Beam-induced EMI and detector electronics

Gary Bower, SLAC
Nick Sinev, University of Oregon
Yasuhiro Sugimoto, KEK

*talk given by M. Woods, SLAC

Important Contributors

- Ray Arnold, SLAC
- Karl Bane, SLAC
- Eric Colby, SLAC
- Joe Frisch, SLAC
- Doug McCormick, SLAC
- Marc Ross, SLAC
- Mike Woods, SLAC
- Hitoshi Yamamoto, Tohoku University
- Japan-US Cooperative Program in High Energy Physics by JSPS

Beam RF effects at Colliders

SLC

Problem with EMI for SLD's VXD3 Vertex Detector

- Loss of lock between front end boards and DAQ boards
- Solved with 10 μsec blanking around beamtime – front end boards ignore commands during this period

PEP-II

Heating of beamline components near IR due to High-order Modes (HOMs)

- S. Ecklund et al., *High Order Mode Heating Observations in the PEP-II IR*, SLAC-PUB-9372 (2002).
- A. Novokhatski and S. Weathersby, *RF Modes in the PEP-II Shielded Vertex Bellows,* SLAC-PUB-9952 (2003).
- Heating of button BPMs, sensitive to 7GHz HOM, causes BPMs to fall out

HERA

Beampipe heating and beam-gas backgrounds

- HOM-heating related to short positron bunch length

UA1

Initial beam pipe at IP too thin

- not enough skin depths for higher beam rf harmonics

Beam RF effects at ILC IR?

	SLC	PEP-II e^+	ILC
Electrons/Bunch, Q	4.0×10^{10}	5.0×10^{10}	2.0×10^{10}
Bunch Length, σ_z	1 mm	12 mm	0.3 mm
Bunch Spacing	8 ms	4.2 ns	337 ns
Average Current	7 nA	1.7 A	50 μA
$(Q/\sigma_z)^2$ relative	92	1	256

PEP-II experience

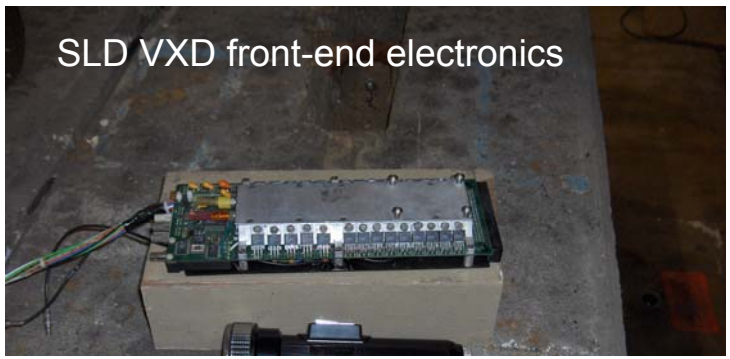
- HOM heating scales as $(Q/\sigma_z)^2$
  - same scaling for EMI affecting detector electronics?
  - does scaling extend to mm and sub-mm bunch lengths?
  - need a cavity of suitable dimensions to excite
- IR geometry (aperture transitions, BPMs) has similar complexity as for ILC
- VXD and other readout systems ok for EMI in signal processing

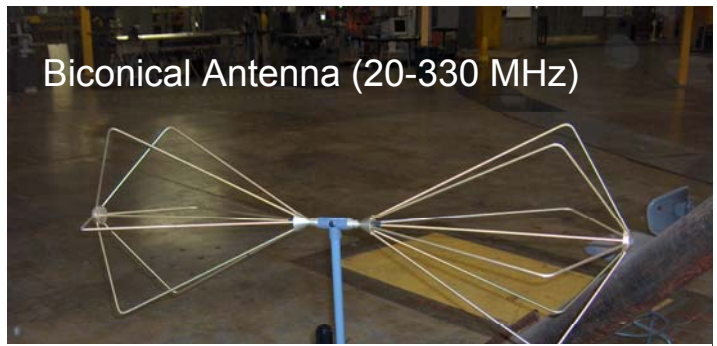
ILC Considerations

- HOM heating ok because of small average beam current
- EMI affecting Signal Processing and DAQ? Impact on Detector Design and Signal Processing Architecture?

