30 MeV RFQ LINAC PARAMETERS

D.A.Demikhovsky, A.P.Maltsev, E.A.Myae, V.I.Stolpovsky,
V.A.Teplyakov, E.F.Troyanov, V.A.Zenin, A.V.Zherebtsov

Institute for High Energy Physics, Serpukhov, 142284, USSR

The 30 MeV RFQ Linac is used as an injector for the 1.5 GeV fast cycling booster of IHEP proton synchrotron [1,2]. The linac was put into operation in 1977 and since 1983 it is a part of the accelerating complex [3].

The linear accelerator consists of a 100 KeV ion gun, 3 sections of the linac itself (the initial section with 2 MeV output energy and two other sections in the main part of the accelerator with 16 and 30 MeV, respectively) and debuncher. The main parameters of the machine are as follows:

Output energy	29.7 MeV
Beam current (max)	90 mA
Accelerator structure length	25.3 m
Container diameter:	
initial section	0.52 m
main section	0.42 m
Normalized emittance (for 90% of particles)	0.7π cm·mrad
Momentum spread with debuncher for 90% of particles	$\pm$0.3%
Beam pulse duration (max)	10μ s

The ion gun has a plasma cathode source and discharge chamber of small volume ($\sim$1.5 cm^3). This provides a possibility to operate in pulse-train mode with 20 Hz repetition frequency using a pulsed hydrogen filling of the source discharge chamber.

A spatial homogeneous high frequency quadrupol focusing was used for the first time just at the linac initial part [4]; this type of focusing is now world-known as RFQ. A space-periodic RF focusing is applied for the accelerating-focusing channel of the linac main part where the accelerating gaps are formed by "horn"-like electrodes [5].

The accelerating structures of the initial part and main part of the linac are built on a base of small-size H-cavities with longitudinal magnetic HF field. The cavities are excited by power amplifiers connected to the accelerator subsections through a system of directed couplers forming a high-speed feedback at high power level.

Many experiments on the accelerator beam dynamics and beam parameter mesurements (emittance, momentum spread) were fulfiled using the "standard" methods, some auxiliary measurements were carried out as well [6]. Particularly, for measuring and tuning the beam travelling efficiency through the accelerator sections and for localizing the beam losses a movable radiation monitors are used. A surface quality of the accelerating gaps and resonator training conditions are monitored with X-rays emission measurements (no beam) along the accelerator.

Numerical calculations of the accelerator output beam parameters were carried out using experimentally measured characteristics of the ion source beam. Space charge forces were taken into account. Figs. 1,2 illustrate particle distribution in the transversal phase planes xx', yy' and fig. 3 shows the energy distribution. Contours on fig. 1 include 90% of beam current and are in a good agreement with corresponding experimental data.

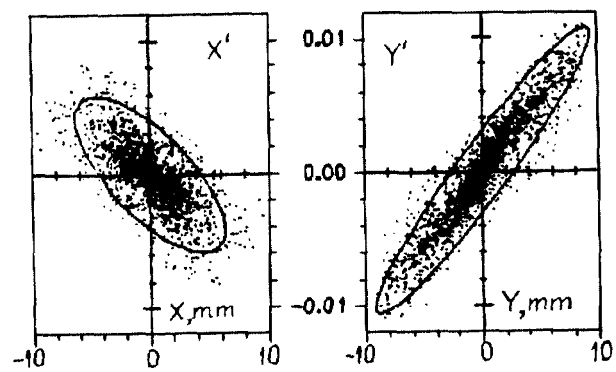

Fig. 1. Linac output particle distribution in transversal phase space.

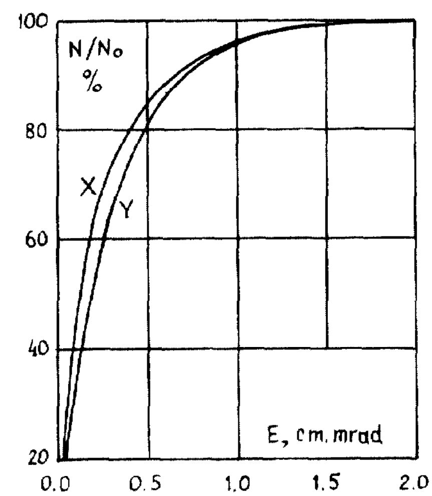

Fig. 2. Calculated distribution of beam current vs emittance.

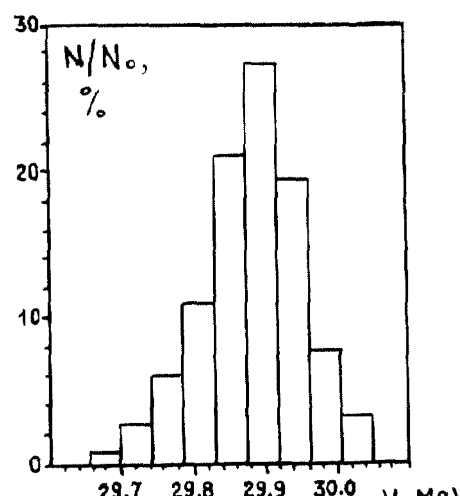

Fig. 3. Calculated beam energy spectrum.

