

## BNL-101760-2014-TECH RHIC/AP/105;BNL-101760-2013-IR

# The PHENIX Axial Field Magnets Effects and Correction

G. Parzen

August 1992

Collider Accelerator Department Brookhaven National Laboratory

## **U.S. Department of Energy**

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

### DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

## AD/RHIC/AP-105

### RHIC PROJECT

## Brookhaven National Laboratory

### The PHENIX Axial Field Magnets Effects and Correction

G. Parzen

August 1992

.

# The PHENIX Axial Field Magnets, Effects and Correction

#### G. Parzen

Accelerator Development Department Brookhaven National Laboratory July 1992

### 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.<sup>1</sup> However, they are still small compared to the effects due 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.<sup>2</sup> 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<sup>3</sup>

$$\Delta \nu = \frac{1}{4\pi\rho} \int ds \ (\beta_x \beta_y)^{\frac{1}{2}} \left\{ a_1 - \frac{1}{2} c_0 \left[ \frac{\alpha_x}{\beta_x} - \frac{\alpha_y}{\beta_y} + i \left( \frac{1}{\beta_x} + \frac{1}{\beta_y} \right) \right] \right\}$$

$$\exp \left[ i \left( -\overline{\nu}_x \theta_x + \overline{\nu}_y \theta_y \right) \right] \right\}$$

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

$$\theta_x = \psi_x / \nu_x, \quad \theta_y = \psi_y / \nu_y$$
(2.1)

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

$$B_x = -B_0 \ a_1 \ x$$

$$B_s = -B_0 \ c_0$$
(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  $\Delta \nu$ 

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

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

$$\Delta \nu = 3.5 \times 10^{-3}$$
, PHENIX piston magnet (2.4)

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

$$\Delta \nu = 100 \times 10^{-3}$$
 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<sup>1</sup>, 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

I wish to thank Tom K. Shea and Sebastian White for providing the computed field data for the PHENIX axial field magnets.

## References

n *U*.

- G. Parzen, Solenoid Effects and Correction in RHIC, BNL Report AD/RHIC/AP-102 (1992).
- 2. T.K. Shea and S. White, Field Maps of PHENIX Magnets, Memo to G. Parzen (1992).
- G. Guignard, The General Theory of Sum and Difference Resonances, CERN 76-06 (1976).
- G. Parzen, ν-Splitting Due to Random Skew Quadrupole Fields, BNL Report AD/RHIC/AP-72 (1988).

Tune Splitting in the Presence of Linear Coupling, Proc. 1991 IEEE PAC, p. 1615 (1991).