# Beam Loss Study at High Intensity Proton Linac

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*Abstract*

A brief description of the beam loss detection system at the Moscow Meson Factory Linac (MMFL) is given in this report. Results of the precise tuning of the linac using beam loss monitor information are discussed. The influence of energy matching between DTL and DAW structures on particle losses is shown.

## 1. INTRODUCTION

To keep induced radioactivity to a low level and to retain hands-on maintenance is a task of major importance at the high intensity accelerator [1]. For that reason the beam loss control system becomes one of the most significant parts of the machine.

The initial beam tuning at the MMFL [2] is made using time-of-flight measurements [3]. From the results of those measurements the phases and amplitudes of the rf fields in the accelerating cavities were found. The beam transverse stability is provided by electromagnetic quadrupole gradient adjustments which are found from numerical calculations.

During all steps of the linac tuning, as well as during production shifts, the quality of the operation is controlled using beam loss monitors. Here the description of the beam loss monitoring equipment and the results of the particle loss reduction are presented.

## 2. BEAM LOSS MONITORING SYSTEM

There are about 40 beam loss monitors (NaJ + photo multiplier) in each of three sectors ( 9 accelerating cavities) of the DAW part of the linac (fig.1). They are placed in the middle between adjacent DAW sections 1 m away from the beam line.

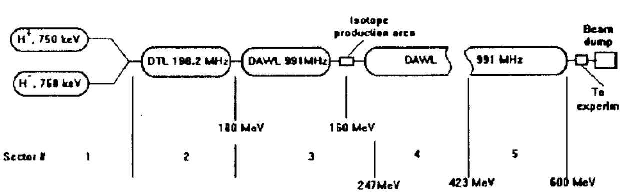


Figure 1. Layout of the Moscow Meson Factory Linac

Absolute calibration of #2 and #19 monitors installed at the places corresponding beam energies 100 MeV and 157 MeV was conducted by means of striking 0.1 - 1.0 mA proton pulse current against a copper absorber. Having 1000 V on the photo multiplier we found that at the energy range of 100-157 MeV the sensitivity of the monitors is in the range of 278-580 mV/mkA. This was followed with the relative calibration of all of the 40 monitors using a light signal which was equivalent in magnitude to the beam loss signal. Then varying the voltage on the photo multiplier in the range between 1000 V and 1450 V the sensitivity of all the monitors was equalised to the 1 mV/nA/m linear losses.

For the rough estimation of the particle losses, especially operating with very low beam currents, needed for some experiments we use another monitoring system which consists of a number of thermal neutron monitors, about one per accelerating cavity. Nonlinearity of these monitors at the counting rate up to $0.7 \cdot f$ per second ( where f is linac repetition rate) does not exceed 30%.

## 3. EXPERIMENTAL RESULTS

Typical operation schedule of the MMFL consists of four six to eight week production shifts per year. Delivering the beam to experimental installations beam losses should be reduced to less then 0.1% at the pulse current of 10 mA and less then 0.2 % at the pulse current of 20 mA. It is realised usually in several steps:

- Preliminary tuning. The phases and amplitudes of the fields in all of the DTL and DAWL cavities are adjusted following the data taken from the previous production shift. In the absence of the rough error the typical beam loss histogram along the third linac sector (100-250 MeV) is shown in Fig. 2. Integral loss level after such data restoration is equal 4-6 % at the beam pulse current of 5-7 mA. The dots along the abscissa represent 44 beam monitors. The numbers of accelerating cavities from #6 to #14 are also shown.
- The next step is the reduction of the relative losses to the level $(1.0\text{-}0.5)\cdot 10^{-3}$ at the beam peak current of 5-7 mA. Our experience shows that the main fraction of the losses occurs due to imperfect restoration of the field amplitudes and phases in both DTL and DAWL cavities. Due to the significant length of the drift space between a bunch phase probe and DAWL ( ~1.0 m) even the small energy deviation at the output of the DTL, say 0.2%, leads to the beam mismatching in the longitudinal phase space at the input of DAWL. For that reason the fine tuning of the accelerator is executed as follows:

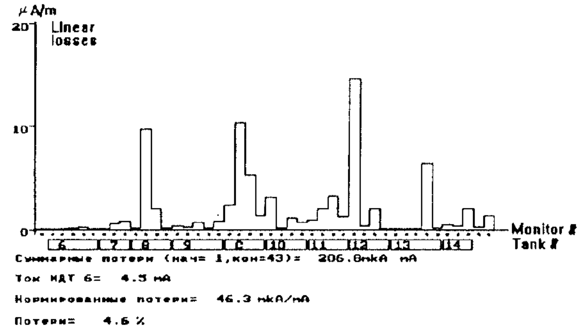


Figure 2. Beam loss histogram after restoration of the acceleration mode from previous production run

1. Beam energy is adjusted at the exit of DTL to its design value. Beam energy measurements are carried out in the two ways:

a) Absolute energy measurement using time-of-flight method.

b) Relative energy measurement using ΔT-procedure. By means of the phase variation in the last DTL cavity the beam energy at the input of the DAWL is set to (100.1±0.1) MeV.

