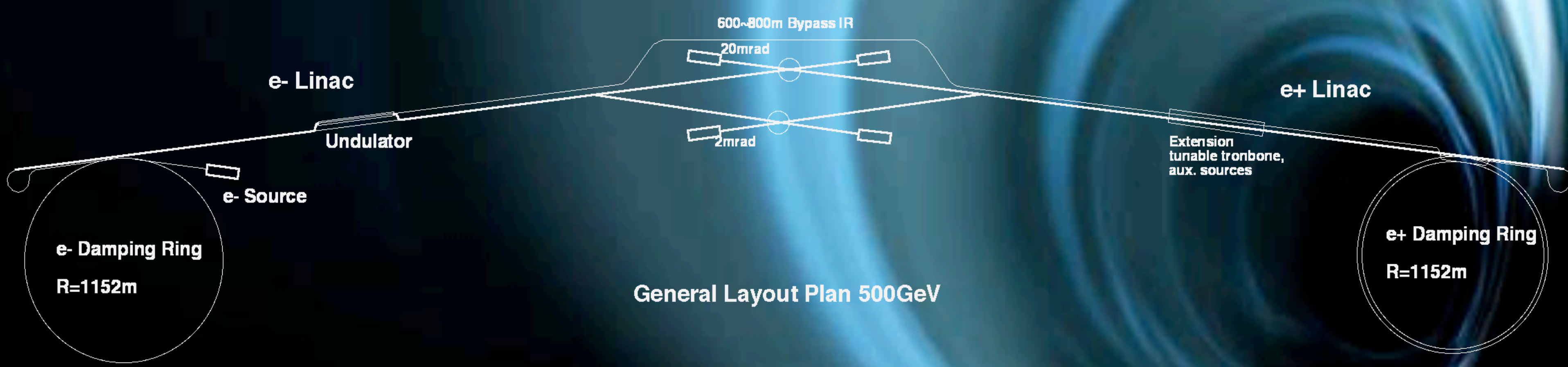
EPAC2006 6/27/2006

Developments in Beam Instrumentation and New Feedback Systems for the ILC

H. Hayano, KEK



Discussions

1. ILC BCD of Instrumentations.

   BPMs, Profile monitors, Beam Feedbacks

   functions, specifications, required number

2. R&D status for ILC Instrumentations.

   BPMs (ML-BPM, BDS-BPM)

   BSMs (DR-BSM, ML-BSM, BDS-BSM)

   Beam Feedbacks (IP-FB)

Baseline Configuration Documents on Instrumentation & Controls

http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd%20home

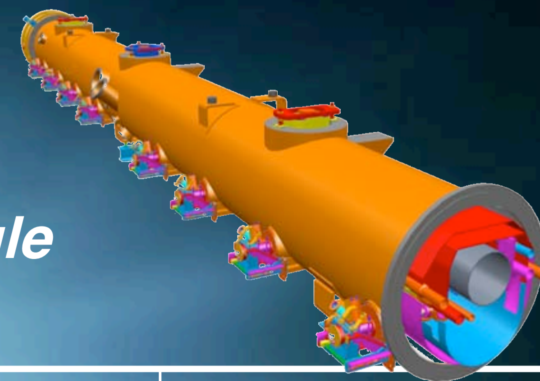
Major Target:

The sophisticated integration of basic monitors, orbit control, LLRF control of various acceleration system and beam generation control.

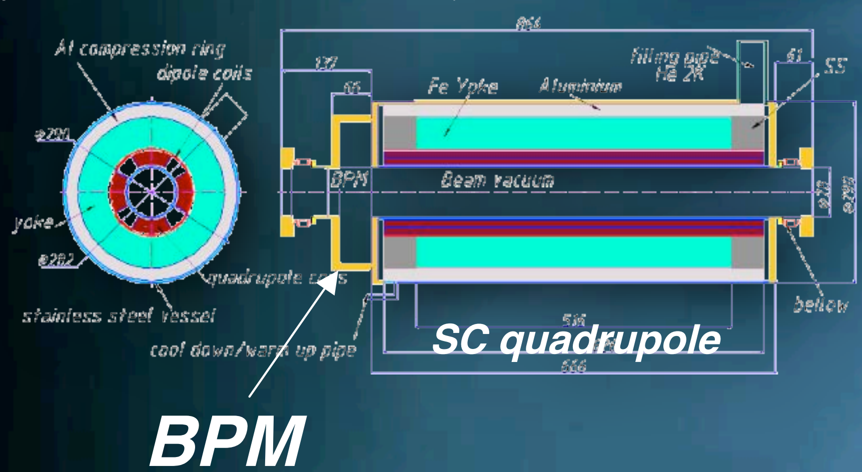
11 Instrumentation and Controls

- 11.1 Controls Standard Architecture
- 11.2 Timing System
- 11.3 Diagnostic Interlock Layer
- 11.4 Global Network
- 11.5 Machine Protection
- 11.6 Low level RF
- 11.7 Feedback
- 11.8 Integration with Instrumentation
- 11.9 Machine Detector Interface
- 11.10 Instrumentation – Beam position monitors
- 11.11 Instrumentation – Beam profile monitors (transverse)
- 11.12 Instrumentation – Longitudinal
- 11.13 Instrumentation – other (intensity, loss, ring)

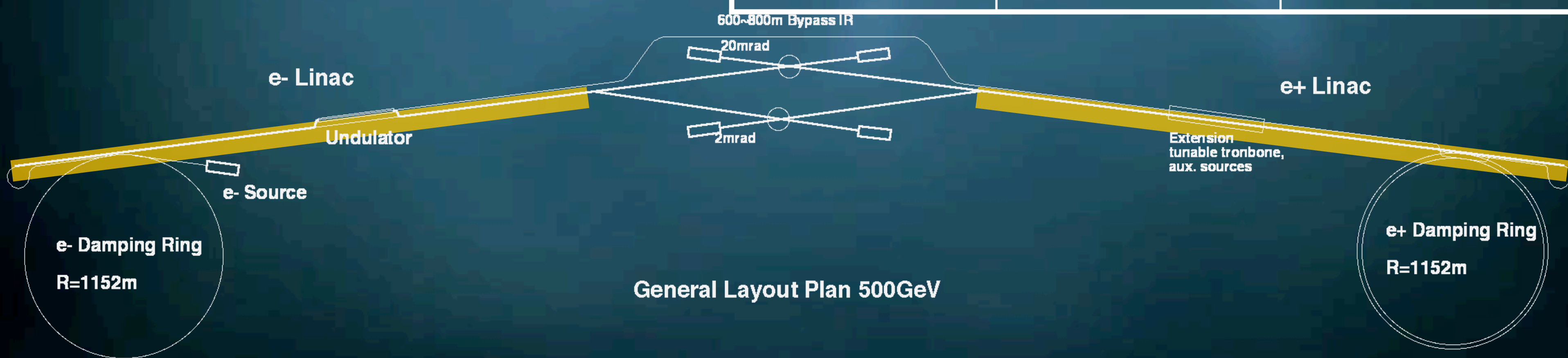
Main Linac BPM



Quad-BPM package in center of 12m cryomodule

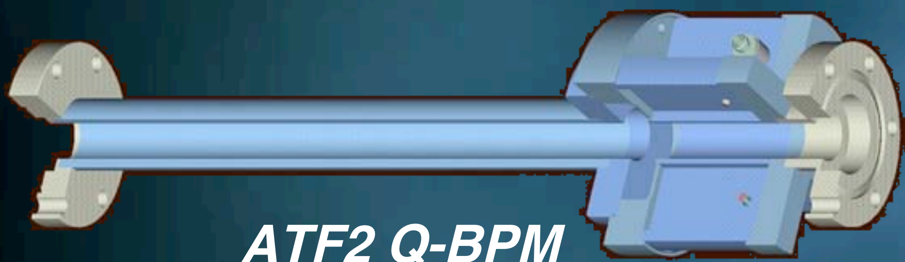


Parameter	Requirement	Comments
Quantity	~800	Every quadrupole
Environment	Cold	In cryomodule
Aperture	~ 78 mm	BPMs not to be limiting aperture
Resolution	0.5 micron	at 2E10 electrons
Stability	<10 microns	Over cryomodule thermal cycling
Temporal resolution	bunch-by-bunch	~3000 bunches

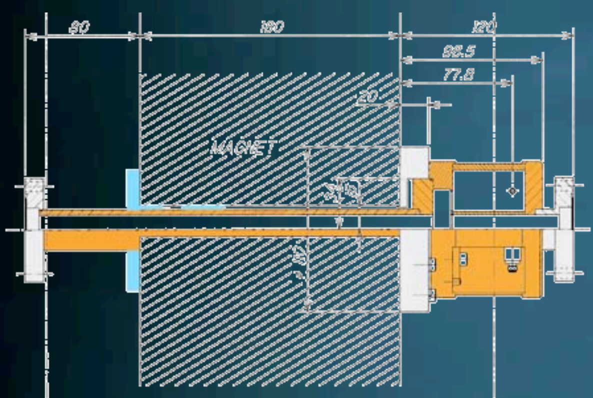


BPM for Beam Delivery System

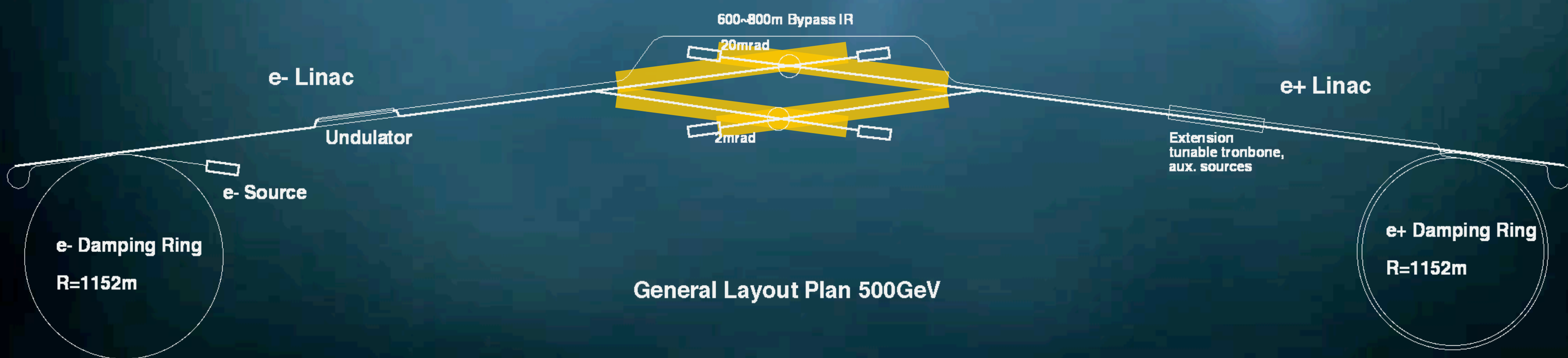
Cavity BPM mounted in Quadrupoles



ATF2 Q-BPM



Parameter	*Requirement*	*Comments*
Quantity	*~400*	
Aperture	*Various sizes*	
Resolution	*~σ/4 ~250 nm*	
Stability	*<10 microns*	*long term*
	< 1 micron / hour	*Energy Spectrometer only*
Temporal resolution	*bunch-by-bunch*	*many places, assume all*



