Examples for experiments that can be done at the T9 beam line

Example 1: Use a Webcam as a particle detector (2015 winning proposal, Leo4G)

Successful proposals for the Beamline for Schools competition don't have to be complicated to be successful.

The team Leo4G asked a very simple but creative question: *Can a particle beam be photographed with a commercial Webcam?* The CMOS sensors used in such devices are made from silicon. When charged particles cross the image sensor they will ionize the silicon and these charges may be large enough to be detected by the sensor. If a Webcam indeed is able to detect particles if could be used as a low cost detector, for example to observe cosmic radiation in the classroom.

Example 2: Pion decay (2015 winning proposal, Accelerating Africa)

High energetic gamma radiation is a very important tool for many applications in nuclear research but hard two produce. It can be generated by injecting particle beams into magnetic undulators but this requires expensive and complicated devices.

It has been suggested that a crystalline undulator (for example a carbon crystal with boronated layers) could be used to produce "light" in the gamma-ray regime. The team placed their crystal into the beam and tried to align the lattice to the axis of the beam. Behind the crystal, charged particles in the beam were deflected with a magnet while the gamma rays produced in the crystal were detected by calorimeter. The Cherenkov detectors were used to identify positrons (as they were believed to produce the most gamma rays) and a scintillator was used as a trigger.

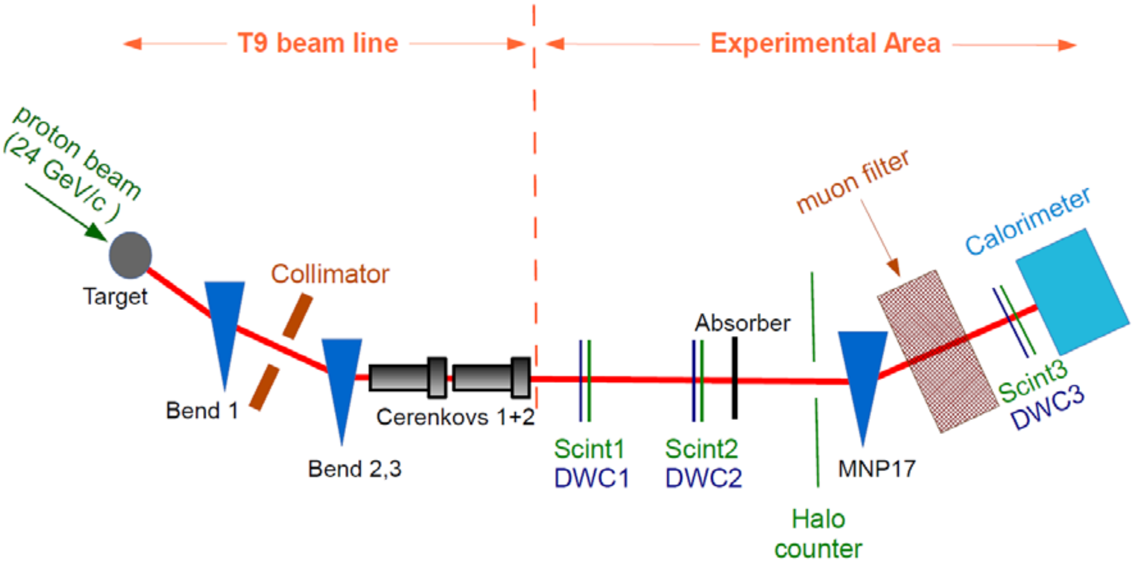
Example 3: Pion decay (2014 winning proposal, Odysseus' Comrades)

The primary PS proton beam hits a target and produces pions. These pions can decay in muons or, with a much lower probability, into electrons. The experiment tries to measure the relative probability for a pion to decay into a muon or electron. It used the Cherenkov counters to identify the pions. The delay wire chambers provided tracking information and the calorimeter measured the energy of the decay electron. Finally the scintillators and halo counters were used as input to the trigger (e.g. to identify muons).

