E214: ATLAS

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Abstract goes here

1 Introduction

Introduction text

2 Theory

2.1 The ATLAS detector

To detect the various particles created by the collisions, the ATLAS detector consists of several layers.

The inner detector helps determining the particle paths as precisely as possible. Determining the momentum of charged particles is made possible by utilizing a solenoid magnet surrounding this system, creating a 2 T magnetic field in which a particle with charge q experiences a force of

$$\vec{F} = \frac{d}{dt}\vec{p} = q\vec{v} \times \vec{B},$$

from which it is possible to calculate the momentum.

- The innermost layer consists of semiconductor pixels (pixel detector, PD), which allow for precise reconstruction of vertices.
- The semi-conductor tracker layer (SCT) serves the same purpose, but with long strips that make covering a larger surface area more practical.
- The transition radiation tracker (TRT) consists of thin, long tubes (drift chambers) with inhomogeneous medium filling in the space between them. A particle passing through this medium emits transition radiation. The photons created this way, along with the particle itself, interact with the gas inside the tubes, causing ionizing. As there is a voltage applied to an electrode in the middle and the tube, the electrons are drawn to the electrode, contributing to an electric pulse. As the transition radiation is strongest for particles with high velocity, the strength of the signal can be used to identify the lightest particles, electrons and positrons.
- The solenoid superconductor magnet mentioned above, creating the magneti field $\vec{B}$ which is parallel to the colliding beams.

The layers surrounding the inner detector are the following:

- The electromagnetic calorimeter (ECAL) is made of accordion-shaped lead and stainless steel sheets responsible for interacting with the particles passing through, creating an electromagnetic shower. The liquid argon between the sheets is ionized by the particles passing through, and the created free electrons are drawn to a copper electrode. The signal strength can be related to the deposited energy. This calorimeter stops photons, electrons and positrons entirely. Hadrons and muons also deposit some energy here, but they pass through to reach the outer layers. The cooling system is a cryostat.

- The hadron calorimeter (HCAL) interacts strongly with the entering particles. The iron tiles induce hadronic showers. The particles thus created enter the scintillation tiles producing light, and these photons are carried away in an optical fiber to a unit which measures light intensity, from which the deposited energy can be calculated. The scintillation material is liquid argon, so a cooling system is used in this layer as well.

- The muon calorimeter is needed to measure the energy of the muons: these particles pass through all the previous layers with losing only part of their energy. This unit is supplemented by a larger magnetic system consisting of toroid magnets; thus the muon system is capable of determining the momentum independently of the inner layers. The tiles making up this layer consist of thin tubes filled with gas, and work on the principle of ionization, similarly to the TRT tubes.

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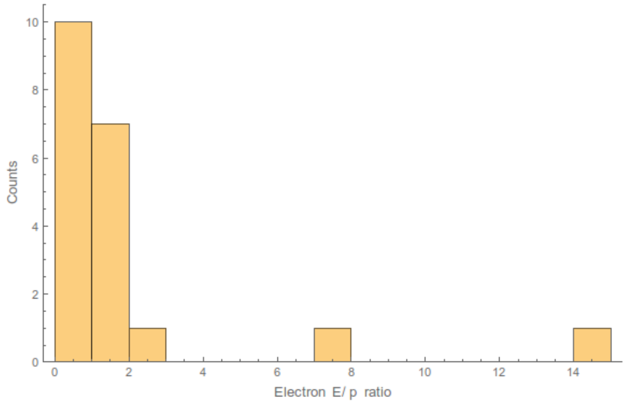

Figure 1: Electron E/p histogram.

3 Experimental setup

4 Procedure

4.1 Atlantis

As our first task, we looked at examples in the event display software Atlantis. This way we got familiar with the working of the ATLAS detector. We had to complete two introductory tasks as described below.

4.1.1 Electron energy

We looked at the first twenty electron events in the learning data-set, determining the momentum by the track radius and the energy of the ECAL clusters by manually selecting the region. The results are summed up in Table 1. The histogram made of the E/p ratios is shown in Figure 1

4.1.2 Muon momentum comparison

As our second task, we compared the measured muon momentum in the muon spectrometer and the inner detector. Calculating the differences between the two methods (Table 2), we noticed some cases where the muon seems to have gained momentum. The average energy loss is 6.87 GeV.

