NLC R&D

D. L. Burke

DOE Annual Program Review
SLAC
April 9-11, 2003

NLC Activities for the Past Year

- Accelerator Design centered around ILC-TRC studies.
- Technology R&D focused on the RF R&D.
  - Modulator, klystron, SLED-II, and structures.
- Remainder squeezed hard by budget limitations. Emphasis (in rough order of priority):
  - Damping Ring and ATF
  - Vibration and Stabilization
  - Ground Motion and Site Studies
  - Polarization – Electrons with E158, and Studies of Positron Production
- Limited number of people active in international and national evaluations beyond the TRC – it is a growing load.

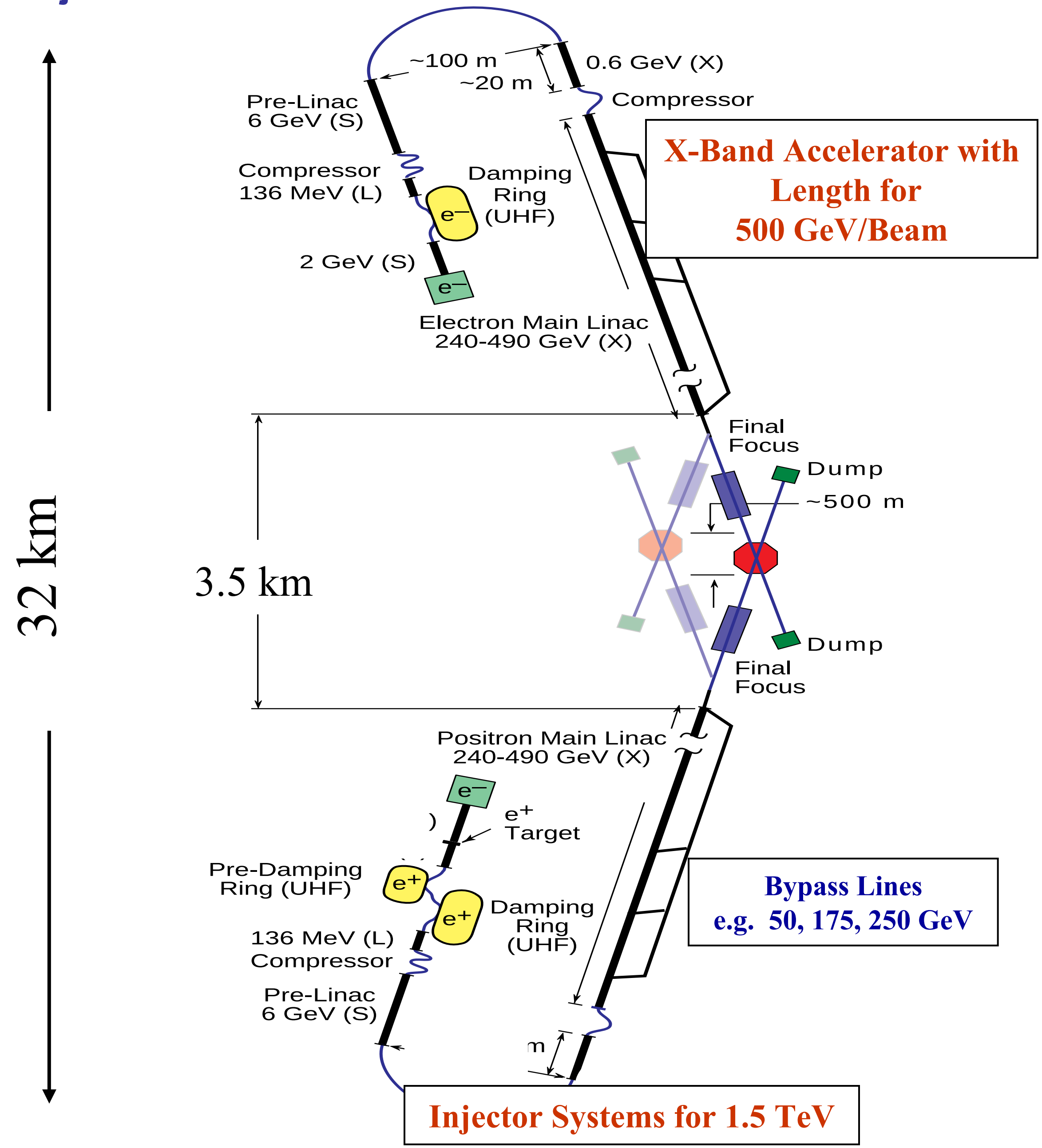
Configuration

Major iterations:

Zero-Order Design
(1996)

DOE "Lehman" Review
(1999)

Snowmass 2001
(2001)



Interlaboratory Collaboration for R&D Towards TeV-scale Electron-Positron Linear Colliders

International Linear Collider Technical Review Committee

ILC-TRC

International Linear Collider Technical Review Committee

Greg Loew (SLAC) Chair

http://www.slac.stanford.edu/xorg/ilc-trc/2002/

TRC Members from NLC and JLC

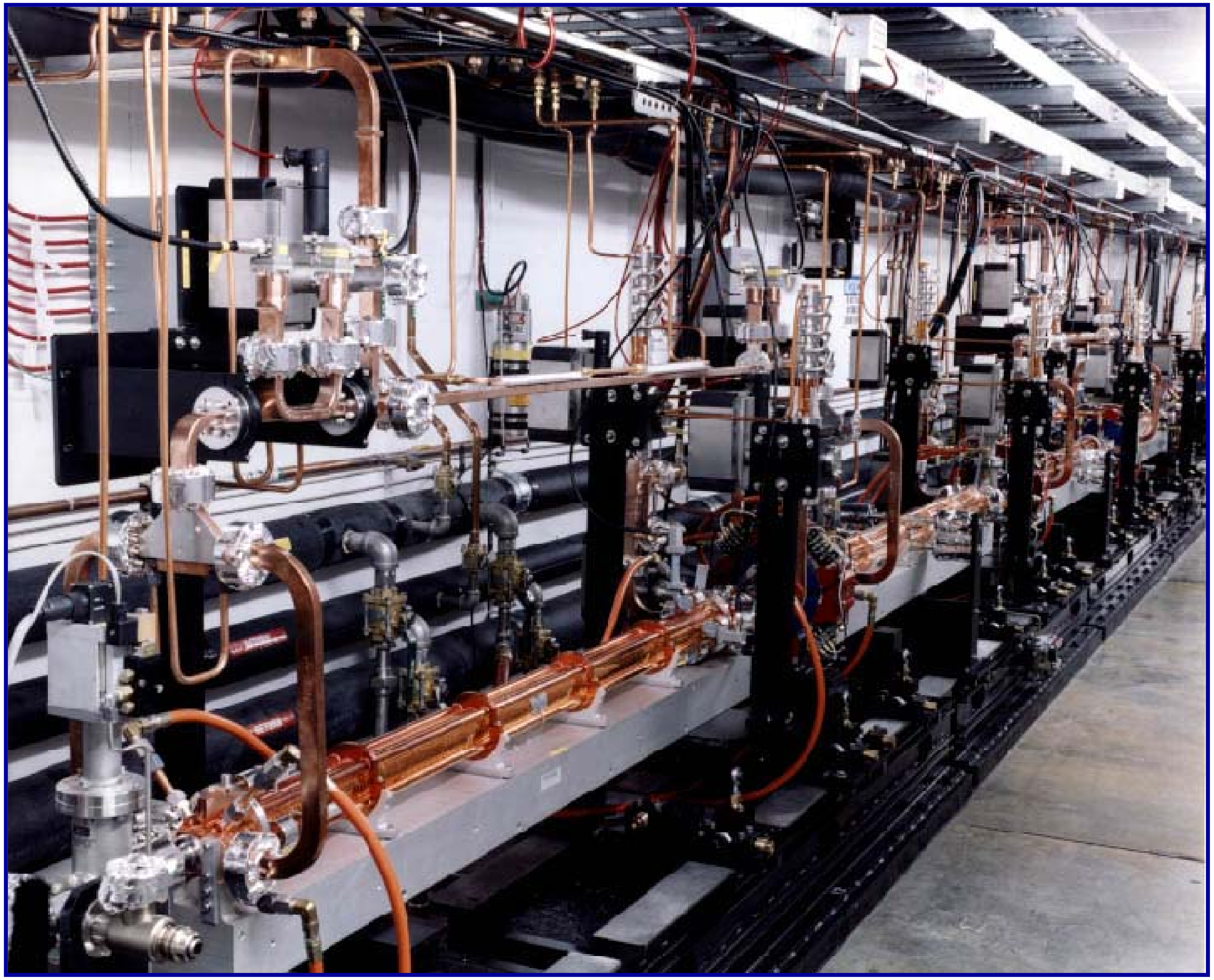
C. Adolphsen	Yong Ho Chin
K. Kubo	R. Pasquinelli
N. Phinney	T. Raubenheimer
M. Ross	P. Tenenbaum
Nobu Toge	P. Wilson
A. Wolski	K. Yokoya

- Formed in 1994 by all world-wide laboratories working in HEP.
- Technical Review in 1995 (web site).
- Charged in 2001 by ICFA to reassess technical status and establish work that remains to be done to be able to build a TeV linear collider.

NLC/JLC(X) SLED-II Baseline Design

- Phase-I of the 8-Pack will demonstrate the feasibility of a SLED-II rf system similar to that presently in use at the NLCTA and first described in the NLC ZDR in 1996.
- This demonstration will occur in 2003.
- The NLC Collaboration, together with our JLC collaborators, presented to the world community (ILC-TRC) a SLED-II Baseline Design for an X-Band collider.

The NLC Test Accelerator at SLAC



The NLCTA with 1.8 m accelerator structures (ca 1997).

