KEK's research plans for the early next century

H.Sugawara, Osaka, 2000

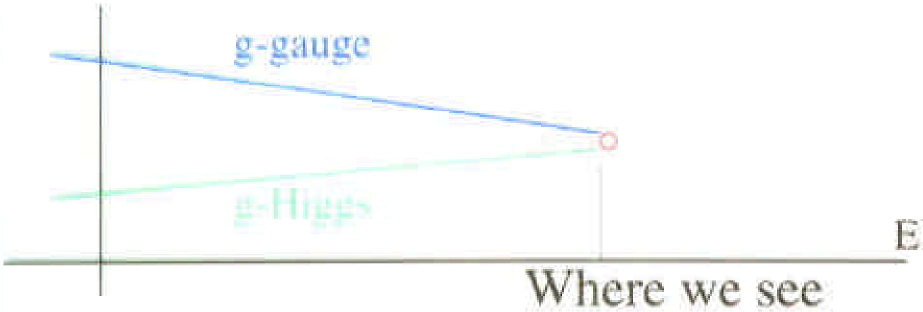
Target of our research

(1) Gauge interactions

$(E_8 \rightarrow SO(10) \rightarrow SU(5) \rightarrow SU_3 \times SU_2 \times U_1 \rightarrow U_1)$

(2) Higgs interactions (including flavor physics)

These two will be unified in higher dimensions



Where we see
the extra-dimension = m_{pl} ?

symmetries
- gauge symmetry → recovered at high energy
- accidental symmetry → broken at high energy
- B, L, P, CP, CPT, R, · · ·

Gauge interaction is better understood.

BEPP-4M,CESR,BEPC,LEP,SLC,HERA,TEVATRON,(RICH),・・・

high energy supersymmetric grand unified theory.

- ◎ broken supersymmetry LHC, LC(Ⅱ)
- ◎ proton decay

Higgs interaction

not even the Higgs particle has been found.

◎ LHC, LC(Ⅰ)

indirect research

◎ ν - physics $g_1 H \overline{L} L$

◎ cp-violation $g_2 H \overline{q} q$

Early 21st century
・physics of the Higgs interaction
・signs of supersymmetry

KEK

◎JLC(I) → JLC(II)

Higgs superparticle

(international collaboration)

◎ ν ····· K2K → JHF

◎ $\not{cp}$ ···· KEKB

$10^{33} \rightarrow 10^{34} \rightarrow ?$

$\not{CPT}$ → JHF

Toward 10^{34} $cm^{-2}s^{-1}$ and Beyond

▼ Remove the LER blowup, anyway:

- ◆ Apply solenoid field in the arc.
- ◆ Special machining of the inner wall of the chambers.
- ◆ Introduce antechambers.

▼ Once the blowup is solved, the luminosity will boost to $5\times10^{33}cm^{-2}s^{-1}$.

- ◆ LER/HER current = 1.65/0.72 A.
- ◆ Assuming the beam sizes and the beam-beam parameter (ξ_y=0.03), that are already achieved at KEKB.

▼ $1\times10^{34}cm^{-2}s^{-1}$ will be achieved by

- ◆ Increasing beam current up to the design.
- ◆ Improving the injector.
- ◆ 0.6 m bunch spacing might be necessary (upgrade of the feedback system is required).
- ◆ Crab cavities will improve the beam-beam parameters, if necessary.

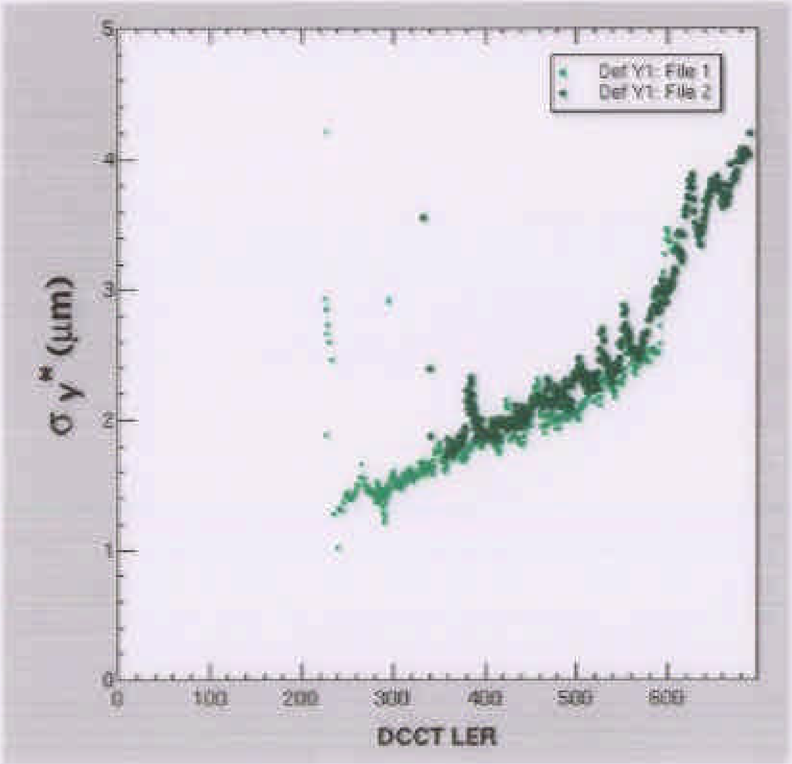
▼ Without major changes on the design, $1.5\times10^{34}cm^{-2}s^{-1}$ is within the scope of KEKB.

Parameters of KEKB

(6/19/2000) Achieved/Design(model)

	LER	HER	
Horizontal Emittance	30	30	nm
Beam current	550 (2600)	450 (1100)	mA
Number of bunches	1146 (2700)		
Bunch current	0.48 (0.96)	0.39 (0.41)	mA
Bunch spacing	2.4 (1.2)		m
Bunch trains	8 (159 bunches each)		
Horizontal size at IP $\Sigma_x/\sqrt{2}$	120 (145)		μm
Vertical size at IP σ_y^*	2.4 (1.45)	2.4 (1.45)	μm
Emittance ratio $\varepsilon_x/\varepsilon_y$	2.7 (1)	2.7 (1)	%
β_x^*/β_y^*	70 / 0.7	70 / 0.7	cm
beam-beam parameters ξ_x/ξ_y	0.053 / 0.033 (0.05 / 0.05)	0.030 / 0.019 (0.05 / 0.05)	
Beam lifetime	110 @ 550 mA	320 @ 450 mA	min.
Luminosity (Belle CSI)	19.4×10^{32}		$cm^{-2}s^{-1}$
Luminosity record per day / per week	90 / 504		pb^{-1}

Vertical beam size estimated from the specific luminosity per bunch is determined by the **LER** Current.