4.2 Electron energy calibration

As the detector is not ideal, we need to calibrate the different regions to account for the differences in their characteristics. We chose sections of $\Delta\eta = 1.25$ and $\Delta\varphi = \pi/2$ ($-2.5 \leq \eta \leq 2.5$, $-\pi < \varphi < \pi$). Using the well-known Z^0 mass, we used cuts to limit ourselves to each of these intervals and iterated the process of scaling the individual values. We also introduced a transverse momentum dependent correction, finally a constant shift. Our final *ElecCalib.C* contents can be seen in Section 7. The mass obtained after three iterations is

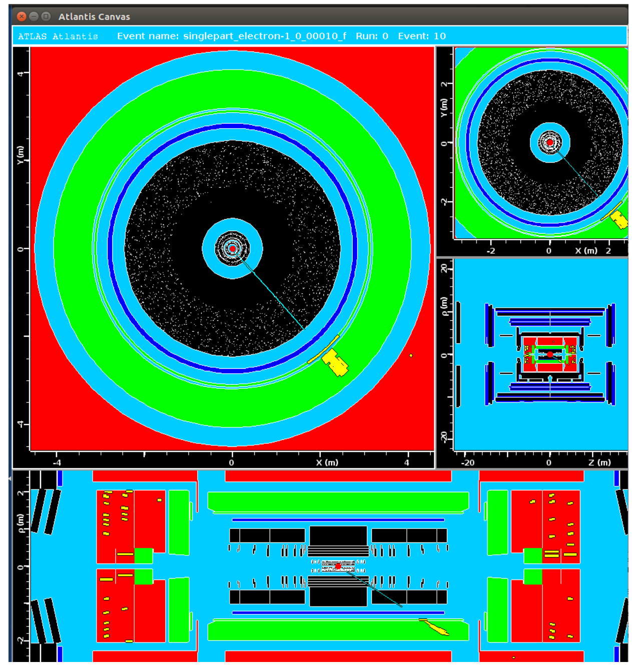

Figure 2: An (artificial) electron track as viewed in ATLANTIS.

#	I.D. (GeV)	ECAL (GeV)	E/p
1	26.2	54.7	2.09
2	22.78	35.2	1.55
3	244.35	223.2	0.91
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	66.67	78.3	1.17
7	7.55	56.6	7.50
8	129.82	162.9	1.25
9	3.27	47.7	14.59
10	79.01	66.2	0.84
11	95.93	78.7	0.82
12	37.4	30.6	0.82
13	89.35	86.5	0.97
14	235.24	242.3	1.03
15	105.14	105.3	1.00
16	N/A	N/A	N/A
17	28.62	28.1	0.982
18	53.41	46.4	0.869
19	32.92	64.3	1.95
20	105.64	80.8	0.765
21	N/A	N/A	N/A
22	93.52	82.1	0.878
23	113.98	92.7	0.813
24	155.35	283	1.82

Table 1: Electron task

#	I.D. (GeV)	M.C. (GeV)	Diff. (GeV)	η	ϕ°
1	85.28	53.92	31.36	1.437	21
2	43.4	43.83	-0.43	-0.767	25
3	241.37	237.02	4.350	-2.438	230
4	48.89	44.77	4.12	0.567	311
5	168.16	177.62	-9.46	-1.809	244
6	117.32	96.56	20.76	1.621	152
7	71.94	64.96	6.98	0.699	3.8
8	199.91	199.44	0.470	1.797	67
9	57.84	50.01	7.830	-0.287	241
10	71.1	0	71.1	1.181	312
11	100.75	94.11	6.64	-1.636	48
12	38.26	34.48	3.78	0.189	326
13	105.19	108.68	-3.490	1.163	224
14	236.12	263.61	-27.49	2.286	103
15	131.69	125.51	6.180	-1.763	255
16	152.24	157.69	-5.450	-1.874	27
17	35.23	32.18	3.05	0.395	326
18	54.19	50	4.19	0.229	336
19	84.75	68.09	16.66	0.773	260
20	104.26	107.98	-3.72	1.421	78

Table 2: Muon assignment. The first column shows the Inner Detector measured momentum values, the second column the muon calorimeter momenta, the third column the loss of momentum (negative values show an increase in momentum), the fourth column η, the pseudorapidity, the last column the azimuthal angle.

