Principles of Superconducting Linear Accelerator

January 21-25, 2013
Duke University

Instructors:
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SNS/ORNL

Purpose and Audience

This one-week course is aimed at accelerator physicists, engineers and technicians who want to learn the principles of Superconducting Linear Accelerators (SCL). Particular emphasis will be given on **understanding and applying the design concepts to determine and optimize the basic parameters of SCL**.

Objectives

The course will focus on fundamental **principles of superconducting linac and their design**. Accelerator theory pertaining to SCL will be presented and applied to the design of several accelerator subsystems. Emphasis will be given to understand the multi-dimensional constraints that govern the design of an SCL and familiarize the students with the iterative process aimed at finding an adequate compromise between the various constraints.

Instructional Method

The course will combine **lectures and computer labs** with a team approach involving the students. Appropriate software to work through the design of accelerator subsystems that will satisfy a given set of requirements will be provided.

Course Content

The lectures will cover the **general principles of SCL** including the use of popular computer codes to design and optimize simple SCL, including accelerating lattice and superconducting radio frequency (SRF) accelerating structures. The course will cover basic beam transport theory including the description of beams, beam transport and acceleration and how to apply codes to design an accelerating lattice. The course will also include basic electromagnetics design of SRF cavities, beam loading and other RF interactions in SRF cavities, and general considerations for cryomodules and cryogenics.

Reading Requirements

The recommended text is “RF Linear Accelerators” by Thomas Wangler, Wiley & Sons publishers (to be provided by the USPAS). The material in the textbook will be used as a reference, and **will be accompanied by extra material written by the instructors**, covering both accelerator theory and support information for the computer codes used in the course.

Credit Requirements

Students will be evaluated based on their performance: 35% homework, 35% computer lab sessions and 30% final exam.

Introducing each other

- Instructors
  - Kim, Sang-ho (SNS/ORNL)
  - Doleans, Marc (SNS/ORNL)
- Students
  - Berrutti, Paolo (FNAL)
  - Brown, David (SNS/ORNL)
  - Cowie, Louise (STFC Daresbury Lab.)
  - De Michele, Giovanni (Ecole Polytechnique Federle de Lausanne)
  - Garcia-Bonilla, Alba-Carolina (Universidad Nacional de Colombia)
  - Gu, Zhenghao (Indiana University)
  - Hanna, Bruce (FNAL)
  - Liu, Honghuan (Indiana University)
  - Sliger, Chase (SNS/ORNL)
  - Wu, Yuan Hui
  - Yee-Rendon, Bruce (CINVESTAV)

