TEST FACILITIES for LC

K.KUBO (KEK)

Major facilities:

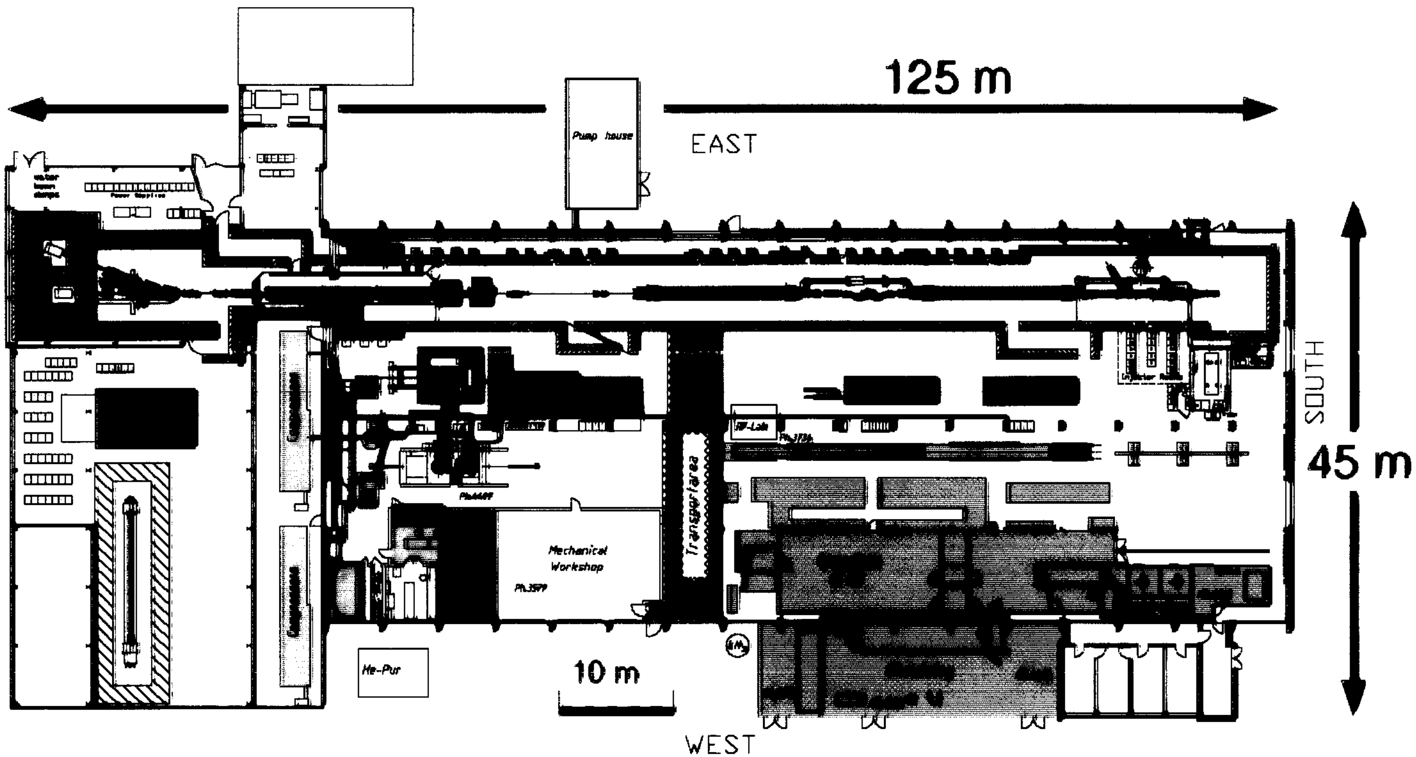
- DESY:
  - TTF (TESLA Test Facility)
- SLAC:
  - FFTB (Final Focus Test Beam)
  - ASSET (Accelerator Structure SETup)
  - NLCTA (NLC Test Accelerator)
  - (SLC)
- KEK:
  - ATF (Accelerator Test Facility)
- CERN:
  - CTF (CLIC Test Facility)

This is not an overall review.
Concentrate on a few subjects for each lab.
CTF is not covered.

Hans Weise (DESY), Tor Raubenheimer (SLAC) and Hitoshi Hayano (KEK) helped preparation.

Page 2~9: from web pages of Snowmass meeting WGM3:
http://www-project.slac.stanford.edu/lc/wkshp/
snowmass2001/m3/Talks/ Lutz-_7-03.pdf and Hans-_7-03.pdf

TESLA Test Facility (TTF)



Cavity Treatment and Assembly

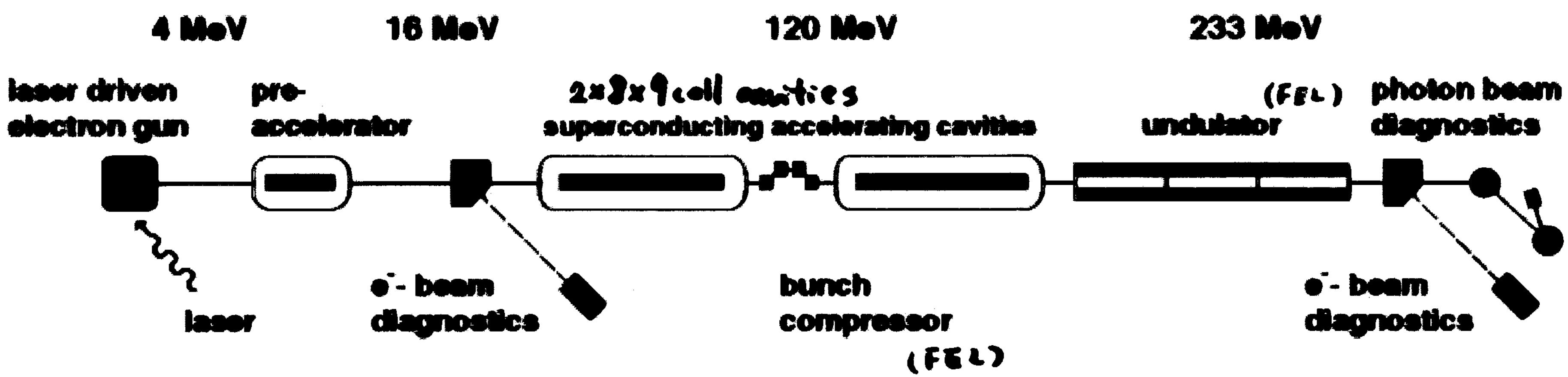
Cavity Testing (RF System / He Plant)

Cryomodule Assembly

TTF Linac and Free Electron Laser

H.Weise /2001

TESLA Test Facility Linac



Challenges for TESLA cavities

- Accelerating gradient
  - For 500 GeV center-of-mass
    - $E_{acc} = 23$ MV/m @ $Q_0 = 1 \cdot 10^{10}$
  - For energy upgrade to 800 GeV
    - $E_{acc} = 35$ MV/m @ $Q_0 = 5 \cdot 10^{9}$
- Pulsed operation
  - Frequency detuning due to Lorentz force requires additional RF power

- What material quality is really needed?
- What is the best manufacturing technique ?
- How to prepare the best surface for RF superconductivity?
- How to compensate the Lorentz-force detuning?

