

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

$$\begin{aligned} A_{SL} = 7.8 \text{ mm} & \quad \text{corresponds to} \quad 4.6 \sigma \\ A_{SL} = 4.8 \text{ mm} & \quad \text{corresponds to} \quad 2.8 \sigma \end{aligned}$$

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

$$\begin{aligned} A_{SL} = 15.5 \text{ m} & \quad \text{corresponds to} \quad 7.3 \sigma \\ A_{SL} = 14.5 \text{ m} & \quad \text{corresponds to} \quad 6.8 \sigma \end{aligned}$$

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

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References

1. T. Garavaglia, S.K. Kauffmann, R. Stiening, SSC Report SSCL-269 (1990).
T. Garavaglia, S.K. Kauffmann, R. Stiening and D.M. Ritson, SSC Report SSCL-268 (1990).
2. V. Visnjic, Fermilab Publication 90/80 (1990).

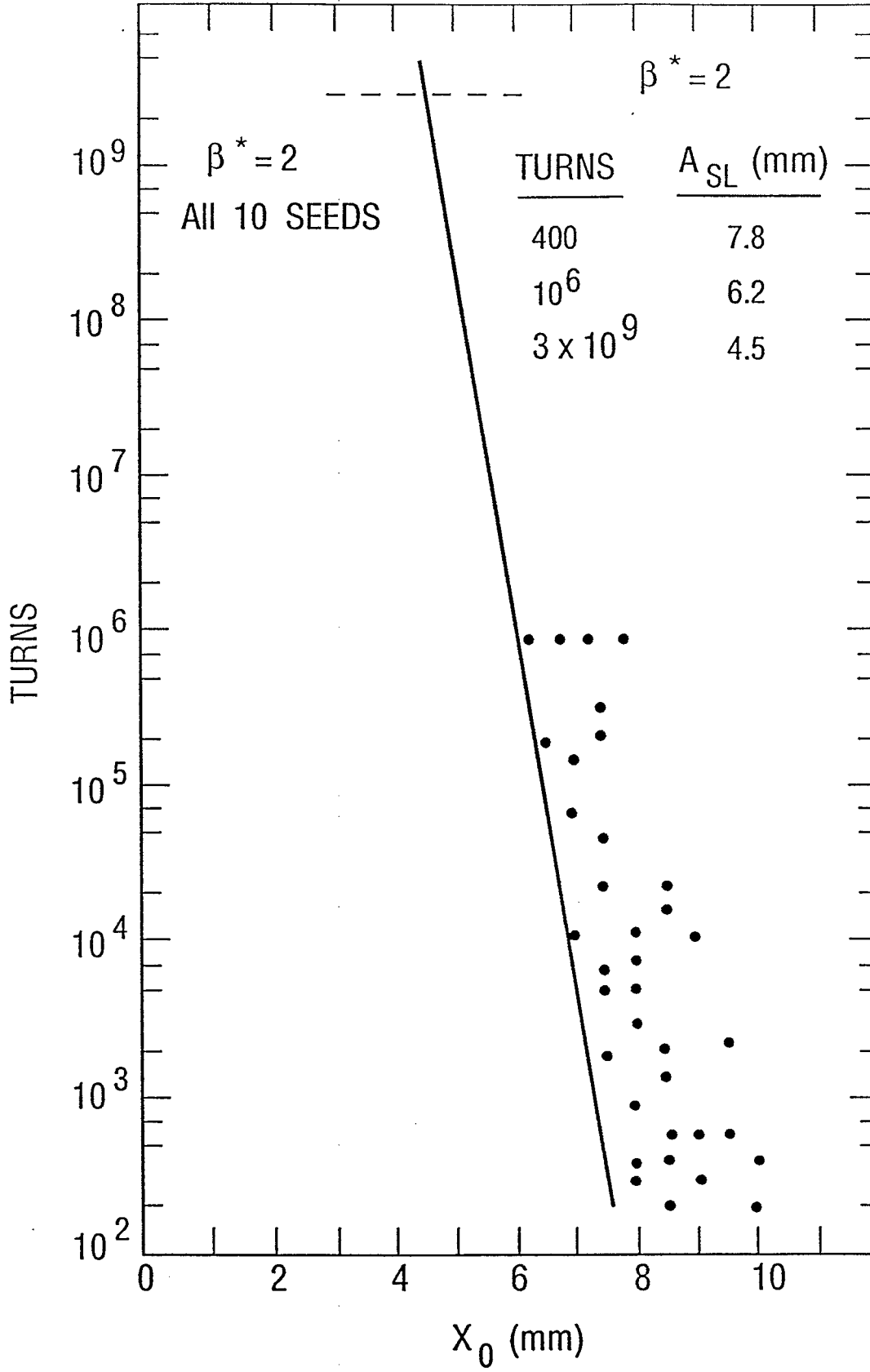


Figure 1: Survival times versus particle initial amplitude x_0 . $\beta^* = 2$ RHIC lattice. Ten different distributions of random field errors.

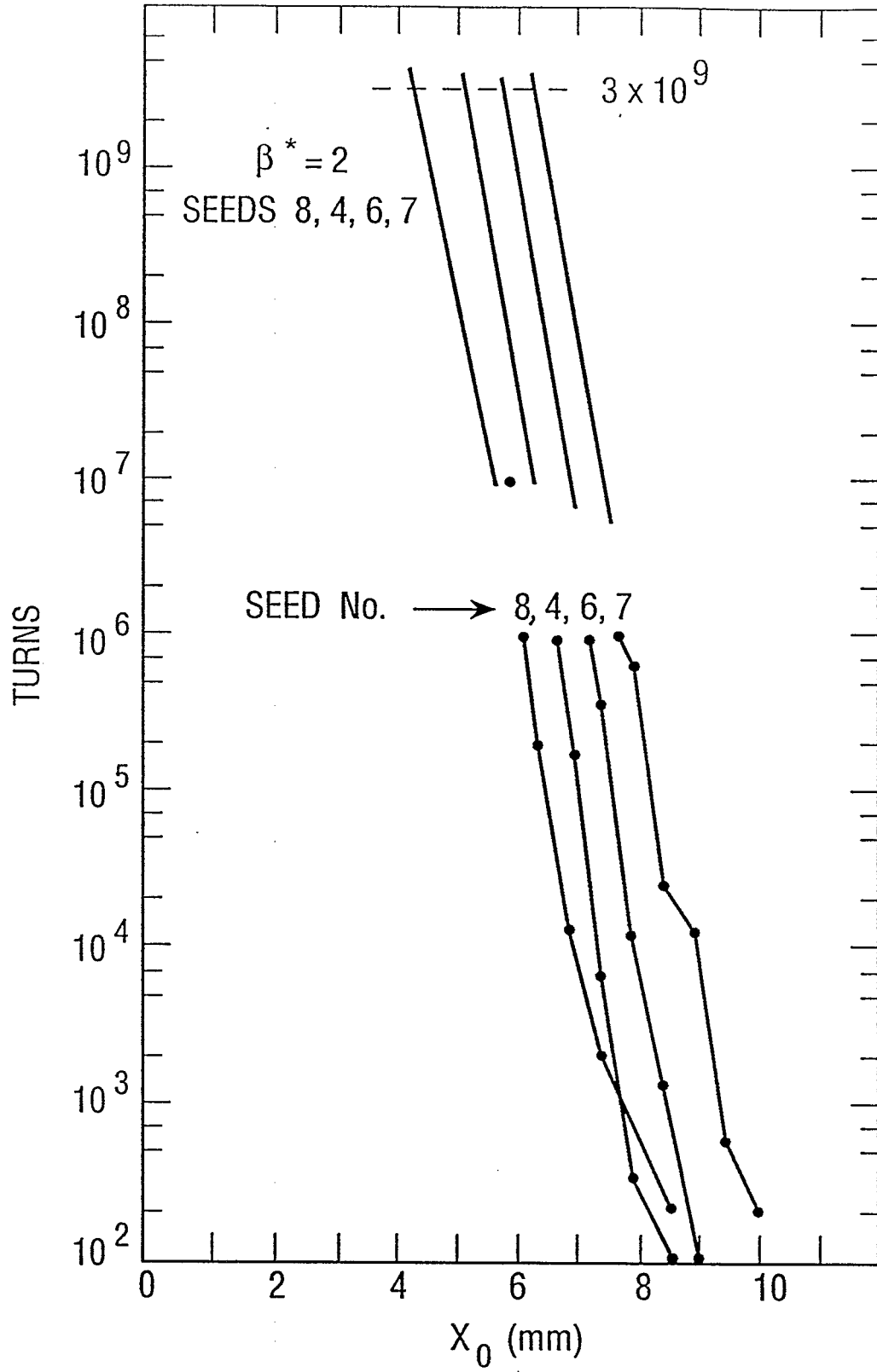


Figure 2: Survival times versus initial particle amplitude, x_0 for individual distributions of field errors corresponding to seeds 8, 4, 6 and 7. $\beta^* = 2$ RHIC lattice.

