Example experiments

Beamline for Schools 2025

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Introduction

In order to succeed in Beamline for Schools (BL4S) you can either propose an experiment yourself or take one of the examples described in this document and work out the details of that experiment. We suggest you to have a look at the proposals of the winning experiments of the previous editions of the competition to understand how detailed you should describe your experiment. One question frequently arising is:

What is a beam and a beamline? In particle physics, the term 'beam' refers to a large number of particles (e.g. photons or protons) moving in the same direction. These particles can be accelerated to high energies. The term 'beamline' commonly refers to a straight section of a particle accelerator leading the particles to an experimental area. You can learn more about the beam and detectors available for your experiments in our Beams & Detectors document

Compare how different materials absorb the beam

1895 Wilhelm Conrad Röntgen discovered that photons with a certain energy (he called them X-rays) can be used to make images of the internal structure of an object. This is because different materials absorb more or less X-ray photons. Later on, physicists realized that other particles (e.g. electrons) can also be used in a similar way. What happens to a beam (e.g. electrons, positrons, or protons) when it passes through a material? If you measure how well different materials absorb different particles, you may be able to learn about the internal structure of an object, even when using other particles than X-ray photons. **Please note:** You can look at solids and liquids, but only non-combustible, non-biological materials can be tested at CERN and DESY.

Build and test your own detector

Design your own detector and calibrate it with a beam at CERN or DESY! A particle detector does not have to be a high-tech device that is beyond the reach of a team of high-school students. In the early days of particle physics, cloud chambers and photographic emulsions were used as particle detectors. Even some electronic detectors are easy to build. You can also test an "every-day life" object as a particle detector. In 2015, one of the two winning teams tried to use a webcam as a detector for other particles than photons. You could also consider building your particle detector following the instructions for "Do-it-yourself" detectors that you can find on the web. For example, you can find tutorials to build a cloud chamber, a silicon detector or even a spark chamber. Other examples of self-made detectors tested by BL4S winners are the Cherenkov detectors of the Italian and Mexican winning teams in 2017 and 2021, or the wire chambers of the Dutch winning team in 2023. Finally, one winning team in 2022, inspired by the functioning principle of cloud and bubble chambers, decided to study whether it is possible to detect particles using supercooled water. The idea was that the supercooled water would change from liquid to solid state when an ionising particle passes through.

Generate your own photons

Photons can have different energies. We can detect photons within a certain energy range with our eyes. These photons are called 'visible light'. You may also know examples of photons with relatively higher energy: 'ultaviolet', 'X-rays' or 'γ'; and photons with relatively lower energy: 'infrared', 'microwave' or 'radio'. Although photons are not part of the beam available for the BL4S experiments, you could generate photons in your experiment! For this you can use the interaction between the beam that is available for BL4S and a target. For example, one of the winning teams in 2021, detected photons, namely X-rays, which are created when charged particles pass from one medium to another with different dielectric properties. Hence, the created photons are called 'transition radiation'. Moreover, a winning team in 2024 detected photons created when charged particles move close to a periodic conductive surface. This is called the Smith-Purcell effect. How can you create and detect photons?

Study different ways to detect photons

Electrons in an atom can only take certain specific values of energy called 'energy levels' of electrons. When a particle passes through a material, it can transfer energy to the material. This energy can be absorbed by the electrons of the atoms. Consequently, the electrons are at higher energy levels. Electrons can get rid of this additional energy by emitting a photon. Certain materials can absorb the energy of ionising particles and emit the absorbed energy in form of photons. These materials are called 'scintillators'. Scintillators are used as particle detectors. When an ionising particle passes through a scintillator, a tiny amount of photons is emitted.

How can we detect these photons? These photons can be converted into an electric signal by a Photo Multiplier Tube (PMT). Such PMTs have been around for more than 80 years and are still indispensable for certain applications. However, there is a new technology based on Silicon. Such Silicon Photo Multipliers (SiPMs) have a number of advantages over traditional PMTs (e.g. cheaper and no need for high voltage) but they also have some disadvantages (e.g. smaller sensitive surface and higher noise level). You could propose an experiment that compares the performance of PMTs and SiPMs to read-out a scintillator.