➢ ***EMI Standards needed for Accelerator and Detector in IR region***

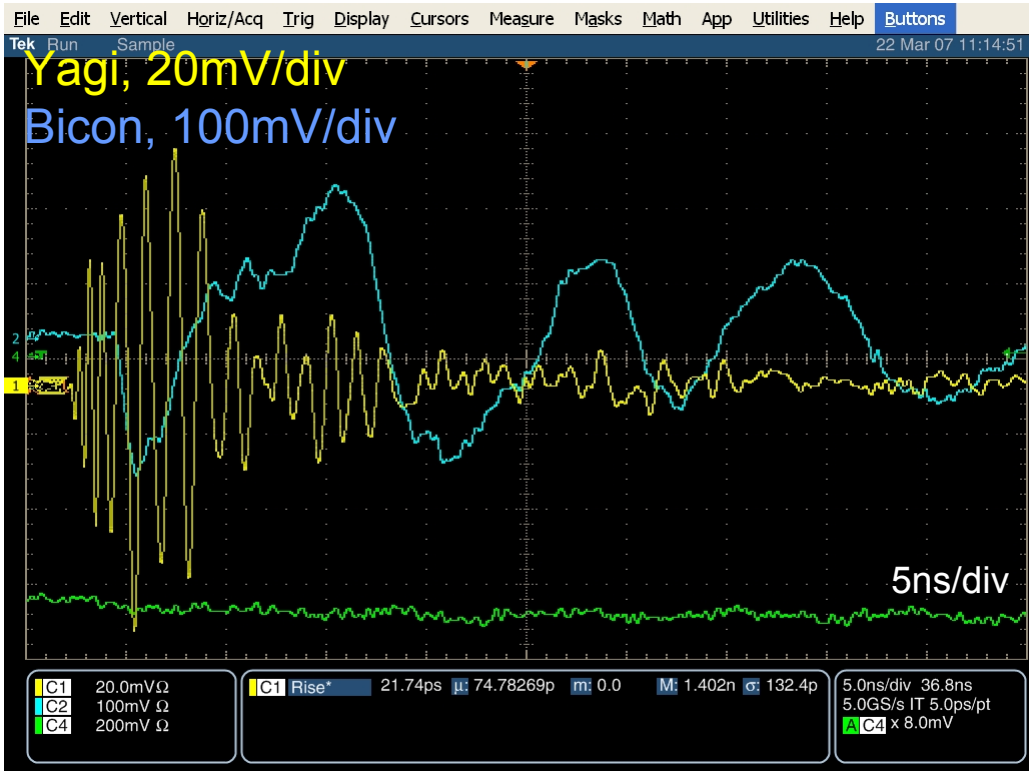
EMI Studies at SLAC ESA



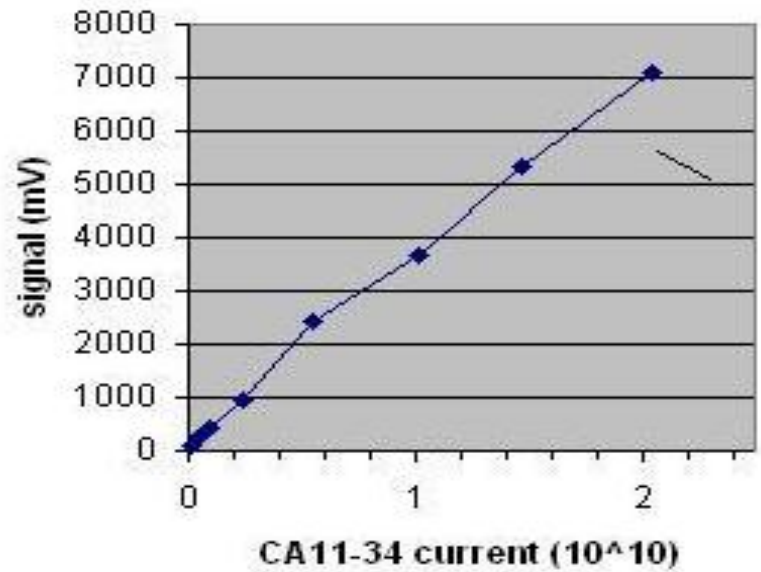


- EM fields within the beam pipe are contained by the small skin depth.
- But dielectric gaps emit EM radiation out of the beam pipe.
- Common “gaps” are camera windows, BPM feedthroughs, toroid gaps, etc.

