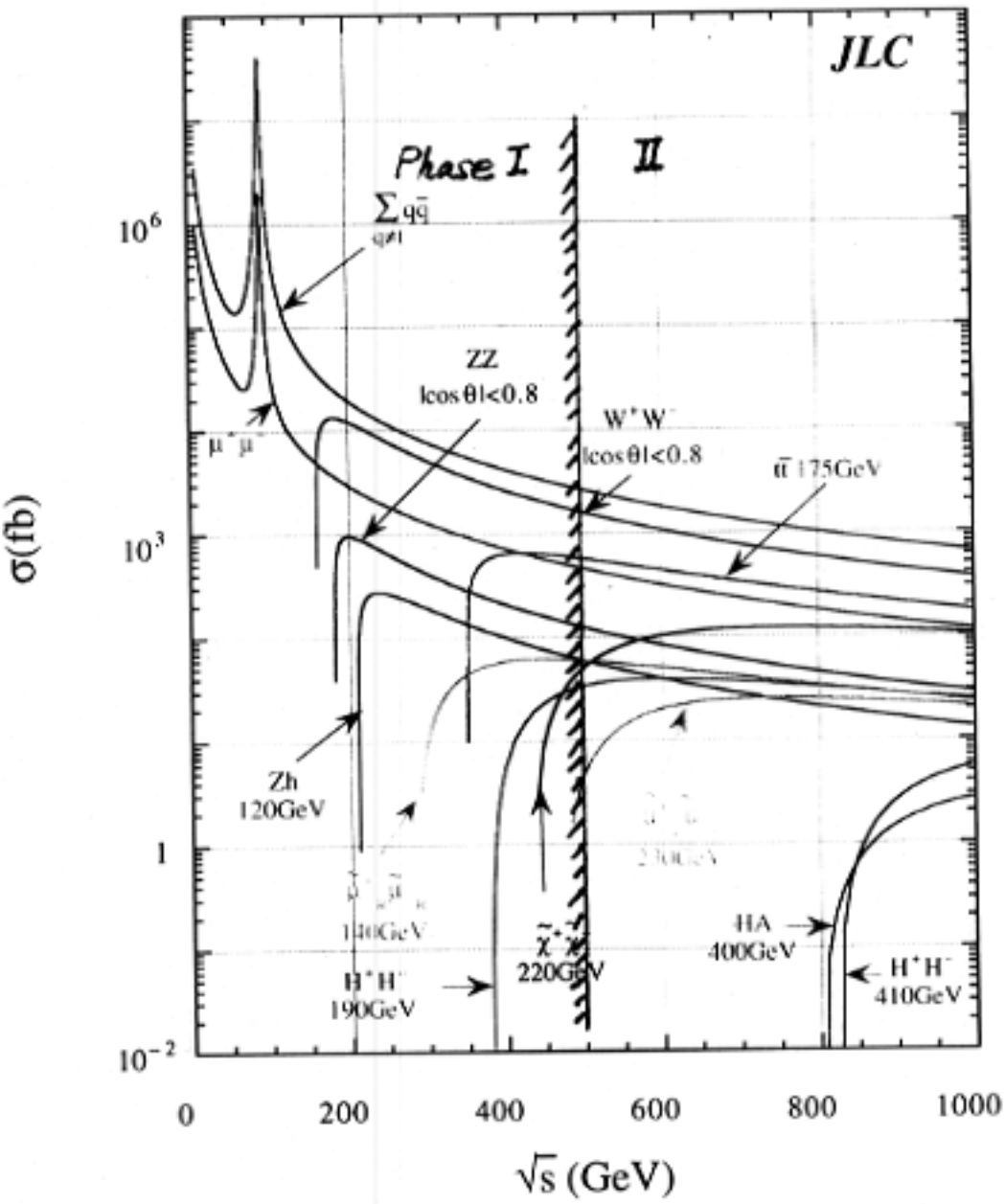
Linear Collider R&D

KEK Activities

- Physics Target
- Accelerator Test Facility
- ~~X-band System~~
- C-band System
- Physics and Detector Activities

Takayuki Matsui
KEK

Presented at
ICFA Seminar
Fermilab - 5-8 October 1999


JLC
Phase I
II
$\sum_{q\neq l} q\bar{q}$
ZZ
|cosθ|<0.8
W⁺W⁻
|cosθ|<0.8
μ⁺μ⁻
tt̄ 175GeV
Zh
120GeV
H⁺H⁻
190GeV
χ̃⁺χ̃⁻
220GeV
HA
400GeV
H⁺H⁻
410GeV
σ(fb)
10^6
10^3
1
10^{-2}
0
200
400
600
800
1000
√s (GeV)

Physics Targets of the e^+e^- linear collider

1000 fb^{-1} (5 years) Phase I

Higgs ~ 0.5M events

$m_{Higgs} < 215$ GeV (95% CL)

(All EW)

Top ~ 0.5M events

$m_{Top} = 174.3 \pm 5.1$ GeV

(FERMILAB-

W/Z ~ 10M events

Further Precision Electroweak Tests

SUSY ~ 50K events

Suggested by $\sin^2\theta_w$

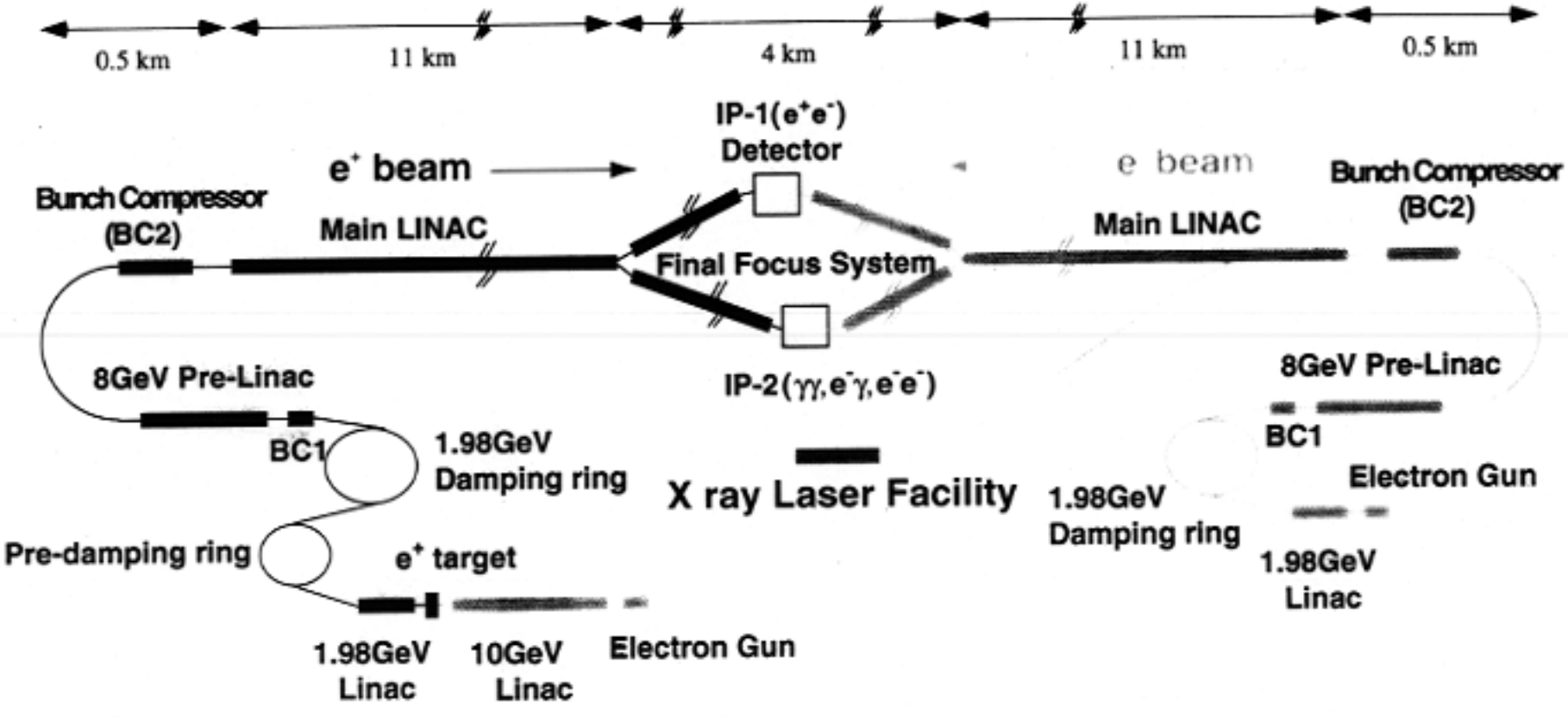
K. Yokoya.

250GeV (CM) Hi-Lum Parameters of JLC

		A	X	Y	
Luminosity	$10^{34}/\mathrm{cm}^2\mathrm{s}$	0.44	0.79	1.31	
Nominal Lum.[3]	$10^{34}/\mathrm{cm}^2\mathrm{s}$	0.32	0.54	0.88	$\propto n_b N^2/4\pi\sigma_x^*\sigma_y^*$
Bunch Population	10^{10}	0.75	0.55	0.70	
No. of bunches/pulse		95	190	190	
Bunch separation	ns	2.8	1.4	1.4	
Linac length/beam[7]	km	2.50	2.65	2.86	Cavity $L \times 1.25$
AC power (2 linacs)	MW	56	60	65	
Beam power/beam	MW	2.14	3.14	4.00	
Loaded gradient[4]	MV/m	57.6	54.2	50.2	
Bunch length σ_z	μm	90	80	80	
$\gamma\epsilon_x$ (DR exit)	10^{-6}m	3	3	3	
$\gamma\epsilon_y$ (DR exit)	10^{-6}m	0.03	0.02	0.02	
$\gamma\epsilon_x$ (IP)	10^{-6}m	4	4	4	
$\gamma\epsilon_y$ (IP)	10^{-6}m	0.06	0.04	0.04	
Cavity align. tol.[6]	μm	19	23	17	Transverse short-range wak
β_x^*	mm	10	6	6	
β_y^*	mm	0.1	0.1	0.1	
IP beam size σ_x^*	nm	404	313	313	
σ_y^*	nm	4.95	4.04	4.04	
Diagonal angle σ_x^*/σ_z	mrad	4.49	3.92	3.92	
Disruption param D_x		0.094	0.102	0.130	
D_y		7.67	7.90	10.06	
Pinch enh. H_D[5]		1.38	1.45	1.49	$E_b = 125$ GeV
Υ_{ave}		0.048	0.052	0.067	
δ_{BS}	%	1.46	1.46	2.31	
n_γ		0.80	0.76	0.97	

