BNL-104104-2014-TECH

AGS.SN228;BNL-104104-2014-IR

Gamma-Transition Studies

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June 1987

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U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

7/1/87

Number 228

AGS Studies Report

Date(s) June 5, 1987 Time(s) 0800 - 2400

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Subject Gamma-Transition Studies

Observations and Conclusion

We were able to successfully jump transition in the AGS with good bunch structure and < 1/2% losses (~ x 10 improvement from normal operation) at an intensity of 1.2×10^{13} circulating protons. Figures 1, 2, and 3 show the bunch movement in going through transition.

To achieve this, the present ring horizontal high field quads were reconnected to form three doublets (A^+C^-, E^+G^-, I^+K^-) with 3 $\lambda/2$ separation and a new special blowout circuit was built to give a fast decay time. Figure 4 shows the design value of the current pulse with a 60 msec rise time and a 4 msec decay time obtained from the normal Acme power supply. Figures 5 and 6 show the oscilloscope traces of the current pulse and the time at which the transition phase was jumped. If the magnetic field slope is the same as the current decay slope, we would have a $\Delta\gamma_{tr}$ = 1.9/msec as shown in Figure 7. This gives an enhancement factor of 32 over the normal $\dot{\gamma}$ = 0.06/msec and would theoretically give lossless transition passage at 2.0×10^{13} protons. The addition of a high frequency rf cavity to increase the bunch area can raise this limit by a factor of 2-3 (Accelerator Division Technical Note No. 265).

The beam quality after transition looks good and we made the following comparison with IPM scans which show an apparent 20% smaller emittance than in the normal accelerator. This smaller bunch size also results in the onset of "bunch tearing" and will probably require the high frequency cavity to compensate for it. The ε_H values given in Table I are derived from the measured horizontal beam size and includes both the inherent transverse emtitance and the transverse spread resulting from the momentum spread in the beam.

TABLE I

IPM Runs

Condition	Normal Machine	γ_{tr} Test Jump
Q	7×10^{12}	12×10^{12}
ε_H 100 msec	31.8	28.9
ε_H 400 msec	79.5	59.2
ε_V 100 msec	21.3	19.3
ε_V 400 msec	45.3	30.7
$R\ \frac{(\varepsilon_H + \varepsilon_V)\ 400}{(\varepsilon_H + \varepsilon_V)\ 100}$	2.40	1.86
Date	1/14/87	6/5/87

The PUE system was used to check the available aperture and we found that after transition we could move the beam from -0.703 cm to + 0.623 cm without beam loss.

We also measured γ_{tr} to check the model calculation from "MAD" W^+ case (Table III). The following describes the measurement method. The results in Table II lead us to believe that the model works reasonably well and that we are achieving the predicted behavior.

Acknowledgments

Thanks to J. Post's group for quadrupole reconnections with no polarity errors and to A. Feltman, J. Funaro, and L. Mazarakis for a blow-out circuit that gave us 10,000 pulses with not a single miss and achieved our design criteria.

Measurement of γ_{tr}

$$\gamma_{tr}^2 = \gamma^2 \left(1 + \frac{R}{f}\frac{\Delta f}{\Delta R}\right)$$

1. R known → 12845.3 cm @ quad centers
   $\langle r\rangle_{PUE}$ = −0.4 cm)

2. γ from measuring Gauss clock count (= g)

   $p = 0.075 + 5.05 \times 10^{-4} \times g = \beta\gamma m$ [GeV/c]

3. β from f_{rf}/f_∞ f_∞ from R (see 1) (f_∞ is rf frequency for particles traveling at the speed of light, i.e., $\beta = 1$)

4. $\frac{\Delta f}{\Delta R}$ from radial scan, using <PUE> to get ΔR, rf frequency to get Δf, correct for $\Delta R_{actual} = 1.2\ (\Delta R)_{PUE}$

See figures of Δf vs. r (Figures 8, 9) and tables (Table II) of results.

