KEK-SLAC X-Band Design Miniworkshop

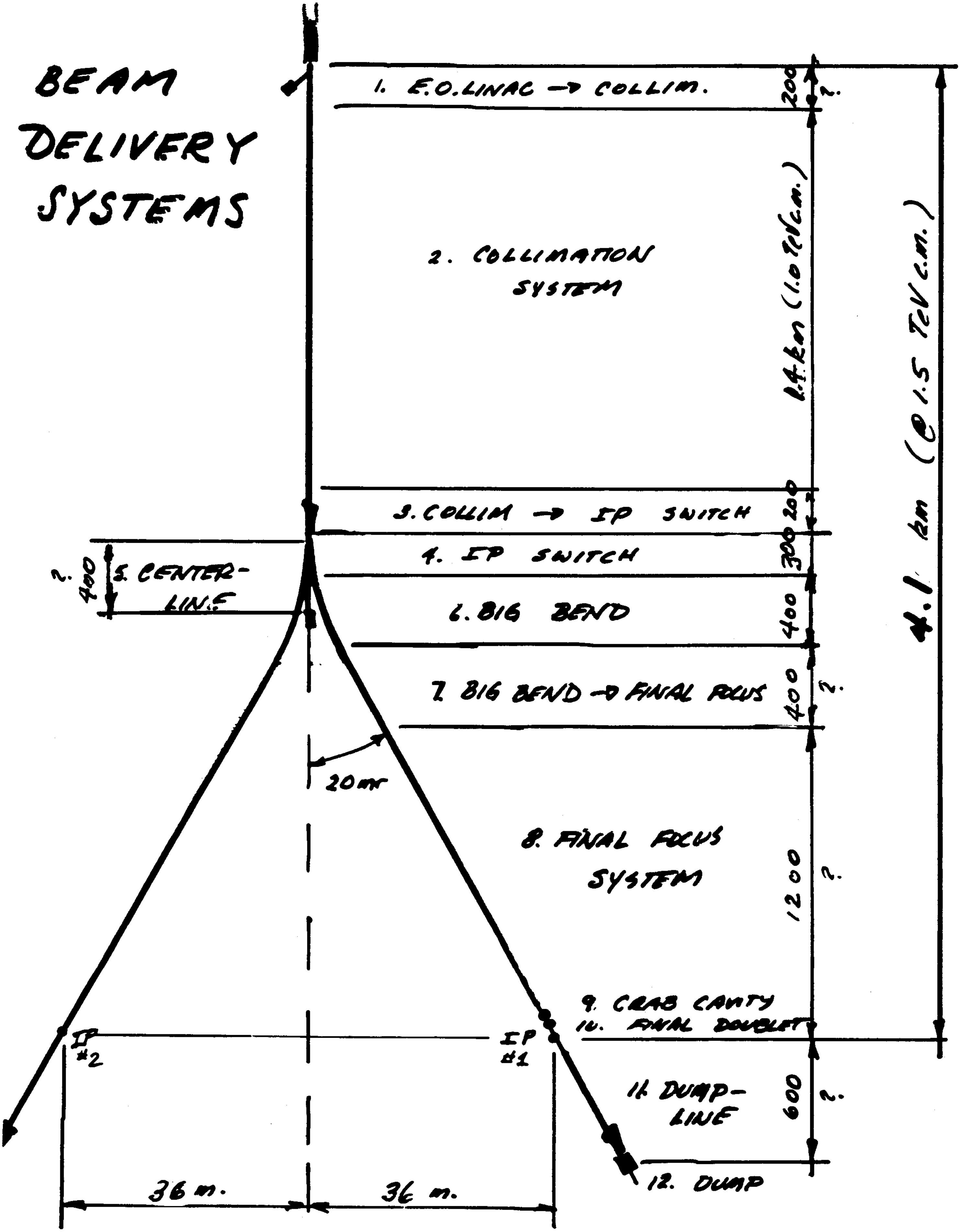
December 5, 1994

Overview of

NLC Beam Delivery and Removal

Subsections

1. E.O.Linac -> Collimation
2. Collimation system
3. Collimation -> IP Switch
4. IP Switch
5. Centerline
6. Big Bend
7. Big Bend -> Final focus
8. Final focus system
9. Final doublet
10. Crab cavity
11. Dumpline
12. Dump



BEAM DELIVERY SYSTEMS
1. E.O.LINAC → COLLIM.
200
?.
2. COLLIMATION SYSTEM
1.4 km (1.0 TeV c.m.)
4.1 km (@ 1.5 TeV c.m.)
3. COLLIM → IP SWITCH
200
4. IP SWITCH
300
?.
400
5. CENTER-LINE
6. BIG BEND
400
7. BIG BEND → FINAL FOCUS
400
?.
20 mr
8. FINAL FOCUS SYSTEM
1200
?.
9. CRAB CAVITY
10. FINAL DOUBLET
IP #2
IP #1
11. DUMP-LINE
600
?.
12. DUMP
36 m.
36 m.

E.O.Linac -> Collimation

Function

- Beta and dispersion match
- Coupling removal?
- E.O.Linac instrumentation
- E.O.Linac dump(line)
- Passive protection

Special Issues

- None

Status

- Begin

Major decision branches

- Extent of instrumentation

Collimation system

Function

Collimate transverse and energy halos
E.O.Linac beam-quality verification?

Special Issues

Wakes
Passive protection
- Materials
- Incoming halo specification

Jitter amplification
Chromatic correction
Tolerances
Length containment

Status

2nd generation design
Beampipe radius change required
Quad string minimization required
Q: Vacuum capability of plated graphite?
Absorber design not complete

Major decision branches

Three or four phases of collimation?
Length for 1.5 TeV c.m.?

Collimation -> IP Switch

Function
Beta and dispersion match

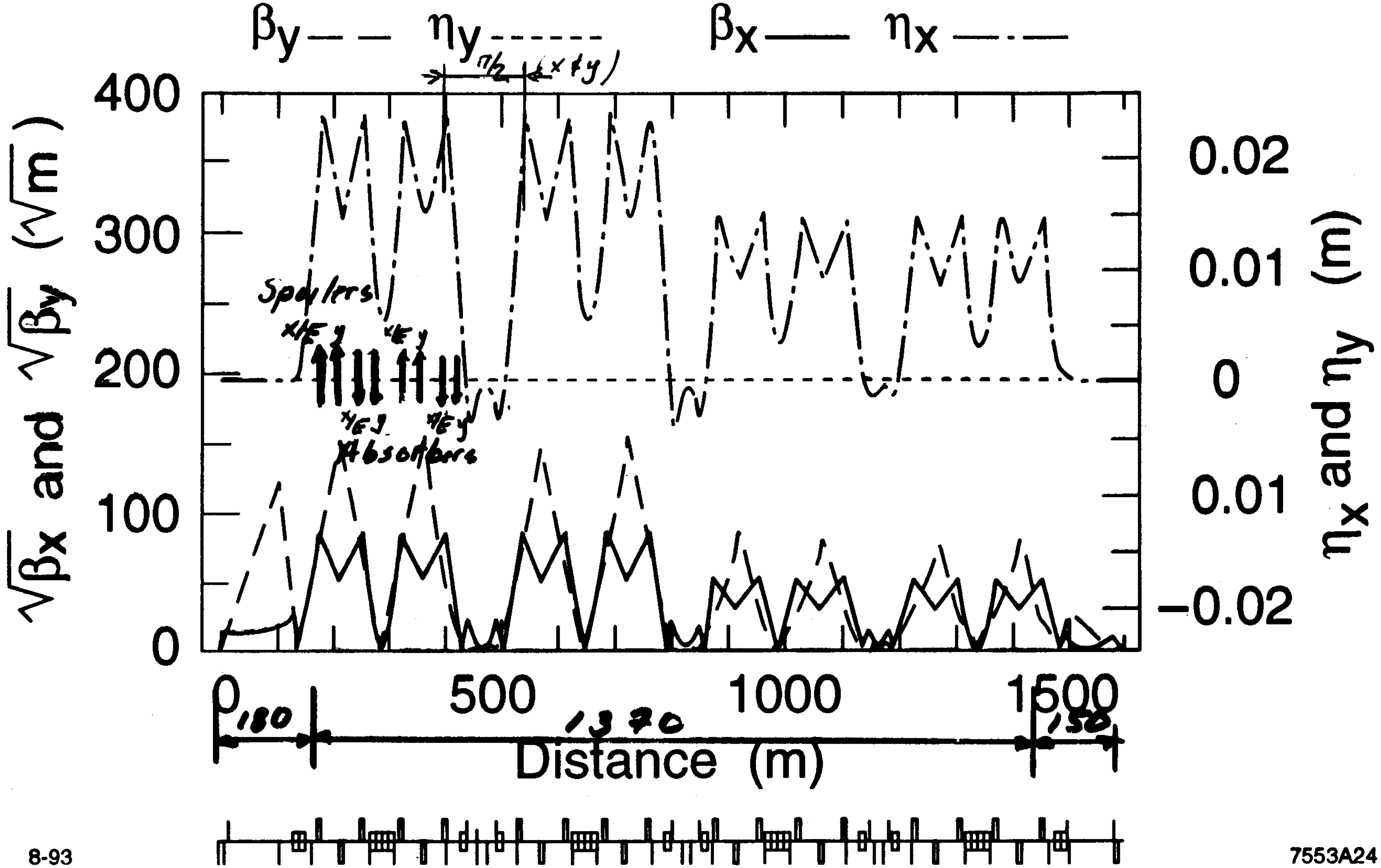
Special Issues
None

Status
1st generation design

Major decision branches
None

Collimation System Lattice

2 planes x 2 phases x 2 times



8-93

7553A24

IP Switch

Function

3-way switch to either IP or centerline
Beta and dispersion match to Big Bend
Post-collim. beam-quality verification

Special Issues

Machine protection

Status

1st generation design, not 3-way, no instrum.
Match to Big Bend dispersion

Major decision branches

Mechanical motion or purely electrical?
Specification for switching frequency

Centerline

Function

Post-collim. beam-quality verification for collimation system tuning

Special Issues

None

Status

Zero

Major decision branches

To include this functionality or not?

Big Bend

Function

Muon protection for detector (÷100)
Allows for two IPs
Allows for crossing angle change (hopefully it would never come to that!).

Special Issues

Emittance growth
- **from synchrotron radiation**
- **from filamentation**

Ease of alignment
Length containment
Magnet design, if combined fctn.

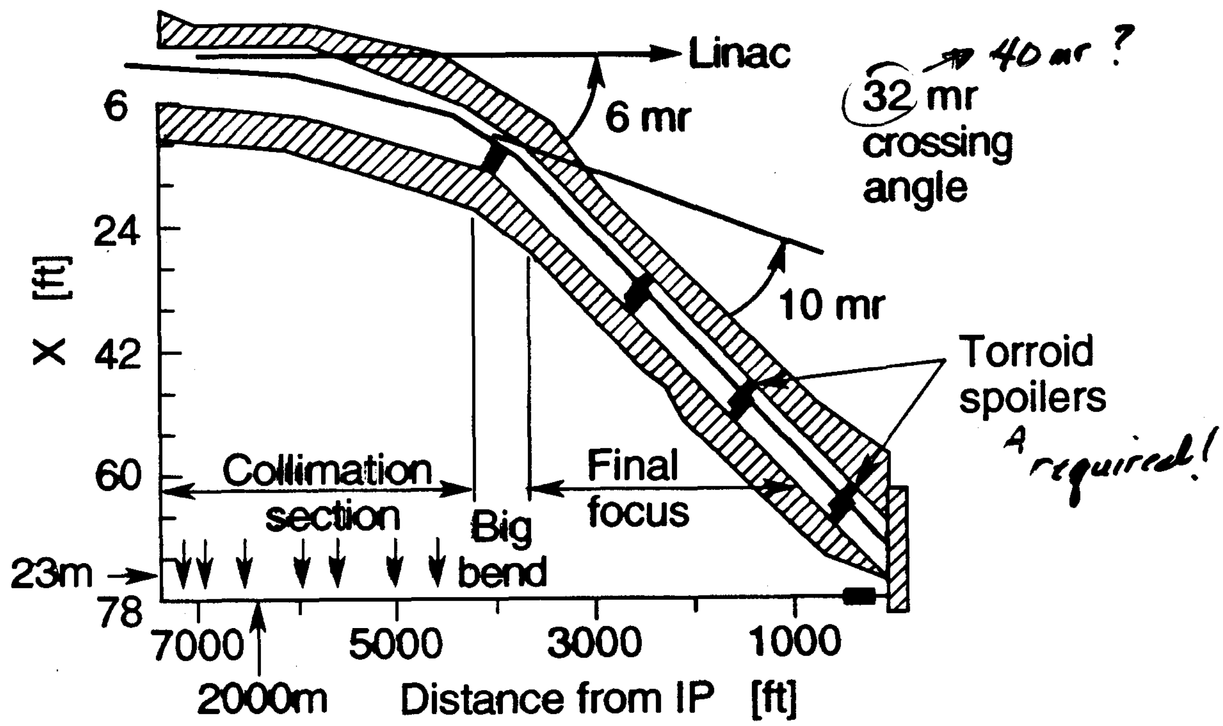
Status

1st generation combined function design
Need separated function design
+ tolerance calculations

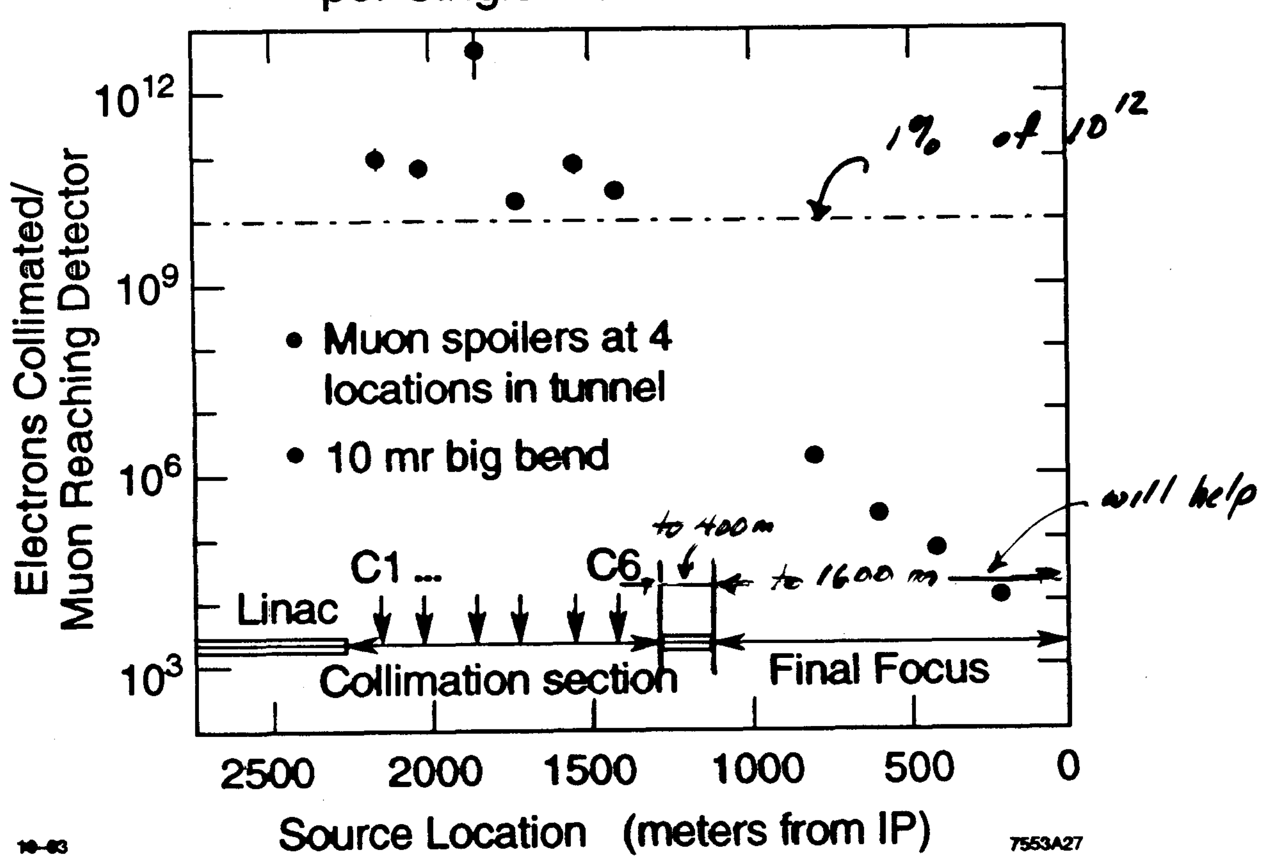
Major decision branches

Combined or separated function bends?
↑ 2x length

Muon Background Studies



Allowed Particles Incident on Collimator per Single Muon in Detector



Big bend -> Final focus

Function
- Beta and dispersion match
- Coupling removal
- E.O.Big_Bend beam-quality verification

Special Issues
- Operational ease

Status
- Begin

Major decision branches
- Coupling correctors preceding β match?

Final focus system

Function

- Compensate final doublet chromaticity
- Final beam-halo collimation
- Aberration removal

Special Issues

- Tolerances
- Ease of operation
- Length optimization (in progress)
- Detector synch. rad. backgrounds

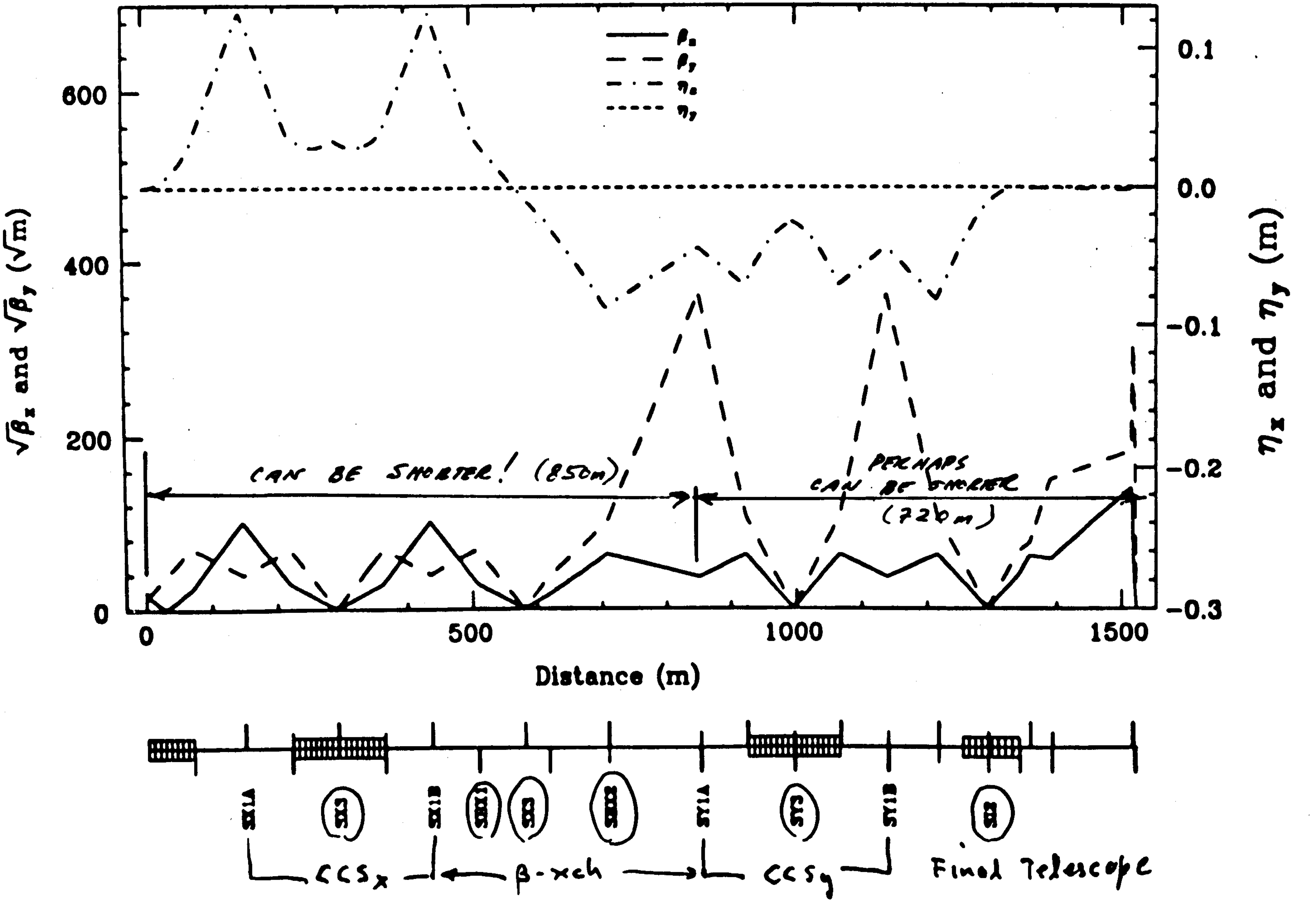
Status

- 1st generation design

Major decision branches

- Chromaticity (H. and V.) of doublet:
  - Free length to IP?
  - Horizontal IP divergent angle?
- Tolerance specification
- Emittance growth from synch. rad.
- "Brinkmann" sextupoles or not?
- Anti-symmetric dispersion function?

TLCFF: TLC FF $\beta_x^* = 10.0$ mm, $\beta_y^* = 0.10$ mm, $l^* = 2.0$ m (11/14/94)

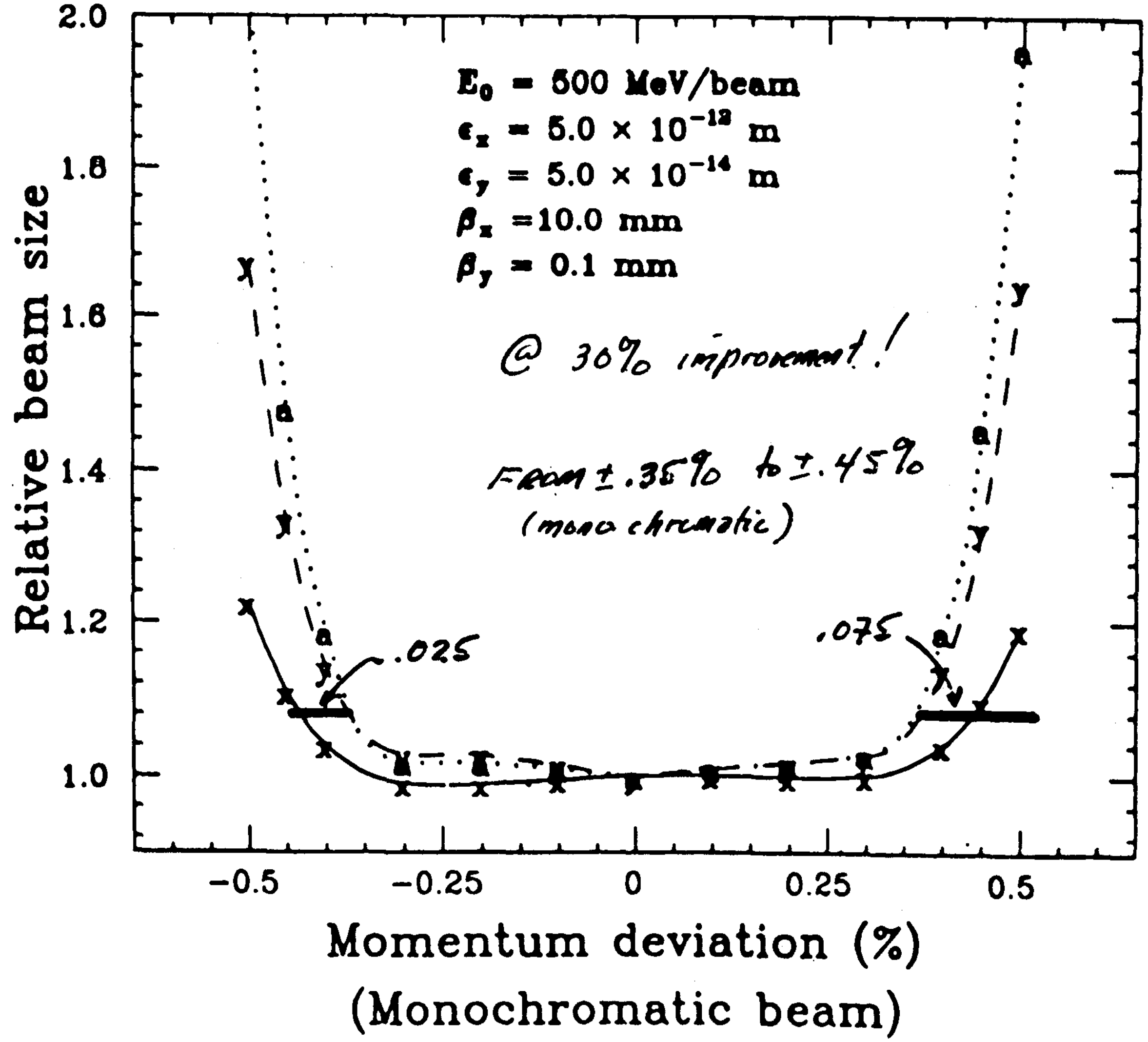


Parameter	1 TeV original	1 TeV "optimized"	1.5 TeV original	1.5 TeV "optimized"
L_B [m]	43 ←÷2½→	17	77	22
η_{SD} [mm]	45	10.8	42	11.6
β_y^{SD} [km]	160	88	160	95
β_x^{SD} [km]	6.4	1.0	8.0	1.34
k_{SD} [m^{-2}]	2.8	23	3.1	21
θ_B [μrad]	489	297	373	361
$\Delta k/k$	$8 \cdot 10^{-5}$	$6 \cdot 10^{-5}$	$1.2 \cdot 10^{-4}$	$5.6 \cdot 10^{-5}$
Δx [μm]	0.4 ←?→	0.1	0.4	0.1

length reduced by about a factor 3 ?!

Band pass plot: TLCFF 11/14/94

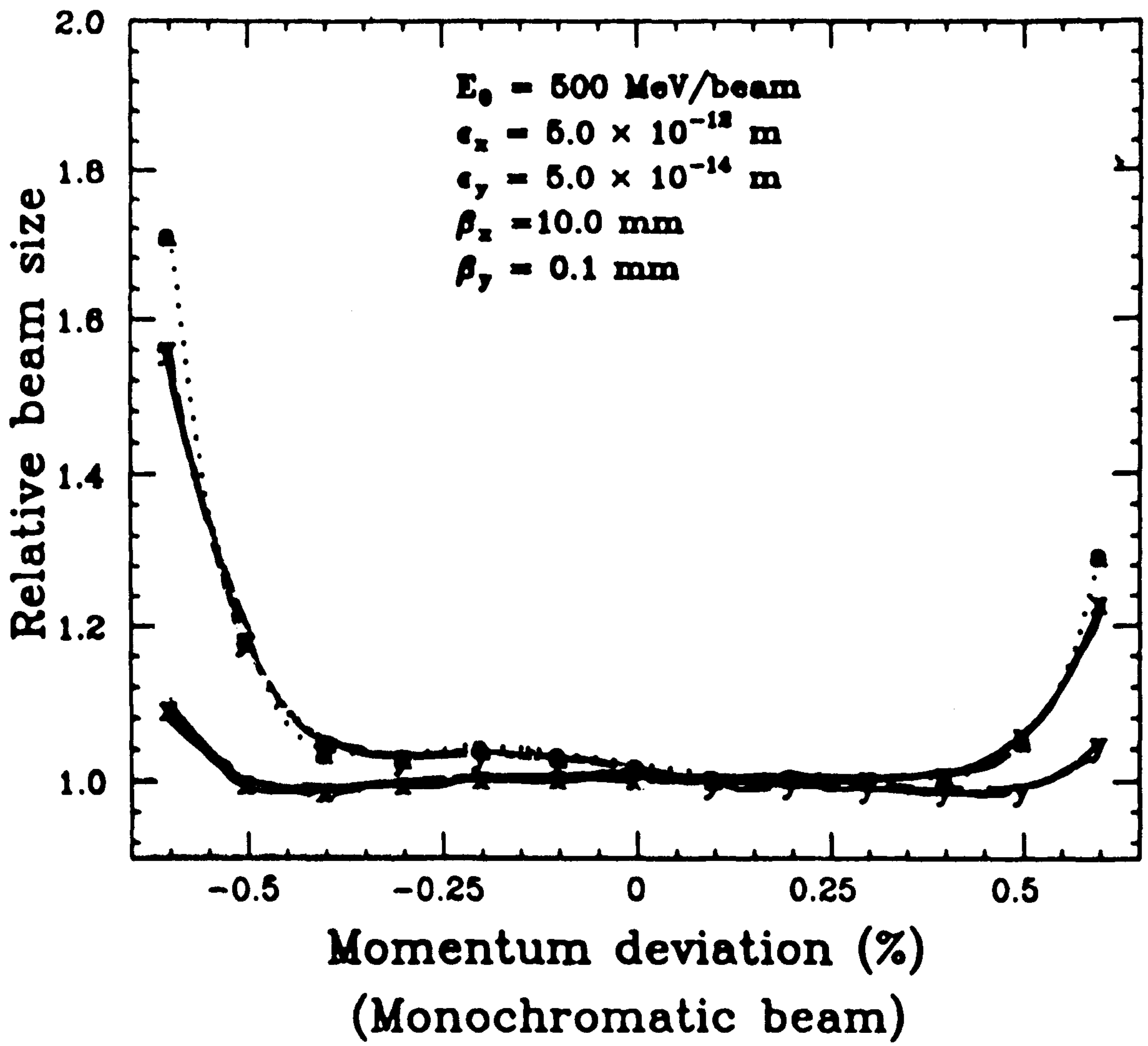
Without chromatic correction of any telescopic sections



w/ "BRINKMAN" SEXTUPOLES

Band pass plot: TLCFF 11/14/94

With chromatic correction of all telescopic sections



Crab cavity

Function

Compensation of 40 mr crossing angle

Special Issues

Phase tolerance on rf. (feedback system proposed)

Multi-bunch operation

Status

Begin

Major decision branches

IP disp. function not possible for 40 mr!

Is 40 mr crab cavity possible?

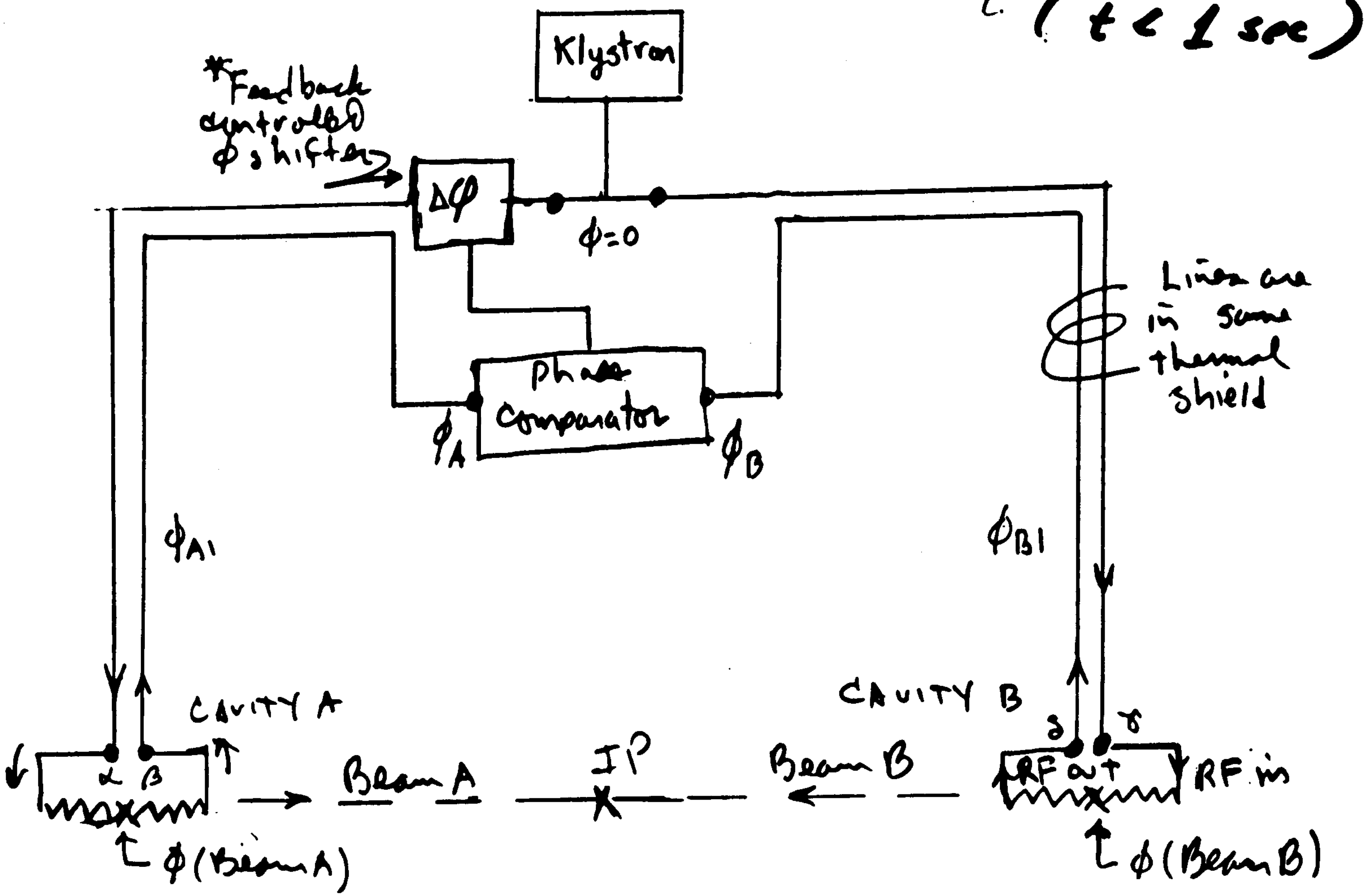
FEEDBACK FOR CRAB CAVITY PHASE CNTRL

Scheme for Feedback and control of $\Delta\varphi$

P. Wilson

$(\Delta\varphi)_{TOL} \sim \frac{1}{50} \Delta\varphi_{1°C.}$

$(t < 1 \text{ sec})$



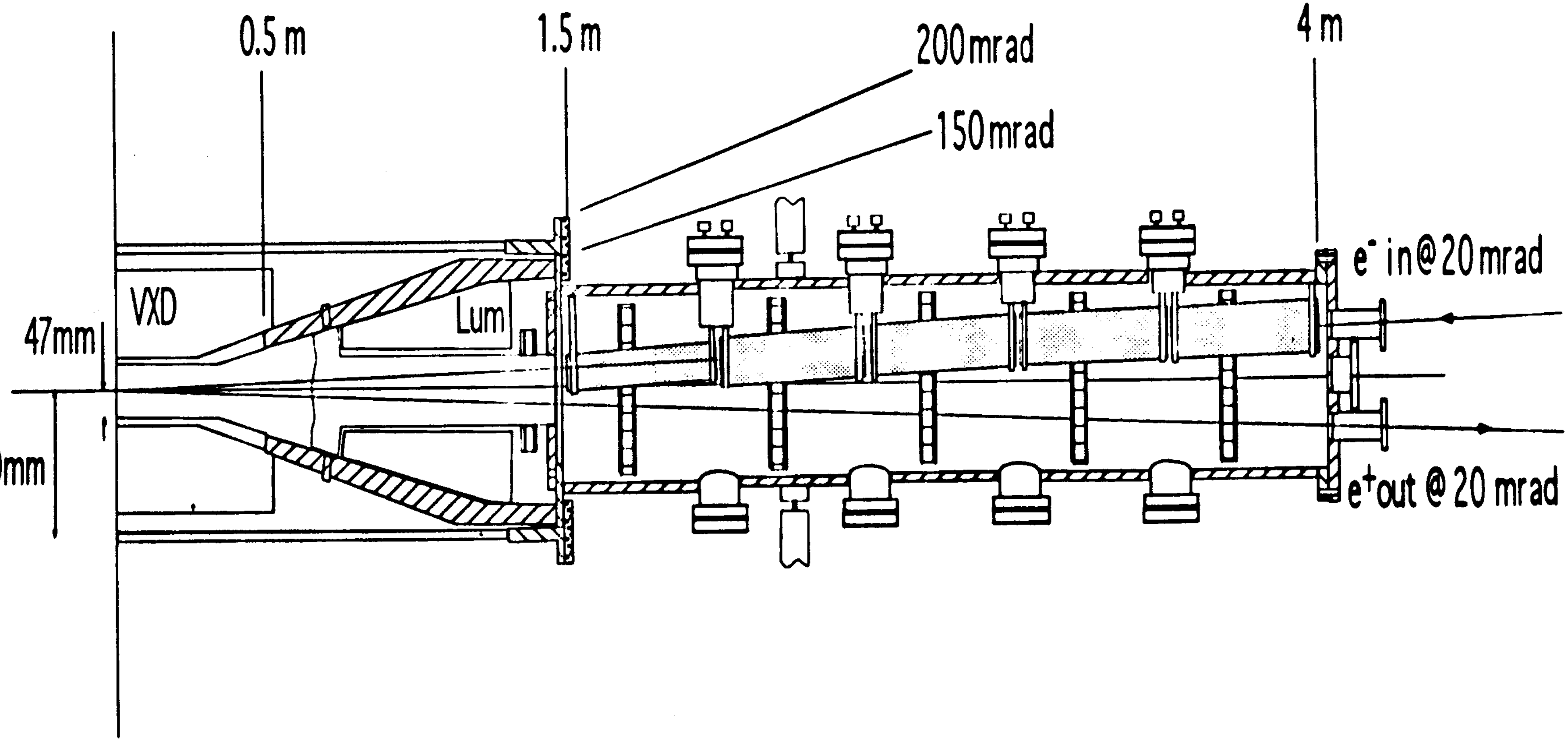
Final doublet

Function
   Parallel (approx.) to point imaging

Special Issues
   Stabilization (≈ 0.5nm)
   Detector backgrounds
   Wakefields

Status
   1st generation design

Major decision branches
   Free length to IP (backscattering issue)?
   Horizontal IP divergent angle?
   Permanent or superconducting?
      crossing angle impact
      detector impact


0.5 m
1.5 m
200mrad
150mrad
4 m
VXD
Lum
47mm
250mm
e- in@20mrad
e+out @ 20 mrad

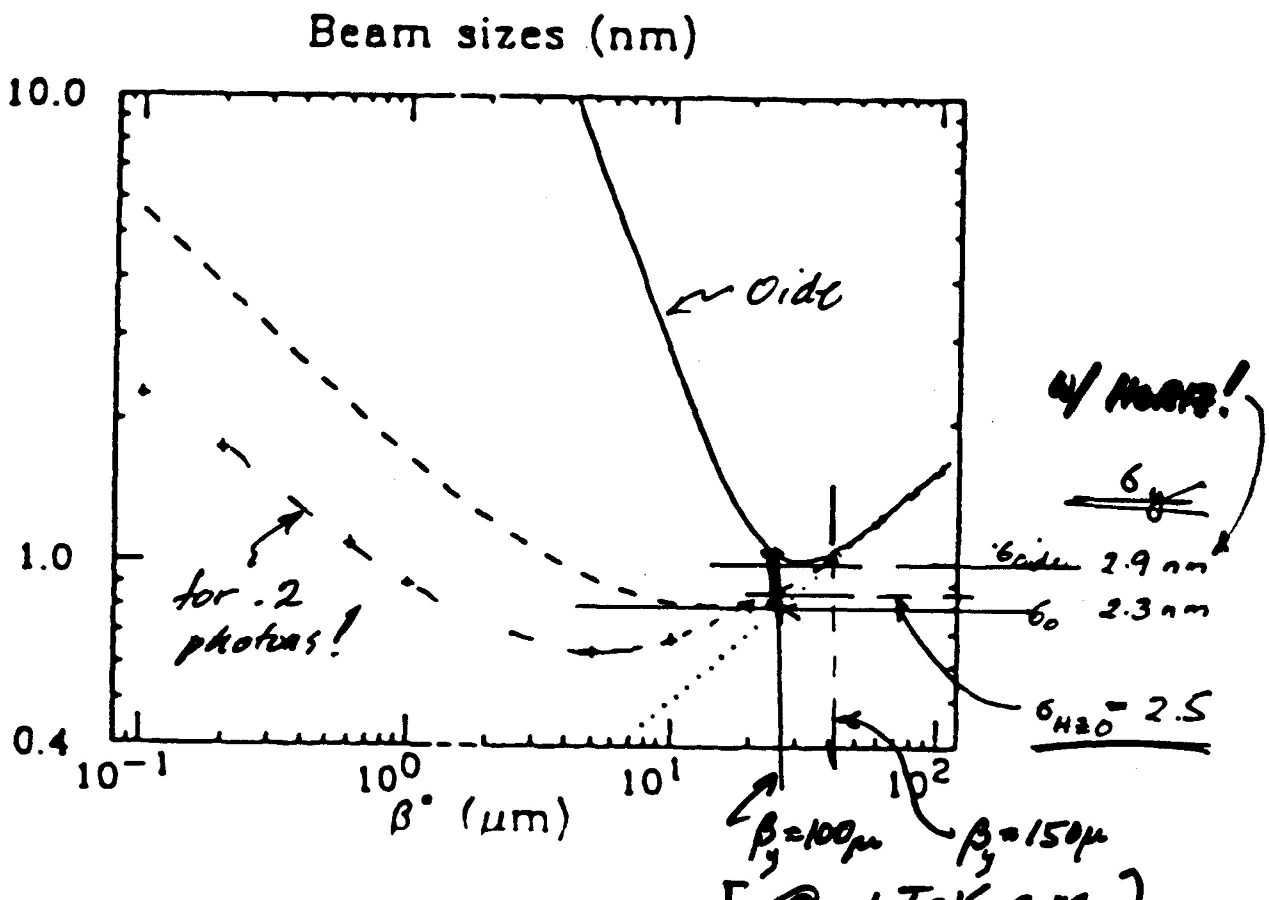
NLC IP Region Working Parameters

Parameter	0.5 TeV	0.5 TeV*	1.0 TeV	1.5 TeV	Comments
L_0	0.5	0.8	1.06	1.07	
L	0.7	1.0	1.4	1.6	Luminosity w/ Pinch
σ_x	320 nm		360 nm	360 nm	Variable
σ_y	3.2 nm		2.3 nm	2.3 nm	
ε_x	10^{-11}		1/2 10^{-11}	1/3 10^{-11}	$\gamma \varepsilon_x = 5\ 10^{-6}$ m-rad
ε_y	10^{-13}		1/2 10^{-13}	1/3 10^{-13}	$\gamma \varepsilon_y = 5\ 10^{-8}$ m-rad
β_x	10 mm		25 mm	37 mm	
β_y	100 µm		100 µm	150 µm	
$\sigma_{x',y'}$	30, 30 µrad		14, 23 µrad	10, 15 µrad	IP Divergent Angle
σ_z	100 µm		100 µm	100 µm	Bunch Length
θ_d	3.2 mr		3.6 mr	3.6 mr	Bunch Diagonal Angle
$\pm \Delta_{box}$	$< \pm 4\ 10^{-3}$		$< \pm 4\ 10^{-3}$	$< \pm 4\ 10^{-3}$	Square Energy Profile Width
$D_{x,y}$	.07, 7.3		.04, 8.8	.03, 5.2	Disruption Parameter
H_d	1.3		1.4	1.5	Enhancement from Pinch
Θ_D	.25 mr		.17 mr		Max. Disrupt. Angle @ Beam Energy
Y	.09	.11	.28	.42	Upsilon Parameter
δ_B	.03	.04	.12	.16	Mean Energy Loss to Beamstrahl. γs
n_γ	.8	1.0	1.1	1.1	# of Photons per Electron
N_{Had}	.04	.07	0.3	0.3	# of Hadronic Events / Cross.
N_{jet5}	.001		0.03		# of Mini-Jets per Crossing

Oide Limit for

Non Gaussian Distributions

(scaled from H, Z & O)



• w/ Horizontal Motion

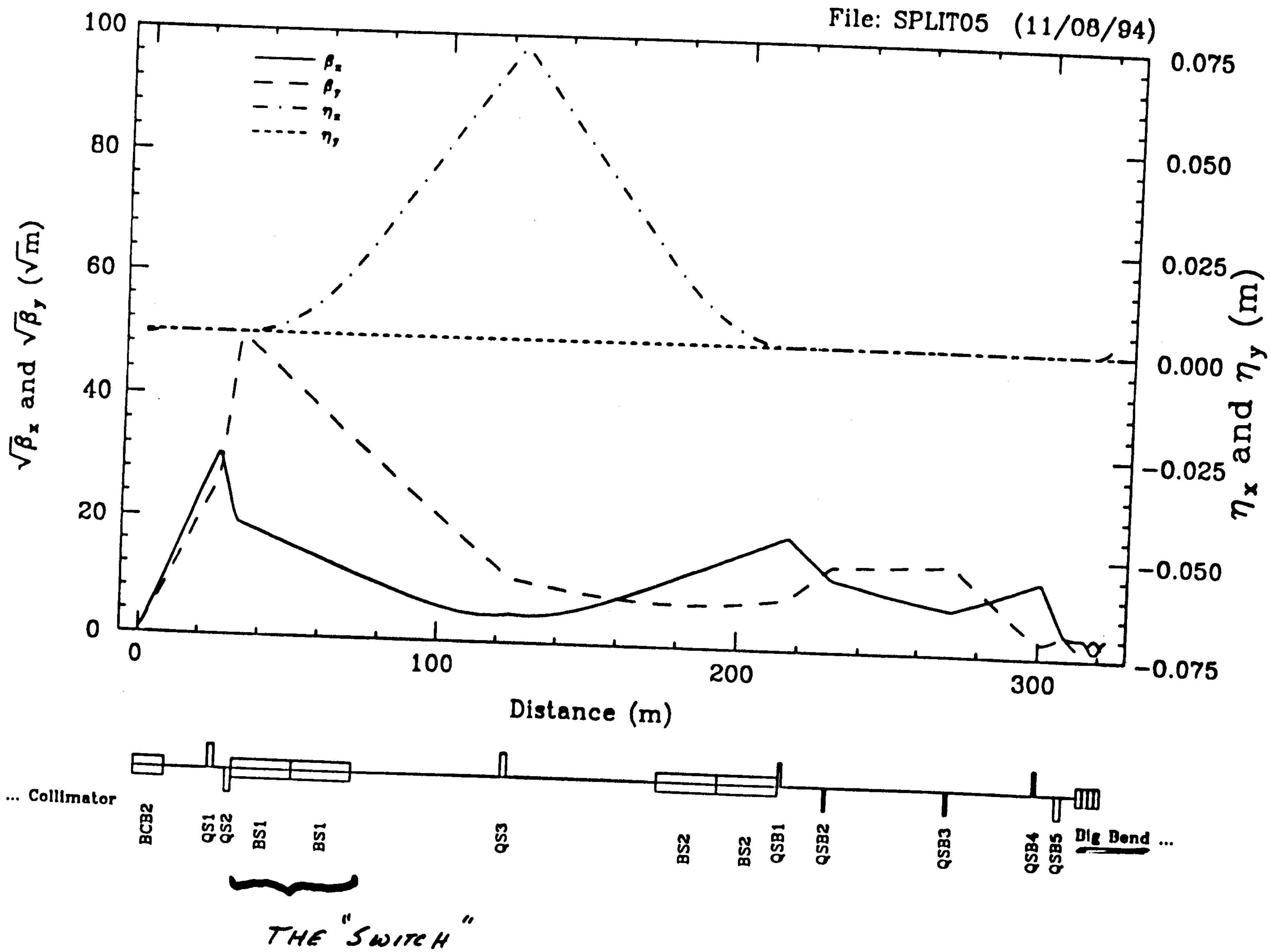
σ_{OIDE} = 2.9 nm

photons = 2.2 ← "Gaussian" appropriate!

can "soften" Q2 somewhat

(σ_{oide} → 2.6 nm ?)

Beam Switch for alternate Final Focus systems



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Dump

Function
Absorb 10 MW beam

Special Issues
Window
Heat removal
Radiation removal

Status
"Engineered" design

Major decision branches
None known

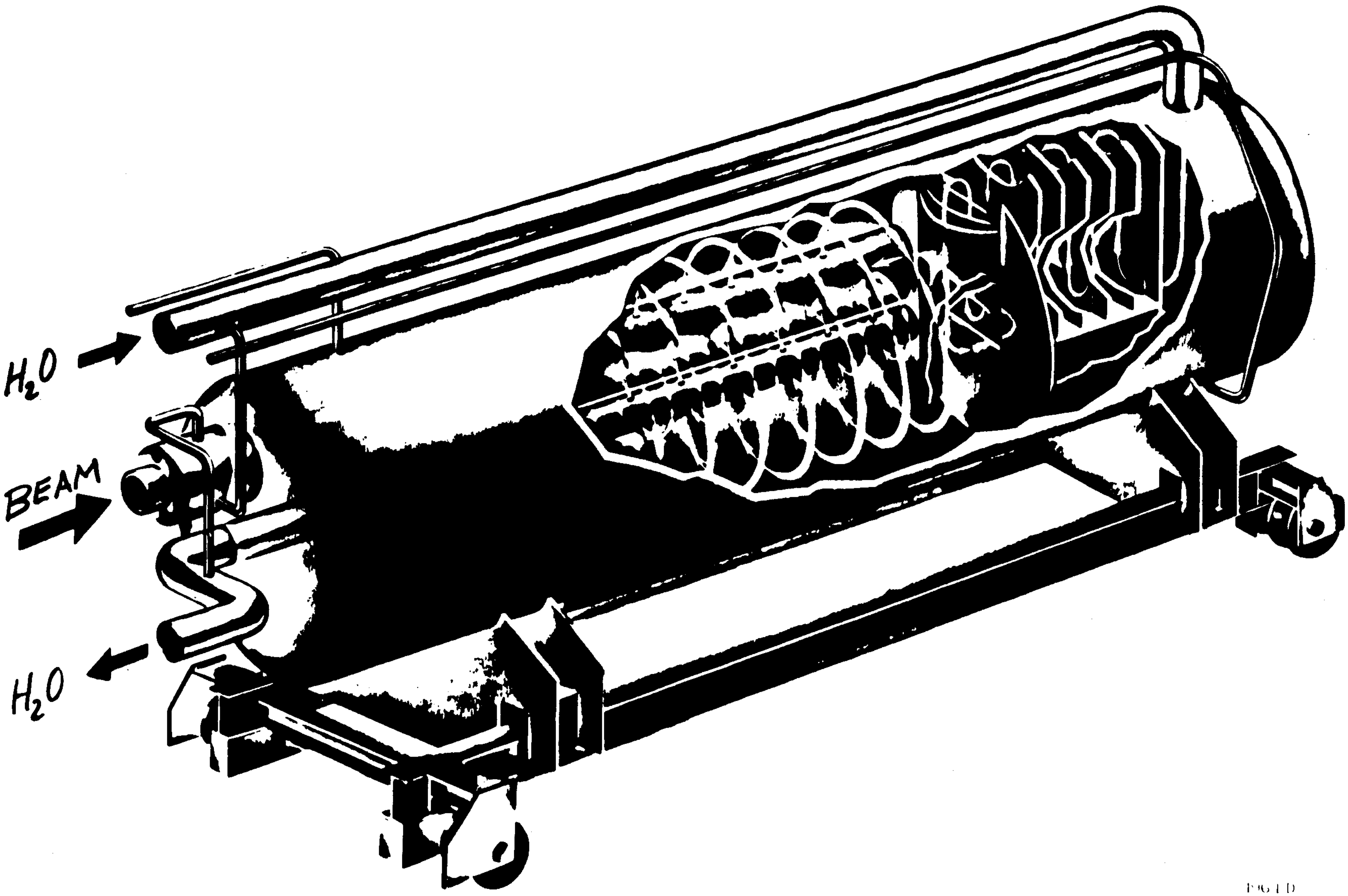


FIG 1D

Dumpline

Function

Transport beam from IP to dump
IP beamsize and position monitoring
Beam energy monitoring
Beam polarization monitoring
Post IP test and secondary beams?
Energy recovery (tempting)?

Special Issues

Detector & instrumentation backgrounds
Radiation levels
Component protection

Status

Begin (complete task)

Major decision branches

First post-IP quad position
First post IP collimation
Parasitic uses of beam?
Secondary beams?

Requirements for Detector

Characteristic features are that all physics processes can be recognized in terms of known fundamental particles (leptons, quarks and gauage bosons).

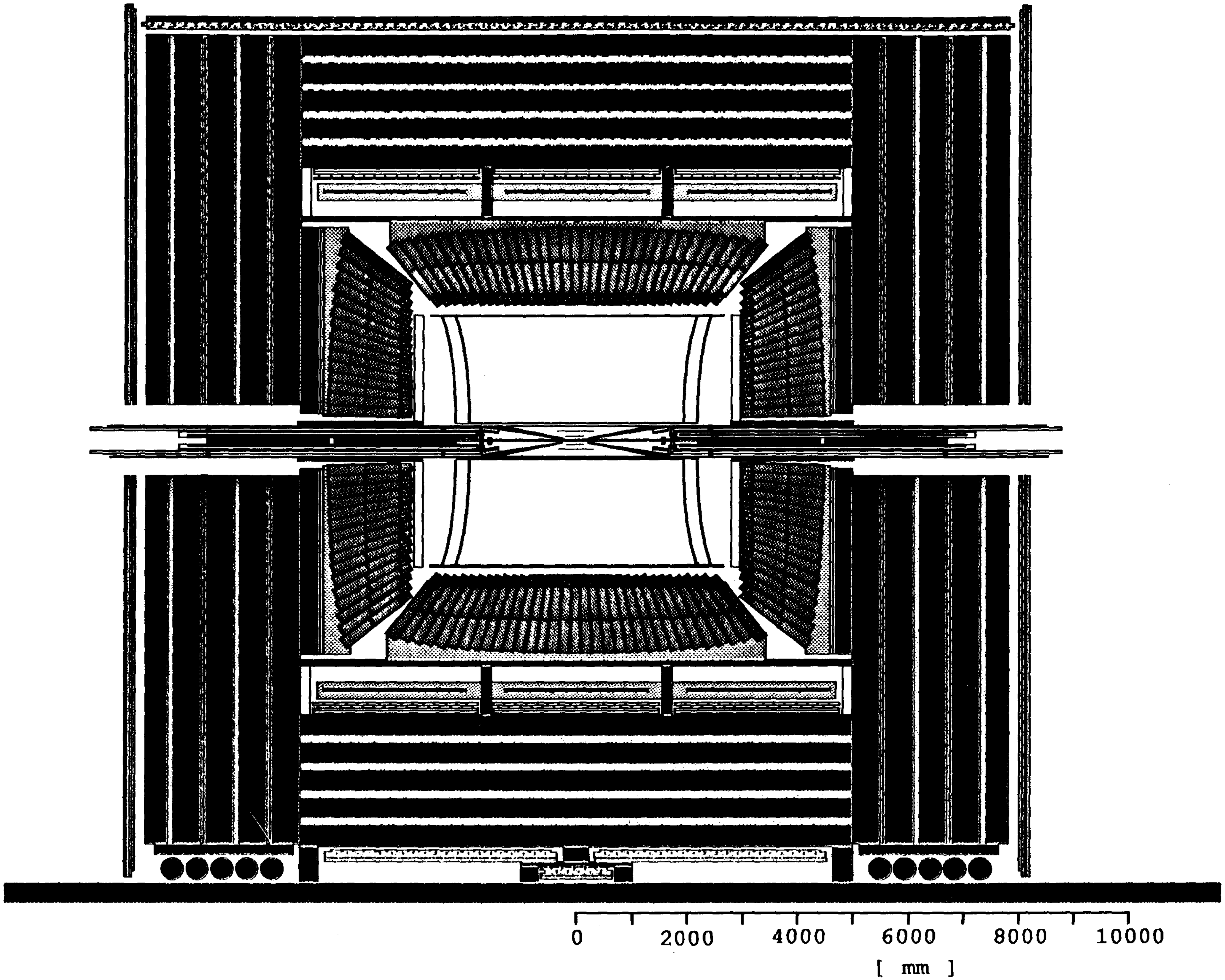
To make muximum use of this advantage, we have to design a detector so as to exclusively reconstruct all final state particles except for neutrinos.

