NEW IMPLEMENT IN TRACEWIN/PARTRAN CODES: INTEGRATION IN EXTERNAL FIELD MAP

D. Uriot, CEA Saclay, 91191 Gif sur Yvette cedex, France,

N. Pichoff, CEA Bruyères-le-Châtel, BP 12, 91680 Bruyères-le-Châtel, France.

Abstract

The calculation of particle trajectories in external dynamic and/or static electromagnetic fields has been implemented in TraceWIN and PARTRAN codes [1]. The four field maps can be superposed. In TraceWIN (envelope code), the field is linearised around the synchronous trajectory. In PARTRAN, a RK4 integration in a measured or calculated field map is made. Results are produced for various projects like SPIRAL2, PISI and AIRIX.

INTRODUCTION

The TraceWIN/PARTRAN codes package has been developed in CEA and is used in various linac projects. TraceWIN is an envelope code capable to perform various functions like automatic matching or linac errors studies. It has a powerful and user-friendly interface. It is also able to run automatically PARTRAN and TOUTATIS, multiparticle codes and to process graphically its results [1].

Until then, both codes were using classical elements where the beam dynamic was issued from analytical calculations. Recent needs have pushed us to implement the dynamic of beams in external magnetostatic, electrostatic or electromagnetic field maps. These field maps can be 1D (on the axis in cylindrical symmetry, using an expansion of the field out of the axis), in 2D ((r,z) in cylindrical symmetry configuration or (x,y) in transverse fields), or in 3D. Moreover, these 3 kinds of field maps can be superposed.

These new possibilities have been extensively used recently:

- for SPIRAL2 project, to put in evidence the transverse kick of quaterwave resonator, and its coupling with solenoid focalisation.
- for PISI project, to calculate the extraction of a low current heavy ions beam from an electrostatic source, through a Einzel lens and a Wien filter,
- for AIRIX project, to calculate the transport of a 2 kA beam focalised with solenoids through an induction machine.

SPIRAL 2 PROJECT [2]

The proposed LINAG driver for the SPIRAL 2 project aims to accelerate a 5 mA D^+ beam up to an energy of 20 A.MeV and an 1 mA beam for Z/A=1/3 up to 14.5 A.MeV. It consists in an injector (two ECRs sources + Radio Frequency Quadrupole) followed by a superconducting section based on an array of independently phased cavities [3]. The QWR description is carried out by 3D electric and magnetic field maps. The transverse focalisation is carried out by superconducting solenoids described by a 1D magnetic field map. All the matching and correctors calculations between the four tanks have been performed using TraceWIN functionalities giving 1 mm misalignment error randomly distributed on cavities and solenoids. The final multiparticle simulation is made with PARTRAN. The simulation has been performed with a 100.000 macro-particles Gaussian distribution at the first tank input. The whole computation requires about half an hour, considering a two millimetres step for extern fields and one centimetre step for space-charge computations. Figure 1 shows transverse envelopes for the deuteron beam (green). The beam centroid motion due to the QWR steering and misalignment is clearly visible (pink).

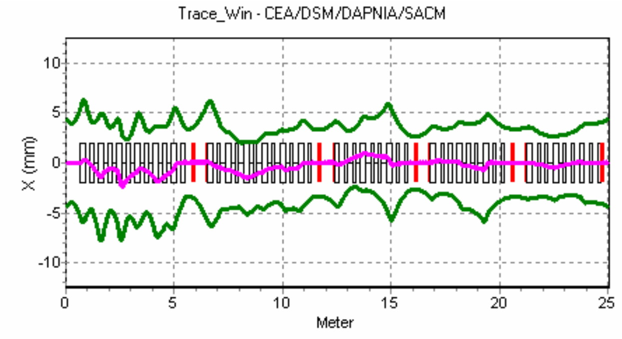

Figure 1: Transverse beam envelope behaviour

The multiparticle distribution along the structure is very close to the envelope behaviours (figure 2). The output space phase distributions are shown figure 3.

