BEAM TRANSPORT SYSTEM FOR THE INS 176CM SECTOR FOCUSING CYCLOTRON

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Abstract

Beam transport system of the INS SF Cyclotron consists of low, medium and high resolution courses. Magnetic field measurement was performed for all optical elements. Test of beam transport was done for all courses.

Using the $^{12}C(p,p)^{12}C$ resonances at 9.13 and 14.23 MeV, beam energy resolution was measured for the high resolution course, which consists of two dipole, two quadrupole, and two sextupole magnets.

1. Beam emittance

Emittance of the extracted beam from the cyclotron was measured. Measuring equipment consists of two narrow slits and an ionization chamber, which are drived by electrical motors and pneumatic cylinders. Widths and distance of these slits are 0.5 mm and 2m, respectively. Some results are shown in Figs.1 and 2. Measured emittances are about 15 and 25 mmmrad, for horizontal and vertical, respectively.

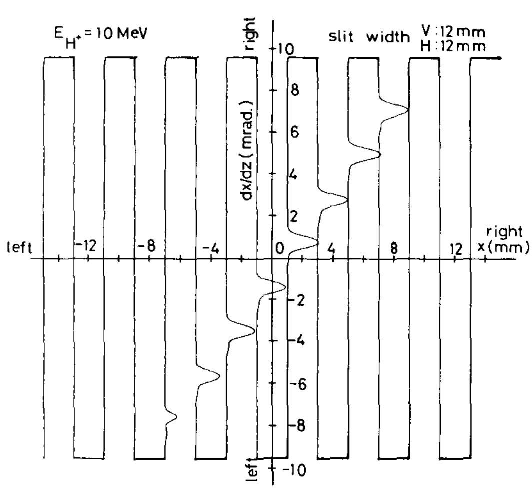

Fig.1 Horizontal beam emittance measurement.

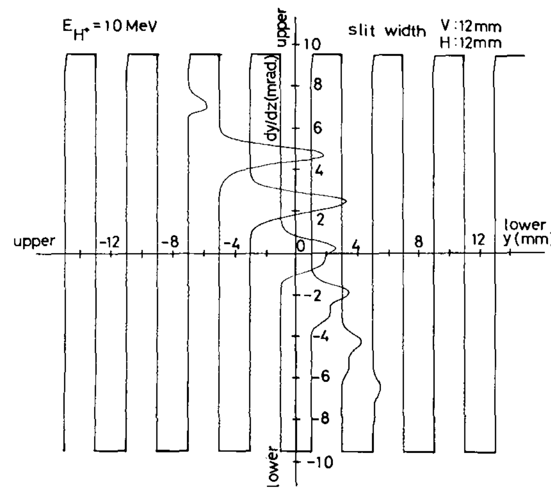

Fig.2 Vertical beam emittance measurment.

2. Beam transport system

The total layout is illustrated in Fig.3. Number of courses is 11: 2 low resolution courses in Cave-1, 5 medium resolution courses in Cave-2A &-2B and 4 high resolution courses in Cave-3A &-3B. Beam energy resolutions of high, medium and low resolution courses were designed as 10^{-4}, 10^{-3} and 10^{-2}, respectively. The design data of the magnets constituting the beam analyzing system are listed in table 1.

3. Beam analyzing system of high resolution courses

Beam analyzing system of the high resolution courses consists of two quadrupole and two dipole magnets. These are set in the order as QDDQ. This system can be operated in two modes, i.e. analyzing-cleaning or analyzing-analyzing system. A flat field, edge focusing type with equal entrance and exit angles was chosen for the dipole magnets because of a mechanical simplicity. The window-frame type structure was adopted, because compared with an ordinary H type magnet, it can produce a radially uniform field with higher degree of precision using