TABLE II

Gauss Clock	12900	15900	21900	28700	
Pulse	Off	1/2 Value	Off	On (10 V)	Off
$\Delta f/\Delta r)^{cm^{-1}}_{corr}$	149±12	176±17	-178±8	-150±12	-256±8
f_{rf}x 10^6 Hz	4.41306	4.42788	4.44165	4.44816	
γ	7.1	8.62	11.91	15.56	
P GeV/c	6.59	8.03	11.14	14.57	
β	0.990	0.9934	0.9965	0.9979	
γ_{tr}	8.50±0.1	9.52±0.2	8.3±0.2	11.4±0.3	7.95±0.4
γ_{tr}(model + current trace)	8.45	9.22±0.3	8.45	11.4±0.2	8.45

TABLE III

CONFIGURATION: W+
At Locations "17": (B D), (F H), (J L)
(A C) (E G) (I K)

Strength, W	Horiz. Tune	Vert. Tune	Gamma-tr
.10	8.679	8.779	8.694
.20	8.655	8.775	9.485
.30	8.617	8.769	10.788
.40	8.569	8.760	12.637
.45	8.542	8.755	13.801
.50	8.513	8.750	15.162
.55	8.482	8.744	16.771

CONFIGURATION: W+
At Locations "5": (B D), (F H), (J L)
(A C) (E G) (I K)

Strength, W	Horiz. Tune	Vert. Tune	Gamma-tr
.10	8.678	8.779	8.713
.20	8.654	8.775	9.568
.30	8.617	8.769	11.016
.40	8.569	8.760	13.165
.45	8.541	8.755	14.589
.50	8.512	8.750	16.340
.55	8.480	8.744	18.552

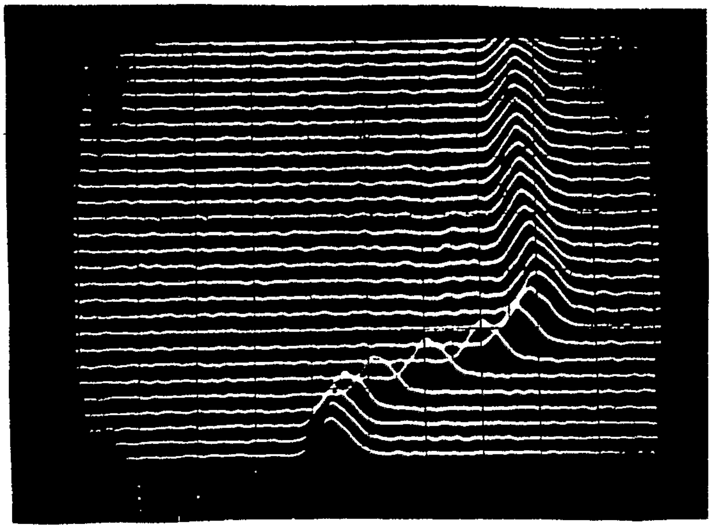

Fig. 1. 1.2 x 10^{13} every other turn
20 nsec/box.

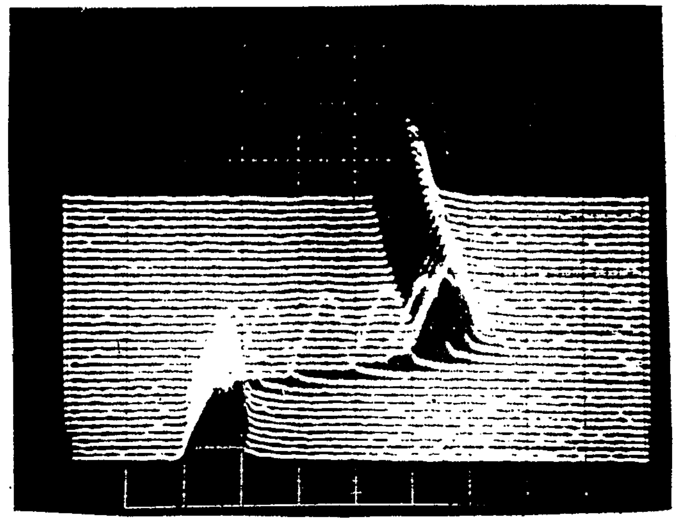

Fig. 2. 1.2 x 10^{13} every turn
20 nsec/box.