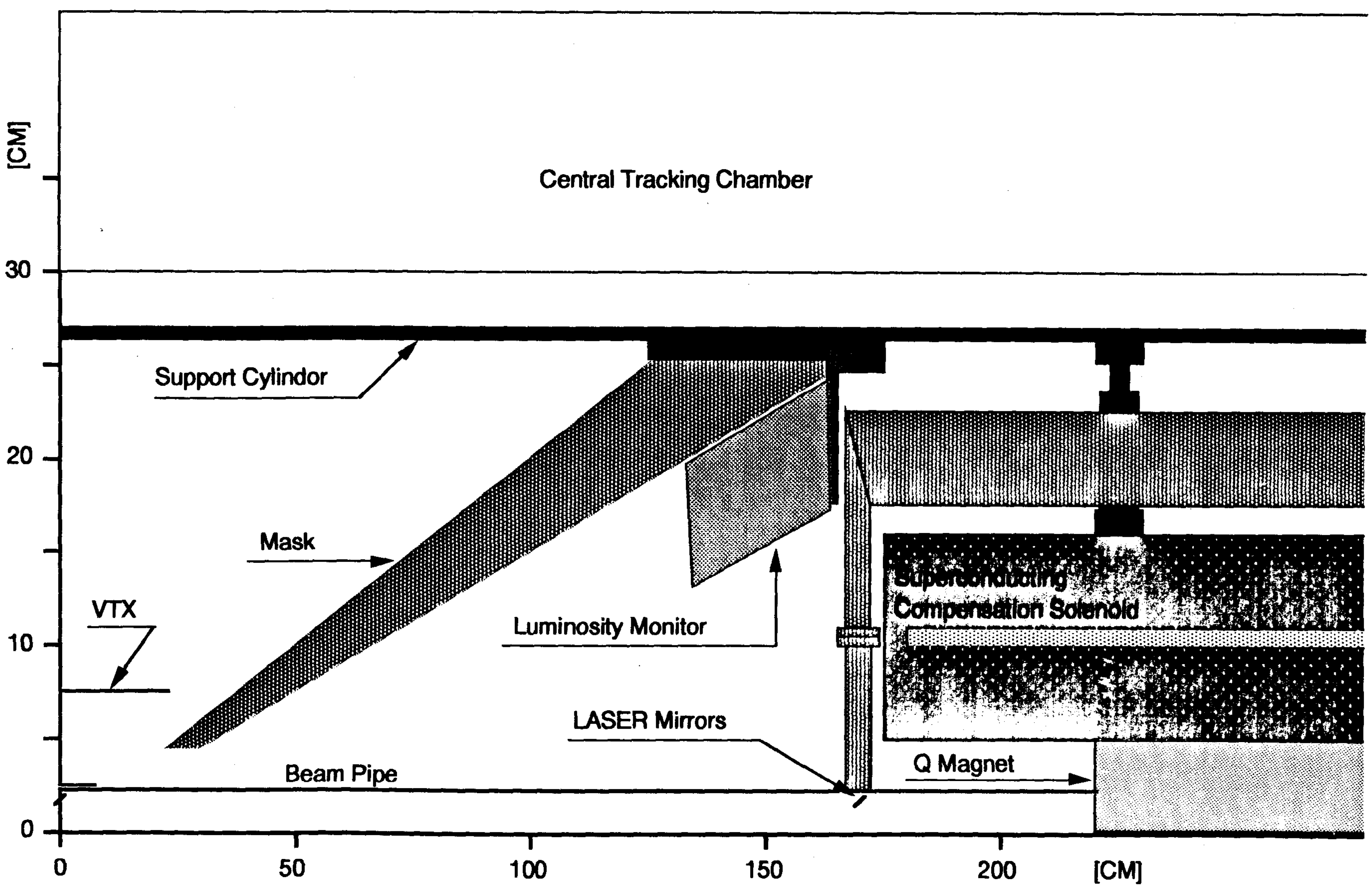
Reconstructions of W and Z in jet invariant mass are very important in order to use large decay branching fractions.

Identification of b-quarks by vertex detection is important for detailed studies of top and Higgs.

The detector should be capable of confirming the narrow decay width of, for instance, Higgs.

1) Hermetic calorimetry in the polar angle region of $|\cos\theta| < 0.98$.
2) Jet invariant mass resolution comparable with natural widths of W and Z.
3) Lepton pair recoil mass resolution ($e^+e^- \to Zh$) < 300 MeV.


0
2000
4000
6000
8000
10000
[mm]


[CM]
Central Tracking Chamber
30
Support Cylindor
20
Mask
VTX
Luminosity Monitor
10
Superconducting
Compensation Solenoid
LASER Mirrors
Q Magnet
Beam Pipe
0
0
50
100
150
200
[CM]

DETECTOR	TYPE	CONFIGURATION	PERFORMANCE
VTX (Vertex Detector)	Silicon CCD	Pixel Size ; 25 μm Number of Layers ; 2 layers Layer Position ; r=2.5cm & 7.5cm Thickness ; 500 μm / layer $\lvert \cos\theta \rvert < 0.95$	Position Resolution ; $\sigma = 7.2$ μm Impact Parameter Resolution δ [μm]; $\delta^2 = 11.4^2 + (28.8/p)^2 / \sin^3\theta$
CDC (Central Drift Chamber)	Small-cell Jet Chamber	Radius ; r = 0.3 - 2.3 m Length ; l = 4.6 m Number of Sampling = 100 $\lvert \cos\theta \rvert < 0.70$ (full sampling) $\lvert \cos\theta \rvert < 0.95$ (20 samplings)	Position Resolution ; $\sigma_x = 100$ μm (/ axial wire) $\sigma_z = 2$ mm (/ stereo wire) Momentum Resolution ; $\sigma_{Pt} / Pt = 1.1\mathrm{x}10^{-4}\, Pt + 0.1\%$ $\sigma_{Pt} / Pt = 5\,\mathrm{x}10^{-5}\, Pt + 0.1\%$ (with vertex constraint)
CAL	Lead + Plastic Scintillator Sandwitch (Compensated)	EM part ; thickness = 29 Xo cell size = 10cm x 10cm HAD part ; thickness = 5.6 λo cell size = 20cm x 20cm Si Pad ; pad size = 1cm x 1cm $\lvert \cos\theta \rvert < 0.99$	Energy Resolution ; $\sigma_E / \sqrt{E} = 15\% / \sqrt{E} + 1\%$ (e & γ) $\sigma_E / \sqrt{E} = 40\% / \sqrt{E} + 2\%$ (hadron) Si Pad Position Resolution ; $\sigma = 3$ mm Si Pad e/π Rejection = 1/50
MUON	Single Cell Drift Chamber	Number of Superlayers ; 6 $\lvert \cos\theta \rvert < 0.99$	Position Resolution ; $\sigma = 500$ μm Pt > 3.5 GeV (barrel)

* All momentum and energy are expressed in [GeV].

CDC R&D

Goal

$$\frac{\sigma_{p_T}}{p_T} = 1.1\times10^{-4}\,P_T(GeV)\oplus1.5\times10^{-3}$$

Simulation

B = 2 Tesla
r_{in} = 30 cm
r_{out} = 230 cm
L = 460 cm
n = 100 points
σ = 100 μm

⟶ *Goal : achievable*

But

L = 460 cm : Very long !

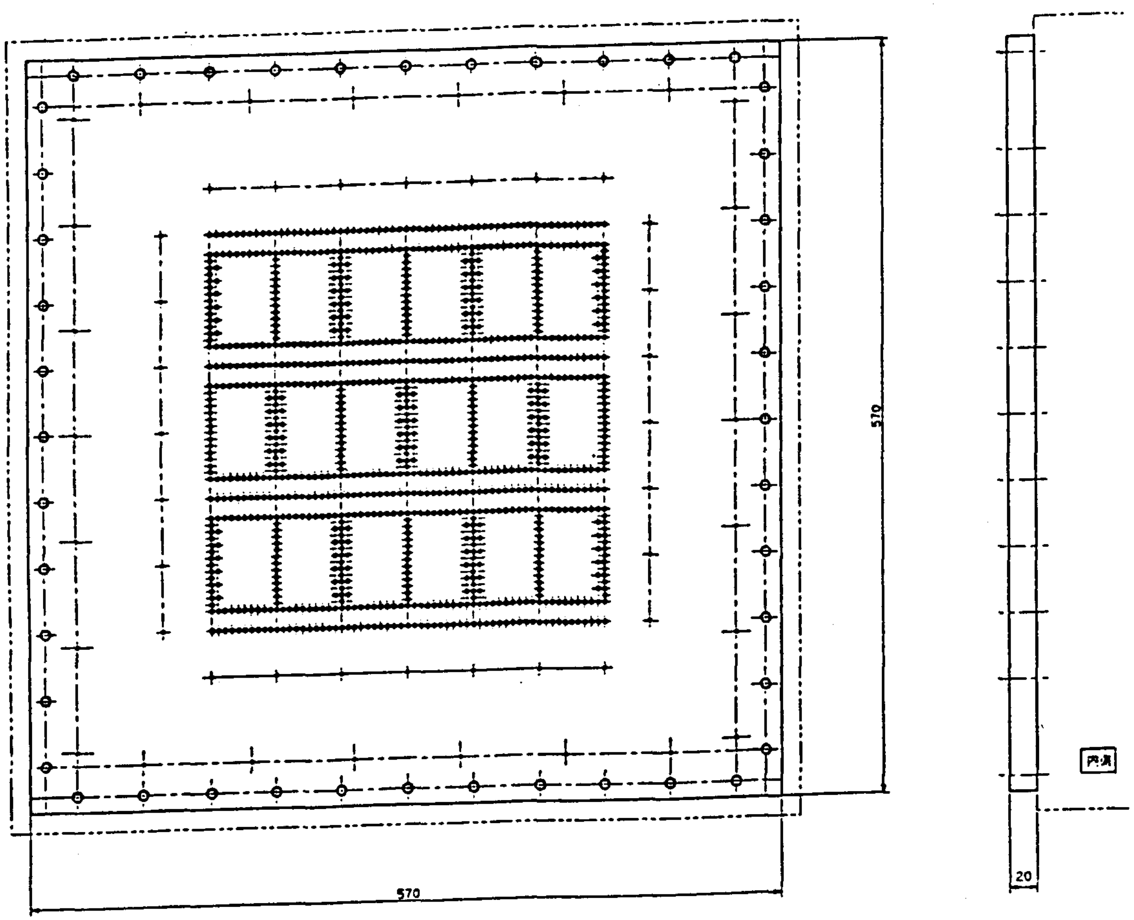
Wire sag due to gravitational and electrostatic forces will be large.

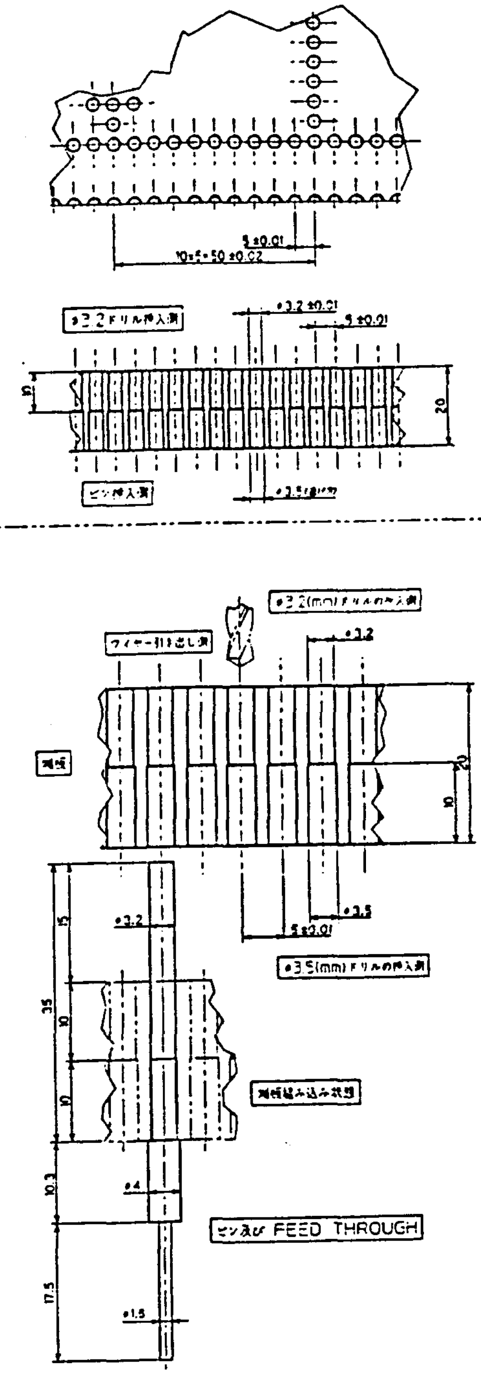
Verify this can be corrected.

⟶ Tension must be adjusted to a good accuracy for each wire.

⟶ Test Chamber

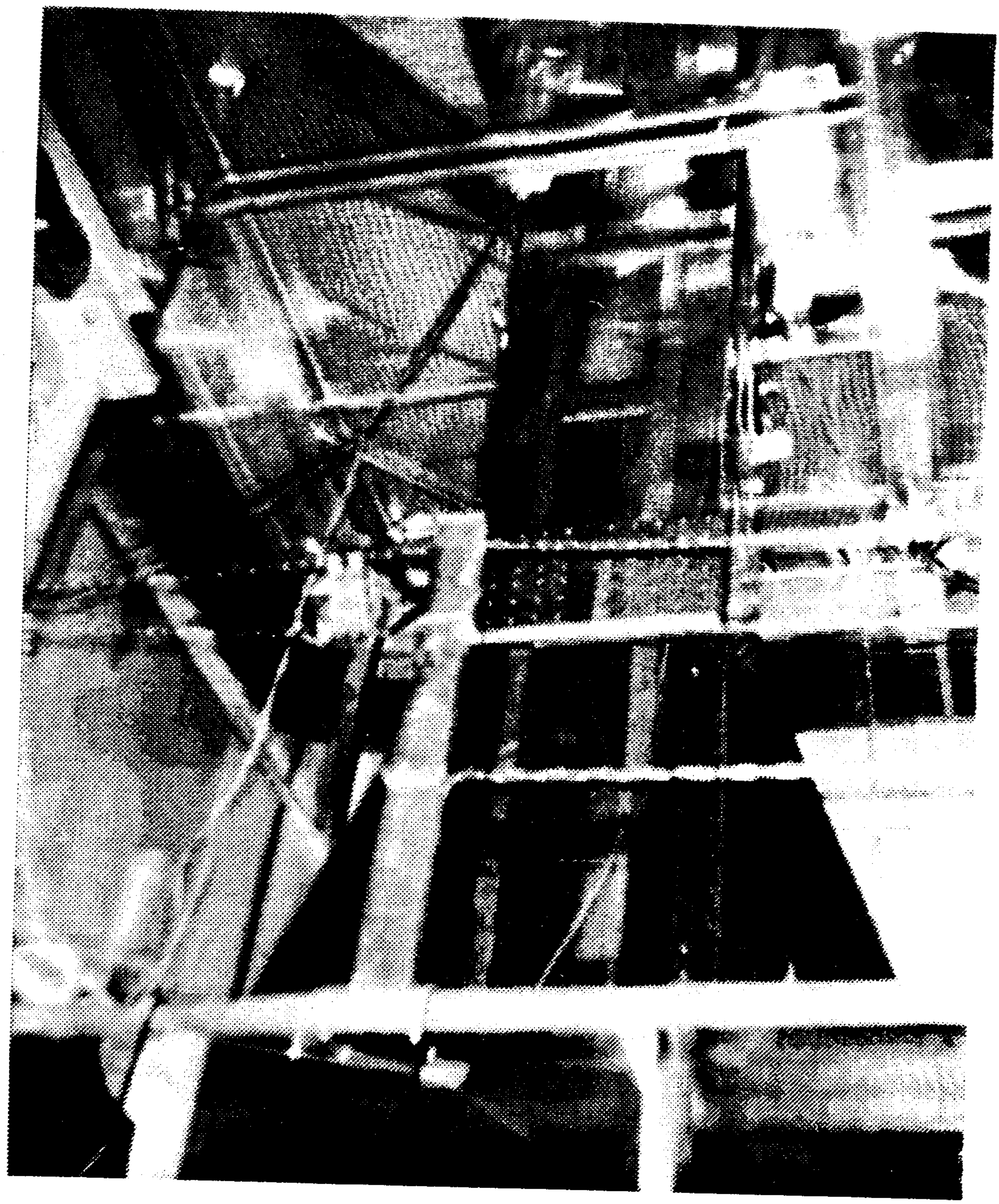
JLC CDC Test-Chamber



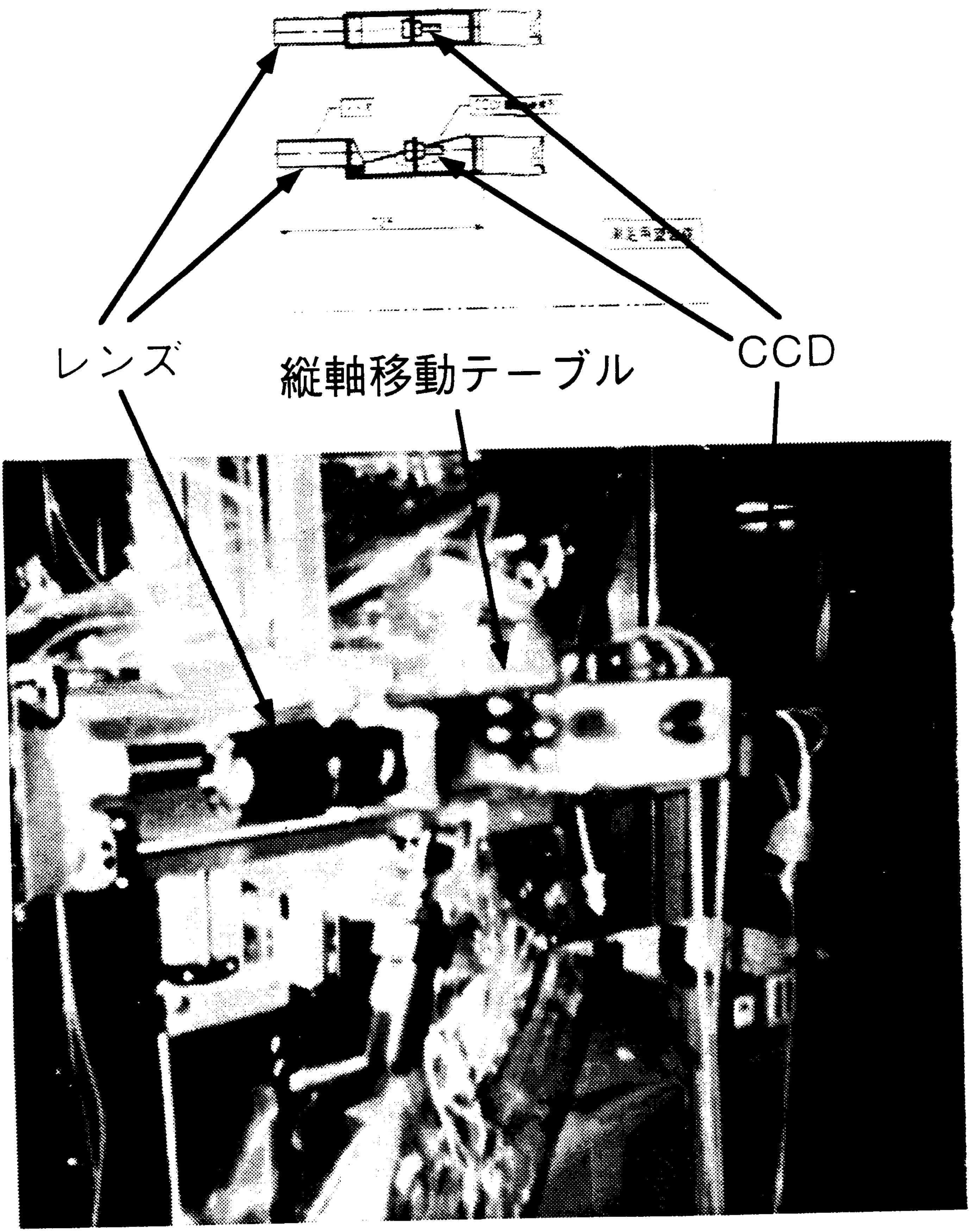


JLC test chamber 全体図

460cm



Wire径　sense　30μm
　　　　field　120μm


レンズ
縦軸移動テーブル
CCD

Calorimeter R&D

Goal

$$\frac{\sigma_E}{E} = \frac{0.15}{\sqrt{E(GeV)}} \oplus 0.01 \qquad \text{(EM)}$$

$$\frac{\sigma_E}{E} = \frac{0.40}{\sqrt{E(GeV)}} \oplus 0.02 \qquad \text{(Had)}$$

Simulation

Pb : Scintillator = 4 : 1
EM : Pb 4.0 mm
Had : Pb 8.0 mm → *Goal : achievable*

cf) ZEUS T-36 (Beam test results)

$\sigma_E / E = 0.23/\sqrt{E}$ (EM)

$\sigma_E / E = 0.44/\sqrt{E}$ (Had)

SPACAL

$\sigma_E / E \sim 0.13/\sqrt{E}$ (EM)

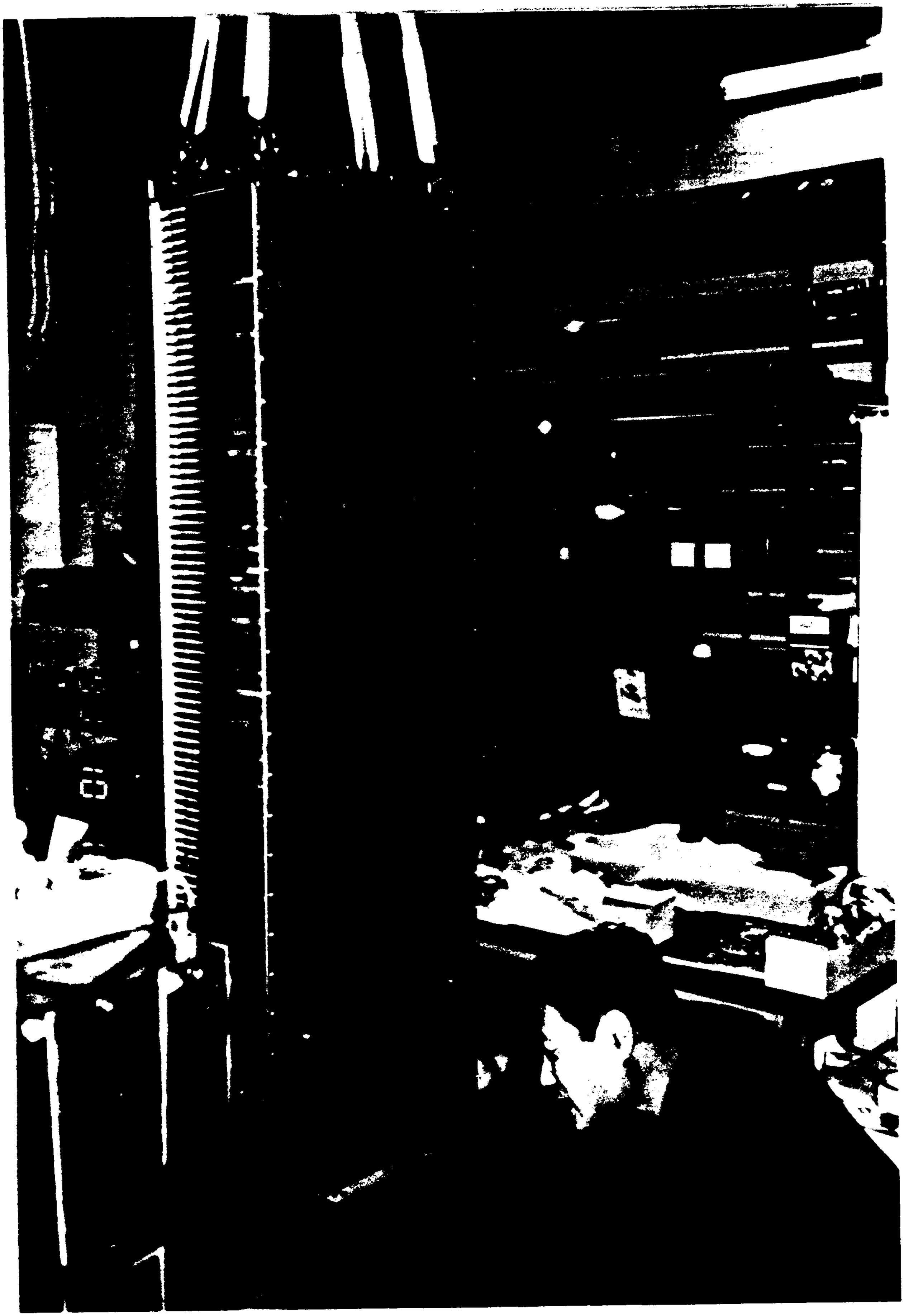
$\sigma_E / E \sim 0.30/\sqrt{E}$ (Had)

Beam Test

Preshower+Si-pad+EM+Hadron

(ZEUS type Lead/Sci Sanndwich)

10 mm Pb + 2.5 mm Scinntilator
Wave Length Shifter : Y-7 30 ppm (2mm thick) x 2
PMT : R580 x 2



Status of CDC R&D

We have constructed a 4.6 m long test chamber.

1) Machining errors on the wire holes within tolerance

→ $\Delta x < 10\ \mu m$

2) Wire tension uniformity

→ $\Delta T < 1\ \%$ (relative)

inspite of initial tension drop by ~3 %
in the first two weeks due to wire creeping.

→ To be continuously monitored to check longer term stability.

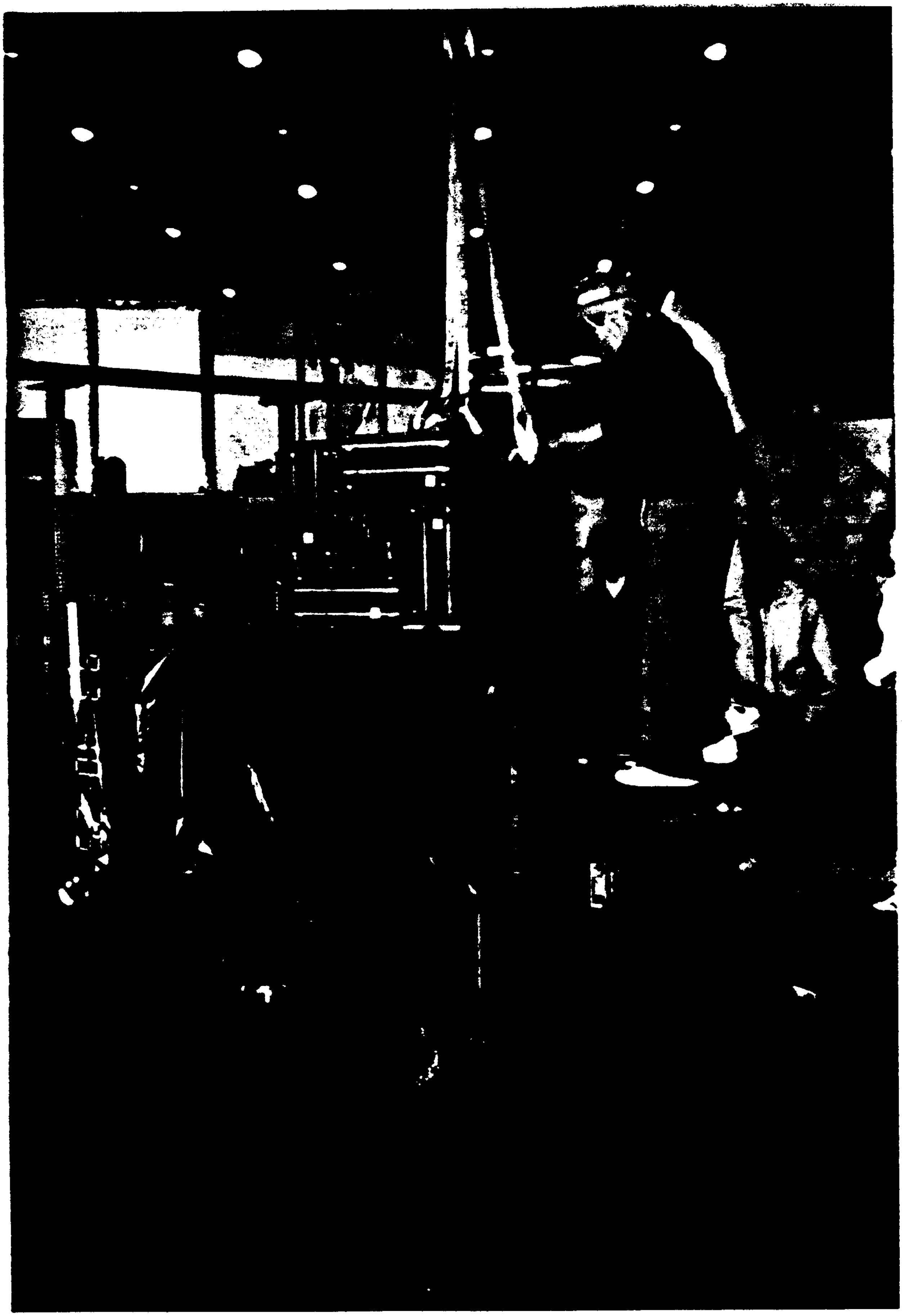
3) Wire sag (gravitational/electrostatic)

→ To be measured by a telescopic microscope equipped with a CCD camera.

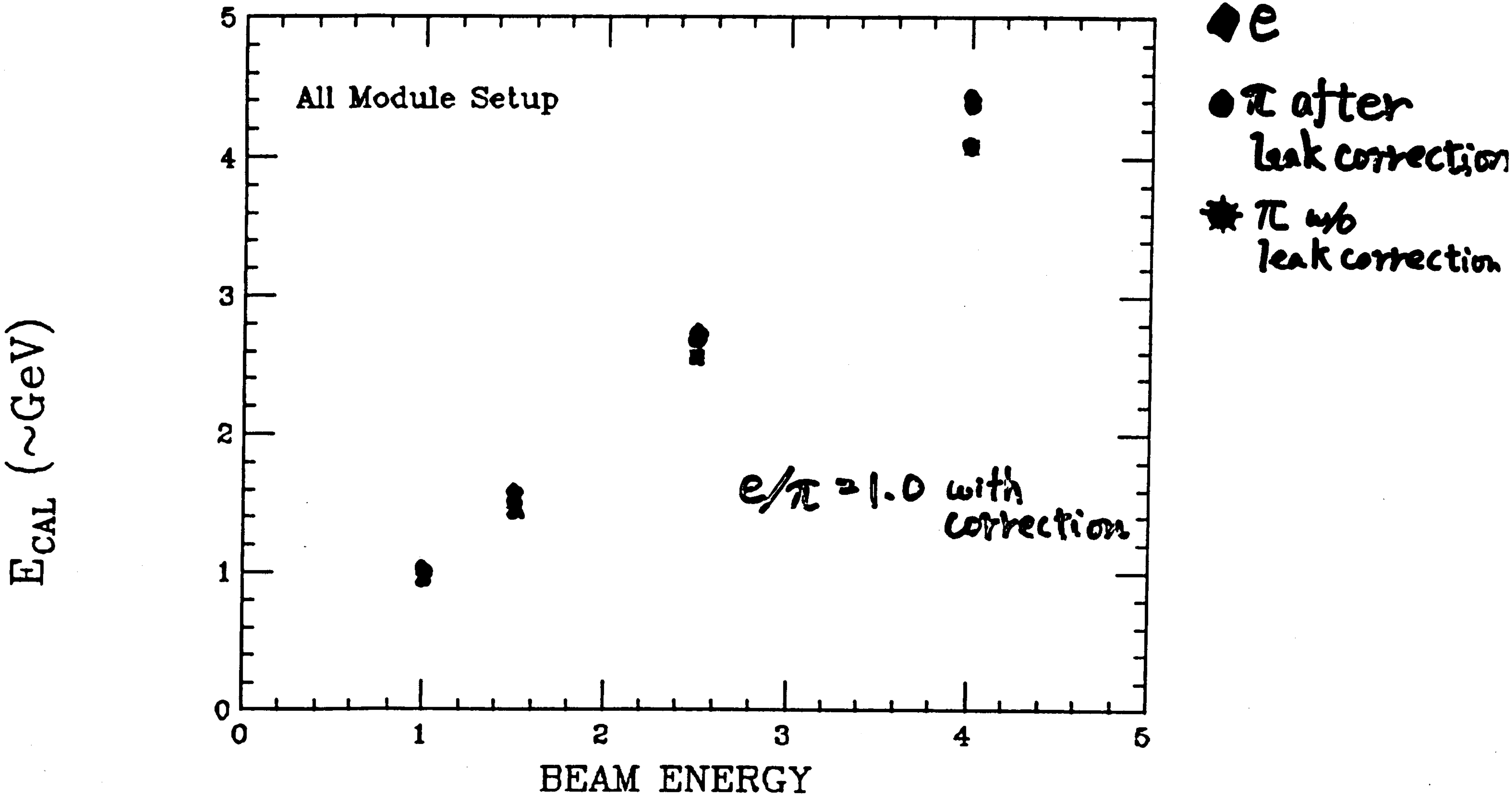
$\sigma_{xy} < 3\ \mu m$ (resolution)
1 mm x 1 mm (visual field)
1 mm (focal depth)

→ A precision mover will be ready soon.

→ Measurements



SWCAL Energy Liniarity



π-Leak corrected with GEANT 321 + FLUKA

Status of Calorimater R&D

What have been achieved

Test module made Beam test done	for	Baseline design SciFi option

- e/π=1 confirmed
- e/π separation works well

Detailed studies to undertand the test results are going on.

Future Plan

Fine-sampling EM SW test	→	to make sure 1mm thick scintillator works
CDF-type tile/fiber test	→	to reduce WLS volume
Optical read-out in 2 tesla	→	Test of FMPMT, HPD, VAPD in 2 tesla scheduled this July
Tune shower simulation	→	to optimize design and for detector simulation

LC
INTERACTION REGION
SUBGROUP

Chris Adolphson
Gordon Bowden
Dave Burke
Pisin Chen
Kim Cook
Spencer Hartman
Stan Hertzbach
John Irwin
Lew Keller
Tom Markiewicz
Gholam Mazaheri
Tor Raubenheimer
Ron Ruth
Francisco Villa

Specification of IR:

Essentially UNCHANGED since
LC '92 - Garmisch
LCWS '93 - Hawaii
We are still looking at problems
There are NO design solutions as yet
(should thus be easy to reconcile with JLC design!)

Dominated by uncertainty of
if we can and how can maintain
2.2 - 3.0 nm vertical spots

Detector:
LC Physics Workshops '91, '93 ⇒
SLD-like detector adequate
We have NOT done any physics simulations locally

Backgrounds:
SYNCHROTRON RAD → Assumptions of beam tails + collimation

BEAM-BEAM INT. → Looks ok
HADRONIC EVENTS.

MUON BACKGROUNDS: SPOILERS REDUCE FLUX x100 TO LEVEL OF 1μ / 10^{12} INCIDENT

TOLERANCES

IR group serving as a clearing house for vibration concerns for the whole machine. Clearly issue of final quad doublet is most severe.

For example:

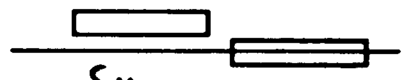
2% Luminosity loss from y spot position

corresponds to $\sigma^2 = \sigma_0^2 + (\Delta\sigma)^2$

$\frac{\Delta\sigma}{\sigma} = \sqrt{2\Delta\mathcal{L}} = 20\%$, or 0.6 nm jitter in y spot position.

Source multipliers connect this number back to various possible motions of Q1 and Q2 at the final doublet

$\frac{dy_{IP}}{dy_{Q1}} = 1.59$



$\frac{dy_{IP}}{dy_{Q2}} = -0.59$

$\frac{dy_{IP}}{dy_{Q1+Q2}} = 1.00$

These calculations need to be firmed up and translated into engineering specifications on the final doublet support structure. For now, consider worst case:

π mode oscillation of Q1 and Q2

$dy_{Q1,Q2} = dy_{IP} / (1.6 - (-0.6)) = 0.3$ nm

Beam-beam attraction eases this tolerance

RMS motion eases tolerance by √2

Sharing 2% ΔL loss beyond final doublet tightens tolerance

FINAL FOCUS TOLERANCES

J. IRWIN

4 DISTINCT TIMES —

JITTER	1) REP. PERIOD - 20	(FAST) STEERING FEEDBACK	- GOOD SIGNAL
STABILITY	2) ~ 10 min	— SLOW FEEDBACK — DISP., WAIST & SKEW TUNING	.. SPOT SIZE
TUNE	3) DAYS	CHROMATICITY & SEXT ABERR.	
SET-UP	4) MONTHS	SURVEY + BB ALIGNMENT + LATTICE DIAG.	

$\Delta\Sigma/\Sigma = 2\%$

Table III
NLC Tolerances w/ [illegible]

Time Scale	Generator (IP coord.)	Final Quadrupoles	Other Quadrupoles Worst	Other Quadrupoles RMS	Sextupoles	Dipoles	
τ_0 (20/ν_{rep}, STEERING)		Δx	or	Δy	n/a	n/a	
	x' y'	0.08 μ 8 nm (3 nm [illegible])	0.32 μ 35 nm (10)	0.24 μ 2[illegible] nm (4)	[illegible]		$\propto \epsilon$
τ_1 (2/10 min, DISPERSION)		Δx	or	Δy	n/a	n/a	
	$x'\delta$ $y'\delta$	34 μ (0.[illegible] μ) 2[illegible] nm	1.7 μ 71 nm	1.0 μ 47 nm	[illegible]		$\propto \frac{\epsilon}{\delta_{rms}}$
τ_2 (WAIST & SKEW)		(2) $\Delta k/k$	or	$\Delta\theta$	(1) Δx or (1) Δy	(2) $\Delta B/B$ or $\Delta\phi$	
	x^2	$4.7\ 10^{-4}$	$4.5\ 10^{-3}$	$6.2\ 10^{-3}$	0.30 μ	$1.6\ 10^{-3}$	(1) $\propto \left(\frac{1}{\xi_y}\right)^{5/3}$
	y^2	$1.9\ 10^{-5}$	$2.9\ 10^{-4}$	$1.3\ 10^{-4}$		37 μrad	
	$x'y'$	11.3 μrad	129 μrad	80 μrad	0.68 μ		(2) $\propto \frac{1}{\xi_y} \propto \frac{\beta^*}{\epsilon^*}$
τ_3 (DAYS, OTHER TUNABLE ABERRATIONS)			k_s		$\Delta k/k$ or $\Delta\theta$	n/a	
	$x^2\delta, y^2\delta$		0.69 m^{-2}	0.33 m^{-2}	$1.4\ 10^{-2}$		
	$x'y'\delta$		1.27 m^{-2}	0.38 m^{-2}	15 mrad		
	$x^3, x'y^2$	1.4 m^{-2}	0.75 m^{-2}	0.37 m^{-2}	$1.6\ 10^{-2}$		
	y^3, x^2y'	0.40 m^{-2}	0.50 m^{-2}	0.23 m^{-2}	3.4 mrad		

MONTHS -

+ STATIC TOLERANCES (some $\propto \frac{\epsilon}{\delta^2_{rms}}$)

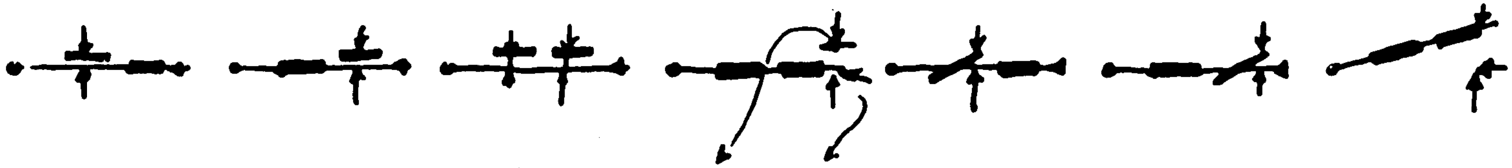
+ CAPTURE TOLERANCES (after [illegible]) + INCOMING BEAM TOL.

JITTER STRATEGIES → PASSIVE ISOLATION

+ ACTIVE STABILIZATION { field or quad support } if necessary.

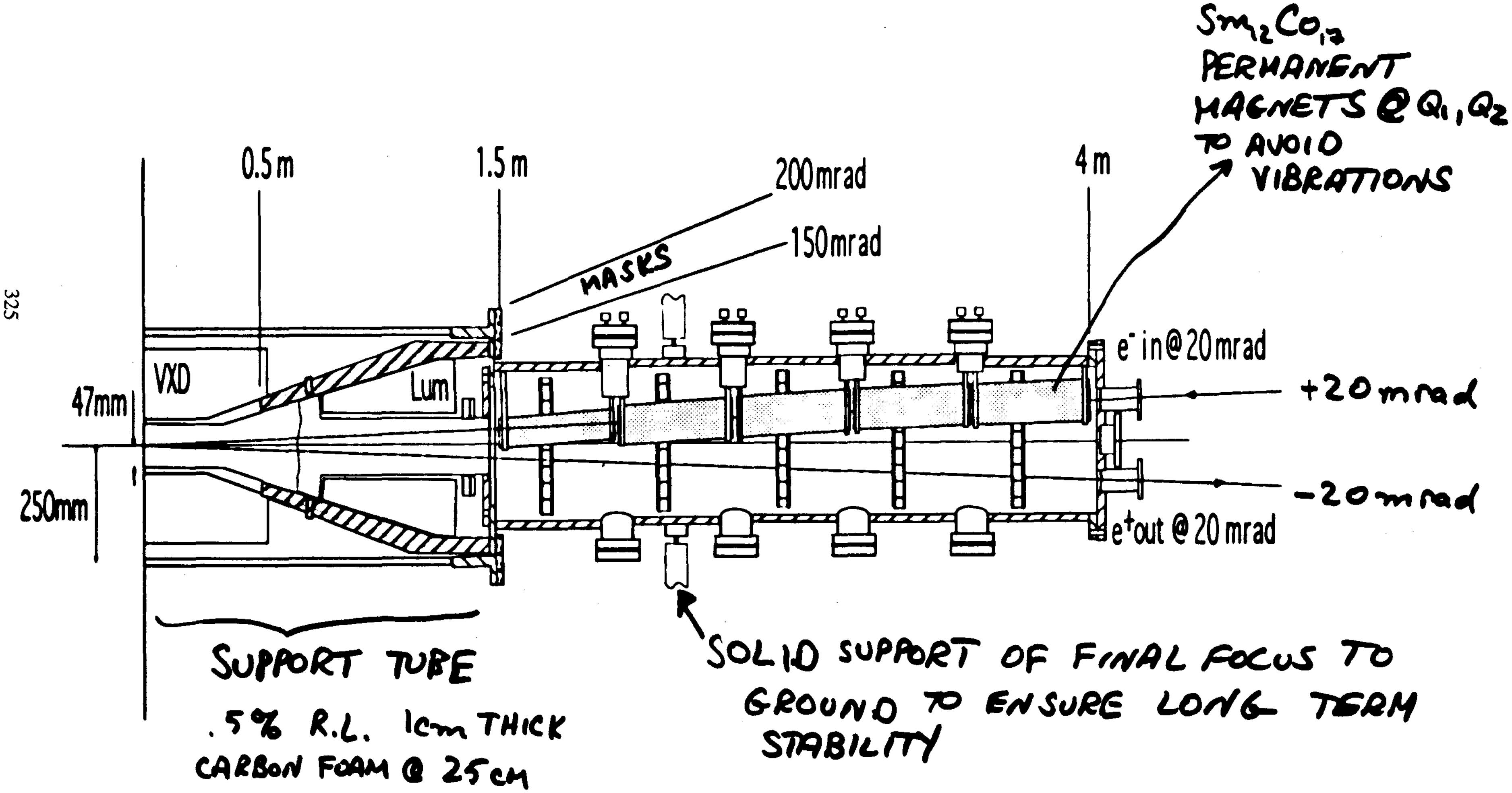
— SOURCE MULTIPLIERS —

J. IRWIN



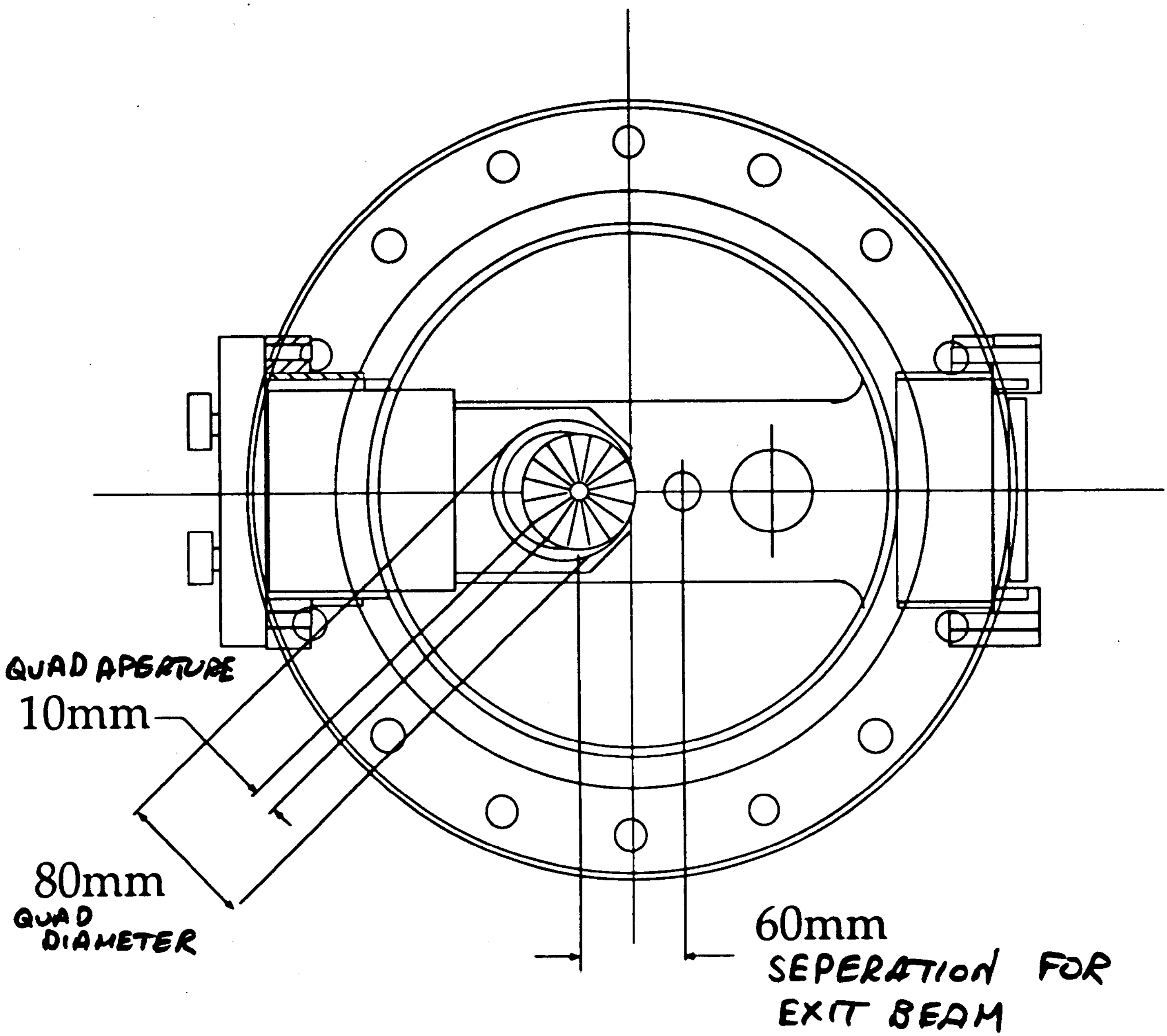
	δy_{Q1}	δy_{Q2}	δy_D	δy_E	$R_E\,\delta y'_E$	δy_{T1}	δy_{T2}	δy_{TD}
$\frac{\delta y_{IP}}{\delta y_i}$	+1.59	−.59	+1.00	0	−1	+.08	−.04	0.22
$\frac{\delta \eta_1}{\delta y_i}$	−1.59 +.41 −1.18	.59−1.14 −.55	−1.73	+1.73 (.1μ RMS's)	3.41	−.08	−.03	−1.01
$\frac{\delta \eta_2}{\delta y_i}$	−.41 +.03 −.38	1.14 −.17 .97	−.59	.59	.38	−.004	.07	0.66
$\frac{R\,\delta y'_{IP}}{\delta y_i}$	.77	.23	1.00	1.00	−.97	−.14	.09	0.55
$\frac{\langle \delta y_{IP}^2 \rangle_{SA} / \sigma_{IP}^2}{C_i (\delta y_i / \sigma_E)^2}$				3.3				

CONCEPTUAL I.P. DESIGN



325

X SECTION @ 1.5m



Possible Correction Schemes:

Measure acceleration or velocity and feed back signal to drive either crystal magnet supports or steering coils.

Measure change in B field seen by beam and drive corrector coil to null

Passive isolation of magnets from source of vibrations

Beam based feedback

Questions

Source terms:

Spectra of ground motion as a function of
- geology
- environment

Coherence of noise sources as a function of frequency and direction

Normal modes of support structures

Detectors:

Accelerometers, geophones, etc.:
- Sensitivity
- frequency response
- cost vs. sensitivity
- practicality

Pick up coils:
- Signal to noise in accelerator environment
- Inertial support for coil
- Practicality of mounting in quad bore
- Ideas for other detectors or mounting locations

Feedback schemes:

Devise scheme, given source spectra properties and detector response, to drive correcting element.

Work In Progress

Source terms:

Measurements of the frequency dependence and coherence of local of ground motion spectra using geophones listed below and their associated DAQ. In particular FFTB tunnel investigated so as to correlate results with spot size measurements from last run.

Detectors:

Accelerometers, geophones, etc.:

Study the response and calibration of two MARK Products L-4C 1 hz geophones w/ 1kg suspended mass

Survey the literature to find cost/sensitivity of other devices

Pick up coils:

Have pickup coil supported on a pneumatic isolation leg within a short length of permanent magnet.

RF BPM at FFTB:

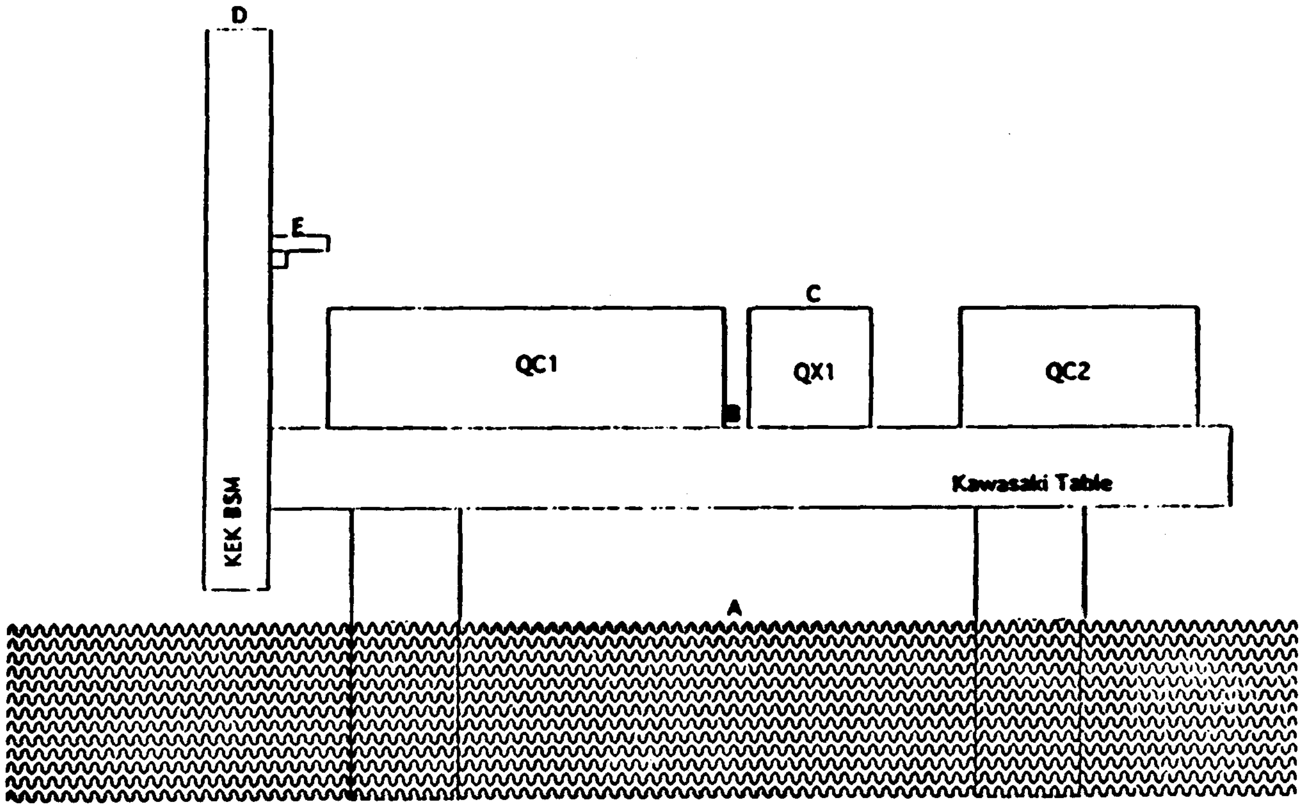
Integrated RF BPM/ spot size monitor w/ 1 nm sensitivity is under construction for January FFTB run.

Will be mounted at location of current laser spot size monitor.

Will drive corrector coil. Try to see level to which we can stabilizize beam

Feedback schemes:

Plan to model a feedback scheme but have not yet begun.

