Recent development in orbit stability and the feedback system at KEK Photon Factory and PF-AR

T. OBINA / Photon Factory, KEK

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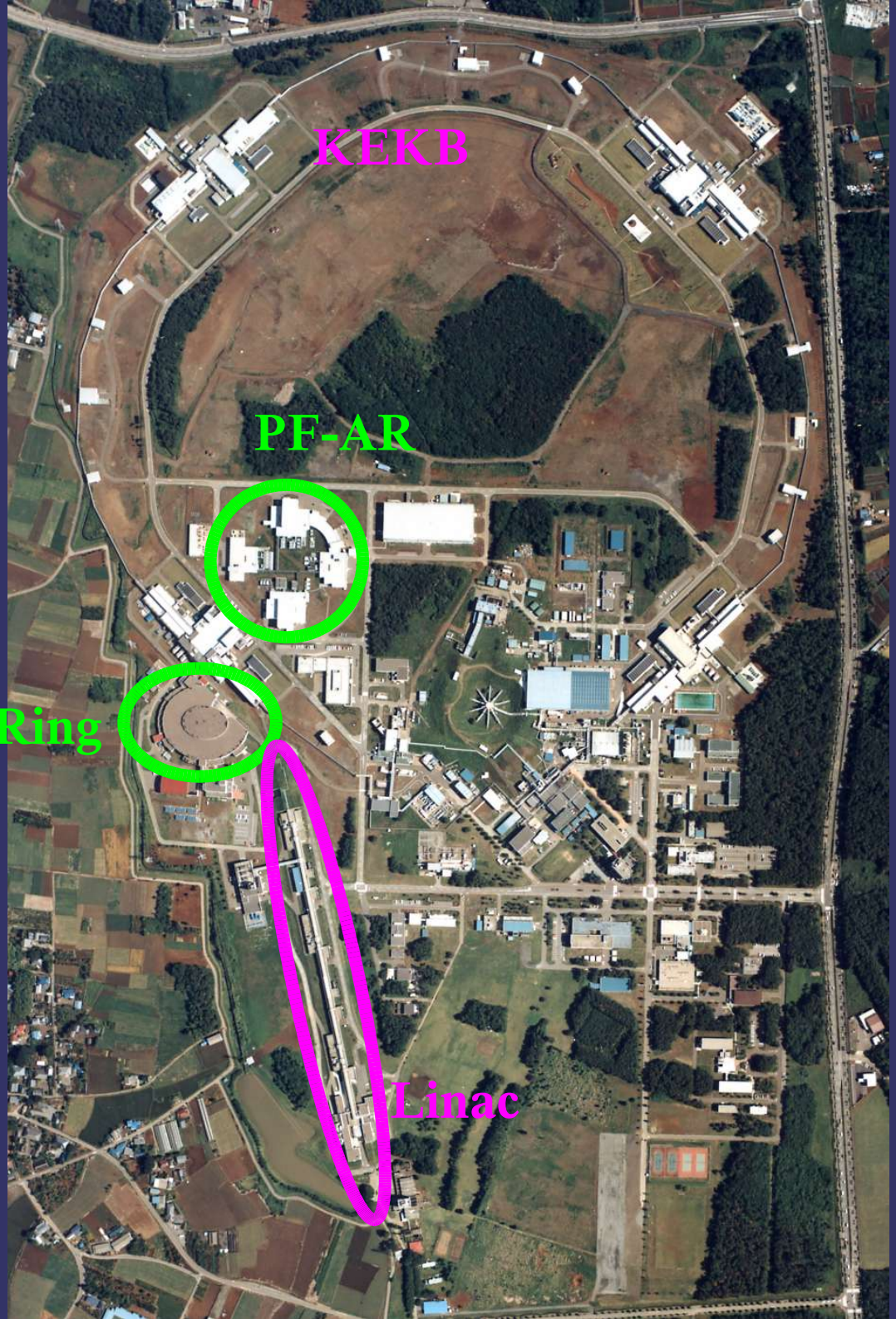
Overview

- Group/Member
  - Control: T.Obina
  - Monitor: T.Honda, K.Haga, M.Tadano
  - Magnet: Y.Kobayashi,K.Harada,T.Miyajima,S.Nagahashi
  - ID: S.Yamomoto, K.Tsuchiya, T.Shioya
  - Head of Light Source division: T.Kasuga
  - ....and many other contributers....

1) Photon Factory(PF)
   1-1) Orbit stability
   1-2) Feedback system for new undulator

2) PF-AR(PF-Advanced Ring)
   2-1) Orbit stability
   2-2) Injection with Pulsed-Quadrupole Magnet

KEK Site Map



Main Parameters

		PF	PF-AR
Energy	E [GeV]	2.5	6.5
Circumference	C [m]	187.07	377.26
Emittance	ε_o [nm×rad]	35.78	295.17
Energy Spread	σ_E/E	7.28474E-04	1.14586E-03
Momentum Compaction	α	6.16870E-03	1.27625E-02
Betatron Tune			
horizonta	ν_x	9.66	10.15
vertical	ν_y	4.25	10.19
Synchrotron Tune	ν_s	0.0142295	0.0567625
Chromaticity			
horizonta	ξ_x	-12.570	-14.250
vertical	ξ_y	-11.529	-13.159
Energy Loss	U_0 [keV/rev.]	398.853	6660.751
Damping Time			
horizonta	τ_x [msec]	7.787	2.454
vertical	τ_y [msec]	7.822	2.457
longitudin	τ_z [msec]	3.921	1.230
Revolution Frequency	f_{rev} [MHz]	1.60253	0.79466
RF Frequency	f_{RF} [MHz]	500.100	500.100
Harmonic Number	h	312	640
RF Voltage	V_{RF} [MV]	1.70	17.30
Bunch Length	σ_z [mm]	9.40128	15.40534
RF Bucket Height	$(\Delta E/E)_{RF}$ [%]	1.217590	0.992220

