Update on kicker R&D at KEK

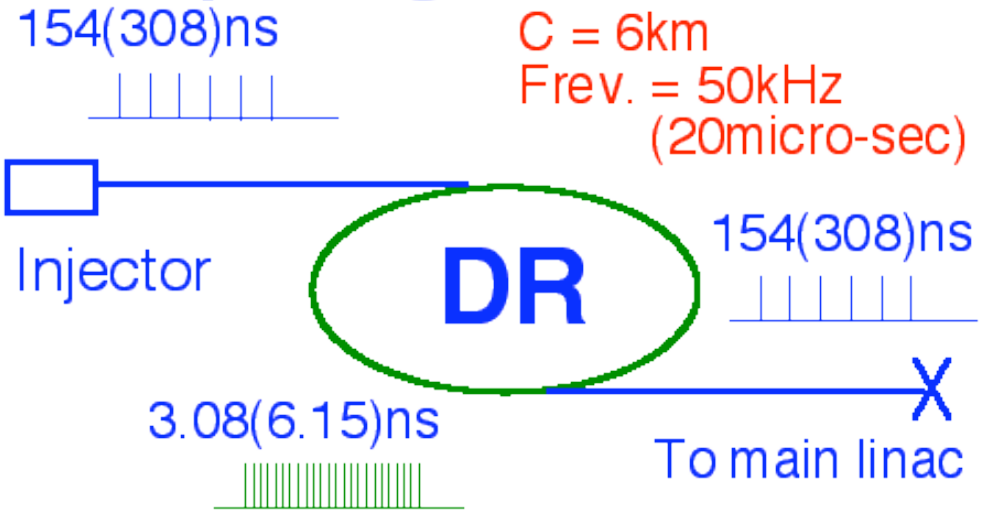
T.Naito(KEK)

Contents

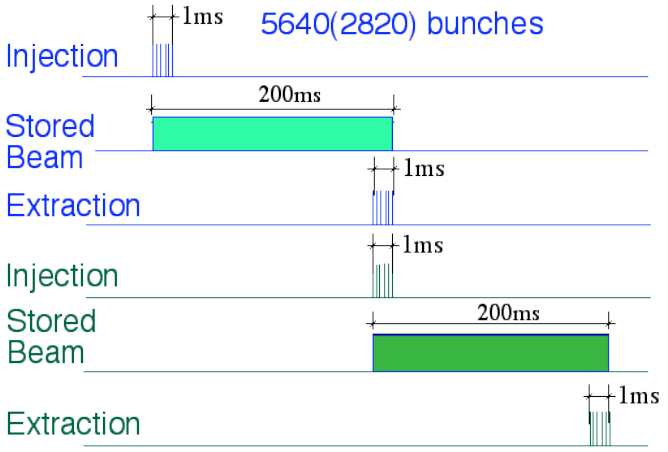
- Design of multi-unit strip-line kicker system for ILC
- Beam test of single unit strip-line kicker in ATFDR
- Further experiment plan in ATFDR
- Beam extraction plan from ATFDR to Ext line

