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Scintillation spectrometric supertelescope for cosmic ray muons monitoring

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Main characteristics of the muon supertelescope (IZMIRAN, Moscow) are presented, one of the four sections has been modernized recently. Now the scintillator of 10 cm thikness is used, the electronic tract and the system of data collection are renovated. Monitoring of cosmic rays workind as a part of the worlwide net of muon telescopes is the main scientific task of the instrument. Besides in parallel it is possible solving different spectroscopic problems. For this purpose the signal is supplied to multi channel and high speed amplitude-digital transformer, which control the module of analyzed events.

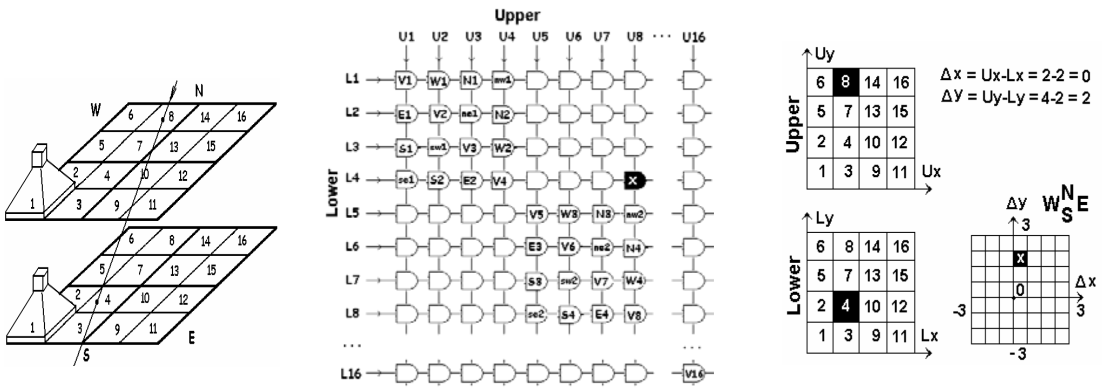
1. Introduction

In the world there are several permanently working ground based muon telescopes. Regarding the construction the most successful project is the multi directional scintillation super telescope in Nagoya working from 1971 year [1] or the similar multidirectional scintillation telescope of the Brazil-Japan collaboration in Sao Martinho [2]. Several ground based scintillation telescopes with less effective area are in operation, for instance the telescope in Hobart [3], the hodoscopes in Moscow [4], the telescope in Belgrade [5]. A considerable modernization of the IZMIRAN supertelescope allows not only extending the geography of operating muon super telescopes, but getting a device working in the spectroscopic regime, i.e. counting muons and determining their energy losses. This would provide a possibility for solving astrophysical problems as well as problems of nuclear physics.

Muon telescopes are better suited for observations of cosmic ray anisotropy than neutron monitors. First of all, because they have a more narrow directness and that there are several instruments directed differently in one point of observations. In some cases such a telescope may substitute a group of neutron monitors with different location on the globe. Using data of the muon detectors is complicated by the large temperature effect characteristic for the muon component. However the method of crossed telescopes [6] helps removing variations of atmospheric origin but practically conserving anisotropic variations. Besides data of high altitude probing of the atmosphere are available for each station [7], which are required for temperature corrections. Muon telescopes allows extending studies of CR variations for higher rigidities providing the same, or even larger, statistical accuracy of observational data.

2. Telescope Construction

The super telescope has four identical sections with effective area of 4 m^2 each (Figure 1a). Eight elementary detectors 1×1 m^2 form the section, four in the upper and four in the lower levels. A distance between levels is about 2 m. Therefore for each elementary telescope the telescope with narrowly directed geometry is realized, for the section (if all 9 directions are summarized) – the telescope of cubic geometry and for the whole instrument – the telescope of semi cubic geometry. For the telescope of two plane detectors (U and L) with k_X and k_Y detectors for each coordinate, using the corresponding number of coincidences it is possible arranging $m=(k_X\times k_Y)^2$ telescopes and selecting $n=(2k_X-1)\times(2k_Y-1)$ independent directions of particle arrival. If each plane contains $4\times4=16$ detectors, then it would be



a) construction

b) realization of all coincidences (partly shown)

c) selection of independent directions

Figure 1. Scintillation telescope. Realization of double coincidences

possible arranging m=256 independent double coincidences (Figure. 1b) and selecting n=49 independent directions of particle arrival. Figure 1c illustrates a principle for selection of independent directions of registration. Detectors of upper and lower panels, which simultaneously have registered incoming particle, are shown in the left part of this figure. As shown in Figure 1a direction of particle arrival can be determined using coordinate difference of upper Ux, Uy and lower Lx, Ly detectors. A count rate of the single counter is N =200 imp/sec, a vertical count rate 44 imp/sec, for inclined telescope it is 14 imp/sec. Geometric factor of such a detector is 0.26 $m^2 ster$, all 16 vertical detectors 4.2 $m^2 ster$.

