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Measurements of d (h*frev) / dR and Eh

R. E. Thern

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Collider Accelerator Department

Brookhaven National Laboratory

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AGS Complex Machine Studies

(AGS STUDIES REPORT Number 313)

Measurement of d(h*frev)/dR and ξ_h

Study Period:	10 April 1994, 9:00 am - 21:00 pm
Participants:	R. Thern, M. Tanaka, E. Bleser + MCR
MCR:	N. Williams / K. Zeno, P. Carolan / C. Whalen
Reported by :	M. Tanaka
Machine:	AGS_ Accel. on h=8
Beam:	User3, low intensity 3 x 10^{12} ppp, No chromaticity corrections
Tools:	IPM, Orbit PUE's, Tune Meter, HP5371A Frequency Analyzer
	Gauss Clock.
Aim:	*To Measure Q_h and $h*f_{rev}$ vs $<x>_{pue}$, $x(c5)_{ipm}$ at various times*

I. Introduction

During the machine studies[MS] period in March and early April, we observed substantial large closed orbit distortions throughout the AGS cycle, which varied from -28 mm to +16 mm, peaking around E20[L. Ahrens]. Therefore, previous to this study a few selected main magnets were moved as the first step to reduce the orbit distortions [E. Bleser]. The main purposes of this study are as follows:

- to get AGS orbit data for the next magnet move,
- to measure the mean radius $<x>_{pue} = <R>$ from PUE's and x(c5) from IPM for calibration,
- to measure $d[h*f_{rev}]/d<x>$ and the chromaticity $\xi_h = \Delta Qh/(\Delta p/p)$,

at various times and radius, and to compare the results with MAD predictions to understand the basic machine performance.

II. Setup and Data Taking

The stored commands for the FY94/SEB setup were reloaded and executed after recovering the polarized proton MS. The data were taken at 4 different times as shown in figure 1:

Data#1 at t = 0.7 s from t_o, p = 2.632 GeV/c (from Gauss clock counts by IPM)†,
Data#2 at t = 1.1 s, p = 4.278 GeV/c,
Data#3 at t = 1.5 s, p = 16.942 GeV/c,
Data#4 at t = 1.7 s, p = 21.926 GeV/c.

† p = 2.33 + 0.00050568*GC [GeV/c]

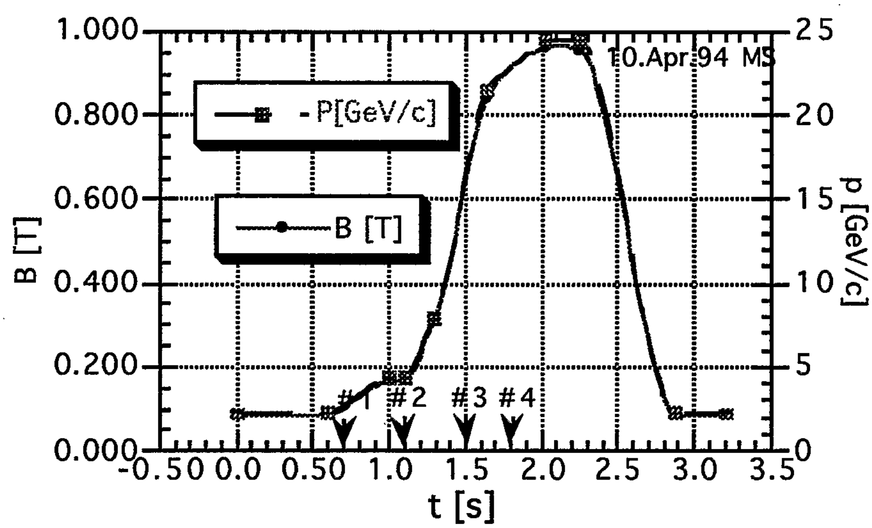

Fig.1. AGS main magnet setup.

