Press release

Johannes Gutenberg-Universität Mainz
Dr. Renée Dillinger-Reiter

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After three years: first particle collisions at unprecedented energies at LHC start tomorrow

ATLAS detector more powerful than ever – with major contributions from Mainz University Tomorrow (on July 5th) protons are expected once again colliding with each other at speeds close to that of light in the Large Hadron Collider (LHC) at CERN, also giving physicists of the PRISMA Cluster of Excellence of Johannes Gutenberg University Mainz something to celebrate. Over the last three years, they have made important contributions to the upgrade of the ATLAS detector, ensuring that it can cope with even greater volumes of data during Run 3 of the worlds largest particle accelerator. As a result the researchers hope to gain new insights into the universe of the very smallest particles.

On 22 April, following the more than 36-month maintenance and revamping phase, protons were once more allowed to circulate in the 27-kilometer ring of the LHC – although initially at low energy. The power of the accelerator has been continuously ramped up over the past few weeks, resulting in tomorrows official launch of its physics program. Protons will then be collided at a total energy of 13.6 trillion electron volts (13.6 TeV) – in other words, 6.8 TeV per electron beam.

For Run 3, the LHC team has significantly improved the capability of the accelerator and taken it to the limits of its capacity. The LHC will not only be generating particle collisions at previously unseen levels of energy but there will also be unparalleled numbers of these collisions. The four detectors of the LHC also had to undergo extensive remodeling to ensure they can keep pace with this and be able to process and analyze the correspondingly massively increased flow of data. Among these is the ATLAS detector and physicists based in Mainz played a prominent part in its modification.

Ultrafast electronics made in Mainz

“Our team in Mainz has taken considerable responsibility with regard to the ATLAS experiment at the LHC,” says Prof. Volker Büscher who, together with Prof. Stefan Tapprogge, has been working principally on the so-called ‘trigger’ system. This has a fundamental role in the real-time analysis of data. “In principle, our detector is a gigantic camera that ‘photographs’ many million particle collisions every second,” explains Büscher. But it is impossible to store the data for all these pictures. Instead, the trigger system considers each image and decides, in real time, whether it is of interest or not and thus should be saved or discarded. As the LHC will be generating even greater numbers of particle collisions during Run 3 there will be much more data per second for the new trigger system to process. “The challenge here is to make it possible to sort through more data within a few microseconds without losing interesting physics,” adds Büscher. And this is achieved with the help of fully-automated high-speed electronics. Its logic components employ the very latest innovations and it operates at the very frontier of technology. “In every second, our Mainz system is capable of processing more than 2 terabytes of data – that is equivalent to the information that can be stored on almost 500 DVDs” – something that is hard to imagine.

At the core of the trigger is a device produced in-house in Mainz; six to seven years of effort were required to develop the core electronics components designed to examine the products of the particle collisions. Other components and elements of the trigger system have been contributed by partners from throughout the world – including those based in USA, Sweden and UK. Four members of Büscher's team are currently on-site at CERN in order to commission and calibrate the new trigger electronics and monitor the system during the on-going experiments.

An improved view of muons

Another project in which Mainz-based researchers are involved is the overhaul of the ATLAS muon spectrometer. Muons are heavier 'cousins' of the electron. They are of particular interest to physicists as they are created, for example, during the decay of Higgs bosons. "The construction of the innermost muon detectors in the form of the New Small Wheels (NSW) was one of the most comprehensive tasks of the ATLAS upgrade project. We had to remove the previous Small Wheels from the ATLAS detector and then develop the New Small Wheels," clarifies Prof. Matthias Schott. "There are two NSWs, one on each side of the detector." The NSWs will be using two different detector technologies to process the mass of data produced during Run 3. The various components take the form of eight layers of Micromegas detectors and Small-Strip Thin Gap Chambers (STGCs) with a total active surface area of more than 2,500 m2. Prof. Schott's team at the PRISMA detector laboratory has been participating in the NSW project for years and has constructed more than 100 ultra-planar detector systems that have been successively integrated in the NSW system since 2020. Following the successful assembly of the two NSWs in a large construction hall on the CERN site – a process that took several years – the first NSW was transported to and installed in the ATLAS detector on 15 July 2021, for which it had to be lowered 100 meters into the ATLAS cavern. The second NSW joined the first on 4 November 2021. "This was an absolutely precision job and a masterpiece of logistical planning," points out a delighted Matthias Schott.

New Physics on the horizon?

It was in 2012, during Run 1 of the LHC, that ATLAS, together with another LHC experiment, detected the Higgs boson. "This scientific sensation opened up new possibilities for unraveling the greatest mysteries offered by our universe," recalls Büscher. During Run 2, from 2015 to 2018, the physicists at CERN were able to study the properties of the Higgs boson and test in detail the theory behind the Standard Model of particle physics. While the model does indeed provide a very accurate description of how the natural world is constructed from a few elementary building blocks there are various phenomena it is unable to explain. For instance, it is still unclear what dark matter is made of and why there is so much more matter than antimatter in the universe. The objective during Run 3 of the LHC is to more precisely determine the properties of the Higgs boson and find answers to the above mysteries. These answers may involve new particles and forces that could help solve the dark matter conundrum. The physicists in Mainz are excited about these new possibilities and are looking forward to working with the Run 3 data.

The ATLAS detector

ATLAS (A Toroidal LHC ApparatuS) is the largest particle detector that has ever been integrated in a particle accelerator. It is roughly as tall as a five-story building. The rings of its magnet system are the most prominent feature of ATLAS. It consists of eight 25-meter long superconducting magnetic coils that surround the enclosed beam tube. They generate a ring-shaped, so-called toroidal magnetic field that is used to bend the paths of muons created at the center of the detector barrel. A second magnetic field within the detector is used to measure the momentum of all particles resulting from collisions. More than 3,200 scientists and engineers from 177 institutes and 38 countries are collaborating in the ATLAS experiment. Among these are 18 institutions based in Germany.

contact for scientific information:

Prof. Dr. Volker Büscher
Experimental Particle and Astroparticle Physics (ETAP)
Institute of Physics and PRISMA+ Cluster of Excellence
Johannes Gutenberg University Mainz
55099 Mainz, GERMANY

phone +49 6131 39-20399
E-mail: buescher@uni-mainz.de

Prof. Dr. Matthias Schott
Experimental Particle and Astroparticle Physics (ETAP)
Institute of Physics and PRISMA+ Cluster of Excellence
Johannes Gutenberg University Mainz
55099 Mainz, GERMANY
phone +49 6131 39-25985
E-mail: schottm@uni-mainz.de

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