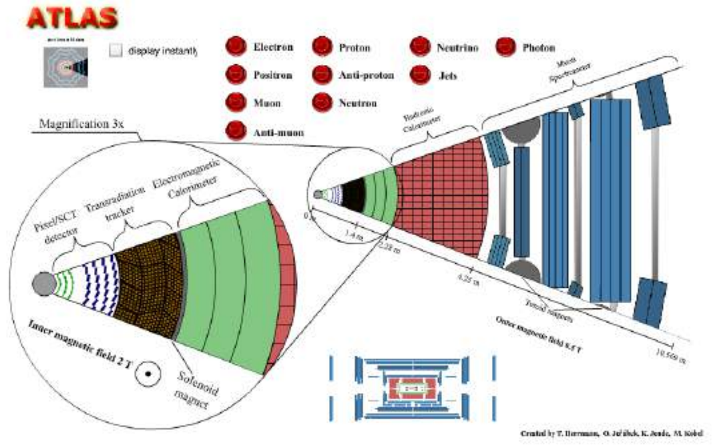
Finding the Mass of Bosons

Figure 1



Source : http://bit.ly/2tYW7Ub

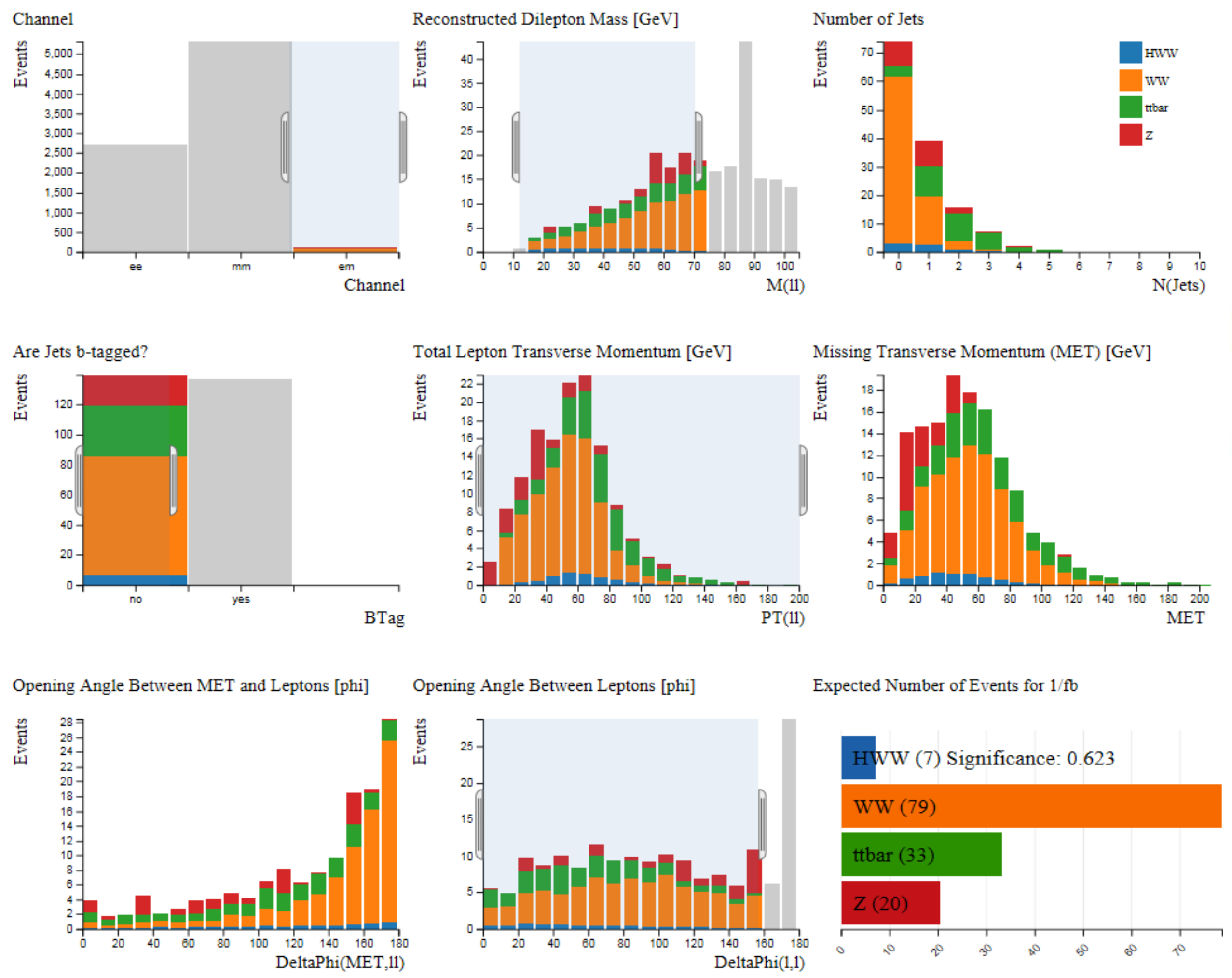
The ATLAS Detector

Particles collide in the detector, the products of the collision shoot out of the beam and into the tracker. The tracker then determines how fast they are going by measuring the time taken to go through the silicon layers and the curvature of their path, this curvature is caused by the force exerted on them by the magnet, (non-charged particles such as neutrons travel straight and charged particles curve, depending on whether this charge is positive or negative). Through the curvature and the velocity I can work out the momentum and therefore the mass of the particle, this can help us to identify the particle. The Higgs boson does not directly show up in the detector since it is extremely unstable and decays into other particles almost immediately. However I can detect what the Higgs decays into and therefore I will analyse the data and from these decay products I can find the Higgs.

