Non-EC R&D

KEK
Junji Urakawa
2011.7.7 at INFN

Discussing issues :

1. Experimental confirmation for the threshold of Fast ion instability
Need clear data sets to benchmark the programs.

2. Fast kicker development
Need long term reliability check of fast kicker pulsers

3. Impedance measurement of fast kicker strip-line
Planning to do it at ATF2 beam line

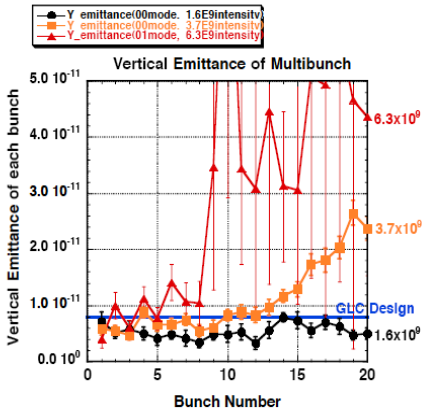
4. Tuning method confirmation for 2pm vertical emittance realization in the ring.

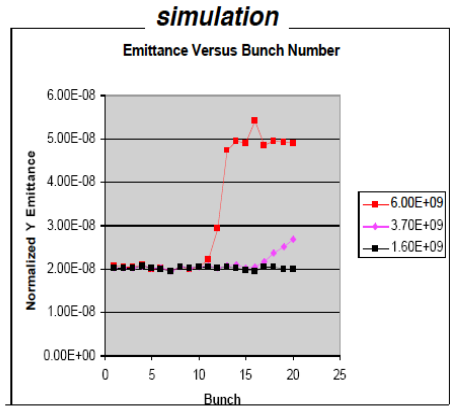
5. Beam instrumentation development

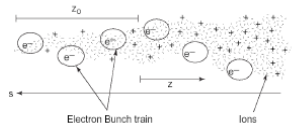
Miscellaneous
Circumference correction by chicanes in the ring
Wiggler effect
Multi-bunch instability precise study

Study on the fast ion instability at ATF

Preliminary result of
Fast Ion Instability simulation







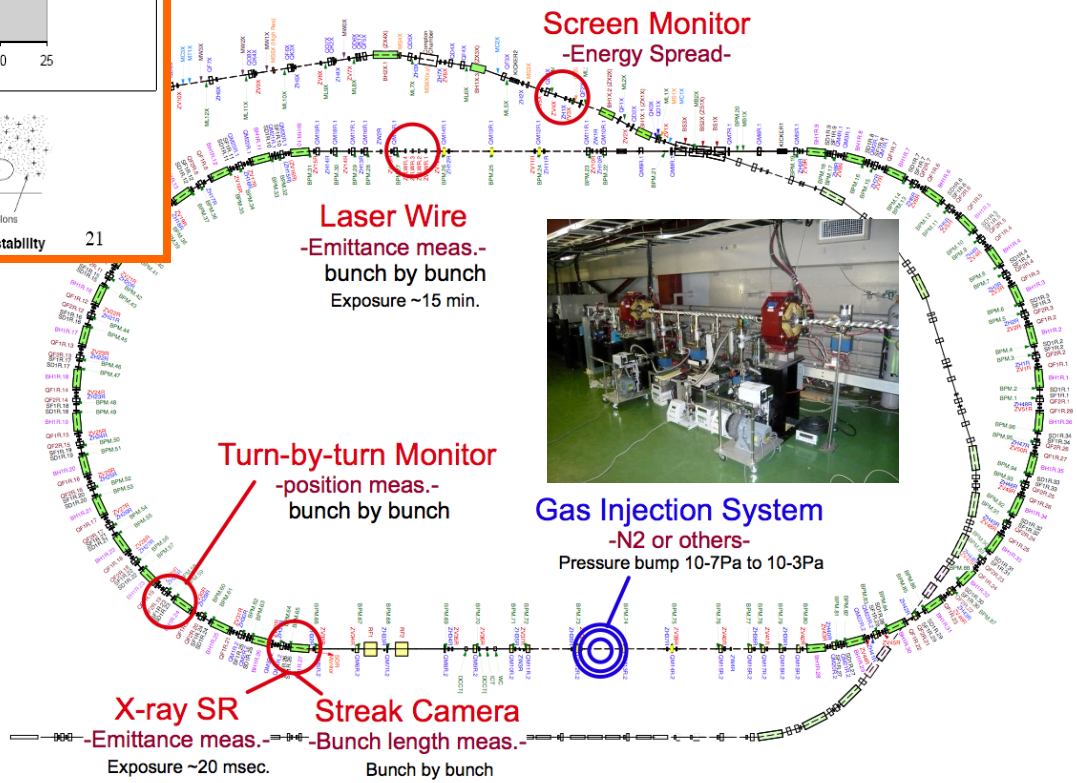
Schematic of the Fast-Beam Ion Instability

21

Behavior of Y emittance is very similar.

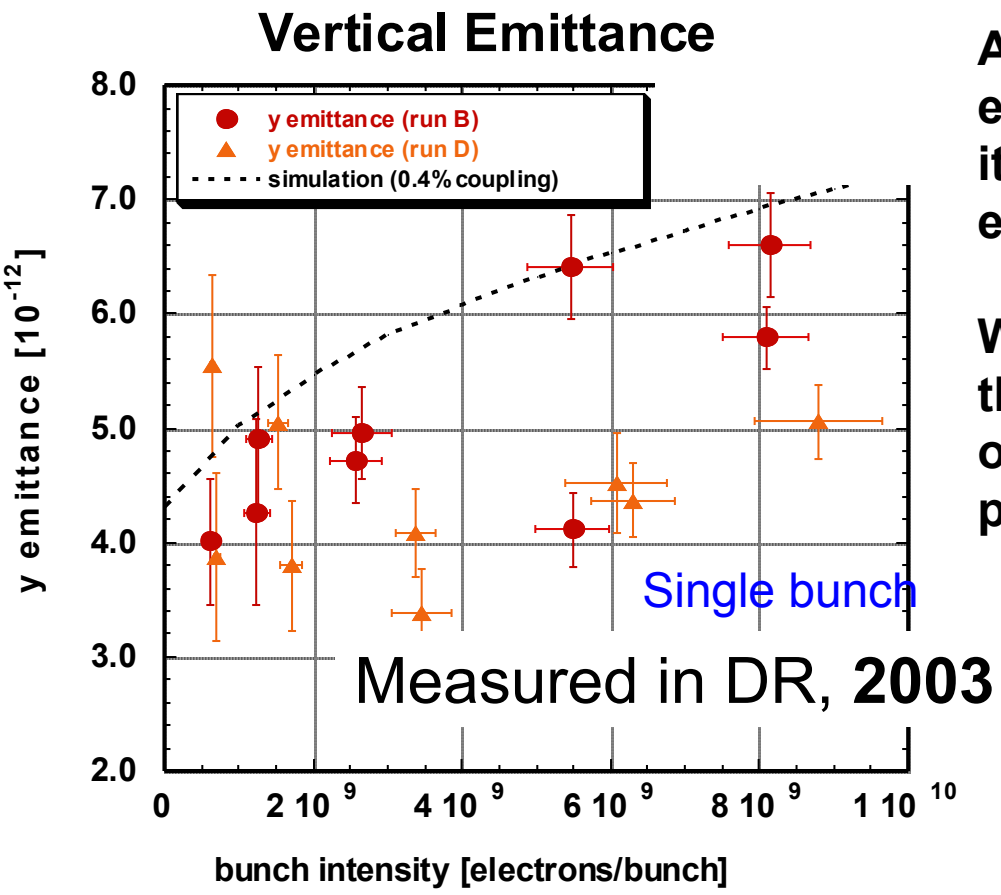
ATF 2004

- Distinguish the two ion effects: beam size blow-up and dipole instability.
- Quantify the beam instability growth time, tune shift and bunch train gap effect
- Provide detailed data to benchmark simulations with experiment.



In this June, we measured ~30pm vertical emittance by X-SR and have to confirm this value by laser wire. When we will get the stable beam with low emittance less than 10pm, We will do the fast ion study again.

Emittance tuning at ATF long time ago



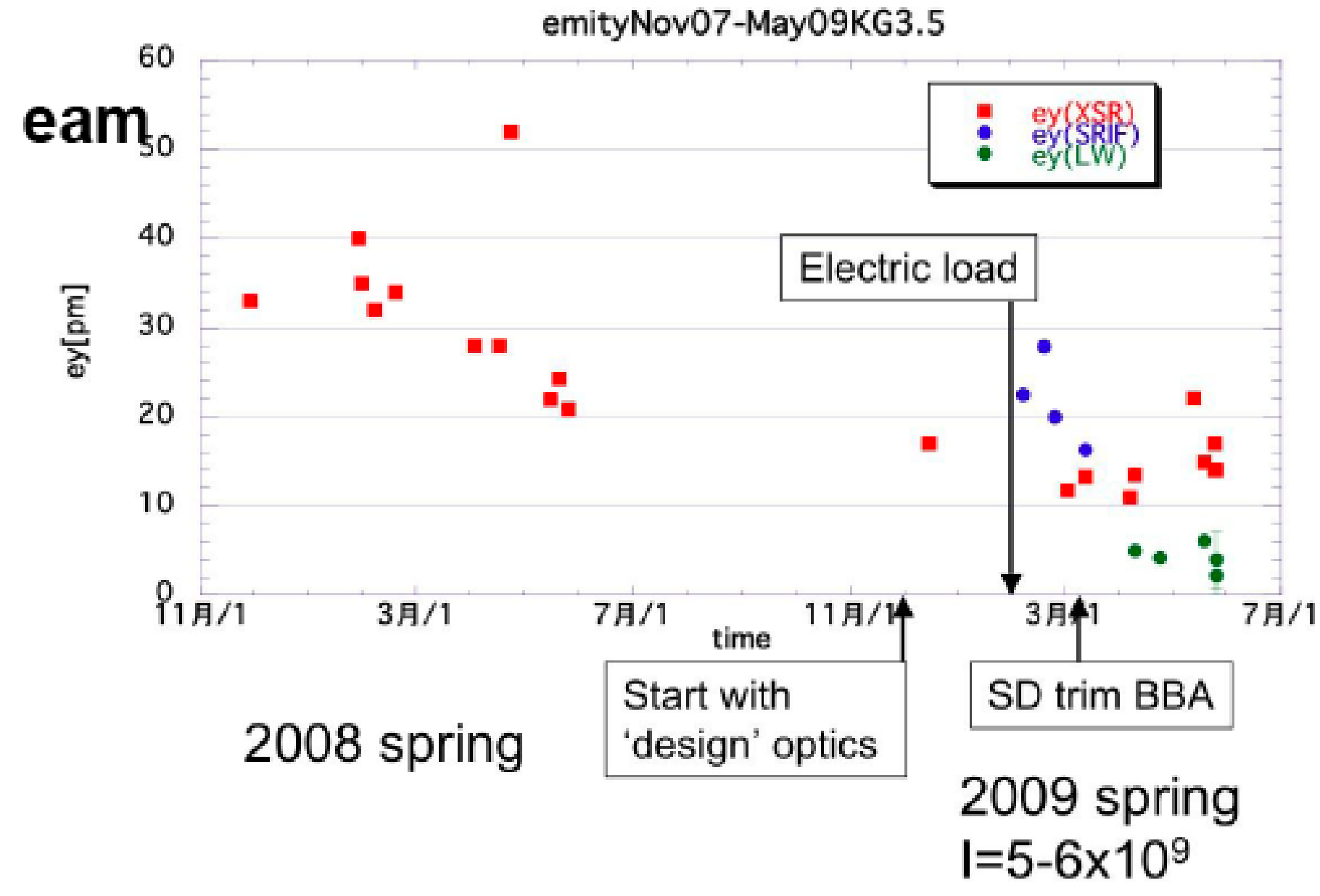
ATF achieved about 4pm vertical emittance but we could not reproduce it from 2006 and the measured vertical emittance is about 20pm usually.

We checked the damping ring to find the reason and will realign all magnets of DR in this summer shutdown precisely.

