Experiments with pulse supplies and strip-lines at ATF, Plans for fast extraction kicker for ATF2

Junji Urakawa (KEK) at ILC Damping Rings R&D Workshop – ILCDR06, Cornell University

1. Fast Kicker R&D at ATF
2. Instrumentation at ATF
3. Prospect of ATF and ATF2

1.Fast Kicker R&D at ATF

Purpose : To show the technology on fast pulse PS does not give limitation within present our thoughts if we reduce the length of strip-line kicker about 30cm except for the problem of small coherent oscillation of neighboring bunches in the ring and other instability problem in the ring.

1.We should evaluate the emittance growth due to the about 0.5%(?) coherent oscillation by fast kicker with fast damping (~1msec) due to de-coherence etc.

2.We should select the reliable hardware system according to easy tuning, reliable operation, simplicity of construction/beam commissioning and total cost reduction.

Outline of Fast Kicker R&D Program

- The problem
- The specs.
- Present Technology on Pulse PS , ATF experimental Results
- Other Current ideas

The problem

Linac beam:

- 2820 bunches(5640 bunches), 308nsec(154nsec) spacing (**~ 300** km)
- Cool an entire pulse in the damping rings before main Linac injection

ILC damping ring beam:

- 2820 bunches(5640 bunches), closely spaced
- Eject every n^{th} bunch into linac (leave adjacent bunches undisturbed?)
- Minimum damping ring circumference depends on minimum realistic bunch spacing (kicker speed and instability issues)

What an interesting problem!

There are physicists from ANL, CERN, Cornell, Daresbury, DESY, Fermilab, Frascati, Harvard, Illinois, KEK, LBNL, Minnesota, SLAC, and so on.

1. Reliability of fast kicker system.

2. Impedance of fast kicker system.

3. Effect of small coherent oscillation due to tail field of fast kicker.

4. Technology of feed-forward to stabilize the beam orbit of extracted beam.

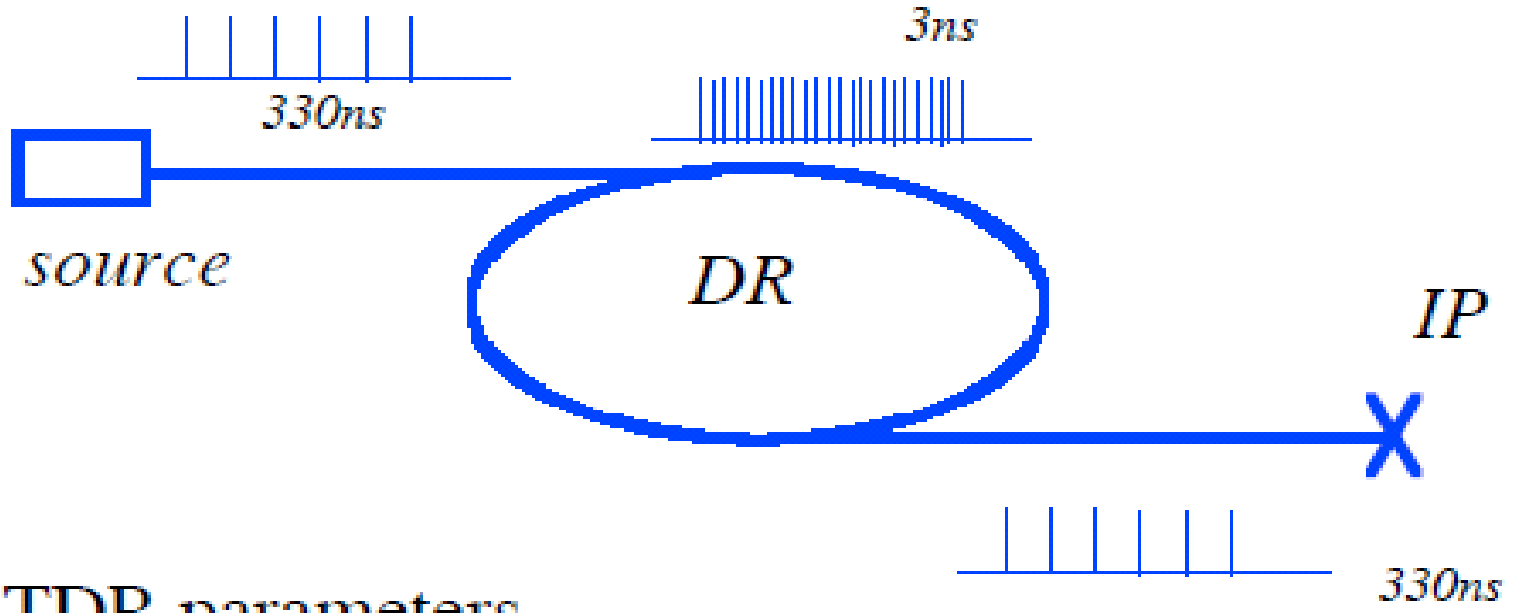
What we have to work with.

Extraction:

- damping is finished, bunches are small (several microns (rms) in diameter) ; Need the demonstration of the experiment with fast kicker, high quality electron beam and precise emittance/orbit measurement at extraction line.
- kicker must preserve beam emittance for still-orbiting bunches as well as the kicked bunch.

Need the measurement in the ring also.

The specs.

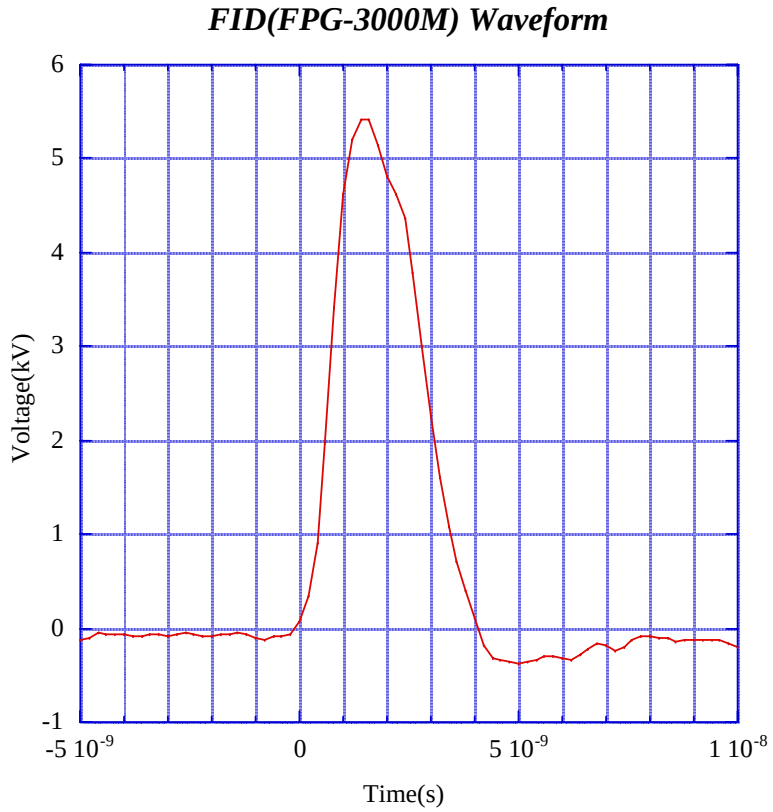


TDR parameters

impulse: 100 G-m (3 MeV/*c*) ± 0.07 G-m (2 keV/*c*) @5GeV
At β~50m, 0.6mrad kick
residual (off) impulse: 0 ± 0.07 G-m (2 keV/*c*)
Rep. Rate in burst mode: 3MHz (or 6MHz)
rise/fall time: <3.077ns
leading edge < 3.1ns, trailing edge < 3.1ns

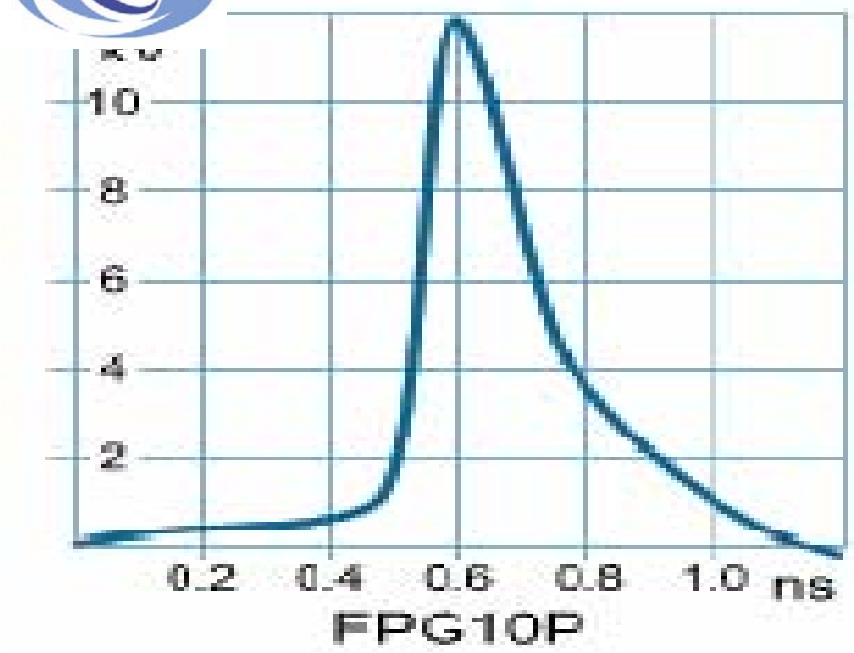
Pulse generator

FID Technology has very fast and high repetition rate pulse generators. The specification meets our requirements for the high voltage pulse source. We tested the kicker performance by using the pulse PS.



