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THREE-DIMENSIONAL TRIM COIL FIELD IN THE VINCY CYCLOTRON

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Трехмерное поле корректирующих концентрических катушек в циклотроне VINCY

Магнитное поле корректирующих концентрических катушек было получено с помощью трехмерного программного обеспечения. Представлено сравнение результатов 2- и 3-мерных расчетов. 3-мерные расчеты корректирующих концентрических катушек показали отличие в их радиальных градиентах по сравнению с 2-мерными расчетами. Также существует заметная зависимость вклада корректирующих концентрических катушек от уровня магнитного поля.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Three-Dimensional Trim Coil Field in the VINCY Cyclotron

The trim coil magnetic field in the VINCY cyclotron was performed with the help of the three-dimensional (3D) software. The comparison of the 2D and 3D trim coil calculation results are presented. The 3D calculations of trim coil show some difference in their radial gradients as compared with the 2D results. The noticeable trim coil response dependence on the magnet field level also occurs.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1996

1 Introduction

The trim coil field contribution obtained with a set of azimuthal 2D models is suspected of the possible systematic errors. The reason for that could be a rectangular form of the sector shims in the 2D models instead of theirtapered form in reality.

The purpose of this Note is to perform a cross-check of the 2D calculation for the trim coil field contribution. To this end the latest 3D magnet model, mentioned in [1], is used. Trim coil parameters for the 3D simulation are given in the Table and in Fig. 1 (see also Ref. [2]). The axial distance of all the coils from the midplane was 8.31 cm $\div$ 9.19 cm. The coil current was taken equal to 200 A. The three main coil currents have been chosen for calculations equal to 250 A, 600 A and 1000 A. The armco permeability table was used in the model.

Coil number	Inner radius, cm	Outer radius, cm	Number of turns
1	8.50	17.30	10
2	18.30	27.10	10
3	30.60	39.40	10
4	40.48	48.40	9
5	48.76	55.80	8
6	59.36	66.40	8
7	67.44	73.60	7
8	73.94	80.10	7
9	81.12	86.40	6
10	86.72	92.00	6

2 Calculation Results

The 3D calculations (VF TOSCA-OPERA-3D software) for the trim coil in the very center, in the middle of the radial range and near the final radius were performed. In Fig. 2 (dashed line is for the main coil current 250 A, solid line - for 600 A) and Fig. 3 (main coil current 250 A) the azimuthal averaged coil field contributions are shown.

There is quite noticeable trim coil response dependence on the magnet field level. The more saturation of the ferromagnetic elements, the less the trim coil field contribution occurs. Nevertheless, the deviation from the linear performance of the trim coil response on its current hardly appears when the current varies from 100 A to 200 A at the same main coil current value.

The comparison of the 3D calculations with the 2D results (Figs. 4 and 5) shows good agreement of both methods (dashed line is the 3D method, solid line - 2D method). But there is some difference in the radial gradients (3D gradients are

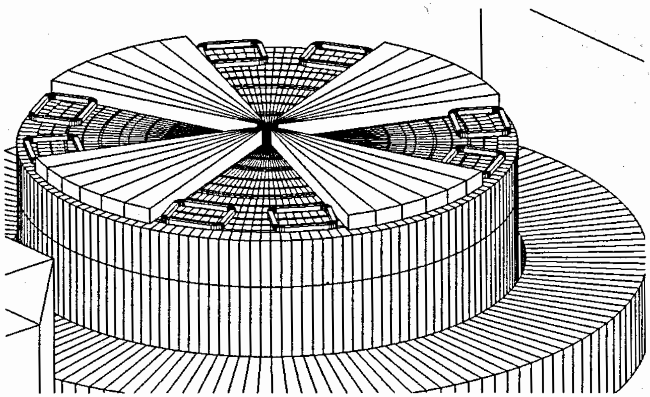

Figure 1: Layout of trim and harmonic coils

about 20 % less than the 2D ones), field values at 600 A (3D values are about 20 % less than the 2D ones) and the very center bump magnitudes.

The 3D nature of the calculations manifests itself in the azimuthal variation of the coil field response shown in Fig. 6 (X-axis: azimuth, degree; Y-axis: radius, cm; Z-axis: coil responce, Gauss) and Fig. 7 (X-axis: radius, cm; Y-axis: azimuth, degree). This effect causes distortion of the 4th and 8th harmonics due to the trim coils being on (Fig. 8 and Fig. 9). But modification these harmonics is rather small ($\leq$ 40 Gs) as compared with the tolerance, imposed by the beam dynamics.

Having in mind the above-said, one can ask: how optimal is the trim coil design, based on the 2D calculations only? Besides the difference in the trim coils responses and the 4th and the 8th harmonic distortions in the 2D and 3D methods there is also another factor, connected with the recently adopted field shimming concept. With the azimuthal shimming, the residual B-mean radial gradient became lower. So the number of trim coils, their radial positions and optimal currents to get isochronous fields should be at least revised.