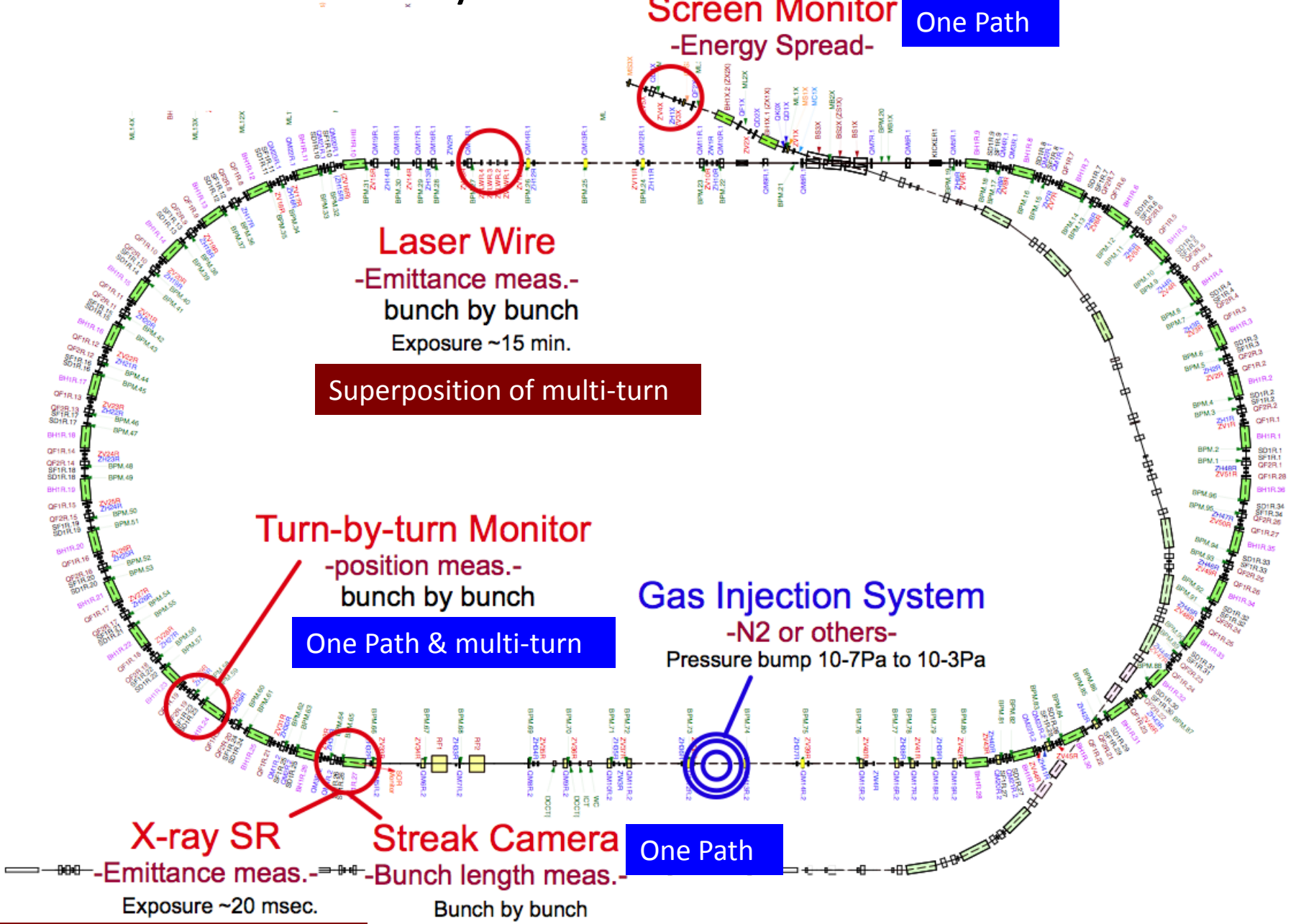
Necessary works

- optics retuning
- beam based realignment
- BPM re-positioning

ATF vertical emittance

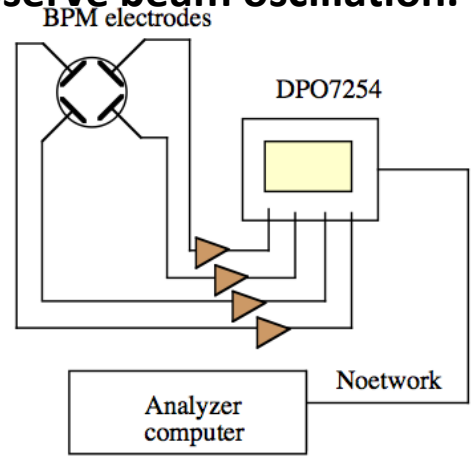


Devices for FII study

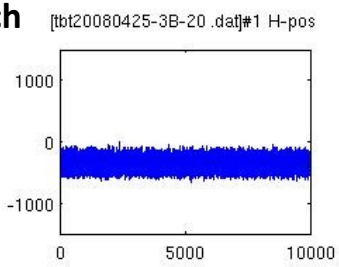
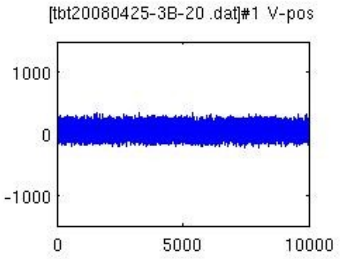
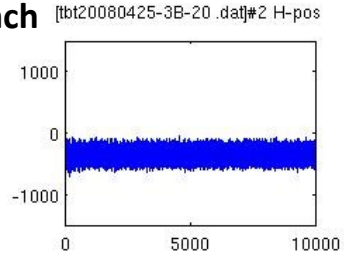
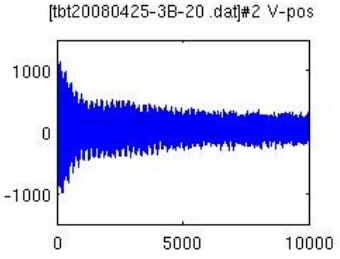
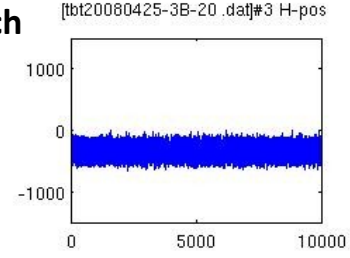
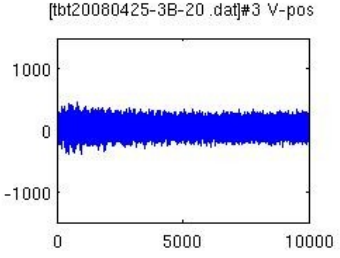


Measurement of beam position bunch by bunch

BPM signals are memorized into Oscilloscope (DPO7254, 0.1ns time resolution) during 10000 turns and we can observe beam oscillation.



When we gave the dipole oscillation to second bunch, we observed no oscillation on 1st and 3rd bunches.

	Horizontal pos. (w/o kick)	Horizontal pos. (with kick)
1st bunch		
2nd bunch		
3rd bunch		

Three bunch signals from button electrode with 2.8ns bunch spacing.

FII study on 2007/3/13-14

5mA/20bunches

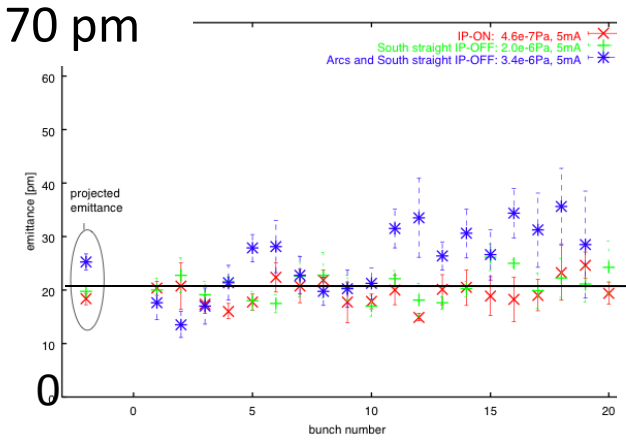


Figure 7: emittance of multi-bunch beam at 5mA/20bunches

10mA/20bunches

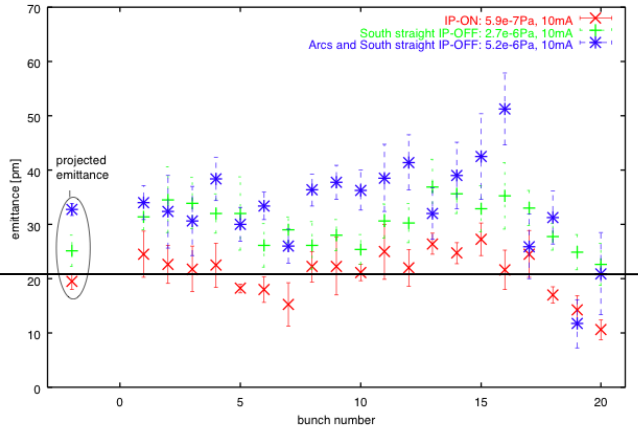


Figure 8: emittance of multi-bunch beam at 10mA/20bunches

20mA/20bunches

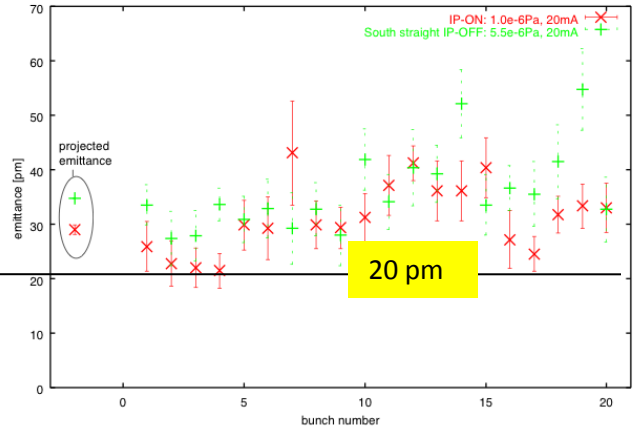


Figure 9: emittance of multi-bunch beam at 20mA/20bunches

We measured emittance of each bunch in a 20-bunch beam in the DR with a laser-wire monitor. No clear emittance blow-up along a train was observed up to 20mA/train.

One of the reason may be the bigger vertical emittance compared with the data taken in 2004.

2008 Fast Ion Work at ATF

Studies will continue with ongoing improvements: lower emittance, controlled pressure bump, etc.

New laser wire will be installed by the end of 2011.

Experimental Results measured by laser wire in DR

Table 2: vacuum pressure in 2004

ion pump status	11mA	26mA	31mA
normal	4.0×10^{-6} Pa	6.0×10^{-6} Pa	6.5×10^{-6} Pa

2007

20pm

10pm

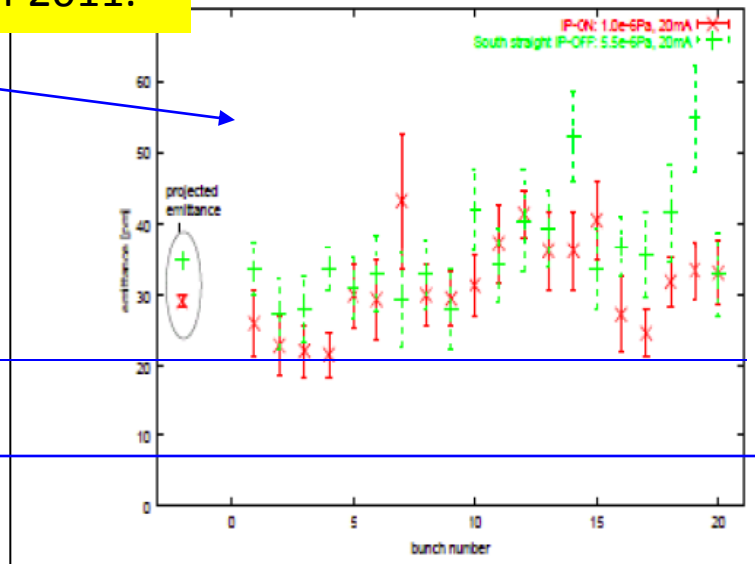


Figure 9: emittance of multi-bunch beam at 20nA/20bunches

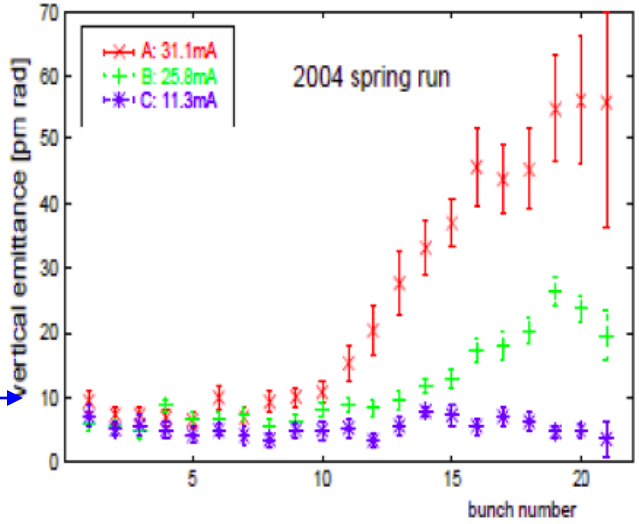
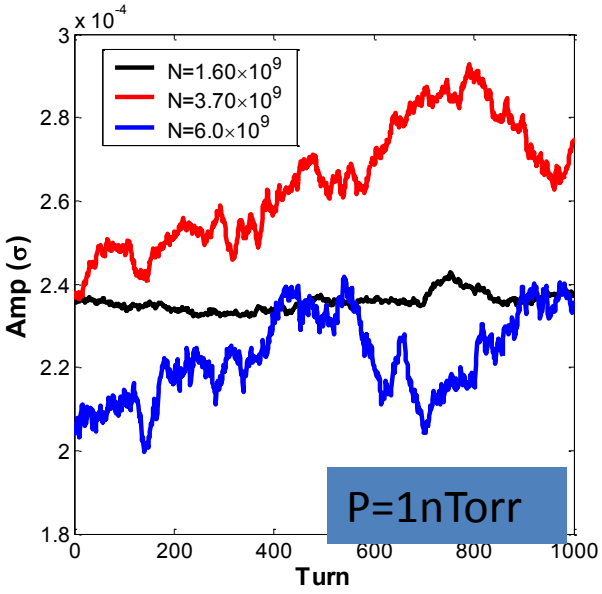
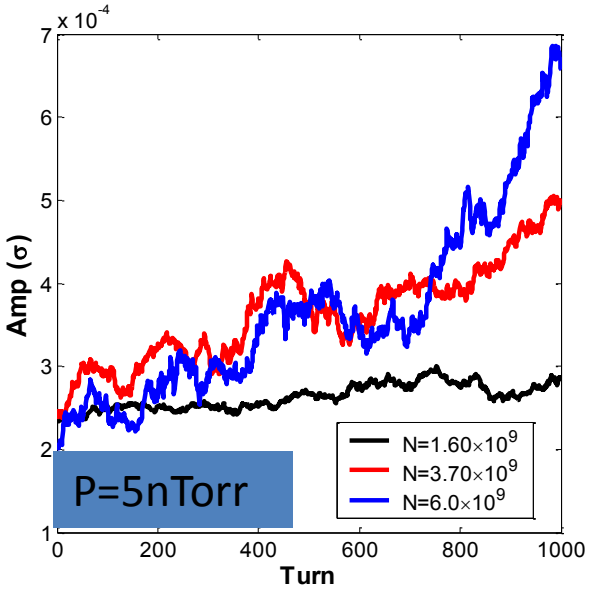