Specifications

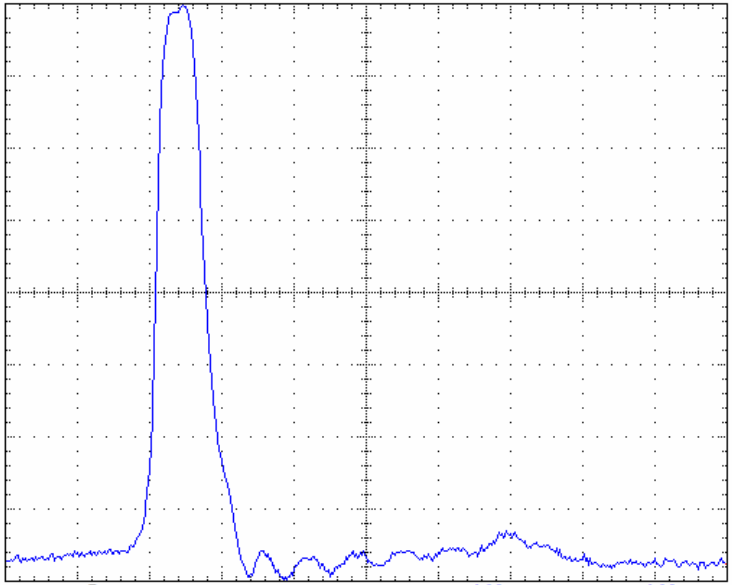
Amplitude at 50 ohm : 5 kV
Rise time : 1-1.4 ns
Pulse width at 50% of amplitude : 2-3 ns
Maximum Pulse Repetition Frequency in burst mode : 3 MHz



FPG10P

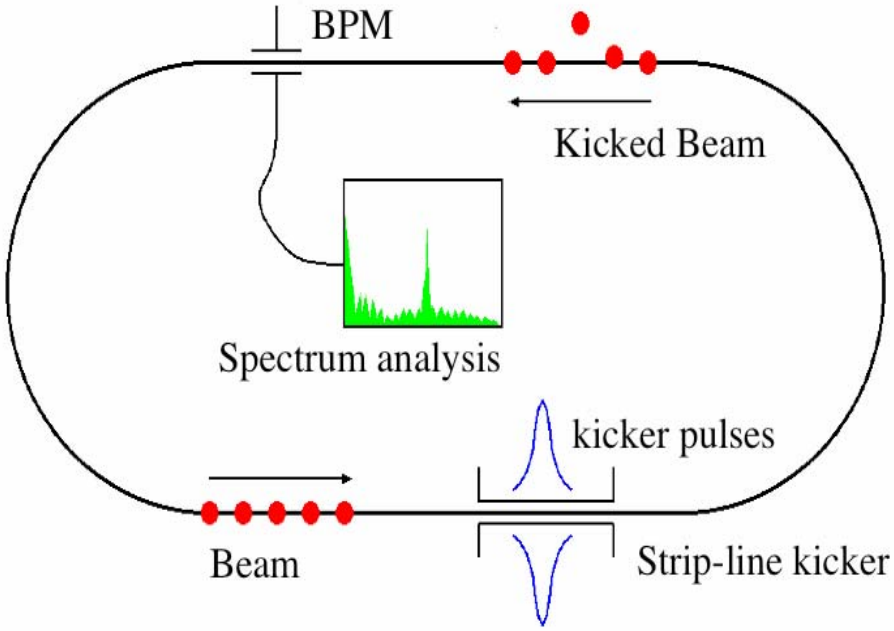

FPG10 & FPG 20

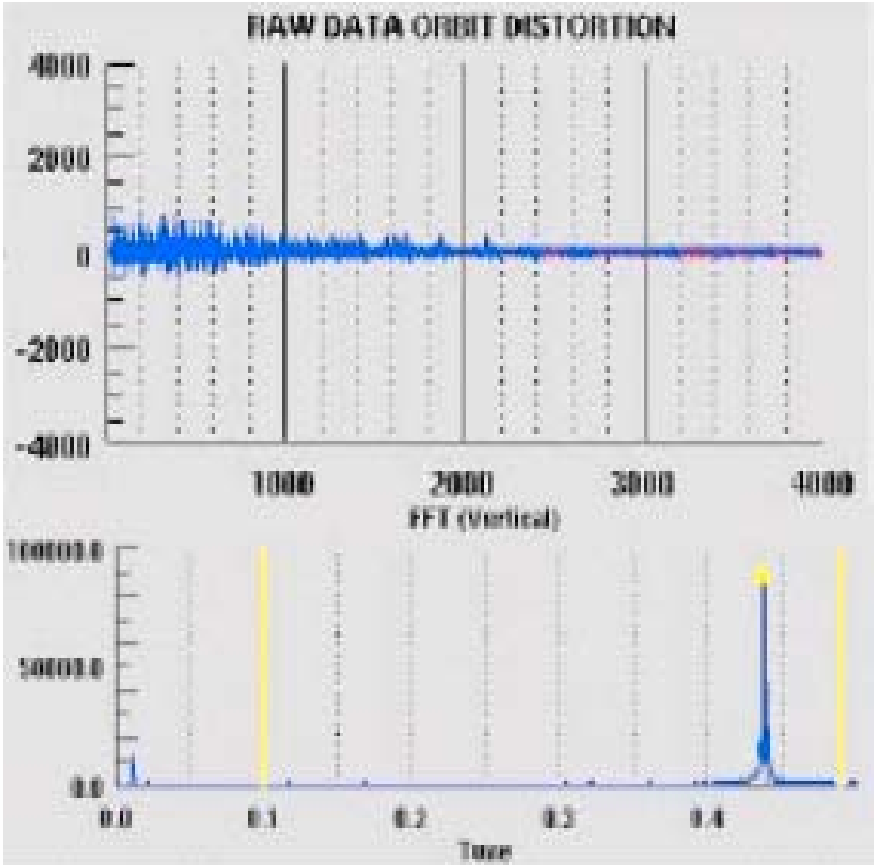
Horizontal : 2 nsec/div,
Vertical : 624 V/div
10kV, 20kV : possible but 3MHz PS is not available at present.
The technology of fast pulse PS will be upgraded soon.