EMI Measurements near ceramic gap

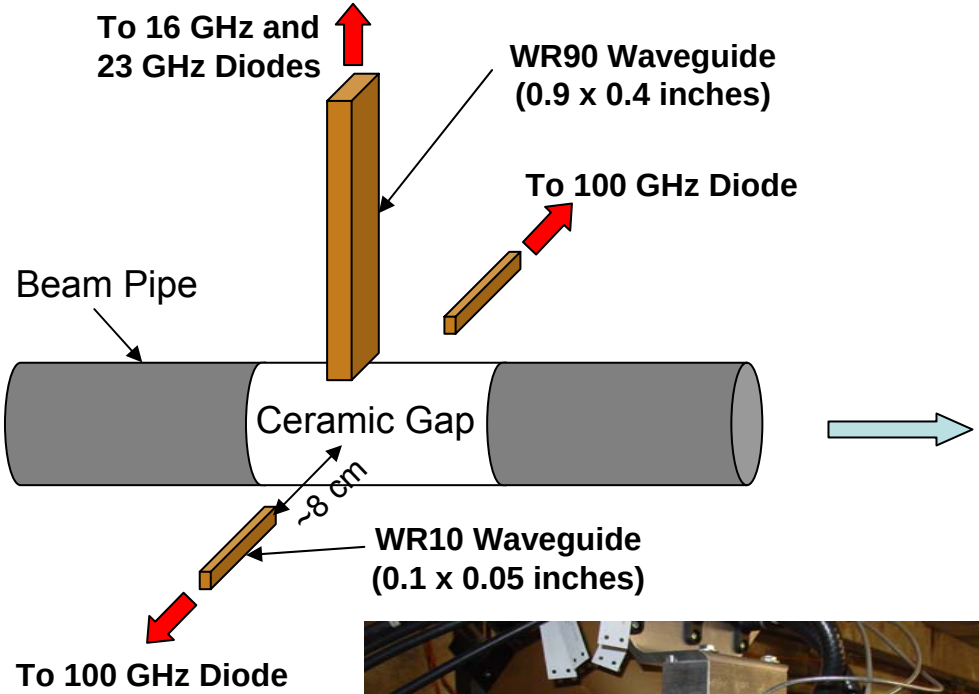


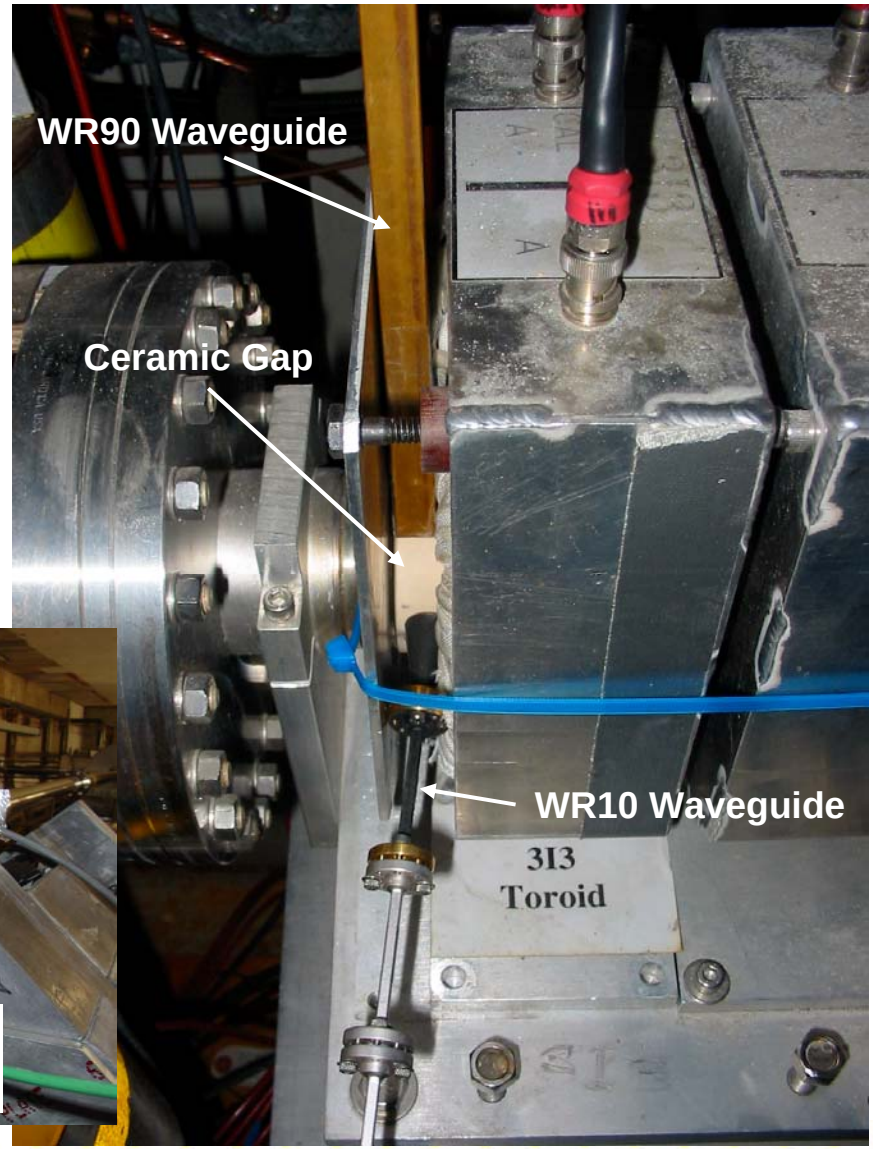
EMI signal vs bunch charge

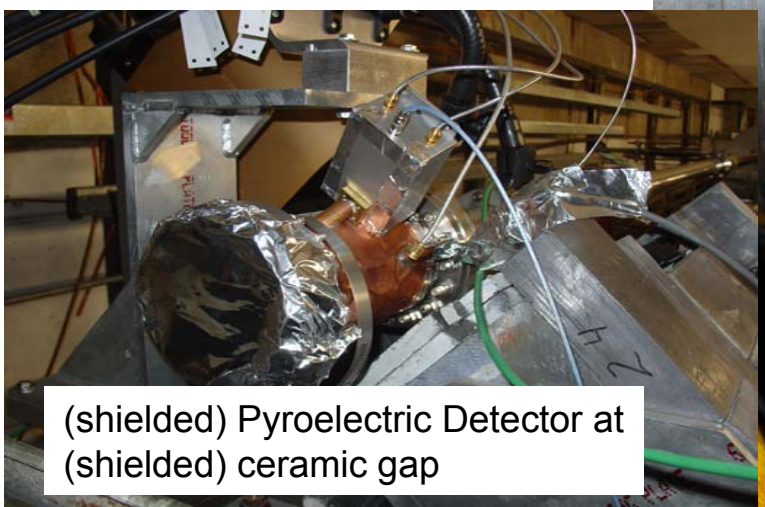


- Antennas placed near (~1 m) gaps observed EMI up to ~20 V/m.
- Pulse shapes are very stable over widely varying beam conditions, indicating they are determined by the geometry of beam line elements.
