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Concept and layout of the EAS delayed particles arrival time distribution measurements at Aragats cosmic ray observatory

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Abstract. At the location of MAKET ANI EAS installation we construct special detector for investigation of delayed particles. New device partly used equipment of Solar Neutron Telescope operated at same location. Both installations use plastic scintillators over viewed by PM of same type for measuring arrival time and particle density. Surface of new, 60cm thick detector is $4m^2$. and $60cm$ thickness. Planned anti-coincidence shielding for vetoing charged particles will help to detect predominantly neutrons, approaching yet poor understood problem of EAS neutron content. First results of measurements, along with investigations of afterpulsing of detector are presented.

1 Introduction

The structure of EAS generated by high energy cosmic particles is extremely complex. Event by event analysis of EAS lateral and longitudinal structure implies many simultaneous measurements of incident particles' densities and arrival times connected with trigger. Modern installations are detecting as much EAS characteristics as possible. Only detailed knowledge of EAS secondaries will allow to solve the inverse problem of determination of type and energy of primary, as well as the construction of strong interaction model. The most universal KASCADE [1]experiment is measuring electromagnetic and hadron component of EAS. MAKET [2]and GAMMA [3] installations located at ARAGATS Cosmic Ray Observatory are equipped with detector system that makes possible to measure the EAS incidence angles and density distribution of charged component. GAMMA has additional possibility to measure muon density distribution with $150m^2$ underground detector. Any additional information recorded with each event can be very useful for EAS reconstruction and also may improve our understanding of EAS development in atmosphere. This report describes an experiment running at Mt. Aragats intended to detect the delayed particles in EAS. In this experiment Multihit TDC (MTDC) is used with neutron scintillation detector, to ensure detection of delayed neutrons. Experimental investigations of delayed particles availability in EAS are very rare, and no detailed knowledge is available yet. On the other hand, theoretical calculations demonstrated, that EAS contain delayed particles, particularly neutrons. Delay time was calculated to be in region from several tens nanoseconds up to several tens microseconds. MTDC provides full scale 32 mcs with resolution 0.5 ns. Experimental installation was mounted and test runs were carried out. Afterpulsing in the PM and electronics was investigated.

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2 NEUTRON SCINTILLATION DETECTOR

Solar Neutron Telescope (SNT) [4, 5] consists of four housings containing $1m^2$ large plastic scintillator of 0.6 m thickness. Each housing has two holes for installing PM layout. One of the holes was occupied with PM layout used for neutron monitor facility, and the other one was used for EAS delayed particles detection. Thus both experiments were running simultaneously. Neutron telescope is placed in location of MAKET installation that provides triggering for neutron time experiment. The time measurements have been made with respect to timing trigger of MAKET installation. PM layout used in neutron time detector (NTD) is similar to that used in timing system of ANI installation. It contains FEU49 type PM and constant fraction discriminator (CFD). The time resolution of PM layout equipped with 5cm thick scintillator was estimated experimentally. Measurements showed that resolution is no worse than 4ns. It is very important to point, that the neutron timing detector (NTD) detects also the main part of shower i.e. the EAS charged component. This property of NTD means, that the main detector response originated from shower will be generated before the expected hit of delayed particle occurs. The problem is that the main response pulse can cause a delayed pulse in detector system. This afterpulse will seem to be response from delayed par-

