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Citation: AIP Conference Proceedings **944**, 44 (2007); doi: 10.1063/1.2818548
View online: http://dx.doi.org/10.1063/1.2818548
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/944?ver=pdfcov
Published by the AIP Publishing

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Abstract. HiSPARC is a project where high school teachers and students work together to study cosmic rays. The combination of hands-on experience and truly participating in a scientific collaboration opens the eyes of many high-school students for the scientific and technological world surrounding us. In this way HiSPARC helps to achieve the targets set in Lisbon 2000 to increase the number of students completing a scientific or technical study, in 2010 by 15%. This paper gives an overview of the project with the emphasis on its implementation in the Dutch educational system.

Keywords: Cosmic Rays, Outreach. School project, Education
PACS: 01.40.ek; 01.40.ed

INTRODUCTION

There appears to be a gap between the content and method of science teaching in high-schools on one hand, and the nature and practice of modern scientific research in academic and industrial laboratories on the other. This gap manifests itself in the vague and often incorrect notions large numbers of pupils entertain of the scientific enterprise, of scientific culture and of scientific and technical professions. Bridging this gap stimulates more students to make a well-informed choice for scientific and technical studies and careers and reverses the current trend of declining number of science students [1].

Inspired by projects in the US, the High School Project on Astrophysics Research on Cosmics HiSPARC, was founded in 2002, at a workshop of scientists and science teachers at the NIKHEF in Amsterdam. Started originally in Nijmegen as NAHSA, this collaboration of students, scientists and teachers to study the scientific mystery of cosmic rays, is expected to motivate not only students and teachers but scientists as well.

Cosmic rays have been studied for nearly a century. In this century the physics puzzles surrounding cosmic rays have multiplied in number and provide an unprecedented scientific challenge. Much has been learned about their interactions with the Earth' atmosphere, providing a tool to measure cosmic ray fluxes and energies with reasonable precision. These measurements allowed the focus of attention to shift to the question of the origin of the particles. In fact, cosmic rays provide a window on our universe that is quite different from the traditional optical and other electromagnetic wave observations.

Particle physics and astronomy are fields of physics that enjoy good popularity among young people, including those with an otherwise weaker scientific interest. The combination of hands-on experience and truly participating in a scientific collaboration opens the eyes of many high-school students for the scientific and technological world surrounding us. In this way HiSPARC helps to achieve the targets set in Lisbon 2000 to increase the number of students completing a scientific or technical study, in 2010 by 15% [2]. In June 2004 the yearly European award for innovation of the Altran Foundation was awarded to the HiSPARC project for its approach to outreach and education in science and technology [3].

This paper gives an overview of the project with the emphasis on its implementation in the Dutch educational system. It aims to provide other projects with use full tips based on our experience so far. It should not be seen as a scientific evaluation of the project.

COSMIC RAYS

The earth is continuously bombarded by particles (nuclei and elementary particles) from outer space. The energy of these particles varies form rather modest to extremely high; imagine the energy a top ten tennis player gives to the ball, concentrated in an object about 10^{15} times smaller!. These cosmic particles or rays form the object of our research because of the following scientific questions:

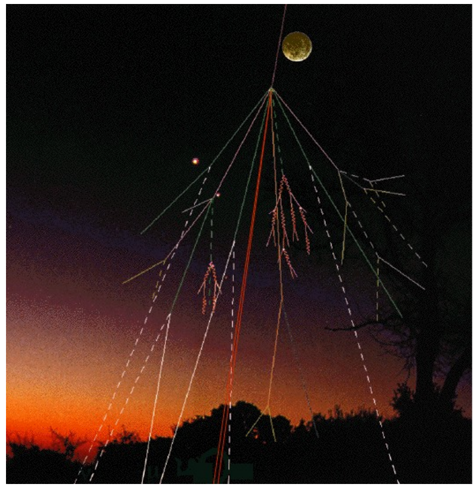

FIGURE 1. Artist impression of the formation of a cosmic air shower [4].

