University Based Linear Collider Accelerator R&D

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Can university groups do accelerator physics?

Accelerators are BIG, EXPENSIVE devices.

Many university HEP groups have concentrated on <u>detector</u> projects, perhaps because they believe these are:

- more suitable in scale for a university group than would be an accelerator physics project
- more practical, given their prior experience in detector development.

Is this really true? Should university groups stay away from accelerator physics projects?

Of course university groups can do accelerator physics!

There are interesting, important projects whose scope is ideal for a university group.

The (inter)national labs welcome our participation and will help us get started, as well as loaning us instrumentation.

Many projects involve applications of classical mechanics and classical electrodynamics. These are perfect for bright, but inexperienced undergraduate students.

The projects are REALLY INTERESTING. (Also, it's fun to learn something new.)

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Recent U.S. history concerning university R&D

January, 2002:

- most university LC groups were already affiliated with SLAC; most were doing detector simulations.
- there was little planning underway to attract new groups (for example, with Fermilab orientations).

April - May, 2002 workshops at FNAL, Cornell and SLAC:

- meetings focused largely on concrete R&D topics
- almost no Higgs sensitivity *vs*. stuff talks

Fermilab, Cornell, SLAC workshops

Tom Himel (SLAC) was the hero of the workshops: he assembled "The List" of ~110 accelerator projects, including both NLC and TESLA topics. It's full of great stuff.

www-conf.slac.stanford.edu/lcprojectlist/asp/projectlistbyanything.asp

These workshops led to a 50% increase in U.S. university participation in LC R&D.

About half of the new participants took on accelerator projects!

An example from Himel's list…

ID 61 project_size Medium skill_type physicist

short project description Acoustic sensors for structure and DLDS breakdown

Detailed project description understand the acoustic emissions from breakdowns and how the sounds propogate so that the use of acoustic sensors can improved in diagnosing breakdowns.

Needed by whom NLC and TESLA

present status In progress, help needed

Needed by date 6/1/2003

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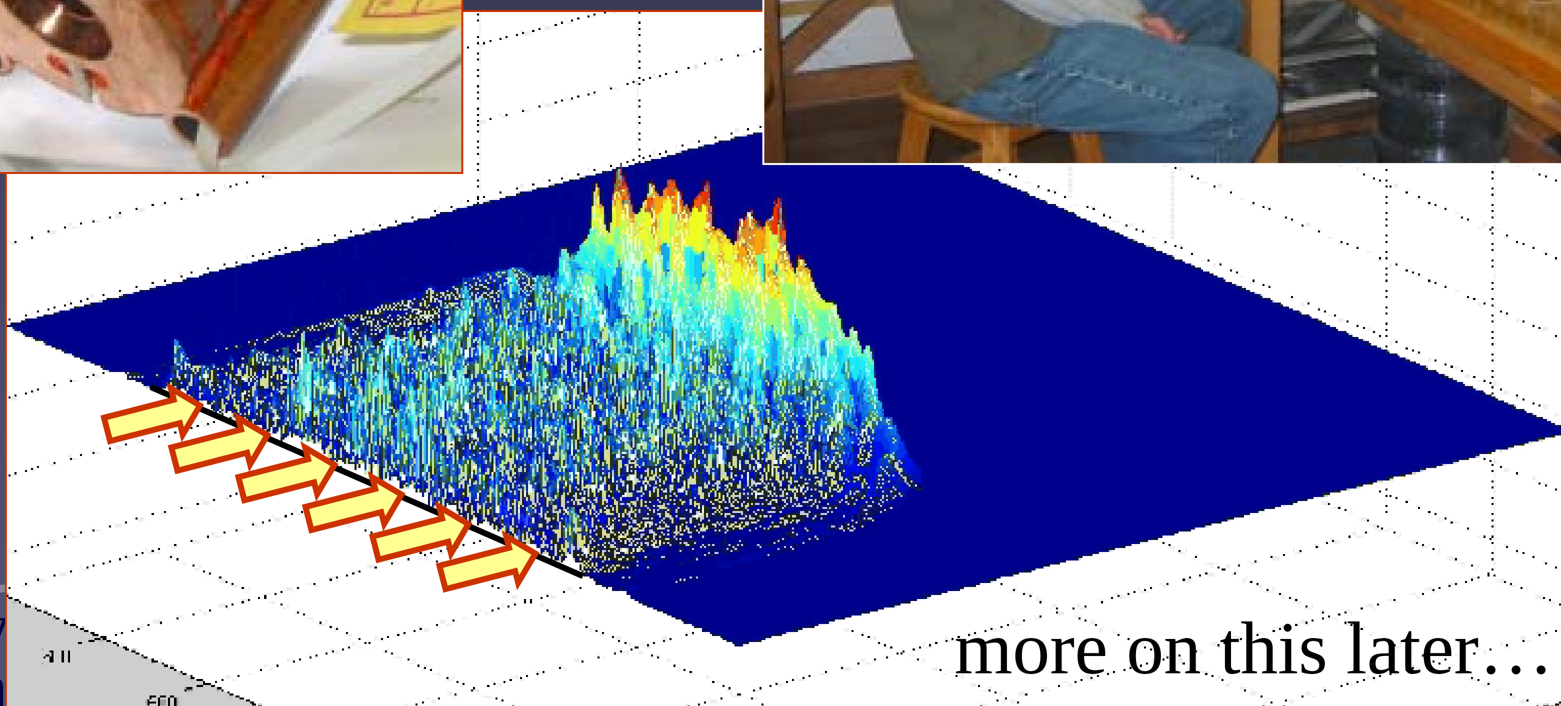
…and what we've been doing with it



more on this later…

We organized ourselves.

A University Program of Accelerator and Detector Research for the Linear Collider

University Consortium for Linear Collider R&D

and

Linear Collider Research and Development Working Group

October 22, 2002

…renewal submitted November, 2003

The result:

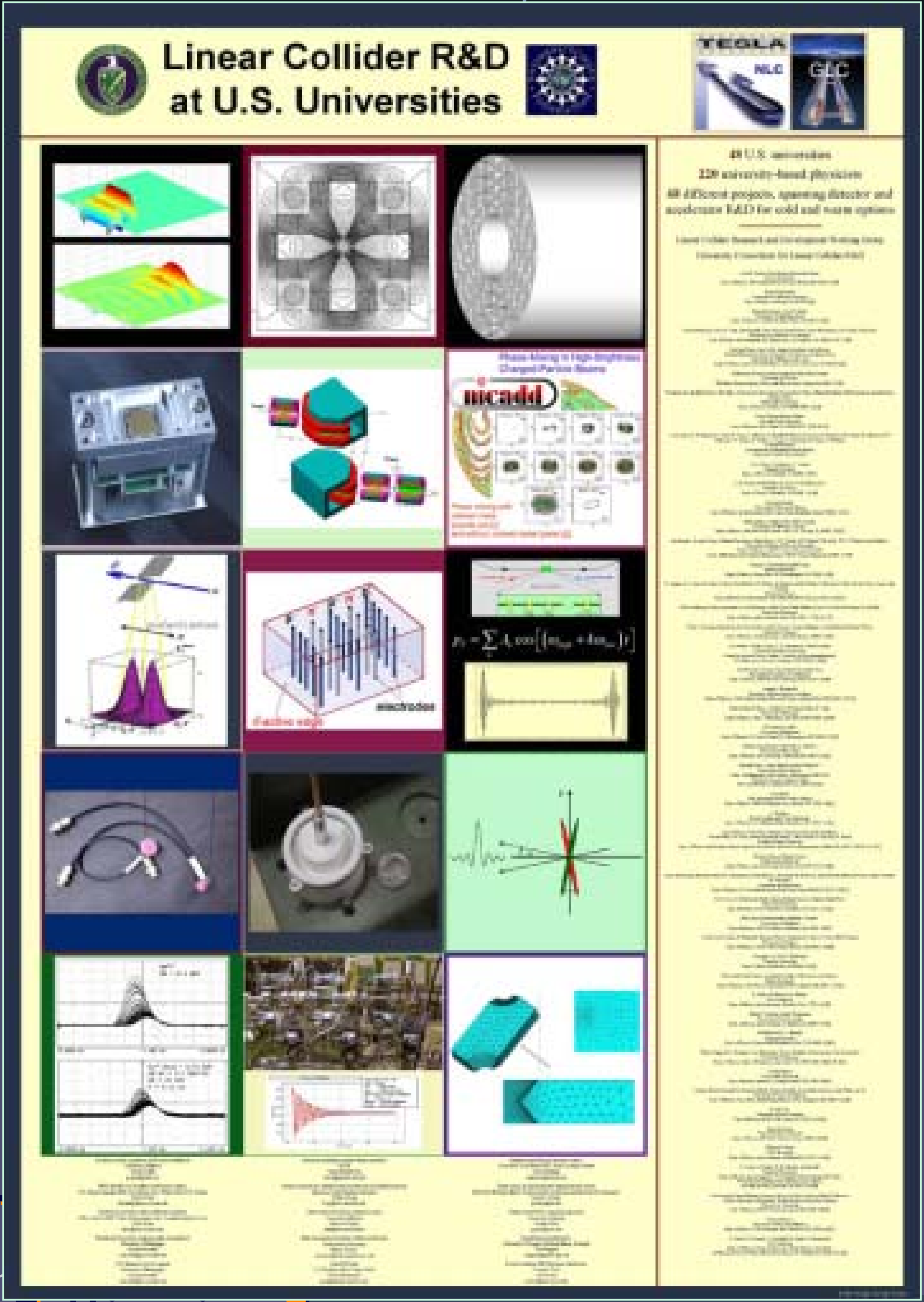
- 71 new projects
- 47 U.S. universities
- 6 labs
- 22 states
- 11 foreign institutions
- 297 authors
- 2 funding agencies
- two review panels
- two drafts
- 546 pages
- 8 months from t_0

