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STATUS AND EXTENDED BEAM DYNAMICS SCENARIOS FOR THE SECOND INJECTION BEAM LINE AT MESA

A. Kalamaiko†[1], K. Aulenbacher[1,2,3], M.A. Dehn[1], S. Friederich[1],
[1]Institute of Nuclear Physics, Johannes Gutenberg University Mainz, Germany, [2]Helmholtz Institute Mainz, Germany, [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany.

Abstract

The MESA project (Mainz Energy-recovering Superconducting Accelerator) is an electron accelerator with two laser-driven photoelectron sources, which is under construction at the Johannes Gutenberg University in Mainz. The layout of MESA accelerator is shown on Fig.1.

The first source STEAM allows to produce a spin-polarized electron beam. The second electron source MIST (MESA Inverted Source Two) allows to produce highly charged unpolarized electron bunches.

This report presents new investigations on beam dynamics for the separation beamline which allows to transport and compress electron bunches from the second electron source MIST to the first acceleration section of MESA. Several beamline configurations are compared concerning the capability for transport of elevated bunch charges.

INTRODUCTION

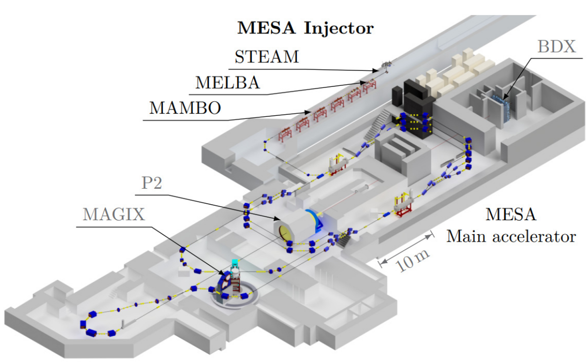

Figure 1: Scheme of MESA accelerator [1].

Two different photoemission electron sources allow to operate MESA [1] in different modes. The first electron source STEAM [2] allows to generate a spin-polarized electron beam from NEA photocathodes, which will operate at a rather low potential of 100 kV in order to ensure operational reliability [3].

The second unpolarized electron source MIST [4] allows to produce unpolarized high charged bunches. MESA aims to achieve an average current of 10 mA, which corresponds to 7.7 pC in one electron bunch, if MESA is operated CW at 1.3 GHz. Hence, 100 keV ($\gamma = 1.2$, $\beta = 0.55$) at 7.7 pC are the basic design objectives for this investigation. The initial bunch length coming from the source is assumed to be 27 ps and is compressed by the buncher system towards the first cavity of the MAMBO pre-accelerator [5].

DIFFERENT INJECTION SCHEMES

A second injection beamline was designed and has already been presented in [6]. It consists of a dogleg made of two dipole magnets with triplet focusing for dispersion compensation, see Fig. 2. The C-shaped dipole magnets also allow for transportation of the spin polarized beam from STEAM to the double scattering Mott polarimeter DSMP, also shown in the upper right of Fig. 2.

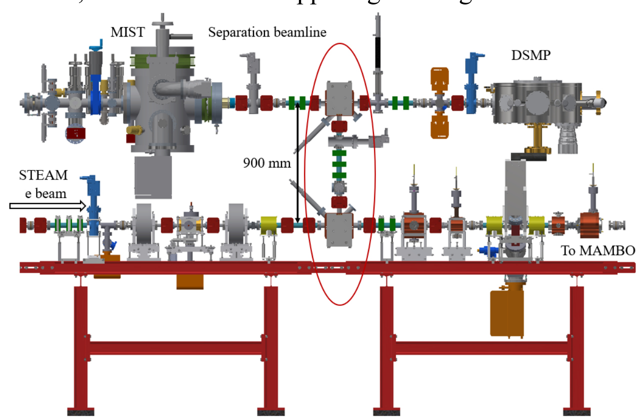

Figure 2: Designed separation beamline with 2 bending magnets.

During our recent studies we have investigated if other arrangements can yield better performances. The three scenarios are:

i) An injection with two dispersion free alpha magnets replacing the dipoles and correspondingly adapted quadrupole focusing.
ii) A straight injection beamline, which can be realized in a rotational symmetric fashion using solenoids.
iii) The configuration shown in Fig. 3 with 200 keV.