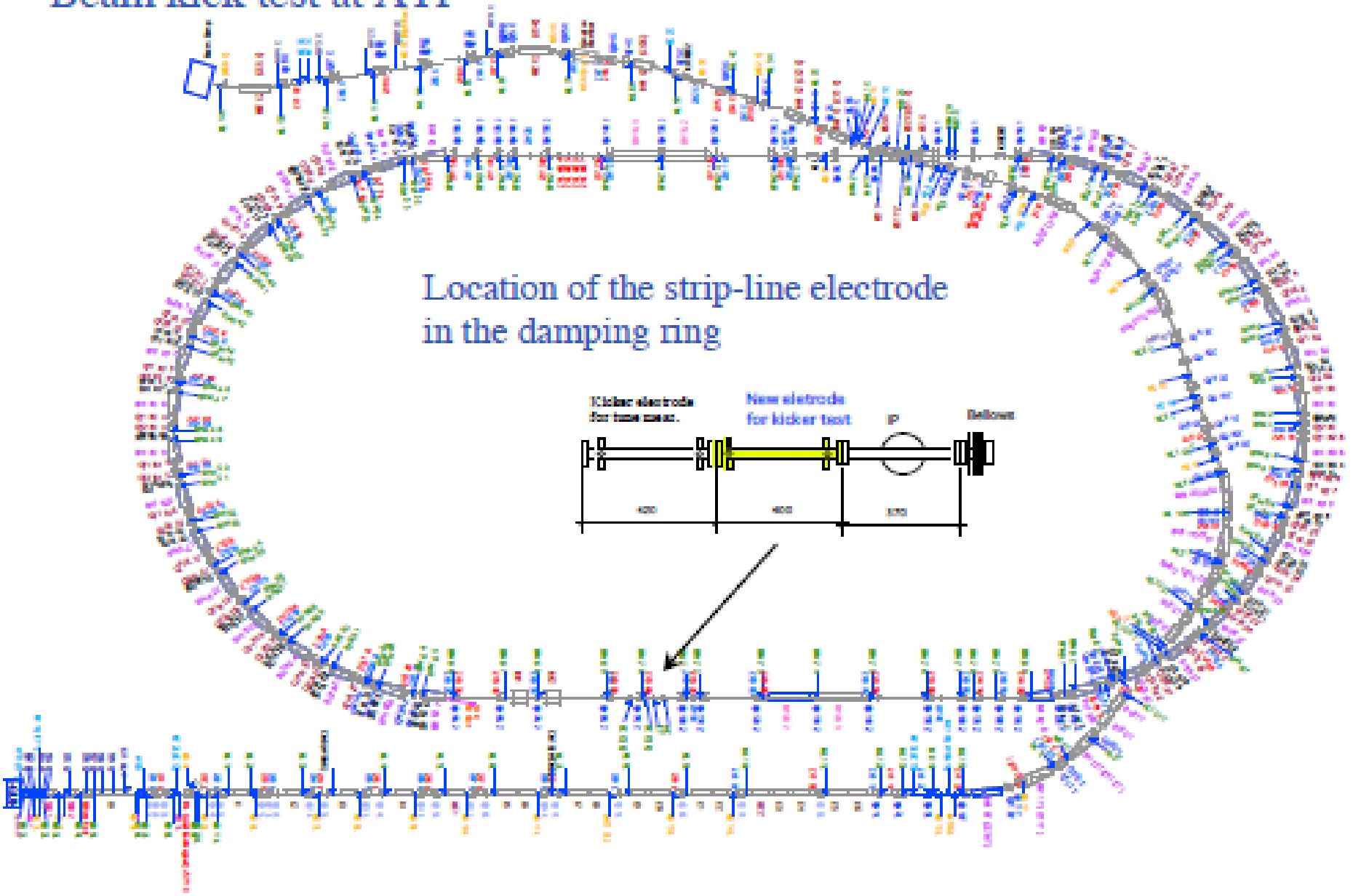
Beam kick experiment at ATF DR

The kicker pulse is applied to the strip-line electrode when the beam goes through the electrode.
The beam kick is observed by a turn-by-turn BPM as the amplitude of the oscillation of the betatron frequency component.
The kick effect is measured by scanning the pulse timing precisely.

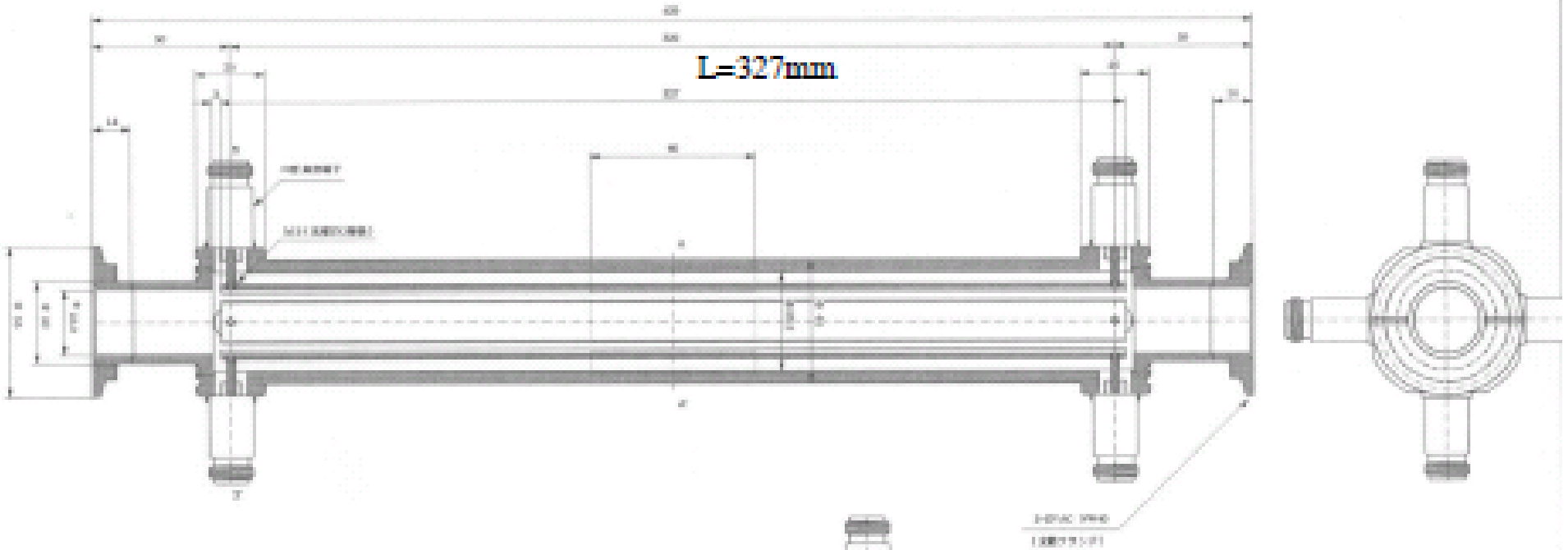


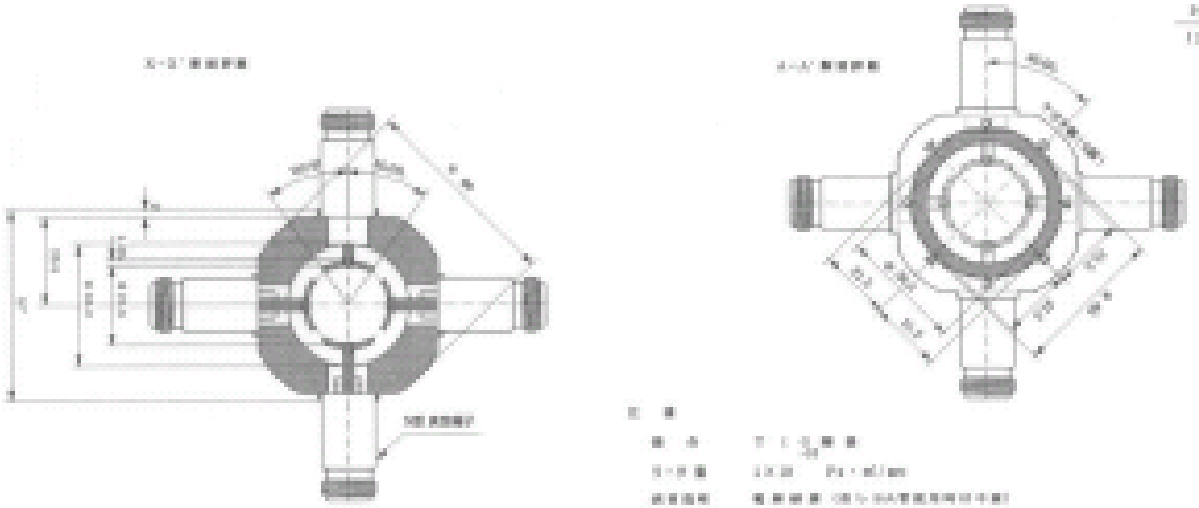


Beam kick test at ATF



ATF Kicker chamber for beam excitation





32.7cm : correspond to rise/fall time of 2.2nsec

Fast pulse PS :