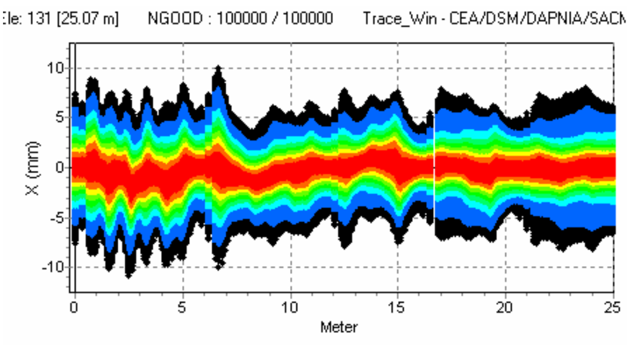

Figure 2: Transverse multiparticle distribution along the linac for deuteron beam.

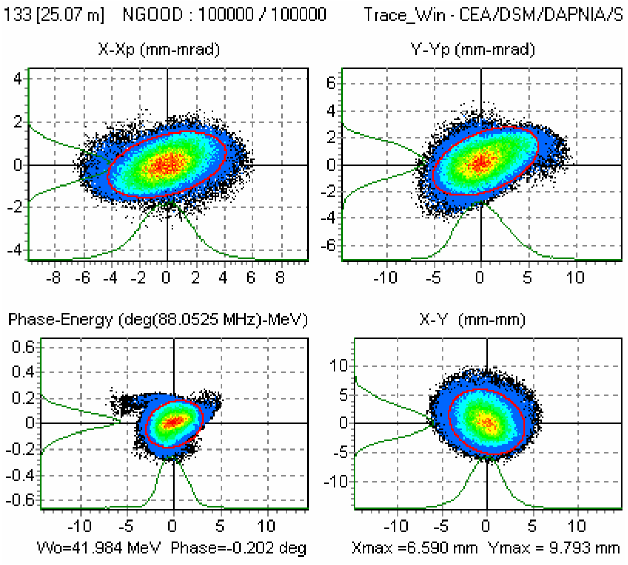

Figure 3: Output distribution for deuteron beam.

Most of emittance growth is due to the phase dependence kick in QWR and transverse solenoid coupling. And these effects are both visible in envelope and multiparticle codes.

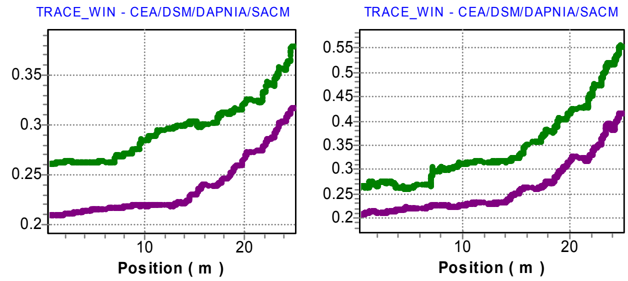

Figure 4: Transverse (violet) and longitudinal (green) rms emittance growths in envelope (left) and multiparticle simulation (right).

In this example, the full linac is described by field maps and the linac tuning computations have been performed with envelope formalism. The results stay very similar in multiparticle simulations allowing to save a lot of computation time.

PISI EXPERIMENT

PISI is an experiment which aims in measuring the photo-ionisation cross section of multi-charged heavy ions. The ions beams are produced with an ECR source. The beam is then focalised with an Einzel lens and goes through a Wien filter mass separator. The beam is then transported toward an “interaction region” where it is kept parallel to a photon beam delivered by the Super-ACO synchrotron light source.

The electrostatic field map in the extraction region has been calculated in 2D using POISSON code [4]. The beam is then transported in this map with PARTRAN. The influence of the source ions temperature and plasma potential has been evaluated.

The figure 5 represents the beam propagation through the extraction geometry of PISI source. The plasma temperature is 10 eV.

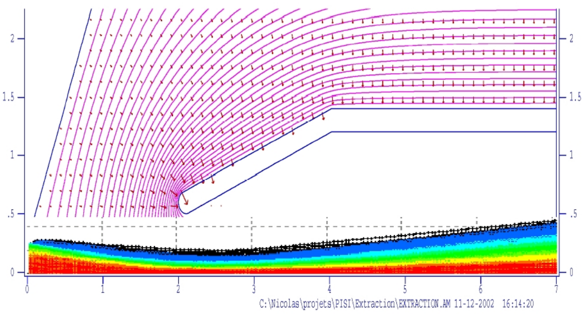

Figure 5: PISI source extraction configuration.