- How and where are these particles accelerated?
- How can they travel through space without losing most of their energy?

Cosmic rays can not be measured directly. When a particle reaches the earth, it collides with nuclei (oxygen and nitrogen) in the earth' atmosphere. The remnants of this collision will collide again and so on. In this way, a shower of particles is created as illustrated in figure 1 that can be detected at sea-level. The more energy a primary cosmic particle possesses, the more secondary particles will be produced and detected. In the course of the development of the shower, secondary particles are spread over a large area, increasing in size with the primary cosmic ray energy. Since they all travel close to the speed of light particles originating from the same primary cosmic ray arrive at the earth surface at almost the same moment.

Detection of cosmic ray showers

The most energetic cosmic rays create particles over an area of more than 10 square kilometers. Using small detectors to measure the particle density at several locations one can estimate the energy of the primary particles. Furthermore, the direction of the primary particle can be deduced from precise time stamps added to each measurement. The distance between the locations where the particle density and arrival times are recorded should ideally be in the order of 500 to 1000 meters, depending on the altitude (sea-level) and energies of interest. In urban areas this is a typically distance between high schools and therefore this measurement is a natural candidate for a successful collaboration between high-schools and scientific institutes.

A detector station

The particle density is measured using a simple, robust detector station. Its sensitive elements are two pieces of scintillation material of half a square meter each. When a charged particle passes through the detector it looses energy. Part of this energy is transformed into light, which is transported via a light guide, detected by a photomultiplier tube and transformed into an electrical signal. When more particles pass through the detector, more light is generated and thus a larger electrical signal is formed.

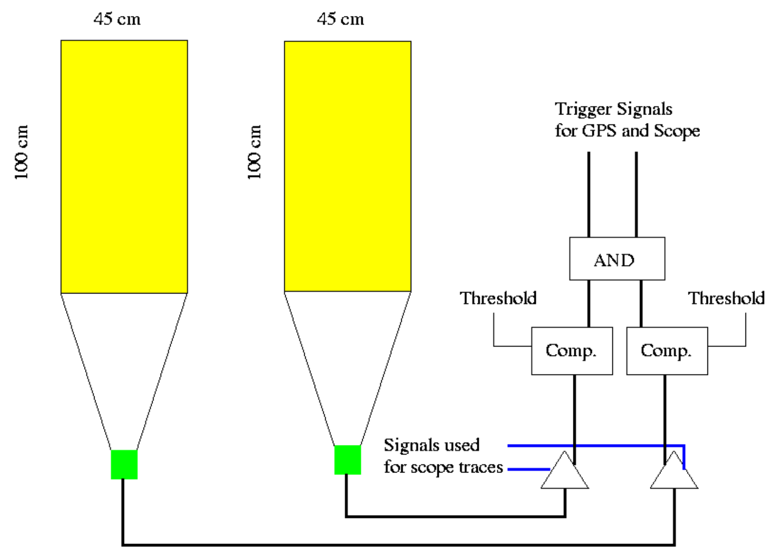

FIGURE 2. **Schematic layout of the detector. The light produced by traversing particles in the two scintillators is transported towards photomultiplier tubes and transformed into electrical signals. Custom designed electronics only selects signals arriving within a small time window from each other.**

The scintillator plates and photomultipliers are installed on the roof in ski-boxes, a cheap and elegant solution to protect these parts from weather influence. The signals of both plates, located about five meters apart (figure 2), are sent to a custom made electronics box located inside the school near a PC. In this box the signals are compared to a threshold value. When the signals from both plates are above threshold and within a set time-window, a trigger signal is sent to a digital oscilloscope where the analogue signal is converted into a digital signal. The digital data is combined on the PC with the GPS (Global Positioning System) time-stamp with an accuracy of 10^{7} seconds and automatically sent over the internet to a central data server. At this server, data from all stations are combined and a off line search for simultaneous events is conducted.

