Status of Fast Pulser and Kicker Work at UIUC and Cornell

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Contributing Personnel :

- LEPP
  - G. Dugan, R. Meller, M. Palmer, D. Rubin
- UIUC
  - G. Gollin, M. Davidsaver, J. Calvey
- FNAL
  - H. Edwards, R. Fliller, J. Santucci

Overview:

- Baseline ILC Damping Ring Configuration
  - 2820 bunches per train with a train repetition rate of 5 Hz
  - Bunch spacing 3.08 ns for 6.7 km baseline ring recommendation
  - Fast stripline kickers
    - Represent the baseline technology recommendation
    - Closely approach the required specifications but technology needs further validation
- Further R&D Requirements:
  - A bunch structure in the main linac utilizing more bunches and smaller bunch charge has been proposed: 5000-6000 bunches per train with train repetition rate of 5 Hz
  - Requires higher duty cycle system
- Present efforts intended to provide input for the Reference Design Report

We chose to evaluate a new technology which has recently been commercialized.

The Fast Ionization Dynistor (FID) is a solid-state switch with extremely fast switch-on time and high peak power capability.

- How long will this thing last in continuous service?
- Will the pulse repeatability be adequate?
- Will there be significant crosstalk to adjacent bunch locations?

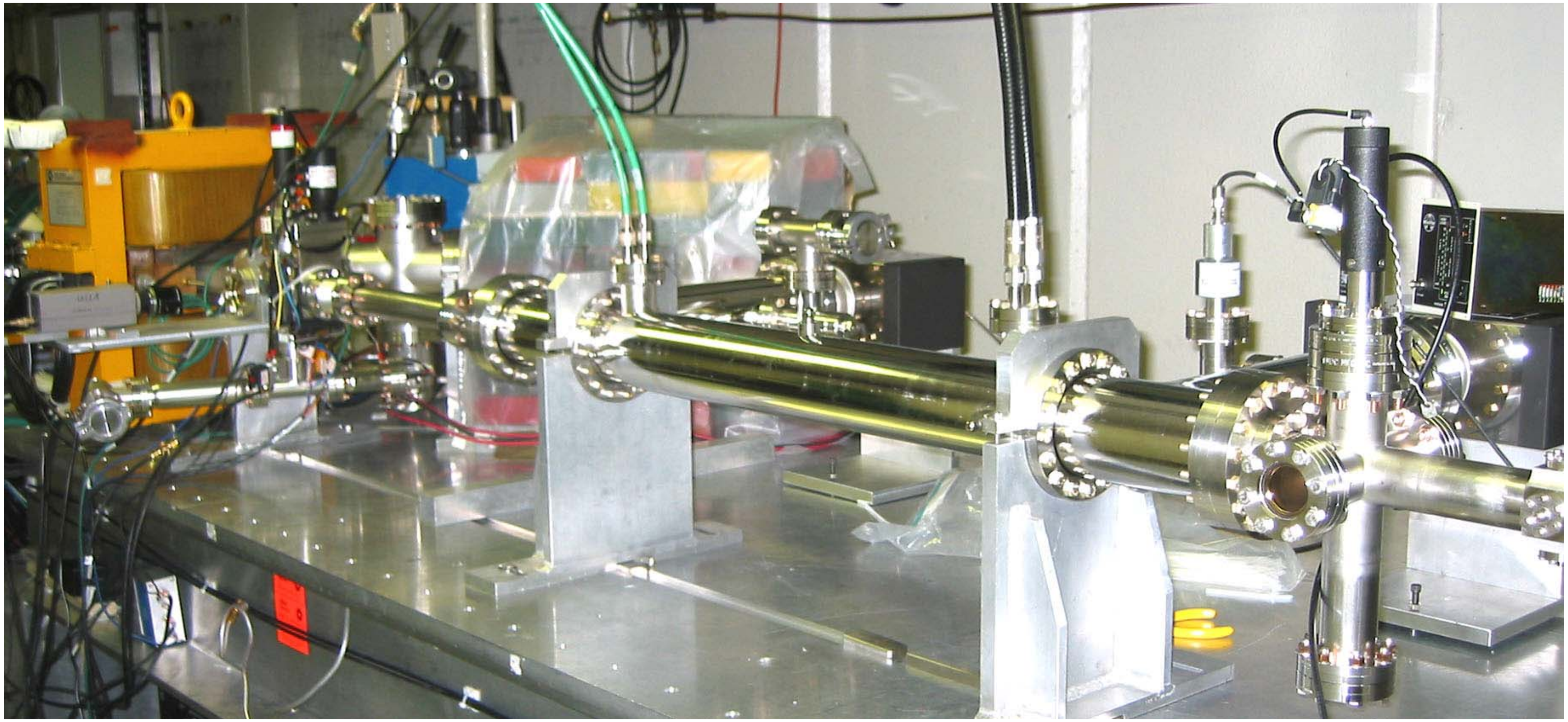
FID Technology Catalog

Pulser:	FPG2-3000-MC2	FPG1-3000	FPB3-3000	FPG10-3000
Output Impedance [Ohm]	50	100	100	100
Maximum Output per channel [kV]	+/- 1	1	3	10
Number of Channels	2	1	1	1
Rise Time, 10-90% of amplitude [ns]	0.6-0.7	0.6-0.7	0.6-0.7	0.6-0.7
Pulse Duration at 90% of maximum	2-2.5	2.5-3	2.5-3	2.5-3
Fall Time 90-10% of amplitude [ns]	1-1.5	1-1.5	1-1.5	1.2-1.7
Maximum PRF in burst mode [MHz]	3	3	3	3
Maximum PRF in continuous mode [kHz]	15	15	15	15
Amplitude Stability, burst mode [%]	0.5-0.7			
Pre-pulse, after-pulse [%]	1.5			
Time Jitter relative to trigger [ps]	20			

The unit that we obtained uses a step-recovery diode as the pulse forming device, which is driven by a resonant network pumped by a solid state switch.

- However, it does not contain an FID. It uses a MOSFET as the pumping device.
  - Our original goal of evaluating a new technology remains untouched.
  - You just have to ask the right questions.