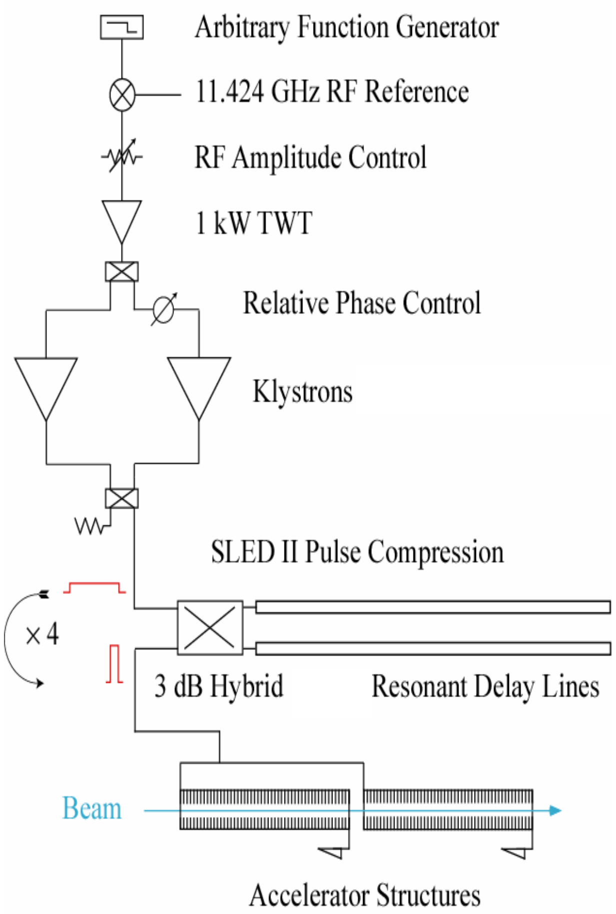
Accelerating gradient of 25 MV/m (loaded) with good wakefield control and energy spread.

Demonstrated ability to reach 500 GeV cms.

X-Band RF Systems

NLCTA SLED-II System (ZDR 1996)

- Conventional PFN modulator
- 50 MW/1.2μs solenoid-focused klystrons
- SLED-II pulse compression
- DDS structures at 40 MV/m

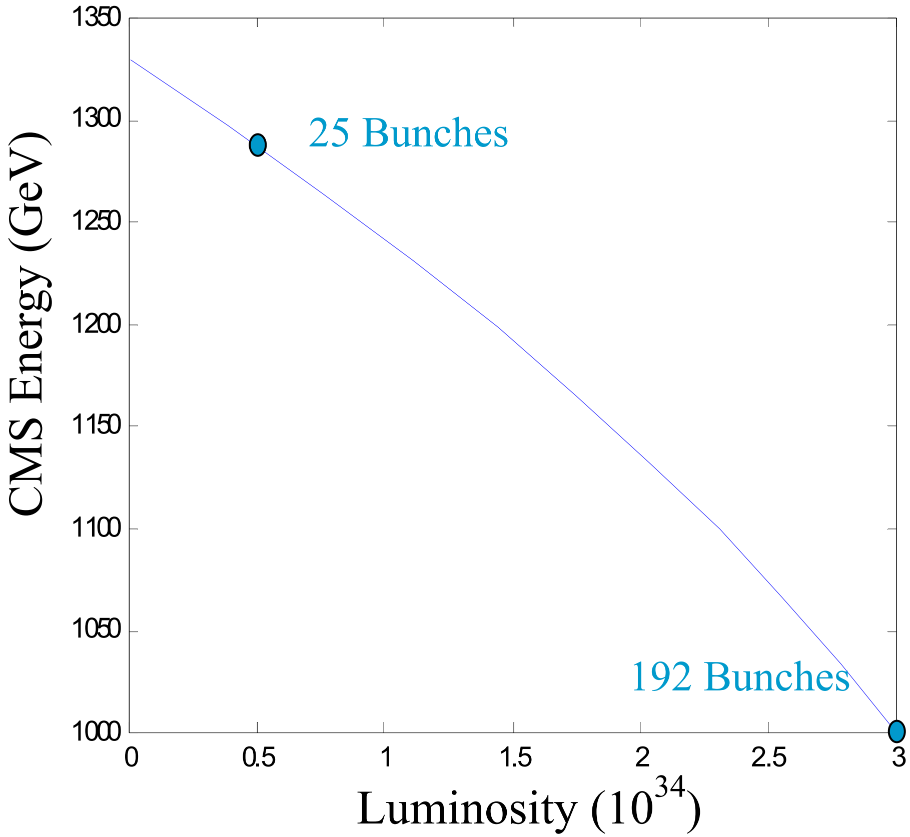


X-Band TeV SLED-II System (Baseline 2002)

- Solid-state modulator
- 75 MW/1.6μs PPM-focused klystrons
- Dual mode SLED-II pulse compression
- DDS structures at 65 MV/m

JLC/NLC Energy Reach

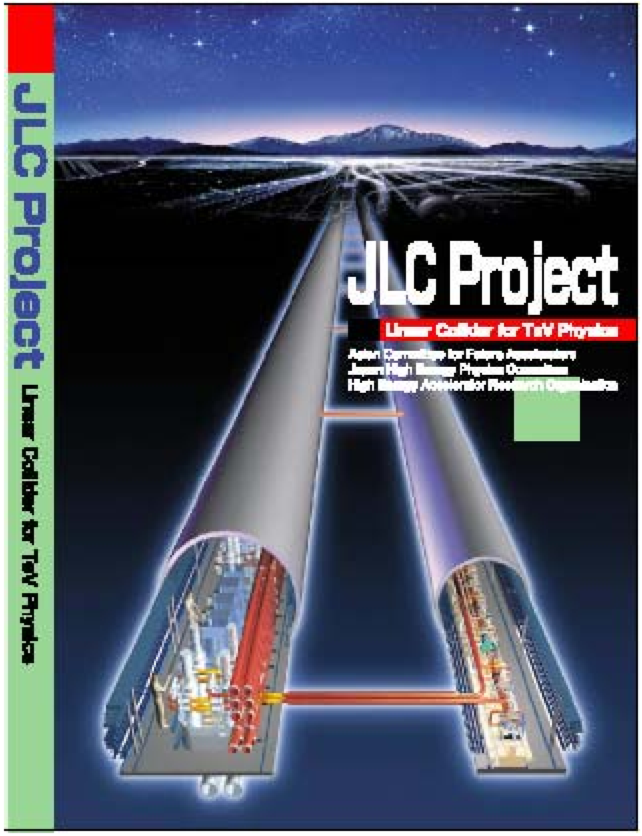
High Energy IP Parameters	Stage 1		Stage 2	
CMS Energy (GeV)	500		1000	
Site	US	Japan	US	Japan
Luminosity (10^{33})	20	25	30	25
Repetition Rate (Hz)	120	150	120	100
Bunch Charge (10^{10})	0.75		0.75	
Bunches/RF Pulse	192		192	
Bunch Separation (ns)	1.4		1.4	
Loaded Gradient (MV/m)	50		50	
Injected $\gamma\varepsilon_x$ / $\gamma\varepsilon_y$ (10^{-8})	300 / 2		300 / 2	
$\gamma\varepsilon_x$ at IP (10^{-8} m-rad)	360		360	
$\gamma\varepsilon_y$ at IP (10^{-8} m-rad)	4		4	
β_x / β_y at IP (mm)	8 / 0.11		13 / 0.11	
σ_x / σ_y at IP (nm)	243 / 3.0		219 / 2.1	
θ_x / θ_y at IP (nm)	32 / 28		17 / 20	
σ_z at IP (um)	110		110	
Υ_{ave}	0.14		0.29	
Pinch Enhancement	1.51		1.47	
Beamstrahlung δB (%)	5.4		8.9	
Photons per e+/e-	1.3		1.3	
Two Linac Length (km)	13.8		27.6	



The NLC/JLC Stage 2 design luminosity is 5×10^{33} cm^{-2} s^{-1} at 1.3 TeV cms.

JLC Roadmap Report

ACFA LC Symposium
Tsukuba, Japan
February 2003



Interlaboratory Collaboration for R&D Towards TeV-scale Electron-Positron Linear Colliders

International Linear Collider Technical Review Committee
ILC-TRC

ILC-TRC Interim Report

ICFA

CERN, October 2002

- "By the end of 2003, we hopefully should know if TESLA can reach 800 GeV at 35 MV/m."
- "By the end of 2003, we hopefully should know if JLC/NLC can meet its main linac [1 TeV] RF system specifications."
- "If yes, then the International Community could make a choice based on the other respective merits of these machines."

JLC(X)/NLC Level I R&D Requirements (R1)

- “Test of complete accelerator structure at design gradient with detuning and damping, including study of breakdown and dark current.”

- “Demonstration of SLED-II pulse compression system at design power level.”

High-Gradient R&D

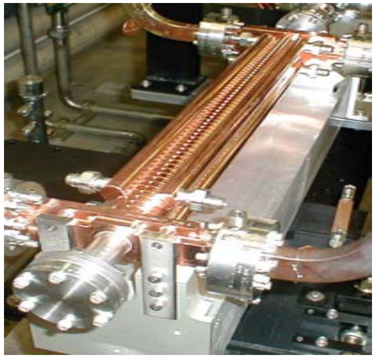
- After improvements to the rf at NLCTA in 2000, realized the 1.8 m long structures were being damaged during processing and would not meet performance at 65 MV/m.

- Launched aggressive R&D program
  - Build and test traveling wave structures and standing wave structures.
  - Improve structure handling, cleaning and baking methods.
  - Study characteristics of rf breakdown in structures, cavities and waveguides.

➯ Have tested 20 structures made from a total of approximately 1000 cells.

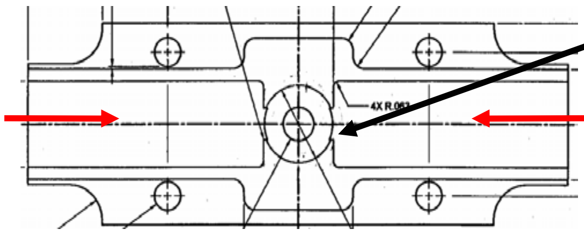
➯ Over 10,000 hr operation at 60 Hz. → 10^9 rf pulses; a total of ~ 10^5 rf breakdown events.

