BEAM SIMULATION AND MEASUREMENTS AT BEAM LINE TO RADEX EXPERIMENTAL AREA OF INR LINAC

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Abstract

In 2015 the Experimental Complex beam lines of INR linac were upgraded. There is a need to study beam dynamics in these lines. The results of beam simulation at beam line to RADEX experimental area and comparison with beam measurements are presented.

INTRODUCTION

INR linear accelerator is a high-current proton beam source for researches on nuclear physics and applied researches. The Experimental Complex is the main experimental area of INR linac. The facility of Experimental Complex consists of the beam lines, the multipurpose Neutron Complex and complex of proton therapy. The Neutron Complex includes in turn: 1) the beam dump RADiation EXperiment (RADEX) facility, together with time-of-flight spectrometer; 2) the Pulsed neutron source; 3) the Lead slowing-down spectrometer.

RADEX INSTALLATION

RADEX installation makes it possible to generate high-intensity neutron fluxes in the target by high-current proton beams. It gives unique opportunities for nuclear materials testing under irradiation. For instance the radiation tests of fusion reactor candidate materials for first wall can be carried out in conditions close to the expected in reality. The installation has a vertical irradiation channel inside the beam stop for horizontally incident protons with energies up to 209 Mev. The researches in the field of neutron-nuclear interactions using the time-of-flight technique in special channels are also carried out at RADEX.

When working with a RADEX installation last time in April, 2016 the beam parameters were as follows: beam energy 209 MeV, pulse current 10 mA, pulse duration 0.3÷115 µs at pulse repetition rate 50 Hz.

The operation modes of Experimental Complex beam lines for different beam parameters are well studied [1]. But in 2015 beam lines were upgraded: re-aligning of beam line elements relative to beam axis was carried out and some new power supplies for quadrupoles were implemented. Therefore, there is a need to study beam dynamics in the new magnetic lattice of the channel to RADEX experimental area additionally.

BEAM MEASUREMENTS UPSTREAM THE EXPERIMENTAL COMPLEX

To study beam dynamics in the channel to RADEX installation it is necessary to determine correctly transverse beam parameters at its input. The measuring area at the linac exit (upstream the beam line to RADEX) is shown in Fig. 1. The following equipment is displayed at this area: 1) 8 quadrupole magnetic doublets D106÷D113 supplied from a common current source; 2) 4 quadrupole magnetic doublets D114÷D117 supplied from different current sources; 3) 3 wire scanners WS1÷WS3; 4) beam cross section monitor (BCSM).

BCSM is developed to provide non-intercepting measurements of beam parameters. Monitor operation is based on utilization of residual gas ionization. BCSM enables to observe proton distribution in beam cross section (Fig. 2) during adjustment and operation of the linac. The transverse beam profiles can be obtained from beam cross section too [2].

Wire scanners are used for transverse beam profile measurements [3]. The measurements by wire scanners may be carried out only at 1 Hz pulse repetition rate to avoid excessive equipment activation and damage of accelerator components due to their overheating in the point of significant beam losses.
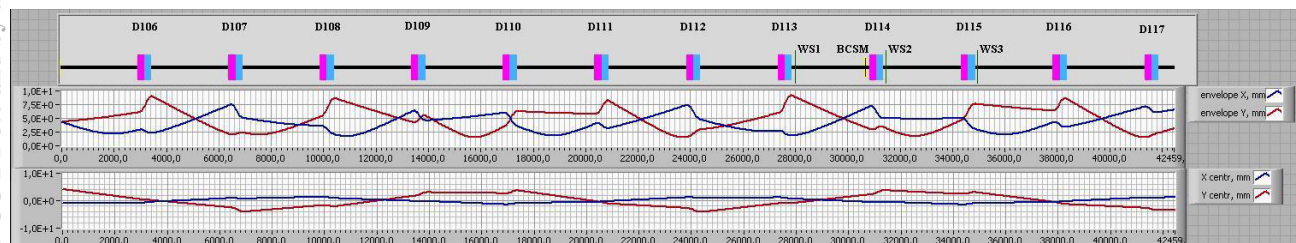

