

**D3.1.x Let's Accelerate Particles: learn about the LHC
accelerator by playing a game**

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1 Introduction / Demonstrator Identity

1.1 Subject Domain

Motion of particles in electric and magnetic fields, acceleration of particles, High Energy Physics at CERN

1.2 Type of Activity

Workshop with students: Introduction to elementary particles followed by hands-on activity with PCs. The students follow interactively all stages of acceleration of particles by playing an educational game

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Visits to research centres (virtual/physical) aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

2 Rational of the Activity / Educational Approach

- Introduction to High Energy Physics
- Understanding of scientific concepts and phenomena
- Active participation in modern physics research
- Emulation of cutting edge research work using playful learning environments
- Develop skills of teamwork

2.1 Challenge

School curriculum focuses on the fundamental concepts of physics. That is undoubtedly necessary as a basis to understand more complex concepts. However, focusing on discoveries made centuries ago and ignoring recent advances promotes an antiquated view of physics and fails to spark the students' interest towards it. It is necessary for them to learn how physics has evolved and what the current scientific view of the world around us is. This will not only give them a more complete view of what physics represents but also motivate them to take an interest in the physical sciences.

In this exercise, the students use an attractive learning environment which helps them to get acquainted with the most advanced technological equipment. They are expected to understand quite complicated processes which take place in order to operate the world's most powerful accelerator. They are also encouraged to collaborate with their teammate and answer knowledge and assessment questions.

2.2 Added Value

- Learn about the motion of charged particles in electromagnetic fields
- Understanding of scientific concepts and phenomena
- Familiarize themselves with cutting edge technology required to build world's most complicated accelerators
- Virtual visits to CERN and its experiments
- Live discussion with researchers at CERN
- Develop skills of teamwork

3 Learning Objectives

School curriculum is usually limited to basic physics concepts that were discovered decades ago. While this is an important foundation for the understanding of modern physics, it also leaves the students with a very antiquated view of physics.

With this demonstrator we aim to present to the students a realistic view of how modern particle physics research is conducted at the most advanced particle accelerator in the world, the LHC, and its experiments. This will not only give students a detailed view of the advances in particle physics but will also teach them about the structure of matter, the existence of a multitude of subatomic particles and their interactions. In addition it introduces them to the most advanced technological progress and helps them understand the challenges and difficulties presented when particles are accelerated at unprecedented energies.

3.1 Domain specific objectives

The students will learn about subatomic particles and their interactions, the structure of matter and the four fundamental forces in nature. They will also learn how particles move in electric and magnetic fields and how large numbers of particles are focused together to produce pencil-like beams. Finally they will visualize the products of collisions of such beams of particles.

3.2 General skills objectives

Students will learn to apply their knowledge of electric and magnetic forces in practice in order to achieve their ultimate goal guided along all steps by the professional LHC engineers.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics applications on their own. They have to gather the answers to the knowledge questions (the correct answers are provided afterwards) and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

4.2 Student needs addressed

The students involved in this exercise should have basic knowledge of physics and electromagnetism. Also a basic knowledge of the structure of the atom (or even elementary particles) is desired. Students work on PCs using the LHC game (played using the Flash software) which is intuitive and easy to use. It is part of the software developed by CERN within the CERNland applications which include a number of other games for younger ages.

Students of ages 12-15 will enjoy playing the game.

5 Learning Activities & Effective Learning Environments

• Question-eliciting activities

- Lecture about particle physics and accelerators as giant microscopes by experts
- Lecture about CERN and the LHC and accelerating techniques by experts
- Discussion/question/answer session with the students and teachers and experts from CERN

- **Active investigation**

- Introduction to the different stages of the LHC game software that will be used
- LHC interactive game
- Possible video Conference with other schools (for students)
- Understanding of scientific concepts and phenomena
- Emulation of cutting edge research work
- Involvement in high end scientific research
- Develop skills of teamwork

More Specifically:

- Students will learn the principles of basic science, concepts beyond the school curriculum
- Students will learn through playing games.
- Students will engage in hands-on activities which will allow them to understand and become familiar with the work of physicists working in the field of high energy physics. They will learn about probing matter deeper and deeper using accelerators and different particle beams. They will also learn about the use of accelerators in everyday life (hospitals, sterilization etc).

Science topic: Electricity and Magnetism and Particle physics.
(Not part of most national curriculums)

Class information

Year Group:

Age range: 12-15

Sex: **both**

Pupil Ability: **Basic computer usage required**

Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection.

*Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? **In a laboratory equipped with PCs***

*Health and Safety implications? **None***

*Technology? **PCs with Flash Player installed, A projector***

*Teacher support? **It is desired that the teacher talks to the students before the activity takes place. This will make it easier for the students to absorb better the impact of the game.***

Prior pupil knowledge: **Basic understanding of electromagnetism, the basic forces and atomic structure.**



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Individual session project objectives (*What do you want pupils to know and understand by the end of the lesson?*)

The aim of the lesson is twofold. First the students will understand important principles of the structure of matter. Second they will learn that scientists at CERN try to further probe matter in subatomic dimensions and they will become familiar with the technological advances that help us uncover the mysteries of nature.

As an additional outcome it can be combined with the art classes and the students to be asked to make their own visualization of the products of particle collisions and/or produce short artist videos which explain their findings.

Assessment

Collect answer to knowledge and assessment questions

Differentiation

How can the activities be adapted to the needs of individual pupils?

By adjusting the duration of time spent in each phase and the discussion in between.

Key Concepts and Terminology

Subatomic particles, structure of matter, fundamental forces, electric and magnetic fields, interaction of particles with electromagnetic fields, particle accelerators, dipole and quadrupole magnets

Science terminology:

-see above-

Arts terminology:

Particle collision visualization, Photographs, video, paintings



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Session Objectives:

At the end of the session they should have completed successfully all the steps needed to accelerate and collide particles at the LHC. They should have answered correctly the knowledge and assessment questions. Finally they should have discussed with their teachers the applications of accelerators in everyday life.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONS Features	Student	Teacher	Potential arts activity
<p>Phase 1: QUESTION: students investigate a scientifically oriented question</p>	<p>Students pose, select, or are given a scientifically oriented question to investigate. <i>Balance and navigation</i> through <i>dialogue</i> aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through <i>dialogue</i> between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through <i>dialogue</i> with different ways of knowledge inspired by <i>interdisciplinarity</i> and personal, embodied learning. <i>Ethics and trusteeship</i> is an important consideration in experimental design and collaborative work, as well as in the initial choice of question</p>	<p>The purpose of this introductory phase is to provoke the curiosity of the students by making them aware of the cutting edge research done at the European Center of Particle Physics (CERN). The principle idea is to point out the importance of this research as well as the difficulties humanity faces when studying nature. As soon as the goals of the scientists are</p>	<p>Teachers should make a brief introduction to their students about the elementary particles, CERN, general concepts of basic research in High Energy Physics and engage them in watching videos about CERN and the LHC accelerator, since the main part of this activity focuses on understanding the</p>	<p>Possible initial collaboration with arts teachers to visualize elementary constituents of matter</p>



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		<p>understood, the question of “how is that made possible?” is the next natural step. They will, therefore, become familiar with the new technologies developed in order to construct and operate the giant accelerator and the experiments installed in it. To do so, they will try to answer general purpose teacher’s questions, watch videos and use the web to gather more information.</p>	<p>principles behind the operation of particle accelerators and their applications in everyday life.</p>	
<p>Phase 2: EVIDENCE: students give priority evidence to</p>	<p>Students determine or are guided to evidence/data, which may come from <i>individual, collaborative and communal activity</i> such as practical work, or from sources such as data from professional scientific activity or from other contexts. <i>Risk, immersion and play</i> is crucial in <i>empowering</i> pupils to generate, question and</p>	<p>This Phase follows the general purpose introductory Phase 1. The aim of this Phase is to give students a broader understanding of the</p>	<p>The teacher has a lot of freedom when explaining the various concepts of this phase. He/she is expected to choose a procedure that best suits his/her school</p>	<p>Possible collaboration with arts teachers to visualize and draw particle accelerators</p>



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	<p>discuss evidence.</p>	<p>difficulties involved in achieving particle acceleration at High Energies. To do so, the interaction of particles with electromagnetic fields is presented in this phase. The behavior of different particles is studied based on scientific evidence. The process of accelerating particles is divided in three logical steps based on the behavior of particles in electromagnetic fields as well as the interactions between particles: 1) accelerating particles, 2) bending particles and 3) focusing particles.</p>	<p>curriculum as well as the current level of the class. A general recommended approach when teaching these concepts is to present only the basic physical principles that govern the interaction of particles with each other as well as with fields, and then pose questions to the students that aim at extracting from them the optimal way to accelerate particles based on their physical properties and the constraints that stem from them. Naturally, the activity it self will provide the relevant</p>	
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			guidance in order to achieve this goal.	
<p>Phase 3: ANALYSE: students analyse evidence</p>	<p>Students analyse evidence, using active investigation and <i>dialogue</i> with each other and the teacher to support their developing understanding.</p>	<p>This is the most interactive part of the demonstrator and the most important one since students will be asked to play a relatively easy game that requires implementation of the knowledge they gathered in the previous phases. The ultimate goal of the game is to accelerate particles in the LHC following the exact steps that scientists at CERN follow when accelerating beams of protons. The game is simple and well documented. The aim is to give practical meaning to the words “accelerating, bending</p>	<p>Teachers are expected to have tried the game beforehand in order to guide the students through the various steps if needed. The teacher role in this part of the exercise is minimal. They should provide feedback to the students that need it and clarify any notions that haven’t been understood. The use of the game provides a natural framework that the teacher can use in order to help him/her communicate and</p>	<p>Collaborate with arts teachers to draw the effects of magnetic fields</p>



