FY 2004 PROJECT PROGRESS REPORT

ADVANCED BEAM-DYNAMICS SIMULATION TOOLS FOR RIA

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Summary of Expenditures

Institution	Allocated	Spent to Date	Comments
LANL	$180K	$125.3K	$27K for travel and M&S costs for computer operating system upgrades. All other costs are labor including some contractor labor.
LBNL	$160K	$110.0K	All costs are for labor.
ANL	$35K	$35.0K	All costs are for labor.
MSU	$35K	$35.0K	All costs are for labor, 2 Researchers, 0.25 FTE each
Total =	$410K	$305.3K	

Revised FY 2004 Project Plan

Due to both late arrival of funding in FY 2004 and a reduction in funding, a revised project plan was submitted to DOE at their request. This revised plan included the following tasks:

1. To continue to benchmark the RIAPMTQ (formerly called PARMTEQ) and IMPACT codes against existing codes used by ANL and MSU.
2. To add new beam line elements to both RIAPMTQ and IMPACT, including bending magnet and stripper subroutines for IMPACT. For the strippers there are some unknowns in the basic physics, which are being addressed in experiments carried out by both ANL and MSU. As these stripper subroutines will be under development in FY04, we will use the same stripper software packages that are developed by MSU and ANL.
3. To add the ability to model the important effects of random misalignments, random field errors of cavities and focusing elements, and beam-steering corrections based on simulated beam-position measurements including measurement errors to both RIAPMTQ and IMPACT.
4. Connect the RIAPMTQ and IMPACT codes. The simplest approach is for the two codes to remain separate; the output particle distributions from RIAPMTQ will be used as input for IMPACT. This will give us a complete end-to-end multiparticle parallel tool for fast and accurate beam-loss computations at NERSC. We will also produce, as a design tool, a version of the RIAPMTQ/IMPACT package that runs on a PC computer for lower statistics runs. By the end of this year's project, we expect that the new RIAPMTQ/IMPACT code package will be available for high statistics runs on NERSC for optimization of the candidate designs for the RIA Driver Linac, particularly for the design of collimation systems to control beam losses.
5. Produce a final report and users manual for the codes.

Project Progress

Task 1:

A detailed comparison of simulation results for the heavy-ion beam dynamics in the front end of the RIA driver linac using RIAPMTQ and TRACK has been performed. The rms results of the two codes are consistent, however, there is an unresolved discrepancy regarding halo observed in longitudinal phase space possibly related to different approaches used to model the ANL RFQ. A meeting at ANL to sort this all out is planned this Fall.

The IMPACT code has been installed on the local MSU computers and an initial benchmarking was performed with the MSU LANA code. In simulating the first two sections of the driver linac after the RFQ and before the first stripper, we obtained a reasonable agreement in rms beam size. Two charge states of uranium were transported. The longitudinal phase space distribution of the two-charge state beam at the end of the first two sections showed some discrepancies between the two codes. This is currently under study and is thought to be due to different phases used for the RF cavities in the two codes. Another benchmark was performed to compare the transfer matrix scheme and the numerical integration scheme for simulating beam transport in solenoids. Use of a realistic fringe field in the numerical integration scheme showed significant differences in rms beam size when the length of the solenoid was comparable to the aperture size. This suggests that the effective length approximation presently used in IMPACT might not be valid for short solenoids and a more detailed field distribution is needed in order to accurately model the solenoid. We have also carried out the first IMPACT run for a two-charge state beam out of the RFQ through two strippers and to the end of the whole superconducting driver linac. For this test, the simulation was based on the design of the MSU driver linac. Currently, we are in the process of understanding the simulation results and comparing with the MSU LANA simulations. Meanwhile, we are also in the process of setting up the IMPACT input files describing the ANL accelerator lattice. Running IMPACT with this lattice will give us a benchmark against the TRACK3d code used by our ANL colleagues. Some preliminary benchmarking results are discussed in our recent LINAC 2004 paper referenced below.

Task 2:

Both the RIAPMTQ and IMPACT codes now include the MSU stripping model. Both MSU and ANL have independently supplied charge-stripping models for inclusion in the simulation codes. The effect of stripping on a heavy-ion beam has been parameterized using the correlated energy-loss and angular distributions calculated with the code SRIM. This parameterization is used to regenerate the calculated beam distributions using the Monte-Carlo method after the stripper. The subroutines provided by ANL have not yet been implemented in either RIAPMTQ or IMPACT, however, this should be straightforward and will allow direct comparisons between the two models. Benchmarking against actual stripping data would be useful in the future, if possible. Additionally, the capabilities to model high-voltage platforms within the linac and interdigital accelerating structures have been added to RIAPMTQ.

