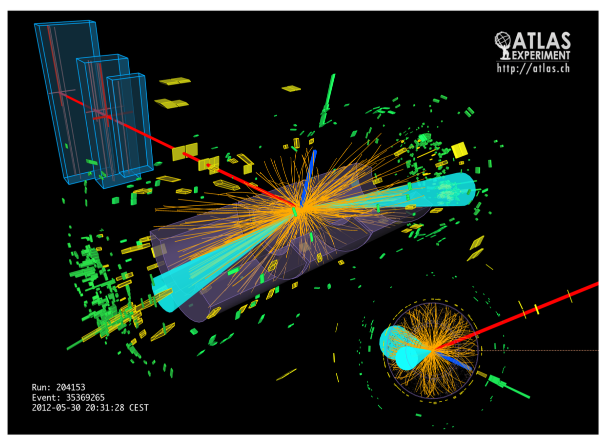

Sensitivity to New Physics via the Study of the Higgs Boson Transverse Momentum at the ATLAS Detector

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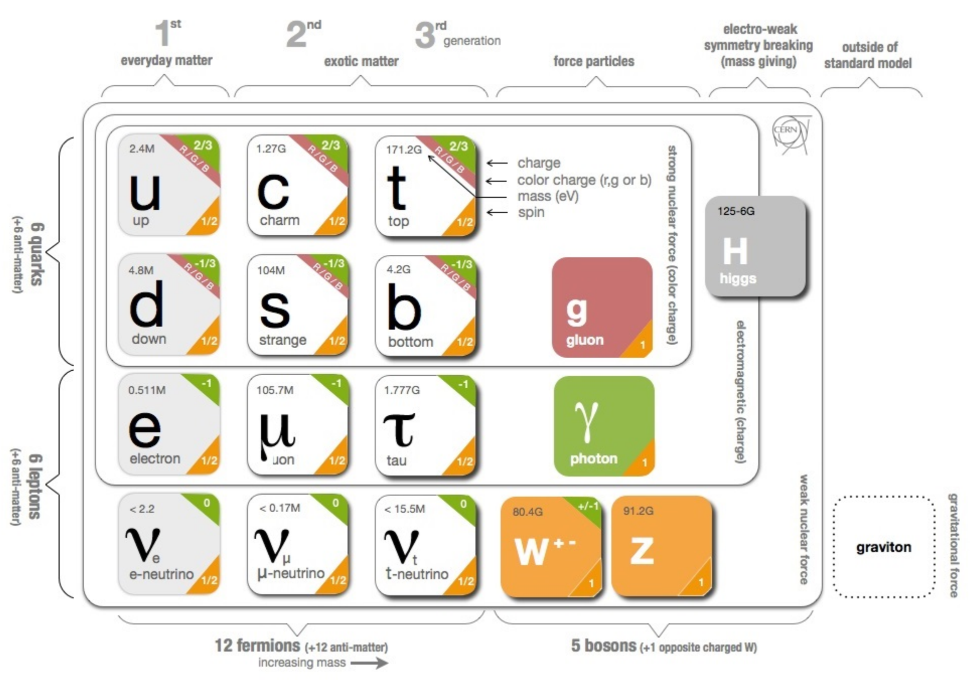
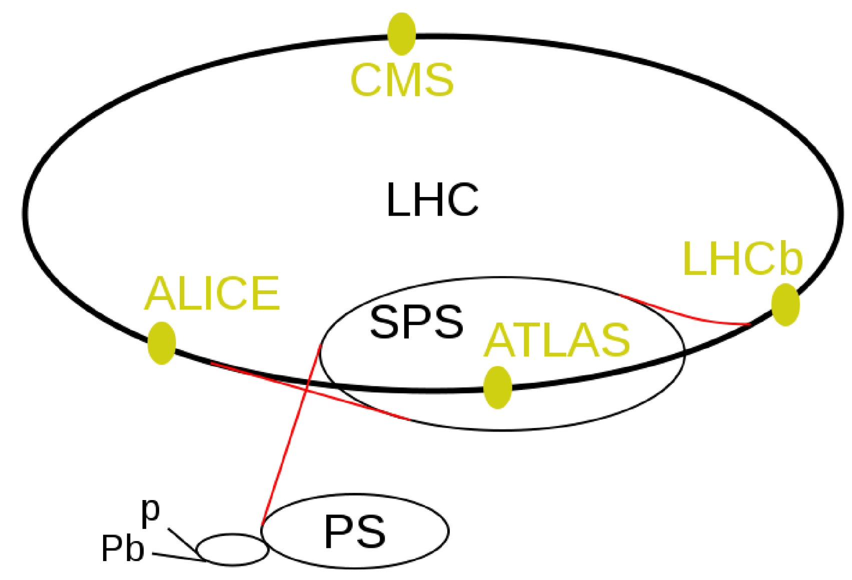
Introduction