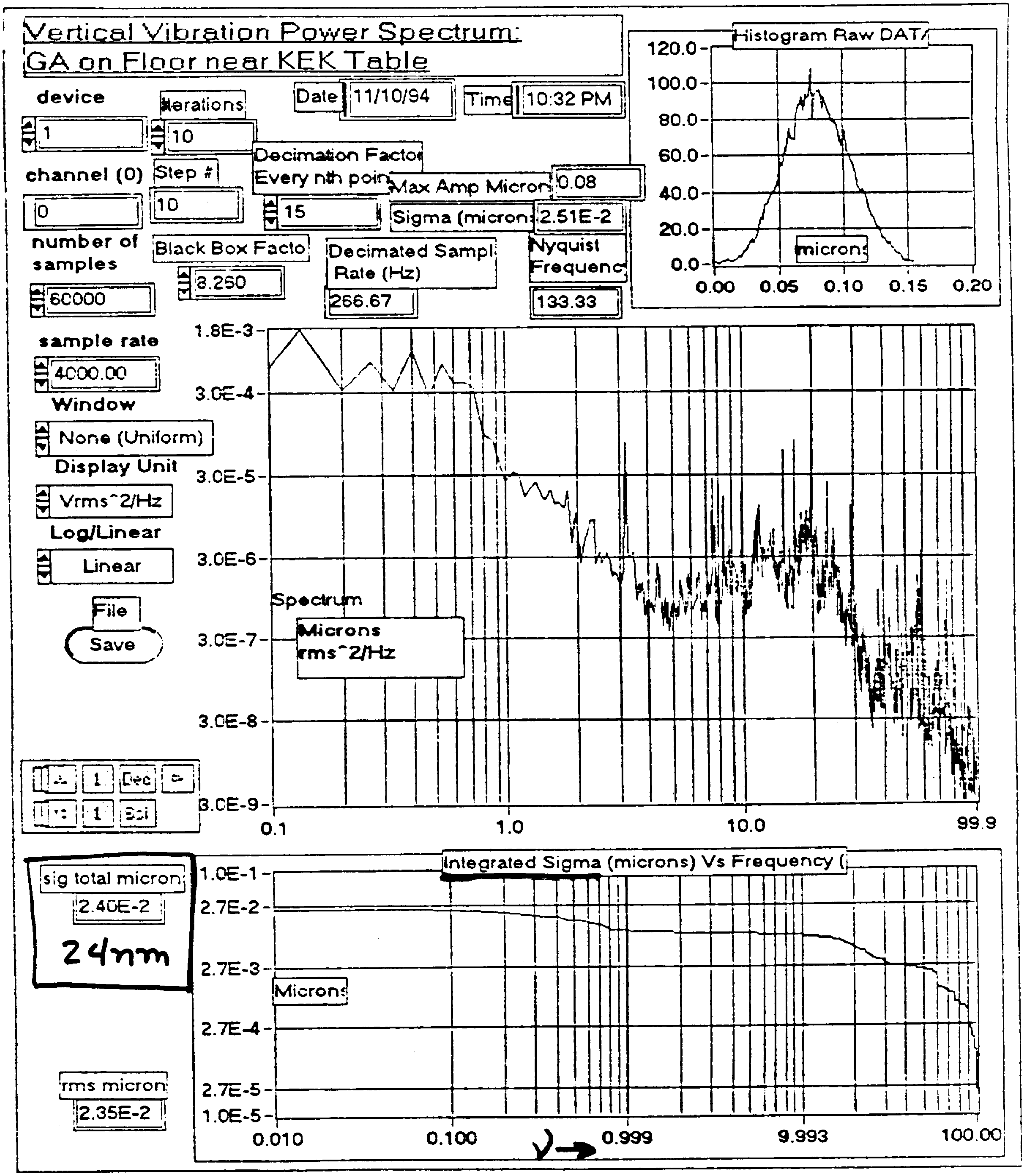


(11-11-94 Data 11:00 pm)

Position of Geophone	rms vibration amplitude 1-100Hz (nm)
Concrete Floor near KEK Table	24
Center of KEK Table	28
KEK BSM	37
Orsay BSM	69
QC1	27
QX1	26
QC2	32
QC3	60
QC4	22
QC5	23
Concrete Floor near QC5	19

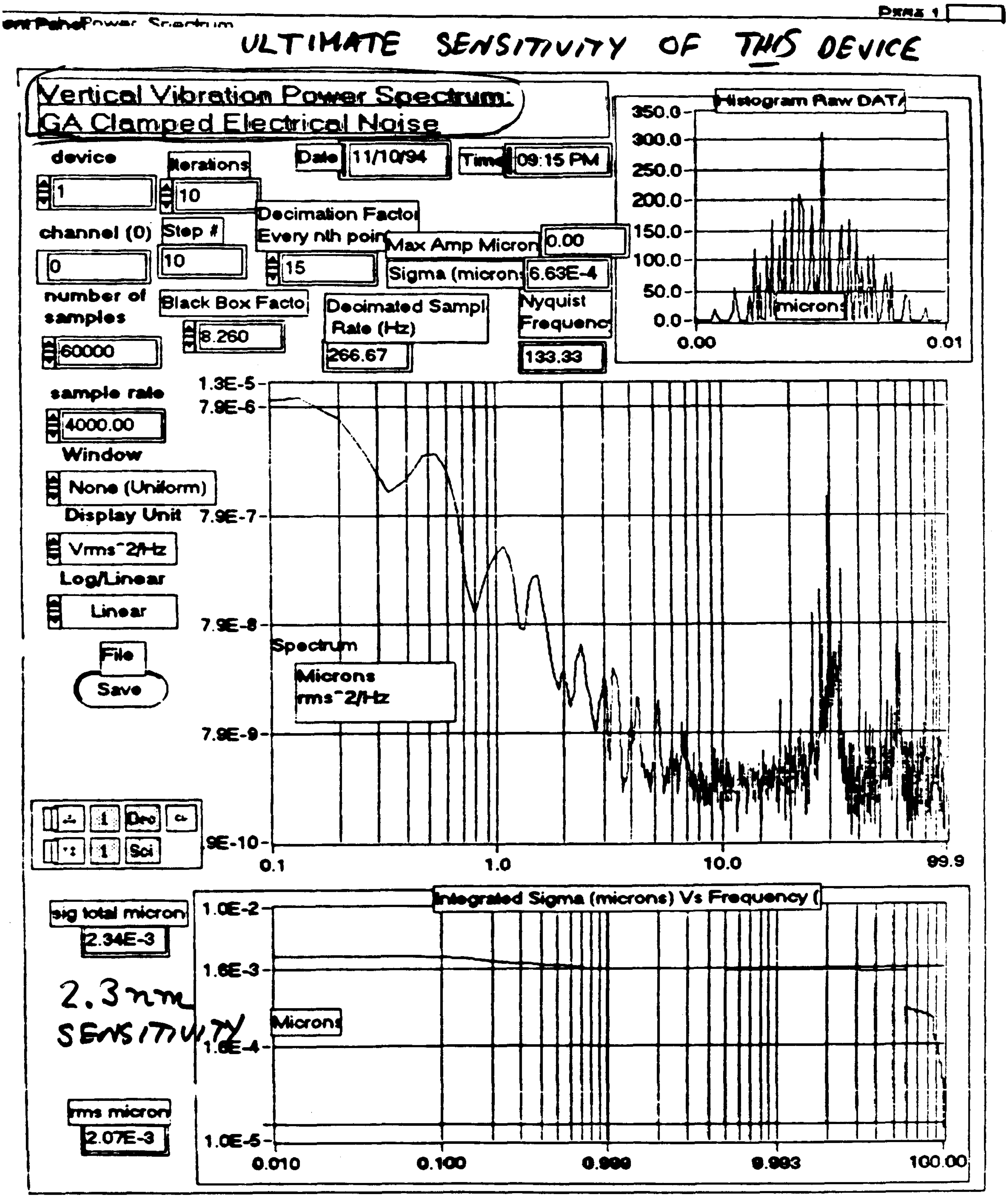
Table 1

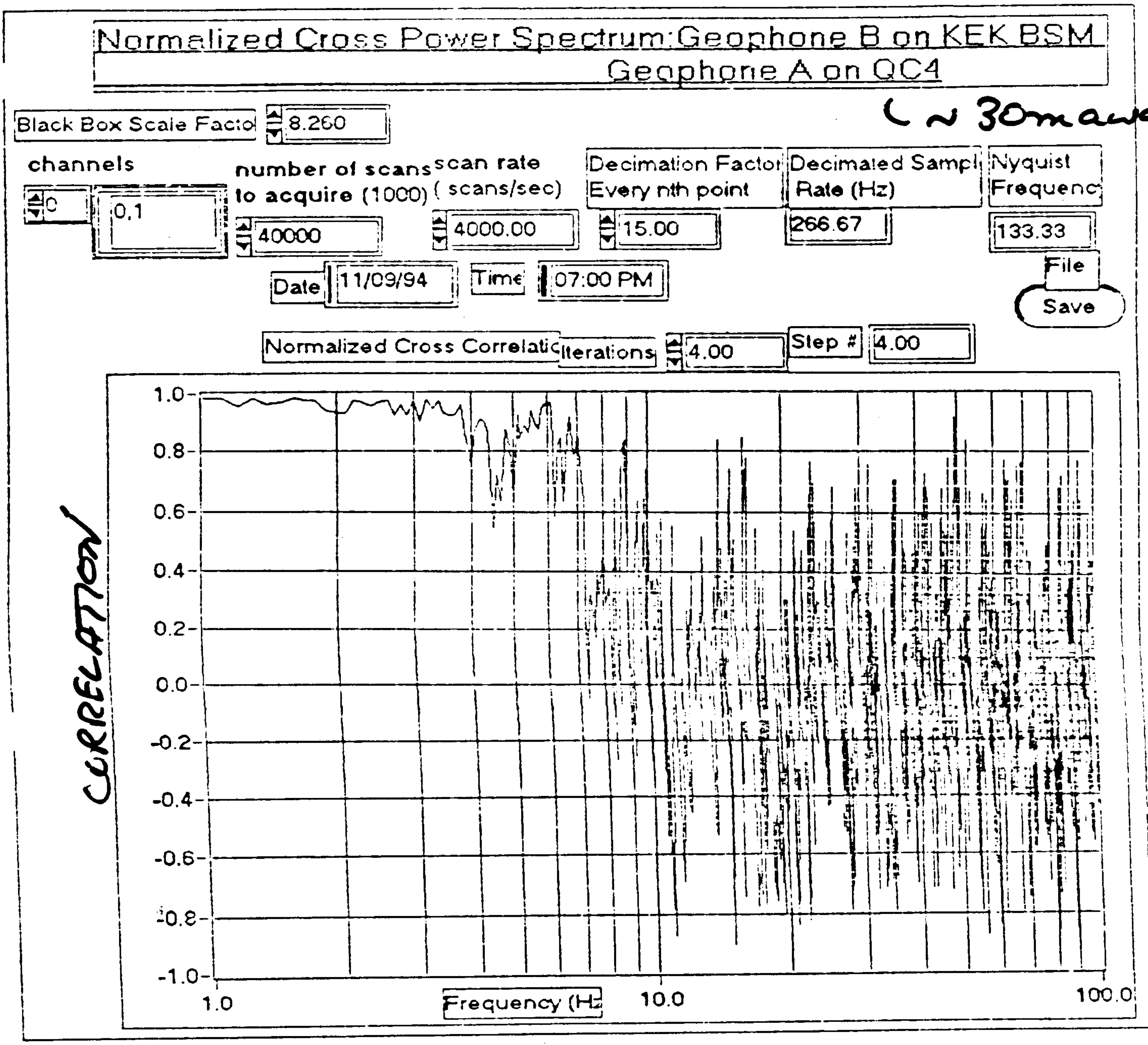
Front Panel



Vertical Vibration Power Spectrum:
GA on Floor near KEK Table
device
1
Iterations
10
Date
11/10/94
Time
10:32 PM
channel (0)
0
Step #
10
Decimation Factor
Every nth point
15
Max Amp Micron
0.08
Sigma (microns)
2.51E-2
number of samples
60000
Black Box Factor
8.250
Decimated Sample Rate (Hz)
266.67
Nyquist Frequency
133.33
Histogram Raw DATA
microns
sample rate
4000.00
Window
None (Uniform)
Display Unit
Vrms^2/Hz
Log/Linear
Linear
File
Save
Spectrum
Microns rms^2/Hz
Integrated Sigma (microns) Vs Frequency
sig total microns
2.40E-2
24nm
Microns
rms microns
2.35E-2

ULTIMATE SENSITIVITY OF THIS DEVICE





(~ 30m away

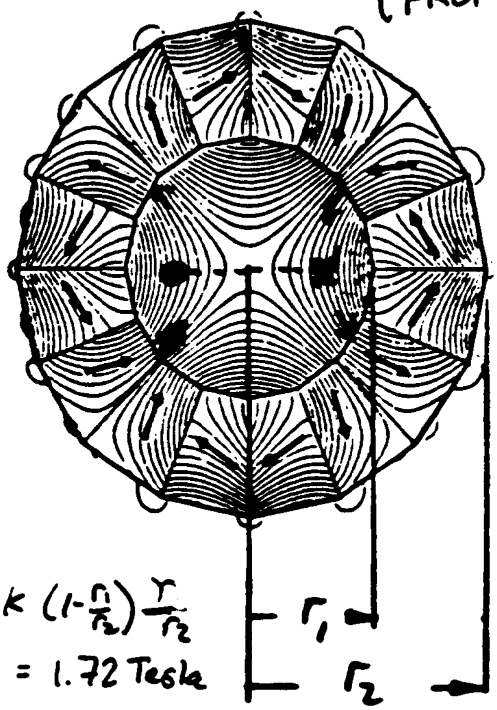
GOOD CORRELATION OF GROUND MOTION
$\lesssim$ 7 Hz OVER ~ 30m

NEED TO UNDERSTAND CORR. VS distance
for any feed back scheme to work.

G. BOWDEN
S. SMITH [redacted]

Potential Solution to Reduce Effect of Higher Frequency Vibration LOCAL MAGNETIC STABILIZATION

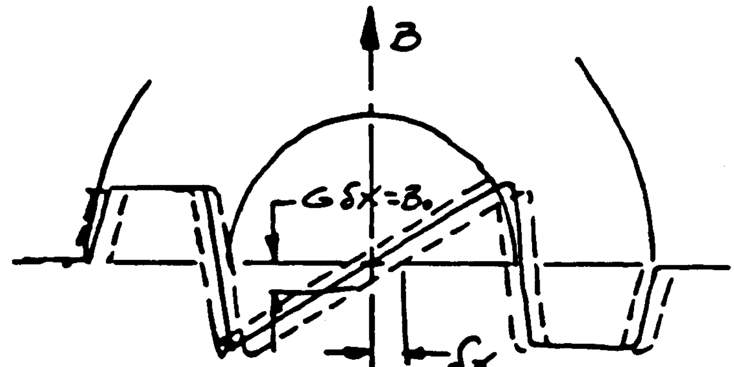
16 block Sm_2Co_{17} QUAD (FROM CORNELL)



$B(r)=k\left(1-\frac{r_1}{r_2}\right)\frac{r}{r_2}$

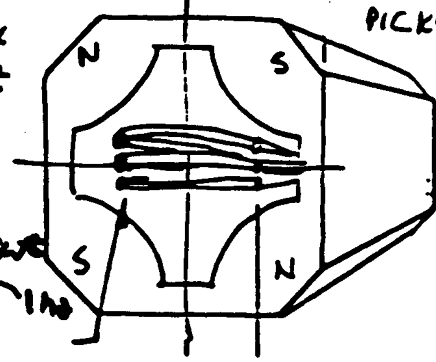
$B(r_1) = 1.72$ Tesla

$\frac{dB}{dr} = G = 3.44\ T/cm$



$\delta x \approx 1nm$ seismic motion induces uniform dipole field $B = G \cdot \delta x = 3.44$ milliGauss

MAGNET MOVES AROUND INERTIAL PICKUP COIL



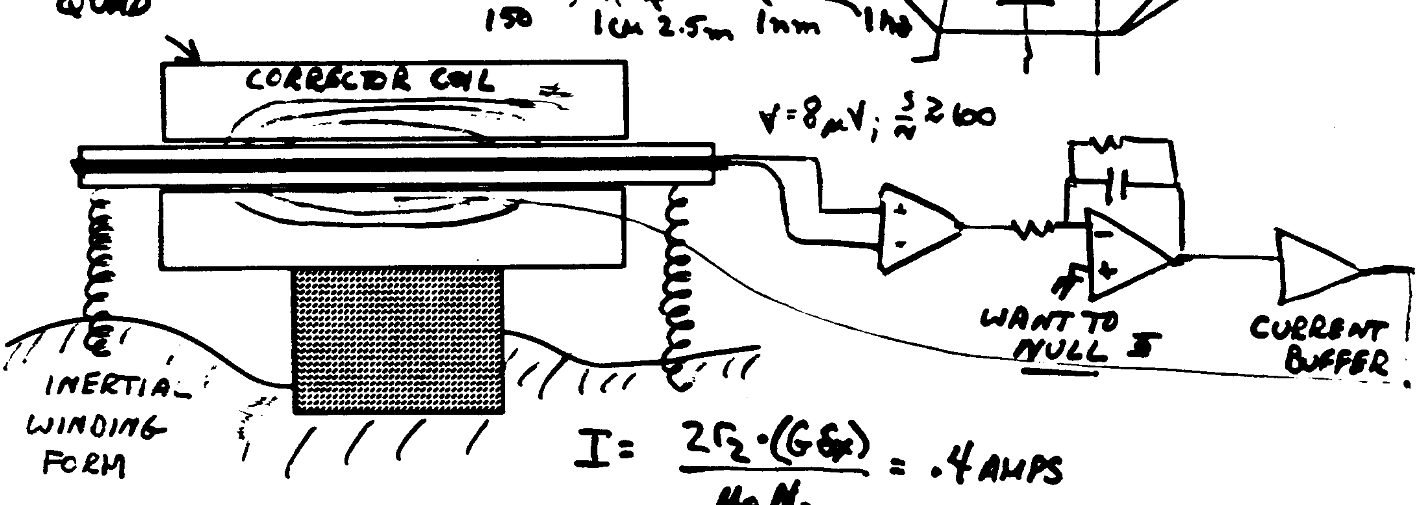
$V = \frac{d\Phi}{dt} = A\frac{dB}{dx}\frac{dx}{dt}$

$A = ndL$

$x = \delta x \sin\omega t$

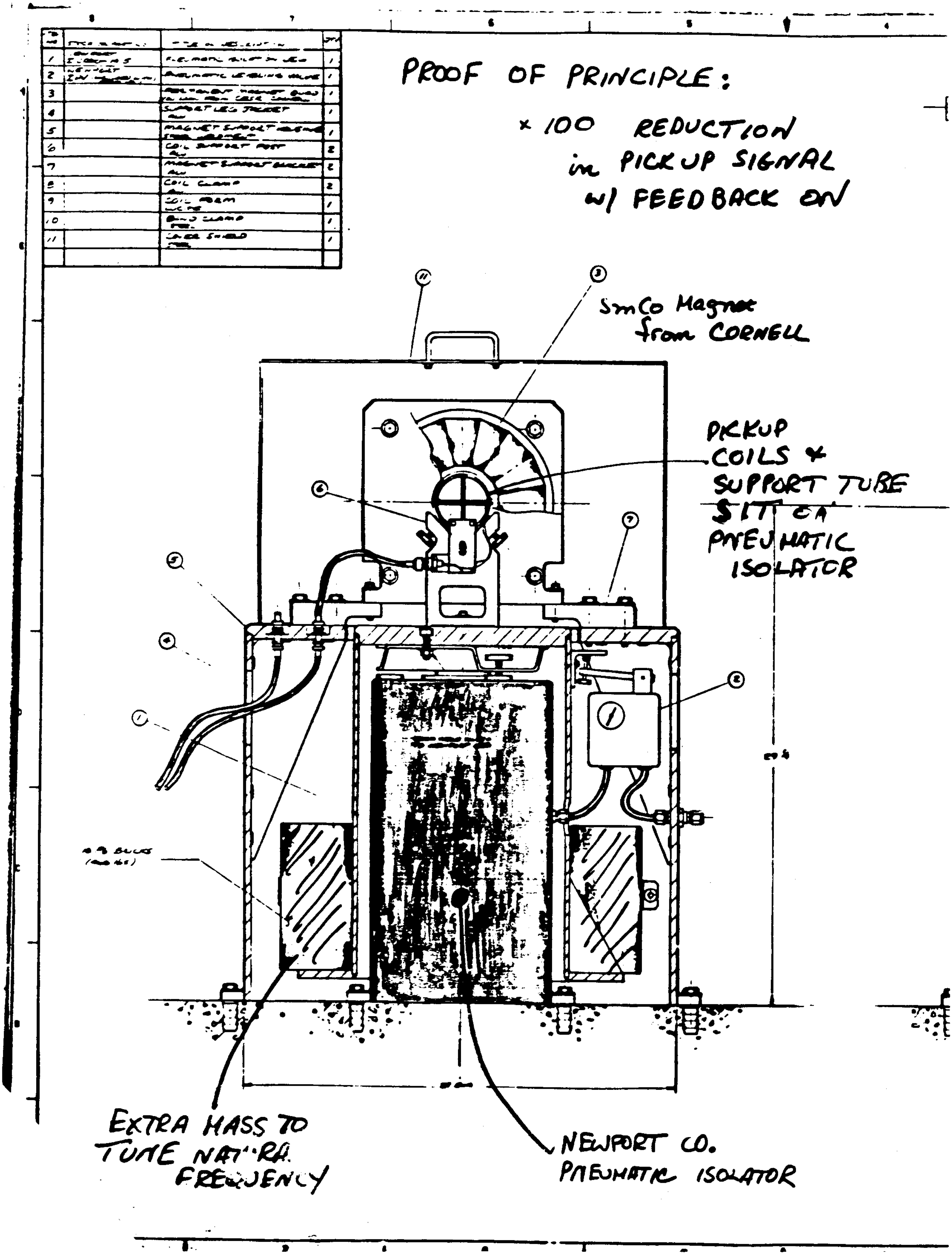
$V = ndL \cdot G \cdot \delta x\, \omega \cos\omega t$

(n = 150, d = 1cm, L = 2.5m, δx = 1nm, 1Hz)

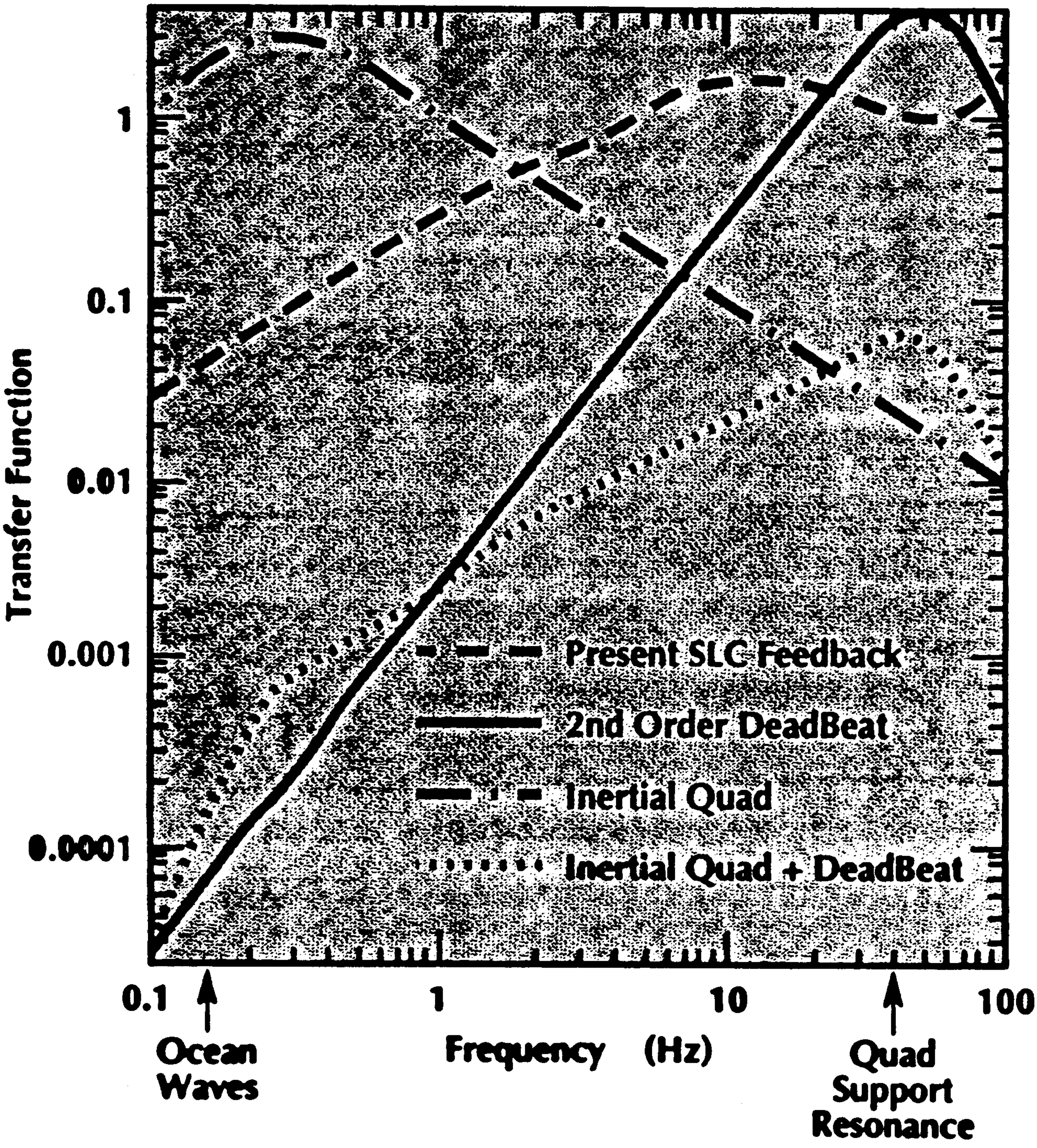


$I = \frac{2r_2 \cdot (G\delta x)}{\mu_0 N_D} = .4$ AMPS

N_D = 50 turns ; $R = 5\Omega \Rightarrow V = 2V$


PROOF OF PRINCIPLE:
× 100 REDUCTION
in PICKUP SIGNAL
w/ FEEDBACK ON
SmCo Magnet
from CORNELL
PICKUP
COILS &
SUPPORT TUBE
SIT ON
PNEUMATIC
ISOLATOR
EXTRA MASS TO
TUNE NAT'RAL
FREQUENCY
NEWPORT CO.
PNEUMATIC ISOLATOR

Vibration Reduction Strategies



10-93
7653A17

Other Issues

Backgrounds: No new results since LCWS 1993

e+e- pair creation in field of colliding bunches
hadrons produced by photons from beam-beam effect
Synchrotron radiation
Muon Backgrounds

Distortion of energy spectrum of colliding beams due to beam-beam interaction:

No explicit work done. See Miller in LCWS 93.

Crossing angle: assume 20 mrad per beam, not yet optimized

Detailed Engineering Design of IR area: nothing new yet

- Beam Spot Diagnostics near IP
  - Laser wires or other diagnostics
  - Interferometer
- Vertex Detector
- Support tube
- Beam Pipe

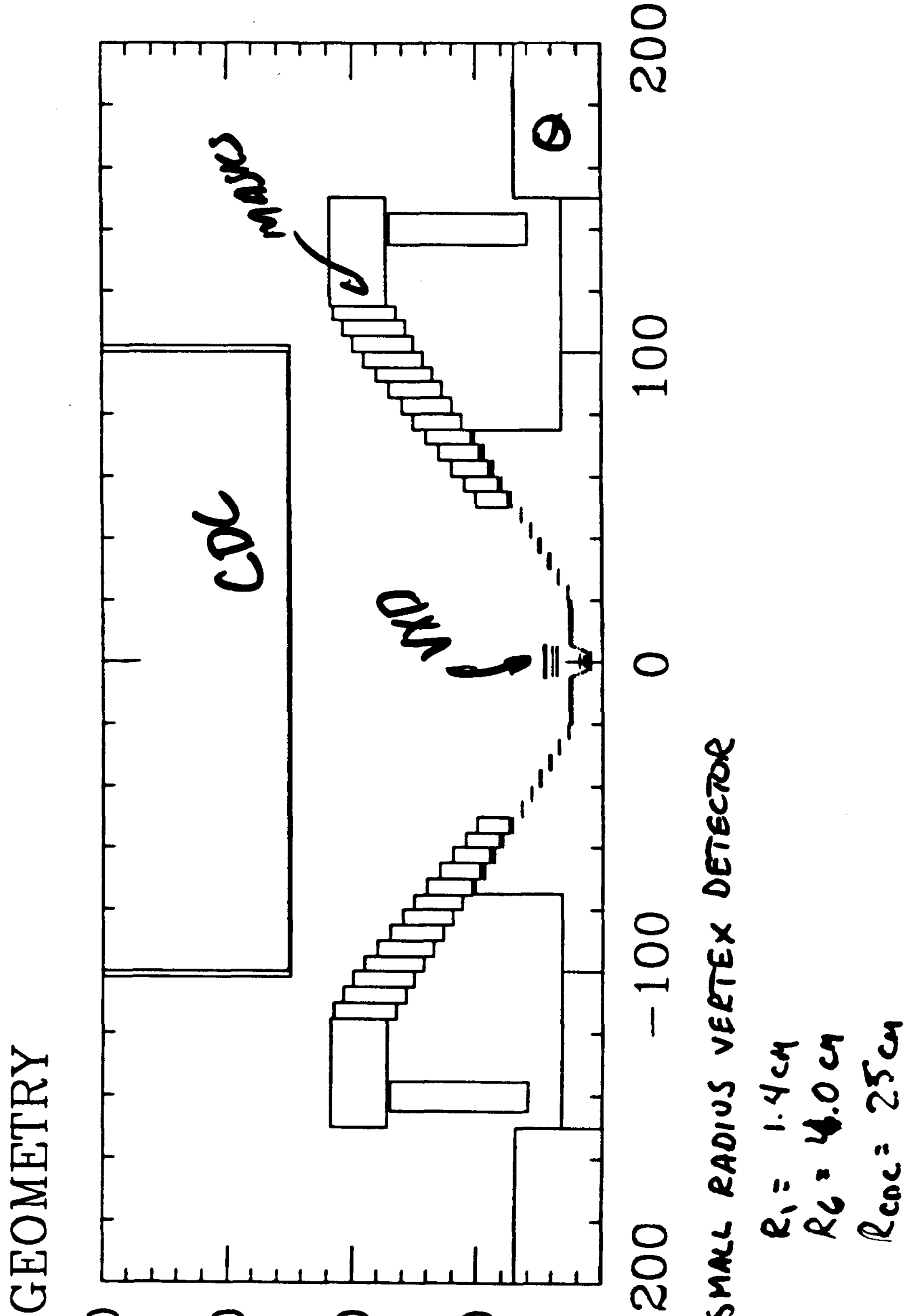
Polarized source and conservation of polarization: Yes.

One or Two IP's: assume Yes

any real design work done within John Irwin's FF group.

e - Gamma and Gamma-Gamma Implications

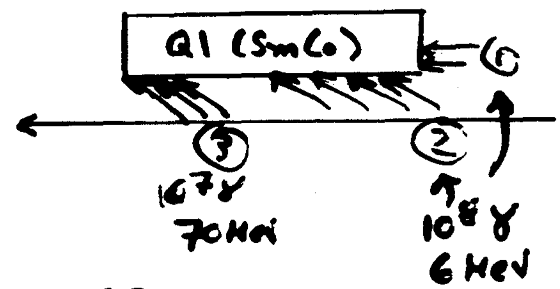
No real work done. Assume for the moment that other IP is reserved for these interactions.



NLC GEOMETRY
40
30
20
10
0
−200
−100
0
100
200
CDC
VXD
MASKS
Q
SMALL RADIUS VERTEX DETECTOR
R1 = 1.4cm
R6 = 4.0 cm
RCDC = 25cm

H. de Staebler
G. Punkar
[redacted]

Propogate SR Photons into NLC Detector : EGS



Step 1:

Input:

SR Photons from Sources 1, 2, 3 hitting Q1

Output:

"Score" (record) all particles crossing plane at z=1.5 m

- **26K particles, 95% photons, mostly from Source 3**

Step 2:

Input: Take into account 20 mrad Xing angle:

- **Rotate and offset rays from step 1**

  $\Delta x' = 20$ mrad

  $\Delta x = 0.02 \times 1.5$ m = 3 cm

Output: Score Photons and $e^{\pm}$ hits in VTX and CDC for each of 2 NLC "proto-detectors"

1.) **Small Radius pixel based VXD + CDC**
2.) **Larger Radius pixel based VXD + CDC**

EXPECT 10^{-3} WITH 8σ COLL

Results: For 2 (e+, e-) 500 GeV bunch trains each with 10**12 particles and 1% flat tail to 10σ

20 = 1% occ. → 10^{-4} in SLD VTX; norm

	#photons / train	$\#e^{\pm}$ / train	$\#e^{\pm}$ / mm^2 / train
Small radius VXD			
VXD-L1 (1.4 cm)	2.28E+04	7.92E+04	27.2
VXD-L6 (4.0cm)	1.56E+05	4.48E+05	18.6
CDC (25cm)	2.62E+06	1.54E+04	
Larger Radius VXD			
VXD-L1 (6.0 cm)	2.36E+05	2.00E+05	3.32
VXD-L6 (20 cm)	6.11E+05	7.00E+03	0.1
CDC (25cm)	1.77E+06	1.40E+03	
	$\langle E_\gamma \rangle \sim 2$ MeV	$\langle E \rangle \sim 20$ MeV	

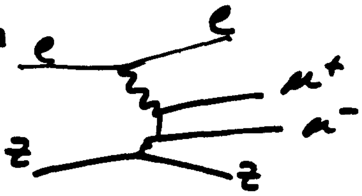
Results: For 2 (e+, e-) 250 GeV bunch trains ABEL Beam-Beam Interaction code as input

	#photons / train	$\#e^{\pm}$ / train	$\#e^{\pm} / mm^2$ / train
Small radius VXD			
VXD-L1 (1.4 cm)	200	6200	1.98
VXD-L6 (4.0cm)	0	800	0.34
CDC (25cm)	4.2E+04	200	
Larger Radius VXD			
VXD-L1 (6.0 cm)	200	200	0.002
VXD-L6 (20 cm)	1000	0	0
CDC (25cm)	4200	0	

L. KELLER
[redacted]

MUON BACKGROUNDS

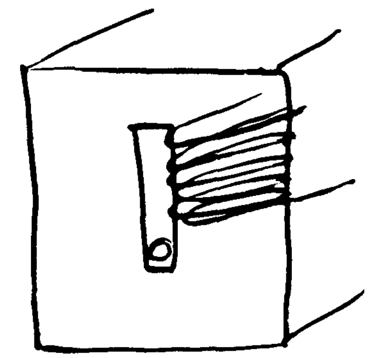
Produced by Bethe-Heitler pair production

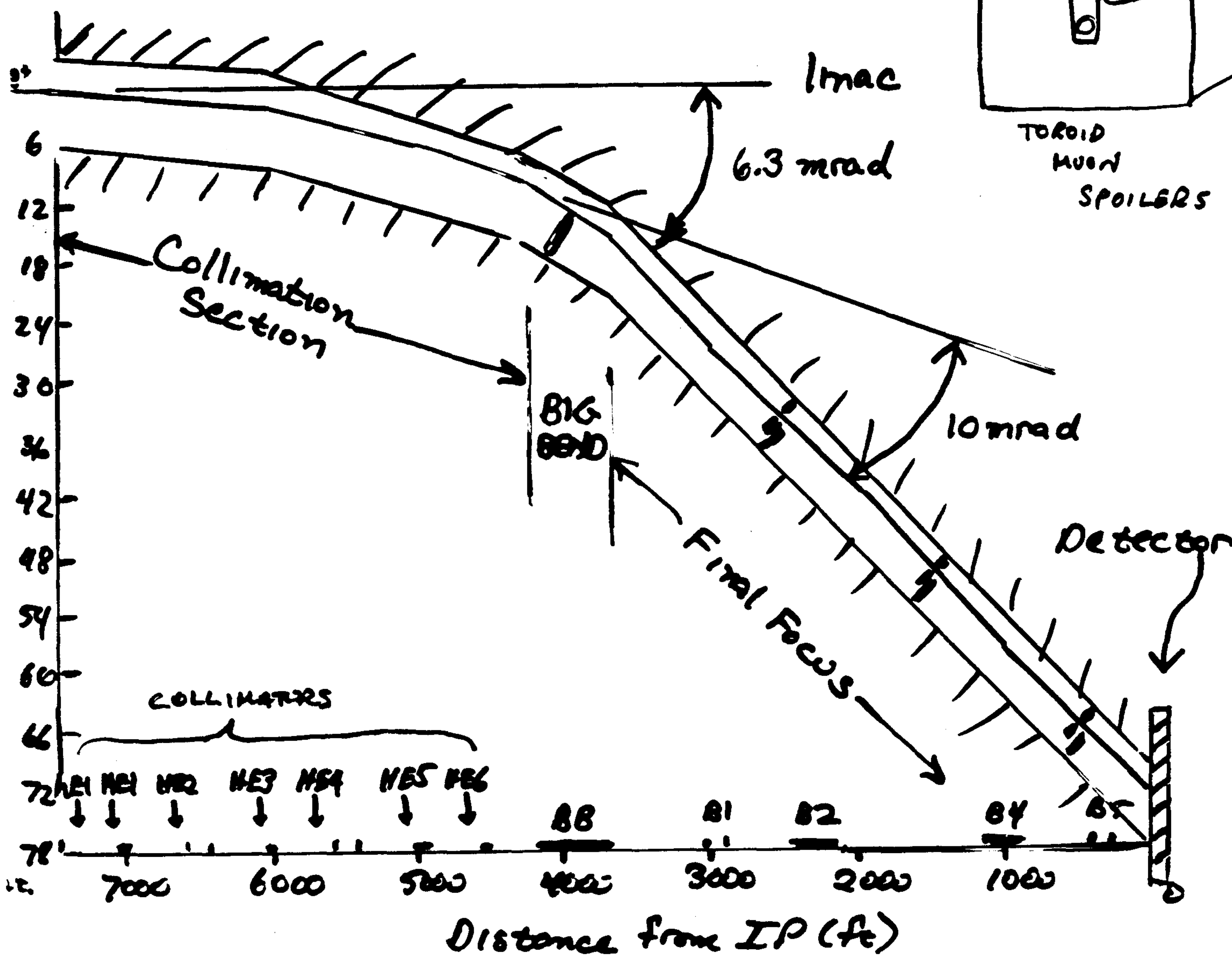


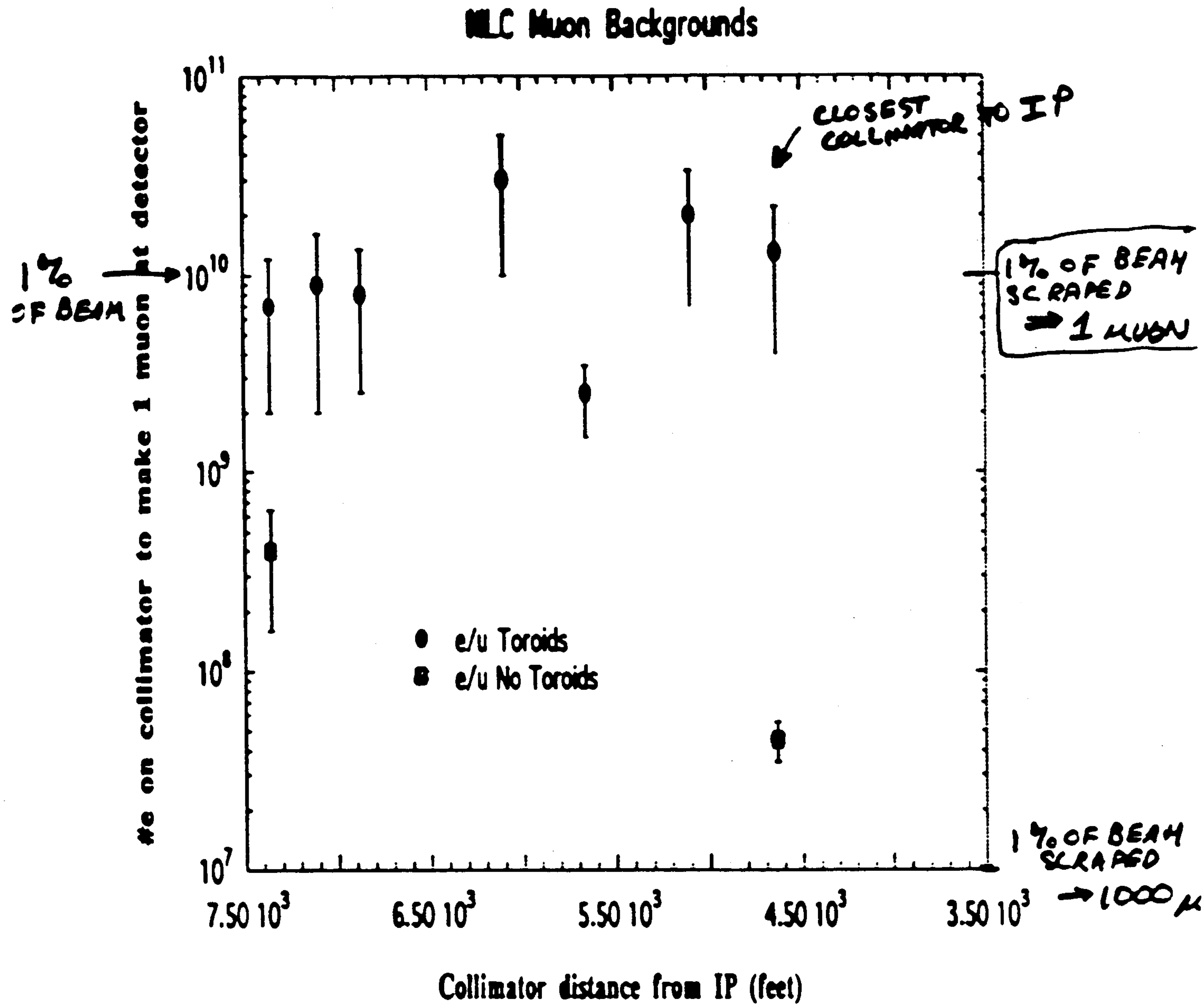
@FF COLLIMATOR

Tool: MC program developed by Feldman for Mark II and SLC final focus to produce muons and transport them

STUDY PLACEMENT OF MUON SPOILERS







- **Magnetized iron toriods give about x150 improvement**
- **Best to fill tunnel completely : round toroids in a rectangular tunnel don't work as well**
- **Small tunnel (5' x 5') is 5-10x better than large tunnel (10' x 10')**
- **Removing BIG BEND is about x10 worse**
- **5-10x more muons reach the IR, but don't hit a 6 x 6 m^2 detector**

Experimental Apparatus

General feeling that it is way too early to think about a detailed apparatus. For now simulations have assumed:

Vertex detector:	6 planes, pixel based, at various radii
Magnetic Field:	2 Tesla — no optimization done
Masking:	Tungsten Masks from 190-200 mrad
Timing:	Assume sub 1 ns timing possible in both calorimeter and tracking systems
Lum. Monitor:	Place at ±1.5 m to avoid backsplash

Assume SLD detector for the rest

- Tracking Resolution and Granularity
- Calorimetery Resolution and Granularity
- Muon Coverage
- Acceptance

DAQ issues: not yet addressed

Extracted Beams:see John Irwin's Beam Disposal subgroup

- Energy spectrometer
- Compton polarimeter
- BSM monitors
- Small angle Bhabba LUM monitor

Calibration (?): not addressed

- Z pole running
- Varying # of bunches / train

Problems to be considered for JLC

- Damping ring
  new problem .... ion. see ATF

- Compressor
  consistent design with 1-stage compressor

- Pre-Linac
  - energy
  - frequency $?

- Power Source
  higher peak power, longer pulse than NLC
  - see Klystron developement.
  - dark current study

- Acc. Structure
  - length 1.3 m , not really optimized
  - chokemode cavity

- Final Focus
  - small φ. no problem
  - feedback within pulse (D.Burke)
    with no crab cavity ?
  - 1.5 TeV
    serious design (to say no ?)

Parameters Summary

R. RUTH

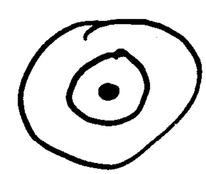
12/8/94.

- No Fundamental problems with JLC / NLC parameters
- differences between parameter sets are relatively minor and involve technical choices.
- understanding these technical choices can improve NLC / JLC Designs.

Highlights

- Injectors:
  - No important differences
  - Jitter Tolerances
  - Beam loading compensation
  - Positron Acceleration. S or L ?
- Damping Rings → problem ... ions ?
  - Similar Designs. , Energy
  - Wiggler vs bending → damping
  - ATF → important !
- Compressors
  - Should there be 1 or 2 ?
  -

- R F power Systems
  - Trade off : pulse Compression vs Klystron power } $\eta \sim$ const
  - Pulse Compression "new" ideas.
    - High Power Switch.
    - lumped delay lines.
  - Modulators
    - Blumlein type
    - CABLE energy Storage? (Cassel)



- Technology → good progress
- VLCTA → important.

Accelerator Structures

- Detuned structures are "in"
- Damped / Detuned ~ "in"
- lengths = ? 1.3 → 1.8
- a/λ = ? .16 → .18
- Technology ⇒ good progress.
- KEK/SLAC collaboration important

Final Focus

- Spot Sizes ~ same
- To crab or not to crab?
- Vibration Tolerance?
- Detailed Design Differences

Bottom Line

$\mathcal{L} \gtrsim 5 \times 10^{33} \, cm^{-2} sec^{-1}$ 500 GeV.

$\gtrsim 2 \times 10^{34} \, cm^{-2} sec^{-1}$ 1.5 TeV

E = 500 GeV starting.

= 1 TeV Definite upgrade.

= 1.5 TeV Possibility Open.

DR and BC

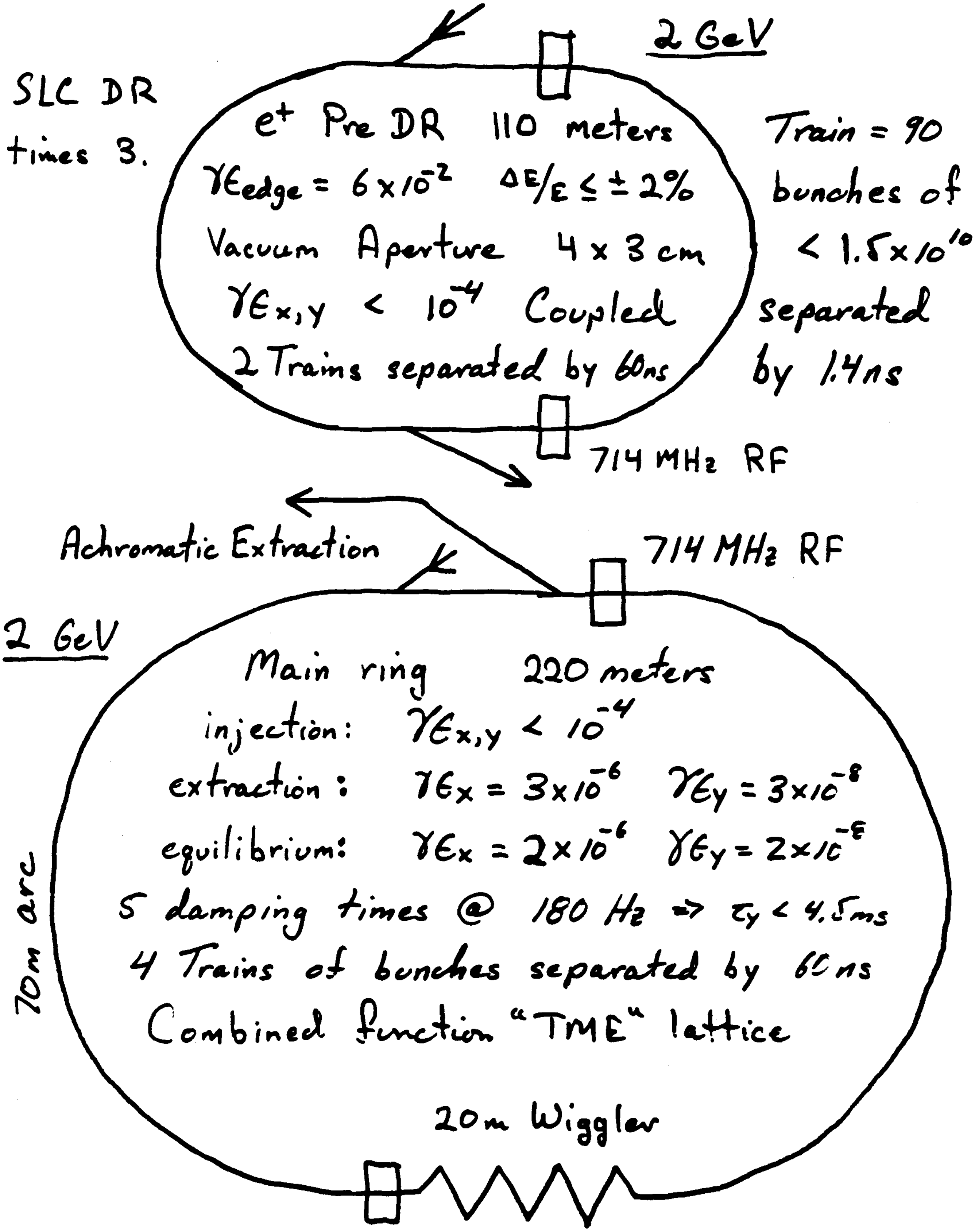
DR and BC goal – generate beams with very good stability and reliability.

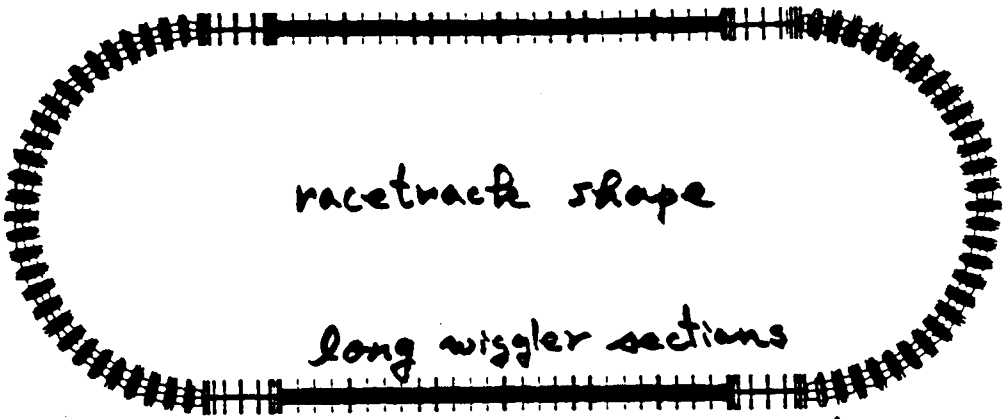
Parameters for JLC and NLC are similar – NLC bunch current slightly larger – JLC initial ε is slightly larger and rep. rate is slightly different.

⇒ JLC and NLC final designs will probably be very similar.

⇒ At this time some difference in approaches / technology

ATF will demonstrate many of the choices : wigglers, kickers, vacuum design, single/double compressor.


SLC DR
times 3.
2 GeV
e+ Pre DR 110 meters
γεedge = 6×10⁻² ΔE/E ≤ ±2%
Vacuum Aperture 4 x 3 cm
γεx,y < 10⁻⁴ Coupled
2 Trains separated by 60ns
Train = 90
bunches of
< 1.5×10¹⁰
separated
by 1.4ns
714 MHz RF
Achromatic Extraction
714 MHz RF
2 GeV
Main ring 220 meters
injection: γεx,y < 10⁻⁴
extraction: γεx = 3×10⁻⁶ γεy = 3×10⁻⁸
equilibrium: γεx = 2×10⁻⁶ γεy = 2×10⁻⁸
5 damping times @ 180 Hz => τy < 4.5ms
4 Trains of bunches separated by 60 ns
Combined function "TME" lattice
70m arc
20m Wiggler



in zero-dispersion region

Figure 4.20: Schematic layout of the JLC damping ring.

reduction of the damping time

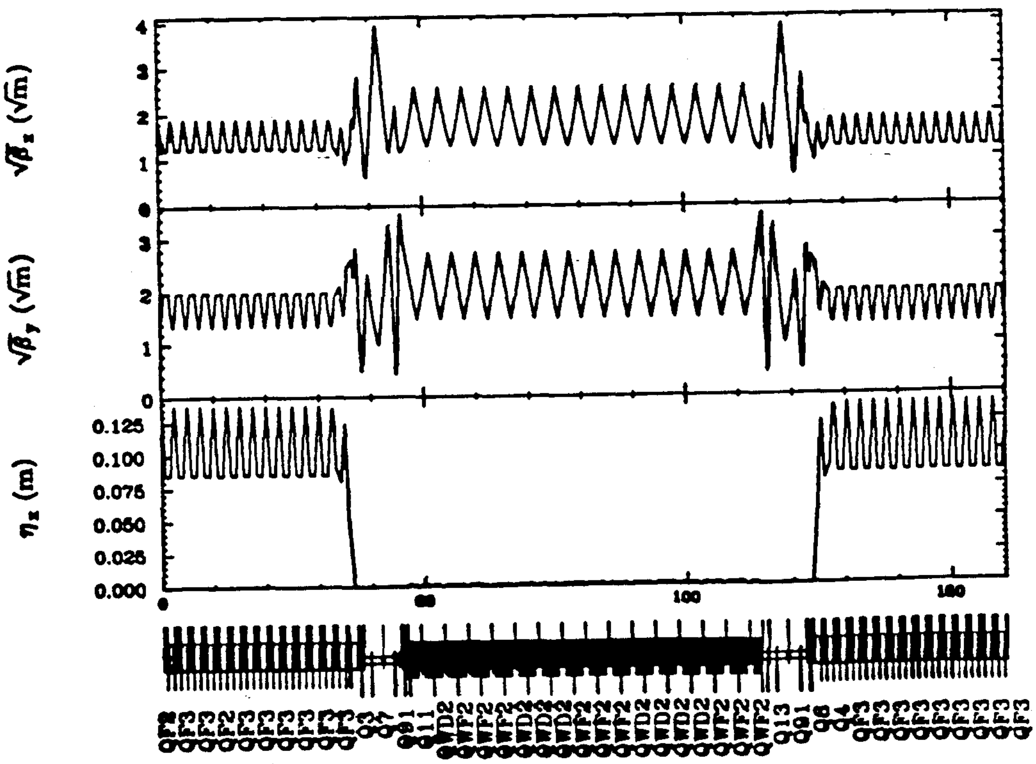


Figure 4.21: Lattice parameters of half of the damping ring.

Lattices

NLC

TME arcs – strong damping

$\alpha \downarrow$ ~ 1/3 JLC

Short hybrid wiggler 20m $\hat{B} \sim 22kG$

50% of damping

(No ϵ decrease)

JLC

FOoF arcs – weak field (looser align.)

α larger

Long E+M wiggler 140m $\hat{B} \sim 17kG$

80% damping

ATF

FOoF arcs – weak field 25Hz

α larger

E+M wiggler 20m $\hat{B} \sim 17kG$

20% damping

RF Parameters for the NLC and ATF Damping Rings (Dec, 1994)

Cavity	Related Properties	NLC	ATF
f_{rf} [MHz]	Accelerating Frequency	714	714
h	Harmonic Number	524	330
V [MV]	Total Cavity Voltage	1.5	1.0
β_f	Cavity Coupling Parameter	12	2.4
$R\ (= \frac{V^2}{2P})$ [$M\Omega$]	Loaded Shunt Impedance/Cavity	3.3	1.8
Q	Loaded Quality Factor	2040	6500
T_{fill} [μs]	Cavity Fill Time	0.91	2.90
$\frac{\Delta E}{E}$ [%]	Bucket Height	3	2.2
N_c	Number of Cavities	4	4
Klystron	**Related Properties**	**NLC**	**ATF**
P_b [kW]	Total Beam Power	925	94
P_c [kW]	Total Wall Loss	85	69
P_{max} [MW]	Maximum Klystron Output Power	1.2	0.250
N_k	Number of Klystrons	4	1
Beam	**Related Properties**	**NLC**	**ATF**
E [GeV]	Beam Energy	2.00	1.54
I [A]	Maximum (dc) Beam Current	1.0	0.60
N_t	Number Bunch Trains	4	2-5
N_b	Number Bunches/Train	75	10-60
n_b [10^{10}]	Number Particles/Bunch	1.5	1-3
U_0 [keV]	Radiation Loss/Turn	635	156
U_{hom} [keV]	Higher Order Mode Loss/Turn	2[illegible]0	-
σ_z [mm]	Bunch Length	3.5	3.1
α	Momentum Compaction	0.0005	0.0019
ϕ_s [deg]	Synchronous Phase	54	81
ν_s	Synchrotron Tune	0.0048	0.0080

NLC and JLC RF systems very similar
Large beam loading. 1~2 MW klystron
power. Transients (MPS) are question. $\Delta\phi_s$
is a question.

Vacuum

NLC

10^{-9} Torr — $\Delta\nu_y \sim 0.02$ ion instab.

Ante chamber in bends plus pumping chamber

Double ante chamber in wiggler

JLC / ATF

6×10^{-8} Torr — check $\Delta\nu_y$ ions

Ante chamber in bends

Double pumping chamber in wiggler

Kickers

All designs use double/triple/quad/ kicker systems 5×10^{-4} $\Delta\theta/\theta$ tolerance

Pre-DR kickers stronger but looser.

