# Physicists discover new class of pentaquarks

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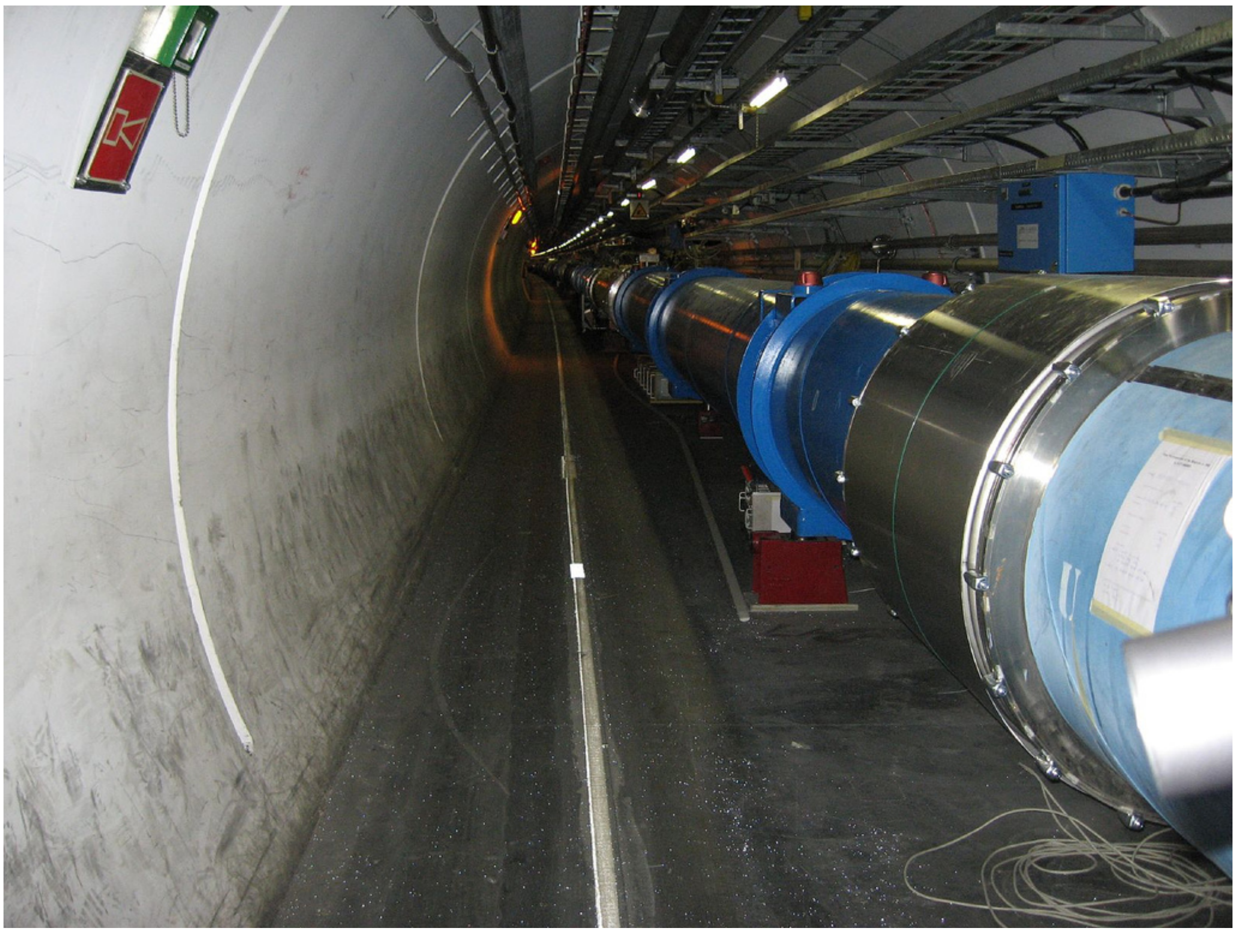

Large Hadron Collider dipole magnets. Credit: CERN

Tomasz Skwarnicki, professor of physics in the College of Arts and Sciences at Syracuse University, has uncovered new information about a class of particles called pentaquarks. His findings could lead to a new understanding of the structure of matter in the universe.