Funded by NSF* and DOE

*planning grant only

Scope of U.S. university work in this initiative

proposals to DOE + NSF	# (03)	$ (03)	# (04)	$(04)
Accelerator Physics	33	$1,003 k	29	$1,151 k
Luminosity, Energy, Polarization	9	$171 k	9	$238 k
Vertex Detector	3	$119 k	3	$173 k
Tracking	11	$396 k	11	$597 k
Calorimetry	12	$515 k	13	$855 k
Muon System and Particle ID	3	$149 k	3	$194 k
Total	71	$2,354 k	68	$3,208 k
Funding received from DOE		~$900 k		$900 k (pending)
Funding received from NSF		$150 k		



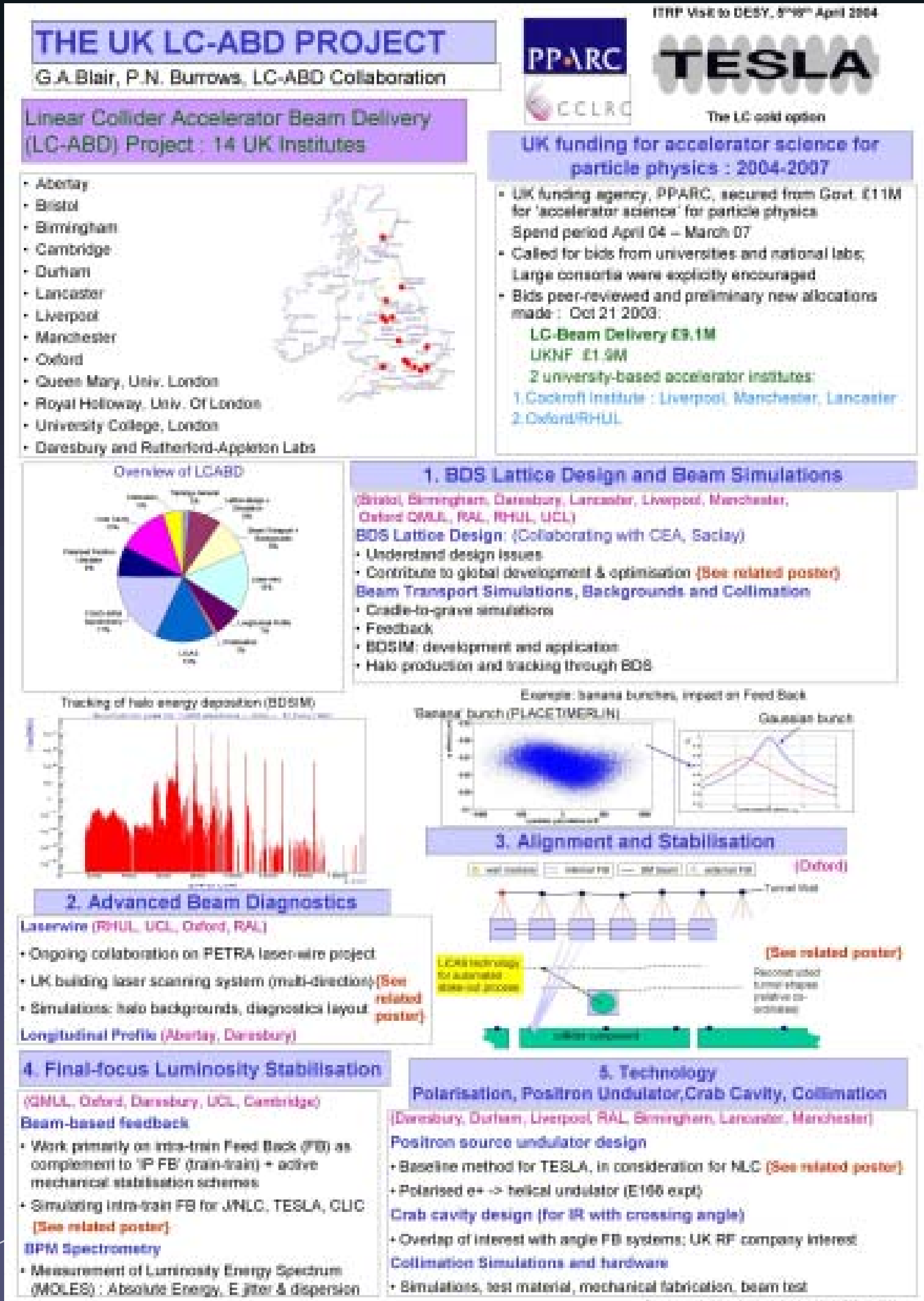
Here come the professors!

Faculty of the world unite!

Self-organizing efforts seem entirely possible.

participants

graphics from 15 of 68 projects



LC at U.K. universities

Coherent effort to address beam delivery system issues.

Very good idea: technology-neutral, important, and done cooperatively nationwide.

Information about particular projects

Physicists in Africa, Asia, Europe, North, and South America participate in accelerator and detector projects.

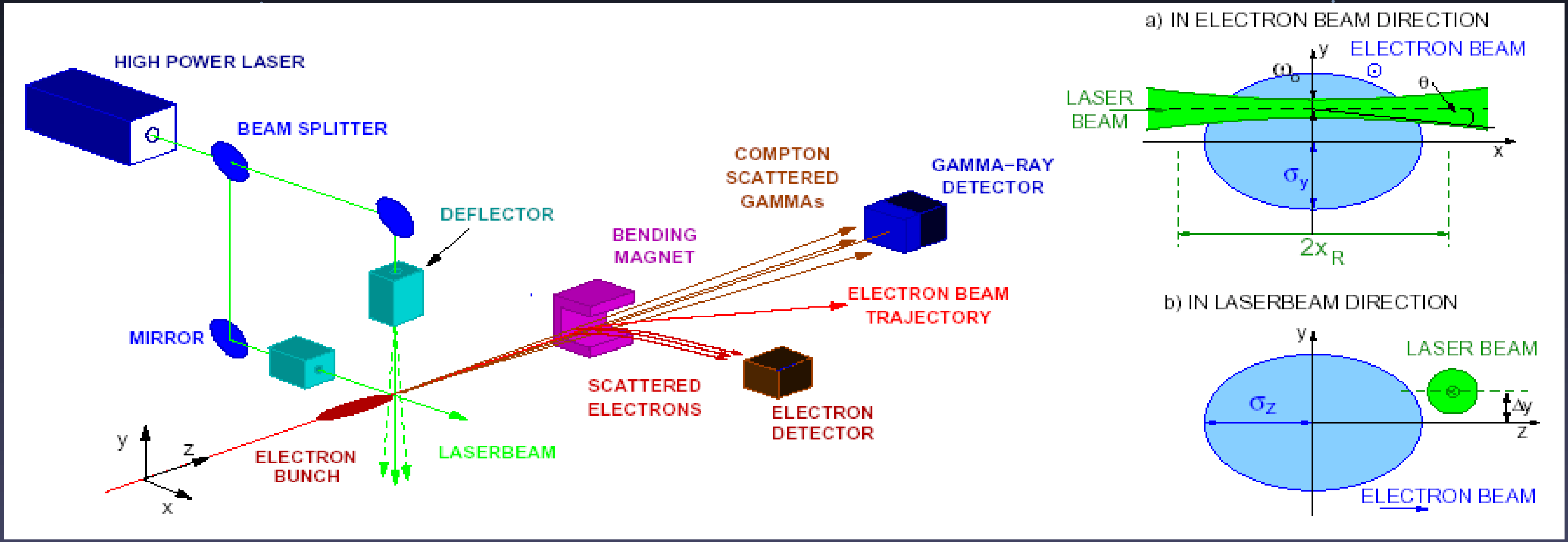
That's too much to cover in a 15 minute talk!

Let's look briefly at a handful of accelerator projects, then in more detail at one of them.

I wish I had enough time to say something about each of them.

Laserwire beam diagnostic tool

(Grahame Blair: Royal Holloway, with several collaborating institutions)



Tightly focused laser beam is scattered by electrons.

Laser is scanned across electron beam path to measure beam properties.

Working on laser stability, and so forth now.

