EXPERIMENTAL AND THEORETICAL STUDIES OF A LOW ENERGY H- BEAM

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Abstract

The Front End Test Stand (FETS) at the Rutherford Appleton Laboratory (RAL) is intended to demonstrate the early stages of acceleration (0-3 MeV) and beam chopping required for high power proton accelerators. At the moment, the RFQ is under construction and there is a need to understand the matching of the Low Energy Beam Transport (LEBT) into the RFQ as conclusive as possible. The parameter of interest may include solenoid settings, steering effects but also the influence of the post acceleration of the ion source and potential effects of space charge compensation. Two emittance scanner are installed and can be combined with a scintillator acting as a beam profile monitor and auxiliaries like current measurement.

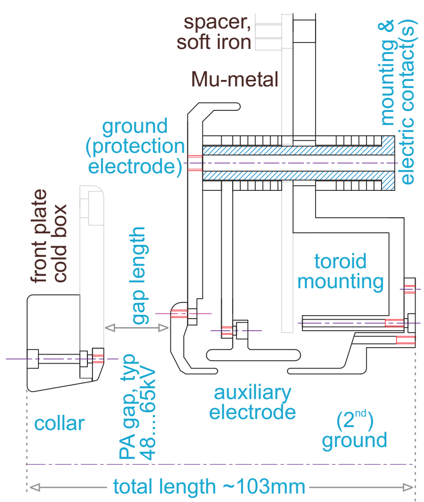

Figure 2: Cross section of the technical design of the new post acceleration. Mounted on 3 insulation pipes with spacers for alignment but here only one is shown.

INTRODUCTION

High power proton particle accelerators (HPPAs) in the megawatt range have many applications including drivers for spallation neutron sources, neutrino factories, transmuters for transmuting long-lived nuclear waste products, and energy amplifiers. In order to contribute to the development of HPPAs, to prepare the way for an upgrade to the ISIS accelerator and to contribute to the U.K. design effort on neutrino factories, a front end test stand FETS is being constructed at the Rutherford Appleton Laboratory (RAL) in the U.K. The aim of the FETS is to demonstrate the production of a 60 mA, 2 ms, 50 pps chopped H^- beam at 3 MeV with sufficient beam quality. FETS consists of a high power ion source, a three solenoid magnetic low energy beam transport LEBT, a 324 MHz, 3 MeV, four-vane radio frequency quadrupole RFQ , a fast electrostatic chopper, and a comprehensive suite of diagnostics [2, 3].At the time of writing the ion source and the LEBT are operational. Design of the chopper and RFQ are well progressed and the rf system for the RFQ has been commissioned to 1 MW. It is planned to test the RFQ first time with beam by 2013.

Concerning the transport into the RFQ, all components from the ion source extraction with sector magnet, the

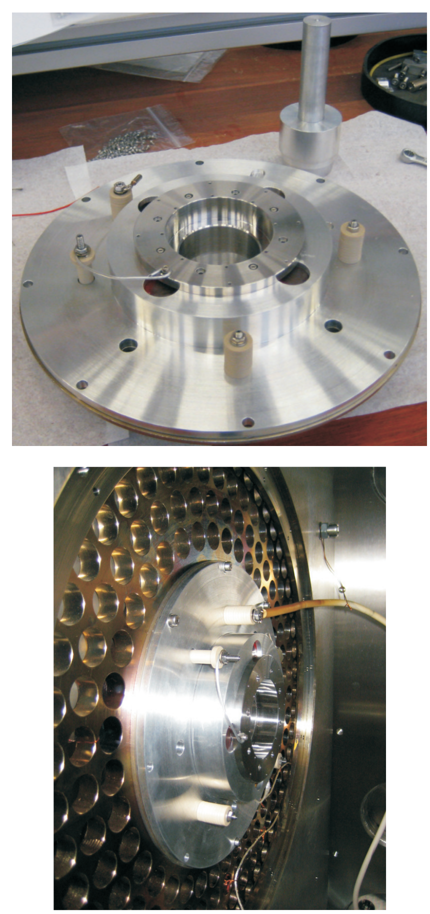

Figure 3: Top: The assembled PA with all 3 electrodes and connectors. Bottom: The PA mounted on the semi-permeable wall.

