JPD/lmg

PS/DR Note 2002-080 (Min.)
12.05.2002

Summary Notes of the 5th NLC-MAC Meeting (SLAC: 9th – 11th May 2002)

1. Introduction

Meetings of the NLC Machine Advisory Committee (NLC-MAC) with S. Osaki/BNL as chairman, have been regularly held every six months from May 2000 and alternating between SLAC and FNAL. I participated in all except for the last one because of the LHC financial crisis and reported them in PS/DR Notes 2000-20, 2000-45 and 2001-26. This note summarises the main highlights of the fifth meeting held at FNAL from 9th to 11th May 2002. It was attended by D. Sutter as DOE observer(!).

The main highlights of the meeting are:

- The BNL laboratory will join the US collaboration on Linear Colliders, presently constituted by FNAL, LBL, LLNL and SLAC.

- The launching with top priority of a common SLAC/FNAL project, the so-called 8-Pack, constituted by the construction of one standard cell of RF power source powering two girders with 6 accelerating structures, each for the validation of the NLC power source and operating from Summer 2004. This is a challenging project with a very aggressive schedule, considering the status of the various components. This date is politically important as it corresponds to when the choice of a preferred technology for a sub-TeV Linear Collider is anticipated to be made.

- The status of the behaviour of the structures under high accelerating gradient:
  Thanks to an aggressive R&D effort, 70 MV/m unloaded gradient without damage and an acceptable rate of breakdowns, corresponding to the NLC specification, have been demonstrated in 50 cm long structures with 3% group velocity during 5000 hours operation in NLCTA. Their performance is limited by pulse heating in the couplers. Their wakefields are still too high and the damping for multibunches operation has not yet been introduced.

- A test of the Undulator Based Positron generation "à la TESLA" including polarization is envisaged in the FFTB using the SLC beam at 50 GeV in a large collaboration. A detailed proposal will be made at the next MAC meeting in October.

- The FNAL expertise on Linear Collider is slowly building-up but is limited by the available resources in budget (3 M$) and in manpower due to the other programmes with a higher priority, especially the Tevatron. Following recommendations from the previous MAC meeting as well as from a recent DOE review worrying about the TEVATRON's (lack of) progress, the work plan and resources (budget and manpower) of FNAL have recently been refocused by cutting down the budget of the R&D on Neutrino Factory, Muon Colliders and the low field magnet developments.

- The overall NLC progress is limited by the available budget allocated to the NLC collaboration which is presently 19.3 M$ for the Fiscal Year 2002 (from which about 16 M$ for SLAC and 3 M$ for FNAL) and which will be similar in FY 2003, although an increase (30 M$?) is expected in 2004. Additional resources may possibly be provided by interesting Universities in small projects with proper or possibly DOE/NSF funds (Small Business Initiative).

- The estimation with US standards for the cost of a 500 GeV linear Collider based on TESLA technology would rise to 6.13 G$, thus 23% more than a similar Linear Collider based on NLC technology and estimated at 5.0G$ when including 15% inflation and 20% contingency. This is the result of a TESLA Engineering Study & Review which was presented to the FNAL Accelerator Advisory Committee held the following week. Although it was not presented to the NLC-MAC, it is nevertheless included for completeness in this report.

2. RF Power Source and "8-Pack" Project Demonstration

The nominal RF power source layout is presented in Fig. 1. It is based on 8 × 75 MW klystrons powered by a single induction modulator with 3.2 μs long pulses and feeding 4 DLDS lines with 510 MWatts of RF power in two modes, each one powering six accelerating structures 90 cm long. It is foreseen to be demonstrated in two phases:

- The so-called 8-Pack phase I (Fig. 2), based on 2 × 75 MW klystrons from which the 2.4 μs long pulse is compressed by a factor 4 with a novel idea of dual Mode SLEDII compressor and providing 600 MWatts RF pulses during 400 ns for tests of components. The facility is supposed to be built before the end of the year for operation and tests in 2003.

- The so-called 8-Pack phase II (Fig. 3) which corresponds to one full cell of the standard NLC RF power source with nominal components and powering two girders with 6 accelerating structures each via a 117 m long DLDS. It is supposed to be built in 2003 for operation and tests from Summer 2004.

The overall schedule is summarized in Fig. 4.

3. Status of the Main RF Components

An induction modulator powering 4 × 50 MW klystrons has been built but was damaged due to arcing in one klystron. The cause has been identified and the modulator correspondingly protected. An 8-Pack modulator is being built (Fig. 5).

A klystron with full performance has not yet been demonstrated. The status of the various prototypes is summarized in Fig. 6. The last XP3 prototype failed due to gun oscillations (reason not fully identified). A Task Force under the responsibility of G. Caryotakis, and focusing on the fabrication of a new XP4 klystron, has been launched to deliver a klystron before the end of the year. G. Caryotakis does not seem to believe in this programme considering that the required performance (power increased from 50 to 75 MW and pulse length increased from 1.6 to 3.2 μs in order to reduce the overall NLC cost) are now too difficult. He is working on the design of a Sheet-Beam klystron funded in parallel by the DOE!

Many DLDS components with transformation of modes (Fig. 7), including a fast phase switch (Fig. 8) have been built and tested with low power. They are very close to specification. They are foreseen to be tested with power within the frame of the 8-Pack phase 1. They open a new world in RF technology with an impressive potential.

The over-mode pulse compression with SLEDII is especially attractive at high frequency because losses are reduced. It could be a possible candidate for CTF3 RF pulse compression (possibly by a factor 5) of the RF generated by the Drive Beam Linac. S. Tantawi would be prepared to help!

4. RF Breakdowns and Damages in the Accelerating Structures

The structures are tested in NLCTA where RF pulses of about 200 MW during 400 nsec are available (Fig. 9). For comparison with a reference, they are always tested in pairs.

An operation history of the RF conditioning of various structures clearly indicates increasing field performances (Fig. 10) and smaller damages (Fig. 11) with reduced group velocity. This is consistent with the breakdown model developed at SLAC and based on an analysis of the power available for breakdown.

In parallel, a systematic pre-processing procedure, (based on Wet Hydrogen Firing followed by vacuum bake-out then post bake-out particle free handling and in situ bake-out), (Fig. 12) has been established to prepare the structures.

Acceptable rates of 1 breakdown per 10 hours have been demonstrated (Fig. 13) at the nominal accelerating field of 70 MV/m (unloaded).

The performance is limited by the input coupler due to pulse heating at sharp corners (Fig. 14). A new coupler is under fabrication with rounded corners. A mode converter type input coupler is also envisaged (Fig 15).

Standing wave structures also demonstrate acceptable performances (Fig. 16) limited only by the coupler. New couplers are under fabrication.

Tests of structures with high phase advance (150 degrees) to limit the single bunch wakefields and with Damping/Detuning to reduce the long range wakefields for multi-bunch application are foreseen early next year. If successful, 12 of them will be built for tests with the 8-Pack power source in 2004.

5. TESLA Engineering Study & Review

A TESLA engineering study by H. Edwards and H. Garbincius (Fig. 17) has been requested by the FNAL management in November 2001 in order to:

- understand the TESLA cost estimate as done in DESY;
- understand the overall project scope integration & schedule;
- review the cost and procedures in case TESLA would be built in FNAL using US standards;
- identify alternative options for the construction and R&D of interest because of US specific and industry context.

The TESLA project has been revisited and adapted for a possible construction in the US concentrating on the most costly items (Fig 18).

Assuming first a construction in Europe, the TESLA cost estimate has been reviewed "à la US" (Fig. 19) by including the manpower cost 6933FTE × 51K€/y), the Administrative overheads (25% of DESY operating budget), a 15% inflation till the end of construction and 20 % contingency. It rises from 3.14 GEuros as estimated by DESY to 5.2 GEuros (4.7 G$). The European TESLA cost has then been compared to the cost of TESLA, if built in the US, where the industrial US manpower is estimated to be 27% more expensive then in Europe and the US personnel cost 44% more expensive in FNAL than in DESY, correcting for the inflation and adding 20% contingency. The costs rise to 6.13 G$, thus 30% more than if built in Europe(!) and 23% more than the NLC cost estimate of 5.0 G$.

The report then concludes by recommending a US TESLA collaboration independently of where it will be built (Fig. 20).

6. Conclusion

Impressive progress (except on Klystrons) has been done on the NLC during the last year. Nevertheless, an important programme of R&D is still necessary to develop the NLC technology. The progress is limited by the resources made available by the DOE to the NLC collaboration (19.3 M$ in FY 2002 and 2003). Within these limited resources, the first priority has been correctly put on the building of one cell of the RF power source for operation in 2004.

This schedule does not include any contingency, neither in time nor in resources, and it is considered unrealistic given the status of the various components (especially the klystrons and the accelerating structures). A more realistic schedule is certainly 2005 or 2006, possibly too late for a reasonable technology evaluation and comparison with TESLA when the first high gradient cryo-module compatible with a 800 GeV energy is foreseen to operate in TTF2 from 2004.

