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Tune Measurement and Nu-Quad Calibration at H-and Heavy-Ion (08+) Injection Fields

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Subject Tune measurement and Nu-Quad calibration at H^- and Heavy-Ion (O^{8+}) Injection Fields

Observations and Conclusion

The purpose of these studies was (1) to determine the polarities of the Nu-Quad strings which are occasionally in question due to inadvertent reversal of power cables; (2) to establish the correct noninteger parts of the tunes for heavy ions (O^{8+}) spiraling in the AGS at injection; and (3) to obtain calibrations of the Nu-Quads at the H^- and heavy-ion injection fields.

The horizontal and vertical Nu-Quads are located in straight-sections 1,5,9,13,17 and 3,7,11,15,19 respectively and are used to adjust the AGS tunes at injection. Using the PIP (pulsed injection parameter) device the tunes and chromaticities at injection for spiraling protons and heavy ions (O^{8+}) were measured for various settings of the Nu-Quads. The results are summarized in tables I and II.

To obtain the tunes listed in Table I from the PIP data, we have assumed that the integer part of the tune is 8 and that the chromaticity is less than zero. Both of these assumptions have been verified by independent measurements and by the BEAM program. Once the sign of the chromaticity is known, the correct non-integer part of the tune and the correct chromaticity can be extracted from the PIP data. (The chromaticity is calculated by the PIP program using the known value of $\dot{B}$ at injection and the measured shift in the tune as the B-field is ramped.) Figures 1 and 2 are plots the data from Table I showing that as the NUQH counts become more negative the horizontal tune increases, and as the NUQV counts become more positive the vertical tune increases. This establishes the polarity of the Nu-Quad strings.

From the slopes of the lines fitted to the data points in Figures 1 and 2 we have the following Nu-Quad calibrations (for protons at injection):

$$\Delta \text{ (HORZ TUNE) / NUQH COUNT} = -2.22(8) \times 10^{-4}$$
$$\Delta \text{ (VERT TUNE) / NUQV COUNT} = 2.38(4) \times 10^{-4}. \quad (1)$$

These values are in good agreement with the values of -2.46×10^{-4} and 2.39×10^{-4}, respectively, calculated by the BEAM program. (The BEAM program uses field measurements of the Nu-Quads done by E. Jablonski and V. Buchanan, AGSCD Technical Note No. 128, August 24, 1971.)

To obtain the tunes listed in Table II we have assumed that the integer part is 8 and have used the polarity information from figures 1 and 2 to determine whether or not the non-integer part of the tune is greater or less than 1/2. Having established on which side of the half-integer the tune lies, the PIP data then yield the correct non-integer part of the tune and the chromaticity with the correct sign. Figures 3 and 4 are plots of the data from Table II. The slopes of the lines fitted to the data points yield the following Nu-Quad calibrations for O^{8+} at injection:

$$\Delta \text{ (HORZ TUNE) / NUQH COUNT} = -6.4(4) \times 10^{-4}$$
$$\Delta \text{ (VERT TUNE) / NUQV COUNT} = 5.8(9) \times 10^{-4}. \quad (2)$$

These values are in good agreement with the values of -6.9×10^{-4} and 7.0×10^{-4}, respectively, calculated by the BEAM program. We note that since the effect of the Nu-Quads scales as Q/pc where Q is the charge on the particle of momentum P, we expect the calibrations given in equations (2) to be a factor of $644/(1797/8) = 2.87$ larger than those in equation (1). Multiplying (1) by this factor we obtain -6.4×10^{-4} and 6.8×10^{-4} in good agreement with (2).

The maximum survival time for O^{8+} spiraling in the AGS during this study was 1.8 ms and was achieved with NUQH and NUQV set at -203 and 70 respectively. From Table II we see that this corresponds to an operating point in tune space with $\nu_H = 8.789$ and $\nu_V = 8.653$. The tune-shift per turn measured by PIP at this operating point was 1.9×10^{-3} in both the horizontal and vertical planes, which means that in 111 turns the horizontal tune will go through 9. Since the period of revolution for O^{8+} at injection is approximately 22 μs, 111 turns corresponds to 2.4 ms which is longer than the observed survival time for spiraling O^{8+} beam. We conclude that passage through the 9th integer resonance is not responsible for the observed beam loss at 1.8 ms. The loss is probably due to the beam crashing into the inner wall of the vacuum chamber as the B-field is ramped.

TABLE I

Measured tunes and chromaticities for protons of momentum P≃ 644 MeV/c spiraling in the AGS at injection.