http://acfahep.kek.jp/wg-meeting/199903/program/yokoya.ps

Schematics of JLC accelerator complex



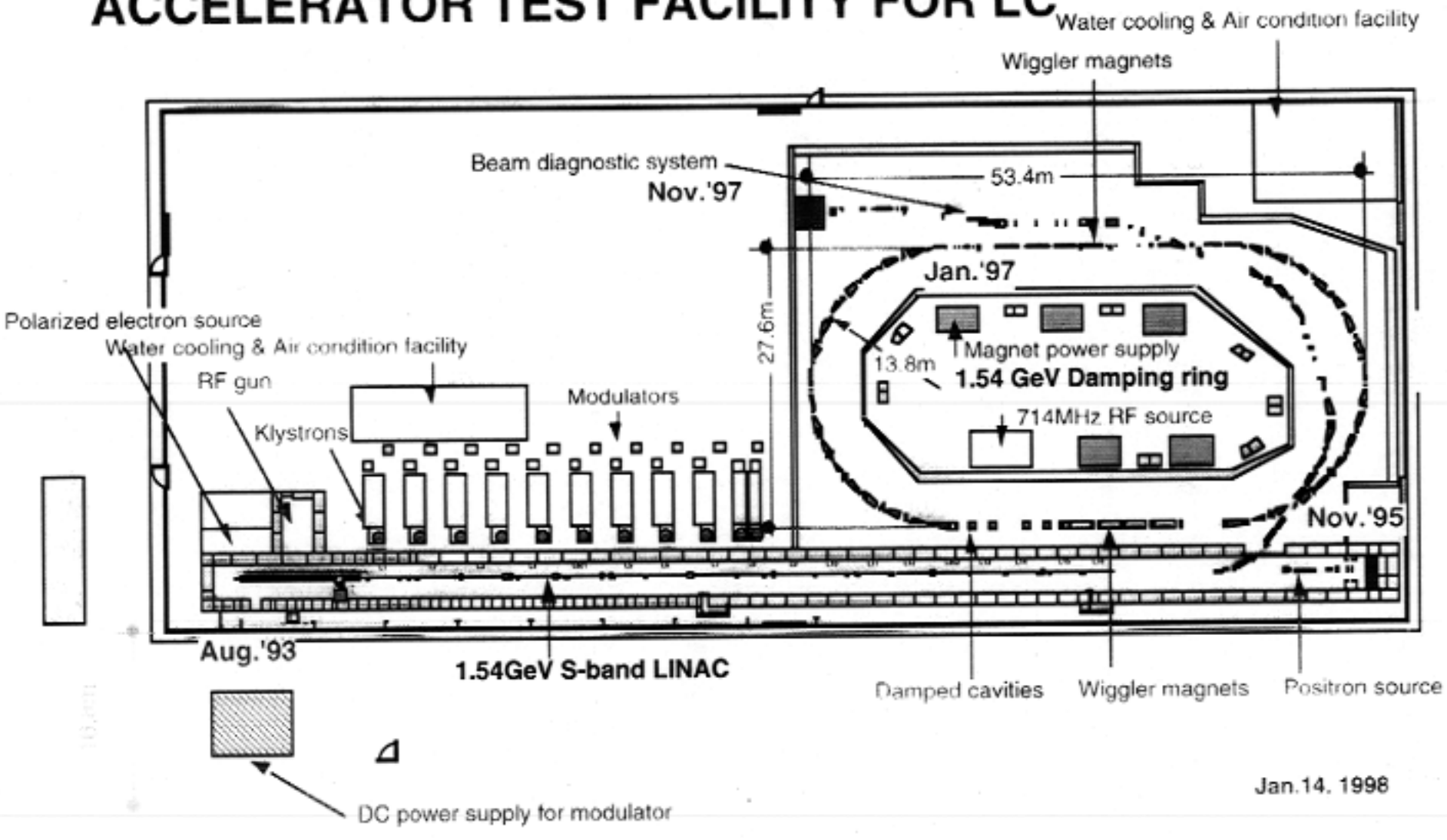
J. Urakawa

Beam Commissioning and Study
started since Jan. '97

International Collaboration with SLAC,
DESY, BINP, PAL, IHEP(Beijing), CERN,
INP, SEFT, and LBNL(9 Lab.)

Collaboration in Japan
Tokyo Metropolitan University,
Kyoto University,
Tohoku University,
Tokyo Science University,
Tohoku Gakuin University,
Nagoya University,
Yokohama National University,
Toho University, Waseda University(9 Univ.)

ACCELERATOR TEST FACILITY FOR LC



Jan.14. 1998

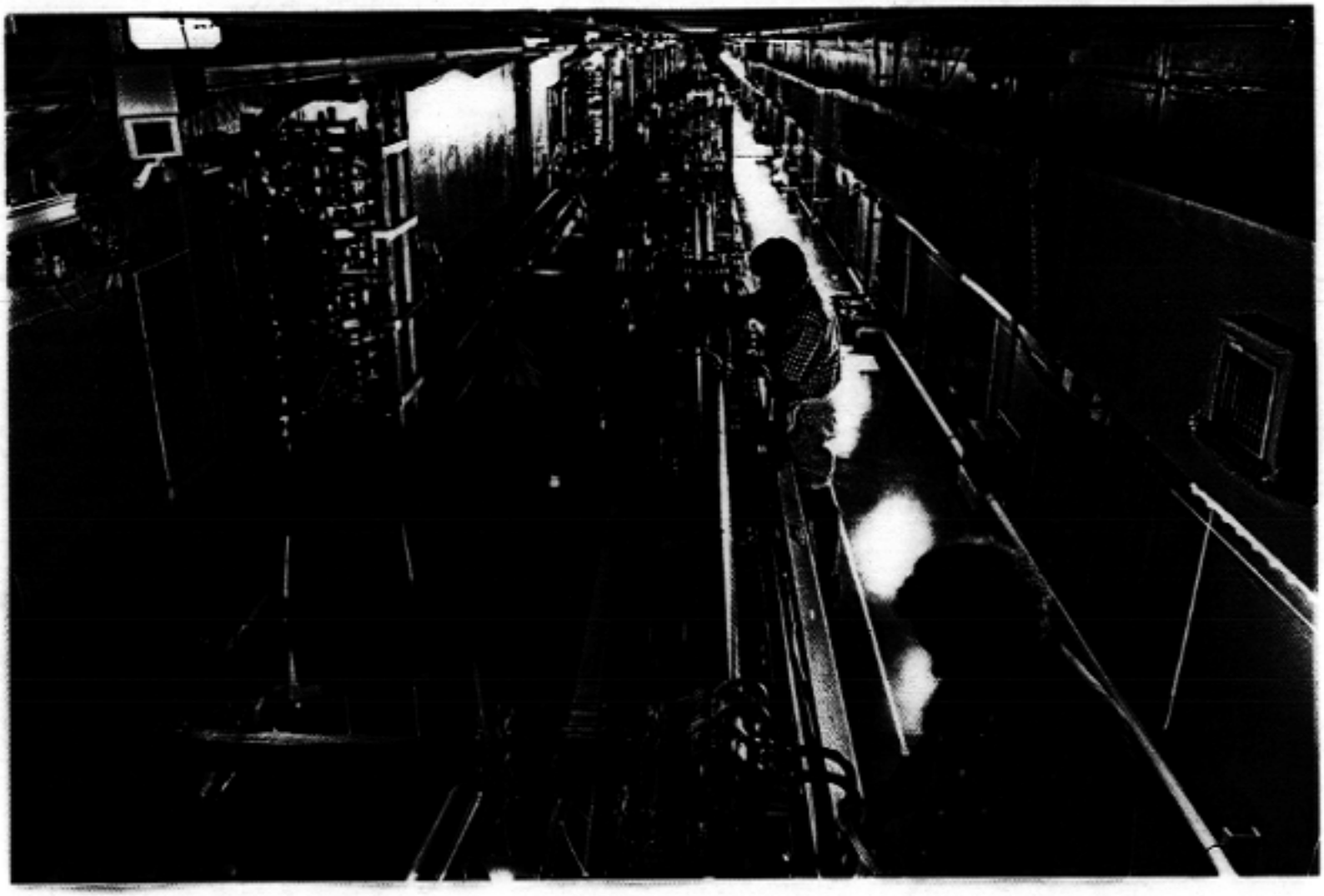
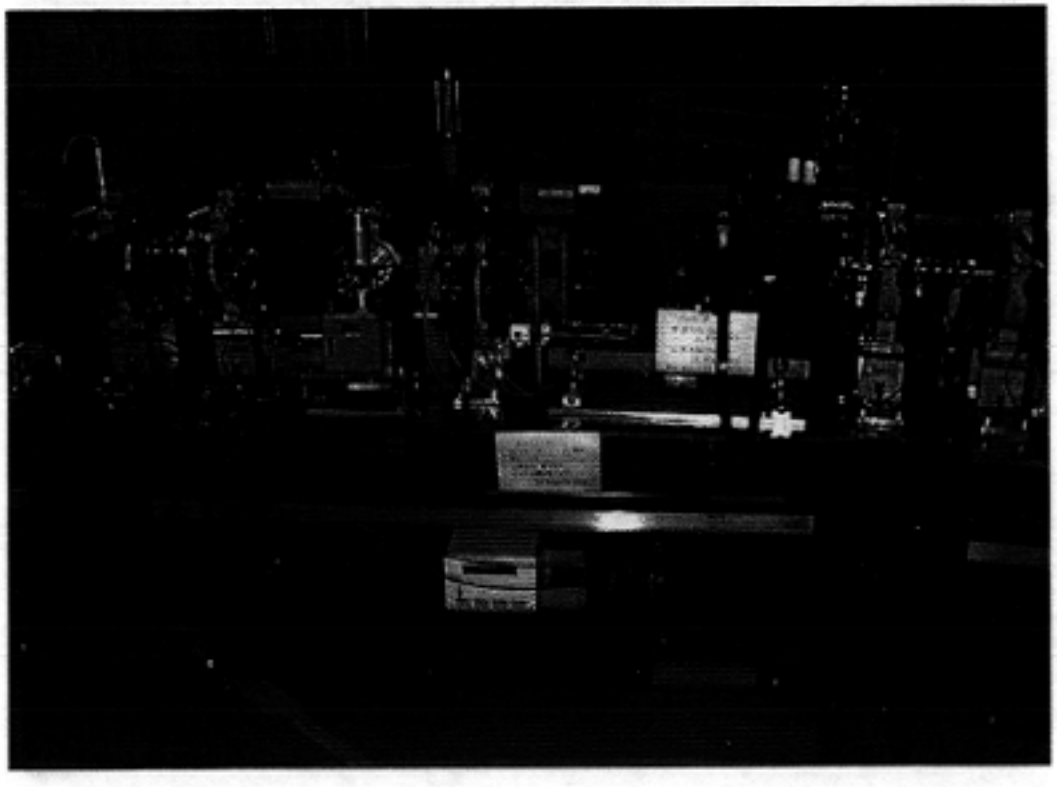


photo : T. Omori

ATF Linac

		[Goal]
Maximum Beam Energy	**1.42 GeV**	**1.54 GeV**
Maximum Gradient with Beam	**28.7 MV/m**	**30 MV/m (Average)**
Beam Intensity		
Single bunch	**2.4×10^{10}**	**2.0×10^{10}**
20 Multi-bunch	**7.56×10^{10}**	**4.0×10^{11} (Total)**
Energy Spread	*0.37%*	
Single bunch	*(1.0 % @ 2.4×10^{10})*	**< 0.38 %**
20 Multi-bunch with ECS	**0.37 %**	**< 0.38 % (FWHM)**
Emittance $\gamma\varepsilon_x$ (at 80 MeV)		
Single bunch	**2.5×10^{-4}**	**$< 3.0 \times 10^{-4}$**
20 Multi-bunch	**$\sim 7 \times 10^{-5}$**	**$< 3.0 \times 10^{-4}$ (rms)**

ATF Damping Ring Normal Cell



ATF Damping Ring Normal Cell (May 22, 1997)

