BNL-105674-2014-TECH

BNL/SNS Technical Note No. 106;BNL-105674-2014-IR

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March 2002

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USDOE Office of Science (SC)

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Introduction

In the note linac dump optics is revisited in the view that the vacuum window has moved from the dump to near the last quadrupoles. Before the window moved to near quadrupoles optics was such that that the beam size was blown up to 60 mm radius at dump by creating waist near the quadrupoles by using last two set of two quadrupoles with two power supply instead to one long quadruole . Figure 1 shows the beta function along the linac dump line. When the window brought near the quadrupoles the same optics did not worked because it was creating small beam size at the window and temperature rise in the window was too much. So the quadrupoles were redistributed in the same length and try to create bigger beam size at the window namely 3 cm in diameter (95%). It needed two more power supply. The beam size on the dump stop will depend on the thickness and material of the window.

The linac dump will be used to commission the CCL and SRF linac from 200 MeV to 1000 MeV. The constrains are shown in table 1

Table I: Linac Dump Constrains

Energy (MeV)	Unnor RMS Emittnace (mm mrad)	$\beta\gamma$	Beam size at window (mm,dia)	Beam size at dump beam stop (mm dia)	Power (kW)	Beam Power (W)outside 203.2 mm dia
200	0.227	0.69	30	120	??	750
1000	0.595	1.81	30	120	7.5	750

Beam size at Window

The available aperture for the quadrupoles near window is 55 mm radius. The end to end simulation shows that the beam extant is up to 7 sigma, (see figure 2, at 7 sigma beam 4.5e-4), therefore maximum beam size for 95% beam is 30 mm in diameter.

Beam Size at Dump Beam Stop

The specification for the beam size at the linac dump beam stop is 120 mm in diameter with a centroid error of +- 50 mm and the maximum beam power out side 203.2 mm must be lower than 750watts [1]

Window Scattering and Energy Loss

As H- traverse through the window it deposited two electrons and the some energy due to straggling and suffer from multiple and nuclear scattering. The energy deposited by one H- due to two electrons is1.12 MeV at 1000 MeV and 0.22 MeV at 200 MeV in relatively short distance in the window. Figure 3 shows the rms multiple scattering angles as function of proton energy and figure 4 shows the energy loss per proton as function of proton energy for 2 mm of Be, Al, and Inconel. Figure 5 and 6 shows the rms scattering angles as function of thickness for Be, Al, and Inconel at 200 and 1000 MeV respectively. Figure 7 shows the energy loss per proton as function of thickness for Be, Al, and Inconel for 200 and 1000 MeV.

The window material under consideration is Inconel base on thermal and stress analysis and material handling consideration [2]. The idea is take advantage of this window and the provide the required beam size at linac dump beam stop through multiple scattering. If one chooses the window thickness (2 mm of Inconel) such that it provide proper beam size at linac dump beam stop at 1000 MeV then for 200 MeV scattering angle is to big and simulations shows that 40% beam get lost in the flight tube (beam tube between window and linac dump beam stop with 18.8 inches ID) and beam size is too big at linac dump beam stop. On the other hand if one chooses window thickness (0.5 mm of Inconel) such that it provide proper beam size at linac dump beam stop for 200 MeV, then for 1000 MeV required beam size at dump beam stop can be achieve by some help of optics.

Optics

We have consider two type of optics solution depending on the window scattering angle (window material and thickness):

(1) Using thin window (for example 0,5 mm of inconel) which provide required beam size at linac dump beam stop at 200 MeV. The beam slowly expended up to window and window multiple scattering provides required beam size at linac dump beam stop for 200 MeV. Figure 8 shows the transport output. For 1000 MeV case, beam form a waist before the window and provide proper beam size ant window and dump with help of multiple scattering from the window. Figure 9 shows the transport output for 1000 MeV case.