Rise time<1.4nses

Fall time<3.6nsec

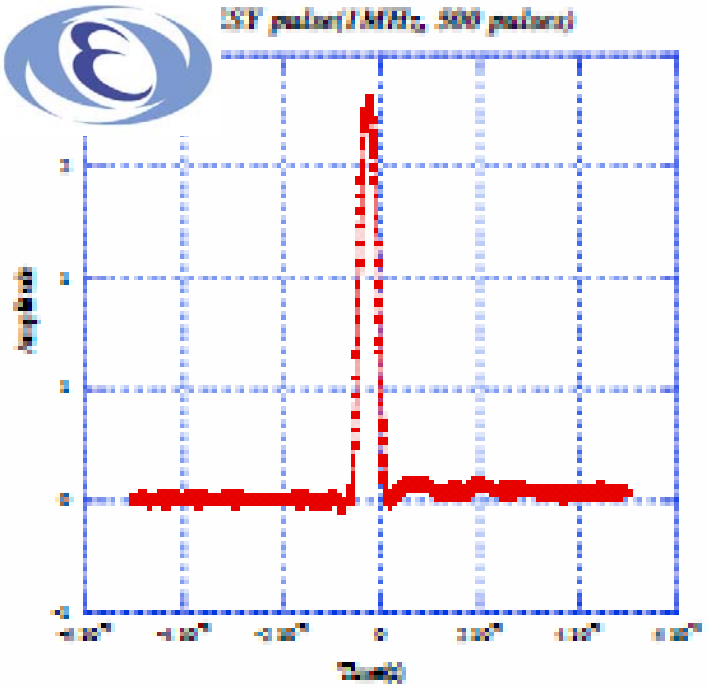

Strip-line
Electrode
Pulse Power supply

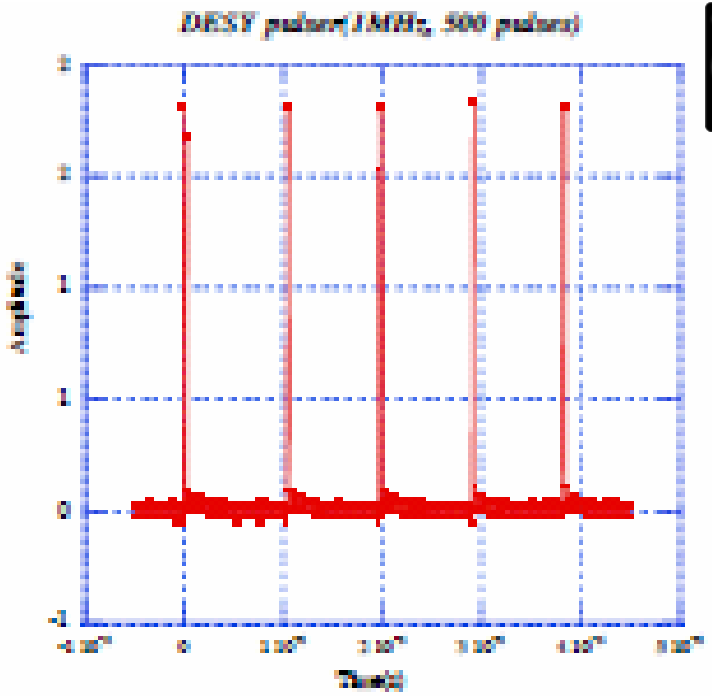
We tested three kinds of fast pulse PS's.

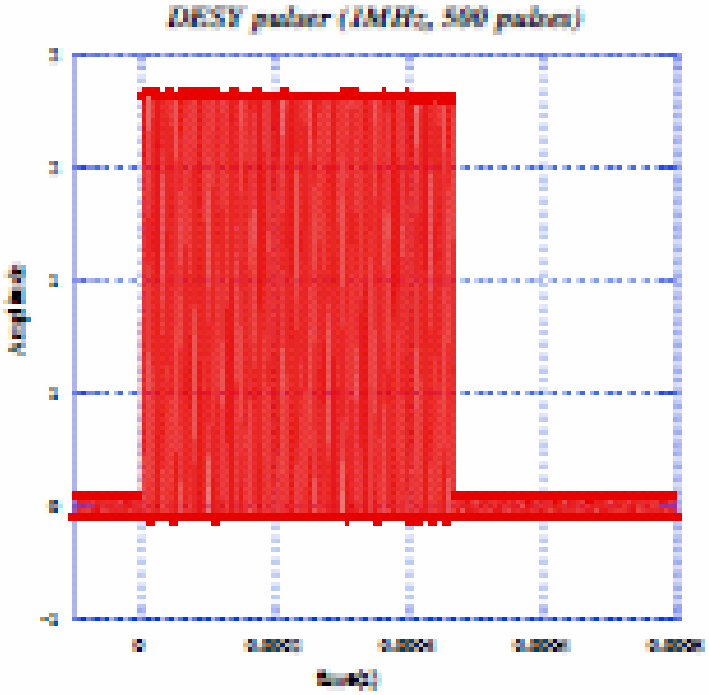
1.FID (FPG5 – 3000M)
5kV peak, rise time ~1.4ns, timing jitter less than 30ps

2.DESY Behlke HTS-80-UF
2.5kV peak, rise time~3ns, timing jitter less than 30ps

3.LLNL pulse PS (Selected for ATF2 project.)
+/- 3.1kV peak, rise time~5ns



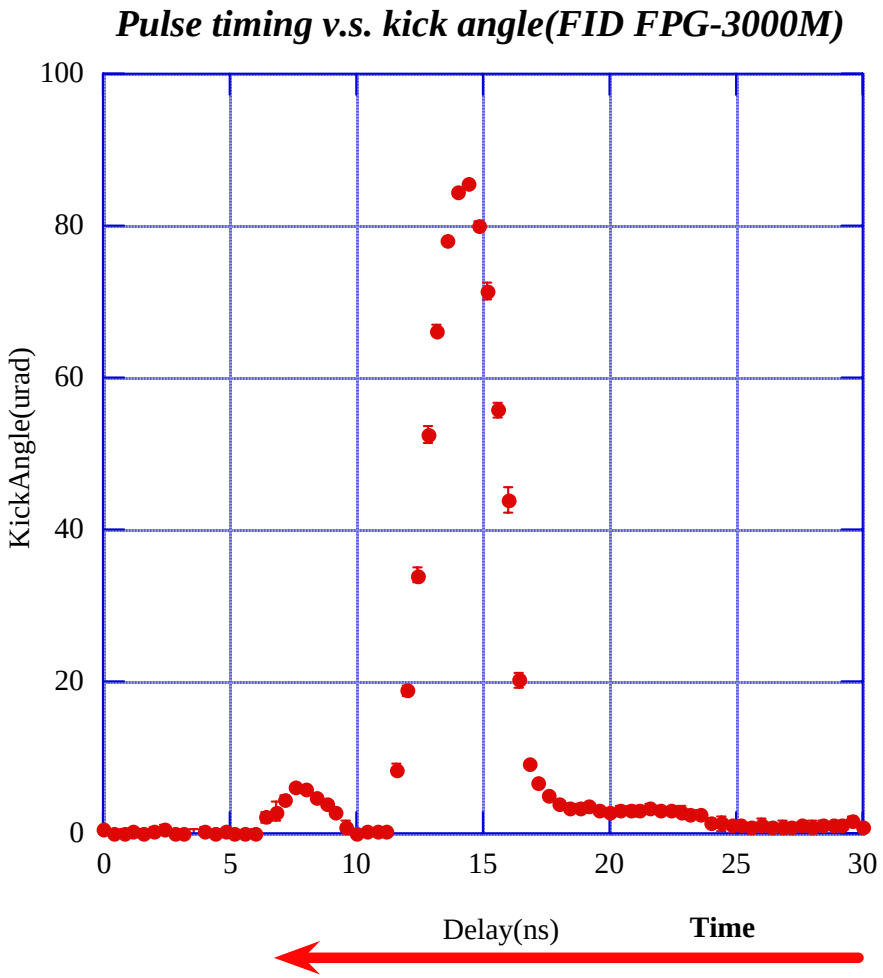




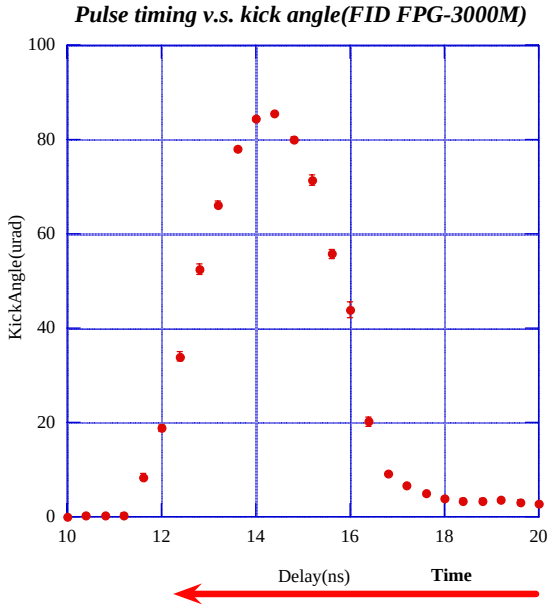
Behlke HTS-80-UF

The droop of the 500pulses is 5x10-3.