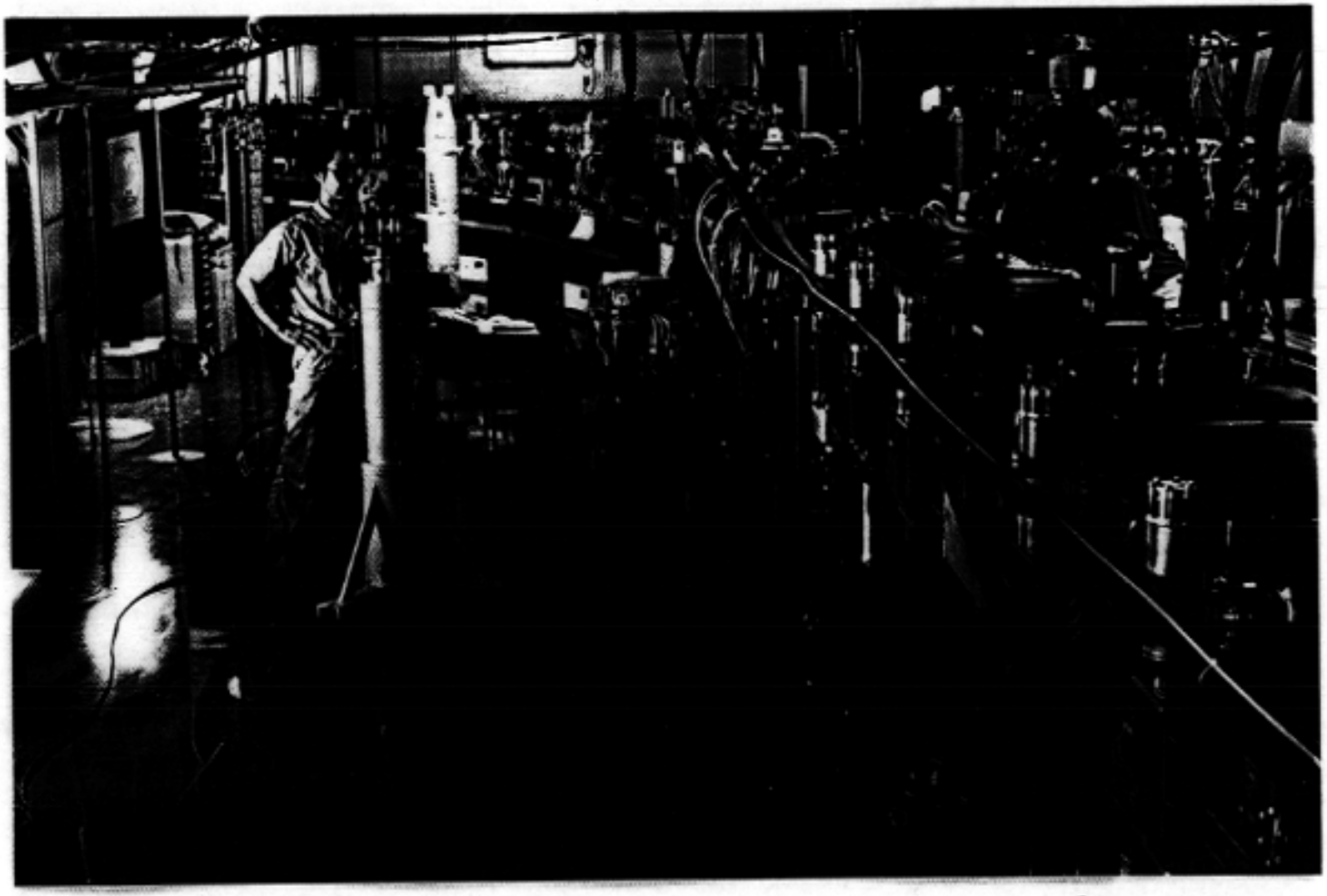
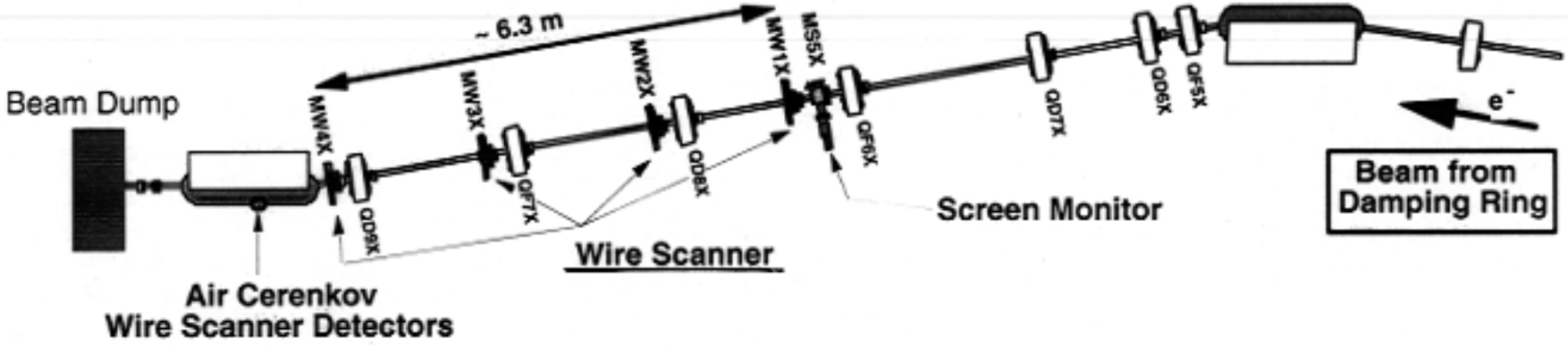


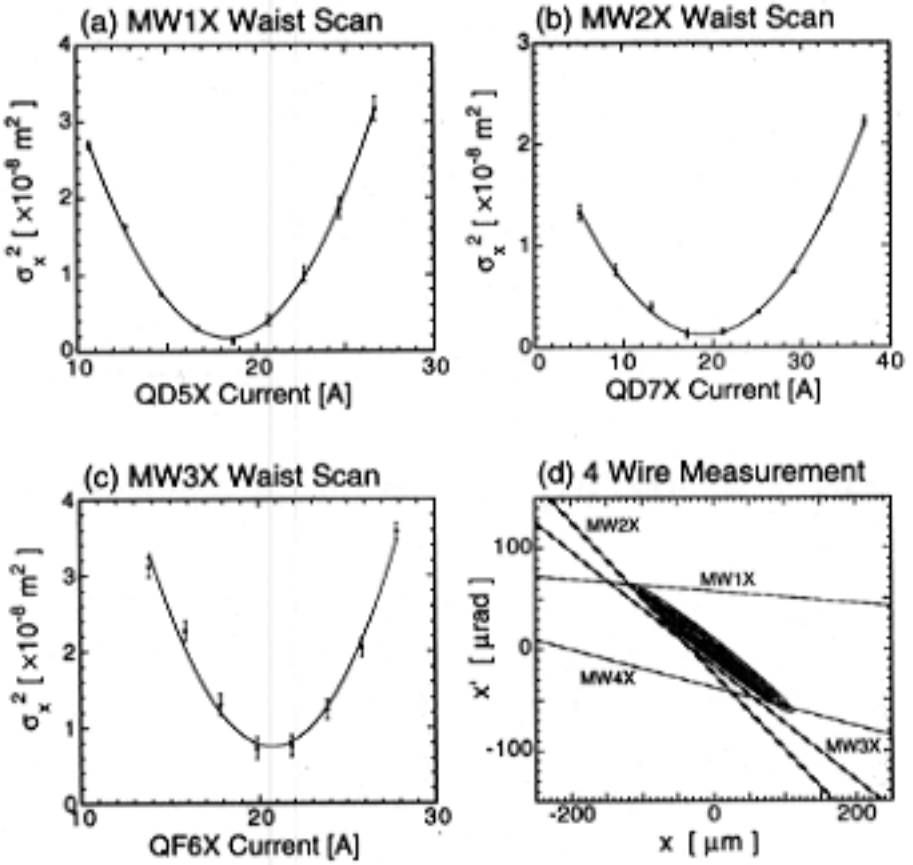
photo: T. Omori


~ 6.3 m
Beam Dump
MW4X
MW3X
MW2X
MW1X
MS5X
QD9X
QF7X
QD8X
QF6X
QD7X
QD6X
QF5X
e-
Beam from
Damping Ring
Screen Monitor
Wire Scanner
Air Cerenkov
Wire Scanner Detectors

T. Okugi et al.

Horizontal Emittance Evaluation

Two different methods are used for horizontal emittance evaluation. One is a waist scan method, and the other is a four wire method. The waist scan method is the method to evaluate a beam emittance by measuring a beam size with single wire scanner while changing strength of a quadrupole magnet located upstream of the wire scanner.The four wire method is the method to evaluate a beam emittance by measuring beam sizes with four wire scanners.



Method	Monitor	Emittance [nm]	B_{mag}
Waist Scan	MW1X	1.47 ± 0.06	1.03 ± 0.07
Waist Scan	MW2X	1.27 ± 0.06	1.00 ± 0.03
Waist Scan	MW3X	1.38 ± 0.05	1.02 ± 0.05
Four Wire	All Monitors	1.29 ± 0.11	1.06 ± 0.34
Average		1.37 ± 0.03	α_x:3.83 β_x:6.77

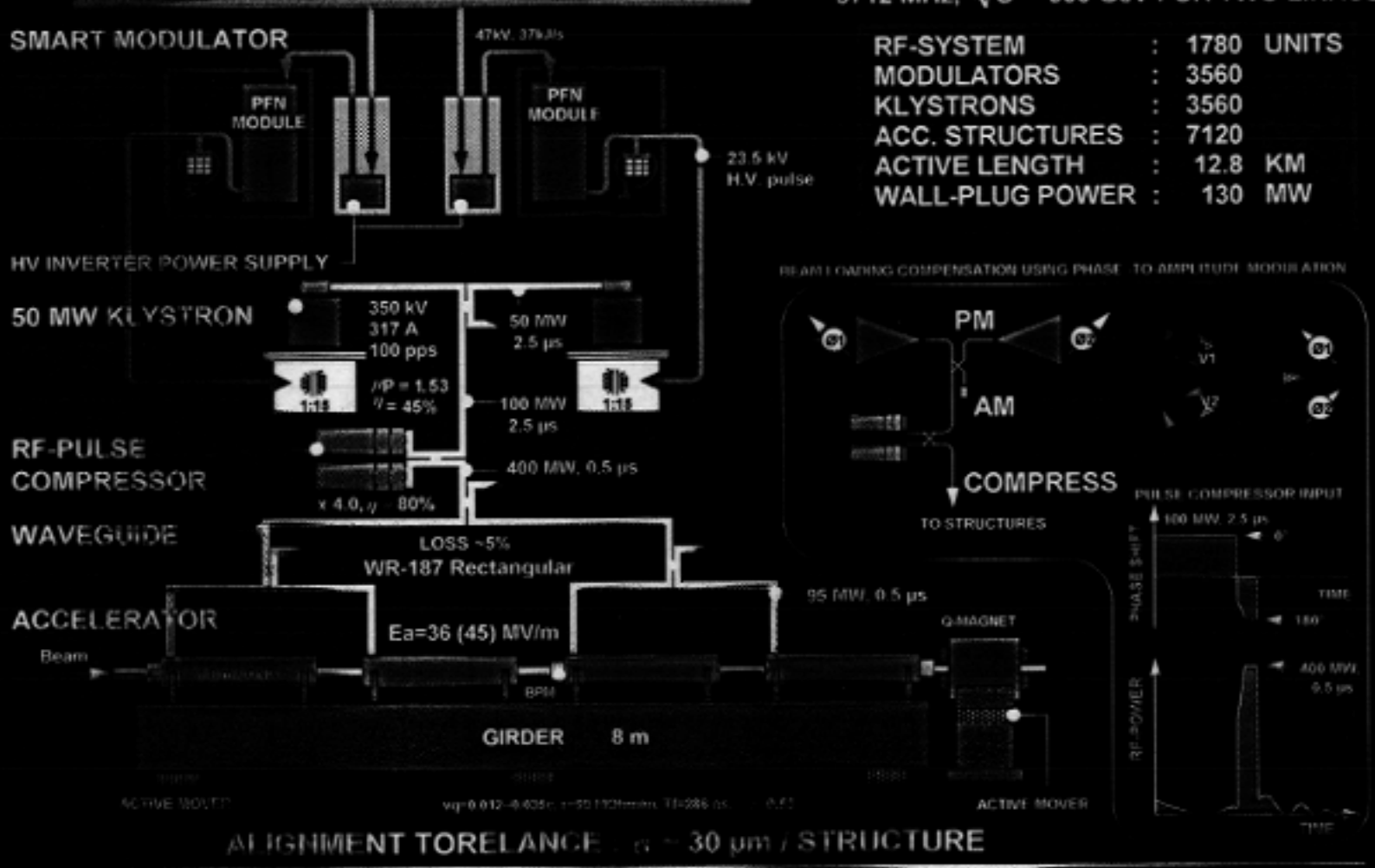
ε_x : 1.29 ± 0.11 $\times 10^{-9}$ radm. 1.47 with intra-beam

