Beam Loss and Machine Protection - Welcome!

U.S. Particle Accelerator School 2023,

January 30 – February 3, 2023

3rd edition

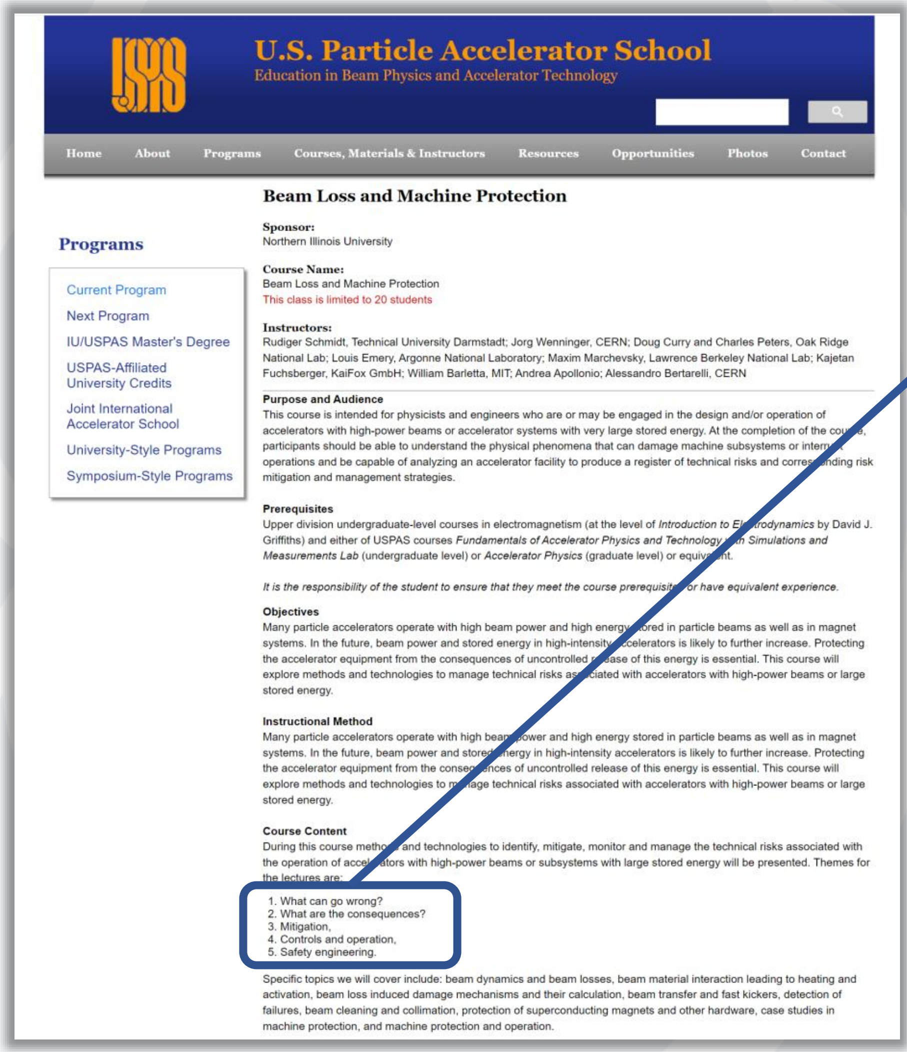
2014

2017

Welcome again!
2023

What we will be talking about

Topics



U.S. Particle Accelerator School
Education in Beam Physics and Accelerator Technology

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Programs

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Beam Loss and Machine Protection

Sponsor:
Northern Illinois University

Course Name:
Beam Loss and Machine Protection
This class is limited to 20 students

Instructors:
Rudiger Schmidt, Technical University Darmstadt; Jorg Wenninger, CERN; Doug Curry and Charles Peters, Oak Ridge National Lab; Louis Emery, Argonne National Laboratory; Maxim Marchevsky, Lawrence Berkeley National Lab; Kajetan Fuchsberger, KaiFox GmbH; William Barletta, MIT; Andrea Apollonio; Alessandro Bertarelli, CERN

Purpose and Audience
This course is intended for physicists and engineers who are or may be engaged in the design and/or operation of accelerators with high-power beams or accelerator systems with very large stored energy. At the completion of the course, participants should be able to understand the physical phenomena that can damage machine subsystems or interrupt operations and be capable of analyzing an accelerator facility to produce a register of technical risks and corresponding risk mitigation and management strategies.

Prerequisites
Upper division undergraduate-level courses in electromagnetism (at the level of *Introduction to Electrodynamics* by David J. Griffiths) and either of USPAS courses *Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab* (undergraduate level) or *Accelerator Physics* (graduate level) or equivalent.

It is the responsibility of the student to ensure that they meet the course prerequisites or have equivalent experience.

Objectives
Many particle accelerators operate with high beam power and high energy stored in particle beams as well as in magnet systems. In the future, beam power and stored energy in high-intensity accelerators is likely to further increase. Protecting the accelerator equipment from the consequences of uncontrolled release of this energy is essential. This course will explore methods and technologies to manage technical risks associated with accelerators with high-power beams or large stored energy.

Instructional Method
Many particle accelerators operate with high beam power and high energy stored in particle beams as well as in magnet systems. In the future, beam power and stored energy in high-intensity accelerators is likely to further increase. Protecting the accelerator equipment from the consequences of uncontrolled release of this energy is essential. This course will explore methods and technologies to manage technical risks associated with accelerators with high-power beams or large stored energy.

