Searching for New Physics at ATLAS

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Project Aim

The Z' is a hypothetical particle predicted by several extensions to the Standard Model, such as the Sequential Standard Model. It is a heavier version of the Standard Model Z boson, and is expected to lie on the TeV scale.

The aim of the project was to analyse simulated data from ATLAS in order to optimise the search for the Z' in the dielectron decay channel ($Z' \rightarrow e^+e^-$).

The Z' has been the subject of extensive searches at the LHC. The current lower limits on the Z' lie at 3.65 TeV for the dielectron decay channel [1].

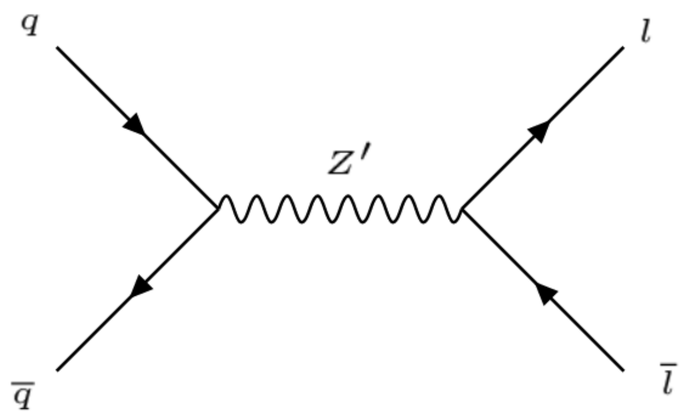

Fig. 1- a quark-antiquark pair annihilating to form a Z' which decays to a dilepton pair.

Samples

The project used simulated data from ATLAS at a centre of mass of 7 TeV, comprised of Z' samples at masses of 1.5, 2 and 2.5 TeV, as well as background samples.

These samples were produced with Monte Carlo event generators such as PYTHIA.

The main background was from the Drell-Yan process, which is due to quark-antiquark annihilation producing a Standard Model Z boson which decays to a dilepton pair.

Event Selection

When a potentially interesting event has been identified in the detector, there may be a number of additional electrons in the vicinity not related to the signal event.
After rejecting electrons in lower resolution areas of the detector, the two electrons with the highest transverse momenta that pass the selection criteria are used to reconstruct the Z'.

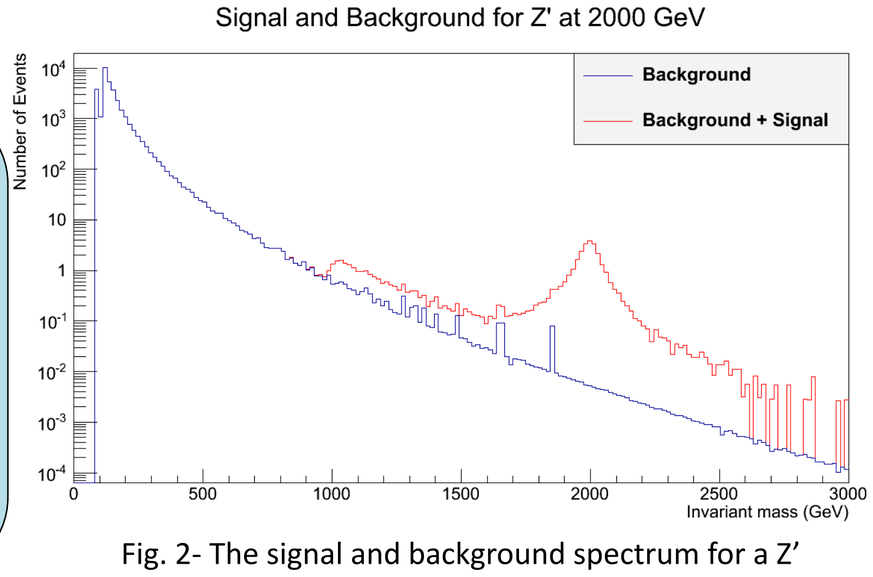

Fig. 2- The signal and background spectrum for a Z' at 2000 GeV.

Linear Cuts

A set of linear cuts were also investigated to increase the discovery significance. A linear cut on the transverse momenta, for example, would remove all events above or below a given momenta. These were able to remove a higher amount of background compared to the standard ATLAS selection criteria, albeit at the expense of a greater loss of signal events.

Discovery Significance

Before a discovery can be announced, a hypothesised signal must be detected to a significance of 5 σ compared to the expected background, a probability of achieving this result from random fluctuations in the background alone of around 1 in 3 million.

