2.30. Beam simulation: main beam transport in the linacs and beam delivery systems, beam halo modeling and transport, and implementation as a diagnostic tool for commissioning and operation (UCLC)

Accelerator Physics

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Cornell

Year 1: $16,060
Year 2: $21,060
Year 3: $32,640

This copy of the FY04 proposal is a placeholder until a progress report is available.

2 Beam dynamics calculations and experiments, and accelerator design

2.1 Beam simulation: main beam transport in the linacs and beam delivery systems, beam halo modeling and transport, and implementation as a diagnostic tool for commissioning and operation.

Personnel and Institution(s) requesting funding

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Project Overview

This project will cover simulations of main beam transport in linear colliders, with an emphasis on integrated damping ring to IP simulations; studies of the sources and transport of beam halo from its origin to the IP; implementation of modeling tools as a diagnostic for addressing commissioning and operational issues. Each of these topics is discussed in turn in the following paragraphs. Complete and robust simulation and modeling tools are critical to the evaluation of design and commissioning of NLC and TESLA, and our goal is to develop software with the flexibility to investigate the properties of both machine.

Main beam transport

One of the most essential features of a linear collider is the need for the preservation of a very small vertical emittance during beam transport from the damping ring to the IP. The best estimate of what is required to do this comes from integrated simulations of beam transport from the damping ring to the IP. Elaborate simulation programs have been developed at SLAC, DESY and CERN for the linear collider projects, in which errors can be incorporated, and realistic tuning algorithms can be explored, based on the expected performance of diagnostic systems. The errors are both static and dynamic, and include initial alignment errors, instrumentation resolution, ground motion and mechanical noise. Dynamic stabilization schemes and linac-based and IP feedback can be incorporated.

The worldwide effort in this area could benefit from additional manpower working in collaboration with the existing investigators to refine the simulation tools and develop improved tuning algorithms. We propose to join these ongoing beam simulation efforts, providing additional manpower, as well as fresh perspectives.

We will work closely with our collaborators, who have extensive experience in beam simulation, to identify critical issues which, in the context of the worldwide effort, require attention.

Particular areas of interest to us include the exploration of the tolerance of the baseline emittance preservation schemes to diagnostic faults, realistic modeling of the bunch compressors, and the effects of lattice mismatches. Also, one of our aspirations is to develop the machine model so that it can eventually interact with the control system in such a way that we can use it to diagnose and correct machine errors. Until a real control system exists, we can simulate that as well and begin to understand how the operational problems will become evident and then how they might be addressed.

We would also like to explore the utility of simulations of beam transport from the source to the damping ring.

Our group has considerable experience developing computer models to study the properties of stored and accelerated beams, and for the evaluation of machine performance and diagnosis and correction of guide field errors etc. We have done extensive simulation of single particle dynamics, beam-beam interaction, long range interaction of multiple bunch beams, and of the injection process for both CESR (5.3GeV) and for CESR-c(1.9GeV). We also created a detailed simulation of the positron production process in our linac in order to improve efficiency, and a rudimentary model of a superconducting linac to explore the dependence of single and multi-bunch stability on cavity parameters. We are well equipped to contribute to the effort to model beam transport in a high energy linac.

Beam halo modeling and transport

Understanding and control of beam halo is a crucial issue for linear colliders. The extent of the beam halo impacts the design of the collimation systems and muon spoilers, which in turn determine background conditions at the detector. The collimation systems are also an essential part of the machine protection system, a key issue for machine reliability.

One of the principal open issues in the baseline linear collider designs is the absence of a fully developed pre-linac collimation system. Working with our collaborators, we propose to develop a realistic design for such a system.

Beam halo typically explores regions of the vacuum chamber far from the central axis, where magnetic field nonlinearities, often ignored in main beam transport simulations, may be important. We propose to study the transport of halo particles, represented as longitudinal and transverse beam distribution tails, from the damping ring to where the halo is intercepted, exploring, for example, the effects of nonlinear field errors.

The baseline linear collider collimation systems have been designed to cope with a relatively high level of beam halo, based on previous linear collider experience. This level is typically much larger than simple estimates would indicate. A more basic understanding of the origin of beam halo would allow a better optimization of the collimation system design. We propose to simulate the sources of beam halo (e.g, due to scattering processes in the damping rings, dark current in the linac cavities, etc.) and track these particles from their sources to the collimation systems, where they are removed from the beam. Comparisons will be made to the assumed halo used for the design of the baseline collimation systems for NLC and TESLA, and to the SLC beam halo experience.

