29th International Cosmic Ray Conference Pune (2005) **00**, 101–104

Setup and first results of the HiSPARC experiment

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In Nijmegen, a high school array is being constructed since 2001. The educational aim of this experiment is to have high school students participate in a true scientific undertaking. This Nijmegen Area High School Array (NAHSA) currently consists of eight stations located in a relatively compact area. This NAHSA initiative forms the seed of a national experiment called HiSPARC (High School Project on Astrophysical Research with Cosmics), which currently consists of five clusters of detector stations centered around scientific institutes in Amsterdam, Groningen, Leiden, Utrecht and Nijmegen. In 2004 HiSPARC won the international ALTRAN foundation for innovation award. Within HiSPARC, high school students build and operate the detector located at their high school and have full access to all the HiSPARC data through the internet. The data consists of the full digital scope traces of the signals from both scintillator detectors that make up a station. The setup of an individual station as well as the setup of a cluster will be discussed. The results from analysis, including energy estimates, of coincidences from two and three stations within the Nijmegen cluster will be presented, as well as the largest events we have recorded so far in Amsterdam and Nijmegen.

1. Experimental Setup

HiSPARC is a national Dutch initiative, which aims to build a large national network of cosmic ray detectors on high schools. The goal is twofold. HiSPARC wants to create enthusiasm within high school students and teachers for the exact sciences by having them participate in a scientific experiment. Furthermore, HiSPARC wants to be a scientific experiment, investigating cosmic rays at energies between 10^{16} and $10^{19.5}$ eV. As a scientific experiment, new features are added with respect to previous detectors. Firstly, Flash-ADC readout is used for every single detector station. Secondly, the cosmic ray detector is organized in clusters, with typical distances between clusters of about 50 km. This will allow a search for long range correlations and would even allow for particle-interferometry should correlations be found. Each of these clusters consists of an array of particle detectors and is centered around a scientific institute which provides the local organization and support. Representatives from the clusters meet regularly for national coordination.

1.1 An individual station

The active elements of an individual station, located at a high school or scientific institute, consists of two plates of scintillator with an effective area of $0.5\,\mathrm{m}^2$ each. The thickness of these plates vary, but our baseline is 2 cm thick BICRON BC408 scintillator. The produced light is guided, using a fish-tail lightguide, into a phototube (Electron Tubes 9125 SB) The detector is glued together and wrapped in aluminum foil and black pond foil by high school students. Afterward each complete detector station, including PM and electronics is calibrated and tested by high school students at the scientific institute before installation at school.

The signals of the individual tubes are sent to a custom made coincidence unit, which creates a trigger when both PMs give a signal within $1\,\mu$s. The trigger is sent to a GPS unit (Trimble, ACUTIME 2000) and a digital oscilloscope (PicoScope ADC 212). The coincidence unit, GPS and flash ADC will be replaced by custom made electronics, which is designed by ALTRAN as part of the 2004 ALTRAN award. Using a LabView program the oscilloscope traces of both scintillator plates is being read out and combined with the GPS timestamp for each trigger. Each scope trace lasts $5\,\mu$s, and is binned in 20 ns units. Each station takes several triggers

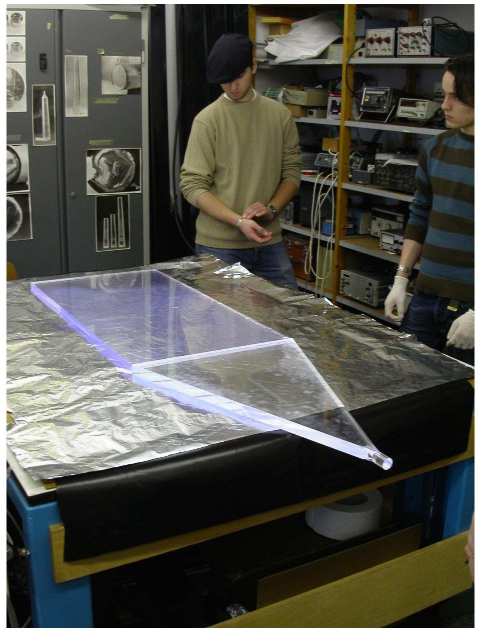

Figure 1. High school students assembling a detector.

per minute. The data of all the individual stations is sent to a central server, where the combination between stations take place as well as further analysis.

