The Next Generation Linear Collider

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June 1998

Importance of Energy Frontier e^+e^- Collider Affirmed by the World Community

UNITED STATES

"A TeV-scale electron-positron collider offers unique opportunities to extend and complement experiments done at the LHC."

U.S. DOE HEPAP Subpanel on Vision for the Future of High-Energy Physics, S. Drell (Chair) 1994.

"The committee recommends support of an international effort leading toward a complete design and cost estimate of an electron linear collider ..."

National Research Council National Academy of Sciences Committee on Elementary-Particle Physics, B. Winstein (Chair) 1998.

"The Subpanel recommends that SLAC be authorized to produce a Conceptual Design Report for this machine ..."

U.S. DOE HEPAP Subpanel on Planning for the Future of U.S. High Energy Physics, F. Gilman (Chair) 1998.

ASIA

"The e^+e^- Linear Collider project is the next principal project for research in high energy physics in Japan."

Subcommittee on Future Projects of High Energy Physics in Japan, S. Komamiya (Chair) 1998.

EUROPE

"A positive step ... appears to be a linear collider."

European Committee for Future Accelerators, ECFA 1990.

NLC Design Criteria

Collider Optimized for Physics at 1.0 TeV.

(compatible with few hundred GeV to 1.5 TeV)

Initially –	500 GeV	5×10^{33} cm^{-2} s^{-1}

Proven rf technology.
Linac sized for 1 TeV.
Sources and Final Focus for 1.5 TeV.

Adiabatically –	1 TeV	$\geq 10^{34}$ cm^{-2} s^{-1}

Upgrade –	1.5 TeV	$\geq 10^{34}$ cm^{-2} s^{-1}

First stage compatible with highest energy.
May require longer rf development.

KEK - SLAC Collaboration on Linear Colliders

1996 SLAC NLC ZDR (Snowmass)
KEK JLC Design Study

SLAC-KEK Workshop at KEK launched working groups:
- Parameters
- Accelerator Structures
- Pulse Handling

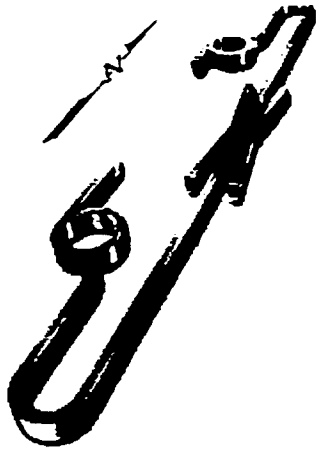
1997 Common "optimization" process . . .

Examples of Technical Optimization

	SLAC	Status	KEK
Klystron	75 MW	←	130 MW
Rf Phasing	Δt	?	Δf
Pulse Handling	SLED II	→	DLDS
Structure	1.8m RDDS	←	1.3 m DS

1998 Memorandum of Understanding

Expanded SLAC-KEK Study Groups



Next Linear Collider

August 20, 1998

International Participation:

As part of the continuing work on the design of a linear collider, SLAC in the United States and KEK in Japan are finalizing a formal agreement on the development of a common design for a 500 GeV (upgradable to 1 or 1.5 TeV) linear electron collider.

The following links describe the current parameters of the International model. Also on the web are historical and local working models from each laboratory. The local models are the basis of the continuing detailed design work and cost model development pursued at each laboratory.

International Collider Information:

- Parameter sheets, modeling information.
- ISG meetings.
- Proceedings from LC97.
- ILC-TRC International Linear Collider Technical Review Committee

International Collider Facility Pages:

Final Focus Test Beam

The FFTB (SLAC) is a facility to investigate the factors which limit the size and stability of the beam at the collision point for a linear collider.

Accelerator Test Facility

The ATF (KEK) is a program to experimentally confirm the feasibility of damping an electron beam for a linear collider. This facility is in Japan as part of the (J)LC Accelerator Research program.

NLC Test Accelerator

The NLCTA (SLAC) is an accelerator facility to test X-band (11.424 GHz) accelerator sections, rf power compression, and beam loading compensation methods.

Japanese (KEK) Collider Work:

Part of the (J)LC Accelerator Research program at KEK, the JLC Home Page contains links and information about the Japanese effort toward the development of a next generation of linear collider.

United States (SLAC, et. al.) Collider Work:

- Internal working group meeting Schedules and notes.
- Beamline lattice Decks and Plots (ZDR lattice)
- Work Breakdown Sheets (WBS)
- NLC Baseline Roll-Out Review - 3/18/98
- CD-1 Progress Review 6/25 - 6/26/98
- Accelerator Physics Index
- NLC Notes
- LCC Notes
- Systems:
  - LaserSystems
  - Magnet counts and Specifications.
  - S-band studies.
  - Damping ring notes: Physics discussions, Mechanical Engineering, and "ZDR Meeting Notes".
  - Beam Delivery Systems.
  - Timing and RF distribution systems
  - Machine Protection and Beam Containment Systems.
- The NLC Zeroth-Order Design Report (ZDR) contains the collider proposal presented at Snowmass '96.
- An Image Collection and Archived Announcements from Snowmass '96

Additional information:

- SLAC has an ATF page which contains additional information not found on the KEK web sites.
- Some information from the weekly ATF meeting at SLAC.
- The Accelerator Department at SLAC (responsible for accelerator design, upgrades, and operations), or the Accelerator Research departments at SLAC (for future accelerator concepts)

SLAC-KEK ISG
Parameters Subgroup

Table 1. IP and linac parameters for the ILC

	500 GeV			1 TeV		
	A	B	C	A	B	C
CMS Energy (GeV)	524	500	487	1048	1000	969
Luminosity w/ IP dilutions (10^{33})	7.5	6.25	5.0	15	12.5	10
Repetition Rate (Hz)		120			120	
Bunch Charge (10^{10})	0.78	0.98	1.13	0.79	0.98	1.14
Bunches/RF Pulse		87			87	
Bunch Separation (ns)		2.8			2.8	
Injected $\gamma\varepsilon_x/\gamma\varepsilon_y$ (10^{-8}m-rad)		300 / 3			300 / 3	
$\gamma\varepsilon_x$ at IP (10^{-8}m-rad)	400	500	600	400	500	600
$\gamma\varepsilon_y$ at IP (10^{-8}m-rad)	6	10	14	6	10	14
β_x/β_y at IP (mm)	10/0.125	12/0.160	15/0.200	10/0.125	12/0.160	15/0.200
σ_x/σ_y at IP (nm)	279/3.8	350/5.7	434/7.7	197/2.8	247/4.1	308/5.5
σ_z at IP (μm)	100	125	150	100	125	150
Υ (Beamstrahlung Param.)	0.13	0.10	0.08	0.39	0.30	0.22
Pinch Enhancement	1.6	1.6	1.6	1.6	1.6	1.6
Beamstrahlung δ_B (%)	4.8	4.0	3.0	12.2	10.7	8.5
# Photons per e^-/e^+	1.15	1.17	1.10	1.49	1.53	1.46
Rf overhead (%)		8			8	
Average rf phase (deg.)	11.6	13.0	11.4	11.9	13.0	12.3
Linac Tolerances (μm)	16.4	16.4	15.2	13.1	13.1	12.1
Unloaded Gradient (MV/m)		77			77	
Effective Gradient† (MV/m)	59.7	56.9	55.4	59.6	56.8	55.3
Active Linac Length (km)		4.22			8.63	
Power/Beam (MW)	3.4	4.1	4.6	6.9	8.2	9.2
# of Structures per linac		2342			4792	
Structure Length (m)		1.8			1.8	
Structure Iris (a/λ)		0.17			0.17	
Structure Atten. (τ)		0.55			0.55	
Shunt Impedance (MΩ/m)		95			95	
Fill Time (ns)		118			118	
Q		7800			7800	
# of Klystrons per linac		1562			3195	
Klystron Peak Pwr. (MW)		75			75	
Klystron Pulse Length (μs)		1.5			1.5	
Pulse Method		4/4 DLDS			4/4 DLDS	
Pulse Comp. Gain (85% eff.)		3.4			3.4	
RF System Efficiency (%)		38			38	
Total AC Power (MW)		94			191	

† Effective gradient includes rf overhead (8%) and average rf phase cos $\overline{\phi}_{rf}$.

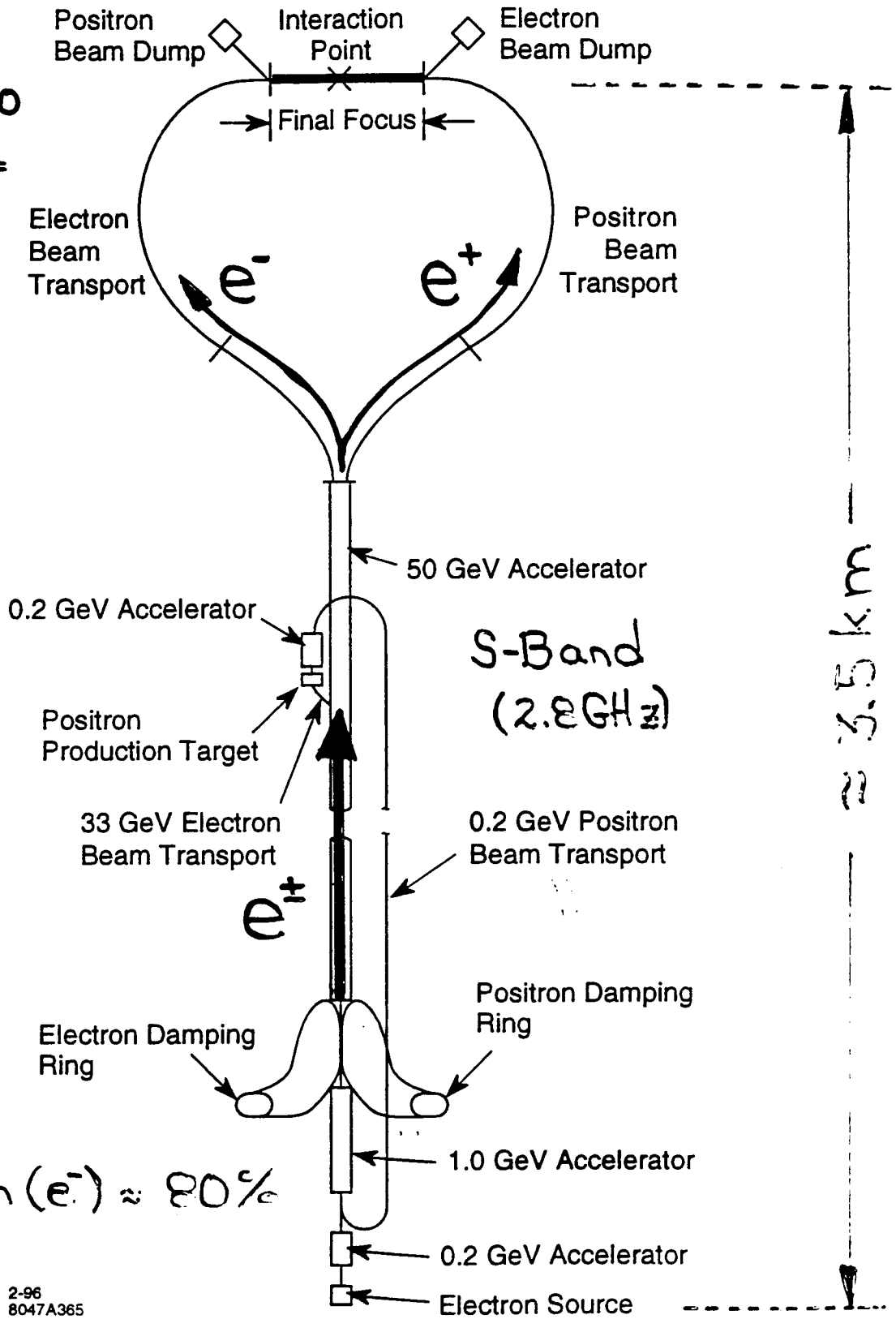
... to be entered as single set in ILC-TRC tables.

