Learning with ATLAS@CERN

GUIDE OF GOOD PRACTICE

Learning with ATLAS@CERN

EACEA
Education, Audiovisual & Culture Executive Agency

Education and Culture DG

Lifelong Learning Programme

Editors:

Angelos Lazoudis, Sofoklis Sotiriou, Christian Reimers, Monika Moises, David Smith

Authors - Contributors

BMUKK (Austrian Federal Ministry of Education, The Arts and Culture)
Christian Reimers, Monika Moises, David Smith

NKUA (National Kapodistrian Univesity of Athens)
Stelios Vourakis, Christine Kourkoumelis

SU (Stockholm University)
Erik Johansson

UoB (University of Bimingham)
Lynne Long

EA (Ellinogermaniki Agogi)
Angelos Lazoudis, Sofoklis Sotiriou

HEUREKA
Hannu Salmi

SHS (Swedish House of Science)
Cecilia Kozma, Lena Gumaelius

UBT (University of Bayreuth)
Gabriele Fröhlich

CERN (European Organization for Nuclear Research)
Helfried Burckhart

Artwork:

Ellinogermaniki Agogi
Sylvia Pentheroudaki

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Disclaimer

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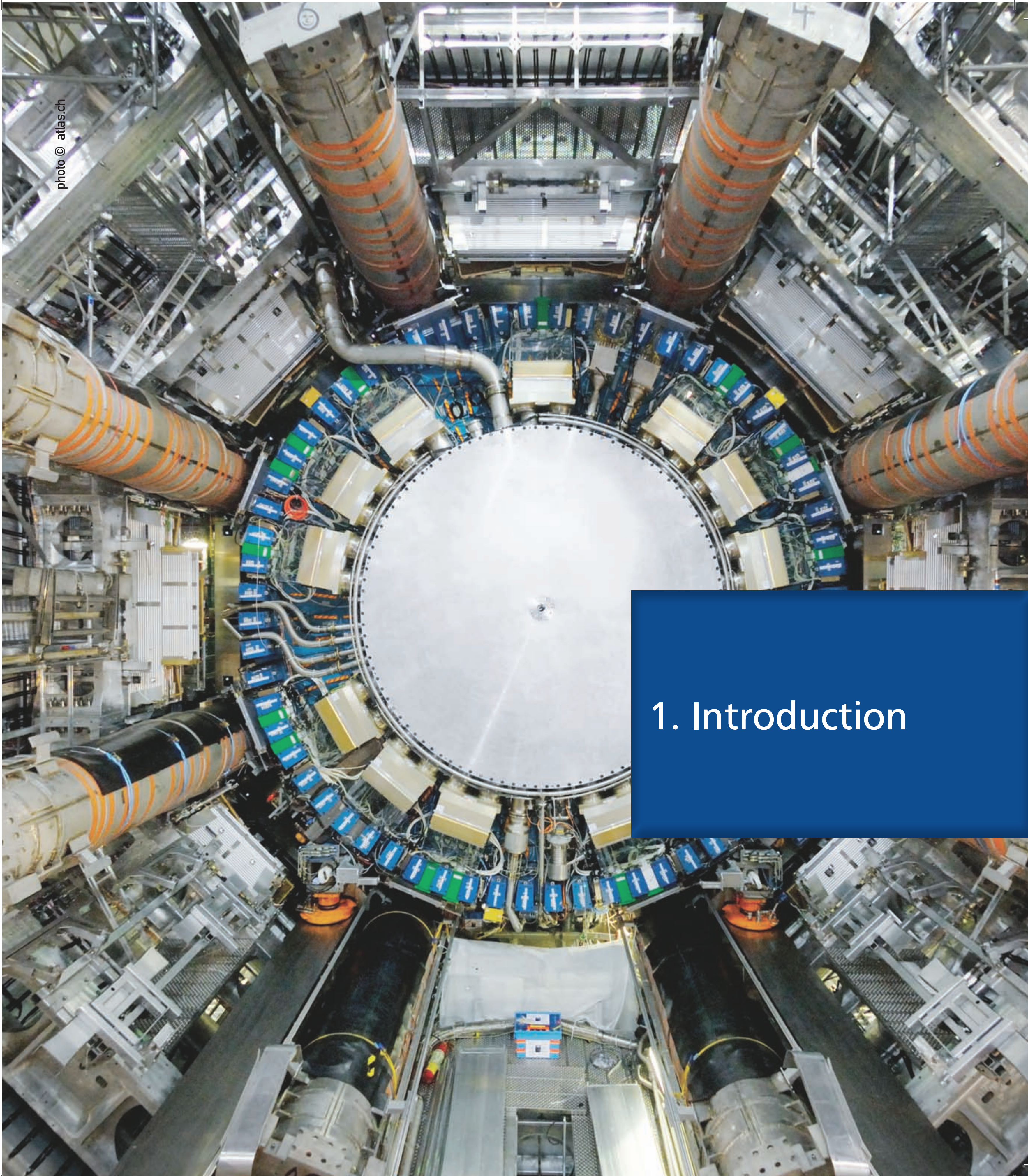
Acknowledgement

This report, as part of Work Package 7, was prepared by BM:UKK and forms the second deliverable of the exploitation work package. The ATLAS@CERN Guide of Good Practice is developed in the context of Deliverable 7.2 where the pedagogical approach and all project outcomes are analytically described.

1. Introduction



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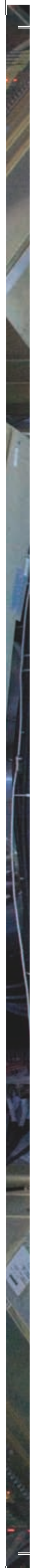
This guide documents the aims and achievements of the Learning with ATLAS@CERN project which is a collaboration of educational and research institutions from Greece, Finland, Sweden, Austria, United Kingdom, Switzerland and United States of America. The purpose of the guide is to provide a compendium of practice designed to inform and assist the science community in schools, the higher education and research institutes and the general public. Significant milestones are highlighted in the guide signposting those outcomes that impacted on the overall conclusion of this project.

The project brought together expertise from foremost scientific and educational research communities. These communities together with user communities across Europe, designed, developed, tested, implemented and communicated an innovative pedagogical framework for use in formal and informal science learning. The timing of the project was designed to coincide when the new gigantic detector ATLAS became operational at CERN (August 2008). The detector was designed to explore the fundamental building blocks and forces of nature, and to probe deeper into matter than ever before.

Described in this guide are the learning scenarios which form the cornerstone of the 'Learning with ATLAS@CERN' project. The project's aim was to develop and implement a set of learning scenarios called missions that were based on the inquiry model of learning utilizing advanced and interactive technologies. Details of the pedagogical concepts and learning practices, including the training framework, are addressed and evaluated as well as the technological environment in which this project was delivered.

This guide concludes with a structured set of guidelines and recommendations to foster effective collaboration between researchers and the educational sector (formal and informal) hence creating valuable and meaningful learning experiences for all.



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2. Learning with ATLAS@CERN Approach

This project proposed a change both in the pedagogical approach adopted in schools and the science learning networks. Traditionally science education has utilised deductive learning and ATLAS@CERN adopted an inquiry-based model. The inquiry model starts by using observation and curiosity and then stimulates the curiosity by problem solving experimentation in both real and virtual settings. Associated with the new pedagogical model is a structured training framework for teachers to familiarize themselves with the new approach, the prepared learning material and the scientific community networks.

The vision for the scientific network was the establishment of a wider outreach community whereby schools, universities, research and public communities would have access to information, assistance, potential collaborations and clients. The ATLAS@CERN project establishes a solid foundation for this vision with the consortium partners drawn from many fields and using their own networks and collaborating closely developing a wider web of contacts and resources.

2.1 Pedagogical Approach

Using technology in education can certainly have an impact but without a strategic learning underpinning that impact can be short-term. The effective adoption of an inquiry-based model ensures that students encounter several types of learning actions so necessary for higher order thinking and assimilation. The prepared learning scenarios (missions) encompass various learning communities, differentiated scaffolds and a diverse tool box all of which establishes a broad context for learning and achievement.

The pedagogical approach was disseminated to teachers via training workshops and the learning missions were trialed and delivered through two implementation phases. Both events were validated using quantitative analysis.

2.2 Learning Communities

ATLAS@CERN, as with other lifelong learning projects, highlights the need for a greater collaboration within the various communities. This project demonstrates the great depth of resource and expertise that universities, research institutions, schools and public communities can share with each other and has in fact only just started to mine the potential of such collaborations.

The short-term result has been the wealth of material available to the schooling and public sector and the amount of collaboration that is actually possible using the current technologies. Summer schools, webinars, access to databases and open days are just some of the experiences that have and are available to the project participants. Longer term there is a developing confidence that the succession of science researchers from the school sector will be assured.

2.3 Web Environment

Much of what has been achieved with pedagogy and learning communities has been made possible through the Internet. The ‘Learning with Atlas’ portal and the project homepage form the nexus to the other resources available contained within the project partners own databases. It is also an important forum for news and events such as the ‘Student Event Challenge’, CERN Open Day and various publications and conferences that are pertinent. One of the anticipated outcomes of this project is the continued development of this site with further contributions by the project partners ensuring its continual use by current users and more importantly future users.

3. Technical Platforms and Tools

To find and use the pedagogical materials and tools in your lessons several services and software tools are provided. In order to search for appropriate educational materials all documents and links are provided via the ATLAS@CERN education and outreach portal, where they are connected with helpful metadata. This ensures the allocation of the materials to your purposes. Furthermore, tools are available e.g. for data analysis. In this section you get an introduction into the main features of the ATLAS@CERN services and tools.

3.1 ATLAS@CERN homepage

The project homepage can be found at http://www.learningwithatlas.eu/ . From the user site (see Figure 3.1) users have access to several informations and tools of distinct levels:

A. **About:** General information about the project and current activities
B. **Consortium:** Presentation of the project partners
C. **Educational Ressources:** access to the science education repository (i.e. learning objects, missions and analysis tools)
D. **Learning with ATLAS:** links to actual ATLAS event displays and the document “Physics with ATLAS”
E. **ATLAS Experiment:** facts about the ATLAS detector
F. **CERN:** facts about CERN
G. **Contact:** contact form for messages
H. **Activities:** list of past and current activities

A. **About.** This section includes information about the Learning with ATLAS @CERN project and it’s main objectives.
B. **Consortium.** The partners of the project along with a short description of their profile and links to their organizations websites are listed in this area.
C. **Portal.** In this section a description of the “Learning with ATLAS@CERN Educational and Outreach Portal” is included followed by the portal’s website link. A full description of the Portal is given in deliverable D.3.1
D. **Educational Resources.** As the project moves forward educational resources such as training materials, guides of implementation, developed learning missions etc will be added in this section.
E. **ATLAS Experiment.** This section contains short description of the ATLAS experiment/detector.
F. **CERN.** CERN and its outreach activities are presented here in brief.
G. **Contact.** The Learning of ATLAS@CERN Coordinator’s information is listed in this area along with a web form allowing for the direct communication with the coordinator via email.
H. **News.** This section includes news about Learning of ATLAS @CERN activities such as workshops, masterclasses, training activities, conference presentations.

The website and portal link to each other.

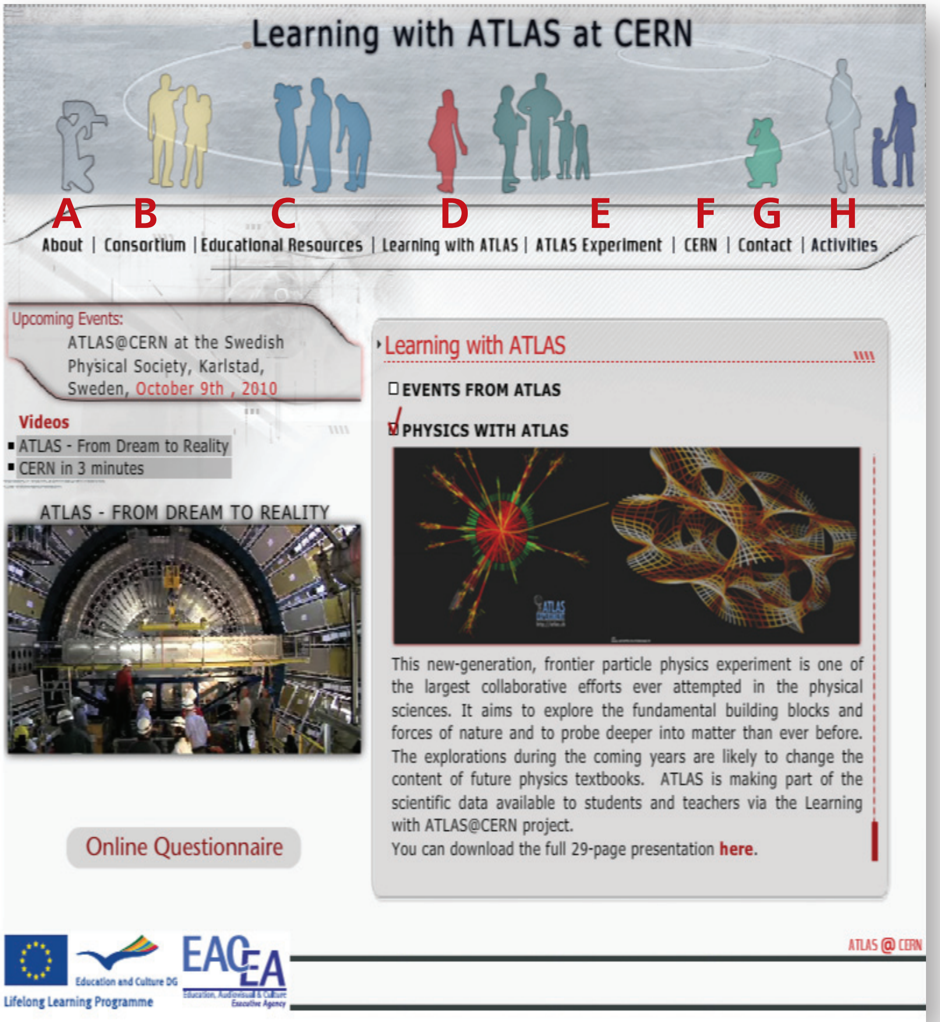


Figure 3.1: *ATLAS@CERN project homepage*

In the section "Learning with ATLAS" you find "Events from ATLAS" which redirects you to the homepage http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html which shows you news from the ATLAS experiment with event displays. Also in this section you find "Physics with ATLAS" and therein a document about the ATLAS experiment and ATLAS detector, the physics at ATLAS as well as the general parts about the Large Hadron Collider (LHC), exploring particle collisions, energy and mass.

3.2 ATLAS@CERN Education and Outreach Portal

3.2.1 General Information and Usage of the portal

The portal can be found at http://www.learningwithatlas-portal.eu/. Behind the user interface (see Figure 3.2), the site is organized into following distinct sections after login:

A. **Home**
B. **ATLAS@CERN Repository**
C. **ATLAS@CERN Tool-Box (accessible if you are registered user)**
D. **Learn More**
E. **News**
F. **Help**

Figure 3.2: *ATLAS@CERN education and outreach portal*

The organisation reflects the aim of the project to focus on pedagogy, learning communities and a viable web environment. The user is guided to learning interactions, resources and contributions as well as a general information section for those just naturally curious! The intention with such organisation is that it will aid the retrieval of desired resources and also improve the search ability of the site particularly for the school based sector.

Figure 3.3: *ATLAS@CERN education and outreach portal view of a registered user*

The great advantage with this site is that nearly all the resources are free available to the public and hence the education sectors which was one of the main aims of this project. It is also intended that this site continues to be a focal point for science education well after the project has concluded.

The portal and project website link to each other. The portal has had 253 registered user accounts and 250 articles submitted. During the last year the portal had 35 000 reads (hits).

3.2.2 Searching for learning resources

Searching and Downloading

After the user registration and authentication, one is able to search through the ATLAS@CERN repository and download the material of his choice. In the ATLAS@CERN Repository one can search for Educational Content and Learning Missions following the respective links in the Explore ATLAS@CERN section of the ATLAS@CERN Repository. There by using the provided user interfaces you can find the material you are looking for. You can also browse through the top rated material in each category. You can download the file from the provided link and also you can view and download the xml file containing the metadata record of the material.

3.2.3 Create your own ATLAS@CERN Mission

Inquiry Based Teaching

The focus of the pedagogical framework of the ATLAS@CERN missions is on Inquiry Based Science Education. Over the last decade inquiry instruction has been introduced as the cornerstone to the science teaching standards. Within the context of the teaching standards, inquiry is defined as the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn, Davis, & Bell, 2004).

Inquiry Based Teaching is a teaching strategy where teachers facilitate student-centered learning and research, acting more as a colleague and guide rather than the dispenser of knowledge. The central aim is to develop students' intellectual autonomy. Adopting this strategy can become a powerful tool for teachers who want to develop students' capacity to think for themselves. For teachers who want to adapt situations for individual needs, it is also a good way to understand how a specific student thinks about a particular problem.

Creating of ATLAS@CERN mission

In the Appendix 6.2 an Educational Scenario Template is presented for applying Inquiry Based Teaching at both primary and secondary education levels making use of the digital resources from the Learning with ATLAS@CERN Educational and Outreach Portal. You could use this template to create your own ATLAS@CERN mission, e.g. as a slide presentation, and use it in the classroom as well as share it with the ATLAS@CERN community through uploading to the Learning with ATLAS@CERN Educational and Outreach Portal.

3.2.4 Share your resources

For uploading your own content like learning objects and learning missions you need to be a registered user. Learning with ATLAS@CERN is trying to build a community of users interested not only in downloading educational material, but also in developing novel material through use or re-use of existing works.

Metadata Authoring

To facilitate this need the ATLAS@CERN portal offers a user friendly web based interface for uploading material. In order to upload new Educational Content or Learning Missions it must be first tagged with metadata according to the IEEE LOM standard. This is done by employing the ATLAS-LOM Metadata Authoring Tool. Instructions on how to use this tool are provided in the help section of the portals website.

Upload your resources

After the user registration and authentication and the generation of a related metadata file with the Metadata Authoring Tool, one is able to upload resources through the ATLAS@CERN repository. In the ATLAS@CERN Repository one can upload Educational Content and Learning Missions following the respective links in the Share your Content section of the ATLAS@CERN Repository.

