On the future plan of KEK for ILC(International Linear Collider)

Junji Urakawa(KEK)

2004.10.24

Contents

Simple explanation until now.

ILCSC was organized under ICFA. ILCSC made ITRP and Task Force, the technology selection (Warm or Cold) for main linac was done by ITRP on Aug. 2004. Task Force is discussing the organization on GDI. Selection of GDI Director is doing under Task Force. Also, it will be select the place for GDI until the end of Feb..

International Linear Collider is called as ILC and we do not use TESLA.

GDI Central Team will complete the CDR of ILC and the TDR until the end of 2007.

ILC Site will be decided in 2008 (Mega Science Forum of OECD organized FALC (Funding Agency for LC) in last year(2003). Japanese Government people attended two times.

Ground Breaking of ILC is planned from 2009 to 2010

KEK and High Energy Physics Society of Japan will announce following sentence.

We intentionally contribute the R&D of ILC.

KEK is center of Asian regional team for GDI.

ATF is COE (Center Of Excellence).

ILC Site will be decided in 2008 (Mega Science Forum of OECD organized FALC (Funding Agency for LC) in last year(2003). Japanese Government people attended two times.
Ground Breaking of ILC is planned from 2009 to 2010.
KEK and High Energy Physics Society of Japan will announce following sentence.
We contribute the R&D for ILC in the framework.
KEK will become Asian Regional Team for GDI.
ATF will be important R&D place for ILC.
First ILC Workshop at KEK will be held from 13 to 15 in Nov..

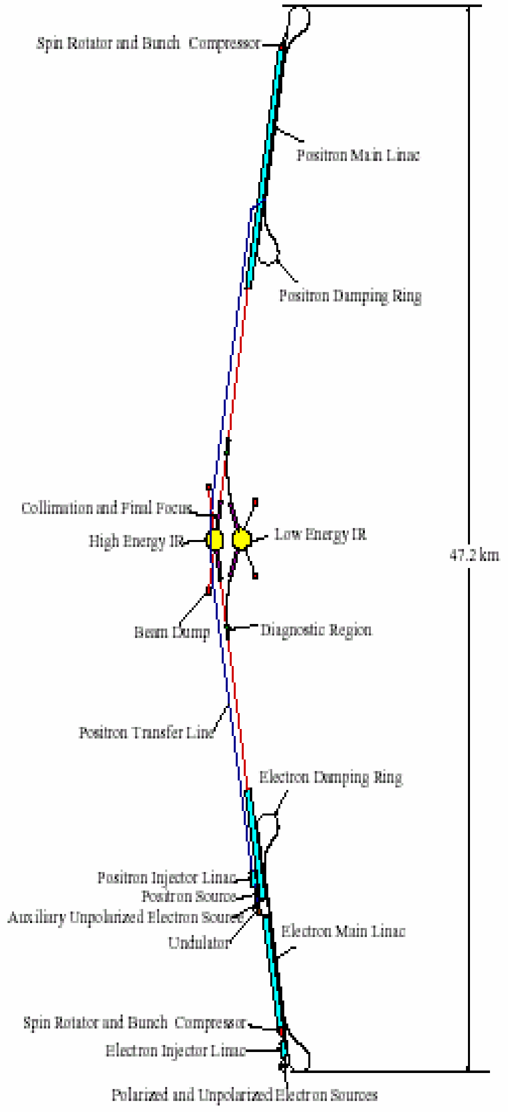
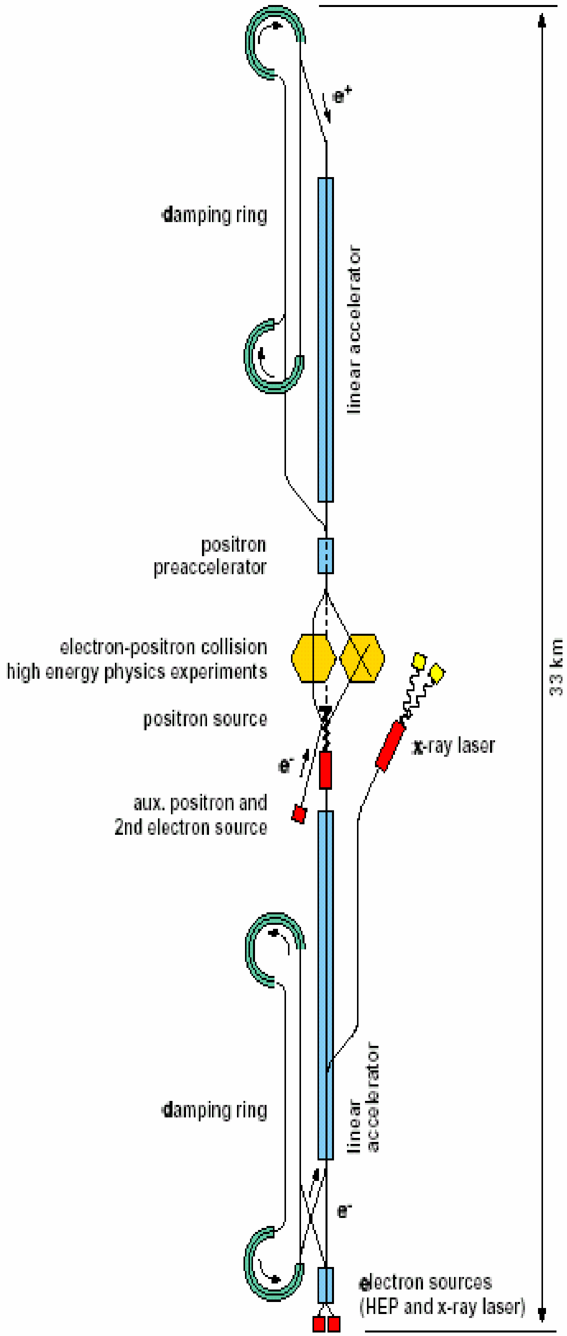
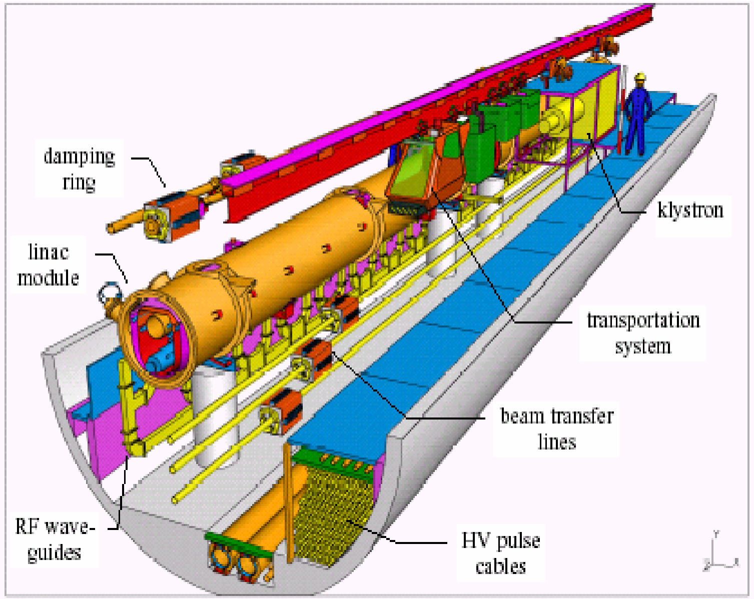


Figure 1.1: Overall Machine Layout, 500 GeV c.m.



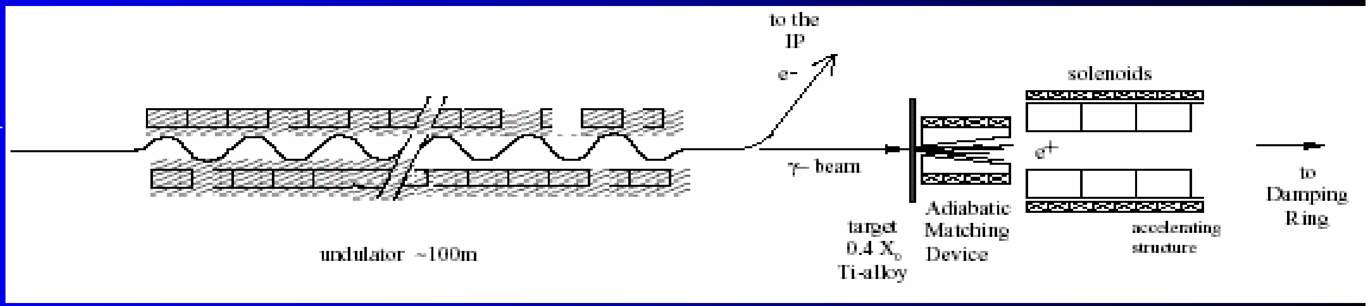
Case Study by US.
TESLA 47.2km
DESY TESLA 33km

Problem
Positron Source
Damping Ring
Coupler
Complicated Structure
One Tunnel or Two Tunnels

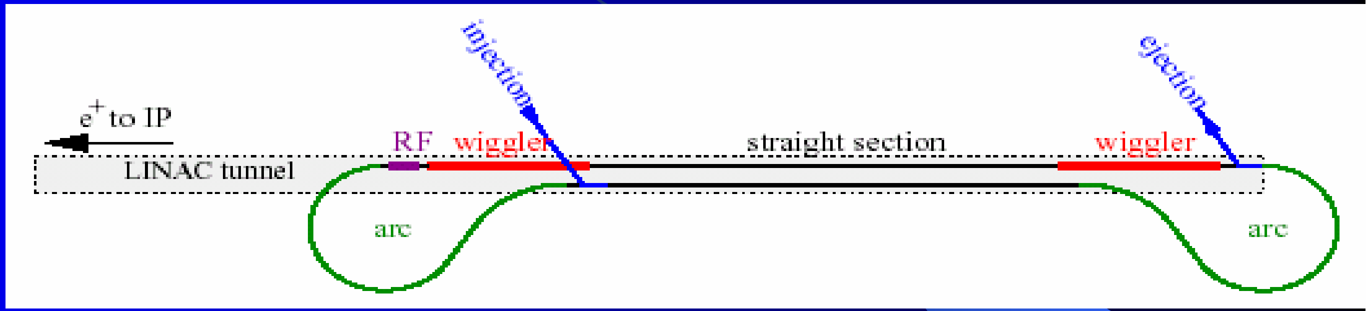


2004/12/12

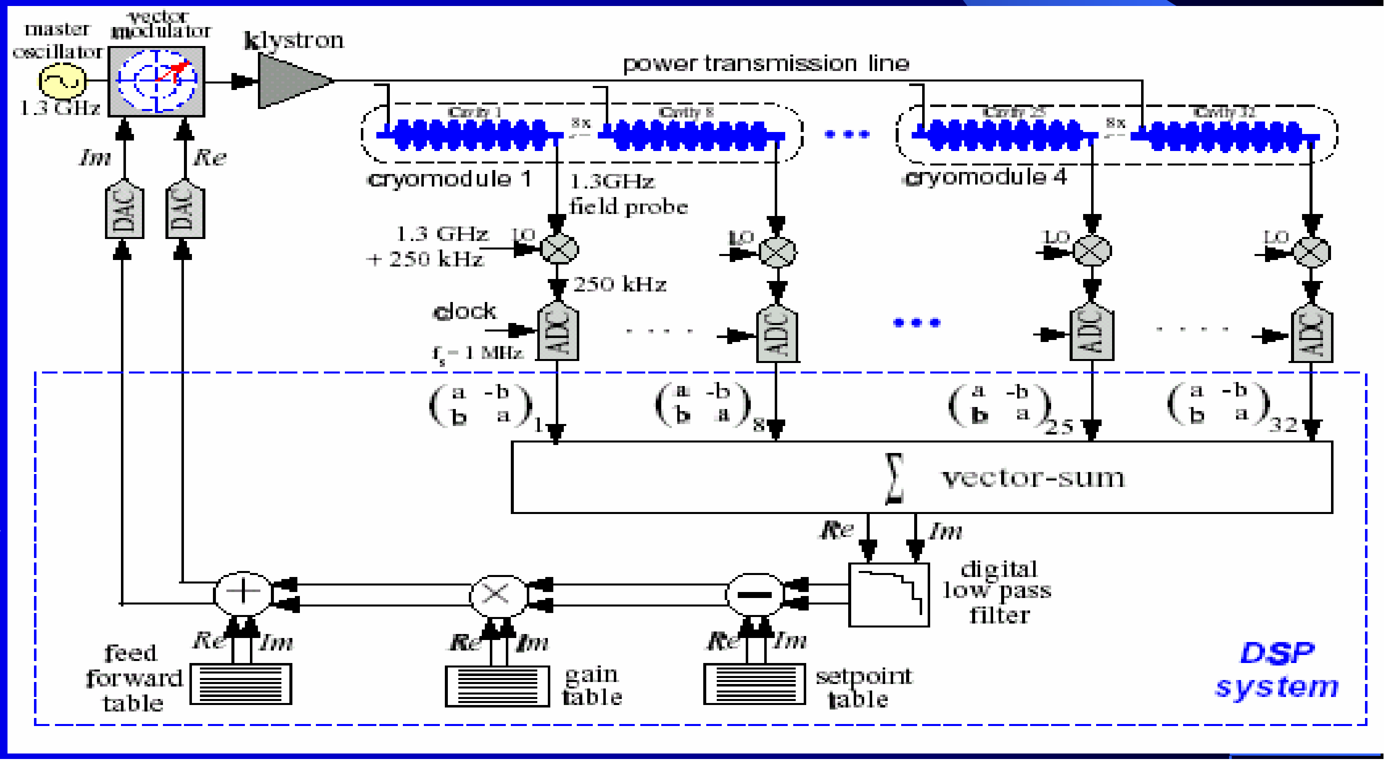
Positron generation using long wiggler(>100m) with 150GeV electron beam and transportation of electron beam to the IP



17km Damping ring,
Fast Kicker
3MHz Rep. Rate
Less 20nsec Rise and Fall Time
Long Wiggler >400m



Feedback system and Coupler
9 cells/cavity
12 cavities/module
3 modules/klystron
Module length:16.8m
1 module system:1.0 Oku¥
1TeV : 2000 modules



2004/12/12

Damping Ring Issues : ATF Study Issues How to make the design of small DR? Very fast and stable kicker is necessary.