Distribution:

CLIC Steering Committee
PS Management Board
C. Detraz
P. Lebrun
L. Maiani
S. Myers

Fig 1

NLC 1 TeV Main Linac RF System
(Snowmass Baseline)

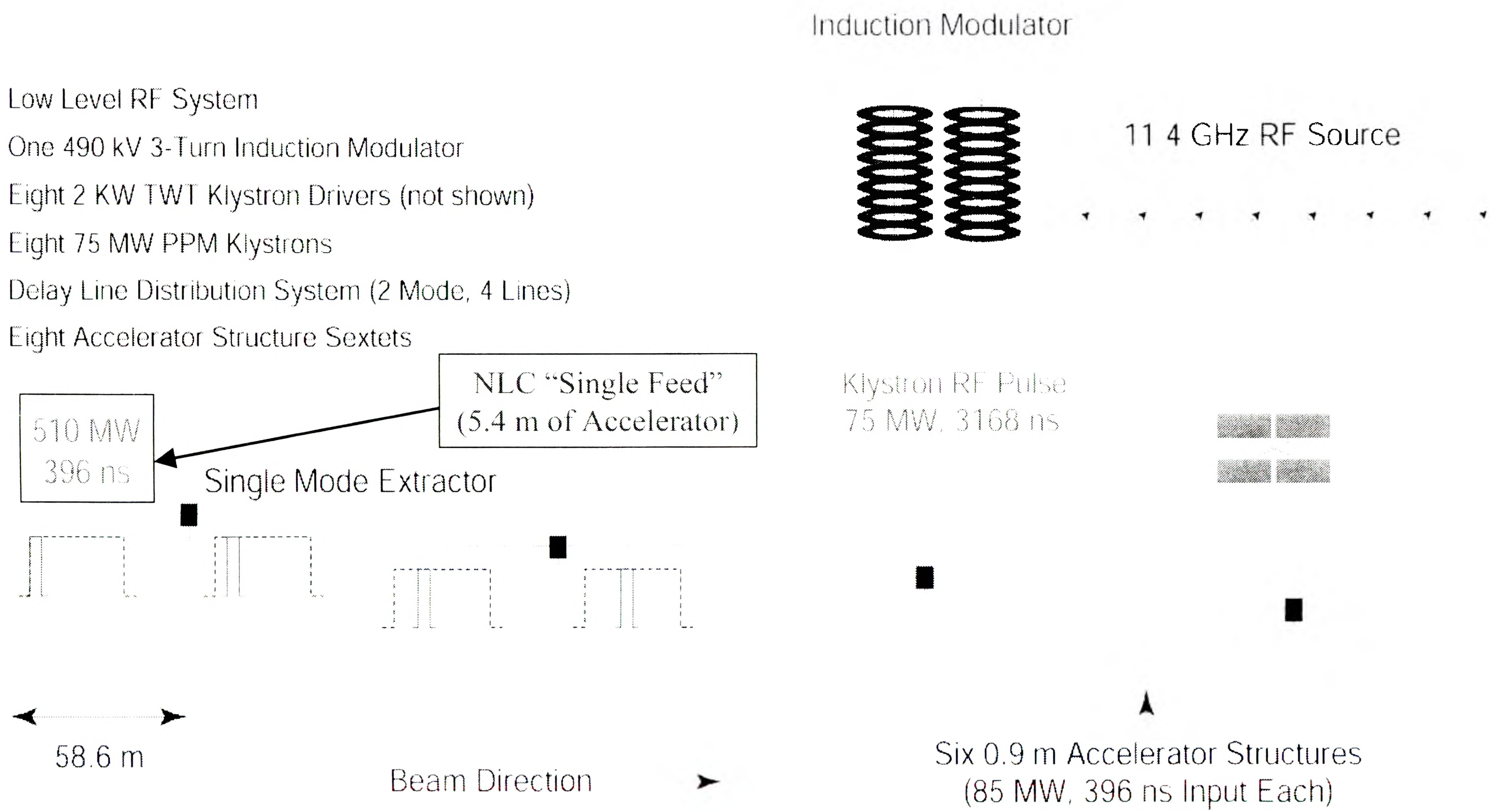


Fig. 2

Full power dual-moded SLED-II system

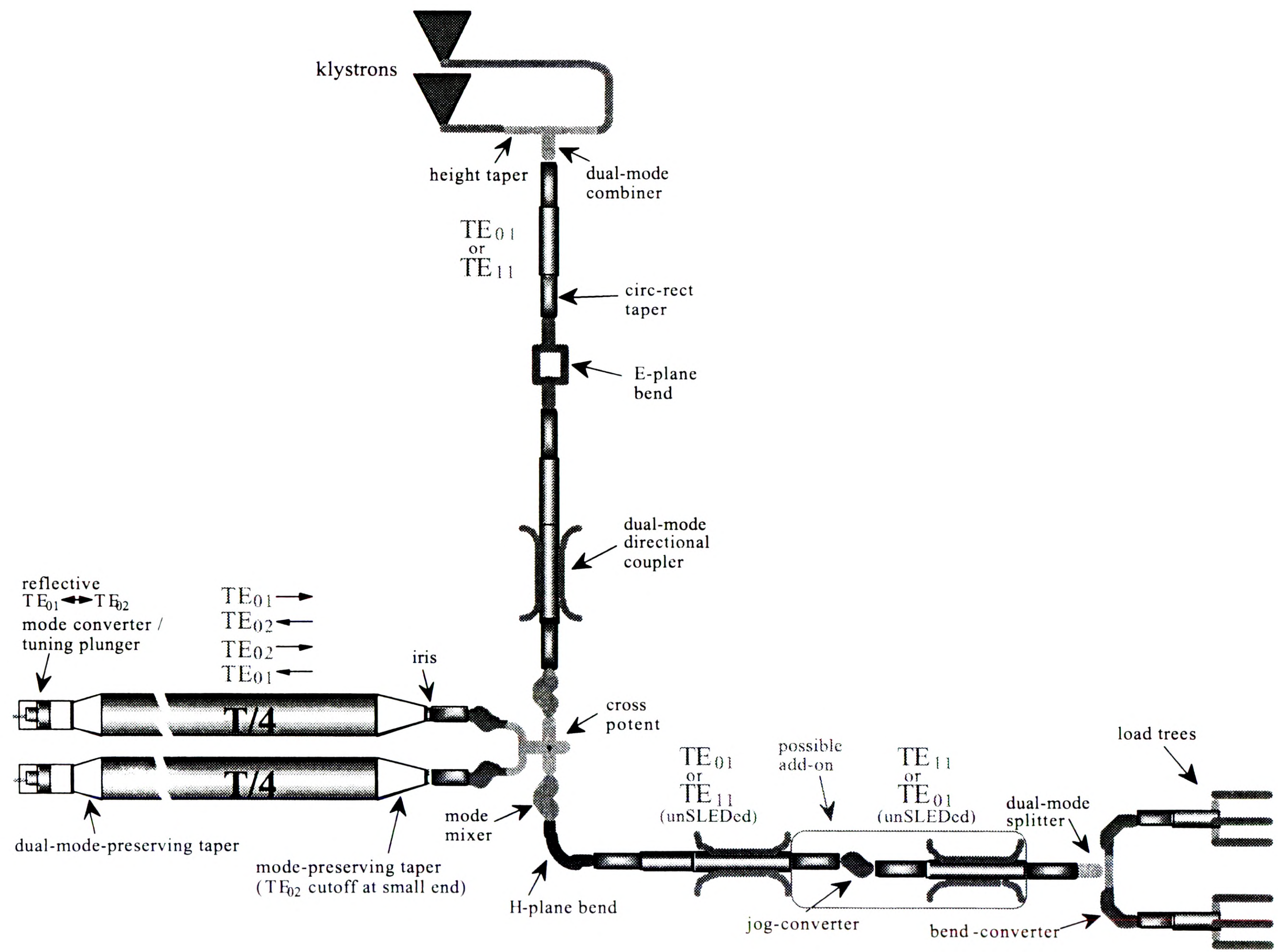
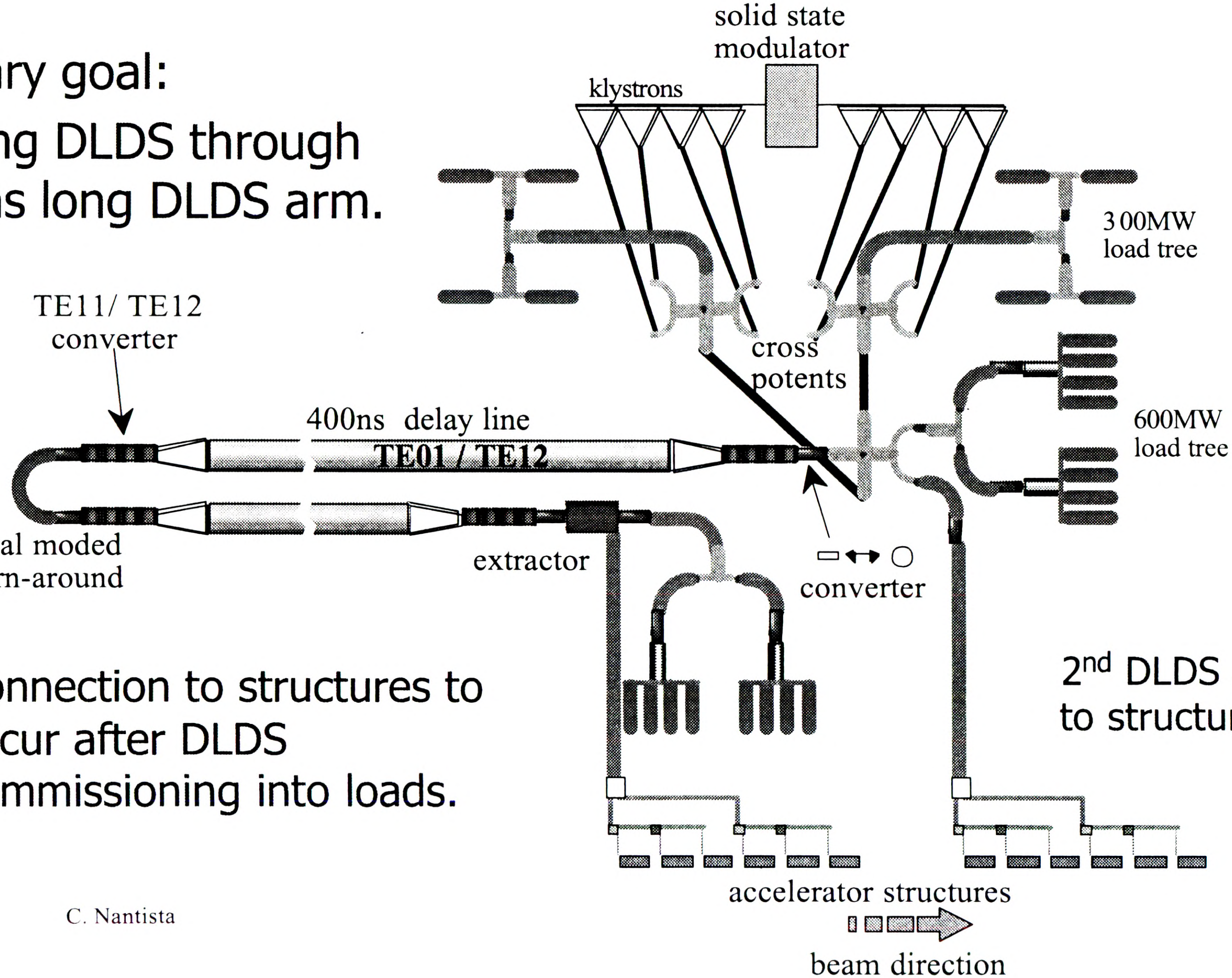