Pulsed acceleration at TESLA

Superconducting cavities at high gradients ⇒ **Pulsed operation to reduce average cryogenic losses**

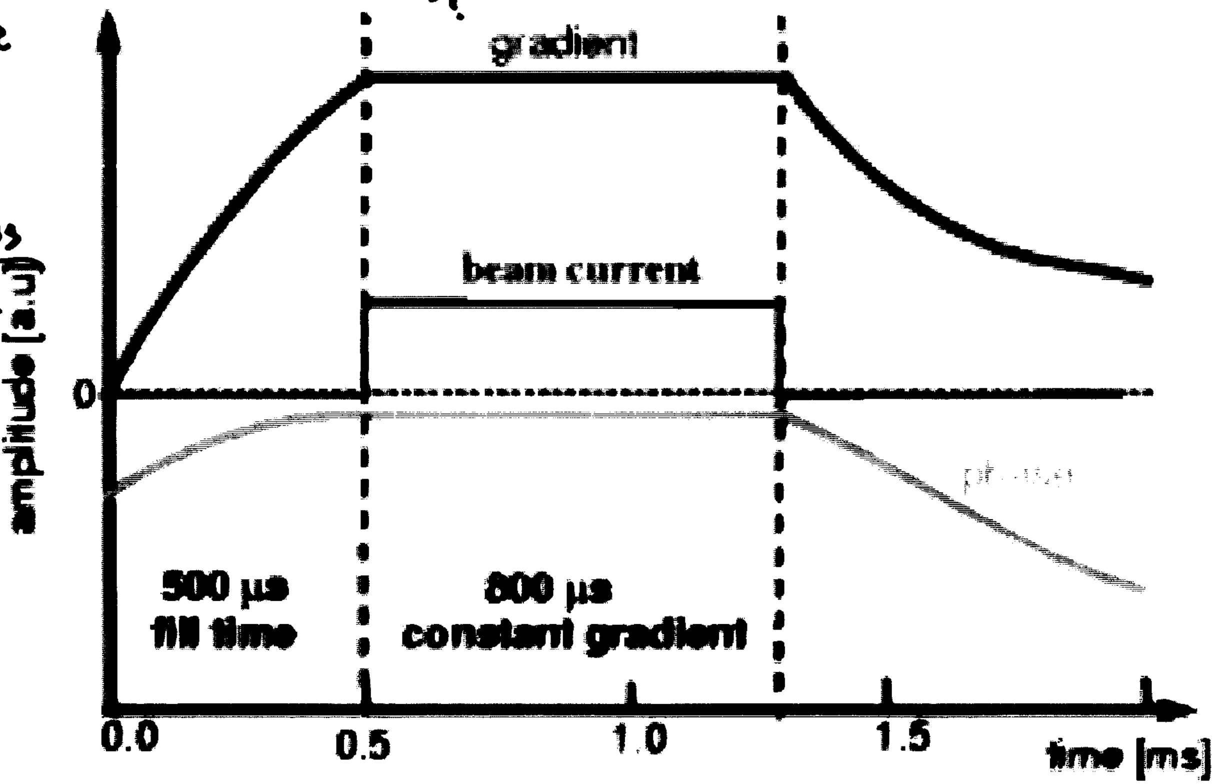
$Q_0 > 10^{10}$
Still can not accept losses in CW operation.

Pulsed operation: 500 µs fill time + 800 µs constant gradient

10 Hz repetition rate ?

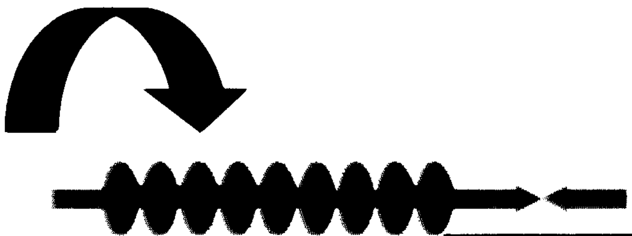
Keep gradient and phase constant with beam.

$P_{in} = \underbrace{P_{beam}}_{\text{beam loading.}} + P_{out} + \underbrace{P_{loss}}_{\text{small.}}$

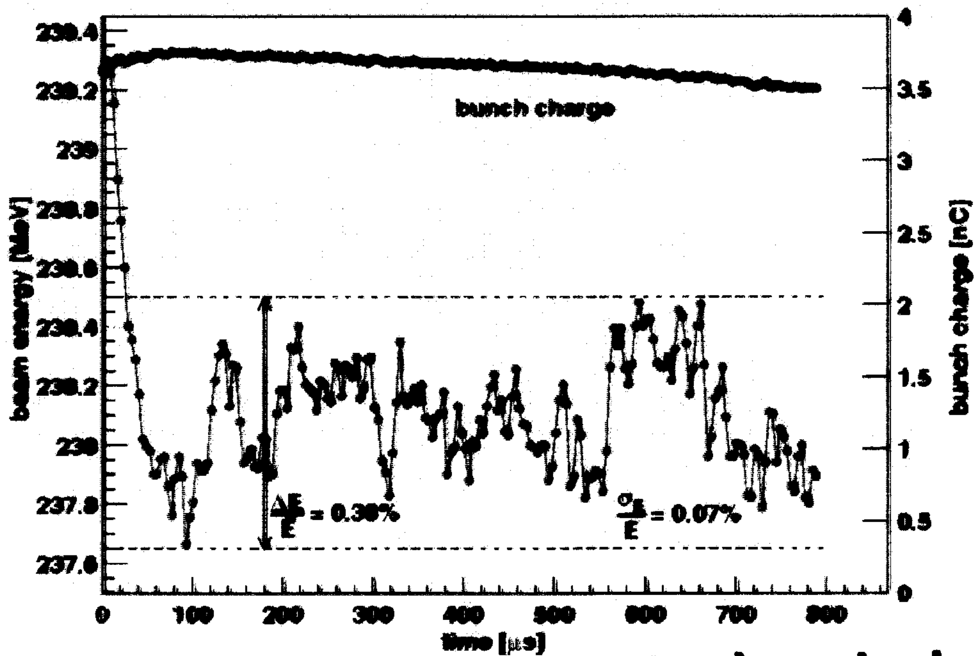


TTF Operation

- acceleration of 800 µs long pulse trains
- full beam loading
- gradients up to 23 MV/m with beam
- approx. 9000 hours of operation
- FEL operation



500 GeV c.m.



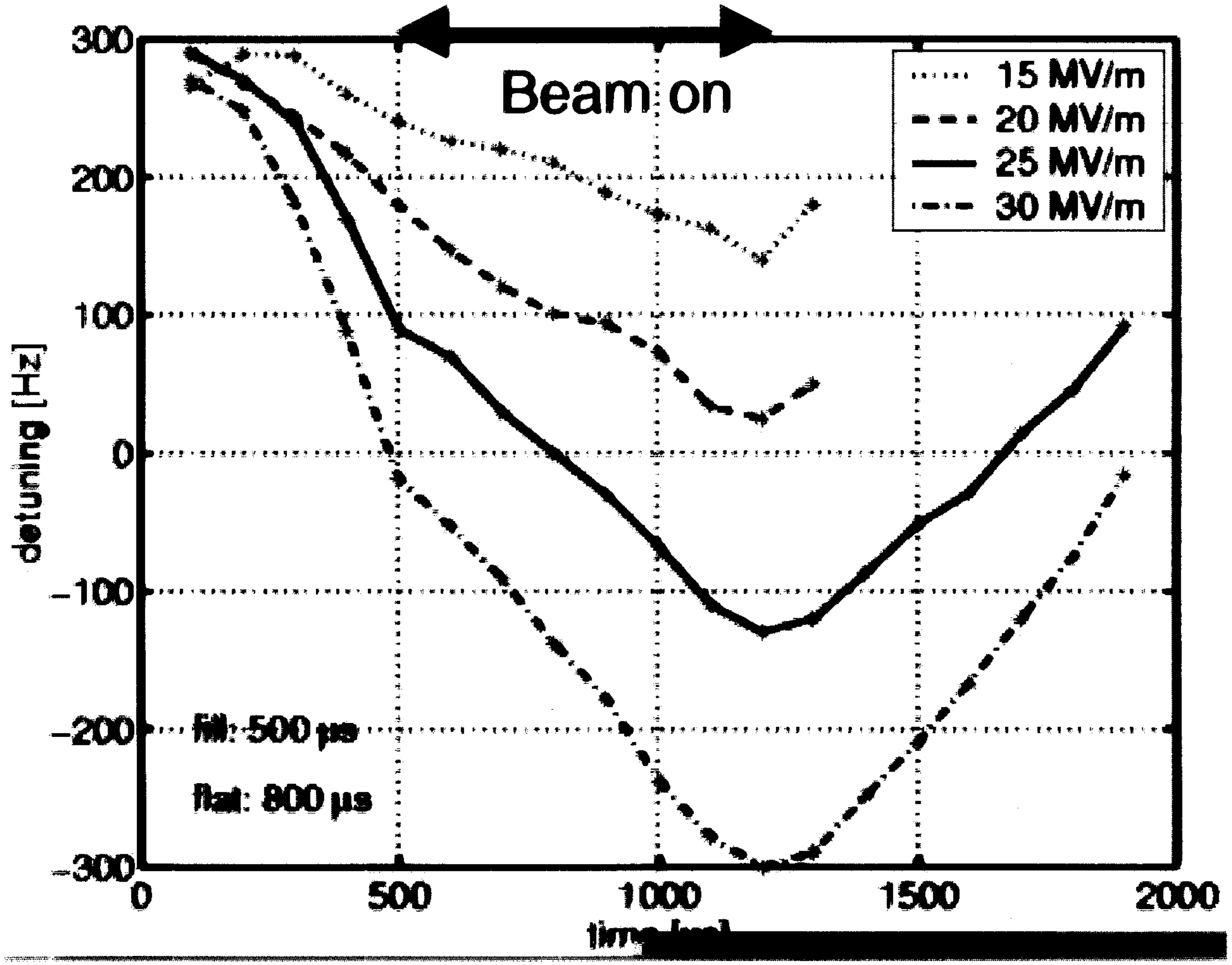
RF beam loading compensation

$\frac{\Delta E}{E}, \frac{\sigma_E}{E}$ (bunch-to-bunch) < single bunch

Frequency detuning during RF pulse

S.C. Cavity is not rigid. (like a spring).

