Lattice Design Lectures

JAI lectures - Michaelmas Term 2021

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Outline

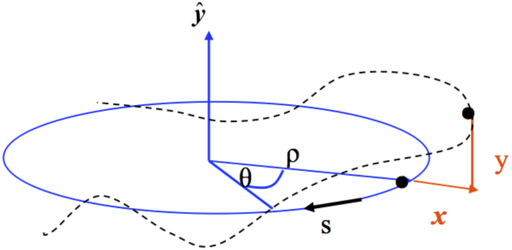
Introduction

- How to install and run MADX.
- How to use elements and sequences as inputs.
- How to extract information about Twiss functions, tunes, orbits...
- Matching, Tracking and Plotting.
- Some examples.

What is MADX?

MAD (Methodological Accelerator Design) is a program for accelerator design and simulation.

- Uses a sequence of elements placed sequentially along a reference orbit,
- The reference orbit is the path of a charged particle having the central design momentum of the accelerator through ideal magnets.
- The reference orbit consist of a series of straight line segments and circular arcs.
- Local curvilinear right handed coordinate system.



What is MADX useful for?

- Multiplatform.
- Very flexible and possible to extend.
- Made for complicated applications.
- Mainly designed for large projects (LEP, LHC, CLIC, FCC).

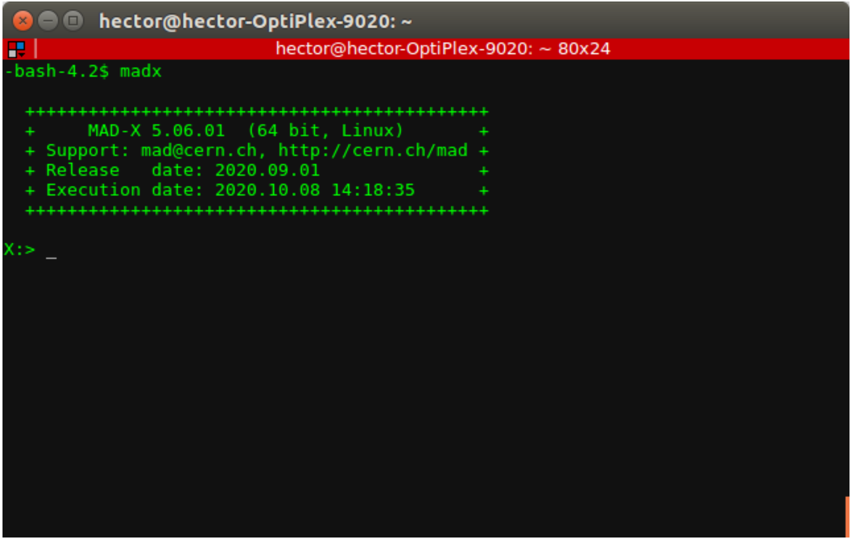
What is MADX not useful for?

- A program for teaching.
- Easy for beginners.
- Friendly graphical user interface.

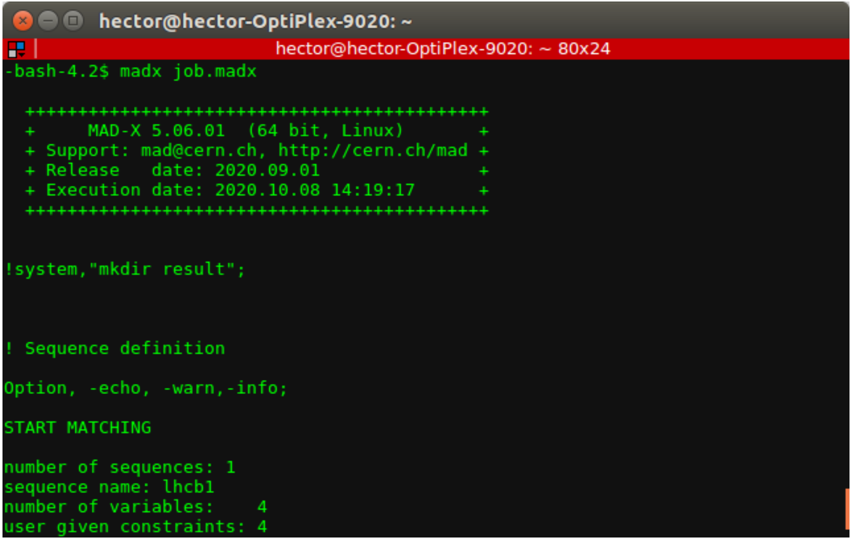
Installing MADX

- MADX website: https://mad.web.cern.ch/mad/
- Go to releases and download the last version.
- MAD-NG: under development.

