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Long Term Stability in RHIC

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1. Introduction

A study of long term stability has been done for RHIC. The results reported here are for the RHIC lattice with non–linear field multipoles up to tenth order. Synchrotron oscillations and tune ripple are not included in these results. Tracking runs were done for about 10^6 turns. A ten hour beam lifetime in RHIC corresponds to about 3×10^9 turns.

For the RHIC lattice with $\beta^* = 2$, the dynamic aperture appears to decrease as the required survival time is increased up to 10^6 turns. One run done for about 8.8×10^6 turns may indicate that the dynamic aperture may be leveling off for large enough survival times. In 10^6 turns the dynamic aperture has decreased by about 20%. A simple straight line extrapolation to 3×10^9 turns, would give a loss in dynamic aperture of about 35%.

For the RHIC lattice with $\beta^* = 6$, the dynamic aperture does not change much for survival times above about 500 turns. The dynamic aperture has leveled off or is decreasing very slowly after about 500 turns. The $\beta^* = 2$ lattice appears to require runs for longer than 10^6 turns to get an accurate result for the dynamic aperture, while $\beta^* = 6$ lattice may require only 500 turns.

Further studies are being planned that may clarify the above results. These include the study of a $\beta^* = 0.5$ lattice, the use of point magnets, and the inclusion of synchrotron oscillations and a tune ripple.

2. $\beta^* = 2$ Results

This section presents tracking results for a RHIC lattice with 6 $\beta^* = 2$ crossing points. Figure 1 shows the survival times found for 10 distributions of random field errors. For each distribution the starting value of x_0 is varied and the corresponding survival time found. The straight line in Fig. 1 is roughly a plot of the stability limit, A_{SL}, as a function of the survival time. These results indicate that A_{SL} is slowly decreasing for longer survival times. A_{SL} decreases from 7.8 mm for a 400 turn survival time to 6.2 mm for 1×10^6 turns. Extrapolating to 3×10^9 turns, 10 hours in RHIC, one finds $A_{SL} = 4.8$ mm, a decrease of about 35% in the dynamic aperture.

The dynamic aperture is specified by finding the 4–dimensional surface x, x', y, y', space such that particles that start inside this surface are stable for a given survival time.

In the following tracking studies only one point on this surface is found; this is the point found using the starting conditions x_0, y_0, $x'_0 = y'_0 = 0$, $\epsilon_{x,0} = \epsilon_{y,0}$. It is assumed that the dynamic aperture is correlated with x_0. If x_0 decreases for larger survival times, then it is assumed that the dynamic aperture also decreases.

Figure 2 tries to examine the extrapolation results for 3×10^9 turns by plotting the results for individual seeds. The worse seed, seed 8 was run longer, and was found to go unstable at 8.8×10^6 turns, which indicates that the dynamic aperture may be decreasing less rapidly with the survival time than given by the straight line extrapolation.

RHIC Performance if $A_{SL} = 4.8$ mm for $\beta^* = 2$

For $\beta^* = 2$, A_{SL} may go from 7.8 m for 400 turns to 4.8 mm for 3×10^9 turns (10 hours).

For Au at $\gamma = 100$, after 10 hours, $\sigma_x = 2.4$ mm and

$$A_{SL} = 7.8 \text{ mm} \quad \text{corresponds to} \quad 4.6\ \sigma$$

$$A_{SL} = 4.8 \text{ mm} \quad \text{corresponds to} \quad 2.8\ \sigma$$

An appreciable effect, due to long range stability, seems likely in this case. Other effects, synchrotron oscillations, gradient ripple, beam–beam effects, might increase this effect.

3. $\beta^* = 6$ Results

This section gives the tracking results for a RHIC lattice with 6 $\beta^* = 6$ crossing points. Figure 3 shows that the dynamic aperture decreases little for longer survival times using the straight line extrapolation, A_{SL} decreases from 15.5 mm to 14.6 mm for 3×10^9 turns.

There appears to be little long range stability effects for the $\beta^* = 6$ lattice.

RHIC Performance for $\beta^* = 6$

For Au at $\gamma = 30$ after 10 hours, $\sigma_x = 3$ mm

$$A_{SL} = 15.5 \text{ m} \quad \text{corresponds to} \quad 7.3\ \sigma$$

$$A_{SL} = 14.5 \text{ m} \quad \text{corresponds to} \quad 6.8\ \sigma$$

There appears to be little effect due to long range stability for $\beta^* = 6$.

