ILC Damping Ring Fast Kicker Work at UIUC and Fermilab

Snowmass ILC

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Two kinds of kicker designs

We're investigating two kind of kicker designs.

- Fourier series pulse compression kicker (an RF device)
- stripline kicker

Initial modeling-of-concept of the FSPCK is finished, but I need to finish writing it up. Preliminary RF engineering studies are underway at UIUC and FNAL. (We are in the VERY early stages of this.)

Stripline kicker tests are underway in the 16 MeV electron beam at Fermilab's A0 Photoinjector Laboratory. (First data last week!)

Participants

This project is part of the US university-based Linear Collider R&D effort (LCRD/UCLC)

Cornell

Gerry Dugan
Joe Rogers†

Fermilab

Tug Arkan
Euvgene Borissov
Harry Carter
Brian Chase
David Finley
Chris Jensen
Timergali Khabiboulline
George Krafczyk
Shekhar Mishra
François Ostiguy
Ralph Pasquinelli
Phillipe Piot
John Reid
Vladimir Shiltsev
Nikolay Solyak
Ding Sun

Univ. Illinois

Joe Calvey
Jason Chang
Michael Davidsaver
Justin Phillips
George Gollin
Mike Haney
Jeremy Williams

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The specs

Dog bone (TESLA TDR) kicker specs:

- impulse: 100 G-m (3 MeV/*c*) ± 0.07 G-m (2 keV/*c*)
- residual (off) impulse: 0 ± 0.07 G-m (2 keV/*c*)
- rise/fall time: < 20 ns

6 km damping ring kicker specs:

- impulse strength and stability requirements are likely to be similar to those for a dog bone kicker
- rise/fall time: < 6 ns, though gaps between bunch trains may permit slower fall times.

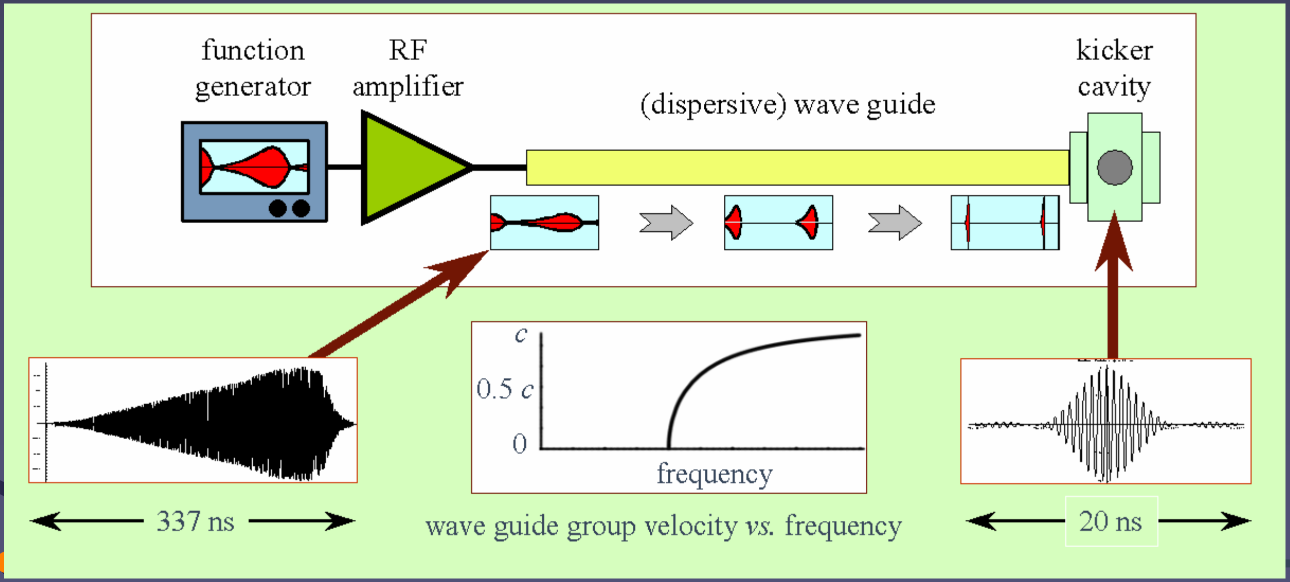
We're interested to see if we can achieve ~5 ns rise/fall times.

Fourier series pulse compression kicker

Instead of a pulsed kicker, construct a kicking pulse from a sum of its Fourier components.

Combine this with a pulse compression system to drive a small number of low-*Q* cavities.

Illinois, Fermilab, Cornell are involved.



FSPCK overview

Functional units in the system, upstream to downstream:

- Arbitrary function generator
- RF amplifier (±10% full bandwidth: traveling wave tube amplifier?)
- Waveguide (1.3 GHz cut-off frequency)
- RF cavity (*Q* = 25, ~1.8 GHz center frequency)

Total system power might be 60 kW (or more!!)

FSPCK modeling

Our modeling includes an ability to incorporate

- simple geometrical errors: waveguide length, waveguide cut-off frequency, cavity center frequency, cavity *Q*, …
- amplifier errors: gain *vs.* frequency, phase *vs.* frequency, harmonic distortion, intermodulation distortion
- amplifier noise, including interaction of noise with nonlinear effects like intermodulation distortion

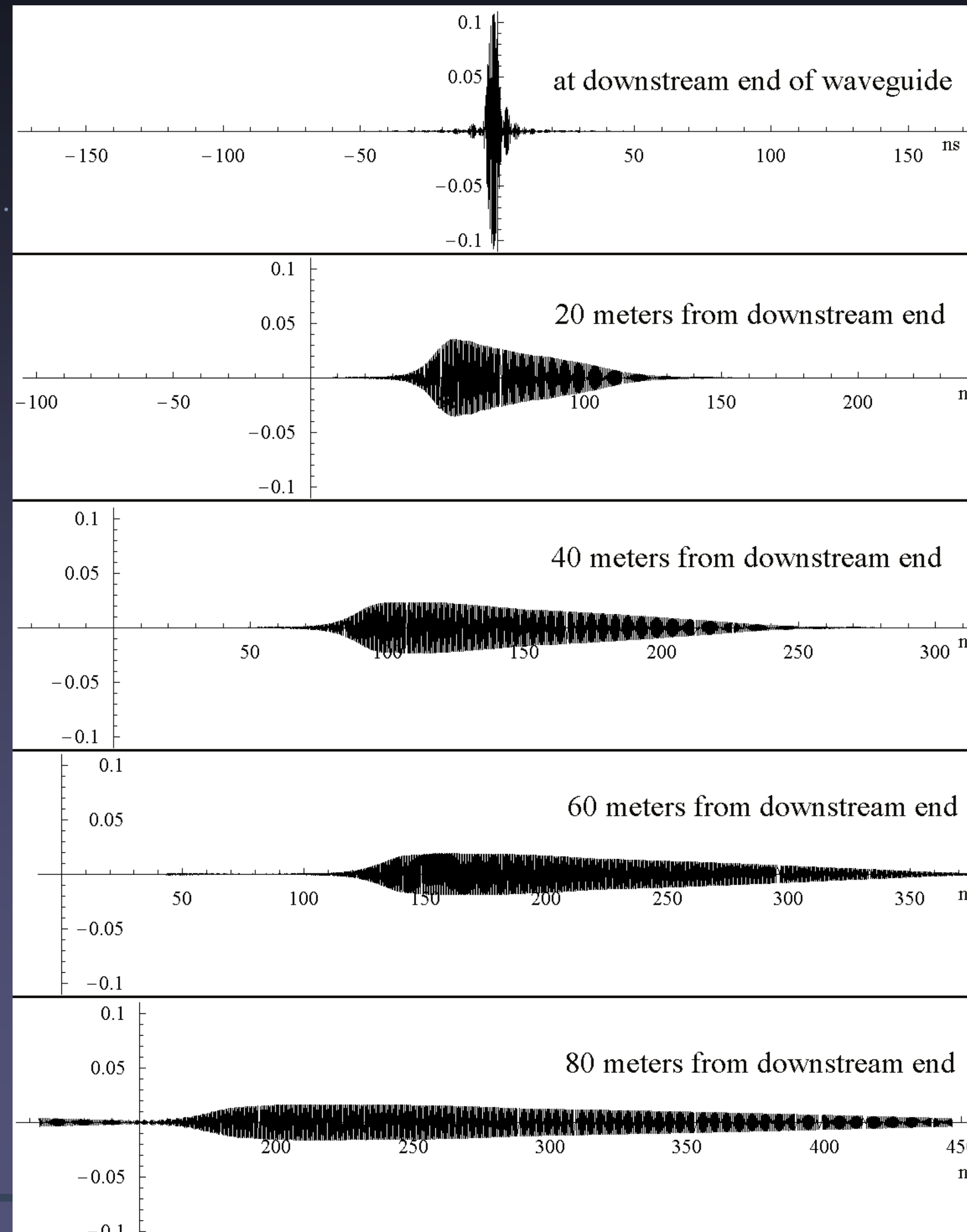
It's this last effect– noise combining with second-iorder intermodulation distortion– that may be the most significant challenge