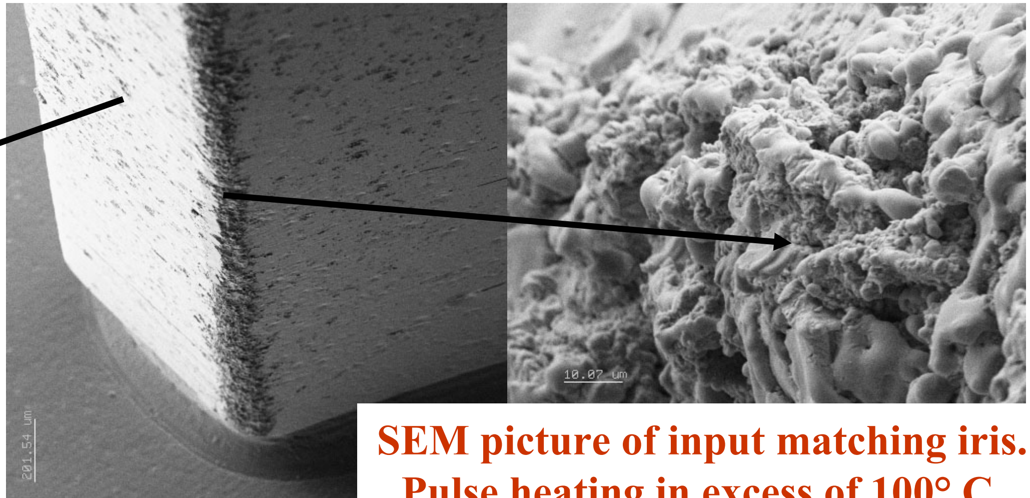
T-Series Structures – 50 cm long low group velocity structures with high shunt impedance.



RF Pulse Heating

T53VG3
(Original Coupler Design)

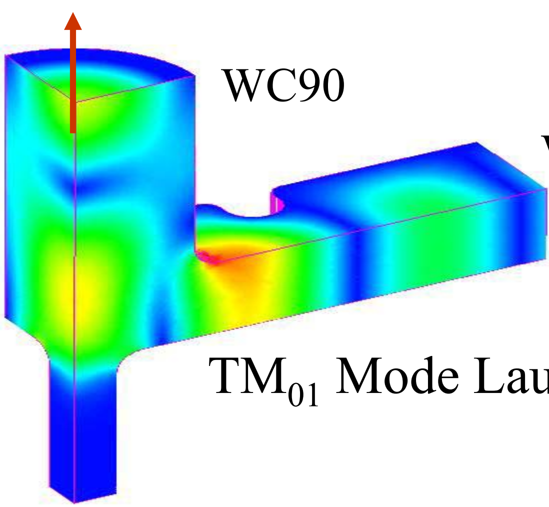




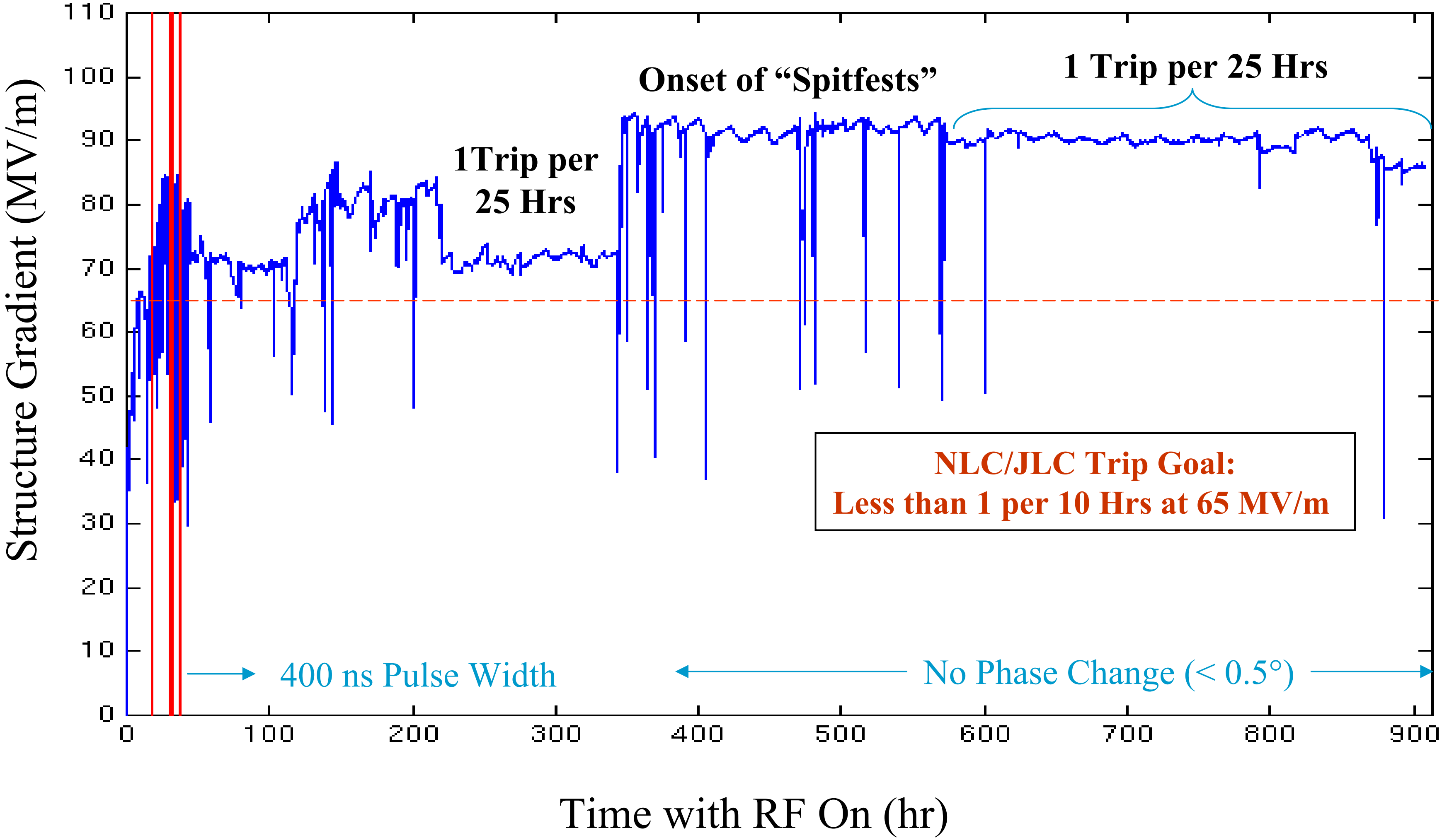
SEM picture of input matching iris.
Pulse heating in excess of 100° C.

New Mode-Converter (MC)
Coupler Design

Pulse heating less than 3° C.



T53VG3MC Processing History
(Low-Temperature Couplers)



H-Series Structures

- The T-Series design cannot be used in the NLC/JLC.
  - **The average iris radius, <a/λ> is smaller (0.13) than desired (0.17-0.18), yielding a transverse wakefield 3 times larger than considered acceptable**.

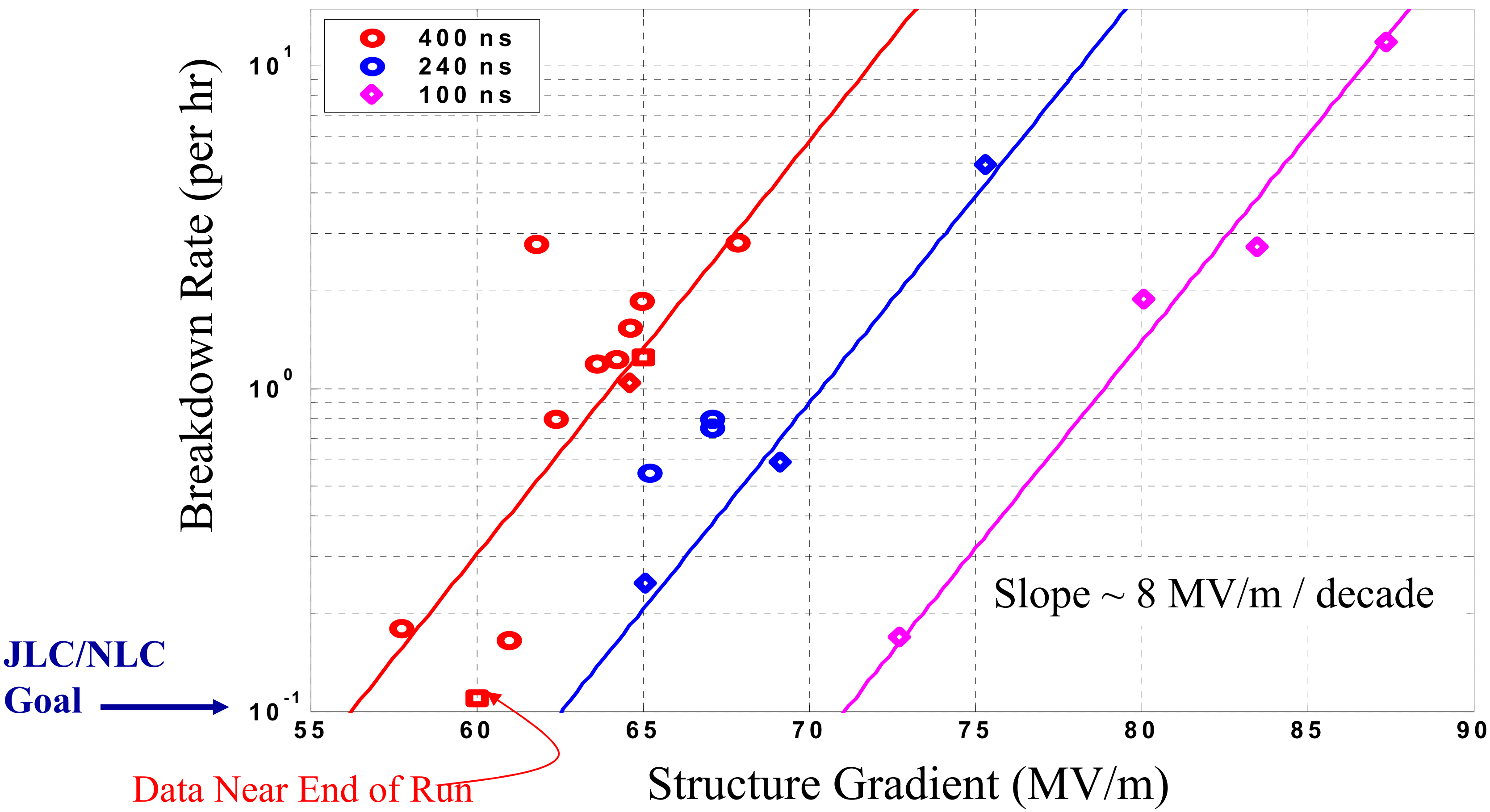
- Now moved to designs with <a/λ> = 0.17-0.18 (called the H-Series because the phase advance per cell is 150°).