- Fast Ion Instability and Electron Cloud Instability
- Damping Wiggler Issue
- Beam Injection and Extraction Scheme
- There are many proposed designs in the world.

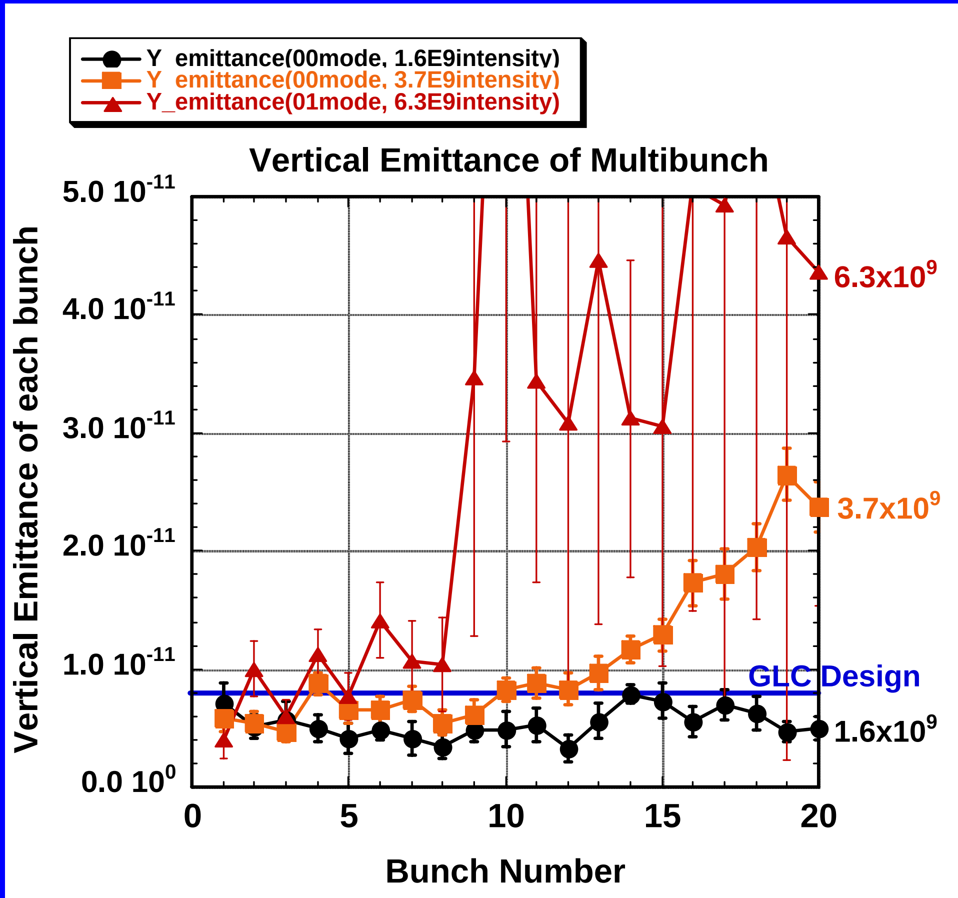
1.Burst Fourier series kicker

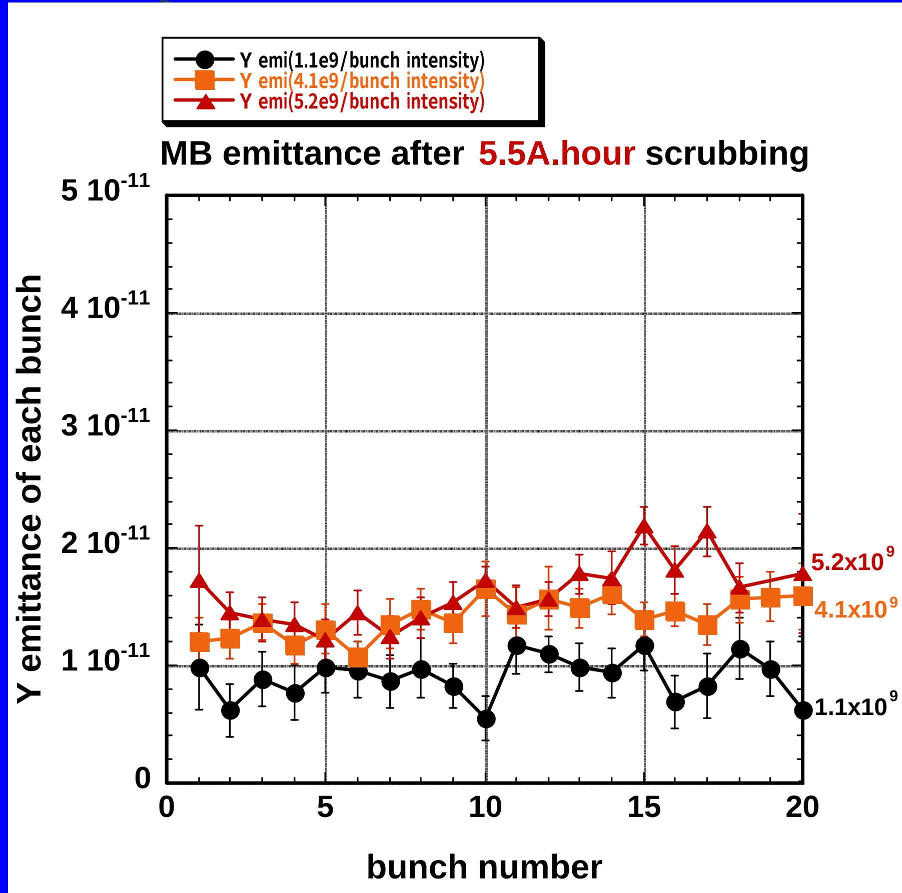
2.Very fast kicker

Thank to International Collaborators for useful information.

Fast Ion Instability: Experimental Results at ATF

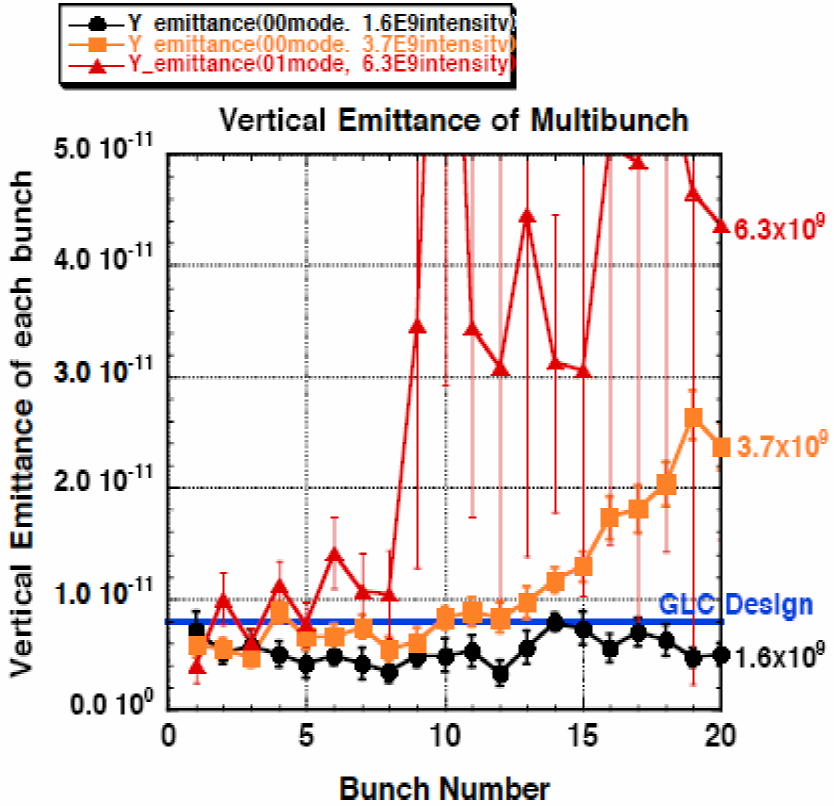
Required vertical emittance : 1pm・rad



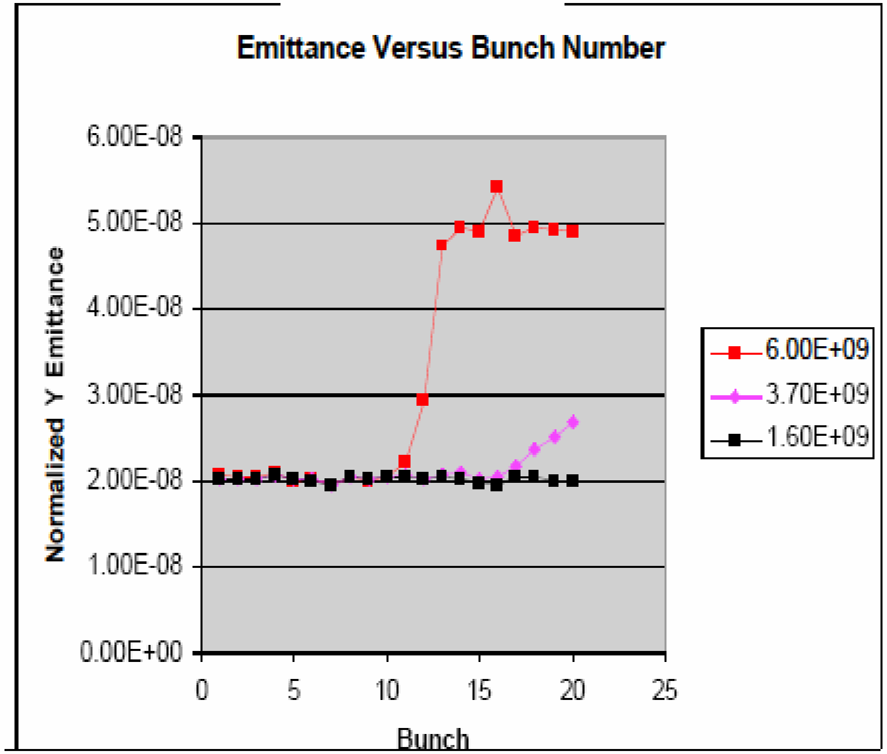


Vacuum Pressure$<10^{-8}$ Pa

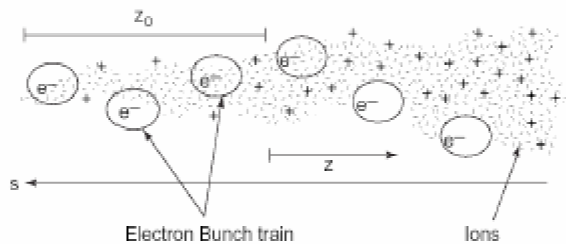
Preliminary result of Fast Ion Instability simulation



simulation



Behavior of Y emittance is very similar.



Schematic of the Fast-Beam Ion Instability

Electron Cloud Instability
B-Factory(KEKB and PEP-II) can contribute to this study.

ATF will start the study of wiggler from this Nov..

Nobody knows 400m long damping wiggler is workable or not. Total length of ATF wigglers is only 8.4m but this study is very important because the performance of the damping wiggler is not demonstrated clearly.

