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PIC SIMULATION OF THE HIGH CURRENT BEAM FOR THE LIA

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Abstract

High current beams emitting and transport of the linear induction accelerator (LIA) injector are simulated by a PIC code. And then beam transport and accelerated with space charge from injector exit to the LIA exit is simulated by another PIC simulation code and the slice beam parameters variability are also presented by this paper.

INTRODUCTION

The new type linear induction accelerator DRAGON-II is performed a multi-pulse x-ray flash radiography. The accelerator is delivered several about 20MeV (about 2% over the flattop), 2.0kA, 90ns(FWHM), 2000mm.mrad beams. To achieve the radiographic performance specifications, the time integrated beam spot size on the target should be less than 2mm. However, the interactions between the high energy intensity beams with the target may disrupt the beam spot size. These beam parameters make the new accelerator transport system the complicated system ever designed to transport a high current, high energy and long pulse beam. And designing the new accelerator transport system is challenging.

The DRAGON-II consists of pulse power system (triggering synchronizer, Marx generators and Blumlein lines), accelerator platform (injector, accelerator modules, beam transport system, beam downstream system), auxiliary system (vacuum system, isolated gas supply and water-cooling device). The pulse system that powers the injector for the new accelerator is capable of producing a 2.5-3 MV output pulse that is 90ns (FWHM). With the 2.5-3 MV diode voltage the cathode emits an about 2.0-2.5 kA pulse electron beam with more than 90ns (FWHM) current/energy "flat-top". After leaving the diode, the beam is accelerated by induction cells to 2.5-3MeV. Following the injector, these are a series of accelerator cells which consist of four accelerator cells and a vacuum cell. At the accelerator exit the beams are accelerated by all cells to about 20MeV. The beam downstream system focuses the high energy beams to target less than 2mm for the x-ray flash radiography.

The accelerator transport system consists of three sections. The first, a solenoid transport system consists of several large size solenoids which diameter are about 450mm. Namely the first transport system is the injector beam transport system. The second section consists of a series of solenoids which named accelerator cell solenoid. The second system transports the beam between the injector and the accelerator exit. The third transport system is the beam downstream system, the target beam line. In this paper we discuss the model of the transport sections; from the cathode to the accelerator exit.

THE INJECTOR

A particle simulation code named CHIPIC [1] is utilized to model the transport of a 90ns pulse beam from the cathode emitting, through the anode hole, and to the injector exit. Particle simulations can provide additional information on the performance of the beam line, for example the beam slice emittance. Figure 1 shows the geometry for the PIC simulation and the transport solenoids.

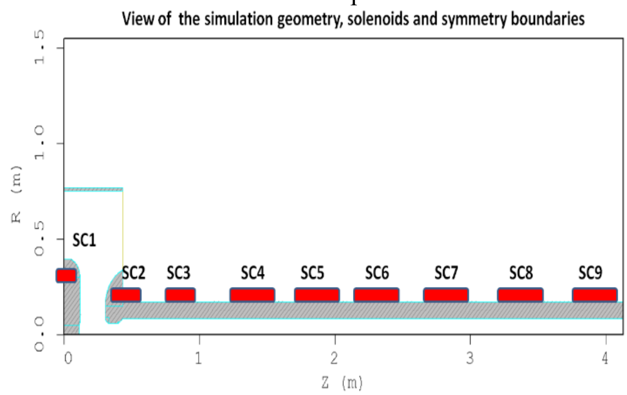

Figure 1: The geometry for the Injector simulation.

By the POSSION/SUPERFISH code, we obtain the injector axial magnetic field that Figure 2 shows. All the solenoids are designed at a lower tilt/offset that about 1mrad/0.5mm for the corkscrew control.

