BNL-104102-2014-TECH

AGS.SN226;BNL-104102-2014-IR

Measurement of Chromaticity at H? Injection Momentum with aÿ D.C. Power Supply Connected to the Main Magnets

C. Gardner

June 1987

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

6/22/87

Number 226

AGS Studies Report

Date(s) June 7, 1987 Time(s) 11:00 - 1400

Experimenter(s) C. Gardner, E. Gill, W. van Asselt

Reported by C. Gardner

Subject Measurement of Chromaticity at H^- Injection Momentum with a D.C. Power Supply Connected to the Main Magnets

Introduction

The purpose of this study was to measure the horizontal and vertical chromaticities of the AGS with $\dot{B} = 0$, so that one can compare these measured chromaticities with those calculated by the BEAM and MAD codes at zero $\dot{B}$. (When $\dot{B} \neq 0$ eddy currents are set up in the vacuum chambers which produce sextupole fields in the machine. These fields contribute to the chromaticity one normally measures, making comparison with values calculated at zero $\dot{B}$ difficult.) Both the BEAM and MAD codes use in their calculations information provided by detailed maps (made by R. Thern) of the static magnetic field in the midplane of the AGS magnets, and should give accurate results for the calculated chromaticities at zero $\dot{B}$. Measurements of the chromaticities at zero $\dot{B}$ provide a useful test for the validity of these codes.

Procedure

To achieve zero $\dot{B}$ at injection, a d.c. power supply was connected to the main magnet bus (with the Siemens MG set disconnected). The current delivered by the supply, and hence the field in the main magnets, was controlled by issuing commands to the label ZBDOT in AGAST. The field was monitored with a Hall probe located in magnet #242 which gave a reading on a DVM in the MCR proportional to the field at the probe. A half-turn of beam was injected into the machine and the magnetic field, as indicated by the Hall probe, was adjusted so that the beam circulated around the machine for at least 1 ms. Under these conditions, the PIP (Pulsed Injection Parameter) program was used to determine the horizontal and vertical tunes for several different magnetic fields.

Observations and Results

The horizontal and vertical tunes obtained by the PIP program for several different magnetic fields are listed in Table I and are plotted as functions of the Hall probe voltage in Figures 1 and 2. The slopes of the lines fitted to the data in the figures are

$$\frac{\Delta Q_H}{\Delta V} = 0.56(1) \; ; \; \frac{\Delta Q_V}{\Delta V} = -\, 0.048(6) \qquad (1)$$

where V is the Hall probe voltage in mV and Q_H and Q_V are the horizontal and vertical tunes. We can calculate the horizontal and vertical chromaticities from these slopes as follows. If we change the magnetic field in the main magnets from B to B + ΔB, then the tunes change by the amounts

$$\begin{aligned} \Delta Q_H &= -\, Q_H \, \xi_H \, \Delta B/B \\ \Delta Q_V &= -\, Q_V \, \xi_V \, \Delta B/B \end{aligned} \qquad (2)$$

where ξ_H and ξ_V are the horizontal and vertical chromaticities. Since the magnetic field is proportional to the Hall probe voltage, we have

$$\Delta B/B = \Delta V/V. \qquad (3)$$

Thus (2) becomes

$$\begin{aligned} \xi_H &= -\, (\Delta Q_H/Q_H)/(\Delta V/V) = -\, \frac{V}{Q_H} \, \frac{\Delta Q_H}{\Delta V} \\ \xi_V &= -\, (\Delta Q_V/Q_V)/(\Delta V/V) = -\, \frac{V}{Q_V} \, \frac{\Delta Q_V}{\Delta V}. \end{aligned} \qquad (4)$$

Using Equations (1) and V = 37.45, Q_H = 8.678, Q_V = 8.884 in (4) we obtain

$$\xi_H = -\, 2.42(5) \; ; \; \xi_V = +\, 0.20(3) \qquad (5)$$

These measured chromaticities, obtained with $\dot{B}$ = 0, agree very well with the chromaticities ξ_H = - 2.4, ξ_V = + 0.2 calculated by the BEAM code at the H^- injection field, and with the chromaticities [1] ξ_H = - 2.6, ξ_V = + 0.3 obtained by the MAD code at the same field.