- Pulse amplitudes varied in proportion to the bunch charge but were independent of the bunch length. Observe ~1/r dependence on distance from gap.

RF Bunch Length Detectors in ESA

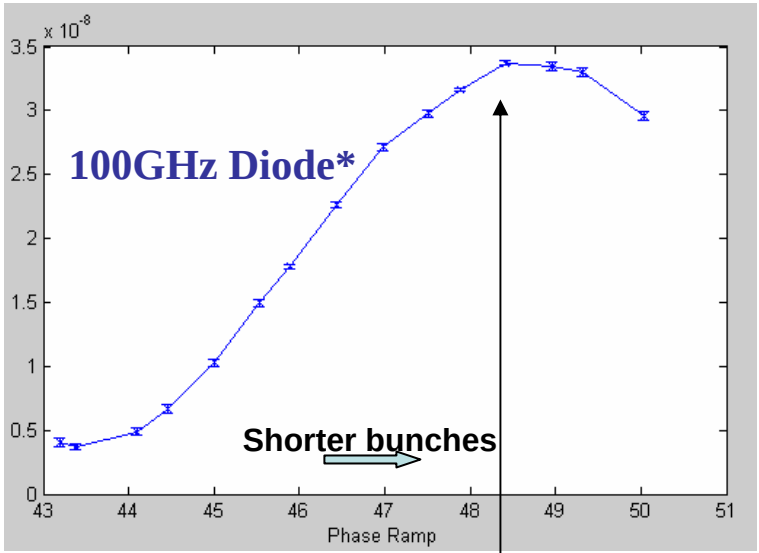


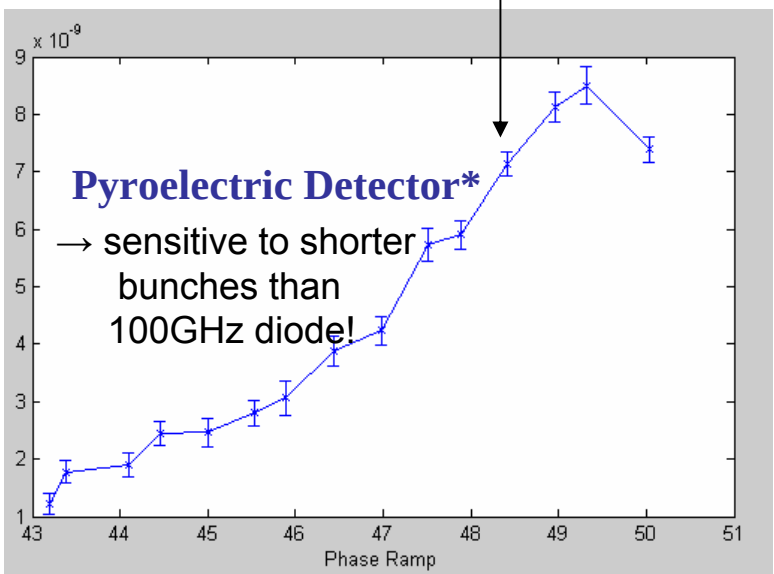




(shielded) Pyroelectric Detector at
(shielded) ceramic gap

Bunch Length Measurements vs Linac rf Phase





Radiated Power Spectrum at Ceramic Gap

$$P(\omega) \propto Q^2 \cdot \exp\left(-\frac{\omega^2 \sigma_z^2}{c^2}\right)$$

