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# **C-MAD User's MANUAL**

Version 3.0.1

Mauro T. F. Pivi<sup>#,1</sup>

Contributors: Kiran Sonnad<sup>2</sup>, Alex Chao<sup>1</sup>, Claudio Rivetta<sup>1</sup>,  
Theo Demma<sup>3</sup>.

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<sup>1</sup>SLAC National Accelerator Laboratory,  
2575 Sand Hill Road,  
Menlo Park, CA-94043, USA

<sup>2</sup>Cornell university, Ithaca, New York

<sup>3</sup>LNF INFN Frascati, Italy

<sup>#</sup>contact: [mpivi@slac.stanford.edu](mailto:mpivi@slac.stanford.edu)

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# Installation

C-MAD is running on NERSC and the executable is on the directory  
/global/u1/m/mpivi/codes/cmad\_mpi

# Libraries

fftw: already linked if running on NERSC. Need to download if running on other  
computer system.

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# INPUT FILE

Following here below, a line by line explanation of the input file with the related input parameters. The input file should be named with the extension “.in”.

There are no initial random seeds, so that two identical input files should produce two identical output results.

**WARNINGS file:** “cmad\_out\_200\_warnings.dat” is the output file to check for warnings, errors and communications about the run. If the program unexpectedly stops, please check this file.

## • First line of the input file. Comment Line.

Comment line, the User can use it for referencing the lattice, dates and comments.

## • Macro-electrons in the cloud

This is a simulation parameter. Number of macro-electrons, each one representing a cluster of electrons in the cloud.

Actually the code allows the simulation up to 100,000 macroelectrons.

## • iread

[Switch: 0 or 1]

Assumed electron distribution at input. Typically the electron distribution can be read from a file and then this switch parameter is set to 1 or assumed uniformly distributed over an area around the beam and the switch should be then set to 0.

## • Beam Particle Species

Beam particle specie to be simulated. Specify: “Positrons”, “Protons” or “Electrons”

## • Beam Energy

Beam energy in Units of electronVolt. Ex: specify 5.0e9 for 5 GeV.

## • Bunch population

Effective number of particles per bunch.

Example: 1.1e11 particles per bunch in the LHC beam.

## • Beam macroparticles

Number of macro-particles to use in simulations, each one representing a number of beam particles. The user can specify up to 300,000 particles

## • Number of turns

## • Synchrotrone tune, $\nu_s$

## • Normalized Horizontal and Vertical Emittancies

$\gamma_{ex}, \gamma_{ey}$  [m rad]

Normalized horizontal and vertical emittancies.

## • Bunch Length, Energy Spread

[meter] and

Specify the bunch length and the energy spread. In general, the bunch length is re-computed by C-MAD according to the lattice matching conditions

$$\sigma_z = \frac{\sigma_{p0} |\eta|}{2\pi \nu_s} C$$

Where  $\eta$  is the slippage factor and C the circumference.

The bunch length is needed at input only if the synchrotron tune or the momentum compaction are set to null.

If the bunch length is recomputed by the code a message is generated in the warning file.

## • **nsigmaz**

Extent of the bunch in simulations. The bunch is cut at the number of sigma specified here. The full bunch extent is (-nsigmaz, +nsigmaz). Example if it is specified nsigmaz = 4 the bunch extent is (-4 sigmaz, +4 sigmaz) for a total of 8 sigmaz. Typically use between 2 and 4.

## • **Momentum compaction,**

To be consistent, the momentum compaction alpha SHOULD be taken from the MAD lattice file “optics.dat”. Please, include as many as precision numbers as possible. This parameter is not used by the code if the “kicks”  $\geq 1$  and this line is skipped.

Example: “0.1726712435E-03”

## • **Number of bunch slices**

Number of slices in which the bunch is divided.

The interaction between the bunch and the electron cloud is dealt numerically by the code by first dividing the bunch in a certain number of slices (ibunchslices) and then applying the electric field of all the particles in a slice to the cloud and viceversa applying the electric field of the electron cloud to each particle in the slice.

It is important to input a number of slices large enough to correctly integrate the equation of motion of the electrons during the bunch passage. Although, a large number of bunch slices may increase the computational time and slow down the simulations.

Our recommendation is to use a number of slices greater than 10 times the number of electron oscillations during the bunch passage.

Example: compute the number of electron oscillations for an electron initially located at a transverse position (1 sigmax, 1 sigmay) during the bunch passage. Then multiply the number of complete oscillations by 10 to obtain ibunchslices. Assume the number of electron oscillations is 3 like in the SPS bunch then

ibunchslices > 30. Typically, one may want to use 50 or higher for this case to increase the tracking resolution.

