Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, October 30-31, 2014

Investigation for interaction between residual gas and proton beam

K. M. Park*, H. S. Kim, S. P. Yoon, H. J. Kwon, Y. S. Cho
Korea Multipurpose Accelerator Complex, Korea Atomic Energy Research Institute
**Corresponding author: kmpark77@kaeri.re.kr*

1. Introduction

The electromagnet, vacuum, and radio frequency (RF) are fundamental building blocks of accelerator. Among them, vacuum is important factor related to beam loss and radiation background since interactions between the accelerated particles and the residual gas may degrade the beam quality[1]. Therefore, most of the accelerators demands ultra-high vacuum except for linear accelerator in which particles travels to the target 1 time. The linear accelerators and normal vacuum devices are usually operated between 10^{-7} and 10^{-8} Torr. We have also tried to set up test stand for ion source generated in the pressure range from 10^{-7} to 10^{-8} Torr. As basic research for base pressure, we have examined the interactions between the accelerated particles and the residual gas in high vacuum based on the results of residual gas analysis (RGA).

2. Experiments

2.1 Vacuum system and RGA

Fig.1 shows a schematic diagram of our vacuum system. The chamber size, made of stainless steel, was around 600 × 300 × 300 mm^3 and pumping system for the chamber was designed with a turbo molecular pump (TMP) with displacement of 450 l/s, Osaka Vacuum, TG450FCAB, connected to a scroll pump with displace of 300 l/min, ANEST IWATA Cor. Roughing line wasn't connected to chamber, directly and RGA, PFEIFFER Vacuum, quadrupole mass spectrometer, was set up to chamber center.

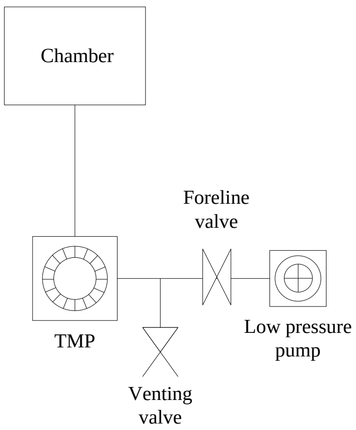


Fig. 1 Schematic diagram of vacuum system.

2.2 SRIM code

SRIM calculated the energy loss, ion distribution and beam loss when atoms traveled vacuum chamber at 5.2 x 10^{-3} Torr.

3. Results and Discussion

3.1 Residual gas

Table 1 represents the sort of residual gas and their partial pressure at total pressure of 4.0×10^{-8} Torr. The results of RGA showed the residual gases were Ar, CO_2, H_2, H_2O, C_xH_x, N_2/CO, and O_2 and most of residual gas was considered as H_2O since its partial pressure took up over 90 % when compared to total pressure[2]. Such a result enabled to assume that residual gas was H_2O at 4.0×10^{-8} Torr.

Table I: Residual gas and partial pressure

Sort of gases	Partial Pressure (Torr)
Ar	1.2×10^{-10}
CO_2	1.2×10^{-10}
H_2	1.4×10^{-10}
H_2O	3.6×10^{-8}
C_xH_y	1.4×10^{-10}
N_2/CO	1.0×10^{-9}
O_2	8.2×10^{-10}
Total pressure	4.0×10^{-8}

3.2 Number of collisions per second

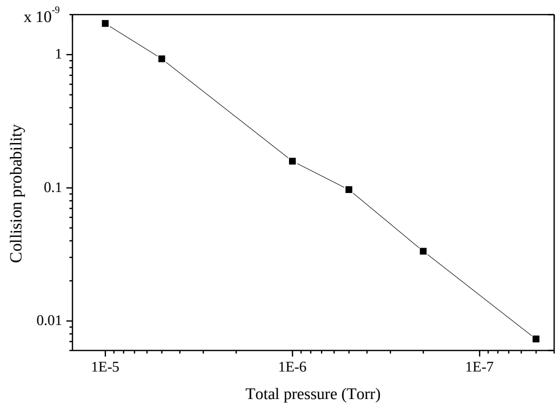


Fig. 2 Collision probability versus total pressure.

