Study of the VBF Higgs production channel Higgs(→invisible) with the ATLAS Experiment at the HL-LHC

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Abstract

We describe a projection for a measurement to observe the invisible decay of a Higgs produced via the vector boson fusion (VBF) channel with the ATLAS detector. In the context of the high luminosity LHC (HL-LHC) upgrade, we report on the anticipated sensitivity to these invisible decays and a projected upper bound on the invisible Higgs decay branching ratio once the HL-LHC data collection has finished.

Background

- LHC (Large Hadron Collider)— **the world's most powerful microscope**! High energies = small length scales.
- Collides fast-moving protons to produce new particles
- New particles = new physics? Hints of dark matter and SUSY?

The ATLAS Detector

- 5 story apparatus with **micron precision**!
- Measures charged particle tracks bending in a magnetic field

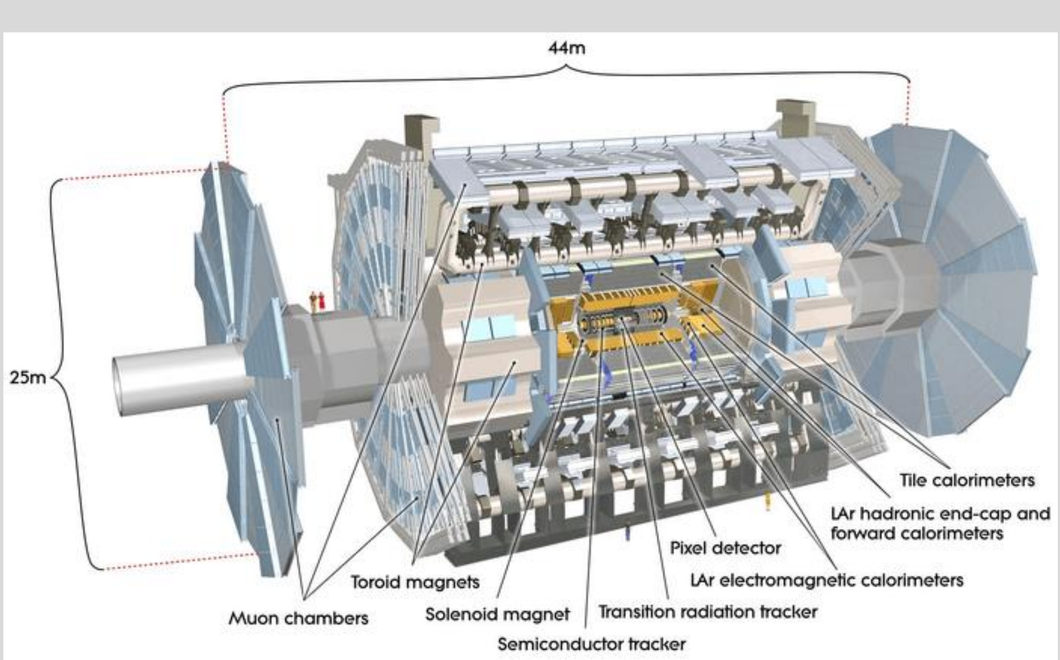

Figure 1: A schematic diagram of the ATLAS detector. Image credit: https://arxiv.org/pdf/0910.3081.pdf

RESEARCH QUESTION

With an increased dataset and new detectors, what might the upgraded LHC teach us about the nature of dark matter?

The Higgs Boson

- The keystone of the Standard Model of particle physics
- Gives mass to all fundamental particles
- Celebrated discovery in 2012, but no new particles since then
- A surprising connection: **could the Higgs interact with dark matter particles**? What would it look like?

