Linac 4 – Transfer Line

CERN – Linac 4 Beam Dynamic Group

Abstract
A new H-accelerator Linac4 at CERN is under construction for achieving a higher beam quality, which is required for ultimate LHC Luminosity. As the Linac4 beam is characterised by a high charge density at low energy, space charge dominated behaviour of the beam is expected. Hence, the beam control is particularly critical. Along the 80m long Linac the focusing structure has to be designed tight in transverse and longitudinal directions for reducing the space charge driven emittance growth. The design of the 177m transfer line poses an even greater challenge. The transverse focusing structure is extended and any longitudinal focusing is vanished. The beam quality is suffering uncompensated space charge effects, therefore the design of the transfer line becomes especially critical.

General Introduction
The new H-accelerator Linac4 at CERN will serve as injector to the PS Booster and replaces the old proton-accelerator Linac2. It raises the PS Booster injection energy to 100MeV and so it enables the production of a double the brightness of the beam, whereby amongst others an accelerator area of 2.3 times the LA 4 becomes feasible. Special features of Linac4 are the hydrogen ion (H) source as well as the chicane section. The hydrogen ion source is an enhancement of the DESY (HH-Germany) hydrogen ion source for the generation of higher average beam current as well as higher peak current. In the chicane section Linac4 bunches, which would be injected into unstable regions of the PSB phase space or dumped while injection, are removed from the bunch train.

Space Charge Effects – Theory

From the Maxwell equations follows the Lorentz force, which is experienced by a test particle at position \( x \) with charge \( e \). This force can be expressed by a defocusing strength \( K_x \). This additional defocusing strength can be treated similar to magnetic field errors \( ( \Delta B ) \), whose tune shift is defined by the present formula. Closing the beam current and the averaging of \( ( \Delta B ) \) divided by the square of beam size are replaced by the number of particles \( N \) and the transverse normalised emittance \( \epsilon^2 \). As a result the tune shift depends on constants, particle radius \( r \) and \( \epsilon \), and the ratio of \( N \) and the relativistic variables \( \gamma \).

Transfer Line Layout

In these plots the development of the beam size as well as the dispersion from the outlet of Linac4 (left) to the injection point of the PSB(right) are presented. The schematic diagram between the two plots illustrates the sequence of beam optical elements. Bending magnets and the injection kicker magnets are marked by yellow lines. Red and green lines represent quadrupoles depending on their polarisation. The position of the debunker cavity is labelled by the blue line. Along the transfer line bunch features are arranged to form an unperturbed, upstream the debunker cavity intense space charge effects cause an inevitable degradation of the beam quality. At the saturation of the space charge effects the debunker cavity is used for the reduction of the correlated energy spread. The third feature of the transfer line is the vertical chicane. As an adiabatic chicane design is demand, this part is characterized by a high phase advance. The fourth quality of the transfer line is the distributor section, where the aperture limits of the kicker magnets require a high phase advance lattice design as well. A more detailed description of the distributor section layout and distribution progress is presented in.

Conclusion

The layout of Linac4 as well as transfer line Linac4–PSB are confirmed and their reliability is proven. Furthermore, Linac4 is shown inserted in the future accelerator chain, where it is the fundamental of future upgrades. Thus beam loss control systems and emittance growth control systems are implemented for higher performances. As results of the Linac4 project particle beam characterised by higher beam brightness become feasible, which leads to higher luminosity at experiments like CMS, Atlas or LHCb.