Compact Accelerator for Proton Therapy

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Abstract

The conceptual design of the compact H⁻ synchrotron for proton therapy is proposed. Main features of this accelerator are small size, simplicity in control and maintenance and possibility to be vertical placing on the wall of a room. The structure and main parameters are described in this project

1. INTRODUCTION

Main features of the accelerator for proton therapy have been described in [1]. It is to be very simple in design and operation. Below we consider proton synchrotron structure which has several important advantages as compared with the accelerator described in [1]: lesser dimension of the accelerator on the whole, the bending magnets and quadrupoles, simple betatron tunes correction. This synchrotron is adapted to vertical mounting and vertical disposed beam transfer lines and treatment rooms. However, a few complications are take place in this scheme: the complicated process of slow extraction because of the lesser beam size, greater intensity of the injected beam, presence of the quadrupoles in accelerator structure.

2. ACCELERATOR STRUCTURE

The particles are accelerated in following way. H⁻ ions of ≈12 MeV energy are injected into the synchrotron, accelerated up to the energy required, guided to one of the inner recharge targets by momentum-field disadjustment and/or local horizontal orbit distortion (a bump) and ejected from the synchrotron by the main fields of the bending magnets.

The two triplets of the quadrupoles and edge fields of bending magnets are used for beam focusing (edge focusing). Such focusing scheme provides small dimenions of the accelerator and lesser apertures of the bending magnets and quadrupoles. The synchrotron has four long straight and eight short straight sections what is enough to place the injection-ejection devices, accelerating station and beam correction elements. Main parameters of the accelerator are given in the Table 1. Transverse motion function for one superperiod may be seen at the Fig.1.

Table 1
Main synchrotron parameters

Intensity	10^{11} p/s
Particle type	H⁻
Injection energy	12 Mev
Ejection energy	70÷250 MEV
Repetition rate	5 Hz
Flat top duration	30 ms
Orbit circumference	35.2 m
Number of superperiods	2
Superperiod structure: $O_1FO_2DO_2FO_1B_1OBOBOBOB_1$, B_1,B - the edge vertical focusing magnets, F and D - focusing and defocusing quadrupoles, accordingly, O, O_1 and O_2 - straight sections	
O_1 length	1.5 m
O_2 length	0.2 m
O length	0.4 m
Total number bending magnets	10
Field length of B	3.0 m
Field length of B_1	1.5 m
Edge angles of B and B_1 (on entrance and exit)	0.286 rad
Bending magnets field gradient	0
Bending radius	3.82 m
Injection field	0.131 T
Maximum field	0.636 T
Field gradient lengths of F and D	0.2 m
Normalised gradient for F-lens	2.5 m^{-2}
Normalised gradient for D-lens	4.6 m^{-2}
Maximum field gradient in lenses	11.2 T/m
Horizontal tune, Q_r	0.717
Vertical tune, Q_z	1.235
Maximum value of β_r in magnets	8.1 m
Maximum value of β_z in magnets	5.0 m
Maximum of dispersion in magnets	11.5 m
Transition energy	absent
Chromaticity $dQ/(dp/p)_{r,z}$	-0.16; 3.2736
Aperture in magnets R*Z	120*35 mm^2
Half-aperture in lenses	50mm
Vacuum	$5 \cdot 10^{-10}$ Torr

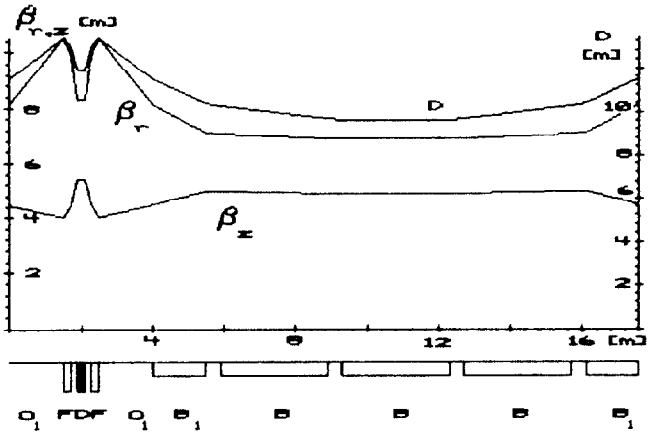

Figure 1. Transverse motion function for one superperiod.

CORRECTION SYSTEM AND BEAM TO TARGET GUIDING

The following correction systems are provided in the accelerator:

1. First harmonics of horizontal orbit distortion cos[R], sin[R].
2. First harmonics of vertical orbit distortion cos[Z], sin[Z].
3. Sum resonance $Q_r+Q_z = 2$
4. Tunes.

For correction of horizontal distortions and tunes, complementary winding at bending magnets and quadrupoles are provided. Also, the complementary windings in magnets serve to produce the bump for guiding of beam to the inner recharge targets. The targets are placing in straight sections "0". For vertical distortion correction horizontal field correctors are provided. To correct the sum resonance skew quadrupoles are served.

ACCELERATION SYSTEM

The syncrotron accelerates ions to 250 Mev energy in 100 ms. 1.4 kV voltage is required for 30° equilibrium phase, and momentum spread dp/p is ±0.3%. The resonators are place in two neighbouring straight sections O_1. The rest two sections O_1 are intended for injection system. Main parameters of the acceleration system are presented in the Table 2.

Table 2
Acceleration system parameters

Harmonic number	2
Frequency change of RF	2.71÷10.46 MHz
Acceleration time	0.1 s
Acceleration voltage	1.4 kV
Equilibrium phase	30°
Number of resonator (on in reserve)	2

REFERENCES

[1] A.E.Bolshakov, L.L.Goldin et al."Accelerator for proton therapy", in Proceedings of 2nd European Particle Accelerator Conference, Nice, France, June 1990, pp.1821-1822.