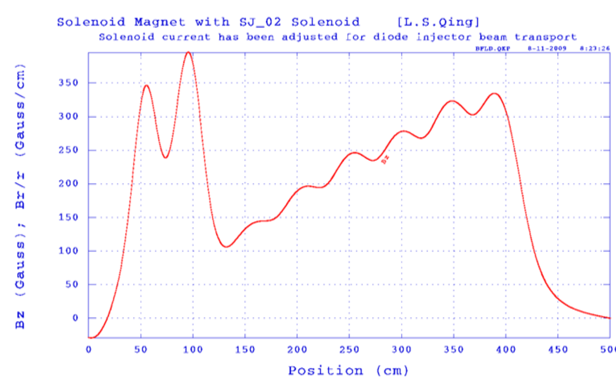

Figure 2: The axial magnetic field of the Injector.

A voltage pulse V(t) is applied to the injector. The different voltages lead to the different emit beam currents and the different cathode-anode gaps also lead to the different beam currents that Table.1 shows.

Table 1: Emit Beam Currents with the Voltages

Voltage Mv	Emit current A
1.2	738
2.4	1893
3	2543
3.6	3231
4.8	4679

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The transport of the high current electronic diode beams is simulated in different excitation currents for solenoids. The slice beam emittance is less than 220mm.mrad and the envelope radius is lower 10mm at the injector exit that meet with the goal of controlling the emittance/radius at the injector exit for the accelerator. These beam parameters are decided by the all solenoids and the beam transport can be optimized by the PIC simulation. Figure 3 shows the beam transport which has been optimized. The optimized beam radius is about 9mm and the beam current is about 2.54kA. The slice beam rms emittance is about 100mm.mrad.

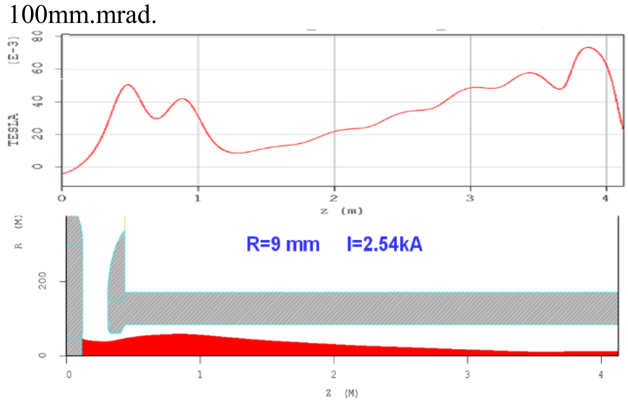

Figure 3: The beam transport which has been optimized.

THE ACCELETATOR

This section reports the results of PIC simulations for beam transport from the injector exit to the LIA accelerator exit. We use particle simulation code named OPAL [2] to model the slice beam about 5ns pulse width transport.

The initial beam parameters are about 2.6MeV, 1000 mm-mrad. The slice beam is transported through the LIA accelerator using solenoidal magnetic focusing fields which is an efficient and convenient means that has been used in all LIAs. The magnetic field produced by these magnets is called the tune of the accelerator. Figure 4 shows a plot of the axial magnetic flux density on axis as calculated by the POSSION/SUPERFISH code.

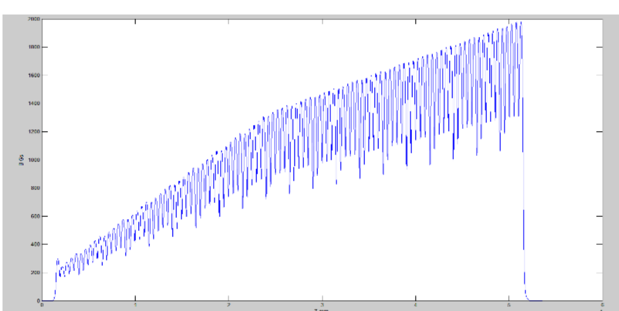

Figure 4: The axial magnetic field of the Accelerator.

We also use the POSSION/SUPERFISH code for the accelerator gap electric field calculation. Figure 5 shows the electrostatic potentials for this simulation with 200 kV across the gap. Only the features of the gap region that might affect the field on axis were included. Figure 6 shows the resulting field on axis, which was used with the gap locations to create an input file for PIC simulations.