4. Examples of Long Time Growth

This section shows 3 examples of runs that go unstable after several hundred thousands of turns. $x_{\max}$, $y_{\max}$, the largest x and y around the ring is plotted as a function of the turns in Figs. 4, 5 and 6.

The time intervals, during which growth occurs, usually last for several thousands, or some times several ten thousands of turns.

Acknowledgments

The writer wishes to acknowledge the help provided by the tracking studies of T. Garavaglia, S.K. Kauffmann, R. Stiening, D.M. Ritson,[1] and V. Visnjic[2].

References

1. T. Garavaglia, S.K. Kauffmann, R. Stiening, SSC Report SSCL-269 (1990).
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2. V. Visnjic, Fermilab Publication 90/80 (1990).

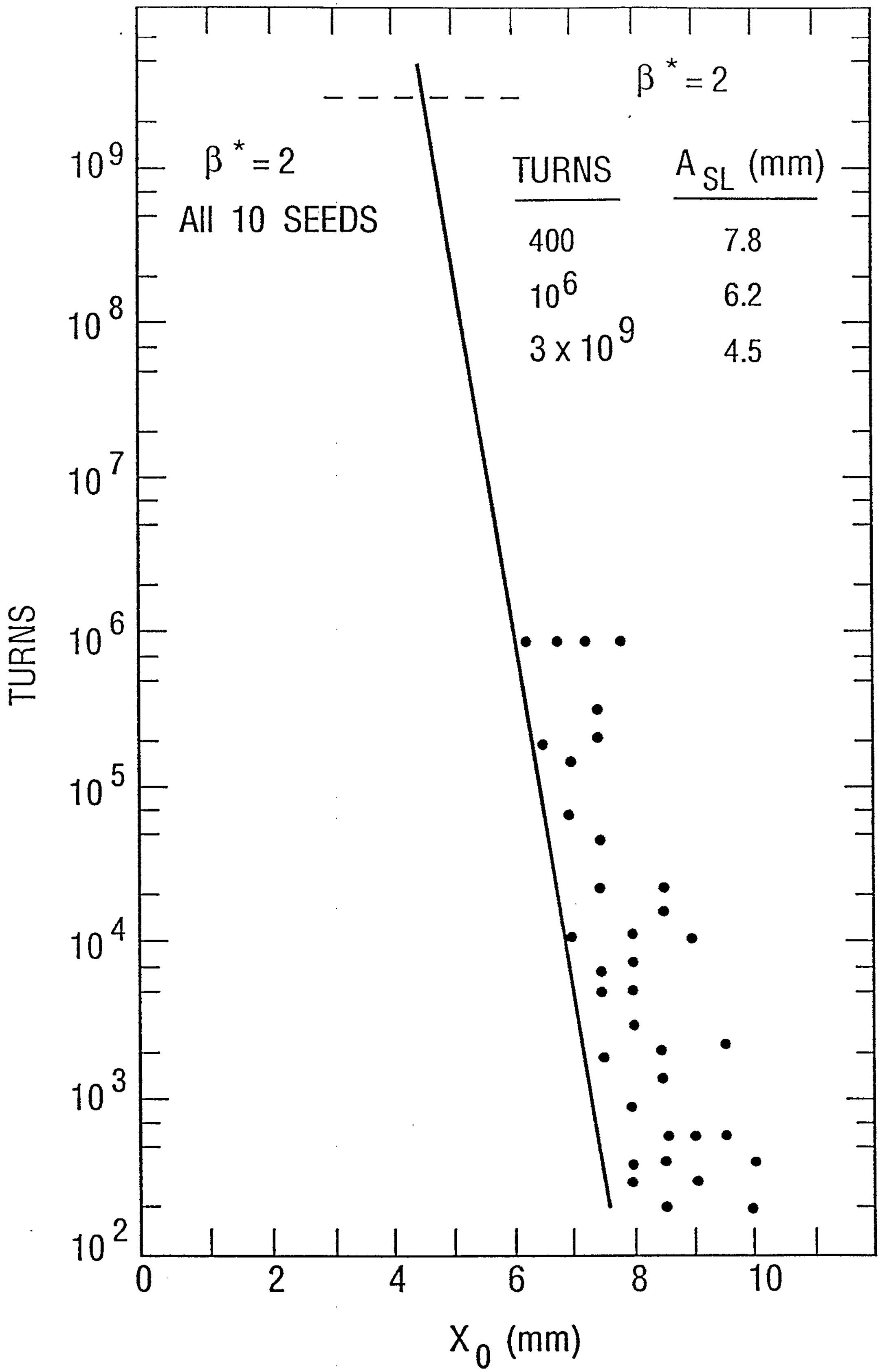

Figure 1: Survival times versus particle initial amplitude x_0. $\beta^* = 2$ RHIC lattice. Ten different distributions of random field errors.

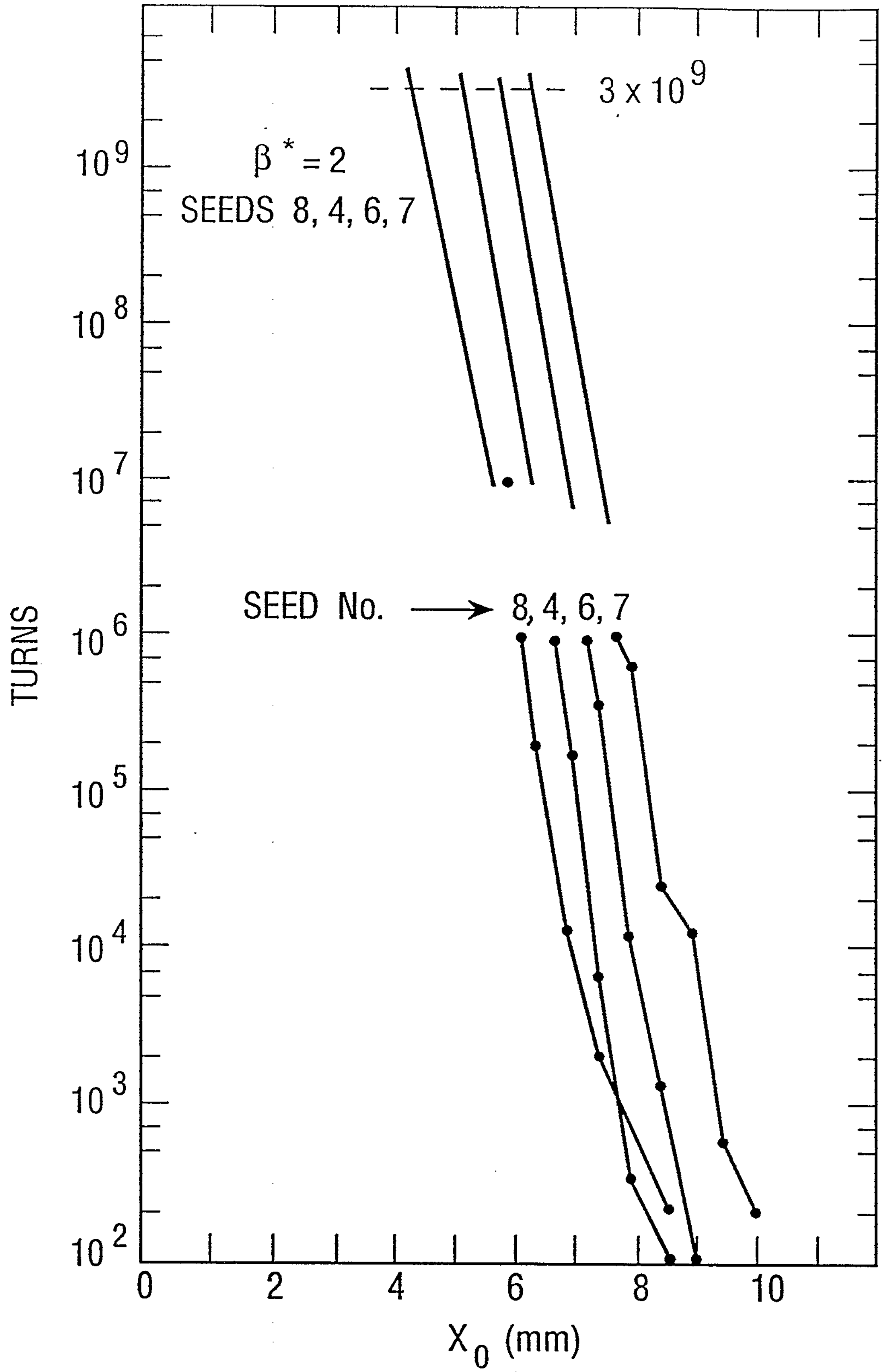

Figure 2: Survival times versus initial particle amplitude, x_0 for individual distributions of field errors corresponding to seeds 8, 4, 6 and 7. $\beta^* = 2$ RHIC lattice.

