

LS-67
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RACETRACK AT ANL

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Thanks to the assistance and patience of Albin Wrulich at LBL, the most recent version of the accelerator tracking code RACETRACK is now operational at Argonne on ANLHEP. Access to this program can be obtained by running the program HEP2:[AR.KRAMER.RACETRAC]RACE.EXE. An input file FOR005 and output file FOR006 are all that is required. A sample data file DEMO.DAT (Table I) and an instruction file RACETRACK.GUIDE are included in this directory.

This program has been tested in a mode which should agree with PATRICIA-84.9 for the "ideal" CDR lattice. Figure 1 shows the comparison of the dynamic aperture for both programs. The $\delta p/p = 0$ apertures agree exactly, while the apertures differ slightly for $\delta p/p \neq 0$. This mode tracks a single particle with starting coordinates: $x, x' = 0$ and $z = \sqrt{\frac{\beta_z}{k \frac{\beta_x}{x}}}$, $z' = 0$ (z is vertical in RACETRACK). Since x can't be set equal to zero without making $z = 0$, this study approximated the $x = 0$ aperture limit by setting x small and k large ($x \approx 10^{-3}$ mm and $k \approx 10^6$).

In addition to the single particle mode, RACETRACK also has the ability to run multiple particles distributed on the boundary of an ellipse in both the horizontal and vertical planes. For each of n coordinates (x, x') on the horizontal ellipse, n particles are generated with (z, z') distributed on a vertical ellipse. For n particles specified in the INITIAL COORDINATE block, n^2 particles will actually be tracked. If any one particle fails to satisfy the stability criteria (i.e., remains inside the dynamic ($|x|$ or $|z| \leq 10^7$ mm) or the specified physical apertures for the required number of turns) then the amplitude of the x and z ellipses are reduced and tracking is attempted

again. The amplitude of the z-ellipse is related to the x-amplitude by the emittance ratio k , as described above. The distributed version of RACETRACK required $n \leq 6$ particles but this has been modified in the ANL version to $n \leq 10$ (note: the distributed version did not warn the user if $n > 6$ was used and could therefore generate erroneous results). This option with 4×4 and 8×8 particles, yielded identical results to the single particle dynamic aperture in Figure 1. However, the multiple particle tracking will yield the smaller of the positive or negative horizontal apertures for distorted (nonsymmetric) apertures similar to that shown in Figure 1.

RACETRACK can also handle non-ideal elements by introducing zero length dipole kicks with systematic or random error fields. For dipole strength and roll errors, horizontal and vertical kicks can be introduced within the "ideal" dipole (with bend angle θ) which give an angular kick

$$\Delta x' = \theta \frac{\delta B_o}{B_o}$$

and

$$\Delta z' = \theta \alpha$$

where $\delta B/B$ is the strength error in dipole field and α is the roll angle from the vertical direction of B_o . Quadrupole placement errors can also be simulated in this same way, with an angular kick equal to the integrated dipole field resulting from quadrupole offsets δx and δz where

$$\Delta x' = K\ell \delta x$$

and

$$\Delta z' = K\ell \delta z$$

for K = the normalized gradient strength and ℓ = length of the quadrupole.

Figure 2 shows the results of the dynamic aperture for the CDR lattice with 10^{-5} errors ($\delta x = \delta z = 10^{-5}$ m, $\delta B_o/B_o = 10^{-5}$, $\alpha = 10^{-5}$ radians). The momentum errors tracked were limited to $\pm 1\%$, since the closed orbit finder had difficulty with dispersion (η) calculations for the lattice with $\pm 2\%$ momentum errors.

RACETRACK also allows physical aperture to be set at any element in order to yield a nonlinear physical aperture limit for real or ideal accelerators. These physical apertures can be either rectangular ($|x| < a$ and $|z| < b$) or elliptical ($\frac{x^2}{a^2} + \frac{z^2}{b^2} < 1$). For comparison with PATRICIA and PATRIS, the rectangular apertures were set to be $a = 30$ mm and $b = 20$ mm at every sextupole, at the undulators and at the beta max quads Q2 and Q3. The resulting nonlinear physical aperture for the CDR lattice is shown in Figure 3. Attempts to run a 10^{-4} error lattice yielded closed orbit calculation problems even for $\delta p/p = 0$. Since the present version of RACETRACK doesn't have a correction (neither first turn nor distortion suppression) algorithm included, correcting the 10^{-4} error lattice wasn't possible.