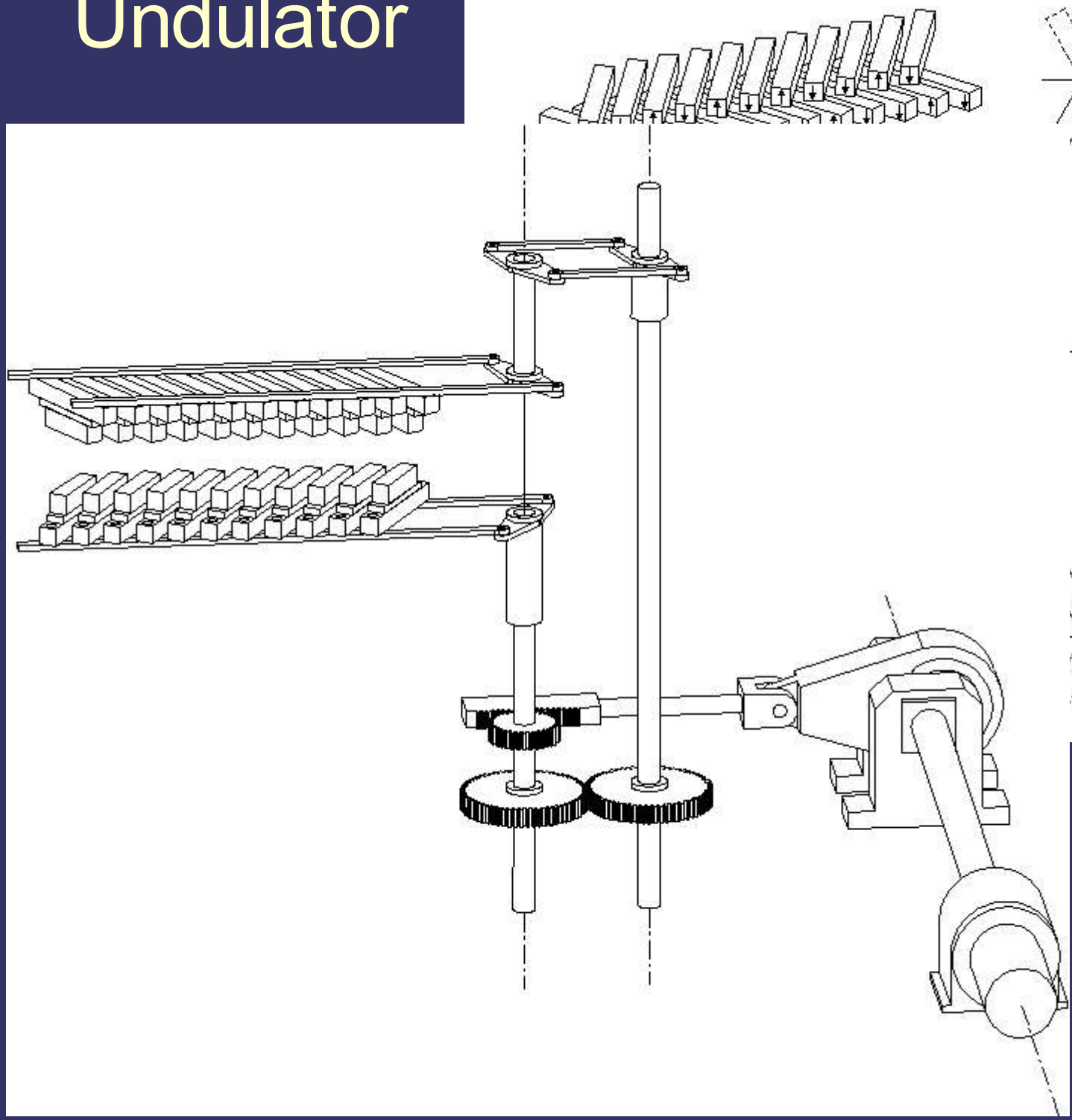
1-1) Orbit Stability at PF-Ring

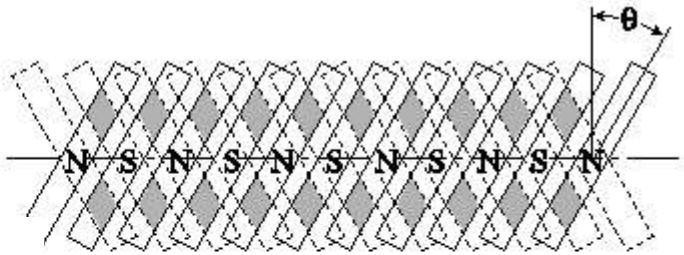
- Fast orbit feedback system works very stably
  - Global Feedback Cycle: 12ms
  - BPM resolution: 3um(peak-peak, 1sec)
  - Please refer to IWBS2002 proceedings
- There are no significant improvement after IWBS 2002 except for...
  - Increase # of eigenvalues: 8 -> 12
    - Max 28 (65BPM x 28Correctors)
- New Project: Upgrade of straight section
  - Shutdown Mar/2005 - Sep/2005
  - Main purpose
    - Increase number of straight section
      - Magnet triplet -> doublet + short straight section
      - Number of IDs 7 -> 11 + 2 short
    - Replacement of VERY old instruments ... more than20 years!!
  - number of BPMs, Correctors will be increased
    - We are now designing new data acquisition system

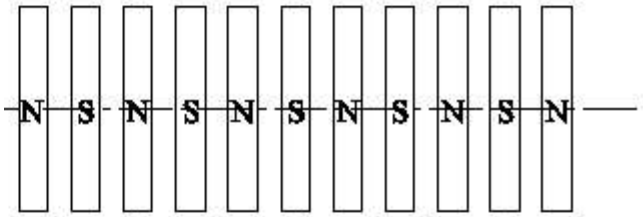
1-2) Local Feedback System for New Undulator

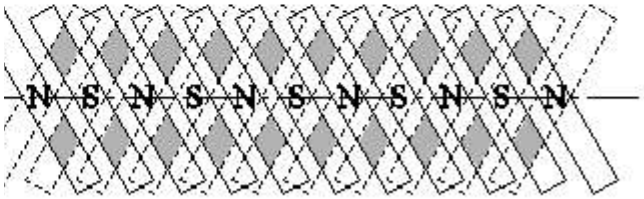
- New Undulator for circular-polarized beam
  - Switch right-handed/left-handed/linear polarization
  - Use mechanical switching
    - not Apple-II type
    - Chevron switch
  - Switching speed: 0.8Hz
- Unfortunately, this undulator was installed in the PF ring only for several months ..... another undulator have been used for users operation.

