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memorandum

Los Alamos Neutron Science Center, LANSCE-1
Accelerator Physics and Engineering Group

To/MS: Distribution
From/MS: H. Takeda, LANSCE-1, H817
Phone/Fax: 5-0820/5-2904 x7
Symbol: LANSCE-1:99-127 (TN)
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Email: htakeda@lanl.gov

ACCELERATION OF LOW ENERGY 2.5 MeV H^- BEAM WITH CCDTL

1. Abstract

In this memo, we explore the possibility and the difficulties of accelerating a low energy H^- beam from RFQ (2.5 MeV) using a CCDTL structure instead of a DTL structure. The advantage of using the CCDTL is that the beam diagnostics and the magnetic optics can be separated out and placed outside of the accelerating structure. The DTL which utilize the length more with acceleration than the CCDTL structure encloses each long section of accelerating structure inside a resonant tank. There, placing of diagnostics and external adjustment of transverse focusing optics inside of the tank is difficult. On the other hand, the CCDTL does not accelerate a beam at the inter-segment spacing between the cavities. To accelerate a beam at a comparable length as it required for the DTL, we need a high electric field in the cavity, and also the smaller drift tube bore size which increases a shunt impedance and utilizes rf power efficiently.

This particular study was performed to replace the DTL with CCDTL for the SNS project at the low energy end of the accelerator. The 402.5 MHz rfq beam passes through chopper sections in the MEBT area. Then, the beam from the MEBT section is injected into a 805 MHz CCDTL structure. With this scenario, most of design difficulty is condensed in the CCDTL section. Namely, the frequency doubling transition make the beam longitudinal bunch twice longer in phase in the CCDTL structure. In fact, if the phase rampling is too rapid, the beam could be lost longitudinally along the shrinking Separatrix (although we need to assume a rapid phase ramping to reach a reasonable acceleration in a short distance). Without the beam mismatch error, or beam optics error, or other errors, the design can transport and accelerate an H- beam to 20 MeV only with a minor beam loss. However, results show that the margin of error is very thin: with a slight mismatch, the beam can hit the CCDTL bore 0.75 cm radius or 1.00 cm bore near 20 MeV.

2. The optimized cavity design according to the beam energy.

We briefly discuss some aspects of cavity design which were performed by Jim Billen. The cavities were designed with a specific manner which requires a particular linac design.

We assumed a slightly larger bore radius than was used in the cavity design performed in the Superfish code: we assumed that the bore radii increased stepwise at β=0.1 from 0,75 to 1.0 cm in our Parmila simulation (Figure 1) instead of increasing continuously from 0.75 to 1.0 cm. Some of the design aspects are graphically shown in the figures 1, 2, and 3. The length of designed linac is 25 m which accelerates the beam to 20 MeV. This is compared with 8.3 m if DTL is used for the same acceleration.

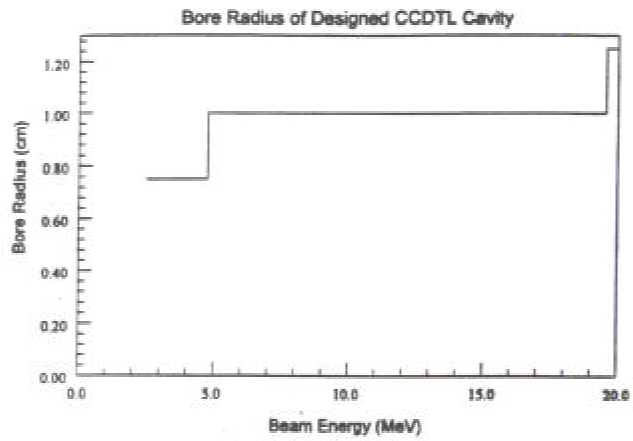

Fig. 1. Bore radius assumed in the Parmila simulation.