The beam dynamic simulations of the different arrangements were made with the program packages CST Studio Suite® [7]. The phase space is plotted at the entrance of MAMBO.

Figures 4-7 show nonlinear distortions caused by space charge effects. The RMS parameters are summarized in Table 1.

Table 1: Longitudinal phase space parameters for the different scenarios.

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Scenario	Bunch charge [pC]	$(\Delta E/E)_{rms}$ [%]	Δs_{rms}[mm]
dogleg	7.7	1.6	1.78
α-dogleg	7.7	1.3	1.1
straight	7.7	1.25	0.9
200keV dogleg	39	1.0	3.45

200 keV operations would open the door to operate at higher bunch charges and/or average currents of ~50 mA. However, this would require some technical modifications. Apart from minor adaptations such as increasing the fields of the magnets and adaptation of the buncher the most prominent would be to replace the first section of MAMBO. This normal conducting graded-beta section is designed for the existing injection energy of 100 keV.

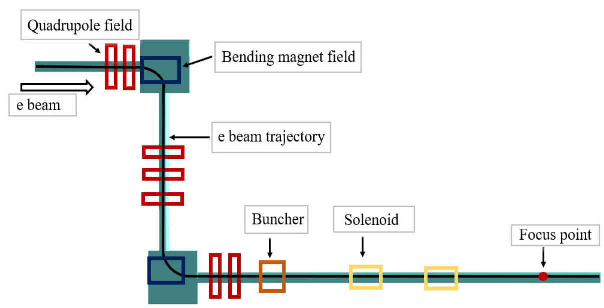

Figure 3: CST model of the injection beamline. 90° dipole magnets (blue), quadrupoles (red), solenoids (yellow), buncher (brown).

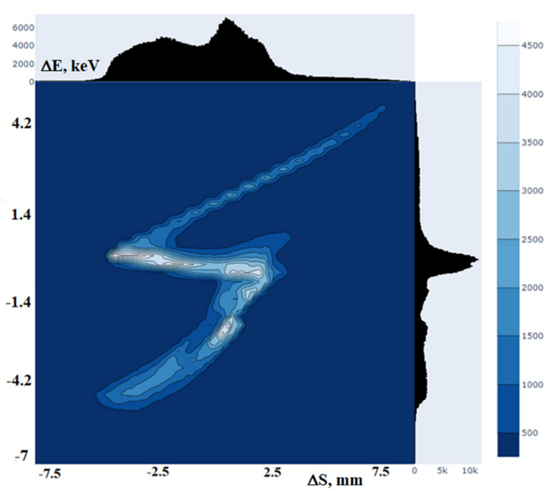

Figure 4: The longitudinal phase space of the 100 keV/7.7 pC electron bunch in the entrance of the first acceleration section of MAMBO after "dogleg" beamline model with 2 bending magnets.

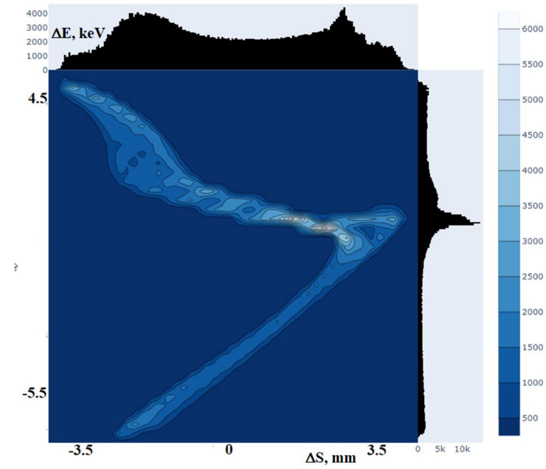

Figure 5: The longitudinal phase space for the 100 keV/7.7 pC electron beam for straight beamline with 2 solenoids.

