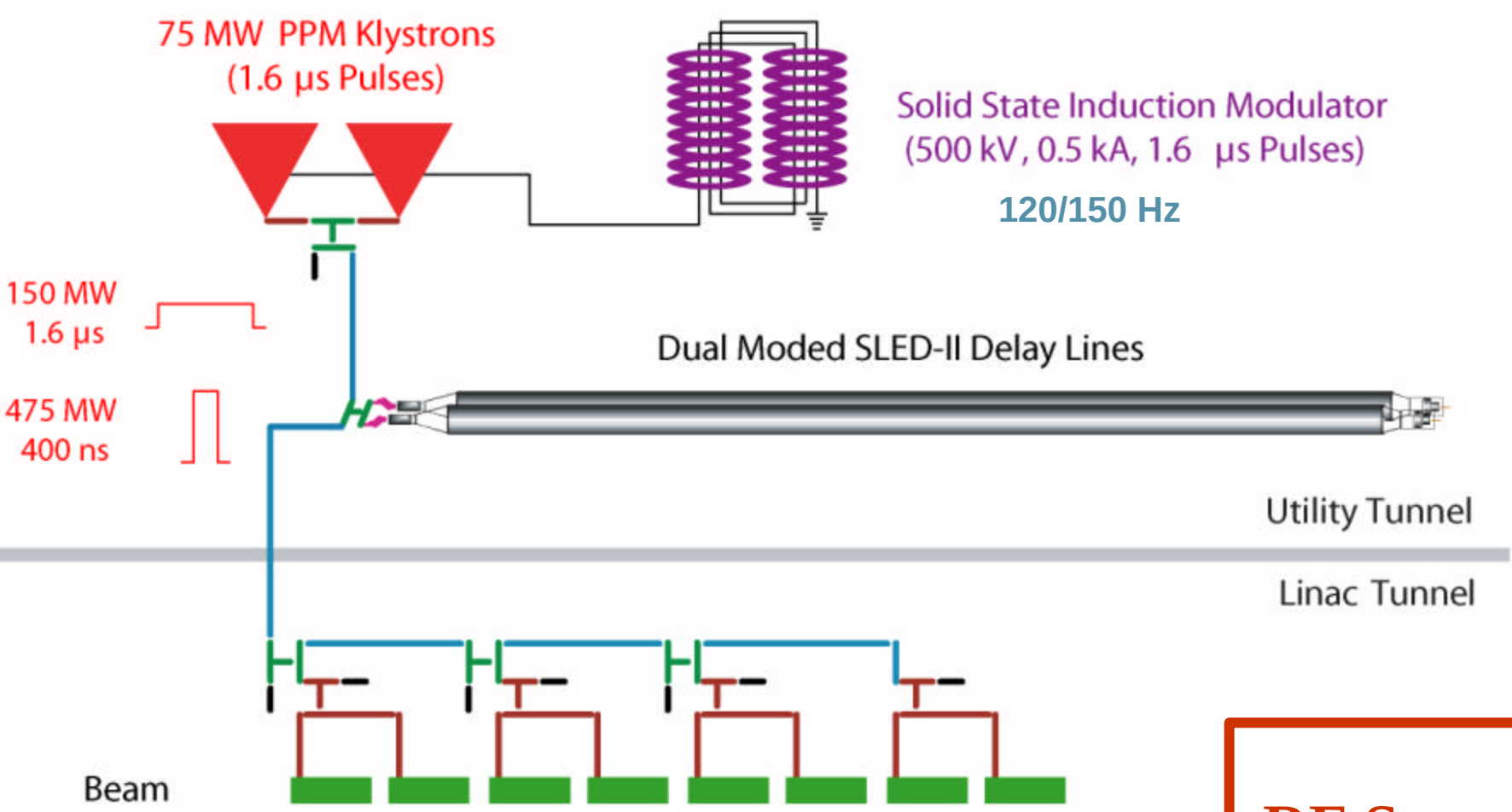
The X-band Linear Collider preparation - *status and plans*

presented by Marc Ross on behalf of the NLC / GLC groups

13.11.2003



RF System: Copper Accelerator

- *Design:* KEK, Fermilab and SLAC
- *Production:* KEK, Fermilab, LLNL and SLAC
- *High Power Test:* KEK and SLAC

X-band test facilities

GLCTF at KEK

2003

1 test position /w full power @100Hz

(3 in 2004)

beam in 2005

2 x 50 MW pk klystrons

KEK Tristan Assembly Hall

NLCTA at SLAC

1996

4 test positions /w full power @60 Hz

(8 in 2004)

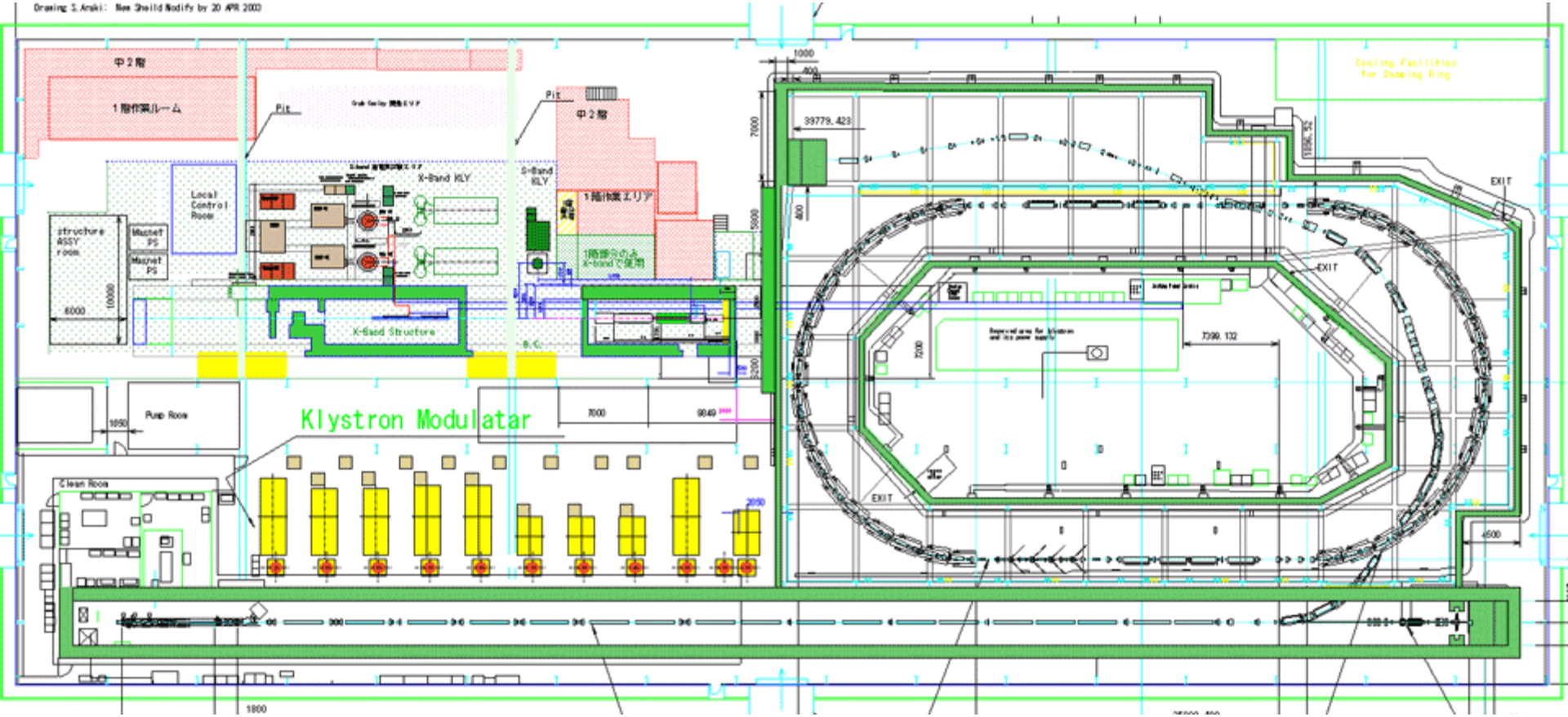
170 ns beam

9 x 50 MW pk klystrons

SLAC End Station B


GLCTF at KEK in April 2003

? ? ? ? ? ? ? ? ? ? ? ?



The Accelerator Test Facility at KEK

1.3 GeV Damping Ring and S-band linac
100 MW X-band structure testing
1998 →

The world's largest LC test facility

World's lowest emittance beam:

$\varepsilon_y = 4$ *pm-rad*

below X-band LC req's

Tevatron 1984: " Make and test magnets *(structures)* as fast as possible"

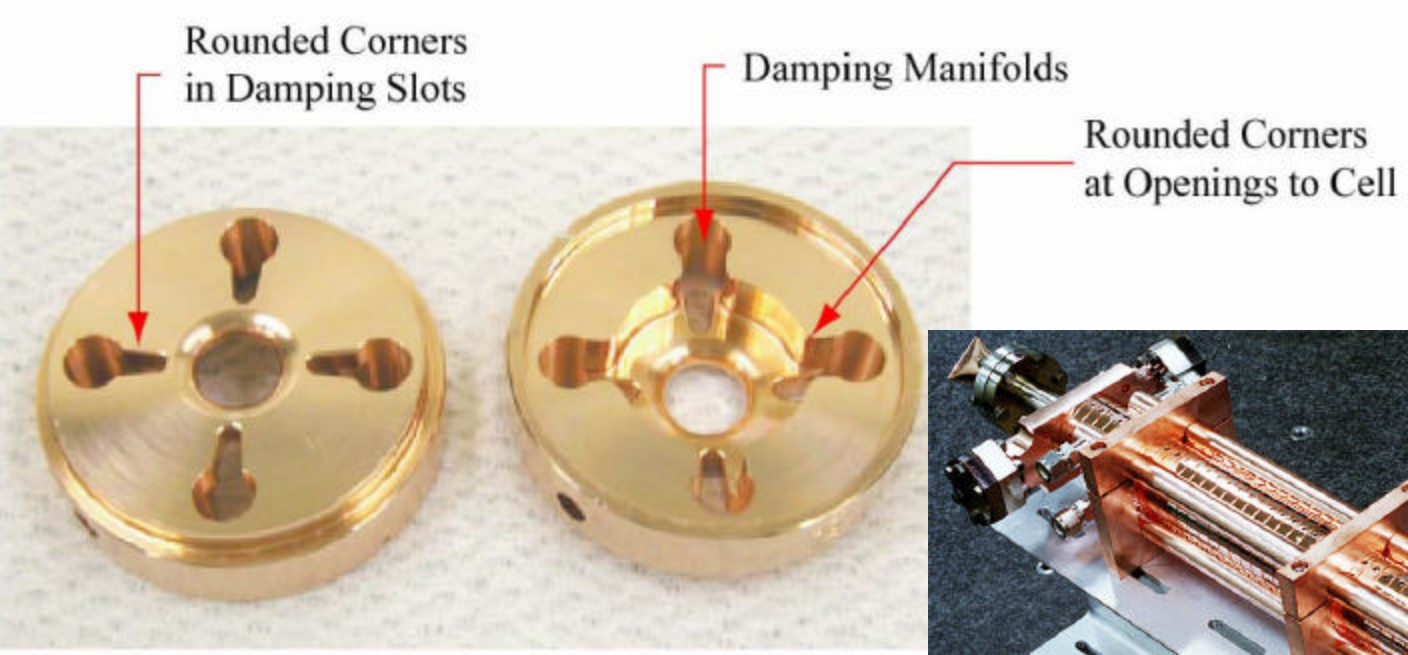
A. V. Tollestrup

X-band structure production

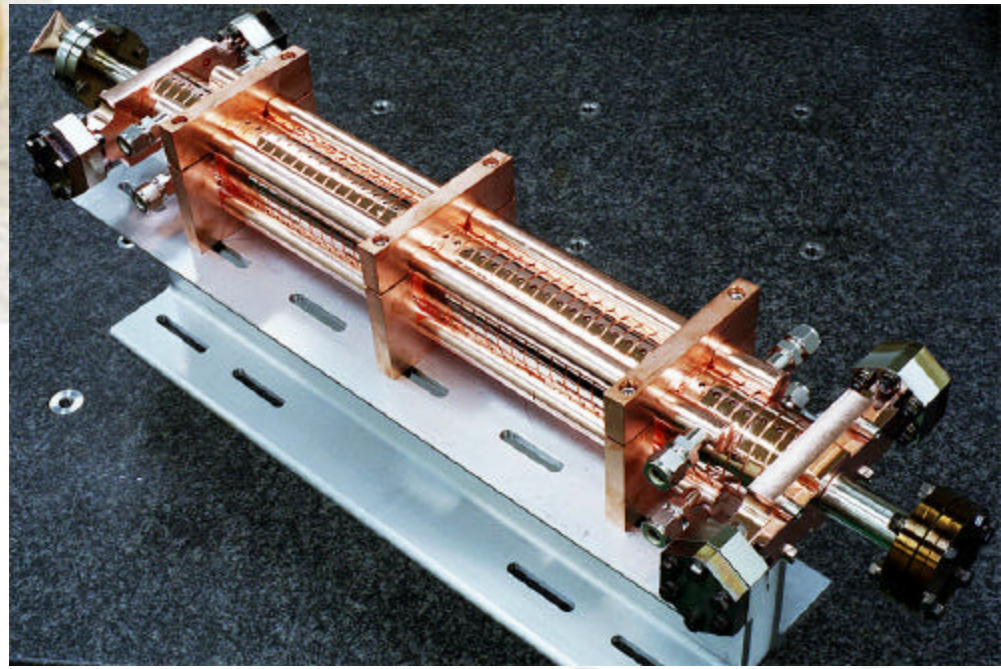
- Structure RD: *three – fold focus*
  - *Electrical design*
    - coupler, power flow and gradient
  - *Materials / fabrication process*
    - particulates, surface, grain size and chemistry
  - *Test and understand*; validate with beam
    - diagnostics, post-mortem and analysis