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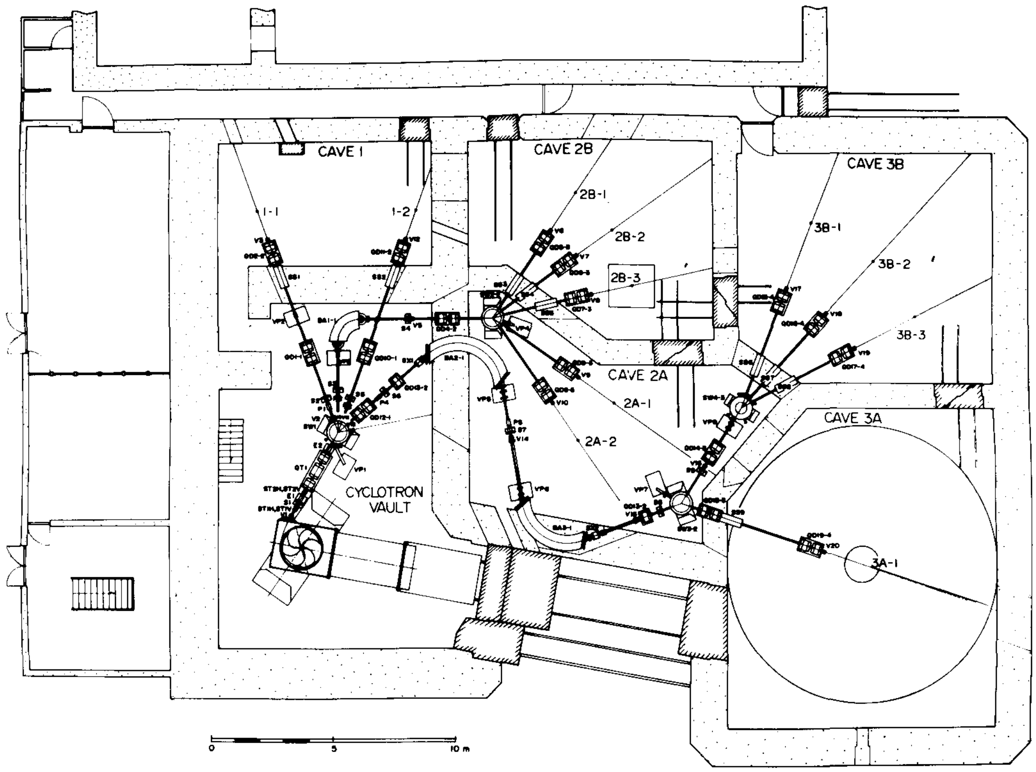

Fig.3 The layout of the beam transport system. Abbreviations are; V1=vacuum valve #1 : ST1H=steerer #1 horizontal : S=slit and stopper box : E=emittance measurement apparatus : QT=quadrupole triplet : VP=vacuum pump : SW=switching magnet : P=profile monitor : QD1-1=quadrupole doublet #1 operating on the power supply #1 : SS=shield shutter : BA=beam analyzer : SX=sextupole magnet : 2B-1=beam course #1 in the cave 2B.

much smaller weight of magnet steel. Magnetic field measurements were made in the median plane by a high precision measuring system using a Hall element. Figure 4 shows azimuthal variations of the field near the beam entrance end of the 120° magnet. The field shapes are almost identical at different radii. The effective position of the field boundary is estimated as 0.4 mm inside of pole edge. Figure 5 shows azimuthal scans of the field for the 120° magnet at several radii. The azimuthal variation of the field is about 4×10^{-4}, which is consistent with the value deduced from the mechanical precision of the magnet gap. Radial variation of the field, averaged azimuthally from the pole edge to the distance of 60 cm inside of the magnet, is within 1×10^{-4} as shown in Fig. 6. For the 100° magnet, similar field data were obtained.

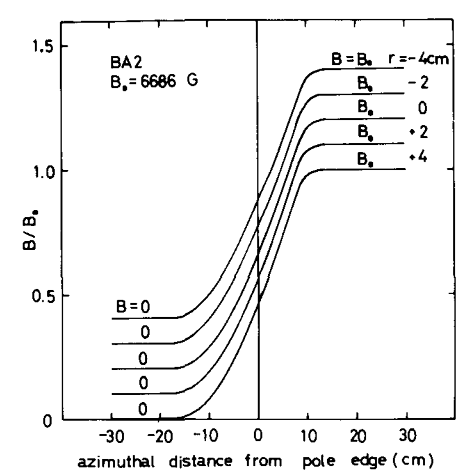

Fig. 4 Azimuthal variations of the magnetic field near the entrance of the 120° beam analyzing magnet. r is the radial distance from the central orbit.