Waveguide compresses pulse

Pulse compression!

Maximum amplitudes:

- entering ~0.016
- exiting ~0.1



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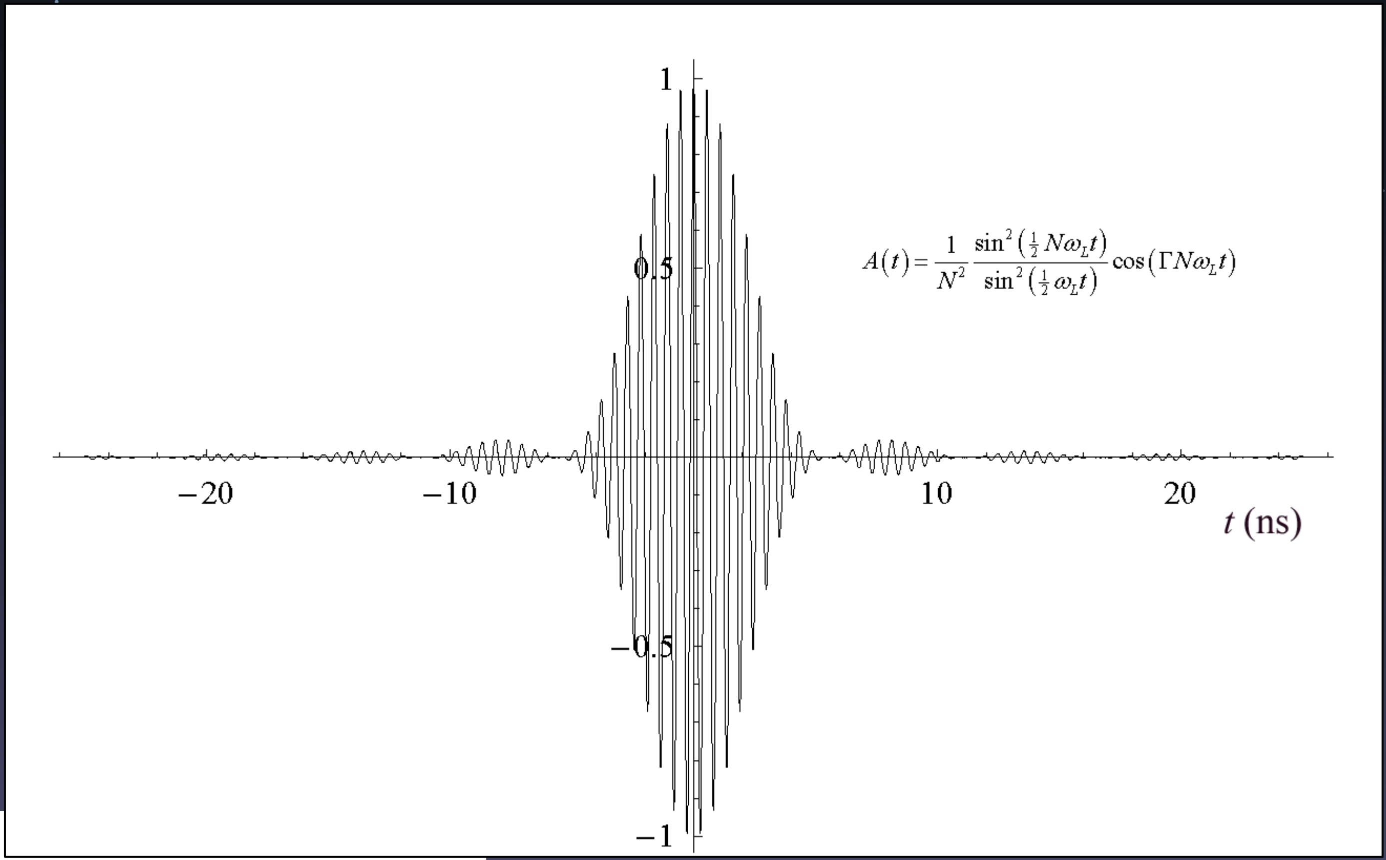
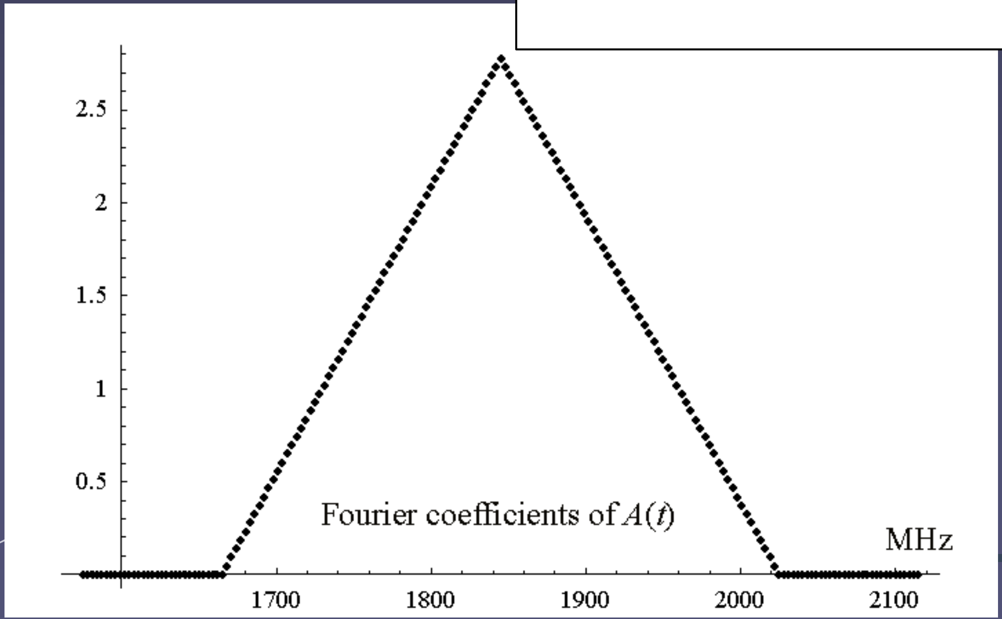
RF cavity





- $Q = 25$
- center frequency 1845 MHz

RF work at UIUC

We've been borrowing lab space in an instructional lab in ECE (Electrical and Computer Engineering) for some of our work.