- 2003 structure production rate:
  - 16/year
  - (almost) fully featured

RD Goal:
Fully featured structure (slots...)
Maximum efficiency
Sustainable gradient
'breakdown rate'

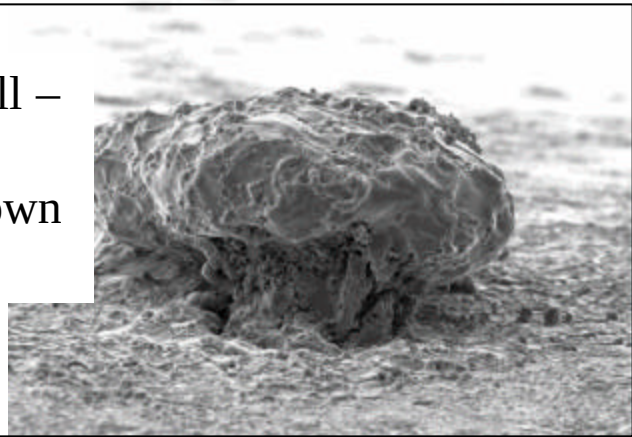


Structure fabrication includes:



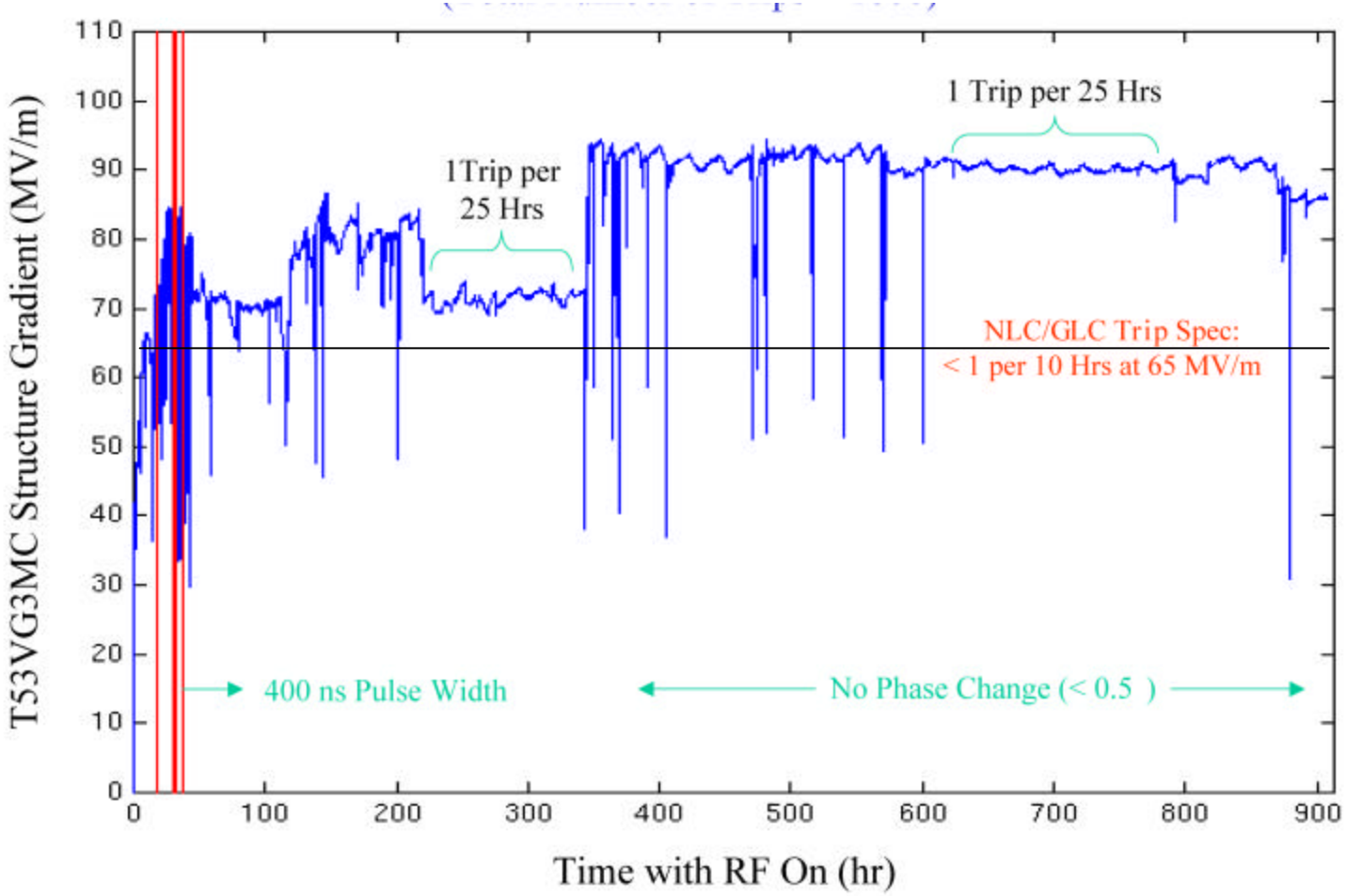
- good copper
- high quality commercial machining
- light chemical etch
- in-house brazing, diffusion bonding
- vacuum fire or hydrogen fire
  - increases grain size
- in-situ bake
- nominal clean room process

SS inclusion in cell wall – covered with and surrounded by breakdown 'craters' →

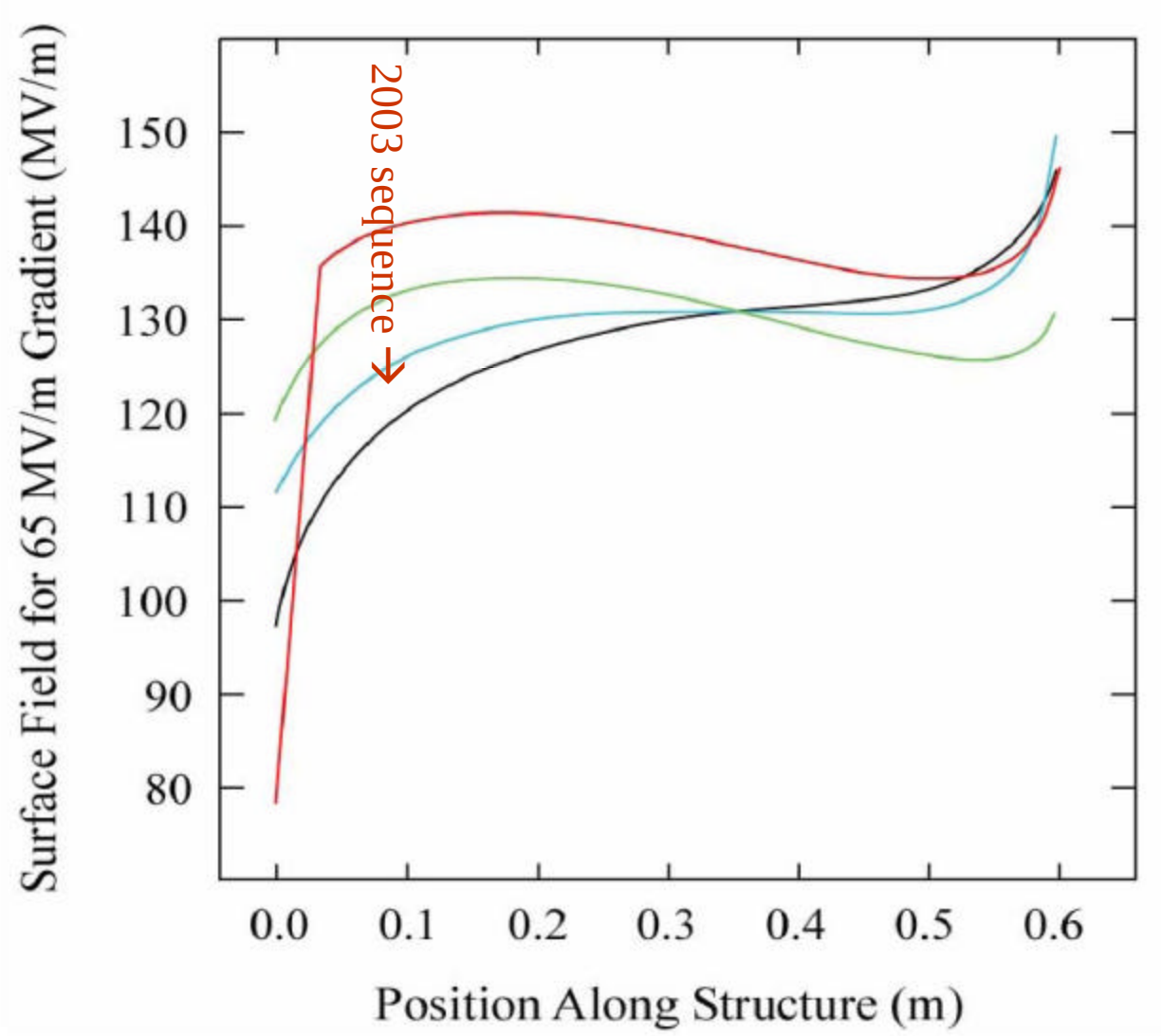


Test structure performance

Operations history – Test Structure (2002)



Linac/ Structure parameters

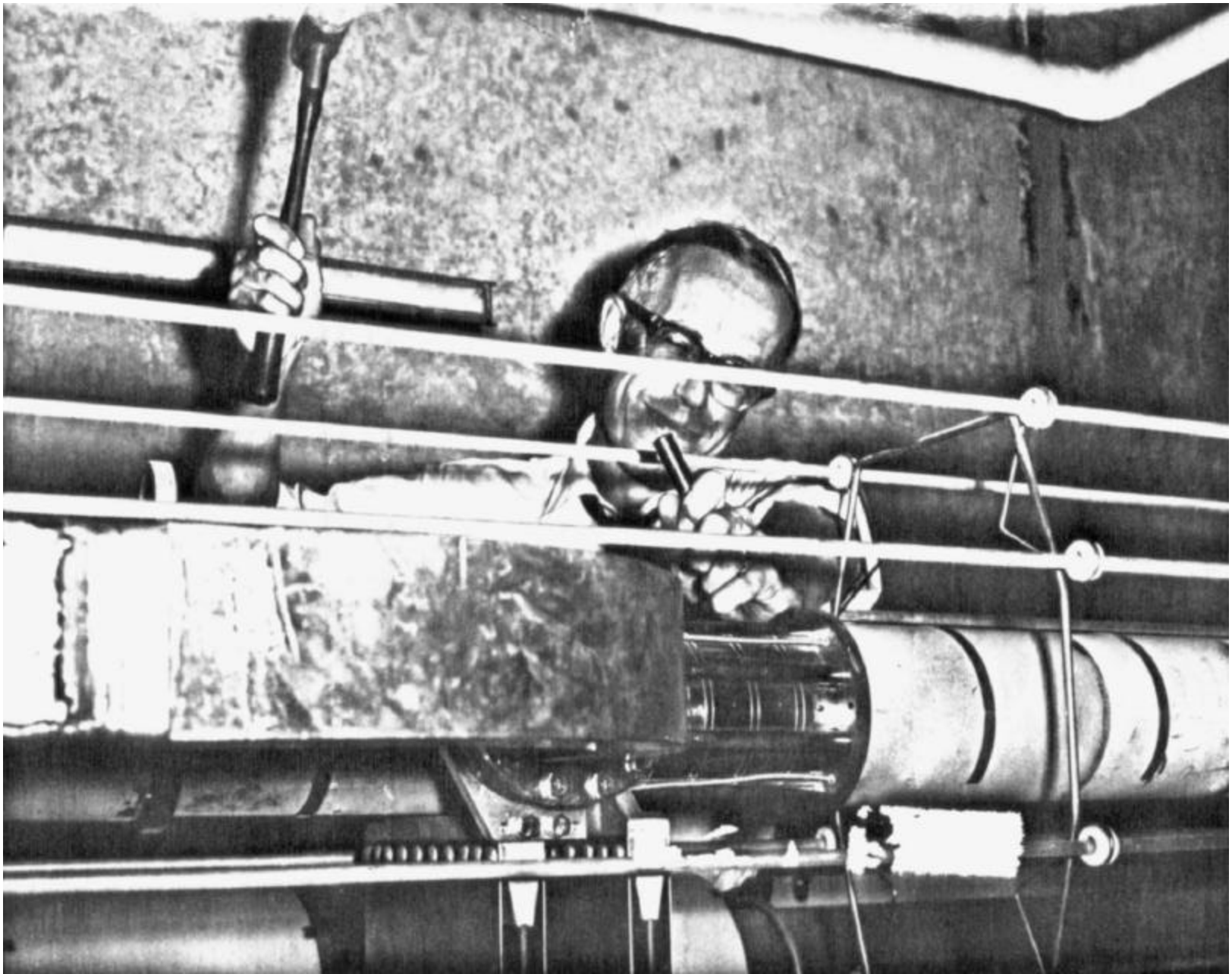


65MV/m unloaded gradient
7.5 km / linac @ 500 GeV

Adapt power, surface field and gradient along length to improve breakdown performance