Undulator



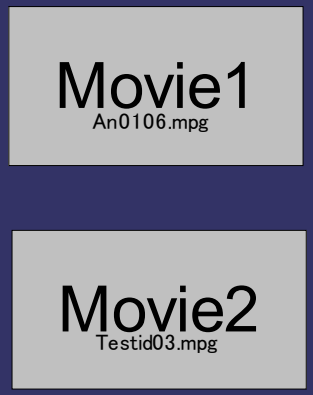




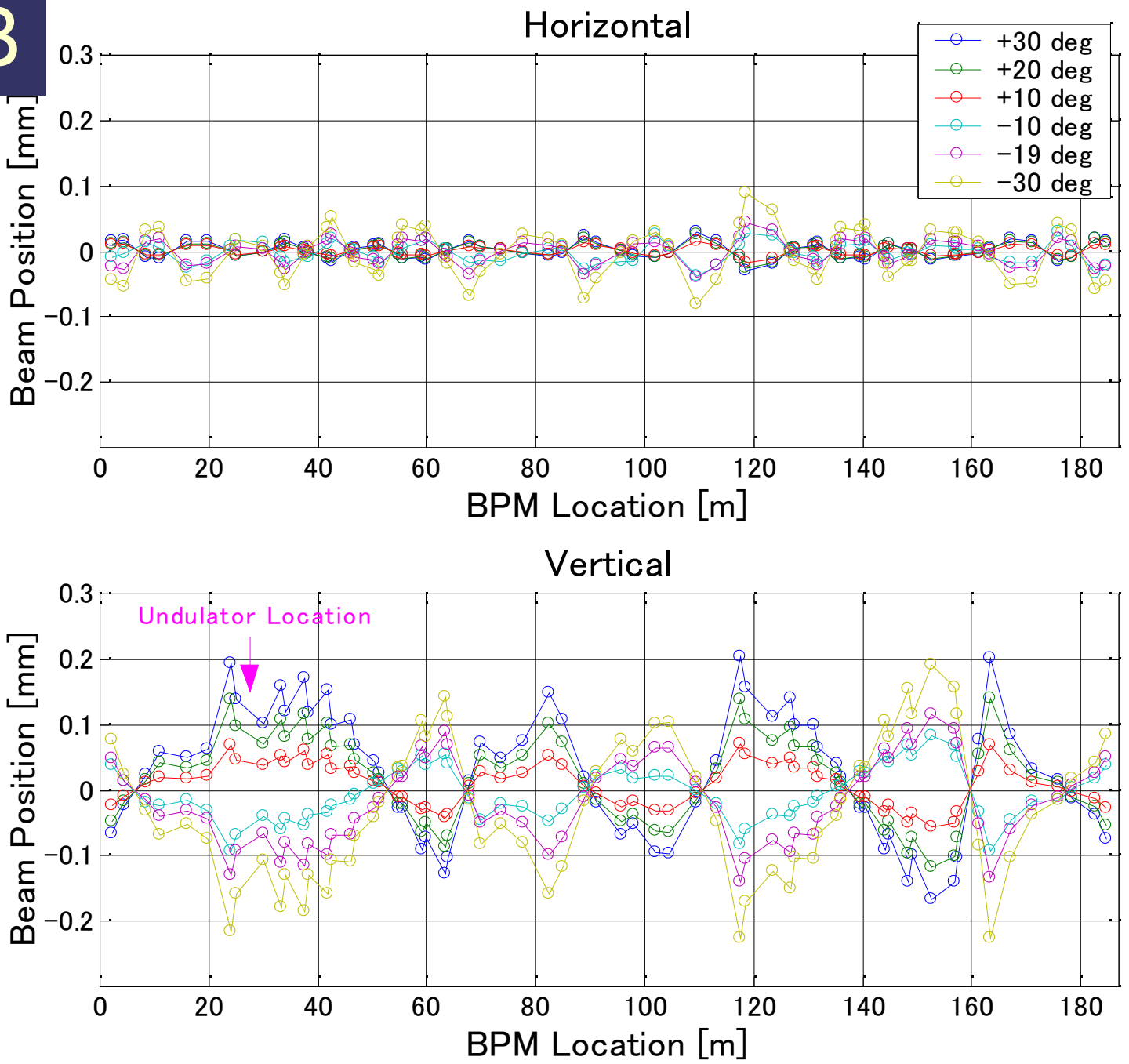


Movie

- External File



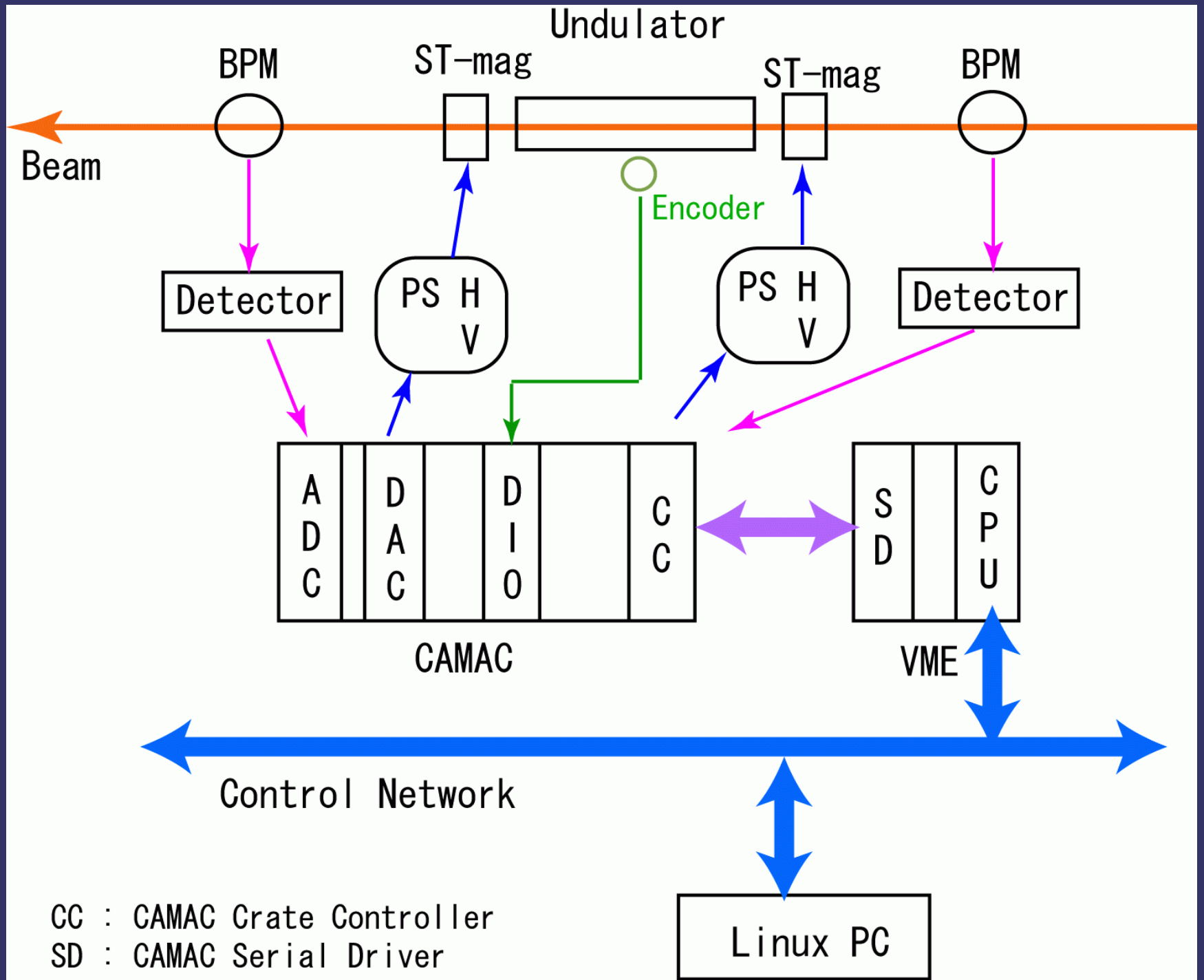
Result: without FB



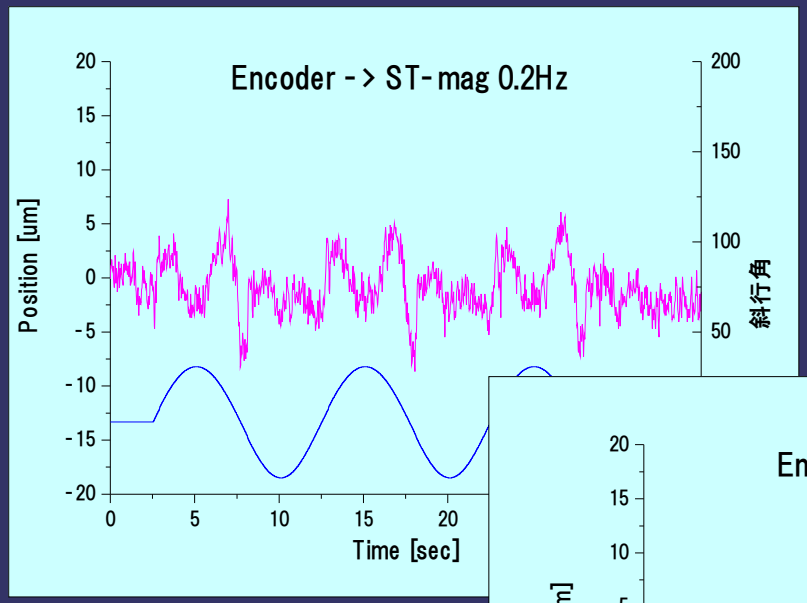
FB system

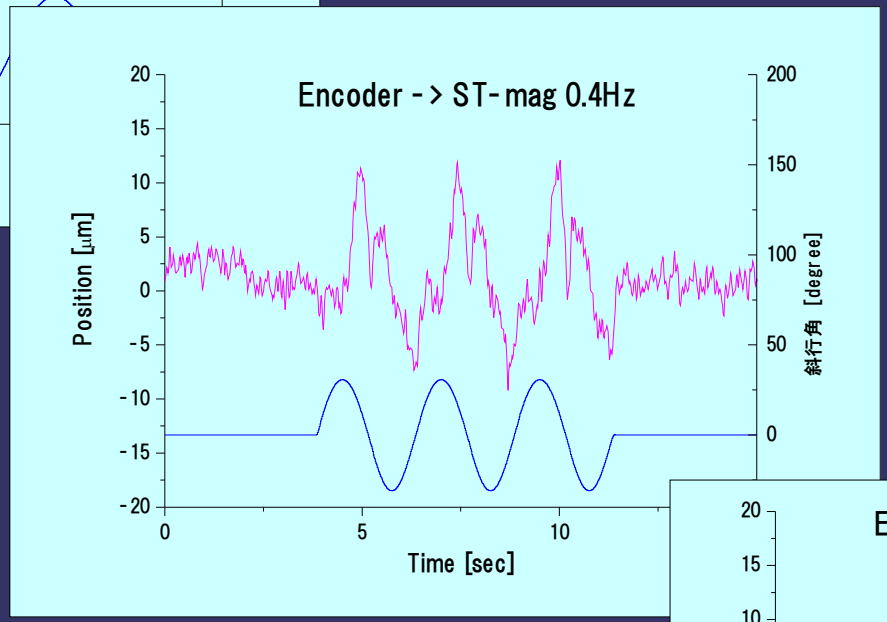
- Limitation:
  - No time/budget.....
    - We used existing CAMAC modules
  - FB cycle 50Hz
  - No start trigger for encoder output
    - GPIB control only
- Control/Data Acquisition
  - EPICS based system