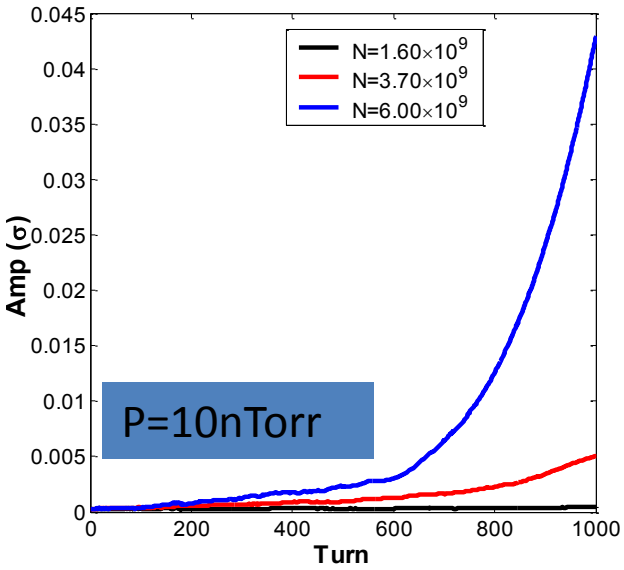
Figure 10: data taken in 2004

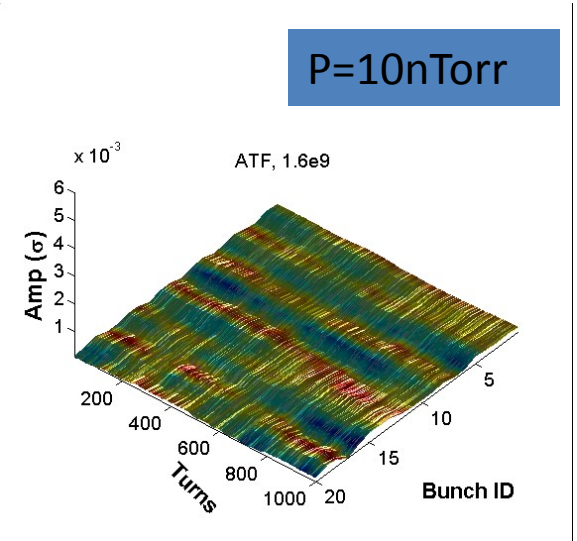
0.1nTorr is OK or not. Hope several 0.1nT OK.

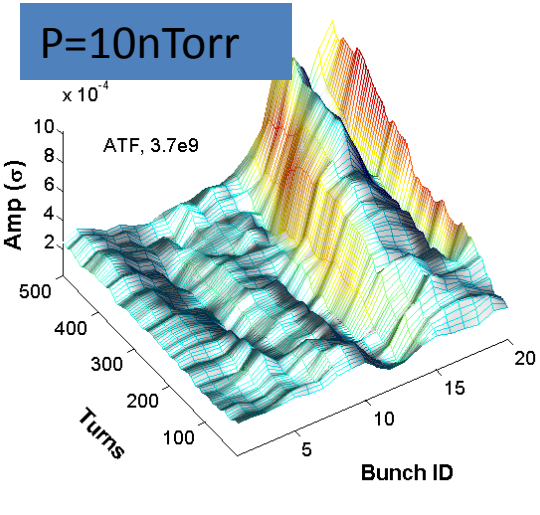
FII at ATF

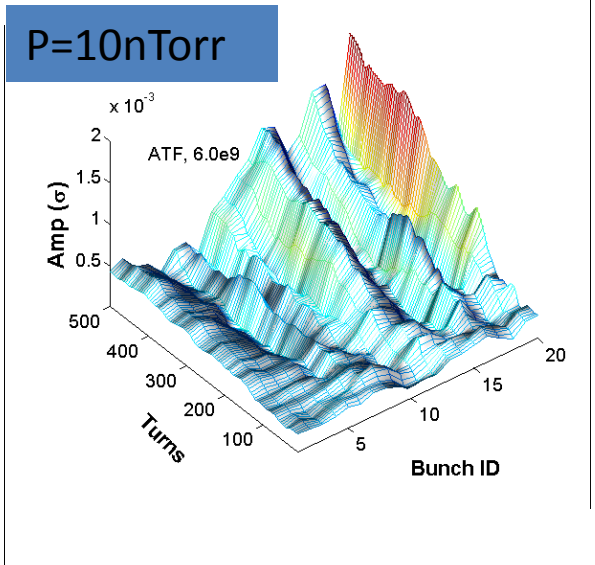

x 10^-4
N=1.60×10^9
N=3.70×10^9
N=6.0×10^9
Amp (σ)
Turn
P=1nTorr


x 10^-4
N=1.60×10^9
N=3.70×10^9
N=6.0×10^9
Amp (σ)
Turn
P=5nTorr


N=1.60×10^9
N=3.70×10^9
N=6.00×10^9
Amp (σ)
Turn
P=10nTorr

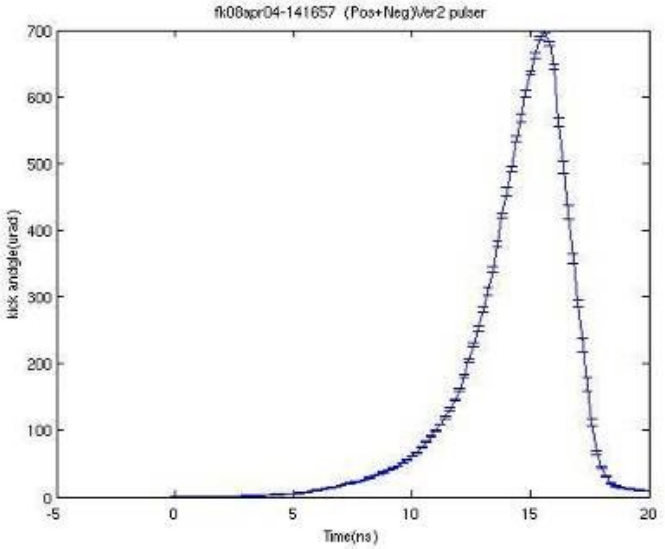

P=10nTorr
x 10^-3
ATF, 1.6e9
Amp (σ)
Turns
Bunch ID


P=10nTorr
x 10^-4
ATF, 3.7e9
Amp (σ)
Turns
Bunch ID

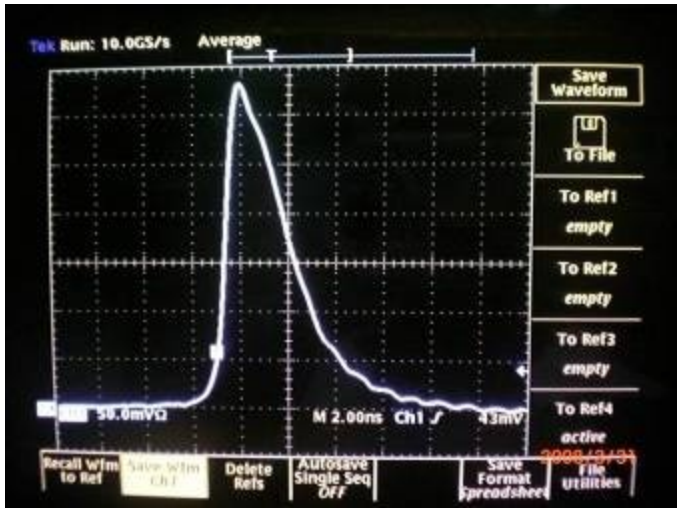

P=10nTorr
x 10^-3
ATF, 6.0e9
Amp (σ)
Turns
Bunch ID

Fast Kicker R&D

- Right: Kicker pulse measured from bunch timing scan. Deflection amplitude is as expected from pulsers providing approximately ±10 kV.
- 0.44mrad kick by 30cm strip-line.



Pulser: FID FPG 10-6000KN



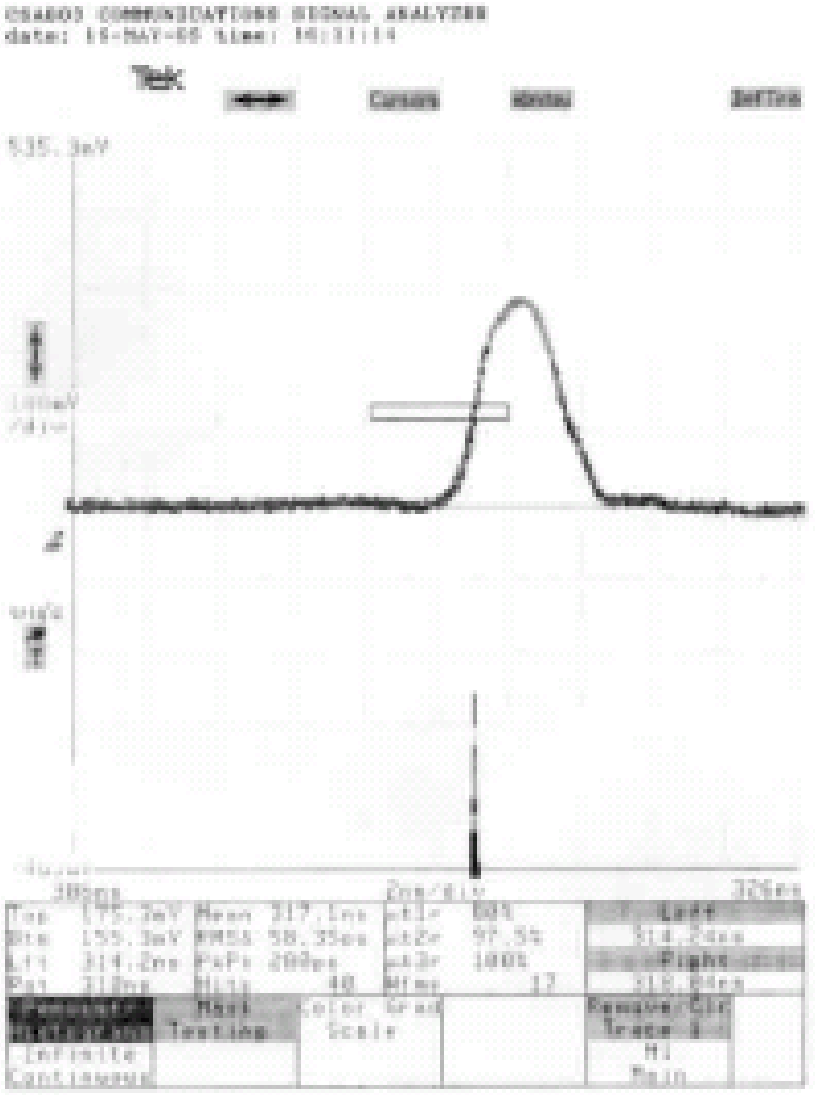
Maximum output voltage	10 kV
Rise time, 10 – 90%	< 1 ns
Rise time, 5 – 95%	< 1.2 ns
Pulse duration at 90% peak amplitude	0.2 – 0.3 ns
Pulse duration at 50% peak amplitude	1.5 – 2.0 ns
Output pulse amplitude stability	< 0.7%
Maximum pulse repetition frequency	6.5 MHz
Number of pulses per burst	110 (max)
Burst repetition frequency	5 Hz

FPG5-3000M pulser(FID GmbH)

Specifications

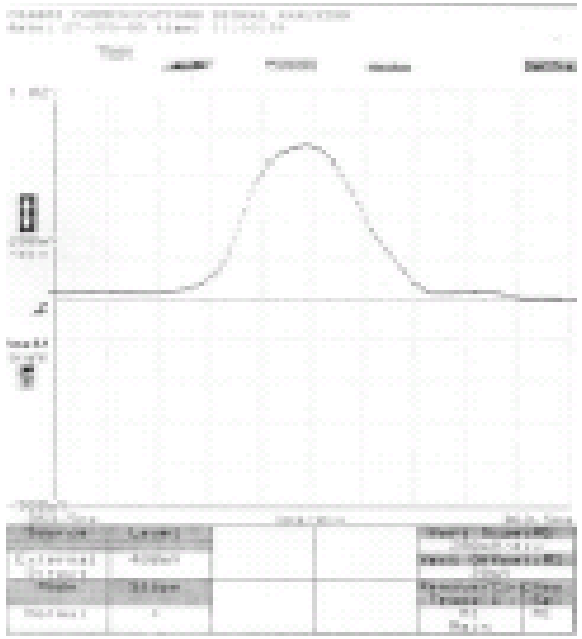
Maximum amplitude at 50 ohm - 5 kV
Rise time - 1-1,2 ns
Pulse width at 50% of amplitude - 2-3 ns
Polarity - negative or positive
Delay time between output pulse and triggering
- not more than 200 ns
Jitter - not more than 100 ps
Triggering - Internal and External - 5-15 V, 10-20 ns
Maximum PRF in burst mode - 3 MHz

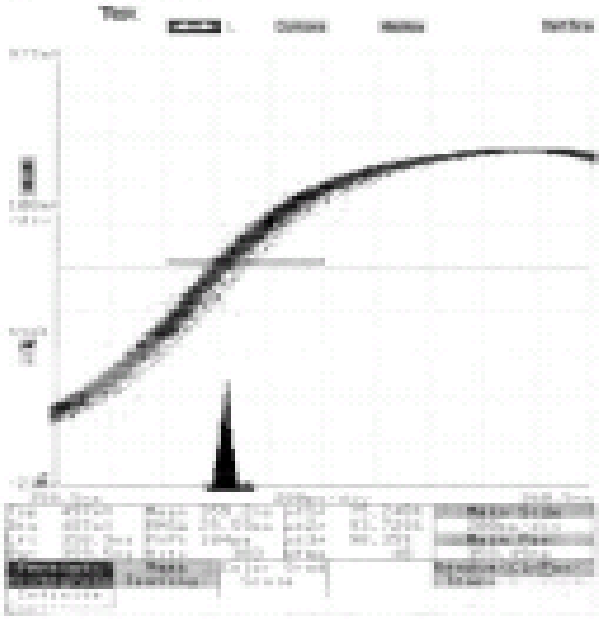
This results are typical one. Now, fast pulse PS is improved, see next slid.