Goals of the Course

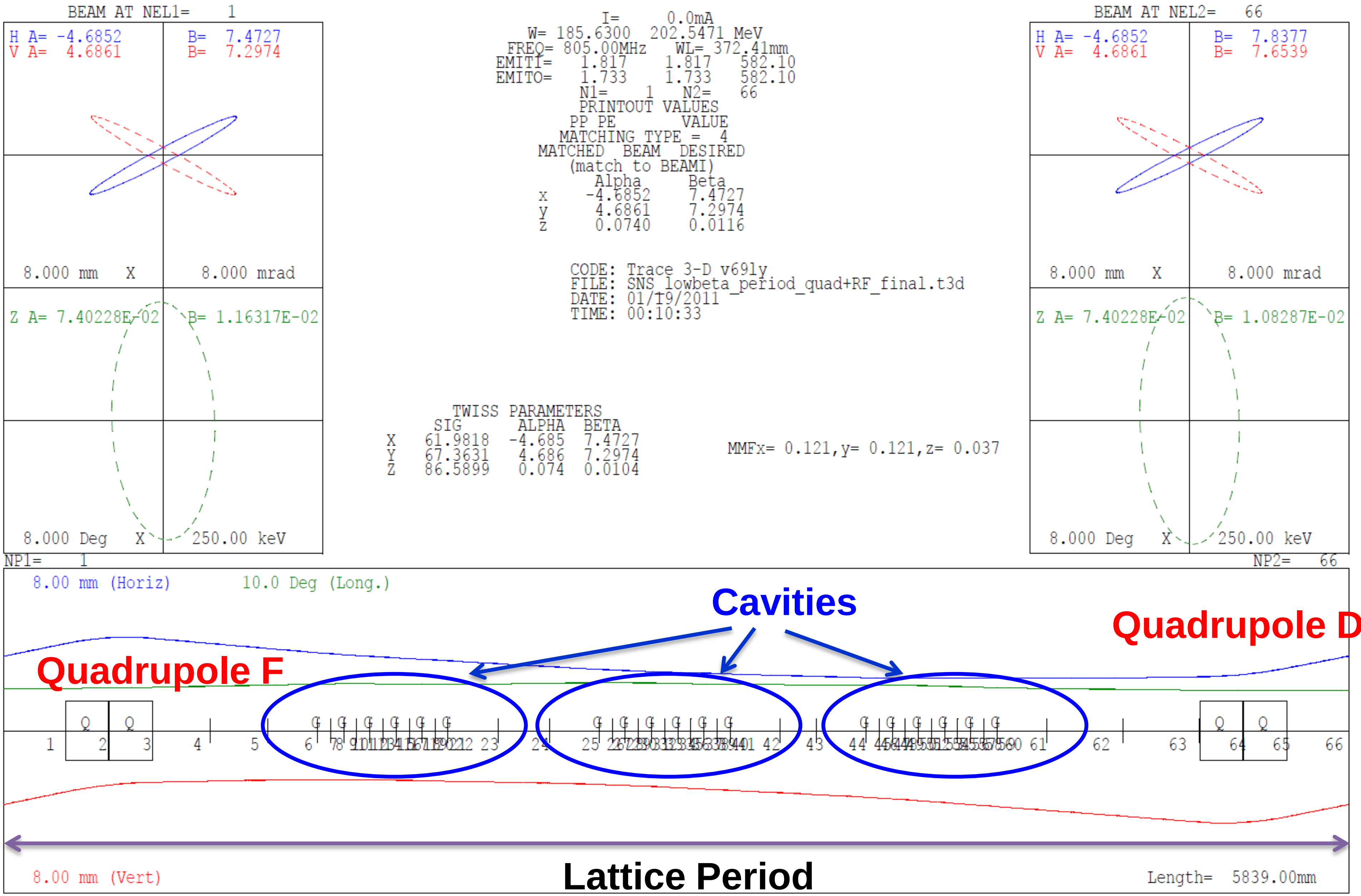
- Learn the basics of superconducting radio-frequency linacs
- Get experience with common computer codes
- Develop concrete understanding of particle acceleration in superconducting linear accelerators
- Provide practical tools and models for basic design of SC linacs
- Connect model to actual machines

You will learn

Superconducting Linac architecture design
Basics of Lattice design (T3D)
Basics of Beam Matching (T3D)
RF requirements (detuning, Qex, beam loading..)
Cryogenic requirement
Phases in SCL cavities
SRF cavity design (understand of fields and parameters)
SRF fundamentals

