TRACKING EXPERIENCE WITH PATRIS AT BNL*

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ABSTRACT

We present some of the results of our tracking investigations using PATRIS. Both short-term and long-term tracking, using large numbers of particles, were performed and analyzed. When switching from short-term (1000 turns) to long-term (the maximum achieved was 10 million turns) tracking mode, we observed a small (about 14%) reduction of the dynamic aperture. We also empirically confirmed that the distinction between short-term and long-term tracking becomes meaningful for a number of turns of the order of 100,000 rather than 10,000, i.e. that 10^5 is the threshold which must be crossed to get any appreciable difference between a 1000-turn run and a longer one. We have also found that a high density of initial conditions employed in tracking is somewhat more important for accurate determination of the dynamic aperture than a large number of turns.

1 INTRODUCTION

One of the main purposes of particle tracking in an accelerator is to determine the dynamic aperture, i.e. the region of stability in the machine, containing the initial conditions for which the particle motion will be stable. "Stable" in the tracking context means survival of a certain specified number of turns. This number, chosen for the purposes of computer simulation, was selected in conformity with the available computational resources, rather than being close to the actual number of turns being operational in a well-designed machine. In the past, when computer resources were more limited, this number was limited to 400 to 500 turns, while at present it is typically 1000 for short-term tracking and significantly greater for long-term tracking, where the available resources usually dictate the magnitude of that "significantly greater" number. Currently, this number will be in the vicinity of 10^6 or even beyond it.

2 MOTIVATION FOR TRACKING STUDIES; TOOLS SELECTED FOR TRACKING

In our tracking studies, we were motivated by our desire to understand better the nature of the dynamic aperture, in particular its possible dependence on the number of tracking turns. We wanted to verify or disprove some claims that it shrinks as one starts probing a very large number of turns (vicinity of one million or more).

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The tracking tool of our choice was the tracking code PATRIS,¹ run on a CRAY-2 computer. PATRIS was chosen for two reasons. First, it belongs to a class of codes which have been historically acceptable for tracking. Second, we know it very well and fully control its procedures and algorithms. The code is symplectic; it treats drifts, dipoles and quadrupoles to first order, by propagating the particles along trajectories which are solutions of linearized equations of motion. On the other hand, nonlinearities are simulated as thin lenses. The CRAY-2 was selected as the most powerful computer we had access to. It is fast and fairly accurate in the single precision mode, and it allows vectorization, which was crucial for simultaneous tracking of a large number of particles, up to 5000 per tracking run.

The lattice for tracking was RHICAGR.² The reason for its selection was that it is simpler than the "official" RHIC lattice, and unlike the "official" lattice it was not subject to constant changes. Moreover, the results are probably easier to understand, but the conclusions we derive should have a more general validity. Up to now, this lattice has been "ideal," i.e. without errors of any kind and with chromaticity correcting sextupoles as the only type of nonlinearities.

The program activities can be roughly classified into two categories: (a) short-term tracking activities, and (b) long-term tracking activities.

3 SUMMARY OF SHORT-TERM TRACKING ACTIVITIES

3.1 Short-Term Tracking; General Information

We started with short-term tracking activities, with the intention to move on later to work on long-term tracking. The number of turns we selected for short-term activities was $N = 1000$. Particles were launched from the middle of a defocusing quadrupole QD, with the initial conditions being always constrained by the

$$X' = Y' = 0 \quad (1)$$

condition, and in the eight different directions in the (ϵ_x, ϵ_y) plane. These directions are shown in Figure 1. Because of mid-plane symmetry of the ideal lattice, only directions 1 through 5 had to be examined.

In the initial phase of the investigations both physical and dynamic aperture were determined for all eight directions and for the momentum deviation values

$$\delta = -0.6\%, -0.4\%, -0.2\%, 0.0\%, +0.2\%, +0.4\%, +0.6\%. \quad (2)$$

Subsequent studies were restricted to the on-momentum ($\delta = 0$) case.

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Figure 1.
Eight selected directions
in the emittance plane

3.2 Dynamic Aperture and Particle Loss Criterion

Whereas in the search for physical aperture any particle was lost when it struck a magnet, in the search for dynamic aperture it was considered lost if its transverse coordinates (X, Y) violated the condition

$$\sqrt{X^2 + Y^2} \leq 1000 \text{ mm.} \quad (3)$$

This condition is being checked at every nonlinear element and also at the two aperture limitations which appeared to be in insertion dipoles.

3.3 Automated Searching Procedure

To determine the boundary of the dynamic aperture in a particular direction in the emittance plane, one has to launch several particles with different magnitudes of emittance all lying on the same direction. If these initial values are properly chosen, some particles will survive the tracking while others will be lost. One then concludes that the boundary of the dynamic aperture lies between the smallest emittance that gives rise to particle loss and the greatest emittance of all surviving particles being closer to the origin than any lost particle along this direction. Initial attempts to investigate this by adjusting the initial tracking emittances by hand, and then readjusting them subsequently for more accurate limits on the dynamic aperture, proved to be too time consuming, given the variety of directions in the emittance plane and the need to explore both dynamic and physical aperture (the latter with sextupoles both on and off) for on-momentum and several off-momentum values. To overcome this problem, we developed an automated searching procedure.

The automated procedure worked as follows. An interval $(\epsilon_0^{\min}, \epsilon_0^{\max})$ was chosen on the particular direction of interest. $\epsilon_0^{\min}$ was usually taken to be zero, while $\epsilon_0^{\max} = 15 \pi \text{mm}\cdot\text{mrad}$ was empirically found to be large enough to guarantee the loss of a particle launched from an $\epsilon_0^{\max}$ initial condition. This interval $(\epsilon_0^{\min}, \epsilon_0^{\max})$ was divided into N equal subintervals, and $(N + 1)$ particles equally spaced along that direction were launched. Our choice was $N = 25$. The emittances of the launched particles were

$$\epsilon_0^{\min}, \epsilon_0^{\min} + \Delta\epsilon_0, \epsilon_0^{\min} + 2\Delta\epsilon_0, \dots, \epsilon_0^{\min} + N\Delta\epsilon_0 = \epsilon_0^{\max} \quad (4)$$

where

$$\Delta\epsilon_0 = (\epsilon_0^{\max} - \epsilon_0^{\min}) / N. \quad (5)$$

Next we determined which particles were lost by violating the condition (3) or equivalent conditions in the case of searching for the physical aperture. Among them, we select the particle with the smallest emittance $\epsilon_{\text{LOST}}^{\min}$. All tracked particles with smaller emittances, of course, survived. Among these surviving particles we selected the survivor with the largest emittance $\epsilon_{\text{SURV}}^{\max}$. (See Figure 2.) Of course, $\epsilon_{\text{LOST}}^{\min} > \epsilon_{\text{SURV}}^{\max}$ and they satisfy the relation

$$\epsilon_{\text{LOST}}^{\min} - \epsilon_{\text{SURV}}^{\max} = \Delta\epsilon_0 = (\epsilon_0^{\max} - \epsilon_0^{\min}) / N. \quad (6)$$

Now we select new bounds

$$\epsilon_1^{\min} = \epsilon_{\text{SURV}}^{\max}, \quad \epsilon_1^{\max} = \epsilon_{\text{LOST}}^{\min}, \quad (7)$$

subdivide this new interval into N subintervals of the size

$$\Delta\epsilon_1 = (\epsilon_1^{\max} - \epsilon_1^{\min}) / N, \quad (8)$$

and repeat the tracking with a new set of $N + 1$ initial conditions, corresponding to the emittances that would result from a subdivision of the new interval $(\epsilon_1^{\min}, \epsilon_1^{\max})$ in a manner analogous to (4) and (5). This is then the second iteration of our automated searching procedure, which continues with iterating until the subinterval between the lost particle with the smallest emittance and its closest surviving neighbor with even smaller emittance becomes smaller than some predetermined ϵ . We then conclude that the boundary of the dynamic aperture lies in this final subinterval. In this manner, the dynamic and physical apertures were determined for all directions and all values of momentum deviation.

At this stage tune dependence on the amplitude was also determined from the tracking data by using FFT. One example of the results is shown in Figure 3. The solid line shows the results obtained by MAD³ and SYNCH⁴ on the basis of linear theory.⁵ The groups of hollow circles are the values obtained from the tracking data supplied by PATRIS. For small values of amplitude, where the linear theory is a good approximation, the agreement is very good.

Figure 2.
Equidistant particles along a direction in the emittance plane.
All are tracked with these initial conditions. Some are lost (L)
while others survive (S) the tracking.

Fig. 3 Tune-Shift vs. Horizontal Emittance for case #1

Phase-space plots were also generated for future use. They revealed the presence of third- and fifth-integer resonances, as obvious from Figures 4 and 5. Details are reported in Ref. 6, 7, and 8.

3.4 Problems with the Automated Searching Procedure; Elusiveness of the Dynamic Aperture

The previously described method of searching for the dynamic aperture by the automated iterative procedure also presented some problems. The searching procedure was rapidly converging but in doing so it constricted the searched interval on the emittance direction so quickly that it also missed some lost particles. The reason became obvious. The initial subinterval $\Delta\epsilon_0$ was big enough to allow the existence of some unstable but not tracked particles with emittances smaller than $\epsilon_{\text{SURV}}^{\text{max}}$, the emittance of the last acceptable survivor. After that, the algorithm iterated in the interval $(\epsilon_{\text{SURV}}^{\text{max}}, \epsilon_{\text{LOST}}^{\text{min}})$ which was already above the instability threshold. This threshold was not discovered since no particles were tracked in that region of instability. This is shown in Figure 6. This resulted in a systematic overestimation of the dynamic aperture, in particular in directions 2 and 4 (Figure 1).

