DESIGN OF 1 GEV, 30 mA PROTON LINAC WITH SUPERCONDUCTING CAVITIES

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At the moment there are not problems of fundamental nature in CW proton linac construction with energy of 1 GeV and current of 30 mA. That is why the main problems have economic and technical aspects [1,2]: high economic efficiency (total electric efficiency >50 %), its reliability and radiation purity, linac design have to permit modernization with changing of beam performances demanded, linac design has to apply perspective methods and materials tested in actual practice.

The most expedient way of obtaining of such proton beams is acceleration in linear accelerator with superconducting (SC) accelerating resonators .

The scheme of CW proton and negative ion of hydrogen linear accelerator (LAP) with energy of 1 GeV and current up to 30 mA with superconducting accelerating resonators (SCR) in the main part is shown in Fig.1.

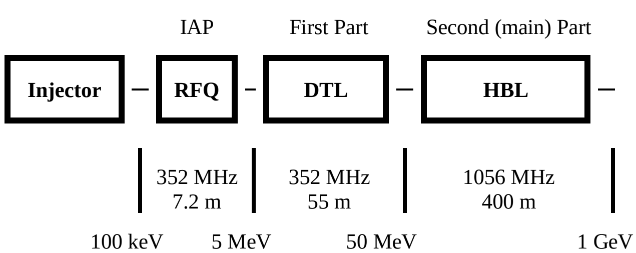

Fig.1.
1 GeV, 30 mA CW linac scheme.

The following main statements are used in its design.

1. Reliability: low voltage injector; low beam losses; CW mode; decreased number of RF channels.

2. Economic efficiency: superconducting cavities in the main part of linac; short length because of high accelerating rate.

3. Radiation purity: beam losses are not more than 10^{-4} [3] because of acceptance reserve of accelerating-focusing channels.

4. Linac consists of three parts. Initial part - RFQ structure, accelerating field frequency f_1 = 352 MHz. First part - three DTL resonators, frequency f_1 = 352 MHz. Main part - accelerating structure consists of 248 nine-cell axially symmetric cavities with elliptical shaped cells excited at the frequency f_2 = 1056 MHz.

Odd frequencies ratio f_2/f_1 = 3 allows if necessary to simultaneous acceleration of protons and negative hydrogen ions.

The main parameters of linac are presented in the Table 1. The parameters will not change for the case of acceleration of hydrogen negative ion beam.

The RF system and automatic control system are proposed as classic linac. For decrease of number of RF channels the possibility of excitation of several (6-2) SCR in main part by one RF amplifier is considered. Klystrons are used as RF amplifiers (1.3 MW klystrons - in initial and first parts, 400 kW klystrons - in main part).

In order to provide superconductivity in the SCR, its surfaces by layer are cooled to 2K by liquid helium. The total thermal power removed by helium is 5 kW.

Module of the main part of the linac with two SC cavities and PM quadruple lens is shown in the Fig.2.

Codes of LIDOS.Advisor package [4-7] were used for beam dynamic calculation Main problem is to prevent particle losses in high-energy accelerator part. Two main dangerous effects leaded to increase transverse beam size would be set: influence of phase motion on transverse one and random errors (within the limits of tolerances) in tuning and installations of channel elements. First effect is peculiar features of superconductng channel. In ordinary “warm” channel influence of phase motion on transverse one is weak effect, but in this case this influence is rather high because of high amplitude of accelerating field. This effect is most conspicuous in high-energy accelerator part with low (50-100 MeV) particle energy

High Beta Linac (HBL) part of LIDOS.Advisor package makes it possible to determined channel main parameters, demanded tolerances for elements installation, to reveal influence of various factors on beam parameters in the channel and at accelerator output. Initial and final particle energy, distribution of accelerating field amplitude and equilibrium phase along the accelerator, emittance, current are specified as initial information. Mean-squared errors of position of focusing lens ends, focusing fields, rotation of lens median axes, amplitude and phase of accelerating fields are used as additional initial data. Based on these data, channel random realization are calculated and statistic characteristics of beam parameters are derived. Simulations on the base of LIDOS.Advisor.HBL show that mismatching factor of transverse beam sections increases to the boundaries of

Table 1

Parameter	Initial Part	First Part	Second Part
Type of accelerator, resonator	RFQ	DTL	9-cell resonators
Injection energy, MeV	0.1	5	50
Output energy, MeV	5	50	1000
Frequency of accelerating field, MHz	352	352	1056
Number of resonators	1	3	248
Period of focusing, m	$\beta\lambda$	$2\beta\lambda$	$14\beta\lambda$
Acceptance, specified,π cm·mrad	0.27	2.0	2.0
Effective emittance, specified, π cm·mrad	0.1-0.15	0.15-0.3	0.3-0.4
Equilibrium phase, degree	-(40÷35)	-30	-30
Phase width, degree	360÷36	36÷20	60÷20
Pulse spread at output, %	0.32	0.1	0.04
Resonator length, m	7.2	18.5-17.6	0.4-1.12
Diameter of resonator, cm	20.2	55.0	29-26
Aperture diameter, mm	5	20	30
Accelerator length, m	7.2	55	400
Power for beam, MW	0.15	1.35	28.5