ILC-TRC

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

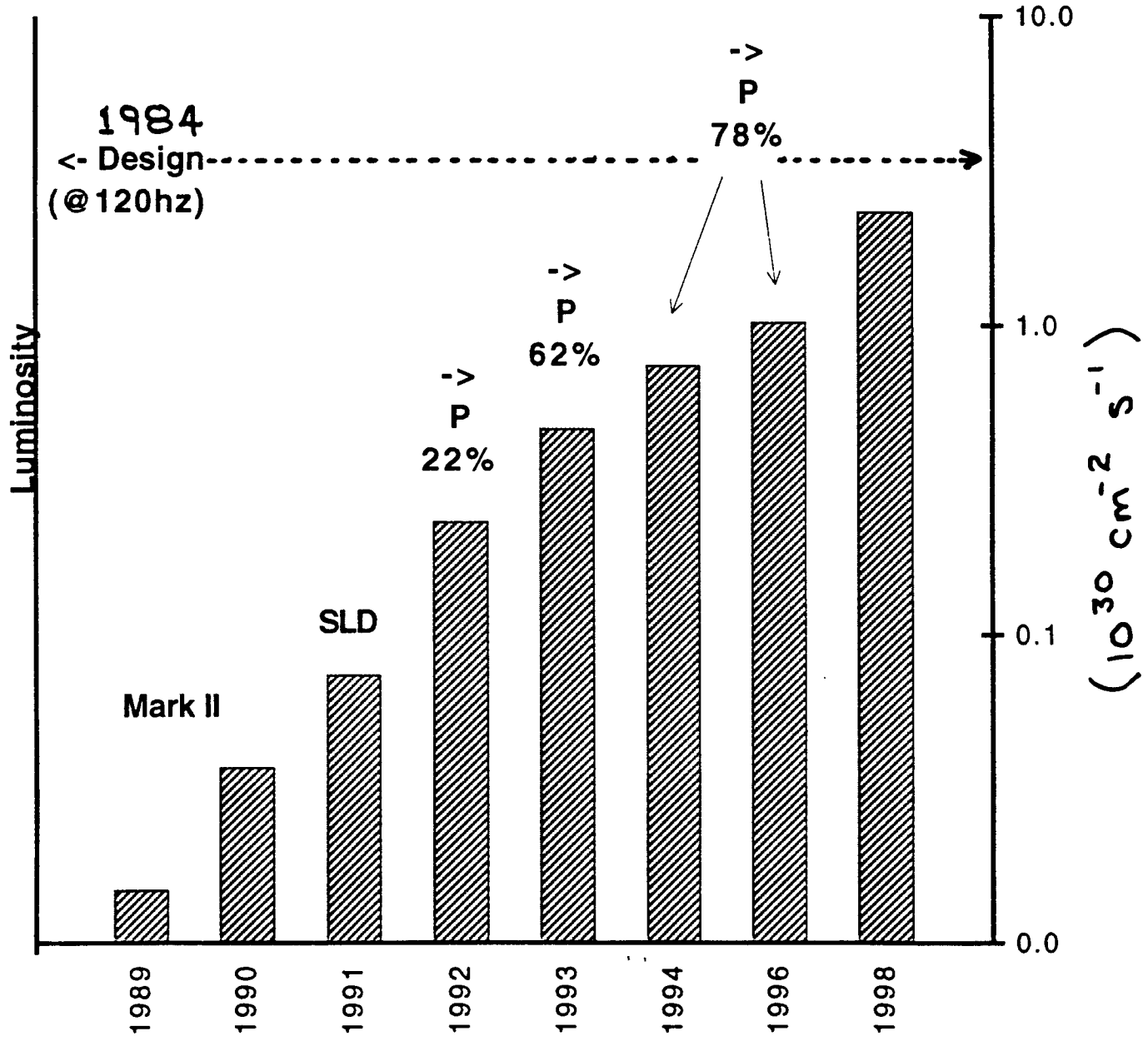
The Stanford Linear Collider

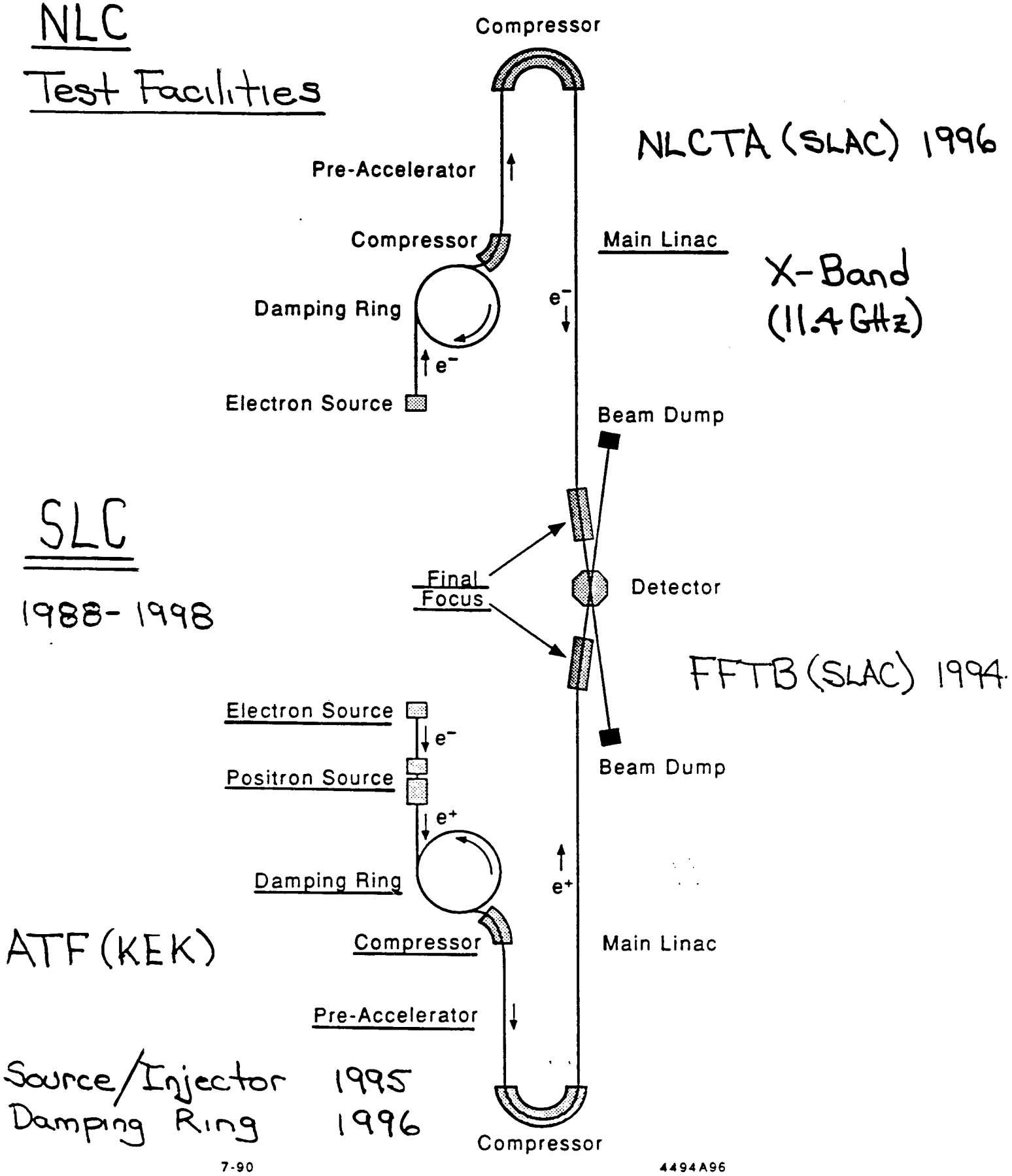
$e^+e^- \rightarrow Z^0$



Polarization (e^-) ≈ 80%

SLC Performance History

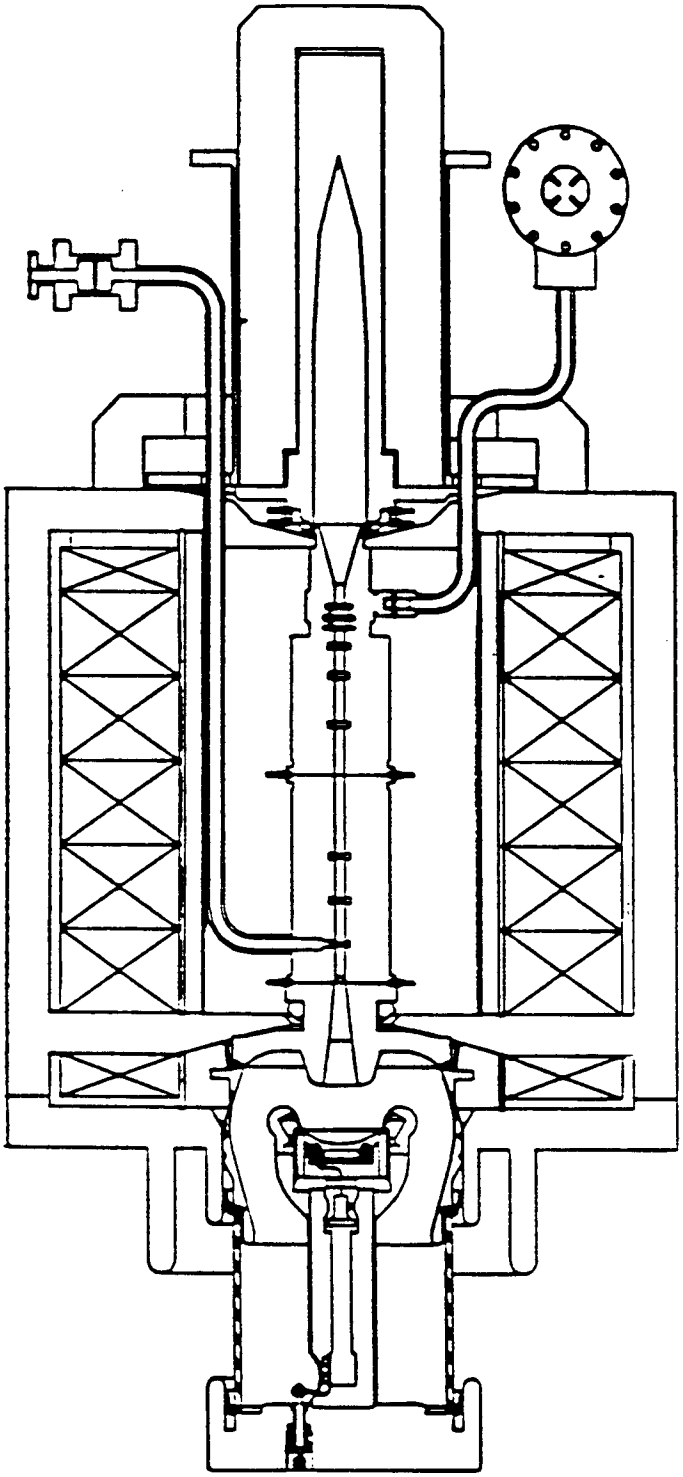




Schematic Layout of the Next Linear Collider

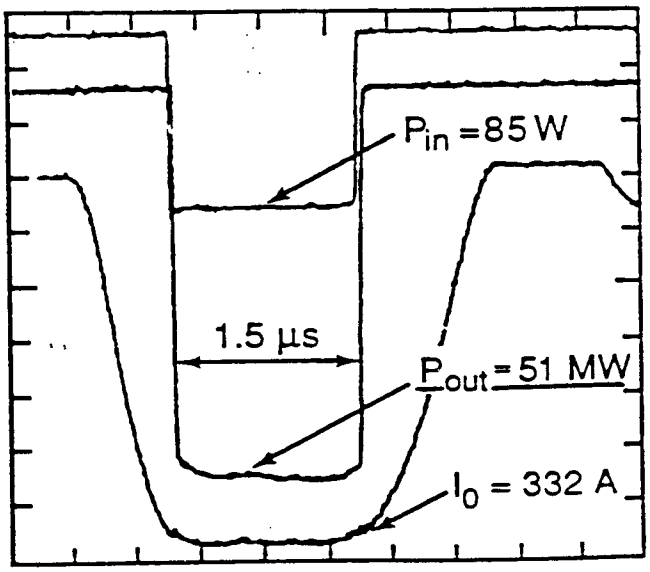
Solenoid-Focused X-Band Klystron

(XL Series)



