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COMPUTER ANALYSIS OF THE MUTUAL FIELD INFLUENCE OF THE SUPERCONDUCTING SECTOR MAGNETS

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COMPUTER ANALYSIS OF THE MUTUAL FIELD INFLUENCE OF THE SUPERCONDUCTING SECTOR MAGNETS

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Численный анализ взаимного влияния по магнитному полю секторных магнитов со сверхпроводящей обмоткой

В работе приведены результаты расчета магнитной системы циклотронной установки со сверхпроводящими обмотками. Расчеты выполнялись путем численного решения нелинейного интегрального уравнения относительно трехмерного вектора индукции магнитного поля. По ходу работы было обнаружено сильное размагничивающее влияние на данный секторный магнит со стороны соседних магнитов 6-секторной структуры циклотрона. В результате был сделан вывод о необходимости расчета полной структуры при проектировании магнитной системы.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Computer Analysis of the Mutual Field Influence of the Superconducting Sector Magnets

The results of calculation of the cyclotron magnetic system with superconducting coils are given. The calculations were performed using a solution of non-linear three-dimensional sector integral equation for the magnetic field induction. A strong demagnetization effect of the neighbouring sector of the 6-fold azimuthal cyclotron structure was observed. The final adjustment of the system parameters should be done for a total 6-sector structure.

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

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An employment of a cyclotron facility with superconducting sector magnets for accelerations of heavy ions up to an energy of 300-400 *MeV/nucleon* is under consideration now at the Laboratory of Nuclear Problems, JINR [1]. The calculations of mutual magnetic field influence of sector cyclotron magnet using a solution of non-linear 3-dimensional vector integral equation for the magnetic field induction are given here. The computer code MAGSYS was used for the calculation [2]. As it was shown earlier [2] the accuracy of the calculation can be about 0.5% for azimuthally mean field and about $4 \div 5\%$ for the flutter in the middle part of radial range of the sector magnet. For superconducting magnets in the field induction range 4-5 *T* due to strong saturation of iron the accuracy of calculation increases. *Figure 1* shows the calculational model of the sector magnet. The magnet body volume has been considered as a set of triangular prisms with an assigned magnetization value for every prism. Since for the superconducting magnet due to pole piece saturation the field contribution of sector coil amount to 40% of the total value it was only natural to evaluate a mutual field influence of the adjacent sector magnet. This is why in the calculation a single sector (*Fig. 1*) and three neighbouring sectors (*Fig. 2*) have been considered. *Figure 3* presents the results of the calculation. It can be seen that at the same coil excitation level for the 3-sector case the "hill" field is approximately by 1.6 *T* or by 40% lower than in the case of a single magnet calculation. The result obtained can be explained by the fact that only a part of the field flux goes through the magnet yoke. The main part of the flux in the 3-sector case is passing through the intersector space. The effect is distinctly seen on the example of the azimuthal field distributions given in *Fig. 4*. For a comparison the excitation level of 3 sector coils has been increased from

$JW_1 = 3.2 \cdot 10^6$ At to $JW_3 = 5 \cdot 10^6$ At. For the azimuthal field dependence with $R = 3.9$ *m* in the $\phi = 22°$- $30°$ range a negative field value is about 8 *kGs* or 20% of the "hill" field in the 3 sector case. But in the single sector case the field sign does not change inside a period of the 6-fold azimuthal structure. A "hill" field dependences versus coil excitation are given for 1 and 3 sectors at a radius of $R = 2.5$ *m* in the upper part of *Fig. 3*. A strong demagnetization effect of the neighbouring 2 sectors can be seen from these curves. This effect requires a corresponding increase of the coil excitation level to get a necessary azimuthally mean field value of the accelerator. In *Fig. 3* it is also seen that a magnet opposite to a given one introduces a noticeably less change of the maximum field. *Figure 5* shows the results of the field harmonic analysis in the case of an isolated sector and 3 sectors under the above said adjustment of the 3-sector excitation level. It appears (*Fig. 5*) that the flutter values on both cases differ by a factor of two nearly everywhere. The mean field curves also behave differently for the considered configurations of the magnetic system.