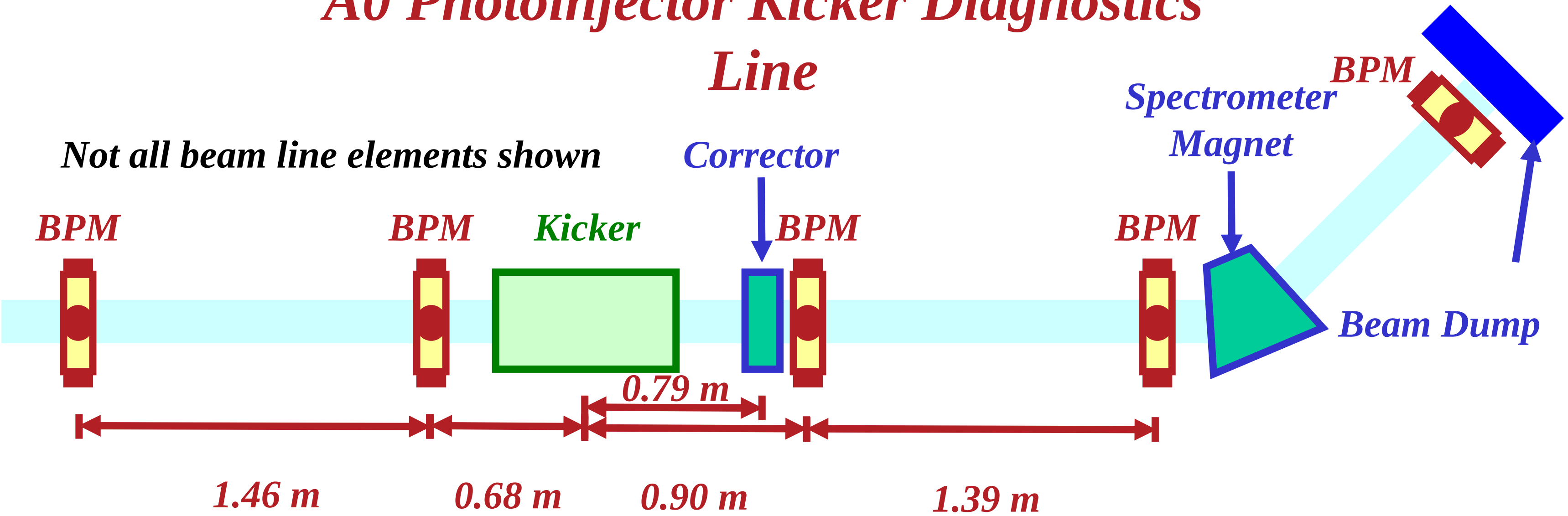
A0 Kicker, Looking Upstream



A0 Diagnostic Line

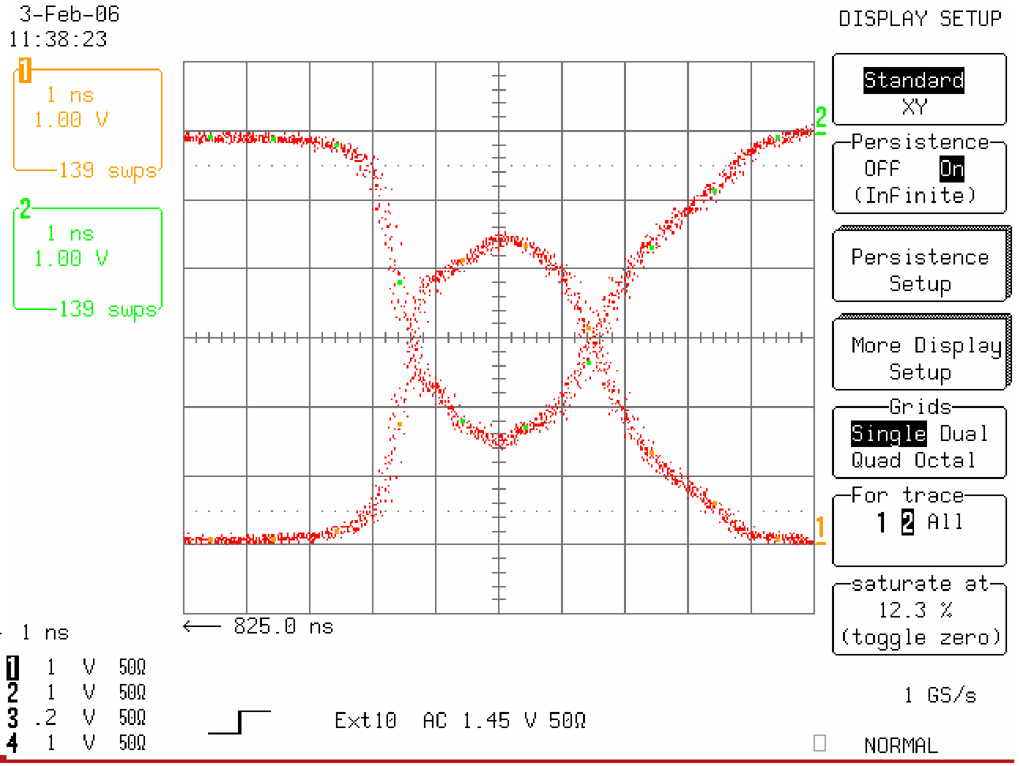
A0 Photoinjector Kicker Diagnostics Line

Not all beam line elements shown



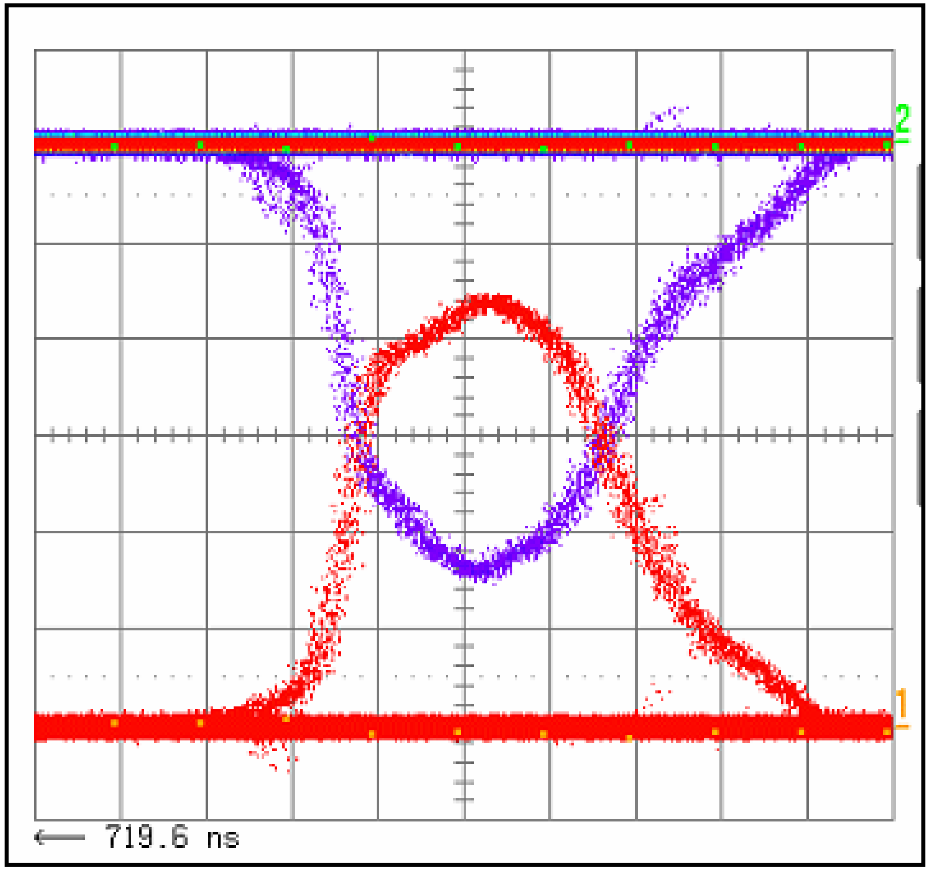
Version 1: Test Results

- Present focus is on obtaining a suitable high voltage pulser
  - Pulser width: $w_{max} = 2t_{bunch} - 2t_{stripline} \sim 4$ ns, for $t_{bunch} \sim 3$ ns and $t_{stripline} \sim 1$ ns
  - Have acquired a FID Technology F5201 Pulser for evaluation:
    - Dual channel: +/-1 kV with 0.5% - 0.7% typical amplitude stability
    - 0.7 ns rise time / 2.0 ns top of pulse / 1.2 ns fall time
    - 3 MHz max. burst rate with 15 kHz max. average rate with <20 ps timing jitter
  - Up to 10 kV devices available with similar specifications
- Initial tests at A0 Photoinjector
  - Stripline kicker provided by FNAL
  - DAQ system provided by UIUC collaborators (G. Gollin, *et al*)
  - Figure shows both polarity pulses as observed after kicker with 46 dB attenuation (200V/div)
  - Failure in power and timing circuits during beam test
  - Unit was repaired and failed again during a bench test

