BNL-104655-2014-TECH

AGS/AD/Tech Note No. 232;BNL-104655-2014-IR

# Some Corrections for the AGS Booster

X. F. Zhao

January 1986

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.

Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Accelerator Division Technical Note

No. 232

# Some Corrections for the AGS Booster

X.F. Zhao, S. Tepikian, S.Y. Lee

January 29, 1986

## 1. Introduction

The AGS booster is important for the RHIC project, the AGS polarized proton project and the future upgrade of AGS projects. In this paper, we shall study some of the correction systems in the booster. Section 2 reviews briefly the booster lattice of Ref. 1 and Section 3 discusses the effect of the chromatic sextupoles. Section 4 discusses the depolarization resonance strength for the polarized proton and the closed orbit correction for random alignment error. The conclusion is given in Section 5.

Our study was performed in Nov.-Dec. 1985 prior to the Booster Task Force. A more updated study will be worked out by E.D. Courant. We feel however that our study may be useful. Thus we publish this as an AGS Tech. Note.

## 2. Booster Lattice

Figure 1 show the lattice function for the BNL Booster design. The betatron phase advance of each FODO cell is approximately 72°. Two missing dipole half cells are arranged[2] in the manner of easing the injection and extraction problems. The machine consists of six superperiods. The circumference of the Booster is 1/4 of that of the AGS. The betatron tune is $Q_x = Q_y = 4.75$. The systematic half integer stopbands at Q=3 and 6 are far away from the proposed operation tune. Figure 2 show the half integer stopband width[3] as a function of the betatron tune with 4 sextupole magnet (2 family) per superperiod. We observe that the half integer stopband width at $Q_x = Q_y = 4.75$ is 0.006, which is a rather small number. The stopband width (with 4 sextupoles/superperiod) depends strongly with the tune at $\nu \simeq 6$. However at the proposed operation point, the stopband width is small.

## 3. Chromatic Correction Sextupoles

Almost all modern accelerators have very elaborate chromatic sextupole correction schemes. Although the booster is a simple machine, one should investigate the implication of various sextupole correction schemes in detail. Figure 3 shows the tune and beta-function modulation as a function of momentum deviation of particles for two family of sextupoles (two variables SF and SD only) with one, two, three and four pairs of sextupole respectively. First, we note that the higher order effect is important for one pair of sextupole. With increasing number of pairs of sextupole, the momentum dependence becomes linear. Figure 4 shows the amplitude dependence coefficients of the betatron tunes, i.e. $\alpha_{xx} = \partial\nu_x/\partial\varepsilon_x$, $\alpha_{yy} = \partial\nu_y/\partial\varepsilon_y$ and $\alpha_{xy} = \partial\nu_x/\partial\varepsilon_y$ as a function of the betatron tune[4]. We observed that the present arrangement has a peak at $\nu = 5.4$. On the other hand, when four pairs of sextupoles are used, the singularity disappear. It is therefore preferable to have a sextupole next to every quadrupole.

The reason[5] for the peak of $\alpha_{xx}$, $\alpha_{xy}$ and $\alpha_{yy}$ at tune $\nu_x = \nu_y = 5.4$ is due to the fact that the dispersion function $x_p$ becomes negative at the $S_F$ location. The chromatic "focusing" sextupoles become defocusing. Therefore these coefficients, $\alpha_{xx}$, $\alpha_{xy}$ and $\alpha_{yy}$ are large.

## 4. Strength of Depolarizing Resonances

Figure 5 shows the spin depolarization resonance strength in the booster. Here we have assumed vertical misalignment of $\Delta Y \leqslant \pm\ 0.1$ mm and rotation angle error of $\leqslant \pm\ 0.1$ mrad for the calculation of the imperfection resonance strength. These random alignment errors give rise to an rms closed orbit error of 0.37 mm. A set of horizontal and vertical orbit dipole correctors are assumed to restore the rms closed orbit to within 0.2 mm (corrected to within 0.08 mm in the present configuration).

For a 10 cm long kicker with 10 cm magnet aperture, the maximum strength needed is about 76 Gauss. The number of the kickers needed is about 10 in the booster ring. When the alignment error is increased by a factor of 2 i.e., $\Delta Y \leqslant \pm\ 0.2$ mm and rotation angle of $\pm\ 0.2$ mrad, the strength of the kicker needed will be increased approximately by a factor of two. The number of correction kickers needed remain about the same. The rms closed orbit error is 0.76 mm and 0.15 mm before and after the local corrections.