Having in mind the observed noticeable field influence of the neighbouring sector with the superconducting coils on each other it seems interesting to perform a comparison of the magnetic field of the full 6-sector system (*Fig. 7*) with the 3-adjacent sector system. *Figure 7* presents the results of this calculation under the same level of coil excitation. As can be seen from *Fig. 6* the difference between two cases for the flutter and mean field is in the range of 25% for $R > 2$m and is about 40% for smaller radii.

According to the results of calculation done in the paper one may conclude that the approximate parameter evaluation of the superconducting sector magnetic structure within above said accuracy limits 25%-40% is possible only for more than 3 adjacent sectors. The final adjustment of the parameters should be done for a total 6-sector structure.

For the calculation we used the parameters of the magnetic system reported in ref. /1/

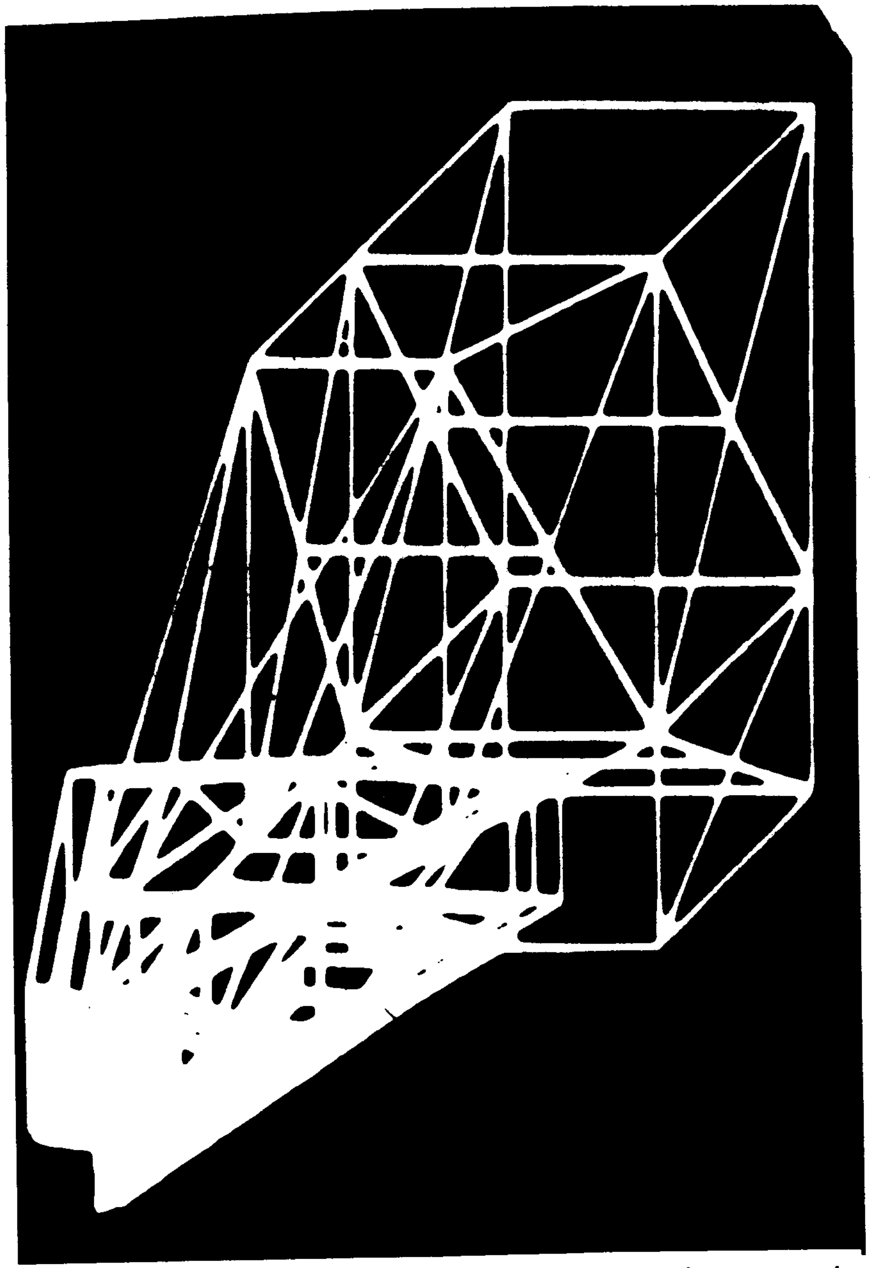

Fig. 1. A display representation of the sector magnet.

