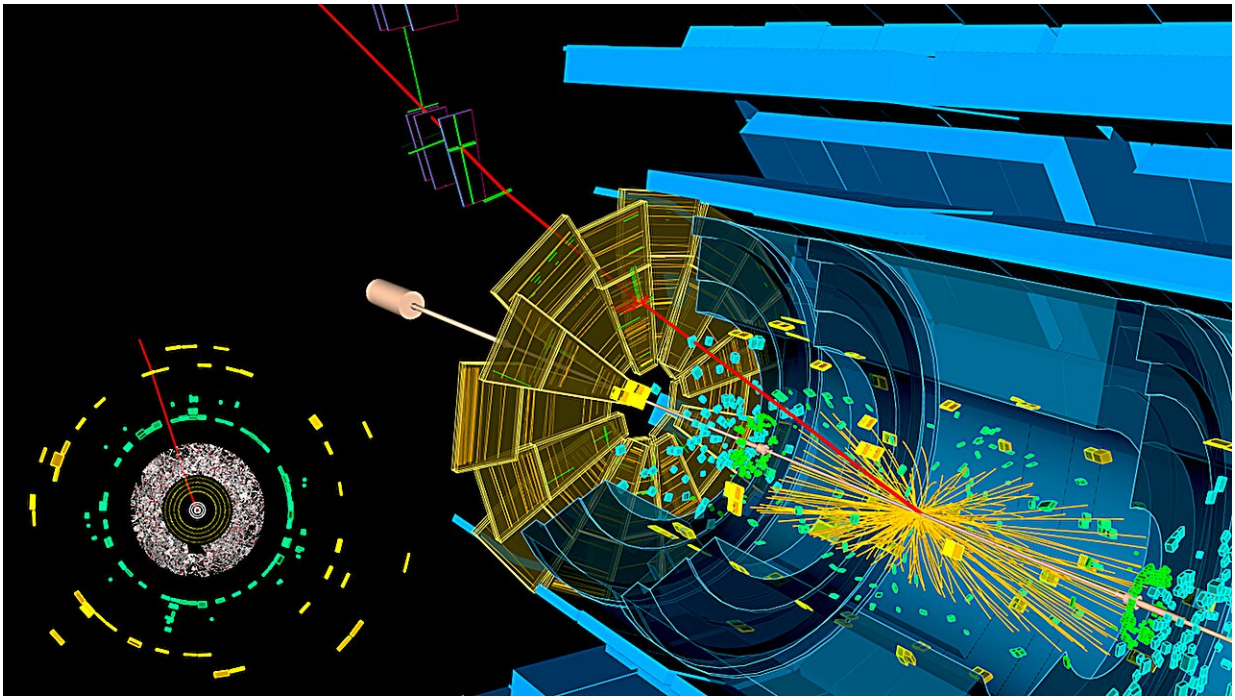
Engineers overcome radiation challenge with custom silicon chips

July 25 2025, by Grant Currin



The team's chip processes information from millions of collisions each second. Credit: ATLAS Experiment 2025 CERN

The Large Hadron Collider (LHC) is tough on electronics. Situated inside a 17-mile-long tunnel that runs in a circle under the border between Switzerland and France, this massive scientific instrument accelerates particles close to the speed of light before smashing them together. The collisions yield tiny maelstroms of particles and energy

that hint at answers to fundamental questions about the building blocks of matter.