Beam Profile Monitors for damped beam

9 laserwire station:

1) Damping rings

(2 locationsone for a dispersion - free , for a non-zero dispersion region.),

2) Ring to BC transport,

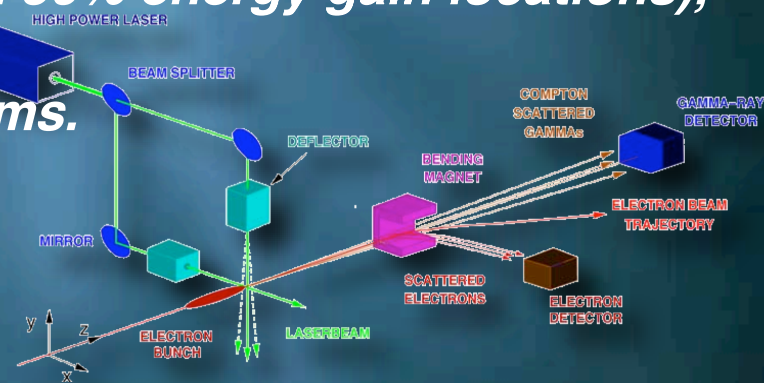
3) between the two BC stages,

4) BC to main linac transport,

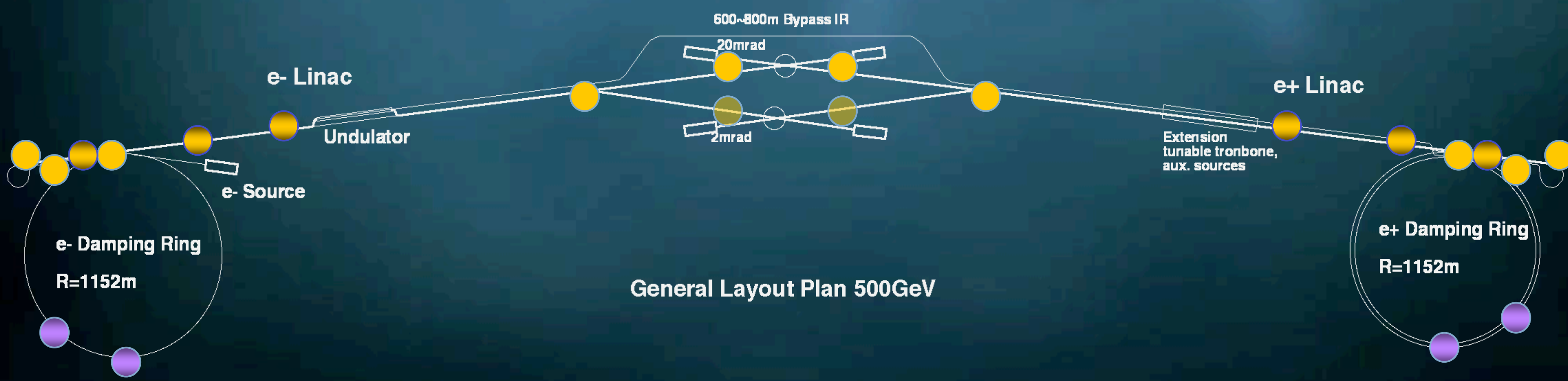
5) within the main linac (3 sets; at the 10%, 25% and 50% energy gain locations),

6) at the entrance to BDS,

7) within BDS, downstream of the collimation systems.



Each laserwire system has 3 to 5 interaction chambers distributed along a fraction of a betatron cycle, for ~40 meters.
Each interaction chamber has a focal system for x ,y ,u scan direction.



Beam-based Feedback Loops

A summary of anticipated beam-based feedback loops;

for Damping Ring

1)Injection trajectory control,
2)Dynamic orbit control,
3)Bunch-by-bunch transverse feedback,
4)Extraction orbit control,

for Ring-to-Main Linac (RTML)

5)Pre-Turnaround emittance correction,
6)Turnaround trajectory feed-forward,
7)Post-Turnaround emittance correction,
8)Beam energy at bunch compressor (two stages),

for Main Linac

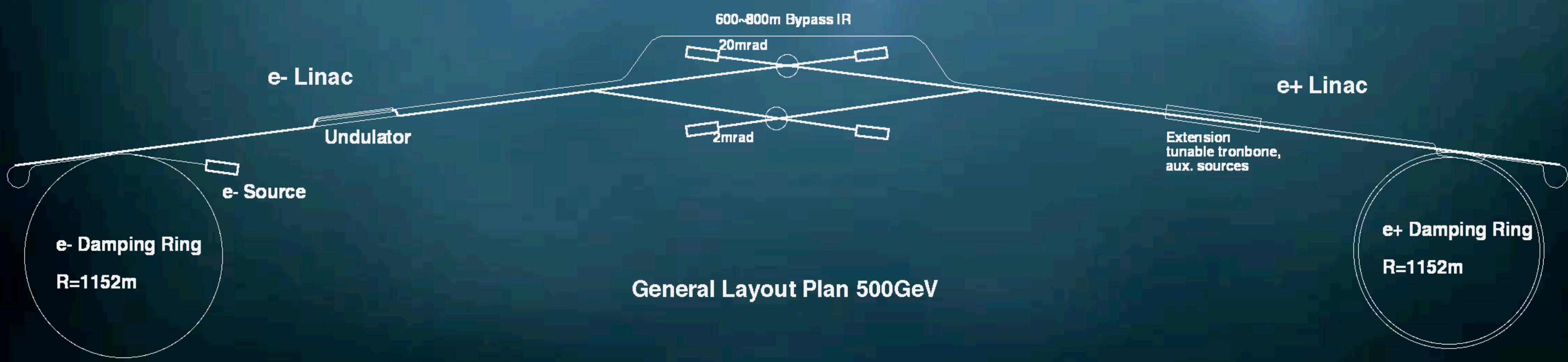
9)Dispersion measurement and control,
10)Beam energy (several cascaded sections),

for positron source

11)Beam energy at undulator, for BDS
12)Trajectory feedback from pulse to pulse,

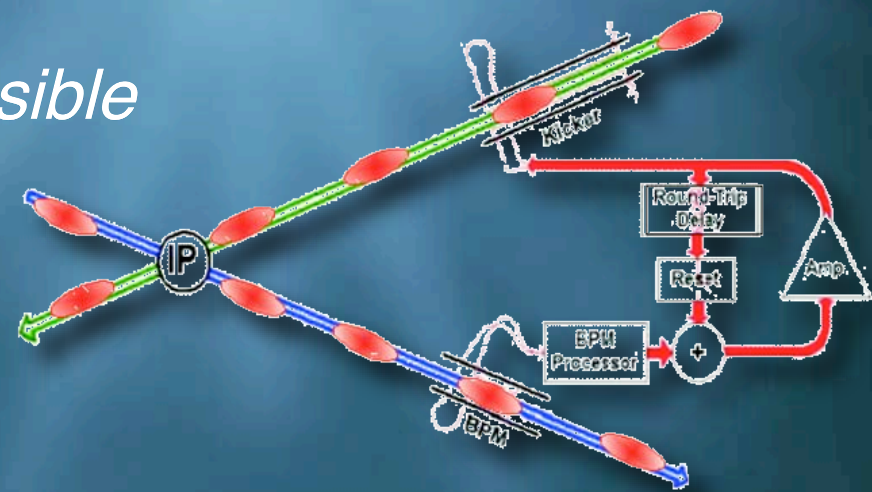
for Interaction Point

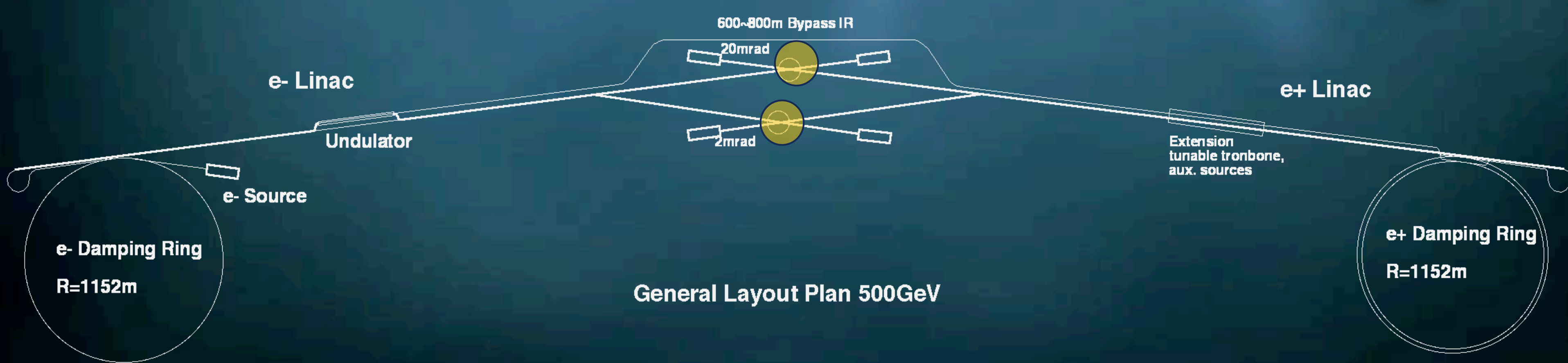
13)Trajectory feedback from pulse to pulse,
14)Trajectory feedback within bunch-train.



