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Preliminary Test of Multi-layer Faraday Cup for Quality Assurance of Proton Beam Energy

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1. Introduction

KOMAC (Korea Multi-purpose Accelerator Complex) has operated 100-MeV proton linear accelerator since 2013. A quality assurance (QA) of proton beam energy is required to provide exact energy users want to know. As a general method to estimate proton energy, the range in the wedge-shaped polycarbonate phantom was measured using radio-chromic film. Recently, a new beam energy QA system using Multi-layer faraday cup (MLFC) was introduced for in-situ proton energy monitoring. To confirm performance of MLFC for quality assurance, beam energy measurement test and data post-processing was conducted. In this paper, we will describe the overall configuration of beam energy QA system and its test results.

2. Methods and Results

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2.1 Multi-layer Faraday Cup (MLFC)

MLFC is a proton range verifier which is composed of a stack of thin conducting metal layers separated by insulating layers. The measurement of peak channel of ionization radiation generated by protons completely stopped makes it possible to estimate incident proton energy. The MLFC (Pyramid, MLFC-128-125) is capable of measuring proton energy from 30 to 125 MeV. It consists of 128 copper clad FR4 with a thickness of 0.508 mm separated by 76 μm Kapton^{TM} film. [1] A 128-channel electrometer (Pyramid, I128S) was used to integrate charges individually from each plate. [2] The overall device configuration is described in Fig. 1

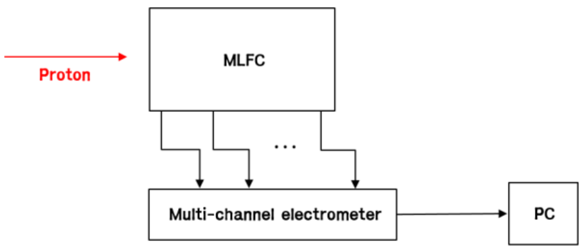

Fig. 1. Overall configuration of proton energy QA system

2.2 Proton Energy Measurement Test

Proton energy measurement test was conducted at the TR102 of which flux is about 10^6~10^7 #/(cm^2·pulse) for space radiation effect test. Four kinds of initial beamline energy (33, 57, 80, 102 MeV) was extracted and passed through the beam window and the air causing energy loss. Fig. 2 shows setup of the MLFC at the device under test (DUT). A Monte-Carlo simulation was conducted using Stopping and Range of Ions in Matter (SRIM) to verify accuracy of energy measurement at DUT. [3] The measured peaks of four kinds of energy are described in Fig. 3. A few data on both sides of the peak channel were used for calculation of centroid and fitting. To convert channel data to energy data, the channel-energy calibration curve provided from manufacturer was used. As shown in Table 1, the measurement and calculation results shows good agreement within 1%.

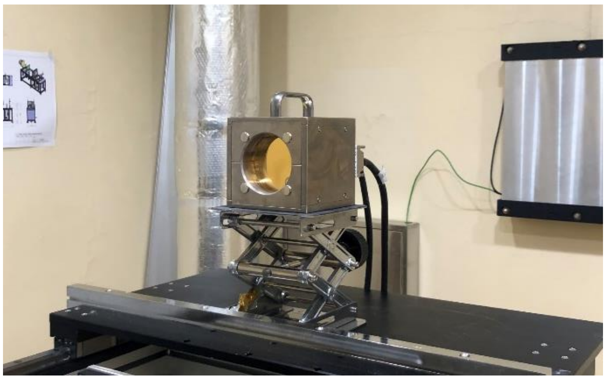

Fig. 2. Setup of the MLFC at the device under test (DUT)

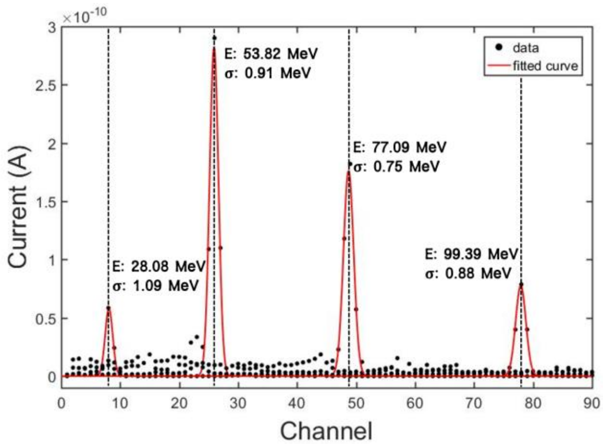

Fig. 3. Measured peaks of four kinds of initial beamline energy (33, 57, 80, 102 MeV)

Table 1. A comparison of measured energy with calculated energy.

