MAIN RESULTS OF THE MAGNETIC FIELD MAPPING FOR HIRFL SSC

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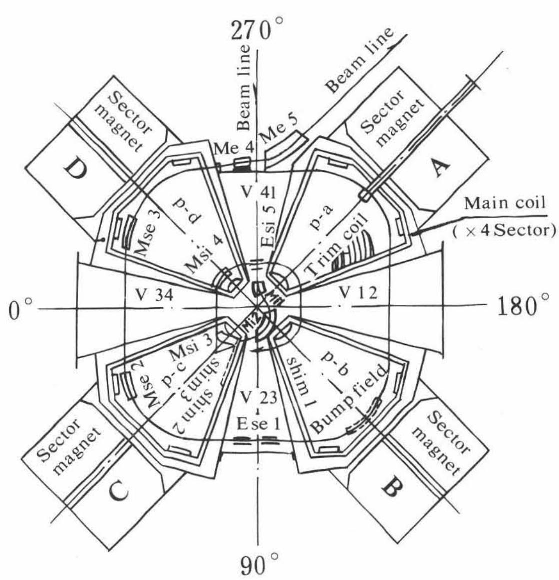
ABSTRACT

In this paper, the sector magnets, magnetic field mapping system and isochronization method are brifly presented, the main results of the magnetic field mapping are introduced.

1. SECTOR MAGNET SYSTEM OF SSC

1.1 Sector Magnet
Fig.1 gives a schematic mid plane view of the magnetic elements of SSC including injection and extraction devices.



The design and construction of sector magnet were already presented in international journal[1]. Let us brifly recall its main characteristics and give the functions of the coil power supply.

Injection mean radius is 1.00 m, extraction mean radius 3.21 m, magnet gap 10 cm and sector angle 52°. Pole profiles are used to obtain a ratio $\bar{B}ex/\bar{B}in\sim1.05$ at the field level of 16KG; 4 main coils, each having 48 turns, are used in series for 4 sectors, the max. current is 4000 A and corresponding voltage about 185 V, maximum amp. turns of the auxiliary coil is 2.5% of main coil maximum amp. turns; 4 trim coils, each having 36 pairs, are enclosed in tight boxes screwed on each pole face. Among them, 25 pairs are called isochronous coil in series for 4 sectors and others 11 pairs called correction coil individually sector by sector.
The specification of the power supply are given in Tab.1. DAC converters of 18 bit and 16 bit stabilized in the temperature of 40±0.1°C are used, the stabilities are better than $2x10^{-6}$/8h and $4x10^{-5}$/8h, respectively. Total number of power supply is 62, all of power supply are controlled by a microcomputer.

Table.1: Specification of the power supply

curr.(A)/ volt.(V)	stability/ 8h	adjusting precision	remark
4000/185	$5x10^{-6}$	$5x10^{-5}$	1 for m.c.
110/34	$1x10^{-4}$	$5x10^{-4}$	4 for a.c.
300/75	$1x10^{-4}$	$5x10^{-4}$	25 for i.c.
300/30	$1x10^{-4}$	$5x10^{-4}$	32 for c.c.

1.2 Magnetic Field Mapping System
The mapping system is almost the same as one used in the first sector measurement in 1983[2]. The measuring arm covers the radial distance from 840 to 3420 mm with 94 temperature controlled hall probes. The data is checked by a fitting method of Spline function. 4 NMR probes are used for the balancing of 4 sectors and monitoring the field stability. They are put on each sector axis at a given radius of 252 cm.

The calibration accuracy of hall probe by using NMR Gaussmeter is better than ±1 Gauss from 6 to 17 KG. The position accuracy of hall probe is about ± 1' in azimuthal direction, and ±0.5 mm in radial direction, the reproducibility of the field is about $\pm 1\times10^{-4}$. A 360° mapping with step of one degree takes about 5 hours.

2. ISOCHRONIZATION, MEASURING PROCEDURE AND MAIN RESULTS

The isochronization has been obtained by refering the method used at GANIL[3] and RIKEN[4]. The measurement was performed in the case that the vacuum chamber had been assembled with the sector magnets.

2.1 Excitation Procedure

The cycling of magnet was firstly studied in order to obtain a reproducible and fast stabilizing field distribution. The time chart for exciting the sector magnet is given in Fig.2, the reproducibility of the field distribution along the sector axis was found to be better than 3×10^{-4}. The time required to reach a stable field is about 2 hours for higher field levels and 3 hours for the lowest. The measurement of field stability was performed at the field level of 14 KG with a B-NM20 NMR gaussmeter. The stability of about 1×10^{-5}/8h was obtained (no feed back).

