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Tuneability of the NSNS Accumulator Ring

A. G. Ruggiero

February 1997

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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February 12, 1997

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
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Tunability of the NSNS Accumulator Ring*

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Abstract

The lattice of the Accumullator Ring is described in reference [1]. It is a ring with threefold periodicity and internal symmetry. The choice of the size, shape and focussing is also discussed in the same reference. For convenience, we report in Table 1 a list of the major parameters and the plot of the lattice functions in Figure 1. The lattice is made of 18 FODO cells of which 6 do not include bending magnets. The reference working point requires only two families of quadrupoles, QF and QD. In this report we explore the capability of tuning of such lattice, and we make other considerations which are related.

The Tunability Range

The tuning of the lattice is essentially determined by two sets of quadrupoles QF and QD. Considering the small size of the ring and the relatively few bending magnets, there is also a considerable focussing action on the horizontal plane from the curvature in the magnets, which are sector shaped and thus do not introduce any effect on the vertical plane. We begin by neglecting the presence of the bending magnets and explore the tunability range of the lattice assuming that it is simply made of 18 regular FODO cells. The tunability range is displayed in Figure 2. To tune the ring one acts on the gradients G_F and G_D of the two sets of regular quadrupoles. In Figure 2 we adopt the focussing parameters $K_{F,D} = G_{F,D} / B\rho$, where $B\rho$ is the magnetic rigidity. The operating point is marked with a black circle. It is seen that the range of betatron tunes extends between 0 and 9. The upper limit corresponds to a phase advance of 180^o per cell, which is well known to be the boundary of stability. Obviously, since bending magnets have been here ignored, the periodicty of the lattice is actually 18 and all the FODO cells behave identically.

Next we estimate the tunability range in the presence of the bending magnets. Again we varied the gradient G_F and G_D of the quadrupoles. The result is also shown in Figure 2. The range has a lesser extend when compared to the previous case, but the range of betatron tunes that it is possible to reach is still unchanged in the vertical plane, where $Q_V = 0$ to 9, but in the horizontal plane the horizontal range is limited $Q_H = 0$ to 7. Indeed the bending magnets have no focussing effect on the vertical plane but introduce a substancial contribution in the horizontal plane, where the focussing periodicty is now 3 and no more 18 as it is still in the vertical plane.

Within the range of tunability determined lastly, in the presence of bending magnets, the

* Work performed under the auspices of the U.S. Department of Energy

behavior of the dispersion around the ring varies and deviates considerably from the requirements. In order to preserve the required behavior of the dispersion in the arcs, we explored the range of tunability of the ring by varying only those quadrupoles QF1 and QD1 in the long straights as shown in Figure 1. As expected, the tunability range is even narrower. Also in the vertical plane the periodicity is now down to 3. Moreover, four families of quadrupoles are now in place, of which two (QF and QD) stay unchanged and the other two (QF1 and QD1) vary. This creates within a period a large variation of the β function and thus a reduced range of stability. In terms of betatron tunes the values that it is possible to reach, without losing stability, is only between 3 and 4.5 for both planes. The tunability range for this mode of operation is also shown in Figure 2.

Table 1: NSNS Accumulator Ring

Kinetic Energy	1.0 GeV
Magnetic Rigidity	5.657 T m
Circumference	208.558 m
Periodicity	3 w/ mirror symmetry
Structure	18 FODO Cells
β_{max}	24.0 m
η_{max}	7.95 m
Betatron Tunes, H/V	3.82 / 3.78
Transition Energy, γ_T	3.422
Natural Chromaticity, H/V	-0.928 / -0.958
Dipole, Field	9.874 kG
Length	1.5 m
QF, gradient	0.209 kG / cm
QD, gradient	0.237 kG / cm
Quadrupole length	0.5 m

Location of Resonance Lines

In order to determine good locations of the operation tunes, we need to explore the tune diagram (Q_H, Q_V), and scan the presence of resonance lines that may be caused by systematic (thick solid lines) and random (thin dashed lines) magnetic imperfections and misalignments. The tune diagrams are displayed in Figures 3 to 6. The reference operating point is noted with a black dot, and it corresponds to zero space charge. The region covered by the necktie corresponds to the