Several new capabilities have also been added to the IMPACT code including a multipole module which includes sextupole, octupole and decapole magnets. We have also added a hard edge bending magnet model. The original coordinate-based (z-dependent) particle distribution is transformed into a time-based distribution. This distribution is then transported through a bending magnet by integrating the Lorentz equation in time. Integrating the Lorentz equation in time through the bending magnet will automatically handle the multiple charge state beam and can be extended to include more realistic, multi-component external magnetic fields. For the purpose of benchmarking, we have also implemented a transfer matrix scheme for a bending magnet for comparison. . Since the transfer matrix usually involves expansion with respect to a reference particle of single charge state, for the multiple charge state beam, we need to define reference particles of mean charge state for the different charge states, and furthermore to renormalize all the particle coordinates with respect to these new reference particles as they transport through the bending magnet. We have also implemented the transfer matrix scheme for transporting the multiple charge state beam through solenoids. Now the IMPACT code has two options for a solenoid magnet: either integration through the exact external magnetic field (including fringe fields), or to use the transfer-matrix method with an effective solenoid length.

Task 3:

RIAPMTQ was modified to include the capabilities for simulations of the effects of machine errors including misalignments, and other off-normal operating conditions. Error simulation capabilities already exist in the IMPACT code.

Implementation of realistic steering algorithms based on plausible measurements for the RIA driver linac still need to be incorporated to meet this project objective. ANL is in the process of further developing steering algorithms. LANL has developed such algorithms in the past for the Accelerator Production of Tritium (APT) linac and for the Spallation Neutron Source (SNS) linac. Implementation of several different steering algorithms may be attempted.

Task 4:

Standardized output file formats for RIAPMTQ were agreed upon and have been implemented in the parallel-processor codes so that multiple-charge-state macroparticle beam distributions can be passed directly to IMPACT for end-to-end simulation of the RIA driver linac for beam loss studies. This still needs to be done for the PC-based code package.

Task 5:

Work has not yet begun on the final report. The RIAPMTQ users manual is incomplete to date. The IMPACT manual has been updated to reflect the above mentioned enhancements.

Additional Comments:

The parallel supercomputing code development has been done exclusively by LANL and LBNL with stripping subroutines provided, as mentioned earlier, by ANL and MSU. In addition, both MSU and ANL have provided their most up-to-date linac lattice information in support of the benchmarking activities against their existing codes LANA (MSU) and TRACK (ANL). Both of these codes continue to be developed. MSU has begun the implementation of new beam line elements in their LANA code, both to help in the code benchmarking process against RIAPMTQ/IMPACT as well as in their later use for modeling their RIA design. ANL has continued to optimize their driver-linac lattice for acceleration of multiple-charge state uranium beams starting from the multi-harmonic buncher through the two stripper stations and magnetic chicanes. Initial beam loss and error studies have been performed at ANL for their driver linac design using the TRACK code. Comparison of these results with results from RIAPMTQ and IMPACT will be useful in the future.

We plan to release the RIAPMTQ code to ANL and MSU soon. MSU is particularly interested in being able to simulate the multi-charge state performance of their RFQ. LBNL already has the parallel version of the RIAPMTQ code. LBNL has provided PC IMPACT source code, including all the previously described changes, to LANL, ANL, and MSU.

We were recently encouraged by the interest shown by the heavy-ion accelerator community in our code development for RIA at the LINAC 2004 conference held in Luebeck, Germany in August. Several groups asked if we would be distributing these codes through the Los Alamos Accelerator Code Group for use by the general community.

We expect to carry over the remaining LANL and LBNL FY 2004 funds into FY 2005 to continue work on the uncompleted tasks. Implementation of steering algorithms, resolving benchmarking discrepancies, and documentation are our most important tasks to complete for the FY 2004 work. Finally, we plan on requesting an additional year of continuation funding to tie up loose ends and carry out initial beam-loss simulations for existing designs.

Publications:

1. P. Ostroumov, V. Aseev, E. Lessner, B. Mustapha. “Beam Loss Studies in High-intensity Heavy-ion Linacs,” EPAC 2004, July 5-9, 2004, Lucerne, Switzerland.

2. P.N. Ostroumov. “End-to-End Beam Dynamics Simulations for the ANL-RIA Driver Linac,” LINAC 2004, August 16-20, 2004, Luebeck, Germany.

3. X. Wu, “End-to-End Beam Simulations for the MSU RIA Driver Linac”**,** LINAC 2004, August 16-20, 2004, Luebeck, Germany.

4. T. P. Wangler, R. W. Garnett, K. R. Crandall, J. Qiang, R. Ryne, N. Aseev, P. Ostroumov, D. Gorelov, and R. York, “Advanced Beam-Dynamics Simulation Tools for RIA,” LINAC 2004, August 16-20, 2004, Luebeck, Germany.