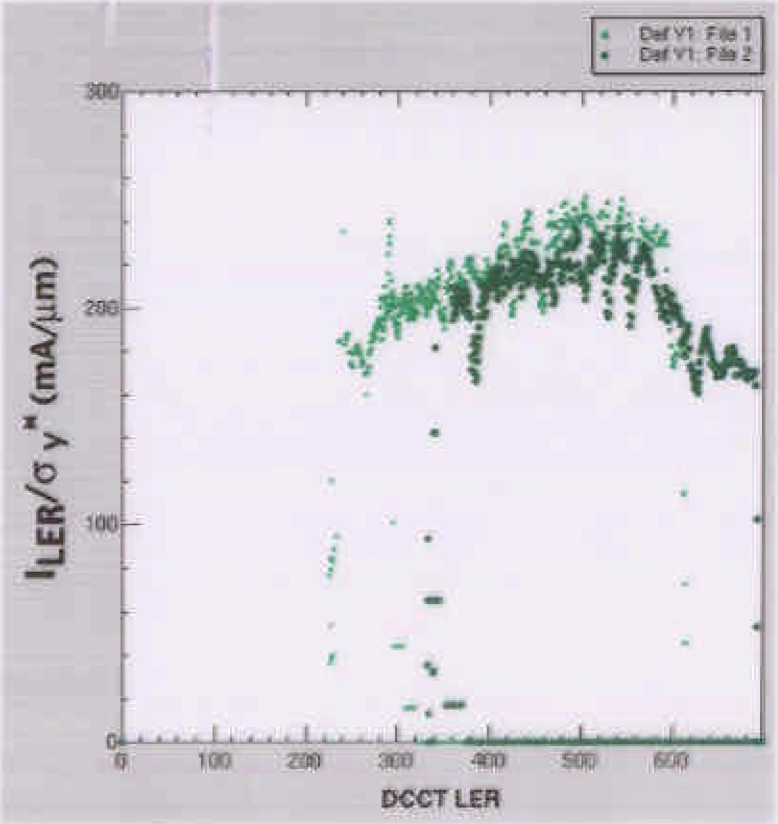


This blowup should be equivalent to the blowup seen by the interferrometer.

Under the presense of this blowup, what is the maximum luminosity?

$$L = \frac{(I_{\rm H}/N_b)I_{\rm L}}{4\pi e^2 f\sigma_x^*\sigma_y^*(I_{\rm L})}R_L$$

The ratio $\left(I_L/\sigma_y^*\right)$ has the maximum 0.24 (A/μm) at I_{LER} = 500 mA:



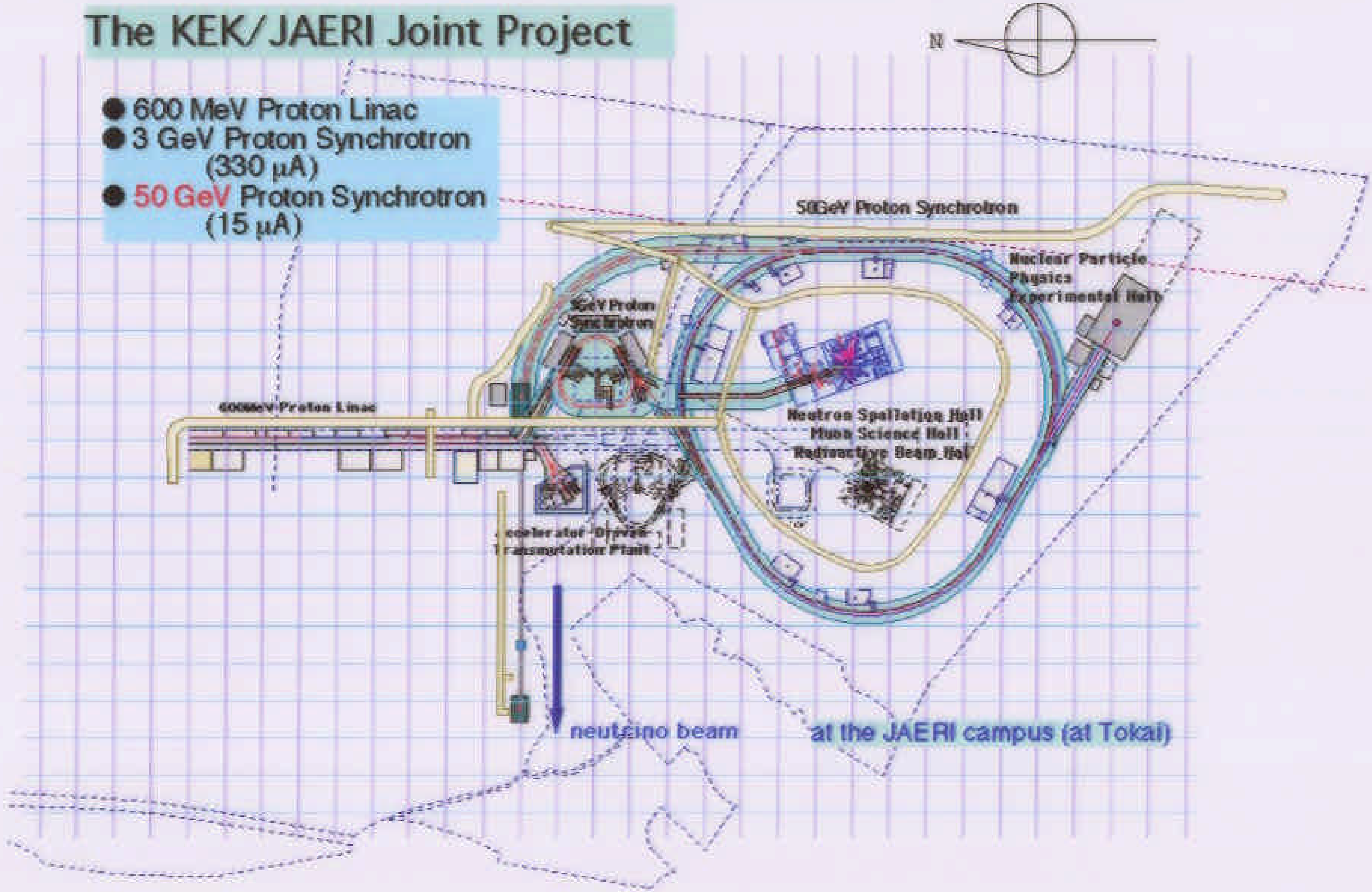
Performances of PEP-II and KEKB

	PEP-II	KEKB
Energy e^+/e^- (GeV)	3.1/9.0	3.5/8.0
Peak luminosity ($10^{33} cm^{-2} s^{-1}$)	2.28	2.04
Current e^+/e^- (A)	1.25/0.75	0.47/0.42
Number of bunches	606	1146
Beta function at IP β_x^*/β_y^* (cm)	50/1.25	70/0.7
Beam sizes at IP σ_x^*/σ_y^* (μm)	170/7.0	112(e^+), 145(e^-) /1. 7
Beam-beam tuneshift e^+ ξ_x/ξ_y e^- ξ_x/ξ_y	0.06/0.04 0.04/0.02	0.036/0.037 0.029/0.023
Max int. luminosity/day (1/pb)	151	90
Max int. luminosity/week (1/pb)	890	505
Int. luminosity by July 25 (1/fb)	16.0	6.9
Number of days for physics run	~ 300 since 5/99	~ 200 since 6/99

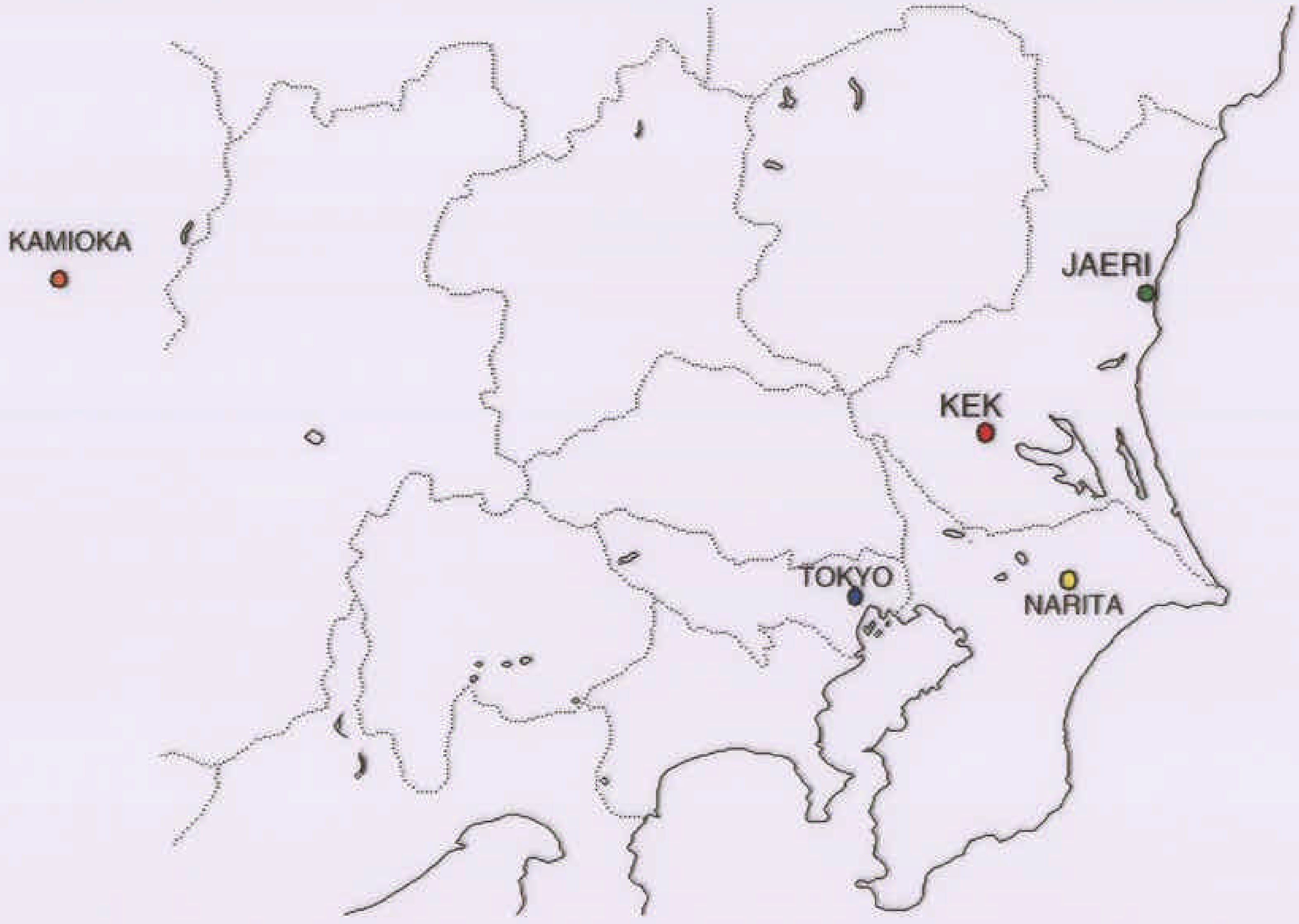
Plan View

The KEK/JAERI Joint Project

- 600 MeV Proton Linac
- 3 GeV Proton Synchrotron (330 μA)
- 50 GeV Proton Synchrotron (15 μA)