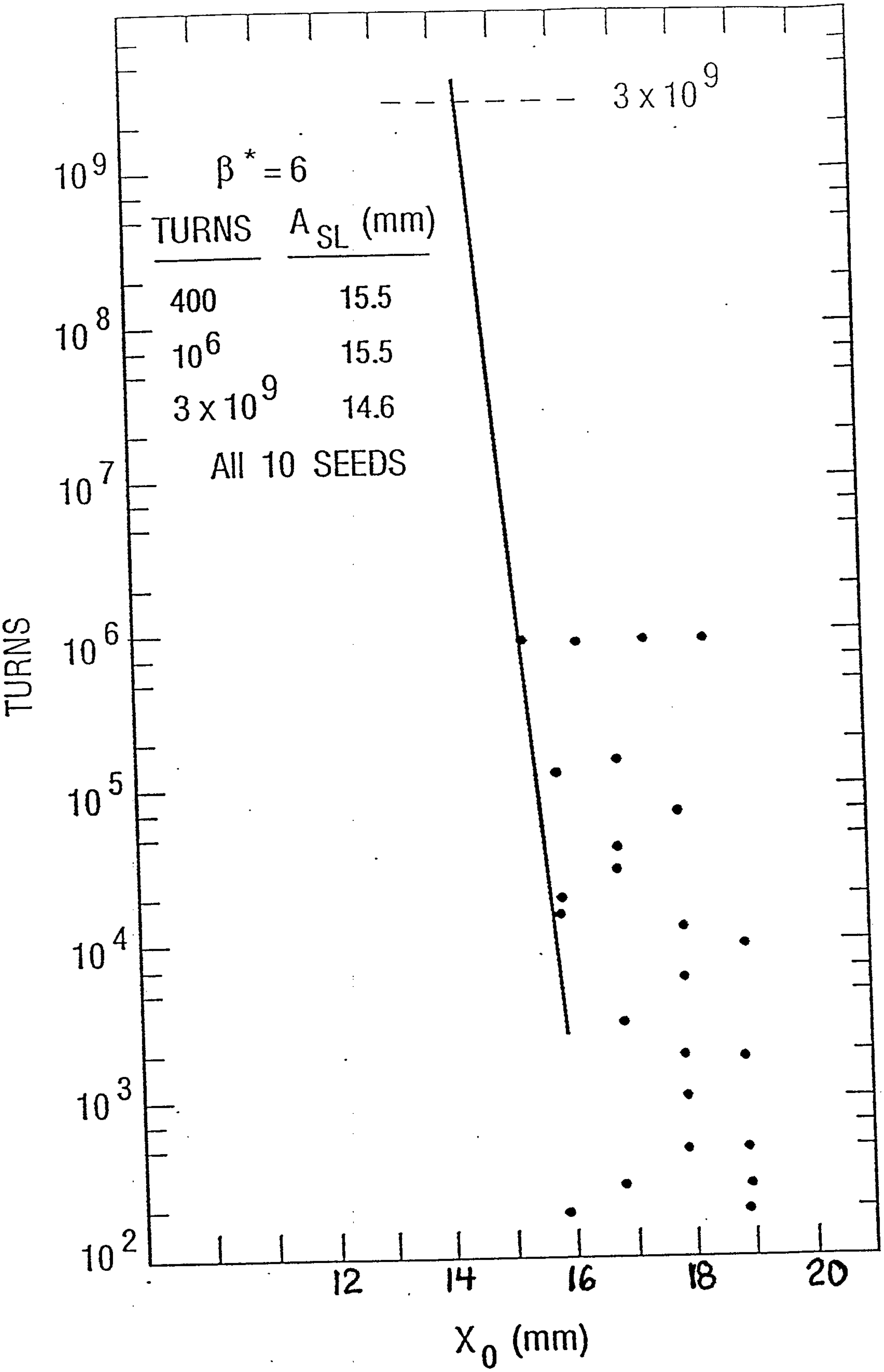

Figure 3: Survival times versus initial particle amplitude, x_0. $\beta^* = 6$ RHIC lattice. Ten different distributions of random field errors.

