Discover the COSMOS Deliverable

Implementation scenarios definition and analysis

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Short Description:

This document will be used for the definition and analysis of educational scenarios in the framework of *Discover the COSMOS*. It contains a template as per the guidelines set out in D2.1 (The Pedagogy of Inquiry Teaching: Strategies for Developing Inquiry as part of Science Education), as well as two examples of the filled in template.

List of Recipients: Discover the COSMOS participants

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1. Executive Summary

1.1 Bridging the gap between schools and research centres

Doing Science and learning about Science is not always the same thing, both from the perspectives of methodology and of everyday practice. Research centres usually do not have integrated outreach programmes to cater to Schools' needs, while teachers and students do not have easy access to research infrastructures, scientific data and tools for data analysis. Thus, very frequently students have very limited access both to "how Science works" and to "what's new in Science".

The *Discover the COSMOS* approach aspires to fill this gap between Schools and Research Centres by a) *demonstrating effective community building* between researchers, teachers and students and empowering the latter to use, share and exploit the collective power of unique scientific resources, that promote inquiry-based learning and appreciation of *how science works*, b) *demonstrating effective integration of science education with e-infrastructures* and c) *documenting the whole process through the development of a roadmap* that will include guidelines for the design and implementation of effective educational and outreach activities that could act as a reference to be adapted for stakeholders in both scientific research outreach and science education policy.

The European Commission sees eLearning as an integral part of education and in the Communication, 'A Digital Agenda for Europe', published in May 2010 (EC, 2010), called for Member States to include *e*-Learning in national policies. Europe's *e*-Infrastructures (high capacity, high performance communication networks and grid empowered resource sharing infrastructures) combined with advanced interfaces and visualization tools, data repositories and digital archives can play a part in this new way of learning.

1.2 How to do this: choosing the inquiry-based model to science education

Access to research infrastructures, raw data, data analysis tools and *e*-infrastructures are necessary, but not sufficient conditions to achieve the above-mentioned goals. In particular, *e*-infrastructures are tools but not goals unto themselves. Teachers and students need to be guided through the whole process by educational scenarios designed with these goals in mind. Therefore, the question arises: "what is the method of choice?".

The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report (Rocard, 2007) brought science and mathematics education to the top of educational goals of the member states. Therein, the authors argued that school science teaching needs to become more engaging, based on **inquiry-based** and **problem-solving** methods designed to meet the interests of young people. According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at schools.

Moreover, it's becoming clearer that the investment in teachers' competencies is a prerequisite in the fruition of these goals, as stressed in an editorial of the journal Science (Burris, 2012). Teachers cannot be viewed as passive receptors of a specific methodology, but as active counterparts of its implementation, undergoing themselves a continuing professional development: *"the challenge of professional development for teachers of science is to create optimal collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers"* (NRC, 1996).

Last, but not least, active participation to "what Scientists do" and practical understanding of "how Science works" may be the catalytic experience which will stimulate a decision for a scientific vocation by students. The IBSE approach is the method of choice to bring about such a change.

2. Description of the Educational Scenario Template for Discover the COSMOS project

2.1 Developing a template for IBSE educational scenarios

The Discover the COSMOS approach employs the Inquiry-Based Science Education (IBSE) approach to design educational scenarios. According to the IBSE model (Bybee et al. 2008), as adopted by the *Discover the COSMOS* project (DtC, 2012), learning by inquiry follows specific phases shown in Figure 1.