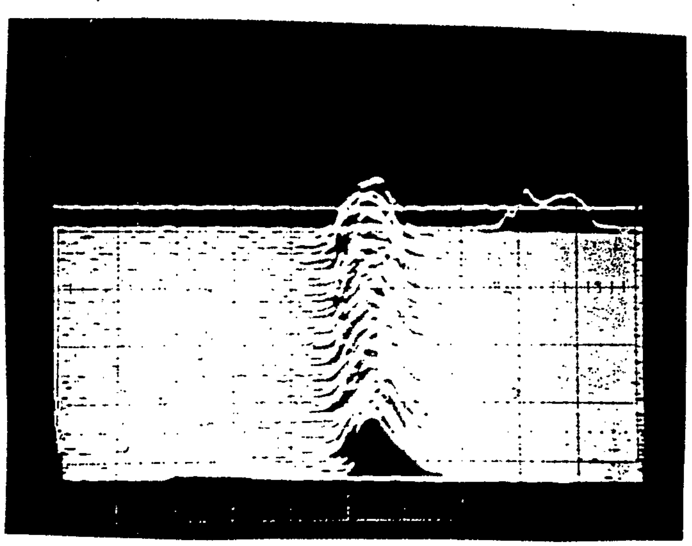

Fig. 3. The 100 msec after transition showing very little growth
20 nsec/box.

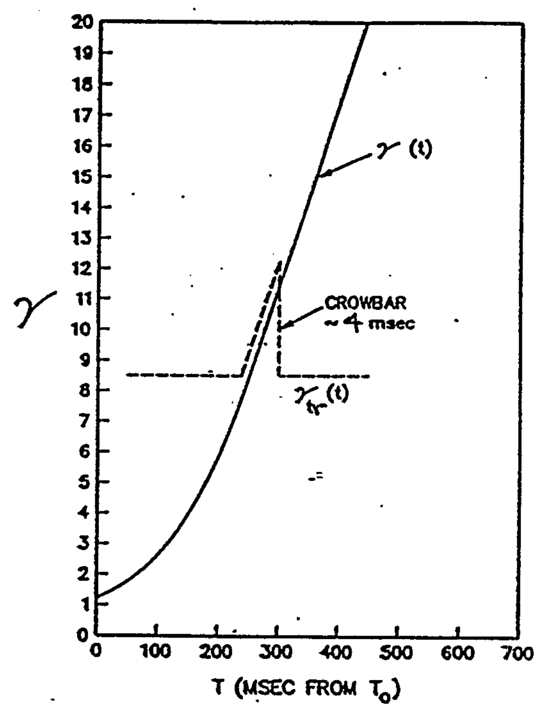

Fig. 4. Quadrupole pulse for altering γ_{tr} in relation to the AGS cycle.

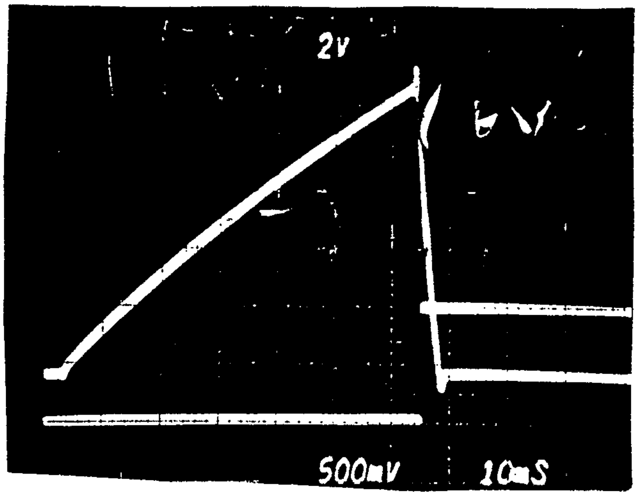

Fig. 5. Quadrupole current pulse and ϕ jump signals 10 msec/box.

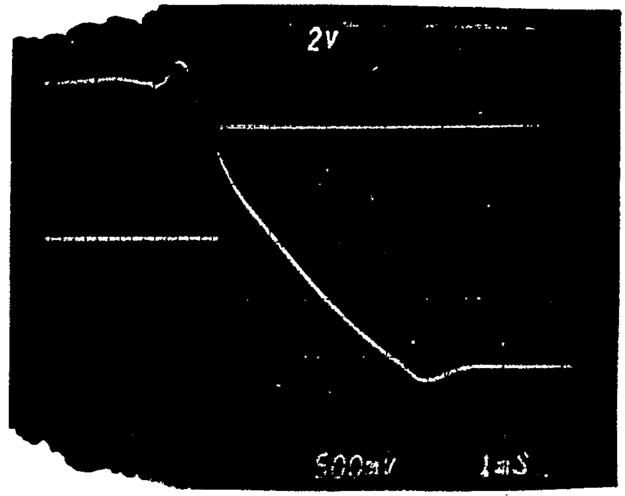

Fig. 6. Quadrupole current pulse and ϕ jump signal 1 msec/box.

