Measurements on the Performance of the IH Accelerator in Linac 3

A. Feschenko, E. Tanke, C. Rivière, R. Scrivens

1 Introduction

During the 1994 Physics run the IH accelerator of Linac 3 provided beam with the parameters shown in Table 1. All of these matched or were better than the expected design values and from simulations, with the exception of the transverse emittance which was larger than expected, but still acceptable for multi-turn injection into the PSB.

The measurements of the effective shunt impedance from the energy of the beam and the power consumption of the tanks was only in fair agreement with the values calculated from bead pull measurements[1] (see Table 2). This could either be due to errors in the shunt impedance measurements, or to the beam in the longitudinal plane being disrupted by incorrect RF settings.

During the 1995 shut down the 101 MHz RF amplifier from GSI of the first IH tank was replaced by the new Bertronix amplifier. As a consequence, the RF parameters for each tank was adjusted with the following tanks unpowered, to find optimal bunch length, energy spread and current for the output beam. The RF parameters of the full ensemble was then slightly adjusted in order to maximise the output beam current. This procedure gave the nominal RF setting for the tanks.

In this note the results of beam measurements with respect to RF parameters are given.

TABLE 1. Beam properties at the exit of tank 3 during 1994 physics run.

Current	60	μAe Pb^{27+}
W	4280	keV/u
εh	1.2	4rms, norm, mm.mr
εv	1.1	4rms, norm, mm.mr
Δφ	2.5 - 4.0	2rms, 101MHz, deg
ΔW	23 - 25	2rms, keV/u

TABLE 2. Measurements of the effective shunt impedance with a) Beam energy and RF power and b) Perturbation measurements during 1994.

	Tank 1	Tank 2	Tank 3	
Zeff a)	212	153	125	MΩ/m
Zeff b)	216	153	141	MΩ/m
Cavity Q value	21200	12550	14370	
RF Power	220	370	345	kW

2 Procedure

Measurements were made of the beam energy spread, mean energy, bunch length and beam current. as a function of the RF parameters. These parameters were measured in the following way:-

i Energy Spread - Using the spectrometer magnet ITF.BHZ11 and SEMgrid ITFS.MSG10 with the transverse beam optics adjusted for best resolution. As the entrance slit was not placed in the beam (to shorten measurement time) the values are comparative. Values are given for half the full width of the beam seen above a certain threshold on the SEMgrid (10% of the peak signal).

ii Mean Energy - Measured using the same equipment as for the energy spread but taking the central peak position. This gives an approximative measurement of the mean energy.

iii Bunch Length - Measured with the Bunch Length and Velocity Detector (BLVD) which is positioned approximately 1.5m downstream of tank 3. The values given are 2 rms.

iv Beam Intensity - Measured by integrating the signals on the spectrometer SEMgrid, the results are then quoted as a fraction of the nominal settings (labelled as “trans” in Figs 1-5). This gives a comparison of the currents for different settings.

These measurements were made firstly with just tank 1 powered. Then its nominal settings were used and tank 2 powered and adjusted etc. By this method the effects of each tank could be seen more easily.

The values of the quadrupoles for the transportation of different final energies had previously been found by simulation and were in all cases found to give good beam transmission. However, no optimization of these parameters has been attempted.

For tanks 1 and 3 RF adjustment, the output beam parameters are compared with the data from simulations performed with the LORAS code [2]. The beam input parameters used are those originally specified in the linac 3 design report [3] and not those measured during the linac commissioning. For the bunch phase spread the beam has been transported a distance equivalent to the BLVD measurement position.

3 Results

The measured results and comparison with some simulated data are shown in Figs 1-5. A description of the measurement procedures is given in section 2. For the measured results is the command value while for the simulations the RF parameters are given relative to the design settings. In each case a vertical line shows the nominal working point, defined by the setting-up procedure (see section 1).