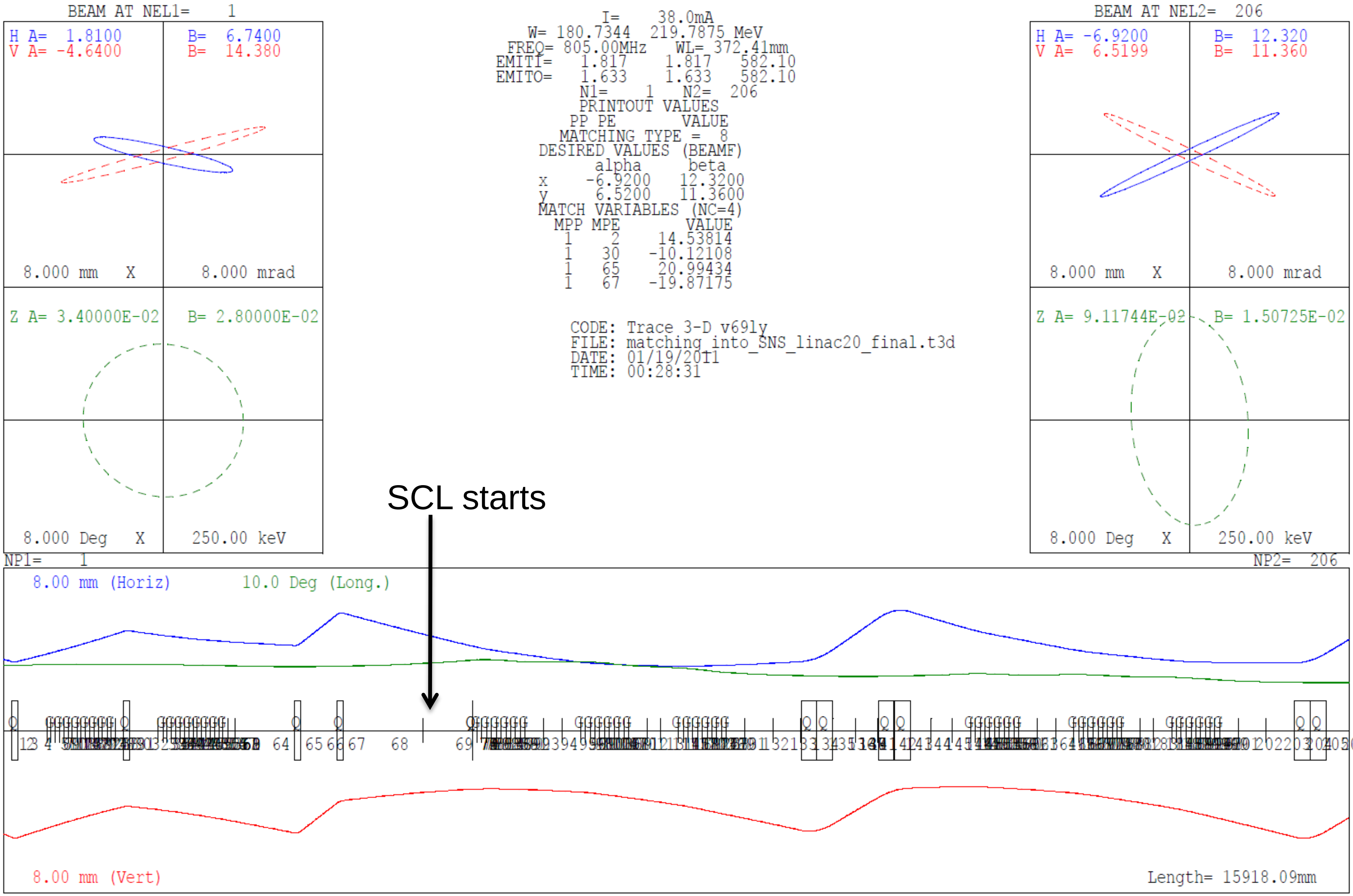
Some examples like…

SCL Lattice

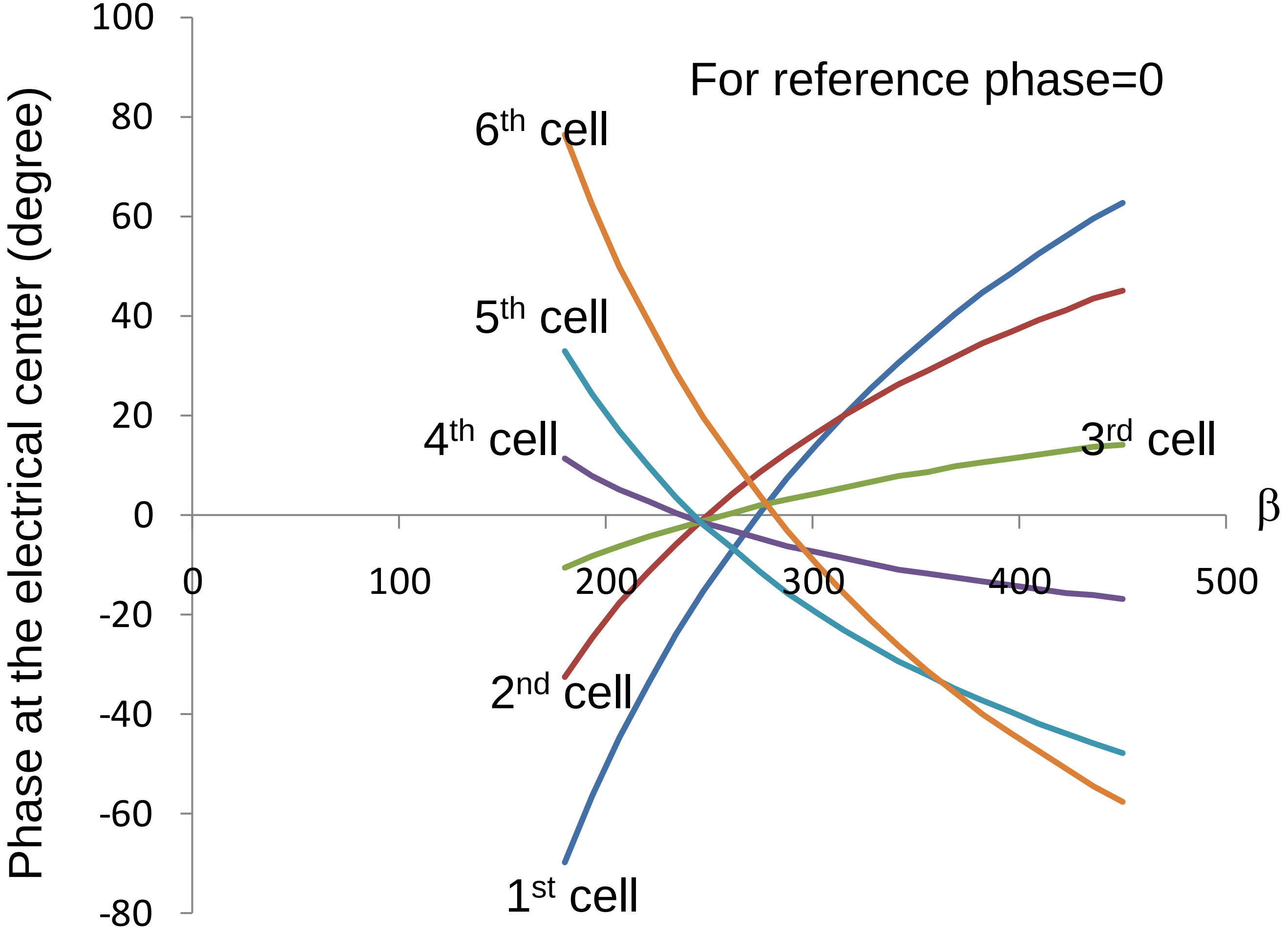


BEAM AT NEL1= 1
H A= -4.6852 B= 7.4727
V A= 4.6861 B= 7.2974
8.000 mm X 8.000 mrad
Z A= 7.40228E-02 B= 1.16317E-02
8.000 Deg X 250.00 keV
NP1= 1
I= 0.0mA
W= 185.6300 202.5471 MeV
FREQ= 805.00MHz WL= 372.41mm
EMITI= 1.817 1.817 582.10
EMITO= 1.733 1.733 582.10
N1= 1 N2= 66
PRINTOUT VALUES
PP PE VALUE
MATCHING TYPE = 4
MATCHED BEAM DESIRED
(match to BEAMI)
Alpha Beta
x -4.6852 7.4727
y 4.6861 7.2974
z 0.0740 0.0116
CODE: Trace 3-D v69ly
FILE: SNS_lowbeta_period_quad+RF_final.t3d
DATE: 01/19/2011
TIME: 00:10:33
TWISS PARAMETERS
SIG ALPHA BETA
X 61.9818 -4.685 7.4727
Y 67.3631 4.686 7.2974
Z 86.5899 0.074 0.0104
MMFx= 0.121, y= 0.121, z= 0.037
BEAM AT NEL2= 66
H A= -4.6852 B= 7.8377
V A= 4.6861 B= 7.6539
8.000 mm X 8.000 mrad
Z A= 7.40228E-02 B= 1.08287E-02
8.000 Deg X 250.00 keV
NP2= 66
8.00 mm (Horiz) 10.0 Deg (Long.)
Cavities
Quadrupole D
Quadrupole F
Q Q G G G G G G G G G G G G G G G G G G Q Q
1 2 3 4 5 6 23 24 25 41 42 43 44 60 61 62 63 64 65 66
Lattice Period
8.00 mm (Vert)
Length= 5839.00mm

