Detector Calibration and Data Acquisition System in the Roland Maze Project

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***Abstract*— The Roland Maze Project is a network of CR detectors to be distributed on the roofs of high schools in Lodz, Poland. Each school in the network has 4 plastic scintillation detectors of the area nearly 1m^2 each. In this work we present details of detector construction, and the concept of electronics suitable for planned measurements. We also discuss results of calibration and uniformity measurements of the detector with respect to the position of muon passing through.**

I. Detector Morphology

Detectors are built of scintillator tiles of dimensions 10cm × 12cm × 0.5cm. Scintillator tiles were made by IHEP – Protvino (Russia). Two layers of tiles form 1cm thick scintillator. Light is collected by 12 wave length shifting (WLS) fibres (BCF 91A, 1mm diameter, double coated) from one row of 10 pairs of tiles. There are 8 rows. In total 2 × 10 × 8 = 160 tiles and 96 fibres. All fibres are viewed on one side by Photonis XP1912 PMT. Details of detector construction are shown in photo 1.

Fig. 1. WLS fi bres in the scintillating tiles and assembling the detector.

Each row of scintillator tiles with fibres is wrapped in Tyvec, and then the whole detector is wrapped in black plastic foil and aluminium foil.

Detectors were assembled by high school students. The students were cutting fibres and Tyvec, preparing scintillation tiles and putting all together.

II. Detection Methods

We performed measurements of homogeneity and efficiency factor of detectors in MAZE experiment. We put two 1 m^2 detectors one 25 cm above another. We examined the anode signal from PMT XP1912 collected from both detectors at the same time. We used one byte 16 MHz FADC with 2 channel input and 256 bytes memory per channel.

Localization of penetrating particle was provided by a pair of small scintillator counters one on a top of another, and both on the 1 m^2 detectors. This produces trigger signal when muon penetrates the system. View of the experimental setup is presented in Fig. 2 and in the photo 3. The ADC system is shown in the photo 3.

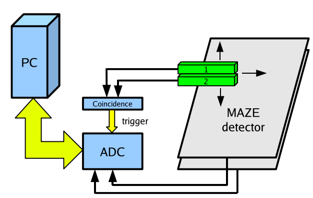

Fig. 2. Schematic view of experimental setup.

We placed the triggering telescope on different places and registered amplitudes of anode signals.

III. Detector Homogeneity

PMT collected light from the WLS fibre. Some light is being attenuated in the fibre. Signals from particles penetrating at different places might be different in amount of light at PMT. This is observed as changes of most probable maximum signal amplitude corresponding to single penetrating particle detection.

From Figures 5 follows that inhomogeneity of signal amplitudes related to particles crossing at different points is

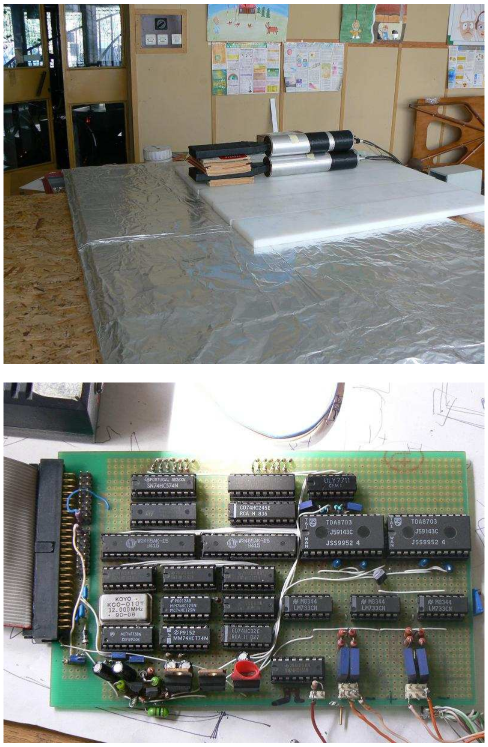

Fig. 3. Experimental setup and ADC.

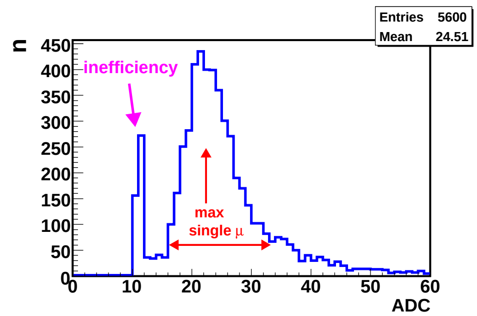

Fig. 4. Distribution of maximal amplitudes from top detector. The no–signal (background, noise) level is set near to 11.