The remedy for this problem was to start tracking with a much larger number of particles and then in the next iteration to choose a less constricted interval, which extends further toward the origin in the (ϵ_x, ϵ_y) plane from the detected lost particle with the smallest emittance $\epsilon_{\text{LOST}}^{\text{min}}$. This new interval is now big enough to contain presumably all unstable particles with emittances smaller than $\epsilon_{\text{LOST}}^{\text{min}}$, not tracked in the first iteration. The new iteration, with the higher density of particles per emittance interval, will now catch most of them. In this way, each iteration is catching unstable particles without grossly overshooting those with emittances where instabilities start. This method is slower but safer. To determine the dynamic aperture with an accuracy of $0.01 \pi \text{mm}\cdot\text{mrad}$, we selected the number of particles $N = 250$ for subdivision of a selected interval in any iteration, and after that iteration we selected as the interval for the next iteration, the part of this selected interval that contained the detected lost particle with the smallest emittance $\epsilon_{\text{LOST}}^{\text{min}}$ together with its first 25 adjacent survivors in the direction of the origin. One extra iteration was needed compared with the simpler scheme, but this time no overestimation of the dynamic aperture occurred, as confirmed by the investigations described in the next section.⁸

This improved procedure revealed the presence of many holes within the initially determined (and usually overestimated) dynamic aperture. We suspect that this problem arose for many researchers who relied on determining the dynamic aperture by tracking a few particles, and we caution against this practice. Some awareness of the problem was privately conveyed to us by our colleagues.^{9,10} All these features were sufficiently intriguing to justify a more detailed investigation, which is the subject of the next section.

INITIAL PARAMETERS OF PARTICLE #16 : XA= -8.9705MM XPA= 0.0000MRAD YA= 0.0000MM YPA= 0.0000MRAD
 OR : EMITTANCES(Pi-mm-mrad) -----> EPSX: 9.00 EPSY: 0.00

Figure 6.

Same equidistant particles as those tracked and represented in Figure 2. As before, they are represented by "o." Particles which were not tracked but which would have been lost had they been tracked are now represented by "x."

3.5 Probing the Dynamic Aperture with a Large Number of Particles; External Regions of Stability

In the subsequent investigations all five directions in the (ϵ_x, ϵ_y) plane were examined, in the emittance intervals $(0.0, 25.0) \pi\text{mm}\cdot\text{mrad}$. A total of 25,000 equally spaced particles were launched in each direction and tracked for 1000 turns, as usual. This means a subdivision into intervals of the size

$$\Delta\epsilon = (25/25000) = 0.001 \pi\text{mm}\cdot\text{mrad}. \quad (9)$$

The number of turns that each particle made was recorded. Regions of stability interspersed by regions of instability were found. This is shown in Tables 1 through 6, which appear at the end of this paper.

Each table represents the number of turns a tracked particle successfully completed. There are four sections on each page. The first column represents a particle number in the set of 5000 particles tracked in one run. The second column represents the number of turns the particle completed. The third column represents the horizontal initial emittance. Vertical emittance is not shown since it is zero in this run. The next three sections are continuations of the first, placed beside it to save space.

Table 1 starts with particle number 3701 with the emittance $12.4500 \pi\text{mm}\cdot\text{mrad}$. The run started from a particle (number 1 in the sequence, not shown here) with the emittance $10.0 \pi\text{mm}\cdot\text{mrad}$. No lost particles were detected in two other runs that covered the emittance intervals below $10.0 \pi\text{mm}\cdot\text{mrad}$, and no particle in this run was lost in the sequence number 1 through 3700. For this reason the table starts at particle number 3701. From the table it is obvious that very few particles were lost in the emittance interval $(12.450, 12.649) \pi\text{mm}\cdot\text{mrad}$, covered by this table. These lost particles look more like a set of "holes" at larger emittances than the edge of the dynamic aperture. The next 200 particles (numbers 3901 through 4100) all survived, hence we omitted the corresponding table. Table 2 covers particles number 4101 through 4300. It reveals more holes than Table 1 but still a vast majority of particles survive 1000 turns. Table 3 suddenly shows a different picture. Instead of holes, continuous emittance intervals where particles are lost appear. Table 4, on the other hand, looks again like Table 2, even though emittances are greater here than in Table 3. We now have continuous emittance intervals

where particles are stable and some holes separating these intervals. This picture continues into Table 5, with the exception of its last section, where again we have regions of instability interspersed by regions of stability. Finally, Table 6 reveals unstable particles, with a couple of isolated particles which did survive 1000 turns.

From this set of tables it is obvious that what we call "dynamic aperture as the region of stability of particle motion" is somewhat tricky and also to some extent arbitrary. Figure 7 shows a rough qualitative sketch of the number of successfully completed turns as a function of the initial emittance for case 1 (see Fig. 1 for classification). Although every hole could not be represented in this sketch, it should convey the qualitative picture of regions of stability interspersed by regions of instability. We can conditionally use the name "dynamic aperture" for the compact central region of stability which in this case covers the emittances from 0.0 up to 12.4700 $\pi\text{mm}\cdot\text{mrad}$, and we can call the more distant finite intervals, where particles survive the tracking, the "external regions of stability."

At this point we would like to offer a clear explanation of why it is so easy to overestimate the dynamic aperture. By using a small number of particles one has a good chance of missing not only isolated holes but also finite intervals of instability, e.g. the interval spanned by particles number 4324 and 4333 in Table 3, because of the presence of adjacent finite regions of stability such as the region spanned by particles 4341 and 4346. Or even worse, if one starts tracking from large emittances with few particles, which are mainly lost, and

Figure 7.
Sketch of the number of completed turns as a function of the emittance. Direction # 1.

then reduces the amplitudes until all start surviving the tracking, then one is risking a significant overestimation of the dynamic aperture since even the innermost particle may end up in a distant external region of stability such as the thick region spanned by particles number 4766 and 4841 in Table 5. For this reason, our initially designed automated searching procedure malfunctioned. On the other hand, our improved version of the searching procedure pinpointed the real edge of the dynamic aperture, precisely at the value of the emittance $12.4700 \pi \text{ mm-mrad}$, revealed in our unusually dense probing of the stability regions under tracking.⁸

Three fundamental questions arise at this point:

1. Do these external regions of stability, lying beyond the central compact region, which we conditionally call the "dynamic aperture," survive if we increase the number of tracking turns beyond 1000?
2. What happens with the central region if the number of turns is much greater than 1000? Does it shrink and, if so, how much?
3. What happens if we significantly increase the density of particles used to probe the stability regions? Will holes start appearing in the external regions of stability or even in the central region?

The third question is the toughest, since it must be tackled in conjunction with the first two. Or, to be precise, given the potential dependence of a particle's stability verification on the number of tracking turns, one would have to increase the number of tracking turns and the density of initial conditions simultaneously. Before even contemplating this kind of research, one has to come up with some answer to the first two questions. This was indeed the subject of our long-term tracking investigations.

4 SUMMARY OF LONG-TERM TRACKING ACTIVITIES

4.1 Long-Term Tracking; General Information

Before embarking upon a long term tracking study, one has to achieve the following two objectives: (a) an assessment of the possible contributions due to computer roundoff error, and (b) vectorization of the tracking code, if one intends to track a large number of particles per computer run.

Having in mind long-term tracking with a large number of particles per run, we made sure that both objectives had been achieved before we launched a real long-term tracking run.

4.2 Roundoff Error; An Assessment of Its Impact

To assess the impact of the roundoff error, tracking runs were undertaken with sextupoles present in the lattice, but with zero strength. In this case, the following two quantities are separately invariant:

$$u^2 + u'^2 = \epsilon_x, \quad (10)$$

$$v^2 + v'^2 = \epsilon_y, \quad (11)$$

where

$$u = X/\sqrt{\beta_x}, \quad u' = \alpha_x X/\sqrt{\beta_x} - \sqrt{\beta_x} X', \quad (12)$$

$$v = Y/\sqrt{\beta_y}, \quad v' = \alpha_y Y/\sqrt{\beta_y} - \sqrt{\beta_y} Y'. \quad (13)$$

Particles with several different initial emittances were tracked for 10^4 and 10^6 turns and these two invariants were computed and recorded as functions of the number of turns. The results are shown in Tables 7 and 8, at the end of this paper.

The entries in the tables show that these two invariants exhibit a linear change with the number of turns. Since the quadratic invariants Eqs. (10) and (11) grow (or diminish) proportionally to the number of turns N , it follows that the quantities (u, u', v, v') and subsequently (X, X', Y, Y') suffer from an error proportional to $\sqrt{N}$. This proves that what we are detecting in this test is indeed a result of the computer roundoff, which is proportional to $\sqrt{N}$.

Furthermore, the tables shows that the rate of error accumulation is closer to 10^{-12} than to 10^{-11} per turn. This means that even after 10^7 turns the total accumulation will affect the emittance by an amount lying between 10^{-5} and 10^{-4} . Therefore, the roundoff error will not affect the evaluation of the dynamic aperture by more than several parts in 10^{-5} , for 10 million turns!