⇓



Frequency detuning due Lorentz forces of the electromagnetic field in the cavites:

$\Delta f = K \cdot E_{acc}^2$ significant at high Eacc

$K \approx 1\ Hz / (MV/m)^2$

Remember:

Cavity bandwidth with main coupler is ≈ 300 Hz

Need more input RF power if not compensated.

Piezoelectric tuner

M. Liepe, S. Simrock, W.D.-Moeller

Piezo-Actuator:

l=39mm

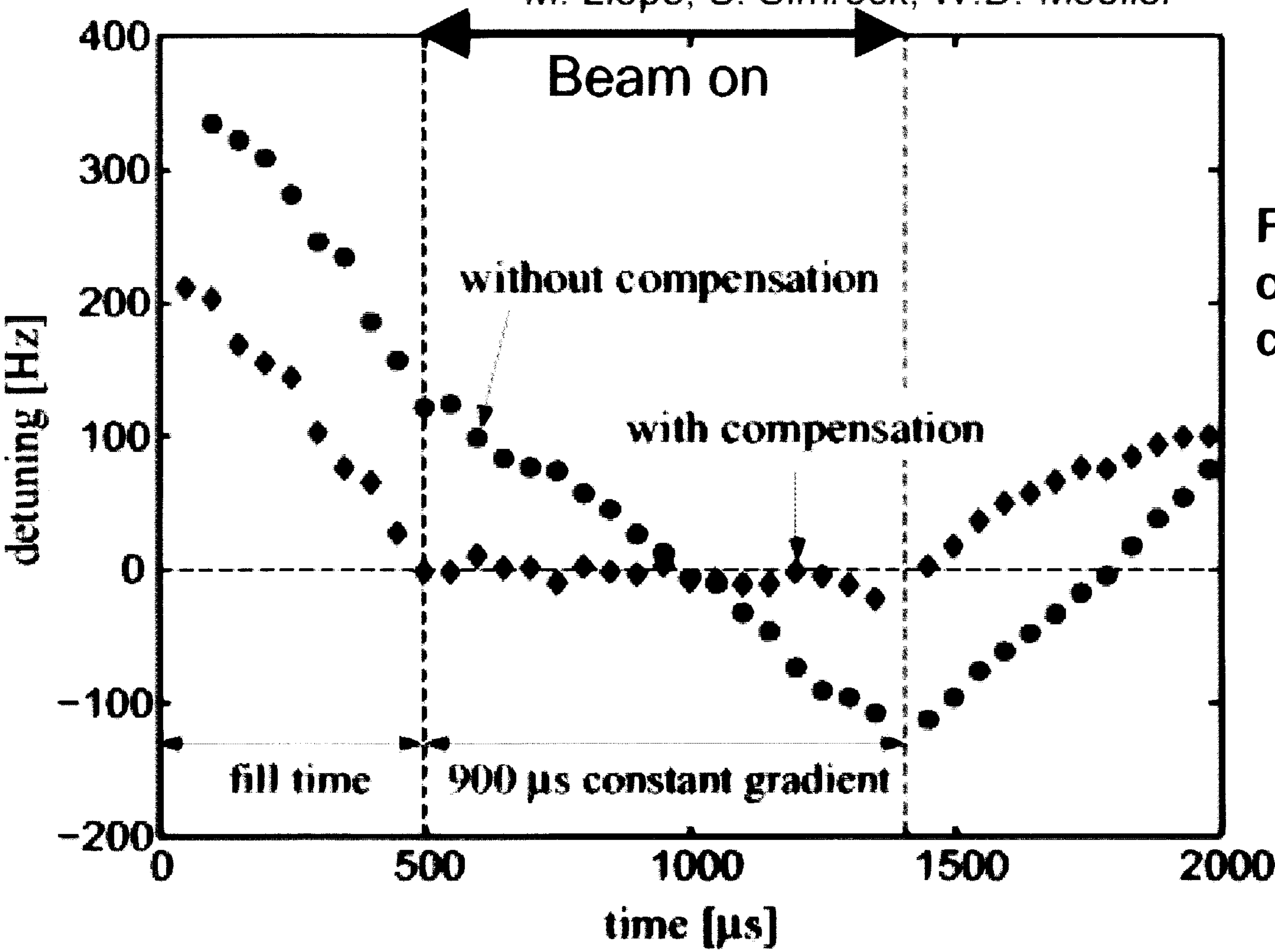
U_{max}=150V

Δ l=3µm at 2K

$\Delta f_{max,static}$=500Hz

Frequency stabilisation during RF pulse using a piezoelectric tuner

M. Liepe, S. Simrock, W.D.-Moeller



Frequency detuning of 200 - 250 Hz compensated!

TTF operation demonstrated:

High accelerating gradient comparable to TESLA-500 design.

The first module operated with beam at 21-22 MeV/m.

The second one (assembled earlier) about 19 MeV/m

(limited by input coupler, new couplers are improved)

Stable operation for a long time. (~10,000 hours)

Production and acceleration of long bunch train.

With full beam loading.

Small bunch-to-bunch energy difference (with RF control).

Detuning compensation using piezo.

(Reduce overhead RF power. Needed for TESLA-800.)

Schedule for the next months

~April 2002: Operation of the present setup.

The last six weeks: full beam loading at 21 MV/m (max. gradient module ACC1).

May 2002:

Install the superstructure at position ACC1. (2x 9cell cav./input coupler)

Replace ACC2 by another module with 25 MV/m cavities.

October 2002:

Start installation of TTF2 (elongation of the present setup).

Install modules ACC3 to ACC6 until beginning of 2003.

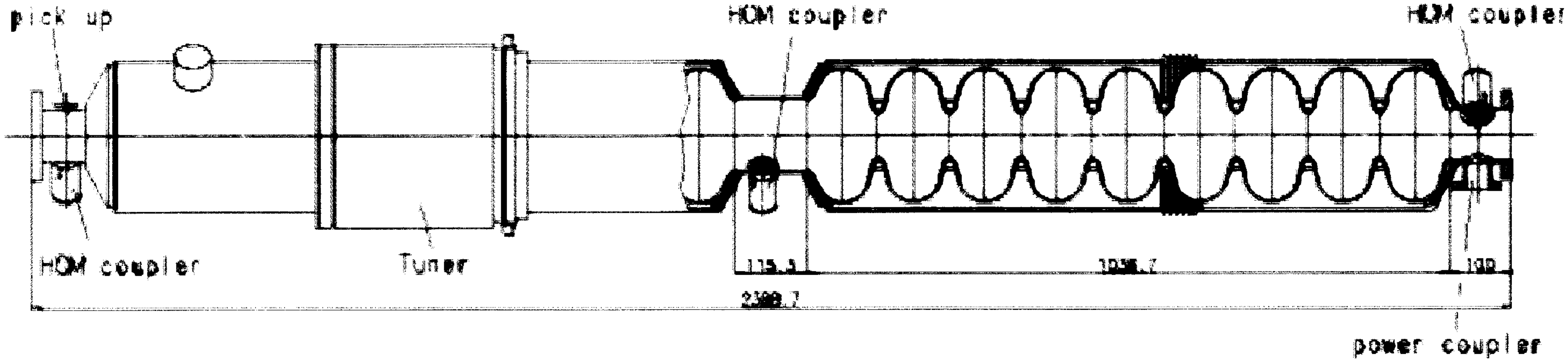
The test of those modules could start in spring 2003.