Measurements of real beam characteristics (emittance, momentum spectrum) were carried out with the devices installed downstream the debuncher in a special measurement branch of the injection channel. For the emittance measurements movable slits and multistrip profilometers are used. The signals from the strips are averaged over strobe pulse duration which has several fixed intervals equal to ~1,2 or 4 booster revolution periods (1.2, 2,5 or 5 μs).

Fig. 4. illustrate beam current distribution versus emittance for two intensity levels. One can see some difference between horizontal and vertical emittances and emittance increase with beam current. Unnormalized beam vertical emittance for 80 mA current is equal to 3π cm·mrad at 90% level, i.e. normalized emittance is $E\beta\gamma$ =0.76 π cm·mrad. This is very close to the calculated values. The behaviour of emittance values versus intensity for beam current level 90 and 95% is shown in fig. 5 for 30-80 mA beam current interval.

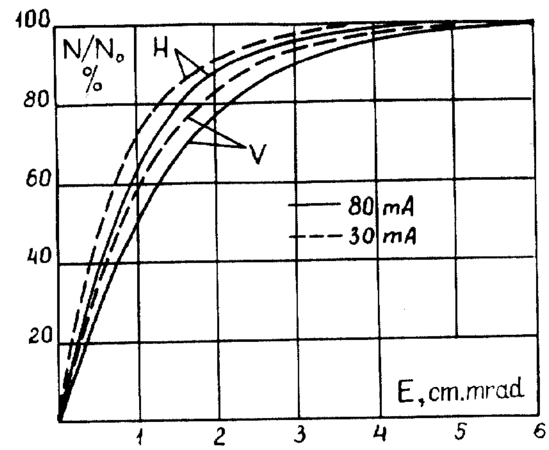

Fig. 4. Experimental distribution of beam current vs emittance.

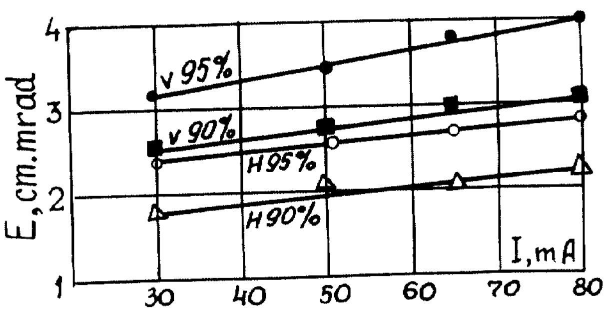

Fig. 5. Dependence of emittance on beam current.

At current pulse flat-top the emittance shape and value remain practically unchangable (for example, effective emittance of 5 μs pulse practically coincides with the instantaneous one).

Detailed momentum spectrum measurements show strong dependence of this parameter even on a rather small missteering of the resonators and RF supply system tuning. With an accurate tuning of RF system a total momentum spectrum width of ±0.3% can be obtained. But typically the spectrum width is ±0.4 % while its shape and mean energy remain quite constant both along individual pulse flat-top and from pulse to pulse within a train of 30 booster cycles which supplies the main 76 GeV accelerator with protons.

A larger width of momentum spread leads to some decrease of synchrotron capture in the booster (95% with $\Delta p/p=\pm0.3\%$, 85% under usual operation mode).

In a booster injector mode the linac system faults were of 1.5% during physical runs of 1987. The number of electrical breakdowns in the resonators is constantly recorded during linac operation periods. This allows one to check up the long-time changes of the accelerating gap electric strength. Typical statistics for one of the runs is given on fig. 6. Vertical axis corresponds to the number of 8-hour shifts with a given percentage of electrical breakdowns; horizontal axis is a sum (over all accelerator sections) percentage of breakdowns defined as a ratio of "wrong" pulses to a total number of pulses per shift. One can see that the average number of breakdowns does not exceed 0.3%, for the first RFQ section this number is 0.05%.

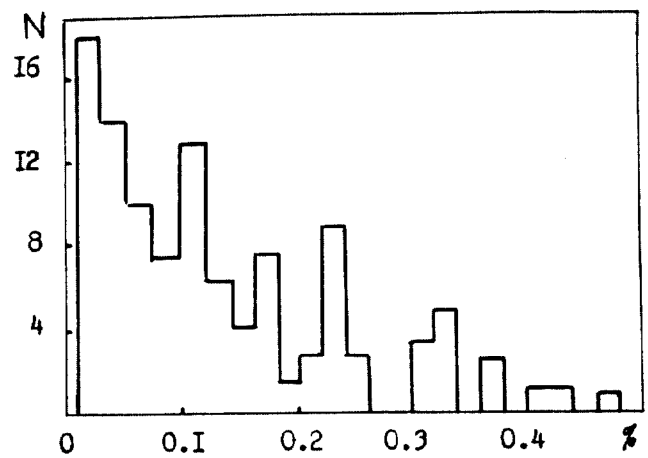

Fig. 6. Electrical breakdown statistics.

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