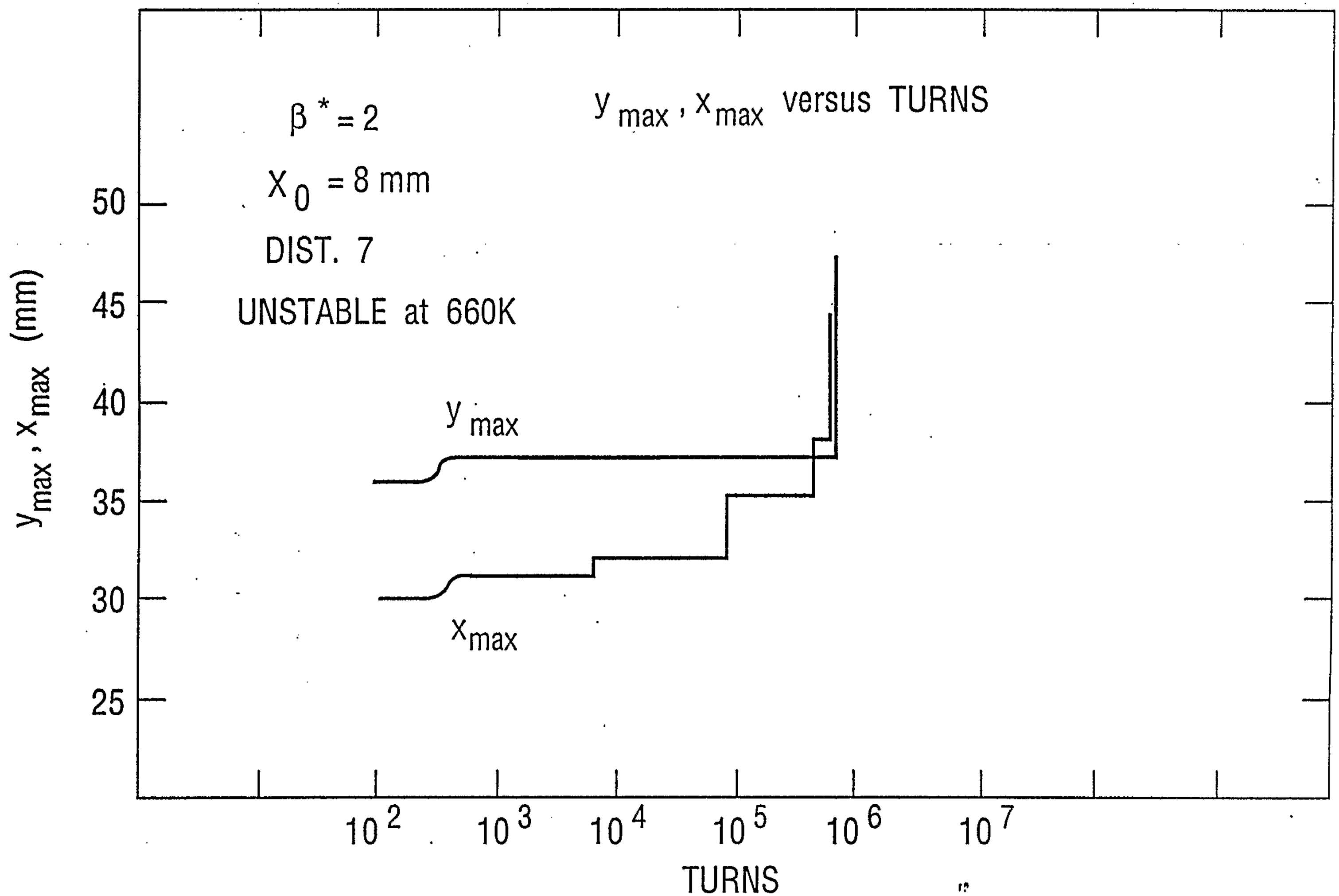

Figure 4: Particle growth versus time. $\beta^* = 2$ lattice, $x_0 = 8$ mm. Unstable after 660,000 turns. $x_{\max}$, and $y_{\max}$ are the maximum x and y attained around the ring. Seed = 7.