Measurement result of FPG5-3000M

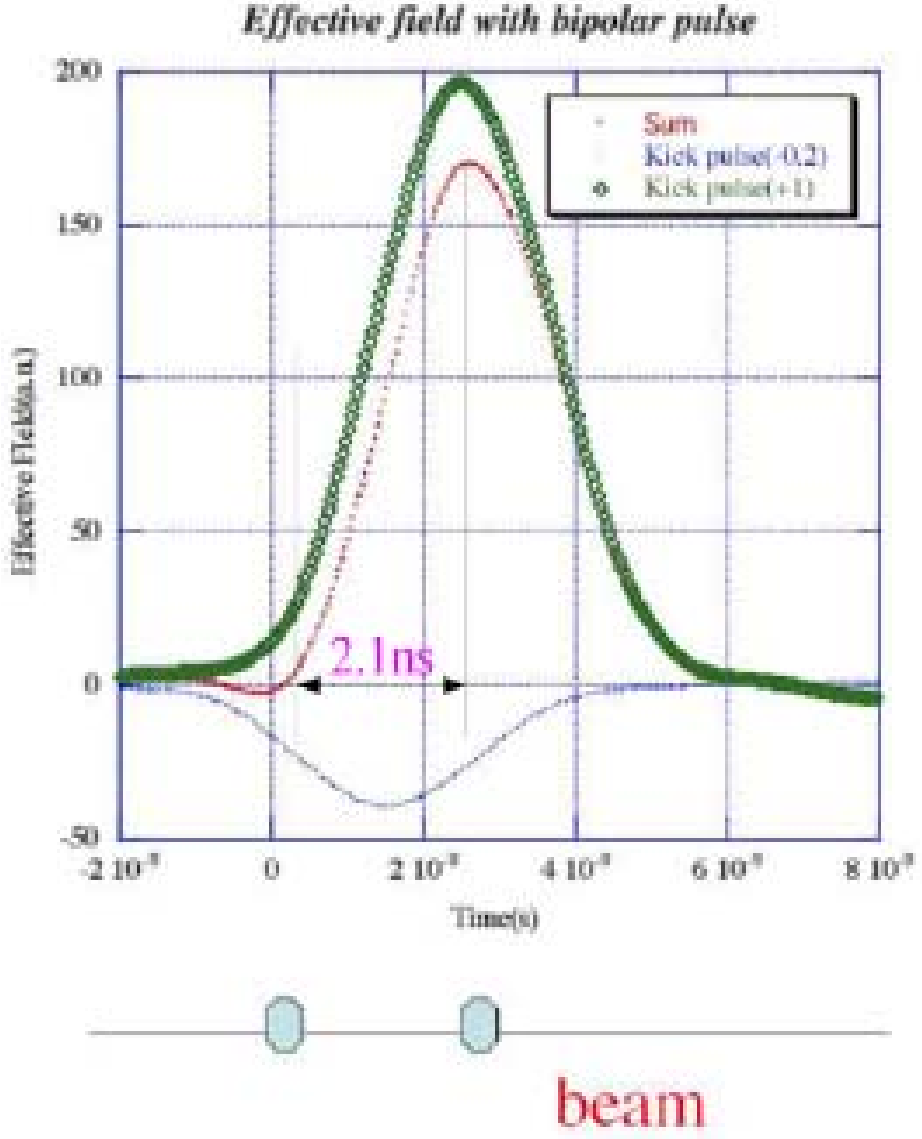


Rise time~3.2ns
Kick angle ~91μrad
(calc. 94.7μrad)



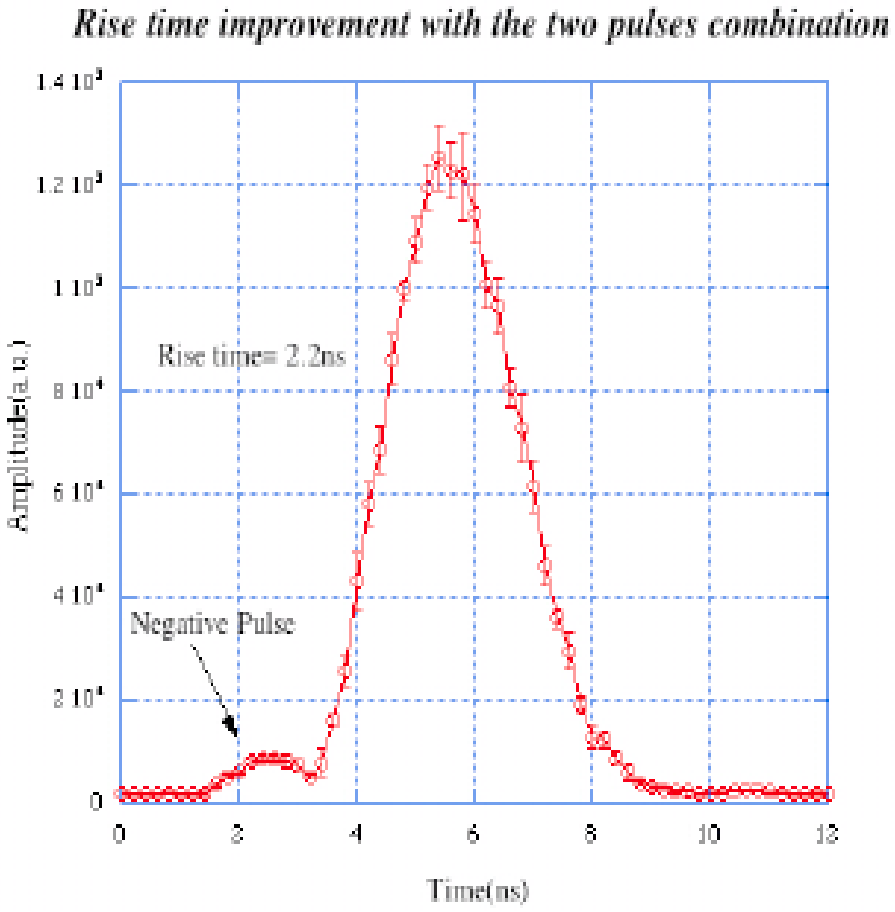
Expanded horizontal scale

Rise Time improvement by using bipolar pulse



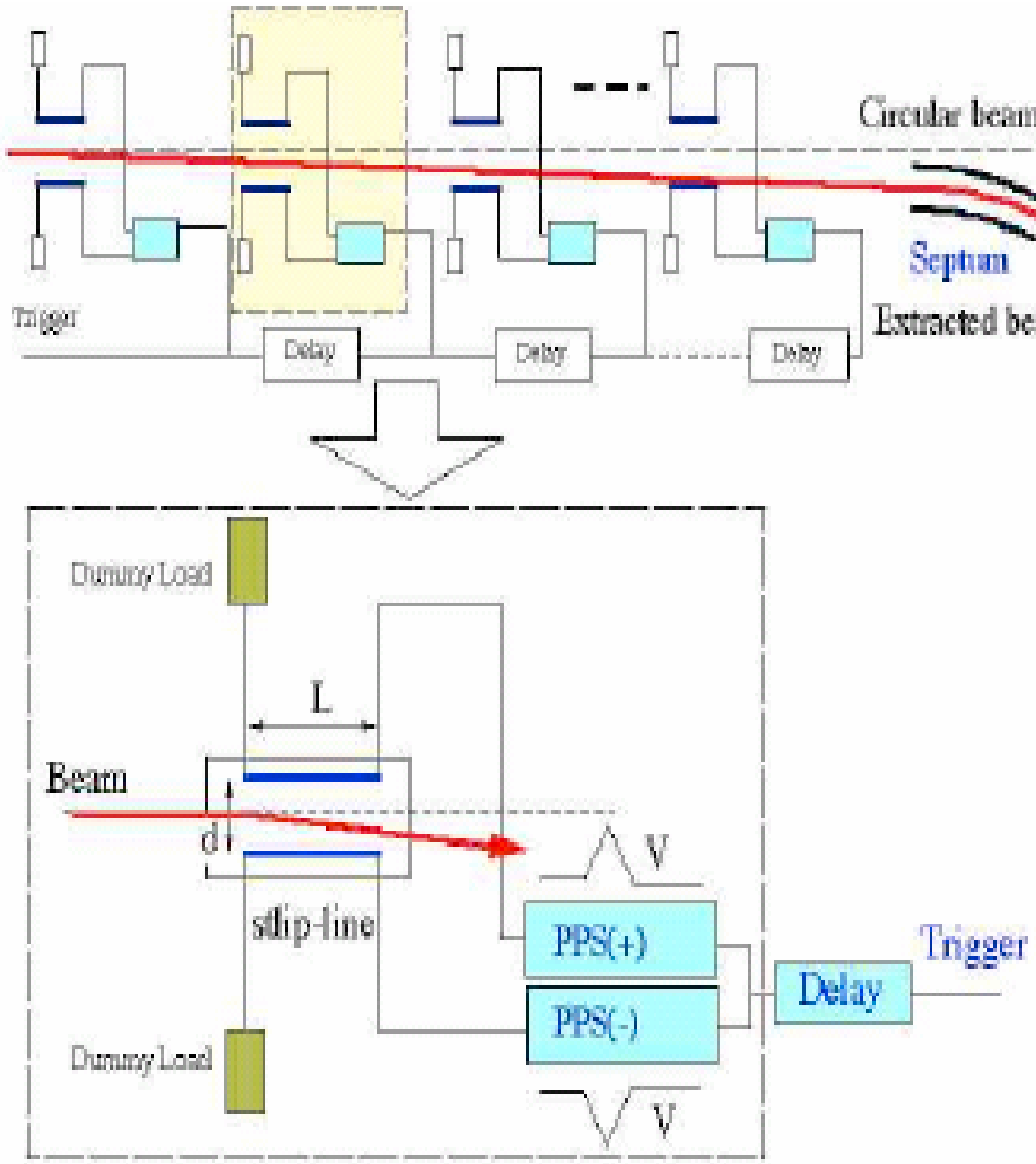
The figure shows the positive pulse(+1), the negative pulse(-0.2) and the sum of the pulses. The rise time of the sum signal is improved for the positive pulse from 3.2ns to 2.1ns. The most significant result of this idea is that the method will be able to make the zero cross field at any timing, for example, the previous beam timing.