RACETRACK is also able to track with synchrotron oscillations. At the end of each revolution or after each cavity, the momentum and phase of the particles (all particles have the same value) are changed and the linear and nonlinear elements are corrected for the change in normalized strength, which are then used for the next sequence of elements. Two tests were run on the CDR lattice with and without errors. The starting momentum error was 1% and phase equal to the synchronous phase $\approx 133^\circ$ for $V_{rf} = 8.25$ MV and $U_o = 6$ MeV/turn. In both cases, the dynamic aperture was equal to the minimum aperture for $\delta p/p = \pm 1\%$ or 0, without synchrotron oscillations.

Table I RACETRACK Input Data for CDR Lattice

FLEXIBILITY / 6 GEV LIGHT SOURCE

SINGLE ELEMENTS-----

UND * 0		3.0
WIG * 0		3.0
D2 * 0		0.35
D4 * 0		0.375
D5 * 0		0.71
D6 * 0		0.29
D7 * 0		0.50
Q1 * 2	.20283516	0.5
Q2 * 2	-.5283049	0.9
Q3 * 2	.5706265	0.5
Q4 * 2	.6495486	0.5
Q5 * 2	-.83111333	0.5
QH1 * 2	.5452074	0.5
QH2 * 2	-.8639510	0.9
QH3 * 2	.82033497	0.5
BND * 1	-.0400713	2.45
SU1 * 3	-2.43340	
SU2 * 3	2.63150	
SH1 * 3	-1.59385	
SH2 * 3	1.36340	
SD2 * 3	2.04120	
SF * 3	-2.3206097	
SD * 3	1.7831354	
SAP * 3	.0	
SU3 * 3	.0	
SH3 * 3	.0	
MON * 1		
CX1 * 1		
CY1 * -1		

NEXT

BLOCK DEFINITIONS-----

1	1	
UND	UND	
D2	D2	
D4	D4	
D6	D6	
D5	D5	
D7	D7	
B12	Q1	D2
B23	Q2	O2
B34	Q3	D4
B85	BND	O5
B47	Q4	D7
B58	Q5	D7
B46	Q4	D6
BB4	BND	D4
B33	QH3	D2
B22	QH2	D2
B11	QH1	WIG
B12-	D2	Q1
B23-	D2	Q2
B34-	D4	Q3
B85-	D5	BND
B47-	D7	Q4
B58-	D7	Q5
B46-	D6	Q4
BB4-	D4	BND

Table I (continued)

B33- D2 QW3

B22- D2 QW2

B11- WIG QW1

NEXT

STRUCTURE INPUT-----

8*(SAP

```

UND MON B12 SU1 CX1 D2 MON B23 SU2
D2 MON B34 SU3 CY1 D4 MON BB5 SD CY1
D5 MON B47 MON B58 SF CX1 D7 MON
B58 MON B46 SD2 CY1 D5 MON BB4 SW3 CY1
D4 MON B33 SW2 D2 MON B22 SW1 CX1
D2 MON B11 B11- MON D2
CX1 SW1 B22- MON D2 SW2 B33- MON D4 SW3
CY1 BB4- MON D5 CY1 SD2 B46- MON B58-
MON D7 CX1 SF B58- MON B47- MON D6
CY1 SD BB5- MON D4 SU3 CY1 B34- MON D2
SU2 B23- MON D2 CX1 SU1 B12- MON UND SAP
UND MON B12 SU1 CX1 D2 MON B23 SU2
D2 MON B34 SU3 CY1 D4 MON BB5 SD CY1
D6 MON B47 MON B58 SF CX1 D7 MON
B58 MON B46 SD2 SW3 CY1 D5 MON B54 CY1
D4 MON B33 SW2 D2 MON B22 SW1 CX1
D2 MON B11 B11- MON D2
CX1 SW1 B22- MON D2 SW2 B33- MON D4 SW3
CY1 BB4- MON D5 CY1 SD2 B46- MON B58-
MON D7 CX1 SF B58- MON B47- MON D6
CY1 SD BB5- MON D4 SU3 CY1 B34- MON D2
SU2 B23- MON D2 CX1 SU1 B12- MON UND SAP
    
```

NEXT

PRINTOUT OF INPUT -----

NEXT -----

LINEAR OPTICS CALCULATION-----

ELEMENT 120

NEXT

CHROMATICITY CORRECTION-----

SF 0.0

SD 0.0

NEXT

TRACKING PARAMETERS-----

1000

25 29.54 -2.111

5 -0.02 0.02

NEXT

INITIAL COORDINATES---RECTANGULAR-----

8 0.0 45.0 0.500

NEXT

LIMITATION OF APERTURE--(half apertures H - V in mm)-----

SF RE 1000. 1000.

