Status of the Fermilab Drift Tube Linac

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Abstract

For an eight month period, the Fermilab Drift Tube Linac operated while one of its quadrupoles was not available. The machine was retuned during this period to minimize beam losses, and a complete set of data for these conditions, including residual radioactivity readings, was recorded. During the last shutdown, the drift tube (#19 in Tank 5) was replaced and now has a fully functional quadrupole. Again, a complete set of data for the normal conditions was recorded. The two sets of data have been analyzed using the PARMILA code running under PC-WINDOWS in order to determine the accuracy of the simulations.

Introduction

In December 2003, the quadrupole in drift tube #19 in Tank 5 developed a short and was turned off. A new tune with a different set of quadrupole currents was then developed to minimize beam losses in the high energy Linac. The Linac has run with this tune for more than eight months. Then, as a part of preparations for the most recent shutdown, the residual activation along the linac was measured. During the shutdown the residual magnetic field on the last three quadrupoles in Tank 5 was measured to verify the quadrupole polarities. The shutdown was also used to correct and check the readings of the quadrupole currents in the transition section and high energy Linac. These new data have provided an opportunity to test the accuracy of PARMILA simulations.

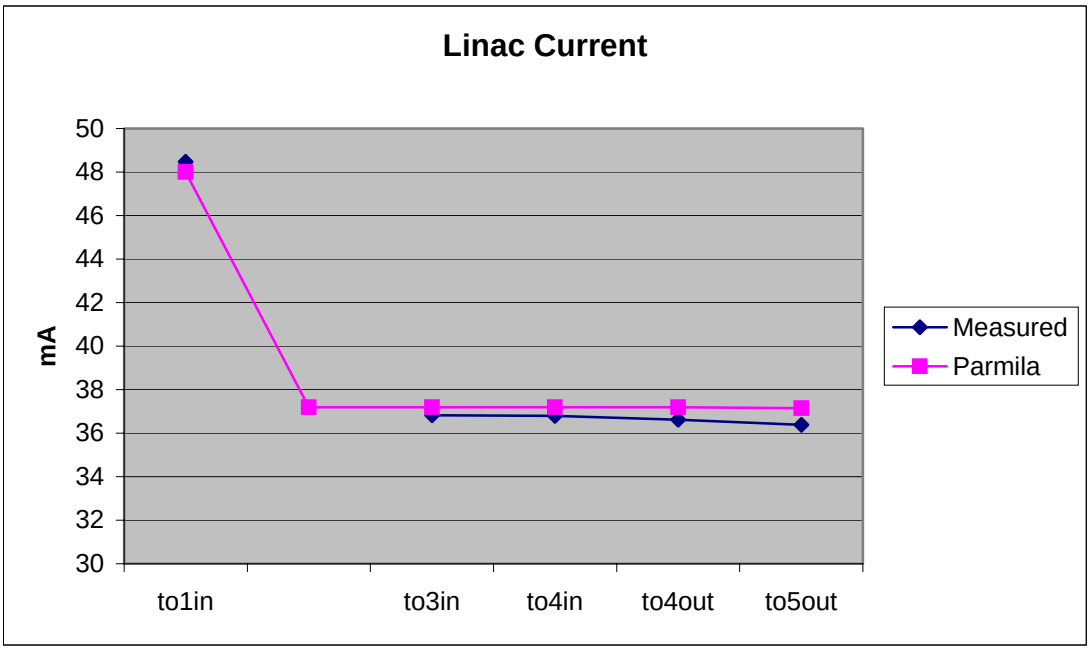

Figure 1, shows simulated and measured currents at entrances of Tank#1, 3 and 4 and exits of Tank# 4 and 5.

Results

In the reference 1 it was shown that PARMILA accurately describes the capture and transmission of the H- beam along the DTL linac. Figure 1 is from reference 1, shows good agreement between measured and simulated currents in the in whole DTL linac. In the present simulation the beam starts at the center of the 90-degree magnet and is transported through two quadrupole triplets and the Buncher cavity as shown in Figure 2. The input beam parameters at the entrance to the transport line after the ninety degree bend magnet were adjusted to achieve the best transmission along the Linac with input emittances of ε_x =1.5 and ε_y=1 π mm-mrad as measured with Emittance Probes 4 and 5.

