$\bar{P}$ Note 510

8/23/91

An Updated AP2 Beamline TURTLE Model

M. Gormley, S. O'Day

Abstract

This note describes a TURTLE[1] model of the AP2 beamline. This model was created by D. Johnson and improved by J. Hangst. The authors of this note have made additional improvements which reflect recent element and magnet setting changes. The magnet characteristics measurements and survey data compiled to update the model will be presented. A printout of the actual TURTLE deck may be found in appendix A.

AP2 Quadrupole Magnets

The quadrupoles in the AP2 beamline were taken from seven basic categories of magnets(each variety having a nominal effective length and excitation curve). Each of these categories is described by a six character labelling convention which follows: SQAxxx,SQBxxx,SQC0xx,SQC1xx,SQDxxx,SQExxx and LQExxx. Figure 1 gives the nominal excitation curve for each magnet type. Table 1 gives parameterizations of the excitation curves in figure 1[2,3]. Table 2 gives the serial number of the magnet at each beamline position with differences between individual magnets reflected by their differing effective lengths[4].

By knowing the current at which a particular magnet operates and its effective length, one may deduce a gradient from the excitation curve. This information is provided in table 2 and the details of how one extracts the current from PBAR control system readback are given in table 3[5].

For completeness, it is noted that the quadrupole apertures and drift spaces between beamline magnets found in table 2 and appendix A were verified by hand measurement.

AP2 Dipole Magnets

The apertures listed and the bending angles predicted by data in table 4 for AP2 beamline dipole magnets were checked by hand measurement and calculation. Accounted for are recent enlargements of the vertical apertures of some AP2 "left bend" magnets(IB4 and IB5) [6] as well as the replacement of two injection line dipoles(D:HT730-1). The bending angles of the pulsed septum[7] and injection kicker magnets were extracted by a TRANSPORT[8] fit using secondary emissions monitor data.

AP2 Survey Data

The vertical height of the beamline from the "left bend" to the debuncher orbit was checked in survey data[9]. In particular, the angle and height with respect to the debuncher ring of the injection line beam pipe at the entrance to D4Q5 was found to be well-represented in the model.

References

1. D.C. Carey, "TURTLE(Trace Unlimited Rays Through Lumped Elements)", NAL-64(1978).

2. D.E. Johnson, "Small Quadrupole Excitation Data",$\bar{P}$note # 419.

3. B.C. Brown, "Excitation Curves of Small Quadrupoles for TEV I Beam Line Use",$\bar{P}$note # 418.

4. Private comm. with D. Harding.

5. R.Peters, "Debuncher Bus Currents and Lattice Calculations, PBAR internal memo(1986).

6. D. Trbojevic, "Raising the Acceptance of the AP2-Line", FNAL TM-1589(1989).

7. J.A. Satti and S.D. Holmes, "A Pulsed Septum Magnet for the Fermilab

Antiproton Source",IEEE Trans. Nu. Sci.,NS-32#5(1985).

8. K. Brown,F.Rothacker,D.C.Carey,Ch.Iselin, "Transport: A Computer Program for Designing Charged Particle Beam Transport Systems", CERN 80-04(1980).

