CURRENT STATUS OF THE MAINZ ENERGY-RECOVERING SUPERCONDUCTING ACCELERATOR PROJECT *

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Abstract

The Mainz Energy-Recovering Superconducting Accelerator (MESA) project at Johannes Gutenberg-Universtität Mainz has started in 2012 and is in full swing now. This paper presents the current status of the project with a glance on cryogenics, superconducting RF, accelerator lattice design and the normal conducting injector.

INTRODUCTION

MESA is designated for two modes of operation – an energy recovering mode (ER, 105 MeV, pseudo internal target and beam currents of up to finally 10 mA in stage 2) and an external mode (EB), with polarized electrons of up to 150 μA at 155 MeV for high precision experiments on parity violation and Weinberg angle (P2-experiment). The main parameters are listed in Table 1. Both experiments require a large range of flexibility of the accelerator and its components. From the machine point of view the P2-experiment requires extreme stability of most beam parameters which is being considered during all design phases. Meanwhile the multi-turn ER mode with the two passes is very interesting for accelerator physics. We will present the current situation, the ongoing construction works and latest conceptual developments with respect to the beginning of the commissioning of stage 1 in 2017.

Table 1: MESA operation modes

Parameter stage 1 (2)	EB	ER
Energy [MeV]	155	105
Beam current	150 μA	1 mA (10 mA)
Bunch charge [pC]	0.12	0.77 (7,7)
max. Beam power [kW]	22.5	105 (1050)

The new accelerator MESA will be built in former experimental halls of the Mainzer Mikrotron (MAMI), the present 1.6 GeV CW electron accelerator (Fig. 1). The double sided concept for MESA (see Fig. 2) with the two linac straights and vertical stacking of the return arcs was foremost presented in [1] and has been developed further since [2–4].

THE SITUATION AT THE FACILITY

Civil Works and Radiation Protection

To keep interferences with the ongoing physics programme at MAMI as low as possible the first major step

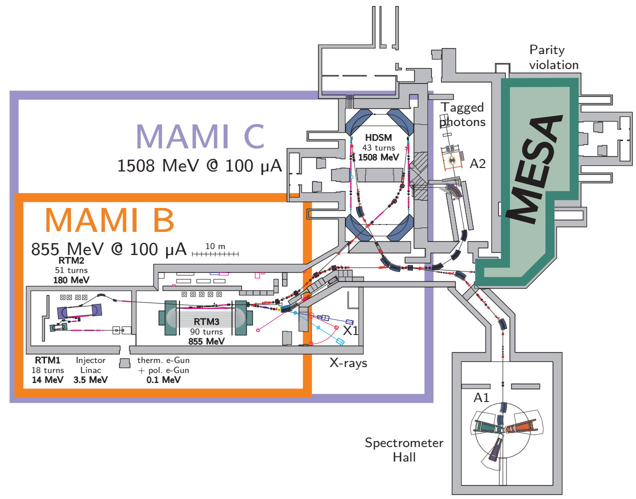

Figure 1: Floor plan of the MAMI accelerator. The space for MESA is marked in green.

was to erect a sufficient shielding between the construction site for MESA and the MAMI beam transfer lines. That should provide maximum safety even at full beam losses of 100 μA at 1.5 GeV in that area. The construction is now finished and simulations with FLUKA [5] show reasonable agreement to measured radiation doses. Hence the site will soon be deregulated and the constructions necessary for infrastructure of MESA (i.e. cooling water, the LHe supply etc.) can be started at the end of this year.

DIAGNOSTICS AND FEEDBACK SYSTEMS

The P2-experiment is of fundamental importance for the physics programme at the institute and also for the accelerator design. MESA will utilise several different beam diagnostic systems similar to the diagnostics at MAMI. At MAMI RF cavities operated at the fundamental bunch frequency (2.45 GHz) or the first or third harmonic are well established and yield CW position information or relative phases. Monitors of similar functionality can easily be manufactured in our own workshops for the frequency of MESA at 1.3 GHz.

