Fifth International Accelerator School for Linear Colliders

Syllabus of Introductory and Elective Courses

October 25 – November 5, 2010

Villars-sur-Ollon, Switzerland

Introductory Courses

Lecture I1: Introduction (3 hrs)
Barry Barish, Caltech

- Tera scale physics
- ILC and LHC
- Layout of the ILC
- Parameter choices & optimization
- Other possible future lepton colliders: CLIC and the muon collider
- Detectors

Lecture I2: ILC (3 hrs)
Barry Barish, Caltech

- e- and e+ sources
- Bunch compressors and spin rotators
- Damping rings
- Main linac
- Beam delivery system
- Civil construction issues

Lecture I3: CLIC (3 hrs)
Frank Tecker, CERN

Part 1: Warm RF technology
- A linear collider at higher energy
- Normal conducting RF structures
- Gradient limits
- Frequency choice
- Wakefields and damping
- Pulse train formats
- Differences ‘warm’ and ‘SC’ RF collider

Part 2: CLIC scheme and CTF3
- CLIC layout at different energies
- CLIC two-beam scheme
- Drive Beam generation
- CLIC Test Facility CTF3
- RF power production

- CLIC main beam generation
- CLIC damping rings
- CLIC alignment and stability

Lecture I4: Muon Collider (3 hrs)
Bob Palmer, BNL

- Muon collider basics
- Machine layout
- Major sub-systems
- Challenges

Course A: Accelerator Physics

Lecture A1: Linac (12 hrs)
Daniel Schulte, CERN

1. Joint Session of Courses A & B: (3 hrs)
   One of the most fundamental choices for a future linear collider is the choice of the acceleration technology in the main linac. The lecture will introduce into the beam dynamics issues of this area and how they are driven by the acceleration technology. The design of the main linacs of ILC and CLIC will be presented. The effect will be discussed of single and multi bunch wakefields in the transverse and longitudinal plane. It will be illustrated how the mitigation of the wakefield introduces other beam dynamics problems like dispersion. A short introduction into the process of parameter optimisation will be given using the example of CLIC.
2. Accelerator Physic Session: (9 hrs)
   The lecture will deepen the discussion of the main linac beam dynamics issues and extend it into a more quantitative regime. The design of the lattice and its optimisation will be investigated. The origin of static imperfections will be discussed and the correction techniques that can be used to mitigate their effect will be studied in detail. Particular emphasis will be on the beam-based alignment algorithms. Analytical and numerical tools to make quantitative predictions of the beam performance will presented. Similarly, the origin of dynamic imperfections and the mitigation strategies will be discussed. In particular, the design and performance of beam-based feedback will be detailed.

Lecture A2: Sources (6 hrs)
Masao Kuriki, Hiroshima University/KEK

The lecture consists of two main parts: electron source and positron source. For each part, related fundamental physics and various subsystems are explained, to understand general concepts of particle sources, especially for ILC and CLIC. It includes the fundamental process of particle generation, electron and positron source concepts, forming a bunched beam, beam transportation, spin rotation, bunch compressor, etc.

A good text book for the particle sources of linear colliders does not exist. Corresponding chapters in accelerator part of RDR (Reference Design Report of ILC http://www.linearcollider.org/cms/?pid=1000025) is a good reference.

Lecture A3: Damping Rings (12 hrs)
Mark Palmer, Cornell University

The goal of this set of lectures is to provide an overview of the physics of storage rings and then to apply these concepts to understand the parameter choices and key design challenges of linear collider damping rings. The first two lectures will focus on the general concepts of linear beam dynamics and optics design and their application to current LC damping ring designs. The final two lectures will review the key technical and physics challenges for building and operating these rings, with a particular emphasis on currently active R&D topics.

- Lecture A3, Part 1 – Damping Ring Basics
  - Introduction to Damping Rings
  - General Linear Beam Dynamics
- Lecture A3, Part 2 – Low Emittance Ring Design
  - Radiation Damping and Equilibrium Emittance
  - Damping Ring Lattices
- Lecture A3, Part 3 – Damping Ring Technical Systems
  - Systems Overview
  - Review of Selected Systems for ILC and CLIC
  - R&D Challenges
- Lecture A3, Part 4 – Beam Dynamics
  - Overview of Impedance and Instability Issues
  - Review of Selected Collective Effects
  - R&D Challenges

Recommended Accelerator Physics Texts:

- K. Wille, *The Physics of Particle Accelerators – an introduction*, translated by J. McFall (Oxford University Press, 2000).
- S. Y. Lee, *Accelerator Physics*, 2nd Edition, (World Scientific, 2004).

Lecture A4: Beam Delivery Systems and Beam-Beam (6 hrs)
Andrei Seryi, John Adams Institute

- Beam delivery system overview
- Focusing the nanometer beams
- Collimation, extraction, beam utilization
- Beam-beam interactions
- Machine-detector interface, luminosity and background
- Beam control, ensuring collision of nm beams

Course B: RF Technology

Lecture B1: Room Temperature RF (12 hrs)

Walter Wuensch, Erk Jensen and Alexej Grudiev, CERN

The purpose of this series of lectures is to give the student a broad understanding of the main rf issues which drive the design of normal-conducting linear colliders. The lectures begin with an introduction to the basic ideas of rf acceleration and then move on to cover the two main acceleration concepts and some of the main performance limiting issues.

