ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC29

SIMULATION OF THE LANSCE PSR INJECTION AND EXTRACTION BEAMLINES*

S. Sosa Guitron†, J. Barraza, G. Dale, E. Henestroza, J. W. Lewellen, J. Upadhyay, C. E. Taylor
Los Alamos National Laboratory, Los Alamos, NM, USA

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2024). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

Abstract

The Los Alamos Neutron Science Center (LANSCE) accelerator delivers high intensity proton beams for fundamental science and national security experiments since 1972. The Proton Storage Ring (PSR) accumulates a full 625 µs macro-pulse of proton beam and compresses it into a 290 ns long pulse, delivering an intense beam pulse to the Lujan Neutron Science target. The proposed LANSCE Modernization Project (LAMP) is evaluating necessary upgrades to the accelerator that will guarantee continuous beam operations in the next decades. Upgrades to the PSR and its high-energy injection and extraction beamlines are being considered to handle the higher beam intensity enabled by the LAMP upgrades in the front-end. For the PSR upgrades studies, we are building models of the PSR injection and extraction lines in codes such as elegant and Impact-T, that allow for detailed particle tracking and, depending on the code, space-charge effects, improving the fidelity with which we can model beam dispersion and the beam halo in the high-energy transport. This work describes the LANSCE PSR injection and extraction lines and the corresponding simulation models. The models are compared to available beam diagnostics data where available.

INTRODUCTION

The LANSCE accelerator facility at the Los Alamos National Laboratory (LANL) represents a unique capability for delivering high-intensity beams for multiple nuclear and neutron experiments: H^+ beam is delivered to the Isotope Production Facility (IPF), H^- beams to the Lujan Center, the Weapons Neutron Research (WNR), proton-Radiography (p-RAD) and Ultracold Neutron (UCN).

To keep this facility fully functional in years to come, a possible upgrade, encompassed in the LANSCE Modernization Project (LAMP), is being evaluated for the facility front-end [1]. A possible front-end upgrade involves new H^+ and H^- sources, capable of producing up to 35 mA beam current, a factor of two of what is currently delivered by LANSCE ion sources. With these potential upgrades in the horizon, we are investigating the effects of doubling the peak current in the 800-MeV transport beamlines and the PSR, to identify necessary upgrades that accommodate the front-end upgrades.

As part of these efforts, we are developing updated models of the high-energy transport beamlines. We have models for all the beamlines in code TRANSPORT code [2], a particle tracker code with matrix representation of the beamline elements. We are interested in new updated models with modern beam dynamics codes, such as elegant [3] and Impact-T [4], to develop a better understanding on beam halo, and to have better prediction capability. An additional motivation to use elegant is to match the beamlines to the existing model of the PSR, enabling a comprehensive model of the injection scheme.

This paper describes the status on new beam physics models for the Ring Injection (RI) and Ring Extraction (RO) beamlines.

PSR INJECTION BEAMLINE

The PSR accumulates the 625 µs chopped macro-pulse from the LANSCE linac into a 290 ns, high-intensity proton bunch that is then delivered to the Lujan target. The 800-MeV, H^- beam coming out of the 805-MHz Linac is transported to the PSR entrance through Line-D (North and South), and the Ring Injection (RI) beamlines. The RI beamline was last upgraded in 1998 for a new injection stripping scheme, maximizing the deliverable current to the experiments [5]. A description of the beamline in its original configuration and details on the 1997 PSR upgrade is included in Fitzgerald's paper [6].

Line-D and RI are a series of horizontal and vertical bends to match the PSR entrance and quadrupoles to keep the beam transversely focused. There are no dedicated elements for longitudinal focusing. Line D has a horizontal 90° bend, the region of highest dispersion, and two vertical drops: a 5 m drop known as the waterfall, and a 3.3 m drop produced by a 26° skew section of the beamline spanned by skew-quadrupoles LDQS01 and RIQS01.

To generate new models of the ring beamlines, we wrote a Python script to translate the existing TRANSPORT input files into elegant and Impact-T files. Most of the beam transport elements (drifts, bends and quads), including the representations for edges and fringe fields have equivalents in elegant and are easily mapped. In elegant, we chose transport elements capable of symplectic tracking instead of matrix representations. The main issue found in translating the lattice files was in how the two codes represent bends at arbitrary coordinate rotation angles, relevant for a correct mapping of the skew section. By default, TRANSPORT bends a beam to the right in the direction of travel. To produce a deflection in any other direction, the bend is wrapped between two coordinate rotations. In elegant, one specifies the tilt angle on the bending magnet with respect to the longitudinal coordinate axis. To gain confidence in our models, we compared them against wire scanner data. Wire scanners are one of the main diagnostic systems present through all the high-energy transport lines. Figure 1 shows the transverse rms size calculated by all codes and compared to wire scanner data.