During the data taking, high field chromaticity sextupoles were turned off to minimize possible non-linear effects. The circulating beam intensity was $2\text{-}3 \cdot 10^{12}$ ppp. This note analyzes the two after_transition data sets #3 and #4 since these sets are more complete and reliable than #1 and #2. *e.g.*, we started loosing some of the beam when $\langle x \rangle_{pue} < -10$ mm or ~ > +5 mm at t = 0.7 s and had a difficulty with tune measurements.

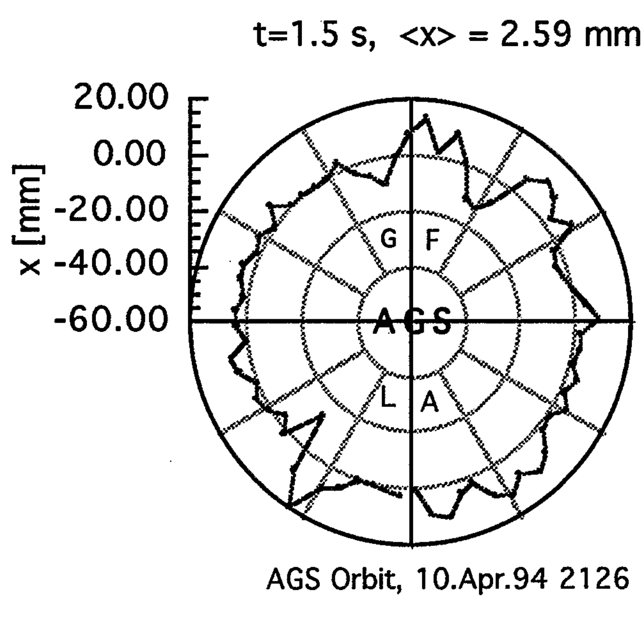

Fig.2. A typical AGS Orbit at t =1.5 s during this MS.

Figure 2 shows a typical AGS orbit during the MS. All the $\langle x \rangle_{pue}$ values and its errors were recalculated by removing apparent bad PUE's from a single pulse measurement.

✍ PUE's are located at straight sections 2,4,8,12,14,18 where β_x and D_x are at average while IPM is located at straight section C5 where β_x and D_x are at maximum. There were ~62 good ones out of 70 PUE's.

✍ It should be noted that the peak-to-peak variation was reduced by about 50 % to ± ~13mm from the unwanted orbit distortions before the MS. This value is still substantially high since the ideal orbit should be less than ± 3-5 mm. Two extreme points in superperiod K are likely due to unstable PUE's.

The mean beam radius <x> was varied from about -13 mm to +7 mm by changing the voltage of the radial shifter [RS] as shown in figure 3.

