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EPA LATTICE MATCHING

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1. INTRODUCTION

During the design [1], the EPA lattice was optimized to fulfill the numerous constraints by using all the available parameters, mainly the positions and strengths of the quadrupoles and bending magnets.
Once the machine is built, the number of available parameters shrinks to the strength of the lattice quadrupole magnets only. In EPA, they are split in four families powered by four independent power supplies: HR.QFW, HR.QFL, HR.QFN, HR.QDN.

Nevertheless, an operational machine needs some flexibility in order to:
- move it's transversal tunes Qx,Qy,
- adapt to different working energies where the characteristics of some elements can change mainly due to magnetic fields saturation effects.

This is the reason why an extra trimming quadrupole family, HR.QTR, has been intoduced at the optimum location [2], and the highly saturated bending magnets tracked [3] then modelled [4].

In addition, due to space problems around the injection area, four over twelve quadrupoles of the HR.QFN family were replaced by another quadrupole type using an independent power supply, HR.QFI, but breaking the nice lattice symmetry (fig.1).

The goal of this note is to check the proposed matching method to serve as a basis for the on-line Configuration Update program, which as a part of the Modelling applications [5] will be used in operation to modify the EPA configuration.

2. CONSTRAINTS

With the small number of parameters available, all the numerous design constraints cannot be completely fulfilled but can be set in order of preference [6]:
- big axis symmetry: two identical cells
- transversal tunes: overall phase advances
- injection conditions: PI horizontal phase advance between injection kickers,
- stability and damping: Dispersion function = zero in the straight sections,
- slicing conditions: Equal Twiss parameters and PI vertical phase advance between Beta-Bump quadrupoles,
- Beta beating: Periodic solution in the arcs and small axis symmetry.

Remark: Although the synchrotron integrals had a considerable impact on the EPA lattice design, the matching method does not try to fit them. In fact, for a given bending magnet, they are dependent only on the local Dispersion function and Twiss parameters in the bending magnets which come as a result of the matching.

3. MATCHING METHOD

The proposed method is based on MAD matching capabilities[7] using one EPA cell (half of the ring) with three markers in positions B,C and D (fig.1) of the injection kickers and septa.

The CELL matching mode with symmetry is used in order to fulfill the first condition which consists in the big axis symmetry. Then three fitting conditions have to be fulfilled:
- a coupling of the two extremities of the cell (points A and F of fig.1) imposing (with a high weight) the corresponding phase advance (transverse tunes) as well as an equivalence (with a low weight) of the Beta function (reduction of the Beta beating and small axis symmetry).
- a constraint on the Dispersion function and it's derivative at the injection septum (point C) (damping and stability conditions).
- a coupling of the two injection kicker locations (points B and C) imposing (with an intermediate weight) the corresponding phase advance (injection conditions) as well as an equivalence (with a low weight) of the Beta function (Beta beating and slicing conditions).

4. TEST OF THE METHOD

The above method has been used to rematch the lattice with the nominal transverse tunes and using different bending magnet models corresponding to the different working energies then to adjust the lattice to different transverse tunes.

4.1 Adjustment to the bending magnet model

The Mad listing corresponding to the matching of the lattice with the nominal tunes (Qx = 4.46, Qy = 4.38) and the 600 MeV bending magnet model [4] is attached:

- The big and small axis symmetry are completely respected without any Beta beating in horizontal and negligeable in vertical

  Points A and F: Bx = 14.705 + 1E-3 ; By = 3.020 + 6E-3
  Points B,C,D and E: Bx = 13.633 + 1E-3 ; By = 3.135 + 6E-3

- The dispersion functions, injection and slicing conditions are ideal;

  Points B-C and D-E: Dx = Dx' = 0 ; MUx = MUy = 0.025 + 1E-3

- The maximum Beta function is reduced:

  Bx(max) = 15.3 m ; By(max) = 14.6 m

Remark: Linear optics as well as chromatic functions like for example the chromaticities are derived from the parameters of the bending magnet model [4] which has been adjusted to give a representation for on and off momentum particles behaviour similar to the results of the tracking program ORBIT of M.Bell.

4.2 Adjustment to different operation energies

EPA is supposed to work at a constant operationel energy, E = 600 MeV. Nevertheless, an energy range has been foreseen in order to cope with eventual klystron problems or energy upgrading of LIL:

$$500 \text{ MeV} < E < 650 \text{ MeV}$$

Therefore the bending magnet has been measured and modelled [4] also at these two extreme energies (fig 2). Table 1 summarizes the main parameters of the lattice after matching as well as the required quadrupole strengths.

Thanks to the trimming quadrupoles (fig 3 and table 1) located at the optimum position for this purpose [2], the lattice is easily retuned without any major modification of it's characteristics. The variation with energy of the sextupole component of the bending magnet induces a small perturbation of the natural chromaticities (fig 3), which are easily compensated by the two dedicated sextupole families: HR.XNH and HR.XNV.

4.3 Adjustment to different transverse tunes:

In order to test the flexibility of the lattice as well as of the matching method, a large area of the tranverse tunes area has been covered (fig 4):

$$4.15 < Qx,y < 4.85$$

Table 1 summarizes the main parameters of the lattice after matching with the nominal values.

In any case, the required tunes have been exactly reached with an optimum Dispersion function and horizontal phase advance between kickers. Moreover, the matching is perfect (penalty function < 5E-6) and all the constraints exactly fulfilled even for extreme tunes except for vertical tunes greater than 4.70 (cases 12,13,14). In these three cases, the horizontal parameters are acceptable but the lattice is highly mismatched in the vertical plane as shown on fig 5 which plots the maximum of the Beta function in both planes in function of the corresponding tune.

Therefore, limiting the maximum acceptable of the Beta function to 25 meters which corresponds to an EPA acceptance (with an ideal closed orbit) of:

$$EPSx = 100 \text{ mm-mrad} \quad ; \quad EPSy = 12.5 \text{ mm-mrad}$$

the EPA lattice is perfectly matchable with the proposed method in a broad tune area:

$$4.20 < Qx < 4.90 \quad ; \quad 4.15 < Qy < 4.70$$

5. POWER SUPPLIES STRENGTH REQUIREMENTS

In any of the studied cases, the required quadrupole strengths are well inside the available power range specifications (table 1).

The HR.QTR trimming quadrupole family, implemented in order to correct locally the variation of the bending magnets characteristics with the operating energy, has been found to be extremely useful for tuning the machine to different transverse tunes specially in the cases of high vertical tunes. Their strength, limited not by the magnet (design identical to the HR.QFN, HR.QDN quadrupole magnets) but by the power supply, is still sufficient.

Finally, the rematching of the lattice by MAD needs changes of the quadrupole strengths in the arcs only, HR.QFW, HR.QFL, HR.QTR, whereas the quadrupole strengths in the straight sections, HR.QFN, HR.QFI and HR.QDN do not necessitate any modifications (at least as long as the lattice is correctly matched).

6. CONCLUSION: CONFIGURATION UPDATE

The developped matching method is proposed to serve as a basis for the modelling program, Configuration Update [8], to be used in operation to match the EPA configuration.

It has been shown to be easily usable to adapt the lattice to different bending magnets corresponding to the EPA operation energy range as well as to transverse tunes covering a large working area with a limited number of constraints.

The only bad point consists in the necessary computer time for matching (nearly 200 elements), which, still acceptable on the IBM (20 to 40 sec.) lasts as long as 4 to 5 minutes on the PRDEV computer.

REFERENCES

[1] J.P.Delahaye,A.Krusche: The LEP Electron Positron Accumulator, Basic Parameters and Lattice Structure, PS/LPI Note 82.8

[2] J.P.Delahaye: Effect and correction of an integrated focussing error strength in the EPA bending magnets, PS/LPI Note 83-4

[3] M.Bell,J.P.Delahaye: Particle Tracking in the EPA Bending Magnet, PS/LPI Note 83-9

[4] M.Bell,H.Kugler: The EPA Bending Magnet and its Representation in the Full description of the Machine; PS/LPI Note 86-01 reviewed on 23/04/86

[5] J.P.Delahaye,H.Kugler,F.Perriollat: Proposition pour un service de "Modelling On-Line", PS/CO Note 84-22

[6] F.Perriollat: Minute of the EPA modelling meeting no 2 (20/06/85)

[7] F.C.Iselin: The MAD program , CERN-LEP-TH/85-15

[8] A.Levy-Mandel: Le "Configuration Update". Cahier des charges et guide de l'utilisateur; 21 Mars 1986.