Site of JAERI at Tokai



JHF

1)Neutrino physics

close to bimaximal

$$U_{MNS} = \begin{pmatrix} \frac{1}{\sqrt{2}} - \mu, & \frac{1}{\sqrt{2}} + \mu, & \bar{\varepsilon} \\ -\left(\frac{1}{2} + \frac{\mu - \lambda}{\sqrt{2}}\right) - \frac{\varepsilon}{2}, & \left(\frac{1}{2} - \frac{\mu + \lambda}{\sqrt{2}}\right) - \frac{\varepsilon}{2}, & \frac{1}{\sqrt{2}} + \lambda \\ \left(\frac{1}{2} + \frac{\mu + \lambda}{\sqrt{2}}\right) - \frac{\varepsilon}{2}, & -\left(\frac{1}{2} - \frac{\mu - \lambda}{\sqrt{2}}\right) - \frac{\varepsilon}{2}, & \frac{1}{\sqrt{2}} - \lambda \end{pmatrix}$$

μ: solar

λ: atmospheric, K2K, MINOS, OPERA, ····

$\mathrm{Re}(\varepsilon) \simeq \theta_{13}$: JHF, MINOS, OPERA, ····

$\mathrm{Im}\varepsilon$: CP-violation → ν-factory

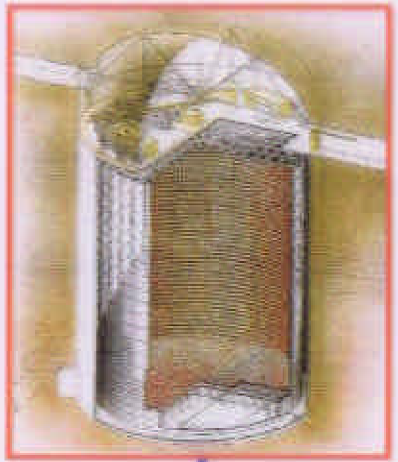
2)~~C~~PT check

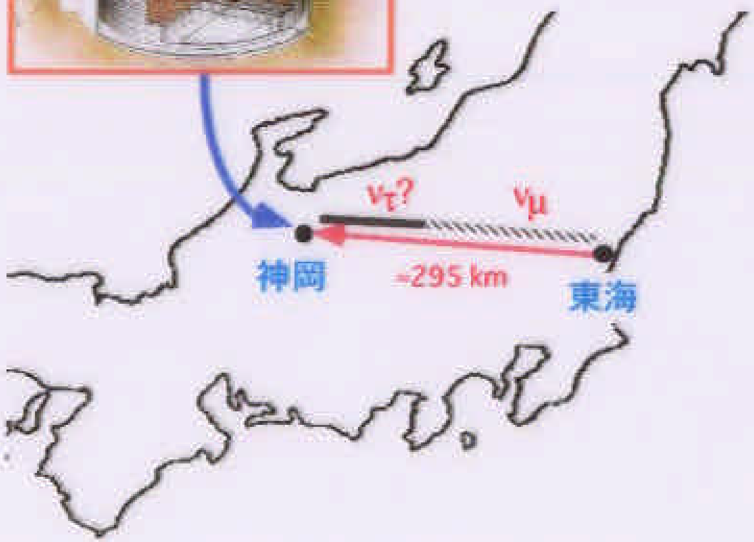
◎ antiproton source
anti hydrogen   hyperfine splitting

$\sim 10^{-13}$

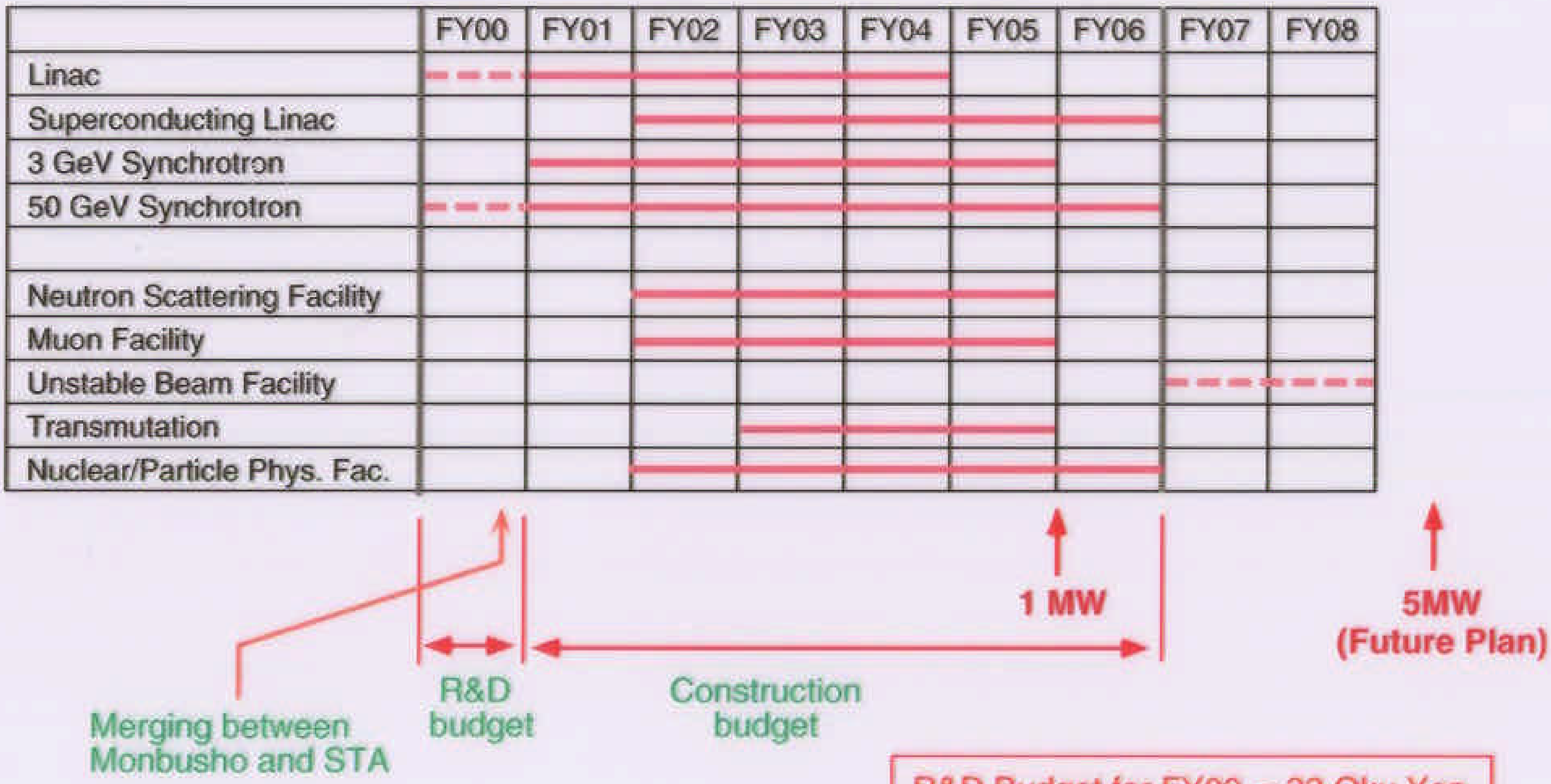
Nuclear/Particle Physics (1)