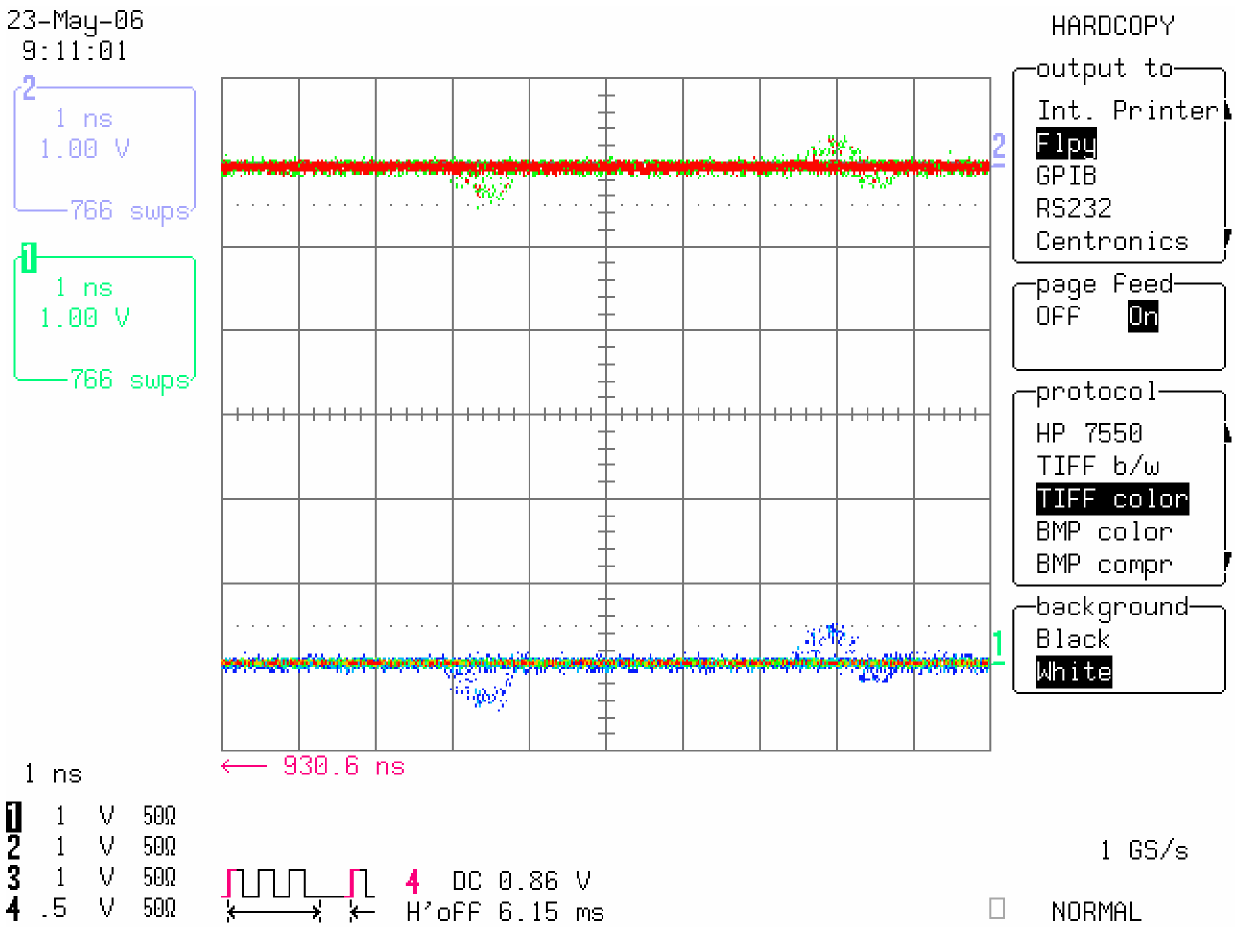


Timing diagnostics

- Pulser waveforms with scope externally triggered from timing support system
  - Note additional dispersion of traces in time domain.
  - Better timing support may be needed.
  - Traces with pulser off show backward-coupled signals from passing charge bunch.
  - These beam induced signals verify that the pulse overlaps the beam passage in the kicker.