One can also compare these measurements with those obtained at non-zero $\dot{B}$. At injection, with $\dot{B}$ = 4.3 Gauss/ms, the chromaticities obtained by the PIP program are [2]:

$$\xi_H = -1.5\ (1)\ ;\ \xi_V = -0.9\ (1). \qquad (6)$$

Comparing these values with those given in (5) we see that the sextupole fields, due to the eddy currents produced when $\dot{B}$ = 4.3 Gauss/ms, increase the horizontal chromaticity by 0.9 and decrease the vertical chromaticity by 1.1.

Other measurements of the chromaticities near injection with $\dot{B}$ = 2 and 4 Gauss/ms have been made by Ahrens and van Asselt [3] and are summarized in Table II along with the calculated and measured chromaticities discussed above. We note that in the table, the chromaticities obtained by Ahrens and van Asselt have been corrected for an error in the calibration of the PUE's by multiplying by the factor of 0.8. (The error in the PUE calibration is discussed in Reference 4.) In Figures 3 and 4, the measured chromaticities from Table II have been plotted and show clearly the linear dependence of the chromaticities on $\dot{B}$.

At the magnetic field for which the Hall probe voltage was 37.70 mV, the horizontal and vertical tunes were also measured using the fast Fourier transform capability of the Lecroy #9400 digital oscilloscope. The tunes were found to be

$$Q_H = 8.808\ ;\ Q_V = 8.876 \qquad (7)$$

which agree very well with the tunes measured by the PIP program (see Table I). We note that when $\dot{B}$ is nonzero, the tunes obtained from the Fast Fourier transform will in general differ from those obtained from the PIP program. The reason for this is that when $\dot{B} \neq 0$, the tunes vary over the period of measurement so that the Fast Fourier transform gives an average tune while the PIP program gives the instantaneous tune at the beginning of the measurement period. When $\dot{B}$ is zero, the tunes do not change over the measurement period and both measurements should give the same result.

References

1. E. Auerbach, E. Bleser, R. Thern. Comments on the AGS Chromaticity, AGS/AD/Tech. Note No. 276, February 25, 1987.
2. C. Gardner and L. Ahrens. A Method for Determining the Position, Angle, and Other Injection Parameters of a Short Pulsed Beam in the Brookhaven AGS, IEEE, NS-32, No. 5, October, 1985, pgs. 1888-1890.
3. L. Ahrens and W.K. van Asselt. Measurements of Chromaticities and Eddy Current Effects at Low Fields, AGS Studies Report No. 206.
4. E. Bleser. Dependence of the Frequency on the Radius at Extraction, AGS Studies Report No. 202.

TABLE I

Zero $\dot{B}$ Data Summary

ZBDOT Command	Hall Probe Voltage (mV)	Horizontal Tune	Vertical Tune
2630	37.26	8.566(10)	8.893(2)
2637	37.36	8.619(5)	8.887(2)
2647	37.45	8.678(5)	8.884(2)
2660	37.57	8.748(5)	8.877(2)
2670	37.70	8.808(5)	8.872(2)
2680	37.80	8.868(5)	--

TABLE II

P(GeV/c)	$\dot{B}$ (Gauss/ms)	ξ_H	ξ_V	Source
0.64	4.3	-1.5	-0.9	Measured (Ref. 2)
0.65	4.0	-1.2	-1.2	Measured (Ref. 3)
0.65	2.0	-1.8	-0.6	Measured (Ref. 3)
0.64	0	-2.42	+0.20	Measured (this report)
0.65	0	-2.4	+0.2	Calculated (BEAM code)
0.65	0	-2.6	+0.3	Calculated (MAD code)