The beam output (x, x’) phase-space distribution is plotted in figure 6. In these conditions (very low beam current, and beam far from the extraction hole border), the larger contributor to the final emittance is the plasma temperature.

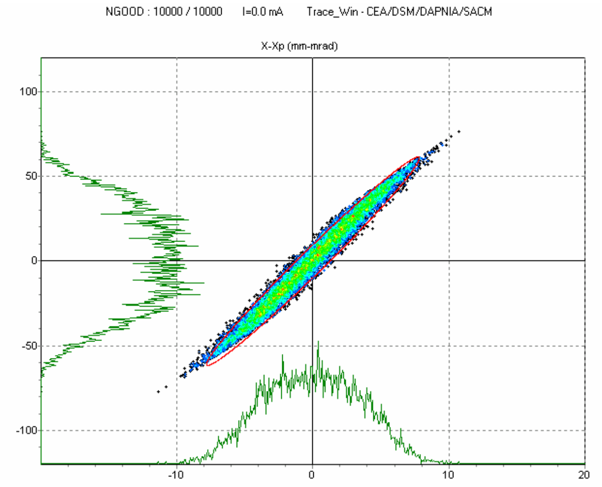

Figure 6: Output beam distribution in (x,x’) phase-space.

AIRIX LINAC

AIRIX [5] is a high current (up to 3 kA) electron linac aiming in x-ray production for radiography. The beam is produced by a 4 MV diode and accelerated to 20 MeV with induction cells. The transverse focalisation is done with solenoids. AIRIX has been successfully calculated and designed with an 1D envelop code, ENV [6]. Nevertheless, the measured focal spot is still bigger than the predicted one. This could arise from different effects which would not be taken into account with a simple 1D envelope model. For this reason, the calculation of AIRIX beam transport has been implemented in the TraceWIN and PARTRAN codes. The PARTRAN calculation has been done using 10,000 particles with a 2 mm step size. The field of the solenoids and the accelerating cells are superposed. The behaviour of the particle transverse distribution in the linac is plotted on figure 7. The beam is finally focused with a solenoid to a millimetric size.

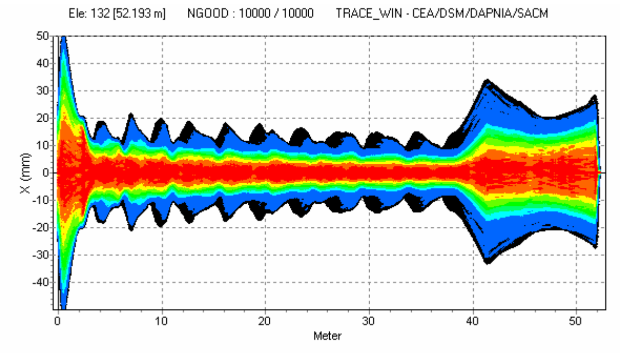

Figure 7 : Beam transverse distribution along AIRIX.

The behaviour of the 4D transverse rms normalised emittance is plotted on figure 8. The growth is about 60%, mostly at low energy. The beam size on target is about twice this obtained by 1D envelope code.

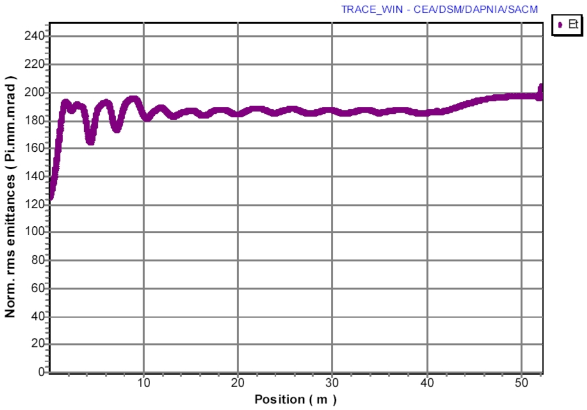

Figure 8: Emittance behaviour in AIRIX.

CONCLUSION

TraceWIN and PARTRAN codes now permit simulations in field maps keeping the user-friendliness and speed advantages of the TraceWIN envelope code. This new functionality has allowed to obtain a better representation of external fields in a linac, especially coupling terms and non-linearity.

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