Presentation 8

The LEP Model at Injection

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8.1 Description of the LEP model

All the optics computations are done with MAD. Therefore all the descriptions of the optics are done in terms of a MAD input. Such an input is available under VM by invoking LEPDB. The MAD input so obtained contains the LEP structure as described in the design report [1], to which is added the systematic quadrupole and sextupole components in the dipoles. These components have been provided by the magnet group according to measurements done after the shimming of the dipoles, they are listed in Table 8.1. The shimming of the dipoles was done after the measurement of the phase advance per cell in the crash program in July 1988. The value of the quadrupole component has been multiplied by 1.11, this factor has been in the official database since 1989, in order to make the tunes predicted by the model closer to the measured ones. It is compatible with the error on the measurement of the quadrupole component.

	MB	MBI	MBR	MBW
$K/10^{-6}m^{-2}$	-4.82	-5.69	-0.44	-6.13
$K'/10^{-6}m^{-3}$	-14.85	-9.28	-14.85	64.95

Table 8.1: Systematic quadrupole and sextupole components in the LEP dipoles

In order to understand the single particle optics, some more components have been added in the LEP magnets.

- In the arc quadrupoles an octupole and a 12-pole component have been estimated by V. Remondino in 1989. All the superconducting quadrupoles have been measured and the two main field errors 12-pole and 20-pole have been taken into account. The errors defined in this way have been introduced in the MAD optics computations by means of the file VCQMM VER01 on my A disk. This file is listed in Appendix 1. In this file an aperture limitation, which models the vacuum chamber, is put at the end of the arc quadrupoles.

- The octupole and decapole components in the dipoles have been measured at the same time the quadrupole and sextupole components were measured but they have not been put in the official database because they must be specified as thin lenses. The redefinition of the dipoles for level 3 of the database can be done with the file MULTDIP VER01 on my A disk in order to include these components. This redefinition is shown in Appendix 2. It has to be noted that the quadrupole and sextupole components in the dipoles have been also redefined in terms of thin lenses in order to avoid symplecticity problems. In order to recover the value of the tune derivatives the thin sextupole component is equal to the sextupole component multiplied by the dipole length and multiplied by 1.04.

- The skew quadrupole components in the dipoles have been measured in machine experiments [2]. They have been introduced according to the specifications in this reference as shown in Appendix 3. They are introduced as thin lenses, their definition is done together with that of the multipoles in the dipoles by means of the file MULTDIP VER01 in my A disk.

- A skew sextupole component has been put together with the skew quadrupole so that both field errors are the same at 20mm from the axis. This comes from the results in ref. [2].

In what follows, only the injection optics will be considered : there are already many unsolved problems in this field.

All the multipole components described above are used for all subsequent calculations.

8.2 Tunes

The tunes associated with new optics are listed in Table 8.2.

	Qh pred.	Qh meas.	Qv pred.	Qv meas.
Qh=76 [3]	0.20	0.24	0.26	0.20
90° (unpublished)	0.385	0.400	0.285	0.356

Table 8.2: Tunes for two new optics

For the 60° lattice, the discrepancy is smaller than it was before introducing the factor 1.11 which corrects the quadrupole component measured in the dipoles. For the 90° the large discrepancy in the vertical plane might arise from a large closed orbit distortion and uncompensated coupling. The error associated with one bit in the power supplies of QF and QD is about 0.006 at injection. As there are about 770 quadrupoles in LEP, random excitation errors, ΔKl, may lead to a tune error of : $\Delta Q = \frac{1}{4\pi}\Delta Kl < \beta > \sqrt{770} = 290\Delta Kl$.

With a minimum Kl value of about 0.026 (QF and QD) and a setting error of about 10^{-3}, the order of magnitude of the error on the tune is 0.007 at least.

Conclusion : The difference between predicted and measured tunes might arise from random setting errors and power supply resolution. No dramatic implication is expected.

8.3 Tunes derivatives

It has always been noticed that the chromaticities were very wrong when setting a new optics. Three examples of discrepancies between prediction and measurement of the first derivatives of the tunes are shown in Table 8.3.

It is possible to bring the predicted and measured chromaticities in agreement within some units by multiplying the sextupole component measured in the dipoles, given in Table 8.1, by 6.5. This correction factor has obviously not been put in the database because it was felt to be much too large. In fact it appeared in the discussions during the workshop that the uncertainty on the measured sextupole component could justify a correction factor of the order of about 4, without excluding the above value.