AGAST COMMANDS NUQHB	NUQVB	PLANE	TUNE +/-.0050	CHROMATICITY
-800	1050	HORZ	8.7104	-1.3
-600	1050	HORZ	8.6741	-1.0
-400	1050	HORZ	8.6277	-1.0
-300	1050	HORZ	8.6026	-1.2
-200	1050	HORZ	8.5803	-1.1
0	1050	HORZ	8.5357	-1.0
0	250	VERT	8.7629	-1.0
0	450	VERT	8.8090	-0.9
0	650	VERT	8.8561	-1.0
0	850	VERT	8.9049	-0.9
0	1000	VERT	8.9409	-0.8
0	1050	VERT	8.9613	-
0	1650	VERT	9.0934	-0.9

NOTE: Beta-Quads were OFF
$\dot{B} \simeq 4.7$ Gauss/ms

Peaker: DICPK = 1105
DIFPK = 2877

TABLE II

Measured tunes and chromaticities for heavy ions (O^{8+}) of momentum P≃ 1797 MeV/c (Tandem at 13.5 MV) spiraling in the AGS at injection.

AGAST COMMANDS NUQHB	NUQVB	PLANE	TUNE +/-.0050	CHROMATICITY
-283	70	HORZ	8.8369	-1.0
-263	70	HORZ	8.8279	-0.7
-243	70	HORZ	8.8128	-0.9
-223	70	HORZ	8.8018	-0.7
-203	70	HORZ	8.7887	-0.8
-183	70	HORZ	8.7729	-0.7
-163	70	HORZ	8.7611	-0.7
-143	70	HORZ	8.7500	-0.7
-203	0	VERT	8.6100	-0.8
-203	20	VERT	8.6252	-0.7
-203	35	VERT	8.6298	-0.8
-203	50	VERT	8.6383	-0.9
-203	70	VERT	8.6526	-0.8

