IIT Mandi

Course number : PH 625
Course Name : Data Analysis in Particle Physics
Credit Distribution : *2-0-4-4*
Intended for : UG/PG/I-PhD/PhD elective
Prerequisite : PH621 (Computational Methods for Physicists), PH612 (Nuclear and Particle Physics)
Mutual Exclusion : None

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1. Preamble:

The objective of the proposed course is to introduce students to one of the most advanced computing methods for data analysis. This course will start with the basic ideas of numerical computing using C++ followed by various numerical techniques in the ROOT. ROOT is a framework for data processing and mining, born at CERN, at the heart of the research on high-energy physics which can be used in any field including Astro physics, Neuroscience etc.. In ROOT powerful mathematical and statistical tools are provided to operate on your data. The full power of a C++ application and of parallel processing is available for any kind of data manipulation. Data can also be generated following any statistical distribution and models, making it possible to simulate complex systems. From this course, students learn how to connect real world physics with experiments and interpretation of physical phenomena using data analysis. Students will have hands-on experience with the latest studies from the Large Hadron Collider at CERN and the discovery of Standard Model particles as well as beyond Standard model search.

Course Outline: The course will cover the basic ideas of data processing, handling and mining with various numerical techniques for physics analysis in ROOT framework developed by CERN. Starting from basic C and C++ computing this course aims to develop the skills of applying powerful mathematical and statistical tools provided in ROOT on data for advanced computing. Will also cover the idea of Monte Carlo simulation and complex systems simulation using statistical distributions.

2. Course Modules with quantitative lecture hours:

(a). Data in Experiments, Particle Physics [4 hours]

i. Brief overview of experiments in High Energy Physics. RHIC & CERN experiments.
ii. Data from Experiments: Pulse processing, Timing and energy resolution, Tracking, Particle Identification (PID).
iii. Analysis Methods: Acceptance, Efficiency, Error Calculations, Observable quantities.
iv. Data Structure/Type/Format and algorithms from experiments and handling.

(b). Recalls [10 hours]

i. Brief Overview of C^{++}: Program Organization and Control Structures loops, arrays, and function, Error, Accuracy, and Stability. Transition from C to C^{++}.
ii. Brief Overview of numerical analysis in C^{++}: Curve Fitting, ROOT finding, Integration and differentiation, Interpolation and Extrapolation

(c). ROOT Framework and Familiarities [in root/pyroot/rootpy] [15 hours]

i. Introduction to ROOT: Is an object-oriented programming framework based on C^{++} developed by CERN. Originally designed for particle physics, but it is used in other applications such as astronomy and data mining. ROOT has capability to work in any field and potential to scale globally.
ii. ROOT installation: ROOT is available on Linux, Mac, and (as a beta release) on Windows. The latest stable ROOT release is updated.
iii. ROOT preliminaries:
iv. Mathematical foundation, input, output, functions
v. Histograms handling: Writing and reading: Basic, Binning, Statistical analysis: 1D, 2D, 3D
vi. Tree handling: Writing and reading of the key feature of root
vii. Libraries and useful tools
viii. Fitting data: Formulas, Reading data, Writing data, TFI functions, Fittings.

(d). Visualization in ROOT [in root/pyroot/rootpy] [10 hours]

i. Histograms:1D, 2D, 3D and asymmetric binning
ii. Trees, TProfiles, TBrowser
iii. Graph Plotting: TCanvas, TGraph, TGraphError, Graphs with asymmetric error.
iv. Markers and legends
v. Histograms fittings with functions

(e). Statistical analysis and Error methods [7 hours]

i. Statistical Analysis
ii. Statistical Error: Gaussian Method, Delta theorem, Bootstrap method
iii. Systematic Error Estimation

(f). Data Generation & Models [5 hours]

i. Concept of simulation
ii. Random Generators
iii. Monte Carlo simulation and data generation

(g). Data Analysis: Class Project [5 hours]

i. Astro Physics data analysis
ii. High Energy Physics data analysis

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3. Text books:

1. Let Us C: Authentic guide to C programming language Yashavant Kanetkar
2. Let Us C++ by Yashavant Kanetkar
3. https://ROOT.cern/manual/
4. Introduction to Elementary Particles by David J. Griffiths
5. Techniques for Nuclear and Particle Physics Experiments by William R. Leo
6. Statistical Methods in Experimental Physics by Fred James

4. References:

1. Let Us C++ Solutions by Yashavant Kanetkar
2. ROOT.cern.ch

3. cern.ch
4. rhic.bnl.gov

5. Similarity with the existing courses:
(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.	Course Code	Similarity Content	Approx. % of Content
1.	PH621	4 hrs	8%
2.	CS571	2 hrs	4%

6. Justification of new course proposal if cumulative similarity content is >30%:

NA