International Masterclasses

Summary:

The "International Particle Physics Masterclasses" provide an opportunity for high school students to be "scientists for a day". We as scientists aim to generate an interest in nuclear and particle physics among high school students and their teachers.

Aims:

The goal is to familiarize the students with the work being done at CERN and the LHC in particular. The researchers explain the basics of particle physics and why it is important. They also demonstrate the fundamentals of particle detector operation and explain the way particles interact with them and leave a characteristic signature according to their different types.

The students who most likely have never come into contact with particle physics are shown what a real researcher does, and how new particles are discovered. This gives students a realistic and exciting look at the research being done at CERN and stimulates an enthusiastic interest in it. It also inspires teachers to talk to their students about particle physics and shows them a way to integrate it into their class at a level that is suitable to their students. Our aim is to drive the students to learn more on their own and investigate further (and even pursue a career in physics ..).

Main activities:

Morning

- Lecture about particle physics by experts
- Lecture about CERN and the LHC and detectors by experts
- Discussion/question/answer session with the students and teachers and experts

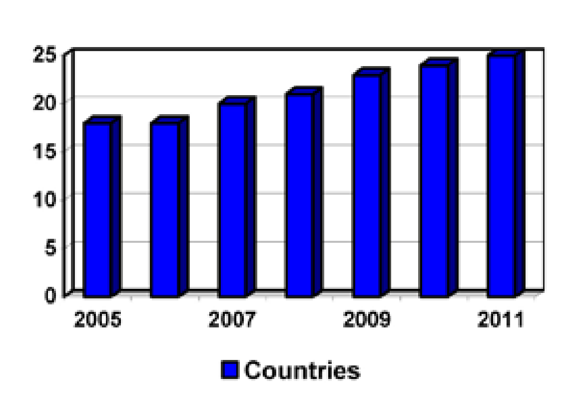
Afternoon

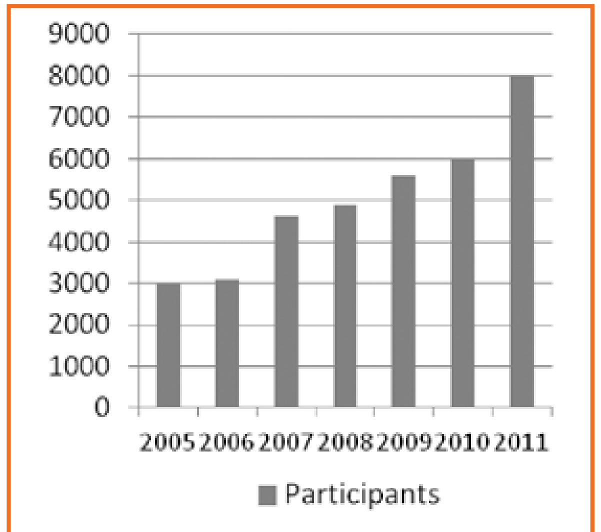
- Introduction to the software that will be used (Hypatia or Minervafor the ATLAS experiment)
- LHC interactive event analysis
- Video Conference with other schools (for students)
- Quiz (for students)

International Masterclasses

Narrative:

The selected high school students of the last two years go to their nearby University or Research center.Some travel from a distance of up to 250 km and have to arrive from the night before. The morning lectures start with an introduction to the Standard Model of particle physics and an explanation of why it is important to modern physics in general. The experts talk about the constituents of matter, their properties, interactions and forces that govern their behavior. Also, about the issues that are still open to modern physics (like the Higgs boson) and how the researchers plan to explore those areas.
The following lectures explain the work being done today at CERN and the LHC. The audience is told about the experiments that are conducted there and the results that the research hopes to get from them. In particular the experts focus on the ATLAS experiment and how this is going to help explore some of the unknown aspects of physics that were described earlier. Then there is a Q&A session with the students where they can ask questions, get clarifications on the issues discussed and explain their own views on physics in general. The teachers participate in this section and are free to ask questions of their own or help to answer their student's questions. After lunch, there is an introduction to the HYPATIA event display that will be used in the laboratory exercises. The students and teachers are told how to identify the different particle tracks in the detectors. They are told why we can't see certain particles (like the Z boson) and how we can infer their existence from its decay to other tracks. In the first exercises, the students learn to distinguish between electrons and muons. In the second exercise the students make use of the invariant mass technique to account for short-lived particles, like the Z boson, whose decay products (electron-positron or muon-antimuon) are measured. Z particle decays are mixed with background events from other physical processes and the students have to tell them apart. The exercises use real LHC collision events recorded by the ATLAS experiment. In each event, electrons or muons are identified through their characteristic behavior, and their energy and momentum are added to form the energy E and momentum p of the parent decaying particle, which can then be used (with the usual E-p equation) to find the decaying particle's invariant mass. The latter is then recorded. If the pair of particles really stems from Z particle decay, the resulting invariant mass distribution will feature a peak around the corresponding mass. The participants determine this distribution by making a histogram of the masses of Z particles they discover. After the laboratory exercise is finished, the students and their teachers gather in a classroom where there is a discussion about their results. They also have the opportunity to discuss their results with the corresponding from students from other countries and the moderator team at CERN through video conference. Through that connection they can compare their results and determine who came closer to the expected result. Finally there is a quiz which includes questions about the subjects that have been discussed throughout the day, with the best team getting a prize from CERN. Currently the masterclasses run in about 25 countries in a 3-week interval in March of each year, with 130 Universities and about 8,000 students participating.





End user - involved actors: The physics masterclasses are suitable for 17 and 19 year old high school students, and the are separate ones for teachers as well

Location: The masterclasses are held at universities and research centers in large cities

Languages available: The material is available in various languages. Currently English, Greek, German, Portuguese, French, Czech, Finish, Hungarian, Israeli, Italian, Dutch, Norwegian, Polish, Serbian, Swedish, Slovakian, Spanish, and South African

Where to find the application or case: The main website is http://physicsmasterclasses.org/neu/index.php

Duration: The Masterclasses take up an entire day. The lectures are held in the morning and the laboratory exercises in the afternoon

Evaluation parameters: Questionaires to the students are distributed every few years and evaluated by the organizers (Technical Un.of Dresden). A recent evaluation can be found in: Physics Education 42 (2007) 636-644

Connection with the curriculum: The masterclasses have an indirect link with the school curriculum in the areas of electromagnetism, atomic and subatomic structure and basic physics

Teachers' Competencies

1	subject matter/content knowledge	x
2	nature of science	x
3	Multidisciplinary	
4	knowledge of contemporary science	x
5	variety of (especially student-centred) instructional strategies	x
6	lifelong learning	
7	self-reflection	
8	teaching/ learning processes within the domain	x
9	using laboratories, experiments, projects	x
10	common sense knowledge and learning difficulties	
11	use of ICTs	x
12	knowledge, planning and use of curricular materials	
13	Information and Communication Technologies with Technological Pedagogical Content Knowledge	

Mapping best practices with main principles

PATHWAY

1. Building interest in natural science phenomena and explanations:

The masterclasses teach the students the basics about particle physics. They explain the interactions between the different particles and demonstrate the results in the laboratory exercises.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

After the morning lectures there is a Q&A session covering topics such as the importance of science and the ties of scientific research and everyday life.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The masterclasses revolve around the central theory of particle physics, the Standard Model. They explain its importance and through the laboratory exercise demonstrate the scientific research process in this field.

4. Understanding students' concepts and learning style about of science phenomena:

The students are given the opportunity to ask questions and voice their opinion on both the Masterclass sessions and the subject matter being discussed. For example they often make suggestions about how this material could be covered within the school physics lessons.

5. Relevance of the content to daily life of students:

This is usually covered in the Q&A session as mentioned above.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The laboratory exercise gives the students the opportunity to engage in "real" scientific research using the same methodology and data that real researchers use in their work.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitating of results:

The masterclasses give the students both theoretical knowledge about particle physics in general and practical hands-on experience on how scientific research is done.

8. Doing science: experimenting, analyzing, interpreting, redefining explanations:

The students analyze real data that are recorded at CERN.

9. Assessment: formative ~ of students' learning and the summative ~ of their progress:

Questionnaires show that all students liked the experience.

10. Cooperation among teachers and with experts:

Teachers participate in parallel sessions with similar activities. They also discuss didactic matters with the university teachers, such as the integration of the material covered in the masterclasses into the school curriculum.

There sessions are not mandatory and they are held only by the institutions that choose to do.