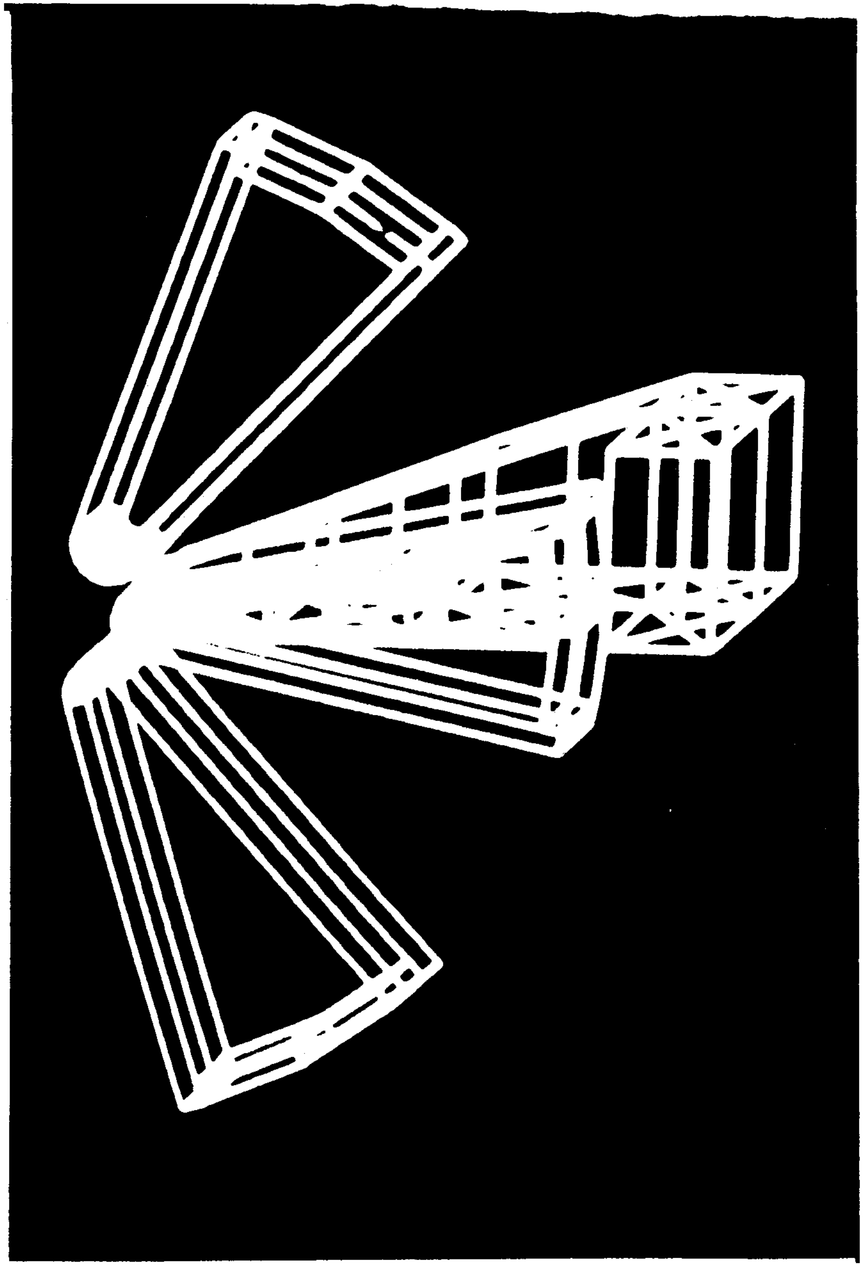

Fig. 2. Three sector magnets.