2. ΔT-procedure is carried out along the whole DAWL. In the course of this step the beam's absolute energy is measured at three regions: 160 MeV ( the intermediate energy extraction region with matching cavity downstream of the forth regular DAW cavity), 247 MeV ( downstream of the 9th regular DAW cavity), 380 MeV (downstream of the 16th regular cavity).

3. Fine tuning of the quadrupole gradients and steering magnets in the region between DTL and DAWL as well as in the intermediate energy extraction region 160 MeV.

The sequence of the steps 2 and 3 is fairly arbitrary and may be repeated.

Here are more details. ΔT-procedure is carried out only to find the phases as the amplitudes during last 2 years remain unchanged. There is no need for phase scanning procedure in DTL during each operation shift because the longitudinal parameters may be easily controlled using the bunch length monitor and absolute energy measurement at the output of the DTL . Only if at the beam peak current of 5 mA the length of the bunch exceeds 13° (rare case) the phase scanning procedure is necessary. The deviation of the absolute energy may be easily corrected varying the phase of the last DTL cavity. Variation of the field parameters in the DTL are connected mainly to tube replacements in the RF power amplifier.

Quadrupole gradients along the linac correspond to design values except for DTL-DAWL matching region and intermediate energy extraction region. The matching gradients in the last two regions were found experimentally. Beam centre of mass correction is carried out only in these two regions. To keep the beam losses low usually a small variation of the correcting and focusing fields are needed.

Fig. 3 shows the beam loss histogram along Linac sector 3 (250 MeV) after steps 2 and 3 are done. A similar picture could be seen in sector 4 (423 MeV). The losses shown here slightly exceed the real value due to a noise signal corresponding ~1 mkA.

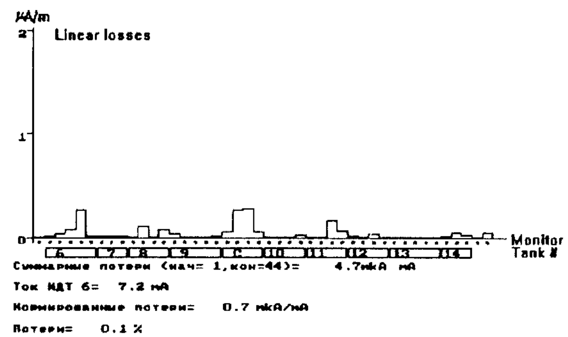


Figure 3. Beam loss histogram at the sector 3 of the Linac after ΔT-procedure completion

The increase of the beam peak current having accelerator parameters unchanged leads to an increase of the relative beam losses (Fig.4). In principle this phenomena may be overcome by increasing the feedback amplification. If the DTL cavity fields are changed it leads to beam energy variation at the input to DAWL. Fig.5 shows the increase of the beam losses five times due to deviation of the DAWL input energy 0.3% (the scale of Fig.5 is 10 times greater than that of Fig.4). Fig.6 shows the integral losses in the linac

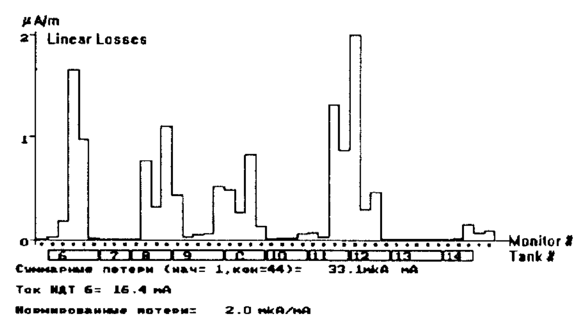


Figure 4. The effect of peak current enhancement on beam losses

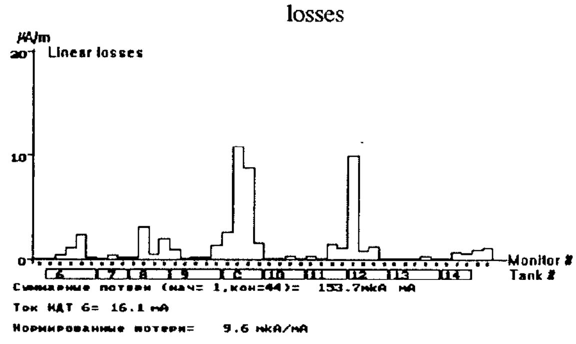


Figure 5. -0.3% energy offset at the output DTL

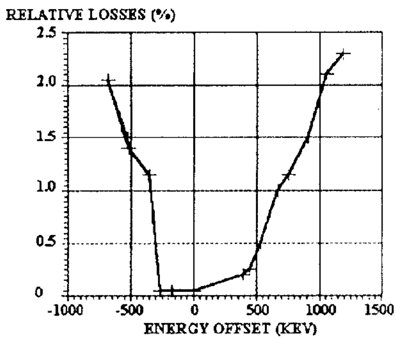


Figure 6. Relative beam losses vs energy offset at the input of the DAWL

sector 3 (100-250 MeV) vs. DTL output energy variation. Here the beam loss increase occurs due to both: DTL output energy deviation and bunch phase shift at the input of DAWL because of the drift space between the bunch phase monitor (which is used in feed back control) and the input of DAWL.

## 4. CONCLUSION

The beam loss monitoring system is a very sensitive and powerful instrument providing linac fine tuning and obtaining high quality beams.

## 5. ACKNOWLEDGEMENTS

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