Cracking the mysteries of physics using computers, I

Prof. Sarah Eno, Prof. Shabnam Jabeen

Course Descrip on:

This course provides training in fundamental physics and in the basic tools needed to contribute to experimental or theoretical frontier research in computationally intensive physics, such as experimental particle physics, theoretical plasma physics, and theoretically cosmology. You will learn kinematics, relativity, the standard model of forces and particles, theories of new particles and forces, particle interactions with matter, Linux, C++ and computational tools useful for frontier physics research. (3 credits)

Specific objec ves are:

- To learn about the wide variety of physics research areas that require strong computational skills, and the types of problems that can be tackled once some basic skills in this area have been acquired.
- To learn the basic computing environment used in most types of computationally intensive research
  - Linux
  - Computing languages. For example C++
  - Code and observations sharing through logbooks.
  - ROOT - An object-oriented framework for large-scale data analysis based on C++
- To learn enough physics to complete a preliminary project in this area. For this semester, the project will be in particle physics. Topics to be learned include:
  - Relativistic kinematics
  - The fundamental particles, their production modes in proton-proton collisions, their decay modes.
  - The fundamentals of a high energy physics detector and accelerator.
- Use current data and these skills to complete a project in computational physics. For this semester, it will be a rediscovery of the Higgs boson
  - Access the large data sample acquired during the 2012 run of the LHC
  - Use your knowledge of particles to select events consistent with those of the Higgs boson when it decays to 4 leptons
  - Reproduce the Higgs discovery plot from the CMS paper

Prerequisites:

calculus and a high school level introductory physics survey course. No previous experience with computers is required.

Classes:

Lecture: Tuesday, Thursday 11:00 – 12:15 PM (PHYS 3301)

Attendance:

Your attendance is critical to your success. Participation in class and discussion sections will be part of your grade.

Contact Information:

Prof. Shabnam Jabeen

Office: Physical Sciences Complex, Building 415, room 3107 Phone: (301) 405-2365 Email: **jabeen@umd.edu (mailto:jabeen@umd.edu)**

Office hours: Any time is good. You can contact me any time via email. For a meeting just send me an email and we'll schedule a time that is good for you.

TA: TBA

Office : **Email**:

Office hour: TBA

Text

Here is a prototype of the book being written for this course specifically.

ElementaryExperimentalHiggsPhysics-1.pdf

If you would like to review vectors, here is a brief introduction.

Vectors.pdf

Homework

Link to Homework Page

There will be a homework assignment for most weeks. All assignments will be posted on elms. Late homework will not be accepted except in the case of illness verified by a doctor's signature.

Paper Presentation

The student will write a **3000-3750 words paper** (Limit of words for Physical Review Letters) on the significance and methodology of some discovery in the fields of particle physics, astroparticle physics or plasma physics. Each student presents their paper at the end of the semester.

Logbook

You will be allocated a personal logbook where you will keep a record of your work.

https://sites.google.com/a/physics.umd.edu/honrxxx/logbook

Grading:

Your grade will be based on the following:

Paper/presentation	50%
Homework	25%

Logbook	25%

Topics Covered

PHYSICS (and other stuff)

1. Introduction to fundamental particles and forces and their properties. The fundamental Fermions and their properties
2. **Forces** as particle physicists view them, connection to particles, the bosons and their properties
3. Special **relativity**: distance, time, speed, momentum, energy, force, Relativistic particle collisions and Particle decay kinematics
4. Particle **detection** through their interaction with matter. Particle detectors: Calorimeters, ionization, semiconductor and scintillating detectors, particle detectors: identification of particles.
5. Particle **accelerators**: Linear and Synchronous accelerators. Colliding beams and luminosity
6. Parton distribution functions and particle **production** in pp collisions
7. **Higgs production** in proton--proton collisions. Focusing on the "golden channel" Higgs decay -- H-->ZZ--> 4leptons production in pp collisions
8. Introduction to **statistics**. Comparison of measurements to theoretical models, visualization of data
9. Measurements, fits, Parameters, uncertainties
10. Understanding and getting the LHC collision **data**
11. what is a **simulation**? Generating and understanding simulated data for signal and background
12. Event yields, efficiency, acceptance, and visualization of analysis information

COMPUTING

1. establish a log book
2. ssh, basic **Linux** commands, how to connect to HEP cluster, account setup
3. making and running scripts,
4. **C++**, variables, loops,logic statements,classes
5. **root**: Using C++ plotting a function,random numbers and filling a histogram, plotting options, ntuples
6. **Simulation**, Understanding the structure of simulated data root files and the difference from collision data
7. writing code to analyze an **ntuple**
8. batch systems
9. Getting the code ready to use basic event **objects** in the analysis: electrons, muons, Missing energy, jets
10. Developing code to apply **selection cuts** on properties of event objects
11. plotting selected data, background and signal events. Exploring different event properties, e.g. Z boson mass
12. Measuring cross section for Higgs production