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LONGITUDINAL EMITTANCE MEASUREMENT OF THE 100 MeV PROTON BEAM

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Abstract

The results of the longitudinal emittance measurements carried out at the exit of the DTL part (100 MeV) of the 600 MeV Moscow meson factory linac are presented. A Longitudinal emittance is determined from the bunch length measurements carried out at the exit of the last DTL cavity for three different and well known values of the accelerating field amplitudes. A Bunch length is measured by means of the bunch shape monitor with the phase resolution better than 1^0 at the DTL rf frequency. The results of the emittance measurements are used for a beam longitudinal matching between the DTL and the DAW parts of the linac.

Introduction

A multiple increasing of the rf accelerating frequency in an H^+ and H^- ion linac occurs at the energy approximately 100 MeV. Therefore it is necessary to match properly the longitudinal emittance with the acceptance of the following linac stage. The longitudinal matching at the Moscow meson factory linac is provided by using 5th tank of the DTL part. This tank operates as an executive element in the feedback system to dump a longitudinal coherent oscillations of the beam. Thus, in order to tune up a longitudinal motion in the region of 100 MeV it is very important to know a longitudinal beam emittance.

Experimental setup

A method of the longitudinal emittance determination was described elsewhere [1]. It was shown, that a restoration of the phase space ellipse is possible if the bunch lengths are measured three times after the device with a linear transformation of the beam longitudinal parameters. The transformation matrices M_i (i=1,2,3) of this device must be known. A phase ellipse at the entrance of this device may be written as:

$$A\phi^2+2B\phi h+Ch^2+1=0,$$

where $\phi=\varphi-\varphi_c$, $h=(p-p_c)/p_c$, φ_c and p_c are phase and momentum of a particle at a center of the ellipse. The parameters of the ellipse may be determined from expressions [1]:

$$C = 4\frac{d(k_2-k_1)+(k_2^2-k_1^2)}{d^2(g_2^2-g_1^2)+4d(k_1g_2^2-k_2g_1^2)+4(k_1^2g_2^2-k_2^2g_1^2)},$$

$$B = Cd/2 , \qquad A = \frac{B^2g_1^2-2Bk_1-Ck_1^2}{1+Cg_1^2} ,$$

where $$d = \frac{k_1^2(g_2^2-g_3^2)+k_2^2(g_3^2-g_1^2)+k_3^2(g_1^2-g_2^2)}{k_1(g_3^2-g_2^2)+k_2(g_1^2-g_3^2)+k_3(g_2^2-g_1^2)} .$$

The coefficients k_i and g_i describe the tangents $h=k_i\phi+g_i$ to the phase ellipse at the entrance of the linear device (fig.4). These coefficients are expressed through the r_{mni} elements of matrices M_i^{-1} and measured bunch lengths ΔF_i:

$$k_i= r_{22i}/r_{12i} , \qquad g_i= \frac{\Delta F_i}{2}\,\frac{r_{21i}r_{12i}-r_{11i}r_{22i}}{r_{12i}} .$$

The fifth tank of the DTL stage of the INR linac was used as a bunch rotator for the linear transformation of a phase ellipse. Computer simulation has shown [2], that a motion of the particles with respect to each other in a bunch is kept linear in a wide range of the amplitude variation from zero up to the maximum possible value for the injection phases near -100^0. Besides it was shown, that the ΔF_i values should be measured at the lowest possible level of the phase spectrum because in this case only a longitudinal phase portrait is approximated by an ellipse satisfactory. In this case the phase ellipse being determined includes almost 100% particles. The bunch shape analyser (BSA) with the phase resolution of 1^0 at the frequency of 198.2 MHz [3,4] was used for the measurements of the bunch lengths.

Results and Discussion

During the measurements the 100 MeV stage of the linac operated with the nominal rf parameters setting. The bunchers were off and a peak current was 10 mA. The design rf field amplitude and phase in the 5th tank has been determined earlier.

The phase ellipse at the entrance of the fifth tank was restored by using the phase spectrum measurements for the following amplitudes: E=0, $E=0.7E_n$, $E=1.3E_n$, where E_n is a design value. Fig.1,2,3 show the corresponding phase spectra. The restored phase ellipse at the entrance of the bunch rotator and the tangents corresponding to the ΔF_i for the amplitudes aforementioned are presented in Fig.4. Fig.5 shows the experimental phase width vs the rf field amplitude of the bunch rotator. The same figure shows the curve corresponding to the phase widths which have been obtained by the transformation of the restored ellipse. The ellipses determined by the aforementioned technique just beyond the 5th tank operating in a nominal mode as well as at the entrance of the first DAW accelerating cavity are presented in fig.6.