Ions in Linacs of Future LC

Future linear colliders have long trains of bunches and/or very dense bunches

⇒ Significant ion densities thru
Tunnelling ionization
or
Collisional ionization and trapping

Effects

(1) Non-uniform distribution
⇒ skew fields and β-coupling

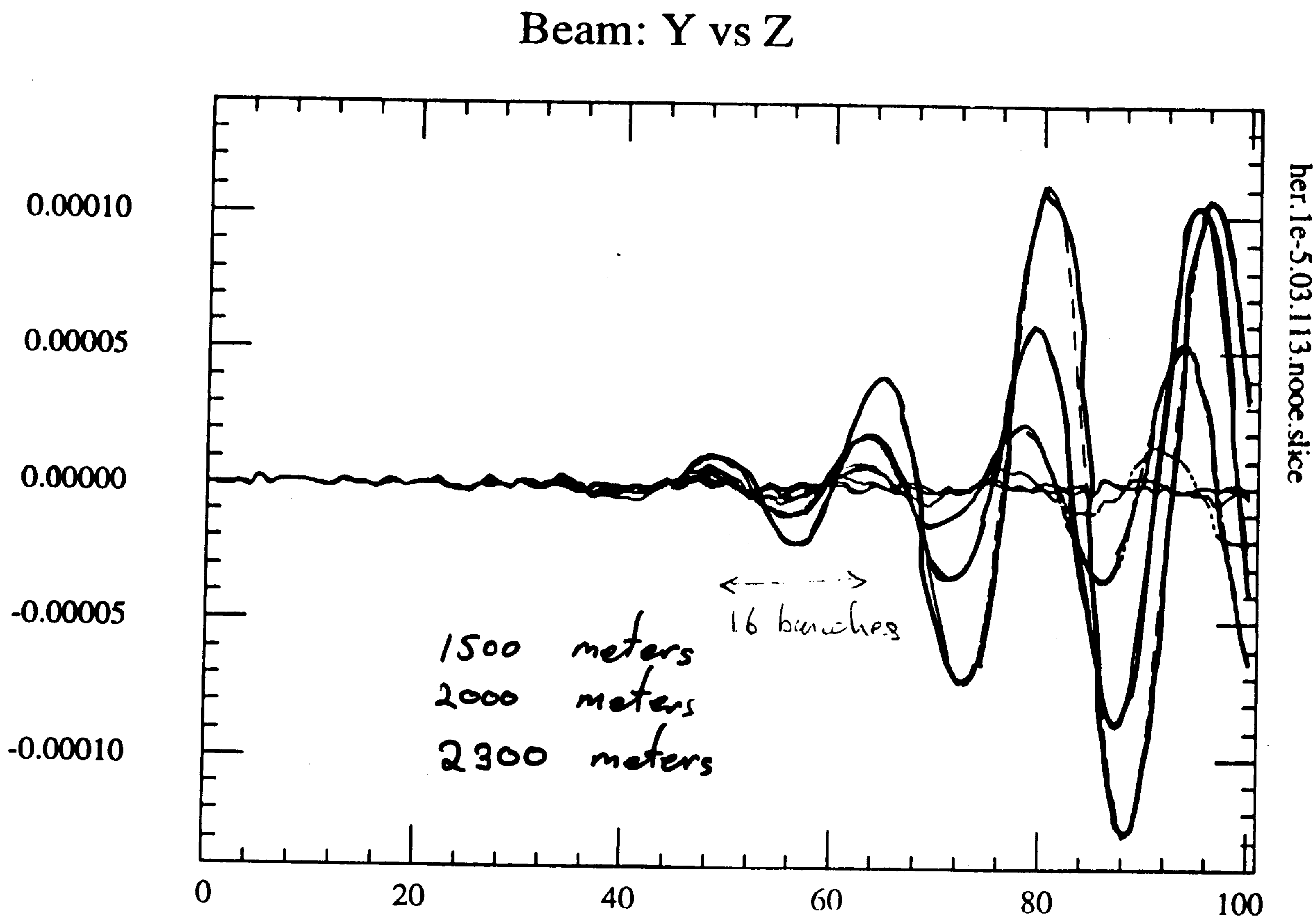
→ (2) Focusing variation between bunches
⇒ filamentation of ε dilutions

→ (3) Bunch-to-bunch coupling
⇒ two stream instability

(4) Y-Z correlation
⇒ kicks to beam tail

(5) Generation of beam halo
⇒ Similar to intense ion beams

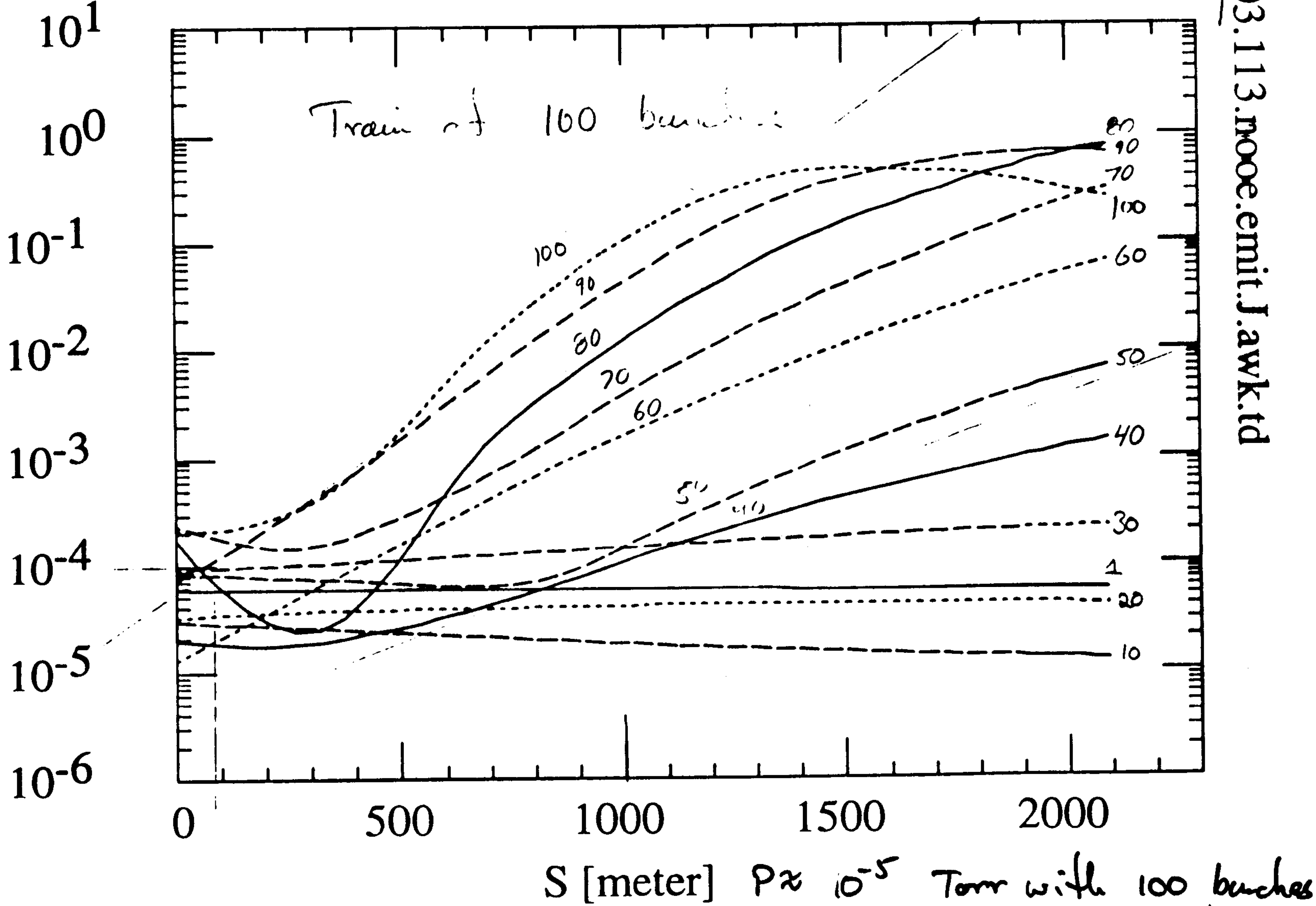
360



Beam: Y vs Z
0.00010
0.00005
0.00000
-0.00005
-0.00010
0
20
40
60
80
100
her.1e-5.03.113.nooe.slice
16 bunches
1500 meters
2000 meters
2300 meters

Normalized Actions vs. S in ~~Pre-linac~~ B-fact.

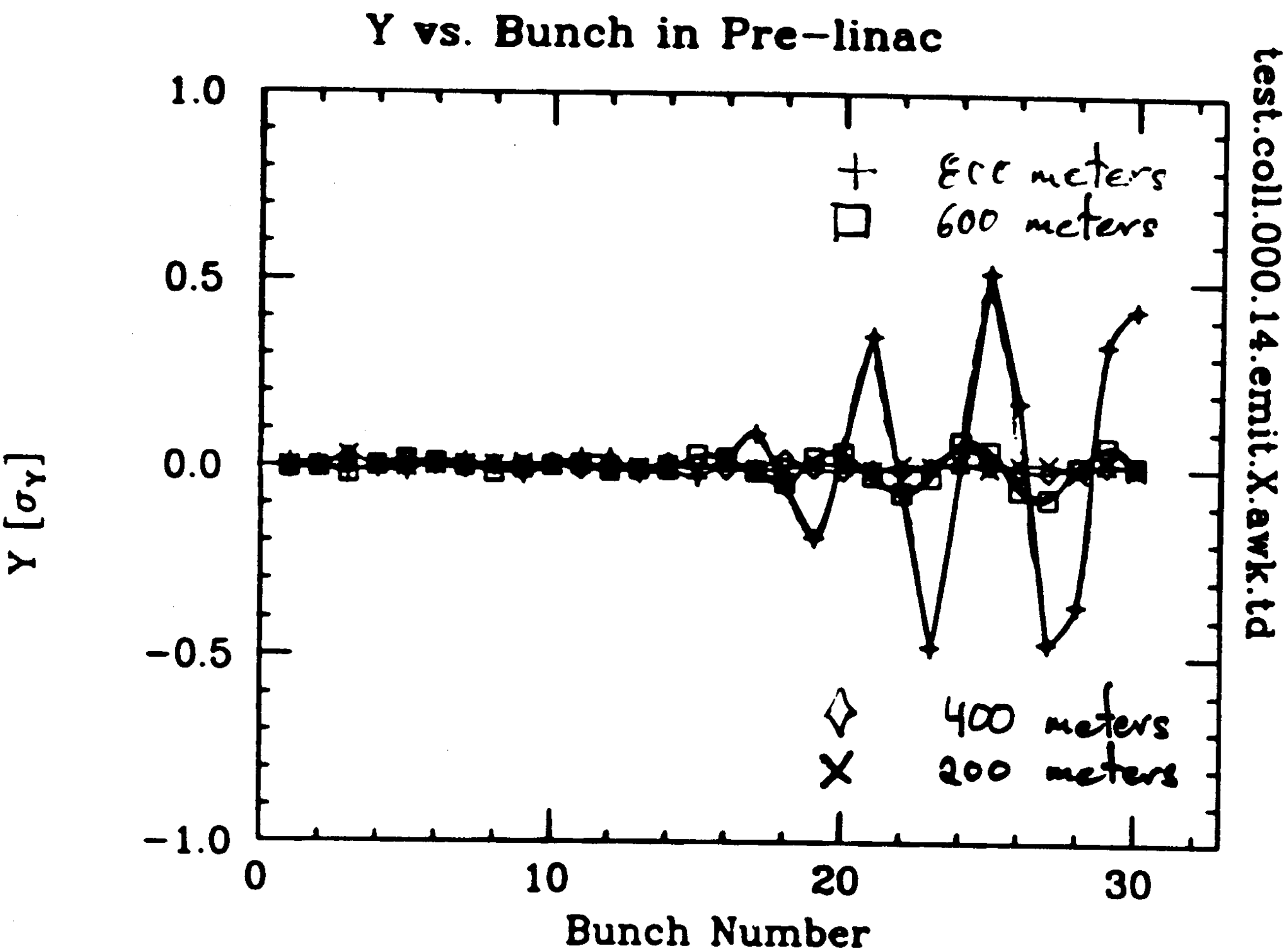
In B-fact => 12μs growth



S [meter] P ≈ 10^{-5} Torr with 100 bunches

bunch 90 increases in amplitude by 10^{5} in 1700 meters

bunch 45 increases ... by ... in 2300 meters



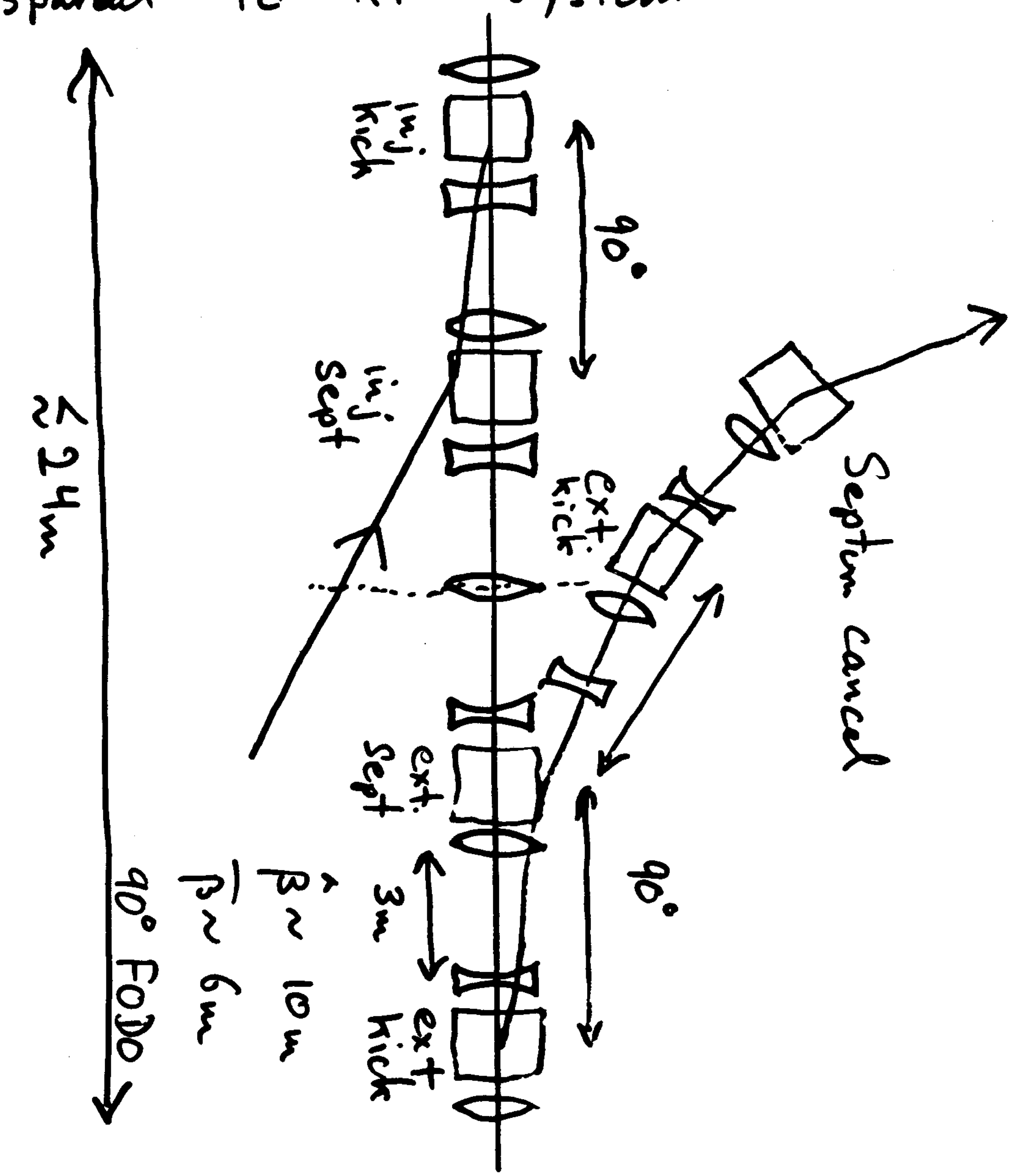
1st 30 bunches in NLC-pre linac with 10^{-7} Torr CO gas. Starts from noise in the bunch train positions. Expodential growth with $\sqrt{\text{distance}}$ s.t. $\propto e^{k\sqrt{s}}$

$k \propto \frac{N^{3/2} P}{\sigma_x \sigma_y}$

K. Kubo

(4) 3 Kicker System for DR

Two kickers 180° apart for extraction
(one inside and one outside ring)
Two bends (septum and dipole) 180° apart
Injection kicker 360° from extraction.
Transparent to RF system



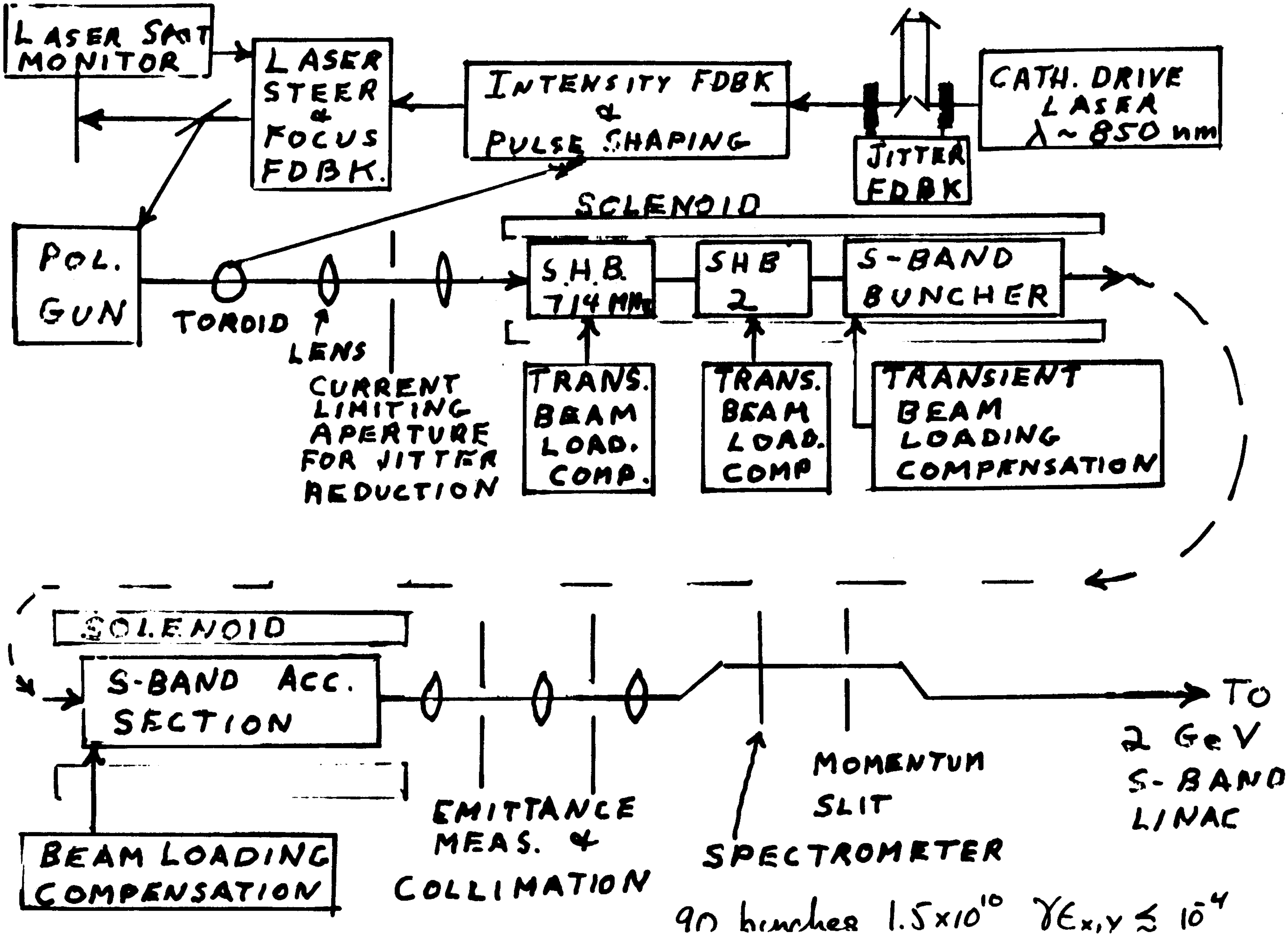
Source and Pre-Injector Issues / Comparisons

	NLC	JLC-X
e- Sources	Polarized e- DC gun	Thermionic gun RF photocathode gun Poralized e- gun
Bunch separation	1.4 ns	1.4 ns
Total numbe of bunches	90	100
Bunch population	1 E+10	0.7 E+10
Bunch length (FWHM)	< 10 ps	< 10 ps
Micro stability (rms)	1 %	1 %
Macro stability (rms)	0.25 %	0.25 %
SHB	714 MHz SHB x 2	714 MHz SHB x 2
Beam loading compensation	Reduce R; (x1/10) Phase step drive (0 - 45 deg)	Double feed BL compensation
Buncher	2856 MHz TW	2856 MHz single-cell cavity x 4
Pre-Injector		
Beam energy	~70 MeV	~80 MeV
Accelerator section	2856 MHz TW ~1.5m long (14 MeV/m) ~1.5m long (33 MeV/m)	2856 MHz ~1 m-long(14 MeV/m) ~2 m-long(33 MeV/m)

Injector Linac Issues / Comparisons

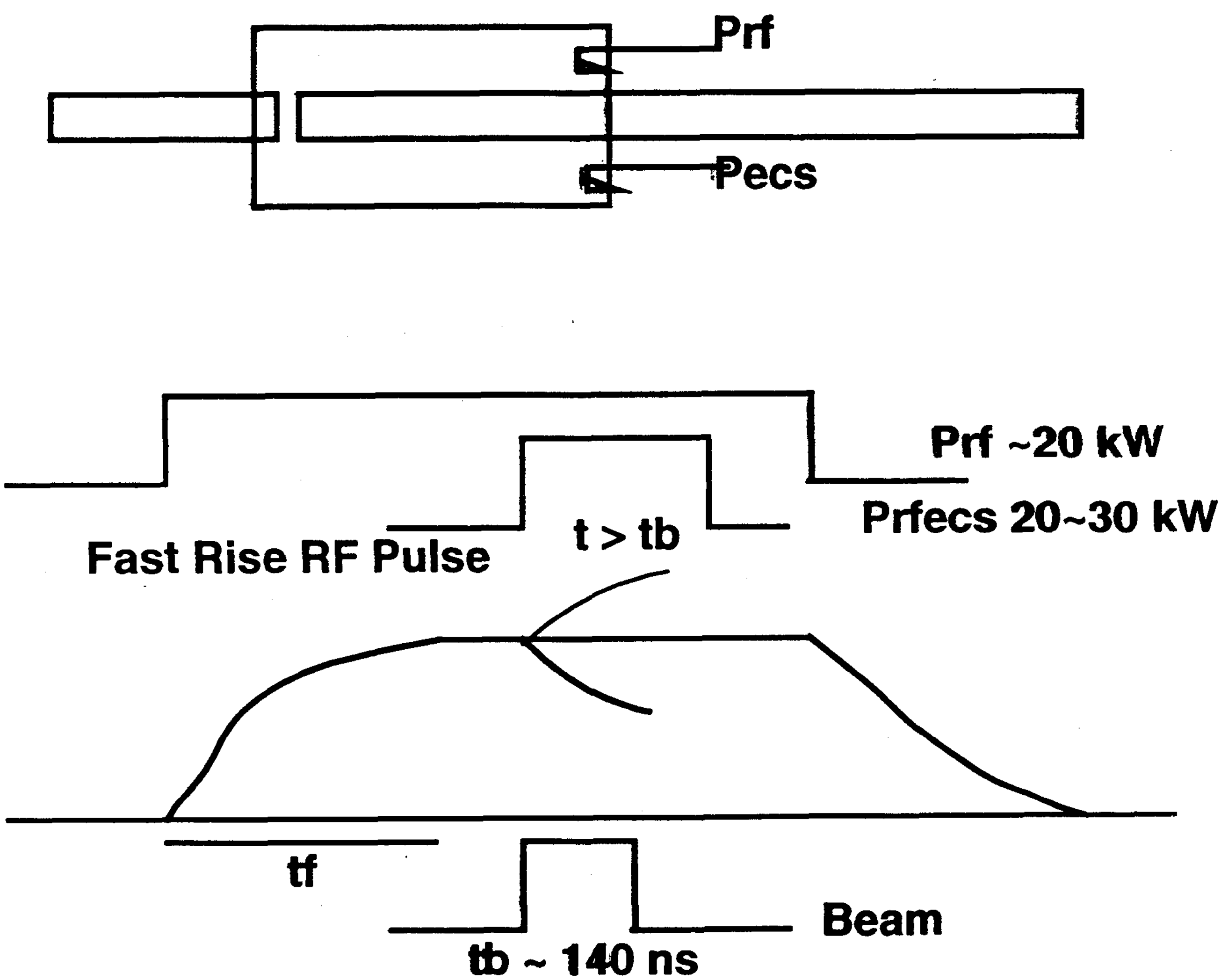
	NLC	JLC-X
Beam Energy	2 GeV	1.98 GeV
Total number of RF unit/Linac	8 with space for Δf upgrade	10 (5) + ECS x 2
RF Unit		
Klystron	150 MW, 3.5 μs	85 MW, 4.5 μs (170 MW, 4.5 μs)
RF pulse compression	SLED 135 MW => 400 MW average pver pulse	Two irises SLED 80 MW => 300 MW peak average pver pulse
Accelerating structure	3 m-long CG TW x 4	3 m-long CG TW x 2 (x 4)
Accelerating gradient	30 MeV/m maximum 22 MeV/m with beam loading	52 MeV/m maximum 40 MeV/m with beam loading

NLC INJECTOR (BASELINE)



SHB
Double Feed Beam-Loading Compensation

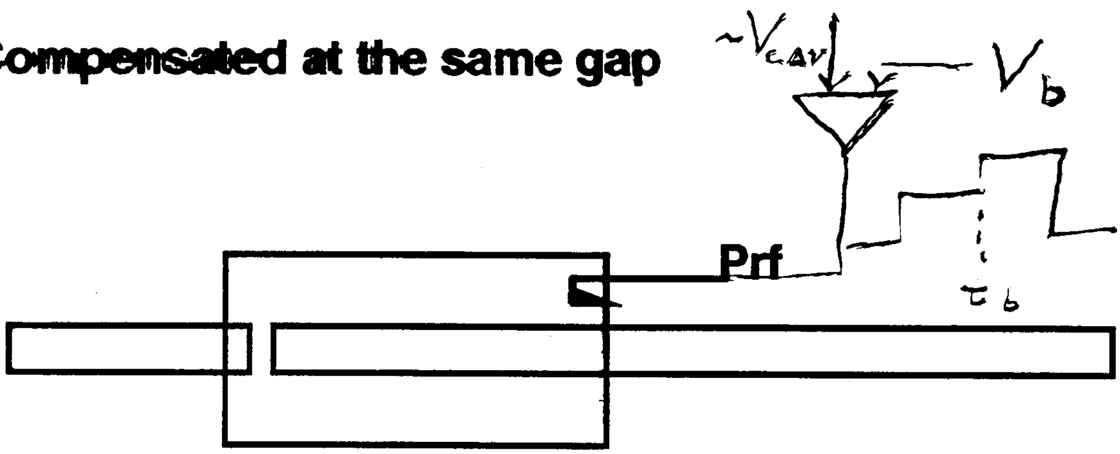
* Zero current to the design bunch population
* Compensated at the same gap



STakeda/SHB

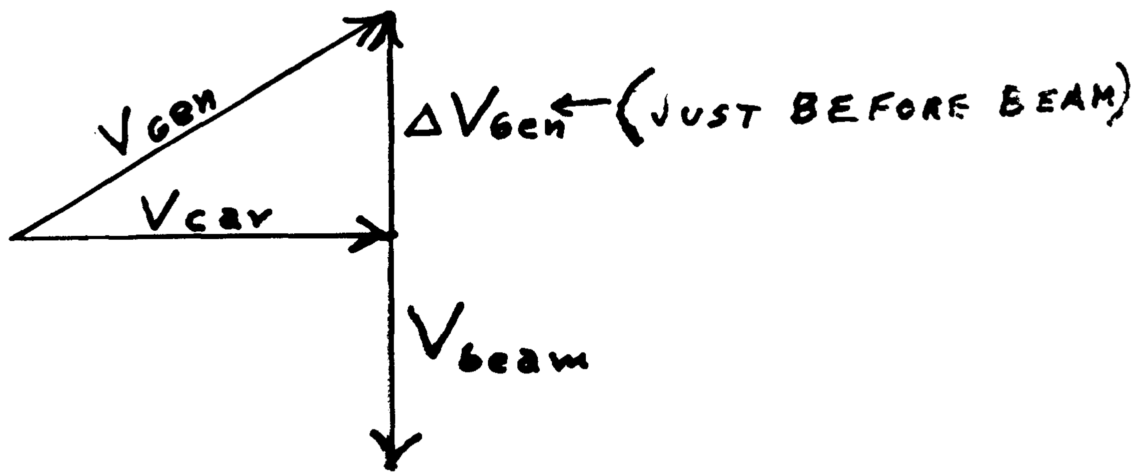
SHB
Double Feed Beam-Loading Compensation

* Zero current to the design bunch population
* Compensated at the same gap



BEAM LOADING IN SUBHARMONIC BUNCHER

ASSUME BUNCH 90° OUT OF PHASE WITH VOLTAGE.



$$V = \frac{2\beta^{\frac{1}{2}}}{\beta+1}\underbrace{\left(P\frac{R}{Q}Q_0\right)^{\frac{1}{2}}}_{\text{PHASOR}} - \frac{a_1}{2}\underbrace{I_0}_{\text{PHASOR}}\frac{R}{Q}\frac{Q_0}{1+\beta}$$

$$P = \frac{V^2}{\left(\frac{R}{Q}\frac{Q_0}{\beta}\right)}\left(\frac{\beta+1}{2\beta}\right)^2 + \left(\frac{a_1}{2}\frac{I_0}{2}\right)^2\left(\frac{R}{Q}\frac{Q_0}{\beta}\right)$$

$$\boxed{P_{min} = \frac{a_1}{2} I_0 V \left(\frac{\beta+1}{2\beta}\right)}$$

S. H. B. BEAM LOADING (CONT)

FOR SECOND SHB:

$\frac{a_1}{2} I_0 \sim 1$ A.

$V \sim 100$ kV

$P_{min} \sim 100$ kW $\quad \beta = 1$

$P_{min} \sim 50$ kW $\quad \beta \gtrsim 10$

(SLC $P_{SHB} \sim 5$ kW)

"OPTIMUM IMPEDANCE"

$$\left(\frac{R}{Q} \frac{Q_0}{\beta+1}\right) \lesssim \frac{V}{\frac{a_1}{2} I_0}$$

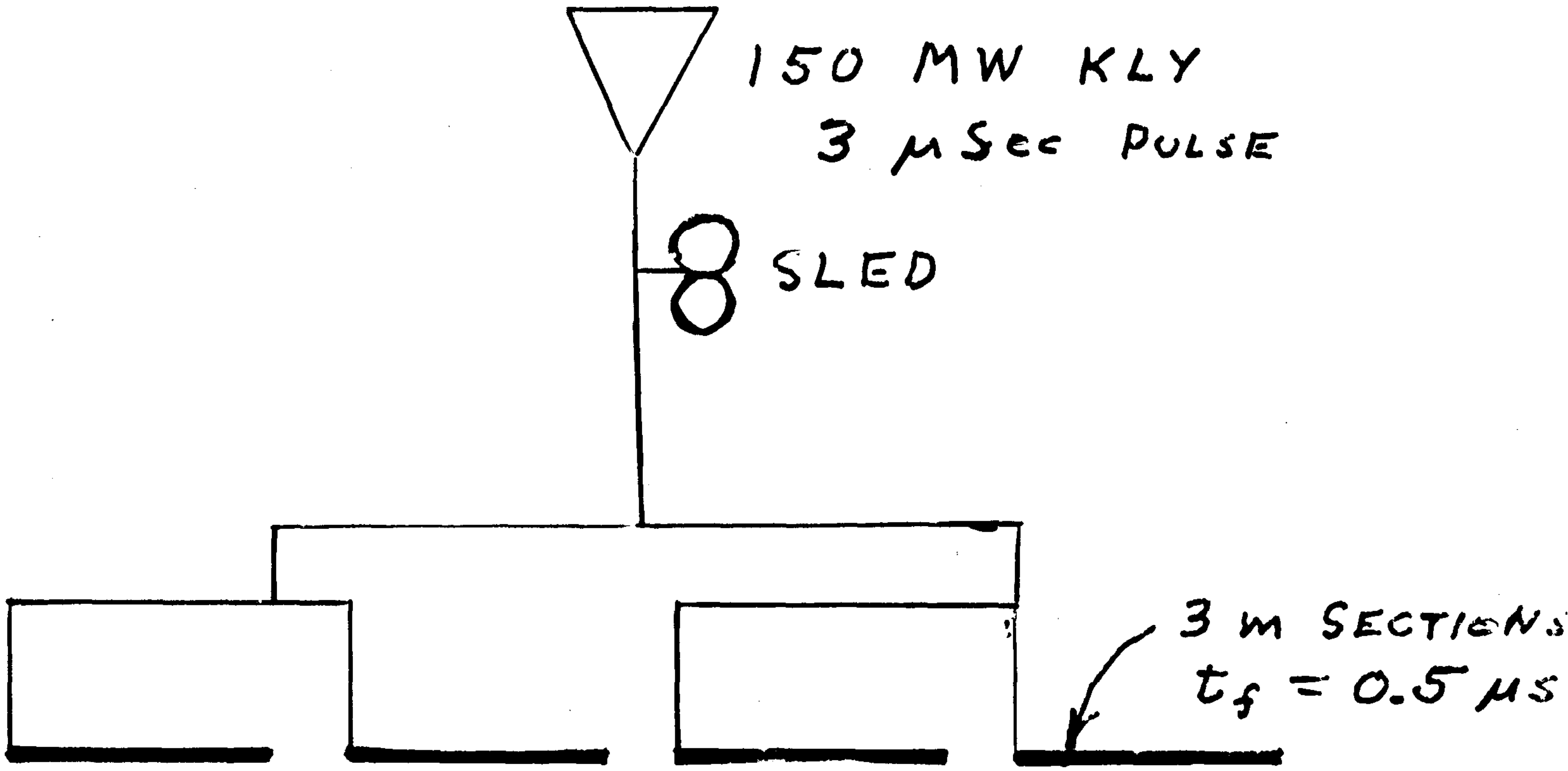
$$\sim 100 \text{ k}\Omega$$

BEST TO MAKE R/Q SMALL

BECAUSE:

$$V_b \sim \frac{a_1}{2} \frac{I_0}{2} \frac{\omega R}{Q} t_b$$

NLC S-BAND LINAC MODULE



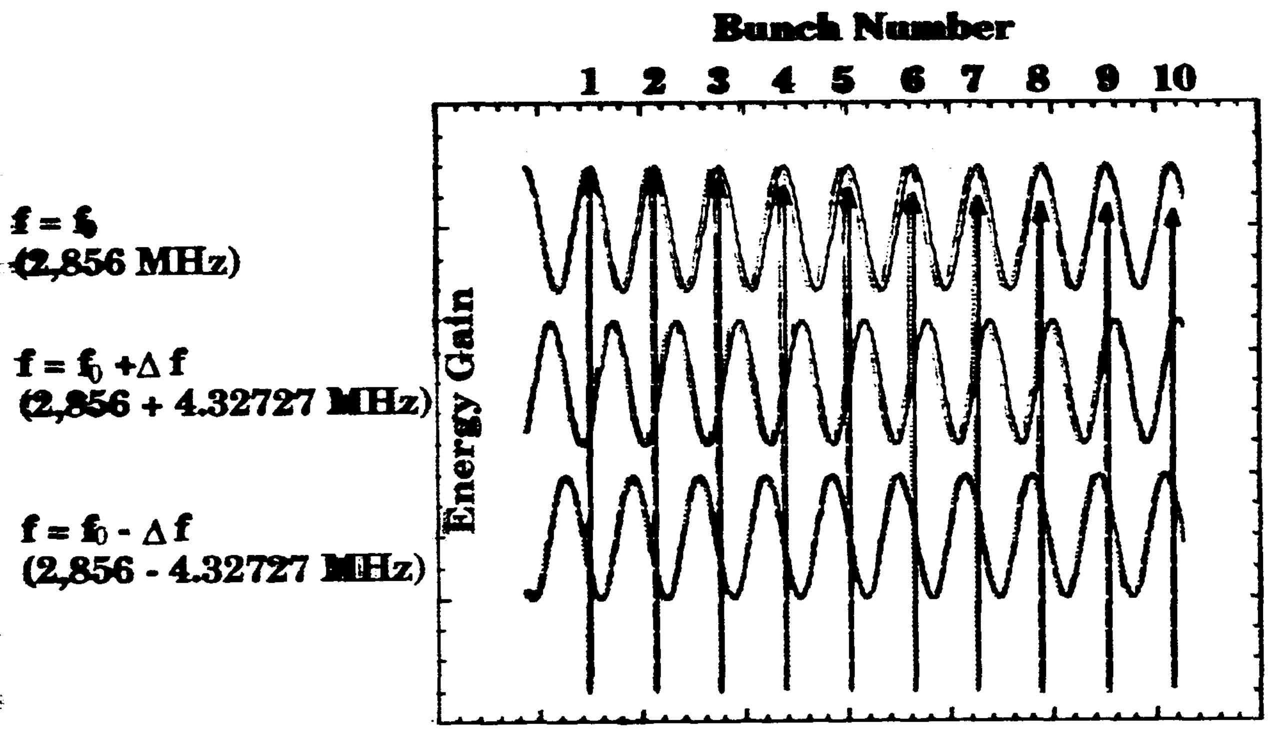
ACCELERATES 1 AMP x 126 ns BEAM BY 260 MeV

(4 KLYSTRONS + ~50 m PER GeV)

Pre-Linac Issues / Comparisons

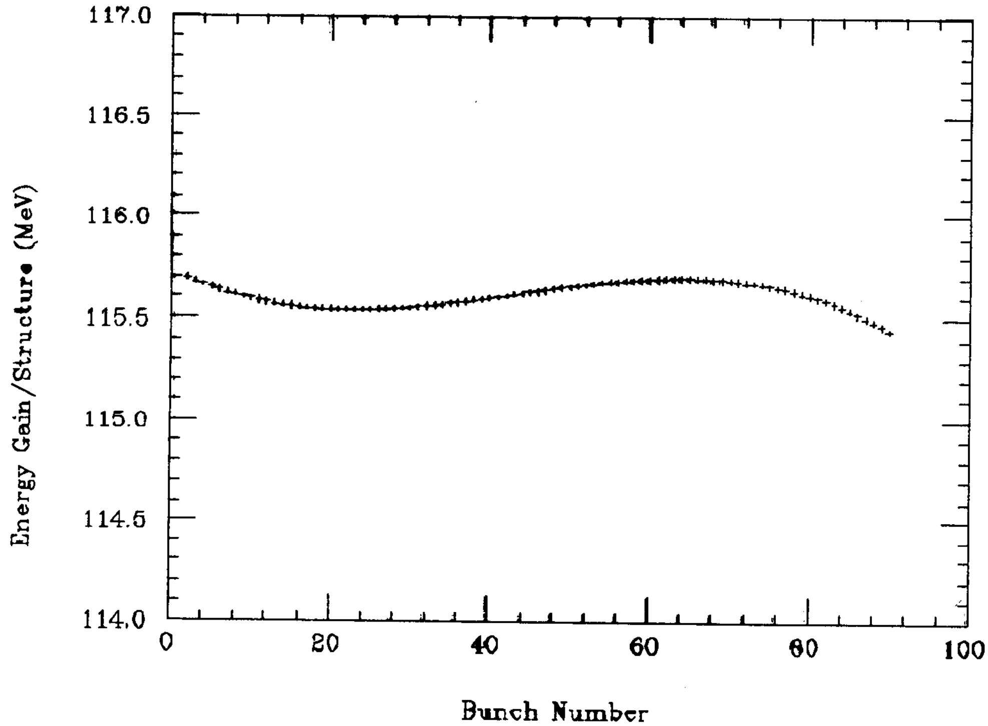
	NLC	JLC-X
Beam Energy	10 GeV	10 GeV
Total Length	~500 m	~300 m
Total number of RF unit/Linac	32	34 (17) + 4 for ECS
RF Unit		
Klystron	150 MW, 3.5 μs	85 MW, 4.5 μs (170 MW, 4.5 μs)
RF pulse compression	SLED 135 MW => 400 MW average over pulse	Two irises SLED 80 MW => 300 MW average over pulse
Accelerating structure	3 m-long CG TW x 4	3 m-long Shintake choke-mode structure x 2 (x 4)
Accelerating gradient	30 MeV/m 22 MeV/m with beam loading	52 MV/m maximum 40 MeV/m with beam loading
Energy Compensation System		
Scheme	Δt or combination of Δt and Δf	Δf
Configuration		(3 m long for f+Δf) x 2 (3 m long for f-Δf) x 2
ΔE after compensation	0.1 % (10 % without correction)	0.1 % (6.6 % before ECS)
Flexibility	Adequate	High flexibility
ΔE jitter	< ±0.03 %	< ±0.025%

Principle of Energy Compensation System

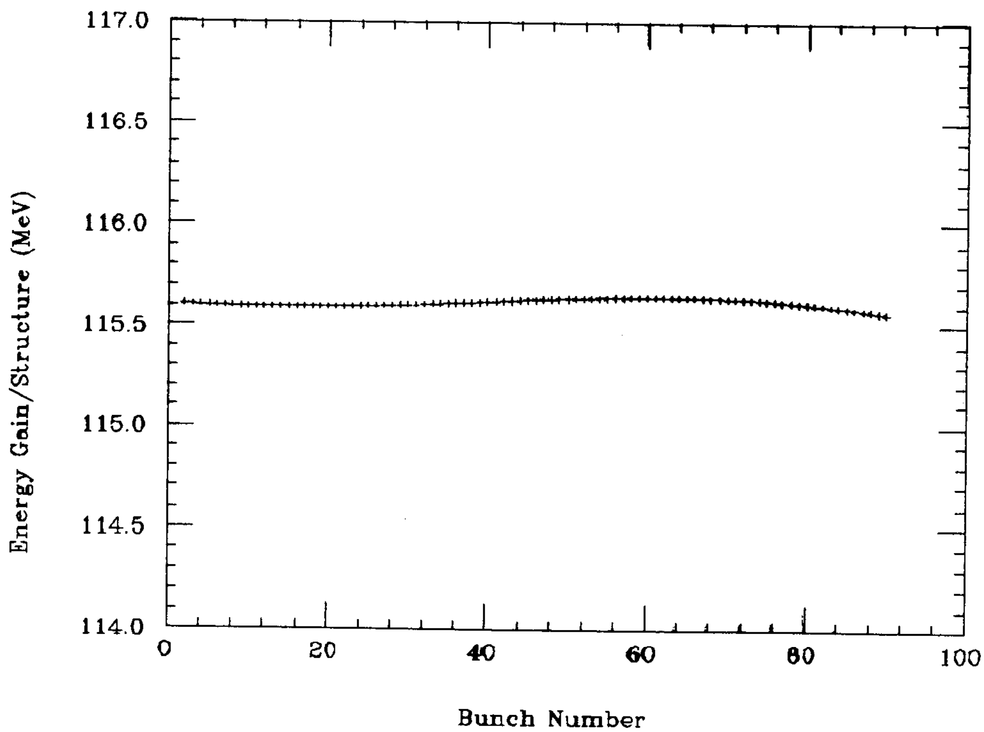


Takeda/EnergyCompSys/940711

Energy Distribution of 90 Multi-bunch After ECS



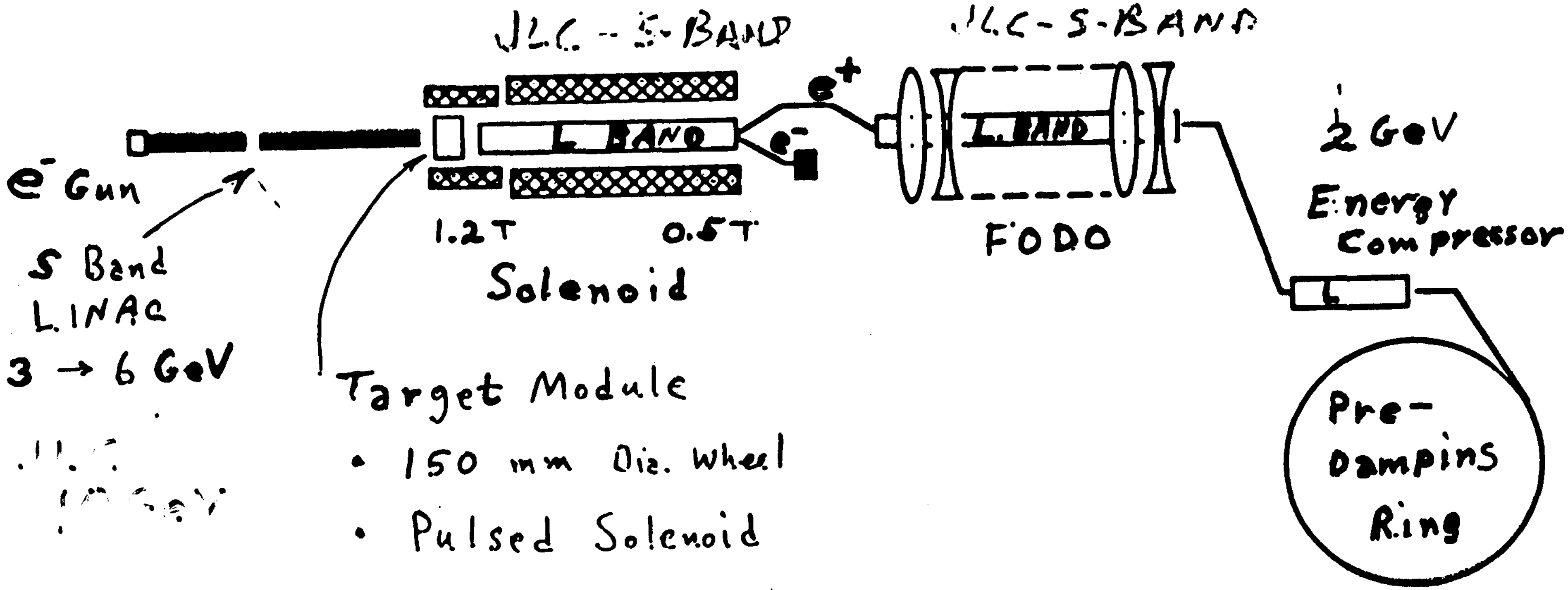
Ne=0.63E+10, Nb=90, 1.4ns, -00, 16:0
ds=090.0, Emax=-5.7 MV, Inj=-120, df=1.923232 MHz



Ne=0.63E+10, Nb=90, 1.4ns, -00, 16:0
ds=090.0, Emax=-10.9 MV, Inj=-120, df=0.961616 MHz

STakeda/BeamECS/941202

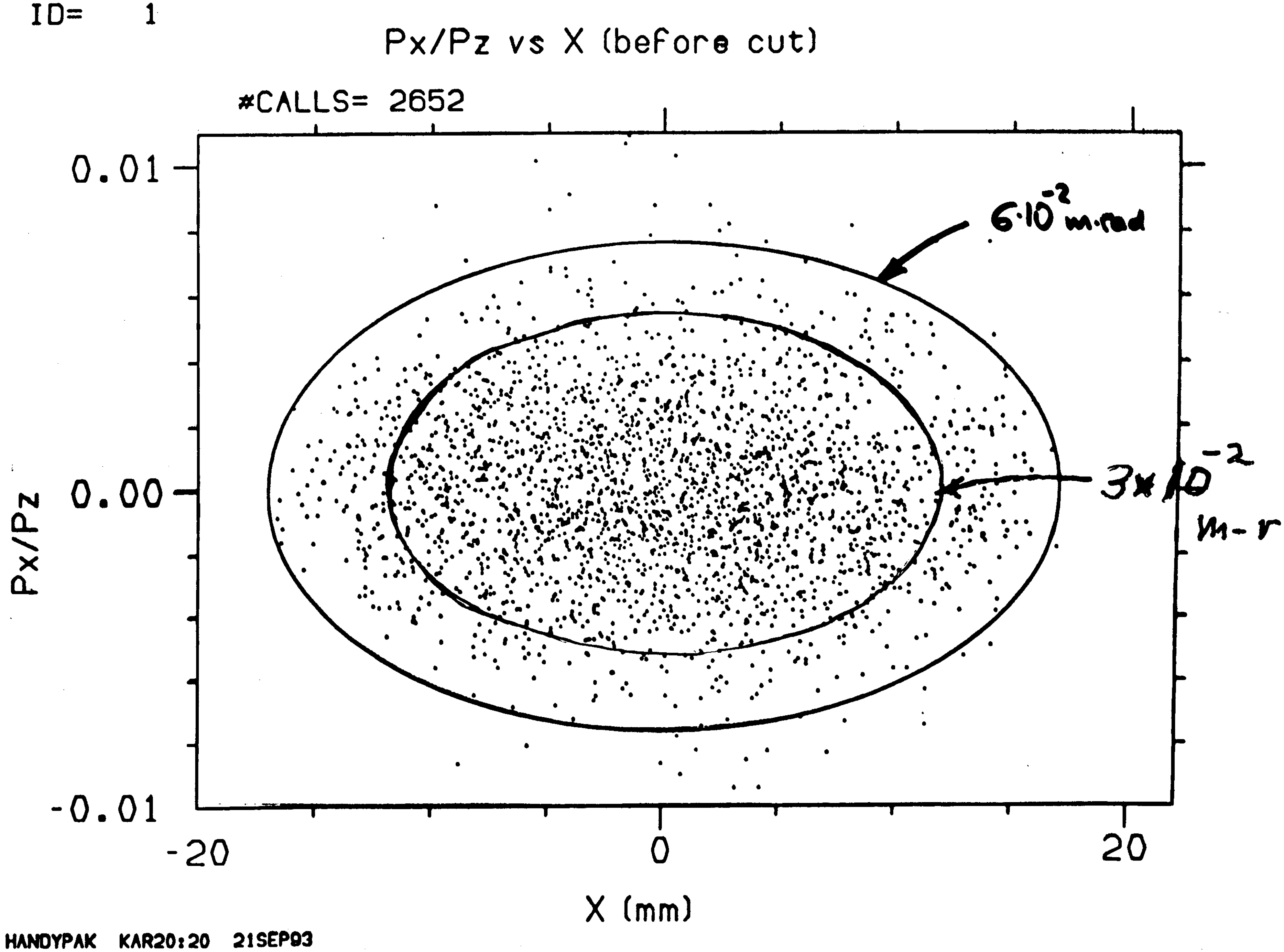
Draft
NLC Positron System

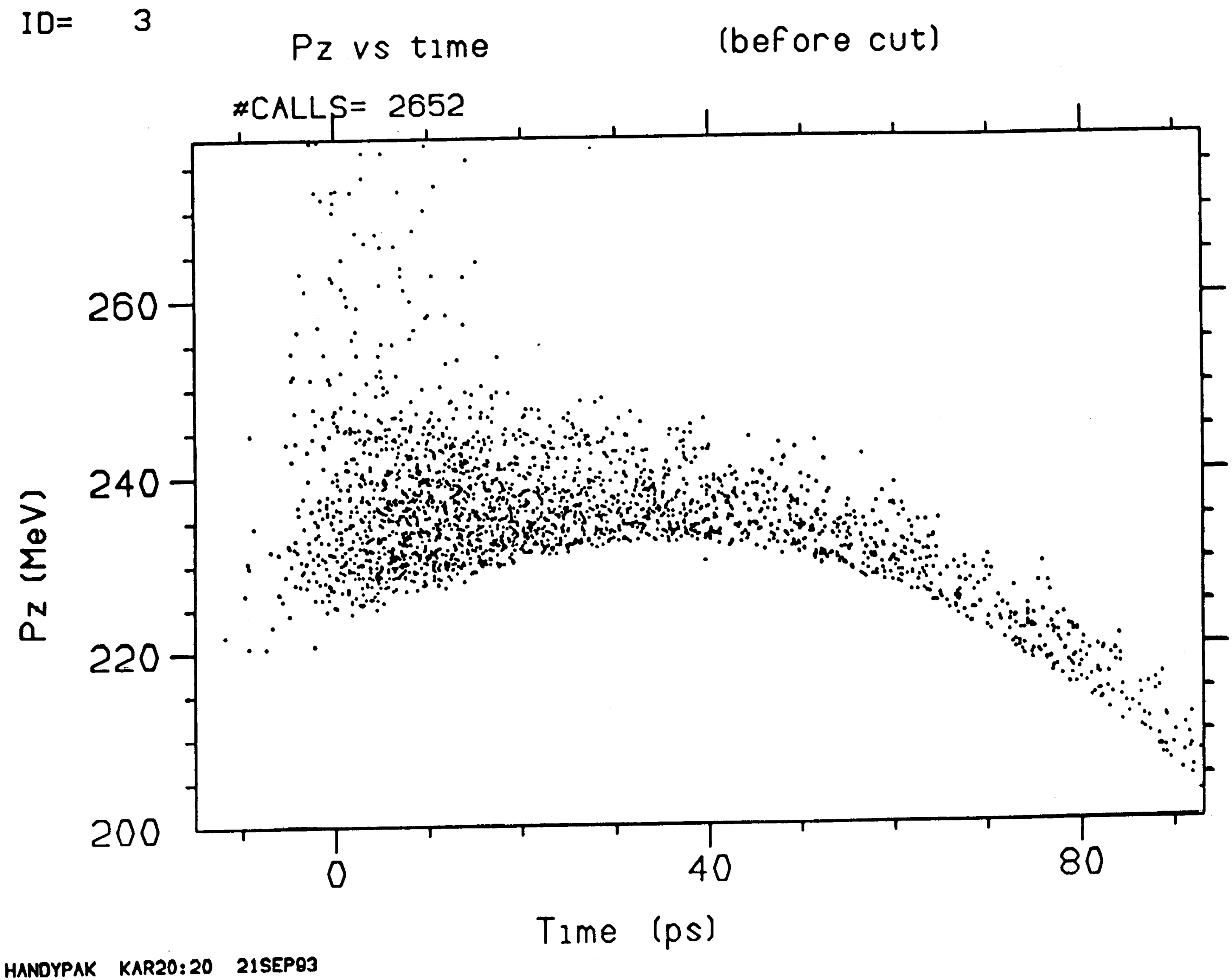


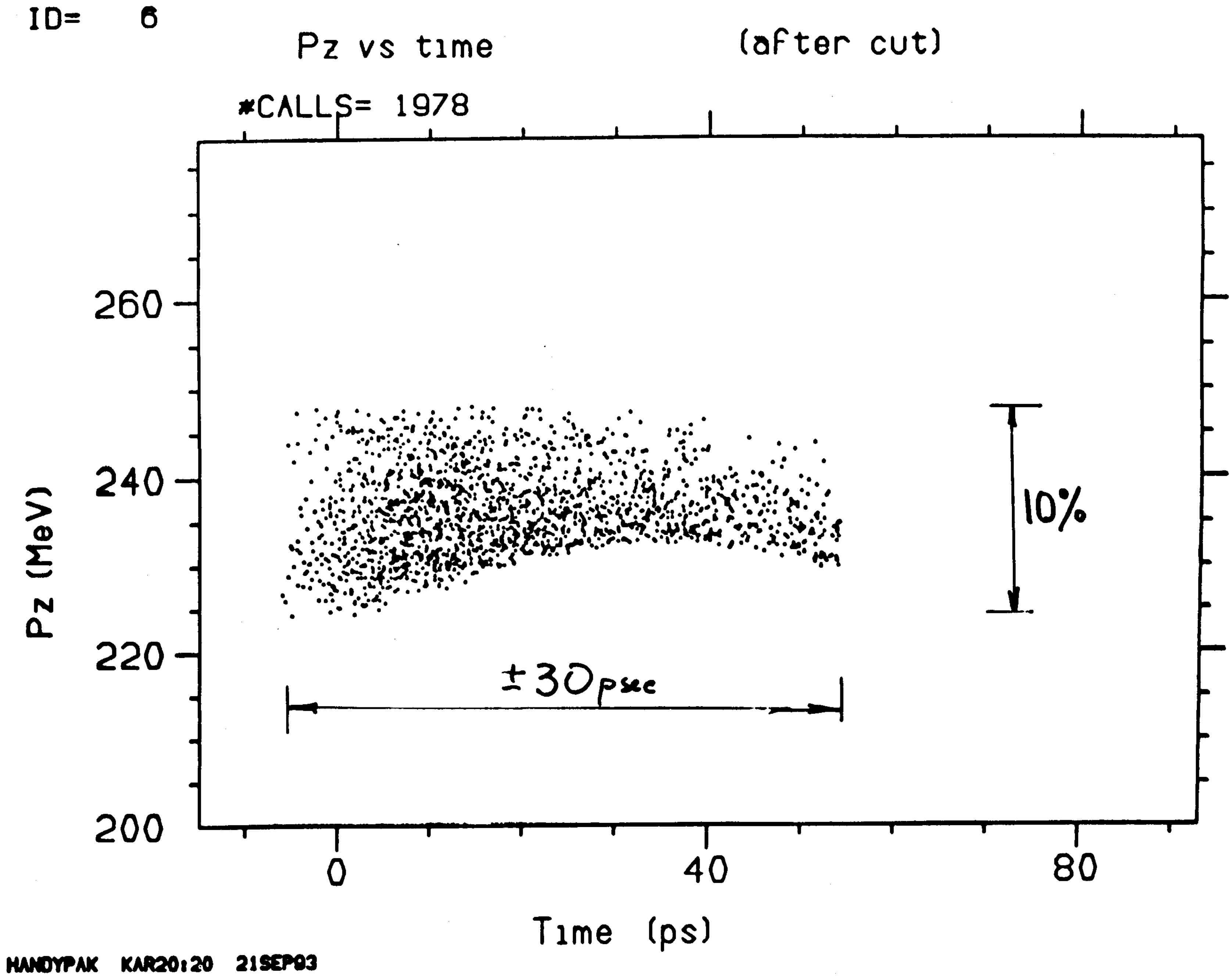
	unit	SLC existing reference	CLIC	JLC	NLC	VLEPP	DESY/ THD	TESLA
General Parameters								
Ne⁺ per pulse	10^{10}	3 to 5	0.6	~~40~~ 70	63	20	360	4000
number of bunches per pulse		1	1 to 4	~~70~~ 100	90	1	125	800
pulse duration	μs	3 ps	2.3 ps	~~0.2~~ 0.14	0.126	-	2	800
bunch spacing	ns	-	0.8	~~2.8~~ 1.4	1.4	-	16	1000
repetition frequency	Hz	120	1700	150	180	~150	50	10
Full Bunch width e⁺	ps			30	60			
Positron Source Type			SLC-type			wiggler/undulator based		
Primary Beam								
energy	GeV	30	1.8	10	3.0	150	≥150	≥150
Ne⁻ per pulse	10^{10}	3 to 5	6.2 to 25	~~54~~ 47	135	20	360	4000
beam power	kW	17 to 29	31 to 124	~~130~~ 114	121	721	≥4326	≥9613
linac frequency	MHz	2856	1250	2856	2856	14000	2998	1300
wiggler length	m	-	-	-	-	~150	35 (≥150)	35 (≥150)
wiggler period	cm	-	-	-	-	~1.0	3.6 (~1.2)	3.6 (~1.2)
peak field	T	-	-	-	-	0.5	1.7 (~0.9)	1.7 (~0.9)
number of photons per electron		-	-	-	-	100	350 (~350)	350 (~350)
Conversion Target								
material		W(75)Re	W	W(74)Re	W(75)Re	W, Hg	Ti alloy	Ti alloy rotating 50 m/s
thickness	X_0	6.0	4.0	6.0	5.0	0.5	0.4	0.4
rms spot size of prim. beam	mm	0.6	1.0	1.2	1.6	1.0	0.7	0.7
temperature rise per pulse	K	200 to 300	-	~~~600~~ 300	200	200	~800	~800
mean deposited power	kW	4.2 to 6.0	10 to 41	~40	40	0.2	5.9	14
Ne⁺ per pulse at exit	10^{10}	180 to 300	2.5 to 10	~~1200~~ [illegible]	800	60	3930	43700
Collection System								
matching device *		AMD	AMD	AMD	AMD	Li-Lens G=15 T/m	AMD	AMD
initial field	T	7.0	7.0	8.0	7.0	-	10	10
taper parameter	m^{-1}	-	-	50	-	-	30	30
end field	T	0.5	0.5	0.8	0.7	-	0.62	0.62
length (Flux conc.)	m	0.15	-	0.18	0.2	0.01	0.5	0.5
wavelength of accel. structure	m	0.1	0.24	0.105	0.21	-	0.1	0.1
min. iris radius	mm	9.0	16.0	13	20	-	9.0	9.0
gradient	MV/m	30	20	30	20	-	30	15
pre-damping ring required		Y	Y	Y	Y	-	N	N
Ne⁺ per pulse at entrance of (pre-)damping ring	10^{10}	4.5 to 7.5	1.6 to 6.4	~~160~~ 140	126	50	720	8000
efficiency incl. dephasing	%	2.5	64	14	14	-	18	18
γA of the (pre-)damping ring **	π m	0.01	0.36	0.027	0.06	0.1	0.012	0.012
energy of (pre-)damping ring	GeV	1.15	1.8	1.98	2	30	3.15	4.5
energy accept. of match. device	MeV	20	20	40	30	-	±30	±30
Polarization								
degree of polarization	%	-	-	-	-	~75%	(max. 70%)	(max. 70%)

