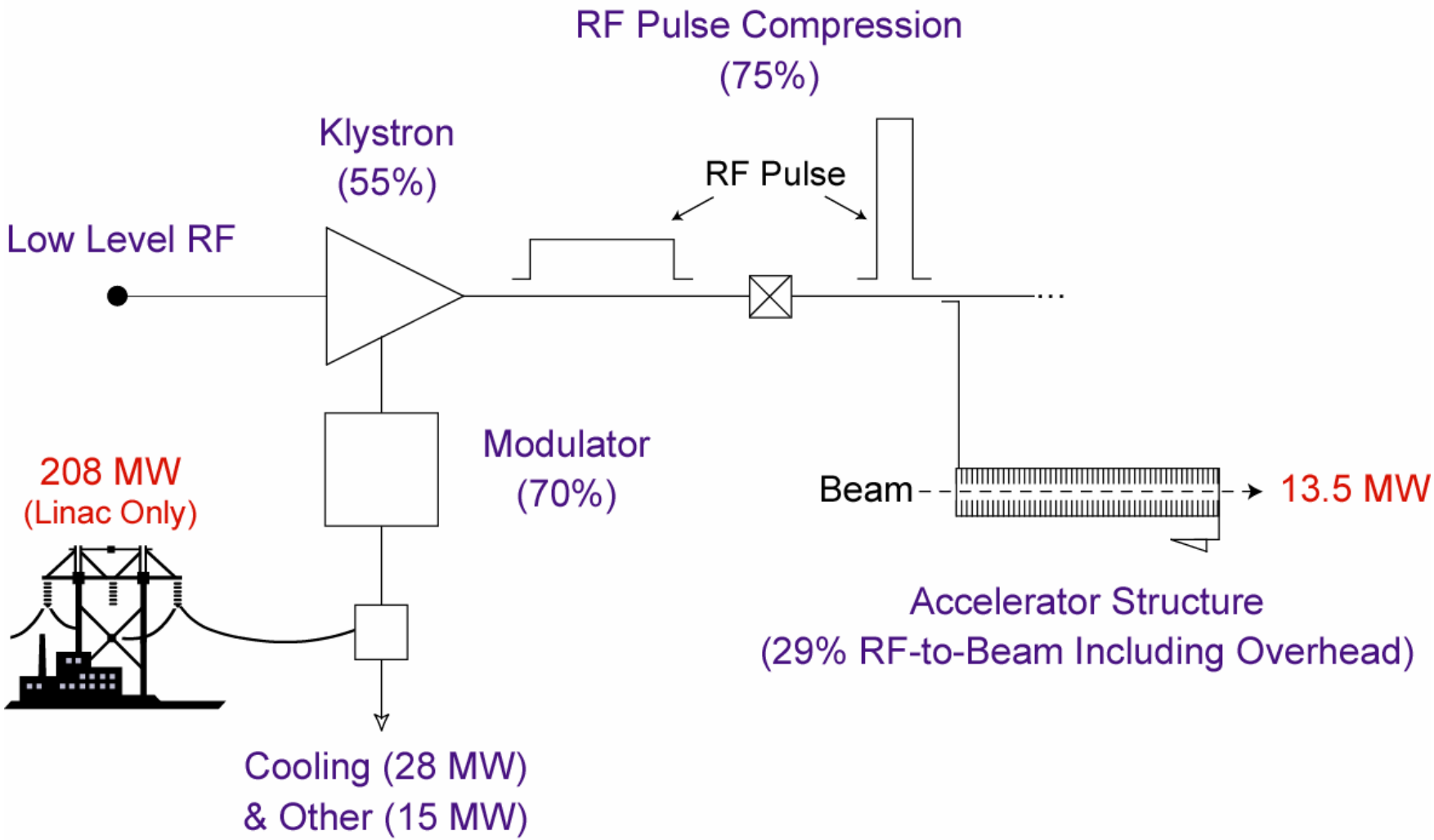
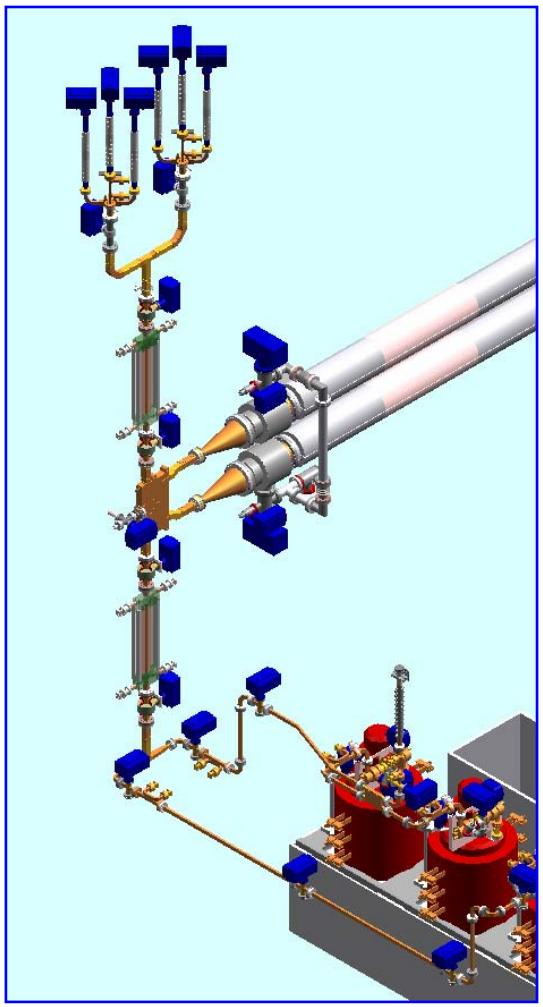
The NLC/GLC X-Band Linear Collider

Main Linac RF Power Unit



David Schultz, SLAC

A Linac RF unit demonstration for the NLC/GLC X-Band Linear Collider



Outline:

The NLC/GLC Main Linac RF 'unit'

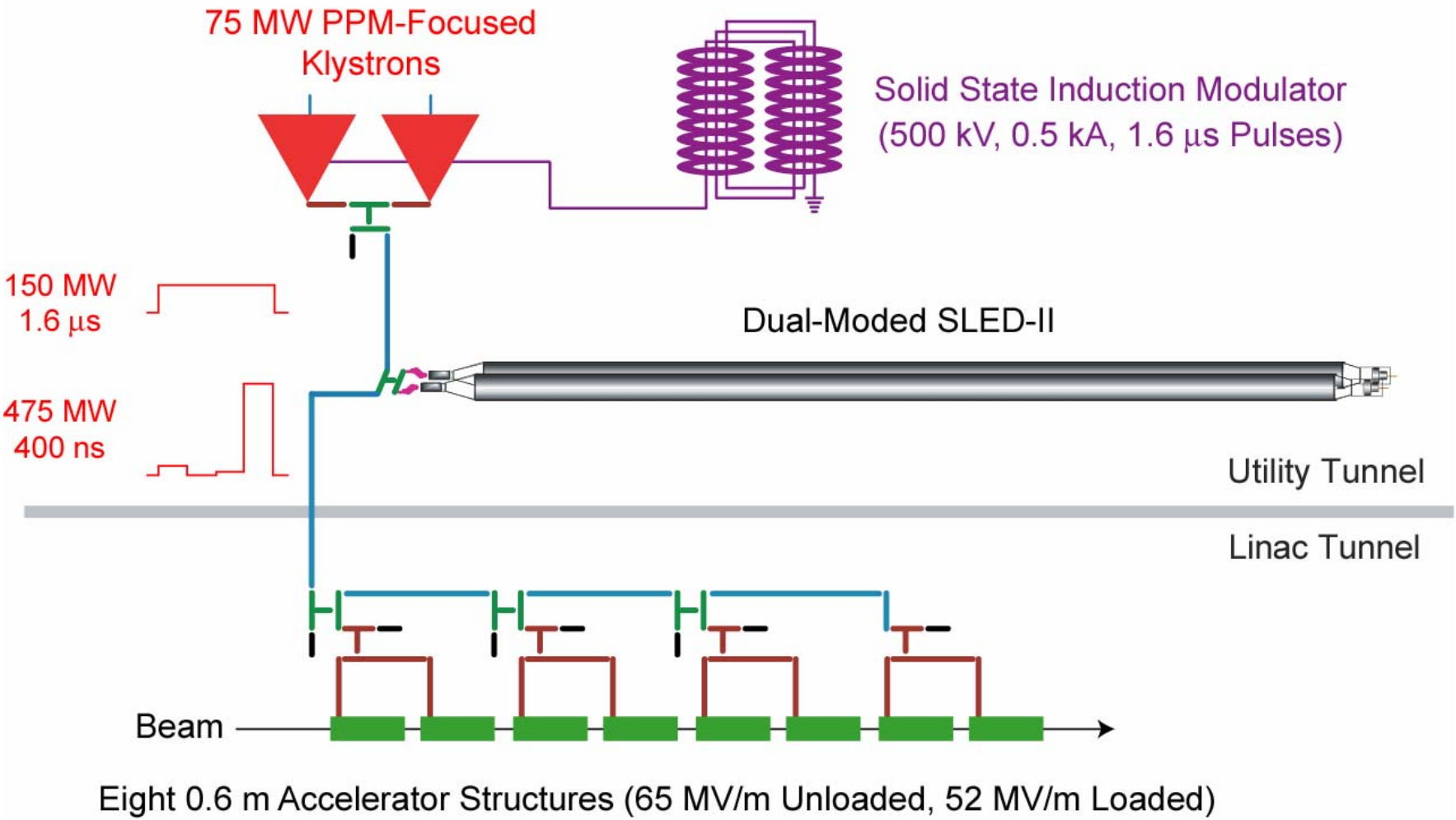
- Modulator
- Klystrons
- RF Pulse Compression
- Accelerator Structures

