Lecture Bad Honnef

A cooperative project between the Scientific Community and High Schools.

Jef Colle and Frits Hidden (HiSPARC, NL)

Intro

In June 2004 the 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. This project has been initiated to integrate research and teaching: its starting point is an important problem in fundamental science. Where do high energy cosmic rays come from? Why do they have such enormous energy? Even the popular press is paying attention. A large number of projects around the world are looking for the solution to these questions, amongst others is the Auger Project in Argentina. The topic of "Cosmic Rays" also has an intersting history and research into it has resulted in a number of Nobel Prices. Topics such as high energy neutrinos and gamma bursts also are related to "Cosmic rays".
The solution of this problem obliges the participants at all levels to acquire the necessary scientific background, master scientific methods and develop technical skills. Only in the HiSPARC project, the teaching and research are not restricted to the university level, but include many participants at the level of high-school science classes.
Let's begin with an overview of what we will cover with you

Summary

- The origin of HiSPARC
- HiSPARC project: Description
- Movie: Student Involvement during the assembly
- Implementation of the Project at the school
  - Structure of Education in The Netherlands
  - Plans to broadly implement HiSPARC
    - Knowledge of Science course:
    - Curriculum
    - Practical Assigments
    - Final Work: the happy few?
- Vision of the Future

The origin of HiSPARC

In the year 2000 the European governments committed to providing a flourishing economy by 2010 mainly by making large investments in R&D. At this time, it looks like this target will not be reached and one of the causes is the shortage of scientists and engineers.
This is not only due to the steady decline of birth rates in Western Europe since the 1960's, a number of other factors contribute as well.
Among these is **the public image of science**: science is perceived as difficult and abstract, it has no particularly high social and the scientific professions are not seen as glamorous and exciting. We don't see Ferrari's in front of the NIKHEF!
In addition, it has become increasingly difficult for science to attract the interest of teen-age children amidst an **abundance of other attractions**. There is strong competition for example from the entertainment industry; these age groups represent a Billion Euro Market for their video clips and computer games.
In spite of this challenge, scientific research has shown that the future career direction of students is determined mainly in the first two years of Junior High School. So it is important

that during that time we provide the students with a complete picutre of science that not only shows it as fun, but also as exciting. The current curricalum does not provide enough opportunities to accomplish this goal, something new has to be added. This is the basic incentive for the start of the HiSPARC Project.
It started in Nijmegen as NASHA and its success there triggered the 2002 session of scientists and teachers at NIKHEF. That was the the beginning of HiSPARC.
Students, scientists and teachers will work together to produce data that will assist in getting closed to answering the "rittle" of Cosmic Rays. The collaboration on a real scientific problem is expected to motivate not only the student but the teachers and scientists as well. Could it be the creation (beginning) of a "Community of Learners"?

Project HiSPARC Description

The earth is continuously bombarded with particles from space, cosmic rays. These particles find their origin somewhere in the universe.
There are particles that originate from the sun and these cause amongst others Northern Light; there are other particles that wander in the Milky Wayand reach earth…. But there are also particles with enormous energy that probably originate from outside the Milky Way. These enormous energies are unbelievably large, above 10^{20} eV or the energy of a tennis ball at a velocity of 200 KPH... (at CERN they can reach up to 10^{16} eV). One of the major questions and a subject of scientific research are to determine where these particles come from and how they acquire their energy. Unfortunately, this type of collision is very rare, approximately once per year per 100 km^2 and as a result, they are difficulty to detect in space by using balloons or satellites.
Ground measurements are one of the ways to determine the consequences of the collision of this particle with molecules from the atmosphere.
A high-energy particle comes in contact with the atmosphere and collides with molecules in the air (Oxygen or Nitrogen). These collisions cause a storm of 100 to 1000 million other particles. Such a storm is called a shower and descends to earth mainly as gamma rays, electrons and especially muons and covers an area of approximately 100 km^2. So you need a number of measuring stations, spread over 100 km^2 (this is about the surface of Amsterdam). HiSPARC has its measuring stations on the roofs of a number of schools in Amsterdam, Nijmegen, Leiden Groningen and Utrecht. These are the clusters of HiSPARC.
So how does one measure such a possible shower of particles?
Each school has 2 detectors. Each detector consists of a "scintillation plate", a light conductor, and a photomultiplier. The scintillation material is a type of plastic with imbedded molecules that are excited by the impacting particles, after which these molecules emit a light (blue light). In other words, when a particle passes through the plate, the plate emits light. This light is transmitted by the light conductor to the photomultiplier, which converts the light into an electric signal.We do not want to measure all particles that impact the detectors, only those particles that could come from a shower. So we need to apply a selection. This is where the second detector comes into play. The two detectors are connected with a GPS system. We measure only if particles impact both detectors at the same time, within 2 microsec. Such a measurement is called a coincidence. At that moment you have chance that the particles are part of a shower. Such an event (data from the 2 detectors and the time from the GPS) are registered in the computer and transmitted to a central database. If a number of measuring stations (minimum of 3) in the area have measurements at the same time, there is a good chance that we are dealing with a particle shower.To determine if you have identified a particle shower, the central database is searched for a 3-fold coincidence, meaning measurements from 3 stations at approximately the same time. From those events you must now determine the properties of the primary particle (the cosmic particle the collided with molecules in the atmosphere). Where did this particle come from and how large was its energy? The direction of the particle can be determined from the small time differences at