Assisted by Liming Zhang, an associate professor at Tsinghua University in Beijing, Skwarnicki has analyzed data from the Large Hadron Collider beauty (LHCb) experiment at CERN's Large Hadron Collider (LHC) in Switzerland. The experimental physicist has uncovered evidence of three never-before-seen pentaquarks, each divided into two parts.

"Until now, we had thought that a pentaquark was made up of five elementary particles [called quarks], stuck together. Our findings prove otherwise," says Skwarnicki, a Fellow of the American Physical Society.

Skwarnicki is part of a team of researchers, including members of Syracuse's High-Energy Physics (HEP) Group, studying fundamental particles and forces in the Universe. Most of their work takes place at the CERN laboratory, whose LHC is the biggest, most powerful particle detector in the world.

It is within the LHC that protons are flung together at high energies, only to collide with one another. What lies inside the particles, when cracked open, helps scientists probe the mysteries of the fundamental universe.

Studying proton collisions from 2015-18, Skwarnicki has confirmed the existence of substructure within a pentaquark. The giveaway, he says, was a trio of narrow peaks in the LHC kinematic data.

Each peak refers to a particular pentaquark—specifically, one divided into two parts: a baryon, containing three quarks, and a meson, with two quarks.

A peak also suggests resonance, a short-lived phenomenon during particle decay, in which one unstable particle transforms into several others. Resonance happens when protons (a type of baryon) meet—or, more accurately, glide into one another—during an LHC collision.

What is unique about each of these three pentaquarks is that its mass is slightly lower than the sum of its parts—in this case, the masses of the baryon and meson. "The pentaquark didn't decay by its usual easy, fall-apart process," Skwarnicki says. "Instead, it decayed by slowly and laboriously rearranging its quarks, forming a narrow resonance."

Understanding how particles interact with and bind together is Skwarnicki's specialty. In 2015, he and then Ph.D. student Nathan Jurik G'16, Distinguished Professor Sheldon Stone and Zhang made headlines with their role in LHCb's detection of a pentaquark. Theorized a half century earlier, their discovery drew on LHC data from 2011-12.

LHCb's latest data utilized an energy beam that was nearly twice as strong. This method, combined with more refined data-selection criteria, produced a greater range of proton collisions.

"It also gave us 10 times more data and enabled us to observe pentaquark structures more clearly than before," Skwarnicki says. "What we thought was just one pentaquark turned out to be two narrow ones, with little space between them."

The data also revealed a third "companion" pentaquark. "All three pentaquarks had the same pattern—a baryon with a meson substructure. Their masses were below appropriate the baryon-meson thresholds," he adds.

Skwarnicki's discovery occurred relatively fast, considering that LHCb stopped collecting data less than three months ago.

Eric Sedore, associate CIO for infrastructure services in Information

Technology Services (ITS), played a supporting role. His Research Computing Team provided the necessary computer firepower for Skwarnicki to achieve his goals.

In addition to Skwarnicki and Stone, HEP includes Professors Marina Artuso and Steven Blusk and Assistant Professor Matthew Rudolph. The group currently is building an apparatus on campus called the Upstream Tracker (UT), being shipped to and installed at CERN next year as part of a major LHCb upgrade.

"The UT will significantly enhance LHCb, which is composed of about 10 different sub-detectors. I am hopeful that the UT will lead to more discoveries," says Skwarnicki, adding that Artuso and Stone are the UT Project's leader and deputy, respectively.

Skwarnicki is excited about LHCb because it helps explain how the smallest constituents of matter behave. His latest discovery, for instance, proves that pentaquarks are built the same way as protons and neutrons, which are bound together in the nucleus of an atom.

"Pentaquarks may not play a significant role in the matter we are made of," he says, "but their existence may significantly affect our models of the matter found in other parts of the universe, such as neutron stars."

Provided by Syracuse University