  Five H-Series structures have been built and tested so far:

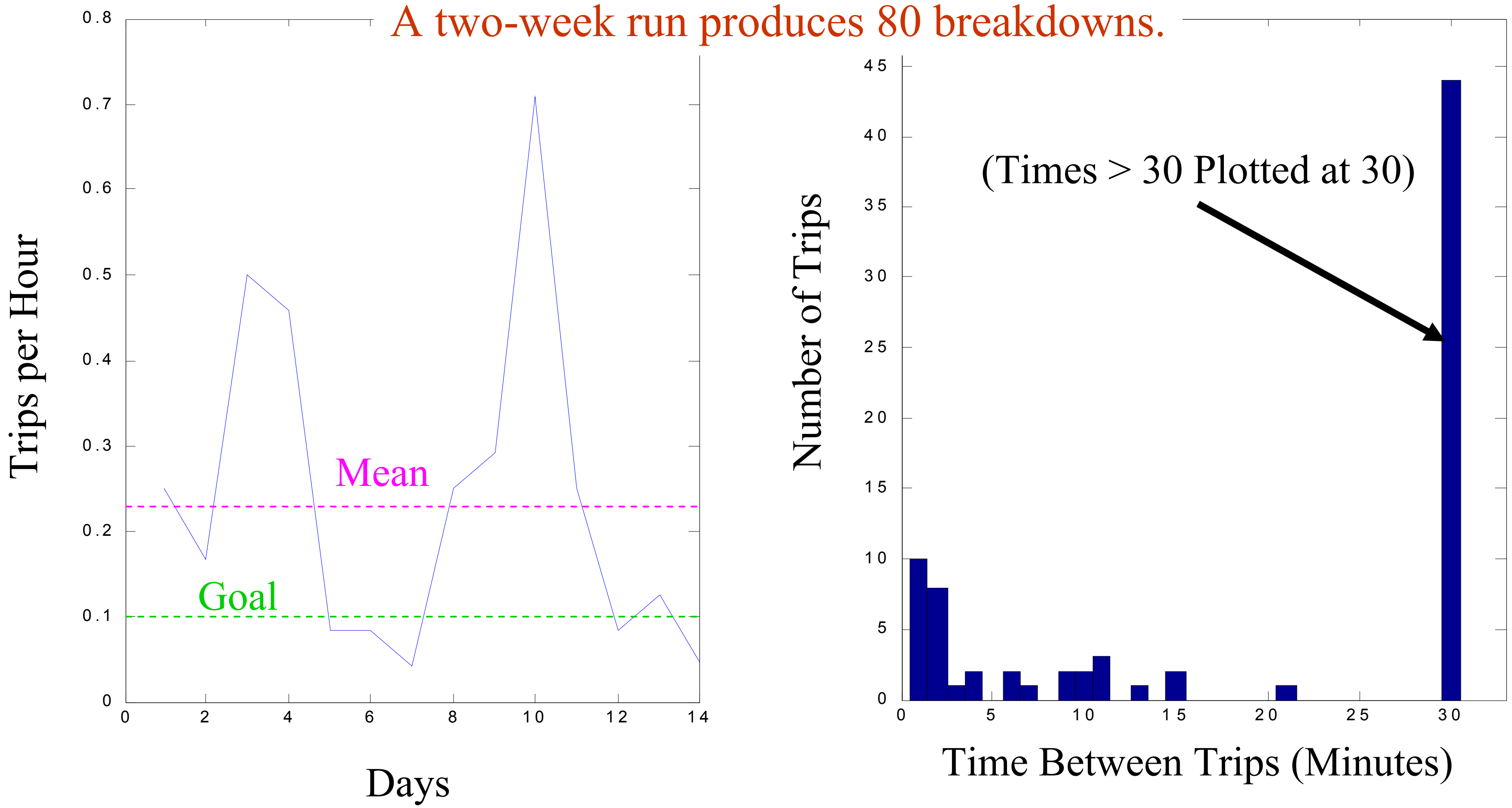
  - **H90VG5: High-temperature couplers prevented full processing.**
  - **H60VG3: High-temperature couplers – body breakdown rate OK at 65 MV/m.**
  - **FXB002: First H60VG3 produced by Fermilab – no hydrogen preprocessing, and would not high-gradient process above 70 MV/m.**
  - **H90VG3 and H60VG3_6C presently under test.**

Six full-featured DDS cells.

H90VG3 Breakdown Rates



Breakdown Statistics for H60VG3(6C)
(65 MV/m, 400 ns)



To date have 900 hrs of rf on this structure, and continuing to run ….

High-Gradient Plans

- H60VG3_6C performs acceptably at 65 MV/m, but we think we can do better.
- To improve rf efficiency and provide more operating overhead, we will focus on the $a/\lambda = .17$ version of this structure (H60VG3S17).
- A first test structure of this design is being built without damping slots.
- The main goal for the next year is to have eight DDS structures of this design operating at 65 MV/m in the NLCTA linac with power provided by the SLED-II, and to accumulate ~ 2000 hours of high-gradient operation.

→ Next slides.

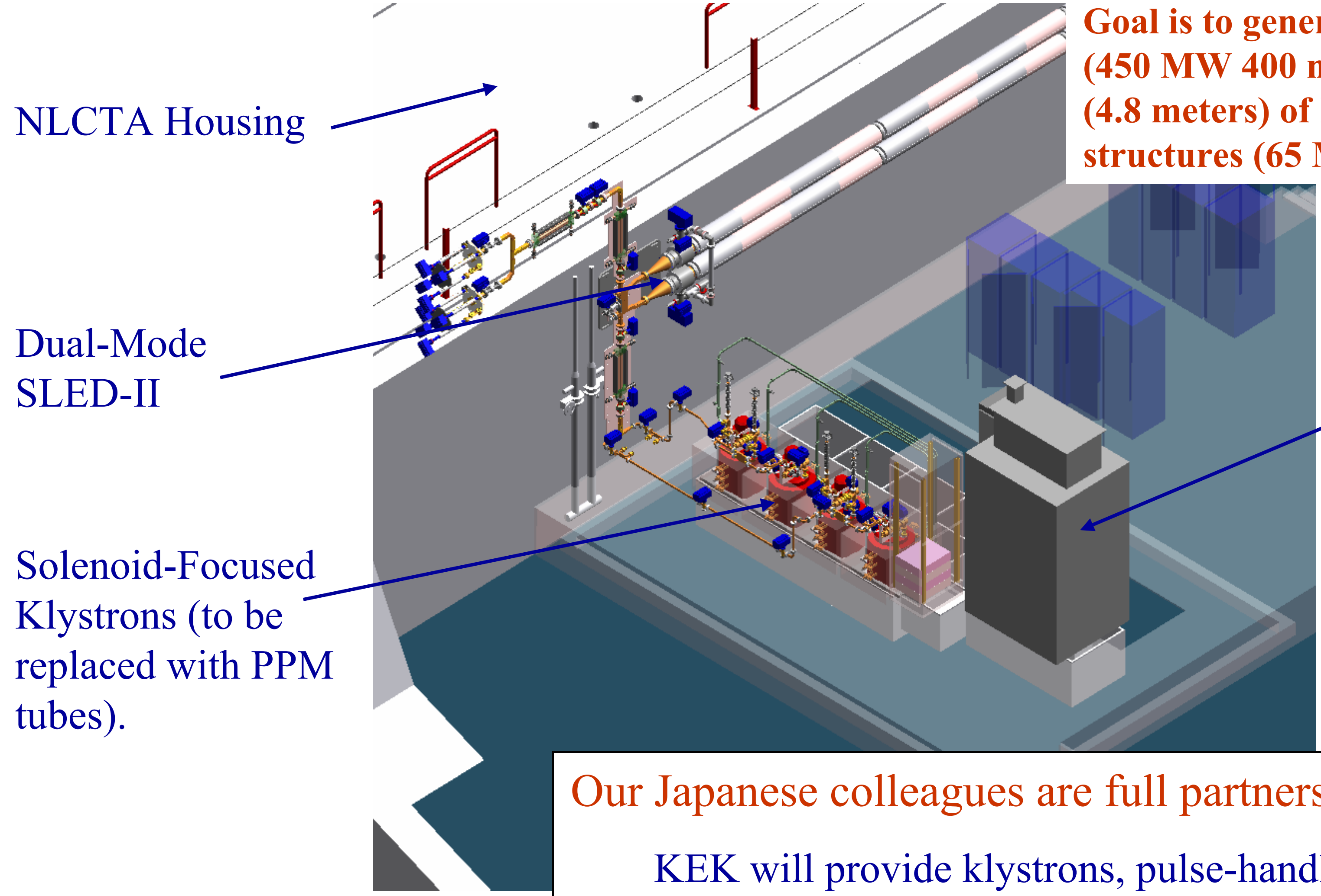
Fermilab and KEK will build structures for this "TRC R2" demonstration.

- We will continue to study two alternate possibilities that might provide dramatically better gradients:

Standing-wave structures with low pulse temperature rise couplers.

Structures with Mo and W irises (built by CERN).

NLC/JLC SLED-II Baseline Test



Goal is to generate an RF pulse (450 MW 400 nsec) for a girder (4.8 meters) of high-gradient structures (65 MV/m).

Our Japanese colleagues are full partners in this plan.

KEK will provide klystrons, pulse-handling, and accelerator structures, and will participate in testing.