2. The first results

The HiSPARC experiment started in Nijmegen, where the first stations got built in 2001 under the name NAHSA. The first results originate from the Nijmegen cluster, which is most advanced with respect to data analysis. The setup of this cluster has been simulated, using the AGASA particle density distribution [1], assuming a Poissonian distribution of particles around the average number of expected particles at each detector plate. The AGASA density distribution has been scaled down by a factor of 2 to account for the altitude difference between Akeno and the Netherlands. We keep track of the uptime of each station by checking for periods without data and by checking the dead-time after each trigger, as can be seen in Figure 2. Using the measured particle flux [2] from other experiments, an absolute prediction for the number of coincident events between schools can be found. In Figure 2 this prediction is compared to actual measurements, which are corrected for random coincidences.

Using the same particle density distribution, it is possible to estimate the energy of events that triggered at least three stations. However, with a few assumptions, a lower limit of the energy can be given for events triggered by two stations only. The assumption being that the energy is minimal, thus the shower comes in as vertical as possible and the shower core lies on the line connecting the stations. As the energy spectrum is steeply falling, this actually gives a reasonable estimate of the most probable energy. The reconstructed energy spectrum is compared to the simulation and the agreement can be seen in Figure 3. Again, the simulation is normalized to the total uptime of the corresponding combination of stations. The right hand side of Figure 3 shows the measured and simulated energy distribution for events which are triggered in the three nearest stations. For

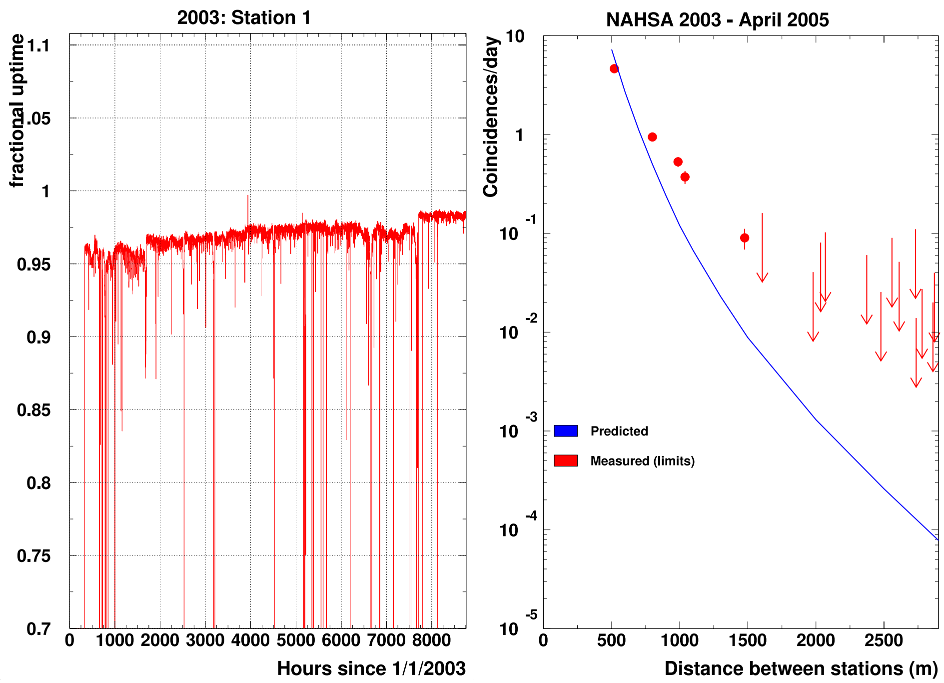

Figure 2. Left: the uptime distribution of detector 1 during 2003. Right: the number of measured and expected coincidences between stations as function of distance.

these events an energy estimate can be given, assuming the correctness of the simulation, without any additional assumptions.

