

The LHC as an electroweak boson collider: A novel laboratory for dark matter, the origin of neutrino mass and other new electroweak phenomena.

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Overview

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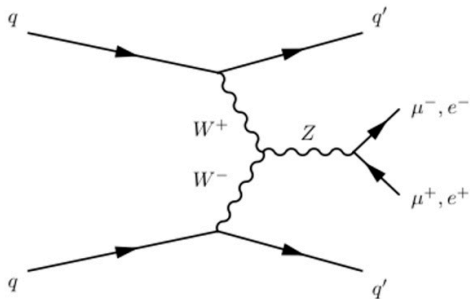
Main Project

- Use new techniques to search for and measure **dark matter** and the mechanism for the **origin of neutrino mass** at the ATLAS experiment at the LHC.
- These techniques involve using weak boson fusion as a mechanism for the production of exotic particles, such as dark matter and neutrinos.

Authorship Qualification Project

- The plan for my project is to determine **jet energy resolution** from data in order to make precise jet measurements.

The LHC as an electroweak boson collider.

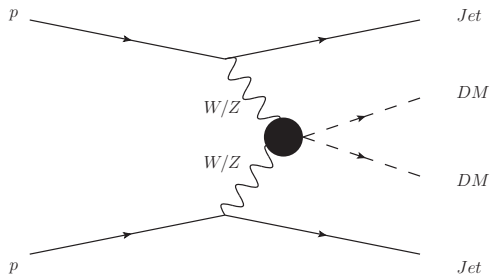


Vector Boson Fusion (VBF) features:

- 2 jets,
 - No colour flow,
 - $Z \rightarrow l^+ l^-$,
 - $W \rightarrow l \nu$
- We can look at any electroweak process; using the electroweak properties to identify the process.

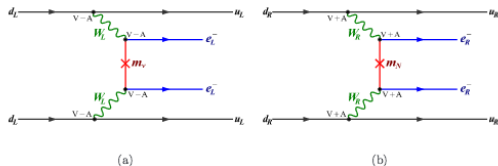
Diagram from: arXiv:1401.7610

Dark Matter

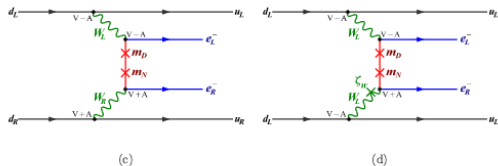


- Signature of Dark Matter: **Missing Energy.**
- Number of Effective field theories and number of models within these.

Origin of Neutrino Mass



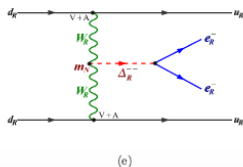
(a) Light neutrino exchange



(b) Heavy neutrino exchange

(c) Neutrino and heavy W exchange

(d) Neutrino and light W exchange



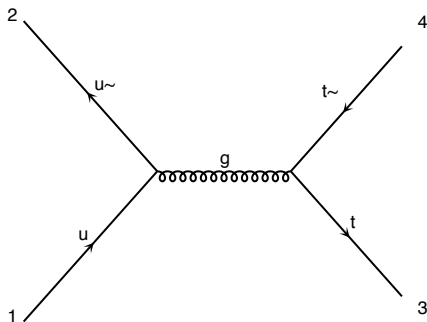
(e) Doubly charged Higgs Triplet exchange

Diagrams from: arXiv:1206.0256

MadGraph SM

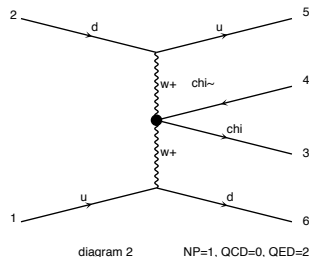
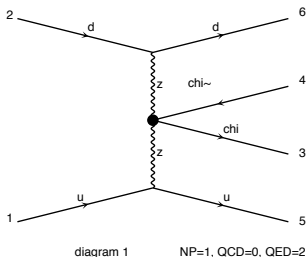
MadGraph is a programme that allows me to generate an event in ATLAS that abides by my specifications for parameter values. There are a number of models within the programme, such as the standard model, where I have been able to generate events such as:

$$p\,p \rightarrow t\,\bar{t}$$



We have been in touch with external theorist (Prof. Matthew Buckley) in order to receive some Dark matter models. I have also used these models to produce events for a number of dark matter events. One of which:

$$p p \rightarrow \text{DM DM} + 2\text{jets}$$



These generated events give cross sections and different models that are based on different effective field theories.

Parameters changed between models:

- DM Mass
- EFT Scale
- Dimensionality

D5a

$$\mathcal{L}_{\text{D5a}} = \frac{1}{\Lambda} \bar{\chi} \chi \left[\frac{Z_\mu Z^\mu}{2} + W_\mu^+ W^{-\mu} \right]$$

D5b

$$\mathcal{L}_{\text{D5b}} = \frac{1}{\Lambda} \bar{\chi} \gamma^5 \chi \left[\frac{Z_\mu Z^\mu}{2} + W_\mu^+ W^{-\mu} \right]$$

- MadGraph produces a file which, after being altered by Pythia, can be fed into the analysis software, Rivet.
- Produces physics plots.
- Rivet has a number of analyses written in the programme.
- I will be able to write my own analysis for the dark matter models.
 - Switch to VBF $Z + \text{jets}$ model
 - Write analysis to replicate VBF $Z + \text{jets}$ analysis
 - DM analysis

Need to take into account:

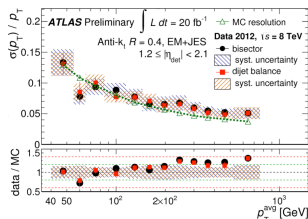
- What fraction of these events are observable?
- How can the sensitivity be enhanced?
 - Kinematics and angles of jets?
- How do the backgrounds affect the sensitivity?
 - Eg. $Z \rightarrow \nu \nu + 2\text{jets}$
 - Need to be simulated and compared.

Jet Energy Resolution

The plan for my project is to determine jet energy resolution from data in order to make precise jet measurements.

This measurement is vital for:

- The measurement of the cross-sections of Jets, dijets, multijets and vector bosons accompanied by jets.
- Top-quark cross-sections and mass measurements.
- Determination of missing transverse energy.



Plot from: ATLAS-CONF-2015-017

- Attending relevant meetings
- Up and running with the code from Michaela and Jacob.

Summary

- All software for the Dark Matter investigation has been set up - Just need to test it with similar, but known processes.
- Up and running the Jet Energy Resolution code, soon to be adapting it for purpose.