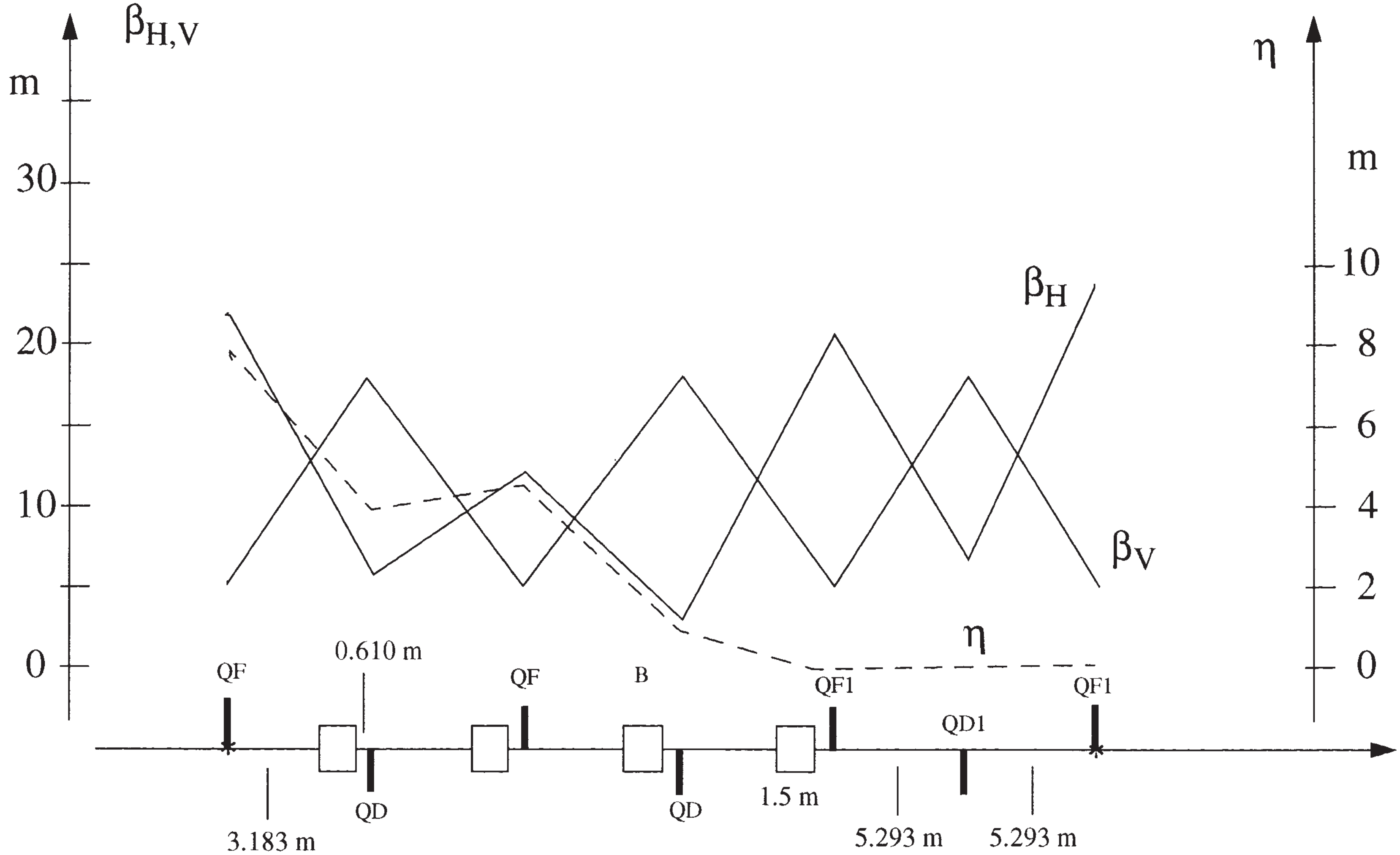

Figure 1. Half-Period Lattice Functions and Structure

range of betatron tunes that the beam is expected to occupy in the presence of space charge, with a maximum tune depression of 0.2.

It is seen that the range of betatron tunes occupied by the beam during storage, assuming the reference working tunes shown in Table 1, is crossed by one systematic second-order resonance $Q_H - Q_V = 0$, and by four fourth-order systematic resonances: $2Q_H - 2Q_V = 0$, $2Q_H + 2Q_V = 15$, $3Q_H + Q_V = 15$, and $Q_H + 3Q_V = 15$. There are also four third-order random resonances, of which two can be excited by regular sextupolar field errors, and the other two by skewed sextupole field errors. The linear coupling resonance can be caused by systematic and random skew quadrupole errors. The second-order coupling resonances can be caused by systematic and random regular octupole field errors, as well by the space-charge forces. These resonances do not cause beam losses, but a thermalization of the two transverse betatron emittances, since the following condition applies $\varepsilon_H + \varepsilon_V$ = constant. This condition can actually be beneficial since ultimately it will make easier beam "painting" during injection, by allowing energy transfer from one plane of oscillation to the other. Nevertheless, because of the proximity of the two values of betatron tunes, there may be operation difficulty especially when trying measuring their values. This effect is reduced by splitting the two betatron tunes enough apart. The resonance $2Q_H + 2Q_V = 15$ is

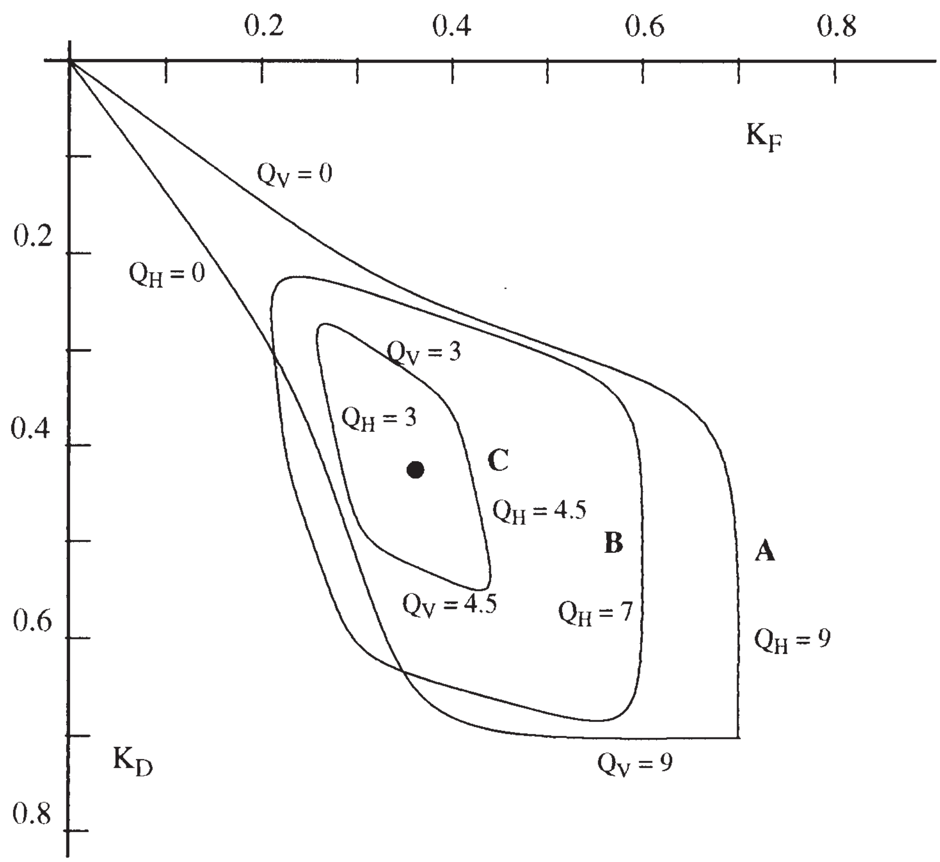

Figure 2. Tunability Range in the KF, KD plane (in m^{-2})
A. 18 FODO Cells without bending magnets
B. Bending magnets included
C. Tuning only with QF1 and QD1 in the insertions

driven by the space-charge forces and may lead to beam losses, and should thus be avoided. Space-charge forces cannot drive the skew resonances $3Q_H + Q_V = 15$ and $Q_H + 3Q_V = 15$, which can be driven only by external skewed octupole field errors. It is not clear whether the other fourth order resonances $4Q_H = 15$ and $4Q_V = 15$, when they are driven by space-charge or by external forces, can have any adverse effect on the beam.