ε_y : 4.11 ± 0.16 $\times 10^{-11}$ radm. 1.47 ($\varepsilon_x \times 10^{-2}$)

T. Shintake, H. Matsumoto ....

C-band LC

C-band LINAC RF-SYSTEM LINEAR COLLIDER



5712 MHz, $\sqrt{S}$ = 500 GeV FOR TWO LINACS

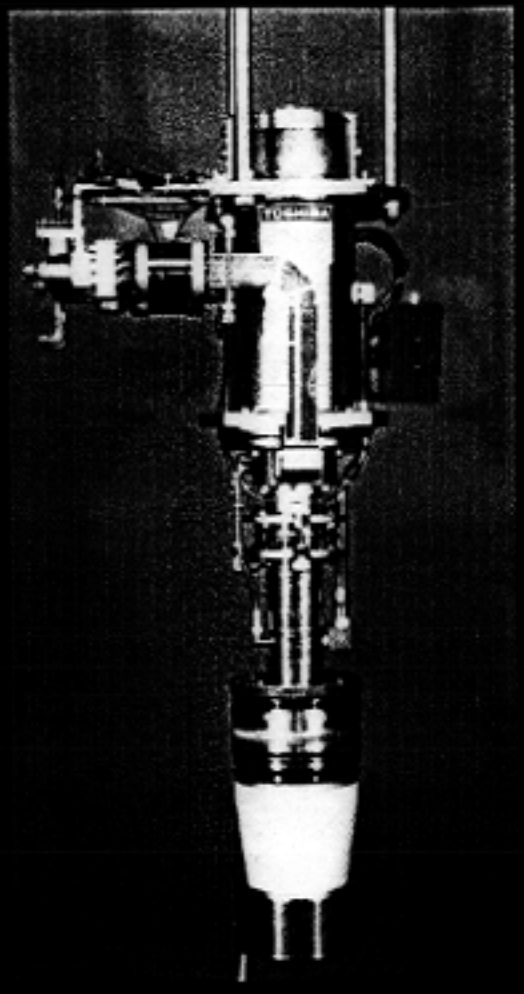
RF-SYSTEM	:	1780	UNITS
MODULATORS	:	3560	
KLYSTRONS	:	3560	
ACC. STRUCTURES	:	7120	
ACTIVE LENGTH	:	12.8	KM
WALL-PLUG POWER	:	130	MW

ALIGNMENT TORELANCE ... 30 μm / STRUCTURE

Linear Collider

C-band Klystron Development

Accumulated operating time is 4,500 hours since April in 1998



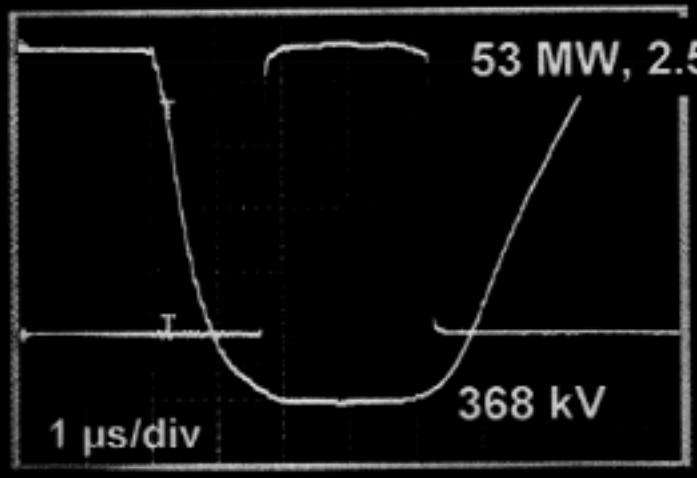
Traveling-wave output structure

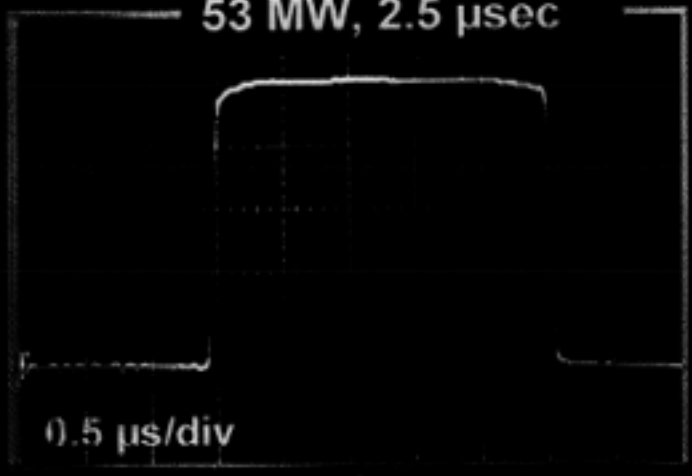
Solenoid Focus (4.6kW)

1.5 μP

Dispenser Cathode (D74.5mm,6.3A/cm²)

