SLOW BEAM EXTRACTION EXPERIMENTS AT TARN II

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Abstract

Beam test of a slow extraction system has been performed at the injection energy (10 MeV/u) for α particles in order to study the feasibility of the system. Beam spill time of 0.7 second has been achieved for 3 x 10^5 extracted particles although the effect of the current ripple in the magnet power supplies are observed.

I. INTRODUCTION

In order to respond to the increasing needs for biomedical research utilizing ion beams with intermediate energies(several hundreds MeV/u), a slow beam extraction system has been designed and constructed at TARN II. The system consists of an electrostatic septum(ESS), a magnetic septum(SM), a sextupole magnet(SX) and three bump coils

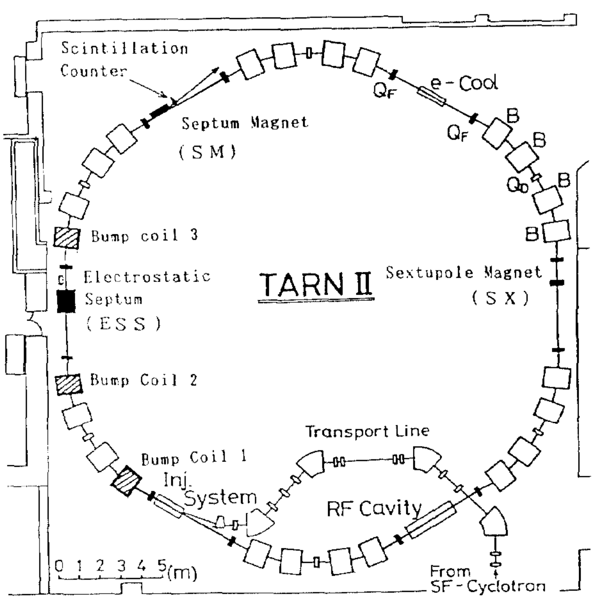

Fig. 1 Layout of the slow extraction system of TARN II.

attached to the ordinary lattice dipole magnets as shown in Fig. 1. The horizontal betatron tune is shifted from 1.70 to 1.6666···by decreasing the field gradients of radially focusing quadrupole magnets after acceleration. In Table 1, designed hardware equipments for the slow extraction system are listed up. All the equipments have been studied off-line beforehand and then are installed into the ring. In the present paper, their typical characteristics are briefly described together with the recent results of the beam test.

II. HARDWARE EQUIPMENTS

A. *Electrostatic Septum (ESS)*

In order to reduce the beam loss, the first septum is an electrostatic type with a septum wires made of Re-W alloy 90 µm in diameter stretched with spacing and tensions of 1.25 mm and 600 g, respectively. The negative high voltage is applied to an electrode made of titanium opposing to the septum wires with the earth potential. Up to now, already a high voltage more than 90 kV has been safely applied for the gap of 10 mm whereas the designed value is 85 kV for the highest energy. With evacuation utilizing a tarbo-molecular pump and a Cryogenic pump with pumping speeds of 200 l/sec and 1600 l/sec,respectively, the final end of the vacuum pressure at the chamber of the electrostatic septum has reached 1 x 10^{-10} Torr after a baking process.

Table 1

Hardware Equipments for Slow Beam Extraction

Sextupole Magnet	$B''L/B\rho$ = 0.3015 1/m² (DC mode)
Electrostatic Septum	E = 70~ 85 kV/cm, L = 1.0 m, Deflection Angle = 5.8 mrad, Septum Thickness = 0.15 mm
Septum Magnet	B = 5 kG, L = 1.0 m, Deflection Angle = 85.2 mrad, Septum Thickness = 9 mm
Bump Coil 1	Deflection Angle = 5.4 mrad
〃 2	〃 =-7.1 mrad
〃 3	〃 = 7.1 mrad

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B. Septum Magnet (SM)

In order to suppress degassing rate, the second septum is made of solid iron block instead of laminated plates although it assumes DC operation. The septum thickness allowable for the present case is 9 mm and the current density in the septum coil amounts to 78 A/mm^2 for the highest excitation of 5kG. It is found that the temperature rise of the septum coil in the air is below 30°C for the maximum excitation current of 2500 A and is well in a range of practical use. As the insurating materials for return and septum coils, ceramic coating and sheets of Kapton are used, respectively, large degassing rate is anticipated. However, the end pressure of 2.2 x 10^{-10} Torr has been attained at the septum magnet chamber by evacuation with a turbo-molecular pump of pumping speed of 400 *l*/sec.

C. Sextupole Magnet (SX)

As an exciter of the resonance, a sextupole magnet made of soft iron block is utilized at the position shown in Fig. 1. The needed strength of the sextupole for extraction is S (=B"L/Bρ) =0.3015 1/m^2 (Table 1). The beam life time was measured for various strength of the sextupole as shown in Fig. 2. If we assume the injection and maximum extraction energy of 10 MeV/u and 350 MeV/u, respectively, the ratio of the magnetic rigidity between injection and maximum energies amounts to 6.4 times and if the sextupole magnet is DC operated its strength, S, at the injection energy amounts to 1.9 1/m^2, which is found to lead to a short beam life as shown in Fig. 2. So the sextupole magnet is changed to be ramped during acceleration time of TARN II as long as about 4 sec.