We do not have previous RF engineering experience, so we're learning as we go.

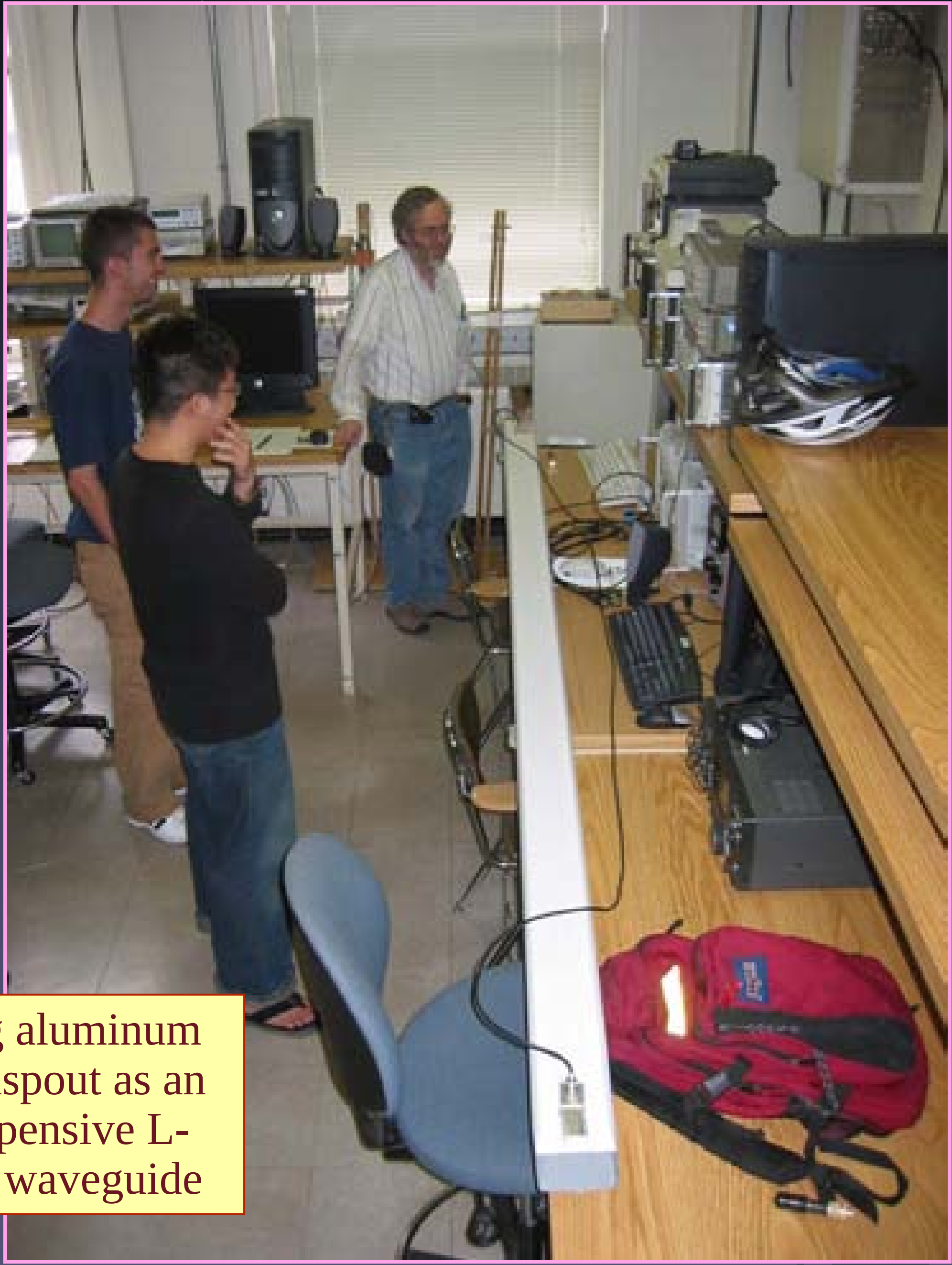
We discuss things with Fermilab's RF group. When we are further along, they'll drive south to spend a few days at UIUC working with us.

In the RF lab at UIUC

Cheapest source of L-band waveguide: Lowe’s!

(It’s actually aluminum downspout.)

Since then we’ve borrowed real waveguide from Fermilab.