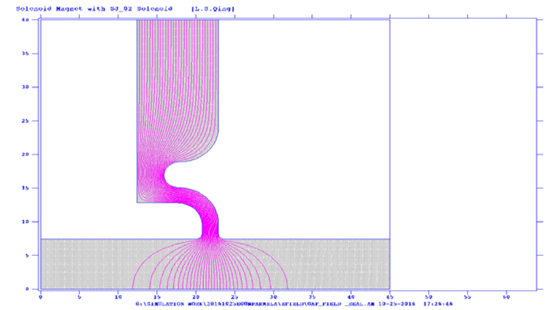

Figure 5: Equipotentials of the accelerating electric field in the region of the DRAGON-II gap for 200-kV gap voltage. Simulation was performed using the POSSION/SUPER-FISH code.

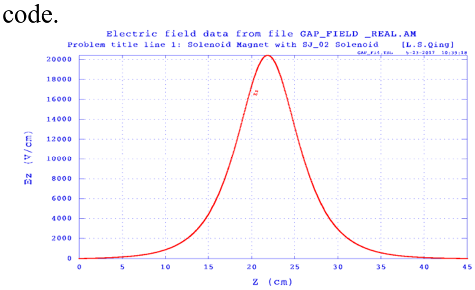

Figure 6: Accelerating electric field on axis calculated by POSSION/SUPERFISH for the DRAGON-II cell.

We use the PIC code OPAL to simulate beam transport from the injector exit to the accelerator exit for the DRAGON-II within the beam pulse. Space charge in particle slices are included in the simulations.

Figure 7 shows the particle load of 1000000 particles for a 5ns pulse of a nominal 2.6MeV, 2kA Gaussian distribution beam with a normalized emittance of 1000 mm-mrad at the injector exit of DRAGON-II.

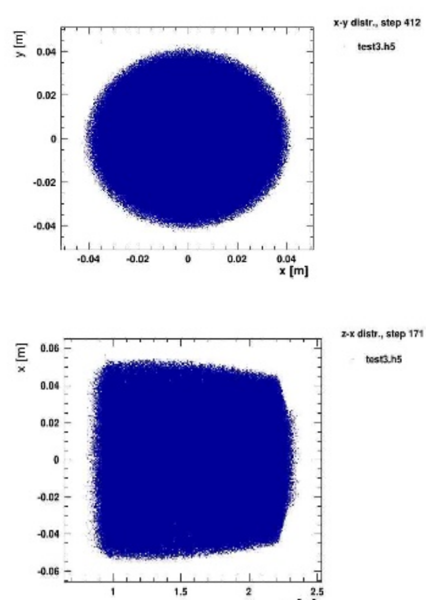

Figure 6: Initial particles space at injector exit for a 2.6 MeV, 2 kA and 1000 mm-mrad beam.

Figure 7 shows the particle longitudinal load for the 5ns pulse at the accelerator axis position about 1.5m, 10m, 20m and 30m of DRAGON-II. And figure 8 shows the reference particle energy gains via the accelerator gap voltage.