Bunch-by-bunch trajectory Feedback at IP

- *bunch spacing 300ns or 150ns (90m or 45m)*
- *pick-ups & kickers are placed several m away from IP*
- *acting on both direction*
- *correction speed : ~3MHz*
- *Digital correction algorism possible*





Critical Instrumentations

1. **BPM for Main Linac**

   cold environment, cleanable,
   70mm diameter chamber
   but need high resolution

2. **BPM for Beam Delivery System**

   extreamly high resolution

3. **Beam Profile Monitors for damped beam**

   non-distractive, high resolution

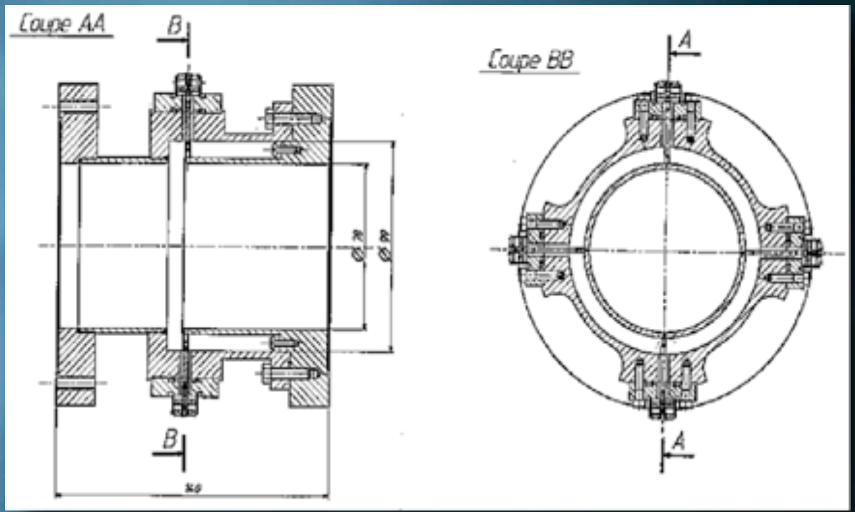
4. **Bunch-by-bunch trajectory Feedback at IP**

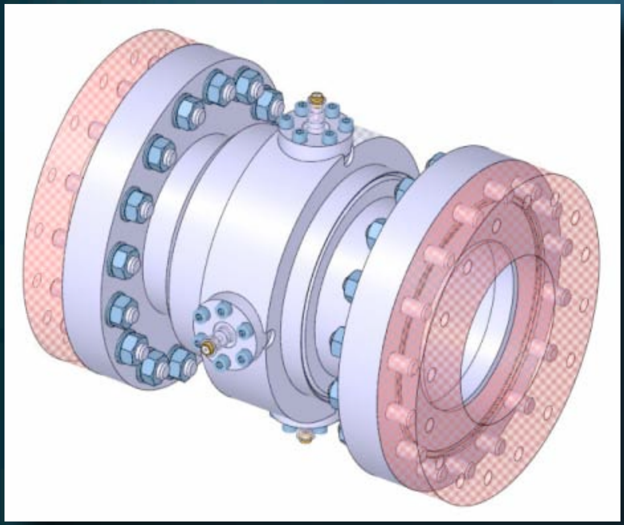
   less than 300ns latency

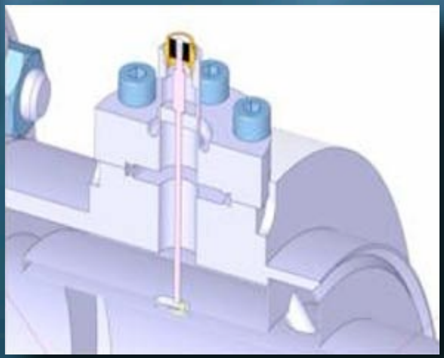
Major Instrumentation R&D

CEA Saclay / re-entrant BPM R&D

initial test at TTF ACC1 module
2nd model will be at TTF ACC7 module





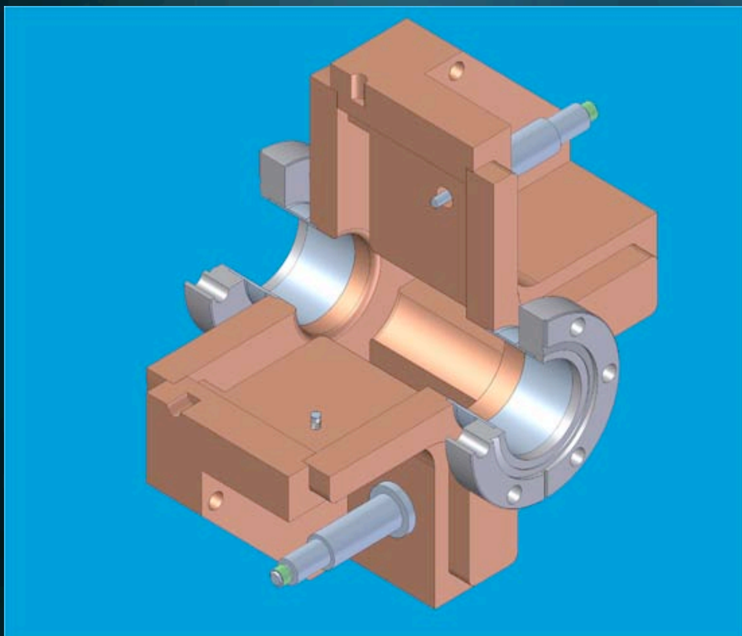


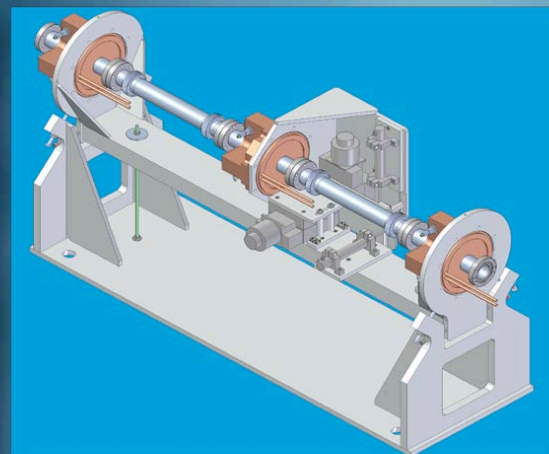
cleaning by HPR through 12 holes on re-entrant part.

resolution : ~1 micron achieved

SLAC Main Linac BPM R&D

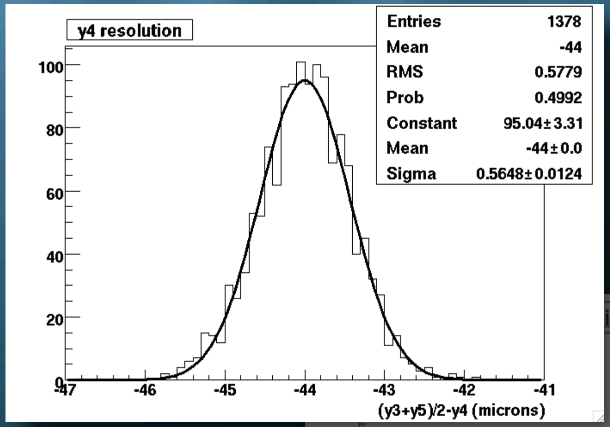
cavity BPM at 2.9GHz frequency (36mm beam pipe dia.)

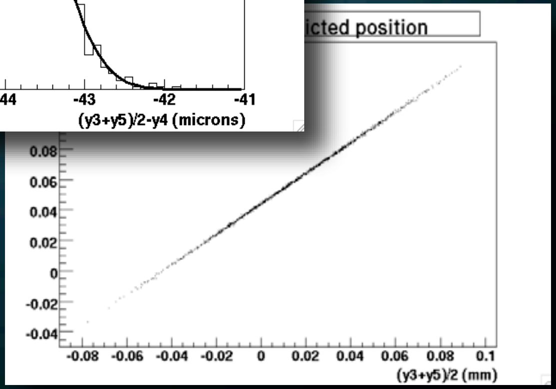




3 BPM setup at ESA

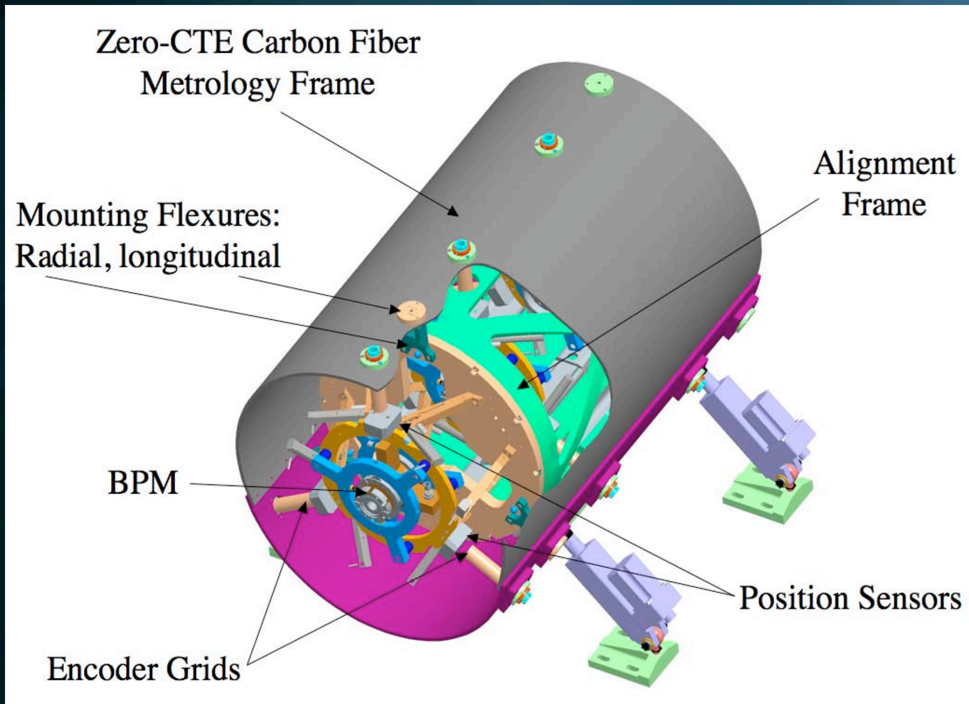
Waveguide Slot on beam pipe
for HPR cleaning
Q~500 for bunch signal separation

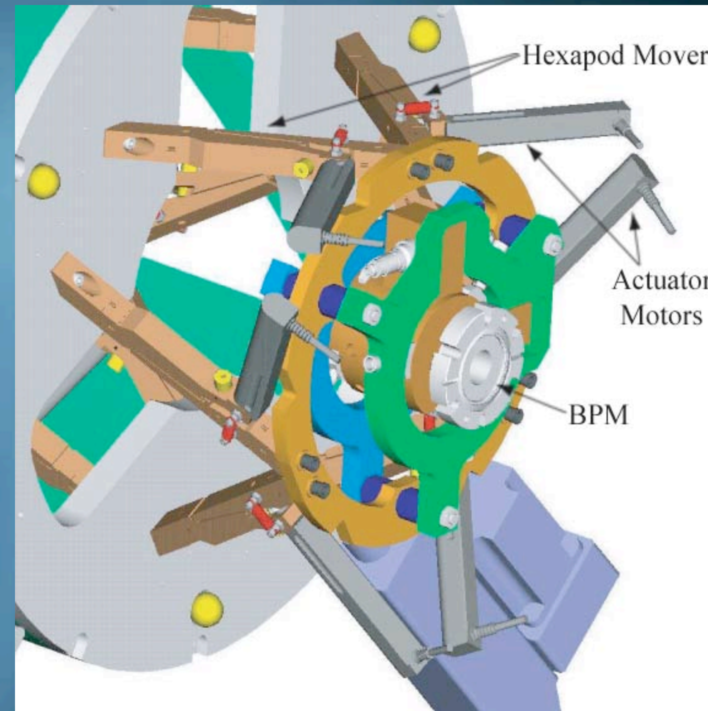




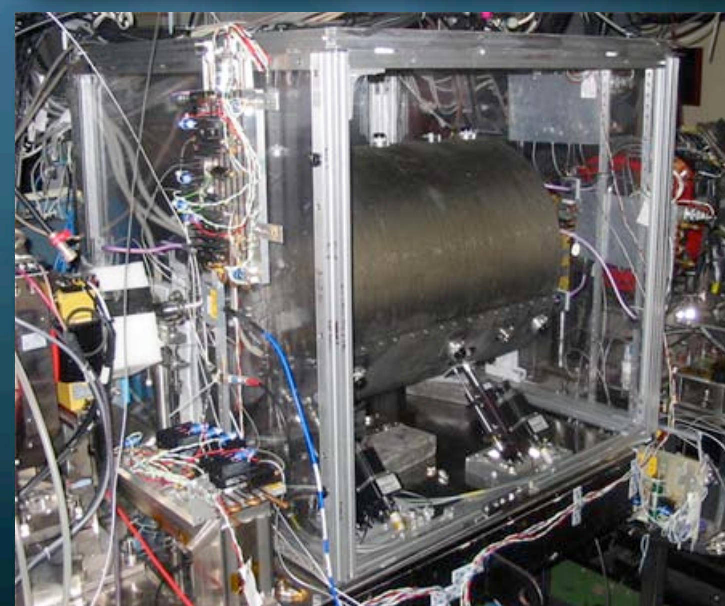
resolution 0.46 micron @ 1.5E10 electrons

