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Muon hodoscope with scintillation strips

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Abstract

Measuring system of scintillation muon hodoscope with WLS light collection for the study of the processes in the heliosphere and terrestrial atmosphere is described. Procedures of testing and adjusting of basic modules and muon hodoscope as a whole are presented.

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1. Introduction

Muon flux on the Earth surface is formed as a result of the interactions of primary cosmic rays (PCR) with nuclei of atmospheric atoms. Passing through the heliosphere PCR flux is modulated by processes related with solar activity and affects the PCR flux intensity and anisotropy. PCR modulations lead to the muon flux variations on the surface.

Directions of muon tracks at the ground level are close to directions of parent PCR particles. It allows us to associate variations of the angular distribution of the muon flux with the PCR flux variations. Thus, we have a possibility to investigate different phenomena in the heliosphere with a facility at the ground level which is able to detect angular distribution of muon flux in the real time mode. On the other hand, the intensity of the muon flux at the Earth's surface is sensitive to different thermodynamic atmospheric processes (seasonal, local, turbulence events, rapid variations of air density, etc.). These processes also modulate the muon flux. Thus, changing of muon flux

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intensity and time-angular distribution give us a possibility to have an overall picture of the atmosphere, magnetosphere and near heliosphere and to follow dynamics of their changing. The method of remote diagnostics of the Earth atmosphere and near-terrestrial space is named a muon diagnostics [1].

For solving problems of muon diagnostics, the coordinate-tracking detectors – muon hodoscopes were elaborated in MEPhI (Moscow). Muon hodoscope is capable to register small variations of the muon flux, passing through the detector from all directions of the upper hemisphere. These detectors must have a large sensitive area, sufficient to provide necessary muon statistics, and have a good spatial and angular resolution.

Muon diagnostics method was developed with the first in the world muon hodoscopes created in MEPhI: TEMP (1995) [2] with sensitive area 9 m^2, angular resolution about 2°, and URAGAN (2005) [3] with total sensitive area about 45 m^2, angular resolution better than 1°. With the help of the hodoscopes, possibilities for muon diagnostics to early detection and investigation of the active processes in the atmosphere and near-terrestrial space were demonstrated [4 – 6].

During the exploitation of TEMP and URAGAN, specific requirements to the new generation of muon hodoscope were formulated: sensitive area more than tens of square meters; angular resolution better than 2°; muon registration efficiency better than 95%; modular design to provide easy installation and transportation; low sensitivity to variations of environmental parameters (pressure and temperature at the facility location).

2. Scintillation muon hodoscope

For a new scintillation muon hodoscope (ScMH), a long narrow strip of plastic scintillator with wavelength shifting (WLS) fiber optics was chosen [7]. This technique is widely used for construction of large area tracking detectors for neutrino registration in accelerator experiments [8, 9]. Scintillation detectors are reliable, durable, relativity cheap and low sensitive to variations of environmental parameters. The large attenuation length of light in WLS (> 5 m) gives the possibility to construct the coordinate detector systems of a large area.

2.1. The supermodule

Each supermodule (SM) consists of several (not less than two) X – Y coordinate planes (CP) mounted on a common frame. SM uses several CP to give a possibility to estimate the track parameters. Each CP provides measurements of X and Y coordinates of muon track passing point. Each CP consists of two coordinate layers with orthogonally oriented detection elements. The coordinate layer consists of two adjacent modules – basic non-dismountable modules of the detector, consisting of 64 scintillation strips in a common housing.

General view of the ScMH SM with four coordinate planes is presented in Fig. 1. Sensitive area of CP (3.4×3.4 m^2) and the distance between them (1 m) ensures a wide zenith angle aperture of muon registration 0° – 75°, that gives a possibility to perform the muon diagnostics of the atmosphere up to 15 – 20 km altitude within 100 km around the detector. The SM angular accuracy for single muon events for such configuration is better than 1°.

2.2. The basic module

As a detection element of the basic module (BM), scintillation strips produced by extrusion technology with dimensions $10.6 \times 26.3 \times 3460$ mm^3 (polystyrene with 2% p-Terphenyl and 0.02% POPOP, by AMCRYS-H [10]) are used. To increase the light collection, the strip surface is coextruded with a thin (150 μm) layer of the mixture of polystyrene and titanium dioxide, this layer ensures a high coefficient of diffuse reflection. Along one of the wide strip sides, a special groove is milled. WLS fiber (Kuraray Y11-175 [11]) with 1 mm diameter and about 5 m light attenuation length (for 500 nm wavelength) is glued in the strip groove with a special optical glue.

When a relativistic charged particle passes throw the strip, some of the photons form a scintillation flash penetrating into the fiber, are shifted to the “green” part of the spectrum, and reach the photodetector.