Frontline physics for teachers and students

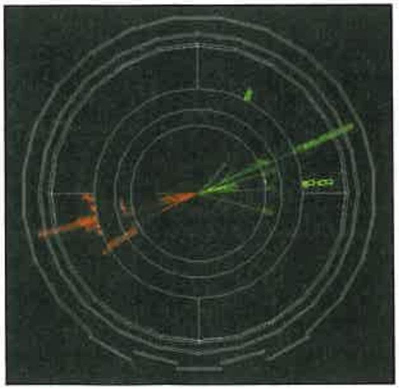
K.E. Johansson
Department of Physics, Stockholm University, and Stockholm House of Science, AlbaNova University Centre, Sweden

Today's research projects can enrich physics education at school and complement the traditional way physics is taught. The projects described here explore the Milky Way and the most fundamental level in the interior of matter with the aim to increase both the understanding of and the interest in natural science. Research councils and other financing bodies are starting to appreciate the importance of this type of education projects for the future of science, but a lot still remains to be done.

The world of particles

With the Hands on CERN education project [1, 2] the students can "take part" in a modern particle physics experiment at the forefront of scientific research using scientific data transmitted via Internet. The primary aim is to show particle collisions from the physics frontline and to stimulate interest in science and technology. Hands on CERN complements the traditional physics education and confronts the students with contemporary physics and technology at its most fundamental level.

With high energy particle collisions it is possible to study the smallest building blocks in Nature—the quarks and the leptons. Some of these build up the world we see around us, some existed naturally only at the beginning of time, the Big Bang, but are now produced in high energy collisions at a few large physics laboratories in the world.



◄ **Fig. 1:** The production in an e^+e^- collision at 91 GeV at the LEP collider of a Z^0 particle that instantly decays into a quark and an antiquark, which give rise to sprays of particles that are detected in the DELPHI detector.

The scientific data come from the DELPHI experiment [3] at the Large Electron Positron Collider (LEP) at CERN. Until year 2000 LEP was producing high energy collisions between electrons and positrons. During the first phase of LEP the collision energy was 91 GeV and a single Z^0 particle was produced in the collisions (Fig. 1). During the second phase the collision energy was increased to around 210 GeV sufficient to produce WW and ZZ pairs. With these data virtually all components of the Standard Model, with the exception of the top quark and the Higgs particle, can be explored—the quarks and leptons, the gluon and the electroweak and strong interaction.

We often encourage the students to look at the Particle Adventure [4] to get an introduction to the world of particles. In order to make the students more familiar with elementary particles the web exercises are complemented with laboratory experiments. The classical Thomson e/m experiment and the Millikan experiment on the electron charge, make the students familiar with elementary particles and the manipulation of them with electric and magnetic fields.

The structure of the Milky Way

It is not possible to see very far in the Galactic plane in the optical wavelength region. This is due to the absorption caused by clouds of dust that are distributed among the stars in the galaxy. This interstellar medium is however quite transparent to radiation from the well known 21.1 cm line in atomic hydrogen. This radiation makes it possible to study the distribution of hydrogen in our Galaxy and thereby study the spiral structure.

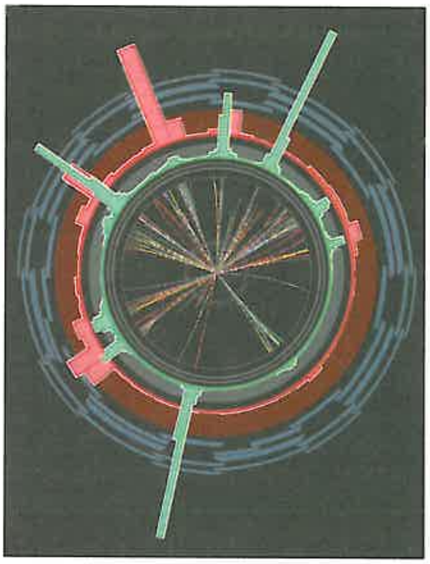
▲ **Fig. 2:** Students in front of the radio telescope with which they explored the Milky Way.