1. Introduction to rf acceleration (E. Jensen)
    a. Basic concepts
    b. Features of travelling and standing wave accelerating structures
2. Linear-collider acceleration concepts (E. Jensen)
    a. Two-beam acceleration
    b. Klystrons and rf pulse compression
3. Issues related to strong rf-to-beam coupling (A. Grudiev)
    a. Beam loading – getting efficiency and transient beam loading compensation
    b. Transverse wakefields – Short and long range. HOM damping techniques
4. High-power issues (W. Wuensch)
    a. Introduction to the physics of breakdown
    b. High-power scaling laws
    c. Technology for high-gradients

Lecture B2: Superconducting RF (12 hrs)

Jean Delayen, ODU-CAS

1. Purpose and Audience:
   This course is intended to instruct the students in the physics and technology of rf superconductivity and its application to particle accelerators. The course is designed for students pursuing accelerator physics as a career or engineers who have been working with particle accelerators and desire to familiarize themselves with the srf technology.
2. Objectives:
   The aim of this course is to provide the student with an understanding of the physics underlying rf superconductivity, its technological development, and a realistic view of its practical implementation to particle accelerators with opportunities as well as limitations.
3. Course Content:
   This course will provide a survey of the underlying physics and technology of rf superconductivity and its applications to particle accelerators. More specifically, we will discuss: physics of the superconducting state, low-temperature properties of materials, cryogenics, cavity design, gradient and temperature optimization, microphonics, power and HOM couplers, frequency tuners. We will also discuss the state of the art and the limitations of the srf technology, as well as the avenues that are being pursued to extend its reach (new processes, materials, etc) and the tools and techniques being used in that endeavor.

4. Prerequisites:
   A good understanding of Classical Mechanics and Electromagnetism at the level that would be expected of a first-year graduate student. Some exposure to thermodynamics, solid state physics, and microwave engineering would be beneficial.
5. Course Description:
   - Basics of superconductivity
     - Experimental aspects of superconductivity and early phenomenological theories
     - Ginzburg-Landau theory
     - BCS theory
   - Surface impedance
     - Normal state surface resistance
     - Superconducting state surface resistance
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   - High field effects and SRF limitations
     - Field emission
     - Multipacting
     - Quenches
     - Q-slopes
     - Trapped magnetic field
     - Residual surface resistance
     - Properties of niobium
   - Accelerating cavity design
     - RF and cavity fundamentals
     - Electromagnetic modes and their properties
     - HOM issues
     - Lorentz detuning
   - Cavity and cryomodule engineering
     - Cavity fabrication
     - Cavity processing and surface preparation
     - Couplers
     - Tuners
     - Cryomodule design and assembly
   - SRF R&D
     - Pushing the limits of niobium
     - Alternate fabrication techniques
     - Alternate processing techniques
     - Alternated materials
     - Analytical techniques

Lecture B3: LLRF and High Power RF (9 hrs)
Stefan Simrock and Zheqiao Geng, ITER

1. Audience:

This course is intended for accelerator physicists, engineers and students with some familiarity with accelerator technology, electronics systems, and basic mathematical knowledge.

2. Objectives:
   The students will gain an understanding of the various aspects of RF Systems beginning with the basic concepts for high power rf generation and the control of cavity field in presence of field perturbations. State-of-the-art hardware and applications software will be presented.
3. Course Syllabus:
   Starting with a short description of the components of an rf system the requirements for field control and high power generation will be presented. Sources for field perturbations such as microphonics, Lorentz force detuning and beam loading will be discussed. This will be followed by a general introduction to control theory as a prerequisite for the understanding of field control and resonance control
   - Introduction to RF Systems
     a) Concept of High Power RF System
     b) Concept of Low Level RF System
   - Introduction to control theory
   - LLRF Systems
     a) Requirements for LLRF control
     b) Source of field perturbations
     c) Cavity field control
     d) Cavity resonance control
     e) LLRF Hardware
     f) LLRF Control applications
   - High Power RF
     a) Klystron
     b) High voltage modulator
     c) RF power distribution
   - Other topics (if time permits):
     a) Timing and Synchronization
     b) Beam feedbacks
     c) Introduction to requirements engineering
4. Reading Assignments:
   See Control Theory and Math lectures from CERN School on Digital Signal Processing at http://cas.web.cern.ch/cas/Sweden-2007/Lectures/Sigtuna-lectures.htm <https://owa.desy.de/exchweb/bin/redir.asp?URL=http://cas.web.cern.ch/cas/Sweden-2007/Lectures/Sigtuna-lectures.htm>
   and LLRF and High Power RF lectures from previous LC Schools
   http://www.linearcollider.org/cms/?pid=1000401
   <https://owa.desy.de/exchweb/bin/redir.asp?URL=http://www.linearcollider.org/cms/?pid=1000401>