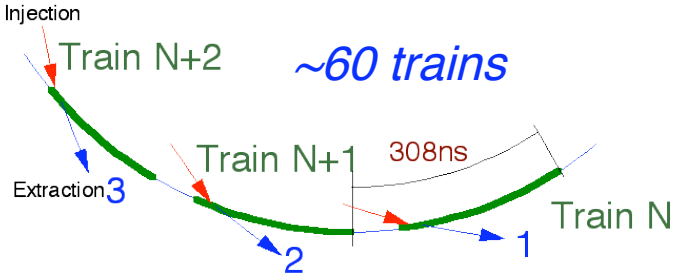
Beam cycle of DR

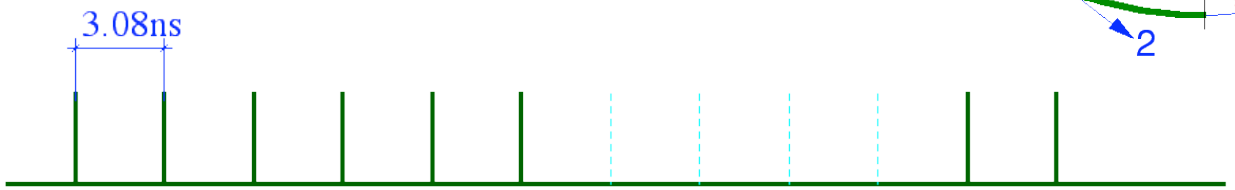
Bunch spacing

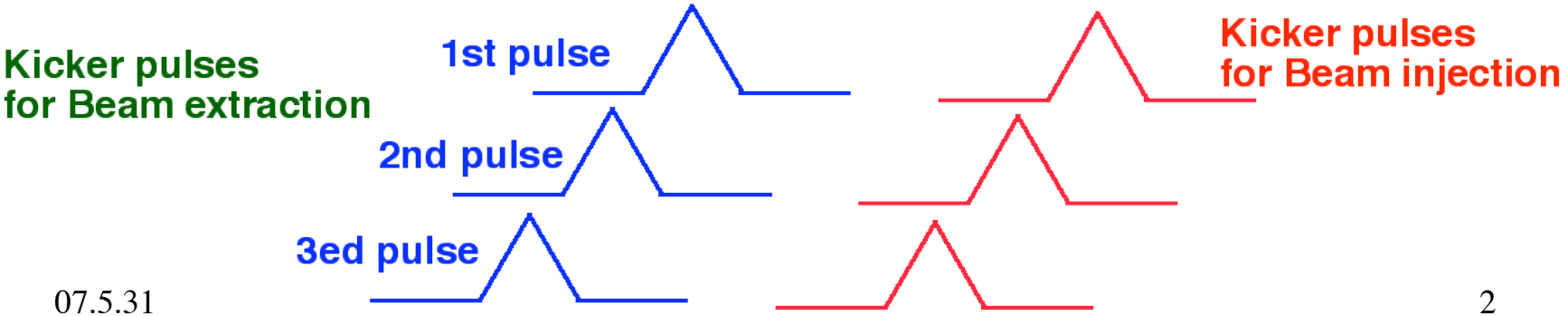


Beam Storage Sequence in DR









ILC DR kicker parameters

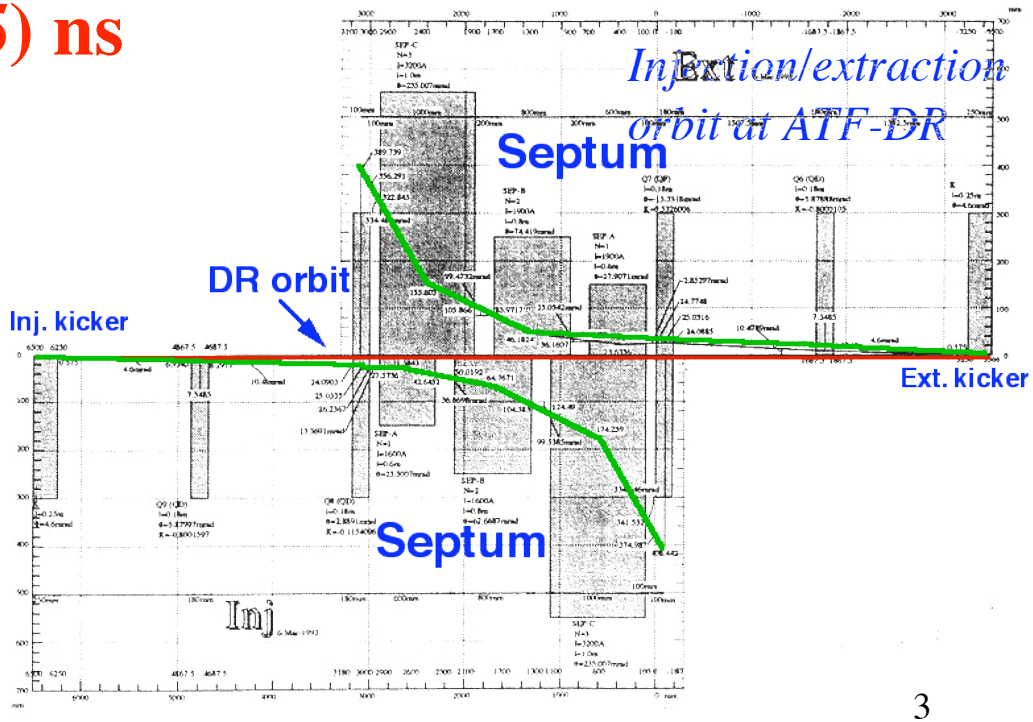
Specification

Kick angle θ~0.6mrad or $\int Bdl \sim 0.01 Tm$ @5GeV, β~50m

Stability 7×10^{-4}

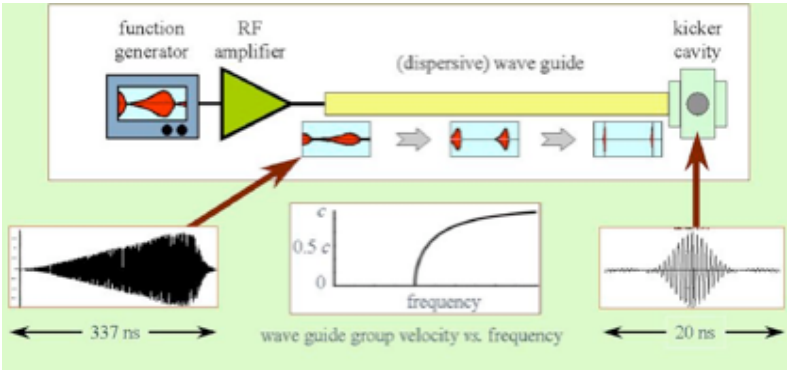
Rep. Rate 6.5(3.25)MHz, 1ms burst, 5Hz

Rise/fall time of the field **< 3.08 (6.15) ns**

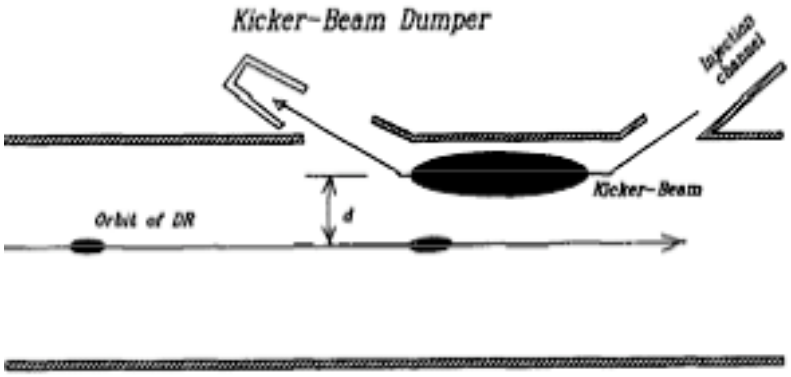


New proposal for the ILC kicker

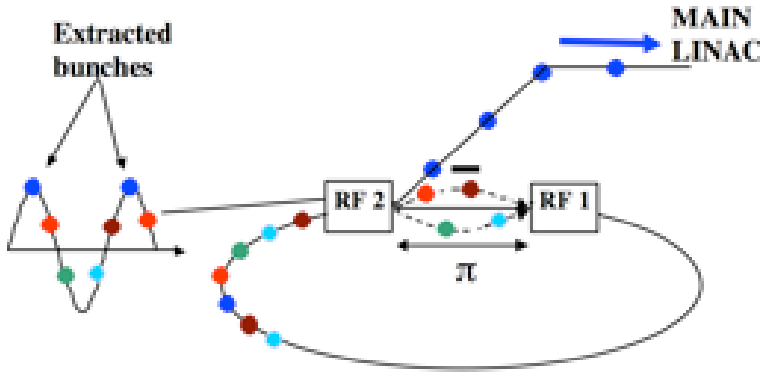
Fourier series kicker



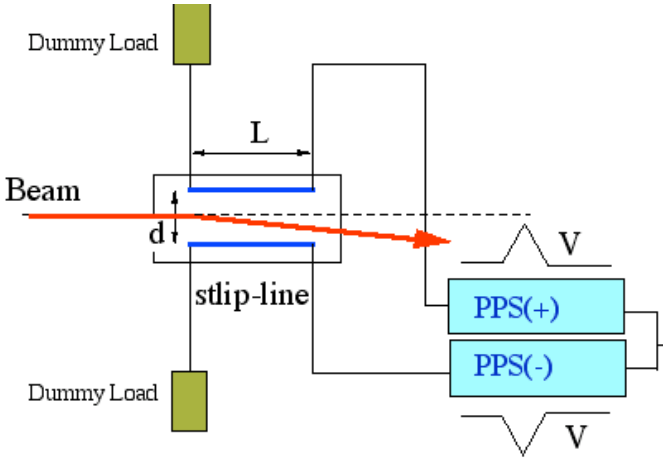
Beam-Beam kicker



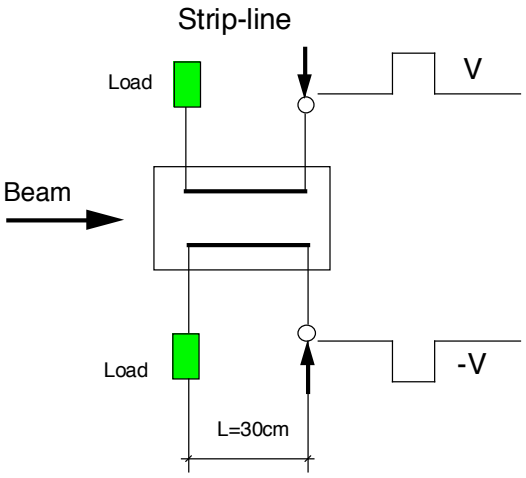
RF deflector



Strip-line kicker

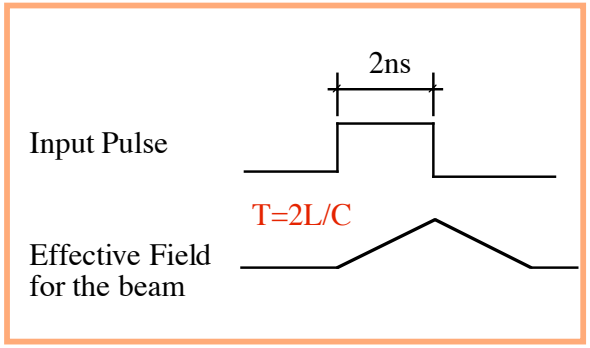


Kick field of the strip-line kicker

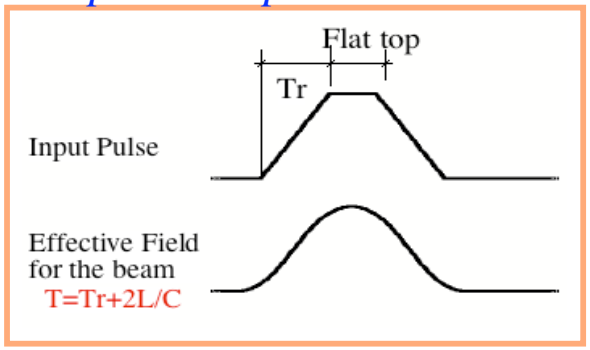


$$\Delta\theta \propto \int_{t}^{t+2L/c} V(t)dt$$

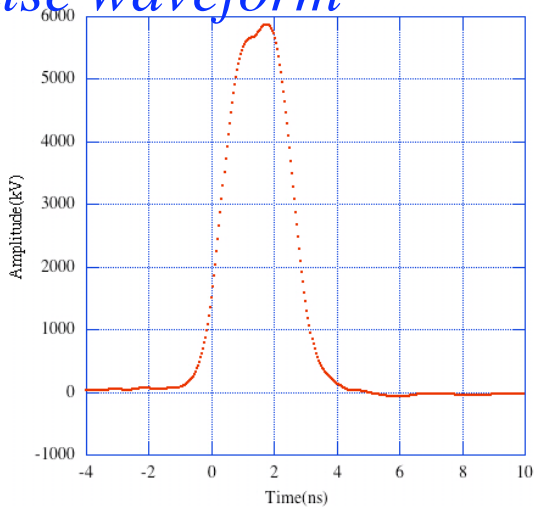
Rectangular pulse



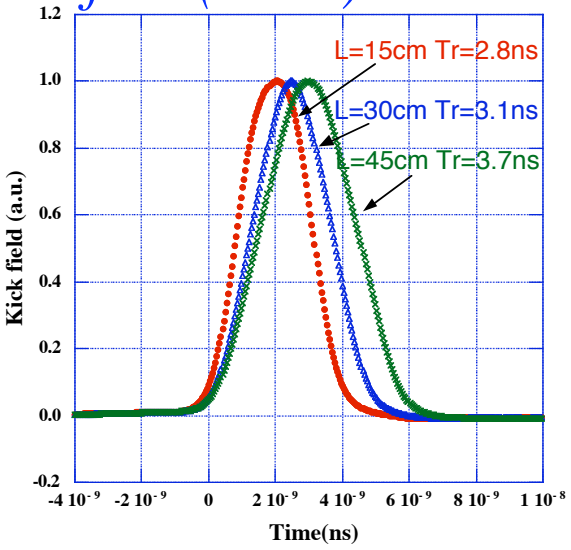
Trapezoidal pulse



Pulse waveform



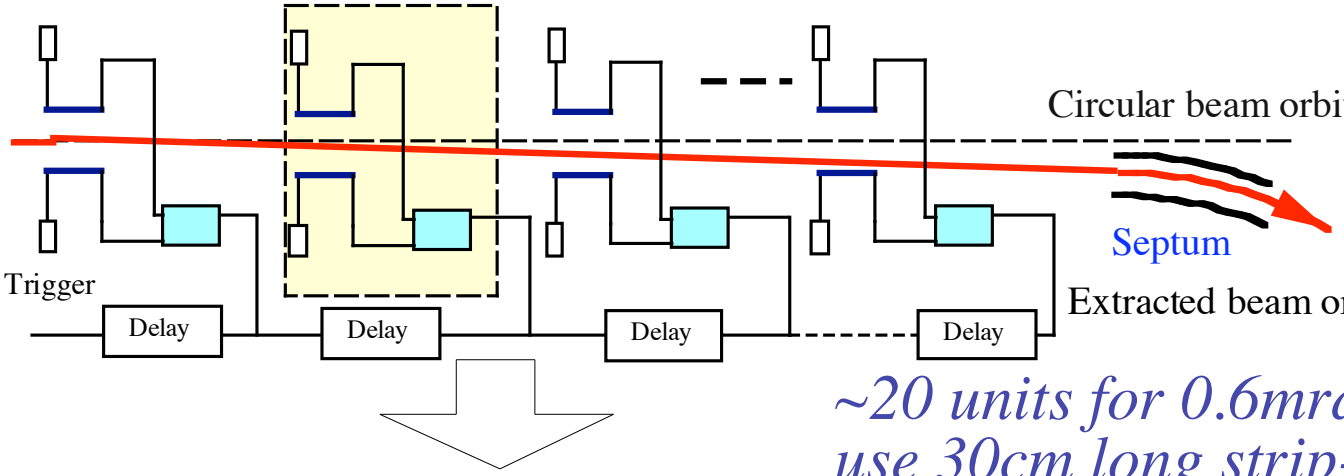
Kick field(calc.)



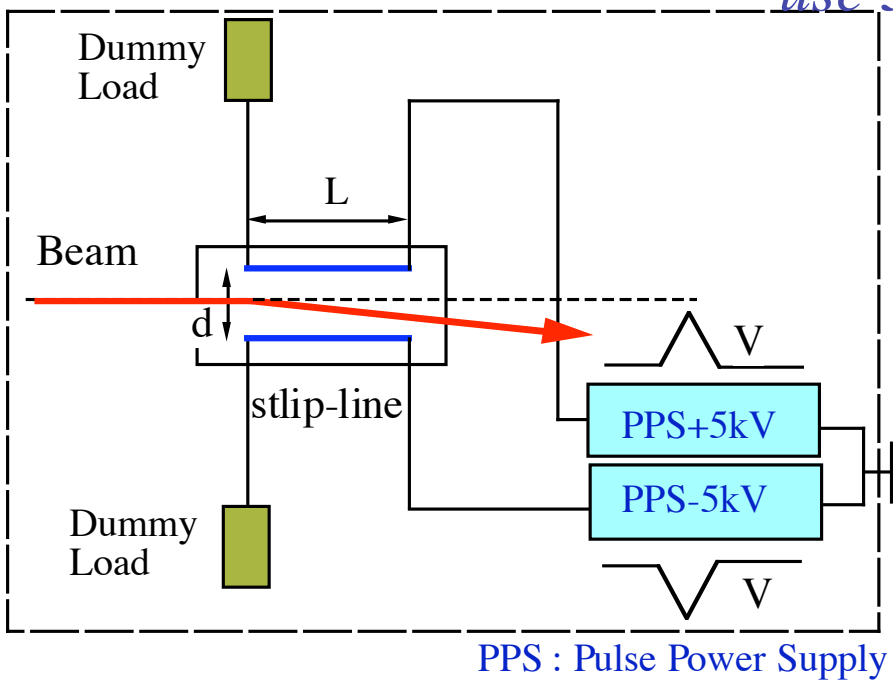
Rise time :1%~100%
Fall time : 100%~1%

- *The counter direction kicker pulse makes the transverse kick to the beam (Panofky-Wenzel theorem)*
- *The kick field is defined as the integration of the electromagnetic field when the beam go through the strip-line.*

Design of Strip-line kicker system



~20 units for 0.6mrad kick angle, when use 30cm long strip-line, +/-5kV pulse



PPS : Pulse Power Supply

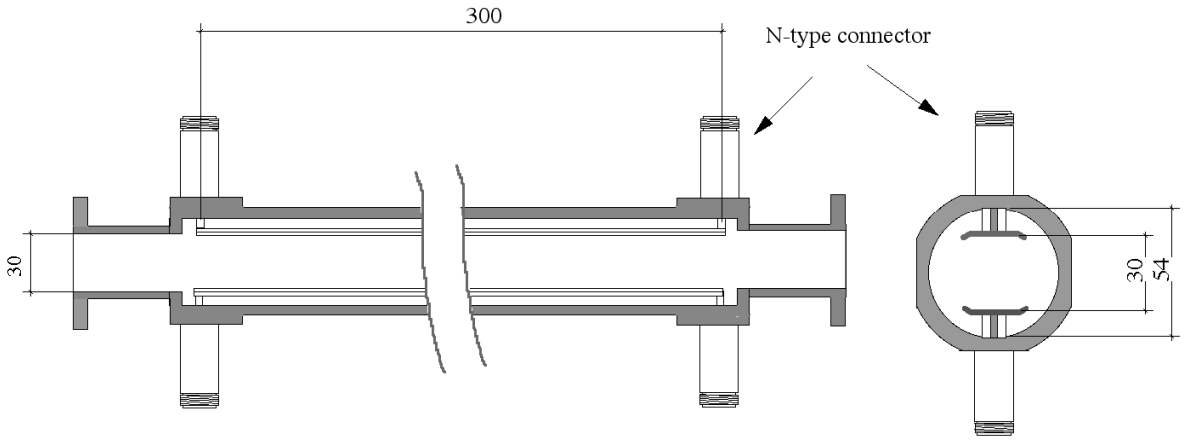
$$\Delta\theta = 2g\frac{eV}{E}\frac{L}{d}$$

L = strip – line length
d = distance between the electrodes
V = pulse voltage
E = Beam energy

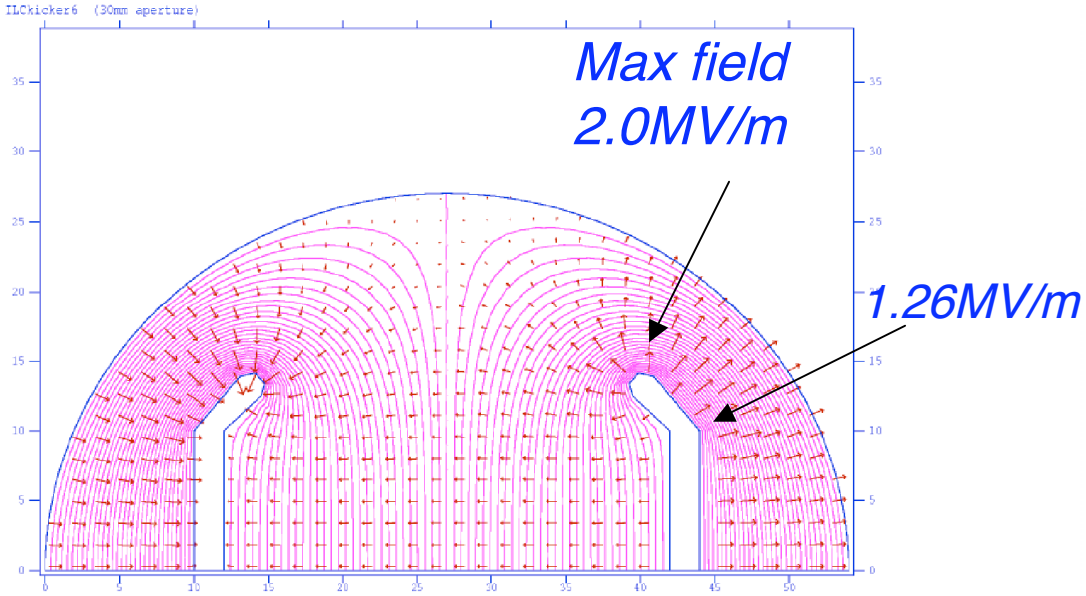
$$g = \tanh\left(\frac{\pi\omega}{2d}\right)$$

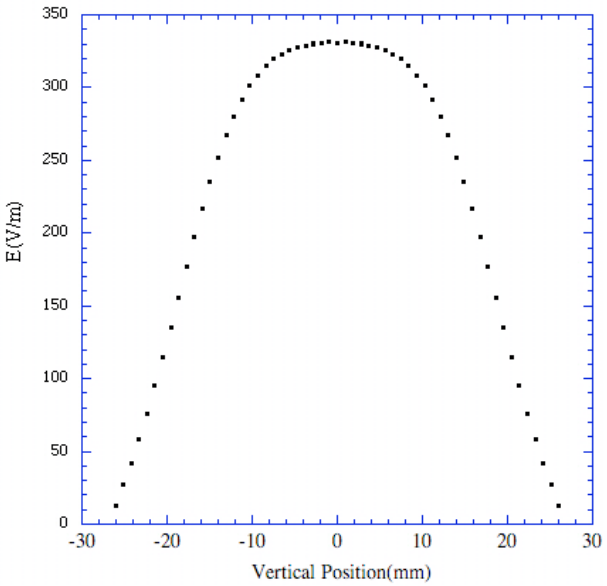
ω = strip – line width
d = distance between the electrodes

Design of Strip-line electrode



The shape of the electrode is designed to keep good uniformity of the deflecting field. The calculated flatness is 0.07% in the area of +/-1.8mm from the center.





Geometric factor(analytical) =0.955

Pulse power supply

There are 3 types of candidates for the kicker pulse source.