In these calculations, the only beam restrictions were the overall apertures of the drift tubes, since there was no information about transverse beam size at different positions along the linac.

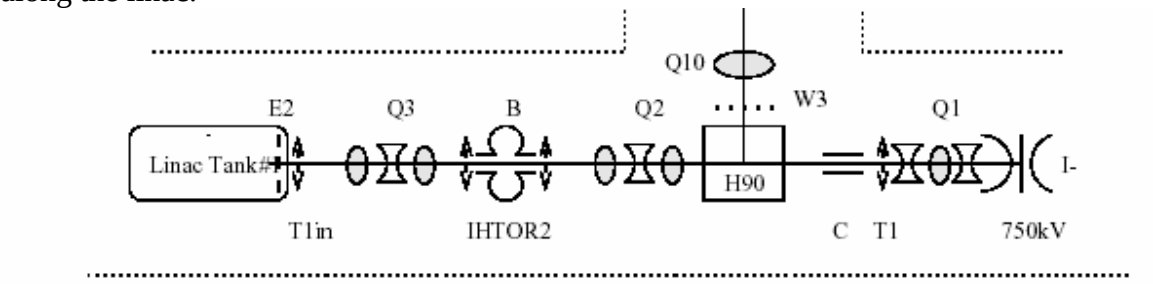

Figure 2.750keV line. Beam goes from left to right, starts from I- coulomb and enters Linac Tank#1. Simulation starts from the exit of H90 bend.

At the very beginning of the shutdown, as soon as beam was turned off, a radiation survey of the whole Linac was performed. Measurable residual activation was found only at three different locations: in Tank 4 near drift tube eight, and in Tank 5 between drift tubes six and eight and between seventeen and twenty two. In Parmila, of the 10000 particles that are launched, 7339 particles are captured and exit Tank1. The additional particles are lost at positions as indicated in the graphs below.

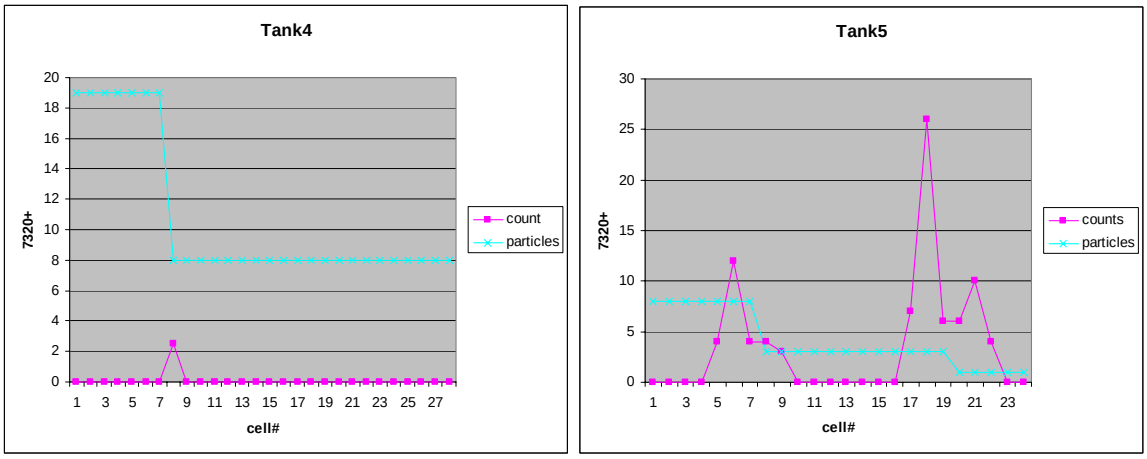

Figure 3 shows particle loss(blue) and activation counts(red trace) in Tank#4 and 5. Particle loss in simulation coincides with measured activation hot spots.