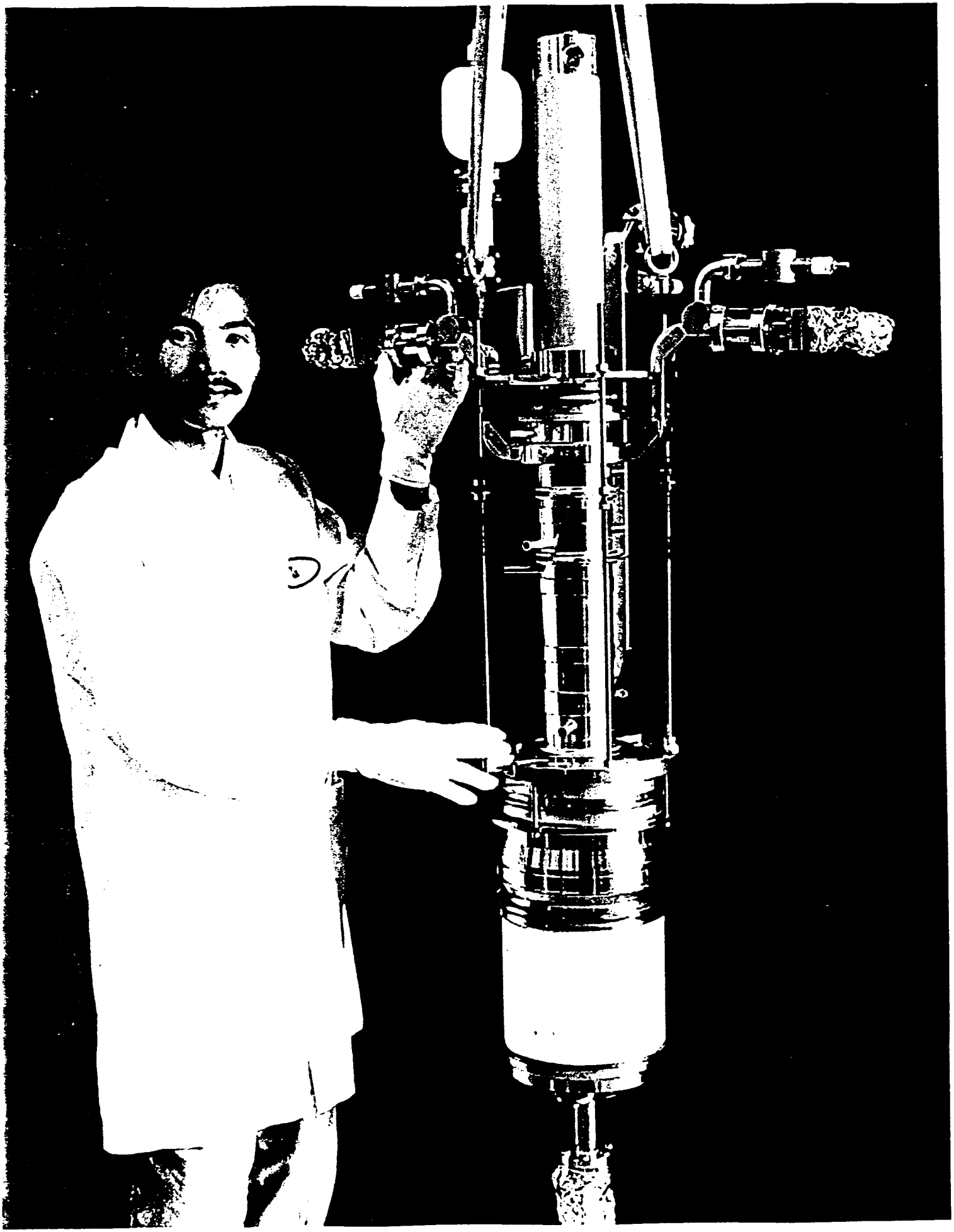
V_0=415 kV
f_0=11.455 GHz
Efficiency = 37%

XL1 Klystron Test Data

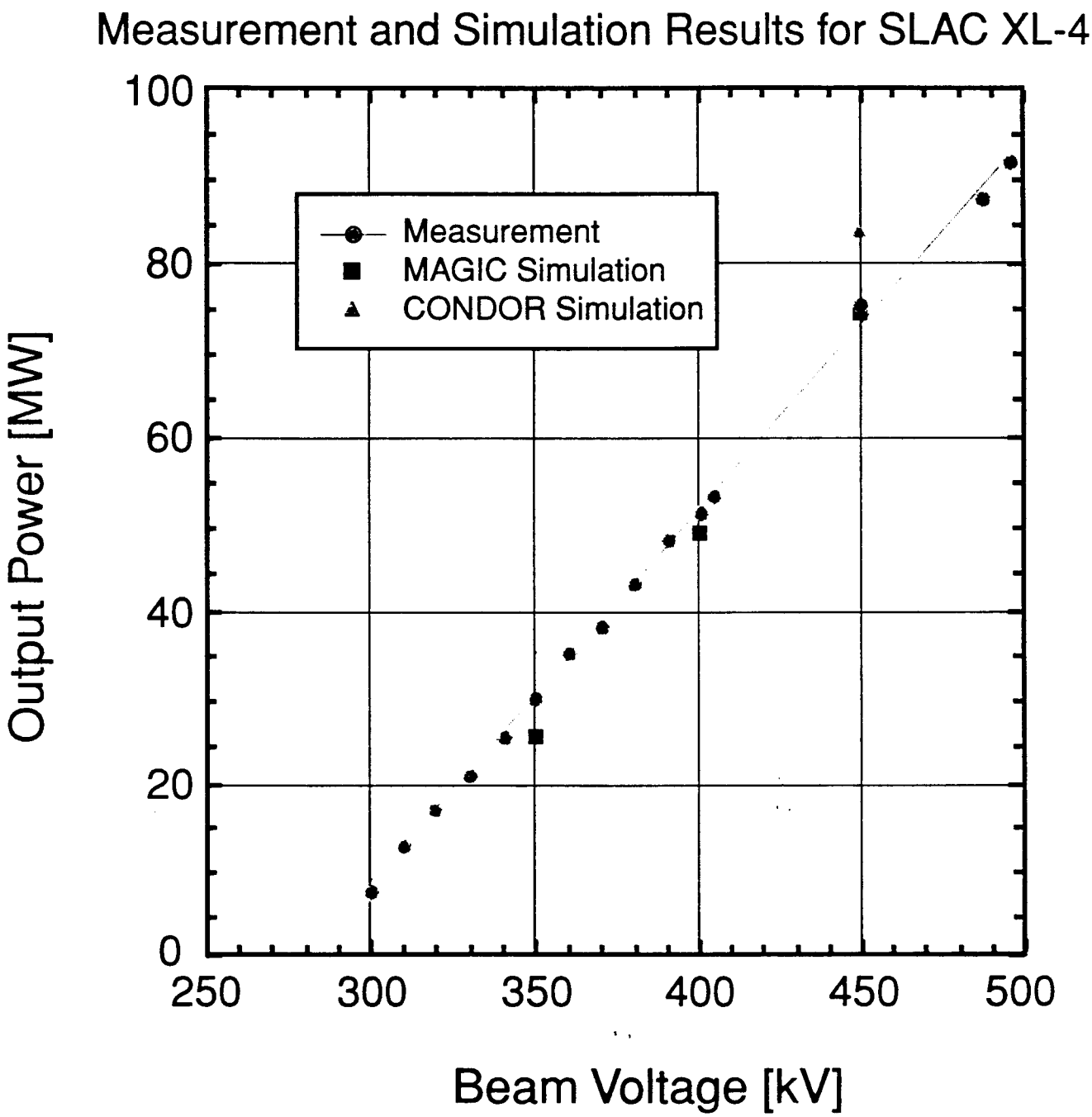


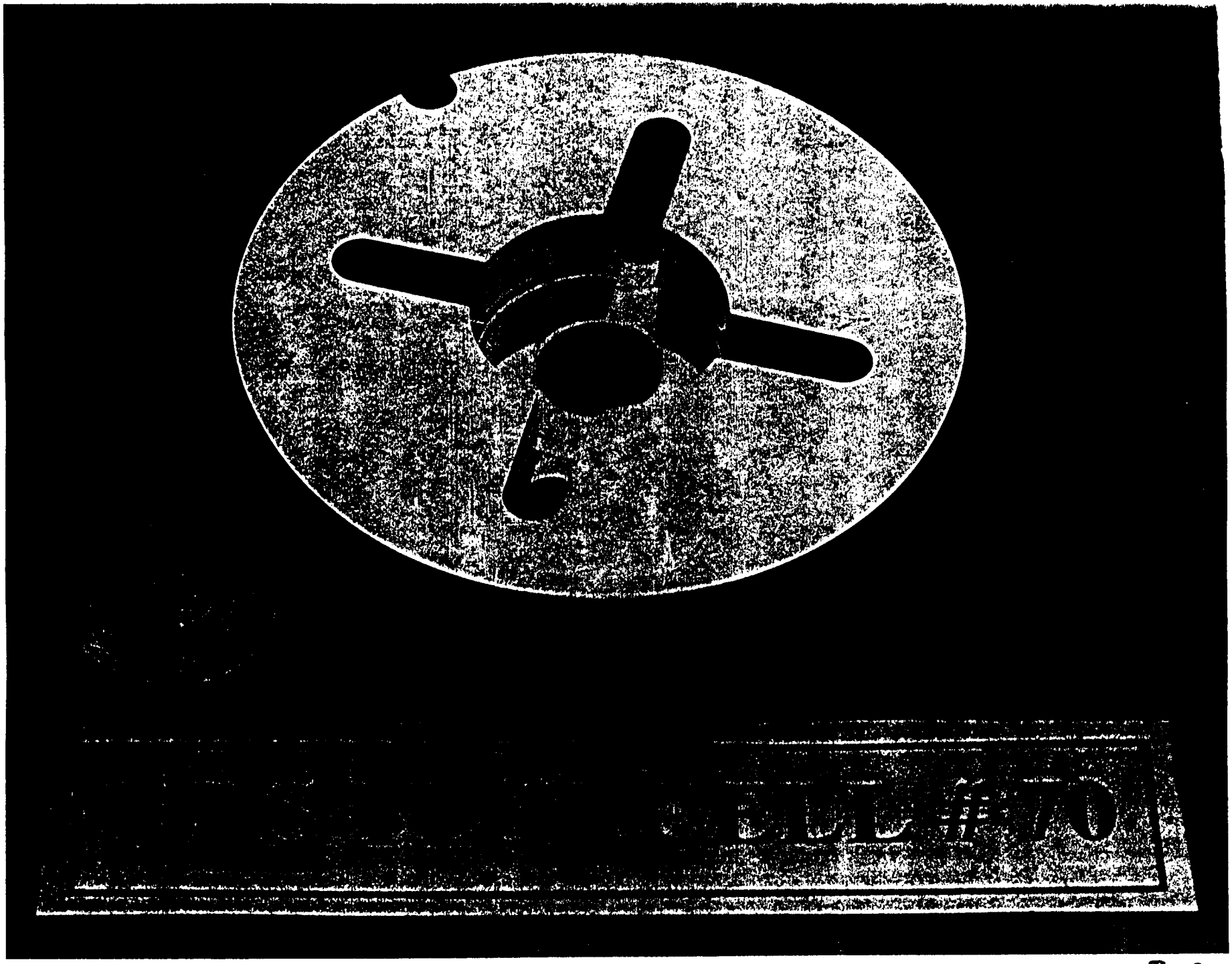
500 ns/div

Production run of six 75 MW XL4's completed.