1) HTS-50-08-UF(BEHLKE GmbH)

FET ON switch module

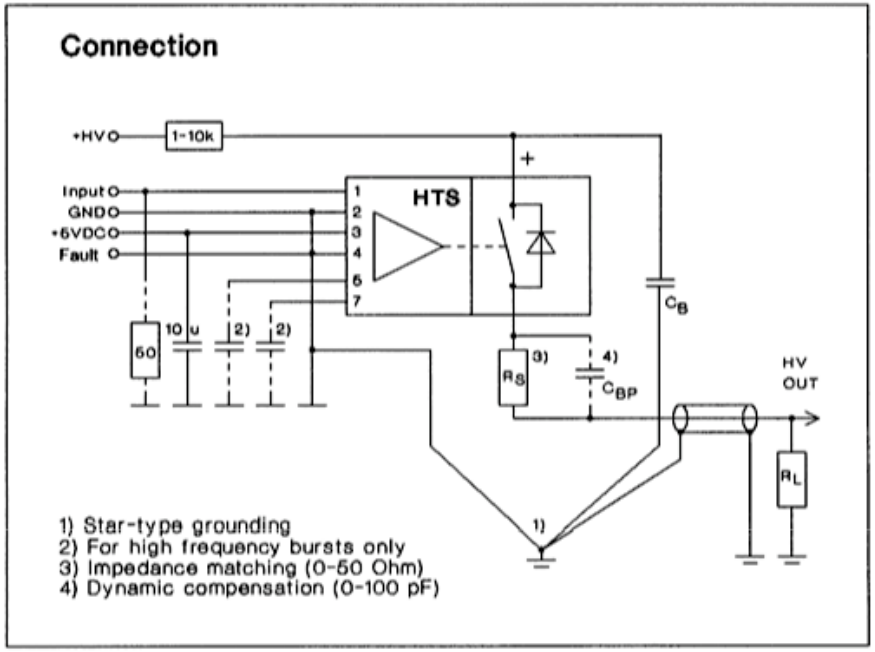
2) Adder Drive Boards(LLNL)

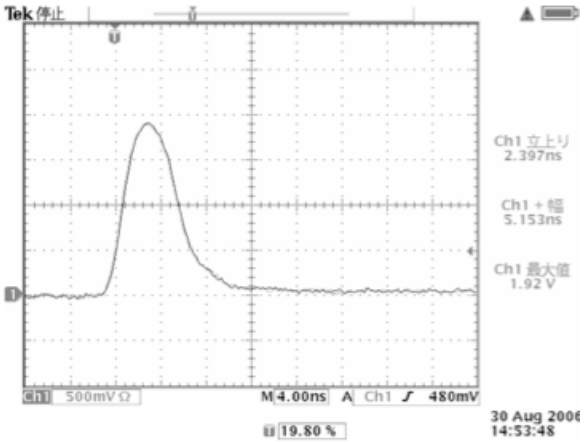
FET ON switch(stacked)

3)FPG 5-3000M(FID GmbH)

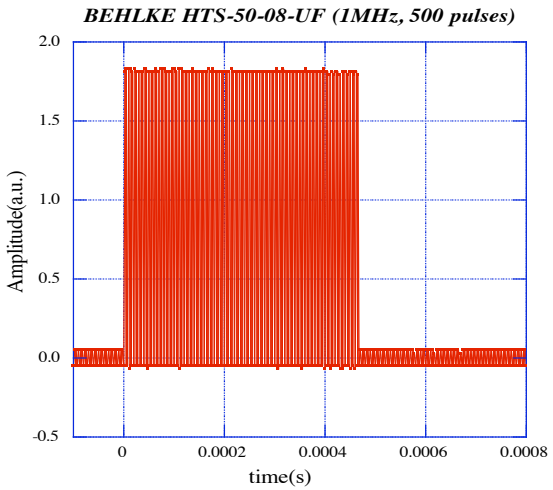
Fast Recovery Diode OFF switch

BEHLKE HTS-50-08-UF



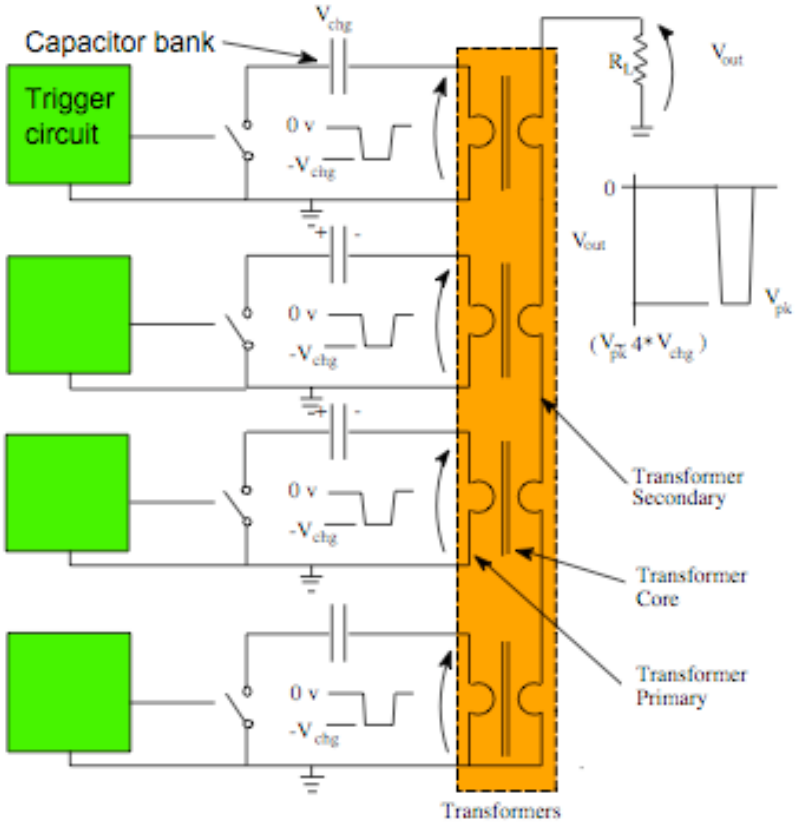


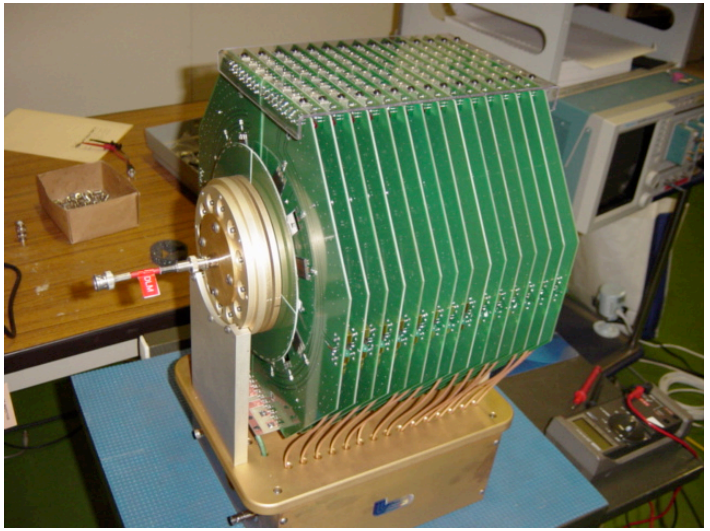
Rise time ~3ns at 2.5kV output

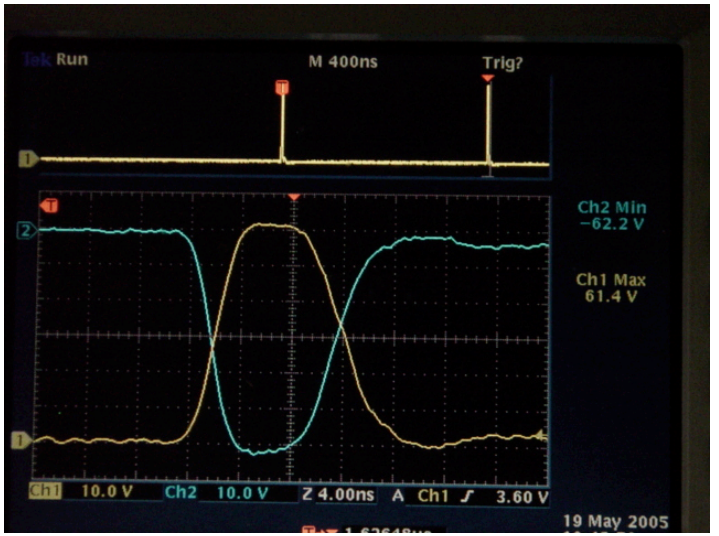


Burst pulses(1MHz, 500pulses)
droop:5x10^{-3}

Adder Drive Board(LLNL:Ed Cook)





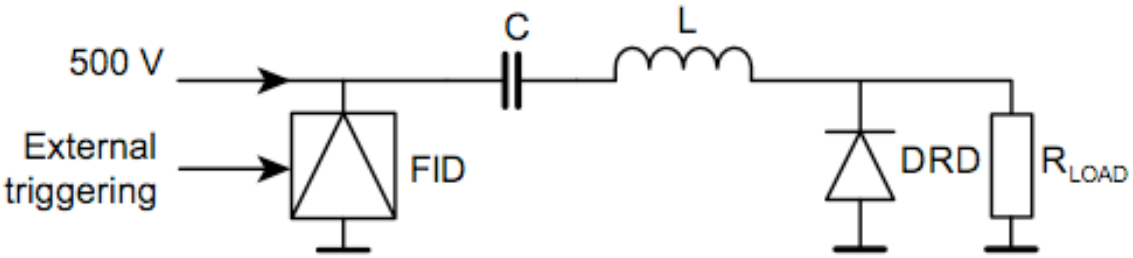


This high voltage pulse power supply is basically developed for the drive pulse of the induction linac.

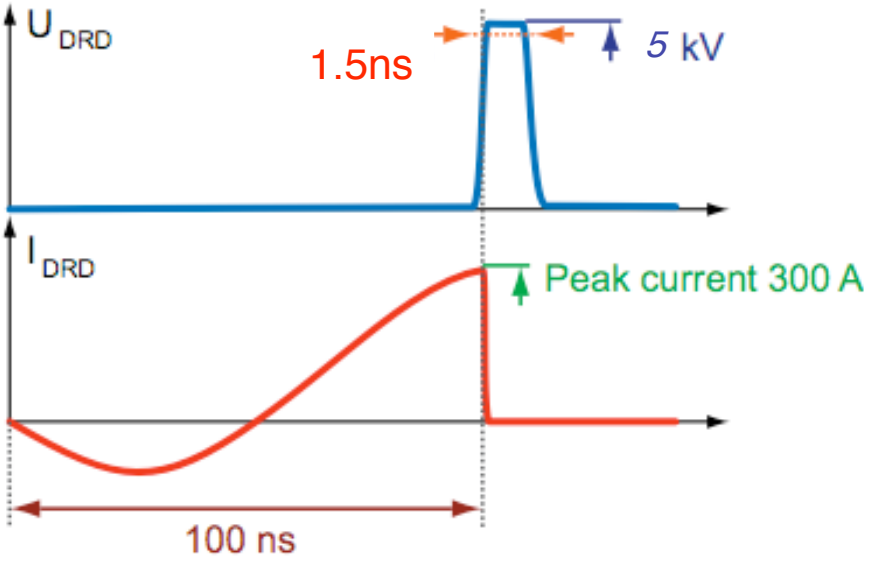
+/-3.1kV, 500kHz, 500 pulses, ~4ns rise time, 10ns pulse width

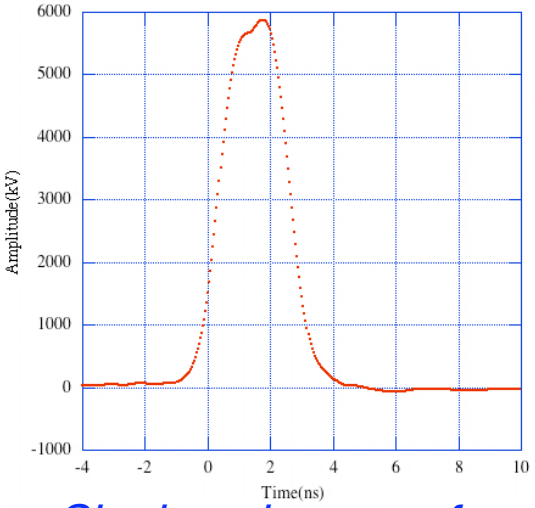
FET(DE275) on time: 2ns

FID FPG5-3000M(1)