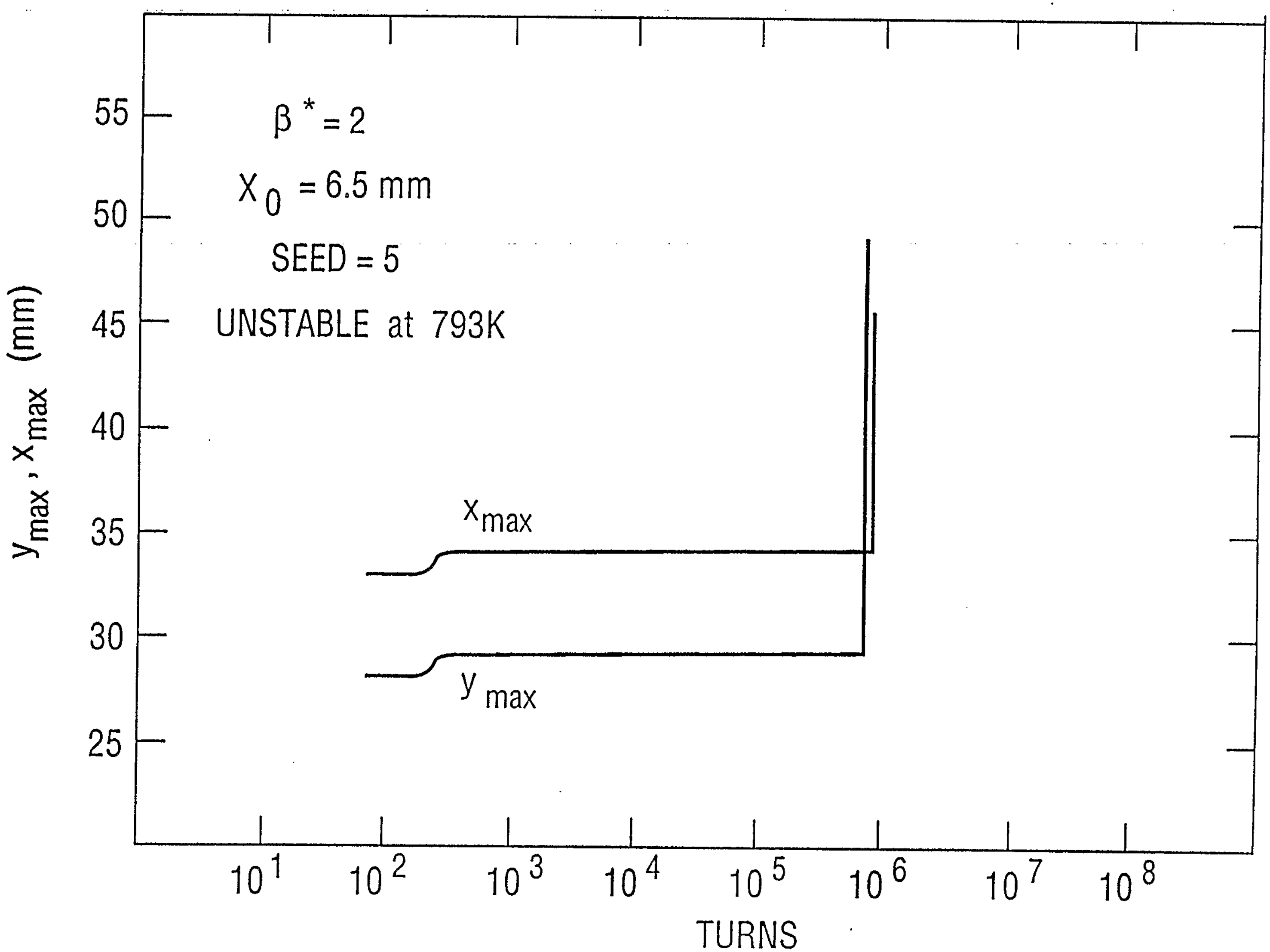

Figure 5: Particle growth versus time. $\beta^* = 2$ lattice, $x_0 = 6.5$ mm. Unstable after 793,000 turns. Seed = 5.