KEK Modelling Group

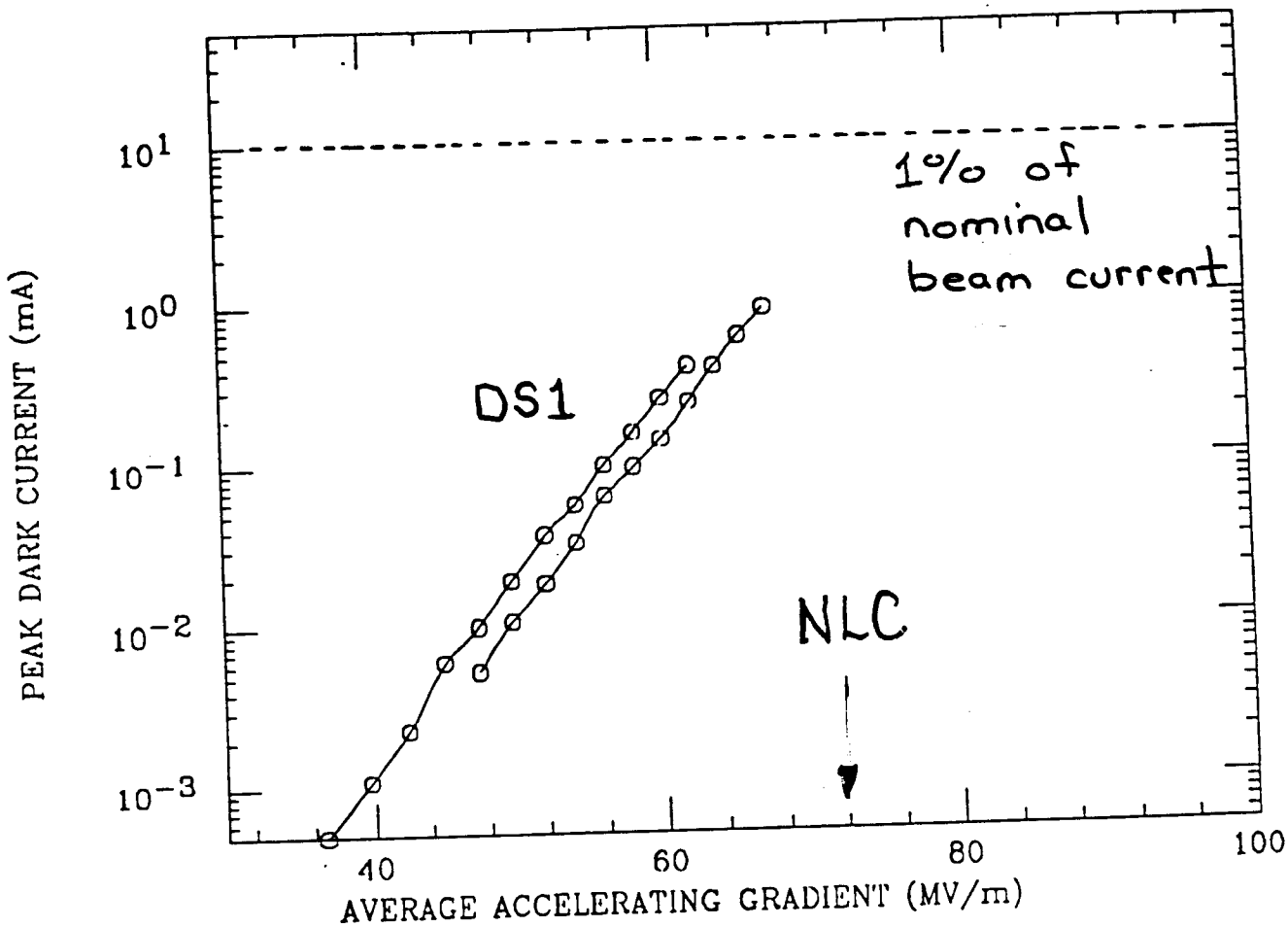




MC0310I-9

High Gradient (X-Band)

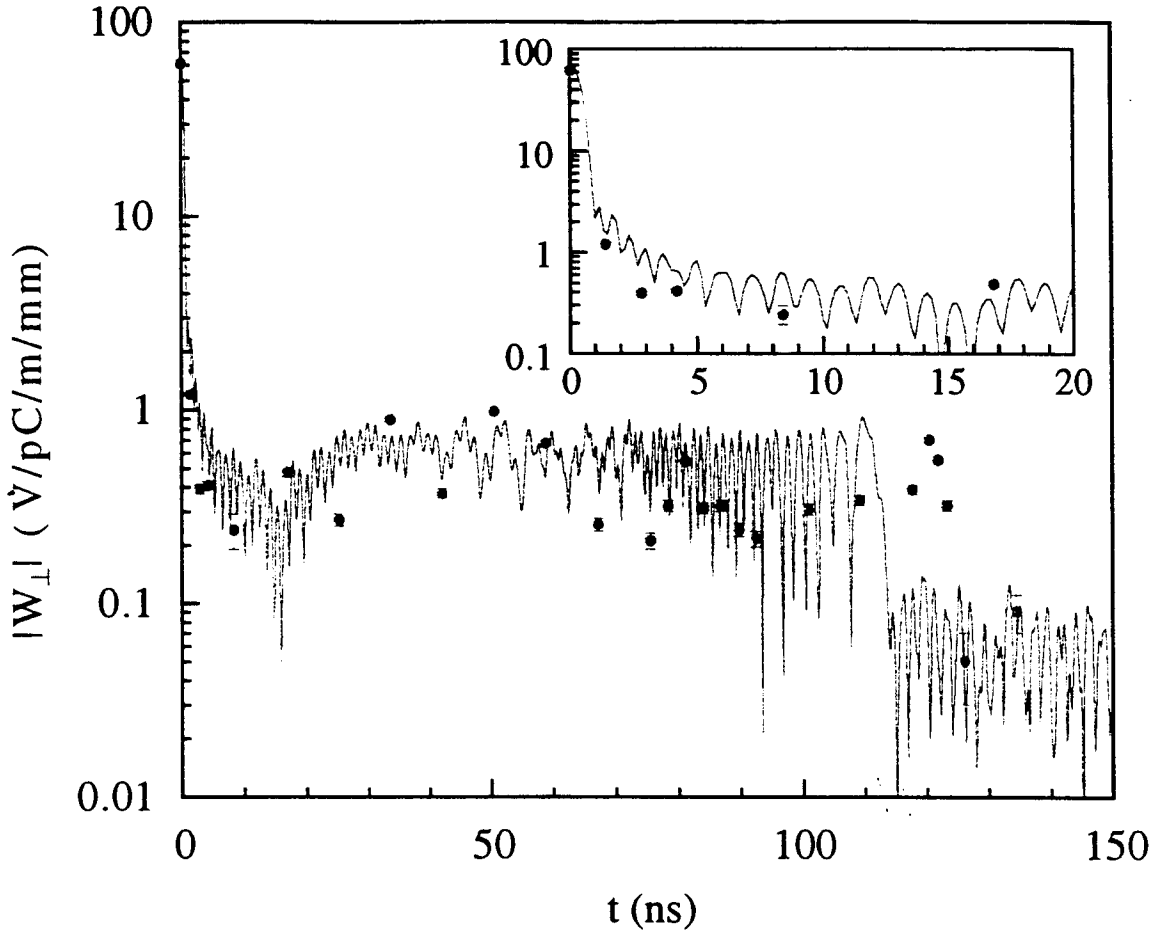
Dark Current



Continuing to work on cleanliness in manufacture to reduce processing time.