Rise time improvement



The rise time improvement was observed by applying the two pulses which has opposite polarity, different amplitude and shifted timing.

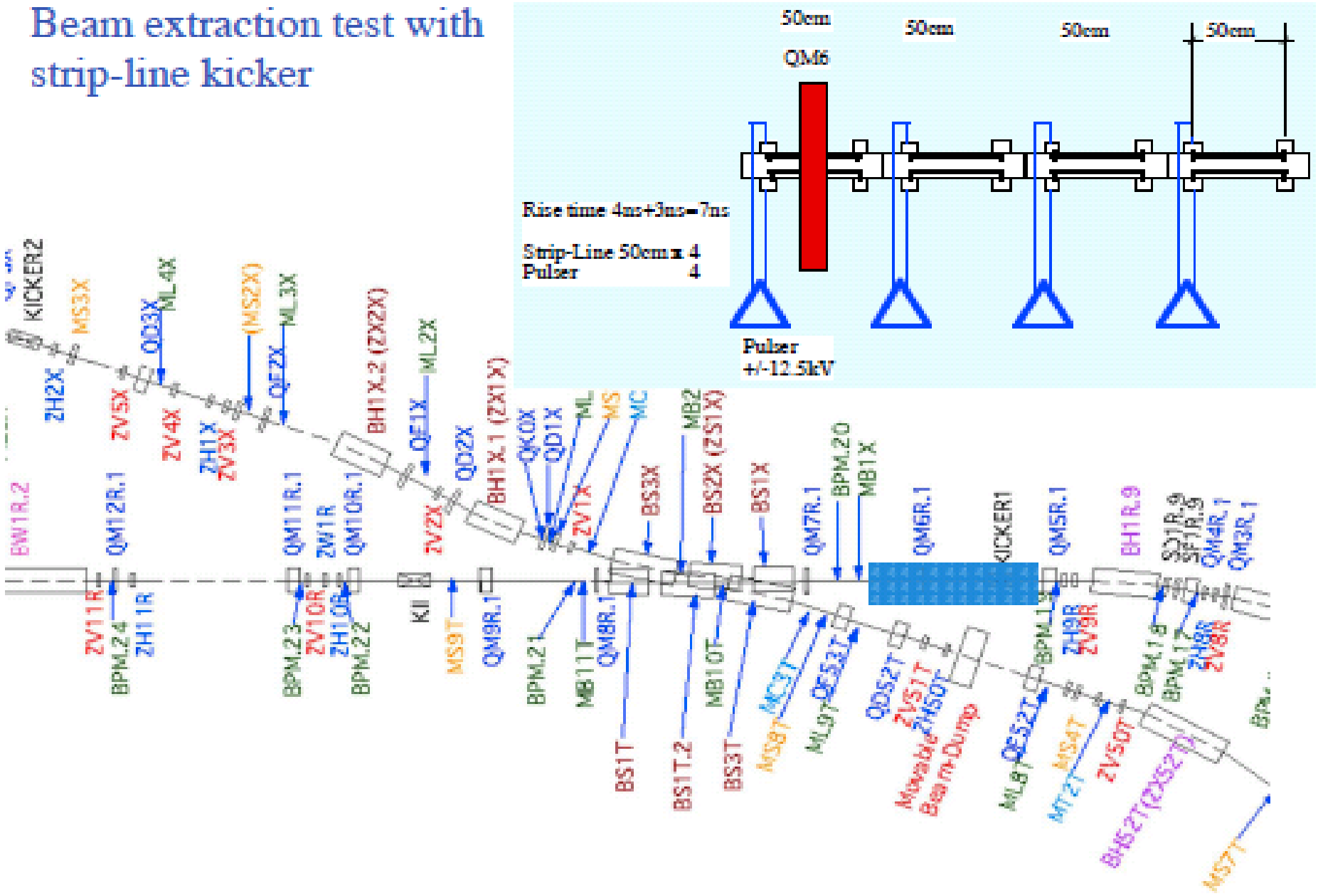
The graph shows the timing scan result at the combination of the 100% positive pulse and the 15% of negative pulse. The rise time, at the right side slope, improved from 3.2ns to 2.2ns. The small amplitude at right side of the main pulse is the negative kick.

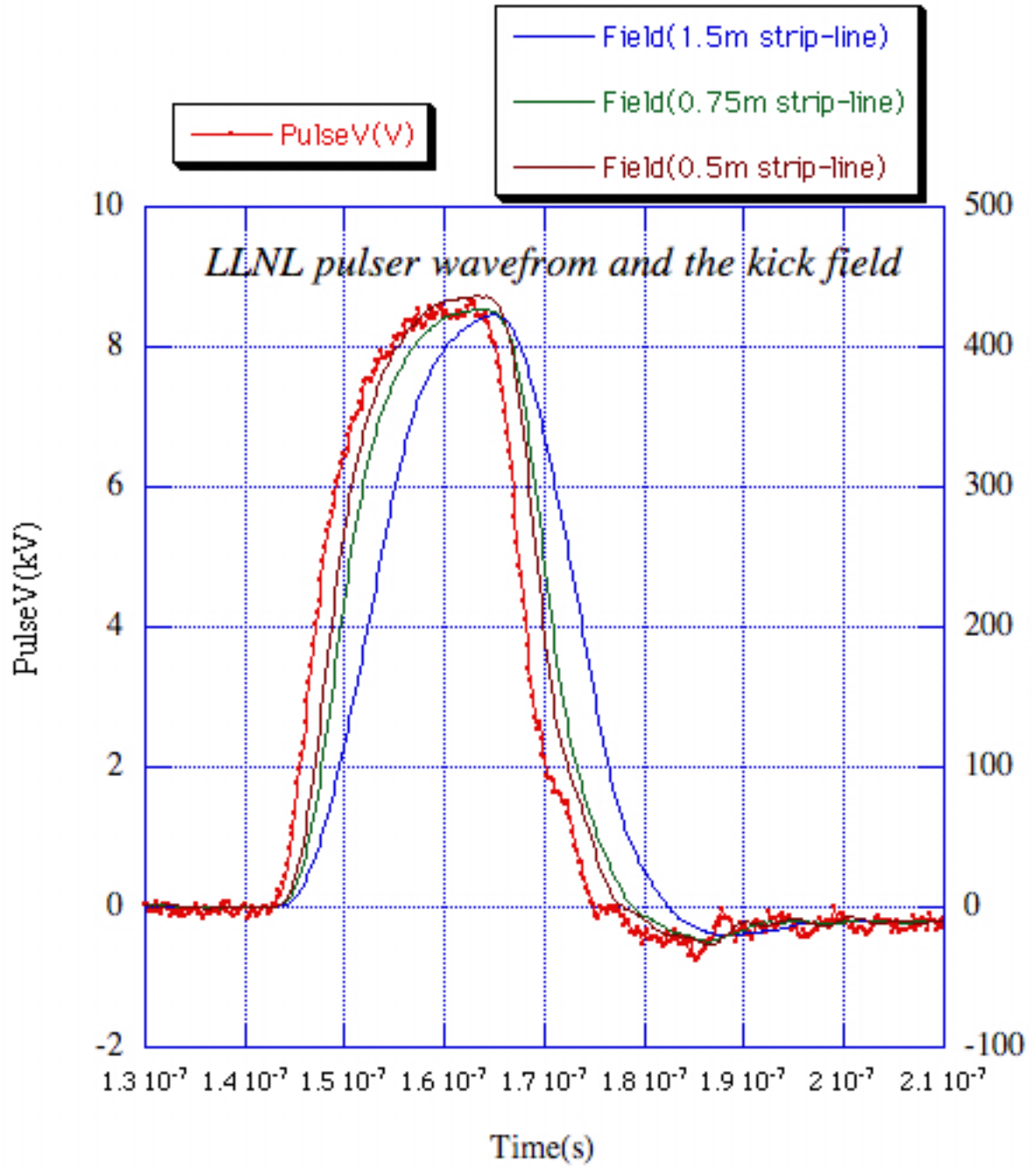


Example of ILC fast kicker system
Total length : 5m
More than 15 sets
Length of strip-line :30cm
Peak voltage : +/- 5kV
Proposed by T.Naito

Figure 1: Schematic layout of the ILC strip-line kicker system.