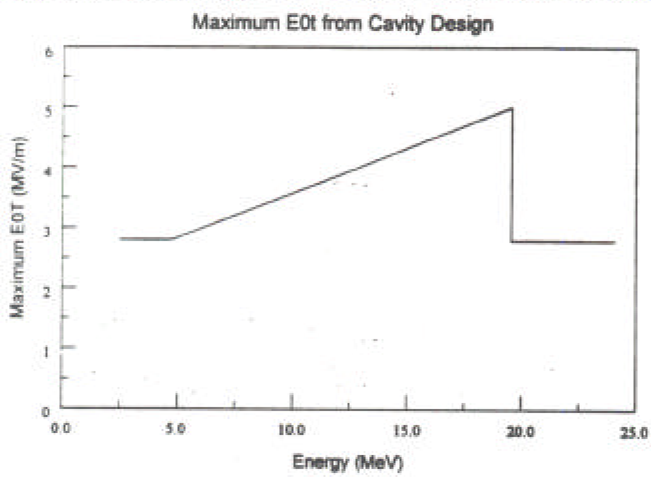

Fig. 2. Maximum E0T allowed by the designed cavities.

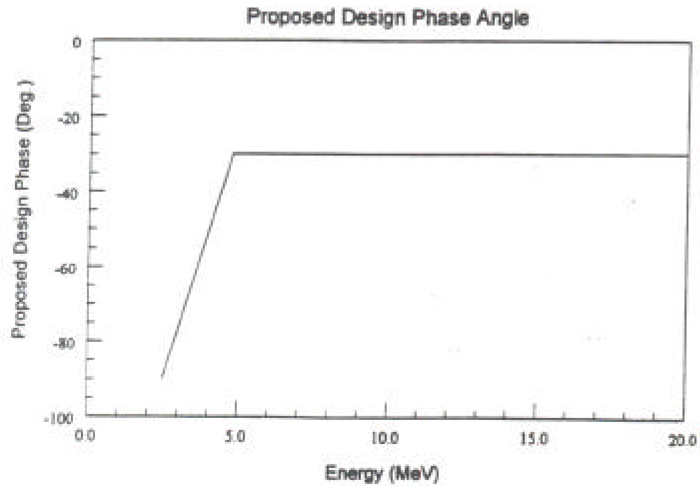

Fig. 3. Proposed design phase angle in the CCDTL cavities. The rapid ramp at the low energy accommodates both shrinking phase width of separatrix and a better acceleration.

3. Actual design parameters after reducing beam transverse size and minimizing longitudinal loss.

The matching section from the MEBT consists of the first 4 quadrupoles following each segment and the first two cavities of the first two segments which are operated at -90°. After the matching section, the quadrupole strengths are kept nearly constant (Gl= 2.6 T gradually reduced to 2.4T). This produced about 80° zero current phase advance per period. The rapid ramping of E0 at the beginning made the longitudinal phase advance slightly over 90° for short sections. However, this made the beam captured better in the separatrix. Then, the phase advance reduced to 60° at 20 MeV.

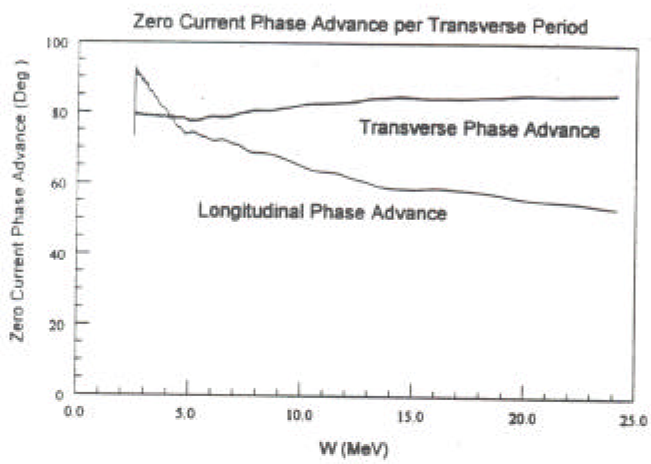

Fig. 4. Zero current phase advance per transverse period. The quadrupoles are set such that approximately 80° phase advance is maintained.