Wakefield Amplitude

Measurement and Prediction

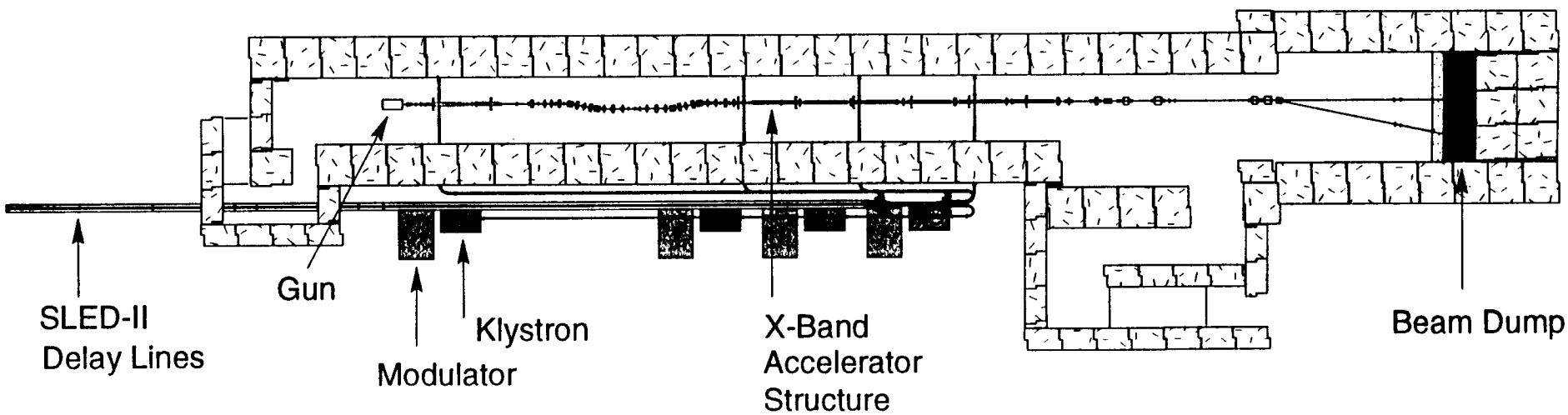


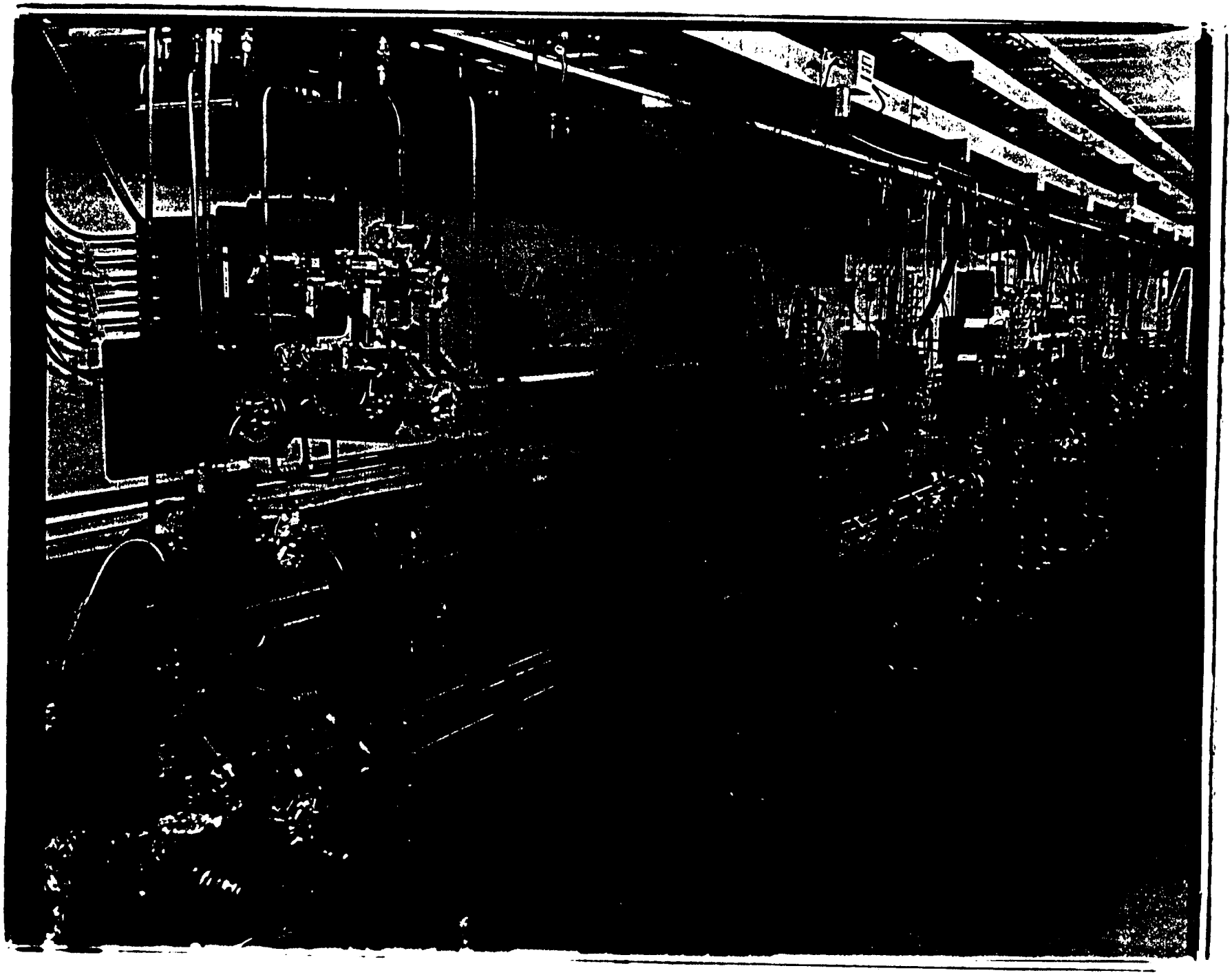
Next Linear Collider Test Accelerator

GOALS

- *To construct and reliably operate an engineered model of a section of the NLC high-gradient linac.*

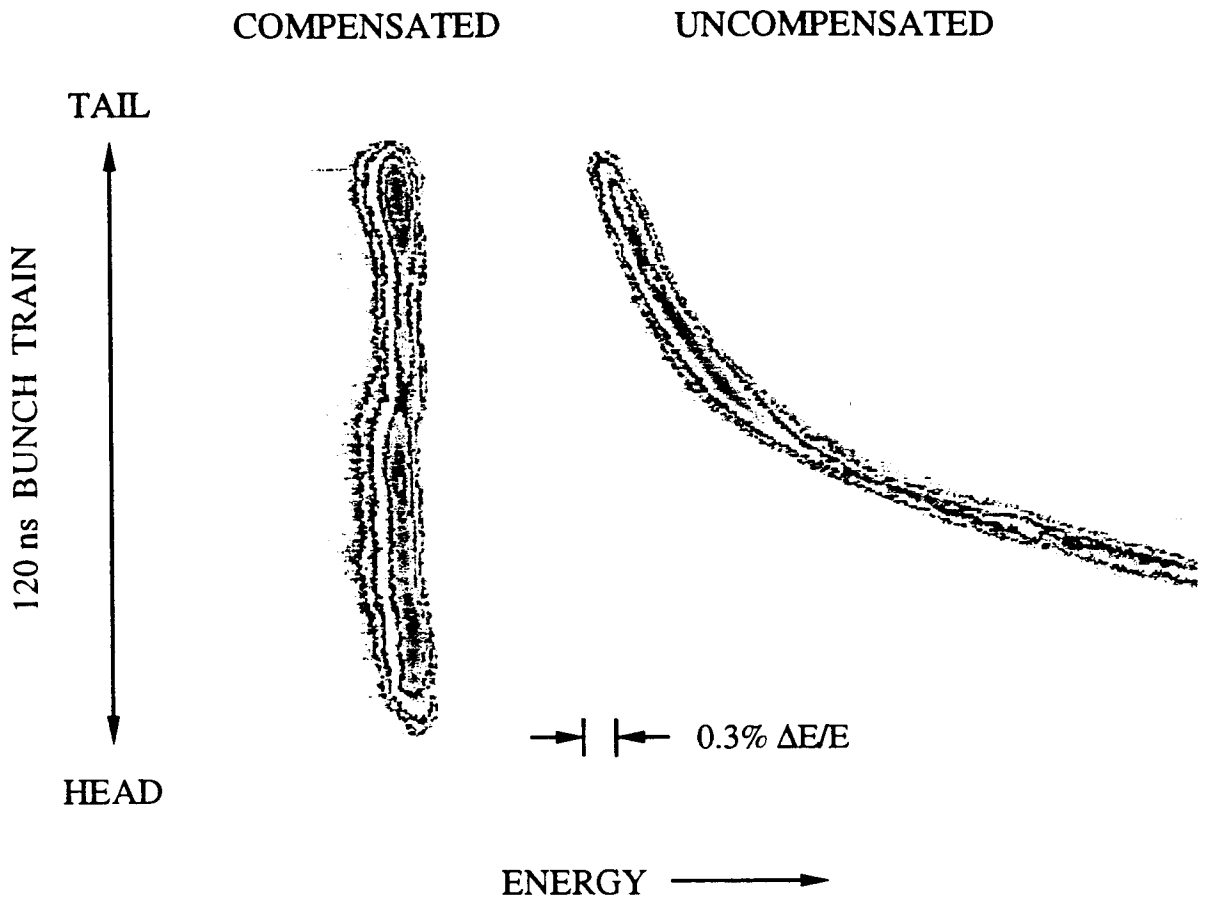
- *To test those beam dynamics questions coupled to acceleration.*





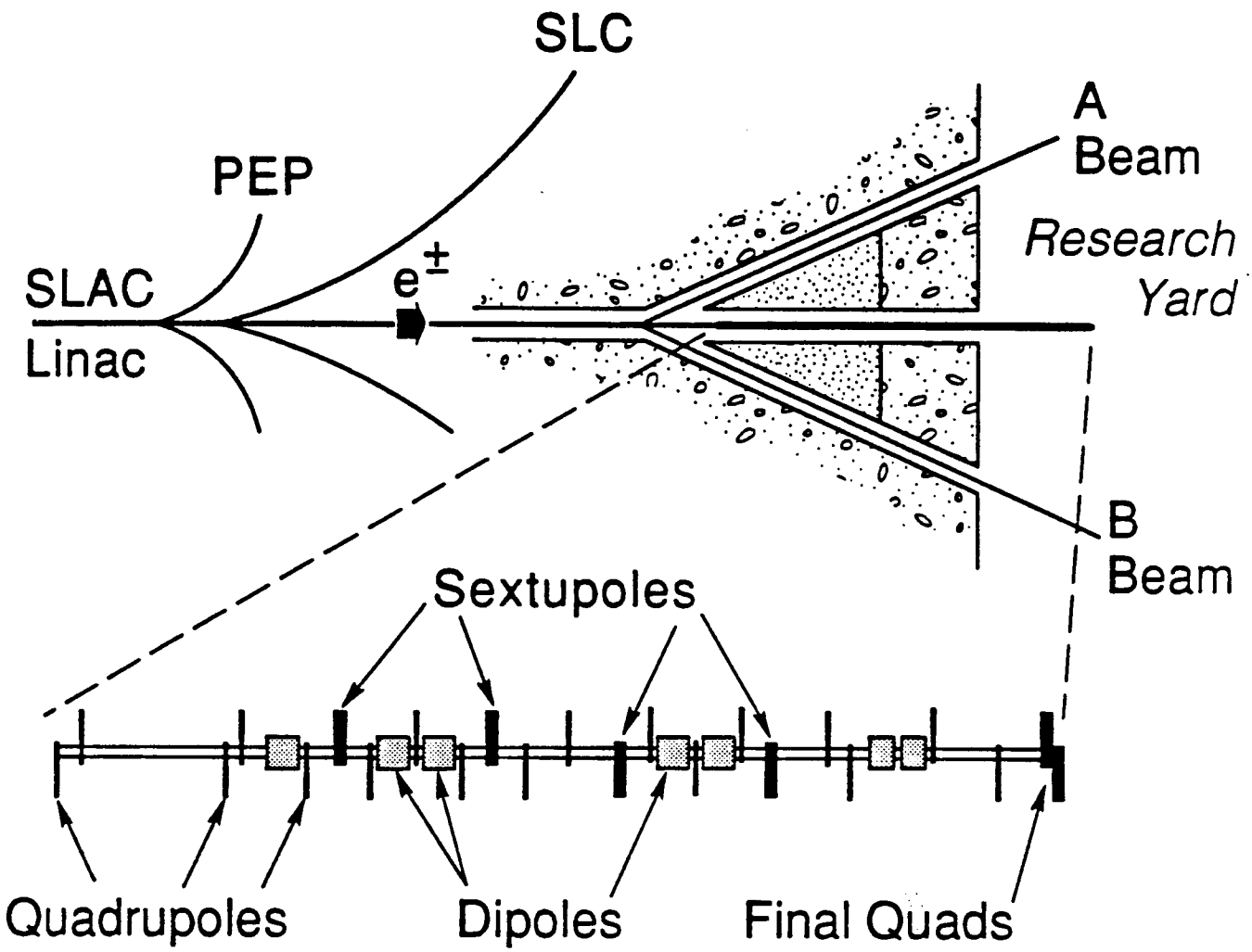
MC0332A-4/5

BEAM LOADING COMPENSATION



RF Station	Unloaded Gradient (MeV/m)	% Loading
0	47	14
1	44	17
2	37	17

FFTB



8-90 **Final Focus Test Beam** 6700A2

Complete prototype of final focus.