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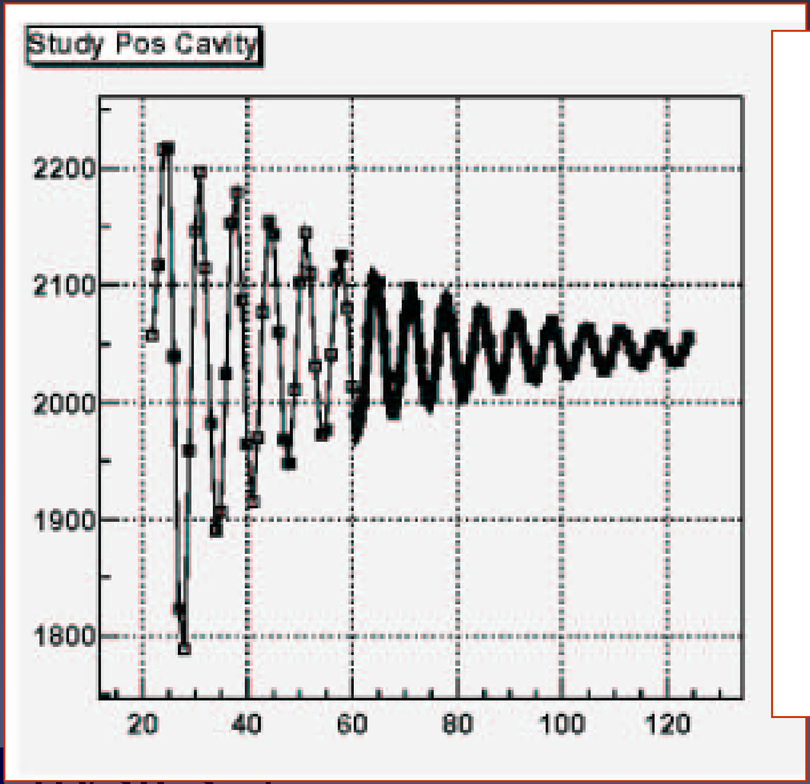
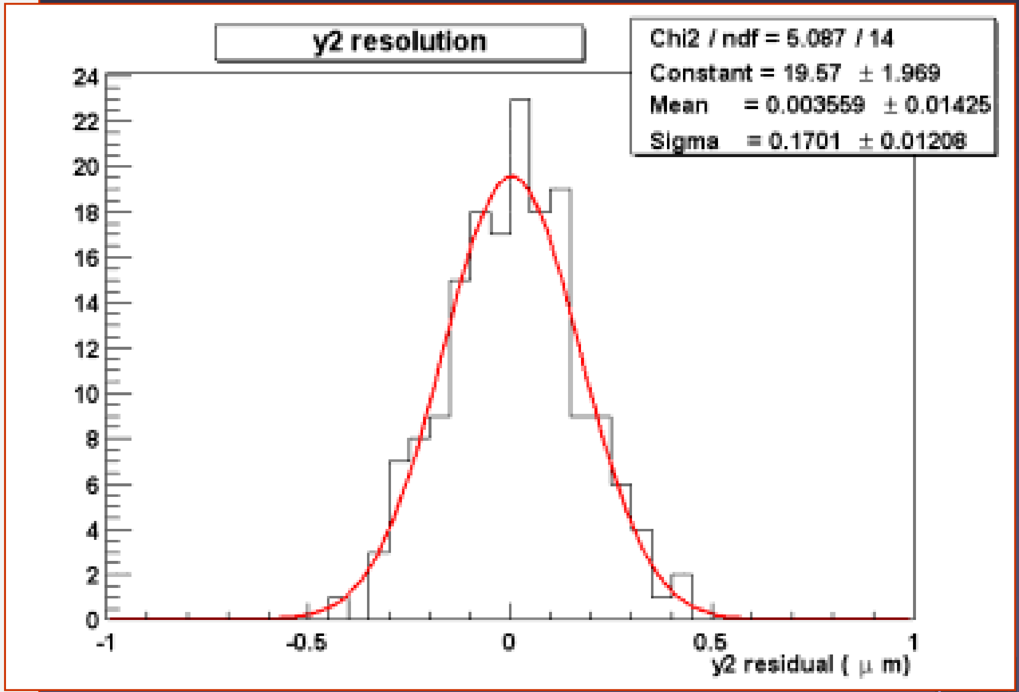
RF Beam Position Monitors for Measuring Beam Position and Tilt

(Yury Kolomensky, UC Berkeley)

Analysis of test beam data from KEK ATF using SLAC-built device.

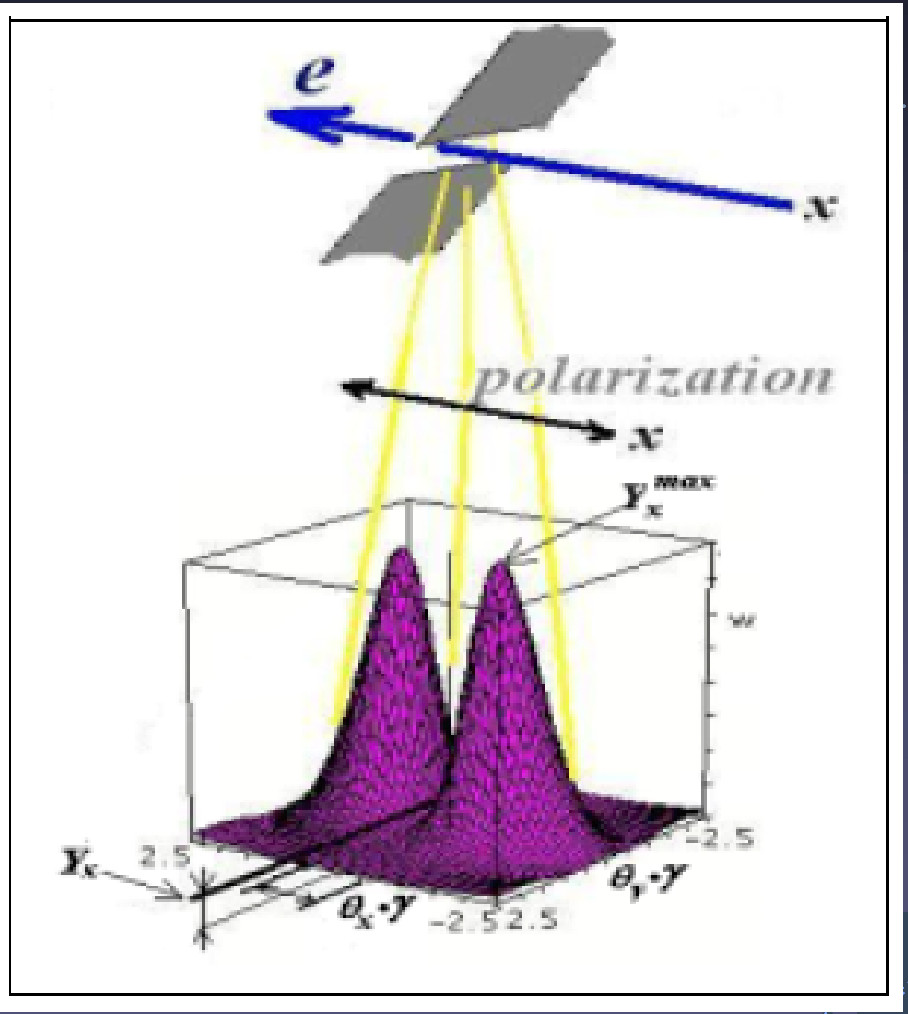




Beam Test Proposal of an Optical Diffraction Radiation Beam Size Monitor at the SLAC FFTB

(Yasuo Fuki, UCLA)

Simulation work so far.