The interactions between the most fundamental constituents of matter are predicted by the standard model of particle physics (SM). The fundamental constituents predicted by the SM can be seen in the following infographic:[1]



In order to study the interactions and thus test the SM one needs very large amounts of energy. The CERN Large Hadron Collider (LHC) achieves the these energies.[2]

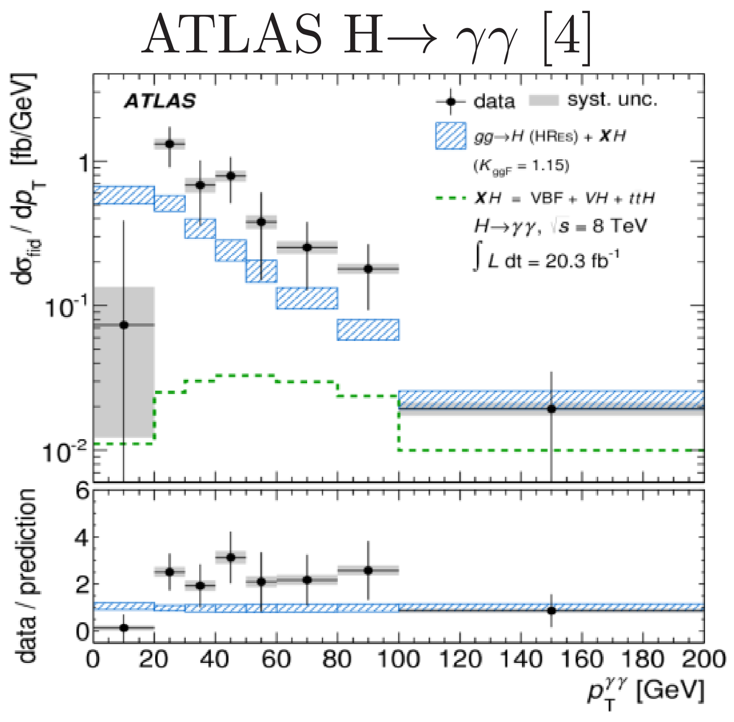


It collides protons at these energies which break up and there constituents and interact forming things like Higgs bosons: p p → H j where p is a proton H is a Higgs boson and j is a jet.

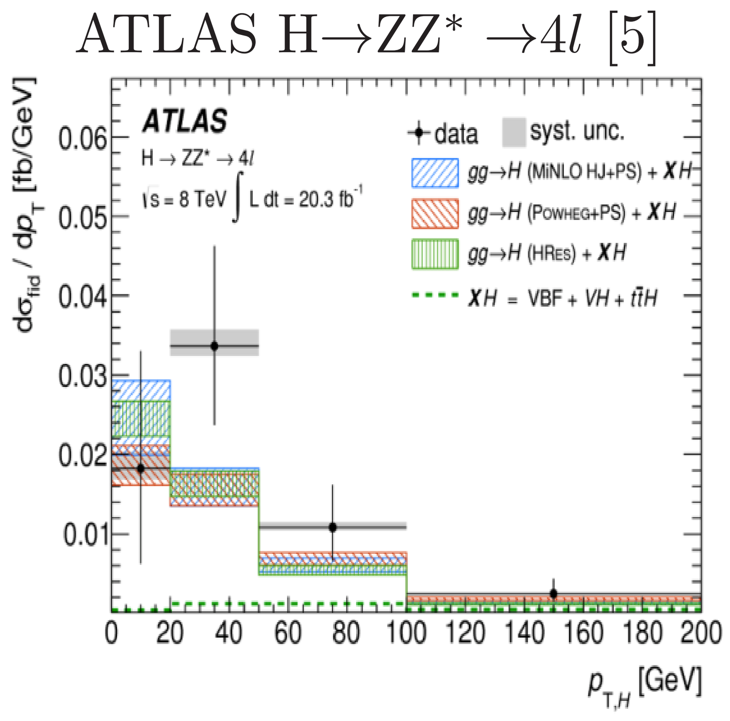
The Problem

The following plots compare the predicted P_T cross-sectional data (shaded regions) and the actual data (the dots) for Higgs production at the LHC for a centre of mass energy of 8TeV.