Introduction

Linac beam (TESLA TDR):

•2820 bunches, 337 nsec spacing (~ **300** kilometers)

•Cool an entire pulse in the damping rings before linac injection

Damping ring beam (TESLA TDR):

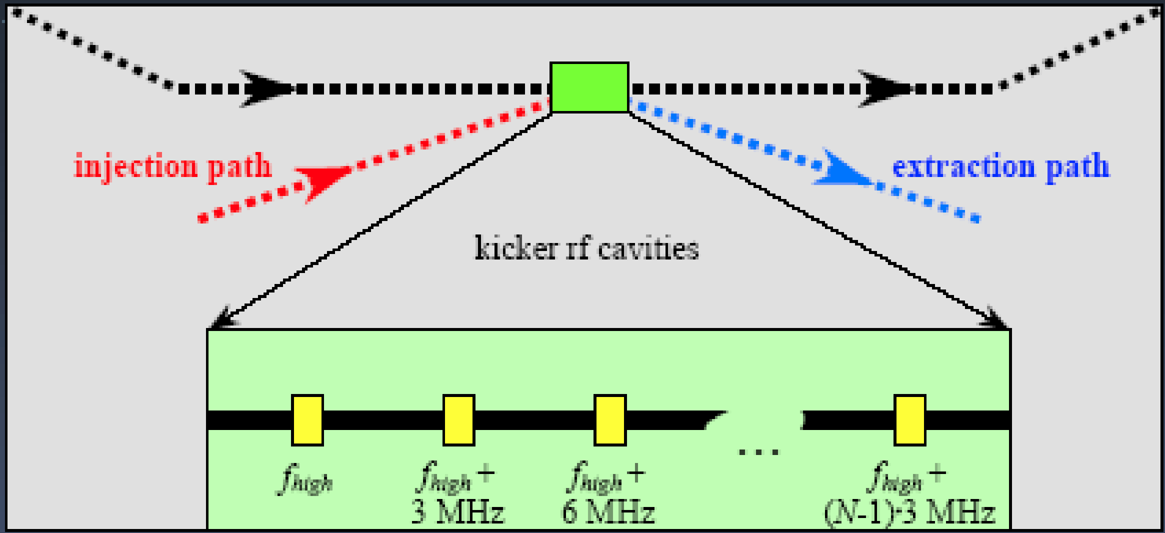
•2820 bunches, ~20 nsec spacing (~ **17** kilometers)

•Eject every n^{th} bunch into linac (leave adjacent bunches undisturbed)

Kicker speed determines minimum damping ring circumference.

We are investigating a "Fourier series kicker": use a series of rf cavities to create a kicking function with periodic zeroes and an occasional spike. Perhaps closer bunches/smaller damping ring will be possible?

A different idea: "Fourier series kicker"



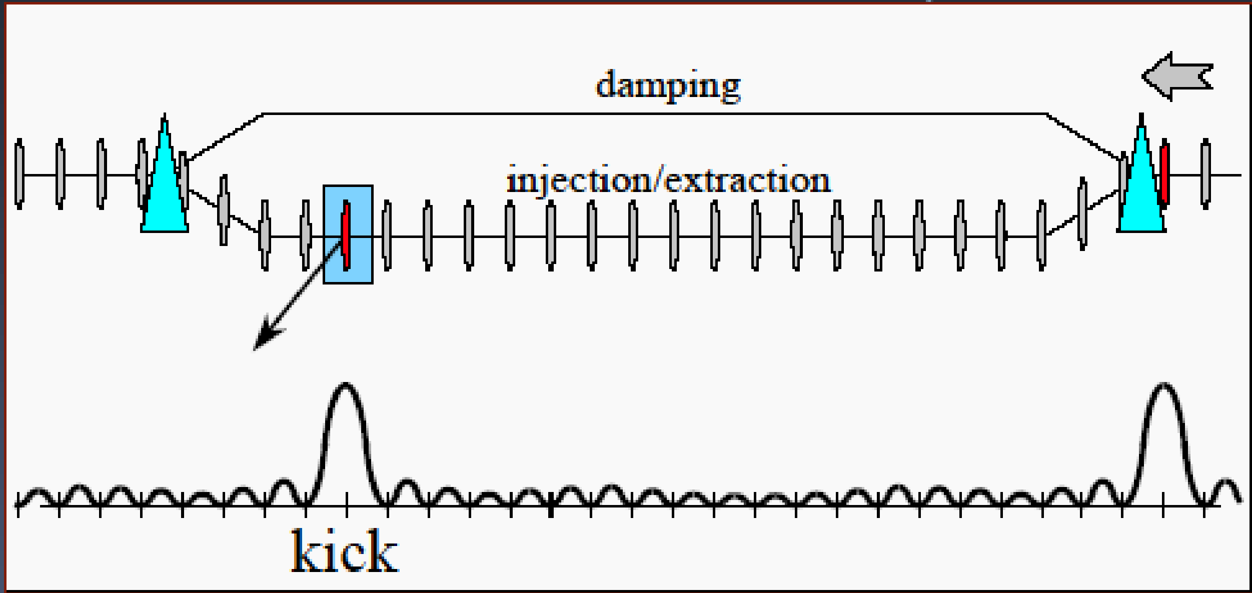
Kicker would be a series of *N* "rf cavities" oscillating at harmonics of the linac bunch frequency 1/(337 nsec) ≈ 3 MHz:

$$p_T = A\left[\sum_{j=0}^{j=N_{cavities}-1} A_j \cos\left[\left(\omega_{high} + j\omega_{low}\right)t\right]\right]; \quad \omega_{low} = \frac{2\pi}{337\ \text{ns}}$$

Damping ring operation with an FS kicker

Fourier series kicker would be located in a bypass section.

While damping, beam follows the upper path.



During injection/extraction, deflectors route beam through bypass section. Bunches are kicked onto/off orbit by kicker.

SCRF and transverse kick minimize beam-induced fields in cavities.

Comparison of the three designs

	~3km(e^+/e^-)	~6km(e^+/e^-)	Dogbone(e^+/e^-)
Energy	5GeV	5GeV	5GeV
Circumference	3.067km	6.114km	17km
Natural emittance	0.623nmr	0.548nmr	0.8nmr
Transverse damping time	19.2/19.2mses	26.7/26.7mses	28/50msec
Current	883mA	443mA	160mA
Bunch spacing	3.628nsec	6.0nsec	20.0nsec
Energy loss/turn	5.34MeV	7.73MeV	21MeV
Tunes Qx, Qy	51.28, 31.59	56.58, 41.61	72.28, 44.18
Chromaticities ξx, ξy	-128, -70.2	-74.4, -55.4	-125,-68
Momentum compaction	2.86×10^{-4}	1.42×10^{-4}	1.2×10^{-4}
Natural bunch length	6.03mm	6.00mm	6.00mm
Natural energy spread	1.16×10^{-3}	1.51×10^{-3}	1.3×10^{-3}

TESLA Parameters

	500GeV	800GeV
Accelerating Gradient	23.8MV/m	35.0MV/m
Repetition Rate	5Hz	4Hz
Beam Pulse Length	950μm	860μm
Number of Bunches/Pulse	2820	4886
Bunch Spacing	337nsec	176nsec
Charge per Bunch	3.2nC	2.2nC
Beam Size at IP	553nm, 5nm	391nm, 2.8nm
Bunch Length at IP	0.3mm	0.3mm
Luminosity	3.4×10^{34}	5.8×10^{34}

1.4×10^{10} particles/bunch

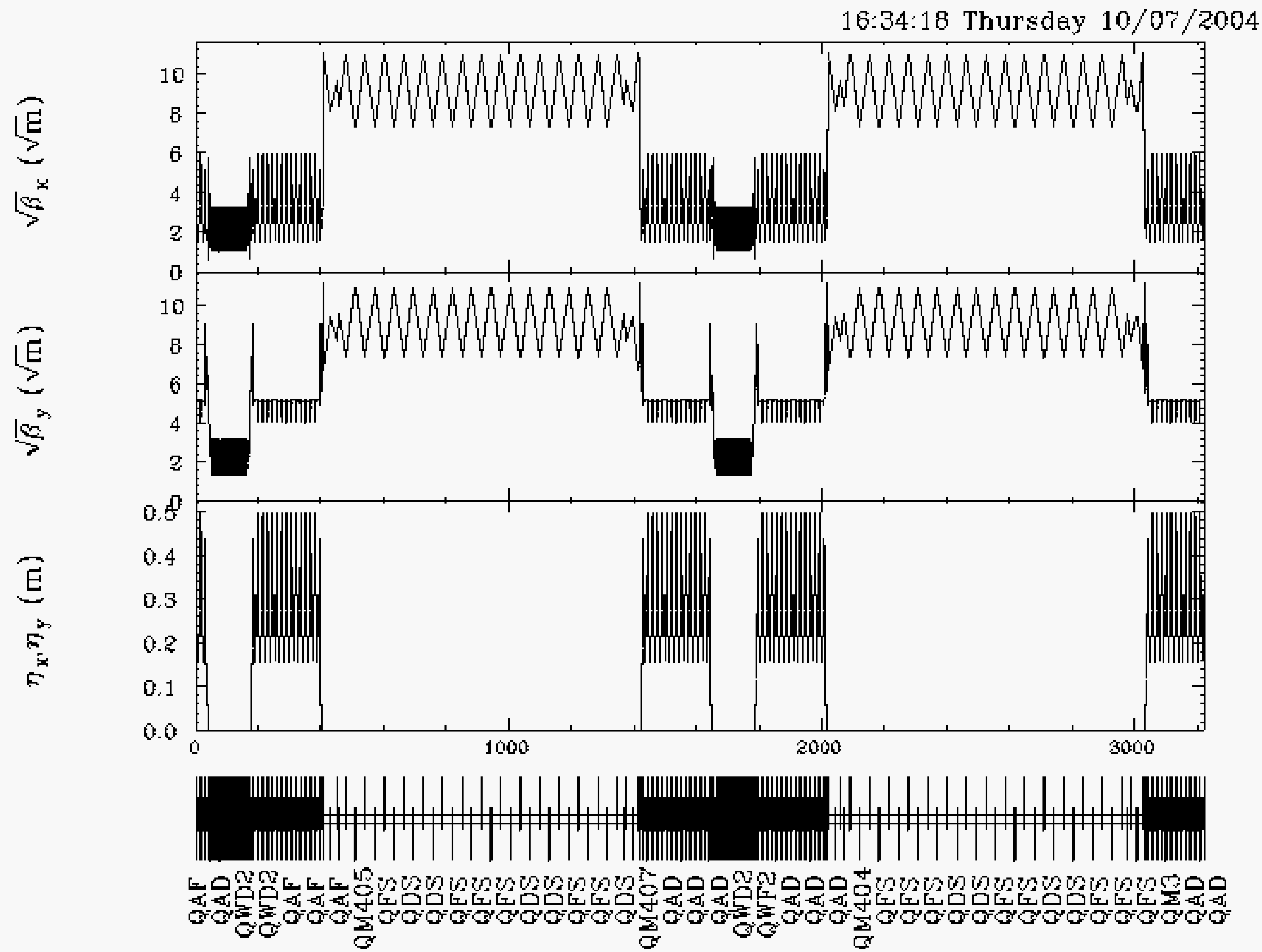
176nsec bunch spacing

Select Parameters of 800GeV case.

Dr_TME5.1 Parameters

Energy		5 GeV
Circumference		3223.82 m
Equilibrium emittance		3.97e-10 m
Revolution Frequency		92993 Hz
Damping time		12.2/12.2/6.08 msec
Number of bunch train		60
Number of bunches/train		43
Train spacing		61.6(58.8) nsec
Bunch spacing		2.8 nsec
Number of particle/bunch		1.4e10
Current		528 mA
Energy loss/turn		8.85 MV
Tune νx , νy		45.364, 24.557
Momentum compaction factor		3.62e-4
Effective voltage		16 MV
Bucket height		1.45 %
Equilibrium bunch length		7.37 mm
Momentum spread		0.136%
Dynamic Aperture (to be multiplied by square root 2)	δ=-1%	30 σ_0
	δ=-0.5%	48 σ_0
	δ=0%	64 σ_0
	δ=0.5%	40 σ_0
	δ=1%	30 σ_0

2004/12/12



16:34:18 Thursday 10/07/2004
$\sqrt{\beta_x}$ ($\sqrt{m}$)
$\sqrt{\beta_y}$ ($\sqrt{m}$)
η_x, η_y (m)
0
2
4
6
8
10
0.0
0.1
0.2
0.3
0.4
0.5
0
1000
2000
3000
QAF
QAD
QWD2
QWD2
QAF
QAF
QAF
QM405
QM407
QAD
QWD2
QWF2
QM404
QFS
QDS
QM3

Example : 179nsec b. spacing 2.2nC/b. Ring rf 714MHz Reduce gap space. Increase number of bunch.

