OPERATION EXPERIENCE OF CYCIAE30 INJECTOR

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Abstract

A 30 MeV compact cyclotron, CYCIAE 30 has been working as a supplier of medium and short live time radioactive isotopes for more than four years. To meet the increasing requirements of medical isotopes, it is asked that the machine should continuously run at a high level of beam intensity. But last September, it was difficulty to get the beam more than 100 μA. Some troubles came from the injector were found in the injection system. In this paper, the injection system and the existing problem will be described briefly and the proposal to improve the injection system is given.

1 INTRODUCTION

CIAE medical cyclotron is a fixed-field, fixed-frequency isochronous machine. Maximum energy of accelerating H- ions is up to 30 MeV and extracted beam intensity of more than 350 μA has been archived. Low power consumption less than 100 kW is suitable for industrial use. Design of the machine was reported elsewhere [1,2,3].

An external multicusp ion source is used for CYCIAE 30. The H- beam produced from the ion source is injected into the central region axially. The injection line consists of steering magnet, Einzel lens, buncher, solenoid and electrostatic deflector, a high voltage electrostatic field channel. Through the channel the beam will enter the machine horizontally away from vertical direction. The channel should keep spiral shape since the particle affected simultaneously by magnetic field in the central region. The beam will be further accelerated by the RF field once the particles leave the injector channel and enter the magnet gap. Simulation of the beam dynamics were done to keep the beam loss as less as possible in the central region [4]. Fig 1 shows the central region of CIAE 30 MeV cyclotron.

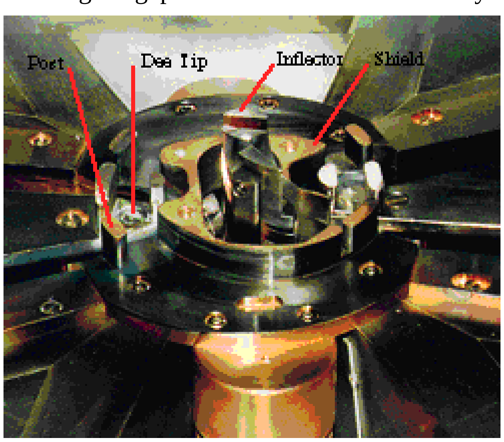

FIG. 1. Central Region of CIAE 30 MeV Cyclotron

Four years after the machine put into operation, the injection system works at a reasonable efficiency. The machine usually worked with the beam more than 200 μA according the isotopes production purpose until last September when the machine had a hard time to get 100 μA beam. Two positions damaged were found by beam when the central region of the cyclotron was checked. One spot is inside the deflector, a part of the electrostatic channel. That is easy to be understood since the beam pass through that channel. But another damaged place is located on the wall of RF shielding wall. Thus the further study for the injector was carried out as shown following.

2 ELECTROSTATIC FIELD FORMED BETWEEN THE DEFLECTOR AND RF SHIELDING PARTS

The beam dynamics study did when the machine designed was based on an assumption that the ion after the deflector effected by two field forces only: magnetostatic field and RF field from Dee puller. Before that the electrostatic field between the two electrodes of the deflector would change the beam direction from vertical to horizontal.

From the damaged spot on the wall of the RF shielding parts, we suppose that there is another field exists in the region between the deflector electrode and RF shielding wall. The field is estimated by a three dimensional finite different code. The geometry used in the calculation is shown in Fig. 1. And the potential distribution is given in Fig. 2. The maximum electric field in the interested region is as high as a half of those inside the deflector channel. In fact, another deflection channel is formed between a deflector electrode and RF shielding wall. This field will make the injected beam expand and part of beam will enter this extra deflection channel. It would be more serious once the current of the steering magnet is not set properly. The beam would be deflected into the shielding parts by this field. That is the reason why the RF shielding wall was damaged. A new deflector is used to replace the old one now. The machine seems work well for months.

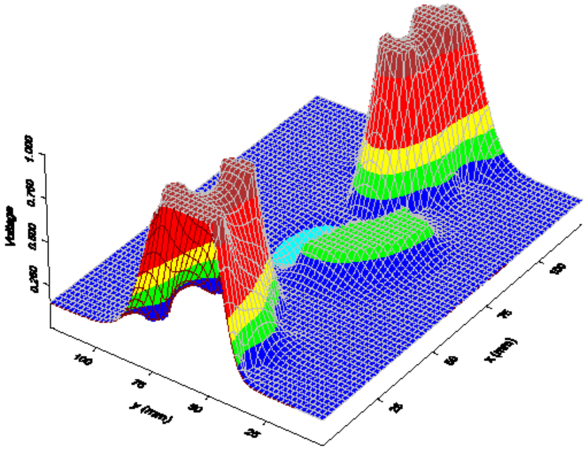

FIG. 2. The potential distribution in the central region of CYCIAE 30

3 OPTICS CALCULATION OF INJECTION LINE

The beam damages the deflector wall since beam divergence inside the deflector channel. Some stripped copper skin is sometimes found during the operation caused by beam loses on the electrodes' wall. Time after time the gap between the electrode increases. Then higher deflecting voltage would be required since the gap becomes bigger. Also the damaged spot destroy the channel shape that would make injection even more difficulty.

The operation records of the cyclotron show that the focus of the beam line is not strong enough since the measured beam becomes higher with the lens current increasing. The injection line is shown in Fig 3 (the solenoid is inside the magnet of the cyclotron). To improve the injection, the beam spot should be limited to smaller size. Several schemes have been tried to provided the better focus of the beam line and smaller beam envelope inside the deflector.

