Popular-scientific summary

To see the components of matter we need to look beyond what our eyes can see. Event most advanced microscopes cannot reveal electrons nor protons. But we will feel their presence when we turn on the light, use phones, or warm ourselves by the sun. Each phenomenon in nature is the result of four basic interactions operating on a dozen, well-known, particles.

Studies of the rules by which matter was created have entered the stage where we create objects that exist in the early stages of the Universe, and whose evolution has led to the current state. The creation of the Universe is considered to happen in so-called "Big-Bang" process, an anomaly in where extremely dense and immense energy became a source of heavy particles and interactions. In the Large Hadron Collider (LHC), we observe a fraction of this energy – in the circular accelerator, protons are accelerated, and in four places the proton beams are collided. The energy created in the collision materializes in the form of, usually several hundred, particles and photons, which are recorded by detectors. Measurements of energy, vertices of production and decays of these particles are used to make conclusions concerning the possible matter constituents and interaction.

The resolution of such measurements increases with protons' energy. The complexity of detectors and methods of analyzing data follows the rise of energy and density of collisions. The most sensitive parts of the detectors (usually the innermost) are under the influence of huge flux of traversing particles and tent to provide the incorrect measurements. Eventually they require replacement. The cost of these devices is very high, so at the design stage, the radiation-hard materials should be selected, what will extend the duration of the detector. But how can you predict how many particles will be created in processes of colliding protons with energy and densities never produced before? To achieve this, the physics models of interactions are being developed, which after each new experiment are updated and verified. As a result, experiments on the LHC could successfully collect data in 2010-2012 (Run I period) and 2015-2019 (Run II) and provided new guidelines for models for the next period, Run III, which will start in 2021.

Physics models usually contain several parameters that describe different physical processes. Some of them, e.g. the production of particles with large momentum and angles relative to protons, are well described by theory (Quantum Chromodynamics, QCD). On the other hand, low-energy particles produced at small angles are only partially recorded by detectors and it is difficult to describe them by one coherent theory. Therefore, this component poses a major threat to detectors – it is less understood and not entirely predictable.

This project aims to estimate how many particles will be produced in proton-proton collisions by the end of Run III data collection period. These calculations are crucial for the prediction of radiation damage in LHCb's silicon detectors. Existing models will be compared to the data and, in case of discrepancies, a new tuning of parameters will be proposed. The LHCb spectrometer provides very good identification of particles in a wide range of momentum, which is unique among the LHC experiments. This allows for the measurement of the flux of specific hadrons, not just total fluency, where the greatest uncertainties occur. The data-driven estimation of fluence is a new approach that enables the online monitoring of effects of radiation damages.

To complete the task, results from previous studies are necessary, such as an inelastic proton-proton cross-section, a very good knowledge of the parameters of the beams and the pattern in which they collide. The results of the project will be used to assess whether detectors will need to be replaced before the end of data collection and whether they work properly. The updated measurements of multiplicities and forward energy flow will also make an important contribution to the projects of new experiments.