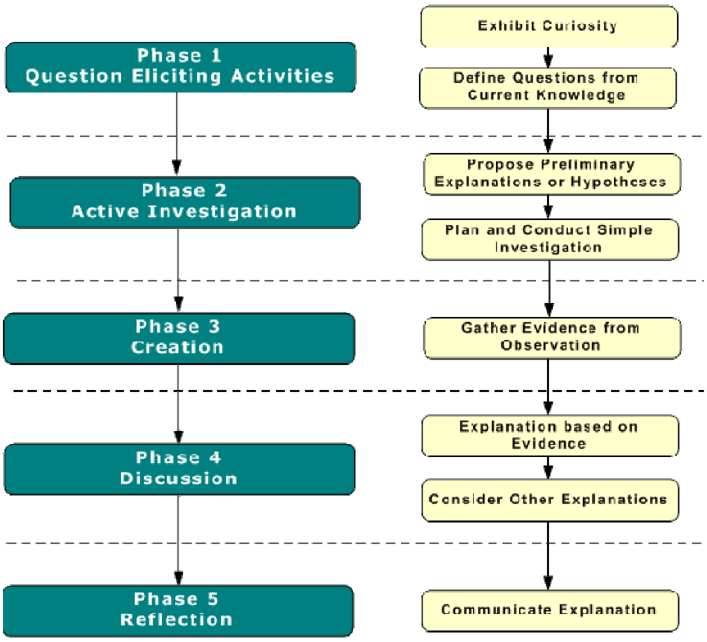


Figure 1. The five phases of an IBSE educational scenario.

To help in the development of educational scenarios conforming to this standard, a template is proposed to guide educators and scenario developers. In addition to that, two examples of scenarios conforming to this standard are given.

2.2 Description of the Educational Scenario Template in Narrative Format

Describing an Educational Scenario Template	
1. Title of the Educational Scenario Template	Inquiry Based Teaching
2. Educational Problem	Main problems a) theoretical and abstract teaching b) textbook based instruction c) no demonstration infrastructure available d) students misconceptions
3. Educational Scenario Template Objectives	**Knowledge** The learners should know and understand specific concepts and the analogies between them. **Skills** The students should be able to: • Explore the research procedures themselves • Perform research efforts that are taking place as a structured discovery within the frame of organised teaching. • Design and conduct scientific investigations. • Formulate and revise scientific explanations and models using logic and evidence • Recognise and analyze alternative explanations and models. **Attitudes** The students should be able to: • acquire an appreciation for basic Science Education matters through the exposure in similar topics • Communicate and defend a scientific argument **Career decision** The students should obtain a good idea of "how Science works" and of "what Scientists do" in order for them to consider a scientific carrer.
4. Characteristics and	**Cognitive**

Describing an Educational Scenario Template	
Needs of Students	The students have less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005, OECD 2010). **Physiological** The average age of students is 15-16 years. **Needs** The students should: • develop abilities necessary to do scientific inquiry • develop understandings about scientific inquiry • identify questions and concepts that guide scientific investigations • design and conduct scientific investigations • use technology and mathematics to improve investigations and communications • formulate and revise scientific explanations and models using logic and evidence • recognize and analyze alternative explanations and models • communicate and defend a scientific argument
5. Educational Approach of the Educational Scenario Template (a) Description of the Educational Approach rationale (b) Parameters that	(a) From a pedagogical perspective, **Inquiry Based Learning** is often contrasted with more traditional expository methods and reflects the constructivist model of learning, often referred to as active learning, so strongly held among science educators today. According to constructivist models, learning is the

Describing an Educational Scenario Template	
guarantee the implementation of the Educational Approach	result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences (Osborne & Dillon, 2008). In classrooms where students are encouraged to make meaning, they are generally involved in "developing and restructuring [their] knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention" (Newton et al, 1999). However, we use *inquiry based learning* in a more specific manner, referring to a specific teaching model: an iterative process of (1) question eliciting activities, (2) active investigation by students, (3) creation, these are (4) discussed already at early stages of the process, leading to (5) reflection about knowledge and the learning process, which in turn leads to new and refined questions (1) and the process goes on for another cycle. (b) Students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses. Moreover, students must have access to PCs that are connected to the Internet.
6. Learning Activities:	
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.

Describing an Educational Scenario Template	
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.
7. Participating Roles:	**Students** • Perform scientific prediction • Recording observations • Perform prediction compared to results • Develop experimental models **Group Participant** • Use or evaluate a technique

Describing an Educational Scenario Template	
	• Use science to explain **Teacher** • Presents ideas and evidence in science • Asks questions • Identifies Misconceptions • Applies scientific methods • Develops experimental models • Provides historical and contemporary examples
8. Tools, Services and Resources	**Tools:** Hardware • Computer • Projector Software • Text, image, audio or video viewer • database • VLE **Resources:** • Figure, graph, slide, problem statement, simulation, experiment, table, self assessment, exercise, questionnaire, exam.