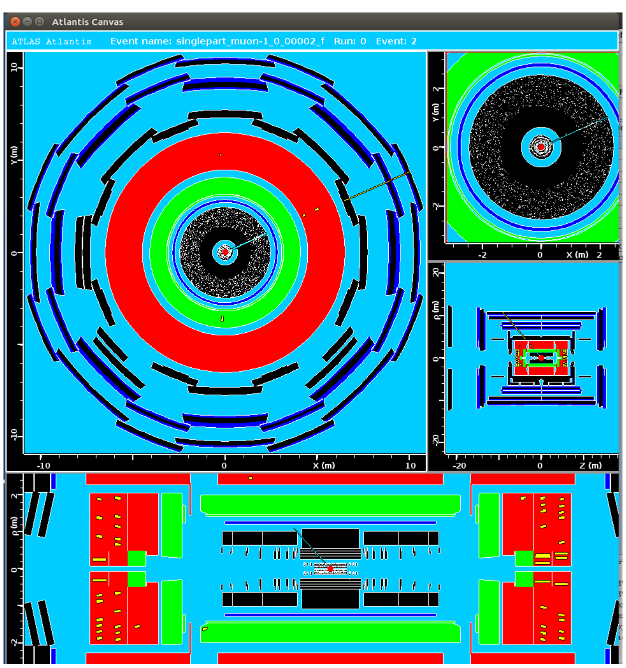

Figure 3: Artificial muon event as seen in Atlantis (the panel with quantitive informations has been cropped for better visibility).

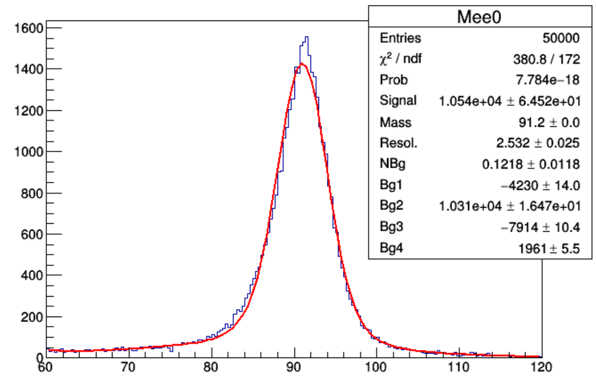

Figure 4: Final iteration fitting of Z^0

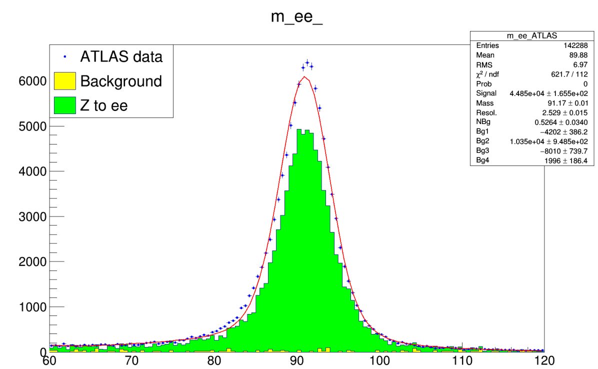

Figure 5: Z^0 mass from ATLAS data

91.1975 ± 0.0204 GeV, with resolution 2.5315 ± 0.0251, we considered this precise enough for our purposes. Figure 4 shows our fitting.

