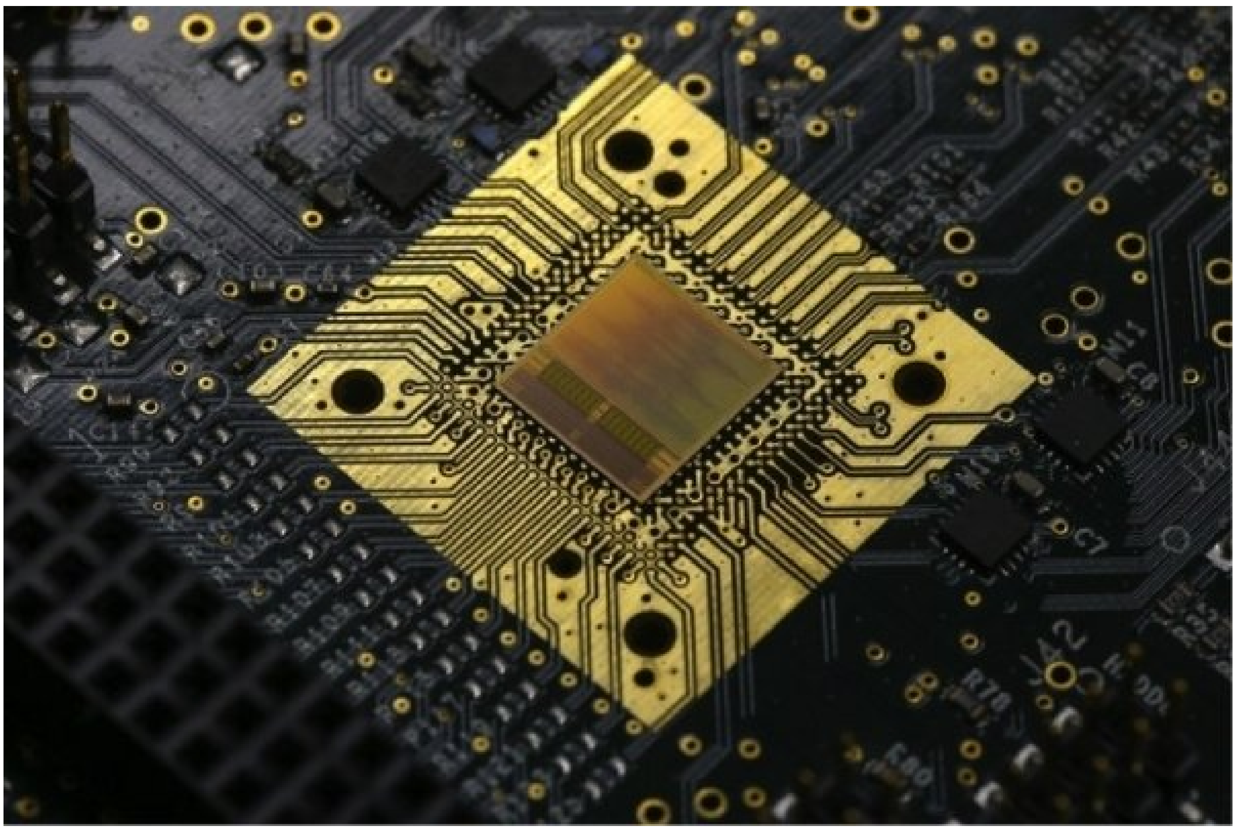
Chip developed by Brazil researchers will be linchpin of LHC upgrade

April 18 2018, by José Tadeu Arantes



The Large Hadron Collider will be entirely upgraded, and ALICE, one of its four major experiments, will be equipped with a new particle detection system comprising 88,000 units of the SAMPA chip. Credit: FAPESP

A Brazilian chip will be used to upgrade the detection system used in A

Large Ion Collider Experiment (ALICE), one of the four major experiments at the Large Hadron Collider (LHC), the world's most powerful particle accelerator, located on the Franco-Swiss border. The chip is called SAMPA and was designed at the University of São Paulo's Engineering School (Poli-USP) in Brazil.