A Higher-Tune Lattice

To avoid the presence and crossing of the fourth order systematic resonances, it was judged more prudent to move the operating tunes away and toward larger values. The case of $Q_H = 4.23$ and $Q_V = 4.27$ has therefore been considered. This case will also reduce the growth rate of potential transverse resistive-wall instability by a factor of two compared to the reference case. The new operating tunes are shown in Figure 6. It is seen that the beam tune-spread is not crossed by any systematic resonance up to and including fourth order, with the exclusion of the coupling resonance. Nevertheless some third and fourth resonances caused by random magnet field imperfections are in the proximity, but they are not expected to cause excessive disturbance, and should be easily controlled eventually by some external multiple field correctors. This also proves the tunability of the lattice of the Accumulator Ring as originally proposed in [1]. The location and size of the magnets are of course unchanged. The only changes apply to the gradients of the quadrupoles, shown in Table 2 together to new global lattice parameters. The envelope and dispersion functions are shown in Figure 7. It is seen that the dispersion is unchanged. Also the behavior of the vertical envelope function β_V is regular and unchanged. On the other end, the horizontal envelope function β_H is somewhat distorted, which is expected since a change of the betatron tunes has to be compansated by a change of the amplitude functions. The distorsion is nevertheless modest and does not have consequences to the magnet size or to the injection insertion.

Table 2: Parameters for the Higher-Tune Lattice

QF gradient	0.216 kG / cm
QD gradient	0.260 kG / cm
QF1 gradient	0.248 kG / cm
QD1 gradient	0.271 kG / cm
Betatron Tunes, Q_H / Q_V	4.23 / 4.27
Transition Energy, γ_T	3.40314
Natural Chromaticity, H/V	-1.085 / -0.995

References

[1] A.G. Ruggiero, et al., "The NSNS Accumulator Ring", BNL/NSNS Technical Note No. 001, August 5, 1996, Brookhaven National Laboratory.

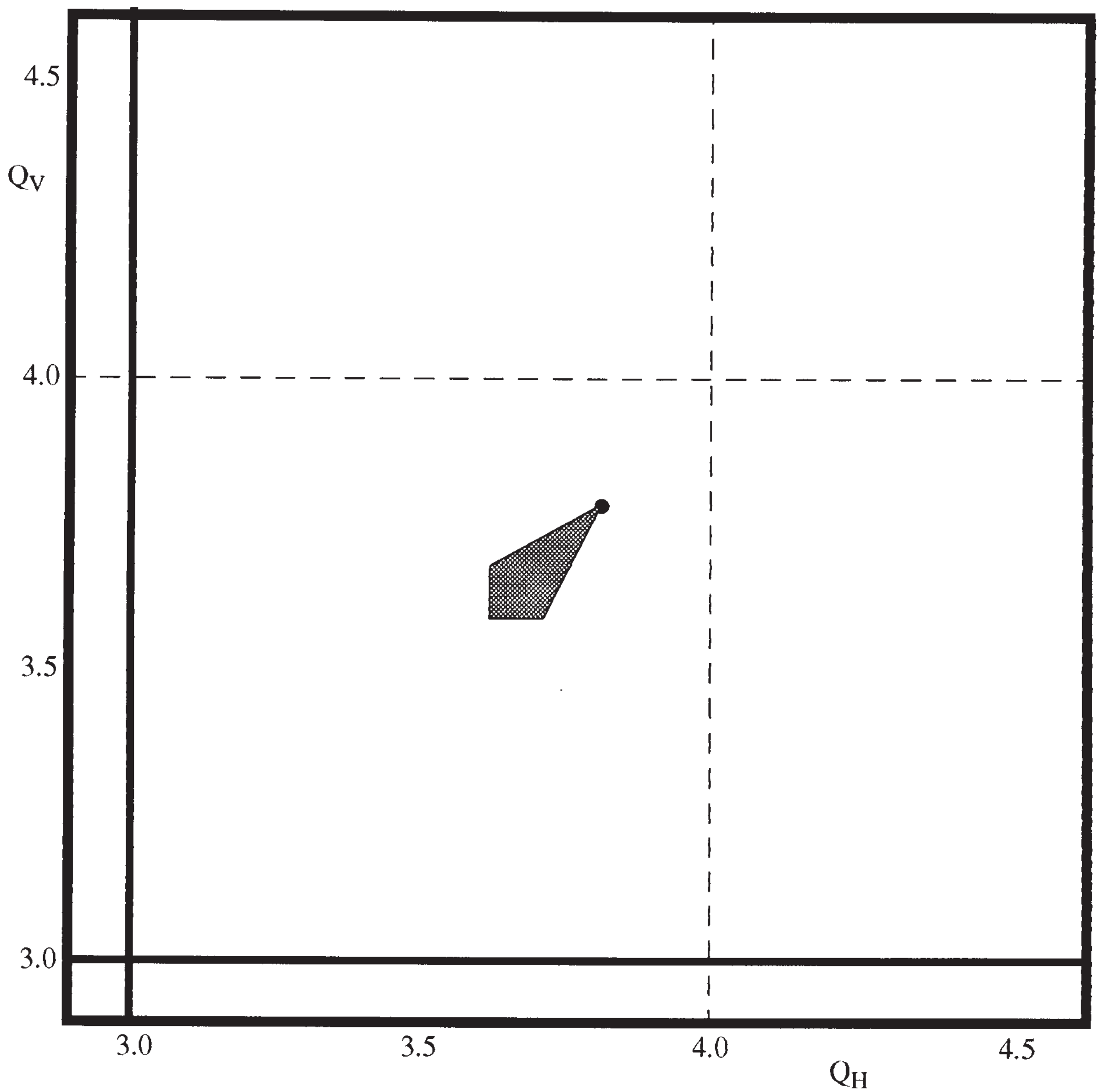

Figure 3. Tune Diagram with First-Order Resonances.