9. E. Dijak et al., AP2 line survey logbook,pg18-35(1987).

Figure 1

TRANSFER CONSTANT VS FIELD

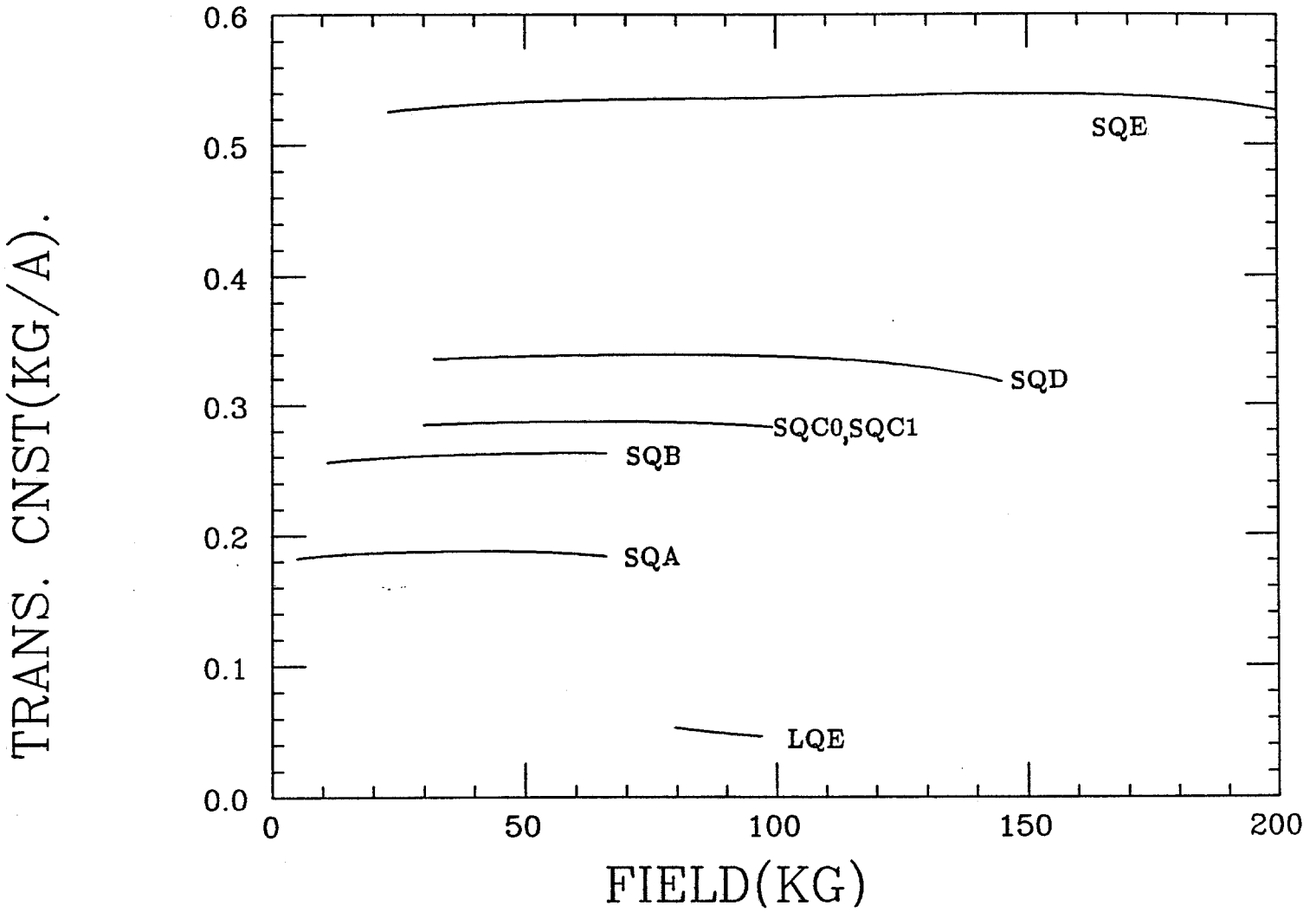

Table 1 AP2 Quadrupole Excitation Formulae

$X = \int B'dl\ (kG)$

$Y =$ *Transfer Constant* (kG/Amp)

$Y = a + bX + cX^2 + dX^3 + eX^4$

	SQAxxx	SQBxxx	SQC0xx	SQC1xx	SQDxxx	SQExxx
a	1.798E-1	2.507E-1	2.762E-1	2.761E-1	3.253E-1	5.100E-1
b	6.347E-4	5.900E-4	4.589E-4	4.632E-4	6.173E-4	9.367E-4
c	-2.105E-5	-1.196E-5	-7.336E-6	-7.450E-6	-1.120E-5	-1.366E-5
d	3.597E-7	1.321E-7	6.476E-8	6.609E-8	1.045E-7	9.151E-8
e	-2.627E-9	-6.778E-10	-3.050E-10	-3.107E-10	-4.077E-10	-2.230E-10

Note that $X = Y \times current = 79.59 + .02897 \times (current - 1500)\ kG$ for LQExxx.

