29th International Cosmic Ray Conference Pune (2005) **8**, 267-270

Scintillation detector for shower array of EAS-BARS project

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A new type scintillation detector for the shower array will be used in EAS-BARS experiment (MEPhI, IHEP, INR) which is aimed at measurements of various EAS component characteristics in the knee region. Shower array will include 48 counters deployed over the area 220 m x 60 m around liquid-argon ionization calorimeter BARS (18 m length, 3 m diameter). The scintillation detector with area 1 sq. m has an octagonal shape with a photomultiplier located in the centre. The detector has a good time and amplitude resolution, low weight and low cost. Front-end electronics allows to obtain a dynamic range from 1 up to 10^4 particles, timer clock 1 ns, and to control the temperature inside the detector. In the control system, various modes of calibration (time, amplitude, linearity range) are foreseen.

1. Introduction

The purpose of the project is creation of the experimental complex for carrying out investigations of EAS in the PeV range of energy around the knee with simultaneous measurements of high energy muons by means of liquid-argon spectrometer BARS. There are no experiments in which muon energy in EAS is measured in TeV interval. This circumstance is important as for classical approach to investigations of CR composition, so for checking of new ideas about the knee origin. If the knee is the result of interaction change, very high energy muons must appear [1].

2. EAS-BARS project

This experiment is the prepared on the base of the big liquid-argon spectrometer BARS [2], located at the neutrino channel of IHEP accelerator (Protvino). Arrangement of detectors of electron-photon component and of spectrometer BARS is shown in Fig. 1.

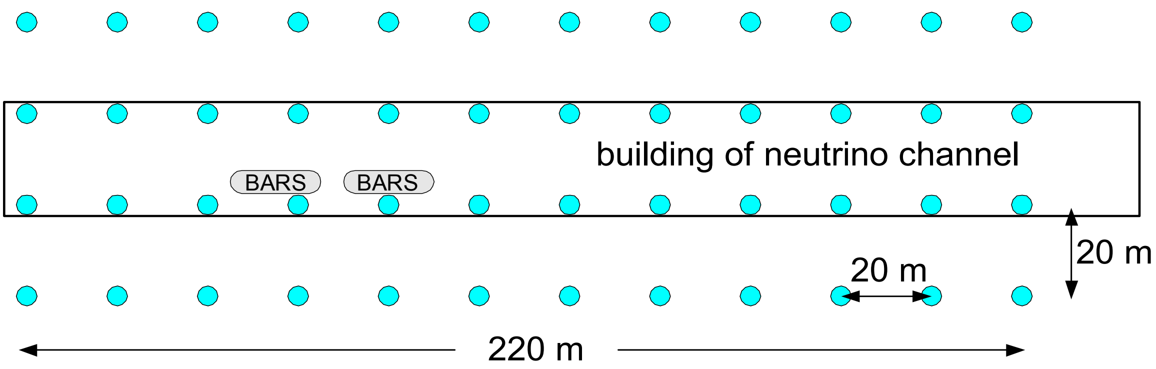

Figure 1. Shower array and spectrometer BARS.

Large area of registration (> 50 м^2), a high spatial resolution (6 cm), the ability to register separate particles and cascades, an opportunity to trace their development in depth (thickness of the detector ranges from 500 g/cm^2 up to 3000 g/cm^2), low threshold calorimetry allow to use the spectrometer BARS for the solution of problems of physics of cosmic rays. Since 1996, the spectrometer was used for experiments in horizontal flux of muons, where for estimation of energy characteristics of muon component a new method of spectrometry of high energy muons – pair meter technique [3] was used. The advantage of this method is the absence of the upper limitation on measured energy of muons. To provide registration of showers from primary particles with energy around the knee, the array with total area about 10^4 m^2 consisting of 48 scintillation counters is being created. Event registration by the complex setup (spectrometer BARS + shower array) is initiated by the signal from a scheme of coincidences of shower detectors or from the own trigger system of the spectrometer BARS. Systems of control and data read-out for EAS-BARS allow to include in the complex the new detectors. The setup will detect not only vertical EAS (up to 40°), but also inclined EAS, that gives a possibility to investigate transition from usual electron-photon showers to pure muon showers.

