

ON-LINE MODEL OF THE SNS MEDIUM ENERGY BEAM TRANSPORT LINE*

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Abstract

An on-line model of the beam dynamics in the SNS Medium Energy Beam Transport line (MEBT) has been developed using MATLAB Graphics User Interface. The model performs beam simulation using TRACE-3D and/or PARMILA codes. The input data for the simulation are generated on-line using settings of the transport line elements read from the EPICS control system. Simulated beam profiles are compared with wire scanner measurements on-line. Various tools are provided for estimating and fitting input beam parameters, which are not measured in the MEBT. This paper provides a description of the model and presents results of experimental tests during commissioning of the SNS Front End.

INTRODUCTION

The Front End Systems (FES) of the SNS accelerator is discussed in details elsewhere [1]. The medium-energy beam-transport section (MEBT) is part of the FES beam – line serving to transport 2.5MeV 38mA beam of H⁻ from the RFQ exit to the drift-tube linac (DTL) entrance. The MEBT is a fairly complicated 3.6m transport line consisting of 14 quadrupole focusing magnets, 4 buncher cavities, chopper system and suite of diagnostics devices.

The nominal transverse beam beta-function in the MEBT is not periodic but rather irregular with three distinct regions: input matching section of 4 quadrupole magnets, chopper section of 6 quadrupole magnets in a symmetric configuration and output matching section of 4 quadrupole magnets. Transverse beam size can be measured at 5 locations along the MEBT using dual plane wire scanners [2]. Longitudinal focusing is rather periodic. There are no in-line instruments for direct measuring of the longitudinal beam size. Space charge is strong enough to provide coupling between horizontal, vertical and longitudinal planes and must be taken into account in beam dynamics simulations.

During commissioning beam current and input beam Twiss-parameters in the MEBT can deviate significantly from the design values. Optical functions required for particular experiments can be different from the nominal one. Therefore an operator needs a beam dynamic simulation tool available on-line in the control room to facilitate tuning of the MEBT parameters. The MEBT on-line model was written in Oak Ridge and tested during the SNS FES commissioning. Details of the implementation and test results of the model are presented.

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

THE SNS MEBT ON-LINE MODEL IMPLEMENTATION

General Structure

The MEBT on-line model consists of graphical user interface (GUI) for controlling model parameters and representing output information; beam dynamics simulation engine performing actual calculation of beam dynamics; input/output module providing data exchange between the model and beam dynamics calculation engine; EPICS access library providing data exchange between the model and the accelerator hardware; and several high-level algorithms performing MEBT-specific functions described later. Schematic diagram of the model is shown in figure 1.

All elements except beam dynamics simulation engine are written in the MATLAB [3].

Beam Dynamics Simulation

The core of the on-line model is a beam dynamics simulation routine. In order to minimize development time and efforts we decided to use the same simulation codes that are used for the SNS linac design and off-line simulations within the SNS collaboration. For faster calculations TRACE-3D beam envelope code is well suited; particle-tracking code PARMILA can be selected for more accurate simulation. Operator using the GUI screen does selection of the simulation code. Standard TRACE-3D/PARMILA input and output files are used for data exchange between the model program and the simulation program. Simulation program is called from the MATLAB using the standard OS command call.

Communication with Accelerator Hardware

The MEBT on-line model can create input file for the simulation engine using input from the GUI or reading actual settings from the accelerator hardware. The GUI input can also be used for controlling settings of the quadrupole magnets and bunchers in the MEBT. Measured data from the wire scanners can be read into the model for comparison with simulation results. This type of data exchange is done through the EPICS control system using MATLAB Channel Access (MCA) library, which is supported for Linux and Windows operating systems [4].

HIGH LEVEL ALGORITHMS

What gives the on-line model its power and flexibility is the possibility to write data processing layer between

