ITW2022

Study Groups

FINAL REPORTS

CONTENTS

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Particle Accelerators

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1) Key ideas

In term of relevance, we believe that the first key idea is to pique student's curiosity. Our students need to be curious and ask questions about the world around them. It is important that students build their own knowledge through asking questions (and making searches to grasp the answers) both in student groups as well as in the larger classroom setting with the teacher. Asking questions will induce more involvement into the subjects discussed in the classroom, and in turn a more passionate and accurate research and work to answer those questions, in small group.

It is probably worth to spend a few words, at this point, on students' group. Peter Liljedahl, Professor of Mathematics Education in the Faculty of Education, and an associate member in the Department of Mathematics, at Simon Fraser University in Canada, and author of several books upon the didactics of mathematics at high school, from an age of 12 to 18 years old, has established, based on his studies and class experiences, that three is the right number of students in a class working group, in order that all the students can really profit of the collaborative experience.[1, 2]

Once the teacher will have steered the students' curiosity, to lead them to ask questions about what is the universe made of, what are we made of, and other more structured questions that the teacher itself can inspire, that naturally leads to the understanding that particle accelerators are the tool to get those answers.

This is our second key idea. Particle accelerators, both present ones and future colliders, are needed to answer the questions that we previously have led the students to ask. We need to reach higher and higher energy levels in order to discover the answers of the contemporary big physics questions.

That brings to our next key idea: a variety of accelerators exists (fixed target and beam to beam) and they are all useful and essential. Students should understand the differences and similarities between their working principles: this is also a good mean to show how important is the classical physics studied at high school. Indeed, acceleration, keeping the beam on the chosen trajectory, focusing the particles in the beam in order to obtain a point like beam cross section (useful to increase the probability of proton-proton interaction) are all calculated through the effect of the Electric and Magnetic field on charged particles (that is the Lorentz force).

But it would be a mistake not to draw pupils' attention to the relativistic effect, $E = mc^2$, which is 'the effect' which allows accelerated beams to create new more massive particles when smashed one against another.

It would also be useful, and convenient, and also appealing for our student, to focus on the CERN accelerating system, as it is so large, and its development with time, from the first ProtonSynchroton, in the far 1959 to the latest LHC in 2010, can throw light on the evolution of the accelerating processes and the technological effort required to obtain that. But, we also believe that our student should have a realistic view of the many other machines spread around the world (a research can be suggested to groups of students to cover the different countries).

Lastly, but not less important, we want to address the question of the positive spillover that the technology developed for accelerators has on the daily life. The most relevant to human life is the use for curing cancer: the accelerators allow to target the tumoral cells with a precision not reachable with other tools, and minimizing the distructive effects of healthy cells.

1. Building Thinking Classrooms in Mathematics, Grades K-12: 14 Teaching Practices for Enhancing Learning.
2. https://wipebook.com/blogs/news/building-thinking-classrooms

2) Best practice example

Students need to understand why we need higher energy, and before being told why we had to build more powerful accelerators, they can discover, for the first time in their life, that subatomic particles exist and are all around them via a cloud chamber. This experiment is very attractive in high school and it is not expensive or complicated to build with students. Students can also use the films from bubble chambers for an added activity in order to study particle tracks. Once students experience cloud chambers, bubble chambers, or possible other sources of particle evidence, they can start to realize why we build particle accelerators.

3) Helpful material and resources

1. https://www.youtube.com/watch?v=BEnaEMMAO_s OXFORD SPARKS (https://www.oxfordsparks.ox.ac.uk/)
2. https://www.youtube.com/watch?v=pQhbhpU9Wrg CERN (complete overview, experiments and data taking) lenght 2:52
3. https://www.youtube.com/watch?v=RDdPuL-uOQc CERN (accelerators and related technology) lenght 3:19
4. https://www.youtube.com/watch?v=FLrEghnKncA CERN (accelerator system, very complete, commented) lenght 6:15
5. https://www2.physics.ox.ac.uk/sites/default/files/2012-04-24/accelerate_cheatsheets_all_89230.pdf
UNIVERSITY OF OXFORD (demonstration examples and info sheets for students)
6. https://home.cern/science/accelerators/accelerator-complex/panoramas CERN
(link to a pop-up graphic of CERN Accelerator chain, with 3D tour of each part, both machines and experiments)
7. https://fcc-cdr.web.cern.ch/ CERN (everything you may like to know about future accelerators)

Particle Detectors

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1) Key ideas

When teaching particle detectors to students, the key idea we want to communicate is linked to how scientists work: that *scientists can observe the effects caused by a particle, and from that evidence work out what that particle is*. We have focussed here on the nature of particle detection rather than the technology because we believe that this key idea is core to the nature of science, and in understanding it, students will acquire a deeper understanding of the scientific process. Additionally, once they understand this concept it is easier for them to understand the technology itself – they understand that we are looking for evidence of a particle, not the particle itself. In addition, this helps remove misconceptions such as the idea that particle detectors actually "trap" or "see" the particle.

There are also not many direct links to particle detectors within most curricula, so having the focus being on how science works allows it to be applicable to more classroom and will also benefit the students whether or not they continue with STEM, as it improves their scientific literacy. However, they are some areas which can be linked to particle detectors within the curriculum: see Figure 1 for some examples.

