DEVELOPMENT OF TRANSPORTATION SYSTEM FOR LOW ENERGY ELECTRON GROUP

Shinichi Kato#[1], Michikazu Kinsho[2], Kazami Yamamoto[2] and Masahiro Yoshimoto[2]
[1]Tohoku University, Sendai-shi, Japan
[2]Accelerator Division in J-PARC Center, Tokai-mura, Japan

Abstract

In the J-PARC RCS, we installed the H0 Collimation System in order to remove the particles which scattered by charge-exchange foil because these caused the significant losses at the downstream of injection point. From the result of simulation, it was suggested that we could know the angle relation between the direction of the scattered particles and the side of the absorber if we could detect low energy electrons created in absorber. However, that isn't achieved yet because of the large noise around the H0 Collimation System. Then, we devised that we transported these electrons to the low noise place which is distant from the accelerator ring. To achieve this, we should develop the transportation system for low energy electrons. Then, we are developing this system using solenoid magnet.

INTRODUCTION

In the J-PARC RCS, the significant losses were observed at downstream of injection point. The causes of these are the large angle scattering of the injection and circulating beam at the charge-exchange foil. Then, we installed the H0 Collimation System in order to remove these large scattered particles [1] [2]. The absorbers which were parts of the H0 Collimation System were installed on right and left to the beam line. Furthermore, the absorbers can be adjusted their angle of beam side. From the result of simulation, it became clear that the H0 Collimation System operated most efficiently when the angle of scattered particle and the beam side of the absorber were parallel.

In this simulation, it became also clear that a lot of electrons were created in absorber if the particles grazed the side of the absorber. The simulation result and the schematic drawing are shown in Fig. 1. If scattered particles begin to graze the absorber, the electrons occur in large quantities. This means that we can understand relative angle between scattered particles and the side of the absorber and maximize efficiency of the H0 Collimation System if we detect these electrons. In addition, this angle relation can be detected within accuracy of several mrad. Therefore, we may be able to detect a position and an angle of beam halo in the same time if we can detect electrons created in the absorber and optimize the absorber. The schematic drawing is shown in Fig. 2.

Therefore, we installed electron detector just under the absorbers. At this place, the beam loss is very large. In the RCS, it is known that the device which amplifies electrons (for example, Micro Channel Plate which is called MCP) makes a big noise when the beams collide that directly. For that reason, we adopted the electrode as the detector. The picture of the detector and electrode are shown in Fig. 3.

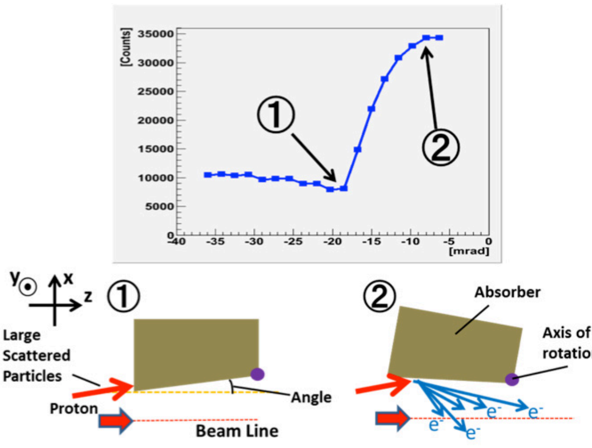

Figure 1: Upper figure shows the number of created electrons. Horizontal axis is the angle of the side of the absorber to the beam line. Lower figure shows the schematic drawing of the absorber rotation.

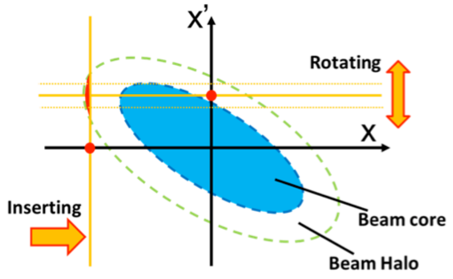

Figure 2: The schematic drawing of a position and an angle detection. Blue is the beam distribution in horizontal phase space. Red area is the beam halo which collides with absorber. Red points are the position and the angle value which may be able to detect.

However, the signal acquired to the electrode had many noises. So we couldn't measure even the difference between inserting and withdrawing the absorber. The main components of these noises were the electric field by the circulating beam and the switching frequency of power supply of the magnets.

#skato@post.j-parc.jp

One of the solutions of this problem is that we transport electrons to the place distant from the duct and detect them in order to avoid noises. So, we are developing this system using solenoid magnet.

In addition, we suggest generating electron cloud artificially by putting lots of low energy electrons into ring. The transport system using solenoid magnet may be needed to realize this suggestion.