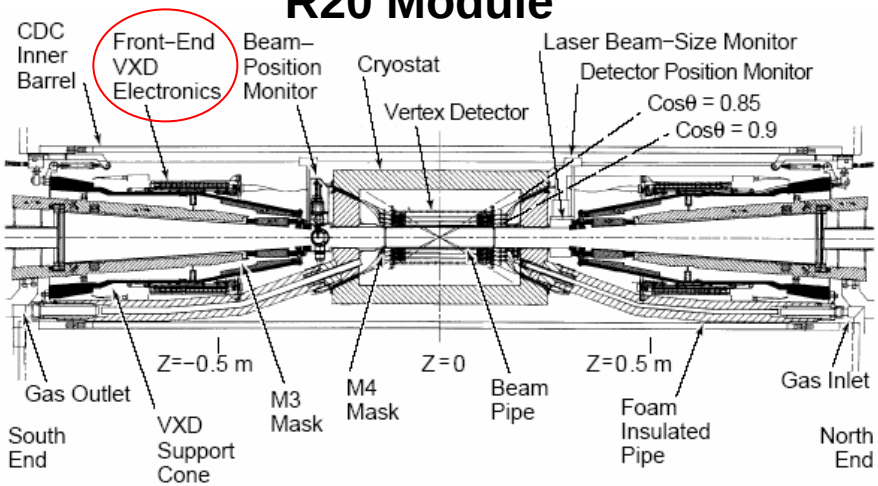
for σ_z=500um, 1/e decrease is at f=100GHz

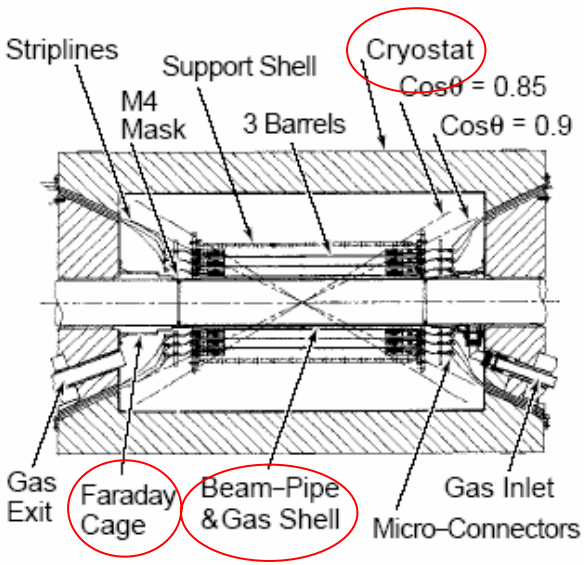
23GHz Diode was insensitive to bunch length

(phase ramp determines relative timing of beam wrt accelerator rf)