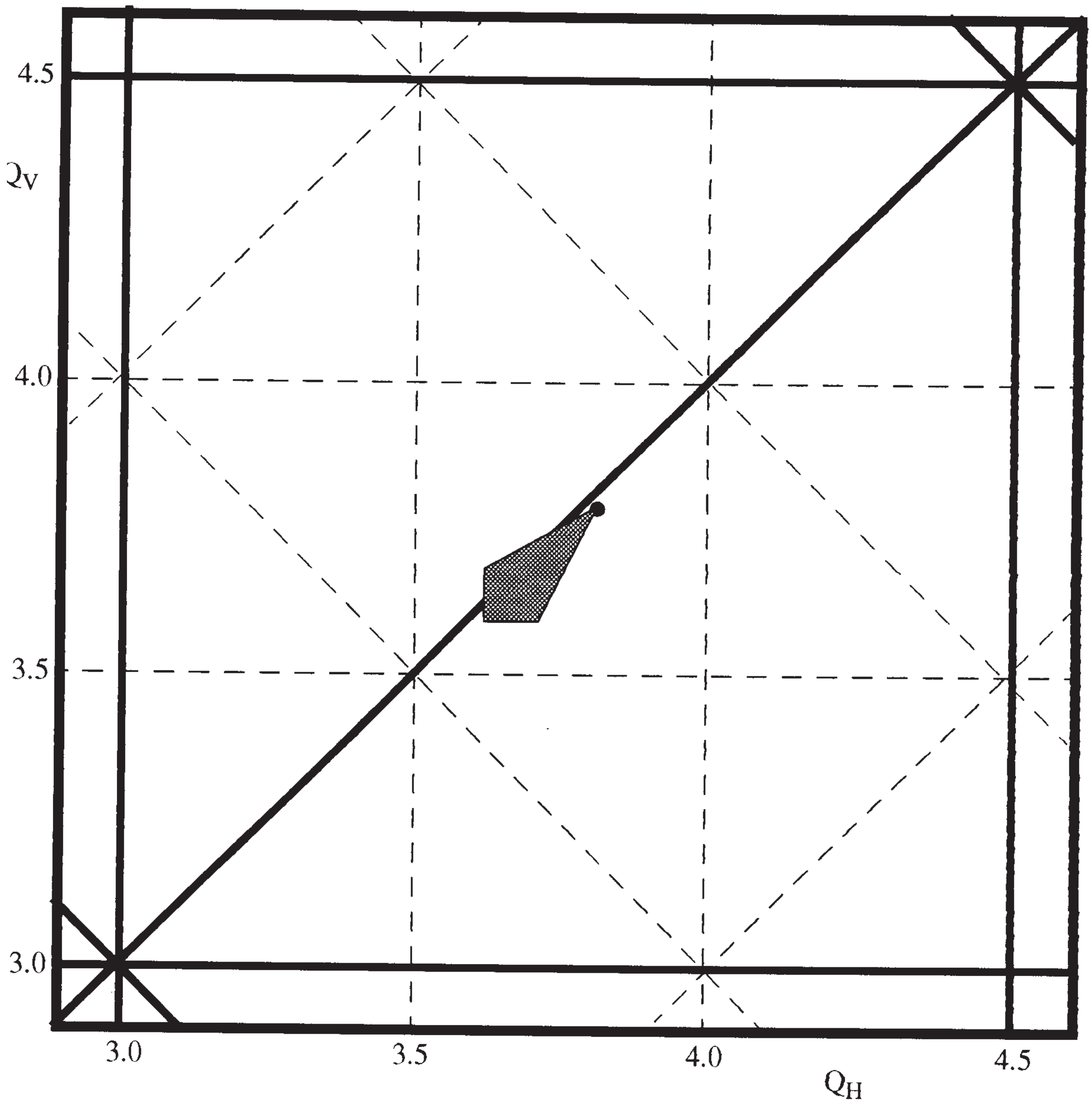

Figure 4. Tune Diagram with Second-Order Resonances.

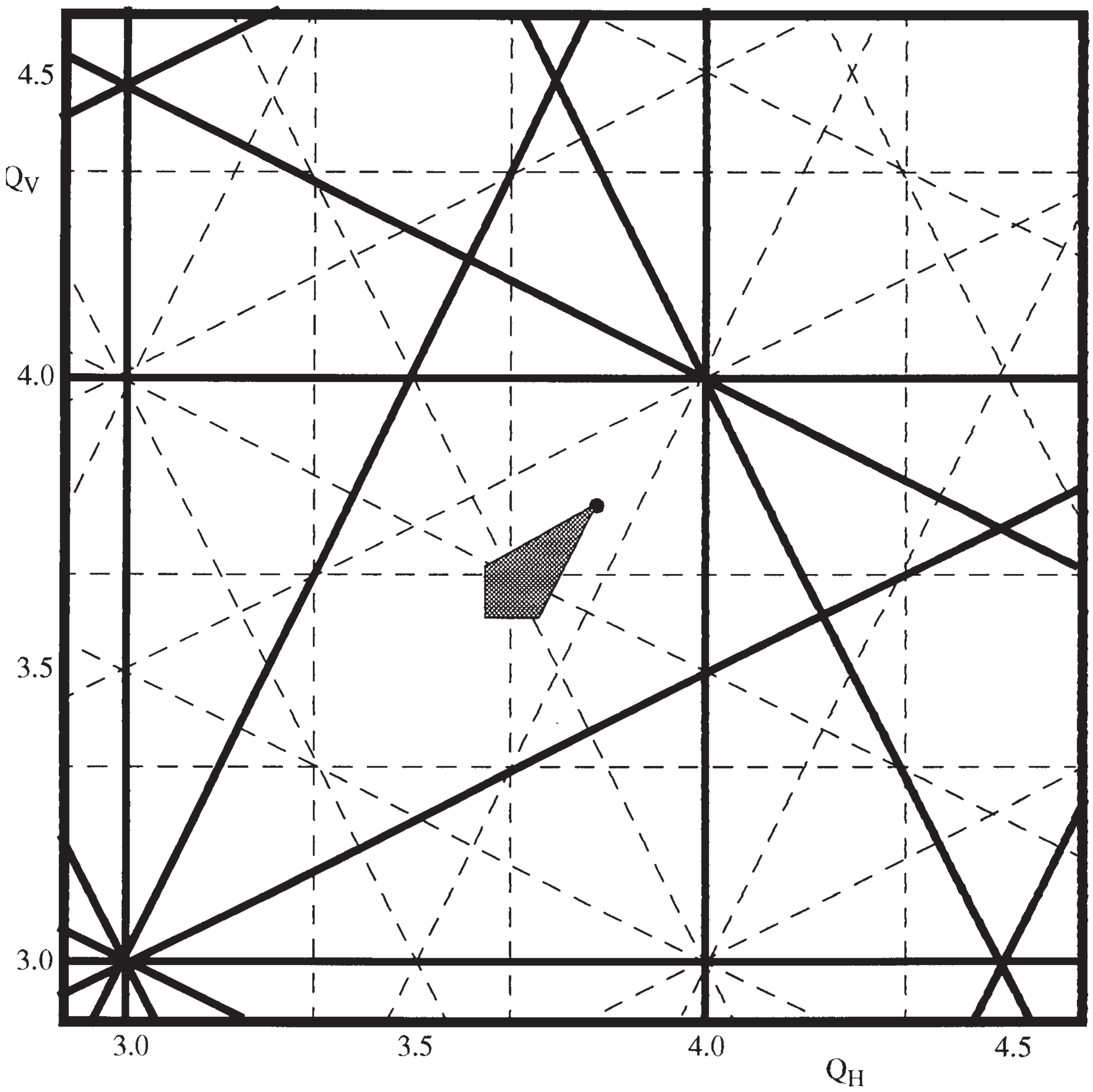

Figure 5. Tune Diagram with Third-Order Resonances.

