

# Accelerators for High Power RACE



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# Outline

- Some characteristics of microwave RF linac accelerator guides and RF power sources.
- Given a particular accelerator guide, selection of an energy and beam current operating point for maximum neutron production.
- Three options potentially available from IAC spares and surplus equipment.
- Cost and schedule for each option.

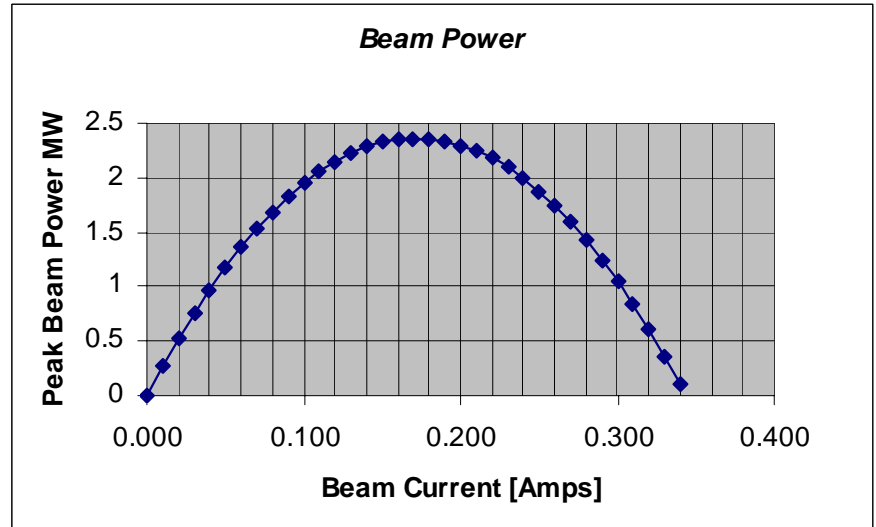
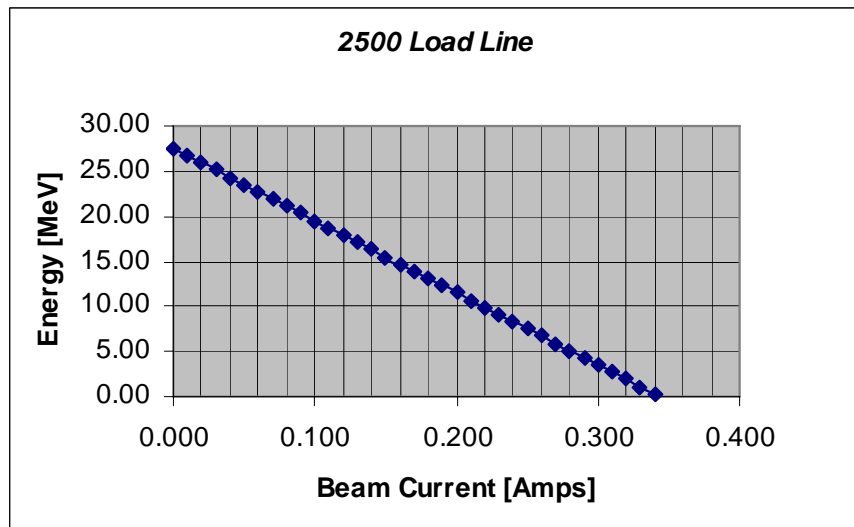
# Fundamentals

A simple performance measure of RF cavity linacs that incorporates accelerator guide properties, input power, and beam current, is the load line of a particular accelerator structure. If  $E$  is the beam energy produced in Mega-electron volts, then;