The resonances that the polarized proton will see are $\gamma G = 2$ and 3. The polarized proton is accelerated through $\gamma G = 3$ with $\alpha = \Delta(\gamma G)/\Delta\Theta = 5 \cdot 10^{-6}$. The resonances strength of $10^{-4}$ (see Fig. 5) is below 1% depolarization. At $\gamma G = 2.15$, the injection polarized beam will be stacked for tens or turns. Following the Courant and Ruth[6], the depolarization effect of beam storage is proportional to $\|\varepsilon\|/\lambda \simeq 5 \cdot 10^{-5}/(2.15 - 2) \simeq 3.3 \cdot 10^{-4}$ (see eq.(37) of ref. 6), therefore the injection stacking will not harm the polarization of the beam.

## 5. Conclusion

In conclusion, we have studied some features of the correction scheme of the AGS Booster lattice at BNL. Although two pairs of sextupoles is adequate for the chromatic corrections, we found that 4 pairs of sextupoles per superperiod help (1) to reduce the higher order ($\geqslant 2$) contribution in the tune vs. $\Delta p/p$ variation and (2) to reduce the tune vs. betatron amplitude by a factor of 100.

When two pairs of sextupoles are used, the tune vs. amplitude coefficients depend strongly on the tune of the machine. This may suggest that 4 pairs of sextupoles would be more appropriate for the booster sextupole corrections.

We have also calculated the depolarization resonance strength for the polarized proton. With the proposed proton acceleration rate , the only resonance at $\gamma G = 3$ for the polarized proton operational range of the AGS booster gives little depolarization ($\leqslant 1\%$).

## REFERENCES


1. AGS Booster Conceptual Design Report. BNL-34989R

2. Y.Y. Lee, Private communication.

3. G. Parzen, Non-linear variation of the betafunction with momentum, BNL-51706.

4. A.A. Garren, A.S. Kenney, E.D. Courant and M.J. Syphers, A User's Guide to SYNCH.

5. E.D. Courant, to be published.

6. E.D. Courant and R.D. Ruth, The acceleration of polarized protons in circular accelerators, BNL-51270.

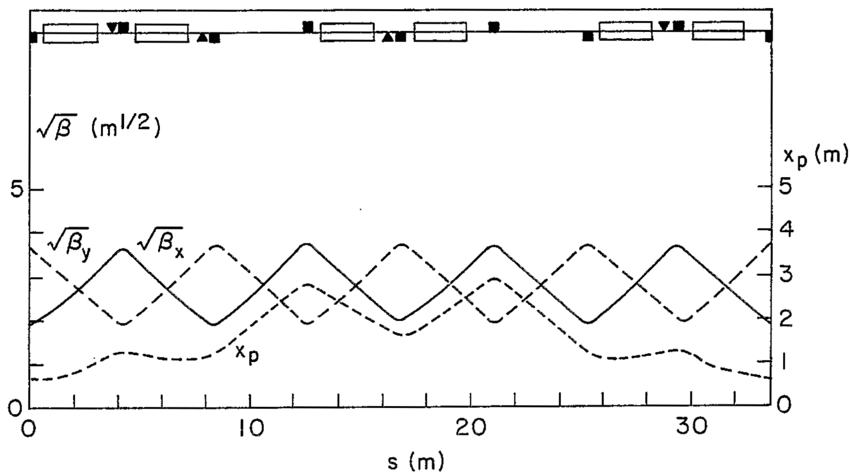


Figure 1. Booster lattice functions. The tune is $\nu_x = \nu_y = 4.75$. Superperiodicity equals to 6. Shown in the figure, $\nabla$ represents the sextupole location.