Another way of explaining the above discrepancy for the 60° case is to change the polarity of a SF1 family in a single octant. However this does not work for the 90° lattice.

	Qh' pred.	Qh' meas.	Qv' pred.	Qv' meas.
Qh=76[3]	2.	-20.	3.	20.
90° /cell (unpublished)	1.	-7.	1.	9.
standard machine	22.4	3.	-7.4	7.

Table 8.3: Tune derivatives for three optics

Conclusion : open problem, it is examined again below in connection with the vertical dispersion and the dynamic aperture.

8.4 Vertical dispersion

In order to try to stick to reality, a closed orbit distortion has been introduced. The quadrupoles QF and QD have been displaced randomly with an uniform error distribution. The command in MAD is :

EALIGN,TYPE=MQ,DY=0.00024*RANF(),DX=0.002*RANF()

Then the correction is done with MICADO, using 100 correctors. In this way, the closed orbit distortion in the arcs must be far from a betatron oscillation. Its r.m.s. values are 1.17mm horizontally and 1.35mm vertically. Under these conditions the vertical dispersion D_y has an r.m.s. value of only 3cm for the machine which contains all multipoles described in section 8.1, but no correction for the chromaticity problem.

If the sextupole component in the dipoles is multiplied by 6.5, the r.m.s. D_y becomes 4.9cm. With the SF1 family inverted, the r.m.s. D_y becomes 5.8cm. Another attempt has been done in order to explain both a big value of D_y and the chromaticity error. The sextupole component of the dipoles of 3 half cells has been multiplied by 900, which restores the chromaticity when the sextupole components used in the machine are put in the model. Then the r.m.s. D_y becomes of the order of 10cm depending on the place, i.e. the amplitude of the closed orbit distortion where the substitution is done.

If the vertical chromaticity is made equal to 50, the r.m.s. Dy becomes 28cm, i.e. comparable to what is measured.

Conclusion : it is rather hard to obtain a vertical dispersion comparable to what is measured under standard conditions.

8.5 Horizontal dynamic aperture

It has been measured by kicking a circulating beam by means of the injection kicker [3]. The tunes were Q_h=.372, Q_v=.297 and Q_s=0.085. The chromaticity was not measured, a standard current file had been loaded, the wigglers were off. If the kick angle is 0.109mrad, a decrease of the current is observed. From this decrease, we infer a cut of the transverse distribution at a number 2.4 of r.m.s. beam size. Summing the amplitude corresponding to the kick and this number, we obtain the maximum stable amplitude. It amounts to 17.2mm at the beta value of 136m. From this we deduce an acceptance of 2175nm.

In order to simulate this, particle trajectories are launched in I1 with a zero slope a vertical amplitude corresponding to $2.4\sigma_v$ and horizontal amplitudes in increasing order. Then we determine the maximum one for which the trajectory does not touch the vacuum chamber during 200turns. This is done for some initial amplitudes of the synchrotron oscillation. The results are listed in Table 8.4. All the machines have a closed orbit distortion as defined above, and an uncompensated coupling.

Synchrotron amplitude/10^{-3}	0	-2.4	-5.0
Theoretical machine	58	40	32
Sextupoles in dipoles ($K'_{meas} \times 6.5$)	44	32	20
SF1 family inverted	50	32	16
Sextupoles in 18 dipoles ($K'_{meas} \times 6.5$)	16	12	0
$Q'_y = +50$	40	18	14

Table 8.4: Dynamic apertures expressed in σ_0

One could question that 200 turns is enough because the horizontal damping time at injection is about 10000 turns. In order to estimate this, tracking over 6000 turns has been done for the worse situation, i.e. sextupole defect concentrated on 18 dipoles (note this corresponds to an integrated component 20 times that of the SD sextupoles in the same region). The results are shown in Table 8.5.

Synchrotron amplitude/10^{-3}	0	-2.4
200 turns	16	16
6000 turns	15	10

Table 8.5: Dynamic apertures as function of the number of turns for the machine with sextupoles concentrated on 3 half cells

It has to be noted that the effect of the damping over say 1000 turns is enough to reduce the amplitude of the particle at 16σ with no synchrotron oscillation to a stable one. With synchrotron oscillation, the particles with amplitude up to 13σ are stable over at least 1600 turns so that the a similar argument could be applied. This is why a small number of turns has been chosen, with the big advantage of a reduced computer time.