(2) Using thick window (for example 2 mm Inconel), which provide the proper beam size at window and multiple scattering provide required beam size at linac dump beam stop for 1000 MeV (see figure 11). The optics is similar to type 1 for 200 MeV case. For 200 MeV(see figure 10), hope for beam power is low enough at the time of commissioning and associated activations magically low with in acceptable limit due to beam spill.

Other cases were considered when the emittance is higher than the design emittance for 1000 MeV case. Figure 11 and shows the cases when emittances are 2 and 4 time of the design emittance. Table II shows the required quadrupole gradient for all these cases

Table II: Quadrupoles Strength for different cases.

Window thickness (mm)	Incone l 0.5	Inconel 0.5	Inconel 2.0	Inconel 2.0	Inconel 2.0	Inconel 2.0
Energy (MeV)	200	1000	200	1000	1000	1000
Emittance (rms, unnor.) (mm mrad)	0.595	0.227	0.595	0.227	0.454	0.908
Grad. Q11 (T/m)	0.55	3.5	0.58	1.3	0.805	1.52
Grad. Q12 (T/m)	-0.11	-3.0	-0.44	-0.49	-0.215	-1.18
Grad. Q13 (T/m)	-0.016	3.7	0.33	0.05	0.475	0.87
Grad. Q14 (T/m)	0.035	-1.7	0.16	0.04	0.431	0.42
Grad. Q15 (T/m)	0.098	2.9	-0.12	0.15	-0.394	-0.34
Grad. Q16 (T/m)	-0.07	-3.0	-0.36	-0.77	-0.97	-0.97
Grad. Q17 (T/m)	0.019	1.9	0.22	0.50	0.59	0.60
Losses in Flight tube (%)	4.5	0.3	40	2.2	2.3	2.4
Beam Outside 8 inch dia (%)	35	0.25	85	4.5	4.5	4.5

PARMILA Simulations

Since TRANSPORT simulation does not include window multiple and nuclear scattering effects and space charge effects PARMILA was modified to include scattering effect. The simulations results are included in table II.

Discussions

In the case of 1000 MeV beam with nominal emittance (0.227 mm mrad, rms, unnor.), quadrupoles gradient are running low, the question was raised that if one can remove these two power supply, this means that one excluding any possibility of higher emittance and order of 40% loses in the flight tube for energies lower than 1000 MeV a at beam commissioning time. More over with two less power supply optics is three time more sensitive to errors for beam area at window at 1000 MeV in case of twice the nominal emittance.

Acknowledgement

I will like to acknowledge S. Henderson for several discussions and suggesting two addition power supply.

References
[1] Ken Chipley, Private communication
[2] G. R. Murdoch, SNS-NOTE-ENGR-40, 28 January 2002

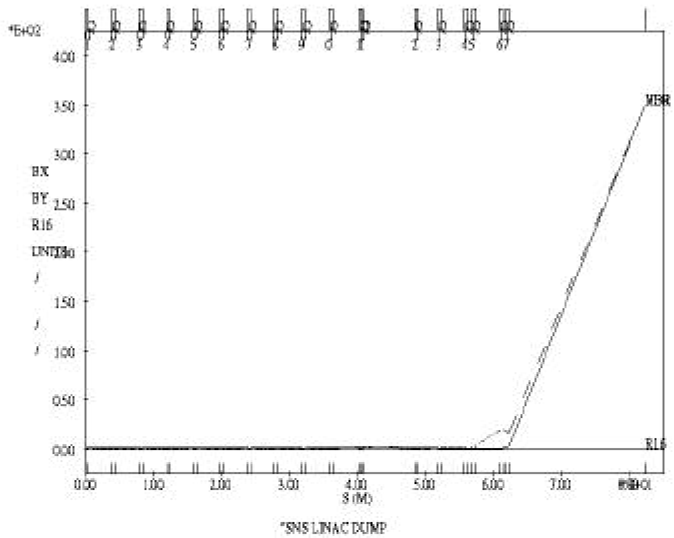

Figure 1: Beta function along the linac dump line before window moved near quadrupole.