Solid-State Modulator

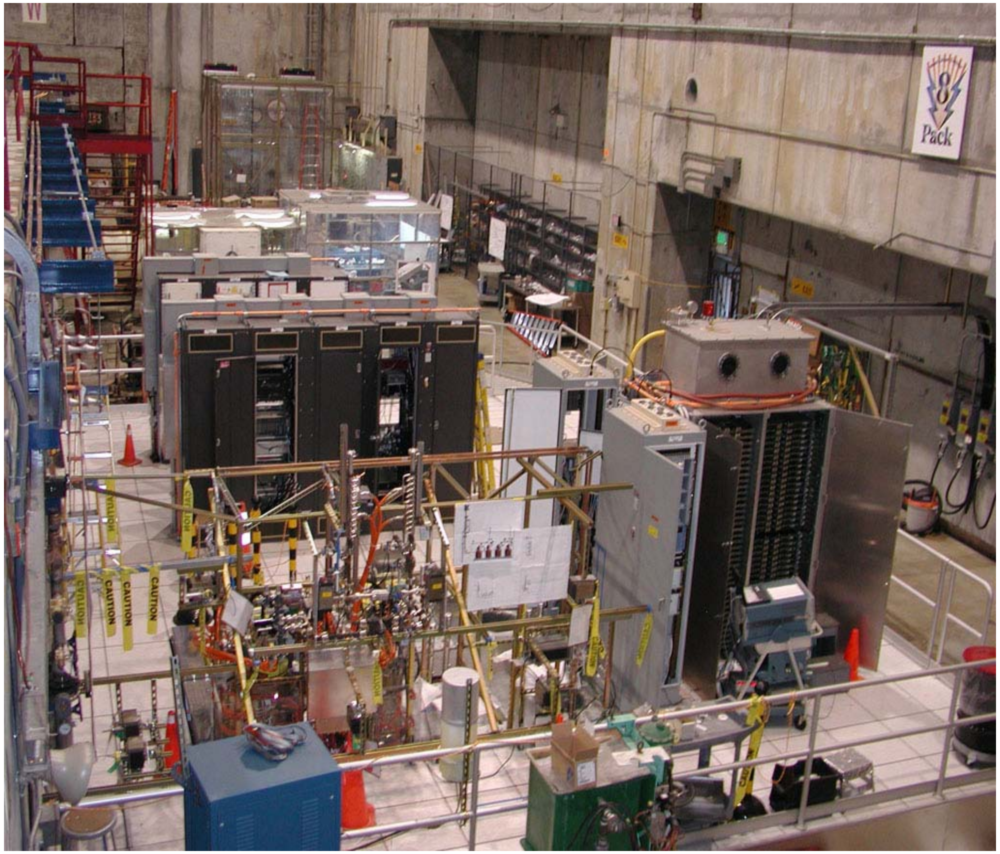
- Modulator is on-line and driving four XL-4 klystrons.

- Software and control logic being tested and debugged.

  → Next slides.

- All SLED-II designs passed microwave "cold tests" and components are in production.

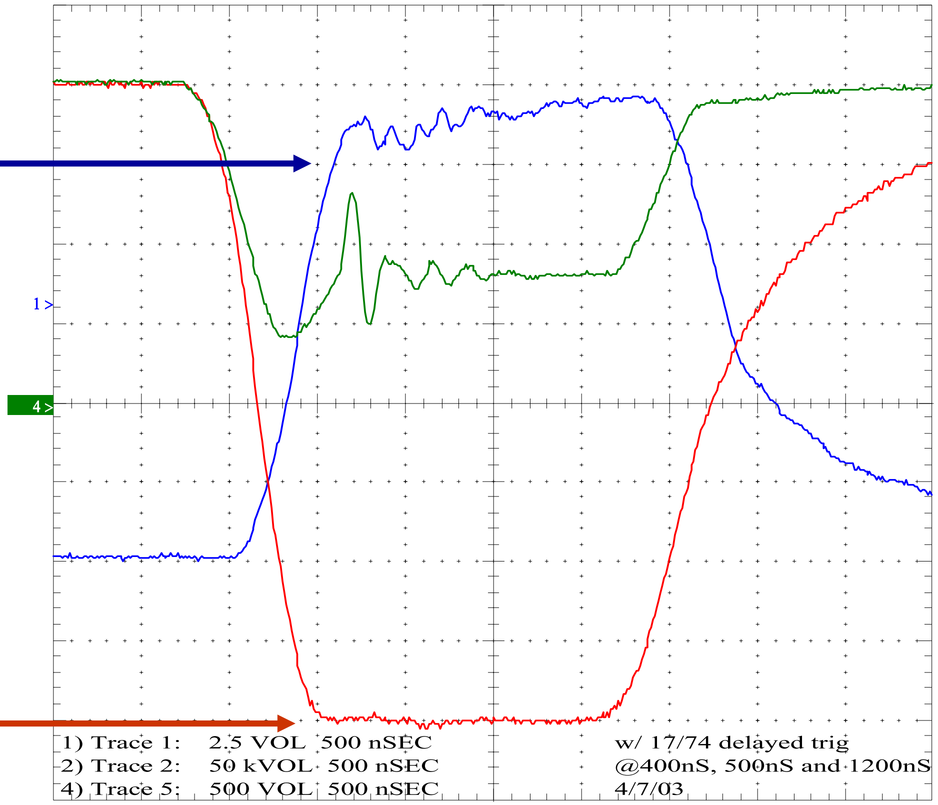
  → Power tests to loads in June.



Solid State Modulator Commissioning

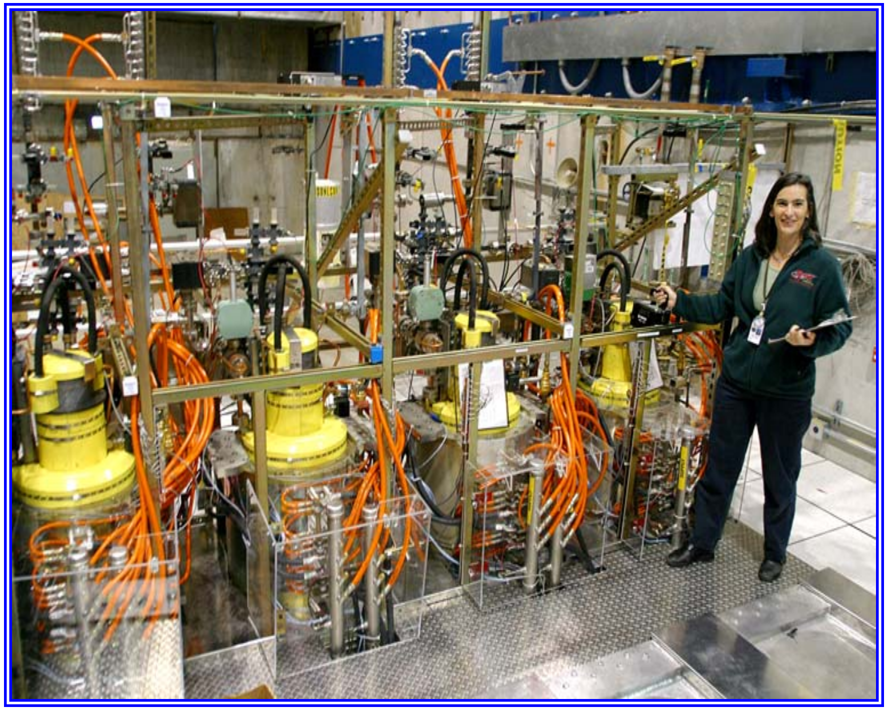
250 A

400 kV

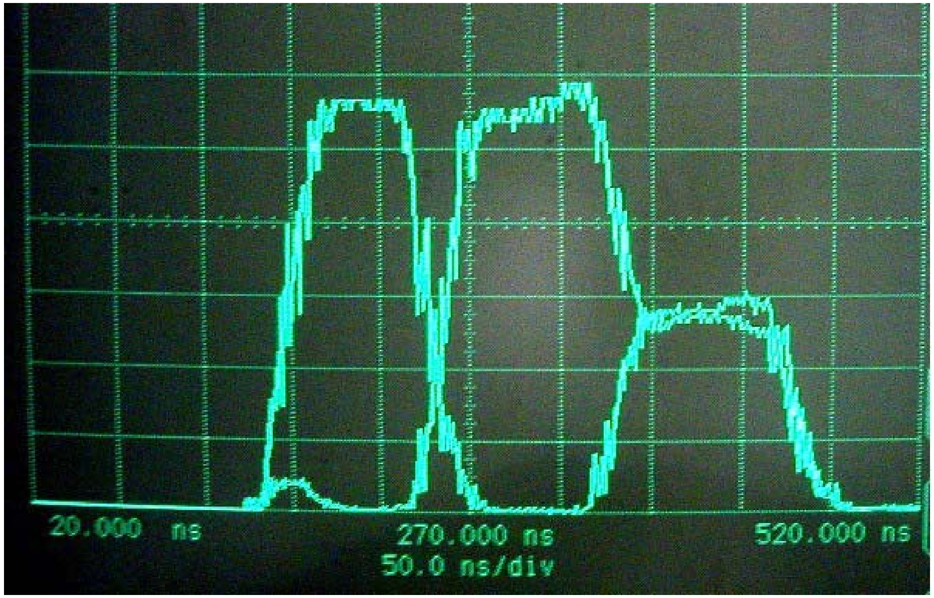


Voltage pulse flattened by delayed firing sequence of boards in the IGBT stack.

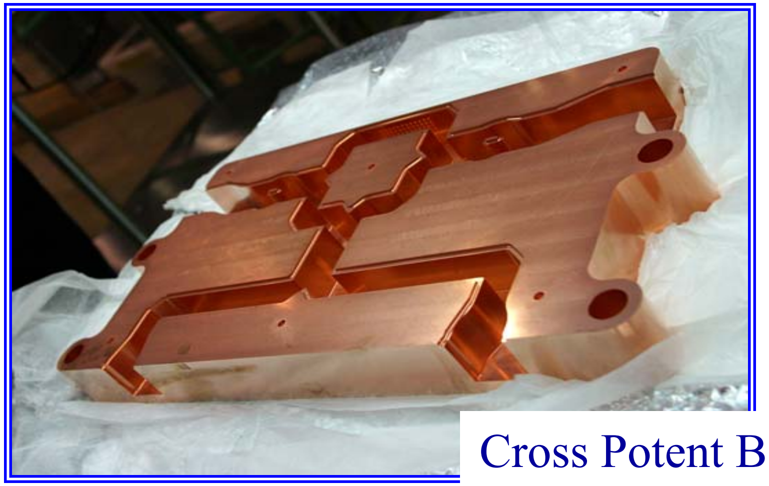
XL-4 Klystrons, LLRF, and Controls



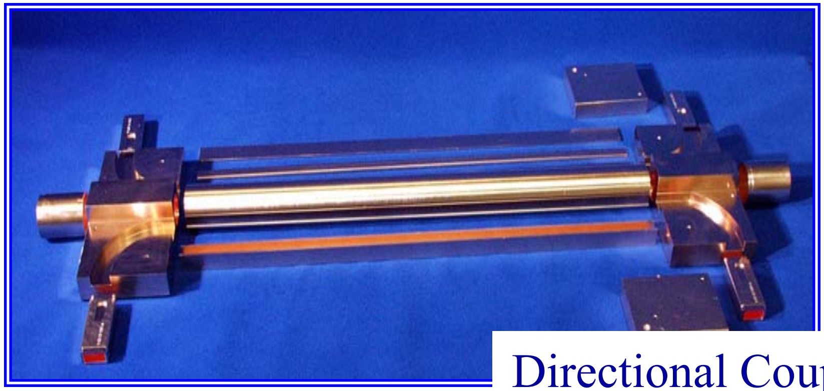
Scope trace below shows phase manipulation of pairs of klystrons alternately sending all power to one load, then the other, then splitting it between the two.



