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The Dynamical Aperture of Booster

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THE DYNAMICAL APERTURE OF BOOSTER

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THE DYNAMICAL APERTURE OF BOOSTER

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ABSTRACT

We calculate the dynamical aperture of the booster with sextupoles due to chromatic corrections, eddy currents and the saturation at the high energy. The Dynamical aperture is found to be 93 mm for the eddy current at the injection and 110 mm for the saturation at high energy, which is considerably larger than the beam pipe dimension of 75 mm x 35 mm.

I) Introduction

The dynamical aperture of the BNL-AGS booster will be limited mainly by the sextupole magnet components. The conventional iron magnet is known to have very little high multipoles. At least it is not easy to use the multipole expansion technique to analyze the magnets. In this paper, we shall discuss the dynamical aperture due to the sextupoles in the booster. There are three sources of sextupole contributions in the booster: the chromatic sextupoles, the sextupoles due to the eddy current in the beam acceleration, and the sextupoles due to the saturation of the iron magnets. These sextupole strengths have been calculated in refs. 1-5). We shall evaluate the dynamical aperture due to these sextupoles.

II) The chaotic dynamical aperture(ref. 6)

The motions of the particles in the accelerator is governed by the Hamiltonian

$$H = \frac{1}{2}\left(\dot{x}^2 + \dot{y}^2 + \overline{b_1}\,x^2 + \overline{b_1}\,y^2\right) + \overline{b_2}\left(x^2 y - \frac{1}{3}y^3\right)$$

where $\overline{b_1}$ is the average focusing strength of the beam and $\overline{b_2}$ is the average sextupole strength that the particle experienced. These nonlinear elements are important in the chromatic correction and in the control of the coherent instabilities. This Hamiltonian is the well-known Henon-Heiles problem . The dynamical aperture can be evaluated to be

$$X_c = 266\ \overline{b_1}/\overline{b_2} \qquad (mm)$$

Using this simple scheme, we can estimate the dynamical aperture due to the sextupoles. The dynamical aperture is called the chaotic dynamical aperture.

III) Tracking calculation

A conventional method of defining the dynamical aperture is to use the beam tracking in the computer. We used two tracking programs , PATRICIA(ref.7) and ORBIT(ref.8). he tracking program can assess the aperture more correctly. By allowing the particle passing the booster 2500 turns, we obtain the dynamical aperture of 93 mm, which is considerably larger than the beam pipe dimension 75mmx35mm. The following parameter has been used in the study:

sf	=	.03588	/m^2	
sd	=	-.80131	/m^2	
B"(eddy)	=	.24	T/m^2	Tech note #4
B"(saturation)	=	-.284	T/m^2	Tech note #5

Table 1 lists the dynamical aperture of the booster with different options. We note that the dynamical aperture agree reasonably well with the tracking result for the case of eddy current contribution at the injection energy. Based on this agreement we shall point out that the dynamical aperture at the high energy is about 10% better.

The Chaotic Dynamical Aperature due to SEXTUPOLES

Lattices:	RHIC	BOOSTER		
		proton	rate*2.5	Heavy ion
B(Tesla)	3.4420	1.2000	1.2000	1.2000
RHO(m)	243.8800	13.9167	13.9167	13.9167
Ncell/arc	12.0000	4.0000	4.0000	4.0000
Phas.adv/cell	90.0000	72.4500	72.4500	72.4500
Phas.(rad)	1.5708	1.2645	1.2645	1.2645
L(m)/cell	29.6220	8.4075	8.4075	8.4075
Theta(bend)	0.0389	0.3491	0.3491	0.3491
L*Theta	1.1508	2.9348	2.9348	2.9348
Betamax	50.0000	13.5000	13.5000	13.5000
Q	28.8300	4.8300	4.8300	4.8300
Qcell	18.0000			
Chrom.(cell)	-24.0000			
Chrom.(tot)	-57.0000	-5.0000	-5.0000	-5.0000
circumf(m)		201.7800	201.7800	201.7800
Chrom. sext.	3.1416			
<B1>	0.0032	0.0226	0.0226	0.0226
<B2>c	0.0128	0.0498	0.0498	0.0498
enhance fac	1.4828	1.0000	1.0000	1.0000
<B2>	0.0190	0.0498	0.0498	0.0498
Aperture(mm)	45.1589	120.8508	120.8508	120.8508
TRACKINGS	48.0000			assume accel rate
System. Sext.				slower by fact. 3
sig.a2		eddy cur	eddy cur	eddy cur
sig.b2	3.2000	0.7800	1.9500	0.7800
<B2>systemat	0.0131	0.0320	0.0801	0.0320
<B2>tot	0.0231	0.0592	0.0943	0.0592
Aperture(mm)	37.1509	101.6381	63.8164	101.6381
		saturation	saturation	saturation
<B2>sat		0.0223	0.0223	0.0223
Aperture(mm)		110.3263	110.3263	110.3263
Random Sext.				
sig.a2	0.0499			
sig.b2	0.0499			
<B2>random	0.0003			
<B2>total	0.0231			
Aperture(mm)	37.1480			

IV) Conclusion

In conclusion, we calculated the dynamical aperture for the booster with the sextupole magnets. We found that the dynamical aperture is considerably larger than the booster beam pipe . Three methods give good agreement with each other. If the higher magnet error is small in the magnet, we have plenty of the aperture for the operation of the booster.

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