Example experiments

Beamline for Schools 2026

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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 that you 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

In 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 realised 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 particles other 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 "everyday life" object as a particle detector. In 2015, one of the two winning teams tried to use a webcam as a detector for particles other 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: 'ultraviolet', '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 the 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.

Creating neutral pions

The beam at T9 mostly consists of charged particles as the magnets we have at the beamline cannot steer neutral particles that are produced when protons from Proton Synchrotron hit the primary target. However we can produce neutral particles by introducing a secondary target! By using a graphite target, and bombarding it with protons, positive pions or negative pions should produce neutral pions (0)! However, the lifetime of the 0 is just 85 attoseconds, very very short. They decay almost on the spot. Luckily, the 0 particles will decay into two photons with a huge probability. These two photons get their energy from the mass and the kinetic energy of the 0. The energy of the photons can be measured by lead-glass calorimeters. You can try to infer the very short existence of 0 particles by a measurement of the properties of the photons that originate from their decay.

Explore what happens to the beam

Once a beam has done its duty we have to make sure that it does not cause any dangers to people or the environment. The colliders at CERN are equipped with sophisticated beam dump facilities. In the T9 are a concrete wall absorbs the beam and converts its energy, eventually, to heat. That is the theory. In reality the beam also contains muons that cannot be stopped that easily. These muons are not harmful but it is still interesting to measure how many of them escape from the experimental area. You could design an experiment that tries to detect these muons. How may of them escape from T9 and how sharply is this beam focused? At what distance from T9 can these muons still be detected? How do they compare to the background of cosmic muons?

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.

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 what 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 protons can be used to treat diseases (e.g. certain types 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.