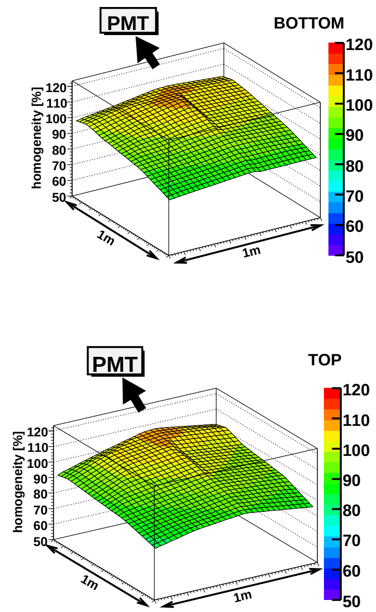

Fig. 5. Relative inhomogeneity in % for top and bottom detectors.

smaller than the width of amplitude distribution presented in the Figure 4.

IV. Detector efficiency

Detector is inefficient when the coincidence in triggering system indicates passage of charged particle and there is no signal from 1 m^2 detector. The counts with maximum ADC at background level presented in the Figure 4 represent events with no particle signal (inefficiency). The inefficiency on about 10% level is expected, since 1/13-th of the total detector area are the spaces between scintillator tiles. The detection area (total area covered by scintillation tiles) is equal to 0.96 m^2, and total detector area is 1.05 m^2 due to 1 cm wide spacers between rows of scintillation tiles.

Result of efficiency measurements for different positions of triggered system is presented in the Figure 6 for the bottom and top detectors. On the horizontal axis there is a distance from the edge of the detector to the end of the triggered system scintillator (see top photo 3). The asymmetry in the efficiency along the horizontal axis is due to that method of indicating position of the triggered system (at 0 cm both triggered scintillator are above the detectors, and for 100 cm both are largely outside detectors). Changing right/left the triggered symmetry is producing expected right/left change in results of efficiency.

V. WLS fibre attenuation

Inhomogeneity is likely to be due to light attenuation in Wave Length Shifting (WLS) fibres. We use St. Gobain–Bicron, 1mm diameter, double coated, BCF–91A fibre. It absorbs blue light from the scintillating tiles and emits green light.

The amplitude of the signal is proportional to the number of photons entering PMT cathode. Instead of maximal value of 256 amplitudes obtained every 1/16 microsec we used maximum of average of 5 subsequent amplitudes - $ADC_{<5>}$. With signal form $\sim$ exp(-t/(RC)), where RC is about 1 microsec $ADC_{<5>} = 0.88 \cdot ADC_{MAX}$. In Fig. 7 we show the position of maximum $ADC_{<5>}$ for top and bottom detector as a function of distance from the position of triggered system to the photomultiplier along a fibre, i.e. fibre length. The correlation of the amplitude with attenuation in the fibre looks good. However the signal loss due to the attenuation in the fibre is larger than quoted by the manufacturer [1]: 1/e loss at length larger than 3.5 m, which corresponds to losses smaller than 1.25 dB/m. In our case 1/e loss is for about 1.9 m. This might be due to fibre bending (see lower photo 1).

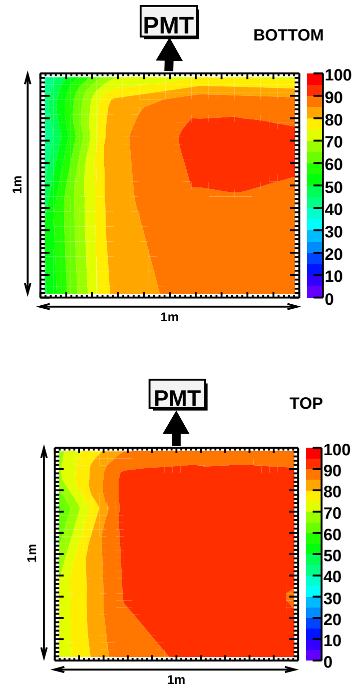

Fig. 6. Efficiency of the detectors. Small efficiency at left edge and near to PMT edge is related to the registration method – see text in the Section IV for more detailed description.

VI. Hardware controller

The hardware system allows for realization of observational goals in the following way. We plug the Photonis XP1912 PMT to the socket and self made high voltage divider, with +HV at the anode. The signals were taken from anode and from the 6^{th} dynode for amplitude measurements and from the last 10^{th} dynode for timing. The HV amplifier (see photo 8) allows for remote control of high voltage, measure the anode (not divider) current and temperature. All signals are symmetrized and amplified. The amplitude signals (from anode and 6^{th} dynode) have RC of $\sim$1 μsecond, and the timing signal is much shorter, but its amplitude is artificially limited. Such signals from all 4 detectors are transmited via twisted cables of equal length to one hardware controller. Each particle signal from 1 m^2 detector is separately processed in the controller and sent to the on–line computer. Each signal data has 'timing' with $\sim$3 ns accuracy and 2 $\times$ 16 amplitude 10 bit data points every 200 ns for anode and 6–th dynode. 4 points are prior to triggered 'timing' signal. 3.2 μs oscilloscope view has about 0.8–1.0 μs before the signal. Signal RC fall has 1 μs. Computer can work out the max. amplitude from precise information about beginning of the signal and a few points of sampling.

