PHYS 2559: Particle Physics Detectors and Simulation with Python **JTERM 2021**

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Syllabus

This course will survey fundamental principles in the field of particle physics and various techniques used for particle detection and physics studies. Most topics will include interactive tutorials written in Python allowing students to build on examples to develop a more intuitive feeling for the physical process discussed both at the level of the fundamental particles and their interactions with detector technologies. This course will also serve as an introduction to scientific computing libraries using Python and representative software tools used for modeling the production of physics events, simulation of detector performance, and the display and analysis of data.

Additional details

Reading assignments will be based on freely available materials.
This course will make use of open source software and open data sets.
Aspects of working in the PYTHON language will be discussed throughout the course.
Students will work on projects in teams of 2–3 throughout the course.
Course participation will include peer assessment exercises.
Prerequisites: Phys1660/2660, or instructor permission (Students are expected to have completed at least one introductory programming class).

Day 1

- Setting up your computing environment
- Review of Python basics
- Working with scripts and notebooks
- Plotting in PyROOT and Matplotlib
- A short history of particle physics
- Reading: Discovery of the muon, review of standard model
- Exercises: Practice programming with physics calculations

Day 2

- Quark-parton model
- Particle accelerators
- Numerical solutions to kinematic equations
- Working with 4-vectors
- Scattering examples
- Reading: Parton structure, Deep Inelastic Scattering
- Exercises: Calculations with relativistic kinematics

Day 3

- Interactions of particles with matter
- The Bethe-Block formula
- Stopping power
- Hadronic interactions
- Reading: Bethe-Block formula, Bragg peak
- Exercises: Simulation of dE/dx energy losses

Day 4

- Materials used in particle detection
- Signals: charge and light
- Gaseous Detectors
- Silicon detectors
- Scintillation
- Photon Detection
- Reading: Overview of particle detection technologies
- Simulation project: SiPM

Day 5

- Tracking detectors
- Calorimeters
- Muon detection
- Particle identification
- Reading: Papers on particle detection systems
- Research project: write brief reports describing modern particle detector systems

Day 6

- Presentations of reports on particle detectors
- Anatomy of a physics event model
- Running an event generator and analyzing the results
- Reading: Tutorial on physics generators
- Project: plotting physics quantities and event display

Day 7

- Exploring physics events in more detail
- Invariant mass, boosting and rest frames
- Reconstructing events
- Parton showering
- Reading: Notes on event reconstruction
- Exercise on hadron-level analysis, jet finding

Day 8

- More about detectors and detector performance considerations
- "Detector-level" data
- Review of detector emulation and examples of realistic data
- Exploring open data sets and tools though the CERN Laboratory

Day 9-10

- Guided analysis exercise(s) in PYTHON

<u>Materials</u>:

- Review of particle physics (https://pdg.lbl.gov/)

- Publicly available notes on particle detectors from Physics School Program at CERN, Fermilab, and other Laboratories
- Review papers available through the UVa library on detector technologies and specific devices (eg the silicon photomultiplier)
- Online PYTHON resources (eg, https://www.programiz.com/python-programming)
- Course notes and sample code in scripts and Jupyter notebooks
- All software used on this course is freely available and open source