SLAC/LLNL nm-BPM R&D



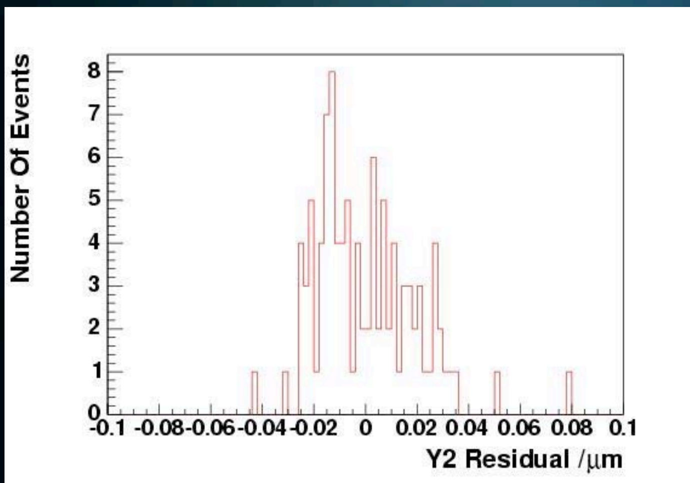


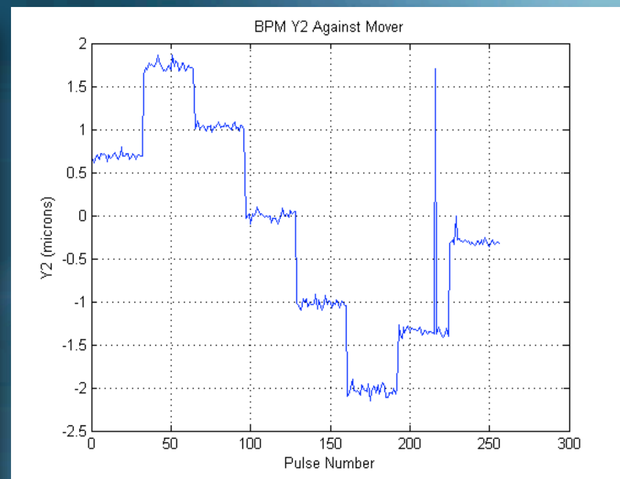
6.4GHz BINP cavity BPM
3 BPMs are mounted
on regid precise mover
double down conversion
+ 14bit ADC 100Ms/s
Carbon fiber metrology frame
as a reference frame

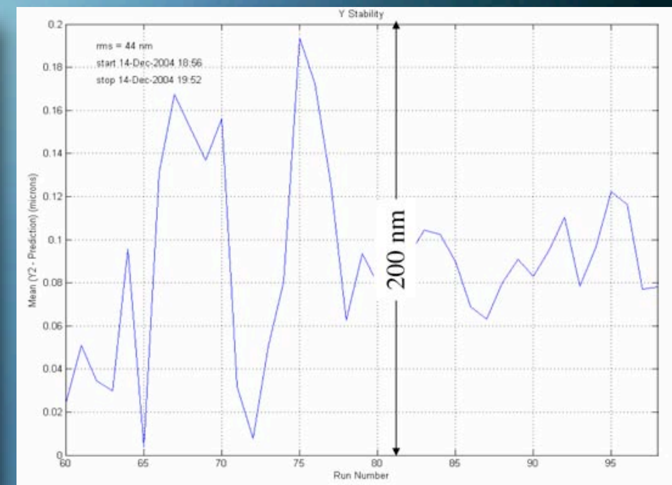


SLAC/LLNL nm-BPM R&D

ATF single bunch beam test





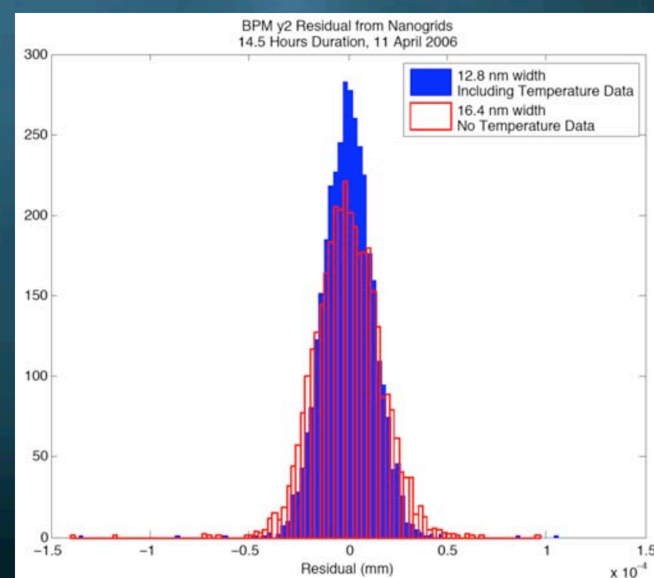


***17nm* resolution achieved**

1 hour stability ~44nm(rms)

BPM mechanical stability

meas. system noise : ~5nm
center BPM residuals relative to metrology frame:
16.4nm for no use of temp. correlation,
12.8nm with temp. correlation.



KEK nm-BPM R&D

Three KEK Cavity BPMs

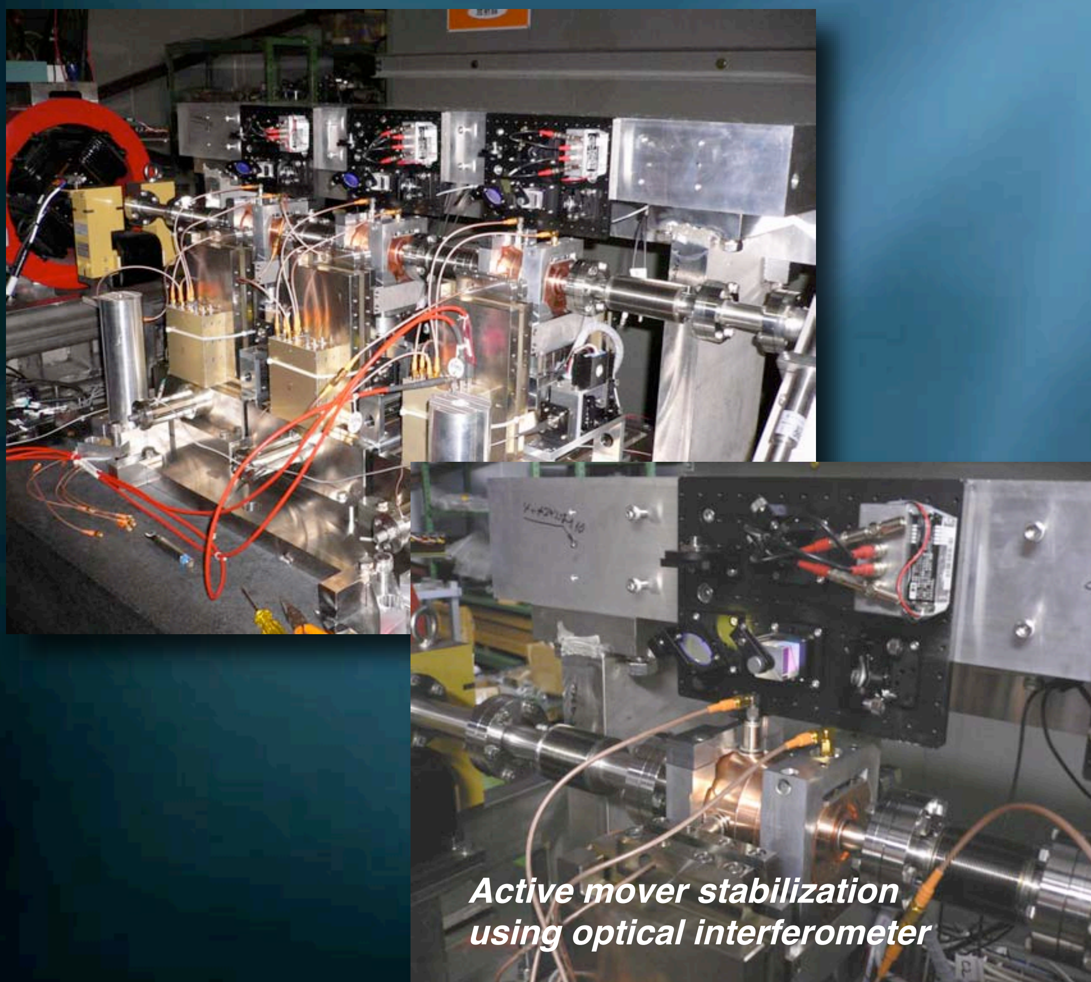
Mover system with an active stabilization using an optical interferometer.