Figure 3.4: *Explore ATLAS@CERN resources and share your educational content under the ATLAS@CERN Repository tab in the Portal*

3.3 Analysis Tools

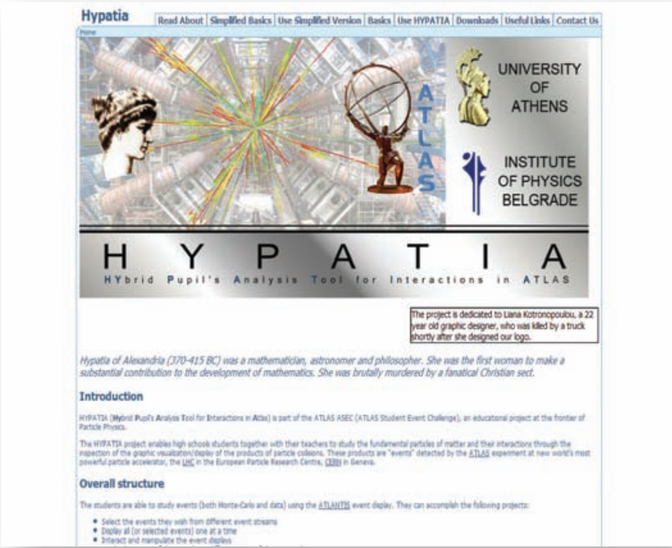
The ATLAS@CERN Tool-Box contains links to three interactive analysis tools (AMELIA, HYPATIA & MINERVA) that allow users to explore that ATLAS experiment at CERN in an intuitive way, which is much friendlier to the public through 3D and 2D animations of physical processes in a game like approach. The web pages of the three analysis tools include detailed information on the use of the tools and support materials for teachers and students.

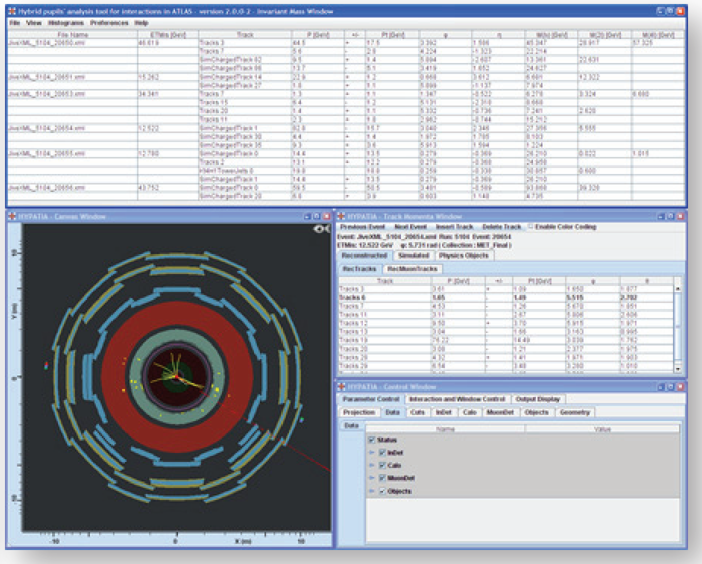
3.3.1 AMELIA 3D Analysis Tool

AMELIA is an application with focus on particle physics processes in ATLAS. This will allow students and other users to decode the collision events that unfold after the head-on collisions of protons at the Large Hadron Collider.
http://amelia.sourceforge.net/index.html

3.3.2 HYPATIA 2D Analysis Tool

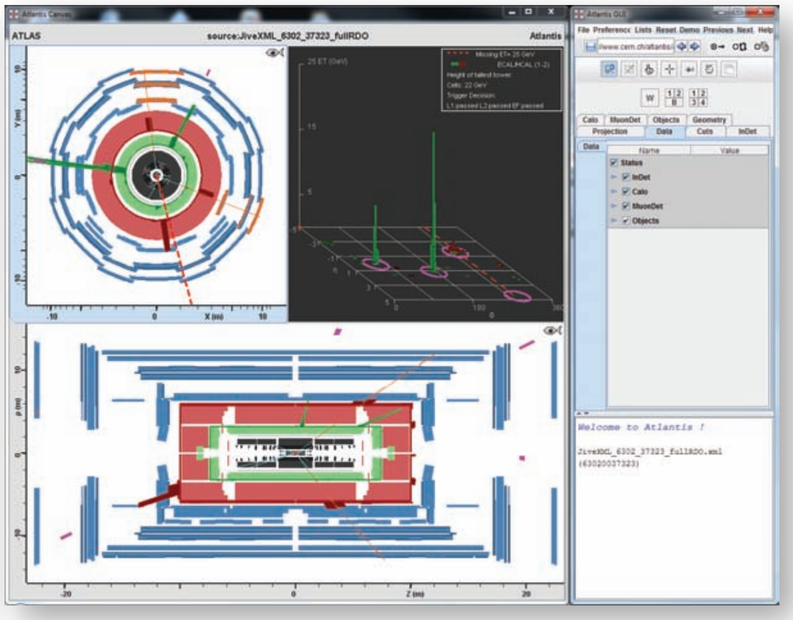
HYPATIA is an event analysis tool for data collected by the ATLAS experiment of the LHC at CERN. Its goal is to allow highschool and university students to study the fundamental building blocks of nature and their interactions through the graphical representation of ATLAS event data. It can also be used by physicists for the analysis of ATLAS events.
http://hypatia.phys.uoa.gr/





3.3.3 MINERVA 2D Analysis Tool

MINERVA is a tool for students to learn more about the ATLAS experiment at CERN. It is based on a simplified setup of the ATLAS event display, Atlantis, which allows users to visualise what is happening in the detector. The aim is to look at ATLAS events and try to recognise what particles are seen in the detector.
http://atlas-minerva.web.cern.ch/atlas-minerva/



4. ATLAS@CERN Missions

Figure 4.1: *Navigation to the Learning with ATLAS@CERN education and outreach portal*

The learning activities can be accessed by navigating to http://www.learningwithatlas.eu/ and then clicking educational resources (see Figure 4.1). If you click on the Link "Learning with ATLAS@CERN Education and Outreach portal" you get to the Portal, where the user will find learning scenarios specifically developed for the project, that have been organized according rating, popularity and currency. Experts and users have the opportunity to rate the scenarios according to the learning content and its effect on students. It is intended that these scenarios will be added to on a regular basis.

4.1 Short description of existing ATLAS@CERN missions

A short description of the learning missions (Tables 4.1 & 4.2) is set out below to provide the reader with an overview of the type of material that has been focused on in the development of these inquiry-based learning modules. The missions are also organized by their rating.

4.1.1 Missions for Schools

Strange Particles in ATLAS (Erik Johansson)
http://www.learningwithatlas-portal.eu/en/node/93596

Is Cosmic Radiation Dangerous? (Timo Suvanto)
http://www.learningwithatlas-portal.eu/en/node/93592
(http://timosscience.blogspot.com/2010/03/is-cosmic-radiation-dangerous_25.html)

Link between ISS and CERN (Christian Reimers)
http://www.learningwithatlas-portal.eu/en/node/93572 (EN)
http://www.learningwithatlas-portal.eu/en/node/93571 (DE)

Mobile ATLAS@CERN (Christian Reimers)
http://www.learningwithatlas-portal.eu/en/node/93574 (EN)
http://www.learningwithatlas-portal.eu/en/node/93573 (DE)

Cloud Chamber Inquiry Based Teaching (Julie Boyle)
http://www.learningwithatlas-portal.eu/en/node/93704

Conservation of momentum in particle collisions (Angelos Lazoudis)
http://www.learningwithatlas-portal.eu/en/node/93575

Identifying particles in ATLAS and determining the Z0-mass (Cecilia Kozma)
http://www.learningwithatlas-portal.eu/en/node/93701

Table 4.1: Most popular learning scenarios for schools
Mobile ATLAS@CERN. Students are taken through a series of questions using software on their mobile phones. Students discuss their answers and then move to an introductory hypothesis 'How do you get an estimate of Z branching ratios?' Students are then given a series of research activities around this hypothesis and they discuss their findings. The final phase of this activity is for students to start their research task "Measurement of Z0 decays & as at LEP. ***http://www.learningwithatlas-portal.eu/en/node/93574 (EN)*** ***http://www.learningwithatlas-portal.eu/en/node/93573 (DE)***
The link between the International Space Station and Cern. Students are sent on a small web quest with various questions to find the answers to. The questions are graded and the teacher should negotiate with the student the questions they should attempt. Students present their findings and then using their previous activity as a model they then proceed to an investigation about cosmic rays. After discussing the process of research investigation and presenting their findings students are then guided to a research questions involving ATLAS such as "How do the Z boson decays affect the final states of quasar jets. ***http://www.learningwithatlas-portal.eu/en/node/93572 (EN)*** ***http://www.learningwithatlas-portal.eu/en/node/93571 (DE)***
Practicing Physics Principles and Ideas with ATLAS at the Large Hadron Collider at CERN. This is an inquiry based learning scenario that could be used for able GCSE students as an extension or enhancement; or for A level students at the start of their course, prior to studying particle physics, to find out more about the experiments at CERN and to practice calculations, powers of 10 etc. It is also a possible activity to prepare for a visit to CERN . Students are led through preliminary investigation questions, moving to some basic physics relating to mechanics, heat etc, and can do some basic curriculum calculations using facts and figures found on the CERN web pages fact sheets. They can then explore some physics principles using the 'Angels and Demons' story. Results are discussed and feedback is given to students leading to the final question of discussing the role of physics in society. Some of the suggested calculations could be used in isolation to give interesting examples for certain parts of the school Physics curriculum. ***http://www.learningwithatlas-portal.eu/en/node/93555***
Identifying particles in ATLAS and determining the Z0-mass. Students are given an introduction to particle physics with a demonstration of a cloud chamber and muon detector. They then move to an introduction to Minerva and work on detecting decays and calculating the Z-mass. Students present their results and there is evaluative discussion. ***http://www.learningwithatlas-portal.eu/en/node/93701***

- **Conservation of momentum in Particle Collision.** The teacher presents a background of physical concepts and laws using video. Students are then asked to conduct an investigation using a series of internet searches to discover amongst other things how to apply the conservation of momentum principle. Students will gather evidence from their investigations and discuss their findings in an open forum pursuing other possible avenues of investigation.
- **Identifying particles and their properties in detectors.** This is an inquiry based learning scenario - an extension & enhancement - for able A Level students who have recently studied the particle physics content of their syllabus; or it could be used as practice for synoptic questions at the end of the A Level course. The students are given a series of guiding questions to assist them with research into particle detectors and the principles of how they work, using information on the CERN website. They are then invited to present and discuss their findings as a possible class exercise. Then students are directed to the Minerva website and, working in groups, learn how to recognise five key events in the software displays. They then investigate 20 events from that site, looking for Z boson decays, and collecting and collating data. They can then calculate the invariant mass of the Z boson, and compare results.
- **Fun facts about the LHC and Elephants.** This is an amusing and innovative web quest. The scenario takes students through information about the LHC and other detectors in CERN and poses questions requiring students to apply their knowledge using elephants!

4.1.2 Missions for Universities

- Identifying LHC events with HYPATIA (Stelios Vourakis)
  http://www.learningwithatlas-portal.eu/en/node/93604
- LHC ATLAS detector accelerator events tracks (Christine Kourkoumelis)
  http://www.learningwithatlas-portal.eu/en/node/93560 (GR)
- **Strange Particles in Atlas.** This is a scenario for undergraduate students in their third year. Students start with understanding the fundamental properties of particles. The scenario then progresses to determining the mass and lifetime of the short-lived neutral strange particle, the K0s and understanding its composition. The scenario concludes with a discussion about possible extensions of the exploration such as the exploration of invisible particles.

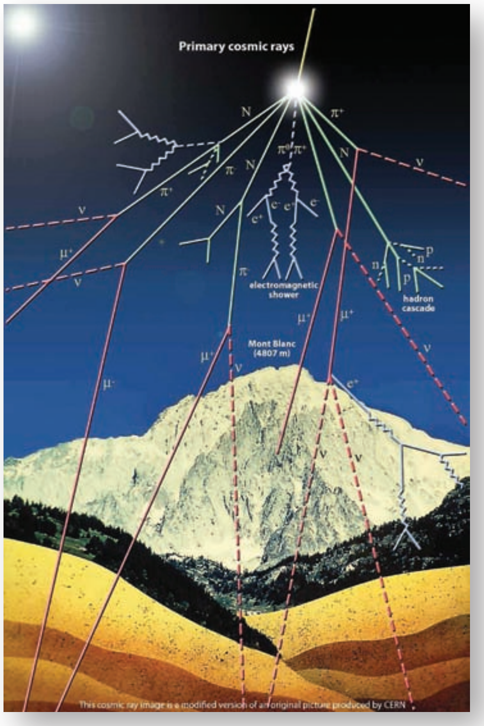
Table 4.2: Most popular learning scenarios for universities
• **Identifying Particles and their Properties for Detectors.** This scenario consists of a general introduction of the ATLAS experiment at the LHC at CERN. Students will b e using MINERVA to visualize collisions from the proton to proton beam. Initially students will be asked to identify specific events such as Z and W decays. Using the information gathered from Minerva the mass and lifetime of the particles can be determined. Using the values of the mass and width of the Z the number of nentrinos that exist can be investigated. As an extension students can try looking further into the tt decays. http://www.learningwithatlas-portal.eu/en/node/93556
• **Identifying LEPTONS, Z Bosons and HIGGS at the LHC using the HYPATIA interactive tool.** Students start with a table and are asked to identify if the events contain and electron or a muon and the relevant track number. The scenario develops to the final stage where Students are given a file of few events one of which is a Higgs bosondecaying to four leptons. After being given appropriate instructions are asked to recognize the Higgs event and write down the event number. (Danish version)

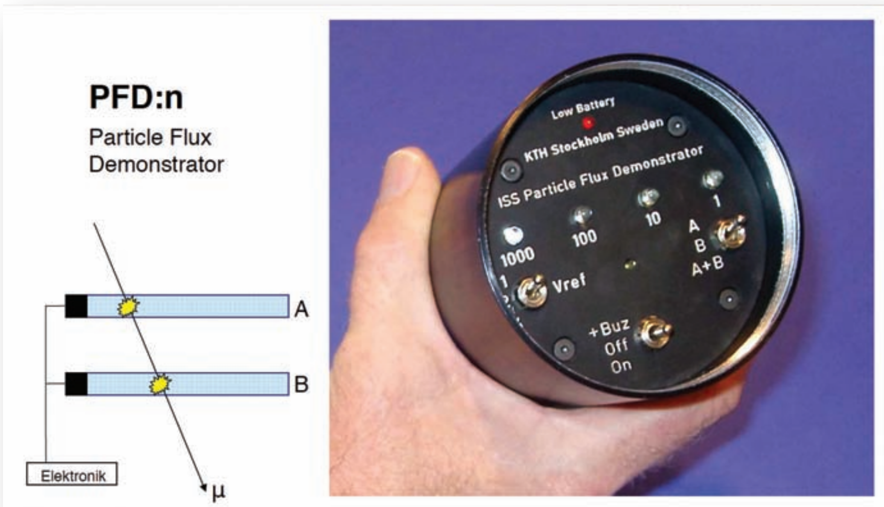
4.1.3 Missions for Science Centers
Cosmic Muons scenario at the House of Sciences

Cosmic Muons (Cecilia Kozma)
http://www.learningwithatlas-portal.eu/en/node/93774

Description. The Earth's atmosphere is constantly hit by particles from space, so called cosmic radiation. When these particles hit the atmosphere a shower of new, short lived particles are formed. One of these particles is the muon. In this scenario we describe how the muon flux can be measured in the classroom using muon detectors in Stockholm House of Science. These measurements can then be compared to measurements done at ISS. The importance of the Earth\'s atmosphere and magnetic field is discussed.

The students measure the flux of Cosmic Muons at Earth using two different types of muon detectors. The students are then able to compare their data to measurements done with similar detectors at the ISS. After comparing the results on Earth and on ISS the importance of the Earth's atmosphere and magnetic field is discussed.





Activities at CERN for the EU Project “Learning with ATLAS at CERN”

Helfried J. Burckhart, CERN, Geneva, Switzerland

The experiment ATLAS is accumulating data of proton-proton collisions at the accelerator LHC at CERN. The main purpose is of course to understand the basic constituents and forces of nature. The aim is in particular to confirm (or disprove) the so-called “Standard Model”, by finding (or excluding) the Higgs particle. But education is also an important aspect: the ATLAS collaboration includes about 1000 PhD students. The project “Learning with ATLAS at CERN” (LA@CERN) complements the educational aspects by addressing students at high school level. Novel teaching and learning methods stimulate the students’ interest in natural science in general and in physics in particular.

The CERN group of the LA@CERN collaboration participated in the project on 3 aspects:

- Receive student groups in the ATLAS Visitor Centre (AVC)
- Develop data visualization tools
- Provide real data for usage by the LA@CERN tools

ATLAS Visitor Centre

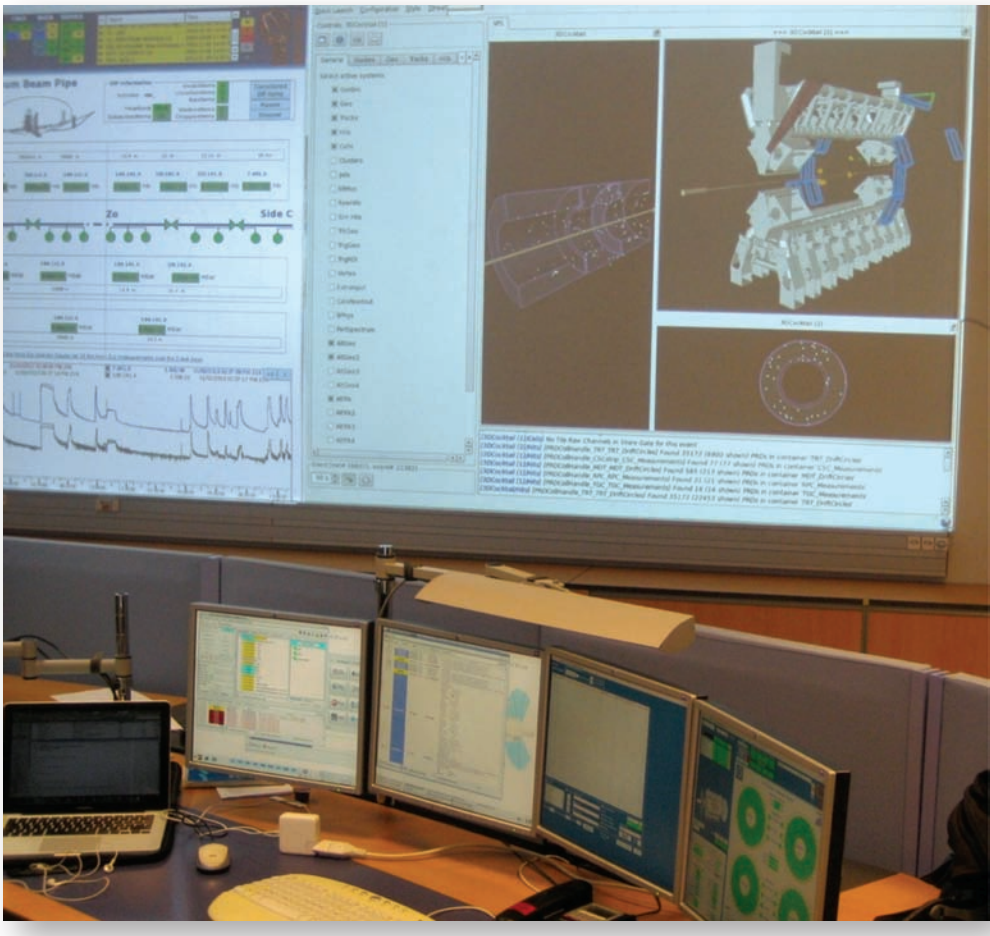
A visitor centre has been set up at the site of the ATLAS experiment in order to explain the ATLAS detector, the operation of the experiment, and the scientific objectives to a wide-ranging audience, including interested laymen, children, students, scientists, decision-makers (e.g. in politics, industry, science) and VIPs. The AVC features quite a number of interactive devices and of display screens explaining, what the purpose of ATLAS is and how the detector is built and operated. Highlights are two smart screens to explore the detector and to have virtual tours in the ATLAS cavern and in the LHC tunnel. In addition, visits include showing a movie in 3D about the detector. The main attractions, however, are the view into the ATLAS control room itself, where the visitors can watch the ATLAS scientists at their work, and a graphical visualization of the collisions in quasi real time, called “event display”. The guide uses this together with an interactive display, which explains the different categories of collisions, to introduce the student to the LA@CERN project and to suggest exploring further in this way the physics studies carried out at ATLAS. This approach to first showing what the scientists do and then giving the tools to repeat this investigation in a similar way with real data has proven to have tremendous impact on the interest of the students. The technical possibilities for the students to do this are either to follow Master Classes, which are regularly organized, or to use the tools and packages on the LA@CERN internet portal (true?).

