ATLAS experiment sets strong constraints on supersymmetric dark matter

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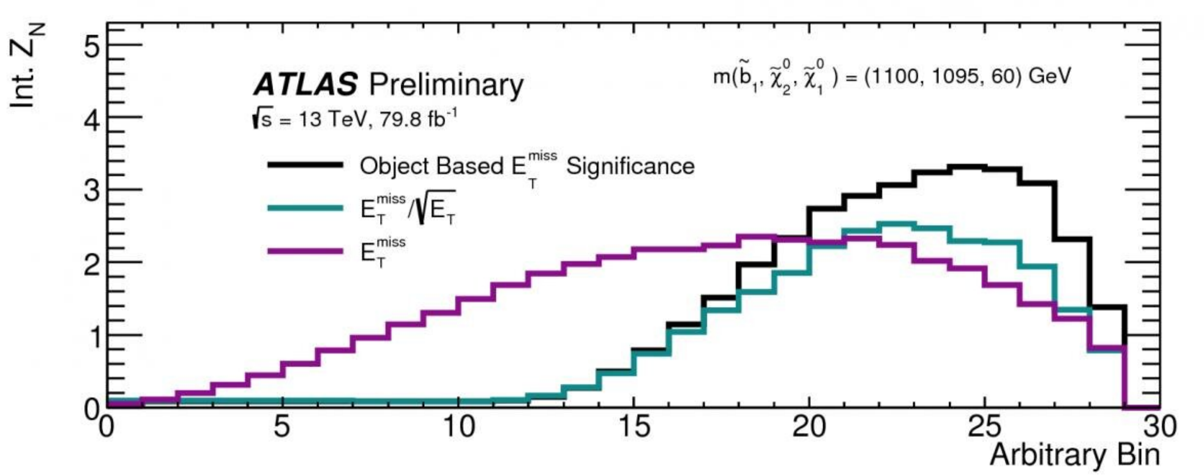

Figure 1: A comparison of the significance for the signal plus background hypothesis (vertical axis) of a chosen supersymmetric model obtained by selecting events using the new object-based ETmiss significance variable (black line), compared to the previous approximation (ETmiss/ET, cyan) or to selecting events using only the measured missing transverse energy (ETmiss, mauve). Higher significance is found for the new variable. Credit: ATLAS Collaboration/CERN

Dark matter is an unknown type of matter present in the universe that could be of particle origin. One of the most complete theoretical frameworks that includes a dark matter candidate is supersymmetry. Many supersymmetric models predict the existence of a new stable, invisible particle called the lightest supersymmetric particle (LSP), which has the right properties to be a dark matter particle.

The ATLAS Collaboration at CERN has recently reported two new results on searches for an LSP that exploited the experiment's full Run 2 data sample taken at 13 TeV proton-proton collision energy. The analyses looked for the pair production of two heavy supersymmetric particles, each of which decays to observable Standard Model particles and an LSP in the detector.

Identifying missing energy

A central challenge of these searches is that dark matter candidate particles would escape the ATLAS detector without leaving a visible signal. Their presence can only be inferred through the magnitude of the collision's missing transverse momentum (E_T^{miss}) – an imbalance in the momenta of detected particles in the plane perpendicular to the colliding protons. In the dense environment of numerous overlapping collisions generated by the Large Hadron Collider (LHC), it can be difficult to separate genuine E_T^{miss} from fake E_T^{miss} originating from mis-measurement of the visible collision debris in the detector.

To resolve this difficulty, ATLAS developed a new E_T^{miss} significance variable that quantifies the likelihood that the observed E_T^{miss} originates from undetectable particles rather than from mis-measured objects. Unlike previous calculations based entirely on the reconstructed event kinematics, the new variable also considers the resolution and misidentification probability of each of the reconstructed particles used in the calculation. This helps discriminate more effectively between events with genuine and fake E_T^{miss}, respectively, as shown in Figure 1, thus improving ATLAS' ability to identify and partially reconstruct dark matter particles.

