DETAILED STUDIES REGARDING THE NEW INJECTION SYSTEM AT THE LINAC I AT ELSA

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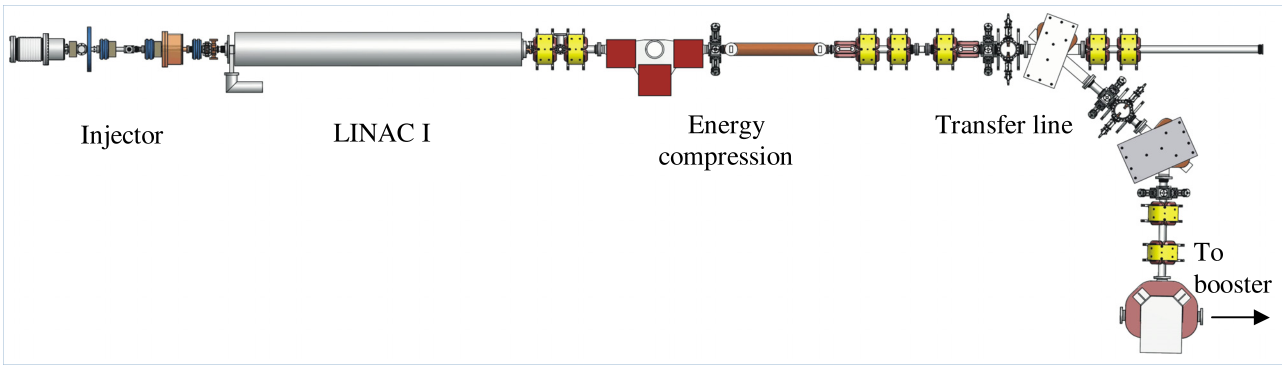

Figure 1: Overview of the new injection system which will be installed at the linear accelerator LINAC I at ELSA.

Abstract

In order to enhance the operating capabilities of the Bonn University Accelerator Facility ELSA, a new injector is currently under commissioning. Its purpose is to allow a single pulse mode as well as to increase the current of the unpolarized beam provided to the external hadron physics experiments. Therefore, the injector will produce an up to 2 microseconds long pulse of 500 mA beam current or a single electron bunch with 2 A pulse current. Design and optimization of the injector were performed with EGUN, PARMELA and numerical simulations based on the paraxial equation. A 1.5 ns long pulse is produced by a thermionic electron source with 90 kV anode-cathode voltage, then compressed and pre-accelerated by a subsequent 500 MHz RF cavity and a four-cell travelling wave buncher. After acceleration of the electrons to up to 25 MeV in the main linac the natural broadening of the energy distribution in the particle ensemble due to the acceleration process will be reduced by an energy compression system. Studies have been conducted concerning the adaptation of the optical elements in the transfer beamline to the subsequent booster synchrotron with respect to the new requirements of the injection into the synchrotron and its acceptance.
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90 KV ELECTRON GUN

The 90 kV gun is based on a design used in the SBTF test facility at DESY. The design of the cathode conus was adjusted with the computer code EGUN to fulfill the requirements of 2 A single pulse and 500 mA long pulse operation. With a 34 mm wide anode cathode gap this gun has a perveance of 0.16 µA/V$^{3/2}$ and delivers a 4.3 A space charge limited current at 90 kV. The normalized emittance for a 2 A pulse at the gun exit is $\varepsilon = 22.8\ \pi$ mm mrad. In single pulse mode the gun, together with this pulser, is expected to deliver FWHM ≤ 2 ns pulses with a peak current of 2 A.

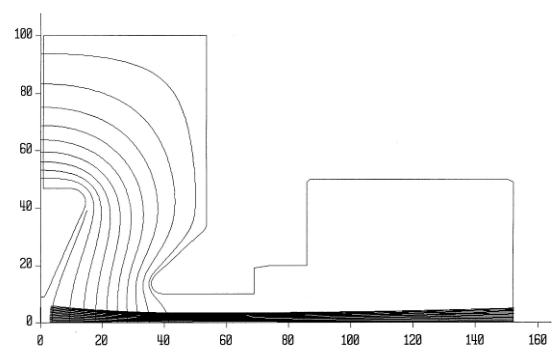

Figure 2: Gun geometry r vs. z in mm with equipotential lines and space charge limited electron rays calculated with EGUN for an anode voltage of 90 kV.