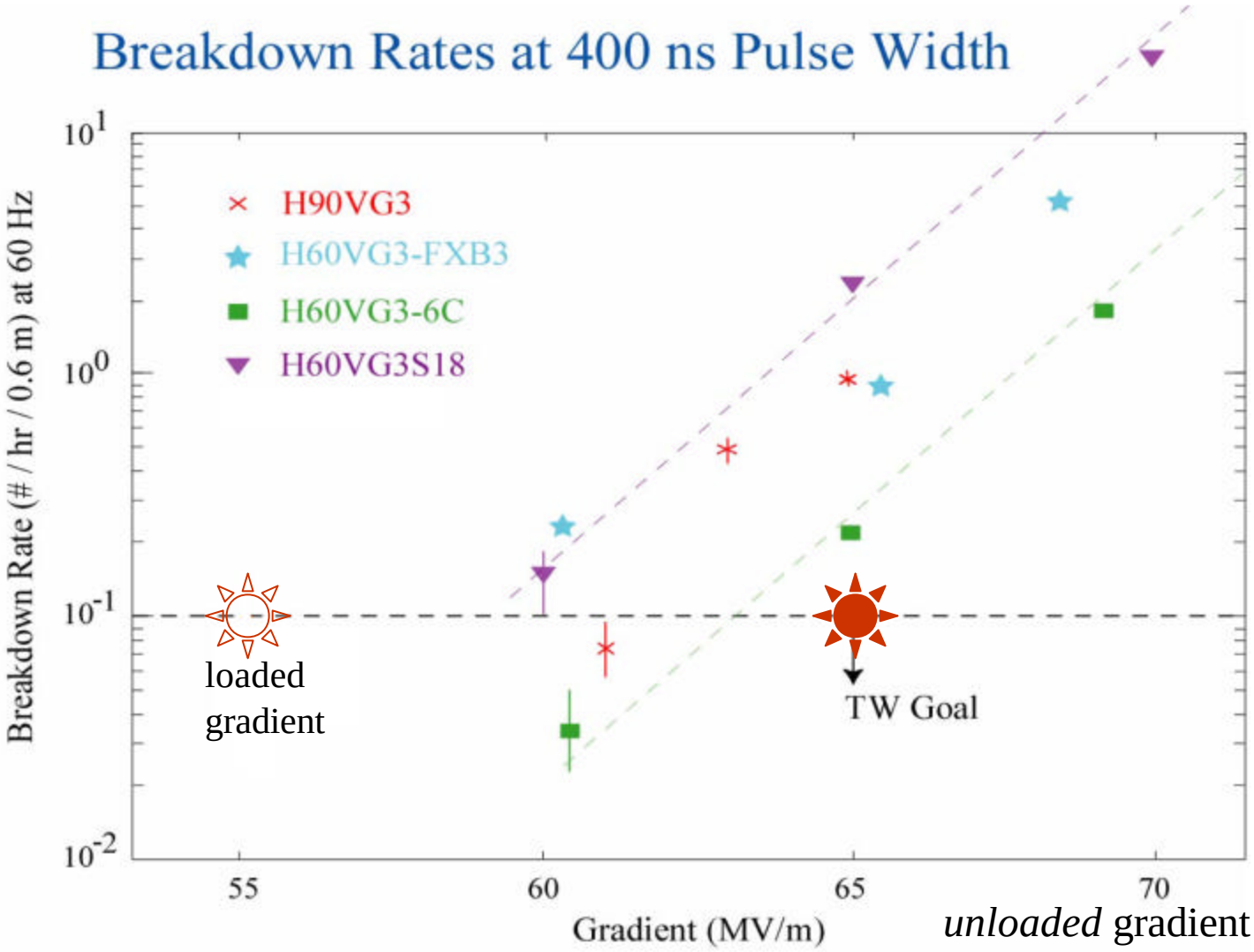
Maintain the dipole mode performance needed for beam quality → 'detuning'

Deflecting mode detuning ca. 1968 → the commissioning of SLAC



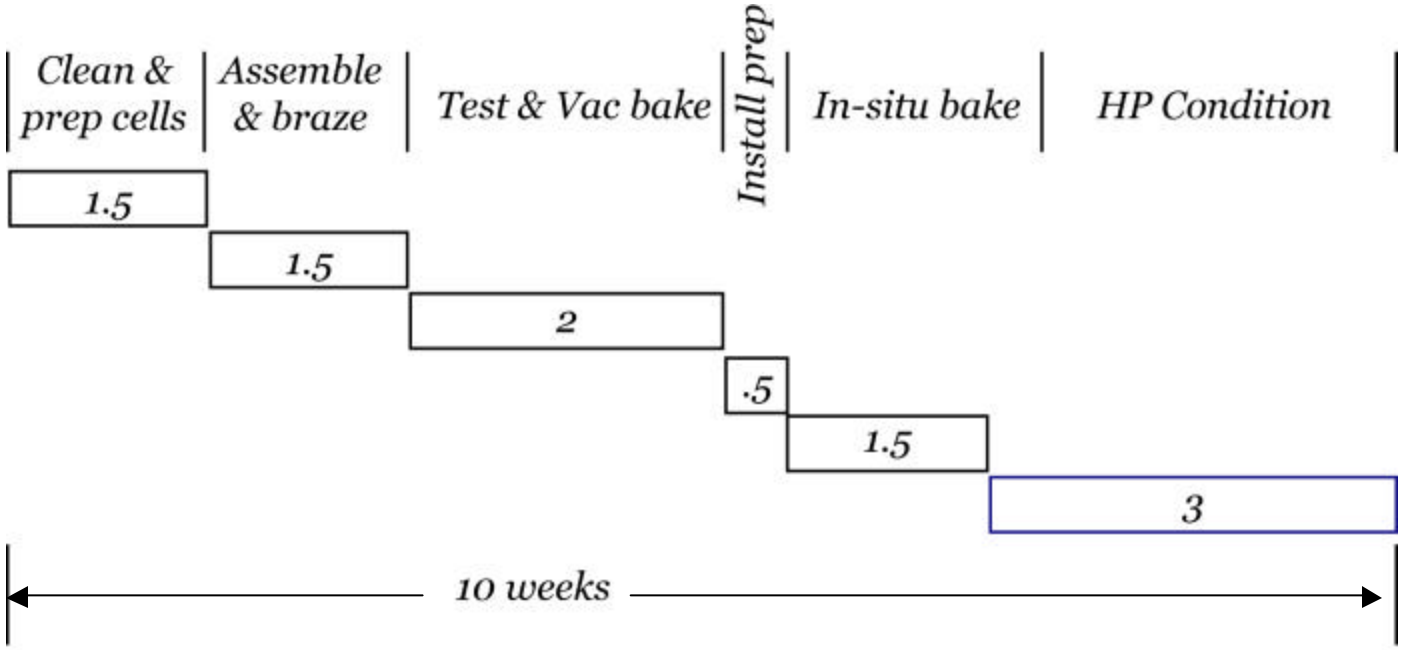
- breakdown events are grouped in time: 1/hour is really a single group of 10 in a few minutes
  - seen at SLC with the high gradient positron source accelerator

Structure performance summary



Breakdown rates depend on process history

Structure Testing & Processing



from machined cells to high gradient in 10 weeks – *FNAL, SLAC & KEK*

NLCTA/GLCTF operate ~ 4000 hours / year

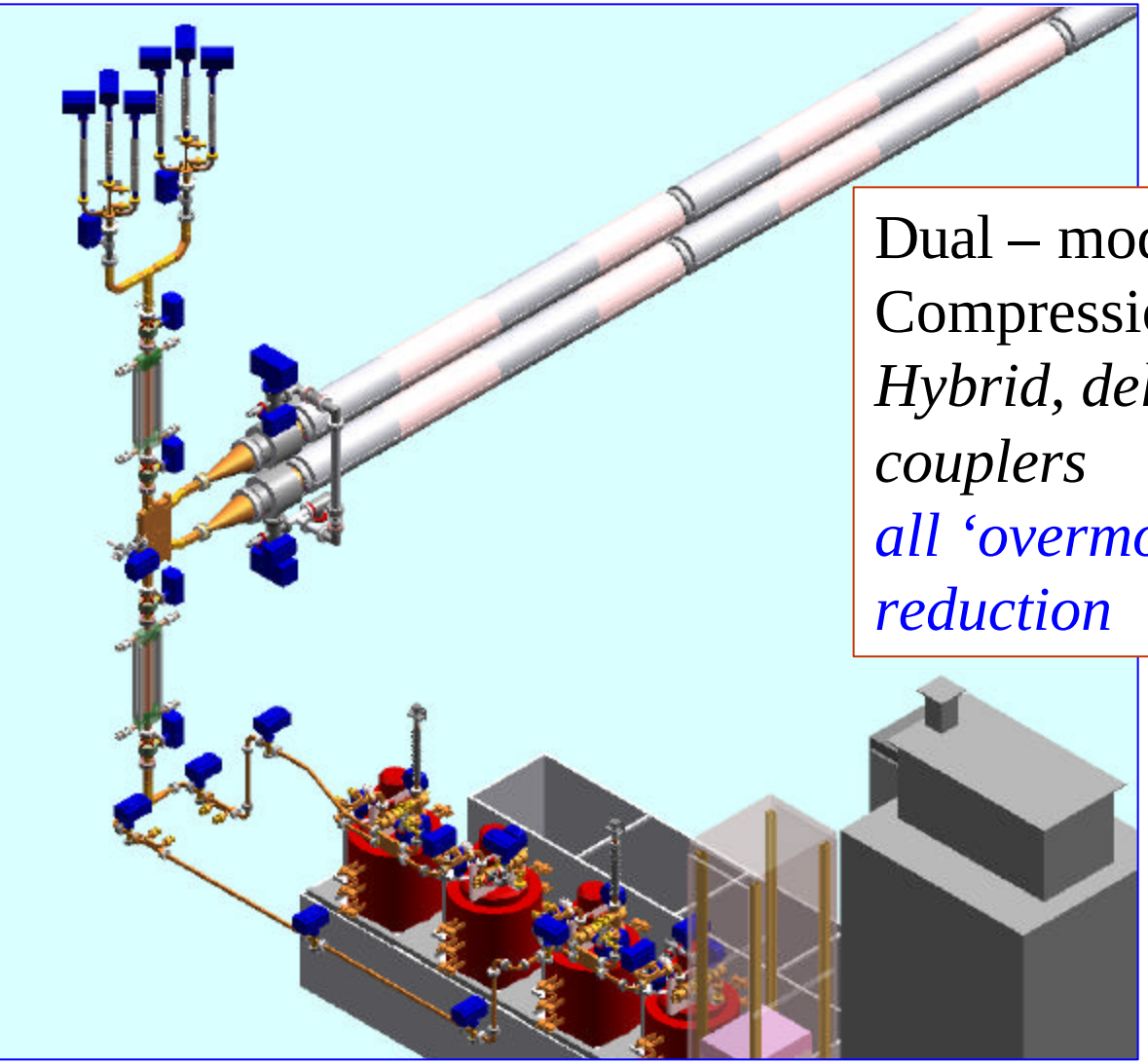
Production rate:

~ 16 x 0.6m/year

=10 m / year

= 650 MeV/year

X-band RF Distribution



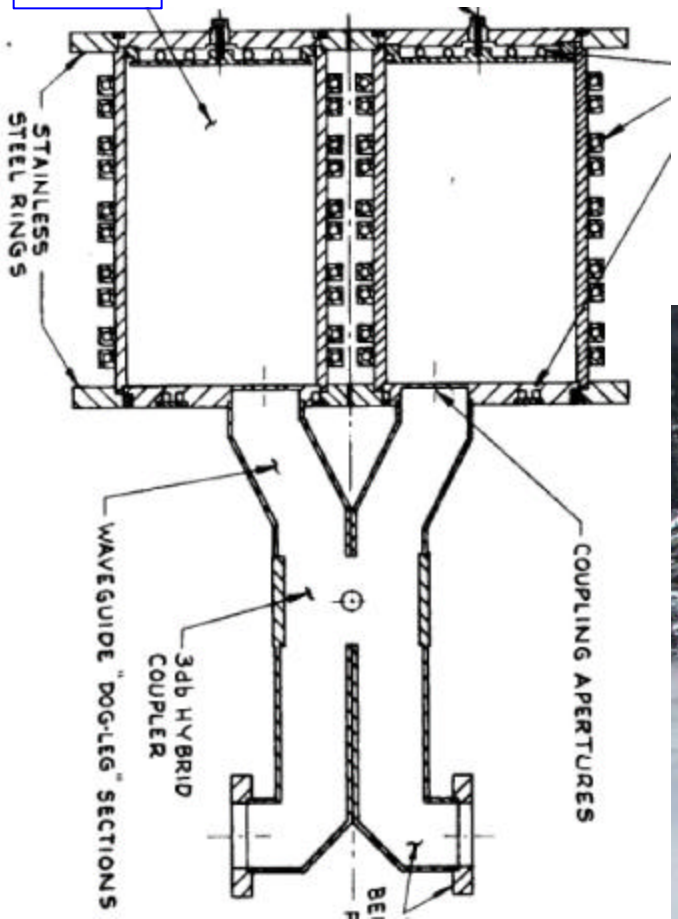
Dual – mode SLED II Compression System
Hybrid, delay lines and couplers
all 'overmoded' for loss reduction

Full scale, nominal system – phase 1: *not connected to structure*

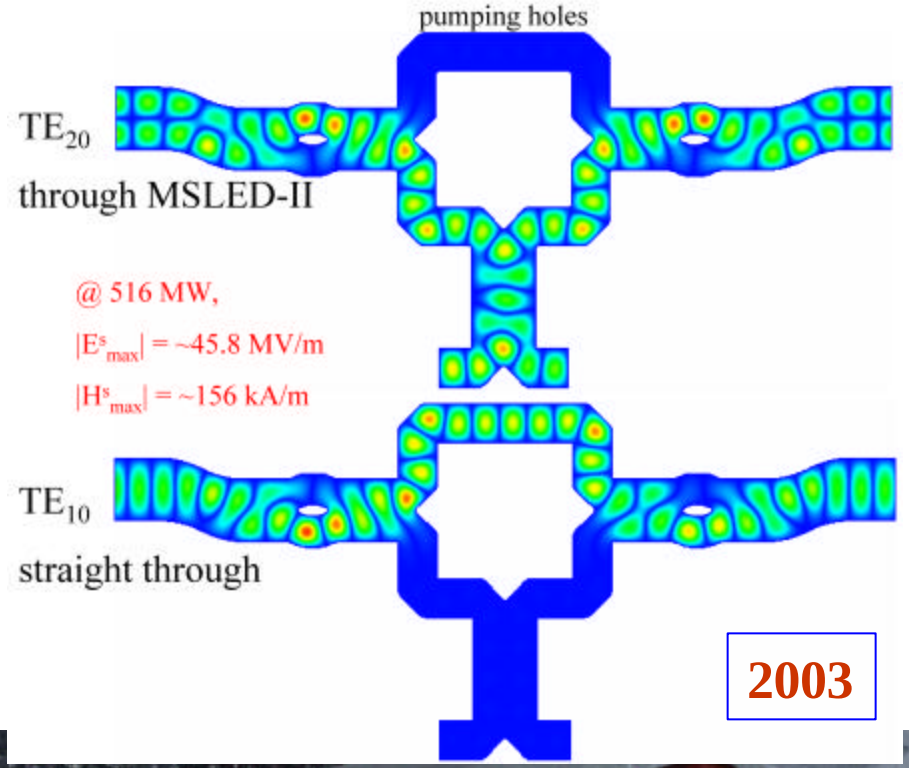
Milestone:
475 MW, 400ns
at the load tree