Plan of ATF fast beam extraction bunch-by-bunch.





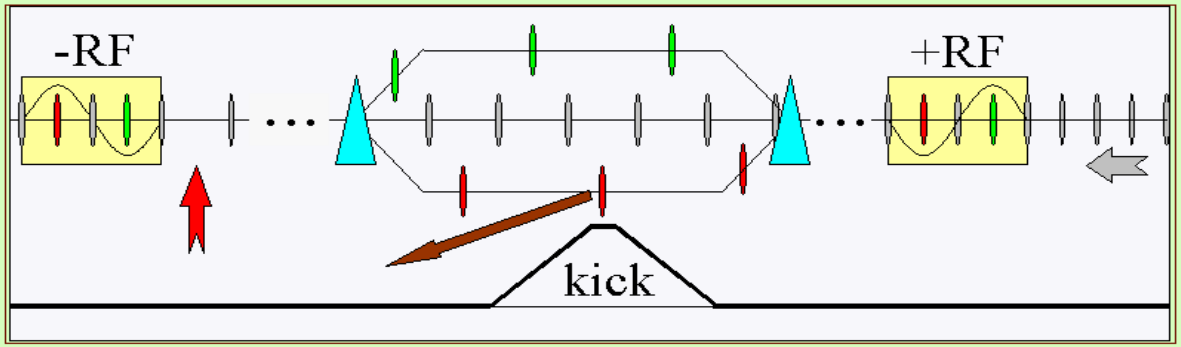
We have to develop +/- 8kV peak, rise time~5ns pulse power supplies and 4 sets of 0.5 m strip-lines to kick the beam with bunch spacing 7nsec by 5mrad.

LLNL and SLAC have the technologies for this pulse PS.
We want to keep the good collaboration for ILC.

Other Current ideas

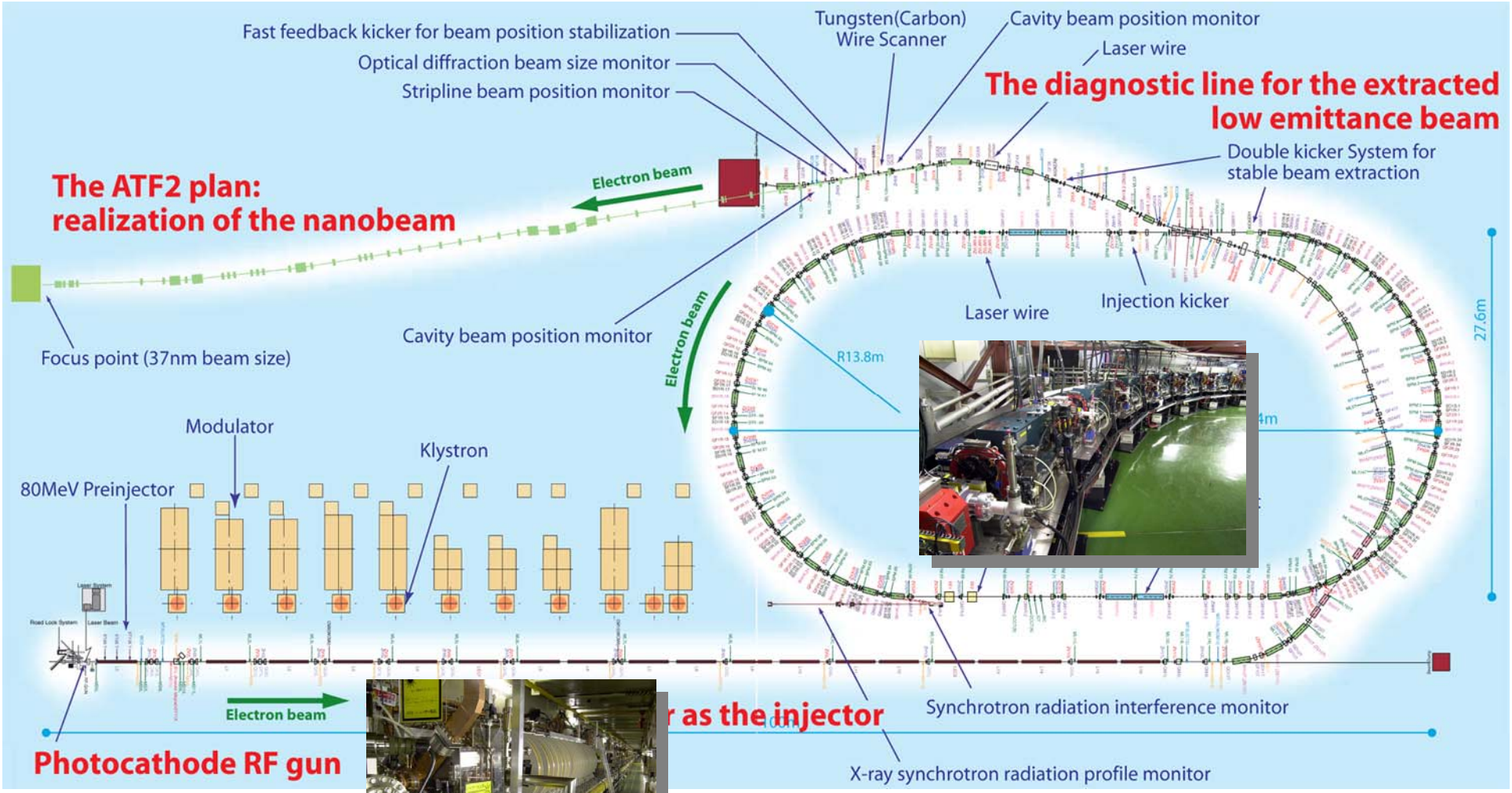
Separate the beam so that it travels along multiple paths.
Demands on kicker are less severe: it only sees every 4th bunch.
The system needs to be studied in detail: how to do it, what happens when it is installed in a damping ring.
Cornell, Frascati, KEK etc. are thinking along these lines. KEK manufactured low level electronics system for FS kicker but we have no manpower for this experiment.
FS (Fourier Series) Kicker, RF Kicker

longitudinal RF followed by dispersive section

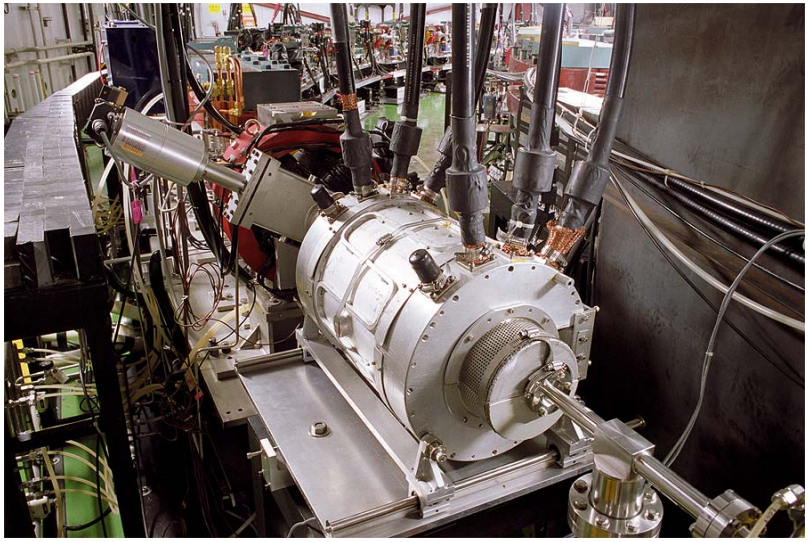


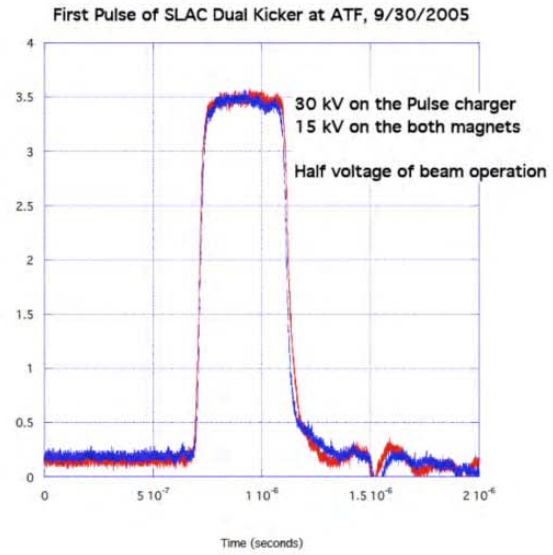
- kicker rise, fall times can be 4× bunch spacing
- could be combined with #1 to accommodate longer fall-time kicker

