BUNCH SHAPE MONITORS FOR THE DESY H$^-$ LINAC

A.V.Feschenko, A.V.Liiou, A.N.Mirzojan, A.A.Menshov, P.N.Ostroumov
Institute for Nuclear Research, Moscow 117312, Russia
N.Holtkamp, C.Kleffner, M.Nagl, I.Peperkorn
Deutsches Electronen Synchrotron, DESY
Notkestrasse 85, 22603 Hamburg, Germany

Abstract

For better tuning and control of the longitudinal beam parameters two Bunch Shape Monitors (BSM) and one Bunch Length and Velocity Detector (BLVD) have been developed and installed in the DESY H$^-$ linac (Linac-III). The BSMs have a standard function to measure the longitudinal distribution of particles in bunches and the mechanical layout has been optimized in order to fit the extremely narrow space between the DTL tanks. The BLVD has an additional feature to measure the beam absolute energy and is installed downstream of the Linac. Due to the use of a thin wire as a source of secondary electrons the devices can be used as a non-destructive beam diagnostic tool during Linac operation. The performance of the BSMs as well as the results of the Linac-III beam studies using the new devices are presented.

1. INTRODUCTION

A longitudinal distribution of the charge in the bunches (a bunch shape) is one of the most important parameters of a beam in an ion linear accelerator. This characteristic can be used both for beam dynamics studies and for precise tuning of the accelerator. Information about a bunch shape in the DESY Linac-III allows to improve quality of the accelerated beam. The design of the BSMs was based on the long term experience of the Institute for Nuclear Research of Russian Academy of Sciences [1,2,3]. The principle of operation of the BSMs is based on the coherent transformation of longitudinal distribution of charge of the analyzed beam into a spatial distribution of low energy secondary electrons through transverse RF modulation. Though this principle was directly used in the BSMs for the DESY Linac-III much work has been done to satisfy mechanical requirements thus resulting in rather intricate and precise design of the detectors.

The measurement of the average energy is based on the time of flight method. The initial idea to use precise longitudinal mechanical translation of the BSM for energy measurements [4] was firstly implemented in the Bunch Length and Velocity Detector (BLVD) for the CERN Linac-III [5]. The subsequent analysis of measurement errors enabled us to find solutions to improve the accuracy which then have been applied in the BLVD for the DESY Linac-III.

2. GENERAL DESIGN OF THE DETECTORS

The BSMs are installed in the intertank sections between the Alvarez tanks. The simplified general assembly drawing of the BSM is presented in fig. 1. The BSM consists of the two assembly units: the main unit (1) containing the rf deflector combined with the electrostatic lens and the detector of electrons and the target actuator (2) with the target unit. The target actuator and the main unit are installed in the intertank sections using the existing spare flanges. Due to different diameters of the intertank sections the lengths of the actuators (2) for the BSM-1 and BSM-2 are different. The main units (1) are identical for the two BSMs. The difference of the diameters of the intertank sections is compensated by using the additional spacer (3) between the flange of the intertank section and the flange of the main unit.

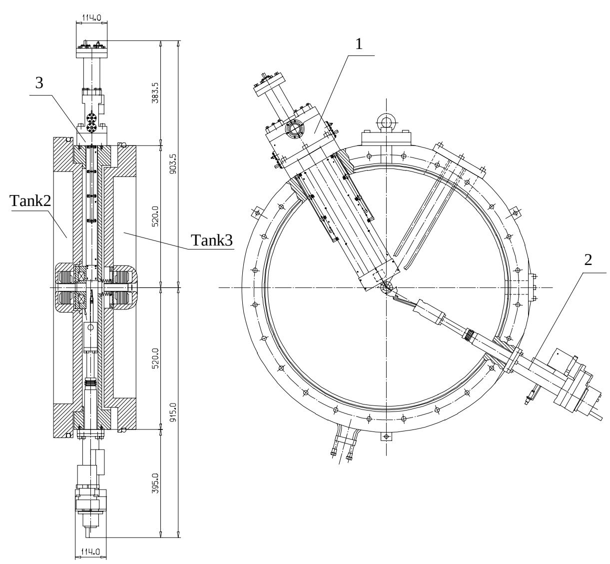

Fig. 1 General assembly drawing of the BSM

A three dimensional view of the BLVD is presented in fig. 2. The BLVD consists of the following main elements: body of the detector (1), target actuator (2) with the target unit, rf deflector combined with electrostatic lens (3), registration unit (4), permanent adjustable magnet (5) to steer the electrons vertically, glider (6) with the actuator (7) to provide longitudinal translation of the detector, bellows (8,9) and support 10.