$$E = A (P)^{1/2} - B i .$$

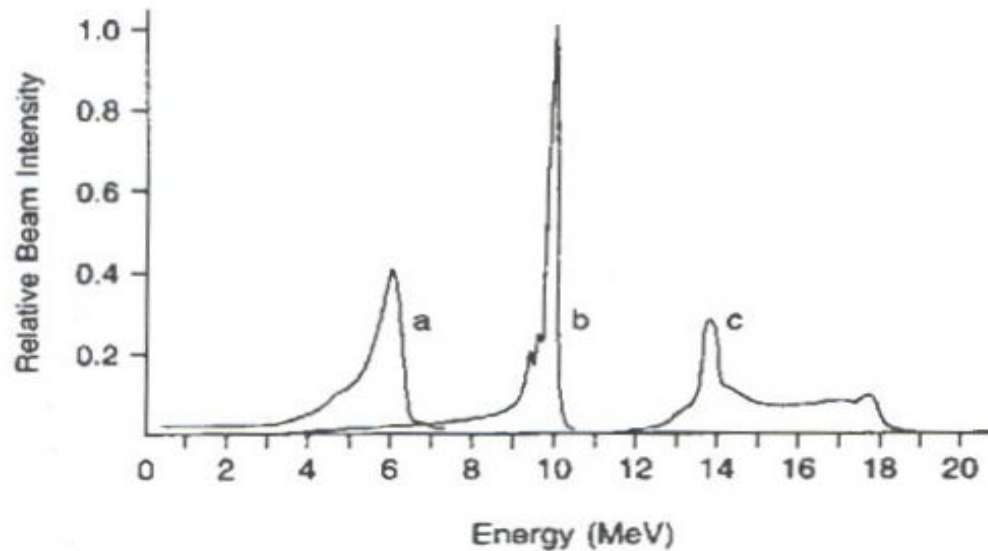
$A$  and  $B$  are constants that depend on guide characteristics (number of cavities, shape, resonant frequency etc.)  $P$  is the radio frequency power in MW and  $i$  is the instantaneous beam current transported through the guide in amps.

In the load line shown below  $P$  is about 3.8MW. Note there is a maximum in beam power at a beam current of 150mA, this will not be the operating point giving the greatest neutron yield.



# Cont; Beam Loading and Energy Spread

In a typical case only somewhere between 50-80% of the beam will be in the useful energy region. This number depends on tuning, pulse length, etc. I will assume this factor to be 0.6.



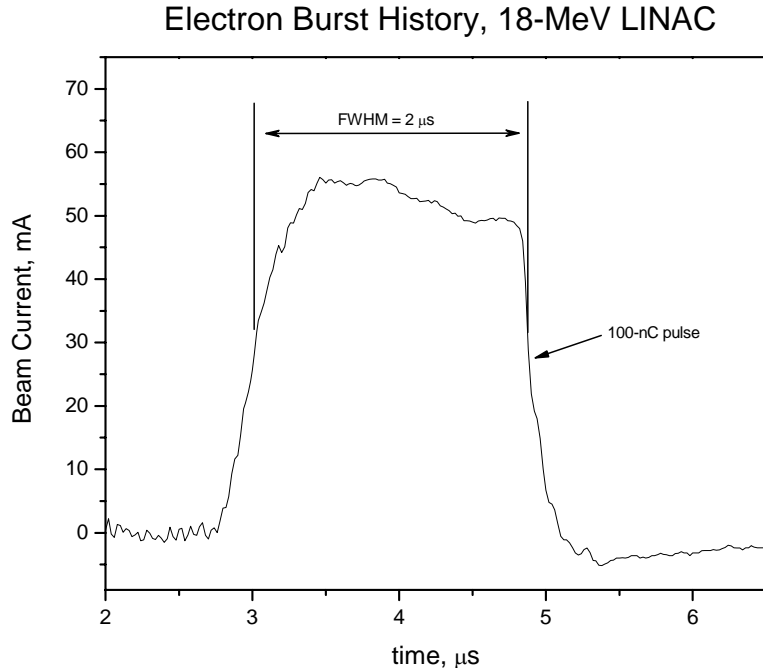
Beam Loading: a, heavy; b, optimal; c, light

# Cont; RF Power Issues

Rf power is generated by pulsed systems in order to achieve the high powers needed. The limitations of such systems is specified by a concept call the Duty Cycle or simply the Duty.