ATF
Accelerator Test Facility



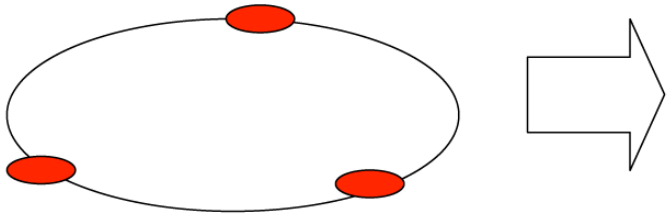
ILC like beam extraction at ATF (1)



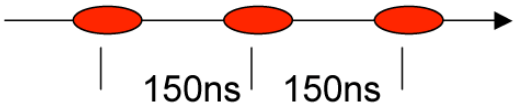


Store 3 bunches in DR by 3 injections

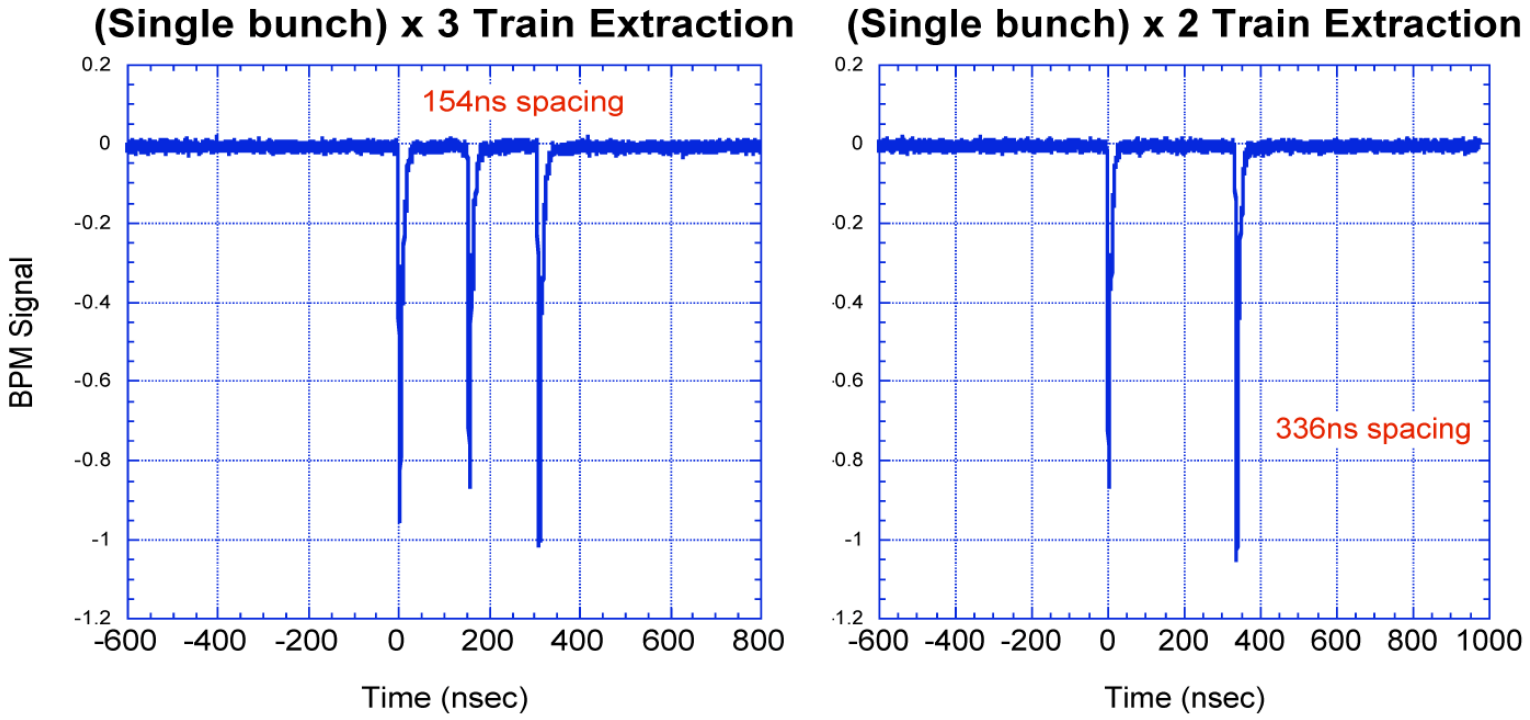
Injection kicker 60ns(rise/fall/flat-top)



ILC like beam bunches for EXT line and ATF2



ILC like beam extraction at ATF (2)



New beam mode at EXT-line and ATF2.

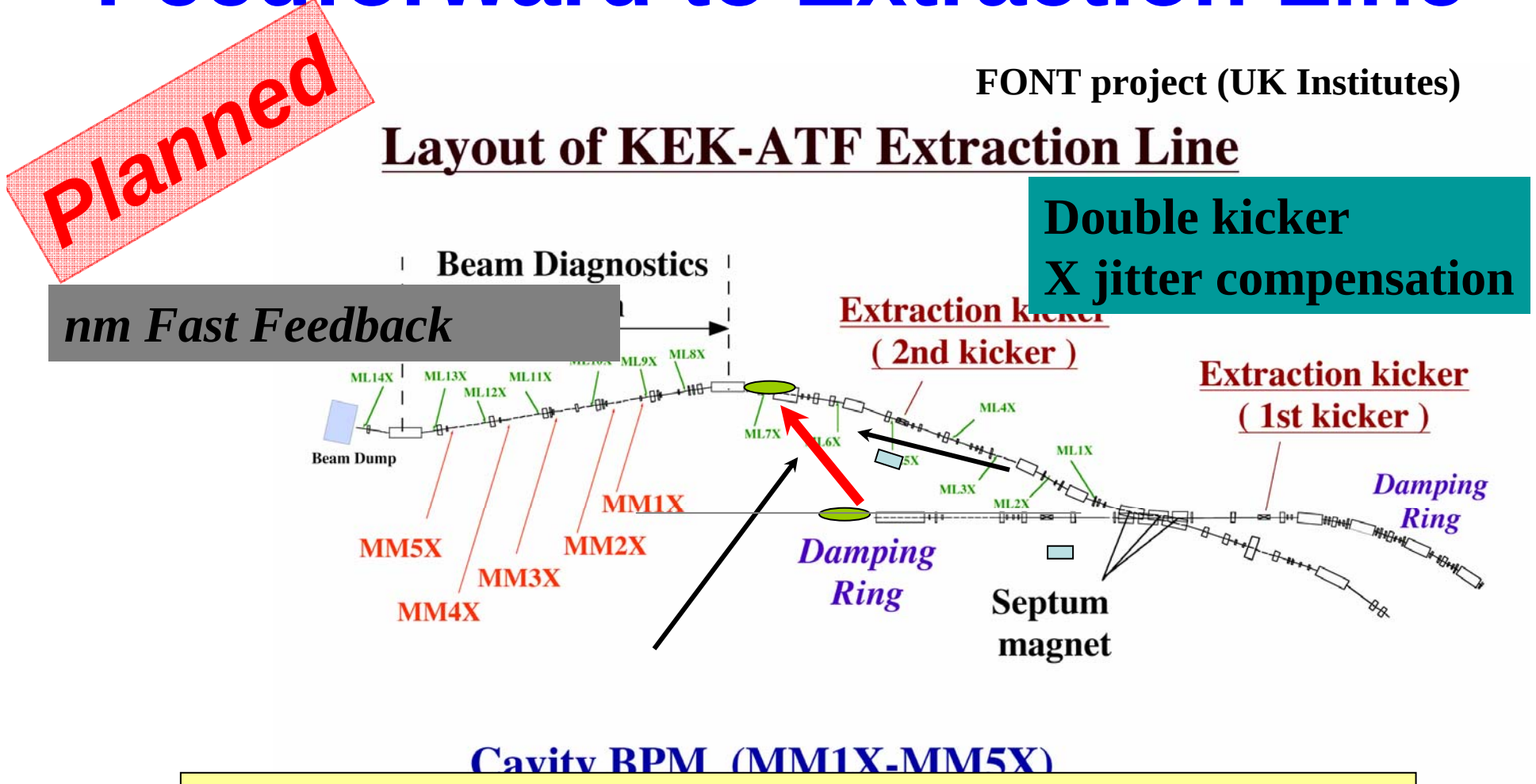
Feedforward to Extraction Line

Planned

FONT project (UK Institutes)

nm Fast Feedback

Double kicker
X jitter compensation



μm Feedforward (DR BPM -> EXT Line new strip line kicker)

Prospect of ATF and ATF2

- ATF International R&D will generate necessary results for ILC, especially how to control high quality beam, develop many kinds of advanced instrumentation, educate young accelerator physicists and engineers.
- ILC like beam which means 20 bunches with bunch spacing about 300nsec.
- Realization of about 35nm beam for long period.