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 04/25/86 14:00:23 JPD MAD
 INPUT  FILE: EPA600MA MAD A1  RECORDS = 102
 OUTPUT FILE: OPTICS LISTING A1
0EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986),          "MAD" VERSION: 4.15      RUN: 25/04/86  14.00.27
0MATCHING OF BEAM LINE "EPAH" AS A CELL, SYMM = T
0-------------------------------------------------------------------------------------------------------------------------------
0BEGIN MIGRAD MINIMIZATION, TOLERANCE =   0.10E-05
0  PENALTY FCT.    CALL      TIME    E.D.M.      PARAMETER NAME        PAR. VALUE       PAR. ERROR
   0.179191E-05      87     3.037   0.239E-06   QFWH[K1]               0.110753E+01    0.100000E-04
                                                 QTRH[K1]              -0.668658E-01    0.100000E-04
                                                 QFLH[K1]               0.137569E+01    0.100000E-04
                                                 QFNH[K1]               0.565923E+00    0.100000E-04
                                                 QDNH[K1]              -0.568929E+00    0.100000E-04
                                                 QFIH[K1]               0.533551E+00    0.100000E-04
0MIGRAD MINIMIZATION HAS CONVERGED
0  PENALTY FCT.    CALL      TIME    E.D.M.      PARAMETER NAME        PAR. VALUE       PAR. ERROR
   0.167234E-05      88     3.075   0.239E-06   QFWH[K1]               0.110753E+01    0.515467E-05
                                                 QTRH[K1]              -0.668722E-01   -0.236619E-04
                                                 QFLH[K1]               0.137569E+01   -0.488435E-05
                                                 QFNH[K1]               0.565922E+00   -0.263501E-05
                                                 QDNH[K1]              -0.568925E+00    0.115959E-04
                                                 QFIH[K1]               0.533550E+00   -0.441543E-05
1EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986),          "MAD" VERSION: 4.15      RUN: 25/04/86  14.00.27
 MATCHING SUMMARY FOR BEAM LINE "EPAH"
-------------------------------------------------------------------------------------------------------------------------------
POS.  ELEMENT OCC.    DIST   CONDITION  QUANTITY    WEIGHT          ACTUAL          MINIMUM         MAXIMUM         PENALTY
NO.   NAME    NO.    [M]    TYPE       NAME                        VALUE           VALUE           VALUE           CONTRIBUTION
-------------------------------------------------------------------------------------------------------------------------------
    0           0    0.000  BEGIN "EPAH"
                                        BETX                        1.463316E+01
                                        BETY                        3.037769E+00
                                        ALFX                        5.580359E-17
                                        ALFY                       -4.054589E-17
                                        DX                          2.680448E-08
                                        DY                          0.000000E+00
                                        DX'                         0.000000E+00
                                        DY'                         0.000000E+00
                                        MUX                         0.000000E+00
                                        MUY                         0.000000E+00
    0           0    0.000  BEGIN COUPLE
                                        BETX        1.000000E-01    1.463316E+01
                                        BETY        1.000000E-01    3.037769E+00
                                        ALFX        0.000000E+00    5.580359E-17
                                        ALFY        0.000000E+00   -4.054589E-17
                                        DX          0.000000E+00    2.680448E-08
                                        DY          1.000000E+01    0.000000E+00
                                        DX'         0.000000E+00    0.000000E+00
                                        DY'         1.000000E+02    0.000000E+00
                                        MUX         1.000000E+02    0.000000E+00
                                        MUY         1.000000E+02    0.000000E+00
   75 M         1   17.330  BEGIN COUPLE
                                        BETX        1.000000E-01    1.363297E+01
                                        BETY        1.000000E-01    3.140991E+00
                                        ALFX        0.000000E+00    4.452458E-03
                                        ALFY        0.000000E+00   -6.400328E-03
```

Annex : MAD listing after EPA Nominal matching

				DX	0.000000E+00	-2.600175E-07		
				DY	1.000000E+01	0.000000E+00		
				DX'	0.000000E+00	1.907333E-08		
				DY'	1.000000E+02	0.000000E+00		
				MUX	1.000000E+01	7.396471E-01		
				MUY	1.000000E+01	7.203689E-01		
90	M	2	26.721	CONSTRAINT				
				DX	1.000000E+00	2.600288E-07	0.000000E+00	0.000000E+00	6.761499E-14
				DX'	1.000000E+00	1.907251E-08	0.000000E+00	0.000000E+00	3.637608E-16
105	M	3	36.111	END COUPLE				
				BETX	1.000000E-01	1.363297E+01	1.363297E+01	1.363297E+01	3.260040E-16
				BETY	1.000000E-01	3.140991E+00	3.140991E+00	3.140991E+00	1.877170E-17
				ALFX	0.000000E+00	4.454182E-03	4.452458E-03	4.452458E-03	0.000000E+00
				ALFY	0.000000E+00	-4.833625E-03	-6.400328E-03	-6.400328E-03	0.000000E+00
				DX	0.000000E+00	2.600179E-07	-2.600175E-07	-2.600175E-07	0.000000E+00
				DY	1.000000E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
				DX'	0.000000E+00	-1.907333E-08	1.907333E-08	1.907333E-08	0.000000E+00
				DY'	1.000000E+02	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
				MUX	1.000000E+01	1.239647E+00	1.239647E+00	1.239647E+00	5.600856E-12
				MUY	1.000000E+01	1.220369E+00	1.220369E+00	1.220369E+00	3.818962E-12
194	D1	4	62.832	END COUPLE				
				BETX	1.000000E-01	1.463336E+01	1.463316E+01	1.463316E+01	4.050057E-10
				BETY	1.000000E-01	3.050700E+00	3.037769E+00	3.037769E+00	1.671924E-06
				ALFX	0.000000E+00	-1.956768E-15	5.580359E-17	5.580359E-17	0.000000E+00
				ALFY	0.000000E+00	-3.178013E-15	-4.054589E-17	-4.054589E-17	0.000000E+00
				DX	0.000000E+00	2.680492E-08	2.680448E-08	2.680448E-08	0.000000E+00
				DY	1.000000E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
				DX'	0.000000E+00	4.026253E-17	0.000000E+00	0.000000E+00	0.000000E+00
				DY'	1.000000E+02	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
				MUX	1.000000E+02	2.230000E+00	2.230000E+00	2.230000E+00	2.654159E-16
				MUY	1.000000E+02	2.190000E+00	2.190000E+00	2.190000E+00	3.105803E-14
194	D1	4	62.832	END "EPAH"				
				BETX		1.463336E+01			
				BETY		3.050700E+00			
				ALFX		-1.956768E-15			
				ALFY		-3.178013E-15			
				DX		2.680492E-08			
				DY		0.000000E+00			
				DX'		4.026253E-17			
				DY'		0.000000E+00			
				MUX		2.230000E+00			
				MUY		2.190000E+00			

0 TOTAL = 1.672338E-06

0FINAL VALUES FOR PARAMETERS

0 PENALTY FCT.	CALL	TIME	E.D.M.	PARAMETER NAME	PAR. VALUE	PAR. ERROR
0.167234E-05	88	3.119	0.239E-06	QFWH[K1]	0.110753E+01	0.515467E-05
				QTRH[K1]	-0.668722E-01	-0.236619E-04
				QFLH[K1]	0.137569E+01	-0.488435E-05
				QFNH[K1]	0.565922E+00	-0.263501E-05
				QDNH[K1]	-0.568925E+00	0.115959E-04
				QFIH[K1]	0.533550E+00	-0.441543E-05

ELEMENT SEQUENCE I HORIZONTAL I VERTICAL

POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	BETAX [M]	ALFAX	MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	BETAY [M]	ALFAY	MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
BEGIN	EPAH	1	0.000	14.633	0.000	0.000	0.000	0.000	0.000	0.000	3.038	0.000	0.000	0.000	0.000	0.000	0.000
1	D1	1	2.928	15.219	-0.200	0.031	0.000	0.000	0.000	0.000	5.861	-0.964	0.122	0.000	0.000	0.000	0.000
2	QFWH	1	3.118	14.695	2.921	0.033	0.000	0.000	0.000	0.000	6.487	-2.373	0.127	0.000	0.000	0.000	0.000
3	QFWH	2	3.308	13.058	5.581	0.036	0.000	0.000	0.000	0.000	7.713	-4.166	0.131	0.000	0.000	0.000	0.000
4	D3R	1	3.647	9.563	4.748	0.040	0.000	0.000	0.000	0.000	10.805	-4.972	0.137	0.000	0.000	0.000	0.000
5	SYB	1	3.647	9.563	4.748	0.040	0.000	0.000	0.000	0.000	10.805	-4.972	0.137	0.000	0.000	0.000	0.000
6	Q2R	1	3.656	9.475	4.682	0.041	0.000	0.000	0.000	0.000	10.897	-4.944	0.137	0.000	0.000	0.000	0.000
7	D2R	1	3.668	9.363	4.653	0.041	0.000	0.000	0.000	0.000	11.017	-4.972	0.138	0.000	0.000	0.000	0.000
8	Q1R	1	3.686	9.206	4.232	0.041	0.000	0.000	0.000	0.000	11.185	-4.554	0.138	0.000	0.000	0.000	0.000
9	D1R	1	3.741	8.744	4.119	0.042	0.000	0.000	0.000	0.000	11.695	-4.662	0.139	0.000	0.000	0.000	0.000
10	B	1	4.360	5.074	2.029	0.057	0.000	0.000	0.123	0.400	14.365	0.731	0.146	0.000	0.000	0.000	0.000
11	D1R	2	4.415	4.852	1.973	0.059	0.000	0.000	0.145	0.400	14.284	0.725	0.146	0.000	0.000	0.000	0.000
12	Q1R	2	4.433	4.786	1.759	0.060	0.000	0.000	0.152	0.406	14.248	1.308	0.147	0.000	0.000	0.000	0.000
13	D2R	2	4.445	4.744	1.748	0.060	0.000	0.000	0.157	0.406	14.217	1.306	0.147	0.000	0.000	0.000	0.000
14	Q2R	2	4.454	4.712	1.719	0.060	0.000	0.000	0.160	0.407	14.192	1.369	0.147	0.000	0.000	0.000	0.000
15	SYB	2	4.454	4.712	1.719	0.060	0.000	0.000	0.160	0.407	14.192	1.369	0.147	0.000	0.000	0.000	0.000
16	D3R	2	4.792	3.645	1.435	0.073	0.000	0.000	0.298	0.407	13.288	1.300	0.151	0.000	0.000	0.000	0.000
17	QTRH	1	4.971	3.165	1.247	0.082	0.000	0.000	0.371	0.411	12.802	1.417	0.153	0.000	0.000	0.000	0.000
18	QTRH	2	5.150	2.750	1.070	0.091	0.000	0.000	0.445	0.416	12.275	1.522	0.155	0.000	0.000	0.000	0.000
19	D3	1	5.988	1.505	0.416	0.159	0.000	0.000	0.793	0.416	9.913	1.296	0.167	0.000	0.000	0.000	0.000
20	SY	1	6.288	1.325	0.182	0.193	0.000	0.000	0.918	0.416	9.160	1.215	0.172	0.000	0.000	0.000	0.000