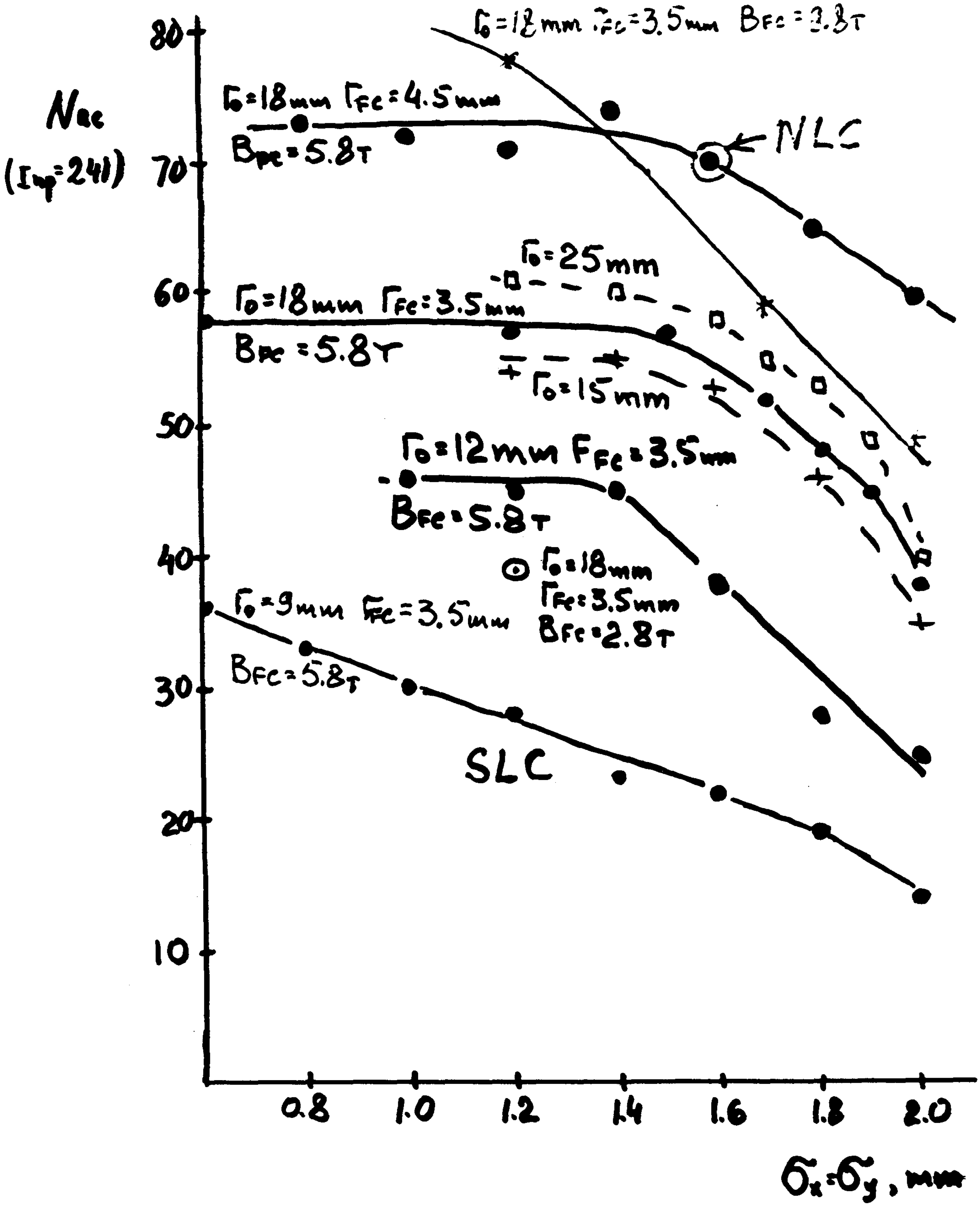
* AMD = adiabatic matching device, realized as flux concentrator
** γA = normalized acceptance

Tab. 1 Positron Source parameters of various linear collider projects. SLC parameters are given as reference. Parameters in brackets refer to the option of a polarized source in case of DESY/THD and TESLA.


ID= 1
Px/Pz vs X (before cut)
#CALLS= 2652
0.01
0.00
-0.01
Px/Pz
-20
0
20
X (mm)
$6 \cdot 10^{-2}$ m·rad
3×10^{-2} m-r
HANDYPAK KAR20:20 21SEP93


ID= 3
Pz vs time
(before cut)
#CALLS= 2652
260
240
220
200
Pz (MeV)
0
40
80
Time (ps)
HANDYPAK KAR20:20 21SEP93


ID= 6
Pz vs time
(after cut)
*CALLS= 1978
260
240
220
200
Pz (MeV)
0
40
80
Time (ps)
10%
±30psec
HANDYPAK KAR20:20 21SEP93



N_{ac} (I_{inj}=241)
r_0=18mm r_{FC}=3.5mm B_{FC}=3.8T
r_0=18mm r_{FC}=4.5mm B_{FC}=5.8T
NLC
r_0=25mm
r_0=18mm r_{FC}=3.5mm B_{FC}=5.8T
r_0=15mm
r_0=12mm r_{FC}=3.5mm B_{FC}=5.8T
r_0=18mm r_{FC}=3.5mm B_{FC}=2.8T
r_0=9mm r_{FC}=3.5mm B_{FC}=5.8T
SLC
80
70
60
50
40
30
20
10
0.8
1.0
1.2
1.4
1.6
1.8
2.0
$\sigma_x=\sigma_y$, mm

Bunch Compressors Comparison

	Single	vs	Double BC
Length / Complexity	⊕		⊖
Space Charge	⊖		⊕
Nonlinearity	-		-
Multibunch Beam Loading Compensation	⊕		-
No S-band Possibility after BC	⊕		-

If we can make a low impedance DR, we increase the acceleration voltage to reduce the bunch length in DR.

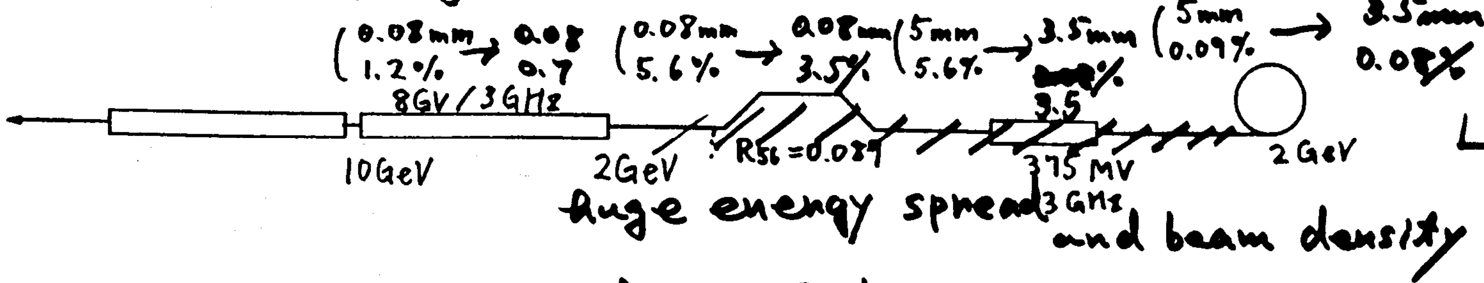
So, we can reduce the position shift due to the beam loading in DR and loosen the tolerances in the single BC.

Need more study for Single Stage BC! (Both)

Simple is Best but not Easy!

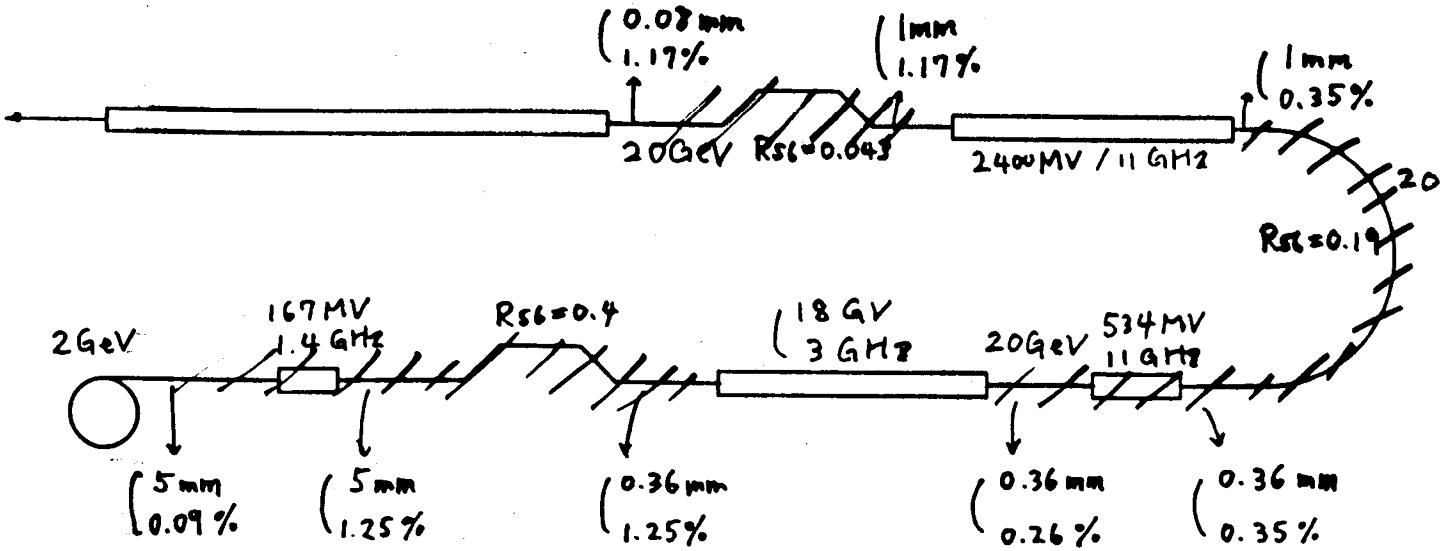
Challenging scheme is better for Linear Collider. Kikuchi proposed at Emittance '93.

Single-stage Scheme



Length ~100m

Two-stage Scheme



Length ~1500m (JLC)

~600m (NLC)

Schematic View of BC system

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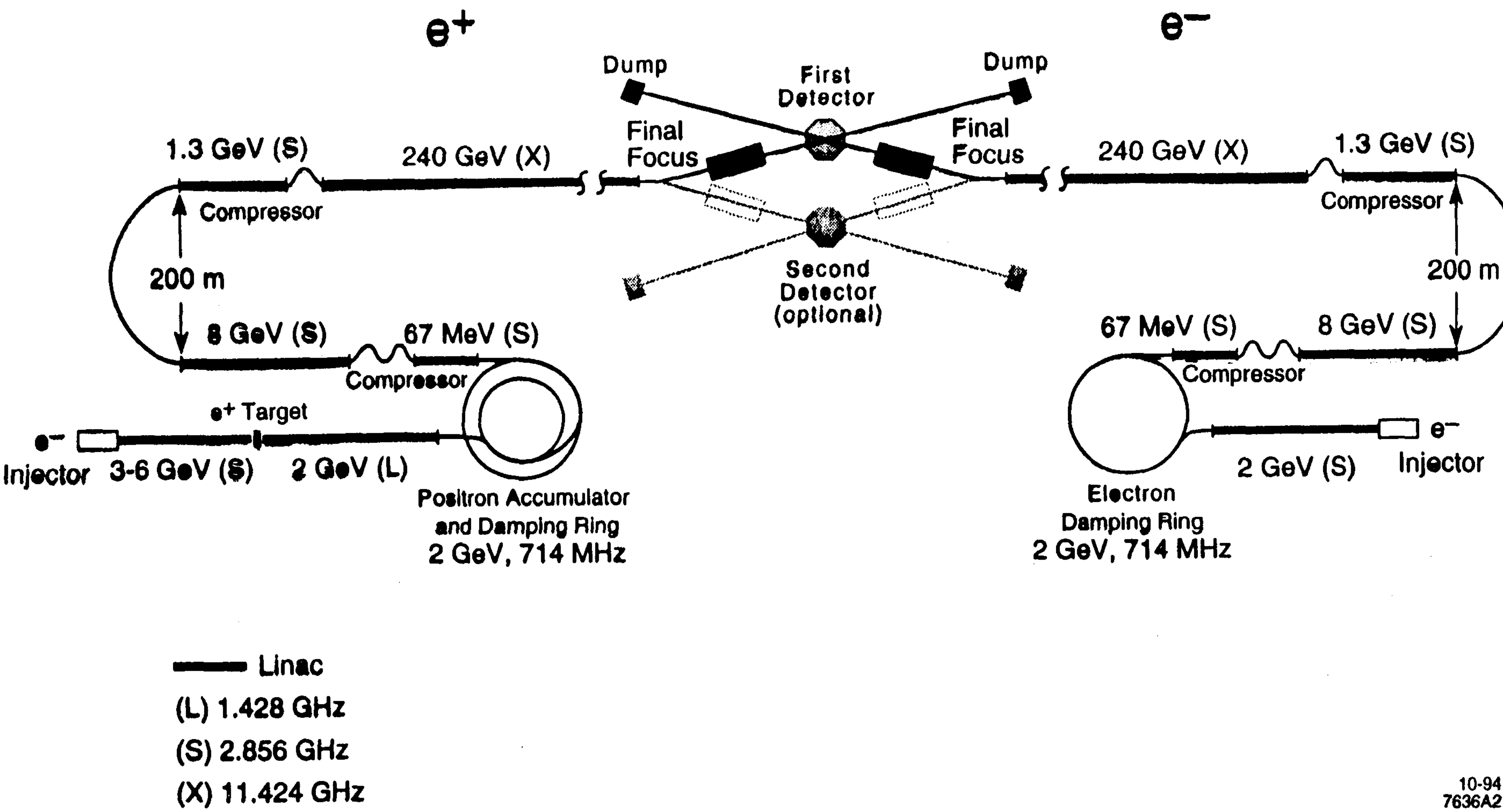
NLC Diagram

not to Scale



NLC Instrumentation

December 8, 1994

Outline

Table of BPM, beam size and other instrument

Updated from Monday's presentation
Represents a union rather than an intersection of efforts
Questions about requirements

Machine Protection - Power control sequences

How can linac train current be quickly reduced?

Stabilization

Long term alignment stability
Vibration - recent results from SLC linac

Requirements for Transverse Beam Position

Meas.		location	resolution (pulse to pulse error -> signal to noise)	stability beyond which recalibration is required	accuracy (initial placement)	bunch train
X,Y	Beam Position	Injector /Pre-Linac	<1μm		<50μm	average
		Damping Ring	<1μm		<50μm	av.
		Bunch Compressor	<1μm		<10μm	av.
		Linac				
		Stripline (3000 ea)	<1μm	1 -2 μm wrt quad center	<10μm	av.
		Structure	<1μm	5μm	<10μm	av.
		Multi-Bunch	<100nm			few bunch
		Final Focus	<10nm	<10nm	<1μm	av.

Key Parameter: **Re-calibration interval** (and re-calibration time)

What are the characteristic stability time scales? How many may be beyond stability tolerance? How can they be found?

At SLC BPM offsets are measured to about 30μm using e+/e- technique. After a few days the distribution is about 100μm RMS.
Quad alignment is measured <100microns. It degrades after 2 months.

Possible techniques:

- Quad Shunt
- Coupling from Quad to BPM electrodes
- Signal injection and processing
- Quad Field monitoring - not necessarily a BPM issue

BPM Resolution, Accuracy and Stability

Requirements for Main Linac BPM's (nom. striplines):

Accuracy - Reference to external locating reference (initial placement)

10μm

Resolution - Short, pulse to pulse noise rejection

<1μm

Stability - Long term repeatability

<1μm

Resolution specification should be achievable - scaling from FFTB

Accuracy of initial placement may not be so tight

Stability is the most difficult tolerance

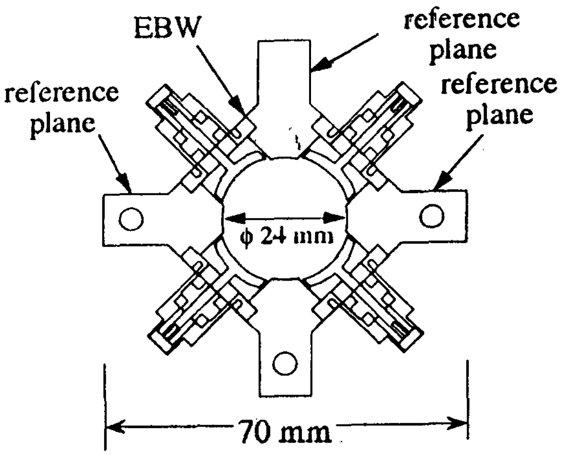
Bolt BPM to Quad cores (to be tested at KEK)

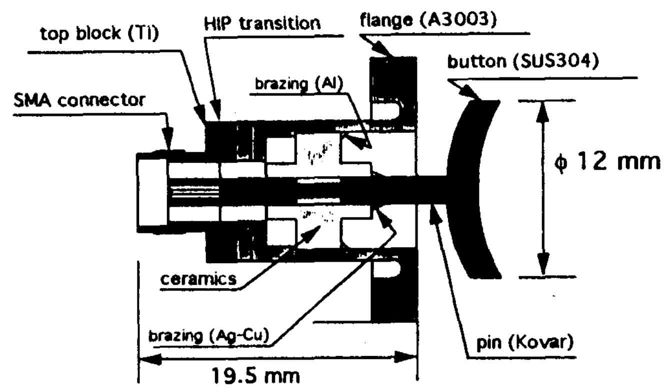
What is FFTB experience?

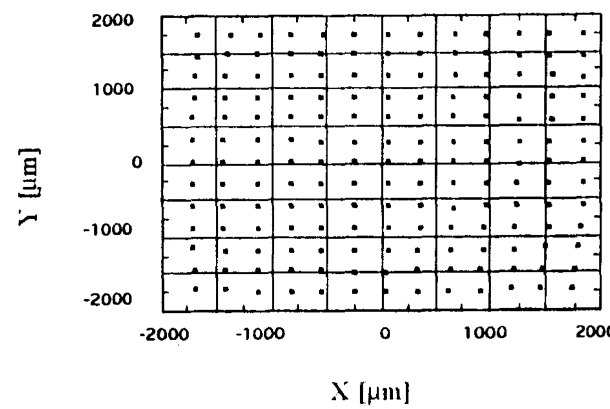
What calibration procedures are needed?

Higher bandwidth increases calibration difficulty

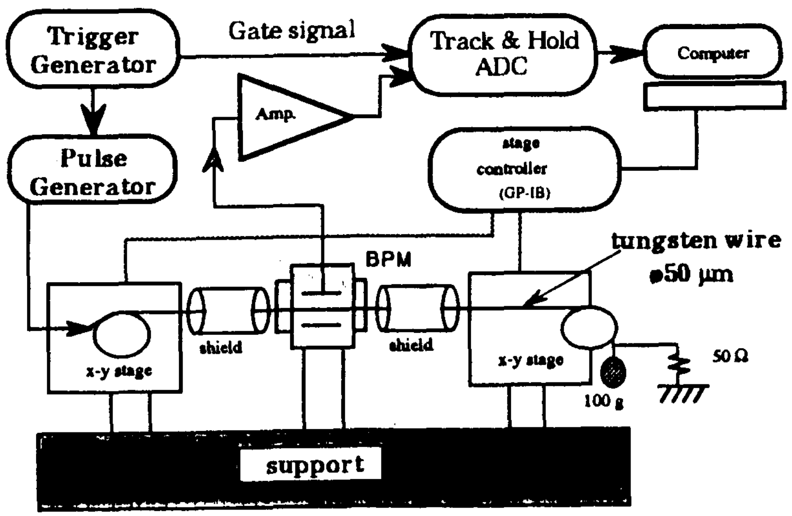
ATF DR Button BPM



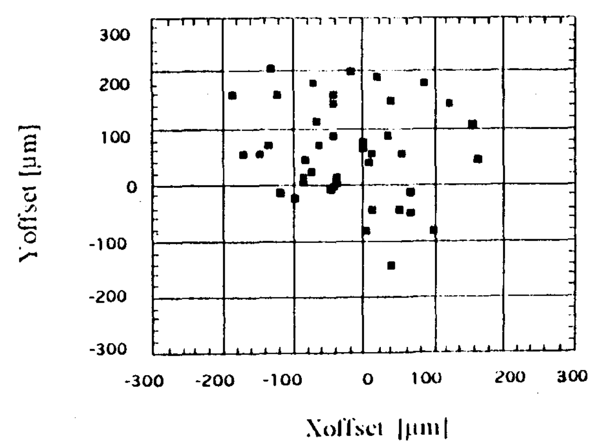




mapping



Calibration Stand



electrical offset

Transverse Size

Meas.		location	resolution (detectable size change)	accuracy (systematic error)	bunch train	# of unit	possible candidates
σx,σy	Transverse Size	Injector /Pre-Linac	50μm		av./each	30	wire scanner
		Damping Ring	20μm for σx 2μm for σy		av./each	3	synchrotron radiation/Compton scattering
		Bunch Compressor	1μm		av./each	20	synchrotron/ Compton scattering
		Main Linac	0.3 ~ 1μm	<10%	av./each	100	Compton scattering
		Final Focus	0.3 ~ 1μm	<10%	av./each	20	Compton scattering
		Final Focus	3~30nm	<10%	each.	2	Compton scattering
		Final Focus	<1nm	?	each	1	Compton scattering

Number of units is scaled from the number in the SLC linac, assuming 4 per group. Five or more may be required in order to accurately correct coupling errors.

What accuracy is required for coupling correction? for emittance control?

What range of sizes is important? For SLC linac 50 x is used.

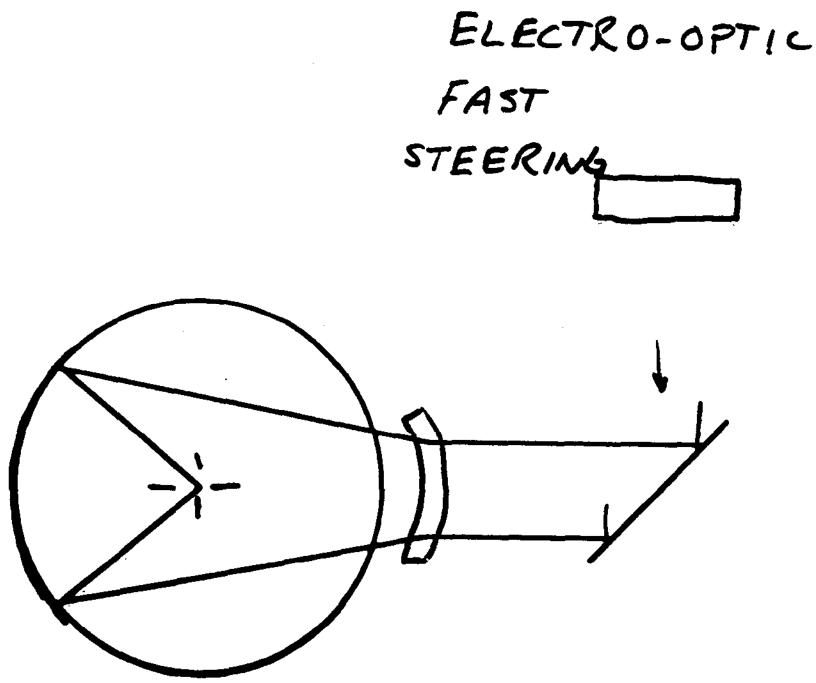
What sort of Compton scattering monitor is best? Two candidates - interference fringe device and laserwire device.

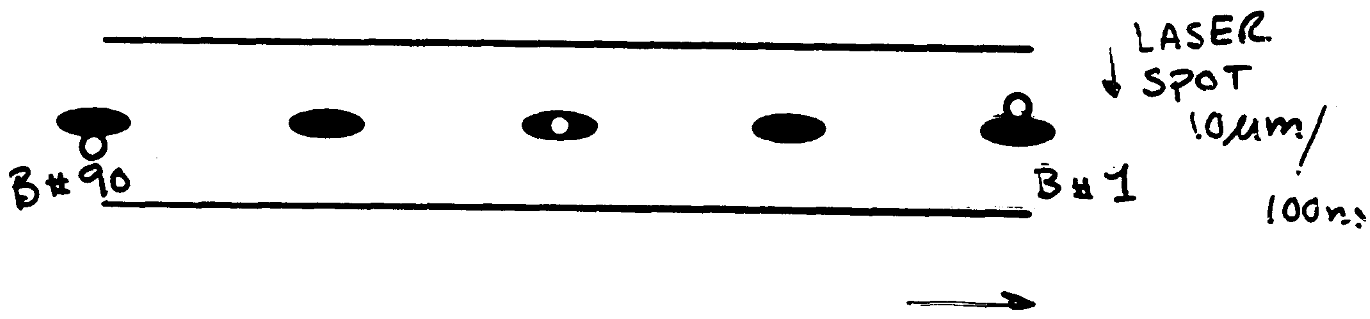
Single pass size monitor - measures projected size of train bunches.

Laserwire and Interference Fringe Compton scattering beam size monitor - comparison

Disadvantages	Laserwire	Interference
	Diffraction dependent spot shape	Higher laser power needed
	Limited minimum spot size	Limited dynamic range
	Calibration is more difficult	Mechanical stability
	More complex optics - radiation damage to optics	

SINGLE PASS LASERWIRE SCANNER





Easily adapted to fringe (shintake)
Compton monitor

Bunch Spacing

Most important at entrance to Main Linac

Meas.		location	resolution	accuracy	bunch train	# of unit	possible candidates
Delta Z bet. bunches	Bunch Spacing	Bunch Compressor	0.01mm (0.03ps) 0.1 degree X	0.03mm (0.1ps)	each	2	Auto-correlation of fast pulse or coherent radiation
		Main Linac	0.01mm (0.03ps) 0.1 degree X	0.03mm (0.1ps)	each	4	Auto-correlation of fast pulse or coherent radiation

What are phase difference tolerances? Are these devices needed at places other than the linac entrance?

Beam Power Limiting and Restoration sequences
(Machine Protection System)

Avoid rapid changes in damping ring average current

Vary the number of bunches in the train slowly - from the injector

Emittance increase control in linac

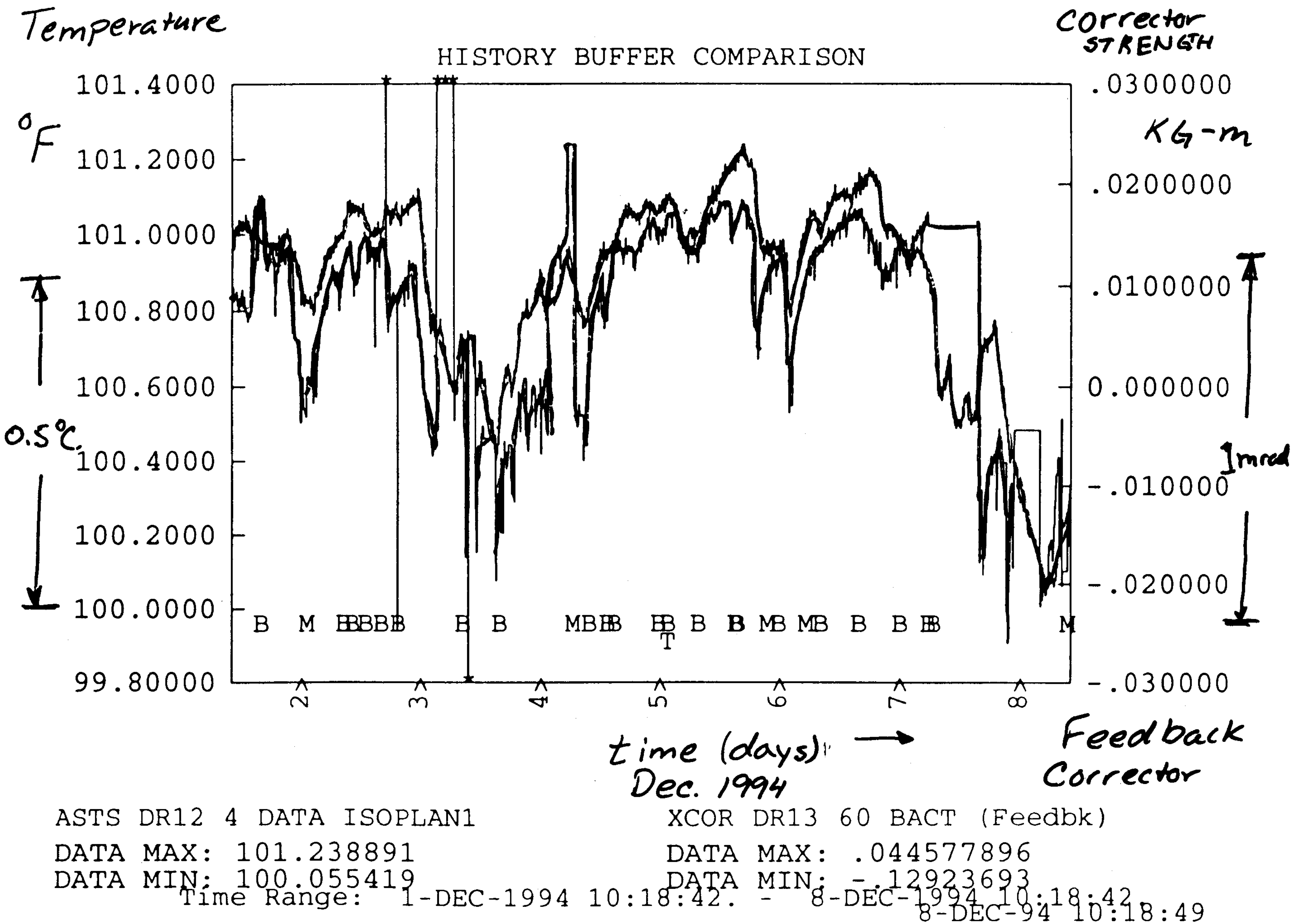
3 to 4 orders of magnitude increase required

Can this be done in the damping ring - anti-damping?

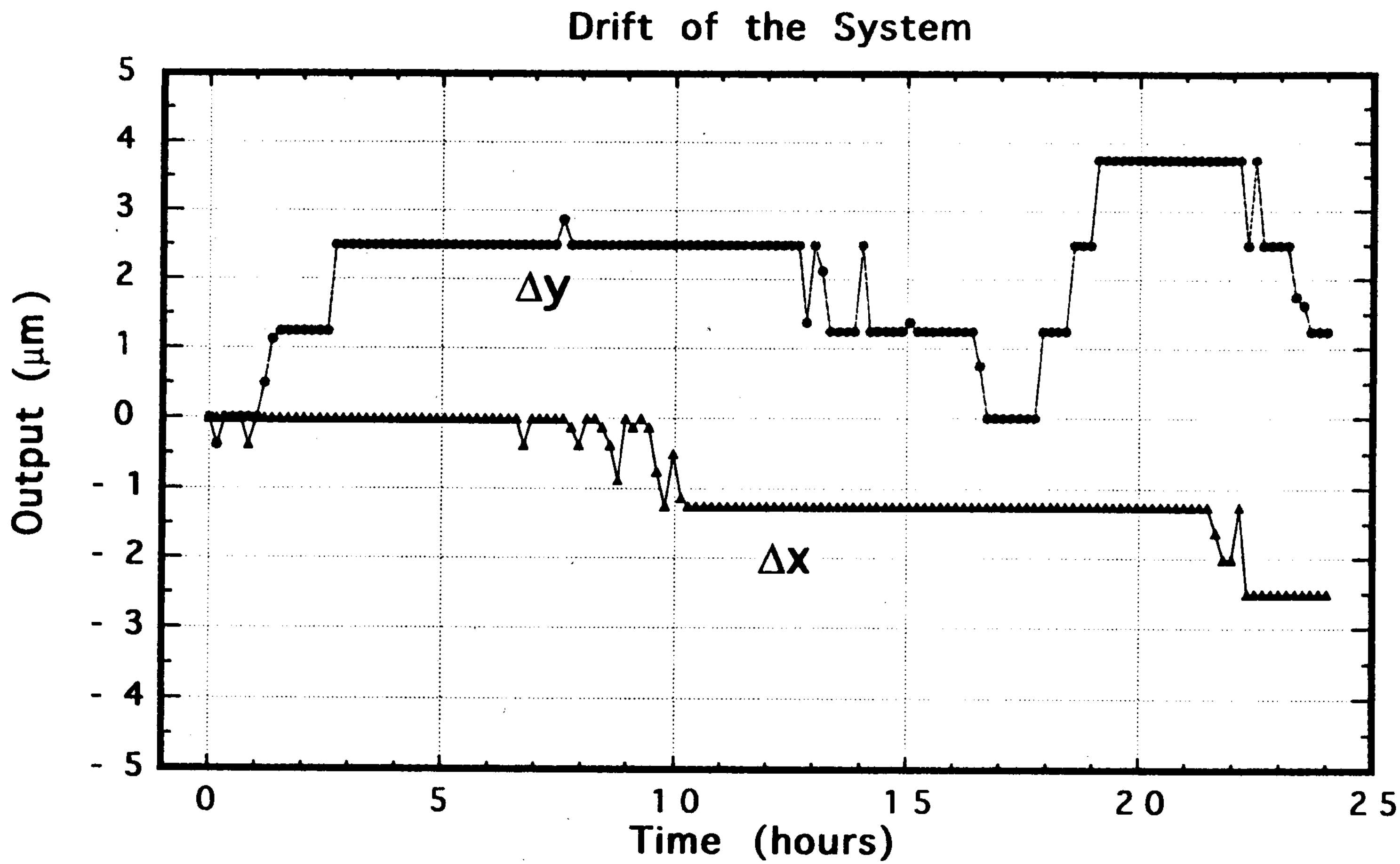
A linac entrance aperture filling I_0 single bunch train is too small by the end of the linac to prevent damage

How many other emittance - increasing controls are required?

Thermal feedforward will be needed for heavily loaded linac structures

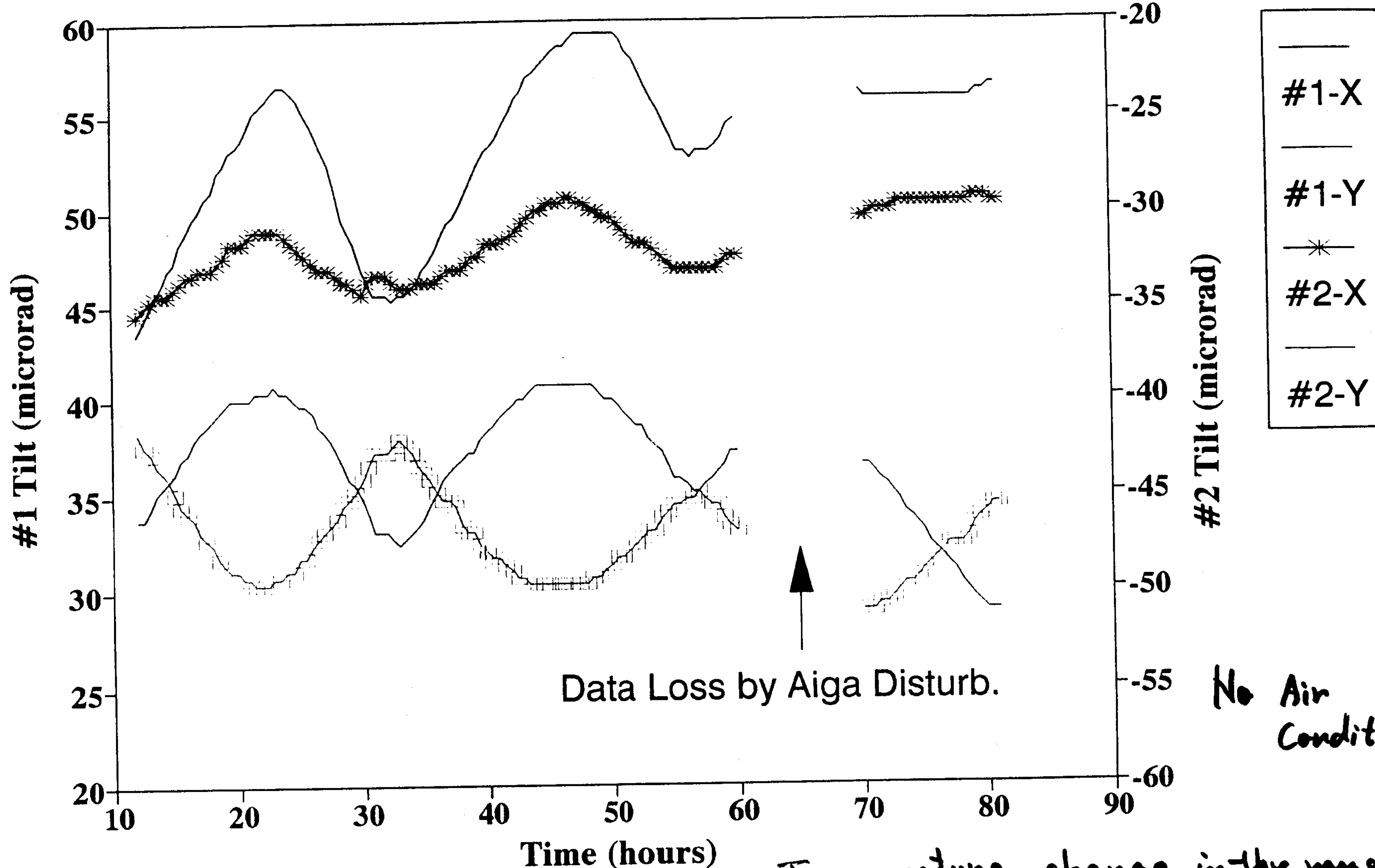


Temperature
°F
HISTORY BUFFER COMPARISON
Corrector STRENGTH
KG-m
101.4000
101.2000
101.0000
100.8000
100.6000
100.4000
100.2000
100.0000
99.80000
.0300000
.0200000
.0100000
0.000000
-.010000
-.020000
-.030000
0.5°C
1mrad
B M BBBBB B B MBBB BB T B B MB MB B B BB M
2 3 4 5 6 7 8
time (days)
Dec. 1994
Feedback Corrector
ASTS DR12 4 DATA ISOPLAN1
DATA MAX: 101.238891
DATA MIN: 100.055419
XCOR DR13 60 BACT (Feedbk)
DATA MAX: .044577896
DATA MIN: -.12923693
Time Range: 1-DEC-1994 10:18:42. - 8-DEC-1994 10:18:42
8-DEC-94 10:18:49


Drift of the System
Output (μm)
Time (hours)
Δy
Δx
5
4
3
2
1
0
- 1
- 2
- 3
- 4
- 5
0
5
1 0
1 5
2 0
2 5

Thermal Distortion of the Table

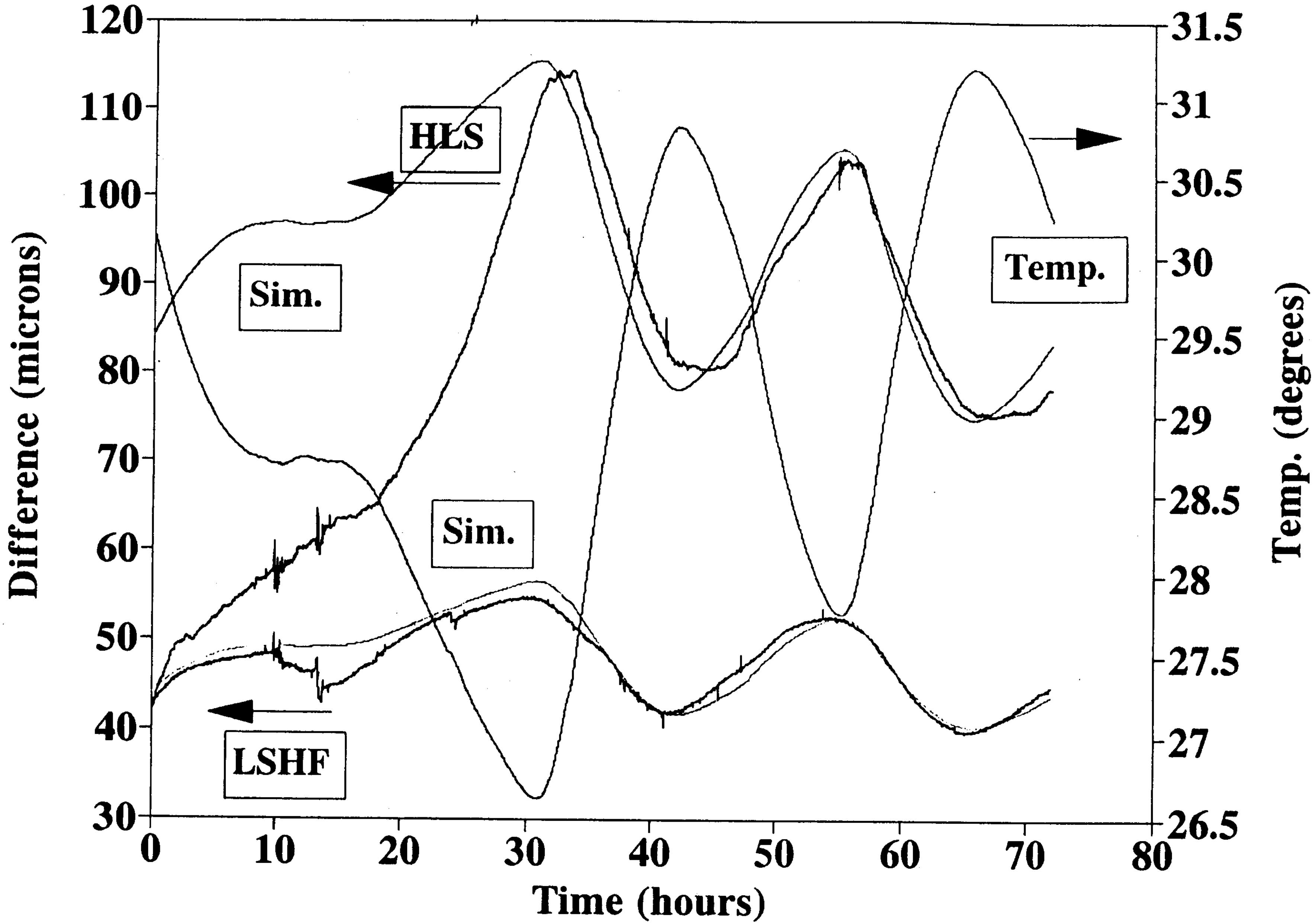
1994/08/23 - 08/26



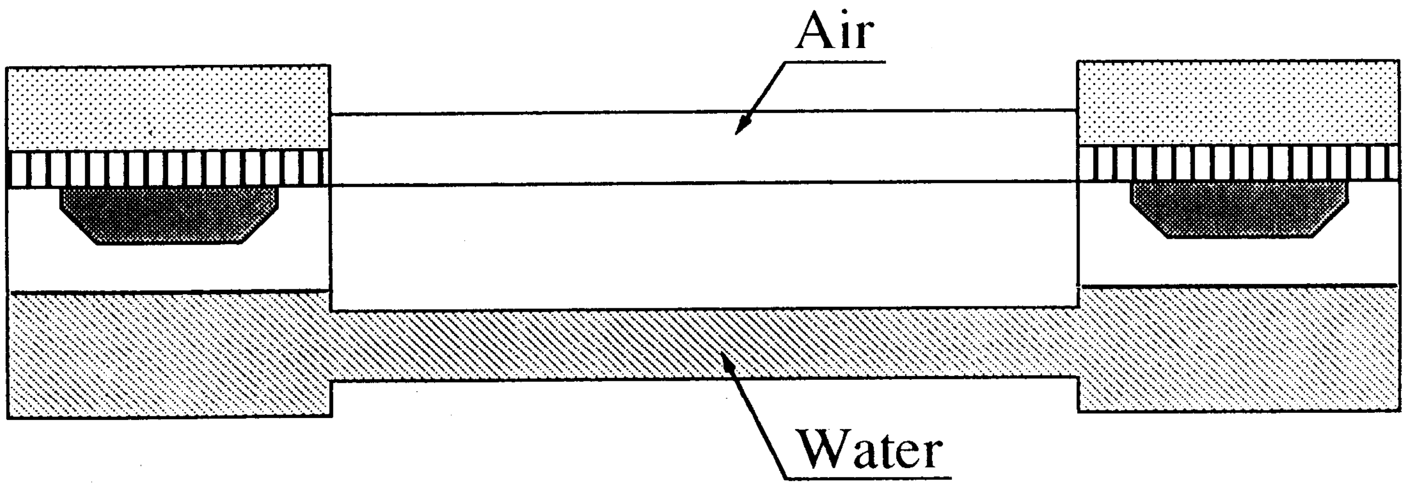
No Air Conditions

Temperature change in the range of 28 to 36°C.

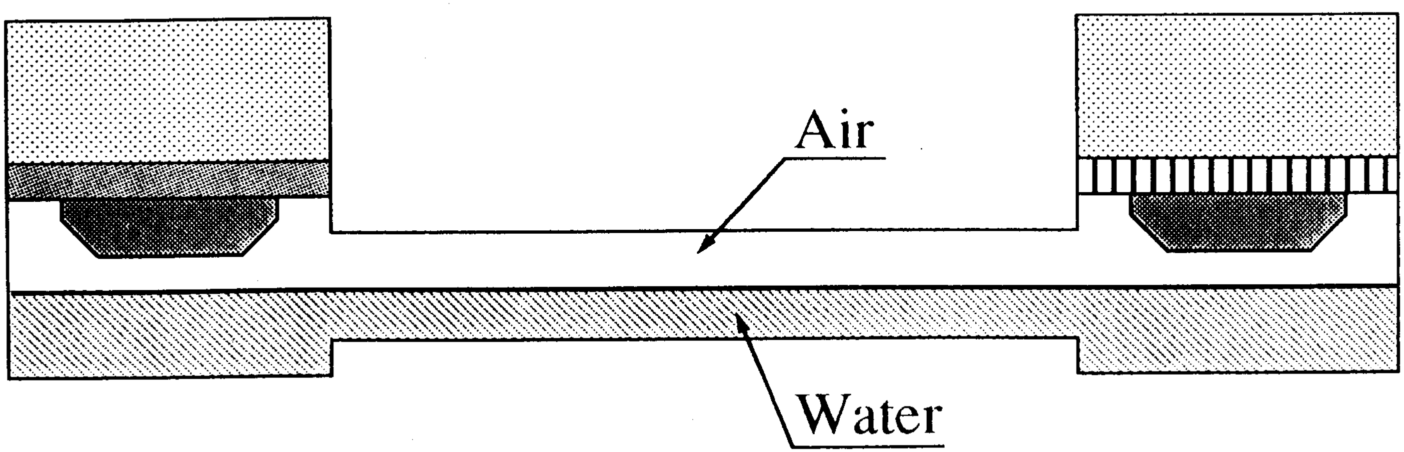
394


HLS
Sim.
Sim.
Temp.
LSHF
Difference (microns)
Temp. (degrees)
Time (hours)
120
110
100
90
80
70
60
50
40
30
31.5
31
30.5
30
29.5
29
28.5
28
27.5
27
26.5
0
10
20
30
40
50
60
70
80

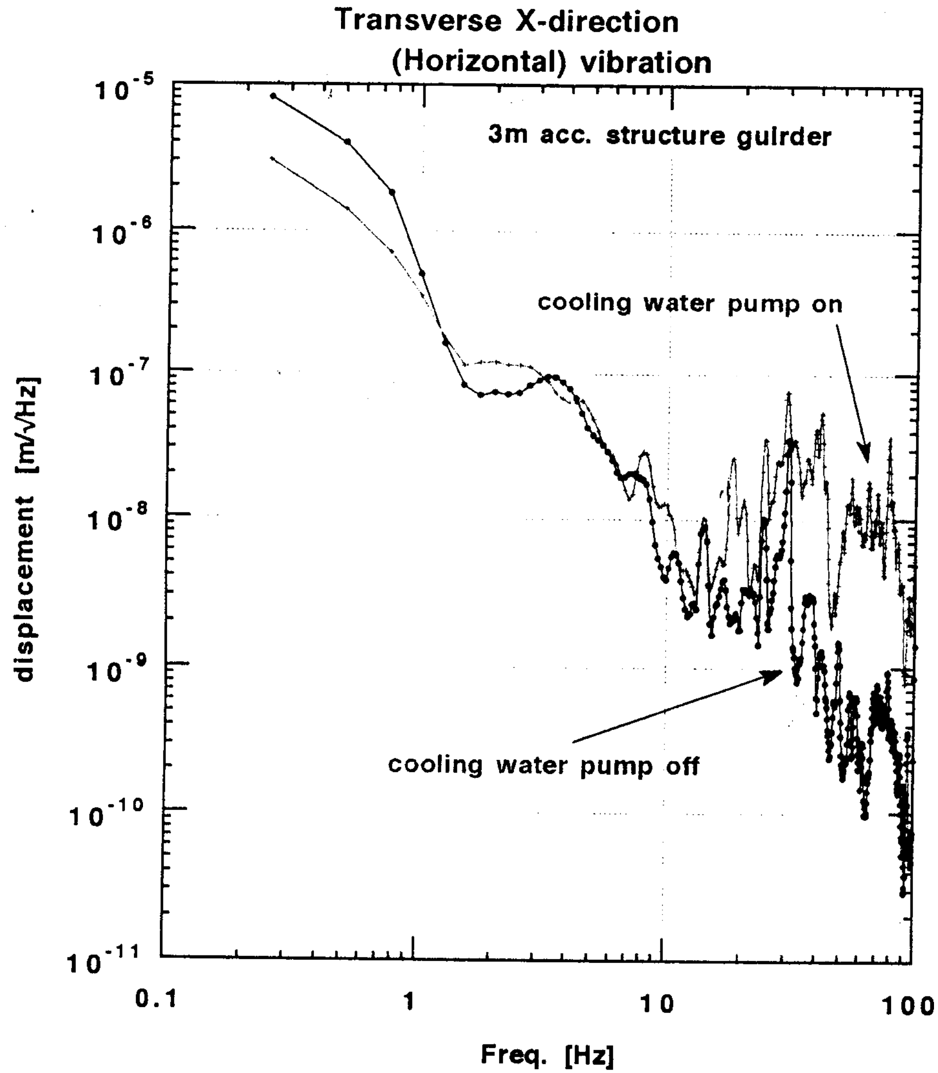
Water Hydrostatic Level

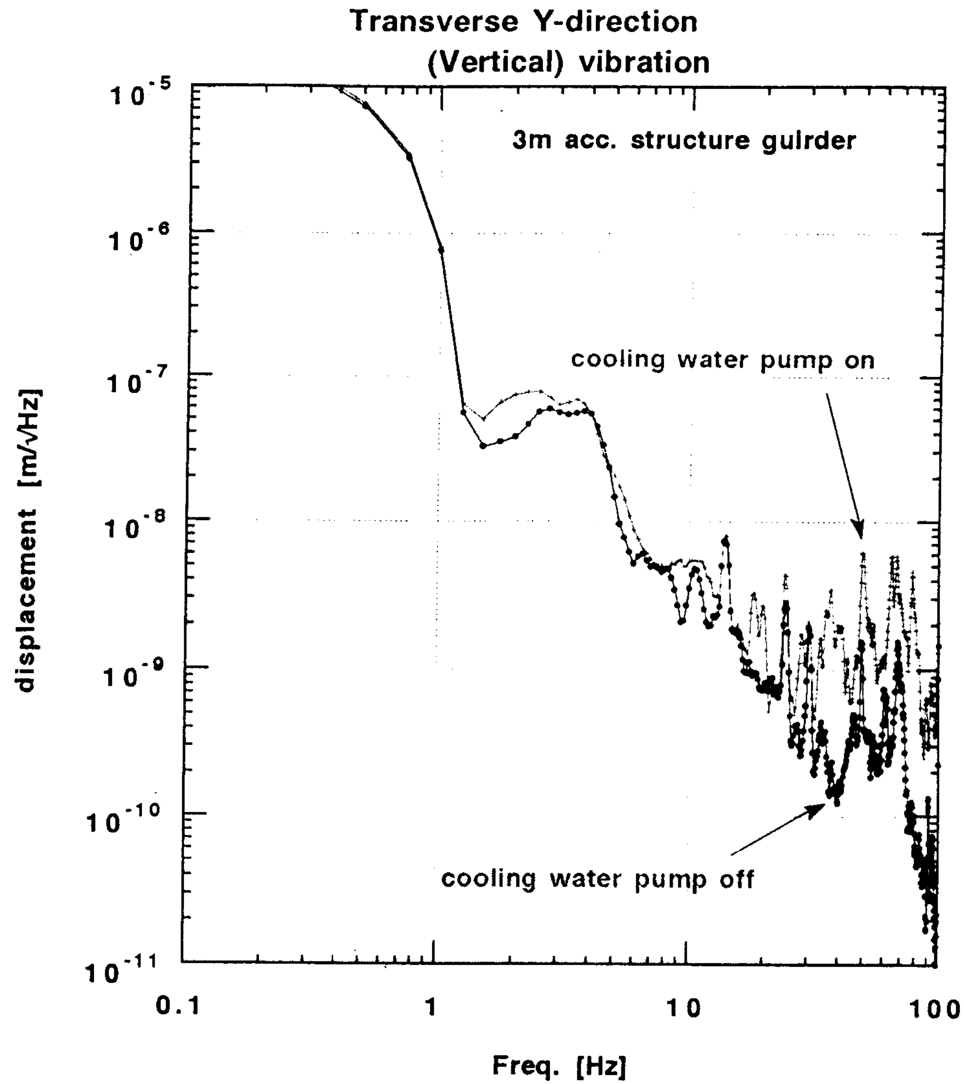


(a) filled (HLS)



(b) half - filled (LSHF)





pump ON rms ($\geq$ 1Hz) = 0.3 μm

no problem !