* This work benefitted from the use of the LANSCE accelerator facility. Work was performed under the auspices of the US Department of Energy by Triad National Security under contract 89233218CNA000001.
† salvador@lanl.gov

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC29

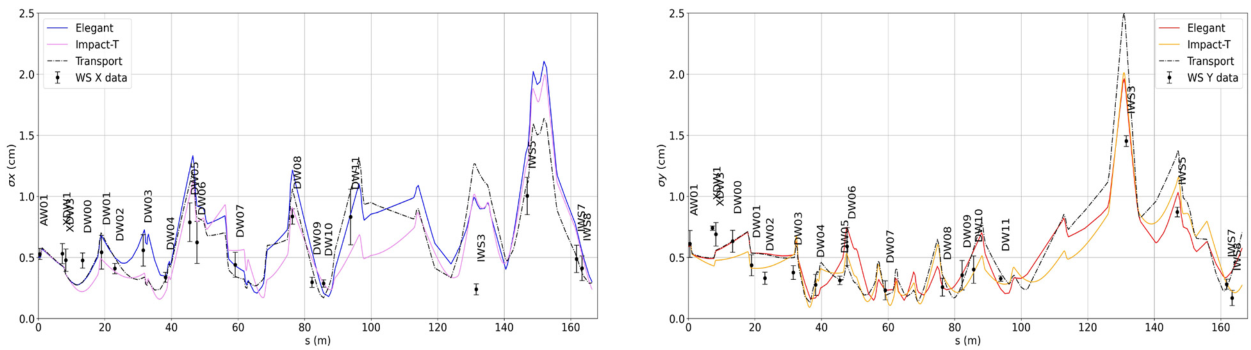

Figure 1: Horizontal (left) and vertical (right) rms beam sizes in Line D and RI using TRANSPORT, elegant and Impact. Comparison of model and data points from wire scanner measurements show reasonable agreement.

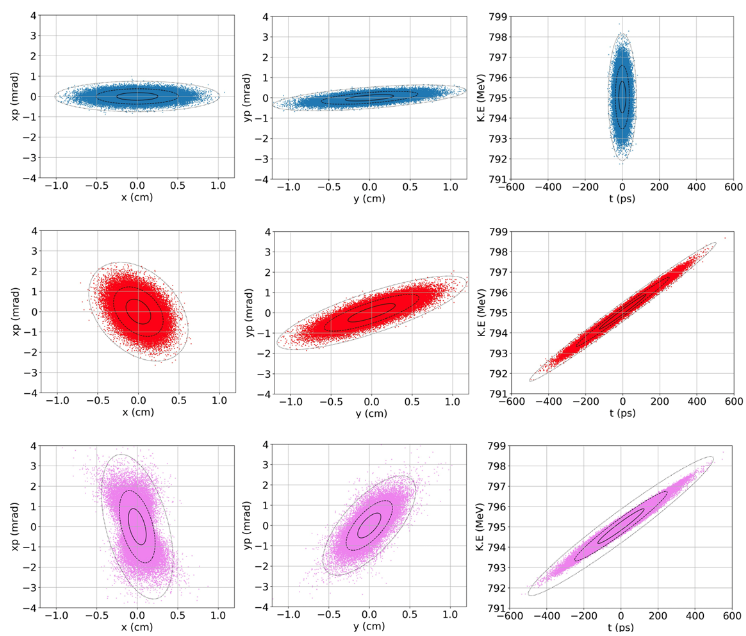

Figure 2: Phase space of micro-bunch at the start of. Line D (top row) and at the stripper foil location in elegant (middle row) and Impact-t (bottom row). Horizontal, vertical, and longitudinal phase spaces are columns from left to right.

We use the new injection beamline models in elegant and Impact-T to model the beam dynamics of a 50-pc, H$^-$ micro-bunch from the exit of the 800-MeV Linac to the PSR stripper-foil location. We use 10^6 macroparticles to represent the micro-bunch. The top row in Figure 2 shows the phase space of the micro-bunch at the exit of the Linac, the starting location. We use the same beam distribution in both elegant and Impact-T simulations.

