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The Carpet-3 EAS array: a current status

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The Carpet-3 extensive air shower array is now under construction at the Baksan Neutrino Observatory. The array is located at an altitude 1700 meters above sea level, and it consists of surface detection stations, situated close to each other for best sensitivity to extensive air showers with lower energy, and of an underground muon detector with a continuous area of 410 sq. m. The energy threshold for vertical muons is 1 GeV. The main aim of the array is to study the primary gamma radiation with energy above 100 TeV. The design of the Carpet-3 EAS array gives a possibility to carry out research on the composition of primary cosmic rays around the knee. It is planned that the Carpet-3 EAS array will be in full operation by the end of 2021. An overview of the current state of the experiment is presented, and its prospects are discussed.

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1. Introduction

Ultrahigh energy gamma-ray astronomy is of great interest for investigating the mechanisms of the origin of photons with energy above 100 TeV. One of the probable mechanisms of their origin is the decay of neutral pi mesons. In turn, they can be born in hadron and photon-hadron interactions that must be accompanied by neutrino born in these interactions. In case of such a scenario, our galaxy should exist acceleration sites of charged particles to several PeV are also called Galactic PeVatrons. Recent observations have not only predicted [1] such accelerators but also confirmed [2] their existence. But to create theoretical models, more observations are needed and, therefore, more facilities and experiments aimed at registering photons with energies of more than 100 TeV. The Carpet-3 extensive air shower (EAS) array is a new stage in the development of the old facility that has been operating since 1974. In this work, we provide an overview of the current state of the facility and future prospects.

2. Carpet-3 EAS array

The Carpet-3 EAS array located at the Baksan Neutrino Observatory, which is located near Mount Elbrus (North Caucasus) at an altitude of 1700 m above sea level and coordinates 43°16'37.2"N 42°41'24.0"E. In figure 1 shows the current layout of the Carpet-3 facility. It includes a surface array and an underground muon detector (MD).

The facility uses two types of scintillation counters. The first one is a liquid scintillation counter of 0.49 m^2 area (length and width is 70 cm) and 30 cm thickness. One vertical equivalent of muon (VEM) corresponds to 50 MeV (data was obtained by Monte-Carlo). The second one is a liquid scintillation counter of 1 m^2 area (length and width is 100 cm) and 5 cm thickness where one VEM corresponds to 11 MeV.

2.1 The surface array

The surface array consists of a big square detector (the Carpet array) continuous area 196 m^2 with 400 liquid scintillators at the center. Also, it is separated into 25 units with 16 scintillators in each. There are five detectors around the Carpet array, each of 9 m^2 areas with 18 liquid scintillators. Four detectors located at 30 m distance and one is at 40 m distance from the array center. Additionally, 39 detectors are installed, which consist of 9 plastic scintillators with an area of 9 m2.

The anode signals from the counters are summed up in each detector and the cable is transmitted to the hardware room. In which anode signals are branched. The first one is connecting to an analog-to-digital converter (ADC) manufactured by Caen, model V1742. Data from the ADC is preserved in a waveform for subsequent processing and determining energy release in detectors. The second anode signal to a constant fraction discriminator (CFD) also manufactured by Caen, model V816. The CFD is a timing discriminator whose threshold depends on the amplitude of the input signal, which allows obtaining a more accurate response time of the detector. It generates a logical signal, the rising edge of which exactly corresponds to the exceeding of the threshold. These signals are transmitted to a programmable field-programmable gate array (FPGA, Caen V2495) to generate a global trigger. Also to a time-to-digital converter (TDC, Caen V1190A) for measuring the relative