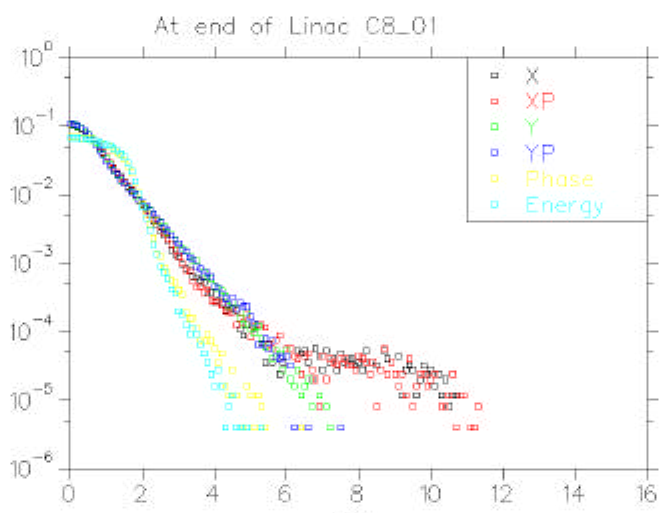

Figure 2 , Beam (x, y, xp, and yp) profiles at end of linac

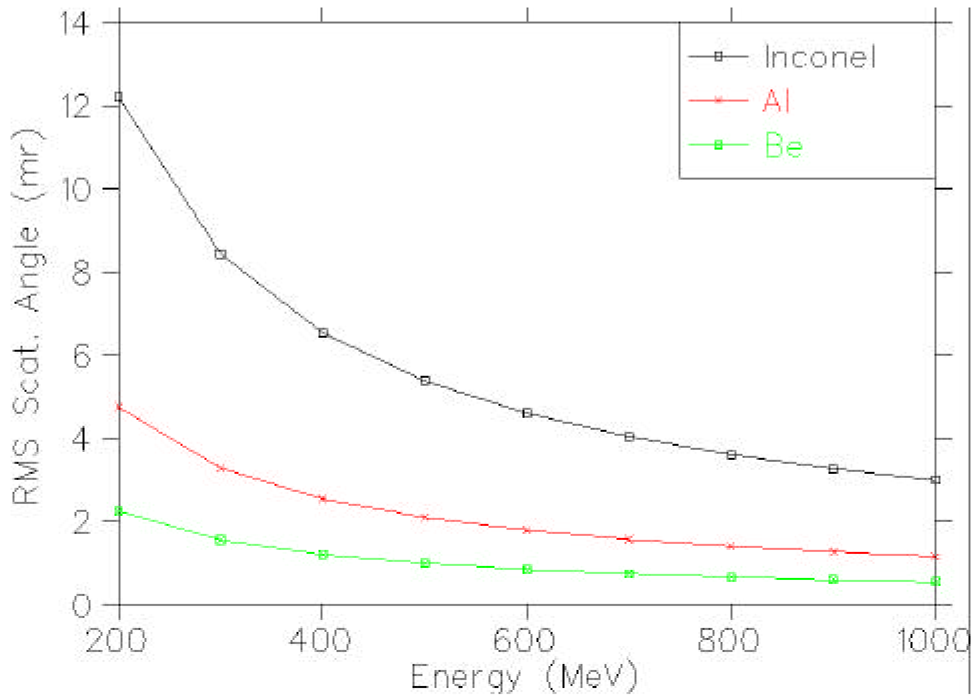

Figure 3: RMS multiple scattering angle as function of proton energy for 2.0 mm thick window for Be, Al and Inconel.