SAMPA has been tested in several countries and analyzed by an international group of experts. It passed with flying colors and received the green light for large-scale fabrication. Taiwan-based TSMC will produce all 88,000 units required to upgrade ALICE.

"The new chips will be used to instrument two of ALICE's detectors: the TPC [Time Projection Chamber] and the MCH [Muon Chamber]," says Munhoz , associate professor with habilitation at USP's Physics Institute (IFUSP) and one of the leading researchers behind the chip's development. "The TPC tracks the charged particles produced in the LHC. The MCH specifically measures muons."

It is worth recalling here that the muon is an elementary particle similar to the electron, also with an electric charge of ?1e and a spin of 1/2, but with 200 times its mass. The muon is classified as a lepton.

The development of SAMPA had the support from the Sao Paulo Research Foundation.

Understanding SAMPA's role in ALICE

Munhoz explained how the TPC works and SAMPA's role in the device. The TPC is ALICE's main detection system. It basically consists of two concentric cylinders, the larger of which is 5 m in length and 5 m in diameter. The region between the two cylinders is closed at both ends and filled with gas. The particle beams that are destined to collide travel along channels inside the smaller cylinder, where the environment is predominantly vacuum.

The ion collisions produce thousands of particles, which pass through the wall of the inner cylinder, ionize the gas atoms, and pass through the outer cylinder before being absorbed.

A large electric potential difference is applied between the closed ends. This knocks electrons off the gas molecules, then the electrons are driven to either end of the cylinder. The positions of the charges are determined, and from these, the paths and nature of the particles produced in the collisions are identified.

To determine the positions of the hits and the incident charge values, the ends of the cylinder are covered with grids comprising more than 500,000 pads or channels. Each set of 32 channels will be instrumented with a SAMPA chip. The MCH works somewhat differently, but the principle is the same.

SAMPA optimizes the process scanning twice the area

"The job done by each chip is to read out the incident charges, transform the readout into a voltage signal, convert the signal from analog to digital, perform internal digital processing, and send the information to external processors," says Munhoz, who coordinates the FAPESP-funded Thematic Project. "All the chips operating together will produce those famous images of collisions showing jets of thousands of particles, each of which follows a specific path."

SAMPA will replace the current generation of chips used in ALICE. In the existing configuration, two chips are needed for each set of 16 channels: one only reads out charges and generates the corresponding voltage signal, while the other converts the analog signal into bits and performs digital preprocessing of the bits. With much more compact electronics, one SAMPA chip will perform both operations and process 32 channels instead of 16.

Once the chips have been produced in Taiwan, they will be tested one by one in Sweden. They will be installed in ALICE in 2019-20, when the entire LHC will undergo an upgrade to increase the rate of collisions between lead nuclei by a factor of 100.

"This itself makes SAMPA necessary because the existing equipment wouldn't be able to handle such a huge increase in the collision rate," Munhoz said. "Today, ALICE is operating at 500 collisions per second. In 2021, it's expected to operate at 50,000 collisions per second. The scientists foresee that this will increase the probability of rare events such as the production of heavier quarks or the formation of light-element anti-nuclei."

The main focus of ALICE is the study of quark-gluon plasma, which is formed when very high levels of energy break the bonds between quarks and gluons so that they are no longer confined in hadrons (protons, neutrons, mesons) and move about freely.

"Two decades ago, no one knew whether such plasma really existed," Munhoz said. "In the mid-2000s, with the first experiments performed at RHIC at Brookhaven National Laboratory in the US, the scientific community became convinced that quark-gluon plasma could be produced in the laboratory. We're now entering a phase of greater precision, in which we're looking for more accurate measurements in order to achieve a deeper understanding of the properties of this plasma. The increased frequency of collisions in the LHC should make this possible."

According to Van Noije, FAPESP's support has been fundamental in bringing the project to fruition. He expects the development of SAMPA in Brazil to effectively contribute to future measurements by ALICE, enabling the international scientific community to obtain much more data and a deeper understanding of the fundamental nature of matter and, by extension, of the universe itself.

Provided by FAPESP