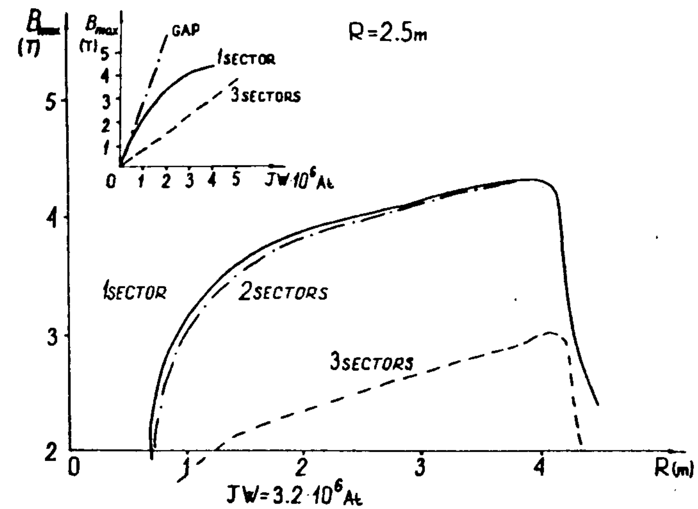

Fig. 3. A "hill" magnetic field.

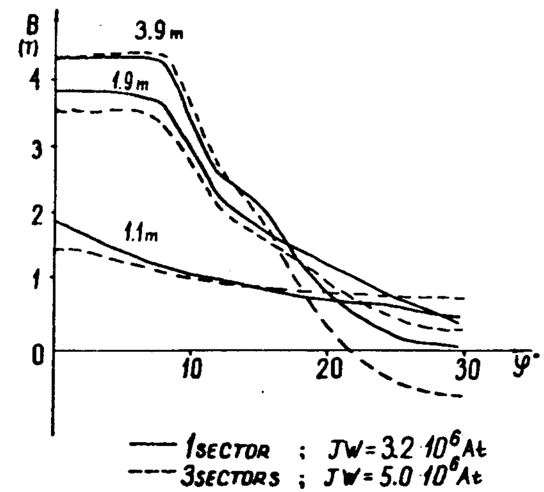

Fig. 4. An azimuthal distribution of the field.

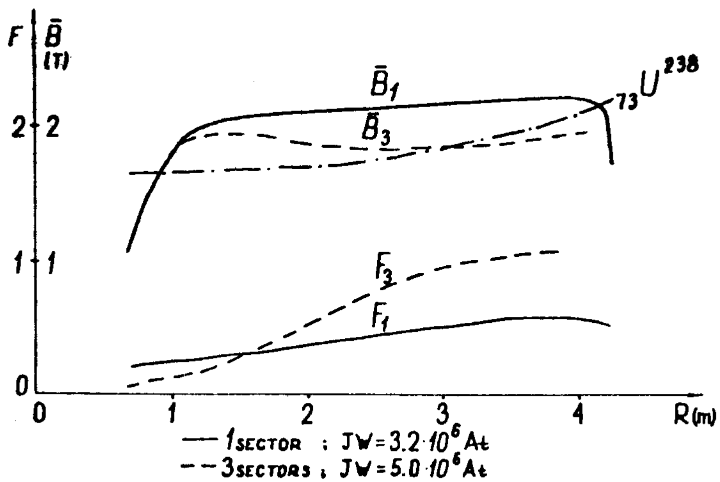

Fig. 5. A mean field and flutter (1 and 3 sectors).

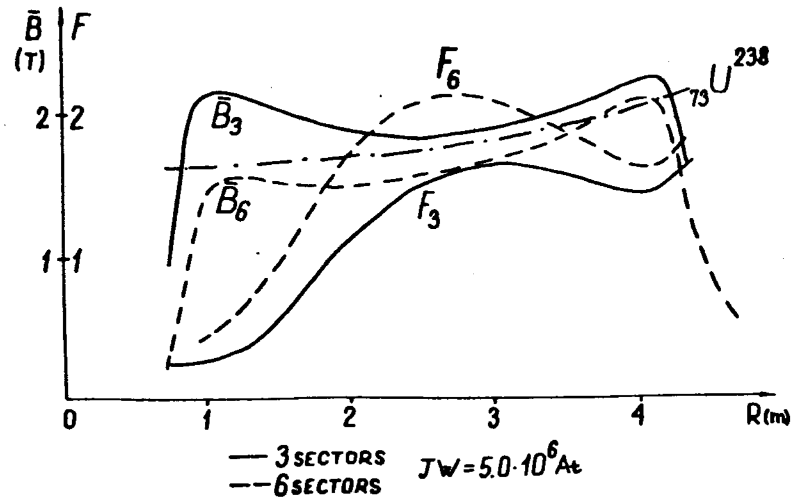

Fig. 6. A mean field and flutter (3 and 6 sectors).