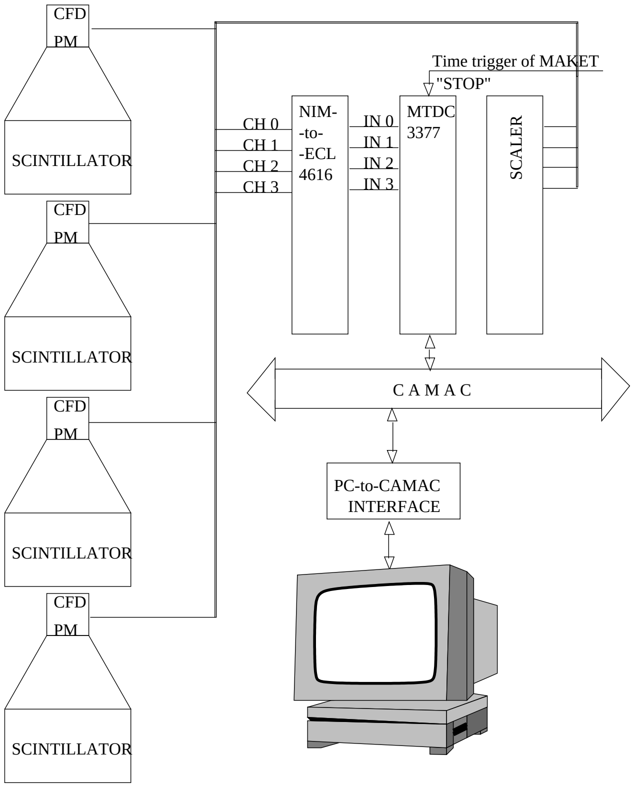

Fig. 1. A block diagram of neutron timing system.

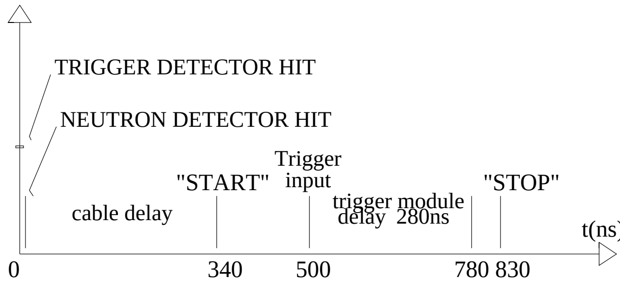

Fig. 2. A delay diagram of neutron timing system.

ticle. Possibility of afterpulses appearance depends on NTD layout construction. The possible ways of afterpulses generating in actual NTD are afterflashes in scintillator, remaining gas excitation in PM, ion feedback in PM, afterpulses in electronic and reflections in signal cables. The tests of electronics jointly with cables show, that there is no random after pulse there. The afterpulse measurements of PM are described in section 4. Only unknown afterpulses are those caused by afterflashes in the scintillator.

3 EAS DELAYED PARTICLE TIMING SYSTEM

Schematic design of timing system is depicted in Fig.1. It contains four scintillation detectors equipped with PM layout. Each PM is connected to MTDC via CFD and NIM-ECL translator. MTDC 3377 is a 32-channel time-to-digital converter designed for drift chamber applications. It is considered to have low dead time, optimized with a low conversion time and a high speed ECL data port for fast readout. Operation mode selection is programmable. Namely, the following features can be chosen in our experiment: -full scale range from 8ns to 32mcs -LSB 0.5, 1, 2, or 4ns -”COMMON STOP” or ”COMMON START” mode -number of hits recorded per event from 1 to 16. In order to do correct choice of MTDC operation mode all delays in this experiment were measured or estimated with accuracy of a few tens of nanoseconds. These delays are shown and explained in Fig.2. This time diagram is composed as an example in case when MTDC operates in ”common stop” mode. Zero point in this time diagram corresponds to EAS hit at MAKET installation. The same EAS hits the NTD a little later (a few nanoseconds) because NTD scintillators are placed a little below of MAKET detectors plane. Thus, in case of ”common stop” mode it is possible to register particles, that have delay no more than 500ns with respect to EAS arrival. This restriction comes from the arrangement of installation and delays in electronics. Time measurement region can be enlarged by delay of STOP signal. In this way the observation region can be extended up to the full scale of MTDC i.e. 32mcs. Software for MTDC has been developed in order to provide an environment that simplifies handling with setup and further development of data acquisition software. Online acquisition program gives timing data event by event. Data recorded for each event contain the delay time of EAS hit and delayed pulse for each detector with respect to STOP signal, as well as number and real time of actual event. These data are sufficient for calculating delay of afterpulse of each particular detector with respect to the EAS hit in the same detector. The real time recorded in each event is intended to be used as a tag for combining MAKET data with delayed particle timing data. It will make possible to have EAS characteristics (determined by MAKET installation) of each timing event, and therefore to perform selection of events according to EAS core position, size, etc. It is necessary to point, that GPS based special time synchronization of both installation is realized, that ensures correct time tagging of events.

