INTEGRATING THE TRACK BEAM SIMULATION CODE TO IMPROVE ATLAS OPERATIONS*

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Abstract

At the Argonne Tandem Linear Accelerator System (ATLAS) we are integrating TRACK, three dimensional particle tracking software that numerically integrates the equations of motion, into the accelerator control system. ATLAS delivers a variety of ions (1 – 238 AMU) at various energies (1 – 15 MeV/u) to multiple targets. By comparing simulated and observed performance, model driven operations will improve the understanding of the facility, reduce tune times, and improve the beam quality for these diverse operating conditions. This paper will describe the work to interface TRACK with the real-time accelerator control system, and the results of simulations used to characterize and configure the accelerator.

INTRODUCTION

Accelerator operations at ATLAS need to be flexible and versatile to accommodate the variety of operating configurations. ATLAS operates two sources to six target lines, as shown in Fig. 1. Experiments are changed 1-2 times per week. Ion species range from protons to ^{238}U, and energies from 0.5 to >15 MeV/u. In addition to stable beam delivery, radioactive ion beams (RIB) can be produced via the in-flight method or by reaccelerating fission fragments from the CARIBU [1] source. RIB delivery poses a particularly difficult challenge since the RIB intensities are typically much too low <10^6 pps to monitor using conventional Faraday cups and wire scanners. For these cases the accelerator is first configured for a pilot beam of sufficient intensity then scaled to match the rigidity of RIB. While a compact particle detector is being developed to aid the tuning of low intensity beams at ATLAS [2], these situations could benefit particularly from component settings accurately predicted using simulation software.

To improve the efficiency and reliability of ATLAS operations, the beam tracking software TRACK [3] is being interfaced with the ATLAS control system. The goals of this effort are to identify regions of significant beam loss and areas of distortion which then lead to significant loss, and to reduce the setup time for accelerator configuration and optimization. Besides displaying beam characteristics for real time configurations, the simulations will be able to predict component fields for previously unencountered situations and configurations – when new equipment requires a reconfiguration, or during in-flight radioactive ion beam production when the 6D beam distribution changes dramatically at the production target. The graphics outputs of the simulations, which show the evolution of the beam through the accelerator (Fig. 2), will be a great training aid for operations staff and experimenters, and finally a more accurate understanding and model of the machine will evolve as the differences between the expected and observed accelerator performance are investigated.

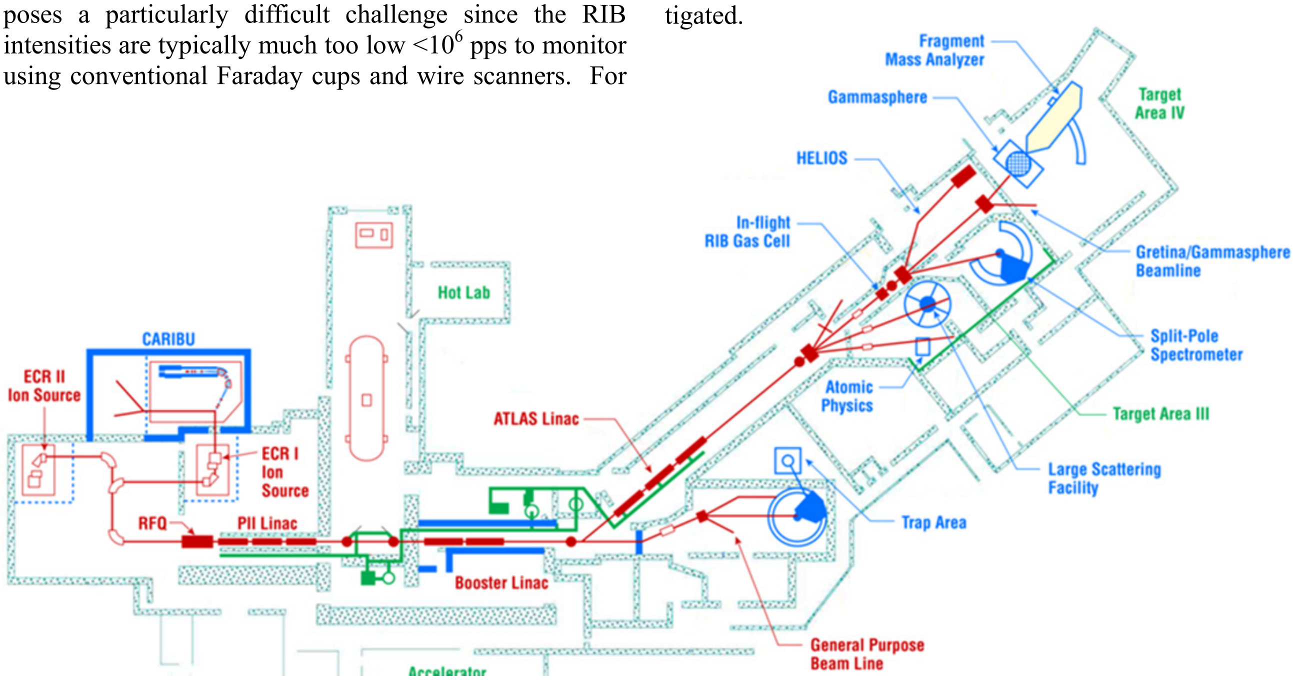

Figure 1: The ATLAS accelerator layout.