Figure 1: The accelerator area upstream the Experimental Complex beam line and beam tracing across it. D - quadrupole magnetic doublets; WS – wire scanners; BCSM – beam cross section monitor.
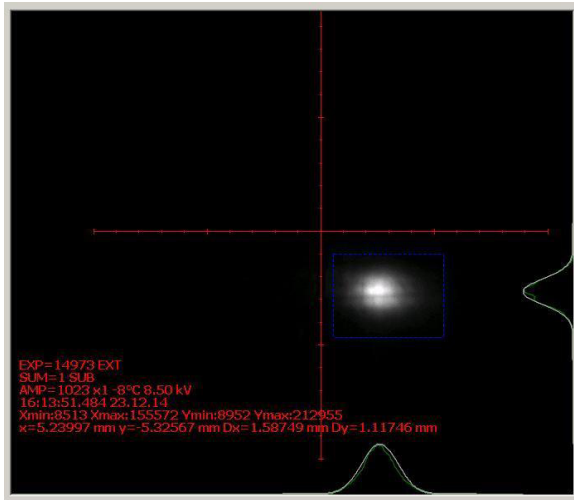
Figure 2: The example of beam cross section measurement by BCSM.

beam envelope for $5\varepsilon_{rms}$ emittance containing approximately 90% of the entire beam is shown in Fig. 1. BCSM location is arbitrary chosen as an input point for beam line to RADEX. The parameters of phase ellipses in this point (α_x, β_x, γ_x, α_y, β_y, γ_y) are calculated through α_{x0}, β_{x0}, γ_{x0}, α_{y0}, β_{y0}, γ_{y0}.
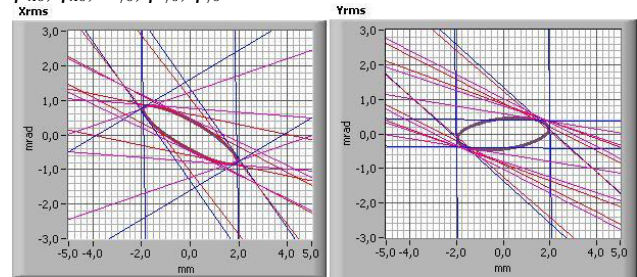

Figure 3: Determination of rms transverse emittances by wire scanners measurements.

The results of rms beam size and beam centre measurement at the point of wire scanner longitudinal location for each transverse phase plane represent vertical lines. The measurements have been made for different magnetic field gradients in doublets D106÷D113 by varying the current in common current source. Then the disposition of all the lines has been transferred by matrix technique to input point of measuring area located upstream the region of variable fields. The rms phase ellipses are inscribed with the iteration algorithm in central parts of the space separated by the rms beam size lines (Fig. 3). The values of rms emittances $\varepsilon_{x\ rms}$, $\varepsilon_{y\ rms}$ and their parameters α_{x0}, β_{x0}, γ_{x0}, α_{y0}, β_{y0}, γ_{y0} are determined here graphically ($\varepsilon_{x\ rms} \approx \varepsilon_{y\ rms}$, so the notation ε_{rms} will be used). Tracing of the beam centre and