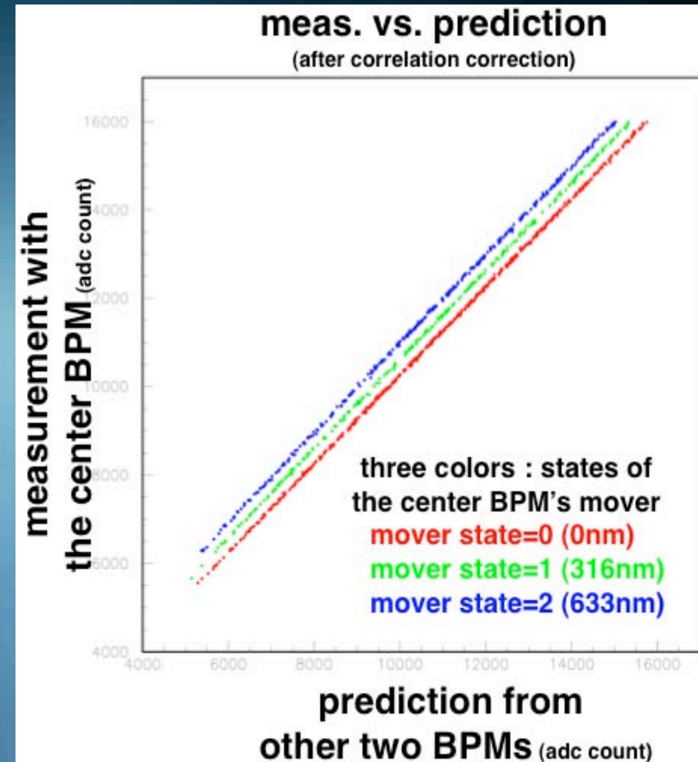
single down conversion and analog phase detection electronics.

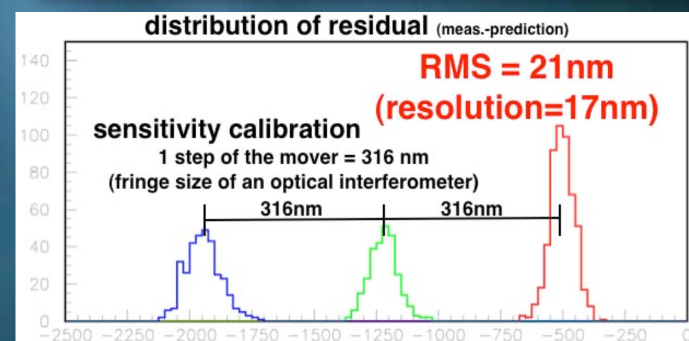
Performance

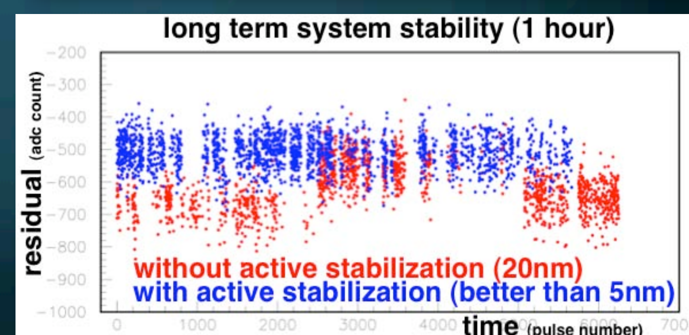
Resolution of the BPM: 17nm

Active mover stabilizes the system better than the resolution.



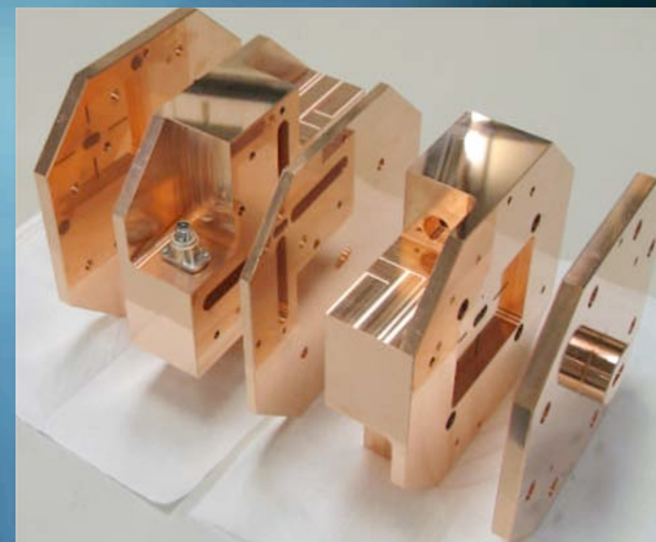






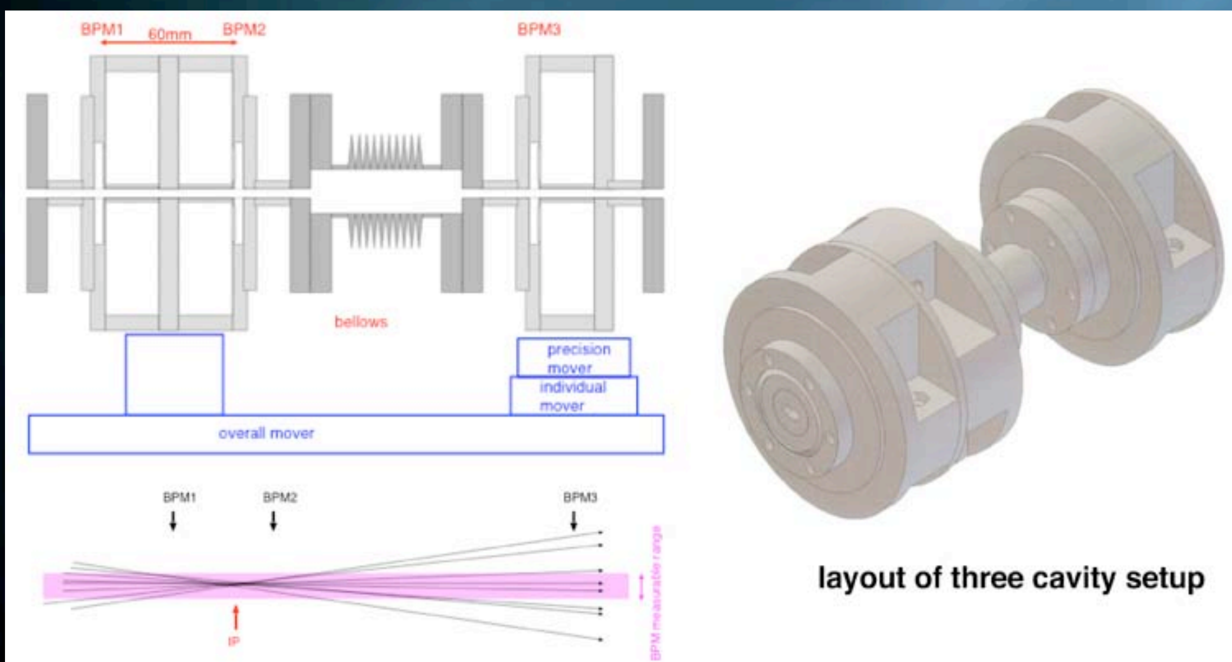
ATF2 IP-BPM R&D (KEK)

orbit stability measurement ATF2 IP.
target: ~1nm resolution.
rectangular cavity for x-y isolation.
position sensitivity: 2 times more for x
4 times more for y than BINP BPM.
resolve angle by optimaized location for IP.



Cold model of two cavities region

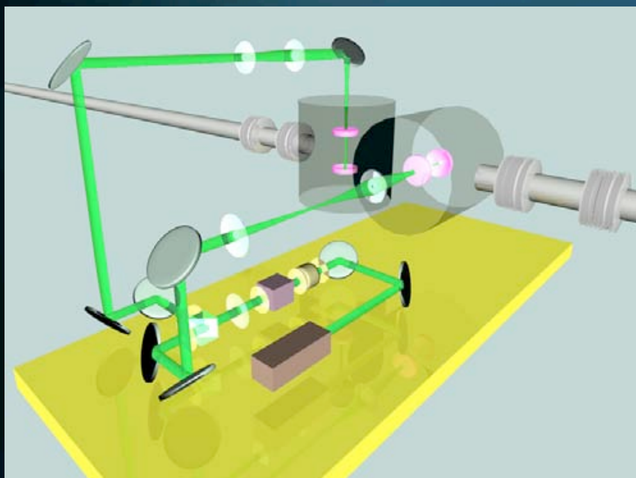
beam test of this cold model:
sensitivity was half of expected.
(need more study)

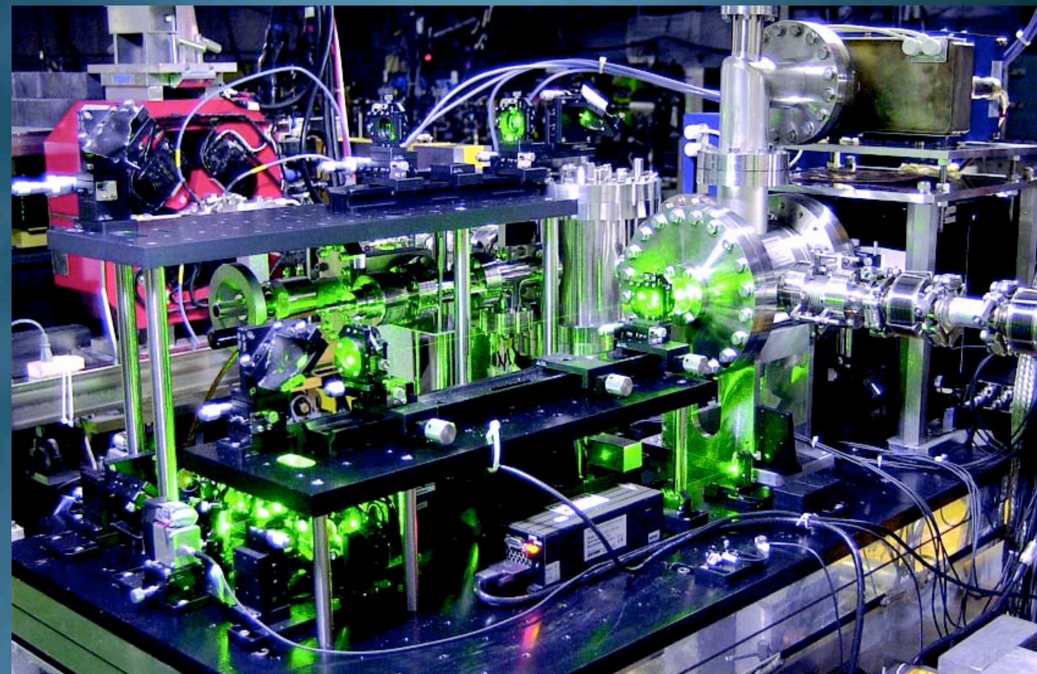


BPM arrangement for IP

Laser Wire R&D at ATF DR

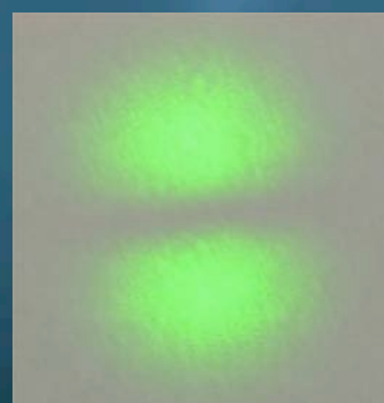
300mW 532nm Solid-state CW Laser
fed into optical cavity.
optical cavity lockin feedback by piezo.



