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OPERATIONAL EXPERIENCE OF THE FIRST 20 MEV TANK OF THE INR LINAC

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Abstract Experiments with the proton beam acceleration in the first 20 MeV tank of the INR meson factory linac are presented. The detail investigation of the transverse beam parameters and longitudinal bunch shape are given.

INTRODUCTION

The H^+, H^- linac of the INR meson factory is under tuning now. Recently the beam acceleration in the first 20 MeV Alvarez tank has been studied in detail [1]. The preparation to accelerate the H^+ beam up to 100 MeV is under way. The results of the beam parameter measurements are presented.

The sketch of the main experimental equipment is shown in the Figure 1.

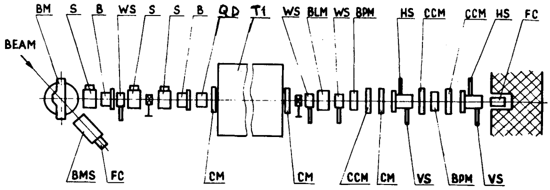

FIGURE 1 The layout of the experimental equipment. Legend: BM - bending magnet, BMS - emittance monitor, FC - Faraday cup, S -solenoid, B -buncher, WS -wire scanner, QD -quadrupole doublet, T1 -tank № 1, CM -current monitor, BLM -bunch length monitor, BPM -bunch position monitor, HRM -3rd harmonic cavity monitor, VS -vertical slit, HS -horizontal slit.

The beam acceleration has been provided at 1 Hz repetition rate but the tank has been driven at 10 Hz. The longitudinal and transverse beam parameters were compared in the 10 Hz and 100 Hz rf operation mode in order to ascertain a degree of the cavity heat loading influence on the beam parameters. The change of the beam position and phase spectrum was insignificant.

DETERMINATION OF RF AMPLITUDE AND INJECTION ENERGY

To determine an rf amplitude in the first tank we used both traditional amplitude scan method [2] and the method based upon the phase spectrum measurements [3]. The rf amplitude setting results were discussed in ref 1.

Typical experimental phase spectra of the accelerated beam for different rf amplitudes are given in Figure 2.

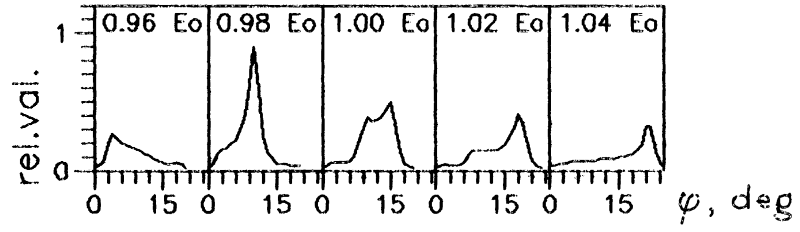

FIGURE 2 Typical phase spectra for different rf amplitudes.

The dependence of the phase spectrum maximum and bunch length ΔF on E/E' are presented in Figure 3.

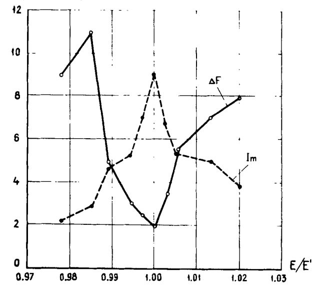

FIGURE 3 Phase spectrum maximum and bunch length as the functions of the rf amplitude.

As the phase advance of the small longitudinal phase oscillations does not depend on the injection energy, the method of rf amplitude definition is not sensitive to a injection energy error. The measurements made for two energies W_0 and $0.99W_0$ gave the same value of E'.

The analysis of the experimental curves shows, that the accuracy of E' experimental determination is about 0,1% and the error of nominal rf amplitude determination is less then 0.2%. After the rf amplitude was precisely determined, the amplitude scan experiment was used to find nominal injection energy more precisely. The nominal energy was taken to satisfy a cutoff condition $E_c=0.835E_0$.

There is the two-cavity buncher at the entrance of the first tank. The setting of rf phase was carried out separately for two cavities using the phase scan experiment while the first tank is excited to the nominal amplitude.

BEAM PARAMETERS MEASUREMENT AT THE INJECTION LINE

Beam emittance monitors of the slit-multiwire collector type are used at the injection line. By using the results of emittance measurements the phase ellipse parameters are found. The values of α, β, γ and ε are used to calculate beam optics and matching conditions between low energy transport line and the first tank acceptance. The results of emittance measurements are used to calculate the dependence of r.m.s. emittance on the beam current fraction. The results of the multiple emittance measurements at the injection line are given in Figure 4. The main purpose of the injection line is to match a beam emittance and the linac acceptance. The matching section of the injection line consist of three solenoids and one quadrupole doublet. The computer optimization providing 4-dimensional matching (without bunchers) is used to tune the matching section. The experiments have shown that from 10% up to 20% of the beam is lost at the matching section. The losses are caused by collimators placed at the entrance