BEAM STUDY AT RADEX BEAM LINE

The beam line to RADEX experimental area is shown in Fig.4. It stretches from BCSM location to inlet to RADEX facility. The distance from RADEX inlet to RADEX target is about 4 m. Many beam monitors are not displayed in this scheme. Multiwire secondary-electron emission monitor (SEM Grid) consisting of two mutually perpendicular grids is located 2 meters from RADEX inlet. The other elements of beam transportation line are quadrupole magnetic doublets, single quadrupole magnetic lenses and bending magnets MBV1÷MBV4. The system of four magnets elevates the beam by 4.2 m from the level of accelerator to the level of Experimental Complex.
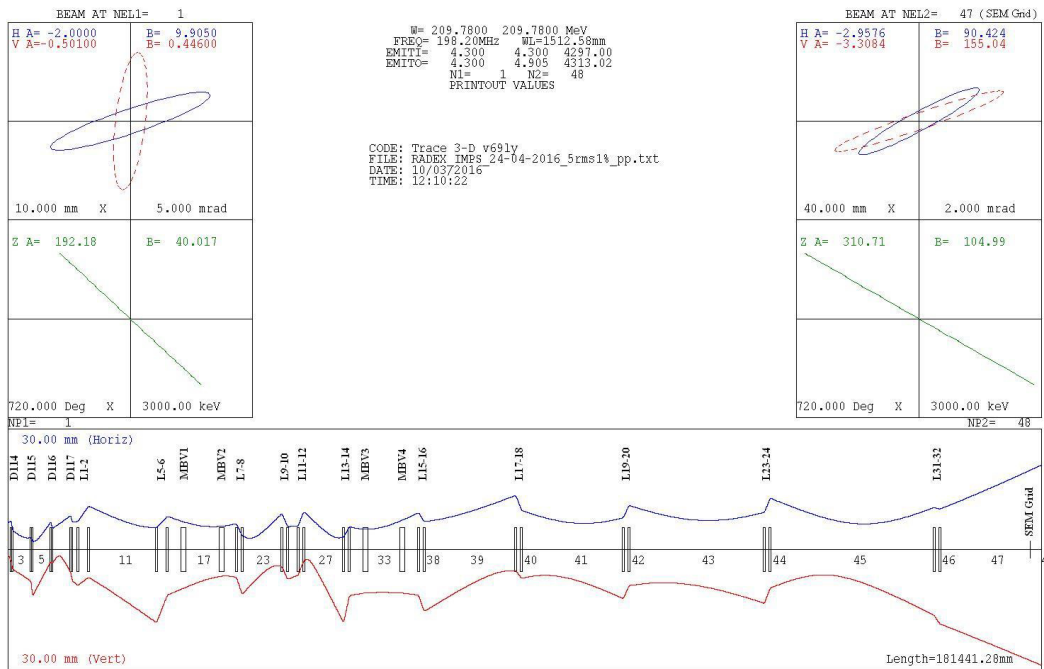

Figure 4: The beam line to RADEX experimental area and beam tracing across it. D - quadrupole doublets; L - quadrupole lenses; MBV - vertical bending magnets; SEM Grid - multiwire profile monitor.

Since the beam line has been upgraded it was necessary to study beam dynamics in modified conditions. TRACE 3-D code was used for beam dynamics simulation through magnetic elements of beam line. The value of input transverse emittances in both phase planes was assumed to be $5\varepsilon_{rms}$. The input parameters of phase ellipses (α_x, β_x, γ_x, α_y, β_y, γ_y) have been determined earlier. Series of simulation tests was carried out at different currents in focusing elements. Applicable result is shown in Fig. 4. The currents from this simulation variant were set in corresponding focusing elements. Then the currents in some focusing elements were slightly corrected to minimize beam losses along the beam line.

SEM-grid profiles presented in Fig. 5 demonstrate good agreement between simulation and measurement results.
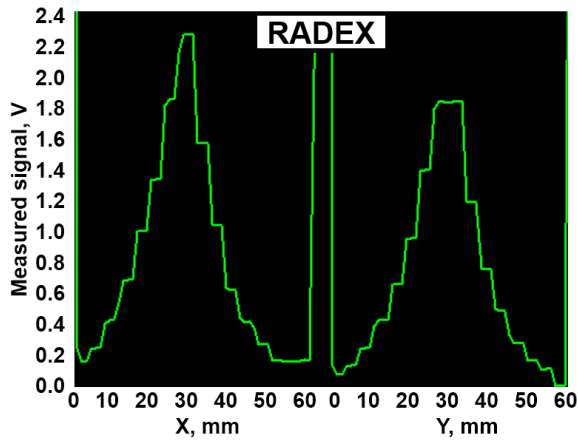

Figure 5: The result of beam profiles measurement by SEM Grid.

CONCLUSION

The considered algorithm of transverse beam profiles measurement and treatment at linac exit is actively used to get transverse beam emittances. The determination of these parameters, in turn, enables to carry out the correct beam dynamics simulation through Experimental Complex beam lines. TRACE 3-D code was used for this purpose. All the procedures in general with additional online field tuning effectively provide proper beam parameters at the target with minimal beam losses along the beam line.

REFERENCES

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