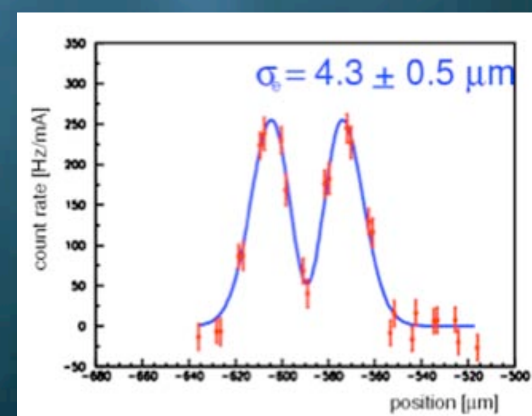


monopole mode wire:
14.7μm laser wire for X scan
5.7μm for Y scan
(whole scan: 15min for X, 6min for Y)
~ 4μm resolution

scan by actuating whole optics table.



dipole mode wire



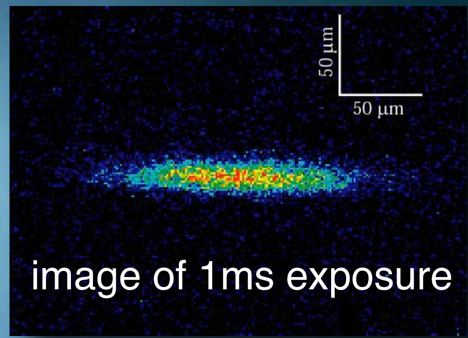
4.3 μm beam size meas.
demonstrated.
~2 μm resolution.

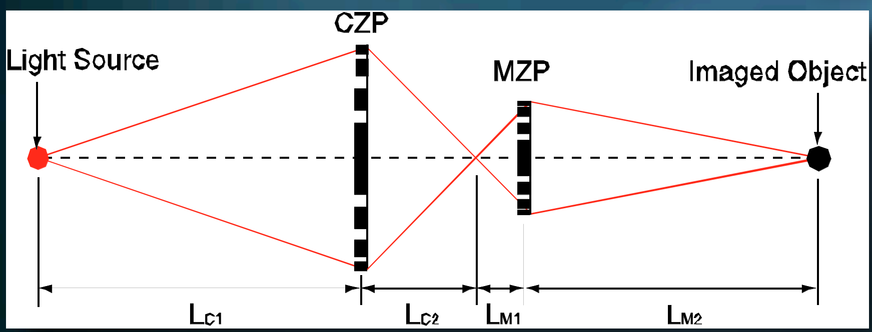
XSR monitor R&D at ATF DR

X-Ray Telescope using Zone Plate at 3.2KeV

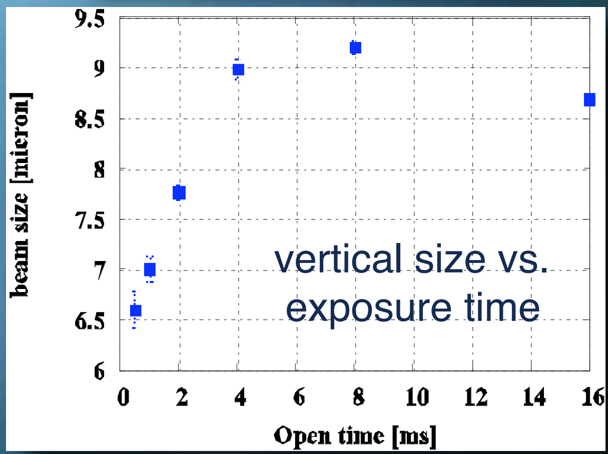
- ***magnification : 20***
- ***resolution : ~1 µm***
- ***integration time : > 1ms***

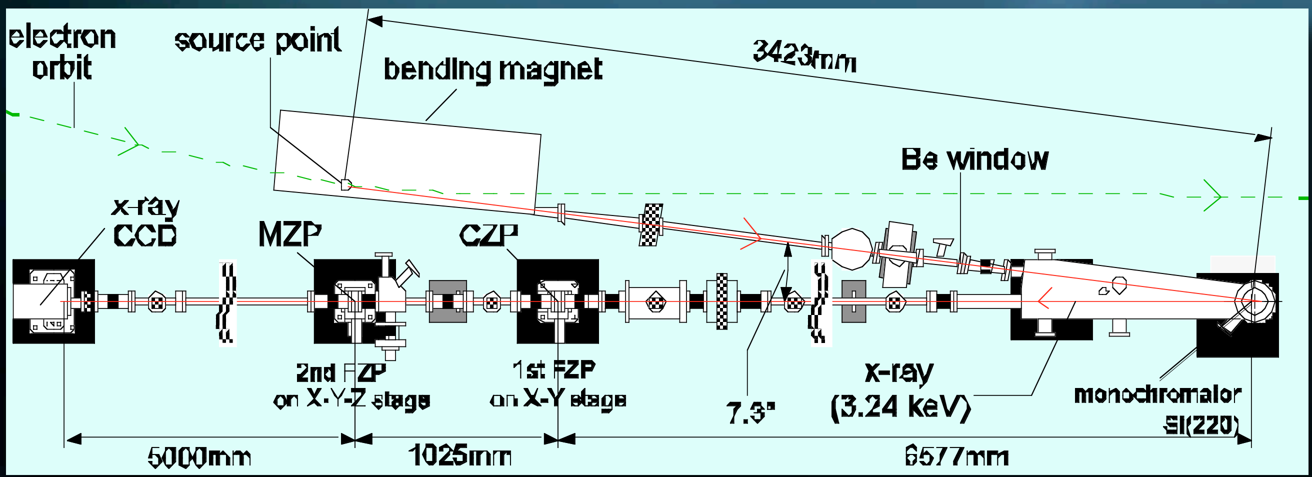
Zone plate

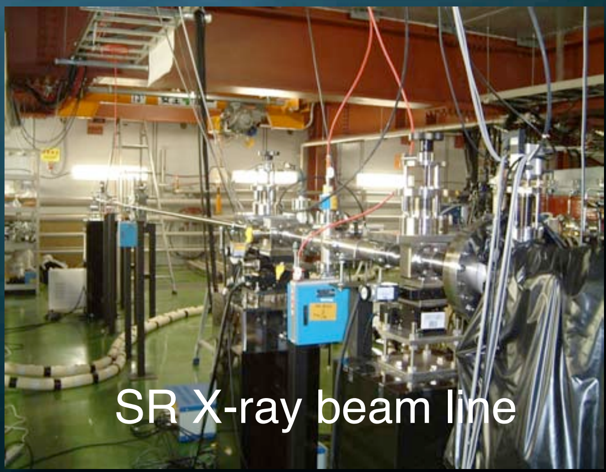




SR X-ray Optics



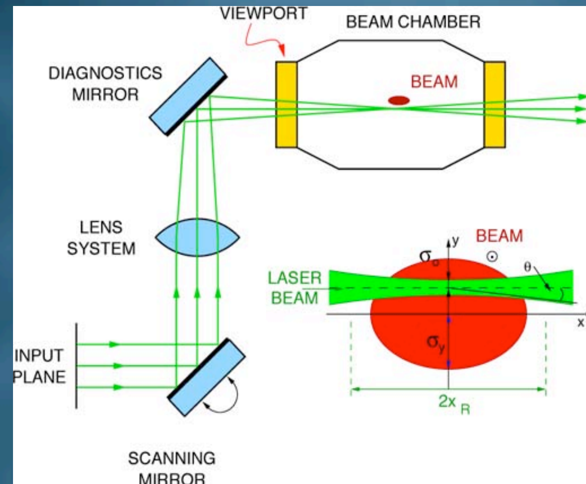


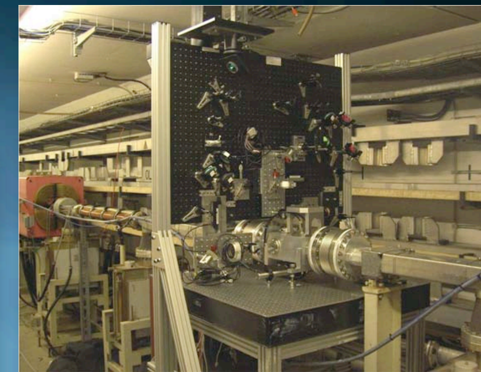


RHUL Laser Wire at PETRA

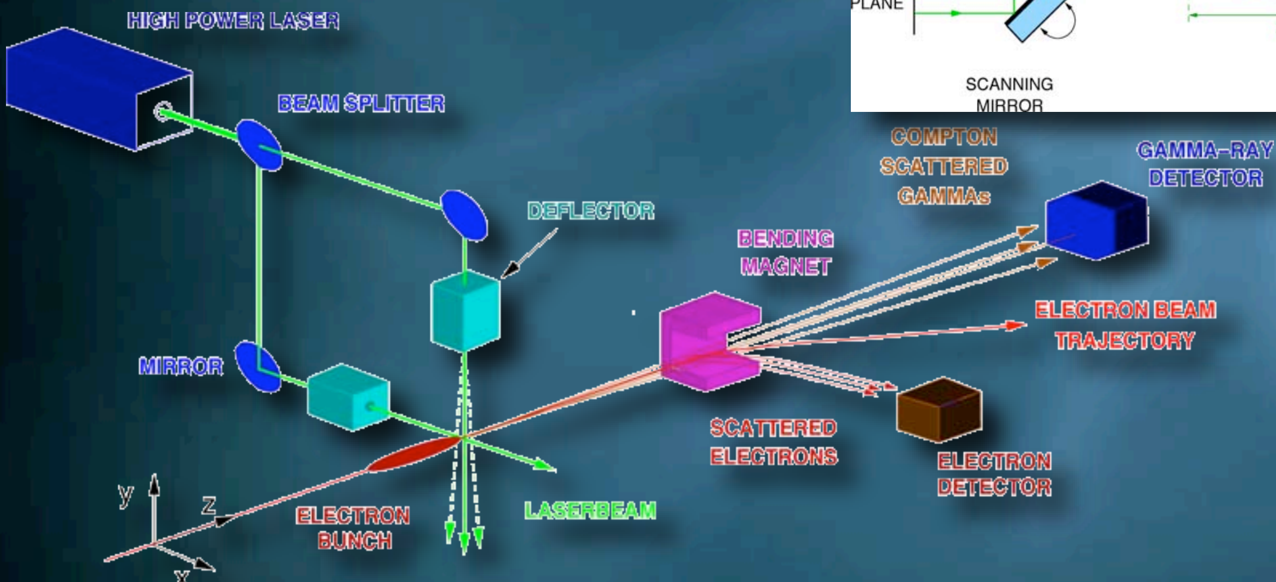
RHUL, Oxford, DESY, SLAC, KEK

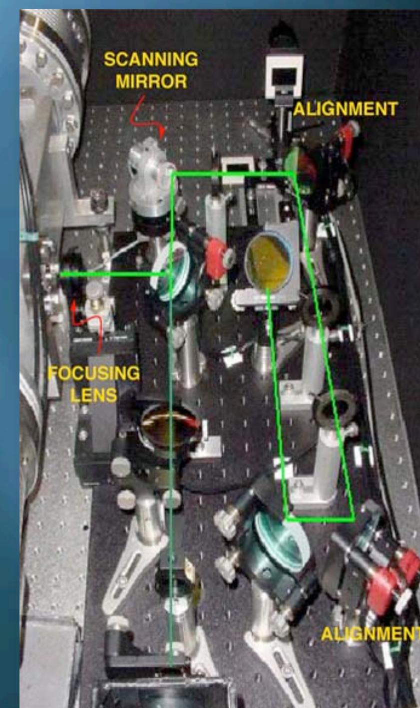
focus high power pulse laser into beam, detect gamma-ray at downstream.