SLED hybrids: 1973-2003

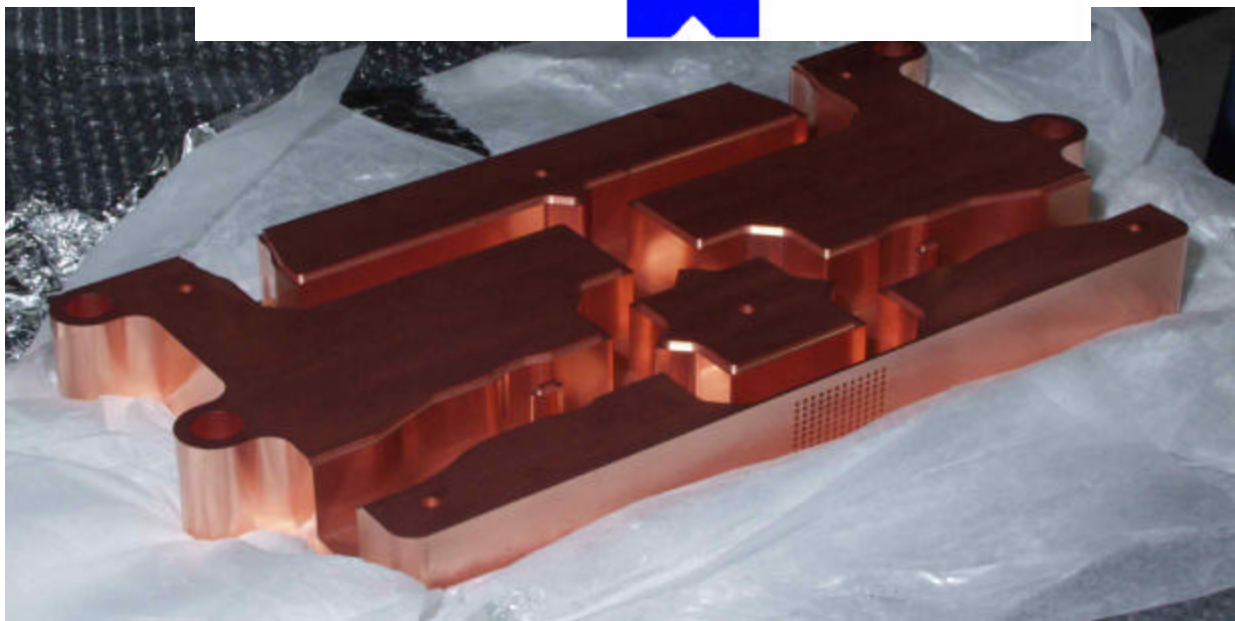
1973



Sled Head Simulations

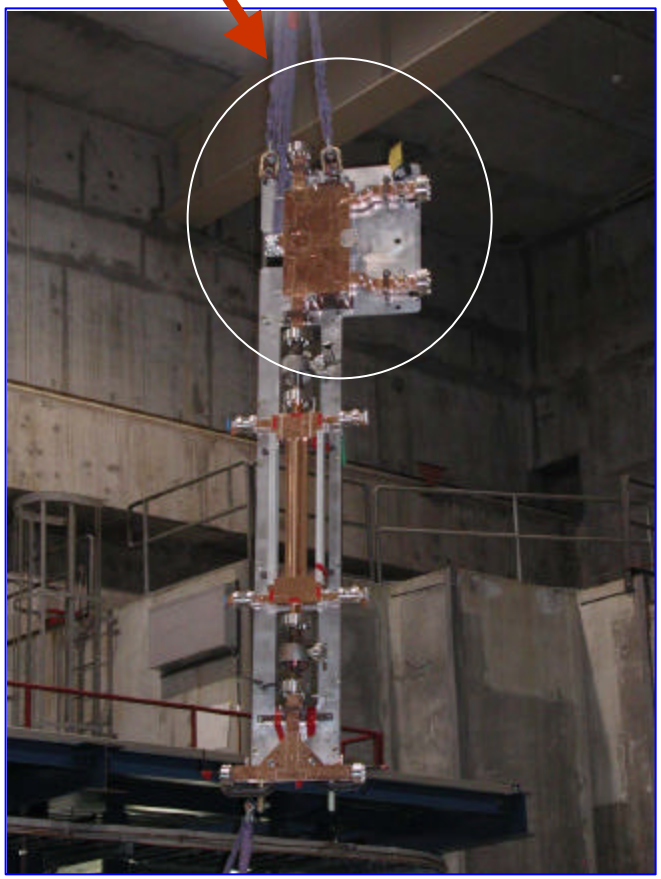


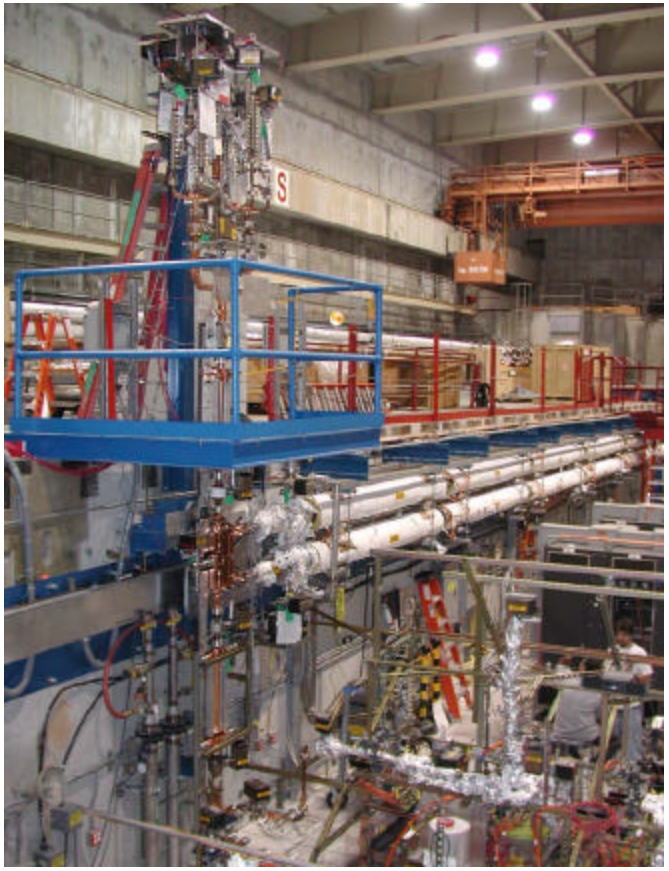
2003



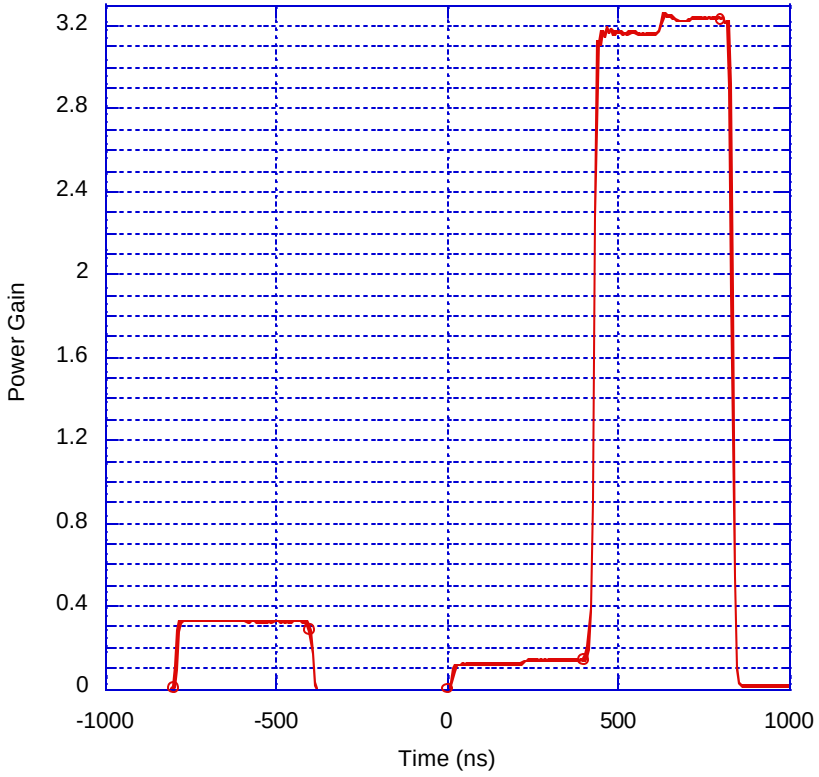
NLCTA Installation September 03

SLED 4 port hybrid





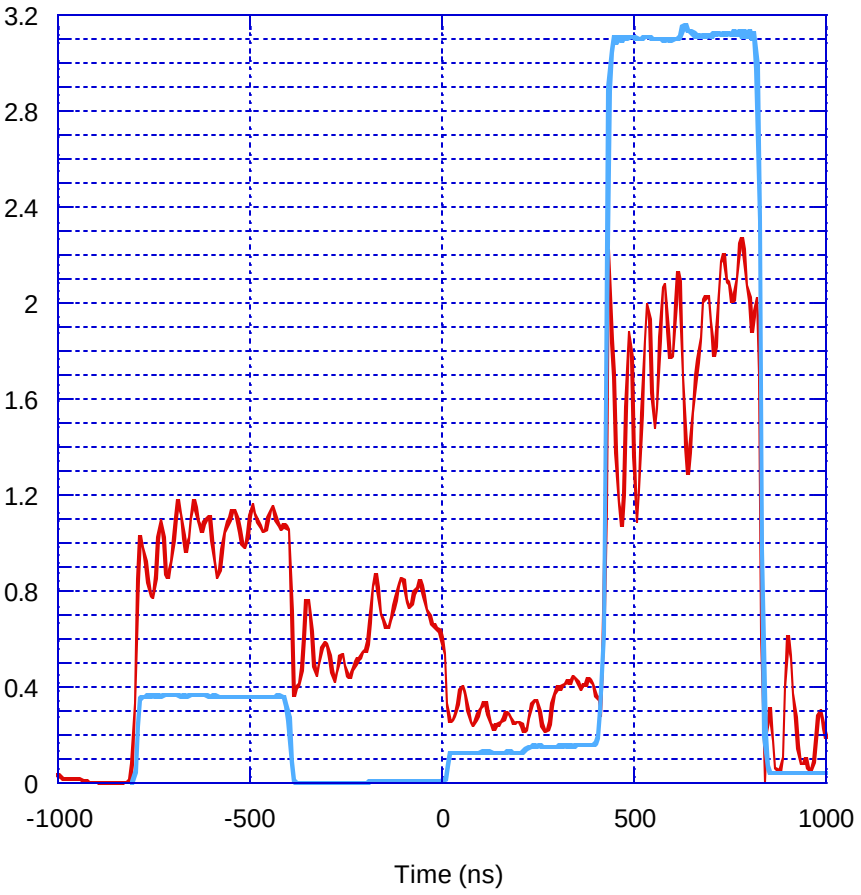
SLED 2 ‘warm’ tests

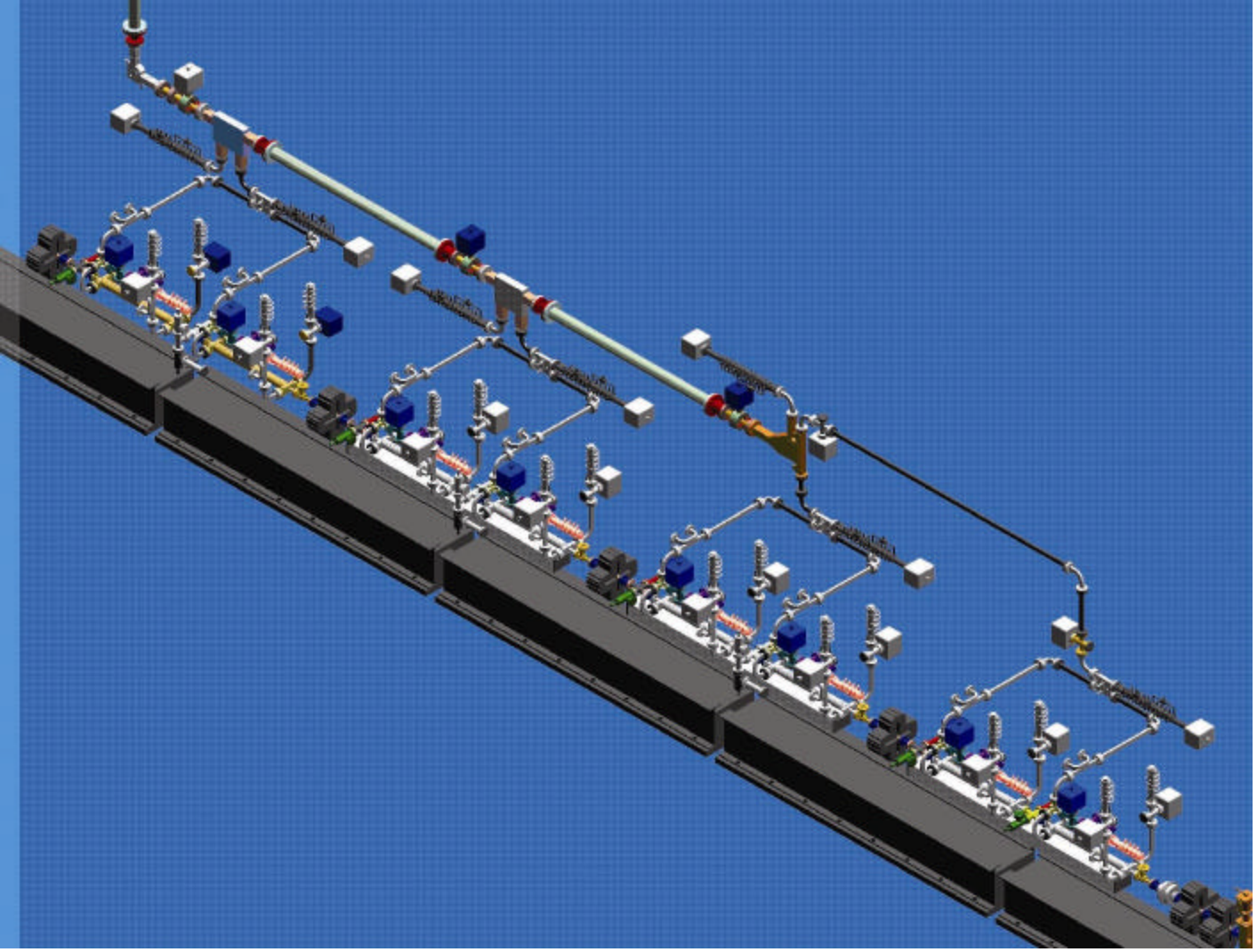


- Gain tests of the dual mode system showing inter-modal contamination and total gain ~3.2 → close to theoretical max

10^3 x Measured Power at the TE11 Arm
Measured Power at the TE01 Arm

Comparison between the signal seen at the TE11 Arm with the signal at the TE01 Arm



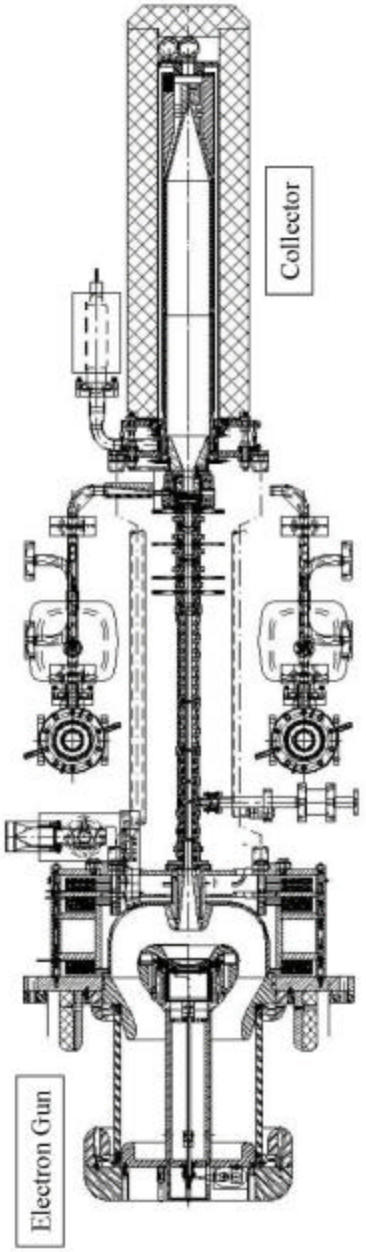


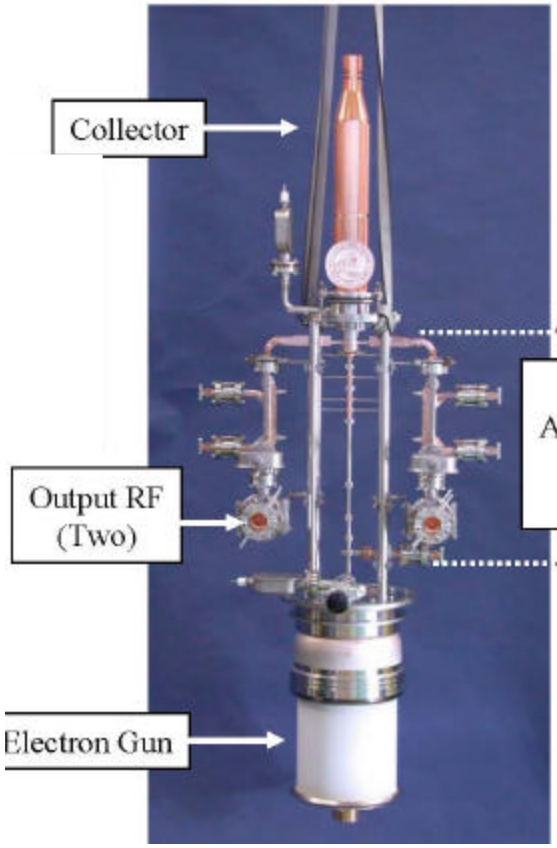
Connect SLED 2 to NLCTA March 2004

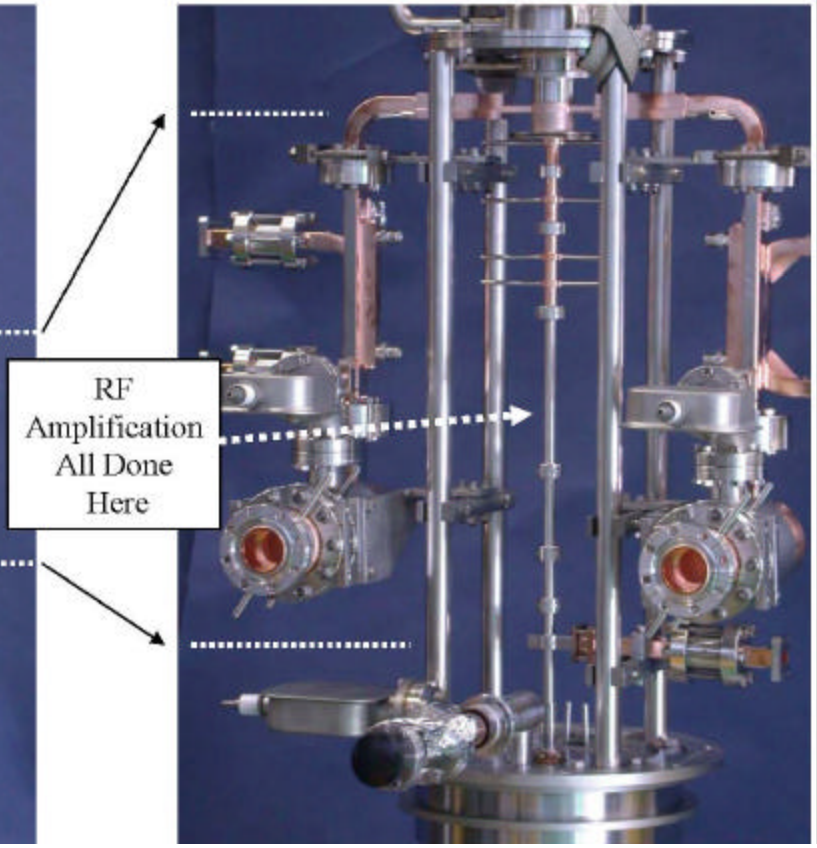
- Connect the output of the new SLED 2 system to the structure testing stations in NLCTA
  - Doubles the number of testing stations
- complete NLC/GLC RF system

- Toshiba/KEK & SLAC
- Permanent magnet focusing
  - efficiency improved 2x without solenoid
- tested successfully summer ‘03

