# Status of the Roland Maze Project (EAS Array at Schools)

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***Abstract*— The Roland Maze Project [1] is a network of CR detectors distributed on the roofs of high schools in Lodz, Poland. The main scientific goals of the project are studies of cosmic rays at the highest energies, measurements of Extensive Air Showers (EAS) at knee energies and observations of the local variations of cosmic ray muon flux. We describe the actual status of the project realisation, high school students participation in detector construction and other activities related to the Project.**

## I. Introduction

The idea to create a school based network of Extensive Air Shower (EAS) arrays in Lodz, Poland, come after the $27^{th}$ International Cosmic Ray Conference held in Hamburg in 2001 [2], [3], [4], [5], [6]. In 2002 we have first students willing to participate and help in construction, and soon there were about 30 high schools in Lodz 'ready' to participate and host the detectors. In the end of 2003 and beginning of 2004 we received funds from the budget of the City of Lodz Council for the pilot experiment with 10 schools. Funds were spent for materials to construct detectors and also for training of students.

The leading idea was to create cosmic ray detectors suitable for scintific program (i.e. interesting from the Institute side), and with participation of high school students in construction and data analysis (i.e. interesting for schools), and supported by the local political authorities as promotion of modern technologies and scientific technics.

## II. General idea and description

The idea is to create a number of independent small EAS arrays, and use urban infrastucture to keep them running on a large area and connect off–line via internet. High Schools are very good canditates as hosts for such arrays (providing power and internet connection). The correlation of events observed on the large area can be done off–line thanks to precise time label attached to each event. The accurate time can be provided by the local GPS antenna.

In Europe larger towns are so densely populated that nearest High Schools are within less than 1 km in many cases. With a suitable network this would allow to observe a Giant EAS in a several schools 'at the same time'. Precise local time registrations with accuracy $\sim$10 nanoseconds allows to determine the EAS direction by comparison of timing from those schools. This is a way to observe the highest energy Cosmic Rays. More realistically, the target energy range can be above $10^{18}$ eV, which is interesting range because of existing discrepances in a flux determination between different experiments.

Having 2 or more detectors locally there is a posibility to study small EAS and repeat the work of EAS discoverers: R. Maze and P. Auger [7]. Having 3 or more detectors locally there is a possibility of determining directions of the small EAS (energies around $3{\cdot}10^{14}$ eV) with expected trigger rate about 1/minute. Although this energy range of EAS is very well covered by 'professional' arrays the problem of the mass composition around the knee in the energy spectrum is still open and waiting for solution. At least studies of these showers can be very good excercise for students and their teachers.

Registering the single muon counting rate is important for studying 'space weather' and possibly a chance to see very high energy gamma–ray burst [8]. The array detectors cover relatively large area and expected muon counting rate $\sim$180 per second per 1 m$^2$ can provide large statistics. Muon counting rate is anti–correlated with the local atmospheric pressure and has (much weaker) dependence on the atmospere properties at 8–14 km level. For large disturbances of geomagnetic field (e.g. due to Forbush decrease or other solar activities - space weather) 1–4% changes in the muon flux can be observed. Expected large counting rate can provide good statistics for detail studies of such variations and interplanetary inhomogenity which might cause the variations of the primary cosmic rays.

## III. Scientific targets

The Project has 3 main scientific goals:

- Giant Air Showers (coincidences between schools),
- Extensive Air Showers (local coincidences),
- single detector counting rate.

The construction of the detector and data acquisition system were planned to meet requirements of above listed tasks. The detector is made of plastic scintillator (based on polystyrene) and is 1 cm thick. The single school unit has 4 identical detectors of 1 m$^2$ each. These detectors will be separated by

10–20 meters, differently at different school roofs.
Small thickness of the detector should largely eliminate gamma–ray induced cascades within the detector. As there is $\sim$10 times more gammas than electrons in EAS, gamma induced cascade can mimic large density charged particle event. We hope to register mainly electron/positon component for EAS events and muon component for uncorrelated events. For Giant Air Showers each school unit is approximately one detection point. Large particle densities can be registered in 4 detectors and can be compared between themselves to eliminate local gamma–ray induced cascades which artificially increase local charged particle density. On another end, the low particle densities can be estimated hodoscopically from 4 detectors, which is better method than via single amplitude measurement from one larger detector.
The hardware system is designed to fulfil requirements of physical and astrophysical tasks. The GPS adjusted timing system will have accuracy of nearly 3 nanosec. This is due to the M12+Timing Oncore GPS receiver and Oncore Timing2000 antenna (made by Motorola) which provide every second signal (1PPS) with accuracy generally better than 10 nanosec. These signals are registered with on board clock system with accuracy of 3 nanosec which can be averaged over long time and interpolated. The dynamics of photomultiplier (Photonis XP1912) is large due to double view of the output signals: from anode and from the $6^{th}$ dynode (about 30 times weaker). This would allow to register passage of a single muon and also up to about 15000 particles at the same time without saturation of the amplifier/ADC system.
The registration system is free from a dead time.