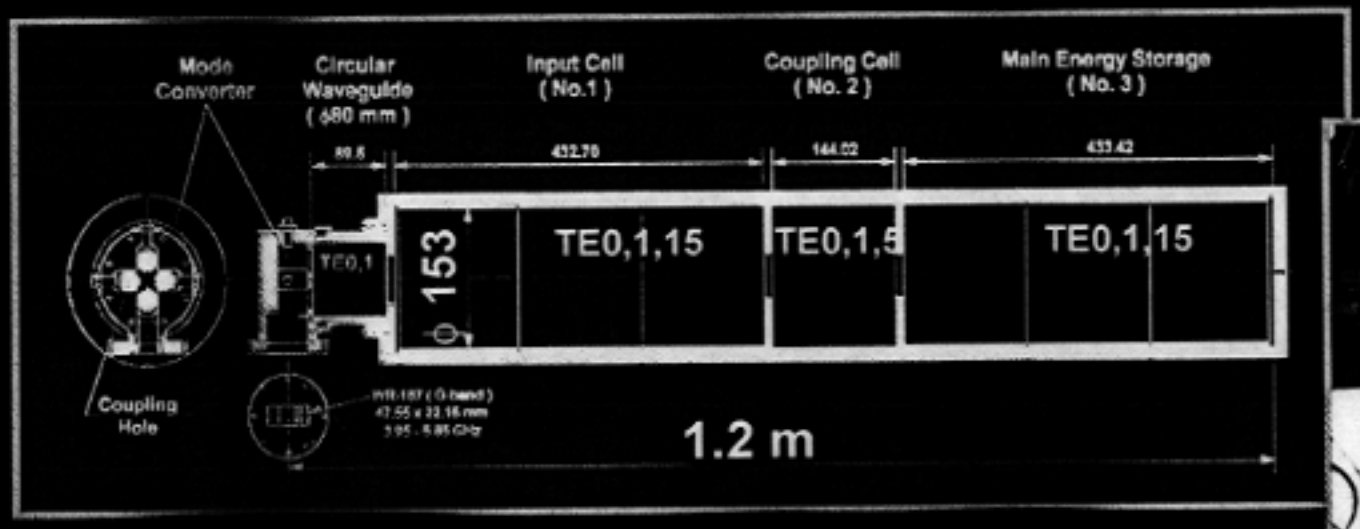
TOSHIBA E3746 No.2



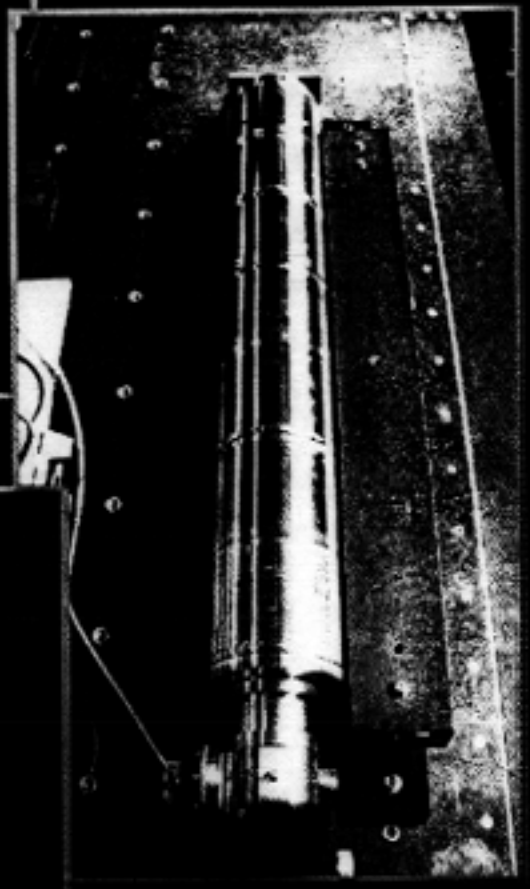


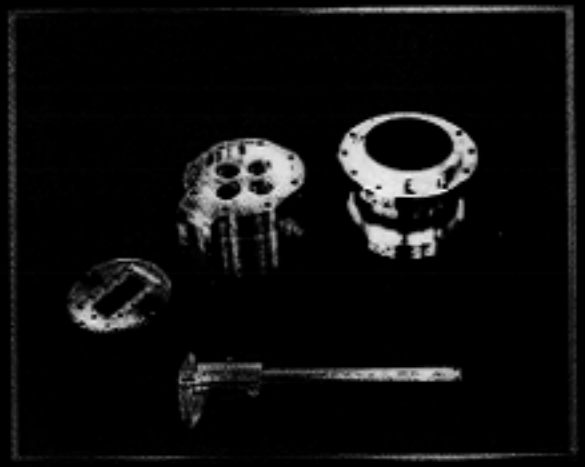
53 MW, 2.5 μsec, 50 pps, 44%

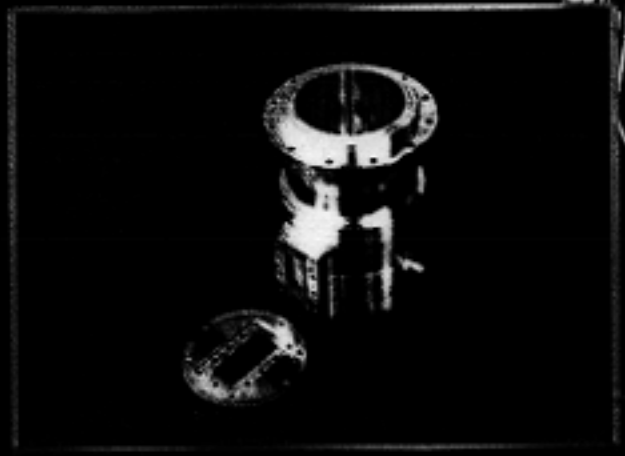
RF Pulse Compressor



Cold-Model Cavity



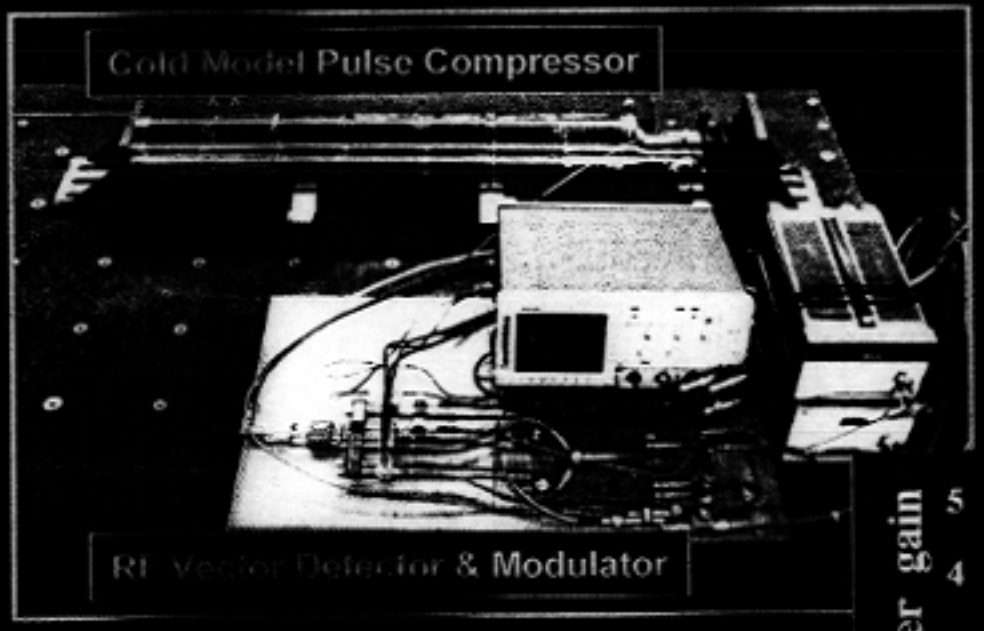




Mode Converter

New High-Efficiency Scheme

Demonstration Aug. 1998



* System efficiency can be made higher.
* HV modulator design becomes easy.
(Allow slow rise time & a few % ripple.)

