Searching for invisible particles with the ATLAS Experiment

July 27 2017

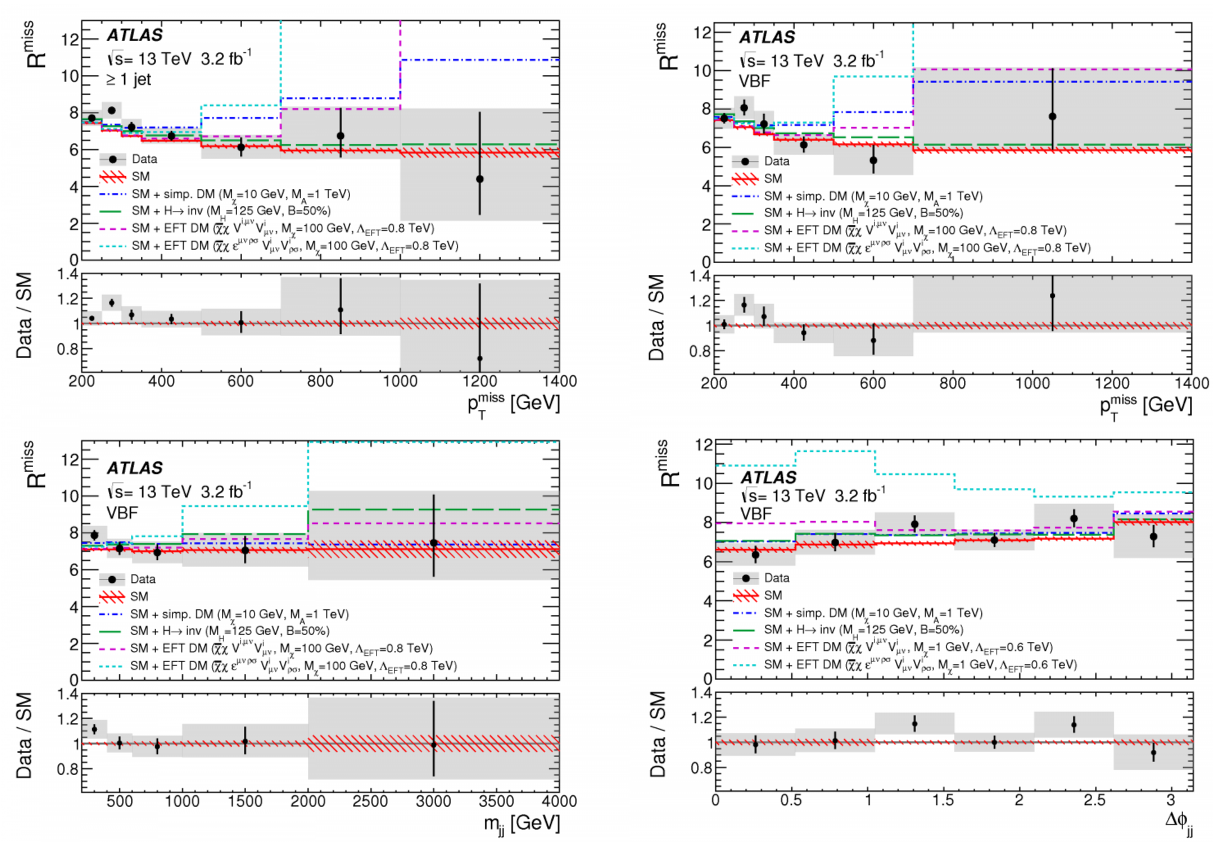

Figure 1: Measured data compared with the prediction from the Standard Model (solid red line), and from the Standard Model plus a variety of new invisible phenomena near the limit of ATLAS sensitivity (dotted/dashed lines). Credit: ATLAS Collaboration/CERN

As the Large Hadron Collider (LHC) smashes protons at a centre-of-mass energy of 13 TeV, it creates a rich assortment of particles that are identified through the signature of their interactions with the ATLAS detector. But what if the collider produces particles that travel through ATLAS without interacting? These "invisible particles" may provide the answers to some of the greatest mysteries in physics.

One example is dark matter, which appears to make up 85 percent of the mass in the universe, but has not yet been conclusively identified. Scientists infer its existence through astrophysical observations, including galaxy formation and gravitational lensing. However, they know more about what it isn't than what it is. There is no single theory of dark matter; different predictions have different implications for its properties and how it interacts.

The invisible particles produced in LHC collisions carry away energy, resulting in an apparent imbalance in the energy/momenta of the observed visible particles. Theories predict that if the invisible particles exist, more events with large imbalance and other distinctive patterns of visible particles could be detected by the ATLAS Experiment. Comparing the number of such events predicted by theory to the number of events observed in the detector is a way of searching for invisible particles indirectly.

