Advanced Accelerator R&D

Accelerator Research Departments A & B

Advanced Computations Department (ACD) included as appendix

Presented by:

Mark Hogan, ARDB

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Accelerator Research Department Missions

ARDA Mission:

The ARDA department has two primary missions, which are complementary:

•To support the Accelerator Department and PEP II

•To lay the theoretical and technical foundation for the next generation of particle accelerators.

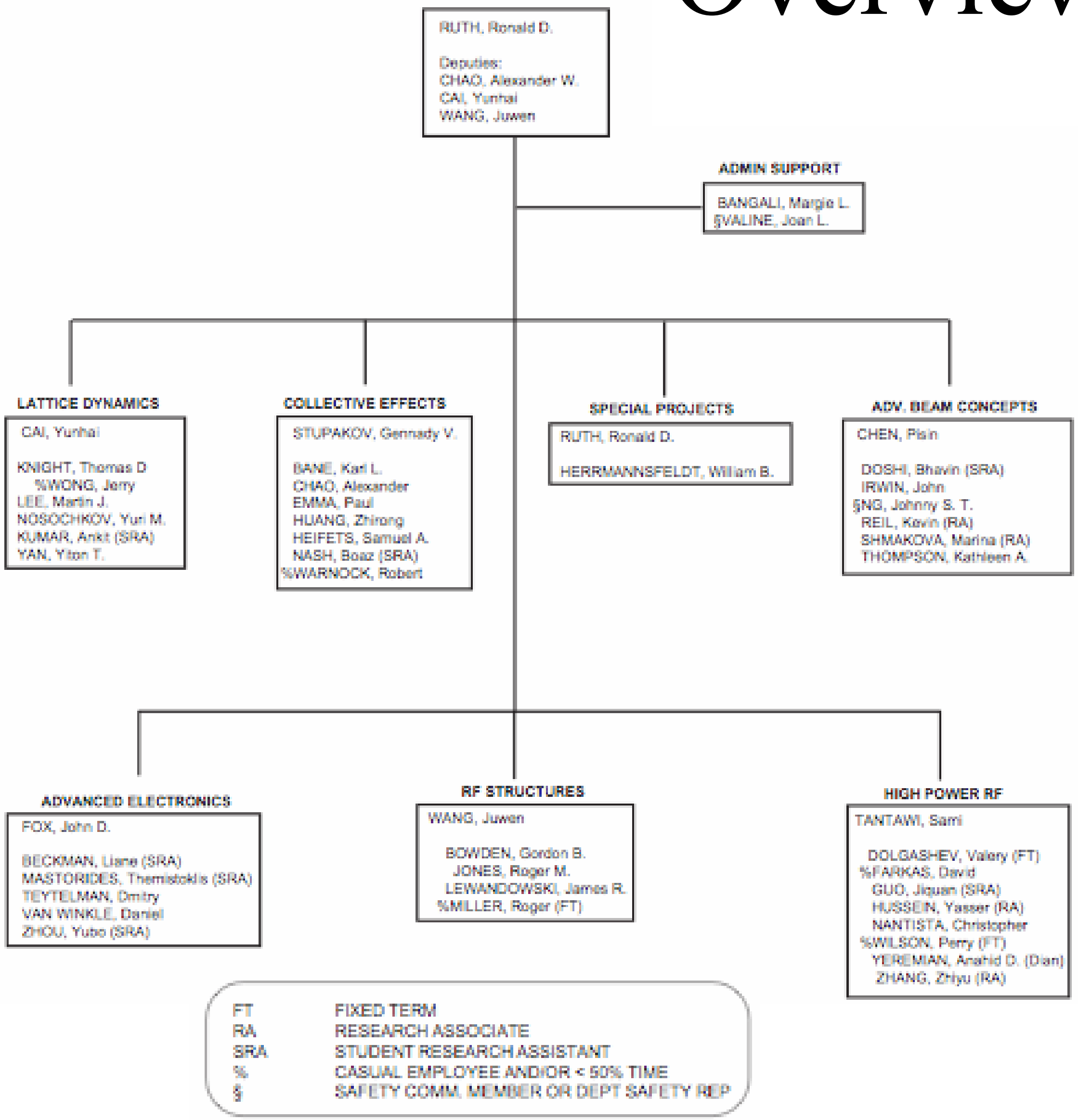
ARDA also participates in special projects designed to advance the state of the art of accelerator physics; for example, the development of the Final Focus Test Beam and the construction of the Next Linear Collider.