SD RE 1000. 1000.

SAP RE 1000. 1000.

SU1 RE 1000. 1000.

SU3 RE 1000. 1000.

NEXT

ENDE=====

LS 8 DAS UW 800 Meter 11/27/85
 6-GeV Light Source $\mu_x = 2.204$ $\mu_y = 0.737$ S.L. Kro

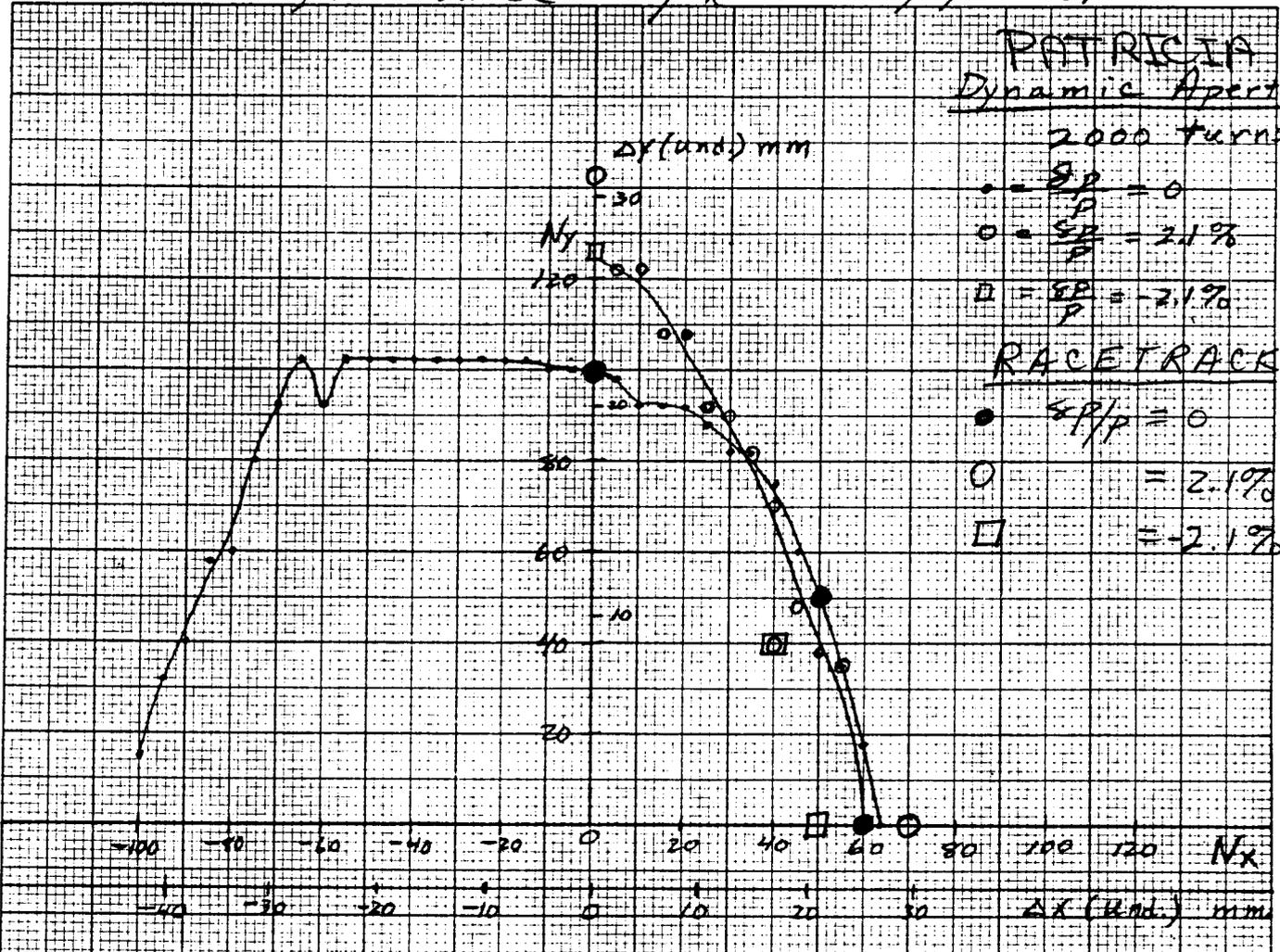


Figure 1 Comparison of Ideal Lattice
 Dynamic Aperture for CDR Lattice

Fig. 2 Aperture for CDR LATTICE W 10^{-5} error