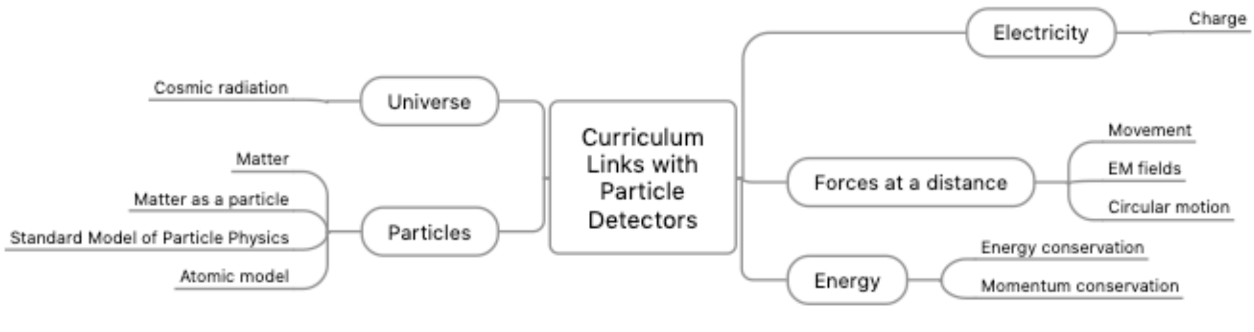


Figure 1: A mind map showing different curriculum links to the topic of particle detectors.

However, to carry out the activity itself, it is important that they do also understand the skeleton of a basic detector. As such, we have decided to use a simplified version of the ATLAS detector, as this is a general detector. We have summarised the key components and what they do in the list below:

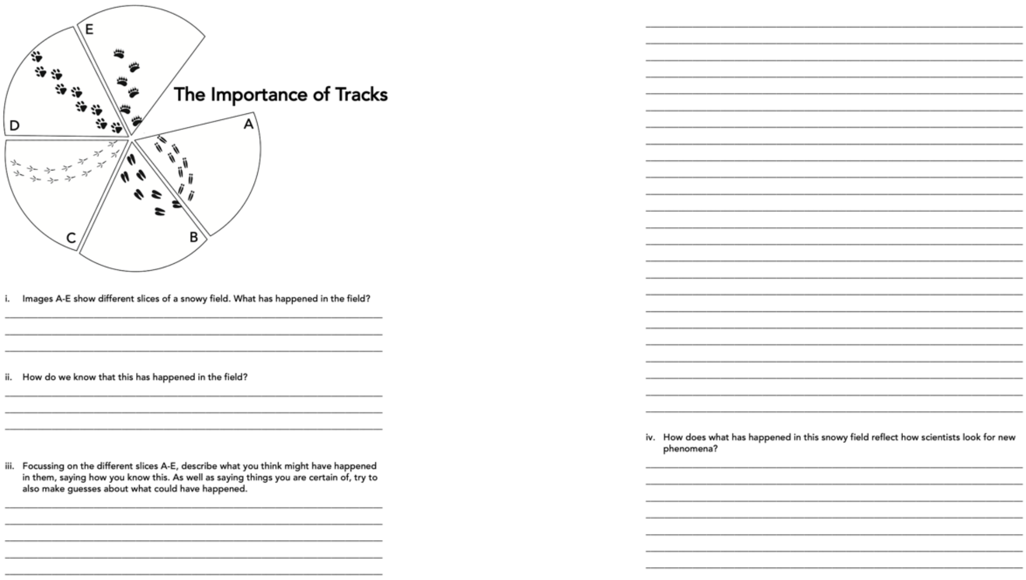
- Inner detector
  - Tracks charged particles.
- Electromagnetic Calorimeter
  - Measures the energies of lightweight or massless particles that interact with the electromagnetic field.
- Hadronic Calorimeter
  - Measures the energies of particles that are hadrons (protons, neutrons, and other composite particles made of quarks).
- Muon Spectrometer
  - Tracks muons

- Magnets
    - Bends the path of charged particles to measure momentum and charge.

This list is a starting point: if teachers wish to add more detail, they can do so using the resources below or others. However, as stated above, we have focussed here on the methodology of detection, and how that links to the process of science, rather than the exact nature of the technology.

2) Best practice example

Before introducing particle detectors to students, it is important to first link in with their current knowledge and understanding of how we detect things in general. This can be done most obviously through linking to tracks and footprints and getting students to realise we can "see" that something has been there without needing to visually see the object or animal itself. An example worksheet of how this could be done can be seen in Figure 1.


The Importance of Tracks

i. Images A-E show different slices of a snowy field. What has happened in the field?

ii. How do we know that this has happened in the field?

iii. Focussing on the different slices A-E, describe what you think might have happened in them, saying how you know this. As well as saying things you are certain of, try to also make guesses about what could have happened.

iv. How does what has happened in this snowy field reflect how scientists look for new phenomena?

Figure 2: An introductory worksheet that gets students thinking about how tracks indicate existence of things.

Once you've introduced the concept of using tracks to detect objects, you can then actually introduce particle detectors. We have put together two different suggestions: one that is a worksheet, suitable for older students, and one that is a physical activity, suitable for younger ones (although adapt as needed for your students – you know your classes best!). In both situations, the detectors are introduced as objects which produce certain "tracks" due to different types of interactions, and then the different sections of those tracks act as clues to work out what the particle is. Whilst this does act as an introduction to particle and detector physics, the key concept that is being communicated and taught is the way scientists use evidence to build up a picture of a phenomenon or thing.

