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Start to end Beam Dynamics Simulation Studies of a 30 MeV Travelling Wave RF Electron Linac

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1. Introduction

As a part of indigenous accelerator development programme for societal applications, a number of accelerator projects have been taken up by DAE, India. To achieve this goal a 30 MeV electron linac that will be used as a neutron generator, has been proposed to be built at BARC, Mumbai. This paper presents the results of electron beam tracking simulations for a 30 MeV travelling wave RF electron linac. This is a general purpose facility for neutron generation and will produce 10 n/sec for measurement of neutron cross-section of (n, gamma), (n, xn) and (n, f) reactions. For the pulsed mode operation of the present linac preferential operation parameters have been determined from the results of beam dynamics studies.

This beam dynamics study uses the electron-tracking algorithm ASTRA [1] and explores the quality of electron beam [2], [3], [4], [5] to determine the optimized beam parameters that minimizes the induced radioactivity in the structure for hands on maintenance and predict the beam quality for the safe linac operation.

2. General Layout of the Linac

A schematic layout of the 30 MeV linac is shown in Fig.1. The linac consists of a DC thermionic gun, followed by a bunching and accelerating section. An electron gun having LaB cathode injects the beam of 50-70 keV in to the linac. The buncher section consists of 4 coupled cavity biperiodic accelerating cells operating in $\pi/2$ mode at a frequency of 2856 MHz and each of length 45, 48, 50 and 52 mm respectively. The accelerating sections consist of a S-band linac which is composed of one SLAC type travelling wave cavity of length 3 m operating at a frequency of 2856 MHz. Beam focusing is ensured by solenoids over the buncher section and the accelerating cavity.

Table 1: Input beam parameter at injection

Input Beam Parameter	
No. of macro particles	25000
Distribution	Gaussian
Beam current	500 mA
Energy	50 keV
Energy Spread	2 keV
Beam size	3.0 mm
Transverse Emittance	6 π mm-mrad

For the present work the longitudinal electric field components on the symmetry axis (r=0) of the buncher cells have been computed using CST MWS as shown in Fig.2. One period of a S-band 2p/3 mode SLAC travelling wave cavity along with the input and output coupler half cell and their fringing fields in the beam tube is shown in Fig. 3. Fig. 4 shows the solenoid field profile. For all the simulations presented in the following, we have used the following input beam parameters that are given in Table 1. A typical simulation result at the end of the linac is presented in Table 2.

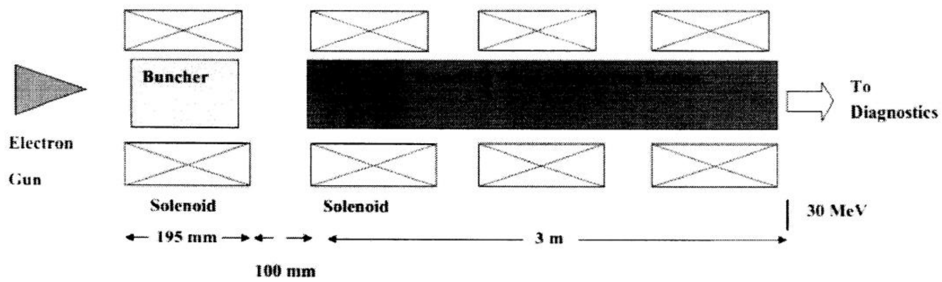


Fig. 1 Schematic Layout of the 30 MeV linac

Table 2: Simulation Result at the Linac end

Input Beam Parameter	
Energy	30.84 Mev
Energy Spread	1518 keV
Bunch Length	4.965 mm
Beam size	8 mm
Transverse Emittance	31.35 π mm-mrad

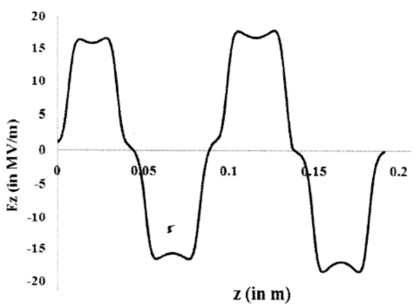


Fig. 2 Longitudinal electric field profile of buncher (from CST MWS)

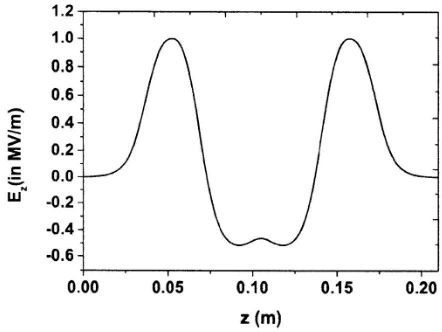


Fig. 3 Longitudinal Field profile of one period of SLAC travelling wave cavity (from Superfish)

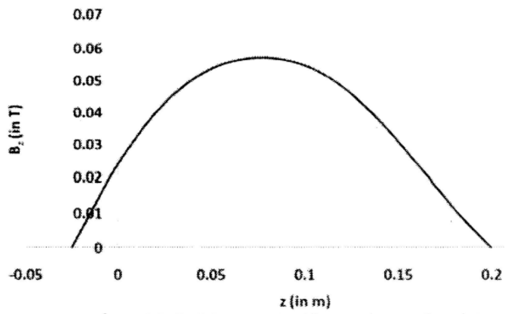


Fig. 4 Solenoid field profile (from CST Particle Studio)

3. Longitudinal Dynamics

The energy gain along 30 MeV linac is shown in Fig. 5. The energy spread along the entire length is shown in Fig. 6.