Run MADX


hector@hector-OptiPlex-9020: ~
hector@hector-OptiPlex-9020: ~ 80x24
-bash-4.2$ madx
++
+   MAD-X 5.06.01 (64 bit, Linux)   +
+ Support: mad@cern.ch, http://cern.ch/mad +
+ Release   date: 2020.09.01   +
+ Execution date: 2020.10.08 14:18:35   +
++
X:> _

Run MADX


hector@hector-OptiPlex-9020: ~
hector@hector-OptiPlex-9020: ~ 80x24
-bash-4.2$ madx job.madx
++
+   MAD-X 5.06.01 (64 bit, Linux)   +
+ Support: mad@cern.ch, http://cern.ch/mad +
+ Release   date: 2020.09.01   +
+ Execution date: 2020.10.08 14:19:17   +
++
!system,"mkdir result";
! Sequence definition
Option, -echo, -warn,-info;
START MATCHING
number of sequences: 1
sequence name: lhcb1
number of variables: 4
user given constraints: 4

MADX syntax and input structure

Open | Save

3_FODO_match.madx
~/scratch0/JAI_lectures

```
! ## Definition of elements
! Define two quadrupoles (note the deferred assignments).
qf_type: quadrupole, l=1.5, k1:=kf;
qd_type: quadrupole, l=1.5, k1:=kd;

! ## Definition of the sequence
! A short fodo of 10 m.
fodo:sequence, refer=exit, l=10;
qf: qf_type, at=5;
qd: qd_type, at=10;
endsequence;

! ## Definition of the strength
kf=+0.25;
kd:=-kf;

! ## Definition of the beam
beam, particle=proton, energy=7000;

! ## Activation of the sequence
use, sequence=fodo;

! ## Operations
! A simple twiss and plot
select, flag=twiss, column=name,s,betx, bety, alfx,alfy;
```

```
! ## Operations
! A simple twiss and plot
select, flag=twiss, column=name,s,betx, bety, alfx,alfy;
twiss, file=before_matching.twiss;
plot, haxis=s, vaxis=betx, bety, colour=100, noversion=true, title='before matching';

! ## Matching
match, sequence=fodo;
  global, q1=.25;
  global, q2=.25;
  vary, name=kf, step=0.00001;
  vary, name=kd, step=0.00001;
  lmdif, calls=50, tolerance=1e-8;
endmatch;

! ## Operations
twiss, file=after_matching.twiss;
plot, haxis=s, vaxis=betx, bety, colour=100, noversion=true, title='after matching', interpolate=tr

! ## Output
value, table(summ,Q1);
value, table(twiss,qf, betx);

! ## Conversion ps2pdf
! This command assumes that in your system the command ps2pdf is available
system, 'ps2pdf madx.ps FODO_match.pdf';

! ## Exit
quit;
```

Fortran 95 Tab Width: 8 Ln 37, Col 1

MADX basic output

```
hector@hector-HP-EliteBook-840-G1: ~
hector@hector-HP-EliteBook-840-G1: ~ 107x35
select, flag=twiss, column=name,s,betx, bety, alfx,alfy;

twiss, file=FODO.twiss;

enter Twiss module

iteration:   1 error:   0.000000E+00 deltap:   0.000000E+00
orbit:   0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00

++++++ table: summ

            length             orbit5               alfa            gammatr
                10                 -0                  0                  0

                q1                dq1            betxmax              dxmax
      0.3159191546      -0.4863193631        16.65487108                  0

             dxrms             xcomax             xcorms                 q2
                 0                  0                  0       0.3159191546

               dq2            betymax              dymax              dyrms
     -0.4863193631        16.65487108                  0                  0

            ycomax             ycorms             deltap            synch_1
                 0                  0                  0                  0

           synch_2            synch_3            synch_4            synch_5
                 0                  0                  0                  0

           synch_6            synch_8             nflips
                 0                  0                  0
plot, haxis=s, vaxis=betx, bety, colour=100, noversion=true, title='FODO';

Plot - default table plotted: twiss

 CXPLOT-X11  1.50 initialized
```

Matching

- Manually matching optics in MADX might be a hard task.
- MADX does it for you.
- How?
  - Select a sequence.
  - Initiate the matching routine.
  - Select variables and constraints.
  - Two types of constraints:
    - Global variables.
    - Local variables.

Tracking and Plotting

Tracking

- Particles can be tracked though the magnetic elements of your lattice.
- Two different ways:
  - MADX TRACK.
  - PTC (Polymorphic Tracking Code).

Plotting

- You can plot any output $(\beta, \alpha, x, y ...)$.

Some examples

Resources

- Many examples available at the MADX website.
- MADX Primer
- I uploaded the examples to the JAI lectures website.