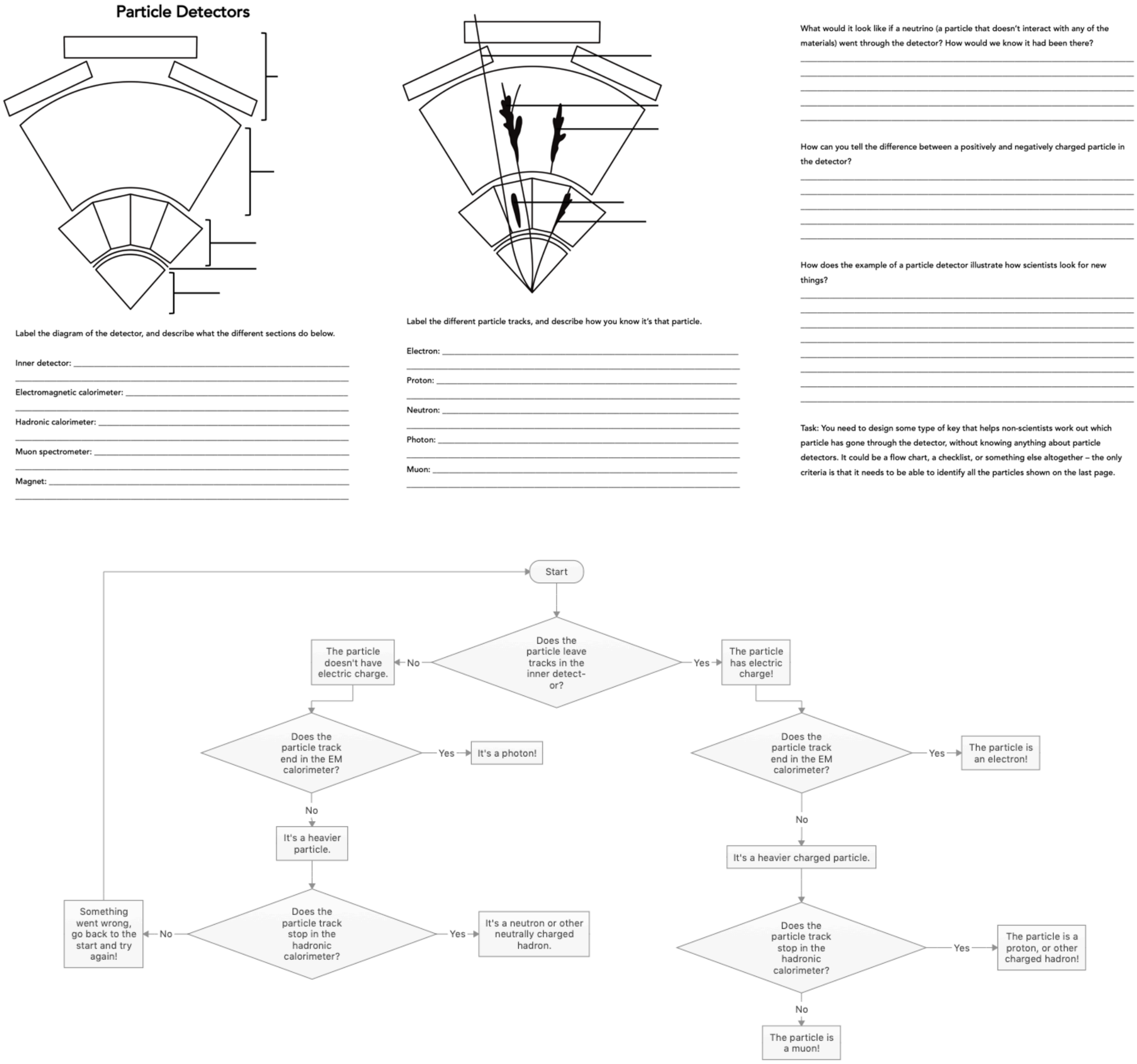


Figure 3: Worksheet-based version of activity, introducing a simplified ATLAS detector and key particle tracks.

A simplified version of the ATLAS detector is used to illustrate the key components of a detector. The worksheet should be accompanied by a short presentation on how the detector works (see section 1 for an outline, which students can use to label and describe the detector. Then, depending on the age and ability of the students, they can either use problem solving to work out which particle is which from the tracks, or can be given a support such as the flowchart to work it out. The questions on the final page stretch and challenge the students to really think about the nature of detection and the techniques we use to differentiate between particles. As an extension, once students have built a key to determine particles, they can attempt to identify particles from actual ATLAS events. An easier version of this is giving them the above key and getting them to use that for identification.

A more simplified, interactive way of teaching the same content involves getting students to act out the roles of matter particles and forces by drawing out a large version of the detector on a playground or classroom floor and getting them to move through it. The different properties of the particles are represented by different accessories worn by the students. The students that represent the parts of the detector either don't interact, leave a track (high five) or deposit energy (hug and stop) with the particle depending on the particle properties. Some examples of this can be seen in Figure 4.