## • **Electron Cloud density**, [Units: electron/m<sup>3</sup>]

IN GENERAL, THIS IS NOT THE RING AVERAGE CLOUD DENSITY!

This because the next line “Cloud density factor” let one specify the cloud density in various elements of the ring.

THE RING AVERAGE CLOUD DENSITY IS PRINTED IN THE OUTPUT FILE:  
cmad\_out\_119\_statistics.dat.

## • **Electron Cloud density factor**, [Units: 6 real numbers]

Let one specify the cloud density in various beam line elements type:

DRIFT, BEND, WIGG, QUAD, SEXT, OTHER.

For each element type, the 6 parameters scale the electron cloud density value as specified in the previous input line. (At the moment, the WIGG elements are represented by BEND elements.)

Example: “0.0 1.0 1.0 2.0 1.0 1.0”

which means that assuming for example an ‘electron cloud density’ in the previous line is 1e13 e/m<sup>3</sup>, the cloud densities are:

0, 1e13, 1e13, 2e13, 1e13, 1e13 e/m<sup>3</sup>

respectively in drifts, bends, wigglers (bends), quadrupoles, sextupoles and other magnets.

NOTE: if all the 6 factors are set to 1.0, then the electron cloud density is also the average cloud density in the ring.

## • **Electron cloud size**, [Units of beam $\sigma_x$ , $\sigma_y$ ]

This parameter represents the extent of the electron cloud in Units of beam sigmax and sigmay. The extent is both in the positive and negative directions [ $\pm$  size\*sigmax,  $\pm$  size\*sigmay]. It is used to define the domain for the computation of the Poisson equations.

Example: “10” the electron cloud extend  $\pm 10 \sigma_{\text{max}}$  and  $\pm 10 \sigma_{\text{may}}$

## • Case of “Constant Beta Functions” or “Continuous Focusing”

The line is active only if the first parameter:  $\text{kicks} \geq 1$ .

If the first parameter  $\text{kicks} = 0$ , the line is skipped.

If the first parameter is  $\text{kicks} \geq 1$ , the interactions between the beam and the cloud occur in a fixed number of Interaction Points (IP) per turn and we are in the so called “continuous focusing” case, meaning that the beta functions are constant at the IP locations around the ring.

The 8 parameters in this line are:

- |                                     |           |
|-------------------------------------|-----------|
| 1. Beam cloud IPs per turn          | - kicks   |
| 2. Circumference                    | - circumf |
| 3. Average horizontal beta function | - betx    |
| 4. Average vertical beta function   | - bety    |
| 5. Average horizontal beam size     | - sigx    |
| 6. Average vertical beam size       | - sigy    |
| 7. Horizontal tune                  | - nux     |
| 8. Vertical tune                    | - nuy     |

A large number of IPs or kicks are preferable, since it is preferable to have weaker interactions in several locations rather than stronger interactions in fewer locations.

IMPORTANT: The optics is determined by these lattice parameters and the next three lines in the input files are skipped. C-MAD will generate *ad hoc* optics files named *RING\_sectomap.dat* and *RING\_optics.dat* and will copy them in the directory ‘/Optics\_Files’.

## • Machine Optics Files from MAD

Next three lines.

If the parameter  $\text{kicks} \geq 1$  in the previous line, the next 3 lines are skipped.

Instead, if the parameter  $\text{kicks} = 0$ , the next 3 lines completely specify the optics from the MAD files:

1. line: exact name of the MAD sectomap file (case sensitive)



2. line: exact name of the MAD optics file (case sensitive)
3. line: specifies two values: 1) the line number of the first ring element in the optics file. 2) the number of columns in the optics file\*. see Figure 1.