ARDB Mission:

ARDB

The primary goal of ARDB research is to push the envelope of advanced accelerator technology, particularly in the areas of high-gradient (>GeV/m) acceleration and low-emittance beams.

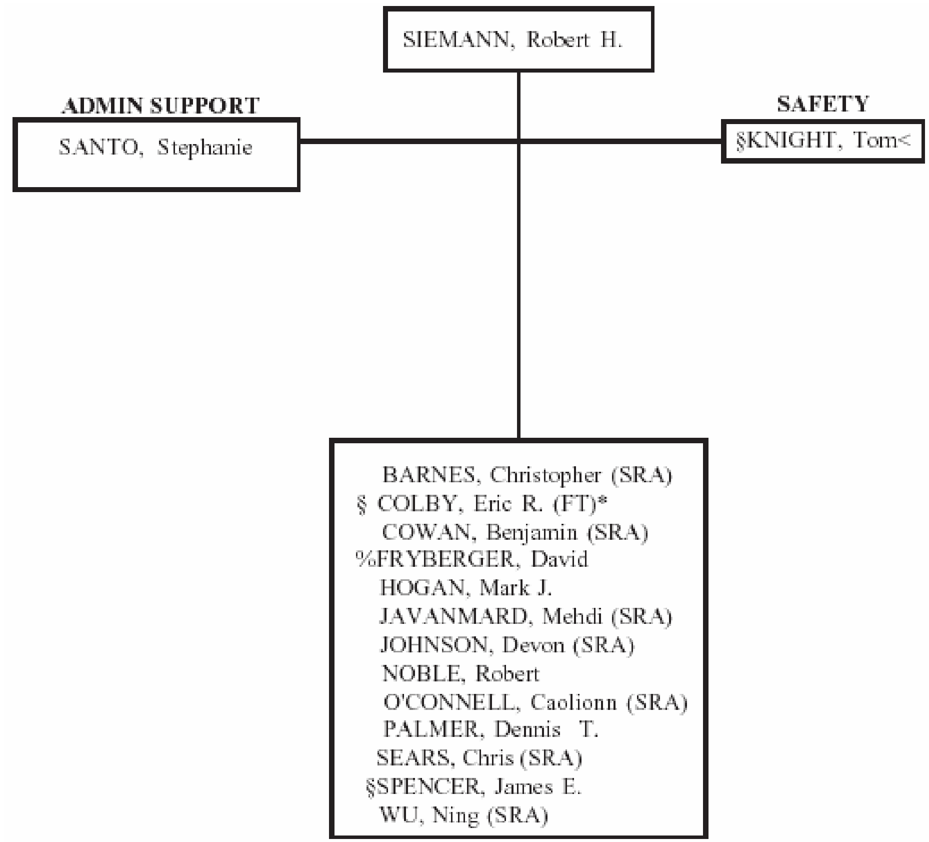
Overview of ARDA



37 Members:

- 5 Faculty (2 Emeritus)
- 23 Physicists and Engineering Physicists
- 3 Postdocs (RAs)
- 8 Grad. Students (SRAs)
- 3 Admin. Support

Overview of ARDB



SRA STUDENT RESEARCH ASSISTANT
% CASUAL EMPLOYEE AND/OR ≤ 50% TIME
§ SAFETY COMM. MEMBER OR DEPT SAFETY REP
< HOME DEPT. IS ARDA, ≤ 25% TIME IN ARDB
* PANOFSKY FELLOW