All data is freely available via the internet. Not only from single stations, but also our best energy and direction estimates for these coincident events are given to high-school students and teachers to use. The presentation of this data is constantly under development to match the needs of teachers and students.

HIGH-SCHOOL PARTICIPATION

HiSPARC provides a rich context for science education and allows students and teachers to participate directly in actual research projects. In contrast to standard learning activities, the reward of participating in the project is not only in the mastering and understanding of the subject material, but also to make a contribution to the advance of knowledge itself. What is more students are highly enthusiastic and motivated by the realization that their work contributes to science either in the form of a detector that functions for a number of years or as a contribution to a scientific paper [6]. What is important is that these students are not visitors to scientific institutions, they are there as collaborators. It may be expected that this will motivate students and improve the quality of the learning process.

It is important to stress that all HiSPARC activities of pupils take place within the normal school curriculum. The Netherlands don't know a system of summer schools such as the US nor are extra curricular science clubs very common. Therefore HiSPARC has to find a natural place in the high-school curriculum[1].

The simplicity of the design allows the construction of the detector to be done by high-school students. Up and till two years a go, the main role of HiSPARC in the schools was the making of a detector serving as a subject for the student Masterpiece (see annex 1). All though this is a great activity for students and is rather successful it is not sufficient to anker the project in school. Moreover, building the detector alone does not give a realistic and complete

[1] For teachers the situation may be slightly different. They tend to participate on the basis of private interest or to be able to develop themselves and their subject further.

picture of modern science. The challenge of the HiSPARC project is therefore to get students involved in the data analysis. This is not straight forward since most students will perceive this as a difficult and likely even a somewhat boring activity. In the past two year, a lot of energy has been put in the development of material to be used in the classroom to prepare students. Further one also needs to cater for the large group of students that has no ambitions for a career in science.

Educational Tools

To make sure developed material is used it has to be easy accessible. Hereto one of the participating teachers has developed a HiSPARC Virtual Learning Environment (HiSPARC –VLE[2]) [7]. Material can be uploaded and downloaded and as such it forms an ideal communication platform. All courses cited below are accessible through the VLE.

Science students

Scientific oriented high school students form the primary target group of the project. The ultimate goal is to involve them in the data analysis and make them enthusiastic for a career in science. Hereto courses are offered that provide the student with sufficient background knowledge:

1. A completely web based course treating different aspects of cosmic rays and their detection. It uses applets and an electronic scorecard.
2. An in depth 'classic' course about cosmic rays and their detection, aimed at the really science oriented students.

The Practical Assignments, mandatory in the Physics program, are small projects where students learn to define a research question, set up a 'project plan' execute this and come to a conclusion. They are ideally suited for students to learn to work with actual data. Typical subjects are:

- Well researched topics with known results such as the correlation between the number of events and air pressure or distance between the detector plates.
- More methodological topics such as how information on the direction of the rays can be obtained or if one can differentiate between measurements of electrons and muons[3].

The actual data analysis can be part of the Masterpiece which should contain at least 80 hours of work resulting in a thesis. Only a limited number of students will choose HiSPARC as the topic for their Masterpiece. They address question such as:

- What is the direction and energy of the incoming particles, do they come from a specific direction. This will involve a considerable amount of statistic analysis etc.
- Real open research questions such as what is the cause of the increase in detected events when a thunderstorm nears?
- Detector response
- Theoretical topics like acceleration of these particles.

The student Masterpieces have already resulted in some interesting results specifically on the correlation between rain and the cosmic ray flux.

In 2010 a new physics curriculum will be implemented at Dutch high schools. It is based on the concept-context approach and it will be offered in the form of modules. Schools are free in choosing their own context modules as long as they comply to set concepts. Parallel to this a new science course is developed integrating all science subjects. HiSPARC is developing material for both the new physics curriculum and the new science course. Cosmic rays form an excellent context to teach elementary particle physics. It also allows for the use of data of ongoing experiments like Pierre Auger, Antares etc. An interesting point to mention here is that material from the CROP project in Nebraska forms the bases of one of the these modules. This is a very concrete result of an international collaboration between a number of cosmic ray high school projects in Europe and the US [10].

