The European Organization for Nuclear Research (CERN) studies the smallest components of matter using accelerators, including the Large Hadron Collider (LHC). At the LHC, beams of protons or lead nuclei are accelerated to huge energies and collided head-on inside detectors (including ALICE) to observe new particles produced in this way and interactions between them. Colliding such small objects requires a very precise process of accelerating and controlling the beams. This can be compared to a situation where we want to shoot down a bundle of arrows fired by a group of archers using a similar bundle of arrows fired in the opposite direction by a similar group of archers, only that the “arrows” are much smaller and their velocities are close to the speed of light.

Therefore, the task is challenging and, in practice, it can be achieved only for a few types of atomic nuclei (including protons). In the standard process of preparing a beam for a collision, some particles that deviate from others are absorbed in special barriers called collimators. The project’s objective is to study the possibility of using bent silicon crystals to intercept such particles and direct them to a special fixed target placed inside the ALICE detector. Such a setup will provide the most energetic beam ever collided with a fixed target. Another asset is that the target can be built using virtually any material. Such a unique experimental configuration will produce experimental data to answer some of today’s outstanding questions in particle physics, including physics of quarks and gluons, the quark-gluon plasma, physics of astroparticles and more. Most of these phenomena are not accessible otherwise.

The possibility of using crystals to control the path of particles results from the principles of quantum mechanics but is actually very easy to illustrate. A crystal has an ordered internal structure, in particular it may have a layered structure, where crystal planes are separated from each other with empty space, creating a sort of a railway track. Particles that strike at the crystal follow along the track to leave the crystal without any significant disruption. In addition, the crystal may be bent in the production process, which means that the tracks inside the crystal are bent as well, making it possible to change the particle’s trajectory. The process is very efficient: a crystal a few millimetres long may cause deflections equivalent to the strongest available magnets with the length of several meters.

The study will be done using a special particle tracking simulation code that models the entire machine and calculates trajectories of particles to simulate the actual behaviour of the LHC. The developed machine layout will be optimized to provide a sufficient number of particles impacting the target without affecting the regular operation of the LHC. This will be followed by experimental campaigns to prove the correctness of the proposed system.

Using crystals to control the trajectory of particles is an entirely new technology, and it is not commonly used in accelerators yet. The project would be the first case of using crystals to collide particles with a fixed target inside a detector, which opens up completely new research opportunities and provides important experimental data to extend our knowledge of particle physics.