Expect to get 25~30 MV/m for modules ACC3~ACC5.

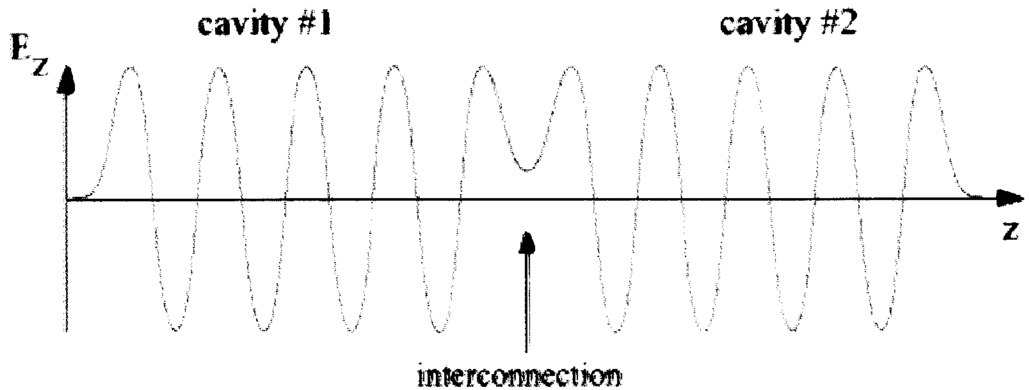
ACC6: electropolished cavities, higher gradients.

TESLA 2 x 9 Superstructure

J. Sekutowicz, M. Liepe et al.



Field profile:



Benefits:

- 6% larger active accelerating length as compared to normal nine-cell design
- less main and HOM couplers

FFTB (Final Focus Test Beam)

200 m Final Focus prototype. E=46 GeV.

Demonstrate optics and tuning of FF (e.g. 3rd-order chromatic correction).

Achieved beam size σ_y~60 nm. ($\varepsilon_y \sim \varepsilon_{y,\mathrm{LCXdesign}} \times 500$)

Development of diagnostics:

- Beam position measurement ~25 nm
- Magnet(1/4 ton) movers ~300 nm
- Beam based alignment ~microns
- Stabilization of conponent ~ nms
- Beam size nms by laser interferometer monitor.

Beam-beam interaction, non-linear QED (e-laser collision).

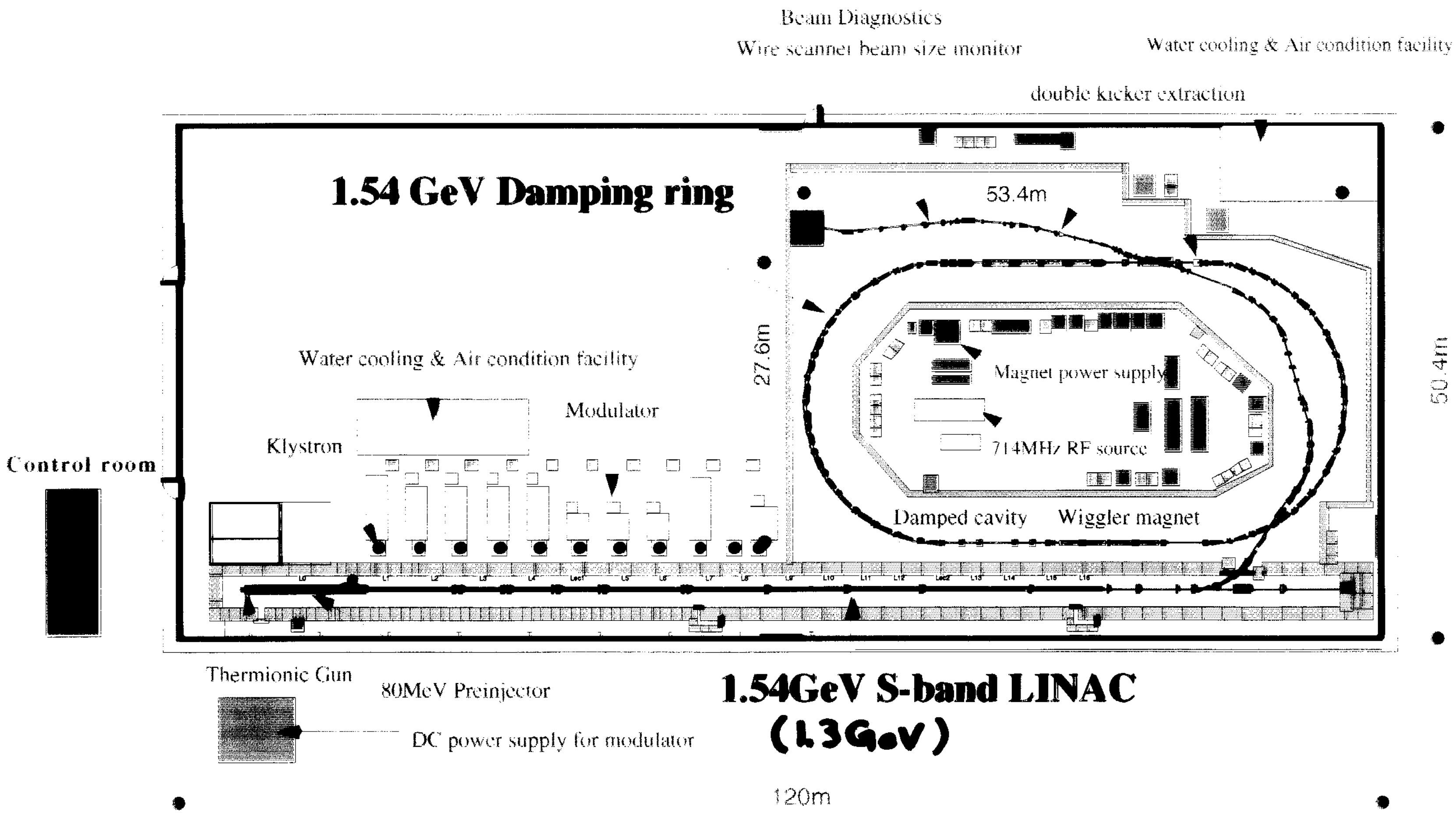
Now used to study machine protection system, etc.

ASSET(Accelerator Structure SETup) :
Wakefield measurment
Good agreement with calculations → We can trust calc. → we can design DDS.
Demonstration of wakefield suppression by "detuned structure"
(damped-detuned)

NLCTA (NLC Test Accelerator):
-development of SLED-II pulse compression
-development of X-band 50 MW XL-4 klystrons (over 10 of them operating)
-demonstration of beam loading compensation
-presently used as rf structure test facility to address gradient limitations.

'8-pack' : demonstration of (new) RF system of X-band LC.
1st step : Fall 2002
full test : in 2003

Accelerator Test Facility for (J)LC (at KEK)



Production of Low emittance, multibunch beam.