which the stations were "hit" and the energy can be determine from the strength of the signals (a measurement of the density of the resulting muons and the spread of the shower).The project has two distinct components; first the construction and maintenance of the detectors and second, the research performed with the detectors. We have a short movie for you showing the construction of the detectors. This movie was made by the students as part of HiSPARC. The detectors are built at NIKHEF by students under the supervision of scientists…

Implementation of the Active Project

HiSPARC involves students in the later years of HAVE and VWO (the last 2 years of HAVO and the last 3 years of VWO). This part of High School was reorganized a few years ago and is now called *the second phase*. The reforms emphasize self-study... The emphasis is on self-activation and independence of the student, the teacher is also a coach of the learning process. New to this *2the phase* is a Thesis (ProfielWerkStuk – PWS) with an expected learning period of 80 hours. The construction of the detectors was for most students a part of this thesis.

Students elect 1 of 4 major profiles : Social Studies and Culture, Social Studies and Economics, Nature and Health, Nature and Technology. The last two profiles cover the scientific tracks; Nature and Health provide preparation for Medical and Biology studies whereas Nature and Technology prepare for pure and applied sciences.. At this time, Chemistry and Physics are required in both nature profiles but this will be changed in 2007 when you can choose the Nature and Health profile without Physics!!!! They will however add a more *Core Scientific Course* for these science profiles. What this new course will be is not yet clear but it will be more general and cross sectional (?). Here, HiSPARC can possibly fill a gap.

Plans to broadly Implement HiSPARC in Education

At the start, HiSPARC was used as PWS , this works well with building detectors… but it has become clear this year, now that the detectors are built, that it is not sufficient to anker the project in the school. This approach, supplemented with lectures and group discussion on the Internet, reached a dead-end when concentrated only on PWS. Students see the PWS to much and "Thesis". HiSPARC has to be included in the everyday learning of the students. So more activities are being added to HiSPARC. These new plans are in development and the initial results are very encouraging.

Let's review the possibilities

<u>All students</u>

- Junior high school (the first 3 years of HAVO and VWO)
  As I mentioned in the introduction, research has shown that students determine in this first phase if they want to pursue exact sciences. They do not know yet how, but they do know whether they are interested in exact or inexact fields. It is therefore very important at this phase to provide a good view of science. HiSPARC is developing a project for these students and we hope to pilot it during the next school year. It will be an inclusive project in cooperation with Mathematics, Biology and Geography (only few schools in the Netherlands have *Science* in Junior High school)

- Senior High School
  Knowledge of Science is a course in the second phase. It is a course that all students must follow, whether in exact science, literature or economic directions,. The course covers science in general and its impact to society as a whole. There are 2 ways in which HiSPARC can be presented and used.

The first approach is from the point of view of Astronomy. Most topics of Astronomy can be developed with examples from HiSPARC. This approach was used at "Het Amsterdams Lyceum" with approximately 80 students. The course material was developed in en electronic learning environments and is available to the other schools.

The second approach used the topic of radiation. Using this approach, the detection methods of HiSPARC can be used to cross over to implementations in other areas such as medical . It can include also the environmental impact of radiation. This approach is being developed for the upcoming school year.