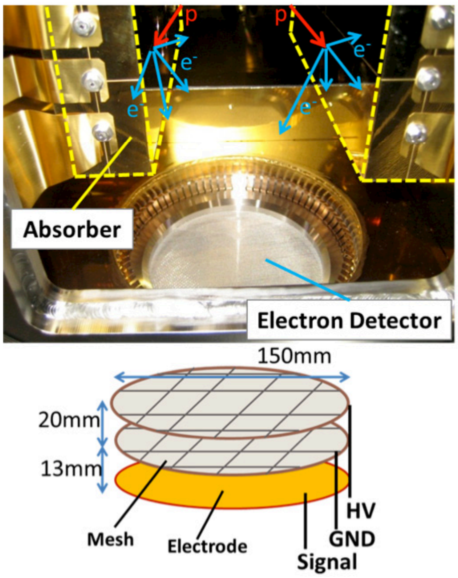

Figure 3: Upper figure is the picture of the absorbers and the detector. Lower figure is schematic drawing of the detector.

THE ELECTRONS FOR DETECTION

The electron detector (electrode) was installed at the bottom of vacuum chamber including the absorbers. The distributions of electrons which were created in absorbers on the detector surface are shown in Fig. 4. These results were obtained from GEANT4 which is particles reaction simulation. The electrons were widely distributed over the whole electrode surface. On the other hand, in the x-x' phase space, the electrons weren't distributed around the center because the absorbers which are source of electrons were installed in right and left from circulating beam. Assuming that these electrons are beams, the beam emittance is about 0.10 m rad.

The momentum distributions of electrons on the detector are shown in Fig. 5. From this result, it became clear that the main momentum of z direction was about 300 keV/c. And, the maximum momentum of x or y direction was about 600 keV/c.

DEVELOPMENT OF SOLENOID TRANSPORTATION SYSTEM

The Plan for Design

We made some restriction to consider the transportation system. First, we assumed that the port of vacuum chamber was made at top of it and the solenoid tube was set on it. In other words, we assumed that the solenoid tube was extended vertically to the beam duct. Next, we assumed that the solenoid tube was independent of the beam duct. In this case, it is expected that the magnetic field from Solenoid magnet won't affect the circulating beam. In addition, we expect that electrons will converge by edge field of solenoid and we may be able to make detector size small. On the other hand, we assumed that the detector was installed in the solenoid tube in order to exclude the influence of the edge filed at the exit from consideration. Finally, we assumed the radius of solenoid tube was 95 mm which was the same as the port size.

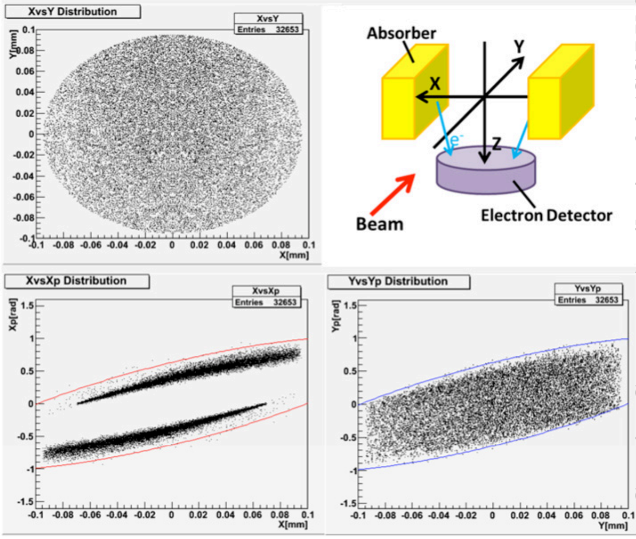

Figure 4: The distributions of electrons on the detector surface. Upper figure is x-y distribution. Lower right figure is x-x' and left is y-y' distribution. Red and blue lines are a hundred emittance.

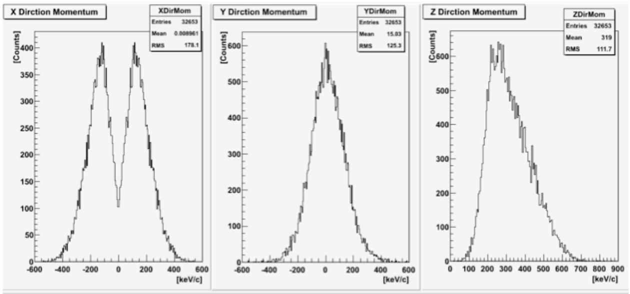

Figure 5: The momentum distributions of electrons on the detector. The left is x direction, the center is y direction and the right is z direction.

Transport Calculation

We performed the transport calculation of electrons using Transfer Matrixes. Those were approximated the edge filed of entrance and solenoid tube as thin lens respectively.

In the Foregoing paragraph, the electrons have momentum about 600 keV/c at the maximum to a radial direction of the solenoid tube. For example, if we want to suppress the radius of curvature of these electrons to 10 or less mm in the solenoid tube, the magnetic field is required about 60 mT. Then, we considered magnetic field intensity between 10 mT to 100 mT. In passing, the focal length of electrons which have momentum about 300 keV/c to a longitudinal direction of the solenoid tube is about 52 mm.