ATF. Single Bunch Parameters

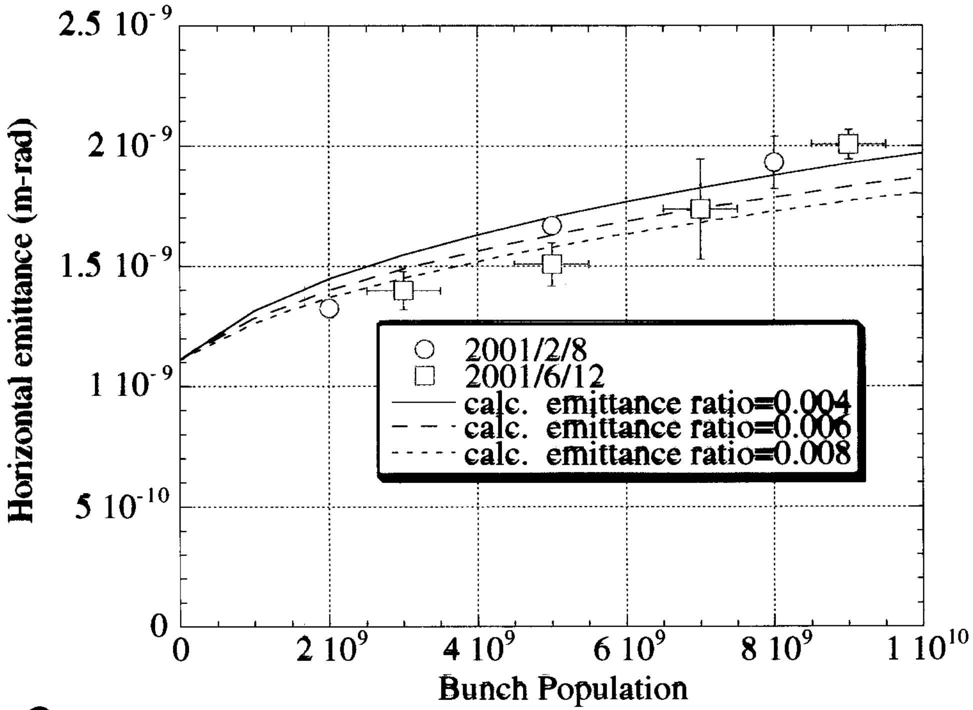
	ATF Achieved	ATF Design	(J/N)LC Design
Energy (GeV)	1.3	1.54	1.98
No. of paticles/bunch	1.0×10^{10}	2.0×10^{10}	0.75×10^{10}
Horizontal Emittance $\gamma\varepsilon_x$ ($\times10^{-6}$ m-rad)	2.8* 5.1**	3.0	3.0
Vertical Emittance $\gamma\varepsilon_y$ ($\times10^{-8}$ m-rad)	<2.8* $\lesssim$5**	3.0	3.0

*single bunch, low intensity, **single bunch high intensity
Intensity dependence is consistent with calculation of intrabeam scattering.

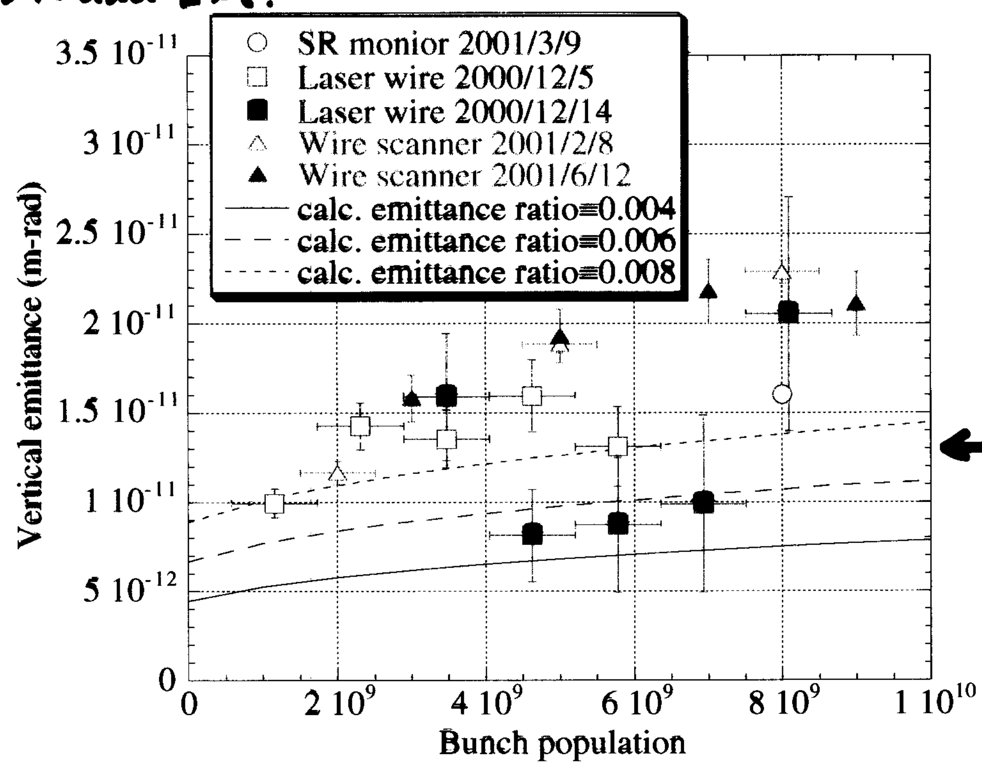
Wigglers OFF → long damping time : need to test with wigglers ON.
(low rep. rate)

Emittances vs. Intensity

ε_x : Extracted beam, measured by wire scanners,



ε_y : in DR and Ext.

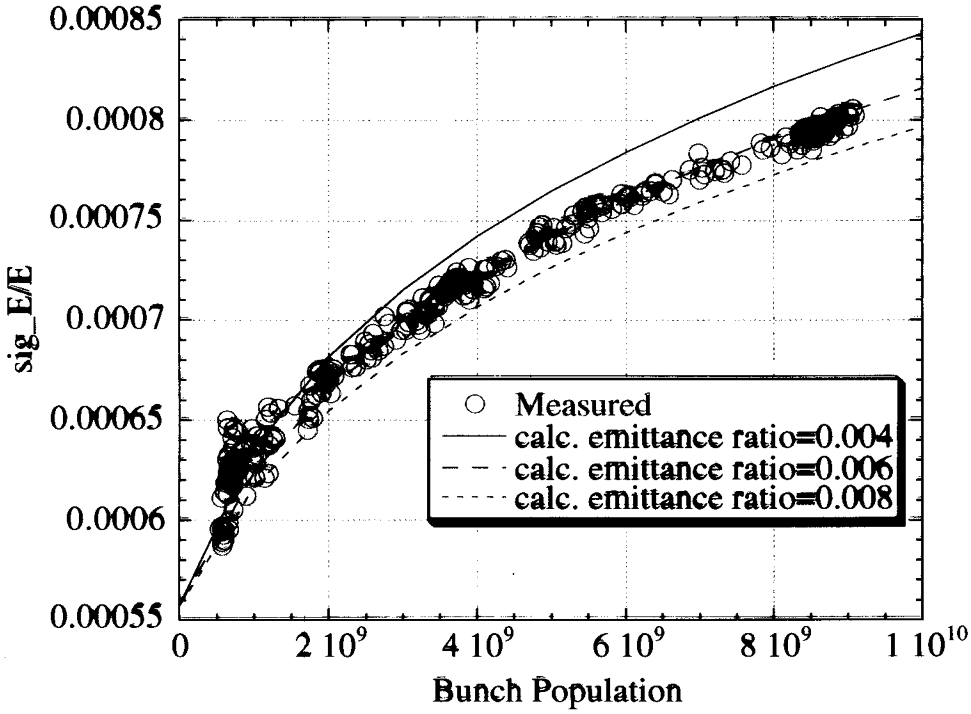


← $\gamma\varepsilon_y = 3\times10^{-8}$ m-rad.

small ε_y → high particle density → strong IBS.

ε_y measurement should be improved.

Energy Spread vs. N



Strong intrabeam scattering (IBS)

High density (small emittance)

Low energy (1.3GeV) (1.98 GeV for NLC/JLC)