5kV, ~1.5ns rise time

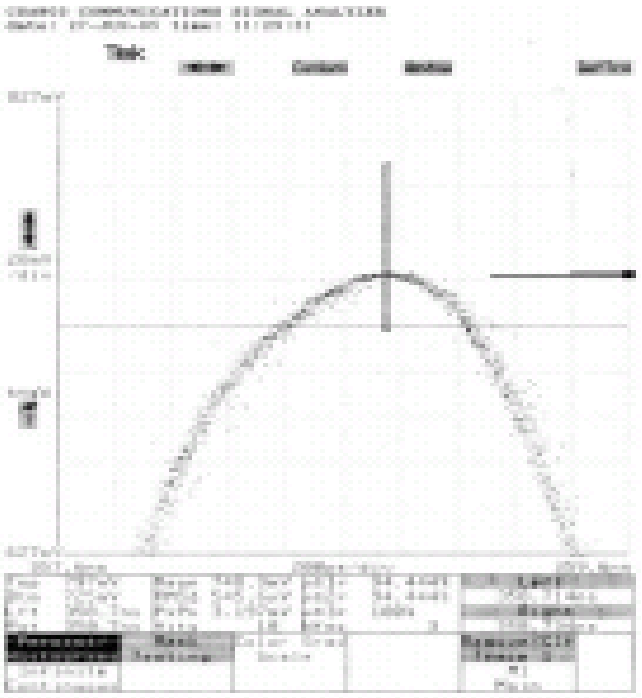
Pulser characteristics



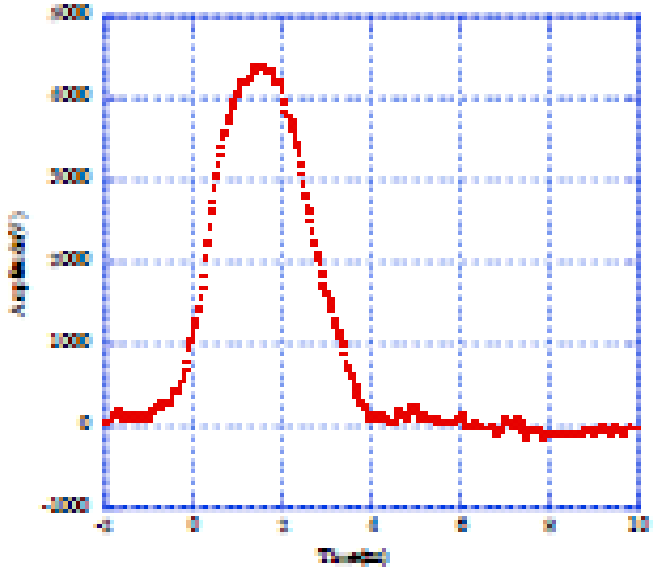


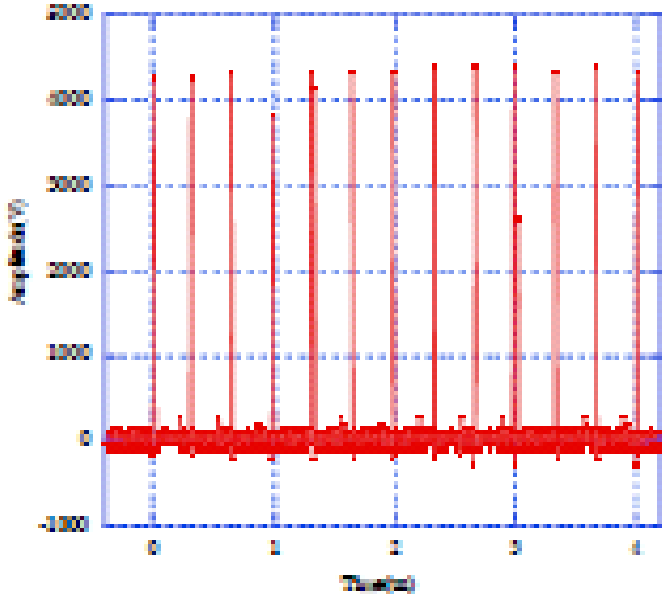
After tuning of th circuit,

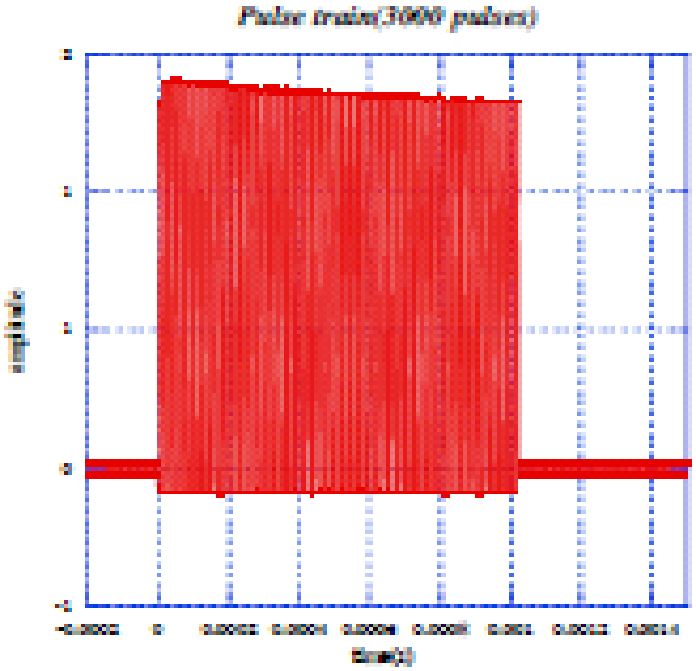
FID(FPG5-3000M) pulser
Pulse width(FWHM) = 2ns
Pulse height = 5kV
Rise time = ~1.5ns
Time jitter = ~29 ps
Amplitude Jitter = 0.72%
(limited by the scope resolution)



FPG-3000M 3MHz, 3000plses

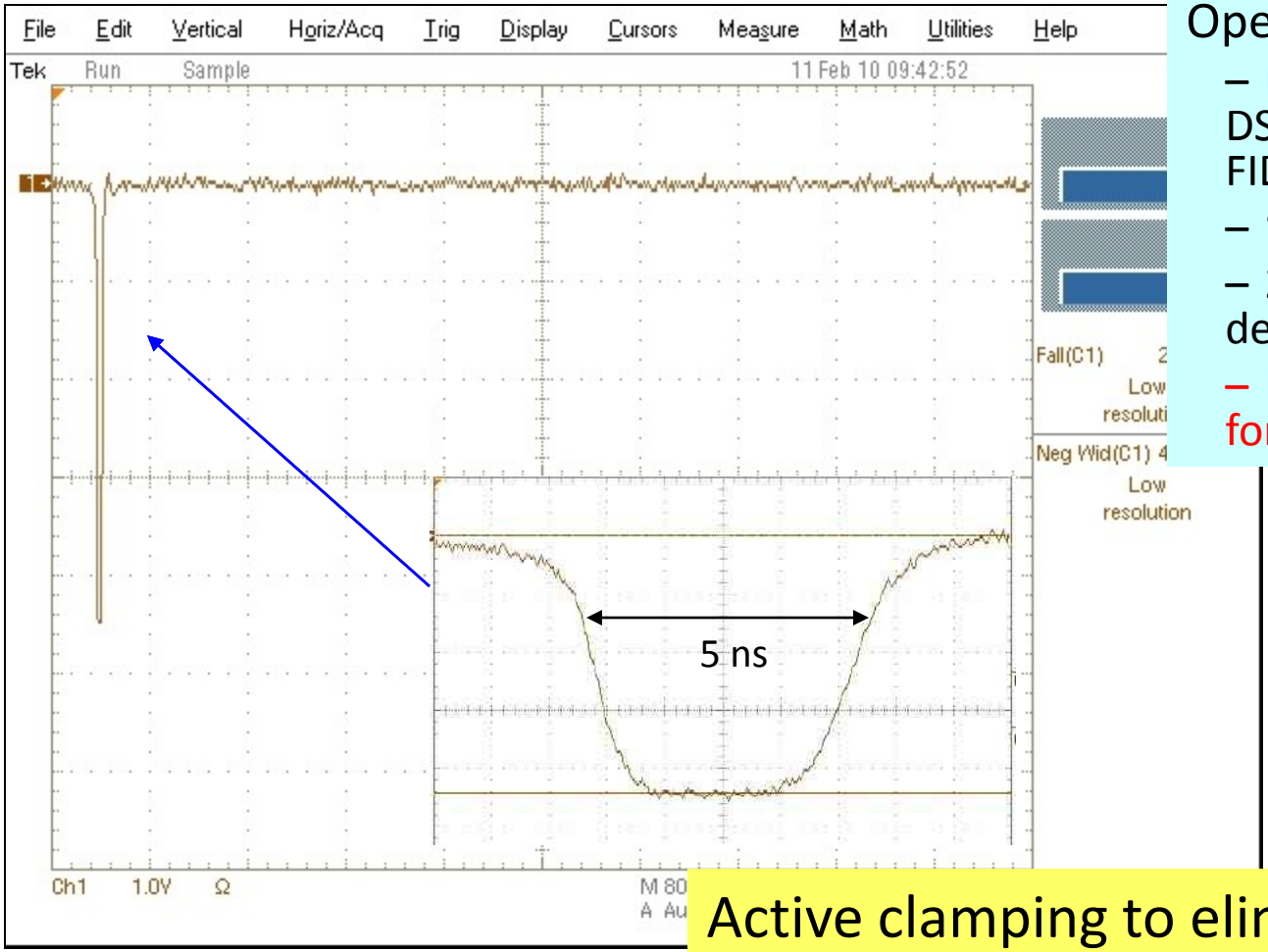






*The 4th pulse is ~10% smaller than the others.
*A few % of droop was observed in the 3000pulse train.

Output Waveform: No Post-pulse



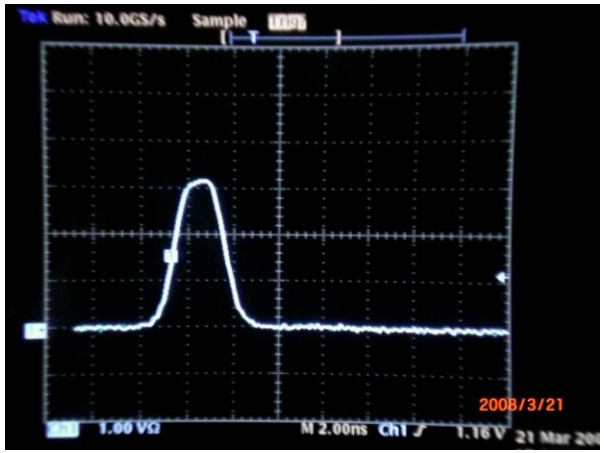
Opening Switch Program

- Functionally similar to DSRD systems marketed by FID GmbH
- "Open source" design
- 2-ns prototype demonstrated (FY08)
- Developing 4-ns modulator for ATF2

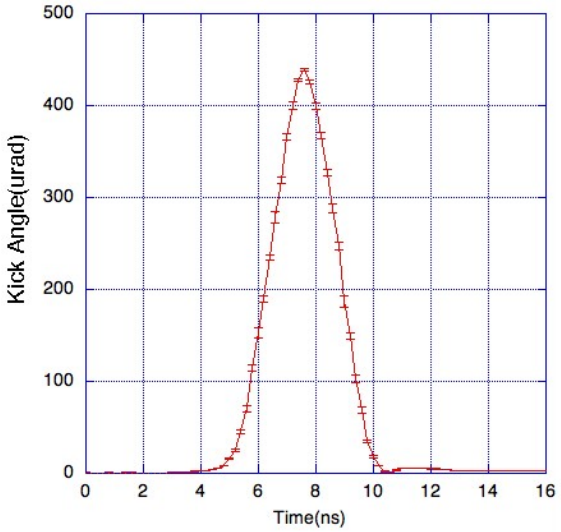
Active clamping to eliminate post-pulse

Single unit test
(To confirm 3ns of the rise time of the strip-line kicker)

- The time response of the kick field is strongly depends on the waveform of the drive pulse and the length of the strip-line electrode.
- FID pulser have 1.5ns rise time, 5kV peak voltage, 3MHz and 3000 burst pulse.
- The time response was tested when the drive pulse was applied to the 30 cm long strip-line electrode.
- The time response of the strip-line kicker was measured by measuring the betatron amplitude in ATF-DR. The measured rise time was 3ns, which meets the ILC requirement.