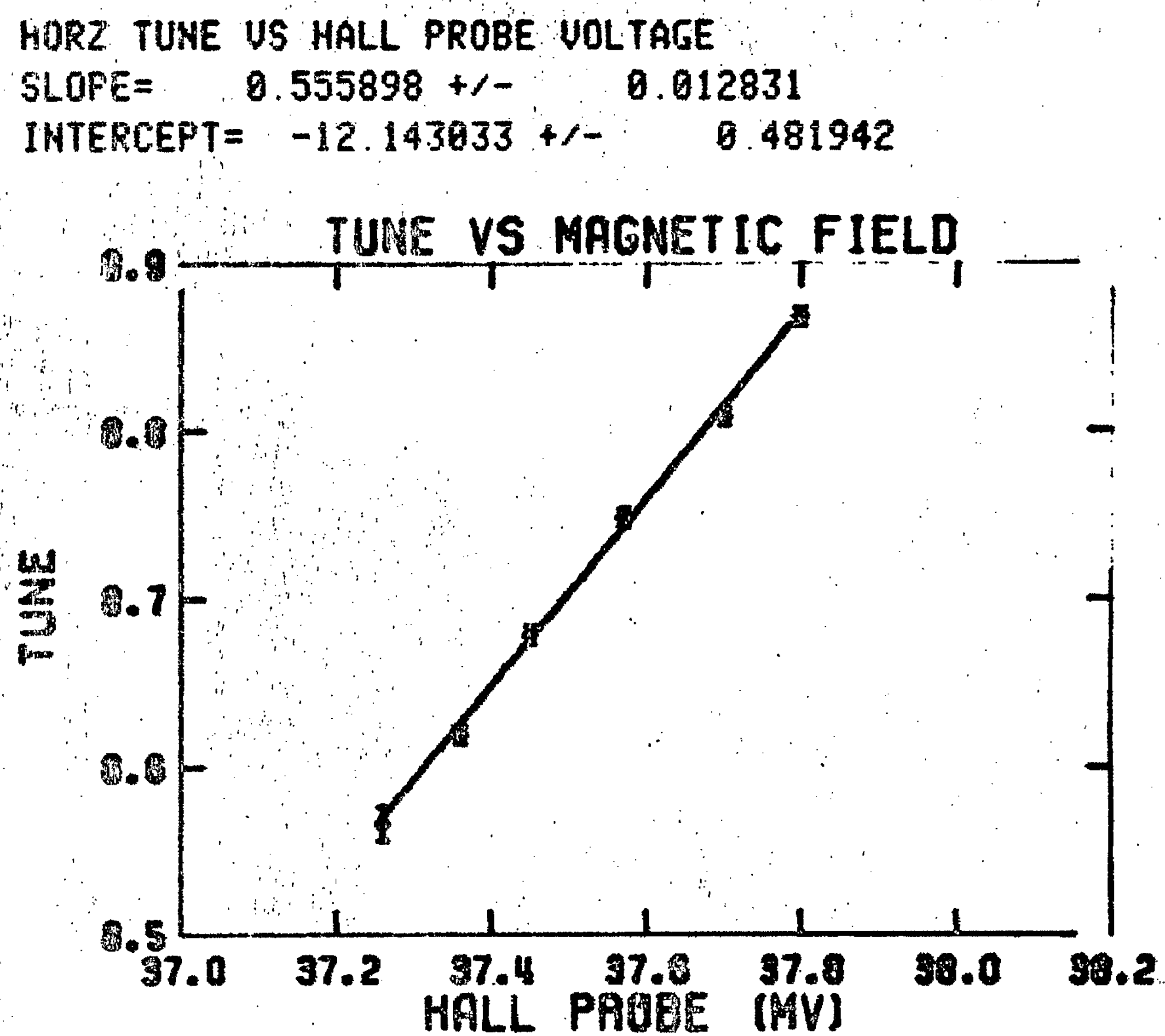
HORZ TUNE VS HALL PROBE VOLTAGE
SLOPE= 0.555898 +/- 0.012831
INTERCEPT= -12.143033 +/- 0.481942
TUNE VS MAGNETIC FIELD
TUNE
0.9
0.8
0.7
0.6
0.5
37.0
37.2
37.4
37.6
37.8
38.0
38.2
HALL PROBE (MV)

