MEPhI tests detector prototypes for future experiments at Large Hadron Collider

August 30 2016

The control room of the experiment on testing of new prototypes of transition radiation detector. Credit: National Research Nuclear University

In June and July 2016, a group of young scientists at MEPhI tested detector prototypes for future experiments at the Large Hadron Collider with the participation of colleagues from LPI (Russia), MSU (Russia), the University of Bonn (Germany) and the University of Bari (Italy).

The prototypes should accomplish the division of various particles, including protons and kaons, at energies of several teraelectron volts (TeV). A sharp growth in high-energy particle production in proton collisions on the LHC is connected with increased energy of colliding particle beams. Since 2015, the collision energy on the accelerator has grown up to 13 TeV. Together with the decrease of the interval between collisions, this change should expand the horizons of existing research up to the scale of energies and conditions achievable only during the Big Bang.

Studying physics arising in such extreme conditions, scientists from all over the world hope to answer the most relevant questions from the field of physics of high energies, such as the origin of the dark matter and the existence of supersymmetry and to confirm or dismiss the predictions of the Standard Model, the current theory of particles and fields.

The experiments have strict requirements for measuring equipment. The methods require equipment updates and modification to guarantee high efficiency and productivity during the registration of physical processes. Professor Anatoliy Romaniuk, who has been the Head of MEPhI ATLAS group and ATLAS TRT collaboration for several years, told about the ideas, which are in the basis of TRT and new prototypes:

"ATLAS Transition Radiation Tracker (TRT) is a part of ATLAS inner detector and is aimed at the registration of traces (tracks) of particles, measuring of their impulses and their identification on the basis of transition radiation phenomenon. Transition radiation is the radiation by charged particles of photons (quantums of electromagnetic interaction) at the moment of passing the border between two environments with different refraction indexes. Its peculiarity is that its probability (intensity) is measured in dependence on the Lorentz factor, which is different for particles of different mass and same energy. This peculiarity allows, for example, successfully separate electrons from pi-mesons in ATLAS experiment using the information from TRT. TRT detector, created by employees of our university, doesn't have analogues in the world. Many developments have found application in other international experiments in physics of high energies and astrophysics, where our employees have taken part: transition radiation detector for HERA-B (DESY) experiment, transition radiation detector for TRT

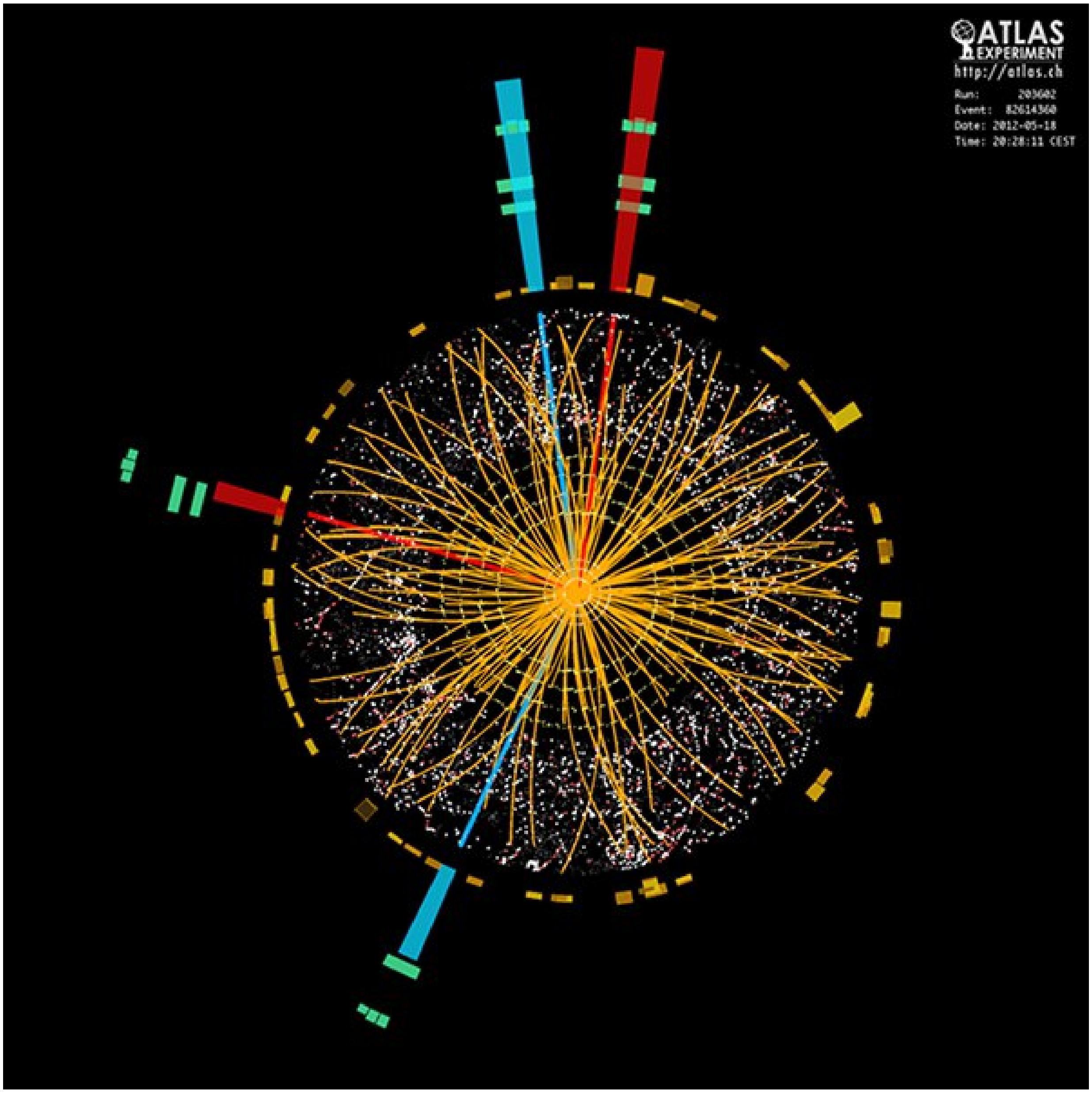
AMS experiment (International Space Station), front tracking detector for ZEUS (DESY) experiment and others.