Fig 3

8-Pack DLDS Layout

Primary goal:

Testing DLDS through 400 ns long DLDS arm.



Connection to structures to occur after DLDS commissioning into loads.

2nd DLDS arm connected to structures as available

C. Nantista

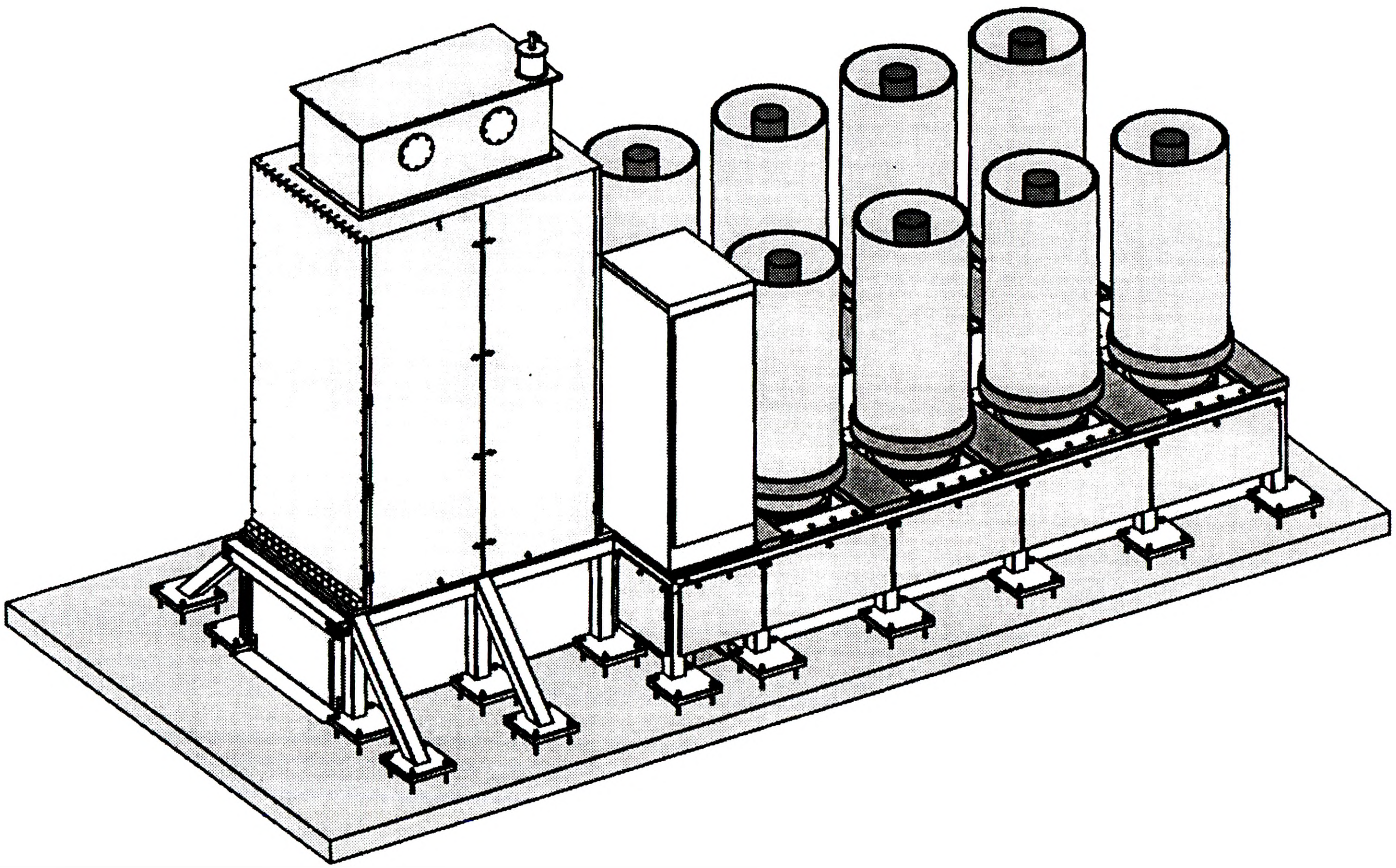
fig 4

High Gradient 8-Pack

Calendar	2002	2003	2004
Structures			
	"H" Test Series ….		
		Produce 5.4 m of "H" Structures	
		"HDDS" Test Series	
		Produce 5.4 m of "HDDS" Structures	
8-Pack Phase-I	Civil and Infrastructure		
	Commission 4-Dog Modulator		
	Produce 2 Klystrons …….		
		SLED-II and DLDS Component Tests	
Phase-II			
	Construct 8-Pack Modulator		
		Produce 8 Klystrons …………..	
		Produce DLDS Long Arm …………	
			Full System Tests
		……. Produce DLDS Short-Arm	

Fig. 5

NLC Solid State Induction Modulator
8-Pack DFM Tests at NLCTA



Bechtel Nevada

J. de Lamare
05/09/02

Permanent Magnet Klystron (NLC Prototype)

- Needed Performance:
  - Permanent Magnet | 75 MW | 3.2μs | 120 Hz
- Demonstrated Performance:
  - Solenoid Magnet | 75 MW | 1.5μs | 120 Hz
  - Solenoid Magnet | 55 MW | 2.4 μs | 60 Hz
  - Prototype Perm. Mag. | 50 MW | 2.4 μs | 120 Hz
  - Permanent Magnet #1 | 79 MW | 2.8 μs | N/A
  - Permanent Magnet #2 | No RF | 3-3.2 μs | 120 Hz
  - Permanent Magnet #2* | 50 MW | 1.5 μs | 120 Hz
  - Permanent Magnet #2* | 70 MW | .3 μs | 60 Hz

  (*Repeatable Numbers. Higher Performance Compromised by Driven Oscillation at 11.7 GHz)
- Key Challenges for This Class of Klystrons
  - High Average Power – 28.5 kW at 11.424 GHz (> State-of-the-Art)
  - Permanent Magnet Focussing – Much More Difficult Than Solenoid
  - Oscillations, Breakdowns, Spurious Modes, Multipactoring, Windows