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TRACK BACKGROUND

The TRACK simulation software was developed by the Argonne Physics Division to study beam evolution through superconducting linear accelerators, and is still maintained and upgraded regularly. TRACK numerically integrates the equations of motion for particles through 3D fields. Many basic component fields (dipole magnets, quadrupole magnets, acceleration tube, etc.) can be expressed analytically based on a few parameters, while more complicated geometries and more accurate fields can be mapped from third party software and imported into TRACK. TRACK also accounts for space charge forces using a Poisson solver, and includes matching and optimization routines.

Configured correctly, TRACK produces very accurate results by optimizing the number of integration steps independently for each component and by using realistic imported 3D fields. The accuracy of TRACK for predicting and characterizing both the transverse and longitudinal performance of complicated accelerating components was reported for the commissioning the ATLAS RFQ [4-5]. The measured time structure, transverse profile, and energy spread of the beams matched very well with the TRACK simulations.

BUILDING THE TRACK INPUT FILES

To interface TRACK with the real time accelerator configuration data for the component's set values, the component geometries and the beam characteristics are aggregated and parsed to create the two main TRACK input files: the accelerator configuration file and the beam configuration file. The accelerator configuration file includes the component sequence, the individual component geometries, and the associated electric and magnetic fields. The beam configuration file includes the beam species, the 6D distribution, and parameters for matching and optimization.

The sequence of accelerator components is dynamically created from the control system based on the beam source and the target listed for the experiment. An additional database was created to store all the relevant fixed information for each component such as length, aperture radius, etc. The component field levels are calculated using the control system set values and appropriate scaling. Scales from the RF control module output to a superconducting resonator field are based on energy gain measurements logged when configuring the resonator phasing. Based on the known input and output energies the effective voltage of the resonator can be calculated. It is then possible to determine the scale between the RF control module output and the effective resonator voltage by applying the normalization used to simulate the associated 3D resonator field. With years of logged resonator phase scans, statistically accurate resonator scale factors are possible. For magnetic components, dipoles and quadrupoles, power supply output current versus generated magnetic fields can be measured directly with a hall probe or the magnetic field can be continuously monitored using a hall probe.

The beam configuration file is generated from the species information, a beam distribution at a given plane, and energy information – from a Si detector, the ATLAS time of flight system, or the high resolution monitoring of the potential of the source high voltage platform. Before the beam is bunched a pepper pot emittance meter [6] can provide the necessary transverse 4D distribution information then TRACK can simulate the bunching process through the multi harmonic buncher before the RFQ. After the beam is bunched longitudinal information is available after each accelerating section from energy and timing signals generated with Si detectors.

TRACK RESULTS FOR ACCELERATOR OPERATIONS

The ATLAS control system runs on LINUX based computers, so the LINUX version of TRACK has been used for this application. Unfortunately there are no graphical outputs, so custom graphics were developed with the control system software libraries. Figure 2 shows the graphical display outputs. The top row from left to right shows the two transverse and the longitudinal phase space plots. The maximum and rms horizontal and vertical radii are plotted on the middle row, and the maximum and rms beam pulse length in degrees of the harmonic frequency are plotted on the bottom. The columns along the right show the component names in the control system listed by position. These labels will be incorporated into the envelope plots in the future.

TRACK has been used to provide nominal component settings for previously unencountered configurations, typically after significant upgrades like the recent efficiency and intensity upgrade [7]. With a pepper pot measured beam distribution upstream of the first buncher, TRACK simulations indicated quadrupole and superconducting solenoid settings to transport the beam through a completely new transport section, the new RFQ, and a reconfigured PII linac. Results were excellent as a significant portion of the beam was transported with these predicted settings and subsequent fine tuning was easily achievable. Recently a He leak in an old cryostat of split-ring resonators required the resonators and solenoids to be taken offline during the middle of beam delivery to an experiment. TRACK simulations successfully predicted the settings for the adjacent optical components to achieve 100% transmission.