Initial Attempts

The events are separated into two types Monte Carlo (data simulated from past runs of the LHC), this is displayed as solid colours of types that are defined by the key of the histogram) and actual data represented by dots with error bars. I then can measure how relatively how different the error bars are from the MC data, this difference can be made more significant by making cuts of my graph , if the difference is significant enough it reveals new decay processes, this was the method used to find the Higgs initially .

Atlas have a Histogram analyser on the educational section of their website and I used this to work out some of the cuts I could try to use to find the Higgs and to gain some understanding of data analysis. (This picture is of the histograms after some cuts have been made to increase the significance of the Higgs) source: http://bit.ly/2plU3Rz



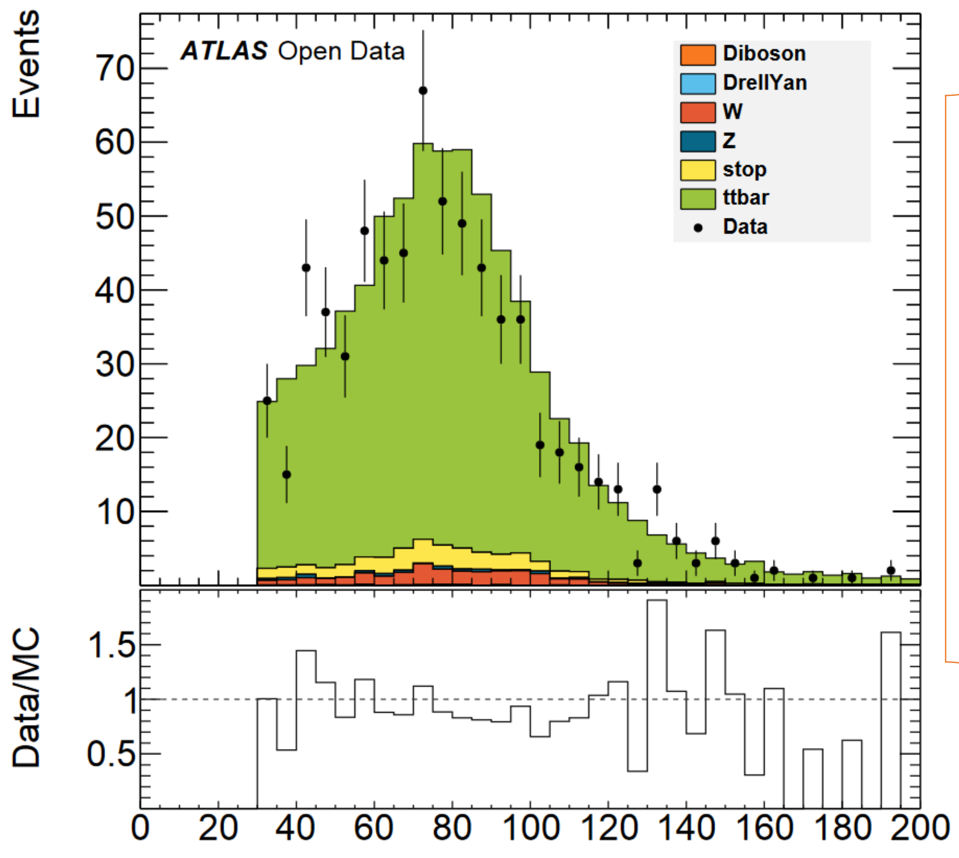


Figure 2

W boson (Figure 2-4)