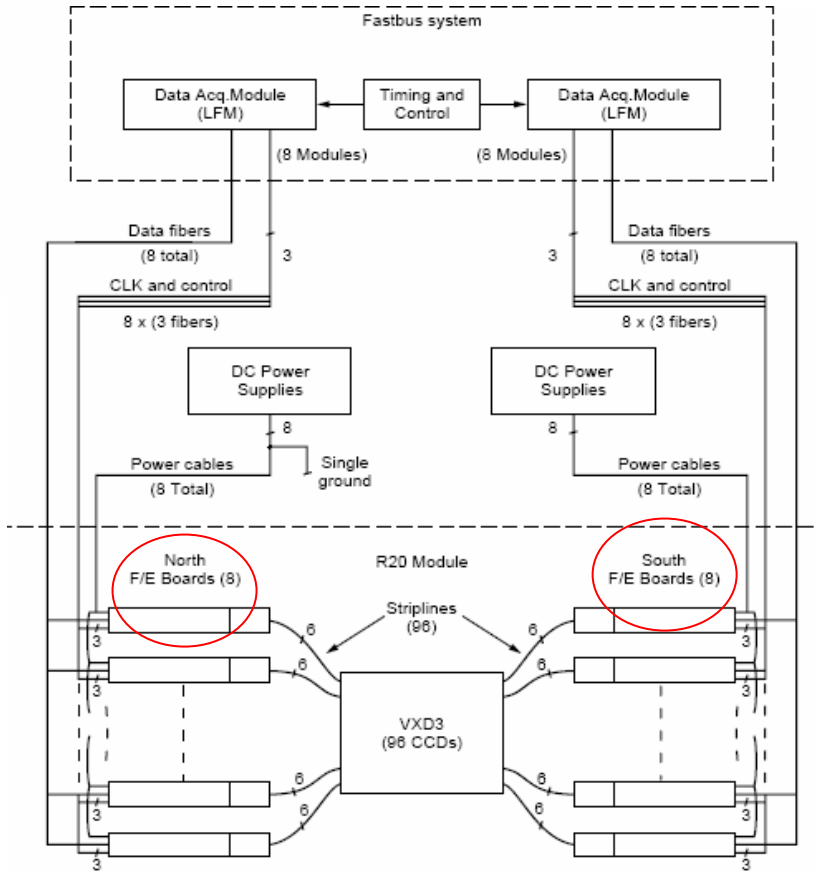
SLD Vertex Detector

R20 Module

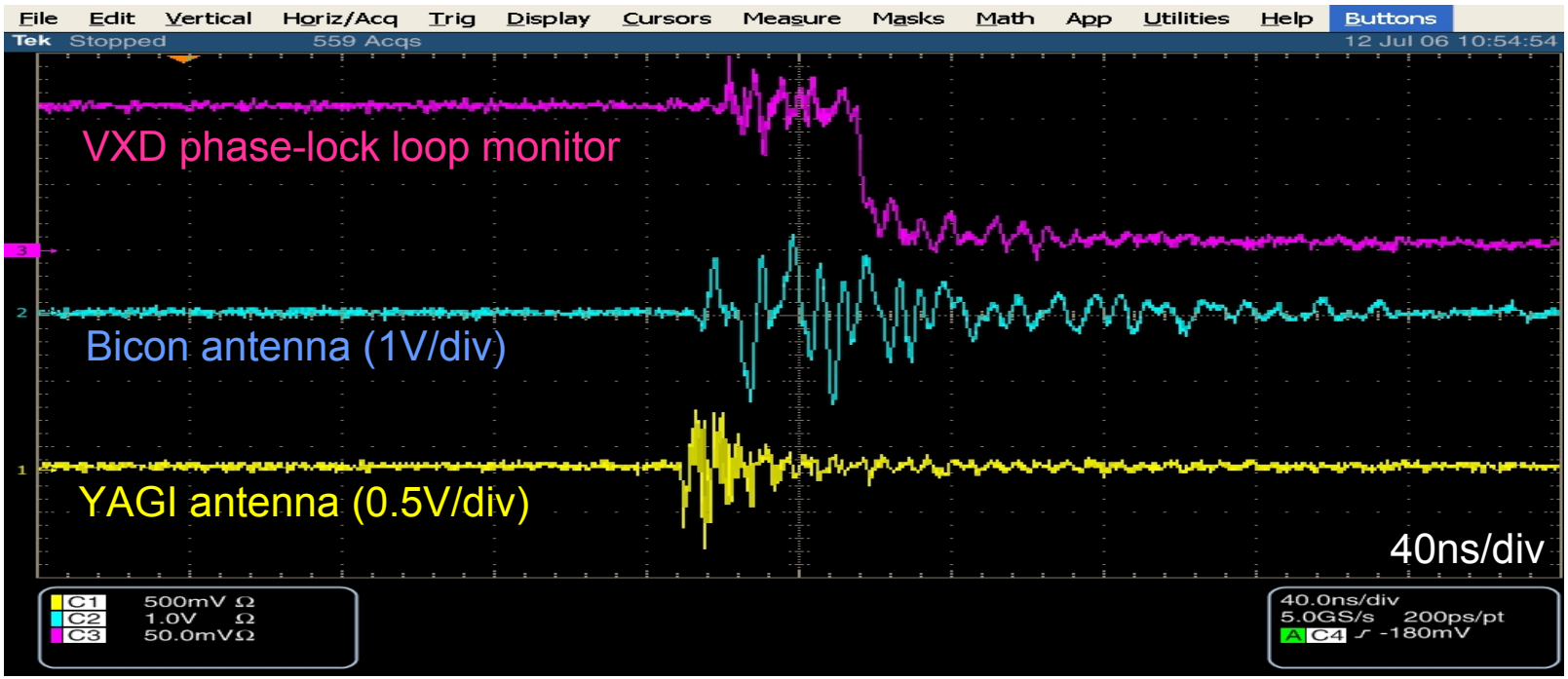




Electronics



SLD VXD electronics studies



→ VXD front-end electronics placed near ceramic gap. When exposed to sufficient EMI the phase-lock loop monitor signal drops.

- Phase lock loop lost lock on about 85% of beam crossings when the module was exposed to ~20 V/m of EMI (YAGI measurement on 2.5GHz bandwidth scope)
- Phase lock loop lost lock failure rate drops to 5% at ~1 V/m of EMI.