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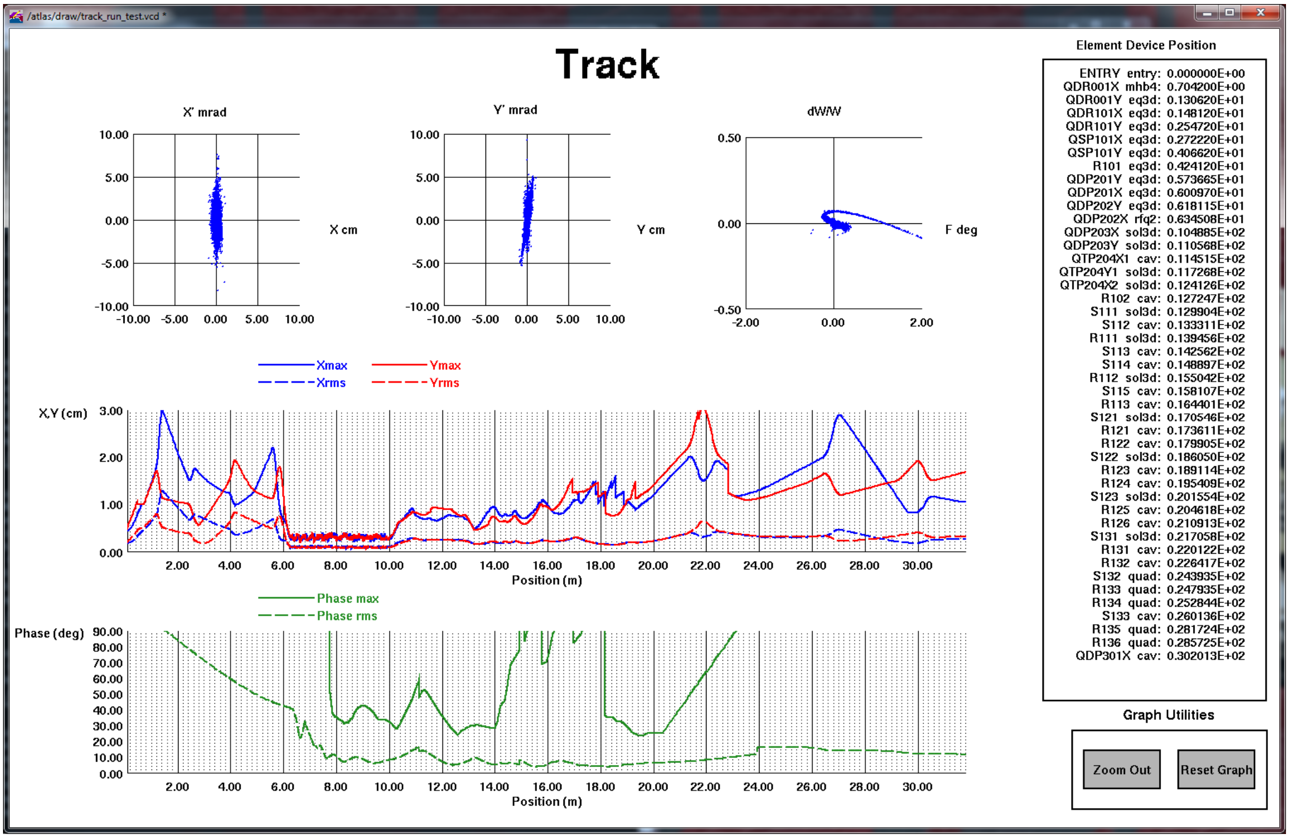

Figure 2: Graphics created for TRACK within the ATLAS control system: phase space distributions (top), maximum and rms envelope plots (middle), beam pulse width (bottom).

FUTURE WORK

As this effort continues the graphics output will be refined and functionality added to enable user interaction and rescaling of the plots. Custom scaling factors will be implemented for unmeasured components, and a special effort will be made to determine the field strength of the bunching cavities. Most importantly a user interface will be developed to allow simulation customization: user defined regions of the accelerator to simulate, and input of matching and optimization conditions.

SUMMARY

Operations at ATLAS need to be flexible and versatile; accelerator configurations are changed 1-2 times per week, and a wide range of masses and energies are delivered from a combination of sources and targets. We are integrating the TRACK beam simulation code into the ATLAS control system to improve operations, and increase the accelerator setup and optimization efficiency. TRACK is very accurate software, but this accuracy relies on realistic beam distributions and component definitions. Integrating TRACK into routine operations will refine the model and ultimately produce better results. TRACK simulations have already successfully predicted fields for previously unencountered accelerator configurations. The refinement of the accelerator model and development of a quality user interface will be a powerful tool for the ATLAS operations staff.

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