

STATUS OF TRACEWIN CODE*

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Abstract

Well known in the community of high-intensity linear accelerators, the transport code TraceWin is able to simulate a beam from the source to the target using either simple linear model or multiparticle simulations including 2D or 3D space-charge. Continuously developed at CEA Saclay since 15 years, it is today the reference code for projects such IFMIF, ESS, MYRRHA, SPIRAL2, IPHI, SARAF... The accuracy of his predictions associated with an original and powerful GUI and its numerous features have made its success, with a community of 200 users worldwide in 45 laboratories. It is now used on a larger perimeter that its initial skills. The aim of this paper is to summarize the TraceWin capabilities, including implemented last ones.

INTRODUCTION

The TraceWin code was initially developed to fulfil the special requirement of high intensity linear accelerators. It has been maintained by CEA Saclay, France for more than 15 years. Since 2009, it is distributed under a CEA commercial license, required for each identified user to pay an annual symbolic financial contribution. Due to this special status allowing users to request specific developments and our willingness to help them as fast as possible, the code has been gradually enriched with new features and advanced tools to finally become a global tool box oriented to accelerator design and realistic simulations.

One of the main specificity of TraceWin, probably unique in the plethora of existing codes, is to make possible to run different models with various levels of sophistication. Thus, model complexity can be gradually increased from envelope optic with hard edge linearized elements and space-charge to massive tracking 3D simulations using PIC space-charge, field maps, and use of automatic tuning procedures in realistic (imperfect) accelerators.

MAIN FEATURES

Software

Six versions of the software are available for 32 and 64 bits Mac, Linux and Windows operating systems. They all use common very powerful GUI, figure 1, allowing to compute, print and plot all quantities of interest of the accelerator and the beam. A free limited version for test or the last full version release can be downloaded at <http://irfu.cea.fr/Sacm/logiciels/index3.php>. Six associated batch versions and a dedicated server allow automatic run of the code on a multicore computer network.

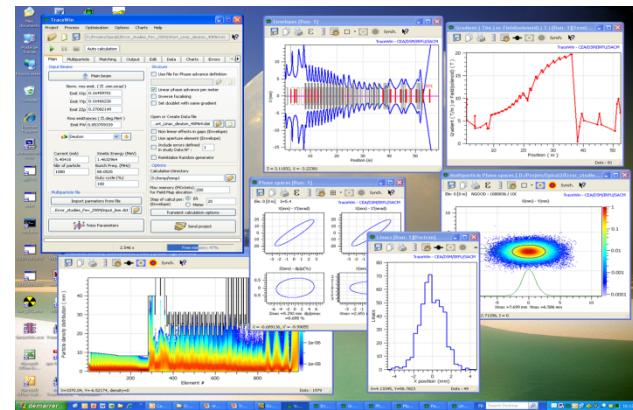


Figure 1: TraceWin screenshot example.

Even if originally dedicated to high intensity proton linacs, it is today used for more exotic applications, like electron machine, spectrometer, ILC IP [1]... A simulation with up to 10^8 particles can be easily made on a multicore desktop in one day.

TraceWin Main Features

Here are the main features of TraceWin code:

- a full documentation including examples,
- electrons and ions transport, with distribution generated/red in several format,
- envelopes and macro-particle tracking modes on multi-core machines,
- fully compatible with the free independent beam plot/analysis tool: PlotWin [2],
- a wide range of elements (see next page) with possible user-defined ones,
- linear and PIC 2D and 3D space-charge routines with possible user-defined ones,
- automatic beam tuning procedures (possibility to use diagnostics),
- dynamics charts allowing to visualize machine and beam behaviors during matching and tuning,
- beam scattering on residual gas,
- H- stripping on residual gas or in magnetic field,
- possible transport of two beams in the same structure,
- exhaustive error studies using a Monte-Carlo approach, based on a client/server architecture and a statistical analysis module,
- Halo [3] and beam loss analysis with location of particle loss.
- transient time module (figure 2),
- acceptance calculation,
- Hofmann stability diagram.

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List of Supported Elements:

- 1-2-3D static and RF overlapping field maps,
- Drift Tube Linac (DTL),
- Coupled Cavity Linac (CCL),
- Radio Frequency Quadrupole (RFQ) with Toutatis module [4],
- solenoids,
- magnetic and electrostatic dipoles and quadrupole including higher order components,
- magnetic and electrostatic steerers,
- electrostatic accelerating structure,
- vertical and horizontal slits (scare or circular),
- pepper pot,
- various types of diagnostics,
- user-defined elements.