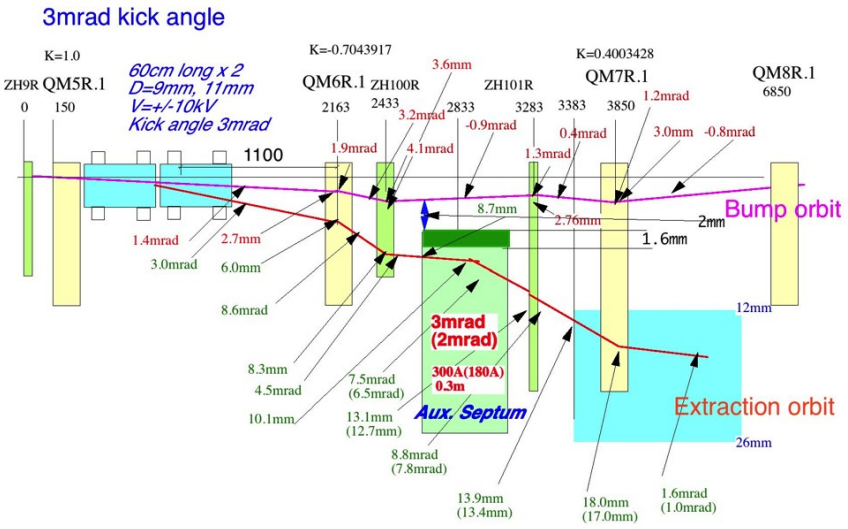


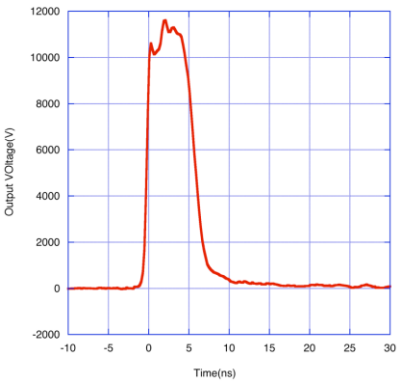
Waveform of FID pulser
5kv peak, 1.5ns rise time



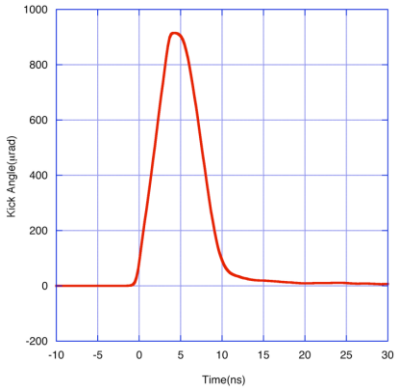
Beam extraction test

- *The beam extraction test was proposed to confirm the performance of the strip-line kicker.*
- *The pulsed magnet kicker was replaced to two units of 60cm long strip-line kicker.*
- *To help the lack of the kick angle, a local bump orbit and an auxiliary septum is used.*

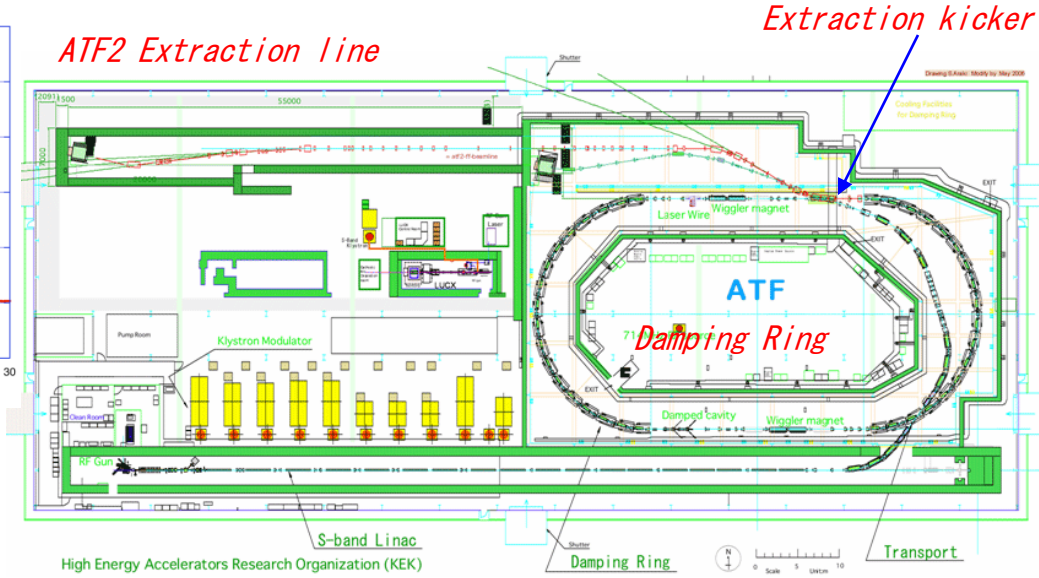




Kicker pulse



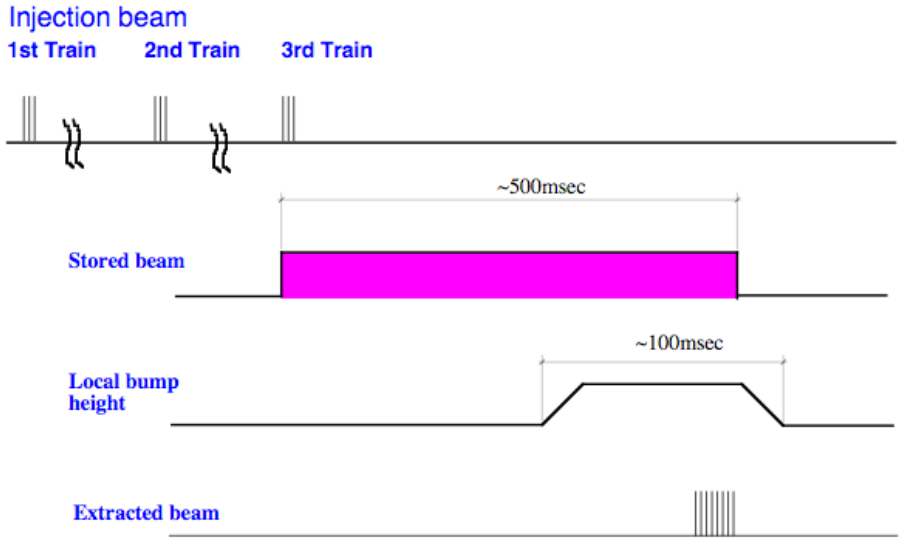
Kicker field

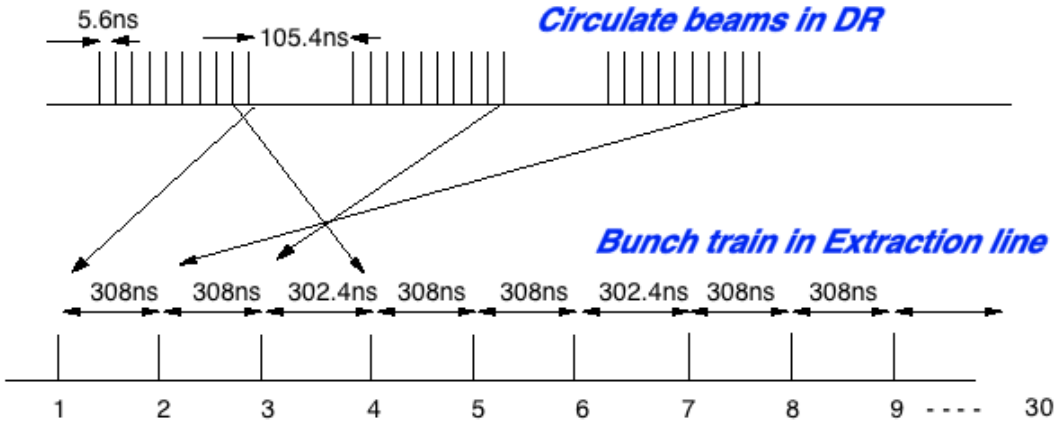


Beam extraction test

The time sequence is that ,

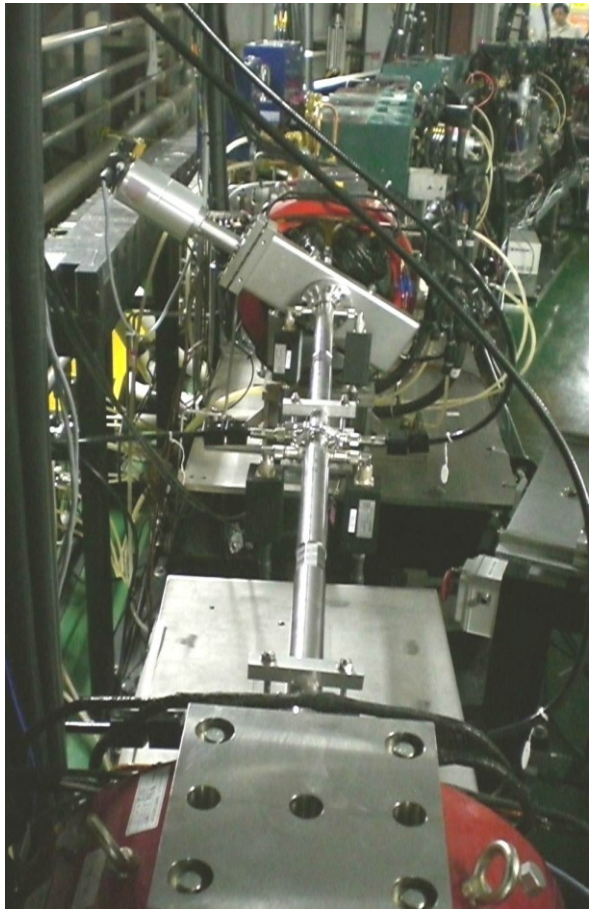
1. *10 bunches with 5.6ns bunch spacing beam is injected to the DR three times, 30 bunches total.*
2. *The local bump orbit is excited gradually after all of beam is damped.*
3. *The beam is kicked out bunch-by-bunch by the strip-line kicker.*
4. *The local bump orbit is return to zero.*

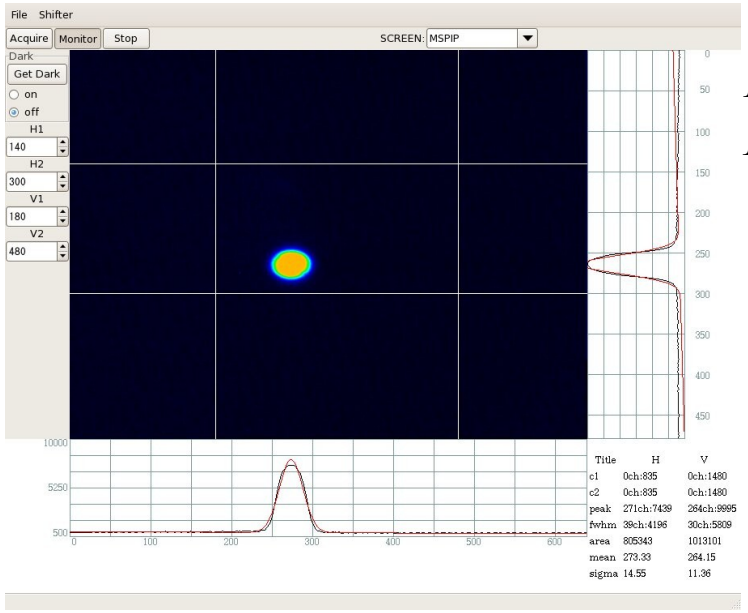




Single bunch extraction

Beam Extraction succeeded from DR to ATF2
2009.Oct. 22.





Beam profile at MS1X

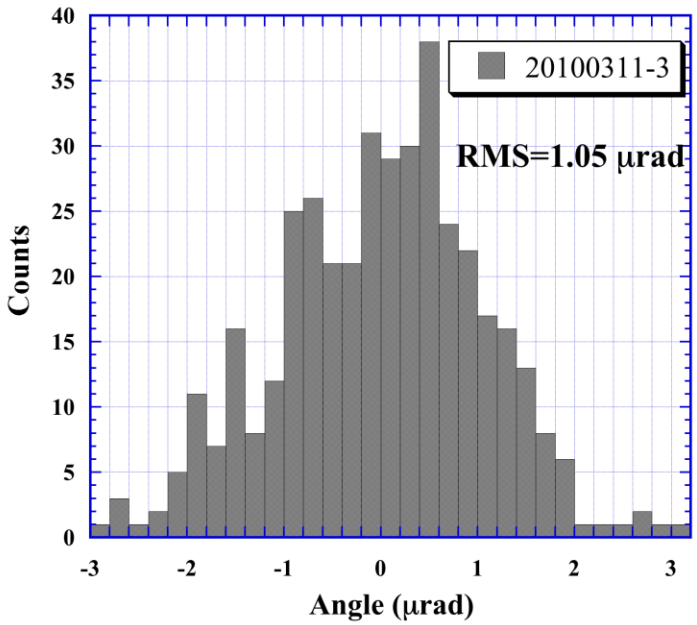
Firs Beam extraction was confirmed 2009/Oct/22 by the screen monitor at 2m downstream of the extraction septum.