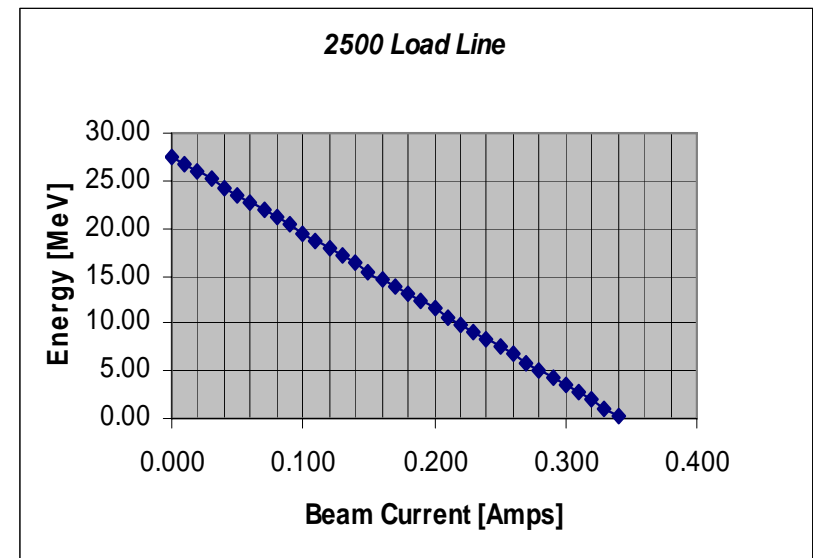
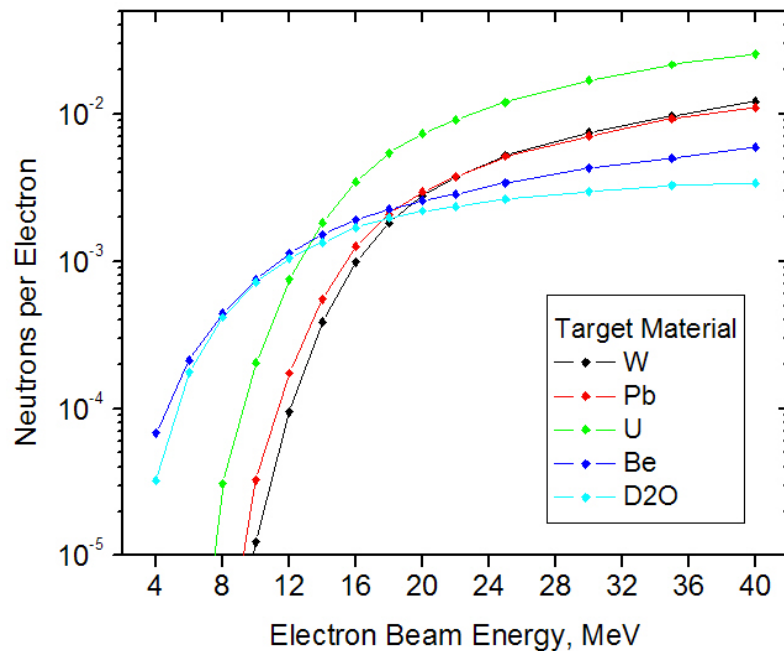
Duty= pulse on time/ time between pulses

for our systems this number is less than .01 or 1%. (There are 2 “Duty’s, one for the RF one for the electron beam, the former is ~10% larger than the latter).

