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FORTRAN Code Additions for Inclusion of Special Functions in MAD

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For pure-periodic accelerator lattice, MAD provides a very convenient description due to the feature of line multiplication. For example, consider the AGS Booster which has six superperiods: If one of them is described as

SUPER: LINE = (L1, L2,, Ln),
then the whole machine is given by

BOOSTER: LINE = (6 * SUPER).

However, if the machine is not purely periodic, then some of the periods would have to be described individually.

When the differences in the periods can be described in terms of mathematical functions which can be written or accessed in Fortran (or some other machine language), relative simplicity in lattice description can be retained; it is not necessary to go to an enumeration of each and every element in the MAD input file. This can be achieved by producing the necessary machine element definitions as a Fortran output file which looks like lines of MAD definitions and then using this file later to be part of the MAD input definition.

Let us consider the Booster, where each bending magnet has two sextupoles with random strengths. Thus, we have 72 end-sextupoles (with random strengths) in the full lattice. A description of the machine may then be separated into two parts: (1) a description of the 72 sextupoles and (2) a description of the rest of the machine.

Appendix I gives an example of a CDC program which produces this two-part description. The first part, a (Fortran) program MADINP, generates the set of 72 sextupole definitions which are written in MAD-input format on the output file "Tapell". The strengths for the 72 sextupoles can be evaluated by any desired Fortran program, e.g., a randomly distributed Gaussian, etc. In the second part, the regular MAD input sequence contains the description of the remainder of the machine together with the MAD instruction.

CALL, 11 brings in the previously defined sextupole descriptions from the file "Tapell". The program then operates on a lattice whose complete description is provided by both parts.

An illustration of output for this combined Fortran-MAD description is given in Appendix II.

NAME,STMFZ,T176,P1. ***** APPENDIX I *****

ACCOUNT,NAME,ACC#,ACC#.

REQUEST,TAPE11,*PF.

ATTACH(NAG1,NAGSCLIB1)

ATTACH(NAG2,NAGSCLIB2)

ATTACH,BNLX.

LIBRARY(NAG1,NAG2,BNLX)

FTN(ROUND,OPT=2)

MAP(OFF)

LGO.

ATTACH,MADTRK,ID=EHA.

ATTACH,LIB1,MADLIB,ID=EHA.

LIBRARY,LIB1.

MADTRK.

%%EOR

PROGRAM MADINP (TAPE11,OUTPUT)

C

C THIS PROGRAM WRITES INTO TAPE 11 EACH OF 72 SEXTUPOLE ELEMENT

C DEFINITIONS AFTER SEXT. STRENGTHS ARE CALCULATED AS RANDOM

C NUMBERS WITH GAUSSIAN DISTRIBUTION (MEAN=0, SIGMA=0.5)

C

REAL G05DDF

REAL Z

WRITE(11,90)

C

CALL SEED SUBROUTINE

CALL G05CBF(0)

DO 50 K=1,72

C

CALL RANDOM NUMBER GENERATOR

C

20 Z=G05DDF(0.0,0.5)

C

CHECK FOR THE RULE OF 3*SIGMA=1.5

IF (ABS(Z) .GT. 1.5) GOTO 20

WRITE(11,92) K,Z

50 CONTINUE

STOP

90 FORMAT("TITLE!" / "BOOSTER RANDOM SEXTUPOLES")

92 FORMAT(" SEXTUPOLE,S",I2.2,"L=.01,K2=",F10.8)

END

%%EOR

CALL,11

TITLE!

* BOOSTER.

!
!
!
!
!

DIPOLES, QUADS AND CHROMATIC SEXTUPOLES:

SBEND,BND,L=2.4,ANGLE=.1745329

!

QUADRUPOLE,QF,L=.5,K1=-.554034

QUADRUPOLE,QD,L=.25,K1=.590959

!

SEXTUPOLE,SF,L=.10,K2=-5.60249

SEXTUPOLE,SD,L=.10,K2=5.10859

!