21	D3R	3	6.627	1.291	-0.081	0.235	0.000	0.000	1.059	0.416	8.369	1.123	0.179	0.000	0.000	0.000	0.000
22	SYB	3	6.627	1.291	-0.081	0.235	0.000	0.000	1.059	0.416	8.369	1.123	0.179	0.000	0.000	0.000	0.000
23	Q2R	3	6.636	1.293	-0.094	0.236	0.000	0.000	1.063	0.420	8.348	1.159	0.179	0.000	0.000	0.000	0.000
24	D2R	3	6.648	1.295	-0.104	0.237	0.000	0.000	1.068	0.420	8.320	1.155	0.179	0.000	0.000	0.000	0.000
25	Q1R	3	6.666	1.300	-0.171	0.239	0.000	0.000	1.075	0.464	8.273	1.490	0.179	0.000	0.000	0.000	0.000
26	D1R	3	6.721	1.321	-0.215	0.246	0.000	0.000	1.101	0.464	8.109	1.469	0.180	0.000	0.000	0.000	0.000
27	B	2	7.340	2.070	-1.040	0.308	0.000	0.000	1.577	1.088	4.777	3.437	0.196	0.000	0.000	0.000	0.000
28	D1R	4	7.395	2.188	-1.095	0.312	0.000	0.000	1.637	1.088	4.405	3.289	0.197	0.000	0.000	0.000	0.000
29	Q1R	4	7.413	2.229	-1.205	0.314	0.000	0.000	1.657	1.155	4.287	3.417	0.198	0.000	0.000	0.000	0.000
30	D2R	4	7.425	2.258	-1.218	0.315	0.000	0.000	1.671	1.155	4.205	3.382	0.199	0.000	0.000	0.000	0.000
31	Q2R	4	7.434	2.281	-1.238	0.315	0.000	0.000	1.681	1.163	4.142	3.373	0.199	0.000	0.000	0.000	0.000
32	SYB	4	7.434	2.281	-1.238	0.315	0.000	0.000	1.681	1.163	4.142	3.373	0.199	0.000	0.000	0.000	0.000
33	D3R	4	7.772	3.246	-1.614	0.335	0.000	0.000	2.075	1.163	2.202	2.362	0.217	0.000	0.000	0.000	0.000
34	QFLH	1	7.962	3.721	-0.840	0.344	0.000	0.000	2.243	0.596	1.495	1.419	0.234	0.000	0.000	0.000	0.000
35	QFLH	2	8.152	3.864	0.098	0.352	0.000	0.000	2.300	0.000	1.087	0.763	0.258	0.000	0.000	0.000	0.000
36	D5	1	8.515	3.827	0.004	0.367	0.000	0.000	2.300	0.000	0.725	0.235	0.325	0.000	0.000	0.000	0.000
37	SXH	1	8.665	3.832	-0.035	0.373	0.000	0.000	2.300	0.000	0.688	0.017	0.359	0.000	0.000	0.000	0.000
38	SXH	2	8.815	3.848	-0.075	0.379	0.000	0.000	2.300	0.000	0.715	-0.201	0.393	0.000	0.000	0.000	0.000
39	D5	2	9.177	3.937	-0.169	0.394	0.000	0.000	2.300	0.000	1.052	-0.729	0.462	0.000	0.000	0.000	0.000
40	QFLH	3	9.367	3.816	0.794	0.402	0.000	0.000	2.243	-0.596	1.445	-1.372	0.486	0.000	0.000	0.000	0.000
41	QFLH	4	9.557	3.353	1.603	0.410	0.000	0.000	2.075	-1.163	2.130	-2.293	0.504	0.000	0.000	0.000	0.000
42	D3R	5	9.896	2.390	1.243	0.429	0.000	0.000	1.681	-1.163	4.018	-3.287	0.522	0.000	0.000	0.000	0.000
43	SYB	5	9.896	2.390	1.243	0.429	0.000	0.000	1.681	-1.163	4.018	-3.287	0.522	0.000	0.000	0.000	0.000
44	Q2R	5	9.905	2.367	1.222	0.430	0.000	0.000	1.671	-1.155	4.079	-3.295	0.523	0.000	0.000	0.000	0.000
45	D2R	5	9.917	2.338	1.209	0.431	0.000	0.000	1.657	-1.155	4.159	-3.330	0.523	0.000	0.000	0.000	0.000
46	Q1R	5	9.935	2.297	1.096	0.432	0.000	0.000	1.637	-1.088	4.274	-3.206	0.524	0.000	0.000	0.000	0.000
47	D1R	5	9.990	2.179	1.043	0.436	0.000	0.000	1.577	-1.088	4.637	-3.352	0.526	0.000	0.000	0.000	0.000
48	B	3	10.609	1.418	0.230	0.494	0.000	0.000	1.101	-0.464	7.901	-1.452	0.541	0.000	0.000	0.000	0.000
49	D1R	6	10.664	1.395	0.189	0.500	0.000	0.000	1.075	-0.464	8.063	-1.474	0.542	0.000	0.000	0.000	0.000

POS. NO.	ELEMENT NAME	SEQUENCE OCC. NO.	DIST [M]	I I	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	I I	VERTICAL BETAY [M]	ALFAY	MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
50	Q1R	6	10.682		1.390	0.118	0.502	0.000	0.000	1.068	-0.420		8.109	-1.148	0.543	0.000	0.000	0.000	0.000
51	D2R	6	10.694		1.387	0.110	0.504	0.000	0.000	1.063	-0.420		8.137	-1.152	0.543	0.000	0.000	0.000	0.000
52	Q2R	6	10.703		1.385	0.097	0.505	0.000	0.000	1.059	-0.416		8.158	-1.117	0.543	0.000	0.000	0.000	0.000
53	SYB	6	10.703		1.385	0.097	0.505	0.000	0.000	1.059	-0.416		8.158	-1.117	0.543	0.000	0.000	0.000	0.000
54	D3R	6	11.041		1.403	-0.150	0.544	0.000	0.000	0.918	-0.416		8.945	-1.210	0.549	0.000	0.000	0.000	0.000
55	SY	2	11.341		1.559	-0.369	0.576	0.000	0.000	0.793	-0.416		9.696	-1.293	0.555	0.000	0.000	0.000	0.000
56	D3	2	12.179		2.688	-0.979	0.643	0.000	0.000	0.445	-0.416		12.057	-1.524	0.567	0.000	0.000	0.000	0.000
57	QTRH	3	12.358		3.069	-1.146	0.653	0.000	0.000	0.371	-0.411		12.585	-1.423	0.569	0.000	0.000	0.000	0.000
58	QTRH	4	12.537		3.510	-1.323	0.662	0.000	0.000	0.298	-0.407		13.074	-1.309	0.571	0.000	0.000	0.000	0.000
59	D3R	7	12.876		4.495	-1.588	0.676	0.000	0.000	0.160	-0.407		13.984	-1.379	0.575	0.000	0.000	0.000	0.000
60	SYB	7	12.876		4.495	-1.588	0.676	0.000	0.000	0.160	-0.407		13.984	-1.379	0.575	0.000	0.000	0.000	0.000
61	Q2R	7	12.885		4.525	-1.616	0.676	0.000	0.000	0.157	-0.406		14.009	-1.317	0.576	0.000	0.000	0.000	0.000
62	D2R	7	12.897		4.564	-1.626	0.676	0.000	0.000	0.152	-0.406		14.041	-1.320	0.576	0.000	0.000	0.000	0.000
63	Q1R	7	12.915		4.625	-1.830	0.677	0.000	0.000	0.145	-0.400		14.077	-0.745	0.576	0.000	0.000	0.000	0.000
64	D1R	7	12.970		4.830	-1.882	0.679	0.000	0.000	0.123	-0.400		14.160	-0.751	0.576	0.000	0.000	0.000	0.000
65	B	4	13.589		8.250	-3.847	0.695	0.000	0.000	0.000	0.000		11.561	4.577	0.584	0.000	0.000	0.000	0.000
66	D1R	8	13.644		8.682	-3.953	0.696	0.000	0.000	0.000	0.000		11.061	4.472	0.585	0.000	0.000	0.000	0.000
67	Q1R	8	13.662		8.828	-4.349	0.696	0.000	0.000	0.000	0.000		10.896	4.886	0.585	0.000	0.000	0.000	0.000
68	D2R	8	13.674		8.933	-4.376	0.696	0.000	0.000	0.000	0.000		10.778	4.858	0.585	0.000	0.000	0.000	0.000
69	Q2R	8	13.683		9.016	-4.438	0.696	0.000	0.000	0.000	0.000		10.687	4.886	0.585	0.000	0.000	0.000	0.000
70	SYB	8	13.683		9.016	-4.438	0.696	0.000	0.000	0.000	0.000		10.687	4.886	0.585	0.000	0.000	0.000	0.000
71	D3R	8	14.021		12.282	-5.215	0.702	0.000	0.000	0.000	0.000		7.648	4.098	0.591	0.000	0.000	0.000	0.000
72	QFWH	3	14.211		13.808	-2.712	0.704	0.000	0.000	0.000	0.000		6.443	2.324	0.595	0.000	0.000	0.000	0.000
73	QFWH	4	14.401		14.288	0.219	0.706	0.000	0.000	0.000	0.000		5.834	0.926	0.600	0.000	0.000	0.000	0.000
74	D1	2	17.330		13.633	0.004	0.740	0.000	0.000	0.000	0.000		3.141	-0.006	0.720	0.000	0.000	0.000	0.000
75	M	1	17.330		13.633	0.004	0.740	0.000	0.000	0.000	0.000		3.141	-0.006	0.720	0.000	0.000	0.000	0.000
76	D6	1	18.087		13.668	-0.051	0.748	0.000	0.000	0.000	0.000		3.333	-0.248	0.758	0.000	0.000	0.000	0.000
77	QFNH	1	18.266		13.442	1.306	0.751	0.000	0.000	0.000	0.000		3.494	-0.656	0.766	0.000	0.000	0.000	0.000
78	QFNH	2	18.445		12.745	2.568	0.753	0.000	0.000	0.000	0.000		3.809	-1.112	0.774	0.000	0.000	0.000	0.000
79	D7	1	20.840		3.863	1.141	0.808	0.000	0.000	0.000	0.000		12.503	-2.519	0.831	0.000	0.000	0.000	0.000
80	QDNH	1	21.019		3.539	0.677	0.816	0.000	0.000	0.000	0.000		13.186	-1.274	0.833	0.000	0.000	0.000	0.000
81	QDNH	2	21.198		3.372	0.262	0.824	0.000	0.000	0.000	0.000		13.404	0.064	0.835	0.000	0.000	0.000	0.000
82	D8	1	22.025		3.155	0.000	0.865	0.000	0.000	0.000	0.000		13.350	0.002	0.845	0.000	0.000	0.000	0.000
83	D8	2	22.853		3.372	-0.262	0.906	0.000	0.000	0.000	0.000		13.398	-0.060	0.855	0.000	0.000	0.000	0.000
84	QDNH	3	23.032		3.539	-0.677	0.914	0.000	0.000	0.000	0.000		13.179	1.277	0.857	0.000	0.000	0.000	0.000
85	QDNH	4	23.211		3.863	-1.141	0.922	0.000	0.000	0.000	0.000		12.495	2.521	0.859	0.000	0.000	0.000	0.000
86	D9	1	25.594		12.688	-2.562	0.977	0.000	0.000	0.000	0.000		3.822	1.118	0.915	0.000	0.000	0.000	0.000
87	QFIH	1	25.784		13.428	-1.306	0.979	0.000	0.000	0.000	0.000		3.487	0.656	0.923	0.000	0.000	0.000	0.000
88	QFIH	2	25.974		13.668	0.050	0.982	0.000	0.000	0.000	0.000		3.317	0.244	0.932	0.000	0.000	0.000	0.000
89	D10	1	26.721		13.634	-0.004	0.990	0.000	0.000	0.000	0.000		3.131	0.006	0.969	0.000	0.000	0.000	0.000
90	M	2	26.721		13.634	-0.004	0.990	0.000	0.000	0.000	0.000		3.131	0.006	0.969	0.000	0.000	0.000	0.000
91	D10	2	27.467		13.681	-0.059	0.999	0.000	0.000	0.000	0.000		3.300	-0.233	1.007	0.000	0.000	0.000	0.000
92	QFIH	3	27.657		13.444	1.298	1.001	0.000	0.000	0.000	0.000		3.465	-0.642	1.016	0.000	0.000	0.000	0.000
93	QFIH	4	27.847		12.707	2.557	1.004	0.000	0.000	0.000	0.000		3.795	-1.101	1.024	0.000	0.000	0.000	0.000
94	D9	2	30.230		3.889	1.143	1.059	0.000	0.000	0.000	0.000		12.357	-2.491	1.081	0.000	0.000	0.000	0.000
95	QDNH	5	30.409		3.565	0.677	1.066	0.000	0.000	0.000	0.000		13.033	-1.261	1.083	0.000	0.000	0.000	0.000
96	QDNH	6	30.588		3.399	0.260	1.075	0.000	0.000	0.000	0.000		13.249	0.061	1.085	0.000	0.000	0.000	0.000
97	D8	3	31.416		3.183	0.000	1.115	0.000	0.000	0.000	0.000		13.201	-0.002	1.095	0.000	0.000	0.000	0.000
98	D8	4	32.243		3.399	-0.260	1.155	0.000	0.000	0.000	0.000		13.256	-0.065	1.105	0.000	0.000	0.000	0.000
99	QDNH	7	32.422		3.565	-0.677	1.164	0.000	0.000	0.000	0.000		13.041	1.258	1.107	0.000	0.000	0.000	0.000

1EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986), "MAD" VERSION: 4.15 RUN: 25/04/86 14.00.27
TWISS PARAMETERS FOR BEAM LINE "EPAH" DELTA(P)/P = 0.000000 SYMM = T

POS. NO.	ELEMENT NAME	SEQUENCE OCC. NO.	DIST [M]	I I	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	I I	VERTICAL BETAY [M]	ALFAY	MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
100	QDNH	8	32.601		3.889	-1.143	1.171	0.000	0.000	0.000	0.000		12.366	2.489	1.109	0.000	0.000	0.000	0.000
101	D7	2	34.996		12.763	-2.563	1.227	0.000	0.000	0.000	0.000		3.782	1.096	1.166	0.000	0.000	0.000	0.000
102	QFNH	3	35.175		13.459	-1.298	1.229	0.000	0.000	0.000	0.000		3.473	0.643	1.174	0.000	0.000	0.000	0.000
103	QFNH	4	35.354		13.682	0.060	1.231	0.000	0.000	0.000	0.000		3.316	0.236	1.183	0.000	0.000	0.000	0.000
104	D6	2	36.111		13.633	0.004	1.240	0.000	0.000	0.000	0.000		3.141	-0.005	1.220	0.000	0.000	0.000	0.000
105	M	3	36.111		13.633	0.004	1.240	0.000	0.000	0.000	0.000		3.141	-0.005	1.220	0.000	0.000	0.000	0.000
106	D6	3	36.869		13.668	-0.051	1.248	0.000	0.000	0.000	0.000		3.331	-0.246	1.258	0.000	0.000	0.000	0.000
107	QFNH	5	37.048		13.442	1.306	1.251	0.000	0.000	0.000	0.000		3.491	-0.654	1.266	0.000	0.000	0.000	0.000
108	QFNH	6	37.227		12.745	2.568	1.253	0.000	0.000	0.000	0.000		3.805	-1.110	1.274	0.000	0.000	0.000	0.000
109	D7	3	39.621		3.863	1.141	1.308	0.000	0.000	0.000	0.000		12.484	-2.515	1.331	0.000	0.000	0.000	0.000