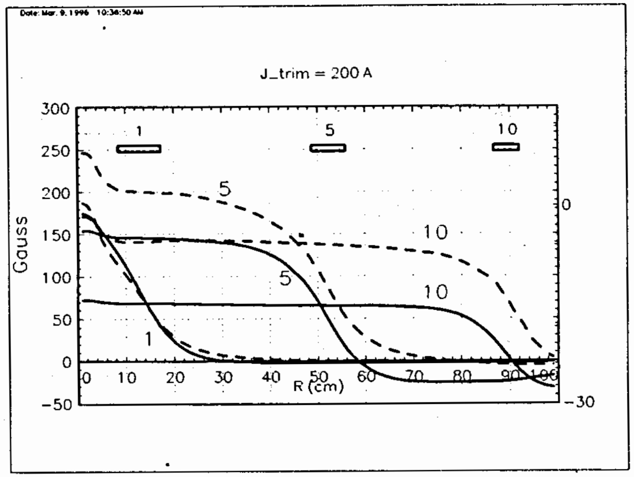

Figure 2: Mean field contribution from trim coils No 1, 5, 10.

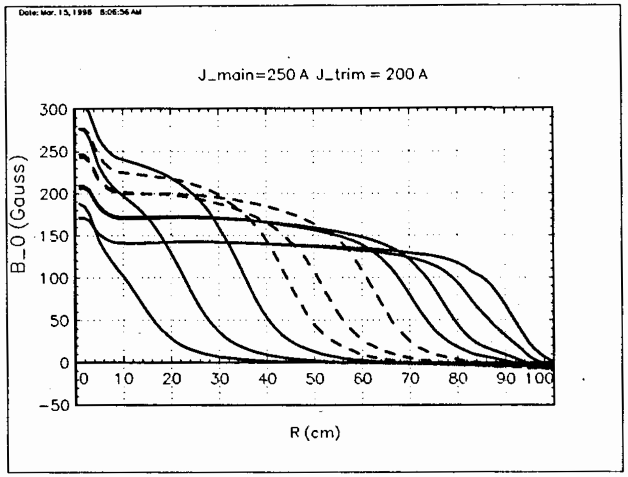

Figure 3: Mean field contributions from all the trim coils.

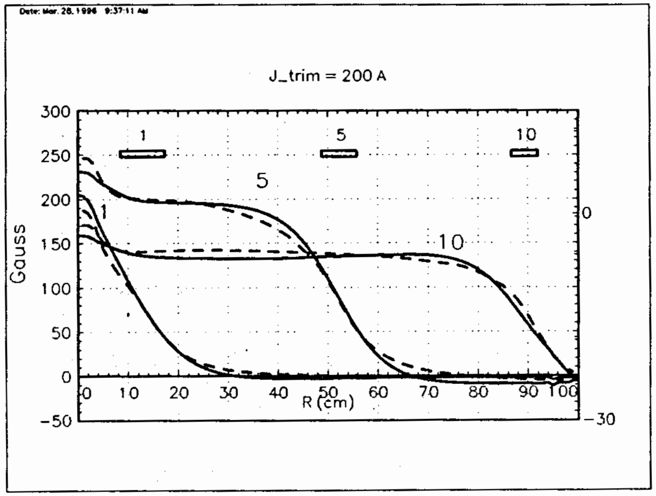

Figure 4: Trim coil mean field. The main coil current 250 A.

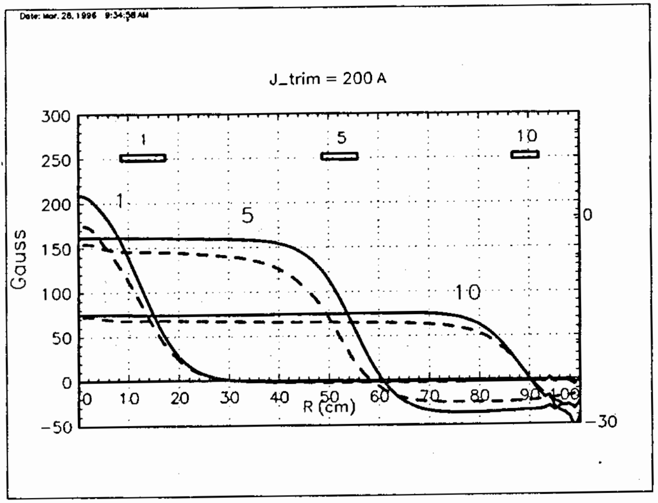

Figure 5: Trim coil mean field. The main coil current 600 A.