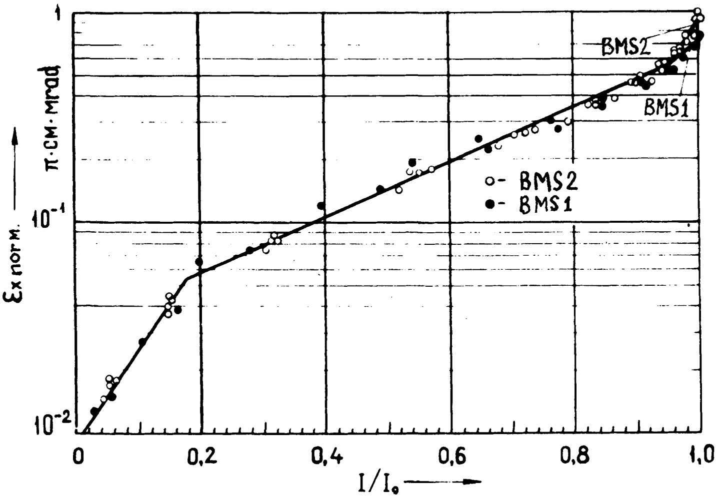

FIGURE 4 Horizontal plane emittance measurement results at the two points along injection line (BMS1 and BMS2 are placed at 2.5m and 7.5m after injector accordingly), I_{BMS1}=150mA, I_{BMS2}=110mA.

of buncher cavities. This collimators are used to avoid cavity loading produced by secondary emission electrons originating due to beam losses. In spite of these losses the tuning of focusing channel provides ~100 mA beam current at the linac entrance. The reproduction of operation conditions enables to obtain 75–100 mA current without additional tuning. Manual tuning was used to get maximum current after any interruption of operation. The fraction of accelerated particles was 29% for 95 mA input current. The theoretical coefficient is 30% without space charge. It means that there are no losses because of transverse motion in the first tank and the beam is sufficiently matched to the linac. The matching procedure takes into account variation of phase ellipse because of space charge effects. Six dimensional matching (bunchers turn on) theoretical condition was not succeeded to obtain because of focusing force limitations. Nevertheless the fraction of accelerated particles was 67% for single and

80% for two operating buncher cavities accordingly. This values coincide with theoretical ones. The maximum value of accelerated current was 46 mA.

ACCELERATED BEAM PARAMETERS MEASUREMENT

Two methods were used to measure emittance at the tank exit. 1. Beam profiles for different gradients of the focusing channel were measured. Variation of gradient leads to changing of transverse oscillations phase advance. In this case the beam profiles represent different projections of a beam phase portrait. The results of profile measurements were used to calculate r.m.s. parameters of the beam emittance. Moreover the gradient variation leads to the beam position changing, the value of changing being equal to 4.5 mm in horizontal and 1 mm in vertical planes. 2. Slit and wire collector was used. The plate with horizontal and vertical slits was installed instead of the first wire scanner. The direction of the plate displacement was 45° with respect to vertical and horizontal planes. The second wire scanner was used as a beam collector (Figure 1). The beam fraction vs normalized emittance is given in Figure 5.

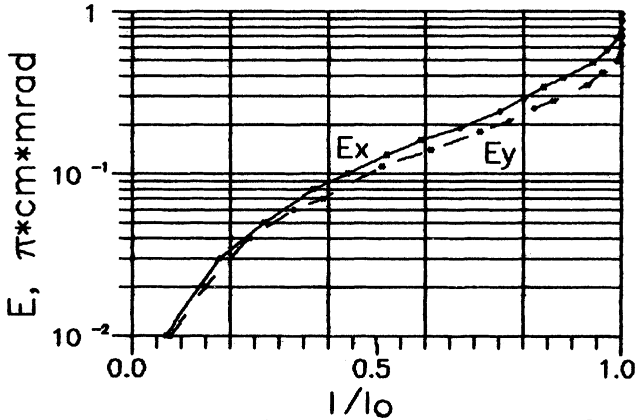

FIGURE 5 The dependence of the accelerated beam fraction on the normalized emittance value.

The value of effective emittance, containing ~ 100% particles, is limited by the acceptance of the first 22 focusing periods (the aperture diameter equals to 15 mm). In the case of the maximum output/input current ratio (29% without bunchers) the accelerated beam emittance turned to be the largest and was found equal to acceptance of the tank focusing channel. The experimental data show that the total emittance at the tank N 1 exit is 5-8 times smaller than the acceptance of the next cavity focusing channel. The r.m.s. dimensions of the beam are 6-10 times smaller then the channel aperture. The resolution of the bunch length measurements was better than 1^o (f=198.2 MHz). The length of the bunches depends upon the operation mode and was varied from 20^o up to 30^o. Because of comparatively large values of dumping and phase advance of the longitudinal oscillations the phase portrait is close to canonical ellipse. Therefore the bunch length measurements can be used to derive momentum spread. The 20^o-30^o bunch length corresponds to $\Delta p/p$= (1.0-1.5)%. At the exit of the tank № 1 unaccelerated particles are presented. The measurements of longitudinal density distribution inside and outside of the bunch showed that the number of unaccelerated particles is less then 1% of the total output current.

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REFERENCES

1. Yu.V.Bylinsky et al. The 1989 Part. Accel. Conf., (Chicago, March, 20-23, 1989).
2. Jameson R.A. et al. LAMPF Report, LA-6863, (Los Alamos, 1978).
3. Feschenko A.V., Ostroumov P.N. Proceedings of the 1986 Linac Conf., (Stanford, June 2-6, 1986), p.323.