Figure 1

VERT TUNE VS HALL PROBE VOLTAGE
SLOPE= -0.472585 +/- 0.059509
INTERCEPT= 26.527415 +/- 2.228954

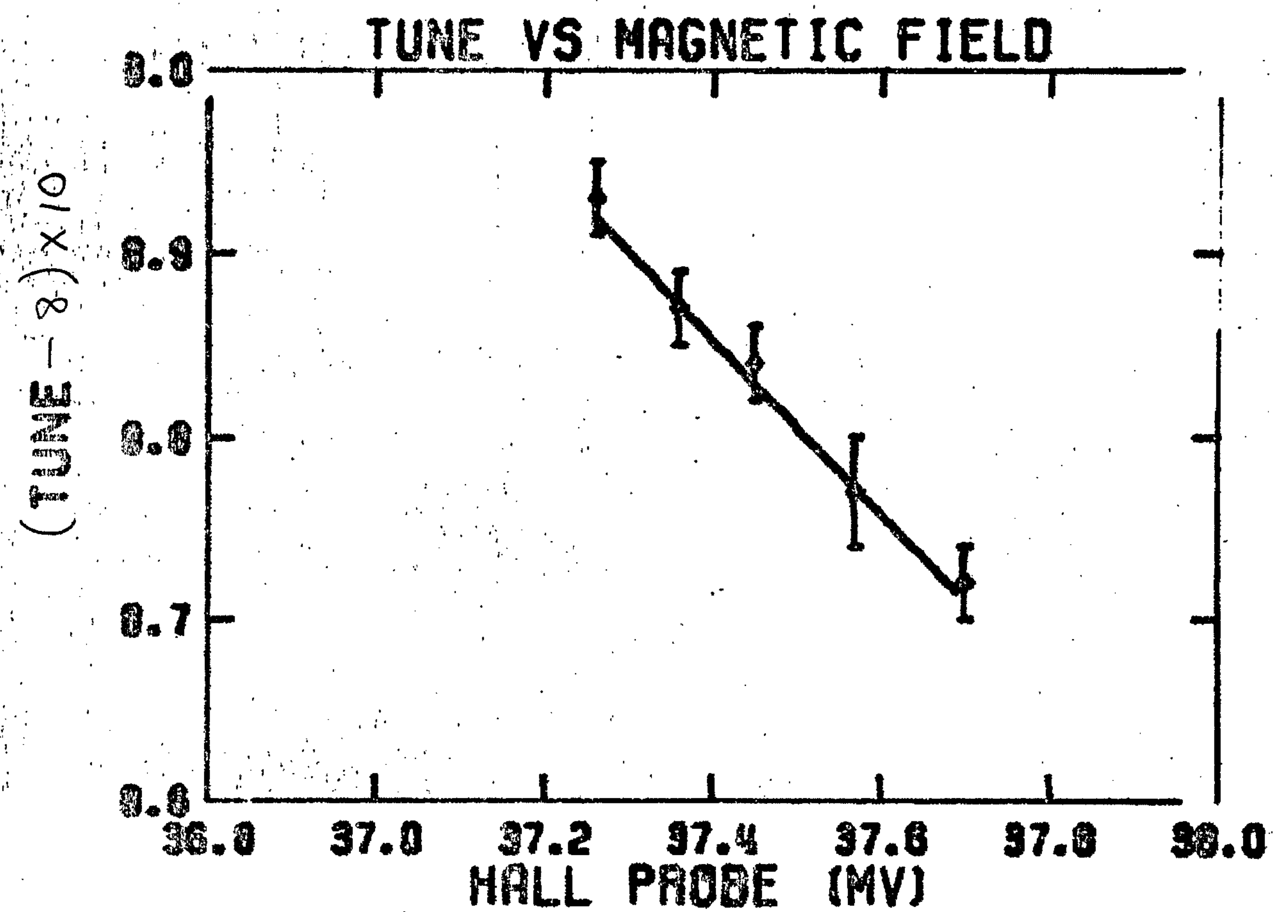

Figure 2

Measured Chromaticities vs $\dot{B}$

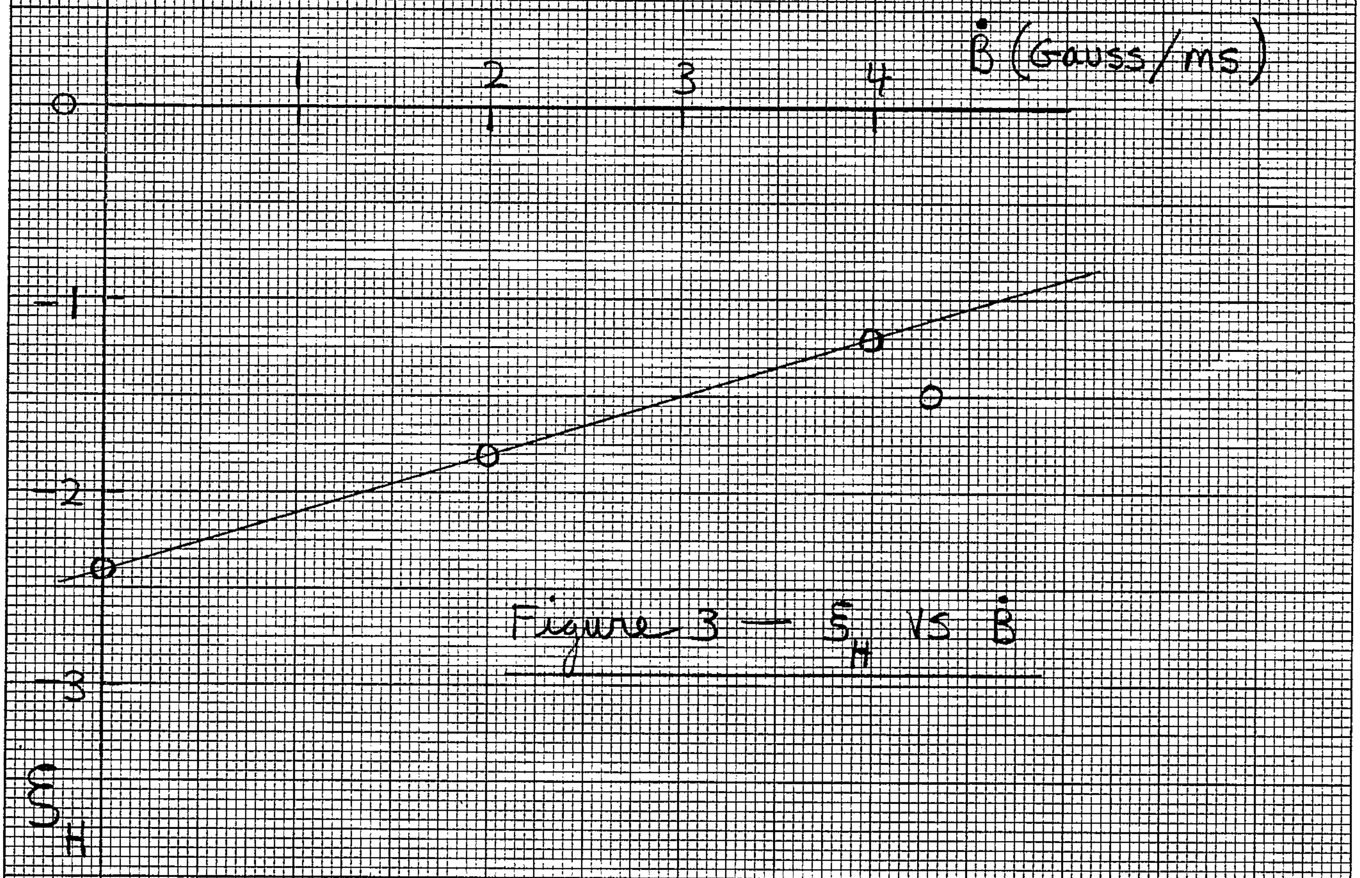