NLC/GLC Baseline

'8-Pack' Project Implementation

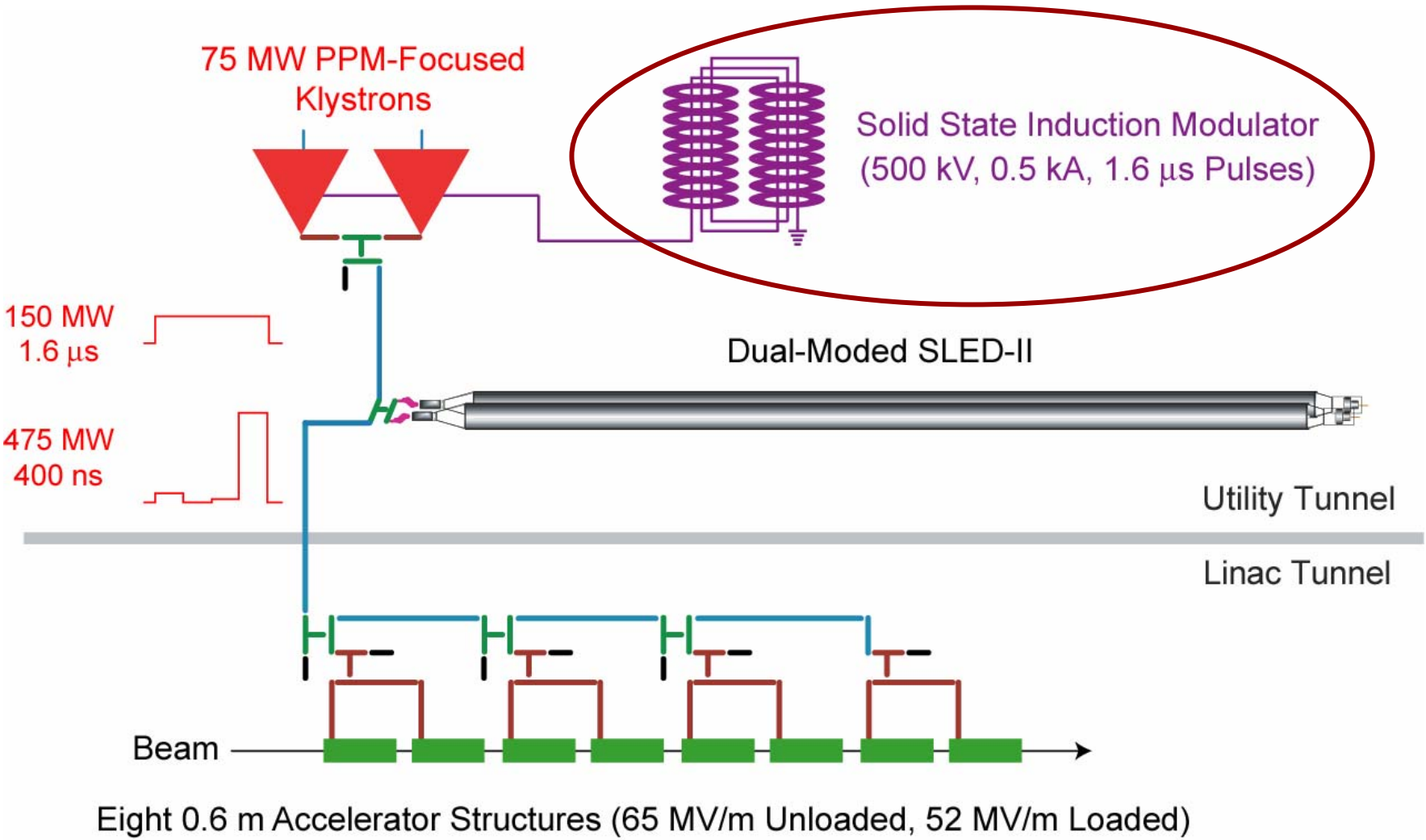
Further Improvements

NLC/GLC X-Band Linac Baseline RF Unit
(One of ~2000 at 500 GeV cms, one of ~4000 at 1 TeV cms)



Eight 0.6 m Accelerator Structures (65 MV/m Unloaded, 52 MV/m Loaded)

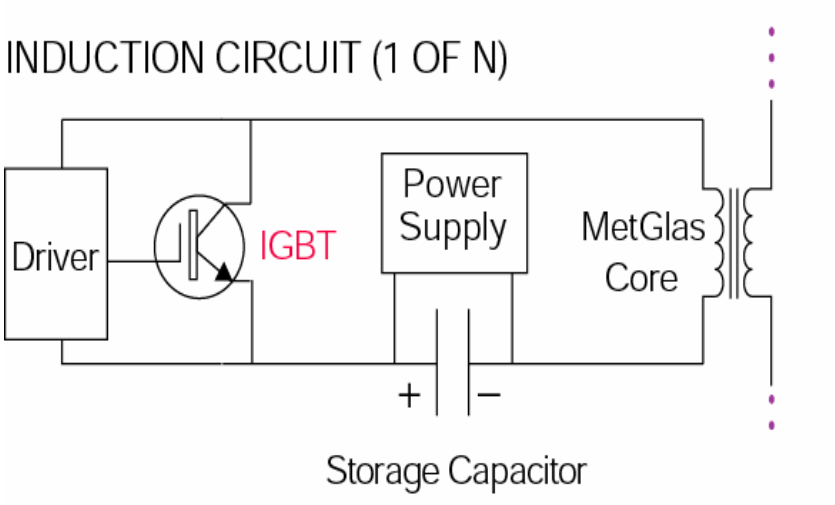
NLC/GLC X-Band Linac Baseline RF Unit
(One of ~2000 at 500 GeV cms, one of ~4000 at 1 TeV cms)

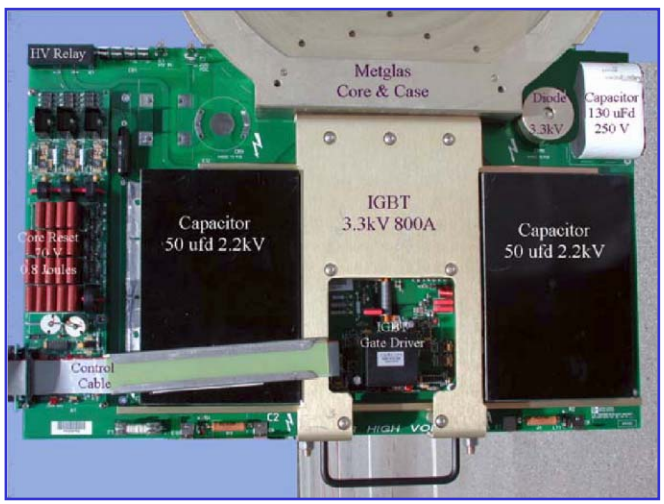


Eight 0.6 m Accelerator Structures (65 MV/m Unloaded, 52 MV/m Loaded)