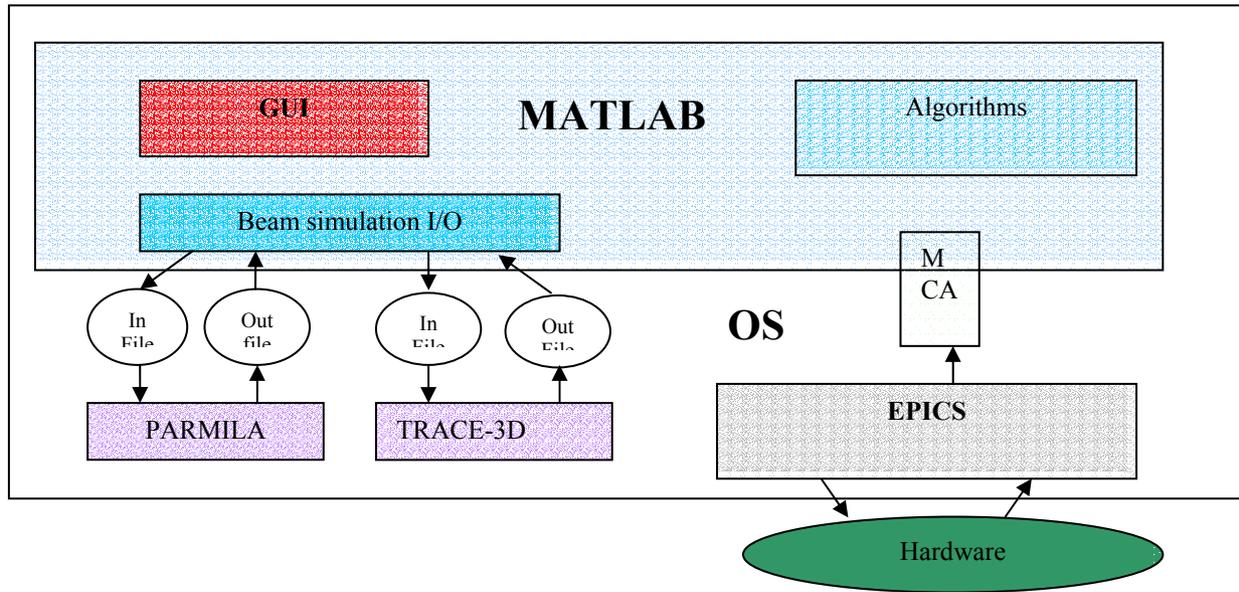


Fig 1 Schematic diagram of the MEBT on-line model.

the hardware and the simulation engine using very efficient MATLAB language. Using this mechanism one can include in simulation important hardware specific features, which is difficult or impossible to describe in terms of standard TRACE-3D or PARMILA input language. The same mechanism allows building of various optimization algorithms combining both measured and simulated data. There are two high level algorithms currently implemented in the MEBT on-line model: correction of quadrupole magnets strength due to proximity effect and input parameters search routine.

Correction of the Quad Proximity Effect

Quadrupole magnets surrounding chopper target in the MEBT are so close to each other that their fringe fields overlap. Correction to integrated focusing strength due to this effect is significant and has to be taken into account in simulation [5]. Unfortunately correction can't be described by static constant because it depends on the strengths of neighboring quads and should be calculated each time when current in the magnet coil is changed. Calculation of the correction term based on measured magnetic field distribution is included in the on-line model and can be switched on and off from the GUI.

Input Beam Twiss-Parameters Search

Twiss-parameters of the beam at the MEBT entrance are generally unknown. Those parameters are calculated using beam dynamic simulations but accuracy of the result can't be confirmed by direct measurements due to absence of any beam diagnostics upstream of the MEBT. This is a common problem in beam dynamic simulations because any model requires right input parameters in

order to produce results close to measured values. Simultaneous measurements of beam profile at 5 locations in the MEBT are used to find best approximation for the input parameters. Optimization algorithm embedded in the on-line model minimizes the difference between measured beam sizes and one calculated in beam simulation by varying input Twiss-parameters. Set of input parameters corresponding to the minimum difference is used in all subsequent simulations unless parameters of the beam line upstream of the MEBT change. When the ion source or RFQ settings change, optimization procedure should be repeated to find new set of input parameters. The procedure described above represents a way of indirect measurement of input beam parameters. In principle, it always converges to right values provided sufficient number of profile measurements along the beam line is available.

GRAPHICAL USER INTERFACE

The interface for the MEBT on-line model is written using the MATLAB and destined for the operative and convenient modeling of the beam dynamic both during the accelerator operation and for the theoretical researches.

Snapshot of the GUI screen is shown in fig. 2. The interface consists of two main parts: MEBT parameters values assignment and results representation. The quads strengths and cavities parameters can be read from file, loaded directly from the hardware or assigned manually