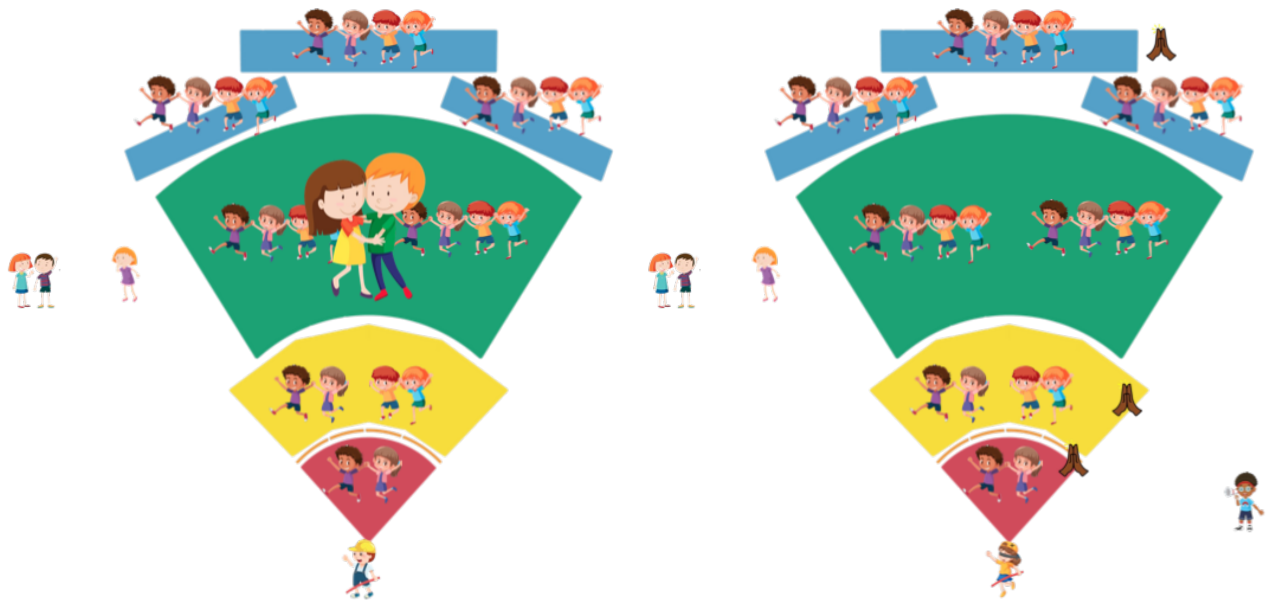


Figure 4: A drawn example of some of the student interactions in the interactive version of the activity.

3) Helpful material and resources

- Parcerisas, D. et al. ADMIRA project: teaching particle physics at high school with Timepix detectors. Phys. Educ. 57, 025018 (2022).
- Perimeter Institute. Beyond the Atom: Remodelling Particle Physics, Second Edition. (2021). https://resources.perimeterinstitute.ca/products/beyond-the-atom-remodelling-particle-physics.
- Keller, O. DIY Particle Detector. (2022).
- CERN. How to make your own cloud chamber. (2015). https://home.cern/news/news/experiments/how-make-your-own-cloud-chamber.
- ATLAS. Hands on Particle Physics. International Physics Masterclasses. (2013). https://atlas.physicsmasterclasses.org/en/wpath_ziele.htm
- CERN. Voyage into the world of atoms. (2018). https://youtu.be/7WhRJV_bAiE.

These are just some starting suggestions, and we highly recommend checking out other resources, especially those created by CERN itself and its experiments.

Computing in Particle Physics

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1) Key ideas in Computing in Particle Physics

There are multiple modes in the computing of particle physics. Opportunities to model and simulate particle physics are important and tangible concepts for students. This leads to a conceptualization and understanding when students graphically express various data sets. Computing particle physics means talking about facilities (CERN), hardware (transistors), software (programming), and data processing. Our curriculums all generally cover the data processing, producing graph and graphical analysis. For particle physics this aspect is the easiest to incorporate in our curriculum.

In general, we were not able to see straight connections to our curriculum. We found out that there were separate subjects to train students in different competences such as programming, physics, technology and computer science.

We have had different experiences and approaches in our individual practices. For example, in Colombia (at the Gimnasio Campestre in Bogota) we have been working with two portable muon detectors designed by MIT (Muon watch detectors), which are used for students in their last year interested in particle physics to register and analyze data. In Spain and Germany, students are often involved in the Masterclass given by CERN in collaboration with other research centers. During this workshop, students interested in particle physics are introduced to simulations, data acquisition and analysis of collision events at CMS and ATLAS. In the case of the USA, students are involved in data acquisition and analysis through projects that are lined up to the interests of the teachers. In the specific case of our group, physics and astronomy are the resources for students to develop these competences.

2) Best practice examples for Computing in Particle Physics

Since we consider the topic to be quite advanced and outside our curricula, we have gathered a list of different resources mostly related to computer science in particle physics, but we have also included some applications that might be interesting to work on other topics which are more commonly studied in our classrooms.

An example on how to use computing in the classroom would relate to astronomy classes, where students use real data to plot redshift data in order to see the acceleration faster than that is calculated by Hubble's Constant at the scales of 200 Mpc. Students determine the red shift from photos, use a spreadsheet program and plot the data obtained. This method of obtaining real data and processing this data is the same process that can be used to see how the Higgs Boson was determined to exist.

In order to continue along the same line, we think CERN's open data offer a great opportunity for our students to develop computing skills and also to be aware of how science works. That's why we have chosen as our main topic the Masterclasses organized by the IPPG (Internacional Particle Physics Outreach Group) and celebrated at different times of the year using CERN's open data. We also suggested replicating the masterclasses in our own classrooms. These masterclasses are appropriate for last year physics students and it is usually the most advanced students who make the most out of it, but we think it could be a good idea for the whole group to experience it. The best way to introduce this activity in our classroom is to do it at the end of the school year, when particle physics content has already been studied in class and the students have a certain level of understanding of particle physics.