using aluminum downspout as an inexpensive L-band waveguide

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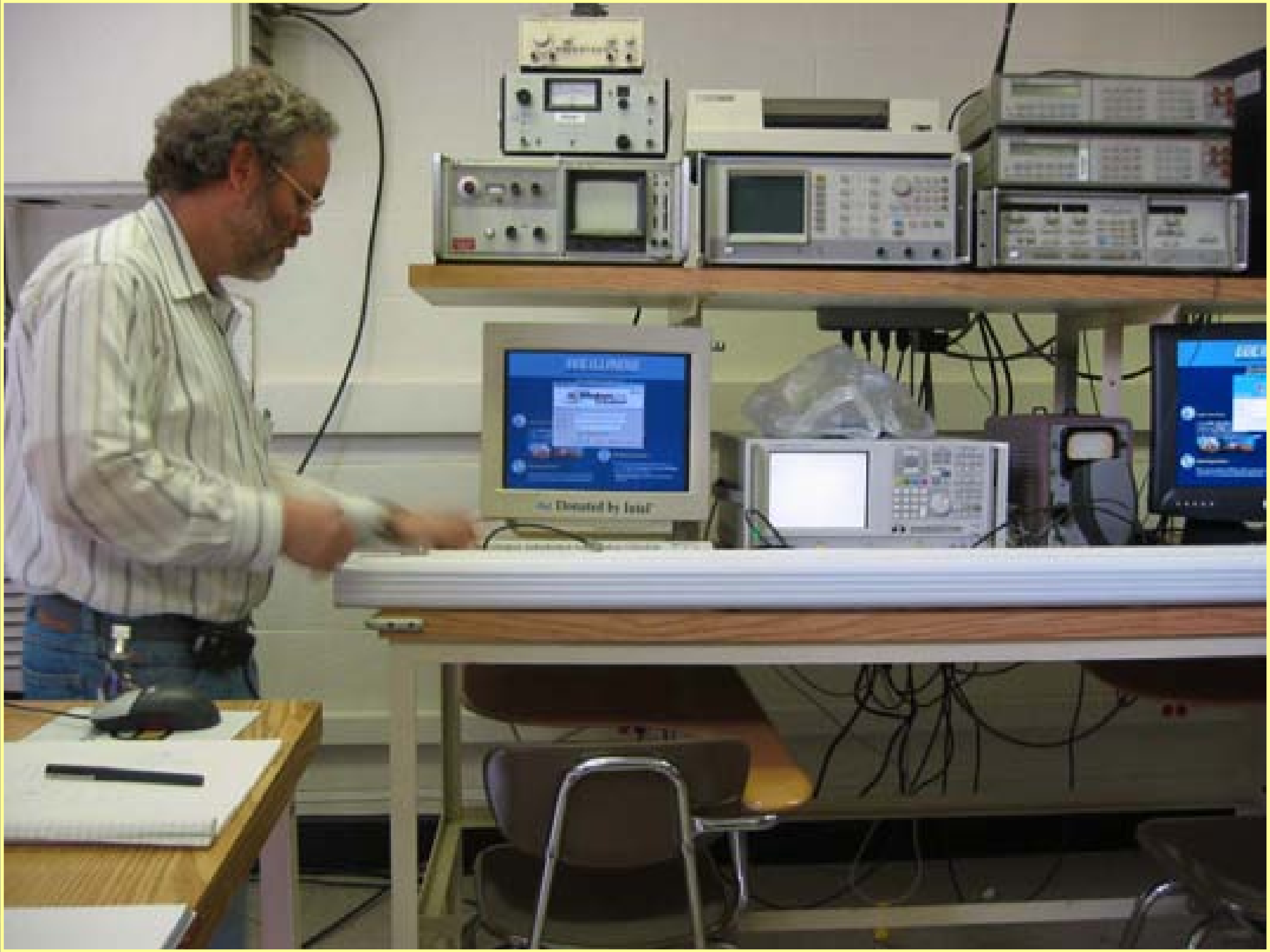
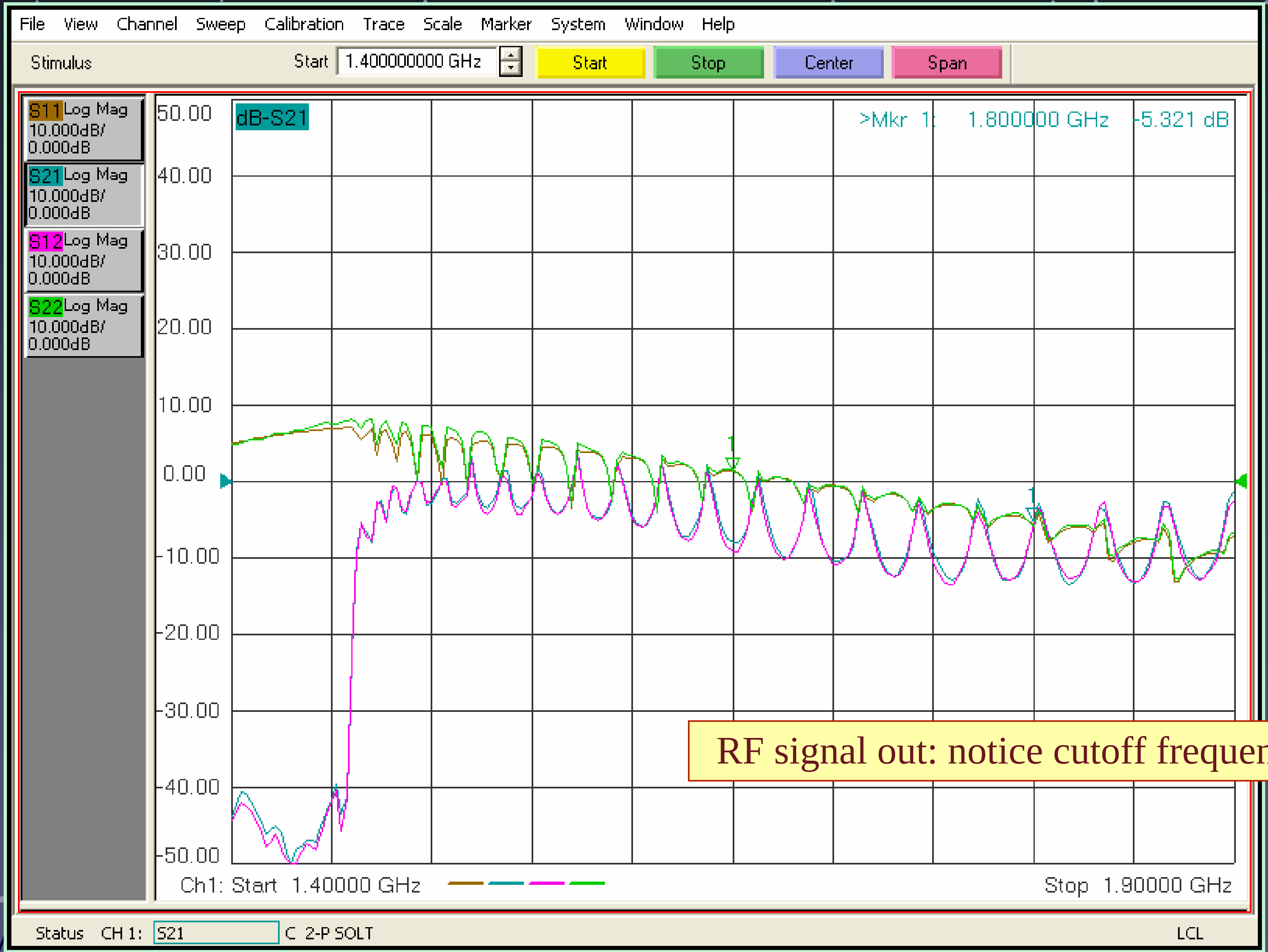
Measuring cut-off frequency in “L-band” downspout



Cut-off frequency and complicated frequency structure



UIUC/FNAL stripline kicker studies

Start with a simple kicker whose properties are calculable and can be understood independently of those of the A0 electron beam.

Most important: how well can we measure a device's amplitude and timing stability with the A0 beam?