FFTB Collaborating Institutions

BINP (Novosibirsk/Protvino)

DESY

Fermilab

IBM

Kawasaki

KEK

LAL(Orsay)

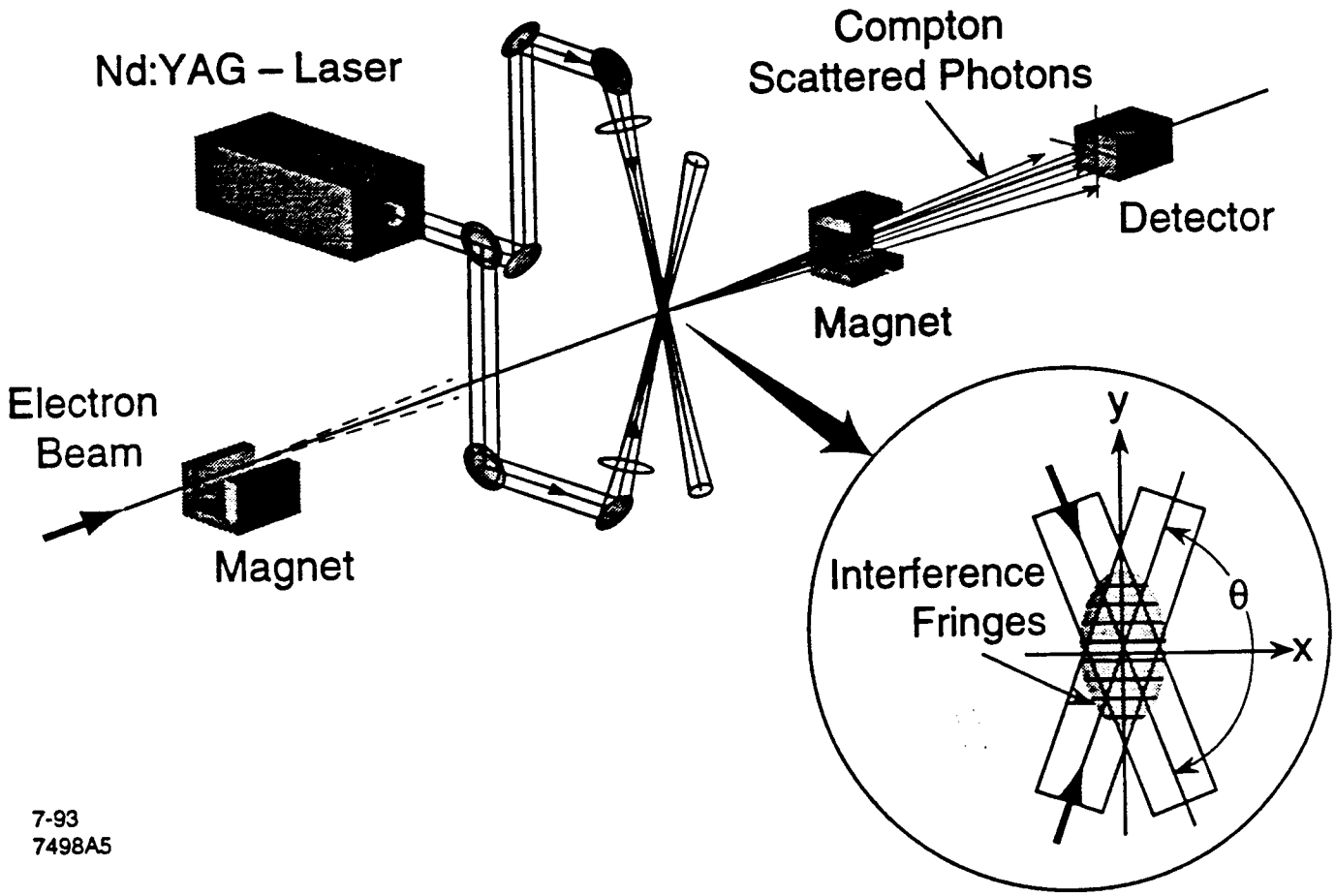
MPI(Munich)

Rochester

SLAC

Final Spot Size Measurement

KEK
Kawasaki



7-93
7498A5

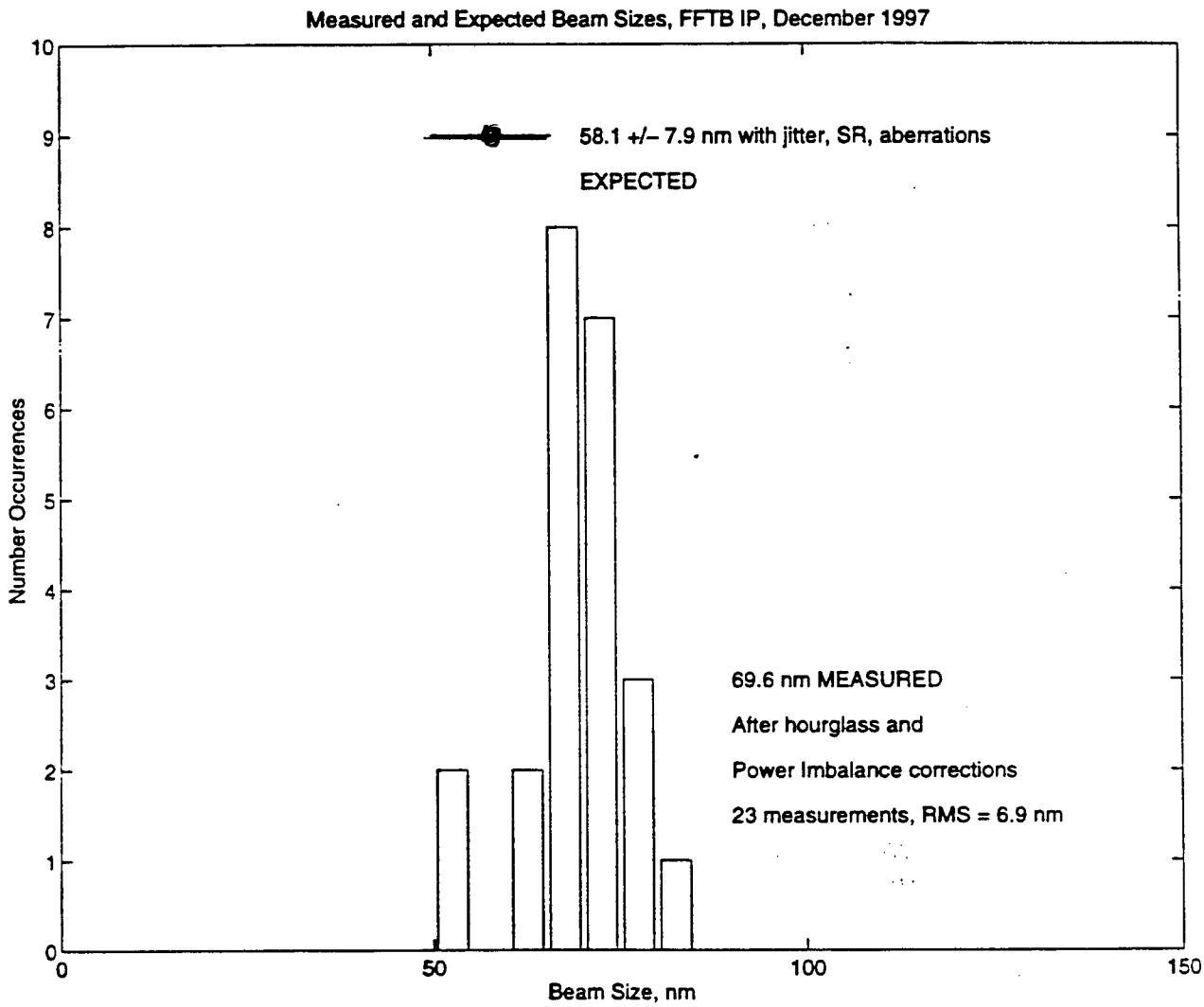
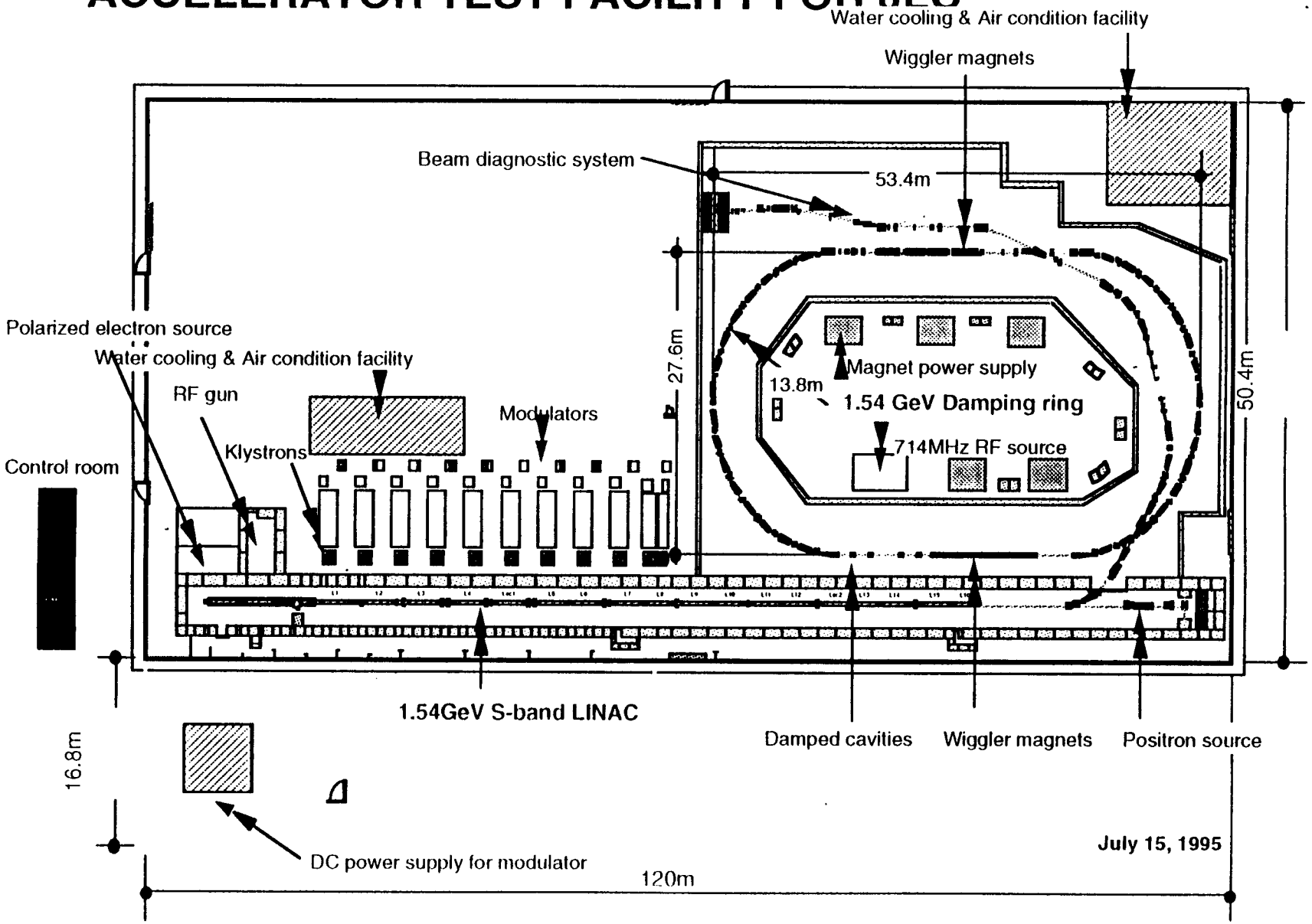


Figure 1: Comparison of measured and expected FFTB beam sizes.

Demonstrated beam control and demagnification required for the NLC.