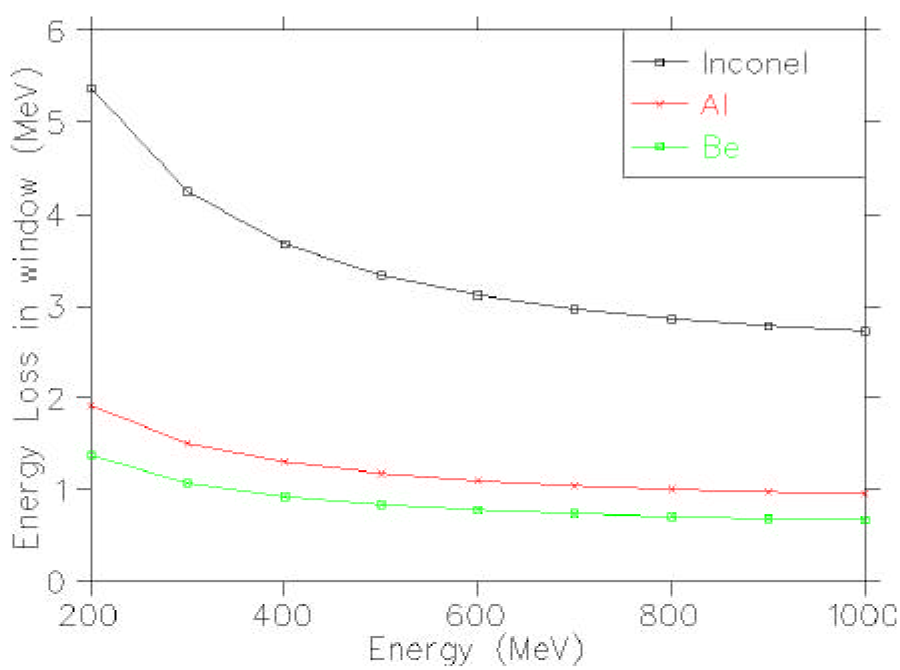

Figure 4: Energy loss per proton in 2 mm thick window as function of proton energy.

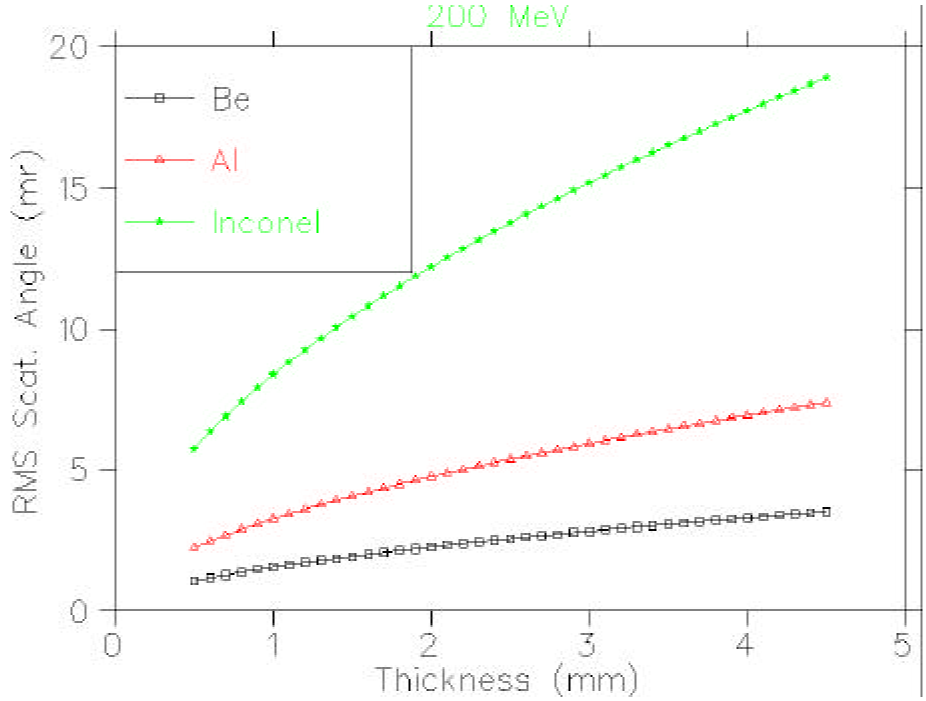

Figure 5: RMS multiple scattering angle as function of window thickness for 200 MeV protons.