The Solid State IGBT Modulator

Inductively sum many low voltage sources





Hybrid 2-Pack modulator

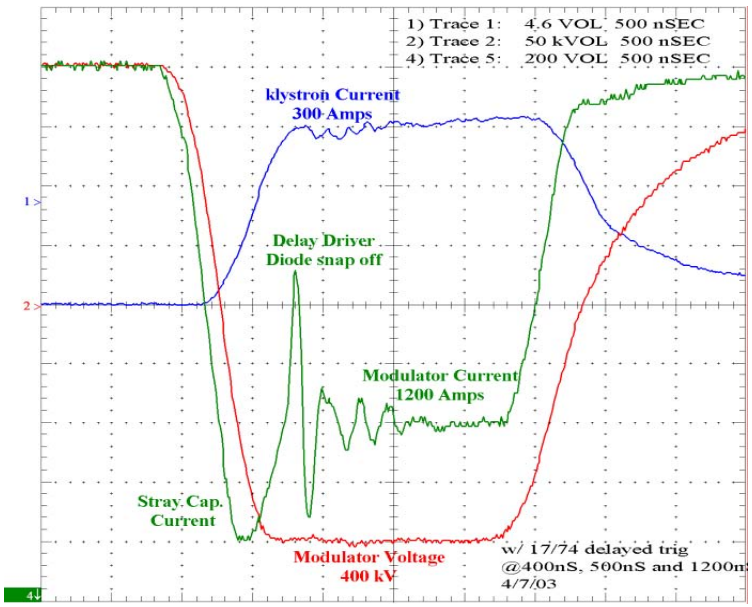
'8-Pack' IGBT Modulator

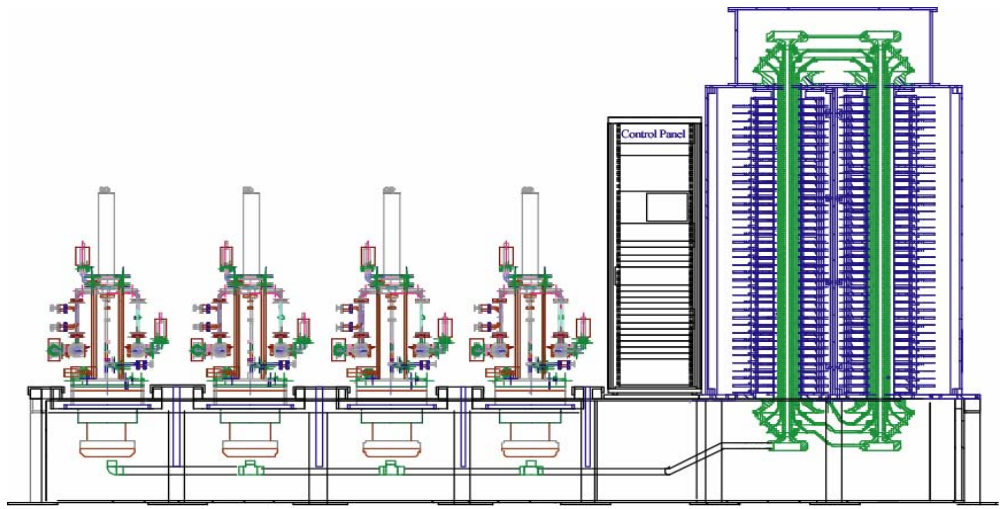
76 Cores

Three-Turn Secondary

» 1000 Hours of Operation

Waveforms When Driving Four 50 MW Klystrons at 400 kV, 300 A Each



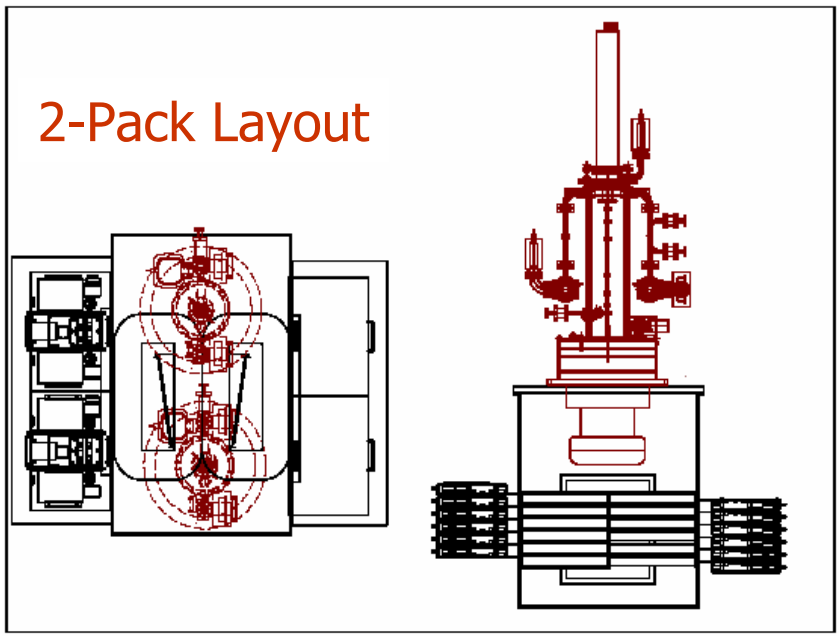


1.6 μs: 400±3kV, ±0.7%

Next Generation: The '2-Pack'

Features

- 6.5 kV IGBTs with in-line multi-turn 1:10 transformer.
- Industrialized cast casings.
- Improved oil cooling.
- Improved HV feed through.



The Bechtel-LLNL-SLAC Team

A hybrid 2-Pack modulator is currently running at SLAC.

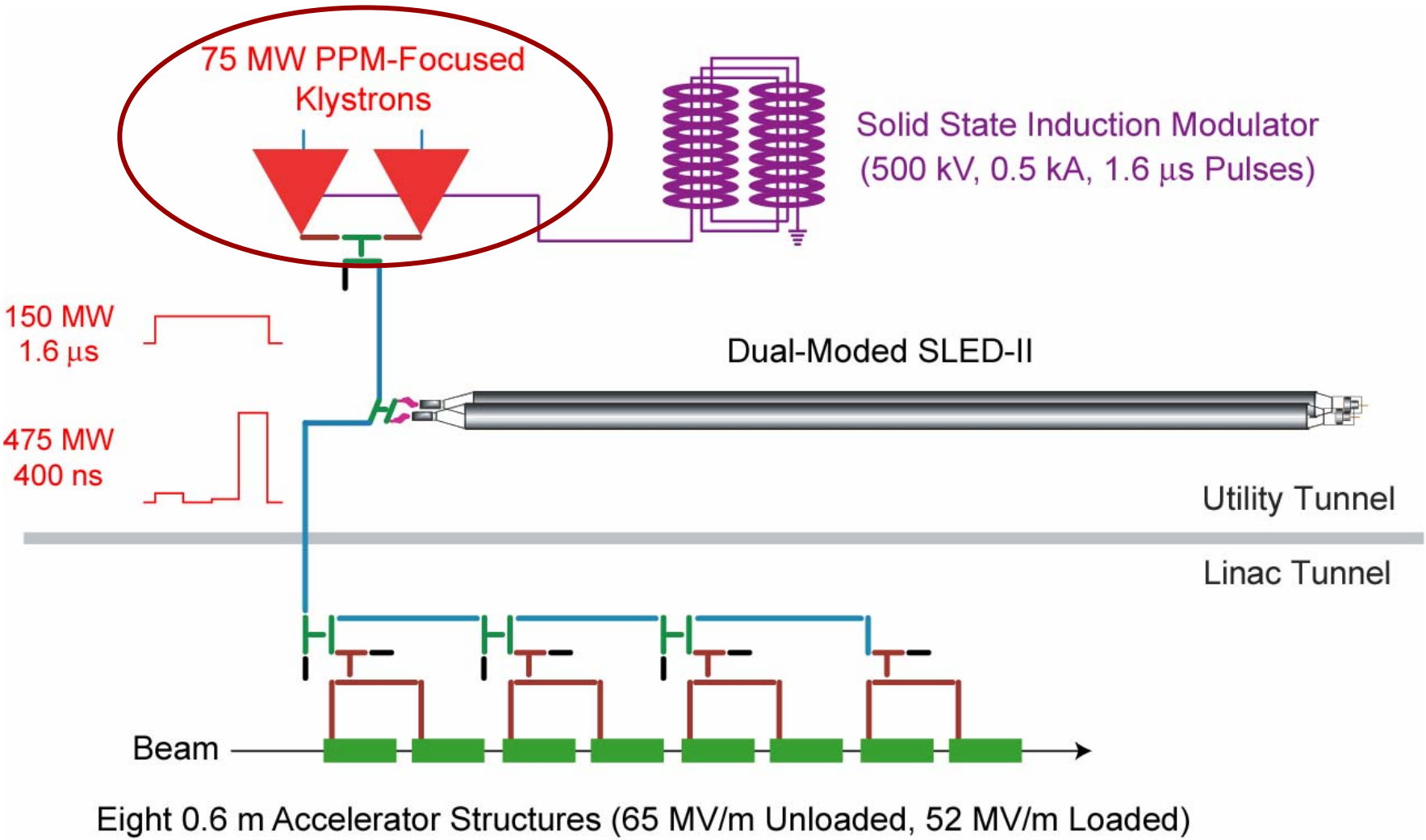
Modulator Performance
(1.6 ms Pulse Width)

	Config	Load	Voltage (kV)	Current (A)	Rate (Hz)	Efficiency (%)
Achieved	8-pack	Water	500	1000	10	
	8-Pack	Four XL4 Klystrons	400	1200	60	58
	2-Pack Hybrid	Water	500	500	120	60
NLC/GLC Baseline	2-Pack	Two PPM Klystrons	500	500	120	70

2-Pack efficiency is lower than goal due to hybrid transformer – expect > 70% in next version with integrated transformer.

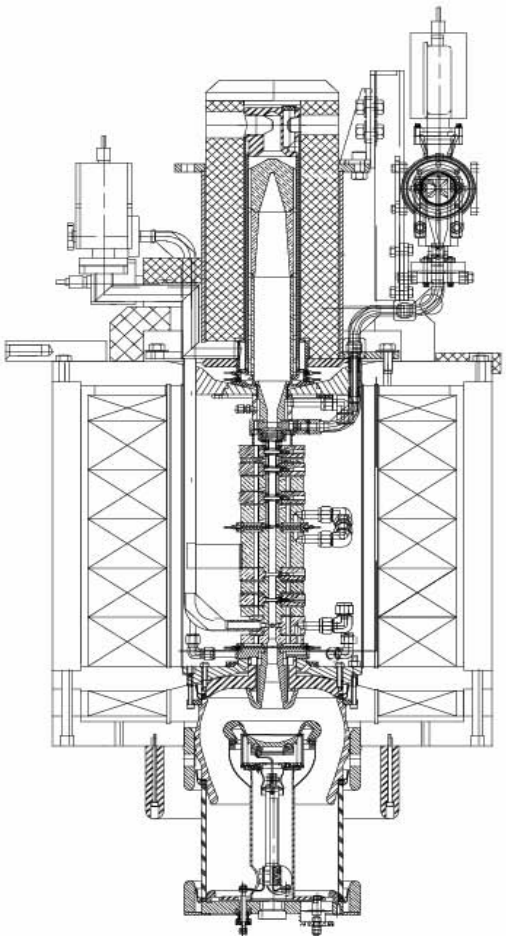
NLC/GLC X-Band Linac Baseline RF Unit

(One of ~2000 at 500 GeV cms, one of ~4000 at 1 TeV cms)



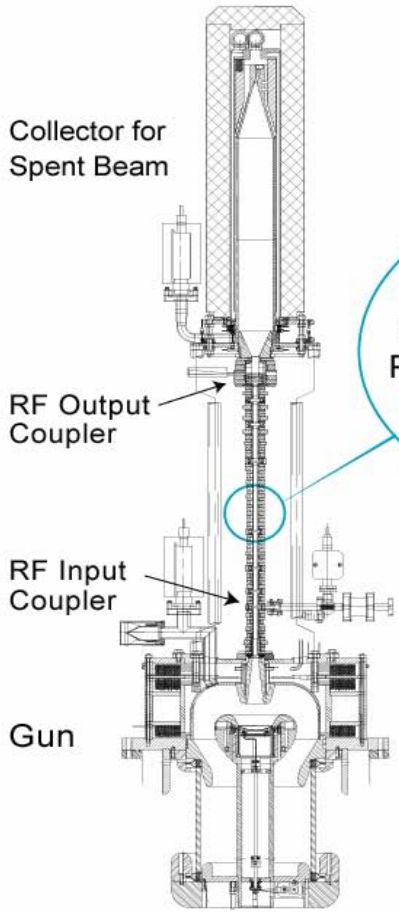
X-Band Baseline PPM Klystrons

Solenoid-Focused Tubes: Have Twelve, 50 MW Tubes for Testing, However Solenoid Power = 25 kW.



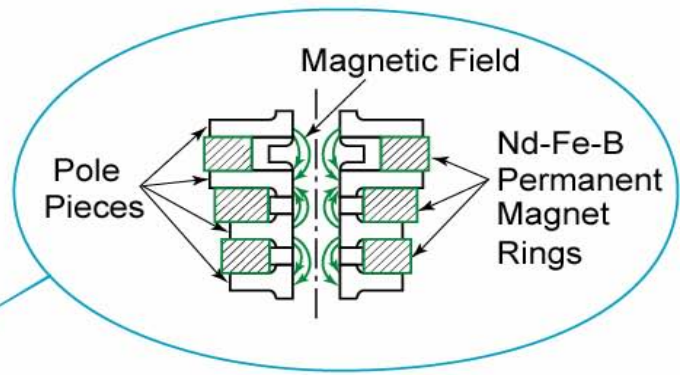
1.7 m

Developing Periodic Permanent Magnet (PPM) Focused Tubes to Eliminate the Power Consuming Solenoid.



