APPLICATION OF LANA CODE FOR DESIGN OF ION LINAC [1]

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Abstract

The LANA (Linear Accelerator Numerical Analysis) computer code has been developed at the INR during 1991-1995. This code is designated for 3-dimensional beam dynamics simulation including space charge effects in DTL, CCL, IH and similar linear accelerating structures as well as for the design of an accelerator containing cavities of these types of structures. The accelerator design is performed in the two- or three-dimensional imported ”realistic” electromagnetic field distribution in the accelerating cells.

The fundamental concept of the LANA code from the very beginning of its development was to provide the fullest possibly graphical representation of the beam behavior during the simulation process. It opens an opportunity for understanding of the most complicated non-linear beam dynamics’ problems.

1 INTRODUCTION

The LANA code has been developed as a powerful tool to design and study of the beam dynamics in linear accelerators. The main purpose of the code is a design and simulation of the linacs that can be a combination of the different types of the accelerating structures.

The code has been programmed using FORTRAN programming language. LANA is a user friendly code -- the comments occupy about 20% of the total code FORTRAN text. The modular structure of the program permits to transfer the code to the different platforms. However, the graphical support has been developed for the IBM PC only in the present version of the code.

2 MODELS AND ALGORITHMS

A design of the longitudinal linac geometry is usually done by the code with assumption of so called “square wave” approximation of the accelerating field in the gaps. However, using 2-3 steps of the iterative procedure the geometry can be fully generated for self matched “realistic” field distribution. The simulation procedure can be performed both for the “square wave” field, or “realistic” distributions.

The realistic fields are to be calculated using some available electromagnetic codes like SUPERFISH for 2-D, MAFIA for 3-D or similar. The calculated fields distributions inside the aperture of the accelerating channel can be imported to LANA code. The certain coordinates are assumed for the points where the imported fields should be defined. These data are interpolated linearly on all three coordinates when they are needed during the simulation process.

2.1 Linac Structue Representation

The linac in the code is considered as a number of cavities with an independent rf power feeding. This means that the accelerating field amplitude and phase can be different in the sequential cavities. The linac to be simulated can be a combination of DTL, IH, CCL or any similar structure cavities. Each cavity can consist of several separate sections (modules). Focusing and/or magnet (for bending in horizontal plane) systems may be included in front of the first section and downstream each section. The focusing systems can consist of quadrupoles, solenoids and drifts. The magnet system besides the bending magnets by them self may include also stripper foils. The stripper foil is a thin element. The equilibrium charge state after stripping and the standard deviations for the scattering in the transverse plane and the energy spread in the longitudinal phase space must be defined as input parameters.

The dipoles, quadrupoles and solenoids are simulated using standard matrix formalism [1]. The simulation of the accelerating gap is done using formulas of the iteration procedure [2]. This procedure has been improved for the 3-D beam dynamic and space charge calculation.

2.2 Beam Representation

The LANA code uses a 3-dimensional multi-particle Monte Carlo model of the beam. All particles are traced separately sequentially and independently through the elements of the focusing and the magnetic systems, the drift spaces and accelerating cells.

The interaction between the charged particles is taken into account only in certain points along the accelerating cell or focusing element and is used as a constant up to the end of the current step. The space charge effects can be ignored in order to avoid long-time calculations for the low current beams. The 3-D space charge calculation is valid for bunched beams of ions. The method [3] is based on the analytic relations between charge density and electric fields for a distribution with 3-D ellipsoidal symmetry in real space.

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3 GENERAL ABILITIES

Flexible input and wide spectrum of the resources provided by the LANA code give an opportunity to perform the simulation of the beam dynamics according to the different assumptions and to estimate and compare the corresponding influences on the beam quality.. This feature permits to consider different aspects of the beam dynamic problem such as space charge effects, “realistic” fields distributions in the accelerating cells with axisymmetric or with arbitrary 3-D approximations and others.

The graphical interface permits to interact to the code very efficiently during the design and simulation process. Particularly this feature gives an opportunity to research the complicated beam dynamics outside the stable region limited by separatrix in the longitudinal phase space [4,5].

The Monte Carlo method and widely developed features for the statistical analysis allow to use this code as a perfect tool during the accelerator commissioning [6,7].

3.1 Main Opportunities Provided by the Code

The code performs the statistical calculations of the rms beam parameters by the first and second momentum analysis. The time-of-flight measurements are simulated by calculating the first and third harmonics of the longitudinal beam particles distribution at the destined points. The special technique originally proposed in [8] has been introduced for the tuning of the constant phase velocity accelerating structure for optimal beam dynamics.

A special algorithm has been developed for tuning of the transverse focusing structure in order to transport the beam accelerated to the intermediate energy through the accelerator. This kind of simulation is especially useful for turn-on procedures of the linac.

The code simulation permits to estimate the influence of accelerating field amplitude and phase errors on the beam dynamics.

The simulation session is always under user’s control and can be interrupted any time with further restart from the end of any fully simulated cavity. This feature permits to make the repetitive calculations quickly.

3.2 Avilable Output Information

Beam parameters are graphically displayed on the PC screen during the simulation process. This information includes the phase space distributions of the beam particles on each of three phase space planes and all maximal and rms envelopes transverse and longitudinal as well as the position and trace of the reference particle. All this information is renewed after simulation of each accelerating cell or of each element of the focusing or bending magnet systems situated between the accelerating sections.

The typical screen picture is presented in the fig.1. The cavity being simulated for this example is the first DAW cavity of the Moscow meson factory linac. The upper line shows the service information including the cavity and cell numbers, rf phase shift indicating scanning procedure, number of the particles being simulated and the beam average energy.