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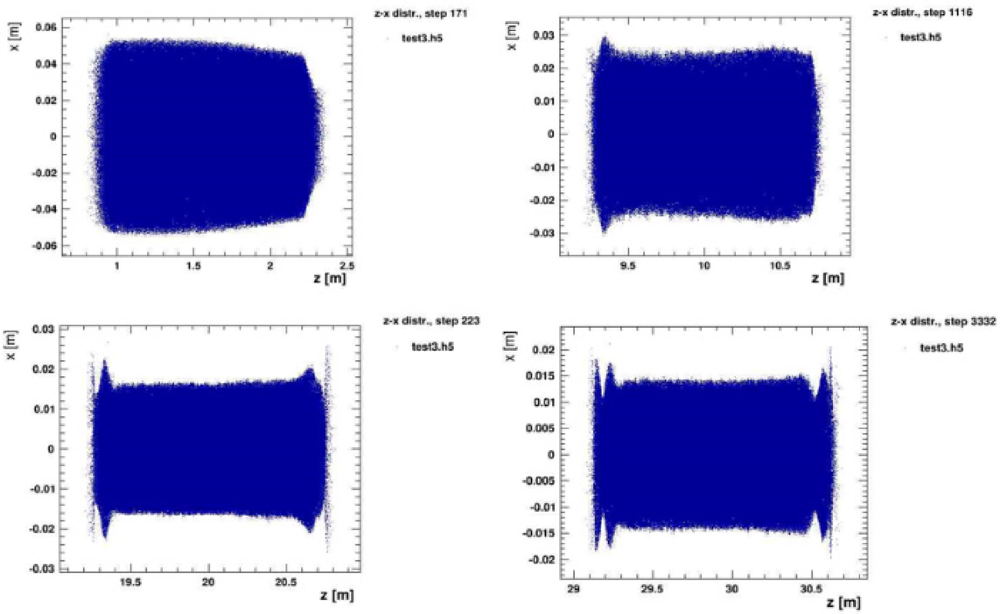

Figure 7: Particles longitudinal space at the different axis position about 1.5m, 10m, 20m and 30m of DRAGON-II.

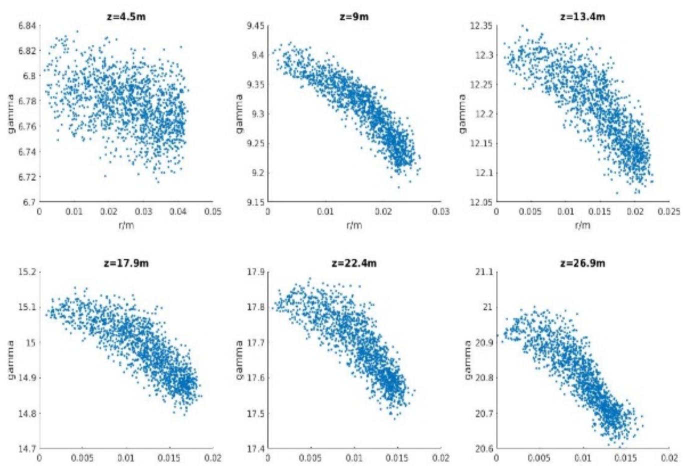

Figure 9: The slice beam(~0.25ns) energy spectrum.

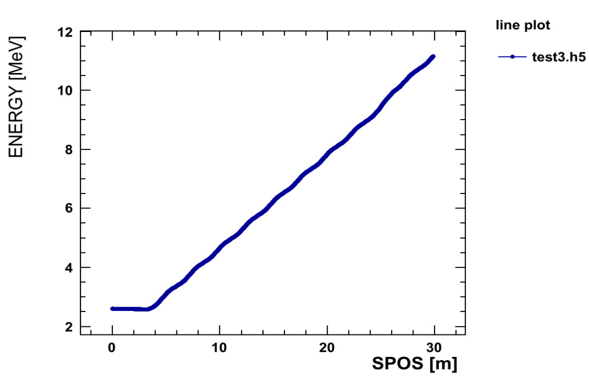

Figure 8: The reference particle energy.

An important figure of merit in the performance of DRAGON-II is the slice beam energy spectrum variability.Figure 9 shows the slice beam (~0.25ns) energy spectrum at the accelerator different axis position.

CONCLUSIONS

PIC simulations provide significant information about the performance of the LIA beamline by including a variety of physics models for transport components. Simulations for the DRAGON-II beamline have been performed including space charge and other effects. Estimates of the energy variation of the slice beam and particles longitudinal space at the different axis position can be determined with different transport magnetic fields.

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[2] The OPAL Framework User's Reference Manual, PSI-PR-08-02.