October layout for SLED commissioning

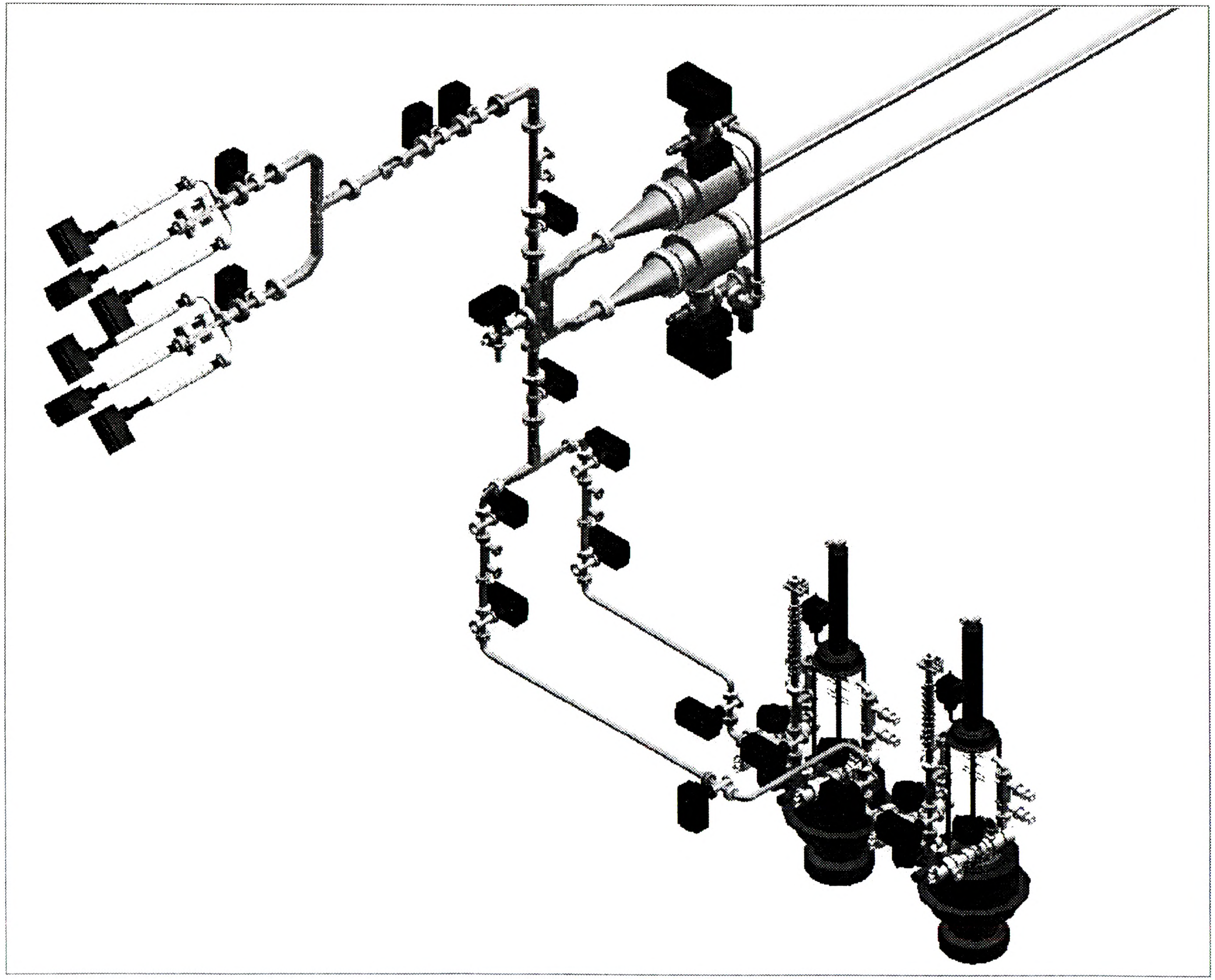
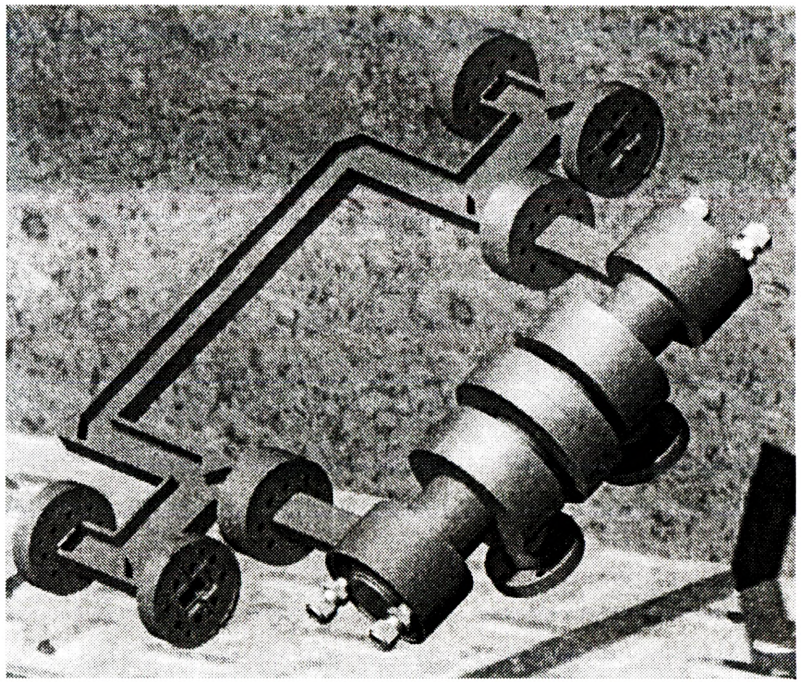
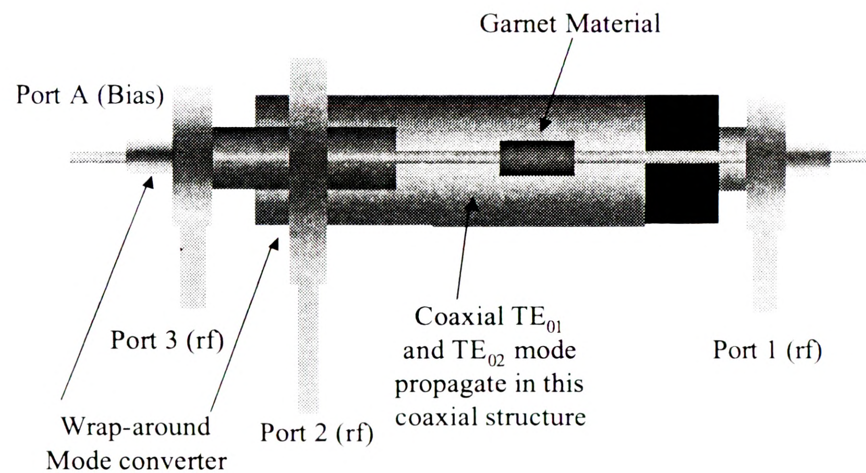


Fig. 8



Rendering of circulator composed of two “H” hybrids and nonreciprocal phase shift section. Cover of the hybrid section is removed.

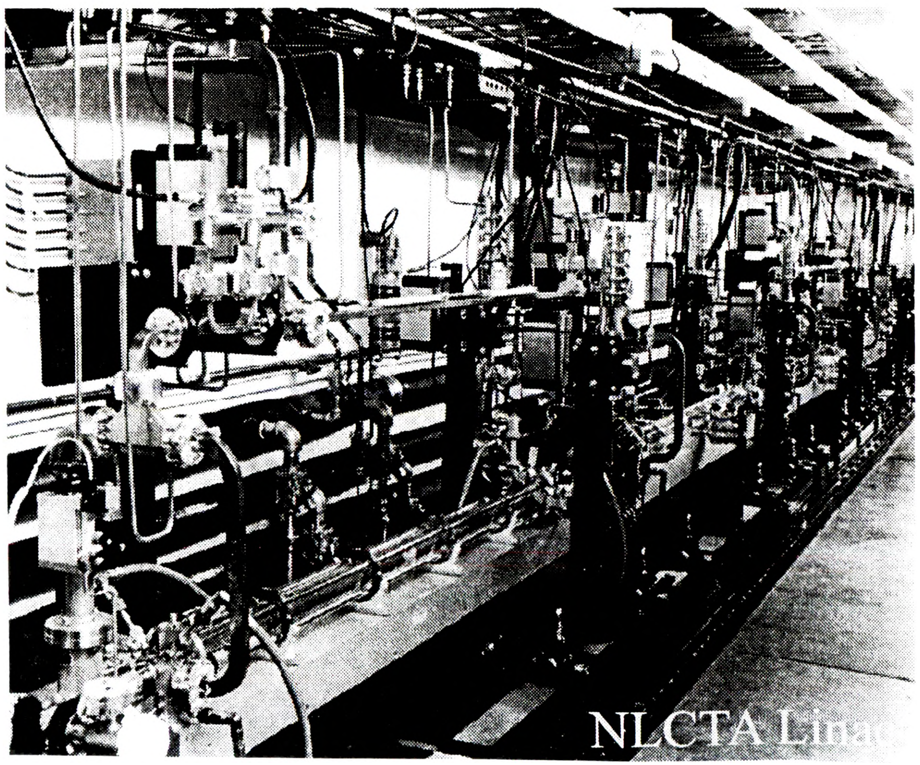


An elegant way to synthesis the hybrid as an integrated part of the device.