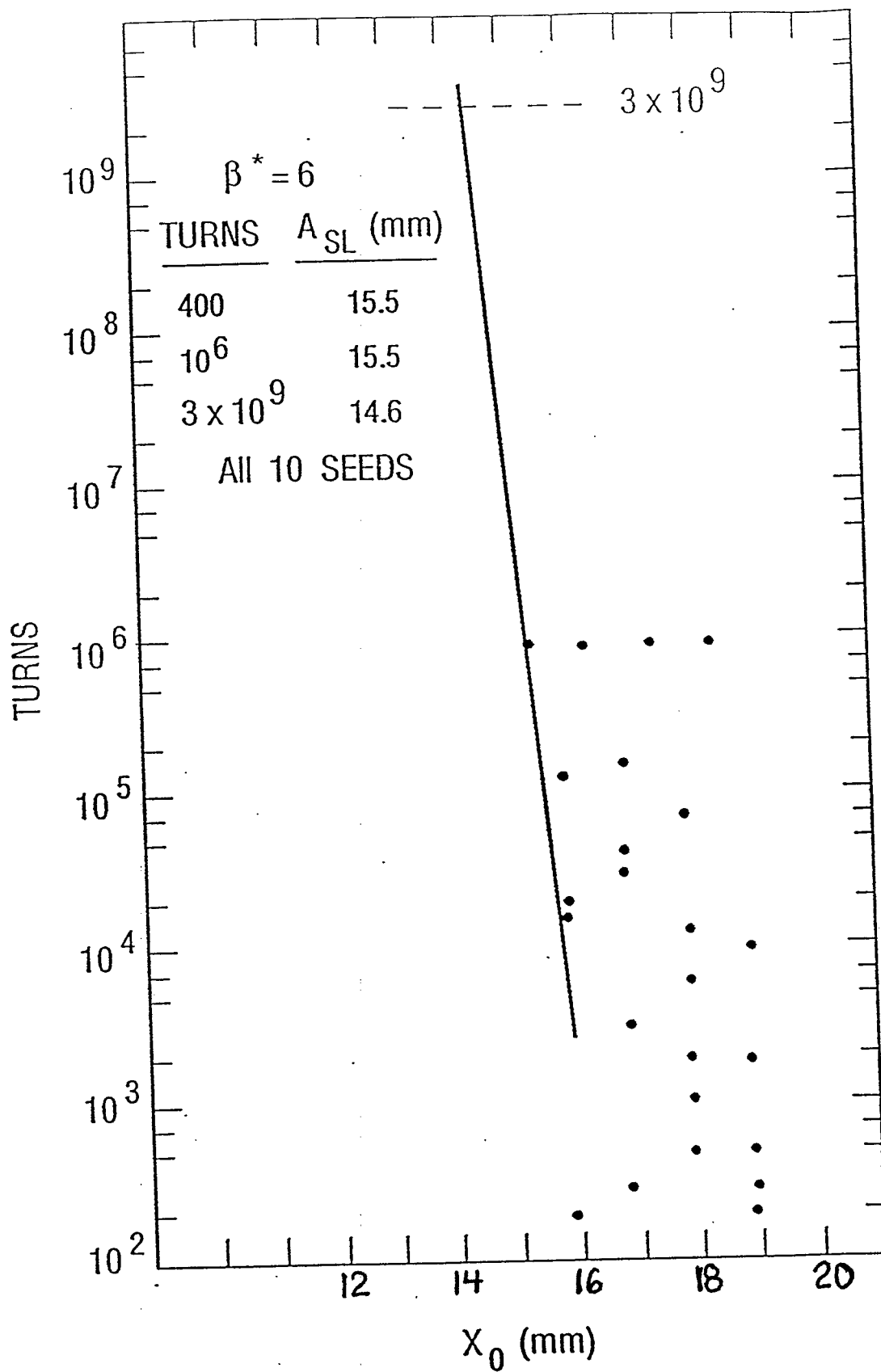


Figure 3: Survival times versus initial particle amplitude, x_0 . $\beta^* = 6$ RHIC lattice. Ten different distributions of random field errors.