The value of σ_0 is 0.330mm and the r.m.s. energy spread at injection is $0.35 10^{-3}$ without wigglers and $0.7 10^{-3}$ with wigglers and the β_h is 20m at the starting point. The measured dynamic acceptance corresponds to 20 σ_0. We see that for a maximum synchrotron amplitude of $-2.4 10^{-3}$ the two last cases in Table 8.4 arrive below the measured value. Otherwise the dynamic acceptance stays above 5570nm, i.e. about twice the measured value. In fact in the experiment the truncation was estimated to be done at 2.4σ which would represent only $0.74 10^{-3}$ maximum synchrotron amplitude if the truncation is due to synchrotron motion. Therefore the above estimate of 5570nm could even be pessimistic.

Conclusion : the dynamic aperture estimated with tracking is substantially above the measured one.

8.6 Horizontal anharmonicity

The variation of the horizontal tune with amplitude has been estimated by A. Hofmann (this workshop) to be $+1.14 \cdot 10^4$ m^{-1} rad^{-1}. The computation of this variation has been done, for the models described above, by means of the variation of the normalised phase advance with amplitude. This quantity is available in the output of MAD tracking. The technique consists of tracking some trajectories with increasing amplitudes up to 2mm over 100 turns. A small amplitude of 0.01mm provides the linear tune. Another small amplitude of 0.1mm confirms it. Then the normalised phase corresponding to the 0.01mm amplitude is subtracted from the normalised phase of trajectories with 1 and 2mm amplitude in order to get the change of tune with amplitude. It is checked that this variation is quadratic. The results are given in Table 8.6, together with the computation of anharmonicity with HARMON. For the latter calculation, only the sextupoles are taken into account and there is no coupling or closed orbit effect.

	$\frac{\Delta Q_h}{x^2/\beta}/\mathrm{m}^{-1}$ tracking	HARMON
Theoretical machine, no coupling compensation	-418.	
Theoretical machine with coupling compensation	1270.	-803
Sextupoles in dipoles*6.5	3200.	-887
SF1 family inverted	715	-1220
Sextupoles in 3 dipoles*900	-9400	-11790

Table 8.6: Horizontal anharmonicity for amplitudes up to 2mm

Conclusion : it is not possible to find any agreement between measured and computed values. Probably some more refined analysis is needed.

References

[1] LEP DESIGN REPORT. Vol II CERN-LEP/84-01
[2] LEP Performance note 31. A.M. Fauchet, T. Fieguth, J.P. Koutchouk.
[3] LEP Performance note 37. J. Poole.
[4] LEP Performance note 30. J. Miles, G. Schroeder, A. Verdier, E. Weisse.