While shown to be a successful approach, there are limitations. What if the theoretical models of dark matter are wrong? What if an entirely different phenomenon is the cause of invisible particles? Currently, when theoretical models are shown to be incorrect, it can be difficult and time-consuming to re-use the data to test new models. To do so requires an understanding of how these particles were recorded in the detectors, how the events were selected, and how the Standard Model processes that mimic these particle patterns were modeled.

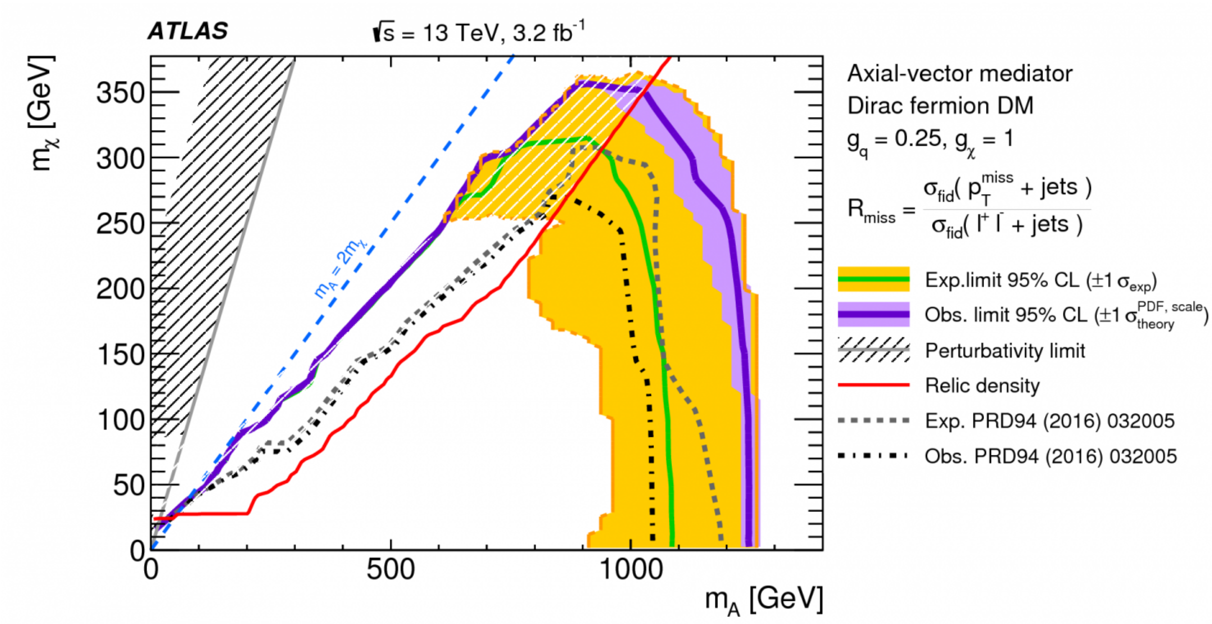

Figure 2: Region of Dark Matter and mediator particle masses actually excluded (up to the solid purple line) and expected to be excluded (up to the green solid line) with this measurement. Dotted grey lines show previous results from a comparable dedicated search. Credit: ATLAS Collaboration/CERN

ATLAS physicists have developed a new measurement-led approach, which is designed to be detector-independent and allows for easy re-interpretation of the data in future. In this approach, a quantity R^{miss} is defined, which is sensitive to the production rate and properties of any invisible particle(s). This quantity is measured versus various properties of the collision events, including the amount of momentum imbalance and the energy/momenta of the visible particles. The value of this quantity along with changes in these measured properties is found to provide sensitivity to invisible particles. Known decays of Z bosons produced in LHC collisions into invisible neutrinos mean this quantity is non-zero, even in the absence of a new invisible phenomenon. This quantity is carefully corrected for detector inefficiencies, leaving a measurement free from experimental bias and independent of any new physics hypothesis (Figure 1). Any physicist can then easily compare the predictions of their model against this measurement.

To demonstrate the new approach, the measurement is used to test three distinctly different theoretical models of dark matter, where it is produced either (1) via the strong force, (2) through the decays of Higgs bosons, or (3) via the electroweak force. No evidence of dark matter is observed and so ATLAS is able to place stringent constraints on these theories (Figure 2). The constraints are competitive with existing approaches that aim to test these specific theories and complementary to measurements from space-based indirect detection experiments.

More information: Measurement of detector-corrected observables sensitive to the anomalous production of events with jets and large missing transverse momentum in pp collisions at 13 TeV using the ATLAS detector (arXiv: 1707.03263): arxiv.org/abs/1707.03263

Provided by ATLAS Experiment