ICAP 06

Chamonix 2-6 Oct. 2006
Chamonix Mont-Blanc

technical program

Sunday, Oct. 1

13:00 Bus 1 Geneva Airport – Chamonix
16:00 Bus 2 Geneva Airport – CERN – Chamonix
16:15 Bus 2 CERN – Chamonix
17:30 Registration at „Le Majestic“
19:30 Welcome Cocktail offered by the city of Chamonix at „Le Majestic“
20:00 Bus 3 Geneva Airport – Chamonix

Monday, Oct. 2

Chair: Stephan Russenschuck
9:00 Welcome
9:10-9:45 Computational beam dynamics for SNS commissioning and operation, J. Holmes, ORNL
9:50-10:25 Computational needs for ILC, D. Schulte, CERN

10:30 Break

Chair: Frank Schmidt
11:00-11:25 Massive tracking, E. McIntosh, CERN
11:30-11:55 Accelerator modeling with PTC, E. Forest, KEK
12:00-12:25 Driving term experiments, R. Bartolini, Diamond

Chair: R. Schuhmann
11:00-11:25 Highly Accurate 3-D Magnetic Field Solver, S.Manikonda, MSU
11:30-11:55 Large Scale Parallel Wake Field Computations with PBCI, E. Gjonaj, Darmstadt
12:00-12:25 Low-Dispersion Wakefield Calculation, M. Kärkkäinen, Darmstadt

12:30 Lunch break

Chair: Oliver Boine-Frankenheim
14:00-14:25 The ORBIT simulation code, A.Shishlo, ORNL
14:30-14:55 Simulation of single bunch collective effects, G. Rumolo, CERN
15:00-15:25 Space charge induced resonance trapping, G. Franchetti, GSI

Chair: Bill Trowbridge
14:00-14:25 EM Field Simulation Based on Volume Discretization, R. Schuhmann, Paderborn
14:30-14:55 Geometry of Electromagnetism L. Kettunen, Tampere
15:00-15:25 Maxwell's Equations in Non-Inertial Frames Based on Diff.-Forms, S. Kurz, Bosch

15:30 Break

Chair: T. Weiland
16:00-16:25 High-Performance Self-Consistent Electromagnetic Modeling of Beams, J.Cary, Tech-X
16:30-16:55 Geometrical methods in computational electromagnetism, A. Bossavit, Paris
17:00-17:25 Coupled transient thermal and electromagnetic finite element simulation of quench in superconducting magnets, B. Trowbridge, Oxford

Tuesday, Oct.3

Chair: Oliver Boine-Frankenheim
9:00-9:35 Simple maps in accelerator simulations, S.Peggs, BNL
9:40-10:05 Simulation of the FAIR synchrotron magnets, H. De Gersem, Darmstadt
10:10-10:35 Beam dynamics simulation studies for the HESR, A. Lehrach, FZ Jülich

10:40 Break

Chair: Frank Schmidt
11:00 Poster 1

13:00 Excursion to the “Aiguille du Midi“

Chair: Etienne Forest and Jean-Luc Vay
18:00-18:25 Rigorous global optimization, K. Makino, MSU
18:30-18:55 CHEF, A Framework for Accelerator Optics and Simulation, J. Ostiguy, FNAL
19:00-19:25
Recent Progress on the MaryLie/IMPACT Beam Dynamics Code, R.Ryne, LBNL
19:30-19:55
Simulation of Secondary Electron Emission with CST Particle Studio (TM), F. Hamme (CST)

Wednesday, Oct.4

Chair: Daniel Schulte
9:00-9:35 Computational needs for the XFEL, M.Dohlus, DESY
9:40-10:15 Wish-list for large-scale simulations for future radioactive beam facilities, J.Nolen, ANL
10:20-10:45 Accurate, efficient wakefield simulation with the parallel finite element time-domain code T3P, A. Candel, SLAC

10:50 Break

Chair: Rainer Hasse
11:00 Poster 2
and
Software exhibition panel

13:00 Lunch break

Chair: Eric Sonnendrucker
14:00-14:25 Parallel simulation of Coulomb collisions for high-energy e-cooling, D. Bruhwiler, Tech-X
14:30-14:55 Analysis of Measured Transverse Beam Echoes in RHIC, S. Sorge, GSI
15:00-15:25 Status of FFAG simulations, F. Meot, DAPNIA

Chair: Valeri Lebedev
14:00-14:25 Large accelerator control systems, K. White, Jefferson Lab
14:30-14:55 Beam control and monitoring with FPGA based electronics, N. Eddy, FNAL
15:00-15:25 The Fermilab Accelerator Control System, J. Patrick, FNAL

15:30 Break

Chair: Martin Berz
16:00-16:25 Strong-strong beam-beam simulations, T. Pieloni, CERN
16:30-16:55 Self-consistent simulations of high-intensity beams and e-clouds, J.-L. Vay, LBNL
17:00-17:25 Benchmarking of space charge codes against UMER experiments, R. Kishek, Maryland
17:30-17:55 Simulation of coherent instability thres-holds with space charge in the FAIR rings, O. Boine-Frankenheim, GSI

Chair: Ursula van Rienen
16:00-16:25 Accelerating Cavity Design for the ILC, A. Kabel, SLAC
16:30-16:55 Numerical Computation of SIS 100/300 Kicker Impedances, B. Doliwa, Darmstadt
17:00-17:25 2-D Electromagnetic Model of Fast-Ramping SC Magnets, B. Auchmann, CERN
17:30-17:55 Comparison of h- and p- Refinement in a Finite Element Maxwell Time Domain Solver, C. Kraus, PSI

19:30 Conference Dinner at “La Calèche”

Thursday, Oct.5

Chair: Andreas Kabel
9:00-9:25 High perfor-mance data interface for EM simulations, A. Adelmann, PSI
9:30-9:55 Parallel PIC codes, F. Wolfheimer, TU Darmstadt
10:00-10:35 Differential Algebraic High-Order 3-D Vlasov Solver, M.Berz, East-Lansing

Chair: Jeff Holmes
9:00-9:25 Accelerator description formats, N. Malitsky, BNL
9:30-9:55 The universal accelerator parser, D. Sagan, Cornell
10:00-10:25 CSTs commercial beam physics codes, U. Becker, CST

10:30 Break

Chair: Robert Reyne
11:00-11:35 The GRID, Les Robertson, CERN
11:40-12:05 Adaptive two-dimensional Vlasov simulation of particle beams, E. Sonnendrucker, IRMA
12:10-12:35 Accelerator Modeling under SciDAC: Meeting the Challenges of Next-Generation Accelerator Design, Analysis, and Optimization, P. Spentzouris, FNAL

12:40 Closing session

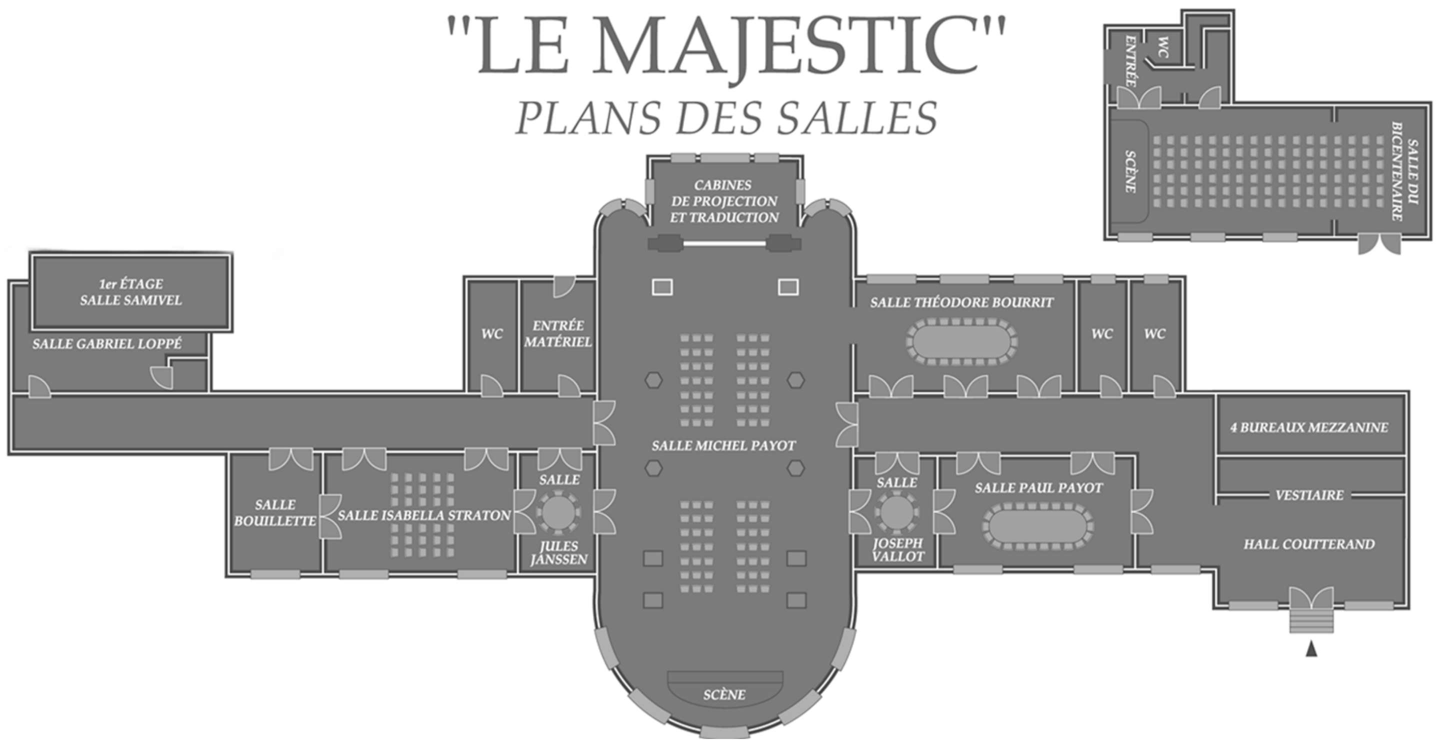
Friday, Oct. 6

9:00 Bus Chamonix – CERN – Geneva Airport
11:30-13:00 Presentations on LHC and CLIC physics
14:30-17:30 Technical Visits at CERN
17:45 Bus CERN – Geneva Airport

Salle Michel Payot
Salle Isabella Straton
Salle Paul Payot
Chamonix

"LE MAJESTIC"

PLANS DES SALLES



ICAP 2006 gratefully acknowledges the generous support of

Contribution ID tags:

MO M1 MP 02

Weekday – Session Type – Location - Number

Weekday:

MO/TU/WE/TH/

Session Type:

MP	Morning Plenary Oral Session
AP	Afternoon Plenary Oral Session
M1-2	Morning Parallel Oral Session
A1-4	Afternoon Parallel Oral Session
P	Poster Session
SE	Software Exhibition Panel

Location:

MP	Salle Michel Payot
IS	Salle Isabella Straton
PP	Salle Paul Payot

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MOAPMP - Plenary Session 2

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MOMPMP - Plenary Session 1

Computational Beam Dynamics for SNS Commissioning and Operation

MOMPMP01

J. A. Holmes, S. M. Cousineau, D.-O. Jeon, A. P. Shishlo, Y. Zhang (ORNL) D. A. Bartkoski (UTK)

The computational approach is providing essential guidance and analysis for the commissioning and operation of SNS. Computational models are becoming sufficiently realistic that it is now possible to study detailed beam dynamics issues quantitatively. Increasingly, we are seeing that the biggest challenge in performing successful analyses is that of knowing and describing the machine and beam state accurately. Even so, successful benchmarks with both theoretical predictions and experimental results are leading to increased confidence in the capability of these models. With this confidence, computer codes are being employed in a predictive manner to guide the machine operations. We will illustrate these points with various examples taken from the SNS linac and ring.

Funding: SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U. S. Department of Energy.

Computational Needs for ILC

MOMPMP02

D. Schulte (CERN)

The ILC requires detailed studies of the beam transport and of individual components of the transport system. The main challenges are the generation and preservation of the low emittance beams, the protection of the machine from excessive beam loss and the provision of good experimental conditions. The studies of these effects leads to specifications for the different accelerator components and hence can significantly impact the cost.

Funding: This work is supported by the Commission of the European Communities under the 6th Framework Programme, contract number RIDS-011899.

