hodoscope to study cosmic ray muon flux variations was created in MEPhI. The basic characteristics of the hodoscope (sensitivity area, precision of the muon track reconstruction, ‘live’ time etc.) are comparable with other hodoscopes (TEMP and URAGAN) of MEPhI. Modular design is a distinctive feature of the detector, supplying relatively easy transportability, and low maintenance requirements give a possibility of a long-term autonomic operation. First results of the cosmic ray muon variation study by means of the scintillation muon hodoscope are presented and discussed.

1. Introduction

Passing through the heliosphere, primary cosmic ray flux is modulated by processes related with solar activity, that leads to the muon flux variations on the Earth surface. Also, the intensity of the muon flux at the surface is sensitive to different powerful thermodynamic atmospheric processes. Thus, measuring of muon flux intensity and temporal-angular distributions gives us a possibility to investigate different phenomena in heliosphere, magnetosphere and atmosphere. The method which provides this way of remote monitoring is named a muon diagnostics [1].

For implementation of the method of muon diagnostics, the coordinate-tracking detectors of muons – hodoscopes – are necessary. Taking into account the experience of the muon hodoscope design and operation: TEMP (1995) [2] and URAGAN (2005) [3], a new scintillation muon hodoscope (ScMH) was created (MEPhI, 2010 – 2014) [4]. ScMH is capable to register small variations of the muon flux passing through the detector from all directions of the upper hemisphere. The basic characteristics of the ScMH (sensitivity area, precision of the muon track reconstruction, ‘live’ time etc.) are comparable with TEMP and URAGAN. But the ScMH has some competitive difference: modular design, supplying relatively easy transportability, and low maintenance requirements which give a possibility of long-term autonomic work.

2. Scintillation muon hodoscope

2.1. The setup

A new scintillation muon hodoscope is a coordinate-tracking muon detector which consists of identical detectors – supermodules (SM). Each SM has a sensitive area about 11.6 m², a good spatial



(about 2.5 cm) and angular (better than 2°) accuracy, a wide zenith angle aperture of muon registration $0^\circ - 75^\circ$. A long narrow strip (with dimensions $10.6 \times 26.3 \times 3460 \text{ mm}^3$) of plastic scintillator with wavelength shifting (WLS) fiber optics is a basic detection element of ScMH [5]. SM consists of four X – Y coordinate planes (CP) mounted in a common assembly. General view of the ScMH SM is presented in figure 1.

Each CP consists of two coordinate layers with orthogonally oriented strips, which provides measurements of X and Y coordinates of muon track passing point. The coordinate layer consists of two adjacent modules – basic non-dismountable modules (BM) of the detector, consisting of 64 scintillation strips in a common housing. BM has a single photodetector to receive light pulses from all its strips. One end of each WLS fiber is positioned opposite the corresponding cell of 64-channel multi-anode photomultiplier tube (MAPMT).

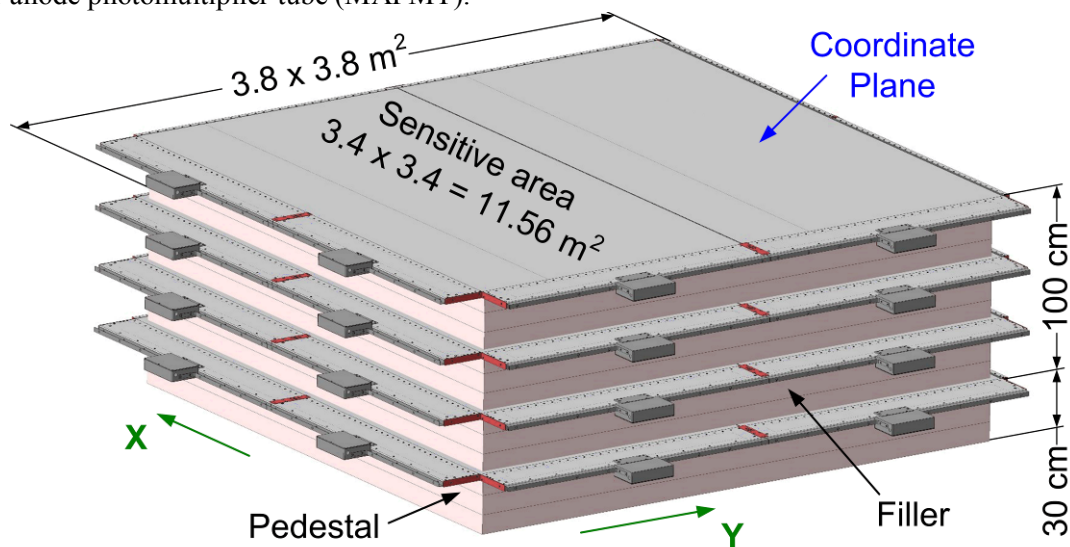


Figure 1. A general view of the wide-aperture scintillation muon hodoscope.

