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BEAM TEST OF THE PHYSICS APPLICATIONS AT THE BEAM COMMISSIONING OF THE RAON ACCELERATOR

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Abstract

The RAON accelerator has been constructed for various fields of science programs since 2011. The installation of the low-energy superconducting accelerator section (SCL3) had finished in 2022 and the cooling of the cryogenics system has started after the installation. Prior to the SCL3 section, the beam commissioning has been carried out for a few years with 14.5 GHz ECR ion source at the injector section of the RAON accelerator and had successfully performed for several quarter-wave resonator (QWR) cryomodules at the front of the SCL3 section in October 2022. For successful and efficient beam commissioning, various beam physics studies have been conducted for several years, and physics applications have been also developed. Here we will introduce various physics applications used for beam commissioning and show the results of these beam tests.

INTRODUCTION

In the RAON accelerator [1], the beam generated by the ISOL system or an ECR-IS is accelerated by the low energy superconducting linear accelerator (SCL3) section after passing through the low energy beam transport (LEBT) section [2], the radio-frequency quadrupole (RFQ) accelerator, the medium energy beam transport (MEBT) section. After the SCL3 section, the beam can be used at the low energy experimental hall or re-accelerated through the high energy superconducting accelerator (SCL2) section for the in-flight (IF) system and high energy experiments after passing through the post accelerator to the driver linac transport (P2DT) section [3]. The schematic layout of the RAON accelerator is shown in Fig. 1.

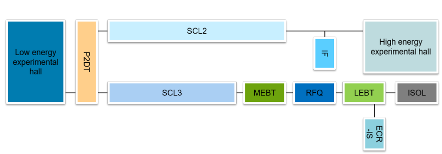

Figure 1: Schematic layout of the RAON accelerator. Beam generated by ISOL system or ECR-IS can be accelerated by superconducting linear accelerator sections (SCL3 and SCL2).

After the installation of the injector section in the RAON accelerator, the beam commissioning has been started with the stable ion beam generated by the 14.5 GHz ECR-IS since 2020. An argon was used for the first beam experiment at the low energy experimental hall, and the beam information at the beam commissioning is listed in Table 1. After the installation of the superconducting cavities in SCL3 section in 2022, the beam commissioning for this section is continuing. Prior to the beam commissioning, various kinds of beam physics studies have been conducted, and several physics application tools to be used at the beam commissioning have been developed with MATLAB program [4]. At the tool, the beam data can be obtained from the RAON control system based on the EPICS system and analysed with beam dynamics simulations like TRACK [5] and DYNAC [6] codes. Here we will introduce the physics application tools used at the RAON beam commissioning and present the beam test results of these tools.

Table 1: Beam Parameters

Parameters	**Value**	**Unit**
Beam	40Ar9+	-
Energy @LEBT	10	keV/u
Energy @MEBT	507	keV/u
Beam emittance	< 0.1	mm.mrad
Beam current	~ 30	μA

PHYSICS APPLICATIONS

For successful beam commissioning, the beam parameters like twiss parameters and emittances should be identified with diagnostic devices. At first, The data from Allison scanner located at the LEBT section is analysed, and the beam parameters are obtained. Figure 2 shows the physics application tool for the analysis of Allison scanner data and beam optics simulations. With the obtained beam parameters, beam optics simulations with an ELEGANT code [7] are carried out through the LEBT section, and the beam is matched to the RFQ requirement at the end of LEBT section in the tool. After the beam optics simulations, particle tracking simulations can be carried out at the tool.

To obtain the beam parameters at each section, the beam sizes are measured with three or four wire scanners and data of wire scanners is analysed. At each section, four wire scanners are located, and beam parameters are calculated by using the transfer matrix formalism. Figure 3 shows the result of the beam parameter calculation and beam matching at the LEBT section, and the result of the MEBT section is shown in Fig. 4. The beam parameters calculated from the wire scanners are compared to the result of Allison scanner, and the results are consistent within about 10 percent.

In addition to previous physics applications, the tool with a quadscan method is under development. As changing

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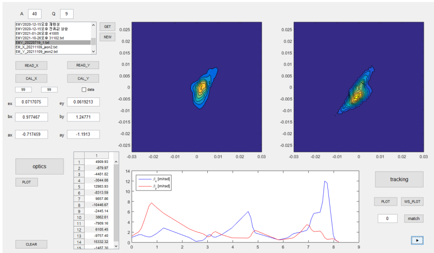

Figure 2: Physics application tool for the analysis of Allison scanner data and beam dynamics simulations. Data of Allison scanner located at LEBT section is analysed, and the beam optics simulation is carried out with the obtained beam parameters.

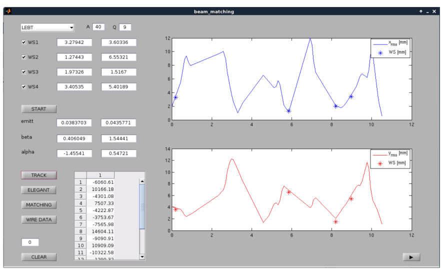

Figure 3: Beam test result of beam matching tool at the LEBT section. Beam sizes are obtained with four wire scanners, and beam matching is carried out with calculated beam parameters.

