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ß Quad Excitation; ß Function Measurement

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Subject β Quad Excitation; β Function Measurement

Introduction

Correction of the β function distortion resulting from remnants effects in the magnets (due to the fact that the periodcity of the open and closed magnet gaps with respect to the backleg magnet yokes does not vary in step with the cell structure) can in principal be accomplished with the β quads located at straight sections 2, 8, 12, 18 in each superperiod.[1,2,3] This distortion is significant at 50 MeV, i.e. almost 25% at the number 5 and 15 straight sections in the horizontal and vertical planes respectively. At 200 MeV it should be of the order of 12%. Although the β quads were excited during the early part of the 1970's as part of the AGS conversion program, it was never established that they improved the operation of the machine. Therefore they were eventually ignored except for a brief period in 1977 when it was discovered that they introduced a vertical orbit distortion when they were powered. The reason for this was not investigated at the time and again they were forgotten.

Because the vertical β function distortion is greatest at the number 15 straight sections where the fast quadrupoles for the polarized proton project are located, and which in principal represent the limiting vertical aperture, it should be possible to gain additional vertical acceptance and hence potentially greater intensity by exciting the correction quadrupoles. It should also be noted that for heavy ions where the injection field is ≃ 95 Gauss, the correction is absolutely necessary.

In order to measure the β function and hence the distortion and its correction at one point in the lattice, one can use the fast quads themselves. The procedure is based on the fact that an individual quadrupole will produce a tune shift that is proportional to the β function at its location. The small amplitude expression is

$$\Delta Q = \frac{1}{4\pi} \beta_o \frac{\Delta(G\ell)}{B\rho},$$

where $G\ell$ is the integrated gradient length of the magnet and β_o is the local β function.

A more exact expression for large ΔQ is[4]

$$\beta_o = \frac{2\ B\rho}{G\ell} \frac{\text{Cos } 2\pi Q - \text{Cos } 2\pi Q_o}{\text{Sin } 2\pi Q_o},$$

where $\Delta Q = Q - Q_o$.

Observations and Discussion

The current required to obtain the correction calculated in Reference 2 is 5.6 amperes.[5] This requires a command of 2800 (4000=8 Amps) and the polarity is plus for elements 2 and 8, and negative for elements 12 and 18. There are eight separate supplies and hence magnet strings. The ring is divided in half and six 2's, 8's, 12's and 18's are in series for each string. When powered in this manner, some loss in beam intensity was observed. The chief reasons for this is shown in Figure 1 which is a vertical difference orbit taken near injection, i.e. (β quads on - β quads off). Similar differences in the horizontal plane showed no significant orbit distortion. This pattern is different than that seen in 1977 which was consistent with a single dipole perturbation. Here it seems that there are two or more perturbations. By taking differences with only a single string excited, it was possible to isolate the bumps to strings B-2 and B-12. Subsequent investigation on the ring located an external connection error at B-2 and what appears to be an internal, i.e. within the coil package error at E-12. Correction of the error at B-2 and temporarily bypassing E-12 resulted in the elimination of the vertical dipole perturbations.

Measurements of the tune shift produced by exciting the β quads were made before correcting the errors noted above. Although the direction of the shift is as expected from the results of Reference 2, they must be repeated when the E-12 unit is repaired in order to check the calculations.

In order to measure the β function at one of the number 15 straight sections, the fast quad at G-15 was employed. Currents of 100, 240, and 300 amperes were obtained by pulsing the unit with the low voltage supply only at ≈ 9 msec after injection. At 300 amperes some beam was lost, but not at 240 amperes. It was not possible to center the beam in the quadrupole since the orbit measurement system malfunctioned. Starting out at a vertical tune of 8.876, tune shifts of -0.027, -0.073 and -0.090 were measured at the currents given above. Based on the following calibration, $\Delta Q_V = 0.3$ for 540 Amps in 12 units at 4.48 GeV/c with $\beta_o = 22$ meters using the small amplitude expression, we find using the exact expression a $\beta_{15} = 1.386 \times 22$ M for the 300 ampere measurement and a $\beta_{15} = 1.42 \times 22$ M for the 240 ampere case. However, the observed tune changes were not corrected for any change due to an equilibrium orbit shift that could have been the result of powering the fast quad. Again, this could not be checked because of the orbit system failure.

The change of the tune change due to the fast quad when the β quads were brought on was also measured. This gave a check on the proper polarity of the β quads, but because of all the problems mentioned above, the uncertainty in the magnitude of the change was too great to give a useful result.