For the student analysis collision events of different categories are selected and organized in a random sequence. With the help of interactive analysis tools (such as Hypatia, Minerva or Amelia) the student measures the parameters of the different particles emerging from the collisions and combines the particles in order to find out whether they are the result of the decay of a mother particle (e.g. Lamda, K0, or in the end maybe even the Higgs particle).

In this way the students follow to some extent the path the “real” scientist has taken and also learn about the ATLAS detector and the specific characteristics of the different particles and get a feeling for their relative abundance.

Futhermore, the students also get some insight into the laws of statistics.

Young ATLAS Visitor



nt Display

4.2 Exemplary implementation of ATLAS@CERN missions in schools

4.2.1 Conservation of momentum in particle collisions
Ellinogermaniki Agogi, Greece

Students will determine the total momentum from all particles tracked after a particle collision and will calculate (magnitude & direction) the missing momentum by applying two different methods of adding vectors. This learning mission follows the inquiry-based teaching method as depicted in Figure 6.1. According to the proposed inquiry-based approach the mission is devided in 5 main phases as analytically presented below.

General Overview

PHASE 1

The teacher tries to attract the student's attention by presenting:

a) the physical concepts and laws on which the activity will be based on (momentum, conservation of momentum and energy).

b) the LHC @ CERN (3 min video),

c) the different types of elementary particles (brief introduction),

d) particle collision animations (proton-antiproton collision)

Background: So far mass, velocity, acceleration, force and energy, and the way Newton's laws tie them together has been discussed in class.

Also students know the difefrence between scalars & vectors:

Vector quantities have two characteristics, a magnitude and a direction. Scalar quantities have only a magnitude. When doing any mathematical operation on a vector quantity (like adding, subtracting, multiplying ..) you have to consider both the magnitude and the direction.

Introduction of Physical laws & Concepts

PHASE 1

A. Newton's Laws

Newton's **first law** states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This is normally taken as the definition of **inertia**. The key point here is that if there is **no net force** acting on an object (if all the external forces cancel each other out) then the object will maintain a **constant velocity**. If that velocity is zero, then the object remains at rest. If an external force is applied, the velocity will change because of the force.

The **second law** explains how the velocity of an object changes when it is subjected to an external force. The law defines a **force** to be equal to change in **momentum** (mass times velocity) per change in time. Newton also developed the calculus of mathematics, and the “changes” expressed in the second law are most accurately defined in differential forms. For an object with a constant mass **m**, the second law states that the force **F** is the product of an object’s mass and its acceleration **a**: F = m * a

For an external applied force, the change in velocity depends on the mass of the object.

The **third law** states that for every action (force) in nature there is an equal and opposite reaction. In other words, if object A exerts a force on object B, then object B also exerts an equal force on object A. Notice that the forces are exerted on different objects.

PHASE 1

B. Conservation of momentum

Momentum is defined to be the mass of an object multiplied by the velocity of the object.

The **conservation of momentum** is a fundamental concept of physics along with the conservation of energy and the conservation of mass and states that, within some problem domain, the amount of momentum remains constant; momentum is neither created nor destroyed, but only changed through the action of forces as described by Newton’s laws of motion.

Dealing with momentum is more difficult than dealing with mass and energy because momentum is a **vector quantity** having both a magnitude and a direction. Momentum is conserved in all three physical directions at the same time.

PHASE 1

LHC @ CERN & the ATLAS experiment

The Large Hadron Collider (LHC) is a gigantic scientific instrument near Geneva, where it spans the border between Switzerland and France about 100m underground. It is a particle accelerator used by physicists to study the

smallest known particles – the fundamental building blocks of all things. It will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the Universe.

Two beams of subatomic particles called ‘hadrons’ – either protons or lead ions – will travel in opposite directions inside the circular accelerator, gaining energy with every lap. Physicists will use the LHC to recreate the conditions just after the Big Bang, by colliding the two beams head-on at very high energy. Teams of physicists from around the world will analyse the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.

Show 3 min video about CERN

PHASE 1

The building blocks of matter

Molecules are built up from the **atom**, which is the basic unit of any chemical **element**. The atom in turn is made from the **proton**, **neutron**, and **electron**.

It turns out that protons and neutrons are made of varieties of a still smaller particle called the quark. At this time it appears that the two basic constituents of matter are the **lepton** (of which the electron is one type) and quark; there are believed to be six types of each.

Each type of lepton and quark also has a corresponding **antiparticle**: a particle that has the same mass but opposite electrical charge and magnetic moment.

**** This introduction should be brief since the students hear for the first time the terms quarks, leptons etc*

Question Eliciting Activities

PHASE 1

Students are engaged by scientifically oriented questions imposed by the teacher

1. Does the momentum depend on the direction of the velocity?
2. What is an isolated system?
3. What does "conservation of momentum" really mean?
4. In collisions does the kinetic energy need to be conserved?
5. How are elementary particles classified?
6. When particles collide are new particles created or not?
7. What type of research is performed at CERN?

Active investigation. Plan & conduct simple investigation

PHASE 2

The goal of the exercise is students to learn:

a) to measure vectors' angles and convert radians to degrees of angle

b) to add vectors in 2 dimensions

c) to apply the conservation of momentum principle

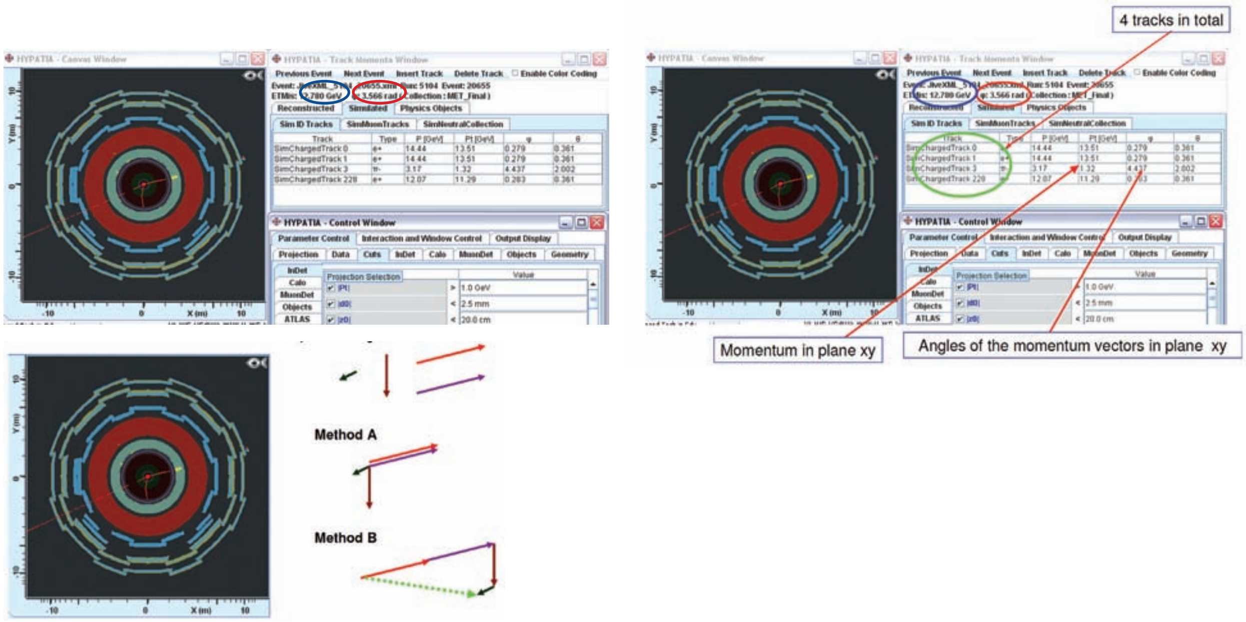
A. Use the HYPATIA Analysis Tool

Students will determine the total momentum from all particles tracked and will calculate (magnitude & direction) the missing momentum by applying two different methods of adding vectors (in our case the momentum vectors are lying on the plane perpendicular to the collision axis).

B. Preparation (HYPATIA)

1. Read the “Vector analysis” & “Momentum” section in the physics school book
2. Download the HYPATIA tool (use the simplified version) from the site: http://hypatia.phy.bg.ac.yu/
3. Run HYPATIA and select to view specific tracks (the one’s the teacher has recommended)

Students propose possible explanations to the questions that emerged from the previous activity



PHASE 3 Gather evidence from observation

Using the HYPATIA Analysis Tool

Each student finds the angle of every track in degrees of angle (HYPATIA tool gives the angles in radians). Alternatively, the tracks on HYPATIA can be given to students as a printout so they can calculate the angles by using a protractor.

The missing momentum is determined by adding up all vectors and comparing the result with the expected value of zero.

PHASE 4 Discussion. Consider other explanations

Each student presents his/her calculations and results about the conservation of momentum.

The calculations are compared to the expected results Students calculate their percentage of error.

PHASE 5 Reflection. Communicate explanation

Each classroom produces a report with the information about the momentum of every particle track or jet on the x- and y-axis (2 dimensions) and the total momentum.

4.2.2 Case study at Austrian School – Mobile ATLAS@CERN

Keywords: statistical errors, branching ratios, decays

Age range: 16+ years

Introduction

The following article describes a case study in an Austrian school about the effects of the implementation of the learning scenarios developed as a result of the 'Learning with ATLAS@CERN' project. This case study does not conform to rigorous research methodology but provides a framework to describe the events and interaction between a teacher who participated in the 'Learning with ATLAS@CERN' training program and their class.

The class is a senior physics class comprising males and females and the minimum age of the students is 16. These students have all passed their compulsory schooling in the sciences and have selected and been accepted into this academic stream with the option of pursuing studies at university. The teacher attended a training workshop in Austria where the learning missions were explained and demonstrated, the platform where learning material was stored and accessed and the HYPATIA tool was demonstrated.

This article describes the learning sequence for a particular period of 5 x 50 minute lessons. Particular learning material and classroom practices are detailed and attention is focused on the engagement of the students.

Pre-Learning Mission

The teacher carried out an attitude towards science survey in the class before starting with the ATLAS@CERN learning mission. The survey started with some general science attitude questions about learning science and how scientists do experiments. The survey finished with questions relating to particle physics. The most significant response was that information is considered scientific when it is supported by a bit of research. One of the lowest responses was the enjoyment of studying science in previous science classes. This ATLAS@CERN learning mission also uses the materials and tutorials of the Hands-on CERN website on ***http://hands-on-cern.physto.se/hoc_v21en/.***

As mobile learning with mobile applications is used, the teacher has to ensure that each school student or student group have an appropriate equipped mobile device either owned by the student or provided by the school. Alternatively, the mobile applications are also available as online version, which could be accessed by any internet browser with a flash player plugin. The used technology and the mobile applications are described in detail in section 4.6.

Lesson Sequence

To exhibit curiosity the students are shown the mobile applications of mobile ATLAS@CERN (moCERN). The students go through the application either on their own mobile devices or with the online version on the schools computers. Using the applications they learn relevant facts about technical and scientific aspects of particle physics and the ATLAS detector as part of the LHC accelerator of the CERN organisation. At the end of each investigated application the students take the quizzes on moCERN to make first assessment of their knowledge.

Next the students define questions from their current knowledge. They are divided into groups with a maximum of 5 students each. The students have to develop tag clouds about the information they have explored from the moCERN applications and link their received tag clouds where there are common areas between all groups afterwards. During this activity the teacher lead the class about areas of further questions or research from each of the areas defined. The

Fig. 4.2: Starting point for the description of learning activities: the ATLAS@CERN mission "Mobile ATLAS@CERN"

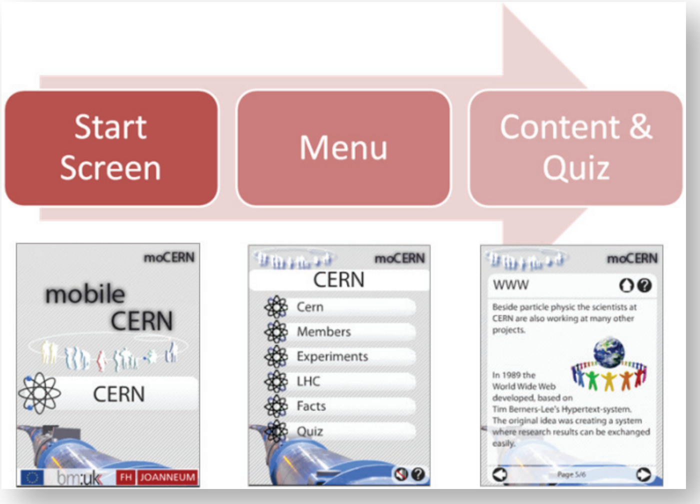


Fig. 4.3: Exemplary Structure of the "Mobile ATLAS@ CERN" (moCERN) application about CERN.

following resource of the European Particle Physics Outreach Group (EPPOG) could be useful for this part ***http://eppog.web.cern.ch/eppog/Resources/PhysicsOnTheStreets/experiments.html***

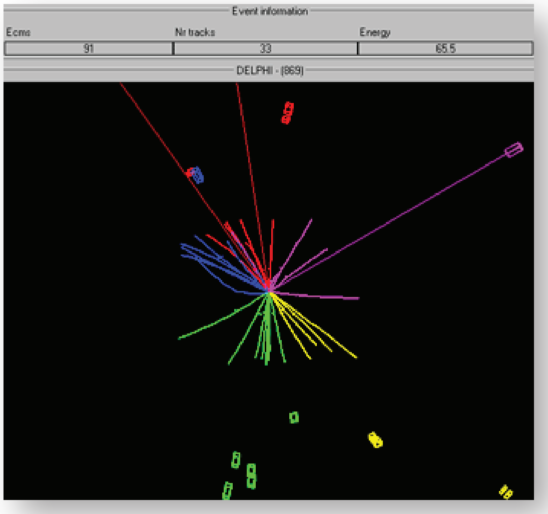


Fig. 4.4: The picture shows a very unusual Z decay. The Z particle has decayed into two quarks that have emitted no less than three gluons. The result is five jets of particles, here coloured in red, green, blue, yellow and magenta.

To propose preliminary hypotheses a question is asked to the class: How do you get an estimate of the Z branching ratios? The teacher divides the class into groups and has them research the collision library on ***http://hands-on-cern.physto.se/hoc_v21en/index.html***. Each group investigates 10 links counting these decays (e.g. Electron, Muon, Tau, 2-jet, 3-jet, 4 or more jets).

In the next step students plan and conduct simple investigation, where each group calculate the branching ratios from the events they have analysed. Then, each group compare their results to the standard model ***http://hands-on-cern.physto.se/hoc_v21en/index.html*** and report their findings as a visual presentation. This gives feedback to students on their research approach, findings and conclusions.

For gathering evidence from observation the teacher divides the students into new groups and introduces students to their new research task "Measurement of Z0 decays & the coupling constant of the strong force, as at LEP". The Large Electron-Positron collider (short LEP) was used from 1989 until 2000 in the same tunnel where now LHC is placed. The students following the scheme developed and described at ***http://www.physicsmasterclasses.org/mc/orga_exercises2.html***.

In the educational phase of exploration of research question students use this time to gather evidence and formulate the data. The teacher lead discussion about statistical error and optimum ways to interpret results. Groups then have a peer review of their work. Each group show their work to another group. The work is evaluated on clear presentation of the findings, demonstrated understanding of the problem and clarity of the solution. This process is in preparation to the final presentation before the entire group. The following site gave access to experts ***http://www.physicsmasterclasses.org/participate/register_student.htm***.

Finally, students present their findings in both visual and hard copy to reflect their research results.

4.2.3 Case Study 1: CERN at the School Laboratory: Science Teacher Training Seminar at Ellinogermaniki Agogi

Introduction

Ellinogermaniki Agogi and the Physwwics Department of the University of Athens organized a 5-day training seminar at Ellinogermaniki Agogi school on November 20th to 24th, 2010 with the theme “CERN at the School Laboratory”. 46 science teachers participated to this seminar. 33 of them presented their views in the framework of discussions and focus groups that were organized the last day of the seminar. The age distribution of the participants is shown in Figure 4.5.

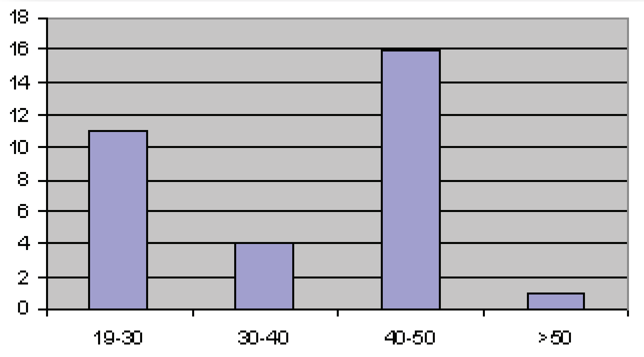


Figure 4.5: The age distribution of the 33 teachers who took part to the discussions with the members of the LA@CERN team.