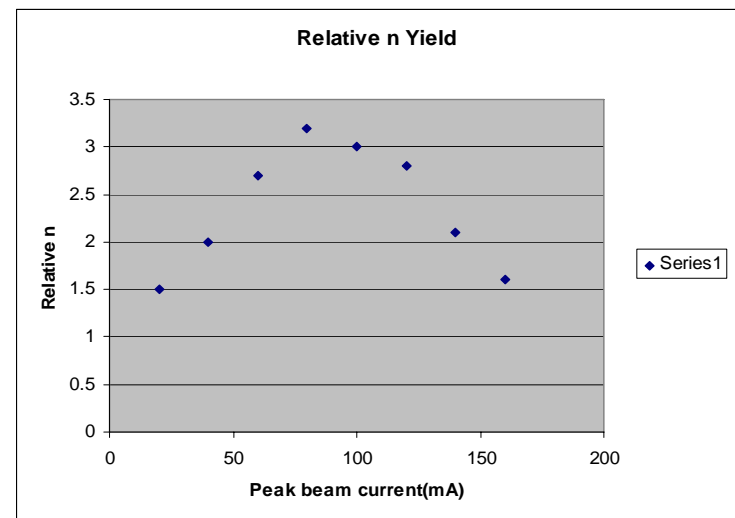
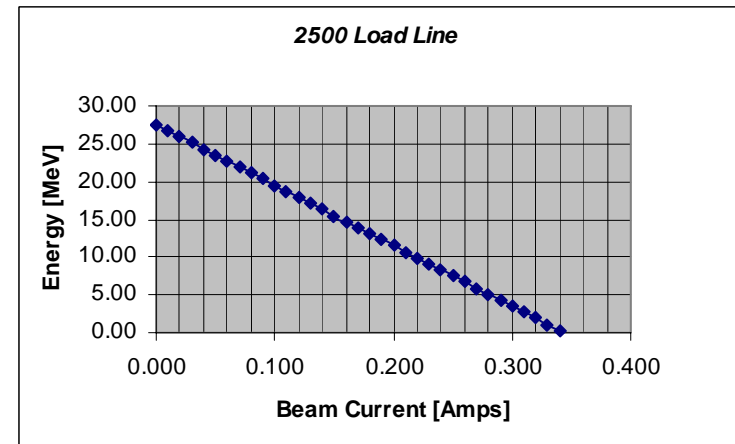
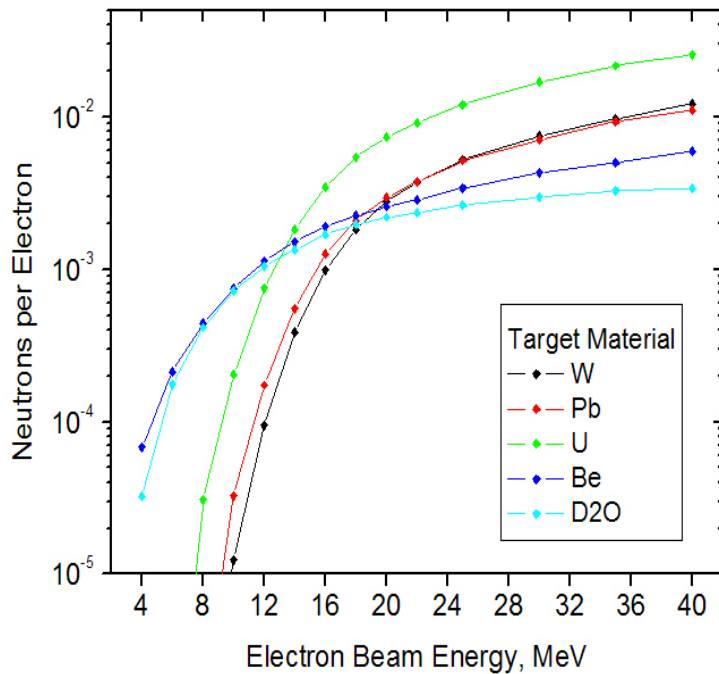


# Accelerator Operating Point for Maximum Neutron Production

In order to find where a particular accelerator guide will produce the greatest neutron yield for a given RF input power we need to combine the Load Line with the neutron production properties of the target.

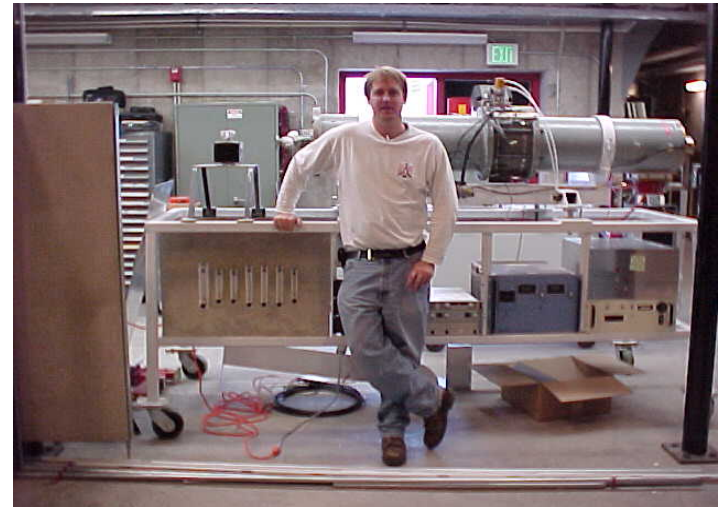


# Example 1: Currently Deployed Accelerator on ISU RACE and “20kW” Upgrade (MALE)



# Example 1 cont.

- A) The maximum neutron output occurs at  $\sim 80$  mA peak beam current, this corresponds to a beam energy of 21.1 MeV. The modulator/RF power system being used at IAC has a maximum Duty of 0.09%, therefore, the beam power at which maximum neutron output occurs is 1519W. The neutron yield on a U target would be  $3.6e12$  n/sec times 0.6 for the beam energy distribution or about  $2e12$  n/sec.
- B) With the High Power Modulator (MALE) the duty is 0.6% so that the neutron output would be  $2.4e13$  n/sec. This would be a 11kW beam. The MALE modulator would likely require electrical power upgrades at a reactor site.



