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# Tolerance on ?? Fluctuations in the Dipole

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# AD/RHIC/AP-87

#### RHIC PROJECT

# Brookhaven National Laboratory

## Tolerance on $\Delta \theta$ Fluctuations in the Dipole

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#### Tolerance on $\Delta \theta$ Fluctuations in the Dipole G. Parzen

The fluctuation of  $\Delta \theta$  along the dipole increases the effective  $\Delta \theta$  to be used in computing the closed orbit effect. A result for the effective rms  $\Delta \theta$  is

$$\Delta \theta_{ef}^2 = \Delta \theta_{av}^2 + \Delta \theta_f^2 \left( \Delta(\sqrt{\beta})/2\sqrt{\beta}_c \right)^2 \tag{1}$$

 $\Delta(\sqrt{\beta})$  is the change in  $\sqrt{\beta}$  over L/2; L is the dipole length.  $\Delta(\sqrt{\beta}) = 1.5 \text{ m}^{1/2}$  in RHIC.  $\beta_c$  is  $\beta$  at the dipole center.

 $\Delta \theta_{av}$  is the rms average  $\Delta \theta$  in the dipole.

 $\Delta \theta_f$  is the rms amplitude of the  $\Delta \theta$  fluctuation around the average  $\Delta \theta$ .

For RHIC dipoles, above gives

$$\Delta \theta_{ef}^2 = \Delta \theta_{av}^2 + (0.15 \ \Delta \theta_f)^2$$

For  $\Delta \theta_f = 2$  mr, rms, the  $\Delta \theta_{ef}$  is increased from  $\Delta \theta_{ef} = 0.5$  mr rms to  $\Delta \theta_{ef} = 0.58$ , a 17% increase. The increase in the overall  $\Delta \theta_{ef}$ , including the survey error of 0.5 mr rms, is 10%.

 $\Delta \theta_f = 2 mr rms may be a reasonable choice for a tolerance on <math>\Delta \theta_f$ .

The above results assume a model where  $\Delta \theta$  along the dipole is as shown below:



Note, the tolerance on  $\Delta \theta_{av}$  would still be 0.5 mr rms.

The closed orbit error with this model can be computed from

$$\Delta y \sim \sum_{dipoles} \int ds \ \Delta \theta \ g(s)$$
$$g(s) = \sqrt{\beta} \ \cos \left(\pi \nu - (\psi - \psi_o)\right)$$

$$\Delta \theta = \Delta \theta_{av} + \Delta \theta_f \ f(s)$$

Assuming that  $\Delta \theta_{av}$  and  $\Delta \theta_f$  vary randomly from dipole to dipole, and f(s) has the shape in the above figure, then one derives the above result for the rms effective  $\Delta \theta$ .

A more accurate result than Eq. (1) for  $\Delta \theta_{ef}$ , which includes the effect of the variation in the betatron phase over the dipole, is the following

$$\Delta \theta_{ef}^2 = \Delta \theta_{av}^2 + \Delta \theta_f^2 \Bigg[ \left( \frac{\Delta(\sqrt{\beta})}{2\sqrt{\beta}_c} \right)^2 + \left( \frac{L}{4\beta_c} \right)^2 \Bigg]$$

The added term due to the phase variation can usually be neglected.