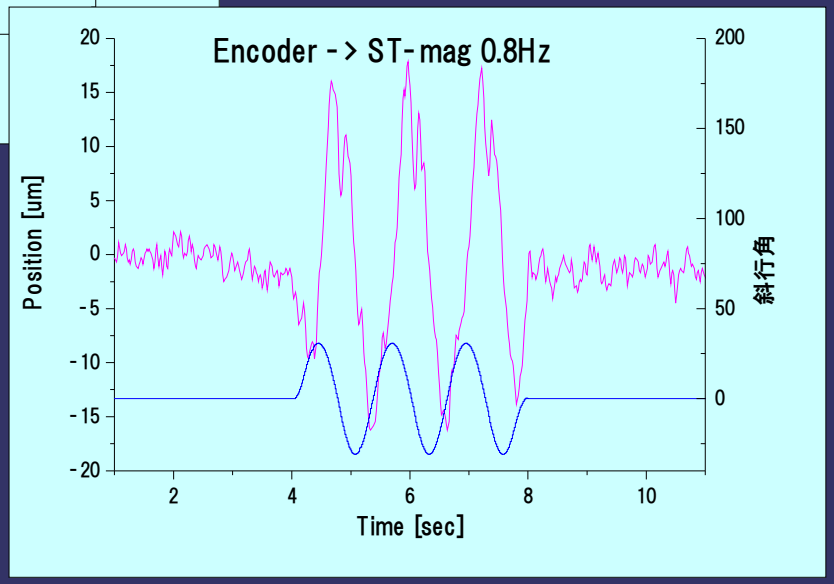
Block Diagram of FB System



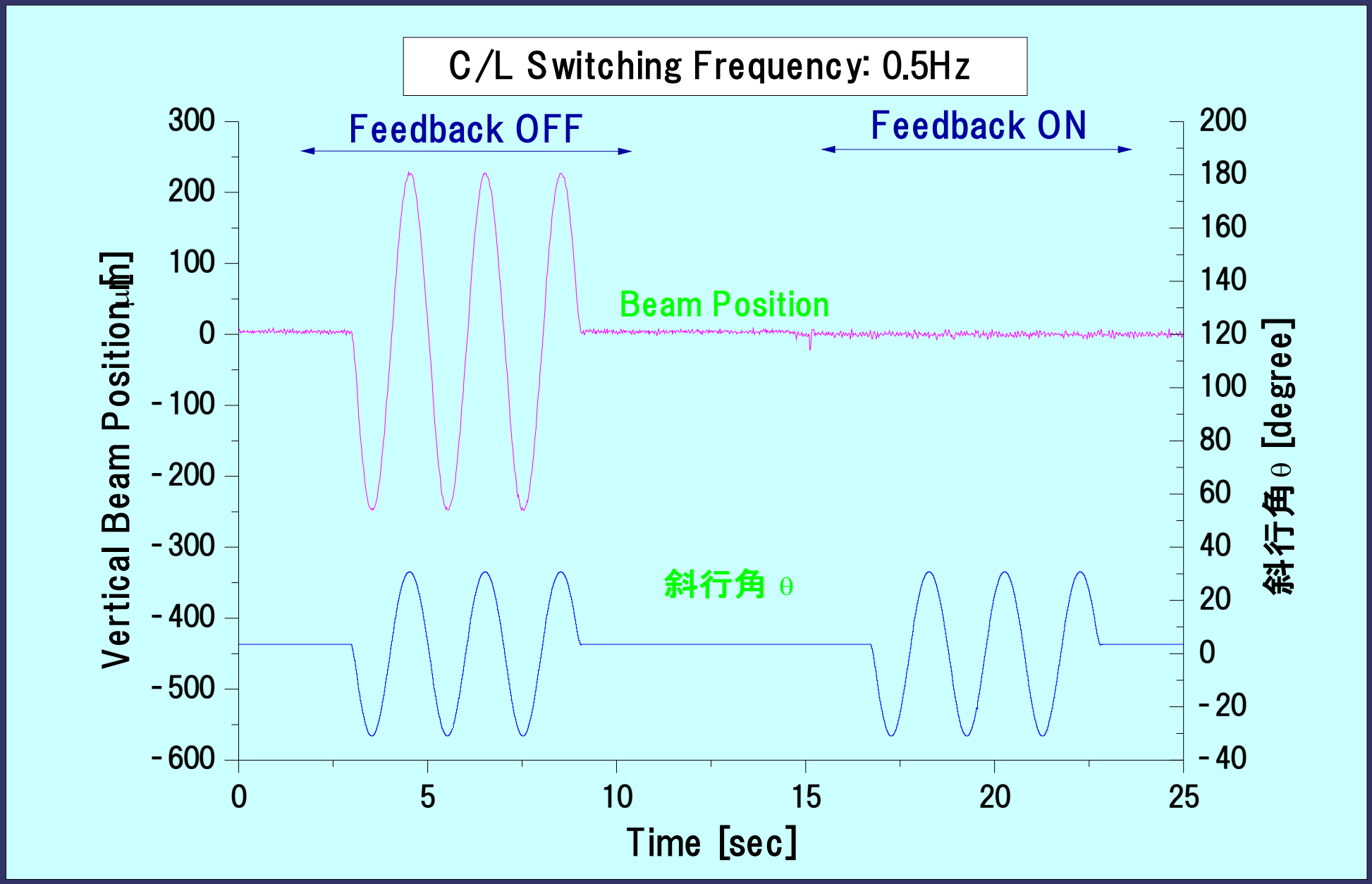
Result: Feedforward with Encoder



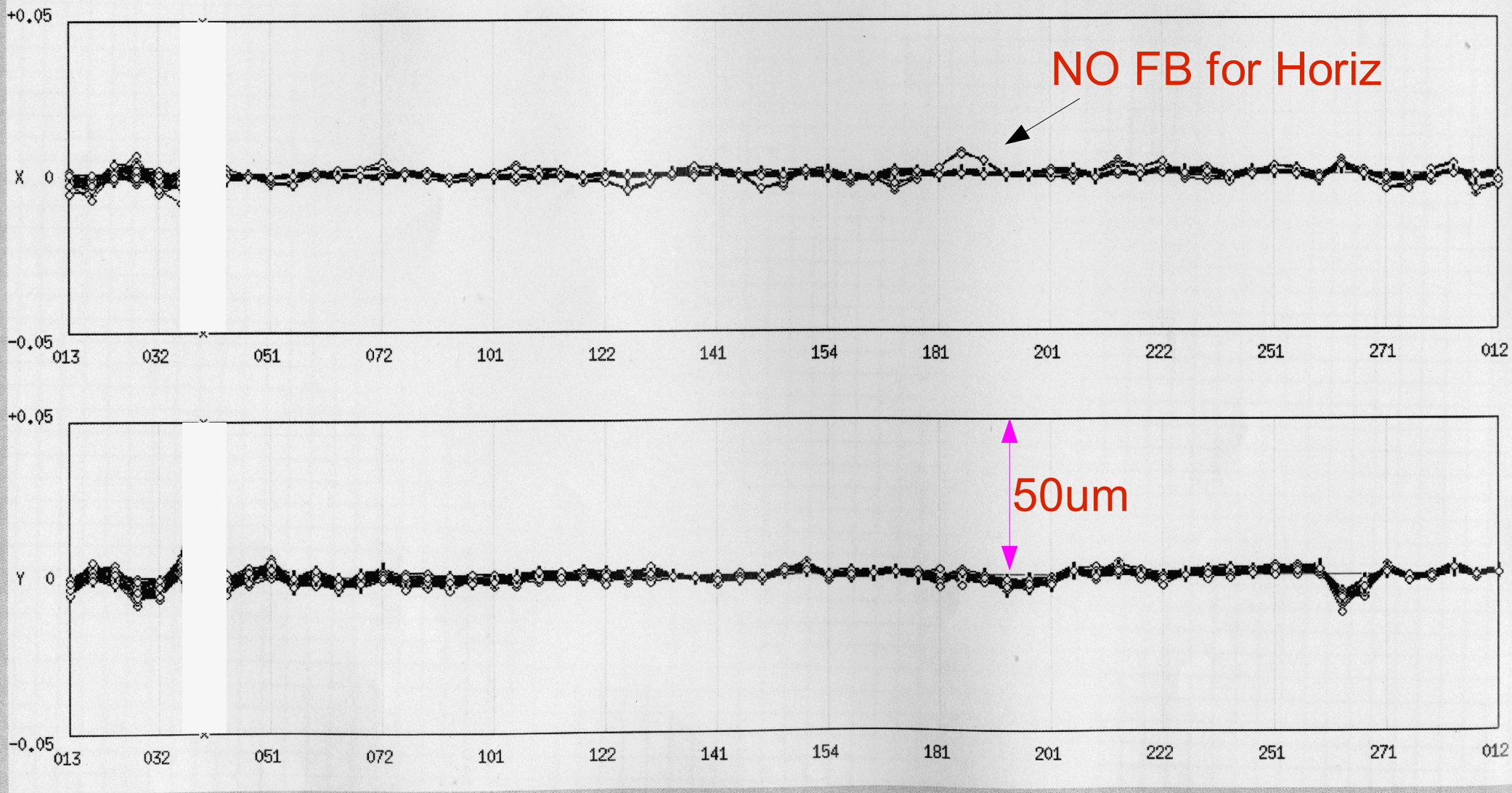




Feedforward+Feedback



COD with FB



現在時刻 : 2003. 6.16 17:22:32
上書開始時刻 : 2003. 6.16 17:22:06

X Scale(±) 0.05 mm
Y Scale(±) 0.05 mm

ビーム位置の表示方法 ビーム位置の絶対値 基準軌道の相対値

○：FB許可 ×：FB禁止

モード 書き換え 重ね書き 停 止

画面クリア

閉じる

Next step...

- This undulator will be installed in PF-AR
  - 1.5 year later
- Increase Encoder output resolution
  - 12bit -> 16bit
- Increase FB cycle
  - 50Hz -> 1kHz
  - ADC+FPGA+DAC system on cPCI (PXI)
- Improve analog front-end circuit

- How to avoid the interference of Global Orbit FB?
  - PF-AR : no problem
    - slow COD measurement/correction in every 10sec

2-1) PF-AR Status

- More than 20 year old machine
- PF-AR Upgrade Project in 2001
  - Replace Vacuum duct => Increase lifetime
  - Increase number of ST-mag => Orbit correction
  - No (or limited) budget for
    - Power supply of large magnet (B,Q,S)
    - RF Cavity
    - BPM electronics/Fast orbit correction
- We are still using
  - Old BPM-switching system
    - Replaced Mechanical SW->Mercury SW
    - Reliability of the measurement is greatly improved!!
  - Old detection circuit