3. The highest energy events

The highest energy events are those that trigger detectors at the largest distances. Both in Amsterdam and Nijmegen events have been found that trigger detectors at more than one kilometer distance. The largest events so far are triggered in three stations. On February 4th 2005 an event was seen in Amsterdam, where the distances between detectors were 845, 1216 and 1535 m, and on March 19 2005 an event was recorded in Nijmegen, where the distances were 988, 2477 and 2780 m. The energy of the latter event has been estimated to be almost 8×10^{19} eV. Using the data, the chance probability of the occurrence of this triple coincidence has been estimated to be less than 3×10^{-4}. For both of these events, the data shows multiple peaks in most traces, indicating that the distance between detector and shower core is large.

4. Conclusion and outlook

Currently about 35 stations are operational in 5 clusters in the Netherlands. Tools for taking data and analyzing the results exist and are being improved. Next, the data taking will be optimized and more stations will be added. Furthermore, better and cheaper electronics will be used. This will allow more high school students to come in contact with this exciting field of research. Apart from the expansion of HiSPARC, we are also active in organizing a european wide collaboration between the high school array initiatives. Meetings between

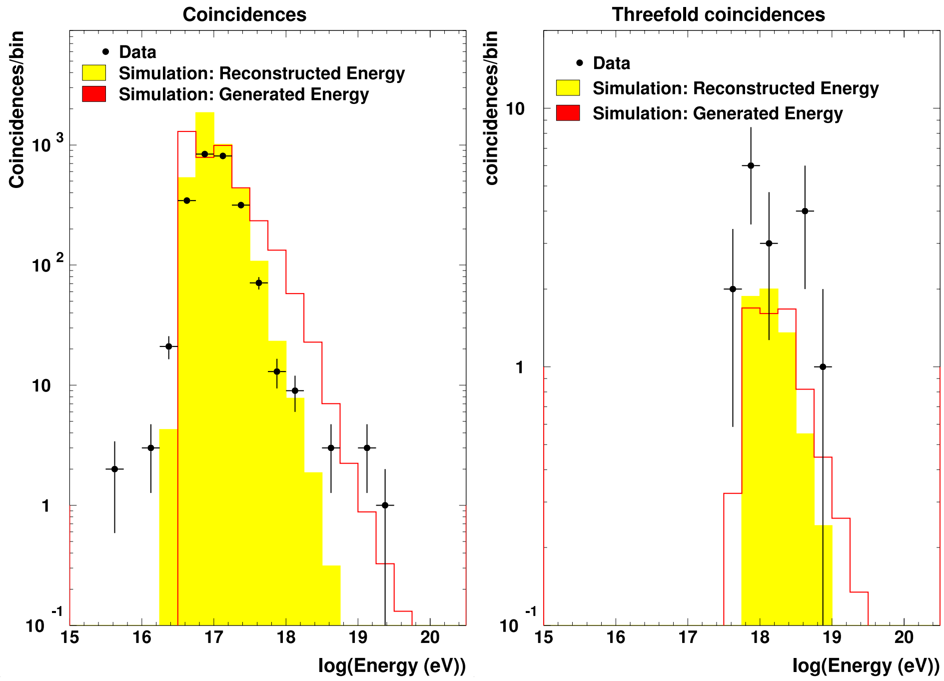

Figure 3. Left: Energy estimate from coincident events at a distance of 500 m. Right: Threefold coincidences where the distances between detectors are 520, 800 and 1038 m.

representatives of these arrays are taking place. Furthermore, we collaborate with the outreach aspects of the LOFAR radio antenna array which is being constructed in the Netherlands. This has resulted in the LORUN experiment in which radio antennas are combined with particle detector information in Nijmegen [3]

References

[1] M. Takeda et al., Astroparticle Physics 19, 447 (2003).
[2] M. Nagano and A. A. Watson, Rev. Mod. Phys. 72, 689 (2000).
[3] A. Nigl et al., these proceedings.