These positions are exactly where residual activation was found. Looking at beam envelopes from Parmila simulations, it can be seen that the largest beam is at two locations in Tank 5 and to some degree at three locations in Tank 4. The majority of particles are lost along the first twenty four drift tubes in Tank 1, where the particle energy is less than seven MeV, well below the neutron production threshold, which can explain why the observed activation is only at tanks 4 and 5. Figure 4 shows the x and y beam envelopes and phases of individual particles with respect to the phase of synchronous particle.

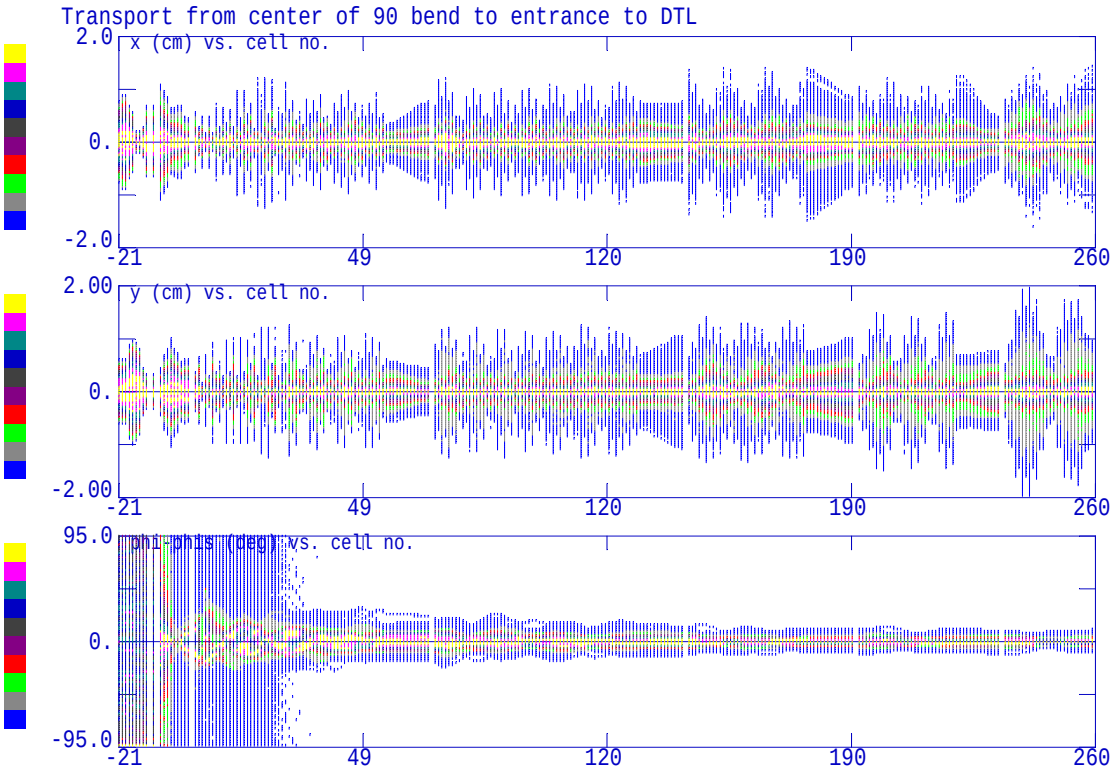

Figure 4. The plots on the top and in the middle are beam widths in X and Y plan at exit drift tubes. The bottom plot is distance in 200MHz degrees from synchronous particle. The yellow is 90% of the beam and blue indicates less than 10% of beam

In the transition section right after Tank 5 there are three wire profile monitors. The measured wire profiles were fitted with Gaussian functions to compare with the rms values of beam sizes calculated by Parmila. Figure 5 shows a comparison of the measured wire sigmas and Parmila rms values of the beam at the wire locations.

