Mad-X a worthy successor for MAD8?

F. Schmidt

CERN, 1211 Geneva 23, Switzerland, Tel: ++41-022-7675245, Frank.Schmidt@cern.ch

Abstract

MAD-X is the successor at CERN to MAD-8, a program for accelerator design and simulation with a long history. We had to give up on MAD8 since the code had evolved in such a way that the maintenance and upgrades had become increasingly difficult. In particular, the memory management with the Zebra banks seemed outdated. MAD-X was first released in June, 2002. It offers most of the MAD-8 functionality, with some additions, corrections, and extensions. The most important of these extensions is the interface to PTC, the Polymorphic Tracking Code by E. Forest. The most relevant new features of MAD-X are: languages: C, Fortran77, and Fortran90; dynamic memory allocation: in the core program written in C; strictly modular organization, modified and extended input language; symplectic and arbitrary exact description of all elements via PTC; Taylor Maps and Normal Form techniques using PTC. It is also important to note that we have adopted a new style for program development and maintenance that relies heavily on active maintenance of modules by the users themselves. Proposals for collaboration as with KEK, Japan and GSI, Germany are therefore very welcome.

Key words: Accelerator Optics Design, Symplectic Integrator, Normal Form Analysis
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1 Introduction

Originally it was planned to replace the MAD8 [1] code by a C++ version called MAD9 [2]. A project like this made sense at the time since MAD8 had become unmaintainable due to its complexity and its old fashioned structure all written in FORTRAN77. This grand new start was intended to make use of the powerful C++ object oriented tools for a transparent code structure, very general and flexible element and lattice description and making use of modern Normal Form techniques. In practice, it turned out that the MAD9 structure was so complex that bug fixes became very time consuming. Moreover there were serious timing issues that could not be resolved leading to very slow performance of the code compared to MAD8.

Table 1
Module Keepers, People in RED are collaborators from outside CERN

Module	**Description**	**Keeper**	**Status**
C6T	SixTrack [3] Converter	F. Schmidt	Ok
CORORBIT	Orbit Correction	W. Herr	OK
DYNAP	Tracking Postprocessing	F. Zimmermann	OK
EMIT	Emittance, Radiation	R Assmann	OK
ERROR	Error Assignment	W. Herr	OK
IBS	Intra-Beam Scattering	D. Brandt	OK
MAKETHIN	Thinlens Converter	H. Burkhardt	OK
MATCH	Matching Procedures	O. Brüning	OK
PLOT	Plotting	T. d'Amico	OK
PTC_NORMAL	Normal Form Coefficients	A. Bolshakov	prepared
PTC_TRACK	Thicklens Lattice Tracking	A. Bolshakov	prepared
SURVEY	Machine Survey	A. Verdier	OK
SPACE-CHARGE	Space Charge Effect	O.Boine Frankenheim	planned
SXF	Standard eXchange Format [4]	F. Pilat	OK
TOUSCHECK	Touscheck Effect	C. Milardi	prepared
THREADER	Beam Threading	T. Risselada	OK
TWISS	Optics Parameters	F. Schmidt	OK
THINTRACK	Thinlens Lattice Tracking	A. Verdier	OK

After many months of futile attempts to make use of MAD9 to do the much needed LHC design and simulation studies the LHC optics design team decided to look for an alternative. A crash program was started to rewrite MAD8 with a core program written in C with interfaces to independent modules written in either C or FORTRAN. In the summer of 2002 a first version of MAD-X [5] was released. In the meantime the code has matured to fully cover all issues concerning the LHC. The first section describes the present status of MAD-X proper.

Structurally and concerning the physics MAD-X offers nothing new with respect to MAD8. In particular Normal Form tools cannot be easily added. Moreover, we have suppressed all problematic modules like the thick lens tracking and modules needed for small machines, which had to be omitted due to lack of symplecticity. To overcome this deficiency we have linked MAD-X with the PTC [6] code described in the second section.

Lastly, the future plans for MAD-X are outlined.

2 Mad-X proper

The main new features of MAD-X can be summarized as follows:

- Core part in C with dynamic memory allocation.
- Truly independent modules with interfaces to the core for data access.
- Making use of existing and debugged modules of MAD8 in Fortran77.
- Retaining only those features of MAD8 that are sound and concentrate on those modules that are needed for the LHC design.
- Use PTC for small machines and Normal Form calculations.
- Adding constructs to the input language like: WHILE and IF .. ELSE .. ENDIF .
- Powerful "macro" structures.
- Improved table handling.
- CVS version management.
- Linux, MAC and Windows versions available.

In the past CERN has assigned considerable manpower for writing accelerator design codes. For MAD-X it was decided to replace this dedicated person by a team of module keepers which still represents a substantial amount of manpower, but less work for the individual module keeper. In addition, there is one MAD-X custodian who is responsible for the overall functioning of the code. We expect that this team approach of module keepers, who are mostly themselves active users of their module, will lead to faster bug fixes and better, more usable modules.