High Power Circulator/Switch

High Gradient Studies at NLC Test Accelerator (NLCTA)

C. Adolphsen, B. Baumgartner, G. Bowden, D. Burke, J. Cornuelle, V. Dolgashev, J. Frisch, E. Garwin, R. Kirby, K. Jobe, R. Jones, F. LePimpec, Z. Li, G. Loew, R. Loewen, D. McCormick, R. Miller, C. Nantista, C.K. Ng, M. Ross, R. Ruth, T. Smith, S. Tantawi, J. Wang and P. Wilson



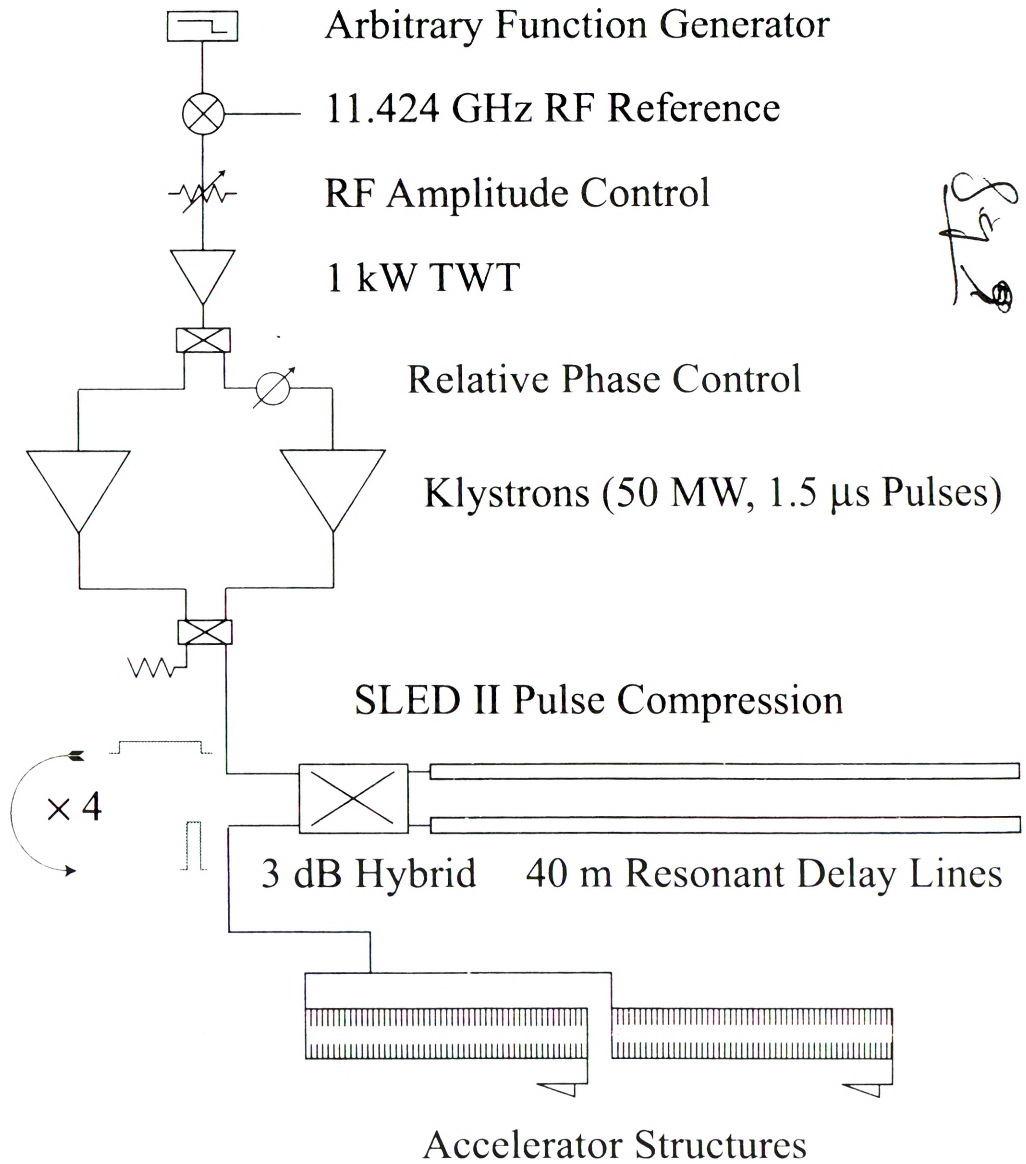


Fig 10

Operation History of Six Test Structures

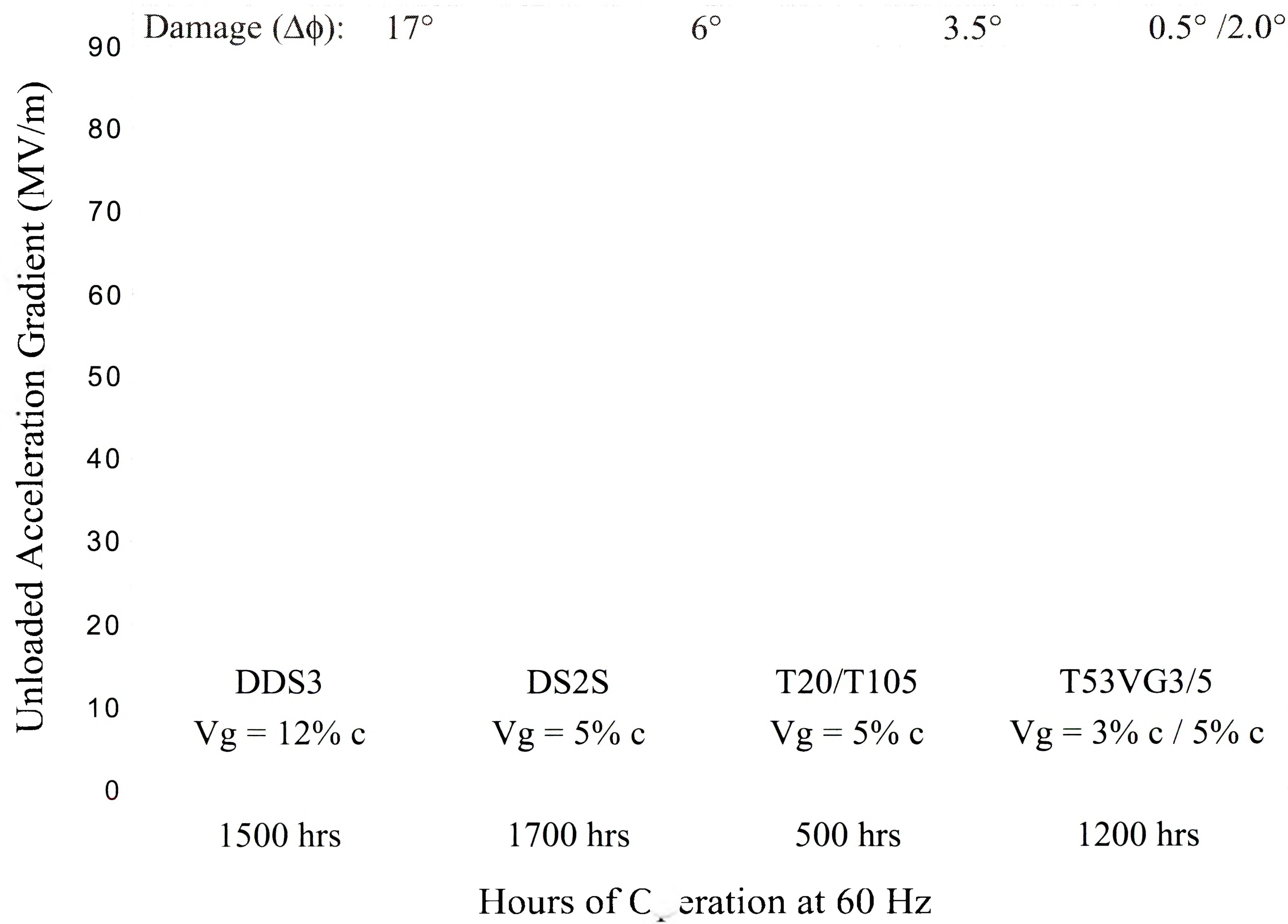
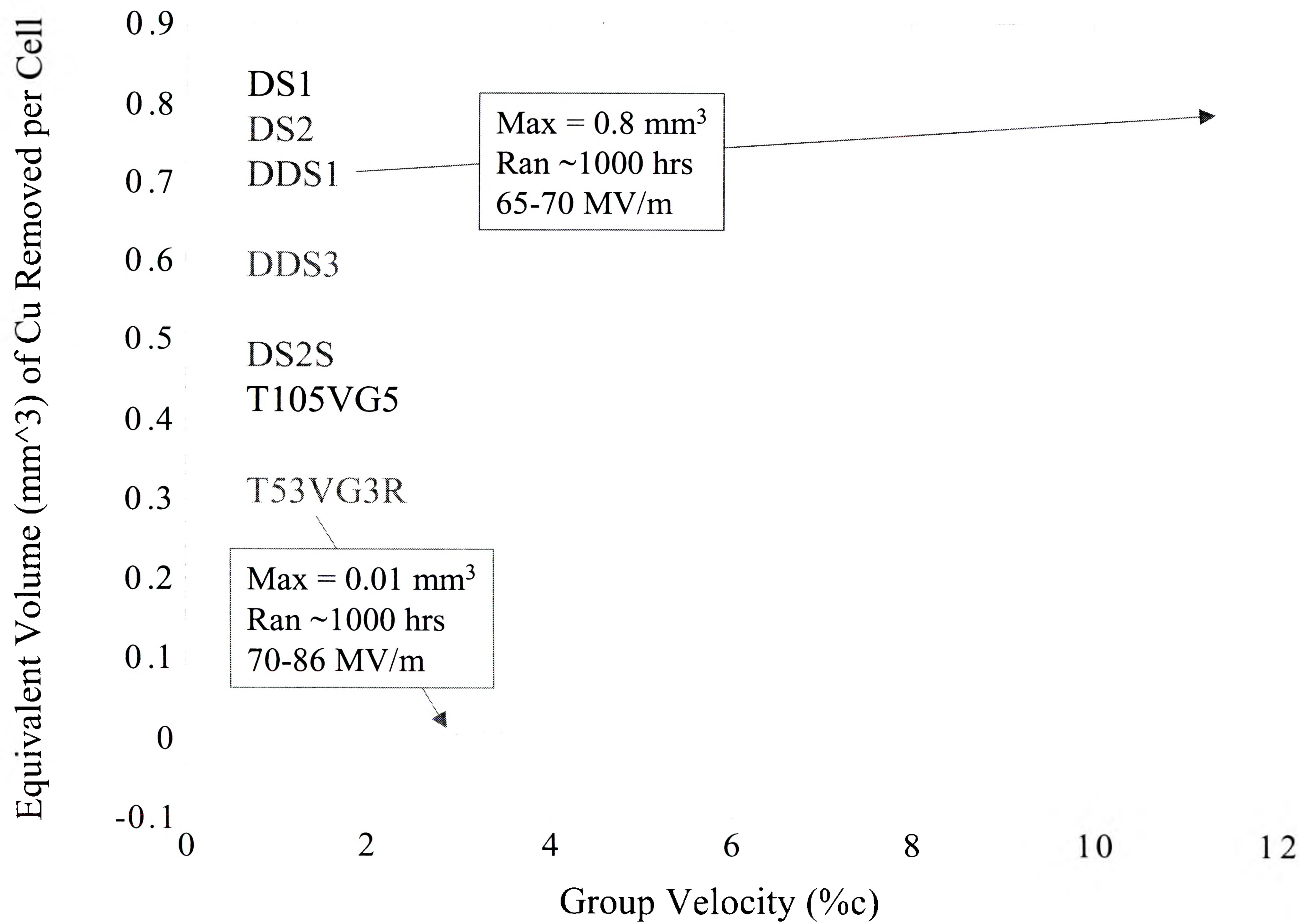