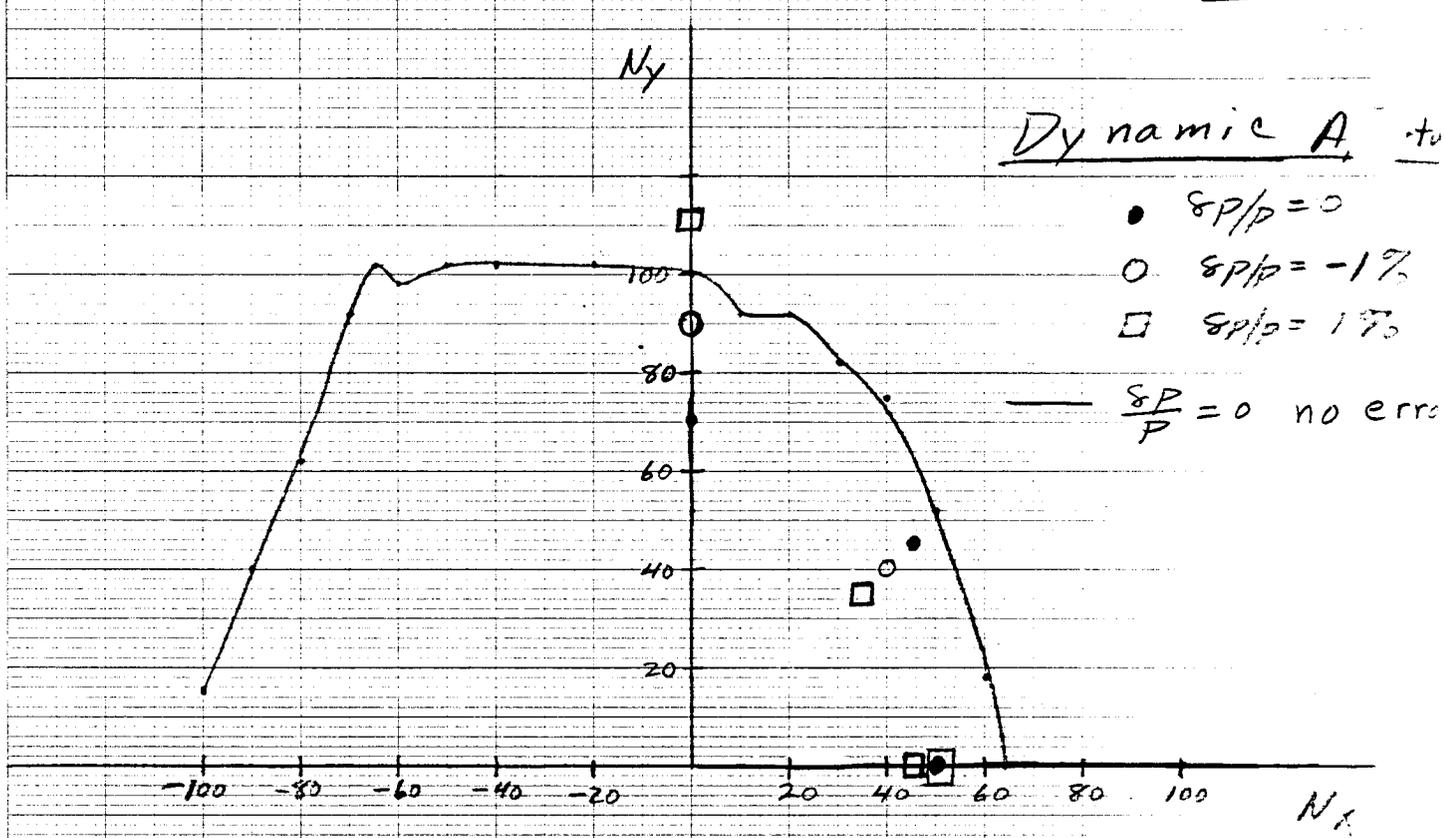
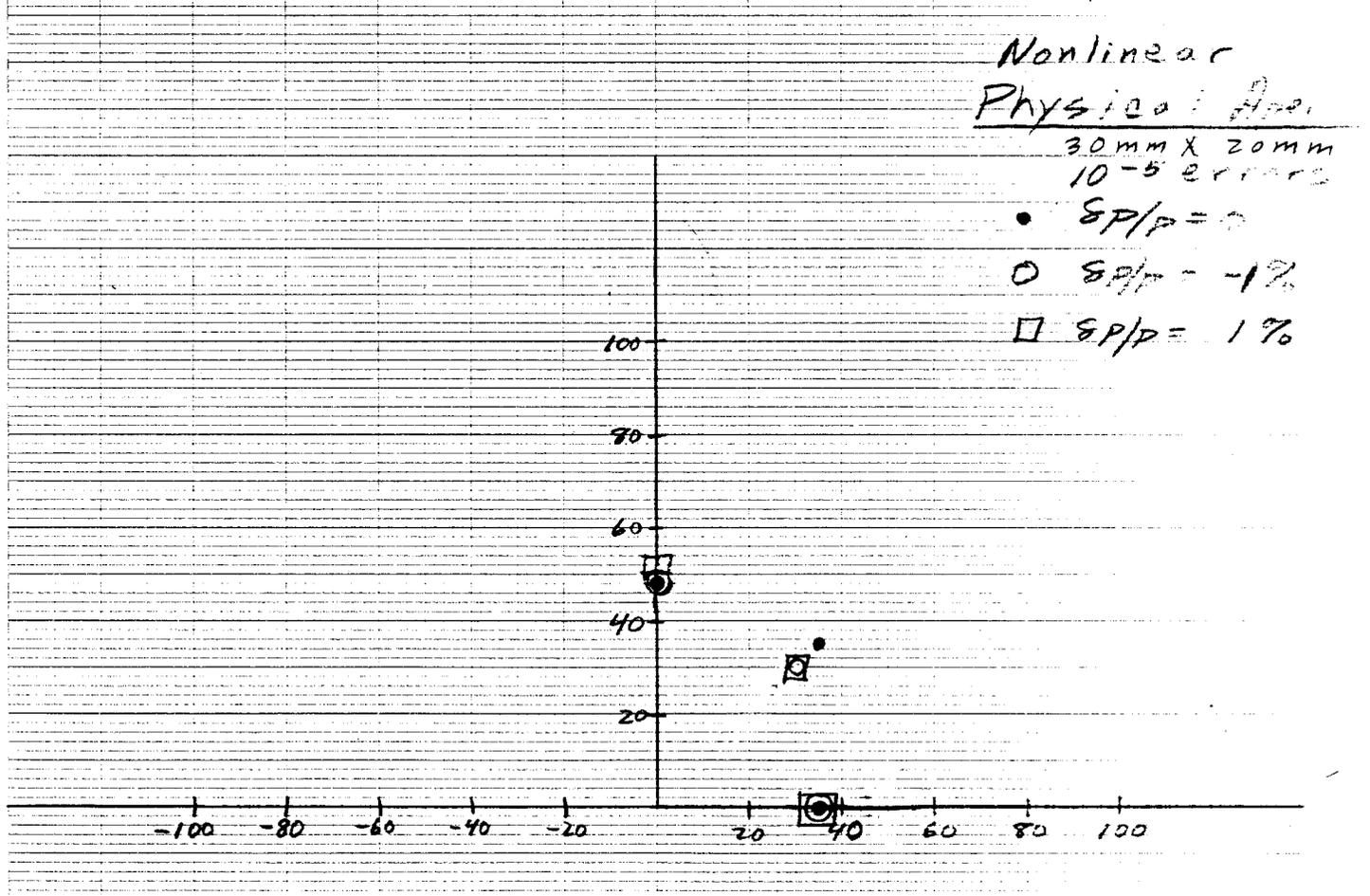


Fig. 3 Physical Aperture for CDR Lattice W 10^{-5} error



46 1331

10 X 10 TO 1/4 INCH
KEUFEL & LESSER CO. MADE IN U.S.A.