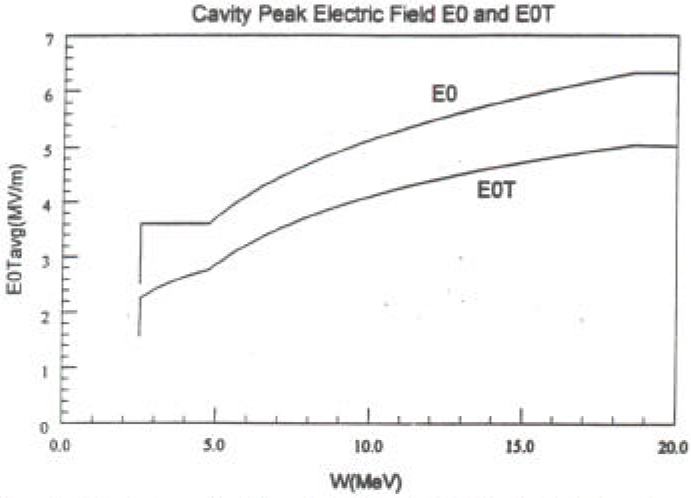

Fig. 5. Cavity peak electric field E0. This is designed to minimize the envelope oscillation with full current.

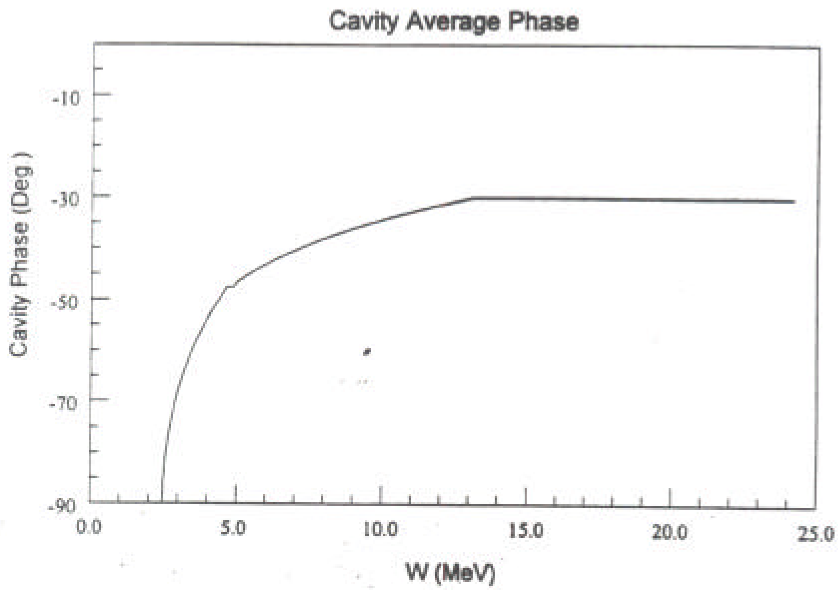

Fig 6. The design phase is ramped very rapidly at the beginning. This increases the acceleration and shortens the accelerator.

