ISP220 Honors Project: Analyzing LHC Collisions in the ATLAS Detector

Spring 2014

Document 1, March 23, 2014

Overall Project Due: Last Day of Final Exam Week, May 2, 2014
Exercises described in this first of two sets of directions to be done by Friday, April 4, 2014.
Instructions for the rest will be provided in a week. So if you get through this quickly, you can move forward.

The Aim of the Project

In this project you will analyze actual events which have been collected by the ATLAS experiment during the last year. There are two actual physics analyses that you'll perform, one which will explore the contents of the proton and the other will be a search for Higgs Bosons hidden inside of the data. (Obviously, since the Higgs Boson has not been discovered yet, the Higgs events are actually simulated events which are scattered throughout.)

These tools are from an international "master class" that was held in cities around the world. In it, high school kids and teachers assembled near universities and laboratories with particle physicists and received lectures and were taught how to use the tools that we'll use. Then in pairs the students did their work and uploaded their results to a central server in Norway were the results were combined. At the end, each site reported their results in a global video conference and the combined results were viewed. We didn't take part at MSU, but I think I will do this from now on! With that hands-on assistance the project was completed in what the organizers tell me was about 2 hours of work. It will take you a little longer since you'll be working individually, but of course you can collaborate if you like. You'll all have independent datasets.

I'll refer you in this document to portions of the website that was used for training and then we'll go our own way for the actual analysis.

There are two sets of resources, besides the links that follow. This document and two talks that introduce Particle Physics (beyond where we are in class) and the data you'll use are at:

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

There you'll currently find:

ISP220_inspirationaltalk.pdf, which is about Particle Physics. Go ahead and look at this now. It's a little out of date, but still a good introduction to the ATLAS detector. Here's one from the Duke Mastersclass for High School kids that was actually last week! ATLAS_Masterclass_Intro_1.pdf

ISP220_MinervaInstructions.ppt.pdf is also there and it's about the project. I'll refer to it below.

We'll do this in phases. First, you'll do some learning on-line about the detector. Next, you'll install the program and go through some testing. Then, finally I'll point you to larger datasets that you can analyze. Let's get the bugs ironed out on Phase 1 this week.

The Project Report

I'd like a report that will have the following sections:

1. **The LHC (2)**
   1.1. What it is (0.5)
   1.2. How it accelerates particles (0.5)
   1.3. The layout (1)
2. **The ATLAS Detector (2)**
   2.1. What it is. (0.5)
   2.2. How it detects particles (0.5)
   2.3. A cross section of the detector (1)
3. **W Bosons (2)**
   3.1. What are they?
   3.2. How were they discovered?
   3.3. What kinds of signatures do they leave in the detector?
4. **Z Bosons (2)**
   4.1. What are they?
   4.2. How were they discovered?
   4.3. What kinds of signals do they leave in the detector?
5. **Higgs Boson (2)**
   5.1. What is it?
   5.2. What kinds of signals will the Higgs Boson leave in the detector?
6. **Data Collection**
   6.1. This will be your "logbook" for each session during which you did analysis work and your learning. Handwritten on blank sheets of paper, numbered. It's your scientific logbook, just like we all keep. I've even copied one of my own logbooks for you to use (at the end of this document). There will be two of them:

   Learning Log

   - For your "learning" part, there are two "Exercises" below which will be short tutorial sessions that you should enter into your "log," so indicate on a sheet:
     - Write the date and time,
     - what you saw in each event,
     - what choices you made, what the computer told you,
     - what you did to fix your mistakes
     - *...A narrative of your effort, in first person singular.*

   Data-taking Log

   - When you start analyzing events, you'll keep a log just like you were in the control lab analyzing data.
   - Then each day that you work on ATLAS, document your session:
     - Write the date, time started
     - Indicate your dataset name (you'll see)

- Indicate what event numbers you looked at
- Write down your comments and observations...what puzzled you, what thought processes you used. You know, your logbook.

6.2. Results

- Results from your Data-taking sessions will be entered into tally sheets that I'll give you

7. Summary (1)

7.1. Your Conclusions

7.2. Your Impressions

Where drawings are required (like 1.1, 1.3, 2.3, etc), I don't want graphics taken from the web. The sketches don't have to be elaborate. You can generate them on a computer drawing program, or better yet, make hand-drawn sketches. Seriously. Do it by hand, using a ruler and a curved edge so that they look neat and nice. I want the work to be through your fingers, and into your brain!

I don't want a huge paper from you. But I would like complete paragraphs and sentences. I've indicated roughly how many pages which hopefully will gauge the depth of your research and reporting.