It is planned to repeat most of these measurements and in particular to measure the β function at as many of the number 15 straight sections as possible in order to check the superperiod symmetry of the AGS at injection.

References

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mvh

+2800, -2800

***** DIFFERENCE PLOT USING FILE VER *****
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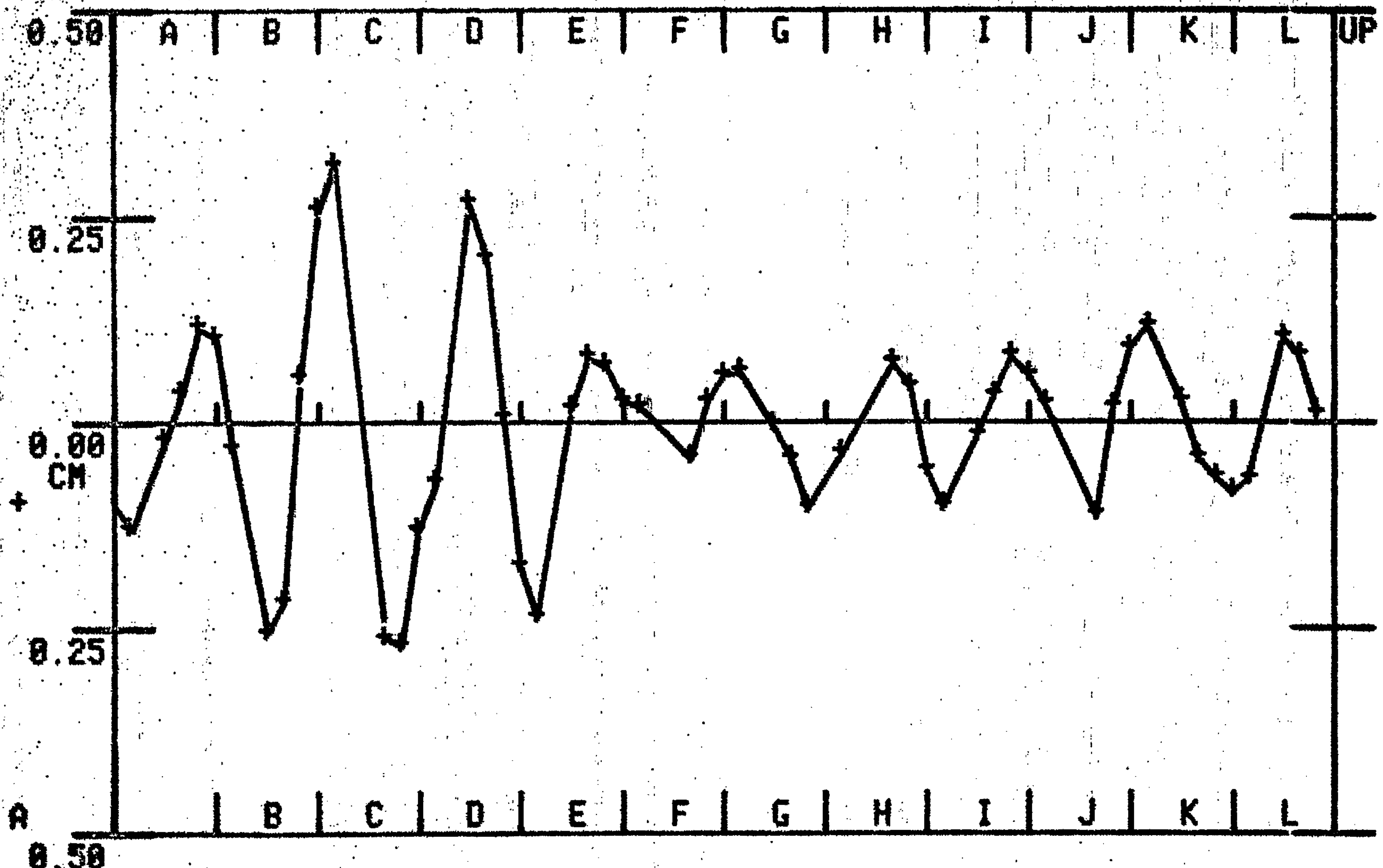

R(RESTART),E(EXIT),S(SAVE FILE),N(NO OUTPUT),L(LOOP),C(NORMC),<CR>(LOOP ONCE):