In Tab. 1 a list is given of all relevant modules with name, purpose and module keeper (people in "red" are collaborators external to CERN).

On the MAD-X website [7] one can find a "News" link which shows the changes between versions, the documentation based on "html" files and derived from them a "ps" and a "pdf" version, a "Keyword and Subject Index", a link to "Source and binaries" and one link to "Examples" for all modules and a facility to report bugs found in MAD-X by its users. Lastly, one can subscribe to a MAD-X newsgroup and a mailing list.

3 PTC

E.Forest's Polymorphic Tracking Code PTC [6] is a kick code or symplectic integrator and therefore ideally suited to describe all elements symplecticly and to arbitrary exactness. The degree of exactness is determined by the user and the speed of his computer. The code is written in an object oriented fashion using Fortran90. Therefore, it becomes much easier to describe arbitrarily complex accelerator structures. The other main advantage is that the code is inherently based on the map formalism [8] and provides MAD-X with all the associated tools.

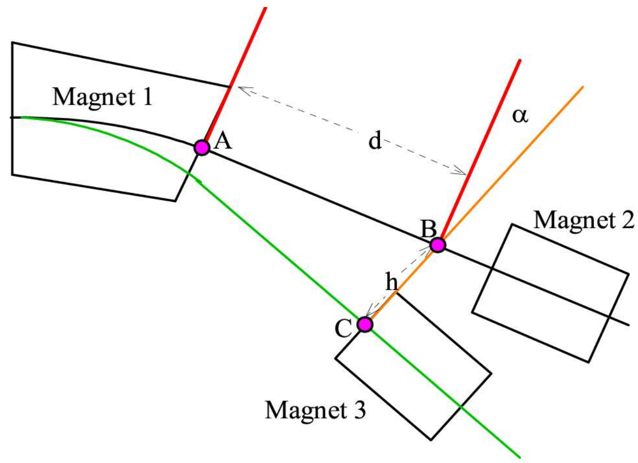

Fig. 1. Patching 2 Beam Lines (taken from Ref [6])

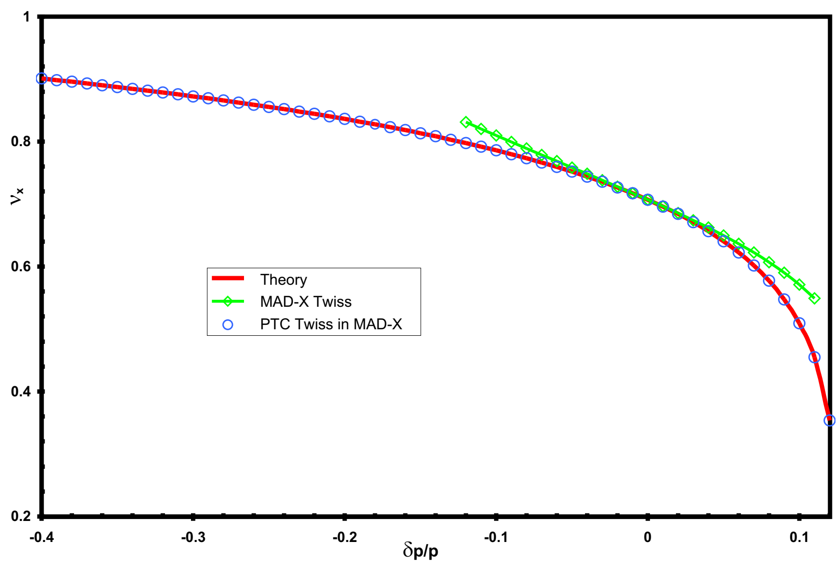

Fig. 2. Off-momentum tune of simple cyclotron.

One particular advantage is the fact that PTC allows to treat more complex beam line arrangements that can no longer be described by a simple sequence of elements. Fig 1 shows an example in which the beam comes back to the same element but with a different energy. PTC handles all the coordinate system transformations by a built-in "patch"ing mechanism.

PTC allows to treat elements correctly even for very large momentum deviations. This becomes apparent in the simple cyclotron example that can be described analytically. The authors of Ref [9] have demonstrated that MAD8 disagrees at large momentum deviation. In Fig 2 one finds the same problem with MAD-X. However, using the very same MAD-X input file as an input for PTC, one can perfectly reproduce the analytical result.

4 Outlook

The latest MAD-X version V2.11 is quite mature for the LHC design work. There is however still a significant effort needed to guarantee full integrity of the code, in particular concerning memory management issues. The main upgrade path is to make full use of PTC which is now solidly linked to MAD-X. In particular, it is planned to use nonlinear coefficients calculated with PTC in the MAD-X matching.

References

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