The Masterclasses offered by CMS and ATLAS would be both appropriate, but CMS are a bit easier to use in the classroom since they don't require a specific software. For ATLAS Masterclasses it is required to download the MINERVA software.

3) Helpful material and resources for Computing in Particle Physics

The main idea of our resources considering the discussions we have had to promote interdisciplinary projects which will allow students to benefit from integrating different ideas especially in particle physics.

CERN provides our main examples with two different types of Masterclasses we can use in our classes, such as the one involving the experiments such as ATLAS (MINERvA) and CMS. In both cases, students will work interactively while developing their inquiry and argumentative skills, following the scientific method.

There are other resources that may be used in the classroom, that involve both software and educational materials as a source for teachers to expand in particle physics and/or other subjects in their classes. These are listed as follows:

1. MediPix: This corresponds to a TimePix device with Silicon Sensor. It can be used to identify some particles such as neutrons, electrons, etc, and measuring energies. This data can be used for data analysis in the classroom.
2. PhET(Physics Education Technology, University of Colorado): It is a website which offers different teaching resources, including simulations which can be used to develop interactive virtual labs inside the classroom.
3. KiCad (a Cross Platform and Open Source Electronics Design Automation Suite: It is an open source software used for electronics designers which we thought may be used in specific classes such as robotics. Even though it is not directly linked to particle physics, it may be used while discussing and/or designing simple activities for students interested in hardware.

Other types of resources.

We were also able to find other resources that involve quantum physics such as the following game, which mentioned it will will offer a platform for students to learn the basic concepts of Quantum mechanics while playing in an environment designed for it (https://ridhima.design/particle-in-a-box). However, in the online version the game crashes before reaching that point and we were not able to test it. The idea behind this project can be seen as an opportunity to get students and teachers with programming skills and interest for video games involved in the development of instructional material in particle physics. Once this idea is fully developed, it can contain several elements that could lead students to inquire, develop, create and design things, while at the same time develop several of the abilities we want students to gain in our class environment.

- Masterclass particle physics (in German)
  Basics and data evaluation, qualification for CERN – MINERvA – material
- International Masterclass – detectors, theory, MINERvA, other Masterclasses
- CMS master class
  https://cms.cern/interact-with-cms/cms-physics-masterclass
  http://www.i2u2.org/elab/cms/ispy-webgl
  https://www.i2u2.org/elab/cms/cima/ (list of old masterclasses to do in the classroom)
- MINIPIX
- Open source computing Jupyter Notebook
- PhET University of Colorado – Physics (quantum phenomenon), Chemistry
- MINERvA Masterclass (neutrinos)
- KiCad
- Particle in a Box

Medical Applications of Particle Physics

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1) Key ideas

The events that particles experience in medical physics organically organizes the key ideas to be taught as follows: (1) particle production, (2) particle-human body interaction, and (3) particle detection.

1. *Particle production.* How is the particle to be used in the diagnosis or treatment produced? At what energy do they enter the human body?
    a. Kinematics: the motion of the accelerated particles can be described and analyzed using kinematics and kinematic equations.
    b. Electric and kinetic energy: the particles possess electric and kinetic energy which is related to their ability to penetrate the human body.
    c. Magnetic force on charged particles: the Lorentz force is used to guide the particles along a preferred path.
    d. Electric force on charged particles: the electric force is used to accelerate the particles to give them energy before they enter the body.
2. *Particle-human body interaction.* How do these particles interact with human cells, tissues, or organs? What are the safety concerns related to the particles' interaction with the body?
    a. Bragg peak: the graph that describes the loss of energy of a particle that travels through matter shows a peak at the end, the Bragg peak.It shows that most energy is lost at the end of the path of the particle (see figure 1). It is useful because it allows us to concentrate a large part of the power of the beam at a tumor.

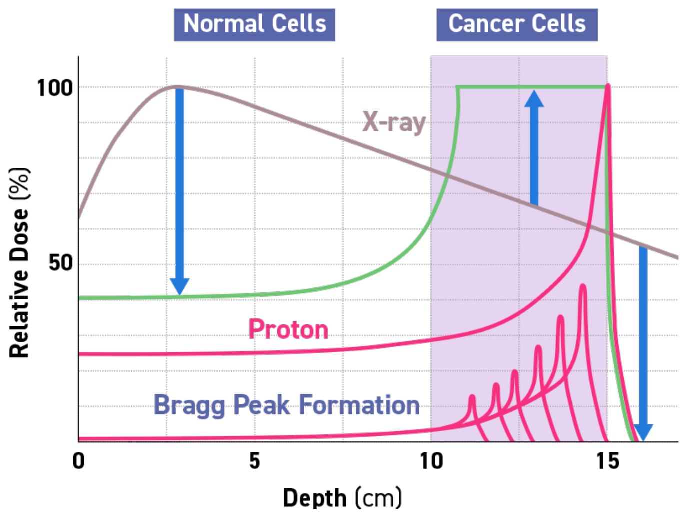


Figure 1: The relative dose of various particles used in radiotherapy at various depths of the human body. Image from Sumitomo Heavy Industries[1].

b. The effects of radiation on human cells, tissues, or organs: the energy from the radiation "*kills cancer cells or slows their growth by damaging their DNA. Cancer cells whose DNA is damaged beyond repair stop dividing or die. When the damaged cells die, they are broken down and removed by the body*[2]" (National Cancer Institute, n.d.). Unfortunately, radiation may also affect the neighboring healthy cells. Hence, scientists and engineers are studying various techniques to focus the radiation only on cancerous cells.