DRIFT,DR30,L=.30

DRIFT,DR29,L=.29

DRIFT,DR59,L=.59

DRIFT,DR99,L=.99

DRIFT,DR40,L=.40

DRIFT,DR370,L=3.7

LINES:

```

LINE,P1=(QD,DR29)
LINE,P2=(DR59,SF,DR30,QF,DR29)
LINE,P3=(DR59,SD,DR30,2*QD,DR370,QF,DR29)
LINE,P4=(DR59,SD,DR30,2*QD,DR29)
LINE,P5=(DR99,QF,DR370,2*QD,DR29)
LINE,P6=(DR99,QD)

```

```

LINE, SL(A,B)=(A,BND,B)

```

PERIODS AND MACHINE

```

LINE, SUPER(X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12) = &
(P1,SL(X1,X2),P2,SL(X3,X4),P3,SL(X5,X6),P4,SL(X7,X8),P5, &
SL(X9,X10),P2,SL(X11,X12),P6)

```

```

LINE, BOOSTER=(SUPER(S01,S02,S03,S04,S05,S06,S07,S08,S09,S10,S11,S12), &
SUPER(S13,S14,S15,S16,S17,S18,S19,S20,S21,S22,S23,S24), &
SUPER(S25,S26,S27,S28,S29,S30,S31,S32,S33,S34,S35,S36), &
SUPER(S37,S38,S39,S40,S41,S42,S43,S44,S45,S46,S47,S48), &
SUPER(S49,S50,S51,S52,S53,S54,S55,S56,S57,S58,S59,S60), &
SUPER(S61,S62,S63,S64,S65,S66,S67,S68,S69,S70,S71,S72) )

```

TRACKING SECTION

USE,BOOSTER

```

TRACK,PARTICLE=PROTON,ENERGY=1.138
START, X=.025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=-.025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=0.000, Z=0.03, S=0, PX=0, PZ=0, DE=0

```

```

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=0.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=0.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=0.00064

```

```

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=-0.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=-0.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=-0.00064
RUN, TURNS=300, FPRINT=5, MODE=SYNCHRO
ENDTRACK

```

```

PARAMETER,SF[K2]=0.0
PARAMETER,SD[K2]=0.0

```

```

TRACK,PARTICLE=PROTON,ENERGY=1.138
START, X=.025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=-.025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=0.000, Z=0.03, S=0, PX=0, PZ=0, DE=0

```

```

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=.00064

```

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=-.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=-.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=-.00064
RUN, TURNS=300, FPRINT=5, MODE=SYNCHRO
ENDTRACK

!

STOP

!

%%EOR

%%EOF

```

1      PROGRAM MADINP (TAPE11,OUTPUT)
      C
      C      THIS PROGRAM WRITES INTO TAPE 11 EACH OF 72 SEXTUPOLE ELEMENT
      C      DEFINITIONS AFTER SEXT. STRENGTHS ARE CALCULATED AS RANDOM
5      C      NUMBERS WITH GAUSSIAN DISTRIBUTION (MEAN=0, SIGMA=0.5)
      C
      REAL G05DDF
      REAL Z
      WRITE(11,90)
10     C      CALL SEED SUBROUTINE
      CALL G05CBF(0)
      DO 50 K=1,72
      C      CALL RANDOM NUMBER GENERATOR
15     C      Z=G05DDF(0.0,0.5)
      C      CHECK FOR THE RULE OF 3*SIGMA=1.5
      IF (ABS(Z) .GT. 1.5) GOTO 20
      WRITE(11,92) K,Z
      50  CONTINUE
      STOP
20     90  FORMAT("TITLE!/" "BOOSTER RANDOM SEXTUPOLES")
      92  FORMAT(" SEXTUPOLE,S",I2.2,".L=.01,K2=",F10.8)
      END