IBS

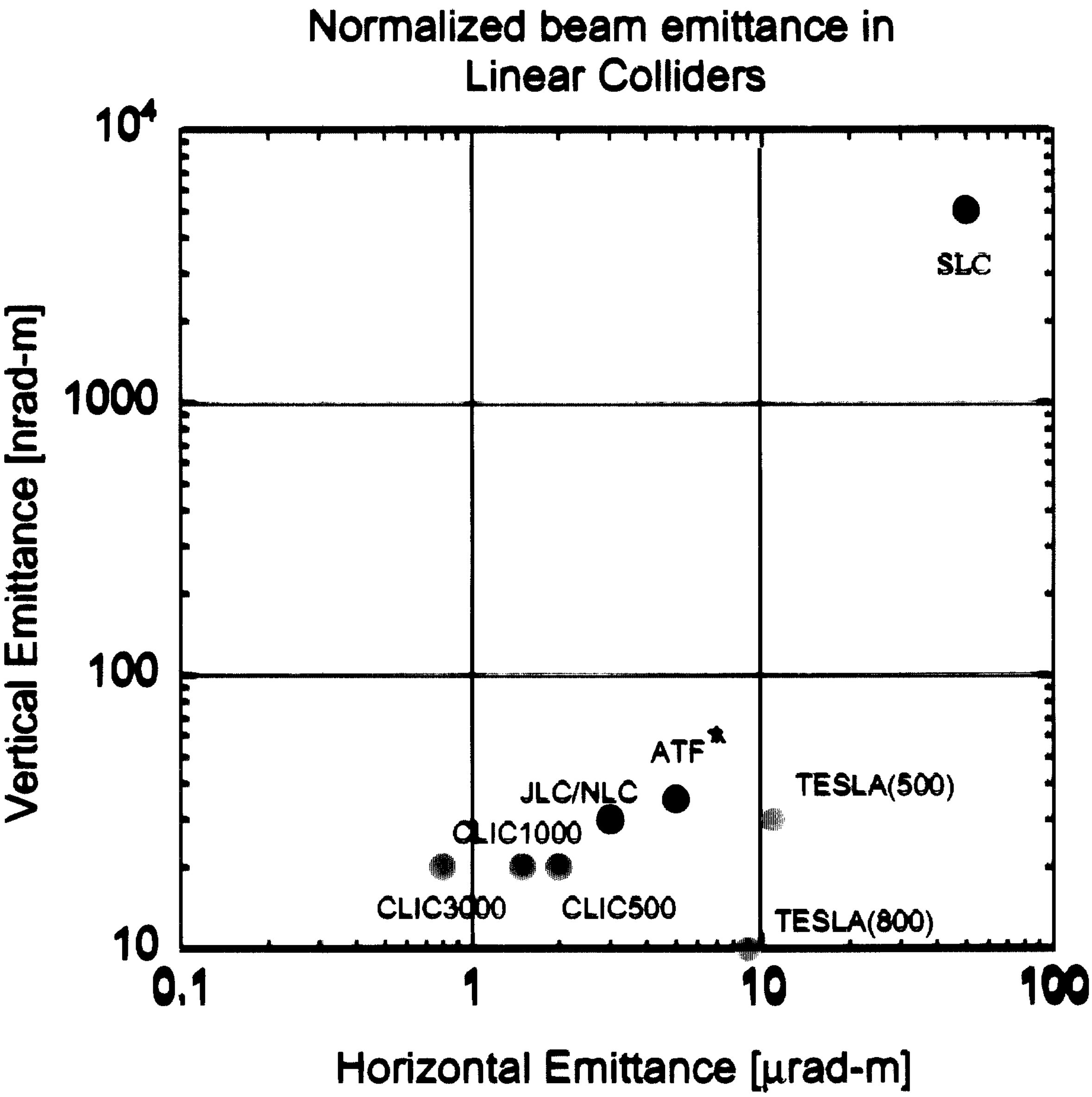
Theoretical calculation is amviguous.

Depend on vertical emittance, which has not been measured very accurately.
(particle density)

⇓

Need more experiment. to answer

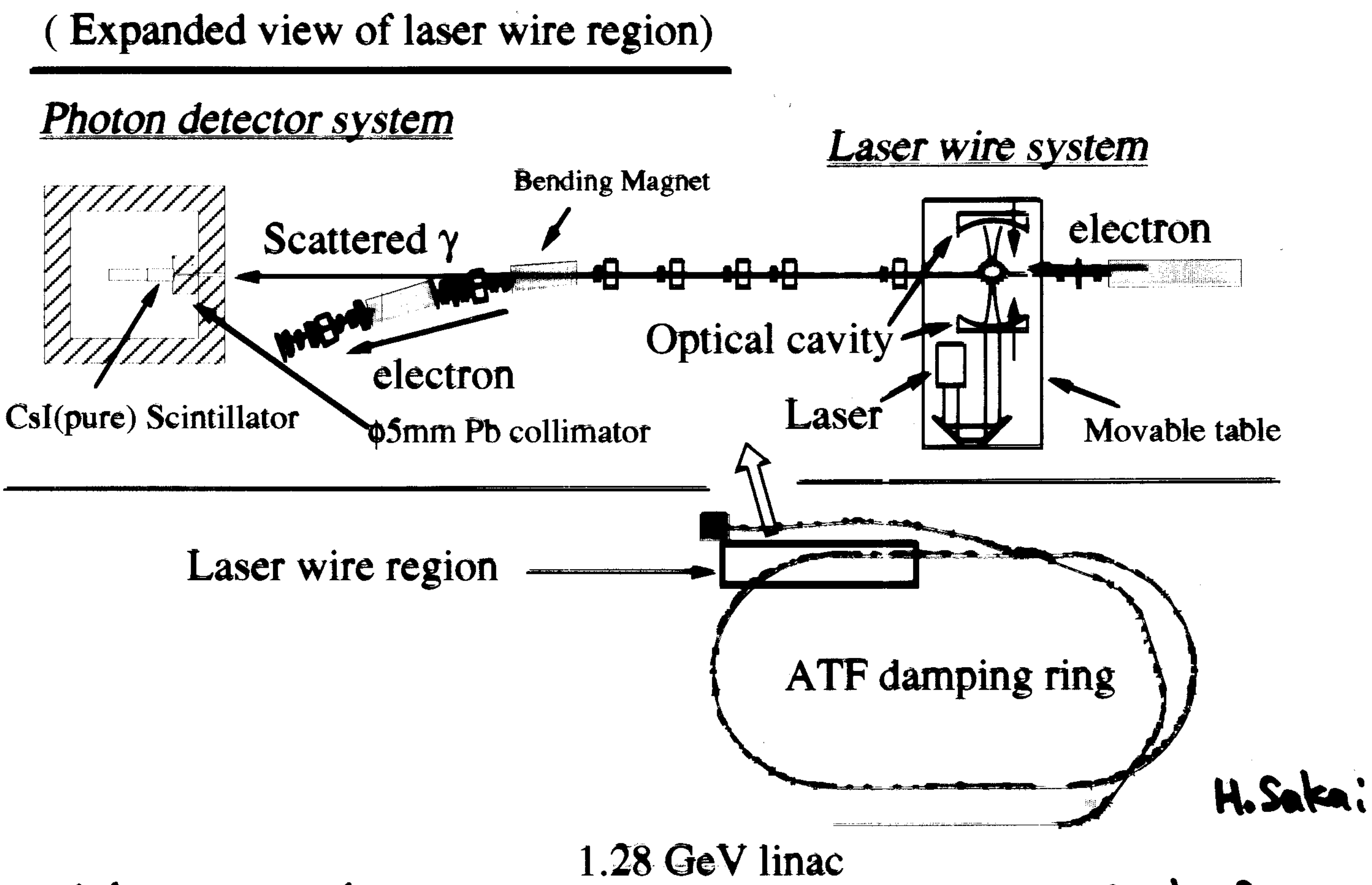
Can we trust calculations?



*: High intensity.

(at Low intencity, ATF achieved JLC/NLC design)

Laser Wire Monitor in Damping Ring



Solid wires destroy beam. can not be used in Ring.

A thin horizontal 'wire' of light is created in an optical cavity, which consists of two mirrors.

When the electron beam hits the wire, gamma rays are produced as Compton scattering.

A scintillation detector detects gamma rays.

The whole optical system is placed on a vertically movable table.
The position is measured with a resolution better than 1μm.

The vertical beam size is measured in a manner similar to conventional wire scanners.