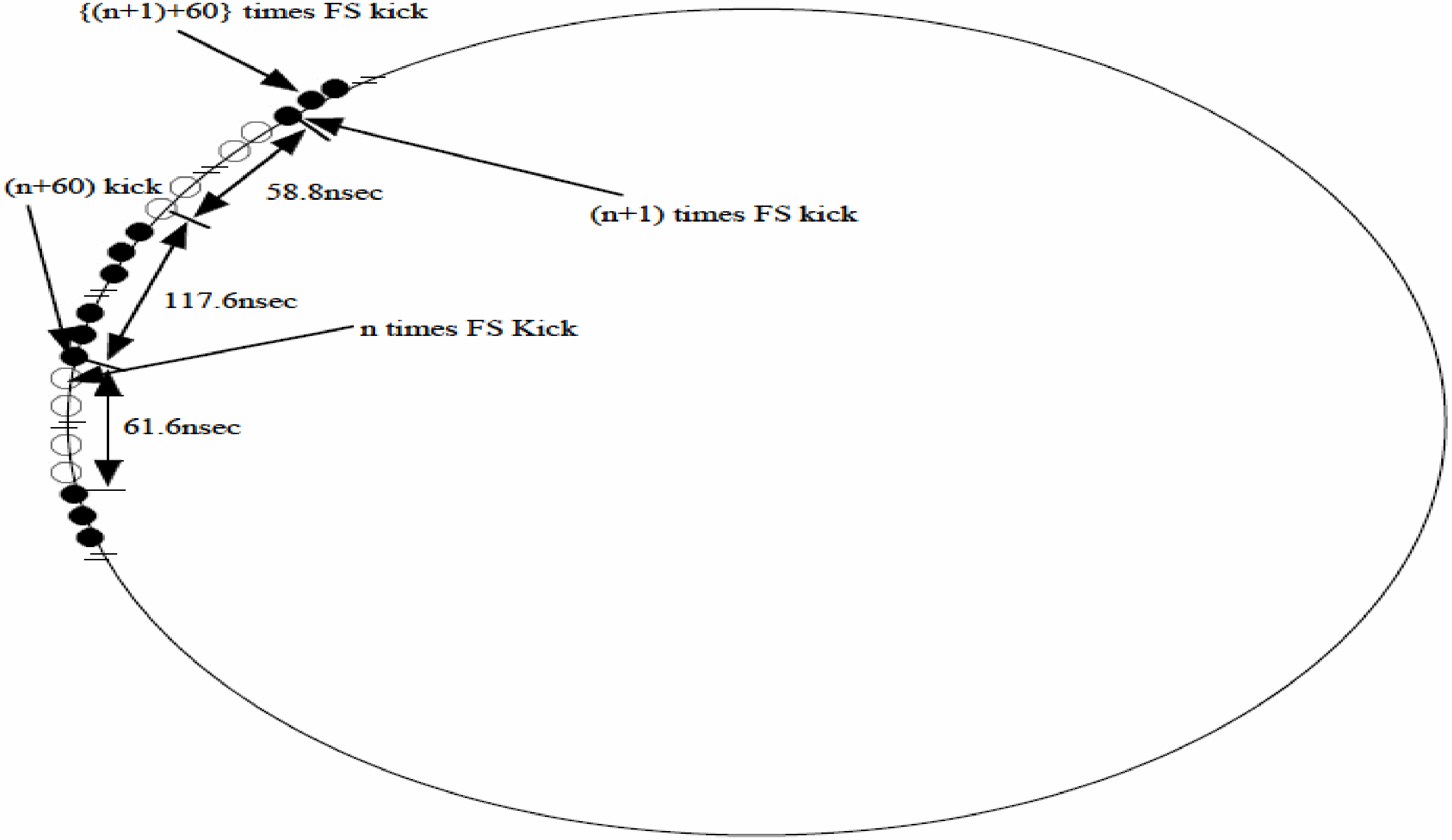
2004/12/12

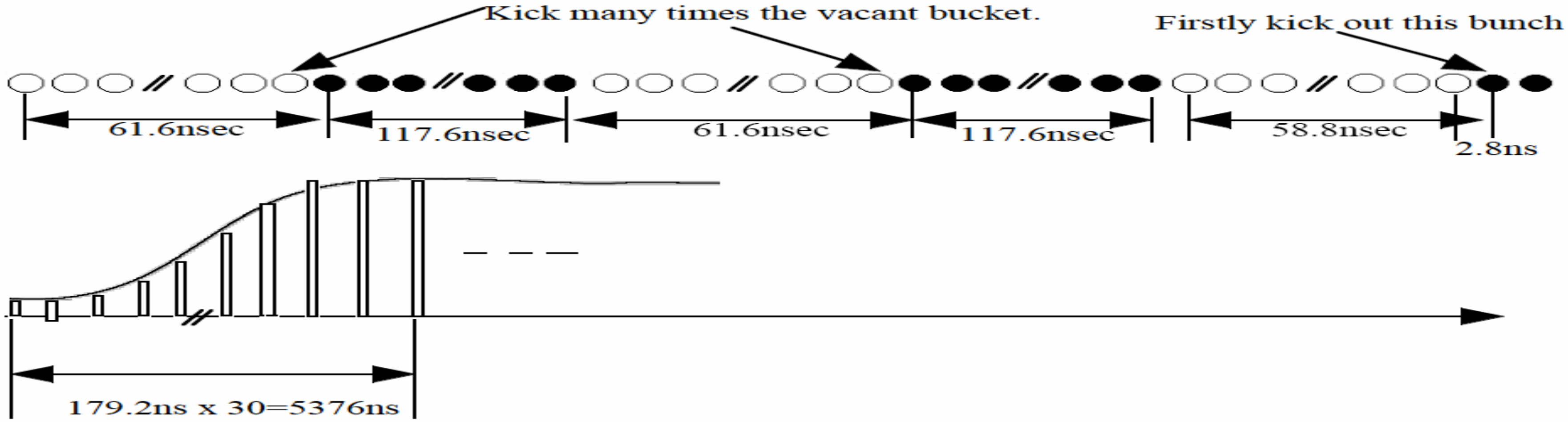
179.2717087nsec, f_0=5.578125MHz, x128=714MHz=f_{rf}, x4=2856MHz

Train Spacing : 61.62464986nsec (=22x2/f_{rf})

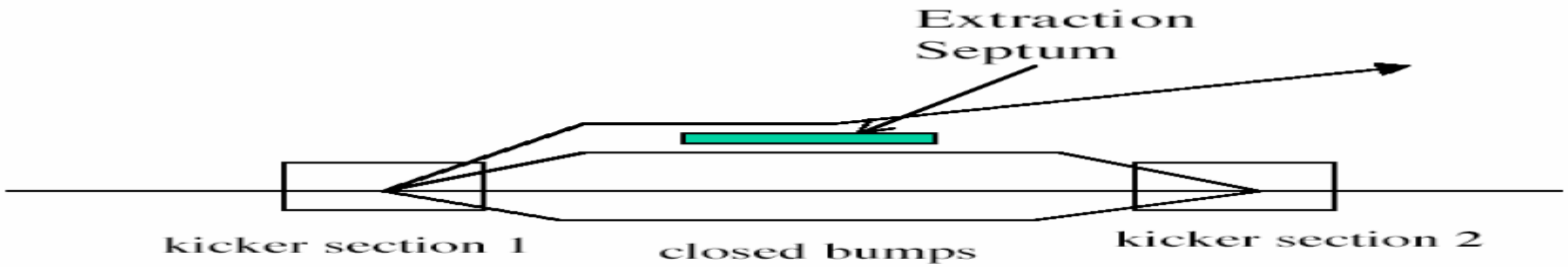
Special Train Spacing : 58.82352941 (=21x2/f_{rf})

60 Trains in DR, 43 bunches/train, Total bunches =2520 bunches
Bunch Spacing=2.8nsec, Bunch Charge=2.2nC
600Hz S-band Linac is Injector with 43 bunches/pulse.
Damping Time is less than 14msec. Seven damping time gives for positron cooling. Damping Time is less than 20msec for electron cooling. DR Circumference is 3.2238km. Chicane is necessary to control the length of the circumference. Lattice is TME. 515.6mA
1.2997GHz=1/179.2717087nsec x 233





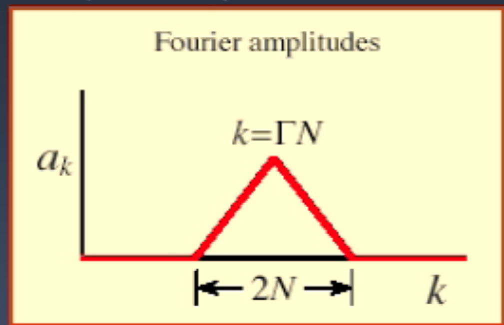
Rise time until $179.2*60*22t_b=236544$ ns is possible. Very stable Fourier series kicker is necessary (Maybe 0.05%).



5Hz, 1msec, 16 (32,64) RF High Power Pulser for Double Kicker which makes Bump orbit in DR. Above values are maybe not optimum.

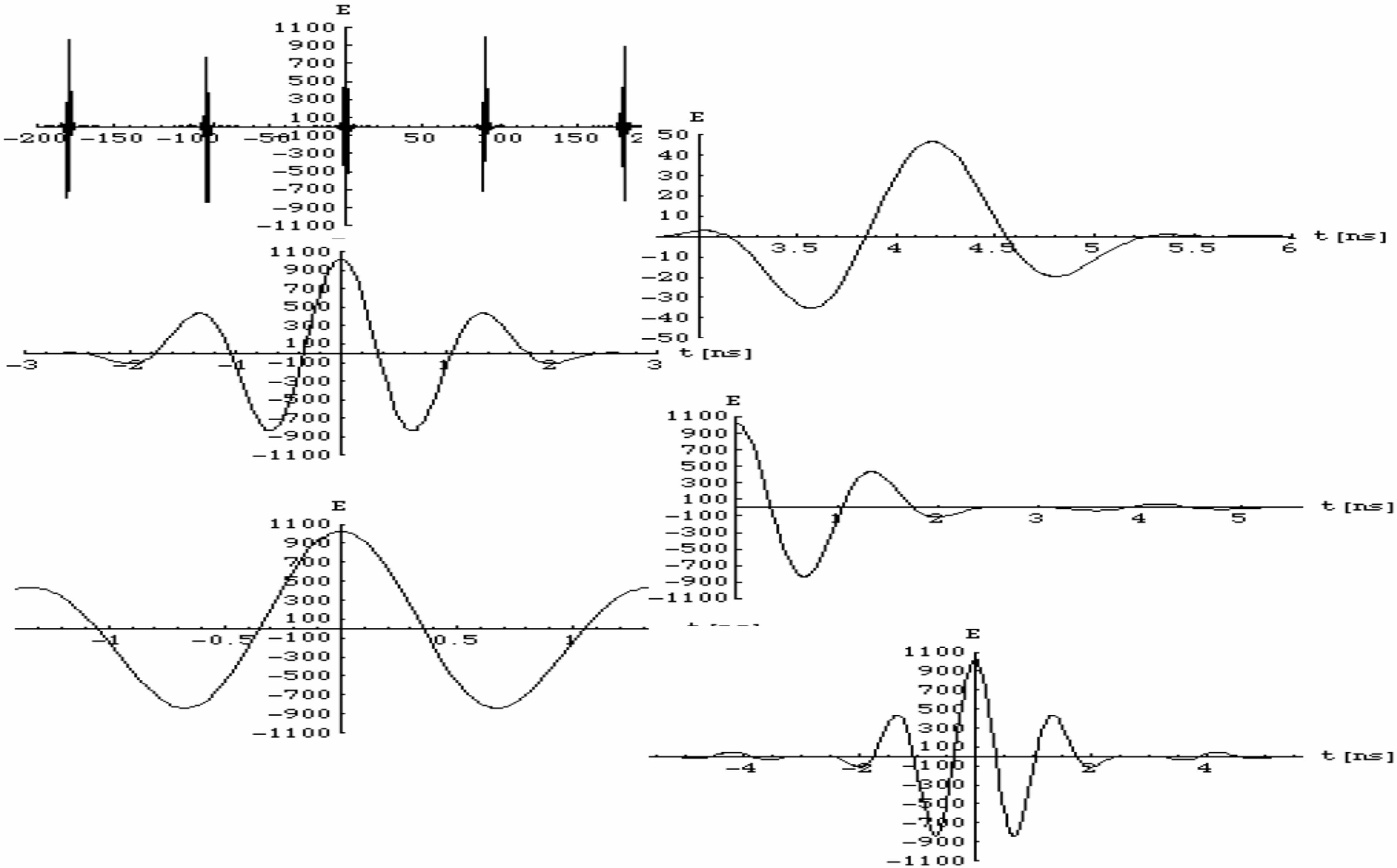
3. high-frequency modulate: this way fractional bandwidth is reduced.

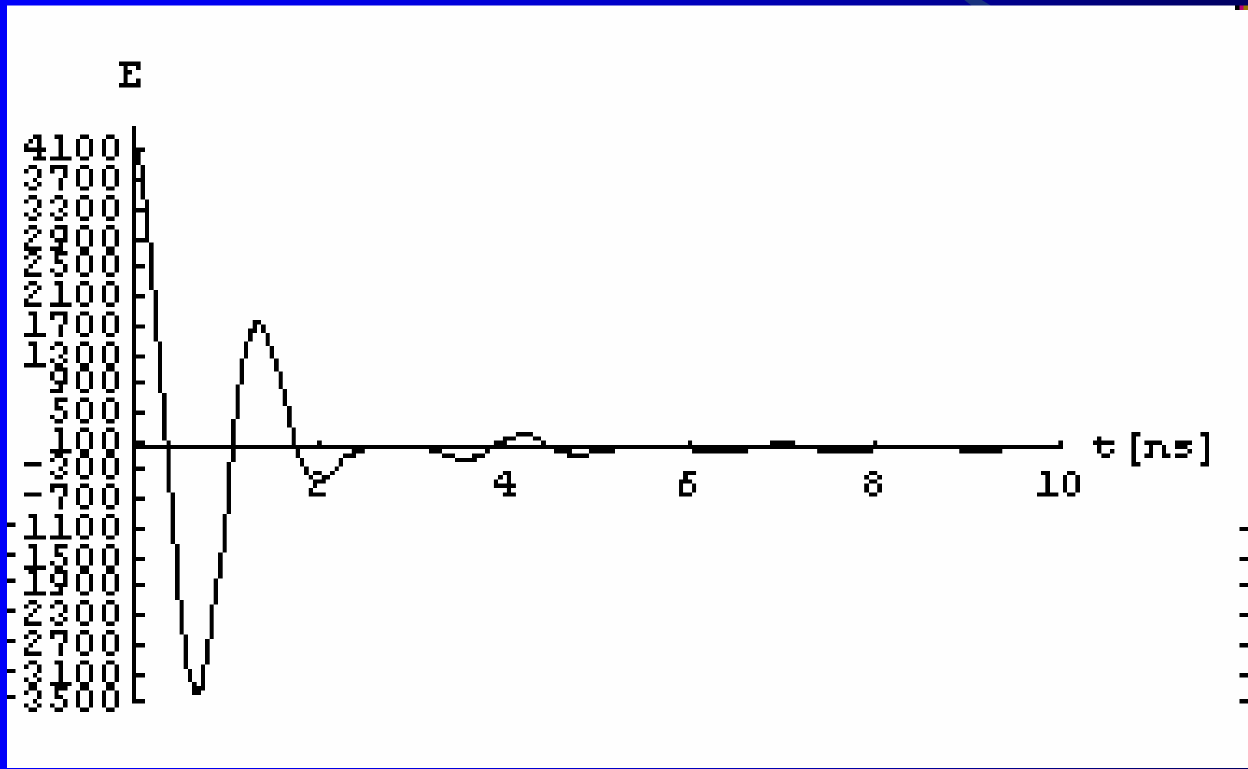
$$\text{kick} \sim \frac{\sin^2(N\omega t)}{\sin^2(\omega t)} \cos(\Gamma N \omega t)$$



714MHz, 33 Cavities
Bunch Spacing
179.27nsec

714MHz damped cavity is used to accelerate beam for ATF-DR. So, I checked the possibility of FS kicker with principal frequency of 714MHz.