BUNCHING

For the single bunch mode the bunching will be achieved by a prebuncher and a travelling wave buncher. In addition, the travelling wave buncher matches the beta to $\beta = 0.891$ at the exit of the structure. The 40 mm wide gap of the 500 MHz nose cone prebuncher is centred at z = 112 cm. In order to weaken the requirements for the gun this frequency has to be as low as possible, but nevertheless has to match with the time structure of the bunch train in the stretcher ring ELSA. Therefore in our case the prebuncher has to work at 500 MHz, which implies that the gun pulse for the single bunch has a

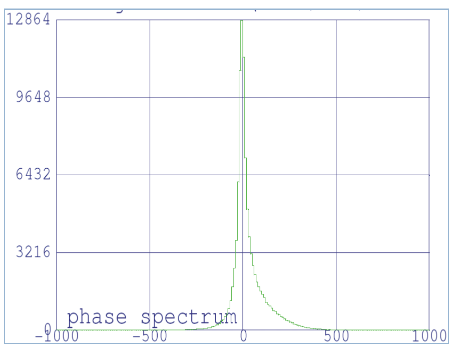

Figure 3: Bunch length after the drift space of 34 cm beyond the Prebuncher.

length in the order of 2 ns. The chosen prebuncher has an untuned resonance frequency of ν_0 = (499.819 ± 0.001) MHz, an unloaded quality factor of Q_0 = 15220 ± 196 and a shunt impedance of R_s = (1.63 ± 0.05) MΩ. With an injected RF power of 400 W a gap voltage of 36 kV is excited. [1].

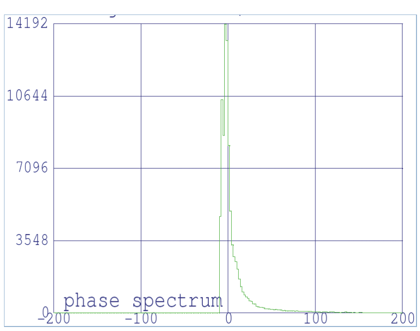

Figure 4: Bunch length after the travelling wave buncher. Shown is the number of particles versus the phase position of the particles relative to the main particle.

The first cell of the travelling wave buncher is centred 34 cm behind the centre of the prebuncher. The 4 cell, 6.7 MV/m structure further compresses the bunches. Having passed a drift space of 8 cm beyond the buncher the beam is injected into the linac section.

The resulting bunch length achieved by the bunching could be predicted with the computer code PARMELA. In Figure 4 the bunch lenght after the prebunching process is shown. Figure 5 shows the bunch length resulting from the travelling wave buncher. Parmela predicts a bunch length of (0.46 ± 0.12) ns inside the first cell of the travelling wave buncher and a bunch length of (0.07 ± 0.04) ns beyond the buncher.

TRANSVERSE BEAM DYNAMICS

The beam pipe has an inner diameter of 34 mm along the injector. Just in front of the entrance of the linear accelerator, the aperture is reduced to 21 mm in order to minimize RF leakage out of the linac. Transverse focussing of the beam is achieved by four solenoids. The position and the strength of the solenoids were determined by numerical calculations based on the paraxial equations. The resulting beam propagation is shown in figure 7. Additionally, the field is set to zero at the gun cathode by means of a bucking coil.

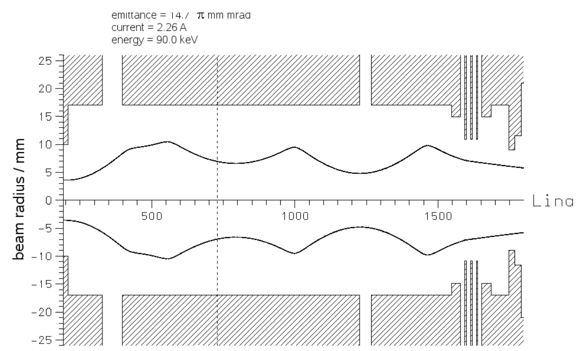

Figure 5: Simulation of a 2 A beam propagating through the beam guiding elements based on the paraxial equations.