# Cost and Schedule Estimate High Power Upgrade of Current Texas Accelerator

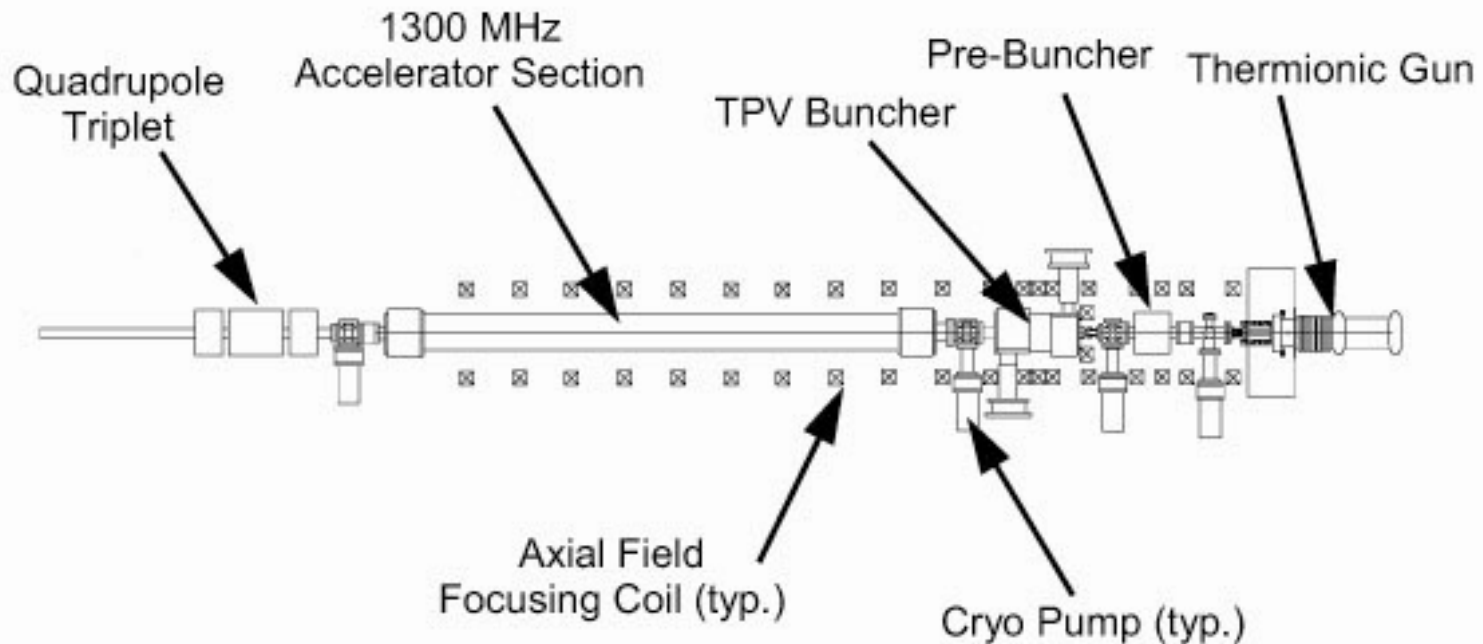
MALE HP S BAND	Total Value	Value of Equipment from IAC	Funds needed
Modulator	\$1,500,000	\$ 1,500,000	
RF System	\$750,000	\$75,000	
Acc. Guide	\$150,000	\$150,000	
Beamline Magnetics		\$ 25,000	
Vacuum System	\$50,000	\$ 50,000	
Facility Costs (estimate)			\$ 110,000
Equipment Totals	\$ 2,450,000	\$ 1,800,000	\$ 110,000
Labor 1 IAC man year	\$ 465,068.00		\$ 132,877.00
TOTAL	\$ 5,365,068	\$ 3,600,000	\$ 242,877



MALE Modulator Chassis, 6'x9' footprint.  
Electrical requirements; 480V, 250A, 3 phase.