c. Relative dose and the units associated with it. Units that are used are Gray (Gy) and Sievert (Sv). Both are J/kg, but Sv is adjusted for the effect on tissue. The graphic below (figure 2) can be used as a guide

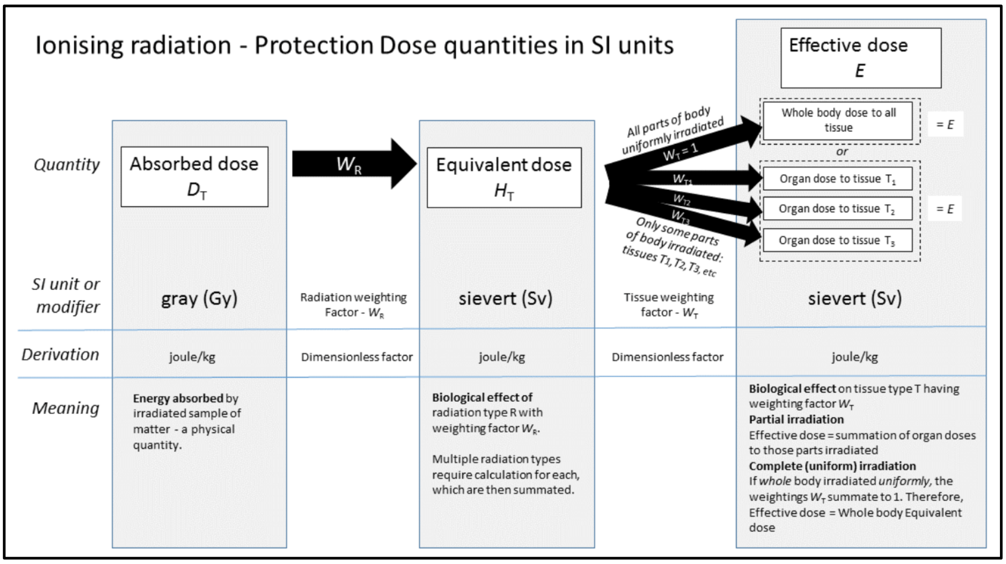
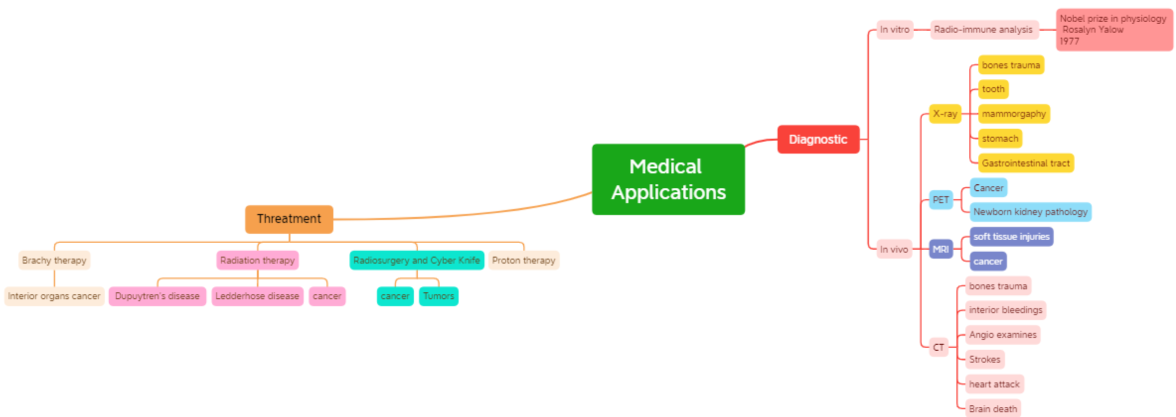


Figure 2: Units of measurement for radiation dose[3]*.*

3. *Particle detection*. What physics, engineering, and/or computer science concepts are required to interpret and visualize the result?
   a. Computer-assisted imaging: computers are used to analyze the emitted particles and make an understandable visualization. Nowadays, these visualizations are in 3D.
   b. Resolution: the ability to distinguish between different tissues. When the resolution is better you can distinguish between two parts of a tissue that are closer.
   c. Multi-modal imaging methods: diagnosis and treatment machines can be placed together to pinpoint the cancer cells and deliver the treatment more accurately.

2) Best practice examples

1. Using a mind map to either begin or summarize the unit or topic on medical applications of particle physics. Below is a sample.



2. In instances where the topic is not a standalone topic or unit, integrations with other topics can be made through examples, word problems, and extensions. Sample integration points are the following:

a. *Energy-mass equivalence*: calculate the energy of the two photons produced by the matter-antimatter interaction.
b. *Alpha particles*: relevance to protons and proton therapy.
c. *Lorentz force*: the magnetic force is used to guide the particles.
d. *Electric charge in a uniform electric field:* the electric field is used to speed up the particles that are used in radiotherapy.
e. *Energy of photons:* compare the energies of photons from different sources to photons for x-ray machines, with a possible segue to dosage and safety.

3. Based on experience, students become more engaged when a topic about the human body is being discussed. A cross-over lesson with a biology teacher is an excellent way to connect the topic in the physics classroom.