4 INVESTIGATIONS of PM AFTERPULSING

The origin of afterpulses was investigated by oscilloscope and two regions of delay for afterpulses were observed. The first region around 120ns is basically due to optical feedback and remaining gas excitation. The second one, in range of 1.3 to 3mcs, is due to ion feedback in the PM. The oscilloscopic measurements couldn’t give the afterpulses’ probability and delay distribution. More detailed analysis of PM afterpulses was carried out by test facility depicted in Fig.3. The measurements were done for all four detectors and the results were similar. HV magnitude was established equal to that used in experiment. The STOP delay was chosen equal to 30mcs in order to make it possible to observe the delay region about 30mcs. That is many times larger than

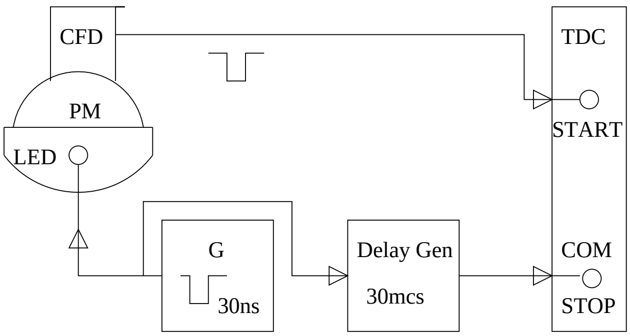

Fig. 3. Block diagram of setup for PM after pulses investigation.

the expected delay of afterpulses. The total number of afterpulses in proper operation of PM and short flashes(about 3ns) amounts to 0.13% of total events number. The near region(100-200ns) contains about 0.1% , and the other pulses are distributed in the region beyond 1300ns. It is important, that there is a region free of PM afterpulse(200-1300ns). The results of these measurements are important, because it is necessary to take into account the PM afterpulses availability in the experimental data.

5 FIRST RESULTS of MEASUREMENTS

Test run of NTD was carried out this year. About 500,000 events were collected. The distribution of delayed pulses in detectors is depicted in Fig.4. Three plots present the distribution of delayed pulses in detectors in respect with the EAS hit response of the same detector. The first plot shows, that in the delay region beyond 1400ns the points density is constant and corresponds to the random hits of the background particles. In the region of delays less than 1400ns one can see a steep monotone decrease with the increase of delay(second plot in Fig.4). More detailed observation of the near region(third plot in Fig.4) shows an additional maximum in the region 100-160ns. One can decide that this additional maximum is due to PM afterpulses (see Section4). Nevertheless, the growth of the distribution and its excess over the background level can't be attributed to the PM or electronics afterpulsing. The detected enhancement could be explained by registration of EAS delayed particles and/or afterflashes in scintillators. The case is under investigation now.

6 CONCLUSIONS

The test run demonstrates that the delayed particle timing system operates properly. Delayed particles in the EAS can be detected and the selection of events using the MAKET data can be performed. Upgrade of Solar Neutron Monitor (with new anticoincidence shielding) will allow to distinguish the delayed neutrons from the delayed charged particles. Second PM can be installed on each NTD housing in order to exclude the PM afterpulses. The afterflashing

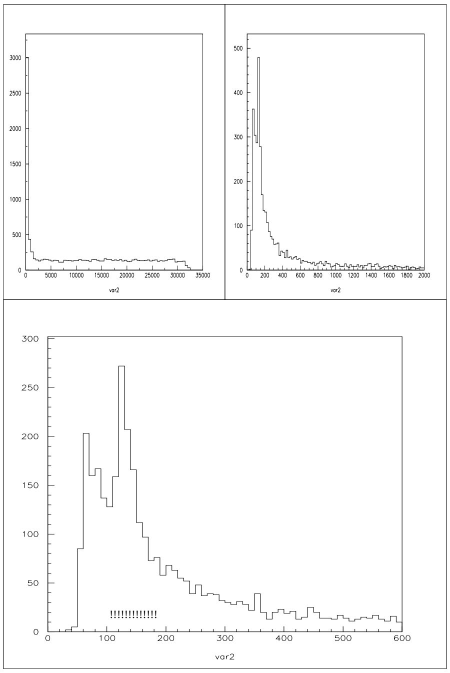

Fig. 4. Distribution of delayed pulses in EAS registration.

phenomena in scintillator has to be investigated in order to estimate its contribution to the experimental data.

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