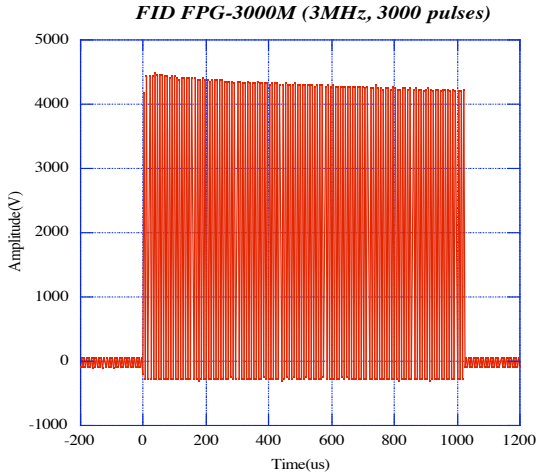


FID : Fast Ionization Dynistor
DRD : Drift step Recovery Diode



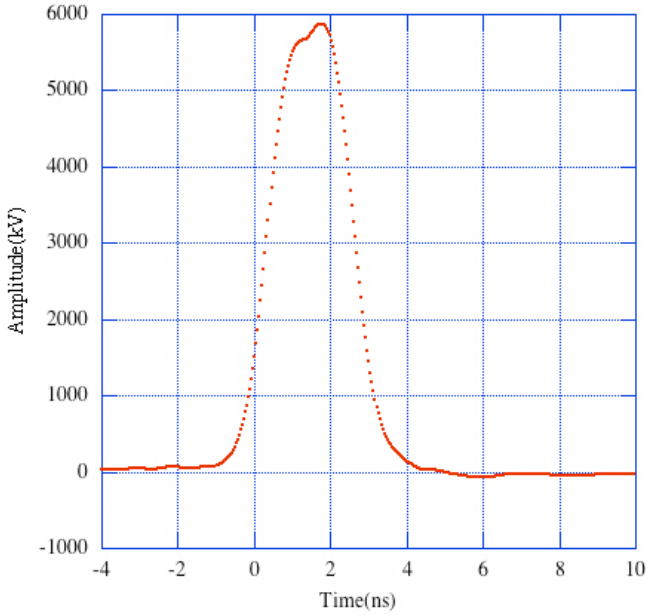


Single pulse waveform

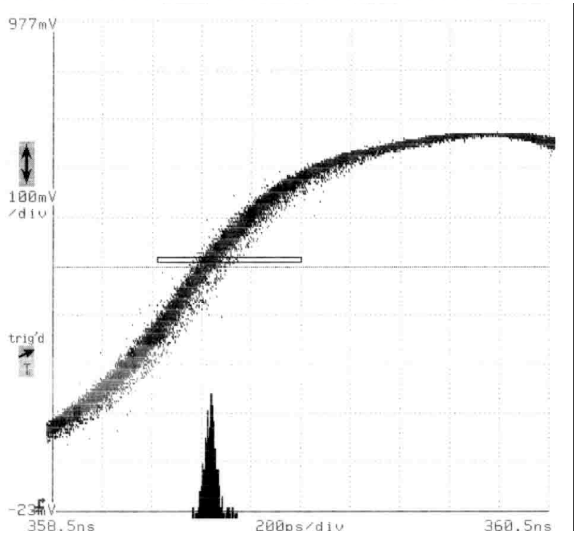


Burst pulses(3MHz, 3000pulses)
droop : ~3%

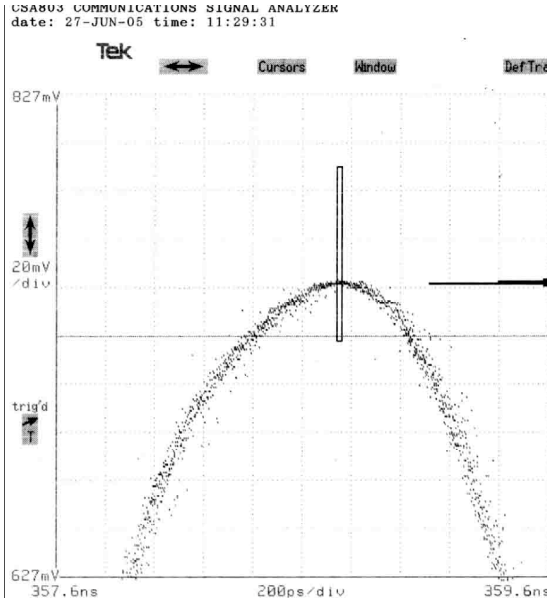
FID FPG5-3000M(2)



Pulse width(FWHM) = 2ns
Pulse height = 5.8kV
Rise time = ~1.5ns(5%~95%)
Time jitter = ~29ps
Amplitude Jitter = 0.72%
(limited by the scope resolution)



Timing jitter measurement
29ps(1s)

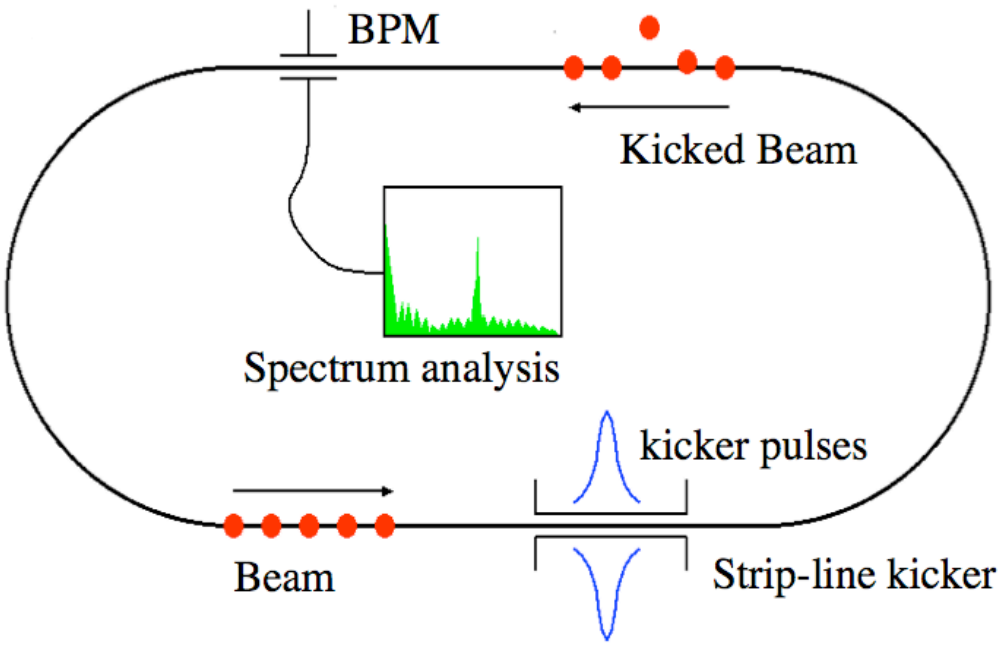


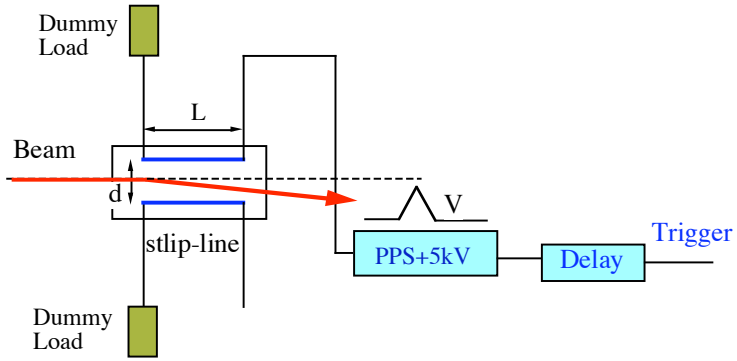
Amplitude jitter measurement
0.72%(1s)

Comparison of pulse power supplies

	Rise Time	High Voltage	Rep. rate
HTS-50-08	3ns △	2.5kV △	1MHz △
Adder Drv.	4ns △	>+/-3.1kV ◎	>500kHz △
FPG5-3000M	1.5ns ◎	5kV ○	3MHz ◎

Beam kick experiment at ATF-DR





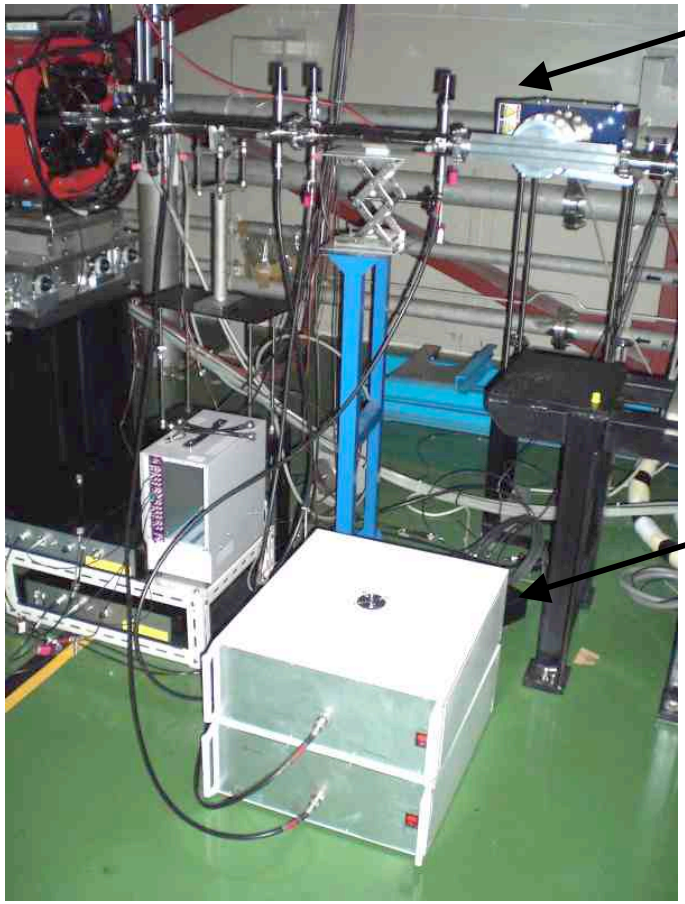
Single unit of strip-line kicker

A) Kick angle measurement by Single-shot BPM

B) Rise/fall time measurement by Turn-by-Turn BPM

C) Rise/fall time improvement by Waveform compensator

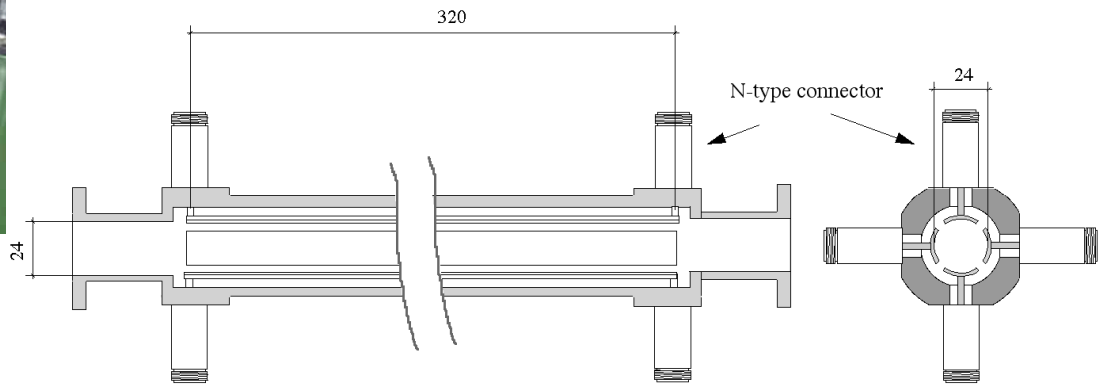
Strip-line electrode for ATF-DR experiment(1)



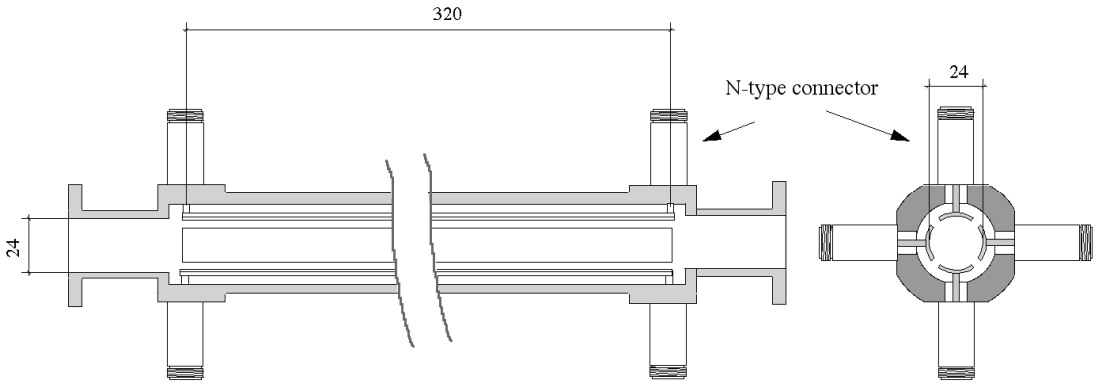
Strip-lines

Pulse power supplies

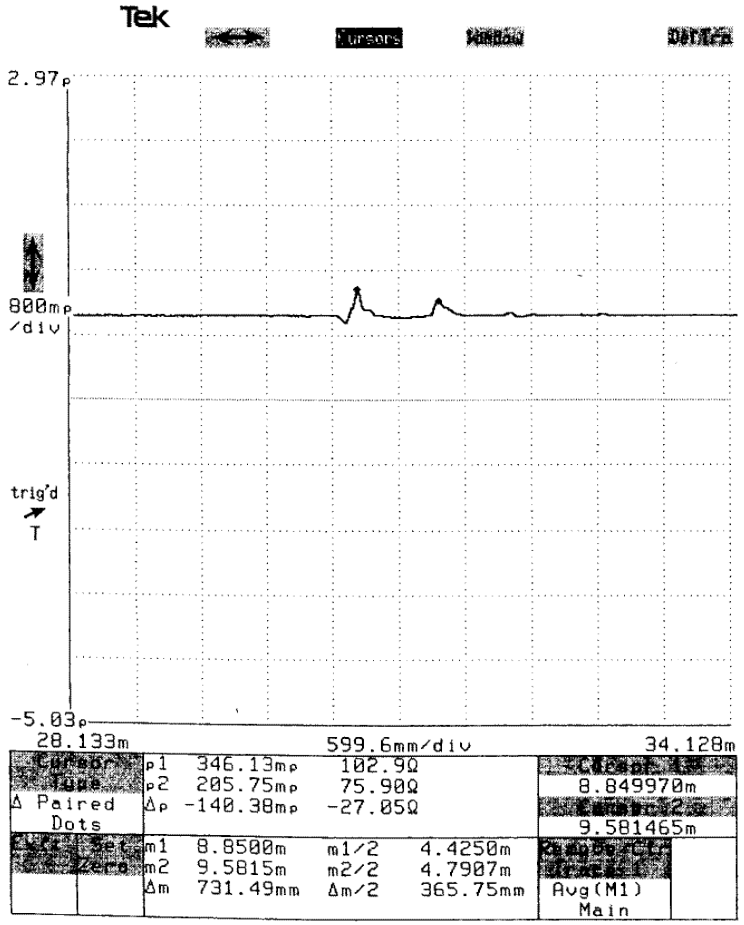
Two strip-line electrodes are used for the experiment. These electrodes was designed for the beam excitation in DR to measure the tune.