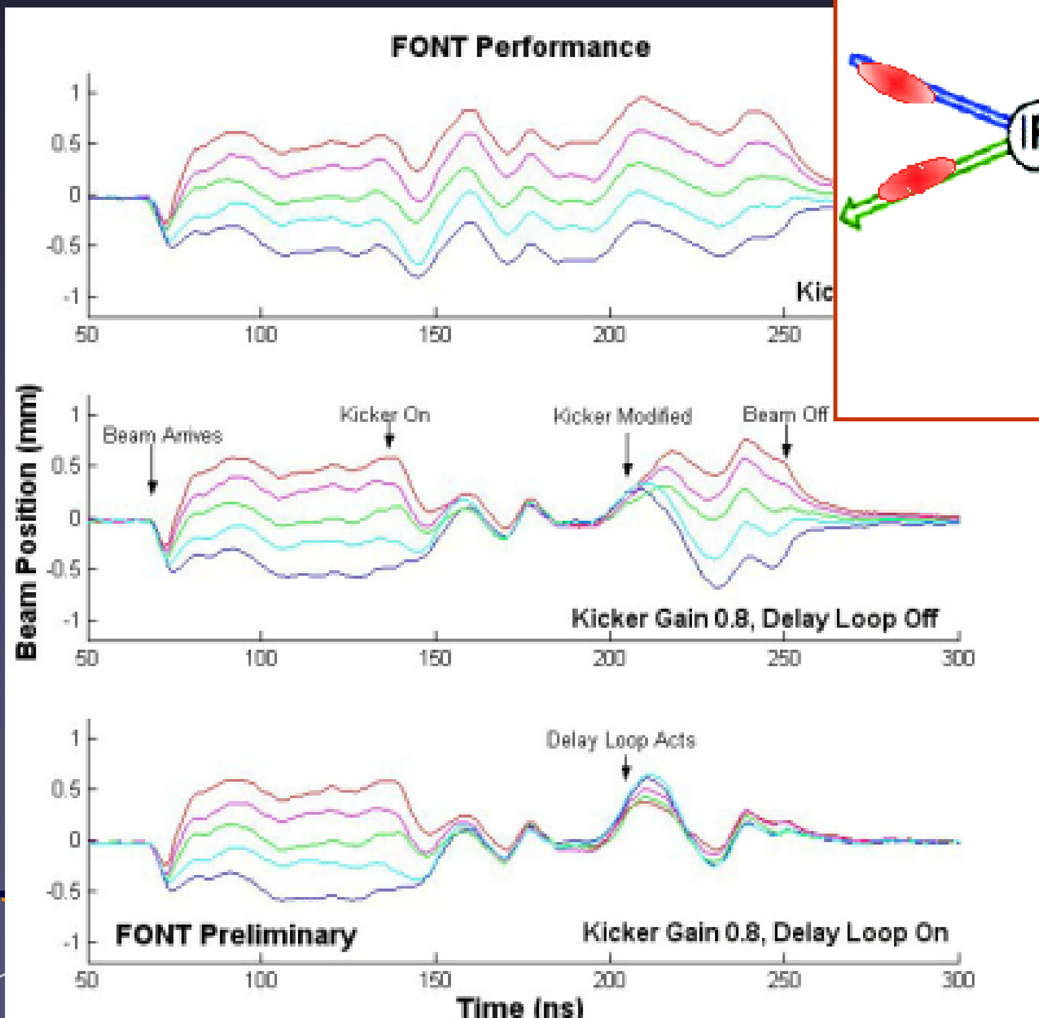


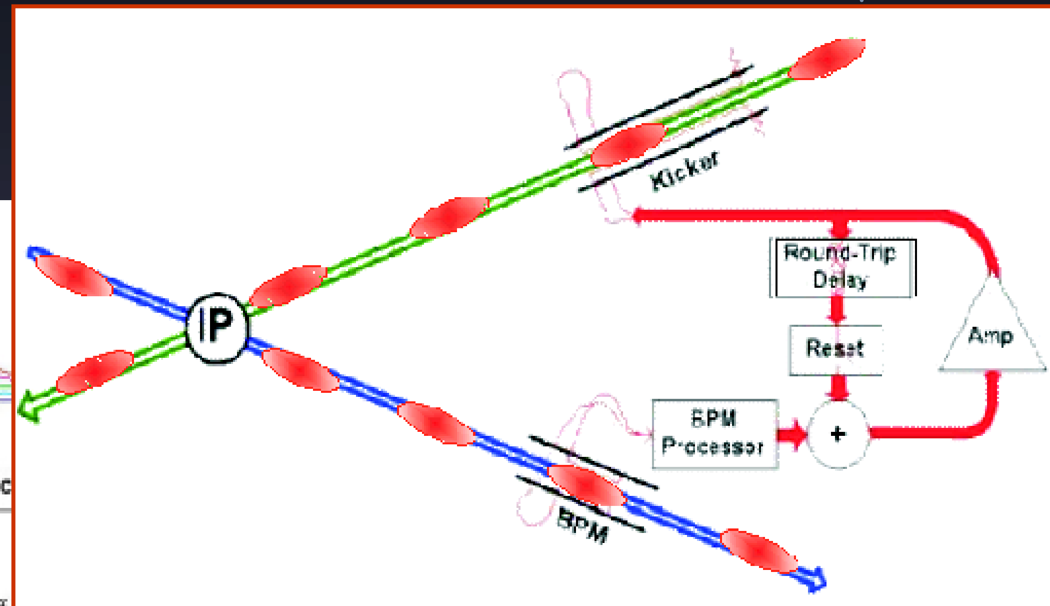
ODR Yield in 0.1/γ angle range

σ: rms transverse beam size

Feedback on nanosecond timescales (FONT)

(Phil Burrows: Queen Mary, Daresbury, Oxford, SLAC)





Correct incoming NLC beam using measurements of other beam after it has passed through the IR.

NLCTA results: it works!

Fast Synchrotron Radiation Imaging System for Beam Size Monitoring

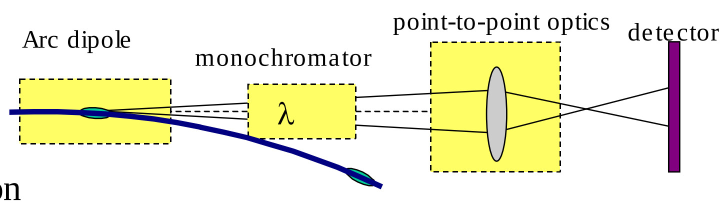
(Jim Alexander, Cornell; Jesse Ernst SUNY Albany)

Exploring possible parameters, configuration for device.

Design for a Synchrotron Radiation Camera for Beamsize Measurement

Basic concept:

1. Refocus SR in the damping rings to make a projected image of the passing bunch.
2. Diffraction limit on source size forces us into the x-ray regime



Goals:

1. definite: Measure σ_x and σ_y
2. possible: Single-bunch resolution
3. optimistic: Intrabunch measurement (i.e. z)
   - Don't yet know if this will be possible.
   - Still working on ideas for this.

Status:

Have started simple simulations for studying optics and detector choices:

1. Optics
   - point-to-point with sufficient magnification
   - Zone plates are one candidate
2. Detection
   - small pixel array is one candidate

Relevant times

	tesla	***nlc***
cycle	*57us*	*743ns*
interbunch	*20ns*	*1.4ns*
bunchlength	*20ps*	*13ps*

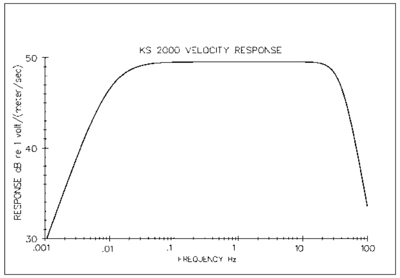
Ground Motion studies versus depth

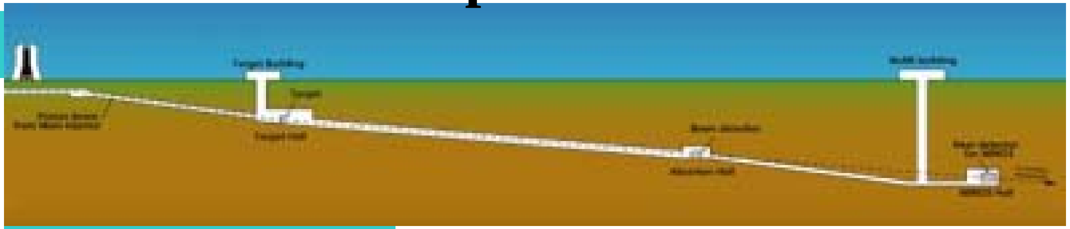
(Mayda Velasco, Northwestern)

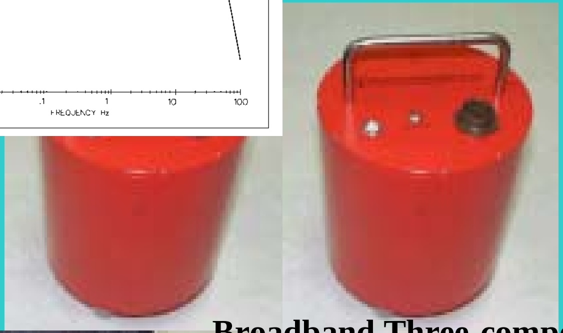
Linear collider R&D: Preparing ground motion study in NUMI

noise versus depth

Equipment ordered by NU (will arrive ~ May 27)







Broadband Three-component Seismometers KS-2000

Portable Data Recorder DL-24

- Northwestern University joined the study, is providing equipment and will participate in the study
- Measurements needed to determine the best depth to locate the next linear collider
- Test at Aurora Mine already done
- Next… Numi Tunnel
  ➔ This was classified as a high priority project (1.5)

Szleper, Velasco, Serye

Ring-tuned, permanent magnet-based Halbach quadrupole

(James Rosenzweig, UCLA)

Progress, both in modeling and in fabrication of prototypes for studies.