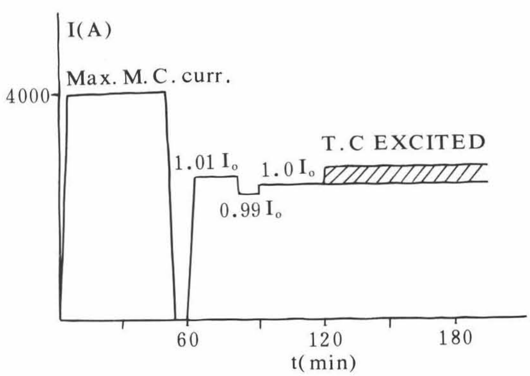


Fig.2: Time chart for exciting the sector magnet.

2.2 Unperturbed Field

No injection and extraction elements are present in these measurements. Before balancing of 4 sectors, the field distributions along each sector axis were measured at 7 field levels of 6, 10, 12, 14, 15, 16 and 17 KG, these field levels correspond to the main coil current of 1158.85, 1932.71, 2328.38, 2749.06, 2990.14, 3291.84 and 3735.68 A, respectively. The maximum difference of the field distributions along sector axis is 3×10^{-3} among 4 sectors. Fig.3 gives the field distributions along the sector axis for 4 sectors. After that, the measurement of the field map (360° field distribution) was carried out at above seven levels. Fig.4 gives the comparison among the mean field differences of the sector B, C and D minus sector A, respectively, it shows the differences of mean field to be less than 5×10^{-4} among 4 sectors.

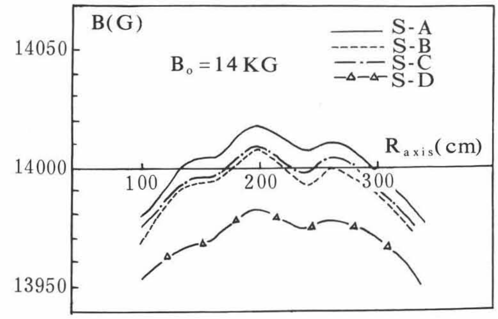


Fig.3: Unperturbed field distributions along the sector axis before balancing for 4 sectors.

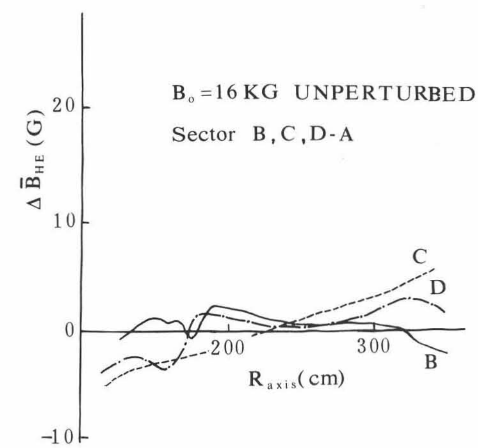


Fig.4: Comparison among the mean field differences of the sector B,C and D minus A, respectively.

Fig.5 gives 7 normalized field distributions along the sector axis, the maximum difference is less than 2×10^{-3} between Rin and Rex (cases Bo≤14 KG), it shows that the field homogeneity is satisfactory. The mean field distributions along the radius are given in Fig.6, it shows $\bar{B}ex/\bar{B}in \sim 1.05$ at the field level of 16 KG.

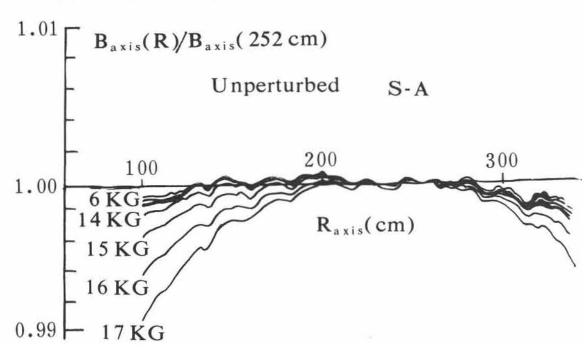


Fig.5: Field distributions along sector axis at 7 normalized levels.