Table 6.1: *Description of the Educational Scenario Template*

3. Examples of educational activity templates

3.1 Galaxy crashes

Name of your Institution: Ellinogermaniki Agogi

Title of the educational scenario template: Inquiry-based teaching – D2.1

Title of your educational scenario: Galaxy Classification and Formation

Educational problem:

Galaxies may be viewed by students to be immutable or even abstract objects. In this scenario students get to "experiment" with galaxies and find out how they are formed and why they have the shapes they do.

Textbook teaching of the subject is inherently limited, due to the dynamic nature of the related processes. Moreover, lack of sophisticated telescopes in schools makes direct observations of galaxies a non-trivial task, to say the least.

This scenario aims to fill these gaps and get students to understand galaxy formation.

Educational scenario objectives:

During this scenario, students will:

1. Learn about the different shapes of galaxies.
2. Learn about the Hubble classification system.
3. Get acquainted with making and studying astronomical observations.
4. Learn about simulations and how they may be used in a scientific context.

Characteristics and needs of students:

Students have limited exposure to stellar objects, these being beyond their range of perception, and limited theoretical knowledge, these being only tangentially treated in the curriculum.

The exercise will also allow students to interact (e.g. by working in pairs) and develop social and collaboration skills, allowing them to see that Science can be a group activity and not only a solitary one. This change of perception may trigger an increased interest in Science in many of them, and possibly a turn to Science careers.

Rationale of the Educational approach and Parameters guaranteeing its implementation:

The activity is designed according to the Inquiry-Based model and it follows a scientific approach. Students are asked to make predictions based on the mater of Galaxy Formation and conduct a research which is supported by indicative question. Based on their research, they are than asked to come up with their own conclusions and compare them to their initial predictions. The whole activity is based on students' creation and observing skills. Students have the opportunity to work with real scientific instruments and simulations of real phenomena and thus develop an understanding of the phenomenon through hands-on activties.

Learning activities:

1. Question-eliciting activities

a. Exhibit curiosity

You may begin your lesson with a presentation of a video or numerous pictures depicting different galaxies. Trigger a small conversation with your class by asking your students what they know about galaxies in general.

You may inform your students about what they will do during this exercise:

- Learn how to classify galaxies
- Study images of galaxies which they will collect themselves using a robotic telescope
- Investigate the origin of the shape of the galaxy they'll observe using simulations.

b. Define Question from current knowledge

During your discussion with students make sure to ask them some of the following questions in order to engage them further and check their background regarding the subject.

1. How do galaxies form?
2. What kind of galaxies are there and how do we classify them?
3. How long does it take for a galaxy to be formulated?
4. How many galaxies are there in the universe?

5. What is a galaxy composed of?
6. What is so special about the centre of galaxies? Why are galactic centres so bright?

2. Active investigation
a. Propose preliminary explanation or hypothesis
Astronomers are able to catalogue galaxies according to their morphology due to the existence of certain classification systems. In order to investigate the origin of these morphologies astronomers use simulations. Students will put themselves in the position of amateur astronomers. Their project includes two main tasks:
a) They will try to classify galaxies according to a classification system
b) They will study the process of their formation using simulations.

a) Show your students pictures of different galaxies and ask them whether they can come up with a classification scheme. Discuss with them their ideas, and try to form a classification system according to their proposals. Make sure that students are keeping notes of their ideas and the classification system they proposed.
After students finalize their predictions, mention the Hubble classification system and ask them whether they are acquainted with it. Discuss with students the Hubble classification system and compare it to the classification system they proposed.

b) Ask your students whether they can imagine how such galaxies are formed. Discuss with them how could these shapes have been created and introduce the central idea of investigating the past of galaxies and the universe in general by creating respective simulations.

b. Plan & conduct simple investigation
After students have made their predictions, in order to prepare for the exercise, ask your students to study the 'Related theory' section of their student's book. You may divide your class into working groups.
Inform your students about the two main tasks of the exercise. In the first part students will be given a copy of the Hubble Tuning Fork worksheet and a set of pictures of different galaxies. Students, divided in groups, will study the morphology of different galaxies and attempt to categorize each of them using their worksheets (Tuning Fork Worksheet.jpg and Students Record.xls).
In the second part students will choose one of the galaxies indicated below and make an observation using a robotic telescope from the DSpace platform. After they retrieve their observation they will study the morphology of the galaxy, classify it and attempt to reproduce its shape using a 'galaxy crash' simulation.
You will be using the DSpace platform in order to perform your observations.