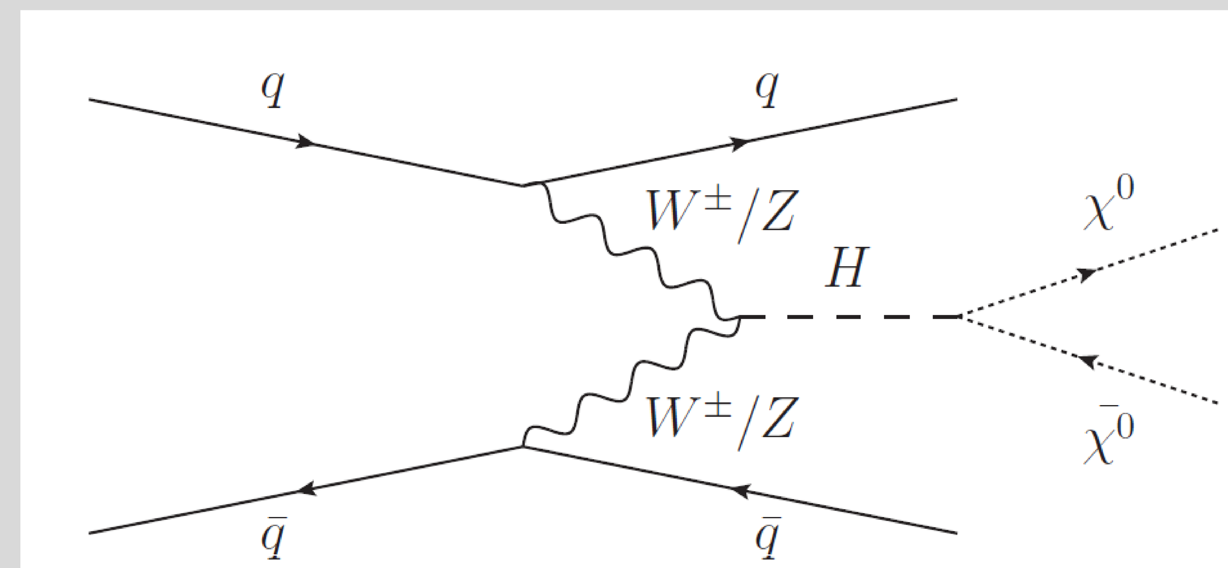

Figure 2: A possible decay of the Higgs boson (dashed line) into dark matter particles (dotted lines).

Jets are Great

- *Jets* = collimated clusters of energetic particles produced by quarks or gluons
- Many processes like VBF Higgs produce jets, which are easy to recognize in the detector
- The momentum and orientation of jets can tell us what particles were created when the protons collided
- Can correctly identify signal ("hard scatter") jets with > 90% efficiency

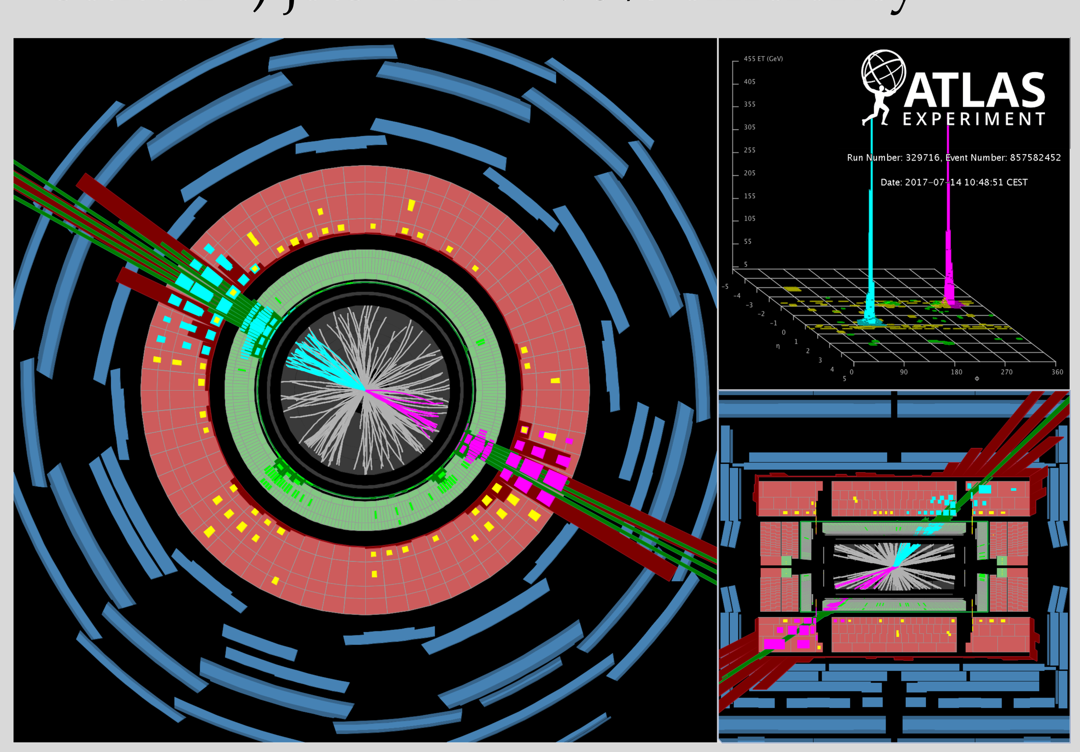

Figure 3: An event display from ATLAS. Two jets (magenta and cyan) are produced and deposit their energy in the detector. Image credit: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun2Physics