- Neutrino oscillation and neutrino mass (SuperK + K2K)
  - The existence of neutrino oscillation was suggested both by a SuperK's atmospheric ν experiment and the K2K ν_μ disappearance experiment.
- From neutrino mass to lepton family mixing (Joint Project)
  - Flux (ν_μ) at the Planned 50 GeV PS > 100 x Flux (ν_μ) at KEK 12 GeV PS
- Future facility ... towards CP violation





Proposed Schedule



R&D Budget for FY00 ≅ 33 Oku Yen

Total Project Cost ≅ 1,890 Oku Yen

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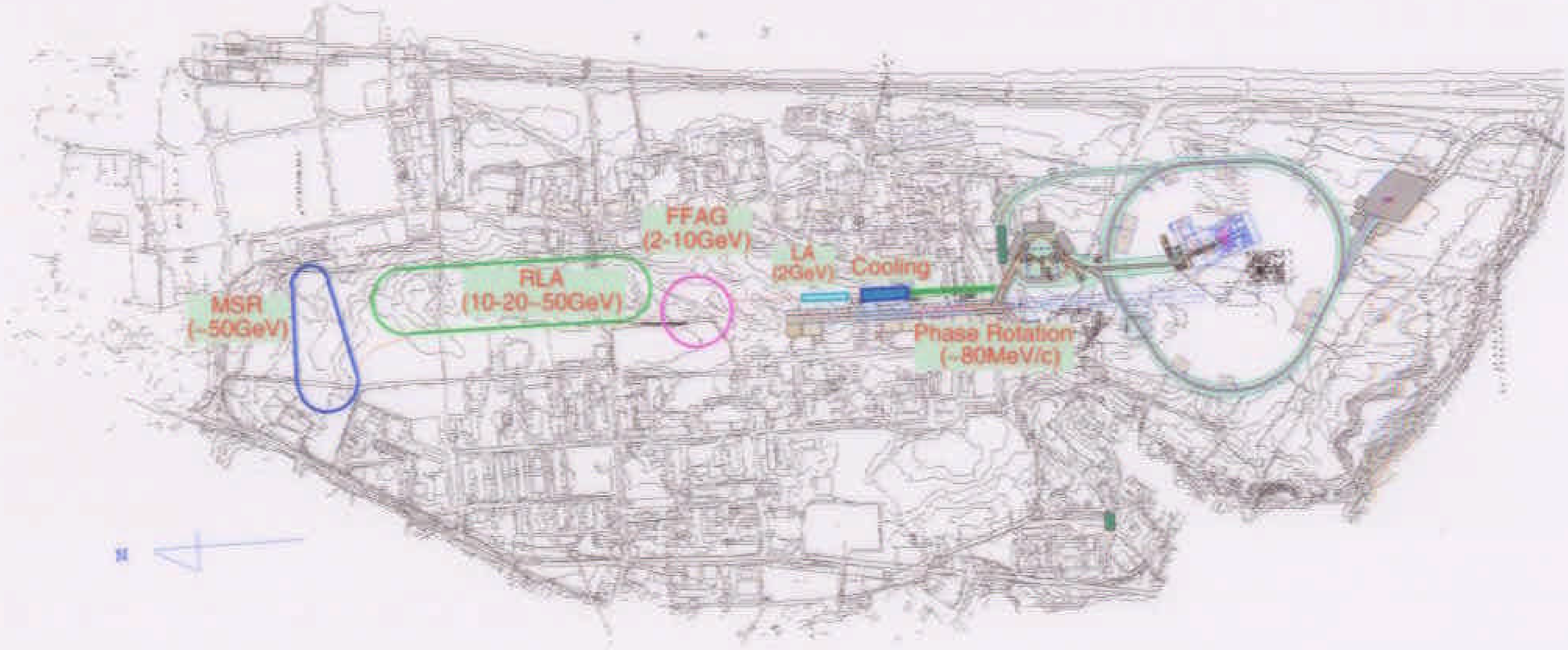
Possible Upgrades

- From 1 MW to 5 MW
  - Strong voice toward 5 MW from neutron scattering community.
  - Also, this upgrade is useful for nuclear transmutation.
- Nuclear/particle physics
  - Neutrino factory
  - Muon factory
  - Anti-proton accumulator ring
  - Ultra cold neutrons
  - Heavy-ion beams at about 20 GeV per nucleon
  - Polarized protons

Neutrino Factory 3/18/2000



JLC Status

- JLC is a Japanese project on e+e- linear collider (LC), which aims at an initial stage oepration at ECM = 500 GeV. The main linac scheme is based on the X-band technology, although as a back-up scheme the C-band R&D is also pursued.
- We intend to realize 500 GeV --> 1 TeV adiabatic upgrade with the same RF system: 55 MV/m loaded acc. gradient, which is realized by:
  - Conventional or solid-state-switch based modulator.
  - 75 MW, 1.53 μs X-band klystron with permanent-magnet focusing.
  - Highly efficient power distribution with DLDS (delay-line distribution system) concept.
  - Damped-Detuned Structure with Rounded corners (RDDS), 1.8 m-long each for accelerating trains of bunches (95 x 1.1E10 elec/bunch, 2.8 ns apart)
- We are yet to demonstrate beam acceleration with ultimate emittance preservation in a full-fledged, complete RF system above; but we have made good progress in recent component R&D.
- We have operated small / medium-scale systems at NLCTA (SLAC) and ATF Linac (KEK) for demonstrating certain aspects of technology that are needed at X-band linacs. ATF Damping Ring at KEK showed (in a limited-scale single bunch operation), obtaining ε_y = (2~3)E-11 m (unnormalized) is feasible.