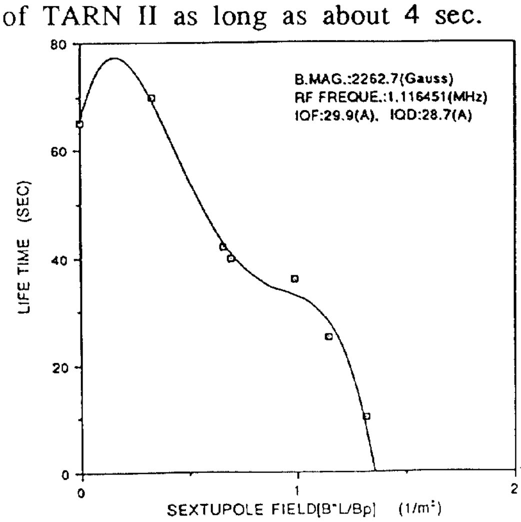

Fig. 2 Dependence of beam life on the sextupole strength.

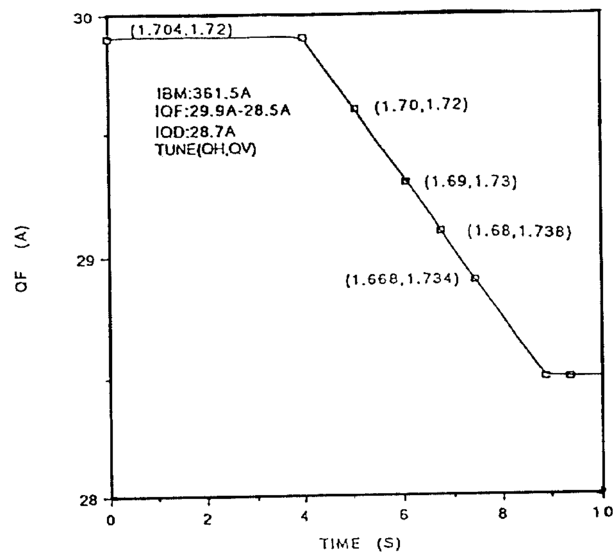

Fig. 3(a) Ramping pattern of radially focusing quadrupole magnets.

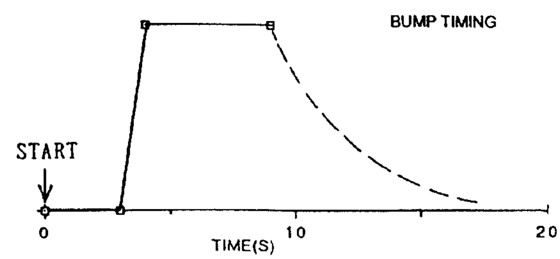

Fig. 3(b) Ramping pattern of bump coils.

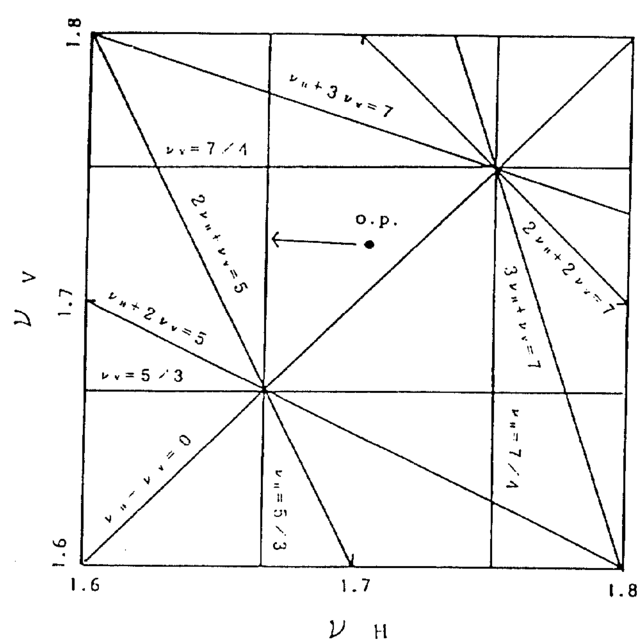

Fig. 4 Working line in the tune diagram during the beam test.