Example:

```
> ILC_DCO4_sectormap.dat
> ILC_DCO4_optics.dat
> 16 14
```

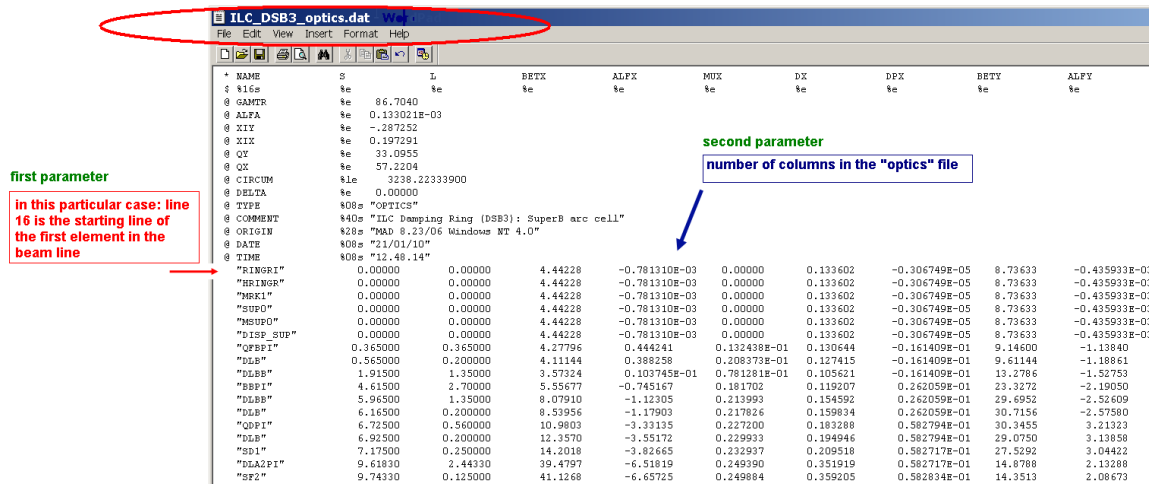


Figure 1. "Optics" file containing the Twiss parameters. The two parameters to specify in the input file are the "starting" line and the number of columns. As shown in the figure, line 16 is the starting line of the first element in the beam line. In this particular case the columns are 14. Thus the parameters to specify are: "16 14".

See Appendix: "Instructions to easily extract from MAD the optics files for C-MAD".

## • Transverse Grid Size, $n_x$ , $n_y$

This represent a quart of the grid domain. The total domain is  $(-n_x, n_x)$  in the horizontal and  $(-n_y, n_y)$  in the vertical directions.

Example: 64 64

## • Position of test particle

Parameter not used anymore. To be removed in the next version.

## • Tracking with/without cloud, “justtrackbeam”

[switch: 0 or 1]

This switch is used to track the beam in a lattice with or without cloud. If justtrackbeam = 1, track the beam without electron cloud where the electron cloud is assumed to have zero density everywhere in the ring, if justtrackbeam = 0 track the beam with an electron cloud distributed over the ring.

## • Beam tracking order

The “iorder” parameter is either 1 or 2 representing the first or second order tracking.

## • Last element

Parameter no used anymore. To be removed in the next version.

## • Frozen Potential

Parameter not used anymore. To be removed in the next version.

## • Beam distribution

If this switch ‘ibeamdistribution’ = 1, then upload the entire beam particle distribution from the file cmad\_input\_beam.in. The file cmad\_input\_beam.in must be present in the home directory.

## • Domain for the Poisson calculation

If this switch ‘openspaceornot’ = 0 then there are open space boundary conditions, if ‘openspaceornot’=1 then there are rectangular “metallic” conducting boundary conditions. The boundary domain is coincident with the “Electron cloud size” parameter.

## • Testing Parameters

Parameters not used anymore. To be removed in the next version.

## • Beam offset, [Units of beam $\sigma_x$ , $\sigma_y$ ]

The parameters “disx, disy” represent the initial linear offset or displacement of the bunch in the horizontal and vertical directions in Units of beam sigmax and sigmay. It may represent a bunch-by-bunch jitter in the beam.

The way the bunch offset is physically implemented in the code for example in the vertical direction:

$$\text{Vertical beam offset} = \text{DISY} * \sigma_y$$

Example: “0 0.1” represents no beam offset in the horizontal direction and a 0.1·sigmay offset in the vertical direction at injection and with respect to the closed orbit.

## • Switch to Overwrite Magnetic Field Values

If ‘B0, G, G’ are non-zero, the code overwrites the lattice values for the B field: in BEND, QUAD, AND SEXT. All other elements are considered drifts.

## • Electron cloud distribution

The “idist” switch is related to the electron cloud distribution that can be specified to be:

idist=0: Quarter-Random

idist=1: Uniformly spaced

idist=2: Cold uniform distribution or

idist=3: Random.