MOM1MP - Particle Tracking and Map Methods

MOM1MP01

Massive Tracking on Heterogeneous Platforms

E. McIntosh, F. Schmidt (CERN) F. de Dinechin (ENS LYON)

The LHC@home project uses public resource computing to simulate circulating protons in the future Large Hadron Collider (LHC). As the physics simulated may become chaotic, checking the integrity of the computation distributed over a heterogeneous network requires perfectly identical (or homogeneous) floating-point behaviour, regardless of the model of computer used. This article defines an acceptable homogeneous behaviour based on existing standards, and explains how to obtain it. This involves processor, operating system, programming language and compiler issues. In the LHC@home project, imposing this homogeneous behaviour entailed less than 10% performance degradation per processor, and almost doubled the number of processors which could be usefully exploited.

MOM1MP02

Accelerator Modeling with PTC

E. Forest (KEK)

The code PTC is an integrator. Most magnets are simulated by explicit symplectic integration with the notable exception of the traveling wave cavity and the “arbitrary field” magnet. The code PTC uses the Taylor Polymorphism pioneered by Bengtsson and also novel beam line structures (would be classes in C++) which permit the arbitrary placement of a magnet in space while preserving the magnet-map object of typical accelerator codes. One salient feature of PTC is that a beam line is not a sequence of magnets, but rather a sequence of containers dubbed “fibres” in PTC. De facto, PTC implements a restricted “fibre bundle.” The implementation of these structures in PTC has allowed us to simulate complex topologies such as recirculators, colliders and “pretzels”. Taylor polymorphism and map normal forms give us the usual perturbation theory of accelerator physics for arbitrarily complex beam lines. We can bypass completely the cumbersome Courant-Snyder approach and the repugnant Sands formalism: these approaches have no place in modern tracking codes. I will review the concepts behind the code and new developments which make it possible to use PTC in conjunction with collective effect programs.

MOM1MP03

Resonance Driving Term Experiments: An Overview

R. Bartolini (Diamond)

The frequency analysis of the betatron motion is a valuable tool for the characterization of the linear and non-linear motion of a particle beam in a storage ring. In recent years, several experiments have shown that resonance driving terms can be successfully measured from the spectral decomposition of the turn-by-turn BPM data. The information on the driving terms can be used to correct unwanted resonances, to localize strong non-linear perturbations and provides a valuable tool for the construction of the non-linear model of the real accelerator. In this paper we introduce briefly the theory, the computational tools and we give a review of the resonance driving terms experiments performed on different circular machines.

MOM2IS - Numerical Methods in Field Calculation 1

A Highly Accurate 3-D Magnetic Field Solver

MOM2IS01

S. L. Manikonda, M. Berz, K. Makino (MSU)

We present a new high precision parallel three dimensional magnetic field solver. This tool decomposes the problem of solving the Poisson equation into the problem of solving the Laplace equation and finding the magnetic field due to an arbitrary current distribution. The underlying theory to find solutions to both these problems using Differential Algebraic methods is developed, resulting in a local field expansion that can be computed to arbitrary order. Using the remainder differential algebraic approach, it is also possible to obtain fully rigorous and sharp estimates for the approximation errors. The method provides a natural multipole decomposition of the field which is required for the computation of transfer maps, and also allows obtaining very accurate finite element representations with very small numbers of cells. The method has the unique advantage of always producing purely Maxwellian fields, and naturally connects to high order DA-based map integration tools. We demonstrate the utility of this field solver for the design and analysis of novel combined function multipole with elliptic cross section that can simplify the correction of aberrations in large acceptance fragment separators for radioactive ion accelerators.

Large Scale Parallel Wake Field Computations for 3D-Accelerator Structures with the PBCI Code

MOM2IS02

E. Gjonaj, X. Dong, R. Hampel, M. Kärkkäinen, T. Lau, W. F.O. Müller, T. Weiland (TEMF)

The X-FEL project and the ILC require a high quality beam with ultra short electron bunches. In order to predict the beam quality in terms of both, single bunch energy spread and emittance, an accurate estimation of the short range wake fields in the TESLA crymodules, collimators and other geometrically complex accelerator components is necessary. We have presented earlier wake field computations for short bunches in rotationally symmetric components with the code ECHO. Most of the wake field effects in the accelerator, however, are due to geometrical discontinuities appearing in fully three dimensional structures. For the purpose of simulating such structures, we have developed the Parallel Beam Cavity Interaction (PBCI) code. The new code is based on the full field solution of Maxwell equations in the time domain, for ultra-relativistic current sources. Using a specialized directional-splitting technique, PBCI produces particularly accurate results in wake field computations, due to the dispersion free integration of the discrete equations in the direction of bunch motion. One of the major challenges to deal with, when simulating fully three dimensional accelerator components is the huge computational effort needed for resolving both, the geometrical details and the bunch extensions by the computational grid. For this reason, PBCI implements massive parallelization on a distributed memory environment, based on a flexible domain decomposition method. In addition, PBCI uses the moving window technique, which is particularly well suited for wake potential computations in very long structures. As a particular example of such a structure, the simulation results of a complete module of TESLA cavities with eight cells each for a um-bunch will be given.

Funding: This work was partially funded by EUROTeV (RIDS-011899), EUROFEL (RIDS-011935), DFG (1239/22-3) and DESY Hamburg

Low-Dispersion Wakefield Calculation Tools

M. Kärkkäinen, E. Gjonaj, T. Lau, T. Weiland (TEMF)

Extremely short bunches are used in future linear colliders, such as the International Linear Collider (ILC). Accurate and computationally efficient numerical methods are needed to resolve the bunch and to accurately model the geometry. In very long accelerator structures, computational efficiency necessitates the use of a moving window in order to save memory. On the other hand, parallelization is desirable to decrease the simulation times. Explicit schemes are usually more convenient to parallelize than implicit schemes since the implementation of a separate potentially time-consuming linear solver can thus be avoided. Explicit numerical methods without numerical dispersion in the direction of beam propagation are presented for fully 3D wake field simulations and for the special case of axially symmetric structures. The introduced schemes are validated by comparing with analytical results and by providing numerical examples for practical accelerator structures. Conformal techniques to enhance the convergence rate are presented and the advantages of the conformal schemes are verified by numerical examples.

Funding: This work was partially funded by EUROTeV (RIDS-011899), DFG (1239/22-3) and DESY Hamburg.

MOA1MP - Numerical Methods in Field Calculation 2

EM Field Simulation Based on Volume Discretization: Finite Integration and Related Approaches

MOA1MP01

R. Schuhmann (UPB)

Today's design and analysis demands for accelerator components request for reliable, accurate, and flexible simulation tools for electromagnetic fields. Amongst the widest spread approaches is the Finite Integration Technique (FIT), which has been used in electro- and magnetostatics, eddy current problems, wave propagation problems, as well as PIC codes. FIT belongs to the class of local approach in the sense, that the discrete equations are derived cell-by-cell by transforming the continuous Maxwellian equations onto the computational grid. Other representatives of local approaches are Finite Differences (FD), Finite Volumes (FV), Finite Elements (FE), and the Cell Method (CM). All these approaches are based on a volume discretization, defined by the three-dimensional mesh. Whereas the close relations between FIT and FD has been known since the beginning of both approaches in the seventies, recent research has revealed that under certain circumstances, also FIT and FE have many important properties in common. In the light of the forthcoming 30 years-anniversary of the first FIT-publication in 1977, this contribution reviews these properties as well as some still existing important differences, and their consequences for the usage of the methods in practice. It is shown that the differences between the main representatives of so-called "geometrical methods" (FIT, FD, FE, CM) are surprisingly small. Some of the recent research on this topic is presented, which has lead to new theoretical insights in computational electromagnetics. Finally the possible impact of these results on the derivation of new simulation methods is discussed.

Geometry of Electromagnetism and its Implication in Field and Wave Analysis

MOA1MP02

L. Kettunen (TUT)

Electromagnetism has a strong geometrical structure which, however, is hidden when the theory is examined in terms of classical vector analysis. Consequently a more powerful framework of algebraic topology and differential geometry is needed to view the subject. Recently, the geometric view has become rather popular among the community of computational electromagnetism, but still it has been asked, whether the more generic view truly enables one to develop new tools applicable to pragmatic field and wave analysis which could not be discovered otherwise. In other words, is the investment needed to study the new subject justified by the advantages brought by the more accurate viewpoint? Such a question is, evidently, not trivial to answer. Not because the larger framework did not have clear advantages, but rather for it takes a considerable effort to understand the difference between the "old" and "new" approach. Second, the advantages tend to be rather generic in the sense, that the geometric viewpoint tends to be more useful in building a software system to solve electromagnetic boundary value problems instead of in finding some handy techniques to solve certain specific problems. This paper makes an attempt to highlight some keypoints of the geometric nature of electromagnetism and to explain which way the geometric viewpoint is known to be useful in numerical analysis of electromagnetic field and wave problems. We start from the basics of electromagnetism and end up with more specific questions related to computing.

A Framework for Maxwell's Equations in Non-Inertial Frames Based on Differential Forms

S. Kurz (Robert Bosch GmbH) B. Flemisch, B. Wohlmuth (IANS)

In many engineering applications the interaction between the electromagnetic field and moving bodies is of great interest. It is natural to use a Lagrangian description, where the unknowns are defined on a mesh which moves and deforms together with the considered objects. What is the correct form of Maxwell's equations and the material laws under such circumstances? The aim of the present paper is to tackle this question by using the language of differential forms. We first provide a review of the formulations of electrodynamics in terms of vector fields, as well as differential forms in the (1+3)- and four-dimensional setting. In order to keep both Maxwell's and the constitutive equations as simple as possible, we set up two reference frames. In the natural material frame, the (1+3)-Maxwell's equations have their simple form, whereas in the co-moving inertial frame, the material laws are canonical. In contrast to existing literature these frames are both retained to benefit from their individual advantages. It remains to construct transformation laws connecting the considered frames. To achieve this, we use a (1+3)-decomposition in terms of general projection operators which do primarily not depend on an underlying metric or on the choice of a spatial coordinate system [1]. The desired transformation laws are established by comparing the different decompositions of an arbitrary p-form with respect to the considered frames. We provide an interpretation in terms of vector fields, and consider the low frequency limit, which is the most relevant case for an implementation into numerical codes. For the description of low frequency electromagnetism, all rigid frames are equivalent. This goes beyond the standard principle of Galilean relativity, where only inertial frames are regarded as equivalent. The proper treatment in the general case is demonstrated by means of an example in rotating coordinates, where the classical paradox by Schiff [2] is resolved.

[1] F. Hehl and Y. Obukhov, Foundations of Classical Electrodynamics. Boston: Birkhäuser, 2003.

[2] L. Schiff, "A question in general relativity," Proc. Nat. Acad. Sci. USA, vol. 25, 1939.

MOA2IS - High-Current Effects 1

The ORBIT Simulation Code: Benchmarking and Applications

MOA2IS01

A. P. Shishlo, S. M. Cousineau, V. V. Danilov, J. Galambos, S. Henderson, J. A. Holmes, M. A. Plum (ORNL)

The contents, structure, implementation, benchmarking, and applications of ORBIT as an accelerator simulation code are described. Physics approaches, algorithms, and limitations for space charge, impedances, and electron cloud effects are discussed. The ORBIT code is a parallel computer code, and the scalabilities of the implementations of parallel algorithms for different physics modules are shown. ORBIT has a long history of benchmarking with analytical exactly solvable problems and experimental data. The results of this benchmarking and the current usage of ORBIT are presented.

Funding: SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U. S. Department of Energy.

Simulations of Single Bunch Collective Effects Using HEADTAIL

MOA2IS02

G. Rumolo, E. Benedetto, E. Métral, F. Zimmermann (CERN) O. Boine-Frankenheim, G. Franchetti (GSI)

The HEADTAIL code is a very versatile tool that can be used for simulations of electron cloud induced instabilities as well as for Transverse Mode Coupling Instability and space charge studies. The effect of electron cloud and/or a conventional impedance (resonator or resistive wall) on a single bunch is modeled using a wake field approach. The code naturally allows either for dedicated studies of one single effect or for more complex studies of the interplay between different effects. Sample results from electron cloud studies (coherent and incoherent effects) and TMCI studies (e.g., for the PS and SPS) will be discussed in detail and compared, where possible, with results from other codes having similar features and/or with existing machine data.

Towards the Description of Long Term Self Consistent Effects in Space Charge Induced Resonance Trapping

MOA2IS03

G. Franchetti (GSI)

In recent studies the effect of the space charge induced trapping has been shown relevant for long term storage of bunches. There the mechanism of emittance growth and beam loss have been studied for frozen bunch particle distribution. However, when beam loss or halo density are large enough, this approximation have to be reconsidered. We present here a first study on the effect of self consistency in frozen models as intermediate step towards fully 2.5 and 3D simulations.