The 'Galaxy Crash' simulation

Students will use the "Galaxy Crash" simulation in order to recreate the shape of the galaxy they have observed with the telescope.
http://burro.astr.cwru.edu/JavaLab/GalCrashWeb/GCSolo.html
During the simulation the students can set several parameters like the inclination of the galaxy, the plane of the galaxy that is perpendicular to the rotation axis, galaxies separation distance (in kiloparsec), the relative masses of the galaxies etc.
After the simulation is initiated the students can get a 3D view of the collision by rotating and zooming the image in the view port.

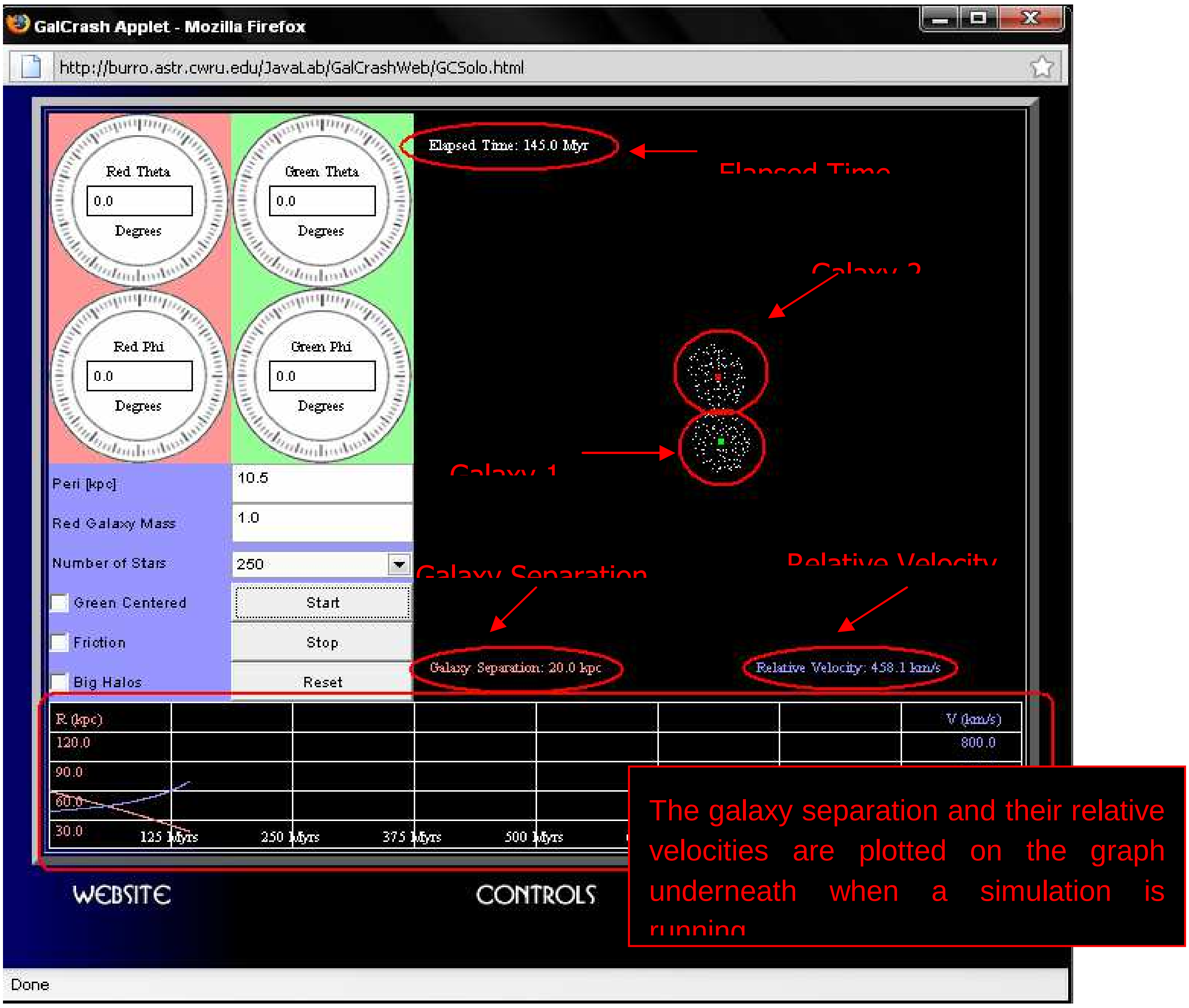


Figure 1. *"Galaxy Crash" simulation (For more information see: http://burro.astr.cwru.edu/JavaLab/GalCrashWeb).*

3. Creation

a. Gather Evidence from observation

As it might take time in order to receive your observation from the robotic telescope, you may perform the observation first.

b. Making the observation

Students may observe one of two the following galaxies:

M51 and its companion, NGC 5195	
Coordinates:	.3:29:53.16, 47:11:48.120
Filter:	Color
Exposure:	180 s

NGC 4038 - The Antennae	
Coordinates:	.2:01:52.68, -18:51:54.00
Filter:	Color
Exposure:	180 s

The information mentioned above is appropriate for making observations using the robotic telescopes of the 'Faulkes Telescopes project' from the DSpace.

In the following steps students study Galaxy Classification systems and learn about Galaxy Formation.

4. Discussion

a. Explanation based on evidence

Ask students to answer the following questions. Students may work in teams as before in order to produce their calculations.

1. How good is the agreement for the classification of each galaxy? Are there some galaxies which are disagreed on more than others?
2. In which class does the galaxy you've observed belongs to? What comments do you have regarding the morphology of the galaxy?
3. Explain which parameters you used for your best model in the simulations you have carried out.
4. How long did it take for this interaction to reach the observed stage?
5. Based on your simulation, describe how the current shape of the galaxy has been formed.
6. Based on your simulation, what do you think will happen to these galaxies in the future?
7. What happens to the relative velocities of the galaxies as they reach their point of closest approach (perigalacticon, or peri for short)?
8. Based on the exercise you performed and on your answers in the previous questions write your report on the given template.