The distribution of electrons after transportation using solenoid magnet which strength is 60mT and the distribution of z direction momentum which exists within 50 mm radius are shown in Fig. 6. From this result, it became clear that electrons are converged around center by solenoid magnet. In addition, it could be confirmed that the convergent point was different with z direction momentum.

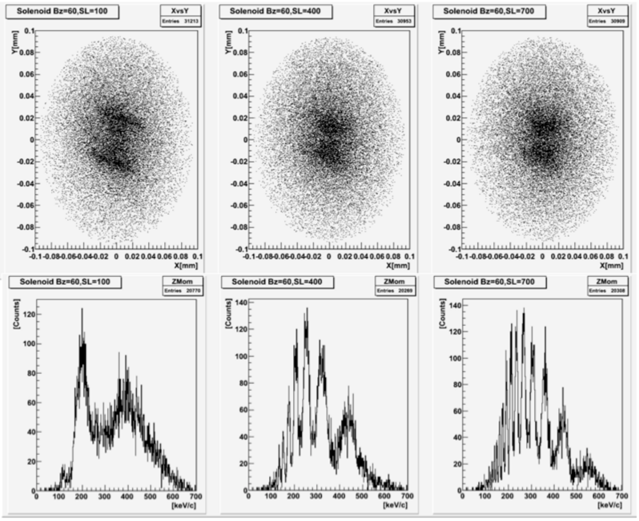

Figure 6: Upper figure is the distribution of electrons. Lower figure is the distribution of z direction momentum within 50 mm radius. The transported range is 100 mm, 400 mm, 700 mm from left to right.

Next, the electron transportation efficiency in the case of that the range of transportation is 1 m is shown in Fig. 7. From this result, about 40 mT is required in order to realize over 90% efficiency.

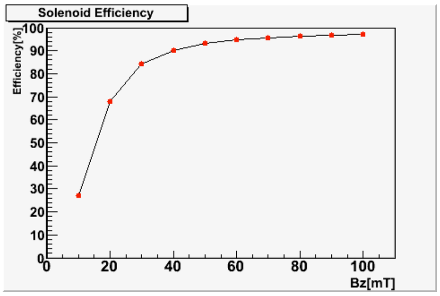

Figure 7: The electron transportation efficiency in the case of that the range of transportation is 1 m.

In order to estimate realistically, we assume that the radius of the detector is 50 mm which is a radius of a MCP marketed. The rate of electrons which may be detected by the MCP is shown in Fig. 8. From this result, it became clear that though the convergent point was different with z direction momentum, this effect was invisible if these were transported over 300 mm because of mixing of the distribution. In addition, it also became clear that the number of electrons which might be detected by the MCP was almost same if magnetic field was over 60 mT.

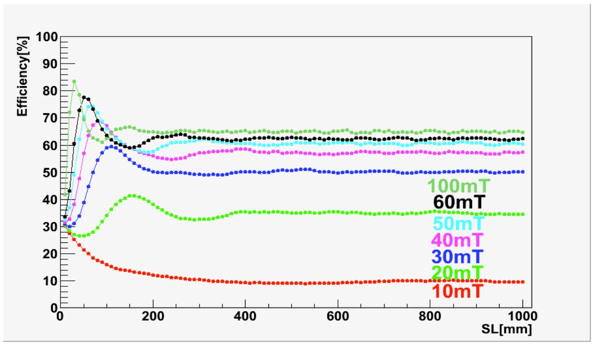

Figure 8: The rate of electrons which can be detected by the MCP.

Finally, the rate of electrons which can be detected by the MCP after transporting 1 m is shown in Fig. 9. From this result, it became clear that the transportation efficiency was about 65% when we used the MCP whose radius was 50 mm and the solenoid whose strength was 60 mT.

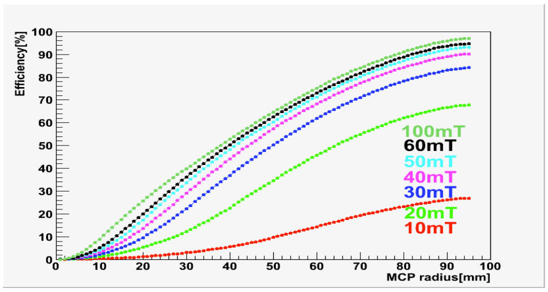

Figure 9: The rate of electrons which can be detected by the MCP. The transportation range is 1 m.

CONCLUSION

We are developing the electron transportation system in order to detect electrons which are created in the absorbers contained by H0 Collimation System. From the calculation results, it became clear that we might be able to detect over 90% electrons which enter into transportation system at 1 m beyond if we applied over 40 mT to solenoid magnet. In addition, if we make detector size small, the decrement of detection efficiency isn't so lots compared with that of detecting area owing to effect of edge field of solenoid magnet.

REFERENCES

[1] K.Yamamoto et al., Proc. IPAC'11, pp1605-1607 (2011).
[2] S.Kato et al., MOPPD07, in these proceedings.