PHY 689 2019
François Méot
Brookhaven National Laboratory

Numerical Simulation of Particle Accelerators and Beams, Hands On
Course Syllabus

Particle Accelerators

They are the latest of high-tech tools. They are nowadays under frantic development and have become the inescapable instruments of modern industry, medicine, research, under a variety of forms, from small room-scale devices to gigantic machines, such as cyclotrons for the production of cancer therapy beams, synchrotron light sources for life sciences, linear accelerators for the production of laser X-rays, gigantic colliders for nuclear and particle physics research: the largest tools ever built by human kind! microtrons, betatrons and other wham-bam-slam-atrons for industrial applications.

This course is An Introduction to Particle Accelerators, Hands On. Particle accelerator science is discovered based on computer simulation of charged particle optics and beam dynamics in accelerators.

During this course we manipulate charged particle beams in most current types accelerators. The objective: learn about them, learn how they work, understand how they are used in research, medicine and industry. We do this in a virtual world of accelerator and beam simulations, just like accelerator physicists and designers do in their labs, working as a team.

Accelerator and beam simulations on computer allow discovering the basic theoretical and practical aspects of their main technological components, including magnets for beam guiding and focusing, radio-wave cavities for acceleration. It allows discovering how these components are combined to form complex accelerator structures. During the course we will simulate the manipulation of beams for cancer therapy, produce synchrotron radiation proper to application in condensed matter research, accelerate polarized ions for nuclear physics research, etc.

This course will allow students to attain a level of knowledge needed to thrive in this field. It will navigate through the following list, as time allows: cyclotron and transverse beam stability, CW acceleration; synchro-cyclotron and longitudinal beam stability, pulsed acceleration; pulsed synchrotrons; particle colliders; light sources and synchrotron radiation damping, insertion devices; electrostatic accelerators and linacs. Numerical experiments will include a variety of beam physics topics, such as phase space motion, optics defects, non-linear dynamics and resonances, synchrotron radiation Poynting and spectral brightness, spin dynamics and other Siberian snakes, in-flight particle decay, purification of rare particle beams, etc.

In confronting basic accelerator theory with numerical simulation outcomes, the course introduces to a wide variety of applied mathematics and numerical methods, from ODE solving to Fourier analysis to interpolation techniques.

This course fosters programming, computing and system software skills, knowledge of computer languages. In a general manner, it will require the students to carry out data production and analysis, programming, debugging and other computer science tasks. Hands-on learning will require using charged particle optics computer programs, the same programs that experts use in the labs. Popular software tools will be used in addition for plotting, data analysis, reporting, including gnuplot, latex or other office tools (writing reports, slide presentations), python.

So... Yes! Laptops are needed, it will be your essential tool. Preferred system: Linus. Otherwise, a Linus emulator or equivalent capabilities. A Fortran compiler is needed. Have gnuplot and a text editor (recommended: emacs) operational on your system, as well as some office tool.

A 3 hour weekly course is organized in the following way:

- introduction to the topic of the day, including an historical overview and the underlying theoretical principles (20 minutes)
- introduction to the mathematical and software tools and techniques to be applied (20 min.)
- hands on computer simulations, accelerator and beam data production and analysis for the rest.

Lecture notes will be provided at the beginning of the session, detailing the numerical simulations to be undertaken and including basic underlying theory.

In a general manner, the home work for the next week will consist in completing the simulation exercises that have been started during the session. Students are expected to return the simulation work completed, and possible other home work assignments, under the form of .pdf documents, produced using latex or other office software.