Seeing the Invisible

- Dark matter is invisible in the detector– no direct observation
- Instead, look for events with large missing momentum compared to original protons
- VBF Higgs → invisible makes two jets + lots of missing momentum = good channel to look for invisible Higgs decays

Requirement	Cut value
Leading jet p_T	>80 GeV
Second jet p_T	>50 GeV
$\eta_1 \cdot \eta_2$	<0
m_{jj}	>1 TeV
$\lvert\Delta\eta_{jj}\rvert$	>4.8
$\lvert\Delta\varphi_{jj}\rvert$	<1.8
$\lvert\Delta\varphi_{j,MET}\rvert$	>1
Third jet veto	25 GeV
E^T_{miss}	>180 GeV

Figure 4: A list of kinematic cuts on jet properties used in the VBF Higgs → invisible analysis. These cuts improve the signal-to-noise ratio when looking for very rare processes.

Projections

- Earlier searches placed upper limits of 58% (CMS) and later 28% (ATLAS) on Higgs → invisible branching fraction
- Preliminary analysis shows percent-level sensitivity to invisible decays
- Close to Standard Model expectation of 0.5% branching fraction

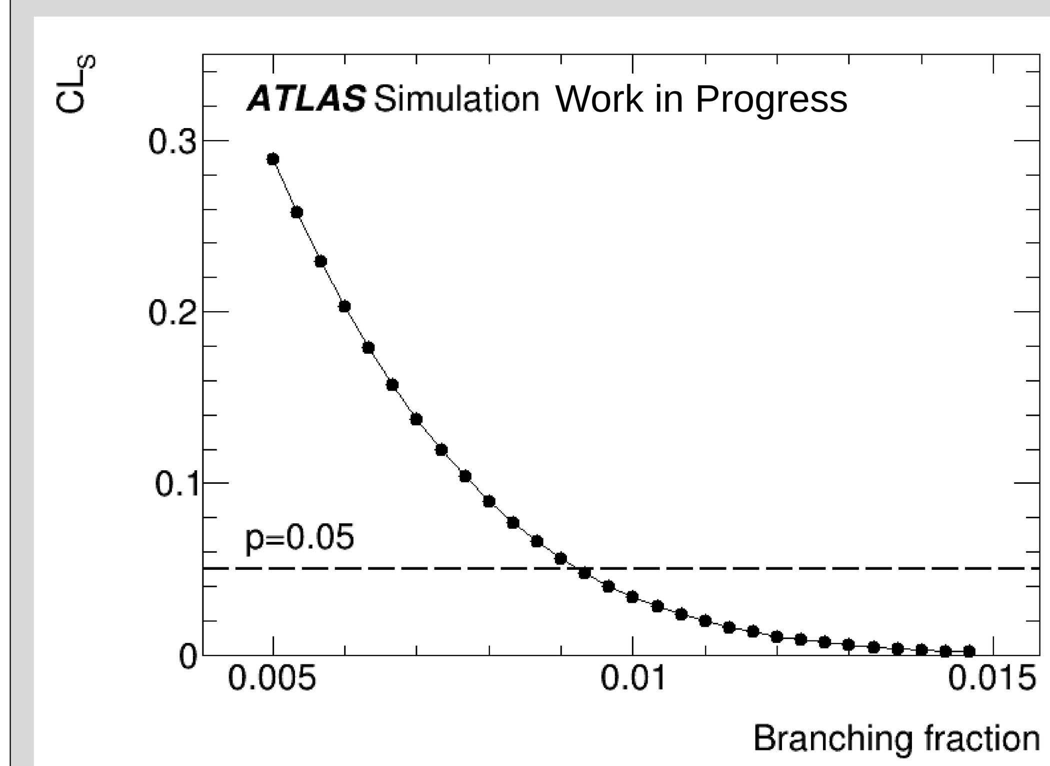

Figure 5: Projected statistical sensitivity to invisible decays. Dashed line indicates p=0.05 significance level, so branching fractions > 1% are excluded.

Conclusions

- The previous limits on the H → invisible branching ratio set in Run 1 and Run 2 searches will be greatly improved after the upgrade.
- Further study with other background processes and increased statistics is still needed to refine this result.

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