Beam line energy (MeV)	Measured energy (MeV)	Calculated energy (MeV)	Difference (%)
33	28.08	28.18	0.35
57	53.82	53.99	0.32
80	77.09	77.61	0.67
102	99.39	99.63	0.24

2.3 Beam Energy Spread

For testing of space radiation effect to electronics, the proton beams should be monoenergetic or near monoenergetic (ΔE/E<5%) [4]. The peak widths in the MLFC spectrum are the convolution of longitudinal range straggling component and the actual energy spread of the beam expressed as [5]

$$\sigma_{MEA}^2 = \sigma^2 + \sigma_{STR,MLFC}^2 \qquad (1)$$

SRIM simulation can provide the longitudinal straggling in the geometry of MLFC as described in Fig. 4. Actual energy spread can be obtained by de-convolution of the longitudinal range straggling in the MLFC from measured peak widths in the MLFC. Measured peak widths, range straggling, actual energy spread, and ΔE/E of four kinds of energy are summarized in Table 2. As ΔE/E, actual energy spread divided by measured energy, falls within 5% for all kinds of energy, it can be concluded that it satisfies the recommended condition for space radiation effect test.

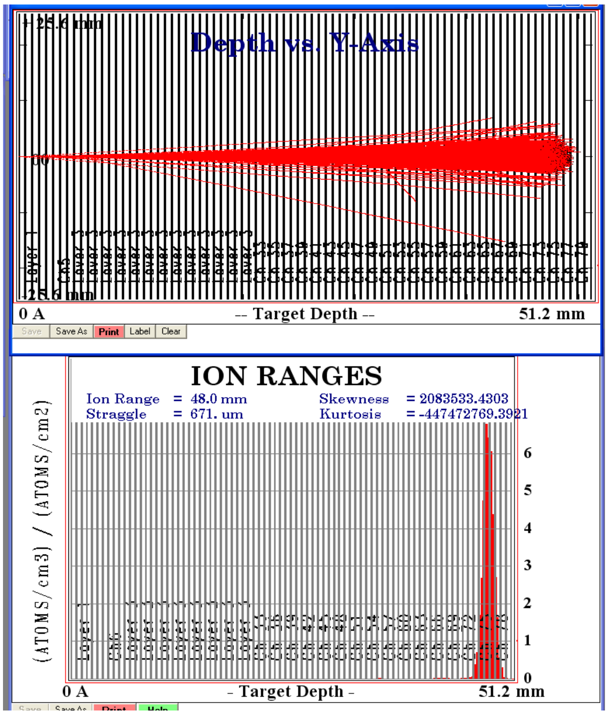

Fig. 4. Longitudinal range straggling calculation as proton enters into the MLFC using SRIM.

Table 2. Measured peak widths, range straggling, actual energy spread, and ΔE/E (%) of four kinds of energy

Beam line energy (MeV)	Measured peak width (MeV)	Range straggling (MeV)	Actual energy spread (MeV)	ΔE/E (%)
33	1.09	0.2	1.08	3.84
57	0.91	0.53	0.83	1.54
80	0.75	0.7	0.27	0.35
102	0.88	0.73	0.5	0.5

3. Conclusions

A new beam energy QA system using Multi-layer faraday cup (MLFC) was introduced and tested. Proton energy measurement test was conducted of four kinds of initial beamline energy (33, 57, 80, 102 MeV). A comparison of measured energy with calculated energy using SRIM simulation shows good agreement within 1%. Actual energy spread is obtained by de-convolution of the longitudinal range straggling from measured peak widths in the MLFC. ΔE/E within 5% satisfies the recommended condition for space radiation effect test. It is expected that MLFC will simplify the QA process and improve the accuracy of the proton energy measurement.

REFERENCES

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