Axial Magnetic Field ~ 2 kG RMS

(~ 5 kG for Solenoid Focusing)



PPM Klystron Performance
(75 MW, 1.6 ms, 120/150 Hz, 55% Efficiency Required)

KEK/Toshiba

Two tubes tested at
75 MW
1.6 ms pulses
50 Hz (modulator limited)
Efficiency = 53-56%

SLAC

Two tubes tested at
75 MW
1.6 ms pulses
120 Hz.
Efficiency = 53-54%
A third tube is under test.

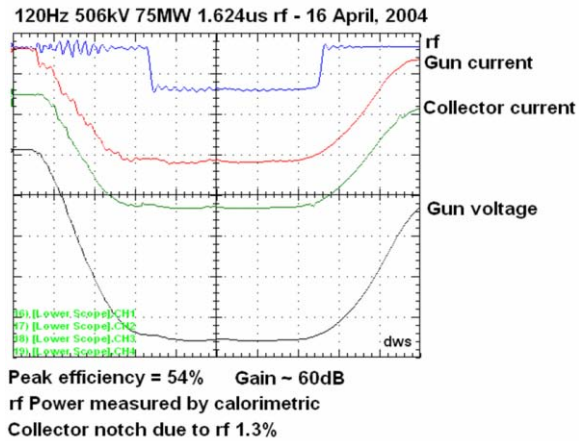
PPM Klystron Performance Overview

Klystron Performance Summary

Klystron	Peak Power	Pulse-Width	Repetition Rate
SLAC XP3 S/N 4	75 MW	1.6 μs	120 Hz
SLAC XP3 S/N 3	75 MW	1.6 μs	120 Hz
KEK PPM S/N 2	75 MW	1.7 μs	60 Hz
	68 MW	1.7 μs	120 Hz
KEK PPM S/N 3	65 MW	1.5 μs	50 Hz
KEK PPM S/N 4	75 MW	1.6 μs	25 Hz
SLAC 75 MW	75 MW	1.5 μs	1 Hz
Prototype	79 MW	2.8 μs	1 Hz
KEK PPM S/N 1	68 MW	1.5 μs	5 Hz
SLAC 50 MW	50 MW	1.5 μs	120 Hz
	55 MW	2.4 μs	60 Hz
	75 MW	1.5 μs	120 Hz
Specifications	75 MW	1.6 μs	120 Hz

Notes: Modulators Limited to 50 Hz
Initial Tubes Not Designed for High Repetition Rates

TRC R2 Done



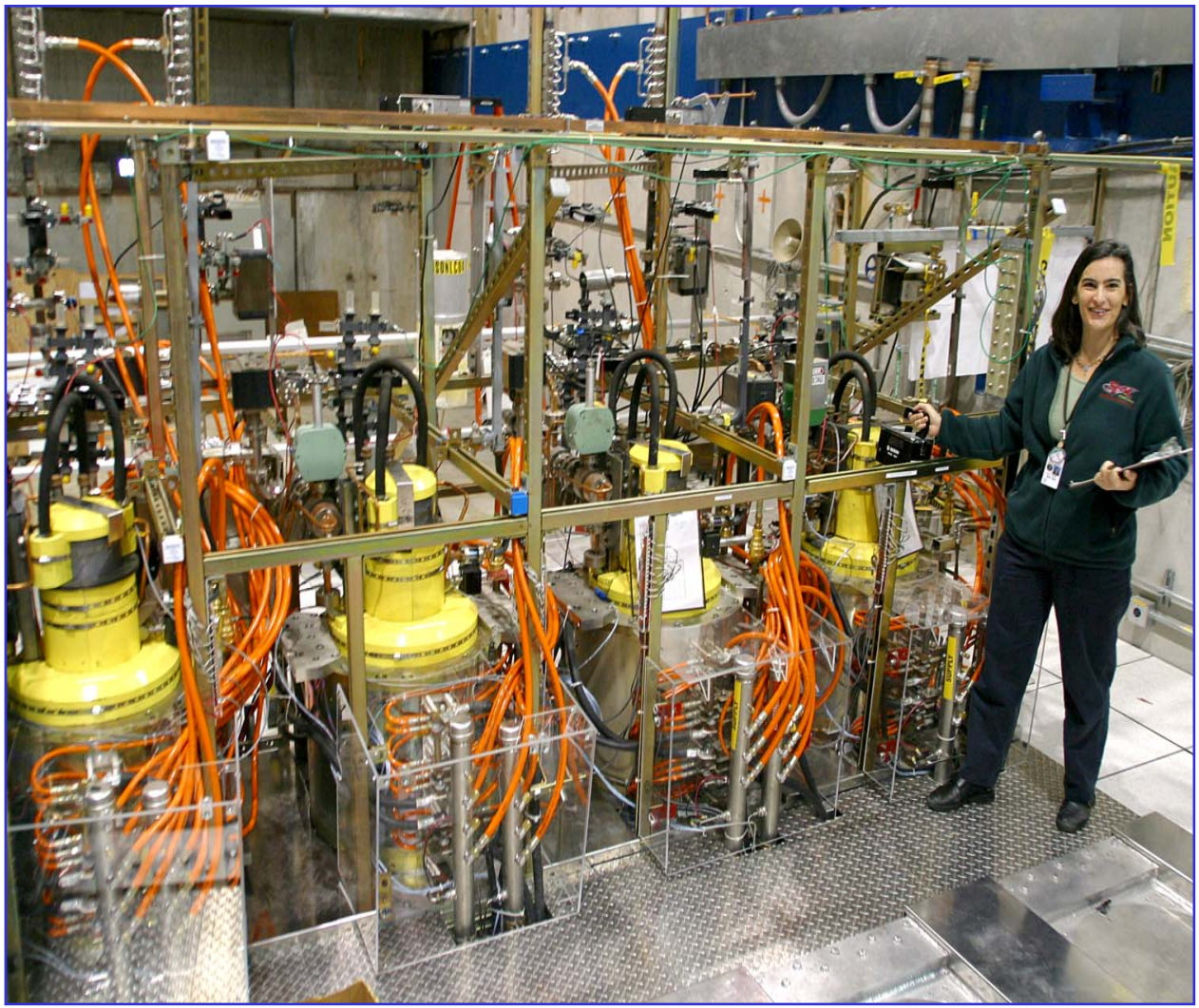
Peak efficiency = 54% Gain ~ 60dB
rf Power measured by calorimetric
Collector notch due to rf 1.3%

TRC R2 requirement of 120 Hz operation has been met.

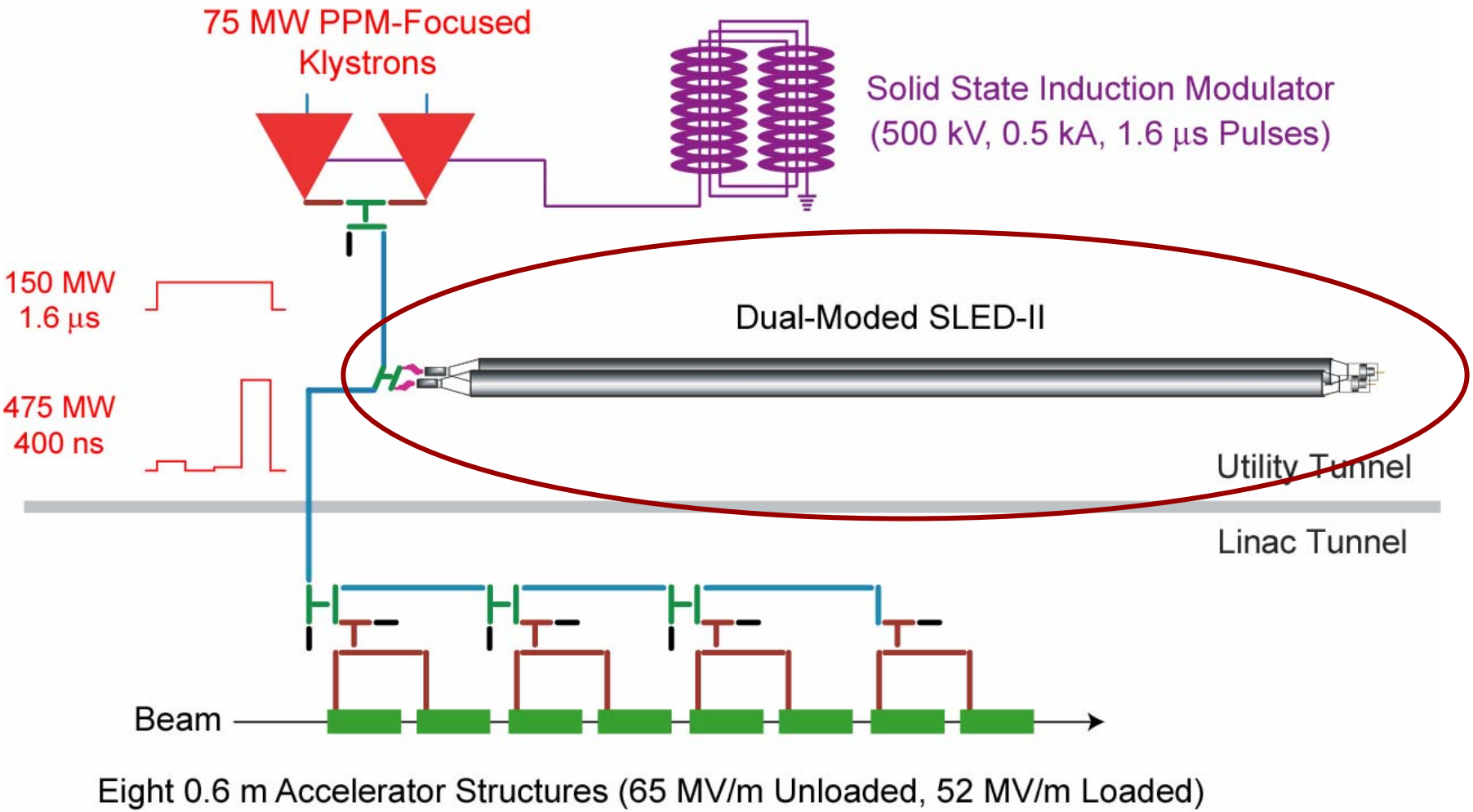
Current Status of the Next Linear Collider X-band Klystron Development Program, Daryl Sprehn, *et al.* ID: TUPKF063, in these proceedings