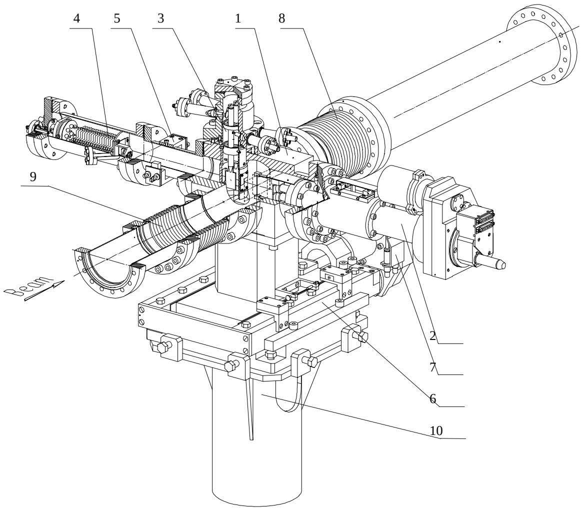

Fig. 2 Three dimensional view of the BLVD

3. SIGNAL DETECTION, RF AND CONTROL SYSTEMS OF THE DETECTORS

To detect the secondary electrons secondary electron multiplier tubes (type: Hamamatsu R596) are used. The gain of the tube can be varied within 4-5 orders of magnitude by changing the supplied high voltage thus eliminating the problem to precisely know the intensity of the electrons. The signal from the SEM tube is amplified by the fixed gain (0.5 V/μA) signal preamplifier and is digitized with 1 μsec time intervals providing information on a behavior of the measured distributions in time at a typical beam pulse length of 30 μsec.

The three detectors have a common independent control system using an IBM PC and one CAMAC crate. Special electronic modules (HV, rf, interface, stepper motor drivers) are housed in three additional CAMAC crates.

The software includes three programs. Two of them are used for signal observation, adjustment of the parameters of the detectors and tuning of the detectors. The measurements and the initial data processing are made with the third program.

The RF reference signal is taken from the reference line of the accelerator (f=202.56 MHz). The deflector of the BSM operates at the fundamental harmonic while the forth harmonic (810.24 MHz) is used for the BLVD.

During the measurements a phase of the deflecting field and the steering voltage are varied between the beam pulses. Total time required for the bunch shape measurement depends mainly on the number of the measuring points in phase. For the energy measurements this time increases due to two or four measurements of the bunch shape, double adjustment of the steering voltage and translation of the detector.

4. SOME EXPERIMENTAL RESULTS

Typical longitudinal profiles at the exits of Tank 1, Tank 2 and Tank 3 for normal mode of Linac-III operation are presented in fig. 3. One can see that the bunch widths are less than 20° at the base line for all the three energies: 10, 30 and 50 MeV.

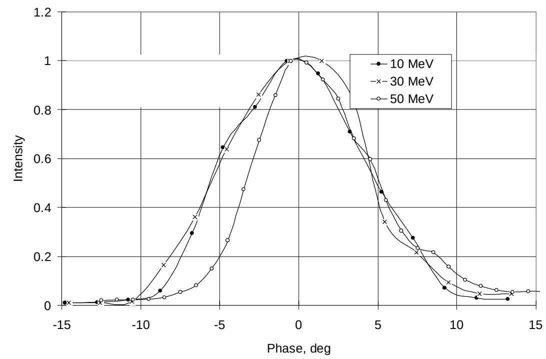

Fig. 3 Typical longitudinal profiles for normal mode of Linac-III operation

Fig. 4 shows the bunch shape evolution along the beam pulse at the exit of the Tank 1.

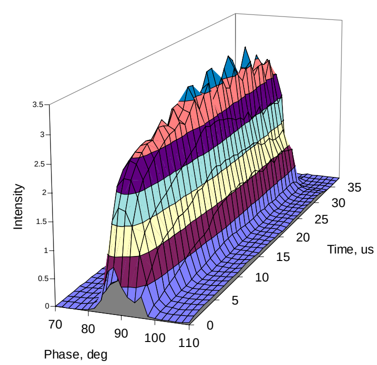

Fig. 4 Bunch shape evolution along the beam pulse at the exit of the Tank 1.

Fig. 5 shows the bunch shape and bunch center evolution as the phase of Tank 3 is varied. One can observe essential variation of both bunch shape and bunch phase position. This is just a result of longitudinal motion of particles. The behavior of the bunch center as a function of tank phase can be used as a good characteristic to set the rf amplitude in the tank. Fig. 6 presents the experimental results for the exit of the Tank 3 along with the three theoretical curves: for the nominal field $E = E_0$, $E = 0.95E_0$ and $E = 1.05E_0$. One can see the field level to be close to the nominal value. (In general these curves must be analyzed taking into account the input energy of beam).

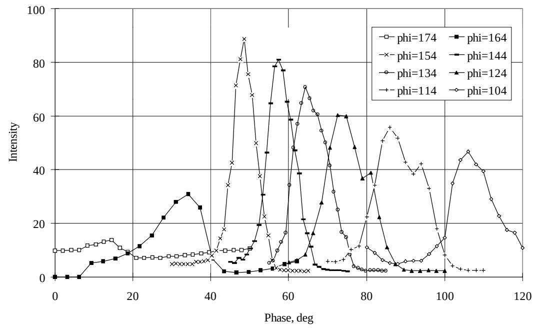

Fig. 5 Bunches for different phases of the Tank 3.