4.3 Measurement of the W-boson mass

After setting up the electron energy calibration file, we tested it on real ATLAS data, as seen in Figure 5. The mass acquired here is in good agreement with the commonly accepted value. As our next step, we tried scaling the QCD background by comparing the ATLAS data points and our stack-plot. We decided that the scale factor $\alpha = 0.35 \pm 0.05$ gave a fair match (the error was approximated by manual trial). Following the guide, we then set up a macro file to visualize the effect of our cuts on the different data sets of W-boson events with different masses, all at once. The measured half maxima and a linear fitting is shown in Figure 7. We found the linear fitting to be

$$\mathrm{HM}(m) = (0.50267 \pm 0.00867) \cdot m + (2.2613 \pm 0.6898)$$

For the real data, we obtained the half max to be at 43.04 ± 0.09, which gives, after inverting the previous relation, a mass of $m_{\mathrm{W}} = 81.12 \pm 2.03$ GeV.

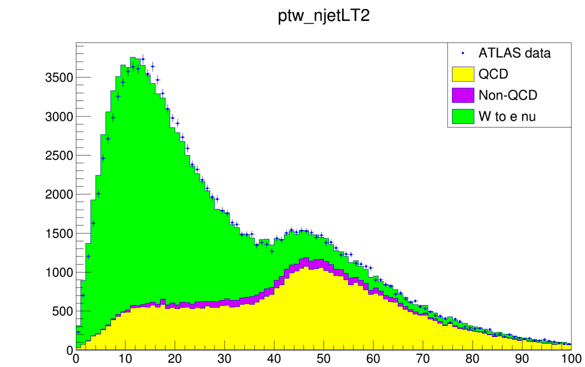

Figure 6: QCD scaled to achieve (by eye) a good match between the stack-plot and the data points.

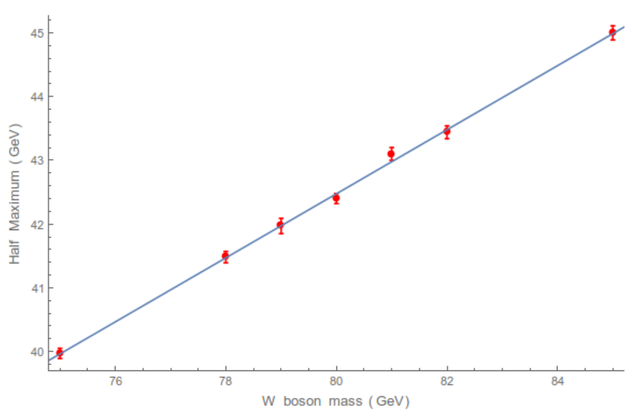

Figure 7: The gauge curve data points with linear fitting.

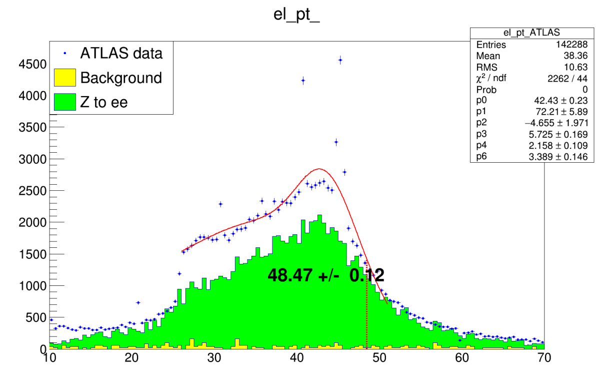

Figure 8: Plot showing the cross-check procedure.

4.4 Cross-check using ATLAS *ee* pair data

The gauge curve can be applied in the case of data for electron-positron pairs. Using the inverse of the gauge function again, we get

$$HM^{-1}(48.47 \pm 0.12) = 91.927 \pm 2.171\,\text{GeV}, \qquad (1)$$

in good agreement with the literature value, which supports our previous works.

4.4.1 Error sources

5 Results

6 Conclusion

References

[1] K. Siegbahn, *Alpha-, beta-, and gamma-ray spectroscopy, Vol. 2* (North Holland Publishing Company, Amsterdam, 1965).

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[3] ATLAS Experiment YouTube channel, `http://youtube.com/TheATLASExperiment`.

[4] W. U. Boeglin, *Scintillation Detectors*, WWW Document, `http://wanda.fiu.edu/teaching/courses/Modern_lab_manual/scintillator.html`.

