# PROTON ENERGY MEASUREMENT USING STACKED SILICON DETECTORS*

Kye-Ryung Kim#, PEFP, KAERI, Daejeon, Korea

Hong-Joo Kim, Jung-Ho So
Kyungpook National Univ., Daegu, Korea

*Abstract*

Proton energy was measured using stacked Si(Li) detectors at the MC-50 cyclotron of KIRAMS (Korea Institute of Radiological and Medical Sciences). The proton energy from the cyclotron was 45 MeV. Generally, using a single semiconductor detector it is not available to measure the proton energy above 30 MeV because the maximum thickness of the commercial semiconductor detector was limited to 5mm. We have used a Si(Li) detector stack consisting of three detectors having different thicknesses of 0.15 mm, 2 mm and 5 mm respectively. The active areas of these detectors are 150 mm$^2$ and 75 mm$^2$. In this paper, we report the preliminary results of energy measurement using these Si(Li) detector stack.

## INTRODUCTION

Some experiments using low flux and high energetic proton beam requires more accurate energy information. In 2004, The PEFP (Proton Engineering Frontier Project) installed a dedicated beam line for the basic and pilot studies of proton beam utilization in the fields of nuclear physics, biological technology and space technology [1]. A few tens MeV proton beam is very useful for these kinds of R&D. The AVF MC-50 cyclotron of KIRAMS has been providing a maximum 50MeV proton beam to the domestic users who are interested in the R&D on these kinds of applications during last few years.

In some experiments of nuclear physics and space technology development, more than 30 MeV proton beam has been used. So we have to consider how we can measure the proton energy more accurately in the range of 10 MeV ~ 50 MeV. A Si(Li) detector can be used for these accurate energy measurements with very low flux proton beam. But the thickness of the commercial Si(Li) is limited to 5 mm. For this reason, the maximum energy range measured by using a Si(Li) detector can not be exceed 30 MeV. A detector stack can solve this problem. Actually, a Si(Li) detector stack has been used for the measurement of gamma ray from $^{137}$Cs [2-4]. In this work, some preliminary results of proton energy measurements for the proton beam more than 30 MeV are presented in the air.

* Work is supported by the 21C Frontier R&D program in the MOST (Ministry of Science and Technology) of the Korean government
# kimkr@kaeri.re.kr

## EXPERIMENT

### *45MeV Beam Line at MC-50 cyclotron*

The 45 MeV dedicated beam line installed at the MC-50 cyclotron of KIRAMS was designed to be suitable for irradiation experiments in the air for the application in the fields of space technology, biological studies and nuclear physics. It is composed of a Faraday cup for beam current measurement, BPM (Beam Profile Monitor), phosphor material coated Al exit window for beam profile monitoring, Au scatterer, Al degrader, PMMA rotating modulator for SOBP (Spread-Out Bragg Peak), dose and depth-dose measuring system and a rotating target as shown in Fig. 1.


Figure 1: 45MeV PEFP beam line installed at the MC-50 cyclotron of KIRAMS.

### *Experimental Set-Up*

The 45 MeV proton beams produced by the MC-50 cyclotron exit the vacuum through a 2 mm thick Al window which is coated by a phosphor material, P43 on the air-side. A collimated proton beam can penetrate many thin Al foils in various thickness of 0.5 mm~4 mm which acts as an energy degrader and it is collimated by a collimator installed in front of the entrance of a vacuum chamber. The vacuum chamber in which the Si(Li) detector is installed has a 50μm thick Al entrance window. The detector stack is composed of three Si(Li) detectors and the thicknesses of these detectors are 150 μm, 2 mm, 5 mm respectively. The 150 μm-thick Si(Li) detector has 75mm$^2$ active area and two electrode layers, 40.4 μgm/cm$^2$-thick Au and 30.1 μgm/cm$^2$-thick Al. The 2 mm-thick Si(Li) detector has 150mm$^2$ active area and two electrode layers, 40.4 μgm/cm$^2$-thick Au and 40.9 μgm/cm$^2$-thick Al. The 5 mm-thick Si(Li) detector has 75mm$^2$ active area and two electrode layers, 200 Å-thick Au and 300 μm-thick Li.

The electronic signals from the Si(Li) detectors biased by 50 V, 220 V and 1 kV high voltage according to detector thicknesses are amplified by three pre-amplifier (ORTEC 142AH) and three spectroscopy amplifier (ORTEC 572A) and are attenuated to proper range for the incidence to the FADC. Figure 2 and Figure 3 depict a schematic view and photograph of the experimental set-up.

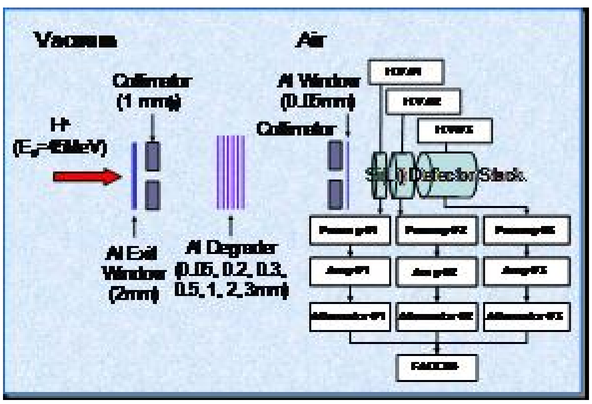



Fig. 2: Schematic view of the experimental set-up.