Figure 4.6: The seminar included a series of invited talks from scientists that are involved in the main research experiments at CERN (ATLAS and CMS). In the photo Prof. M. Korazinos (member of the Board of CERN) presents the research challenges of the LHC experiments.

In the framework of the seminar, scientists working on the CERN research projects (LCH, ATLAS and CMS) presented the recent developments and initial results from the LHC run at CERN. Additionally members of the ATLAS outreach group presented innovative educational tools that create 2D and 3D animations and simulations of physical processes and experiments. Moreover, they have shown how these developed advanced tools can be used to inspire curiosity, enhance the quality of teaching and give to learners the opportunity to interact directly with real scientific data taken nearly at real time from the CERN. Learning by gaining exposure to the ATLAS experiment in a way that is appropriate to every individual’s level of understanding is also important and will be addressed. Finally two hands-on sessions were focusing on the use of the LA@CERN portal. Educators presented educational scenarios for schools and demonstrate how these new educational tools related to the ATLAS experiment can engage science centre visitors in episodes of playful learning.

Πρόγραμμα Σεμιναρίου

Σάββατο 20 Νοεμβρίου 2010: Εισαγωγή – Έρευνα στο CERN

9.30 - 10.00 Προσέλευση
10.00 - 10.15 Εισαγωγή
Χριστίνα Κουρκουμέλη, Καθηγήτρια του Πανεπιστημίου Αθηνών
10.15 - 11.00 Σωματιδιακές Συγκρούσεις και Αντι-ύλη στο πείραμα ATLAS
(Ομιλία στα Αγγλικά με ταυτόχρονη μετάφραση)
Erik Johansson, Καθηγητής του Πανεπιστημίου της Στοκχόλμης
11.00 - 11.45 Φυσική Στοιχειωδών Σωματιδίων στις μεγαλύτερες ενέργειες στον κόσμο
(Ομιλία στα Αγγλικά με ταυτόχρονη μετάφραση)
Peter Watkins, Καθηγητής του Πανεπιστημίου του Μπέρμιγχαμ
11.45 - 12.15 Συζήτηση
12.15 - 13.00 Παρουσίαση του εργαστηρίου CERN
Μιχαήλ Κορατζίνος, Ερευνητής στο CERN

Κυριακή 21 Νοεμβρίου 2010: Η φυσική και οι ανιχνευτές στις Υψηλές Ενέργειες

9.30 - 10.00 Προσέλευση
10.00 - 11.00 Σε ποιες ερωτήσεις ελπίζουμε να απαντήσουμε με τα νέα πειράματα?
Παρασκευάς Σφήκας, Καθηγητής του Πανεπιστημίου Αθηνών
11.00 - 12.00 Πως θα ανιχνεύσουμε τα σωματίδια?
Χριστίνα Κουρκουμέλη, Καθηγήτρια του Πανεπιστημίου Αθηνών
12.00 - 13.00 Η εφαρμογή στην πράξη Ό αιχνευτής μυονίων και η αρχιτεκτονική του συστήματος ελέγχου του ανιχνευτή ATLAS
Θεόδωρος Αλεξόπουλος, Καθηγητής του Εθνικού Μετσόβειου Πολυτεχνείου

Δευτέρα 22 Νοεμβρίου 2010: Οι επιταχυντές του CERN και οι Έλληνες ερευνητές στο CERN

17.30 - 18.00 Προσέλευση
18.00 - 19.00 Σωματιδιακή Φυσική και οι επιταχυντές του CERN
Εμμανουήλ Τσεσμελής, μέλος του Διευθυντηρίου του CERN
19.00 - 20.00 Η λειτουργία του Μεγάλου Επιταχυντή Αδρονίων
Μιχαήλ Κορατζίνος, Ερευνητής στο CERN
20.00 - 21.00 Η Εθνική συμμετοχή στο CERN
Ευάγγελος Γάζης, Καθηγητής του Εθνικού Μετσόβειου Πολυτεχνείου και Εθνικός Εκπρόσωπος της Ελλάδος στο CERN

Πρόγραμμα Σεμιναρίου

Τρίτη 23 Νοεμβρίου 2010: Το πείραμα του αιώνα στο σχολικό εργαστήριο

17.30 - 18.00 Προσέλευση
18.00 – 18.30 Το πείραμα του αιώνα στο σχολικό εργαστήριο – Δουλεύοντας με την ΥΠΑΤΙΑ
Χριστίνα Κουρκουμέλη, Καθηγήτρια του Πανεπιστημίου Αθηνών
Στυλιανός Βουράκης, Ερευνητής, Πανεπιστήμιο Αθηνών
18.30 - 20.30 Εργαστήριο – Παρουσίαση της διαδραστικής εφαρμογής ΥΠΑΤΙΑ και χρήση της από τους συμμετέχοντες. Επίδειξη εφαρμογών για τη σχολική τάξη.
Χριστίνα Κουρκουμέλη, Καθηγήτρια του Πανεπιστημίου Αθηνών
Στυλιανός Βουράκης, Ερευνητής, Πανεπιστήμιο Αθηνών
Καλλιόπη Ιορδανίδου, Ερευνήτρια, Πανεπιστήμιο Αθηνών
Αριάδνη Αντωνάκη, Ερευνήτρια, Πανεπιστήμιο Αθηνών
Άγγελος Λαζούδης, Ερευνητής, Ελληνογερμανική Αγωγή

Τετάρτη 24 Νοεμβρίου 2010: Η υπο-ατομική περιπέτεια»: Εκπαιδευτικά σενάρια για τα σχολεία

17.30 - 18.00 Προσέλευση
18.00 - 18.30 Μαθαίνοντας με το πείραμα ATLAS στο CERN. Οργάνωση του εκπαιδευτικού υλικού που έχει αναπτυχθεί στο CERN.
Άγγελος Λαζούδης, Ερευνητής, Ελληνογερμανική Αγωγή
18.30 – 19.00 Η υπο-ατομική περιπέτεια»: Εκπαιδευτικά σενάρια για τα σχολεία.
Σοφοκλής Σωτηρίου, Ερευνητής, Ελληνογερμανική Αγωγή
19.00 21.00 Χρήση των εργαλείων από τους συμμετέχοντες – Σχεδιασμός Εκπαιδευτικών Δραστηριοτήτων
Άγγελος Λαζούδης, Ερευνητής, Ελληνογερμανική Αγωγή,
Σοφοκλής Σωτηρίου, Ερευνητής, Ελληνογερμανική Αγωγή
Χριστίνα Κουρκουμέλη, Καθηγήτρια του Πανεπιστημίου Αθηνών
Στυλιανός Βουράκης, Ερευνητής, Πανεπιστήμιο Αθηνών

Figure 4.7: *The programme of the 5 day seminar. The programme included 5 three-hour sessions: 3 sessions focusing on the CERN experiments and the data analysis procedures and 2 hands-on workshops where the use of the LA@CERN portal was presented in detail. Participants had the chance to design their own scenarios for classroom use.*

During these workshops the LA@CERN consortium presented its methodology for designing, expressing and representing educational practices in a commonly understandable way along with the implementation of the educational activities following the specific educational approach. In the following session the results from the discussions and the focus groups are presented and analyzed.

Figure 4.8: *The seminar included two hands-on workshops where the LA@CERN portal and its tools were presented to the teachers. Teachers developed and presented educational scenarios for schools and demonstrate how these new educational tools related to the ATLAS experiment can engage science centre visitors in episodes of playful learning.*

2. Data Analysis

During the last day of the seminar a short questionnaire was delivered to the participants. This questionnaire included six key questions which were the main reference for the discussions with the teachers. The teachers' feedback is presented in Figure 4.9.

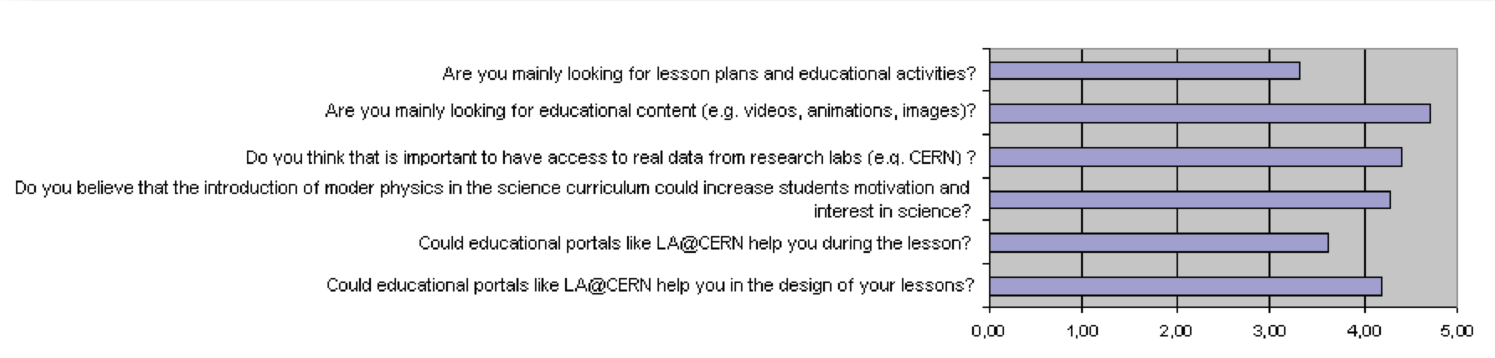


Figure 4.9: *The teachers' feedback following their participation to the LA@CERN seminar. Teachers believe the connection of the school curriculum with issues of contemporary science could increase students' motivation and interest in science. Furthermore teachers are very interested to include such information in their lessons.*

> My students keep asking numerous questions on what is happening at CERN. They are looking for information on the web. Web for them is more familiar than the book. It is not easy for me to explain to them why these issues are not part of their curriculum.
>
> *Greek Teacher (42)*

Teachers believe the connection of the school curriculum with issues of contemporary science could increase students' motivation and interest in science. Furthermore teachers are very interested to include such information in their lessons. The main findings from the discussions could be categorized as following:

- The science curricula have to be updated. They need to include issues of modern science and to offer to teachers and students the opportunity to interact with real scientist to realize "how science works". Many teachers (although it is not foreseen from the science curriculum) perform limited or even significant interventions to their lessons in order to inform their students on what is happening at CERN.

> It is not easy to make interventions to the curriculum. This could lead to problems with the school director or sometimes with the parents. But I am taking this risk as I believe my students have to experience "how science works". LA@CERN offers a unique tool that provides an excellent solution to this problem. I can use ATLAS data and tools to teach curriculum subjects in a different way.
>
> *Greek Teacher (35)*

- Teachers are very interested to use digital resources that are connected with the school curriculum. They prefer also to use raw content rather than ready-made lesson plans. Here we have to say that the participants were quite experienced teachers who have devoted numerous hours working on their lesson designs. The fact is that teachers who are not so experienced prefer ready-made solutions to avoid problems during the instruction.

- Teachers believe that such applications (like LA@CERN) could increase the interest of students as well their motivation in science. According to their view scientific knowledge is by its nature abstract and theoretical. It often contradicts common sense and is developed through controlled experiments in artificial, "unnatural" and idealized laboratory settings. Learning science generally requires hard work and considerable intellectual effort which are not a dominant part of contemporary youth culture. With such applications (e.g. HYPATIA) scientific work and complex phenomena are presented in a game-like exploration and discovery that engages students in the process. Teachers believe that such web-based environments that promote inquiry based science education have to be used for the students laboratory work.

> HYPATIA offers a unique tool that can support students' conceptual change. It is a reference point for interactive science teaching.
>
> *Greek Teacher (42)*

- Scientific achievements may call for admiration, but they also create unease. Many people dislike the image and ambitions of modern physics. They have an emotional and rational fear of scientists who "tamper with Nature" or "play God". Many people react emotionally to the quest of physicists for "The Final Theory", also called "The Theory of Everything" or even the search for "The God Particle". The lofty ambitions of modern science may attract some young people, but are capable of repelling others. Many people feel that science is intruding in 'sacred' areas and are reluctant to accept the idea that science can explain everything since in their minds Nature is sacred and mystical - not explainable, controllable and rational. An avoidance of science in their case may in fact stem from a deliberate choice of values and is thus not something that can be remedied by more information, especially from scientists. Tools like the LA@CERN tools create effective links between scientific achievements and school practice and demonstrate that at the end of the day the search of the "God Particle" could be explained (and demonstrated in the school lab) is an easy and understandable way.
- For many teachers the educational design of HYPATIA is one of the most important features of the application. The fact that the tools offers the chance to the students to make mistakes and involves them in different paths of scientific exploration is the major feature that an environment that promotes inquiry must include.

> HYPATIA is an excellent tool! I am thinking to use this tool in the technology lesson as well. In technology (as there is not fixed curriculum) we can implement a series of such innovative scenarios. HYPATIA could act as a "trap" to identify future scientists!
>
> *Greek Teacher (45)*

The usage of the LA@CERN portal was monitored by the Google Analytics system during the hands-on workshops. The following table presents the parameters that demonstrate the effective use of the LA@CERN portal during the hands-on workshop.

- **50** Visits
- **46** Absolute Unique Visitors
- **1,358** Pageviews
- **27.16** Average Pageviews
- **00:23:15** Time on Site
- **10.00%** Bounce Rate
- **74.00%** New Visits

Table 4.10: *The main parameters that used to monitor the usage of the LA@CERN portal are presented below for the time interval of the hands-on workshops that were organised on 23 and 24 of November 2010. The 46 participants performed 1358 page views exploring the LA@ CERN portal contents. Each one of them has spent about 23 minutes working on the portal.*

4.2.4 Case Study 2: Using HYPATIA in the students laboratory (University Level)

1. Introduction

The Physics Department of the University of Athens has implemented the use of one of the tools of the LA@CERN portal in the laboratory work of the 2nd year undergraduate students of the Department. The laboratory work spans a 3 months period during which students have to perform a cycle of 8 different laboratory exercises focusing in different areas of modern physics. The activity took place in September-October and November 2010 and 15 students were involved in the monitoring procedure. A specific questionnaire was developed for this purpose and the students had to deliver this after realizing the laboratory exercise that was connected with the discovery of the Higgs Boson through the use of the HYPATIA software. In the following sections the Questionnaire and the analysis of the results are presented and discussed.

2. Feedback Mechanism

Ellinogermaniki Agogi team, in collaboration with the research team of the Physics Department of the University of Athens, has developed a questionnaire in order to receive feedback from the use of HYPATIA during the students laboratory work. The questionnaire included seven open questions, offering to the students the opportunity to present freely their views. The first 3 questions were general ones, asking from the students to assess the experience of using HYPATIA, to validate the importance of such tools in the data acquisition process of the large scale scientific experiments and finally to estimate the importance of offering access to real data. The next three questions are focusing on the presentation of the physical process that HYPATIA simulates (and presents). The aim of these questions is to identify if students really understand the natural processes that are taking place and how scientists are trying to map their effects. The final question is discussing the profile of the job of the scientist. It asks from the students to present 4 pros and 4 cons for becoming scientist. The team aims to identify the students' views on future scientific careers. The demonstration of "how science works" through tools like HYPATIA could help students to have a more clear view of the work of a scientist as well as to get a first hand experience of the difficulties but also of the challenges of being a scientist.

3. Analysis of the Findings

The main findings could be categorized as following:

- Students believe that the use of HYPATIA in the framework of the laboratory work is very interesting and motivating. They consider that HYPATIA simulates the scientific process in a unique way and allows them of get a more clear view on how ATLAS detector works.

> I believe that the specific exercise is one of the most interesting experiences I had during my study at the Physics Department.
>
> *Student (20)*

> I believe that the specific exercise is very interesting as it offers the opportunity to "visualize" invisible particles and understand how one of the most complex experiments works.
>
> *Student (20)*

- Students believe that the most important feature of HYPATIA is the use of real data from the ATLAS detector. It is the first time in the framework of their studies that have the opportunity to access real data from such a complex experiment. Students also believe that HYPATIA is a very effective training tool as it is similar to the ones that are used from the Data Acquisition System of the detectors so they can have a very clear view how the process is taking place in reality.

Out of the 15 students 12 were able to explain the natural processes as well as the techniques that are used to track the paths of the elementary particles that crossing the detector. Students were able to explain and to present in detail the role of each component of the detector and the rational for its use. The filtering process that is implemented and the discrimination between "noise" and "signal" were well understood by the students. HYPATIA tools offers a series of quantitative and qualitative parameters that could be used from the students in order to understand the importance of the cut-off values for each parameter.

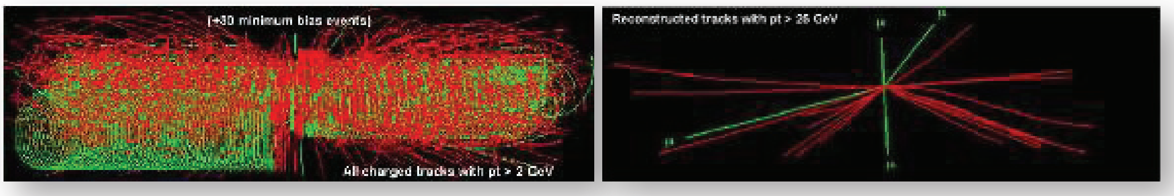


Figure 4.11: *In the framework of the activity students will be involved in tasks like "The LHC Data Challenge": Starting from the event on the right we are looking for the "signature" on the left (images from CERN). By Involving students in such activities and problems in eScience we can demonstrate the importance of tools like HYPATIA in such scientific process.*

- The use of such tools and real data is considered as a qualitative upgrade in their studies that will improve everyday teaching for several reasons:

  Increasing motivation: Students are more likely to feel a sense of personal investment in a scientific investigation as they will actively participate in the research procedure and will add their own aesthetic touches to the different tools they are using for experimentation. Such an approach could help to make science "fashionable" among students. It has to be noted also that inquiry based pedagogy (supported by the use of ICT tools) address a variety of learning styles and strengthen higher order thinking skills essential for success in mathematics, science, engineering, and technology related courses.

> I believe that the specific exercise is motivating as it engages us actively to a research project. It brings us closer to the scientific methodology and helps us to understand the natural processes. It was really the first time that I can say that I understood in detail what is happing at CERN.
>
> *Student (20)*

  Extending the experimentation possibilities: The access to data from frontier experiments (like ATLAS and CMS) can serve as spurs to the imagination, promoting the interest of the students to be involved in scientific investigation. They will personally experience the procedures involved in an authentic research project and thereby gain a far better understanding of science and engineering. In this way their classroom is transformed into a scientific laboratory. The partnership believes that students can come to view the data analysis procedures as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression.