b. Consider other explanations

Ask your students to evaluate the Hubble Galaxy classification.

- Do they believe there should be some extensions to this classification system?
- Do they know of any other classification systems? You may mention the de Vaucouleurs system and ask your students to compare the two systems.(For more information regarding the two systems, see: http://en.wikipedia.org/wiki/Galaxy_morphological_classification)
- Compare the parameters each team used in order to produce the images of the galaxies. Check if all teams have used more or less the same parameters, if not discuss about the different scenarios regarding the formation of the galaxies under investigation.

5. Reflection

a. Communicate explanation

Make an overview of what has been discussed in the classroom during the exercise. You may focus on the following issues:
- Did you face any difficulties when classifying the galaxies from the images provided?
- Can all galaxies be clearly classified using the Hubble classification system?
-Is there need for a more detailed classification system?
- In what way could the classification system be improved?

Furthermore discuss the different shapes of galaxies. You may focus on the following issues:
- What parameters are involved in the shaping of galaxies?
- Why are spiral galaxies more active in terms of star formation?

- How long does it take for a galaxy to form?
- What kind of galaxy is the Milky Way?

Ask your students to present the images they've obtained from their simulations compared to the images from the telescope. Ask students to comment on the similarities and differences between the images. Finally ask your students to comment on the accuracy of the method followed and whether the adaptation of such simulations can in fact produce valuable information for astronomers.

Participating roles:

In this scenario students start by talking about galaxies and what they know about them. After an introduction to the subject they are acquainted with the DSpace platform to learn about galaxy classification and with the *Galaxy crash* simulation to study galaxy formation.

The teacher is a facilitator and guides the students through the process of simulation and experimentation. He/she introduces students to the pertinent concepts, directs them to the problem at hand by asking questions and shows them how to use the DSpace and Galaxy crash tools.