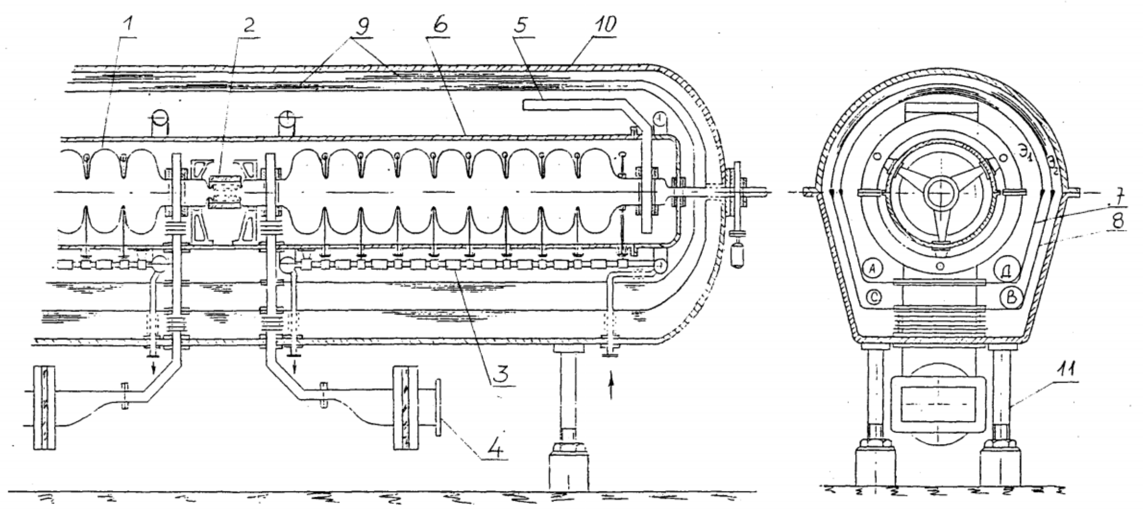

Fig.2.
Module of the main part of the linac with two SC cavities and PM quadruple lens.
1 – accelerating cavity; 2 – permanent magnet (PM) quadruple lens; 3 – nickel bar with cavity frequency fine-tuning elements; 4 – RF input; 5 – loading for high mode suppression; 6 – helium vessel; 7 – heat screen; 8 – radiation screen; 9 - superisolation; 10 - cryostat case; 11 – supports with adjusting devices; A, B, C, D – helium flow system

longitudinal oscillation separatrix up to the 1.8 – 2 in the considered case. If beam phase width at the channel beginning is 50^0, than maximal mismatching is 1.5. Beam phase characteristics at the accelerator output for the channel without disturbances and superposed beam phase portraits obtained with 50 channel random realization are shown in the Figs.3,4.

Phase width of initial beam is 50^0. Initial data were as follows: error of cavity field amplitude – 1%, error of cavity phase – 1^0, transverse displacement of quadruple lens ends – 50 mkm, error of magnetic field gradient in the lenses – 1%, rotation of lens median axes – $0{,}5^0$. Statistic characteristics of beam parameters obtained in 50 random realization are shown in the Fig.5.

Results analysis shows that because of influence of longitudinal phase oscillations and under the influence of random errors transverse beam size with high confidence coefficient will not exceed 5.5 mm. In this case the size of matched equilibrium section in the channel without errors is 3 mm.

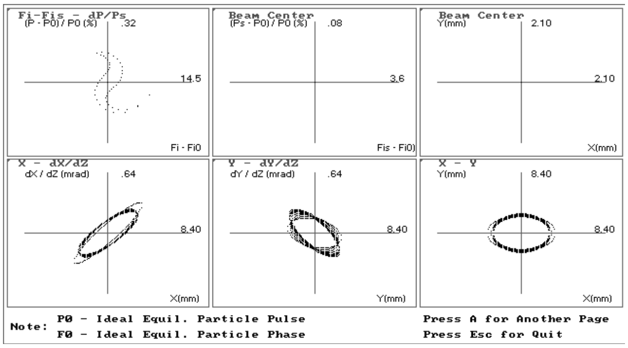

Fig.3.

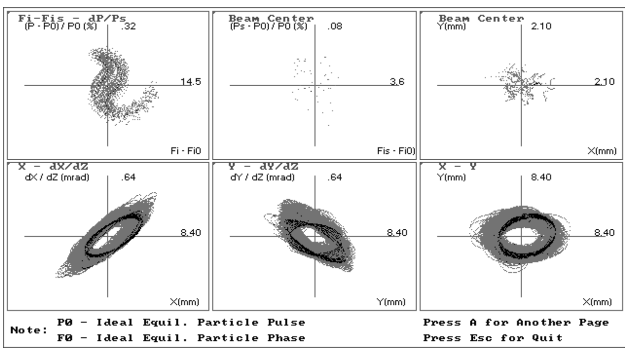

Fig.4.

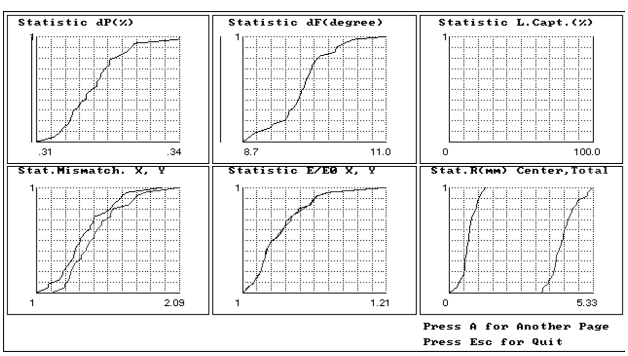

Fig.5.

Fulfilled investigations verify efficiency and reliability of described scheme as well as its practical feasibility.

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