Data acquisition (DAQ) system of ScMH supermodule consists of the following sub-systems: front-end electronic boards for MAPMT signal procession (based on MAROC2 chip); a central DAQ controller for processing of data from all BMs and trigger formation (based on Cyclone III FPGA Development Kit); a PC for data collection, processing and final data storage.

2.2. Data of scintillation muon hodoscope

Experimental data of ScMH represent a sequence of one-minute frames (the live time is about 54 s), which includes: matrices of angular distribution of muons, monitoring data (counting rates of basic modules), number of reconstructed tracks and number of tracks passing through all coordinate planes of the hodoscope, statistics of triggered strips ('hits'), live time of the frame, atmospheric pressure and temperature in the facility hall averaged during a minute, etc.

The time rows of the muon tracks reconstruction efficiency of several coordinate layers of ScMH SM02, with temperature in facility hall and atmospheric pressure are presented in figure 2. The muon track reconstruction efficiency is estimated for each coordinate layer thanks to DAQ system which has a soft condition of master trigger – 5 triggered coordinate layers from 8. The efficiency is calculated as a ratio of muon counting rate with a corresponding coordinate layer to all muon counting rate of SM. This value allows estimating of operation efficiency of each coordinate layer and corresponding basic modules relative to other coordinate layers and quality as a whole. Figure 2 shows that the SM02 of the ScMH operated stably during August 2015, wherein pressure changed from 989 mbar to 1008 mbar, temperature in the facility hall was 23.5°C with $\pm 1.5^\circ\text{C}$ scatter.

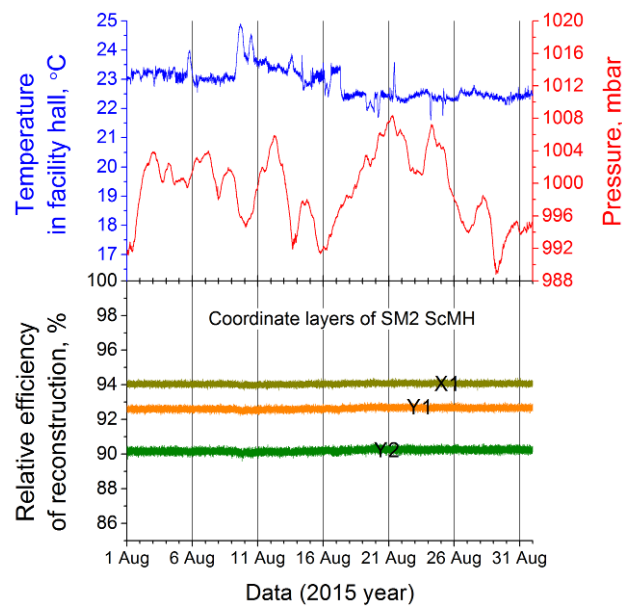


Figure 2. The time rows the muon tracks reconstruction efficiency of several coordinate layers of ScMH SM02 (down), with temperature in the facility hall and atmospheric pressure (up).

3. Detection of various phenomena with scintillation muon hodoscope

3.1. The Forbush decrease in data of scintillation muon hodoscope

The counting rate of the muon hodoscope is sensitive to different processes – in planetary scale, of terrestrial and extraterrestrial origin. The hourly average counting rates of the Moscow Neutron Monitor (min^{-1}), scintillation muon hodoscope (s^{-1}) and muon hodoscope URAGAN (s^{-1}) [6, 7] during second part of June 2015 are presented in figure 4. The responses of these detectors during Forbush decrease of 22 June 2015 are clearly visible in the figure. The counting rates of scintillation muon hodoscope and muon hodoscope URAGAN decreased by about 3%. The counting rate of the Moscow Neutron Monitor decreased by about 6.5%.