The discovery significance [2] is given by the equation

$$Z_0 = \sqrt{2((s+b)\ln\left(1+\frac{s}{b}\right)-s)}$$

where s and b are the number of signal and background events respectively.

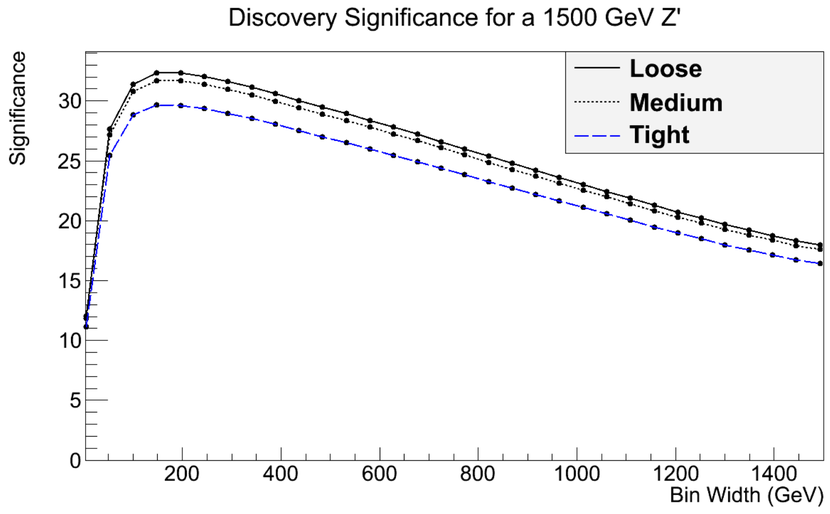

Fig. 3- the discovery significance as a function of bin width for a 1500 GeV Z'.

Comparison of Search Methods

Two methods of searching were compared in this study- these being the use of a fixed window, in which the number of events in a window are compared against the expected background, and an open cut which counts the number of events above a given energy.

It was determined that the search method that gave the best significance was a fixed window with a width of $(0.12\pm0.01)M_{Z'}$.

Conclusions and Results

The Z' is a hypothetical particle predicted by several extensions to the Standard Model. This project focused on a number of studies relating to the search for the Z' using simulated data from ATLAS.

These included looking at the discovery significance for both open cut and fixed window searches, which was determined to be $(0.12\pm0.01)M_{Z'}$. Further studies were conducted on the most suitable trigger for the experiment, as well as the obtainable resolution for a reconstructed dilepton pair.

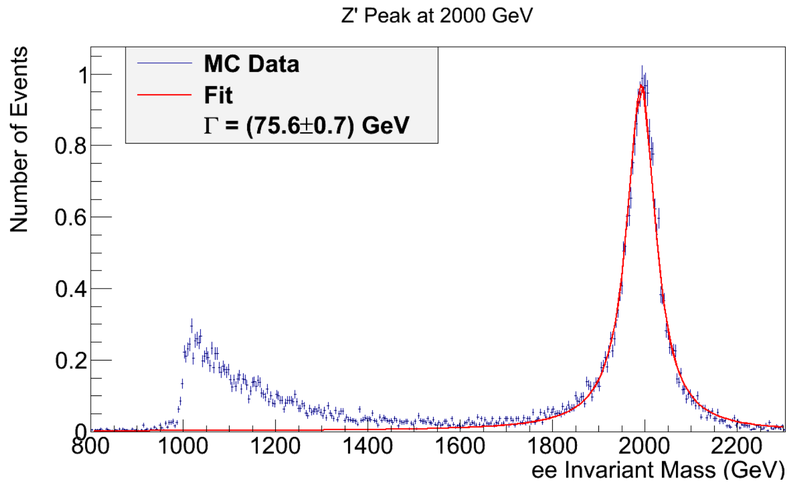

Fig. 4- the fitting of the Z' peak to a Breit-Wigner function. A bremsstrahlung peak can be seen around 1 TeV.

References

[1]-Search for a high-mass resonance decaying into a dilepton final state in 13 fb^{-1} of pp collisions at $\sqrt{s}$ = 13 TeV. Technical Report CMS-PAS-EXO-16-031, CERN, Geneva, 2016.
[2]- Asymptotic formulae for likelihood-based tests of new physics. Glen Cowan, Kyle Cranmer, Eilam Gross, and Ofer Vitells. Eur. Phys. J., C71:1554, 2011.

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