Introduction to Analysis Example Tutorial

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Information about the University of Oklahoma (OU)

- *The Princeton Review* consistently ranks OU among the best in the nation in terms of academic excellence and cost for students.
- The Department of Physics and Astronomy has four research groups:
  - Particle physics
  - Atomic physics
  - Condensed matter physics
  - Astronomy and Astrophysics
- We would welcome applications from ASP2016 participants (see: http://www.nhn.ou.edu)

Who we are

- We are DOSAR: Distributed Organization for Scientific and Academic Research http://www.dosar.org/
- You are welcome to join our bi-weekly video (Vidyo) meetings. Send request to be added to DOSAR email list to Prof. Greenwood: greenw@latech.edu
- If you want long-term grid access, you can request membership in the DOSAR VO

Typical data analysis tasks in particle physics

- Task 1: create files containing simulated data
- Task 2: analyze simulated data
- Task 3: collect real data from detector
- Task 4: analyze real data
- Task 5: compare simulation with real data
  - If there is good agreement, limits can be set on existence of new physical states (i.e. particles)
  - If there is disagreement, further study is needed
    - Possible mistake?
    - Possible new discovery?
- We will illustrate tasks 1, 2, (tutorial steps 1 and 3) and task 4 (tutorial step 2) today

Notes

- In particle physics software tools such Madgraph or Isajet (event generators) and GEANT (to simulate our detector response) are used in Step 1
  - We will use a simple random generator of a Gaussian distribution in Root
- Typically (almost) the same reconstruction software is used for Step 4 and Step 2
- Root is a powerful tool to read and analyze large amounts of data

Root Documentation

- Web page: https://root.cern.ch/
- It is useful to click on: Documentation and then select: Reference Guide
- From there you can look at the documentation and source code for all the Root classes in any version of Root

Condor submission script (run-root.cmd)

```
universe=vanilla
executable=run-root.sh
transfer_input_files = run-root.C
transfer_executable=True
when_to_transfer_output = ON_EXIT
log=run-root.log
transfer_output_files = root.out,t00.root,t01.root
output=run-root.out.$(Cluster).$(Process)
error=run-root.err.$(Cluster).$(Process)
notification=Never
queue
```

Step 1: Create simulated data by running Root on the Grid

- Contents of execution script: **run-root.sh**

```
#!/bin/bash
source /cvmfs/oasis.opensciencegrid.org/osg/modules/lmod/current/init/bash
module load root
module load libXpm
root -b < run-root.C > root.out
```

This command executes Root in batch mode using macro **run-root.C** and routes output to file **root.out**

Step 1: Create simulated data by running Root with macro **run-root.C**

- Create TFile 0 for “run 0” (t00.root)
- Create TTree object (“t0”) to store data in Root
  - Generate 100 “events” each with Gaussian distributed “Energy”
  - Fill TTree branches for each event
- Write TFile 0
- Close TFile 0
- Repeat above steps to create TFile 1 for “run 1” (t01.root)

Step 2: Analyze real data on the grid and with Root

- First we will run a Root macro to read di-muon events and fill a TTree with associated variables such as energy and transverse momentum
- The macro also determines the invariant mass of the muon pairs.
- Finally, we will examine the invariant mass with a Root TBrowser to determine the Zpeak mass

readEvents.C

- Macro to calculate the invariant mass of the first muon pair in each event and then plot the invariant mass in a histogram.
- Only looks at events which contain at least two muons where both muons have transverse momentum, p_T >20 GeV.
- The two selected muons have opposite charge.

Z-boson Plot

- A Z-boson is particle that only lives for a very short time before decaying. We can observe a Z-boson by looking at its decay products. The decay modes of the Z are here

http://pdg.lbl.gov/2016/tables/rpp2016-sum-gauge-higgs-bosons.pdf

- It decays to two muons or two electrons 3.4% of the time.

Determination of the Z boson mass

- A way to determine the Z boson mass uses the following:
  - The TLorentzVector class (http://root.cern.ch/root/html/TLorentzVector.html) is very powerful.
  - If you have two particles and want to know the properties of the particle which produced them, you can simply add them together:
  - TLorentzVector Particle1;
  - TLorentzVector Particle 2;
    - // set up the properties of particle 1 and particle 2
  - TLorentzVector MotherParticle = Particle1 + Particle2;

More Information

- ROOT website: https://root.cern.ch/
- Tutorials: http://root.cern.ch/root/html/tutorials/
- Reference guide for all classes: https://root.cern.ch/doc/v612/classes.html
- ATLAS Z cross-section legacy paper: http://arxiv.org/pdf/1010.2130v1.pdf

Step 3: make TSelector

While running Root:

```
TFile f("t00.root"); //open file
t0->MakeSelector("s0","=legacy"); //create TSelector
f.Close(); //close file
.q
```

This creates two files with code: s0.C and s0.h

We will modify these files to add a histogram of the Energy variable and use them to process the simulated data on the Grid

Conclusion

- After completing Steps 1 - 3 you are in principle ready to scale up and make TTree's with hundreds of variables and create and analyze thousands of files
- If time permits you can try adding your own features to the existing example by adding variables and histograms, etc.
- Good luck and have fun!!