LW optics system at PETRA



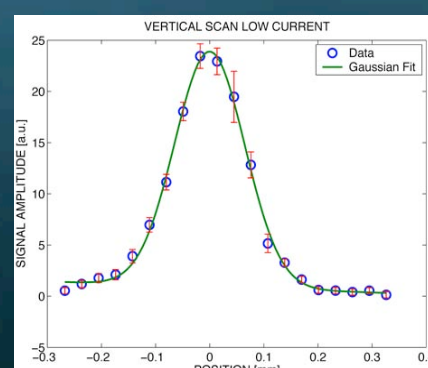


scanning optics

scanning laser beam by Electro-optic techniques with very fast ~100kHz.

can get 100 different position in a 1ms train.

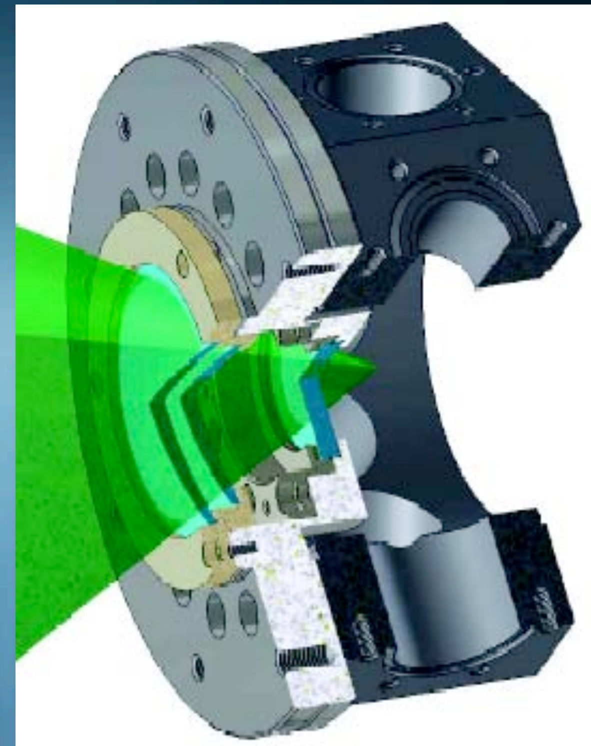
R&D started with slow mirror scan, so far.



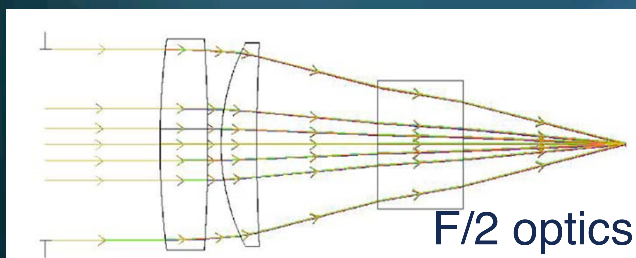
scan of 68 μm beam size

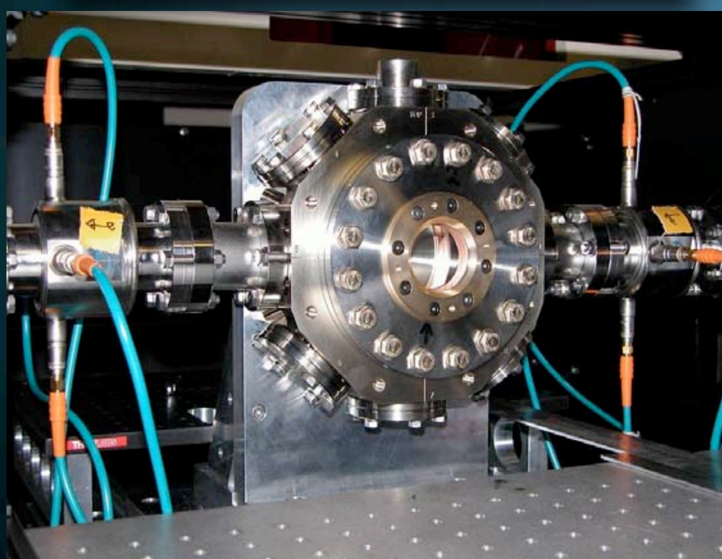
RHUL Laser Wire at ATF

Laser : Nd:YAG 532nm, pulse
focus optics : F/2 doublet + window,
using focused electron beam ~ few micron
need to confirm laser spot size.
will try F/1 optics, fast scanning, etc.

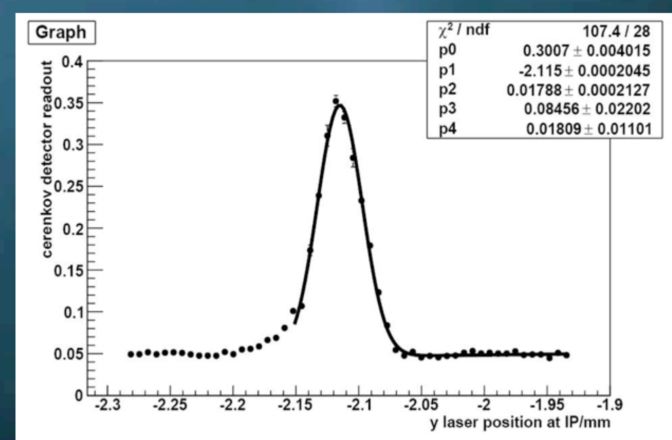


Laser wire chamber concept



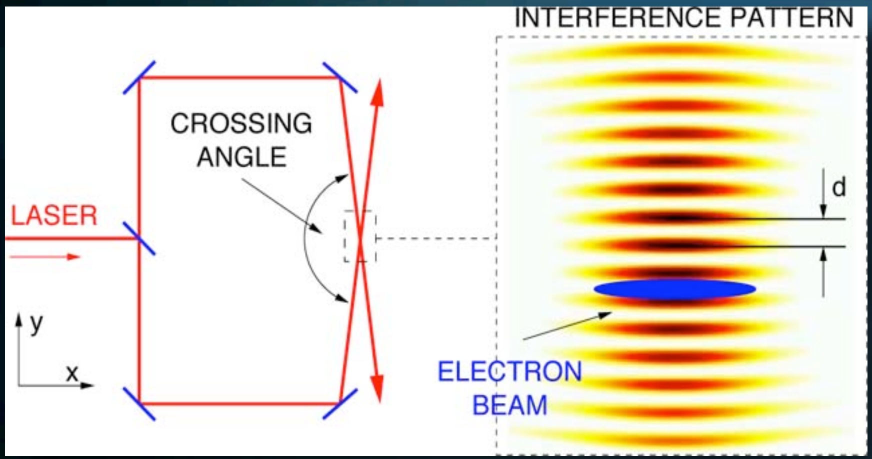


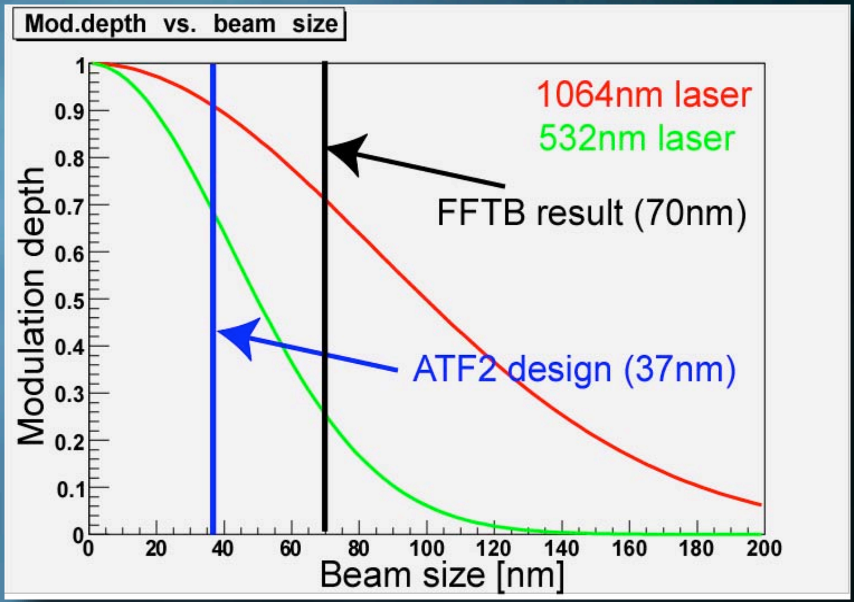
Laser wire chamber with two stripline BPMs

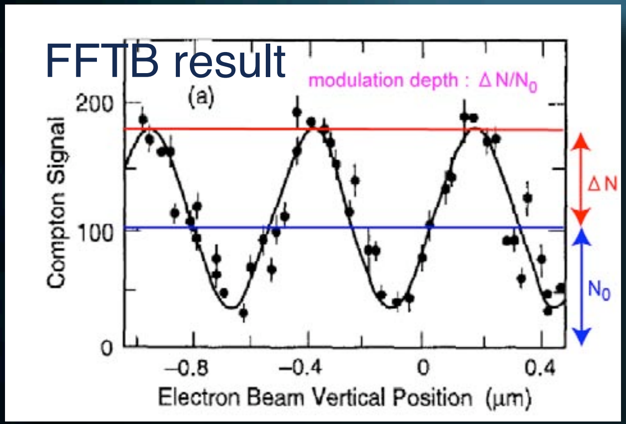


15~20 micron size scan achieved.