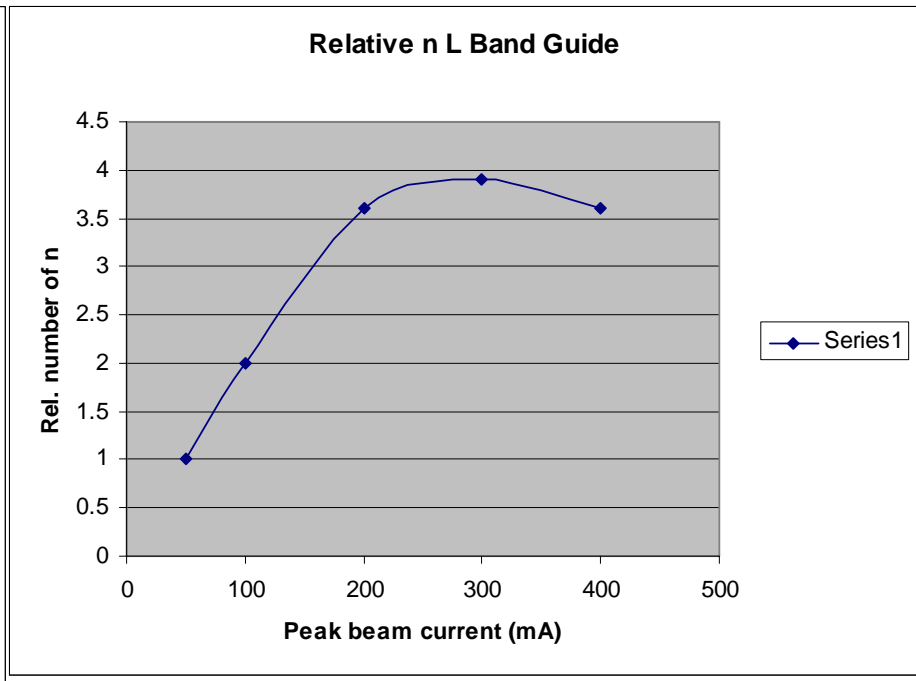
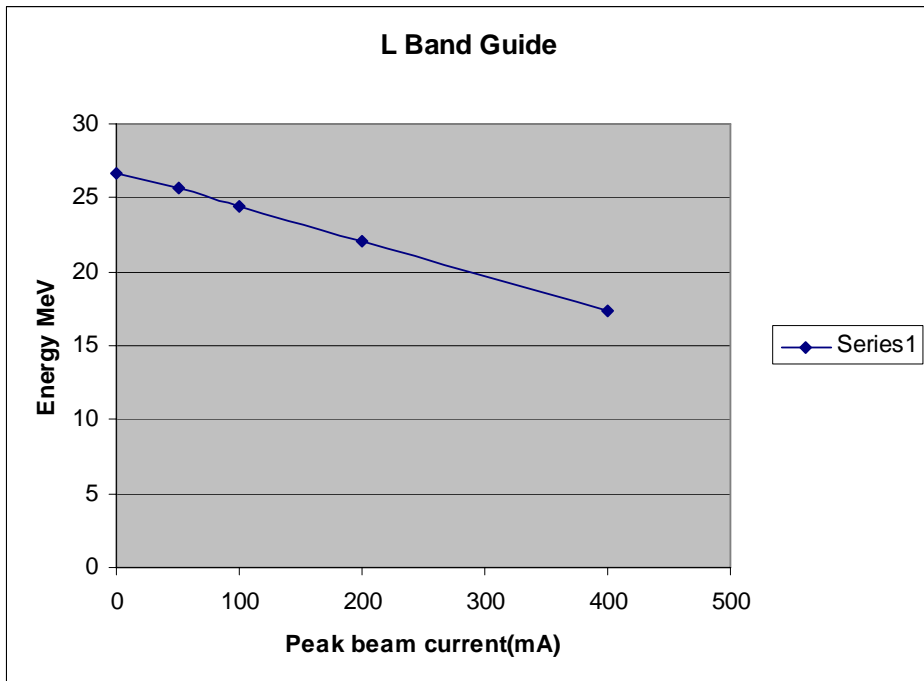
## Example 2, Single Stage L Band Linac

We have available a number of the major components needed to construct a L band linac which can support a larger beam current than our current RACE accelerators. The SSL accelerator would be about 8m long not including the beam line to the target and would require one 10 MW klystron. Installation would require considerable utility upgrades at a typical reactor site. The required space would need to include, modulator, RF system, control electronics and accelerator shielding.