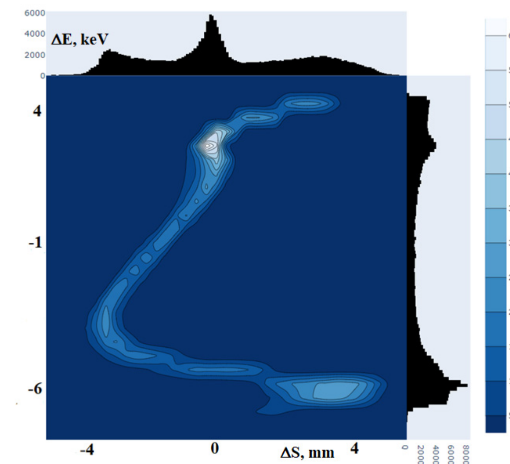

Figure 6: The longitudinal phase space of the 100 keV/7.7 pC electron bunch for "dogleg" with 2 alpha magnets.

200 KEV BEAMLINE

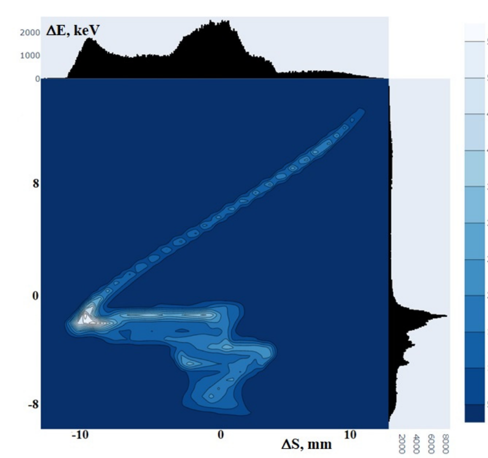

Figure 7: The longitudinal phase space for 200 keV/39 pC

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As a conclusion of the beam dynamic studies we find it reasonable to stay with the simple dogleg injection in spite of the small advantages seen for the other options. The alpha-magnet solution does not allow to extract the beam from STEAM to the Mott-polarimeter (DSMP in Fig. 1) and the straight beamline does not allow operation of the two sources without major installation work,

REMANENCE STUDIES OF DIPOLE MAGNETS

Two special dipole magnets were designed and produced for the designed separation beamline [6]. A very important parameter of the bending magnets is the magnetic field remanence after the procedure of degaussing. The reproducibility of the magnetic field is very important for a stable accelerator operation. The result of the measured magnetic fields after degaussing are presented in Table 2.

Table 2: Magnetic field remanence after procedure of degaussing.

Projection	Mean [μT]	RMS [μT]
B_x	17.39	0.57
B_y	6.04	0.22
B_z	0.16	0.02

A set of 50 measures show that perpendicularly to the bending plane the magnetic field has distribution with 0.57 μT RMS deviation after the degaussing procedure. This means that the electron beam would have and additional RMS angle distortion of 7.7×10^{-2} mRad.

BEAM DIAGNOSTIC

The designed bending magnet need special vacuum chambers, which allow to transport the electron beam from STEAM to MAMBO or bend it by 90°and transport it to the double scattering Mott polarimeter, see Fig. 2. Additionally, to observe the beam position in the separation beamline, it was decided to introduce scintillator crystals into the vacuum chambers. A pneumatic linear driver will introduce two scintillation crystals. The model of designed vacuum chamber is shown in Fig. 8. As a scintillator screen decided to use polished YAG: Ce crystals with 15 mm diameter and 0.15 mm thickness [8].

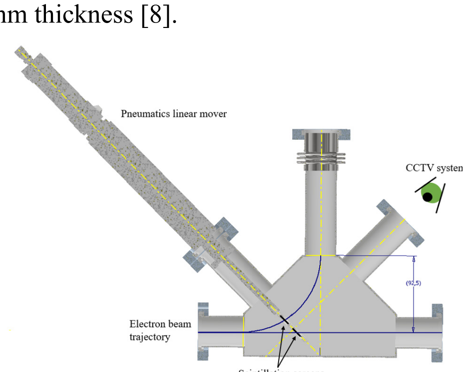

Figure 8: The model of designed vacuum chamber.

CONCLUSIONS AND OUTLOOK

Designed separation beamline allows to transport electron bunch from STEAM to the first acceleration section of MAMBO and compress it to 1.78 mm RMS length with 1.6 % energy spread and rich 10 mA beam current. Potentially, this beamline could allow to transport 200 keV and work with beam current up to 50 mA.

The designed beamline will be built to the end of this 2023 year in the Institut of Nuclear Physics in Mainz. It is expected to start beam operation to the end of this year.

ACKNOWLEGMENTS

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