Example 4: Characterisation of a home-made calorimeter (2014 winning proposal, Dominicus College)

The team grew at their school crystals from PH2PO4. For that they had a couple of small containers with saturated solution of PH2PO4 powder in water and put a very small PH2PO4 crystal in this solution. Then they waited and every day rinsed the crystals and containers with water and put new saturated solution in it and put the crystal back. The crystals grew slowly (ideally about 1 cm a week). Once the crystals were ready they mounted them in plastic tubes and connected them to the photomultiplier tubes (PMTs). The PMTs were connected to a high voltage power supply and to an oscilloscope. When a particle hit the crystals the oscilloscope showed a signal. At CERN they placed their calorimeters into the beam. The beam particles were identified and tracked by the other detectors (Cherenkov, scintillator, DWC). That allowed the team to study the response of their calorimeters to known particles. They could show that their calorimeters are able to differentiate between electrons and muons and that they can measure the energy left by these particles with good accuracy.

Example 3: Measure the particle composition of the beam line at various beam momenta



The incoming 24 GeV/c primary proton beam from the PS impinges on a target. The collisions of the protons with the target nuclei provide a variety of particles. The T9 secondary beam line is set up to select the particles of various momenta, between 0.5 and 10 GeV/c. This selection is based on the deflection in the bending magnets (Bends 1-3) and the collimator, and is further refined by quadrupole lenses.

All particles arriving in the experimental area are counted by two scintillators, SCINT 1 and 2, and their directions are measured with two delay wire chambers DWC1 and 2.

Two Cherenkov counters, installed at the beam entrance into the experimental area allow a first particle identification, as they only give a light signal in case the particle velocity is above a certain adjustable threshold, i.e. if the particle mass is below a set value.

A second information can be obtained using a lead absorber that is inserted into the beam. Electrons will lose a large amount of their energy in the lead whereas most of the hadrons cross the absorber essentially unobstructed. The particles that have interacted or undergone hard scattering in the absorber are flagged with a halo counter.

A magnetic spectrometer is installed inside the T9 experimental zone and it consists of the large aperture MNP17 dipole magnet, another delay wire chamber DWC 3 and the scintillator SCINT 3. With this equipment one can analyze the momentum of the particles emerging from the absorber and count the ones that still have the initial momentum (i.e. the hadrons).

Another redundant measurement is provided with an electromagnetic calorimeter. This allows measuring the energy correctly for electrons, but gives a much lower response for the other particles in the beam. This detector thus allows measuring the electron content in the beam when the absorber is removed.

Finally, a muon filter in the form of a massive iron block can be installed on the beam line, just downstream of the MNP17 magnet. All particles except the muons in the beam are absorbed in the Iron. The count rate in Scint3 will thus be a measurement of the muon content of the beam.

Example 5: Measure the Bragg peak

Particle accelerators are used in modern cancer treatment to destroy the tumour with a beam of hadrons (e.g. protons). The energy of these beams has to be adjusted to the location of the tumour, so as little healthy tissue as possible is damaged. Use the beam line to compare the energy deposited by different particles in varying thicknesses of water. Please note that it is not possible to expose any organic material to the beam.

Example 6: Measure beam absorption properties of materials

Find out how many hadrons and electrons survive different materials! Some particles travel through matter and loose only little of their energy and speed, while others are absorbed completely. Please note: Only inorganic materials can be tested at T9.

Example 7: Detect antimatter

Design your own time of flight system and try to find anti-protons!
The different families of particles in a beam can be discriminated by a time-of-flight-detector using their varying masses. The time-of-flight-detector measures the time it takes each particle to travel between two scintillators. This will help you to distinguish electrons (and their anti-particles, the positrons) from protons (and anti-protons).

Then, to separate protons from anti-protons, use a dipole magnet which deflects antiprotons (negative charged particles) and protons (positive charged particles) in opposite directions. Using two tracking detectors, one before and one behind the magnet, tells you which direction the particle track has been bent.

Example 8: Build and test your own detector

Design your own detector and calibrate it with a 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.