BENCHMARKING

TraceWin have been benchmarked with numerous other codes such as Track (Spiral2, MYRRHA), Parmila (SNS, Unilac) [5], PATH (Linac4), IMPACT (Unilac) [6], LORASR (MYRRHA) [7], Dynac (ESS)[8], Zgoubi (S3), DYNAMIONS (Unilac) [9].

Some code versus experiment comparisons show also good agreement [10, 11].

SOME RECENT EXAMPLES

Transient Simulations

Develop for high reliability ADS program, this new feature allows to simulate the impact on the beam of the field variation in the cavities during their filling/decay times and/or the beam current pulse, using a resonator model including beam loading and LLRF response. This tool was used in order to better understand the beam transient behaviours during RF cavity faults, and the right way to recover the correct output beam parameters without losses.

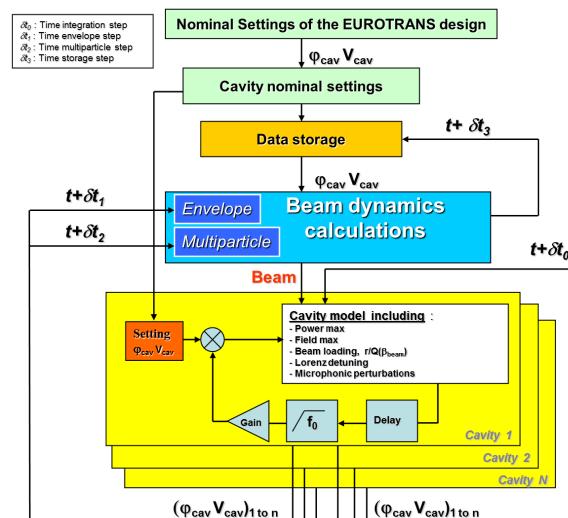


Figure 2: Algorithm of the transient tools.

5: Beam Dynamics and EM Fields

D11 - Code Developments and Simulation Techniques

These studies [12], see figures 3 & 4, have shown that fast returning system can be devised without interrupting the beam. The simulation of the whole MYRRHA linac in the first 10 ms after a cavity failure took ~22 hours.

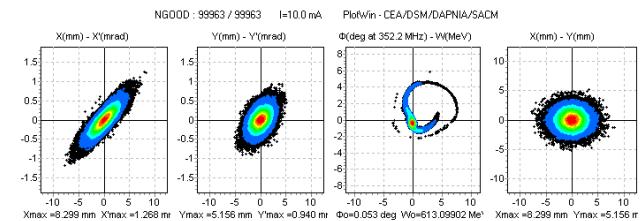


Figure 3: Output beam distributions of the MYRRHA accelerator 150 μ s after a RF cavity failure

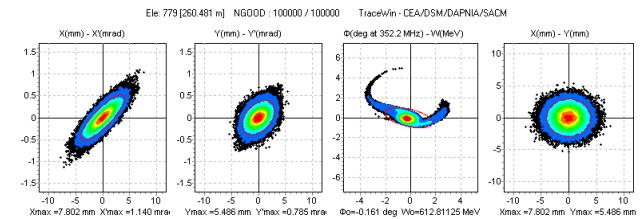


Figure 4: Output beam distributions of the MYRRHA accelerator 150 μ s after a RF cavity failure with compensation.

Error Study

An error study procedure consists in the large scale simulations of linacs combining different random errors on its elements (including diagnostics). Automatic correction schemes, coupling diagnostics with correction elements, can be applied to compensate static errors. Figure 5 & 6 shows the statistical consequences on random errors on beam power probability density and on particle losses probability. Figure 7 shows the particles input beam very close to the acceptance boundaries, explaining the observed losses. They are results of simulations of the transport of 3.10^6 macro-particles in 1000 imperfect linacs. The cumulative statistic (3.10^9 particles) represents about 17 beam bunches of the MYRRHA machine [13].

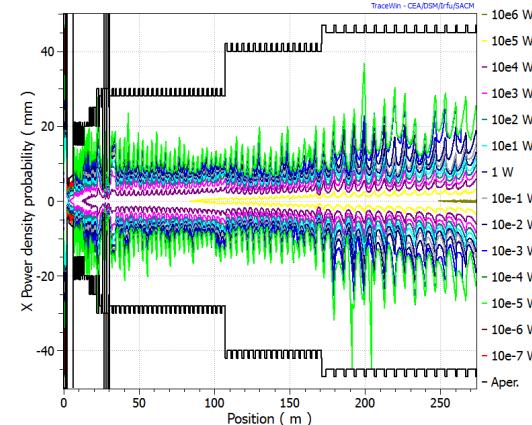


Figure 5: Beam radial power probability levels for the whole start to end MYRRHA linac.