Table 2 AP2 Quadrupole Characteristics

Serial #	Location	Pole Tip ρ (mm)	L_{eff}(in.)	I(Amp)	Gradient(kG/m)
SQC002	Q1	44.6	27.54	376.8319	151.43033
SQC003	Q2	44.6	27.66	314.5763	127.75377
SQC004	Q3	44.6	27.64	314.5763	127.86934
SQC005	Q4	44.6	27.57	376.8319	151.25456
SQC006	Q5	44.6	27.64	376.8319	150.87694
SQC007	Q6	44.6	27.71	376.8319	150.49034
SQC008	Q7	44.6	27.64	110.0741	44.69574
SQC009	Q8	44.6	27.66	110.0741	44.66504
SQC010	Q9	44.6	27.68	110.0741	44.62632
SQC011	Q10	44.6	27.69	110.0741	44.61826
SQC012	Q11	44.6	27.58	110.0741	44.79135
SQC013	Q12	44.6	27.68	110.0741	44.63922
SQC014	Q13	44.6	27.60	110.0741	44.76214
SQC015	Q14	44.6	27.75	110.0741	44.52660
SQA002	Q15	44.6	17.94	23.2896	9.30864
SQB002	Q16	44.6	25.12	83.6194	33.94593
SQD004	Q17	44.6	33.23	83.6389	33.27791
SQB005	Q18	44.6	25.12	218.6175	90.02513
SQB006	Q19	44.6	25.13	157.6510	64.72310
SQB010	Q20	44.6	25.14	157.5918	64.67274

AP2 Quadrupole Characteristics(cont'd)

Serial #	Location	Pole Tip ρ (mm)	L_{eff}(in.)	I(Amp)	Gradient(kG/m)
SQB011	Q21	44.6	25.12	218.6175	90.05381
SQD007	Q22	44.6	32.30	84.6418	34.65668
SQB012	Q23	44.6	25.15	85.0243	34.48774
SQA005	Q24	44.6	17.94	0.0000	0.00000
SQD010	Q25	44.6	32.39	101.4842	41.56328
SQA008	Q26	44.6	17.90	145.1188	59.78236
SQA009	Q27	44.6	17.90	159.7100	65.85175
SQA010	Q28	44.6	17.89	110.6088	45.41544
SQD011	Q29	44.6	32.23	388.7330	156.86168
SQD021	Q30	44.6	32.33	379.0604	153.12376
SQE003	Q31	44.6	51.17	364.3625	148.67979
SQE004	Q32	44.6	51.11	363.1544	148.41911
SQE007	Q33	44.6	51.16	381.6077	154.39642
LQE004	D4Q5	84.1	32.40	1529.0000	97.73200
SQC121	D4Q4	44.6	27.86	282.9890	114.56430
SQC130	D4Q3	44.6	27.90	260.1035	105.34139
SQC152	D4Q2	44.6	27.16	255.1823	106.19350
SQC161	D50Q	44.6	28.05	273.7430	110.16441
SQC176	D5Q2	44.6	28.05	255.2330	102.84424

Table 3a Debuncher Magnet Buses

Logical Bus	Magnets on Bus
0Q	D10Q,D30Q,D50Q
Q2	DnQ2
Q3	DnQ3
Q4	DnQ4
D	all dipoles
SF	DnSj (j odd)
SD	DnSj (j even)
SQ5	DnQ5 (n=1,3,5,6)
SQ6	DnQ6 (n=1,2,3,4,5)
QF	DnQ7 $\longrightarrow$DnQ19 (n odd)
QD	DnQ8 $\longrightarrow$DnQ18 (n even) and D20Q,D40Q,D60Q
LQ5	D2Q5,D4Q5
LQ6	D6Q6

Note that n and j are indices which specify the magnet.

Table 3b Debuncher Bus Currents

Logical Bus	Current
0Q	D:QSS-<D:QSn01>
Q2	D:QSS-<D:QSn02>
Q3	D:QSS-<D:QSn03>
Q4	D:QSS-<D:QSn04>
D	D:IB
SF	D:SEXFI
SD	D:SEXDI
SQ5	D:QSS-<D:QSn05>
SQ6	D:QD-<D:QSn06>
QF	D:QF
QD	D:QD
LQ5	D:IB+<D:QTn05>
LQ6	D:IB+<D:QTn06>

Note that n and j are indices which specify the magnet.