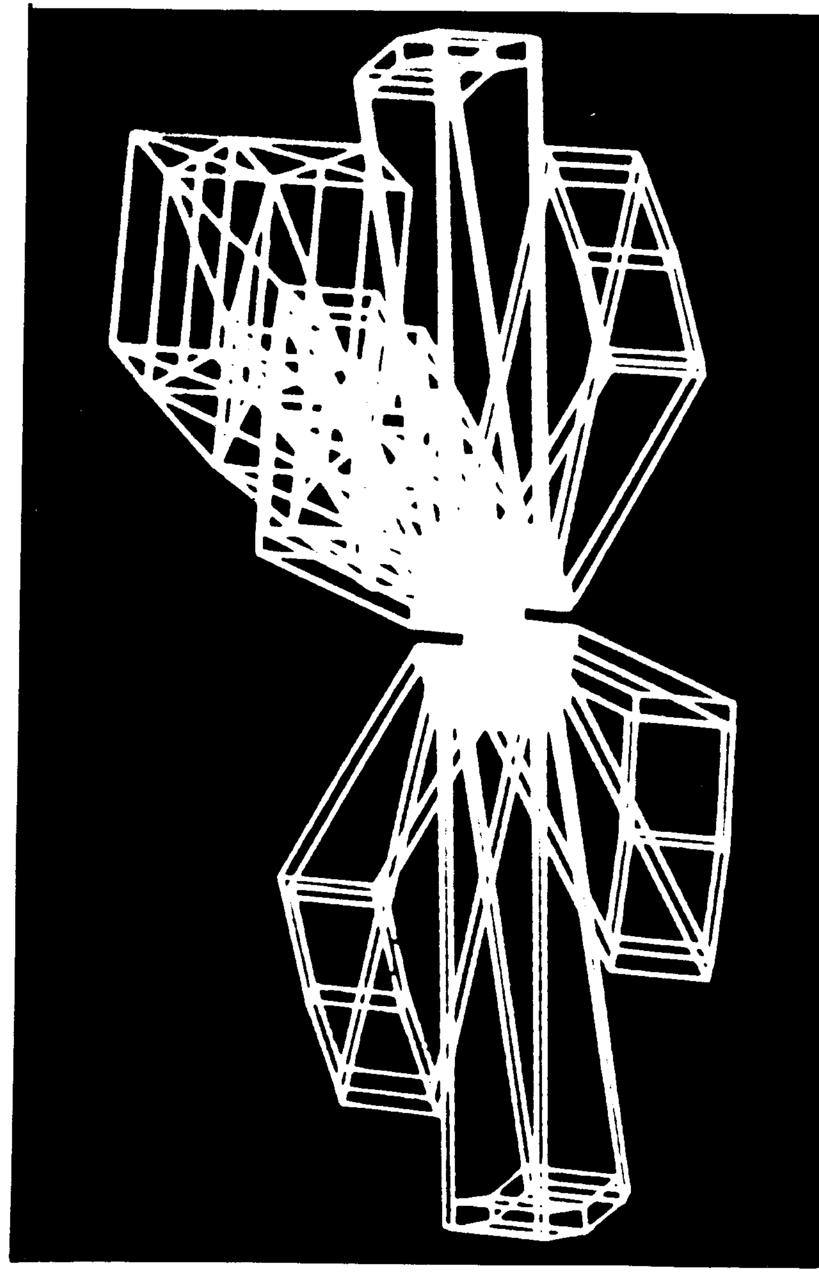

Fig. 7. Six sector magnets.

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