MOAPMP - Plenary Session 2

MOAPMP01

Coupled Transient Thermal and Electromagnetic Finite-Element Simulation of Quench in Superconducting Magnets

C. W. Trowbridge, J. Simkin, S. Taylor, E. Xu (Vector Fields Ltd.)

Resistive, normal zones may propagate through the low temperature superconducting coils. The rise in temperature in the windings and the internal voltages developed during this quench process are a critical issue for magnet safety, in addition the eddy currents induced in support structures during a quench may result in large Lorentz forces that can cause damage. Approximate adiabatic models have been used to achieve good results for the time profile of the current decay*. More accurate methods based on finite element simulations have also been used to obtain temperature and voltage distributions**. This paper describes transient, closely coupled thermal, electromagnetic finite element and circuit simulations developed to model quenching magnets. The program was designed to be efficient for this calculation. It uses nodal finite elements for the transient thermal simulation and edge elements for the electromagnetic simulation. The two simulations can be performed on different symmetry groups so that the model size can be minimized. Circuit models are coupled to the electromagnetic simulator either using filamentary edge loops or with a full volume mesh in the coils. Accurately meshing the coils increases the model size, but it is essential if accurate fields and time derivatives of the field are required. The main source of heat in the coils during quench is resistive loss in the normal zone. However rate dependent losses caused by the changing magnetic field may cause heating and therefore trigger a quench in other coils. Having closely coupled thermal and electromagnetic simulations makes it easy to include these effects and hence greatly improves the reliability of the simulation. Calculated and measured results for a 4 coil superconducting polarized target magnet will be presented. In this system the quench spreads to another coil as a result of rate dependent losses, the calculated results change dramatically if these losses are not included.

* M.N. Wilson, Superconducting magnets p217ff

** S. Caspi et Al, Calculating Quench propagation with Ansys, IEEE Trans. Appl. Supperconduct. Vol 13, No2, pp1714-1717

MOAPMP02

High-Performance Self-Consistent Electromagnetic Modeling of Beams

J. R. Cary (CIPS)

This talk will review some of the recent advances of electromagnetic modeling with the inclusion of charged particles, as is important for beam physics and plasma physics. Important advances include methods for accurately treating boundaries for accelerator cavities, beam pipes, etc.; increasing the maximum stable time step; and algorithms that work well on parallel architectures. Higher-order algorithms with good properties are also of interest. Early cut-cell approaches failed to result in a symmetric linear system and, as a result, can be weakly damped or unstable. Later cut-cell approaches were shown to be symmetric, but they suffered from a reduction of the stable time step. Now available are cut-cell methods that can accurately model curvilinear boundaries with no reduction in stable time step. With Richardson extrapolation, these methods can give frequencies accurate to 1 part in 10^6 with less than 100 cells in each direction. The use of these new algorithms in VORPAL,* a flexible, object-oriented, massively parallel modeling application, will be presented. VORPAL has been used for a number of applications** involving the self-consistent interaction of charged particles with electromagnetic fields. Finally, we will discuss the needs for improvements to self-consistent EM modeling.

* C. Nieter and J.R. Cary, "VORPAL: a versatile plasma simulation code", J. Comp. Phys. 196, 448-472 (2004).

** C.G.R. Geddes,et al Nature 431, 538-541 (Sep. 2004)

Funding: US Department of Energy

Geometrical Methods in Computational Electromagnetism

A. Bossavit (LGEP)

From almost one century, it has been known that vector fields E, H, D, B, etc., in the Maxwell equations are just "proxies" for more fundamental objects, the differential forms e, h, d, b, etc., that when integrated on lines or surfaces, as the case may be, yield physically meaningful quantities such as emf's, mmf's, fluxes, etc. This viewpoint helps separate the "non-metric" part of the equations (Faraday and Ampère), fully covariant, from the "metric" one (the constitutive laws), with more restricted (Lorentz) covariance. The usefulness of this viewpoint in computational issues has been realized more recently, and will be the main topic addressed in this survey. It makes the association of degrees of freedom with mesh elements such as edges, facets, etc. (instead of nodes as in traditioanl finite element techniques), look natural, whereas the very notion of "edge element" seemed exotic twenty years ago. It explains why all numerical schemes treat Faraday and Ampère the same way, and only differ in the manner they discretize metric-dependent features, i.e., constitutive laws. What finite elements, finite volumes, and finite differences, have in common, is thus clearly seen. Moreover, this seems to be the right way to advance the "mimetic discretization" or "discrete differential calculus" research programs, which many dream about: a kind of functorial transformation of the partial differential equations of physics into discrete models, when space-time continuum is replaced by a discrete structure such as a lattice, a simplicial complex, etc. Though total fulfillment of this dream is still ahead, we already have something that engineers –especially programmers keen on object-oriented methods– should find valuable: A discretization toolkit, offering ready-to-use, natural "discrete" counterparts to virtually all "continuous" objects discernible in the equations, fields, differential operators, v x B force fields, Maxwell tensor, etc.

TUMPMP - Plenary Session 3

TUMPMP01

Simple Maps in Accelerator Simulations

S. Peggs (BNL)

Difference systems (described by maps) exhibit much richer dynamical behavior than differential systems, because of the emphasis they place on occasional "high-frequency" transient kicks. Thus, the standard map (with pulsed gravity) displays chaos, while the gravity pendulum does not. Maps also speed up simulations enormously, by summarizing complex dynamics in short form. A new example of richer bahavior, and of dramatic speed up, comes from the representation of interacting electron clouds and ion clouds. Coupled maps are capable of demonstrating the first order phase transitions (from cloud "off" to "on") that are sometimes observed in practice, and enable the extension of electron cloud simulation to include much slower evolving ion clouds.

TUMPMP02

Simulation of the FAIR Synchrotron Magnets

H. De Gersem, S. Koch, T. Weiland (TEMF)

For the future Facility of Antiproton and Ion Research (FAIR) at the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, two superconductive magnet designs are considered. Besides the high field quality in the aperture, the minimisation of eddy-current losses is one of the major design criteria. Due to the relatively fast ramping of the magnets, substantial eddy-current effects arise in the end regions of the yoke of the window-frame SIS-100 magnets and in the Rutherford cable of cos-phi-type SIS-300 magnets. The simulation of these effects requires 3D, transient, nonlinear field simulations. The models are discretised in space by the finite integration technique. A higher-order Runge-Kutta method with error-controlled adaptive time step selection is used for time discretisation. The BH-characteristic is smoothed and consistently extrapolated in order to guarantee a good convergence of the Newton method. Skin layers in ferromagnetic yokes are resolved by a grading mesh. Cable eddy-current effects occur due to the limited electrical insulation between parallel wires in the Rutherford cable. Resolving individual wires by the mesh would lead to huge models and is therefore not an option. Instead, a cable magnetisation model or a cable eddy-current model is inserted in the overall magnet model. Both cable models allow the computation of the Joule losses in the cable and of the deterioration of the aperture field during ramping.
Funding: This work was supported by the Gesellschaft für Schwerionenforschung (GSI), Darmstadt.

Beam-Dynamics Simulation Studies for the High-Energy Storage Ring (HESR)

A. Lehrach (FZJ)

The High-Energy Storage Ring (HESR) of the future International Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt is planned as an antiproton synchrotron storage ring in the momentum range from 1.5 to 15 GeV/c. An important feature of this new facility is the combination of phase space cooled beams and thick internal targets (e.g. pellet targets) which results in demanding beam parameter requirements for two operation modes: high luminosity mode with peak luminosities of up to $2{\cdot}10^{32}cm^{-2}s^{-1}$ and high resolution mode with a momentum spread down to 10^{-5}. To reach these beam parameters one needs a very powerful phase space cooling utilizing high-energy electron cooling and high-bandwidth stochastic cooling. The effects of beam-target scattering and intra-beam interaction are investigated in order to study beam equilibria and beam losses for the two different operation modes.

O. Boine-Frankenheim et al., Nucl. Inst. and Meth. A 560, 245 (2006).

A. Lehrach at al., Nucl. Instr. Meth. A 561, 289 (2006).

F. Hinterberger, Jül-Report No. 4206 (2006), ISSN 0944-2952.

Funding: INTAS grant No. 03-54-5584 (Advanced Beam Dynamics for Storage Rings), EU-FP6 FP6 contract No. 515873(DIRAC Secondary-Beams)

TUPPP - Poster Session 1

TUPPP05

A Space Charge Algorithm for the Bunches of Elliptical Cross Section with Arbitrary Beam Size and Particle Distribution

A. Orzhekovskaya, G. Franchetti (GSI)

Algorithms of analytical and semi-analytical calculation of the electric field for the bunches of variable elliptical cross section are proposed. An arbitrary space charge distribution is fitted on the interval of consideration by the polynom of optimal order. In the case of an axisymmetric 3D ellipsoidal bunch or an arbitrary 2D elliptic cross section of the bunch the analytic solution is derived. For the bunch of variable elliptical cross section proposed method is developed to a numerical method using longitudinal grid. Tests of the field computation show high accuracy of the calculations and good agreement of the algorithms with the general theory. The methods are applied to the space charge modeling for the GSI project "Facility for Antiproton and Ion Research at Darmstadt" (FAIR), where particle loss must be calculated during long term storage, and to the code benchmarking in frame of the project "High Intensity Pulsed Proton Injector" (HIPPI).

TUPPP09

Modeling High-Current Instabilities in Particle Accelerators

A. Schiavi, M. Migliorati (Rome University La Sapienza) G. Dattoli (ENEA C. R. Frascati)

Methods employing integration techniques of Lie algebraic nature have been successfully employed in the past to develop charged beam transport codes, for different types of accelerators. These methods have been so far applied to the transverse motion dynamics, while the longitudinal part has been treated using standard tracking codes. In this contribution we extend the simplectic technique to the analysis of longitudinal and coupled longitudinal and transverse motion in charged beam transport with the inclusion of the non linear dynamics due to the wake field effects. We use the method to model different types of instabilities due to high current. We consider in particular the case of coherent synchrotron instabilities and its implication in the design and performances of high current accelerators. We discuss either single pass and recirculated devices. As to this last case, we also include the effect due to quantum noise and damping.

Funding: This work has been partially supported by the EU commission in the sixth framework programme, contract no. 011935 EUROFEL

TUPPP10

Design and Modeling of Field-Emitter Arrays for a High Brilliance Electron Source

M. Dehler (PSI)

The realization of compact Angstrom wave length free electron lasers depends critically on the brilliance of their electron sources. Field emitters are attractive given their small emission surface and subsequent high current density. The low emittance gun project (LEG) at PSI focuses on developing suitable field emitter arrays (FEA) with a dual gate structure emitting a total current of 5.5A out of a diameter of 500 microns with an emittance in the order of 50 nm rad. Simulations show for idealized emitters that despite micron scale variations of the charge density a low emittance can be obtained by putting the FEA in a pulsed DC diode at 250 MV/m. The challenge lies in modelling all real world effects in the

individual field emitter and assembling these into a global emission model. Field emission is often labeled as a cold emission process, nevertheless quantum physical effects lead to a base line energy spread of an order of 150 meV FWHM for the emitted electrons. Replenishing the conduction band with electrons from deep layers gives a further increase in the momentum spread. For the metallic field emitter used, surface roughness has an important influence on the emission properties. It typically gives an additional field enhancement factor of 2.5 to 3 resulting in lower required gate voltages. Additionally we have a detrimental effect on the transverse momentum spread. Work is in progress on obtaining numerical estimates for these effects using among other things measurements using secondary electron microscopy. Further more, the extraction and focusing gates both both give rise to nonlinear defocusing and focusing forces, which have to be minimized by a careful geometric optimization. Combining all these effects gives a reliable parametrization of the individual emitters, which together with a stochastic spatial distribution of emitter properties is used in the global emission model.

Ultra-Relativistic 3-D Particle-In-Cell Code for Beam-Beam Simulation

TUPPP11

V. A. Vshivkov (ICM&MG SB RAS) M. A. Boronina, V. N. Snytnikov (IC SB RAS) E. Levichev, S. A. Nikitin (BINP SB RAS)

The problem of beam stability at beam-beam effects in the newest projects of super-colliders should be studied by the methods of mathematical simulation that take into account to the full extent the three-dimensional nature of the interaction. For this aim, 3D PIC electromagnetic code in which the particles motion is assumed to be ultra-relativistic has been developed. The following formulation of the problem is considered. Colliding electron and positron beams moves in the region shaped as parallelepiped. The physical process is described by Vlasov–Liouville equations and a set of Maxwell equations that interrelate of the densities of charge and current, and intensities of electric and magnetic fields. A problem on establishing the initial and boundary conditions becoming more complicated with increase of the relativistic factor has been solved up to those factor values of 10^6. The example of the electron and positron bunches collision simulation is presented.