397

A summary table of the rms movement in nanometers follows. All the measurements were done in sector 12 at girder 7 except for quadrupoles 801 which is on a girder like 701 and 901 which is on an instrumentation girder.

Item measured	sec 12 Z Location	Water On	Water OFF
floor	near support	34 nm rms	
light pipe	quarter point	718 nm rms	
light pipe	midpoint	906 nm rms	
girder	quarter point	945 nm rms	
girder	midpoint	989 nm rms	
accelerator (dlwg)	quarter point	1010 nm rms	185 nm rms
accelerator (dlwg)	midpoint	1110 nm rms	190 nm rms
quadrupole	701	278 nm rms	
quadrupole	801	298 nm rms	95 nm rms
quadrupole	901	330 nm rms	

Other Data:

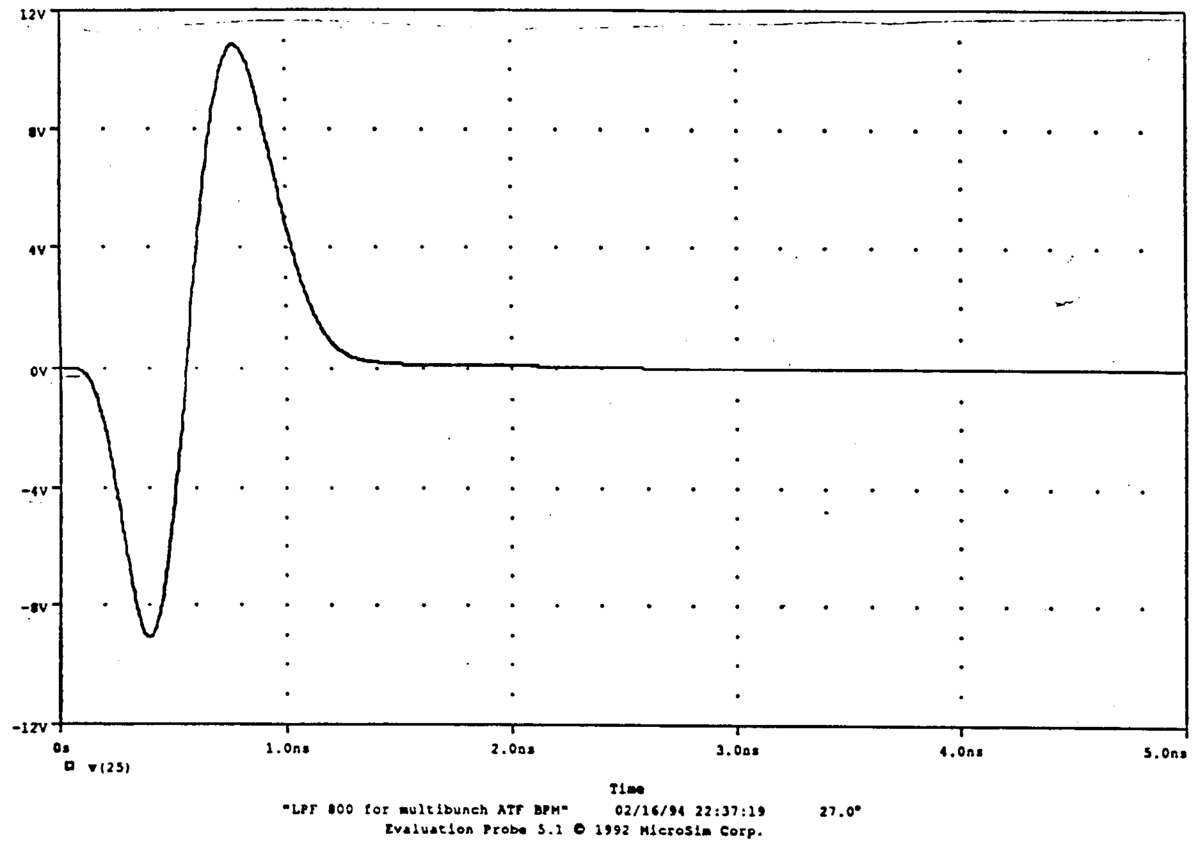
The power spectrum of electrical noise was measured to be orders of magnitude below the data, and therefore not a problem.

Yet to be analyzed:

Cross correlation data was taken between the midpoint of accelerator sections 12-7 and 12-8. Cross correlation data was taken between the midpoint of accelerator section 12-7 and quad 801. Impulse data was taken to determine the resonant frequencies of various structures and quads.

Summary and Conclusions:

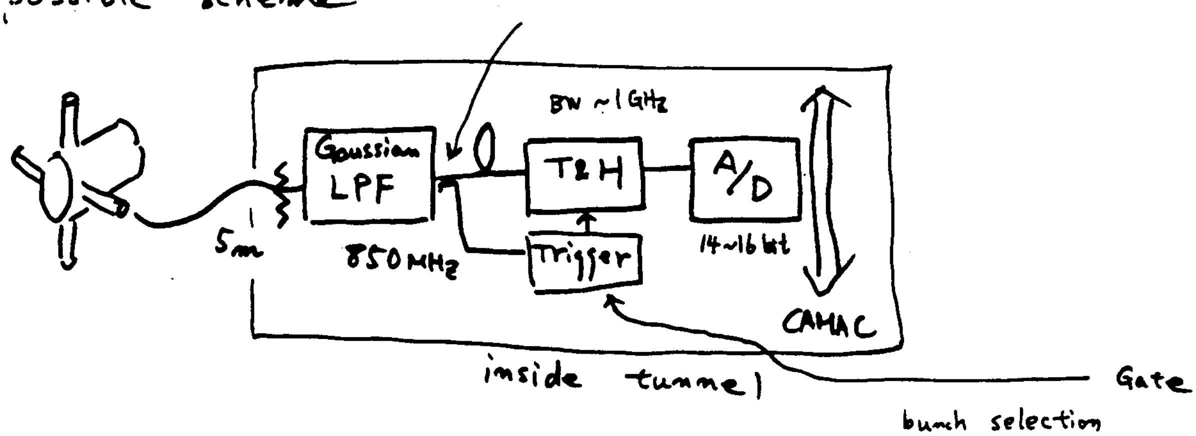
Measurements indicate that a 1 micron rms vertical motion of the accelerator structure drops by a factor of 5 to .2 micron rms motion when the cooling water circuits connected to the accelerator structure are turned off. The quadrupoles have 300 nanometer rms vertical motion with the accelerator structure water on and drop by a factor of 3 to 100 nanometer motion with it off. This indicates that the water turbulence drives the accelerator section motion which translates to the girders and quadrupoles. More analysis of the data taken is yet to be done.



Multibunch BPM

- Fast T&H → need fast T&H
- gating → reject gate sw Noise
- Fast Sampling & fitting → Fast Sampling by oscilloscope? enough accuracy?
- ⋮

possible scheme



③ H.M

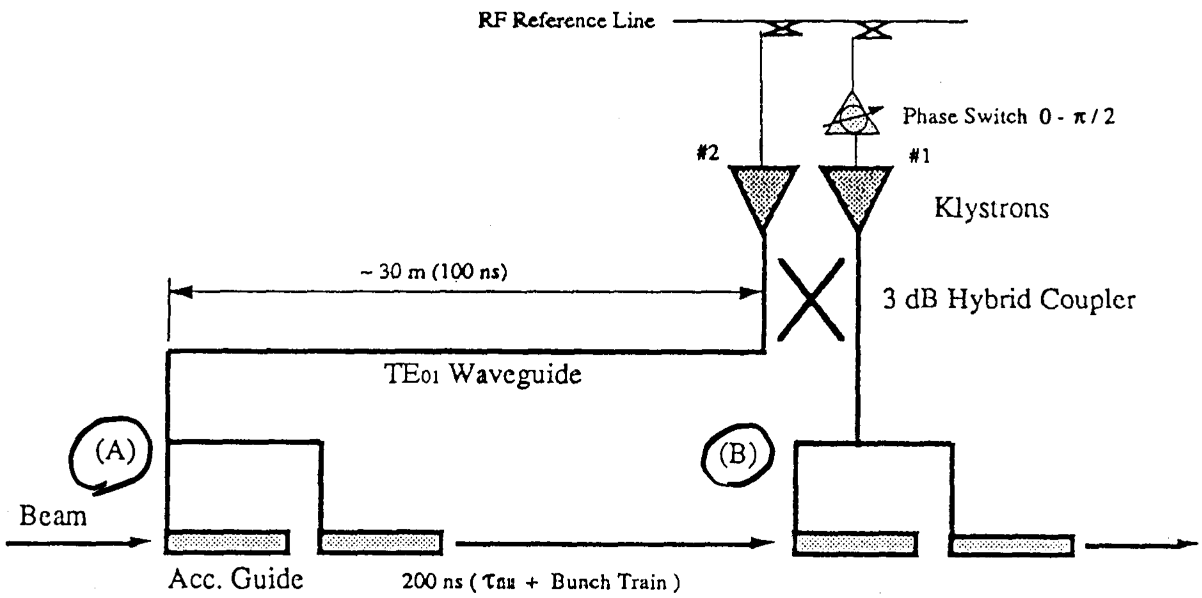


図 1　A Schematic Diagram of an RF Power Distribution System

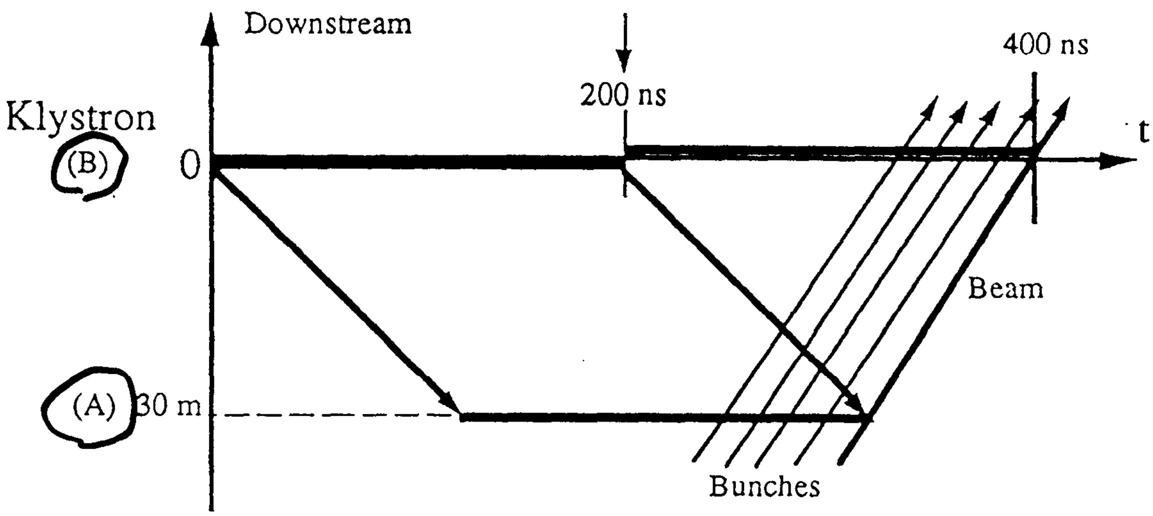


図 2　A Railroad Diagram of RF Distribution

JLC parameters(Ecm=1Tev)

Beam energy	500Gev	
RF frequency	11.424ghz	
No.of particles per bunch	6.9x10e9	
Nr of bunches per pulse	85	(120nsec train)
Bunch spacing	1.40nsec	
Repetition rate	150Hz	
Luminosity	10e34	
Nominal accelerating gradient	76.1MeV/m	
Effective gradient in cavities	57.1MeV/m	
Length of a cavity unit	1300mm	(8413m per beam)
Nr of cavity units(per beam)	6423	
a/L	0.1576	
Filling time(Tf)	120nsec	
Attenuation parameter	0.648	
Vg/c	3.64%	
Rf input per a cavity unit	130MW	(240nsec)
Efficiency(wallplug to RF)	30%	
Total AC power(RF)	194MW(and some more)	

Problem-1) Find differences between this Table and Yokoya Parameters presented this morning.

The prototype RF power source for JLC(Ec=1Tev)

(1)Klystron(XB72k)

RF out	130MW	97MW
Pulse width	500ns	
Efficiency	42%	36%(50MW)
Focusing	Super cond. Mag.	(unit test OK)

(2)x2 or x3 RF pulse compression system

RF input	500ns 130MW	(Design stage)
RF out	240ns 250MW	
Efficiency	>96%	

(3)Blumlein modulator

Output pulse	600kV 500ns(flat top)	500kV 700ns
Effiency	75%	
Pulse trans.	1:5	1:7 was tested
Rise &Fall time	150ns 200ns	250ns(rise)

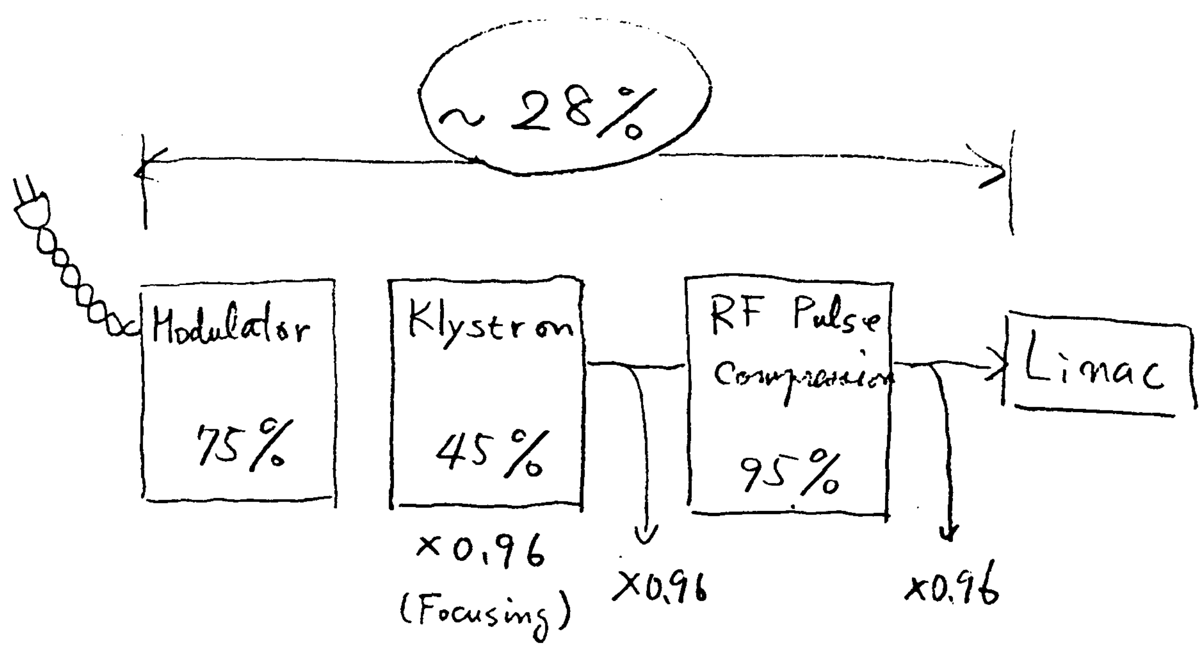


Table-1)XB-72 Parameters

Beam voltage	550kV
Beam current	490A
Max. surface field	273kV/cm
Beam areal compression	110-1
Cathode diameter	72 mm
Current density(Max.)	17A/cm2
Focusin field(Max.)	6.5kG
Number of cavities	5
Frequency	11.424GHz
RF power	120MW
Efficiency	47%
Max. surface Grad. (Output gap)	720kV
Gain	53-56dB

OK?
- Beam Voltage — 620 kV
- Beam Current — 550 A
- Beam Power — 340 MW — Diode is ok.

Problems
- Efficiency — 35% — Need
- Output Cavity — Damaged. (Discharge) — Multi Gap
- Peak RF Power — 95MW (26%)
-

OK(?)
- Window — TE_{11} $\frac{1}{2}\lambda_g$ — 600ns 70MW
- Focusing Solenoid — under Test — B_z ok. to be measured in SLAC (94·Dec)

Next.

Prototype Test.

wall plug ⟶ Linac Input

① ~~Fix Parameters~~ (~~making Prototype etc~~
(τ_{RF})

② ~2~3 years

③ Verify efficiency etc.

④ Problem "Money"

94-Dec-07
SLAC-KEK Meeting

Next in KEK. (Dec 1994 →

① XB72k#6 (95'-July) + 3 months "CONDOR"
5-Cavities 3-cell S.W Output (XL-1 like)

② XB72k#7 (95'-Nov) + 3 months "CONDOR" "FCI II"
6-Cavities 3-cell S.W output (↑)
(?)

③ Drift Tube Dia. 9φ → 14φ η ↑ ? Bz ?
TW out (BINP Structure ?) "ARSENAL"

④ Windows TE11 (Otake Window) TW-Window (Kazakov)
TE01 (BINP)
XB72k#5 (Dec. 94') ← 2-TE11 windows

⑤ Modulator Oil Tank Blumlein (IHI)
L.V test finished
H.V Test 95'-Jan
Distributed PFN 95Fy (China

⑥ Super Cond. Mag Tested in KEK Oct. 94'
SLAC Measurement Next Week

⑦ DLDS. Factor 2 Fy95 (BINP)
Factor 3 (?)

RF Pulse Compression
(Includes transmission of power to acc.

JLC

"DLDS" $\eta \simeq 93\%$ P.G. = 1.85

simple, low risk technology

NLC

X5 SLED-II $\eta = 72\%$ PG = 3.

Proven components
Tested at high power in ASTA
Extensive tests to come in NLCTA
Some improvements needed to meet design

Future:

X8 BPC
Switched SLED-II } $\eta \approx 80\%$ PG = 6.

Loaded Delay Lines
Probably 5-10 lumped cavities/BPC
Implies "ripple"
But correct with low level ϕ modula

Modulator

	JLC	NLC	
Output Voltage (kV)	600	550	
Thyratron (Max kV)	150	80	
PFN Voltage (kV)	120	69	
Pulse Transformer	1:5	1:8	
Pulse Length (μs)	0.5	1.2	1.75
Energy Efficiency	75%	80%	85%
Net efficiency (with Pwr. Supply)	71%	75%	80%
Energy/pulse (J)	225	325	450
		(2 klystrons)	

- Mature technology
- Improvements possible with $$
- Replace with grid-switched klystron? ($\eta \approx 90\%$?)
- Some ripple O.K -- $\pm 2\% \Rightarrow \pm 20^\circ \Delta\phi$ for NLC klystron

Table-1)XB-72 Parameters

		NLC
μK	1.2	0.6
Beam voltage	550kV	535
Beam current	490A	235
Max. surface field	273kV/cm	—
Beam areal compression	110-1	145
Cathode diameter	72 mm	57.2
Current density(Max.)	17A/cm2	{7.4 ave, 10 edge
Focusin field(Max.)	6.5kG	3.0 peak
Number of cavities	5	6 + ...
Frequency	11.424GHz	same
RF power	120MW	75
Efficiency	47%	60%
Max. surface Grad. (Output gap)	720kV	~~73~~0
Gain	53-56dB	57
Output circuit	—	4 cell TW

K?
- Beam Voltage 620 kV
- Beam Current 550 A
- Beam Power 340 MW Diode is OK.

- Efficiency 25%
- Output Cavity Damaged. (Discharge) Need Multi Gap
- Peak RF Power 95MW (26%)
-

)
- Window TE11 ½λg 600ns 70MW
- Focusing Solenoid under Test Bz OK.
  to be measured in SLAC (94·Dec)

original transparency

12-9-94

1.0 TeV c.m.
Basic RF Parameters

See next page for "preferred" NLC Parameters

	JLC	NLC "Realistic"	NLC Future (*)	
Str. Length (m)	1.3	1.8		
Filling time (ns)	120	100		
Ave v_g/c (%)	.036	.060		
No. structures per Kly (Str. Length / Kly)	2 (2.6 m)	2 (3.6 m)		
Accel. Gradient (MV/m) Unloaded / Loaded	76/57 (71/53)	60/45	80/60	(85/63½)
RF Power at Str. (MW)	130	130	230	(260)
MW/m @ 50 MV/m	43	50		
T_p at Accel (ns)	120 + 120 + 10 = 250 (85 bunches)	100 + 105 + 15 = 220 (75 bunches)		
Pulse Comp. System	DLDS	x5 SLED-II	x8 BPC	
Power Gain / Efficiency	1.85/93%	3.6/72%	6.4/80%	(6.8/85%)
Klystron Power (MW)	140	72		(77)
Repetition Rate (Hz)	150	120		
Kly. Pulse Length (μs)	0.50	1.20	1.76	
Klystron Efficiency	45%	60%	60%	(65%)
Modulator Efficiency	71%	75%	80%	(90%)
Net RF Efficiency	30%	32%	38%	(50%)
Wall Plug Power (MW)	225	135	150	125
Total Active Length (km)	2x9.0	2x11.4	2x8.6	(2x8.1)
Number of klystrons	6900	6300	4800	4500

Revised 12/12/94

1.0 TeV c.m.
Basic RF Parameters

P. Wilson
SLAC/KEK Workshop
12/9/94 Summary

	JLC (Mizuno)	NLC (Present Technology)	NLC (Further R&D)
Structure Length (m)	1.3	1.8	1.8
Filling time (ns)	120	100	100
Ave v_g/c (%)	.036	.06	.06
No. Structures per Kly (Str. Length/Kly)	2 (2.6 m)	1 (1.8 m)	2 (3.6 m)
Accel. Gradient (MV/m) Unloaded/Loaded	76/57	85/63.5	85/63.5
Particles/bunch (10^{10})	0.69	1.1	1.1
No. Bunches/Rep Rate (Hz)	85/150	75/120	75/120
MW/m @ 50 MV/m	43	50	50
T_p at Accel (ns)	T_F + T_B + T(switching): 120+120+10=250	100+105+15=220	220
Pulse Comp. System	DLDS	x5 SLED-II	x8 BPC
Power Gain/Efficiency (1)	1.85/93%	3.6/72%	6.4/80%
Pwr. Req'd at Str. (MW)	130	260	260
Klystron Pwr (MW)	140	72	81
Klystron Pulse Length (μs)	0.50	1.20	1.76
Klystron Efficiency	45%	60%	63%
Modulator Efficiency (2)	71%	75%	80%
Net RF Efficiency	30%	32%	40%
Total Active Length (km)	2 x 9.0	2 x 8.1	2 x 8.1
Wall Plug Power (MW)	225	193	155
Number of Klystrons	6940	9016	4508

Notes (1) Includes power transmission to accelerator
(2) Includes ac to dc power supply

941209 ①

J. Wang.
T. Higo

Structure Issues

Issues		SLAC	KEK
• Structure Type		Detuned	Detuned
long range dipole wake		"DDT" manifold	pure detune / medium damp
			(Detuned + Choke mode ? later option)
• RF properties	L_s	1.8m $\frac{a}{\lambda}=0.18$	1.3m $\frac{a}{\lambda}=0.16$
fundamental mode	T_f	100ns	106 ns
	τ	0.5	0.58
cost (# of structures / " klystrons	P_{kly}	90MW/structure	130 MW/structure
	E_{NL}, E_{LD}	50 MV/m →	73 MV/m → 54MV/m
multi-bunch energy compensation		RF ramping	injection timing non-local

		SLAC	KEK
• Dipole mode	$\Delta f_1/f_1$	10%	11%
lowest dipole mode	Q_{ex}	~1000	~2000
&	a	4~5.7 ($\frac{a}{\lambda}$ 0.18)	3.6~5.3 ($\frac{a}{\lambda}$ 0.16)
higher	t	1~2 Gaussian	1~2.4 f_6 gaussian
	N_{cell}	206	150
• Wake field calculation			
Equivalent cirquit		Karl	Kubo→Yamamoto→
Open mode exp.			Yamamoto
Mode matching		Sam's	
MAFIA		Kwok	
Parallel processor		"	
Manifold damping (eq. circ)		Kroll, Kathy, Kwok ···	
• Wake field measurement		ASSET	←

	SLAC	KEK
• Emittance growth calculation	analytical formula	
single bunch	simulations	
multi bunch		
tolerance freq.	Chris	
" alignment	Karl	
	Kathy	
	Kubo	
feedback method		
• Fabrication	Brazing (Cu-Cu contact)	Diffusion bonding
tolerance, QC	dimple tune	no tuning
freq., alignment		
low power (tune check)	Vertical (SW/TW)	Horizontal (SW)
QC (cell/stack)	final tune after brazing	(dimension of cell. simple RF on cell
present status	1.8m	0.3m (1.15m)
δf machining		±0.3MHz
δf bonding		<1MHz
alignment	4μ/16 cell	4μ (40μ)
shrinkage	~0.1mm/16 cell	(0.5mm)

	SLAC	KEK
• High field performances dark current simulation	>55MV/m 1.8m	100MV/m 0.2m stop band in Eacc
• Test of RF unit	ASTA	AR-south exp. hall.
• Test of Linac unit	NLCTA	not proposed yet

RF control
Single / Multi-bunch
Energy compensation
Transverse dynamics
  Wake field, alignment, feedback, ..
BPM
  resolution, accuracy, dark current, ..
  ⋮

• items to be checked & confirmed

Beam Monitoring & Structure Alignment (Using Structure modes)

Material Handling

processing HIP, RF

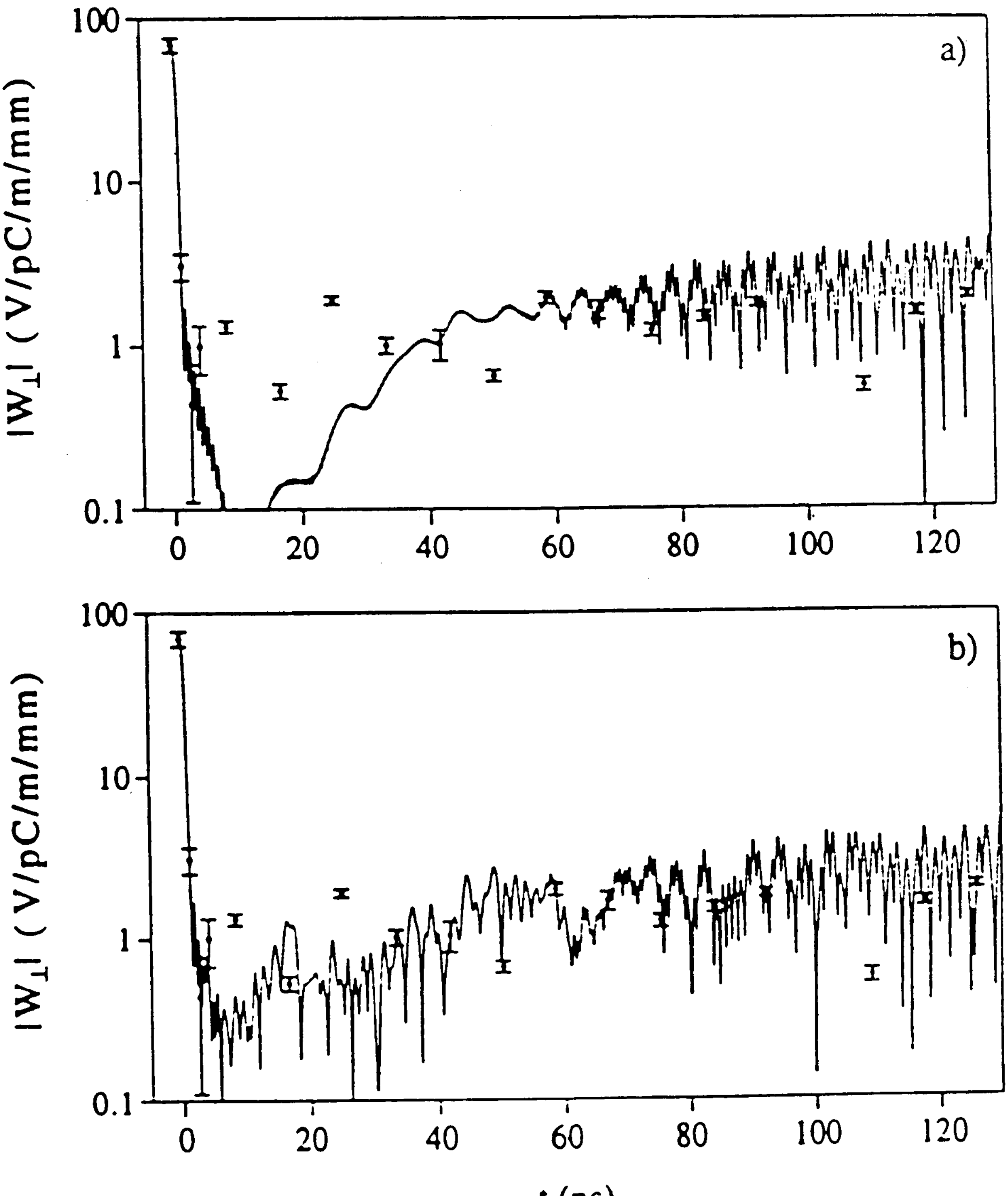
Cleaning HPP

Dark Current Studies

effect (to Beam & BPM) & remedy

Coupler and Wakefields (Simulation & Measurements)

Temperature change due to beam loading



Dipole wakefield amplitude measurements and prediction a) without cell frequency errors and b) with 1.5×10^{-4} rms fractional frequency errors.

Summary of Beam Delivery

12/8/1994 K. Oide

1) The relative phase jitter between two crab cavities must be checked by R&D with real beam (for example using FFTB). Fast common jitters of crab rf are not problem. Slow drift of phase due to temperature change is correctable with steering correctors.

2) The layout strongly depends on the crossing angle.

3) The vibration of final quads with mechanical support for the detector should be checked under realistic environment (water flow for quad if it is iron, or nearby human activities if two IP is necessary).

4) The size of the system is nearly proportional to the beam energy. The maximum energy must be determined at the beginning.

5) Both linear and nonlinear collimation schemes are still alive. The depth of collimation depends on not only the beam energy and also the design of detector, so a simple scaling on the energy can be inadequet.

6) There are several techniques to improve the bandpass and to shorten the length of the final focus:

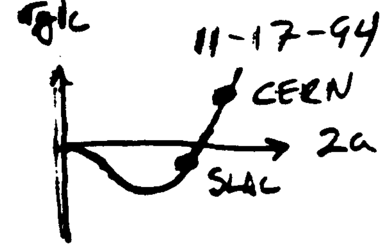
a) Asymmetric dispersion
b) Brinkmann sextupoles
c) "Brinkmann quadrupoles"

Yet the merit of a big bandpass should be stated clearly in the design, otherwise the system becomes uselessly long.

	NLC 1.5 TeV	JLC 1.5 TeV
Crossing	Crab 40 mrad	Nocrab 8 mrad (optional crab)
Layout	Collimate-Bend-FF 	Bend-Collimate-Reverse Bend-FF 
Collimation Length	Linear 4%, 6 σ_x, 35 σ_y 2000 m @ 1TeV	Nonlinear 1.5%, 6 σ_x, 35 σ_y 1000 m @ 0.5 TeV
Chromaticity Correction Bandwidth Length	Symmetric Dispersion Brinkmann Sext ±0.45% 1500 m	Asymmetric Dispersion "Brinkmann Quad" ±1% 900 m
Final Quad	Permanent $B_{poletip}$ = 1.4 T a = 4.5 mm L = 3 m	Normal Conducting Iron $B_{poletip}$ = 1.3 T a =3.2 mm L = 3 m
l*	2 m	2.5 m

RF Separator Structures

PBW
11-17-94



$$V_\perp = \sqrt{r_\perp L P_0}\left(\frac{2}{\tau}\right)^{1/2}\left(1-e^{-\tau}\right)$$

"LOLA - III"
SLAC-PUB-135 (1965)

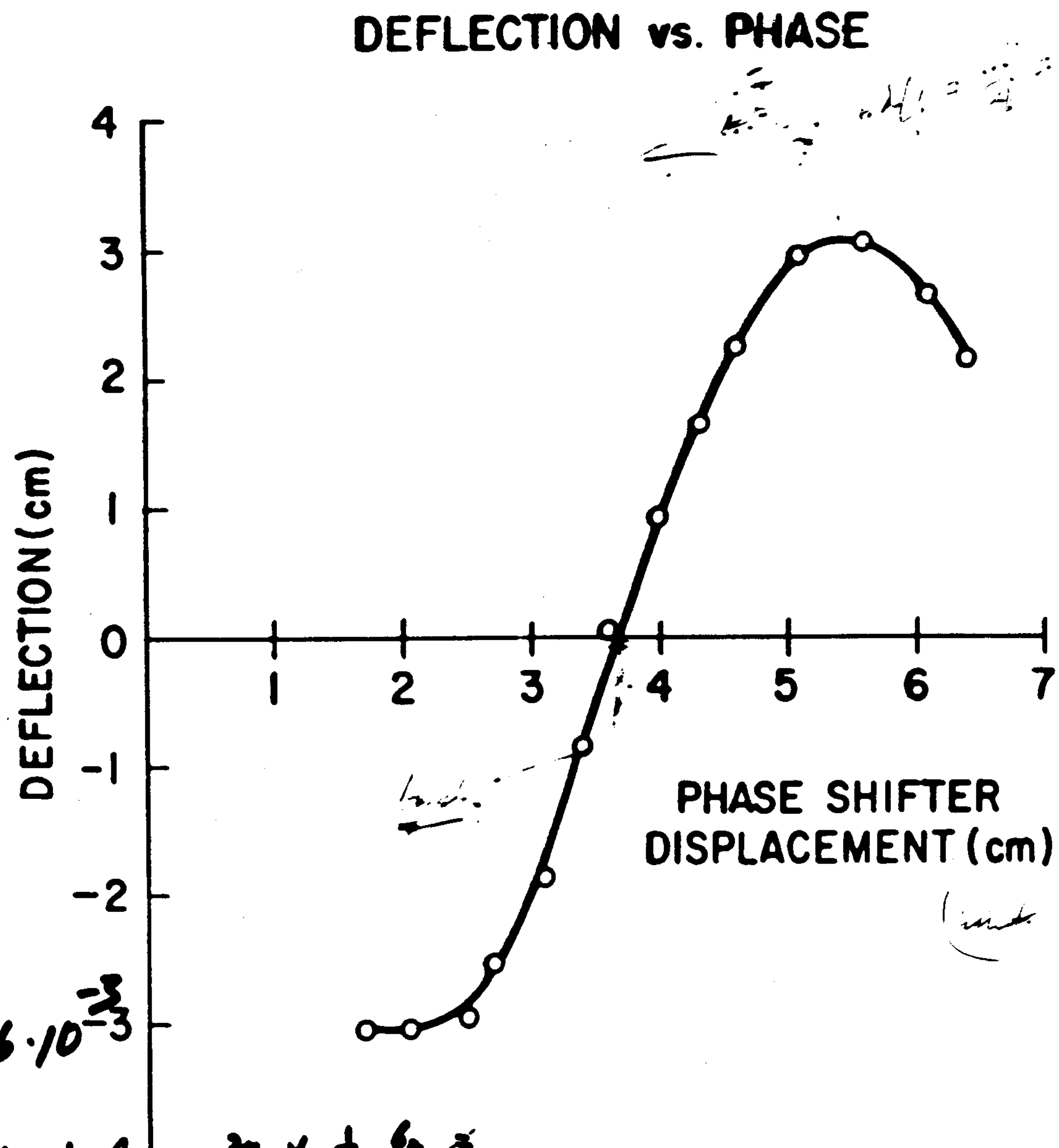
S-Band	scaling	X-Band (11.4 GHz)
$r_\perp$ = 11.7 MΩ/m	$\omega^{1/2}$ (x2)	23.4 MΩ/m
L = 3 m	$\omega^{-3/2}$ (x1/8)	0.375 m
τ = 1.04	constant	1.04
2a = 47 mm	ω^{-1} (x1/4)	11.8* mm
Q = 11,000	$\omega^{-1/2}$ (x½)	5500
v_g/c = −.0078	constant	−.0078
T_F = 1.28 μs	$\omega^{-3/2}$ (x1/8)	160 ns
No. $\frac{2\pi}{3}$ cells = 86	$\omega^{-1/2}$ (x½)	43
$P_\perp c/\sqrt{P_0}$ = 5.3 MeV/$\sqrt{\text{MW}}$	$\omega^{-1/2}$ (x½)	2.65 MeV/$\sqrt{\text{MW}}$

* Largest 2a = 11.4 mm at front of NLC detuned str.

$$\frac{eV_\perp}{E} = 1.14\times10^{-3}\,\lambda_{RF} = 3.0\times10^{-5}$$

At 250×10^9 eV/beam, $V_\perp = 7.5$ MV

$$P_0 = \frac{V_\perp^2}{.805\, r_\perp L} = \frac{(7.5\times10^6)^2}{(.805)(23.4\times10^6)(0.375)} = \underline{8.0\text{ MW}}$$

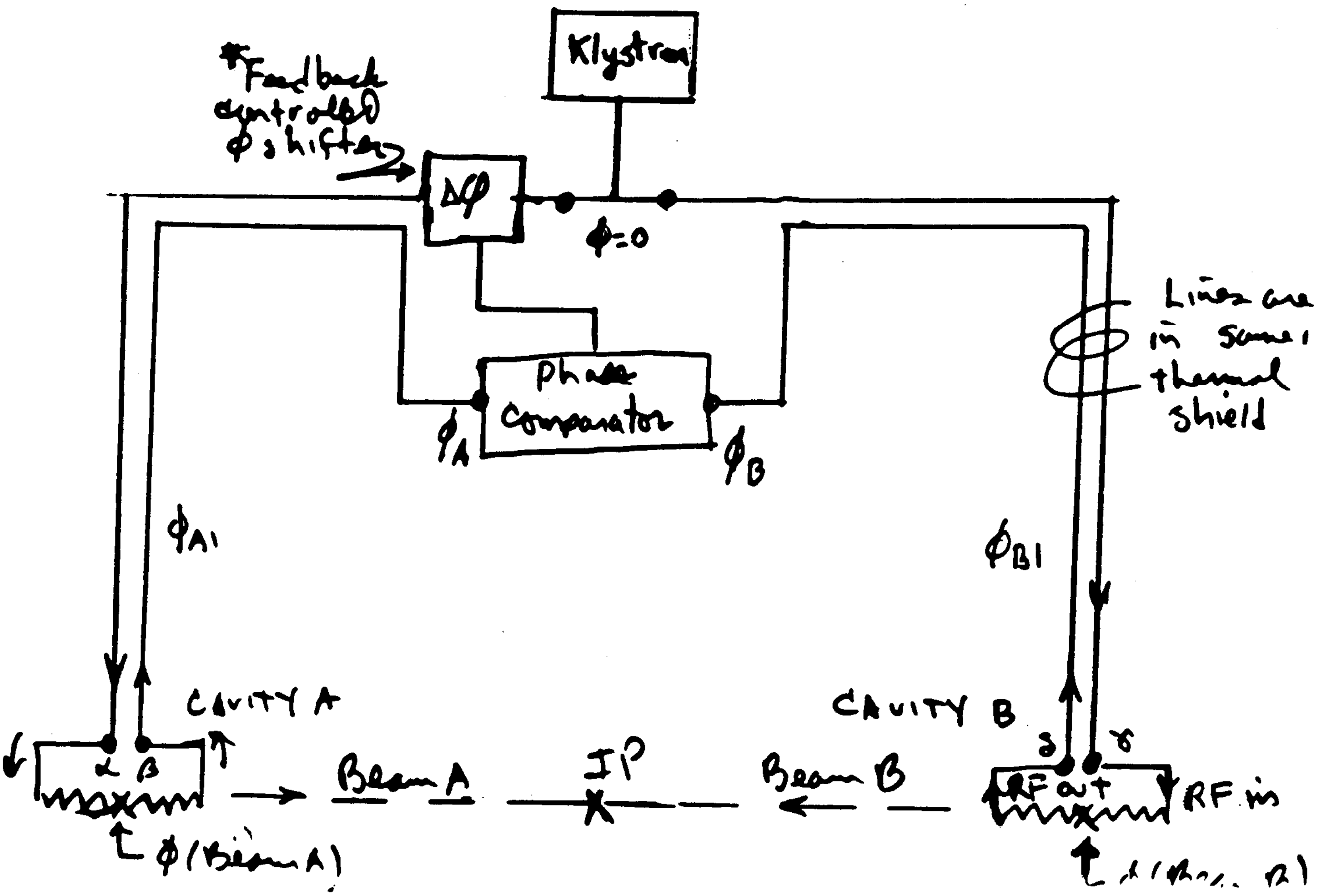


$\frac{1}{50} \cdot \frac{1}{35} = .6 \cdot 10^{-3}$

FIG. 17--Deflection versus phase.

- Precision of phase? ~ $\frac{1}{35}$
- "Multibunch" Wakes ← alignment tolerance! & jitter

Scheme for Feedback and control of $\Delta\varphi$



$\varphi_{A2} = \alpha \to \beta$ $\qquad\qquad$ $\phi_{B2} = \gamma \to \delta$

* Feedback controlled φ shifter:
Slow: mechanical (motor) or thermal (heater)
Fast: Piezo-electric side wall pressure (to 180 Hz)

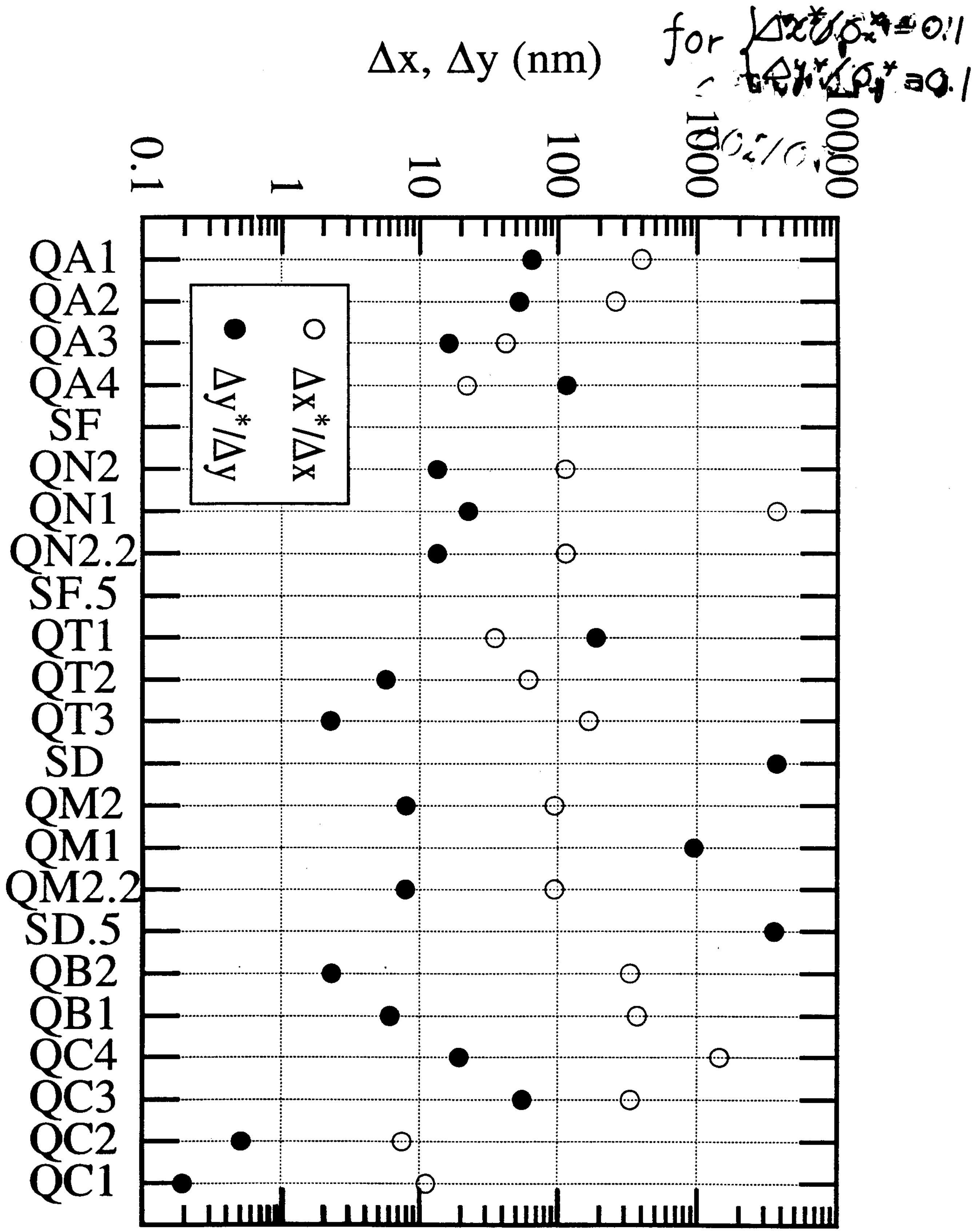
$$\left.\begin{aligned}\phi_A &= 2\phi_{A1} + \phi_{A2} + \Delta\varphi \\ \phi_B &= 2\phi_{B1} + \phi_{B2}\end{aligned}\right\} \phi_A - \phi_B = 2(\phi_{A1} - \phi_{B1}) + (\phi_{A2} - \phi_{B2}) + \Delta\varphi$$

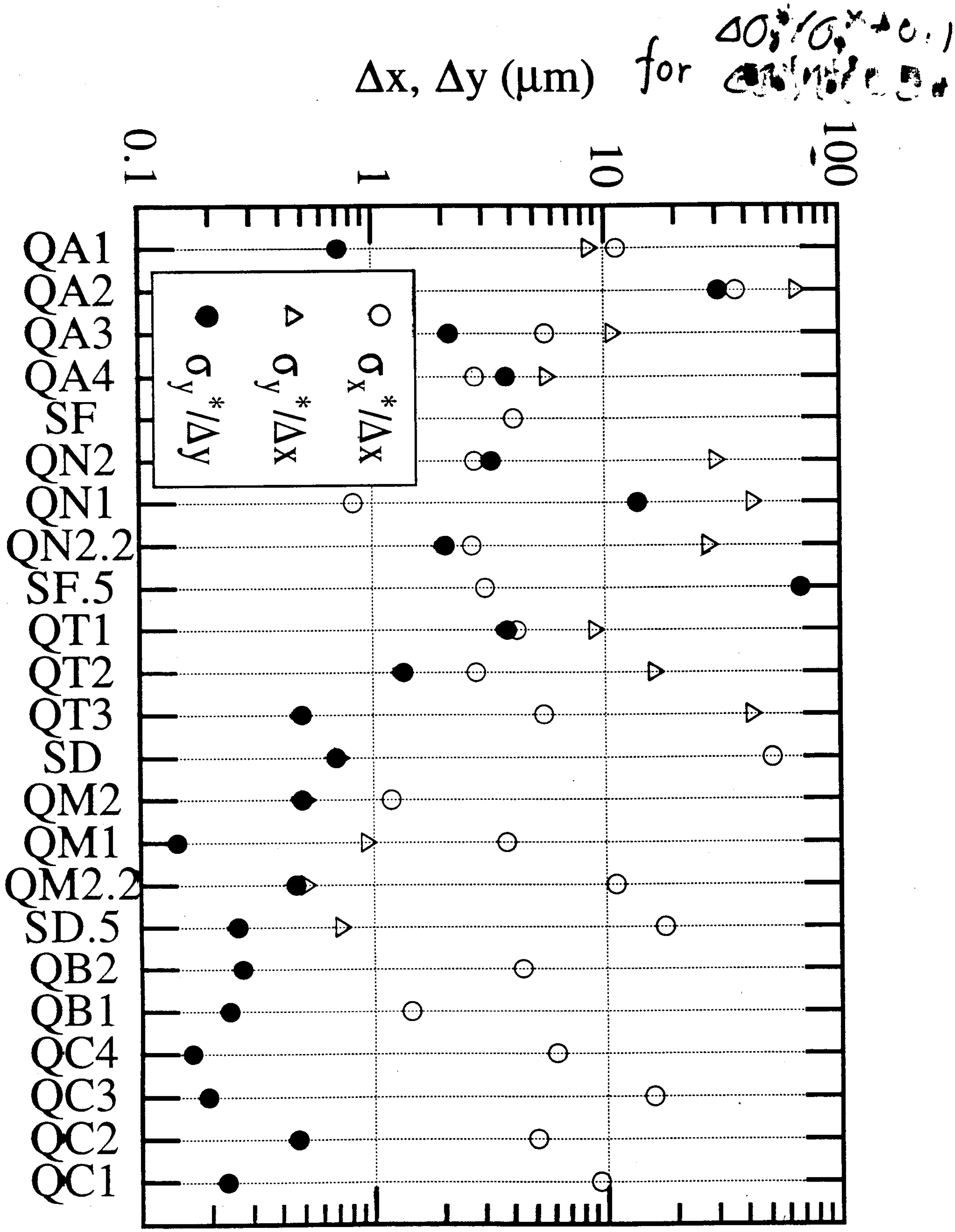
$$= 2\left[\phi(\text{Beam A}) - \phi(\text{Beam B})\right]$$

$\phi(\text{Beam A}) = \phi_{A1} + \frac{1}{2}\phi_{A2} + \Delta\varphi$

$\phi(\text{Beam B}) = \phi_{B1} + \frac{1}{2}\phi_{B2}$

Adjust $\Delta\varphi$ to keep $\phi_A = \phi_B$

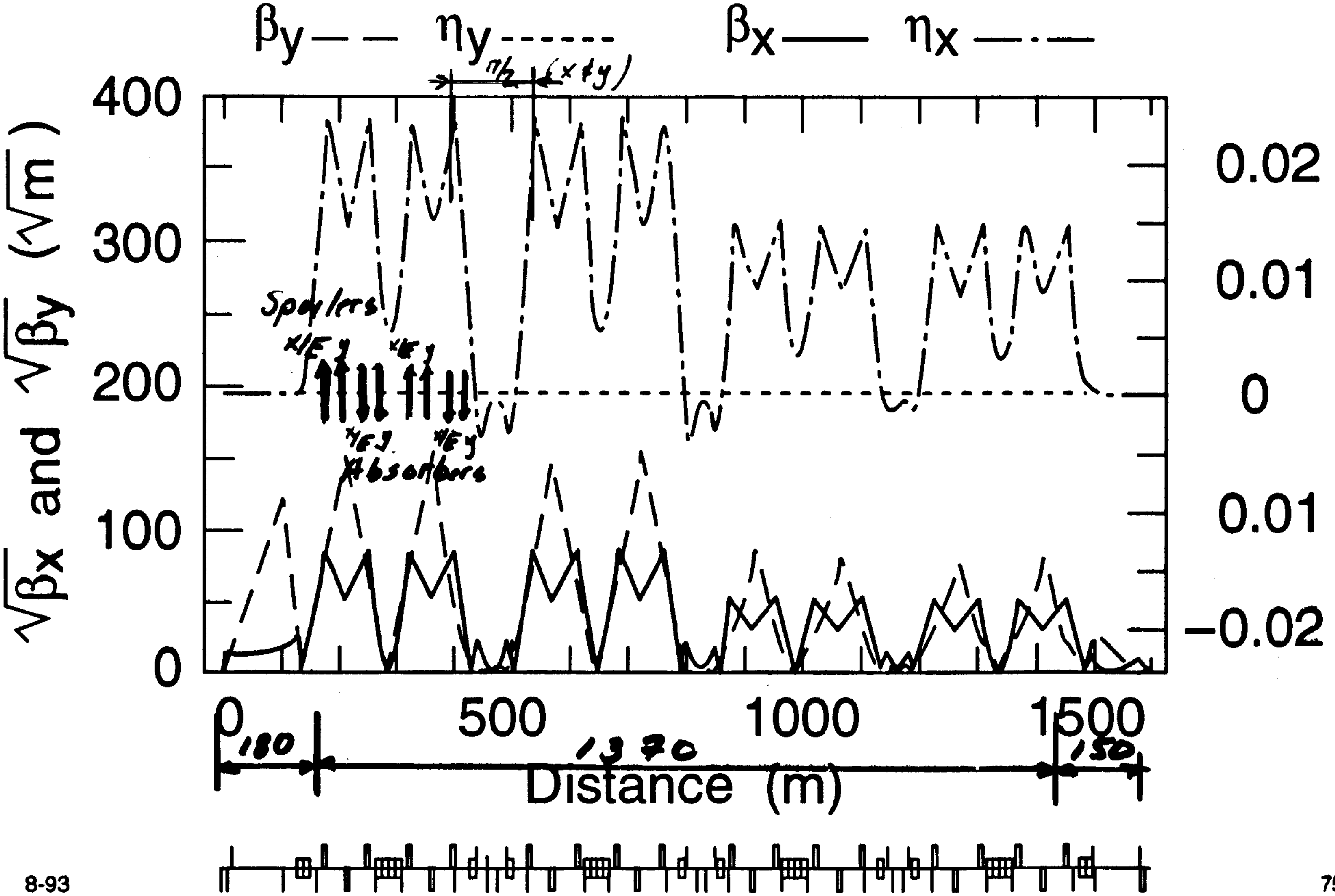

Δx, Δy (nm)
0.1
1
10
100
1000
10000
QA1
QA2
QA3
QA4
SF
QN2
QN1
QN2.2
SF.5
QT1
QT2
QT3
SD
QM2
QM1
QM2.2
SD.5
QB2
QB1
QC4
QC3
QC2
QC1
Δx*/Δx
Δy*/Δy



Δx, Δy (μm)
0.1
1
10
100
σx*/Δx
σy*/Δx
σy*/Δy
QA1
QA2
QA3
QA4
SF
QN2
QN1
QN2.2
SF.5
QT1
QT2
QT3
SD
QM2
QM1
QM2.2
SD.5
QB2
QB1
QC4
QC3
QC2
QC1