The field distributions induced by correction coil were measured along the sector axis only for sector C at 7 field levels. 3 current levels of 80,160 and 240 A were chosen for each coil.

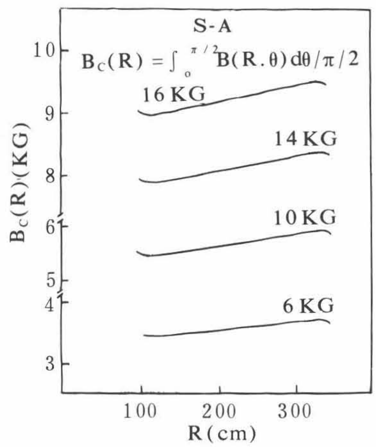


Fig.6: Mean field distributions along the radius.

2.3 Perturbation of Injection Elements and Shimming

The injection elements were taken their place in these measurements,the perturbations of Mi2 and MSI3 were compensated by a combination of plate shimming and pole profile modification (see Fig.1). Under this case,the field maps were measured at 7 field levels,the effects of the injection elements for each sector were obtained compared to the unperturbed one. Fig.7 gives the effects of injection elements for each sector on mean field at Bo=16 KG, it shows that the effects are still obvious and slight super-compensation near injection for sector B and C. Then,the effects have to be corrected on the mean field sector by sector by correction coils.

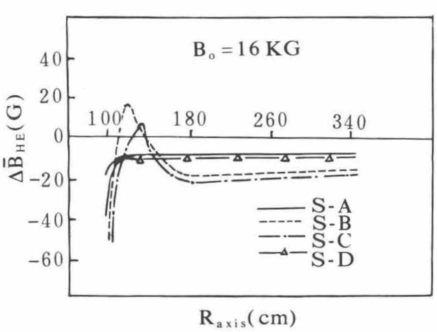


Fig.7: Effects of the injection elements for each sector after compensation by shims.

Fig.8 gives the remaining perturbations for each sector on the main field at Bo=16KG after correction by correction coils,it shows that the corrected results is satisfactory for sector A and D;there are still some remaining perturbations of 10-15 Gauss for sector B and C in the radial region of 130 to 150 cm,however the computer simulation harmonic field produced by them were found to be acceptable. The measuring results show that the perturbations of extraction elements can be neglected.

The measurement of isochronous coil contribution was performed along sector axis for sector-A at 7 field levels,4 current levels of -240,-120,120 and 240 A were chosen for each coil.

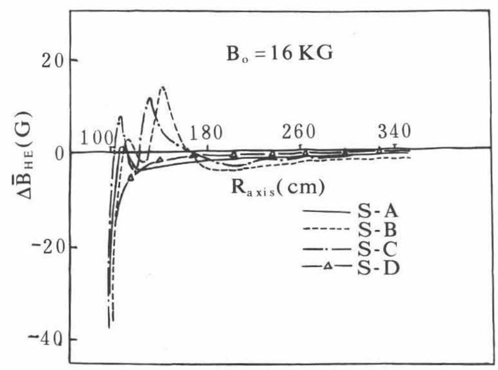


Fig.8: Remaining perturbations of the injection elements for each sector after correction by shims and correction coils.

2.4.Isochronous Field

By using above data,the extensive data Kb and Kr are calculated at 7 field levels. For a given ion (A,Q,frev) to be accelerated at the fundamental frequency frev,required isochronous field distribution along the sector axis and the optimum currents of main and trim coils can be calculated.

Fig.9 gives a typical measuring result of trim coil contributions. Kb and Kr functions of Raxis for 7 field levels are given in Fig.10. The isochronous field distributions along sector axis for 7 ions of C^{4+}-50,C^{6+}-88,N^{7+}-100,Ne^{8+}-22.5,Ar^{16+}-46 and U^{36+}-10 MeV/N were measured. The accuracies (difference between required and measured distribution)are 1-2‰ (no iteration),0.5-1‰ (1-2 times iterations),a typical result is given in Fig.11. Two isochronous field maps of C^{6+}-88 and Ne^{8+}-22.5 MeV/N were measured and the computer simulation acceleration is satisfactory.

An isochronous field distribution along the sector axis and the optimum coil currents for C^{6+} ion for the first beam experiment are given in Fig.12. We successfully obtained the first beam only adjusting the base field of 25 Gauss in the operation.

The optimization of the isochronous field was performed with 15 phase probes on the valley center line.

