DEVELOPMENTS OF LEBT AND INJECTION SYSTEMS FOR CYCLOTRONS AT RCNP

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Abstract

Developments of injection systems for cyclotrons at Research Center for Nuclear Physics (RCNP) Osaka University have been carried recently in order to improve the highly intense heavy ions in MeV region for the secondary RI beam, et al. The cyclotron cascade consists with injector AVF cyclotron of K=140 and Ring cyclotron of K=400. The additional glazer lens on axial injection of AVF cyclotron is one of those and it has been installed for the purpose of increasing beam transmission to the inflector in center region of cyclotron. Another development is additional buncher for the heavy ion injection like Xe which requires high voltage in comparison with proton case. Extension of baffle slits on injection line of Ring Cyclotron also has been done to extend the flexibility of injection orbit. Modification of low energy beam transport (LEBT) from 18 GHz Superconducting (SC)-ECR ion source [1] to AVF injection axis also has been carried.

LEBT FOR 18 GHz SC-ECR

Modification of LEBT from 18GHz SC-ECR to injection of AVF cyclotron has been done. Schematic views of previous LEBT and modified LEBT are shown in Fig 1. Previous LEBT has 110 degree bending magnet and 20 degree electrostatic deflector. With this geometry, beam transmission from FC1 to FC3 shown in Fig. 1 was reaching an upper limit of 80 %. According to the calculation of beam envelope using MadX code [2], it is proved that

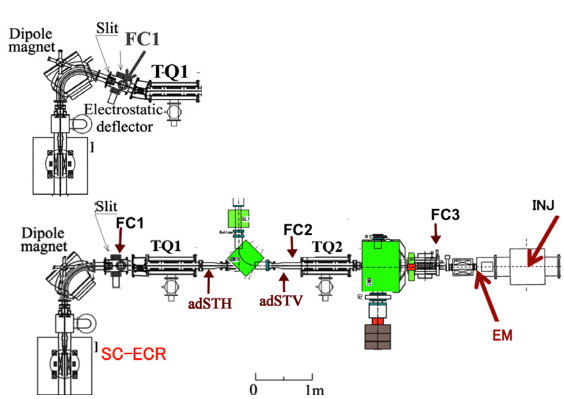

Figure 1: Schematic views of 18 GHz SC-ECR and LEBT components: upper figure shows previous LEBT and lower shows new LEBT. adSTH and adSTV are steering magnets, TQ1 and TQ2 are electrostatic Triplet Q lenses and FC1~3 are Faraday cup.

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the beam with emittance of more than 200 pi*mm*mrad is limited by baffle of 80 mm in diameter [3]. (See upper figure in Fig. 2.) In the case that these bending magnet and electrostatic deflector are changed by simple 90 degree bending magnet, it is expected that beam transmission would be improve due to the looser limitation as shown in lower figure in Fig. 2. After this modification of LEBT, beam transmission more than 90 % has been achieved except the case that large magnetic field leakage from AVF cyclotron which median plane locates 6m below the LEBT, even additional steering magnets shown in Figure 1 have been used to cancel the leakage field. It is also confirmed that beam with more than 200*pi*mm*mrad emittance measured by emittance monitor shown as EM in Fig. 1 has been transported.

INJECTION AXIS OF AVF CYCLOTRON

To improve the beam current accelerated by AVF cyclotron, some components have been added to injection axis. Those are additional buncher and glaser lens.

Buncher

To improve the beam current of heavy ion, especially of Xe, additional buncher has been installed on injection axis. In Fig. 3, existing buncher is shown by "b" and located 2550mm above median plane (MP) of AVF. This existing one makes saw wave by RF combining with 1x, 2x and 3x harmonics and maximum saw voltage is

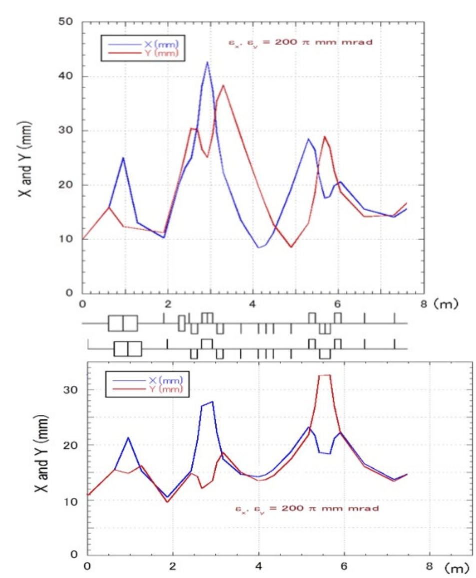

Figure 2: The beam envelopes for previous LEBT and new LEBT calculated by MadX[1]. Both envelopes are assumed the beam emittance of 200 pi*mm*mrad.

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±600 V. This buncher can bunch lighter ion which has small m/q and is accelerated with higher frequency, but the voltage is not enough for heavy ion like Xe. So additional new buncher is expected to help to improve beam current in combination with existing one. New buncher also makes saw wave by charge-discharge circuit with maximum voltage of 0-1200 V at 2 MHz, 0-600 V at 6 MHz and 0-200 V at 20 MHz. The installation position is 4600 mm above the median plane as shown in Figure 3 by “a”. The beam test has been done by $^{22}Ne^{8+}$ with acceleration frequency 9.32 MHz. First optimized beam current at extraction of AVF cyclotron is 2.5 μA with existing buncher only, and is 0.4 μA without any buncher. With this condition and no further optimization for magnets on injection axis, the beam current with only new buncher is 1.7 μA and it is confirmed that the new buncher works well. For the next step, beam test to improve beam current by the combination of these two bunchers would be done.