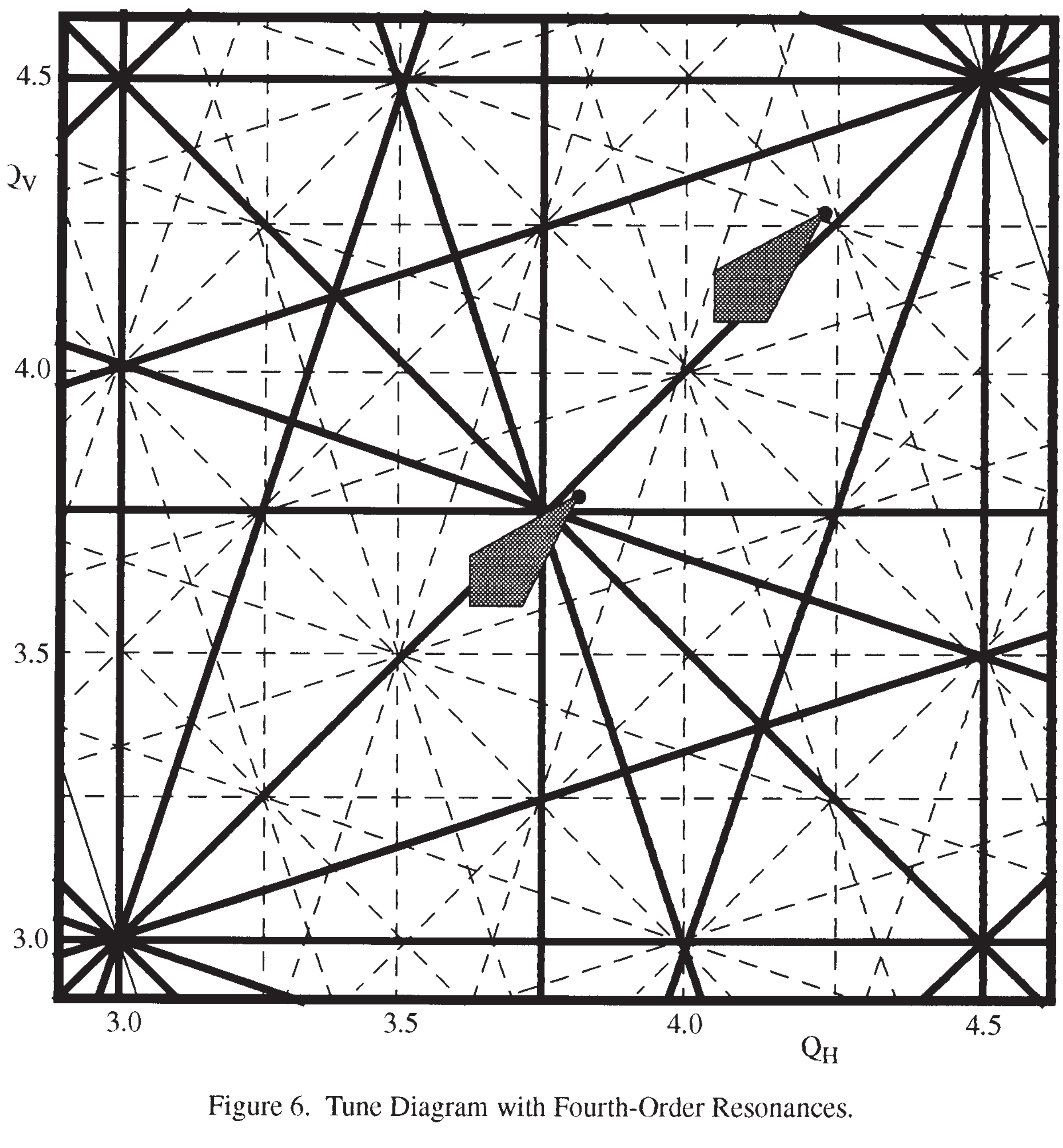

Figure 6. Tune Diagram with Fourth-Order Resonances.