Tools, services and resources:

1. Computers with internet connection and flash
2. DSpace platform

3.2 Conservation of momentum in particle collisions

Name of your Institution: Ellinogermaniki Agogi

Title of the educational scenario template: Inquiry-based teaching

Title of your educational scenario: Conservation of momentum in particle collisions

Educational problem:

Momentum is defined to be the mass of an object multiplied by its velocity. Its **conservation** is a fundamental concept of physics along with the conservation of energy and mass; its 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.

The students will also learn about the structure of matter at a subatomic level, and about the experiments carried out at the Large Hadron Collider at CERN.

Educational scenario objectives:

The scenario helps students understand vectors, how they are added in two dimensions and how conservation of physical quantities represented by vectors (momentum) allows us to infer information about invisible components of an experiment.

Students are introduced to data analysis tools, such as HYPATIA, that display real data from the ATLAS experiment. HYPATIA guides them through the exploration of the experimental data, their analysis and the interpretation of their findings. This procedure starts from the initial design of their activity and progresses through the data acquisition to the presentation of their scientific explanation.

This process, apart from providing knowledge on a particular experiment, exposes students to the scientific method and may provide them with clues as to whether a scientific career might be suitable for them.

Characteristics and needs of students:

The scenario will be an opportunity for students to solve problems of vector algebra, which is substantially different to the scalar algebra they are more usually familiar with. This will be accomplished through interactive tools, which are much more direct than school textbooks.

The exercise will also allow students to interact (e.g. by working in pairs) and develop social and collaboration skills, allowing them to see that Science can be a group activity and not only a solitary one. This change of perception may trigger an increased interest in Science in many of them, and possibly a turn to Science careers.

Rationale of the Educational approach and Parameters guaranteeing its implementation:

This scenario is structured upon the phases prescribed for inquiry-based learning and allows students to make their own discoveries, albeit in a structured and guided way. Thus, during the scenario the students assume the role of the Scientist and gain a first-hand understanding of scientific inquiry.

This is guaranteed by the design of the software, which takes students' needs into consideration. For the implementation of this scenario access to personal computers is assumed.

Learning activities:

6. Question-eliciting activities

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)

Then, students are engaged by scientifically oriented questions imposed by the teacher

a) Does the momentum depend on the direction of the velocity?

b) What is an isolated system?

c) What does "conservation of momentum" really mean?

d) In collisions does the kinetic energy need to be conserved?

e) How are elementary particles classified?

f) When particles collide are new particles created or not?

g) What type of research is performed at CERN?

7. Active investigation

The goal of the exercise is students to learn:

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

to add vectors in 2 dimensions

to apply the conservation of momentum principle

Use of the HYPATIA Analysis Tool

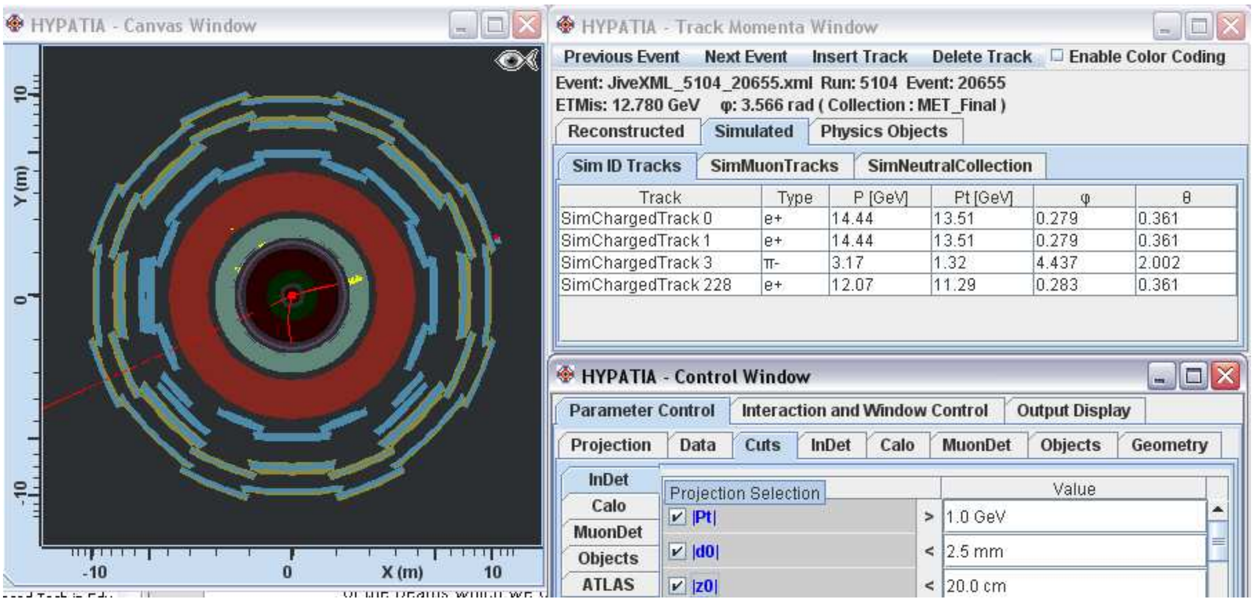
Students will determine the total momentum from all particles tracked and will calculate (magnitude & direction) the missing momentum by applying two different methods of adding vectors (in our case the momentum vectors are lying on the plane perpendicular to the collision axis).