Phase-Correction on Klystron

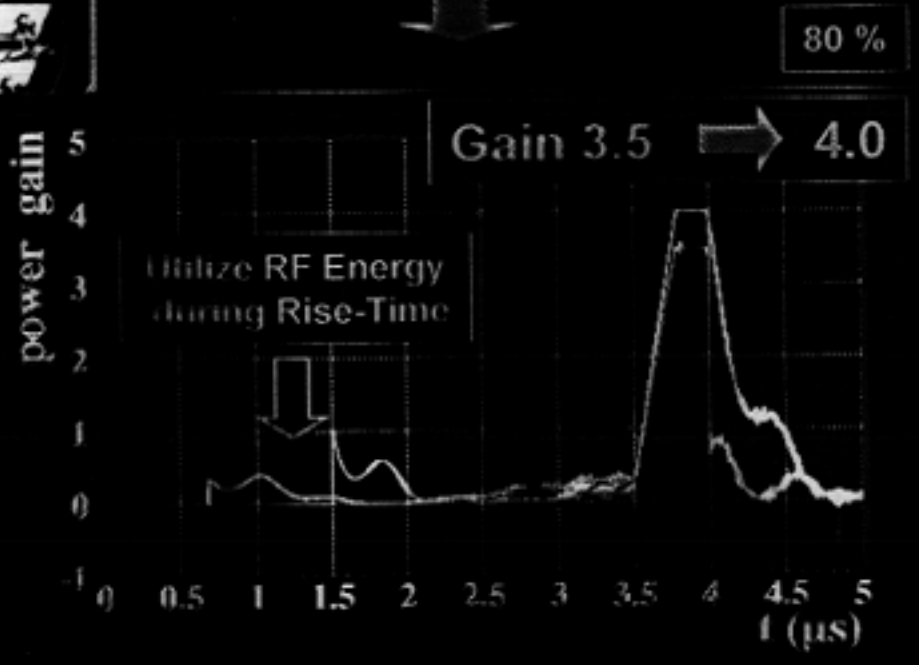
⇩

Flat Phase Output

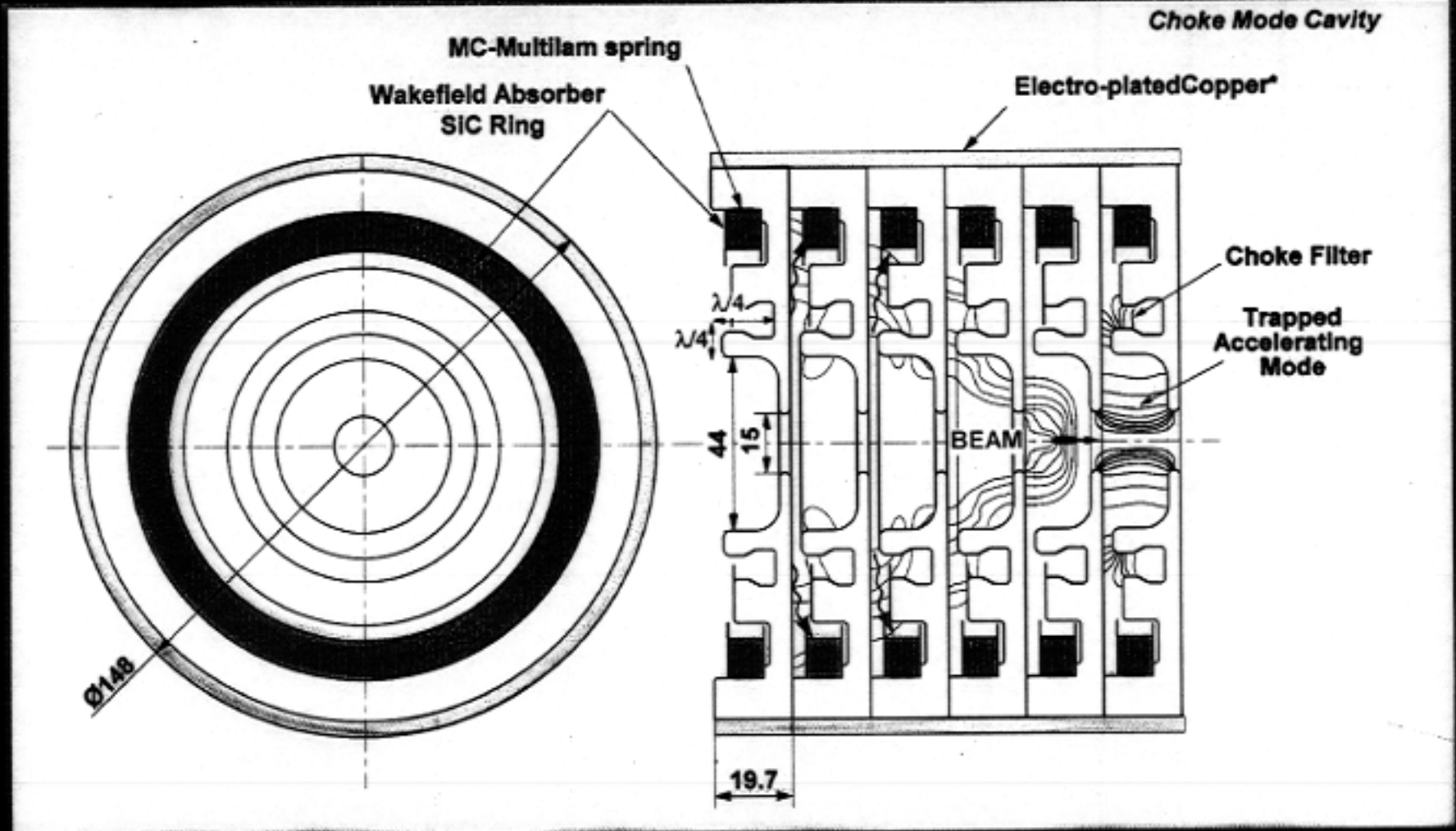
⇩

Gain & Efficiency Improvement

⇩



Choke-Mode Accelerating Structure

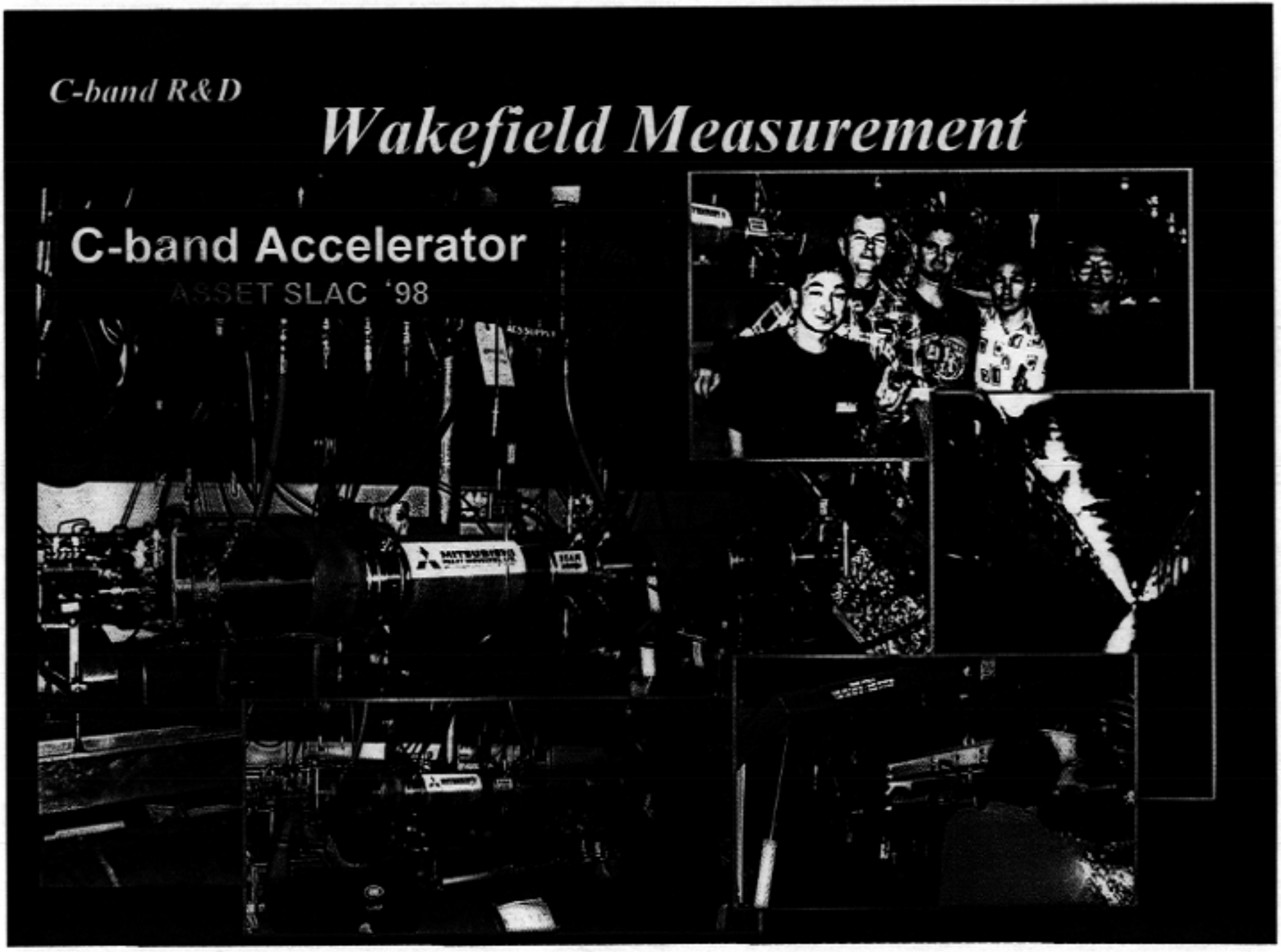


C-band Accelerating Structure

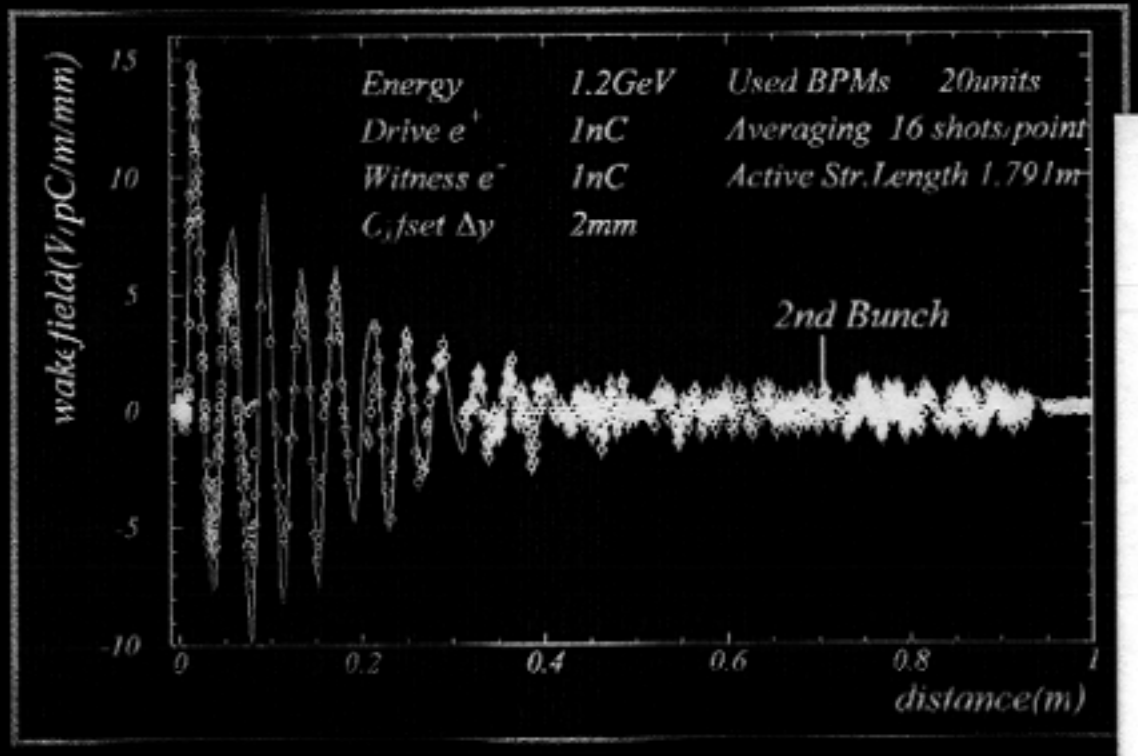
Full Scale Structure
1.8 m long

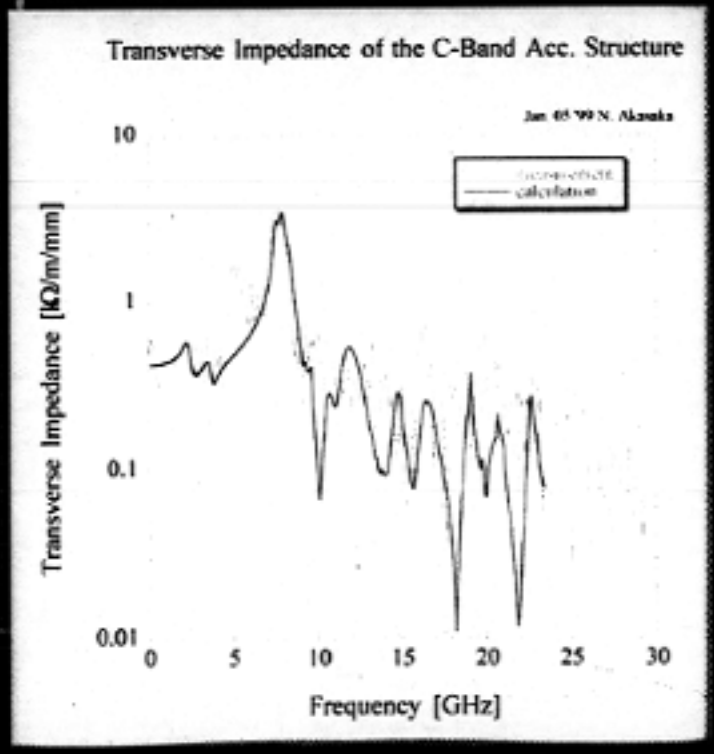
C-band R&D

Wakefield Measurement

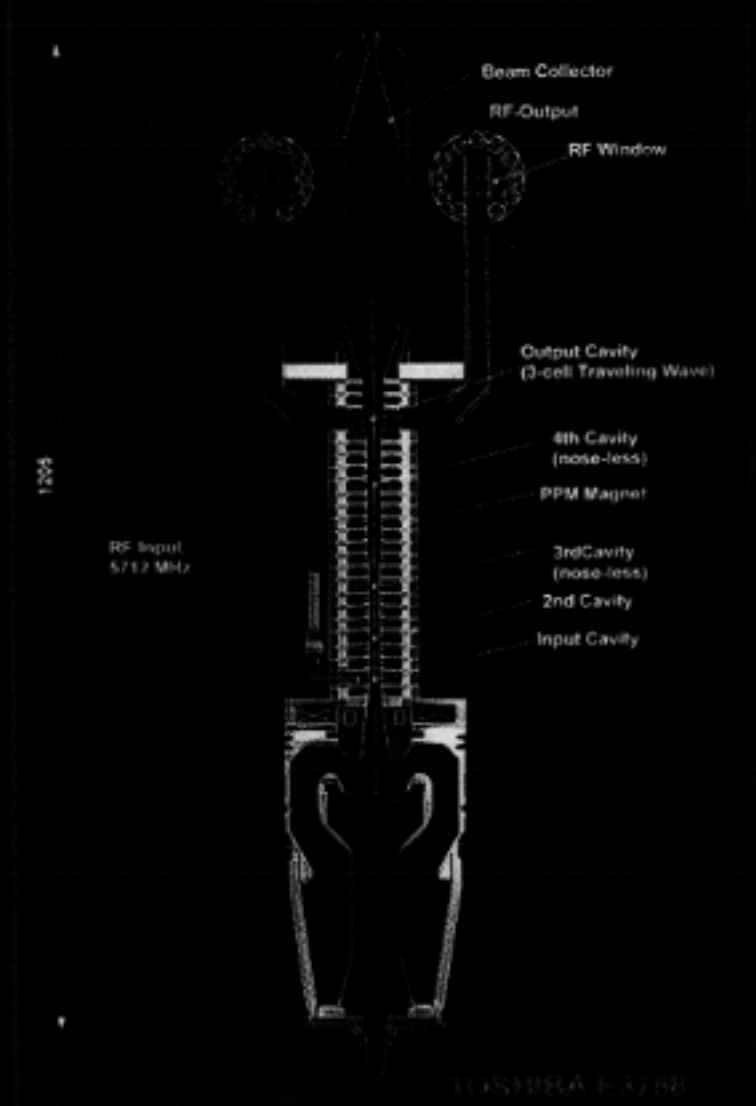


Measured Wakefield

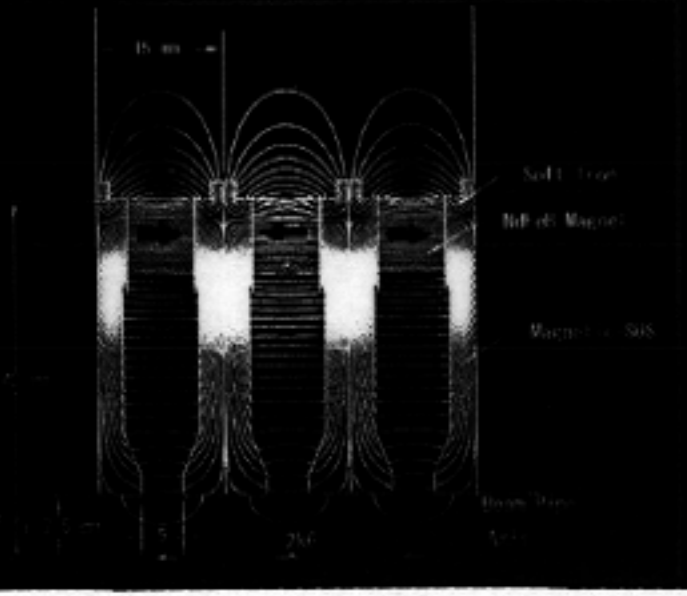




C-band PPM Klystron (1999 Model)



- Periodic Permanent Magnet Focused
- Permanent Magnet : NdFeB
- Designed parameter
  - Peak output : 50 MW
  - Efficiency : 50%
  - μ Perveance : 1.53
  - Voltage : 350 kV
  - Pulse Width 2.5 μsec



ACFA Joint Linear Collider Physics and Detector Working Group

54 Institutions

- Univ. of Melbourne

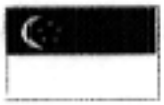
- Beijing Univ.
- IHEP
- Institute of Theoretical Physics, Academia Sinica
- Shandong Univ.
- Tsinghua Univ.
- Zhejiang Univ.

- Indian Institute of Science
- Physical Research Laboratory
- TIFR
- The Institute of Mathematical Sciences

- Akita Keizaihoka Univ.
- Hiroshima Univ.
- KEK
- Kinki Univ.
- Kobe Univ.
- Kogakuin Univ.
- Konan Univ.
- Kyoto Univ.
- Miyagi Gakuin
- Nagoya Univ., N-lab.
- Nagoya Univ., Pol-lab.
- Niigata Univ.
- Niihama NCT
- Ochanomizu Univ.
- Osaka City Univ.
- Osaka Univ.
- Saga Univ.
- Shinshu Univ.
- Tohoku Univ.
- Tohokugakuin Univ.
- Tokyo A&T
- Tokyo Metropolitan Univ.
- Toyama NCMT
- Univ. of Tokyo, ICEPP
- Univ. of Tsukuba

- Chonbuk Univ.
- KAIST
- KIAS
- Konkuk Univ.
- Korea Univ.
- Kyungpook National Univ.
- Seoul National Univ.
- Soongsil Univ.
- Yonsei Univ.

- Mindanao State Univ.
- Univ. of the Philippines



- National Univ. of Singapore

- Academia Sinica
- Central Univ.
- Taiwan Univ.