110	QDNH	9	39.800		3.539	0.677	1.316	0.000	0.000	0.000	0.000		13.166	-1.271	1.333	0.000	0.000	0.000	0.000
111	QDNH	10	39.979		3.372	0.262	1.324	0.000	0.000	0.000	0.000		13.383	0.064	1.335	0.000	0.000	0.000	0.000
112	D8	5	40.806		3.155	0.000	1.365	0.000	0.000	0.000	0.000		13.329	0.002	1.345	0.000	0.000	0.000	0.000
113	D8	6	41.634		3.372	-0.262	1.406	0.000	0.000	0.000	0.000		13.377	-0.060	1.355	0.000	0.000	0.000	0.000
114	QDNH	11	41.813		3.539	-0.677	1.414	0.000	0.000	0.000	0.000		13.158	1.275	1.357	0.000	0.000	0.000	0.000
115	QDNH	12	41.992		3.863	-1.141	1.422	0.000	0.000	0.000	0.000		12.475	2.517	1.359	0.000	0.000	0.000	0.000
116	D7	4	44.386		12.745	-2.568	1.477	0.000	0.000	0.000	0.000		3.793	1.109	1.416	0.000	0.000	0.000	0.000
117	QFNH	7	44.565		13.442	-1.306	1.479	0.000	0.000	0.000	0.000		3.480	0.654	1.424	0.000	0.000	0.000	0.000
118	QFNH	8	44.744		13.668	0.051	1.482	0.000	0.000	0.000	0.000		3.319	0.247	1.432	0.000	0.000	0.000	0.000
119	D6	4	45.502		13.633	-0.004	1.490	0.000	0.000	0.000	0.000		3.129	0.005	1.470	0.000	0.000	0.000	0.000
120	M	4	45.502		13.633	-0.004	1.490	0.000	0.000	0.000	0.000		3.129	0.005	1.470	0.000	0.000	0.000	0.000
121	D1	3	48.430		14.288	-0.219	1.524	0.000	0.000	0.000	0.000		5.842	-0.931	1.590	0.000	0.000	0.000	0.000
122	QFWH	5	48.620		13.808	2.712	1.526	0.000	0.000	0.000	0.000		6.453	-2.331	1.595	0.000	0.000	0.000	0.000
123	QFWH	6	48.810		12.282	5.215	1.528	0.000	0.000	0.000	0.000		7.661	-4.109	1.599	0.000	0.000	0.000	0.000
124	D3R	9	49.149		9.016	4.438	1.534	0.000	0.000	0.000	0.000		10.709	-4.899	1.605	0.000	0.000	0.000	0.000
125	SYB	9	49.149		9.015	4.438	1.534	0.000	0.000	0.000	0.000		10.709	-4.899	1.605	0.000	0.000	0.000	0.000
126	Q2R	9	49.158		8.933	4.376	1.534	0.000	0.000	0.000	0.000		10.800	-4.872	1.605	0.000	0.000	0.000	0.000
127	D2R	9	49.170		8.828	4.349	1.534	0.000	0.000	0.000	0.000		10.918	-4.900	1.605	0.000	0.000	0.000	0.000
128	Q1R	9	49.188		8.682	3.953	1.534	0.000	0.000	0.000	0.000		11.084	-4.485	1.606	0.000	0.000	0.000	0.000
129	D1R	9	49.243		8.250	3.847	1.535	0.000	0.000	0.000	0.000		11.586	-4.590	1.606	0.000	0.000	0.000	0.000
130	B	5	49.862		4.830	1.882	1.551	0.000	0.000	0.123	0.400		14.194	0.750	1.614	0.000	0.000	0.000	0.000
131	D1R	10	49.917		4.625	1.830	1.553	0.000	0.000	0.145	0.400		14.112	0.744	1.614	0.000	0.000	0.000	0.000
132	Q1R	10	49.935		4.564	1.626	1.554	0.000	0.000	0.152	0.406		14.075	1.320	1.615	0.000	0.000	0.000	0.000
133	D2R	10	49.947		4.525	1.616	1.554	0.000	0.000	0.157	0.406		14.044	1.317	1.615	0.000	0.000	0.000	0.000
134	Q2R	10	49.956		4.495	1.588	1.554	0.000	0.000	0.160	0.407		14.019	1.379	1.615	0.000	0.000	0.000	0.000
135	SYB	10	49.956		4.495	1.588	1.554	0.000	0.000	0.160	0.407		14.019	1.379	1.615	0.000	0.000	0.000	0.000
136	D3R	10	50.294		3.510	1.323	1.568	0.000	0.000	0.298	0.407		13.109	1.309	1.619	0.000	0.000	0.000	0.000
137	QTRH	5	50.473		3.069	1.146	1.577	0.000	0.000	0.371	0.411		12.619	1.423	1.621	0.000	0.000	0.000	0.000
138	QTRH	6	50.652		2.688	0.979	1.587	0.000	0.000	0.445	0.416		12.091	1.525	1.623	0.000	0.000	0.000	0.000
139	D3	3	51.490		1.559	0.369	1.654	0.000	0.000	0.793	0.416		9.728	1.295	1.636	0.000	0.000	0.000	0.000
140	SY	3	51.790		1.403	0.150	1.686	0.000	0.000	0.918	0.416		8.976	1.212	1.641	0.000	0.000	0.000	0.000
141	D3R	11	52.129		1.385	-0.097	1.725	0.000	0.000	1.059	0.416		8.188	1.119	1.647	0.000	0.000	0.000	0.000
142	SYB	11	52.129		1.385	-0.097	1.725	0.000	0.000	1.059	0.416		8.188	1.119	1.647	0.000	0.000	0.000	0.000
143	Q2R	11	52.138		1.387	-0.110	1.726	0.000	0.000	1.063	0.420		8.166	1.154	1.647	0.000	0.000	0.000	0.000
144	D2R	11	52.150		1.390	-0.118	1.728	0.000	0.000	1.068	0.420		8.139	1.150	1.647	0.000	0.000	0.000	0.000
145	Q1R	11	52.168		1.395	-0.189	1.730	0.000	0.000	1.075	0.464		8.092	1.477	1.648	0.000	0.000	0.000	0.000
146	D1R	11	52.223		1.419	-0.230	1.736	0.000	0.000	1.101	0.464		7.930	1.456	1.649	0.000	0.000	0.000	0.000
147	B	6	52.842		2.179	-1.043	1.794	0.000	0.000	1.577	1.088		4.656	3.364	1.664	0.000	0.000	0.000	0.000

148	D1R	12	52.897	2.297	-1.096	1.798	0.000	0.000	1.637	1.088	4.292	3.218	1.666	0.000	0.000	0.000	0.000
149	Q1R	12	52.915	2.338	-1.209	1.799	0.000	0.000	1.657	1.155	4.176	3.343	1.667	0.000	0.000	0.000	0.000

1EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986), "MAD" VERSION: 4.15 RUN: 25/04/86 14.00.27
TWISS PARAMETERS FOR BEAM LINE "EPAH" DELTA(P)/P = 0.000000 SYMM = T PAGE 4

POS. NO.	ELEMENT NAME	SEQUENCE OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
150	D2R	12	52.927	2.367	-1.222	1.800	0.000	0.000	1.671	1.155	4.096	3.308	1.668	0.000	0.000	0.000	0.000
151	Q2R	12	52.936	2.390	-1.243	1.801	0.000	0.000	1.681	1.163	4.034	3.299	1.668	0.000	0.000	0.000	0.000
152	SYB	12	52.936	2.390	-1.243	1.801	0.000	0.000	1.681	1.163	4.034	3.299	1.668	0.000	0.000	0.000	0.000
153	D3R	12	53.274	3.353	-1.603	1.820	0.000	0.000	2.075	1.163	2.139	2.302	1.686	0.000	0.000	0.000	0.000
154	QFLH	5	53.464	3.816	-0.794	1.828	0.000	0.000	2.243	0.596	1.451	1.379	1.704	0.000	0.000	0.000	0.000
155	QFLH	6	53.654	3.937	0.169	1.836	0.000	0.000	2.300	0.000	1.056	0.733	1.728	0.000	0.000	0.000	0.000
156	D5	3	54.017	3.848	0.075	1.851	0.000	0.000	2.300	0.000	0.716	0.206	1.797	0.000	0.000	0.000	0.000
157	SXH	3	54.167	3.832	0.035	1.857	0.000	0.000	2.300	0.000	0.687	-0.013	1.831	0.000	0.000	0.000	0.000
158	SXH	4	54.317	3.827	-0.004	1.863	0.000	0.000	2.300	0.000	0.724	-0.231	1.865	0.000	0.000	0.000	0.000
159	D5	4	54.679	3.864	-0.098	1.878	0.000	0.000	2.300	0.000	1.083	-0.759	1.932	0.000	0.000	0.000	0.000
160	QFLH	7	54.869	3.721	0.840	1.886	0.000	0.000	2.243	-0.596	1.489	-1.414	1.956	0.000	0.000	0.000	0.000
161	QFLH	8	55.059	3.246	1.614	1.895	0.000	0.000	2.075	-1.163	2.193	-2.354	1.973	0.000	0.000	0.000	0.000
162	D3R	13	55.398	2.281	1.238	1.915	0.000	0.000	1.681	-1.163	4.128	-3.364	1.991	0.000	0.000	0.000	0.000
163	SYB	13	55.398	2.281	1.238	1.915	0.000	0.000	1.681	-1.163	4.128	-3.364	1.991	0.000	0.000	0.000	0.000
164	Q2R	13	55.407	2.258	1.218	1.915	0.000	0.000	1.671	-1.155	4.191	-3.373	1.992	0.000	0.000	0.000	0.000
165	D2R	13	55.419	2.229	1.205	1.916	0.000	0.000	1.657	-1.155	4.272	-3.408	1.992	0.000	0.000	0.000	0.000
166	Q1R	13	55.437	2.188	1.095	1.918	0.000	0.000	1.637	-1.088	4.390	-3.280	1.993	0.000	0.000	0.000	0.000
167	D1R	13	55.492	2.070	1.040	1.922	0.000	0.000	1.577	-1.088	4.762	-3.428	1.995	0.000	0.000	0.000	0.000
168	B	7	56.111	1.321	0.215	1.984	0.000	0.000	1.101	-0.464	8.087	-1.468	2.010	0.000	0.000	0.000	0.000
169	D1R	14	56.166	1.300	0.171	1.991	0.000	0.000	1.075	-0.464	8.251	-1.489	2.011	0.000	0.000	0.000	0.000
170	Q1R	14	56.184	1.295	0.104	1.993	0.000	0.000	1.068	-0.420	8.298	-1.156	2.011	0.000	0.000	0.000	0.000
171	D2R	14	56.196	1.293	0.094	1.994	0.000	0.000	1.063	-0.420	8.326	-1.159	2.012	0.000	0.000	0.000	0.000
172	Q2R	14	56.205	1.291	0.081	1.995	0.000	0.000	1.059	-0.416	8.347	-1.124	2.012	0.000	0.000	0.000	0.000
173	SYB	14	56.205	1.291	0.081	1.995	0.000	0.000	1.059	-0.416	8.347	-1.124	2.012	0.000	0.000	0.000	0.000
174	D3R	14	56.543	1.325	-0.182	2.037	0.000	0.000	0.918	-0.416	9.138	-1.215	2.018	0.000	0.000	0.000	0.000
175	SY	4	56.843	1.505	-0.416	2.071	0.000	0.000	0.793	-0.416	9.892	-1.297	2.023	0.000	0.000	0.000	0.000
176	D3	4	57.681	2.750	-1.070	2.139	0.000	0.000	0.445	-0.416	12.256	-1.524	2.035	0.000	0.000	0.000	0.000
177	QTRH	7	57.860	3.165	-1.247	2.148	0.000	0.000	0.371	-0.411	12.783	-1.419	2.037	0.000	0.000	0.000	0.000
178	QTRH	8	58.039	3.645	-1.435	2.157	0.000	0.000	0.298	-0.407	13.271	-1.303	2.040	0.000	0.000	0.000	0.000
179	D3R	15	58.378	4.712	-1.719	2.170	0.000	0.000	0.160	-0.407	14.175	-1.371	2.043	0.000	0.000	0.000	0.000
180	SYB	15	58.378	4.712	-1.719	2.170	0.000	0.000	0.160	-0.407	14.175	-1.371	2.043	0.000	0.000	0.000	0.000
181	Q2R	15	58.387	4.744	-1.749	2.170	0.000	0.000	0.157	-0.406	14.200	-1.309	2.044	0.000	0.000	0.000	0.000
182	D2R	15	58.399	4.786	-1.759	2.170	0.000	0.000	0.152	-0.406	14.232	-1.311	2.044	0.000	0.000	0.000	0.000
183	Q1R	15	58.417	4.852	-1.973	2.171	0.000	0.000	0.145	-0.400	14.268	-0.729	2.044	0.000	0.000	0.000	0.000
184	D1R	15	58.472	5.074	-2.029	2.173	0.000	0.000	0.123	-0.400	14.349	-0.735	2.044	0.000	0.000	0.000	0.000
185	B	8	59.091	8.744	-4.119	2.188	0.000	0.000	0.000	0.000	11.686	4.654	2.052	0.000	0.000	0.000	0.000
186	D1R	16	59.146	9.206	-4.232	2.189	0.000	0.000	0.000	0.000	11.177	4.547	2.053	0.000	0.000	0.000	0.000
187	Q1R	16	59.164	9.363	-4.653	2.189	0.000	0.000	0.000	0.000	11.009	4.965	2.053	0.000	0.000	0.000	0.000
188	D2R	16	59.176	9.475	-4.682	2.189	0.000	0.000	0.000	0.000	10.890	4.937	2.053	0.000	0.000	0.000	0.000
189	Q2R	16	59.185	9.563	-4.748	2.190	0.000	0.000	0.000	0.000	10.798	4.964	2.053	0.000	0.000	0.000	0.000
190	SYB	16	59.185	9.563	-4.748	2.190	0.000	0.000	0.000	0.000	10.798	4.964	2.053	0.000	0.000	0.000	0.000
191	D3R	16	59.523	13.058	-5.581	2.194	0.000	0.000	0.000	0.000	7.710	4.161	2.059	0.000	0.000	0.000	0.000
192	QFWH	7	59.713	14.695	-2.921	2.197	0.000	0.000	0.000	0.000	6.486	2.368	2.063	0.000	0.000	0.000	0.000
193	QFWH	8	59.903	15.219	0.200	2.199	0.000	0.000	0.000	0.000	5.862	0.960	2.068	0.000	0.000	0.000	0.000
194	D1	4	62.832	14.633	0.000	2.230	0.000	0.000	0.000	0.000	3.051	0.000	2.190	0.000	0.000	0.000	0.000
END	EPAH	1	62.832	14.633	0.000	2.230	0.000	0.000	0.000	0.000	3.051	0.000	2.190	0.000	0.000	0.000	0.000

1EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986), "MAD" VERSION: 4.15 RUN: 25/04/86 14.00.27
TWISS PARAMETERS FOR BEAM LINE "EPAH" DELTA(P)/P = 0.000000 SYMM = T PAGE 5

TOTAL LENGTH	=	125.663600	QX	=	4.460000	QY	= 4.380000
			QX'	=	-6.121649	QY'	= -6.707610
ALFA	=	0.336912E-01	BETAX(MAX)	=	15.219426	BETAY(MAX)	= 14.364603
GAMMA(TR)	=	5.448062	DX(MAX)	=	2.299581	DY(MAX)	= 0.000000

1"MAD" VERSION 4.15
0DATE AND TIME OF THIS RUN: 25/04/86 14.00.27
0INPUT STREAM AND MESSAGE LOG:

```
                TITLE
                EPA=MATCHING:LATTICE WITH OFFICIAL 600 MEV MODELMAGNET (23 APR 1986),
                !   METHOD USED: STANDARD AS DESCRIBED IN PS/LPI NOTE 85-37
                !
          5     !
                !
                DRIFT,D1,L=2.9285
                DRIFT,D3,L=0.8380
                DRIFT,D5,L=0.3625
         10     DRIFT,D6,L=0.7575
                DRIFT,D7,L=2.3943
                DRIFT,D8,L=0.8275
                DRIFT,D9,L=2.3833
                DRIFT,D10,L=0.7465
         15     !
                QUAD,QFWH,L=0.190,K1=+1.10753000
                QUAD,QTRH,L=0.179,K1=-0.06686580
                QUAD,QFLH,L=0.190,K1=+1.37569000
                QUAD,QFNH,L=0.179,K1=+0.56592300
         20     QUAD,QFIH,L=0.190,K1=+0.53355100
                QUAD,QDNH,L=0.179,K1=-0.56892900
                !
                !
                !   MODELMAGNET:
         25     SBEN,B,L=0.618582,ANGLE=.39270,K1=-.688051,E1=0.0000,&
                E2=0.0000,HGAP=.0225,FINT=0.0
                !HGAP AND FINT RESULT IN PSI=0.0 MRAD
                !   QUADRUPOLES IN MODELMAGNET:
                QUAD,Q1R,L=.0176410,K1=-2.326720
         30     QUAD,Q2R,L=.0093190,K1=-0.487960
                !   SEXTUPOLES IN MODELMAGNET:
                SEXT,SYB,L=0.00001,K2=-4000.0
                !THIS SEXTUPOLE PROVIDES A TOTAL OF -.080 M-2 PER MAGNET
                SEXT,SXH,L=.15,K2=0.
         35     SEXT,SY,L=.3,K2=0.
                !   DRIFTSPACES IN MODELMAGNET:
                DRIFT,D1R,L=0.0553260
                DRIFT,D2R,L=0.0120410
                DRIFT,D3R,&
         40        L=(1.484000-2*(Q2R[L]+D2R[L]+Q1R[L]+D1R[L]+SYB[L])-B[L])/2
                !   DESCRIPTION OF THE MODELMAGNET:
                LH:       LINE=(D3R,SYB,Q2R,D2R,Q1R,D1R)
```

