ONLINE ANALYZER SYSTEM FOR THE DEVELOPMENT OF THE LONG-LIVED CHARGE-STRIPPING FOIL AT THE J-PARC

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Abstract

The carbon stripping foil is the key element for the high-intensity proton accelerator. At KEK, the foil irradiation system using the 645keV H- Cockcroft-Walton accelerator is in operation, which can simulate the energy depositions to the foil with the same amount in the J-PARC. In order to quantitatively observe the foil degradations (such as foil thinning, pin-hole production) during irradiation, online energy and particle analyzing system is under construction. This report outlines the design detail of the analyzing system including the detectors.

INTRODUCTION

The carbon foil is commonly used for H^- charge-exchange injection in a proton accelerator. In a high-intensity machine such as J-PARC, the temperature of foil is estimated to be higher than 1800K, and the commercially available carbon foils degrade rapidly, resulting in rupture, thinning, curling and pinhole production. Then the development of a new long-lived stripping foil is essential for the efficient accelerator operation[1]. For this purpose, the foil irradiation system using the 645keV H^- Cockcroft-Walton accelerator is in operation at the KEK. Due to the large stopping power of the carbon, single passage of 645keV beam through foil can deposit the same amount of energy with that in the J-PARC accelerator by the injected beam and multi-turn traversal of the circulating beam. Observation of foil degradation has been made by visual check during irradiation, and/or by the offline measurement using the alpha-ray thickness gauge [2]. However, the former method is insufficient to quantitate the foil degradation, while the latter one interrupts the irradiation experiments. The online analyzer system is designed to quantitate the foil thinning and pinhole production without any beam stops. Foil thinning can be measured by the energy shift of the outgoing protons through the foil, and the pinhole production can be estimated by counting the unstripped H^- beam through the foil.

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ANALYZER SYSTEM

Lifetime of the stripping foil can firstly be considered as the time when the foil ruptured. However, the time when the amount of unstripped beam exceeds the power capacity of the beam dump should also be the lifetime. At the J-PARC, a carbon foil with a thickness of 300ug/cm^2 is used. When the foil thickness decreases by 30%, the stripping efficiency is reduced by 2% and the heat load on the beam dump reaches the limit of 4kW. The energy difference with 30% thinning of foil becomes 33keV for the 645keV incident. The analyzer system should then be capable of separating this energy difference.

An outline of online analyzer system is shown in Fig.1. Beams passing through the foil will be separated with positive/negative charge by the first dipole magnet, followed by the 2nd dipole which separates the energy difference. The beam size at the foil can be varied from a few mm to more than 10mm in radius to match the experimental conditions. The doublet quadrupole magnets downstream the foil is used to adjust the optics parameter to realize the energy separation at the detector.

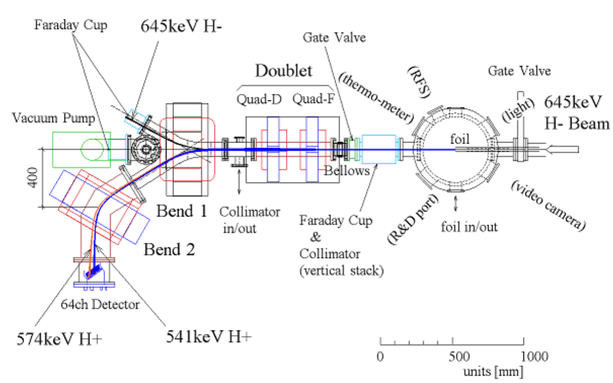

Figure 1: Online analyzer system

FIELD CALCULATION AND MEASUREMENT

At KEK, the fields which were given by the two dipoles and the doublet quadrupole magnets were measured with a Hall probe, and the measured values were compared with the calculated values by field analysis code (OPERA-3d), as can be seen in Fig.2 and 3.

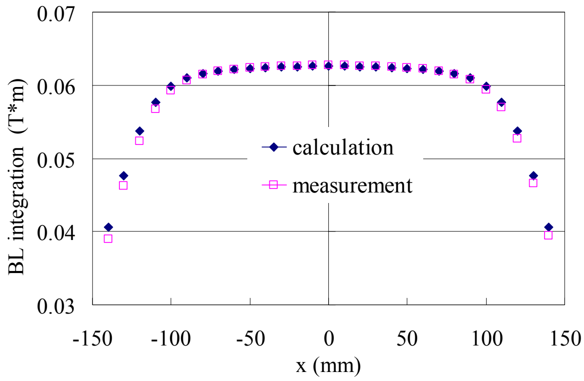

Figure 2a: A comparison between calculation and measurement values of the first dipole (BL integration, that is, the By-component integrated along a beam trajectory).

