ISP220 Honors Project: Analyzing LHC Collisions in the ATLAS Detector

Spring 2014

Document 2, April 5 , 2014

Due: Last Day of Final Exam Week, May 2, 2014

The Data Analysis

By this point, you've been through Exercises 1 and 2, and so you're beginning to get a feel for what events of particular kinds would be like in the ATLAS detector. We do not scan these things by eye – there are billions of them every month. Rather we train computers to do "pattern recognition" analyses and only look at the displays when things go wrong, or when things go very right. Science is much more the former, than the latter.

We're doing the "W-Path analysis" from https://kjende.web.cern.ch/kjende/en/wpath_ziele.htm. It involves three measurements which you can do by keeping a tally of the kinds of events you see and categorize. Note: these are real events, there is no correct answer in the back of the book. You make your best evaluation!

You will find a worksheet called...well, "worksheet.pdf" in

http://www.pa.msu.edu/~brock/file_sharing/QSandBB/extra/HonorsProject/

Use it to keep track. By "tick marks" it the column, I mean whatever stick-marks you use to keep track of counting. To me, that means for "7" I'd have made the marks: . Get what I mean?

Here are your measurements:

1. **W production and decay.** This requires you to scan and classify all of your events. The theory of Weak Interactions predicts that there will be an absolute universality among the leptons. In particular, a *W* Boson's propensity to decay to an electron and a neutrino, should be the same as it's relative probability to decay to a muon and its neutrino (or tau and its, for that matter). So one of your measurements will be to determine the rate:

$$R_1 = \frac{\text{number of } W \to e\nu_e}{\text{number of } W \to \mu\nu_\mu}$$

In your writeup, then report the numerator, denominator, and the ratio. The numerator will be all electrons and positrons and the denominator will be all muons and antimuons.

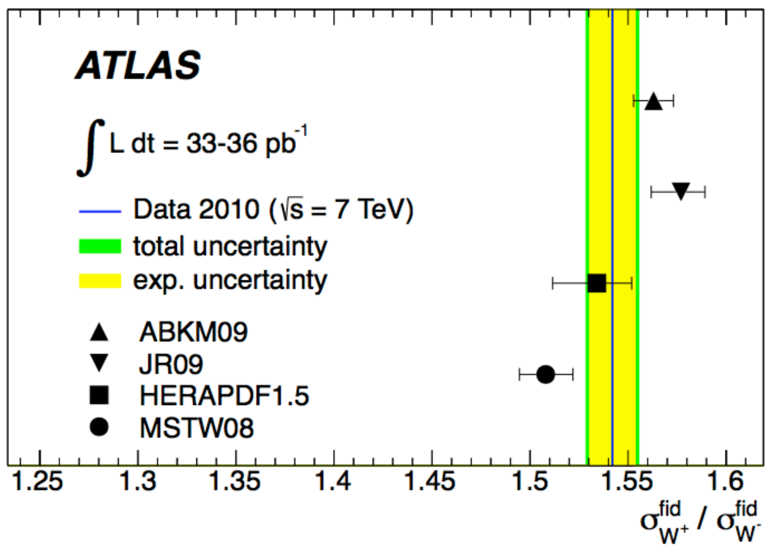
You can calculate it by hand, or you can download and use the Excel spreadsheet "Rs.xls" at

http://www.pa.msu.edu/~brock/file_sharing/QSandBB/extra/HonorsProject/

There, you fill in the yellow numbers and it will calculate the ratio and the uncertainty on the ratio.

2. **The Structure of the Proton.** The theory of how the quarks and gluons distribute themselves in a proton predicts that the rate of $R_2 = \frac{W^+}{W^-}$ should be about 1.5. Here the positive leptons in the numerator are the sum of the positron final states plus the antimuon final states. The denominator is the sum of the electron and muon final states.

The figure below is an actual measurement from last year of this quantity, using in part the data that you've got. The number across the bottom ("x axis") is our quantity R_2. The yellow band is the value from ATLAS while the 4 different black points are the predictions from 4 different groups of theoretical physicists for what that quantity should be. Notice that there's not great agreement among the theorists, but they're scattered around the measurement nicely.



Here are the instructions from the web site for Measurement 2:

https://kjende.web.cern.ch/kjende/en/wpath_proton.htm

As in measurement 1, you can calculate your results by hand or by using the spreadsheet.

3. **Higgs Boson.** The third measurement is a search for the Higgs Boson in one of the many channels in which it decays. In this one, the Higgs Boson decays into two *W*'s and they then decay in the normal ways. This is slightly complicated since the Higgs Boson that we actually found has a mass of about 125*p*[1] but the *W* Boson has a mass of about 80*p*, so two of them would be 160*p* and more than the actual Higgs mass! So the way to think about this is that the *W* Ur Field is still disturbed, but not enough to actually make a real *W* boson, but rather a "virtual" *W* boson which then does manifest itself into *W* boson decay products, but with a total energy that's not that of a real, sitting-there *W*. You can let Matt Strassler explain more here: http://profmattstrassler.com/articles-and-posts/the-higgs-particle/the-standard-model-higgs/decays-of-the-standard-model-higgs/

[1] Remember, that I sometimes write masses as "*p*" meaning the mass of the proton. So 125*p* is 125 times the mass of the proton, or about 125 GeV/c^2.

There are many ways to misidentify such signal events, in particular non-Higgs Boson production of the same final state. One way to try to discriminate the signal from the background is to measure the angle between the outgoing leptons, whether electron or muon. Minerva does that for you. Notice that since the Higgs Boson is neutral, then the two W's must be of opposite signs and hence, their decay leptons will be opposite signs. So only consider those. That is no e-e- or e+e+ final states. Only e-e+ or the same for muons.