KEK-SLAC ISG (Internat'l Study Group) on LC R&D

- Long-standing history of cooperation (since '80s)
- LC concepts with similar technology basis.
- MoU between the lab directors in early 1998 for: Joint efforts of certain pre-(conceptual) design work.
  - Common design parameters.
  - Common or mutually-compatible hardware schemes.

    Joint R&D on DLDS, Accelerating Structure.
    Parallel R&D on Modulators, Klystron.
    Mutual Review on Designs of Injectors, Beam Delivery.
    Increased U.S. participation in ATF at KEK.

  - Information sharing within the US-Japan HEP collab protocol.
  - Periodic general meetings (twice a year)
- Many labs and Univs involved besides KEK and SLAC.
- Report on 2-year activities has been submitted to the lab directors in April, 2000 (KEK Report 2000-7 / SLAC-R-559).
- Possible extension of the ISG collaboration is currently under discussion.

Recent results of ATF

Small vertical emittance with single bunch low intensity

vertical emittance $\varepsilon y = 1.7 \times 10^{-11}$
(beam intensity 2×10^{9})
emittance ratio $\varepsilon y / \varepsilon x =$ 1.3%

measured by wire scanner at Extraction line

large emittance growth by beam intensity is in question

New monitors are commissioned

Laser wire beam size monitor in Damping Ring

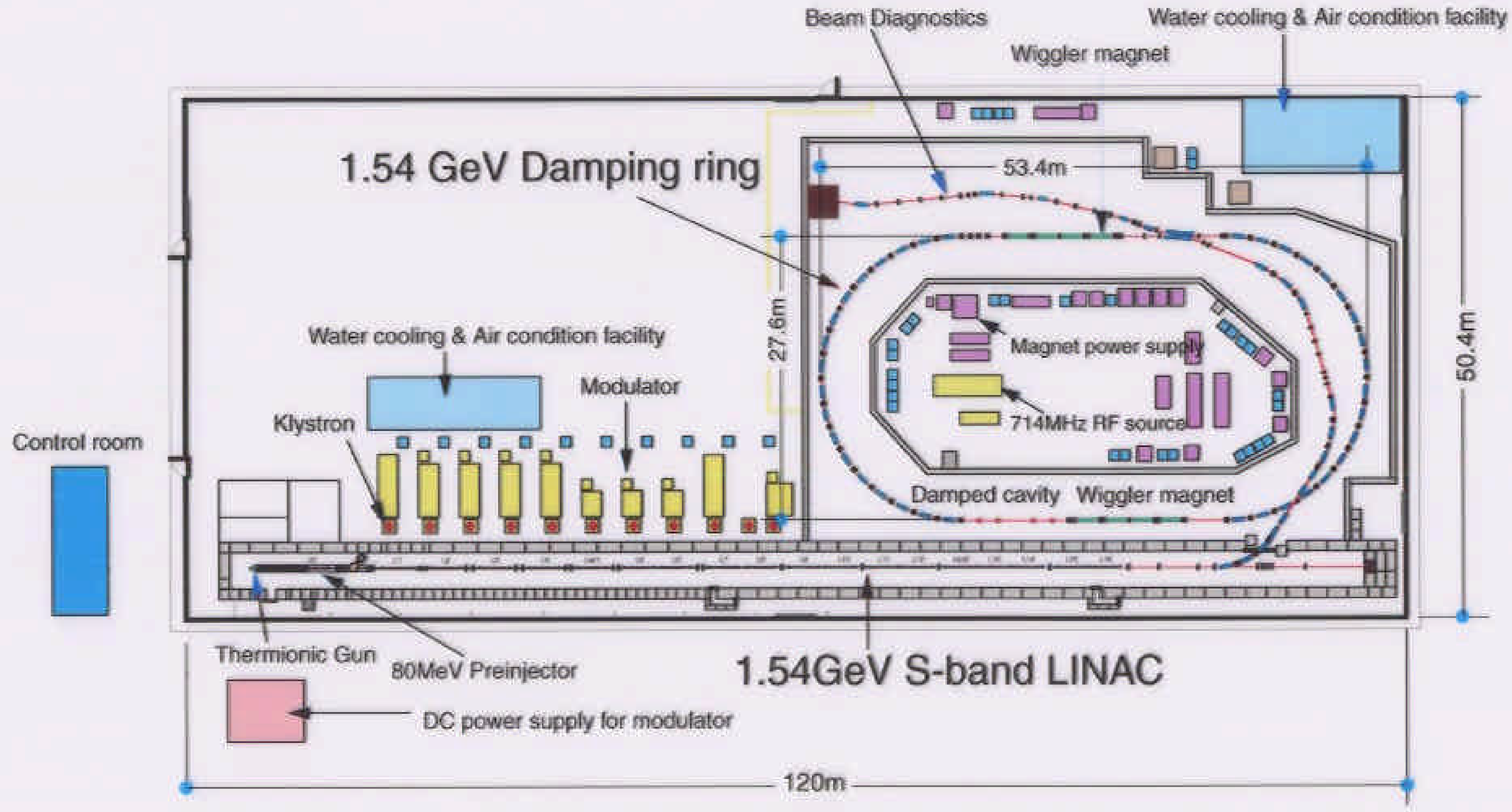
vertical beam size ~12μm ($\varepsilon y \sim 2.6 \times 10^{-11}$)
was consistent with SR monitor