Conclusion

The method for the determination of the longitudinal emittance with the aid of the phase spectra measurements is realized at the

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MMF linac. This method gives possibility to provide the longitudinal matching of the beam between the DTL and the DAW parts of the linac. The preliminary 100 MeV beam study has shown that the beam with 10 mA peak current can be matched successfully with the bucket of the DAW part of the linac even if the bunchers are turned off.

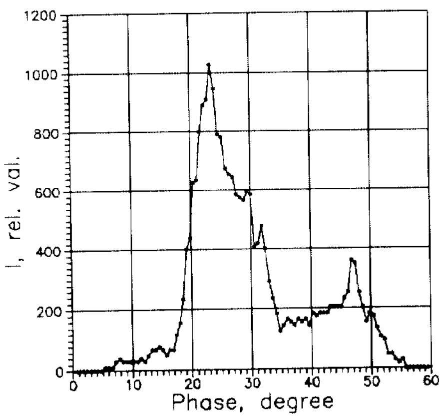

Fig.1 Phase spectrum for the rf field level of E=0 in the 5th tank

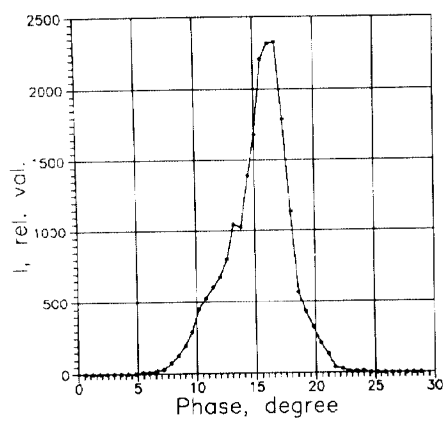

Fig.2 Phase spectrum for the rf field level of $E=0.7E_n$ in the 5th tank

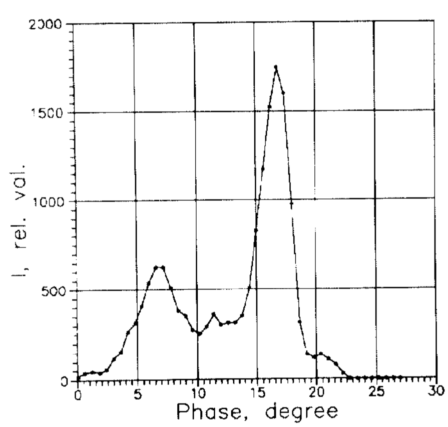

Fig.3 Phase spectrum for the rf field level of $E=1.3E_n$ in the 5th tank

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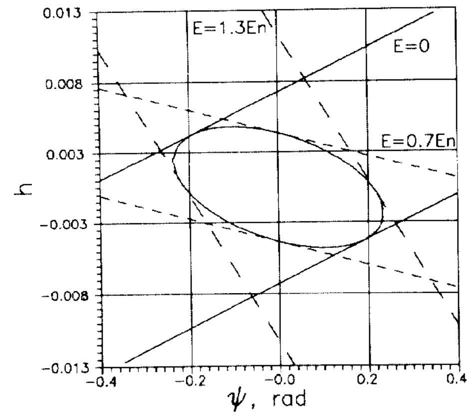

Fig.4 Phase ellipse restored and the tangents at the entrance of the 5th tank

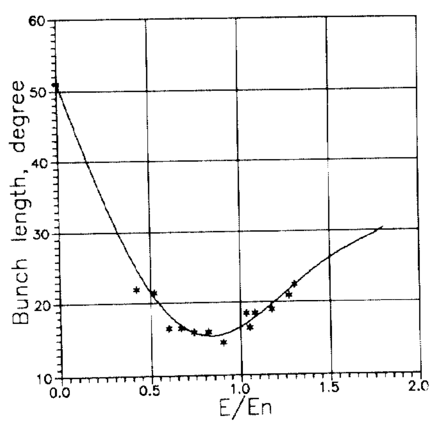

Fig.5 Bunch phase width vs 5th tank rf field amplitude

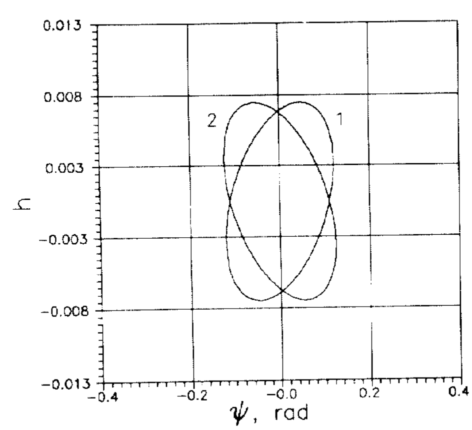

Fig.6 Phase ellipses: 1 - at the 5th tank exit, 2 -at the first DAW cavity entrance