Strip-line electrode for ATF-DR experiment(2)

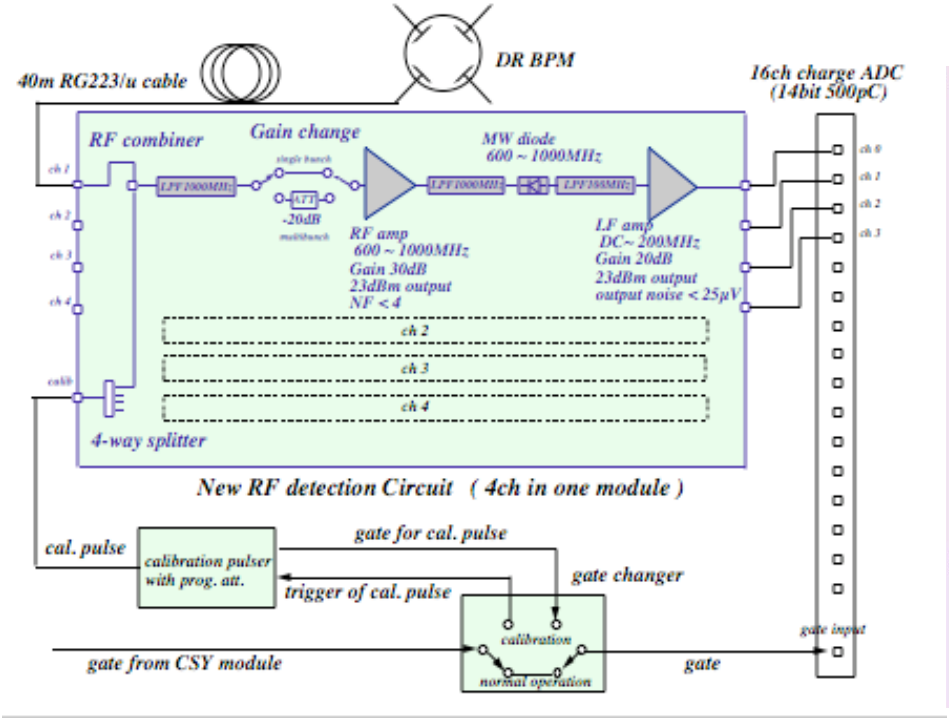


The distance between the electrode and the chamber wall is 5mm, which could avoid the discharge for 5kV pulse transmission.
Strip-line electrodes used N-type feed-through. The matching for 50ohm line is not good enough, but the area is a few cm long.

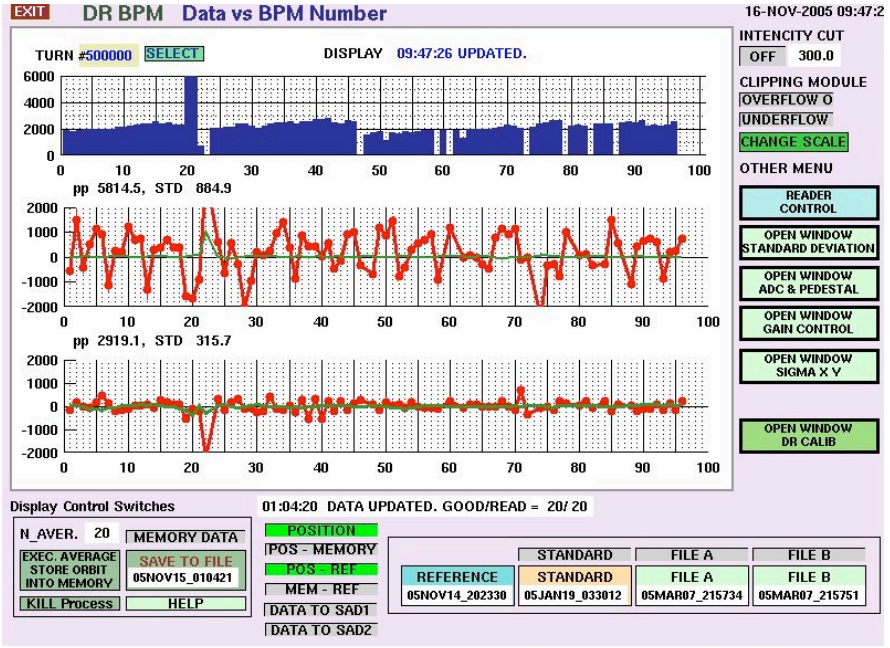


Impedance measurement of the strip-line
Electrode :50.9ohm
Feed-through :103ohm, 76ohm

Single-shot BPM system

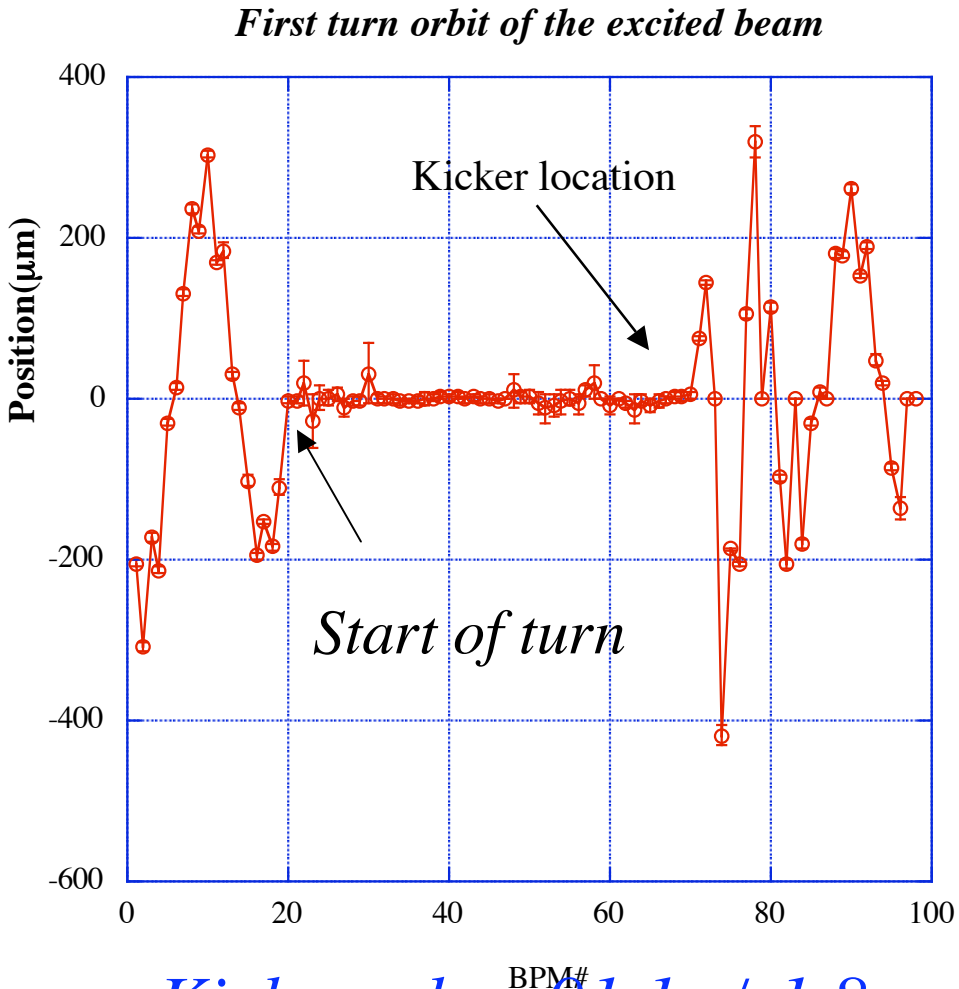


96 BPMs in DR



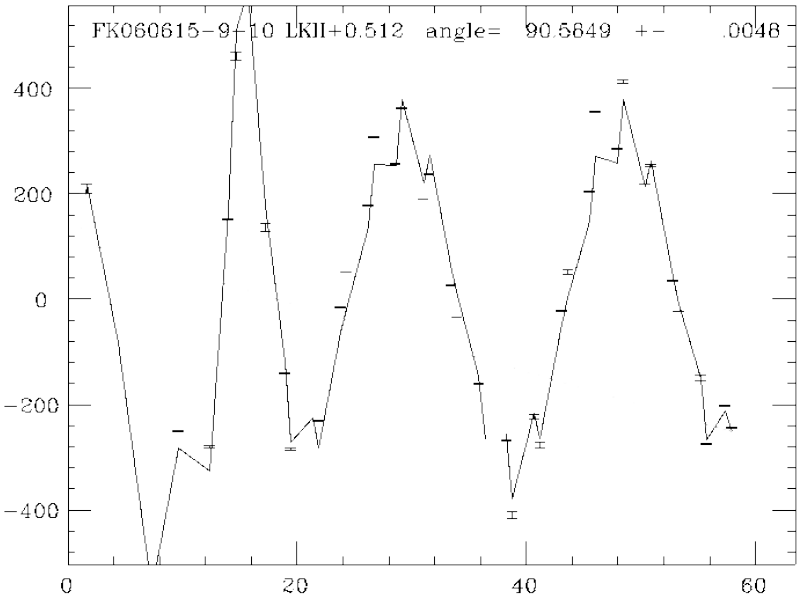
Resolution : ~2μm(rms) at 1x10¹⁰e
(Electronics)

Result of kick angle measurement



The kick angle is estimated from the kicked orbit and R12. The graph shows one turn orbit when the beam kick was just applied. The kicked orbit starts from #70 BPM. The graph shows the kick angle calculation by SAD.