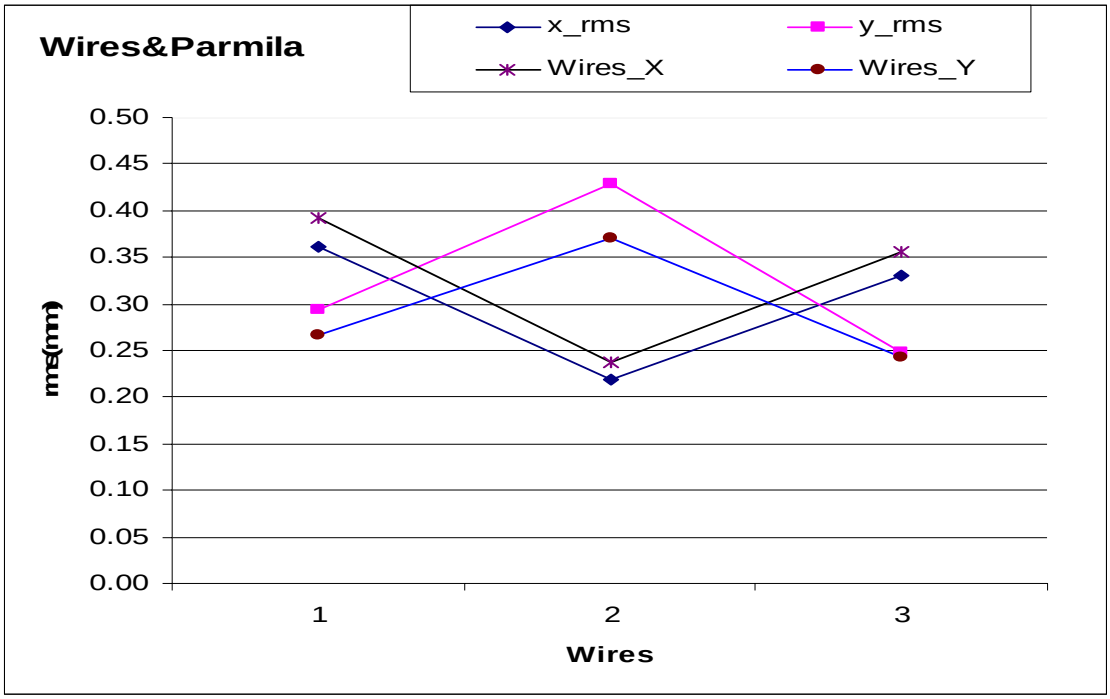

Figure 5 shows beam widths measured with three wires and rms widths reported by Parmila.

The beam emittances calculated by Parmila and measured using the three wire profile monitors are listed in the table below. These are normalized emittances in π mm-mrad. containing 95% of the beam.

	X-plane (π mm-mrad)	Y-plane (π mm-mrad)
Wire Measurement	2.5	5
Parmila	4.5	8.5

Table 1 Reported emittances are normalized, 95% of beam.

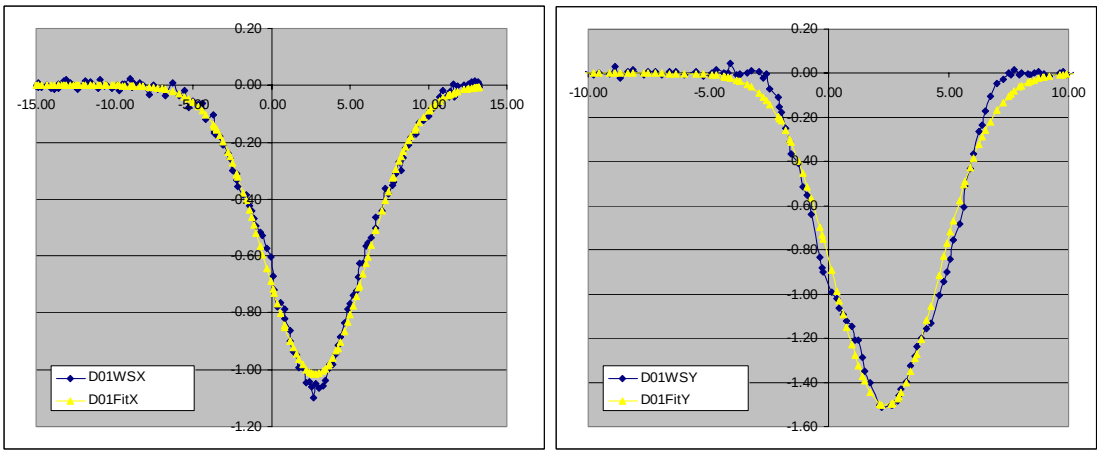

Figure 6. X and Y wire#1 profiles, blue are measured profiles and yellow are Gaussian fits. There are three wires in transition section. Wire 1 is first wire after DTL linac.