Under such assumption, number of collisions per second (NC) was calculated through following equation:

$$NC = \sigma INAL$$ [3]

where σ, I, N, A, L are cross section of H_2O (elastic cross section), beam intensity, atomic density, beam area, and length of vacuum chamber, respectively. When σ = 103 barns, I = 6.25 × 10^{19}/㎡·sec, N = P/kT, A = 5 × 10^{-5} ㎡, L = 0.6 m, P = 4.0 × 10^{-8} Torr, and T = 300 K were used, NC was 2.47 × 10^{-4} interaction/sec and the collision probability was 7.9 × 10^{-12}. It meant that only about 1 neutron in 10^{11} had collision while traversing the target at 4 × 10^{-8} Torr. Fig. 2 shows the variation of collision probability according to reduction of total pressure. It represented that when total pressure reduced gradually, collision probability reduced exponentially.

3.3 SRIM code

At above calculation, beam loss couldn't be examined. To obtain more information for beam, SRIM code was applied but the results for high vacuum wasn't examined. When ions with 50 keV traversed the edge of chamber, beam loss wasn't generated but energy loss as shown in Fig. 3. Average energy represented 4.95 ± 0.19 keV.

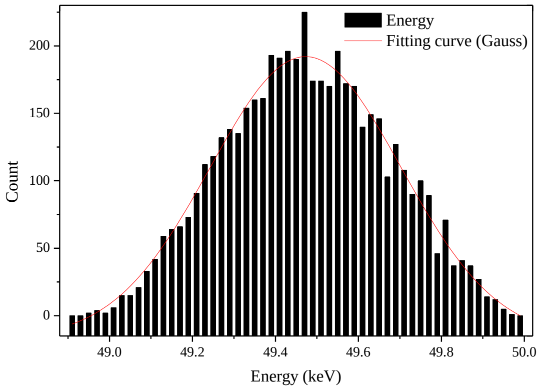
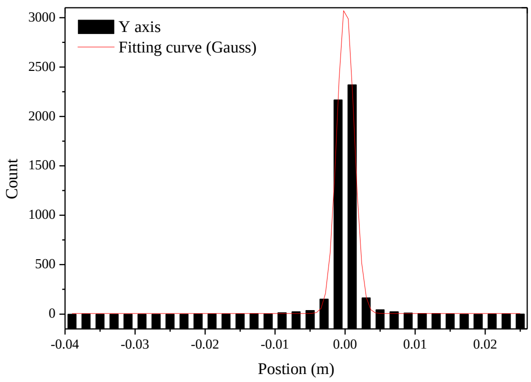
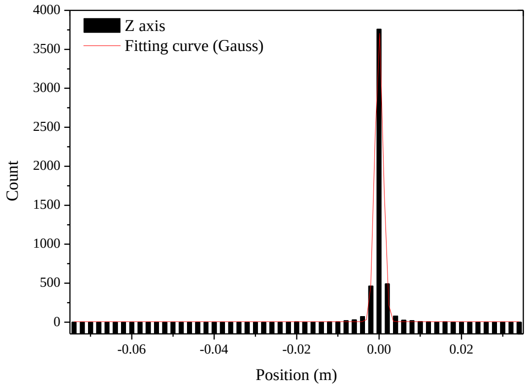


Fig. 3 Distribution of energy

Fig. 4 (a) and (b) show the position distribution for Y axis and Z axis at edge of chamber, respectively. Average position for traversed beam of Y and Z axis were 1.8 × 10^{-5} ± 2×10^{-3} m and -2.5 × 10^{-5} ± 2.28 × 10^{-3} m, respectively.



(a)



(b)

Fig. 4 Ion distribution: (a) Y axis and (b) Z axis.

4. Conclusions

Based on RGA result, the interaction between residual gas and accelerated ion was examined. The residual gases were Ar, CO_2, H_2, H_2O, C_xH_x, N_2/CO, and O_2 and most of residual gas was considered as H_2O. When number of collisions per second was considered, 1 neutron in 10^{11} had collision while traversing the target at 4 × 10^{-8} Torr. Beam loss wasn't generated and energy loss and position distribution was calculated by using SRIM code.

Acknowledgements

This work was supported by Ministry of Science, ICT & Future Planning.

REFERENCES

[1] A. Miura, H. Sako, G.Wei, Residual gas pressure dependence of beam loss, Proceedings of Linear Accelerator Conference LINAC2010, Tsukuba, Japan, pp.587-589, 2010.
[2] K. M. Park, H. S. Kim, H. J. Kwon, and Y. S. Cho, Analysis of vacuum and residual gas in the chamber to generate 10 ns proton beam pulse, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 29-30, 2014.
[3] John R Lamarsh, Introduction to Nuclear Engineering, ADDISON-WESLEY PUBLISHING COMPANY, Massachusetts, pp.44-66, 1983.