PHY684 - Spring 2018

ACCELERATOR

YOUR NEXT FLIGHT SIMULATOR

Across a Speed-of-Light Universe

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THE AGENDA TODAY

- **Get introduced to each other**
- **This introduction**
- **Discuss the project list and how we get organized, by teams, for a 14 week project**
- **A brief review of particle accelerators in history and today**
- **Introduction to the ray-tracing code Zgoubi. And to cross-check means.**

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

◇ **based on computer laboratory work**

◇ **during which we will manipulate**

- **virtual accelerators**
- **charged particle beams**
- **short-lived particles**
- **synchrotron light**
- **relativistic particle life-time**
- **particle spin**
- **and much more**

• This course will introduce most types of existing particle accelerators, their main beam steering, beam focussing and acceleration components,

◇ it will introduce the basic principles on which these technological equipments lean,

◇ as well as the basic principles of beam dynamics in particle accelerators,

◇ *via* numerical simulations using dedicated computer tools.

• Computer simulations taken from real-life laboratory activities constitute the backbone of the course.

• Computer code developments - and debugging ! - will be part of the game.

- **This course also includes**

  - **conducting a project, from start to end, by teams, over the semester.**

  - **Project topics will be discussed and chosen early, during the first two course sessions.**

    - **I will come back on that**

- **This place is also**

◇ **a forum for discussions and deeper**

- insight,

- understanding,

- on whatever topic whenever desired,

- including further/unplanned code developments and simulations.

• **During this semester,**

◇ **we will run beam dynamics computer programs**

◇ **manage the data they produce,**

◇ **we will keep confronting beam dynamics findings from numerical simulations with theoretical expectations,**

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

• **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.**

We will navigate and pick knowledge bricks through the following list, as time allows :

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

◇ **synchro-cyclotron, longitudinal stability, cycled 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.**

- **The course will address the simulation of accelerator technology components: 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 a 2h50 session

- **We start a 2h50 session with (about 20 minutes) :**

(i) On your side: returning your home work

◇ **as a matter of fact,**

- finishing the computer simulations undertaken during the previous session is part (the essential) of the home work.

- the home work is returned under the form of 2-3 slides, to be presented to the group (5 minutes per team)

(ii) On your side, starting on week 3: status of the projects,

◇ **this is under the form of 2 slides presented to the group (2 minutes per team)**

(iii) On my side then (about 20 minutes) :

◇ a short historical introduction (about 10 minutes) in relation with the current topic : cyclotron, synchrotron, synchrotron light, decay-in-flight, or whatever else depending on our progress

◇ an introduction to the computer lab. topic (about 10 minutes), the real work of yours : the accelerator problem of concern and the numerical simulation work to be performed.

This will represent real-life style of work, hours and days !

- the real-work text will be made available in due time, on the web site

(iv) And you again... perform that work !

complete the simulations

◇ **working out the simulations regarding each particular type of accelerator will probably take more than 1 session, we will adapt.**

ACCELERATOR SIMULATION PROJECT

- **Goal : conducting your own accelerator project, just like in real life, from start to end, over the semester.**

- **The plan is the following:**

◇ **We will go through the list of projects, discuss it, today !**

◇ **You'll have 2 weeks to make your choice.**
From then on, you will be on your own.
Questions are welcome of course:
- at all time
- by e-mail (fmeot@bnl.gov), or phone (1 631 344 8204), or here
- time is short : never stay stuck, instead ask/discuss amongst us and proceed !

- **At the end of the semester, this project will be concluded by**
- a presentation to the group, under the form of slides
- a written report, laboratory technical note style

• **For each project, the following is expected :**

◇ **an extended bibliography: history and present status, technical aspects, interest of the technology, future developments, etc.**

This should represent about 20% of the work, of the time spent on the project.

The goal of the bibliography is to

- understand the motivations for the development of a particular line of accelerator, how it evolved in a particular historical context, what it has become today, its applications

- provide a technical documentation relevant to the accelerator project and to its application, including parameter lists, possibly details regarding particular scientific or technological aspects

◇ **For each project a bibliographical document is provided. That can be the starting point for your bibliography.**

◇ **producing the requested computer simulations.**

This is the bulk of the work

◇ **Reporting :**

(i) slides for a 10 minute presentation to the group,

(ii) a written "lab. tech. note" style of report, maximum 10 pages.

My advice, here :

*** Do not wait until the end to start writing. You'd be too late and lack time.**

*** Start writing as you start the project, which is, from the moment you start working on the bibliography !**

*** Hint : if needed, the bibliographical documents can be a source of inspiration regarding the presentation/organization of your written technical note.**