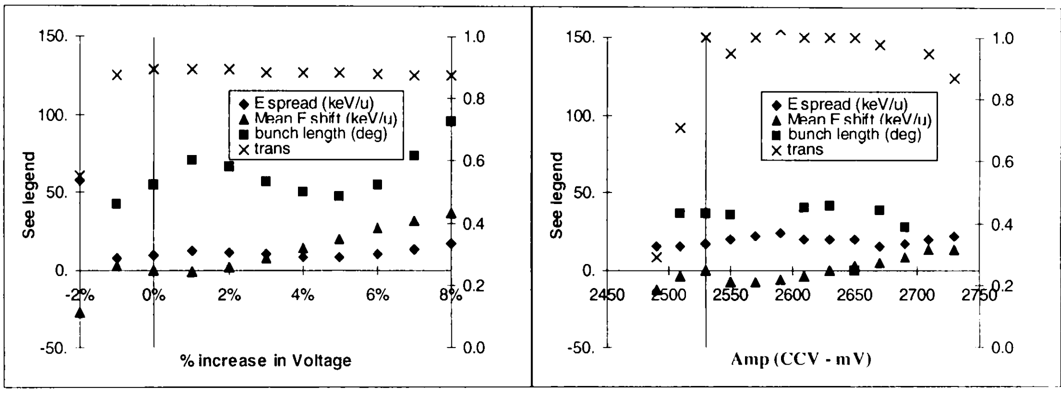

FIGURE 1. Beam parameters at the output of tank 1 as a function of RF voltage. Left - Simulated; Right - Measured.

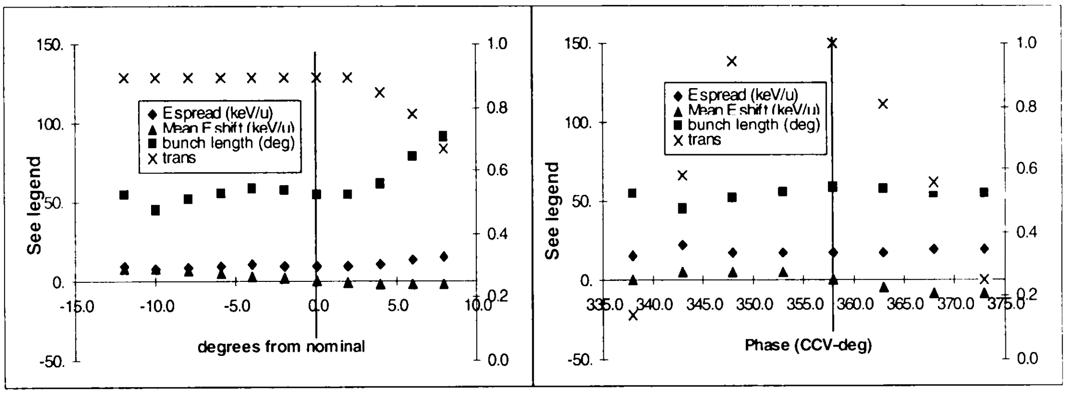

FIGURE 2. Beam parameters at the output of tank 1 as a function of RF phase. Left - Simulated; Right - Measured.

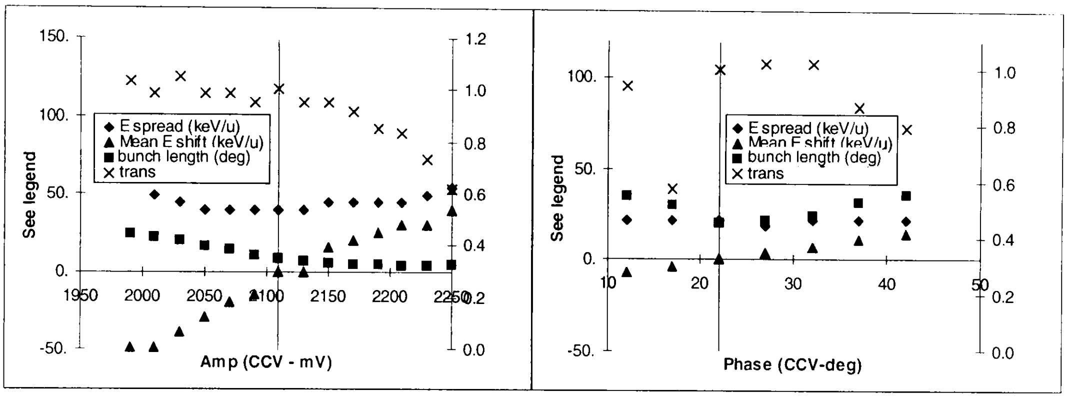

FIGURE 3. Beam parameters at the output of tank 1 as a function of RF voltage (left) and RF Phase (right).

