Media release , 16 July, 2024

Neutrino interaction rates measured at unprecedented energies

A team including researchers from the Laboratory for High Energy Physics at the University of Bern has successfully measured the interaction rates of neutrinos at unprecedented energies using the Large Hadron Collider (LHC) at CERN. A better understanding of these elusive elementary particles can help answer the question of why there is more matter than antimatter in the universe.

Neutrinos are fundamental particles that played an important role in the early phase of the universe. They are key to learn more about the fundamental laws of nature, including how particles acquire mass and why there is more matter than antimatter. Despite being among the most abundant particles in the universe they are very difficult to detect because they pass through matter with almost no interaction. They are therefore often called “ghost particles”. Neutrinos have been known for several decades and were very important for establishing the standard model of particle physics. Nevertheless, most neutrinos studied by physicists so far have been low-energy neutrinos generated in specially constructed facilities.

The FASER International Collaboration, including researchers from the Laboratory for High Energy Physics (LHEP) at the University of Bern, has successfully measured the interaction rates of electron neutrinos and muon neutrinos (two subtypes of neutrinos) with atomic nuclei at the highest energy to date (1 teraelectronvolt or TeV). The measurement was made using the FASERν detector of the FASER experiment, which measures neutrinos produced by particle collisions in the Large Hadron Collider (LHC) at CERN (European Organization for Nuclear Research in Geneva). Notably, this is the first observation of electron neutrinos in an LHC experiment. "This research result is of great importance because the study of neutrinos at such high energies offers the possibility of gaining deeper insights into the fundamental laws of nature, studying rare processes and possibly discovering new physical phenomena," says Akitaka Ariga, particle physicist and head of the FASER group at the Laboratory for High Energy Physics (LHEP) at the University of Bern. The study was published in the journal *Physical Review Letters*.

State-of-the-art forward detection technology

The FASERnu neutrino detector observes high-energy neutrinos produced by proton-proton collisions in the LHC. It is placed underground, 480 meters from the collision point and consists of alternating layers of tungsten plates (with a density comparable to gold) and emulsion films capable of detecting particle tracks with nanometer precision.This 1.1-tonne detector with state-of-the-art technology has been in operation since 2022. "In this study, we analyzed a portion of the data obtained by the FASERν detector in 2022, amounting to 2% of the total data collected so far, so we still have a long way to go," explains Ariga, who is leading the FASERnu project.

Media Relations
Hochschulstrasse 6
3012 Bern
medien@unibe.ch

High-energy neutrinos the key to new physics?
In the FASER experiment, the number of neutrinos detected is to be increased a hundredfold over the next few years, addressing questions about the differences between the three neutrino subtypes and possible unknown forces. The tau neutrino, the third subtype, is difficult to produce and detect at low energies. "The high energy of the FASER experiment makes it possible to generate and study tau neutrinos more efficiently. Little is known about these neutrinos and they could provide new physical insights," remarks Ariga. The FASER experiment will continue to collect data until the end of 2025.

Future experiments, such as the follow-up experiment FASERν2, are expected to collect more than 10,000 times larger amounts of data in order to significantly expand these investigations. In order to one day be able to answer questions such as "Why does the universe consist mainly of matter and only very little antimatter?" or "What is dark matter?", the discovery of previously unknown forces or new particles is essential. "Perhaps we will find 'undiscovered physics' with the high-energy neutrinos," says Ariga.

University of Bern expertise at CERN and Fermilab
CERN is one of the most renowned centers for particle physics and operates the world's most powerful particle accelerator, the LHC. FASER is not the only project of the University of Bern at this major international facility. It was also a founding member of ATLAS, the largest particle detector at the LHC, and continues to play a key role in its operation and further development. At FASER, Akitaka Ariga's research group has also been involved since its conception.

In neutrino research, the University of Bern is also involved in the Deep Underground Neutrino Experiment (DUNE), an international flagship experiment at the Fermilab particle physics research center near Chicago (USA), in which more than 1,000 researchers from over 30 countries are already active and which will generate the most intense neutrino beam in the world.

The FASERnu project in Run 3 has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme and has been supported by the Heising-Simons Foundation and the Simons Foundation.

Publication details:
The FASER Collaboration: *First measurement of ν_e and ν_μ interaction cross sections at the LHC with FASER's emulsion detector*. Physical Review Letters.
DOI: 10.1103/PhysRevLett.133.021802.

Contact:
Prof. Dr. Akitaka Ariga (english)
University of Bern, Laboratory for High Energy Physics (LHEP)
Phone: +41 31 684 46 04
E-Mail: akitaka.ariga@lhep.unibe.ch

Prof. Dr. Michele Weber (german)
University of Bern, Laboratory for High Energy Physics (LHEP)
Phone: +41 31 684 51 46
E-Mail: michele.weber@lhep.unibe.ch

Media Relations
Hochschulstrasse 6
3012 Bern
medien@unibe.ch

University of Bern leading institute of FASERnu neutrino detector

The FASER experiment consists of the FASER detector, which is designed to search for new elementary particles, such as dark matter candidates (dark photons), and the FASERnu neutrino detector. It is looking at collisions happening in the center of the large ATLAS particle detector at CERN's Large Hadron Collider (LHC). A research group led by Michele Weber, Professor of Experimental Particle Physics and Director of the Laboratory for High Energy Physics (LHEP), is involved in the ATLAS detector. Akitaka Ariga's research group has been active in FASER since the design of the experiment. In particular, the Bern group is the leading institute of the FASERnu detector which is collecting data between 2022 and 2025. The FASERnu detector is going to reveal neutrinos' properties with unprecedented sensitivity of all three different kinds (electron, muon and tau neutrinos).

Further information: FASERnu
Further information: ATLAS

The Laboratory for High Energy Physics (LHEP)

The Laboratory for High Energy Physics (LHEP) is a division of the Physics Institute at the University of Bern in Switzerland and is part of the Albert Einstein Center for Fundamental Physics. It conducts research in the field of experimental particle physics, with the main subjects: High-Energy Collider Physics, Neutrino Physics, Fundamental Neutron and Precision Physics, Muon Radiography, Development of Novel Particle Detectors and Medical Applications of Particle Physics.

Further information: https://www.lhep.unibe.ch/

Media Relations
Hochschulstrasse 6
3012 Bern
medien@unibe.ch