VXD electronics failures: observations

EMI Shielding Tests, July 2006

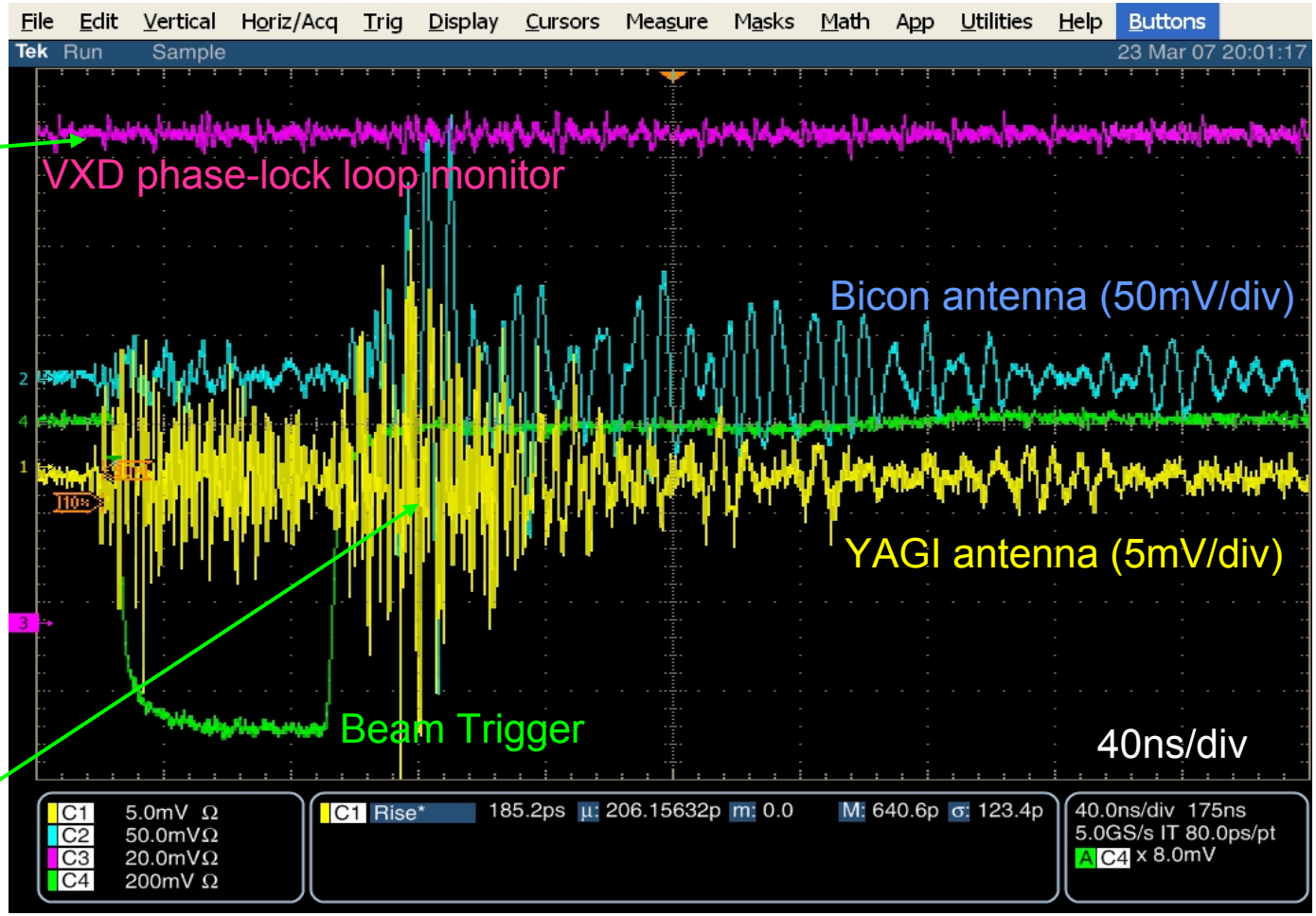
- Placing just the VXD board inside an aluminum foil shielded box stopped the failures.
- Covering the gap also stopped failures.
  - failures not due to ground loops or EMI on power/signal cables
  - failures are due to EMI emitted by gap
  - what frequencies are important?

EMI Shielding Tests, March 2007

- A single layer of common 5mil aluminum foil was placed over the ceramic gap and clamped at both ends to provide an image current path.
- The antenna signal amplitude was reduced by >x10.
- EMI from upstream sources limited the resolution.
- The aluminum foil gap cover stopped VXD failures.
- A 1 cm x 1 cm hole in the gap foil cover emitted enough EMI to cause about 50% VXD failure rate at ~1m distance. (With no foil rate would be 100% at this distance.)
- There was no failure with a 0.6 cm x 0.6 cm hole.

