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Measurements of the Radius of the AGS Beam During FEB (1.4 sec pulse rate)

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OBSERVATIONS AND CONCLUSIONS

Introduction

As a byproduct of vertical tune measurements made during slow beam flat-top,[1] it was determined that the radius of the orbit was 5059.1", if one assumes a β for the particles corresponding to a momentum of 29.0 GeV/c. It was of some interest then, to this author, to study this matter further, since the radius of the circle through the "pedestal stations" is given as 5057.4".[2]

Method

The method assumes a fixed radius R, during various (two here) time intervals during the acceleration cycle. These two intervals I_1 and I_2 were taken to be $450 \geq I_1 \geq 275$ ms, and $580 \geq I_2 \geq 490$ ms; $21 \gtrsim I_1 \gtrsim 9.6$ GeV/c, $28 \gtrsim I_2 \gtrsim 23$ GeV/c. The average radius during I_1 was +0.022 ± 0.006 inch, and during I_2 was −0.335 ± 0.024 inch, the former the average of nine measurements 25 ms apart, the latter the average of ten measurements 10 ms apart, all made with the PUE system (programs ORBED, NORB). The pick-up electrode system was used, then, to validate the assumption of constant R, otherwise the results obtained here do not depend on the pick-up electrodes.

For this method we must make an assumption as to the nature of the dependence of momentum p on the Gauss clock counts g. The simplist assumption may be taken to be $p = H + Gg$, where H and G are offset and slope constants, respectively. Also, one might consider more complex dependencies, an example being $p = H + Gg + Fg^2$. We assume the beam orbit to be a perfect circle. Then $\beta = \pi R f_h/(6c)$, where f_h = frequency of rf drive (12th harmonic of rotational frequency), R = radius of circle, c = velocity of light ($= 1.1802829 \times 10^{10}$ inch/sec), and β = velocity of beam/c. Then, eliminating β, p we get

$$f_h = \frac{6c}{\pi R} \frac{1}{\sqrt{1 + [M/f(g)]^2}} \tag{1}$$

where M = mass of proton ($= 0.9382796$ GeV/c^2), and f(g) is one of the assumed functional dependencies of p or g, as mentioned above. Thus, simplistically, if we make a series of measurements of f_h at various values of g, we may determine the constants R, H, G, F. . . by the method of non-linear least squares, using Eq.(1) and an assumed form f(g). For actual computational purposes, in order to keep the magnitudes of the matrix elements from becoming excessively large or small, it is better to fit the data using the function

$$f_{hn} = \frac{R_{nom}}{R} \frac{1}{\sqrt{1 + [M/f(g)]^2}}$$

where f_{hn} is a normalized frequency given by

$$f_{hn} = \pi R_{nom} f_h/(6c)$$

and R_{nom} may be chosen to be in the vicinity of 5000 inches. Also M and f(g) were taken to be in GeV/c.

For I_1, 92 determinations of f_h were made; for I_2, 42 determinations. The regions I_1, I_2 with the least squares method employed here, had to be separately fitted. The functional form of f(g) was chosen, in each region, on the basis of 1) rapid convergence to a fit whose criterion was of the same order as the pulse-to-pulse variation in frequency (1 Hz for I_1, 3-5 Hz for I_2), 2) for two choices of f(g) resulting in roughly equal fit criteria, f(g) was taken to be the one of simplist form. For I_1, a quadratic dependence on g was rejected because of 2), for I_2 the quadratic was rejected because of 1); no higher order forms for f(g) were considered. Thus for both I_1 and I_2 f(g) was chosen to be H + Gg.

Measurement Details and Results

The HP5345A frequency counter was gated on by a pulse generated by a preset number of Gauss clock counts g for a sampling time of 10 ms. To correct g to the center of this window, g was taken as an average over 12-15 machine pulses for various times t, after injection peaker. These data were least square fitted with

$$g = a + bt + ct^2 \quad (2)$$

Except for occassional jumps of 100 counts, the usual variation (std. dev.) in g was ±25 counts, more or less constant through the time interval of interest (after transition to extraction). Correction was applied for jump (only one seen) mentioned above. No attempt was made to include the ±25 count variation in the errors given for the coefficients R, H, and G.

Three separate sets of data were taken, using different time sequences of data collected on three different dates. Radius shift offset controls remained fixed. A single determinaton of g vs t was used for all three sets. The following table summarizes the results.

Parameters of Fit	DATE 12/9/83	12/11/83	12/12/83	± *
H_1 (GeV/c)	0.0853	0.0834	0.0845	0.0002
G_1 (GeV/c/g)	0.50125	0.50129	0.50140	0.00002
R_1 (inch)	5057.36	5057.37	5057.39	0.01
H_2 (GeV/c)	0.86	0.32	0.67	0.30
G_2 (GeV/c/g)	0.472	0.489	0.478	0.006
R_2 (inch)	5056.78	5056.89	5056.84	0.03
R_1-R_2 (inch)	0.58	0.48	0.55	0.03

(R_1-R_2) PUE (inch) (12/9/83) $0.022 \pm 0.006 - (-0.335 \pm 0.024) = 0.357 \pm 0.025$

$a = -8.459$
$b = 0.01403\ \text{sec}^{-1}$
$c = -4.081 \times 10^{-5}\ \text{sec}^{-2}$

* error estimates based on fluctuation of parameters with number of points fitted (not a std. dev.).

Conclusions

The above table shows that this measurement tends to yield radius changes somewhat larger than that observed by the PUE's. Also, the radius observed in June, 1983 (SEB) during flattop appears to have been due to either an instrumentation problem, or a peculiarity associated with resonant extraction. The above described measurements, resulted in no perturbation of AGS operations. The possibility exists, of course, of perturbing the radius, in a controlled fashion, over definite time intervals, in order to study Gauss clock non-linearity, and PUE behavior, when short pulse repetition time intervals are available.

References

1. D.A. Barge and J.W. Glenn, AGS Studies Report No. 160.

2. O.S. Reading and M. Buchanan, Standard Survey Data, August 20, 1957, p. 1.

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