There are plans to collaborate with "**Kennislink**", a national website for the promotion of science with the broader public. This website became popular in the Netherlands when it was used for the counting of flu cases via the Internet. There are plans for make radiation its next big topic. As a results of the discussions surrounding the Kyoto Protocol, this links well with the current discussion on Nuclear Energy.

A course series was developed and made available to teachers. In addition, we built and electronic learning environ ment where students can work on their project. The main objective of this course is to build enthusiasm and motivation as well as provide the basic knowledge. Students have to be able to explain to an outsider what the purpose is of the detectors on the roof of their school; they have to be able to explain why HiSPARC is so important for the school and themselves.

The ELO(?) will also be used to determine if HiSPARC is interesting and fascinating and can result in the selection of a topic for the student's PWS. This is important as the student who now start working with HiSPARC did not participate in the construction of the detectors. For them the detectors are a "Black Box".The part includes an in-depth description of the HiSPARC projects, how the detectors work and what the goal of the experiment is. In addition, the students will compare HiSPARC with similar projects for example in the US. This way, students will learn that they are not alone in working on this problem. This introduction course will be offered in the virtual teaching environment with individual coaching from the teacher. It is not the intention that everyone does everything but rather that this is viewed as a "Candy Store" for the teachers to shop at.

The next part is to explain the development and implementation of the HiSPARC pilot for the ***students with a science profile***.

We aim only at:

- simple rearrangements of the curricula
- cooperation with teachers of the other natural sciences
- create ready to use material that can be integrated in the courses

We started with a list of topics that are needed to understand cosmic ray research or topics that are somehow related to it. Out aim is to make small sets of material (for 1 – 3 lessons per topic). This list is now a basis for discussions in the HiSPARC trams of the related schools. And now it is in the stage of development.

In the ***Physics course*** we plan to go further.

Some components must be placed in an earlier stage so the students have more time to:

- build up relevant knowledge
- do small experiments
- participate in the symposia with other schools
- communicate with the related academic professionals

Most of the attention will go to the standard practical assignments. In general these assignments have the purpose to teach research skills in a broader perspective. This is a well known list. They can be easily be adopted by the Hisparc project, because Hisparc stimulates experimental work.

With the new electronics of Altran there is the possibility of measuring with 4 detectors on one station. The two extra detectors can be freely manipulate by the students. The other two detectors are part of the UHECR network.
What can students measure?
Most of the research will cover the particles that to the middle range of the Cosmic Ray energy spectrum.
➔ Students can investigate absorption and shielding. These subjects can be set in the context of radiation in general or medicine. It also demonstrate the huge energies of the muons.
➔ Students can investigate differences in the detector positions. This can be used to check the detector setup. It combines with earth sciences and astrophysical themes. It is associated with concepts of thickness of the atmosphere and the direction of the earth magnetic field. It can be used to investigate the frequencies of small airshowers.
➔ Most interesting are the effect of atmospheric variations. This options implies the use of mathematical issues in statistics and correlation. Students learn to cope with large amounts of data. I would like to demonstrate this in greater detail, and I will show you some wonderfull results.
First I let you see how easy students (and in fact everybody) can retrieve data from the database.

1. On the Hisparc website one does a query by filling some of the options in the menu.
2. The server responds with a table and a histogram, showing the counting rate of coincidences per hour.
3. You may notice in this case the date of this histogram: 4th of July, it happens to rain very severely in Amsterdam.

Usually the counting rates are relativily steady. But in extreme wheather conditions the rates go up by more than 100%.
When we put this figures in a standard spreadsheet and we add also the data from other detector stations we get an interesting time-serie. This serie is from November 2004 to February 2005. and you can see other extremes like the one of July 4th.
You can also see smooth variations that are simultaneously in all of the detectors. This is a well known effect and is strongly related to the variations in barometric pressure. These results can easily be obtained by students, because we have a wheather station in our network. In that case the students can make analysis in the following way. In this slide you see that the counting rate decreases with the barometric pressure. And it can be explained by the concept of thickness of the atmosphere: more pressure → more mass / airparticles → less muons at ground level. The Regression Line can be used to eliminate the barometric effects and investigate other relations (like variations with temperature, time of day, variations of the sun etc). Although some of the assignments are not that easy, it is possible for students to accomplish them. But most of the studies gives mostly results that are well documented in the literature.
Analysis of the extremes.
The next part is about the analysis of the effects of extreme weather conditions. This is a poorly known phenomenon. We have seen that with severe rain (not per se a thunderstorm) there are huge peaks in the counting rate of the coincidences. Students can study this effect too. In that case students need more sophisticated research skills. He needs to formulate a hypothesis and maybe he needs to discuss this with academic professionals to make a better progress.
A way to study this effect, is to look at the type of particles involved in this peaks. Students can also get details of the counting rates (e.g. the exact timing of events and the amount of energy that is left in the detector). With some spreadsheet tricks one can make the frequency distribution of the energy deposit in each detector. Low energy is usually associated with electrons, and high energy deposit with muons. When we make a cross- plot of simultaneously