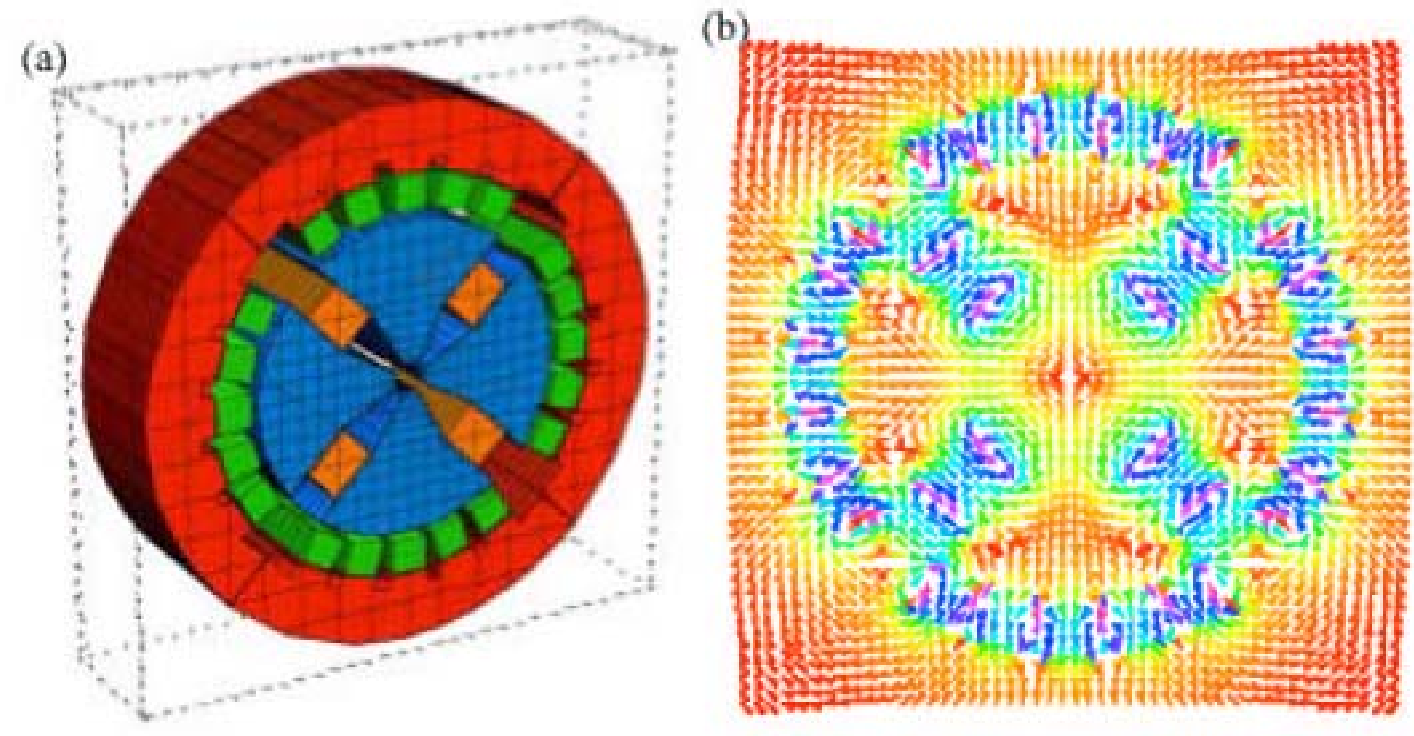


Figure 3. (a) Rendered picture of Halbach ring-tuned permanent magnet-based hybrid quadrupole, from 3D magnetostatic simulation code RADIA. (b) Arrow plot of magnetic field in symmetry plane of the quad.

Design and Fabrication of a Radiation-Hard 500-MHz Digitizer Using Deep Submicron Technology

(K. K. Gan, Ohio State)

Some of the circuit functional blocks have been designed, but none fabricated for test yet.

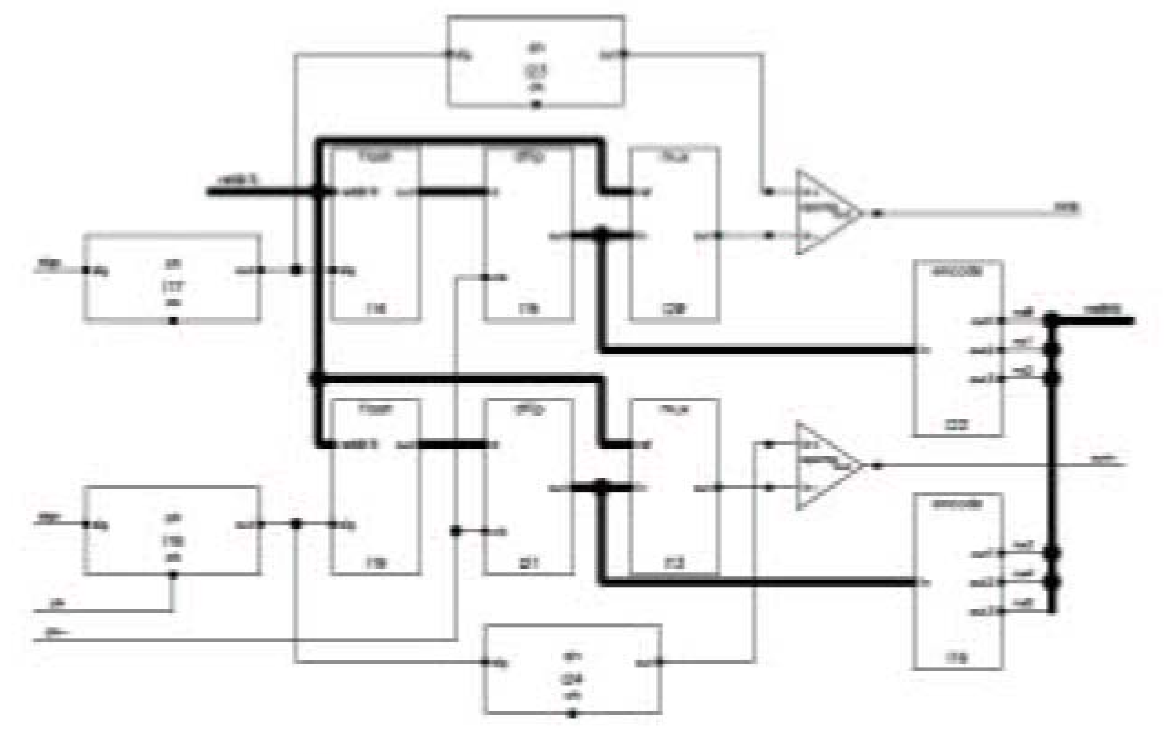


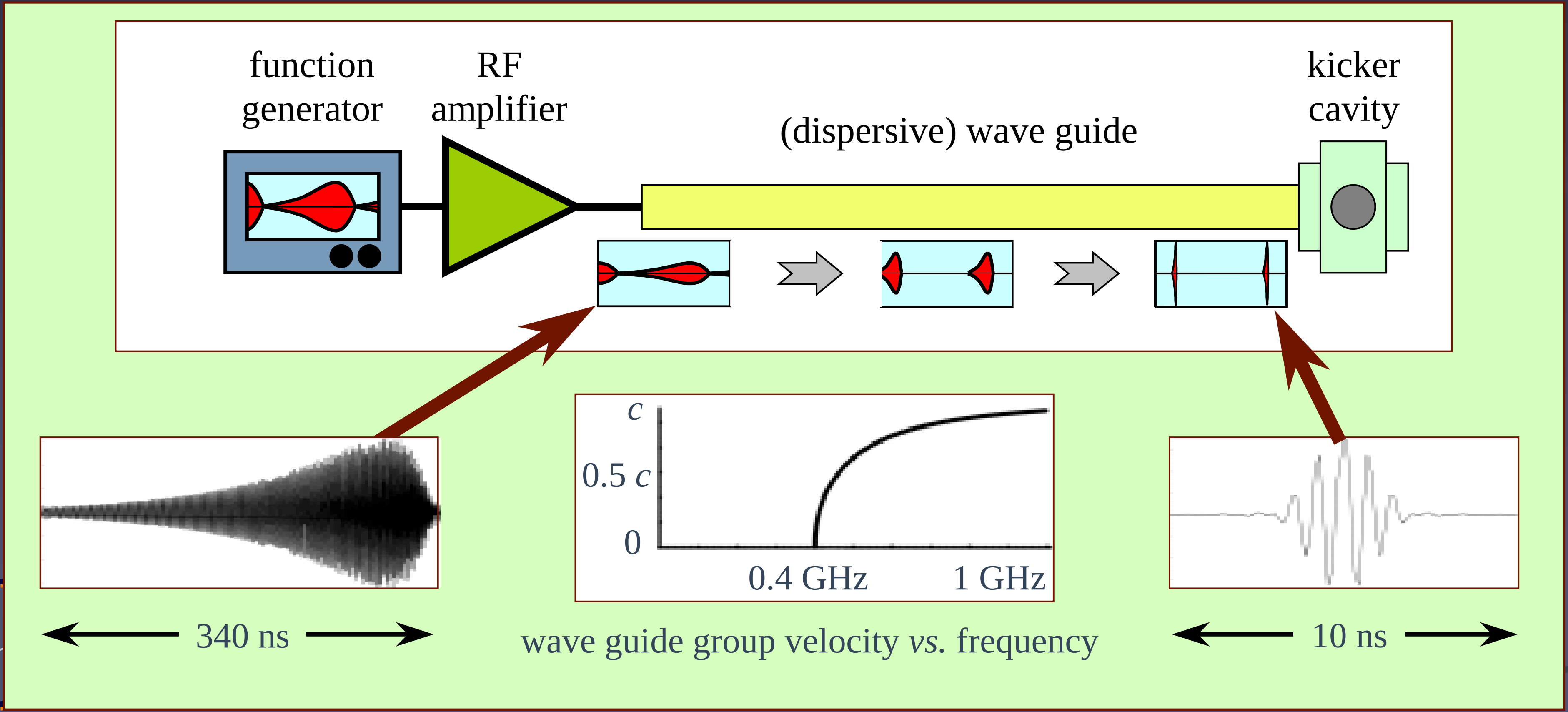
Figure 2. Schematic of a 3-bit cell.

Chirped waveform pulse compression kicker for TESLA damping ring

(Joe Rogers, Cornell)

Dispersive wave guide compresses chirped RF signal.