Table 4 AP2 Dipole Characteristics

Location	Horiz. 1/2 ap.(mm)	Vert. 1/2 ap.(mm)	L_{eff}(in)	Field(kG)
PMAG	63.5	19.05	35.00	17.52152
IB1	56.00	23.177	65.37	9.3516
IB2	46.8	53.98	123.083	11.19202
IB3	46.8	53.98	123.083	11.19202
IB4	80.8	38.00	98.425	9.95147
IB5	80.8	38.00	98.425	9.95147
IB6	46.8	53.98	123.083	11.19202
IB7	46.8	53.98	123.083	11.19202
IBV1	34.29	39.624	60.	12.65242
HT730	50.8	50.8	30.	0.
HT731	50.8	50.8	30.	0.
ISEPT	26.5	19.5	78.71	5.328
IKIK	20.6375	28.575	see	below

The injection kicker is represented by a 6.28399 mRad vertical kick.

```
" AP2 DECAY TURTLE          "
1000
(S.O. CHANGE-20000 TO 1000)
15. 1. 'MM' .1 ; 15. 8.'IN' .0254  ;
13.  10. ; -13.  110.  'APRT' ;
(S.O. CHANGE-TURN ON APERTURES)
1.   3.0   26.0   3.0   26.0   0.0   2.15   8.88900 ;
-60.0 0.1395673  0.10565943  0. 26.030 'DCAY' ;
-16. 200. 1. 'PI' ;
-16. 201. 1. 'MU' ;
-16. 202.  0. 'NU' ;
-16. 300. 11.366;
-16. 301. 1.340;
-16. 302. 20.00;
-16. 303. 5.322;
-16. 304. -0.851;
-16. 305. 20.00;
(ACCEPTANCE PARAMETERS FOR EFFICIENCY TEST)
(LINE BEGINS AT LENS UPSTREAM FOCAL PLANE)
-3. 7.67467;
-5.0  5.90551 80. 10. 'LITH';
-3.0 7.67467  'DSFP';
50. 6. -2.5 2.5 0.1 ;
 51. 1. -12.0  12.0  24. ;
 52. 2.  -5.00  5.00 10. ;
 51. 3. -12.0  12.0  24. ;
 52. 4.  -5.00  5.00 10. ;
3. 22.04943;
16. 4. 63.5; 16. 5. 19.05 ;
(PULSED BUMP MAGNET APERTURE)
20. 180.;2. 1.5; 4. 35.000 17.52152 'PMAG';2. 1.5; 20. -180. ;3. 283.6816;
16. 101. 44.6 ;
16. 100. 66.67 ;
(S.O. CHANGE-HYBERBOLIC QUAD APERTURE)
5.0 27.54 15.1430 100. 'Q1' ;
50.  3.  -50.  50.  25. 'Q01V' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 23.8 ;
5.0 27.66 -12.7754 100. 'Q2' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 29. ;
-7. 0. 0. 0. -.357 0. 0.  'VT2';
3. 31.;
5.0 27.64 -12.7869 100. 'Q3' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 23.8  ;
5.0 27.57 15.1255 100. 'Q4' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 195.4882 'S704' ;
(HISTOGRAMS AT S704)
50. 1. -45. 45. 45. '704H' ;
50. 3. -45. 45. 45. '704V' ;
3.0 73.;
16. 4. 56.00;
16. 5. 23.177;
(IB1 APERTURE)
20. 180. ;2. 1.5; 4.0 65.37 9.3516' B1' ;2. 1.5; 20. -180. ;
3.0 171. ;
(S.O. CHANGED DRIFT SP FROM 156.6299 TO 171.)
5.0 27.64 15.0877 100. 'Q5' ;
50.  1.  -50.  50.  25. 'Q05H' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 38.5  ;
5.0 27.71 -15.0490 100. 'Q6' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 19.68 'S706' ;
 (HISTOGRAMS AT SEM 706)
50. 1. -45. 45. 45. '706H';
50. 3. -45. 45. 45. '706V';
3. 30.;
-7. 0. 0. 0. .357 0. 0. 'VT6';
3. 359.194 ;
5. 27.64 4.4696 100. 'Q7' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.  30.0000 'J707' ;
3. 467.3269 ;
5. 27.66 -4.4665 100. 'Q8' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.  30.0000 'J708' ;