ACCELERATOR TEST FACILITY FOR JLC

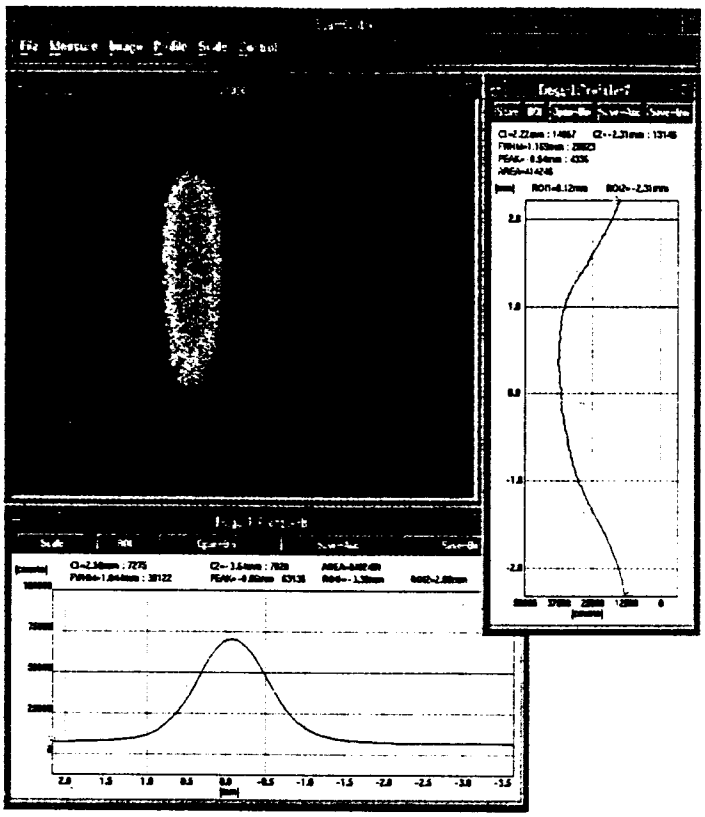


Mid. of Feb. (1997)