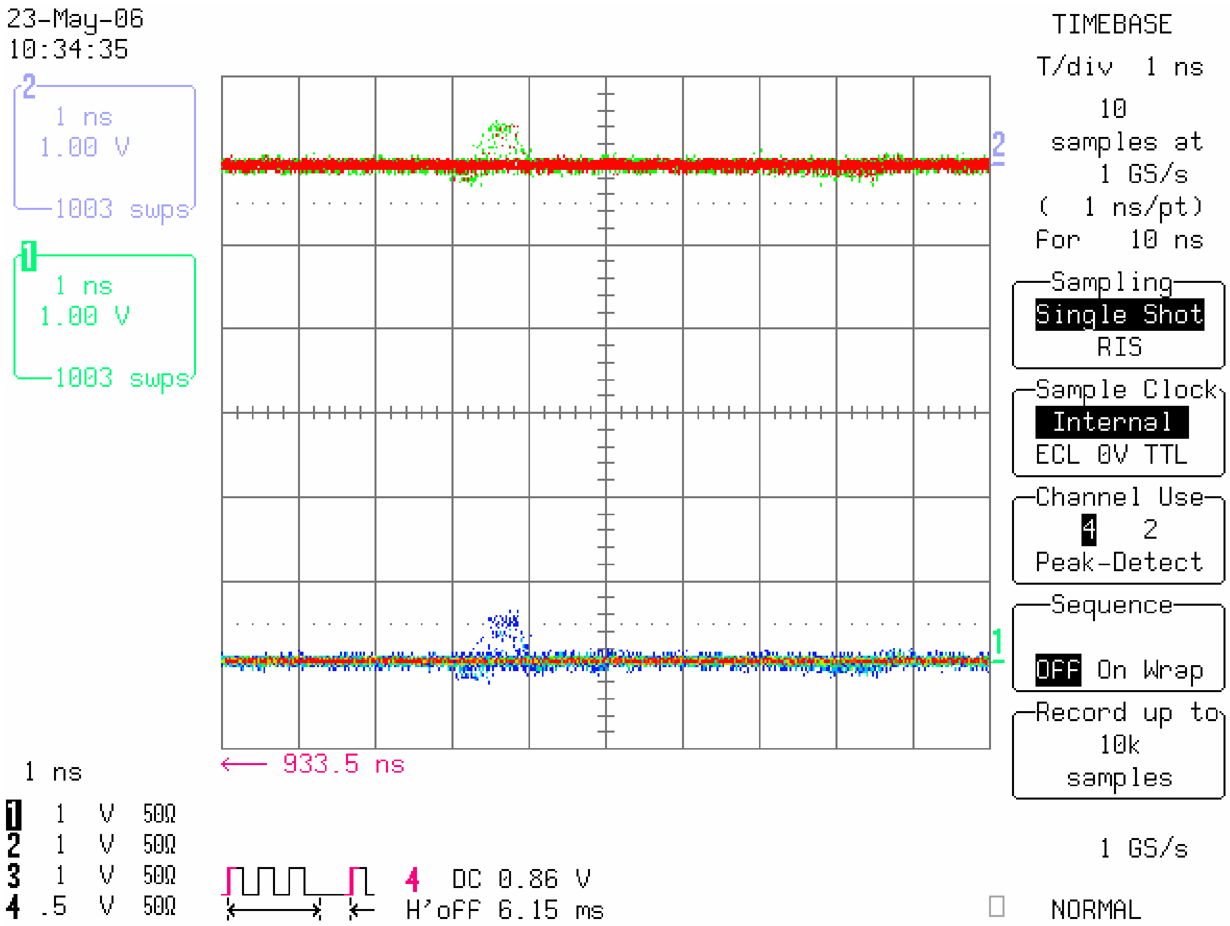


Backward coupled beam signals from 2.3 nC bunch, 200V/div.



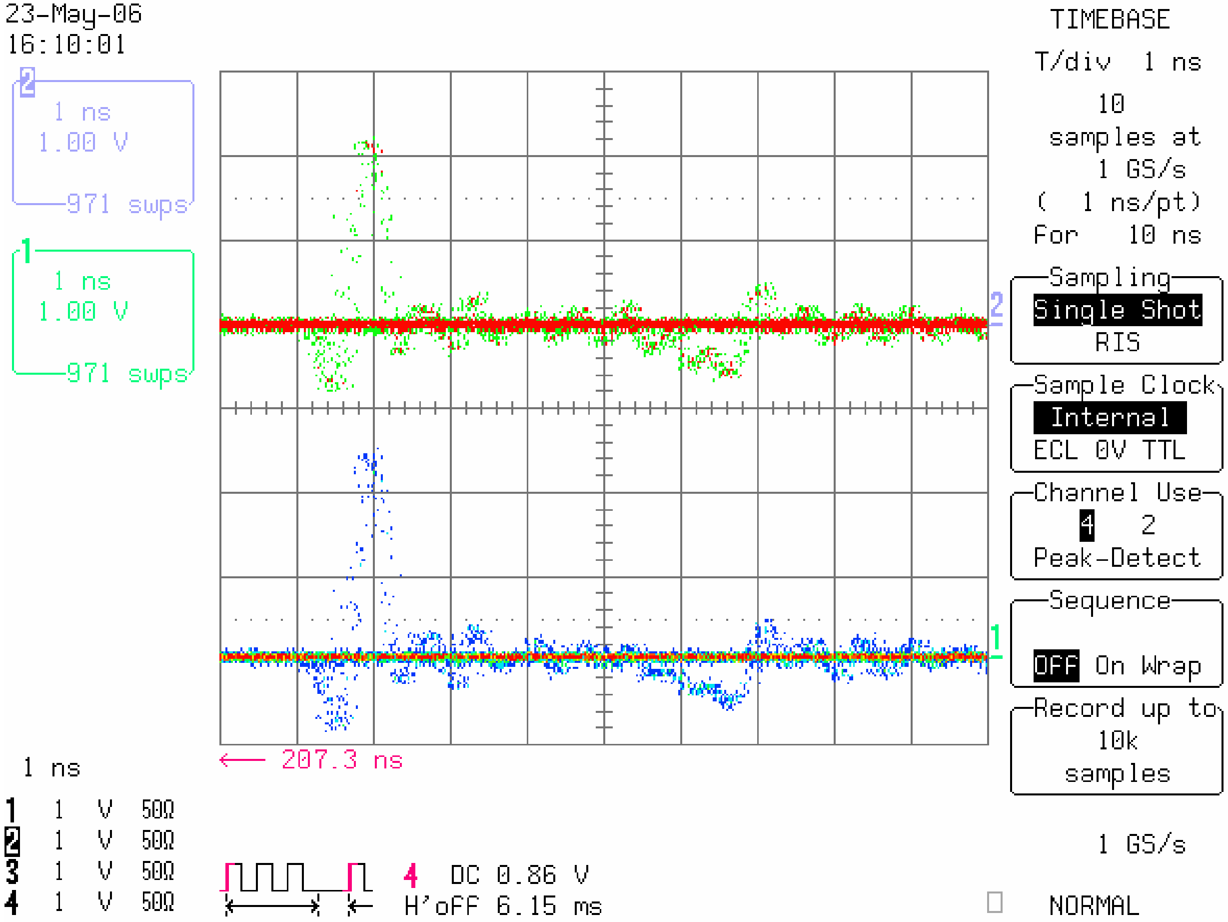
Beam-Induced Signals

Forward coupled beam signals from 2.3 nC bunch, 200v/div. Magnitude comparable to backward pulse.



Beam-Induced Signals

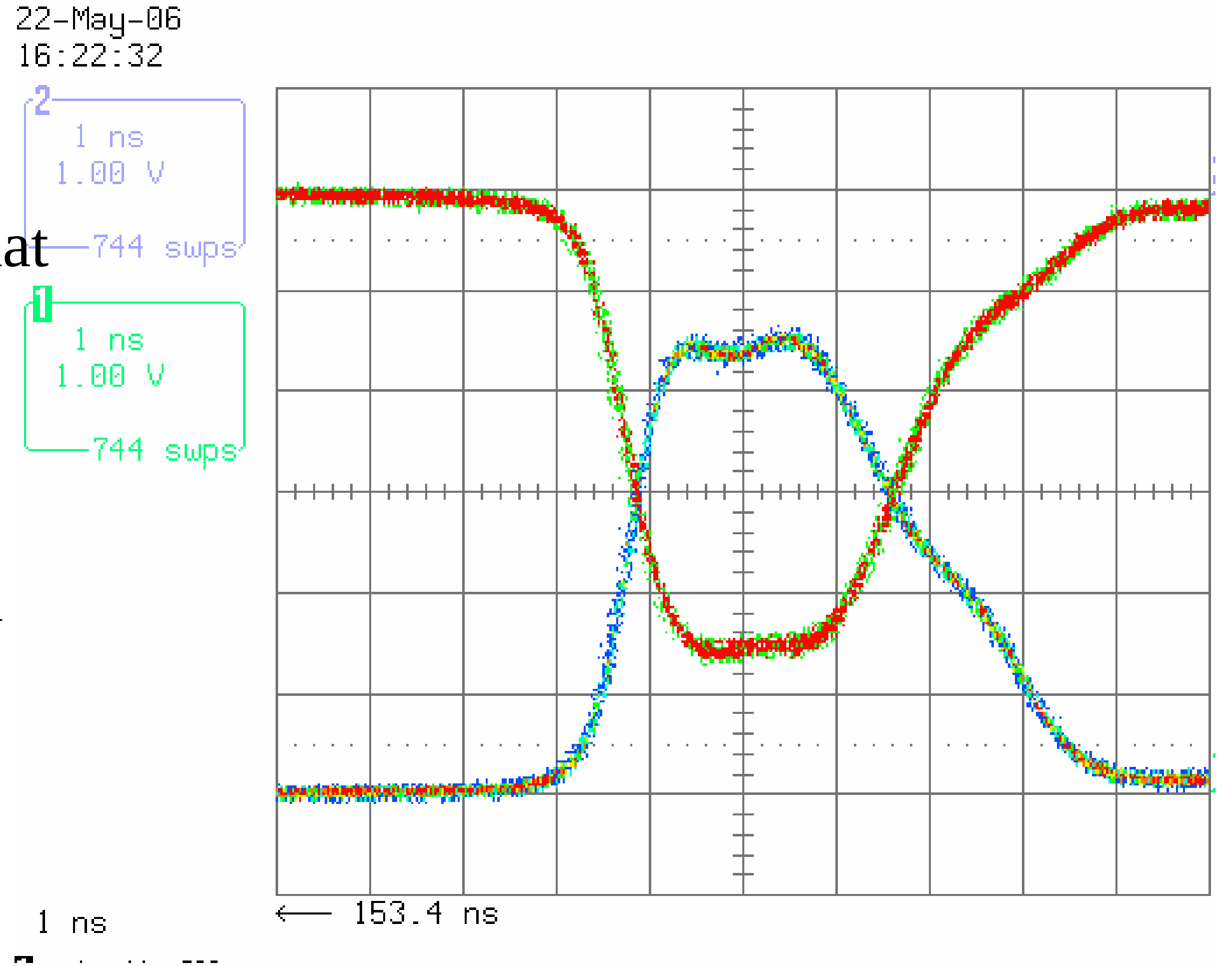
Forward coupled beam signals from 5.2 nC bunch, 100V/div.