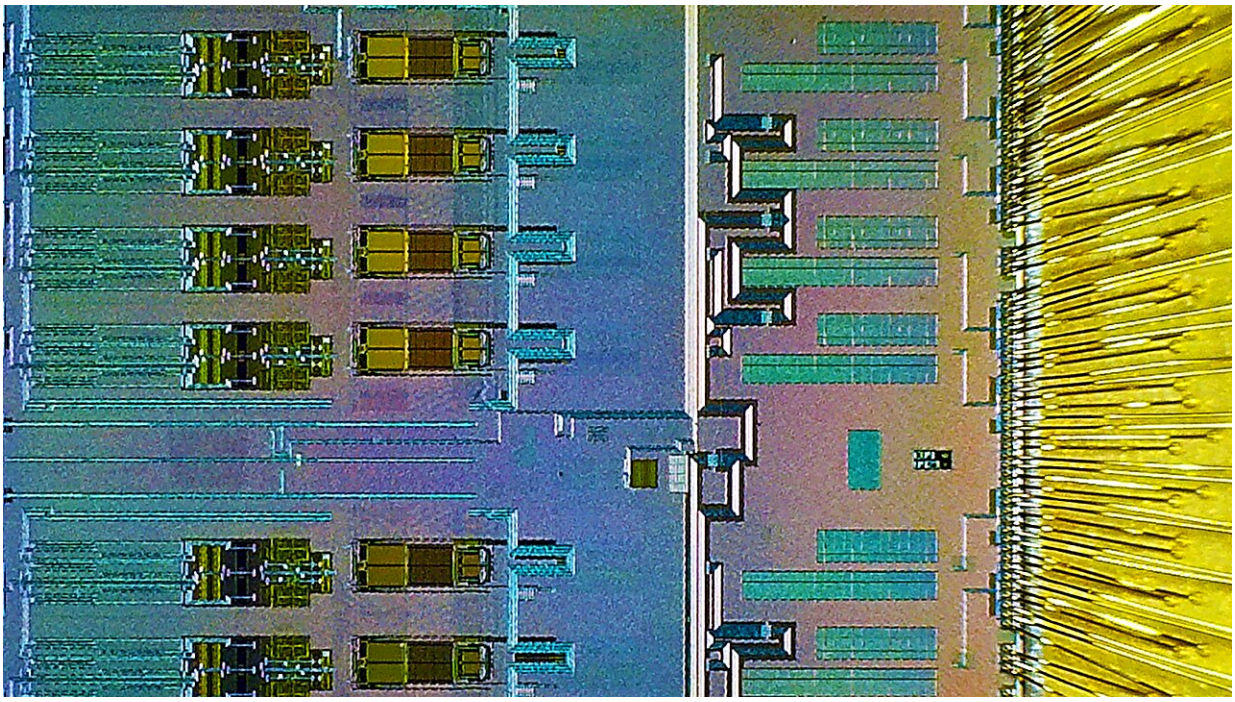
Those collisions produce an enormous amount of data—and enough radiation to scramble the bits and logic inside almost any piece of electronic equipment.

That presents a challenge to CERN's physicists as they attempt to probe deeper into the mysteries of the Higgs boson and other fundamental particles. Off-the-shelf components simply can't survive the harsh conditions inside the accelerator, and the market for radiation-resistant circuits is too small to entice investment from commercial chip manufacturers.

"Industry just couldn't justify the effort, so academia had to step in," according to Peter Kinget, the Bernard J. Lechner Professor of Electrical Engineering at Columbia Engineering. "The next discoveries made with the LHC will be triggered by one Columbia chip and measured by another."

Kinget leads the team that designed specialized silicon chips that collect data in one of the harshest and most important environments in particle physics. Their most recent paper describing this project was published July 1 in the *IEEE Open Journal of the Solid-State Circuits Society.*

"These sort of collaborations between physicists and engineers are very important to advancing our ability to explore fundamental questions about the universe," according to John Parsons, professor of physics at Columbia University and leader of the Columbia team working on the ATLAS detector, one of the LHC's massive instruments. "Developing state-of-the-art instrumentation is crucial to our success."



The latest chip, soon to be installed, precisely digitizes selected signals, capturing details that no existing component could reliably record. Credit: Ray Xu and Peter Kinget

Circuits that resist radiation

The devices the team designed are called analog-to-digital converters, or ADCs. Their task is capturing electrical signals produced by particle collisions inside CERN's detectors and translating them into digital data that researchers can analyze.

In the ATLAS detector, the electrical pulses generated by particle collisions are measured using a device called a liquid argon calorimeter. This enormous vat of ultra-cold argon captures an electronic trace of every particle that passes through. Columbia's ADC chips convert these delicate analog signals into precise digital measurements, capturing

