DESIGN OF A NEW BEAM DIAGNOSTIC LINE AT CERN LINAC3

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ABSTRACT

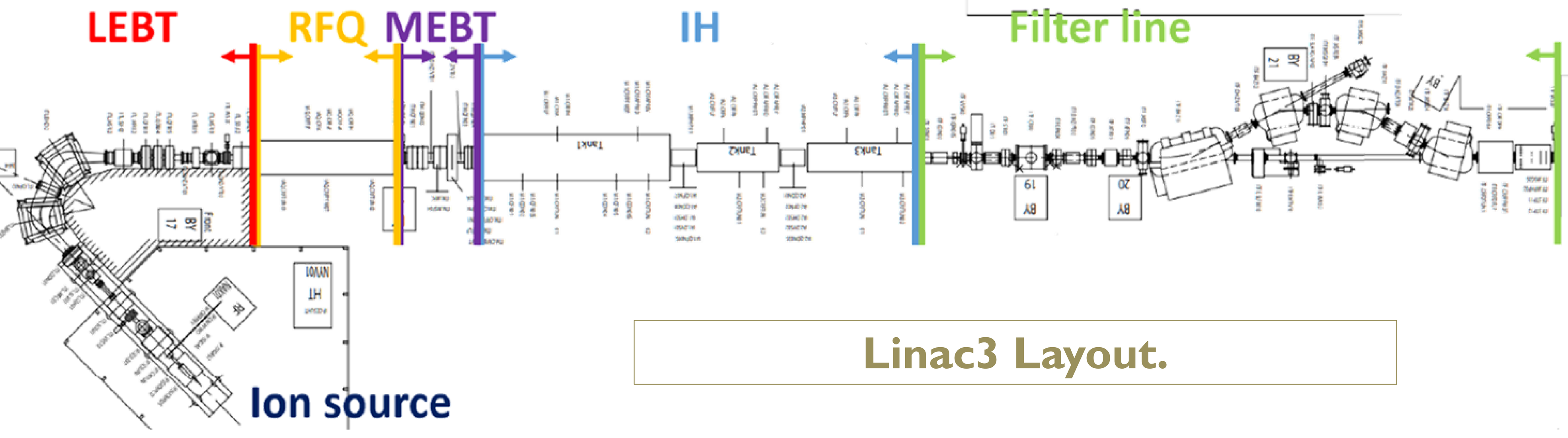
Linac3 is a beam injector at the heart of the CERN Heavy Ion Facility that provides heavy ion beams for the LHC and CERN physics community. Linac3 generates heavy ions using an Electron Cyclotron Resonance Ion Source (ECRIS) that produces several ion species being the most relevant: $^{208}Pb^{29+}$, $^{16}O^{4+}$, $^{40}Ar^{11+}$, $^{129}Xe^{22+}$, $^{115}In^{21+}$, $^{40}Ca^{5+}$ and, $^{84}Kr^{11+}$. No diagnostics is presently available at low-energy before charge state separation in the spectrometer and the devices installed downstream can only be used during dedicated and planned time slots for machine measurements. This work covers the design of a new beam diagnostics line to characterize the properties of the ion beam at source extraction and thus improve the understanding of the beam dynamics and the operational performance of Linac3 without stopping downstream experiments.

INTRODUCTION

CERN is the French acronym (Conseil Européen pour la Recherche Nucléaire) for the European Organization for Nuclear Research, is one of the largest and most respected scientific research centers in the world and houses the Large Hadron Collider (LHC), the largest and highest particle collider, consisting of a 27-kilometer ring, reaching center-of-mass energy collisions at collision points of 13.6 TeV for proton-proton collisions in 2022 and 5.02 TeV/u for Lead-Lead collisions in 2018.

The linear accelerator called Linac3 is the starting point of the CERN Heavy Ion Complex. Linac3 provides ions to the Low Energy Ion Ring (LEIR) which in turn supplies the Proton Synchrotron (PS). Before the ions collide at end of the accelerating chain in the Large Hadron Collider (LHC), the charged particles traveled through the Super Proton Synchrotron (SPS).