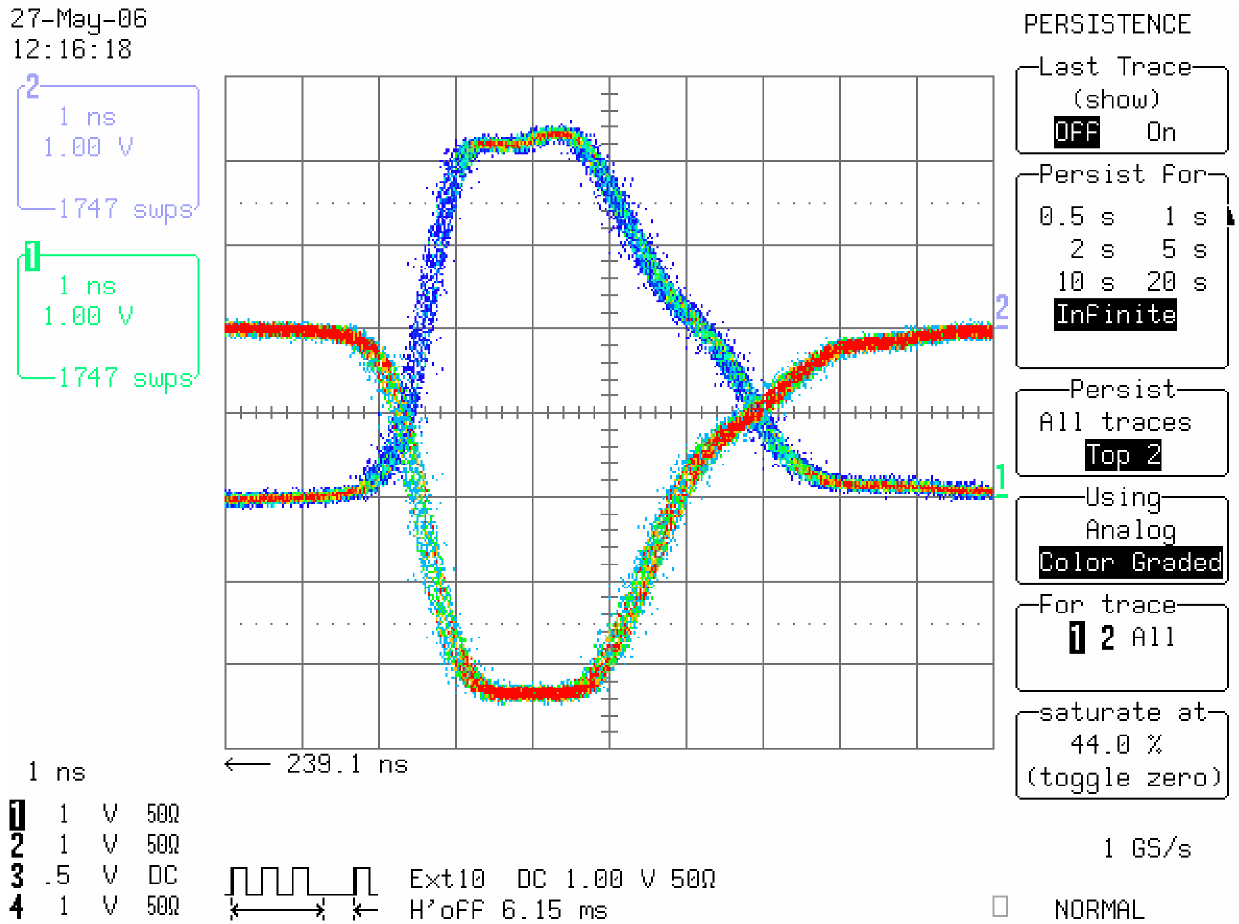
Version 2 of FID Pulser

Replacement pulser

- Function similar to version 1
  – Trailing tail somewhat longer
- Stability
  – Treat full vertical width as +/- 3σ band
  – Suggests ~0.7% amplitude stability, consistent with specification
  – Scope is self-triggered