Figure 3 — ξ_H vs $\dot{B}$

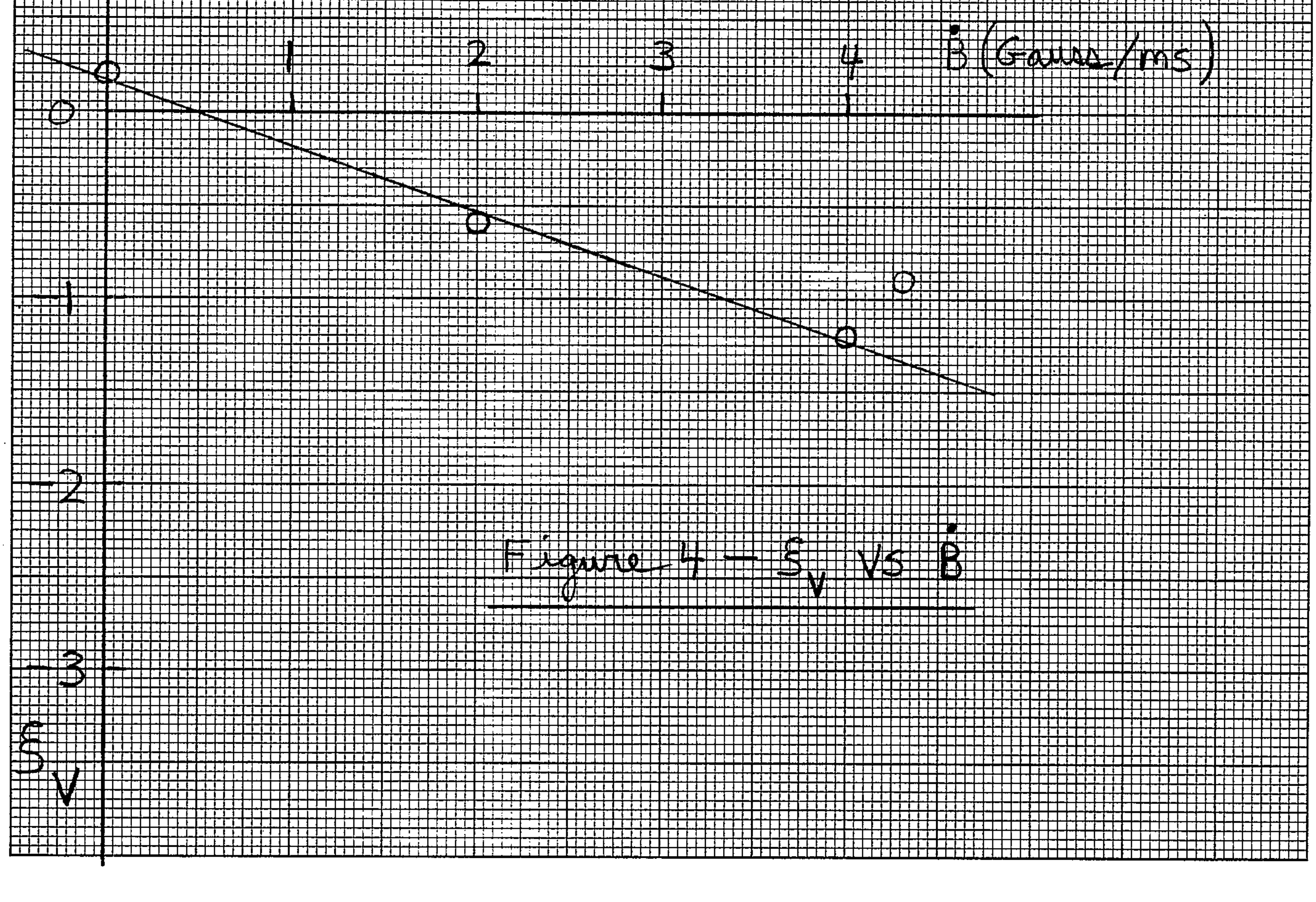

Figure 4 — ξ_V vs $\dot{B}$