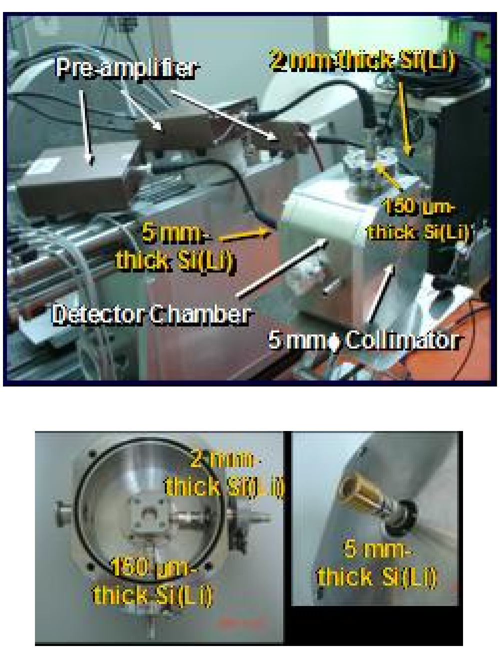


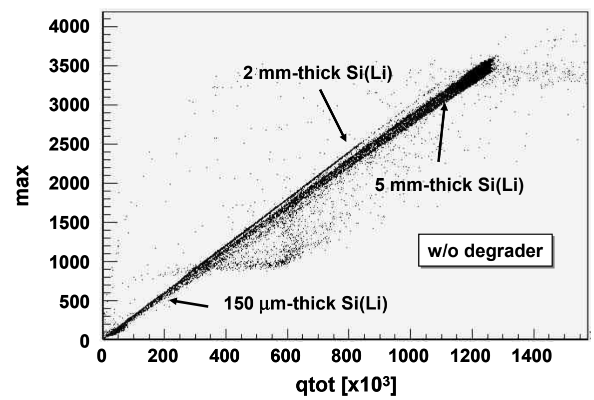

Figure 3: Photograph of the experimental set-up and detectors installed inside detector chamber.

The air gap was 1 m between exit window and semiconductor detectors and Al degrader was installed in the middle of the air gap. The proton energies were varied with a degrader consisting of ten plates, which can be moved independently into the beam path. The thickness of Al was changed from 0.02 mm to 7 mm.

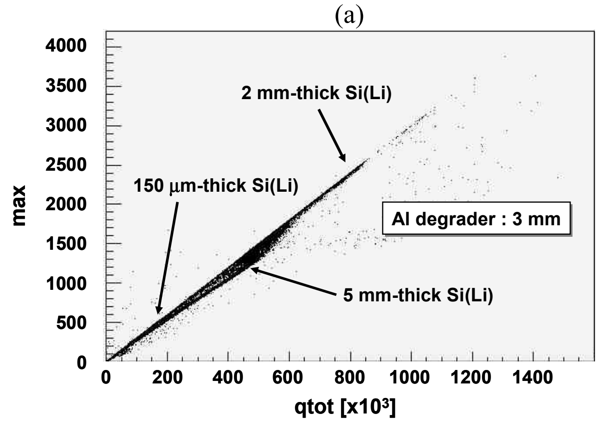
A liquid or plastic scintillator was always installed near the entrance of the detector chamber to monitor the flux to protect against unexpected radiation damage to the Si(Li) semiconductor detector caused by a high proton flux.

## RESULTS

Figure 4 shows maximum pulse height versus total charge produced by high energy proton incident to the detectors for every event. The distribution became broader with the increase of detector thickness and the decrease of proton energy.




(a)

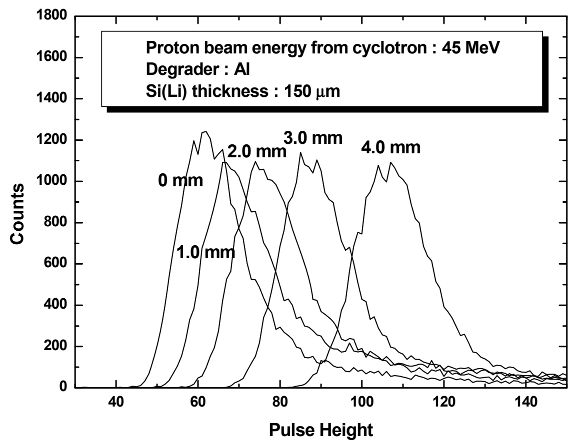



(b)

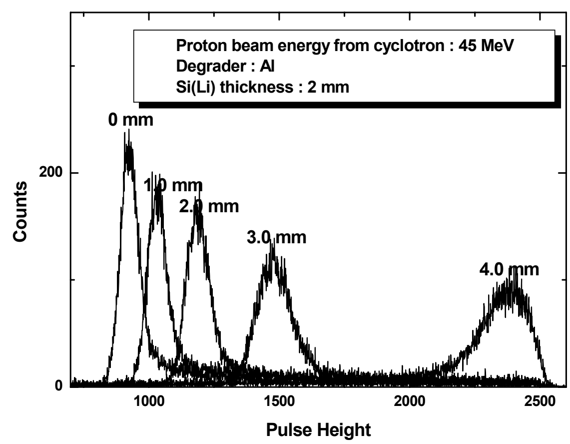
Fig. 4: Maximum pulse height versus total charge, (a) w/o degrader, (b) w/ 3 mm-thick Al degrader.

