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Tracking studies in RHIC using measured magnet data

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1 Introduction

This note presents one approach to using the existing measured data for the field multipoles in Rhic magnets in doing tracking studies of the dynamic aperture. Using the measured data for the field multipoles is complicated by the fact that the multipoles required by the tracking program depend on how the magnets were installed, (on whether the beam enters the magnet at the lead end or at the non-lead end), and on how the magnet is excited, (on the direction of the excitation current)

The magnets are measured in a coordinate system which will be called the neasurement CS. This CS is defined below. The tracking program uses a coordinate system that will be called the tracking CS, and is defined below. In order to be able to find the multipoles in the tracking CS from the measured multipoles in the measurement CS, one needs to know whether the beam enters the lead end or non-lead end of the magent , and the direction of the excitation current. This data is given in several data files as described below.

2 The measurement CS

First, consider the measurement CS for a dipole. The vertical component of the field will be denoted by $\bar{B}_y$. It is defined as positive when it is in the up direction. Up and down are defined by gravity. The x and y coordinates will be denoted by $\bar{x}$ and $\bar{y}$. $\bar{x}$ is positive to the right of the magnet when looking at the magnet from the lead end. $\bar{y}$ is positive in the up direction.

The current excitation will be considered as positive when the $\bar{B}_y$ produced is positive to the right of the magnet, or for positive $\bar{x}$. The above definition of the measurement CS can also be used for a quadrupole, or a sextupole.

For a dipole, the measured field is related to the measured field multipoles by

$$\bar{B}_y = \bar{B}(1 + \bar{b}_1 10^{-4}(\bar{x}/R) + \bar{b}_2 10^{-4}(\bar{x}/R)^2 + \ldots) \quad (1)$$

$\bar{b}_1, \bar{b}_2 \ldots$ are the multipole as given in the measured data. R depends on the type of magnet and is roughly 2/3 of the magnet coil radius.

For a quadrupole, the measured field is related to the measured field multipoles by

$$\bar{B}_y = \bar{G}R(\bar{b}_0 10^{-4} + (\bar{x}/R) + \bar{b}_2 10^{-4}(\bar{x}/R)^2 + \ldots) \quad (2)$$

For a sextupole

$$\bar{B}_y = \bar{S}R^2(\bar{b}_0 10^{-4} + \bar{b}_1 10^{-4}(\bar{x}/R) + (\bar{x}/R)^2 + \ldots) \quad (3)$$

The above results are valid for a positive excitation. Results for either positve or negative excitation can be obtained by multiplying the right hand side in the above by the quantity *signcur* where $signcur = \pm 1$ depending on the sign of the excitation. $\bar{B}, \bar{G}, \bar{S}$ are defined to be always positive.

3 The tracking CS

In a tracking program it is often assumed that the beam goes around the accelerator in the counterclockwise direction. For protons, this requires that the main dipole field be in the down direction. This is true for the yellow ring in Rhic. For the blue ring, the beam circulates in the clockwise direction, and the main dipole field is in the up direction. In the yellow ring, x is chosen to be positive in the outward direction, away from the center of the accelerator. y is then positive in the up direction. In the blue ring, if one choses again to have x positive in the outward direction, y has to be positive in the down direction, as required for x, s, y to be a right handed CS.

Having defined the tracking CS, one can now find the field multipoles in the tracking CS from the measured multipoles. The results depend on whether the beam enters the lead end or the non-lead end of the magnet. This will be described by the quantity $flip$, where $flip = \pm 1$ and $flip = 1$ indicates that the beam enters at the lead end , $flip = -1$ the non-lead end.

The result also depends on the direction of the magnet excitation current which will be described by the quantity $signcur$, where $signcur = \pm 1$.

x and $\bar{x}$ are related by

$$\bar{x} = x\ flip \tag{4}$$

for the yellow ring, and by

$$\bar{x} = -x\ flip \tag{5}$$

for the blue ring.

In finding the field of a magnet in the tracking CS, it is helpful to treat $\tilde{B}_y = -B_y$ instead of B_y. $\tilde{B}_y$ is positive in the main dipole magnets in the blue ring and also in the yellow ring.

In the dipoles in the blue ring, $\tilde{B}_y$ is then given by

$$\tilde{B}_y = \bar{B}(1+\bar{b}_1 10^{-4}((-x\ flip)/R)+\bar{b}_2 10^{-4}((-x\ flip)/R)^2+\ldots)\ signcur \tag{6}$$

where $\bar{B}$ is the absolute value of the field at $x = y = 0$ and is always positive.

In the quadrupoles in the blue ring, $\tilde{B}_y$ is given by

$$\tilde{B}_y = \bar{G}R(\bar{b}_0 10^{-4}+((-x\ flip)/R)+\bar{b}_2 10^{-4}((-x\ flip)/R)^2+\ldots)\ signcur \tag{7}$$

In the sextupoles in the blue ring, $\tilde{B}_y$ is given by

$$\tilde{B}_y = \bar{S}R^2(\bar{b}_0 10^{-4}+\bar{b}_1 10^{-4}((-x\ flip)/R)+((-x\ flip)/R)^2+\ldots)\ signcur \tag{8}$$

The field multipoles in the blue ring tracking CS can be found in terms of the measured multipoles from the above equations provided $flip$ and $signcur$ are known for each magnet. The corresponding results for the yellow ring tracking CS are found by replacing $-x$ by x.

4 Comments on the tracking data files

The lattice in the blue ring is given by SXF (Standard eXchange Format) files on owl.rhic.bnl.gov. For the lattice with six $\beta^* = 10$ crossing points this file is

$$/rap/UAL/ual/ext/SXF/examples/codes/ual/in/rhic\_inj.sxf$$

For the lattice with two $\beta^* = 1$ crossing points this file is

$$/rap/UAL/ual/ext/SXF/examples/codes/ual/in/rhic\_storage.sxf$$

The quantity $flip$ for the magnets in the blue ring is given on a file called $flip\_table$ and this file is

$$/home/parzen/magd/flip\_table$$

On this file, $flip$ is listed as ± 1 for each magnet consecutively. $flip$ is given only for dipoles, quadrupoles and sextupoles.

The quantity $signcur$ can be computed for each magnet from the data on the .sxf lattice file, which lists the strengths of each magnet as $kl[0]$ for dipoles, $kl[1]$ for the quads and $kl[2]$ for sextupoles. For the tracking CS in the blue ring as defined here, the kl have the correct required sign of $\tilde{B}_y$ in each magnet. The $signcur$ can be computed from $sign(kl)$ as follows:

For dipoles

$$signcur = sign(kl[0]) \tag{9}$$

For quads

$$signcur = -sign(kl[1])\ flip \tag{10}$$

for sextupoles

$$signcur = sign(kl[2]) \tag{11}$$

The field multipoles have been measured for all the magnets in the lattice only for the case of warm magnets. This data for all the magnets has been gathered together on one file called $magwarm$ which is located at

$$/home/parzen/magd/magwarm$$

Using these three data files, $flip\_table, magwarm$, and the .sxf file, one can do tracking studies for the case of warm magnet multipoles.

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