Fig. 11

Structure Damage



Structure Pre-Processing Procedure

fig 12

- New Process: Wet Hydrogen Firing
  - 950 °C for 60 Minutes at Dewpoint of 5 °C / 41 °F
  - Followed by Dry Hydrogen Firing to Remove Chrome Oxide
    - (Dry Hydrogen Firing Considered Harmless)
- Modified Process: Vacuum Bakeout (Exhaust)
  - Was: 5 Days at Around 450 °C
  - Changed to: 16 Days at 650 °C
- Modified Process: Post-Bakeout Handling
  - Was: “Standard” SLAC Vacuum Practice
  - Changed to: “Particulate-Free” Vacuum Practice
- New Process: In-Situ Bakeout
  - 220 °C for Approximately 7 Days

T53VG3/5 Breakdown Rate -vs- Gradient
(Last 500 hours of Run, 240 & 400 ns Pulse Widths, Raw Counts Summed)

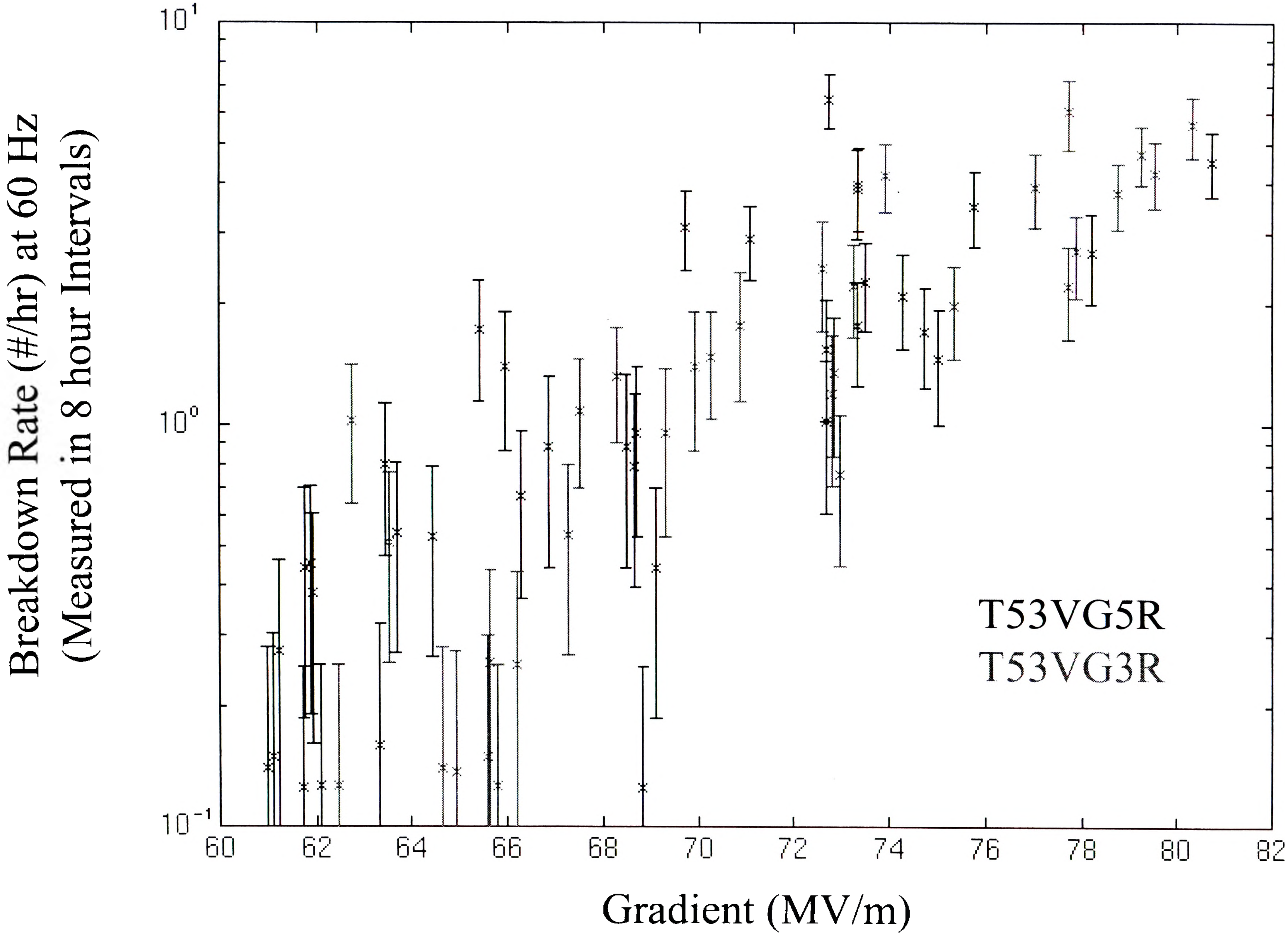
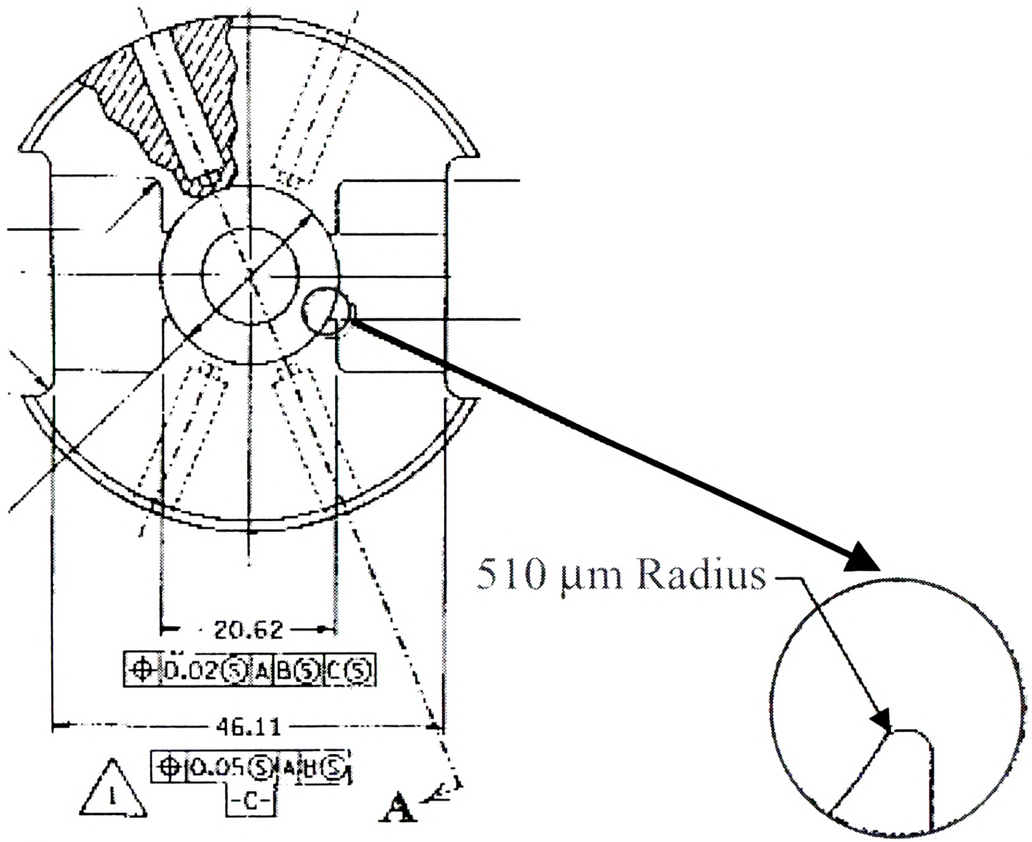