8.7 Appendix 1

MAD input for definition of vacuum chambers and multipoles in QSC, QF and QD
File: VCQMM VER01

```
!DEFINITION OF VACUUM CHAMBERS AND MULTIPOLE ERRORS IN QUADRUPOLES
!STRUCTURE STARTING AT I1 :  IMPORTANT FOR THE LISTS
!
XMES:=0.059  ! DISTANCE AT WHICH THE GRADIENT ERROR IS MEASURED
XMES4:=XMES*XMES*XMES*XMES
!  CHAMBRE A VIDE QSO
 VCQSC :ECOLL,XSIZE=0.06-0.0000,YSIZE=0.060-0.0000  ! 0.0064=C.O.
QSCD   : QUAD,L = LMQSO*0.5,K1 = KQSO,TYPE = MQC
QSO : LINE=(QSCD,VCQSC,ERRQSC,QSCD)
!**  ALL QSC ERRORS HAVE BEEN MEASURED. THE MOST IMPORTANT ONES ARE
!**   12 AND  20-POLE : THEY ARE SPECIFIED AS FIELD ERRORS
 ERRQSC:LIST=(EMQC5,EMQC6,EMQC8,EMQC3,EMQC7,EMQC2,EMQC1,EMQC4)
EMQC1:MULT ,K5L=-0.00210*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00397*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC2:MULT ,K5L=-0.00650*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00414*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC3:MULT ,K5L=-0.00599*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00361*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC4:MULT ,K5L=-0.00626*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00386*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC5:MULT ,K5L=-0.00323*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00272*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC6:MULT ,K5L=-0.00639*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00345*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC7:MULT ,K5L=-0.00533*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00337*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
EMQC8:MULT ,K5L=-0.00471*4*3*2*KQSO*LMQSO/XMES4,&
            K9L=-0.00335*8*7*6*5*4*3*2*KQSO*LMQSO/(XMES4*XMES4)
VALUE,EMQC1[K5L]/LMQSO
VALUE,EMQC1[K9L]/LMQSO
VALUE,EMQC8[K5L]/LMQSO
VALUE,EMQC8[K9L]/LMQSO

!  CHAMBRE A VIDE QS1  , REPRESENTATION DE CHAMBRE CRUCIFORMEA
 VCQS1 :ECOLL,XSIZE=0.08        ,YSIZE=0.0404        ! 0.0043=C.O.
QS1D    : QUAD,L = LMQA*0.5 ,K1 = KQS1,TYPE = MQA
QS1 : LINE=(QS1D,VCQS1,QS1D)

!  CHAMBRE A VIDE QL1 , REPRESENTATION DE CHAMBRE CRUCIFORME
 VCQL1 :ECOLL,XSIZE=0.080  ,YSIZE=0.04
QL1D    : QUAD,L = LMQA*0.5 ,K1 = KQL1,TYPE = MQA
QL1 : LINE=(QL1D,VCQL1,QL1D)

!  CHAMBRE A VIDE QL2 , REPRESENTATION DE LA CHAMBRE CRUCIFORME
 VCQL2 :ECOLL,XSIZE=0.08        ,YSIZE=0.0404
QL2D    : QUAD,L = LMQ*0.5 ,K1 = KQL2,TYPE = MQ
```

```
QL2 : LINE=(QL2D,VCQL2,QL2D)

!****  ERREURS   DK/K  ESTIMATED BY VITTORIO REMONDINO  17.11.89        *********
 QOCT:=  38.0E-4!ERREUR OCTUPOLE A XMES  , NOMINAL= 5.0E-4
 QDOD:= -67.0E-4!ERREUR DODECAPOLE A XMES , NOMINAL = 10.0E-4
!  CHAMBRE A VIDE QD : CHAMBRE ELLIPTIQUE ARC.
 VCQD :ECOLL,XSIZE=0.0655        ,YSIZE=0.035         !**CO RMS 1MM
QDV    : QUAD,L = LMQ ,K1 = KQD,TYPE = MQ
QERRD:MULT,K3L= QOCT*2*KQD*LMQ/(XMES*XMES) &
           ,K5L=QDOD*4*3*2*KQD*LMQ/XMES4
QD : LINE=(VCQD,QDV,QERRD)

!  CHAMBRE A VIDE QF , CHAMBRE ELLIPTIQUE ARC.
!RETRANCHE DE LA DIMENSION CHAMBRE : 5.2MM H ORB. , 1MM H DP , 1.8MM V CO
 VCQF :ECOLL,XSIZE=0.0655             ,YSIZE=0.035         !**CO RMS 1MM
QFV    : QUAD,L = LMQ ,K1 = KQF,TYPE = MQ
QERRF:MULT,K3L= QOCT*2*KQF*LMQ/(XMES*XMES) &
           ,K5L=QDOD*4*3*2*KQF*LMQ/XMES4
QF : LINE=(VCQF,QFV,QERRF)

 RETURN

I1:MARKER
I2:MARKER
I3:MARKER
I4:MARKER
I5:MARKER
I6:MARKER
I7:MARKER
I8:MARKER
LEP:LINE=(I1,HIBL1,RFL1,DISL1,ARC1,DISS1,CAV,RFS1,CAV,LOBS1,I2,&
LOBS2,CAV,RFS2,CAV,DISS2,ARC2,DISL2,RFL2,HIBL2,I3,& ! SEC2 AVEC RF
SEC3,I4,SEC4,I5,&
HIBL5,RFL5,DISL5,ARC3,DISS5,CAV,RFS5,CAV,LOBS3,I6,& ! SEC5 AVEC RF
LOBS4,CAV,RFS6,CAV,DISS4,ARC4,DISL2,RFL6,HIBL4,&  !  SEC6 AVEC RF
I7,SEC7,I8,SEC8)
```

