WORKING GROUP SUMMARY: COMPUTATIONAL CHALLENGES IN HIGH-INTENSITY LINACS, RINGS INCLUDING FFAGS AND CYCLOTRONS*

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Abstract

The design and operation of accelerators with high intensity and high brightness hadron beams make high demands on computational tools. The increase of the intensity of hadron beams requires a more precise investigation of the beam dynamics, the study of further phenomena and the investigation of additional design issues. Thus, more sophisticated physical models are implemented into computer codes, which often causes time-consuming numerical calculations. Hence, this process is accompanied by the development and the application of efficient numerical methods.

INTRODUCTION

What are the computational challenges in high-intensity linacs and rings? Y. Luo and W. Fischer expressed it for RHIC in their paper [1] like this: "The challenge in the lifetime and emittance calculation is to obtain meaningful physics results with limited computing resources and computing time." Certainly, this statement can be generalized to the computational effort for high-brightness high-intensity hadron beams presented within this working group.

Altogether, ten talks and two posters were contributed from working group E to the workshop. During the sessions a great variety of challenges were discussed. Although the computational challenges are often very specific for a certain machine the following list gives an overview about the topics that were addressed.

- Inclusion of more physical phenomena, improved models and appropriate models into the simulation tools for more precise calculations.
- Application and development of appropriate numerical methods.
- Utilization of new hardware.
- Efficient development of simulation software.
- Comparison of simulations and measurements.

ADDITIONAL PHYSICAL MODELS, IMPROVED MODELS

New ideas and new concepts for high-intensity, high-brightness hadron beams require a precise as possible numerical prediction of the included beam dynamics. In [2] and [1] challenging issues for the beam-beam interaction simulations are discussed for eRHIC and RHIC, respectively. For the simulation of the effects of beam-beam collision in eRHIC the code EPIC has been developed in order to meet the special needs of the linac-ring configuration. It includes many physical effects like electron beam disruption, electron beam pinch, the kink instability of the proton bunch, the effect of fluctuating electron beam parameters on the proton beam [2]. The concept of the collision with a low energy electron beam for compensation of proton-proton beam-beam effects is investigated in [1]. The related simulations require multi-particle and million turn tracking for the calculation of the proton beam lifetime and emittance growth. Here, new approaches for the reduction of statistical errors are necessary.

The OPAL library was applied and extended for simulations of the upgrade plans of the PSI high power proton cyclotron facility [3, 4]. Here, a model for the efficient calculation of particle matter interaction is developed in order to simulate the collimator systems together with space charge [3]. Furthermore, for the study of multipacting and dark current phenomena a field emission and secondary emission model is implemented in OPAL. Since OPAL can handle complex geometric surfaces an efficient strategy for the calculation of the particle boundary collision is developed [4].

APPROPRIATE NUMERICAL METHODS

More precise simulations often require more sophisticated numerical methods such that these simulations can be performed efficiently and don't become too time consuming. Especially efficient methods for space charge calculations play an important role.

Often efficient numerical algorithms are already established in numerical mathematics but they are not yet applied or implemented for beam dynamics simulations. Thus, an algorithm of Barnes and Hut is implemented for the fast calculation of the particle - particle interaction of laser cooled ion beams [5]. A semi-analytical solver for the calculation of space charge is developed for the DYNAMION code based on the known analytical formulae for ellipsoidal bunch shapes [6]. A quite different approach that describes the space charge effect by a nonlinear transfer map is given in [7]. This development is done for the code COSY Infinity which is based on differential algebras. The advantage is that the nonlinear dynamics of an intense beam can be extracted directly from the calculations.

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NEW HARDWARE

More precise and hence time-consuming simulations (huge number of particles, a lot of turns) are often performed in parallel. Recently, Graphical Processor Units (GPU) are used more and more for parallel scientific computing. In [8] the transfer of the spin tracking code SPINK to the performance on GPUs and results for the particle tracking on GPUs are reported. The tracking itself is very suitable for the calculation on GPUs and a considerable speed up can be achieved. The simulation of collective effects like space charge is challenging on GPUs. Here, efficient approaches have to be developed, i. g. for charge binning.

SIMULATION SOFTWARE

The efficient simulation of complex beam dynamics requires an efficient development of the related computer codes. In [9] the hybrid code MaryLie/IMPACT(ML/I) is applied for detailed studies of the space charge effects in the proposed CERN PS2. Another approach for efficient code development is shown in [10]. Here, the synergia frame work, that includes physical models as well as numerical libraries, is applied to the simulation of wake functions of laminated magnets.

SIMULATIONS AND MEASUREMENTS

Newly developed software always requires a careful testing. Mostly, the new code is benchmarked against existing simulation tools. A further benchmark against measurements is often not done or it is not possible, for instance in the case that the simulations are performed during the design phase. Nevertheless, in [3] comparisons of measurements and simulations were presented, for instance the investigation of the influence of a trim coil.

An overview of several simulation codes applied for the SNS linac during a ten year period from design to operation is given in [11]. Code comparisons are presented als well as comparisons to measurements.

The joined session with working group F (Beam Diagnostics and Instrumentation) was used to discuss in more detail how a better benchmark of simulation results with measurements can be achieved.

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