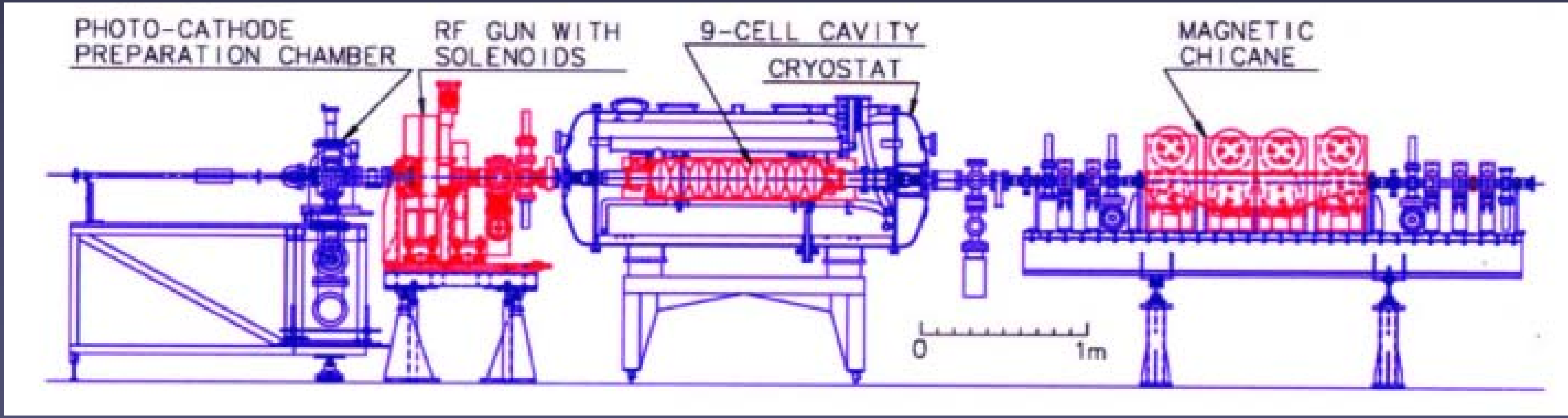
Commercial broadcast RF amplifier ~100kW, but compression generates large peak power for kicking pulse in low-Q cavity.



Fermilab/ Northern Illinois University photoinjector lab

A0 photoinjector lab at Fermilab produces a relativistic (16 MeV now, 50 MeV in a few months), bunched low-emittance electron beam. (It's rather like a TESLA injector.)

This should be an excellent facility for all sorts of device tests as well as beam physics studies!



Investigation of Acoustic Localization of rf Cavity Breakdown

(George Gollin, Univ. Illinois)

Can we learn more about NLC rf cavity breakdown through acoustic signatures of breakdown events?

At UIUC ("UC" = Urbana-Champaign):

- George Gollin (professor, physics)
- Mike Haney (engineer, runs HEP electronics group)
- Bill O'Brien (professor, EE)
- Joe Calvey (UIUC undergraduate physics major)
- Michael Davidsaver (UIUC undergraduate physics major)
- Justin Phillips (UIUC undergraduate physics major)

Marc Ross is our contact person at SLAC.

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Copper dowels from Fermilab NLC Structure Factory

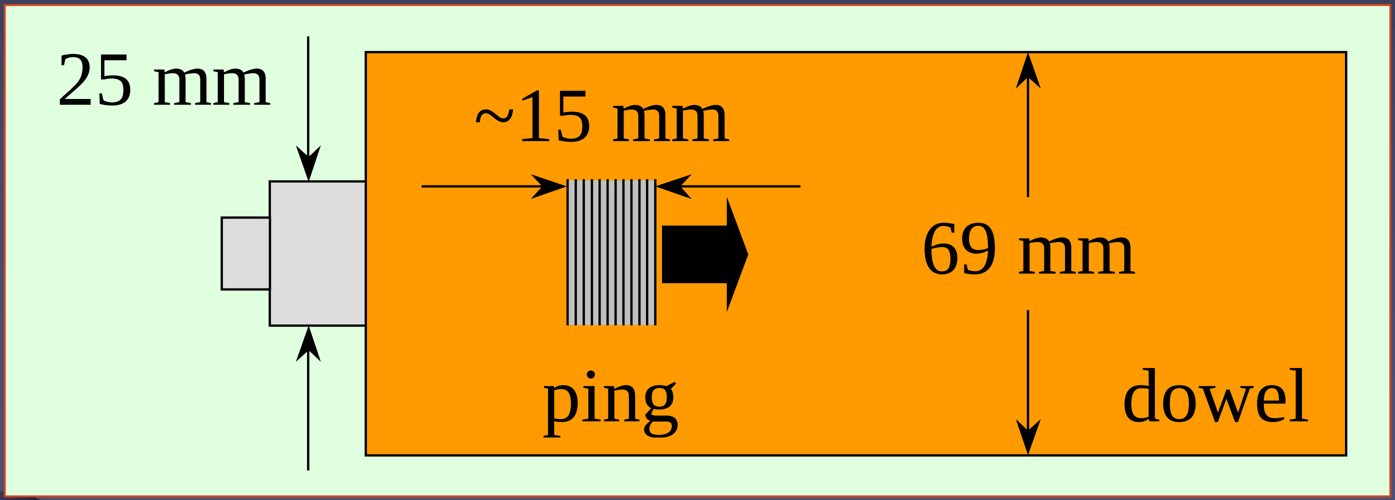
Harry Carter sent us a pair of copper dowels from their structure manufacturing stock: one was heat-treated, one is untreated.

NLC structures are heat-brazed together; heating creates crystal grains (domains) which modify the acoustic properties of copper.

Scattering/attenuation at 1.8 MHz in copper

A "ping" launched into a copper dowel will bounce back and forth, losing energy through

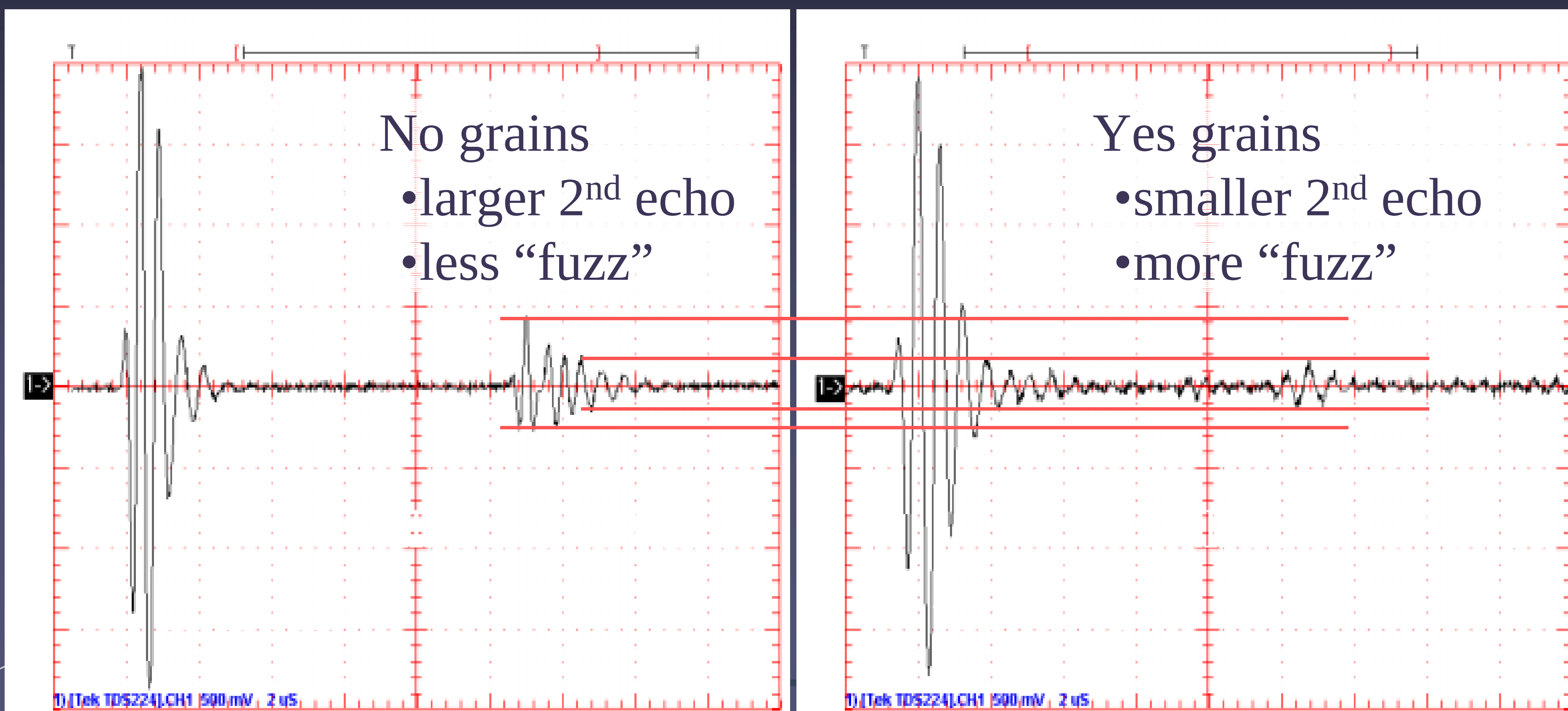
- scattering of acoustic energy out of the ping
- absorption in the transducer
- absorption of acoustic energy by the copper.