3. 467.3269 ;
5. 27.68 4.4626 100. 'Q9' ;
```

```
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.  30.0000 'J709' ;
3. 467.3269 ;
5. 27.70 -4.4618 100. 'Q10' ;
50.  1.  -50.  50.  25. 'Q10H' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.  30.000 'J710' ;
3. 449.361 'S710' ;
 (HISTOGRAMS AT SEM 710)
50. 1. -45. 45. 45. '710H';
50. 3. -45. 45. 45. '710V';
3. 17.965 ;
5. 27.58 4.4791 100. 'Q11' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 35.;
-7. 0. .357 0. 0. 0. 0. 'HT11';
3. 437.3269 ;
-7. 0. 0. 0. .357 0. 0. 'VT11';
3. 25.;
5. 27.68 -4.4639 100. 'Q12' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 497.3269 ;
5. 27.6 4.4762 100. 'Q13' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 449.4685  ;
5.0 27.75 -4.4527 100. 'Q14' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 568.4606  ;
5.0 17.94 -0.93086 100. 'Q15' ;
50.  1.  -50.  50.  25. 'Q15H' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 18.11 'S715' ;
 (HISTOGRAMS AT SEM 715)
50. 1. -45. 45. 45. '715H';
50. 3. -45. 45. 45. '715V';
3. 154.65 ;
5.0 25.12 3.3946 100. 'Q16' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 13.7835 ;
5.0 32.23 3.3278 100. 'Q17' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 40.64438;
16. 4. 46.8; 16. 5. 53.98;
(S.O. CHANGE-HOR,VERT AP)
(IB-2 APERTURE)
-50. 1. -60.  60.  120. ;
-50. 3. -60.  60.  120. ;
20. 180. ; 2. 3.369 ; 4.0 123.083 11.19202 'B2'; 2. 3.369 ; 20. -180. ;
-50. 1. -60.  60.  120. ;
-50. 3. -60.  60.  120. ;
(HISTOGRAMS AT IB-2 EXIT)
3.0  16.1727 ;
5.0 25.13 -9.00251 100. 'Q18' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 26.5503 ;
16. 4. 46.8; 16. 5. 53.98;
(S.O. CHANGE-HOR,VERT AP)
(IB-3 APERTURE)
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
20. 180. ; 2. 3.369 ; 4.0 123.083 11.19202 'B3'; 2. 3.369 ; 20. -180. ;
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
3.0 52.2147 ;
16. 4. 80.8 ; 16. 5. 38.0;
(S.O. CHANGE-HOR,VERT AP)
(IB-4 APERTURE)
-50. 1.  -90.  90.  180. ;
-50. 3.  -60.  60.  120. ;
20. 180. ; 2. 2.396 ; 4.0 98.425 9.95147 'B4'; 2. 2.396 ; 20. -180. ;
-50. 1.  -90.  90.  180. ;
-50. 3.  -60.  60.  120. ;
3.0 24.76897 ;
5.0 25.13 6.47231 100. 'Q19' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 15.7500 'S719' ;
 (HISTOGRAMS AT SEM 719)
50. 1. -60.0 60.0 60. '719H';
```

```
50. 3. -22.5 22.5 45.  '719V';
-6.  1.  65.0 ;
(MOMENTUM SLIT APERTURE)
3. 39.8562 ;
5.0 25.14 6.46727 100. 'Q20' ;
50.  1.  -50.  50.  25. 'Q20H' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 24.80452 ;
16. 4. 80.80; 16. 5. 38.0;
(S.O. CHANGE-HOR,VERT AP)
(IB-5 APERTURE)
-50. 1.  -90.  90.  180. ;
-50. 3.  -60.  60.  120. ;
20. 180. ; 2. 2.396 ; 4.0 98.425 9.95147 'B5'; 2. 2.396 ; 20. -180. ;
-50. 1.  -90.  90.  180. ;
-50. 3.  -60.  60.  120. ;