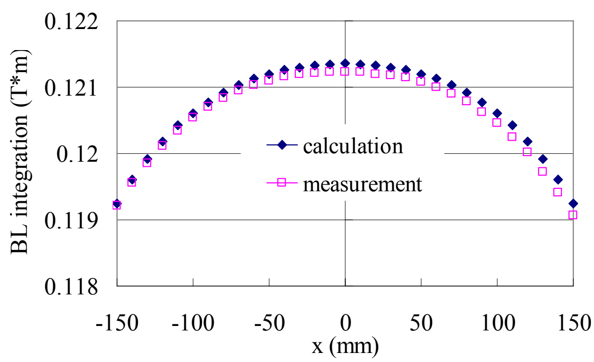

Figure 2b: A comparison between calculation and measurement values of the second dipole (BL integration of the By-component).

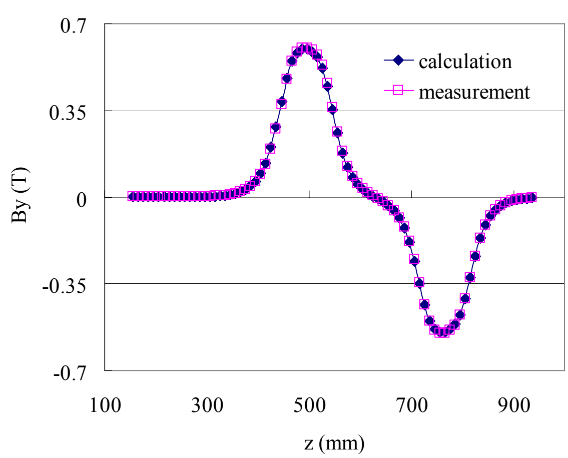

Figure 3: A comparison between calculation and measurement values of the doublet quadrupole magnets (By-component along an offset line by 20mm from the central trajectory).

While the measured fields have some misalignment-related asymmetry, that is included in the field calculation.

BEAM TRACKING

Test beam is assumed which has an emittance of 3π or 10π mm mrad for both planes and momentum spread of ±0.1%. Beam spot sizes at the foil position are changed in order to investigate the life-time dependencies on heat stress. Three optics sets are prepared by tuning the triplets of beam line, which called as 'reference', 'large', and 'small' according to the spot size at the foil position. Table1 shows the twiss parameters at the foil position of three cases of beam spot sizes, and Fig.4a shows the optics of beam line up to the foil position for the reference case.

Table 1: Twiss parameters at the foil position in SI units.

	Reference	Large	Small
βx	1.01455	15.7846	0.382967
αx	-0.120241	-1.85543	-0.151177
βy	1.01442	21.3215	0.616102
αy	-0.120403	6.55282	-0.168269
ηx	0	3.06798	-0.484095
η'x	2.30277	-0.189874	3.33738

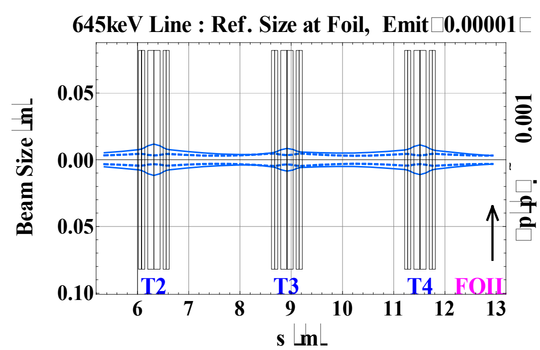

Figure 4a: The optics of beam line for the reference case. Plain and dashed lines show the horizontal and vertical beam sizes, respectively.

Fig.4b shows the trajectories of 541 keV and 574 keV proton beam with an emittance of 10π mm mrad and a momentum spread of 0.1% for the reference case. They are calculated by beam tracking code (TRACY-II [3]) using the measured field data described in the previous section. Beams are well separated by two analyzer bending magnets due to the momentum difference. Fig.4c shows the beam spot sizes at the entrance of detector which are well focused by doublet quadrupole magnets located after the foil. As a result, good beam separation can be expected.