[2] http://elo.hisparc.nl/

[3] Due to time constraints this may be better suited for their large project, their Masterpiece.

Non science students

The non science students we aim to give general knowledge on cosmic rays and to show them something about scientific research in general. The general science course is part of the last two years in High School and mandatory for all students, whether in exact science, literature or economic directions. It covers science and its impact to society as a whole. HiSPARC has developed two modules for this course, one general introduction to cosmic rays and one that treats the subject from the point of view of Astronomy.

Non science students are also actively involved in the HiSPARC project. They do Public Relations, write articles on their experience with HiSPARC in school papers and in communications to the parents. During "open School days" these students create presentations. This approach helps to create a positive image of the project: the fact that their school participates in it is known and regarded as 'cool'.

That this approach works shows the surprisingly high number of non science students that choose HiSPARC as subject for their Masterpiece. They study its organization and one group even made a documentary on the project.

Junior High School

The students of Junior high school form an important special target group. Research has shown that students determine in this first 2 years of high school if they want to pursue exact sciences [11]. Teachers within HiSPARC have therefore developed a interdisciplinary project that targets these students. The students study the topic of radiation in the broadest sense, from different angles by means simple experiments. A pilot had shown to be very successful.

Facts and Impact

In the 5 years that HiSPARC is active 46 detectors have been build for the Dutch network plus one in Sudan and one in Denmark. In Holland 40 schools are actively involved and there is a waiting lists of schools who want to join the network. In 2006 we have done a small survey among the teachers on the role of HiSPARC in the school. On average there were 22 students per year per school that worked on HiSPARC, either on the detector building, data analysis or following a HiSPARC course. If you consider that the total number of freshman students for physics in the Netherlands is in the order of 400 per year this is a promising number.

Four Student symposia were organized where students present there work and eminent scientists such as the Nobel laureate Prof Veltman, give presentations. These meetings are perceived as very stimulating for all participants.

The ultimate is goal to persuade students for a career in science. We know of several examples where HiSPARC formed a decisive factor in their choice for Physics [5]. A number of students indicated that their HiSPARC experience proved to be very beneficial in their studies.

CONCLUDING REMARKS

The success of the HiSPARC project is based on the enthusiastic involvement of scientists and teachers. Teachers are key persons; they have to be supported by both the participating institutes and their school. Since the topic of Cosmic Rays is new to most of them they need to improve their knowledge on this. This has to be facilitated. As such HiSPARC helps in establishing a sustainable relation between schools and universities.

The notion that they participate in a real and ongoing scientific investigation appeals to students. The fact that they themselves and their work are taken seriously has a profound positive effect upon them. Scientists should be aware of this. To maximize the impact of the project at a school it is vital to incorporate all students and not only the science students.

ANNEX 1 THE DUTCH EDUCATIONAL SYSTEM [8]

In the Netherlands children have to attend school from the age of five to 18. To ensure uniform qualifications throughout the country the curriculum and achievement targets for all school types are laid down by law. There are public schools set up by public authorities, usually municipalities, however more than three-quarters of the schools are founded by private bodies such as the Montessori foundation. All schools are eligible for government funding, provided they meet set criteria, and all teachers are paid by the government.

In 2001, the Netherlands spent 5.3% of its GDP (Gross Domestic Product) on education. Education is free of charge for children up to the age of 16. But the parents of secondary school pupils have to pay for textbooks and other teaching materials. All parents, irrespective of income, receive child benefit.

