- PHY684 - Spring 2018 -

ACCELERATOR

YOUR NEXT FLIGHT SIMULATOR

Across a Speed-of-Light Universe

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THE AGENDA TODAY

- **Getting 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 where we are today**
- **Introduction to our flight-simulator engine, the ray-tracing code Zgoubi. And to alternate 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**

- construct and run virtual accelerators, of all sorts

- accelerate charged particle beams

- generate synchrotron light

- watch the relativistic death of short-lived particles

- polarize and shake particle spins

- play with Siberian snakes

- and much more

• **This course will introduce to most types of existing particle accelerators**

◇ **it will introduce**

- the basic principles of beam dynamics in these machines

- their main beam steering, focussing and acceleration components

◇ **Most of that, *via* numerical simulations using powerful 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 course is also**

◇ **a forum for discussions and deeper**

- insight,

- understanding,

- on whatever topic, whenever desired,

- including further ideas of accelerator simulations and code developments

◇ **an opportunity to get contacts with world reknown accelerator laboratories and people, if you wish to explore further a possible future in the field**

- **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 understand these data,**

◇ **present and report results on appropriate media, such as slides, article style of reports**

• 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 ;

◇ strong focusing, pulsed synchrotron ;

◇ FFAG rings ;

◇ storage rings : particle smashers, light sources and insertion devices ;

◇ electrostatic accelerators ;

◇ beam lines

and more

• **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,**

◇ **modeling collective effects as space charge,**

◇ **capture and acceleration of short lived particle beams,**

◇ **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...**

- **Program development and debugging will be inevitable parts of the game/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) Still 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 (up to 15∼30 minutes) :

◇ **a short historical overview - when starting a new accelerator chapter** ($10 \sim 15$ **minutes) : cyclotron, synchrotron, synchrotron light, decay-in-flight, or whatever else depending on our progress**

◇ **an introduction to the computer lab. work planned for the rest of the day** ($10 \sim 15$ **minutes)**

That's the real work of yours : the accelerator problem of concern and the numerical simulation work to be performed.

This is real-life, laboratory style of work, hours and days !

◇ **Dedicated written notes will be made available in due time, on the web site.**

(iv) And you again, the bulk of the activity :

complete this computer lab work

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

ACCELERATOR 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 and discuss it, no later than today !**

◇ **You'll have 2 weeks to make your choice.**

Questions are welcome of course:

- at all time

- by e-mail (fmeot@bnl.gov), or phone (1 631 344 8204), or here

- **Time is tight : during your project, 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 :**

(i) Start with a bibliographical research. An extended bibliography: history and present status, technical aspects, interest of the technology, future developments, etc.

This should represent about 25% 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 applications, 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.**

(ii) The bulk of the work: producing the requested computer simulations, or program developments, or whatever the project is about.

(ii) Reporting :

- slides for a 10 minute presentation to the class,

- a written “lab. tech. note” style of report, up to 10 pages

- **My advice, here :**

*** Do not wait until the end of PHY684 to start writing. You’d be too late and lack time.**

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

*** Hint : the bibliographical documents you are going to discover and consult can be a source of inspiration regarding the presentation/organization of your written technical note.**