MONITORING

In order to measure the position and the current as well as the beam profile, beam instrumentation is installed in the drift space. The injector section is equipped with a faraday cup, a screen monitor, a beam position monitor and wall current monitors to measure the bunching efficiency. Behind the linac a beam pulse monitor, three screen monitors and a BERGOZ integrating current transformer are installed to measure position and pulse charge of the beam. [3]

LINAC

The acceleration section is of constant gradient type operating with a phase advance of 2π/3 per cell. The operating frequency is 2.99802 GHz. The 20 MW RF pulse coupled into the structure has a length of 8 µs. With an electric field of 7.9 MV/m the structure accelerates 800 mA top up to 20 MeV. Due to natural broadening the during the acceleration process, the beam has an energy spread of 5% of the reference energy.

ENERGY COMPRESSION

For a high transfer efficiency of the beam into the following booster synchrotron, the beam should not exceed an energy spread of 0.5% of the injection energy. For that reason an energy compressor consisting of a dispersive debuncher and an RF structure reduces the energy spread to 0.53%. Two quadrupoles in front of the debuncher set the focal point into the symmetry plane of the debuncher. In this way the quadrupoles give the opportunity to vary the energy compression factor K = $\Delta E_{in}/\Delta E_{out}$ independently from the focussing behaviour of the compression system. This is essential to optimize the compression factor for bunches of different length exiting the linac structure. The energy compression system can handle bunch lengths of 4 – 12 degrees of the wavelength of the main linac RF with compression factors of 4.9 to 9.5. [2]

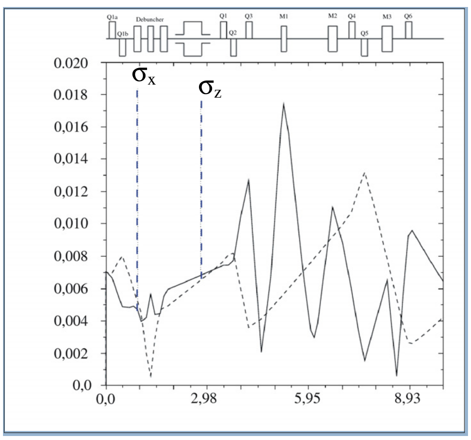

Figure 6: MAD simulation of the transverse beam dynamics of the transfer line. Shown are the horizontal and vertical beam width σ_x and σ_z versus the position in the transfer line.

TRANSFER LINE

The section behind the energy compression system leads the beam into the synchrotron. Optionally, the beam can be transferred straight to an irradiation chamber for low energy and high pulse charge tests. Three dipoles deflect the beam into the booster. To compensate the dispersion of the dipoles two quadrupoles are placed between the second and third dipole.

In order to achieve a high transfer efficiency into the booster, the phase space ellipse of the beam should be within the acceptance ellipse of the booster synchrotron with respect to the edge of the injection septum. To match the twiss parameters to the values needed for the injecton into the booster, three quadrupoles are placed in front of the beam deflection.

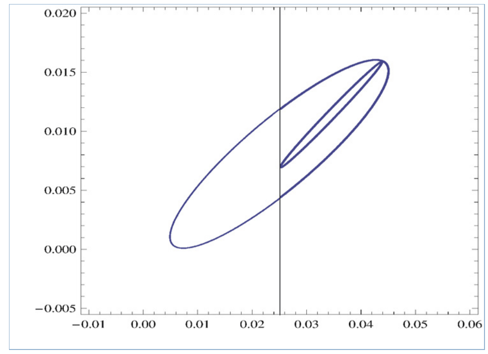

Figure 7: Shown is the acceptance ellipse of the synchrotron at the injection point, the phase space ellipse of the beam and the edge of the injection septum.

CONCLUSION

In order to provide the possibility of operating ELSA in a single bunch mode, a new injector is designed and nearly constructed. The design of the injector for Linac 1 is based on a conservative scheme using a thermionic high intensity pulsed gun, one subharmonic buncher cavity and a travelling wave buncher. The bunching is expected to compress the bunches to less than 0.1 ns before entering the linear accelerator. Unwanted transverse dynamics are compensated by solenoid fields and correctors. The bunches leaves the injector with an energy of about 615 keV. After acceleration up to 20 MeV a energy compressor reduces the energy spread to 0.5%. Afterwards the beam will be matched to the requirements for an efficiency injection into the following synchrotron booster and deflected to the injection point.

REFERENCES

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