  Developing critical capacity: Too often students accept the readings of scientific instruments without question. When students are involved in the proposed activities for example by performing their own experiments and observations, they should as a result develop a healthy scepticism about the readings and a more subtle understanding of the nature of the scientific information and knowledge.

  Making connections to underlying concepts: Our working hypothesis is that amending the traditional scientific methodology for experimentation with visualization applications and model building tools will help students and learners in general to articulate their mental models, make better predictions, and reflect more effectively. Additionally, working to reconcile the gaps and inconsistencies within their mental models, system models, predictions and results, will provide the learners with a powerful, explicit representation of their misconceptions and a means to repair them.

  Understanding the relationship between science and technology: Students will gain firsthand experience in the ways that technological design can both serve and inspire scientific investigation. The HYPATIA learning environment offers the option of teaching students as individuals, in small groups and in large groups while it provides links to other schools and research facilities in their country and abroad.

- The students have identified many pros and cons in their effort to describe the profile of the scientist. They present a variety of views, both positive and negative. The fact is that the students, although they are studying physics and it is probable some of them to follow a scientific career, seem not to have a clear view of "How a scientist work". Clearly this is due to the fact that in most of the high schools in Greece the career counselling does not exist. On the other hand HYPATIA, which has been designed to analyse data from ATLAS offer a unique opportunity to explore that world of science and get a first hand experience of how a scientist works.

4.3 Exemplary implementation of ATLAS@CERN missions in universities

4.3.1 Identifying LHC events with HYPATIA

Laboratory Exercise for 4th year Undergraduate Students specializing in Nuclear Physics – NKUA

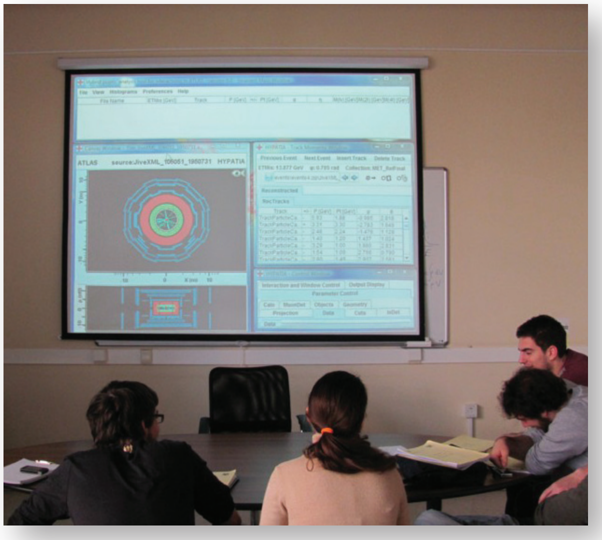


***Fig. 4.12:** Tutorial about the use of the special HYPATIA version which is the core of the exercise.*

The goal of the exercise is to familiarize the university students with the process used in real event analysis by ATLAS researchers. In the process, we also get the opportunity to talk about the standard model, familiarize the students with the LHC in general and the ATLAS experiment in particular, and explain how particle detectors work and what signatures each type of particles leaves.

The Laboratory exercise is performed by fourth year undergraduate students who have chosen Nuclear and Particle physics as the main focus of their studies. It is currently in its second year of application. The exercise is done by teams of three students working together. Each week two teams work in parallel and a total of 10 teams (30 students) will complete it by the end of the semester. In the first year a similar number of students completed the exercise.

A similar exercise was also completed by 35 high school teachers during the November 2010 "CERN in Greece" training seminar. The teachers were also asked to fill in questionnaires about the exercise.

Initially the students attend a lecture with powerpoint presentations and videos for about 1,5h in which the theoretical and practical basis of the exercise is explained. First they are reminded about the standard model and the particles that they'll be studying. Then there is an introduction about the work being done at CERN, the LHC and the ATLAS experiment. The parts of the detector are explained and the students are told what the signature of each particle type is, in each subdetector. Then there is a tutorial about the use of the special HYPATIA version which is the core of the exercise, and finally each part of the exercise is explained in detail. The students are also given a 22 page booklet summarizing everything that was explained in the lecture.

The first part of the exercise requires students to identify electron or muon tracks that are results of Z boson decays. Simulated events are used which contain a multitude of tracks and the students have to decide which of those tracks belong to the Z particle that decayed. Then, they fill in a table with the event and track number and the energy of the tracks they have selected. This part has the goal to familiarize the students with the HYPATIA software and also to teach them the differences between the signatures of each type of particle. It also gives them hands-on experience of how a particle appears on the subdetectors.

The second part is the longest and most important part of the exercise. Here the students have to identify Z particles and decide whether an event is a Z boson decay or a background event. Each student is given a sample of 30 events. These samples are tailor made to contain about half Z decays, few cosmics, few low mass dimuons and some di-jets containing muons. There are 5 groups of events so that each team uses a different group. The events used in this part are real. This is emphasized to the students to make them understand that they will be doing real event analysis in the same way that a physicist doing research would. The students have to select the events that they believe to be Z decays (the number of Z events is not given to the students). Some basic criteria on how to distinguish the Z events from the background are given (invariant mass, isolation, low ETMiss etc). The students are then asked to insert each of the tracks that belong to the Z decay into the invariant mass window where the mass of each Z boson is calculated and also verify by hand one of the calculated masses. When they finish with the event sample, they have to make a histogram with all the masses of the events they selected and see if it gives them a value close to the theoretical mass and width of the Z boson. If not, they have to give an explanation in their report.

***Fig. 4.13:** Work in groups with HYPATIA on data from specific events.*

In this part the students have to use a more complex recognition procedure. They are also taught about the invariant mass and the importance of histograms and why we need a large number of events for reliable analysis of real events. They also get to see the difference between the theoretical values and the ones measured from the experiment. The use of real events emphasizes the connection with the everyday work of a researcher analysing data off the pit.

In the final part the students are given ten simulated events, nine of which are background events and one is Higgs boson decaying into four leptons. The students have to identify the four lepton tracks and in the process “discover” the Higgs boson. This part is used to give the students a sense of discovery and it also allows us to talk about the Higgs and its importance in the standard model.

As their homework the students have to write a report detailing their results and answer judgement questions based on them. This allows us to measure their understanding of the exercise. Also they are asked to explain any discrepancies between their results and the ones expected from theory. Finally, they answer a small questionnaire about the quality of the exercise and give their thoughts and suggestions on improving it.

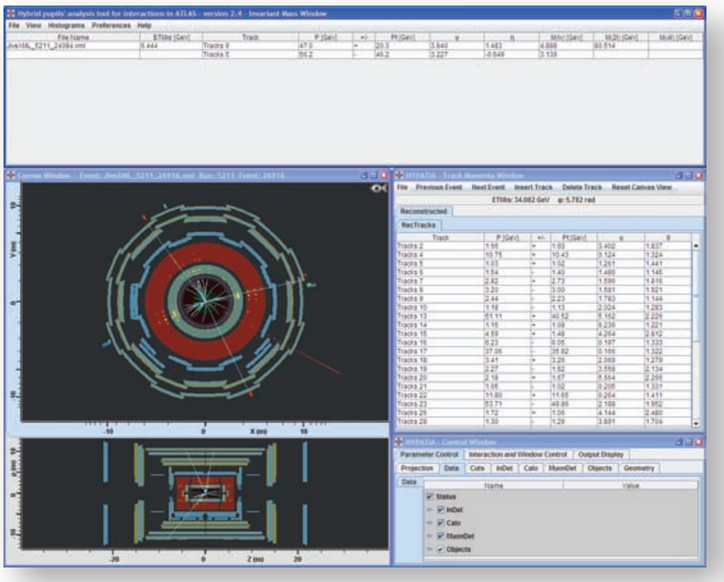


***Fig. 4.14:** Laboratory exercise (part 1)*

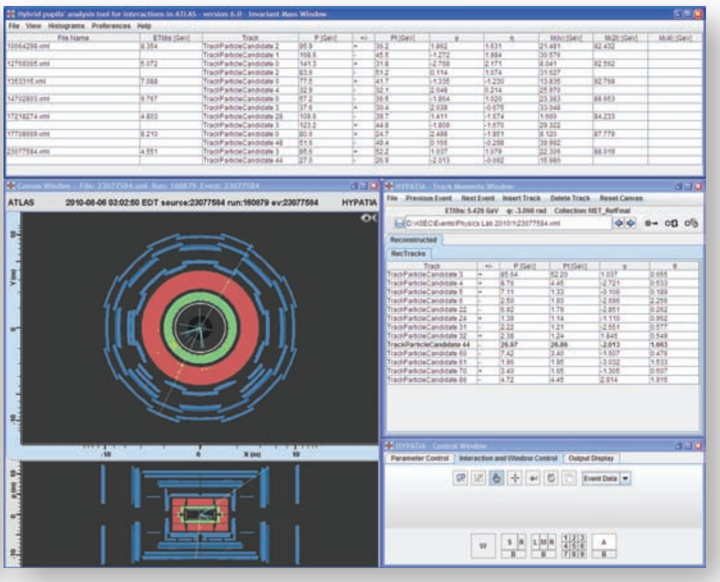


***Fig. 4.15:** Laboratory exercise part 2*

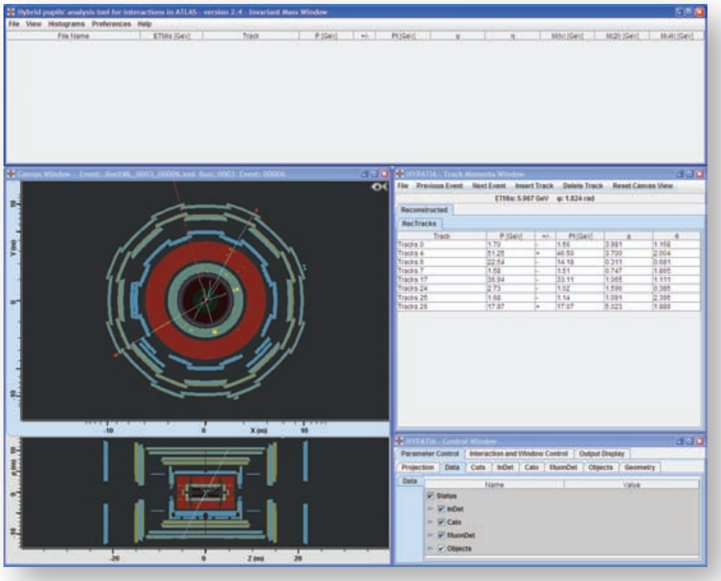


Fig. 4.16: *Laboratory exercise part 3*

4.3.2 Strange Particles in Atlas

The Strange Particle Scenario using particle collisions in the ATLAS Experiment

Fysikum, Stockholm University, AlbaNova, Sweden

Strange particles

Since their discovery some 60 years ago, the strange particles have played an important role in the evolution of particle physics and the understanding of how particles interact and decay.

They immediately puzzled the physicists as they did not behave as expected. Their lifetime was orders of magnitude longer than expected. They were 'strange', and the name is still used. The strange particles are unstable, they have lifetimes or the order of 10-10 and 10-8 s. Still today the strange particles reveal fascinating aspects of the world of particles.

The strange quark

Strange particles are composed of one or more strange quarks. Surprisingly, the quarks have fractional electric charge, either 1/3 or 2/3 positive or negative charge. The strange quark has electric charge -1/3. The kaons are composed of a strange quark and a light antiquark, an anti-u or an anti-d quark.

Particle collisions in ATLAS

In 2009 the new collider at CERN started to produce long awaited particle collisions in large numbers. The ATLAS experiment was one of the huge particle physics experiments at the Large Hadron Collider that registered particle collisions deep underground at the 27 kilometer accelerator ring. The main aim of the ATLAS detector is to search for new discoveries in the head-on collisions of protons of extraordinarily high energy and learn about the basic forces that have shaped our Universe. But these particle collisions in the ATLAS experiment can also be explored by students at school and universities.

The ATLAS detector

At Stockholm University we have focused on the development of exploring strange particles with the complex and colossal ATLAS experiment. The ATLAS detector is huge, about 45 meters long, and more than 25 meters high and wide. ATLAS weighs about 7 000 tons, about the same as the Eiffel Tower and is about half as big as the Notre Dame Cathedral in Paris. High energy particles accelerated in the new CERN collider, the LHC, collide head on in the centre of the ATLAS detector. The numerous particles produced in the high energy collision are detected in the many detector elements of the ATLAS detector. The trajectory, energy, momentum and identity of the particles are determined with the many and complex detector elements.

ATLAS data and the analysis tools

In Stockholm we have used real particle collisions from the first data taking run in December 2009, in particular the production of the neutral strange particles K0 and L0.

The main educational tool to explore particle collisions is the ATLAS event display MINERVA. In the MINERVA event display a particle collision with all the produced particles is displayed in two projections. It is possible to focus on different parts of the detector by zooming in to see what has happened close to the particle collision point or zooming out to get an overview of the produced particles going through the detector. The neutral strange particles decay a couple of centimeters, sometimes tens of centimeters, from the collision point. They become visible via their decay into two particles with opposite charge in the inner detector of ATLAS.

Explorations

The explorations focus on selecting particle collisions containing decays of neutral strange particles, the observation of the decay point, and the determination of the flight distance. Investigating the two particles that the strange particle decayed to, makes it possible to determine the mass of the strange particle. The lifetime of the K^0 and the $?^0$ particle is about a tenth of a billionth of a second (10^{-10} s). In the macroscopic world this is an amazingly short time, but in the world of particles the lifetime is relatively long.

Undergraduate students

Fig. 4.17: Students in Stockholm exploring ATLAS particle collisions

An evening in September 2010, ten university students at Stockholm University and House of Science at AlbaNova university centre explored particle collisions in ATLAS. Five were physics students and five were biology students. The demonstration started with an introduction to particle physics, the ATLAS experiment and the 'Learning with ATLAS' project. The MINERVA event analysis tool was demonstrated, and then the students were let loose on the particle collisions from ATLAS first data taking run at the new collider at CERN.

It did not take long before they had got the knack of exploring particle collisions and spotting the decay of neutral particles in the inner detector of ATLAS (Fig. 4.17). They selected the particles coming from the decaying particle and got the momenta of the selected particles from the event display (Fig. 4.18). With this information they could determine the mass of the decaying K0 particle. They also managed to make an approximate estimate of the K0 particle lifetime.

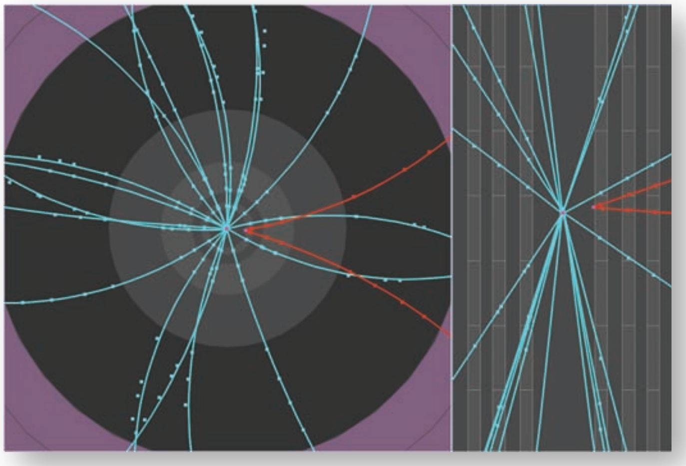


Fig. 4.18: *A K0 particle decaying in the inner detector of ATLAS.*

Evaluation

On a scale from 1 (do not agree) to 5 (completely agree) the students gave the following scores to the education scenario and the exercise.

	Like the scenario	Like the exercise	Recommend to other students
Biology students	3.8	3.0	3.6
Physics students	4.6	5.0	4.8

Neither the biology nor the physics students found the exercise difficult (score 2, they did not agree with the statement that the exercise was difficult). They also agreed that they had enough time for the exercise (score 3.2, i.e. neither too little nor too much time). The majority of the students would recommend the scenario and the exercise to their colleagues, but generally the physics students were more keen on the scenario than the biologists. One of the students said "what a shame that this exercise did not exist when I went to school".

More information:

ATLAS homepage: ***http://atlas.ch/***

The Learning with ATLAS portal (different languages): ***http://learningwithatlas-portal.eu***

4.4 Exemplary implementation of ATLAS@CERN missions in science centers

Case study – Identifying particles in ATLAS and determining the Z0-mass

Target Groups: Science Center, University, School classes)

Masterclasses in Particle Physics in Stockholm House of Science

How do we convince our students to choose a carrier in physics? At House of Science in Stockholm one way of dealing with this issue is to introduce rather advanced experiments using data from CERN, and let the students do particle physics for real.

Background

This event took place at Stockholm House of Science, February 17, 2010 from 9 to 17:30. Students as well as teachers were invited from schools in the Stockholm area. In total 31 students and 5 teachers participated during the day. The students were about 18 years of age and in their last year of upper secondary school.

Stockholm House of Science is a university science laboratory facility for Science and Technology entirely devoted to schools. The activities are accessible to teachers, school classes and individual students. The well-equipped laboratories and the proximity to the research groups allows the visitors to do something extra compared to what the schools can normally offer. The laboratories are staffed by scientists and experienced teachers assisted by undergraduate and graduate students.

Masterclasses and the Z0-scenario

Fig. 4.19: Björn Nordkvist introduces the students to particle physics and the Standard Model.

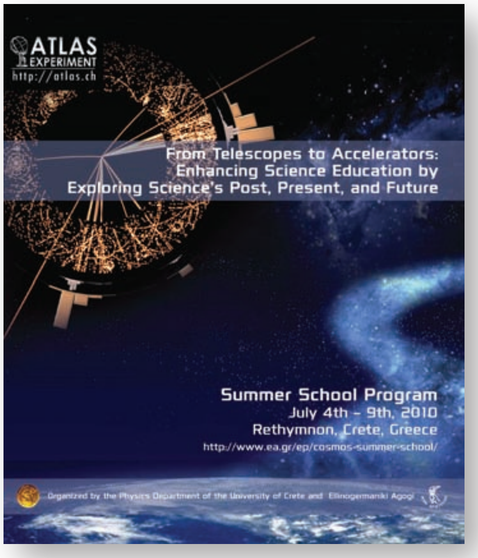
In the morning there were introductory lectures mixed with practical demonstrations related to particle physics. The day started with a short presentation of the Learning with ATLAS-project after which the students were introduced to particle physics and the Standard model. Then followed some hands-on demonstrations in House of Science. In a cloud chamber the students were able to observe tracks from ionizing particles such as alfa- and beta-particles as well as from cosmic muons formed in the upper parts of our atmosphere. A simplified version of a PET-camera was demonstrated and antimatter was discussed. Before lunch the students also got acquainted with LHC and ATLAS in a lecture where facts were mixed with animations and the first few minutes of the movie Angels and Demons.