The TILECAL/ATLAS Detector Control System

TUPPP14

J. Pina, A. Gomes (LIP)

TileCal is the barrel hadronic calorimeter of the ATLAS detector. The main task of the TileCal Detector Control System (DCS) is to enable the coherent and safe operation of the detector. All actions initiated by the operator and all errors, warnings and alarms concerning the hardware of the detector are handled by DCS. TileCal DCS design is being finalized, prototypes of most of the systems were already produced, and some components were already produced and installed in the detector. The low voltage control system is composed by several components with monitoring and control mostly based on the ATLAS developped ELMB boards. The high voltage system is based on the HV-micro boards developed by TileCal. A DCS system covering a small sector of the TileCal barrel was assembled and is already working in the ATLAS cavern, and by October we expect to have already a full partition equipped with low voltage, high voltage and cooling system.

TUPPP16

Integration of a Large-Scale Eigenmode Solver into the ANSYS Workflow Environment

B. S.C. Oswald, A. Adelmann, M. Bopp, R. Geus (PSI)

The numerical computation of eigenfrequencies and eigenmodal fields of large accelerator cavities, based on full-wave, three-dimensional models, has attracted considerable interest in the recent past. In particular, it is of vital interest to know the performance characteristics, such as resonance frequency, quality figures and the modal fields, respectively, of such devices prior to construction; given the fact that the physical fabrication of a cavity is expensive and time-consuming, a device that does not comply with its specifications can not be tolerated; a robust and reliable digital prototyping methodology is therefore essential. Furthermore, modern cavity designs typically exhibit delicate and detailed geometrical features that must be considered for obtaining accurate results. At PSI a three-dimensional finite-element code has been developed to compute eigenvalues and eigenfields of accelerator cavities (*). While this code has been validated versus experimentally measured cavity data, its usage has remained somewhat limited due to missing functionality to connect it to industrial grade modeling software. Such an interface would allow creating advanced CAD geometries, meshing them in ANSYS and eventually exporting and analyzing the design in femaxx. We have therefore developed pre- and postprocessing software which imports meshes generated in ANSYS for a femaxx run. A postprocessing step generates a result file than can be imported into ANSYS and further be analyzed there. Thereby, we have integrated femaXX into the ANSYS workflow such that detailed cavity designs leading to large meshes can be analyzed with femaXX, taking advantage of its capability to address very large eigenvalue problems. Additionally, we have added functionality for parallel visualization to femaxx. We present a practical application of the pre- and postprocessing codes and compare the results against experimental values, where available, and other numerical codes when the model has no

* P. Arbenz, M. Becka, R. Geus, U. L. Hetmaniuk, and T. Mengotti, "On a Parallel Multilevel Preconditioned Maxwell Eigensolver". Parallel Computing, 32(2): 157-165 (2006).

TUPPP23

Numerical Minimization of Longitudinal Emittance in Linac Structures

S. Lange, M. Clemens, L. O. Fichte (Helmut-Schmidt-University) T. Limberg (DESY)

Relativistic electron bunches in linear colliders are characterized by 6D phase spaces. In most linear accelerators, the longitudinal phase space distribution does not interact significantly with the transverse distributions. This assumption allows the use of a 2D design model of the longitudinal phase space. The design of linear colliders is typically based on manipulations in the longitudinal phase space. The two dimensional single bunch tracking code LiTrack (Bane/Emma 2005) allows to simulate bunch-compression up to 3rd order and RF acceleration with wake fields. This code is implemented in Matlab with a graphic user interface front end. In order to improve the ability to simulate a two-stage bunch compression system, which consist of a RF accelerating section, a higher harmonic RF section and a dipole magnet chicane, an extension to the LiTrack code is proposed. An analytical model of this two-stage bunch compression system is defined using the energy and the momentum derivatives up to 3rd order of the system. As a consequence, the energy of the system can now be specified directly, for the simulation criteria the peak current and the symmetry of the charge distributions and be specified via parameters. This extended model allows the definition of bunches with an arbitrary energy, phase space correlation, longitudinal emittance, charge distribution and resulting peak current. A minimal longitudinal emittance is generally considered as a quality factor of the bunch, where the bunch energy, peak current and a symmetric charge distribution are represented as constraints. Under these conditions, a constrained optimization problem is defined to minimize the longitudinal emittance with a predetermined bunch-energy and peak-current with respect to the charge distribution symmetry. For the solution of this problem, LiTrack is extended with a optimization solver based on a SQP formulation to find an optimal bunch corresponding to the newly introduced constraints.

Transverse Coupling Impedance of a Ferrite Kicker Magnet: Comparison between Simulations and Measurements

TUPPP24

E. Arevalo, B. Doliwa, T. Weiland (TEMF)

The driving terms of instabilities in particle accelerators depend on the beam surroundings which are conveniently described by coupling impedances. In the case of critical components, for which analytical calculations are not available, direct measurements of the coupling impedances on a prototype are usually needed. However, this obvious drawback on the design of particle accelerators can be overcome by electromagnetic field simulations within the framework of the Finite Integration Technique. Here we show results from numerical evaluations of the transverse coupling impedance of a ferrite kicker. In order to excite the electromagnetic fields in the device we implement numerically the conventional twin-wire method. A good agreement with experimental measurements is observed, showing a promising way to determine coupling impedances of components of particle accelerators before construction.

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A Time-Adaptive Mesh Approach for the Self-Consistent Simulation of Particle Beams

TUPPP26

S. Schnepp, E. Gjonaj, T. Weiland (TEMF)

In many applications the self-consistent simulation of charged particle beams is necessary. Especially, in low-energetic sections such as injectors the interaction between particles and fields considering all effects has to be taken into account. Well-known programs like the MAFIA TS modules typically use the Particle-In-Cell (PIC) method for beam dynamics simulations. Since they use a fixed computational grid which has to resolve the bunch adequately, they suffer from enormous memory consumption. Therefore and especially in the 3D case, only rather short sections can be simulated. This may be avoided using adaptive mesh refinement techniques (AMR). Since their application in Finite-Difference methods in time-domain is critical concerning instabilities, usually problem-matched but static meshes are used. In this paper a code working on the basis of a fully dynamic Cartesian grid is presented allowing for simulations capturing both, a high spatial resolution in the vicinity of the bunch and the possibility of simulating structures up to a length of several meters. The code is tested and validated using the RF electron gun of the Photoinjector Test Facility at DESY Zeuthen (PITZ) as an example. The evolution of various beam parameters along the gun is compared with the results obtained by different beam dynamics programs.

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TUPPP28

New 3-D Space Charge Routines in the Tracking Code ASTRA

G. Pöplau (Rostock University, Faculty of Engineering) K. Floettmann (DESY) U. van Rienen (Rostock University, Faculty of Computer Science and Electrical Engineering)

Precise and fast 3D space-charge calculations for bunches of charged particles are still of growing importance in recent accelerator designs. A widespread approach is the particle-mesh method computing the potential of a bunch in the rest frame by means of Poisson's equation. Recently new algorithms for solving Poisson's equation have been implemented in the tracking code Astra. These Poisson solvers are iterative algorithms solving a linear system of equations that results from the finite difference discretization of the Poisson equation. The implementation is based on the software package MOEVE (Multigrid Poisson Solver for Non-Equidistant Tensor Product Meshes) developed by G. Pöplau. The package contains a state-of-the-art multigrid Poisson solver adapted to space charge calculations. In this paper the basic concept of iterative Poisson solvers is described. It is compared to the established 3D FFT Poisson solver which is a widely-used method for space charge calculations and also implemented in Astra. Advantages and disadvantages are discussed. Further the similarities and differences of both approaches are demonstrated with numerical examples.

Funding: DESY Hamburg

TUPPP29

Charge Conservation for Split-Operator Methods in Beam Dynamics Simulations

T. Lau, E. Gjonaj, T. Weiland (TEMF)

For devices in which the bunch dimensions are much smaller than the dimensions of the structure the numerical field solution is typically hampered by spurious oscillations. The reason for this oscillations is the large numerical dispersion error of conventional schemes along the beam axis. Recently, several numerical schemes have been proposed which apply operator splitting to optimize and under certain circumstances eliminate the dispersion error in the direction of the bunch motion. However, in comparison to the standard Yee scheme the methods based on operator splitting do not conserve the standard discrete Gauss law. This contribution is dedicated to the construction of conserved discrete Gauss laws and conservative current interpolation for some of the split operator methods. Finally, the application of the methods in a PIC simulations is shown.

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ROCOCO - A Zero Dispersion Algorithm for Calculating Wake Potentials

TUPPP30

R. Hampel, W. F.O. Müller, T. Weiland (TEMF)

Wake fields are a limiting factor due to their collective effects. In colliders and high energy accelerators used in FEL projects short bunches excite high frequency fields which make the computation of near range wake fields inaccurate. Additionally the length of modern accelerating structures limit the powers of certain codes such as TBCI or MAFIA. Both limiting factors, i.e. short bunches and length of accelerating structures - a multiscale problem, can be dealt with in the following way. Using certain zero dispersion directions of a usual Cartesian grid leads to a decrease of the overall dispersion which usually arises by having discrete field values. Combined with a conformal modelling technique the full time step limited by the Courant criterion is used and a moving window is applied. Thus simulations of short bunches in long structures are possible - dispersion and memory problems have been avoided. In this work ROCOCO (Rotated mesh and conformal code) is presented. The zero dispersion algorithm uses a new discretization scheme based on a rotated mesh combined with the established USC scheme and the moving window technique mentioned above. The advantage of an explicit algorithm is joined with the zero dispersion along the beam's propagation direction. A dispersion analysis for the 2D version of the code is shown as well as some results for common structures of accelerator physics - such as collimators and the TESLA 9 cell structure.

Funding: This work was partially funded by EUROTeV (RIDS-011899) and DESY Hamburg.

Eigenmode Expansion Method in the Indirect Calculation of Wake Potential in 3-D Structures

TUPPP31

X. Dong, E. Gjonaj, W. F.O. Müller, T. Weiland (TEMF)

The eigenmode expansion method was used in the early 1980's in calculating wake potential for 2D rotational symmetric structures. In this paper it is extended to general 3D cases. The wake potential is computed as the sum of two parts, direct and indirect ones. The direct wake potential is obtained by an integral of field components from a full wave solution, which stops just at the end of the structure. The indirect wake potential is then calculated analytically through the eigenmode expansion method. This is to avoid the full wave modeling of a very long outgoing beam pipe, which is computational expensive. In our work, the Finite Integration Technique (FIT) with moving mesh window is used to model the structure. The fields are recorded at the truncation boundary as a function of time. These fields are then expanded according to discrete eigenmodes of the outgoing pipe, and the eigenmode coefficients are found out at each time step. Then, the coefficients are transferred into frequency domain and the integral of wake fields along a path to infinity is computed analytically. In the case that the moving mesh window is narrow, appropriate exploration of time domain coefficients is necessary. Numerical tests show that the proposed method provides an accurate result with as less as three modes for a collimator structure.

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TUAPMP - Plenary Session 4

TUAPMP01

Rigorous Global Optimization for Parameter Estimates and Long-Term Stability Bounds

K. Makino, M. Berz (MSU)

The code COSY INFINITY supports rigorous computations with numerical verification based on Taylor models, a tool developed by us that can be viewed as an extension of the differential algebraic methods that also determines rigorous Taylor remainder bounds. Such verified computation techniques can be utilized for global optimization tasks, resulting in a guarantee that the true optimum over a given domain is found. The method of Taylor models has a high order scaling property, suppressing the problem of over-estimation that is a common problem of reliable computational methods. We have applied the method to some of typical optimization tasks in accelerator physics such as lattice design parameter optimizations and the Lyapunov function based long-term stability estimates for storage rings. The implementation of Taylor models in COSY INFINITY has inherited all the advantageous features of the implementation of differential algebras in the code, resulting in very efficient execution. COSY-GO, the Taylor model based rigorous global optimizer of COSY INFINITY, can run either on a single processor or in a multi processor mode based on MPI. We present various results of optimization problems run on more than 2,000 processors at NERSC operated by the US Department of Energy. Specifically, we discuss rigorous long-term stability estimates of the Tevatron, as well as high-dimensional rigorous design optimization of RIA fragment separators.