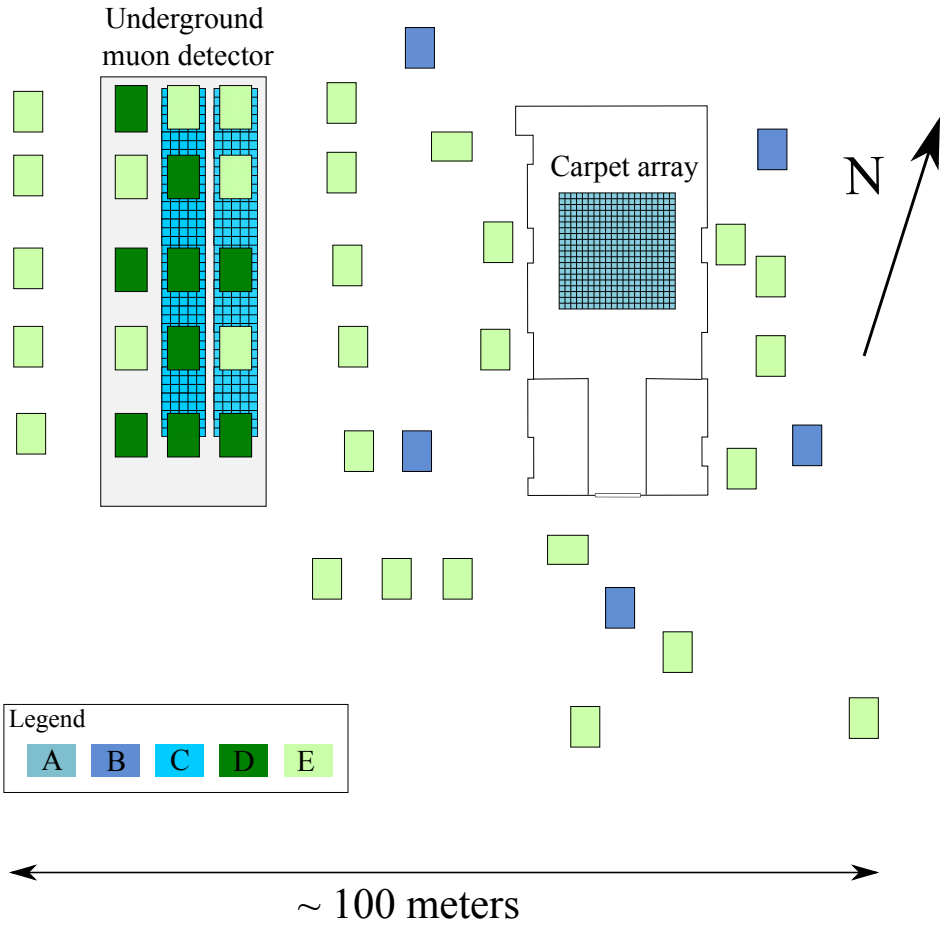

Figure 1: General scheme of the Carpet-3 facility. In the legend: (A) the Carpet array which consists of 400 liquid scintillator, (B) 5 ground detector with 18 liquid scintillator in each, (C) underground muon detector includes 410 plastic scintillators with a total area is 410 m^2, (D) are ready to operate ground-based detectors with 9 plastic scintillators in each and (E) are detectors without plastic scintillators which will be installed during 2021.

delays between triggered detectors and then a reconstruction of the arrival direction of an event. The global trigger is a digital signal of the NIM standard, which is a command to save data from the ADC and TDC to their buffers. After reading, the data is saved on the Carpet-3 online computer.

2.2 The underground muon detector

The underground MD consists of three tunnels, each with an effective area of 205 m2 (41x5 m). The rock absorber above them is equal to 500 g/cm^2, which corresponds to the threshold energy for vertical muons 1 GeV. At the moment, only two tunnels are completely filled with a plastic scintillator counters, which attached to the ceiling of the MD tunnel. The first tunnel (closest to the Carpet array) is fully equipped with new kits of electronics (205 pieces). The second tunnel is partially equipped with new kits of electronics (35 pieces) and 175 old kits of electronics that worked in the previous configuration of the installation (Carpet-2). The new electronics kits consist of two

modules. The first is a proprietary CPD that is used to determine the response time of an individual counter. Time delays are measured using TDC (TDC, Caen V1190B), this will effectively eliminate accidentally triggered counters. The second is also its own developed logarithmic charge-to-digital converter (QDC). Which converts the charge of the anode signal into a sequence of logical pulses and the logarithm of the charge is proportional to the number of these pulses. These sequences of pulses are fed to the counters of logical pulses located in the online computer of the muon detector and then saved to a file.

3. Conclusion

The Carpet-3 air shower array is under construction at the Baksan Neutrino Observatory by step-by-step upgrade and extension. After the final accomplishment of this array, the installation will have sufficient sensitivity to photons with energies of more than 100 TeV. This will allow us to study the origin of such photons, to measure the flux of cosmic diffuse gamma rays, as well as other research on cosmic rays physics.

Acknowledgement

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