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Baksan Underground Scintillation Telescope upgrade and DAQ of additional layers

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Abstract. The project of the Baksan Underground Scintillation Telescope (BUST) upgrade is presented. Additional outer layers of the detectors with fine spatial resolution will be mounted around BUST. Optimal dimensions of a counter, $0.125\text{m} \times 0.125\text{m} \times 0.03\text{m}$ were chosen with a simulation program. The functional diagram of BUSTs DAQ additional layers is presented. Modernization allows us to study the knee region using muon number spectrum measurements.

1 Introduction

BUST located underground at a depth of 850 m of water equivalent was designed to solve a number of physical problems which predetermined its construction and location (Alekseev et al., 1998). The telescope is a four-store building with dimensions of $16.7\text{m} \times 16.7\text{m} \times 11.1\text{m}$ and consists of four horizontal and four vertical planes. The total number of detectors is 3180.

The analysis of the muon groups registered by BUST gives us an opportunity to obtain information about spectrum and composition of primary cosmic rays in the energy range of $1013 - 1016$ eV (Petkov et al., 2008). The coordinates of fired detectors give the initial information for identification parameters of muon groups (arrival direction and number of muon tracks). In general, the number of muons crossing the telescope, n, and the number of the reconstructed muon tracks in a selected event, ntr, should not necessarily coincide with each other. When two or more muons are crossing BUST close enough to each other (comparable with the size of the detector), the number of reconstructed muon tracks will be less than the number of muons crossing BUST. Construction of additional external scintillation layers proposed in the modernization project (Dzaparova et al., 2009) would allow the number of reconstructed muon tracks to be up 1000. These layers used as an anticoincidence protection increase the target mass by a factor of 2.7 and allow registering neutrino bursts from collapsing stars with better efficiency.

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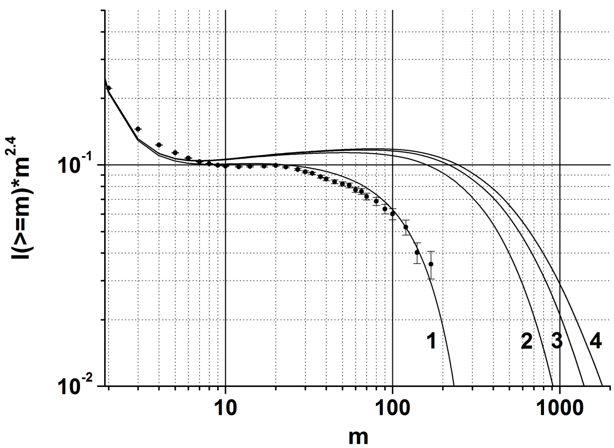

Fig. 1. Integral muon track number spectrum: Points stand for measured data; curve 1 is the estimated spectrum on number of muon tracks (m=ntr) for BUST standard detector; curves 2 and 3 are the estimated spectra for SC1 with sizes 0.25 m and 0.125 m, respectively; curve 4 is the estimated muon number spectrum in BUST (m=nμ).

2 Choice of the optimal size of the elementary detector

To study the possibilities of BUST after its modernization a simulation program was designed. Dependence of spectra of muon groups on muons in BUST for three sizes of the detector was calculated to choose the optimal size of the detector. Three sizes of the detector were ex-

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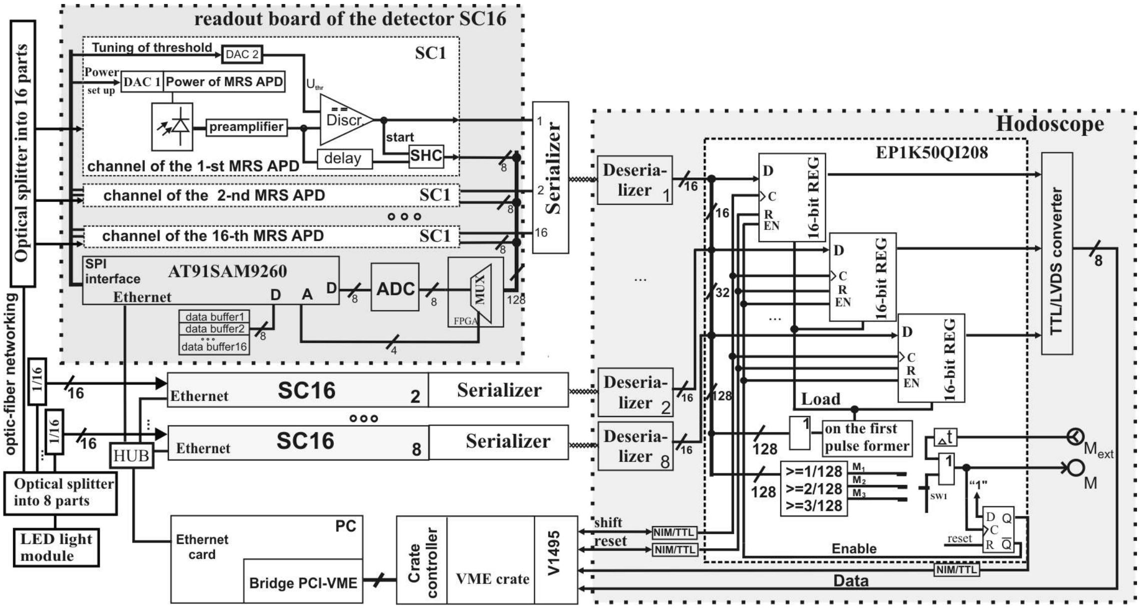