Phase 1: The ATLAS Detector

We've talked about the ATLAS detector and you've seen pictures of it, and now you've even seen it up close. It consists of roughly 5 kinds of detectors that surround the beam in concentric, open cylinders. In class, I've referred to a generic detector: tracking, electron calorimeter, hadron calorimeter, and muon detectors. It is more complicated than that, but you can learn it. What I've not talked about are the end sections of the detector, but the information below will complete that story.

4. 1. Go to and learn about the ATLAS instrument:

https://kjende.web.cern.ch/kjende/en/wpath_teilchenid1.htm

and follow through that page, playing with the interactive detector. On the right hand side, you'll see links to additional information.

4. 2. Read the link on the side "ATLAS Detector"

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

5. 3. Identify Events

In order to piece together events, the individual particles need to be identified and matched together. For our purposes, these are electrons, positrons, neutrinos, jets, and muons. The link https://kjende.web.cern.ch/kjende/en/wpath_teilchenid2.htm

shows you what particles look like in the actual detector at the bottom. Click on the images and notice that they are each packages that open to information about each picture.

The next page
https://kjende.web.cern.ch/kjende/en/wpath_teilchenid3.htm

has more information about the particles of importance.

4. Take the Quiz: “Exercise 1”

There is an interactive quiz on events...notice that some events will have more than one particle, so you will be clicking more than one answer for each of the test events. Remember, you’re logging this work as in 6.1 above.

This will be your first introduction to the MINERVA display, which is a subset of the actual GUI used in ATLAS. In Phase 2 you’ll create an instance of the MINERVA display on your computer.

https://kjende.web.cern.ch/kjende/en/wpath_exercise1.htm

Here the first 36 slides in ISP220_MinervaInstructions.ppt.pdf from http://www.pa.msu.edu/~brock/file_sharing/QSandBB/extra/HonorsProject/ will help.

Phase 2: The MINERVA Display

5. Download the MINERVA display

The MINERVA display is pretty simple to use, but will require some practice. Slide 37 in the above document is aimed at Exercise 2.

You will download the zip[1] file that contains everything you’ll need (except the big dataset). Your computer will unzip it for you automatically, or you’ll double click on it and it should unpack. There are a variety of files and folders inside. But move it to a place where you will do your work. I suggest making a directory `HonorsProject`, and move the minerva folder inside.

You can get it here:

http://www.cern.ch/kjende/downloads/minerva2014.zip

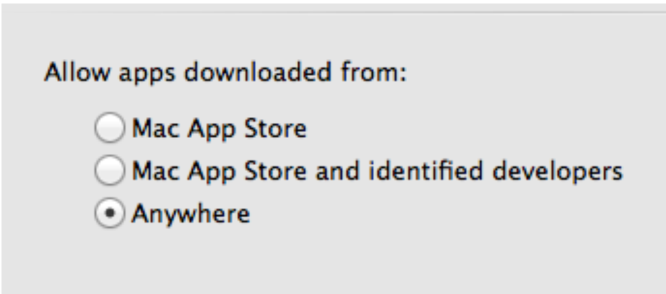
When it unpacks on a mac, the “minerva” directory looks like this:

minerva2013-1	Today 4:56 PM	16.6 MB	Folder
__MACOSX	Jan 30, 2013 7:10 AM	Zero bytes	Folder
atlantis.jar	Jun 16, 2011 11:47 AM	912 KB	Java JAR file
configuration	Jan 30, 2013 7:10 AM	3.6 MB	Folder
events	Jan 30, 2013 7:13 AM	3.8 MB	Folder
geometry	Jan 30, 2013 7:10 AM	223 KB	Folder
help	Jan 30, 2013 7:10 AM	284 KB	Folder
img	Jan 30, 2013 7:10 AM	942 KB	Folder
lib	Jan 30, 2013 7:10 AM	6.6 MB	Folder
share	Jan 30, 2013 7:10 AM	89 KB	Folder

[1] zip is a file format that is commonly used to package files and directories into a very compact size. It’s not usable in the zip format, but when you unpack it either by double clicking on it or because your browser did it for you, you’ll see the contents in a recognizable form. The zip file will be recognized by the name.zip extension. http://en.wikipedia.org/wiki/Zip_(file_format))

On windows, it will look a little different, but I expect that the folders will be the same and that there will also be an `atlantis.jar` application. This is a `JAVA` file, which is a little program written in the `JAVA` language that your computer can read.