  - We can measure/correct COD in every 10sec

2-2) PF-AR Injection system with Pulsed Quadrupole Magnet

- Advantage of PQ-Magnet Injection system
  - Only 1 magnet is enough for beam injection
    - Easy operation
    - Accuracy of manufacturing is not severe
    - Cost effective
  - No need for the Injection bump
    - No coherent oscillation on the stored beam

New Global Standard
for Top-up Injection!!

Why Pulsed-Q injection in PF-AR?

- In PF-AR, top-up injection is IMPOSSIBLE due to the limitation of beam transport line.
  - Injection: 3GeV / Users operation: 6.5GeV
- Coherent oscillation of the stored beam will produce the wakefield
  - Limit the maximum beam current : 65mA

↓ We are interested in:

Can we inject the beam with 1 Pulsed-Q magnet?
Can we break the upper limit of the stored current?

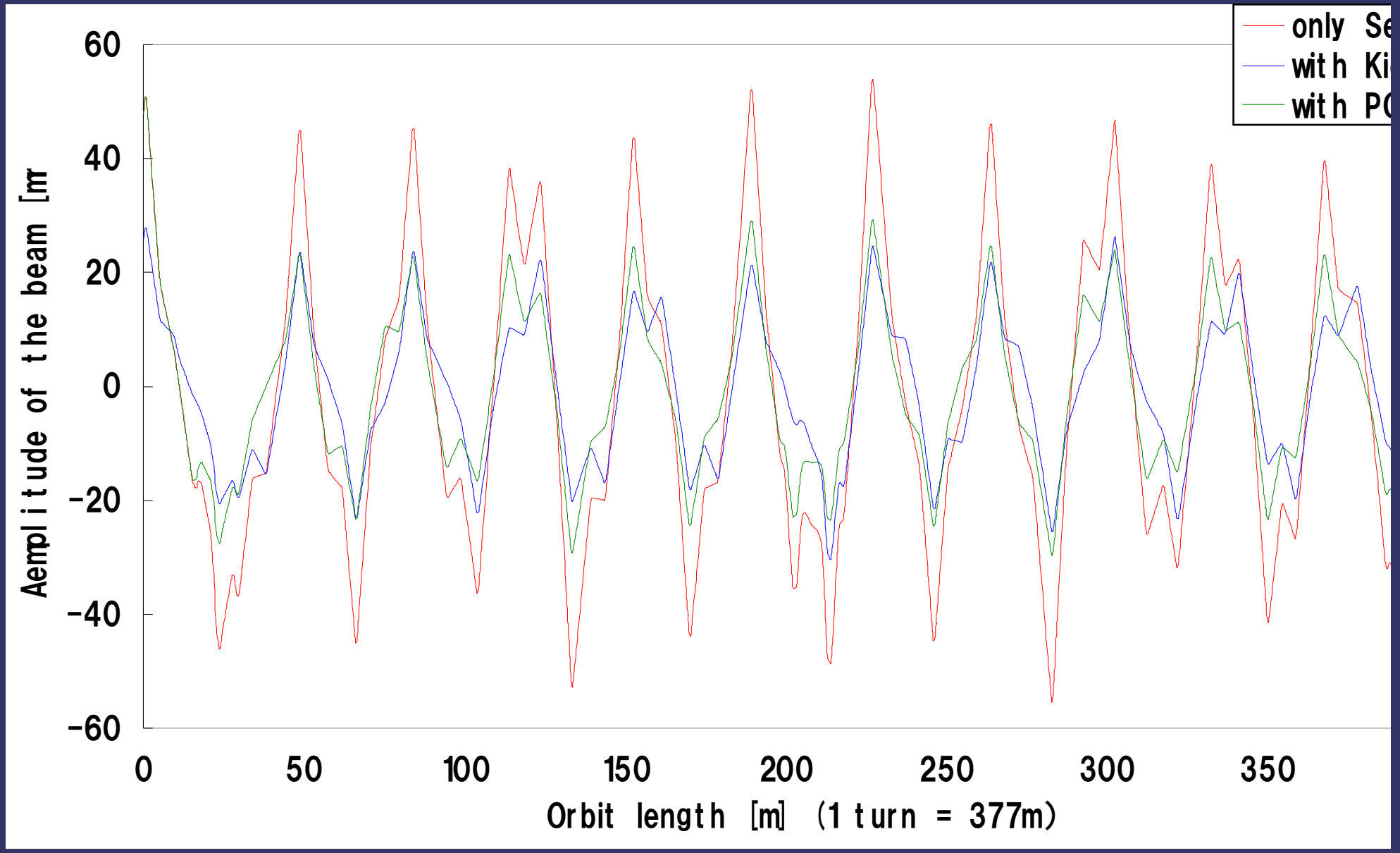
↓ Next step:

Test top-up injection at the other facility

Principle of PQ injection

- A quadrupole magnet has zero field strength at the magnetic pole center and the field strength is proportional to the amplitude of the beam.
  - Stored beam -> passing through center -> no kick
  - Injected beam -> off-axis orbit -> kicked
- Without using the bump orbit by 4- (or 3-) kicker magnets, we can inject the beam.