Image Size

Gated Camera

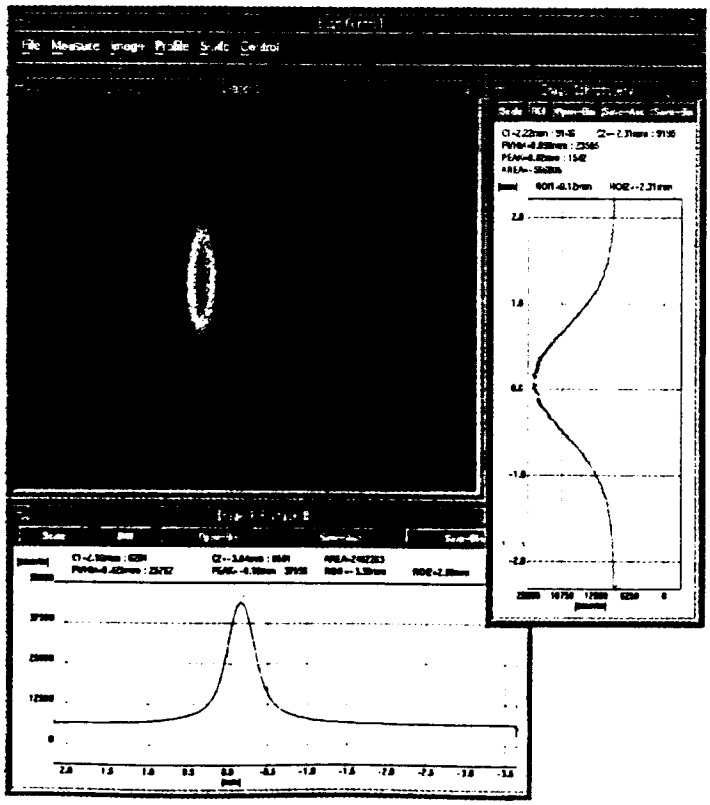
Beam Profile at Injection



$\sigma_y \sim 993 \mu m$

$\sigma_x \sim 443 \mu m$

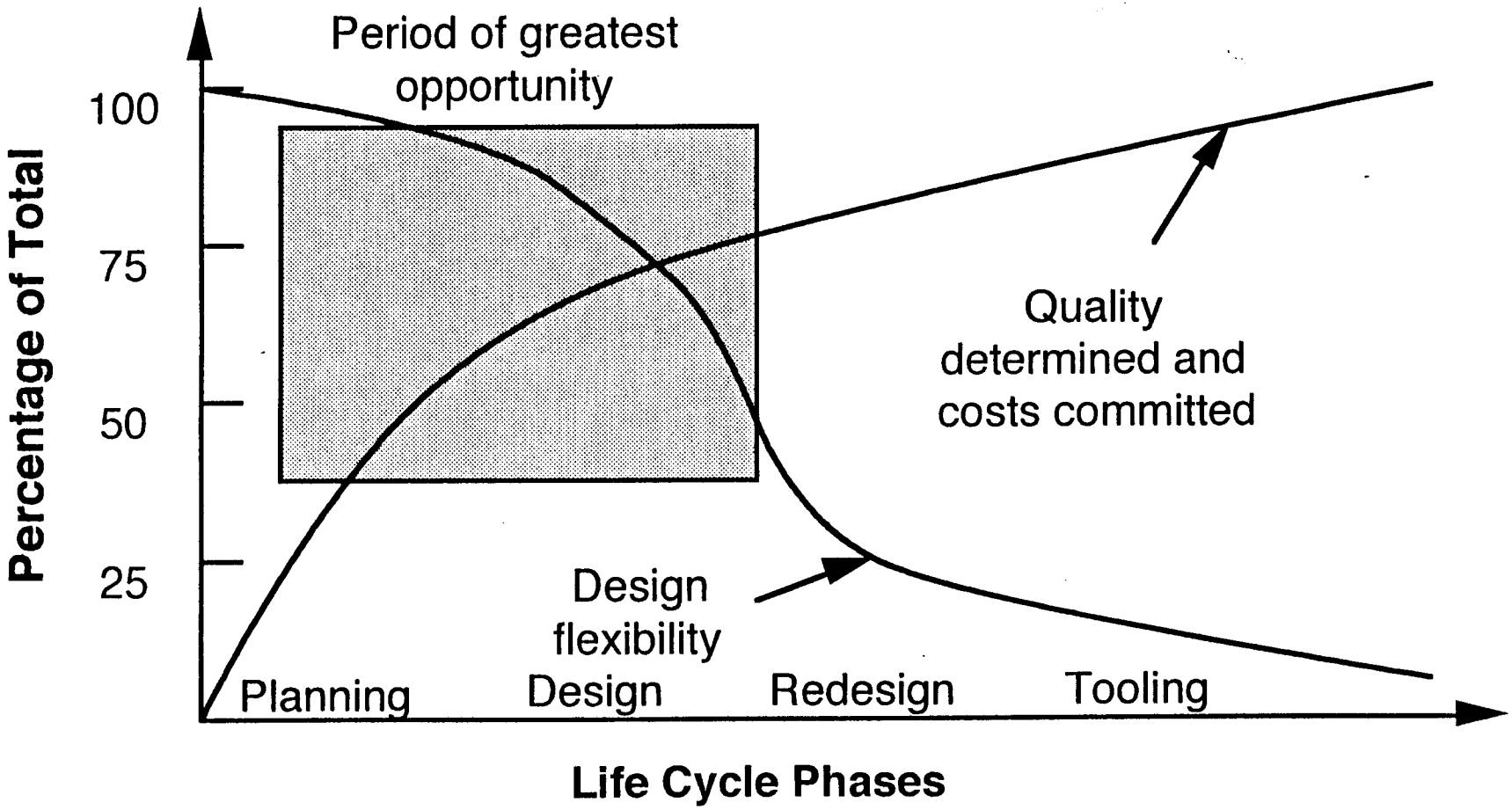
Beam Profile at 640ms from Injection



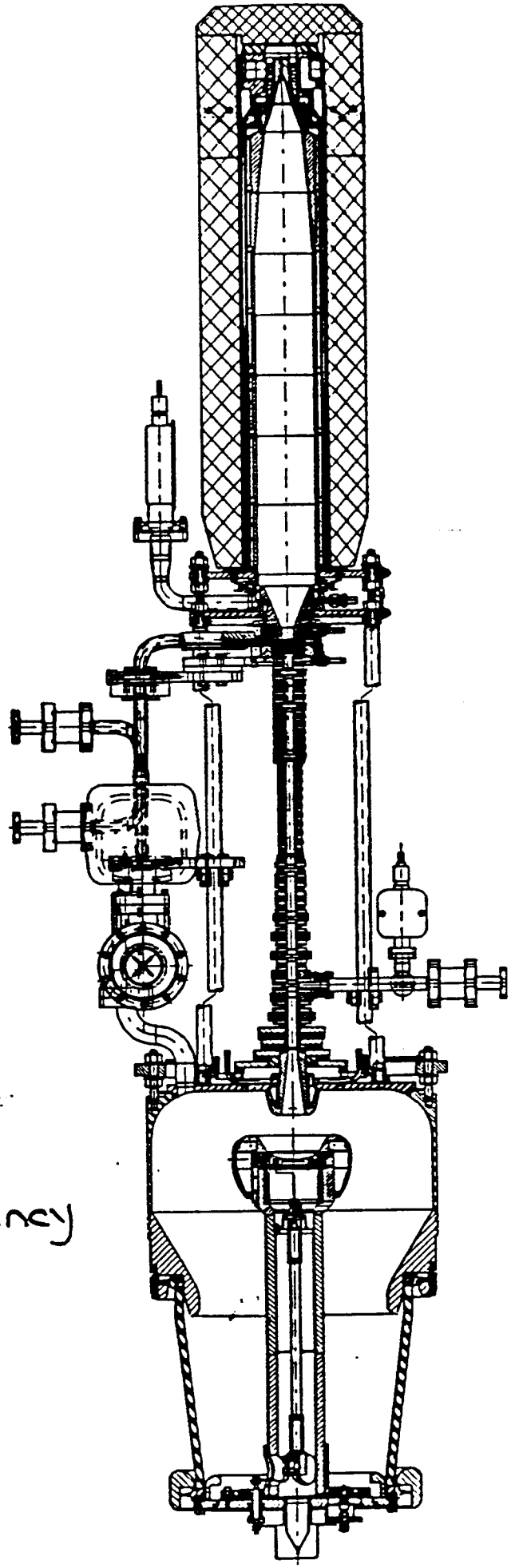
$\sigma_y \sim 600 \mu m$

$\sigma_x \sim 180 \mu m$

Planning - Design
Greatest Window of dfM Opportunity



Periodic
Permanent
Magnet
(PPM)
Klystron

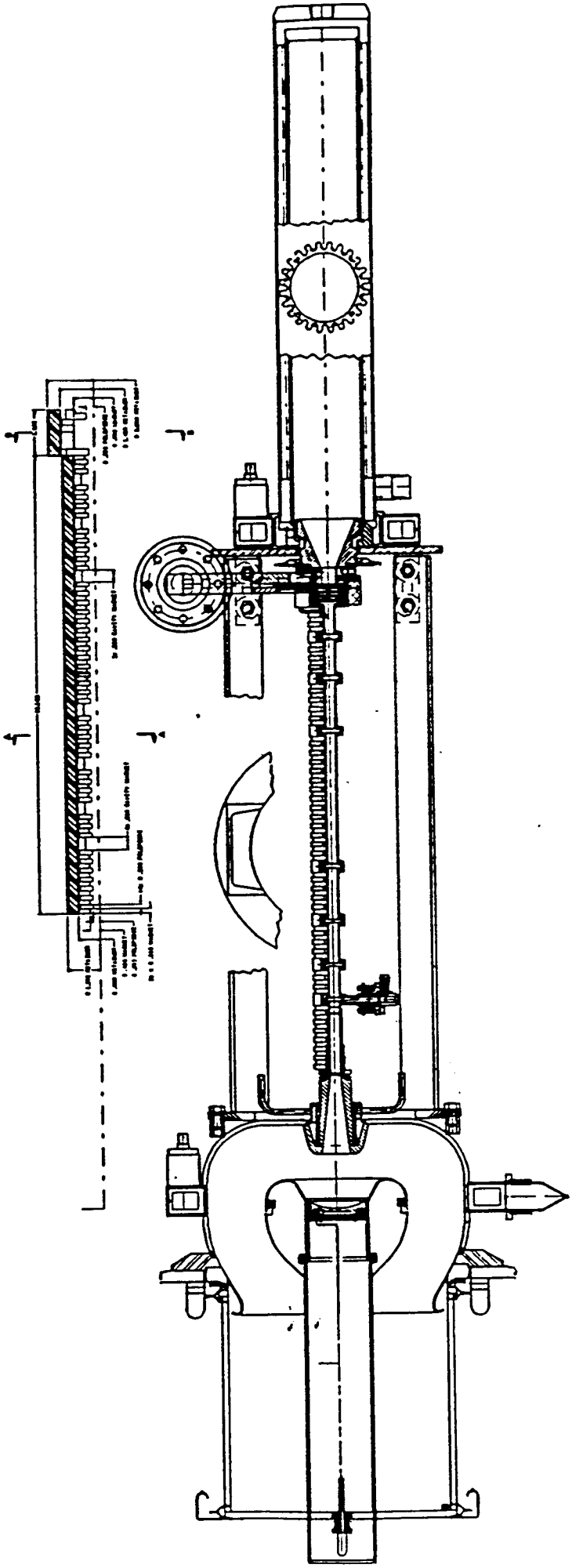


55 MW

1.5 μs

60 % efficiency

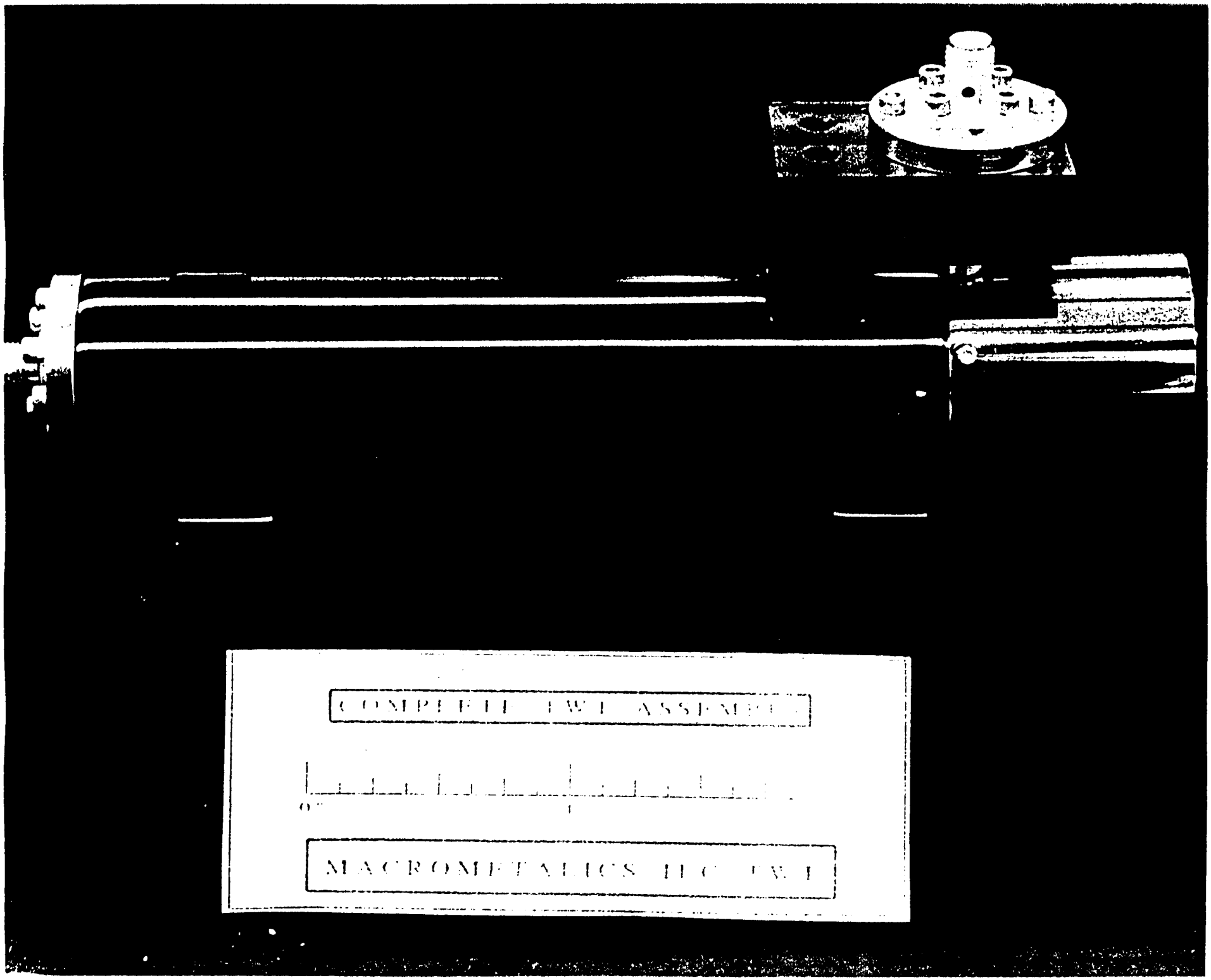
75 XP 1



DfM

75 MW

"NLC Tube"



SBIR

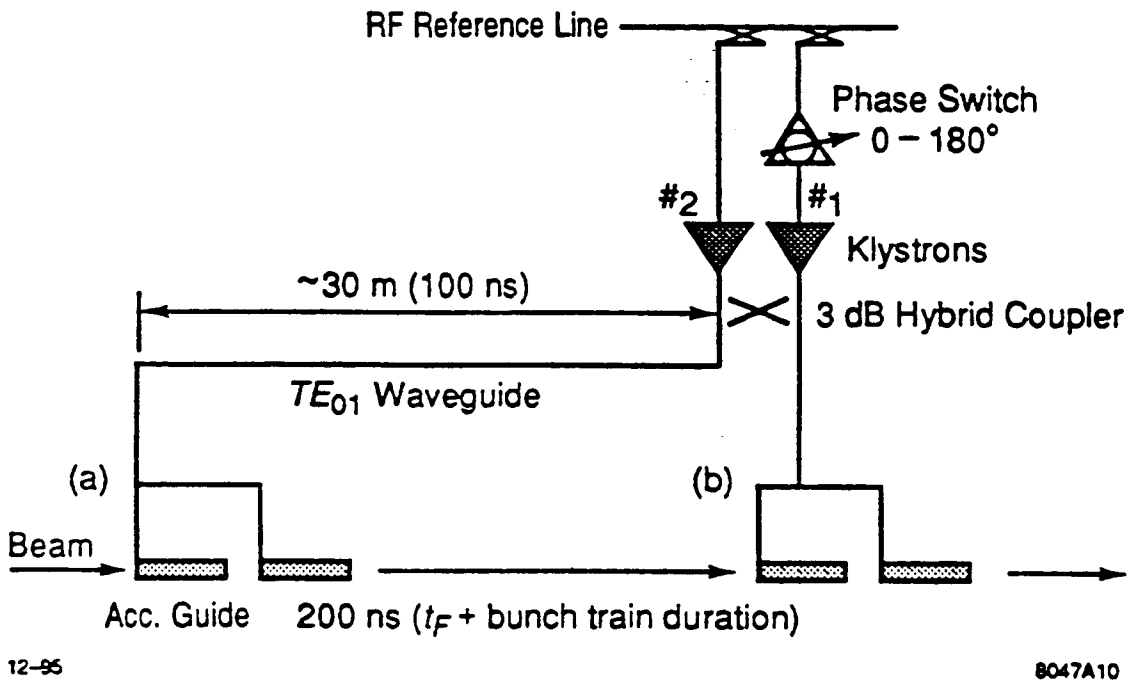
TWT

Klystr

Driver

DLDS Pulse Handling

H. Miguno
KEK/SLAC Workshop
1994



Schematic diagram of the Delay Line Distribution System (DLDS) for the JLC.

Compared to SLED II ...

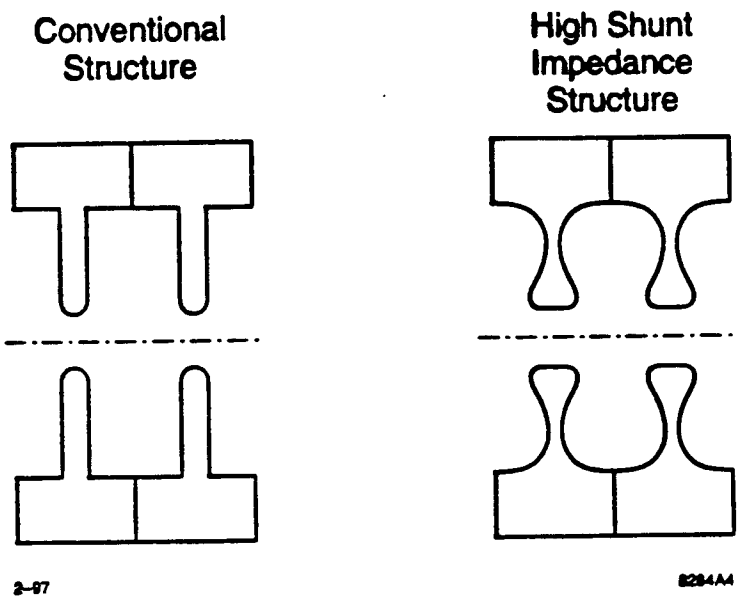
Improved power efficiency (70% → 95%)

Reduced peak power (factor 2)

Reduced temperature sensitivity

Accelerator Design Optimization

1. Structure Redesign



$Q \longrightarrow +15\%$

$r_s \longrightarrow +22\%$

2. Bunch Spacing

1.4 ns $\longrightarrow$ 2.8 ns

G_{NOLOAD} 85 MV/m $\longrightarrow$ 75 MV/m

(same loaded gradient of 65 MV/m)

$\longrightarrow$ Reduce number of required power sources by $\approx 33\%$.

Status ...

- Physics being done at the SLC ... we have a linear collider.

- Damping Ring ... ATF at KEK

  Ring operations underway.

- X-Band Accelerator ... NLCTA at SLAC

  Prototype RF components in hand.

  Multibunch energy compensation demonstrated.

- Final Focus Test Beam

  Required demagnification demonstrated.

- Systematic Feasibility Established ... (NLC ZDR/JLC DS)

$\Longrightarrow$ Ready to move to Conceptual Design phase.

1998 - 2001 Conceptual Design

- Engineering and Design

  Balance between performance, reliability, and cost.

  Coordination with international partners.

- Detector R&D

  Coordination with international partners.

2002 - 2008 Construction

- Another HEPAP Subpanel
- Constuction technically possible in 6-year period.