```

CALL,11

.. READING LOGICAL UNIT NUMBER 11

TITLE!
 BOOSTER RANDOM SEXTUPOLES
 SEXTUPOLE,S01,L=.01,K2= .26815150

10

15

20

25

30

35

40

45

50

55

60

SEXTUPOLE, S02, L=.01, K2= .79001896
 SEXTUPOLE, S03, L=.01, K2= .01327741
 SEXTUPOLE, S04, L=.01, K2= .75835111
 SEXTUPOLE, S05, L=.01, K2= .21552251
 SEXTUPOLE, S06, L=.01, K2= .38512580
 SEXTUPOLE, S07, L=.01, K2= .11723182
 SEXTUPOLE, S08, L=.01, K2= .10217494
 SEXTUPOLE, S09, L=.01, K2= .72525848
 SEXTUPOLE, S10, L=.01, K2= .02999574
 SEXTUPOLE, S11, L=.01, K2= .77338946
 SEXTUPOLE, S12, L=.01, K2= 1.37537151
 SEXTUPOLE, S13, L=.01, K2= .30314707
 SEXTUPOLE, S14, L=.01, K2= .29468836
 SEXTUPOLE, S15, L=.01, K2= .07936180
 SEXTUPOLE, S16, L=.01, K2= .69791837
 SEXTUPOLE, S17, L=.01, K2= .43058779
 SEXTUPOLE, S18, L=.01, K2= .20387384
 SEXTUPOLE, S19, L=.01, K2= .16482684
 SEXTUPOLE, S20, L=.01, K2= .04465487
 SEXTUPOLE, S21, L=.01, K2= .57972974
 SEXTUPOLE, S22, L=.01, K2= .53289603
 SEXTUPOLE, S23, L=.01, K2= .31352783
 SEXTUPOLE, S24, L=.01, K2= .16475909
 SEXTUPOLE, S25, L=.01, K2= 1.08157838
 SEXTUPOLE, S26, L=.01, K2= .19049634
 SEXTUPOLE, S27, L=.01, K2= .20850194
 SEXTUPOLE, S28, L=.01, K2= .24068340
 SEXTUPOLE, S29, L=.01, K2= .13841114
 SEXTUPOLE, S30, L=.01, K2= .17414591
 SEXTUPOLE, S31, L=.01, K2= .76470717
 SEXTUPOLE, S32, L=.01, K2= .17242488
 SEXTUPOLE, S33, L=.01, K2= .47699144
 SEXTUPOLE, S34, L=.01, K2= .01524153
 SEXTUPOLE, S35, L=.01, K2= .79970981
 SEXTUPOLE, S36, L=.01, K2= .62777513
 SEXTUPOLE, S37, L=.01, K2= .61049466
 SEXTUPOLE, S38, L=.01, K2= .09185146
 SEXTUPOLE, S39, L=.01, K2= .77409697
 SEXTUPOLE, S40, L=.01, K2= .25334724
 SEXTUPOLE, S41, L=.01, K2= .17851318
 SEXTUPOLE, S42, L=.01, K2= .06885764
 SEXTUPOLE, S43, L=.01, K2= .77904951
 SEXTUPOLE, S44, L=.01, K2= .04736759
 SEXTUPOLE, S45, L=.01, K2= .66891014
 SEXTUPOLE, S46, L=.01, K2= .07114592
 SEXTUPOLE, S47, L=.01, K2= .45242919
 SEXTUPOLE, S48, L=.01, K2= .18299022
 SEXTUPOLE, S49, L=.01, K2= .69621176
 SEXTUPOLE, S50, L=.01, K2= .23569769
 SEXTUPOLE, S51, L=.01, K2= .28320422
 SEXTUPOLE, S52, L=.01, K2= .46958441
 SEXTUPOLE, S53, L=.01, K2= .86768501
 SEXTUPOLE, S54, L=.01, K2= .54240583
 SEXTUPOLE, S55, L=.01, K2= .47645909
 SEXTUPOLE, S56, L=.01, K2= .27468882
 SEXTUPOLE, S57, L=.01, K2= 1.32968569
 SEXTUPOLE, S58, L=.01, K2= .03429897
 SEXTUPOLE, S59, L=.01, K2= .22696696
 SEXTUPOLE, S60, L=.01, K2= .58914480
 SEXTUPOLE, S61, L=.01, K2= .58914480

```

70 SEXTUPOLE,S65,L=.01,K2=-.71879778
   SEXTUPOLE,S66,L=.01,K2=-.59758812
   SEXTUPOLE,S67,L=.01,K2=-.50851717
   SEXTUPOLE,S68,L=.01,K2=-.35915669
   SEXTUPOLE,S69,L=.01,K2=.39290994
   SEXTUPOLE,S70,L=.01,K2=-.35093736
   SEXTUPOLE,S71,L=.01,K2=.32627242
75 SEXTUPOLE,S72,L=.01,K2=.37872534