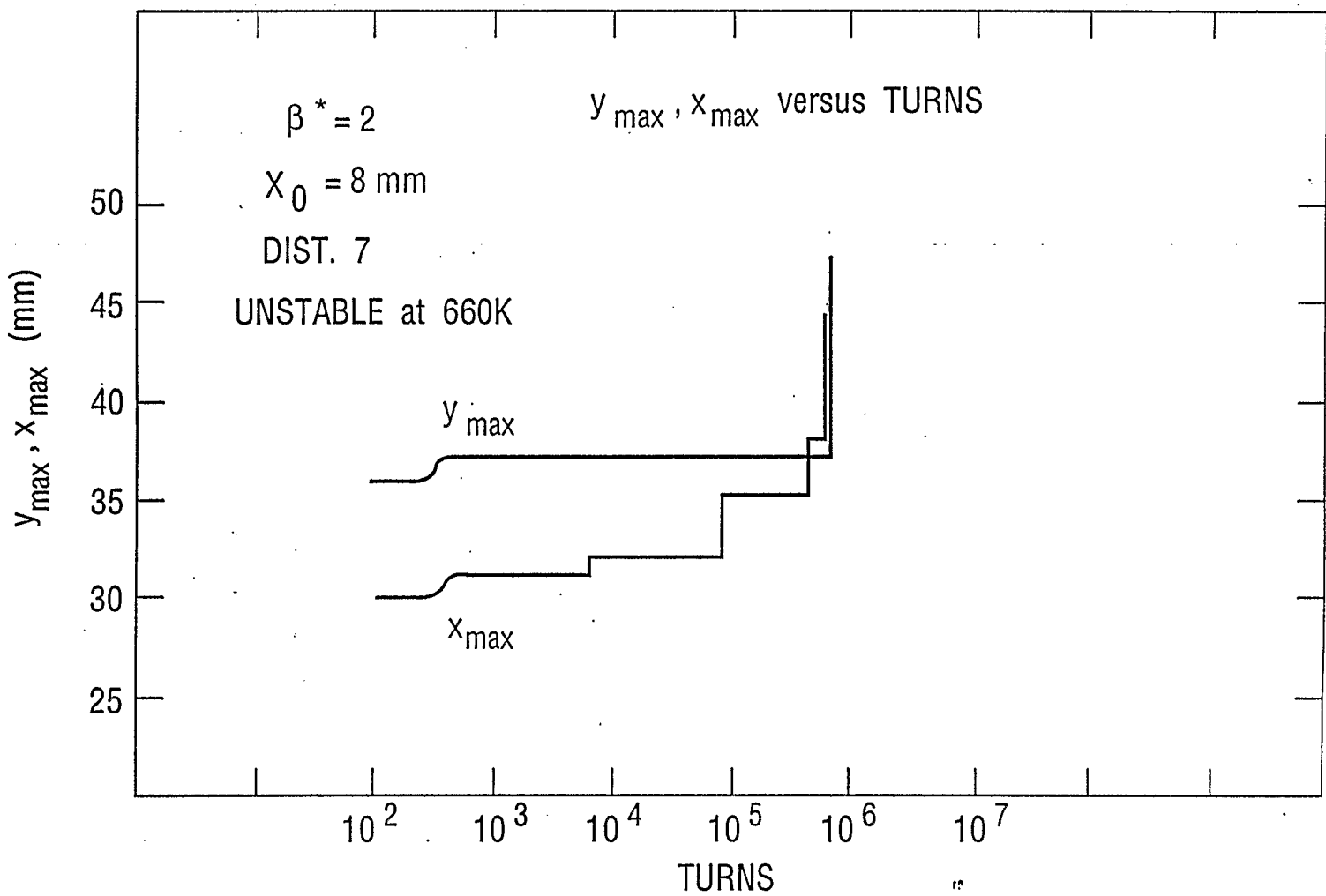


Figure 4: Particle growth versus time. $\beta^* = 2$ lattice, $x_0 = 8 \text{ mm}$. Unstable after 660,000 turns. x_{\max} and y_{\max} are the maximum x and y attained around the ring. Seed = 7.