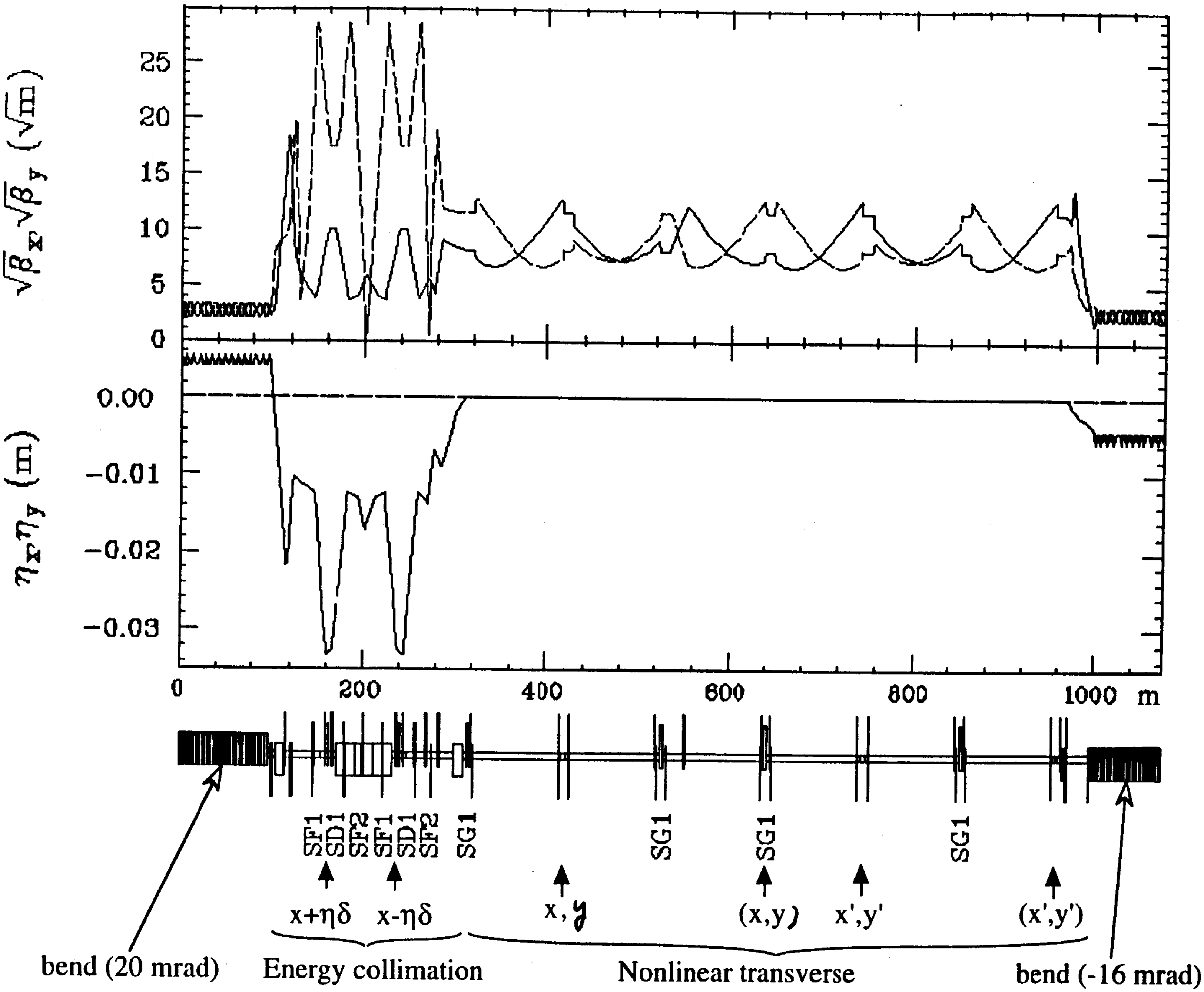
Collimation System Lattice

2 planes x 2 phases x 2 times

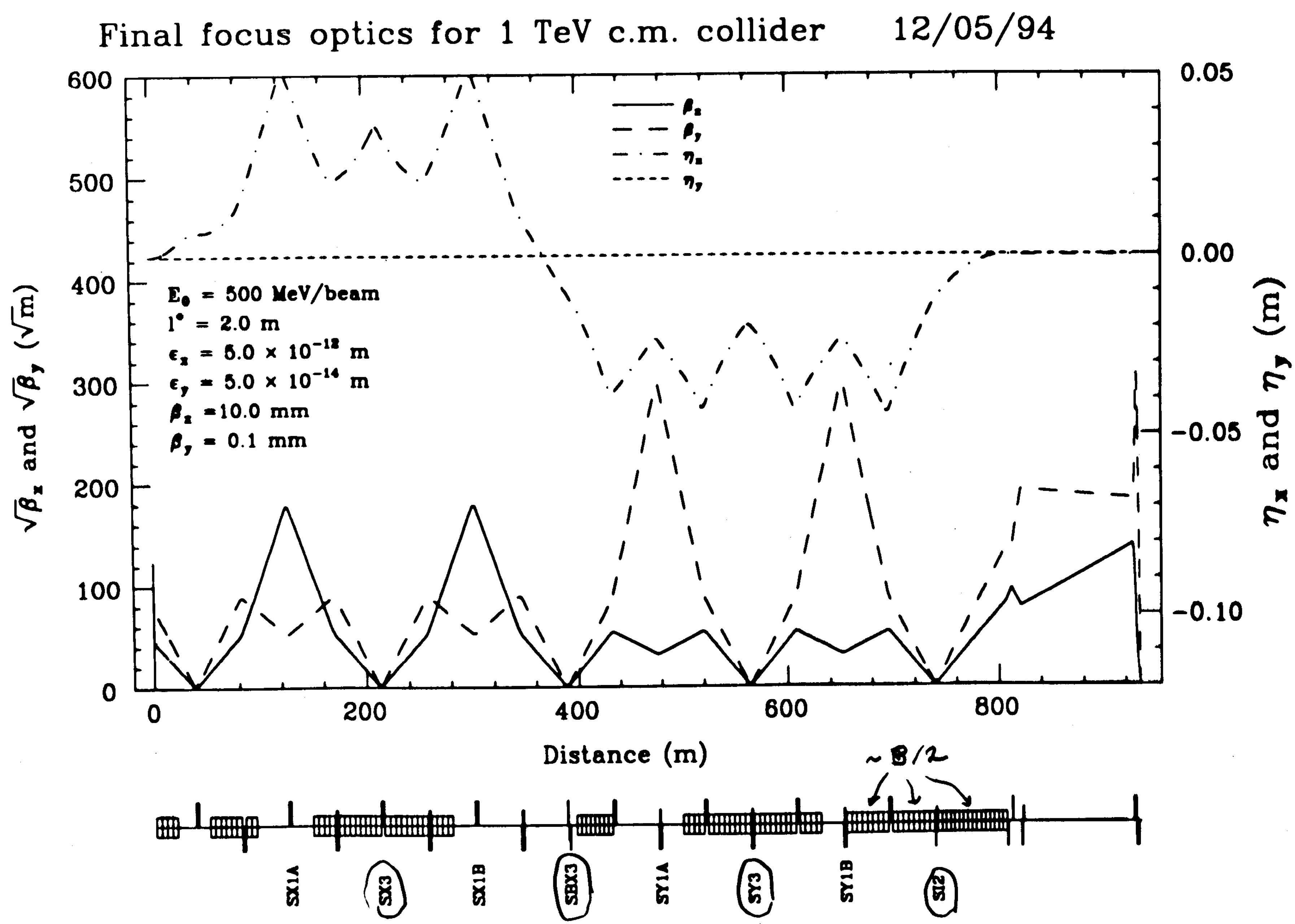


8-93

7553A24



$\sqrt{\beta_x}, \sqrt{\beta_y}$ ($\sqrt{m}$)
0
5
10
15
20
25
η_x, η_y (m)
0.00
−0.01
−0.02
−0.03
0
200
400
600
800
1000 m
SF1
SD1
SF2
SF1
SD1
SF2
SG1
SG1
SG1
SG1
$x+\eta\delta$
$x-\eta\delta$
x, y
(x,y)
x',y'
(x',y')
bend (20 mrad)
Energy collimation
Nonlinear transverse
bend (-16 mrad)

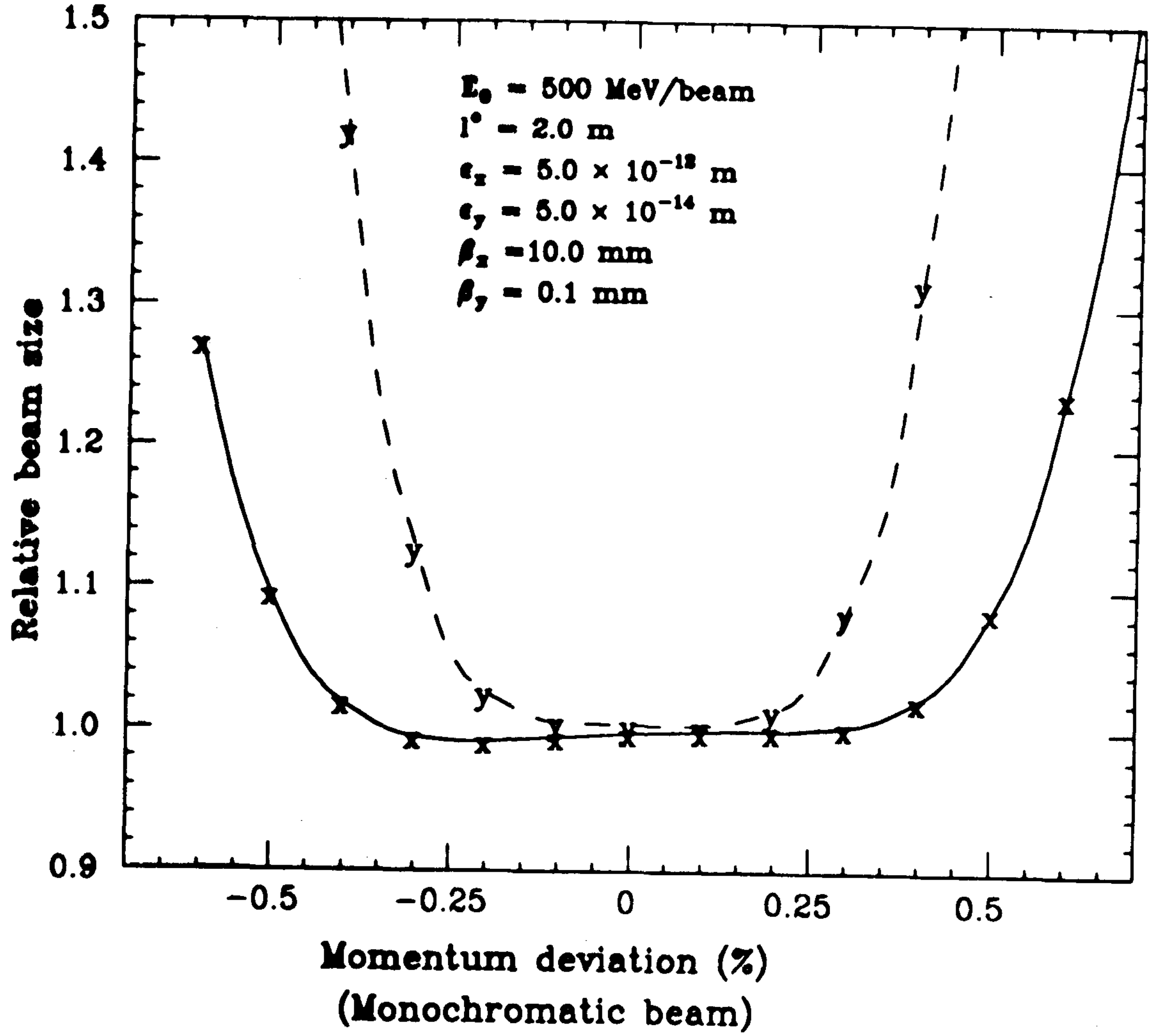


Final focus optics for 1 TeV c.m. collider 12/05/94
$\sqrt{\beta_x}$ and $\sqrt{\beta_y}$ ($\sqrt{m}$)
η_x and η_y (m)
Distance (m)
β_x
β_y
η_x
η_y
E_0 = 500 MeV/beam
l^* = 2.0 m
$\epsilon_x = 5.0 \times 10^{-12}$ m
$\epsilon_y = 5.0 \times 10^{-14}$ m
β_x =10.0 mm
β_y = 0.1 mm
0
100
200
300
400
500
600
0.05
0.00
−0.05
−0.10
0
200
400
600
800
~ B/2
SX1A
SX3
SX1B
SBX3
SY1A
SY3
SY1B
SI2

Band pass plot for 1 TeV c.m. collider 12/05/94

Without chromatic correction of telescopic sections

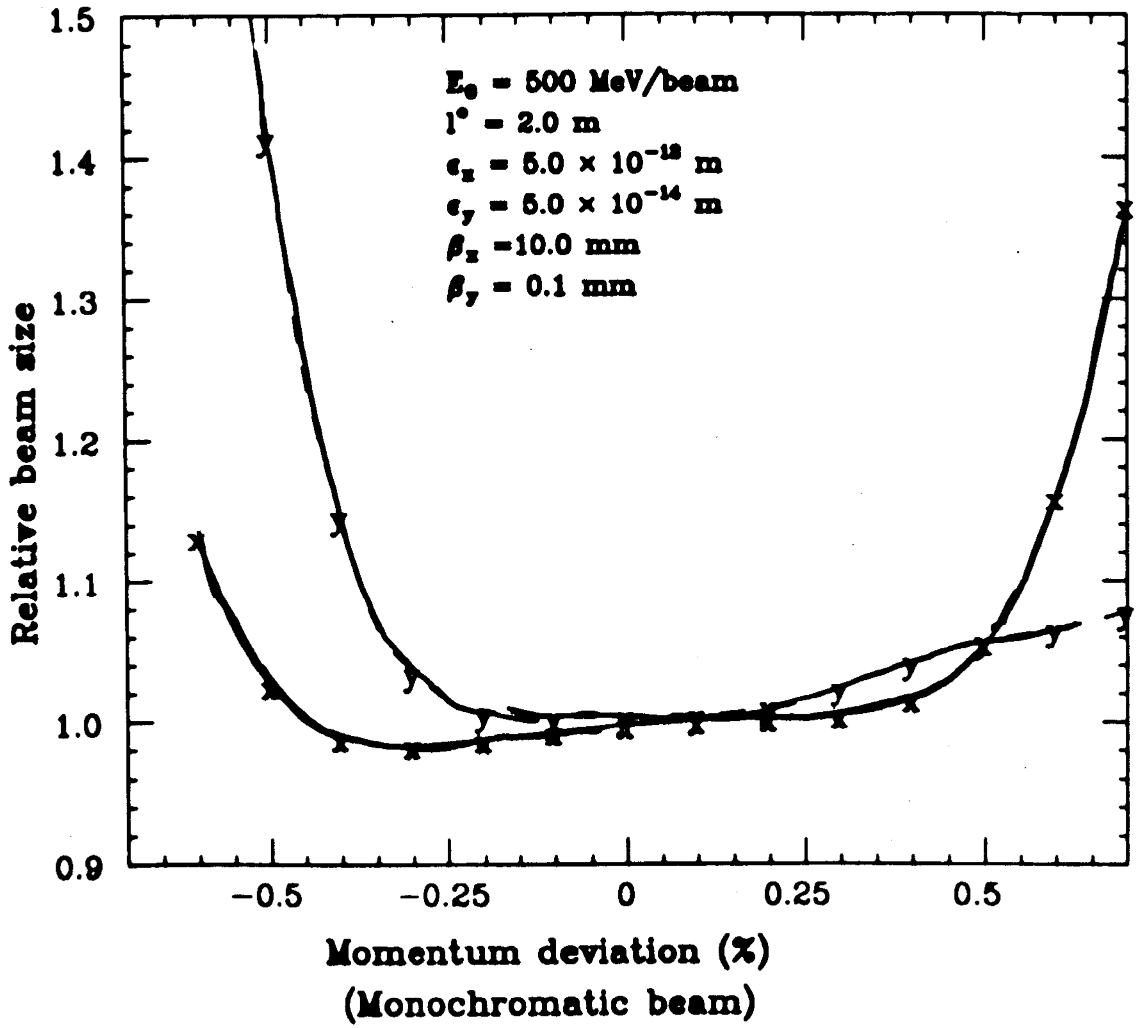
No synchrotrom excitation



Band pass plot for 1 TeV c.m. collider 12/05/94

With chromatic correction of all telescopic sections

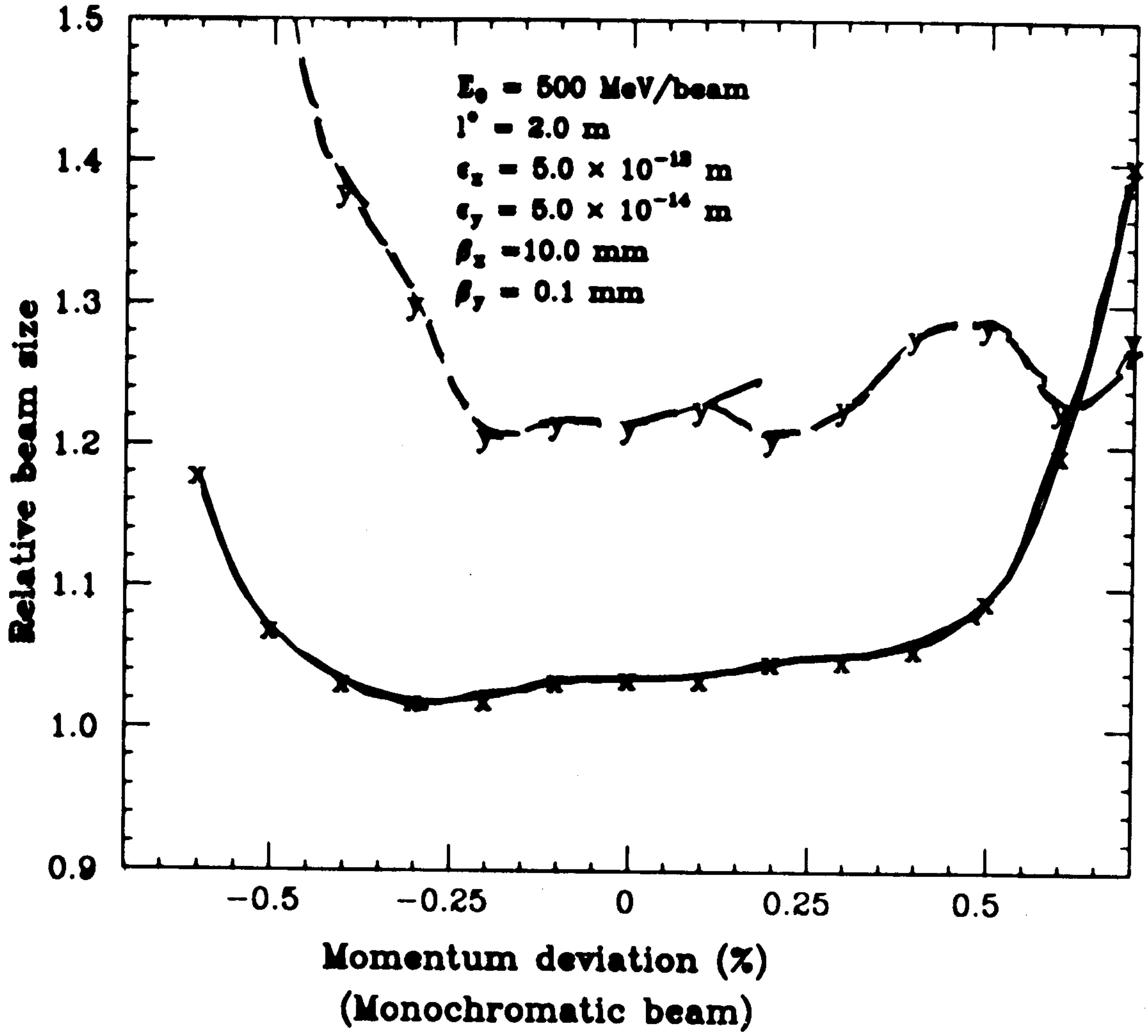
No synchrotrom excitation



Band pass plot for 1 TeV c.m. collider 12/05/94

With chromatic correction of all telescopic sections

Synchrotrom excitation in dipoles and quadrupoles

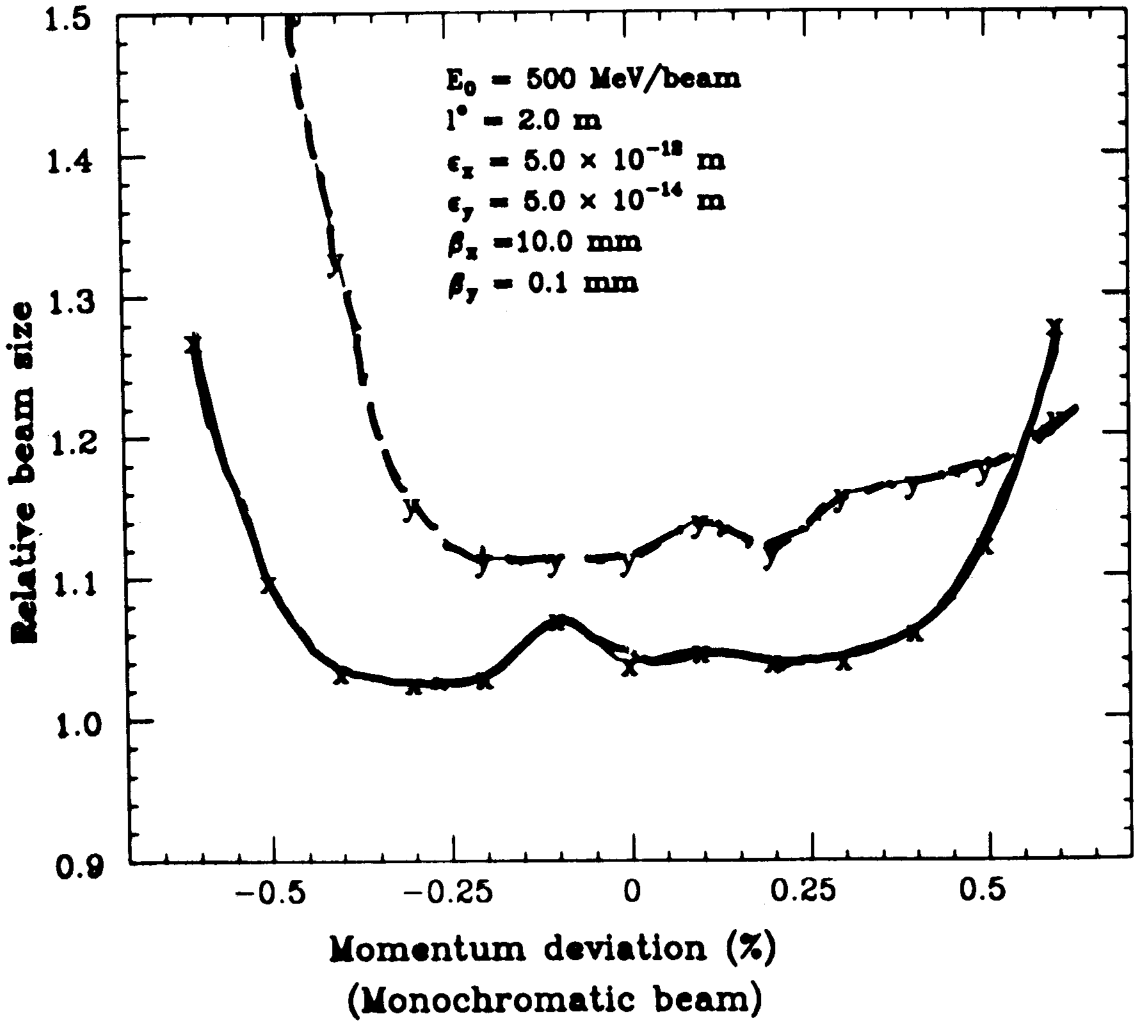


Band pass plot for 1 TeV c.m. collider 12/06/94

With chromatic correction of all telescopic sections

Synchrotrom excitation in dipoles and quadrupoles

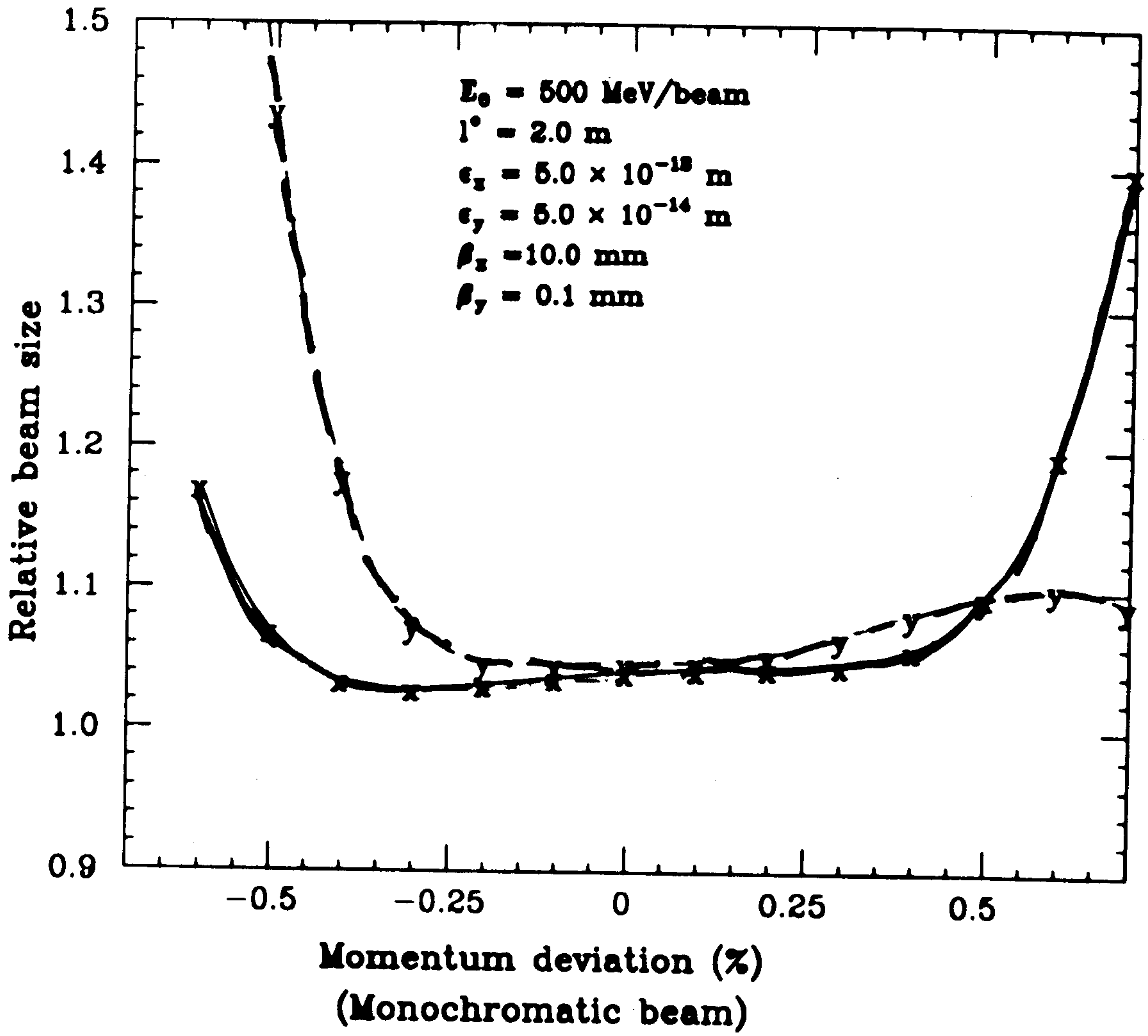
Q2 lengthened from 2.45 to 5.0 m



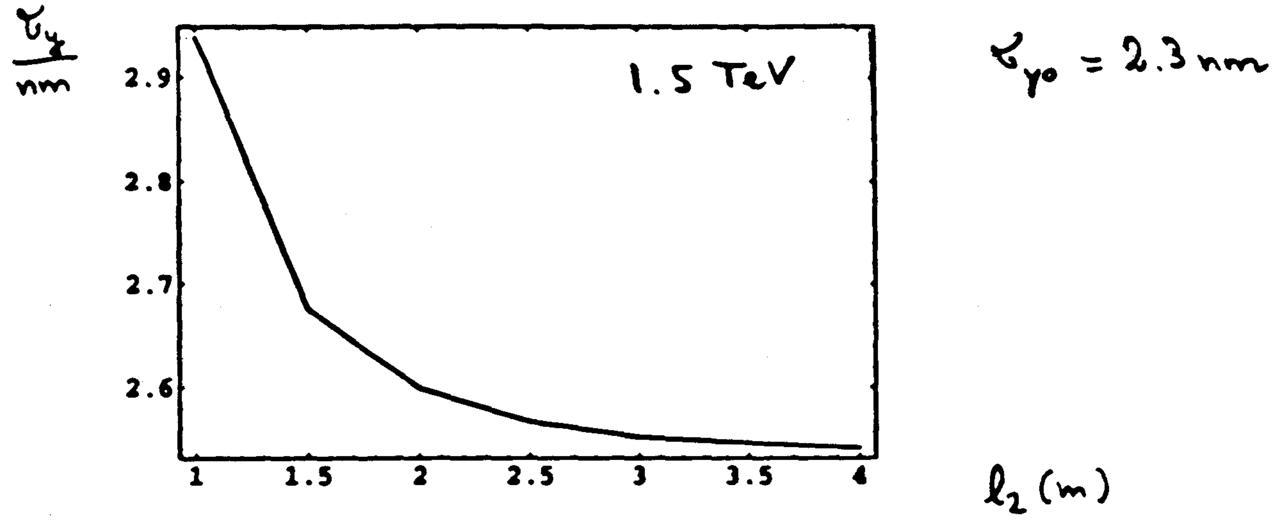
Band pass plot for 1 TeV c.m. collider 12/05/94

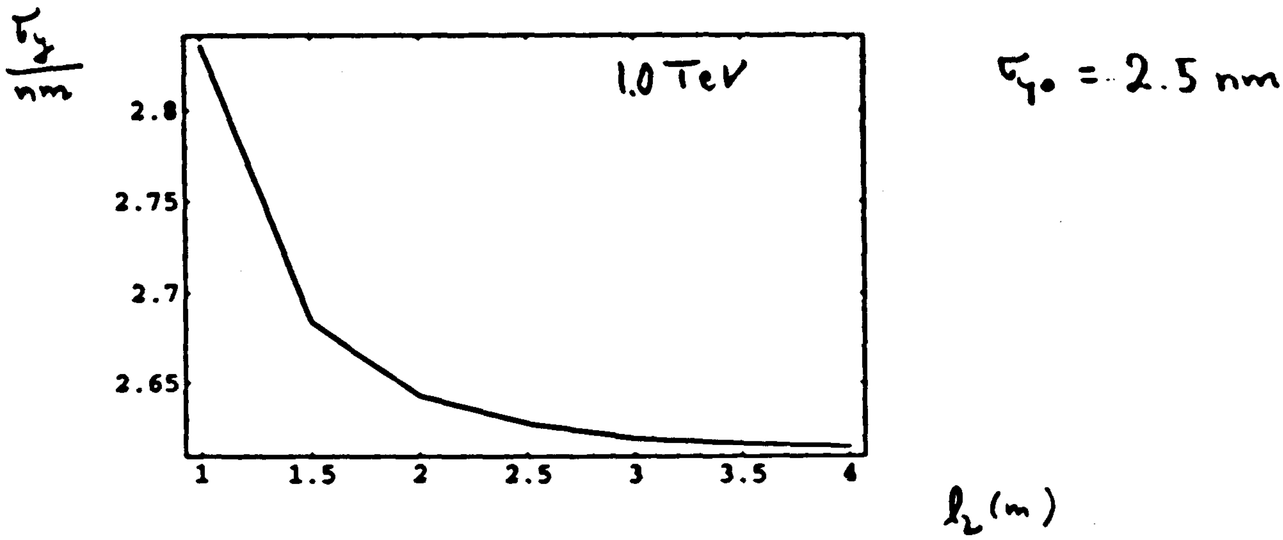
With chromatic correction of all telescopic sections

Synchrotrom excitation in dipoles



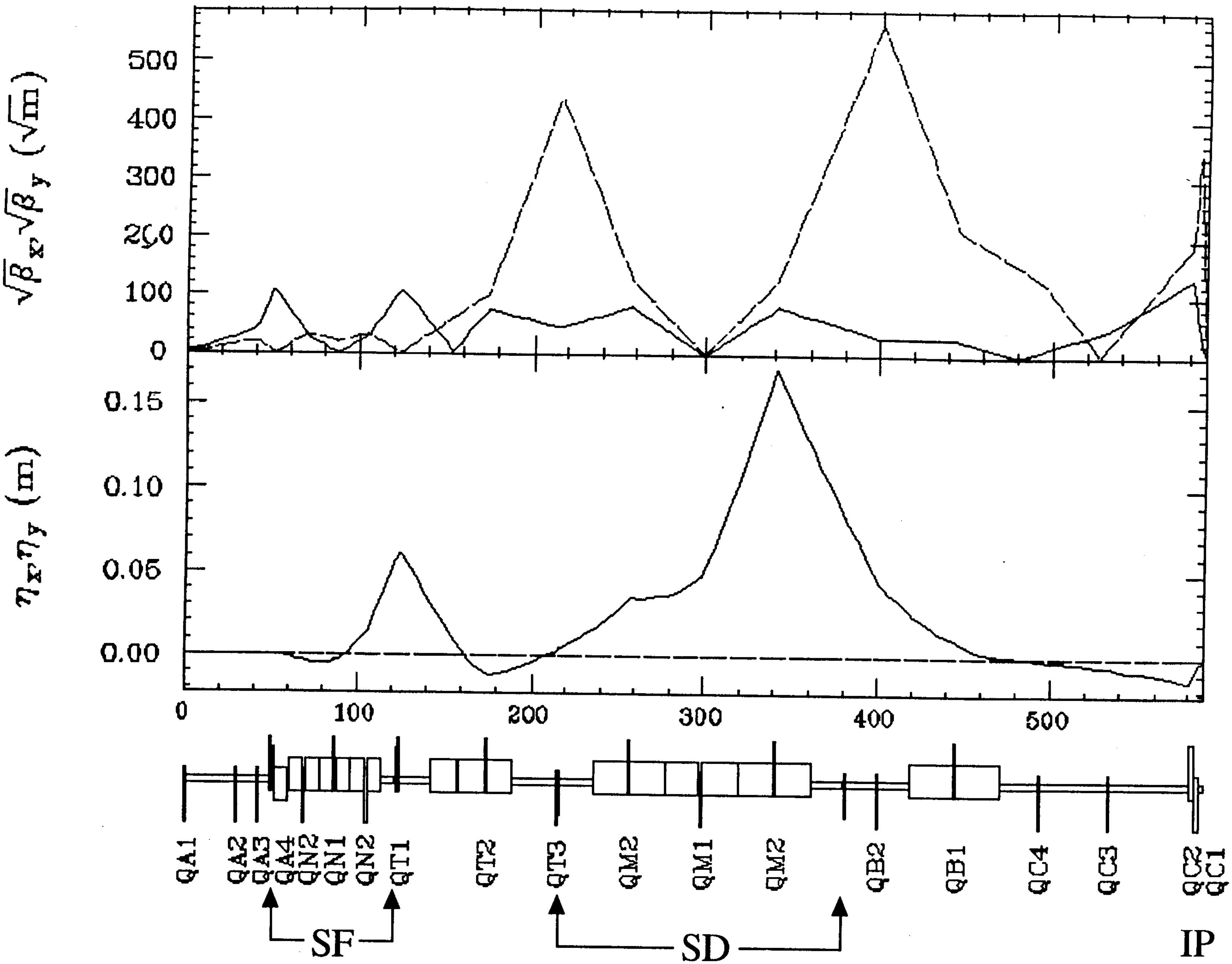
Synchrotron radiation in final doublet



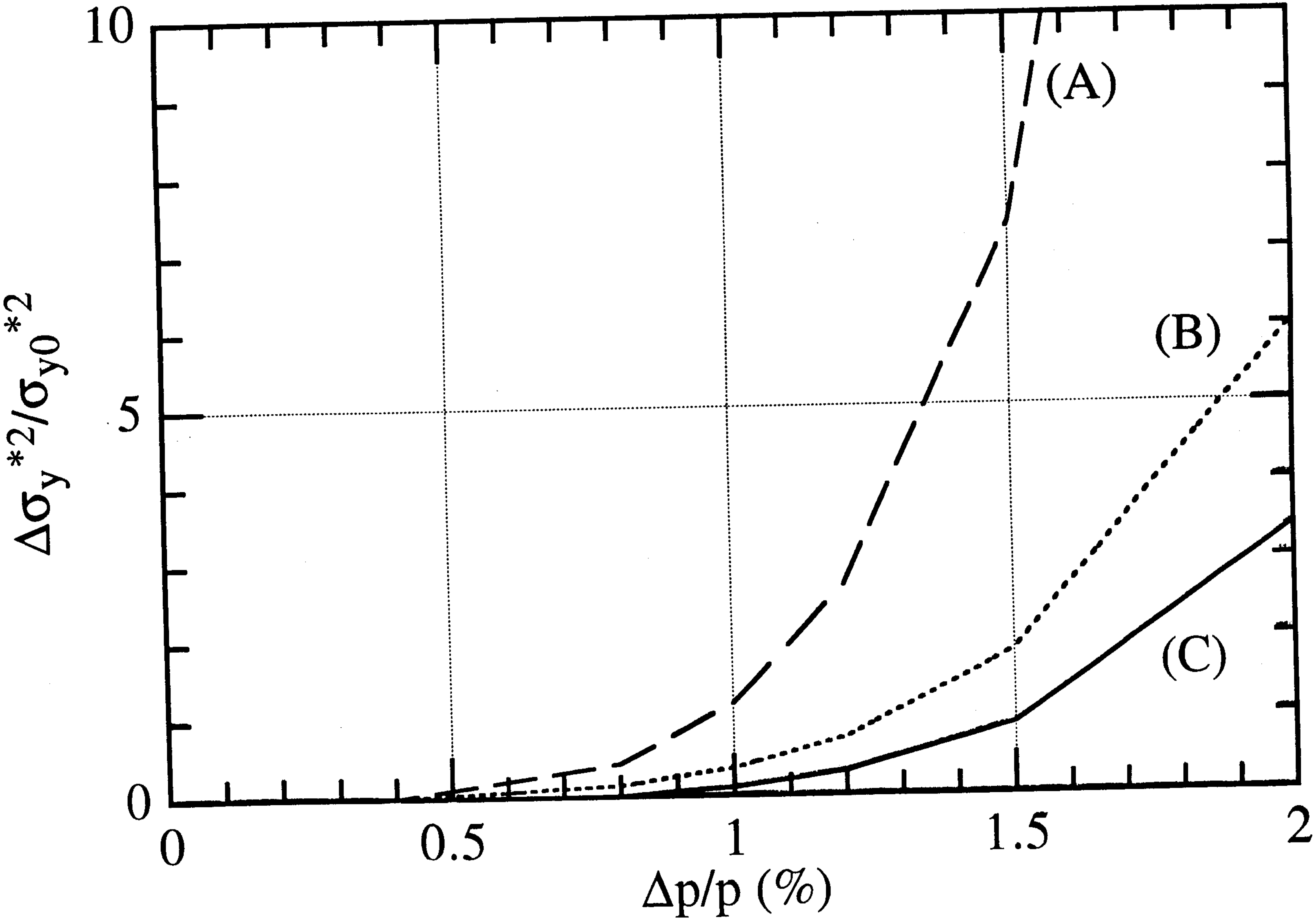


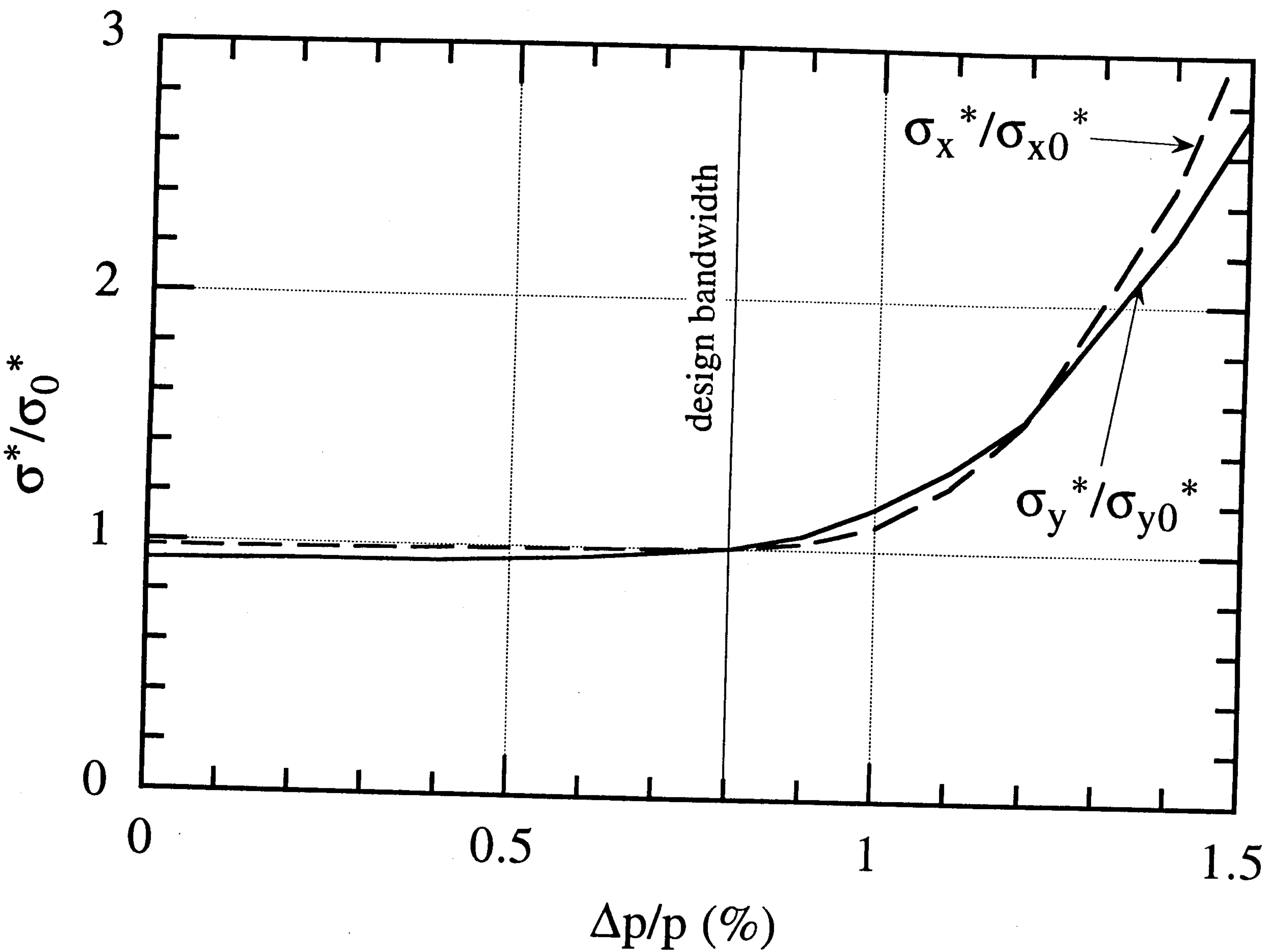
Vertical spot size as a function of Q_2-length (keeping integrated quadrupole field constant, ie. $K_2 \cdot l_2 =$ const.)

$\beta_x^* = 10$ mm

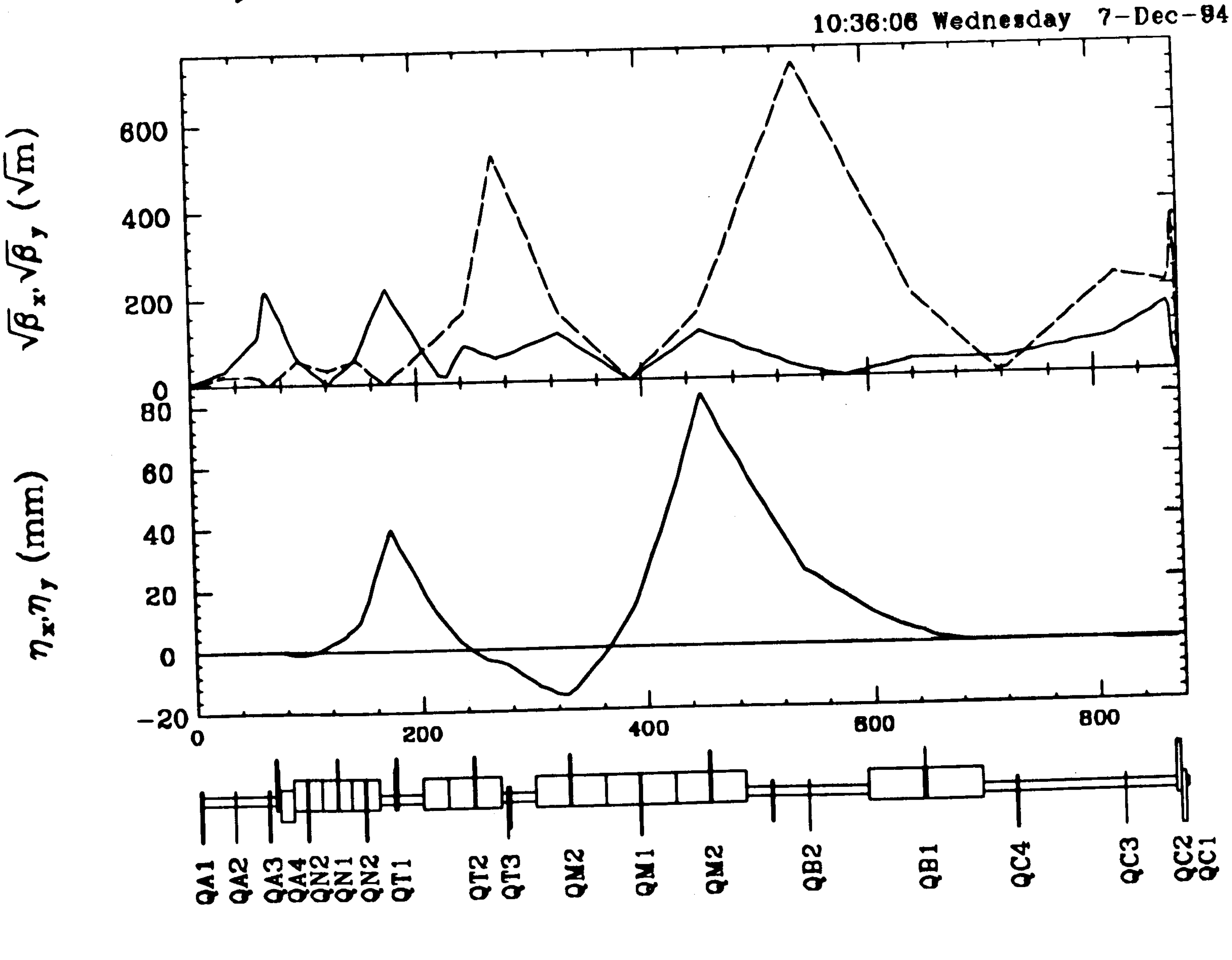


$\sqrt{\beta_x}, \sqrt{\beta_y}$ ($\sqrt{m}$)
500
400
300
200
100
0
η_x, η_y (m)
0.15
0.10
0.05
0.00
0
100
200
300
400
500
QA1
QA2
QA3
QA4
QN2
QN1
QN2
QT1
QT2
QT3
QM2
QM1
QM2
QB2
QB1
QC4
QC3
QC2
QC1
SF
SD
IP


10
5
0
0
0.5
1
1.5
2
(A)
(B)
(C)
$\Delta\sigma_y{}^{*2}/\sigma_{y0}{}^{*2}$
$\Delta p/p$ (%)


3
2
1
0
σ*/σ0*
design bandwidth
σx*/σx0*
σy*/σy0*
0
0.5
1
1.5
Δp/p (%)

$\beta_x^* = 10$ mm $\beta_y^* = 100$ μm $\Delta p/p < 1.0$ % (750 GeV)



NLC IP Region Working Parameters

Parameter	0.5 TeV	0.5 TeV*	1.0 TeV	1.5 TeV	Comments
L_o	0.5	0.8	1.06	1.07	Luminosity w/o Pinch
L	0.7	1.0	1.4	1.6	Luminosity w/ Pinch
$n_B \times N$	90 .65 10^{10}	90 .78 10^{10}	75 1.1 10^{10}	75 1.1 10^{10}	
σ_x	320 nm		360 nm	360 nm	Variable
$\sigma_{y,o}$	3.2 nm		2.3 nm	2.3 nm	
$\sigma_{y,Lat}$			2.4	2.6	w FDSR + LAT w/o SR.
ε_x	10^{-11}		1/2 10^{-11}	1/3 10^{-11}	$\gamma \varepsilon_x = 5\ 10^{-6}$ m-rad
ε_y	10^{-13}		1/2 10^{-13}	1/3 10^{-13}	$\gamma \varepsilon_y = 5\ 10^{-8}$ m-rad
β_x	10 mm		25 mm	37 mm	
β_y	100 μm		100 μm	150 μm	
$\sigma_{x',y'}$	30, 30 μrad		14, 23 μrad	10, 15 μrad	IP Divergent Angle
σ_z	100 μm		100 μm	100 μm	Bunch Length
θ_d	3.2 mr		3.6 mr	3.6 mr	Bunch Diagonal Angle
$\pm \Delta_{box}$	$< \pm 4\ 10^{-3}$		$< \pm 4\ 10^{-3}$	$< \pm 4\ 10^{-3}$	Square Energy Profile Width
$D_{x,y}$	.07, 7.3		.04, 8.8	.03, 5.2	Disruption Parameter
H_d	1.3		1.4	1.5	Enhancement from Pinch
Θ_D	.25 mr		.17 mr		Max. Disrupt. Angle @ Beam Energy
Υ	.09	.11	.28	.42	Upsilon Parameter
δ_B	.015	.02	.07	.08	Mean Energy Loss to Beamstrahl. γs
n_γ	.8	1.0	1.1	1.1	# of Photons per Electron
$L_1/L_{.995}/L_{.95}$	.48/ /	.40/ /	.37/.5/.67	.38/.5/.66	L_t=Lum. fract'n w/ c.m. E≥ tE_o
N_{Had}	.04	.07	0.18	0.23	# of Hadronic Events / Cross.
N_{jet5}	.001		0.014	0.03	# of Mini-Jets per Crossing

w/ 20% coating.

$3 \cdot 10^{-6} \rightarrow 5 \cdot 10^{-6}$ 20+20+20 = 60%

t LINAC → IP.

Tolerance Accounting & Specification

Needed for comparisons of alternative systems

1. Description of tolerance:

if motion, then relative to what

if stability, then relevant time scale

2. Basis of tolerance

What is basic impact(s).

What is total impact permitted, all sources.
(total allotment)

What of total, is alloted to this source?
(the budget)

3. Contingency

What is probability of meeting goal?

Relative to this uncertainty,
what is judicious margin for possiblly larger impact?

Important not to get carried away.

A rough first pass already very helpful.

P. Chen

P. Chen
Dec. 7, 1994

Beam-Beam Effects in NLC 1.0 TeV and 1.5 TeV

Linear Colliders	NLC 1.0 TeV			NLC 1.5 TeV		
$\mathcal{L}[10^{34}\text{cm}^{-2}\text{sec}^{-1}]$	1.05			1.05		
f_{rep}[Hz]	120			120		
n_b	75			75		
$\mathcal{L}_1[10^{-3}\text{nb}^{-1}]$	1.17			1.17		
$N[10^{10}]$	1.1	1.56	1.31	1.1	1.56	1.31
σ_x/σ_y[nm]	360/2.3	360/4.6	254.56/4.6	360/2.3	360/4.6	254.56/4.6
$\sigma_z[\mu m]$	100	100	100	100	100	100
β_x^*/β_y^*[mm]	25/0.1	25/0.1	25/0.1	37/0.15	37/0.15	37/0.15
D_x/D_y	0.049/7.60	0.068/5.36	0.114/6.33	0.032/5.07	0.046/3.57	0.076/4.22
A_x/A_y	0.004/1.0	0.004/1.0	0.004/1.0	0.003/0.667	0.003/0.667	0.003/0.667
H_D	1.29(1.35)	1.25(1.29)	1.29(1.32)	1.47(1.49)	1.41(1.43)	1.46(1.46)
$\bar{\mathcal{L}}[10^{34}\text{cm}^{-2}\text{sec}^{-1}]$	1.35	1.31	1.35	1.54	1.49	1.53
$\bar{\mathcal{L}}_1[10^{-3}\text{nb}^{-1}]$	(1.57)	(1.51)	(1.54)	(1.73)	(1.67)	(1.70)
Υ_0	(0.27)	(0.38)	(0.45)	(0.40)	(0.57)	(0.67)
Υ	(0.27)	(0.38)	(0.45)	(0.40)	(0.57)	(0.68)
δ_B	0.07(0.07)	0.11(0.12)	0.14(0.16)	0.08(0.09)	0.13(0.15)	0.15(0.18)
n_γ	1.2(1.1)	1.6(1.5)	1.9(1.8)	1.1(1.1)	1.5(1.4)	1.8(1.7)
1.0 $\mathcal{L}_{100}/\bar{\mathcal{L}}$	(0.37)	(0.27)	(0.23)	(0.38)	(0.29)	(0.24)
.995 $\mathcal{L}_{99}/\bar{\mathcal{L}}$	(0.50)	(0.38)	(0.33)	(0.50)	(0.39)	(0.34)
.95 $\mathcal{L}_{90}/\bar{\mathcal{L}}$	(0.67)	(0.55)	(0.49)	(0.66)	(0.54)	(0.48)
$N_{pair}[p_\perp \geq 20\text{MeV}]$	(7.04)	(7.92)	(8.84)	(7.04)	(7.75)	(8.47)
N_{had}	(0.18)	(0.25)	(0.30)	(0.23)	(0.30)	(0.36)
N_{jet5}	(0.014)	(0.023)	(0.031)	(0.031)	(0.048)	(0.062)

↑ E/E_0

* The quantities in (...) are from theoretical calculations.

** The quantities not in (...) are either by definition or from ABEL simulations.

No N^2 effect! (but > N)

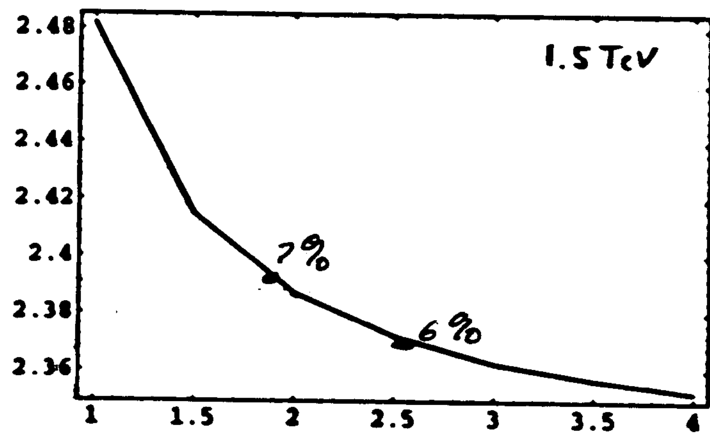
18% eff reduction of $\mathcal{L}$ (?)