- UCLA
- Univ. of Hawaii

- Institute of Physics

JLC detector

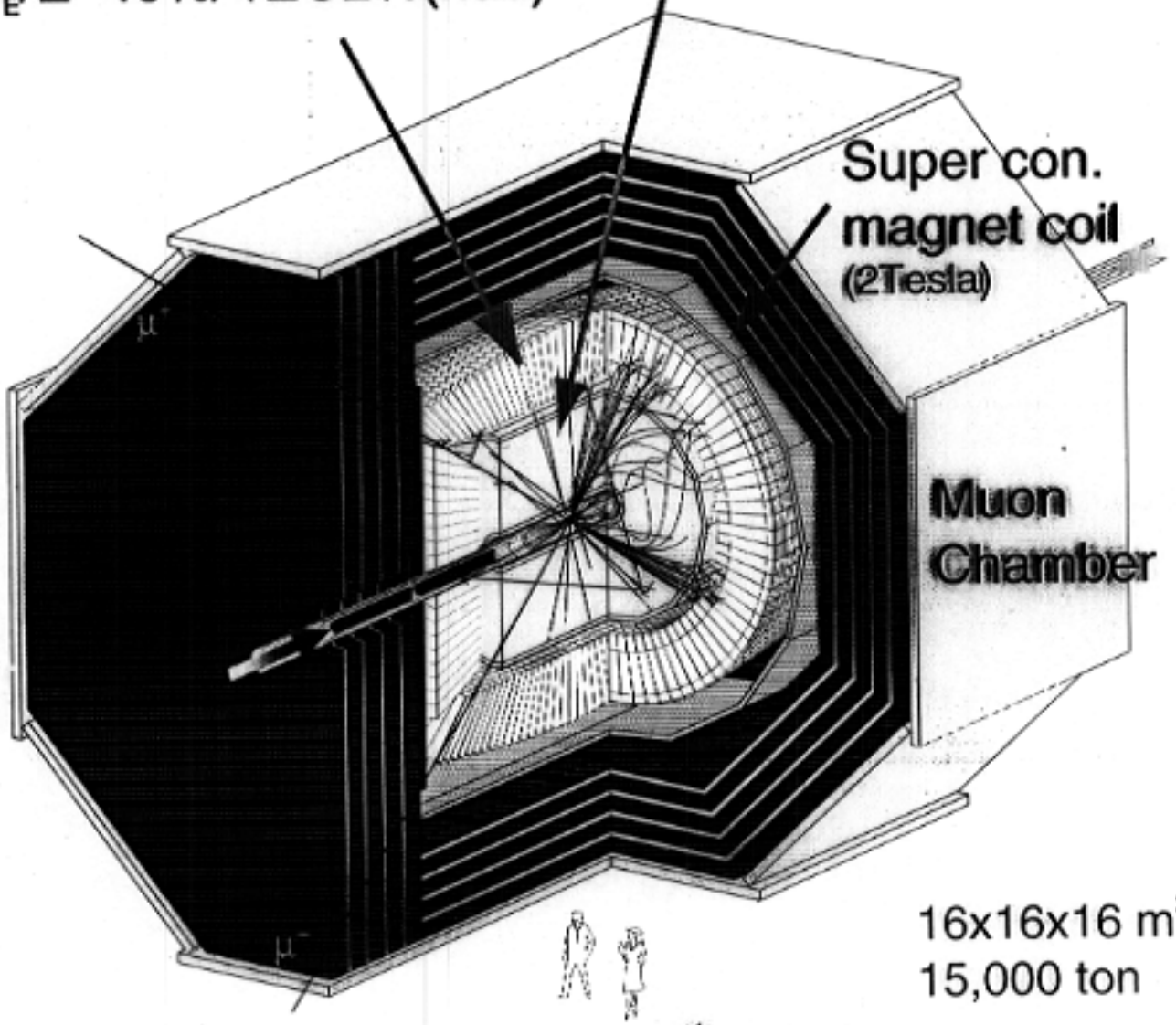
Central Drift Chamber

$\sigma_{P_t}/P_t = 1.1\times10^{-4} P_t \oplus 0.1\%$

Calorimeter

$\sigma_E/E = 15\%/\sqrt{E} \oplus 1\%$ (e,γ)

$\sigma_E/E = 40\%/\sqrt{E} \oplus 2\%$(had)



16x16x16 m^3
15,000 ton

magnifing IP,

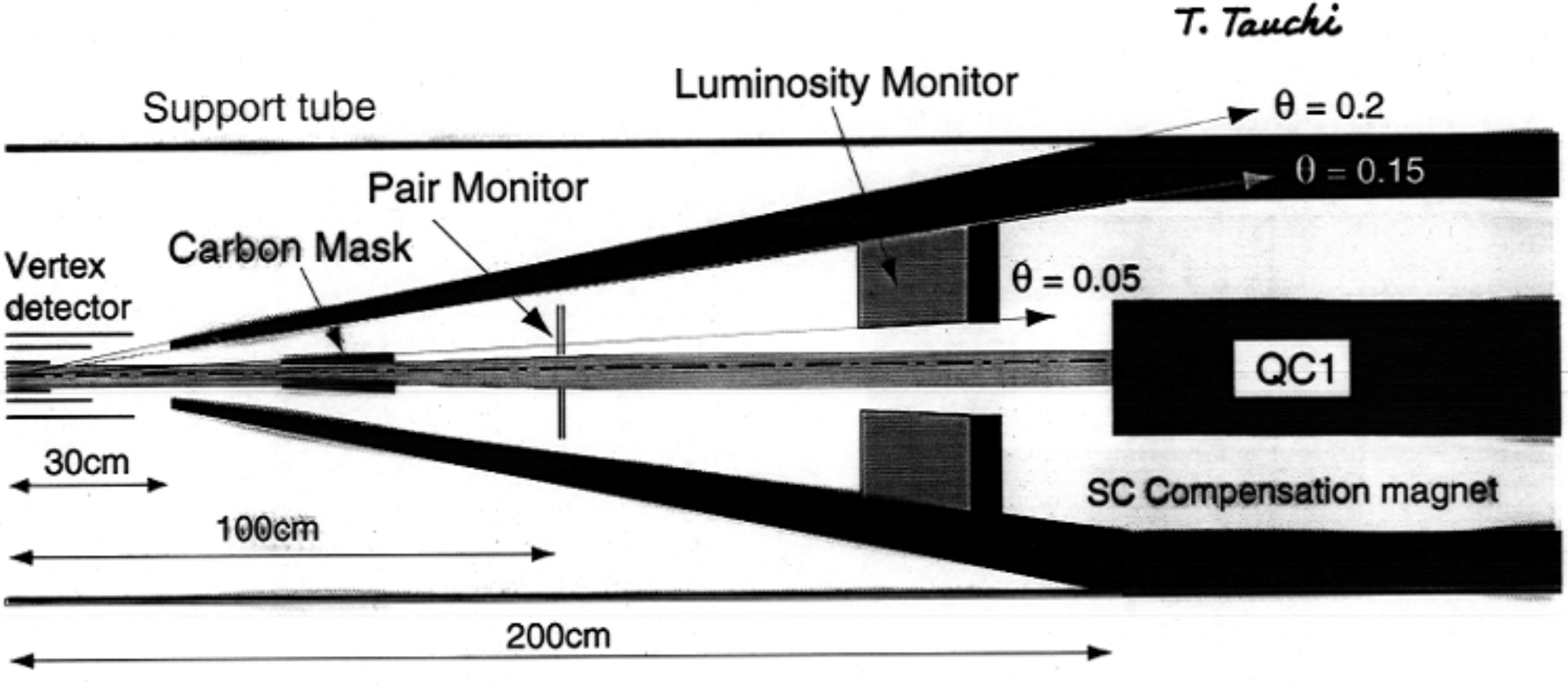
Vertex Detector

$\delta^2 = 11.4^2 + (28.8/P)^2/\sin^3\theta$ (μm^2)

JLC Detector Parameters

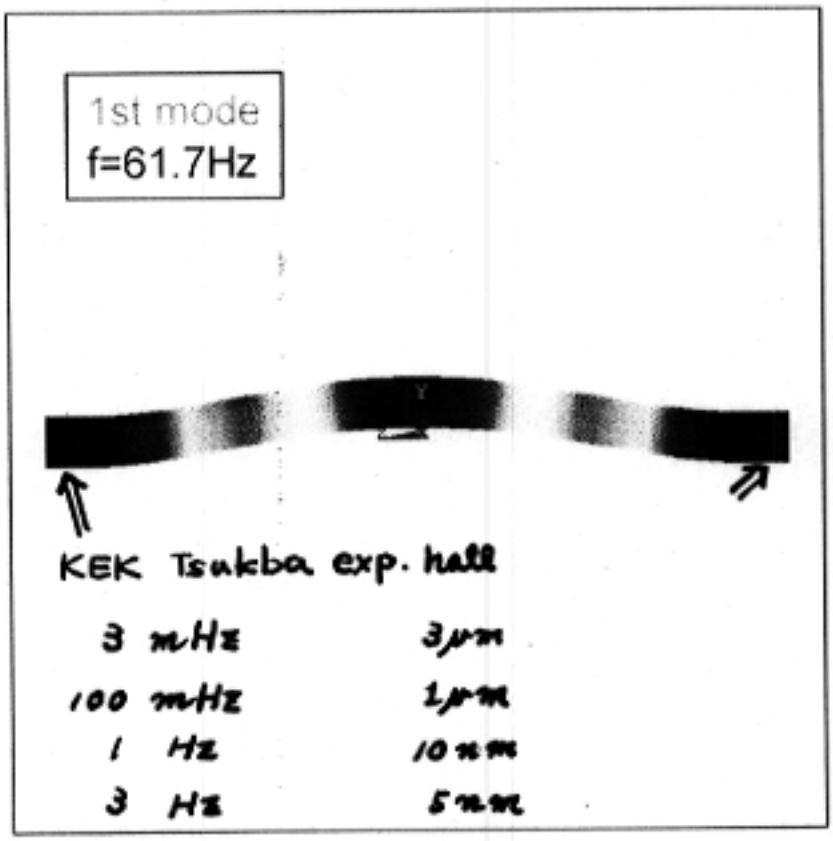
31 August, 1999

Detector	Type	Configuration / Read-out	Performance	Number of Channels & Data			
				Origin	Channel count		Typical data size
					Total	One train	
VTX	Silicon CCD	Pixel size; 25μm Number of layers; 4 Layer position; 2.4/3.6/4.8/6.0cm Thickness; 200μm/layer $\|\cos\theta\| < 0.9$	Position resolution; $\sigma = 4\mu m$ Impact parameter resolution δ(μm); $\delta^2 = 7^2 + (20.0/p)^2/\sin^3\theta$	Thermal noise BG track Signal track		90K 270K Small	360K 1M
		10-MHz (50-MHz) FADC		Total	320M	360K	1.4M
CDC	Small-cell Jet Chamber	Radius; 0.4~2.3m Length; 4.6m Number of sampling; 86 $\|\cos\theta\| < 0.70$ (Full sampling) $\|\cos\theta\| < 0.95$ (20 sampling)	Position resolution; $\sigma_x = 86\mu m$ (by axial wires) $\sigma_z = 1mm$ (by stereo wires) Momentum resolution; $\sigma_{Pt} = 1.1 \times 10^{-4}$ Pt ⊕ 0.1% $\sigma_{Pt} = 5 \times 10^{-3}$ Pt ⊕ 0.1% with vertex constraint	Soft photon Mini-jet Signal track		80K 2M 800K	320K 8M 3.2M
		200-MHz 12-bit FADC		Total	17M	2.9M	12M
CAL	Lead + Plastic Scintillator Sandwich (Compensated)	EM: Thickness; $29X_0$ Cell size; 10cm × 10cm	Energy resolution; $\sigma_E/E = 15\%/\sqrt{E} \oplus 1\%$ (e & γ) $\sigma/E = 40\%/\sqrt{E} \oplus 2\%$ (Hadron)	EM HAD Si Pad	20K 10K 2M	1.2K 0.6K 6.0K	4.8K 2.4K 24.0K
		HAD: Thickness; $5.6\lambda_0$ Cell size; 20cm × 20cm Longitudinal segment; 2 segments					
		Si pad: Pad size; 1cm × 1cm		Total	2M	7.8K	30K
		$\|\cos\theta\| < 0.9$					
		12-bit ADC					
MUON	TGC(?) RPC(?) Drift Chamber(?)	Number of superlayers; 6 $\|\cos\theta\| < 0.99$	Position resolution; ~ mm Pt > 2.2GeV/c; Reach return yoke Pt > 5.2GeV/c; Penetrate return yoke	TBD	TBD	TBD	TBD