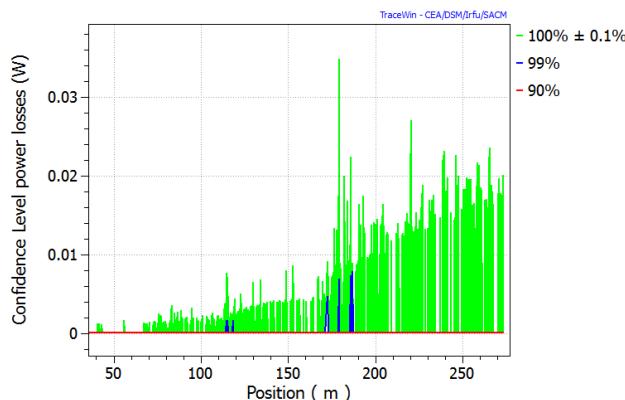


Figure 6: Probability of loss occurring during the set of 1000 simulations along the MYRRHA linac.

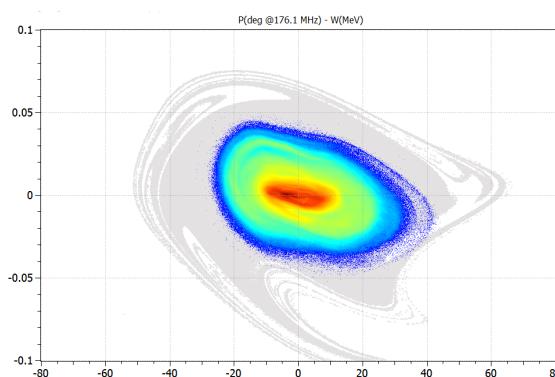


Figure 7: Longitudinal acceptance superposed with the particles input beam distribution.

One-to-one Particle-based Simulation

For the EVEDA project (125 mA, 9 MeV, deuterons) with the objective of very accurate study of the beam losses and halo formation, a start to end simulation has been performed with the same particle number as this in the real bunch, $4.8 \cdot 10^9$ (figure 8 & 9).

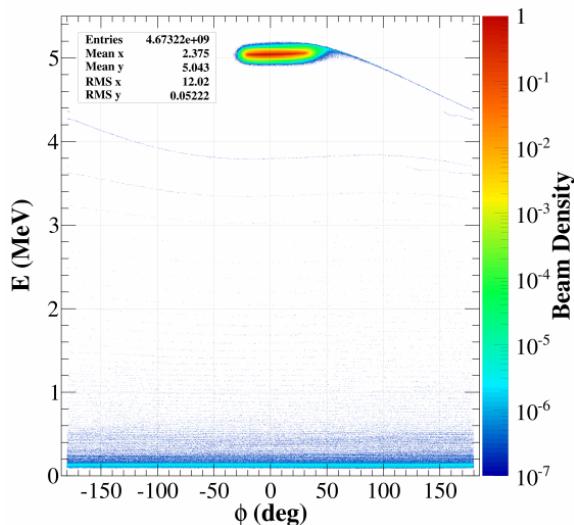


Figure 8: Longitudinal $4.8 \cdot 10^9$ particles density portrait at RFQ output.

One of the challenges was to cope with the 40 TBytes of beam distributions along the linac. The input distribution is given by a source simulation and all entire machine was described by 3D field maps. This simulation took ~ 15 days with 100 cores.

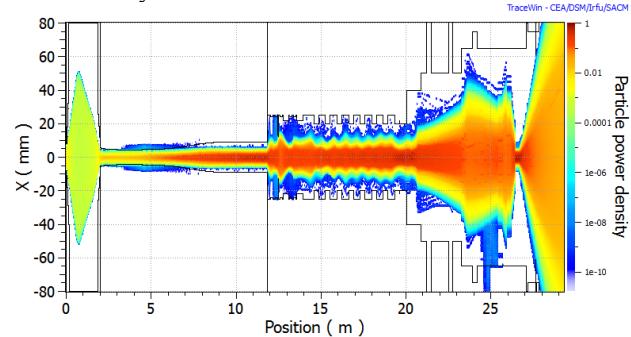


Figure 9: Horizontal beam distribution along the linac.

FUTUR DEVELOPEMENTS

TraceWin is regularly upgraded according to our and users needs, but the main next development, already started since few years, will be to finalize the connection with the EPICs control channel access to implement a “Virtual Accelerator” [14] in TraceWin.

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