ACCELERATORS

A Particle Beam Game
A Speed-of-Light Universe

François Méot

Brookhaven National Laboratory
Collider-Accelerator Department
Upton, LI, NY

This course is an introduction to the physics and technology of particle accelerators,

◇ based on computer laboratory work during which will be manipulated charged particle beams, short-lived particles, synchrotron light, etc.

◇ It will introduce most types of existing particle accelerators, their main optics and acceleration components,

◇ it will introduce the basic principles of beam dynamics and physics they lean on,

◇ *via* numerical simulations using dedicated computer tools,

◇ based on computer simulation practice taken from real-life laboratory activities, hands-on.

◇ Computer code develpoments will be part of the game.

This course also includes

◇ conducting a project, from start to end, over the semester. Topics will be discussed and chosen early, during the first sessions.

and it also is to be considered

◇ a forum for discussions and deeper insight, on whatever topic whenever desired, including further/unplanned code developments and simulations.

During this semester,

◇ students will run beam dynamics computer programs

◇ manage the data they produce,

◇ using small sets of short, *ad hoc*, input data files and other data treatment computer tools which they will be provided.

⋄ **Beam dynamics findings from numerical simulations will be confronted with theoretical expectations,**

⋄ **in an interactive play between both : experimentation regarding particle beams in accelerators and in accelerator components, and the underlying theory.**

Purpose of the course : contribute preparing to

⋄ **the understanding of the physics and dynamics of charged particle beams,**

⋄ **the understanding of the physics and functioning of various accelerator types and components,**

⋄ **the technics/methods/tools for the design of particle accelerators.**

Running computer programs will allow achieving a variety of goals :

⋄ **apply numerical methods to solve problems for which analytical methods have prohibitive limitations,**

⋄ **produce data from numerical simulations,**

⋄ **analyze and understanding these data,**

⋄ **present and report results on appropriate media.**

This course will allow reaching a level of knowledge needed to thrive in the field of accelerator physics and technology, it will navigate and pick knowledge bricks through the following list, as time allows :

⋄ **cyclotron, transverse stability, CW acceleration ;**

⋄ **synchro-cyclotron, longitudinal stability, pulsed acceleration ;**

⋄ **FFAG rings, strong focusing ;**

⋄ **pulsed synchrotron ;**

- storage rings including colliders, light sources, insertion devices ;
- particle collider ;
- electrostatic accelerators ;
- linear accelerators.

The numerical experiments will address beam physics and beam dynamics aspects as

- beam guiding, focussing, acceleration, optical defects,
- non-linear beam dynamics and motion resonances,
- synchrotron radiation damping,
- collective effects as space charge,
- capture and acceleration of short lived particle beams,
- the production of synchrotron light, Poynting vector, spectral brightness,
- polarization and other siberian snakes,
- in-flight particle decay,
- beam purification.

As part of the computer simualtion building blocks, the course will address the simulation of accelerator technology components as bending magnets, quadrupoles, non-linear lenses, accelerating cavities, beam monitoring.

As part of the computer simulation activities, program development and debugging will be part of the lab time.

In addition, and for the reason that this is what numerical simulations are, the course will introduce to a wide variety of applied mathematics and numerical methods, from interpolation to ODE solving to Fourier analysis.

The course will introduce to popular software tools as gnuplot (plotting),

latex (writing).

Organization of the course

A 2×1h40 session will be organized in the following way :

Lecture notes will be provided *via* .pdf files produced under latex. Students are expected to turn in their computer lab time and home work assignments under the same environment. Preparation of lab time experiment sessions will be part of home work assignments.

This computer workshop is organized in the following way:

We will have **15 weeks together, two 1:40 sessions per week.**

The first **2 sessions will be organized in a particular way, aimed at**

(i) introducing - briefly by necessity, 2×1:40hr this is short - to the vast, and rich, world of accelerators

(ii) introducing to the computer game that will be played, Zgoubi.

In order that no one fall asleep being bored by History - a matter that we may have disliked at the primary school ⋄ we will split the 1:40 session into the two topics.

A regular 2×1:40hr session will be organized in the following way:

presntation/introduction to the session topic and to the software tools (20 min.) ; computer simulations and data analysis (2h30).

⋄ a bried review of the underlying theoretical principles of the "topic of the day", 30∼45 minutes. Their, it is assumed that essential knowledge is acquired

prior to the lecture. Guidance, instruction and bibliography will be provided for that.

⋄ presntation/introduction to the session topic, *ad hoc* software tools, computer simulations and data analysis planned.

Home work:

Only minor home work volume is foreseen. Essentially,

⋄ prepare the next lectures by reading a few scientific articles targetted on the subject

⋄ Work on the semester project.

BACKUP SLIDES

- **MULTIPLE-PASS :** **1 up + 1 down, 3 up + 3 down, 5 up + 5 down**
- **MULTIPLE-PASS :** **1 up + 1 down, 3 up + 3 down, 5 up + 5 down**

Numb. of cavities/linac	No color	No color

WEPMW027: "The ERL-based Design of Electron-Hadron-Collider eRHIC"
WEPMW044: "Start-to-End Simulation of eRHIC ERL"

: EIC R&D

VOIVAOIV
leobjcf;
ncpeoi

C. Dubbe
JLab