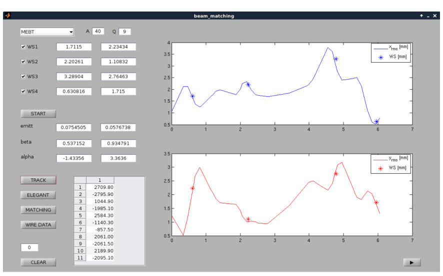

Figure 4: Beam test result of beam matching tool at the MEBT section.

the quadrupole strength, the transverse rms. beam size is measured with a wire scanner located in the downstream of the quadrupole. Figure 5 shows the result of the horizontal quadscan at the MEBT section, and the vertical quadscan result is shown in Fig. 6. The beam parameters obtained by three different physics applications agree well, and the machine setting at each section is carried out with the beam test results.

At the beam commissioning, the beam trajectory is distorted by machine errors, and the orbit correction based on the singular value decomposition (SVD) method [8] is carried with the physics application tool. At the LEBT section, the orbit correction is carried out by using steering magnets and wire scanners [9] because the beam generated by an ECR-IS is in continuous-wave (CW) mode, and one case of beam test result of the orbit correction at the LEBT section

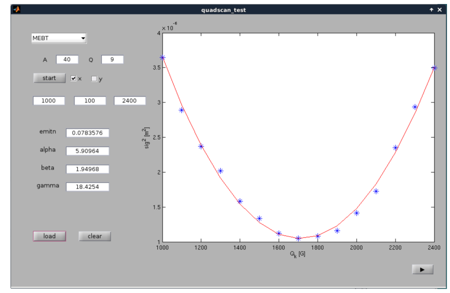

Figure 5: Test result of quadscan tool in horizontal direction at the MEBT section.

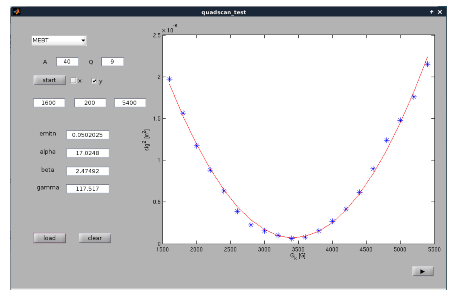

Figure 6: Test result of quadscan tool in vertical direction at the MEBT section.

is shown in Fig. 7. Because of working time of the wire scanners, about 10 minutes are taken for one iteration. After the RFQ, the beam is bunched, and the beam position can be read by a beam-position-monitor (BPM) in real time through the EPICS system. Figure 8 shows the result of the orbit correction at the MEBT section, and the test result at the front end of SCL3 section is shown in Fig. 9. For one iteration, about three seconds are needed to read the beam data and correct the beam orbit at each section. As the beam commissioning at the SCL3 section proceeds, the beam test of the orbit correction at the SCL3 section will be also continued.

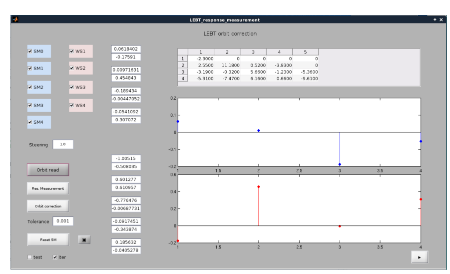

Figure 7: Beam test of brbit correction tool at the LEBT section. Steering magnets and wire scanners are used at the orbit correction.

In addition to the above physics applications, the tool of machine setting and analysis of diagnostics data is also under development and being tested for efficient beam commissioning. Figure 10 shows the physics application for the machine setting at each section, and the consecutive beam

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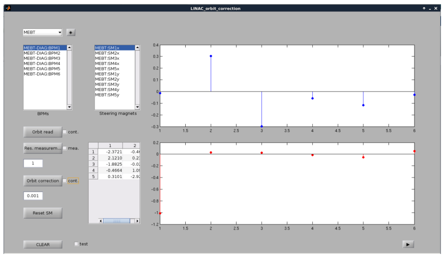

Figure 8: Beam test of orbit correction tool at the MEBT section with steering magnets and BPMs.

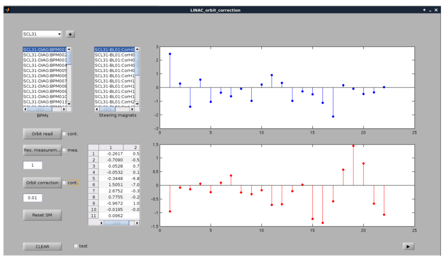

Figure 9: Beam test of orbit correction tool at the front end of the SCL3 section.

measurement with diagnostic devices can be carried out and analysed depending on the beam mass and charge at the tool.

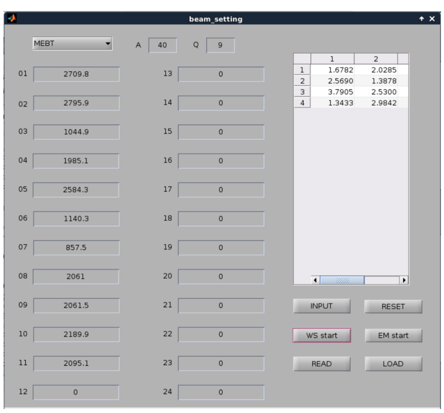

Figure 10: Physics application for the machine setting depending on beam mass and charge at each section.

SUMMARY

We have presented the beam test result of physics applications at the RAON beam commissioning. The data of the beam diagnostics was analysed to obtain the beam parameters, and the beam dynamics simulations were carried out for the proper machine setting and beam matching. In addition, the orbit correction was successfully carried out with steering magnets, wire scanners, and BPMs at each section. The beam commissioning at the RAON low-energy superconducting accelerator section is in progress, and the beam test of the physics application will be continued for the successful beam beam commissioning.

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