8.8 Appendix 2

MAD input for definition of systematic multipole components in the dipoles.
File: MULTDIP VER01

```
!***  REDEFINITION OF DIPOLES FOR INTRODUCING THIN MULTIPOLES   *********
!***  THE SKEW QUADRUPOLES ARE DEFINED SEPARATELY BECAUSE THEY HAVE A ***
!***  DIFFERENT DISTRIBUTION *********************************************

!***********  OLD COMPONENTS BEFORE SHIMMING  ***************************
!OCTB:= 2.9  ! OCTUPOLE GIVEN BY JPG 1.11.88
!DECB:=-3.4  ! DECAPOLE GIVEN BY JPG 1.11.88

!******  LIST OF THE ERRORS GIVEN BY THE MAGNET GROUP  / 7/02/89   *****
RO:=3096.175  ! RADIUS OF CURVATURE
XMES:=0.059  ! DISTANCE WHERE THE ERROR IS MEASURED
XMES2:=XMES*XMES
MSB:=1.0
MSW:=1.0
MSI:=1.0
 SEXB:=-0.8E-4*MSB ! ERREUR SEXTUPOLE(B4,B6) EN ERREUR DE CHAMP A XMES
 OCTB:= 0.5E-4*MSB ! ERREUR OCTUPOLE(B4,B6) EN ERREUR DE CHAMP A XMES
 DECB:=-0.6E-4*MSB ! ERREUR DECAPOLE(B4,B6) EN ERREUR DE CHAMP A XMES

 SEXBW:= 3.5E-4*MSW ! ERREUR SEXTUPOLE(BW) EN ERREUR DE CHAMP A XMES
 OCTBW:= 3.9E-4*MSW ! ERREUR OCTUPOLE(BW) EN ERREUR DE CHAMP A XMES
 DECBW:=-3.2E-4*MSW ! ERREUR DECAPOLE(BW) EN ERREUR DE CHAMP A XMES

 SEXBI:=-0.5E-4*MSI ! ERREUR SEXTUPOLE(BI) EN ERREUR DE CHAMP A XMES
 OCTBI:= 0.2E-4*MSI ! ERREUR OCTUPOLE(BI) EN ERREUR DE CHAMP A XMES
 DECBI:=-2.5E-4*MSI ! ERREUR DECAPOLE(BI) EN ERREUR DE CHAMP A XMES

 DKSF:=1.164723E-3  ! Q'=1 POUR N21D20N3
 DKSD:=6.705506E-4  ! Q'=1 POUR N21D20N3
!SET SEXTUPOLE COMPONENT IN DIPOLES TO ZERO
KSBI := -0.00
KSBW := 0.00
KSB := -0.00
KSBT := -0.00

!********    REDEFINITION OF THIN SEXTUPOLES FOR TRACKING     ************
TRIM:=1.04
! POUR AVOIR LA MEME CHROMATICITE QUE AVEC LA COMPOSANTE REPARTIE
!****  FACTEUR 2 FOR MMB4 : 1 MMB4 FOR 2 B2  *********
 MMB4 : MULT&
         ,K2L= 2*SEXB*2*B2M[L]*TRIM/(RO*XMES2) &
         ,K3L= 2*OCTB*3*2*B2M[L]/(RO*XMES*XMES2) &
         ,K4L= 2*DECB*4*3*2*B2M[L]/(RO*XMES2*XMES2)
!***********  FACTEUR 1.5 FOR MMB6 : 2 MMB6 FOR 3 B2 ****************
 MMB6 : MULT&