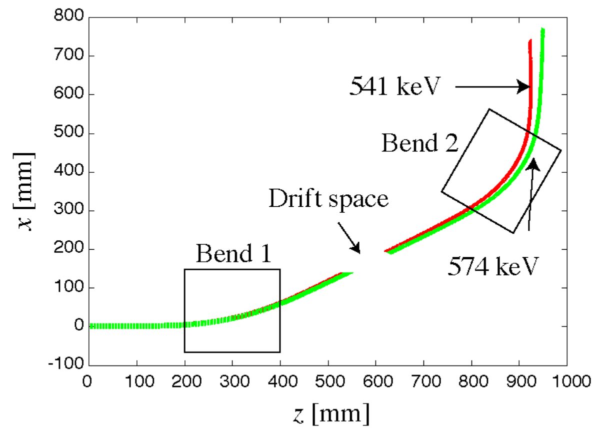

Figure 4b: the beam trajectories of proton beams with kinetic energy of 541 keV and 574 keV.

Bend1 and Bend2 are the 1st and 2nd dipole magnets, respectively. The origin is set to the beginning of measured field data of Bend1. The area where no data is available as a drift space.

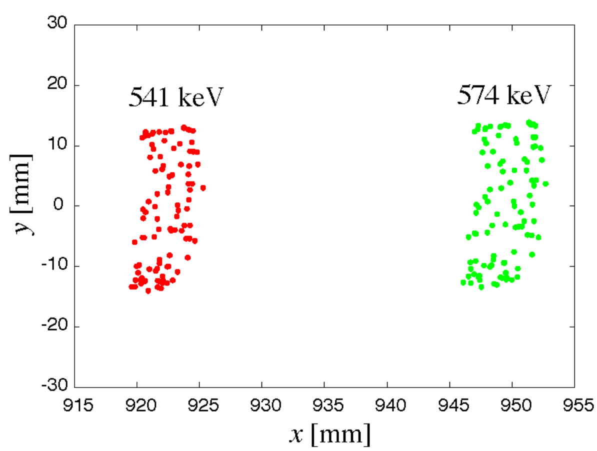

Figure 4c: the beam shape at the entrance of detector x = 800 mm for the reference case.

DETECTOR

The head of detector is composed of ceramic-insulated copper plate of 1.2mm thick, which is stacked into 64 layers as can be seen in Fig.5. Each plate is bent 35 degrees at the middle to prevent direct hit of the incoming beam upon the ceramic insulator at the bottom. Heat deposition upon the head is estimated to be 200W at most, and it is cooled by water through the ceramic insulator. Bias plate to suppress the secondary electron emission is also implemented. The design of readout and data processing system is in progress.

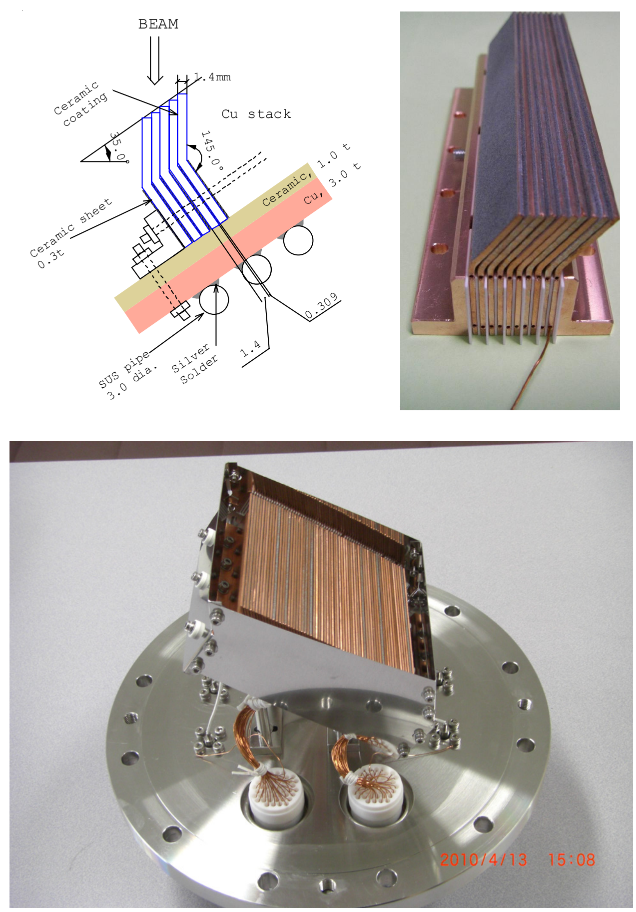

Figure 5: Analyzer detector head.

SUMMARY

Construction of online analyzer system is in progress for the development of a new long-lived carbon stripping foil. The system quantitates the pinhole production and thinning of foils during irradiation test. The field measurements have been finished for each magnet, and the tracking simulation with these data showed a required separation of the outgoing particles from the foil target. The detector head has also been completed. Installation of the system is planned in summer, 2010.

REFERENCES

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