Laser Interference Monitor at ATF2 IP







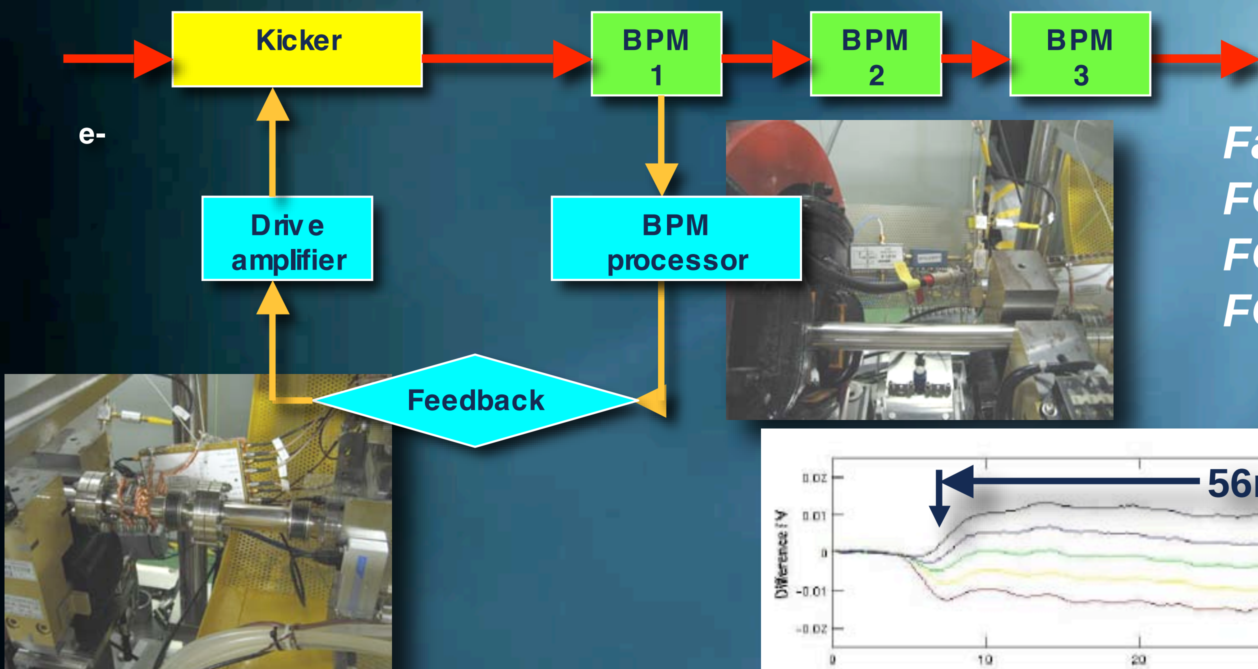
Shintake-monitor result in FFTB

FFTB ~70nm -> ATF2 37nm
modification : Laser wavelength
fringe stabilization FB
new gamma detector

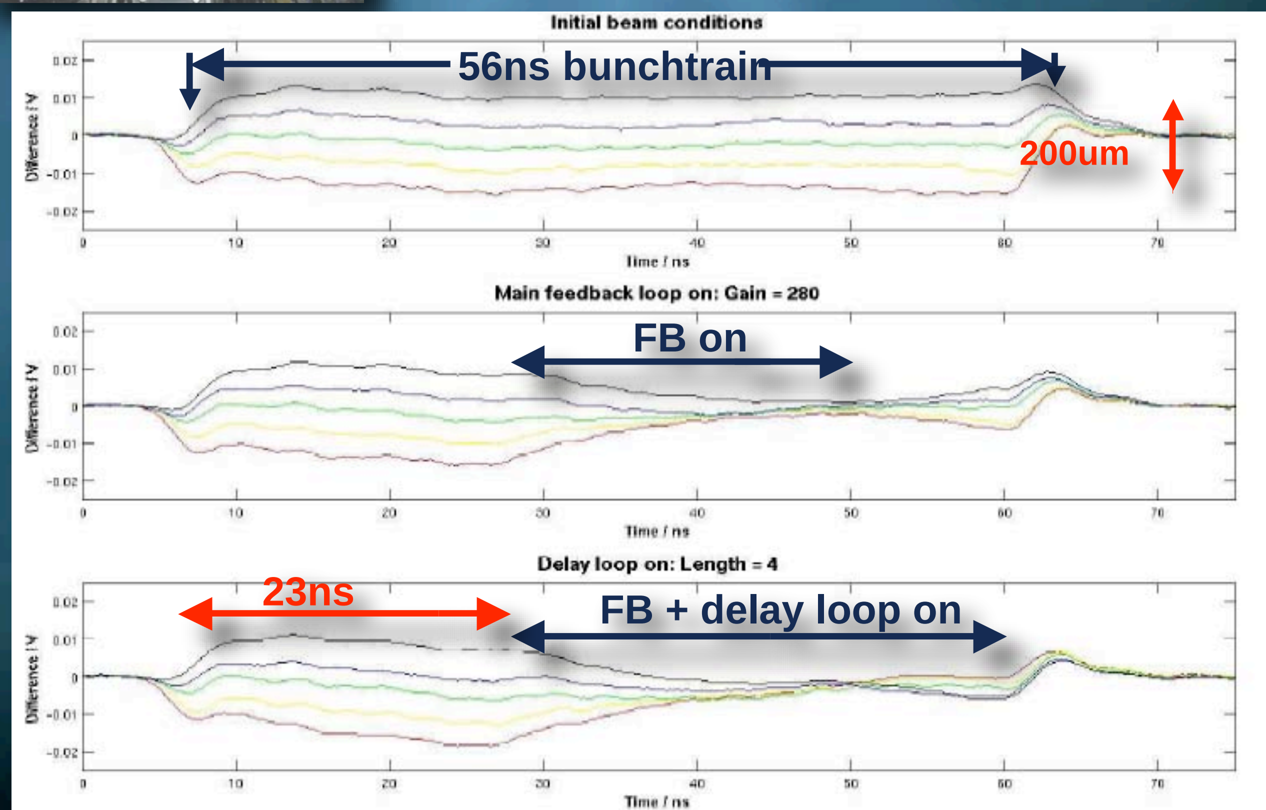
Shintake-monitor from FFTB

FONT : Fast feedback R&D at NLCTA, ATF

Oxford, Daresbury, QMUL, SLAC, KEK, DESY, CERN

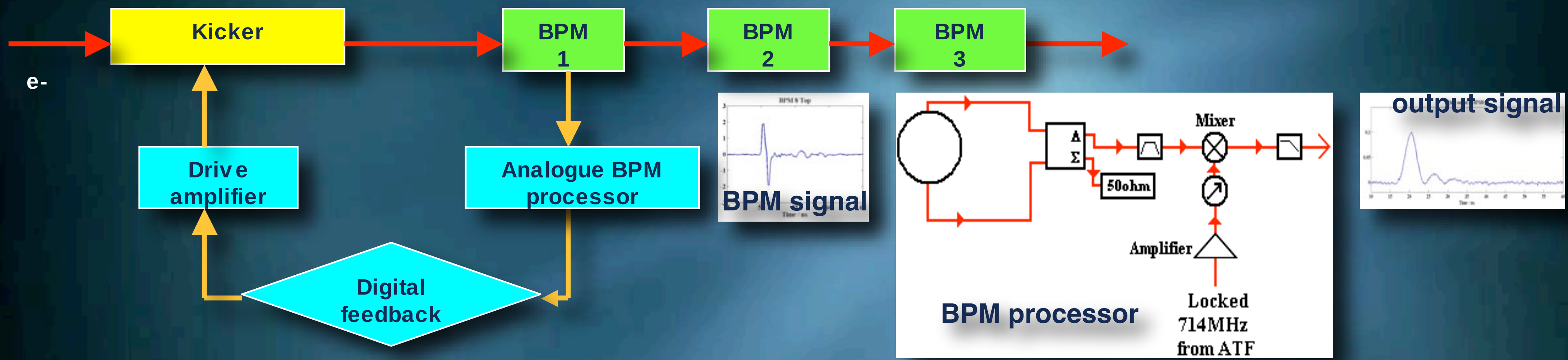


Fast feedback by Analog Circuit
FONT1 (NLCTA) latency : 67ns
FONT2 (NLCTA) latency : 54ns
FONT3 (ATF) latency : 23ns



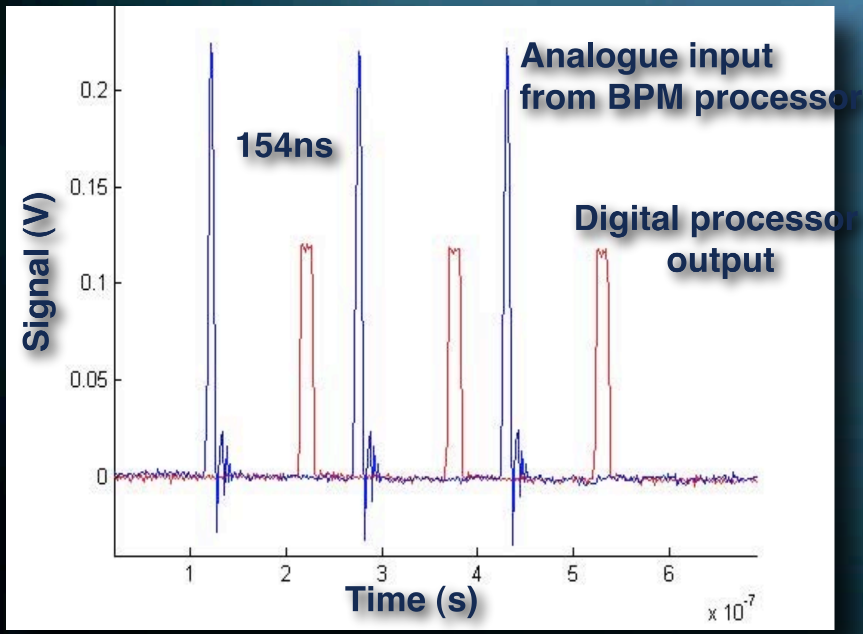
FONT3: Results (June 3 2005):
Delay-loop feedback w. latency 23 ns

FONT4 : digital beam feedback at ATF, ESA



signal pass latency : 25ns
BPM processor:7ns
Digital board:68ns
drive amplifier:40ns *total :140ns*

Latency goal 100ns



June 2006 : board test
Dec. 2006 : closed loop test
Mar. 2007 : closed loop test

FONT4: Digital FB Processor Board

Summary of R&D

1. BPM for Main Linac

re-entrant type : ~1μm resolution,

beam pipe slot cavity : S-band model, 0.46 μm resolution,

2. BPM for Beam Delivery System

SLAC/LLNL nm-BPM : 17nm resolution, 16nm instability,

KEK nm-BPM : 17nm resolution, with active feedback,

KEK IP-BPM : Cold model;twice much sensitivity from BINP-BPM,

3. Beam Profile Monitors for damped beam

ATF-DR LW : ~2 μm resolution by dipole mode scan,

ATF-DR XSR : 1 μm resolution,

RHUL LW : 15~20 μm size scan succeeded in ATF,

ATF2 interference monitor : aiming 37nm size scan,

4. Bunch-by-bunch trajectory Feedback at IP

FONT4 : 140ns latency by digital process board,

The figures and pictures are borrowed from many collabolators and the following web-site:
DESY, ATF, workshop presentations and conference papers.

I would like to appreciate to all of collaborators, paper authers and presenters.

end