         ,K2L= 1.5*SEXB*2*B2M[L]*TRIM/(XMES2*RO) , &
```

```
         ,K3L= 1.5*OCTB*2*3*B2M[L]/(RO*XMES2*XMES) &
         ,K4L= 1.5*DECB*4*3*2*B2M[L]/(RO*XMES2*XMES2)
!****  FACTOR 2 FOR MMBW : 1 MMBW FOR 2 BW  ******************
!!!!!!! ATTENTION !!!! RO IS IN THE DENOMINATOR BECAUSE THE ERRORS ARE
!!!!!!!                EXPRESSED AS A FIELD DEFECT OF A NORMAL DIPOLE
 MMBW : MULT&
         ,K2L= 2*SEXBW*2*BW2[L]*TRIM/(RO*XMES2) &
         ,K3L= 2*OCTBW*3*2*BW2[L]/(RO*XMES*XMES2) &
         ,K4L= 2*DECBW*4*3*2*BW2[L]/(RO*XMES2*XMES2)
!****  FACTOR 2 FOR MMBI : 1 MMBI FOR 2 BI  ******************
!!!!!!! ATTENTION !!!! RO IS IN THE DENOMINATOR BECAUSE THE ERRORS ARE
!!!!!!!                EXPRESSED AS A FIELD DEFECT OF A NORMAL DIPOLE
 MMBI : MULT&
         ,K2L= 2*SEXBI*2*BI[L]*TRIM/(RO*XMES2) &
         ,K3L= 2*OCTBI*3*2*BI[L]/(RO*XMES*XMES2) &
         ,K4L= 2*DECBI*4*3*2*BI[L]/(RO*XMES2*XMES2)

 BINJ:LINE=(BI,MMBI,DBI1,BI,MMBI,QSK)
!ICI 2 MULT CAR IL Y A 1 AUTRE BI PLUS LOIN
!HENCE THE REPRESENTATION IS NOT EXACT !
 BINJ1: LINE = ( BI, MMBI,QSK  , DBI11, BI )!ICI 1 MULT TRIVIALEMENT

B4WL: LINE=(BW1,MMBW,QSK ,DBWL,BW2)
B4WSX: LINE=(BW4,MMBW,QSK ,DBWL,BW3)
B4WS: LINE=(BW3,MMBW,QSK ,DBWL,BW4)
B4WLX: LINE=(BW2,MMBW,QSK ,DBWL,BW1)

 B4: LINE = ( B2L, MMB4,QSK , DBB, B2R)
 B4POLX: LINE = ( B2LT, MMB4,QSK , DBBPOLX, B2RT)
 B4POL: LINE = ( B2L, MMB4,QSK , DBBPOL, B2R)
 B4T: LINE = ( B2LT, MMB4,QSK , DBBT, B2RT )
 B4BE: LINE = ( B2L, MMB4,QSK , DBB3, B2R )
 B4X: LINE = ( B2L, MMB4,QSK , DBBX, B2R )
 B47X: LINE = ( B2L, MMB4,QSK , DBB4, B2R )

 B6: LINE = ( B2L, MMB6,QSK, DBB, B2M, MMB6,QSK, DBB, B2R)
 B67: LINE = ( B2L, MMB6,QSK, DBB1, B2M, MMB6,QSK, DBB4, B2R)
 B68: LINE = ( B2L, MMB6,QSK, DBB, B2M, MMB6,QSK, DBB2, B2R)

 B2S: LINE = ( B2SS, MMB4,QSK )  !  PRES DES QUADS 18 DANS SUPPRESSEURS
B2SS   : RBEN,L =11.550,ANGLE = ANGB2S,TYPE = MB2S,&
              K1= KQB,K2 = KSB,&
              E1 = -0.25*ANGB2S, E2 = -0.25*ANGB2S
```