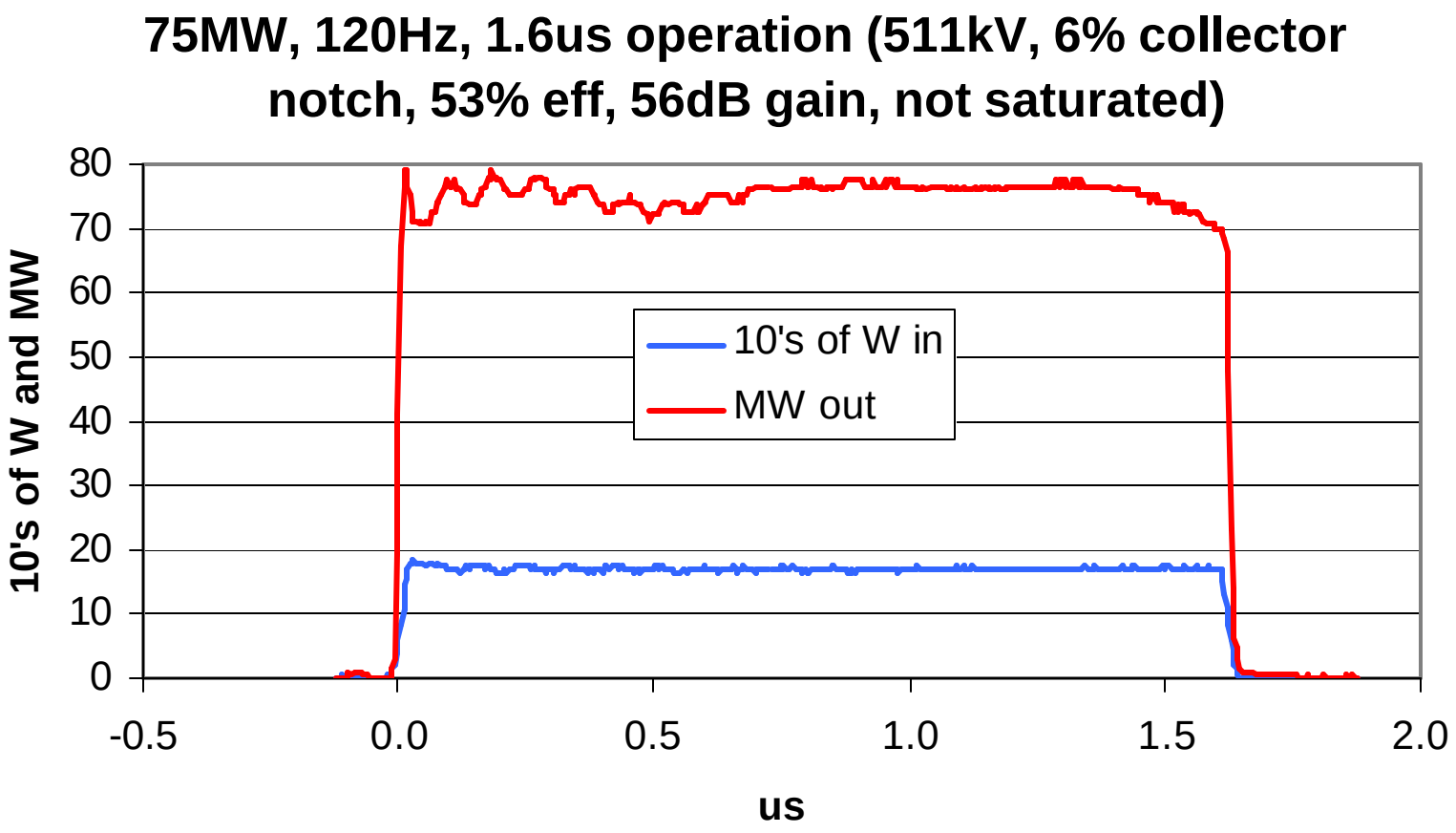
75MW Klystron X band power source





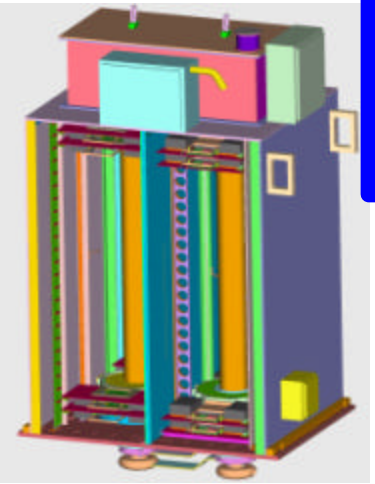


Klystron test

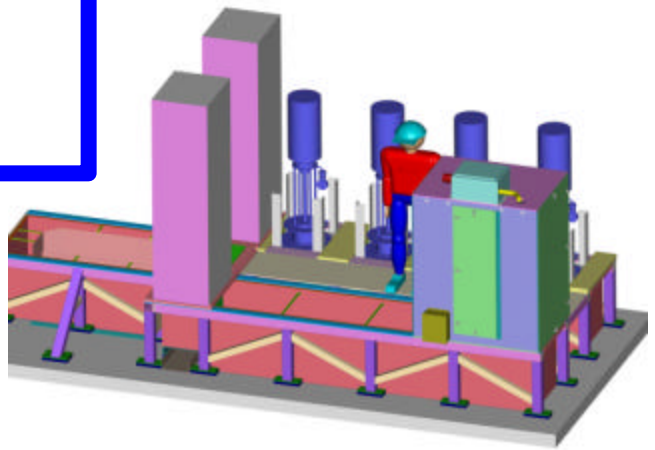


Induction – solid state power converter

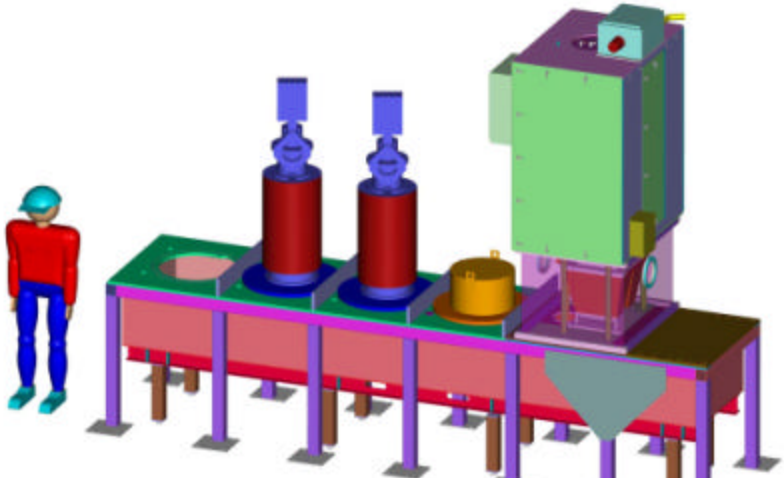
Goal: 500 KV
120Hz
1.6 us



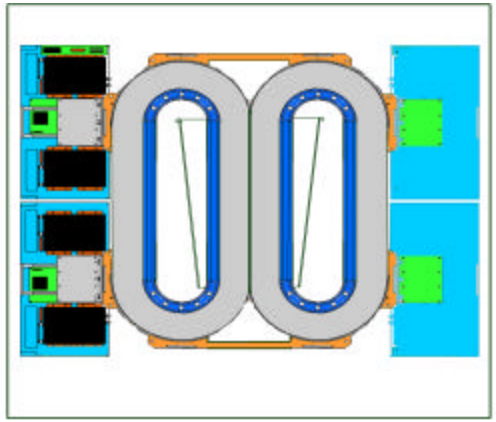
Today: 8/4-Pack in NLCTA



II. Hybrid 2-Pack on 8-Pack NLCTA (3/04)

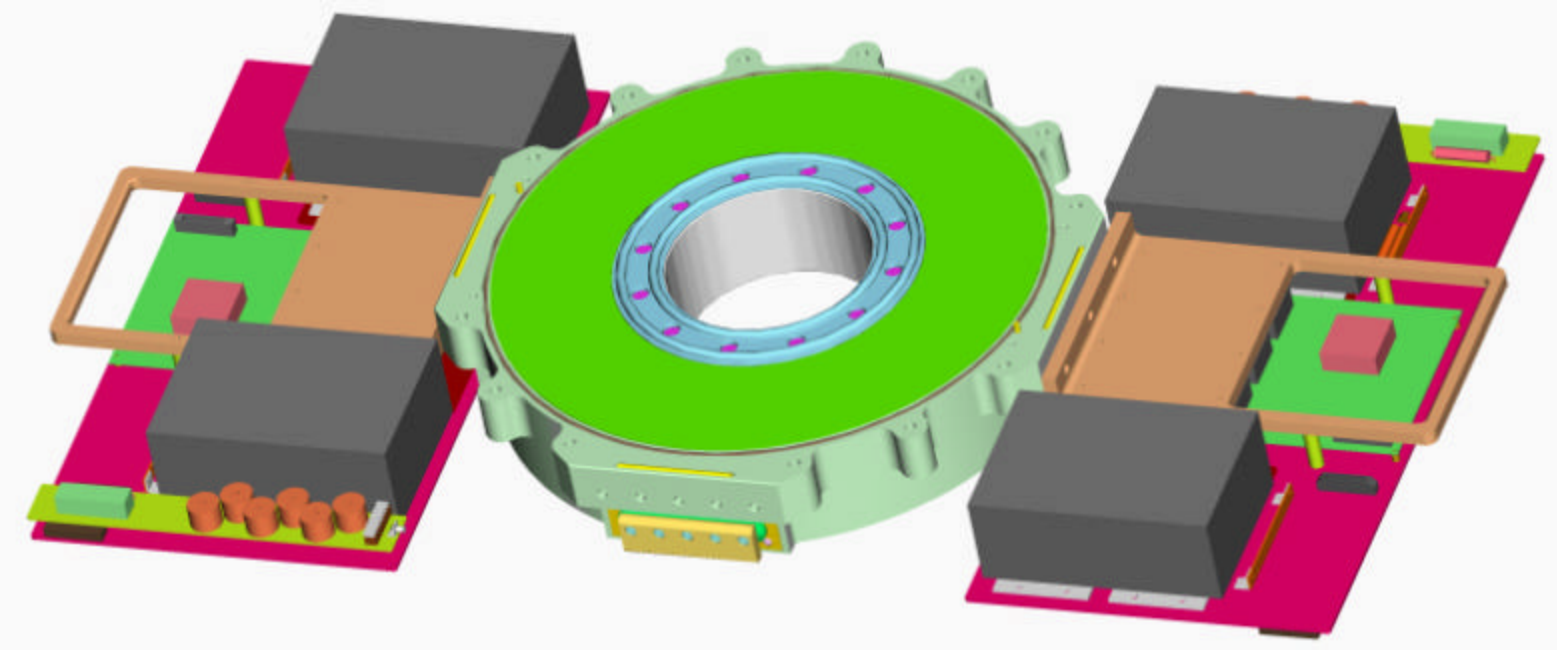


I. Hybrid 2-Pack on 4-Dog Bldg 15 (12/03)

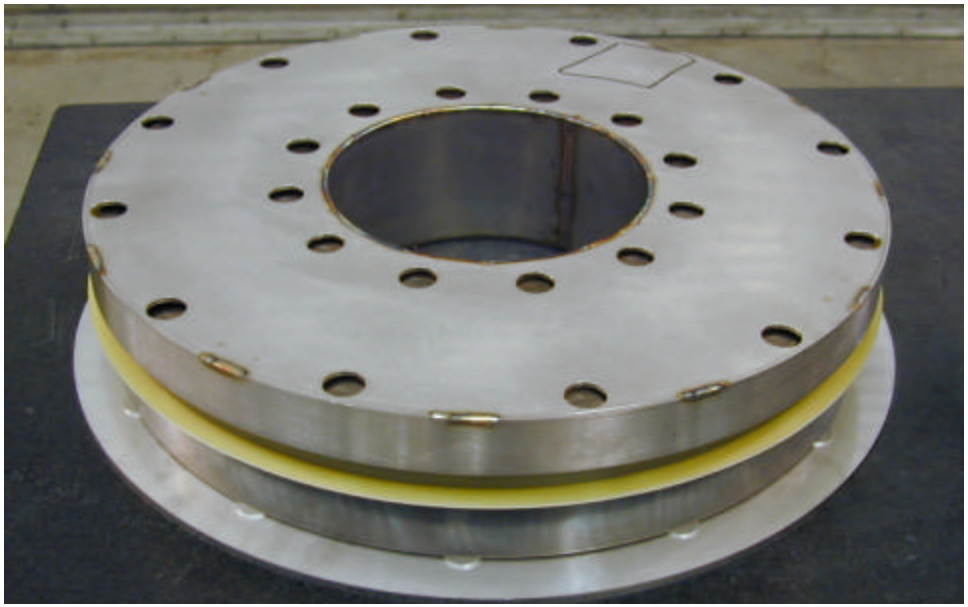


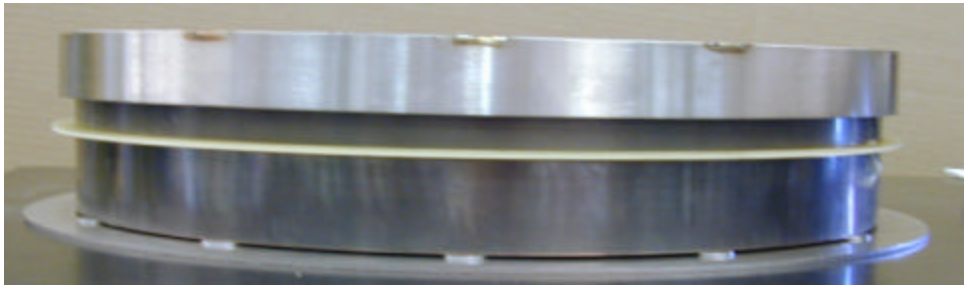
III. 2-Pack Integrated Xfmr Dsgn (9/04)

Metglas Cell w/ Boards



NLC Oil Cooled Metglas Core Assembly





X-band RF summary

- Power converter: *tested at full voltage*,
  - reduced repetition rate
- Source: *2 successful tubes* with ~ 100 hours
- Distribution: *assembly completed; warm test successful*
  - → high power testing began this week
- Structure: ~ *fully slotted structures*
  - → breakdown rates at full unloaded gradient ~ 2 x above goal

USLCSG

- The Accelerator Subcommittee of the US Linear Collider Steering Group (USLCSG) has been charged by the USLCSG Executive Committee with the preparation of options for the *siting* of an international linear collider in the US.
  - This group will (probably) produce a 'bid' to host the linear collider in the US
  - 'options' → → either warm or cold
  - not TESLA nor NLC/JLC but → 'equivalent performance machines'

- The 'Accelerator Subcommittee has produced a written evaluation of cold/warm 0.5 (upgrade to 1) TeV cm with:
  - cost - availability
  - risk - site studies
  - ....

publication 12.2003?