The plastic scintillator (based on polistirol) of 10 cm thickness with photomultiplier are covered by not transparency for light and are painted by the white paint AC599 with large coefficient of diffusive scattering ($\approx$ 0.97 %) for wavelengths of (4000 – 4200 Å) [8] characteristic for plastic scintillator of the cover and photo-multiplier position are chosen minimizing a dependence of output pulse amplitude on a place where a particle crossing scintillator. However, this dependence was not eliminated totally.

In parallel with monitoring it is possible to solve different spectroscopic tasks. For this purpose a signal from detectors is supplied simultaneously to the logical module, which considers pulses according to a given scenario and tranfers them to the high-speed amplitude-digital transformer for the father analysis. An amplitude-digital transformer ЛА-н20-12 with following characteristics is used high speed (50 MHz) 8-channel 12-registers with transformation time of 20ns.

3. Light Collection and Detector Efficiency

The efficiency of scintillation detectors is determined mainly by how efficiently the emitted light is collected to the photo-cathode of the photo-multiplier. However, increasing of the scintillator area leads to reducing of the total light collection and appearance, if special measures are not undertaken, of radical dependence of light collection on a place of particle incident [9,10]. It is possible to reduce this dependence by tuning of reflector geometry and by right choice of light scatter cover, mutual positions of multipliers and plastic scintillators.

A pulse of fluorescenting light can be scattered many times from scintillator walls, so one part of the light would be absorbed by the scintillator matter, but another would be scattered.. As a result of these processes only a fraction η of emitted photons, which have been able to create photo-electrons at the photo-cathode of multiplier, would reach the photo-multiplier. So the amplitude of output pulses from the photo-multiplier would be proportional to η. Let us introduce notation:

α - a probability that a photon would be absorbed in scintillator between scattering,
μ - a reflecting ability of plastic scintillator walls,
ν - a probability that a photon incident at the photo-cathode would create a photo-electron;
σ - a ratio of photo-cathode area to the area of scattering surface.

Considering processes of scattering and absorption it would be possible to right a following expression for efficiency of light collection (11 Clark, 1967): $\eta = \alpha\nu\sigma/(1-\alpha\mu(1-\sigma))$. If a scintillator depth is equivalent to 10 g/cm^2 (for the scintillator of 10 cm), then a relativistic particle would loss along this path about 20 MeV. As an output of photons in the scintillator is about 1 photon per 150 eV, then one relativisyic particle would create about 1.3 10^5 photons. Assuming $\alpha \approx 0.8$, $\mu \approx 0.97$, $\nu \approx 0.05$, $\sigma \approx 0.012$ (a diameter of the photo-multiplier is 15 cm, a total area of scattering surface is 1.6 m^2) we have got that η is only 0.2 % and a number of emitted electrons is about η 1.3 $10^5 \approx 300$ electrons.

4. Stability of Instrument Performance

Stability, finally, is determined by the temperature stability of its components, and for a longer time by their oldness. Therefore special measures should be undertaken in order to eliminate totally the local temperature effect of instrument origin, which in many aspects determines a temporal stability of the instrument. The local temperature effect is caused by temperature effects of scintillator, photo-multiplier, amplifier-discriminator, high voltage supply. Used plastic scintillators have a negative temperature effect with β_S = - 1.5 $\%/^\circ C$ [10], the photomultiplier FEU-49 – positive with β_M =1.8 $\%/^\circ C$ [10], for the modern amplifier-discriminator (in our case amplifier AD8058AR) it is small, about ± 0.001 %/°C, for used high voltage supply it is +0.03 %/°C. The temperature coefficient of the whole detector is β = 0.3 $\%/^\circ C$ and, in reality, rather large. A practice has showed that it is not worth thinking that a mutual compensation of temperature effects of different elements would be a main factor of increasing the detector stability. The temperature stabilization with accuracy of ± 0.5 °C for the whole complex is a unique solution. The high voltage supply equipment should satisfy special requirements. Since the amplifying coefficient of photo-multiplier is $k = aU^{cn}$ (c=0.7, n - a number of dinodes, for FEU-49 cn=7.5) and $dk/k = cn\,dU/U$. Therefore, in practice the required stability of high voltage should be about one order higher than the expected stability of photo-multiplier performance. The coefficient of instability for the scintillator detector (the inclination of count characteristic) in working point is $dN/N : dU/U \approx 5$ times higher than for the neutron monitor.

5. Information System of Data Accumulation and Processing

Information System is oriented for data collection from multidirectional telescopes and integrated withsystem of double coincidence selection [12]., Since a relatively small number of input channels for direction selection leads to square increasing of output channels, namely $(k_X \times k_Y)^2$, the last simplifies the total system. As a results of data processing in real time the instrument variations are under continuous control and the efficiency of each elementary telescope is determined [13].

This report discuss only mai characteristics of the instrument. A full description is available at http://cr0.izmiran.rssi.ru/moST/main.htm , where the method for removing of meteorological variations from data of moun component (barometric and temperature variations), and coupling and acceptance coefficients, diagrams of directions and the geometric factor of the telescope are presented; asymptotic directions of the Moscow super telescope are compared with similar characteristics of other telescopes.

6. Acknowledgements

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