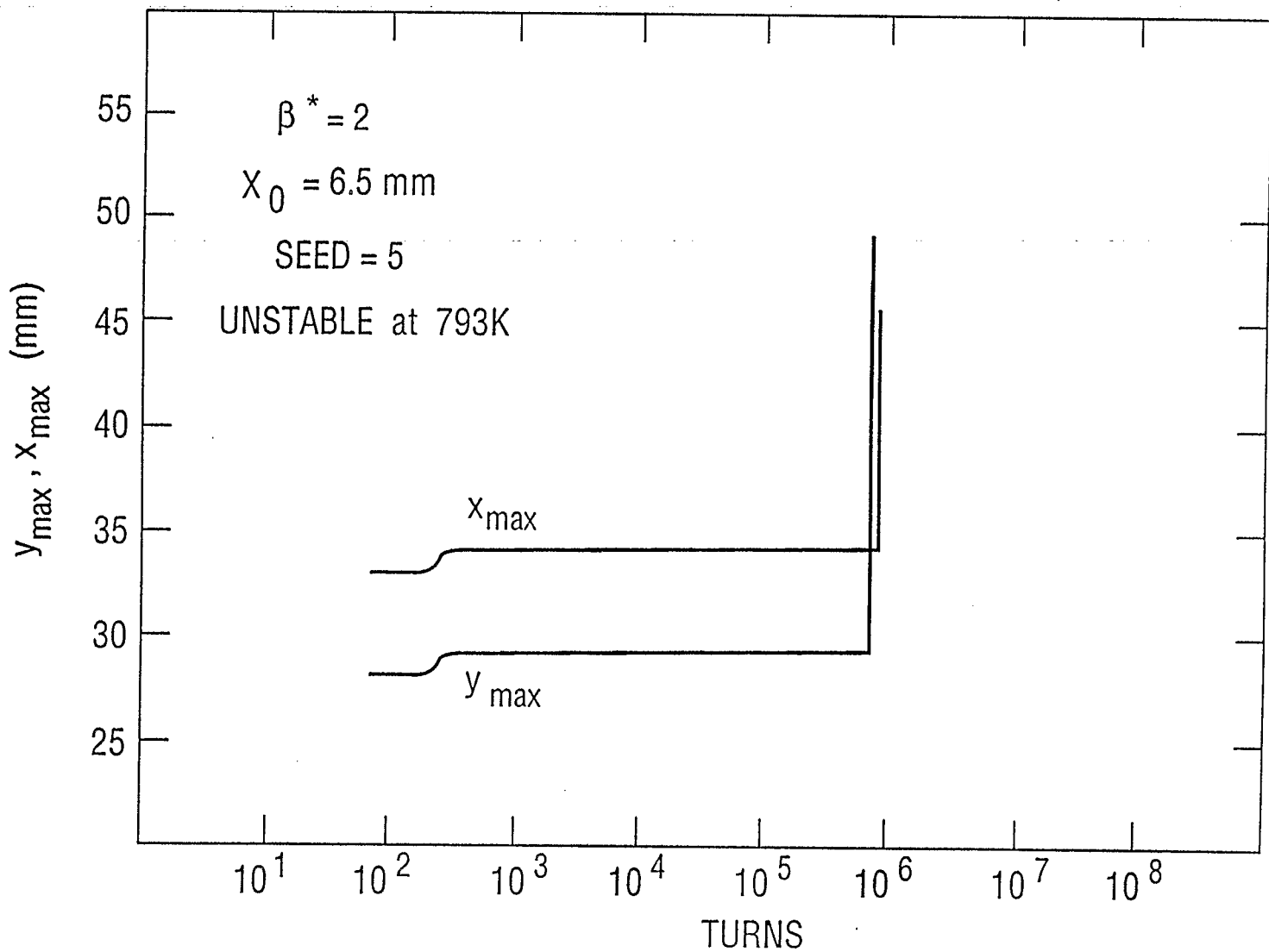


Figure 5: Particle growth versus time. $\beta^* = 2$ lattice, $x_0 = 6.5 \text{ mm}$.
 Unstable after 793,000 turns. Seed = 5.