Cavity BPM in Extraction Line

as a monitor for more stable beam extraction

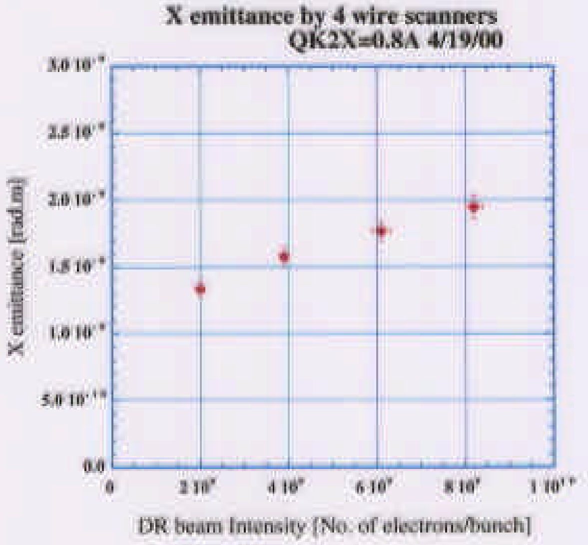
resolution 0.2μm

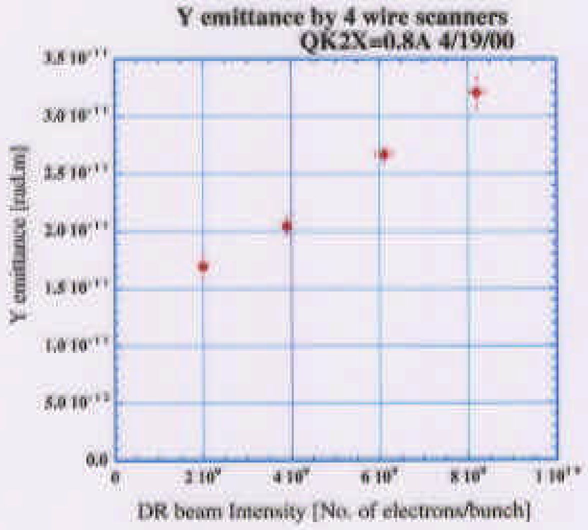
measured vertical beam position jitter ~4μm

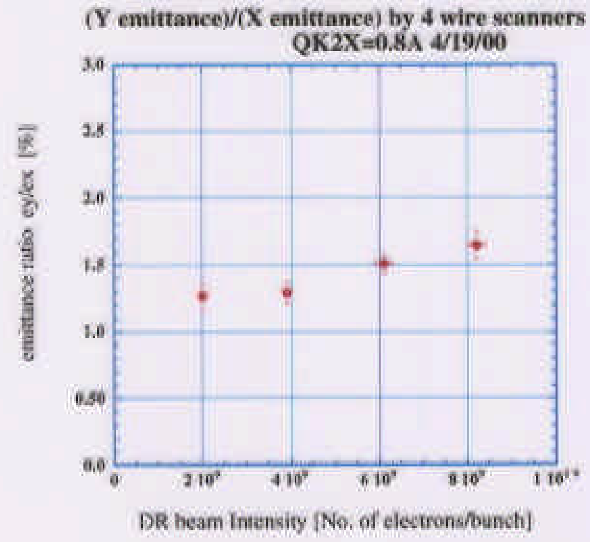


Beam Diagnostics
Water cooling & Air condition facility
Wiggler magnet
1.54 GeV Damping ring
53.4m
27.6m
50.4m
Magnet power supply
714MHz RF source
Damped cavity
Wiggler magnet
Water cooling & Air condition facility
Modulator
Klystron
Control room
Thermionic Gun
80MeV Preinjector
1.54GeV S-band LINAC
DC power supply for modulator
120m

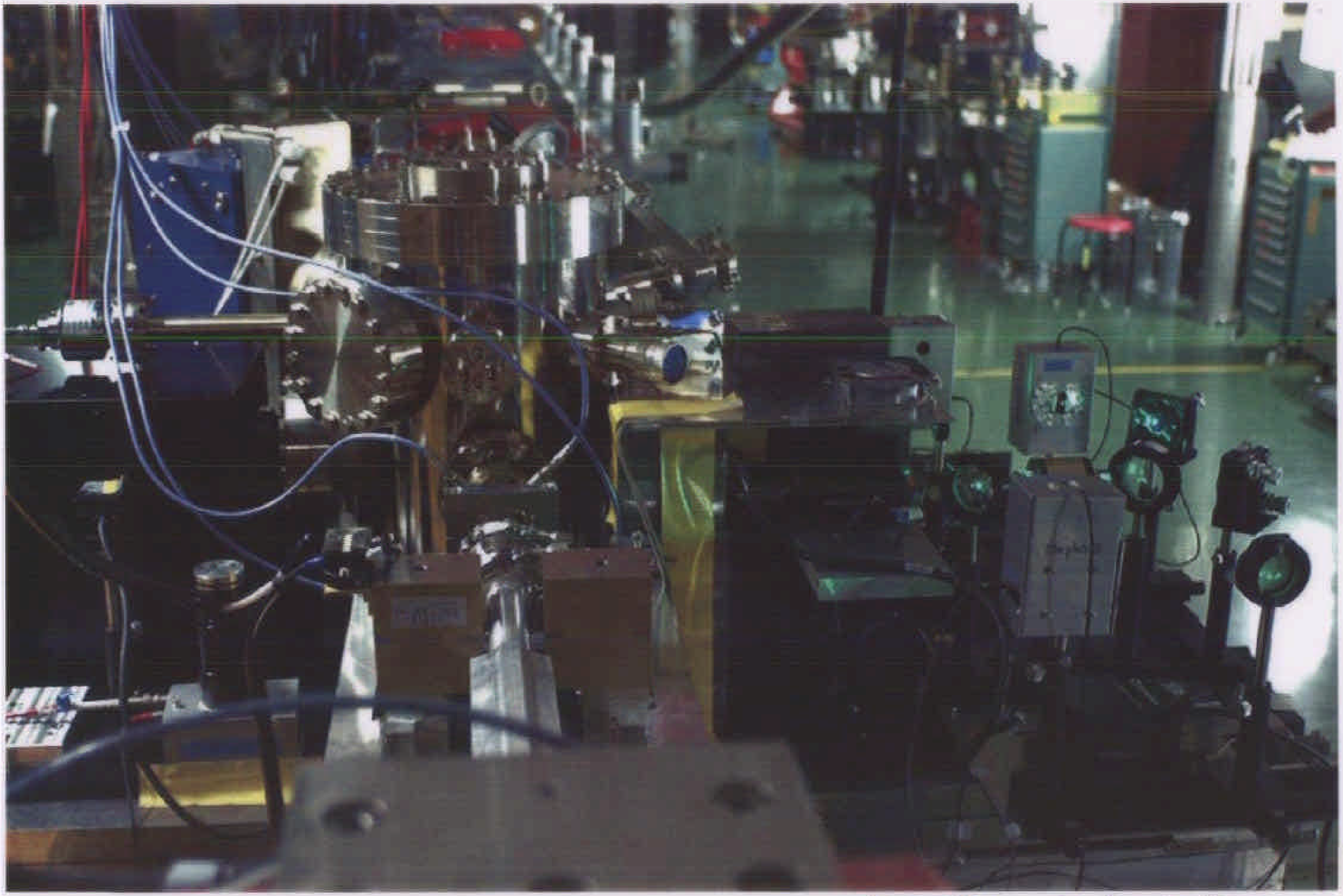
ATF DR
Single bunch emittance measured by wire scanners