16 Members:

- 1 Faculty
- 1 Panofsky Fellow
- 5 Physicists
- 7 SRAs
- 2 Admin. Support

Accomplishments of the Last Year

- 134 Publications
  - 39 in peer-reviewed journals (25 in *Phys. Rev.*)
- Awards
  - **David Pritzkau,** 2003 Dissertation Award from the APS Division of Physics of Beams for his thesis on RF Pulsed Heating.
  - **Dmitry Teytelman,** 2004 Dissertation Award from the APS Division of Physics of Beams for his thesis on "Architectures and Algorithms for Control and Diagnostics of Coupled-Bunch Instabilities in Circular Accelerators"
  - **Sami Tantawi**, 2003 USPAS Prize for Achievement in Accelerator Physics and Technology, for theory and technology of rf components for the production and distribution of very high-peak rf power
- Ph.D.s Awarded
  - **Brent Blue**, PhD degree awarded from UCLA in March 2003, "Plasma Wakefield Acceleration of an Intense Positron Beam"
  - **Yong Sun**, PhD. Degree awarded from Stanford in March 2003, “The Filter Algorithm for Solving Large-Scale Eigenproblems from Accelerator Structures”

Accelerator Research Department A

6 Major Groups:

- Lattice Dynamics
- Collective Effects
- Advanced Beam Concepts
- Advanced Electronics
- RF Structures
- High Power RF

Lattice Dynamics Group

- Yunhai Cai
- Tom Knight
- Martin Lee
- Yuri Nosochkov
- Yiton Yan

See also "B Factory – Machine Status & Upgrades" by M. Sullivan
Wednesday June 2, 2004 10:30AM

Current Activities

- Improve the performance of the PEP-II
  - Design lattice for the upgrades
  - Analyze and correct the machine optics
  - Simulate electron cloud instability and the beam-beam interaction
- Develop and maintain the object-oriented computer programs: LEGO, Zlib, and BBI.
- Study the beam-beam and electron cloud effects in e^+e^- colliders

Model-Independent Analysis (MIA) for PEP-II performance improvement

- With two resonance excitations, one can obtain 2 pairs of conjugate linear orbits at BPM locations with a model-independent analyses (MIA). One then extract, from these 4 orbits, the phase advances and transfer matrix components for fitting a computer model to obtain the virtual accelerator that matches the real accelerator in optics.

- Once virtual accelerator is obtained, one picks a limited number of key lattice components for fitting the computer model to a wanted model that generate the wanted optics characteristics.

- One then dial changes of these key lattice components into the real accelerator and improve the accelerator performance.

Phase advances and transfer matrix components R_{12}, R_{32}, R_{14}, R_{34} among BPMs are measured for SVD-enhanced fitting to obtain the virtual accelerator

Two resonance excitations to obtain 4 independent orbits (x1, y1), … (x4, y4) with MIA

Obtaining phase advances and transfer matrix components, *R*'s from the 4 orbits.

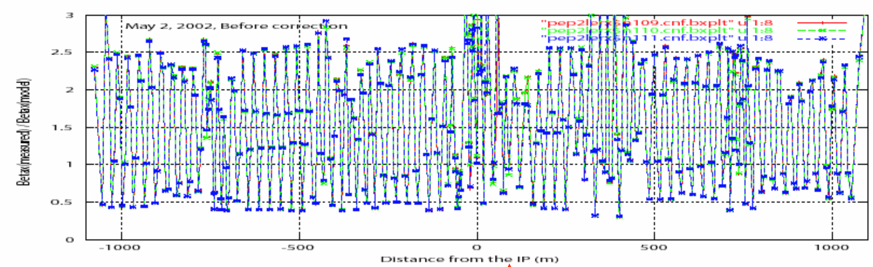
$$
\begin{cases}
(x_1^a x_2^b - x_2^a x_1^b)/Q_{12} + (x_3^a x_4^b - x_4^a x_3^b)/Q_{34} = \mathcal{R}_{12}^{ab}, \\
(x_1^a y_2^b - x_2^a y_1^b)/Q_{12} + (x_3^a y_4^b - x_4^a y_3^b)/Q_{34} = \mathcal{R}_{32}^{ab}, \\
(y_1^a x_2^b - y_2^a x_1^b)/Q_{12} + (y_3^a x_4^b - y_4^a x_3^b)/Q_{34} = \mathcal{R}_{14}^{ab}, \\
(y_1^a y_2^b - y_2^a y_1^b)/Q_{12} + (y_3^a y_4^b - y_4^a y_3^b)/Q_{34} = \mathcal{R}_{34}^{ab}.
\end{cases}
$$