Example

Laser wire scanning

$\sigma_{meas} = 10.2\ \mu m$

$\sigma_{laser} = 7.1\ \mu m$

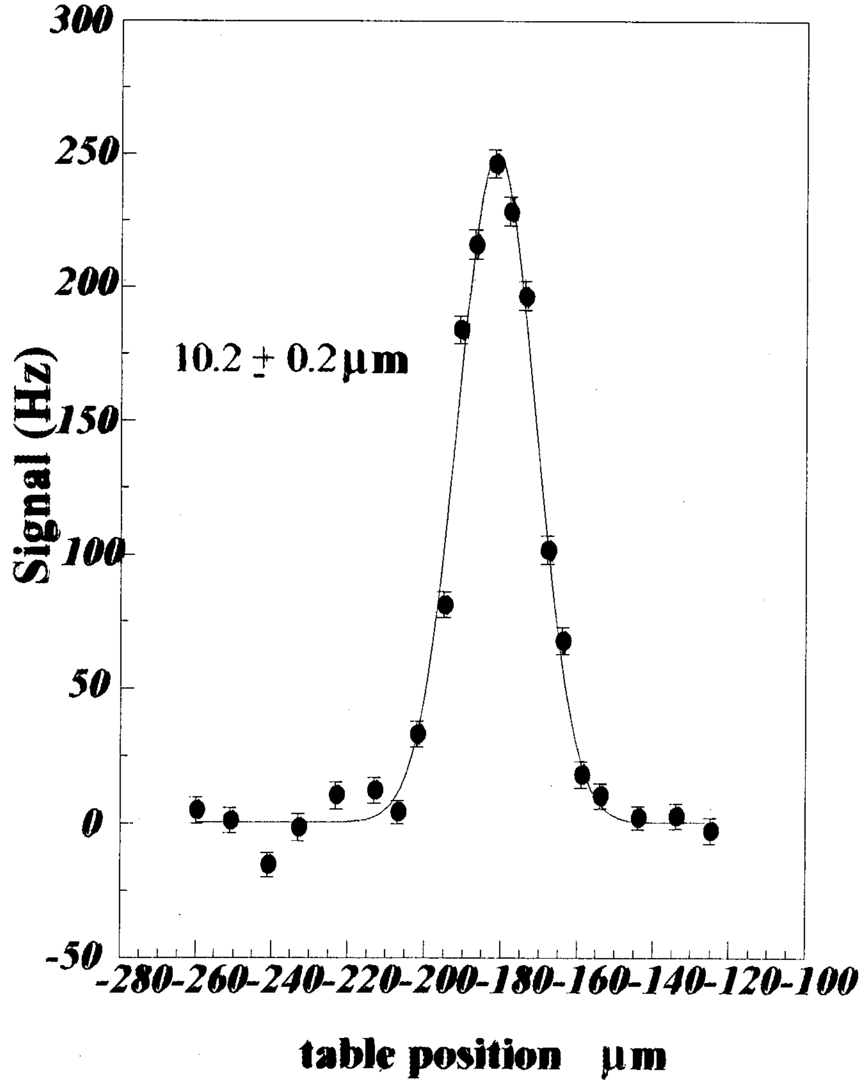
$\sigma_{beam} = 7.3\ \mu m \left(\sqrt{\sigma_{meas}^2 - \sigma_{laser}^2}\right)$

$\beta_y = 5.77$ m

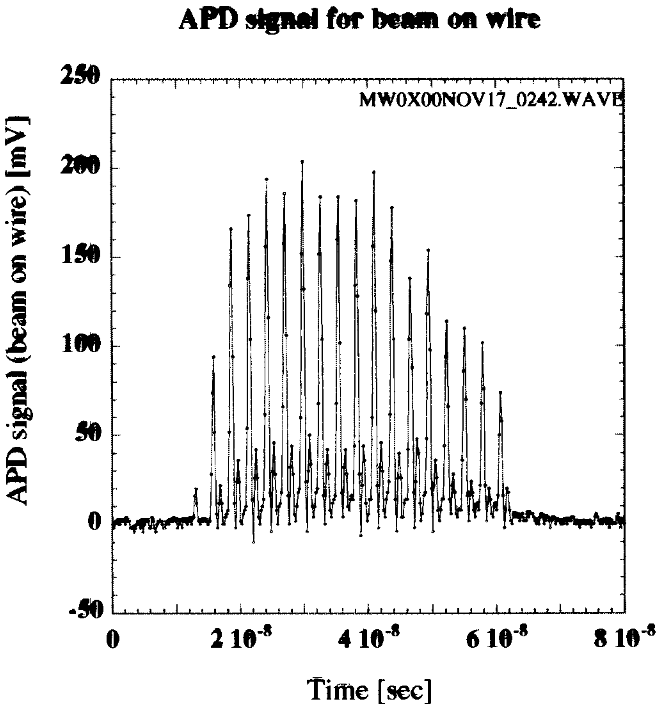
$\eta_y = 0\ (\leq 2\ mm)$

$\varepsilon_y = 0.92 \times 10^{-11}$ rad-m

$\left(\frac{\sigma_{beam}^2}{\beta_y}\right)$ $\gamma\varepsilon_y = 2.3 \times 10^{-8}$



Multibunch signal detection by Avalanche Photo-Diode(APD)



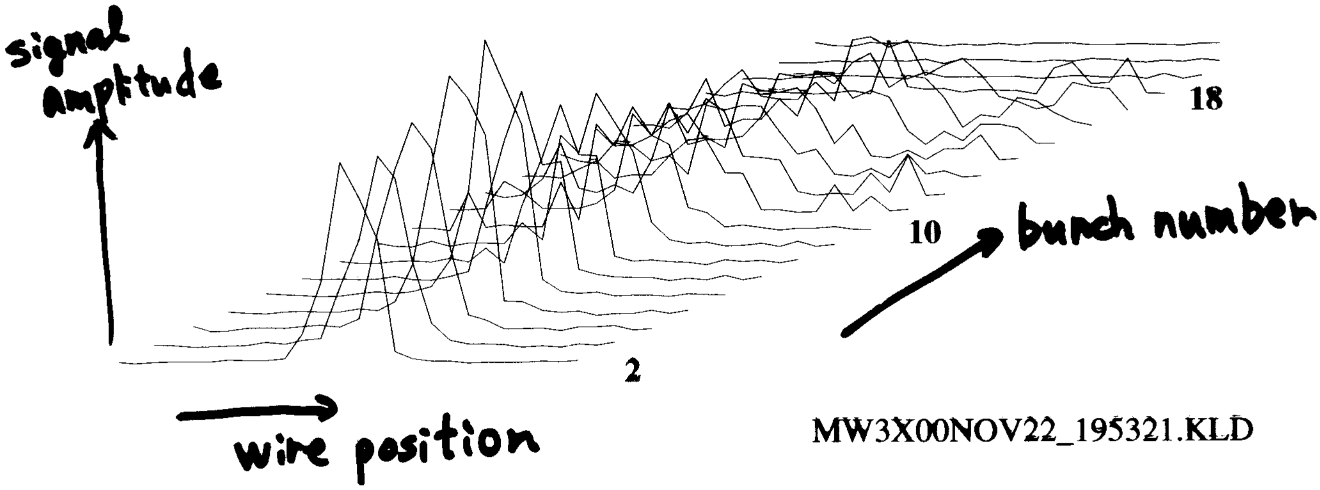
In extraction line.