8-Pack Project Klystrons

Four 50 MW solenoid focused X-Band klystrons



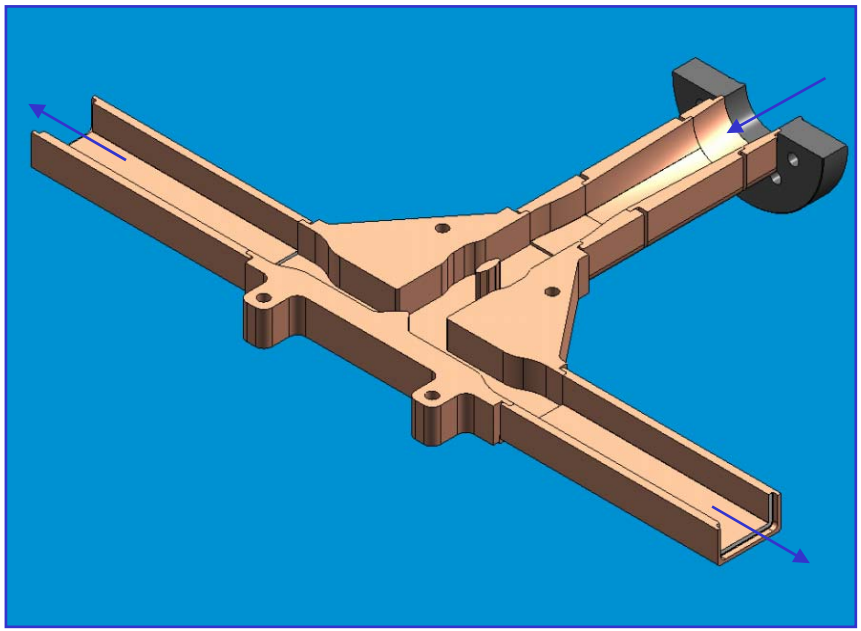
NLC/GLC X-Band Linac Baseline RF Unit
(One of ~2000 at 500 GeV cms, one of ~4000 at 1 TeV cms)

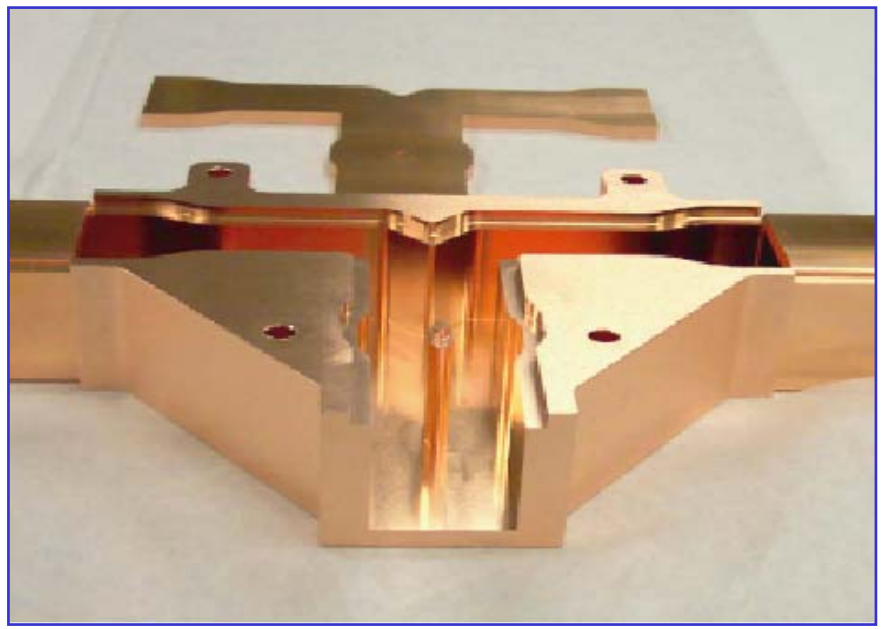


Eight 0.6 m Accelerator Structures (65 MV/m Unloaded, 52 MV/m Loaded)

Over-Height Planar X-Band Waveguide

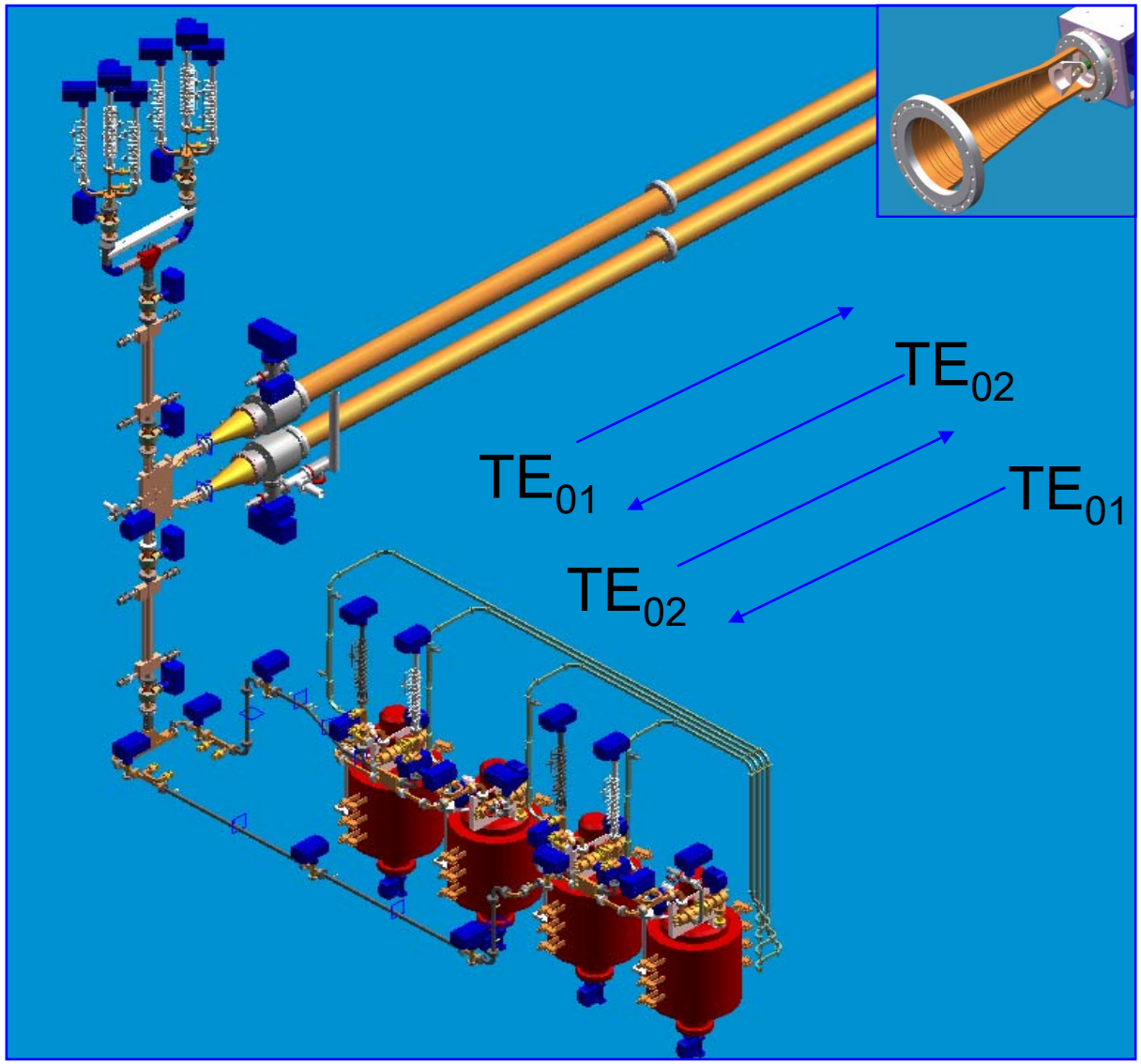
Lower Surface Electric Fields (< 50 MV/m)
and Limited Pulse Heating (< 40° C)
to manage high power levels