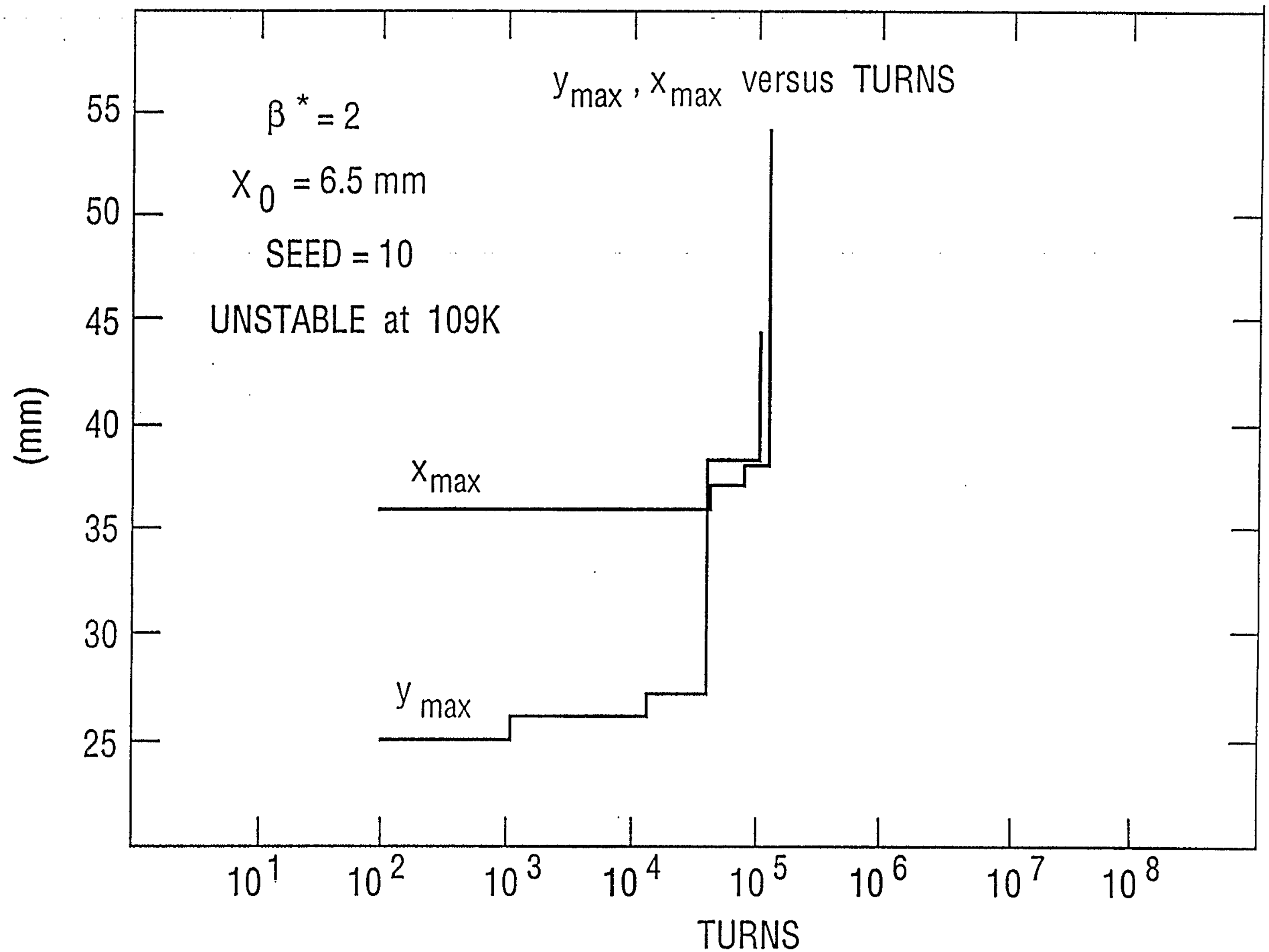

Figure 6: Particle growth versus time. $\beta^* = 2$ lattice. $x_0 = 6.5$ mm. Unstable after 109,000 turns. Seed = 10.