$$min.\sum[\theta \bullet R12 - \Delta x]$$

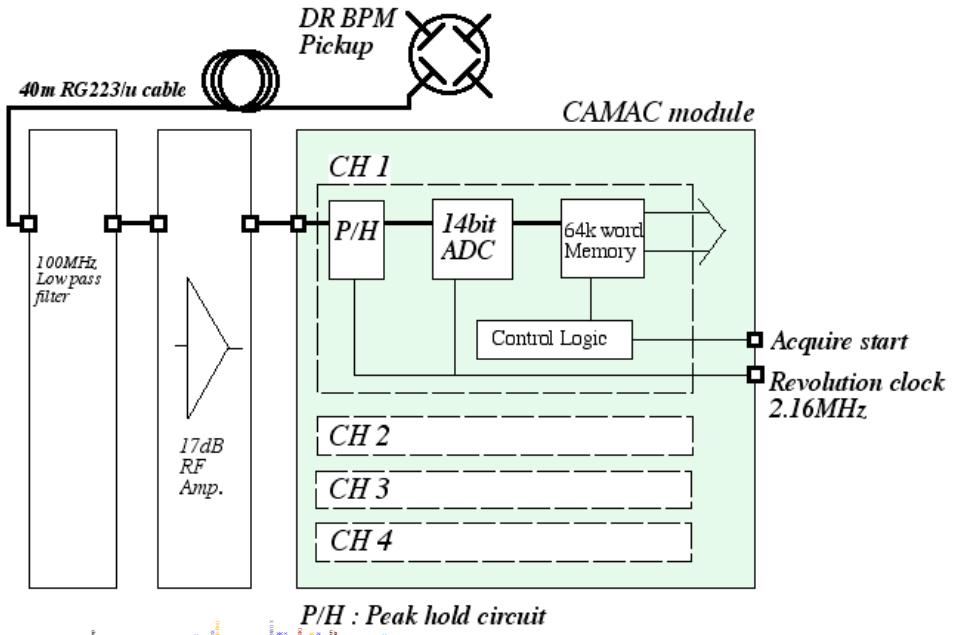


Kicked orbit is fitted by SAD

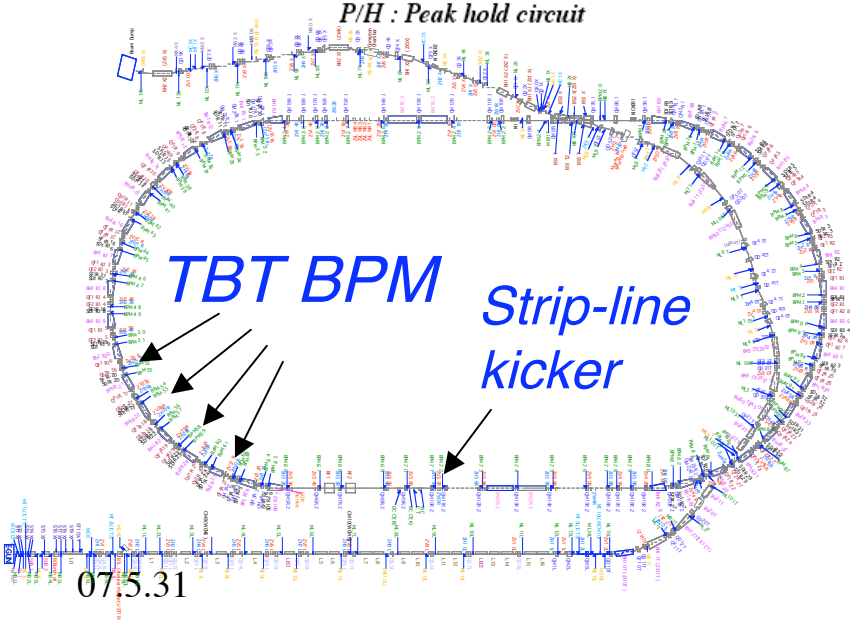
Kick angle =91.1+/-1.8μrad

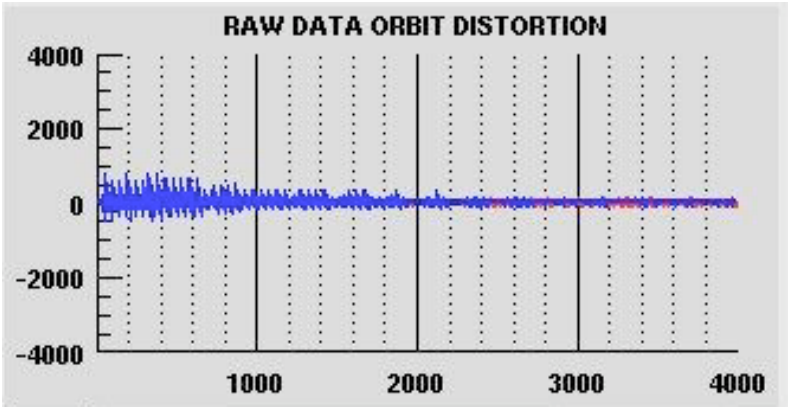
BPM Error(1σ) mean =6.6μm

Turn-By-Turn(TBT) BPM system

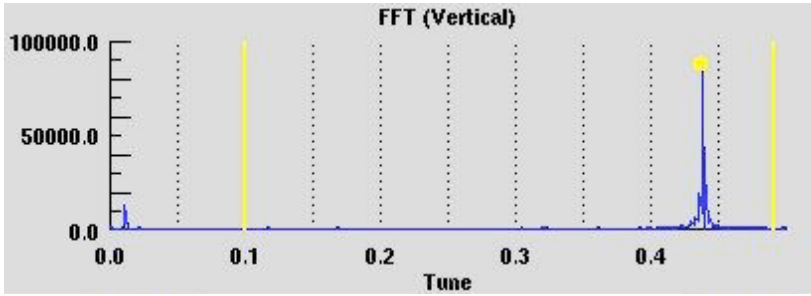


P/H : Peak hold circuit





Beam oscillation during 4000 turn

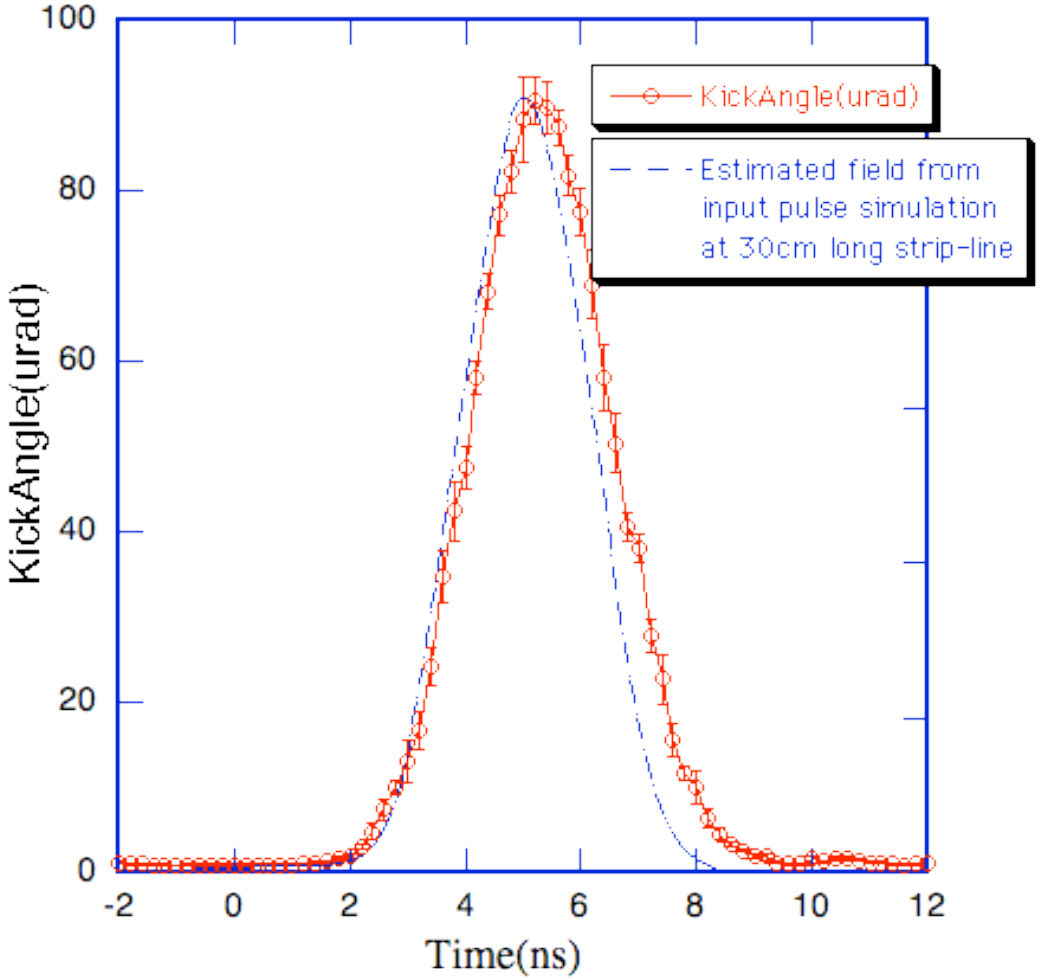


Frequency spectrum

$$y' \propto F(f)$$

This measurement can avoid the noise effect from the other frequencies.

Timing scan of the kick pulse



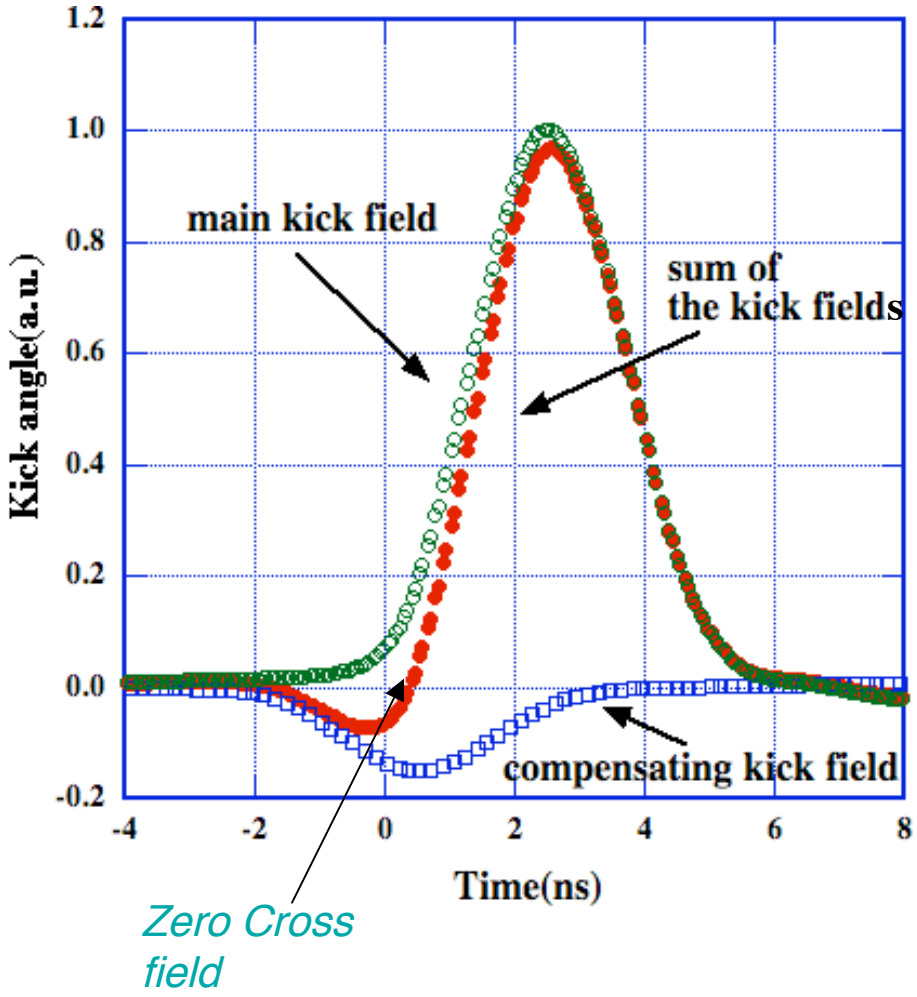
Kick angle is estimated from the amplitude of the betatron frequency of the FFT signal.

Beam kick profile

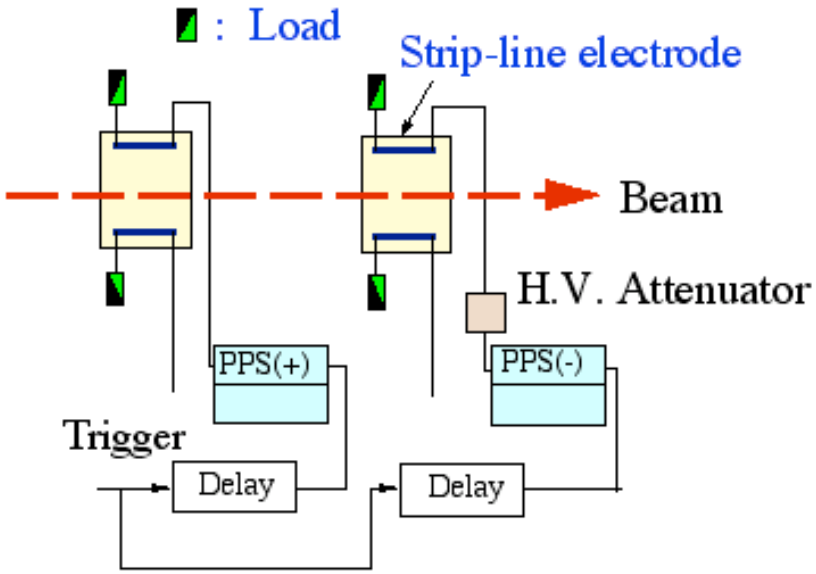
The timing of the kick pulse is scanned for the timing of the beam with 200ps steps. The kick angle is estimated from the beam oscillation amplitude.

Rise time = 3.2ns
(1%~100%)
Fall time = 4.0ns
(100%~1%)

Waveform compensator



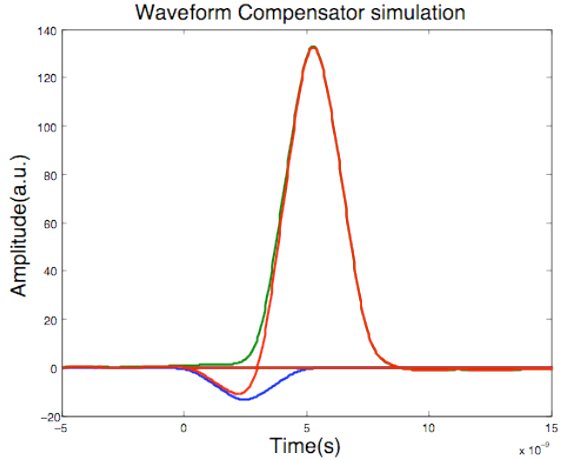
Simulation of waveform compensator



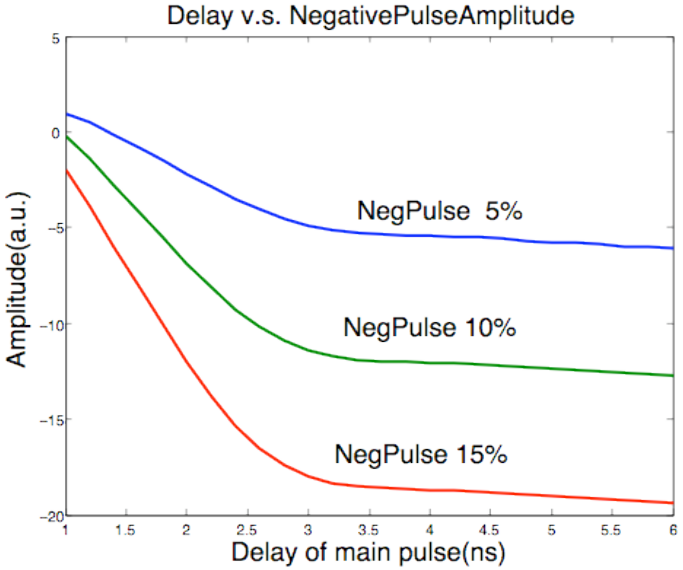
Experimental set up

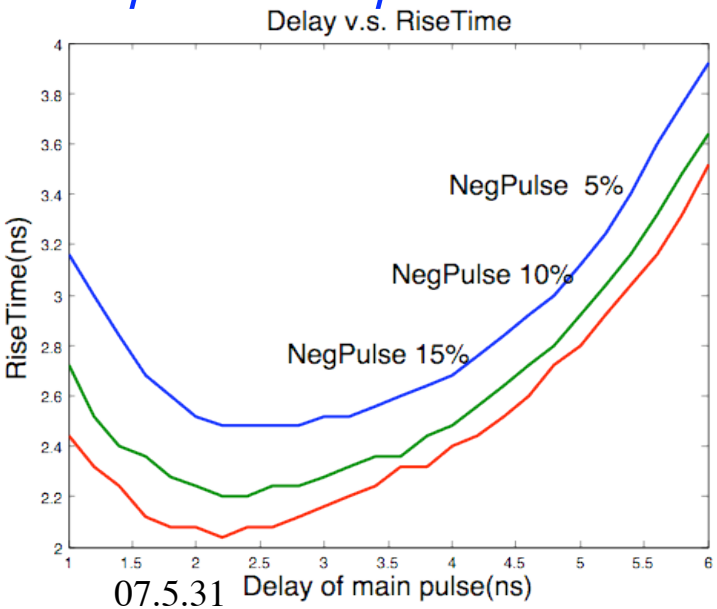
The rise/fall time can be improved by the combination of the positive and negative pulses which have different timings and different amplitudes.