```
                BMOD:    LINE=(LH,B,-LH)
                !
          45    QFW:     LINE=(QFWH,QFWH)
                QTR:     LINE=(QTRH,QTRH)
                QFL:     LINE=(QFLH,QFLH)
                QFN:     LINE=(QFNH,QFNH)
                QDN:     LINE=(QDNH,QDNH)
          50    QFI:     LINE=(QFIH,QFIH)
                !
                M:       MARKER
                !
                CURVH:   LINE=(D1,QFW,BMOD,QTR,D3,SY,BMOD,QFL,D5,SXH)
          55    CURVE:   LINE=(CURVH,-CURVH,M)
                STR1H:   LINE=(D6,QFN,D7,QDN,D8)
                STR2H:   LINE=(D10,QFI,D9,QDN,D8)
                STR1:    LINE=(STR1H,-STR2H,M)
                STR2:    LINE=(STR2H,-STR1H,M)
          60    STR3:    LINE=(STR1H,-STR1H)
                STR:     LINE=(STR1,STR2,STR3)
                EPAH:    LINE=(CURVE,STR,-CURVE)
                !
                !
          65    !USE,EPAH,SYMM
                !PRINT,#S/E
                !TWISS!DELTAP=-0.01/0.0/0.01,CHROM
                !
                !   MATCHING PROCEDURE
          70    CELL,EPAH,SYMM
 0... EXPANSION OF "EPAH" COMPLETE:       194 ELEMENTS,       324 POSITIONS