3. Construction of the scintillation detector

The shower detector is a scintillation assembly with total area 1 sq. m with the octagonal shape divided in sectors (Fig. 2). Thickness of plastic is 20 mm. The light is collected by wavelength shifter bars fixed between the sectors and is transmitted to the photomultiplier located in the center of the detector. The shifter technique allows to use fast PMT with small diameter photocathode (PM-115M) to provide a good time resolution. The scheme of light collection is shown in Fig. 3. Accuracy of time determination for a single muon crossing the counter is better than 3 ns. The radius of curvature of the shifter bar equals to 100 mm, this is a minimal possible radius, when losses do not exceed 10% of light.

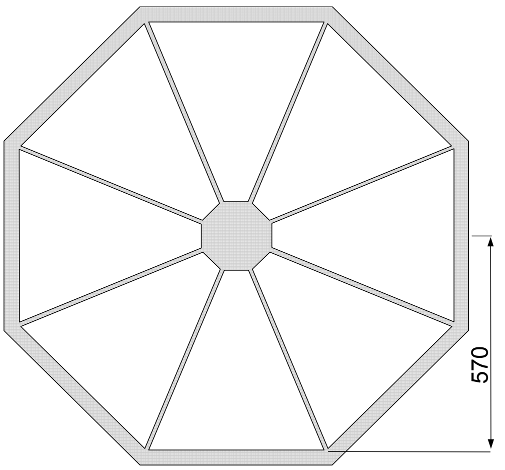

Figure 2. Scintillation assembly of shower detector

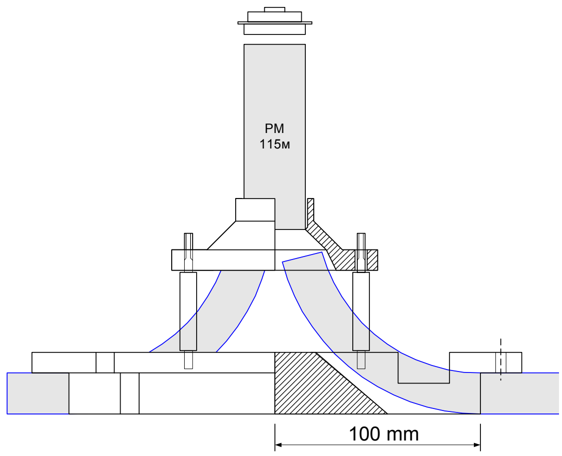

Figure 3. Light collection in the detector

The scintillation assembly, PMT and blocks of front-end electronics (QDC, TDC, HV converter, etc.) are installed inside a termo-insulating box made of rigid polyfoam. Thickness of the walls of the box is 7 cm, that provides temperature stability of the scintillation assembly and PMT when outer temperature (day - night) is rapidly changed.

Light output and PMT noise depend on the temperature, therefore powerful system of temperature stabilisation, which includes two termosensors, a heater and programme of the heater control is used in the detector. Central computer of the shower array permanently fixes the data of the termosensors.

Housing of the detector is made of 1 mm zinced steel and provides protection against atmospheric influences. Detector is fastened on a rotatable frame, that will allow to change orientation of the detector plane (horizontally - vertically), and to conduct measurements of flux in different directions.

In comparison with the standard detector, in the given construction the thickness of plastic is reduced by 2.5 times; in the design, light and cheap synthetic materials are used. This allows to considerably reduce the weight and the cost of the detector. The full weight of the detector is about 100 kg, therefore deployment of the array on the roof of the building is possible.

4. Response of the detector

To provide sufficient energy resolution of the scintillation counter, it was necessary to solve two important problems: to increase the output of light from plastic (and shifters), and to get the uniformity of the response for any co-ordinate of the scintillation plates.

First, the level of light output of the given detector was compared to the detector of the same area but divided in 6 sectors. The sector for the eight-section counter is narrower, and therefore it provides a smaller distance from a point of a luminescence to PMT. It is especially important for edge points of the scintillation assembly where the difference of amplitudes for two detector structures reaches 20%. Secondly, the curvature of the shifter bar, its fixation and the light collector have been optimized. Thirdly, the reflecting material is applied, top and bottom sides of each scittillation plate of the assembly are covered with a material ("tyvek") which has a diffusion reflection factor near 95%.