With the average muon amplitude in ADC=5 from the anode signal we have possibility to count up to 200 particles using anode signal and up to about 15.000 particles (theoretically, with step $\sim$30) from 6–th dynode.

Computer can recognize coherent signals from 4 detectors

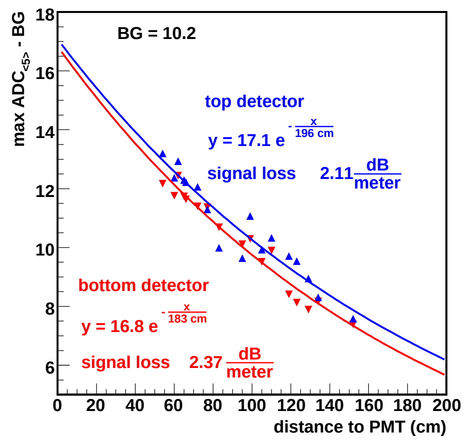

Fig. 7. Position of max ADC as a function of distance to the PMT (see Section V).

using 'timing' of the signals.

The absolute time can be worked out from GPS 1PPS signals interpolation over long time (e.g. 1 hour).

We expect about 1000 particle data per second from 4 detectors. There is a buffer for about 1000 particle data in the interface PCI card in the on–line computer. That buffer would be transmitted (using interrupt) about once per second to computer memory.

This way we obtain in the on–line computer all information required to meet scientific goals.

VII. Data Collection System

One unit consists of 4 detectors 1 m^2 each. Analog signals from all 4 detectors are processed in one of the detector container with the controller. Controller is connected to PC computer. The PC accumulates the data, performs control and adjustment functions, and communicates and transfers data to the central computers in our Institute.

24 V power supply is coming to controller and is distributed to all 4 detectors. The same cables are used also for transmission of control signals to/from HV units.

HV units provide adjustable HV to PMTs, and measure the temperature and PMT anode current. There is one HV unit in each 1 m^2 detector.

From each detector cables of the same length with 4 twisted pairs of wires were used for low voltage and analog data transmission. One pair is used for fast and short 'timing' signal, from the last dynode. One pair transmits anode signal and another pair the signal from the 6–th dynode of XP1912. Analog signals are integrated, with RC = 1 μs, and symmetrized. The 6–th dynode signal is about 30 times weaker than anode signal.

The controller changes analog data to digital form, controls GPS 1PPS signals and fast timing signals with internal clock, communicates with the PC computer via PCI interface.

All ADCs are based on HI5767/2 which are 10 bit A/D converters with max. speed 20 MSPS (Msamples/s). We run

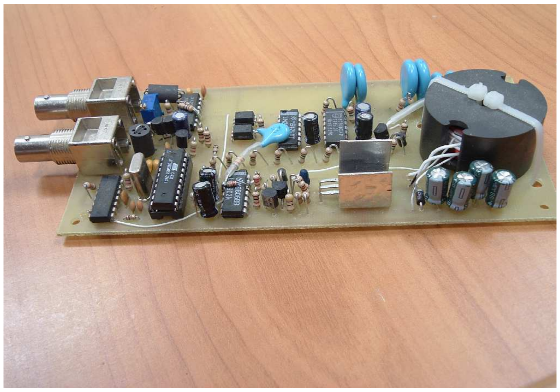

Fig. 8. HV power supply unit.

with 5 MSPS, i.e. the amplitude signals are sampled every 200 ns. The signals from each 1 m^2 detector are digitalized independently when the level of fast 'timing' signal from the last dynode exceeds the threshold. The 2 signals from anode and from 6–th dynode are digitalized in paralell and with the digitalized 'timing' data go to the output buffer.
The 'timing' events come from the GPS as 1PPS signals and from 1 m^2 detectors as the fast signals from last dynodes. The time is referenced for each 'timing' event with counter of local 50 MHz clock (20 ns) and with 8 bit step of 3 ns each.

VIII. Data storing

Before transmission to the central computer data will be stored on the on–line PC disc. Data marked as EAS data would be stored with full information (about once per minute) and then transmitted to the central computer.
For 3 amplitude levels 5 seconds counting rates for each detector separately will be stored and then transmitted to the central computer. These would be used for detector performance tests, "space weather" studies, radon counting rate variation etc.
For about 8 hours we keep information for all signals about amplitude and time (3 ns accuracy). These data can be accessed and processed if required, e.g. during thunderstorms, during related gamma ray bursts etc. After such time unnecessary data would be erased from the disc.

IX. Conclusion

The measurements show that the performance of the detector is good enough for detection of cosmic ray muons and extensive air showers which are targets for the Roland Maze Project.
The detector is a low cost device; the cost of material for 1 m^2 detector (without ADC etc.) is about 600 Euros.
Students can contribute to assembling the detector learning particle detection methods with scintillating material, WLS fibres and PMTs.
In the HELYCON Project (Patras, Greece) the copy of our scintillation detector was made and tested with positive results.

Acknowledgment

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References

[1] http://www.detectors.saint-gobain.com