Examples of Experiments suitable for a test beam facility

Beamline for Schools 2022

Note

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.

Contents

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, liquids or gasses but only non-combustible, non-biological materials can be tested at CERN.

Characterization of MicroMegas (or other) particle detectors

Recently, the Beamline for Schools scientists built four state of the art MicroMegas particle detectors (you can find a description in the "beam and detectors" document). Studying them in full is a long ongoing process that requires a series of measurements in a number of conditions. What is the maximum rate of the detectors? What is their spatial resolution? How do the environmental conditions affect their performance? Many more questions are waiting to be answered. Propose a series of measurements at the CERN beam lines that will allow the characterization of the detectors and will expose their limits. This is your chance to drive our continuous R&D efforts. MicroMegas are not the only detectors at your disposal. Feel free to browse the "beam and detectors" document and propose a series of measurements to study any one of them and help us to improve them.

Characterization of MRPC particle detectors

The Pool of detectors of BL4S includes 3 MRPCs (Multigap Resistive Plate Chambers). These chambers are able to detect very precisely at what moment they have been hit by a particle. In combination with a highly accurate clock (we have clocks with a resolution if 25 ps (where 1 ps=10^{-12} s)) a pair of these MRPCs can be used to measure the time that a particle takes to fly a defined distance (e.g. 5 m). From the time and the distance the velocity of the particle can be calculated. This even works for particles moving at the speed of light. In the past we have operated these MRPCs with a mix of two gasses; SF6 and Freon. This mixture is the best solution from the point of view of detector performance but both gasses have a strong greenhouse potential. You could investigate if the MRPCs can alternatively be operated with more environmentally friendly gasses without (much) compromising their performance.

Build and test your own detector

Design your own detector and calibrate it with the beam at CERN! 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.

Measurement of the beam composition of the CERN T9 Beam line

From 2019 to 2021 the 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 electron beam scattering at 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 T9 beamline at CERN can provide accelerated particles of matter (electrons), but also 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 anti-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 2019 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.

Rivisit one of the experiments performed by a former winning team

Since the first edition of BL4S in 2014 a total of 16 teams have won the competition, and each of them has proposed a very interesting experiment. Each experiment, regardless if it was proposed by a team of high school students or professional physicists, answers some questions and raises new ones too. You could study the past winning experiments and think about how they could be improved or modified in order to allow for measurements that go beyond the original experiment.

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 also 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.