Typically, a pure random particle distribution generates some “noise” level in the calculation of the Poisson equation that scales with the square root number of macro-particles used in the calculation. Also typically, a more uniform particle distribution produces less noise in the calculation and thus allowing fewer macro-particles to be used. As a result the electric field from a uniform distribution is cleaner.

idist = 0 “Quarter-random” electron cloud distribution. 1/4 of the total number

of electrons are randomly distributed and then mirrored in the other quadrants.  
 idist=1 “Uniformly Spaced on grid” sets the electrons uniformly spaced on a grid. This should give the less noise in the calculation.  
 Idist=2 “Cold Uniform Distribution” 1 and only 1 electron is placed at the center of each grid area. Warning: the number of electrons might be very much reduced from the input file number. Warning: the electrons are not uniformly spaced in the horizontal and vertical directions but they are respectively arranged according to the values gridx and gridy.  
 idist=3 “Random” purely random electron cloud distribution.

## • Transverse Feedback System

The classical multi-bunch feedback system and the novel single-bunch broadband feedback system are both included in C-MAD and the main parameters are specified in one single line of the input file. The kicker is assumed to be electrostatic.

CAUTION: the single-bunch feedback system is implemented only for long bunches like in the SPS where the bunch is 1ns long, and it is still an R&D item in year 2010.

If the first parameter  $Gain > 0$ , the feedback system is ON.

If the first parameter  $Gain = 0$ , the feedback is OFF and the line is skipped!

The 6 parameters needed for the feedback system are:

- |   |                                |
|---|--------------------------------|
| 1. Feedback System Gain                             | - $Gain$                       |
| 2. Pick-up location [meter]                         | - $feedback\_pickup\_location$ |
| 3. Kicker location [meter]                          | - $feedback\_kicker\_location$ |
| 4. Horizontal/Vertical feedback                     | - $H, V$ or $HV$               |
| 5. Number of turns for data acquisition before kick | - $Ntaps$ (maximum 10)         |
| 6. Electrodes separation [meter]                    | - $d$                          |

If  $Ntaps > 1$  the user must provide the coefficients  $a_1, a_2 \dots a_{Ntaps}$  in the last line of the input file!

During the run, the feedback system starts to be active after the first  $(2 Ntaps - 1)$  turns.

IMPORTANT: to specify the pickup and kicker locations, look into the “optics” MAD file at the “S” location (typically the second column in the file) of the selected lattice elements. Specify these locations with a precision of 0.01m or better.

Typically, the pick-up and kicker are located 90° phase advance apart: in the MAD “optics” file, use the MUX and MUY parameters to guide you on the phase advance between elements.

In MAD, typically  $MUX[Y] = 2\pi Q_{x[y]}$  with  $Q_{x[y]}$  the horizontal [vertical] tune.

If Ntaps = 1: the momentum kick is simply proportional to the beam centroid offset at the pick-up location

$$\Delta p = Gain \frac{x}{\beta}$$

Where  $p$  is the normalized momentum  $p/p_0$ ,  $x$  is the beam centroid and  $\beta$  is the beta function at the kicker location. In this case, the kicker has no turn delay and act during the same turn as the beam position is recorded by the pick-up.

If Ntaps > 1:

There must be additional files.

The feedback\_configuration.dat file has a vector with parameters:

1. Open [=0] or close loop [=1]
2. Vertical displacement absolute [=0] or dipole [=1] signal
3. Noise in the Receiver (pick-up): no noise [=0] or noise [=1]
4. Noise in the Amplifier (kicker): no noise [=0] or noise [=1]
5. Saturation in the Receiver: no [=0], yes [=1]
6. Upper Limit of the Receiver Saturation: Real Number
7. Lower Limit of the Receiver Saturation: Real Number
8. Saturation in the Amplifier: no [=0], yes [=1]
9. Upper Limit of the Amplifier Saturation: Real Number
10. Lower Limit of the Amplifier Saturation: Real Number

The momentum kick from the electrostatic kicker is:

$$\Delta p = \frac{V}{d} \frac{L}{E}$$

where  $V$  is the kicker Voltage,  $d$  is the electrodes separation (default  $d=0.02$  m),  $L$  is the kicker length and  $E$  is the beam energy in units of  $eV$ .

(In an electromagnetic kicker, not implemented yet, the momentum kick is twice the electrostatic case  $\Delta p = 2 \frac{VL}{Ed}$ ).

In this case, the kicker has a one turn delay with respect to the pick-up.

In general, the voltage is proportional to the feedback gain:

$$V = Gain \cdot yout(n)$$

where  $yout(n)$  is a parameter proportional to the beam centroid offset recorded during the last  $Ntaps$  turns as:

$$yout(n) = a_1 c_{n-1} + a_2 c_{n-2} + a_3 c_{n-3} + \dots + a_{Ntaps} c_{n-Ntaps}$$

here  $n$  is the actual turn number,  $c_i$  are the beam centroid offsets recorded at the pick-up locations during the latest  $Ntaps$  turns and  $a_1, a_2 \dots a_{Ntaps}$  are coefficient provided by the User in the input file and are determined to optimize the feedback system.