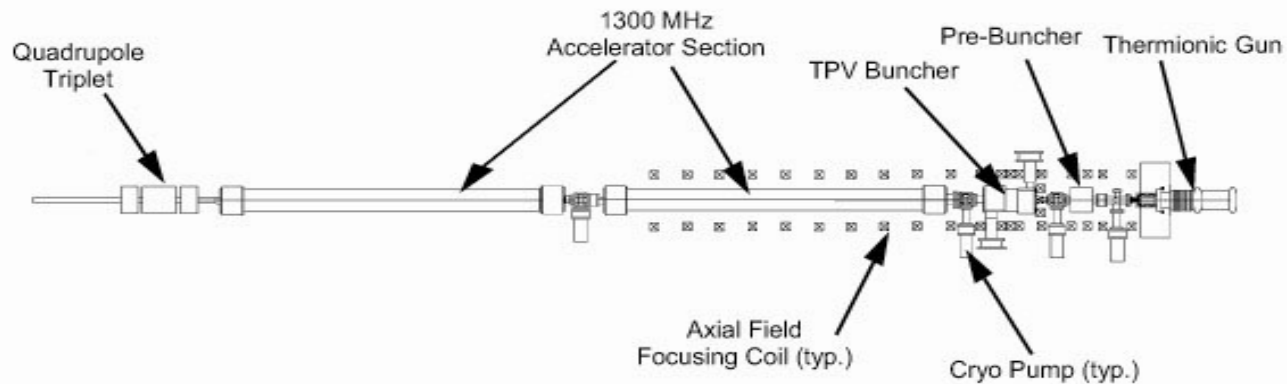
# SSL Accelerator Properties

This accelerator would operate with a pulse length of 8 microsec. and a repetition rate of 360 Hz (Duty=0.29%) with a neutron production rate on a U target of  $\sim 1E14$  (including a .6 beam spread factor). Beam power would be about 17kW with a beam energy of 19.5 MeV.



# Example 3: Two Stage L Band Accelerator

Adding an additional accelerating section to the previous device would require an additional klystron, phase shifters etc. TSL length would be about 12m. Power requirements would nearly double as an additional modulator and klystron would be required. Optimum neutron production would occur with the same Duty as above at a beam energy of 33 MeV and a beam current of 450 mA, a 42 kW beam, resulting in about  $1e15n/sec$ . Space, shielding and utility needs would be significant.



# Cost and Schedule Estimates, L Band Accelerators.

	Total Value	Value of Equipment from IAC	Funds needed
Single Stage Accelerator			
Electron Gun	\$ 180,000		\$180,000
RF System	\$885,000	\$885,000	
Acc. Guide	\$300,000	\$300,000	
Beamline Magnetics		\$ 25,000	
Vacuum System	\$75,000		\$75,000
Water System (excluding facility mods)	\$ 10,000		\$ 10,000
Facility Costs (estimate)			\$ 110,000
<b>Equipment Totals</b>	<b>\$ 1,450,000</b>	<b>\$ 1,210,000</b>	<b>\$ 375,000</b>
Labor 3 IAC man year	\$ 398,630.00		\$ 398,000.00
<b>TOTAL</b>	<b>\$ 3,298,630</b>	<b>\$ 2,420,000</b>	<b>\$ 773,000</b>

SSL Accelerator Costs

	Total Value	Value of Equipment from IAC	Funds needed
Two Stage Accelerator			
Electron Gun	\$ 180,000		\$180,000
RF System 2 needed	\$1,770,000	\$885,000	\$885,000
Acc. Guide 2 needed	\$600,000	\$600,000	
Beamline Magnetics		\$ 25,000	
Vacuum System	\$85,000		\$85,000
Water System (excluding facility mods)	\$ 10,000		\$ 10,000
Facility Costs (estimate)			\$ 110,000
<b>Equipment Totals</b>	<b>\$ 2,645,000</b>	<b>\$ 1,510,000</b>	<b>\$ 1,270,000</b>
Labor 3.5 IAC man year	\$ 465,068.00		\$ 465,068.00
<b>TOTAL</b>	<b>\$ 5,755,068</b>	<b>\$ 3,020,000</b>	<b>\$ 1,735,068</b>

TSL Accelerator Costs