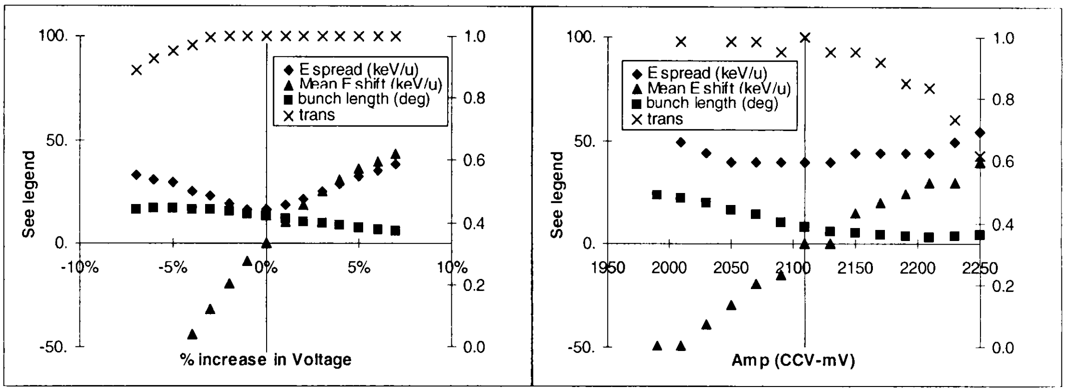

FIGURE 4. Beam parameters at the output of tank 3 as a function of RF voltage. Left - Simulated; Right - Measured.

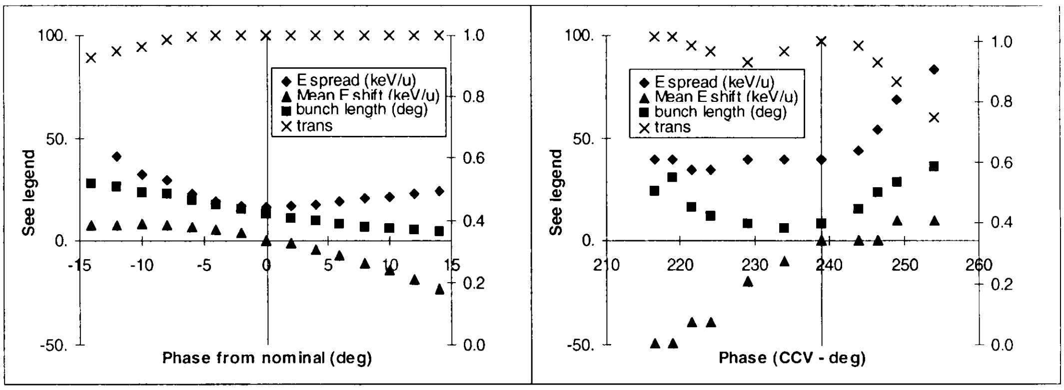

FIGURE 5. Beam parameters at the output of tank 3as a function of RF phase. Left - Simulated; Right - Measured.

The measured beam parameters in Figure 1 show good correspondence with the simulated data. Missing data in the BLVD bunch length measurement are due to the bunch not being measurable. This corresponds to the points of the simulated data where the 4rms bunch width would be greater than 90°, which is beyond the measurement limit of this device. It is difficult to draw any conclusions from the beam measurements as a function of the RF phase of tank 1 (Figure 2), as the response of all the measured parameters was flat until the reduction of current made the measurements impossible. The independent axis for the measurements of beam parameters v RF phase in Figures 2, 3 and 5, may be reversed, as the direction of the movement of the phase of the RF field using the control system is believed to be of opposite sign with respect to the phase simulated with LORAS.