### EXAMPLES

#### - Example 1.

In the input file, the line corresponding to the feedback system may look like this:

```
1.0e3  0.0  50.5  V  1  0.02          ! Feedback System
```

That specifies a 1)  $Gain=1000$  2) pickup location at 0.0 meters 3) kicker location at 50.50 meters 4) feedback system is “V” = Vertical 5)  $Ntaps = 1$  means that the kick is applied during the same turn the data is recorded at the pick-up location 6) the kicker electrodes are separated by a distance  $d = 2cm$ .

#### - Example 2.

In input file the single line may look like this:

```
1.0e3  0.0  50.5  HV  1  0.02          ! Feedback System
```

That contains two differences from the above example 1: here the feedback systems are Horizontal and Vertical as specified by the “HV” parameter and  $Ntaps = 5$  meaning that the kicker acts based on the data recorded at the pick-up location during the last 5 turn.

## • Longitudinal Feedback System

Specify only one parameter that is the longitudinal feedback  $Gain$ .

## • Last line of input file

If the transverse feedback is active and  $Ntaps > 1$  the user must provide the coefficients  $a_1, a_2 \dots a_{Ntaps}$  in the last line of the input file!

The maximum number of  $Ntaps$  is set to 10.

# OUTPUT FILES

## Summary

In order of importance the output files are:

- **cmad\_out\_119\_statistics.dat** Main file: beam data turn by turn
- **cmad\_out\_200\_Warnings.dat** Warnings and communications
- **cmad.f90.out** Main parameters associated with the run
- **cmad\_out\_120\_statistics\_beam\_slices\_c.dat** charge in each beam slice
- **cmad\_out\_120\_statistics\_beam\_slices\_x.dat** horizontal centroid of each slice
- **cmad\_out\_120\_statistics\_beam\_slices\_y.dat** vertical centroid of each beam slice
- **cmad\_out\_120\_statistics\_beam\_slices\_z.dat** longitudinal centroid of each slice
  
- **cmad\_out\_121\_tunes.dat” to “cmad\_out\_128\_tunes.dat”**  
These files contain single particle information for tune analysis
  
- **cmad\_out\_130\_tunes\_footprint\_init.dat**  
**cmad\_out\_130\_tunes\_footprint\_final.dat:**  
These files contain information to plot the beam tune footprint
  
- **cmad\_out\_140\_feedback\_Voltage.dat:** Feedback information: turn and Voltage
- **cmad\_out\_114\_particles\_distributions\_last\_turn.dat**  
Contain all the beam particles information for the 6 dimensional phase space. Refresh every 20 turns and at the very last turn.
  
- **cmad\_out\_114\_particles\_distributions.dat**  
Every 20 turns, writes the information of a fraction of the beam particle (2000).
  
- **cmad\_out\_114\_particles\_losses.dat** Print out the lost particles
- **cmad\_out\_118\_e-distribution.dat** Initial Electron cloud distribution

## • Main output files:

### **cmad\_out\_119\_statistics.dat:**

Main output file that contains major turn by turn information including emittancies, beam sizes, beam losses and centroid positions. Important: The calculated beam size and emittance are the r.m.s. values (not Gaussian fit). In particular, the last column represents the “Average cloud density” computed over the whole ring and taking into account the contributions from the different element types.

The file *cmad\_out\_119\_statistics.dat* has 19 columns representing:

- |                              |  |
|------------------------------|--|
| 1) CpuTime:                  | Computing time for each processor used during run          |
| 2) Time:                     | Physical machine clock time of circulating beam            |
| 3) Proc:                     | Processor (number) that is writing on this file            |
| 4) Turn:                     | Turn number. The starting turn is turn number 1.           |
| 5) Element:                  | Ring element number at which statistic are printed         |
| 6) Distance:                 | Distance of element above from MAD 1 <sup>st</sup> element |
| 7) Sigma <sub>x</sub> :      | r.m.s. Horizontal beam size                                |
| 8) Sigma <sub>xp</sub> :     | r.m.s. Horizontal beam divergence                          |
| 9) Sigma <sub>y</sub> :      | r.m.s. Vertical beam size                                  |
| 10) Sigma <sub>yp</sub> :    | r.m.s. Vertical beam divergence                            |
| 11) Sigma <sub>z</sub> :     | r.m.s. Longitudinal beam size                              |
| 12) Sigma <sub>p</sub> :     | r.m.s. beam energy spread                                  |
| 13) Emittance <sub>x</sub> : | Un-normalized r.m.s. Horizontal emittance                  |
| 14) Emittance <sub>y</sub> : | Un-normalized r.m.s. Vertical emittance                    |
| 15) Centroid <sub>x</sub> :  | Horizontal centroid of the beam                            |
| 16) Centroid <sub>y</sub> :  | Vertical centroid of the beam                              |
| 17) Centroid <sub>z</sub> :  | Longitudinal centroid of the beam                          |
| 18) BunchPopulation:         | Number of particles in the circulating bunch               |
| 19) AvgCloudDensity:         | Average cloud density integrated over the ring             |

### **cmad\_out\_200\_Warnings.dat**

Main file to check warnings and communications about the run.

### **cmad.f90.out**

This file is useful to check main parameters associated with the run, date and time of the run, CPU processors used, summary of input file, summary of lattice parameters, then on the last part of the file it prints the emittance for the first turn element by element and at every turn after the first one.



## • List of other important output files:

### Files:

**cmad\_out\_120\_statistics\_beam\_slices\_c.dat**  
**cmad\_out\_120\_statistics\_beam\_slices\_x.dat**  
**cmad\_out\_120\_statistics\_beam\_slices\_y.dat**  
**cmad\_out\_120\_statistics\_beam\_slices\_z.dat**

These 4 files contain respectively: the particle charge, the horizontal, vertical and the longitudinal centroid positions of each beam slice.

The ring element number where the measurement is taken is specified in the file. In the case of feedback system on, the location corresponds to the pick-up location.

### Files:

**cmad\_out\_121\_tunes.dat**  
**cmad\_out\_122\_tunes.dat**

...

### **cmad\_out\_128\_tunes.dat:**

These are 8 files each containing the BPM positions of 1 test particle taken turn by turn for tune analysis. Each file contains one test particle which is located at the beginning of the run at a different position in the bunch, for example: synchronous particle, 1 sigma, etc.

### **cmad\_out\_130\_tunes\_footprint\_init.da**

This file and the next are used for tune footprint analysis as shown in Figure 2. For each particle, the tunes are calculated according to [1]. Beam particles are printed turn by turn for the first 7 turns in this file (and the last 7 turns in the next file below). Typically, the information of 20,000 is printed. Each particle phase space is plotted for 7 turns (first column) that are shown consecutively in the file. Each particle has an ID number (second column) and a particle status flag (third column) is also shown.

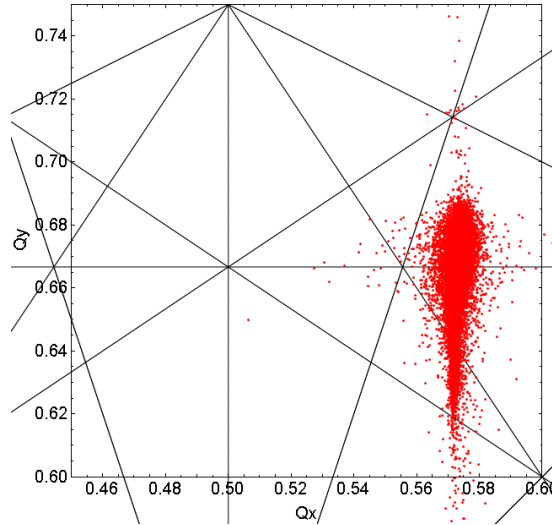


Figure 2. Tune footprint of 20,000 CsrTA particles

Here an example of the output file where two particles are shown for the first 7 turns:

/global/u1/m/mpivi/codes/cmad_mpi_testing/cmad_CESRTA_2085mev_5e12/cmad_out_130_tunes_footp								
* Beam particles BPM signal information for tune footprint analysis, printed at each turn during the INITIAL 6+1 TURNS.								
* Each particle is printed with its ID# number and a Status Flag named lost_or_alive with values 0=lost or 1=alive.								
* Turn	ID#	alive?	x	xp	y	yp	z	dp
1	15	1	0.4320E-04	-0.4747E-05	0.3102E-04	0.7990E-06	-0.2098E-01	0.1678E-03
2	15	1	-0.2030E-04	0.6520E-05	-0.2463E-04	0.1504E-05	-0.1889E-01	0.6309E-03
3	15	1	-0.3234E-04	-0.5690E-05	-0.2568E-04	-0.7035E-06	-0.1456E-01	0.1019E-02
4	15	1	0.5376E-04	0.2326E-05	-0.9484E-06	-0.2328E-05	-0.8511E-02	0.1287E-02
5	15	1	-0.4728E-04	0.4076E-05	0.1579E-04	-0.2071E-05	-0.1455E-02	0.1403E-02
6	15	1	0.1341E-04	-0.6700E-05	0.2146E-04	-0.1058E-05	0.5774E-02	0.1353E-02
7	15	1	0.3275E-04	0.5704E-05	0.3954E-04	0.7765E-07	0.1232E-01	0.1143E-02
1	30	1	0.3536E-03	-0.2107E-05	0.5848E-05	-0.1429E-05	-0.6377E-02	0.1957E-03
2	30	1	-0.2796E-03	0.2581E-04	0.1742E-04	-0.1415E-06	-0.5004E-02	0.3279E-03
3	30	1	0.9965E-04	-0.4015E-04	0.4645E-05	0.1076E-05	-0.3039E-02	0.4213E-03
4	30	1	0.1130E-03	0.3935E-04	-0.1134E-04	0.4058E-06	-0.7146E-03	0.4649E-03
5	30	1	-0.2749E-03	-0.2607E-04	-0.1556E-04	-0.1098E-05	0.1694E-02	0.4535E-03
6	30	1	0.3509E-03	0.4858E-05	-0.5725E-06	-0.1160E-05	0.3903E-02	0.3885E-03
7	30	1	-0.3189E-03	0.1827E-04	0.1788E-04	-0.1240E-05	0.5650E-02	0.2776E-03
1	45	1	-0.9567E-04	-0.8397E-06	0.3285E-04	-0.1914E-05	-0.2013E-01	-0.8123E-03

### cmad\_out\_130\_tunes\_footprint\_final.dat

This file and the previous are used for tune footprint analysis as shown in Figure 2. For each particle, the tunes are calculated according to [1]. Beam particles are printed turn by turn for the last 7 turns in this file (and the first 7 turns in the file just above). Typically, the information of 20,000 is printed. Each particle phase space is plotted for 7 turns (first column) that are shown consecutively in the file. Each particle has an ID number (second column) and a particle status flag (third column) is also shown.

Here an example of the output file where two particles are shown for the last 7 turns:

**/global/u1/m/mpivi/codes/cmad\_mpi\_testing/cmad\_CESRTA\_2085mev\_5e12/cmad\_out\_130\_tunes\_footprint**

% Beam particles BPM signal information for tune footprint analysis, printed at each turn during the LAST 6+1 TURNS.  
 % Each particle is printed with its ID# number and a Status Flag named lost\_or\_alive with values 0=lost or 1=alive.  
 %

% Turn	ID#	alive?	x	xp	y	yp	z	dp
250	2	1	0.1593E-04	0.2912E-05	-0.9663E-04	-0.8690E-05	-0.4138E-03	0.7648E-04
251	2	1	-0.2688E-04	-0.1419E-05	0.1387E-03	-0.3529E-05	-0.1107E-15	0.8129E-04
252	2	1	0.2901E-04	-0.4974E-06	-0.1607E-04	0.1111E-04	0.4138E-03	0.7648E-04
253	2	1	-0.2283E-04	0.2201E-05	-0.1184E-03	-0.5648E-05	0.7787E-03	0.6263E-04
254	2	1	0.1051E-04	-0.3264E-05	0.1163E-03	-0.5266E-05	0.1051E-02	0.4138E-04
255	2	1	0.4079E-05	0.3470E-05	-0.2880E-05	0.1051E-04	0.1200E-02	0.1523E-04
256	2	1	-0.1726E-04	-0.2796E-05	-0.1102E-03	-0.5582E-05	0.1207E-02	-0.1272E-04
250	19	1	-0.1975E-03	0.3210E-05	0.8302E-04	-0.3776E-05	0.2267E-01	-0.6648E-03
251	19	1	0.1544E-03	-0.1510E-04	0.1927E-04	0.9179E-05	0.1795E-01	-0.1137E-02
252	19	1	-0.5710E-04	0.2270E-04	-0.1350E-03	-0.9532E-06	0.1110E-01	-0.1474E-02
253	19	1	-0.4319E-04	-0.2310E-04	0.7398E-04	-0.9283E-05	0.2942E-02	-0.1637E-02
254	19	1	0.1241E-03	0.1848E-04	0.5120E-04	0.1012E-04	-0.5566E-02	-0.1607E-02
255	19	1	-0.1796E-03	-0.1011E-04	-0.1335E-03	-0.2654E-05	-0.1342E-01	-0.1386E-02
256	19	1	0.1986E-03	-0.3232E-06	0.1069E-03	-0.6857E-05	-0.1968E-01	-0.1002E-02
250	97	1	0.1205E-03	-0.4408E-04	0.7168E-04	-0.4110E-05	0.2979E-02	-0.2746E-03