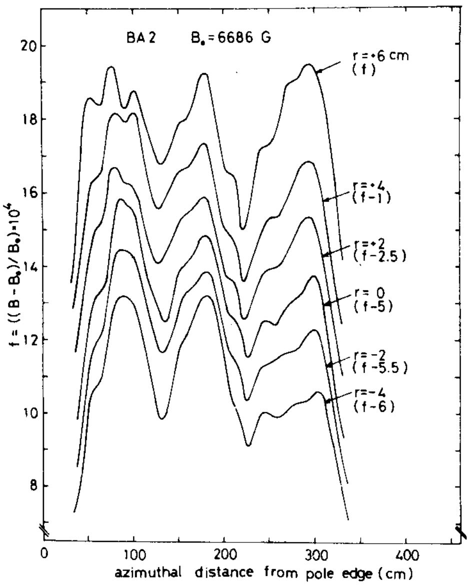

Fig. 5 Azimuthal variations of the magnetic field of the 120° beam analyzing magnet.

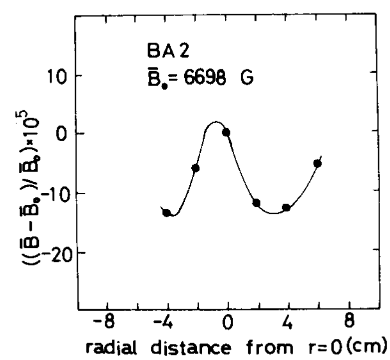

Fig. 6 Radial variation of the field, averaged azimuthally from the pole edge to the distance of 60 cm inside of the 120° magnet.

For the operation mode of analyzing-analyzing system, using entrance and exit slits of 1 mm, first order calculation gives $p/\Delta p \sim 29{,}000$, whereas second order calculation gives $\sim 23{,}000$ in the optimum condition using two sextupole fields.

4. Beam resolution test

Beam resolution test was performed using observation of the narrow resonance at 14.23 MeV in the excitation function of $^{12}C(p,p)^{12}C$. Widths of horizontal slits in s6 and s8 in Fig. 3 are 1 mm. Thickness of the carbon target was $\sim 8\mu g/cm^2$, which corresponds to ~ 0.2 keV of beam energy loss. Typical result is shown in Fig. 7. Measured ΔE is about 2 keV, which is somewhat larger than the calculated value, because of an effect of slit edge scattering (3 mm thickness of Ta). The transmission of this system (I_{s8}/I_{s6}), which is the current ratio of beam stoppers just after the slits of s8 and s6, was 2 % in this experiment.

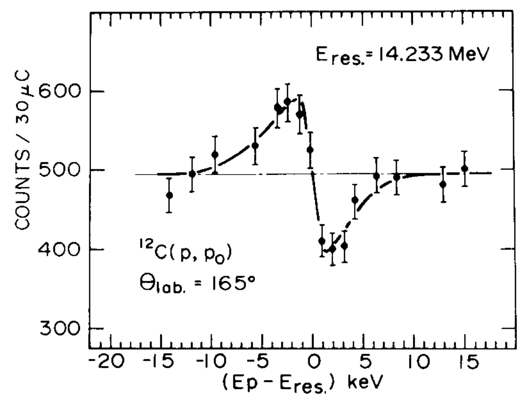

Fig. 7 Typical result of beam resolution test, using the resonance at 14.233 MeV in the excitation function of $^{12}C(p,p)^{12}C$.

Table 1. Design data of magnets for beam analyzing system

	BA1	BA2	BA3
Central radius(cm)	95	180	180
Deflection angle(deg)	90	120	100
Pole gap(cm)	4	5.6	5.6
Pole width(cm)	14	16	16
Parallelism between Poles(mm)	0.01	0.01	0.01
Entrance and exit-angle(deg)	26.4	40.9	30.8
Maximum field(KG)	13	7.4	7.4
Maximum ampere-turns	573A×96t	920A×36t	920A×36t
Maximum ampere-turns of correction coil	-	-	10A 32t
Maximum current density(A/mm^2)	7.2	7.95	7.95
Weight(ton)	3	5	4
Stability of current	$<1\times10^{-5}$	$<1\times10^{-5}$	$<1\times10^{-5}$