The actual work with the scenario, Identifying particles in ATLAS and determining the Z0-mass, started after lunch. The scenario was introduced and guided by Björn Nordkvist, who was a PhD student in Particle Physics at Stockholm university and who also worked as an assistant at House of Science. The students worked together two and two. By using the event analysis tool MINERVA the students analyzed 20 simulated events per group. Among these events there were a couple of Z0-events. The students first task were to analyze the events and find the ones where a Z0 were formed. During the afternoon the students were also invited to the Particle Physics group at Stockholm university. The students then got the opportunity to meet and discuss with real researchers in particle physics and they got a short lecture on what is going on in the field. After their meeting with the researchers the students returned to their events and calculated the masses of the Z0-particles they had found. In a final discussion the students compared their results and concluded that the mass of the Z0-particle was about 90 GeV.

Summary

At the end of the day the Masterclasses, as well as the scenario and the different activities were evaluated. Even though some of the students had no previous knowledge in particle physics before this day, the feedback from the students was very positive. In the morning only one of the students had ever heard about the Z0-particle before. In the evening they had all been able to identify them in the ATLAS-detector and determined it's mass!

4.5 ATLAS@CERN Summer School



The Summer School is a five days training that aims to provide teachers all across Europe with a training on the ATLAS@CERN tools, on related online repositories, and to familiarise them with pedagogical learning theories. Further the event gives them the opportunity to meet with other users and communities and to exchange their experience on the practical usage of learning modules in their every-day-teaching. All interested persons with a pedagogical background are able to get funding for the summer school submitting an application to their ministries. In the course of the ATLAS@CERN project one summer school took place in Crete in July 2010, in the framework of the Natural Europe Summer School.

At the Summer School homepage (***http://www.ea.gr/ep/nature-summerschool/)*** the methodology applied for the training is described as follows: "The course will include presentations and practical sessions (workshops) on WWW and educational uses for teachers (…); strategies for searching information online; introduction to the concept of learning objects; introduction to learning repositories; introduction to preparing, uploading and sharing learning resources; introduction to metadata, educational metadata, and metadata-based searching; presentation in the classroom; pedagogical strategies and best practices for using digital teaching & learning resources in the classroom; and hands-on sessions working on resources related to science." The participants "will be given tools that will allow them to design educational pathways [learning scenarios] on digital content resources (…); they will be able to select an educational pathway of interest, and then navigating through (…) a particular museum or through different collections of various museums. (…) One day will be hosted at the Natural History Museum of Crete where the participants will be introduced to the use of social tagging techniques for describing the museum collections.

Pedagogical Summer School Design
Preparatory Phase
Prior to the actual training, each participant received the course program, access to all relevant online sources and repositories, and to the educational material, empowering them to use the required tools and to get familiar with the training framework
5 Days Training
Following a constructivist learning approach, the teachers had the possibility to further elaborate on their own, developed learning resources and to share their experience with other training participants. The whole training course comprised 13 hours of lectures and 12 hours of hands-on-sessions.
Follow-up Phase
After the summer school and equipped with the trainees guide, the participants could continue to develop their own learning modules, and to publish, share and re-use them through the ATLAS@CERN Platform or related on-line repositories.

Fig. 4.20: ATLAS@CERN Summer School Programme in 2010

4.6 Modern Technologies

4.6.1 Mobile Learning

Mobile Computing (MoCo) is one of the most challenging future fields in computer science, especially in the eLearning field. However, Mobile Computing is an umbrella term and describes any technology that enables people to access information and supports them in daily workflows independent of location.

In recent years there has been much attention focused on integrating technology with science education to improve the level of science learning and encourage more students to pursue science careers. Software development, improved pedagogical practices and an eLearning focus have contributed to an increased focus on science education. The use of mobile technology has broadened the field of eLearning extensively with its popularity and propensity to extend learning boundaries with informality and a wide range of application.

4.6.2 Mobile applications

Mobile applications are software applications developed specifically for mobile devices such as mobile phones. The aim was to develop an application that could be used on mobile devices as well as in the "Learning with ATLAS@CERN" portal as an online version.

The applications are based on an interactive learning approach, which combines constructivist learning principles with the popularity of mobile devices. The user or learner interacts with the educational content, synthesises and processes information, then generates content, meaning and analysis from their experiences.

The mobile applications connected with the "Learning with ATLAS@CERN" project are called mobile CERN or in short moCERN. The applications provide background information about several topics of high-energy physics and used with the appropriate pedagogy brings the learner closer to physical phenomena. In Fig. 4.21 a screenshot of the online version of mobile CERN is presented.

Figure 4.21 *moCERN online version*

The use of mobile devices acts as a stimulus to learning, motivating learners to participate in future learning. The prevalence of mobile devices amongst students at both the school and tertiary level indicates their popularity and potential. The mobile technology is presented with a portability and ease of use that makes it preferred over the range of notebooks. The mobile device has a multi-faceted purpose from its use as a disruptive learning technology to the ability to support individual learners. For the information gathering the mobile applications provide an introduction to the backgrounds and processes of high-energy physics with little or no prior physics knowledge.

The mobile applications can be used in conjunction with other scientific sources, such as books, journals or web sites for more detailed physical or mathematical models and information.

Following each application a quiz can be utilised as a self-assessment tool. A website hosts all project contributions, either for learning online or to get the applications for uploading to your mobile device.

The 20 learning applications are divided into four categories of topics;

First there are general topics, such as

- CERN
- LHC
- ATLAS, etc.

Second there are specific topics,

- Higgs
- Standard model
- Accelerators, etc.

Third the topics are specialised even more,

- Cosmic Rays
- Big Bang
- Black Holes.

And fourth there are historical or person related topics, such as

- Albert Einstein
- Stephen Hawking.

4.6.3 QR codes

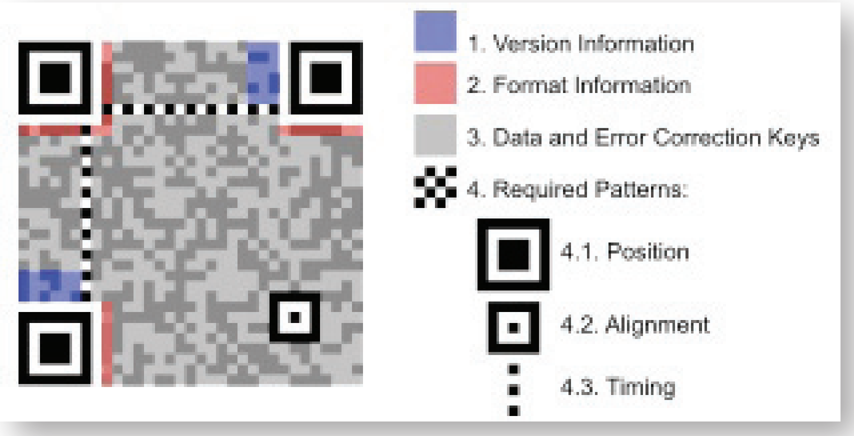


Figure 4.22: *Basic parts of a QR code*

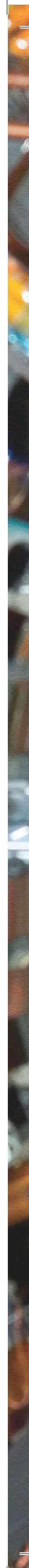
This is a two dimensional (matrix) barcode developed by a subsidiary company of Toyota, Denso-Wave. This bar-code can be read by QR scanners, mobile phones with a camera and smartphone.

The QR stands for Quick Response and is meant to allow users to download content (text, URL, other data) at high speed.

Whilst originally designed to tag automotive parts, the use of QR codes has become very flexible from use on business cards to magazines and exhibits.

With the mobile phone camera you take an image from the QR code and free software like i-nigma or Kaywa detects the code and interprets the information, like an internet link. In the case of mobile applications like moCERN the flash content will be downloaded.

An example of use in an education context is the development by IDEUM of the Electromagnetic (EM) Spectrum multitouch, multiuser exhibit for use in the Adventure Science Centre. A short description can be found following this link ***http://openexhibits.org/research/jims/46*** .The possibilities for the use of this software appear to be limited by imagination only as more and more educational institutions explore its use.



5. Future Directions


photo © atlas.ch

The Learning with ATLAS@CERN project pilots and demonstrates the approach in schools, universities and science centers in Greece, Finland, Sweden, Austria, UK and at CERN. Through a systematic validation process, a structured set of guidelines and recommendations on how effective collaboration between researchers and the educational sector (formal and informal) could create valuable and meaningful learning experiences for all, fostering exploration, discovery, curiosity and collaboration are developed. This section expands on the possible avenues available to the different organisations either involved or associated with this project to expand on the initiatives used in the Learning with ATLAS@CERN project.

5.1 General

At the beginning of the project the Learning with ATLAS@CERN exploitation strategy has been set up in the Exploitation plan in order to facilitate the national training activities and to ensure a long-term implementation of the Learning with ATLAS@CERN approach across Europe. As illustrated in the figure below the main exploitation activities focused on:

- The establishment of a Learning with ATLAS@CERN User- and Community, and the Setup of Clusters
- The organisation and conduction of Learning with ATLAS@CERN activities with the primary target groups (schools, universities and science centers)
- The development of the present ATLAS@CERN Guide of Good Practice

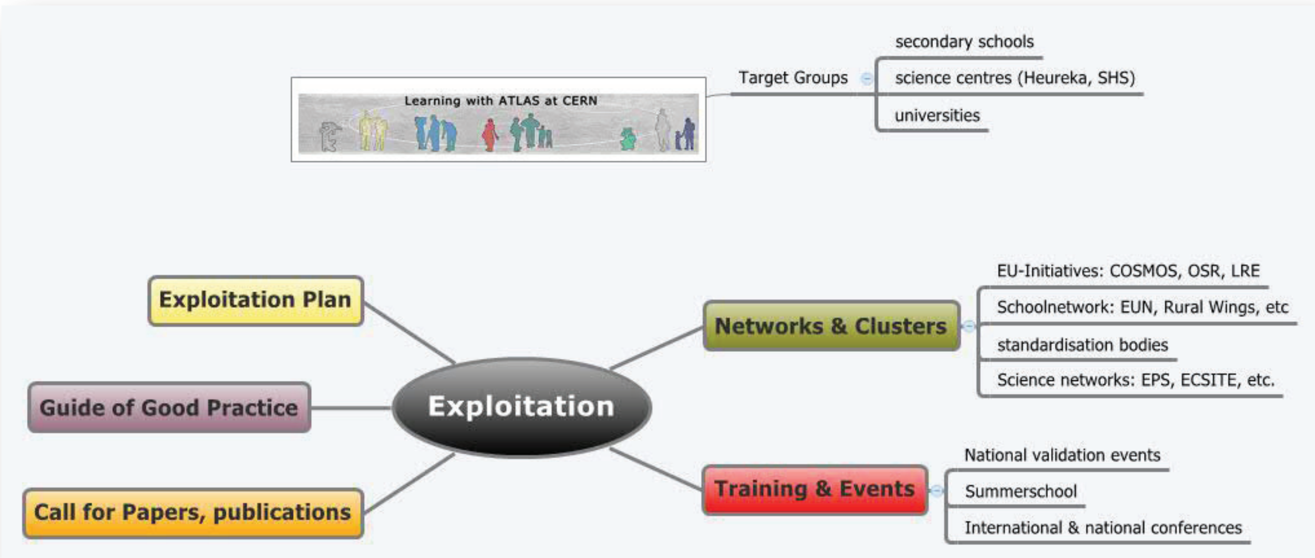
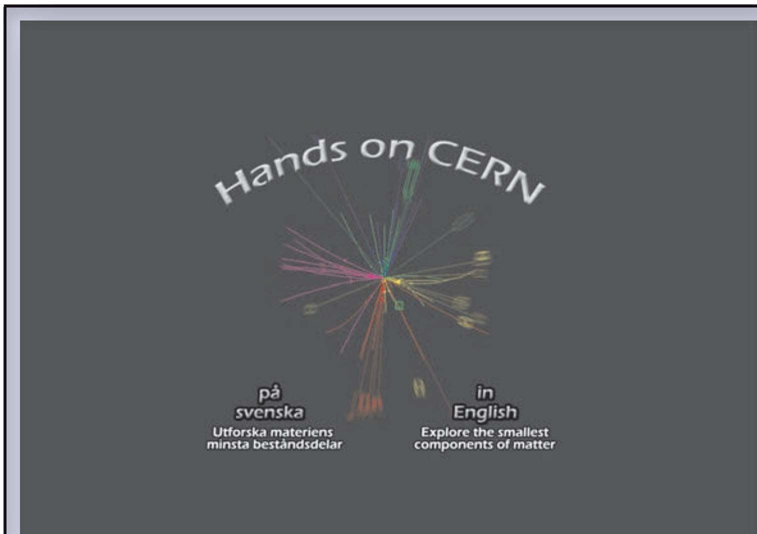


Figure 5.1: *Learning with ATLAS@CERN Exploitation Structure*

5.2 Associated Projects

The Learning with ATLAS@CERN project builds on experiences from the Hands-On-CERN project which was coordinated by Stockholm University and financed by The Knowledge Foundation (http://www.kks.se/) and the QuarkNet project which is coordinated by LBNL and is supported in part by the National Science Foundation and the Office of High Energy Physics, Office of Science, U.S. Department of Energy. Both projects are focusing on school education.



Hands on CERN (HoC)
http://hands-on-cern.physto.se/

Explore the smallest components of matter!

Hands-on-CERN (HoC) is an educational project at the scientific frontier of physics. It is aimed at teachers and high school students studying natural sciences.

The purpose of this project/course is to increase understanding of the most fundamental processes inside matter, and to explain modern research about particle collisions.

The pages of the this website give an overview of the structure of this course and some general information.

QuarkNet
http://QuarkNet.fnal.gov

The science connection you've been waiting for!

The Opportunity: "Your program rejuvenates my soul. It connects me with a cadre of intelligent and excited educators. It reinvigorates my teaching and provides me avenues to extend and enliven the projects that I can offer my students. Without the Quarknet program I am sure that I would have left teaching years ago."

The Players: High school students, teachers and physicsts working together on physics research projects exploring the hidden nature of matter, energy, space and time.

The Questions: What are the origins of mass? Can the basic forces of nature be unified? How did the universe begin? How will it evolve?

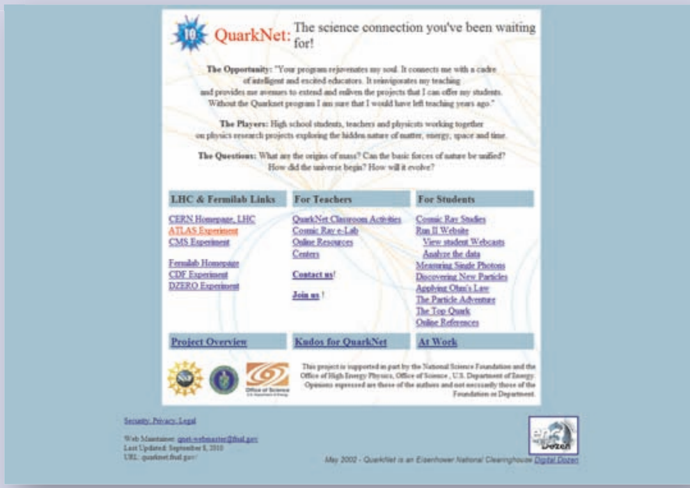


Table 5.1 Associated projects Hands on CERN and QuarkNet

Connection to other projects and initiatives

In this section you can find a list of further websites, content portals and initiatives, where you can search for content. This includes access to repositories and their tools, e.g. for metadata tagging and learning design packaging. The following table gives links to related projects:

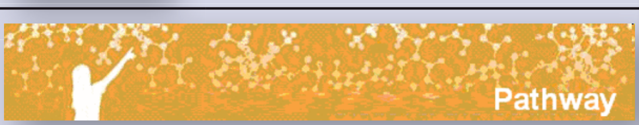
International Projects	
	COSMOS - An Advanced Scientific Repository for Science Teaching and Learning ***http://www.cosmos-project.eu*** ***http://www.cosmosportal.eu***
Open Science Resources (OSR) - Towards the Development of a Common Digital Repository for Formal and Informal Science Education ***http://www.openscienceresources.eu*** ***http://www.osrportal.eu***	
Pathway – The Pathway to Inquiry Based Science Teaching PDG - particle data group, ***http://pdg.lbl.gov/***	

Table 5.2 International projects

National Projects and Initiatives - Austria
ViS:AT (Virtual School – Austria) http://www.virtuelleschule.at
ViS:EU (Virtual School – EU Projects) http://www.schule.at/gegenstand/vis
Bildungsserver in Österreich (Education Server) http://www.bmukk.gv.at/service/links/bildungsserver.xml
Gegenstandsportal (Subject Oriented Portal) http://www.schule.at/

Table 5.3 *National projects in Austria*

National Projects and Initiatives - UK
Science & Technology Facilities Council - Public and Schools **http://www.stfc.ac.uk/Public+and+Schools/1281.aspx**
Stimulating Physics Network **http://www.stimulatingphysics.org/**
IOP - Institute of Physics **http://www.iop.org/education/**
particle physics uk **http://www.particlephysics.ac.uk/**

Table 5.4 National projects in UK

National Projects and Initiatives - Sweden
The Hands on CERN project at Stockholm University, a particle physics education project on the web using data from the CERN electron-postron particle collider (in Swedish and English) ***http://hands-on-cern.physto.se/***
Hands on Particle Physics, the International particle physics Masterclasses using CERN collider data from both electron-positron collisions and proton-proton collisions. It also contains Hands on CERN education project in 15 languages. ***www.physicsmasterclasses.org***
Physics projects for high school students at Department of Physics, Stockholm University (in Swedish) ***http://www.fysik.su.se/skolor_allmanhet/gymnasieprojekt/***
House of Science (Vetenskapens Hus), a physics, astronomy, chemistry and biotechnology laboratory for schools. ***http://vetenskapenshus.se (in Swedish), http://houseofscience.se (in English)***
Swedish resource centre for physics (in Swedish), Nationellt resurscentrum för fysik ***http://www2.fysik.org/***

Table 5.5 National projects in Sweden

5.3 ATLAS@CERN Affiliated Partners

All affiliated ATLAS@CERN partners and interested organisations/individuals receive the affiliation package and are informed about project developments, invited to share project results and to participate in future exploitation events. The project information, its objectives and outcomes are made available to the network.