Linac3 is composed by the ECRIS source producing heavy ion beams at 2.5 keV/u followed by a Low Energy Beam Transport (LEBT) line to filter a single charge state and match to the Radio Frequency Quadrupole (RFQ) (101MHz, 250 keV/u). The beam from the RFQ is matched longitudinally and transversally by the Medium Energy Beam Transport (MEBT) line to the Interdigital H-Type Drift Tube Structure (IH) (at 101 and 202 MHz frequency) that brings the beam to the final energy of 4.2 MeV/u. The beam is further stripped and filtered in the Filter Line before injection into the Low Energy Ion Ring (LEIR).



Linac3 Layout.

The Linac3 does not have any beam diagnostic available up to after the LEBT dipoles, to solve this, a new diagnostic line using pulsed magnets has been proposed.

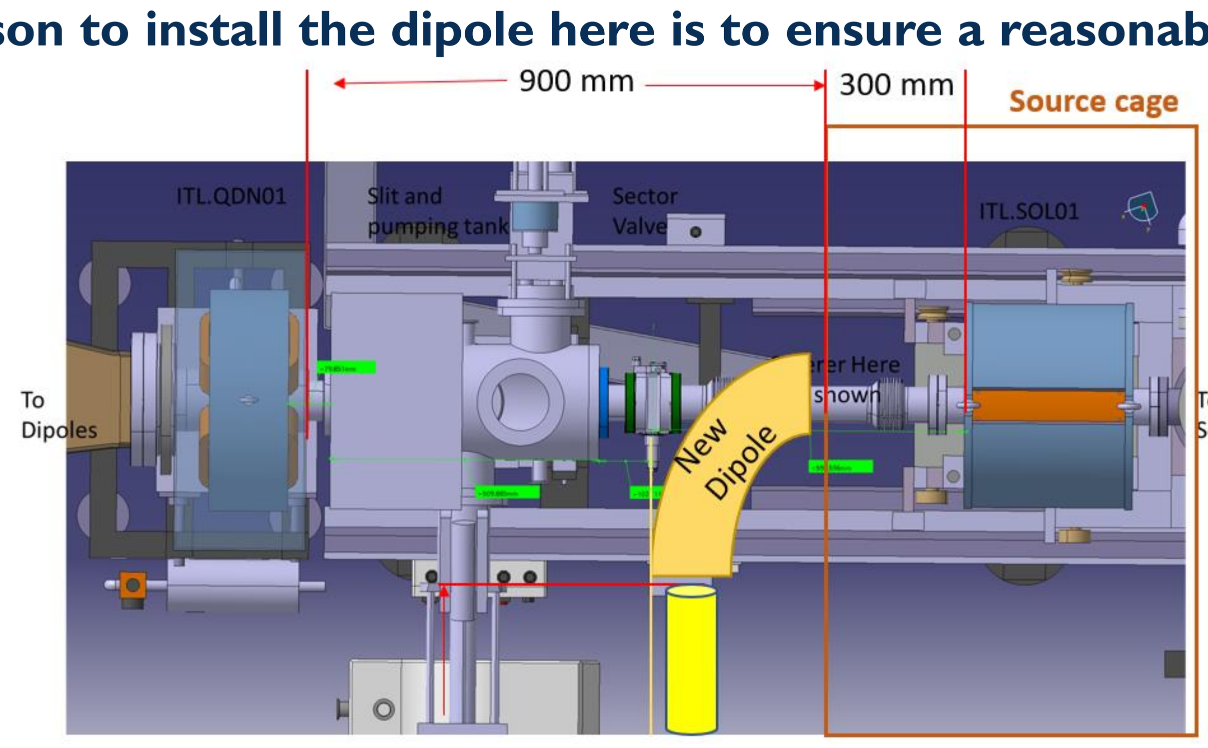
METHODOLOGY

The proposal consists in the installation of a new pulsed dipole in the LEBT where after the source there is a 1.2m space available between the first solenoid and quadrupole to deflect the beam from the existing beam line to a new diagnostic line. The main reason to install the dipole here is to ensure a reasonable reconstruction of the beam properties coming from the source.