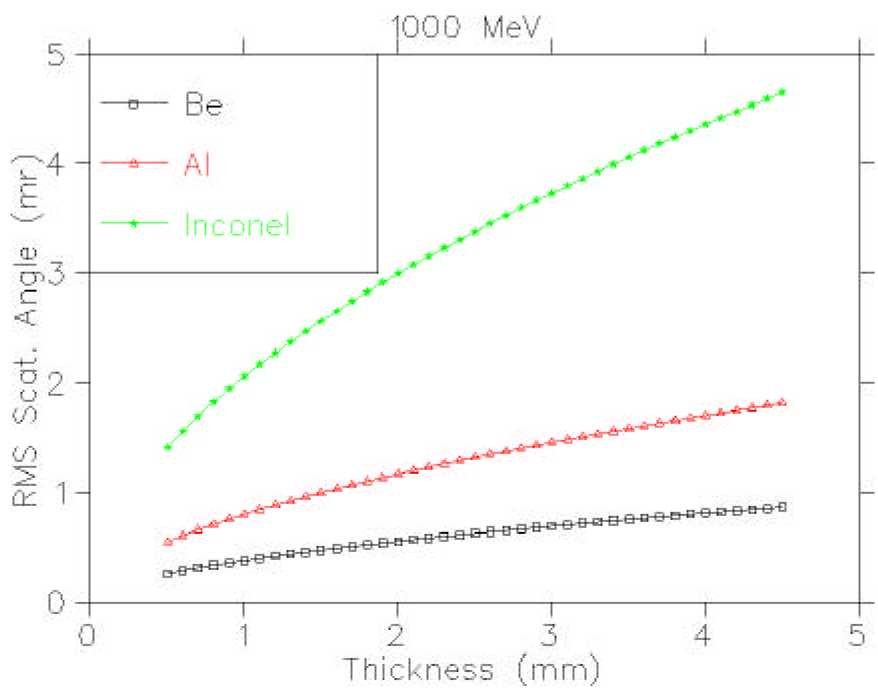

Figure 6: : RMS multiple scattering angle as function of window thickness for 1000 MeV protons.