Funding: DOE, NSF

TUAPMP02

CHEF: A Framework for Accelerator Optics and Simulation

J.-F. Ostiguy, L. Michelotti (Fermilab)

We describe CHEF, an application based on an extensive hierarchy of C++ class libraries. The objectives are (1) provide a convenient, effective application to perform standard beam optics calculations and (2) seamlessly support development of both linear and non-linear simulations, for applications ranging from a simple beamline to an integrated system involving multiple machines. Sample applications are discussed.

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TUAPMP03

Recent Progress on the MaryLie/IMPACT Beam Dynamics Code

R. D. Ryne, E. W. Bethel, I. V. Pogorelov, J. Qiang, J. M. Shalf, C. Siegerist, M. Venturini (LBNL) D. T. Abell (Tech-X) A. Adelmann (PSI) J. F. Amundson, P. Spentzouris (Fermilab) A. Dragt (University of Maryland) C. Mottershead, N. Neri, P. L. Walstrom (LANL) V. Samulyak (BNL)

MaryLie/IMPACT (ML/I) is a 3D parallel Particle-In-Cell code that combines the nonlinear optics capabilities of MaryLie 5.0 with the parallel particle-in-cell space-charge capability of IMPACT. In addition to combining the capabilities of these codes, ML/I has a number of powerful features, including a choice of Poisson solvers, a fifth-order rf cavity model, multiple reference particles for rf cavities, a library of soft-edge magnet models, representation of magnet systems in terms of coil stacks with possibly overlapping fields, and

wakefield effects. The code allows for map production, map analysis, particle tracking, and 3D envelope tracking, all within a single, coherent user environment. ML/I has a front end that can read both MaryLie input and MAD lattice descriptions. The code can model beams with or without acceleration, and with or without space charge. Developed under a US DOE Scientific Discovery through Advanced Computing (SciDAC) project, ML/I is well suited to large-scale modeling, simulations having been performed with up to 100M macroparticles. ML/I uses the H5Part* library for parallel I/O. The code inherits the powerful fitting/optimizing capabilities of MaryLie, augmented for the new features of ML/I. The combination of soft-edge magnet models, high-order capability, and fitting/optimization, makes it possible to simultaneously remove third-order aberrations while minimizing fifth-order, in systems with overlapping, realistic magnetic fields. Several applications will be presented, including aberration correction in a magnetic lens for radiography, linac and beamline simulations of an e-cooling system for RHIC, design of a matching section across the transition of a superconducting linac, and space-charge tracking in the damping rings of the International Linear Collider.

*ICAP 2006 paper ID 1222, A. Adelmann et al., "H5Part: A Portable High Performance Parallel Data Interface for Electromagnetics Simulations"

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Simulation of Secondary Electron Emission with CST Particle Studio (TM)

TUAPMP04

F. Hamme, U. Becker, P. Hammes (CST)

In accelerator physics and high power vacuum electronics the secondary electron emission (SEE) has in many cases an important influence on the physical behavior of the device. Since its analytical prediction even for simple geometries is extremely cumbersome, numerical simulation is essential to get a better understanding of the possible effects and ideas to change the design. The current paper introduces the implementation of SEE within the code CST Particle Studio (TM), which is an easy to use three dimensional tool for the simulation of electromagnetic fields and charged particles. There are three basic types of secondary electrons, the elastic reflected, the rediffused and the true secondary ones. The implemented SEE model is based on a probabilistic, mathematically self-consistent model developed by Furman and includes the three kinds of secondary electrons mentioned above. The paper presents simulation results with focus to the SEE for the absorbed power within an electron collector of a high power tube. As second example the secondary emission process is studied within the superconducting TESLA cavity, which gives some hints for the understanding of multipactor effects in those cavity and filter structures.

WEMPMP - Plenary Session 5

WEMPMP01

Computational Needs for the XFEL

M. Dohlus (DESY)

X-ray Free Electron Lasers (FEL) make use of the principle of Self-Amplified-Spontaneous-Emission (SASE) where electron bunches interact in an undulator with their own co-propagating radiation. They do not require optical resonators and their frequency is therefore not limited by material properties as the reflectivity of mirrors. The performance of X-ray SASE FELs depends exponentially on the beam quality of the electron bunch. Therefore effects in the beamline before the undulator are as important as particle-field interactions of the FEL-SASE process. Critical components are the low emittance electron source, accelerating sections, the bunch compression system and the undulator. Due to the high peak currents and small beam dimensions space charge (SC) effects have to be considered up to energies in the GeV range. Coherent synchrotron radiation (CSR) drives not only the FEL but is also emitted in dispersive sections as bunch compressors. SC, CSR, and wake fields affect significantly longitudinal beam parameters (peak current, correlated and uncorrelated energy spread) and the transverse emittance. Start-to-end simulations use a sequence of various tracking codes (with or without SC, CSR and wake fields) and FEL programs. Usually the particle or phase space information has to be carefully converted for each transition from one tool to another. Parameter studies need many simulations of the complete system or a part of it and beyond that, calculations with several random seeds are necessary to consider the stochastic nature of SASE-FEL process.

WEMPMP02

Wish-List for Large-Scale Simulations for Future Radioactive Beam Facilities

J. A. Nolen (ANL)

As accelerator facilities become more complex and demanding and computational capabilities become ever more powerful, there is the opportunity to develop and apply very large-scale simulations to dramatically increase the speed and effectiveness of many aspects of the design, commissioning, and finally the operational stages of future projects. Next-generation radioactive beam facilities are particularly demanding and stand to benefit greatly from large-scale, integrated simulations of essentially all aspects or components. These demands stem from things like the increased complexity of the facilities that will involve, for example, multiple-charge-state heavy ion acceleration, stringent limits on beam halos and losses from high power beams, thermal problems due to high power densities in targets and beam dumps, and radiological issues associated with component activation and radiation damage. Currently, many of the simulations that are necessary for design optimization are done by different codes, and even separate physics groups, so that the process proceeds iteratively for the different aspects. There is a strong need, for example, to couple the beam dynamics simulation codes with the radiological and shielding codes so that an integrated picture of their interactions emerges seamlessly and trouble spots in the design are identified easily. This integration is especially important in magnetic devices such as heavy ion fragment separators that are subject to radiation and thermal damage. For complex, high-power accelerators there is also the need to fully integrate the control system and beam diagnostics devices to a real-time beam dynamics simulation to keep the tunes optimized without the need for continuous operator feedback. This will most likely require on-line peta-scale computer simulations. The ultimate goal is to optimize performance while increasing the cost-effectiveness and efficiency of both the design and operational stages of future facilities.

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Parallel Higher-Order Finite Element Method for Accurate Field Computations in Wakefield and PIC Simulations

A. E. Candel, A. C. Kabel, K. Ko, L. Lee, Z. Li, C.-K. Ng, E. E. Prudencio, G. L. Schussman, R. Uplenchwar (SLAC)

Under the US DOE SciDAC project, SLAC has developed a suite of 3D (2D) Parallel Higher-order Finite Element (FE) codes, T3P (T2P) and PIC3P (PIC2P), aimed at accurate, large-scale simulation of wakefields and particle-field interactions in RF cavities of complex shape. The codes are built on the FE infrastructure that supports SLAC's frequency domain codes, Omega3P and S3P, to utilize conformal tetrahedral (triangular) meshes, higher-order basis functions and quadratic geometry approximation. For time integration, they adopt an unconditionally stable implicit scheme. PIC3P (PIC2P) extends T3P (T2P) to treat charged particle dynamics self-consistently using the PIC approach, the first such implementation on the FE grid. Examples from applications to the ILC, LCLS and other accelerators will be presented to compare the accuracy and computational efficiency of these codes versus their counterparts using structured grids.

Funding: Work supported by US DOE contract DE-AC002-76SF00515

WEPPP - Poster Session 2

WEPPP01

Recent Developments in IMPACT and Application for Future Light Sources

I. V. Pogorelov, J. Qiang, R. D. Ryne, M. Venturini, A. Zholents (LBNL) R. L. Warnock (SLAC)

The Integrated Map and Particle Accelerator Tracking (IMPACT) code suite was originally developed to model beam dynamics in ion linear accelerators. It has been greatly enhanced and now includes a linac design code, a 3D rms envelope code and two parallel particle-in-cell (PIC) codes IMPACT-T, a time-based code, and IMPACT-Z, a z-coordinate based code. Presently, the code suite has been increasingly used in simulations of high brightness electron beams for future light sources. These simulations, performed using up to 100 million macroparticles, include effects related to nonlinear magnetic optics, rf structure wake fields, 3D self-consistent space charge, and coherent synchrotron radiation (at present a 1D model). Illustrations of application for a simulation of the microbunching instability are given. We conclude with plans of further developments pertinent to future light sources.

WEPPP02

Recent Improvements to the IMPACT-T Parallel Particle Tracking Code

J. Qiang, I. V. Pogorelov, R. D. Ryne (LBNL)

The IMPACT-T code is a parallel three-dimensional quasi-static beam dynamics code for modeling high brightness beams in photoinjectors and RF linacs. Developed under the US DOE Scientific Discovery through Advanced Computing (SciDAC) program, it includes several key features including a self-consistent calculation of 3D space-charge forces using a shifted and integrated Green function method, multiple energy bins for a beams with large energy spread, and models for treating RF standing wave and traveling wave structures. In this paper, we report on recent improvements to the IMPACT-T code including short-range transverse and longitudinal wakefield models and a longitudinal CSR wakefield model. Some applications will be presented including simulation of the photoinjector for the Linac Coherent Light Source (LCLS) and beam generation from a nano-needle photocathode.
Funding: Supported in part by the US DOE, Office of Science, SciDAC program; Office of High Energy Physics; Office of Advanced Scientific Computing Research

WEPPP03

Recent Improvements in the PLACET Tracking Code

A. Latina, G. Rumolo, D. Schulte (CERN) P. Eliasson (Uppsala University)

The tracking code PLACET simulates beam transport and orbit correction in linear colliders from the damping ring to the interaction point and beyond. It is a fully programmable and modular software, thanks to a Tcl interface and external modules based on shared libraries. Recent improvements of the code are presented, including the possibility to simulate bunch compressors and to use parallel computer systems.

WEPPP04

Full Polymorphic Package (FPP) Demonstration and Documentation

E. Forest, Y. Nogiwa (KEK)

FPP is the FORTRAN90 library which overloads Berz's "DA-package" and Forest's "Lielib." Furthermore it is also the library which implements a Taylor Polymorphic type. This library is essential to code PTC, the "Polymorphic Tracking Code." Knowledge of the tools of FPP permits the computation of perturbative quantities in any code which uses FPP such as PTC/MAD-XP. We present here the available HTML documentation.

WEPPP07

Phase Space Tomography at the PITZ Facility

G. Asova, S. Khodyachykh (DESY Zeuthen)

A high phase-space density of the electron beam is obligatory for the successful operation of a Self Amplified Spontaneous Emission - Free Elector Laser (SASE-FEL). Detailed knowledge of the phase-space density distribution is thus very important for characterizing the performance of the used electron sources. The Photo Injector Test Facility at DESY in Zeuthen (PITZ) is built to develop, operate and optimize electron sources for FELs. Currently a tomography module for PITZ is under design as part of the ongoing upgrade of the facility. This contribution studies the performance of the tomography module. Errors in the beam size measurements and their contribution to the calculated emittance will be studied using simulated data. As a practical application the Maximum Entropy Algorithm (MENT) will be used to reconstruct the data generated by an ASTRA simulation.

Funding: This work has partly been supported by the European Community, contract 011935 (EUROFEL)

WEPPP08

Computation of Transfer Maps from Surface Data with Applications to Wigglers

C. E. Mitchell, A. Dragt (University of Maryland)

Simulations indicate that the dynamic aperture of the proposed ILC Damping Rings is dictated primarily by the nonlinear properties of their wiggler transfer maps. Wiggler transfer maps in turn depend sensitively on fringe-field and high-multipole effects. Therefore it is important to have a detailed and realistic model of the interior magnetic field, including knowledge of high spatial derivatives. Modeling of these derivatives is made difficult by the presence of numerical noise. We describe how such information can be extracted reliably from 3-dimensional field data on a grid as provided, for example, by various 3-dimensional finite element field codes (OPERA-3d) available from Vector Fields. The key ingredients are the use of surface data and the smoothing property of the inverse Laplacian operator. We describe the advantages of fitting on an elliptic cylindrical surface surrounding the beam, as well as extensions to more general domain geometries useful for magnetic elements with large saggitta.