The new line starts with a 90° degrees dipole followed by a 1.6 m section that includes two 0.2 m long quadrupoles, with the first at a 0.4 m distance from the dipole exit to improve matching, and a diagnostic box at the end. To ensure a good separation between the charge states, it is necessary to reach a high dispersion at the 1.6 m section. The basic dispersion calculations were made using Pb^{29+} as the central ion beam, and its adjacent charge states Pb^{30+} and Pb^{28+} to calibrate the minimum distance between charge states.

To maximize the charge state separation and beam transmission, and to find an appropriate beam size a routine for beam dynamics simulation has been implemented using TRAVEL with PYTHON that scans the solenoid and quadrupole strength, the dipole face rotation and strength, and the separation between these elements. The optimal position of one slit to cut the undesired charge state was explored. TRACE 3D code has been used to confirm the results.

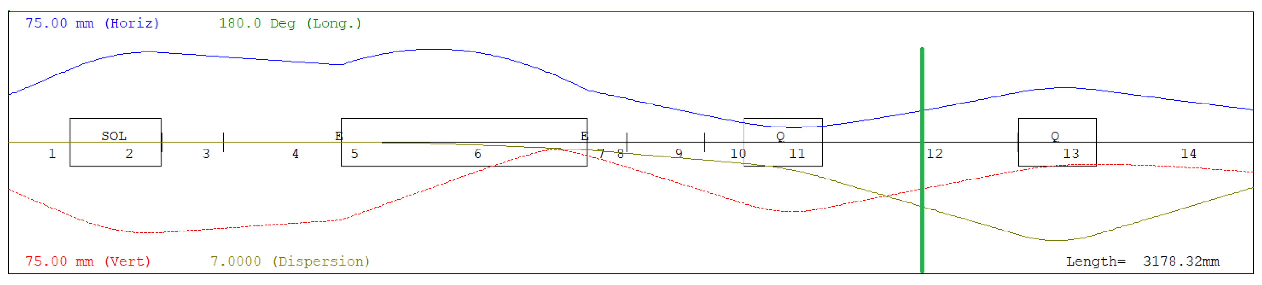
In Travel the input beam used was obtained from previous IBsimu simulations that show a good match with the measurements in previous Linac3 works.



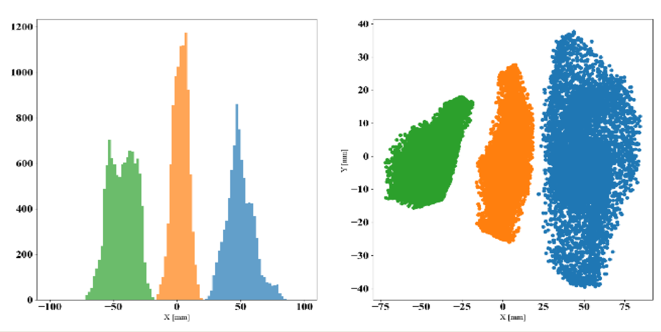
Dipole location for the new diagnostic line.

RESULTS

The best configuration was found in the cases of zero and full space charge effects.



Transverse beam envelopes and dispersion, and the ideal slit position.



Consecutives Lead charge states, 28, 29 and 30.

Simulation results shown that a separation of 3.7 cm between charge states can be reached between adjacent charge states at the slit location.

The line was designed to withstand the uncertainties on space charge where its focal point can vary by controlling the solenoid and quadrupole strengths.

Due to the beam characteristics, a combination of Slit + Faraday cup is proposed for single charge states current measurements. For Transverse emittance measurements the requirements and specifications of an Allison Scanner were found.

CONCLUSION AND ACKNOWLEDGMENTS

An alternative beamline dedicated to characterizing the beam properties such as the beam emittance or estimating the charge states coming from the source was proposed. This has been done by means of multi-particle simulations and ray trace envelope calculations. This result gives a 90 deg, 0.4 m radius dipole as a reasonable option with the ability to contain a divergent beam and separate the different charge states.

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