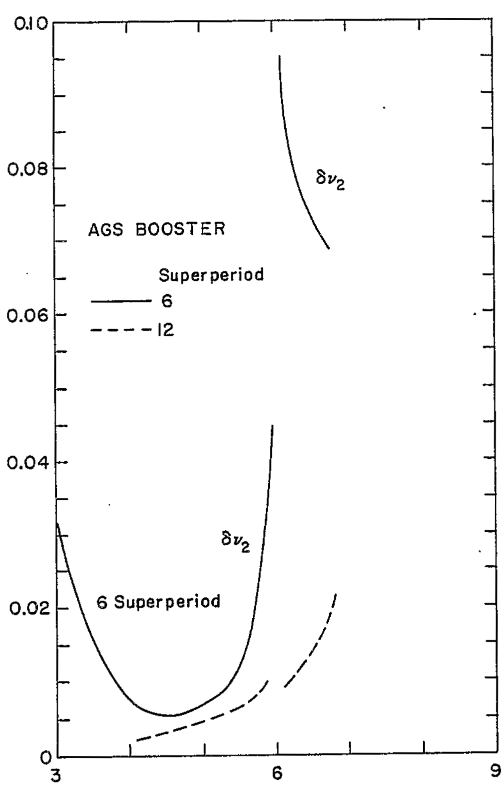


Figure 2. Half integer stopband width of the Booster as a function of tune at the operation point, $\nu_x = \nu_y = 4.75$. The width is about 0.0062.