If you have trouble with this, let me know. There is one Apple neurosis about downloading applications that don't come from the App Store. You need to go to system preferences and click into the Security & Privacy area and allow the computer to download apps from anywhere:



6. Test out the MINERVA display

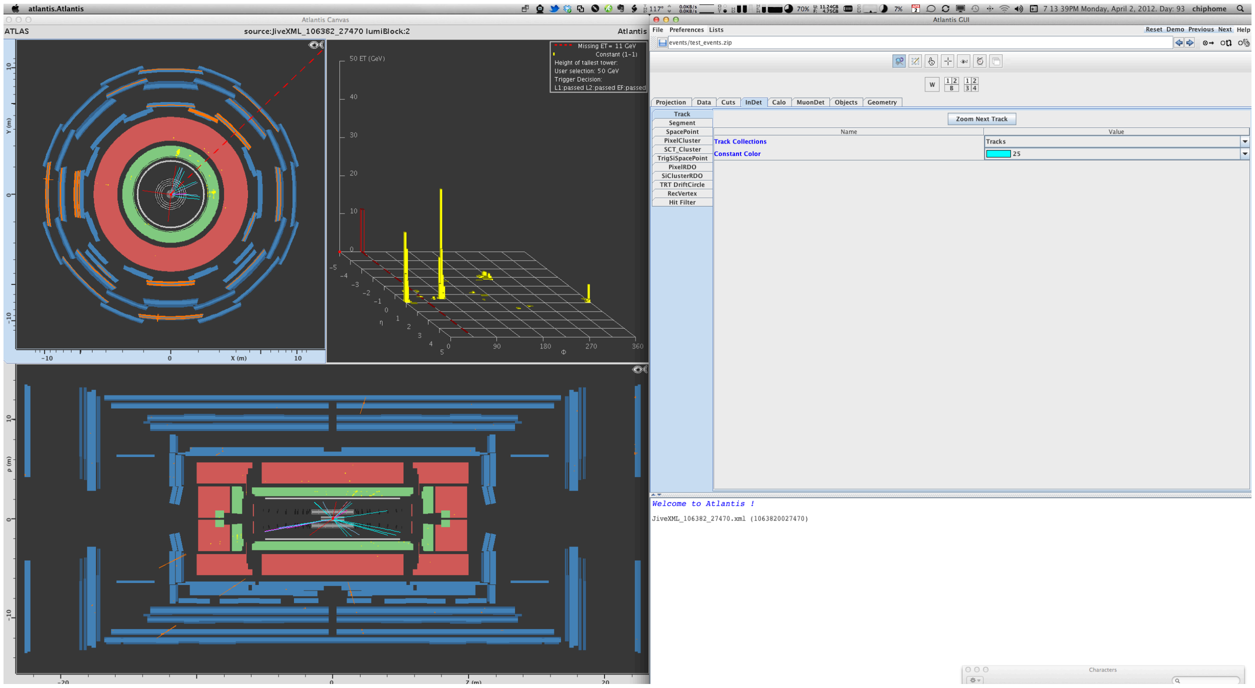
There are test events that will be loaded when you start up the display and there are some tutorials that will show you how to use it.

Here is a screencast:
http://www.youtube.com/watch?v=TNPm7120PjE

Ignore the instructions that he gives about datasets and the tasks. This starts at about 4:30 in the movie.

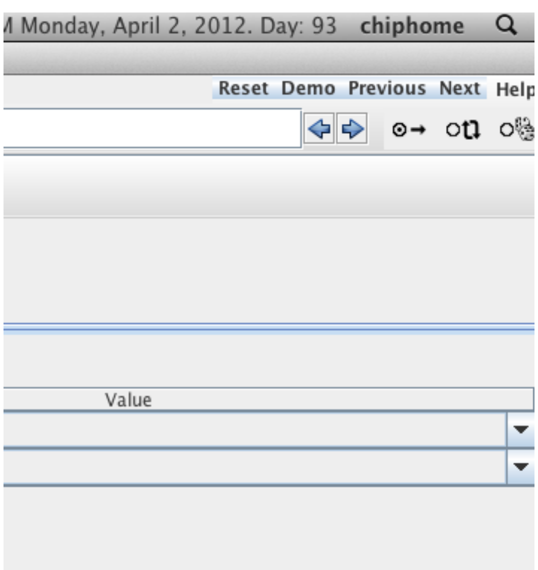
It's a little confusing in some of the details, since he had the screen cut off at the top! Here are screenshots of my version.

The whole thing:



There are 4 windows that appear. On the upper left, is the end view of the central calorimeters, tracker, and the muon system. Below it is the side view. On the middle is a histogram of the energy deposited in each cell. Here's how to think of it. Suppose the detector was a cylinder rolled up from a flat piece of paper. Unroll the paper flat and each cell in which energy could be deposited and read out would now be a little square. The amount of energy in each square is represented by a colored line (or rectangle) growing out of that cell. These are called Lego Plots, for maybe obvious reasons!