The beam output parameters for different simulated RF phases and amplitudes in tank 2 have not yet been processed. The measurement data shown in Figure 3 suggests that the beam parameters cannot be improved using the RF settings.

The beam parameters as a function of RF voltage in tank 3 (Figure 4) show excellent agreement with the simulated values (except for the transmission), showing that the bunch length can be improved at the expense of increased energy spread. It also shows that the energy of the beam can be slightly varied, in contrast with the settings found last year where the RF power could be increased by 15% (7.5% in voltage) without the energy being changed (within the resolution of the spectrometer). This suggests that the RF settings of last year were far from correct.

The phase response of tank 3 (Figure 5) shows good correspondence if the phase shift is assumed to be reversed and taking into account the much wider measured range (50°).

Table 3 shows the beam parameters of Pb27+ at the output of tank 3, measured using the nominal RF settings for each tank (see section 1). The increase in beam current over last year is almost certainly totally due to improvement in the total current from the source. The emittance has also decreased from the previous values, but still shows

TABLE 3. Beam properties at the exit of tank 3 measured during MDs of 1995.

Current	70	μAe Pb^{27+}
ε_h	0.86[1], 0.67[2], 1.04[3]	4rms, norm, mm.mr
ε_v	0.86[1], 0.86[2], 0.63[3]	4rms, norm, mm.mr
$\Delta\phi$	8.0	2rms, 101MHz, deg
ΔW	15	2rms, keV/u

1. Quadrupole and SEMgrid measurement[4].
2. Multi slit emittance[5].
3. LBE emittance before Booster. Pb^{53+} measured.

a blow-up of a factor 2. The reason for this improvement is unknown. It is possible that this blow-up may be caused by the beam steering in the tanks. This has proved difficult to correct as the segmented phase probes used for beam position monitoring are rendered unusable due to the high amount of RF noise. The final beam energy has not been measured due to calibration problems with the energy measurement mode of the BLVD.

The final values for the RF power to each tank is presented in Table 4. The effective shunt impedances calculated from the RF power and beam energy, have improved for all 3 tanks by 5 to 15%. This brings them all to within 10% of the values measured using the perturbation technique.

TABLE 4. RF power for the nominal working points of the 3 tanks after the 1995 start-up, with shunt impedances for a) Beam and b) Perturbation measurements.

	Tank 1	Tank 2	Tank 3	
Z_{eff} a)	236	164	140	MΩ/m
Z_{eff} b)	216	153	141	MΩ/m
RF Power	198	346	308	kW

4 Conclusions and Further MDs

The comparison of measured and simulated data of the energy spread, bunch length and mean energy show good correspondence for tanks 1 and 3, with tank 2 simulations yet to be performed. This suggests that the tanks are working near their theoretical settings and that no measurable improvement in the final beam parameters is possible by varying the RF power phases and amplitudes.

Further measurements should include measurements of the energy spread of the beam using the full spectrometer optics, preferably at all three energies. At the same time the total current should also be measured using a current transformer, to see where the transmission is limited.

It may be possible to improve the beam parameters by varying the axial field distribution using different positions of the capacitive tuners.

5 References

[1] N. Angert et al. "The IH Linac of the CERN Lead Injector" Int.Conf. on Linear Accelerators (1994).

[2] U. Ratzinger and V.T. Nimje "LORAS - A ComputerCode to Calculate the Longitudinal and Radial Beam Dynamics of a Drift Tube Accelerator" GSI Report (1991)

[3] N.Angert et al. "CERN Heavy-Ion Facility Design Report" CERN 93-01 (1993)

[4] N. Catalan "A New Tool to Calculate Emittances from Profile Measurements in the Filter Line of Linac 3" CERN PS/HI Note 95-05 (1995)

[5] M. Crescenti "New Beam Emittance Measurement for Linac 3" CERN PS/HI Note 93-15 (1993)