detected particles we see this distribution. And when we make a time serie of these plots we see that the extreme weather peaks are mostly because of far more simultaneously detected electrons. In the scientific community there were mo explanations found.
It is our hope that these kind of practical assignments and research questions stimulate students to do more and better research in their Master Piece.

Students with a science profile

- Via Curriculum
  Using the normal curriculum, students with exact sciences in their study packet (ik moet een beter woord vinden) learn about the scientific part of HiSPARC such as particle physics, astrophysics, air showers, detection, electronics, and data processing, GPS / Geometry. Other topics can also be included. Some examples are northern lights, solar winds, Electro-magnetic bend (?), extra-terrestrial live, atmospheric phenomenon, weather, ballooning, statistics, medical diagnosis, space travel, and radiology. Even biology, Mathematics, Computer Science, chemistry, geology, meteorology and technical sciences can also play a role.
- Practical Assignments
  The Physics students will go one step further. According to the Physics program, students must perform a number of practical assignments. A number of those assignments will come from HiSPARC. The assignments will cover the research questions will be in the context of Comic Rays but not directly deal with the detection of Ultra High Energy particles. For example :

- By connecting the measuring stations to a weather station we can studies correlations such as whether the number of coincidences is related to air pressure? In this case, the student must define the research question, create a measurement plan, perform the measurements and analyse them to form a conclusion. This is clearly a subject with a know result.
- There are also research questions that are not this clear-cut. For example, we have noticed that is are time an increase of as much as 100% in coincidences when a thunderstorm nears. The questions are : is this caused by an increase of electrons on an increase in muons? It is clear from measurements that there is no increase in muons but what is the answer then, an increase in electron-gamma rays? Someone has even suggested that the Photomultiplier received electrons directly from the thunderstorm.
- The students can also research, in addition to weather, the impact of distance on the detectors. Is the number of coincidences dependent on the earth's magnetic field? Can you infer any information on the direction of coincidences? How can you differentiate electrons and muons in the measurements?

These practical assignments can be combined by the students with research from the massive literature and history of cosmic rays.

PWS – the happy few

In addition to their practical assignments, a number of students will want to continue to be involved with HiSPARC. There are a number of HiSPARC topics that are good candidates for further involvement from students :

- Maintenance and calibration of the detectors : Detectors must be calibrated regularly. This activity uses electronics.
- Public Relations for the project : a number of students will write articles on their experience with HiSPARC in the school paper and in communications to the parents. During "open School days" these students can create presentations. If there are results from HiSPARC, these students could be contacted by the local press.

- Data Analysis – It is the intent that students are involved in setting the direction and primary energy of the UHECR. They will need to know, for example, CORSICA. Students will be cooperating with scientists in developing simulations and error analysis.
- Theory – It is likely that certain students will even be interested in the more theoretical topics of acceleration or the origin of these particles.

These students will not be visitors to the scientific institutions, they will be there as collaborators.

The Future

This summer we start with the development and implementation of the communications environment for the 5 clusters. This environment will contain a portal for announcements and an ELO for the activities of the participants. In this environment, students from the different clusters can collaborate on the same problems, can stay up to date on everyone's progress, and communicate easily with each other.

Expanding and enhancing the network

During the past years, cluster Amsterdam has organized a number of very successfull conferences. Students and scientists presented their work and a real interaction happened between students and scientist and between the students themselves. These conferences were also used to create enthousiam with new students. Next year, we want to expand the conference to a national level.We also want to create workshops and lectures by scientists at the schools.

Collaboration with LOFAR

It is our intent to publish the results in the HiSPARC reviews.Workshops for teachers will also be necessary in the future.