Tungsten wire.
10μm φ

captured by air-cerenkov +APD +10GS/s scope

Y profiles of MW3X

sig_Y = 7.8um to 24um

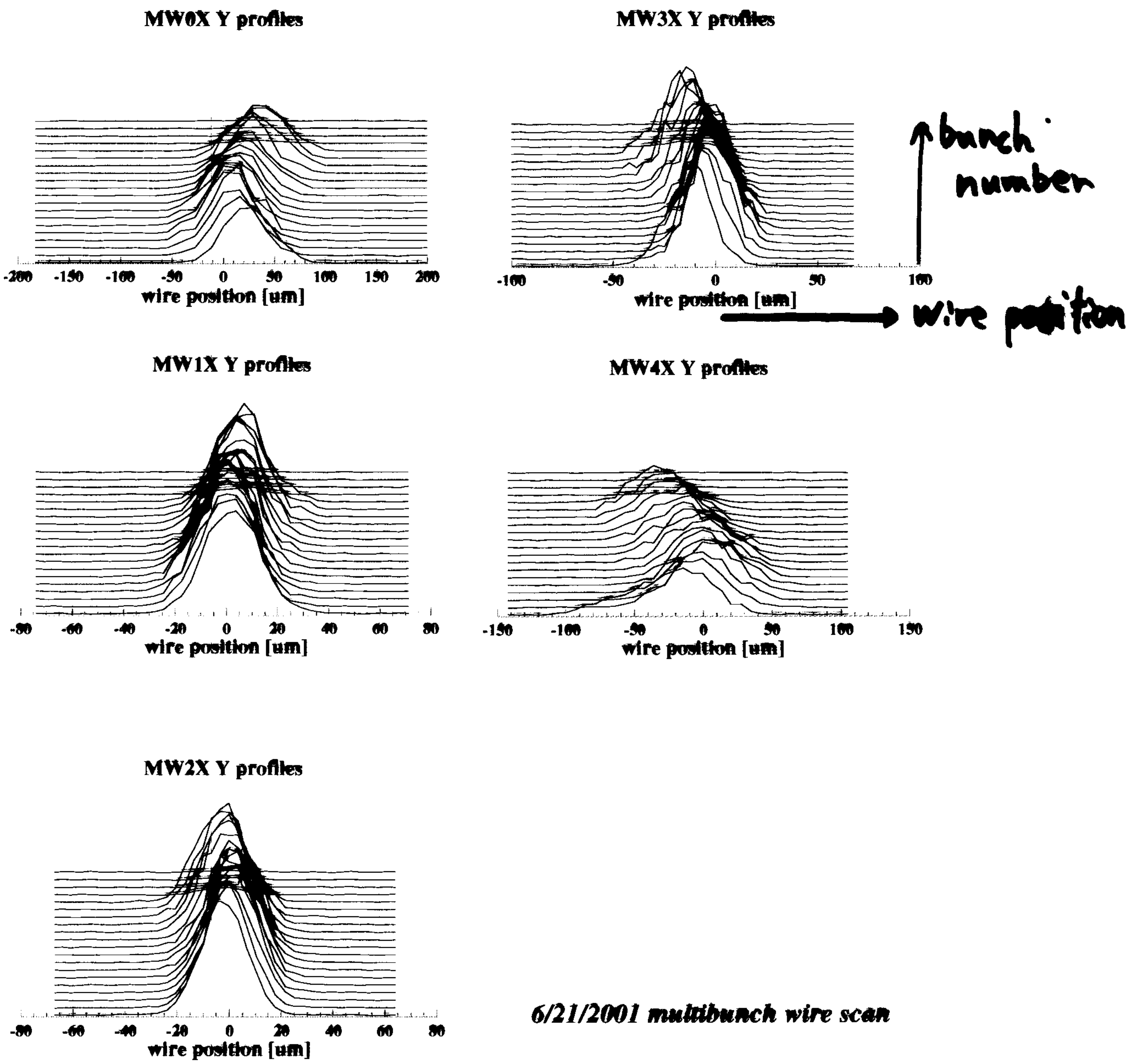


projected profile of each bunch

Multibunch vertical profile

5 wire scanners in Extraction Line

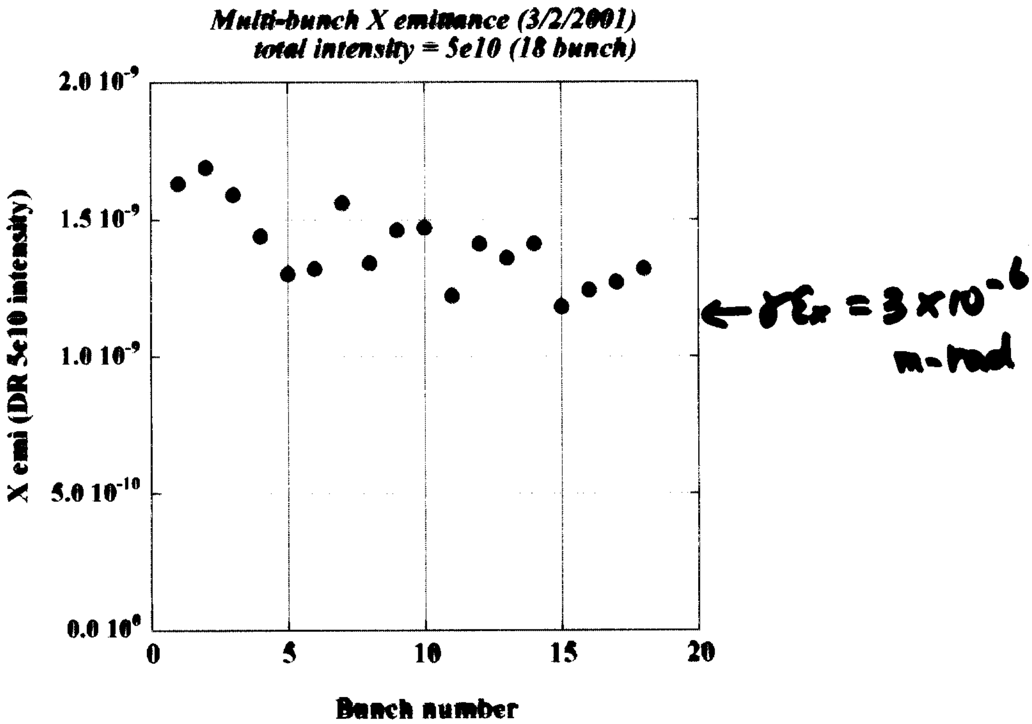
Multibunch Y profiles by wire scanner

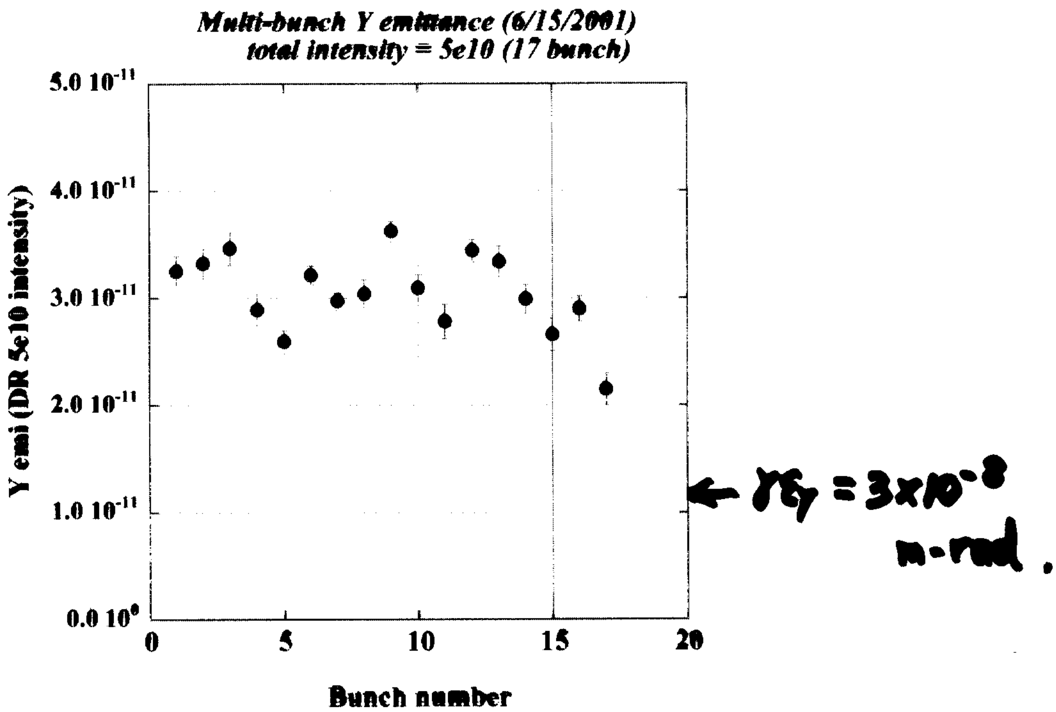


6/21/2001 multibunch wire scan

Emittance of each bunch

(preliminary)





EXT wire scanner
total 5E10 electrons

ATF. Status

Single bunch low emittance

- **Low emittance achieved at low intensity**
- **Intensity dependence from intrabeam scattering (consistent with calculation)** → but. still need more data.

Multibunch

- **Instrumentations have been (and being) developed**
- **Emittance, intensity, stability, still need to work**

ATF. Present and Near Future Plan

Single bunch low emittance

- Beam Based Alignment → lower vertical emittance
- Improve Laser Wire monitor, SR monitor. ------ < Intrabeam scattering experiment.

Multibunch

- Instrumentation (BPM, Detectors for wire scanners)
  (solid wire, laser wire)
- Kicker (flat field)

Other R&D

- Photo Cathode – RF Gun (Operation re-start in 2002 summer)
- X-ray SR monitor (Beam test start Jan. or Feb. 2002)

[redacted]

optical transition radiation monitor (beam size)

optical diffraction radiation monitor (")

Polarized positron production (Pol. laser – e^- collision → Pol. γ --target--> Pol. e^+)

etc.

continued.