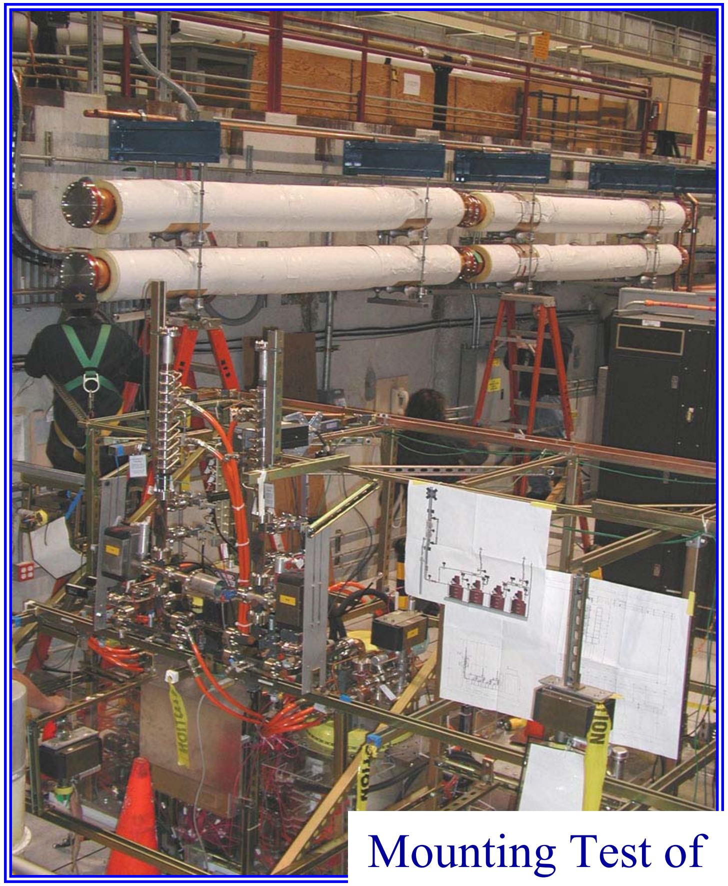
SLED-II Components



Cross Potent Body

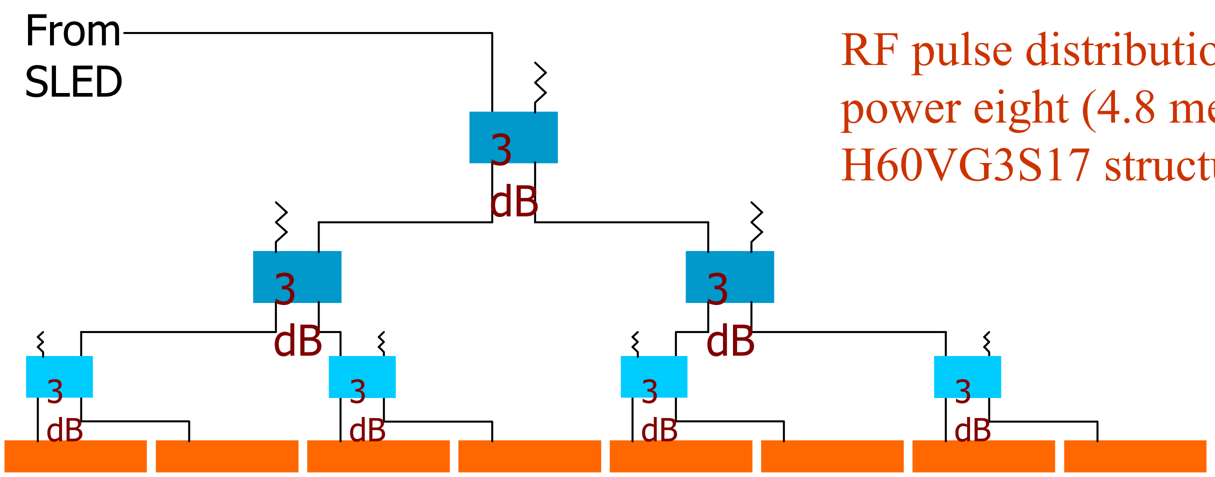


Directional Coupler



Mounting Test of Delay Lines

SLED-II Phase 2 Plans



RF pulse distribution inside NLCTA to power eight (4.8 meters total length) H60VG3S17 structures at 65 MV/m.

• SLAC and KEK to start fabrication of pulse distribution this summer.

• Goal is to complete this next spring, and run 2000 hours of high-gradient operation by end of the year.

• We will be able to do this at the level set by the President's FY04 budget submission.

RF R&D Activities and Plans Through 2004

NLC/JLC SLED-II Baseline Demonstration Schedule

(FNAL, KEK, LLNL, and SLAC)

2002				2003												2004	
Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb

Permanent Magnet Klystrons

Test PPM3 — Test PPM2R — Test PPM4

Test XP3-2 — Test XP3-3 — Test XP4-1

Solid-State Modulator

Commissioning ———————> Operation with XL-4 Solenoid Klystrons ——————————————————>

SLED-II System

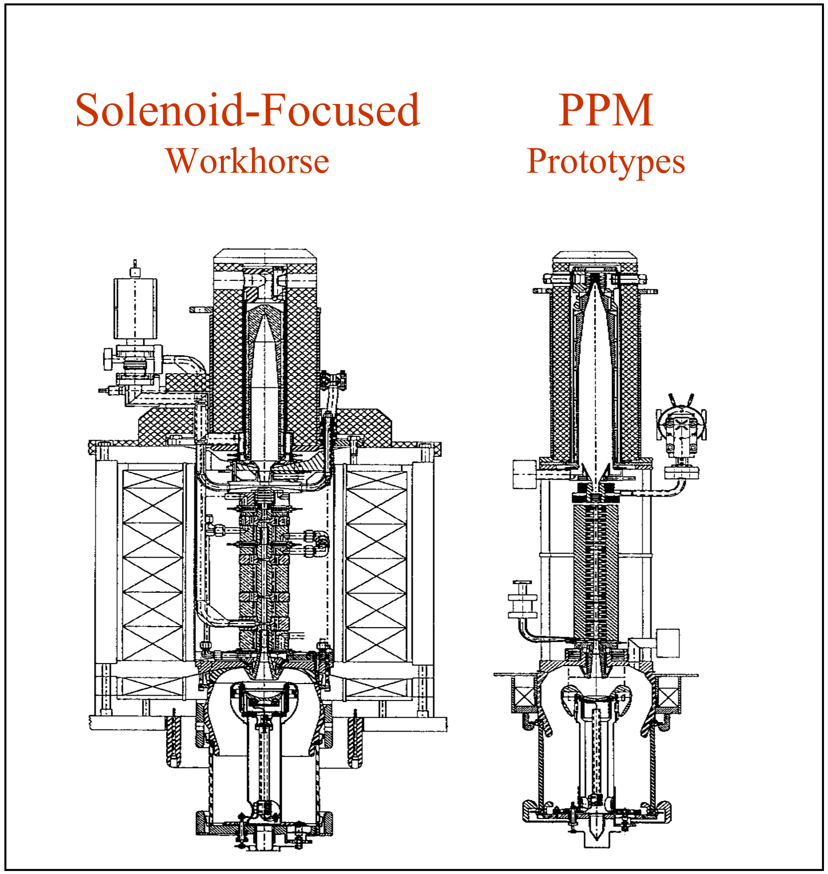
Microwave Tests of Components ——————> Demonstration of Baseline Pulse Compression (TRC R1) ———————> Manufacture Power Distribution ————————————————>

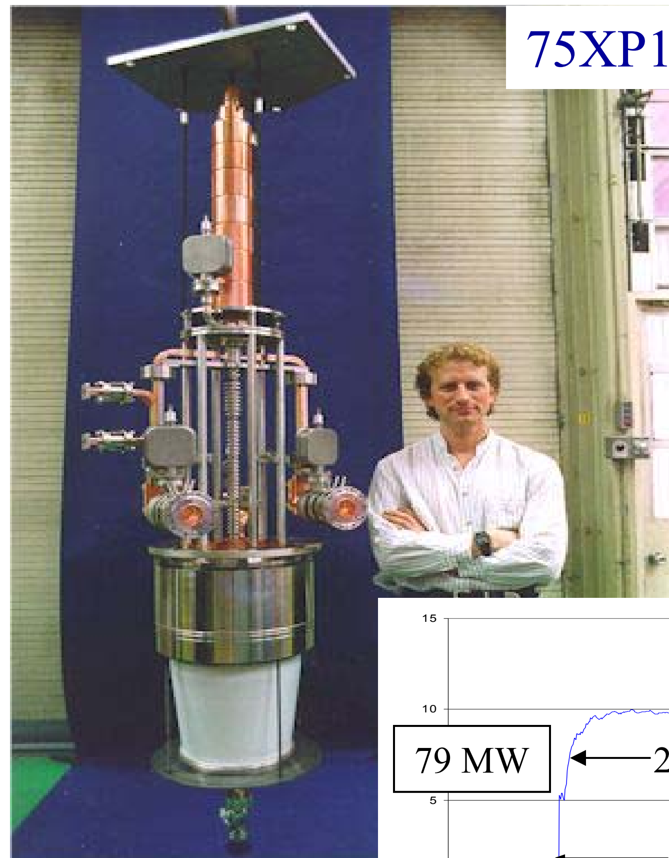
Accelerator Structures

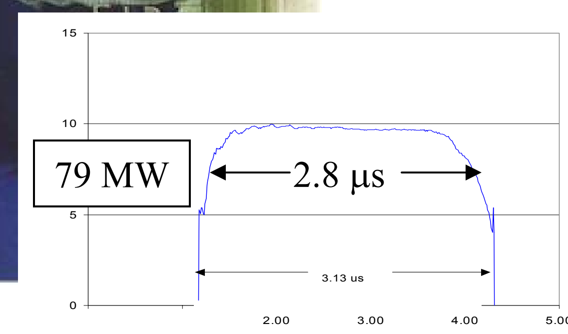
JLC/NLC Structure Development ——————————————————> Demonstrate NLC/JLC Structures (TRC R1) ———————————————————>