3) Helpful material and resources

- YouTube videos
  - How Does a PET Machine Work?
  - How a CT Scan Machine Works
  - What is Proton Therapy?
- Simulations
  - PhET MRI (free)
  - Simulate Linac (paid account to access the simulator feature)
  - Bragg peak calculator
- Lab Activity: model PET Scan Activity: https://aapt.scitation.org/doi/10.1119/1.5033868
- [1]Bragg peak image from: Sumitomo Heavy Industries. (n.d.). Retrieved *from: https://www.shi.co.jp/industrial/en/product/medical/proton-therapy/what-is-proton-therapy.html. Last retrieved: 11 August 2022.*
- [2]National Cancer Institute. (n.d.). Radiation therapy to treat cancer. Retrieved from: https://www.cancer.gov/about-cancer/treatment/types/radiation-therapy. Last retrieved: 11 August 2022.
- [3]Retrieved from: https://en.wikipedia.org/wiki/Gray_(unit). Last retrieved: 11 August 2022.
- Maughan, R. L. (2022, May). Proton therapy delivery: the equipment. Retrived from: https://www.oncolink.org/healthcare-professionals/oncolink-university/proton-therapy-professional-education/oncolink-proton-education-modules/proton-therapy-delivery-the-equipment. Last retrieved: 11 August 2022.

Higgs Physics & Neutrino Physics

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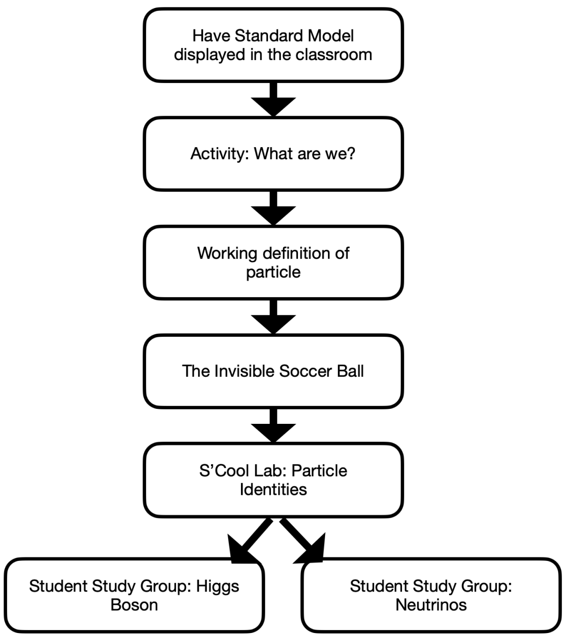
1) Key ideas

Standard Model
- Knowledge of Neutrinos and Higgs is not critical to classical understanding of energy and momentum. It is critical to deeper understanding of "What are we?"
- There is structure beyond the atom
- What is a particle?
- The model that attempts to explain most matter and interactions is The Standard Model
- Neutrinos and Higgs are part of this model.

Higgs Physics
- Mechanism which gives mass to particles
- Needed to complete mathematics of Standard Model
- Your mass is not given to you because of Higgs

Neutrino Physics
- Existence needed to conserve energy and momentum
- Extremely little mass
- Most abundant massive particle
- Mass values still uncertain

2) Best practice example



<u>Standard Model</u>

A basic understanding of the Standard Model and particles is necessary to begin an exploration of neutrinos and Higgs physics. Therefore instruction will focus first on developing a framework.

Having a poster of the Standard Model displayed in the classroom will establish its importance. This is modeled on the idea of the period table being displayed in every chemistry classroom. This can provide a baseline familiarity with the idea that there are more fundamental building blocks of matter than atoms.

Early in the school year we will do an activity to introduce the students to the idea that there are fundamental particles. The students are asked the question: What are we made of? Small group discussion should lead down to at least atoms. Then students will watch the video “What’s The Smallest Thing In The Universe?” to develop a definition of a particle. Then the standard model will be introduced as the organization of all of fundamental particles that explain matter and interactions.

A reading of “The Invisible Soccer Ball” is provided in the helpful resources. This story provides an excellent analogy to how scientists investigate particles which they can not “see” or detect directly. This story first appeared in The God Particle by Leon Lederman and has been edited slightly for clarity and gender inclusivity. This can be read together in class after watching the previous video.

The last part of this instruction will have students use the S’Cool Lab activity Particle Identities to be assigned a particle that fits their personality. Aside from being fun and interesting, this will also bunch students into study groups. These study groups will be assigned to investigate and report on their particles at different times throughout the academic year.

Student Study Groups

At certain points during the school year, students will be asked to work with their similar ‘particles’ to create a short creative presentation that addresses three questions:

- How does the particle relate to what is currently being studied?
- How does the particle fit into the standard model?
- What unanswered questions to scientists have about this particle?

The role of the teacher is to provide resources to the student groups. These resources include readings and online videos. The instructor can also be a resource, but should primarily serve to guide student inquiry. The lack of resources in multiple languages is a challenge to this learning model.

Ultimately, we are not looking for students to be experts. They should be encouraged to convey what they think they understand and what things they could not understand. The teacher can lead discussion after the presentations to establish the key ideas in the proceeding section.