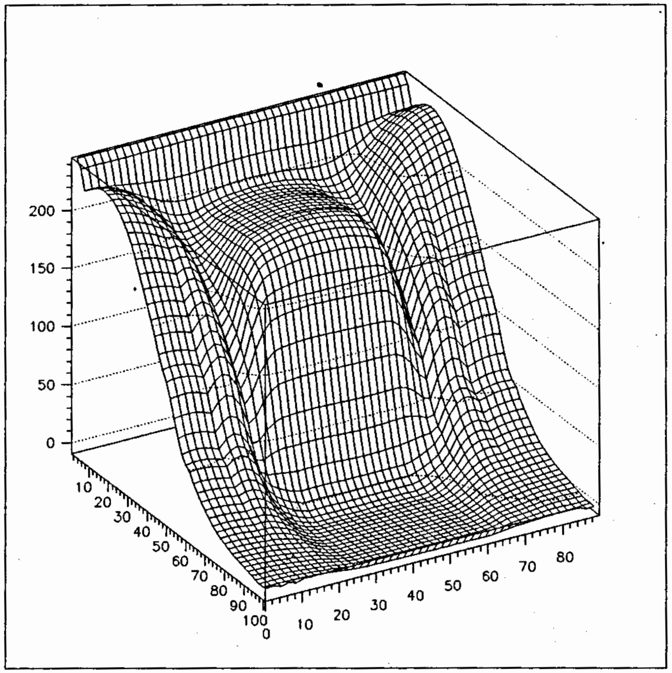

Figure 6: Trim coil number 5 field map. The main coil current 250 A.

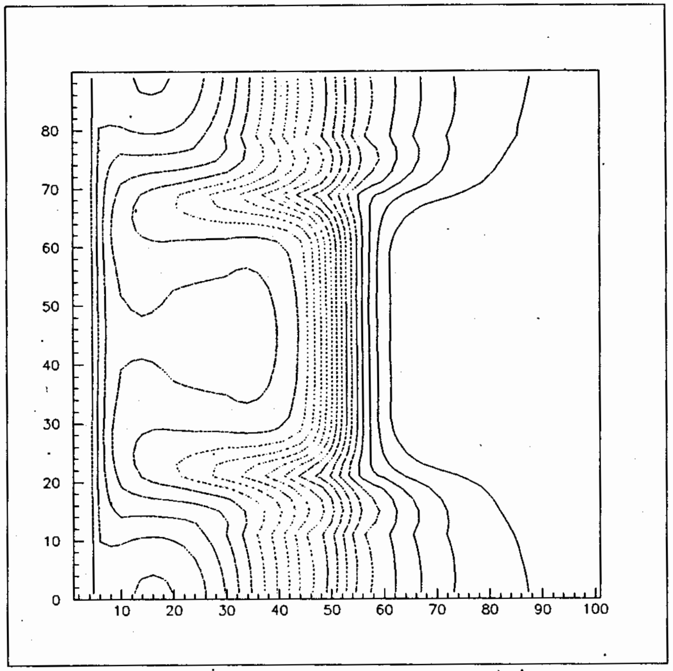

Figure 7: Trim coil number 5 field contour plot. The main coil current 250 A.

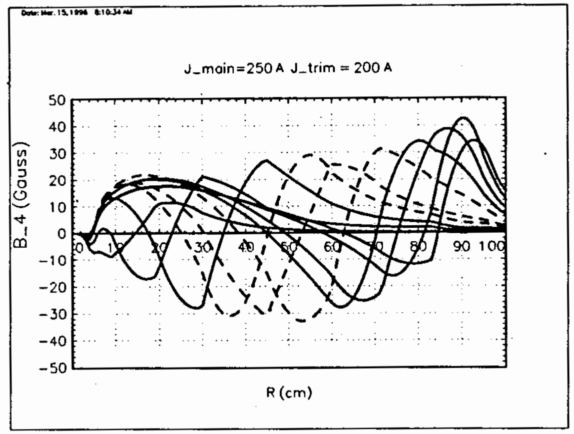

Figure 8: The 4th field harmonic distortion due to the trim coil contribution.

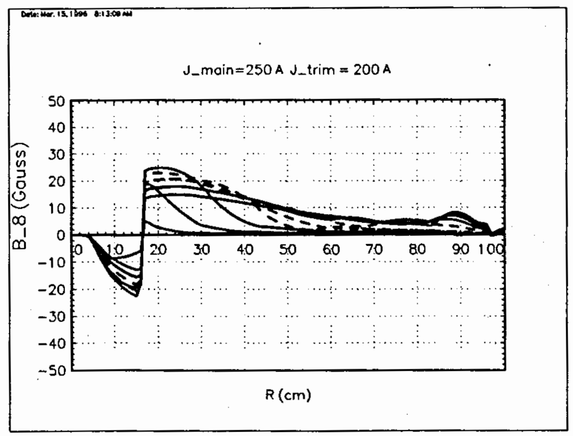

Figure 9: The 8th field harmonic distortion due to the trim coil contribution.

3 Conclusion

- The 3D calculations of trim coils show some difference in the their radial gradients as compared with the 2D results.
- The noticeable trim coil response dependence on the magnet field level also occurs.
- It is proposed to recalculate the optimal trim currents to get an isochronous field, using the 3D trim coil contributions.

References

[1] J. Franko, S.B. Vorozhtsov,D.V. Altiparmakov. "Comparison of the B-field Simulations and the Test Magnet Measurements for the VINCY Cyclotron". TESLA Acceleration Installation Report. December 7, 1995. Dubna - Belgrade.

[2] D.V.Altiparmakov. "Supplement I: Description of the Trim Coils of the VINCY Cyclotron". TESLA Acceleration Installation Report. June 30, 1995. Belgrade.

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