Scope shots

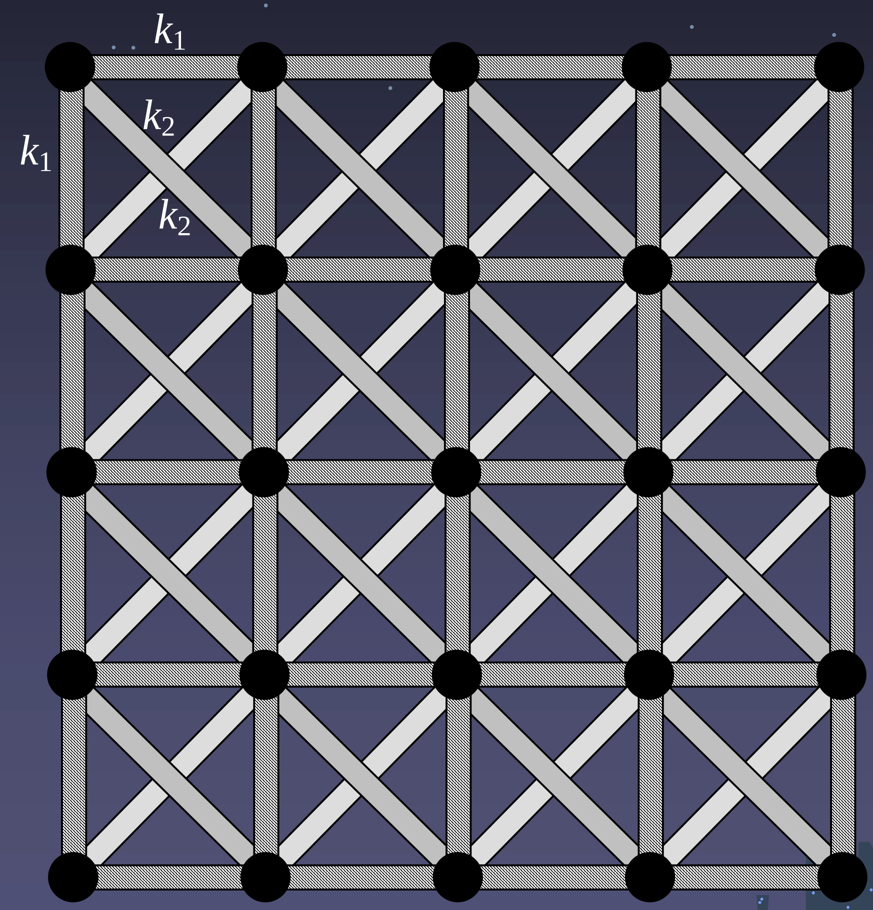
Single transducer: ping, then listen for echoes. Adjust ping energies so that first echoes are approximately equal in amplitude.

Note the difference in sizes of the second echoes as well as the different amounts of baseline activity between the echoes.



Condensed matter modeling, as done by folks in HEP

Initial models: regular (rectangular, 2*D* or 3*D*) grids of mass points connected by springs.

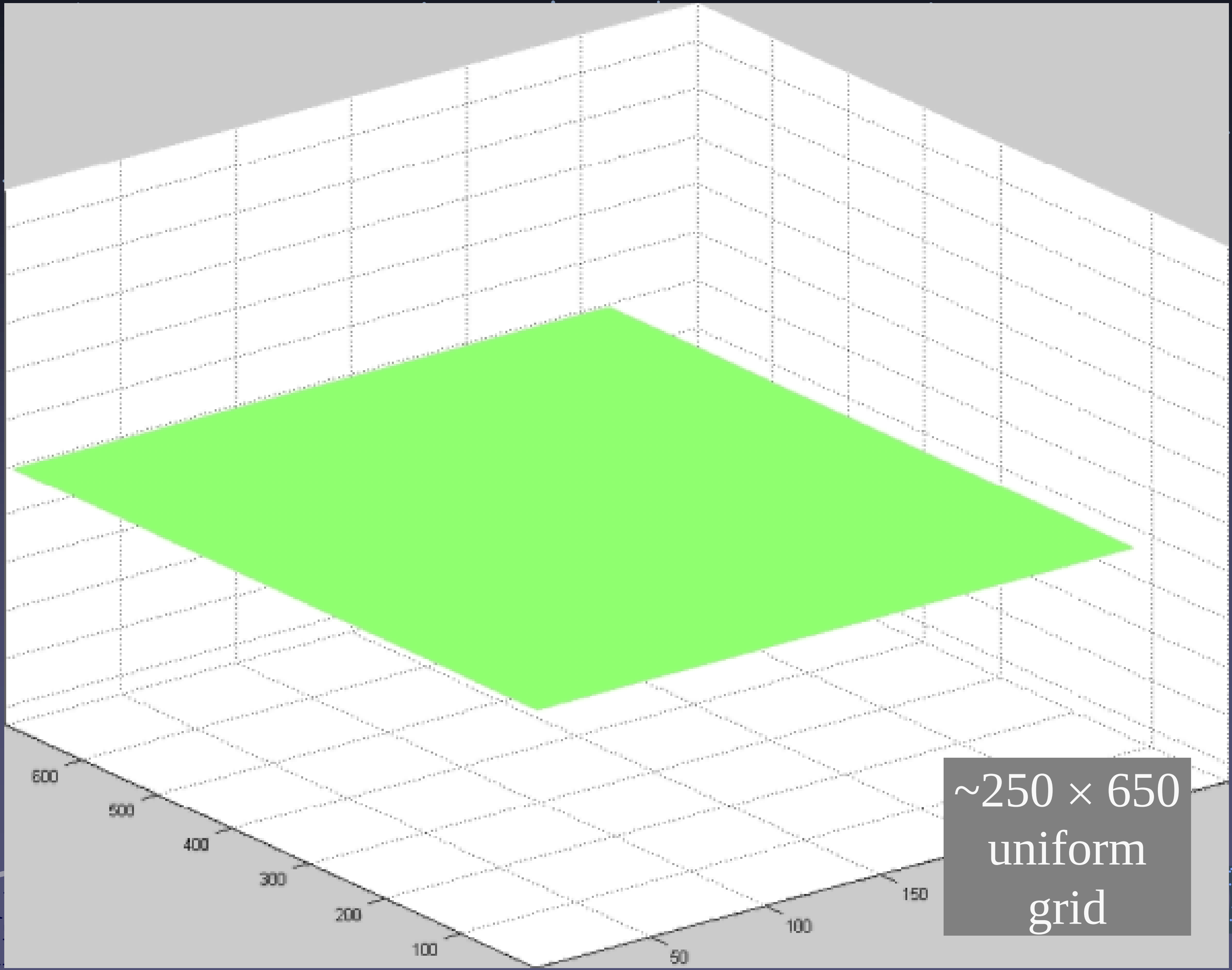


Speeds of propagation for pressure and shear waves are determined by k_1, k_2, and k_1/k_2.

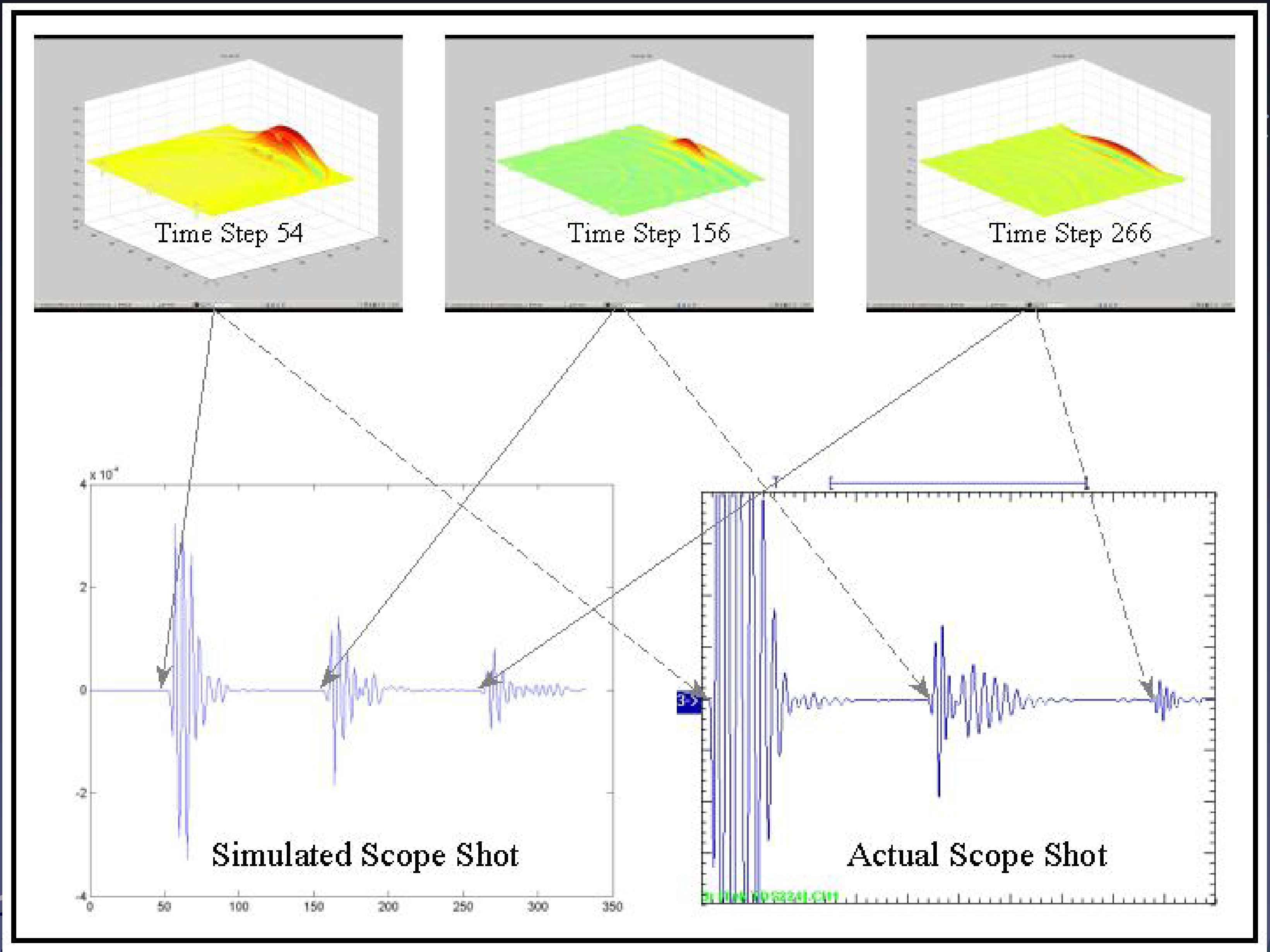
We can vary spring constants arbitrarily.