Cost comparison

- Using DoE standard costing and overhead rules
- Using component costs developed for previous NLC & TDR exercises

Comments:

- US DoE rules (add-ons – mostly direct & not proportional) tend to wash out warm/cold differences in total project cost
- Base cost difference reflects larger cold machine ring and linac

Risk defined: *the chance that one fails to meet basic Luminosity or Energy goals*

Identify those failure modes that are most germane to the technology choice.

- risks common to both choices downplayed

Distinction between *availability/reliability* and *risk*:

- *Availability*: design parameter, amenable to direct engineering approach
  - Things *will* break
- *Risk*: chance one fails to meet basic goal:
  - fundamental failure of theory/RD/design process
  - basic goal: 500 fb-1 at 500 GeV within 5 years
  - A familiar example of a risk:

    1) failure to meet availability goal...

Risk analysis

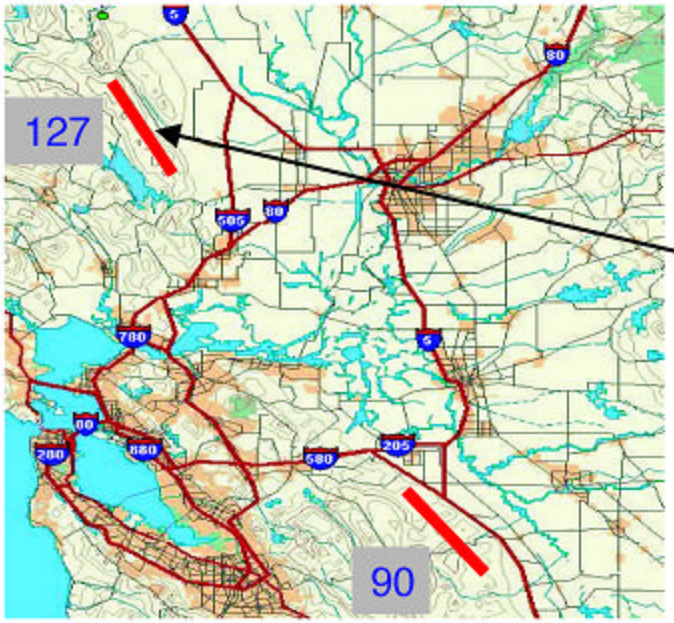
- follows textbook '*scoring & ranking*' process with points related to:
  1. comprehension of problem
  2. stretch from present technology & level of engineering required
  3. impact on machine performance
  4. project stage at which failure is detected
  5. likely mitigation process

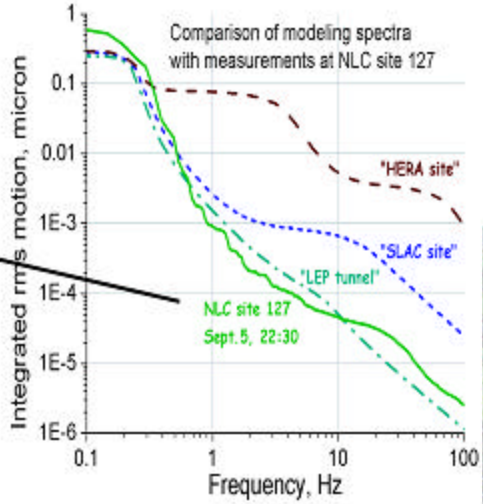
- discovered:
  - large fraction of risks are common to both warm / cold
    - *control system and machine protection issues are very serious*
  - beam delivery issues also serious
    - (detection is late in project)

HEP must aggressively attack *Controls/Instrumentation* issues

- System challenges are clearly greater for HEP machines
- Look at the shift SLAC.DESY.KEK accelerator groups away from HEP toward nuclear/synchrotron radiation/FEL physics and technology
  - very active growth field
- Many accelerator designers have *no intrinsic connection* with HEP

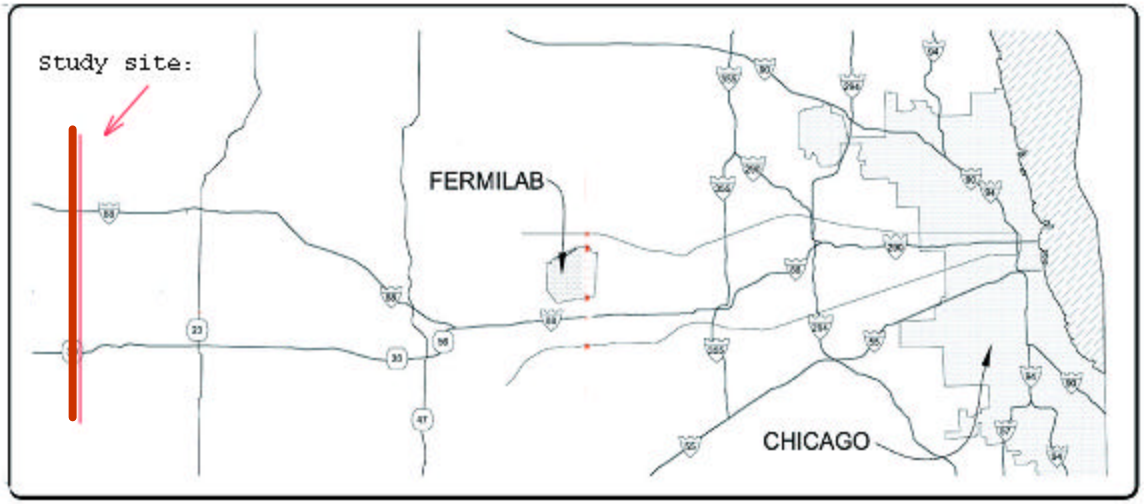
U.S. Linear Collider Site Studies





California

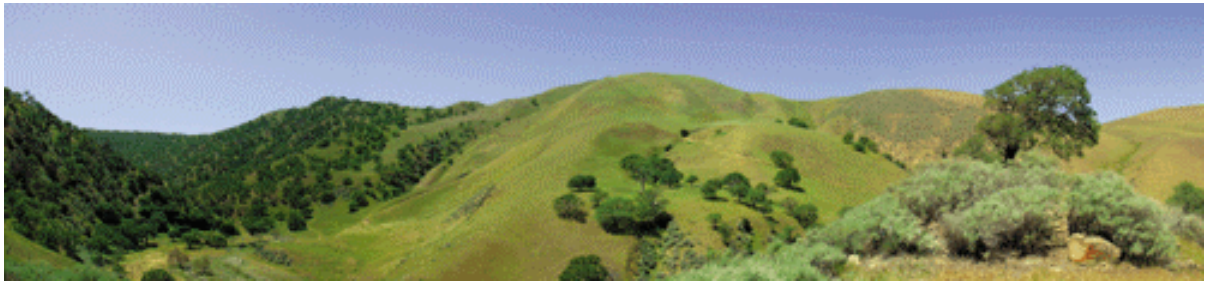
Illinois



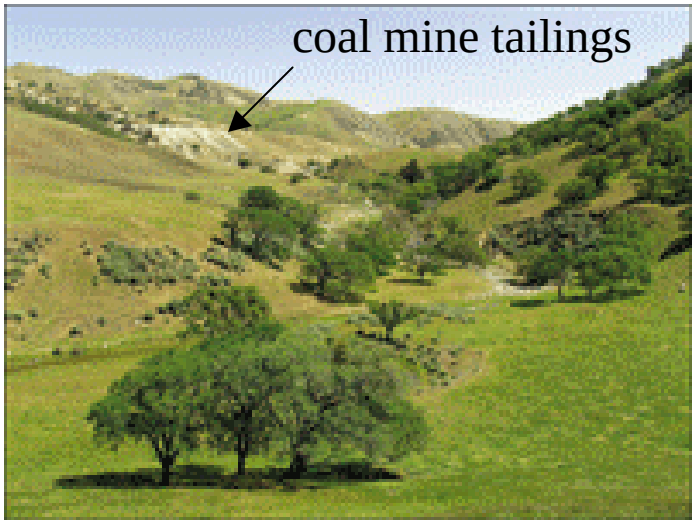
Sample sites studied in Illinois and California
Development of site criteria...

USLCSG Site study *'90'*

Central Valley near Livermore Nat'l Lab



→ very near 19th century coal mining town of TESLA, CA (1850-1920)



(2001)

(1898)

Precision beam monitor RD

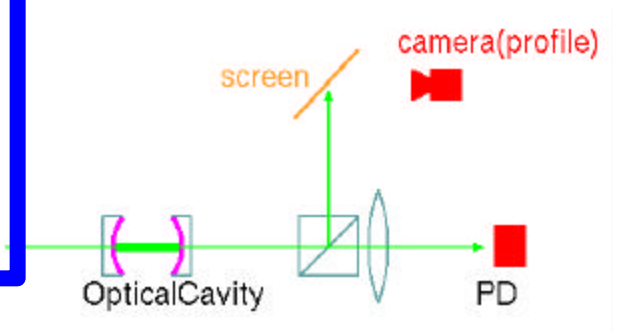
- *primarily based at KEK ATF*

- Laser-based beam size monitors → *'laserwire'*
  - UK/KEK/SLAC/DESY
- precision RF beam position monitors → *'nanoBPM'*
  - SLAC/KEK
- fast intra-train feedback → *'FONT'*
  - UK/SLAC/KEK
- bunch length diagnostics → *'LOLA'* at TTF2/VUV FEL
  - DESY/SLAC

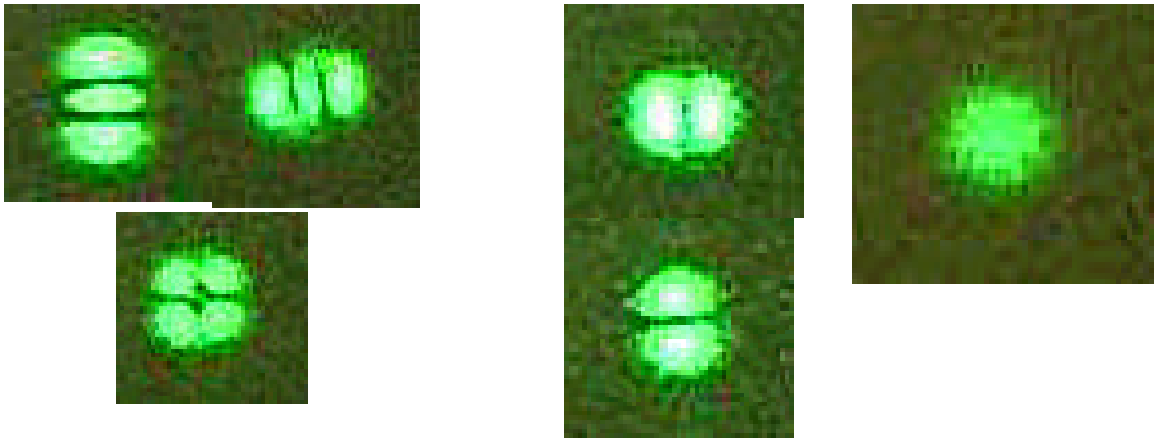
Higher mode resonances

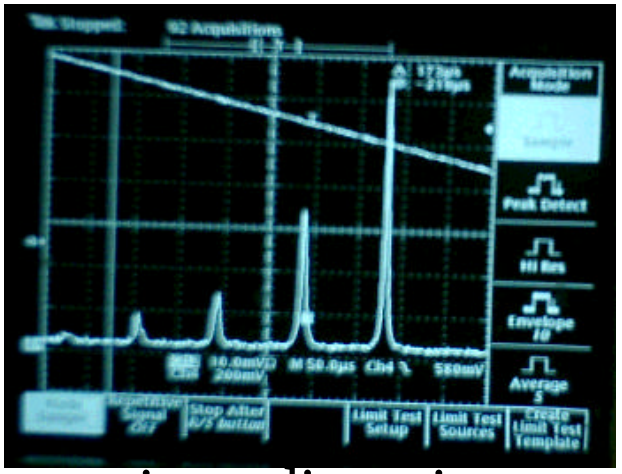
misaligned laser injection

Laser-wire at ATF



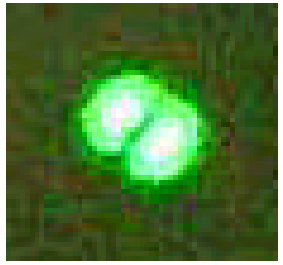
higher order mode resonate in the cavity





mirror distortion ?