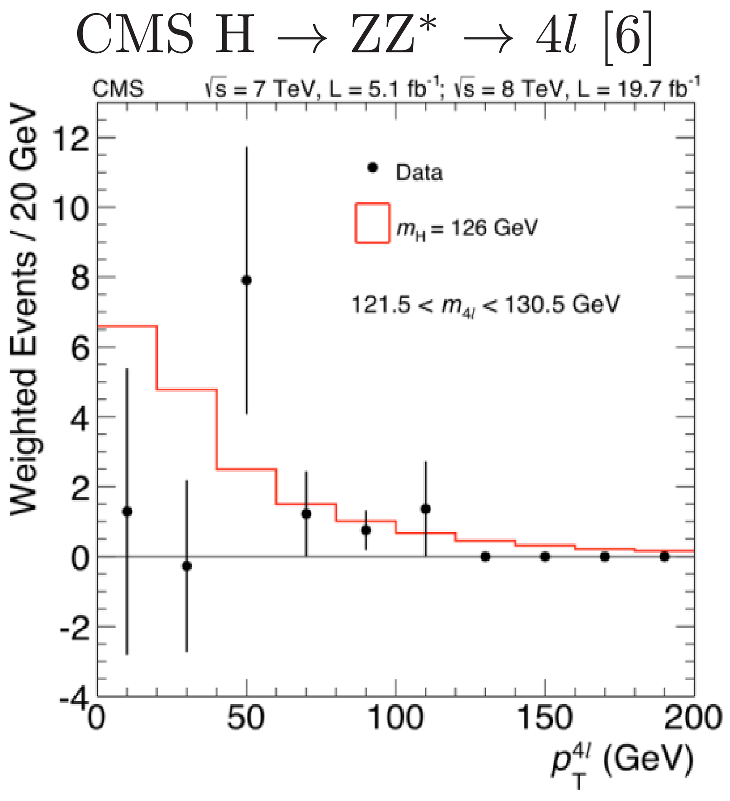
ATLAS H→ $\gamma\gamma$ [4]



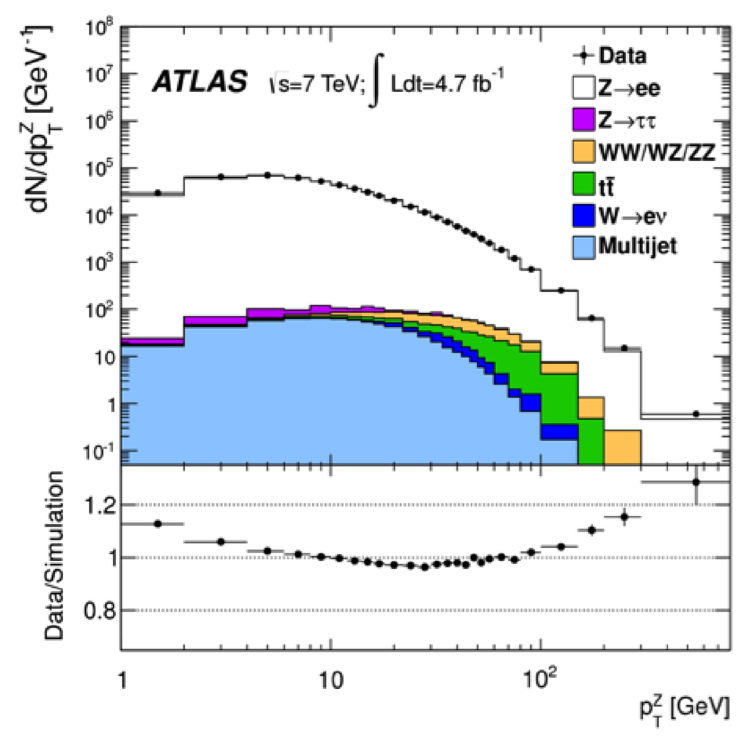
ATLAS H→ZZ* →$4l$ [5]



CMS H → ZZ* → $4l$ [6]