3.0 52.1727 ;
16. 4. 46.8; 16. 5. 53.98;
(S.O. CHANGE-HOR,VERT AP)
(IB-6 APERTURE)
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
20. 180. ; 2. 3.369 ; 4.0 123.083 11.19202 'B6'; 2. 3.369 ; 20. -180. ;
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
3.0 26.5503;
5.0 25.12 -9.00538 100. 'Q21' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 16.1727;
16. 4. 46.8; 16. 5. 53.98;
(S.O. CHANGE-HOR,VERT AP)
(IB-7 APERTURE)
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
20. 180. ; 2. 3.369 ; 4.0 123.083 11.19202 'B7'; 2. 3.369 ; 20. -180. ;
-50. 1.  -60.  60.  120. ;
-50. 3.  -60.  60.  120. ;
3.0  40.6513  ;
5.0 32.30  3.46567 100. 'Q22' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 45.5039 ;
5.0 25.15 3.44877 100. 'Q23' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 16.250 'S723' ;
 (HISTOGRAMS AT SEM 723)
50. 1. -45. 45. 45. '723H';
50. 3. -45. 45. 45. '723V';
3.  335.612;
5.0 17.94 0.00000 100. 'Q24' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 328.9921  ;
5.0 32.29 -4.15633  100. 'Q25' ;
50.  1.  -50.  50.  25. 'Q25H' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 469.85040  ;
5.0 17.90 5.97824 100. 'Q26' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 502.84250  ;
5.0 17.90 -6.58518 100. 'Q27' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 341.2559 ;
(S.O. CHANGE- REMOVED TOR727)
5.0 17.89 4.54154 100. 'Q28' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3. 604.164 'S728' ;
 (HISTOGRAMS AT SEM 728)
50. 1. -45. 45. 45. '728H';
50. 3. -45. 45. 45. '728V';
3. 23.151 ;
16. 100. 66.67 ;
5.0 32.23 -15.68617 100. 'Q29' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 12.0  ;
5.0 32.33 15.31238 100. 'Q30' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 79.31588 ;
16. 4. 34.2900; 16. 5. 39.6240;
(IBV-1 APERTURE; NOTE: APERTURES ROTATED BY COORD. ROTATION)
```

```
20. 90. ; 2. 1.8569 ; 4. 60. 12.65242 'BV1' ;2. 1.8569; 20. -90;
3.0 20.0;
16. 4. 50.8 ; 16. 5. 50.8 ;
(S.O. CHANGE-HOR,VERT AP)
(HT730 APERTURE)
4. 30. 0. 'HT30';
3.0  138.79034 ;
5.0 51.17 -14.86798 100. 'Q31' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 19.6850 ;
16. 4. 50.8 ; 16. 5. 50.8 ;
(S.O. CHANGE-HOR,VERT AP)
(HT731 APERTURE)
4. 30. 0. 'HT31' ;
3.0  22.1743 ;
5.0 51.11 14.84191 100. 'Q32' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 21.0408  ;
-51. 1. -40.0 40.0 80. ;
-52. 3. -40.0 40.0 80. ;
16. 100. 26.9875 ;
(CHANGE QUAD APERTURE TO ACCOUNT FOR SMALL BEAM PIPE)
50.  3.  -50.  50.  25. 'Q33V' ;
5.0 51.16 -15.4396 100. 'Q33' ;
-50. 1. -100. 100. 10.;
-50. 3. -100. 100. 10.;
3.0 91.00 'S733' ;
 (HISTOGRAMS AT SEM 733)
50. 1. -45. 45. 45. '733H';
50. 3. -45. 45. 45. '733V';
16.  100. 66.67 ;
(RESTORE STANDARD CIRCULAR APERTURE)
3.0  91.8020 ;