The window a the right is where you control what you see.

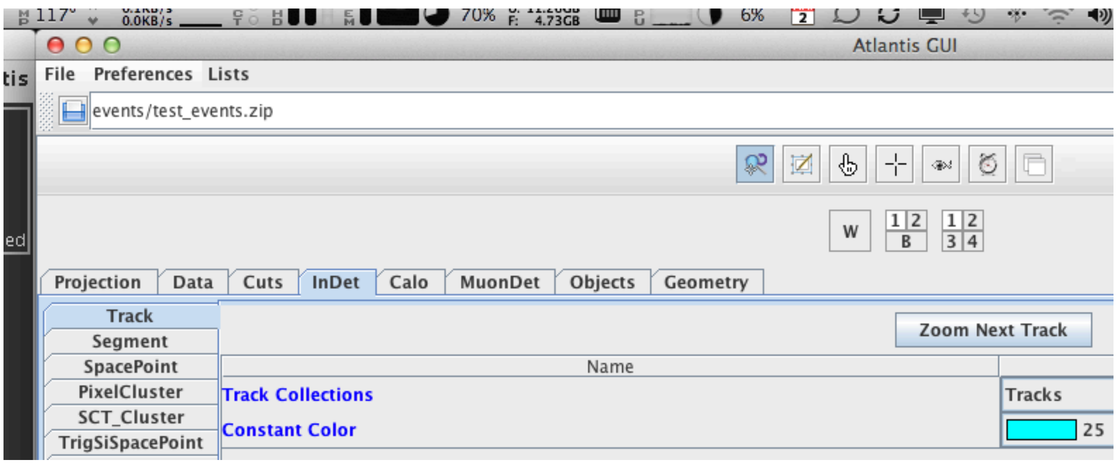


The upper right of the right hand window is blown up here. You can see the Previous Next buttons which cause the program to read the next event, or go back to the previous one.

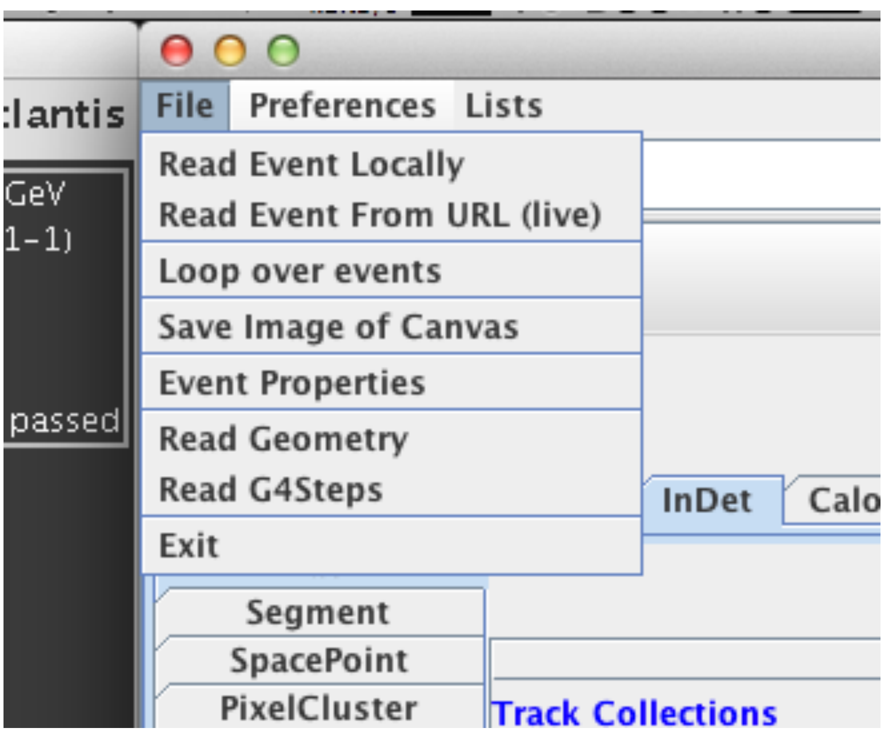
When the program starts up, it's already looking at 2 test events that you should study. What are they?

7. Another Quiz: "Exercise 2"

Your directory contains a file of practice events which are in the folder `events`. There you'll see `exercise2-2014.zip` . Your MINERVA program can gobble up the zip file and unpack it internally, so you just need to open it from within the program. Here's a blowup of the left of the control window and you'll see the File menu, which does exactly what you'd expect.