————————Manufacture Girder of Structures——>

Permanent Magnet Focused (PPM) Klystrons

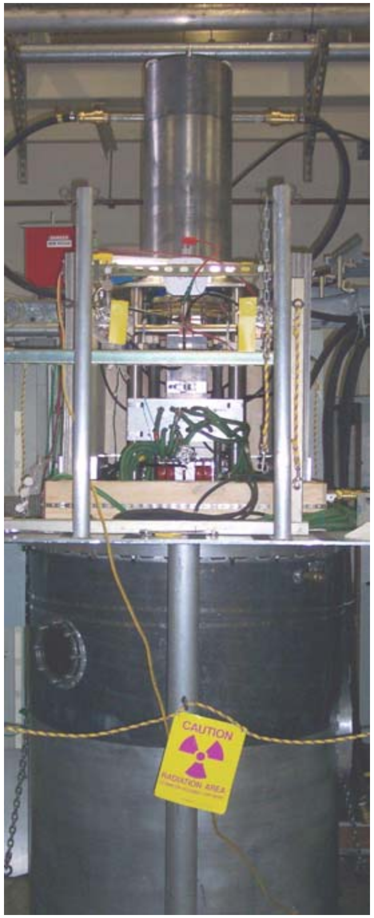






Repetition rate limited to 1 Hz due to lack of cooling.

High-Rep Rate PPM Klystrons



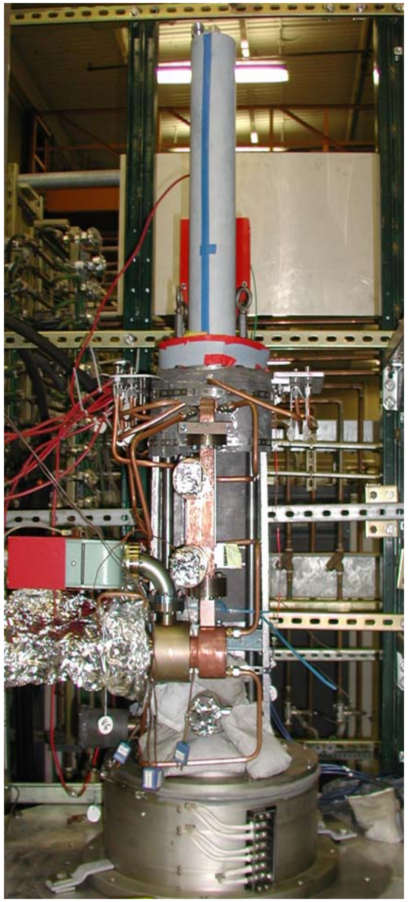
KEK/Toshiba PPM2

Previously achieved 70 MW at 1.5 μs at KEK (limited by modulator performance), and is now under test at SLAC.

PPM4 beginning test at KEK.

SLAC XP3-3 (Rebuild)
Starting tests this week.

XP-4 design nearing completion.



SLAC E158 and Injector Beam Parameters

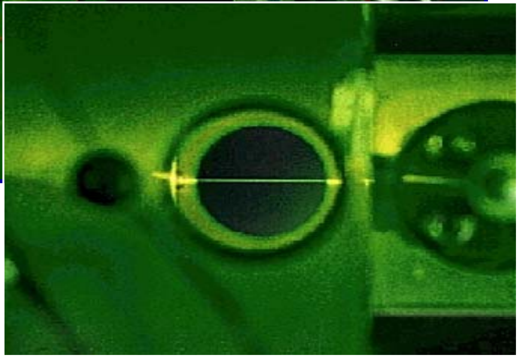
Parameter	E158	NLC-500
Charge/Train	6×10^{11} (*)	14.3×10^{11}
Train Length	300ns	260ns
Bunch spacing	0.3ns	1.4ns
Rep Rate	120Hz	120Hz
Beam Energy	45 GeV	8 GeV
e^- Polarization	80%	80%

(*E158 source can produce 5 times this charge.)

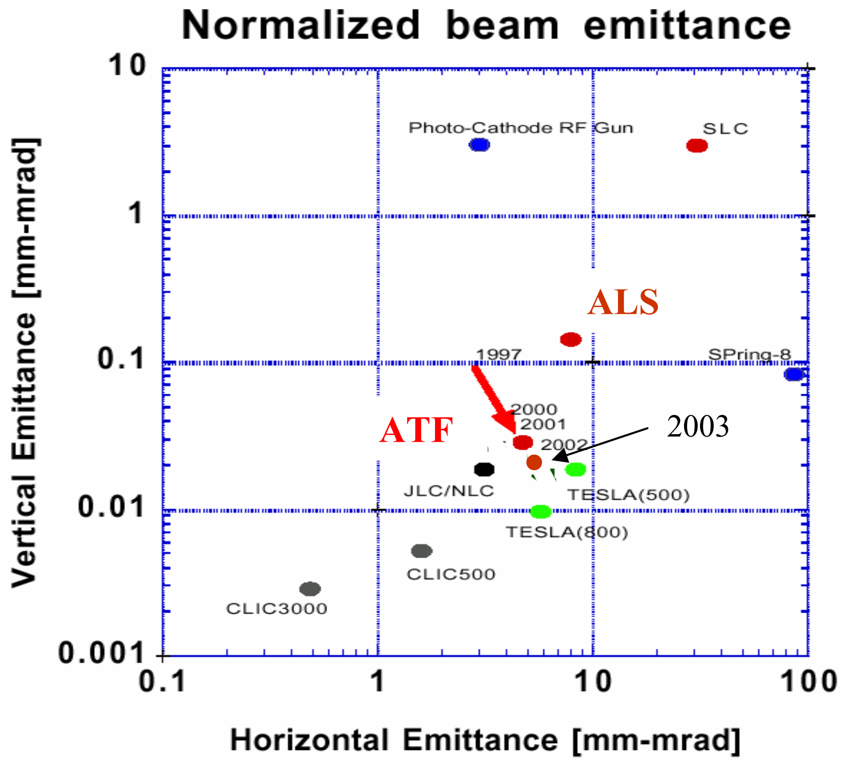
Gradient-Doped Strained GaAs Photocathode

ATF Damping Ring at KEK

SLAC and KEK physicists survey the ring.



"Laser Wire"

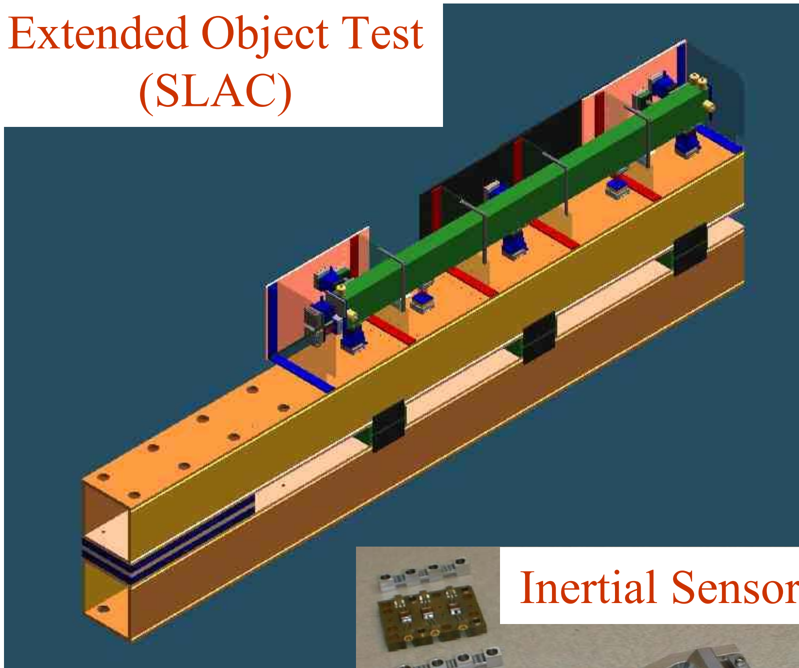


Issues Under Study

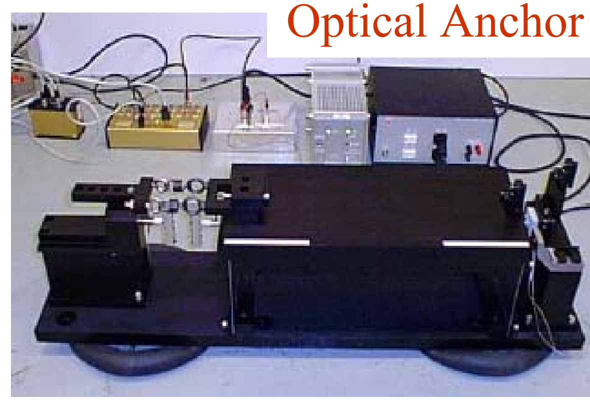
- Intra-Beam Scattering
- Electron Cloud
- Trapped Ions

Stabilization R&D

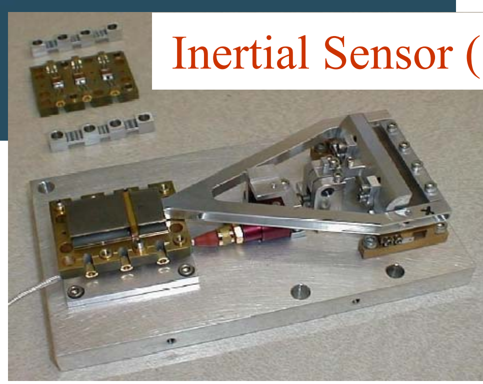
Extended Object Test (SLAC)