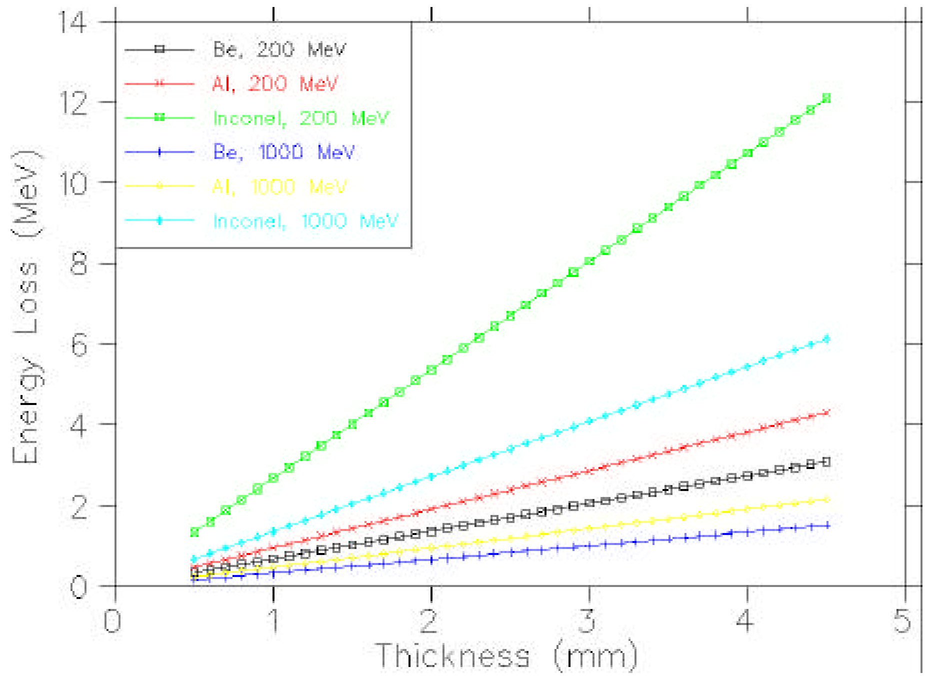

Figure 7: Energy loss per proton as function of (Be, Al, and Inconel) window thickness for 200 and 100 MeV protons.

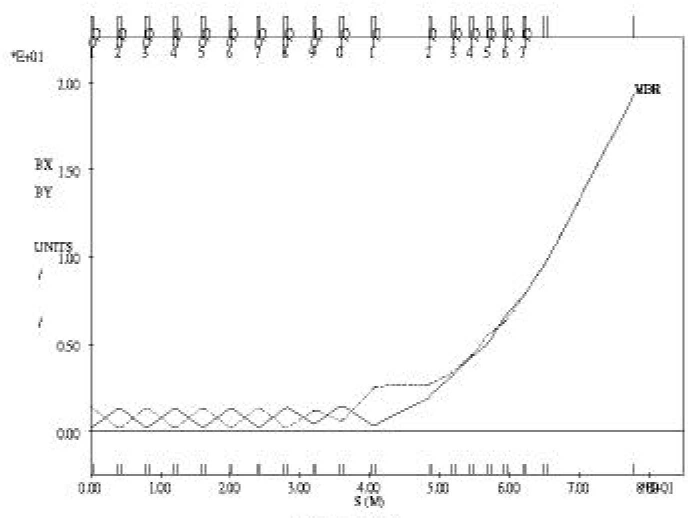

Figure 8: Beta function along linac dump for thin window (0.5 mm of inconel) at 200 MeV.

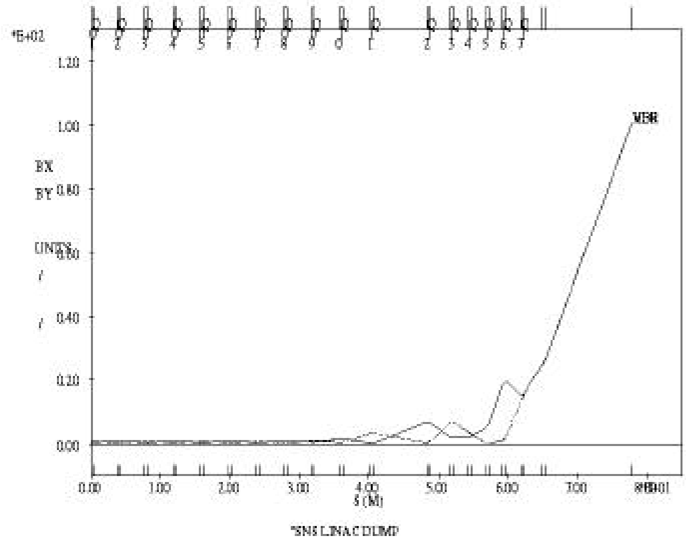

Figure 9: Beta function along Linac dump for thin window (0.5 mm Inconel) at 1000 MeV.