The experience gained over many years of work will allow to take the next step in the development of transition radiation detectors. Tests with new prototypes researched new concepts of transition radiation detectors, which should allow widen the field of particle identification up to the highest energies, possible on modern accelerators".

Graphic representation of the Higgs boson decay into 4 electrons (red and blue lines), recorded at the ATLAS experiment. In the central part we can clearly see changed TRT (red and white dots) on the tracks of charged particles (orange curves), including tracks on registered electrons.

The scheme of the experiment was described by MEPhI young specialist in detectors 28-year old Konstantin Vorobiev, who has 5 years of work experience at ATLAS.

"The whole facility consists of several parts and includes: Cherenkov counter, used as an input flip-flop, aimed at the identification of electrons and Yukawa mesons; the system of the beam stabilization; gas-pixel set-up; two prototypes of a future gas detector, consisting of the gas discharge tubes (straw set-ups), working on the effect of transition radiation; two transition radiation detectors; system of scintillation units for the adjustment of the beam geometry and the coincidence circuit with an input trigger and, finally, a calorimeter for the division of electrons and pi-mesons on return. The coincidence scheme is a useful tool, signaling, that a particle beam goes through all the elements of the facility. As we can see, there are other elements on the facility, apart from new prototypes, which are able to divide particles according to the type, but they have a smaller efficiency, than tested prototypes, and are used to check the quality of the beam.



Graphic representation of the Higgs boson decay into 4 electrons (red and blue lines), recorded at the ATLAS experiment. In the central part we can clearly see changed TRT (red and white dots) on the tracks of charged particles (orange curves), including tracks on registered electrons. Credit: National Research Nuclear University

The researchers needed to answer the questions:

1. Can transition radiation detectors be used for the identification of particles under extremely high energies?
2. If yes, what should the geometry of the detector and radiator be like?
3. Is there a possibility to use the information about exit angle of transition radiation for the improvement of identification?

They had two prototypes on the basis of straw setups, the assembly of which they started long before the start of the experiments. The main differences of these prototypes are in geometrical peculiarity of the straw position. The main difference is that the signal from the ionizing radiation in one prototype was read summarily in each layer, while in another prototype, the reading happened separately for each straw. The first option allows more precise capture of the projection of particles after radiators and minimizes possible losses of particles that miss the detectors.

The first tests were conducted in the laboratory with radioactive sources. The researchers also had several transition radiation detectors with different geometry. A gas-pixel detector was used to test the possibility of using of information about exit angles of photons for particle identification.

The tests have been conducted with beams of electrons and muons, which come to from the SPS accelerator, which is one of the elements of the LHC accelerator system. The energies have reached hundreds of gigaelectron volts. It's not TeV, but a small mass of electrons and muons allows researchers to study Lorentz factors, which can have protons and kaons under extremely high energies. The researchers had one week for all the tests, which were preceded by a month of installation and equipment assembly.

In the first days, when statistics assembly started, there were a lot of things to do. They needed to tune the equipment, the beam geometry, correct faults of the assembly and perform the calibration of the prototypes.

"Some expected effects could be observed during the early testing of prototypes with the help of an up-to-date system of data collection. After the disassembly of the equipment for the experiment, the prototypes were installed in the laboratory, where there is a system of reading off and recording of the signals from detectors, similar to the one which was on the beam. It can be useful in future interpretation of results." says Konstantin.

Daniil Ponomarenko, a post-graduate student, spoke about the primary processing of data from prototypes: "The long period of preparation of the equipment and software in the lab preceded data assembly. Data acquisition systems play the key role in any experiment. They should meet the requirements of the fault tolerance, stability and the speed of work. The efficiency of the record of chosen events should be close to 100 percent.

"We used software that we inherited from previous research of gaseous mixtures, conducted last year. Then it was necessary to adapt all the programs to the new configuration of detectors and improve the functionality of the interface used by operators. We made the maximum automation of error processing, sending crash reports to the experts, the primary processing of the data and their transfer to the RAID long-term storage. A full cycle of program development has been conducted from concept to testing. The second task was the creation of a simple and clear service for online data tracking for the estimation of its quality.

"The data accumulation was successful, and we met the deadline, which is important in CERN laboratories," said Professor Anatoliy Romaniuk.