NOTE: Beta-Quads set at 2800
$\dot{B}$ ≃ 1.14 Gauss/ms

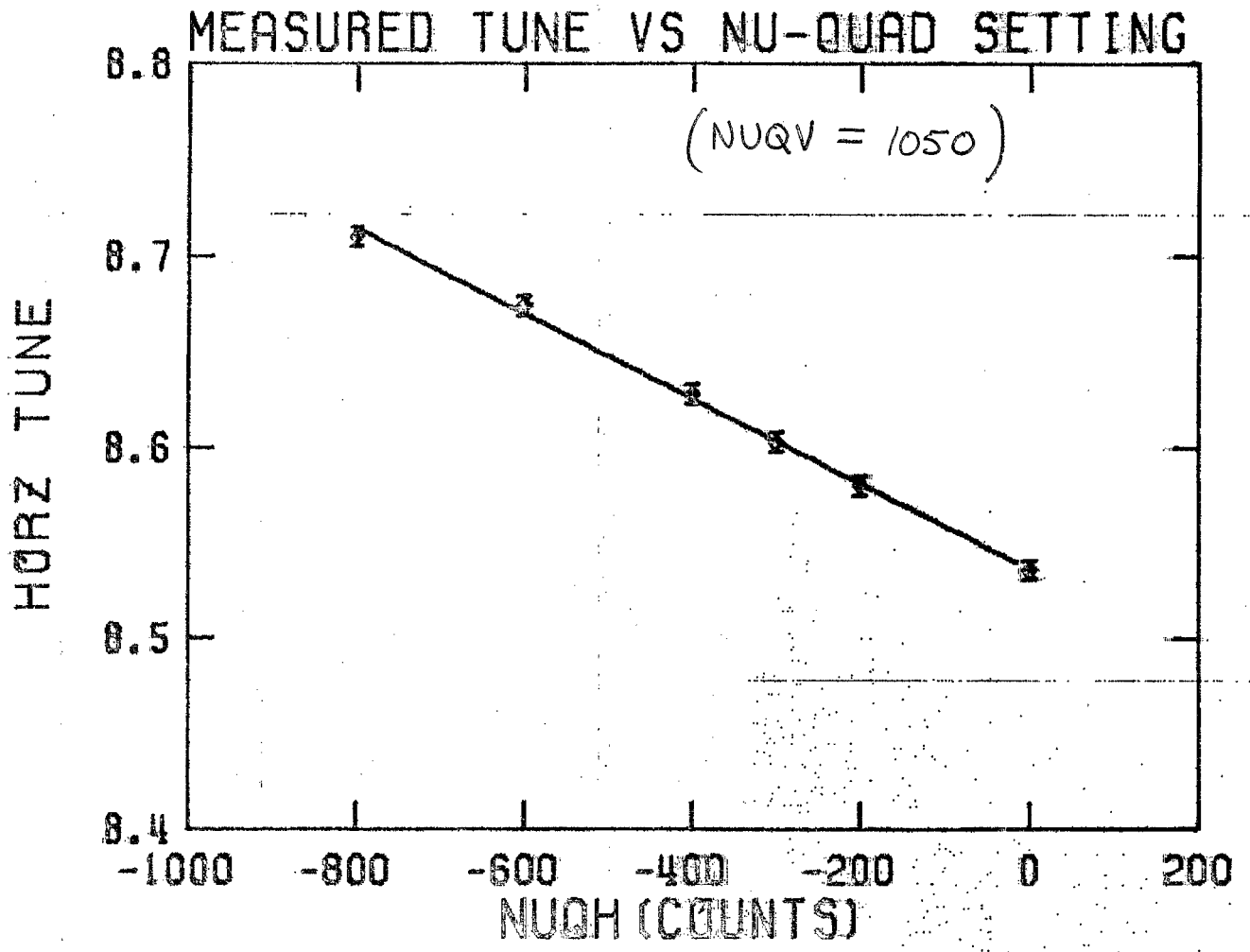
Peaker: DICPK = 81
DIFPK = 2655

NU-QUAD CALIBRATION FOR PROTONS AT INJECTION

SLOPE= -0.000222 +/- 0.000008

INTERCEPT= 8.536785 +/- 0.003628

Figure 1

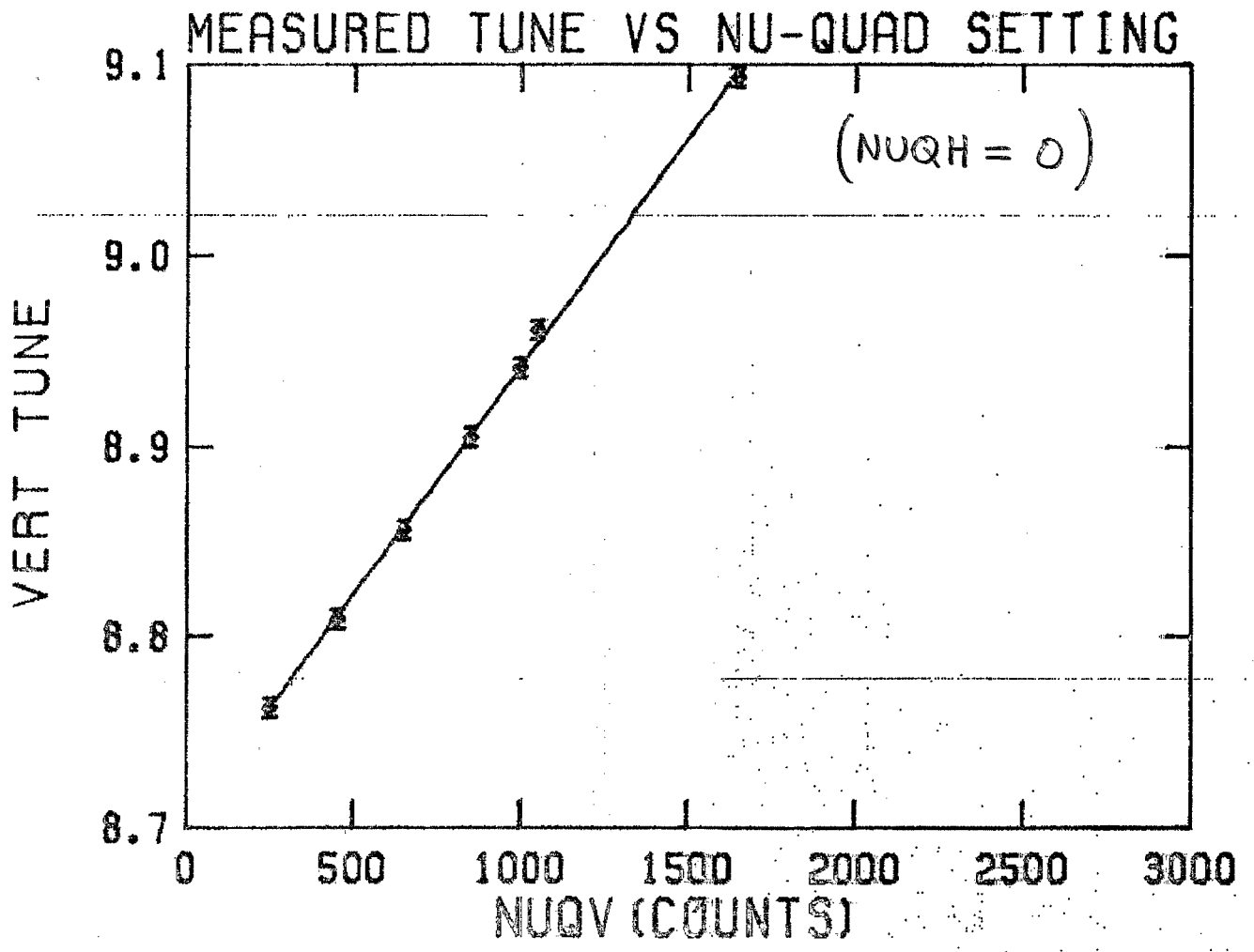


NU-QUAD CALIBRATION FOR PROTONS AT INJECTION