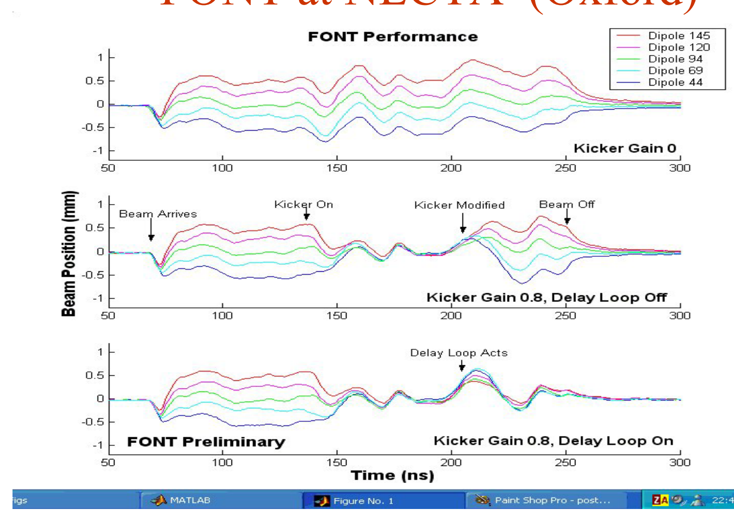
Optical Anchor (UBC)



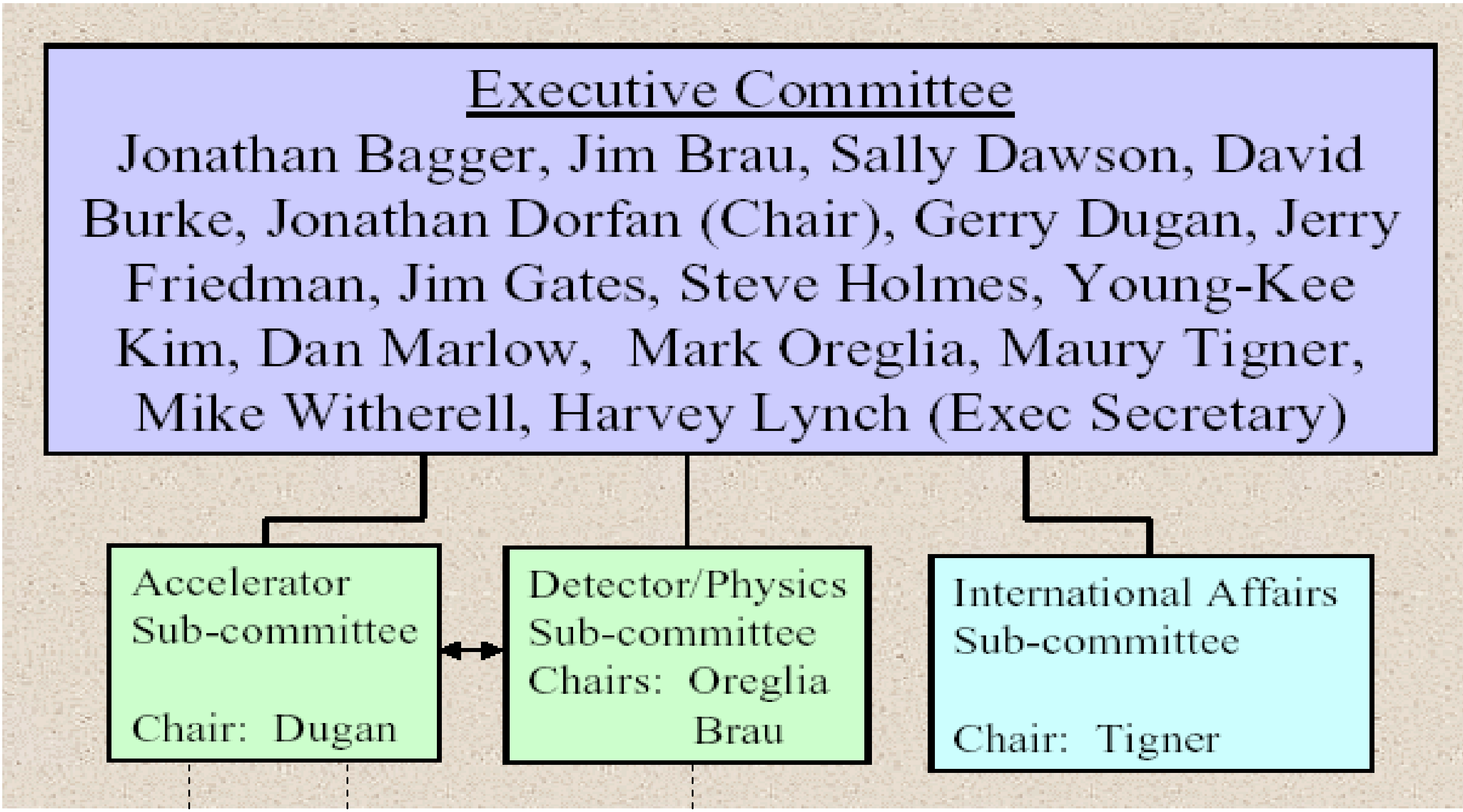
Inertial Sensor (SLAC)



FONT at NLCTA (Oxford)

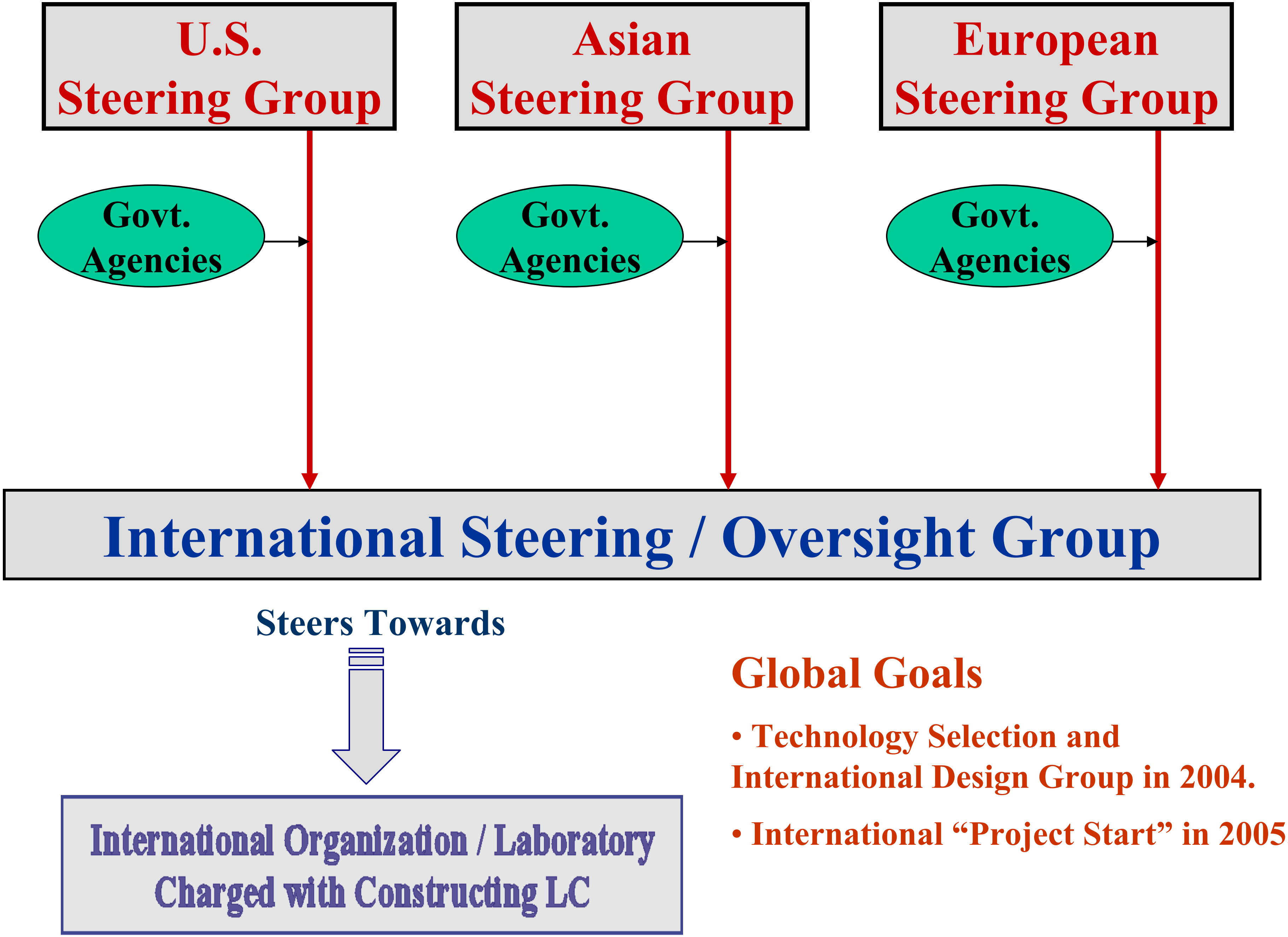


U.S. Linear Collider Steering Committee



TESLA

American Linear Collider Physics Group



U.S. Steering Group
Asian Steering Group
European Steering Group
Govt. Agencies
Govt. Agencies
Govt. Agencies
International Steering / Oversight Group
Steers Towards
International Organization / Laboratory Charged with Constructing LC
Global Goals
• Technology Selection and International Design Group in 2004.
• International "Project Start" in 2005.

NLC Activities for the Next Year

- Accelerator Design centered around USLCSG evaluation. This is expanding to include more on cost and schedule, reliability modeling, and risk assessment, and will include work on the cold option.
- Technology R&D will stay focused on the RF R&D.
  - SLED-II driving 4.8 meter girder of structures at 50 MV/m loaded gradient – a 250 MeV accelerator operated for ~ 2000 hours.
  - Prototype modulator "2-Pack" with next-generation IGBT switches, and PPM klystron prototypes (XP4-1 and 2).
- Remainder will still be squeezed hard by budget limitations, and priority will remain the same.
  - Damping Ring and ATF - nanometer BPM development.
  - Vibration and Stabilization - extended girder studies.
  - Ground Motion and Site Studies
  - Polarization – Studies of Positron Production