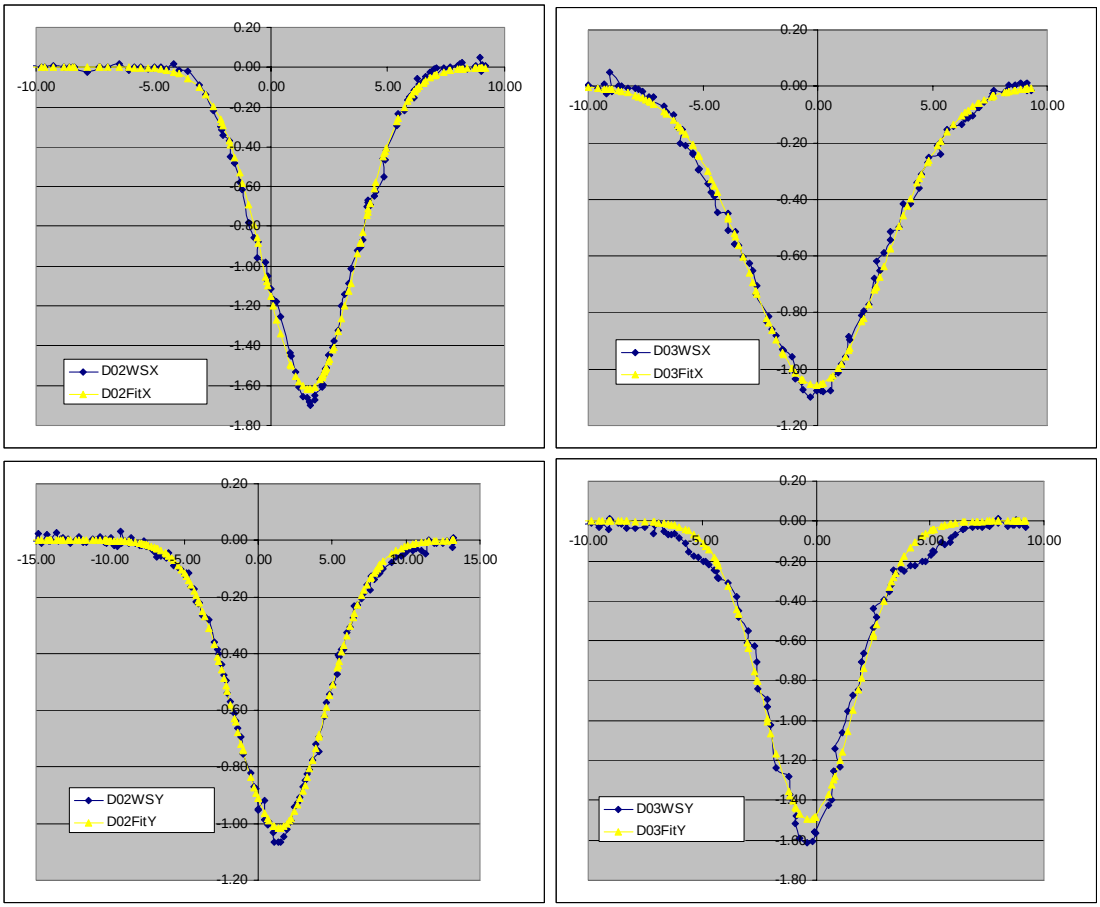

Figure 7, X and Y profiles of the wire 2 and 3 located in the transition section between DTL linac Side Couple structure.

References

[1]Fermilab Drift Tube Linac, Revisited. Milorad Popovic, Fermilab-TM-2245