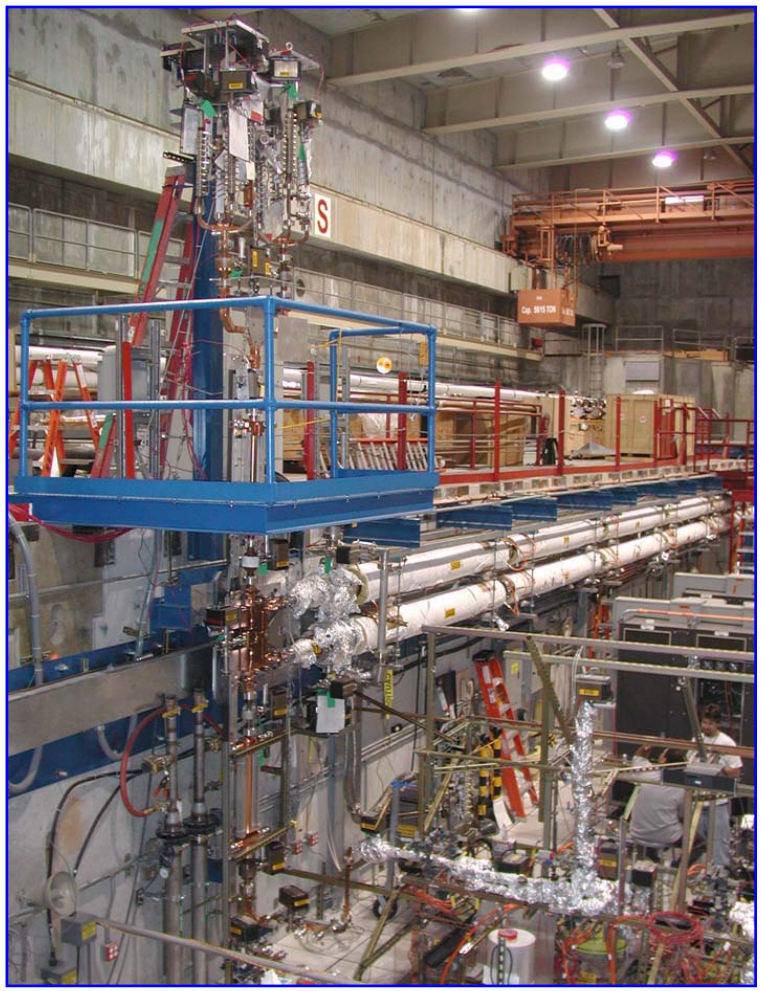
Example: Power Splitter

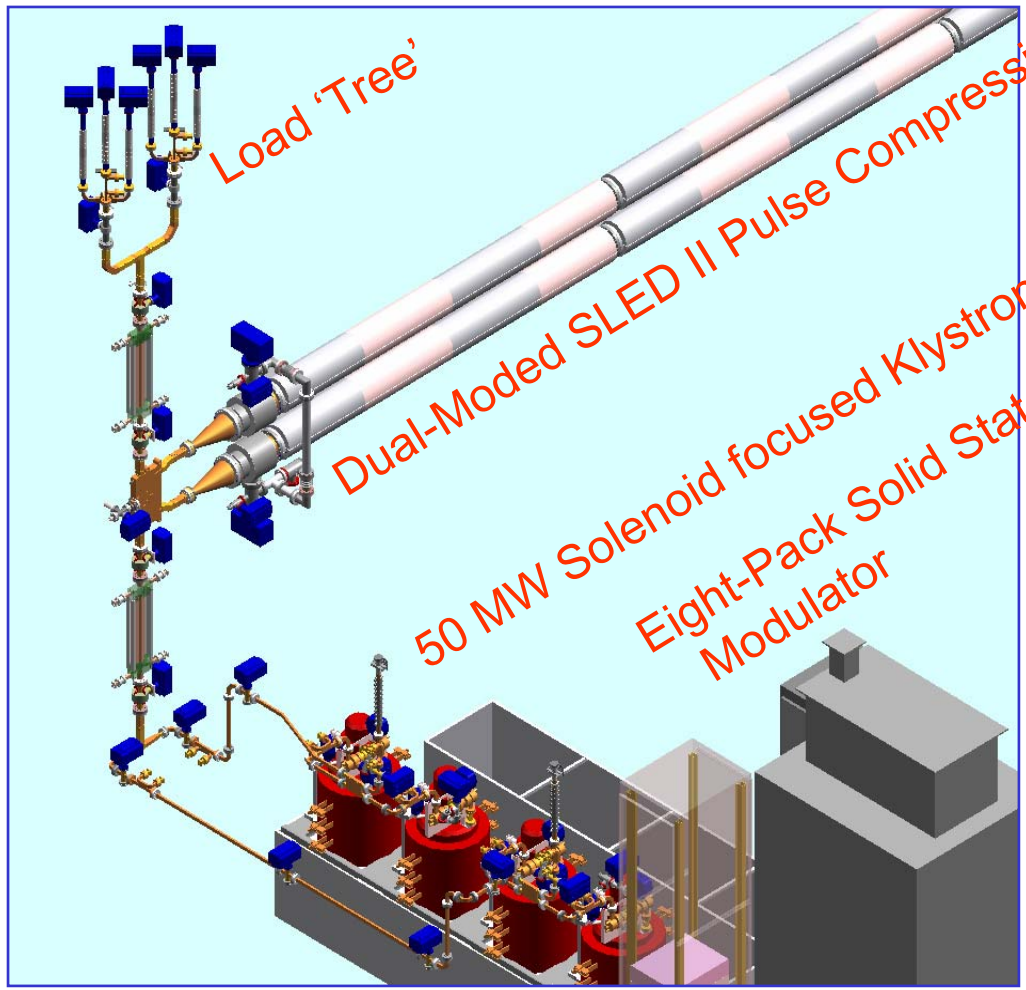
Second Generation SLED II - multimoded



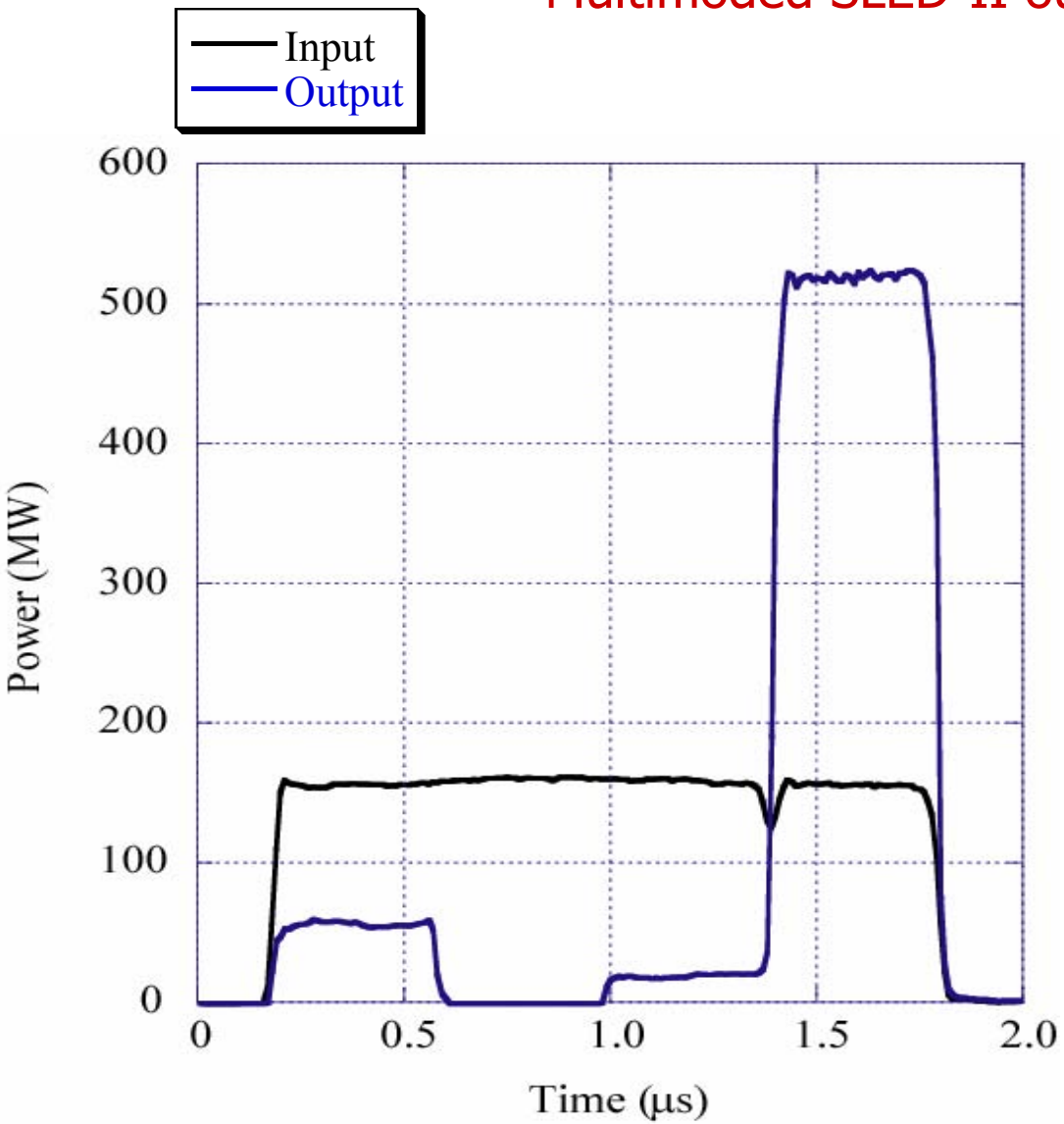
The electrical length of the delay line is the length of the output pulse (400ns).
The physical length can be halved by using two RF modes.