Here is a histogram denoting an analysis of the mass of a W boson), and from the significance graph at the bottom it is visible that the known mass of the Higgs boson, ~125 GeV is shown from this analysis, for it is outside two standard deviations of the MC data. The colours of the graph represent the type of decay that we can detect using the detector.

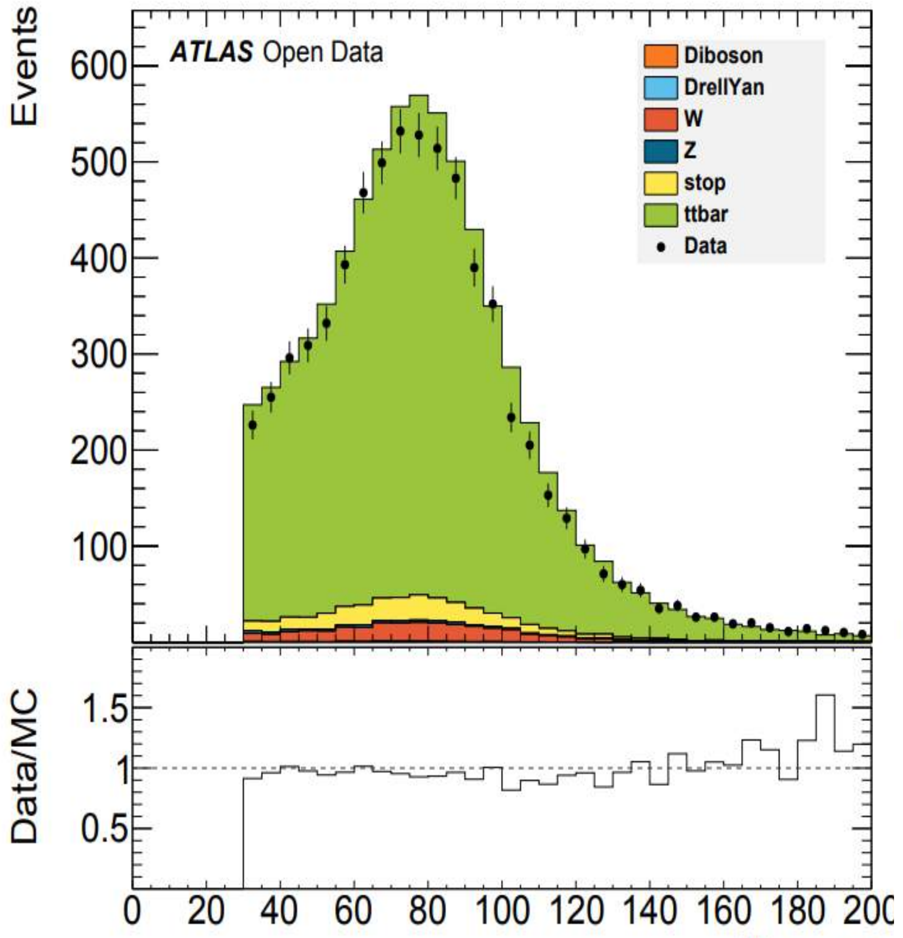


Figure 3

Published results

Name	Mass (GeV)
W boson	80.385 ± 0.015
Z Boson	91.188 ± 0.002
Higgs Boson	125.09 ± 0.24

Figure 7

W boson continued

Here as I compare further data simulated to the Monte Carlo data from 2012 (figure 3); the supposed proof of the Higgs around 120-130 GeV begins to disappear, as that data point is now ~0.2 below the MC data. The accuracy shown in figure 3 isn't good enough so I edited the code for the standard histogram analysis and changed the width of the bars and the range of results down to between 75 GeV and 85GeV as shown in figure 4.