4.3 Vectorization

This was simply a must, if a large number of particles per computer run were to be tracked. The action of each magnet contains a loop with a counter running over the tracked particles and this loop was a natural candidate for vectorization. This was tricky, since the condition (3), which verifies a particle's survival, inhibits vectorization. However, these obstacles were overcome by using some ideas from Ref. 11 and 12. After that, the CPU time for 5000 particles and 1000 turns dropped from 1 hour to 256 seconds.

4.4 Tracking Results

After successful vectorization and roundoff error analysis, a pilot run was made with 100 particles for 10^6 turns. The immediate consequence noted was that the dynamic aperture shrinks, but the external regions of stability do survive one million turns. The results are shown in Table 9, at the end of this paper. The first two sections show the results of the pilot run, if only 1000 turns are requested. As before, the first hole is for the initial emittance $12.4700 \pi \text{mm} \cdot \text{mrad}$. Even though the particle density is much smaller than in the run represented partially in Tables 1 through 6, one sees the presence of holes (particles number 37, 59, 66, 67) and an external region of stability, spanned by particles number 77 through 93. The remaining two sections show the results of the same run if the full number of 10^6 turns are requested. A brief look at these two sections reveals several interesting features. The dynamic aperture is smaller than the same quantity determined for 1000 turns. Its

exact value unfortunately was not determined in this run since our selection of the innermost particle overshot the edge of the dynamic aperture. However, an external region of stability is revealed in the region that was previously part of the compact central region called the "dynamic aperture at 1000 turns." This region is now spanned by particles number 28 through 33. The next external region of stability is now in the area that was previously between the first two holes, but this time the stability region is narrower (particles number 47 through 56). The previous external region of stability (particles number 77 through 93, for 1000 turns) is not completely lost at 10^6 turns. It gets narrower, spanned by particles number 83 through 87, and is accompanied by two isolated stable particles, numbers 91 and 92.

Finally, encouraged by these interesting results, we made a big run with 250 particles for 10 million turns. It consumed about 25 hours of CRAY-2 CPU time. In the slow batch queue, it cost us about 9 hours of CRAY-2 CRU units. The results are presented in Tables 10 and 11, at the end of this paper.

Table 10 shows the results of this long tracking run, if only 1000 turns are being requested. It is presented for a better comparison with the results of the long run, which are displayed in Table 11. Both tables start with particle number 51 since all among the first 50 particles did survive the requested total of 10 million turns. The following remarkable features appear:

1. The dynamic aperture, rigorously determined for 10 million turns, shrinks to about 86% of the dynamic aperture determined with the same rigor for 1000 turns.
2. The external stable regions become narrower but do survive the requested total of 10 million turns. Furthermore, among the particles that do not survive 10 million turns, a relatively small number survive even 1 million turns.
3. There are no holes, i.e. isolated unstable particles imbedded in otherwise stable regions, under a 10-million-turn stability test. Analogs of particles number 187 or 209 from the 1000-turn test do not exist any more. Isolated stable particles such as numbers 119, 145 or 215 still exist. The last case is stable under a 10-million-turn test even though it has highly unstable particles such as 219 and 220 in its proximity. This absence of holes for a high number of turns may be a consequence of the limited density of the initial conditions, and it is quite possible that the holes would reappear under a much higher density of initial conditions. In this run, computer resources forced us to choose an initial emittance spacing of $0.02 \pi \text{mm} \cdot \text{mrad}$, which is 20 times coarser than the previously used finest spacing of $0.001 \pi \text{mm} \cdot \text{mrad}$.
4. Going from 1000 turns to 10,000 turns leaves the dynamic aperture practically unaffected (just a bare 2% decrease). Much higher thresholds must be crossed to see "real things happening."

5. For those particles that survive all 10 million turns, a phase-space diagram during the last 1000 turns is almost identical to a diagram taken during the first 1000 turns. The two are so similar that they were barely distinguishable, or even indistinguishable, under visual inspection. This similarity was present both in the central compact region that we call the dynamic aperture and in the external regions of stability.
6. By failing to probe the dynamic aperture with a sufficient density of initial conditions, one can miss some unstable particles and conclude that the edge of the dynamic aperture is what is actually the outer edge of one of the external regions of stability. Exactly this happened to us during the initial phases of our tracking investigations. This can cause overestimation of the dynamic aperture by much more than 14%, which was the amount of overestimation we discovered after comparing a run for 1000 turns with a run for 10 million turns started from the same initial conditions. Our grossest overestimation, in tracking direction 4 in the emittance plane, with the presence of coupling provided by the sextupoles, was close to 100% for tracking with a low density of initial conditions. Therefore, probing with a higher density of initial conditions offers a better limit on the dynamic aperture, per computer resources involved, than probing with fewer particles but a higher number of turns. This is especially true if the tracking code is properly vectorized. We even dare say that going to a very high number of turns is not very meaningful in the context of searching for the dynamic aperture, unless it is accompanied by a sufficient density of initial conditions!

5 CONCLUSION

We initiated our tracking studies with a clear motivation to understand better the somewhat fuzzy nature of the dynamic aperture. Even before this study we knew that holes in stability regions, i.e. initial conditions of some unstable particles, do exist near the edge of the dynamic aperture. We also knew that some of our colleagues were aware of the presence of these holes.^{9,10} Various claims had also been made about the reduction of the dynamic aperture for a high number of tracking turns. We wanted either to verify or to disprove them. Our attitude was to examine more initial conditions than done by most of our colleagues, i.e. to examine eight directions in the emittance plane (Fig. 1), and for each direction to proceed in small steps. Under the influence of our preliminary results, this attitude eventually resulted in probing the dynamic aperture with a high density of initial conditions.

The results we obtained were interesting and at least partially unexpected. The most significant observation is the existence of external stability regions and their survival under a ten-million-turn test. They have an important

practical consequence on the tracking procedures, namely the need for a relatively high density of initial conditions to avoid possible overestimation of the magnitude of the dynamic aperture. Going to large number of tracking turns also appears to be important. Unfortunately, thresholds that must be crossed are closer to 10^5 turns than to 10^4 turns, so that a significant increase in the number of tracking turns is needed to see real changes. Tracking for 1000 turns looks more like a crude estimate than like a meaningful determination of the dynamic aperture. It also appears that in the absence of unlimited resources one first has to probe the dynamic aperture with a high density of initial conditions to prevent its gross overestimation, and only after that should one try to examine the edge of the dynamic aperture and the adjacent regions by higher numbers of turns. In a practical sense, the dynamic aperture appears to be a fuzzy and elusive concept, and tracking with a few particles for 1000 turns provides only a very rough estimation of the extent of the stability region.

6 REFERENCES

1. J. Milutinovic and A.G. Ruggiero, Comparison of Accelerator Codes for a RHIC Lattice, AD/AP-9, BNL, 1988.
2. A.G. Ruggiero, RHICAGR. A Most Simplified RHIC Lattice, AD/AP-26, BNL, August 1991.
3. H. Grote and F.C. Iselin, The MAD Program, Ver. 8.4, CERN/SL/90-13 (AP) (Rev. 2).
4. A.A. Garren et al., A User's Guide to SYNCH, FN-420, Fermilab, June 1985.
5. T.L. Collins, Distortion Functions, Fermilab-84/114, Fermilab, October 1984.
6. J. Milutinovic and A.G. Ruggiero, Long-Term Tracking with PATRIS. Part 1. Search of Physical and Dynamic Aperture with Sextupoles, AD/AP-34, BNL, January 1992.
7. J. Milutinovic and A.G. Ruggiero, Long-Term Tracking with PATRIS. Part 2. Aberration Effects, AD/AP-40, BNL, April 1992.
8. J. Milutinovic and A.G. Ruggiero, Long-Term Tracking with PATRIS. Part 3. Dynamic Aperture - How Stringent Is This Concept? AD/AP-44, BNL, June 1992.
9. E. Forest, private communications (1987 and later).
10. G.F. Dell, private communication (1992).
11. M. Metcalf, *Fortran Optimization*, Academic Press, London (1985).
12. C.G. Lazou, *Supercomputers and Their Use*, Clarendon Press, Oxford (1988).

TABLE 1. Number of completed turns in the emittance interval (12.450, 12.649) P.i.a. mrad. Direction # 1.

Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt
3701	1000	12.4500	3751	1000	12.5000	3801	1000	12.5500	3851	1000	12.6000
3702	1000	12.4510	3752	1000	12.5010	3802	1000	12.5510	3852	1000	12.6010
3703	1000	12.4520	3753	1000	12.5020	3803	1000	12.5520	3853	1000	12.6020
3704	1000	12.4530	3754	1000	12.5030	3804	866	12.5530	3854	830	12.6030
3705	1000	12.4540	3755	1000	12.5040	3805	1000	12.5540	3855	1000	12.6040
3706	1000	12.4550	3756	1000	12.5050	3806	1000	12.5550	3856	1000	12.6050
3707	1000	12.4560	3757	1000	12.5060	3807	999	12.5560	3857	1000	12.6060
3708	1000	12.4570	3758	1000	12.5070	3808	1000	12.5570	3858	1000	12.6070
3709	1000	12.4580	3759	1000	12.5080	3809	1000	12.5580	3859	505	12.6080
3710	1000	12.4590	3760	1000	12.5090	3810	1000	12.5590	3860	1000	12.6090
3711	1000	12.4600	3761	1000	12.5100	3811	1000	12.5600	3861	1000	12.6100
3712	1000	12.4610	3762	1000	12.5110	3812	1000	12.5610	3862	1000	12.6110
3713	1000	12.4620	3763	1000	12.5120	3813	1000	12.5620	3863	1000	12.6120
3714	1000	12.4630	3764	1000	12.5130	3814	1000	12.5630	3864	1000	12.6130
3715	1000	12.4640	3765	1000	12.5140	3815	1000	12.5640	3865	1000	12.6140
3716	1000	12.4650	3766	1000	12.5150	3816	1000	12.5650	3866	1000	12.6150
3717	1000	12.4660	3767	1000	12.5160	3817	1000	12.5660	3867	1000	12.6160
3718	1000	12.4670	3768	1000	12.5170	3818	1000	12.5670	3868	1000	12.6170
3719	1000	12.4680	3769	1000	12.5180	3819	1000	12.5680	3869	1000	12.6180
3720	1000	12.4690	3770	1000	12.5190	3820	992	12.5690	3870	1000	12.6190
3721	875	12.4700	3771	1000	12.5200	3821	1000	12.5700	3871	1000	12.6200
3722	1000	12.4710	3772	1000	12.5210	3822	721	12.5710	3872	1000	12.6210
3723	1000	12.4720	3773	1000	12.5220	3823	1000	12.5720	3873	696	12.6220
3724	1000	12.4730	3774	1000	12.5230	3824	1000	12.5730	3874	1000	12.6230
3725	1000	12.4740	3775	1000	12.5240	3825	1000	12.5740	3875	1000	12.6240
3726	1000	12.4750	3776	1000	12.5250	3826	1000	12.5750	3876	1000	12.6250
3727	1000	12.4760	3777	1000	12.5260	3827	1000	12.5760	3877	615	12.6260
3728	1000	12.4770	3778	1000	12.5270	3828	1000	12.5770	3878	1000	12.6270
3729	1000	12.4780	3779	1000	12.5280	3829	1000	12.5780	3879	1000	12.6280
3730	1000	12.4790	3780	1000	12.5290	3830	1000	12.5790	3880	1000	12.6290
3731	1000	12.4800	3781	1000	12.5300	3831	1000	12.5800	3881	1000	12.6300
3732	1000	12.4810	3782	1000	12.5310	3832	1000	12.5810	3882	1000	12.6310
3733	1000	12.4820	3783	1000	12.5320	3833	1000	12.5820	3883	1000	12.6320
3734	1000	12.4830	3784	1000	12.5330	3834	1000	12.5830	3884	1000	12.6330
3735	1000	12.4840	3785	1000	12.5340	3835	1000	12.5840	3885	1000	12.6340
3736	1000	12.4850	3786	1000	12.5350	3836	1000	12.5850	3886	1000	12.6350
3737	1000	12.4860	3787	1000	12.5360	3837	1000	12.5860	3887	1000	12.6360
3738	1000	12.4870	3788	1000	12.5370	3838	483	12.5870	3888	1000	12.6370
3739	1000	12.4880	3789	1000	12.5380	3839	1000	12.5880	3889	1000	12.6380
3740	1000	12.4890	3790	1000	12.5390	3840	349	12.5890	3890	1000	12.6390
3741	1000	12.4900	3791	1000	12.5400	3841	1000	12.5900	3891	1000	12.6400
3742	1000	12.4910	3792	1000	12.5410	3842	1000	12.5910	3892	1000	12.6410
3743	1000	12.4920	3793	1000	12.5420	3843	1000	12.5920	3893	1000	12.6420
3744	1000	12.4930	3794	1000	12.5430	3844	1000	12.5930	3894	1000	12.6430
3745	1000	12.4940	3795	1000	12.5440	3845	1000	12.5940	3895	1000	12.6440
3746	1000	12.4950	3796	1000	12.5450	3846	1000	12.5950	3896	1000	12.6450
3747	1000	12.4960	3797	1000	12.5460	3847	1000	12.5960	3897	1000	12.6460
3748	1000	12.4970	3798	1000	12.5470	3848	1000	12.5970	3898	1000	12.6470
3749	1000	12.4980	3799	1000	12.5480	3849	1000	12.5980	3899	1000	12.6480
3750	1000	12.4990	3800	1000	12.5490	3850	1000	12.5990	3900	1000	12.6490

TABLE 2. Number of completed turns in the emittance interval (12.850, 13.049) Pi.mm.mrad. Direction # 1.

Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX
4101	1000	12.8500	4151	1000	12.9000	4201	1000	12.9500	4251	1000	13.0000
4102	1000	12.8510	4152	1000	12.9010	4202	390	12.9510	4252	1000	13.0010
4103	1000	12.8520	4153	1000	12.9020	4203	185	12.9520	4253	1000	13.0020
4104	1000	12.8530	4154	1000	12.9030	4204	924	12.9530	4254	404	13.0030
4105	1000	12.8540	4155	1000	12.9040	4205	317	12.9540	4255	1000	13.0040
4106	1000	12.8550	4156	1000	12.9050	4206	1000	12.9550	4256	1000	13.0050
4107	1000	12.8560	4157	1000	12.9060	4207	1000	12.9560	4257	1000	13.0060
4108	1000	12.8570	4158	1000	12.9070	4208	1000	12.9570	4258	1000	13.0070
4109	1000	12.8580	4159	1000	12.9080	4209	1000	12.9580	4259	1000	13.0080
4110	1000	12.8590	4160	569	12.9090	4210	1000	12.9590	4260	1000	13.0090
4111	1000	12.8600	4161	419	12.9100	4211	651	12.9600	4261	1000	13.0100
4112	1000	12.8610	4162	1000	12.9110	4212	878	12.9610	4262	1000	13.0110
4113	1000	12.8620	4163	1000	12.9120	4213	1000	12.9620	4263	1000	13.0120
4114	1000	12.8630	4164	1000	12.9130	4214	1000	12.9630	4264	1000	13.0130
4115	1000	12.8640	4165	1000	12.9140	4215	625	12.9640	4265	1000	13.0140
4116	1000	12.8650	4166	1000	12.9150	4216	972	12.9650	4266	1000	13.0150
4117	1000	12.8660	4167	1000	12.9160	4217	1000	12.9660	4267	1000	13.0160
4118	1000	12.8670	4168	1000	12.9170	4218	272	12.9670	4268	1000	13.0170
4119	1000	12.8680	4169	1000	12.9180	4219	591	12.9680	4269	1000	13.0180
4120	1000	12.8690	4170	1000	12.9190	4220	1000	12.9690	4270	1000	13.0190
4121	1000	12.8700	4171	1000	12.9200	4221	1000	12.9700	4271	1000	13.0200
4122	1000	12.8710	4172	944	12.9210	4222	1000	12.9710	4272	1000	13.0210
4123	1000	12.8720	4173	397	12.9220	4223	1000	12.9720	4273	1000	13.0220
4124	1000	12.8730	4174	1000	12.9230	4224	1000	12.9730	4274	1000	13.0230
4125	1000	12.8740	4175	1000	12.9240	4225	326	12.9740	4275	1000	13.0240
4126	1000	12.8750	4176	514	12.9250	4226	1000	12.9750	4276	1000	13.0250
4127	1000	12.8760	4177	325	12.9260	4227	1000	12.9760	4277	1000	13.0260
4128	1000	12.8770	4178	1000	12.9270	4228	569	12.9770	4278	1000	13.0270
4129	810	12.8780	4179	1000	12.9280	4229	1000	12.9780	4279	1000	13.0280
4130	1000	12.8790	4180	1000	12.9290	4230	341	12.9790	4280	1000	13.0290
4131	1000	12.8800	4181	1000	12.9300	4231	924	12.9800	4281	1000	13.0300
4132	696	12.8810	4182	1000	12.9310	4232	1000	12.9810	4282	1000	13.0310
4133	1000	12.8820	4183	1000	12.9320	4233	496	12.9820	4283	1000	13.0320
4134	1000	12.8830	4184	1000	12.9330	4234	1000	12.9830	4284	1000	13.0330
4135	1000	12.8840	4185	1000	12.9340	4235	1000	12.9840	4285	1000	13.0340
4136	1000	12.8850	4186	490	12.9350	4236	1000	12.9850	4286	1000	13.0350
4137	1000	12.8860	4187	1000	12.9360	4237	1000	12.9860	4287	1000	13.0360
4138	1000	12.8870	4188	480	12.9370	4238	1000	12.9870	4288	1000	13.0370
4139	1000	12.8880	4189	399	12.9380	4239	1000	12.9880	4289	1000	13.0380
4140	1000	12.8890	4190	1000	12.9390	4240	317	12.9890	4290	1000	13.0390
4141	1000	12.8900	4191	1000	12.9400	4241	1000	12.9900	4291	1000	13.0400
4142	1000	12.8910	4192	1000	12.9410	4242	1000	12.9910	4292	1000	13.0410
4143	1000	12.8920	4193	1000	12.9420	4243	1000	12.9920	4293	1000	13.0420
4144	1000	12.8930	4194	1000	12.9430	4244	1000	12.9930	4294	1000	13.0430
4145	1000	12.8940	4195	1000	12.9440	4245	876	12.9940	4295	1000	13.0440
4146	1000	12.8950	4196	486	12.9450	4246	1000	12.9950	4296	1000	13.0450
4147	1000	12.8960	4197	1000	12.9460	4247	1000	12.9960	4297	463	13.0460
4148	1000	12.8970	4198	713	12.9470	4248	1000	12.9970	4298	1000	13.0470
4149	1000	12.8980	4199	1000	12.9480	4249	1000	12.9980	4299	1000	13.0480
4150	1000	12.8990	4200	1000	12.9490	4250	1000	12.9990	4300	1000	13.0490

TABLE 3. Number of completed turns in the emittance interval (13.050, 13.249) P.m.m.mrad. Direction # 1.