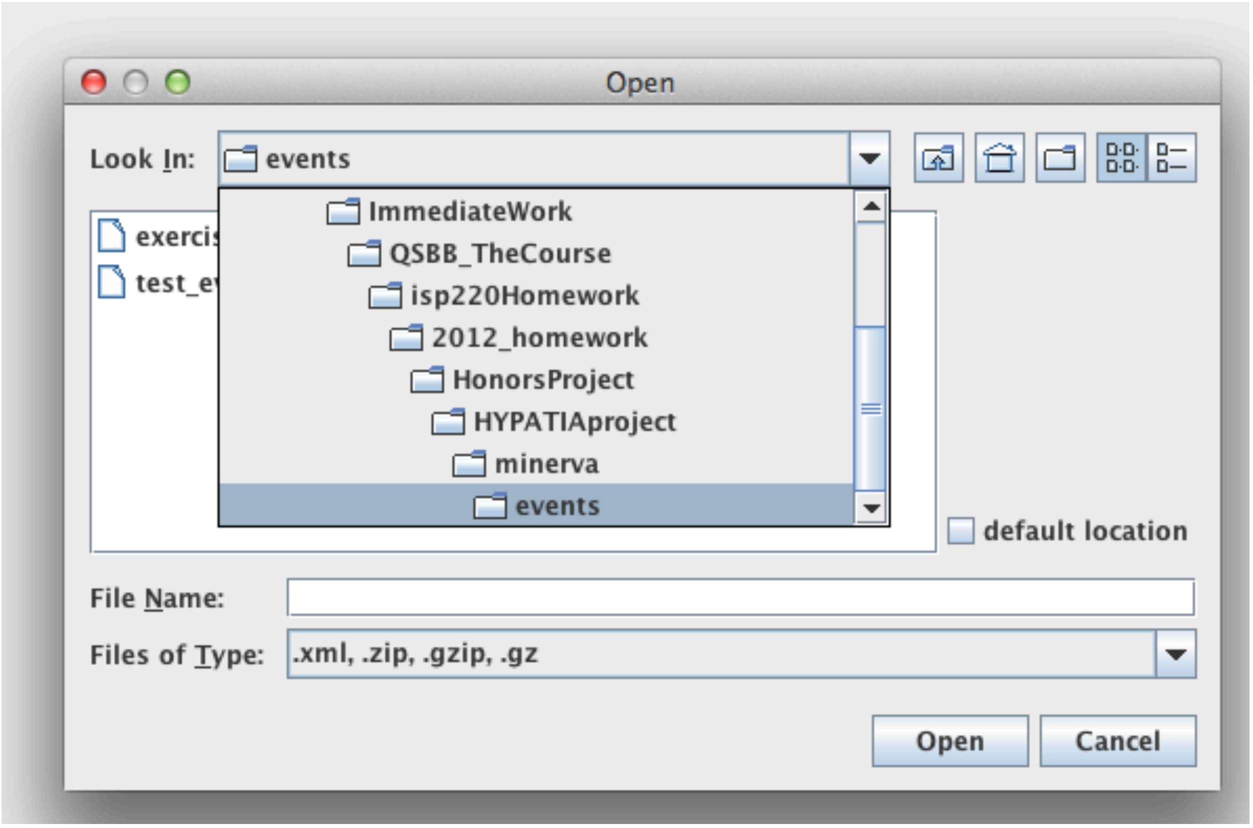


You'll navigate it to find events for your analysis.



Eventually, you'll have your own data for your analysis, but for Exercise 2, you'll open the `exercise2-2014.zip` file. The directory GUI is not what you're used to, so you'll need to play a bit.

Here's what mine looks like:



You navigate to your events folder and find the zip file. The little icon at the top left with the arrow through a folder takes you up a directory level. You'll get used to it.

So find the `exercise2-2014.zip` file and open those events up. There are 10 of them which you should classify, remembering to keep your logbook working.

On
https://kjende.web.cern.ch/kjende/en/wpath_exercise2.htm

there is actually an interactive web form that you can try to enter your guesses. You can cheat and press the Correct answers...and then you're not learning anything since it will fill in the whole table for you. If you do, reload the page and it will erase and you can keep going. Keep track for your log of what you did and what the end results are!

Here is a how-it-looks cheatsheet:
http://physicsmasterclasses.org/downloads/Zpath_cheat-sheet.pdf

Phase 3 will come after we've gotten you running and I'll provide Document 2 in a week or so that will get you into the actual data.

Try to get this done by Friday, April 4.

Logbook:

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