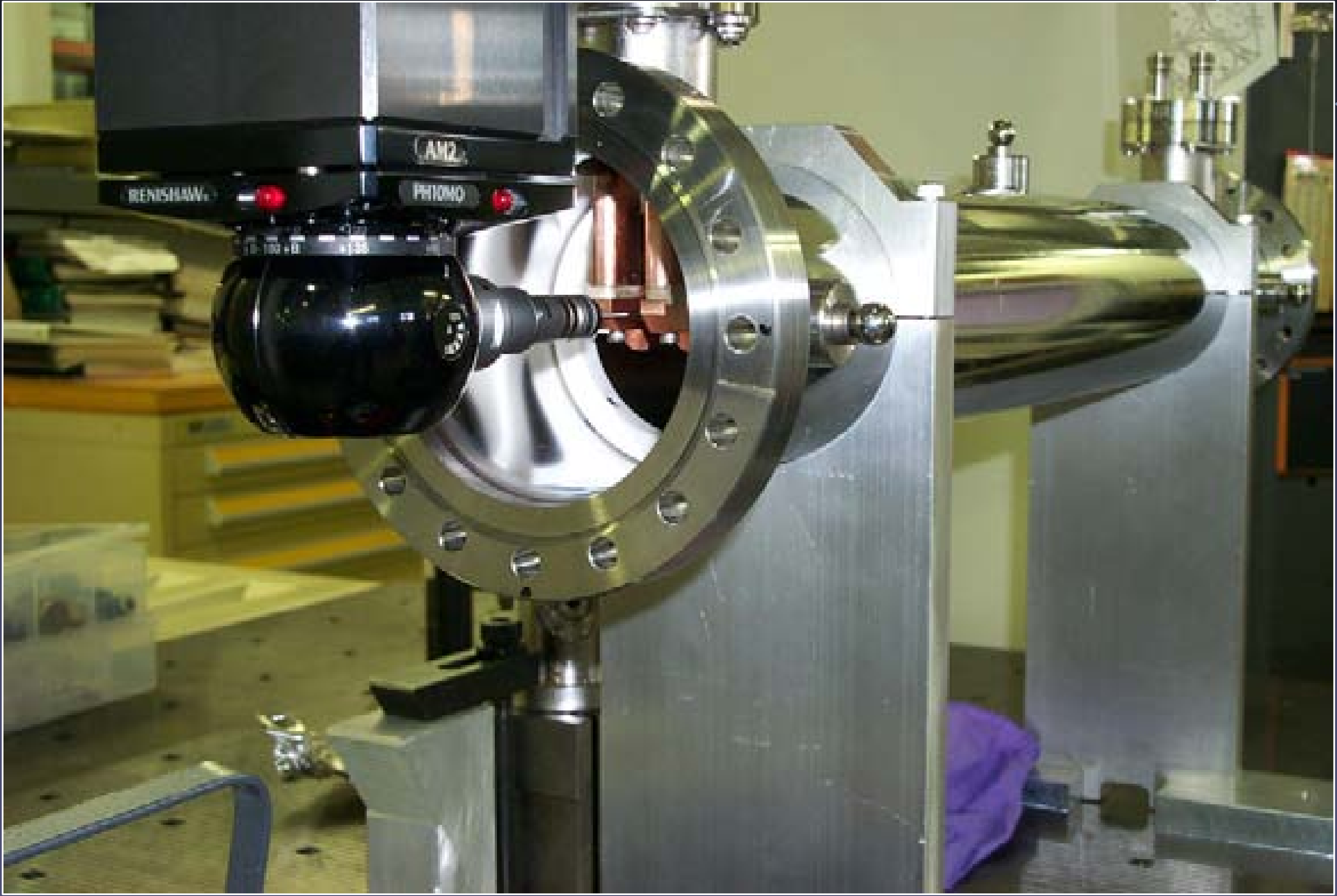
A0 runs at 1 Hz, so performance demands on DAQ and offline analysis processing are not severe.

First significant data were written August 11, 2005. That was a very good day!*

Analysis is just starting: first we need to understand the beam and beamline.