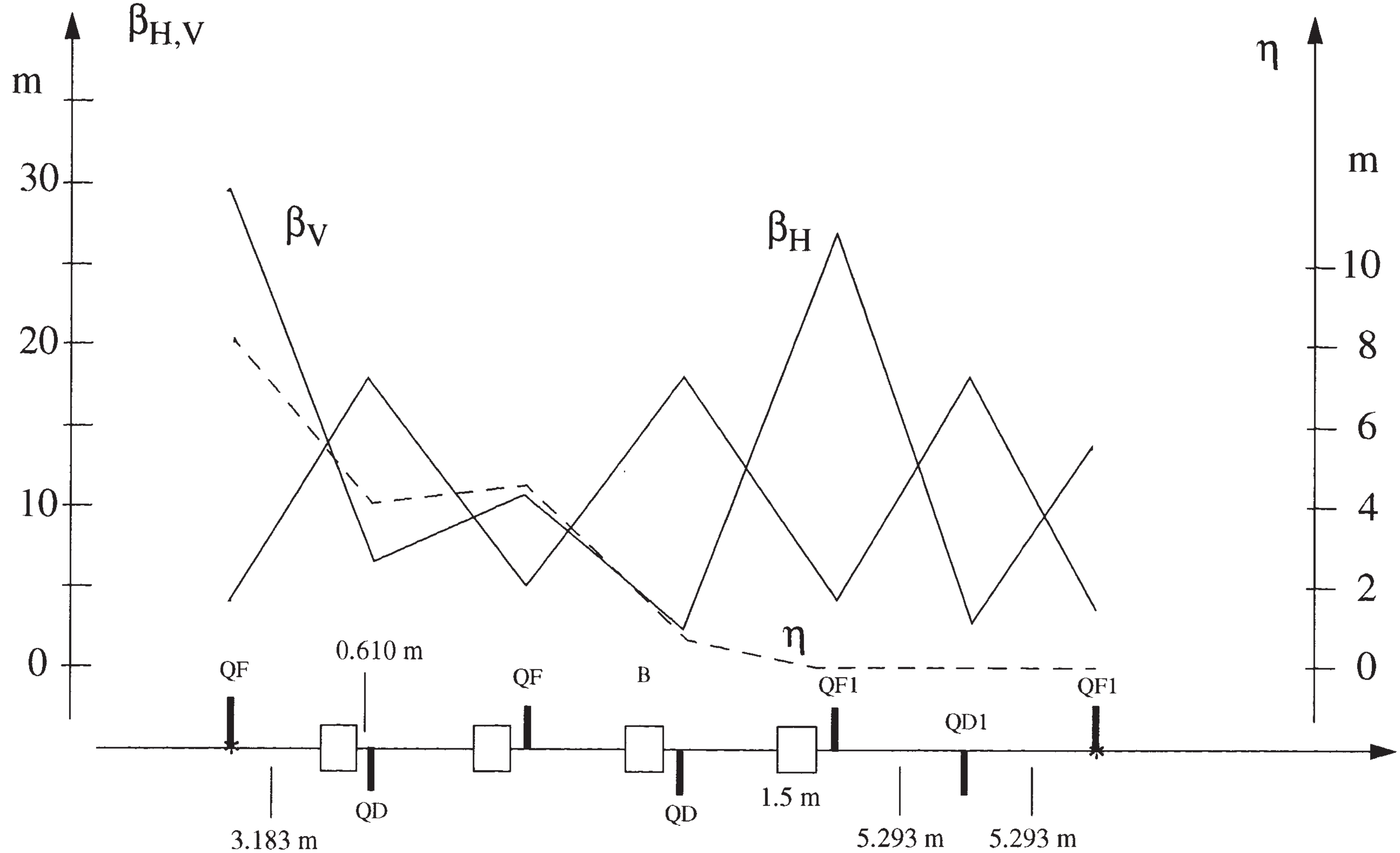

Figure 7. Half-Period Lattice Functions and Structure (Large Tunes)

```
=====================================================================================================
***   RFQ     =           //  402.5
***   NF      =           //  320.
***   KE      =           //  1.0
***   RE      =           //  0.93826
***   PER     =           //  3.0
***   SYM     =           //  1.0
***   ND      =           //  4.0
***   BL      =           //  0.75
***   BC      =           //  3.3356
***   C       =           //  299.7925
***   QL      =           //  0.25
***   DL      =           //  0.61
***   EMC     =           //  470.
***   DPT     =           //  17.4
***   FOIL    =           //  0.0
***   FOID    =           //  0.20
***   T0      CALC        //  RCL  NF   RCL  RFQ  /
***   GM      CALC        //  RCL  KE   RCL  RE   /    1.0  +
***   BT      CALC        //  1.0  RCL  GM   X*X  1/X  -    SQRT
***   CIRC    CALC        //  RCL  C    RCL  BT   *    RCL  T0   *
***   NCL     CALC        //  RCL  ND   0.5  *    1.0  +
  *                       //  RCL  PER  *    RCL  SYM  1.0  +    *
***   CL      CALC        //  RCL  CIRC RCL  NCL  /    2.0  /
***   LL      CALC        //  RCL  CL   RCL  QL   2.0  *    -
***   OL      CALC        //  RCL  LL   RCL  BL   2.0  *    -    RCL  DL   -
   ---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+
***   P       CALC        //  RCL  RE   RCL  BT   *    RCL  GM   *
***   BR      CALC        //  RCL  BC   RCL  P    *
***   RHO     CALC        //  1.0  RCL  SYM  +    RCL  BL   *    RCL  ND   *
  *                       //  RCL  PER  *    PI   /
***   ANG     CALC        //  360. RCL  ND   /    RCL  PER  /
  *                       //  RCL  SYM  1.0  +    /
***   ANR     CALC        //  PI   180. /    RCL  ANG  *
***   SAG     CALC        //  1.   RCL  ANR  COS  -    RCL  RHO  *    100. *
***   BZ      CALC        //  RCL  BR   RCL  RHO  /
***   LONS    CALC        //  RCL  LL   RCL  FOIL -    RCL  FOID -
***           PRNT        //  KE   RE   PER  SYM  ND
-----------------------------------------------------------------------------------------------------
VARIABLE  1 OF TYPE 5 (LQ  STORAGE)
      KE                RE                PER               SYM               ND
       1.000000000       0.938260000       3.000000000       1.000000000       4.000000000
-----------------------------------------------------------------------------------------------------
***           PRNT        //  GM   BT   P    BR   RHO
-----------------------------------------------------------------------------------------------------
VARIABLE  1 OF TYPE 5 (LQ  STORAGE)
      GM                BT                P                 BR                RHO
       2.065802656       0.875027427       1.696030660       5.657279870       5.729577951
-----------------------------------------------------------------------------------------------------
***           PRNT        //  CL   QL   LL   OL   BL
-----------------------------------------------------------------------------------------------------
VARIABLE  1 OF TYPE 5 (LQ  STORAGE)
      CL                QL                LL                OL                BL
       5.793273371       0.250000000       5.293273371       3.183273371       0.750000000
-----------------------------------------------------------------------------------------------------
***           PRNT        //  CIRC BC   BZ   NCL
-----------------------------------------------------------------------------------------------------
VARIABLE  1 OF TYPE 5 (LQ  STORAGE)
      CIRC              BC                BZ                NCL
     208.557841350       3.335600000       0.987381604      18.000000000
-----------------------------------------------------------------------------------------------------
```

```
***          PRNT          //  ANG  SAG  FOIL LONS
-------------------------------------------------------------------------------------------
VARIABLE  1 OF TYPE 5 (LQ  STORAGE)
     ANG                SAG                FOIL               LONS
     15.000000000       19.523063440       0.000000000        5.093273371
-------------------------------------------------------------------------------------------

    ---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+

***  O      DRF          //  OL
***  L      DRF          //  LL
***  D      DRF          //  DL
***  S      DRF          //  LONS
***  F      DRF          //  FOIL
***  DF     DRF          //  FOID

***  GF     =            //  0.381379
***  GD     =            //  -.460338
***  GF1    =            //  0.437669
***  GD1    =            //  -.479015

***  B      MAG          //  BL                BR        BZ
***  QF     MAG          //  QL        GF      1.
***  QD     MAG          //  QL        GD      1.
***  QF1    MAG          //  QL        GF1     1.
***  QD1    MAG          //  QL        GD1     1.

    ---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+

***  .C     BML          //  QF   D    B    B    O    QD
  *                      //  QD   D    B    B    O    QF
***  .CT    BML          //  QF1  D    B    B    O    QD
  *                      //  QD   D    B    B    O    QF
***  .CET   BML          //  QF1  L    QD1  QD1  L    QF1
***  .ARC   BML          //  .CT  .C
***  .PER   BML          //  .CET .ARC

    ---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+

***  RING   CYC       -3 //  .PER
```