Preparation (HYPATIA)

Read the "Vector analysis" & "Momentum" section in the physics school book

Download the HYPATIA tool from the site: **http://hypatia.phys.uoa.gr/Downloads/**

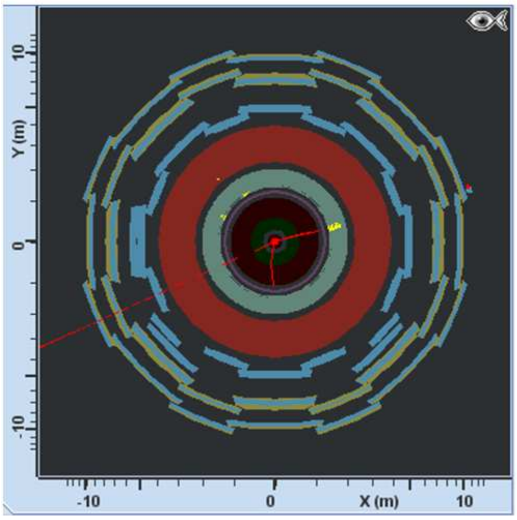
Run HYPATIA and select to view specific track (the ones the teacher has recommended)

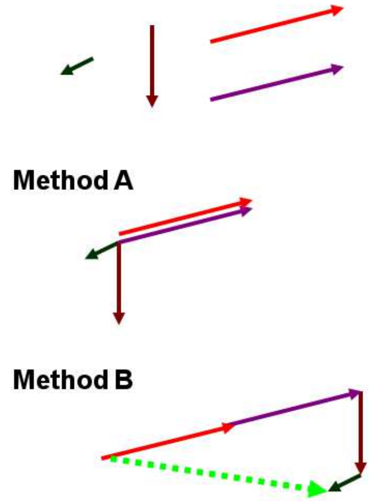


8. Creation using the HYPATIA Analysis Tool

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.





9. Discussion

Each student presents his/her calculations and results about the conservation of momentum. The calculations are compared to the expected results and students calculate their percentage of error.

10. Reflection

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.

Participating roles:

In this scenario are first called to express their ideas on conservation of momentum, in other words to predict how a closed system will predict. At the next step, they will use the HYPATIA tool to find a particle track and measure its angle (i.e. record an observation) and apply the concept of conservation of momentum to predict the direction of missing particles (prediction).

The teacher is a facilitator and does not provide the "right answer". He/she introduces students to the pertinent concepts, and the work carried out at CERN, directs them to the problem at hand by asking questions and shows them how to use the HYPATIA tool. Then he/she allows them to try their own solutions, discussing them with them.

Tools, services and resources:

The scenario requires the use of:

-one PC per 1-3 students and one for the teacher (the PCs should be running the Windows OS, as the software is not yet ready for other operating systems).

-a projector and projector screen so that the students can view the teacher's desktop.

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