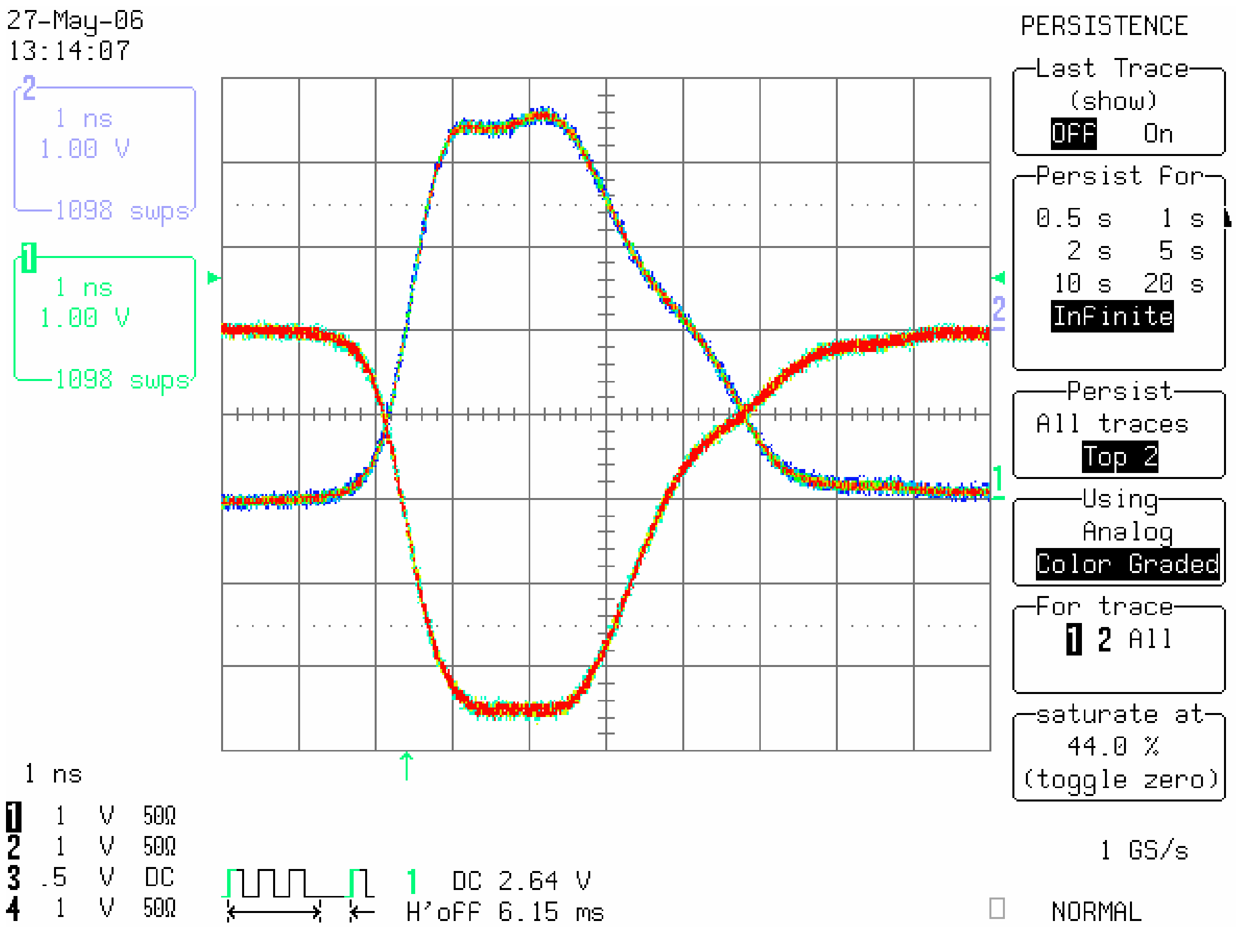


- Pulser waveforms triggered from A0 timing system
  - Oscilloscope is externally triggered



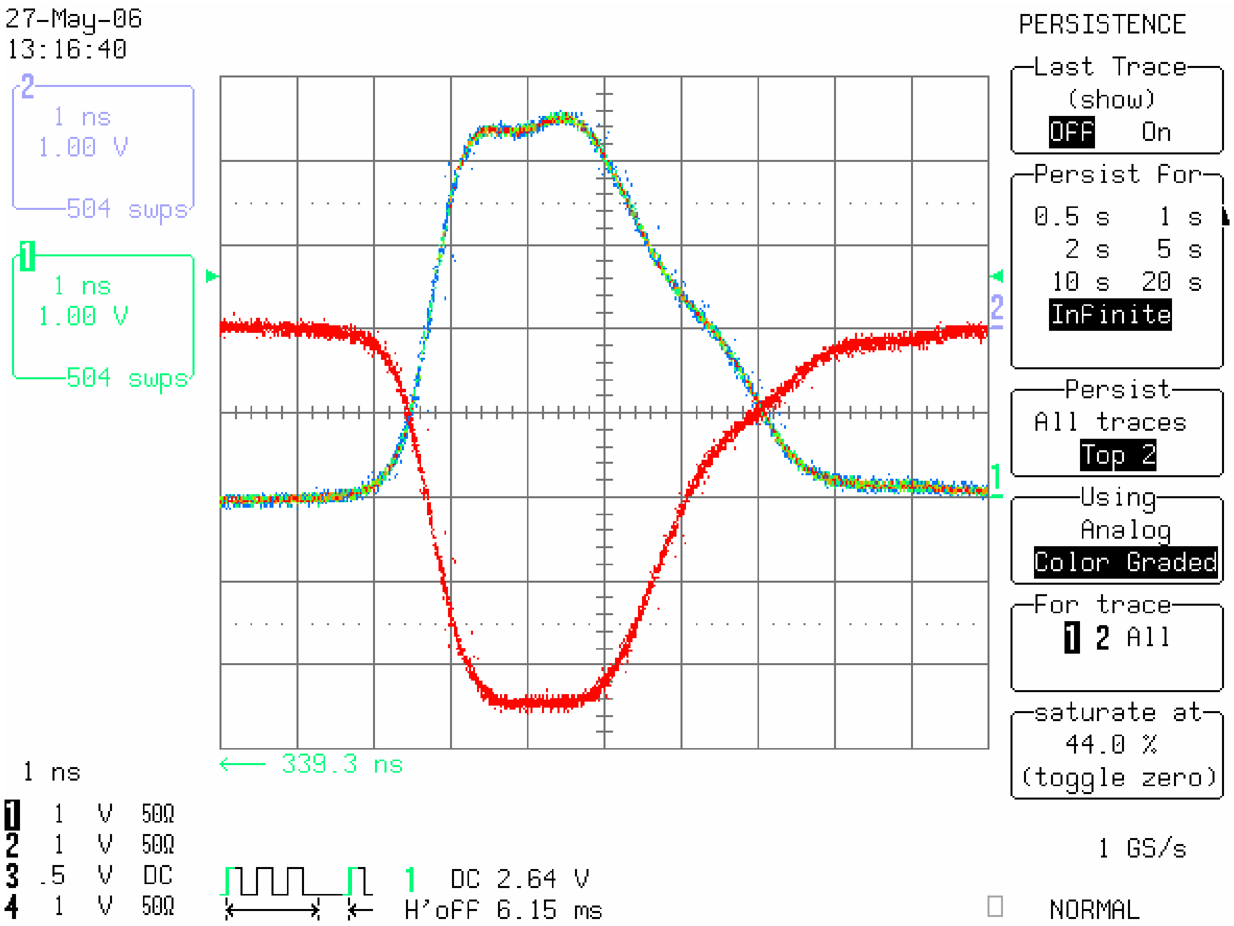
Pulser internal timing

- First pulse of self-generated train
  - Oscilloscope is internally triggered on pulse leading edge



