

Search for Semivisible Jets with Run 2 Scouting Data at the CMS Experiment

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While the Standard Model of particle physics (SM) has been highly successful in describing the properties and interactions of the elementary particles that make up our universe, it remains an incomplete theory. There are unresolved questions on both the experimental and theoretical fronts that cannot be explained by the SM alone. For example, the SM does not account for the masses of neutrinos, once thought to be massless, nor does it incorporate gravity, one of the fundamental forces of nature. Furthermore, astronomical observations such as galactic rotation curves, the cosmic microwave background spectrum, and gravitational lensing around large structures indicate that approximately 85% of the matter in the universe consists of dark matter (DM), an unknown and invisible form of matter not described by the SM.

These gaps in the SM have motivated extensive searches for DM and, more broadly, for physics beyond the Standard Model (BSM). This thesis presents one such search for BSM physics in the form of semivisible jets at the CMS experiment at the Large Hadron Collider (LHC).

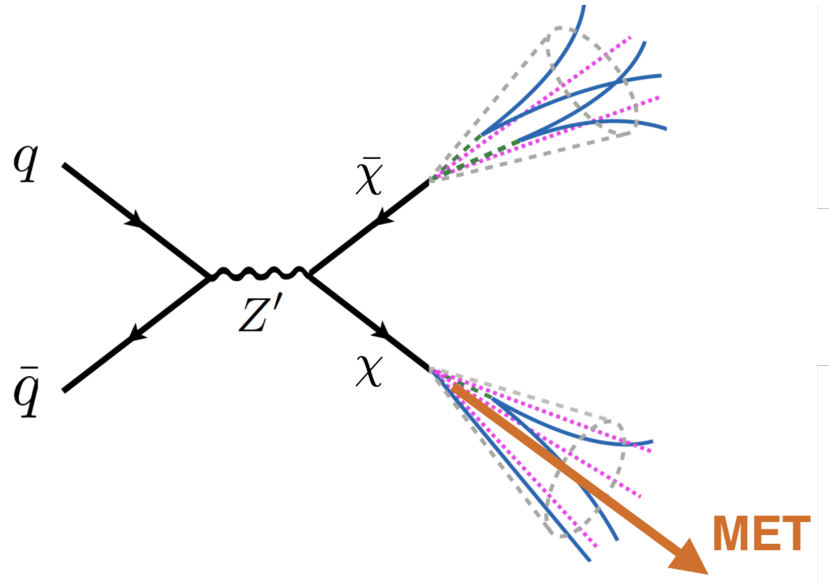


Figure 1: Feynman diagram of the resonant Z' production process. The dark quarks χ hadronize and partially decay to SM quarks, giving rise to the semivisible jet signature.

Semivisible jets are large-radius jets that contain both visible particles and invisible DM. They can arise in a class of theoretical models known as hidden valley dark shower models. These models introduce a hidden dark sector that interacts with the SM via a mediator particle, in this case a new Z' boson. The dark sector behaves like a dark version of Quantum Chromodynamics (QCD), with its own dark quarks that hadronize according to a strong interaction analogous to that of the SM. Depending on the dynamics of the dark sector, a wide variety of experimental signatures can arise. Semivisible jets appear when a fraction of the dark hadrons decay promptly back to SM quarks, while the remainder are stable and invisible, escaping detection as DM.

The analysis in this thesis uses scouting data collected at CMS during Run 2 of the LHC. Scouting is an alternative data-taking strategy introduced in Run 2 that foregoes the full offline reconstruction and instead relies on the coarser reconstruction performed at the trigger level, allowing the collection of events that would not pass conventional trigger thresholds. This approach sacrifices some accuracy in exchange for access to data that would otherwise be discarded, thereby extending the parameter space of many searches and improving sensitivity to lower resonance masses.

To identify the semivisible jet signature, the analysis employs novel machine learning (ML) techniques, including a specially trained Graph Neural Network (GNN) jet tagger based on the physics-motivated LundGraph representation, as well as a machine-learning-based ABCD method for background estimation. By combining these novel ML techniques with the scouting data-taking paradigm, this search advances the dark matter program by probing a previously inaccessible region of parameter space for semivisible jets.