WEPPP10

Implementation of the DYNAMION Code to the End-To-End Beam Dynamics Simulations for Proton and Ion Linear Accelerators

S. Yaramyshev, W. Barth, L. A. Dahl, L. Groening, B. Schlitt (GSI)

With the advanced multi-particle simulation code DYNAMION it is possible to calculate beam dynamics in linear accelerators and transport lines under space charge conditions with high accuracy. Special features like the consideration of field measurements, misalignment and fabrication errors, and data from the real topology of RFQ electrodes, drift tubes, quadrupole lenses lead to the reliable results of the beam dynamics simulations. End-to-end simulations for the whole linac (from ion source output to the synchrotron entrance) allow for the study and optimization of the overall machine performance as well as for calculation of the expected impact of different upgrade measures, proposed to improve beam brilliance. Recently the DYNAMION code is applied to investigation of the beam dynamics for the different GSI-linacs: the heavy ion high current UNILAC, the high current proton linac for the future Facility for Antiproton and Ion Research at Darmstadt (FAIR), and the light ion accelerator for the cancer therapy, to be commissioned in Heidelberg (Germany) in the near future. Recent results of the beam dynamics simulations by means of the DYNAMION code are presented and proposed measures for the facilities tuning and optimization are discussed.

WEPPP11

Comparison of the RFQs for the FAIR High Current Proton Linac

S. Yaramyshev, W. Barth, L. A. Dahl, L. Groening (GSI) A. P. Durkin (MRTI RAS) S. Minaev (ITEP) A. Schempp (IAP)

The antiproton physics program for future Facility for Antiproton and Ion Research (FAIR) at Darmstadt is based on a rate of $7 \cdot 10^{10}$ cooled antiprotons per hour. To provide sufficient primary proton intensities a new proton linac is planned. The proposed linac comprises an Electron Cyclotron Resonance (ECR) proton source, a Radio Frequency Quadrupole (RFQ), and Crossed-bar H-cavities (CH). Its operation frequency of 352 MHz allows for an efficient acceleration to up to 70 MeV using normal conducting CH-DTLs. The beam pulses with a length of 32 mks, a current of 70 mA, and total transverse emittances of 7 mkm will allow to fill the existing GSI synchrotron SIS 18 within one multi-turn-injection up to its space charge limit of $7 \cdot 10^{12}$ protons. Conceptual RFQ designs for two different RFQ types are proposed simultaneously: an RFQ of 4-rod type from the University Frankfurt and a 4 windows type RFQ from Institute for Theoretical and Experimental Physics (ITEP) and Moscow Radio-Technical Institute (MRTI). Studies of the beam dynamics in both RFQs has been done with the versatile multi-particle code DYNAMION. The topology of the RFQ tanks and electrodes is used "as to be fabricated" to provide for the realistic calculations of the external electrical field. The simulations are done under space charge conditions and including influence of the possible misalignments and errors of the fabrication. Simulated results for both designs will be discussed, as well as pros and cons. A comparison of the DYNAMION results with the simulations done by means of the PARMTEQM and LIDOS (dedicated codes for an RFQ design) is presented.

WEPPP12

New Features of MAD-X Based on PTC

P. K. Skowronski, F. Schmidt, R. de Maria (CERN) E. Forest (KEK)

For the last few years the MAD-X program makes use of the Polymorphic Tracking Code (PTC) to perform calculations related to beam dynamics in the nonlinear regime. This solution has provided an powerful tool with a friendly and comfortable user interface. Its apparent success has generated a demand for further extensions. We present the newest features developed to fulfill in particular the needs of the Compact LInear Collider (CLIC) studies. A traveling wave cavity element has been implemented that enables simulations of accelerating lines. An important new feature is the extension of the matching module to allow fitting of non-linear parameters to any order. Moreover, calculations can be performed with parameter dependence defined in the MAD-X input. In addition the user can access the PTC routines for the placement of a magnet with arbitrary position and orientation. This facilitates the design of non-standard lattices. Lastly, for the three dimensional visualization of lattices, tracked rays in global coordinates and beam envelopes are now available.

WEPPP14

Advances in Matching with MADX.

R. de Maria, F. Schmidt, P. K. Skowronski (CERN)

A new matching algorithm and a new matching mode have been developped for MadX in order to increase its potentialities. The new algorithm (JACOBIAN) is able to solve a generalized matching problem with an arbitrary number of variables and constraints, aiming to solve the corresponding least square problem. The new mode (USE lowMACRO) allows the user to construct his own macros and expressions for the definition of the constraints. The new algorithm and the new mode where succesfully used for finding optic transitions, tunability charts and non-linear chromaticity correction. They can be used as a general tool for solving inverse problems which can be defined in MadX using all the available modules (twiss, ptc,track, survey, aperture, etc).

WEPPP15

Simulations of Pellet Target Effects with Program PETAG01

A. Dolinskii, V. Gostishchev, M. Steck (GSI) O. A. Bezshyyko (National Taras Shevchenko University of Kyiv, The Faculty of Physics)

New internal targets play an important role in modern nuclear and high energy physics research. One of such targets is a pellet target which is a variant of a micro-particle internal target. This target has a number of very attractive features when it used in a storage ring. The software package PETAG01 has been developed for modelling the pellet target and it can be used for numerical calculations of the interaction of a circulating beam with the target in a storage ring. We present numerical calculations to study the beam dynamics of the ions in the storage ring, where strong cooling techniques in combination with the pellet target are applied. Some important effects due to the target in combination with electron cooling and its influence on the beam parameters have been considered.

WEPPP17

Tracking Code with 3-D Space-Charge Calculations Taking into Account the Elliptical Shape of the Beam Pipe

A. Markovik, G. Pöplau, U. van Rienen (Rostock University, Faculty of Computer Science and Electrical Engineering) R. Wanzenberg (DESY)

The determination of electron cloud instability thresholds is a task with high priority in the ILC damping rings research and development objectives. Simulations of electron cloud instabilities are therefore essential. In this paper a new particle tracking program is presented which includes the Poisson solver MOEVE for space charge calculations. Recently, perfectly electric conducting beam pipes with arbitrary elliptical shapes have been implemented as boundary conditions in the Poisson solver package MOEVE. The 3D space charge algorithm taking into account a beam pipe of elliptical shape will be presented along with numerical test cases. The routine is also implemented in the program code ASTRA, in addition we compare the tracking with both routines.

Funding: Work supported by DESY, Hamburg

WEPPP21

Efficient Time Integration for Beam Dynamics Simulations Based on the Moment Method

W. Ackermann, T. Weiland (TEMF)

The moment method model has been proven to be a valuable tool for numerical simulations of a charged particle beam transport both in accelerator design studies and in optimization of the operating parameters for an already existing beam line. On the basis of the Vlasov equation which describes a collision-less kinetic approach, the time evolution of such integral quantities like the mean or rms dimensions, the mean or rms kinetic momenta, and the total energy or energy spread for a bunched beam can be described by a set of first order non-autonomous ordinary differential equations. Application of a proper time integrator to such a system of ordinary differential equations enables then to determine the time evolution of all involved ensemble parameter under consistent initial conditions. From the vast amount of available time integration methods different versions have to be implemented and evaluated to select a proper algorithm. The computational efficiency in terms of effort and accuracy serves as a selection criterion. Among possible candidates of suited time integrators for the given set of moment equations are the explicit Runge-Kutta methods, the implicit theta methods, and the linear implicit Rosenbrock methods. Various algorithms have been implemented and tested under real-world conditions. In the paper the evaluation process is documented.

Funding: This work was partially funded by EUROFEL (RIDS-011935) and DESY Hamburg.

WESEPP - Software Exhibition Panel

CST's Commercial Beam-Physics Codes

WESEPP01

U. Becker (CST)

During the past decades Particle Accelerators have grown to higher and higher complexity and cost, so that a careful analysis and understanding of the machines' behaviour becomes more and more important. CST offers userfriendly numerical simulation tools for the accurate analysis of electromagnetic fields in combination with charged particles, including basic thermal analysis. The CST STUDIO SUITE code family is the direct successor of the code MAFIA, combining the numerical accuracy of the Finite Integration Theory and Perfect Boundary Approximation within an intuitive, easy-to-use CAD environment. Automatic Parameter Sweeping and Optimization are available to achieve and control the design goals. In this paper various solver modules of CST PARTICLE STUDIO, CST EM STUDIO and CST MICROWAVE STUDIO will be presented along accelerator-relevant examples, such as:

1. Cavity design using eigenmode solver including calculation of losses, Q-factors, shunt impedance and thermal analysis.
2. Coupler Design, including external Q-factor
3. Wakefield Simulation, including resistive wall effects, also realized for beams slower than speed of light
4. dispersion diagram for the analysis of periodic structures
5. design of guns, including beam emittance studies
6. study of secondary emission processes and dark current effects in accelerating structures.

COSY INFINITY

WESEPP02

M. Berz, K. Makino (MSU)

We will demonstrate the code COSY INFINITY Version 9. Besides the known feature of computations of high order Taylor transfer maps based on differential algebras, the latest version has many new features, many of them using algorithms only possible with differential algebras and Taylor models. Aside from conventional beam dynamics design and optimization tools, we will focus on new features, including rigorous global optimization, computation of remainder bounds for high order maps, minimal symplectic tracking in the EXPO framework, and the ability to integrate high-order maps through user-specified fields. Specific applications will focus on maps of absorbers, wedges, and novel non-cylindrical multipole elements.

Funding: DOE, NSF

WESEPP03

High-Order Algorithms for Simulation of Laser Wakefield Accelerators

D. L. Bruhwiler, J. R. Cary, D. A. Dimitrov, P. Messmer (Tech-X) E. Esarey, C. G.R. Geddes (LBNL) E. Kashdan (Brown University)

Electromagnetic particle-in-cell (PIC) simulations of laser wakefield accelerator (LWFA) experiments have shown great success recently, qualitatively capturing many exciting features, like the production of ~1 GeV electron beams with significant charge, moderate energy spread and remarkably small emittance. Such simulations require large clusters or supercomputers for full-scale 3D runs, and all state-of-the art codes are using similar algorithms, with 2nd-order accuracy in space and time. Very high grid resolution and, hence, a very large number of time steps are required to obtain converged results. We present preliminary results from the implementation and testing of 4th-order algorithms, which hold promise for dramatically improving the accuracy of future LWFA simulations.

Funding: This work is funded by the US DOE Office of Science, Office of High Energy Physics, including use of NERSC.

WESEPP04

The ORBIT Simulation Code: Benchmarking and Applications

J. A. Holmes (ORNL)

The contents, structure, implementation, benchmarking, and applications of ORBIT as an accelerator simulation code are described. Physics approaches, algorithms, and limitations for space charge, impedances, and electron cloud effects are discussed. The ORBIT code is a parallel computer code, and the scalabilities of the implementations of parallel algorithms for different physics modules are shown. ORBIT has a long history of benchmarking with analytical exactly solvable problems and experimental data. The results of this benchmarking and the current usage of ORBIT are presented.

WESEPP05

ROXIE - New Features for Integrated Magnet Design

S. Russenschuck, B. Auchmann, J. N. Schwerg (CERN)

The ROXIE (Routine for the Optimization of magnet X-sections, Inverse field calculation and coil End design) program package was developed at CERN for the design and optimization of the LHC superconducting magnets. In collaboration with the Technical University of Graz, Austria, the program was extended to include the possibility of calculating iron saturation effects using a reduced vector-potential method. ROXIE also includes the method of coupled boundary/ finite-elements, which was developed at the University of Stuttgart, Germany, and which is specially suited for the calculation of 3-dimensional effects in the magnets. The advantage of both methods is that the coils do not need to be represented in the finite-element mesh and can therefore be modeled with the required accuracy. ROXIE is used as an approach towards an integrated design of superconducting accelerator magnets. The methods implemented in the code can, however, also be applied to other applications in magnetic technology, including large air-coil (detector) magnets, solenoids, conventional magnets etc. Clearly, the user's interface has been designed with accelerator magnets in mind. This, however, does not exclude to create numerical models for devices such as actuators or electrical machines. Recently added features include calculation of the working point considering fit-curves for the critical surface, inter-filament coupling currents, inter-strand coupling currents, eddy currents in conductive bulk material, a new material database structure, and a virtual reality interface.