Pulser internal timing

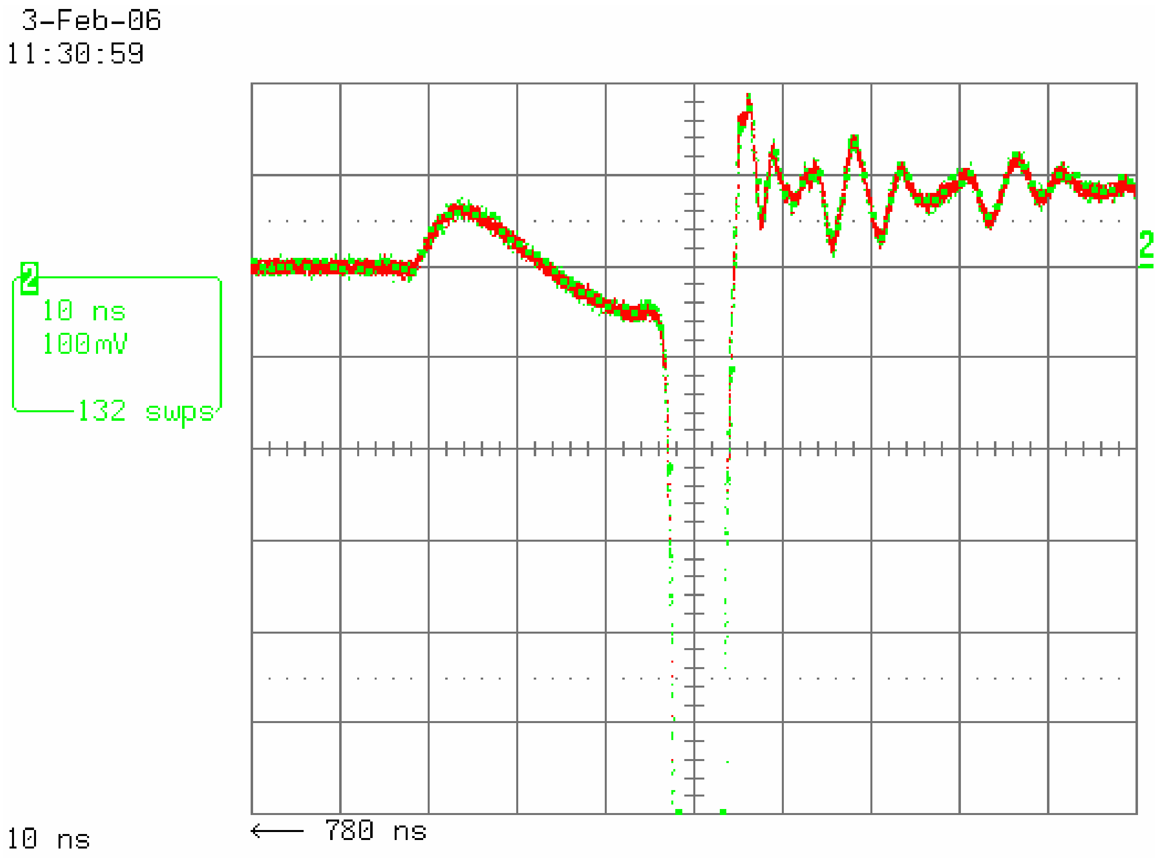
- Second pulse of self-generated train
  - Oscilloscope is internally triggered on first pulse



Crosstalk to cold bunches

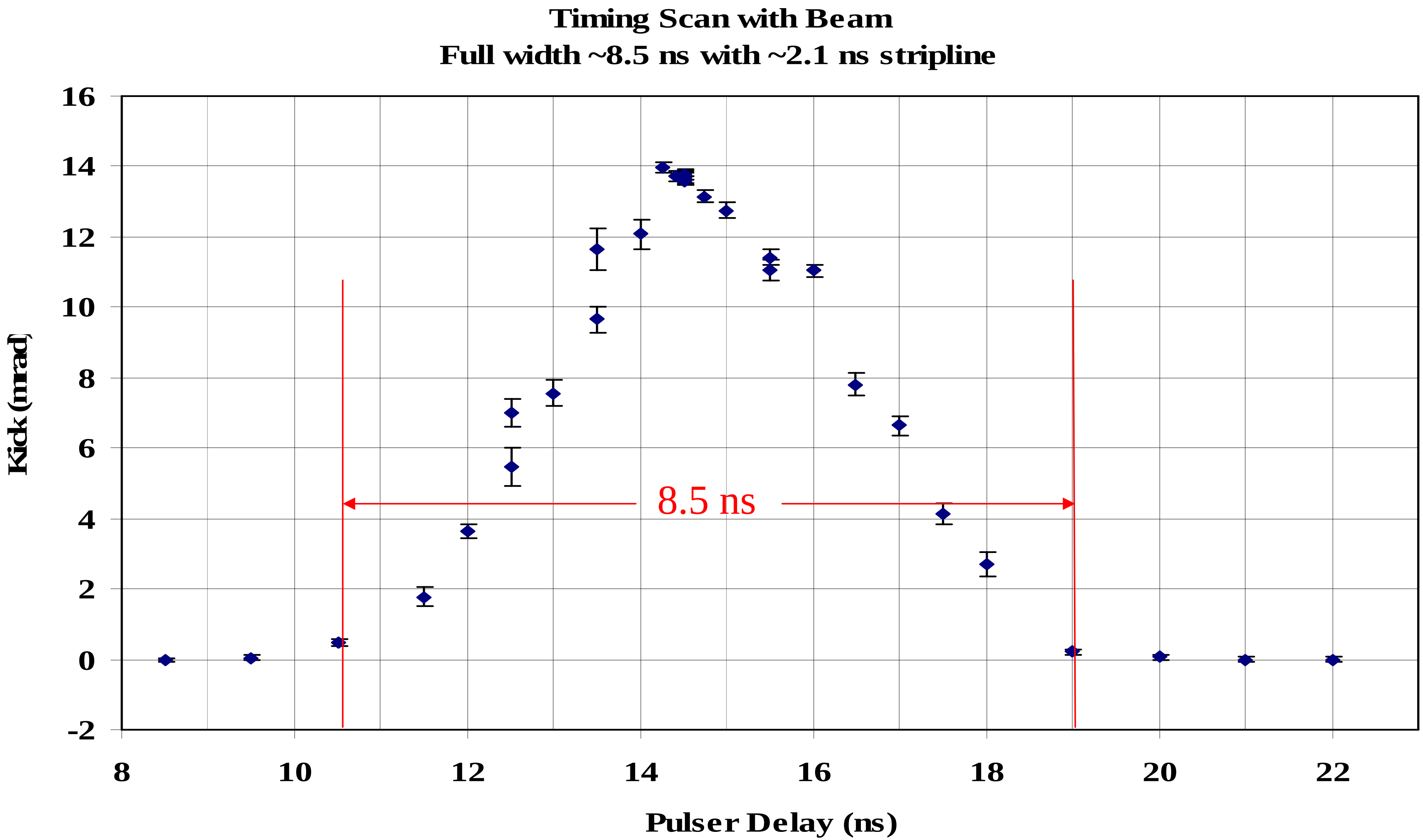
- ***This type of circuit will impact preceding bunches***

  The 30ns charging cycle of the device couples to the output at the level of 1% of the primary pulse amplitude (20V/div).