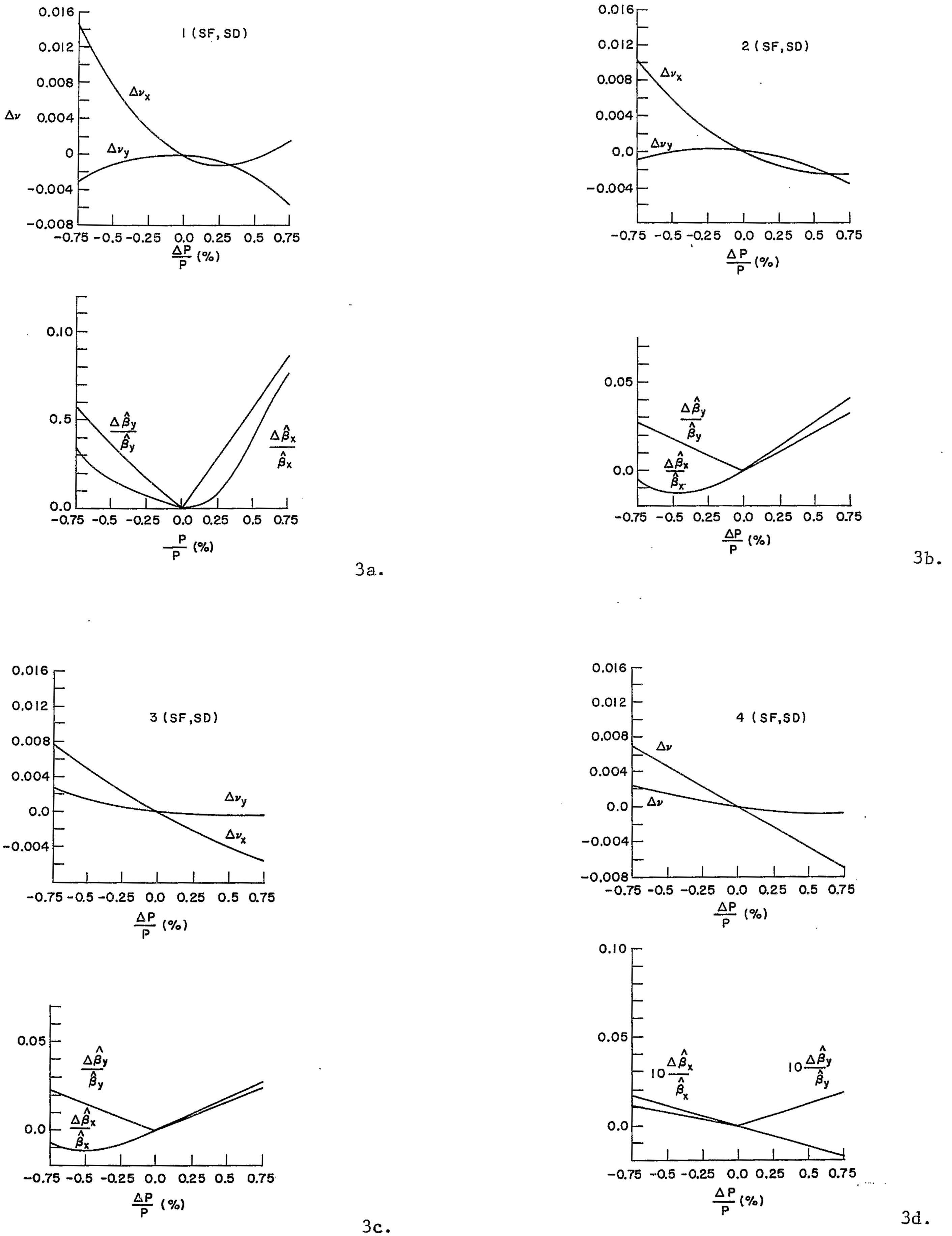


Figure 3. Tune and betatron function is momentum deviation is shown for (a) one pair, (b) 2 pairs, (c) 3 pairs and (d) 4 pairs of sextupoles per superperiod.

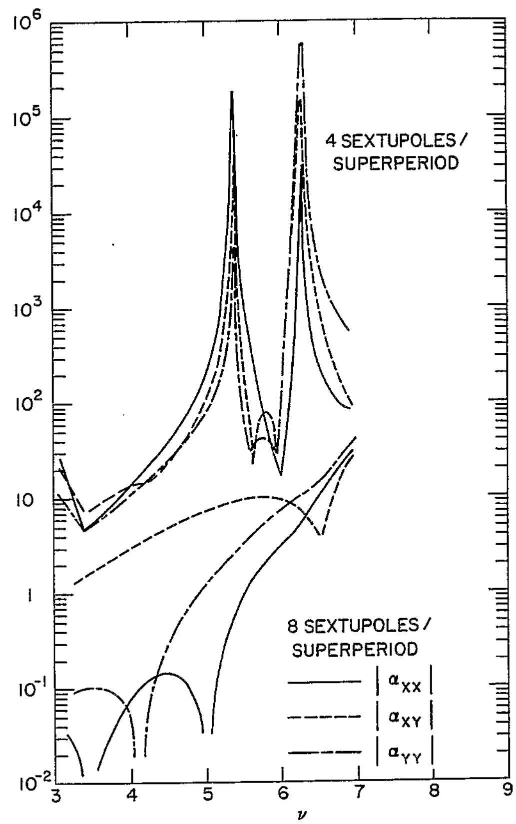


Figure 4. The amplitude dependence coefficient of the betatron tunes, $\alpha_{xx}$, $\alpha_{xy}$, $\alpha_{yy}$ is shown as a function of betatron tune for two family of sextupoles.

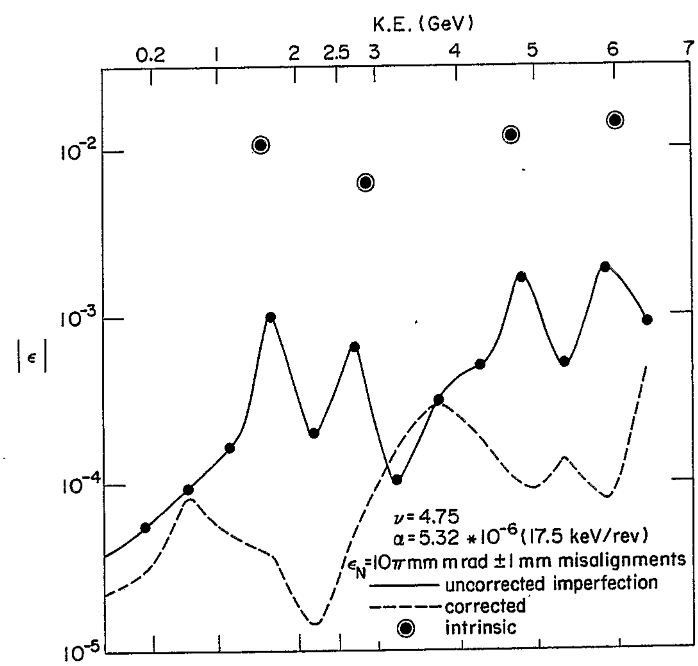


Figure 5. Spin depolarization resonance strength for the Booster. The only important resonance for the polarized proton is $\gamma G = 3$ resonance. The polarized protons will be injected at $\gamma G = 2.15$ and extracted at $\gamma G = 3.6$.