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The PHENIX Axial Field Magnets Effects and Correction

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1. Introduction

The possible linear orbit effects due to the PHENIX axial field magnet have been studied. The linear coupling effects due to PHENIX are considerably larger than those due to the STAR solenoid.[1] However, they are still small compared to the effects due to the expected random skew quadrupole field errors in the magnets. The skew quadrupole correctors provided to correct the effects due to random skew quadrupole field errors should be able to also correct the linear coupling effects due to the PHENIX axial field magnet.

The PHENIX axial field magnet appears to have stronger non-linear fields than the STAR solenoid. Tracking studies to check for possible non-linear effects appear desirable. While solenoids and axial field magnets have been used in previous accelerators, RHIC appears to be different as it requires a large aperture and has strong non-linear fields from the accelerator magnets. A method for describing the non-linear magnetic field of the PHENIX magnets, which is convenient for entering into a tracking program is described below. The tracking studies will require a more detailed knowledge of the PHENIX magnetic field shape.

2. Linear Coupling Effects Due to PHENIX

These results are based on the computed fields for the PHENIX magnets provided by T.K. Shea and S. White.[2] PHENIX has two axial field magnets. One, called the central magnet, is located at the beam crossing point. The second is called the piston magnet and is located further downstream from the central magnet.

The linear coupling effects may be estimated from the driving term, $\Delta\nu$, for the nearby difference resonance. $\Delta\nu$ is given by[3]

$$\Delta\nu = \frac{1}{4\pi\rho}\int ds\ (\beta_x\beta_y)^{\frac{1}{2}}\left\{a_1 - \frac{1}{2}\,c_0\left[\frac{\alpha_x}{\beta_x} - \frac{\alpha_y}{\beta_y} + i\left(\frac{1}{\beta_x} + \frac{1}{\beta_y}\right)\right]\right. \\ \left.\exp\left[i\left(-\overline{\nu}_x\theta_x + \overline{\nu}_y\theta_y\right)\right]\right\} \tag{2.1}$$

$$\overline{\nu}_x = \frac{1}{2}\left(\nu_x + \nu_y + p\right), \quad \overline{\nu}_y = \frac{1}{2}\left(\nu_x + \nu_y - p\right)$$

$$\theta_x = \psi_x/\nu_x, \quad \theta_y = \psi_y/\nu_y$$

ν_x, ν_y are assumed to be close to the resonance $\nu_x - \nu_y = p$. On the median plane, the fields are given by

$$B_x = -B_0\ a_1\ x \\ B_s = -B_0\ c_0 \tag{2.2}$$

where B_0 is the main dipole field.

For each of the PHENIX magnets, $\Delta\nu$, as given by Eq. (2.1), has a contribution from the center region due to the c_0 term, and a contribution from the edges due to the a_1 term.

For the c_0 term or center region one finds the contribution to $\Delta\nu$

$$\Delta\nu = \frac{1}{4\pi\rho}c_0\ L, \quad \text{center region} \tag{2.3a}$$

where L is the effective length of the magnet. For each edge, one finds the contribution to $\Delta\nu$

$$\Delta\nu = \frac{1}{4\pi\rho}\frac{\beta_x\ c_0}{2}, \quad \text{edge region,} \tag{2.3b}$$

using the result $\int a_1 d_s = -c_0/2$. The phase of $\Delta\nu$ has been omitted in Eq. (2.3).

Using Eqs. (2.3), one finds that the largest contribution to $\Delta\nu$ comes from the far edge of the piston magnet at $\beta^* = 2$ and this $\Delta\nu$ is computed to be

$$\Delta\nu = 3.5 \times 10^{-3}, \quad \text{PHENIX piston magnet} \tag{2.4}$$

This $\Delta\nu$ is about 10 times larger than that found for the STAR solenoid.[1] It is still small compared to the $\Delta\nu$ expected from the random skew quadrupole fields in the magnets which has an expected[4] maximum value for $\beta^* = 2$ of

$$\Delta\nu = 100 \times 10^{-3} \quad \text{magnets}$$

3. Possible Non-Linear Effects

In order to study the non-linear effects, the fairly complicated field of the PHENIX axial field magnets have to be entered into a tracking program. One solution is to enter the two PHENIX magnets as a set of point multipoles. Following the same procedure as was outlined for the STAR solenoid[1], each magnet may be represented by a set of point multipoles at each end to represent the transverse Br field, and the longitudinal field B_s is represented by one point multipole at the center of each magnet. It is suggested that B_r, which has only odd multipoles, have multipoles up to r^7 and B_s, which has only even multipoles, have multipoles up to r^6.

For B_s, one needs $\int B_s \, d_s$ over each magnet expanded in powers of r as

$$\int B_s \, d_s = B_0 \left(c_0 + c_2 r^2 + c_4 r_4 + c_4 r^4 + c_6 r^6 \right) . \tag{3.1}$$

For B_r, one needs $\int B_r \, d_r$ over each end of each magnet expanded in powers of r as

$$\int B_r \, d_s = B_0 \left(d_1 r + d_3 r^3 + d_s r^5 + d_7 r^7 \right) . \tag{3.2}$$

The c_n and d_n coefficients can be provided from either computer calculations or magnetic measurements. In addition, one needs a plot of B_s and dB_r/ds as a function of s at $r = 0$ in order to determine where the point multipoles should be located.

The tracking program will have to be modified to handle longitudinal point magnets.

Acknowledgments

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References

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