Fig. 13

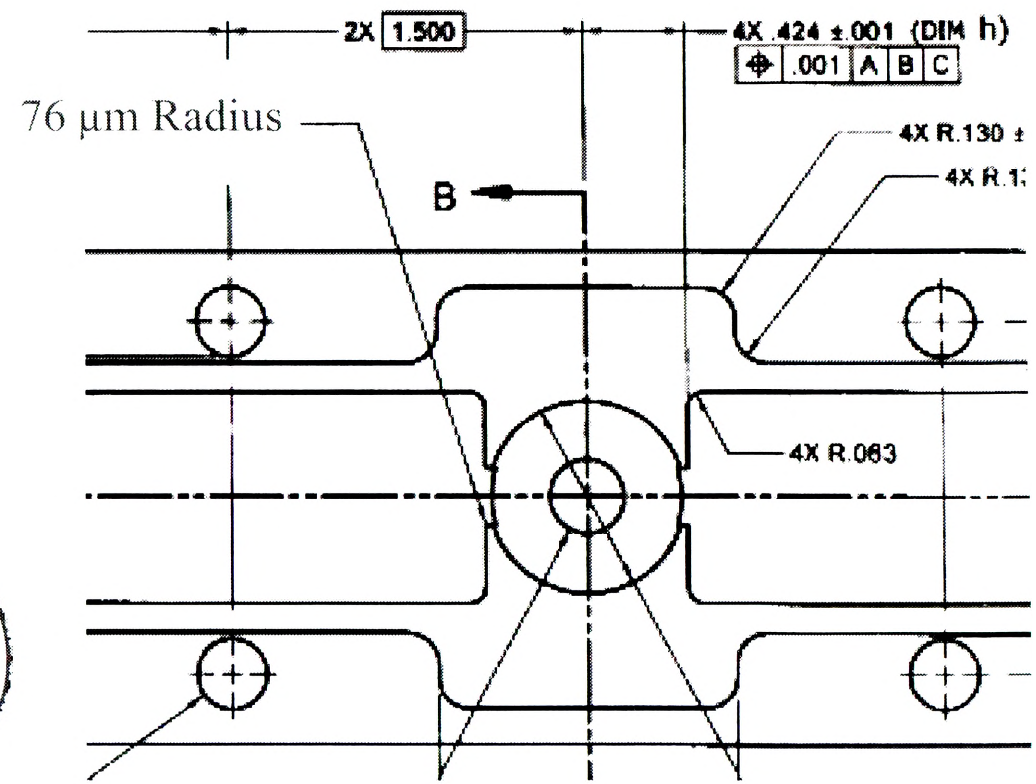
Fig. 14

Input/Output Coupler Cells

RDDS1 and Earlier
DDS and DS Structures



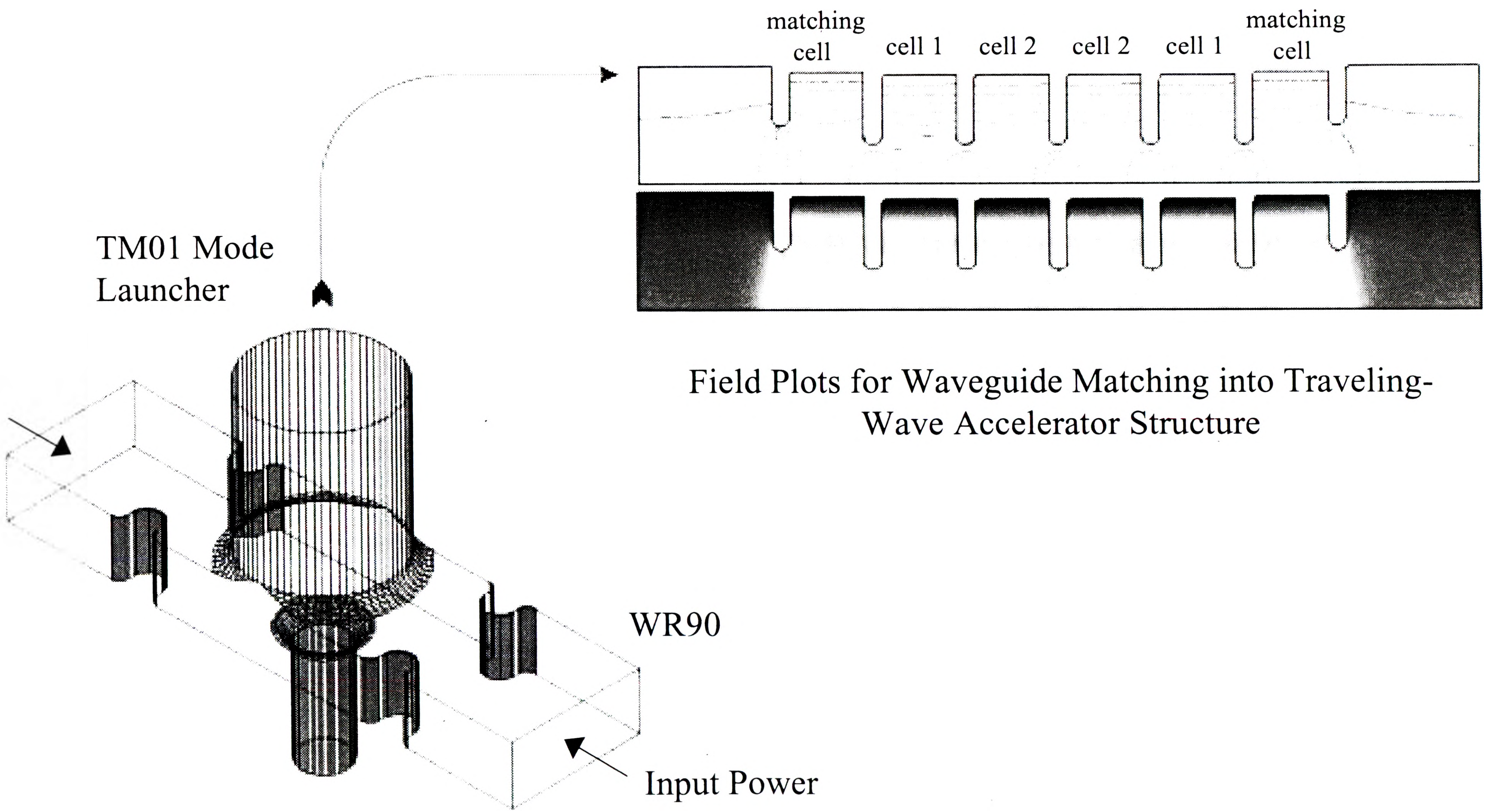
DS2S, T Structures
And Current H Structures



➔ Will Use 3000 µm Radius in Future Structures (ΔT = 20-40 °C)