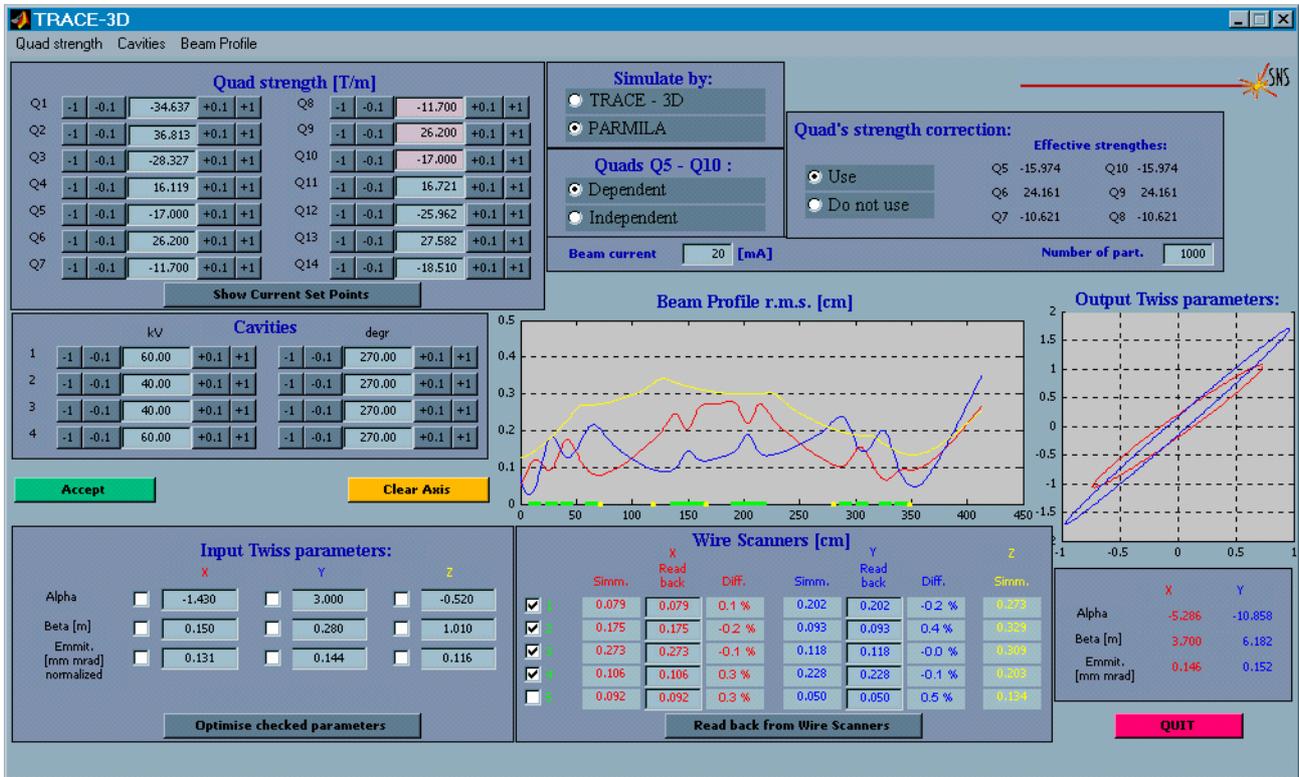


Fig. 2 GUI screen of the MEBT on-line model

by operator. The interface enables to choose the simulation code. The quad proximity effect correction can be switched on or off from the GUI. The calculated values of the beam profile can be compared with the measured ones. Optimal Twiss-parameters of the input beam can be found by fitting model prediction to the measured beam profiles.

CONTROL ROOM EXPERIENCE

On-line model proved to be a useful tool during the Front-end commissioning. Measured beam size agreed with model prediction within wire scanner measurement accuracy when initial Twiss-parameters for the model were found using the best fit to the measured data [1]. Accuracy of the fit is demonstrated in fig. 3, where spread of β and α found from the fit is shown.

ACKNOWLEDGMENTS

Many thanks to Ernest Williams and Carl Lionberger for help with implementation of reliable communication between MATLAB and EPICS.

REFERENCES

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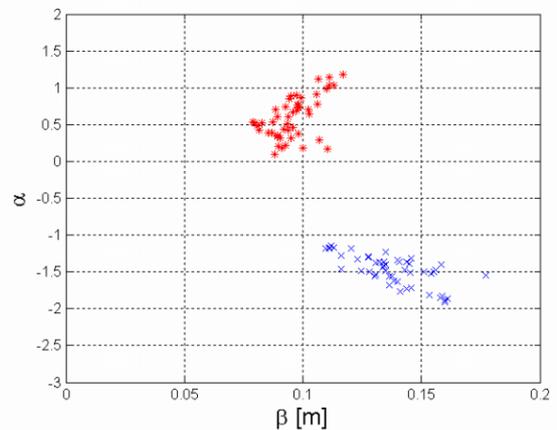


Figure 3. Spread of the input beam Twiss-parameters found using fitting algorithm for different MEBT settings. Red stars – vertical plane; blue crosses – horizontal plane.

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