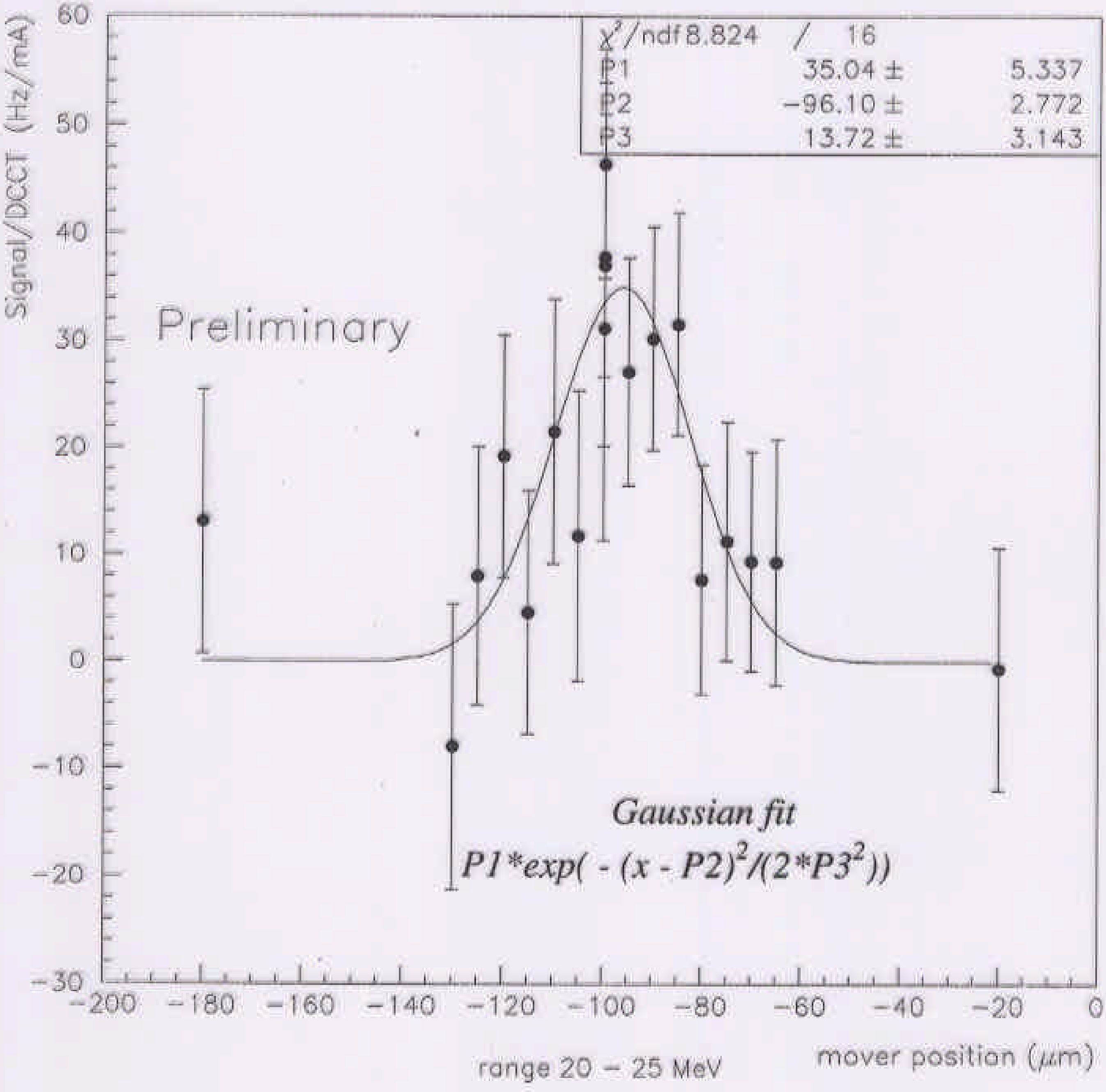


using QK2X=0.8A 4/19/00 meas.



Laser Wire in Damping Ring

Gaussian fit of Laser-wire signal



Phase-I R&D Summary

C-band Klystron	Klystron Modulator	RF Pulse Compressor	Accelerating Structure
50 MW, OK 2.5 μsec, 47 %	110 MW OK 100 pps	Flat Pulse Gain 3.3	1.8 m OK Choke-Mode
Life test >5000 hour, OK. 	Smart modulator using inverter HV charger. Running for klystron life test. 	Three-cell cavity.  1 m long cold model. 	Beam acceleration at 50 MV/m was done at ATF-KEK, with S-band model. HOM damping performance was proved by ASSET-SLAC test, 1998. 

Machine Parameters

Overall Parameter	
C.M. Energy	500 GeV
Nominal Luminosity	4.2×10^{33}
Beam Current	1.6nC x 72 bunch x 100 pps
Spot Size at IP	4 x 300 nm
Bunch Length	0.2 mm
Bunch Separation	2.8 nsec
Main Linac Parameter	
Main Linac Length	14 km
Number of RF Unit	2000 Units
AC Power	200 MW

Klystron	
Klystron Power	50 MW, 2.5 μsec
Modulator	110 MW, 25 kV
Efficiency	50%
RF Pulse Compressor	
Compression Gain	x 3.5
Efficiency	70%
Accelerating Structure	
Accelerating Gradient	36 MV/m (with beam) 45 MV/m (no load)
Shunt-Impedance	60 MΩ/m
Alignment Tolerance	50 μm