Feedback and Feedforward Systems

Parity violating experiments like the P2-experiment measure a tiny asymmetry (here 10^{-8}) in the scattering under the reversal of the longitudinal spin polarisation of the beam (helicity reversal). In consequence, it must be monitored to what extent beam parameters change during the reversal, hence creating unwanted "helicity correlated effects"

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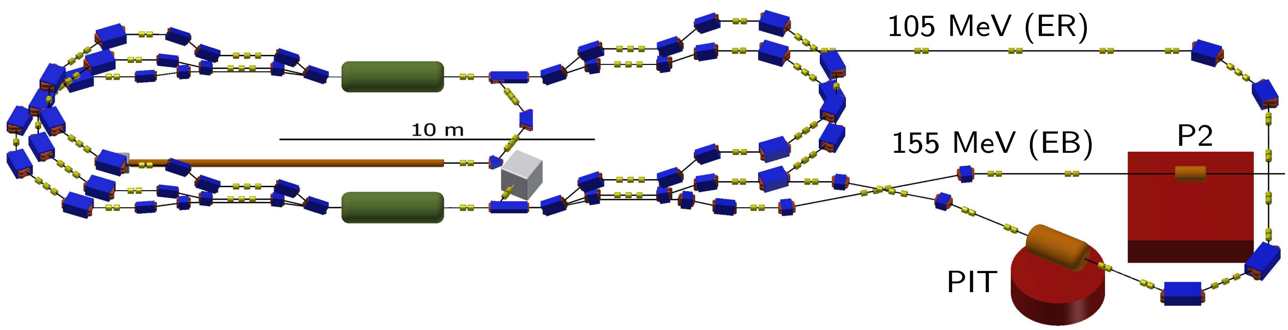

Figure 2: A 3D sketch of MESA: The main accelerator consists of two superconducting linac modules, the vertical beam separations and five 180° arcs. The experiments are an internal experiment for the ER mode with a beam energy of 105 MeV and an external experiment at 155 MeV. The red blocks mark the footprint area reserved for the experiments.

which deteriorate the quality of the signal. At MAMI this was achieved using different and independently operating feedback loops based on individual RF cavity monitors.

Modifications for MESA

For MESA these systems need to be improved over an order of magnitude to detect the expected asymmetry. Feedback alone is not enough because the helicity is going to be flipped randomly after 1 ms compared to 20 ms at MAMI. This makes a programmable feedforward attractive which can be adapted to the individual needs. More detailed studies are currently scheduled at MAMI.

Beam Tests at MAMI

Digital position stabilisation systems have now been successfully tested in the beam line to the A1 experiment at MAMI which operated a first parity violation experiment in the spectrometer hall (Fig. 1). With that PC-based equipment installed different tests (e.g. different optics/beam currents etc.) can be performed rather conveniently.

Energy stabilisation for MESA

Compensating the energy fluctuations by adjusting the accelerating RF however is still in development. The energy deviations can be detected by measuring the time of flight if longitudinal dispersion is present. As opposed to a microtron the superconducting RF of MESA needs an operation mode with little dispersion due to beam breakup instabilities (BBU). Hence a dedicated part of the extraction beam line would be necessary to provide a good relative resolution of a few keV.

At the 130 MeV S-DALINAC non-isochronous acceleration will soon be further investigated [6, 7]. Combined with the intrinsic stability of this mode of operation along with an active feedback the desired stability for the P2 experiment will be within reach.

SUPERCONDUCTING RF

The two superconducting Linacs of MESA will accelerate the beam with 25 MeV each (50 MeV per turn). Two passes are necessary to achieve the projected 105 MeV in ER mode resulting in a total of 40 mA of beam current on each linac.

Those high CW beam currents drive higher order modes (HOMs) in the accelerating structures which eventually leads to BBU.

Recent measurements of Q_{ext} for different HOMs with the TESLA-type cavities at ELBE (two TESLA-type 9 cell modules [8]) suggest beam currents of up to 0.6 mA before BBU sets in [4]. That is in reach with the design goal of MESA stage 1 (1 mA) due to rather conservative assumptions. To overcome the limiting BBU instabilities different cryomodules would be necessary for MESA stage 2.