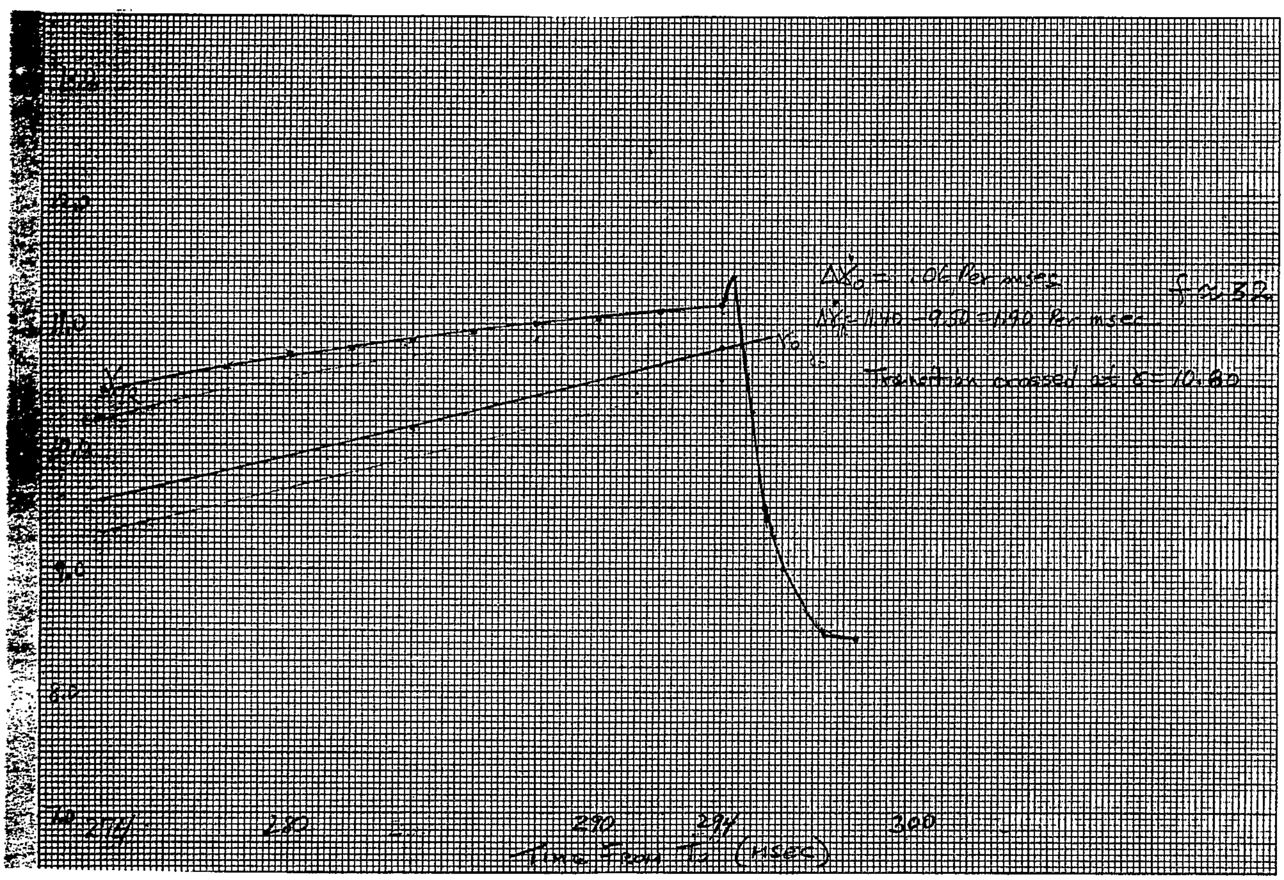

Fig. 7. Quadrupole current pulse converted to γ_{tr} from model and γ_0 showing transition passage at $\gamma = 10.80$ compared to normal 8.45.

Figures 8 and 9 - for calculation of γ_{tr}.