III. PROCEDURE OF BEAM EXPERIMENTS

As the preliminary test of the slow extraction system, the α beam is extracted at the injection energy(10 MeV/u). The field gradient of the radially focusing quadrupole magnets are reduced after beam injection and RF capture as shown in Fig. 3(a). In the process, the operating point in the tune diagram is shifted as shown in Fig. 4. In order to make the beam aperture to be minimum at the entrance of the electrostatic septum, three bump coils are excited by the timing as shown in Fig. 3(b). The intensity of the circulating beam in the ring decreases corressponding to the timing when the signals at the scintillation counter set at the exit of the septum magnet are observed (Fig. 5). The output signals from the photo-multiplier is processed through the electronics system as shown in Fig. 6 to observe the time structure of the extracted beam. As is shown in Fig. 7, the duration of the extracted beam of the intensity of 3 x 10^5 is about 0.7 second although the beam intensity is modulated from 100% to 0% by 50 Hz due to the presence of large current ripple of the power supplies of the magnets in the lattice. The results presented here are very preliminary ones and further study is needed to improve the beam spill and emittance of the extracted beam and so on.

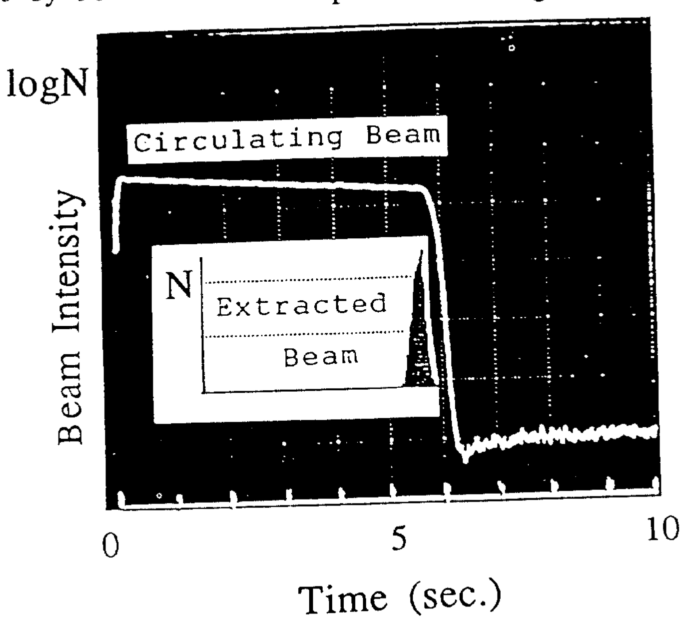

Fig. 5. Time variation of intensities of the circulating and extracted beam.

IV. REFERENCES

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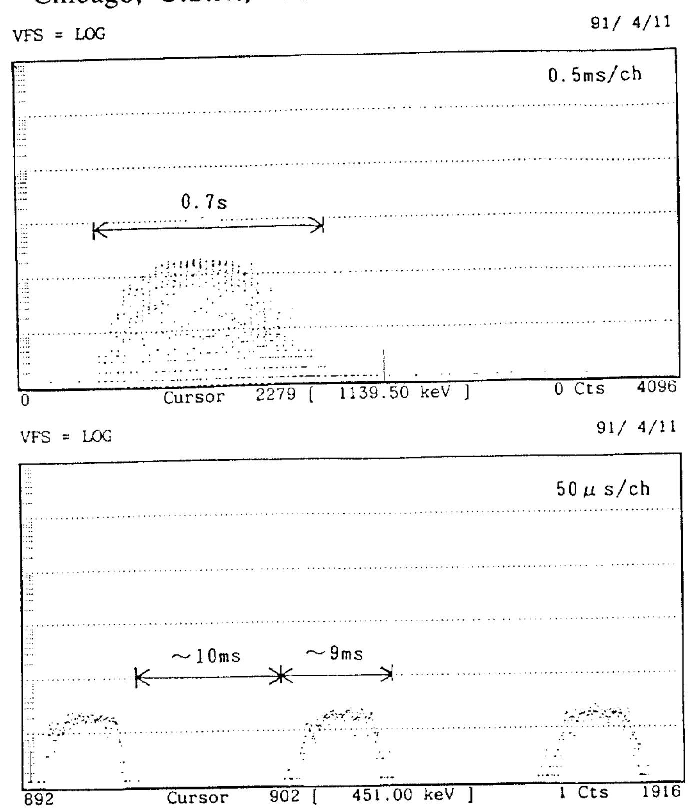
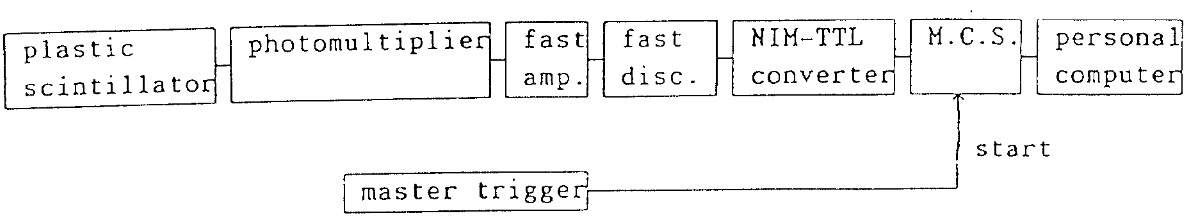


Fig. 7 Time structure of the extracted beam.



(M.C.S.: multi-channel scaling module)

Fig. 6 Block diagram of the electronics system used for detection of the extracted beam.