E
4100
3700
3300
2900
2500
2100
1700
1300
900
500
100
-300
-700
-1100
-1500
-1900
-2300
-2700
-3100
-3500
2
4
6
8
10
t [ns]

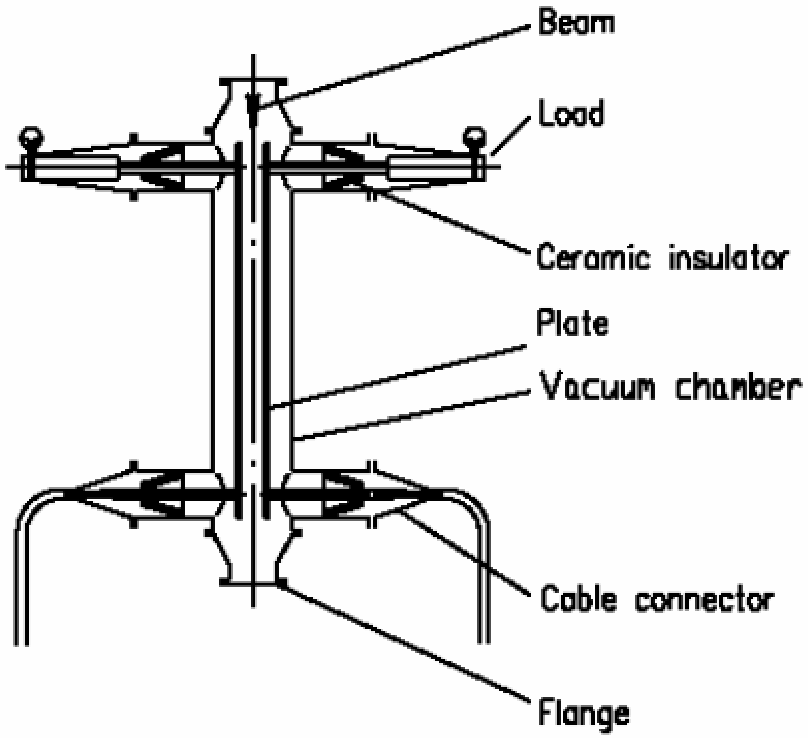
In the case of 2.8nsec bunch spacing, remaining bunches have almost no effect. Double FS Kicker can additionally reduces extra effect by factor 10. Also, we have a possibility to extract 1.4nsec bunch spacing beam because difference of highest peak and second peak of beat wave is more than 50%. Every bunches in Damping Ring are on crest of this FS kicker field. Head and tail of 6mm bunch have almost same kick field due to 714MHz field(0.001 difference). We can control the kick field to more flat by wakefield effect.

Plan of test proposal:
714MHz+/-89.25MHz (5.578MHz, 11.156MHz, 16.73MHz, 22.31MHz, 27.89MHz, 33.47MHz, 39.05MHz, 44.63MHz, 50.20MHz, 55.78MHz, 61.36MHz, 66.94MHz, 72.12MHz, 78.09MHz, 83.67MHz) : Total 33 FS frequency components are necessary. 714MHZ 50kW Klystron is working at ATF-DR. Series of this klystron is available. We have to design low Q-cavity with bandwidth of +/-12.5% or 26.9m long cavity can resonate 33 longitudinal fundamental modes. The design is desk work.

SLAC proposed very fast kicker development recently.

1) The TDR Kicker:
   1) 0.6 mrad (.01Tm), 5GeV, 50 m β, 7e-4 stability, 20 each, many meters long (kicker 'achromat' not possible)
   2) Counter-fed 50 ohm striplines
2) The 'conventional' approach (~SLAC)
   1) Follow and extend the TDR design
   2) FET / Hard tube / Saturable Ferrite
3) Alternatives:
   1) Coherent sum CW standing wave kickers (system) – *Gollin / KEK*
   2) Waveguide close to cut-off (system) – *Gollin / FNAL*
   3) Pulsed traveling wave RF structures (system) – *INFN / Cornell*
   4) Shorted-striplines (just the magnet) – *Wille (Dortmund) / SPEARIII*
   5) *(Hard tube-based pulsers – Frisch)*

Consider the application of this technology at KEK-ATF

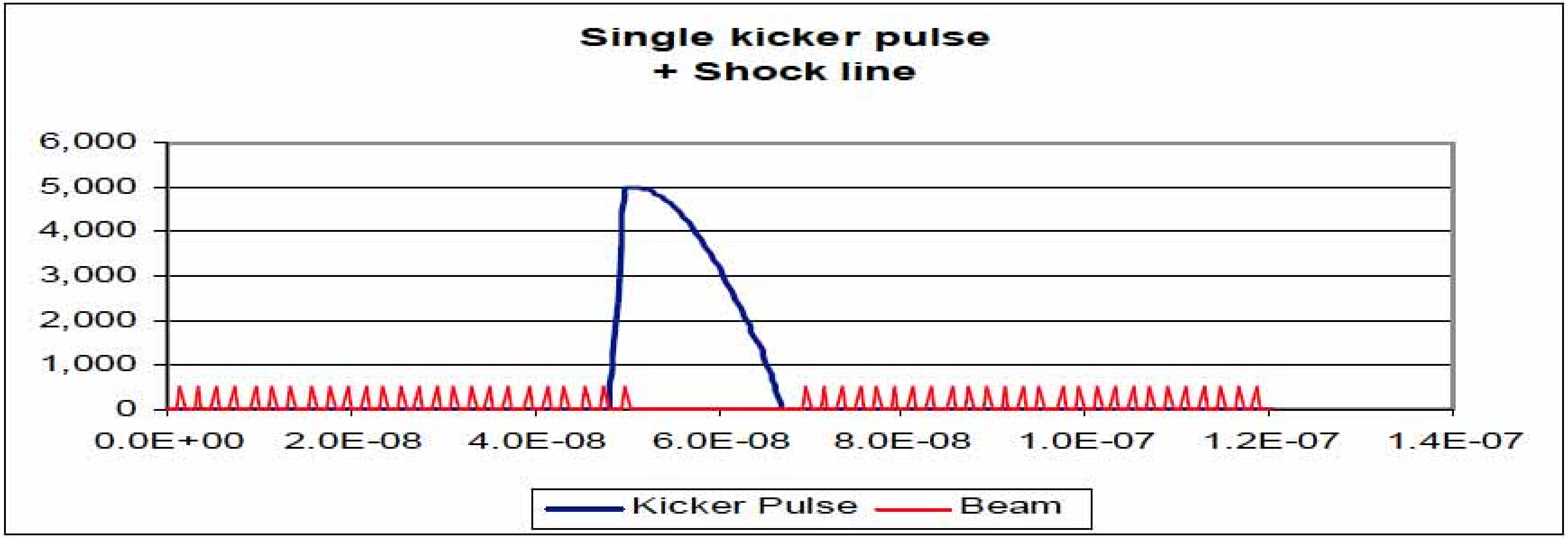


DESY Kicker RD

0.5m Strip-line:20 to 40 Fast Kicker Spec.
100 Gauss-m=3.0MeV/c =30MeV/m x10cm
Stability/Ripple/ Precision=0.07 Gauss-m =0.07% > 0.05%

ATF Experiment Plan by SLAC proposal

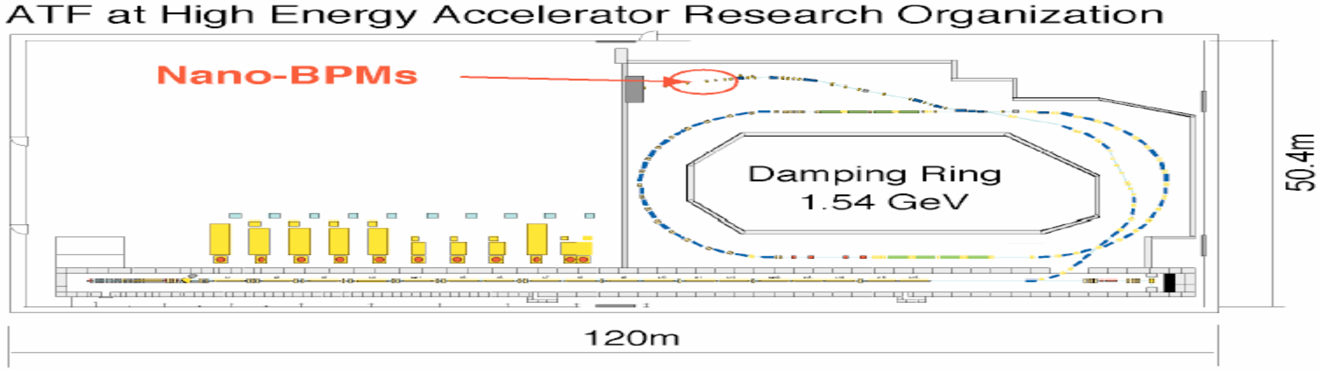
25mm aperture, 20KV, 1.3m kicker is enough to extract (3mrad at 1.3GeV)
(500A, 10MW peak)



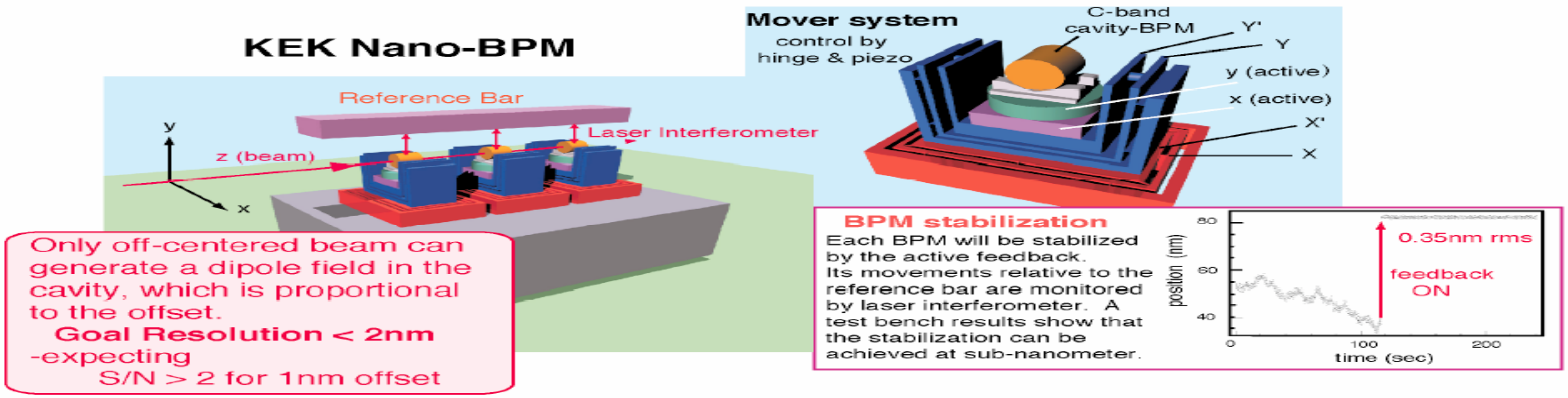
Extracted pulse and Shock line fits into beam

- Pulser / power source
  - Stability
  - Rise time/fall time
  - Repetition rate (3MHz or 1.6MHz)
  - ‘achromat’ + feedback/feedforward/active cancellation schemes
  - Timing rms / voltage rms

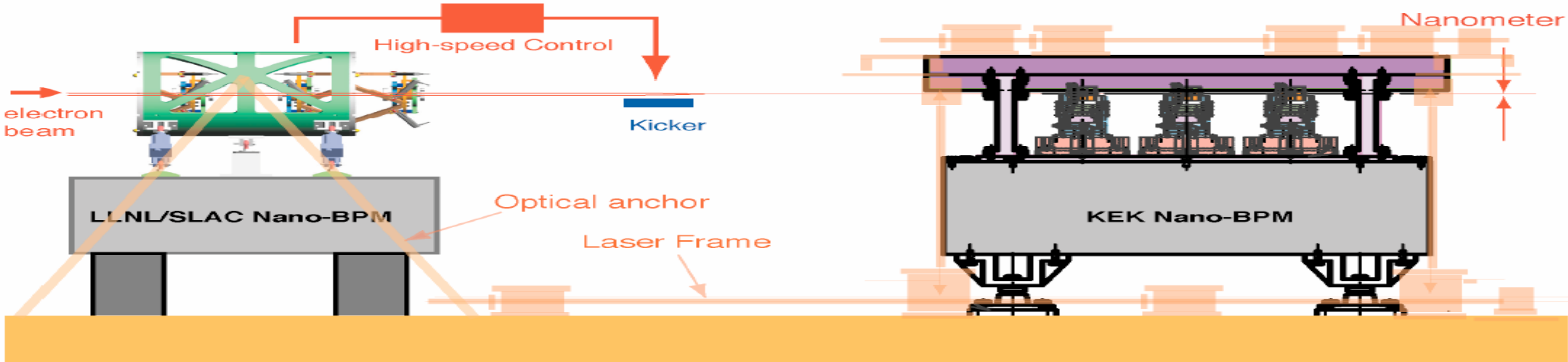
Very important study at ATF is Nano-BPM & Feed-forward for Final Focus System.