Fig. 15

Mode-Convertor Type Input Coupler



Field Plots for Waveguide Matching into Traveling-Wave Accelerator Structure

C. Nantista, S. Tantawi, and V. Dolgashev

Fig 16

SW20PIL Processing History

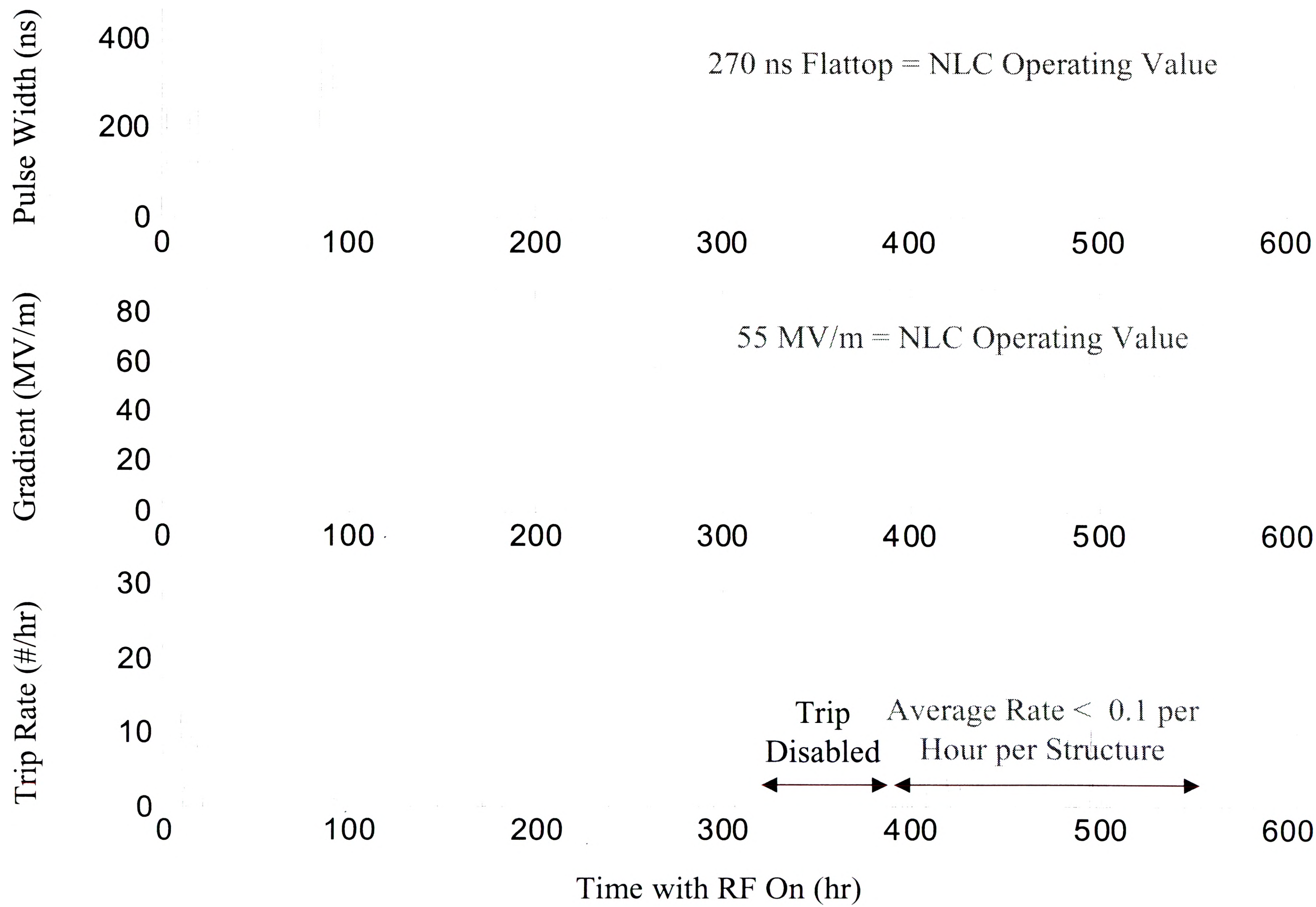


Fig 17 (NLC)

TESLA Engineering Study and Review

Helen Edwards and Peter H. Garbincius

phg – 30nov01, rev. 13may02

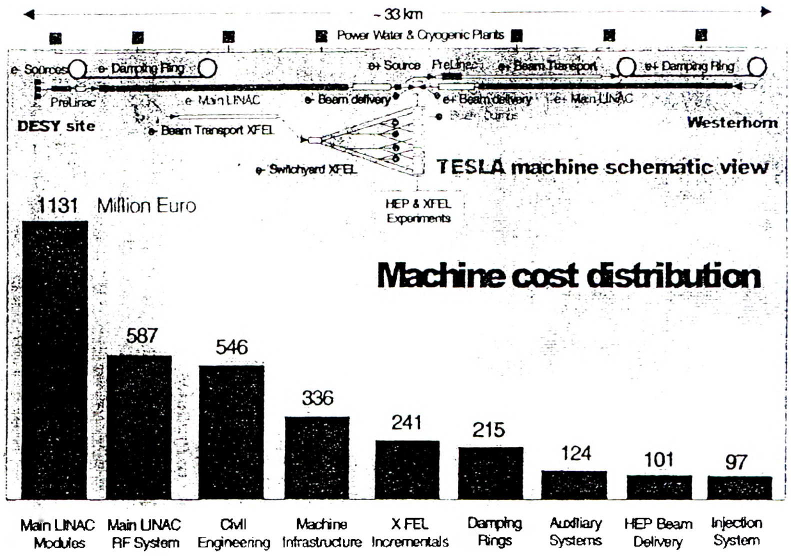
1. Goals: familiarization with TESLA design and cost process
   a. Understand the TESLA Cost Estimate, what was done, its structure, basis, scope, and methodology
   b. Understand the overall project scope, integration, schedule, logistics, etc.
   c. Undertake a re-mapping of the TESLA information into US context to reflect differences in approach between standard US costing procedure and procedures followed by the TESLA collaboration for the Hamburg site.
   d. Identify (but do not investigate) possible alternative options and R&D which might be interesting to develop because of their merit or because of US specific and industry context. (study section leaders, *TESLA contacts*)
2. Procedure (working groups–5 largest ***cost*** elements > 83%)
   a. RF cavities – H. Padamsee, J. Preble, *D. Proch*
   b. Cryostats – T. Nicol, J. Weisend, *C. Pagani*
   c. RF power – R. Pasquinelli, *S. Choroba, S. Simrock*
   d. Civil Engineering – V. Kuchler, *W. Bialowons*
   e. Cryogenics – A. Klebaner, *S. Wolff, H. Quack, Ph. Lebrun*
   f. XFEL incrementals – Y. Cho, *J. Rossbach*
   g. TESLA Project Overview – D. Finley, *D. Trines*

Not incl. (interesting) Damping Rings, Beam Delivery, Injectors

3. Deliverables and Schedule:
   July-Sept – organization, study published material
   Sept-Oct – set up TESLA contacts, present initial scope
   Nov – visit DESY (Frascati/TTF, Dresden/CERN)
   Nov-Dec – mid-term presentation & draft reports
   May ~~Jan~~ 2002 – finalize report and presentations
4. Final Report – will be *reviewed by TESLA Collaboration Management* and participating US lab management prior to final release

Fig 18/NIC

TESLA TDR: 3,136 M Euros plus XFEL plus 6,933 person-years over 8 years construction



Unit Quantities for TESLA-500

- **RF cavities** **20,592**
- **Nb material** **500 tons**
- **Input couplers** **20,592(~1/2 for superstructures but twice the power)**
- **Cryomodules** **2,574 (12 m) or 1,726 (17 m)**
- **Quadrupole packages** **720**
- **Klystrons & Modulators** **572**
- **Cryo plants and halls** **7**
- **Cryo units** **12 (2.5 km, ~16 strings of ten 17 m modules)**
- **Vacuum barriers** **4 per cryounits (~ 500 m sep.)**
- **Main Linac tunnel** **33,500 m**

A Re-Maping of the TESLA Estimate to a U.S. Style Format and Labor Rates

This is not a validation of the TESLA estimate nor an estimate of what TESLA would cost if built in the U.S.

TESLA Project Cost Estimate Comparison	European Union	U.S. (~TEC)
Base cost estimate – from TESLA TDR (to be paid out to industries and companies)	3.136 B Eur	$ 2.822 B
U.S. industrial manpower cost factor of 27 % of $ 2.822 B		$ 0.762B
Personnel Costs from TESLA Institutions – 6933 man-years		
European (51 K Euros/yr)	0.354 B Eur	
U.S. ($ 83 K/yr)		$ 0.575 B
EDIA: Included in Institutional manpower	- 0 -	- 0 -
General and Administrative Overheads		
TESLA: adds 25% of DESY operating budget for business, administration and other overhead functions 35 M Euros per year for 8 years	0.280 B Eur	
U.S.: assume model 30% of laboratory manpower plus 3% of material and contracts (negotiable)		$ 0.280 B
Escalation (Inflation) – TDR quoted as year 2000 prices		
TESLA: to be added at time of approval (assume 15%)	~0.566 Eur	
U.S.: Assume 2%/yr & 2007 average costing date→ 15%		$ 0.666 B
Contingency added to Cost Estimate		
TESLA: none	- 0 -	
U.S.: assume 20%, of above sum		$ 1.021 B
	=========	=======
total estimates	4.336 B Eur	$ 6.126 B
	European Union	U.S.

fig 20

Executive Summary (continued)

of the TESLA report (PHG - H.E.)

- We believe TESLA proposal is sound and developed to appropriate level for this stage of proposal process. We congratulate the TESLA group on their efforts and progress.

- Internationalization issues are timely and critical for further progress. There is clear priority to proceed with international organizational issues, even *before* making technology choice. A management model will be an important and major undertaking.
- Need to bring in new international partners at early stage, before all choices locked-in.

We believe active participation of U.S. in TESLA is in the best interest of assuring a Linear Collider will be built somewhere.

There are three motivations for U.S. to become actively engaged in TESLA R&D:

- to facilitate an informed decision on the *technology choice* for a linear collider;
- to position the U.S. to play a *meaningful role*, if TESLA is chosen; and
- to actively engage in the *internationalization* process for Linear Colliders.