T. Tauchi
Support tube
Luminosity Monitor
θ = 0.2
θ = 0.15
Pair Monitor
Carbon Mask
Vertex
detector
θ = 0.05
QC1
30cm
SC Compensation magnet
100cm
200cm

H. Yamaoka

Spectrum Analysis by ANSYS

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SEP 30 1999
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SUB =1
FREQ=61.696
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RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.101E-04
SMN =-.509E-07
SMX =.101E-04
   .281E-07
   .581E-06
   .121E-05
   .185E-05
   .248E-05
   .311E-05
   .374E-05
   .437E-05
   .501E-05
   .564E-05
   .627E-05
   .690E-05
   .753E-05
   .817E-05
   .880E-05
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   .101E-04
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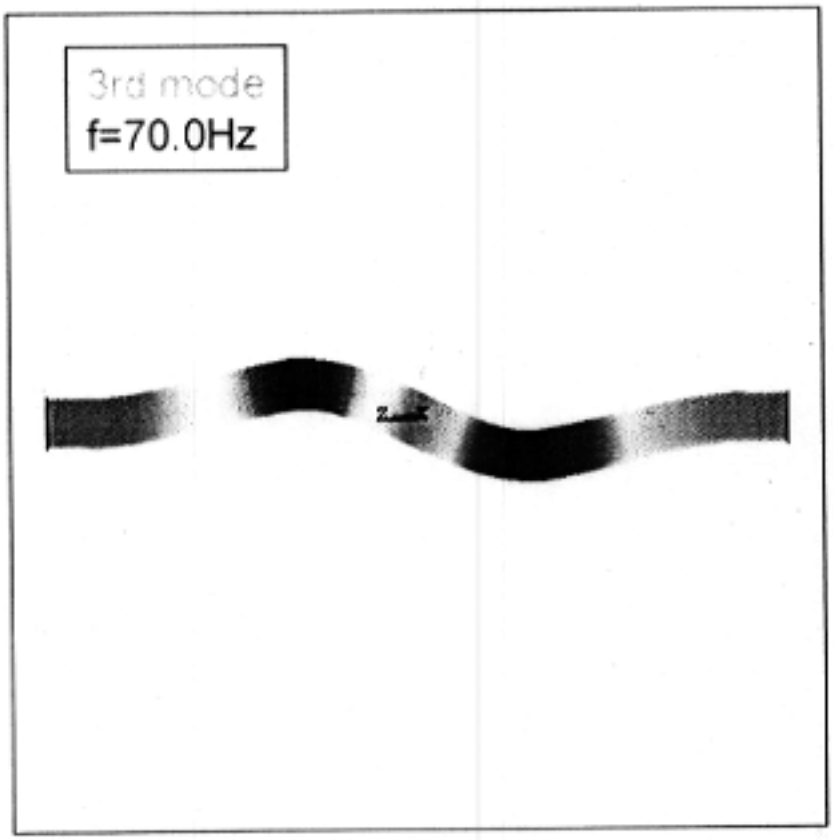
unit : mm

0.28 nm

10 nm

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SEP 30 1999
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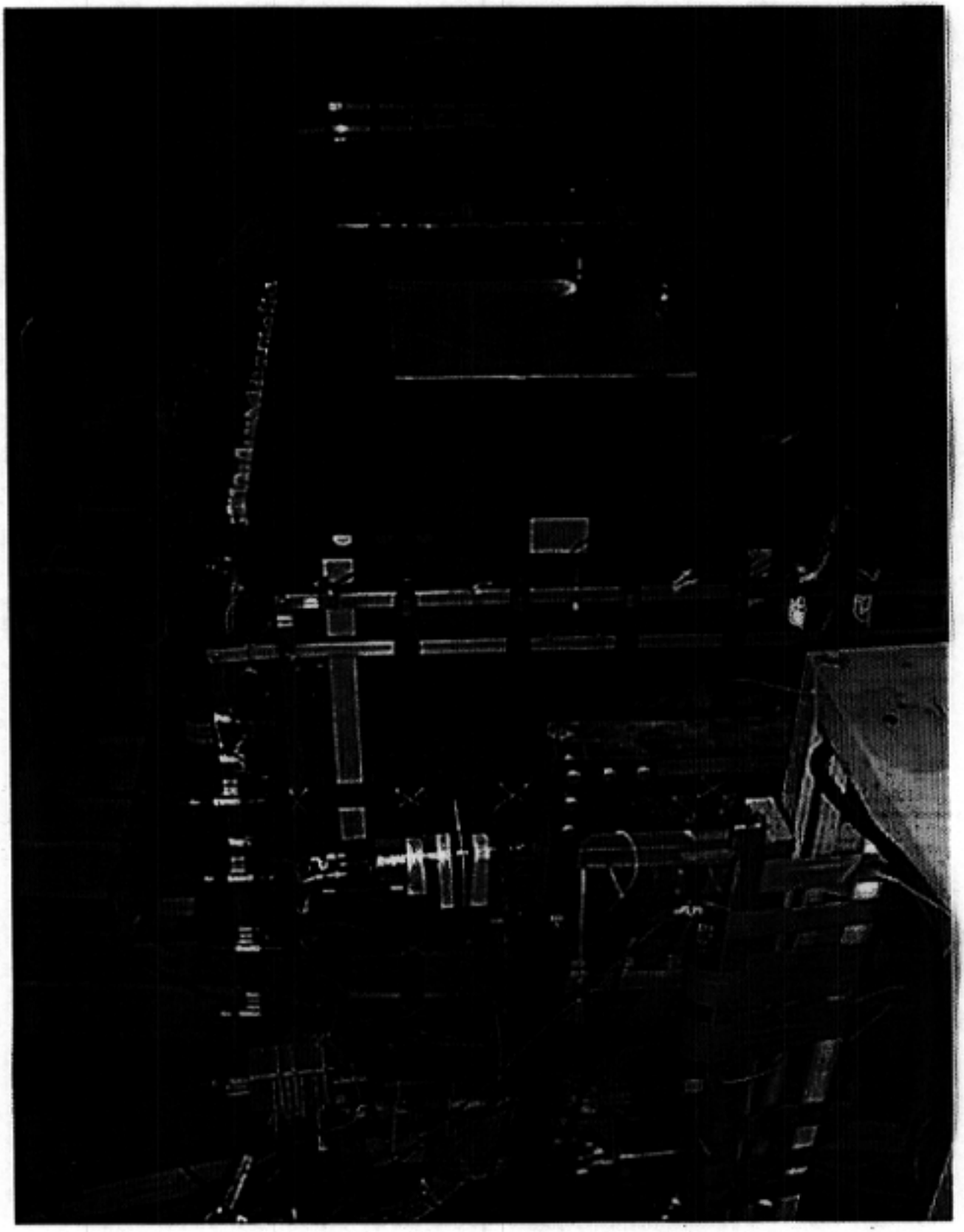
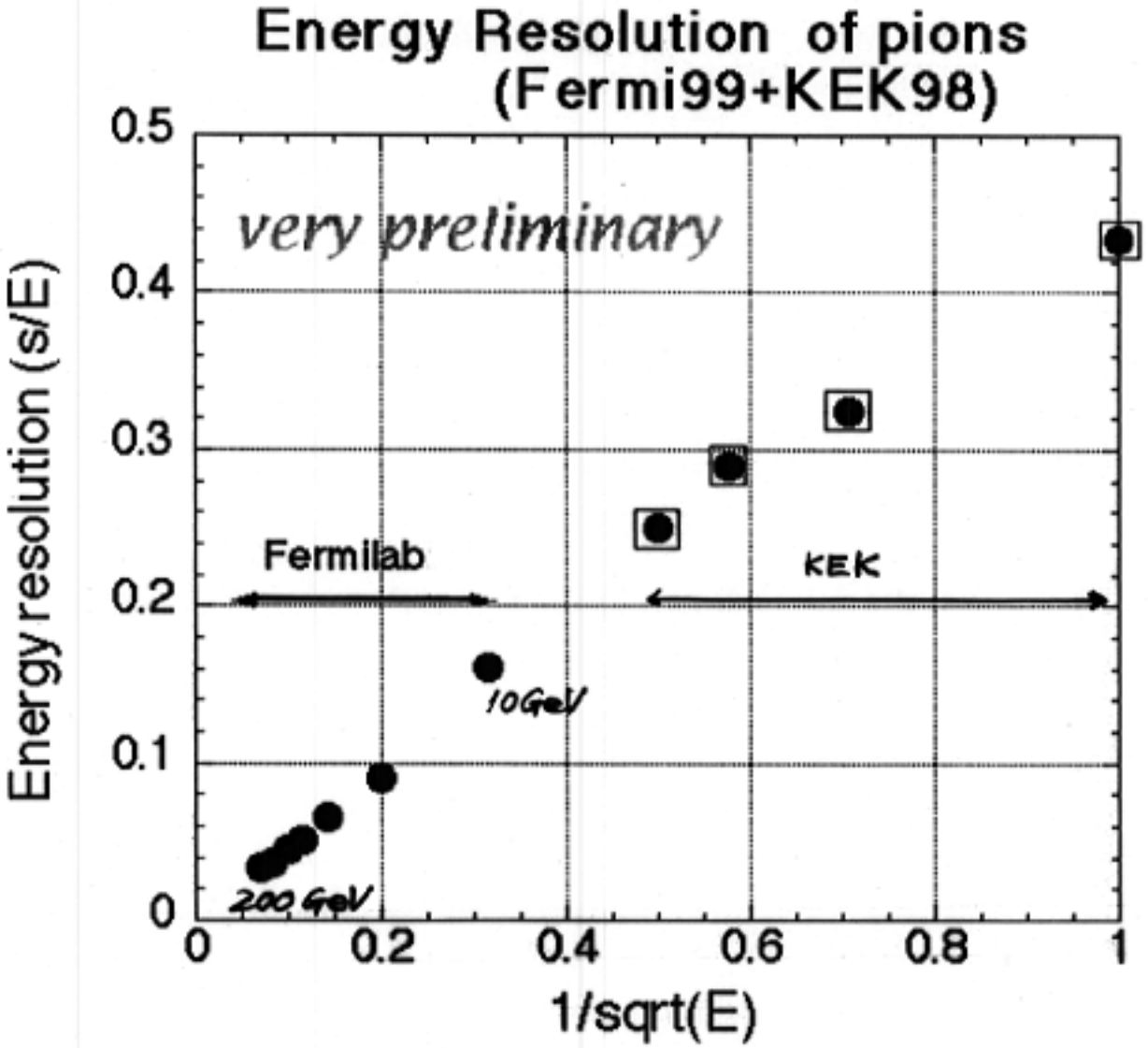
FREQ=69.998
UY          (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.296E-17
SMN =-.295E-17
SMX =.295E-17
  -.291E-17
  -.258E-17
  -.222E-17
  -.185E-17
  -.148E-17
  -.111E-17
  -.739E-18
  -.369E-18
  0
   .369E-18
   .739E-18
   .111E-17
   .148E-17
   .185E-17
   .222E-17
   .258E-17
   .295E-17
```

Fermilab Beam Line MT-6

10 ~ 200 GeV π^-, e^-




Energy Resolution of pions
(Fermi99+KEK98)
very preliminary
Fermilab
KEK
10GeV
200 GeV
Energy resolution (s/E)
1/sqrt(E)
0
0.1
0.2
0.3
0.4
0.5
0.2
0.4
0.6
0.8
1

Many Thanks

for

the Fermilab heart warming hospitality.

- Beam tests for JLC
- ICFA-Seminar

⋮