MAD-X - An Accelerator Design Code

F. Schmidt, P. K. Skowronski (CERN) E. Forest (KEK)

The new modular design of MAD-X program gives large flexibility with respect to previous version of the program. The core of MAD-X is written in C with interfaces to many independent packages in C or Fortran. All consistent MAD8 modules have been retained in MAD-X. For each of these modules a responsible person is assigned who performs bug fixes, maintenance and further developments. This set-up allows for easy implementation of independent code or algorithms as new MAD-X modules. The MAD-X input language has been extended with considerably more flexibility than MAD8. Portability of the code has been a priority and MAD-X is available on several platforms. We provide the complete source code, examples and documentation on the web. From a modern accelerator code one expects more advanced facilities than MAD-X can offer. To this end, MAD-X is linked to the independent Polymorphic Tracking Code (PTC). The main new features are: Maps and Normal Form techniques, symplectic treatment of thick accelerator elements and proper placing of the elements on the accelerator floor. Typical MAD-X runs will be performed that demonstrate the flexibility of the MAD-X input language. Various applications of the combined use of MAD-X and PTC will be given, with emphasis on using Normal Form to describe the non-linearities in accelerator models. Existing complex and also "fantasy" accelerator structures will be depicted together with particle trajectories simulated through them. There will also be examples of structures with complicated 3D positioning of magnets on the accelerator floor.

WEA1MP - Beam Cooling and Intra Beam Scattering

WEA1MP01

Parallel Simulation of Coulomb Collisions for High-Energy Electron Cooling Systems

D. L. Bruhwiler (Tech-X)

High-energy electron cooling requires co-propagation of relativistic electrons over many meters with the recirculating bunches of an ion collider ring. The expected increase of ion beam luminosity makes such systems a key component for proposed efforts like the RHIC luminosity upgrade* and the FAIR project**. Correctly simulating the dynamical friction of heavy ions, during brief interactions with low-density electron populations, in the presence of arbitrary electric and magnetic fields, requires a molecular dynamics approach that resolves close Coulomb collisions. Effective use of clusters and supercomputers is required to make such computations practical. Previous work*** will be reviewed. Recent algorithmic developments**** and future plans will be emphasized.

* `http://www.bnl.gov/cad/ecooling`

** `http://www.gsi.de/GSI-Future/cdr`

*** A. V. Fedotov et al., Phys. Rev. ST/AB (2006), in press.

**** G. I. Bell et al., AIP Conf. Proc. 821 (2006), p. 329.

Funding: This work is funded by the US DOE Office of Science, Office of Nuclear Physics.

WEA1MP02

Analysis of Measured Transverse Beam Echoes in RHIC

S. Sorge, O. Boine-Frankenheim (GSI) W. Fischer (BNL)

The transverse echo amplitudes observed in RHIC will be analysed using particle tracking codes together with different kinetic intrabeam scattering models. We discuss the different diffusion rates observed in proton and heavy ion beams.

Funding: Work supported by EU design study (contract 515873-DIRACsecondary-Beams)

WEA1MP03

Computing Methods in FFAG Accelerators Design

F. Meot (CEA)

There has recently been a regain of interest of Fixed Field Alternating Gradient (FFAG) accelerators, the use of which use is now envisaged in various domains, from the fast acceleration of muon beams in the Neutrino Factory, to high average intensity medical beams, via proton and other electron driver applications. The capability of computer codes to model the FFAG type of accelerator and to perform precision tracking is a concern, in design stages, from both point of views of optics and of magnet design. The difficulties come mainly from, (i) the reference orbit moving with energy, in relation with the large momentum bite in these machines, (ii) the presence of possibly very strong sources of non-linearities, as fields and kinematical effects, (iii) the necessity of exploring large amplitude motion inherent to the capacity of FFAGs to accelerate very large emittances. These questions, the way they are addressed, and the methods/codes in use nowadays to perform FFAG studies will be reviewed. This will be illustrated with contemporary problems, drawn from the Neutrino Factory, medical application of FFAGs, etc.

WEA2IS - Controls and Simulation

Status and Future Developments in Large Accelerator Control Systems

WEA2IS01

K. S. White (Jefferson Lab)

Over the years, accelerator control systems have evolved from small hardwired systems to complex computer controlled systems with many types of graphical user interfaces and electronic data processing. Today's control systems often include multiple software layers, hundreds of distributed processors, and hundreds of thousands of lines of code. While it is clear that the next generation of accelerators will require much bigger control systems, they will also need better systems. Advances in technology will be needed to ensure the network bandwidth and CPU power can provide reasonable update rates and support the requisite timing systems. Beyond the scaling problem, next generation systems face additional challenges due to growing cyber security threats and the likelihood that some degree of remote development and operation will be required. With a large number of components, the need for high reliability increases and commercial solutions can play a key role towards this goal. Future control systems will operate more complex machines and need to present a well integrated, interoperable set of tools with a high degree of automation. Consistency of data presentation and exception handling will contribute to efficient operations. From the development perspective, engineers will need to provide integrated data management in the beginning of the project and build adaptive software components around a central data repository. This will make the system maintainable and ensure consistency throughout the inevitable changes during the machine lifetime. Additionally, such a large project will require professional project management and disciplined use of well-defined engineering processes. Distributed project teams will make the use of standards, formal requirements and design and configuration control vital. Success in building the control system of the future may hinge on how well we integrate commercial components and learn from best practices used in other industries.

Funding: This work was supported by DOE contract DE-AC05-06OR23177, under which Jefferson Science Associates, LLC operates Jefferson Lab.

Beam Control and Monitoring with FPGA-Based Electronics: Status and Perspectives

WEA2IS02

N. E. Eddy (Fermilab)

Modern FPGAs support designs using roughly 10^6 logic gates, pipeline speeds exceeding 200 MHz, internal SRAM, dedicated multipliers for signal processing, clock generation using phase-locked loops, and a variety of single-ended and differential I/O standards, including fast serial links. When interfaced with high-speed ADCs, DACs, and other components commonly found in telecom applications, FPGAs facilitate a wide range of beam control and monitoring applications. Examples include beam-position measurement, low-level RF control, instability damping, and manipulation of accelerator timing signals. Once signals of interest are in digital form, an instrument's FPGA logic and memory provide a natural means to capture data for remote diagnosis–both of beam behavior and of the instrument itself. Finally, FPGA-based solutions provide a flexible, reconfigurable, and reusable toolkit for instrumentation: existing modules are often adapted to implement new applications, and useful code fragments can be quickly copied from design to design.

The Fermilab Accelerator Control System: Simultaneous Operation and Migration of an Increasingly Complex Facility

J. F. Patrick (Fermilab)

The Fermilab accelerator complex supports simultaneous operation of 8 and 120 GeV fixed target lines, a high intensity neutrino source (NUMI), antiproton production, and a 1.8 TeV proton-antiproton collider. Controlling all this is a single system known as ACNET. ACNET is based on a three tier architecture featuring a high degree of scalability, large scale parallel data logging, security, accountability, a states facility, a sequencer for automated operation. In recent years the system has been enhanced to support the demands of the current run, and also modified to reduce dependence in the upper layers on the obsolete VAX/VMS platform. A Java based infrastruture has been developed, and is now used for most middle layer functionality as well as some applications. A port of most of the remaining VMS code to Linux is nearing completion. This migration has been accomplished with minimal interruption to operations.

WEA3MP - High-Current Effects 2

Strong-Strong Beam-Beam Simulations

WEA3MP01

T. Pieloni (CERN)

During the collision of two charged beams the strong non-linear electromagnetic fields of the two beams perturb each other. This effect is called beam-beam interaction. Of particular interest in present and future machines are studies of the behaviour of equally strong and intense beams, the so-called strong-strong beam-beam interaction. After a careful definition of strong-strong beam-beam effects, I describe the applications where such studies are required. A major issue for strong-strong simulations are the computational challenges which are discussed. Finally I shall describe some of the modern techniques and procedures to solve them.

Self-Consistent Simulations of High-Intensity Beams and E-Clouds with WARP POSINST

WEA3MP02

J.-L. Vay, M. A. Furman, P. A. Seidl (LBNL) R. H. Cohen, A. Friedman, D. P. Grote, M. Kireeff Covo, A. W. Molvik (LLNL) P. Stoltz, S. A. Veitzer (Tech-X) J. Verboncoeur (UCB)

We have developed a new, comprehensive set of simulation tools aimed at modeling the interaction of intense ion beams and electron clouds (e-clouds). The set contains the 3-D accelerator PIC code WARP and the 2-D "slice" e-cloud code POSINST, as well as a merger of the two, augmented by new modules for impact ionization and neutral gas generation. The new capability runs on workstations or parallel supercomputers and contains advanced features such as mesh refinement, disparate adaptive time stepping, and a new "drift-Lorentz" particle mover for tracking charged particles in magnetic fields using large time steps. It is being applied to the modeling of ion beams (1 MeV, 180 mA, K+) for heavy ion inertial fusion and warm dense matter studies, as they interact with electron clouds in the High-Current Experiment (HCX). We describe the capabilities and present recent simulation results with detailed comparisons against the HCX experiment, as well as their application (in a different regime) to the modeling of e-clouds in the Large Hadron Collider (LHC).

Funding: Supported by U. S. Department of Energy under Contracts No. DE-AC02-05CH11231 and No. W-7405-Eng-48 and by US-LHC accelerator research program (LARP).

WEA3MP03

Benchmarking of Space Charge Codes Against UMER Experiments

R. A. Kishek, G. Bai, B. L. Beaudoin, S. Bernal, D. W. Feldman, R. B. Fiorito, T. F. Godlove, I. Haber, P. G. O'Shea, C. Papadopoulos, B. Quinn, M. Reiser, D. Stratakis, D. F. Sutter, K. Tian, C. Tobin, M. Walter, C. Wu (IREAP)

The University of Maryland Electron Ring (UMER) is a scaled electron recirculator using low-energy, 10 keV electrons, to maximize the space charge forces for beam dynamics studies. We have recently circulated in UMER the highest-space-charge beam in a ring to date, achieving a breakthrough both in the number of turns and in the amount of current propagated. As of the time of submission, we have propagated 5 mA for at least 10 turns, and, with some loss, for over 50 turns, meaning about 0.5 nC of electrons survive for 10 microseconds. This makes UMER an attractive candidate for benchmarking space charge codes in regimes of extreme space charge. This talk will review the UMER design and available diagnostics, and will provide examples of benchmarking the particle-in-cell code WARP on UMER data, as well as an overview of the detailed information on our website. An open dialogue with interested coded developers is solicited.
Funding: This work is funded by US Dept. of Energy and by the US Dept. of Defense Office of Naval Research.

WEA3MP04

Simulation Studies of Coherent Instabilities Thresholds with Space Charge in the FAIR Rings

O. Boine-Frankenheim, V. Kornilov (GSI) G. Rumolo (CERN)

The control of coherent instabilities induced by different ring impedances is crucial for the proposed FAIR synchrotrons as well as for the LHC injector rings. Space charge effects can modify the instability thresholds. The particle tracking code PATRIC is used to study instability thresholds with self-consistent space charge and external impedance sources. The present status of the code and its validation is described. Results obtained with PATRIC are compared with HEADTAIL simulation results as well as with observations in the GSI and CERN synchrotrons. We also compare the numerically obtained instability thresholds with different dispersion relations. Potential cures for the FAIR rings are tested using PATRIC simulations.
Funding: Work supported by EU design study (contract 515873 -DIRACsecondary-Beams)

WEA4IS - Numerical Methods in Field Calculation 3

Accelerating Cavity Design for the International Linear Collider

WEA4IS01

A. C. Kabel, V. Akcelik, A. E. Candel, L. Ge, K. Ko, L. Lee, Z. Li, C.-K. Ng, E. E. Prudencio, G. L. Schussman, R. Uplenchwar, L. Xiao (SLAC)

The International Linear Collider (ILC) is the highest priority future accelerator project in High Energy Physics whose R&D is presently the focus of the Global Design Effort (GDE). SLAC's Advanced Computations Department (ACD) is involved in the accelerating cavity design for the ILC main linac using the advanced tools developed under the US DOE SciDAC initiative. The codes utilize higher-order finite elements for increased accuracy and are in production mode on distributed memory supercomputers at NERSC and NCCS to perform the large-scale simulations needed by the ILC cavity design. Presently the code suite includes the eigensolver Omega3P for calculating mode damping, the time-domain solver T3P for computing wakefields, and the particle tracking code Track3P for simulating multipacting and dark current. This talk will provide an overview of their applications to the baseline TDR cavity design, and the alternate Low-Loss and Ichiro designs. Numerical results on HOM damping, cavity deformations, multipacting, and trapped modes in multi-cavity structures will be presented. Design issues with the input coupler and the HOM notch filter will also be addressed.