Glaser Lens

To improve the efficiency of AVF injection, additional glaser lens has also been installed. In previous situation of injection axis with only 3 glasers shown as d, e and f in Fig. 1, it was hard to deliver the beam through the region of 0~2000 mm above the median plane where the beam pipe size is narrow of 57 mm in diameter and only the

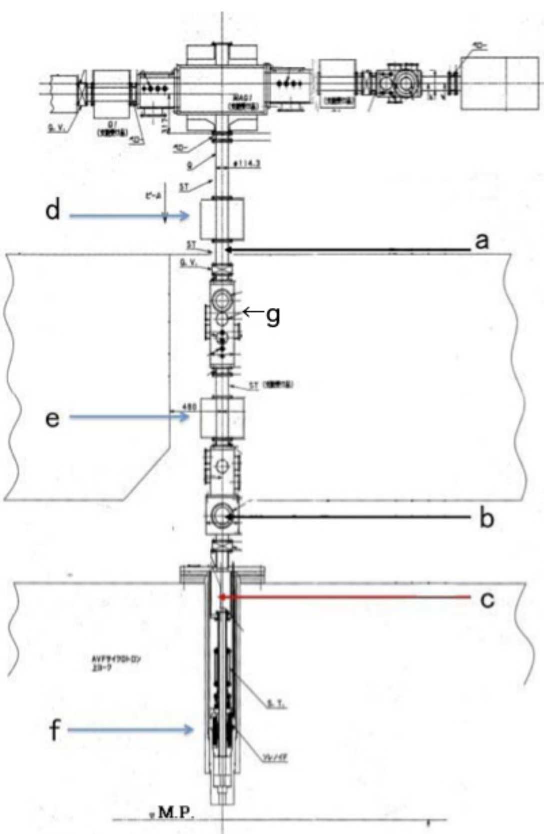

Figure 3: Schematic view of injection axis of AVF Cyclotron. a: new buncher, b: existing buncher, c: new glaser, d~f: existing glaser, g: iris slit.

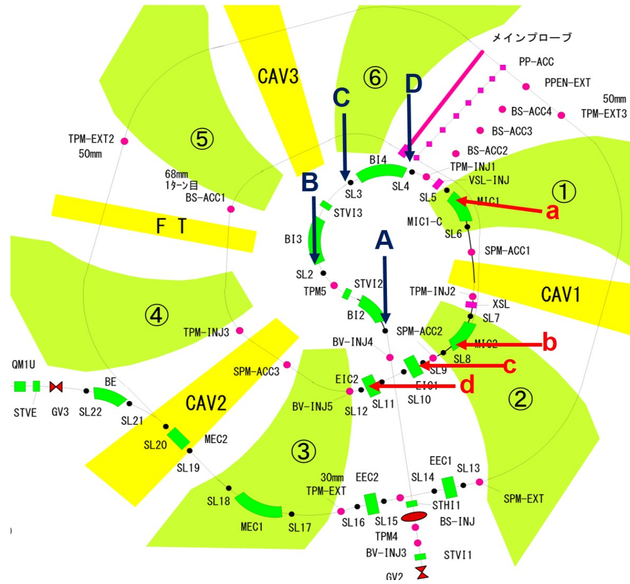

Figure 4: Schematic view of Ring cyclotron: A~D are baffle slits on injection line, a and b are slits of magnetic channel and c and d are electrostatic channel.

beam with the size up to 5 mm at the iris slit shown by “g” in Fig. 3 can be delivered. So new additional glaser is installed at the position of “c” shown in Fig. 3. With new additional glaser, now the beam with the size of 10 mm at the iris slit can be delivered.

INJECTION TO RING CYCLOTRON

To improve the injection efficiency of Ring cyclotron, extentions of baffle slits on beam injection line have been done to expand the flexibility of beam injection orbit. In Fig. 4, A~D show the baffle slits of injection line, a and b are the slit of magnetic channel, and c and d are electrostatic channel. These slits have been extended as far as protection of components works. Figure 5 shows the examples of the extension. After these slit extension, optimum current of MIC2 shown in Fig. 4 has drastically decreased, the current ratio of this MIC2 and analyzing magnet downstream of AVF extraction takes smaller

Figure 5: Examples of baffle slit extension: left figure shows magnetic channel slit extended from 15 mm×15 mm to 33mm×30mm and right figure shows slit of B in Fig. 4 which extended from 30mm×24mm to 36mm×30mm.

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value of 1.3~1.9 than the previous of 2.0~2.5. This means that the optimum trajectory has been changed due to slit extensions. The injection efficiency represented by the ratio of beam current at BS_ACC1 and BS_INJ shown in figure 4 also seems to be improved from 25~65% to 67~97%. To clarify that this efficiency improvement is due to slit extension and to improve the efficiency more, further study should to be done for transport line between AVF cyclotron and Ring cyclotron.

CONCLUSION

Several developments have been done for the purpose of improve the current of the beam accelerated by cyclotrons: LEBT of ion sources has been modified, additional buncher and glaser have been install on injection axis of AVF cyclotron and baffle slits on injection of Ring cyclotron have been extended. Those components work well. For further improvement of beam current, more detail development with those components and existing components combination would be done.

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