### **cmad\_out\_114\_particles\_distributions\_last\_turn.dat**

Print the last turn information for all the survived particles in the bunch. This file can be rather large.

### **cmad\_out\_114\_particles\_distributions.dat,**

### **cmad\_out\_114\_particles\_distributions\_turns\_200\_to\_400.dat and**

### **cmad\_out\_114\_particles\_distributions\_turns\_400\_to\_600.dat**

Print 2,000 beam particles for 200 turns. The first file prints for the first 200 turns then more files are printed according to the final number of turns.

### **cmad\_out\_114\_particles\_losses.dat**

Print the information about each lost particle.

### **cmad\_out\_118\_e-distribution.dat**

Initial electron cloud distribution and physical grid limits information.

## Appendix A

### Instructions to easily extract the optics files from MAD

C-MAD uses two output files extracted from MAD.

It is possible that the optics files for the machine that you are going to simulate are in our Archive. Please, look into the directory “\cmad\Optics\_Files” for the optics file with machine names.

In case you find the two files “\_sectormap.dat” and “\_optics.dat” with the name of your machine, copy them in the “\Optics\_Files” sub-directory located in your main directory. Then you can skip the rest of this all paragraph.

IMPORTANT: In the “optics.dat” file, the line with the NAMES should be the first one.

If you don’t find the two files then you need to run the MAD lattice again (or contact [mpivi@slac.stanford.edu](mailto:mpivi@slac.stanford.edu) for help).

Let’s go.

You will either have a MAD8 or a MADX lattice file.

Two files come with C-MAD and you can find them in the “\Optics\_Files” subdirectory: “MAD8files4CMAD.mad8” and “MADXfiles4CMAD.madx”.

1. **Copy those files into new directories**, for example respectively in:  
     C:\Program Files\mad\mad8  
     C:\Program Files\mad\madx
2. **Copy the respective following line in the MAD8 (or X) lattice file after the line containing the “USE” command:**

CALL, FILENAME="C:\\Program Files\\mad\\mad8\\MAD8files4CMAD.mad8"

**or**

CALL, FILE="C:\\Program Files\\mad\\madx\\MADXfiles4CMAD.madx"

3. **Then run MAD.** The run should generate two optics files:

1. \_optics.dat
2. \_sectormap.dat,

**Rename those files** with more practical names like "CLIC\_optics.dat"  
 "CLIC\_sectormap.dat" to be used then in the C-MAD input file.

4. **Copy them in the “\Optics\_Files” sub-directory located in your main working directory.**

**Important: notes about dealing with Optics Files**

Warning: in the \_optics.dat file, it may happen that some of the element names are too long and they are not included in “”. Example: “QUAD1\_SWT1\_R6 instead of “QUAD1\_SWT1\_R6”, Please make sure that all the names are delimited by “ “.

## Appendix B

### RF CAVITIES

C-MAD includes the option to track the beam both with the RF cavities turned ON or OFF in the MAD file.

If the RF is ON, the matrix element R65 of the cavity is non-zero. C-MAD evaluates the matrix elements R65 and automatically detects if the RF cavities were turned ON/OFF.

**IMPORTANT:** if the RF is turned ON in the MAD file, the user need to be sure that the RF cavity parameters, like VOLT, LAG, HARMON etc. are well defined in the MAD file.

NOTE: Since there is no mechanism of energy loss in the ring in C-MAD yet, the NET energy gain in a RF cavity is set to 0 by default in C-MAD, (this corresponds to setting the kick element vector  $E(6)=0$  in the sectormap file) while the synchrotron oscillation is correctly ON (this corresponds to the R65 matrix element). Thus meaning there is no net energy gain by the beam, but the beam particle experience the synchrotron oscillation correctly. Here, the synchrotron oscillation is linear around the reference particle.

## References

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- [1] A.U. Luccio and N. L. D’Imperio “Eigenvalues of the One-turn Matrix”, Brookhaven National Laboratory Note: C-A/AP/#126, December 2003.