ATLAS probes uncharted territory with LHC Run 3 data

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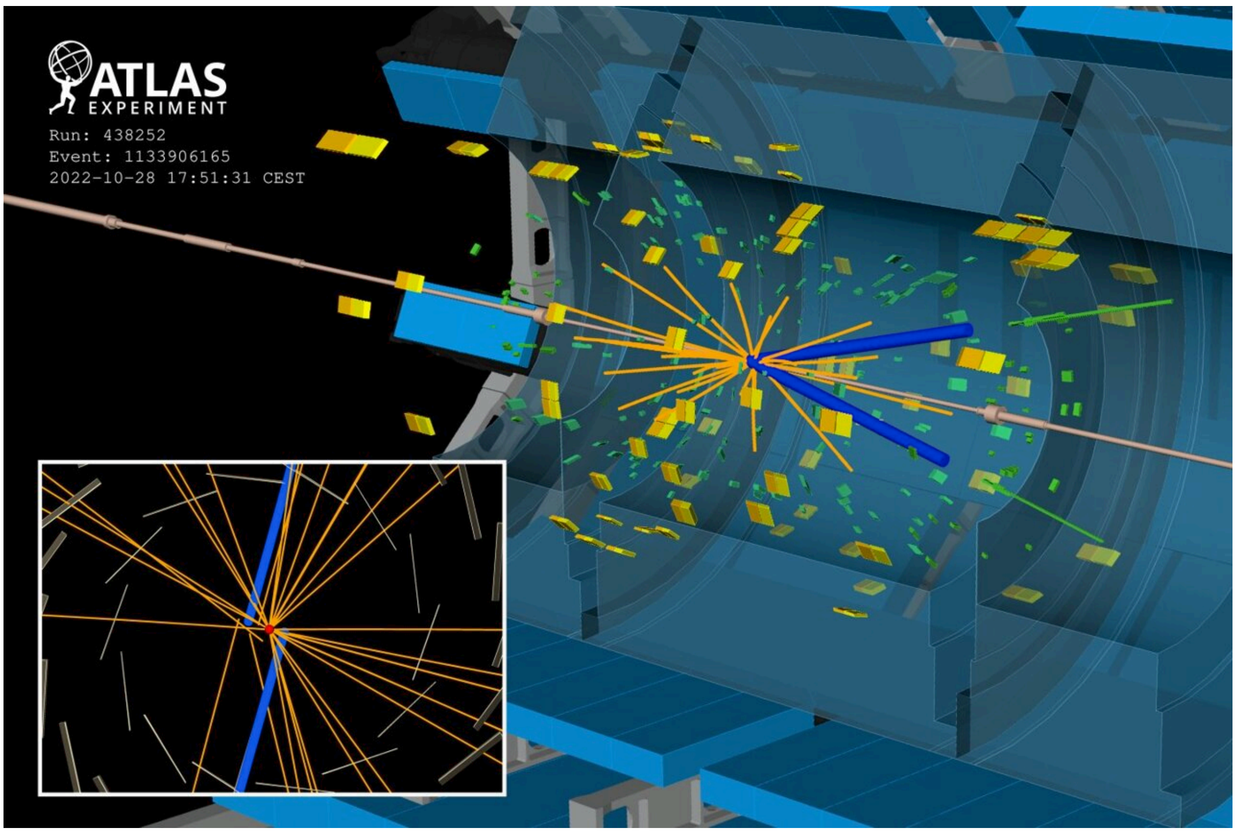

Display of a collision event recorded by the ATLAS detector at an energy of 13.6 TeV, featuring two candidate displaced electrons each represented by a track (blue lines) that points to an energy deposit in the ATLAS calorimeter (green). The inset shows an axial view of the detector, illustrating the electron tracks displaced from the interaction point (red circle) by a few mm. Credit: ATLAS/CERN

Despite its immense success in describing the fundamental building blocks of matter and their interactions, the Standard Model of particle physics is known to be incomplete. Experiments around the globe and in space are therefore searching for signs of new physics phenomena that would guide physicists towards a more comprehensive theory.

At the biannual ICHEP conference, held 17–24 July in Prague, the ATLAS collaboration presented its first results from searches for new physics at record collision energies, targeting magnetic monopoles produced in heavy-ion collisions and long-lived particles created in proton–proton collisions.

Magnetic monopoles are hypothetical particles with only a single north or south pole, making them magnetically charged. Their existence would demonstrate the complete symmetry between electricity and magnetism. It would also confirm aspects of "grand unified theories" beyond the Standard Model that unify the strong, weak and electromagnetic forces at very high energies.

Researchers at the Large Hadron Collider (LHC) are searching for monopoles produced in high-energy collisions. Monopoles would be highly ionizing, meaning they would strip electrons from atoms and would leave behind significant energy deposits in particle detectors.

In a new search for magnetic monopoles, the ATLAS collaboration analyzed its first heavy-ion (lead–lead) collision data from LHC Run 3, which was collected in the autumn of 2023 at an unprecedentedly high energy of 5.36 TeV per pair of nucleons (protons or neutrons).

Specifically, ATLAS researchers looked at ultraperipheral collisions, in which the ions do not collide centrally via the short-ranged strong interaction, but instead pass by close enough to interact through the weaker but long-ranged electromagnetic force. Collisions among lead ions can produce the largest magnetic fields in the universe, with strength up to 10^{16} Tesla.

If a pair of magnetic monopoles was produced in such interactions, it would be the sole particle system to be found in an otherwise empty detector, and it would manifest itself as a concentrated cloud of ionization electrons. Looking for the unique signal features and analyzing backgrounds that could mimic them, ATLAS saw no signs of monopoles in their Run 3 heavy-ion data.

Consequently, the result sets the world's best limits on the production rate of monopoles created in ultraperipheral heavy-ion collisions for monopole masses below 120 GeV. Moreover, this analysis introduces a methodology for studying highly ionizing particles in heavy-ion data from the LHC and beyond.

Most searches for new physics look for new particles that would decay "promptly" and produce decay products that emanate from the LHC's proton–proton interaction points.

However, beyond-the-Standard-Model physics theories, including supersymmetry, also predict "long-lived particles" that would produce decay products away from the interaction point. Such particles require dedicated techniques to reconstruct particle tracks and may have eluded detection in prior searches.

ATLAS has released the result of a new search for a pair of long-lived particles, each of which decays into an electron, muon or tau lepton, resulting in two particle tracks that are "displaced" from the ATLAS interaction point—a rare signature that could be indicative of new physics.

In particular, ATLAS looked for a new signature where one of the long-lived particles travels far enough before decaying so that only a single electron is detected.

This is the first ATLAS search of this type using the 13.6 TeV proton–proton collision data from LHC's Run 3. In preparation of Run 3, ATLAS researchers had enhanced the online collision-event selection—the "trigger"—with the reconstruction of displaced tracks, which enabled the present search for new long-lived particles.

The event yields in all search regions matched Standard-Model expectations. These results set the strictest limits yet on the long-lived supersymmetric partners of electrons, muons, and tau leptons.

With more data from the LHC and its future upgrade, the High-Luminosity LHC, ATLAS physicists will continue their quest to find long-lived particles, magnetic monopoles and other hypothetical particles—all while further refining their search techniques and developing new experimental strategies.

Provided by CERN