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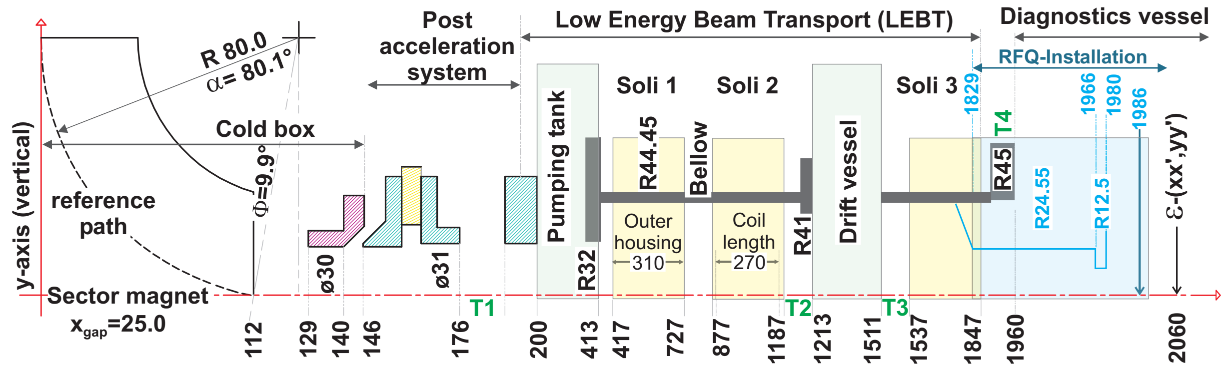

Figure 1: The beamline as it is at at the moment for LEBT commissioning with a diagnostics vessel instead of the RFQ. Shown is the electrode design of the old PA.

post acceleration (PA), drift(s) and solenoids with possible dipole components for steering need to be considered. The slit extraction of the source provides a more elliptical shaped beam distribution $I(x, y)$. An overview of the ISIS Penning source can be found here [5].

Assessing the RFQ Acceptance

One activity at the moment is to commission the LEBT, an intensive overview of the status can be found here [4]. The emittance as well as the maximum current at the end of the LEBT is very close to the FETS requirements but there are persistent offsets in angle as well as in position and it is hard to compensate with the dipole steerer without increasing the emittance. Measurements taken before the solenoids have been installed [6] show strong steering effects of the Post Acceleration (PA). Therefore the question was whether the PA could be improved by a more flexible mounting to counteract these steering effects. During the new design it was also looked to change the electrode shape and gaps to reduce the radial field components.

TECHNICAL DESIGN OF THE POST ACCELERATION

The design idea of the old PA [7] was to build it as compact as possible with a very short gap. A screening electrode was then supposed to provide space charge compensations. Meanwhile a few of the criteria were dropped and the total length can be a increased. A cross section of the new PA is shown in Fig. 2 and some pictures of the assembled and mounted PA are given in Fig. 3. Technically, the most important change to the previous one is the different way of mounting. This is know possible without removing the source. Further technical challenge was that the semi-permeable, vacuum-transparent wall should remain for mounting because of its magnetic properties used to terminate the magnetic stray field from the sector magnet. The actual holders are tubes made out of PEEK arranged like a tripod with spacers to adjust the longitudinal position of each electrode and the whole PA. Furthermore, the insulators have some play of $\approx \pm 2$ mm for offset correction and due to only three mounts a slanted mounting is also possible. The alignment can be done with a plunger shown in Fig. 3.

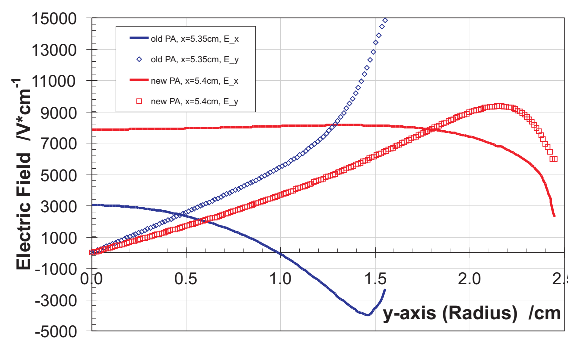

Figure 4: Radial field components of the two PA at the outlet of the protection electrode. E_x is the field component parallel to the beam axis and E_y is the radial (transversal) component.