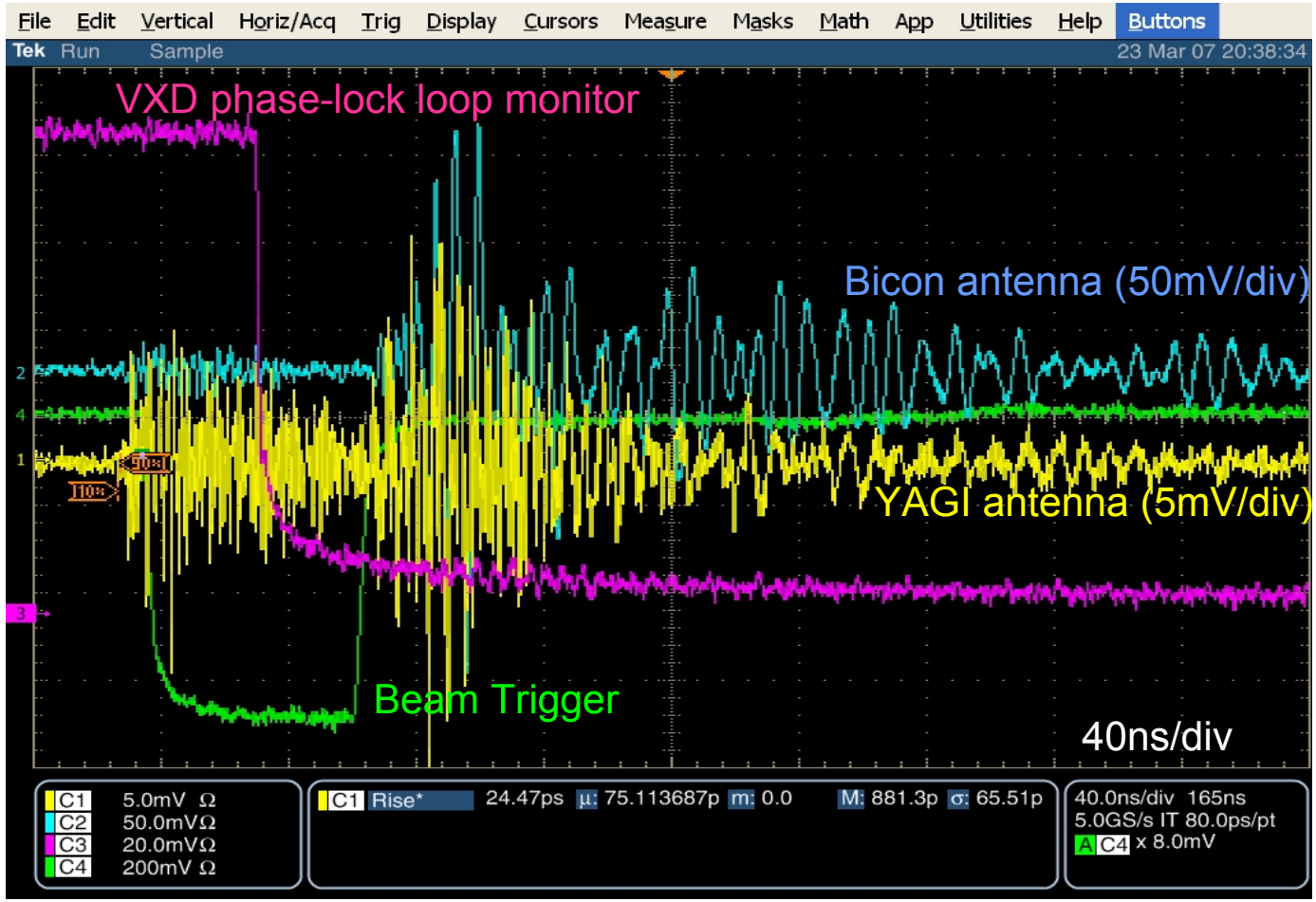
Antenna Signals, gap covered with Al foil

no failures



EMI from gaps (toroids, …) downstream

Antenna Signals, 1cm^2 gap in foil



→ observe VXD electronics failure, but little change in antenna signals

→ indicates VXD electronics sensitive to EMI at higher frequencies than seen by YAGI; dimensions indicate sensitivity at ~30GHz

Next steps

2 dedicated shifts in July 2007 ESA run

- Further shielding studies to understand frequency sensitivity
- Move antennas in z along beamline to check other sources; get both time and amplitude information

Measurements at commercial company (ex. www.ckc.com)

- Can test SLD VXD front end board with EMI source up to 40GHz and 200V/m; measure failure rate sensitivity to frequency and amplitude

- Try to understand why VXD is failing to avoid a similar problem at ILC
- Ultimately, need to develop EMI standards for ILC Accelerator and Detector