Course Content
During this course methods and technologies to identify, mitigate, monitor and manage the technical risks associated with the operation of accelerators with high-power beams or subsystems with large stored energy will be presented. Themes for the lectures are:

1. What can go wrong?
2. What are the consequences?
3. Mitigation,
4. Controls and operation,
5. Safety engineering.

Specific topics we will cover include: beam dynamics and beam losses, beam material interaction leading to heating and activation, beam loss induced damage mechanisms and their calculation, beam transfer and fast kickers, detection of failures, beam cleaning and collimation, protection of superconducting magnets and other hardware, case studies in machine protection, and machine protection and operation.

- What can go wrong?
- What are the Consequences?
- Mitigation
- Controls & Operation
- Safety Engineering

Machine protection is a multi-disciplinary field covering a large spectrum of subjects related to accelerators

Timetable

- What can go wrong?
- What are the Consequences?
- Mitigation
- Controls & Operation
- Safety Engineering

	Over zoom		In person		
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
08:30					
09:00	Welcome	Machine protection for	Beam loss induced damage	Controls and interlocks	Case studies
09:30	Introduction (R. Schmid)	light sources (L. Emery)	(A. Bertarelli)	(D. Curry)	
10:00					
10:30					
11:00	Beam dynamics & beam losses	Beam material interaction	Reliability and availability	Machine protection	Case studies
11:30	circular (K.Fuchsberger)	(B. Barletta)	(A. Apollonio)	and operation (SNS)	
12:00	Beam dynamics & beam losses		(Ch. Peters)	(Ch. Peters)	
12:30	linear (Ch. Peters)				
13:00					
13:30					
14:00					
14:30	Ultra-fast failures	Beam cleaning and	Protection of SC circuits	Machine protection	
15:00	(J. Wenninger)	collimation	(M. Marchewsky)	in plasma accelerators	
15:30		(J. Wenninger)		(D. Curry)	
16:00	Detection of failures				
16:30	(Ch. Peters)	High power targets	Machine protection		
17:00		and their protection	and operation - LHC (J.W.)		
17:30		(Ch. Peters)			

Homework

30 % contribution to grade

- 5 short exercises
- To be completed individually
- Handed out today before lunch

Case Studies

70% Contribution to grade

- To be completed in teams 2-3 people
- Presentation from each team on Friday morning

(1) FCC-hh proton transfer line

- The 100 km FCC-hh collider will be operated with bunches having a population of 1E11 protons. Two beams will circulate is separate beam vacuum chambers (as for the LHC). The bunch spacing will be 25 ns. The FCC top energy is 50 TeV per beam. The injection energy should not be more than a factor 20 lower than the top energy.
- FCC-hh will be filled with groups of proton bunches that are pre-accelerated by the 26 km long LHC which will be recycled to become a fast cycling injector for FCC-hh. The injection energy into the LHC is 450 GeV, the maximum number of proton bunches in the LHC is 2800.
- One would like to transfer the largest possible beam intensity in one shot to minimize the filling time of FCC-hh. What is the intensity that can be transferred safely considering that absorbers can only withstand an impact of around 3 MJ? Try to find ways in the design of the ejection, transfer and extraction systems to obtain the highest possible transfer intensity. Make a conceptual design of instrumentation and machine protection systems for the transfer. What about the transfer energy?

(2) FCC-hh dump for 50 TeV proton beam

- The 100 km FCC-hh collider will store 10600 bunches with a population of 1E11 protons in each bunch. The bunch spacing is 25 ns, the beam energy is 50 TeV.
- Evaluate the stored energy and design a beam dumping system for the FCC-hh.
- What are the challenges for such a system? How could one safely extract the beam? Is one beam dumping system sufficient for each beam? Consider the use of different materials for the dump block.
- What is the impact of and on beam optics and on the overall machine layout (space, straight sections etc.)?

(3) Beam halo

- For very high intensity and high energy accelerators, the number of particles in the halo can be a serious issue. There can be enough particles in the halo to quench or to damage accelerator components, for example the collimators that are supposed to absorb and clean the halo.
- Discuss the energy stored in such beam halo, and the parameters that defined the halo.
- Design one or more instruments to monitor the beam halo.
- Assume that a collimator cuts the halo at 2.5 sigma (sigma = rms beam size). What fraction of the beam will not be cut? Is it the same if the collimator is installed in a transfer line or in a synchrotron?
- Are there other methods to clean the halo?

(4) High intensity neutrino target

- Design a target for a high intensity neutrino beam, 1E14 protons/pulse at 200 GeV.
- The target should obviously survive the impact of the beam. What about repetition rate? Design a protection system for the target. What interlocks would be required, what should be monitored?
- How can you be sure at any time that the target is still intact? How do you diagnose this?
- What about a target for neutron spallation (e.g. protons of 2 GeV, power of 5 MW)?

(5) Dust and machine protection

- Consider dust particles present on the surface of the vacuum chamber. The particles may be charged.
- What may happen when dust particles fall into the beam? How does this depend on the relative charge of the dust and the beam?
- What is the risk to the machine from such falling dust particles?

We are here for you!

- Jorg Wenninger
- Charles Peters
- Louis Emery – part time
- Kajetan Fuchsberger

We wish you (and also us) …

– New insights
– Good discussions
– Fun!

Enjoy!