8.9 Appendix 3

MAD input for definition of skew quadrupole components in the dipoles as thin lenses.
File: MULTDIP VER01

```
!**************************************************************************
!** DEFINITION OF QUADRUPOLE SKEW COMPONENTS AS IN PERFORMANCE NOTE 31 ***
CSK:=1.0
!*****  garanties a mieux que 20% par JPK en personne ( 23.5.90 )
!formulae here as in  perf. note 29
KQSK1:=(20/ENERGY)*CSK*1.06E-4*0.5*1.08
KQSK2:=(20/ENERGY)*CSK*1.08E-4*0.5
KQSK3:=(20/ENERGY)*CSK*0.80E-4*0.5
KQSK4:=(20/ENERGY)*CSK*0.60E-4*0.5
KQSK5:=(20/ENERGY)*CSK*0.86E-4*0.5
KQSK6:=(20/ENERGY)*CSK*0.77E-4*0.5
KQSK7:=(20/ENERGY)*CSK*0.90E-4*0.5
KQSK8:=(20/ENERGY)*CSK*0.96E-4*0.5*1.08

ENERGY:=20
XMSK:=0.020  !  DISTANCE AT WHICH THE RATIO KQSK/K2QSK IS EVALUATED
RPSK:=0.0    ! RATIO BETWEEN THE FIELD ERRORS
!              AT THE POSITION XMSK : K2SKEW = RPSK*2*KSKEW/XMSK

 QSK1 : MULT, K1L = KQSK1 , T1&
         ,K2L=2.*RPSK*KQSK1/XMSK , T2    ! ARC
 QSK1D: MULT, K1L = KQSK1*1.3333333, T1&
         ,K2L=2.*RPSK*KQSK1/XMSK , T2    !  DISPERSION SUPPRESSOR

 QSK2 : MULT, K1L = KQSK2 , T1&
         ,K2L=2.*RPSK*KQSK2/XMSK , T2
 QSK2D : MULT, K1L = KQSK2*1.3333333 , T1&
         ,K2L=2.*RPSK*KQSK2/XMSK , T2

 QSK3 : MULT, K1L = KQSK3 , T1&
         ,K2L=2.*RPSK*KQSK3/XMSK , T2
 QSK3D: MULT, K1L = KQSK3*1.3333333 , T1&
         ,K2L=2.*RPSK*KQSK3/XMSK , T2

 QSK4 : MULT, K1L = KQSK4 , T1&
         ,K2L=2.*RPSK*KQSK4/XMSK , T2
 QSK4D: MULT, K1L = KQSK4*1.3333333 , T1&
         ,K2L=2.*RPSK*KQSK4/XMSK , T2

 QSK5 : MULT, K1L = KQSK5 , T1&
         ,K2L=2.*RPSK*KQSK5/XMSK , T2
 QSK5D: MULT, K1L = KQSK5*1.3333333 , T1&
         ,K2L=2.*RPSK*KQSK5/XMSK , T2

 QSK6 : MULT, K1L = KQSK6 , T1&
```

```
        ,K2L=2.*RPSK*KQSK6/XMSK , T2
 QSK6D: MULT, K1L = KQSK6*1.3333333 , T1&
        ,K2L=2.*RPSK*KQSK6/XMSK , T2

 QSK7 : MULT, K1L = KQSK7 , T1&
        ,K2L=2.*RPSK*KQSK7/XMSK , T2
 QSK7D: MULT, K1L = KQSK7*1.3333333 , T1&
        ,K2L=2.*RPSK*KQSK7/XMSK , T2

 QSK8 : MULT, K1L = KQSK8 , T1&
        ,K2L=2.*RPSK*KQSK8/XMSK , T2
 QSK8D: MULT, K1L = KQSK8*1.3333333 , T1&
        ,K2L=2.*RPSK*KQSK8/XMSK , T2
!*********** debut structure en QF21    ****************************
!QSK:LIST=(131*QSK1,146*QSK2,146*QSK3,146*QSK4,146*QSK5,146*QSK6,&
!          146*QSK7,148*QSK8,17*QSK1)
!***********  DEBUT STRUCTURE EN I1    *****************************
 QSK:LIST=(7*QSK1D,4*QSK1,2*QSK1D,115*QSK1,7*QSK1D,&
           7*QSK2D,124*QSK2,7*QSK2D, &
           7*QSK3D,124*QSK3,7*QSK3D, &
           7*QSK4D,124*QSK4,7*QSK4D, &
           7*QSK5D,124*QSK5,7*QSK5D, &
           7*QSK6D,124*QSK6,7*QSK6D, &
           7*QSK7D,124*QSK7,7*QSK7D, &
           7*QSK8D,115*QSK8,2*QSK8D,4*QSK8,7*QSK8D)

 QT4:LIST=(4*QT4.2,4*QT4.4,4*QT4.6,4*QT4.8)  ! OK POUR LES 2 STRUCTURES
 CURRSK:=  0.0 ! COURANT DANS LES CIRCUITS SKEW EN AMPERE POUR COMPENSATION
 QT4.2 : QUADRUPO, TYPE = MT, L = LMT,TILT,K1=3.0E-4*CURRSK
 QT4.4 : QUADRUPO, TYPE = MT, L = LMT,TILT,K1=-3.0E-4*CURRSK
 QT4.6 : QUADRUPO, TYPE = MT, L = LMT,TILT,K1=3.0E-4*CURRSK
 QT4.8 : QUADRUPO, TYPE = MT, L = LMT,TILT,K1=-3.0E-4*CURRSK

 RETURN
```