## IV. High School Students Participation

One of the basic idea of this project was to introduce high school students to the program of detector construction, related physics and astrophysics, data processing and analysis, and other related topics like public relations (including web pages, forum), seminars at schools etc. In some extent this activity is also being addressed to the teachers, as well.
"Learning by doing" is the form of participation of high school students in the R. Maze Project.

### *A. Assembling the detector*

Groups of 4 students prepare scintillating tiles, cut Tyvec, cut WSL fibres, assemble Tyvec and tiles, knit the fibres into scintillator, screw cover, and finally wrap detector in dark foil and aluminium foil. These take 4–6 hours for one 1 $m^2$ detector. Most of 40 detectors have been already assembled by nearly 40 students. Students participated in assembling of each detector. Some details like wooden base of detector, glueing, cutting and polishing fibers were done by institute staff.

### *B. Testing electronics*

Groups of 2 students were involved in some tests of electronics using pulse generator, digital oscilloscope, PMT, flashing leds etc. These students have opportunity to learn and use modern equipment, otherwise unavailable for them.

Fig. 1. Assembling the detector.

### *C. Cosmic ray muon detectors*

Groups of 2–3 students made another type of detectors, which then would go to their physics laboratories at schools. These are small muon telescopes based on the Maze–type Geiger–Muller tubes made of glass pipe. Each telescope is made of 3–4 G-M tubes working in coincidence. G–M tubes are provided by the Institute, and students make electronics: low voltage and HV power supply, coincidence circuits, counters and display, interface to the PC, box to host the detector. Finally they perform regular measurements of muon counting rate dependence on the muon angle or/and atmospheric pressure, and process these data. Several such devices were already made. One example is described as a separate presentation at this Symposium and was published in Physics Education with students as co–authors [9].

### *D. School sessions and seminars*

Together with schools we have organized so called Scientific Sessions of the Roland Maze Project (photo 2). Four such meetings were held so far in different schools. Students prepare talks related to different aspects of the Project. We invite emminent scientits or someone from advanced technology industry to give an invited talk. Most of the time goes to talks or experimental presentations prepared by students and related to the Project or "Leading Scientific Topic of the Session". In most cases students do discuss their presentation with scientific

Fig. 2. School Scientific Session.

staff of the Institute during preparation of the presentation. We think that these contacts are very important.

### *E. Masterclasses: Hands on CERN*

Having contacts with schools we have organized large groups of students to participate in workshops "Masterclass: Hands on CERN" [10]. These events were coordinated by European Particle Physics Outreach Group [11] on the European scale in 2005 and 2006 to celebrate the World Year of Physics 2005, and will be continued. During the workshop students listen to the profesional lecture about CERN and high energy physics, make a 2 hours exercise on studying about 100 decays of $Z_0$ bosons (exercises on several computers with 2 students processing data from DELPHI detector on LEP). Then they can compare their results with results obtained by other groups in Europe having their workshops at the same time during a video conference moderated from CERN, and finally have a quiz. We have organized 8 workshop events in Lodz, so far.

## V. Present status of the Roland Maze Project

We are still working on the first pilot project which would have detectors on roofs of 10 High Schools in Lodz. We register students who come and express their interest in participating in the Project. We have more than 300 students e-mail addresses. However, only about 40 students are active somehow at one time. And about 15 are very active, i.e. visiting Institute regularly.
Students have assembled about 30 detectors (out of 40 for the pilot part).
Still we have not yet solved all problems with electronics and data collection. We hope now to run first tests of one unit (4 detectors + GPS) in November/December 2006 with final electronics and on–line data acquisition system.

## VI. Conclusions

There are several projects of Cosmic Ray registrations using High Schools infrastructure and engaging enthusiastic students in USA and Canada, and in Europe [12]. Due to long time tradition of Cosmic Ray studies in Lodz, many school physics teachers came across the subject during graduate studies. Communication with them is easier, and therefore we have relatively large number of students participating in our activity, as compared to other EuroCosmics projects in Europe. At least there is a large outreach impact addressed to High School students.
Preparing the R. Maze Project we have put scintific program which we like to realize. The program requires detectors with a special construction, and specially designed electronics which is almost ready. We have to make it as a "low cost" project; the cost of materials for one school unit (4 detectors of 1 $m^2$ each with electronics, housing boxes, GPS, cables, and on–line PC) was smaller than 6000 Euros.

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