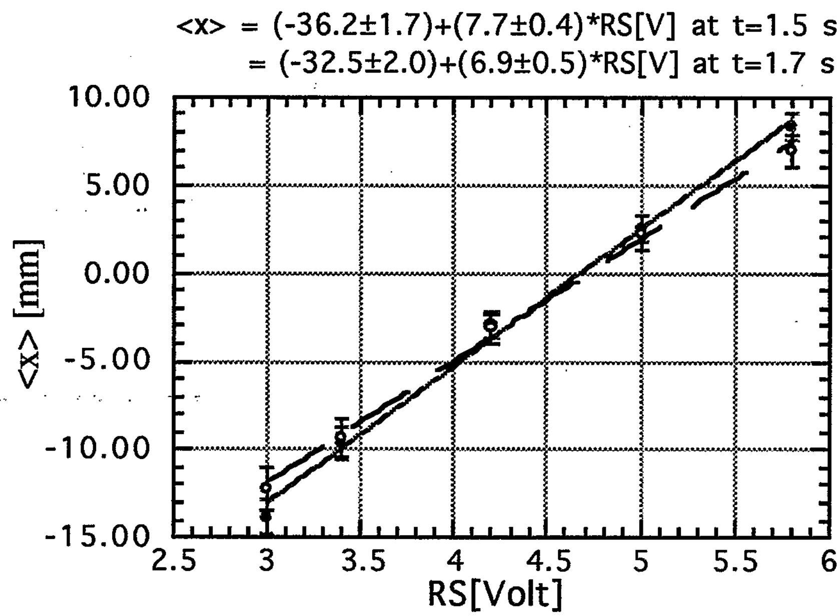

Fig.3. $\langle x\rangle_{pue}$ vs RS[V] at t = 1.5 and 1.7 s.

III. Results and Analysis

All results are summarized in figures 3, 4 and 5 with MAD predictions using the momentum from the gauss clock counts and actual high field quads currents $\{IQ_h, IQ_v\} = \{100A, 150A\}$. The $\langle x\rangle_{mad}$ is calculated by

$$\langle x\rangle_{mad} = \Delta R = \alpha_p \cdot R \cdot (\Delta p/p),$$

where α_p is the compaction factor and R = 128.452 m. is the reference mean radius of the AGS. The $h^* f_{rev}$ is calculated by

$$h^* f_{rev} = 8 \cdot c \cdot (p/E)/(2\pi \cdot (R+\Delta R)),$$

where h = 8, the rf harmonic number, c = speed of light and $p/R = \beta_{rel}$.

III.A <x>pue vs x(c5)ipm

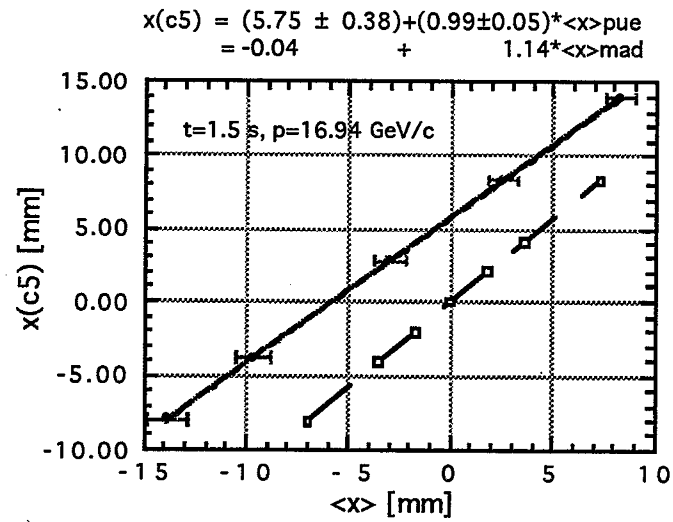

Fig. 3a.

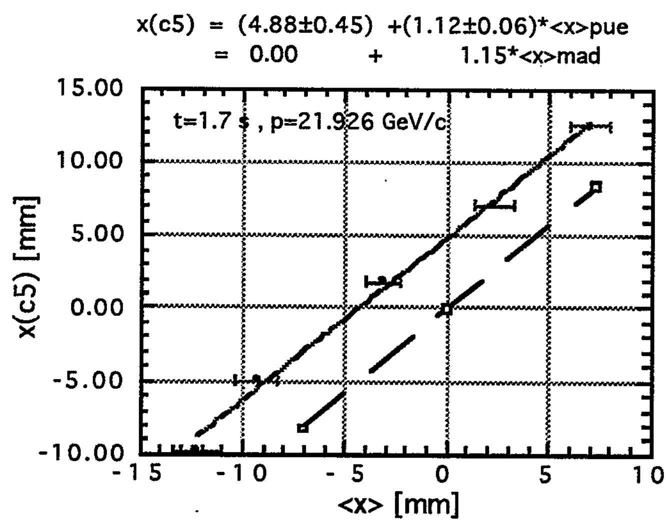

Fig. 3b.

Fig.3. x(C5) vs <x> with MAD predictions at p = 16.942 and 21.926 GeV/c.