transmitted light profiles of each mode

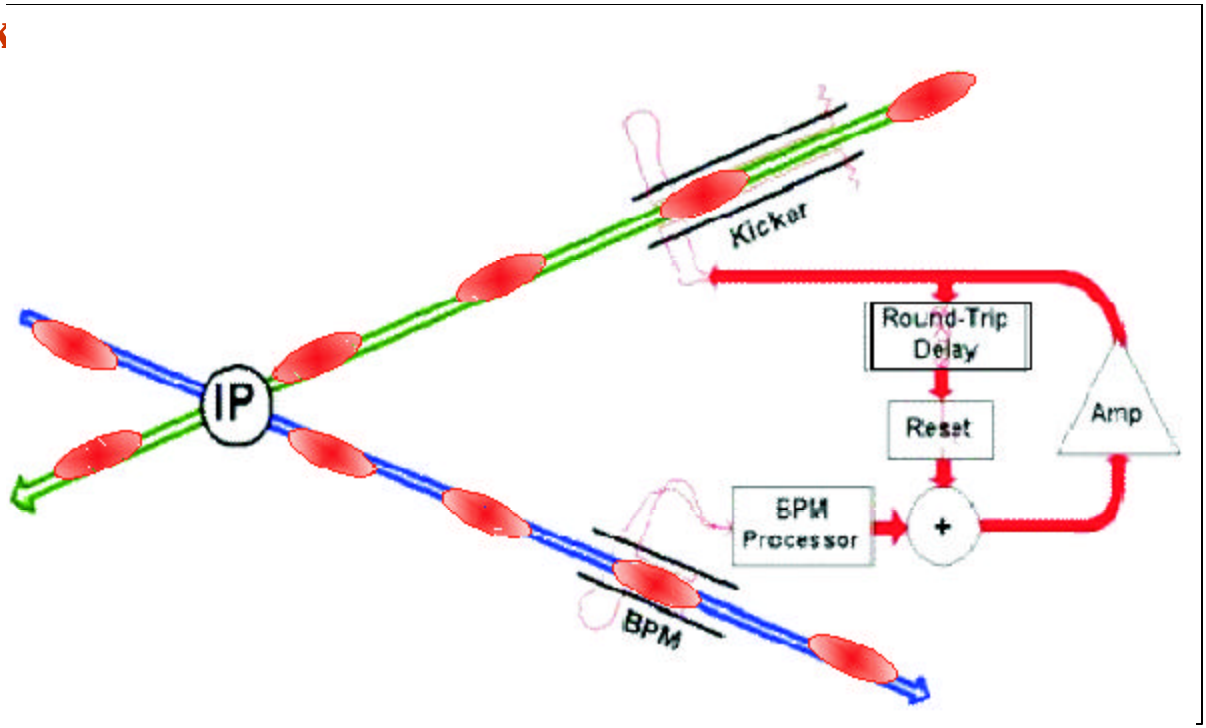


mode degeneration TEM01/10

mirror distortion to split these modes

Beam-based Feedback (FONT)

- **Intra-train beam feedback is last line of defence against ground motion**



- **Key components:**
- **Beam position monitor (BPM)**
- **Signal processor**
- **Fast driver amplifier**
- **E.M. kicker**
- **Fast FB circuit**

Nano-meter BPM studies at ATF

- achieved position resolution (June 2003) y → 40 nm
- trajectory angle resolution (June 2003) y' → 10 urad
- achieved in FFTB (1997) → 25 nm

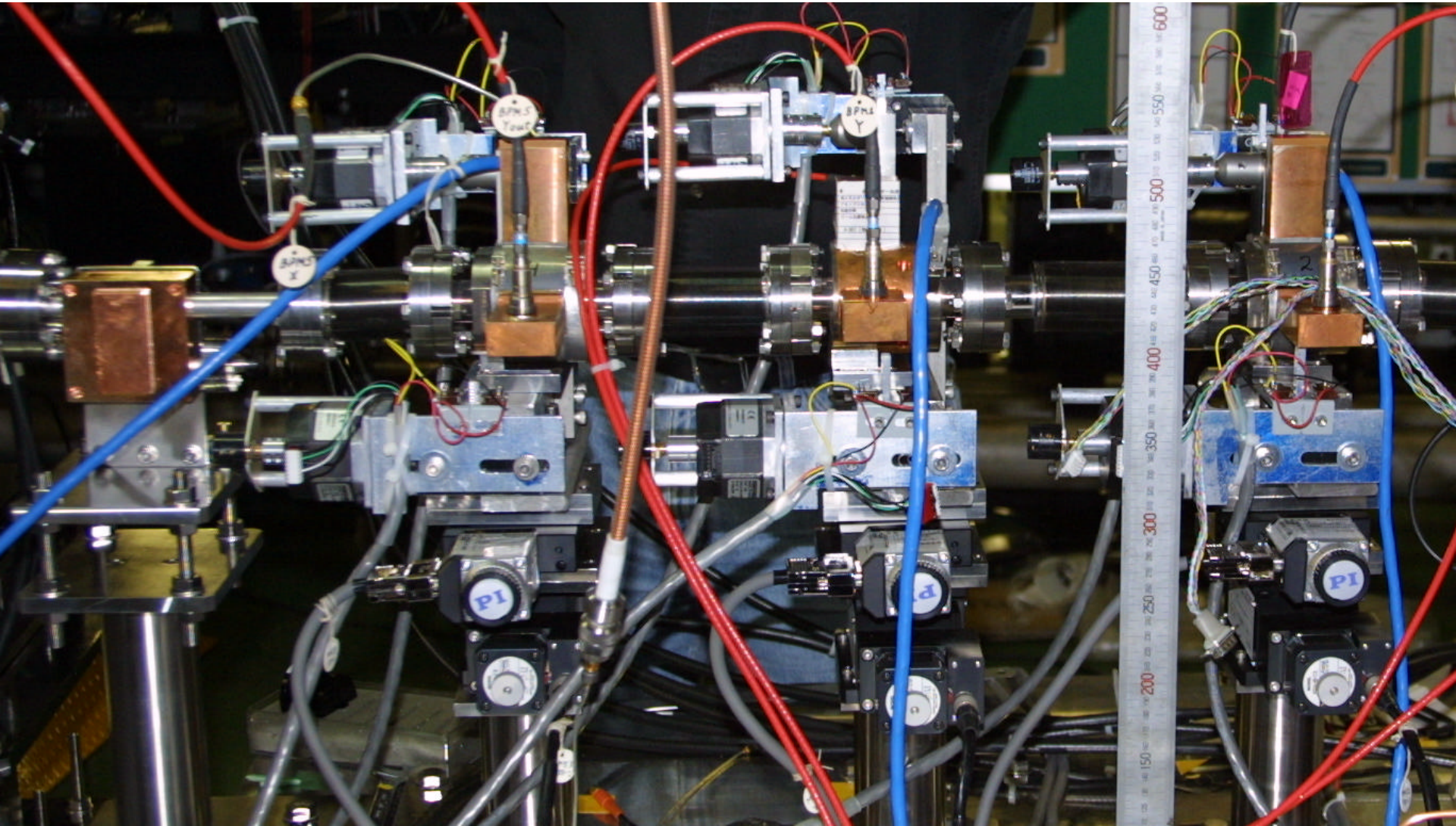
- expect S/N=2 for 1 nm offset (2004)!

- Goal resolution: (March 2004) y → 2 nm
- Goal angle resolution – single BPM y' → 500 nrad
  - (angle resolution from three BPM line) y' → 2 nrad

- Goal position prediction error (2m baseline) y2 → 5 nm
- Goal position prediction error (5m baseline) y2 → 13 nm

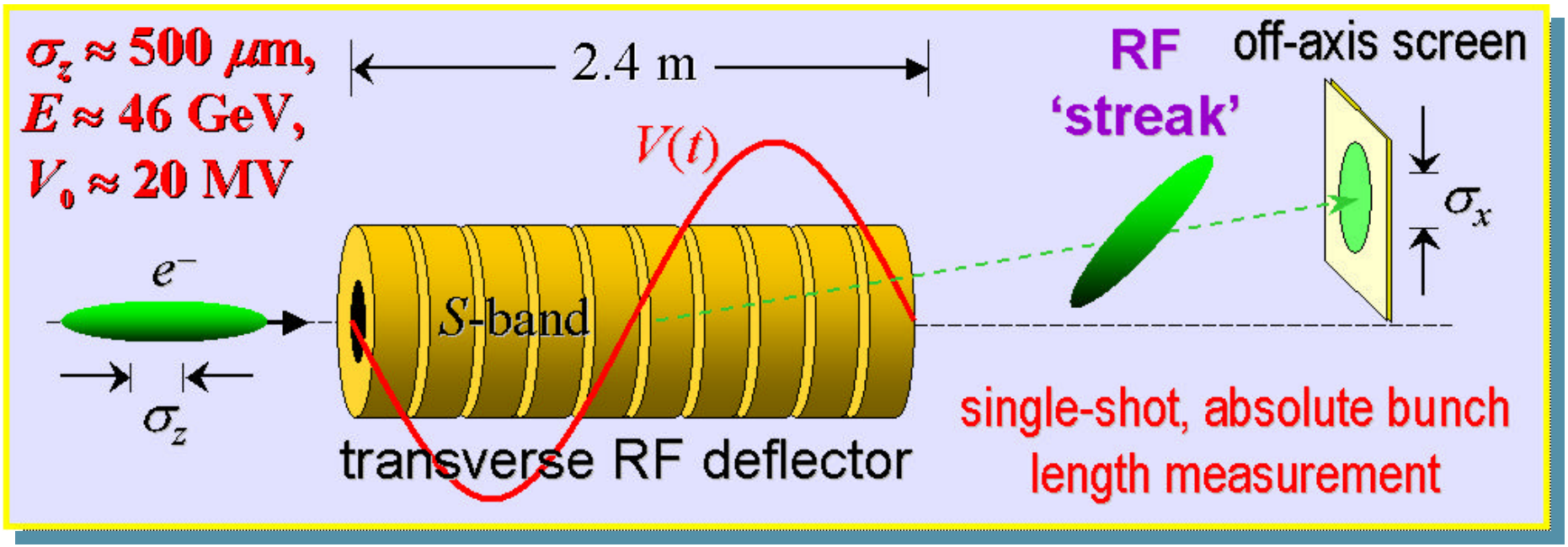
Closeup of BINP cavity BPM's with SLAC/KEK *x x' y y'* movers – 03/03

Resolution tests rely on data from 'triplets' of BPM's – *beam trajectory assumed straight*



Bunch Length - Transverse deflection

Old idea – 1965 'LOLA IV'
Testing in linac sector 29



Brute force
Calibrated
Expensive
Excellent resolution

SLAC LCLS – Krejcik/Emma (EPAC 02)
SLAC/DESY TTF2

Comment:

- Stong, proven, international collaboration (esp. high energy physicists) is an extremely valuable (*political and practical*) asset
  - *urgent*: work to strengthen accelerator development collaboration across the spectrum of RD effort in parallel with the development of design team

Conclusions

Next 6 months are pivotal for the X band technology demonstration

- present status encouraging
- collaboration KEK-SLAC-Fermilab has good vitality

US DoE Statement

- US DoE Office of Science presented its 20 year plan Monday 10.11.2003
- *The linear collider is the top ranked 'mid-term' project*
  - Secretary Abraham's comments are very encouraging

- It is more important than ever that we make the technology choice and get working on one machine