TRC R1 8-Pack configuration, Dec. 2003





Multimoded SLED-II output



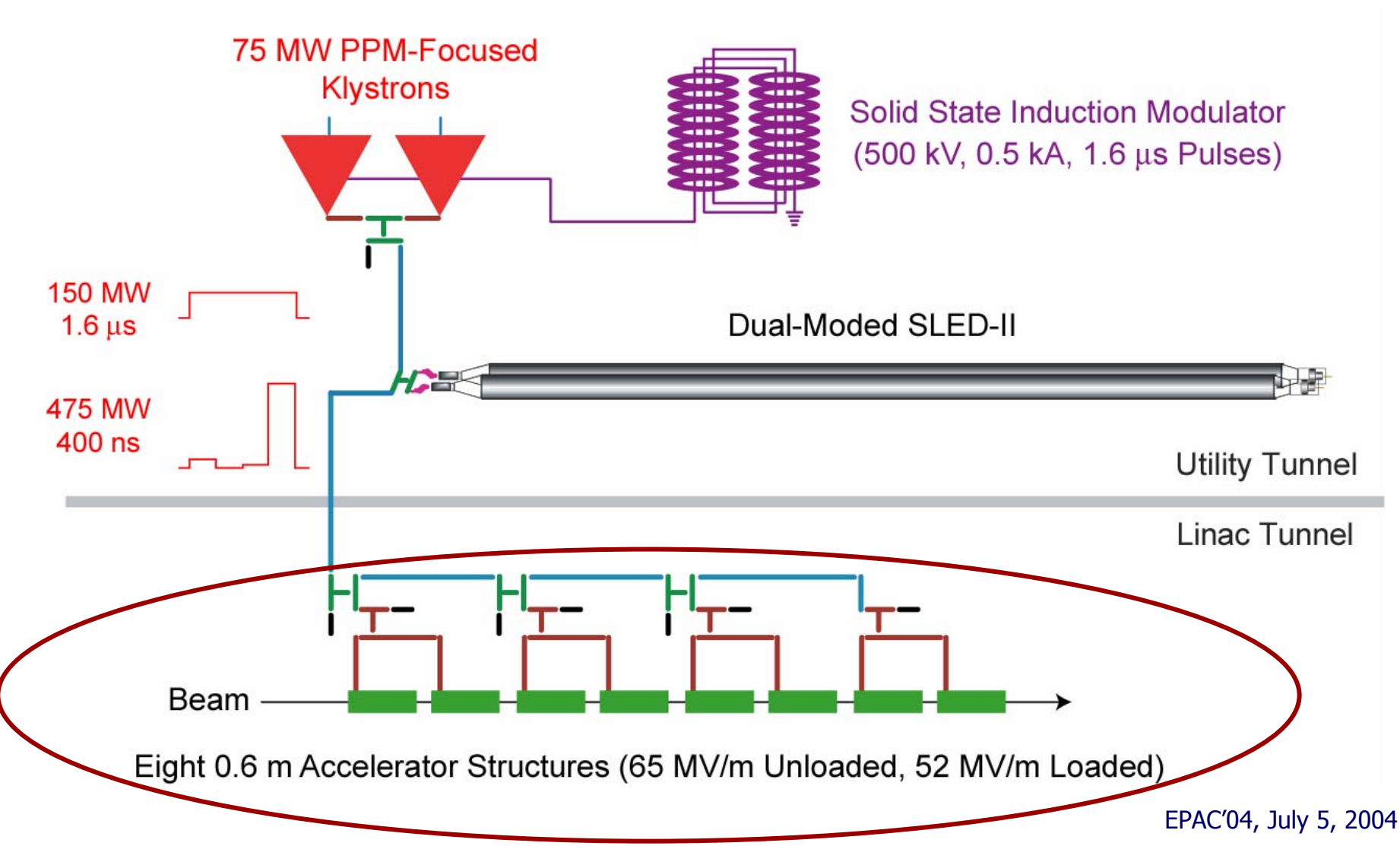
Delivered 580 MW, 400 ns, to loads

Operated 250 hours at 510 MW (475 MW required) with required reliability (pulse rate 30&60 Hz)

TRC R1 Done

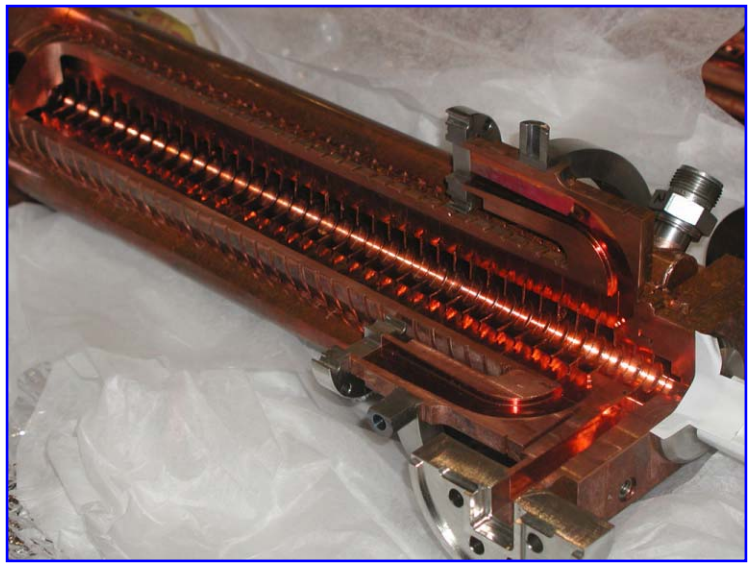
Sami Tantawi (1/27/2004)

NLC/GLC X-Band Linac Baseline RF Unit
(One of ~2000 at 500 GeV cms, one of ~4000 at 1 TeV cms)



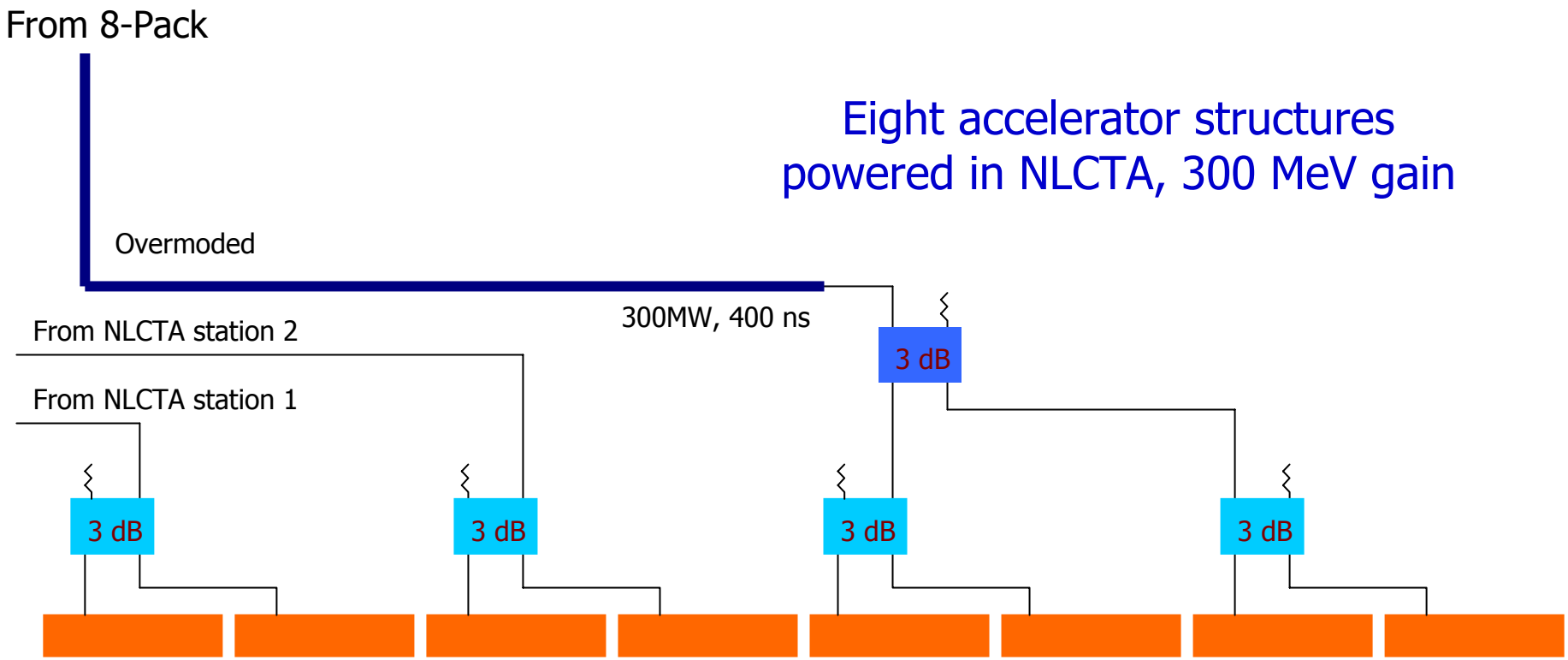
NLC/GLC Accelerator Structure

Cells with Slots for Dipole Mode Damping



Structure cut-away

System Demonstration and Operation

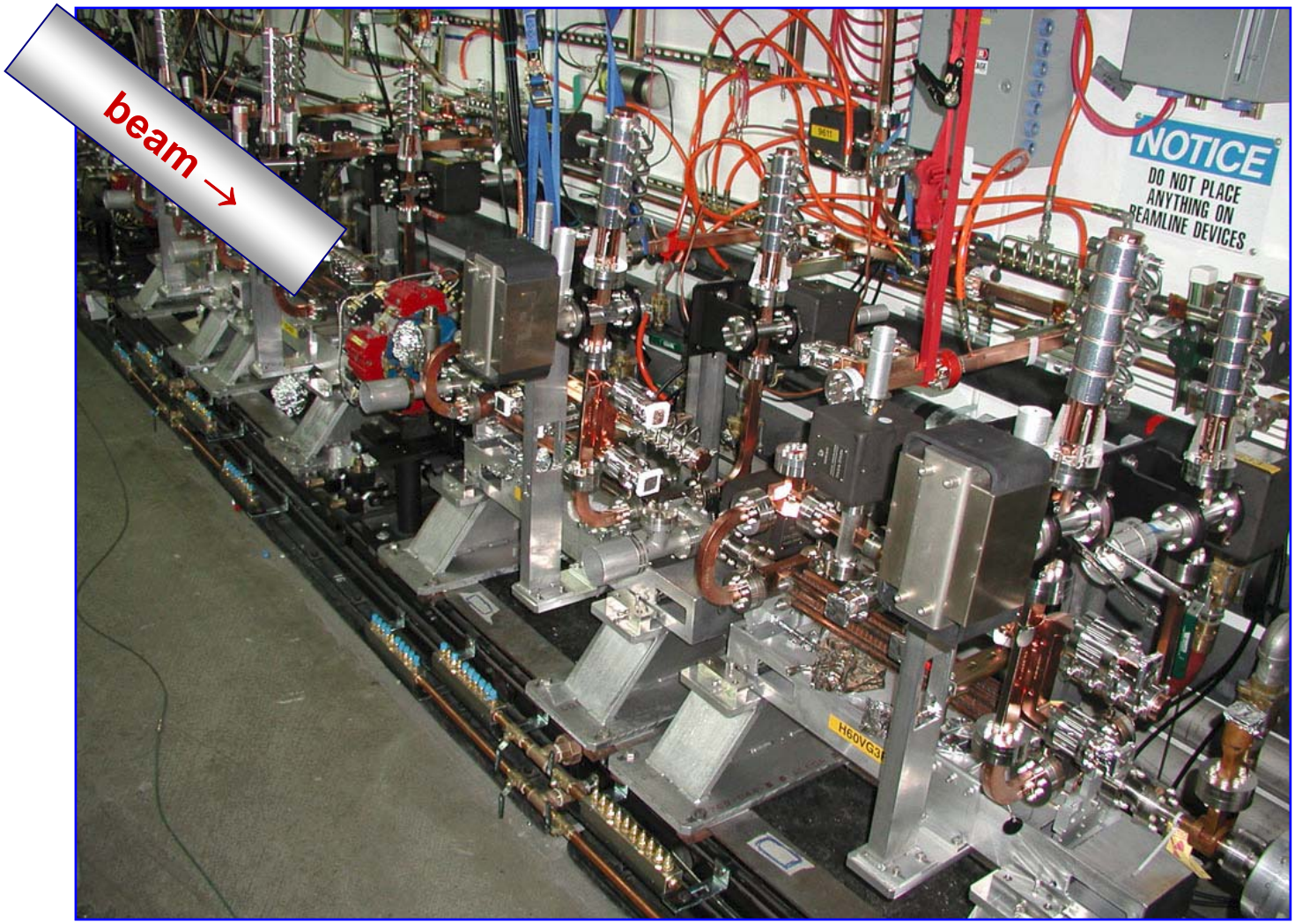


Eight accelerator structures powered in NLCTA, 300 MeV gain

First four structures continue to be powered by original NLCTA stations.