POS	S(M)	NUX	NUY	BETAX(M)	BETAY(M)	XEQ(M)	YEQ(M)	ZEQ (M)	ALPHAX	ALPHAY	DXEQ	DYEQ
0	0.000	0.00000	0.00000	13.79890	4.03046	0.00075	0.00000	0.0000	0.00000	0.00000	0.00000	0.00000
1 QF1	0.250	0.00291	0.00977	13.42936	4.15737	0.00073	0.00000	0.0000	1.46467	-0.51225	-0.00008	0.00000
2 L	5.543	0.12235	0.11427	4.48578	18.08838	0.00031	0.00000	0.0000	0.22495	-2.11958	-0.00008	0.00000
3 QD1	5.793	0.13124	0.11642	4.52148	18.60978	0.00029	0.00000	0.0000	-0.36915	0.05484	-0.00005	0.00000
4 QD1	6.043	0.13977	0.11859	4.86235	18.03463	0.00028	0.00000	0.0000	-1.00790	2.22276	-0.00001	0.00000
5 L	11.337	0.21597	0.23019	27.14877	3.73274	0.00022	0.00000	0.0000	-3.20243	0.47914	-0.00001	0.00000
6 QF1	11.587	0.21741	0.24108	28.01073	3.61259	0.00022	0.00000	0.0000	-0.21392	0.00582	-0.00004	0.00000
7 QF1	11.837	0.21884	0.25198	27.35881	3.72681	0.00020	0.00000	0.0000	2.79779	-0.46686	-0.00006	0.00000
8 D	12.447	0.22262	0.27600	24.06557	4.41799	0.00017	0.00000	0.0000	2.60096	-0.66622	-0.00006	0.00000
9 B	13.197	0.22805	0.30009	19.97899	5.60115	0.04914	0.00000	0.0022	2.81665	-0.91133	0.13046	0.00000
10 B	13.947	0.23477	0.31899	15.71182	7.15197	0.19531	0.00000	0.0171	2.84038	-1.15643	0.25875	0.00000
11 O	17.130	0.30564	0.36448	3.47659	17.82610	1.01899	0.00000	0.0171	1.00322	-2.19676	0.25875	0.00000
12 QD	17.380	0.31782	0.36666	3.10271	18.41579	1.09869	0.00000	0.0171	0.50661	-0.13932	0.38032	0.00000
13 QD	17.630	0.33103	0.36884	2.96020	17.96277	1.21007	0.00000	0.0171	0.06888	1.93400	0.51285	0.00000
14 D	18.240	0.36383	0.37462	3.00247	15.70149	1.52291	0.00000	0.0171	-0.13817	1.77302	0.51285	0.00000
15 B	18.990	0.40174	0.38292	3.34604	13.19040	1.94244	0.00000	0.2432	-0.31731	1.57510	0.60430	0.00000
16 B	19.740	0.43474	0.39285	3.94356	10.97620	2.42677	0.00000	0.5285	-0.47483	1.37717	0.68540	0.00000
17 O	22.923	0.51881	0.46444	10.11548	4.88251	4.60860	0.00000	0.5285	-1.46403	0.53711	0.68540	0.00000
18 QF	23.173	0.52263	0.47275	10.61599	4.74360	4.72445	0.00000	0.5285	-0.52204	0.02294	0.23959	0.00000
19 QF	23.423	0.52637	0.48107	10.62927	4.85921	4.72792	0.00000	0.5285	0.46932	-0.48903	-0.21192	0.00000

20 D	24.033	0.53574	0.49981	10.09941	5.55072	4.59864	0.00000	0.5285	0.39929	-0.64459	-0.21192	0.00000
21 B	24.783	0.54797	0.51949	9.39943	6.66104	4.44983	0.00000	1.1205	0.52868	-0.83585	-0.18435	0.00000
22 B	25.533	0.56128	0.53581	8.53144	8.05826	4.32291	0.00000	1.6944	0.62203	-1.02710	-0.15362	0.00000
23 O	28.716	0.63326	0.57941	6.21859	17.18145	3.83391	0.00000	1.6944	0.10454	-1.83887	-0.15362	0.00000
24 QD	28.966	0.63962	0.58169	6.35621	17.60954	3.85060	0.00000	1.6944	-0.66028	0.14300	0.28751	0.00000
25 QD	29.216	0.64567	0.58397	6.89161	17.04118	3.97835	0.00000	1.6944	-1.50183	2.10858	0.73693	0.00000
26 D	29.826	0.65808	0.59013	6.89962	14.58764	4.42788	0.00000	1.6944	-1.78998	1.91363	0.73693	0.00000
27 B	30.576	0.66977	0.59920	11.66660	11.89696	4.99013	0.00000	2.3106	-1.87823	1.67394	0.76028	0.00000
28 B	31.326	0.67893	0.61040	14.47017	9.56581	5.56504	0.00000	3.0014	-1.83849	1.43425	0.77062	0.00000
29 O	34.510	0.70366	0.70063	29.24227	3.67299	8.01814	0.00000	3.0014	-2.80205	0.41693	0.77062	0.00000
30 QF	34.760	0.70500	0.71167	29.94840	3.56958	8.11466	0.00000	3.0014	0.00000	0.00000	0.00000	0.00000
31 REFL	69.519	1.41000	1.42333	13.79890	4.03046	0.00075	0.00000	6.0027	0.00000	0.00000	0.00000	0.00000

```
CIRCUMFERENCE =    208.5578 M        THETX =  6.28318531 RAD     NUX =    4.23000     DNUX/(DP/P) =   -4.58846
       RADIUS =    33.1930 M         THETY =  0.00000000 RAD     NUY =    4.27000     DNUY/(DP/P) =   -4.24962
 (DS/S)/(DP/P)=  0.0863459            TGAM=(   3.40314,   0.00000)

MAXIMA    --- BETX(   30) =    29.94840    BETY(    3) =    18.60978    XEQ(   30) =    8.11466    YEQ(   31) =    0.00000
MINIMA    --- BETX(   13) =     2.96020    BETY(   30) =     3.56958    XEQ(    8) =    0.00017    YEQ(   31) =    0.00000
------------------------------------------------------------------------------------------------------------------------

    ---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+

***   EMT   BVAL          //              1.       EMC        EMC        DPT       1.

   EMITTANCES UNNORMALIZED  (MM-MRAD)
      EPSX = 470.000000    EPSY = 470.000000    EPSL =  17.400000          SIGL =   1.000000 MM    SIGP =  17.400000 (0/00)
------------------------------------------------------------------------------------------------------------------------
***   ENV   CYAE       -3 //  .PER EMT   1.
------------------------------------------------------------------------------------------------------------------------
 BEAM ENVELOPES (MM,MRAD)
   EMITTANCES (MM-MRAD) --- EPSX = 470.000000   ' EPSXCO =   0.000000      EPSL =     17.400000
                            EPSY = 470.000000     EPSYCO =   0.000000      SIGP =  17.400000 (0/00)
   XTOT = SQRT(XB*XB + XP*XP) + XCO,    ETC.
+                                                                                     DISPLACEMENT =  1.00*SIGMA
```