Part. No.	Turn No. Completed	EP SX	Part. No.	Turn No. Completed	EP SX	Part. No.	Turn No. Completed	EP SX	Part. No.	Turn No. Completed	EP SX
4301	581	13.0500	4351	132	13.1000	4401	301	13.1500	4451	207	13.2000
4302	1000	13.0510	4352	321	13.1010	4402	1000	13.1510	4452	180	13.2010
4303	955	13.0520	4353	1000	13.1020	4403	542	13.1520	4453	628	13.2020
4304	1000	13.0530	4354	330	13.1030	4404	739	13.1530	4454	303	13.2030
4305	1000	13.0540	4355	1000	13.1040	4405	795	13.1540	4455	476	13.2040
4306	1000	13.0550	4356	979	13.1050	4406	1000	13.1550	4456	695	13.2050
4307	1000	13.0560	4357	581	13.1060	4407	243	13.1560	4457	331	13.2060
4308	540	13.0570	4358	126	13.1070	4408	879	13.1570	4458	564	13.2070
4309	1000	13.0580	4359	276	13.1080	4409	1000	13.1580	4459	320	13.2080
4310	1000	13.0590	4360	924	13.1090	4410	855	13.1590	4460	1000	13.2090
4311	1000	13.0600	4361	96	13.1100	4411	798	13.1600	4461	397	13.2100
4312	711	13.0610	4362	118	13.1110	4412	278	13.1610	4462	164	13.2110
4313	360	13.0620	4363	109	13.1120	4413	1000	13.1620	4463	239	13.2120
4314	284	13.0630	4364	288	13.1130	4414	1000	13.1630	4464	791	13.2130
4315	1000	13.0640	4365	394	13.1140	4415	422	13.1640	4465	1000	13.2140
4316	600	13.0650	4366	777	13.1150	4416	471	13.1650	4466	606	13.2150
4317	1000	13.0660	4367	1000	13.1160	4417	862	13.1660	4467	210	13.2160
4318	649	13.0670	4368	1000	13.1170	4418	145	13.1670	4468	706	13.2170
4319	1000	13.0680	4369	143	13.1180	4419	232	13.1680	4469	220	13.2180
4320	508	13.0690	4370	159	13.1190	4420	643	13.1690	4470	258	13.2190
4321	240	13.0700	4371	423	13.1200	4421	398	13.1700	4471	1000	13.2200
4322	362	13.0710	4372	1000	13.1210	4422	1000	13.1710	4472	425	13.2210
4323	1000	13.0720	4373	157	13.1220	4423	346	13.1720	4473	891	13.2220
4324	310	13.0730	4374	364	13.1230	4424	1000	13.1730	4474	1000	13.2230
4325	777	13.0740	4375	82	13.1240	4425	501	13.1740	4475	748	13.2240
4326	122	13.0750	4376	86	13.1250	4426	231	13.1750	4476	781	13.2250
4327	114	13.0760	4377	84	13.1260	4427	180	13.1760	4477	1000	13.2260
4328	105	13.0770	4378	91	13.1270	4428	185	13.1770	4478	1000	13.2270
4329	114	13.0780	4379	134	13.1280	4429	297	13.1780	4479	451	13.2280
4330	303	13.0790	4380	80	13.1290	4430	704	13.1790	4480	557	13.2290
4331	134	13.0800	4381	78	13.1300	4431	164	13.1800	4481	395	13.2300
4332	196	13.0810	4382	1000	13.1310	4432	144	13.1810	4482	964	13.2310
4333	114	13.0820	4383	176	13.1320	4433	573	13.1820	4483	416	13.2320
4334	1000	13.0830	4384	1000	13.1330	4434	452	13.1830	4484	1000	13.2330
4335	1000	13.0840	4385	130	13.1340	4435	418	13.1840	4485	1000	13.2340
4336	1000	13.0850	4386	251	13.1350	4436	189	13.1850	4486	1000	13.2350
4337	704	13.0860	4387	814	13.1360	4437	1000	13.1860	4487	416	13.2360
4338	918	13.0870	4388	657	13.1370	4438	820	13.1870	4488	1000	13.2370
4339	1000	13.0880	4389	680	13.1380	4439	187	13.1880	4489	1000	13.2380
4340	498	13.0890	4390	325	13.1390	4440	248	13.1890	4490	891	13.2390
4341	1000	13.0900	4391	564	13.1400	4441	1000	13.1900	4491	1000	13.2400
4342	1000	13.0910	4392	1000	13.1410	4442	1000	13.1910	4492	1000	13.2410
4343	1000	13.0920	4393	1000	13.1420	4443	885	13.1920	4493	1000	13.2420
4344	1000	13.0930	4394	568	13.1430	4444	183	13.1930	4494	1000	13.2430
4345	1000	13.0940	4395	588	13.1440	4445	263	13.1940	4495	471	13.2440
4346	1000	13.0950	4396	587	13.1450	4446	532	13.1950	4496	506	13.2450
4347	359	13.0960	4397	316	13.1460	4447	817	13.1960	4497	625	13.2460
4348	197	13.0970	4398	1000	13.1470	4448	758	13.1970	4498	1000	13.2470
4349	563	13.0980	4399	194	13.1480	4449	292	13.1980	4499	1000	13.2480
4350	421	13.0990	4400	194	13.1490	4450	1000	13.1990	4500	998	13.2490

TABLE 4. Number of completed turns in the emittance interval (13.250, 13.449) Pi.mm.mrad. Direction # 1.

Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX
4501	295	13.2500	4551	1000	13.3000	4601	1000	13.3500	4651	1000	13.4000
4502	304	13.2510	4552	1000	13.3010	4602	1000	13.3510	4652	1000	13.4010
4503	1000	13.2520	4553	1000	13.3020	4603	1000	13.3520	4653	1000	13.4020
4504	1000	13.2530	4554	1000	13.3030	4604	1000	13.3530	4654	1000	13.4030
4505	1000	13.2540	4555	1000	13.3040	4605	1000	13.3540	4655	1000	13.4040
4506	1000	13.2550	4556	1000	13.3050	4606	1000	13.3550	4656	1000	13.4050
4507	321	13.2560	4557	1000	13.3060	4607	1000	13.3560	4657	1000	13.4060
4508	404	13.2570	4558	1000	13.3070	4608	1000	13.3570	4658	1000	13.4070
4509	781	13.2580	4559	1000	13.3080	4609	1000	13.3580	4659	1000	13.4080
4510	944	13.2590	4560	1000	13.3090	4610	1000	13.3590	4660	1000	13.4090
4511	1000	13.2600	4561	1000	13.3100	4611	1000	13.3600	4661	1000	13.4100
4512	966	13.2610	4562	1000	13.3110	4612	1000	13.3610	4662	1000	13.4110
4513	1000	13.2620	4563	1000	13.3120	4613	1000	13.3620	4663	1000	13.4120
4514	1000	13.2630	4564	1000	13.3130	4614	1000	13.3630	4664	1000	13.4130
4515	375	13.2640	4565	1000	13.3140	4615	1000	13.3640	4665	1000	13.4140
4516	774	13.2650	4566	1000	13.3150	4616	654	13.3650	4666	1000	13.4150
4517	1000	13.2660	4567	1000	13.3160	4617	802	13.3660	4667	1000	13.4160
4518	487	13.2670	4568	1000	13.3170	4618	1000	13.3670	4668	1000	13.4170
4519	1000	13.2680	4569	1000	13.3180	4619	1000	13.3680	4669	1000	13.4180
4520	1000	13.2690	4570	1000	13.3190	4620	1000	13.3690	4670	1000	13.4190
4521	1000	13.2700	4571	1000	13.3200	4621	1000	13.3700	4671	1000	13.4200
4522	1000	13.2710	4572	1000	13.3210	4622	1000	13.3710	4672	1000	13.4210
4523	1000	13.2720	4573	1000	13.3220	4623	1000	13.3720	4673	1000	13.4220
4524	898	13.2730	4574	1000	13.3230	4624	1000	13.3730	4674	1000	13.4230
4525	674	13.2740	4575	1000	13.3240	4625	1000	13.3740	4675	1000	13.4240
4526	1000	13.2750	4576	1000	13.3250	4626	1000	13.3750	4676	1000	13.4250
4527	1000	13.2760	4577	1000	13.3260	4627	720	13.3760	4677	1000	13.4260
4528	1000	13.2770	4578	1000	13.3270	4628	1000	13.3770	4678	1000	13.4270
4529	1000	13.2780	4579	1000	13.3280	4629	1000	13.3780	4679	1000	13.4280
4530	1000	13.2790	4580	1000	13.3290	4630	1000	13.3790	4680	1000	13.4290
4531	1000	13.2800	4581	1000	13.3300	4631	1000	13.3800	4681	1000	13.4300
4532	1000	13.2810	4582	1000	13.3310	4632	1000	13.3810	4682	1000	13.4310
4533	808	13.2820	4583	1000	13.3320	4633	1000	13.3820	4683	1000	13.4320
4534	1000	13.2830	4584	1000	13.3330	4634	1000	13.3830	4684	1000	13.4330
4535	1000	13.2840	4585	1000	13.3340	4635	1000	13.3840	4685	1000	13.4340
4536	1000	13.2850	4586	1000	13.3350	4636	1000	13.3850	4686	1000	13.4350
4537	1000	13.2860	4587	1000	13.3360	4637	1000	13.3860	4687	1000	13.4360
4538	1000	13.2870	4588	1000	13.3370	4638	1000	13.3870	4688	1000	13.4370
4539	1000	13.2880	4589	1000	13.3380	4639	1000	13.3880	4689	1000	13.4380
4540	1000	13.2890	4590	1000	13.3390	4640	1000	13.3890	4690	1000	13.4390
4541	1000	13.2900	4591	1000	13.3400	4641	1000	13.3900	4691	1000	13.4400
4542	1000	13.2910	4592	1000	13.3410	4642	1000	13.3910	4692	1000	13.4410
4543	1000	13.2920	4593	1000	13.3420	4643	1000	13.3920	4693	1000	13.4420
4544	1000	13.2930	4594	1000	13.3430	4644	1000	13.3930	4694	1000	13.4430
4545	1000	13.2940	4595	1000	13.3440	4645	1000	13.3940	4695	1000	13.4440
4546	923	13.2950	4596	1000	13.3450	4646	1000	13.3950	4696	1000	13.4450
4547	1000	13.2960	4597	1000	13.3460	4647	1000	13.3960	4697	1000	13.4460
4548	1000	13.2970	4598	1000	13.3470	4648	1000	13.3970	4698	1000	13.4470
4549	1000	13.2980	4599	1000	13.3480	4649	1000	13.3980	4699	1000	13.4480
4550	1000	13.2990	4600	1000	13.3490	4650	1000	13.3990	4700	1000	13.4490