Figure 3 shows the results from the PUE's and the IPM. It displays a linear relationship between $x(c5)_{ipm}$ and $<x>_{pue}$. If the $x(c5)_{ipm} = 0$ corresponds to the central orbit, the central orbit mean radius is at the $<x>_{pue} = -5.3 \pm 0.3$ mm. The MAD predicted value of $dx(c5)_{ipm}/d<x>_{pue}$ is in excellent agreement with the data at p=21.926 GeV/c but in poor agreement with one at p=16.942 GeV/c.

☞ It is generally assumed that $<x>_{pue} = -4.0$ mm corresponds to the central orbit mean radius.

III.B h*f_{rev} vs <x>pue

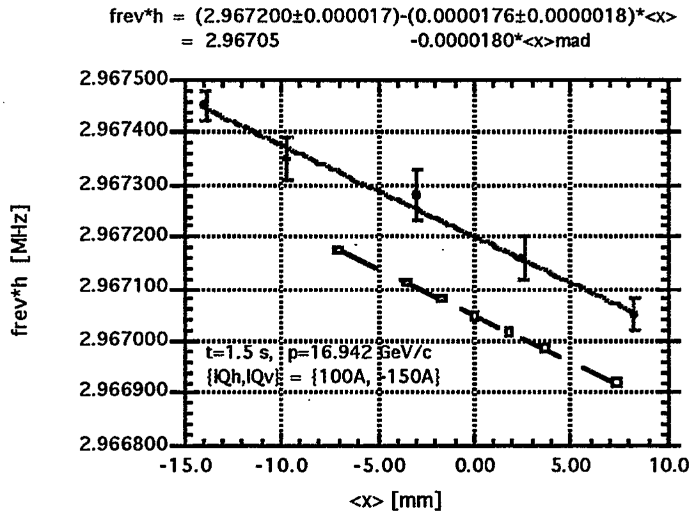

Fig. 4a.

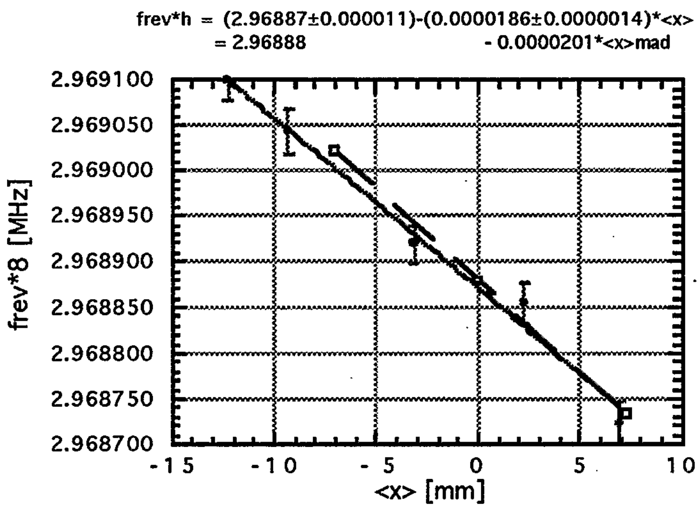

Fig. 4b

Fig.4. h*f_{rev} vs <x> with MAD predictions.

The MAD predictions of d(h*frev)/d<x> are in excellent agreement with both data. Some of the absolute differences in h*frev(~100-240 Hz), could be attributed to the systematic errors in calculating the momentum from Gauss clock counts by 0.5-1.0 %. The Gauss clock calibration could be wrong by 1.8 % [M. Brennan].