Numerical Computation of Kicker Impedances : Towards a Complete Database for the GSI SIS100/300 Kickers

WEA4IS02

B. Doliwa, T. Weiland (TEMF)

Fast kicker modules represent a potential source of beam instabilities in the planned Facility for Antiproton and Ion Research (FAIR) at the Gesellschaft für Schwerionenforschung (GSI), Darmstadt. Containing approximately six tons of lossy ferrite material, the more than forty kicker modules to be installed in the SIS-100 and SIS-300 synchrotrons are expected to have a considerable parasitic influence on the high-current beam dynamics. In order to be able to take these effects into account in the kicker design, a dedicated electromagnetic field software for the calculation of coupling impedances has been developed. Here we present our numerical results on the longitudinal and transverse kicker coupling impedances for the planned components and point out ways of optimization. Besides the inductive coupling of the beam to the external network -relevant below 100 MHz- particular attention is paid to the impact of ferrite losses up to the beam-pipe cutoff frequency.

Funding: Work supported by the GSI and the DFG under contract GK 410/3.

WEA4IS03

2-D Electromagnetic Model of Fast-Ramping Superconducting Magnets

B. Auchmann, S. Russenschuck, R. de Maria (CERN) S. Kurz (Robert Bosch GmbH)

The simulation of pulsed superconducting magnets has gained importance at the verge of fast-ramping cyclotron projects. The ROXIE program has been devised for the design and optimization of superconducting magnets. The 2-D electromagnetic model of a fast-ramping magnet in ROXIE consists of

1. a representation of strands by line currents,
2. a coupling of the finite element method and the boundary element method to take into account the field contribution of the magnet yoke, as well as eddy-current effects in conductive bulk material,
3. a model for persistent currents,
4. a model for inter-filament coupling currents, and
5. a model for inter-strand coupling currents in Rutherford-type cables.

We will present the coupling of all these effects in the mathematical framework of the theory of discrete electromagnetism. We will then proceed to demonstrate how the coupled approach helps to understand a pulsed magnet's behavior. Each of the above effects leaves an identifiable signature in the measured field quality and contributes to the losses. With ROXIE, we can trace measurements to their origin and make predictions based on experience and simulation.

WEA4IS04

Comparison of h- and p- Refinement in a Finite Element Maxwell Time Domain Solver

A. Adelmann, C. Kraus, M. Wittberger (PSI) P. Arbenz (ETH)

Two different frameworks are used and compared: FEMSTER [*] and Ng [**]. FEMSTER is a C++ class library of higher-order discrete differential forms. A discrete differential form is a finite element basis function with properties that mimic differential forms. The library consists of elements, basis functions, quadrature rules, and bilinear forms, i.e. the main building blocks for our FETD solver. Ng on the other hand is a software package providing amongst others basis functions for solving electromagnetic problems. The implemented higher order shape functions for edge- face- and inner-elements were proposed by Schöberl et al. They show a local complete sequence i.e. for each edge, face and element an individual polynomial order can be chosen. For the convergence studies , the electric field in a cubic and cylindrical cavity is initialized randomly and integrated in time. The field was then analysed and compared with the analytic eigenfrequencies of the cavities. We show results of this convergence studies when changing the mesh size and the polynomial order of the basis functions in the FETD solvers. [*] P. Castillo, et. al, Discrete differential forms: A novel methodology for robust computational electromagnetics. Technical Report UCRL-ID-151522, LLNL, 2003 [**] J. Schöberl, S. Zaglmayr. High order Nédélec elements with local complete sequence properties, COMPEL 24, 2, 374, 2005

THM1MP - Parallel Computing

H5Part: A Portable High Performance Parallel Data Interface for Electromagnetics Simulations

THM1MP01

A. Adelmann, A. Gsell, B. S.C. Oswald (PSI) E. W. Bethel, J. M. Shalf, C. Siegerist (LBNL)

The very largest parallel particle simulations, for problems involving six dimensional phase space and field data, generate vast quantities of data. It is desirable to store such enormous data-sets efficiently and also to share data effortlessly between other programs and analysis tools. With H5Part we defined a very simple file schema built on top of HDF5 (Hierarchical Data Format version 5) as well as an API that simplifies the reading and writing of the data to the HDF5 file format. Our API, which is oriented towards the needs of the particle physics and cosmology community, provides support for three types of common data types: particles, structured and unstructured meshes. HDF5 offers a self-describing machine-independent binary file format that supports scalable parallel I/O performance for MPI codes on computer systems ranging from laptops to supercomputers. The following languages are supported: C, C++, Fortran and Python. We show the easy usage and the performance for reading/writing terabytes of data on several parallel platforms. H5part is being distributed as Open Source under a BSD-like license.

Parallel Particle-In-Cell Codes

THM1MP02

F. Wolfheimer, E. Gjonaj, T. Weiland (TEMF)

Particle-In-Cell (PIC) simulations are commonly used in the field of computational accelerator physics for modelling the interaction of electromagnetic fields and charged particle beams in complex accelerator geometries. However, the practicability of the method for real world simulations, is often limited by the huge size of accelerator devices and by the large number of computational particles needed for obtaining accurate simulation results. Thus, the parallelization of the computations becomes necessary to permit the solution of such problems in a reasonable time. Different algorithms allowing for an efficient parallel simulation by preserving an equal distribution of the computational workload on the processes while minimizing the interprocess communication are presented. This includes some already known approaches based on a domain decomposition technique as well as novel schemes. The performance of the algorithms is studied in different computational environments with simulation examples including a full 3D simulation of the PITZ-Injector [*].

*A. Oppelt et al Status and First Results from the Upgraded PITZ Facility, Proc. FEL 2005

Funding: This work has been partially supported by DESY Hamburg.

A Differential Algebraic High-Order 3-D Vlasov Solver

M. Berz, K. Makino (MSU)

We show how the differential algebraic methods for ODEs and the resulting high order map computation can be generalized for solving certain PDEs. The entire PDE solving problem is cast in the form of an implicit constraint satisfaction problem, which is solved via differential algebraic partial inversion methods. As a result, it is possible to describe the solutions of the PDE locally as a very high order expression in the independent variables. Because of the high orders, it is possible to choose the size of the finite elements to be large, which leads to a very favorable behavior in high dimensions. The approach can be parallelized, and as such allows the solution of complicated high-dimensional PDEs in a reasonably efficient way. Furthermore, utilizing remainder differential algebraic methods, it is possible to provide rigorous and reasonably sharp error estimates of the entire procedure. We apply the methods to the study of the Vlasov equation describing the evolution of a beam under internal and external electromagnetic fields. In the case of this particular PDE, it is possible to perform time stepping to arbitrary order with a similar ease as in the case of the corresponing map computation case. Various examples will be given to illustrate the practical behavior of the method.

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THM2IS - Pre- and Post-Processing

Accelerator Description Formats

THM2IS01

N. Malitsky (BNL) R. M. Talman (Cornell University, Laboratory for Elementary-Particle Physics)

Being an integral part of accelerator software, accelerator description aims to provide an external representation of an accelerator's internal model and associative effects. As a result, the choice of description formats is driven by the scope of accelerator applications and is usually implemented as a tradeoff between various requirements: completeness and extensibility, user and developer orientation, and others. Moreover, an optimal solution does not remain static but instead evolves with new project tasks and computer technologies. This talk presents an overview of several approaches, the evolution of accelerator description formats, and a comparison with similar efforts in the neighboring high-energy physics domain. Following the UAL Accelerator-Algorithm-Probe pattern, we will conclude with a next logical specification, Accelerator Propagator Description Format (APDF), providing a flexible approach for associating physical elements and evolution algorithms most appropriate for the immediate tasks.

The Universal Accelerator Parser

THM2IS02

D. Sagan (Cornell University, Department of Physics) D. A. Bates (LBNL) A. Wolski (Liverpool University, Science Faculty)

The Universal Accelerator Parser (UAP) is a library for reading and translating between lattice input formats. The UAP was primarily implemented to allow programs to parse Acelerator Markup Language (AML) formatted files [D. Sagan et al. "The Accelerator Markup Language and the Universal Accelerator Parser", 2006 Europ. Part. Acc. Conf.]. Currently, the UAP also supports the MAD lattice format. The UAP provides an extensible framework for reading and translating between different lattice formats. Included are routines for expression evaluation and beam line expansion. The use of a common library among accelerator codes will greatly improve the interoperability between different lattice file formats, and ease the development and maintenance to support these formats in programs. The UAP is written in C++ and compiles on most Unix, Linux, and Windows platforms. A Java port is maintained for platform independence. Software developers can easily integrate the library into existing code by using the provided hooks.

CST's Commercial Beam-Physics Codes

U. Becker (CST)

During the past decades Particle Accelerators have grown to higher and higher complexity and cost, so that a careful analysis and understanding of the machines' behaviour becomes more and more important. CST offers userfriendly numerical simulation tools for the accurate analysis of electromagnetic fields in combination with charged particles, including basic thermal analysis. The CST STUDIO SUITE code family is the direct successor of the code MAFIA, combining the numerical accuracy of the Finite Integration Theory and Perfect Boundary Approximation within an intuitive, easy-to-use CAD environment. Automatic Parameter Sweeping and Optimization are available to achieve and control the design goals. In this paper various solver modules of CST PARTICLE STUDIO, CST EM STUDIO and CST MICROWAVE STUDIO will be presented along accelerator-relevant examples, such as:

1. Cavity design using eigenmode solver including calculation of losses, Q-factors, shunt impedance and thermal analysis.
2. Coupler Design, including external Q-factor
3. Wakefield Simulation, including resistive wall effects, also realized for beams slower than speed of light
4. dispersion diagram for the analysis of periodic structures
5. design of guns, including beam emittance studies
6. study of secondary emission processes and dark current effects in accelerating structures.

THMPMP - Plenary Session 6

The grid for LHC Data Analysis

THMPMP01

L. Robertson (CERN)

The talk will describe the way in which grid technology is being used to create a service for data handling for the LHC experiments, distributed across about a hundred computing centres around the world. The evolution of the orginal HEP specific services into more general multi-science computing infrastructures will be covered, and some examples will be given of the way in which this infrastructure is being exploited.

Adaptive 2-D Vlasov Simulation of Particle Beams

THMPMP02

E. Sonnendrucker, M. Gutnic, G. Latu (IRMA)

In order to address the noise problems occuring in Particle-In-Cell (PIC) simulations of intense particle beams, we have been investigating numerical methods based on the solution of the Vlasov equation on a grid of phase-space. However, especially for high intensity beam simulations in periodic or alternating gradient focusing fields, where particles are localized in phase space, adaptive strategies are required to get computationally efficient codes based on this method. To this aim, we have been developing fully adaptive techniques based on interpolating wavelets where the computational grid is changed at each time step according to the variations of the distribution function of the particles. Up to now we only had an adaptive axisymmetric code. In this talk, we are going to present a new adaptive code solving the paraxial Vlasov equation on the full 4D transverse phase space, which can handle real two-dimensional problems like alternating gradient focusing. In order to develop this code efficiently, we introduce a hierarchical sparse data structure, which enabled us not only to reduce considerably the computation time but also the required memory. All computations and diagnostics are performed on the sparse data structure so that the complexity becomes proportional to the number of points needed to describe the particle distribution function.

Accelerator Modeling under SciDAC: Meeting the Challenges of Next-Generation Accelerator Design, Analysis, and Optimization.

THMPMP03

P. Spentzouris (Fermilab)

Under the US DOE Scientific Discovery through Advanced Computing (SciDAC) initiative, a new generation of parallel simulation codes has been developed to meet the most demanding accelerator modeling problems for the DOE Office of Science (DOE/SC). Originally sponsored by DOE/SC's Office of High Energy Physics in collaboration with the Office of Advanced Scientific Computing Research, the new simulation capabilities have also been applied to other DOE projects, and to international projects as well. The new software has been applied to many projects, including the Tevatron, PEP-II, LHC, ILC, the Fermilab Booster, SNS, the JPARC project, the CERN SPL, many photoinjectors, and the FERMI@Elettra project. Codes have also been developed to model laser wakefield accelerators and plasma wakefield accelerators; these codes are being used both in support of advanced accelerator experiments, as well as to provide insight into the physics of ultra- high gradient accelerators. In this talk I will provide an overview of the computational capabilities that have been developed under our SciDAC project, and describe our plans for code development under the next phase of SciDAC.

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