TABLE 5. Number of completed turns in the emittance interval (13.450, 13.649) P.i.m.m.rad. Direction # 1.

Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX
4701	1000	13.4500	4751	1000	13.5000	4801	1000	13.5500	4851	454	13.6000
4702	1000	13.4510	4752	1000	13.5010	4802	1000	13.5510	4852	1000	13.6010
4703	1000	13.4520	4753	1000	13.5020	4803	1000	13.5520	4853	1000	13.6020
4704	1000	13.4530	4754	1000	13.5030	4804	1000	13.5530	4854	928	13.6030
4705	1000	13.4540	4755	1000	13.5040	4805	1000	13.5540	4855	755	13.6040
4706	1000	13.4550	4756	1000	13.5050	4806	1000	13.5550	4856	1000	13.6050
4707	1000	13.4560	4757	1000	13.5060	4807	1000	13.5560	4857	1000	13.6060
4708	1000	13.4570	4758	1000	13.5070	4808	1000	13.5570	4858	457	13.6070
4709	1000	13.4580	4759	1000	13.5080	4809	1000	13.5580	4859	1000	13.6080
4710	1000	13.4590	4760	1000	13.5090	4810	1000	13.5590	4860	631	13.6090
4711	1000	13.4600	4761	1000	13.5100	4811	1000	13.5600	4861	374	13.6100
4712	1000	13.4610	4762	1000	13.5110	4812	1000	13.5610	4862	242	13.6110
4713	1000	13.4620	4763	1000	13.5120	4813	1000	13.5620	4863	396	13.6120
4714	1000	13.4630	4764	1000	13.5130	4814	1000	13.5630	4864	746	13.6130
4715	1000	13.4640	4765	881	13.5140	4815	1000	13.5640	4865	576	13.6140
4716	1000	13.4650	4766	1000	13.5150	4816	1000	13.5650	4866	1000	13.6150
4717	1000	13.4660	4767	1000	13.5160	4817	1000	13.5660	4867	678	13.6160
4718	1000	13.4670	4768	1000	13.5170	4818	1000	13.5670	4868	1000	13.6170
4719	1000	13.4680	4769	1000	13.5180	4819	1000	13.5680	4869	1000	13.6180
4720	1000	13.4690	4770	1000	13.5190	4820	1000	13.5690	4870	1000	13.6190
4721	1000	13.4700	4771	1000	13.5200	4821	1000	13.5700	4871	1000	13.6200
4722	1000	13.4710	4772	1000	13.5210	4822	1000	13.5710	4872	453	13.6210
4723	1000	13.4720	4773	1000	13.5220	4823	1000	13.5720	4873	583	13.6220
4724	1000	13.4730	4774	1000	13.5230	4824	1000	13.5730	4874	559	13.6230
4725	1000	13.4740	4775	1000	13.5240	4825	1000	13.5740	4875	404	13.6240
4726	1000	13.4750	4776	1000	13.5250	4826	1000	13.5750	4876	546	13.6250
4727	1000	13.4760	4777	1000	13.5260	4827	1000	13.5760	4877	174	13.6260
4728	1000	13.4770	4778	1000	13.5270	4828	1000	13.5770	4878	1000	13.6270
4729	1000	13.4780	4779	1000	13.5280	4829	1000	13.5780	4879	1000	13.6280
4730	875	13.4790	4780	1000	13.5290	4830	1000	13.5790	4880	1000	13.6290
4731	1000	13.4800	4781	1000	13.5300	4831	1000	13.5800	4881	237	13.6300
4732	893	13.4810	4782	1000	13.5310	4832	1000	13.5810	4882	1000	13.6310
4733	1000	13.4820	4783	1000	13.5320	4833	1000	13.5820	4883	299	13.6320
4734	1000	13.4830	4784	1000	13.5330	4834	1000	13.5830	4884	1000	13.6330
4735	1000	13.4840	4785	1000	13.5340	4835	1000	13.5840	4885	1000	13.6340
4736	1000	13.4850	4786	1000	13.5350	4836	1000	13.5850	4886	425	13.6350
4737	1000	13.4860	4787	1000	13.5360	4837	1000	13.5860	4887	505	13.6360
4738	1000	13.4870	4788	1000	13.5370	4838	1000	13.5870	4888	245	13.6370
4739	1000	13.4880	4789	1000	13.5380	4839	1000	13.5880	4889	1000	13.6380
4740	1000	13.4890	4790	1000	13.5390	4840	1000	13.5890	4890	371	13.6390
4741	1000	13.4900	4791	1000	13.5400	4841	1000	13.5900	4891	1000	13.6400
4742	1000	13.4910	4792	1000	13.5410	4842	876	13.5910	4892	393	13.6410
4743	1000	13.4920	4793	1000	13.5420	4843	1000	13.5920	4893	367	13.6420
4744	1000	13.4930	4794	1000	13.5430	4844	1000	13.5930	4894	184	13.6430
4745	1000	13.4940	4795	1000	13.5440	4845	1000	13.5940	4895	289	13.6440
4746	1000	13.4950	4796	1000	13.5450	4846	1000	13.5950	4896	289	13.6450
4747	1000	13.4960	4797	1000	13.5460	4847	1000	13.5960	4897	215	13.6460
4748	568	13.4970	4798	1000	13.5470	4848	1000	13.5970	4898	153	13.6470
4749	1000	13.4980	4799	1000	13.5480	4849	1000	13.5980	4899	146	13.6480
4750	1000	13.4990	4800	1000	13.5490	4850	410	13.5990	4900	219	13.6490

TABLE 6. Number of completed turns in the emittance interval (13.650, 13.750) P.m.m.rad. Direction # 1.

Part. No.	Turn No. Completed	EPSX	Part. No.	Turn No. Completed	EPSX	Part. No.	Turn No. Completed	EPSX	Part. No.	Turn No. Completed	EPSX
4901	664	13.6500	4951	390	13.7000	5001	205	13.7500			
4902	1000	13.6510	4952	160	13.7010						
4903	1000	13.6520	4953	131	13.7020						
4904	244	13.6530	4954	165	13.7030						
4905	1000	13.6540	4955	510	13.7040						
4906	355	13.6550	4956	80	13.7050						
4907	1000	13.6560	4957	274	13.7060						
4908	132	13.6570	4958	172	13.7070						
4909	122	13.6580	4959	1000	13.7080						
4910	452	13.6590	4960	196	13.7090						
4911	775	13.6600	4961	184	13.7100						
4912	320	13.6610	4962	350	13.7110						
4913	1000	13.6620	4963	515	13.7120						
4914	436	13.6630	4964	545	13.7130						
4915	186	13.6640	4965	178	13.7140						
4916	276	13.6650	4966	159	13.7150						
4917	755	13.6660	4967	1000	13.7160						
4918	375	13.6670	4968	295	13.7170						
4919	1000	13.6680	4969	198	13.7180						
4920	218	13.6690	4970	379	13.7190						
4921	782	13.6700	4971	235	13.7200						
4922	486	13.6710	4972	1000	13.7210						
4923	424	13.6720	4973	282	13.7220						
4924	255	13.6730	4974	100	13.7230						
4925	676	13.6740	4975	172	13.7240						
4926	316	13.6750	4976	525	13.7250						
4927	102	13.6760	4977	580	13.7260						
4928	460	13.6770	4978	1000	13.7270						
4929	250	13.6780	4979	103	13.7280						
4930	834	13.6790	4980	162	13.7290						
4931	167	13.6800	4981	105	13.7300						
4932	334	13.6810	4982	72	13.7310						
4933	82	13.6820	4983	81	13.7320						
4934	540	13.6830	4984	93	13.7330						
4935	1000	13.6840	4985	82	13.7340						
4936	195	13.6850	4986	504	13.7350						
4937	1000	13.6860	4987	108	13.7360						
4938	278	13.6870	4988	232	13.7370						
4939	170	13.6880	4989	140	13.7380						
4940	1000	13.6890	4990	330	13.7390						
4941	168	13.6900	4991	401	13.7400						
4942	160	13.6910	4992	130	13.7410						
4943	73	13.6920	4993	282	13.7420						
4944	112	13.6930	4994	305	13.7430						
4945	186	13.6940	4995	81	13.7440						
4946	1000	13.6950	4996	51	13.7450						
4947	1000	13.6960	4997	55	13.7460						
4948	536	13.6970	4998	91	13.7470						
4949	117	13.6980	4999	81	13.7480						
4950	1000	13.6990	5000	255	13.7490						