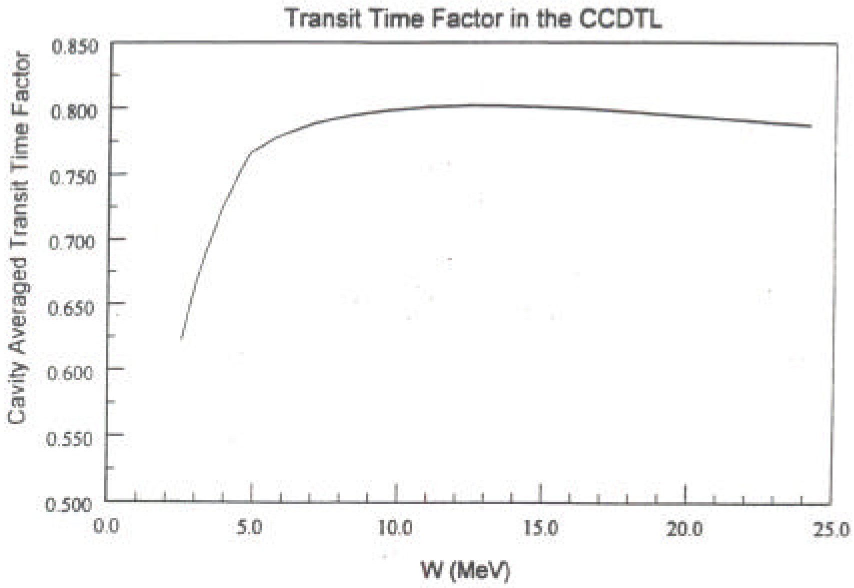

Fig. 7. The transit time factor along the CCDTL for the designed cavities.

4. Beam dynamics behavior.

The beam envelopes x, y, and phase ϕ, and Energy W with respect reference particle are shown in Fig 8. This design was well optimized to minimize the beam envelopes at bunch peak current 112 mA at 805 MHz. The envelope calculations were performed from 2.5 MeV to 24 MeV. The emittance growth along the CCDTL is minimal. However, the coupling between transverse and longitudinal emittance is seen in Fig. 10.

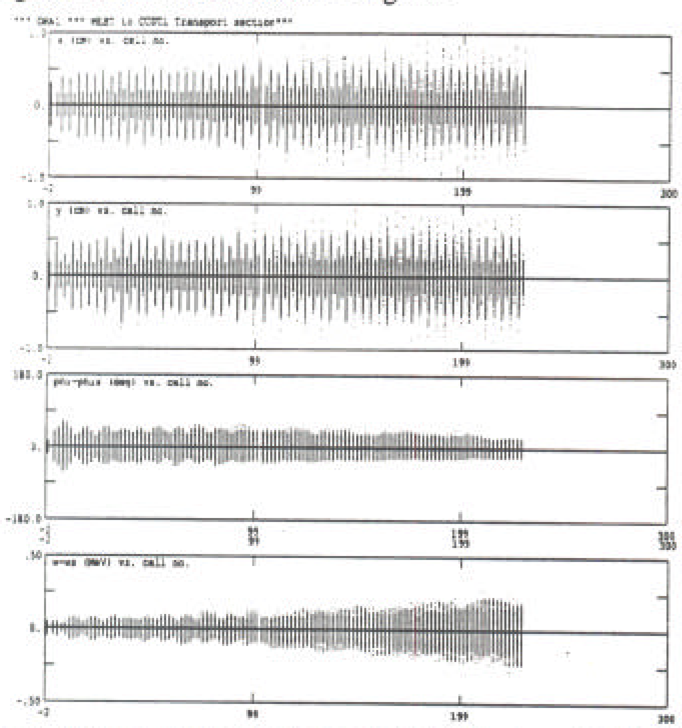

Fig. 8. Beam envelopes along the CCDTL from 2.5 MeV to 24 MeV at 805 MHz.

The maximum beam excursion along the beam line shows that the 1.0 cm bore radius is marginal above 10 MeV (Fig. 9). At most only a few particles in a 10k particle simulation were lost by the aperture.

