Search for Dark Matter Produced in Association with a Dark Higgs Boson with the ATLAS Detector

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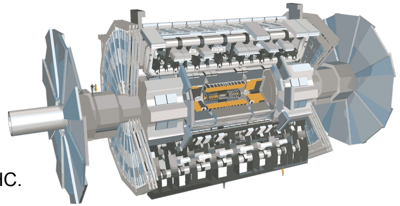
The ATLAS Detector

ATLAS is a general-purpose detector used to study particles produced by high-energy proton-proton collisions at the LHC.

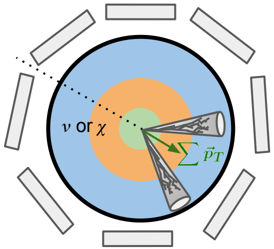


ATLAS is used both for precision standard model (SM) measurements, and to search for new physics beyond the SM. This search looks for evidence of dark matter (DM) production in these high-energy collisions.

Dark Matter Detection with ATLAS

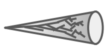
Like neutrinos (ν), DM is expected to pass undetected through the ATLAS detector.

The production of these undetected particles is inferred from an imbalance of momentum transverse to the beam line (a.k.a. E_T^{miss})



$$E_T^{\mathrm{miss}} = -\left|\sum \vec{p}_T\right|$$

shower initiated by quarks/gluons (a.k.a. "jet")

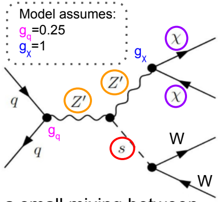


- Inner Tracker
- EM Calorimeter
- Hadronic Calorimeter

The Dark Higgs Model

This search is optimized to be sensitive to a simplified "dark Higgs" (DH) model for DM production via dark-sector mediators.

In this model, the DM χ is produced via a Z' mediator in the dark sector, which also emits a dark-sector Higgs boson s.

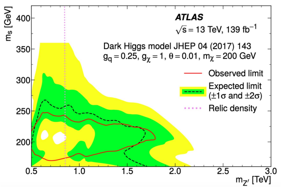


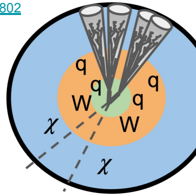
The s decays to a pair of SM W bosons via a small mixing between the s and the SM Higgs.

The masses m_χ, $m_{Z'}$ and m_s are not fixed in the DH model, so to search for the model we simulate events produced via the model in the ATLAS detector over a grid of $m_{Z'}$ and m_s, and look for evidence of an excess consistent with these simulated events in the ATLAS data. m_χ is fixed to 200 GeV for consistency with other LHC searches.

Hadronic WW Decay Channel

https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.126.121802

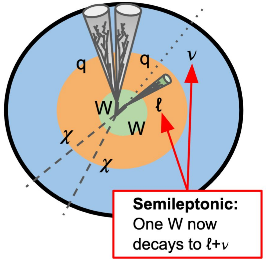




A search for the DH model was completed in the fully hadronic WW decay channel in 2020 ([published in *PRL*](https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.126.121802)). It looked at a final state with jets recoiling against E_T^{miss} from $\chi\chi$ production, with the main SM background coming from hadronically-decaying Z bosons (Z+jets). The search was able to constrain DH model parameters m_s and $m_{Z'}$ in the appx. range 160 GeV < m_s < 240 GeV.

Semileptonic WW Decay Channel

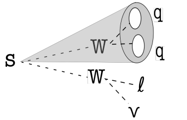
An ongoing search for the DH model looks at the semileptonic WW decay channel, where a pair of jets and a lepton recoil against E_T^{miss}.



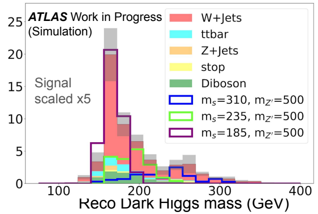
Brings a new challenge:
The semileptonic channel comes with an extra challenge compared with the hadronic channel of having a ν in the final state, which adds additional E_T^{miss} on top of that from the $\chi\chi$.

But also some promising advantages:
Requiring one lepton in the final state substantially reduces the background of SM events, particularly the Z+jets which was dominant in the hadronic channel. In addition, it is now possible to reconstruct the single hadronically-decaying W boson candidate (W_{had}), and reject any events with W_{had} far from the on-shell W mass of 80.4 GeV.

Semileptonic Search Strategy



The selection cuts give excellent signal / background discrimination in the dominant "merged" final-state topology, where W_{had} is reconstructed as one large boosted jet.



We have developed a novel m_s reconstruction strategy, which offers valuable shape discrimination when comparing distributions of simulated DH and SM with the ATLAS data to search for the DH model.