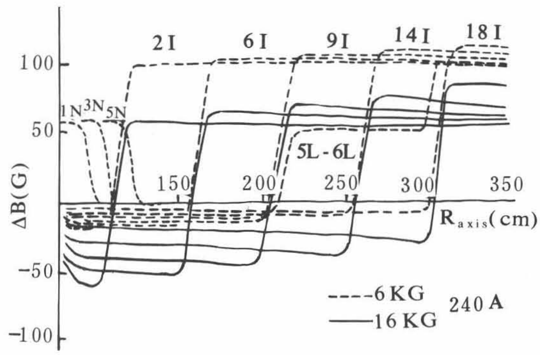


Fig.9: Trim coil contributions along the sector axis.

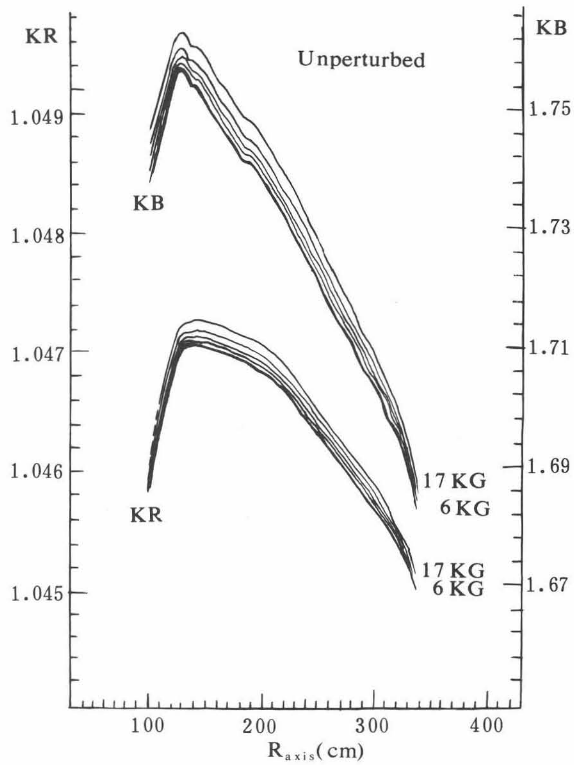


Fig.10: Kb and Kr values for the unperturbed field for 7 field levels.

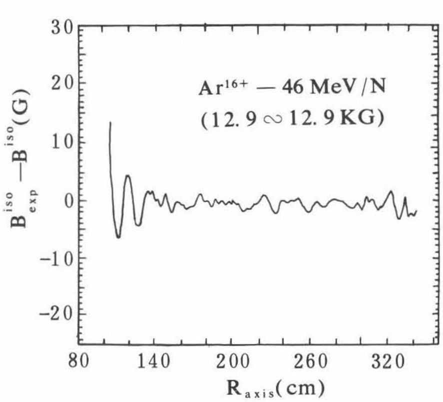
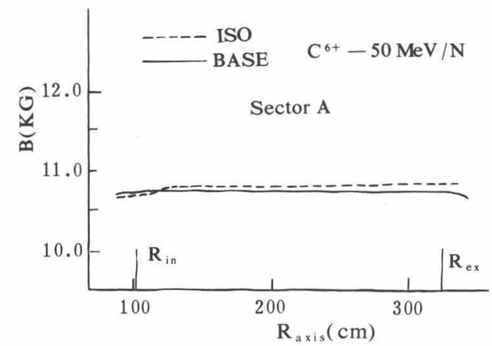


Fig.11: Deviation between the required isochronous field distribution along sector axis of Ar^{16+}-46MeV/N and measured one.



M.C.	2097.35A					
A.C.	0.00A					
I.C.	No	I(A)	NO	I(A)	No	I(A)
	1	0.00	10	14.16	19	14.53
	2	98.59	11	-4.65	20	-3.06
	3	25.23	12	-2.25	21	10.14
	4	-8.53	13	5.60	22	-12.15
	5	6.34	14	10.33	23	-3.68
	6	-4.42	15	14.68	24	71.38
	7	9.67	16	17.83	25	0.00
	8	8.57	17	49.11		
	9	26.43	18	13.57		
C.C.	1	107.56	5	-45.32	9	-27.00
	2	-90.03	6	-98.81	10	-31.55
	3	-90.03	7	42.89	11	-31.55
	4	-45.32	8	-27.00		

Fig.12: Isochronous field distribution along sector axis together with coil currents for C^{6+} ion.

References

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