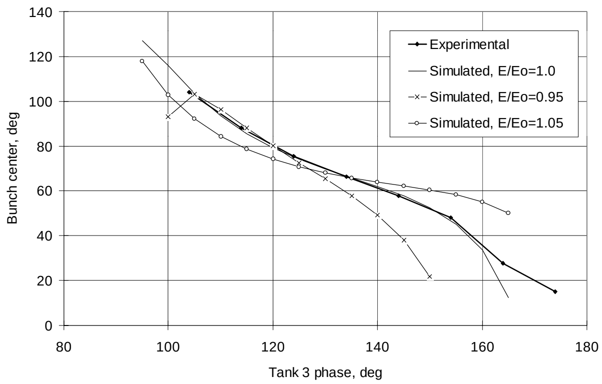

Fig. 6 Experimental and theoretical behavior of the bunch centers at the exit of the Tank 3.

The procedure of energy measurements [5] was modernized to improve the accuracy [6]. To avoid influence of errors of phase adjustment the value of the detector translation was selected to be close to $\beta\lambda/2$, where λ is a wavelength of the deflecting field. To decrease the value of the translation the forth harmonic of the fundamental bunch array frequency was taken as the frequency of the deflecting field. To compensate the influence of external magnetic fields on the electron trajectories adjustment of the steering voltage between the deflector plates is foreseen for both positions of the detector. Measurements are made for two phase ranges shifted by 180° thus enabling to remove errors of measurements arising from non symmetry of the deflecting field. The average value of the two measurements is taken as the correct one. The above measures along with the precise calibration of the detector translation gave the possibility to minimize systematic errors down to ±0.1%. The total error including both systematic and random components is equal to ±0.35%. The value of energy found from the data shown in fig. 7 is equal to (50.04±0.175) MeV.

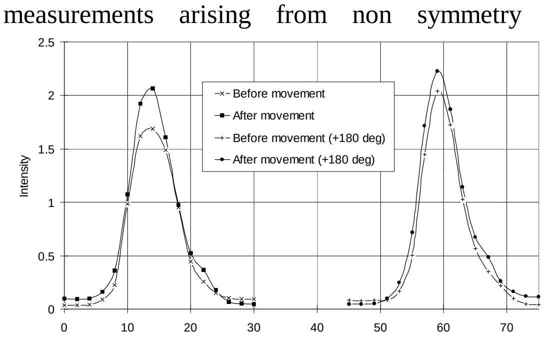

Fig. 7 Results of energy measurements.

5. PROBLEMS AND CONCERNS

In case of H^- ions, besides the low energy secondary electrons, higher energy electrons detached from the ions and scattered at the target are observed. This effect can be seen as a lower intensity maximum in front of the measured bunch. Though the distortions in our case can be neglected, the effect is of importance for precise measurements especially for longitudinal halo observations and is under study now.

6. CONCLUSION

The detectors of longitudinal beam characteristics installed and successfully commissioned in the Linac-III provide qualitatively new information about beam behavior. Information obtained with the detectors enable to reliably set both phases and amplitudes of the accelerating fields in the tanks especially during set up and commissioning. Bunch shape and average energy at the exit of the Tank 3 serve as a good criteria for normal operation of the accelerator. Further matching of the energy spread for the synchrotron can be made with the debuncher installed after the linac.

7. ACKNOWLEDGMENT

The authors are grateful to Dr. D.Trines, Dr. S.Esin and Dr. L.Kravchuk for the support of this work.

REFERENCES

[1] Feschenko A.V., Ostroumov P.N. Bunch Shape Measuring Technique and Its Application For an Ion Linac Tuning, Proc. of the 1986 Linear Accelerator Conference, Stanford, 2-6 June, 1986, pp. 323-327.

[2] Hurd J.W. et al. Bunch Shape Monitor for SSCL Linac. Proc of the 1993 Particle Acc. Conf., Washington, May 17-20, 1993, V.3, pp. 2426-2428.

[3] S.K.Esin, A.V.Feschenko, P.N. Ostroumov. INR Activity in Development And Production of Bunch Shape Monitors, Proc. of the 1995 PAC and Int. Conf. on High-Energy Accelerators, Dallas, 1-5 May, 1995, V.4, pp. 2408-2410.

[4] Ostroumov P.N. Average Velocity Measurement of Accelerated Beam by Means of an Upgraded Bunch Length Detector. INR Preprint - 812/93, May 1993.

[5] Bylinsky Yu.V. et al. Bunch Length and Velocity Detector and its Application in the CERN Heavy Ion Linac. Proc. of the EPAC-94, London, June 27-July 1, 1994, pp. 1702-1704.

[6] A.V.Feschenko, P.N.Ostroumov. Velocity Measurement by Means of Mechanical Movement of a Detector, AIP Conference Proceedings 333. Beam Instrumentation Workshop, Vancouver, B.C. Canada, October, 1994, pp. 478-484.