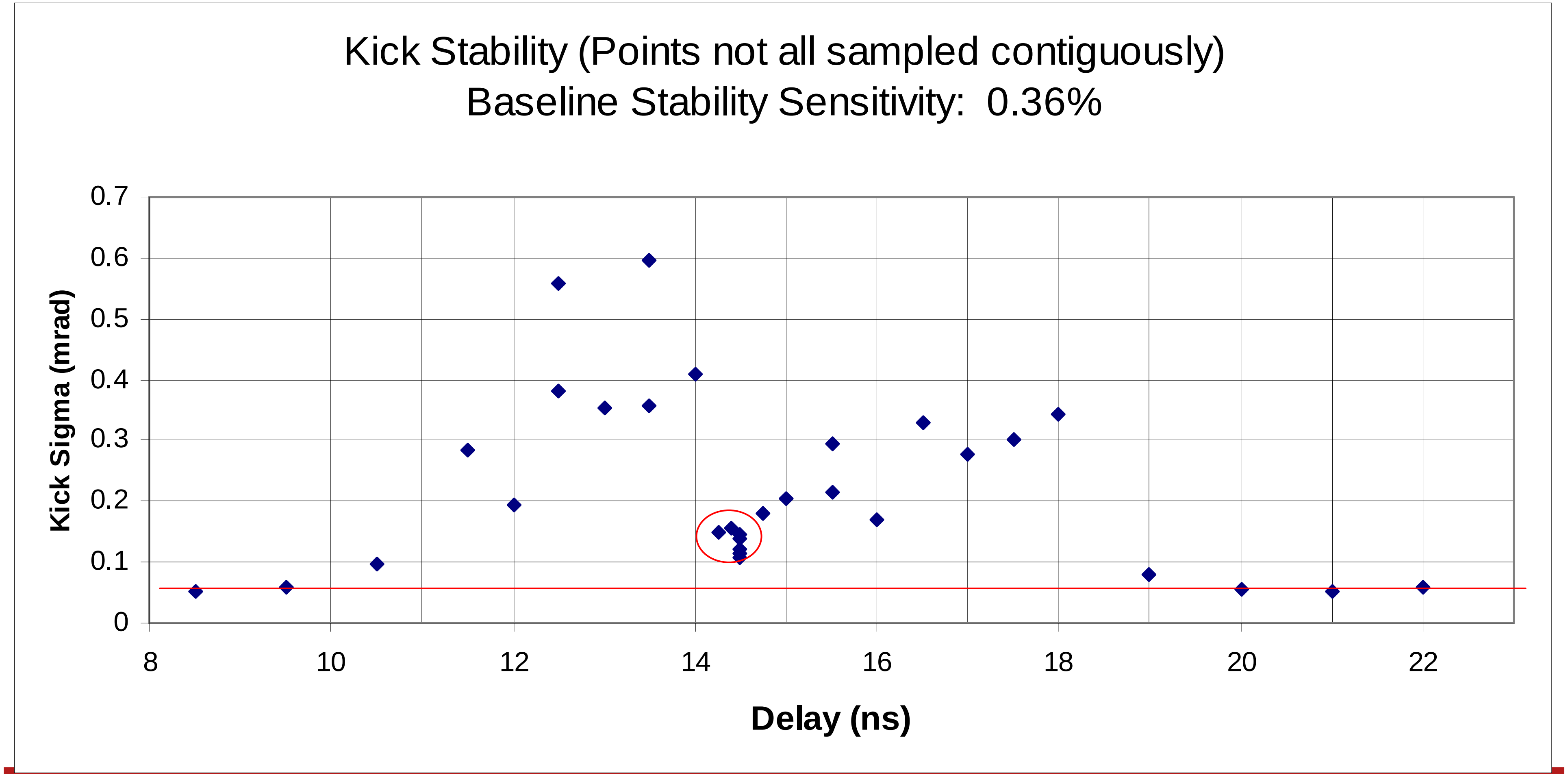
Time Scan of Kick Angle

- Full width: ~8.5 ns



Effective Kick Error

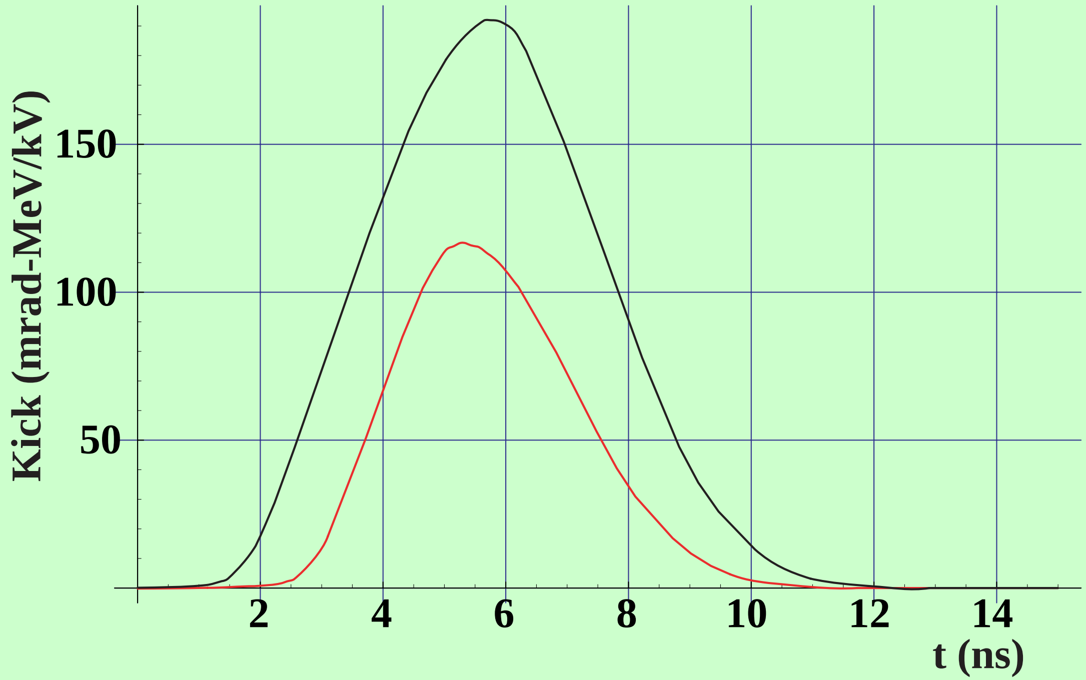
- Ideally want to verify stability at 0.1% level
- Establish baseline stability (beam and DAQ) with straight through tracks at A0
- Top of peak observations have about 2.5-3 times the variation of the baseline
  - Timing Stability (consistent with 100ps RMS noise @ 4mrad/ns slope)
  - Pulser stability (potentially consistent with scope measurements and pulser specifications)



- Extrapolate A0 kick measurements to a hypothetical ILC damping ring kicker:

Simulated Effective Kick

Expected kick from the FPG2-3000-MC2 pulser based on the measured outputs. The black curve represents the 2.1 ns A0 stripline kicker while the red curve is for a 1 ns ILC stripline kicker



Preliminary Conclusions

- Pulse Width
  - Full width ~8.5ns
  - Note that A0 kicker is ~2 ns long
  - With a 1 ns kicker, full width around 6.5 ns
    - ILC requirement is 6.2 ns
- Pulse Stability
  - Appears to be near pulser specification
  - With a long enough kicker, the beam sees the entire integrated pulse, and an effective flat-top occurs
  - With a shorter kicker, effective kick may become a stronger function of pulse shape and timing

A0 Planning

- Potential Improvements
  - Still potentially sensitive to machine stability issues
  - For stability measurements (at the 0.1% level) would like better resolution
    - BPM signal processing
    - BPM spacing (moment arm for angular detection)
    - Better stability timing support for pulser triggering
  - For higher voltage pulsers
    - Corrector magnet needs to be mounted around kicker vacuum chamber to avoid scraping on limited aperture
    - Also minimizes energy corrections in measurement and systematic errors from downstream BPMs
  - Some additional attention to the DAQ
    - DAQ software needs to be able to scan
    - Review of low level BPM control, such as autoranging