Uniformity of the response of plates was estimated by means of comparison of average values of amplitude spectra for muons passing through the limited areas of the detector selected by a counter telescope. Application of shaded masks on the light reflection material allows to achieve practically full (~ 90 %) equalization of signals. Relative amplitudes for various points and the shaded mask are shown in Figure 4.

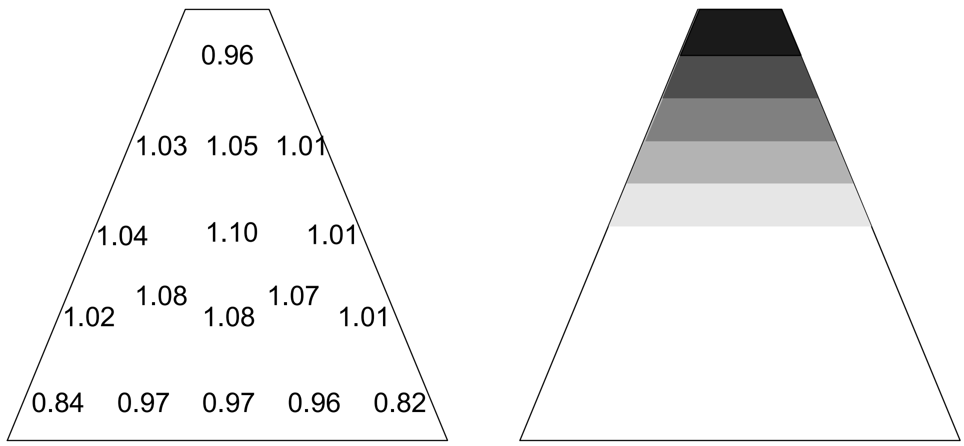

Figure 4. Relative response and the shaded mask used in the detector.

The average signal for single vertical muon corresponds to about 25 photoelectrons. Without a mask, the amplitude in the near-PMT zone is 1.5 times higher than on the edge. Mapping of shaded mask for sectors is done by means of the large-format ink printer under control of the program with a pre-set table of blacking.

5. Front-end electronics

Front-end electronics of the detector provides the possibility to work in several operating modes (registration, monitoring, calibration) and consists of the controller, the measuring part and system of calibration. Communication system is based on CAN-open standard. The controller provides the traffic of the data from the measuring part of detector to the central machine and receives from it the control data (to vary the reference voltages of threshold scheme and of high voltage converter). A required range of temperature is supported by the controller automatically.

In the inner calibration system of the detector two blue LED and flasher-controller, which allows to regulate independently control voltage in the range from 0 V up to 10 V with a good accuracy, are used. Common start signal initiates a flash of LED and QDC strobe. Cross-talks between the controller channels are negligibly small, that allow to implement the linearity test of PMT.

The array detector is considered has worked if anode signal of PMT exceeds the threshold of 0.5 MIP. In this case, timer is started (START_TDC), signals of 12-th and 9-th dynodes are memorized and signal REQUEST is sent. If during a waiting time (2000 ns) the answer appears, the timer stops (STOP_TDC) and signals are digitized; the digitization requires 10 μs. The measuring part (PMT, QDC, TDC) provides dynamic range of measured signals from 1 to 10^4 particles and accuracy of time interval determination (START_TDC – STOP_TDC) 1 ns. Two 12-bit QDC (one for each dynode) and 12-bit TDC are used.

6. Acknowledgements

The work is carried out with a support of the Federal Agency of Atomic Energy of Russia, Ministry of Education and Science (grant no. 1305.2003.2), and the Russian Foundation for Basic Research (grant no. 05-02-08147ofi_e).

References

[1] A.A. Petrukhin. 27 ICRC, Hamburg, 5, 1768 (2001).
[2] S.V. Belikov et al., Preprint IHEP 96-95 (1996).
V.B.Anikeev et al., NIM A 419 p. 596 (1998).
[3] R.P.Kokoulin et al. Proc. 26th ICRC, Salt Lake City, Utah, 2, 28 (1999).
V.B.Anikeev et al. 27 ICRC, Hamburg, 3, 958 (2001).