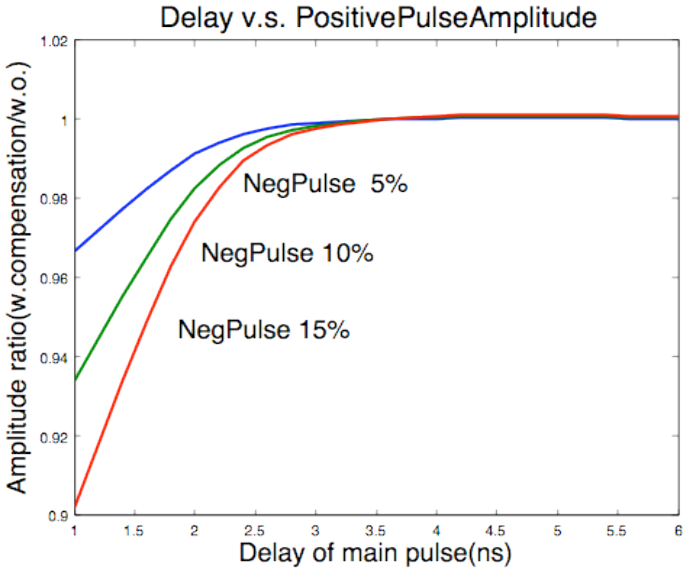
Waveform simulation



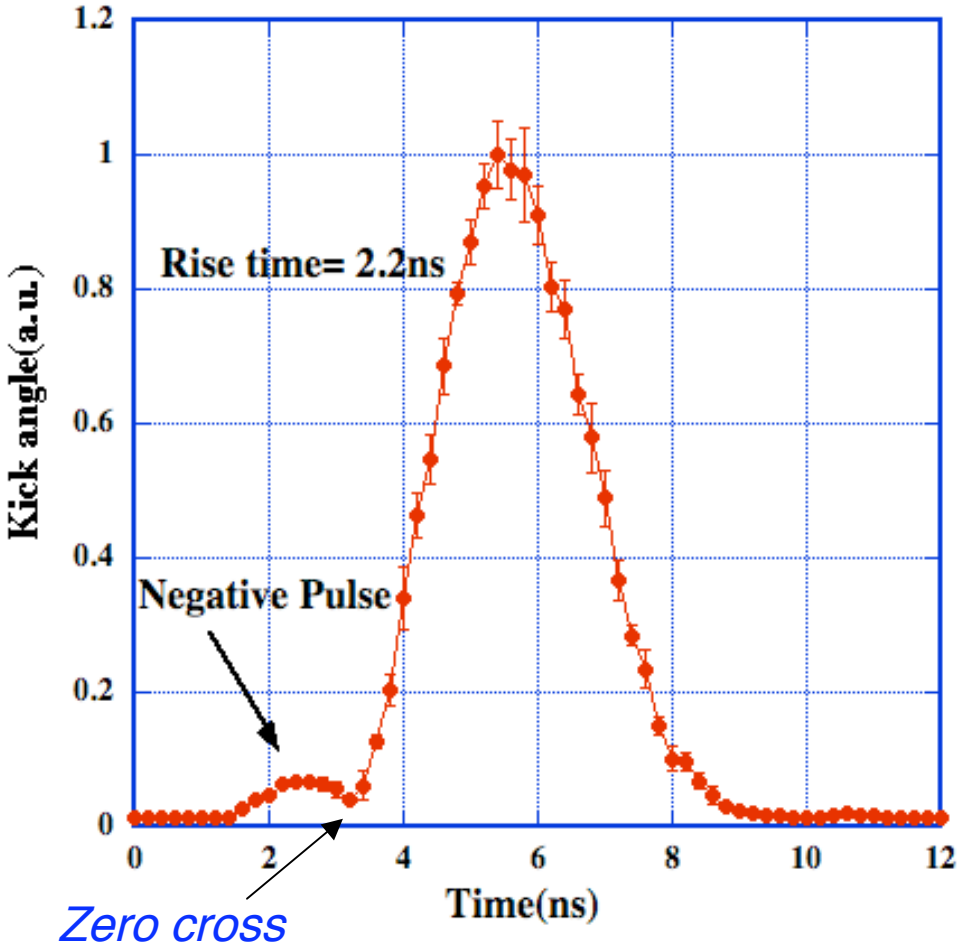
The rise time simulation for the timing and the amplitude of the compensation pulse

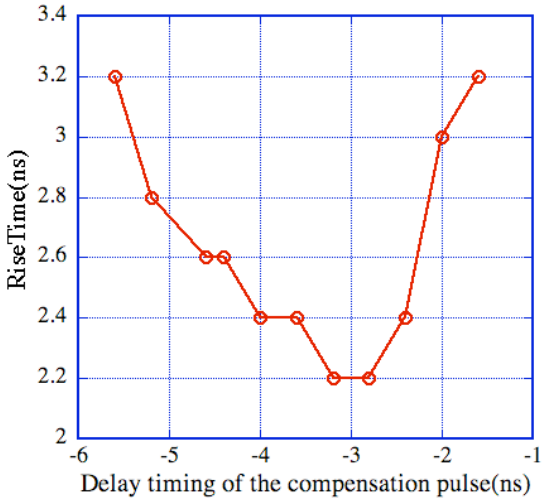


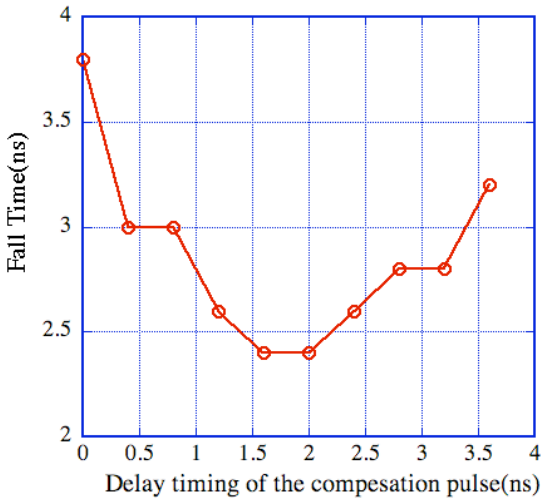




Rise time improvement with Waveform compensator



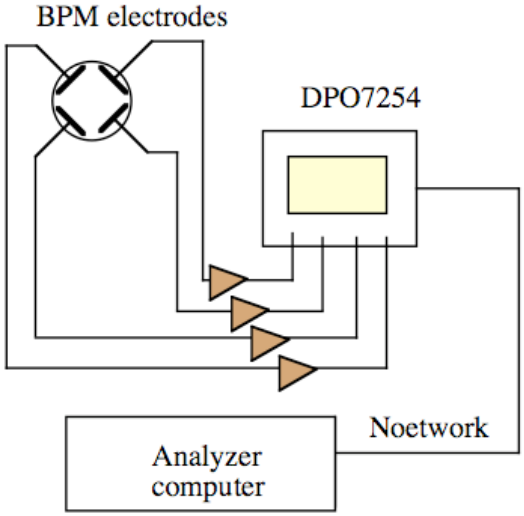


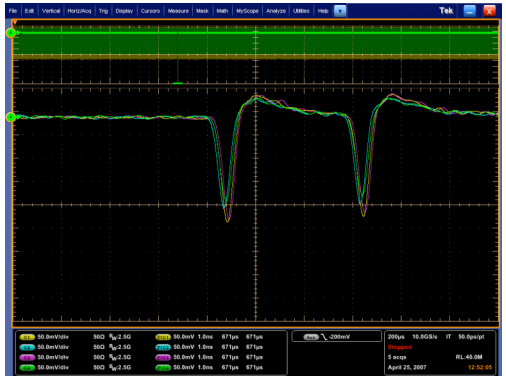


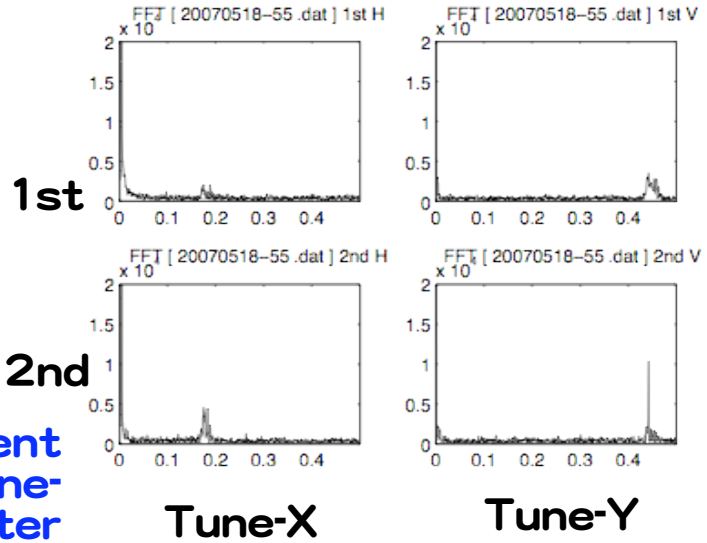
Rise/fall time improvement v.s. timing

Multi-bunch Turn-by-turn monitor to measure the independent kick effect for multi-bunch train

To confirm the kick effect of the strip-line kicker for the multi-bunch, multi-bunch turn-by-turn monitor is developed. This monitor consists of front end circuits(amplifier and filter) and DPO7254 scope. The scope can store the waveform up to 2ms with 100ps time resolution, which means that the waveform data have 4000 turns of the beam position of the multi-bunch.
When the kick pulse is applied to one of the bunches, the kick effect will be observed only for the bunch without any affect for the other bunches.



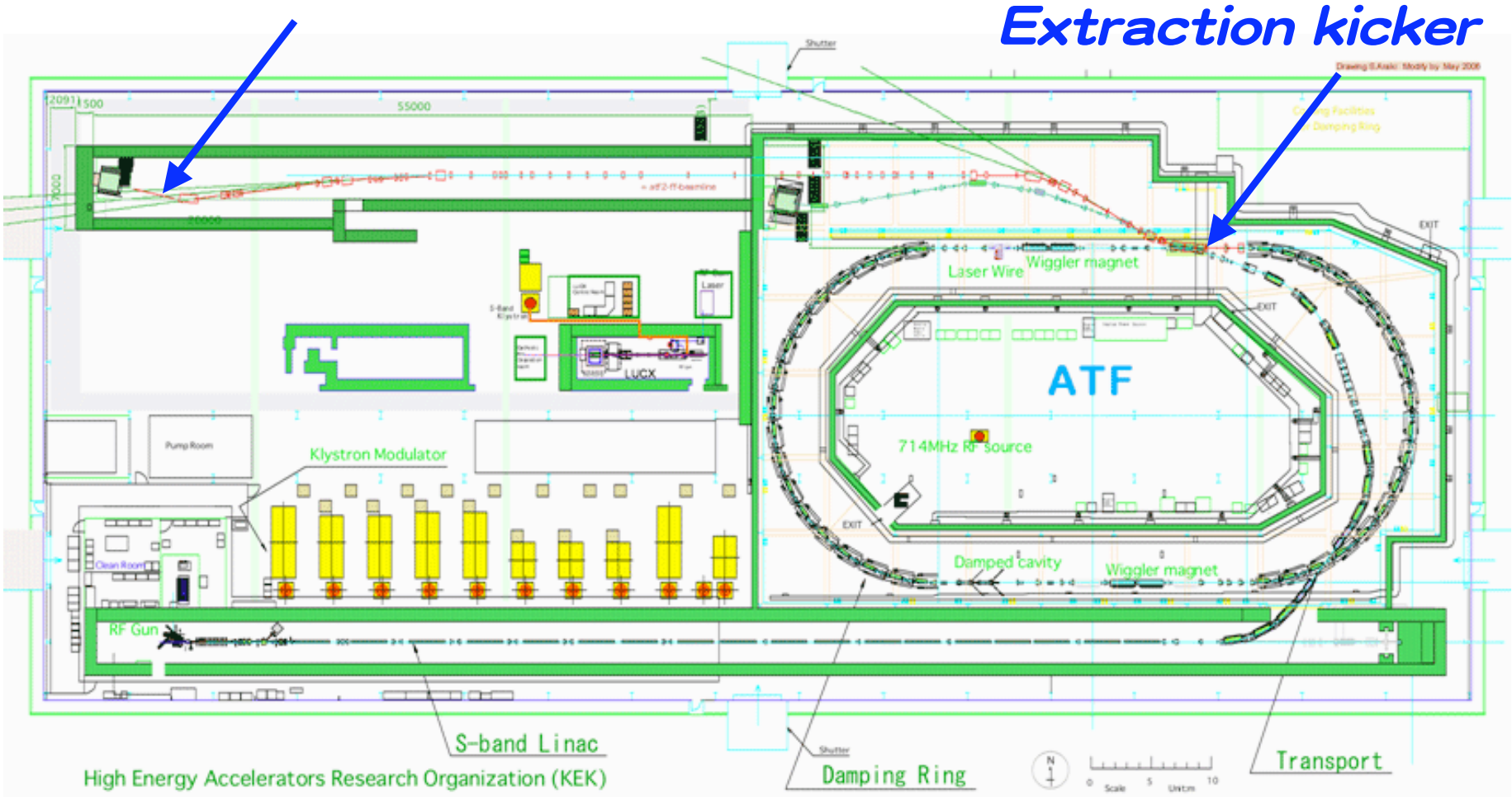




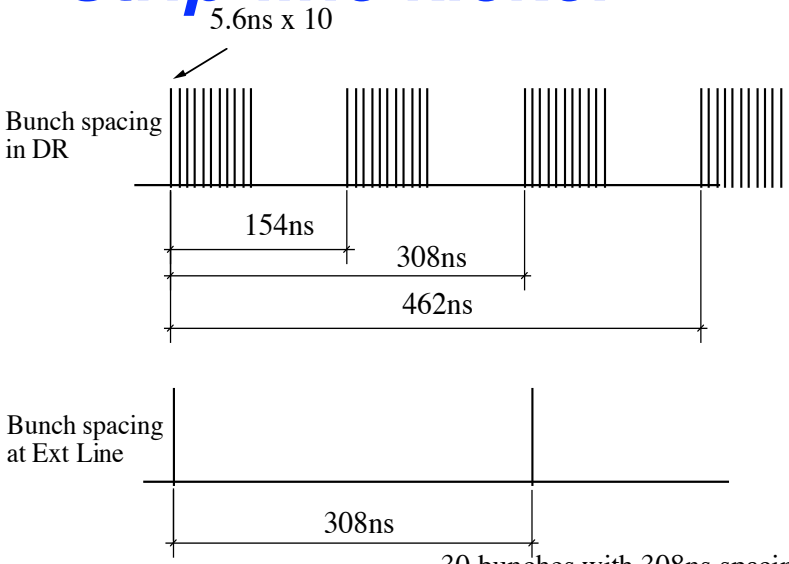
The preliminary results show the different oscillation amplitudes of the tune-X and the tune-Y for the 1st and 2nd bunches at just after injection.