 0... ENTER CELL MATCHING MODE, ELAPSED CPU TIME =        0.041 SECONDS

                !
                !   VARIABLE PARAMETERS:
                VARY,QFWH[K1],STEP=.00001,LOWER= 0.00, UPPER= 1.70
                VARY,QTRH[K1],STEP=.00001,LOWER=-0.28, UPPER=+0.28
          75    VARY,QFLH[K1],STEP=.00001,LOWER= 0.00, UPPER= 1.82
                VARY,QFNH[K1],STEP=.00001,LOWER= 0.00, UPPER= 0.77
                VARY,QDNH[K1],STEP=.00001,LOWER=-0.77, UPPER=-0.00
                VARY,QFIH[K1],STEP=.00001,LOWER= 0.00, UPPER=+0.71
                !
          80    !   FIT AT INTERMEDIATE POINTS
                !
                WEIGHT,BETX=0.,ALFX=0.,DX=1.,DX'=1.,BETY=0.,ALFY=0.,MUX=0.,MUY=0.
                CONSTRAI,M[2],DX=0.,DX'=0.
                WEIGHT,BETX=0.1,ALFX=0.,DX=0.,DX'=0.,BETY=0.1,ALFY=0.,MUX=10.,MUY=10.
          85    COUPLE,M[1],M[3],MUX=0.50,MUY=0.50
                !
                !   FIT AT THE END:
                !
                WEIGHT,BETX=0.1,ALFX=0.,DX=0.,DX'=0.,BETY=0.1,ALFY=0.,&
          90                           MUX=100.,MUY=100.
                COUPLE,#S,#E,MUX=2.2300,MUY=2.1900
                !
                !   PERFORM MATCH
```

```
                MIGRAD,CALLS=2000
 0... END OF "MIGRAD" COMMAND, ELAPSED CPU TIME =       3.075 SECONDS

         95     !
                ENDMATCH
 0... LAST VALUE OF THE PENALTY FUNCTION:  1.672338E-06

 0... LEAVE CELL MATCHING MODE, ELAPSED CPU TIME =        3.120 SECONDS

                !
                USE,EPAH,SYMM
 0... EXPANSION OF "EPAH" COMPLETE:       194 ELEMENTS,       324 POSITIONS

  ... END OF "USE" COMMAND, ELAPSED CPU TIME =       3.124 SECONDS

                PRINT,#S/E
        100     TWISS
 0... SEARCHING FOR CLOSED ORBIT FOR BEAM LINE "EPAH", DELTAP =    0.000000, SYMM = T
  ... ITER.        X              PX              Y              PY              ERROR
  ...     1      0.000000       0.000000       0.000000       0.000000   0.000000E+00
  ... END OF "TWISS" COMMAND, ELAPSED CPU TIME =       3.372 SECONDS