*You have no idea…

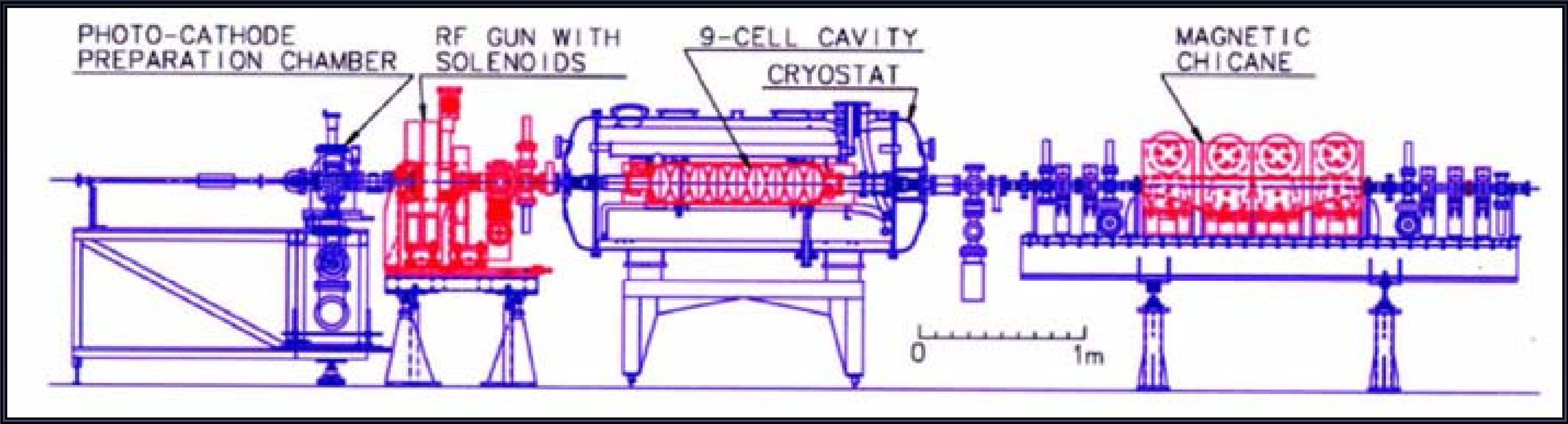
Measuring electrode positions



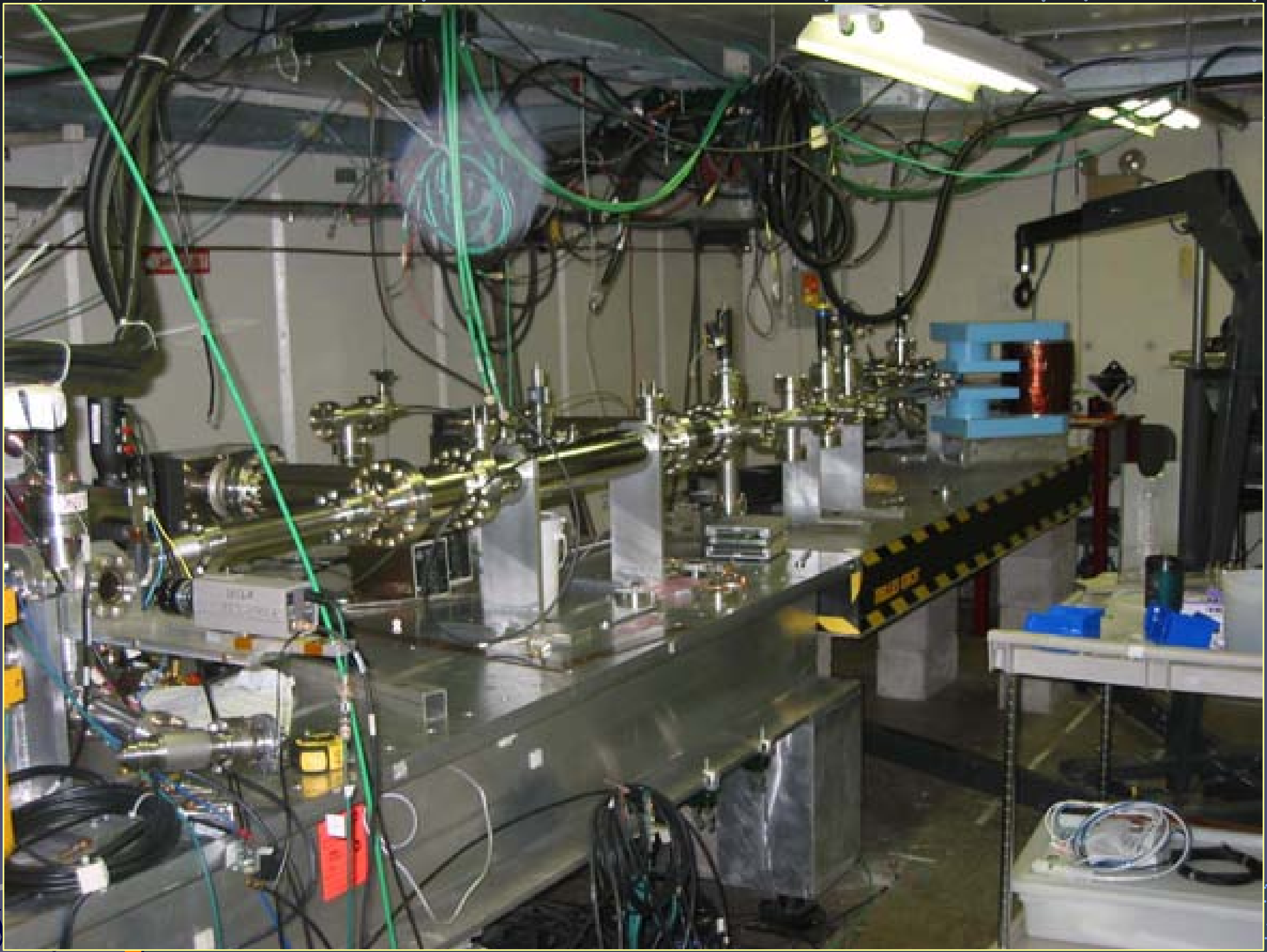
Installing ion pumps

Test it in the FNAL A0 photoinjector beam

16 MeV electron beam, good spot size, so-so emittance.



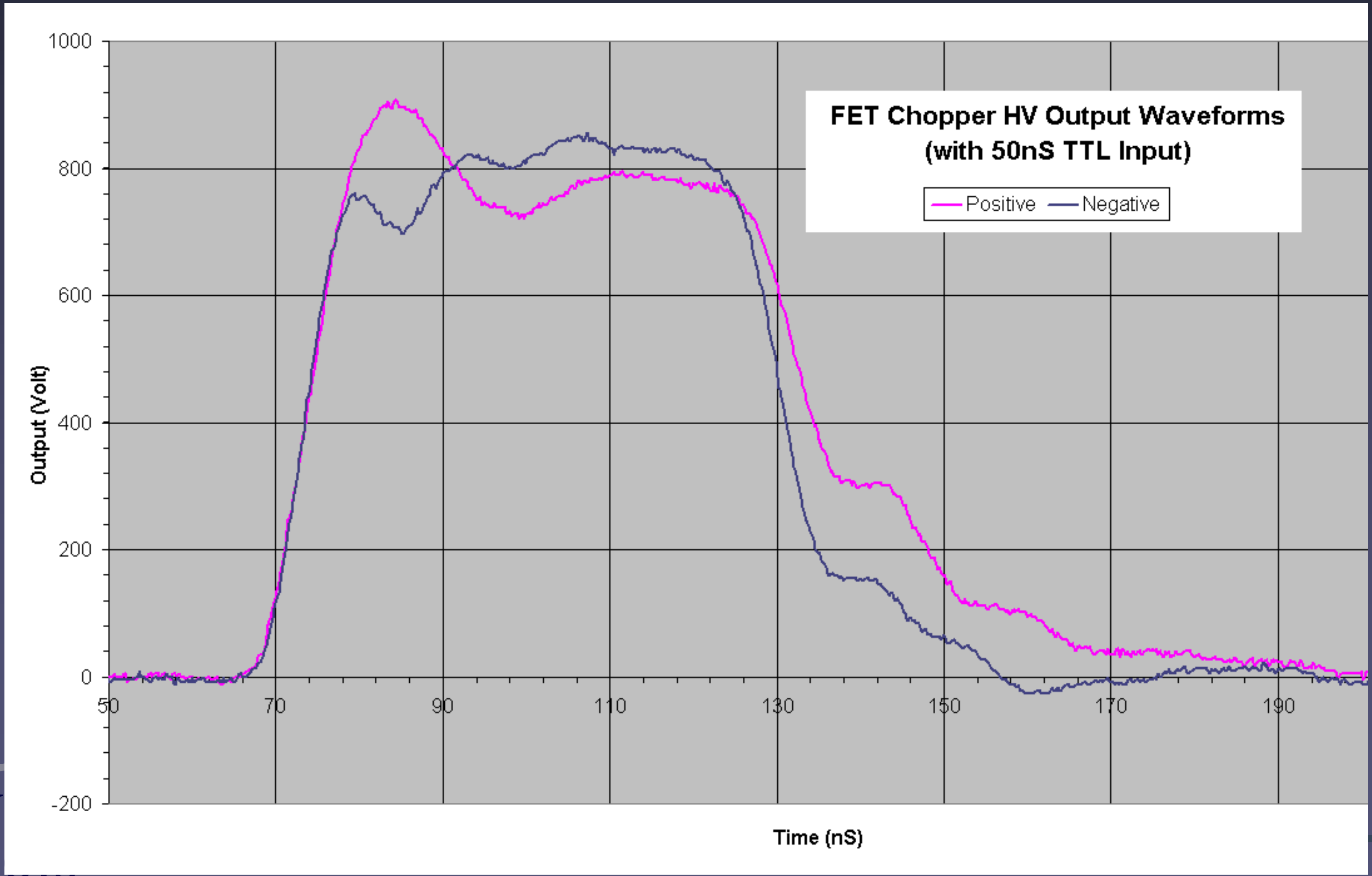
Kicker installed in A0



HV pulsers

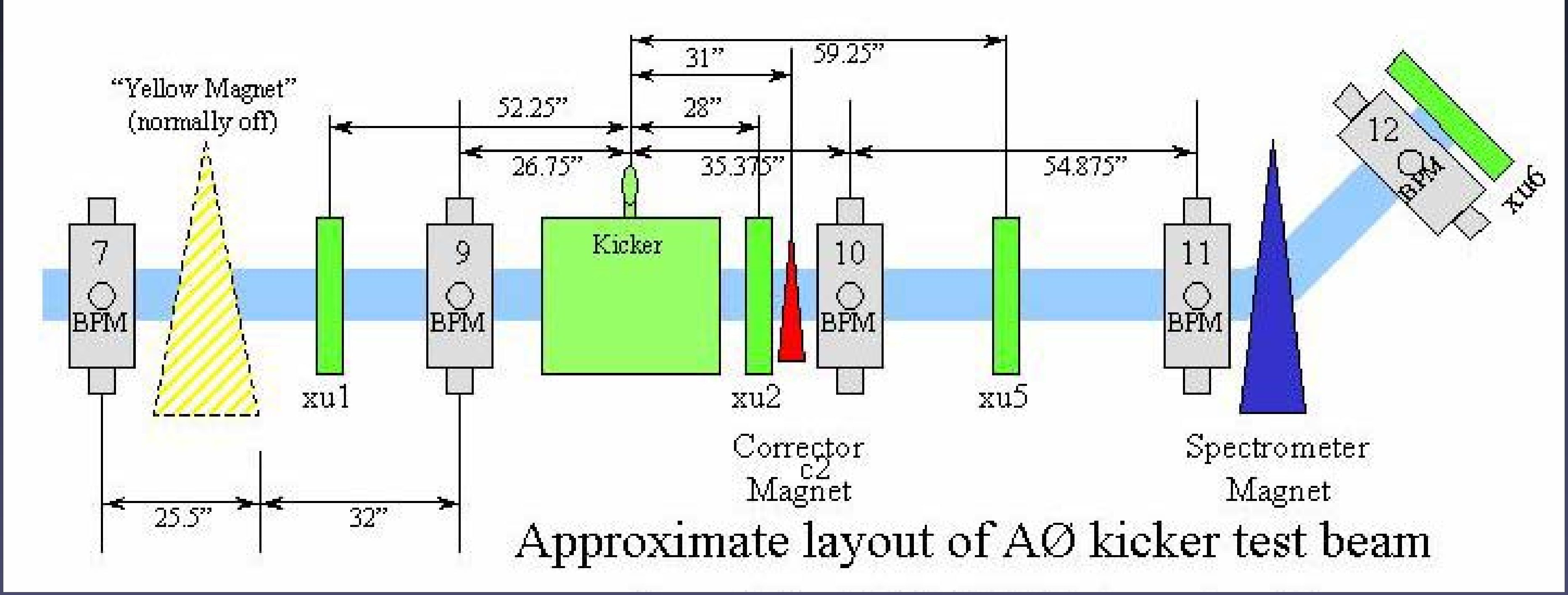
Start with a Fermilab linac chopper HV pulser: ±800 V.