Running 24/7 since first of April; >1000 hours of operation with >90% uptime

Phase 2 beam line installed

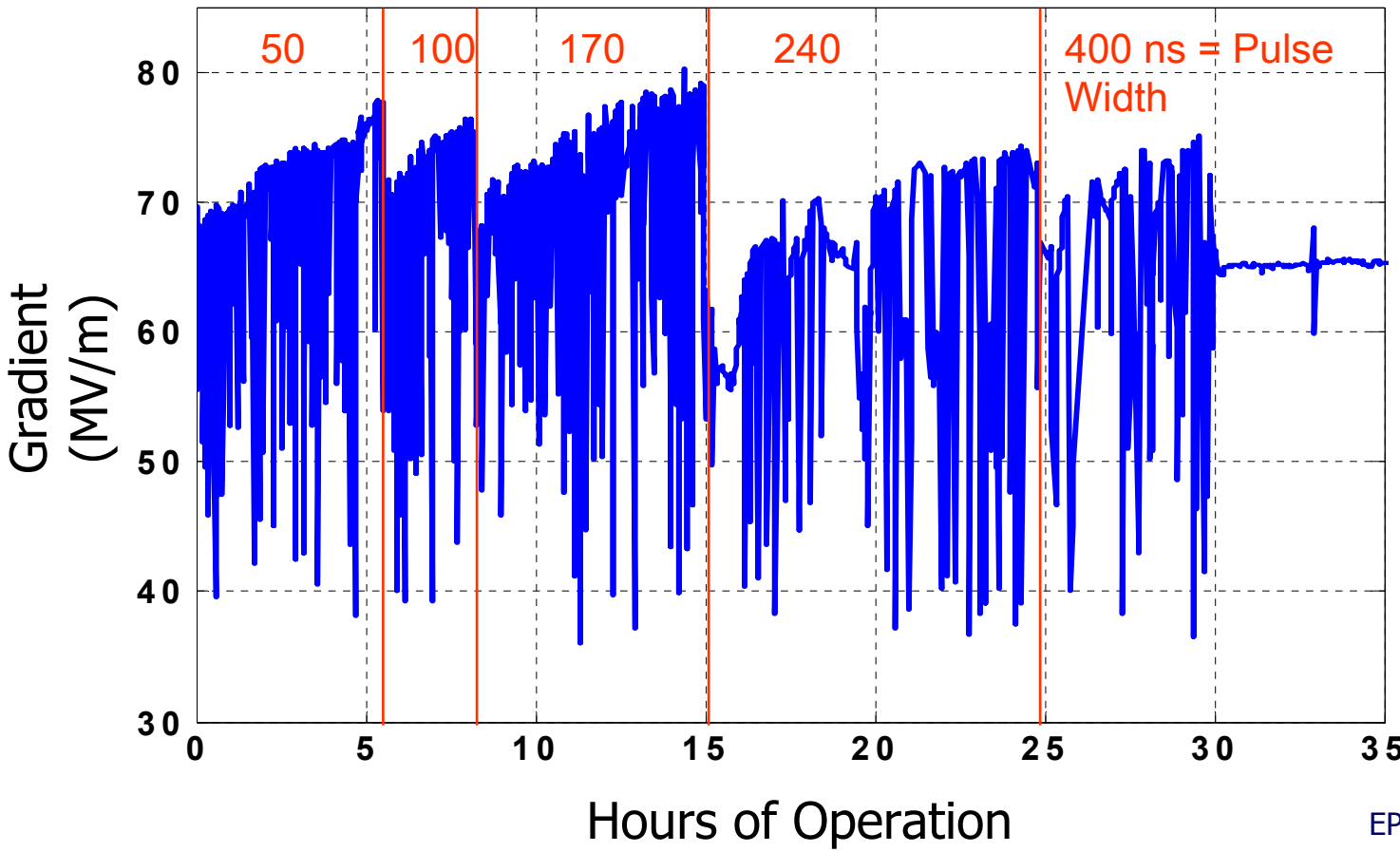


Changing Structures in NLCTA

Install new structure = 8 hours

Pump down = 16 hours (overnight)

High Power Processing = 30 hours



Structure operation history at NLCTA

8 structures have been running for 1000 hours at NLCTA

Recent structure performance:

April 2004	61.1 MV/m	0.10/hour
May 2004	64.9 MV/m	0.16/hour
June 20, 2004	64.9 MV/m	0.085/hour

TRC R1 Done

→ Performance improves with running time.

June operation of NLCTA

(Based on 150 hours of Operation)

Structure	Manufacturer	Gradient (MV/m)	Trip Rate (#/hr)
H60vg4S17-FXD1A	FNAL	65.4	0.18
H60vg3S17-FXC5	FNAL	64.5	0.10
H60vg4S17-3	KEK/SLAC	65.4	0.04
H60vg3S17-FXC3	FNAL	64.5	0.04
H60vg3-FXB6	FNAL	64.8	0.00
H60vg3-FXB7	FNAL	66.7	0.19
H60vg4S17-1	KEK/SLAC	63.2	0.10
H60vg3R17	SLAC	64.8	0.04
Average		64.9	0.085
Average One Month Ago		64.9	0.163

Progress on X-band Accelerator Structure Development for NLC/GLC , Chris Adolphsen, *et al.*
ID: MOPLT126 , in these proceedings

RF Component Efficiencies

Efficiency	Design	Achieved	Comment
Two-Pack Modulator	70 %	60 %	Use Integrated Transformer (> 70% Expected)
PPM Klystron	55 %	53-56 %	~ 60% Possible
SLED II	81 %	78 %	Improve Flanges/Fab/Assembly
Wave Guide Transport	92 %	77 %	Improve Layout Design & Reduce High-Loss WG
Structures	31 %	29 %	Use rounded cell shape

Further Development:

Modulator:

The hybrid 2-Pack modulator is being installed and will be operated with PPM klystrons.

Klystron:

PPM klystrons continue to be produced and tested at SLAC and at KEK/Toshiba.

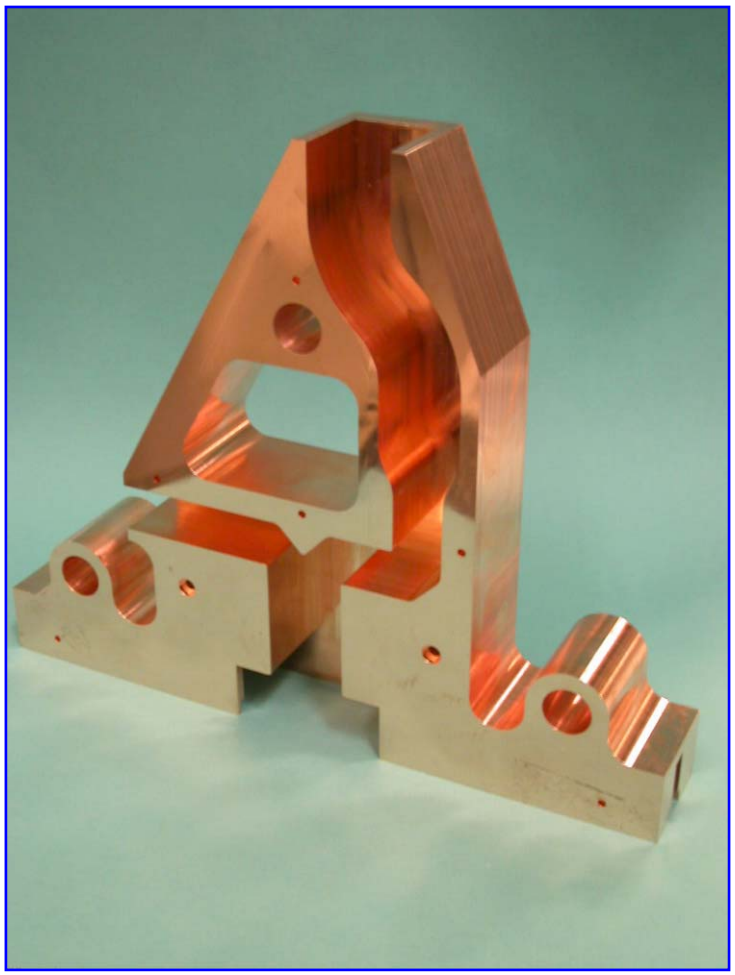
RF Pulse Compression:

The power transmission will be improved and compression efficiency increased.

Accelerator Structures:

Structures are being fabricated and installed on the NLCTA and GLCTA.

Conclusions



The '8-Pack' system has successfully demonstrated the high power capability and reliability of the NLC/GLC baseline RF system.

The components operate at their design levels, and are robust.

Further improvements in efficiency will come with a move towards high volume production.