Here are the instructions from the web site for this measurement:

https://kjende.web.cern.ch/kjende/en/wpath_higgs.htm

Don't bother with the "Analysis" link on the side, since that's aimed at combining the data from around the world for a big video-showdown. We're not about that.

Your Data

Your data sets are found at:

http://www.pa.msu.edu/~brock/file_sharing/QSandBB/extra/HonorsProject/DataSets/

and are assigned to each of you as in the table below. They are all randomly sorted events of real ATLAS data, with maybe some real Higgs Boson events. Which ones? I don't know! Each dataset consists of 50 events which you'll analyze for their features and assign your guess as to their actual origin. No two datasets are the same.

Just click on your set at the above link and it will download to your computer. Put the folder in the directory where you have your Minerva app. It may be in a zipped archive format, or in individual xml files. As you have seen by now, Minerva will read a zip archive and it also will read the individual files if you point it at them by opening.

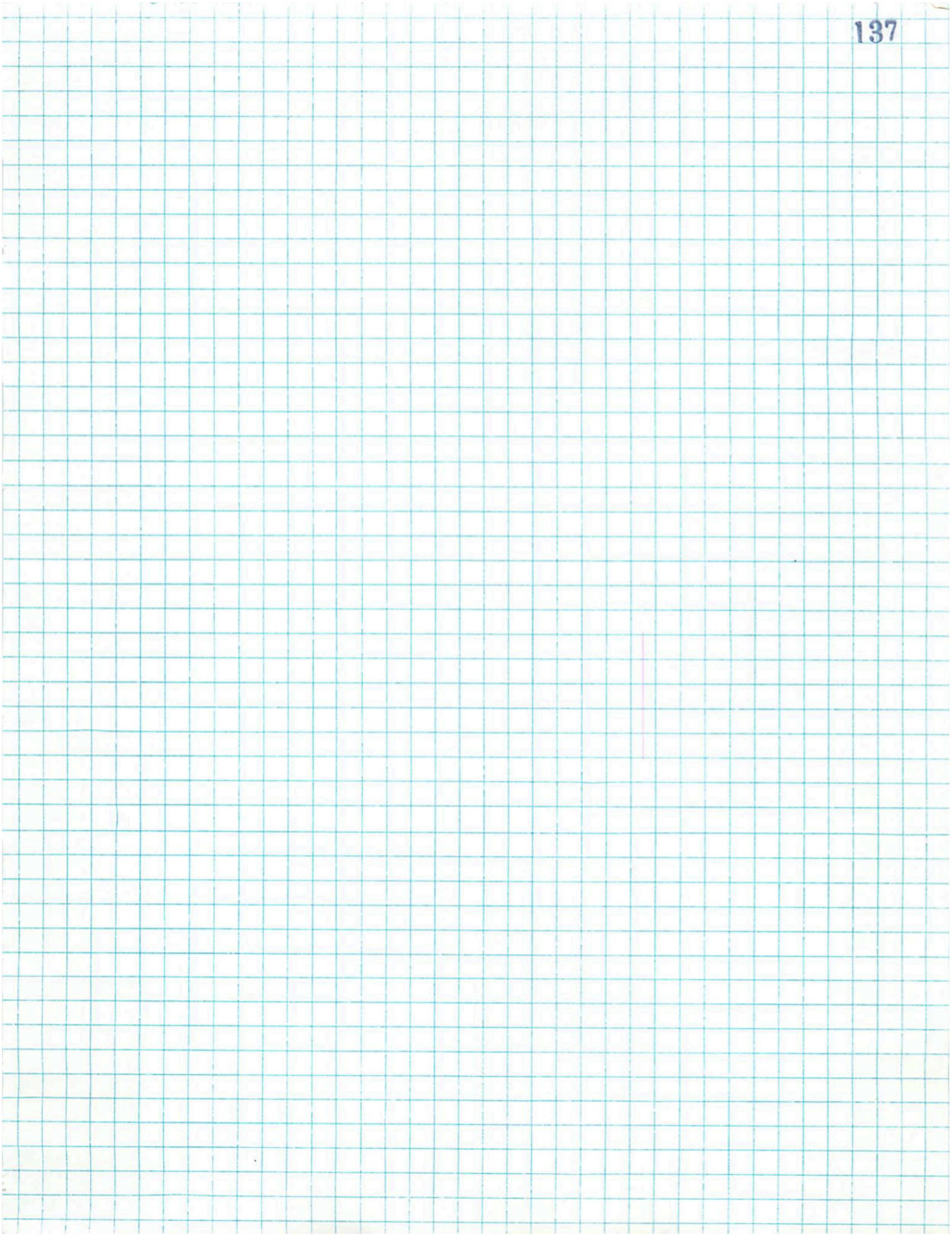
Your Results

What you should turn in is enumerated on the first document. Include your worksheets and the spreadsheet if you use it. If you print out any events, include them. Remember, keep a narrative like you're really doing an experiment...which you are!

Have fun!

Aughton, Michael David	1	A
Bratzel, Claire Louise	1	B
Dekker, Emma Kristian	1	C
Ellenstein, Steffany Shawn	1	D
Ellerby, Island Elena Lee-Rae	1	E
Foland, Elizabeth Ann	1	F
Friedman, Parker Hale	1	G
Glaser, Emily Suzanne	1	H
Gomulinski, Mark Alexander	1	I
Graham, Eva Elizabeth	1	J
Ho, Alexander Hy	1	K
Macdonell, Cooper Robert	1	L
Oderkirk, Elizabeth Noel	1	M
Stauffer, Linsey Scholl	1	N

Logbook:



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