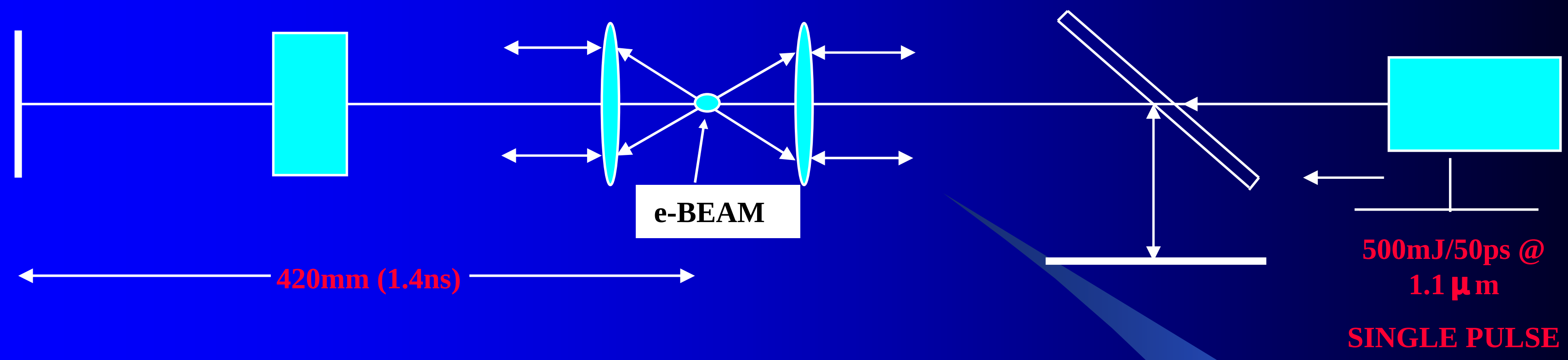
Cavity-BPM system with nanometer resolution (Nano-BPM)

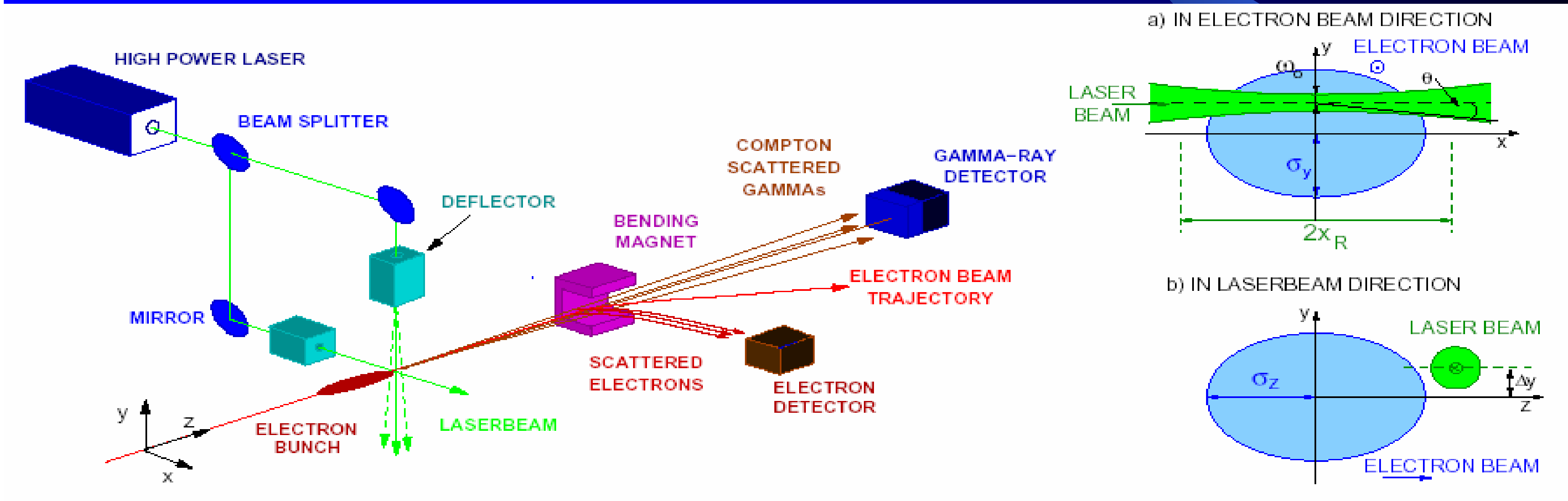


Two Nano-BPMs and High-speed Control System

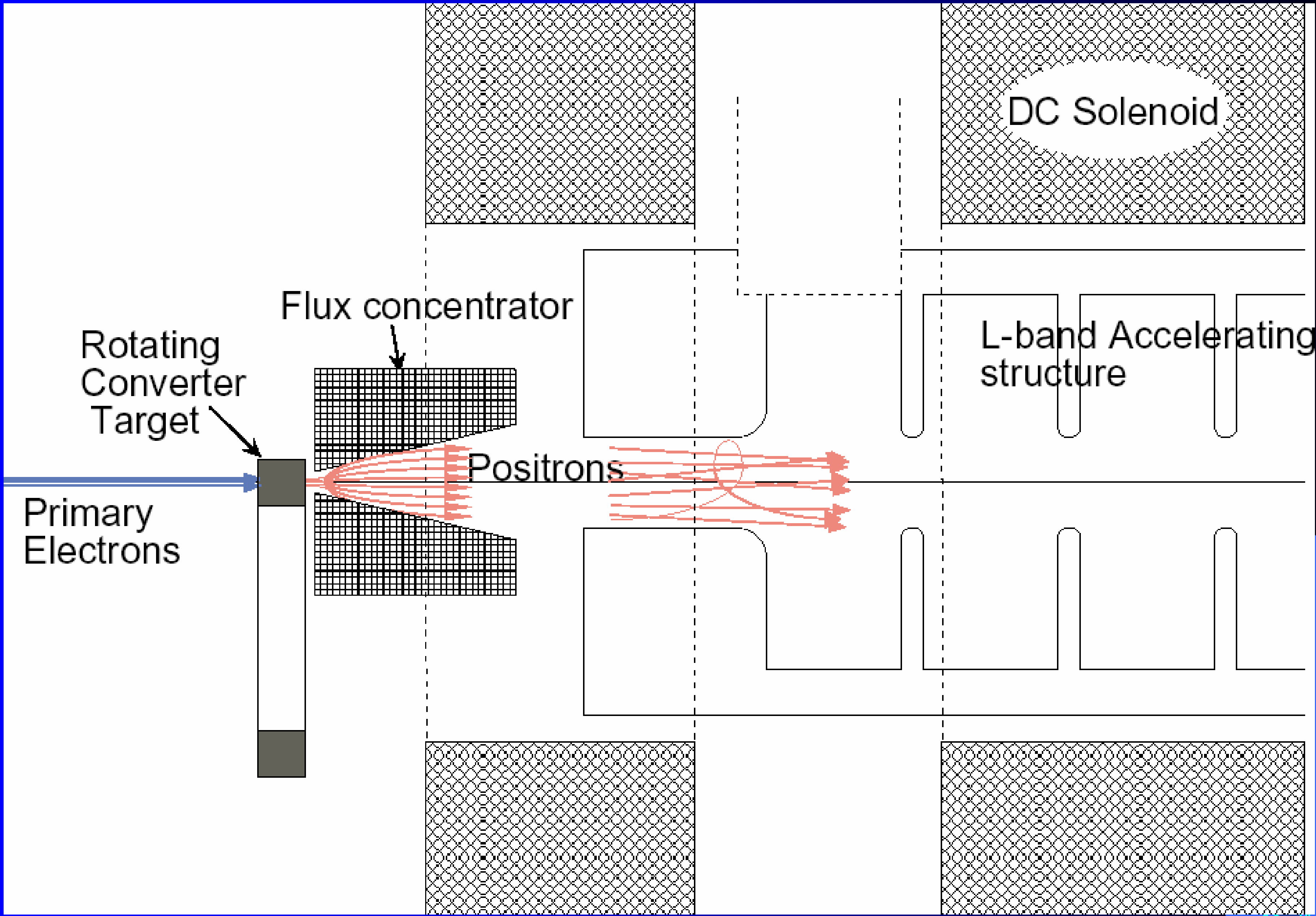


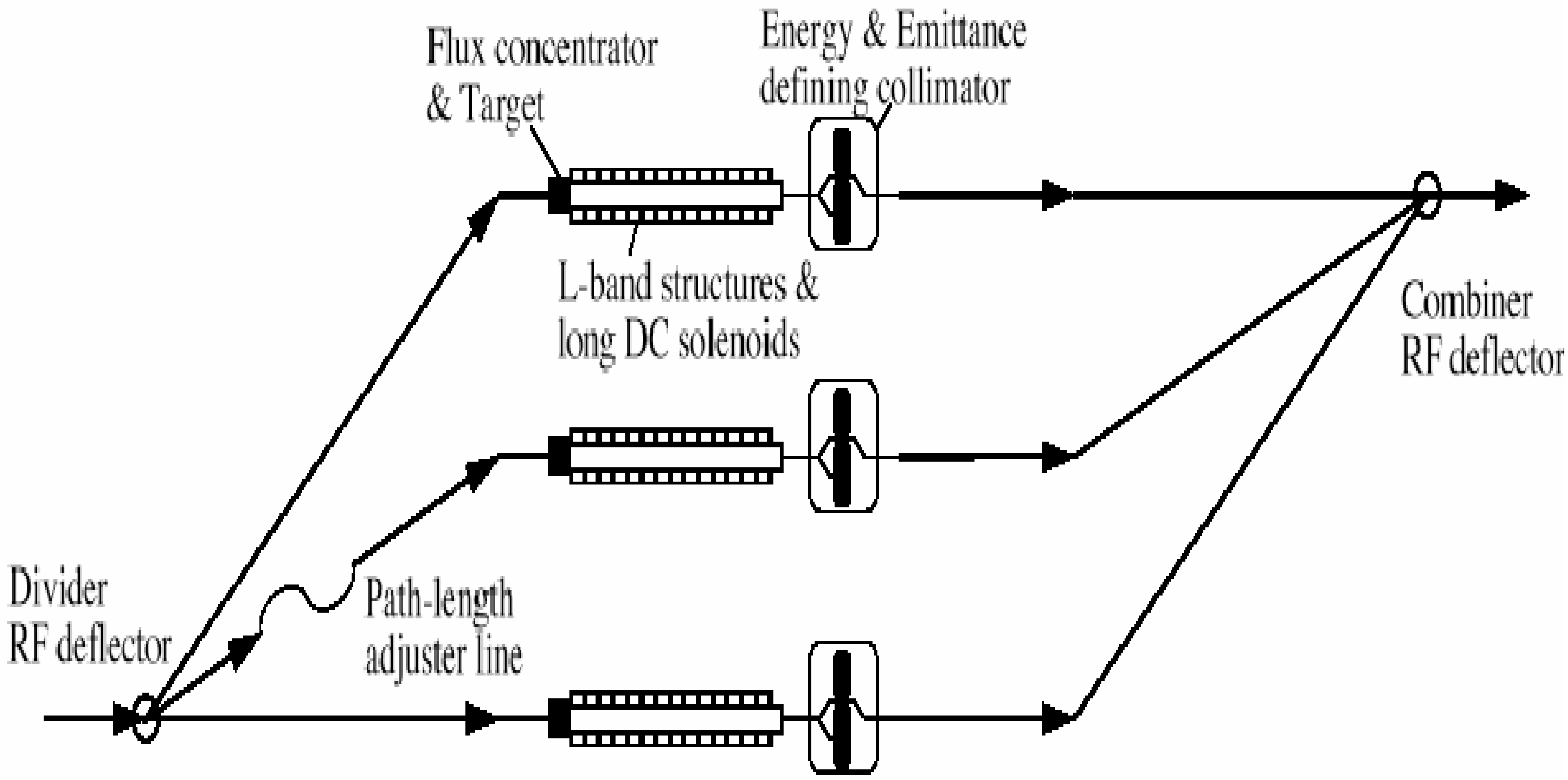
Laser Wire Development at ATF Extraction Line for Beam Delivery System





- **Scan finely focused laser beam through electron beam**
- **Detection of Compton photons (or degraded electrons) as function of relative laser beam position**
- **Challenges**


DC Solenoid
Flux concentrator
Rotating Converter Target
L-band Accelerating structure
Positrons
Primary Electrons



Multi-fixed targets for the positron generation. Beam is separated and combined by RF Deflector (89.25MHz RF?).