Grain boundaries are modeled as sets of mass points with different spring constants.

Propagation of a pressure wave in a homogeneous grid

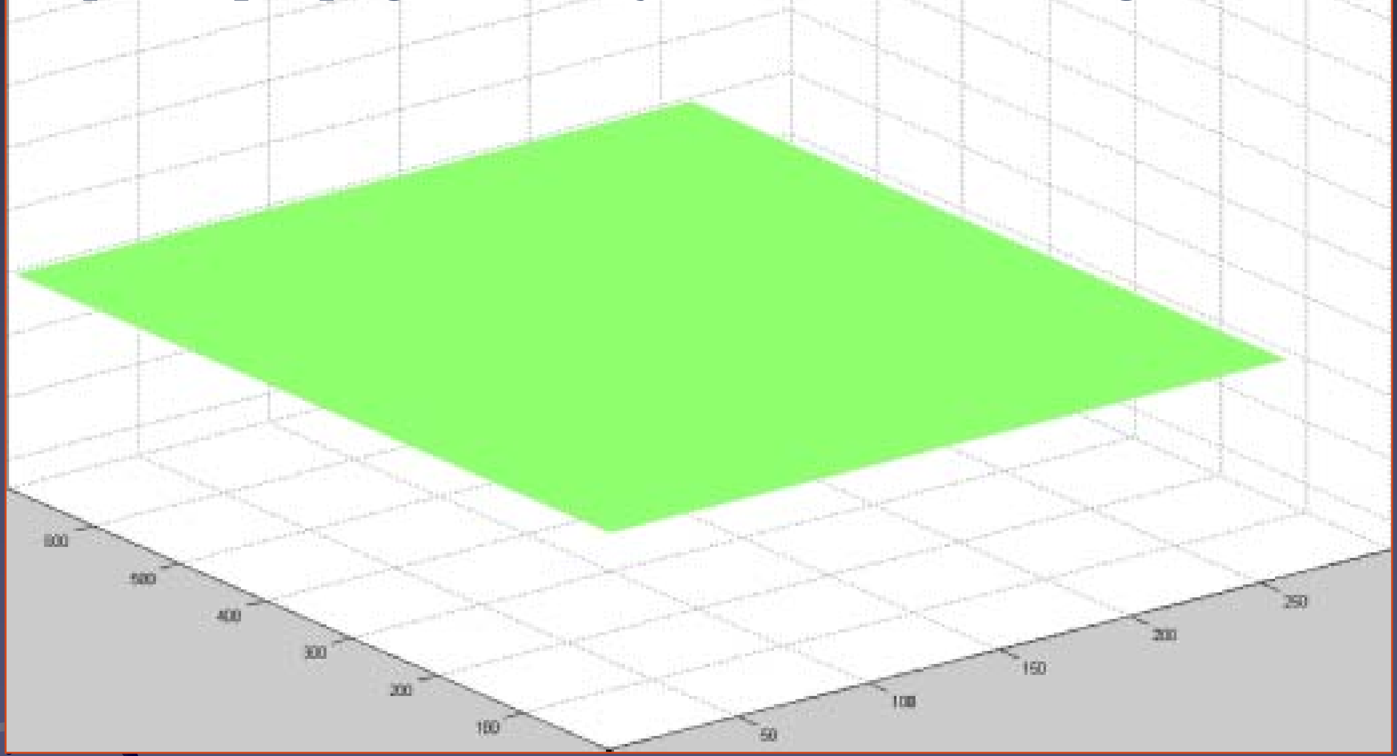


Simulated transducer response



Propagation of a pressure wave through a grainy crystal

Change the spring constants inside thin domain walls around randomly shaped grains to see effects on pulse propagation. Crystal now has 200 grains.



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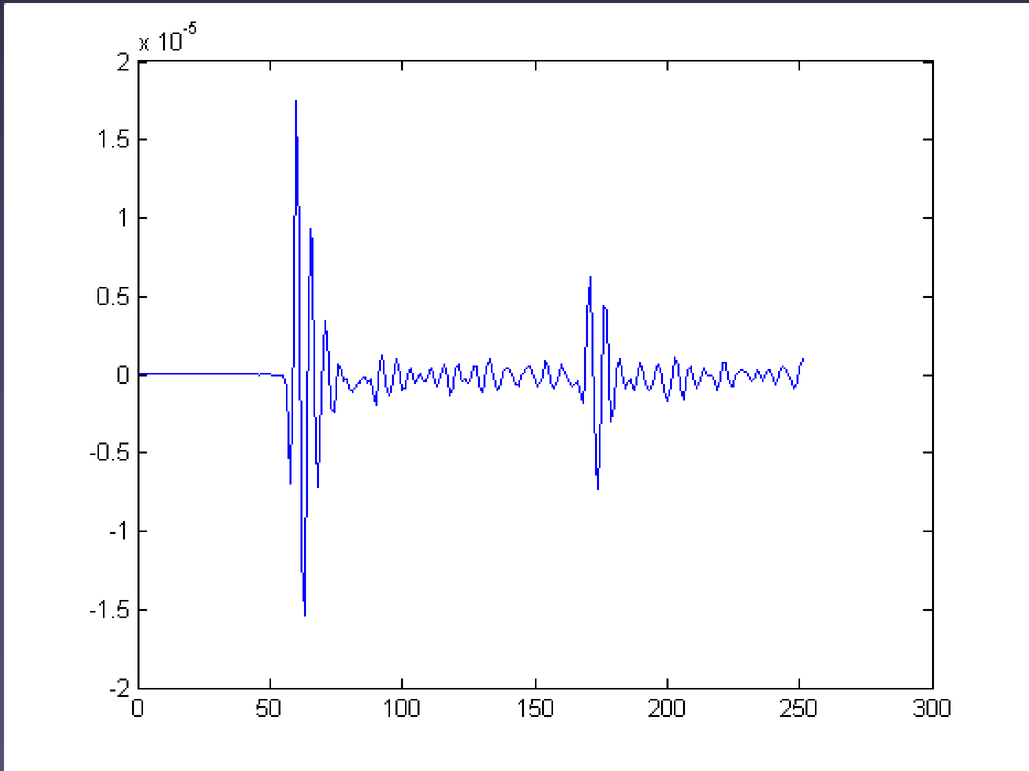
Propagation of a pressure wave through a grainy crystal

Transducer at the far end of the crystal sees direct pulse, then acoustic "glow," then reflected pulse.



What we are working on now

- We have a really good method for placing grains in our simulated copper. We haven't yet worked on selecting parameters to tune the simulation so that it reproduces data.
- Refinement of description of transducer-copper coupling. (Transducer absorbs some of the energy which arrives at its point-of-coupling.)
- Modeling of more complicated (2-*D*, 3-*D*) shapes.
- Porting code to NCSA supercomputers
- Inverting the simulation to uncover what we can learn about the underlying acoustic "event" from sensor data.

We are having a lot of fun (and you can too!)

This particular project is well suited for undergraduate participation.

The students are very good! All three students will continue the work this summer.

We are finding it very natural to work in an area that is new to all of us.

If this summer is as productive as last summer, we will know how much information can actually be derived about breakdowns from acoustic data.

Summary/conclusions

Linear Collider accelerator R&D is a fertile area for university groups. It is too much fun to leave to the accelerator physicists!

Spontaneous organization, without waiting for structure to be imposed from external sources (administrations of large labs, for example), is an effective way to start a new, large, coherent, national R&D effort based at universities.

Realization of the Linear Collider will proceed most smoothly if detector physicists participate actively in the machine design. The accelerator and detector are closely coupled.