III.C Q_h vs dp/p

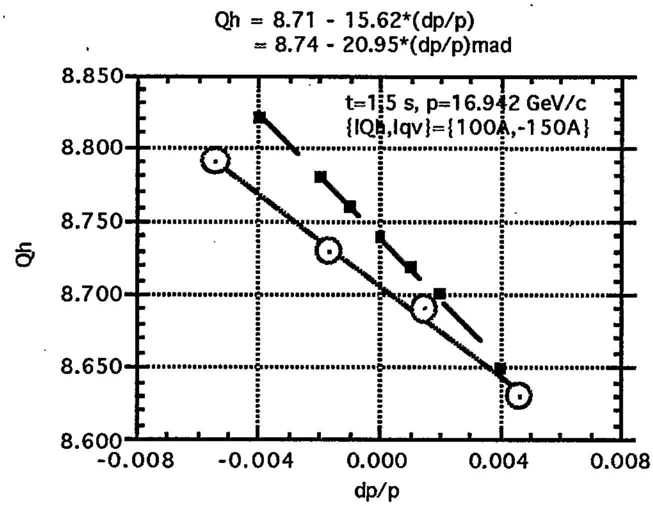

Fig. 5a.

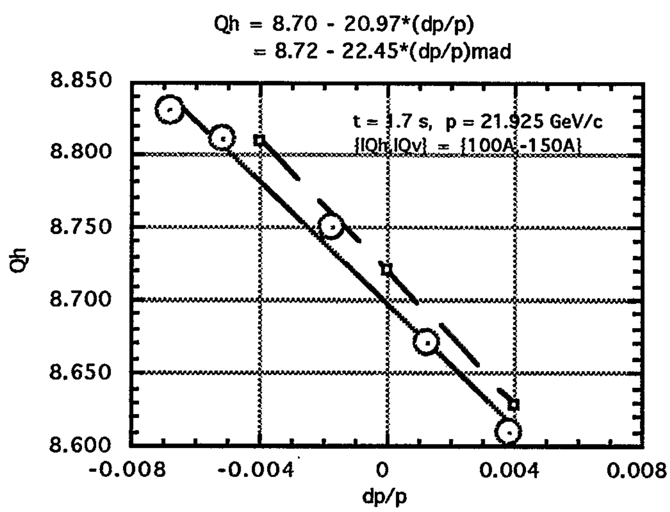

Fig. 5b.

Fig.5. Q_h vs dp/p with MAD predictions.

Figure 5a and 5b show Q_h vs dp/p at p=16.942 and 21.926 GeV/c, respectively, where dp/p = $\langle x \rangle/(\alpha_p \cdot R)$. The measured Q_v value stays constant to be 8.83 ± 0.01 while the MAD predicts Qv = 8.82 ± 0.03. Big circles for measured Q_h indicate that we had some difficulties in measuring Q_h. In the FFT display, there were several broad peaks between 8.5 and 9.0 and each peak had its substructure. At p = 21.926 GeV/c, the measured chromaticity $\xi_h = 21.0$ is in good agreement with the MAD prediction of 22.5 but not for the p=16.942 GeV/c data.

IV. Conclusions

• The two data sets on the horizontal tune[Q_h] and the rf frequency [$h*f_{rev}$] vs the mean radius[<x> < ± 10 mm] at p = 16.942 and 21.926 GeV/c with low intensity proton beam without chromaticity corrections were analyzed and compared with the MAD predictions.
• Despite the fact that the machine was not well tuned yet and we had some difficulties in measuring tunes, the data indicate that the AGS behaved linearly as expected.
• It would be interesting to perform similar measurements at the following conditions:

-at the well-tuned machine,
-at higher momentum(*e.g.*, 25, 27, 29 GeV/c)
-with higher intensity beam(*e.g.*, 10, 20, 30 TP),
-using well prepared and calibrated tools,
-increasing the radial steering range from ±10 to ±25 mm (and beyond untill beam losses occur),
-with chromaticity sextupoles off and on,
-also measuring the transverse beam emittance and the momentum spread,
-etc,

and knowing the machine conditions well (e.g., γ_{tr}-jump, VHF, transverse damper, bumps etc.)