Maybe, three to eight targets are necessary. Defining Collimator is to match Pre-DR Aperture.

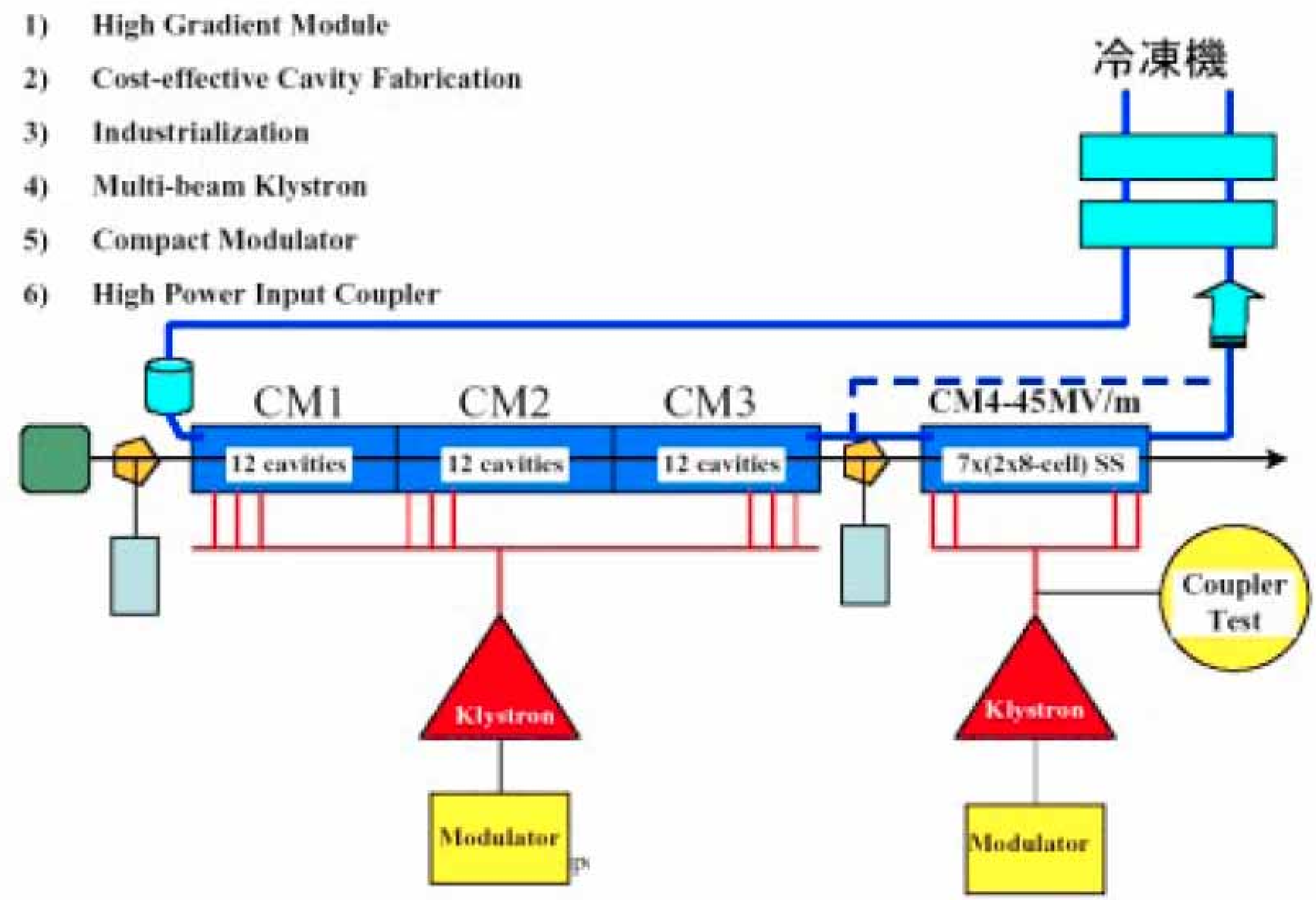


図１：KEK ILC 開発のための試験装置概念図

35MV/m, three Cryomodules and 45MV/m. one Cryomodule, Electron beam source

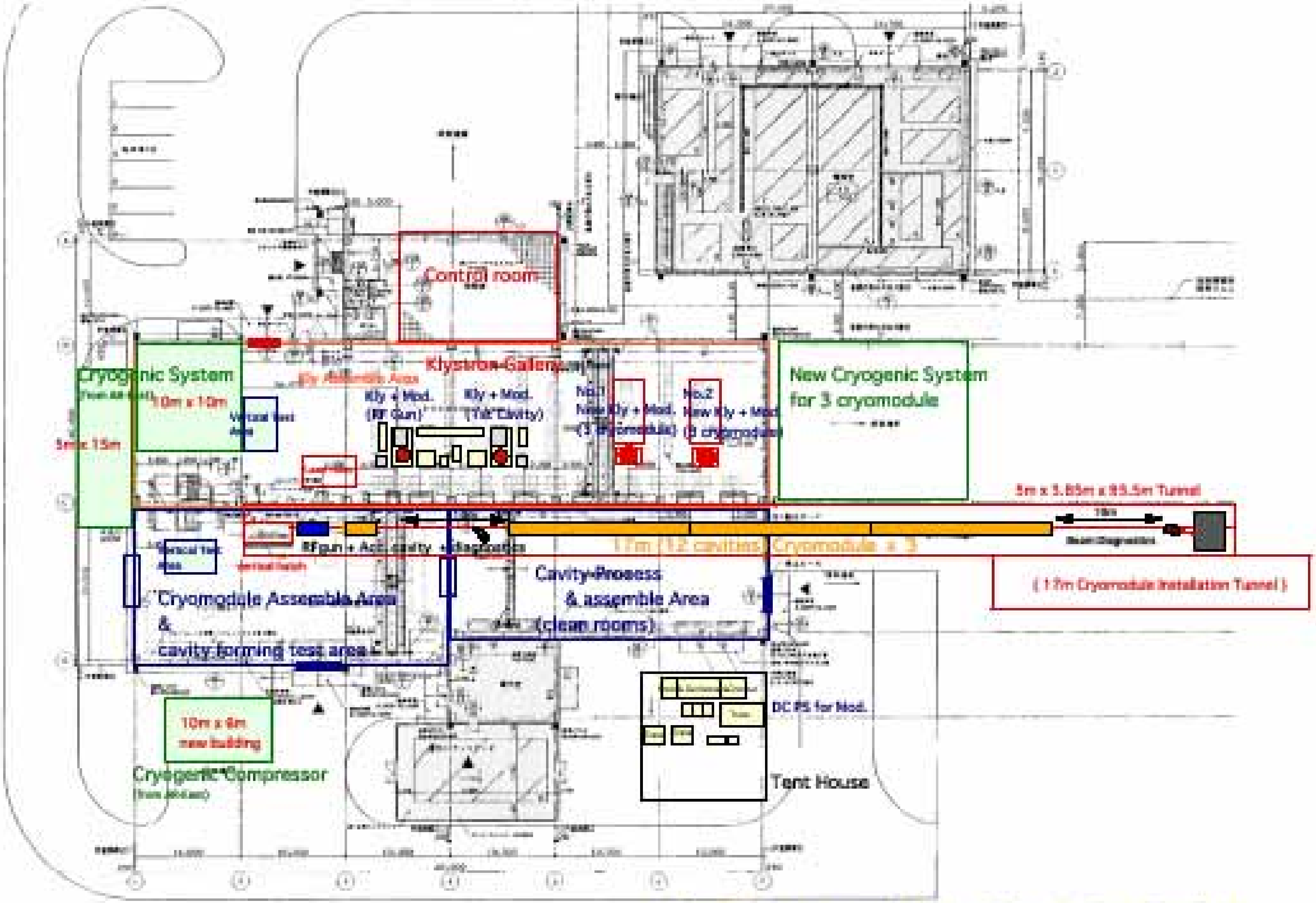
Construction Schedule and tentative budget requests of Super Conducting Test Facility

Assuming reuse of the building for the intense proton injector R&D of J-Parc, total budget request is roughly 19M$.

I skipped the table written in Japanese.

I skipped the comments of K.Saito which was Written by Japanese.

Main LINAC R&D plan comes from note of Kenji Saito. He wants to use the place which injector system for J-Parc is installed.
At present, I think his plan is something big. So, we need more discussion.

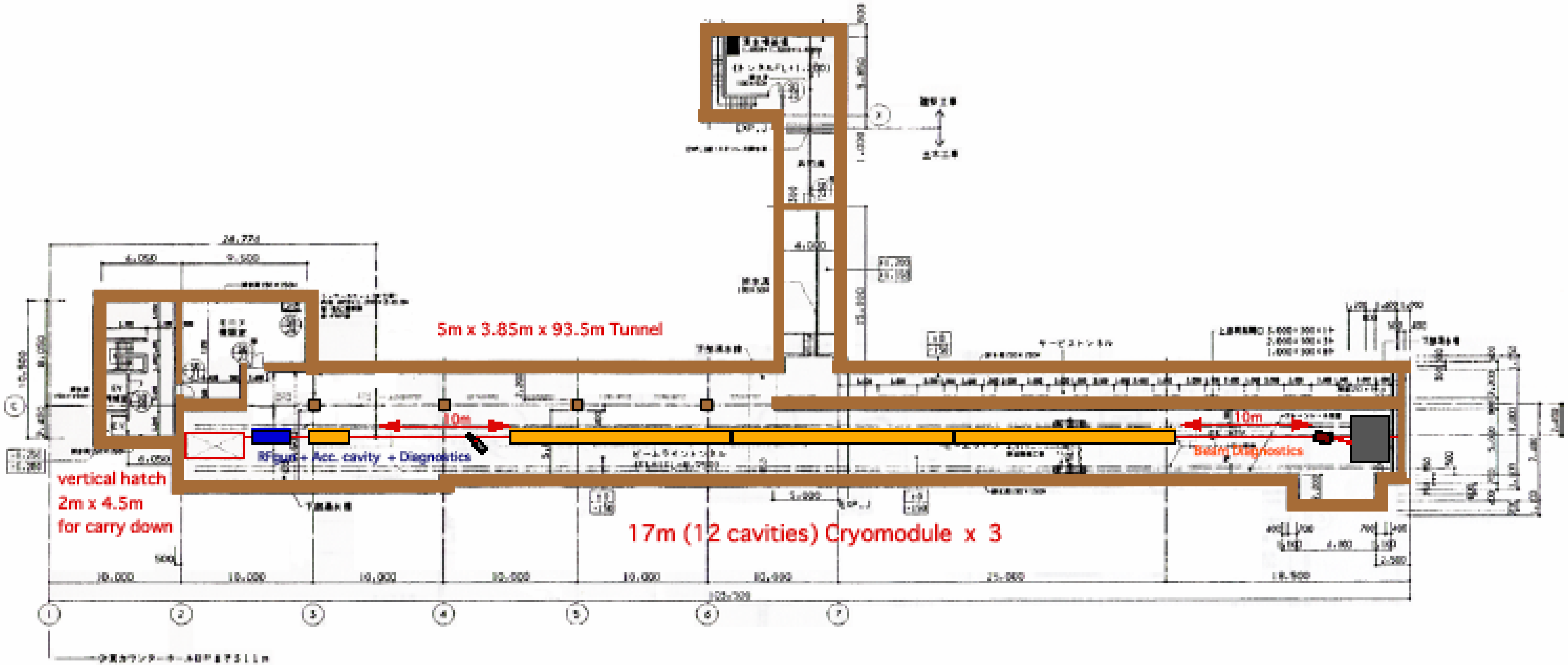


Plan of Superconducting Cavity Test Facility

V2.0 Hitoshi Hayano, 10/06/2004

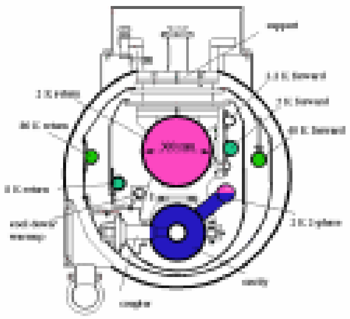
Plan of Superconducting Cavity Test Facility