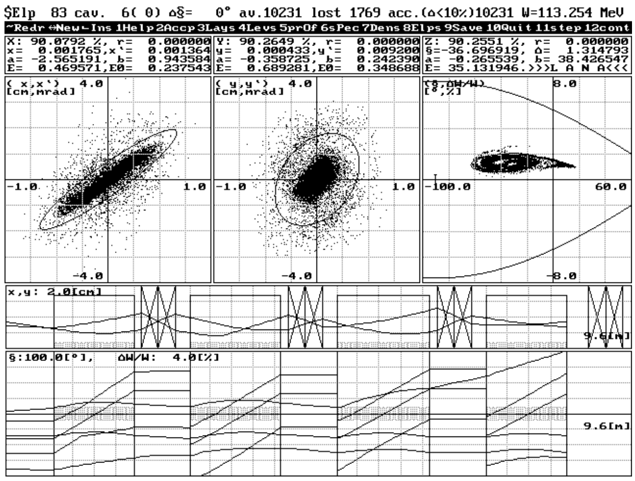

Fig.1 The typical graphical screen provided by the LANA code at the exit the first DAW cavity of Moscow meson factory linac.

By user’s request the code provides additional information concerning distributions of particles in the phase space at any above mentioned position of the information renewal. This numerical analysis information includes:

- rms ellipses for the whole beam or for a defined fraction of the beam for each phase space plane separately and “conservative” separatrix for the longitudinal plane which corresponds to the current synchronous phase and the accelerating field magnitude (which is shown in the fig.1),
- acceptance information - the initial phase space distributions of the particles that has been accelerated to the current position along the linac,
- profiles and spectra of the particles distributions in a form of the histograms,
- pictures of the density distributions for each phase space plane.

All this information is available both in the graphical form on the screen during the simulation and the text output files. The auxiliary information on the generated geometry, the phase scanning, the accelerating fields amplitudes and phases tuning, the transverse focusing tuning and so on is available in a form of text output files too.

4 COMPARISON WITH PARMILA

The comparison of the LANA simulation results with the PARMILA (LANL) calculations [9] have been done during the design of superconducting linac beam dynamic [10]. The phase space portraits at the end of the simulated linac for both codes are overlapping each other. The figures 2 and 3 show the PARMILA particles distributions and LANA rms ellipses.

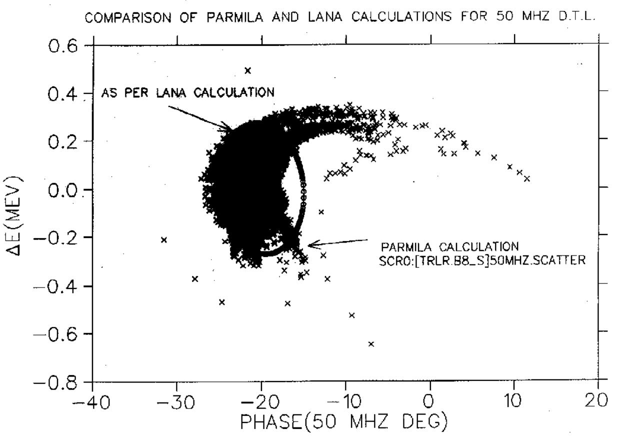

Fig.2 PARMILA's longitudinal phase portrait and LANA's rms ellipse. Preliminary design of the TRIUMF radioactive nuclei beams linac ISAC.

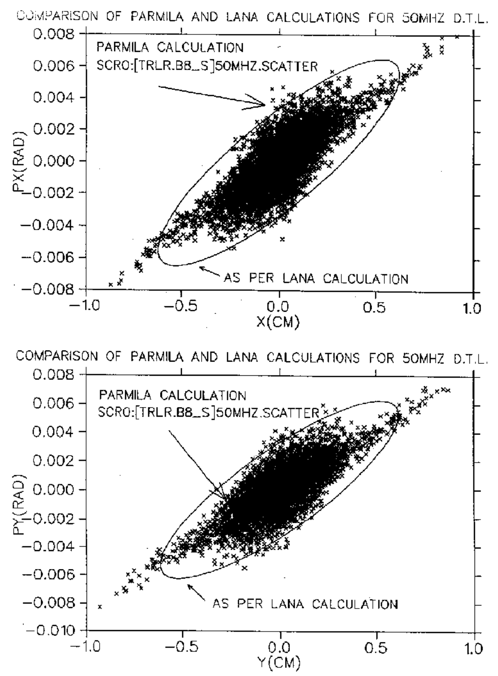

Fig.3 PARMILA's transverse phase portraits and LANA's ellipses. Preliminary design of the TRIUMF radioactive nuclei beams linac ISAC.

5 CONCLUSIONS

Indeed some of the calculations may be performed also by other codes developed for the linacs design, such as PARMILA (LANL), LORAS (GSI) and similar, but LANA's features like convenience of the PC use, the variety and the completeness of the design parameters and their display and graphical representation, the flexibility for input or intermediate data change and the simplicity of the dialog regime and the operator invention practically at any step of the procedure makes LANA more user friendly and provides the designer a better tool for deeper and fuller inside view and understanding of the beam dynamics during the process of the beam acceleration.

The LANA code is especially useful for studying the mostly complicated beam dynamics problems in linacs by novices.

Further development of the code LANA is in progress in order to cover the possibly widest range of simulations for different kinds of the linear accelerator structures.

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