F. Zimmermann —

Synchrotron radiation in final doublet

$\sigma_{y,lin} = 2.236$

σ_y / nm

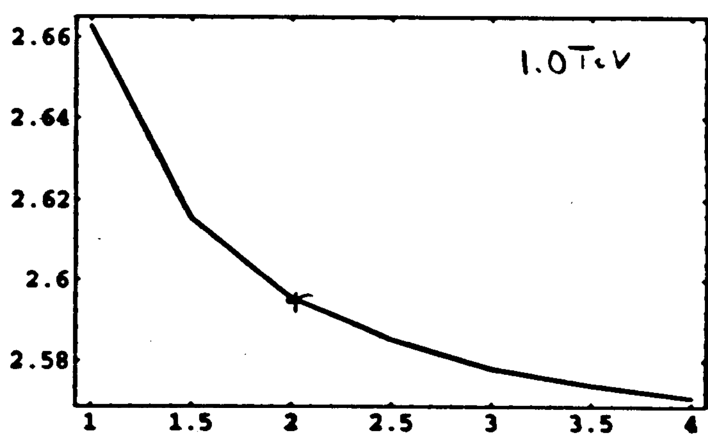


$\sigma_{y0} = 2.23$ nm ↑ w/ LATTICE w/o SR

← w/ FDSR

l_2 / 2.08 m

$\beta_x = 37$ mm



$\sigma_{y0} = 2.48$ nm ↑ w/ LATTICE w/o SR

← w/ FDSR

l_2 / 2.46 m

$K_2 \cdot l_2 = \text{const}$

$\beta_x^* = 25$ mm

EXPERIMENTATION SUBGROUP REPORT

12/9/94

T. Markiewicz
T. Matsui

w/ thanks to
Tim Barklow

Detector strategies are roughly independent of machine design

with exception of backgrounds as discussed in Final Focus working group

Here we take this opportunity to discuss physics driven machine requirements for

- Energy
- Luminosity
- Energy Spread
- Polarization

USE as guide:

DRAFT of Technical Review Committee report for Int'l Collab. for R+D Toward TeV Scale L.C.

OUTLINE

Draft #0, 19 September 1994
Draft #1, 28 October 1994

0.1 Experimentation

R. Settles[1] (Chairman), T. Markiewicz[2] (Deputy Chairman), S. Bertolucci,[3] S. Kawabata,[4] D. Miller,[5] R. Orava,[6] F. Richard,[7] T. Tauchi,[8] and A. Wagner[9]

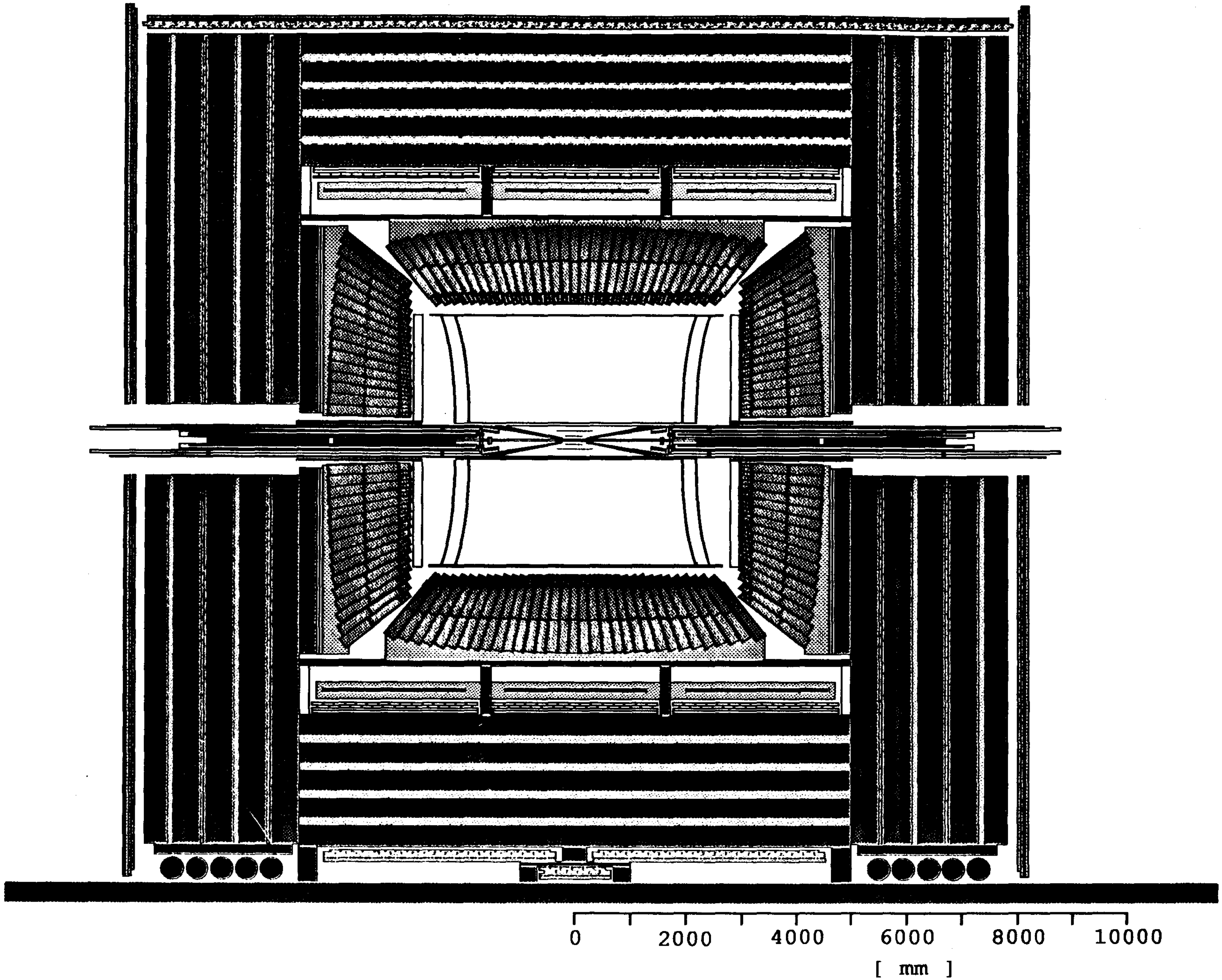

0
2000
4000
6000
8000
10000
[mm]

Table 3: Examples of detector performances used in physics studies up to now.

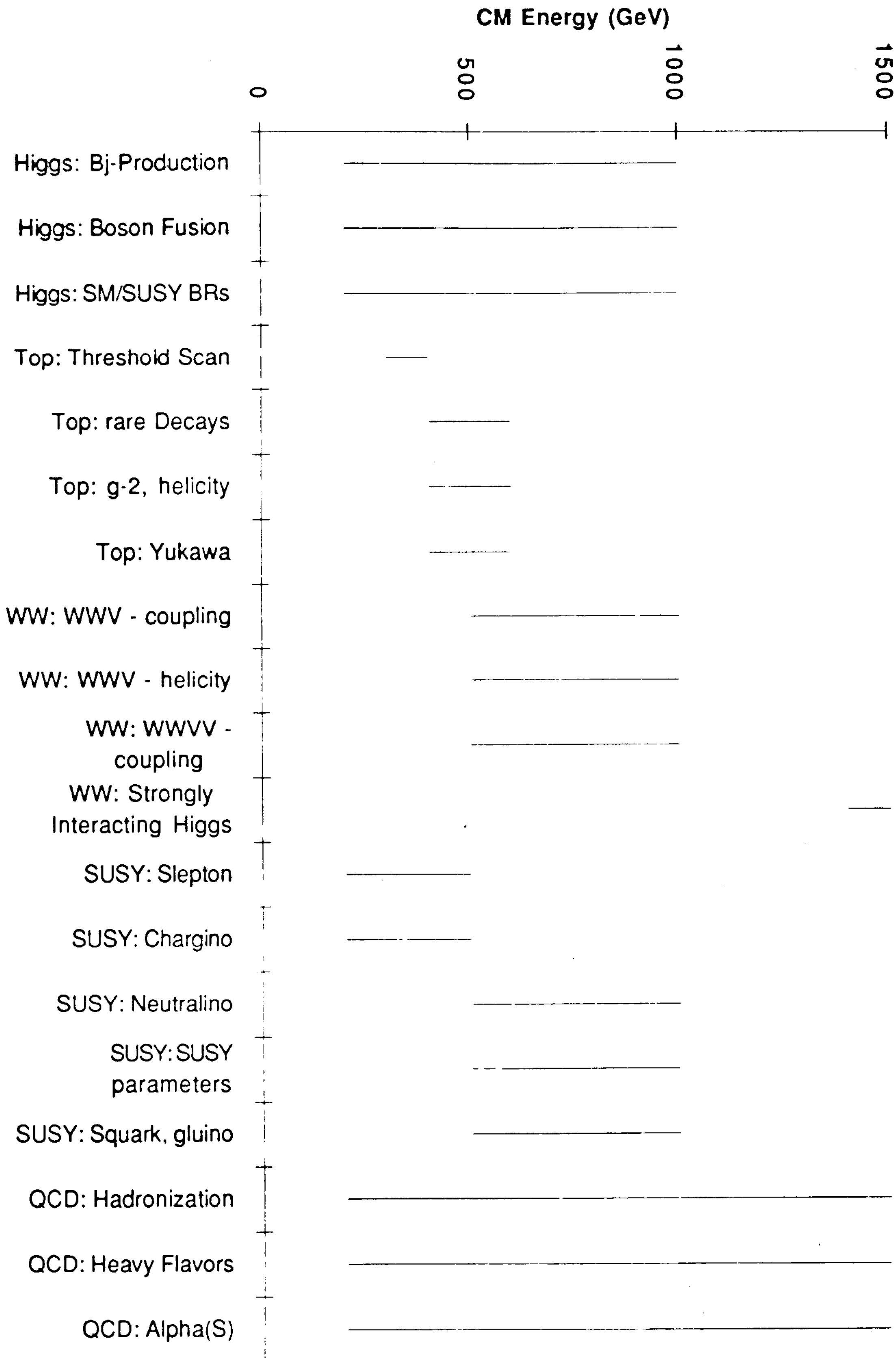
	ee500 1991	ee500 Typical	LEP/SLC-Style	1000GeV Detector	JLC Detector	
Tracking $\frac{\delta p_t}{p_t^2} = C$ $C =$	5-100	10	8	2	1	$\times 10^{-4}\mathrm{GeV}^{-1}$
E-M Calorimeter $\frac{\delta E}{\sqrt{E}} =$	0.02-0.15	0.1	0.2	0.1	0.15	$\sqrt{\mathrm{GeV}}$
Hadronic Calorimeter $\frac{\delta E}{\sqrt{E}} =$	0.3-1.0	0.8	0.9	0.65	0.40	$\sqrt{\mathrm{GeV}}$
Energy Flow $\frac{\delta E}{\sqrt{E}} =$	0.3-0.8	0.5	0.65	0.4	0.3	$\sqrt{\mathrm{GeV}}$
Vertexing $\delta(IP) = A \oplus \frac{B}{p}$ $A =$	5-20	10	25	10	11	μm
$B =$	50-100	50	100	50	28	μmGeV
Hermetic coverage $\lvert\cos\theta\rvert <$	0.70-0.99	0.95	0.96	0.98	0.98	

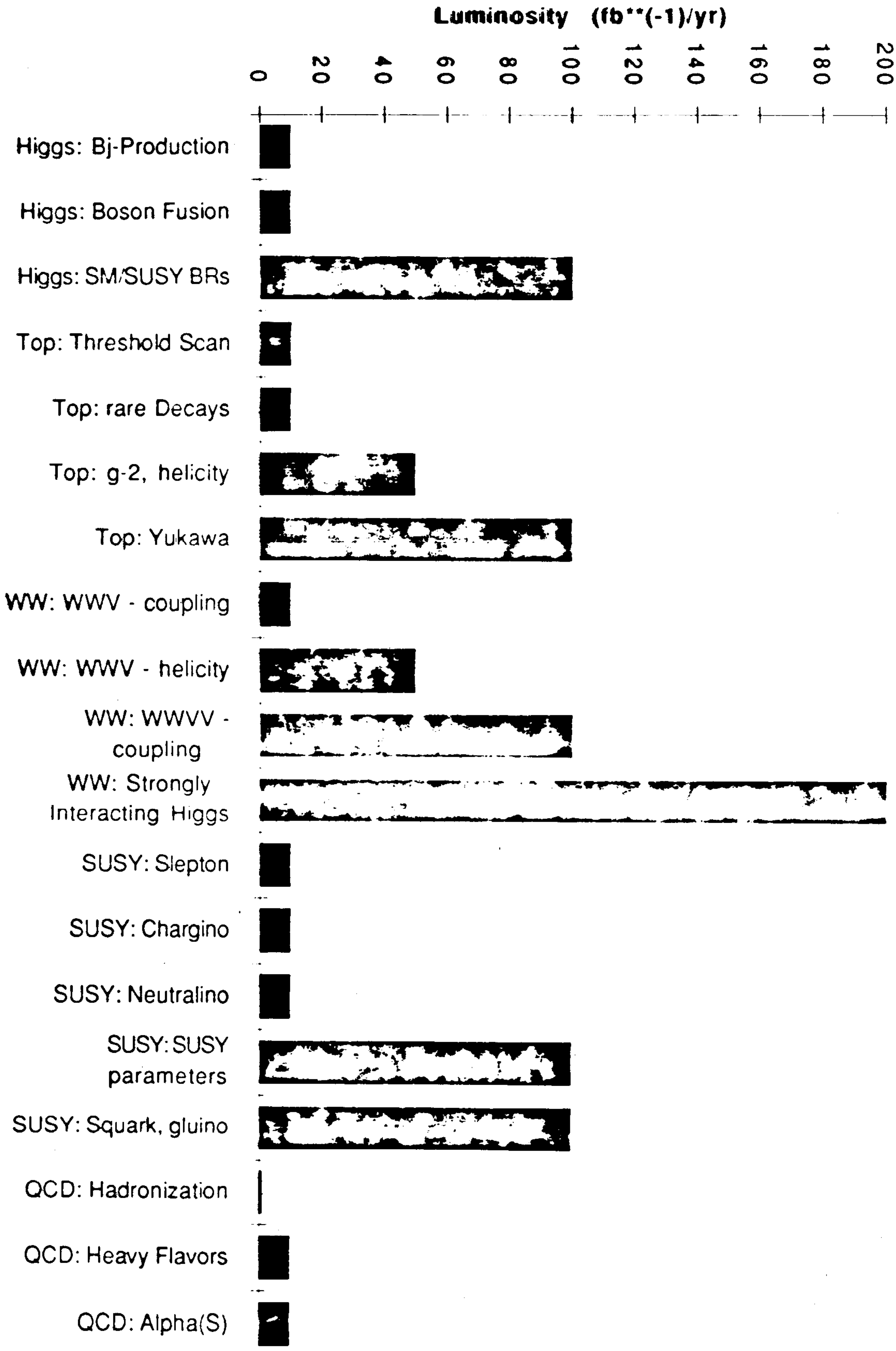
Table 1: **Main** physics issues and the corresponding performance needed for machine and detector aspects. Key: from "-" not important, to "★★★" very important.

PHYSICS	MACHINE				DETECTOR						
	$\int \mathcal{L}dt$ fb^{-1}/y	$\sqrt{s}$ TeV	Narrow $\mathcal{L}(\sqrt{s})^a$	Pol. beams	Hermeticity	Tracking	Calorimetry	3-Dim. Granul.	Lepton I.D.	Vertex Tag	pi/K I.D.
•HIGGS											
Bj-prod.	1-10	.2									
Boson fusion	10	to	★[b]	-	★★★	★★	★★	★★	★★	★★★	★
SM/Susy B.R.	100	1									
•TOP											
Thr. scan	10	$\sim$.35	★★★	★★	★★★	★★	★★	★★	★★	★★★	★
Rare decays	10	.4									
g-2,hel.	50	to		★★	★★★	★★	★★	★★	★★	★★★	★★
Yukawa	100	$\sim$.6									
•WW											
WWV-coupl.	10	$\sim$.5									
WWV-hel.	50	to	★★★	★★	★★★	★★	★★	★★	★★	-	-
WWVV-coupl.	100	1									
Str.-int.Higgs	200	$\sim$1.5			★★★	★★★	★★	★★★	★★	-	-
•SUSY											
Slepton	10	.2									
Chargino	10	to									
Neutralino	10	.5	-	★[c]	★★★	★★	★★	★	★★	-	-
Susy param.	100	to									
Squark,gluino	100	1									
•QCD											
Hadronization	1	For									
Heavy flavors	10	all	-	-	★★	★★	★★	★	★	★★	★
$\alpha_s(s)$	10	$\sqrt{s}$									
•$\gamma\gamma$											
$F_2^\gamma(x,Q^2)$	10		★★	-	★★★	★★	★★	★★	★★	★	★
Flavors	10										
•NEW PHEN.	200	2			★★★	★★★	★★	★★★	★★	★★	
OVERALL			★★★	★★[c]	★★★	★★★	★★	★★★	★★	★★★	★★
$\mathcal{L}(\sqrt{s})$ Detector					★★	★★★	★★	★★	★★	-	-

[a] Here the ★'s indicate how important it is to have a narrow and well-measured c.m.s. energy spread arising from machine and beamstrahlung effects. The detector for mapping the luminosity as a function of $\sqrt{s}$ to high precision is treated in the last row of the table.
[b] If M_{higgs} <600 GeV is discovered, this should be upgraded to ★★ or more.
[c] If supersymmetry is discovered, this should be upgraded to ★★★.

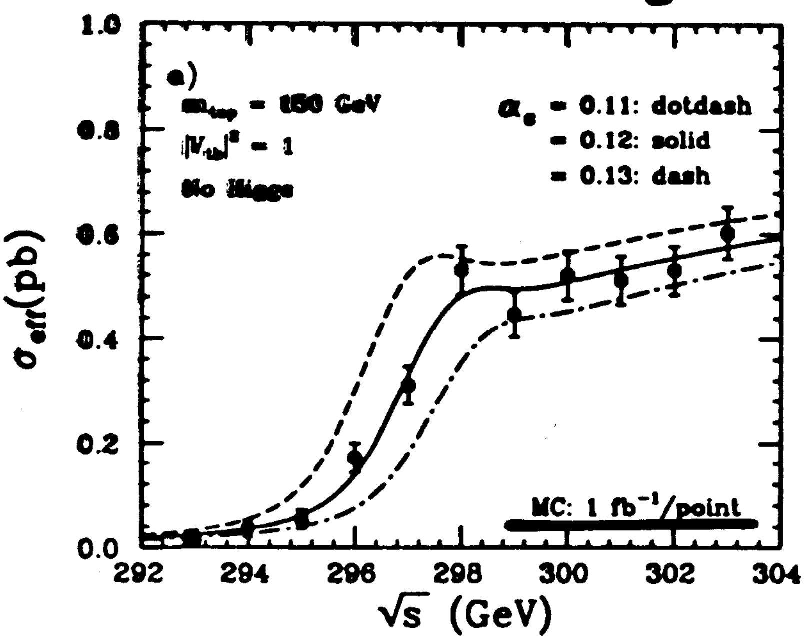
2

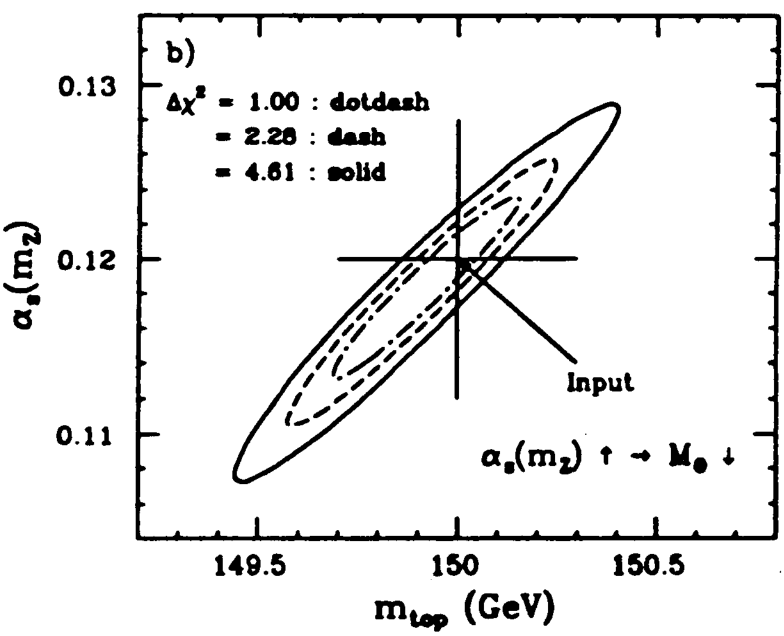

CM Energy (GeV)
0
500
1000
1500
Higgs: Bj-Production
Higgs: Boson Fusion
Higgs: SM/SUSY BRs
Top: Threshold Scan
Top: rare Decays
Top: g-2, helicity
Top: Yukawa
WW: WWV - coupling
WW: WWV - helicity
WW: WWVV - coupling
WW: Strongly Interacting Higgs
SUSY: Slepton
SUSY: Chargino
SUSY: Neutralino
SUSY: SUSY parameters
SUSY: Squark, gluino
QCD: Hadronization
QCD: Heavy Flavors
QCD: Alpha(S)

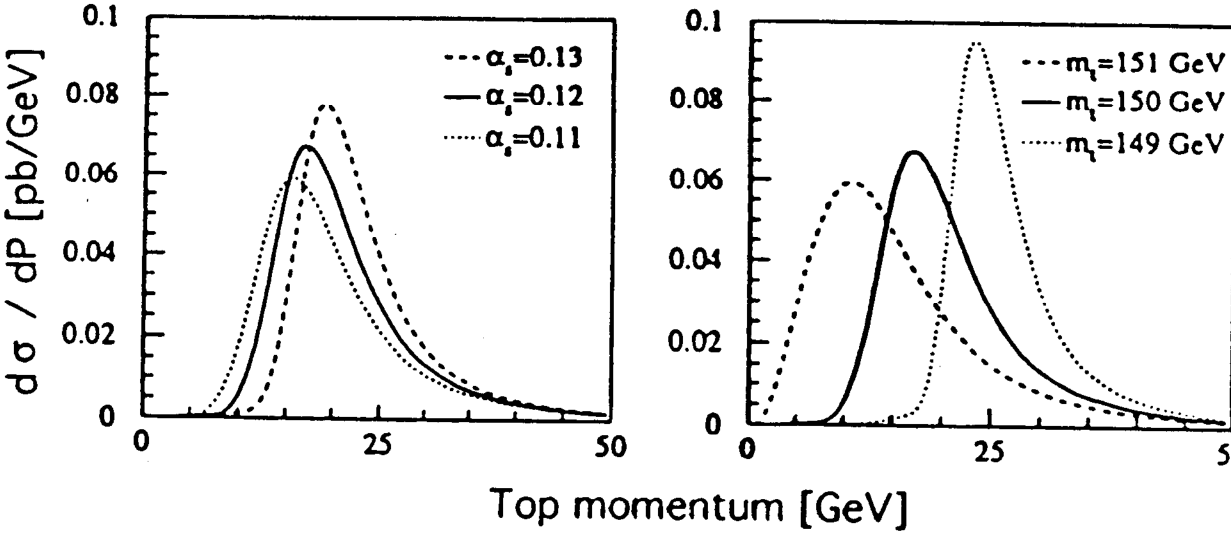

Luminosity (fb**(-1)/yr)
0
20
40
60
80
100
120
140
160
180
200
Higgs: Bj-Production
Higgs: Boson Fusion
Higgs: SM/SUSY BRs
Top: Threshold Scan
Top: rare Decays
Top: g-2, helicity
Top: Yukawa
WW: WWV - coupling
WW: WWV - helicity
WW: WWVV - coupling
WW: Strongly Interacting Higgs
SUSY: Slepton
SUSY: Chargino
SUSY: Neutralino
SUSY: SUSY parameters
SUSY: Squark, gluino
QCD: Hadronization
QCD: Heavy Flavors
QCD: Alpha(S)

Top mass ~ 10 fb^{-1}

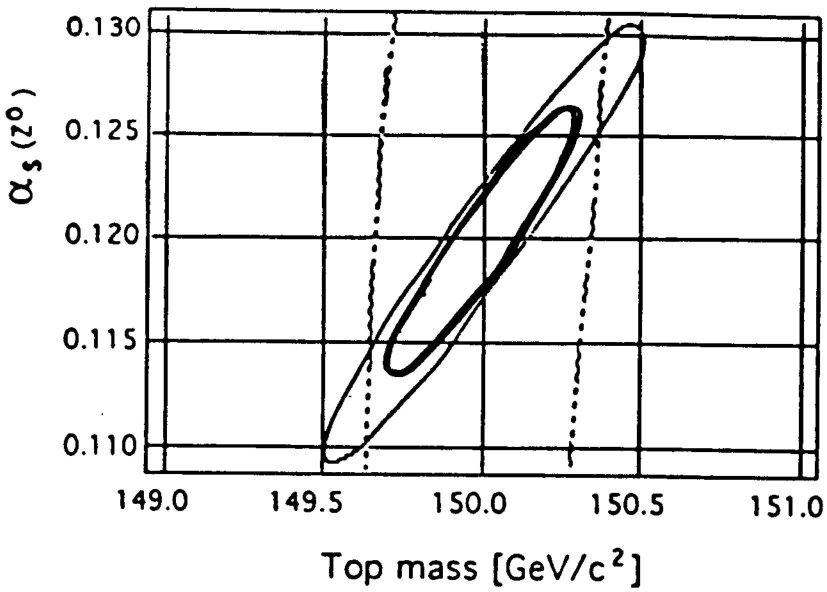
$\Delta E/E \sim 0.1\%$







COMBINED FIT TO P_{Top} and TOP EXCITATION CURVE



10 fb^{-1}

m_t [GeV/c^2]	Δm_t [MeV/c^2]	$\Delta\alpha_S$
120	130	0.005
150	300	0.006
180	520	0.009

MEASURING LUMINOSITY DIST.

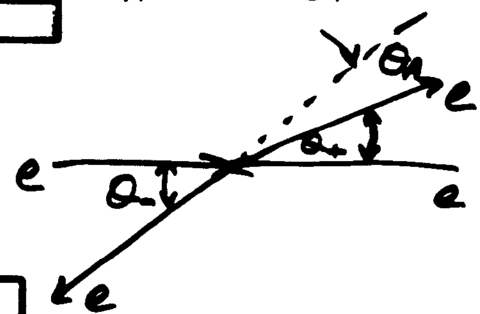
(MILLER + FRARY, 11/7/91)

OLD NLC — OLD DESY — OLD TESLA

Table 1: Parameters assumed for various linac designs.

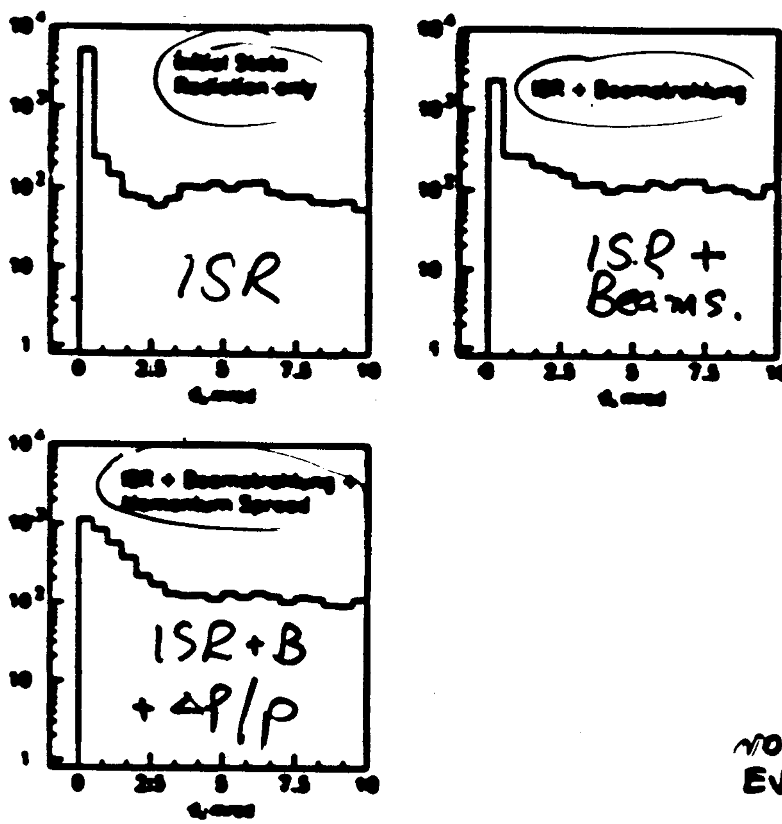
Parameter	Beam 1[6]	Beam 2[7]	Beam 3[8]
Luminosity (10^{33} cm^{-2}s^{-1})	1.4	4.4	2.1
Fraction of events with $\Delta p < 0.01 E_0$ from Beamstrahlung.	0.45	0.26	0.64
Spread in E_0 %.	0.17	0.57	0.1

BHABHA ACOLLINEARITY



$$\theta_A = \frac{\Delta p}{p} \sin\theta$$

measured to 1 mrad



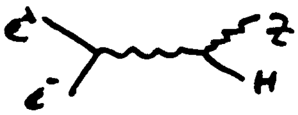
NOT ENOUGH EVENTS IN PEAK TO DE-CONVOLVE $dL/d\sqrt{s}$

Table 2: Fraction of events with $\theta_A < 1$ mrad. $300 < \theta < 800$ mrad.

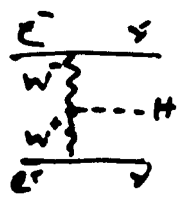
	Beam 1[6]	Beam 2[7]	Beam 3[8]
Initial state radiation.	0.56	0.56	0.56
ISR + Beamstrahlung.	0.24	0.13	0.25
ISR + Beamstrahlung + beam spread.	0.18	0.05	0.22

S.M. HIGGS SEARCH

$e^+e^- \to ZH$ $\left\{ \begin{array}{l} Z \to q\bar{q},\ H \to q\bar{q} \\ Z \to q\bar{q},\ H \to \tau^+\tau^- \\ Z \to \ell^+\ell^-,\ H \to q\bar{q} \end{array} \right.$



$e^+e^- \to \nu\nu H$



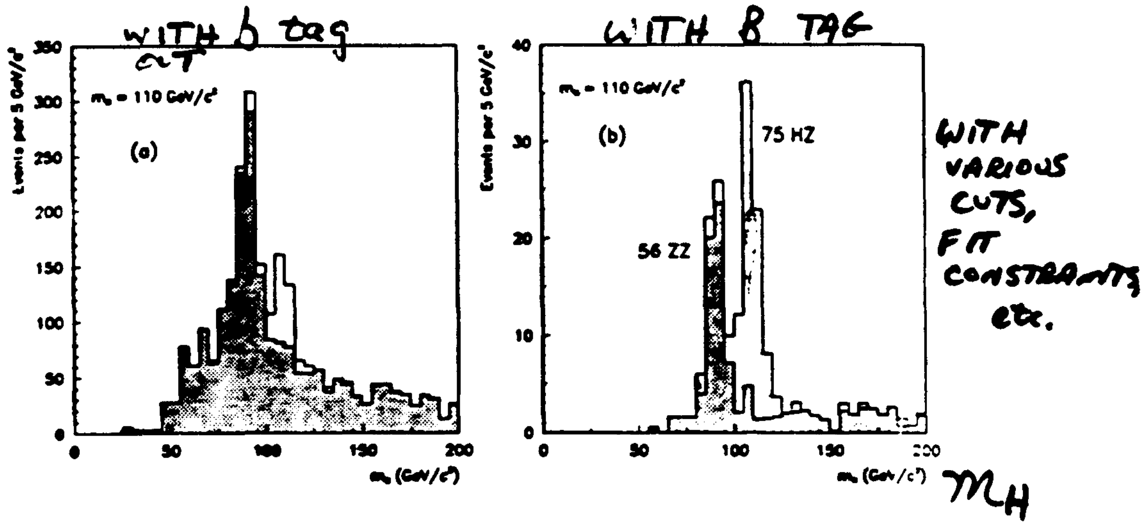


Figure 3: Distribution of the recomputed mass of the Higgs pair in the four-jet topology (a) before and (b) after b-tagging, for all known backgrounds (shaded histogram) and for the signal ($m_H = 110$ GeV/c^2).

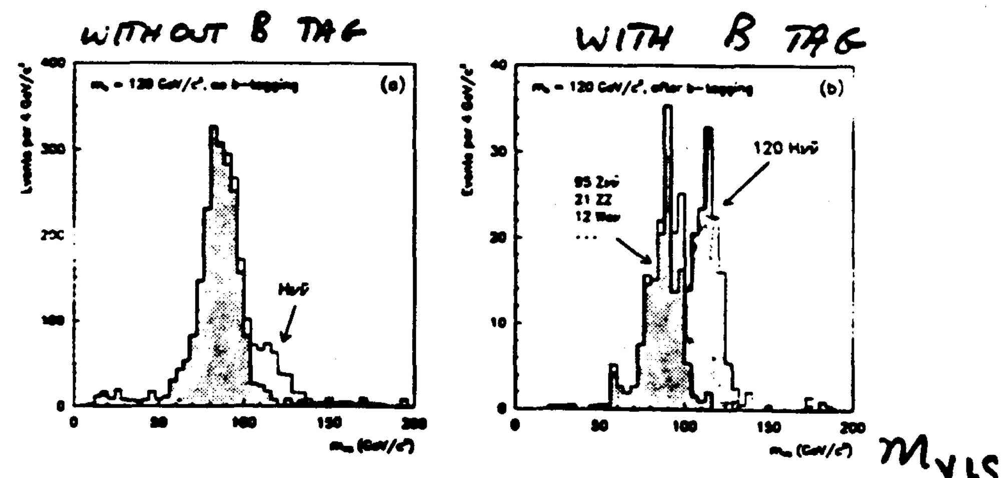
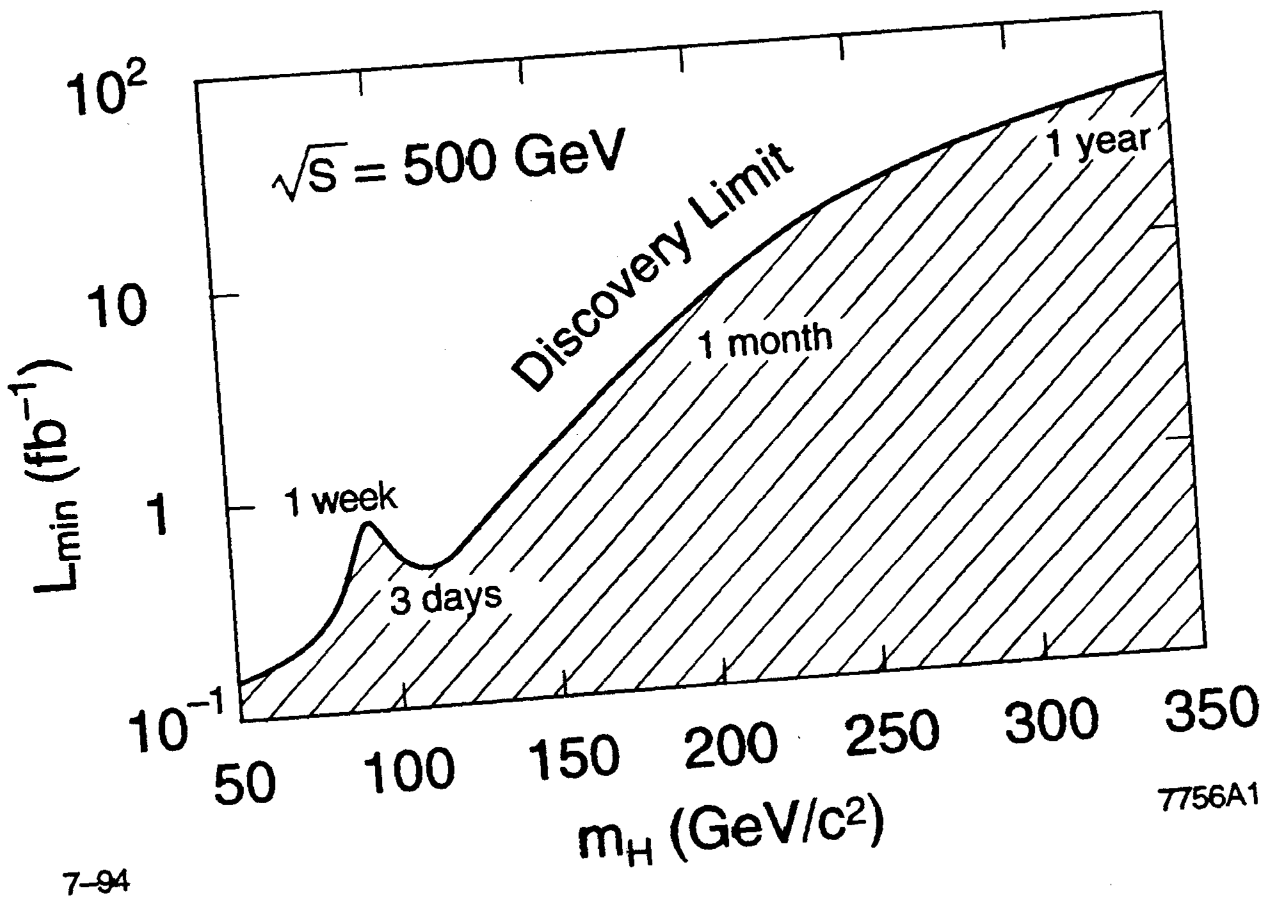


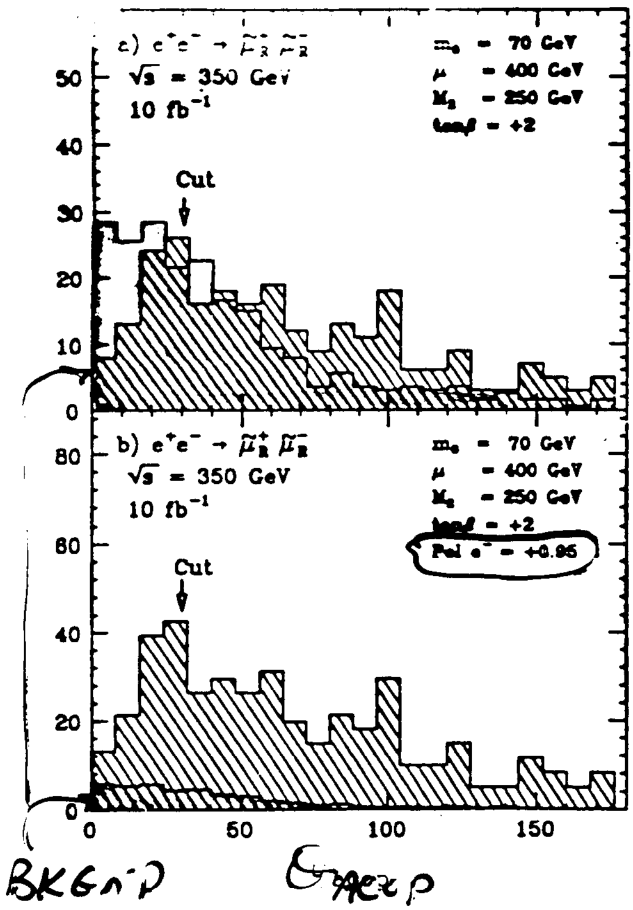
Figure 6: Visible mass distribution in the missing energy channel for all background processes (shaded histogram) and for H$\nu\bar{\nu}$ with $m_H = 120$ GeV/c^2, (a) before and (b) after b-tagging.

ALL TOPOLOGIES
DEMAND 5σ SIGNAL OVER BACKGROUND



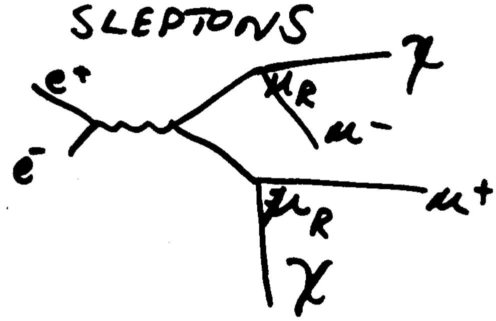
SUPERSYMMETRIC PARTICLES

- EASY TO DETECT IF THEY EXIST & ARE KINEMATICALLY ALLOWED



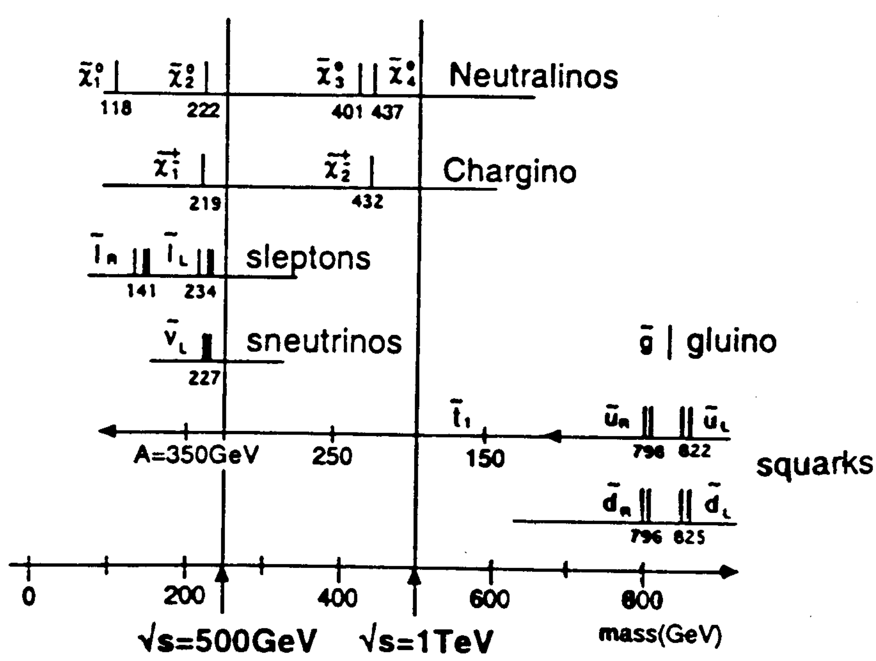
ex:

SLEPTONS



- Acoplanar leptons w/ missing energy

SHUJI ORITO
LCWS '93
PROC.



MORE MSSM MODELS
(G. KANE)

TABLE VI. The same as in Table IV but now for $m_t^{pole} = 170\,\mathrm{GeV}$, $\tan\beta = 20$, $A_0/m_0 = 0$, and $\mathrm{sgn}\,\mu_0 = -1$ (Fig. 9).

Mass limits	COMPASS		CDM		MDM	
(GeV)	Lower	Upper	Lower	Upper	Lower	Upper
h	113	131	116	125	114	119
A	532	1502	564	1020	532	828
$\tilde{e}_L$	244	1069	244	1011	244	832
$\tilde{e}_R$	167	1023	167	1004	167	824
$\tilde{\tau}_1$	144	980	144	960	144	788
$\tilde{\tau}_2$	250	1051	250	991	250	816
$\tilde{\nu}_L$	230	1066	230	1008	230	828
$\tilde{u}_L$	641	1681	677	1156	641	931
$\tilde{u}_R$	631	1611	654	1110	631	924
$\tilde{t}_1$	441	1302	501	883	464	607
$\tilde{t}_2$	584	1579	687	1117	605	814
χ_1^0 =LSP	28	353	34	232	34	152
χ_2^0	51	657	62	432	62	281
$\chi_1^\pm$	50	657	61	432	61	281
$\tilde{g}$	207	1812	249	1257	249	874

GAUGE BOSON STUDIES

ANALYZE
WWV
WWVV couplings

for
ANAMOLIES

$e^+e^- \to$ WW
eνW
ννγ
ννZ
WWZ
WWγ
eeWW

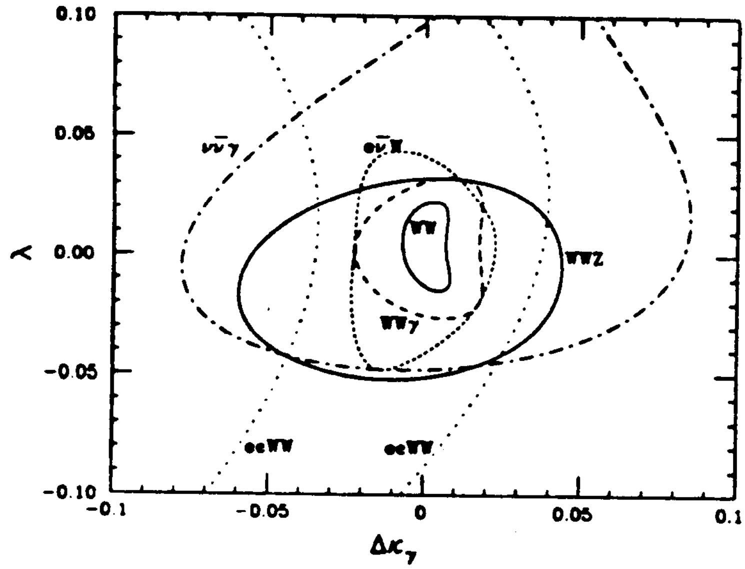


図 1.66: 各反応から得られる、λ-Δκγ 平面上における異常結合定数に対する感度 (95% CL) の比較。

50 fb⁻¹ √s = 500

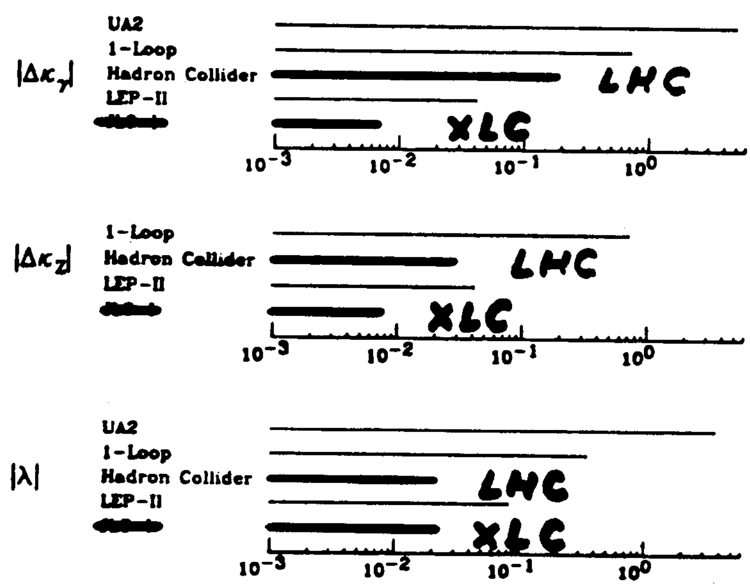
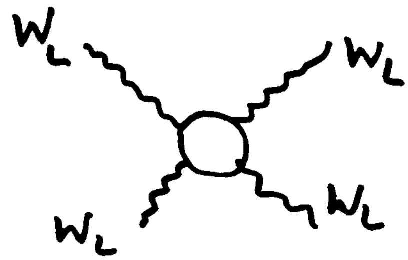


図 1.67: ゲージ粒子の異常結合定数に対する現在の測定限度と将来の実験で期待される精度。結合定数の大きさのみを比較した。

PHYSICS CASE FOR HIGHEST ENERGY

In STANDARD Model

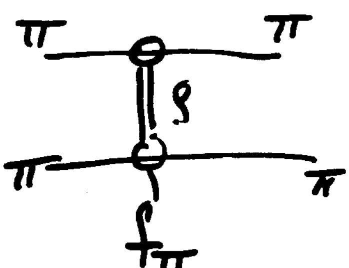


$$\sim \frac{m_H^2}{(250\,\mathrm{GeV})^2}$$

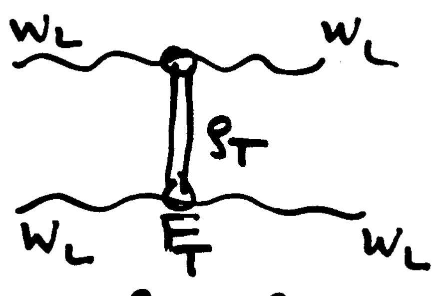
W_L scattering is STRONG & VIOLATES UNITARITY @ $\sqrt{s} \sim 1\text{-}2$ TeV

EVEN if no light ($\lesssim 600$ GeV) Higgs exists going to 1-2 TeV 'guarantees' EWSB

Look for evidence of STRONG EWSB by considering known low energy system



$\Longleftrightarrow$ ANALOGY



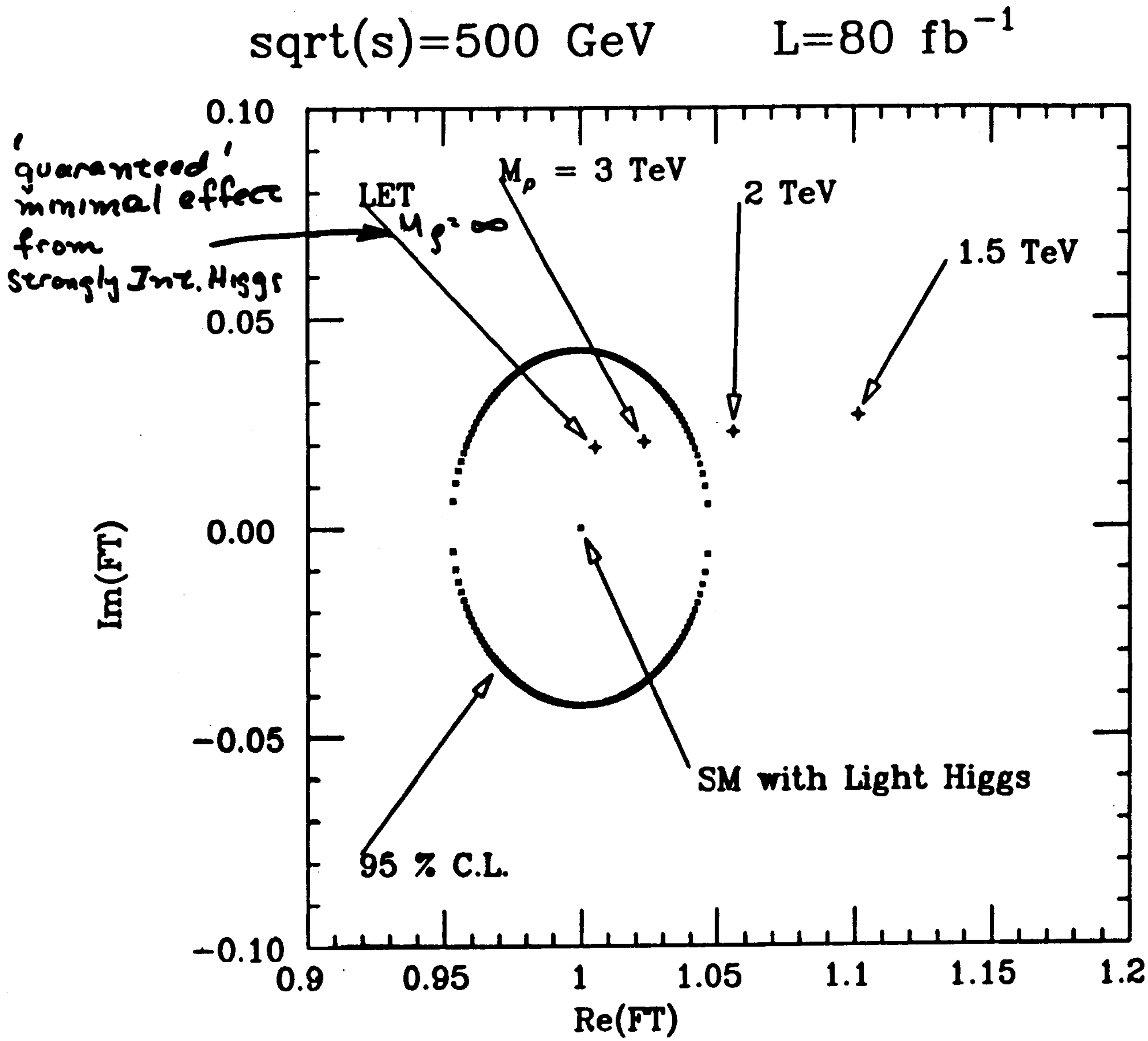
Pion form factor dominated by ρ

W_L form factor F_T dominated by techni-ρ

Analyze $e^+e^- \to W^+W^-$ TO ISOLATE W_L^+, W_L^-

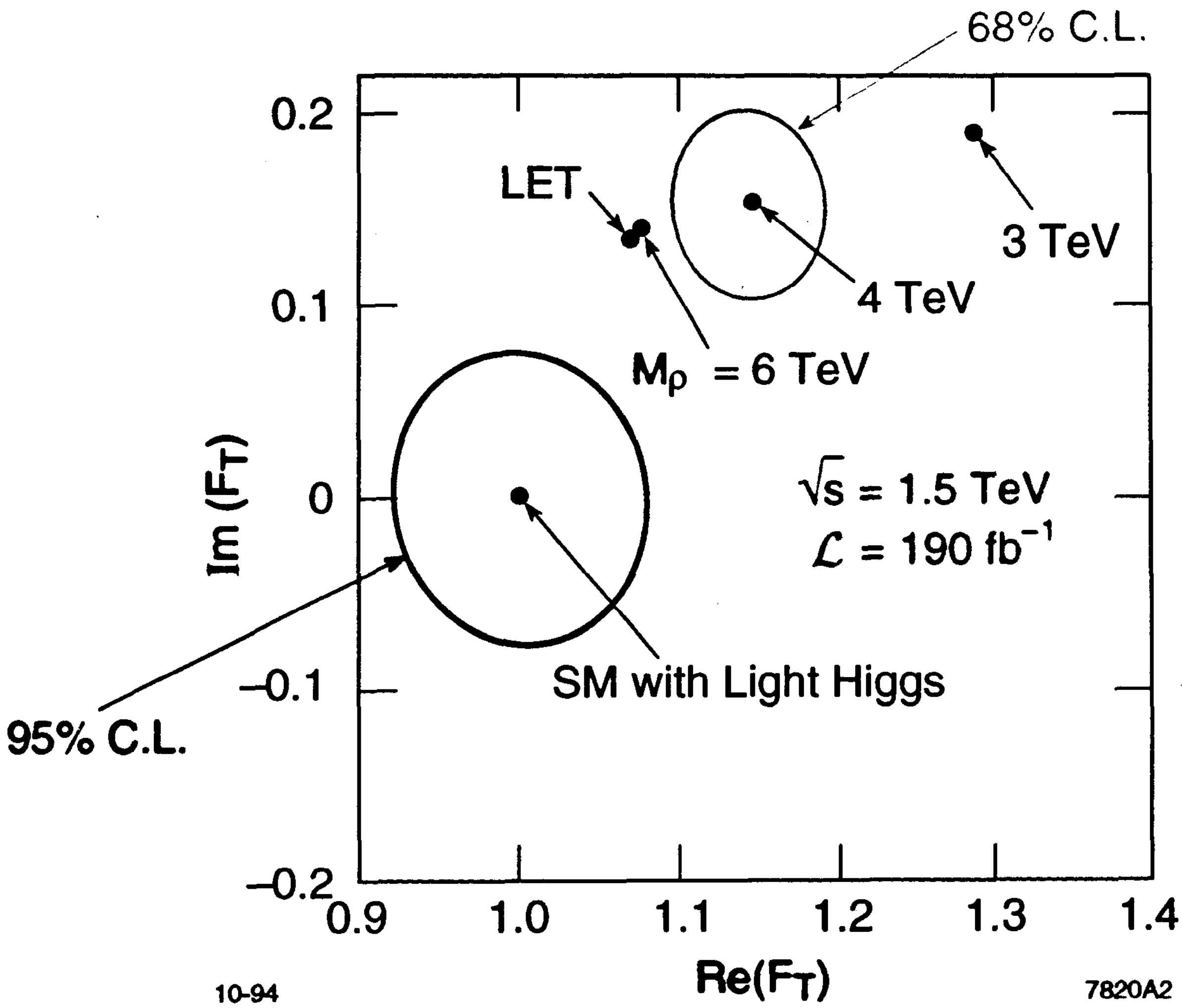
$W^+ \to q\bar{q}$, $W^- \to e\nu$

& EXTRACT $Re(F_T), Im(F_T)$



$W_L W_L$ scattering weak enough at $\sqrt{s}$ = 500 GeV to not be distinguishable from S.M. w/ Light Higgs

Strong Electroweak Symmetry Breaking



$F_T = F_T(M_\rho, \Gamma_\rho)$ is the form factor for $e^+e^- \rightarrow W_L^+W_L^-$ where M_ρ, Γ_ρ = mass, width of a techni-rho resonance.

F_T is analogous to the rho-dominated pion form factor for $e^+e^- \rightarrow \pi^+\pi^-$

A Maximum Likelihood analysis of the production and decay angles of all W^+W^- events isolates $e^+e^- \rightarrow W_L^+W_L^-$