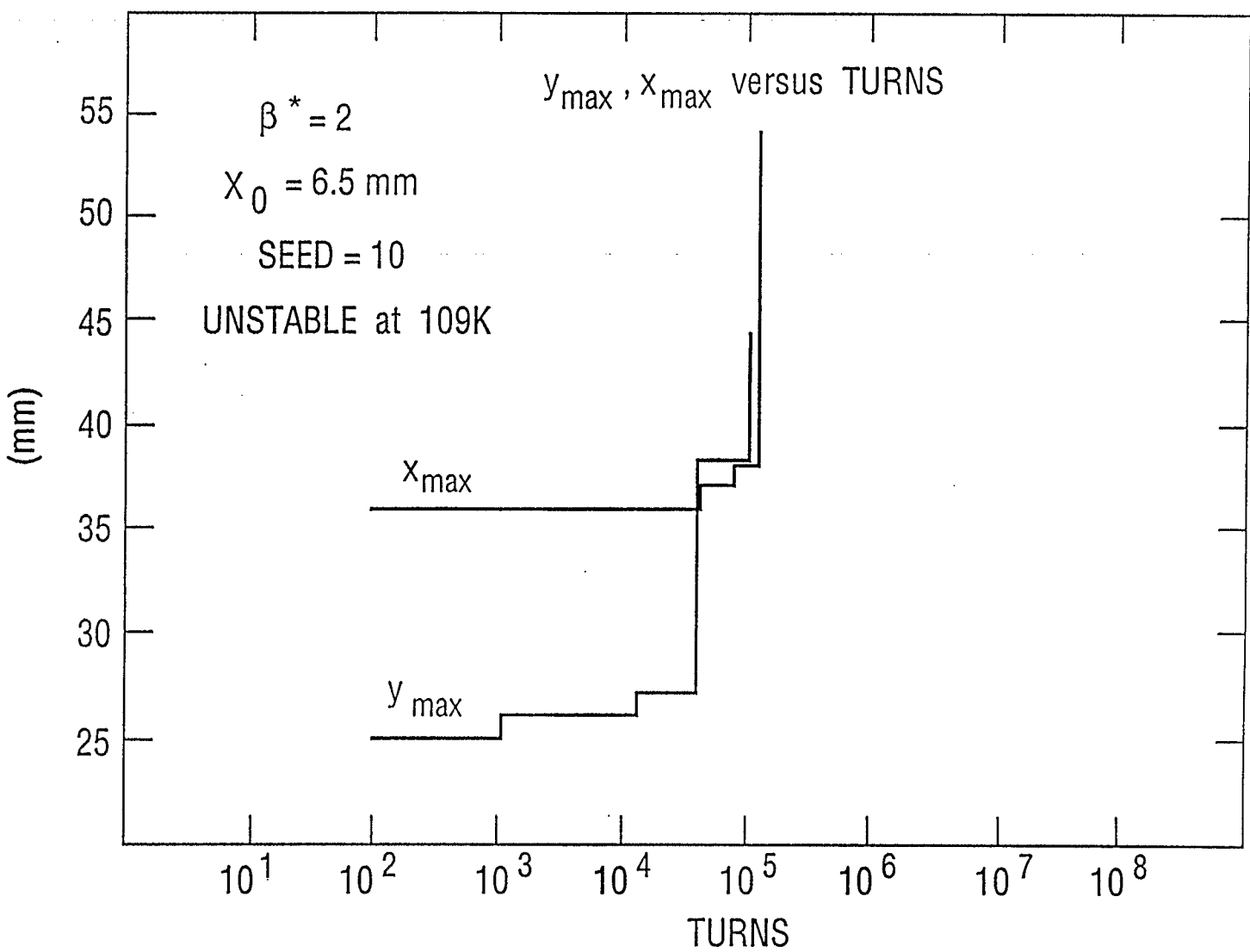


Figure 6: Particle growth versus time. $\beta^* = 2$ lattice. $x_0 = 6.5 \text{ mm}$. Unstable after 109,000 turns. Seed = 10.