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7 Code

```
#include "math.h"
#include "TMath.h"

double ElecCalib(double e_raw, double pt, double eta,
                 double phi, double etiso, double eoverp, double mindrjet)
{
  //double dummy=pt*eta*phi*etiso*eoverp*mindrjet;
  double energy = e_raw ;

if (eta>-2.5 && eta<-2.5/2){
    if (phi> -3.14 && phi< -3.14/2) energy = energy *(91.2/89.79)*(91.19/91.19)*(91.19/91.17);
    else if (phi> -3.14/2 && phi< 0) energy = energy *(91.2/89.76)*(91.19/91.23)*(91.19/91.18);
    else if (phi> 0 && phi< 3.14/2) energy = energy *(91.2/89.69)*(91.19/91.14)*(91.19/91.18);
    else if (phi> 3.14/2 && phi< 3.14) energy = energy *(91.2/89.6)*(91.19/91.09)*(91.19/91.13);
}
else if (eta>-2.5/2 && eta<0){
    if (phi> -3.14 && phi< -3.14/2) energy = energy *(91.2/89.84)*(91.19/91.17)*(91.19/91.15);
    else if (phi> -3.14/2 && phi< 0) energy = energy *(91.2/89.72)*(91.19/91.13)*(91.19/91.17);
    else if (phi> 0 && phi< 3.14/2) energy = energy *(91.2/90.11)*(91.19/91.3)*(91.19/91.25);
    else if (phi> 3.14/2 && phi< 3.14) energy = energy *(91.2/89.92)*(91.19/91.22)*(91.19/91.22);
}
else if (eta>0 && eta<2.5/2){
    if (phi> -3.14 && phi< -3.14/2) energy = energy *(91.2/89.86)*(91.19/91.13)*(91.19/91.16);
    else if (phi> -3.14/2 && phi< 0) energy = energy *(91.2/89.96)*(91.19/91.22)*(91.19/91.22);
    else if (phi> 0 && phi< 3.14/2) energy = energy *(91.2/89.73)*(91.19/91.12)*(91.19/91.16);
    else if (phi> 3.14/2 && phi< 3.14) energy = energy *(91.2/89.91)*(91.19/91.16)*(91.19/91.20);
}
else if (eta>2.5/2 && eta<2.5){
    if (phi> -3.14 && phi< -3.14/2) energy = energy *(91.2/89.92)*(91.19/91.23)*(91.19/91.22);
    else if (phi> -3.14/2 && phi< 0) energy = energy *(91.2/90.01)*(91.19/91.16)*(91.19/91.23);
    else if (phi> 0 && phi< 3.14/2) energy = energy *(91.2/89.82)*(91.19/91.16)*(91.19/91.18);
    else if (phi> 3.14/2 && phi< 3.14) energy = energy *(91.2/89.91)*(91.19/91.12)*(91.19/91.21);
}

if (fabs(pt)>0 && fabs(pt)<20) energy = energy*(91.19/89.26)*(91.19/90.04);
else if (fabs(pt)>20 && fabs(pt)<30) energy = energy*(91.19/90.13)*(91.19/90.79);
else if (fabs(pt)>30 && fabs(pt)<35) energy = energy*(91.19/90.51)*(91.19/90.92);
else if (fabs(pt)>35 && fabs(pt)<40) energy = energy*(91.19/90.68)*(91.19/90.86);
else if (fabs(pt)>40 && fabs(pt)<45) energy = energy*(91.19/91.32)*(91.19/91.1);
else if (fabs(pt)>45 && fabs(pt)<50) energy = energy*(91.19/92.34)*(91.19/91.75);
else if (fabs(pt)>50 && fabs(pt)<60) energy = energy*(91.19/92.31)*(91.19/91.92);
else if (fabs(pt)>60) energy = energy*(91.19/91.89)*(91.19/91.85);

energy = energy - 0.025;


  // if (fabs(eta)>1.5) energy = energy * 91.2/78.2;
  // else if (fabs(eta)>2.0) energy = energy * 91.2/85.4;
return energy;
}
```