We used a small radio telescope with a 2.3 m diameter parabolic antenna to map the Milky Way (Fig. 2). The telescope is set to detect the 21.1 cm atomic hydrogen radiation. By measuring the Doppler effect in the received radiation one can measure the radial movements of the spiral arms relative to us and also calculate the distance from the observed cloud of hydrogen to the Galactic Centre. For these calculations we need to know our own position and speed relative to the centre of the Galaxy, but also the assumption that the tan-

Article available at http://www.europhysicsnews.org or http://dx.doi.org/10.1051/epn:2003308

gential velocities around the Galaxy are practically constant outside the very inner part of the Galaxy. This project is described in more detail in [5].

The assumption of the tangential velocities being practically constant outside the central part of the galaxy has been experimentally verified for several galaxies, but is nevertheless quite surprising. The measured rotational velocities indicate the presence of matter in addition to the matter of the luminous stars. This unknown type of matter, the dark matter, seems to be a very important component of our Universe. One possibility is that the dark matter is composed of supersymmetric particles. These particles could be detected in the high energy particle collisions either at the Fermilab Tevatron or the future proton collider at CERN, the LHC. There experiments like ATLAS could very well discover the hypothetical dark matter particle of the Universe (Fig. 3).



◀ Fig. 3: A simulated proton-proton collision at 14 TeV at the LHC collider. At the collision a large number of particles are produced and detected by the ATLAS detector.

Astronomy and particle physics

For several years we have organised courses in astronomy and particle physics for 17 – 18 year old secondary school students. The students either studied the differential rotation of the Milky Way or the intricacies of high energy particle collisions. Plenary talks by scientists in astronomy, cosmology and particle physics were given to both classes to make all the students familiar with the different subjects and the fascinating connection between cosmology and particle physics. The combination of making their own measurements of the Milky Way with a small radio telescope, using scientific data from high energy particle collisions and having the Standard Model, the Milky Way and the Big Bang explained by scientists created an attractive and fascinating course in contemporary science.

▲ Fig. 4: The Stockholm House of Science on the campus of the AlbaNova University Centre.

The House of Science

Until 2000 this project took place at the Science Laboratory [8] at Stockholm University, a laboratory devoted to teachers and students at school. This laboratory was for many years a platform for many projects in modern science [2, 5-8]. Since 2002 the Science Laboratory has become the Stockholm House of Science [9] (Fig. 4), at present devoted to astronomy, biotechnology and physics, and situated at the AlbaNova University Centre, a joint Stockholm University and Royal Institute of Technology centre.

Summary

During the research project the students realised that they could determine some of the most fundamental quantities in the Standard Model of microcosm and learn about the structure and dynamics of our own galaxy, the Milky Way. With scientific data, the right tools and instructors the students could explore fundamental processes in Nature normally only accessible to scientists. When planning future scientific projects it is essential to keep in mind the importance of promoting the interest in science at school and the role of scientific outreach activities.

References

[1] Hands on CERN home page: http://hands-on-cern.physto.se

[2] Hands on CERN – a Particle Physics Education Project utilising the Internet, K.E. Johansson and T.M. Malmgren, Physics Education 34/5(1999)286-293

[3] DELPHI home page: http://www.cern.ch/Delphi/Welcome.html

[4] The particle adventure homepage: particleadventure.org

[5] Astronomy and particle physics research classes for secondary school students, K.E. Johansson, Ch. Nilsson, J. Engstedt and Aa. Sandqvist, American Journal of Physics. Vol. 69, No. 5, May 2001, p. 577

[6] Stockholm Science Laboratory for Schools, K.E. Johansson and Ch. Nilsson, Physics Education 34/6(1999)345

[7] Experiments in Modern Physics for the General Public, K.E.Johansson and Ch. Nilsson, Physics Education 35/4(2000)256

[8] The physics of 'Copenhagen' for students and the General Public, L. Bergström, K.E. Johansson and Ch. Nilsson, Physics Education 36/5 (2001)388

[9] The House of Science homepage (at present in Swedish): www.houseofscience.org

About the author

Erik Johansson is Professor in particle physics at Stockholm University and Director of Stockholm House of Science, AlbaNova University Centre.