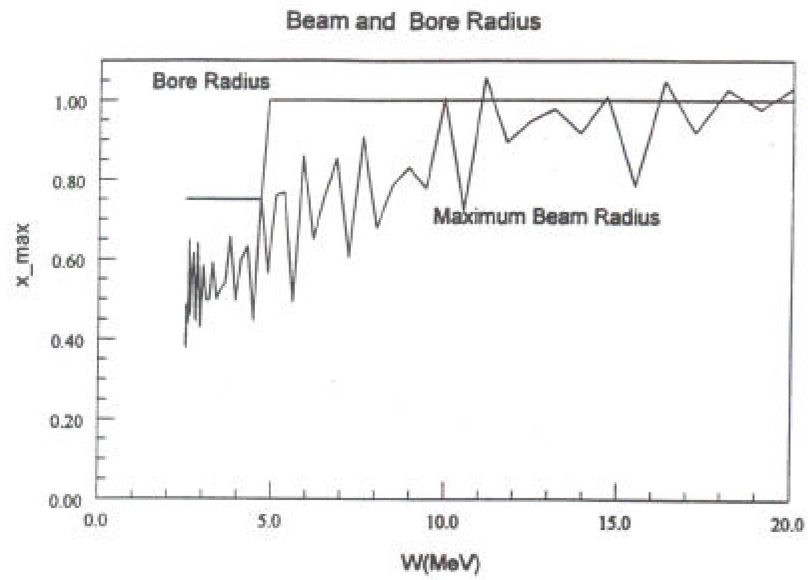

Fig. 9. Maximum beam excursion along the linac. The Bore Radius is also indicated to show that the aperture is very tight for the design. In ths run, one particle was lost among 10000 particles.

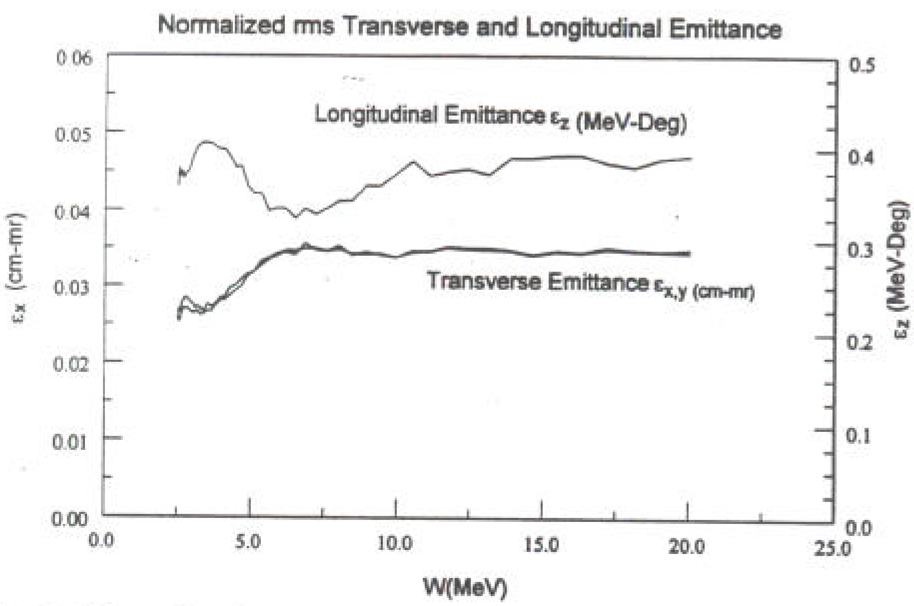

Fig. 10. Normalized rms emittance along the CCDTL.

HT:amg

Distribution:
J. Billen, LANSCE-1, H817
B. Blind, LANSCE-1, H817
N. Bultman, ESA-EA, P946
T. Bhatia, LANSCE-1, H817
R. Granett, LANSCE-1, H817
D. Gilpatrick, LANSCE-1, H817
R. Jameson, LANSCE-1, H817
A. Jason, LANSCE-1, H817
S. Kurennoy, LANSCE-1, H817
W. Lysenko, LANSCE-1, H817
G. Neuschaefer, LANSCE-1, H817
J. Stovall, LANSCE-1, H817
H. Takeda, LANSCE-1, H817
SNS Project Office, H824
LANSCE-1 File