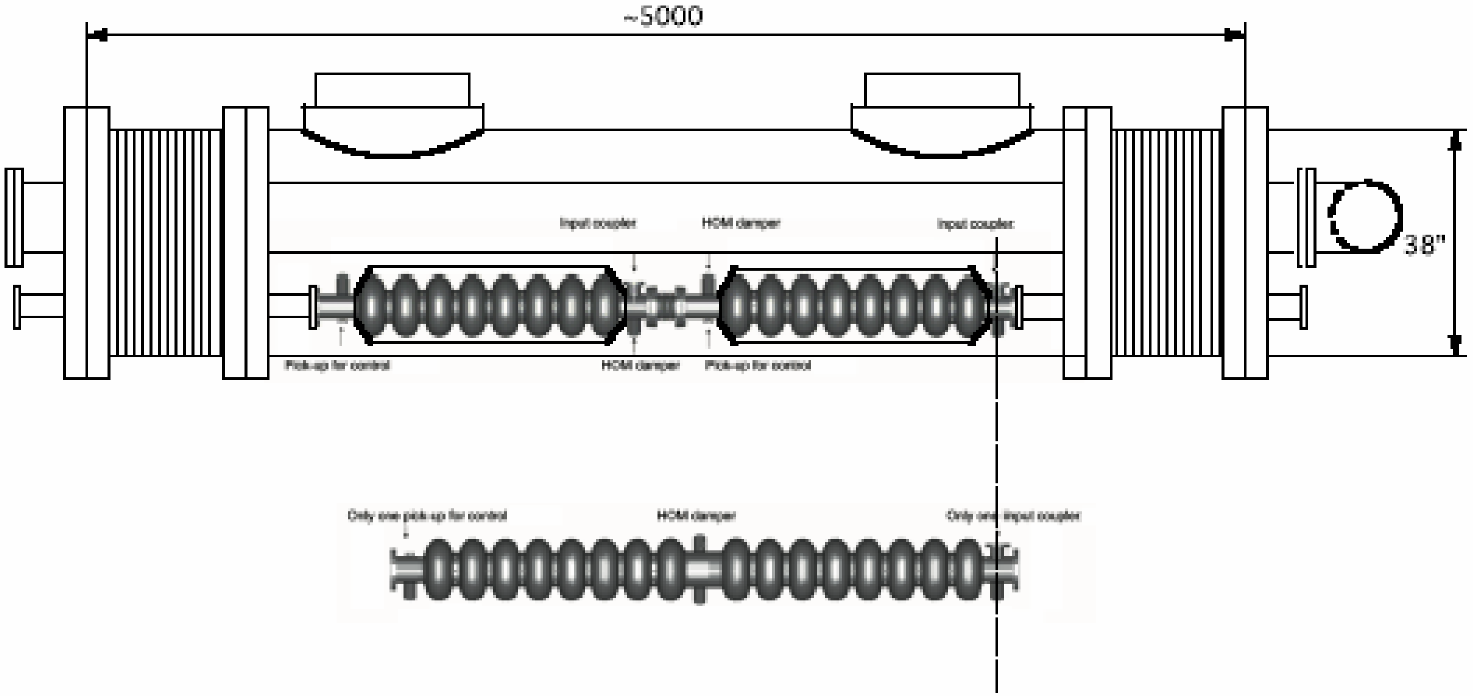
Beam Line in the tunnel



Proposal Plan of two 8cell HG cavities in short cryomodule

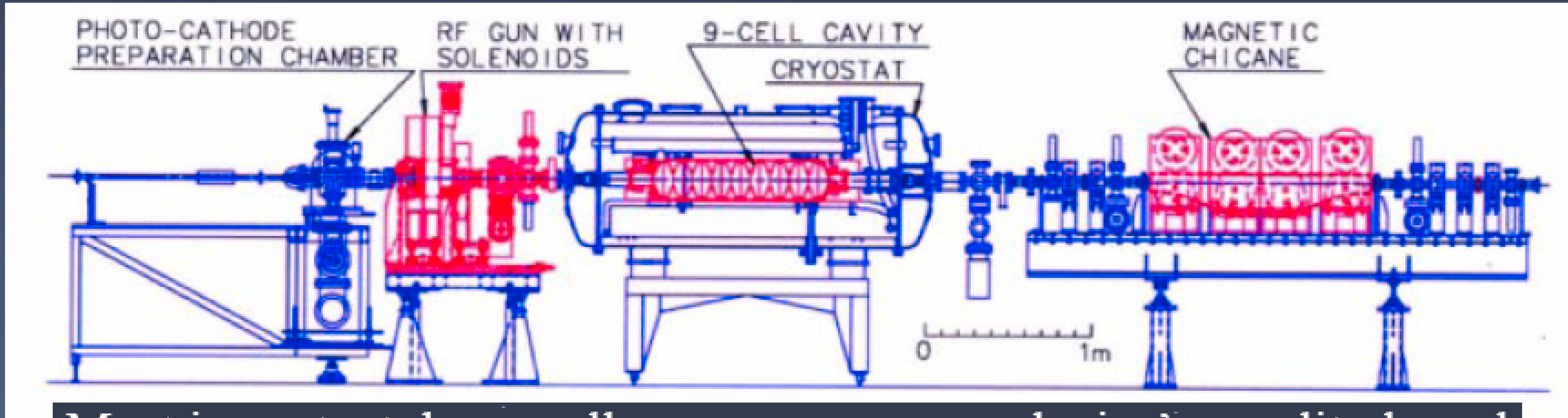
(consider to replace and test of superstructure, also)





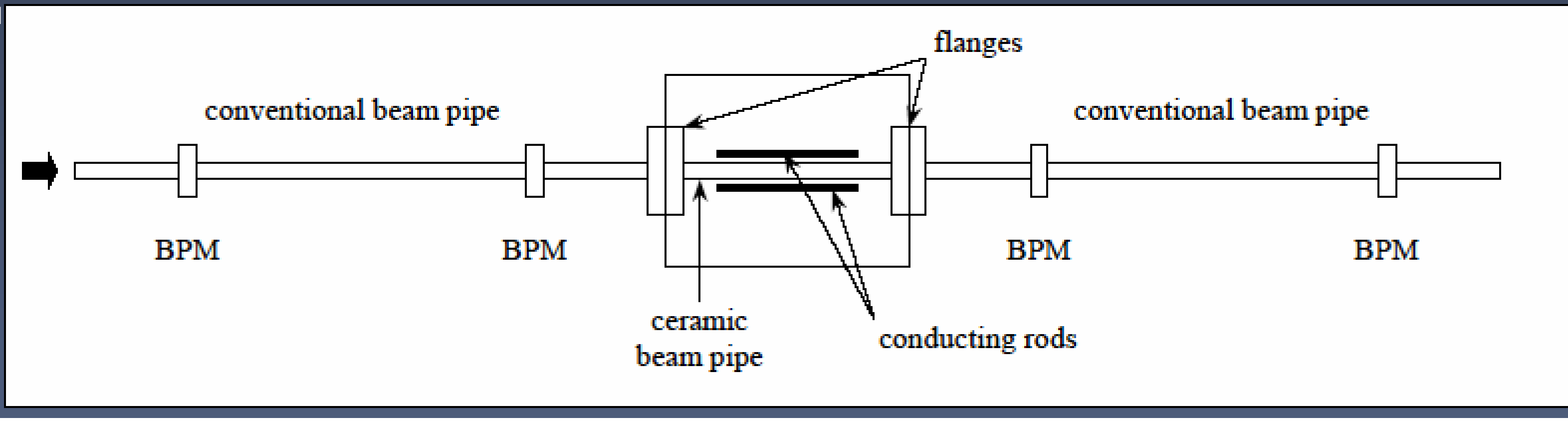
A0 photoinjector lab at Fermilab produces a relativistic, bunched low-emittance electron beam.

This should be an excellent facility for kicker studies!



Most important: how well can we measure a device's amplitude and timing stability with the A0 beam?

To SMTF

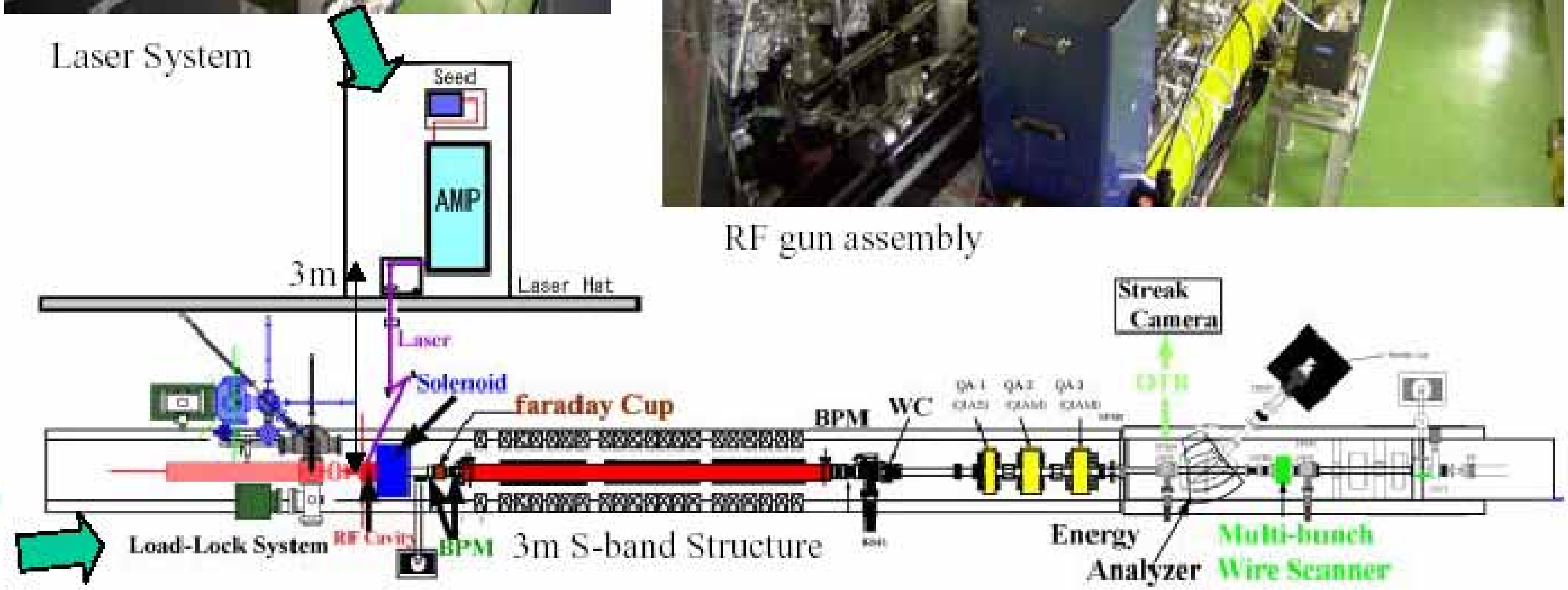


2(

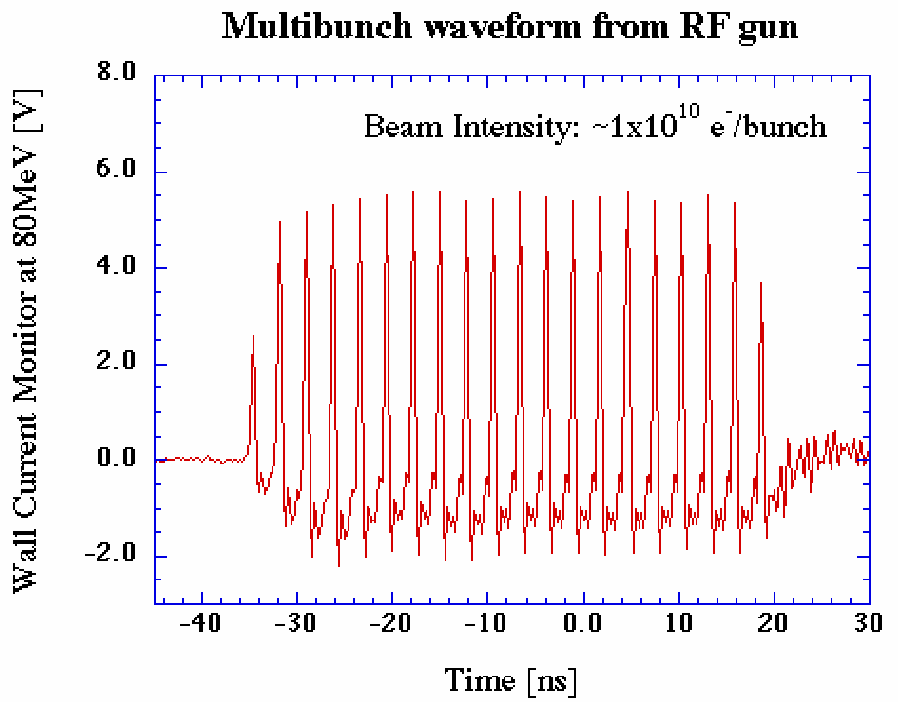
Electron Source

Laser System

RF gun assembly



Multi-bunch e- beam at 80 MeV point



- Beam Intensity

  ~1×10^{10}/bunch
- Normalized Emittance

  $\varepsilon_y = 5 \times 10^{-6}$ rad.m
- Bunch length

  $\sigma_z = 6.4 \sim 7.9$ ps
- Energy spread

  dE/E = 1.0% full-width
- Q.E. of CsTe cathode

  16% initial, 2~3% with RF ON & constant over several months.

Private comments concerning accelerator R&D.

Beam instrumentation R&D is continued at ATF and essential for ILC realization. Micron electron beam is necessary to develop advanced instrumentation devices. DESY TTF2 is also important for ILC and XFEL project.

DESY mainly concentrate the construction of X-FEL and R&D or Design Work for ILC will be limited.

FNAL, J-LAB, BNL, SNS, ANL,LBNL, SLAC are jointly doing R&D. What is CERN?