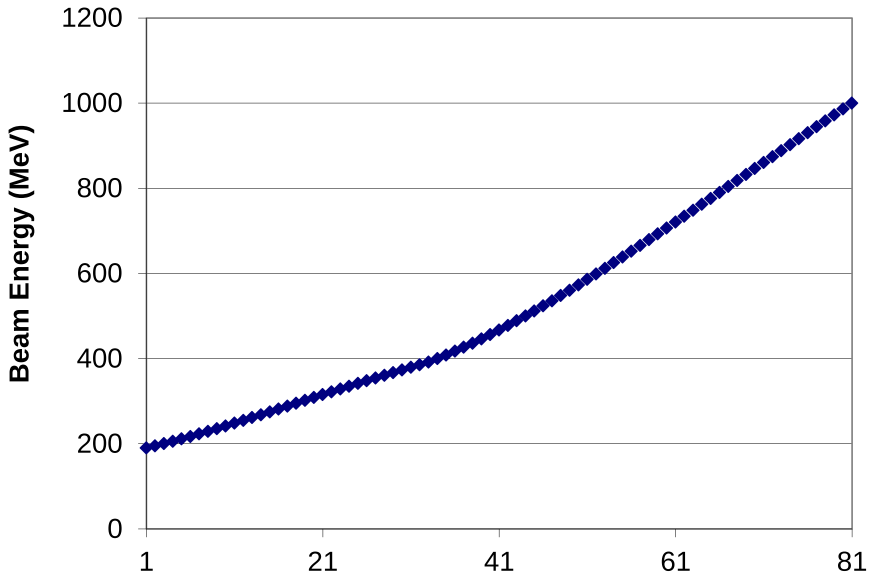
Matching into SCL

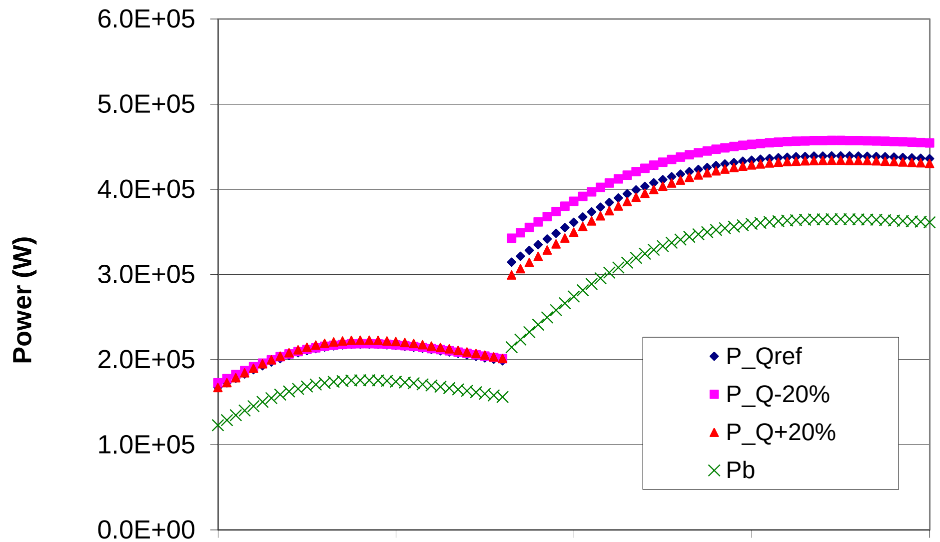


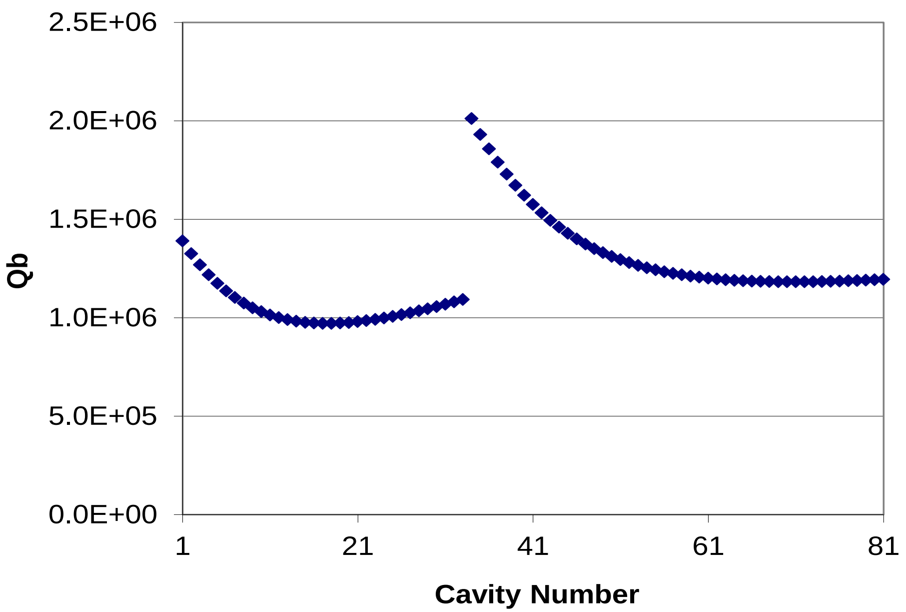
Cavity phases vs. cell phases

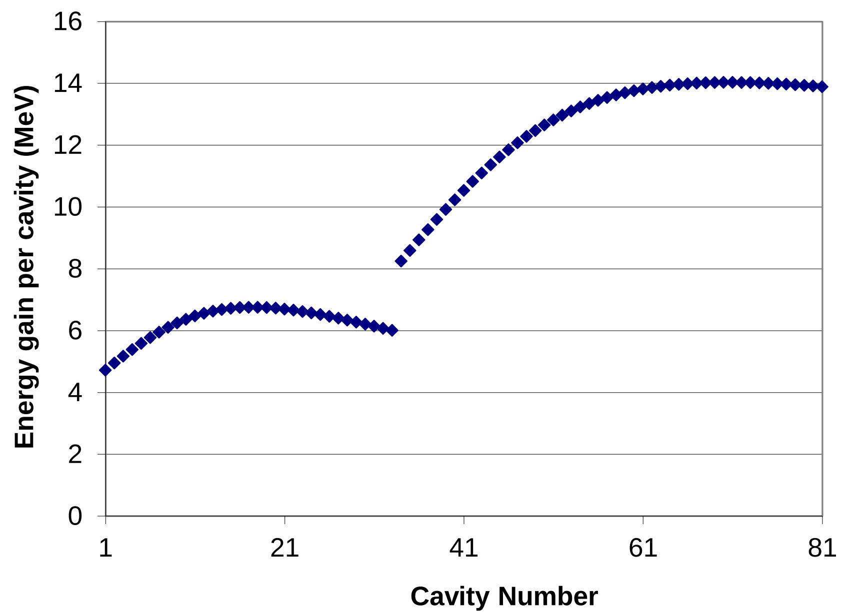


Architectures optimizations and power requirements

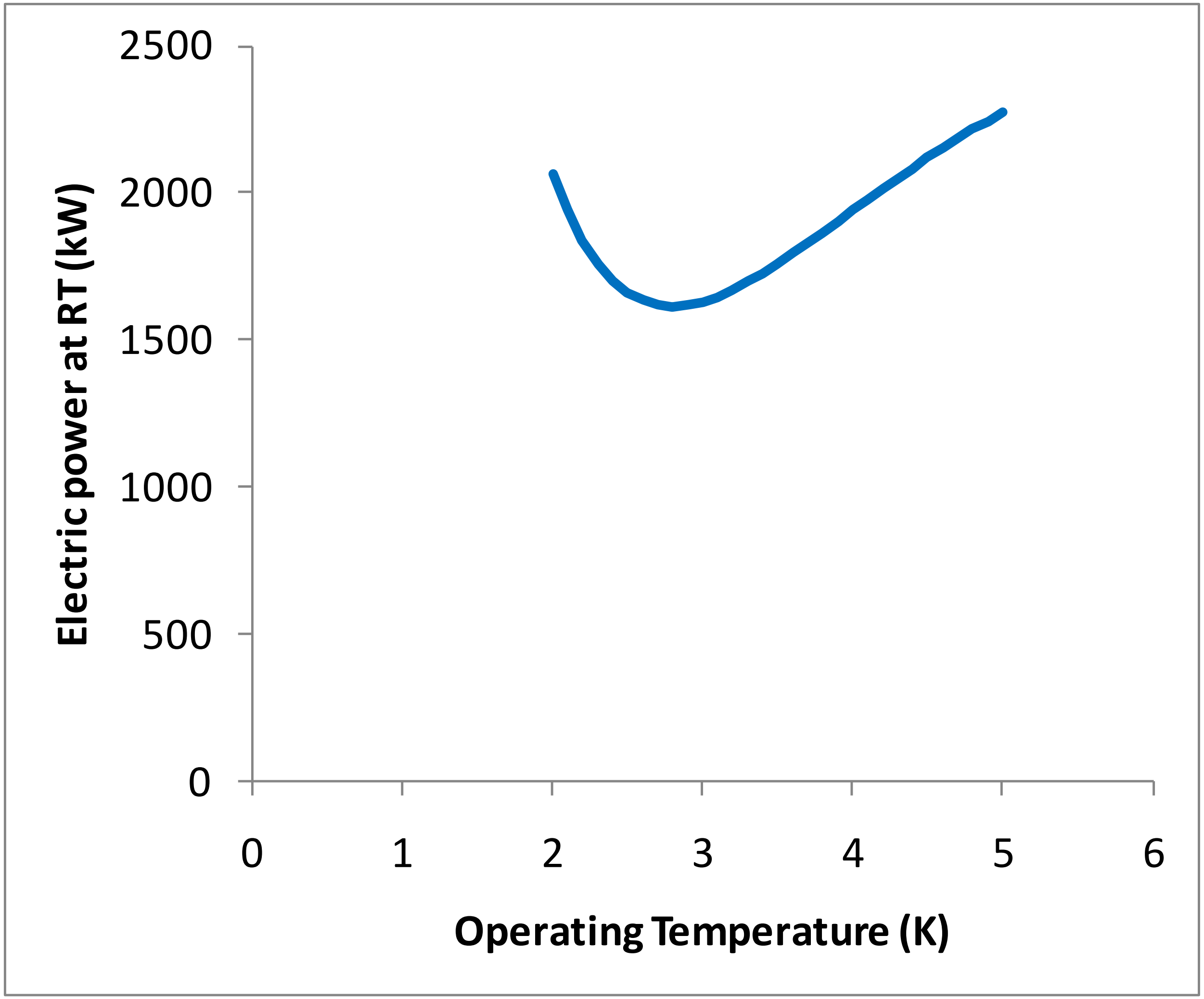




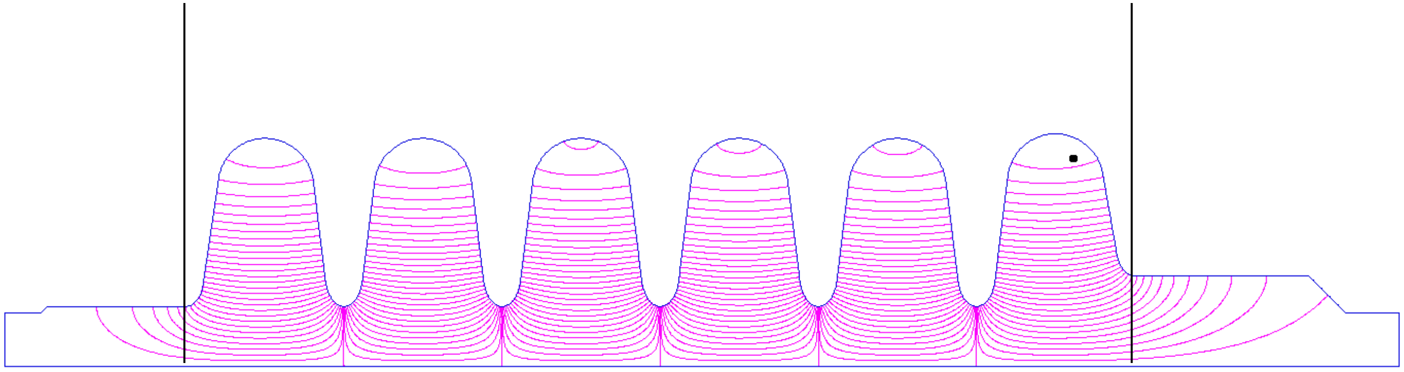




Cryo requirements and optimizations



Cavity design and parameter optimizations



Pulse, CW, Cryomodules, SRF….

Let's Start!!

Contents

1. Brief Introduction of RF superconductivity
2. Elliptical cavity design
3. Basics of beam dynamics
4. RF interaction & beam loading in SRF cavity
5. Introduction of cryomodule
6. Lattice design/matching
7. Design/optimization of SCL layout

Course Structure

- Lectures: 9am-12pm, and 1pm-3pm
- Computer lab: 3pm-5pm
- Homework and study: evening
- Homework to be turned in the next morning
- Final exam presentation: Friday morning
  - We will form 4 problem-solving teams
  - Teams will present SCL design
- Highly interactive between students and instructors