```

.. READING STANDARD INPUT FILE

```

80 TITLE
   * BOOSTER,
   |
   | DIPOLES, QUADS AND CHROMATIC SEXTUPOLES:
   |
85 SBEND,BND,L=2.4,ANGLE=.1745329
   |
   QUADRUPOLE,QF,L=.5,K1=-.554034
   QUADRUPOLE,QD,L=.25,K1=.590959
   |
90 SEXTUPOLE,SF,L=.10,K2=-5.60249
   SEXTUPOLE,SD,L=.10,K2=5.10859
   |
   DRIFT,DR30,L=.30
   DRIFT,DR29,L=.29
   DRIFT,DR59,L=.59
95 DRIFT,DR99,L=.99
   DRIFT,DR40,L=.40
   DRIFT,DR370,L=3.7
   |
   LINES:
100 |
   LINE,P1=(QD,DR29)
   LINE,P2=(DR59,SF,DR30,QF,DR29)
   LINE,P3=(DR59,SD,DR30,2*QD,DR370,QF,DR29)
   LINE,P4=(DR59,SD,DR30,2*QD,DR29)
105 | LINE,P5=(DR99,QF,DR370,2*QD,DR29)
   LINE,P6=(DR99,QD)
   |
   LINE, SL(A,B)=(A,BND,B)
   |
110 | PERIODS AND MACHINE
   |
   LINE, SUPER(X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12) = &
   (P1,SL(X1,X2),P2,SL(X3,X4),P3,SL(X5,X6),P4,SL(X7,X8),P5, &
   SL(X9,X10),P2,SL(X11,X12),P6)
115 |
   |
   LINE, BOOSTER=(SUPER(S01,S02,S03,S04,S05,S06,S07,S08,S09,S10,S11,S12), &
   SUPER(S13,S14,S15,S16,S17,S18,S19,S20,S21,S22,S23,S24), &
   SUPER(S25,S26,S27,S28,S29,S30,S31,S32,S33,S34,S35,S36), &
120 | SUPER(S37,S38,S39,S40,S41,S42,S43,S44,S45,S46,S47,S48), &
   SUPER(S49,S50,S51,S52,S53,S54,S55,S56,S57,S58,S59,S60), &
   SUPER(S61,S62,S63,S64,S65,S66,S67,S68,S69,S70,S71,S72) )

```

125

|%%EOR

TRACKING SECTION

USE,BOOSTER

.. BEAM LINE "BOOSTER" EXPANDED: 312 ELEMENTS, 482 POSITIONS
.. END OF "USE" COMMAND, ELAPSED CPU TIME = 2.413 SECONDS

TRACK,PARTICLE=PROTON,ENERGY=1.138

.. ENTER TRACKING MODULE, ELAPSED CPU TIME = 2.531 SECONDS

130

START, X= .025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=-.025, Z=0, S=0, PX=0, PZ=0, DE=0
START, X=0.000, Z=0.03, S=0, PX=0, PZ=0, DE=0