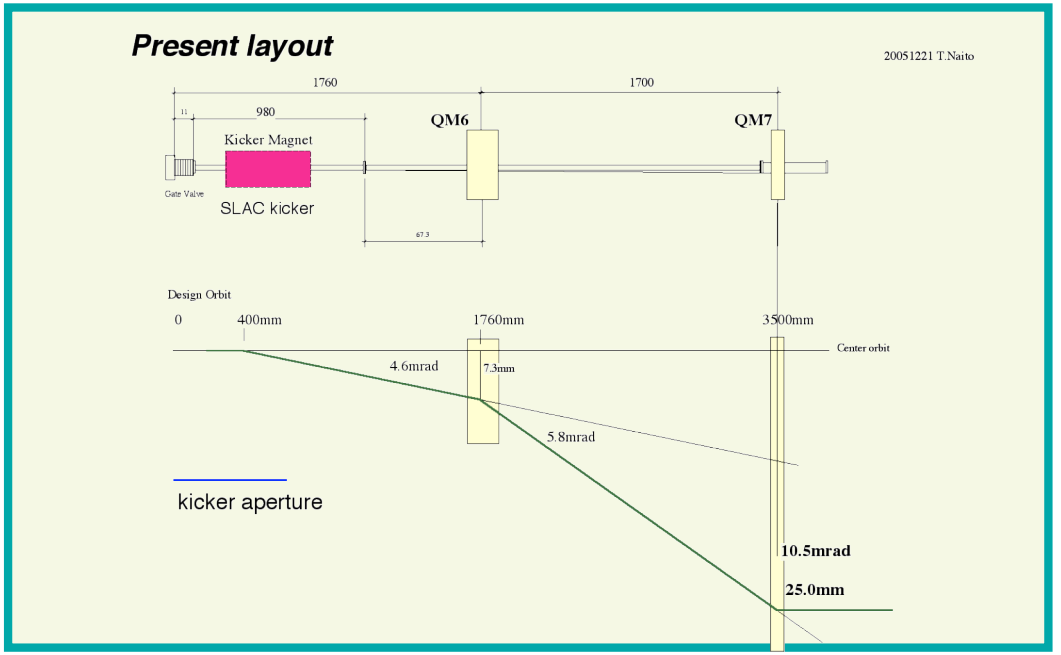
Experiment at ATF2

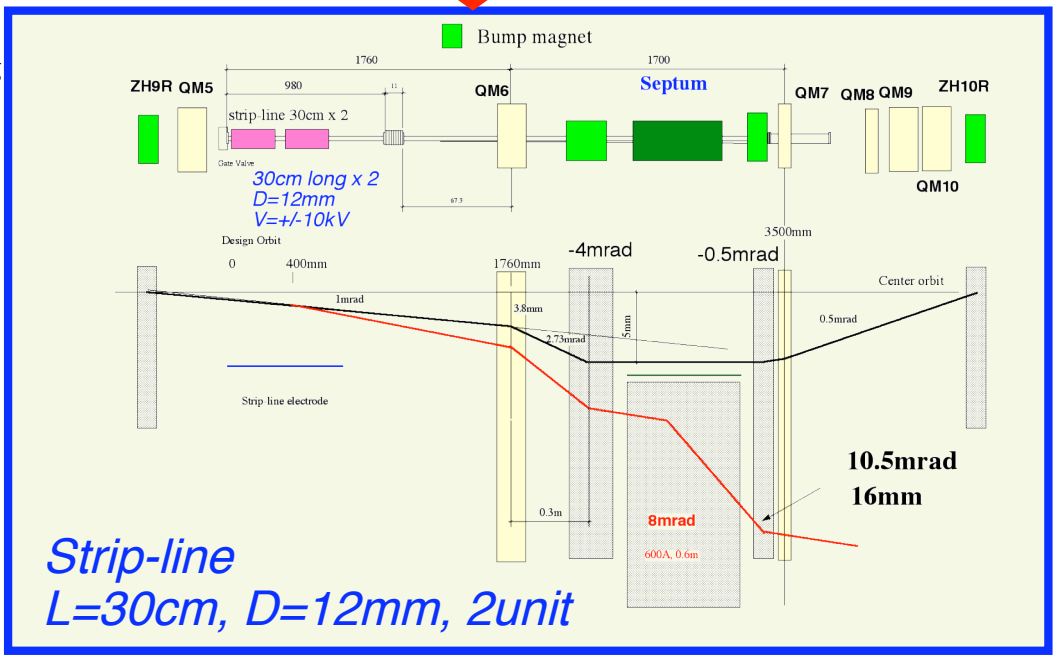
ATF2 - 40nm beam production, measurement ,
single bunch and multi bunch beam handling



Beam extraction experiment with strip-line kicker

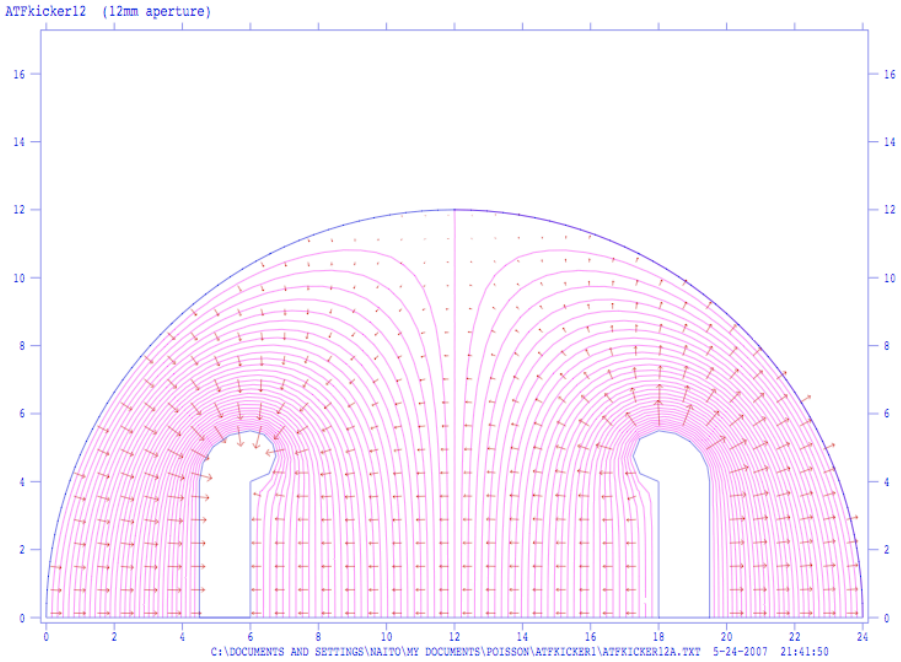


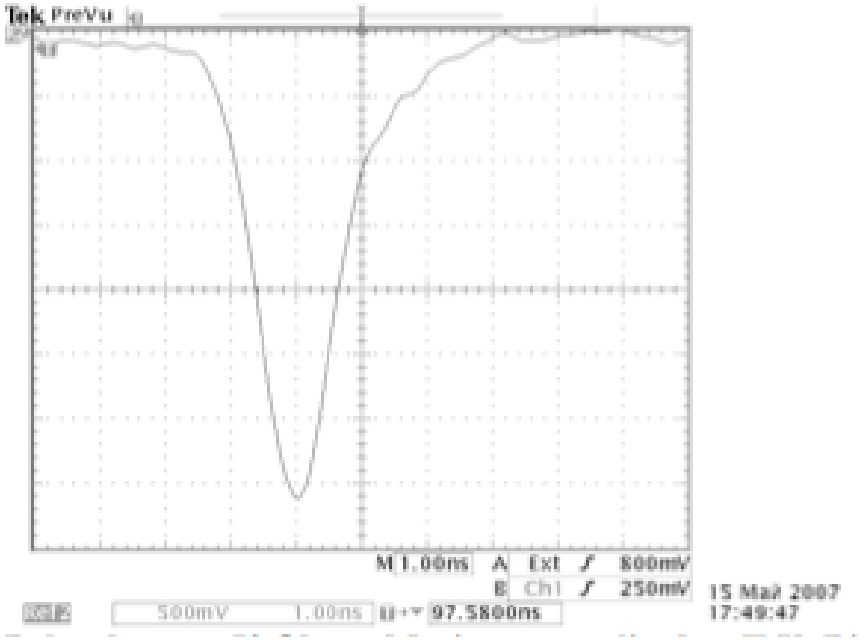




The design of multi-bunch beam extraction with strip-line kicker is under progress. One of the problems is no space for installing the strip-line kicker electrodes. We are considering to add the pulse bump orbit and auxiliary septum magnet.

Strip-line electrode and pulser for ATF beam extraction

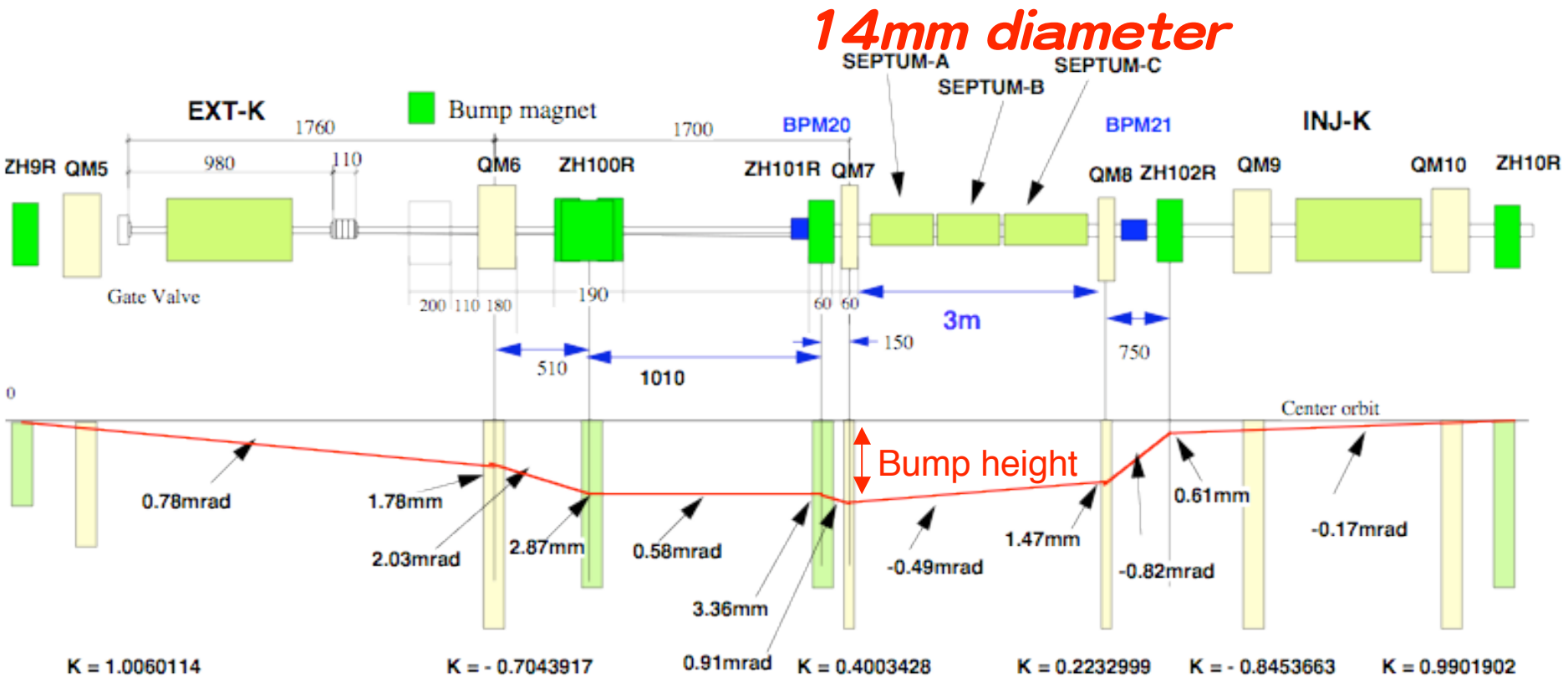




Electrode distance:12mm
Chamber diameter : 24mm
Impedance :50ohm
Max field at 10kV : 4.7MV/m

FID developed 6MHz burst, 7kV peak pulser.

Local bump aperture survey by using present magnets and DC power supplies



The aperture limits at +4mm and -2mm of the bump height were measured, which is assumed that the limits show the miss-alignment of the septum or a large orbit distortion at the location.

Proposed Schedule

• 10kV fast pulser order and test	Summer 2007
•Fabrication strip-line electrodes	Fall 2007
•Fabrication bump magnets and pulse PS	Summer 2007
•Pulse bump magnet test	Fall 2007
•Fabrication Septum magnet	Fall 2007 -
•Install strip-line electrodes and septum	Spring 2008
•Beam test	Spring 2008

Summary

1. Development work of Multiple units strip-line kicker system is carrying out at KEK-ATF. The tentative strip-line electrode shape was designed and the pulse power supplies were evaluated.
2. The beam kick test of the single unit was carried out in the KEK-ATF DR. The measured rise time is 3.2ns and the fall time is 4.0ns, respectively.
3. The rise/fall time improvement by the waveform compensator was tested. The rise/fall time is improved up to 2.2ns and 2.4ns.
4. The multi-bunch monitor has been developed to measure the effect of the target bunch and the other bunches.
5. The beam extraction from the ATF-DR to the extraction line is under going the design , which is the same scheme of the ILC-DR to RTML. The preliminary test of the bump orbit has been done.