The pulse height spectrums for 150 μm- and 2 mm-thick Si(Li) detectors are displayed in Figure 5. The incident proton energies to the two detectors were decreased with the increase of Al degrader thickness.

Pulse height spectrum of three Si(Li) detectors are shown in Figure 6. The pulse width is increased with the increase of detector thickness because of the energy straggling caused by the multiple scattering occurred during passing through thick detector




(a)




(b)

Fig. 5: Pulse height spectrum of (a) 150 μm-thick and (b) 2 mm-thick Si(Li) detector with various Al degrader thicknesses.

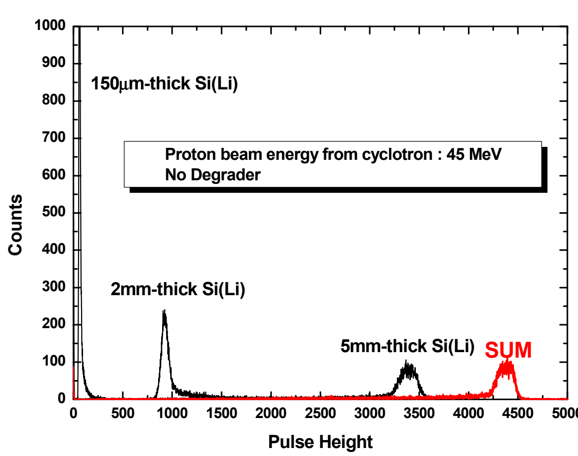



Fig. 6: Pulse height spectrum of three Si(Li) detectors and sum of these signals.

The signals from three detectors were added by some data processing after FADC64. Figure 7 shows the results of this summation process. The pulse height means the total energy of proton beam incident to the Si(Li) detector stack.

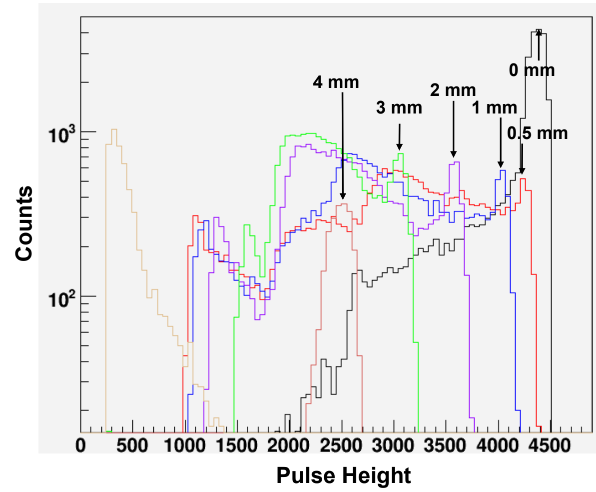



Fig. 7: Pulse height spectrums of sum of three Si(Li) detector signals with various Al degrader thicknesses.

## CONCLUSION

Proton beam energy more than 30 MeV was measured by using a detector stack composed of three Si(Li) detectors with different thicknesses, 150 μm, 2 mm, and 5 mm, respectively. The performance test of the whole experimental setup including data processing for summing three electronic signals from Si(Li) detectors was accomplished. More accurate energy information can be acquired by using this detector stack and calibration of this Si(Li) detector stack have to be done for this kind of application.

## REFERENCES

[1] K. R. Kim, et al., "50Mev proton beam test facility for low flux beam utilization studies of PEFP", proc. of APAC 2004, 2004.

[2] G. Scott Hubbard, et al, IEEE Trans. Nuclear Sciences, Vol. 39, Proceedings of IEEE 1991 NS Symposium, pp. 981-986 (1992).

[3] Robert E. McMurray, Jr. et al, IEEE Trans. Nuclear Science, Vol. 40, Proceedings of IEEE 1992 NS Symposium, pp. 882-889 (1993).

[4] G. Scott Hubbard, et al, IEEE Trans. Nuclear Sciences, Vol. 41, No. 4, pp. 1338-1342 (1994).

[5] Jong-Ho Seon, Sung-Joon Kim, S. H. Min, Y. M. Lee, J. W. Park, Kyoung-Wook Min, T. J. Chung and H. J. Chun, "Proton Irradiation Testing of ATMEL 68360 Processor and GaAs MMICs", IEEE Radiation Effects Data Workshop Record, 2003, pp. 165-168.