MADX status and plans

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MADX status

MADX is a code used to design, optimize and operate many accelerators:

Not exhaustive list: CERN: PSB, PS, SPS, LHC, FCC-ee, FCC-hh, AD, ELENA, LEIR, transfer lines,…; BNL: RHIC, IEC; …

MADX contains the following modules:

TWISS	EMIT	DYNAP
TRACK	APERTURE	TOUSCHEK
SURVEY	IBS	CORRECT
MATCH	MADX-PTC	PLOT

MADX development is coordinated by CERN at cern.ch/madx and driven by the community of users and developers.

MADX structure

The code is written in C/C++/Fortran and open source.

It can be compiled as a standalone executable for Linux/Windows/Mac and as a shared library.

It can be used:

1) to run scripts, 2) interactively executing commands or 3) from Python using the cpymad[1].

In short:

- Machines can be described and sequences or lines of elements, values can be associated to variables and deferred expression.
- Physics modules use a machine description to calculate beam dynamic quantities and populate tables.
- Variables, tables, sequences can be imported, manipulated and exported by user scripts or other modules.

[1] Thomas Gläßle

MADX modules (1)

Module	Descriptions
TWISS	Compute orbit (w radiation), 2nd order transfer maps, 4D Twiss parameter (E-T[1] formalism, sigma matrices using M-R[2]), synchroton radiation integrals[3]
TRACK	Fast symplectic particle tracking with radiation, customized dynamic effects
EMIT	Compute damping terms,equilibrium emittance from 2nd order transfer maps w radiation
MADX-PTC	Uses PTC (recent version) to compute orbit, nth order transfer maps, with radiation, 6D Twiss parameters, normal form analysis, spin tracking

[1] D. A. Edwards and L. C. Teng (1973) Parametrisation of linear coupled motion in periodic systems
[2] G. Ripken and F. Willeke (1988) Methods of Beam Optics but without implementation of solenoid correction.
[3] J. M. Jowett (1986) Introductory statistical mechanics for electron storage rings

MADX modules (2)

Module	Descriptions
SURVEY	Compute machine geometry
TOUSCHEK	Use TWISS to compute lifetime and scattering rates due to Coulomb scattering
IBS	Use TWISS to compute IBS emittance growth due to Coulomb scattering
DYNAP	Use TRACK to compute footprint, smear, Lyapunov exponents
APERTURE	Use TWISS to calculate aperture dimensions in beam std sizes
CORRECT	Use beta functions from TWISS to correct orbit

MADX modeling

Modeling Feature	Twiss	Track	Emit	MADX-PTC
Uniform Solenoid	Y	Y	Y	Y
Multipole errors	Y	Y	Y	Y
Misalignments	Y (first order)	Y (first order)	Y (first order)	Y
Hard edge fringe	Y (bends, sol., RF)	Y (dipole, sol., RF)	Y (dipole, sol., RF)	Y [1]
Ref. frame changes	Y (first order [2])	Y (exact)	Y (first order [2])	Y
Ideal tapering	Y	Y	Y	Y [3]
Radiation	Y (closed orbit only)	Y [4]	Y [4] (no beam-beam)	Y
Beam-beam 4D	Y	Y	N	Y
Spin and polarization	N	N	N	Y

[1] not all flavors available in PTC can be used.
[2] to be extended, work in progress T. Persson
[3] ktap is transferred to PTC, but PTC internal tapering not used

[4] Solenoid with large divergence is being validated (A. Latina, T. Persson).

Developments for FCC-ee

Activities	Twiss	Track	Emit	MADX-PTC
Testing/benchmarking solenoid/radiation/tilt	In progress	In progress	In progress	Not planned
Hard-edge and/or soft edge fringes for quadrupoles, h.o., RF cavities	Potential interest	Potential interest	Potential interest	To be better documented
Generalized multipoles	Potential interest	Potential interest	Potential interest	Not planned
Beam-beam 6D	Not planned	Not planned	Not planned	Not planned
Photon tracking	Not planned	Not planned	Not planned	Not planned
Spin	Not planned	Not planned	Not planned	Enhance

MADX goals and direction

MADX is an essential strong dependency for many activities:

- MADX supported for all current use cases.
- Backward compatibility kept, unless in exceptional case (feature not used in production, important bugs leading to wrong/misleading results). Better interfaces should be added in parallel.

Sometimes new and old users find difficult to understand what the code does and how to control it to obtain the wanted behavior.

- Effort to add a coherent physics manual and improve the user manual.

MADX to continue to be user and developer driven.

- CERN maintainers will encourage collaborations and open to new feature (unless introducing breaking changes or performance penalties)
- Basic support to developer will be given, but integration and compatibility testing is responsibility of the developers.
- MADX to be highly compatible with the Python scientific software stack to support the growing Python community.
- Focus on physical core modules and compromises on non-physics functionalities.

MADX potential activities in 2022

- Maintenance
  - Triage issues. Reply to questions. Basic support to developers. Merge pull requests. Maintain continuous integration tools. Tag and build releases.
- Development
  - Documentation: improve coverage, correctness, coherence of the user manual. Release a physics manual based on MAD8 physics guide.
  - Support FCC studies: radiation validation, enhance control of spin tracking in PTC.
- Other potential developments:
  - support of overlapping elements
  - additional fringe field models, generalized multipoles
  - improve state exchange with Python tools