At the moment the ARIEL e-linac cryomodule is under construction [9, 10]. It also contains two 1.3 GHz cavities but with an optimised shape related to the TESLA design to be capable to accelerate up to 10 mA.

There are a few other cryomodules possible but most of them are still subject of development and would therefore increase the project risk with respect to cost, timeline and technological complication. A definitive decision will be taken in fall 2014.

LATTICE DESIGN

The lattice design is near to be completed for an accelerator with ELBE-type RF modules. The linear optics have been designed with our own matrix programme "beam optics" and also with Mad X [11]. To investigate collective effects and the acceleration itself the simulation was also performed using PARMELA [12]. The basic layout follows a proposal for the LHeC ERL test facility [13] resulting in a two-pass ER mode and a three-pass EB mode.

The return arcs are designed to allow for maximum flexibility: in ER mode both isochronous and non-isochronous acceleration is desired whereas the EB mode will be performed as non-isochronous alone ($R_{56} = -0.3$ mm/‰) to reduce the energy spread.

Using PARMELA both the EB mode and the ER mode have been simulated successfully. Figure 3 shows the beta functions for EB mode as an example. To switch between EB and ER mode the 105 MeV beam is guided to the experimental area while the path length is $(n + 1/2)\lambda$ longer

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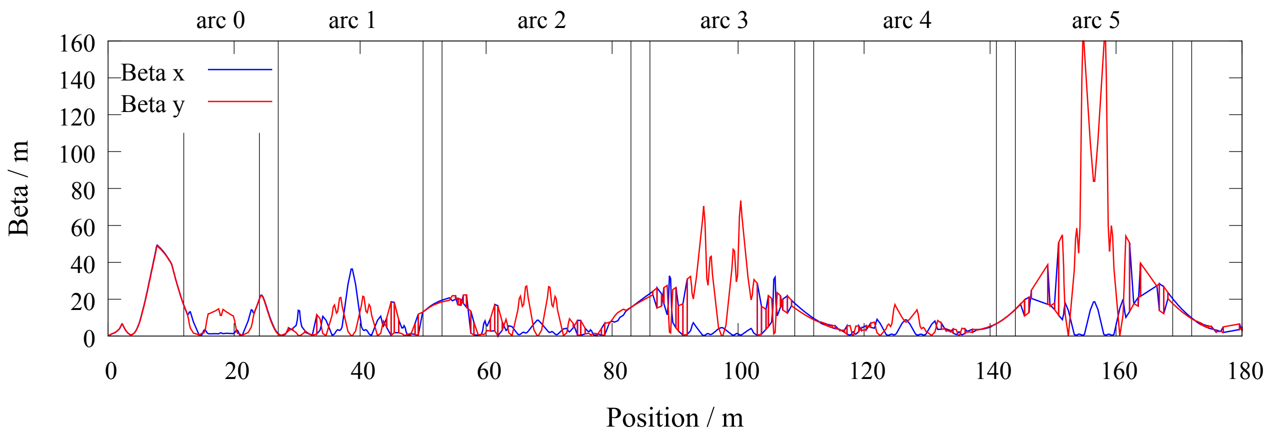

Figure 3: Beam beta functions of MESA in EB mode including space charge calculated with PARMELA.

than for EB mode to decelerate the beam after passing the target. During deceleration the same beam line as during acceleration are used.

INJECTOR LINAC

The 5 MeV Injector Linac is based on the well established normal conducting MAMI Injector which allows easy maintenance and excellent beam quality. This is not accomplished by the linac alone: a chopper/buncher stage following the 100 keV DC electron source will be used to avoid unwanted beam. A CW chopper demonstrator at 1.3 GHz was already successfully operated at the 100 keV test source of MAMI.

SUMMARY & OUTLOOK

The conceptual design of MESA is advancing in many different aspects. As soon as the RF modules have been chosen the fundamental frequency for MESA is fixed and the major parts for the RF systems can be acquired. The accelerator halls will be accessible without restrictions at the end of this year so that all civil works can be organised. At our 100 keV test sources collective effects, Mott measurement and beam transport can be studied in detail whereas MAMI allows to investigate the diagnostics at higher energies.

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