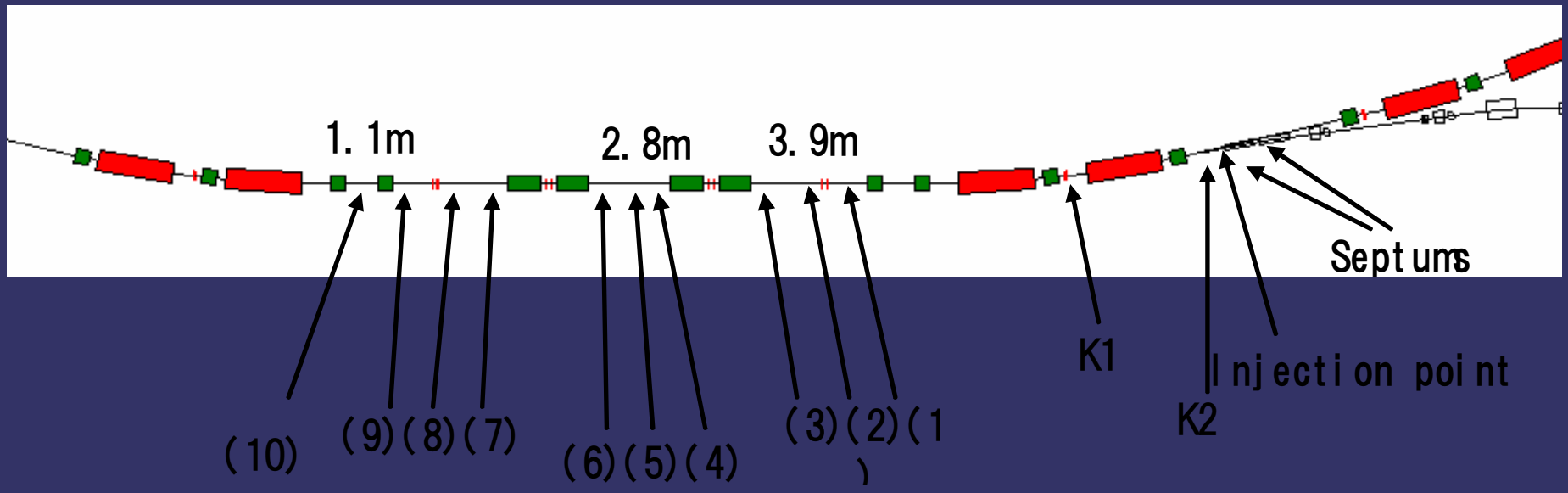
Orbit of injected beam



- Amplitude of injected beam: almost same as kickers

Optimization of PQ location

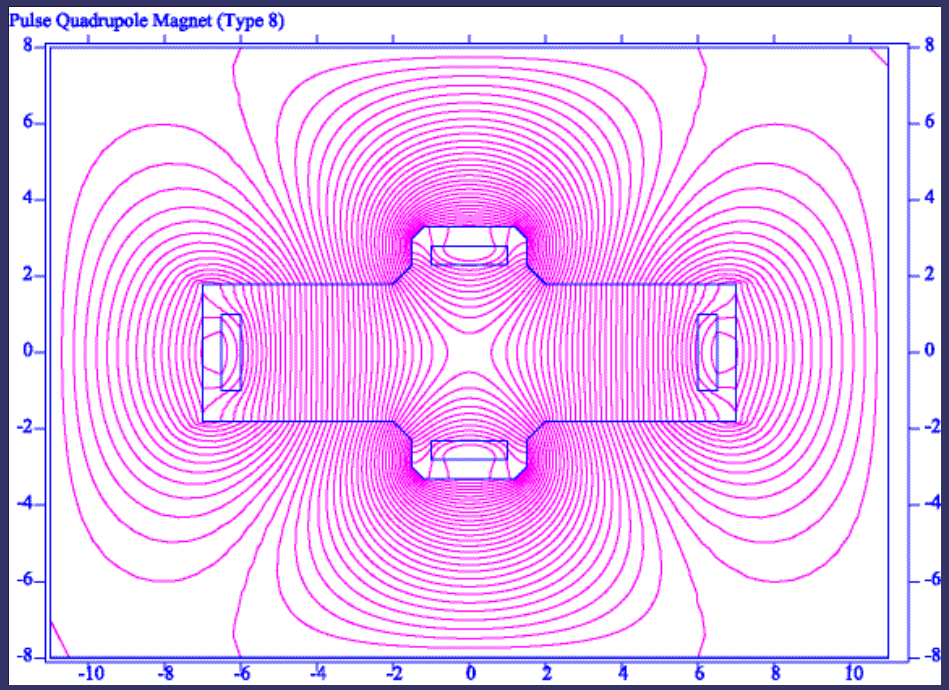
- The oscillation of the injected beam is almost linear even with large amplitude at PF-AR. We can consider the oscillation of the injected beam as a "harmonic oscillator" by using Courant-Snyder invariant (injection emittance).
- We must install before the amplitude of injected beam becomes to its maximum value.

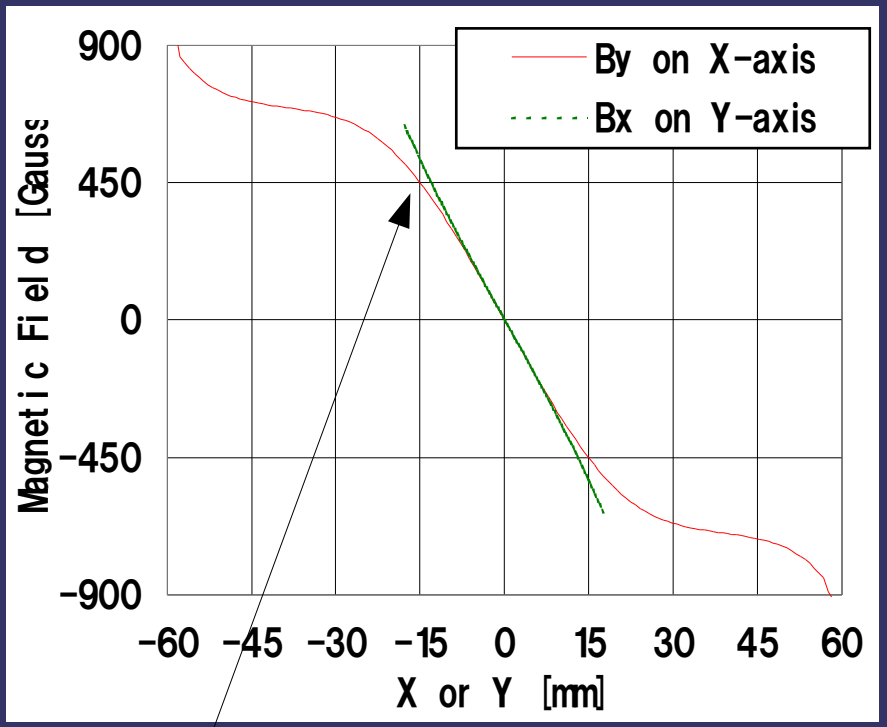


Main Parameters of Pulsed Q magnet

Magnet			
	Length	300	mm
	vertical bore	36	mm
	Horizontal bore	104	mm
	turn number	1	turn
	number of coils	4	
	field gradient	3	T/m
	current	2000	A
	peak current	4000	Ap
	inductanc	1.8	uH
Power Supply			
	output current	-4000	A (peak)
	Pulse shape	half sine, 25PPS	
	Pulse width	2.4	usec