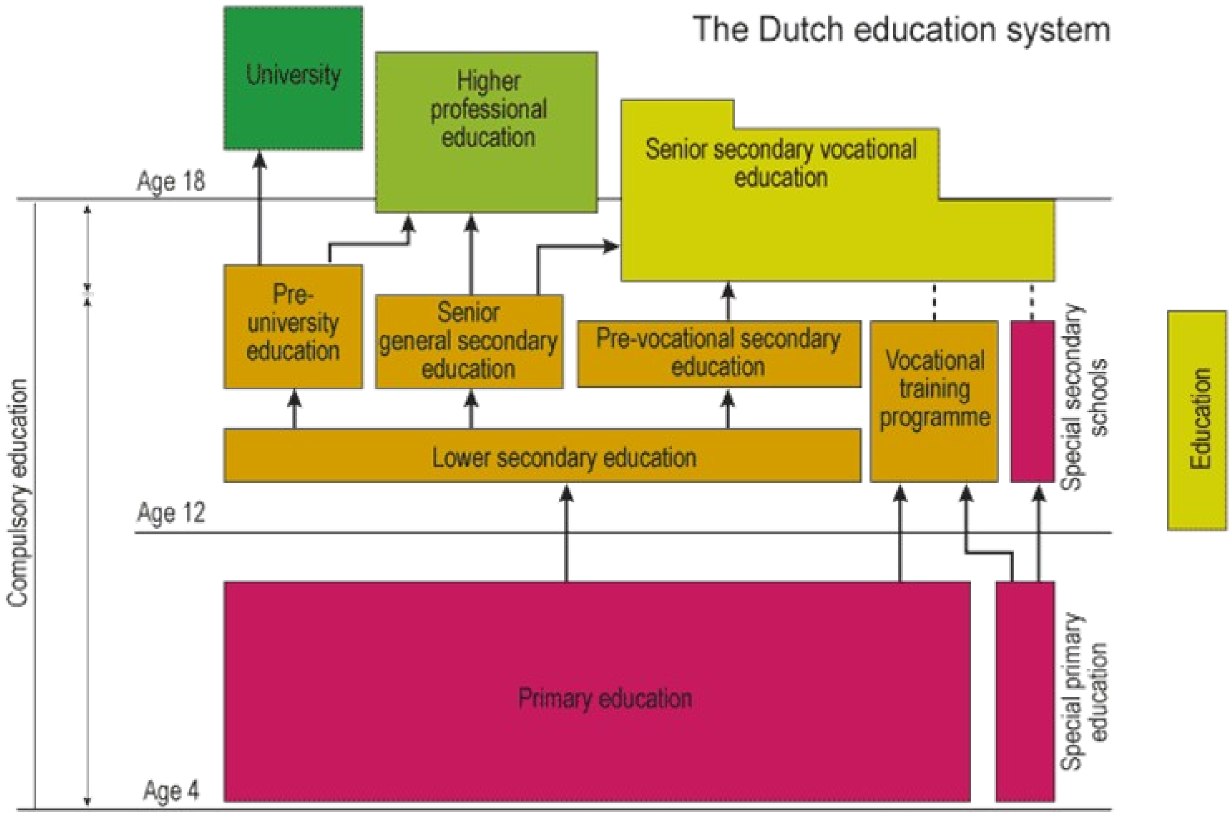

FIGURE 3. An overview of the Dutch education system [9].

The Dutch educational system is organized as indicated in figure 3

- Primary education

Primary schools in the Netherlands cater for children age's four to 12.

- Secondary education

Children from the age of 12 are eligible for admission to one of the three types of secondary education:

1. A 4 year pre-vocational secondary education (VMBO) leading on to secondary vocational education (MBO)
2. A 5 year senior general secondary education (HAVO) leading on to higher professional education (HBO)
3. A 6 year pre-university education (VWO) leading on to university (WO).

Students in the first two to three years of secondary school are all taught the same core curriculum of 15 subjects (Lower secondary education, more or less equivalent to Junior High school)

95.7% of all 17-year-olds in the Netherlands have currently either completed or are still attending secondary school full time.

- Higher education

Higher education comprises higher professional (HBO) and university education (WO). A bachelor-master degree structure was introduced in 2002.

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