Chris Jensen and colleagues built it.



A0 control room

Our part of the beamline, schematically



We took data intended to map out effects of yellow magnet fringe fields, kicker impulse stability,corrector magnet deflection, spectrometer magnet fringe field effects, BPM resolution,…

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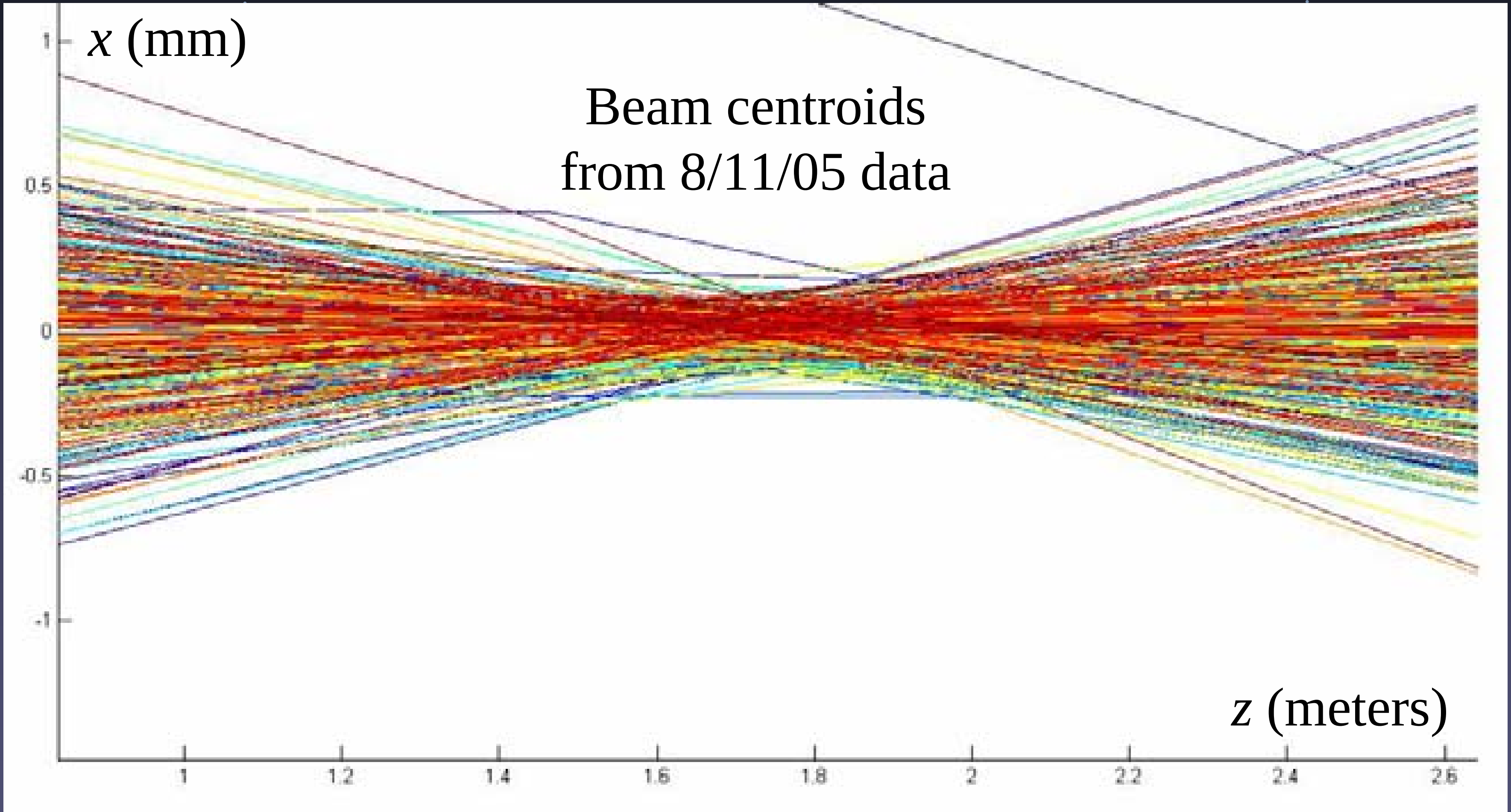
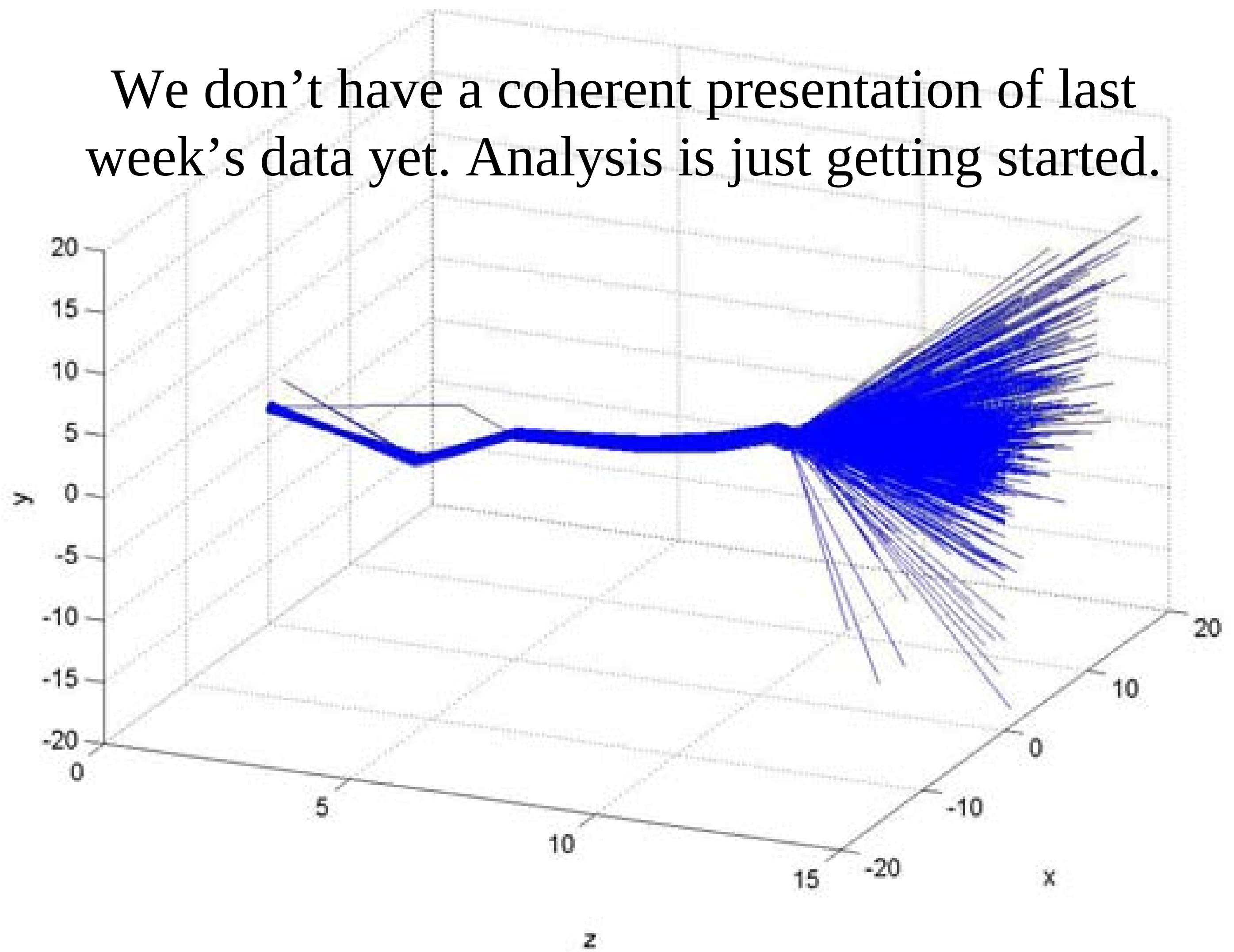
Horizontal beam focus at kicker center