TABLE 7 Invarianta EH ($u \rightarrow 2, u' \rightarrow 2$) & EV ($v \rightarrow 2, v' \rightarrow 2$) vs. Number of Turns

Direction # 2 Epsx: 1.052000000 Epsy: 1.052000000

Turn #	EH(Turn #)	EV(Turn #)
(IC)	1.051999999999957	1.051999999999985
100	1.052000000219628	1.051999999884494
200	1.052000000438760	1.051999999767702
300	1.052000000658936	1.051999999651585
400	1.052000000878230	1.051999999536122
500	1.052000001098470	1.051999999421142
600	1.052000001319215	1.051999999306496
700	1.052000001538168	1.051999999191430
800	1.052000001758287	1.051999999075491
900	1.052000001978151	1.051999998959033
1000	1.052000002197452	1.051999998842440
1100	1.052000002417813	1.051999998726792
1200	1.052000002637897	1.051999998611514
1300	1.052000002857177	1.051999998497514
1400	1.052000003077268	1.051999998383742
1500	1.052000003297564	1.051999998270070
1600	1.052000003516198	1.051999998153910
1700	1.052000003736403	1.051999998037978
1800	1.052000003957389	1.051999997923453
1900	1.052000004176570	1.051999997808501
2000	1.052000004395886	1.051999997694764
2100	1.052000004615657	1.051999997580609
2200	1.052000004836231	1.051999997465565
2300	1.052000005057842	1.051999997349505
2400	1.052000005277577	1.051999997233168
2500	1.052000005498577	1.051999997117974
2600	1.052000005719783	1.051999997002490
2700	1.052000005940030	1.051999996887879
2800	1.052000006160455	1.051999996774526
2900	1.052000006380183	1.051999996660470
3000	1.052000006599428	1.051999996545540
3100	1.052000006820712	1.051999996429380
3200	1.052000007040050	1.051999996314265
3300	1.052000007260332	1.051999996199243
3400	1.052000007478327	1.051999996084845
3500	1.052000007699327	1.051999995970874
3600	1.052000007919638	1.051999995856143
3700	1.052000008140020	1.051999995740303
3800	1.052000008358377	1.051999995625053
3900	1.052000008577714	1.051999995509171
4000	1.052000008797087	1.051999995394695
4100	1.052000009018478	1.051999995278926
4200	1.052000009239578	1.051999995164387
4300	1.052000009459697	1.051999995049883
4400	1.052000009680043	1.051999994934071
4500	1.052000009899729	1.051999994819184
4600	1.052000010119635	1.051999994704282
4700	1.052000010339192	1.051999994589082
4800	1.052000010559837	1.051999994474350
4900	1.052000010781043	1.051999994360010
5000	1.052000011000437	1.051999994246025

TABLE 8. Invariants $EH = (u \cdot \cdot 2 + u' \cdot \cdot 2)$ & $EV = (v \cdot \cdot 2 + v' \cdot \cdot 2)$ vs. Number of Turns

Direction # 2 $E_{px} = 1.052000000$ $E_{py} = 1.052000000$

Turn #	EH(Turn #)	EV(Turn #)
(IC)	1.051999999999957	1.051999999999985
49500	1.052000108881757	1.051999942967129
99500	1.052000218854772	1.051999885366563
149500	1.052000328824143	1.051999827763709
199500	1.052000438773248	1.051999770133946
249500	1.052000548739919	1.051999712533004
299500	1.052000658707705	1.051999654943629
349500	1.052000768697667	1.051999597336930
399500	1.052000878679223	1.051999539747207
449500	1.052000988646270	1.051999482110766
499500	1.052001098608695	1.051999424535174
549500	1.052001208571397	1.051999366932961
599500	1.052001318562318	1.051999309306339
649500	1.052001428516220	1.051999251699669
699500	1.052001538493833	1.051999194090953
749500	1.052001648485870	1.051999136474464
799500	1.052001758436433	1.051999078853235
849500	1.052001868380316	1.051999021253039
899500	1.052001978350489	1.051998963637736
949500	1.052002088302366	1.051998906025780
999500	1.052002198268774	1.051998848435758
1000000	1.052002199370214	1.051998847858670

TABLE 9. Number of completed turns in the emittance interval (11.750, 13.730) P. mm.mrad. Direction # 1.

Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt
1	1000	11.7500	51	1000	12.7500	1	37568	11.7500
2	1000	11.7700	52	1000	12.7700	2	290907	11.7700
3	1000	11.7900	53	1000	12.7900	3	382607	11.7900
4	1000	11.8100	54	1000	12.8100	4	642217	11.8100
5	1000	11.8300	55	1000	12.8300	5	91464	11.8300
6	1000	11.8500	56	1000	12.8500	6	67606	11.8500
7	1000	11.8700	57	1000	12.8700	7	477278	11.8700
8	1000	11.8900	58	1000	12.8900	8	430425	11.8900
9	1000	11.9100	59	419	12.9100	9	36020	11.9100
10	1000	11.9300	60	1000	12.9300	10	13838	11.9300
11	1000	11.9500	61	1000	12.9500	11	73706	11.9500
12	1000	11.9700	62	1000	12.9700	12	15416	11.9700
13	1000	11.9900	63	1000	12.9900	13	194063	11.9900
14	1000	12.0100	64	1000	13.0100	14	1000000	12.0100
15	1000	12.0300	65	1000	13.0300	15	339146	12.0300
16	1000	12.0500	66	581	13.0500	16	463594	12.0500
17	1000	12.0700	67	240	13.0700	17	11851	12.0700
18	1000	12.0900	68	1000	13.0900	18	32797	12.0900
19	1000	12.1100	69	96	13.1100	19	110649	12.1100
20	1000	12.1300	70	78	13.1300	20	367118	12.1300
21	1000	12.1500	71	301	13.1500	21	19272	12.1500
22	1000	12.1700	72	398	13.1700	22	157461	12.1700
23	1000	12.1900	73	613	13.1900	23	49723	12.1900
24	1000	12.2100	74	397	13.2100	24	6363	12.2100
25	1000	12.2300	75	395	13.2300	25	10063	12.2300
26	1000	12.2500	76	295	13.2500	26	40901	12.2500
27	1000	12.2700	77	1000	13.2700	27	11271	12.2700
28	1000	12.2900	78	1000	13.2900	28	1000000	12.2900
29	1000	12.3100	79	1000	13.3100	29	1000000	12.3100
30	1000	12.3300	80	1000	13.3300	30	1000000	12.3300
31	1000	12.3500	81	1000	13.3500	31	1000000	12.3500
32	1000	12.3700	82	1000	13.3700	32	1000000	12.3700
33	1000	12.3900	83	1000	13.3900	33	1000000	12.3900
34	1000	12.4100	84	1000	13.4100	34	8397	12.4100
35	1000	12.4300	85	1000	13.4300	35	6415	12.4300
36	1000	12.4500	86	1000	13.4500	36	17358	12.4500
37	875	12.4700	87	1000	13.4700	37	875	12.4700
38	1000	12.4900	88	1000	13.4900	38	1489	12.4900
39	1000	12.5100	89	1000	13.5100	39	3978	12.5100
40	1000	12.5300	90	1000	13.5300	40	29463	12.5300
41	1000	12.5500	91	1000	13.5500	41	2821	12.5500
42	1000	12.5700	92	1000	13.5700	42	2198	12.5700
43	1000	12.5900	93	1000	13.5900	43	1219	12.5900
44	1000	12.6100	94	374	13.6100	44	1924	12.6100
45	1000	12.6300	95	237	13.6300	45	7116	12.6300
46	1000	12.6500	96	664	13.6500	46	830119	12.6500
47	1000	12.6700	97	782	13.6700	47	1000000	12.6700
48	1000	12.6900	98	168	13.6900	48	1000000	12.6900
49	1000	12.7100	99	184	13.7100	49	1000000	12.7100
50	1000	12.7300	100	105	13.7300	50	1000000	12.7300

TABLE 10. Number of completed turns in the emittance interval (9.750, 13.730) P.i.m.m.rad. Direction # 1.

Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt	Part. No.	Turn No. Completed	EPSt
51	1000	9.7500	101	1000	10.7600	151	1000	11.7500	201	1000	12.7500
52	1000	9.7700	102	1000	10.7700	152	1000	11.7700	202	1000	12.7700
53	1000	9.7900	103	1000	10.7900	153	1000	11.7900	203	1000	12.7900
54	1000	9.8100	104	1000	10.8100	154	1000	11.8100	204	1000	12.8100
55	1000	9.8300	105	1000	10.8300	155	1000	11.8300	205	1000	12.8300
56	1000	9.8500	106	1000	10.8500	156	1000	11.8500	206	1000	12.8500
57	1000	9.8700	107	1000	10.8700	157	1000	11.8700	207	1000	12.8700
58	1000	9.8900	108	1000	10.8900	158	1000	11.8900	208	1000	12.8900
59	1000	9.9100	109	1000	10.9100	159	1000	11.9100	209	419	12.9100
60	1000	9.9300	110	1000	10.9300	160	1000	11.9300	210	1000	12.9300
61	1000	9.9500	111	1000	10.9500	161	1000	11.9500	211	1000	12.9500
62	1000	9.9700	112	1000	10.9700	162	1000	11.9700	212	1000	12.9700
63	1000	9.9900	113	1000	10.9900	163	1000	11.9900	213	1000	12.9900
64	1000	10.0100	114	1000	11.0100	164	1000	12.0100	214	1000	13.0100
65	1000	10.0300	115	1000	11.0300	165	1000	12.0300	215	1000	13.0300
66	1000	10.0500	116	1000	11.0500	166	1000	12.0500	216	581	13.0500
67	1000	10.0700	117	1000	11.0700	167	1000	12.0700	217	240	13.0700
68	1000	10.0900	118	1000	11.0900	168	1000	12.0900	218	1000	13.0900
69	1000	10.1100	119	1000	11.1100	169	1000	12.1100	219	96	13.1100
70	1000	10.1300	120	1000	11.1300	170	1000	12.1300	220	78	13.1300
71	1000	10.1500	121	1000	11.1500	171	1000	12.1500	221	301	13.1500
72	1000	10.1700	122	1000	11.1700	172	1000	12.1700	222	398	13.1700
73	1000	10.1900	123	1000	11.1900	173	1000	12.1900	223	613	13.1900
74	1000	10.2100	124	1000	11.2100	174	1000	12.2100	224	397	13.2100
75	1000	10.2300	125	1000	11.2300	175	1000	12.2300	225	395	13.2300
76	1000	10.2500	126	1000	11.2500	176	1000	12.2500	226	295	13.2500
77	1000	10.2700	127	1000	11.2700	177	1000	12.2700	227	1000	13.2700
78	1000	10.2900	128	1000	11.2900	178	1000	12.2900	228	1000	13.2900
79	1000	10.3100	129	1000	11.3100	179	1000	12.3100	229	1000	13.3100
80	1000	10.3300	130	1000	11.3300	180	1000	12.3300	230	1000	13.3300
81	1000	10.3500	131	1000	11.3500	181	1000	12.3500	231	1000	13.3500
82	1000	10.3700	132	1000	11.3700	182	1000	12.3700	232	1000	13.3700
83	1000	10.3900	133	1000	11.3900	183	1000	12.3900	233	1000	13.3900
84	1000	10.4100	134	1000	11.4100	184	1000	12.4100	234	1000	13.4100
85	1000	10.4300	135	1000	11.4300	185	1000	12.4300	235	1000	13.4300
86	1000	10.4500	136	1000	11.4500	186	1000	12.4500	236	1000	13.4500
87	1000	10.4700	137	1000	11.4700	187	875	12.4700	237	1000	13.4700
88	1000	10.4900	138	1000	11.4900	188	1000	12.4900	238	1000	13.4900
89	1000	10.5100	139	1000	11.5100	189	1000	12.5100	239	1000	13.5100
90	1000	10.5300	140	1000	11.5300	190	1000	12.5300	240	1000	13.5300
91	1000	10.5500	141	1000	11.5500	191	1000	12.5500	241	1000	13.5500
92	1000	10.5700	142	1000	11.5700	192	1000	12.5700	242	1000	13.5700
93	1000	10.5900	143	1000	11.5900	193	1000	12.5900	243	1000	13.5900
94	1000	10.6100	144	1000	11.6100	194	1000	12.6100	244	374	13.6100
95	1000	10.6300	145	1000	11.6300	195	1000	12.6300	245	237	13.6300
96	1000	10.6500	146	1000	11.6500	196	1000	12.6500	246	664	13.6500
97	1000	10.6700	147	1000	11.6700	197	1000	12.6700	247	782	13.6700
98	1000	10.6900	148	1000	11.6900	198	1000	12.6900	248	168	13.6900
99	1000	10.7100	149	1000	11.7100	199	1000	12.7100	249	184	13.7100
100	1000	10.7300	150	1000	11.7300	200	1000	12.7300	250	105	13.7300

TABLE 11. Number of completed turns in the emittance interval (9.750, 13.730) Pi.nm.mrad. Direction # 1.

Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX	Part. No.	Turn No. Completed	EPX
51	10000000	9.7500	101	10000000	10.7500	151	37568	11.7500	201	10000000	12.7500
52	10000000	9.7700	102	10000000	10.7700	152	29097	11.7700	202	10000000	12.7700
53	10000000	9.7900	103	10000000	10.7900	153	38267	11.7900	203	10000000	12.7900
54	10000000	9.8100	104	10000000	10.8100	154	662217	11.8100	204	10000000	12.8100
55	10000000	9.8300	105	10000000	10.8300	155	446883	11.8300	205	10000000	12.8300
56	10000000	9.8500	106	10000000	10.8500	156	67606	11.8500	206	10000000	12.8500
57	10000000	9.8700	107	10000000	10.8700	157	477270	11.8700	207	8818	12.8700
58	10000000	9.8900	108	747728	10.8900	158	430425	11.8900	208	2021	12.8900
59	10000000	9.9100	109	940747	10.9100	159	36020	11.9100	209	419	12.9100
60	10000000	9.9300	110	632786	10.9300	160	13838	11.9300	210	101337	12.9300
61	10000000	9.9500	111	721092	10.9500	161	73706	11.9500	211	5919	12.9500
62	10000000	9.9700	112	645183	10.9700	162	15416	11.9700	212	12310	12.9700
63	10000000	9.9900	113	1012562	10.9900	163	194063	11.9900	213	1677	12.9900
64	10000000	10.0100	114	1631016	11.0100	164	2881408	12.0100	214	2613	13.0100
65	10000000	10.0300	115	510895	11.0300	165	339146	12.0300	215	10000000	13.0300
66	10000000	10.0500	116	786077	11.0500	166	463594	12.0500	216	581	13.0500
67	10000000	10.0700	117	150013	11.0700	167	113851	12.0700	217	240	13.0700
68	10000000	10.0900	118	179461	11.0900	168	32797	12.0900	218	1283	13.0900
69	10000000	10.1100	119	10000000	11.1100	169	110649	12.1100	219	96	13.1100
70	10000000	10.1300	120	344702	11.1300	170	367118	12.1300	220	78	13.1300
71	10000000	10.1500	121	632501	11.1500	171	19272	12.1500	221	301	13.1500
72	10000000	10.1700	122	650123	11.1700	172	157461	12.1700	222	398	13.1700
73	10000000	10.1900	123	1089453	11.1900	173	49723	12.1900	223	613	13.1900
74	10000000	10.2100	124	1183279	11.2100	174	6369	12.2100	224	397	13.2100
75	10000000	10.2300	125	516210	11.2300	175	10853	12.2300	225	395	13.2300
76	10000000	10.2500	126	270377	11.2500	176	40901	12.2500	226	295	13.2500
77	10000000	10.2700	127	922212	11.2700	177	11271	12.2700	227	3680	13.2700
78	10000000	10.2900	128	122583	11.2900	178	10000000	12.2900	228	2072	13.2900
79	10000000	10.3100	129	219116	11.3100	179	10000000	12.3100	229	1678	13.3100
80	10000000	10.3300	130	265061	11.3300	180	10000000	12.3300	230	2897	13.3300
81	10000000	10.3500	131	426372	11.3500	181	10000000	12.3500	231	9893	13.3500
82	10000000	10.3700	132	113804	11.3700	182	10000000	12.3700	232	1630	13.3700
83	10000000	10.3900	133	1117658	11.3900	183	10000000	12.3900	233	10000000	13.3900
84	10000000	10.4100	134	806675	11.4100	184	8397	12.4100	234	10000000	13.4100
85	10000000	10.4300	135	2015107	11.4300	185	6415	12.4300	235	10000000	13.4300
86	10000000	10.4500	136	2204965	11.4500	186	3660	12.4500	236	10000000	13.4500
87	10000000	10.4700	137	314954	11.4700	187	875	12.4700	237	10000000	13.4700
88	10000000	10.4900	138	826148	11.4900	188	1489	12.4900	238	4323	13.4900
89	10000000	10.5100	139	656575	11.5100	189	3978	12.5100	239	1643	13.5100
90	10000000	10.5300	140	953619	11.5300	190	29463	12.5300	240	106943	13.5300
91	10000000	10.5500	141	33497	11.5500	191	2821	12.5500	241	10000000	13.5500
92	10000000	10.5700	142	53599	11.5700	192	2198	12.5700	242	10000000	13.5700
93	10000000	10.5900	143	682700	11.5900	193	1219	12.5900	243	1180	13.5900
94	10000000	10.6100	144	480733	11.6100	194	1924	12.6100	244	374	13.6100
95	10000000	10.6300	145	10000000	11.6300	195	7116	12.6300	245	237	13.6300
96	10000000	10.6500	146	132346	11.6500	196	830119	12.6500	246	654	13.6500
97	10000000	10.6700	147	319832	11.6700	197	10000000	12.6700	247	782	13.6700
98	10000000	10.6900	148	117664	11.6900	198	10000000	12.6900	248	168	13.6900
99	10000000	10.7100	149	602083	11.7100	199	10000000	12.7100	249	184	13.7100
100	10000000	10.7300	150	628656	11.7300	200	10000000	12.7300	250	105	13.7300

END

**DATE
FILMED**

11 / 16 / 93