                !
                STOP
```

Table 1: Main Parameters of the EPA lattice matched to different tunes and operating energies

Case	Bending magnet mode	TUNES REQUIRED Q_x	TUNES REQUIRED Q_y	TUNES REACHED Q_x	TUNES REACHED Q_y	Penalty Function	β_x max (m)	β_y max (m)	$\Delta\beta_x$ A-F ($\pm$ mm)	$\Delta\beta_y$ A-F ($\pm$ mm)	μ_x B-D (mrad/2π)	μ_y B-D (mrad/2π)	D_x C (mm)	normalized quadrupole strength k_q (m^{-2}) HR.QFW (+)	HR.QFL (+)	HR.QFN (+)	HR.QFI (+)	HR.QDN (−)	HR.QTR (±)
0	prototype	4.460	4.380	4.460	4.380	2.10^{-6}	15.3	14.6	1	6	500	500	0	1.10643	1.37140	.56592	.53355	.56893	−.08806
0-1	600 MeV	4.460	4.380	4.460	4.380	2.10^{-6}	15.2	14.4	0	6.5	500	500	0	1.10753	1.37569	.56592	.53355	.56892	−.06687
0.2	650 MeV	4.460	4.380	4.460	4.380	2.10^{-6}	15.0	14.4	0	7	500	500	0	1.10510	1.36944	.56592	.53355	.56892	−.09350
0-3	500 MeV	4.460	4.380	4.460	4.380	2.10^{-6}	14.9	14.8	0	6.5	500	500	0	1.11042	1.38035	.56592	.53355	.56892	−.05219
1	prot	4.540	4.380	4.540	4.380	1.10^{-6}	14.3	14.7	0	6.5	500	500	0	1.13351	1.37093	.56592	.53354	.56892	−.10265
2	proto	4.600	4.460	4.600	4.460	1.10^{-5}	14.3	16.1	1.5	15	500	500	0	1.16000	1.36968	.56593	.53355	.56893	−.14255
3	proto	4.600	4.560	4.600	4.560	2.10^{-6}	14.3	18.7	0.5	7.5	500	500	0	1.14629	1.36865	.56593	.53355	.56893	−.17569
4	proto	4.540	4.640	4.540	4.640	3.10^{-7}	14.9	21.9	0	3	500	500	0	1.15069	1.36823	.56593	.53356	.56893	−.18923
5	proto	4.460	4.640	4.460	4.640	3.10^{-7}	16.3	21.8	0	4	500	500	3	1.12496	1.36862	.56593	.53355	.56893	−.17774
6	proto	4.360	4.560	4.360	4.560	1.10^{-6}	18.7	18.3	1	7.5	500	500	0	1.08942	1.36984	.56592	.53355	.56893	−.13725
7	proto	4.360	4.440	4.360	4.460	9.10^{-6}	18.2	15.7	1.5	14.5	500	500	0	1.09152	1.37096	.56593	.53355	.56892	−.10174
8	proto	4.200	4.300	4.200	4.300	9.10^{-7}	27.2	14.4	0.5	4.5	500	500	0	1.02238	1.37386	.56592	.53355	.56892	−.01203
9	proto	4.300	4.180	4.300	4.180	1.10^{-6}	19.0	19.3	0.5	5.5	500	500	0	1.03699	1.37493	.56592	.53355	.56893	+.02018
10	proto	4.400	4.140	4.400	4.140	2.10^{-6}	15.5	14.1	0.5	6.5	500	500	0	1.06589	1.37469	.56592	.53355	.56892	+.01297
11	proto	4.600	4.200	4.600	4.200	1.10^{-6}	14.4	20.0	0.5	5.5	500	500	0	1.14135	1.37264	.56592	.53356	.56892	−.04910
12	proto	4.840	4.720	4.840	4.720	8.10^{-1}	20.9	77.8	224.5	7.5	500	566	0	1.21138	1.37328	.59527	.56632	.70843	−.01091
13	proto	4.700	4.820	4.700	4.820	8.10^{-1}	17.3	78.3	126.5	1.5	501	565	0	1.16907	1.37278	.59939	.56658	.70859	−.02773
14	proto	4.600	4.840	4.600	4.840	8.10^{-1}	16.4	78.4	60.0	0.5	501	565	0	1.13347	1.37314	.60063	.56662	.70863	−.01637
Maximum normalized Quadrupole Strength (600 MeV)														1.70	1.82	0.71	0.77	0.77	± 0.28

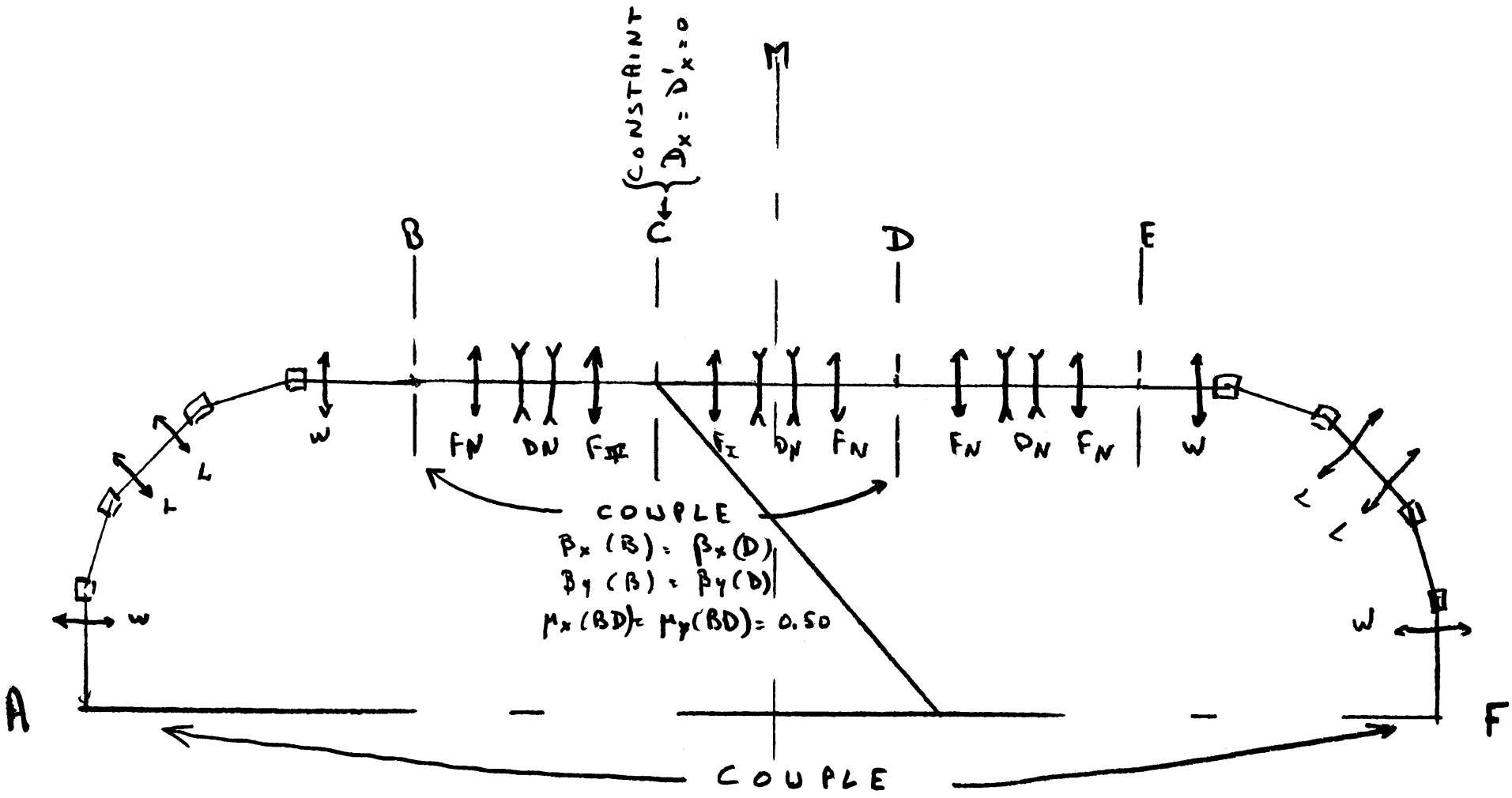

Fig 1: EPA lattice cell and matching method

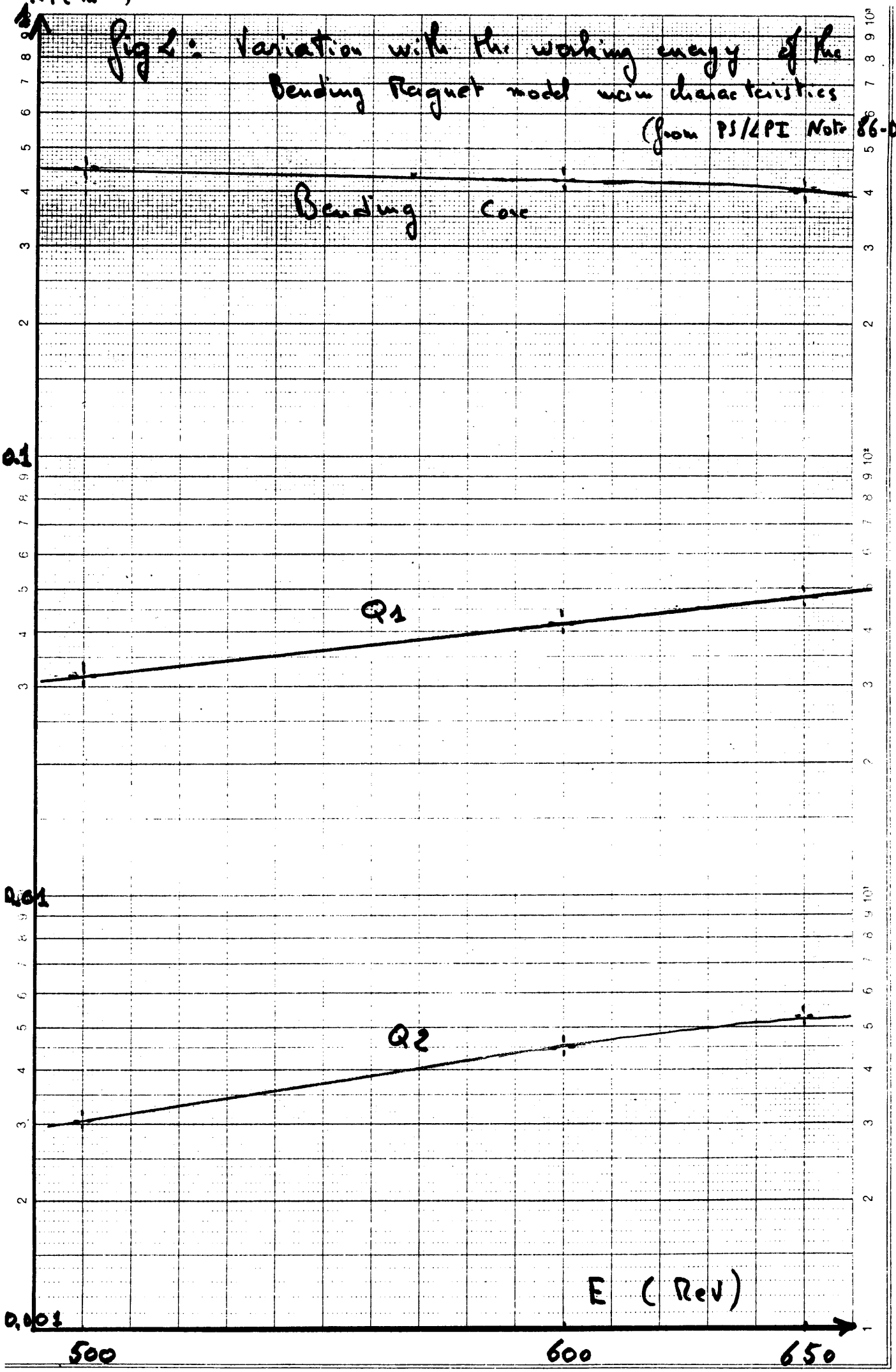

Fig 2 : Variation with the working energy of the bending Magnet model main characteristics (from PS/LPI Note 86-01)

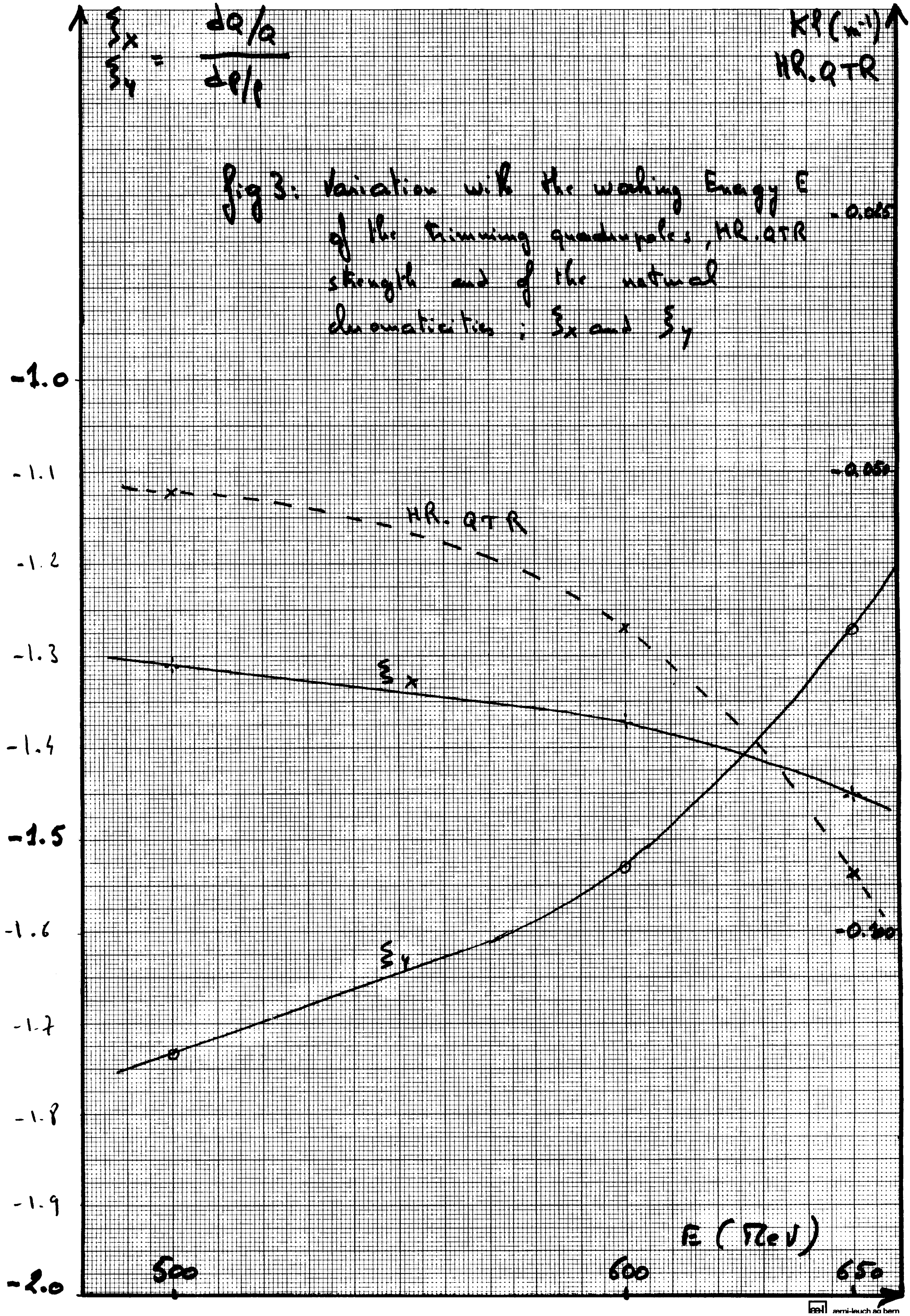

fig 3: Variation with the working Energy E of the trimming quadrupoles, HR.QTR strength and of the natural chromaticities: ξ_x and ξ_y

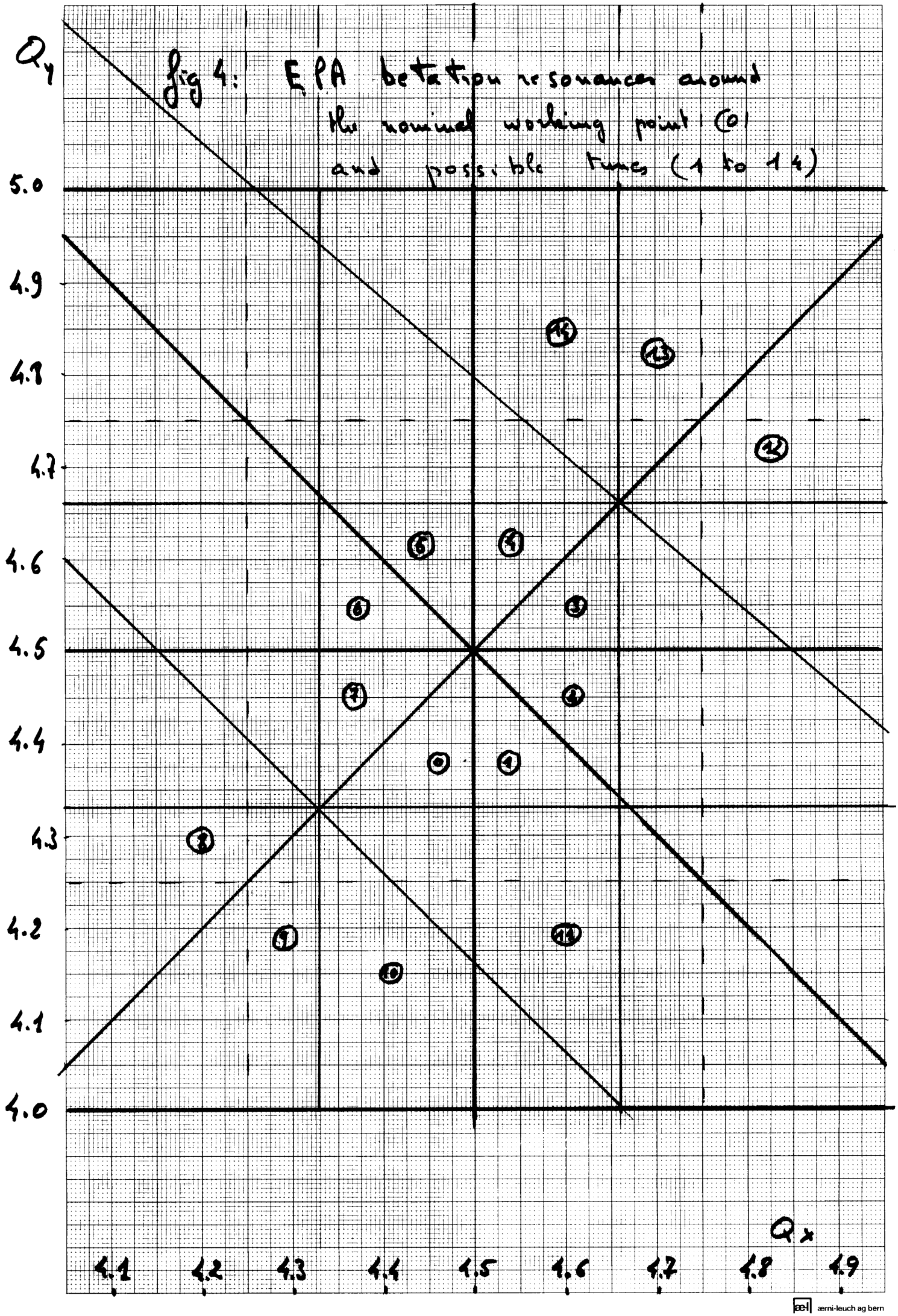

fig 4: EPA betatron resonances around the nominal working point (0) and possible tunes (1 to 14)

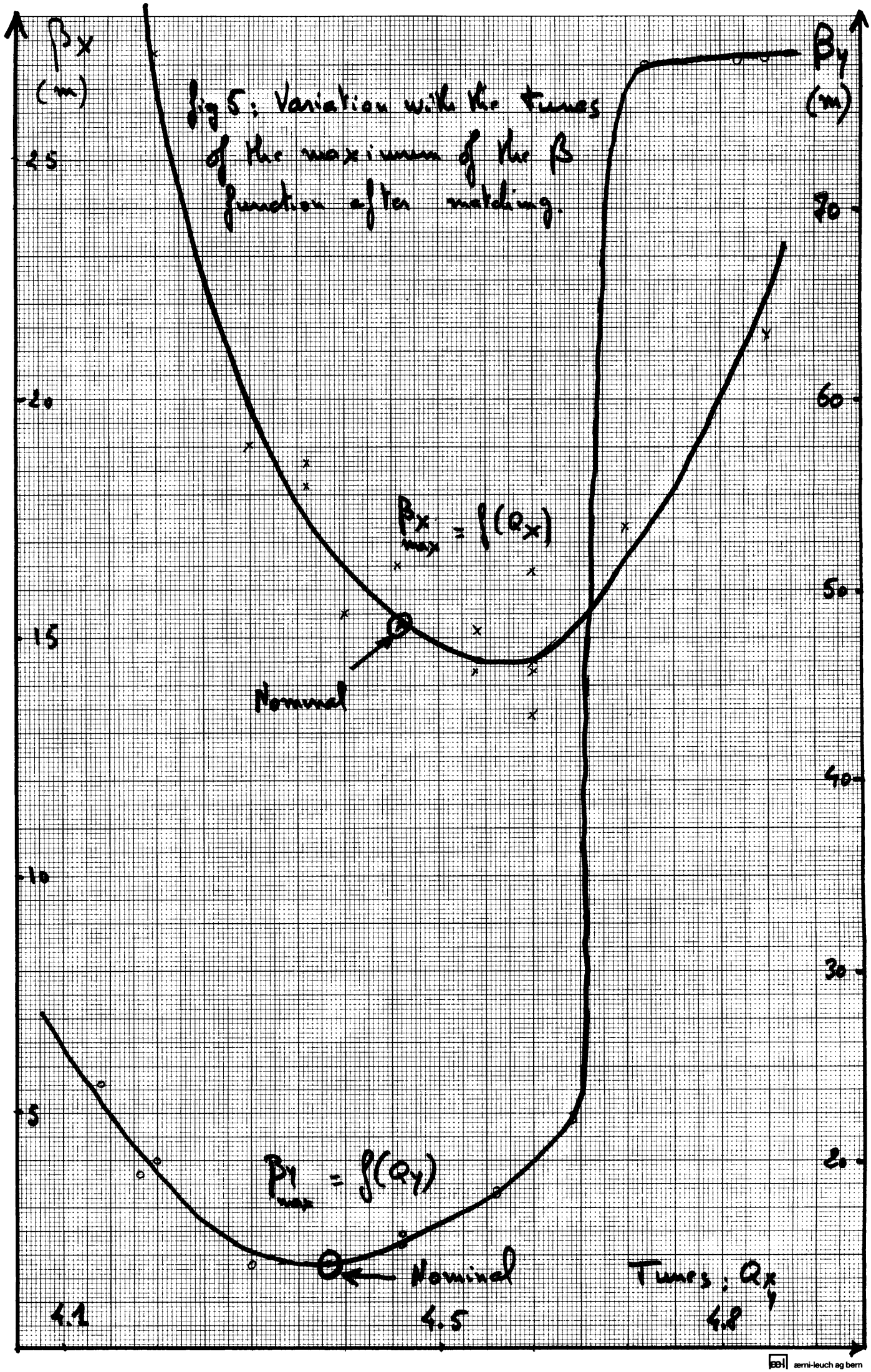

Fig 5: Variation with the tunes of the maximum of the β function after matching.