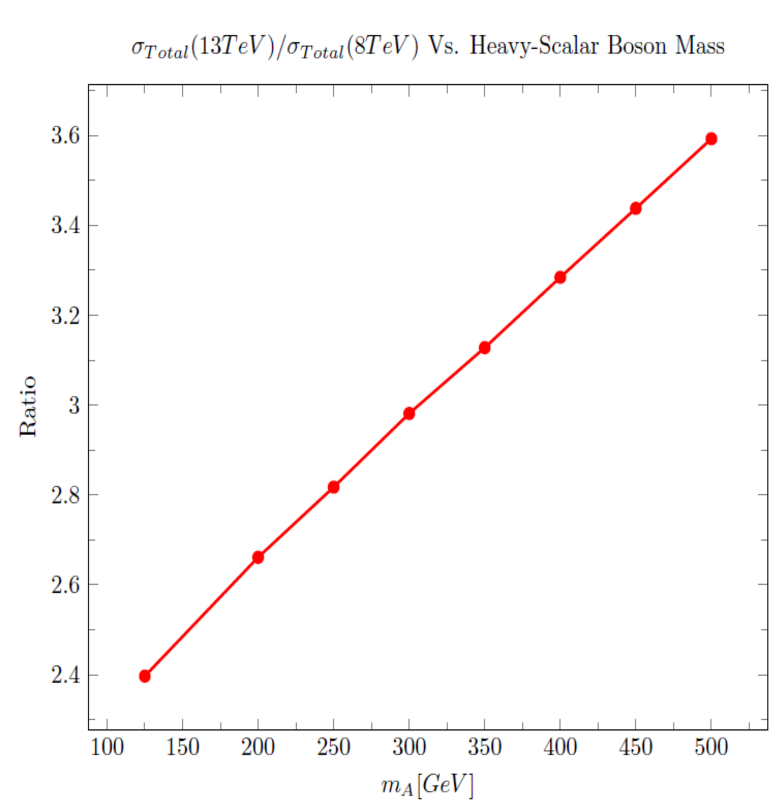
They all show a structure in the actual data that does not correlate with theory between 40 and 100 GeV. This discrepancy could be the result of statistical fluctuations, an error in the model or indicate new physics. Since the same structure is observed at ATLAS and CMS which use different physical mechanisms for detection, statistical fluctuations are unlikely to explain it. Also, the theory so well predicts Z boson production, as seen at ATLAS, Which indicates the unlikelihood of an error large enough to explain the discrepancy.



It is thus more likely the structure indicates new physics. A model that could explain the discrepancy would be if a heavy-scalar boson, not the Higgs,is being produced, which then decays into a SM like Higgs and another particle which escapes the detector. The emission of this other particle would thus give the Higgs more P_T than predicted by the SM which might explain the structure seen in the P_T data.

Scalar Boson Simulation

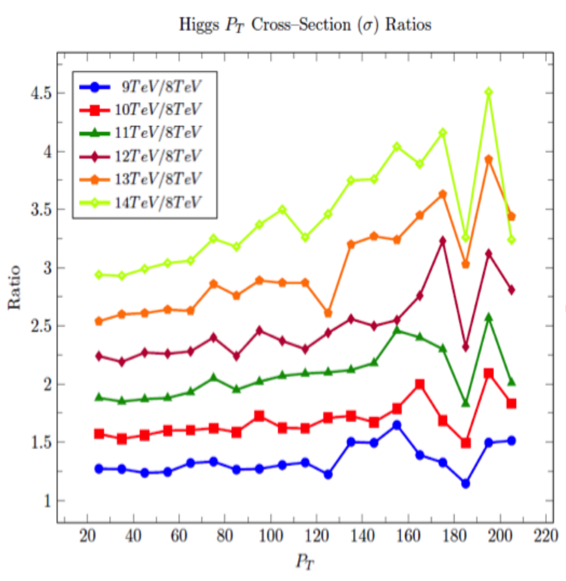
In order to approximate how the heavy-scalar boson model might change the P_T cross-sectional data, simulations were done at 8TeV and 13TeV for the process for the process p p → H where the Higgs is now thought of as a heavy scalar boson (A). Then by varying the mass of A the ratios of the total cross-sections at 13TeV to 8TeV as a function of the mass of the A was obtained:



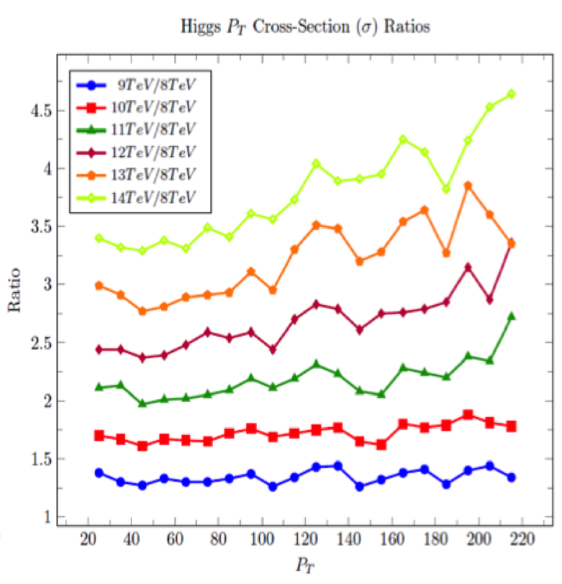
What this plot indicates is that as the mass of A increases the ratio of the total cross-section at 13TeV to 8TeV increases meaning that if there is an A being produced that is decaying into a SM like Higgs and something else, the expectation would be that the amount of Higgs bosons seen at 13TeV would be greater than predicted by the SM.