135

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=0.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=0.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=0.00064

140

START, X=0.025, Z=0.0, S=0, PX=0, PZ=0, DE=-0.00064
START, X=-.025, Z=0.0, S=0, PX=0, PZ=0, DE=-0.00064
START, X=0.00, Z=0.03, S=0, PX=0, PZ=0, DE=-0.00064
RUN, TURNS=300, FPRINT=5, MODE=SYNCHRO

INITIAL PARTICLE POSITIONS

NORMALIZED TO EX = 1.00000000E+00

EZ = 1.00000000E+00

ES = 1.00000000E+00

NUMBER		Q	P	QN	PN	W	PHI
1	X	2.50000000E-02	.00000000E+00	.01291623	.00010209	.00016684	.00125793
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	.00000000E+00				
2	X	-2.50000000E-02	.00000000E+00	-.01291623	-.00010209	.00016684	-.49874207
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	.00000000E+00				
3	X	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	Z	3.00000000E-02	.00000000E+00	.00820490	.00000000	.00006732	.00000000
	S	.00000000E+00	.00000000E+00				
4	X	2.50000000E-02	.00000000E+00	.01291623	.00010209	.00016684	.00125793
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	6.40000000E-04				
5	X	-2.50000000E-02	.00000000E+00	-.01291623	-.00010209	.00016684	-.49874207
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	6.40000000E-04				
6	X	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	Z	3.00000000E-02	.00000000E+00	.00820490	.00000000	.00006732	.00000000
	S	.00000000E+00	6.40000000E-04				
7	X	2.50000000E-02	.00000000E+00	.01291623	.00010209	.00016684	.00125793
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	-6.40000000E-04				
8	X	-2.50000000E-02	.00000000E+00	-.01291623	-.00010209	.00016684	-.49874207
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	.00000000E+00	-6.40000000E-04				
9	X	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	Z	3.00000000E-02	.00000000E+00	.00820490	.00000000	.00006732	.00000000
	S	.00000000E+00	-6.40000000E-04				

PARTICLE POSITIONS AT "#

E"

DURING TURN

5

NUMBER		Q	P	QN	PN	W	PHI
1	X	-1.86852505E-02	-4.03457691E-03	-.00965372	-.00788543	.00015537	-.39099191
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	-3.34901807E-03	.00000000E+00				
2	X	2.13423492E-02	3.66770164E-03	.01102651	.00718617	.00017322	.09192503
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	3.07763013E-03	.00000000E+00				
3	X	-2.60792840E-04	2.72930532E-04	-.00013474	.00052721	.00000030	.28982294
	Z	2.99438545E-02	-2.52046378E-05	.00818954	-.0009216	.00006708	-.00179090
	S	4.25440833E-04	.00000000E+00				
4	X	-1.77652269E-02	-4.04959454E-03	-.00917839	-.00791074	.00014682	-.38678434
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	-3.26525212E-02	6.40000000E-04				
5	X	2.24115729E-02	3.62974731E-03	.01157892	.00711708	.00018472	.08771472
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	-2.60942268E-02	6.40000000E-04				
6	X	4.45412351E-04	3.53062243E-04	.00023012	.00068519	.00000052	.19843131
	Z	2.98139777E-02	-2.73736858E-05	.00815402	-.00010009	.00006650	-.00195347
	S	-2.90247935E-02	6.40000000E-04				
7	X	-1.96290376E-02	-4.00749193E-03	-.01014132	-.00783686	.00016426	-.39529006
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	2.58445178E-02	-6.40000000E-04				
8	X	2.03121497E-02	3.68954748E-03	.01049425	.00722425	.00016232	.09595428
	Z	.00000000E+00	.00000000E+00	.00000000	.00000000	.00000000	.00000000
	S	3.21514759E-02	-6.40000000E-04				