Kick angle measurement

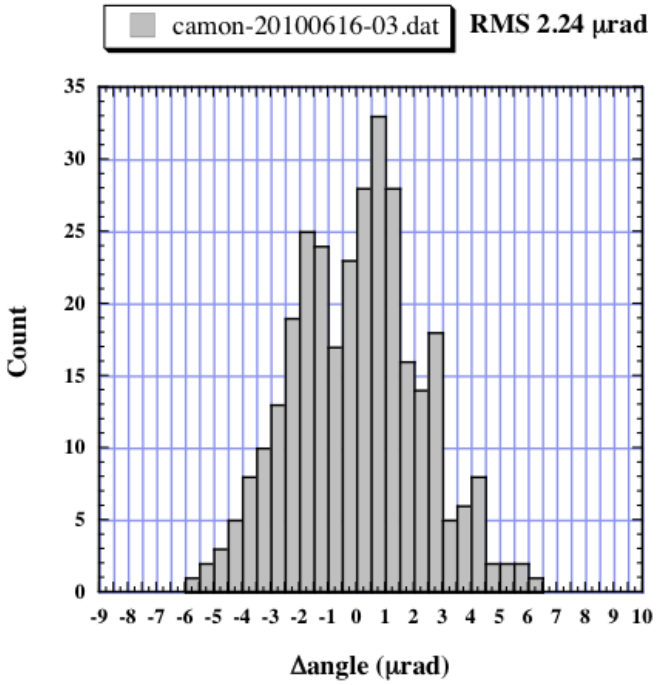
Distribution of fitted angle at EXT entrance

(single bunch)

Jitter 1.05e-6/3e-3=3.5e-4



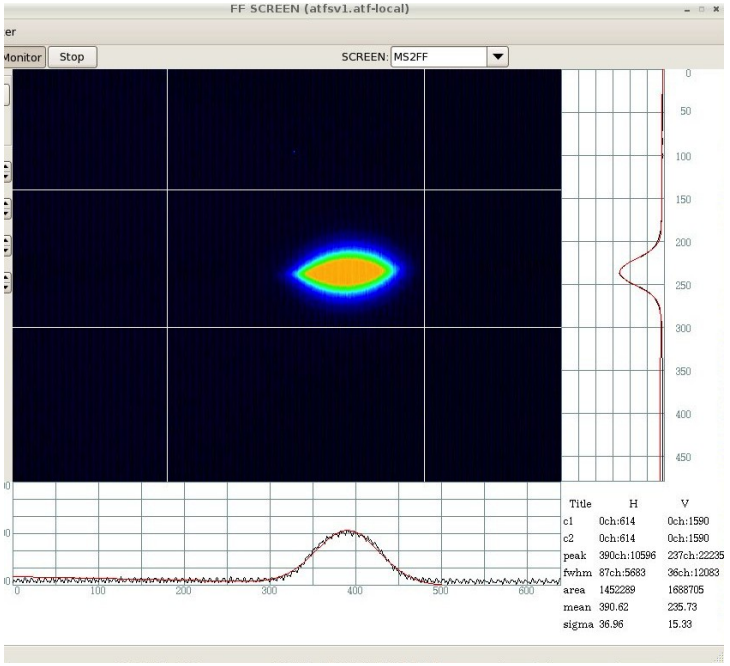
Jitter 2.24e-6/3e-3=7.4e-4

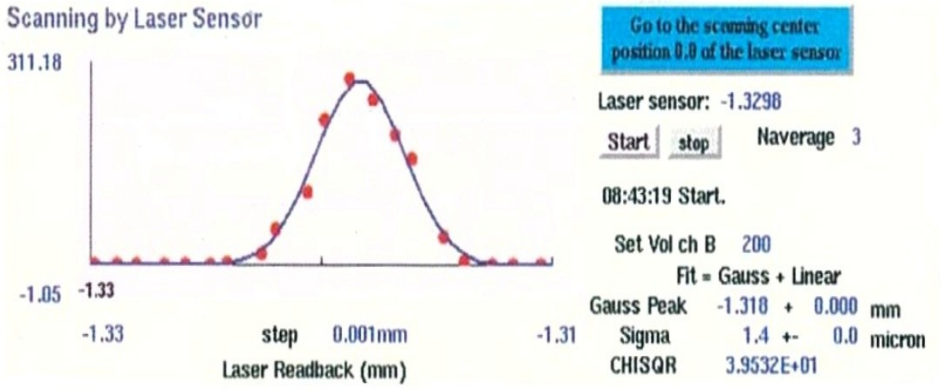


K.Kubo

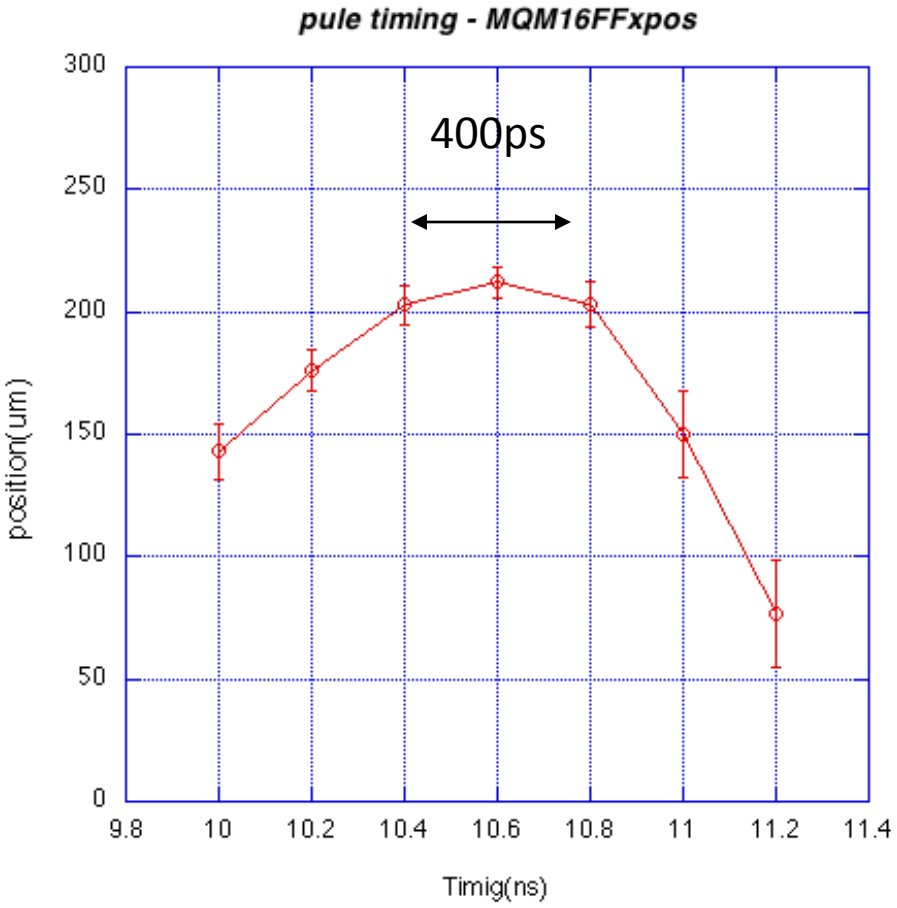
Beam profile of the extracted beam

- *The observed beam profile at the extraction line was same as the extracted beam by the pulsed magnet.*
- *The vertical beam profile of the extracted beam was measured by the MS1IP wire scanner, which is located just downstream of the focus point of the the ATF2 beam line. The measured vertical size was 1.4um, which is limited by the wire size. It means that the extracted beam has no deterioration for the vertical beam size.*
-





Kick field profile

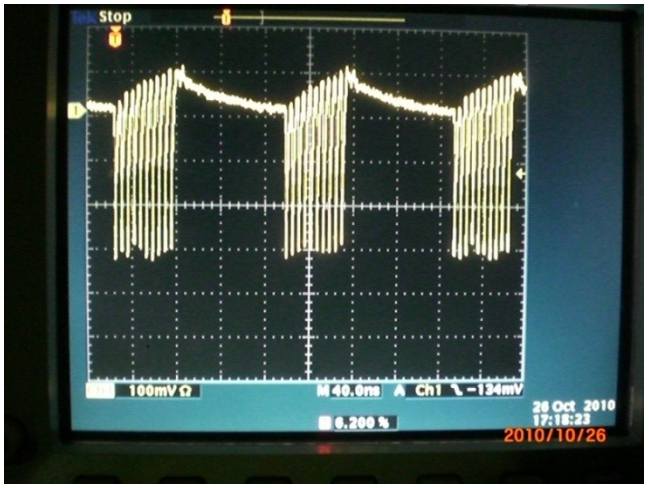


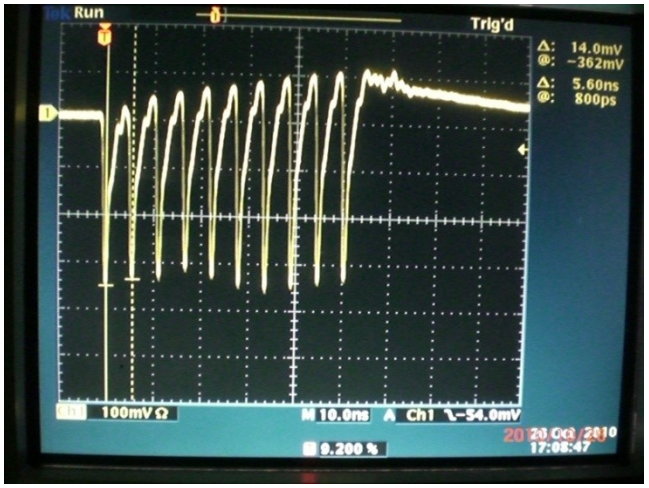
Plot shows the beam position at MQM16FF BPM. The flattop of the kick field is only 400ps and the jitter increased at the both side of the flat top.

The timing of the four pulses needs to careful adjustment.

Multi-bunch extraction

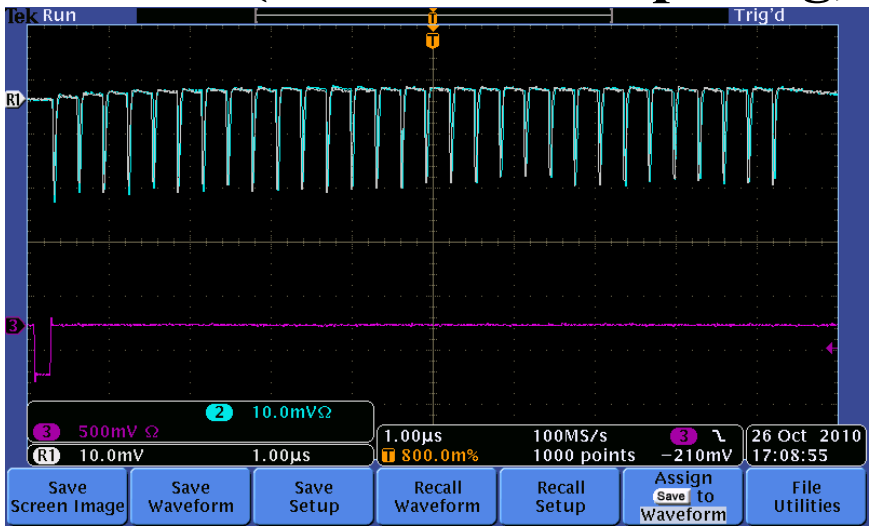
DR bunches(3train, 10bunches, 5.6ns bunch spacing)





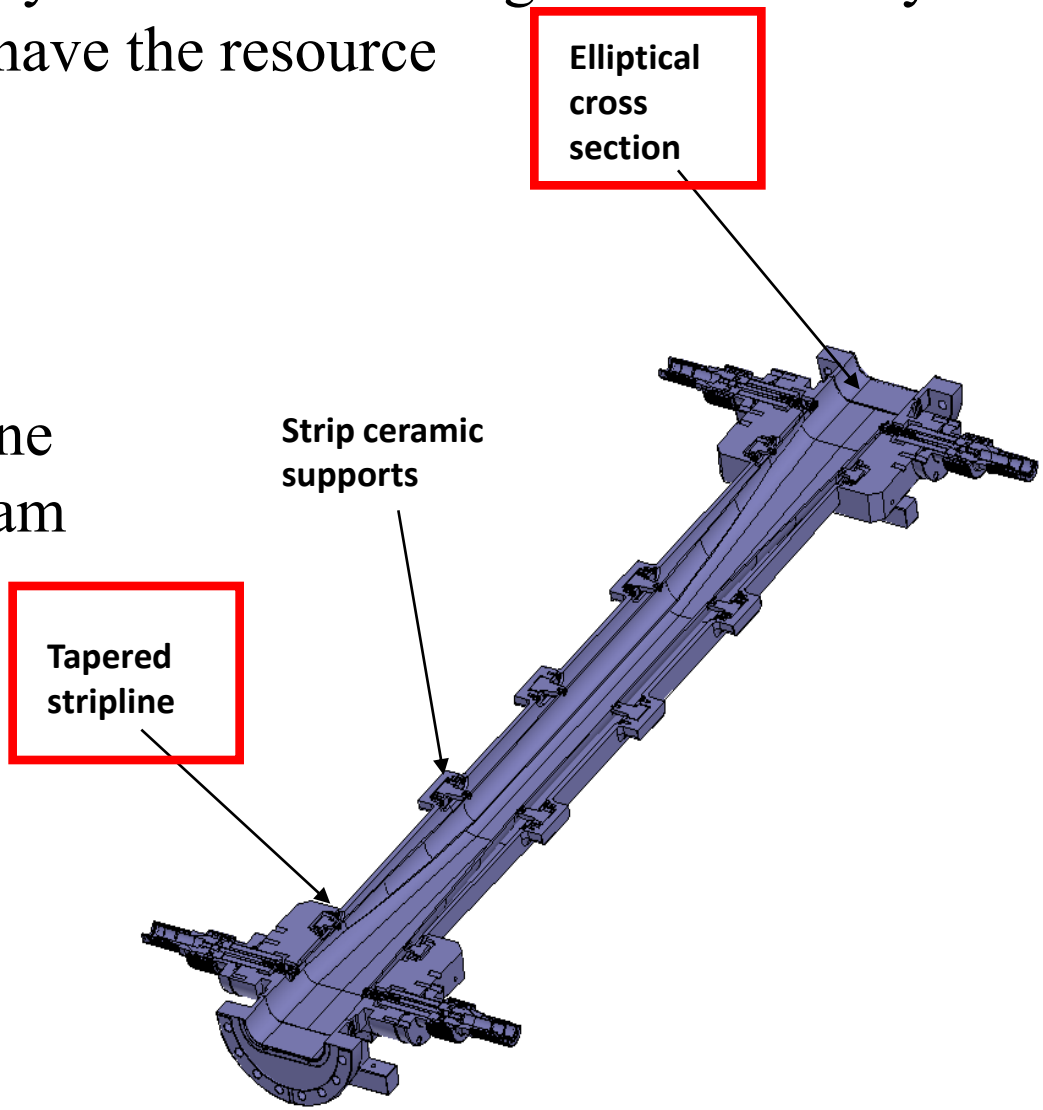
Single train (expanded)

Extracted bunches(308ns bunch spacing, 30 bunches)



Need long term reliability check of fast kicker pulsers
We stopped fast kicker beam extraction study because narrow aperture of strip line disturbs high current operation but use fast pulsers for orbit feedback and beam dynamics study. We think the long term reliability study is important but we do not have the resource for this.