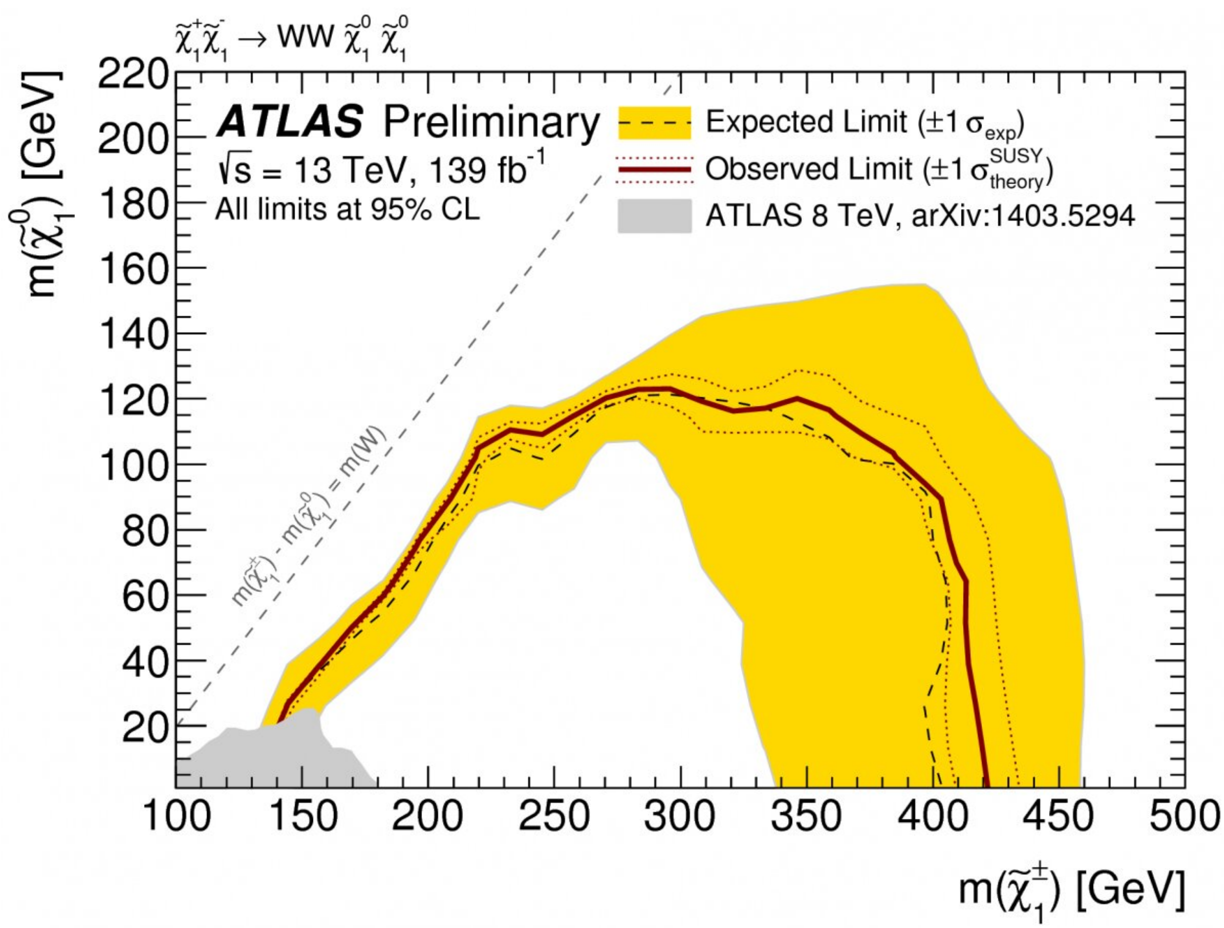

Figure 2: 95% exclusion limits on chargino pair production. The grey shaded region shows the results from Run 1 of the LHC. The new results substantially extend previous limits. Credit: ATLAS Collaboration/CERN

Applying new reconstruction techniques

Both of the new ATLAS searches implement this new reconstruction technique to the full Run 2 dataset. One search looks for the pair production of charginos (the charged superpartners of bosons) and sleptons (superpartners of leptons), respectively, which decay to either two electrons or muons and give rise to large E_T^{miss} due to the escaping LSPs. These signals are very challenging to extract as they look similar to Standard Model diboson processes, where some (although less) E_T^{miss} is produced from invisible neutrinos. Events were selected at high E_T^{miss} significance together with several other variables that help discriminate signal from background. In absence of a significant excess in the data over the background expectation, strong limits were placed on the considered supersymmetric scenarios, as shown in Figure 2.

The second new search targets the pair production of supersymmetric bottom squarks (superpartners of bottom quarks), which both decay to a final state involving a Higgs boson and an LSP (plus an additional b-quark). Then – targeting Higgs boson decays to two b-quarks, as it is predicted to occur 58 percent of the time – the final state measured in the ATLAS detector would have a unique signature: large E_T^{miss} associated with up to six jets of hadronic particles, originating from b-quarks. Again, no significant excess in data was found in this search.

Both results place strong constraints on important supersymmetric scenarios, which will guide future ATLAS searches. Further, they provide an example how novel reconstruction techniques can help improve the sensitivity of new physics searches at the LHC.

More information: Search for bottom-squark pair production with the ATLAS detector in final states containing Higgs bosons, b-jets and missing transverse momentum: atlas.web.cern.ch/Atlas/GROUPS … ATLAS-CONF-2019-011/

Search for electroweak production of charginos and sleptons decaying in final states with two leptons and missing transverse momentum in 13 TeV proton-proton collisions using the ATLAS detector: atlas.web.cern.ch/Atlas/GROUPS … ATLAS-CONF-2019-008/

Provided by ATLAS Experiment