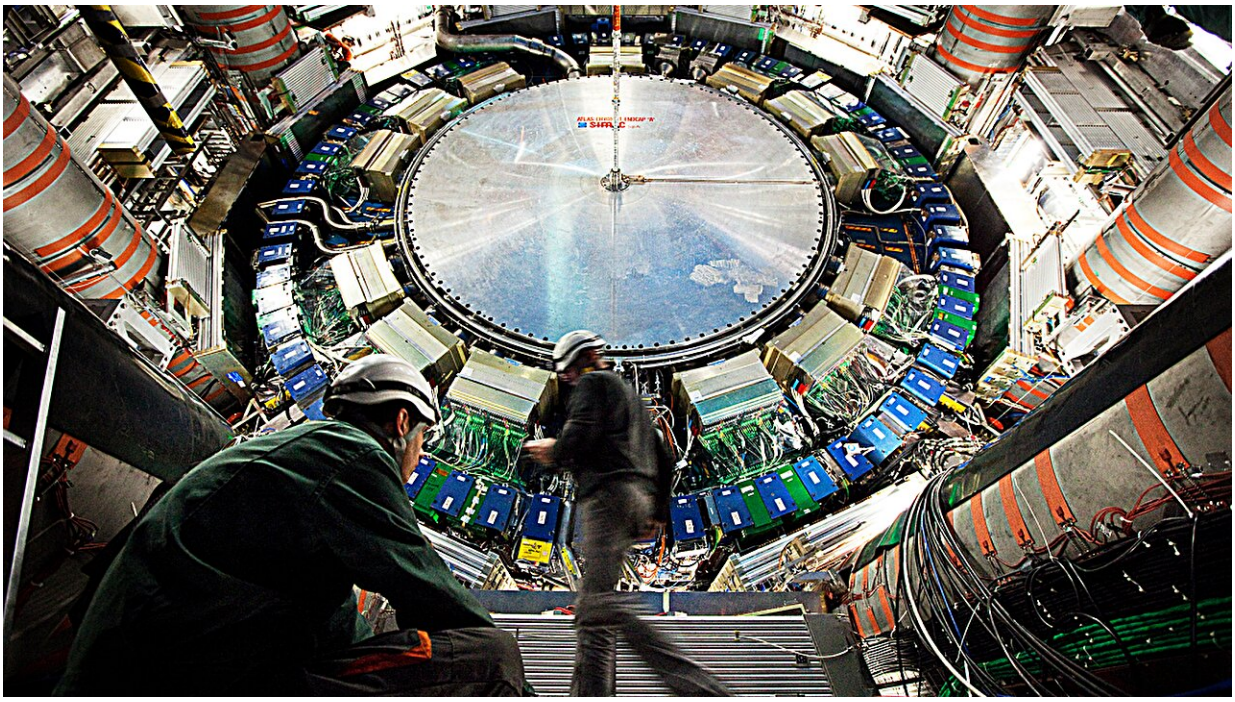
details that no existing component could reliably record.

"We tested standard, commercial components, and they just died. The radiation was too intense," says Rui (Ray) Xu, a Columbia Engineering Ph.D. student who has worked on the project since he was an undergraduate at the University of Texas. "We realized that if we wanted something that worked, we'd have to design it ourselves."

Designing 'high-accuracy' reliability

Instead of creating entirely new manufacturing methods, the team used commercial semiconductor processes validated by CERN for radiation resistance and applied innovative circuit-level techniques. They carefully chose and sized components and arranged circuit architectures and layouts to minimize radiation damage and built digital systems that automatically detect and correct errors in real time. Their resulting design is resilient enough to withstand the unusually severe conditions at LHC for more than a decade.

Two Columbia-designed ADC chips are expected to be integrated into the ATLAS experiment's upgraded electronics. The first, called the trigger ADC, is already operating at CERN. This chip, initially described in 2017 and validated in 2022, enables the trigger system to filter about a billion collisions each second and to instantly select only the most scientifically promising events to record. It serves as a digital gatekeeper deciding what merits deeper investigation.



The Large Hadron Collider's ATLAS detector measures the electrical pulses generated by particle collisions. Its vat of ultra-cold argon captures an electronic trace of every particle that passes through. Credit: 2014 CERN

The second chip, the data acquisition ADC, recently passed its final tests and is now in full production. The chip, which was described in an IEEE paper earlier this year, will be installed as part of the next LHC upgrade. It will very precisely digitize the selected signals, enabling physicists to explore phenomena like the Higgs boson, whose discovery at CERN made headlines in 2012 and led to the Nobel Prize in physics in 2013, but whose exact properties still hold mysteries.

Both chips represent the kind of direct collaboration between fundamental physicists and engineers.

"The opportunity as an engineer to contribute so directly to fundamental

science, is what makes this project special," Xu said.

It further created opportunities to collaborate across multiple institutions. The chips were designed by electrical engineers at Columbia and at the University of Texas, Austin, in close collaboration with physicists at Columbia's Nevis Laboratories and the University of Texas, Austin.

Columbia's chips play a central role in a broader international collaboration coordinated in part by Columbia's Nevis Laboratories. As research at CERN advances, Columbia-designed components will contribute to data acquisition systems that support physicists in analyzing phenomena beyond the current limits of knowledge.

More information: Rui Xu et al, A Radiation-Hard 8-Channel 15-Bit 40-MSPS ADC for the ATLAS Liquid Argon Calorimeter Readout, *IEEE Open Journal of the Solid-State Circuits Society* (2025). DOI: 10.1109/OJSSCS.2025.3573904

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