Conservation of momentum in particle collisions

Name of the Institution: Ellinogermaniki Agogi

Title of the educational scenario template: Inquiry-based teaching

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Version: 1.0

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:

- **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?

- **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

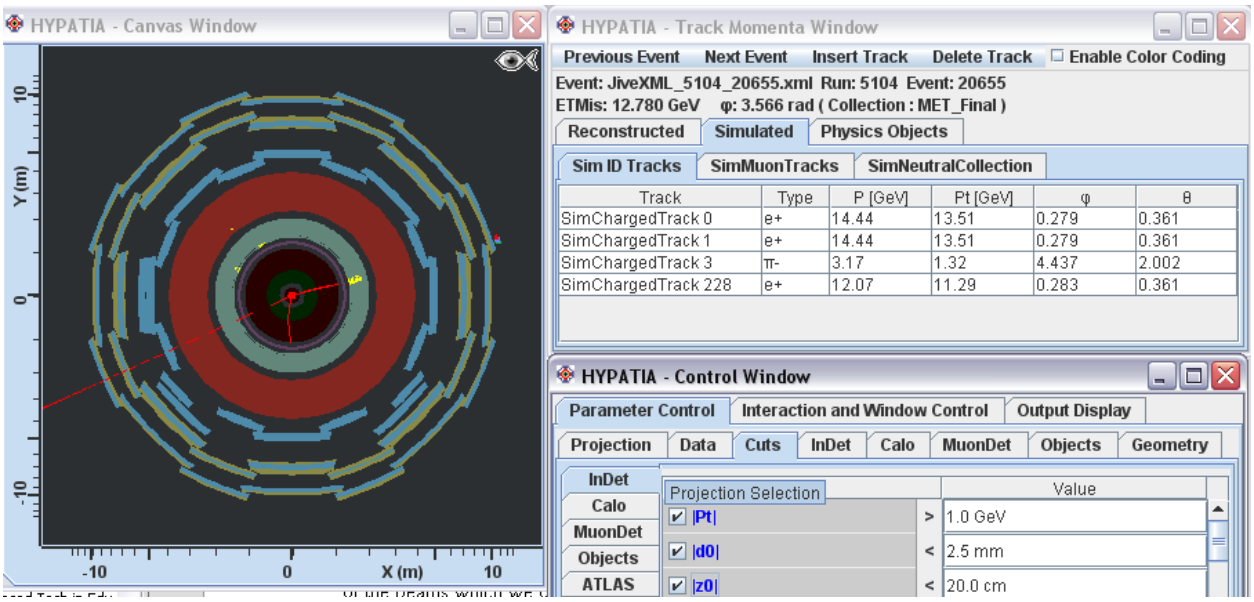
Students will determine the total momentum from all particles tracked and will calculate (magnitude & direction) the missing momentum by applying two different methods of adding vectors (in our case the momentum vectors are lying on the plane perpendicular to the collision axis).

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/**

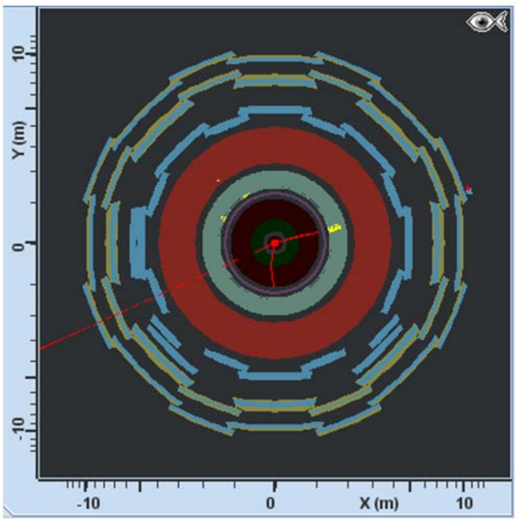
Run HYPATIA and select to view specific track (the ones the teacher has recommended)

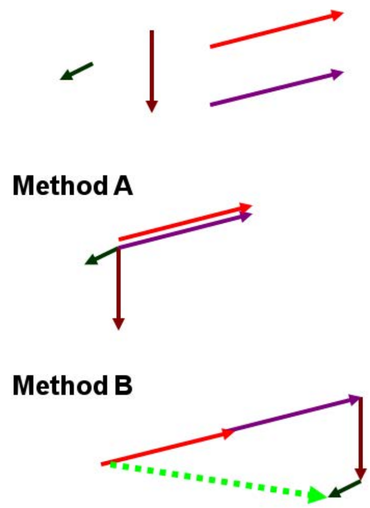


- **Creation using the HYPATIA Analysis Tool**

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.





- **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.

- **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.