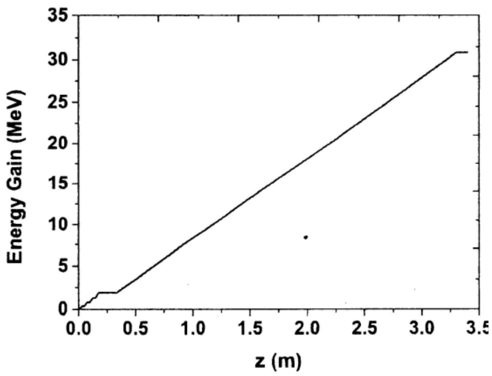


Fig. 5 Energy gain along the 30 MeV linac

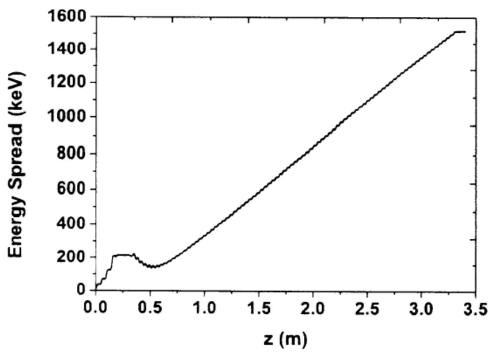


Fig. 5 Energy gain along the 30 MeV linac

4. Transverse Dynamics

The electron beam through the accelerating structure has been tracked with ASTRA with space charge. The radial space charge field may lead to growth of beam size and the beam may hit the cavity wall. The hitting of the electron beam with the cavity wall may induce radioactivity in the linac structure. To compensate the space charge effect a solenoid is applied over the buncher section. Further to focus the beam solenoids have been applied over the accelerating cavity as shown in Fig. 1. The beam envelopes with and without application of solenoid is shown in Fig. 7. Fig. 8 describes the transverse emittance growth along the linac. The plot shows that application of solenoid over the buncher cells and accelerating cavity reduces the emittance growth along the linac structure.

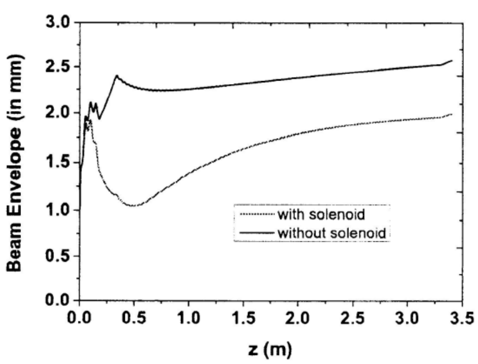


Fig. 7 Beam envelope without solenoid (black curve) and with solenoid (red curve)

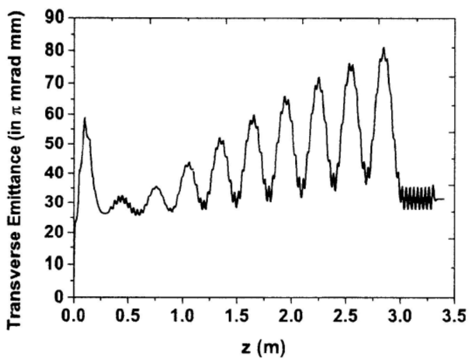
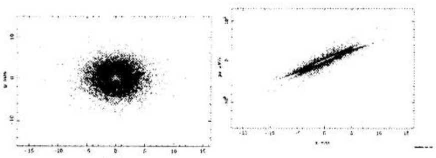
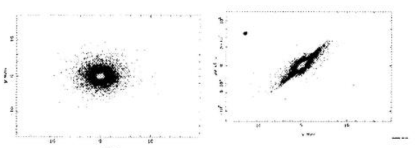


Fig. 8 Transverse emittance along the linac



(a) Beam size and (b) Beam divergence with space charge



(c) Beam size and (d) Beam divergence with solenoid

Fig. 9 Transverse phase space at the end of linac

Transverse phase space of the electron beam at the end of the linac are shown in the Fig. 9 for without space charge effect and with space charge effect along with the focusing effect of the solenoid. It is clear that the solenoid focuses the beam in the buncher section and compensates the space charge field of the beam.

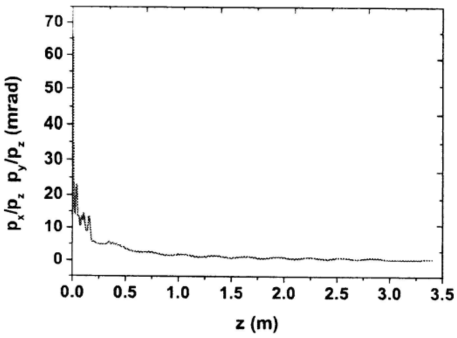


Fig. 10 Beam divergence along the linac

The divergence of the beam is plotted along the linac structure, as shown in Fig. 10. It is clear that the divergence decreases along the linac and beam converges to a smaller spot size. This conclusion can be drawn from the phase plots of the beam size and divergence at the end of the linac.

5. Conclusion

We conclude from these beam dynamics studies that space charge effect plays a pivotal role in the injector. We have applied a solenoid over the injector section and over the accelerating cavity to compensate the space charge effect and focus the beam. An energy spread of ~ 5% improves the quality of the output beam. With a beam size of ~ 8 mm in the bore of aperture diameter 19 mm, the beam loss on the cavity wall is minimized and the heavy irradiation of accelerator components is prevented.

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