SM Simulations

In order to investigate the kinematics of Higgs production and how they will change when the LHC goes from an energy of 8TeV to 13TeV, MadGraph simulations for Higgs production at energies from 8TeV to 14TeV in 1TeV steps were done for the processes p p → H j as well as p p → H j j. The ratios of the P_T cross-sectional data for each energy to 8TeV are:

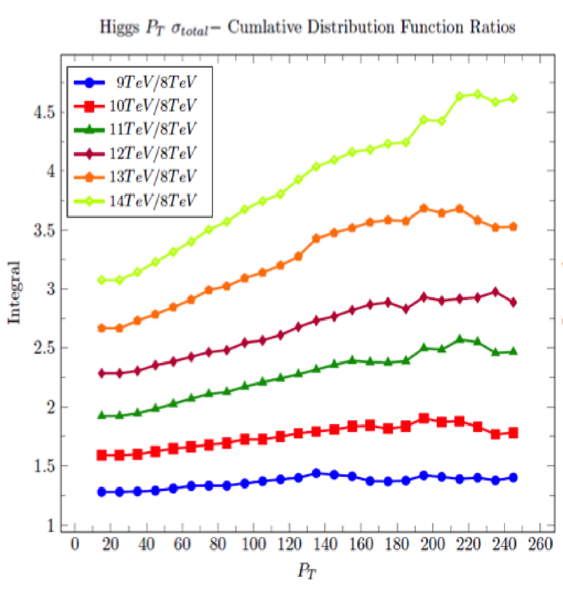


p p → H j

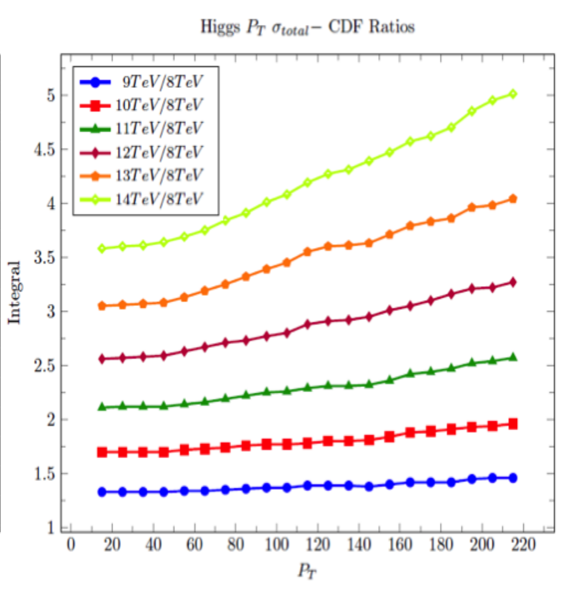


p p → H j j

The ratios of the integrated cross-sectional data is show here:



p p → H j



p p → H j j

These plots are a sample of the kinematic plots that can be produced. All of which make predictions based on the SM that that are usful when compared to actual data as they highlight areas of disagreement between theory and data.

Simulations

MadGraph

MadGraph [3] is simulation software that uses the SM, and extensions of it, as models to simulate particle interactions in particle accelerators. It retunes cross-sectional data of the kinematics of the simulation. The MadGraph simulations used here use the Higgs Effective couplings to gluons and photons model.In which the Higgs bosons is aproximated to couple directly to gluons and photons.

References

[1] CERN Bulletin, (2012). 'GO ON A PARTICLE QUEST AT THE FIRST CERN WEBFEST. INTERNET'. http://cds.cern.ch/journal/CERNBulletin/2012/35/News%20Articles/1473657. Accessed 9 September 2014

[2] Arpad Horvath, (2009). 'Large Hadron Colider'. https://en.wikipedia.org/wiki/Large_Hadron_Collider. Accessed 25 June 2015.

[3] J. Alwall et al 2014 J. High Energy Phy. JHEP07(2014)079

[4] ATLAS Collaboration (Georges Aad (Marseille, CPPM) et al.) 2014 J. High Energy Phy. JHEP09(2014)112

[5] ATLAS Collaboration (Georges Aad (Marseille, CPPM) et al.) 2014 Phys. Lett. B 738 234-253

[6] CMS Collaboration (Serguei Chatrchyan (Yerevan Phys. Inst.) et al.) Phys. Rev. D 89 092007

[7] ATLAS Collaboration (Georges Aad (Marseille, CPPM) et al.) 2014 J. High Energy Phy. JHEP09(2014)145