SLOPE= 0.000238 +/- 0.000004

INTERCEPT= 8.703225 +/- 0.004200

Figure 2

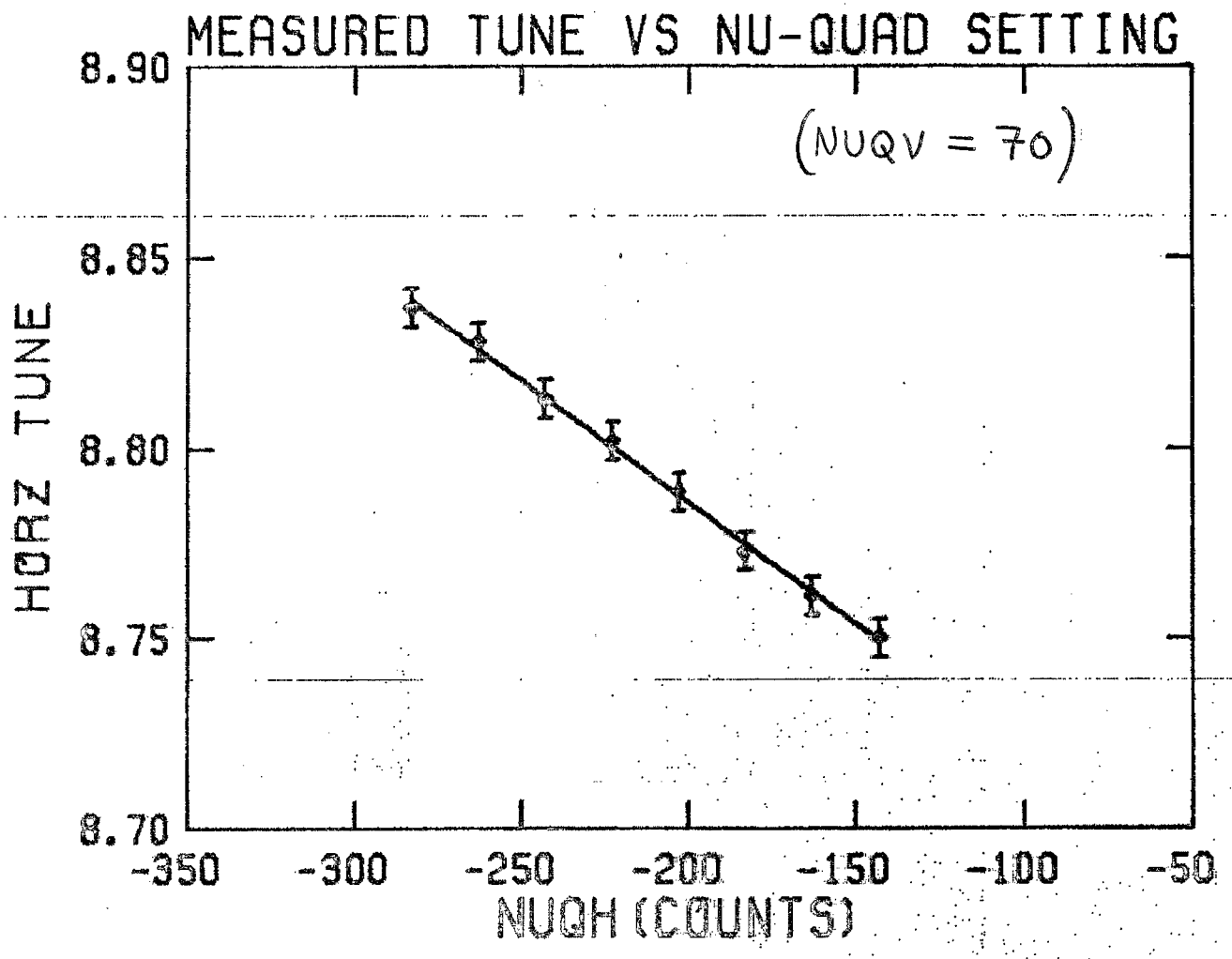


NU-QUAD CALIBRATION FOR O8+ AT INJECTION

SLOPE= -0.000640 +/- 0.000039

INTERCEPT= 8.657704 +/- 0.008405

Figure 3



NU-QUAD CALIBRATION FOR O8+ AT INJECTION

SLOPE= 0.000582 +/- 0.000093

INTERCEPT= 8.610813 +/- 0.003945

Figure 4