Machine commissioning and operation

During machine commissioning, interpretation of measurements of beam position monitors, beam size monitors, cavity higher order modes, etc. will be critical to identification of component failures and implementation of correction algorithms. Typically a simulation is used to compute the effects of the guide field on the beam so that the consequence of various field errors, misalignments, etc. can be anticipated. But during commissioning we must first measure the guide field errors, so that with the help of the models, appropriate corrections can be determined. We plan to develop the modeling tools to extract information about the guide field from the beam instrumentation, so that we can simulate the diagnosis and optimization of machine performance.

Project Activities and Deliverables

The descriptions of year-by-year activities provided below are representative of one possible course of action which seems plausible at this juncture. It should be appreciated that, as we develop a more mature understanding of the issues, and the roles that are most suited for us, and as the needs of the worldwide linear collier effort evolve, it may turn out that the order in which tasks are undertaken is different from what is described below, For example, the beam halo work, described below as being done in the second and third years, could in fact start in the first year, if that turns out to be advantageous. If such a reordering occurs, we expect to produce the same deliverables as specified below, but in different years.

FY2004 Project Activities and Deliverables

During the first year, we will work with our collaborators to assemble, at Cornell, a suite of the existing main beam simulation tools. We will develop expertise in the use of these tools, initially by studying already-solved problems and simple examples. This will allow us to tackle unsolved problems. We will then use the existing codes to address one of the outstanding issues noted above. The exact choice will be determined by the needs and priorities of the worldwide linear collider simulation efforts at that time.

Evidently, a single code, with the capability of modeling damping rings, bunch compressors, linear acceleration, including wake effects, and beam delivery system, does not exist. At present, damping ring to IP simulations are based on mating different codes with emphasis on different physics. We plan to extend the capability of the code that has been developed for modeling CESR and CESR-c dynamics (BMAD) so that we can build a complete end to end simulation, including the beam beam interaction.

To become familiar with the issues involved in the control of beam halo, and to address a known issue in collimation system design, we will undertake a detailed design of pre-linac collimation systems for NLC and TESLA.

The deliverables for the first year will be the capability to use the existing main linac and beam delivery systems simulation routines, and a technical report addressing an outstanding issue in beam simulation. We will also provide improvements to, and/or cross-checking of, some of the existing simulation codes. Finally, we will write a technical report specifying a design for pre-linac collimation systems for NLC and TESLA.

FY2005 Project Activities and Deliverables

In the second year, we will continue to address main beam transport code improvements, and will tackle several other simulation issues which are high priority, and which are suitable for our expertise and interests.

In this year, we will begin to consider what is needed in code development or modification for halo transport. We will build upon existing codes whenever possible. We expect to be able to produce useful results on beam halo transport this year.

We will also develop a strategy for understanding the sources of beam halo.

The deliverables for the second year will be technical reports describing additional code improvements and studies of main beam transport issues. We will also produce codes to do beam halo transport in the main linacs and beam delivery systems. We will write a technical report on the first results from our beam halo transport studies. We will also write a technical report outlining our strategy for understanding and simulating sources of beam halo.

FY2006 Project Activities and Deliverables

In the third year, we expect continue to address outstanding high priority issues in main beam transport.

Based on the halo source strategy developed in the previous year, we will develop codes which simulate the sources of beam halo, and couple these to our halo transport codes. We will compare the results of this work with the assumed halo used for the design of the baseline collimation systems for NLC and TESLA, and to the SLC beam halo experience.

The deliverables for the third year will be additional technical reports describing studies of main beam transport issues. We will produce a technical report documenting our studies of halo sources and halo transport, and the comparisons with linear collider halo design assumptions and SLC experience. Finally, we will write a technical report documenting the diagnostic capability of our codes, including, for example, evaluation and correction of orbit, optical and coupling errors based on beam position monitor data.

Budget justification

This work will be carried out primarily by the personnel noted above from Cornell, with help from our collaborators. We have requested support for one graduate student in the first year of the activity, growing to 1.5 and then 2 in the subsequent years (not included in this budget). Computing equipment support for the student(s), and a small travel allowance for meetings with our collaborators and conference attendance is included.

Indirect costs are calculated at Cornell's 58% rate on modified total direct costs.

Three-year budget, in then-year K$

Institution: Cornell University

Item	FY2004	FY2005	FY2006	Total
Other Professionals	0	0	0	0
Undergraduate Students	5	5	5	15
Total Salaries and Wages	5	5	5	15
Fringe Benefits	0	0	0	0
Total Salaries, Wages and Fringe Benefits	5	5	5	15
Equipment	5	10	20	35
Travel	2	2	3	7
Materials and Supplies	0	0	0	0
Other direct costs	0	0	0	0
Total direct costs	12	17	28	57
Indirect costs	4.06	4.06	4.64	12.76
Total direct and indirect costs	16.06	21.06	32.64	69.76