The middle and bottom rows of Figure 2 show the beam phase space at the location of the stripper foil location calculated by elegant and Impact, respectively. Both codes are in good agreement in calculating the longitudinal phase space. The difference in the transverse phase spaces between elegant and Impact-T is because elegant only has longitudinal space charge model, while Impact-T calculates full 3D space charge effects. Because there is no longitudinal focusing through the injection line, the bunch length rms increases by a factor of 6 at the stripper foil. The Impact-T model provides a better transverse beam halo than other models we have.

EXTRACTION BEAMLINE

We did a similar conversion to elegant from TRANSPORT of the ring extraction line RO. In this case, we use the output beam distribution produced by the PSR elegant simulation as the starting point. This simulation elegant 10^6 macroparticles to represent the accumulated beam pulse to be sent to the Lujan target.

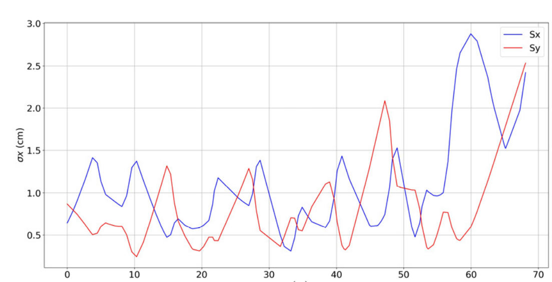

Figure 3: Transverse rms beam size through the RO line calculated with elegant.

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2024). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-THPC29

Content from this work may be used under the terms of the CC BY 4.0 licence (© 2024). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

Figure 4 shows the output configuration space at the target location produced with elegant and a comparison to the temperature monitor at the target showing the beam shape.

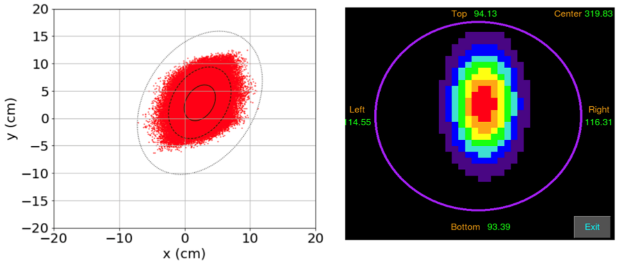

Figure 4: Beam profile produced with elegant simulation model at the Lujan target location vs. a temperature map of the target showing the beam shape.

CONCLUSION

We present the status of on-going effort to generate new models of the PSR injection and extraction lines using elegant and Impact, codes that include models of the space charge. We expect these models to help in the understanding of beam halo formation in the high-energy beamlines at LANSCE, and in improving our predicting capabilities using LANSCE models.

A model of the injection line, formed by Line D and RI lines, was produced in elegant and Impact-T. We benchmarked the models by comparing the models to available wire scanner data, showing good agreement. elegant has a model for longitudinal space charge, but not for the transverse space charge effect, while Impact-T has a full 3D space charge effect calculation. The longitudinal dynamics between the two codes is in good agreement, while Impact-T shows larger beam halo component than elegant. Preliminary RO line results from elegant are presented. We took the output beam from the PSR elegant simulation, but benchmarking still needs to be done.

REFERENCES

[1] Y. Batygin *et al.*, "LANSCE Front-End Upgrade: Preconceptual Design Study", LANL Internal Report, LA-UR-20-24199, June 2020.

[2] D. Carey, K. Brown, and F. Rothacker, "Third-Order Transport with MAD Input: A Computer Program for Designing Charged Particle Beam Transport Systems," Office of Scientific and Technical Information (OSTI), Oct. 1998. doi:10.2172/1454203

[3] M. Borland, "ELEGANT: A flexible SDDS-compliant code for accelerator simulation," Office of Scientific and Technical Information (OSTI), Aug. 2000. doi:10.2172/761286

[4] J. Qiang *et al.*, Limborg-Deprey, *Phys. Rev. Spec. Top. – Accel. Beams,* vol. 9, no. 044204, 2006.

[5] J. Jason, "PSR Injection-Line Upgrade", in *Proc. PAC'97*, Vancouver, Canada, May 1997, paper 8P020, pp. 270-272.

[6] D. H. Fitzgerald *et al.*, "Overview and Status of the Los Alamos PSR Injection Upgrade Project", in *Proc. PAC'97*, Vancouver, Canada, May 1997, paper 9W021, pp. 1012-1014.