Examples of Experiments suitable for Beamline for Schools competition

Beamline for Schools 2023

Contents

Introduction

In order to succeed in Beamline for Schools you can either propose a creative experiment or idea yourself or take one of the examples and work out the details of that experiment. To understand the level of detail necessary to describe your experiment, we suggest you to have a look at the proposals of the winning experiments of the previous editions of the competition.

Measurement of the beam absorption properties of materials

125 years ago Wilhelm Conrad Röntgen has discovered that certain types of electromagnetic waves (he called them X-rays) can be used to make images of the internal structures of objects because different materials are absorbing these rays in different ways. Later physicists realized that other particles, for example electrons, can be used in a similar way. What happens to an electron, positron, or a proton beam when it crosses matter? If you measure how different materials absorb particles, you may even be able to look inside an object using other particles than X-rays. Please note: You can look at solids and liquids, but only non-combustible, non-biological materials can be tested at CERN and DESY.

Design a magnetic dipole

Many of the large experiments at CERN are using strong magnets to deflect charged particles. This allows to measure their momentum. Magnets can also be used to separate charged particles (e.g. electrons, protons) from neutral particles (i.e. photons). Unfortunately, it is difficult to equip all test beam areas with electromagnets. It is for example the case in the CERN T9 test beam area. To address this issue, you could design an assembly of permanent magnets that is able to deflect the beam. Think about how a magnetic field has to look like in order to bend the trajectory of particles (hint: look at the Lorentz force) and how a mechanical design of such a magnet could look like (hint: Look at Halbach arrays). The magnet has to have an opening of at least 5x5 cm in order for the beam to pass.

Build and test your own detector

Design your own detector and calibrate it with a real beam! A particle detector does not have to be a high-tech device that is beyond the reach of a team of students. In the early days of particle physics, cloud chambers and photographic emulsions have been used as particle detectors. Even some electronic detectors are not that complicated to make. You can think about testing an "every-day life" object as a particle detector. In 2015, one of the two winning teams tried to use a camera's image sensor as a particle detector. You could also consider the possibility to build your particle detector following the instructions for "Do-it-yourself" detectors that you can find on the web. You should find tutorials to build a cloud-chamber, a silicon detector or even a spark chamber. Other examples of home-made detectors tested by BL4S winners are the Cherenkov detectors of the Italian and Mexican winning teams in 2017 and 2021. Finally in 2022, one winning team, inspired by the functioning principle of cloud and bubble chambers, decided to test the state transition between liquid and solid water when the liquid is in the supercooling state to detect particles.

Measurement of the beam composition

From 2019 to 2021 the CERN T9 beamline has been completely rebuilt and improved. It should now be possible to get (almost) pure beams of protons, electrons and muons. We have not yet verified in detail if the different beam configurations have the qualities that our simulations have predicted. You could propose an experiment aiming at looking for undesired particles (such as electrons or muons) in a beam that is supposed to only contain protons. Another example is analysing with high precision the electron content of the beam using devices sensitive to particles that interact primarily electromagnetically with the matter, for instance an electromagnetic calorimeter.

Generate your own photon beam

While we cannot generate a photon beam directly, you could generate photons by using the interaction of the beam with a target. For example, one of the winning teams in 2021, detected the transition radiation, X-Rays photons produced when a beam of charged particles crosses the interface between media having different dielectric properties. How can you detect the photons?

Explore the world of Antimatter

The beams at CERN and DESY can provide accelerated particles of matter (electrons at DESY, protons at CERN), and their anti-matter "twins" (positrons and anti-protons). Some of the properties of antimatter have only been theoretically predicted but never been measured in an experiment. Right now, professional physicists at CERN are preparing experiments to measure the properties of antimatter, for example the effect of gravity on antimatter particles. While such experiments are not feasible within the boundary conditions of BL4S, you could compare the properties of particles and antiparticles, when it comes to the properties of ultra relativistic particles, for example by observing how they are absorbed by a material.

Searching 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 dumping a particle beam onto a target and then searching for particles behind it. If you find a particle that was not in the original beam and that does not come from another known source, this could be the evidence of the product of the interaction between the beam and the target. For example, one of the winning teams in 2020 looked at the formation of the Δ^+ particle: a product of the interaction between an electron from the beam and a proton of the material. 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

Despite being apparently very different, Science and Art are both expressions of the human mind. Scientists often use terms like “beauty” to describe a theory and artists do “experiments” in order to try out new ideas. With the Arts at CERN program we are trying to bring the two sides in closer contact. You could think of an experiment that uses the particle beam for an artistic project. For example, by representing the particle traces in a detector in an artistic way. Keep in mind that even though the terms “proton” or “electron” sound familiar to us, nobody has even seen such a particle and it can even be debated if they have any shape or physical appearance at all.

Medical applications

You might have heard about the use of particle beams in medicine. Indeed, these techniques are spreading because beams of high energy particles are particularly useful to treat certain type of tumours. You could think about an experiment that aims at identifying the best particle type for this type of application. Keep in mind that you won’t be able to use biological/leaving material, hence you have to think about a good approximation of human tissues.