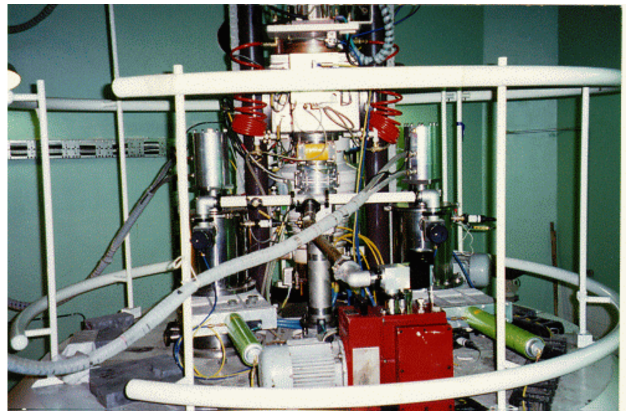

FIG. 3. The injection line of CYCIAE 30

- One triplet is used to replace the solenoid (E&T).
- Two triplets are used. One replaces the solenoid and the other one replaces the Einzel lens (T&T).
- One triplet is used to replace the Einzel lens (T&S).

The simulation results show that One triplet is used to replace the Einzel lens is quite competent to control the beam profile at a better level. The spot at the 8 mm width inlet of the deflector is smaller than 5 mm. The required current of the solenoid is relatively lower. The comparison of the results calculated by TRANSPORT [5] is listed in table 1. And the envelope is shown in Fig 4.

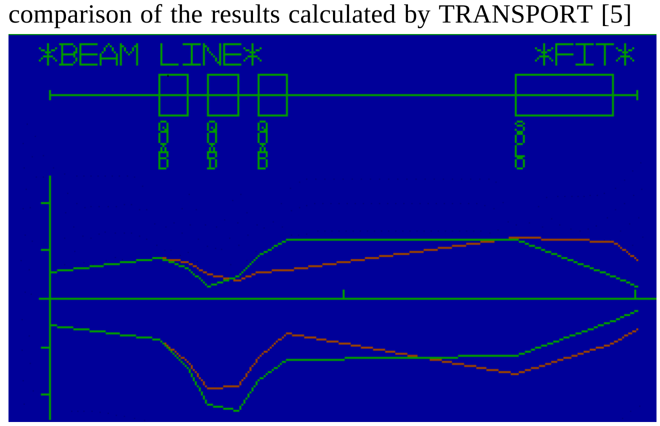

FIG. 4. The Envelope calculated by TRANSPORT

TABLE 1 The Results Comparison of Different Schemes

	Rmax (outside the main magnet)	Rmax (inside the main magnet)	Xmax on target	Ymax on target	Magnetic Field of the Solenoid
E&S	0.95 cm	0.96 cm	0.24 cm	0.24 cm	2.2 kG
E&T	0.95 cm	1.37 cm	0.42 cm	0.63 cm	
T&T	1.63 cm	1.10 cm	0.57 cm	0.21 cm	
T&S	**2.33 cm**	**1.21 cm**	**0.25 cm**	**0.25 cm**	**1.8 kG**

4 THE QUADRUPOLE MAGNET DESIGN

Quadrupole magnet is widely used for beam focus, such as in storage ring and beam transportation system. In the past, quadrupole pole face designed parabollized since conform algorithm used for the field simulation. In the case, the infinite permeability of iron is assumed to keep the constant field gradient in the beam area. But parabola pole face brings following shortcomings: machining difficult, assembling difficult. Besides, the field distribution is not expected constant, but distorted since iron saturation is not considered when the magnet performance computed. The numerical simulation techniques are used to design this kind of magnet. The shape of pole can be chosen freely according to the real requirements and simple machining procedure. According to the magnetic field gradient of a quadrupole for the injection line, The quadrupole magnets are designed and shown in Fig 5. The pole face is broken line shaped. The inner diameter is Φ78 mm. The good field region is about 80 %. The magnetic field gradient from the design is linear. They are shown in Fig 6.

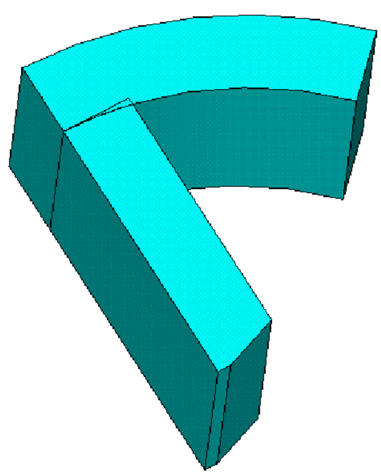

FIG. 5. The Geometry of Quadrupole Magnet with Broken Line Profile Pole Tip

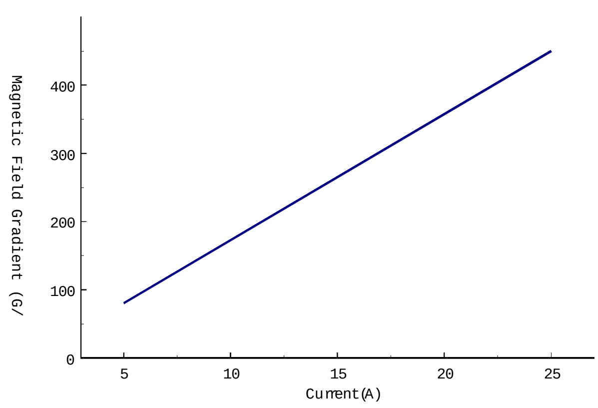

FIG. 6. The Magnetic Field Gradient from calculation

5 CONCLUSION

Injection system is an important part for CYCIAE type cyclotron. From our experience the machine works well once the injector system work well. To improve the machine some R & D job must be taken. A better ion source and a better designed injection line are to get higher beam intensity. Some experiences have been proved that the bottleneck of the machine is ion source and injection system since the magnet quality has ensured very little beam loss when the ion accelerated inside the cyclotron.

6 REFERENCES

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