I can also produce a graph of W boson candidates from W analysis, which will allow us to produce an even more accurate value for the mass of a W boson since there is around 8500 events at the mode rather than the 550 events that I can observe with the TTbar analysis. Since I already know what mass boson has I didn't need to produce the rough graph and instead I just focussed in on the 78-82 GeV region. This more accurate graph gave us the mass of a W boson to be **79±0.5 GeV**.

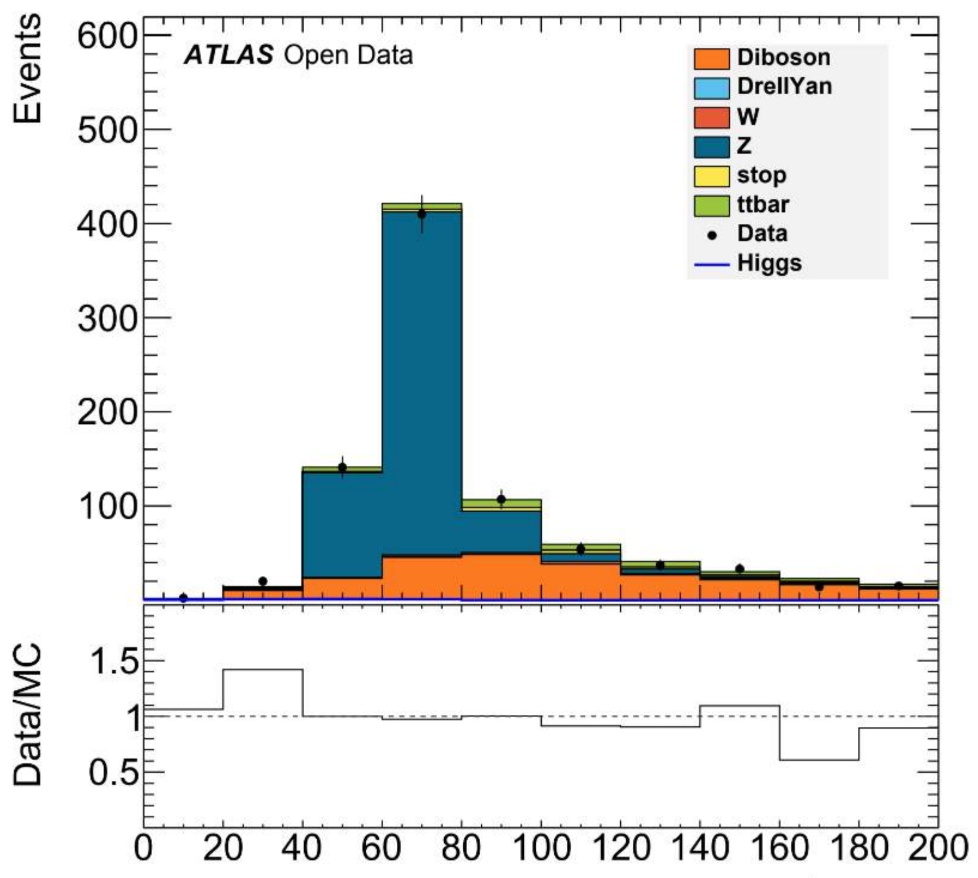


Figure 6

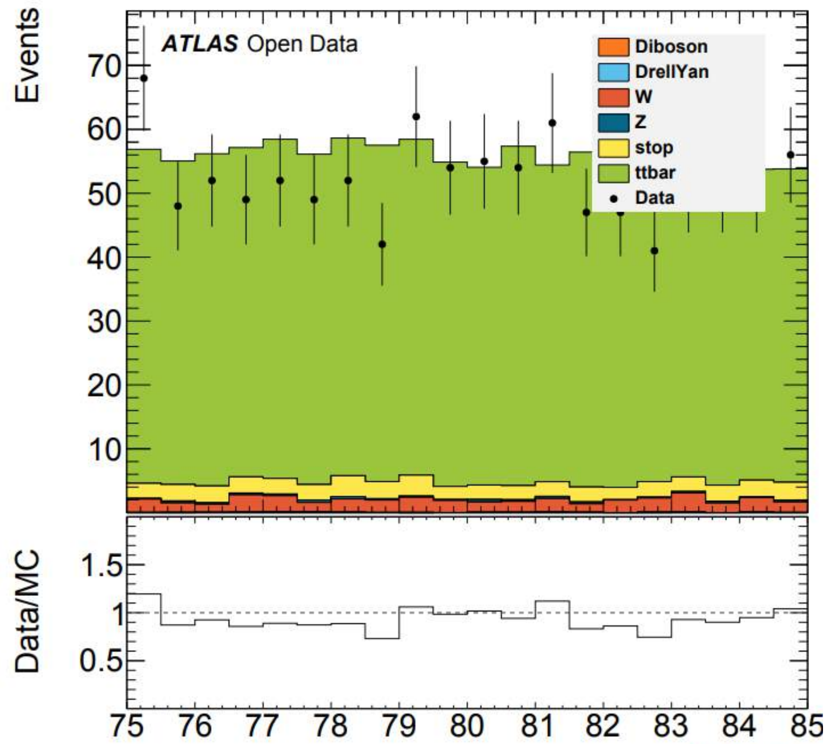


Figure 4

Z boson (Figure 5)

The Z boson is harder to accurately measure the mass of since the number of events is so low so the error bars are extremely high. I would need to get data from more runs of the LHC to measure it to a good degree of accuracy but I can tell that a Z boson has a mass of between **90±5 GeV**, this large uncertainty suggests to me that there is another type of analysis that I could use to find the mass of a Z boson more accurately however it isn't included in the programs that I have access to.

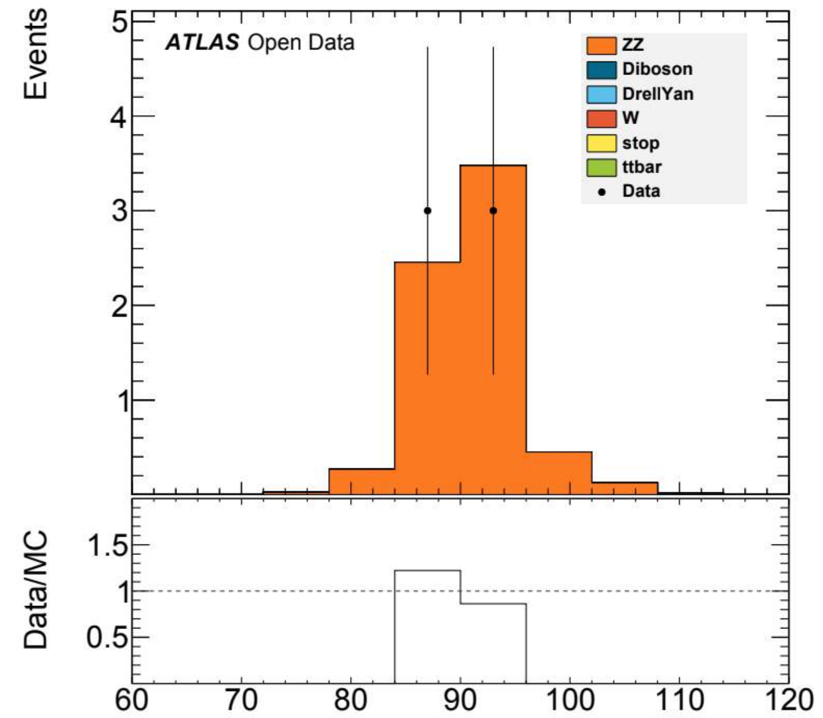


Figure 5

Higgs Boson (Figure 6)

Whilst theoretically I could use a slight bump in this graph of HWW analysis to determine the mass of the Higgs boson, I have a relatively small amount of data and of out of all our 12 million events only about 30 of them had interactions with the Higgs. This is reflecting in the on pixel thick blue line at the bottom of a graph which tells us that the Higgs is there somewhere but we can't it's mass to a good degree of accuracy. The most I can tell is that it has a mass between zero and 200 GeV which is such a large range of that it only tells us that it has a mass. This is where I would use the cuts that I found using the histogram analyser to increase the significance, however the cuts don't carry across the entire data set so whilst it will increase the significance slightly it won't be enough to find the Higgs.

My results

Name	Mass (GeV)
W boson	79±0.5 GeV
Z Boson	90±5 GeV
Higgs Boson	100±100 GeV

Figure 8

Conclusion

I had enough data to determine the mass of a W boson with low uncertainty and high accuracy, across two analyses. I had a high accuracy for the mass of a Z Boson however I had large uncertainties due to a lack of data. This lack of data was most impactful in finding the mass of the Higgs Boson since I only had enough data to determine that it had a mass.