ELECTROSTATIC MODELLING

The primary objective was to reduce spherical aberrations to improve the beam transport. Thus, it was looked for the shape of the electrode and whether it is feasible to increase the apertures to provide more clearance for the beam. Some guidance for the design of einzel lenses was found in [8]. The electro-static modelling has been done with POISSON [9] since the problem is a rotational symmetrical. The protection electrode is almost held at ground via a voltage divider, originally followed by the screening electrode. But the simulations have shown that it is actually difficult, i.e. very high voltages ≥ 15 keV minimum are required to achieve a polarity change on beam axis. But used as an 'auxiliary electrode' it has been turned out to be useful in minimizing radial components which cause the aberrations. This can be verified in Fig. 4 where at the end of the protection electrode both transversal and longitudinal field are computed, as a cut along the radius. The axial distribution is summarized in Fig. 5 for two different radii;

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along the symmetry axis and $r = 10\,\text{mm}$. This was chosen because most of the beam distribution is within this range.

PRELIMINARY EXPERIMENTAL RESULTS

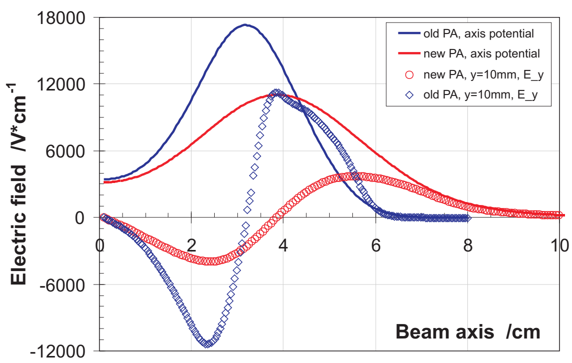

Figure 5: Beam axis potential of the two versions of the post acceleration shown for $r = 0\,\text{mm}$ and $r = 10\,\text{mm}$. The latter is especially important to reduce aberration because most of the beam current density can be expected within ±8. . . 12 mm.

Originally it was planned to test the installation with the two emittance scanners at the end of the LEBT and running the solenoids. But due to problems with the laboratory infrastructure this was not possible but will be performed as soon as possible.

Therefore the only experimental result are current measurements using the toroids along the beamline. Since previous measurements have shown a dependency in current and angle if the PA voltage, i.e. beam energy will be varied. This is shown in Fig. 6

SUMMARY AND OUTLOOK

The paper discussed a new design of the PA for FETS. For the design, the attention was focused on the shape of the electrodes to reduce possible aberrations. Almost of similar importance was to change the mounting and alignment procedure to provide more flexibility. This is especially an issue if the beam is miss-steered which sometimes is difficult to adjust with steering dipoles and ion source sector magnet.

It was planned to present first tests with the emittance scanners but due to several (technical) problems this was not possible but will be carried out in the nearest possible future. Also particle simulations are planned.

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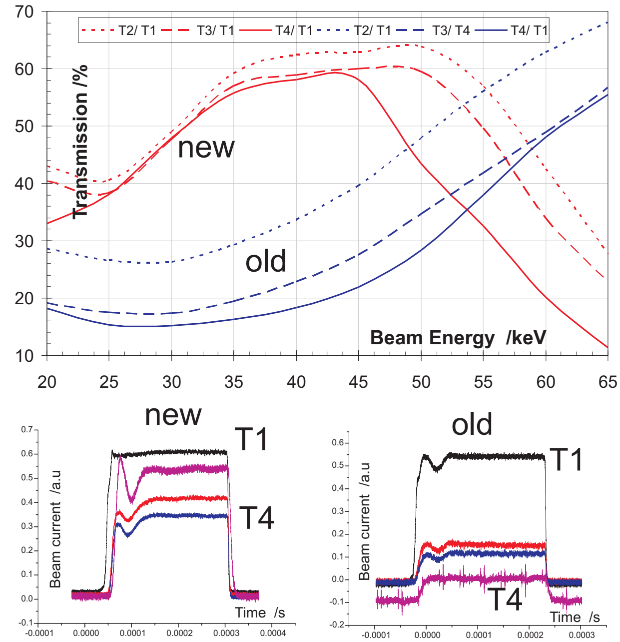

Figure 6: Transmission through the beamline, the current is measured with the 4 toroids. Input current at T1 is almost the same for both the new and old post acceleration. This implies less current density in the outer wings of the tail of the beam.

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