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		and focusing particles” by actively engaging the students in this procedure.	analyze the scientific concepts involved.	
<p>Phase 4: EXPLAIN: students formulate an explanation based on evidence</p>	<p>Students use evidence they have generated and analysed to consider <i>possibilities</i> for explanations that are original to them. They use argumentation and <i>dialogue</i> to decide on the relative merits of the explanations they formulate, <i>playing</i> with ideas.</p>	<p>The goal of this Phase is to make sure the students have mastered the relevant material. Some of the students will have understood the concepts exposed in this activity, whereas others might still have questions whether they choose to come forward with them or not. In this phase they are expected to be able to explain what happens when we try to accelerate particles, how and why it happens. Ultimately, they should work in groups of two (or more) in order to provide suggestions for</p>	<p>The role of the teacher in this part of the exercise is vital. The teacher should try to guide the students by asking questions relevant to the problems and seeking solutions to these problems. He/she should promote teamwork in solving these problems. The utmost importance of the role of the teacher stems from the fact that he/she should try to understand what concepts of the activity</p>	<p>Create short videos showing motion and focusing of particle beams</p>



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		future particle accelerators.	were not understood from the students, and guide them in understanding these concepts by asking the appropriate questions.	
<p>Phase 5: CONNECT: students connect explanations to scientific knowledge</p>	<p>Students connect their explanations with scientific knowledge, using <i>different ways of thinking and knowing</i> ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to <i>interdisciplinary</i> knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.</p>	<p>Phase 5 assumes that a thorough discussion took place in Phase 4, since now the students will be asked to compare the solutions that they proposed with the solutions that the scientific community has chosen for future accelerators. There are many physical concepts and restrictions that can be discussed in this Phase (the speed of light, particle radiation, etc).</p>	<p>The activity itself provides the necessary guidance a teacher may need in order to actively engage the students in this discussion. This is the Phase that the teacher is able to showcase some of the most fascinating ideas of Science and provoke the curiosity of the students for concepts that go beyond the scope of this activity.</p>	<p>Continue visualization using digital modes as well (photos, films)</p>



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			Phases 4 up to 7 can be extended as much as needed based on the interests of the teacher and the students.	
<p>Phase 6: COMMUNICATE : students communicate and justify explanation</p>	<p>Communication of <i>possibilities</i>, ideas and justifications through <i>dialogue</i> with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be <i>immersed</i> in a key part of the scientific process. Such communication is crucial to an <i>ethical</i> approach to working scientifically.</p>	<p>Students compare their results with other students and discuss the results, the different approaches and the possible outcome of the various suggestions. Depending on the school infrastructure and the personnel availability, a remote connection with CERN can be established in this phase so that the students can expose their ideas to a scientist actively</p>	<p>The teacher is the coordinator of this procedure and holds a secondary role as the main goal is to provoke student communication and exchange of ideas on a scientific background. At the end of this phase the teacher should highlight the fact that this is a model of the actual procedure followed by</p>	<p>Students discuss with both science and arts teachers as well as their fellow students their art work created during previous phases</p>



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		engaged with this research and ask questions or further guidance.	scientists when doing research.	
<p>Phase 7:</p> <p>REFLECT: students reflect on the inquiry process and their learning</p>	<p><i>Individual, collaborative and community-based</i> reflective <i>activity for change</i> both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.</p>	<p>The goal of this phase is to sum up the outcomes of the activity. The students could participate in non-competitive questionnaires in order to determine the amount of teamwork and the results produced from each group (scientifically valid suggestions, feasible future experiments, etc).</p>	<p>The goal of the teacher is to sum up the goals of the activity, the new concepts, the achieved results and the possible future applications of what the students learned during the exercise. He/she should also highlight once more the applicability of accelerators in modern life and the high expectations for future technological breakthroughs based on particle accelerators.</p>	<p>The teachers together with the students select few examples in order to make a small exposition for their parents and the public in the form of a science fair</p>





6 Additional Information

- The game exists in different languages: French, English, German and Italian



7 Assessment

There are assessment questions embedded in the ISE LHC game demonstrator. The students' answers can be collected and provide information about the length of the student's understanding and length of involvement in each phase.

8 Possible Extension

There are several other games with the general framework of the CERNlab <http://www.cernland.net/index.php?>.

The Microboy game can also teach in a playful way the chemical composition of atoms.

A natural extension of this Demonstrator –but for older kids- is the HYPATIA demonstrator that studies the collisions of particles after they are accelerated to the desired energy.

9 References

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