POS	S	XB	XP	XCO	XTOT	YB	YP	YCO	YTOT	XPRTOT	YPRTOT
0	0.0000	80.5325	0.0130	0.0000	80.5325	43.5238	0.0000	0.0000	43.5238	5.8362	10.7987
1 QF1	0.2500	79.4468	0.0128	0.0000	79.4468	44.2037	0.0000	0.0000	44.2037	10.4918	11.9464
2 L	5.5433	45.9164	0.0053	0.0000	45.9164	92.2038	0.0000	0.0000	92.2038	10.4918	11.9464
3 QD1	5.7933	46.0988	0.0050	0.0000	46.0988	93.5232	0.0000	0.0000	93.5232	10.8680	5.0330
4 QD1	6.0433	47.8049	0.0049	0.0000	47.8049	92.0667	0.0000	0.0000	92.0667	13.9591	12.4426
5 L	11.3365	112.9598	0.0039	0.0000	112.9598	41.8854	0.0000	0.0000	41.8854	13.9591	12.4426
6 QF1	11.5865	114.7390	0.0038	0.0000	114.7390	41.2058	0.0000	0.0000	41.2058	4.1889	11.4064
7 QF1	11.8365	113.3959	0.0036	0.0000	113.3959	41.8521	0.0000	0.0000	41.8521	12.3146	12.3936
8 D	12.4465	106.3523	0.0029	0.0000	106.3523	45.5682	0.0000	0.0000	45.5682	12.3146	12.3936
9 B	13.1965	96.9027	0.8550	0.0000	96.9064	51.3083	0.0000	0.0000	51.3083	14.6735	12.3936
10 B	13.9465	85.9334	3.3983	0.0000	86.0006	57.9778	0.0000	0.0000	57.9778	17.0740	12.3936
11 O	17.1298	40.4227	17.7305	0.0000	44.1403	91.5329	0.0000	0.0000	91.5329	17.0740	12.3936
12 QD	17.3798	38.1874	19.1172	0.0000	42.7053	93.0345	0.0000	0.0000	93.0345	15.3020	5.1007
13 QD	17.6298	37.3001	21.0552	0.0000	42.8324	91.8831	0.0000	0.0000	91.8831	15.4647	11.1370
14 D	18.2398	37.5654	26.4986	0.0000	45.9710	85.9052	0.0000	0.0000	85.9052	15.4647	11.1370
15 B	18.9898	39.6565	33.7984	0.0000	52.1054	78.7368	0.0000	0.0000	78.7368	16.2840	11.1370
16 B	19.7398	43.0520	42.2258	0.0000	60.3033	71.8249	0.0000	0.0000	71.8249	16.9789	11.1370
17 O	22.9231	68.9513	80.1896	0.0000	105.7575	47.9039	0.0000	0.0000	47.9039	16.9789	11.1370
18 QF	23.1731	70.6365	82.2054	0.0000	108.3847	47.2175	0.0000	0.0000	47.2175	8.5859	9.9566
19 QF	23.4231	70.6807	82.2657	0.0000	108.4592	47.7894	0.0000	0.0000	47.7894	8.2192	10.9478
20 D	24.0331	68.8965	80.0164	0.0000	105.5904	51.0768	0.0000	0.0000	51.0768	8.2192	10.9478
21 B	24.7831	66.4660	77.4270	0.0000	102.0425	55.9526	0.0000	0.0000	55.9526	8.6179	10.9478
22 B	25.5331	63.3228	75.2186	0.0000	98.3241	61.5417	0.0000	0.0000	61.5417	9.1406	10.9478
23 O	28.7164	54.0624	66.7100	0.0000	85.8659	89.8626	0.0000	0.0000	89.8626	9.1406	10.9478

24	QD	28.9664	54.6573	67.0005	0.0000	86.4667	90.9752	0.0000	0.0000	90.9752	11.4546	5.2188
25	QD	29.2164	56.9127	69.2233	0.0000	89.6154	89.4950	0.0000	0.0000	89.4950	19.6580	12.2558
26	D	29.8264	64.6747	77.0451	0.0000	100.5921	82.8021	0.0000	0.0000	82.8021	19.6580	12.2558
27	B	30.5764	74.0493	86.8283	0.0000	114.1160	74.7768	0.0000	0.0000	74.7768	18.9052	12.2558
28	B	31.3264	82.4681	96.8317	0.0000	127.1903	67.0517	0.0000	0.0000	67.0517	17.9461	12.2558
29	O	34.5096	117.2342	139.5156	0.0000	182.2319	41.5488	0.0000	0.0000	41.5488	17.9461	12.2558
30	QF	34.7596	118.6413	141.1950	0.0000	184.4228	40.9598	0.0000	0.0000	40.9598	3.9615	11.4747
31	REFL	69.5193	80.5325	0.0130	0.0000	80.5325	43.5238	0.0000	0.0000	43.5238	5.8362	10.7987

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---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+
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***        FIN          // CORE USE SUMMARY                         MAXIMUM        USED    UNUSED
                             INFF   (ELEMENT DEFINITIONS)        2000(INFMAX)      90      1910
                             FLIB  (F.P. DATA AND STORAGE)       5000(IFLMAX)      74      4926
                             ILIB  (INTEGER DATA)                1000  (IMAX)       3       997
                             CHLIB(CHARACTER DATA)               5000(ICHMAX)     433      4567
                             SFLIB(F.P.CHARACTER DATA)           5000(ISFMAX)      74      4926
                             LQFIL(CALCULATED DATA)             30000 (IQMAX)    1163     28837
   ARRAY DIMENSIONS ARE SET IN COMMON FILES BINFF.CCC, BSTORE.CCC, CSTORE.CCC
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END OF SYNCH RUN AGR