5.3.1 ATLAS@CERN Affiliation Package

- ATLAS@CERN logo
- ATLAS@CERN project presentation (leaflet, in high and low resolution) in English
- ATLAS@CERN document “Physics with ATLAS” in English
- Link to the ATLAS@CERN portal: ***http://www.learningwithatlas-portal.eu***
- Link to the ATLAS@CERN project web site: ***http://www.learningwithatlas.eu***
- Invitation to future ATLAS@CERN activities and events
- ATLAS@CERN Guide of Good Practice

Affiliated partners agree to:

- Communicate the ATLAS@CERN project to the affiliate partner’s network
- Support major ATLAS@CERN activities and events
- Disseminate the ATLAS@CERN portal and educational materials
- Provide the ATLAS@CERN Guide of Good Practice to their affiliate partners’ network

5.3.2 Affiliated Partners, Scientists and Experts

Affiliated Partners

CERN http://cern.ch, Helfried J. Burckhart, CERN
LBNL: Lawrence Berkeley National Laboratory, ***http://www.lbl.gov/*** R. Michael Barnett, Senior Physicist at Lawrence Berkeley National Laboratory
Teilchen.at ***http://www.teilchen.at (to be confirmed)***
HEPHY (High Energy Physics Institute, Austria) ***http://www.hephy.at/ (to be confirmed)***

Table 5.6 Affiliated Partners

5.4 Selection of Dissemination Tools

Austria:

- CERN, ATLAS Experiment: Mr. Martin Aleksa

http://cdsweb.cern.ch/search?ln=de&p=Aleksa%2C+Martin&f=author

- CERN: Mr. Christian Carli

http://cdsweb.cern.ch/search?f=author&p=Carli%2C%20Christian&ln=de

- TU Wien: Mr. Christian Fabjan

http://www.tuwien.ac.at/aktuelles/news_detail/article/6083/

- Science Busters: Mr. Werner Gruber, Mr. Oberhummer, Mr. Puntigam

http://www.sciencebusters.at/

UK

University of Birmingham: Peter M. Watkins, Head of Particle Physics Group, UK

http://eppog.web.cern.ch/eppog/Members/uk.html

Table 5.7: *Network/Cluster of Scientists and Experts*

Learning with ATLAS@CERN

The Learning with ATLAS@CERN project is co-financed by the European Commission within the framework of the Lifelong Learning Programme

Learning with ATLAS@CERN

"The time will come when diligent research over long periods will bring to light things that now lie hidden. A single life time, even though entirely devoted to research, would not be enough for the investigation of so vast a subject.... Our universe is a sorry little affair unless it has in it something for every age to investigate.... Nature does not reveal her mysteries once and for all."
Seneca, National Questions Book 7, first century

The "Learning with ATLAS@CERN" project aims to demonstrate an innovative pedagogical approach that involves students, teachers and the wider public in extended episodes of science learning. The project's basic philosophy is that the learning of science is a process of creating knowledge by learners. Based on the effective use of ICT tools (virtual environments, visualisation technologies, 2D and 3D animations of aesthetic quality, simulation interactive games) the project aims to offer a "feel and interact" user experience, allowing for exploratory learning "anytime, anywhere".

The proposed project's main objectives are:

- **to develop a pedagogical framework that attempts to blend informal and formal learning and to situate learning in real- world contexts.** The project introduces a technologically advanced approach for learning by connecting a wide range of learning environments (schools, universities, science centres, and research institutions).
- **to develop advanced pedagogical scenarios that are shaped around a mission guided by a general scientific question.** During a "Learning with ATLAS@CERN" -mission, learners perform several types of learning actions that can be characterized as productive (experiment, game, share, explain, design, etc.), they encounter multiple resources, they collaborate with varying coalitions of peers, and they use certain tools and scaffolds (e.g., to design a plan, to state a hypothesis etc.). Conceptual scaffolding will be extended through communication tools in the form of leading questions that set a context for the learners.
- **to pilot and to demonstrate the "Learning with ATLAS@CERN" approach in schools, universities and science centres in Austria, Finland, Greece, Sweden, UK and at CERN.** A series of user-centred learning activities (demonstrations, workshops, info days) will be organised in schools, universities and science centres in the participating countries. Further demonstrations will be organised in other European countries with the support of the European Physical Society.
- **to create virtual learning communities of educators, learners and researchers and involve them in extended episodes of science learning.**
- **to perform an extended validation study of the "Learning with ATLAS@CERN" approach.**
- **to provide a common set of guidelines and recommendations on how scientific work can be used to provide an engaging educational experience through the exploration of "real science".**

Several dissemination tools are available in order to promote the ATLAS@CERN approach.

ATLAS@CERN Leaflet [English]:

ATLAS@CERN Poster [English]:

http://virtuelleschule.bmukk.gv.at/fileadmin/atlas/posters/ATLAS-poster_rot_ccw.jpg

In Austria, several national dissemination tools have been developed and made available at the Virtual School Platform.

http://virtuelleschule.bmukk.gv.at/projekte-international/eu-projekte-abgeschlossen/atlascern/

ATLAS@CERN - Lernen mit ATLAS@CERN

Ein Projekt im Lifelong Learning Programme

CERN, die Europäische Organisation für Kernforschung (vom früheren franz. Namen Conseil Européen pour la Recherche Nucléaire), ist eine Großforschungseinrichtung in der Nähe von Genf in der Schweiz, an welcher vielfältige physikalische Grundlagenforschung betrieben wird. Bekannt ist es vor allem für seine großen Teilchenbeschleuniger.

ATLAS (stand ursprünglich für A Toroidal LHC ApparatuS) ist ein Teilchendetektor. Unter anderem soll damit erstmals das Higgs-Boson, ein für die Erklärung der Masse wichtiger Bestandteil, nachgewiesen werden sowie die derzeit kleinsten Bausteine der Materie, Leptonen und Quarks, untersucht werden. Der Bau des LHC wurde im Februar 2008 abgeschlossen. Am 10. September 2008 wurde der ATLAS-Detektor erstmals getestet, die geplante Betriebszeit ist auf 10 Jahre angesetzt.

Das Projekt
Eigentlich wurde das Internet bei CERN erfunden, um WissenschafterInnen die Übermittlung von Informationen zu ermöglichen. Auch heute ist das World Wide Web ein wichtiger Kommunikationsweg für wissenschaftliche Recherchen. Umfangreiche Datenbanken sind öffentlich zugänglich und können ein Katalysator für ein innovatives und motivierendes Lernen werden.
Schulen, Universitäten und Wissenschaftliche Institutionen können als Mediatoren agieren, Informationen aufbereiten und damit Wissenschaft auch für Außenstehende verständlich gestalten.

ExpertInnen aus Wissenschaft und Forschung sollen, gemeinsam mit AnwenderInnen in ganz Europa, das **LA@CERN** (Learning with ATLAS@CERN) entwickeln, testen, einführen und verbreiten. Dies bietet ein innovatives pädagogisches Rahmenwerk für den effektiven Dialog zwischen Wissenschaft und Forschung für den Moment, wenn der neue gigantische Detektor ATLAS beginnen wird, die fundamentalen Naturkräfte zu erforschen und tiefer in die Materie einzudringen als je ein anderes Forschungsprojekt zuvor.
Das Konsortium ist vielversprechend: ein Netzwerk von Institutionen aus Bildung und Forschung garantieren alle erforderlichen Kompetenzen, um die effiziente und professionelle Umsetzung des Projekts zu gewährleisten.

Von einem bisher deduktiven zu einem auf Recherche basierenden Ansatz zu wechseln, könnte zum besseren Verständnis für Wissenschaften beitragen. So werden Neugier und Beobachtung, gefolgt von Problemlösung und Experiment gefördert, in realer wie auch in virtueller Umgebung. Dieser Ansatz ermöglicht den Zugang zu Echtzeit-Daten und interaktiven Analyse-Werkzeugen, 3D- und 2D-Animationen von physikalischen Prozessen in einer spielerischen Herangehensweise und bietet SchülerInnen-zentrierte Materialien und Anwendungen für Projekte und kollaborative Aktivitäten.

Info folder [German]:
http://virtuelleschule.bmukk.gv.at/fileadmin/atlas/info-folder/atlas_cern.pdf

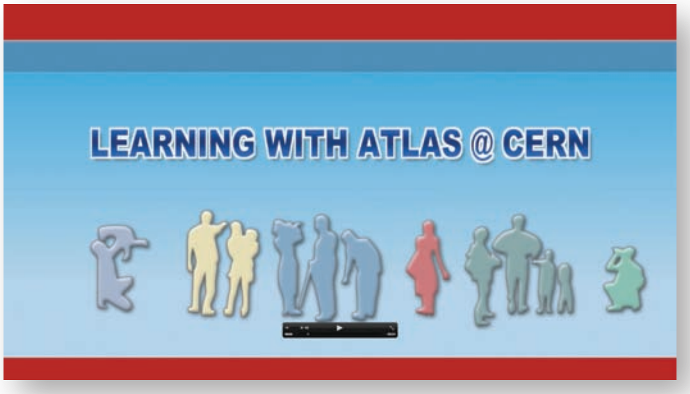
ATLAS@CERN
www.learningwithatlas.eu

Die Ziele des Projekts

- Förderung eines auf Problemlösung, Recherche und Experimenten basierenden MST (Mathematics, Science and Technologies)-Unterrichts
- Errichtung eines Netzwerkes von LehrerInnen, WissenschafterInnen und Lehrplan-EntwicklerInnen
- Errichtung eines Netzwerkes von wissenschaftlichen Institutionen & Science Museen
- Aufbau einer Webplattform mit folgenden Bereichen:
  - Sammlung und Qualitätssicherung von bestehendem eContent
  - LA@CERN Toolbox: Interactive Analysis Tools (3D, 2D Animationen)
  - Ausarbeitung eines LA@CERN Guide of Good Practice

Zielgruppen

Poster (on Page 9) [German]:
http://virtuelleschule.bmukk.gv.at/fileadmin/plakate/ProjektPlakate.pdf



ViS:TV Video “Atlas at Cern – Projektüberblick“ [German]:

http://www.vimeo.com/13281487

5.5 References / Publications

The Learning with ATLAS@CERN deliverable publications like ‘Guide of Good Practise’ and ‘Inspiring Science Learning’ are publications that will have an impact on the future.

“Inspiring Science Learning” book, the report from the Hands on Science conference in Rethymnon, Greece

- **Presentations and workshop at Hands on Science conference, 25-31 July 2010, Rethymnon, Crete**

http://www.hsci.info/

http://www.clab.edc.uoc.gr/hsci2010/

- **“Physics with ATLAS”**

http://www.learningwithatlas.eu/

- **Physics Education**

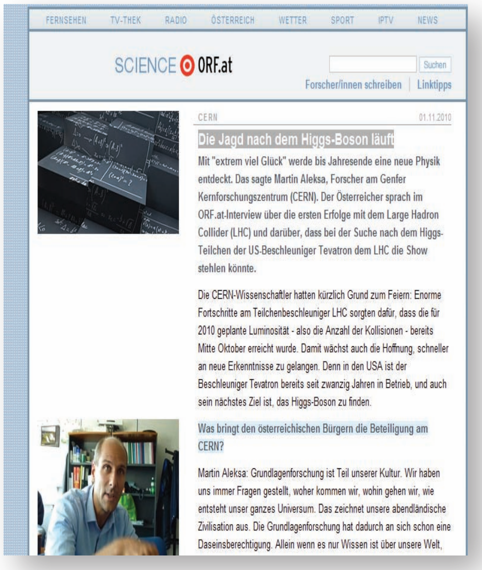
http://iopscience.iop.org/0031-9120

- **Science in Schools (SiS)**

http://www.scienceinschool.org/

- **ATLAS e-News**

http://atlas-service-enews.web.cern.ch/atlas-service-enews/2010/news_10/news_Pathway.php



FERNSEHEN TV-THEK RADIO ÖSTERREICH WETTER SPORT IPTV NEWS

SCIENCE ORF.at

Suchen

Forscher/innen schreiben | Linktipps

CERN 01.11.2010

Die Jagd nach dem Higgs-Boson läuft

Mit "extrem viel Glück" werde bis Jahresende eine neue Physik entdeckt. Das sagte Martin Aleksa, Forscher am Genfer Kernforschungszentrum (CERN). Der Österreicher sprach im ORF.at-Interview über die ersten Erfolge mit dem Large Hadron Collider (LHC) und darüber, dass bei der Suche nach dem Higgs-Teilchen der US-Beschleuniger Tevatron dem LHC die Show stehlen könnte.

Die CERN-Wissenschaftler hatten kürzlich Grund zum Feiern: Enorme Fortschritte am Teilchenbeschleuniger LHC sorgten dafür, dass die für 2010 geplante Luminosität - also die Anzahl der Kollisionen - bereits Mitte Oktober erreicht wurde. Damit wächst auch die Hoffnung, schneller an neue Erkenntnisse zu gelangen. Denn in den USA ist der Beschleuniger Tevatron bereits seit zwanzig Jahren in Betrieb, und auch sein nächstes Ziel ist, das Higgs-Boson zu finden.

Was bringt den österreichischen Bürgern die Beteiligung am CERN?

Martin Aleksa: Grundlagenforschung ist Teil unserer Kultur. Wir haben uns immer Fragen gestellt, woher kommen wir, wohin gehen wir, wie entsteht unser ganzes Universum. Das zeichnet unsere abendländische Zivilisation aus. Die Grundlagenforschung hat dadurch an sich schon eine Daseinsberechtigung. Allein wenn es nur Wissen ist über unsere Welt,

ORF Article, Interview with Martin Aleksa, ATLAS@CERN (01.10.2010; published 01.11.2010)

5.6 Events

5.6.1 Masterclasses

International Masterclasses

The Learning with ATLAS education material and scenaria have been shown and demonstrated at several EPPOG meetings. The ATLAS data will be used in the coming Masterclass sessions. Many of the 100 University laboratories that invite high school pupils and teachers to their laboratories will use ATLAS data and analysis tools to explore W, Z, and K^0 particles. Every year around 6000 high school pupils take part in the EPPOG International Masterclasses.

National Masterclasses

National Masterclasses are an important platform for dissemination and test of innovative education projects. Several components of the Learning with ATLAS@CERN concept and education ingredients can be presented and explained to teachers. Also students could take part in addition to the teachers that participate in the workshops organised at the same occasion. Some events, which took place in 2009 and 2010, and already planned in 2011 are listed below:

- 17 March 2009. The European Masterclasses at House of Science, AlbaNova, Stockholm. First confrontation with 25 students and 5 school teachers presenting the ATLAS experiment, the aim of the physics research and the AMELIA event analysis tool.
- 23 March 2009. Teachers workshop during Crete Masterclass in Irakleio. 20 high school teachers participated.
- 28 March 2009. Teachers workshop during National Technical University of Athens Masterclass in Athens. Information, test and demonstration of the HYPATIA analysis tool. 40 high school teachers participated.
- 31 March 2009, Teachers workshop during University of Athens Masterclass in Athens. Information, test and demonstration of the HYPATIA analysis tool. 20 high school teachers participated.

- 22 April 2009. Masterclass event at the University of Birmingham. Test and presentation of MINERVA analysis tool and ATLAS presentations. 100 schoolchildren and teachers attended.
- February 17 2010, the European Masterclasses were held at House of Science and Stockholm University. During one day 5 teachers and 30 students were participating in different activities related to particle physics using the ATLAS Experiment. The exercises and presentations took part in House of Science and part of the day was devoted to a visit of the particle physics research group at Stockholm University. Around 15 scientists participated in the encounter with the visiting students. The project Learning with ATLAS@CERN was presented and the students and teachers were informed about LHC, ATLAS and tools to analyze particle collisions in ATLAS using the AMELIA event analysis tool. The excercise focused on exploring simulated Z particles in ATLAS events.
- 8 December 2010.Particle Physics Masterclass, Birmingham, 20 A level students participated.

Planned activities in 2011:

- 6 April 2011, Birmingham, Particle Physics Masterclass. Around 130 students expected to participate.
- 9 March 2011, Stockholm, Particle Physics Masterclass. Around 40 students and 10 teachers expected to participate.

The national Masterclasses – many of which are part of the International Masterclass program – are excellent testing grounds for new presentation techniques and new education and analysis tools and excellent opportunities to meet with and inform high school teachers.

Masterclasses at the University of Innsbruck - Institute of Astro- and Particle Physics (Austria)

At the Institute of Astro- und Particle Physics research focuses on Astrophysics and High-Energy Physics. They organise also masterclasses in German.

http://physik.uibk.ac.at/hephy/masterclasses/

5.6.2 Summer Schools

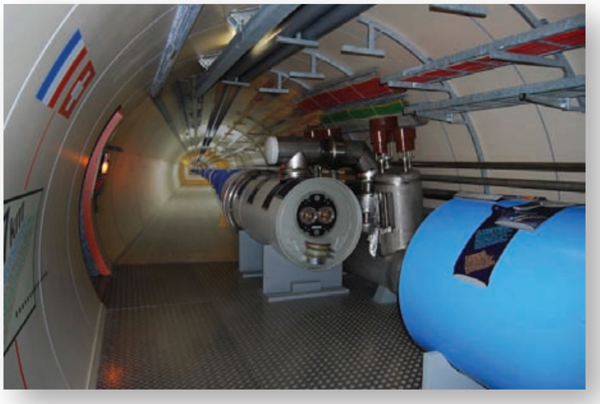
2010

- 4-9 July 2010, Rethymnon, Greece, Summer School "From Telescopes to Accelerators: Enhancing Science Education by Exploring Science's Past, Present, and Future"

5.6.3 Field / Study Trips to CERN

Further informations and contact address for a field / study trip to CERN is given on the website ***http://outreach.web.cern.ch/outreach/*** where you also can book guided tours for groups or individuals.

Exhibition "Microcosm" – CERN's interactive science centre)



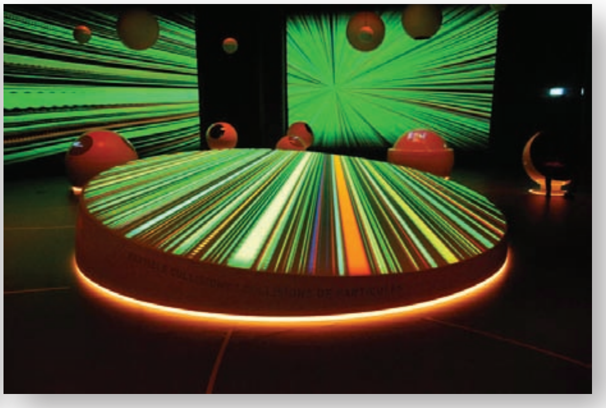
Cosmic rays, antiprotons, quarks and gluons… some of the particles you'll discover in Microcosm!