Impedance measurement of fast kicker strip-line
Planning to de it at ATF2 beam line
We can use the space in ATF2 beam line for INFN fast kicker
Prototype impedance measurement because we can set the appropriate optics and use very precise beam position monitors for the impedance measurement.

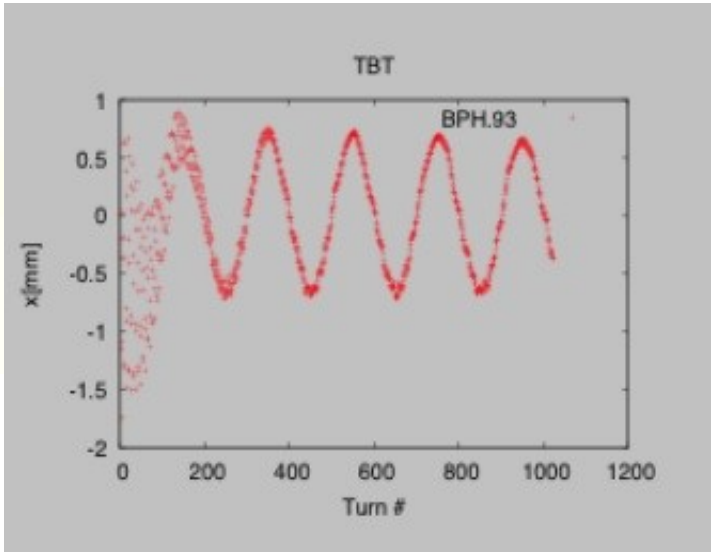


Tuning method confirmation for 2pm vertical emittance realization in the ring.
Many tuning methods were developed and partial tested. Simulation indicated 2pm or less vertical emittance is possible with precise realignment and beam based alignment in the ring.

Beam instrumentation development
Improvement of BPM system was done with FNAL at ATF-DR
Also, necessary beam instrumentation techniques almost confirmed.

BPM Circuit upgrade (FNAL)

Able to measure Injection TBT, Narrowband Orbit, Narrowband Calibration , and Last Turn on every injection



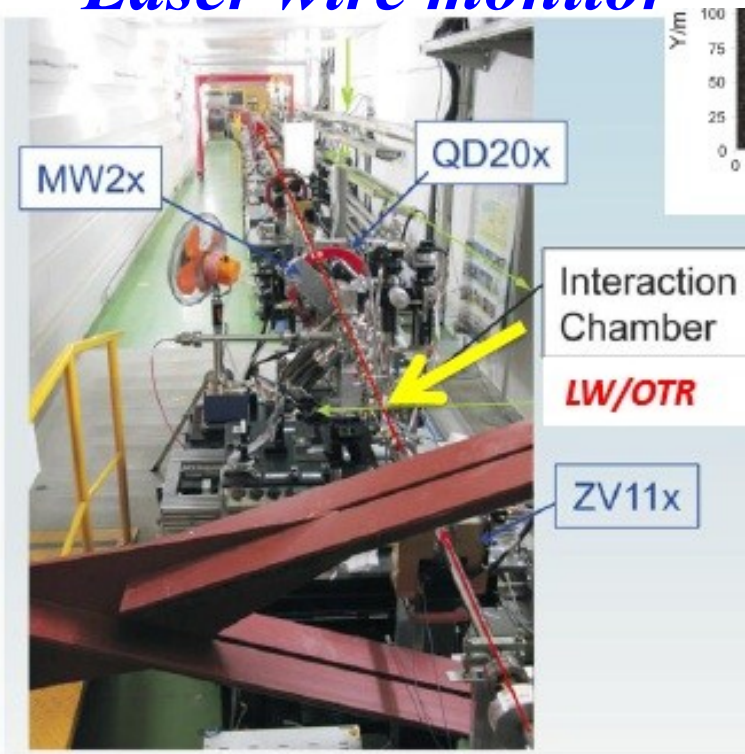
Upgrade of Beam Instruments

- DR BPM readout (FNAL digitizer)
- EXT Strip-line BPM readout (SLAC-LCLS digitizer)
- Multi-OTR monitors

R&D

- EXT Laser Wire
- 4-mirror optical cavity installation
- Single- and Multi-bunch instability

Laser wire monitor



JAI(RHUL,Oxford) / KEK

XSR beam-size monitor （Tokyo Univ., KEK）

Real time beam monitor for ATF DR beam tuning

X-Ray Telescope using Zone Plate at 3.2keV

magnification : 20

- ***Non destructive measurement***
- ***High resolution (< 1μm)***
- ***2D direct imaging of the electron beam***
- ***Real time monitoring (< 1ms)***

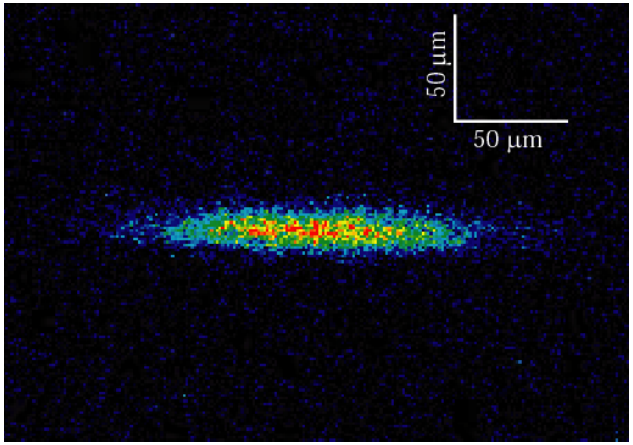
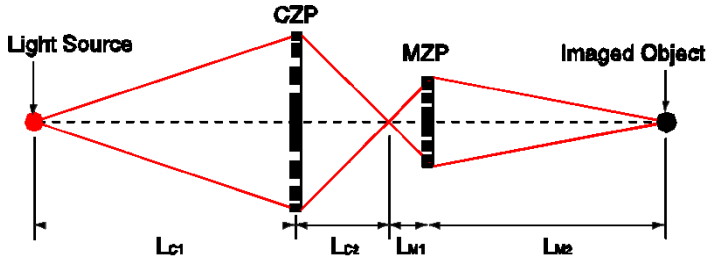
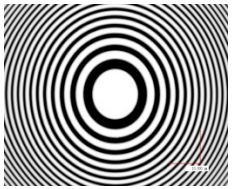


image of 1ms exposure

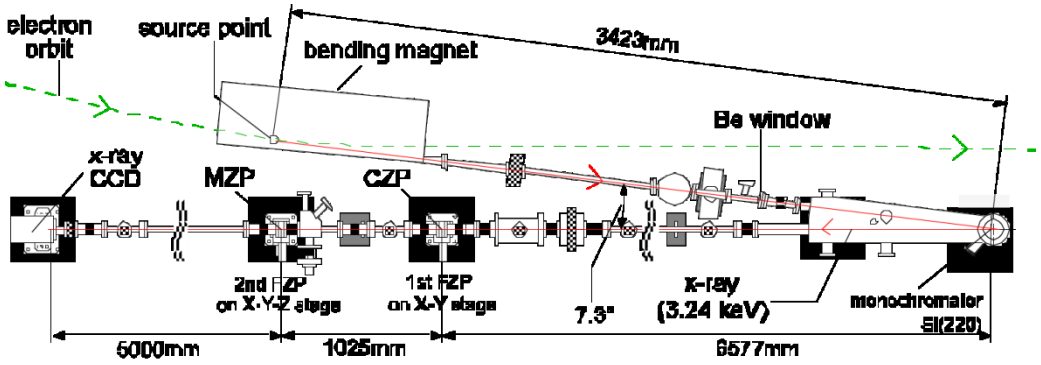
$\sigma x = 48.2 \pm 0.5$ [μm]

$\sigma y = 6.4 \pm 0.1$ [μm]



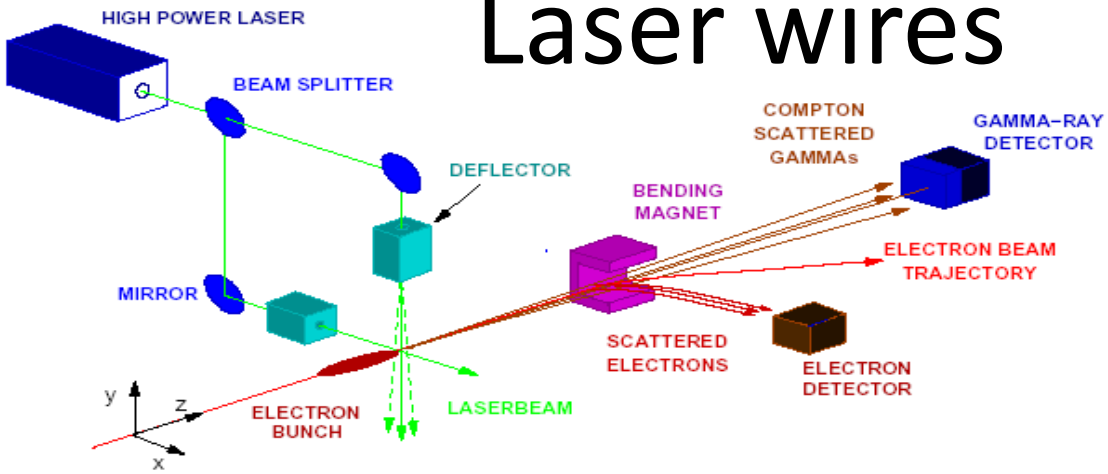


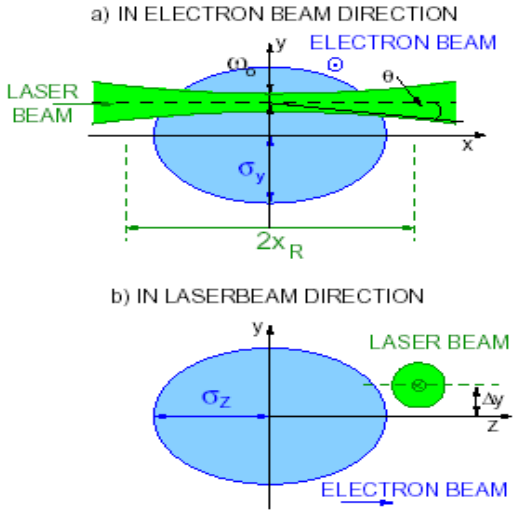
Zone plate



SR X-ray beam line

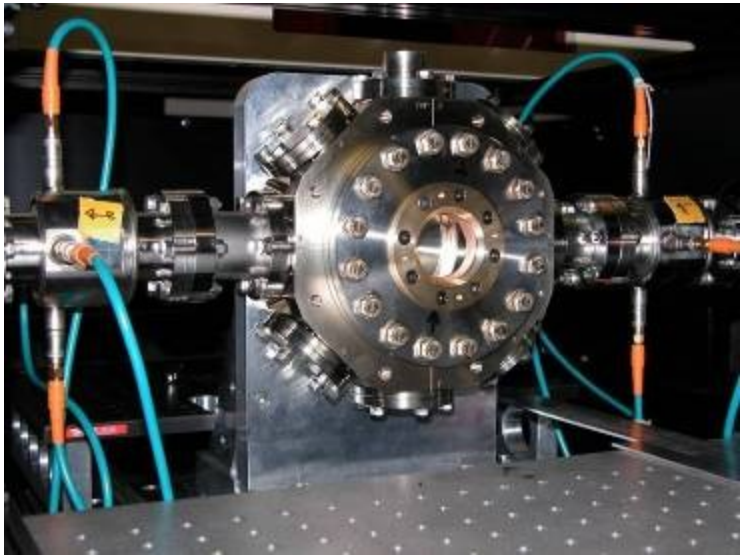
Laser wires

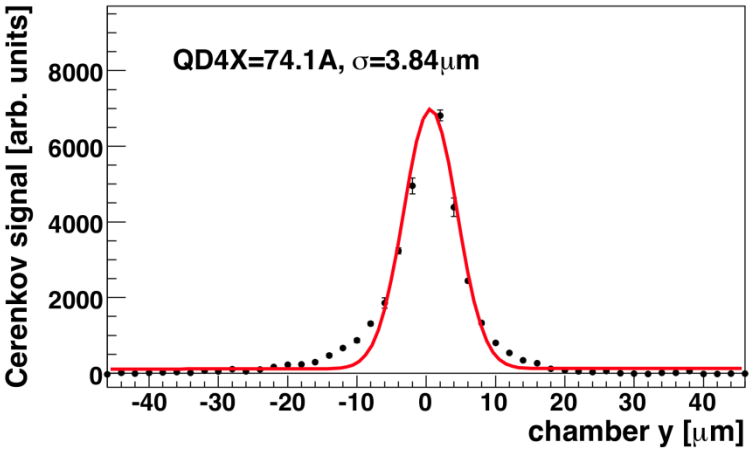




- Goal: non-destructive diagnostics for ILC
- Studies in ATF extraction line
- Aim to measure 1 μm spot beam
- Aim at 150ns intra-train scan
- Presently achieved resolution ~3.0μm (limit by laser quality)