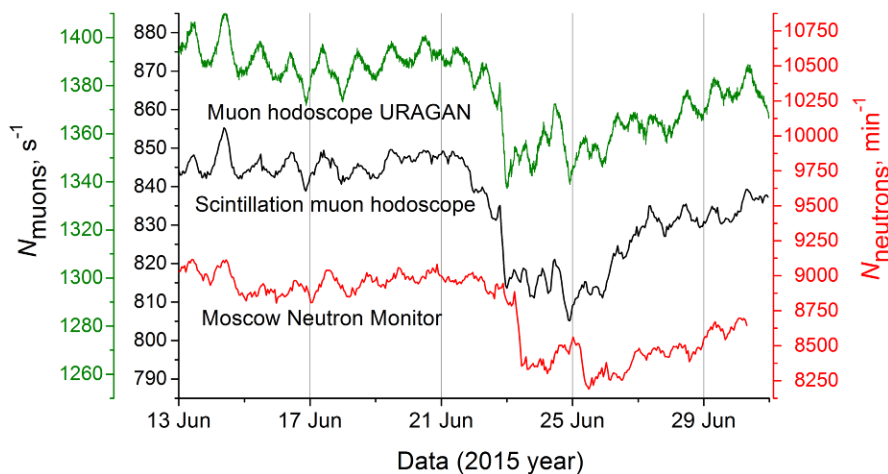


Figure 4. The hourly average counting rates of muon hodoscope URAGAN, scintillation muon hodoscope and Moscow Neutron Monitor during Forbush decrease of 22 June 2015.

3.2. The thunderstorm in data of scintillation muon hodoscope

Active turbulent atmospheric processes, for example thunderstorms, cause sharp changes of anisotropy of the muon flux. To visualize the dynamics of these changes, the ‘muon snapshots’ (muonographies) are used [8]. To improve the contrast of the images, the original matrix is normalized to the averaged during preceding 24 hours. It gives the matrix in standard deviations of detected number of events for every cell. To suppress the high frequency deviation, the filtration procedure is applied for the matrices. Examples of 5-min muon images of ScMH and URAGAN hodoscopes, obtained during thunderstorm of 14 Jun 2014 are shown in figure 5. As it follows from the figure, these detectors exhibited a same decrease level of muon flux from same direction – about 0.47% of scintillation muon hodoscope and about 0.43% of muon hodoscope URAGAN.

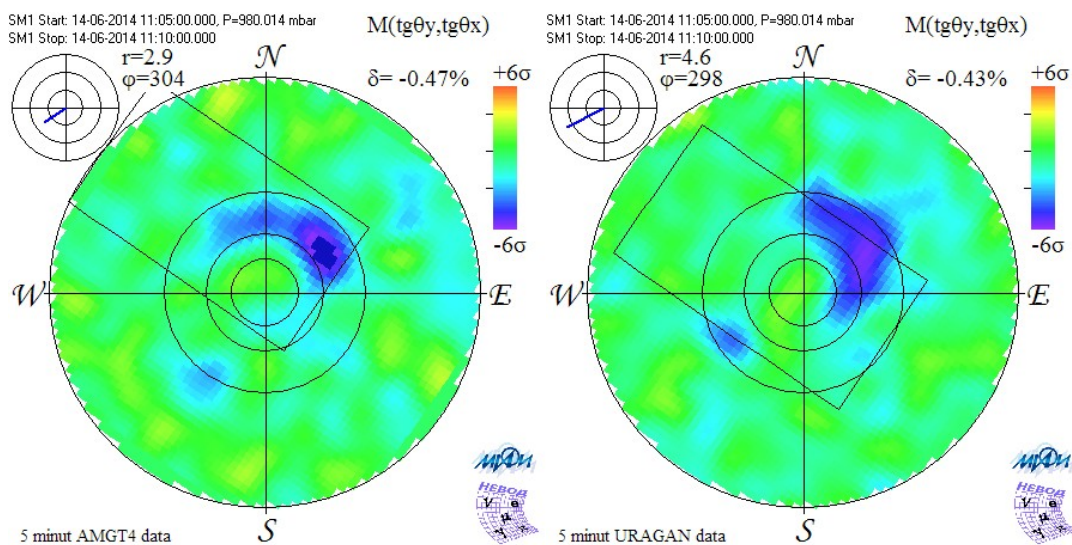


Figure 5. The muon images of scintillation muon hodoscope (left) and muon hodoscope URAGAN (right) during thunderstorm of 14 Jun 2014.

4. Conclusions

The results of the analysis of the scintillation muon hodoscope operation show that the constructive and technological solutions used during the detector design allowed to create the detecting system of scintillation muon hodoscope which ensures required parameters and stability of operation during long time. The created scintillation muon hodoscope is sensitive to events of changing of primary cosmic ray flux and to local events caused by atmospheric processes.

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5. References

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