Fig. 2. The functional block diagram of the data acquisition prototype system.

amined: 0.7m × 0.7m × 0.3m (BUST standard detector), 0.25m × 0.25m × 0.03m (plastic scintillation detector), and 0.125m × 0.125m × 0.03m (as in cosmic-ray experiment EMMA (Akhrameev et al., 2009) plastic scintillation detector, SC1). Calculation was made for standard composition of primary cosmic rays where the knee is at $2 \cdot 10^{15}$ eV per nucleon. Method of computation was described in (Petkov et al., 2008). Characteristics of high-energy ($E \geq 230$ GeV) muon component of EAS were obtained using CORSIKA code (version 6.03, model QGSJET 01C) (Heck et al., 1998). The results of this calculation are shown in Fig. 1. One can see that the knee location in the integral distribution of muon numbers is in the range $200-300$ muons (curve 4), and the spectrum of reconstructed muon tracks for SC1 with size 0.125m × 0.125m × 0.03m in this range coincides with the spectrum of the true number of muons. Therefore, the choice of SC1 with a size no larger than 0.125 m gives us a possibility to reconstruct up to 1000 muon tracks for each event. This condition is necessary to study spectrum and composition of primary cosmic rays in the knee region using spectrum of the muon groups in BUST. Since the calculated SC1 size providing best resolution in muon tracks reconstruction coincides with that one already designed for EMMA, the construction of 16 SC1s (SC16) assembled in a metal sheath was taken as a base.

3 Functional scheme of data acquisition system of additional external scintillation layers of BUST

The additional external scintillation layers will be a massive array composed of 8000 SC16 (128 000 SC1s). Information from these detectors will be the incoming data for the multichannel pulse hodoscope of these layers.

The functional block diagram of the data acquisition prototype system, composed of 128 SC1s is presented in Fig. 2. Electronics readout board of SC16 collects information about every fired SC1 translates the parallel code into a serial one, and then the serializer transfers data through a twisted pair to the input circuit of the multichannel pulse hodoscope. In the input circuit of the hodoscope, the deserializer makes the inverse operation. All input data enter to the counting circuit of fired SC1s and the circuit of 16-bit shifting registers. These diagrams will be realized on the FPGA device (chip EP1K50QI208). The data from the outputs of shifting registers should be then transferred to the proper input of the device V1495 (General purpose VME board) to define both the SC1 that has fired and the timing measurements of the corresponding SC16.

The massive and complex array requires its detector electronics to be multifunctional. Since a spread in the power parameters of multi-pixel avalanche photodiodes with a metal-resistor semiconductor layer structure (MRS APD) is about a few volts the first thing to do is to realize some automatic procedure to set up the best value for the power. The next thing to do is to tune a threshold for SC1 and to check the threshold stability. The tuning process has to take into account the characteristics of the optical path, the aging of MRS APD, and the temperature change in the BUST building. The yearly average temperature in different BUST floors is different, but seasonal changes exceed no more than 2 °C for all placements. We propose to carry out threshold tuning for each SC1 using light pulse which propagates through the optic-fiber network to the geometrically identical point in each SC1. The prototype array will consist of 128 SC1s. A green light emitting diode (LED) in a small optical network may be used as a source of light. Such LED emits light in the range 520nm – 610nm, and this range coincides with sensitivity of MRS APD.

4 Conclusions

The choice of SC1 with a size no larger than $0.125\text{m} \times 0.125\text{m} \times 0.03\text{m}$ gives us a possibility to reconstruct up to 1000 muon tracks for each event. Investigation of muon number spectrum measurements allows one to obtain information about spectrum and composition of primary cosmic rays in the energy range of $10^{13} - 10^{16}$ eV. The functional scheme of additional outer layers of the prototype system has been designed. Electronics readout board of the detector SC16 is under development.

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