With hands-on experiments, models, videos and computer interactives, experience the CERN adventure in science:

How are accelerators used to recreate the conditions at the beginning of the universe? Why are such enormous detectors needed to study the tiniest constituents of matter? And how are thousands of scientists from around the world collaborating to understand the basic building blocks of matter?

- Look at ***http://microcosm.web.cern.ch/microcosm/Welcome.html***

Exhibition "Universe of Particles"



A totally unique experience visiting the exhibition «Universe of Particles»

The entire Universe is made up of particles. But where do they come from? What laws govern their behaviour? The purpose of the "Universe of particles" exhibition is for visitors to confront the great questions of contemporary physics, currently being explored by the CERN via the LHC and other accelerators.

The exhibition's innovative design plunges the visitor into the fascinating world of particles, from the infinitesimally large to the infinitesimally small, from the Big Bang to the present day. The bewildering environment is designed to force visitors to abandon conventional ideas and contemplate a field of research beyond their common experience.

- Look at ***http://outreach.web.cern.ch/outreach/expos_cern/univers_particules.html***

ATLAS Visitor Centre and Control Room

With the start-up of the LHC in 2009, visits to the ATLAS cavern are no longer possible. You can now experience the excitement of frontier science at the new ATLAS visitor centre. Learn about the science of the ATLAS experiment through interactive exhibits, and observe the intense excitement of the ATLAS control room just on the other side of a glass wall. Come and hunt for your own Higgs particle, turn yourself into antimatter or try and beat the ATLAS trigger!

The ATLAS Visitor Centre is one of the possible CERN visits itineraries, which you must book in advance.

- Look at ***http://atlas.ch/atlas_tour/***

Other CERN facilities

Please book your visit in order to get a guided tour and access to facilities in the restricted areas of CERN: ***http://outreach.web.cern.ch/outreach/visites/***

LINAC 2 (Linear Accelerator)

Two linear accelerators generate low energy particles. LINAC 2 accelerates protons to 50 MeV for injection into the Proton Synchrotron Booster (PSB), and LINAC 3 provides heavy ions at 4.2 MeV/u for injection into the Low Energy Ion Ring (LEIR).

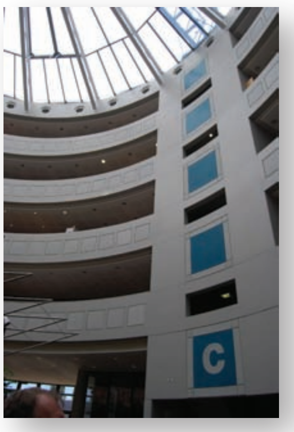
- Look at ***http://www.lhc-facts.ch/index.php?page=linac*** (in German)

LEIR (Low Energy Ion Ring)

LEIR is a central part of the injector chain to supply lead ions to the Large Hadron Collider (LHC) from 2008. It will transform long pulses from Linac 3 into short and dense bunches for the LHC.

- Look at ***http://www.lhc-facts.ch/index.php?page=leir*** (in German)

Building 40 (ATLAS/CMS)



The office building 40 at the Meyrin site hosts many offices for scientists working for ATLAS and CMS.

- Look at ***http://wikimapia.org/350341/Building-40-CERN***

5.7 Recommendations for future actions

In the following pedagogical, organisational, technical recommendations for connecting school and research are given.

5.7.1 Pedagogical Recommendations

Amount of resources

Provide a significant amount of resource to increase the awareness of science, improve the science teacher education program, promote science education in schools and therefore encourage more students to undertake research in the physics field.

Quality of pedagogical resources

The pedagogical materials and resources should be consisting of professional development material, lesson plans, activities and projects, which are conceptional and content checked by experts. The materials should be translated to the national languages to increase teachers' motivation to use them.

Integration of tools, handbooks and guidelines from other projects and repositories

Interactive Tools and information databases should be either utilised from past projects or specifically created in terms of usability (language, implementation for teaching, etc.).

Increase the motivation of target groups to develop, and share own content

Through the organisation of ongoing ATLAS@CERN events, teachers shall become more familiar with the ATLAS@CERN approach and be empowered to upload their own content to the ATLAS@CERN Portal.

5.7.2 Organisational Recommendations

Commitment to continuing contribution

Partner organisations should commit to continue their contribution, e.g. in

- organising and conduct Master Classes
- providing educational outreach activities for the CERN experiments through events
- Improving teacher education courses by including a focus on the pedagogical practices
- Closer collaboration with scientific research institutions such as CERN
- Promoting particle physics research at future conferences
- Submitting papers to various journals aimed at the various range of interests

Activities to sustain the momentum developed by the ATLAS@CERN project

Research institutions should continue to host, organise and promote the following activities to sustain the momentum developed by the ATLAS@CERN project, e.g. by CERN

- Educational Outreach days at CERN
- CERN Summer Schools and Training days
- Promoting technical resources that have been developed by the project partners in the CERN website

Support and provide access to information and resource databases

Partner organisations should support and provide access to information and resource databases that foster innovative practice in science education.

Support and provide access to information and resource databases

Partner organisations should support and provide access to information and resource databases that foster innovative practice in science education

Support the established communication networks

Partner organisations should support the established communication networks that promote exemplar practice and learning.

Integrate the work of ATLAS@CERN in other projects

The ATLAS@CERN approach should be used and exploited in other science related projects and educational portals to ensure the continuous presence.

5.7.3 Technical Recommendations

Provide state-of-the-art web portal

The technical infrastructure should provide a state-of-the-art web portal including e.g.

- Innovative search functionality
- Actual news section

Informational databases that are conform to IEEE standards

The databases and metadata sets should be conform to IEEE standards in order to be able to exchange data with other learning management systems and to be sure that these data could be imported or exported in future actions.

Include new technological standards

Learning with mobile applications and related technologies should be also incorporated to the ATLAS@CERN outreach programme.

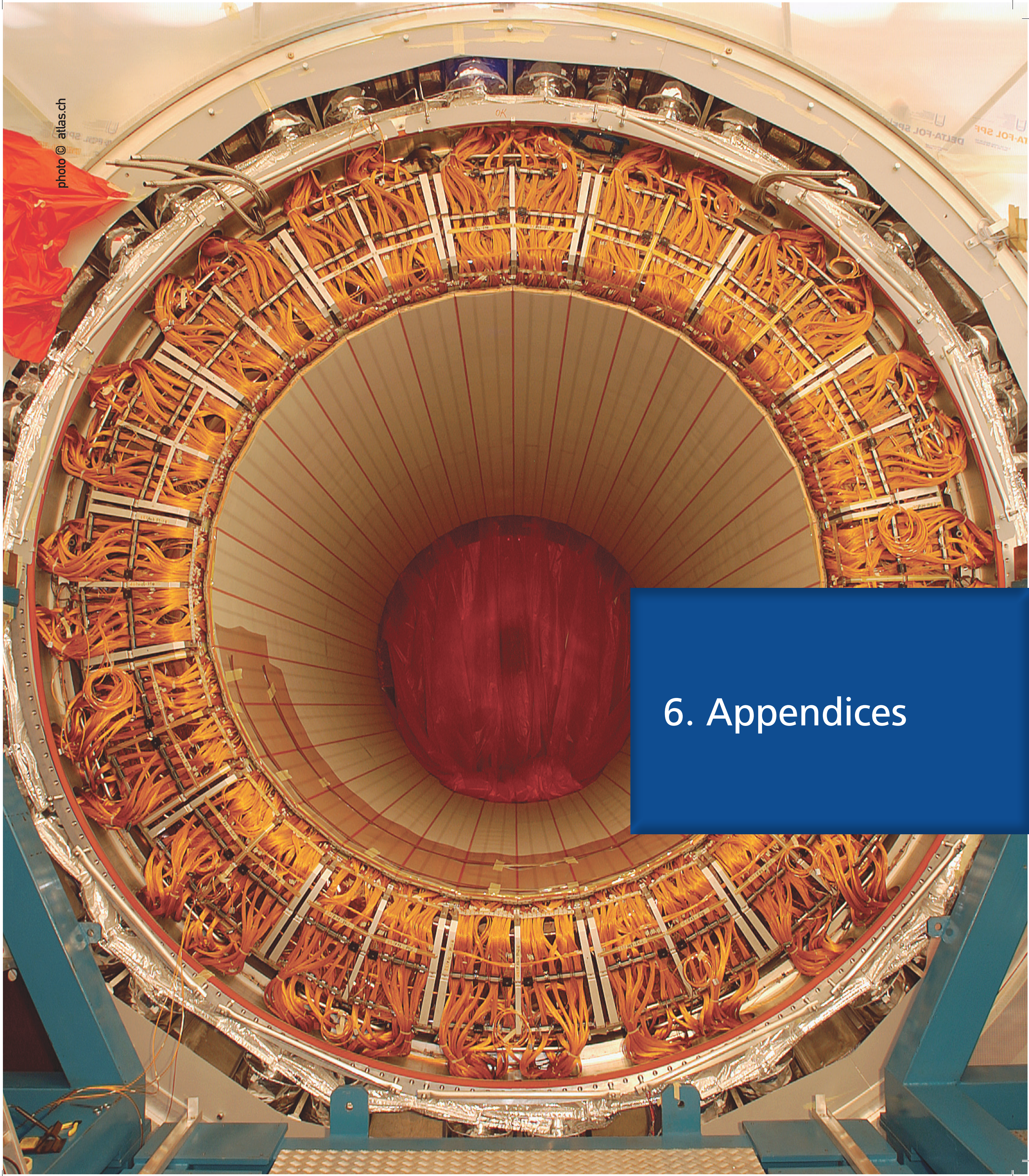


photo © atlas.ch

6. Appendices

6.1 Vocabulary and Glossary

6.1.1 Educational Vocabulary

Dimension	Type and Value	Description
Type	Communicative: Presenting	Presentation of a specific subject/work
	Communicative: Debating	A structured discussion of opposing points of view
	Information Handling: Analysing	Analysing a concept or a problem
	Productive: Synthesizing	Synthesizing data into a new whole
	Experiential: Exploring	Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions.
	Experiential: Experiencing	Performing experiments and observations
Technique	Information Handling: Brainstorming	A problem or idea is defined and all participants make suggestions related to the topic.
	Adaptive: Modeling	Formulate models to explain hypotheses or findings from the observations
	Experiential: Experiment	Designing, Setting up and Performing experiments
	Communicative: Structured Debate	A structured debate based on evidence from observations
	Communicative: Arguing	A verbal dispute
	Productive: Report	Production of a report describing the process and the findings
Interaction	Who: Class based	In the context of the classroom
	Who: Group based	In the context of the groups
	Medium: Face to Face	Face to face interaction of the participating role with others or content
	Medium: Online	Interaction via the use of Internet
	Timing: Synchronous	Synchronous interaction of the participating role with others or content
Roles	Individual Learner	The individual learner
	Group participant	A student participating in a group of students
	Facilitator	The teacher in a role of facilitator of the learning process
	Presenter	The teachers presents the outcomes of the discussion/debate

Tools/ Services	Hardware: Computer	An electronic, digital device that stores and processes information
	Hardware: Projector	A hardware device that enables an image to be projected onto a flat surface
	Software: Text, image, audio or video viewer	A software tool for displaying text, images, audio or video
	Software: Database	Educational Digital Library (e.g. DSPACE Library)
	Software: VLE	Virtual environment which engage users in learning activities (e.g. COSMOS portal)
Resources	Problem Statement	Document for defining a problem
	Slide	Hypermedia document
	Figure	A figure is any graphic, text, table or other representation that is un-aligned from the main flow of text
	Graph	Pictorial representation of information
	Exercise	Document for practicing a skill or understanding
	Simulation	An application that imitates a physical process or object by causing a computer to respond mathematically to data and changing conditions as though it were the process or object itself
	Table	An arrangement of information in columns and lines
	Self assessment	An assessment or evaluation of oneself, one's actions or attitudes by oneself
	Questionnaire	A list of questions by which information is sought from a selected group
	Exam	Document for testing, the knowledge or ability of students
	Other	It can be any of the following resources: Figure, graph, slide, simulation, experiment, table, self assessment, exercise, questionnaire, exam

Table 4.7: Learning Activities description

6.1.2 Scientific Glossary

Following terms are described on the website
http://www.atlas.ch/glossary/glossary.html.

A:
- *accelerator*
- *annihilation*
- *antimatter*
- *antiparticle*
- *antiquark*
- *ATLAS*

B:
- *baryon*
- *baryon-antibaryon asymmetry*
- *beam*
- *boson*
- *bottom quark (b)*

C:
- *calorimeter*
- *CERN*
- *charge*
- *charge conservation*
- *charm quark (c)*
- *collider*
- *colliding-beam experiments*
- *color charge*
- *color neutral*
- *confinement*
- *conservation*

D:
- *decay*
- *detector*
- *down quark (d)*

E:
- *electric charge*
- *electromagnetic interaction*
- *electron*
- *electroweak interaction*
- *eV (electron-volt):*
- *event*
- *exclusion principle*

F:
- *Fermilab*
- *fermion*
- *fixed-target experiment*
- *flavor*
- *fundamental interaction*
- *fundamental particle*

G:
- *generation*
- *GeV*
- *gluon*
- *grand unified theory*
- *gravitational interaction*
- *graviton*

H:
- *hadron*
- *Higgs boson*

I:
- *interaction*

J:
- *jet*

K:
- *kaon (K)*

L:
- *lepton*
- *LHC*
- *linac*
- *luminosity*

M:
- *mass*
- *meson*
- *MeV*
- *microwave*
- *muon*
- *muon chamber*

N:
- *neutral*
- *neutrino*
- *neutron*
- *nucleon*
- *nucleus*

O:

P:
- *particle*
- *photon*
- *pion*
- *plasma*

- *positron*
- *proton*

Q:
- *quantum*
- *quantum mechanics*
- *quantum theory*
- *quark*

R:
- *residual interaction*
- *rest mass*

S:
- *SLAC*
- *spin*
- *stable*
- *Standard Model*
- *strange quark (s)*
- *strong interaction*
- *subatomic particle*
- *synchrotron*

T:
- *tau lepton*
- *TeV*
- *top quark*
- *track*
- *tracking*

U:
- *uncertainty principle*
- *up quark*

V:
- *vertex detector*
- *virtual particle*

W:
- *W± boson*
- *weak interaction*

X:

Y:

Z:

- Z^0 boson

6.2 Scenario Template for a ATLAS@CERN Mission

In the following table the learning activities of the Inquiry-Based Teaching (IBT) pedagogical method are described. This educational scenario could be used to design your own ATLAS@CERN Mission. On the left hand side of Figure 6.2 you find the educational phases of the IBT method and on the right hand side the corresponding learning activities. Figure 6.2 gives a more detailed description of each IBT learning activity.

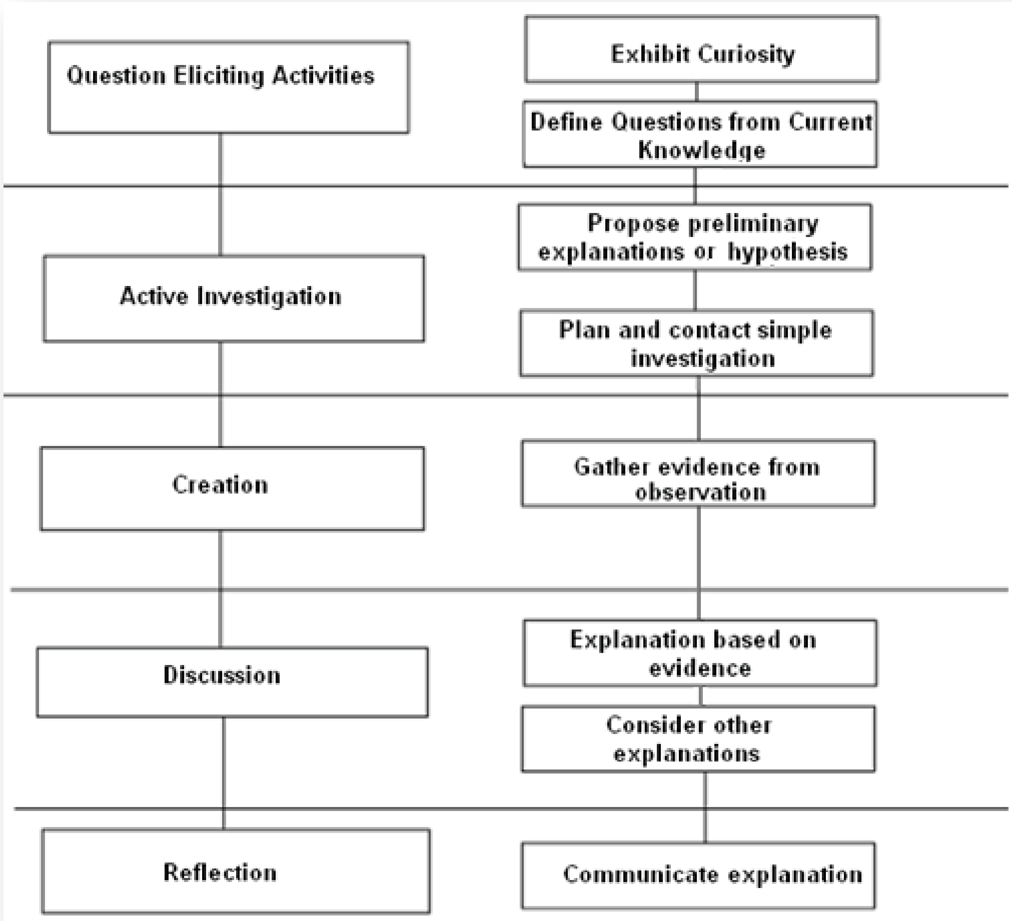


Figure 6.1: *Flow of learning activities for IBT.*

Phase 1: Question Eliciting Activities	**Exhibit curiosity** The teacher tries to attract the students' attention by presenting/showing to them appropriate material. **Define questions from current knowledge** Students are engaged by scientifically oriented questions imposed by the teacher.
Phase 2: Active Investigation	**Propose preliminary explanations or hypotheses** Students propose some possible explanations to the questions that emerged from the previous activity. The teacher identifies possible misconceptions. **Plan and conduct simple investigation** Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions. The teacher facilitates the process.
Phase 3: Creation	**Gather evidence from observation** Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.
Phase 4: Discussion	**Explanation based on evidence** The teacher gives the correct explanation for the specific research topic. **Consider other explanations** Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.
Phase 5: Reflection	**Communicate explanation** Each group of students produces a report with its findings, presents and justifies its proposed explanations to other groups and the teacher.

Figure 6.2: *Description of the Learning Activities of the IBT educational scenario template.*