(DISPLACE BEAM AT D4Q5 AS TRANSPORT PREDICTS)
7.  0.  0.  147.93430  -64.8215  0.  0.  ;
(PUT IN APERTURES OF D4Q5)
16. 100. 500. ;  16. 101.  84.1 ;
5.0 32.4  9.7732  100.  'D4Q5' ;
(HISTOGRAM AT EXIT OF D4Q5)
51.  1.  -40.  40.  80.  '4Q5H' ;
52.  3.  100.  200.  100.  '4Q5V' ;
7.  0.  0.  -108.9  30.65  0.  0.  ;
(S.O. CHANGE-MOVE BEAM TRAJ. BACK TO REF.)
3.  40.48  'L450' ;
(HISTOGRAMS AT ISEP ENTRANCE)
50. 1. -45. 45. 90. 'SEPH' ;
50. 3.  35. 125. 90. 'SEPV' ;
16. 4. 26.5; 16. 5. 19.5;
20. -90. ; 2. 1.0299 ; 4. 78.71 5.328 'SEPT' ;2. 1.0299; 20. 90;
(S.O. CHANGE-PUT IN DIPOLE FOR SEPTUM)
-6.  1.  19.5 ;
-3.  40.00  'SEP1' ;
-7.  0.  0.  0.  35.94873  0.  0. ;
-3.  40.00  'SEP2' ;
-6.  1.  19.5 ;
3.  19.984  'L451' ;
3.  3.937  'VPU4' ;
7.  0.  0.  54.733  5.349  0.  0.  ;
(S.O. CHANGE- ALTER BEAM TRAJECTORY)
16.  100.  66.7 ; 16.  101.  44.6 ;
(QUAD APERTURE RESTORED)
51.  1.  -40.  40. 80. '4Q4H' ;
52.  3.    0.  80. 80. '4Q4V' ;
(HISTOGRAMS AT D4Q4 ENTRANCE)
5.  27.86  -11.45643  100.  'D4Q4' ;
3.  25.358  'L341' ;
51.  1.  -40.  40.  80. ;
52.  3.    0.  80.  80. ;
(HISTOGRAMS AT D4V3 ENTRANCE)
(S.O. CHANGE- REMOVED -16. 100.,101. CARDS)
(D4V3 AS CIRCULAR BEAM PIPE BUT WITH NO APERTURE RESTRICTION )
5.  19.685  0.0  100.  'D4V3' ;
3.  12.157  'L342' ;
3.  15.0    'S403' ;
50.  1.  -54.  54. 108. '403H' ;
50.  3.  -54.  54. 108. '403V' ;
(HISTOGRAMS AT SEM403)
3.  41.157  'L343' ;
3.  19.685  'D4H3' ;
(S.O. CHANGE- REMOVED 6. CARD)
3.  9.921   'L344' ;
3.  3.937   'HPU3' ;
(HISTOGRAM AT ENTRANCE TO D4Q3)
5.  27.90  10.53414  100.  'D4Q3' ;
3.  11.642  'L230' ;
51.  3.  -50.  50.  50. 'INKY' ;
52.  4.  -10.  10.  50. 'IKYP' ;
```

```
6.0  1.  20.6375 ; 6.0 3.  28.575 ;
(S.O. CHANGE- TURNED ON SLIT CARD)
(KICKER ENTRANCE APERTURE AS A SLIT)
3.  62.563  'KIK1' ;
7.  0.  0.  0.  6.28399  0. 0. ;
3.  62.563  'KIK2' ;
6.0  1.  20.6375 ; 6.0  3.  28.575 ;
(KICKER EXIT APERTURE AS A SLIT)
51.  1.  -10.  10.  50. 'KIKX' ;
52.  2.  -25.  25.  50. 'KKXP' ;
51.  3.  -50.  50.  50. 'KIKY' ;
52.  4.  -10.  10.  50. 'KKYP' ;
(HISTOGRAMS AT KICKER EXIT)
3.  6.197   'L231' ;
3.  3.937   'VPU2' ;
5.  27.16  -10.61935 100.  'D4Q2' ;
3.  23.232  'L200' ;
3.  96.500  'RF12' ;
3.  4.3346  'LJM5' ;
3.  9.8425  'D4V1' ;
3.  9.0551  'LJM6' ;
3.  3.937   'HPU0' ;
5.  28.05   11.01644  100.  'D50Q' ;
3.  3.937   'HPU0' ;
3.  23.2323 'L200' ;
3.  88.752  'RF13' ;
3.  3.937   'L20A' ;
3.  9.8425  'D5H1' ;
3.  17.2    'L20B' ;
5.  28.05  -10.28442  100.  'D5Q2' ;
3.  3.937   'VPU2' ;
3.  23.2323 'L200' ;
3.  96.5    'RF14' ;
3.  11.5906 'REPA' ;
-51.  3.  -25.  25.  50. 'ORBY' ;
-52.  4.  -10.  10.  50. 'ORBYP' ;
3.  11.6418 'REPB' ;
51.  3.  -25.  25.  50. ;
52.  4.  -10.  10.  50. ;
-50. 8. 0. 10000. 5000. ;
SENTINEL
SENTINEL
```