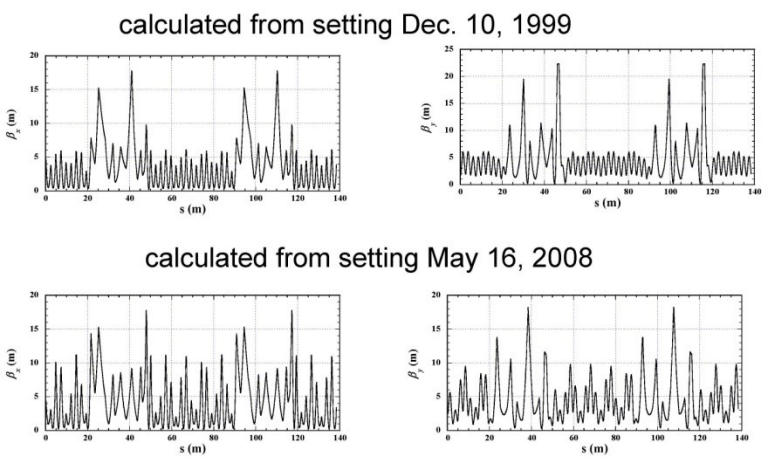
Laser wire chamber at ATF, Oxford and RHUL

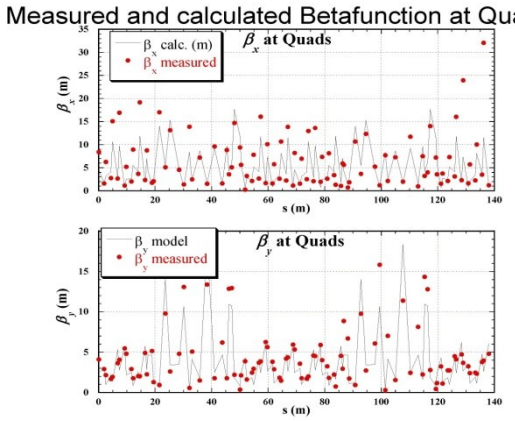


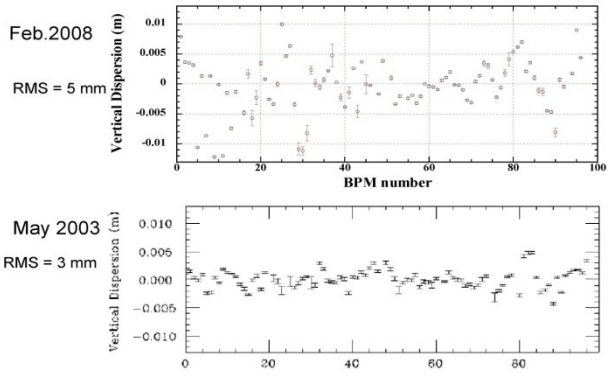


Beam Optics deformation was checked.

Optics retuning is necessary to recover ultra-low emittance.

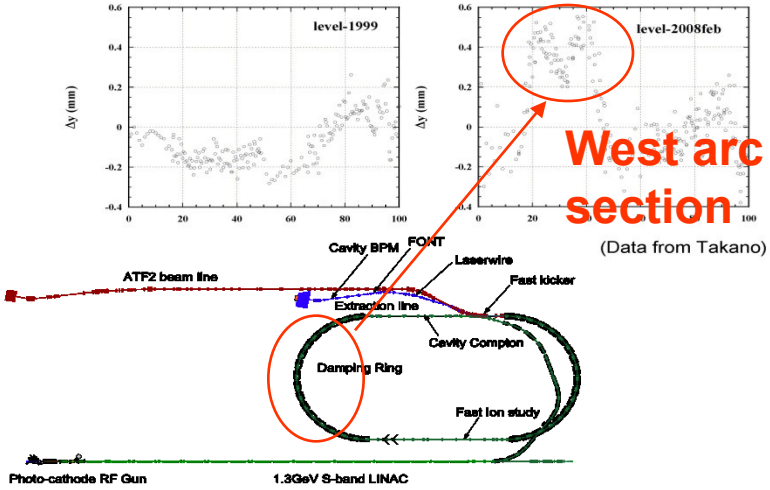






Error of Beam Optics

Change of alignment

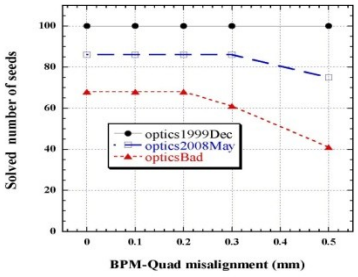


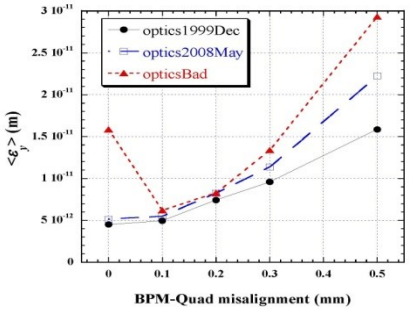
Change of magnets alignment without realignment during long period. Especially, west arc alignment was destroyed by ATF2 floor refurbishment.

Also big earthquake requests us precise realignment precisely.

Effect of BPM alignment

Big difference more than 100μm between BPM center and quad center makes impossible to retune ultra-low emittance.



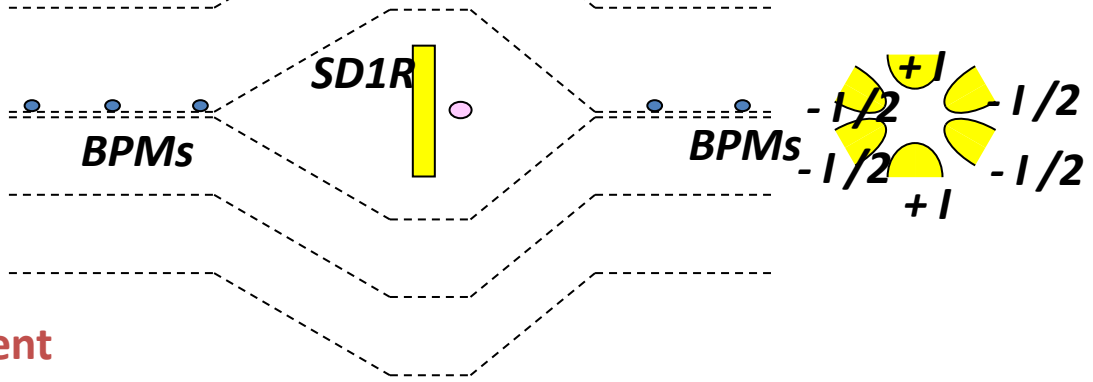


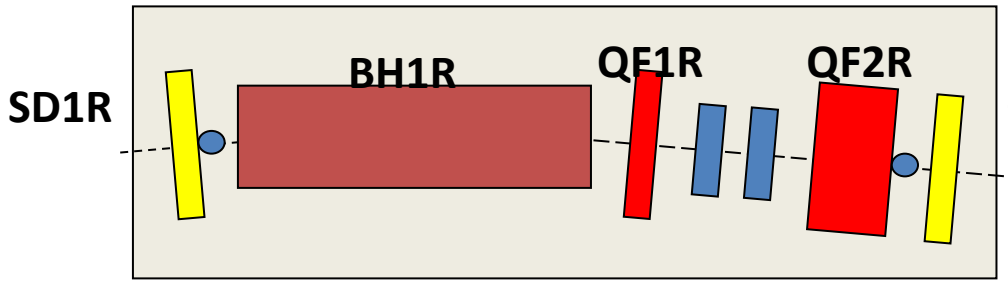
(simulated by K.Kubo)

emittance growth due to the displacement between field center and BPM position

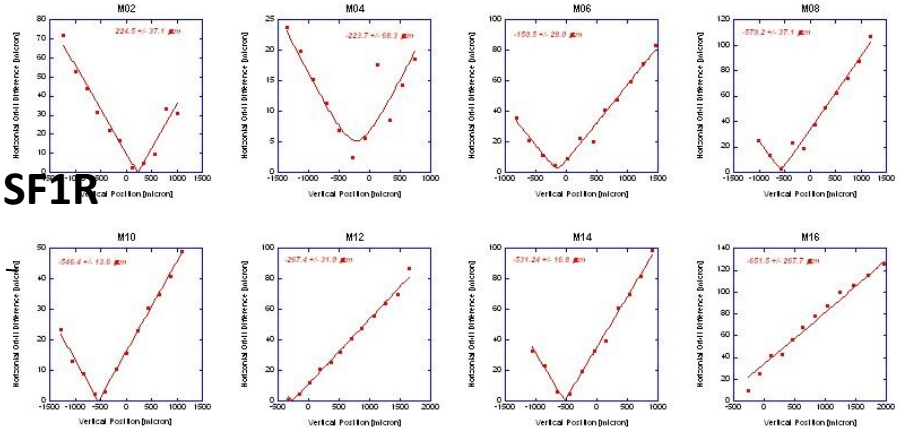
BBA (Beam Based Alignment)

Using trim Coil of sexta, displacement between BPM position and the field center of sexta was measured. BPM misalignment was measured with accuracy of about 30μm and we found big alignment error of about 500μm.





Magnet configuration of ATF DR normal cell



Miscellaneous

Circumference correction by chicanes in the ring skip!
Circumference correction is very important because of large ring, low momentum compaction, damping wigglers etc.
We think this study is not necessary since necessary optics design is not challenging and the control of necessary magnets is not difficult.

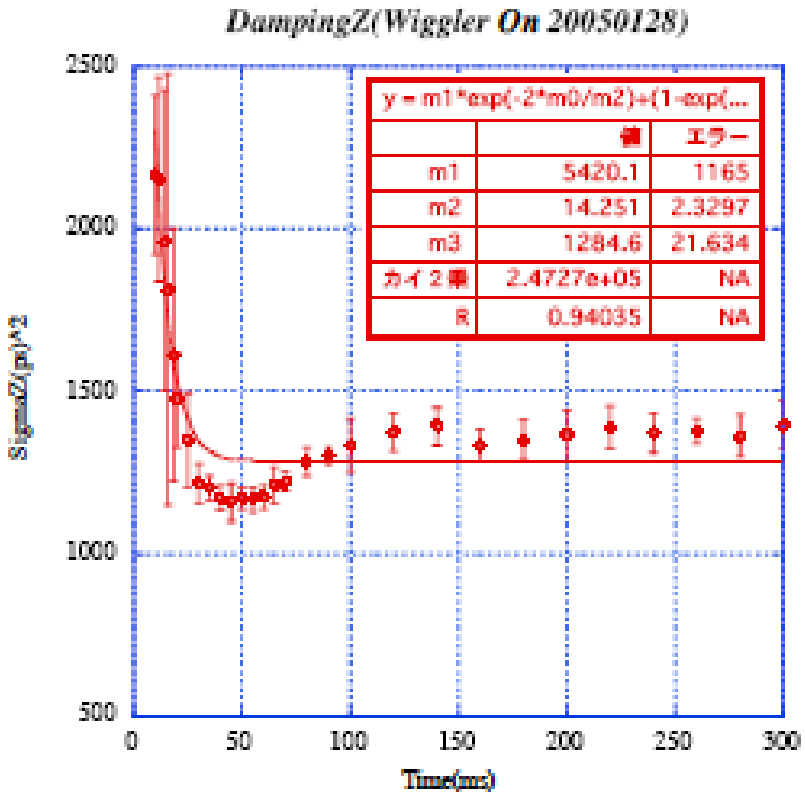
Wiggler effect done! (many 3rd PF rings give us data.)

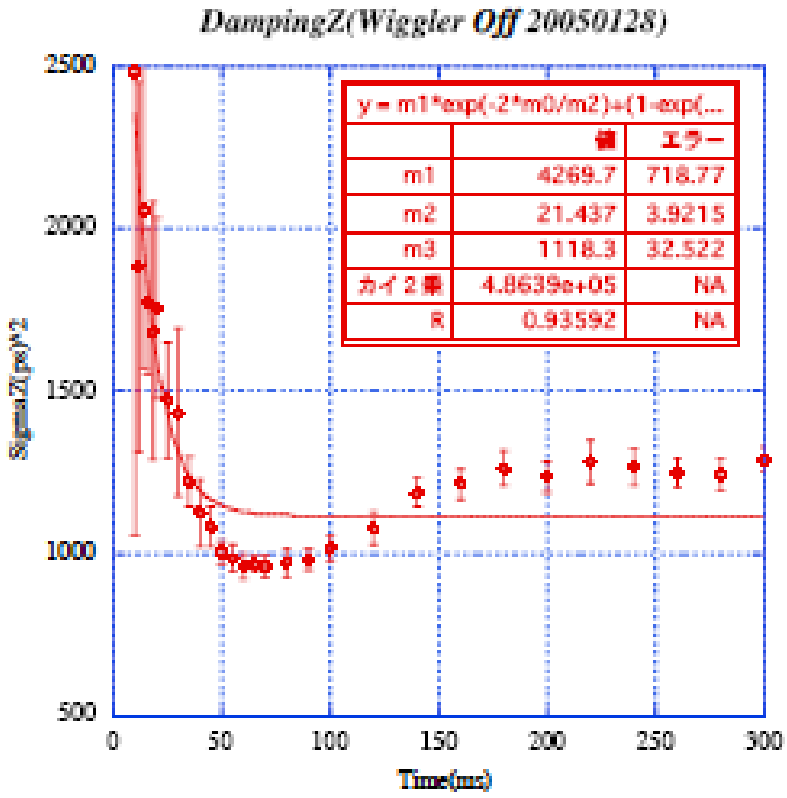
Multi-bunch instability precise study Need!

ATF with wigglers

Four wigglers (L=2m, λ=0.4 m, B=1.4 T)
The IBS growth effects after damping are observed at the horizontal beam size, the bunch length and the energy spread.

Reduction of damping time and of IBS effect observed with wiggler on





ATF long term plan (tentative)