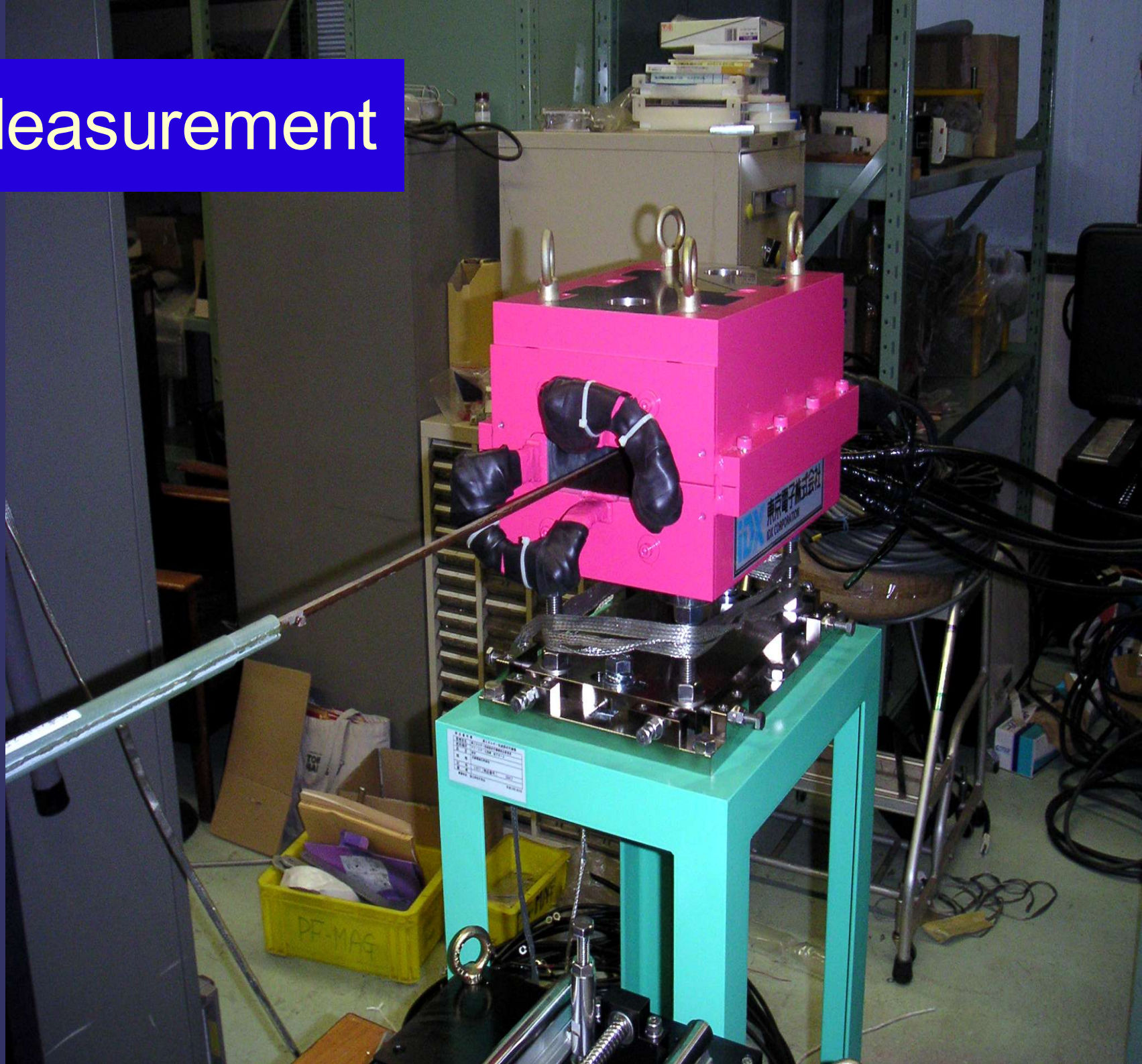
Field Calculation



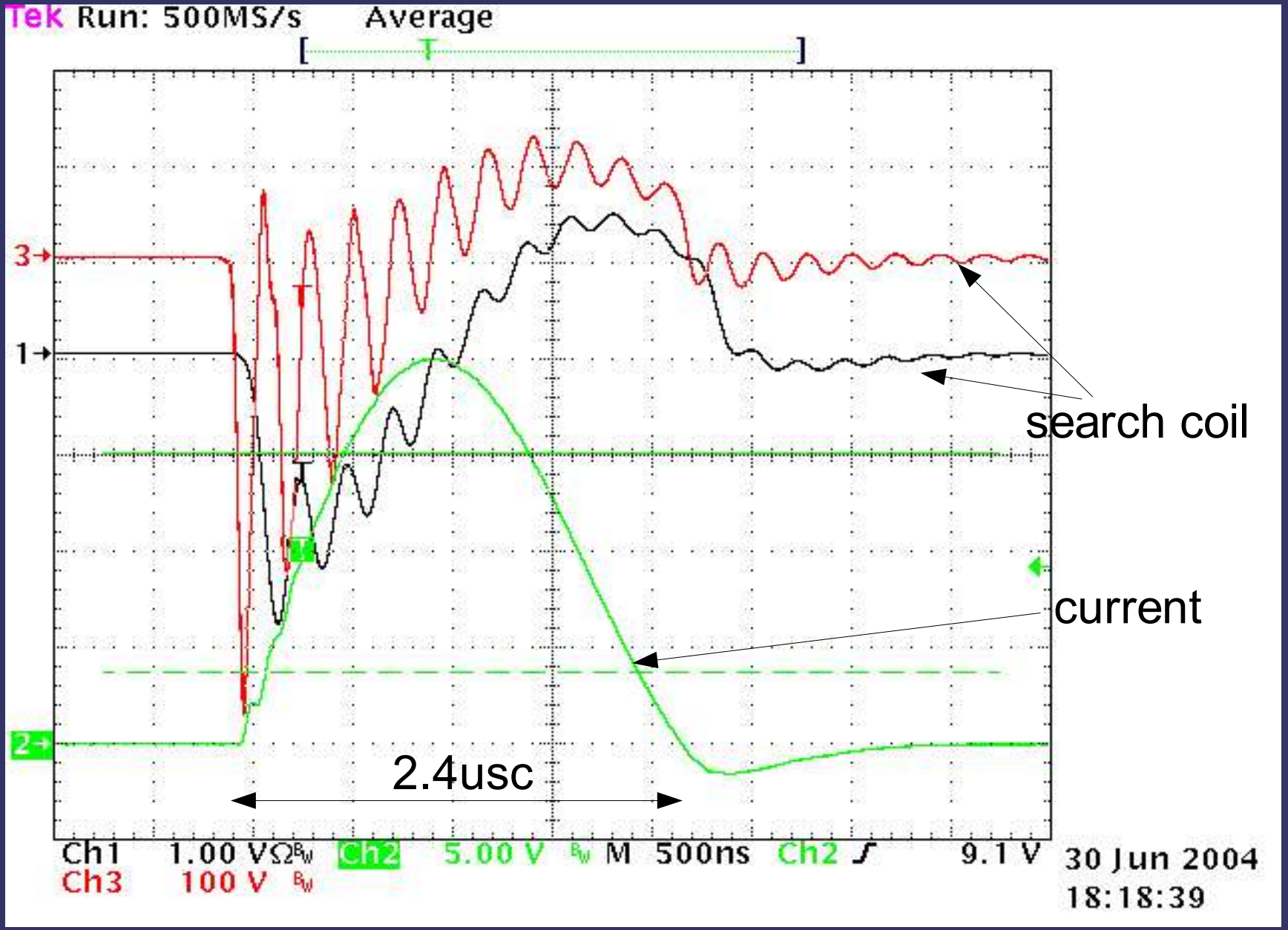


450Gauss = 3T/m, at 15mm
1.1mrad kick

Field Measurement



Typical Pulse Shape



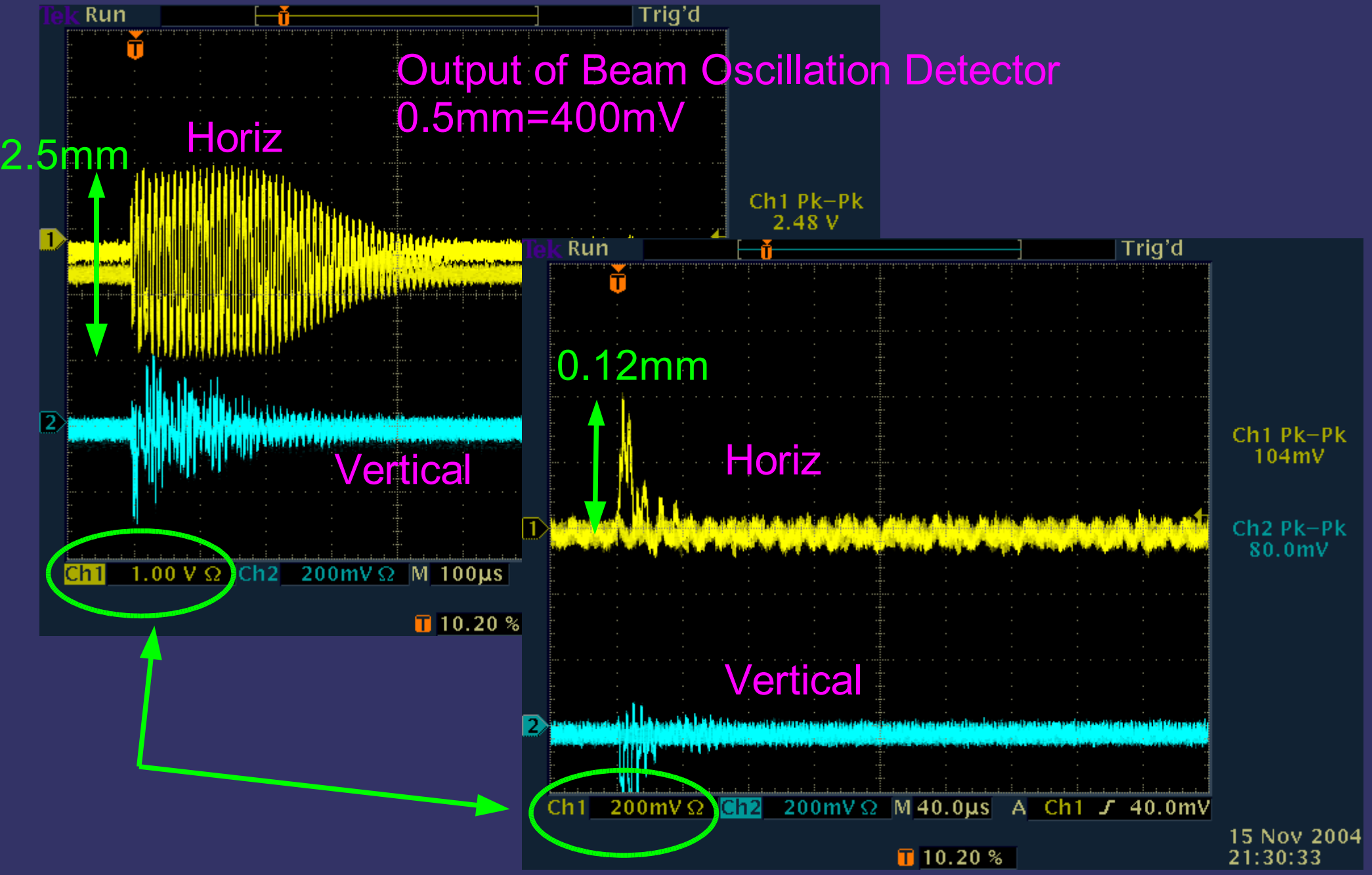
Installation and Beam Test

- Summer/2004
- Installed at south straight section of PF-AR
- Pulse shape have modulated a little because the cable length between PQ and PowerSupply is not equal to the optimum length due to the limitation of the location (for now).

- Beam Test
  - 15/Nov/2004 and 29/Nov/2004
  - total 12Hrs
  - with stored beam
  - with injected beam

- Preliminary result .... next page

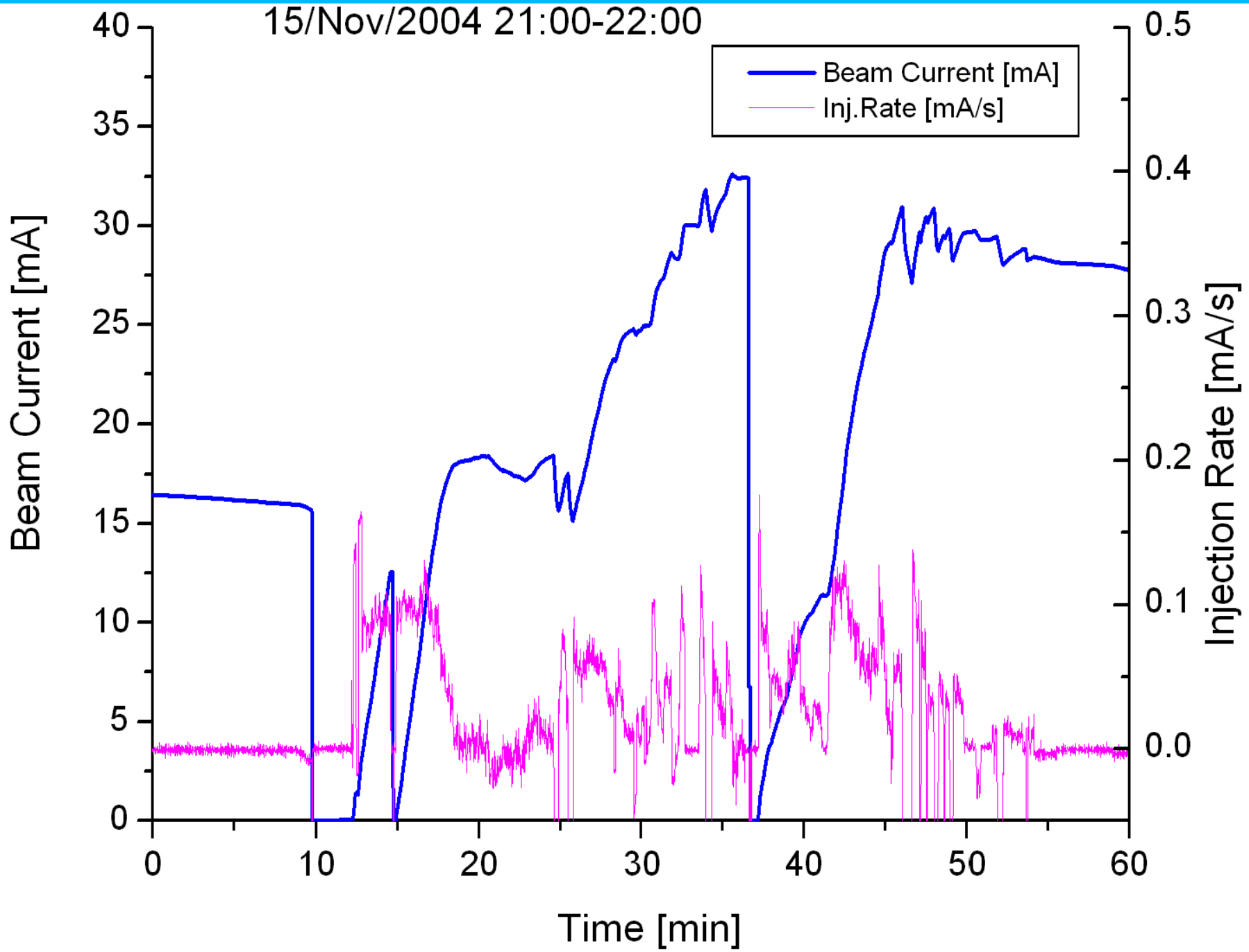
Result: Oscillation of Stored Beam



Beam Current

- Local bump were applied in order to match the center of PQ magnet and the position of the stored beam.
- Amplitude of the stored beam have been reduced!
- Residual oscillation still exists.... we will try again
  - We had some trouble in orbit correction system during the experiment....
-
- We can inject over 30mA (next page)

Beam Current : We can Inject with PQ only



Next step ...

- Continue machine study

- Optimize local bump orbit
- Maximize beam current/injection rate
  - maximum current is smaller than the normal operation at the last experiment. we will investigate more.

- Next week:
  - Observation of injected beam with fast gate camera