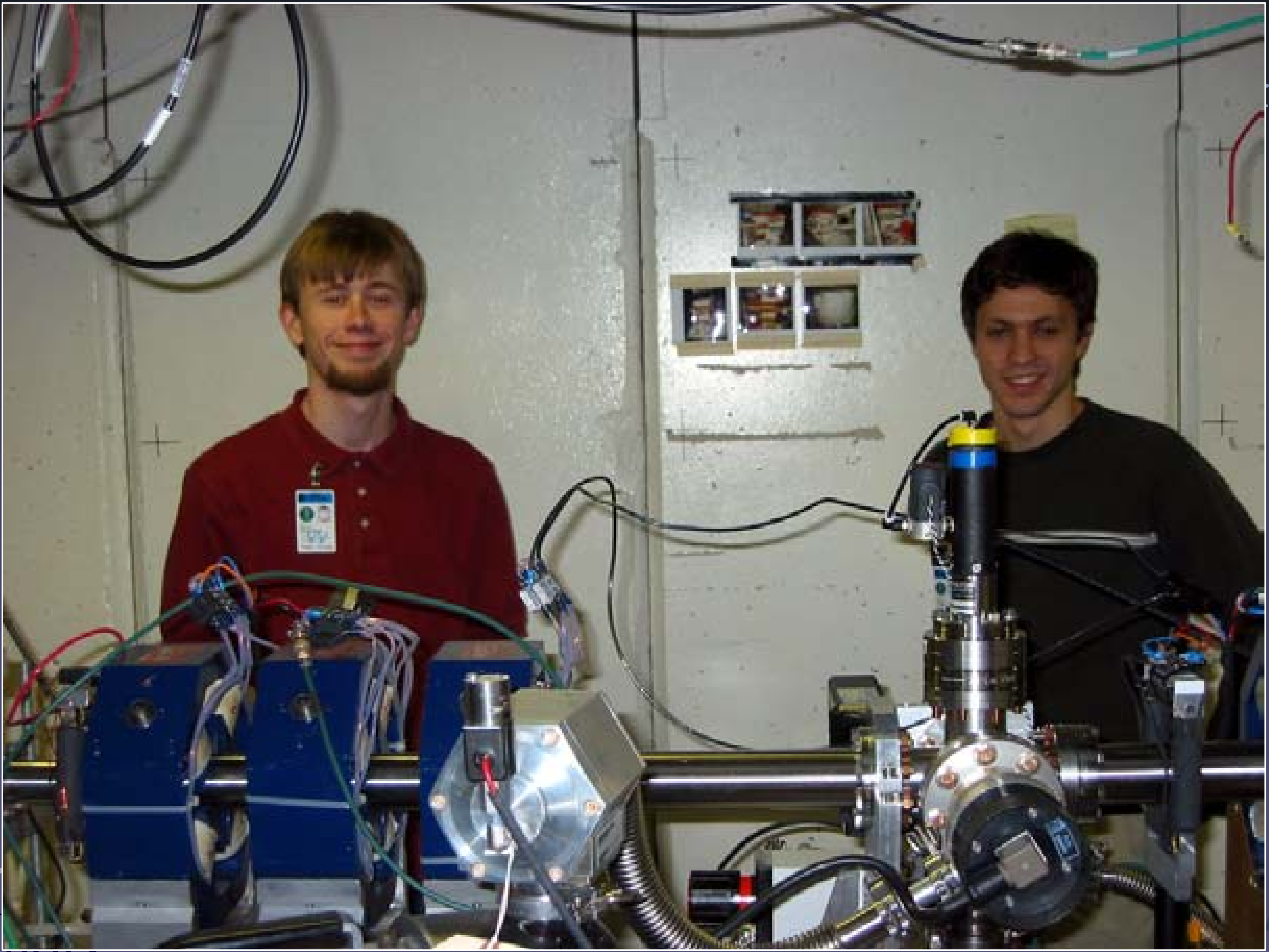
This is adjusted with upstream quads, of course.

Old data

We don’t have a coherent presentation of last week’s data yet. Analysis is just getting started.



UIUC students in A0



Data

61 runs, 200 MB

Small data sample! Analysis done in MatLab

We have a Monte Carlo too.

Everything runs on our laptops, so we bought a new computer:

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Next step: FID pulser

Gerry Dugan has ordered a FID pulser:

- Maximum output into 50 Ohm: ±1 kV
- Amplitude stability in burst mode 0.3 – 0.5%
- Pre- and after-pulses 0.3 – 0.5%
- Rise time 10-90% of amplitude 0.6 – 0.7 ns
- Pulse duration at 90% of Umax 2 – 2.5 ns
- Fall time 90-10% of amplitude 1 – 1.5 ns
- Maximum PRF in burst mode 3 MHz
- Maximum PRF in continuous mode 15 kHz
- Timing jitter, both output pulses vs. trigger 20 ps, max
- Power 110/220VAC, 50/60 Hz

UIUC/FNAL, longer term plans

Analyze kicker data, see what we need to do to make a precise characterization of stripline kicker performance, then run more.

Check out the FID pulser

Continue with RF studies, attempting to make something that will demonstrate pulse compression on the bench

Design, then build a FSPCK module using existing components

Fermilab RF group is involved