Explore the world of antimatter

For every particle, there exists a corresponding antiparticle, which has the same mass but the opposite electric charge. For example, the positron (e^+) is the antiparticle of the electron (e^-). The beams at CERN and DESY are composed of accelerated particles (e.g. electrons at DESY and protons at CERN) or their antiparticles (e.g. positrons and anti-protons, respectively). Some of the properties of antimatter have been theoretically predicted but not yet studied in an experiment. Currently, physicists at CERN are conducting experiments to study different properties of antimatter. For example, the effect of gravity on antimatter has recently been studied at CERN. While such experiments are not feasible within the framework of BL4S, you could compare other properties of particles and antiparticles. For example, you could focus on ultra relativistic particles and their antiparticles and observe whether they are absorbed in the same way by a material.

Study neutrons that were freed by spallation

The detectors available for BL4S (scintillators, delay wire chambers, etc.) are not able to detect neutrons because they can only detect electrically charged particles. However, there are dedicated neutron detectors available at CERN. These neutron detectors can be borrowed for BL4S such that you can detect neutrons in your experiment! For example, when an atom is hit by a particle of the beam, a neutron can be freed from the nucleus. This phenomenon is called 'spallation'. You could detect such neutrons. Moreover, you could compare different materials and study how easy it is to free neutrons from the nuclei of different materials via spallation.

Search for new particles

Many theories predict new very weakly interacting particles, which pass through matter almost without any interaction. These particles can be produced by making the beam cross a target and then searching for particles after the target. If you detect a particle after the target that was not in the original beam and that does not come from another known source, this could result from the interaction between the beam and the target. For example, one of the winning teams in 2020 looked at how Δ^+ particles form. Δ^+ particles result from the interaction between an electron of the beam and a proton of the target. Another good example is the experiment proposed by the Canadian winning team in 2017, aiming at detecting particles with a fractional electric charge.

Combine science and art

Although science and art seem to be very different, they are both expressions of the human mind. Moreover, scientists often use terms like "beauty" to describe a theory and artists do "experiments" in order to try out new ideas. Through the Arts at CERN program, CERN tries to bring arts and science closer together. You could think of an experiment that uses particles in an art project. For example, you could represent the particles' traces in a detector in an artistic way. Keep in mind that even though the terms "muon" or "electron" sound so familiar to us and there are many different visualisations of particles, it is not possible for us to see such particles. We have no idea how they look like and it can even be debated if they have any shape or physical appearance at all.

Develop medical applications

You might have heard that beams of particles are used in medicine. For example, photons (X-rays) can be used to diagnose diseases and proton can be used to treat diseases (e.g. certain type of tumours). You could propose an experiment that aims at identifying the best particle type for diagnosing or treating diseases. Keep in mind that you won't be able to use biological/living material. Hence, you have to think about a good approximation of human tissues.

Measure the lifetime of muons

Physicists know for a long time that muons at rest have a mean lifetime of 2.2 microseconds and that they transform into electrons and neutrinos. Hence, measuring the lifetime of muons once more does not advance science but this is not the point of BL4S. What we are looking for is a proposal, written by students, that not only describes how the lifetime of a muon can be measured (hint: you can google this) but that also takes the many difficulties into account that will come along with such an experiment. For example, while we can detect electrons with the detectors available for BL4S, we cannot detect neutrinos with the BL4S detectors. Moreover, you have to cope with noise from the detectors, relativistic effects, an uncertainty regarding the initial momentum of the muons and much more. Hence, a proposal that describes a muon lifetime measurement in detail has as much chance of winning BL4S as an innovative proposal of an experiment that has never been done before. In the same spirit you can propose to repeat other historic experiments.