3) Helpful material and resources

Particle Adventure (https://particleadventure.org)

Standard Model Poster (https://sleeplessphysicists.org/)

What’s the smallest thing in the universe? - Jonathan Butterworth (https://www.youtube.com/watch?v=ehHoOYqAT_U)

Particle Identities | S'Cool LAB (https://scoollab.web.cern.ch/particle-identities)

The Invisible Soccer Ball.docx (https://tinyurl.com/2p9dv9u3)

The Higgs Field, explained - Don Lincoln (https://youtu.be/joTKd5j3mzk)

Happy birthday! Ten years of Higgs Bosons – past, present, and future! (https://youtu.be/EWaOzslyvaQ)

Your Mass is NOT From the Higgs Boson (https://youtu.be/Ztc6QPNUqls)

Neutrinos: Nature's Ghosts? (https://youtu.be/J8dRZjOD_ME)

Neutrinos, the Standard Model misfits | symmetry magazine (https://www.symmetrymagazine.org/article/february-2013/neutrinos-the-standard-model-misfits)

iSpy WebGL (https://www.i2u2.org/elab/cms/ispy-webgl/)

Antimatter Research

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1) Key ideas

Curriculum and Classroom Connections

Science teachers play a key role in guiding students to become scientifically literate global citizens and stay away from myths. In order to do this teachers should guide their students and make them aware of the latest discoveries in the field of science. Our visit to CERN is definitely going to help us to take students much ahead of the practiced curriculum and connect them with latest developments in the field of Particle Physics.
So far Antimatter is concerned, the biggest challenge in front of our curriculum designing is to break the myth of Antimatter and make our students understand how Antimatter is useful to us. So far individual teaching practices are concerned, spectrum of hydrogen is commonly taught at high school level across all countries. It is the need of this hour to make our students aware of the spectrum of the Anti-Hydrogen.
ALPHA- which has managed to trap antimatter for more than 16mins has already shown neutrality of Anti-Hydrogen atom. ALPHA has also succeeded in observing a line spectrum of the Anti-Hydrogen atom. However this line does not seem to show any difference from its cousin, that of the spectrum of hydrogen. This result is also in agreement with The Standard Model.
Cyclotrons and Synchrocyclotrons are very commonly taught in the high school Physics curriculum but we often forget to bring their attention towards the very useful decelerators. We must teach our students how useful Antiproton Decelerator ELENA (Extra Low Energy Antiproton) is in study of Antiprotons. In order to collect information about a particle and study its nature its better if it does not move in all directions and hence we need to slow it down and that's how ELENA is useful to us.

Key Ideas

For the first time, British Physicist Paul Dirac came up with the ideas of Antimatter in 1928 when was trying to combine The Special Theory of Relativity and Quantum Theory to explain the nature of electron in microscopic world. The Dirac Equation could have two solutions; just as the equation $x^2 = 4$ can have two possible solutions ($x = 2$ or $x = -2$). The negative value implied for electron with negative energy going back in time. So he reinterpreted his problematic solution to denote a positron with positive energy going forward in time. The equation won Dirac the Nobel Prize in 1933. Four years later in 1932, an Experimental Physicist Carl Anderson proved Dirac right by actually observing positron in cloud chamber. This earned Carl Anderson the Nobel Prize in 1936.
Introducing the ideas of antimatter to the students and convincing them is a big work for teachers. Embedding the concept of Antimatter keeping them from myth is also equally important. It is worth introducing students about particle creation and annihilation to make them realize the importance of Antimatter in the universe. They must also be introduced with the fact that Antimatter is real stuff and is actually manufactured in Antimatter Factory in CERN.
When it comes to addressing the curiosities of the students about Antimatter in class, a teacher should always be open in saying that science is an ongoing process and despite decades of discoveries, what we do not know is more than what we know.

2) Best practice example

Introducing antimatter in classroom is a challenge. When you talk about antimatter with students, they have ideas that essentially come from science-fiction such as Angels & Demons and Star Trek that capture the students' imagination. If we want students learn the real science facts, the lesson will relate to their life. Then we will give a meaningful lesson of the antimatter.
Firstly, we motivate students by using the issue "Bananas are radioactive?" or "Bananas produce antimatter? After that, students discuss their ideas and the learning issue will lead them to research the targeted concepts. Next, teacher provides students with hands-on activities to investigate the concept of antimatter. The following are some questions that may help guide this step:

What is antimatter?
How can we detect antimatter?
How much energy is there in antimatter?
How to use energy from antimatter?

Students could use the helpful material and resources to explain their understanding of concepts and the teacher corrects students' misconceptions. Next, students are encouraged to apply what they have learned to answer "How many bananas would you have to eat in order to die from radiation?" or "Could you build a banana-powered generator?" In this activity, the teacher provides an opportunity for students to discuss and compare their ideas with each other. Finally, the important to make the meaningful lesson is to extend their learning conceptions to explain the situation related to life. For examples: students discuss about the uses of Antimatter or give examples of things that correspond to the concept of annihilation such as noise-canceling headphones, opposite numbers, neutralization reactions, viruses and antidotes, cloning, twins, and etc.

3) Helpful material and resources

(links are embedded in the text)
Teaching Resources/Lesson Ideas

- "Antimatter Matters"
- Open Data for LHCb
- Project instructions
- Masterclass
- S'Cool Lab particle trap
- Angels and Demons response from CERN
- Warp Engines of Star Trek
- Particle Identities Game
- Virtual PET Workshop

Videos: Academic

- Physics Girl
- Minute Physics
- Dr. Don, Fermilab
- Dr. Becky

Videos: Popular Culture

- Angels and Demons: Antimatter Creation
- Angels and Demons: Eyeball
- Warp Core Breach

Our Own Creations

- Our own Survey
- Our own survey in Greek
- Our quiz

Background Information: student conceptions and motivation

- Make it Matter
- A Level Physics Students' Understanding
- Linguistic Accuracy
- Things you might not know about antimatter