

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 de-**
velopments
 - ◇ **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 ~ 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 ~ 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.**