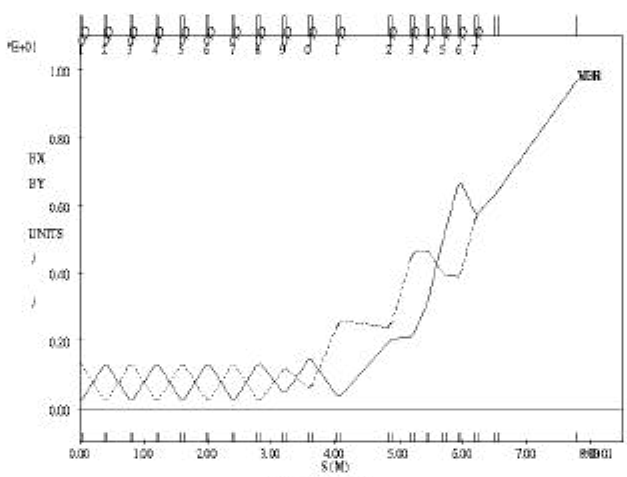

Figure 10: Beta function along linac dump for thick window (2.0 mm of Inconel) at 200 MeV.

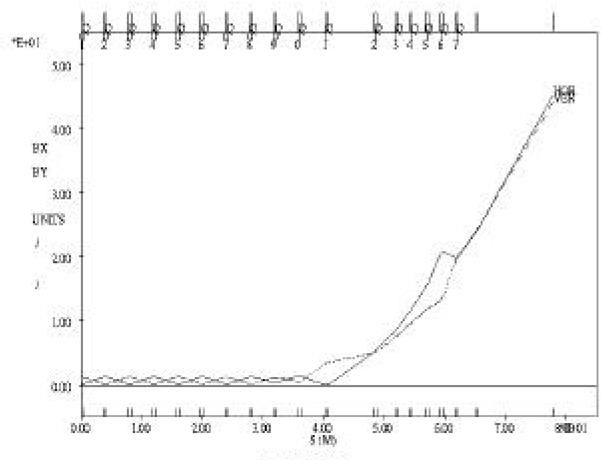

Figure 11: Beta Function along linac dump for thick window (2 mm of Inconel) at 1000 MeV.

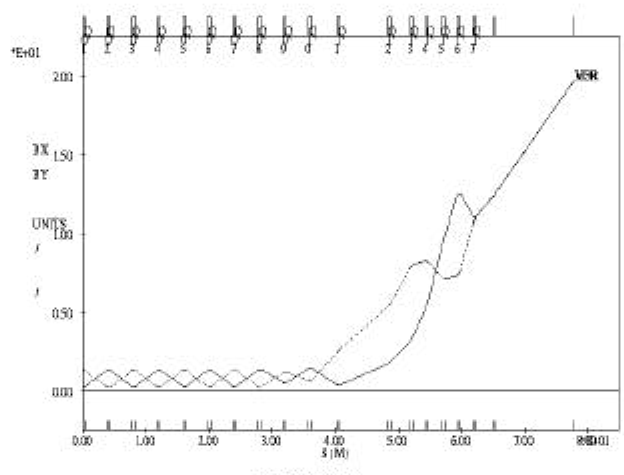

Figure 12: Beta function along linac dump for thick window (2 mm of inconel) at 100 MeV for twice the nominal emittance

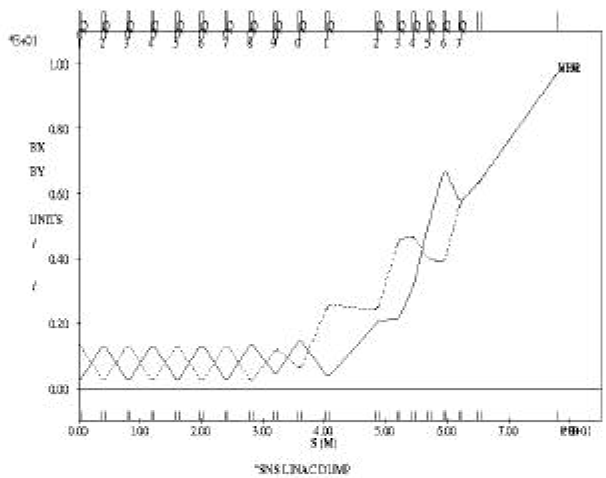

Figure 13: beta function along the linac dump for thick window (2 mm of Inconel) at 1000 MeV for four times the nominal emittance.