Q12 and Q34 are the two invariants representing the excitation strength

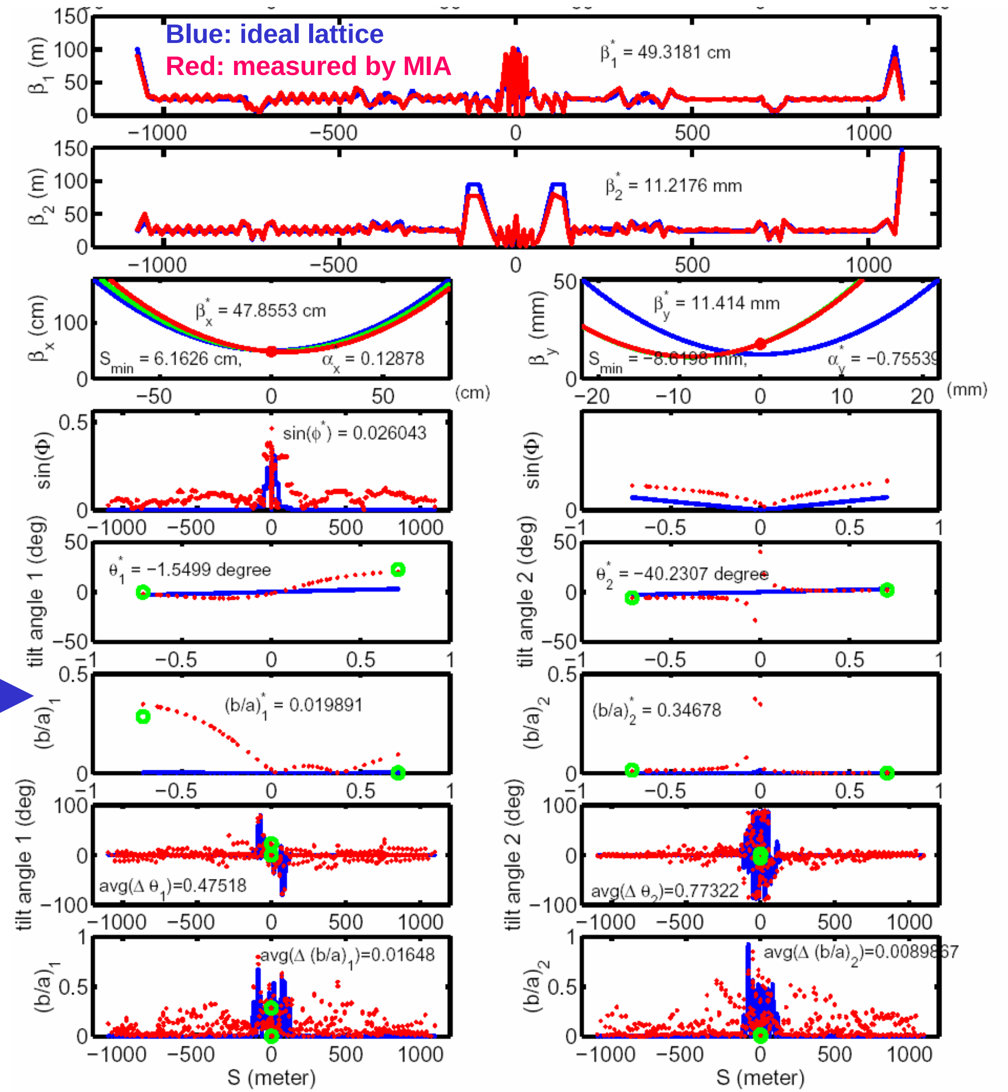
Where, in the measurement frame, *R* is a function of BPM gain and BPM cross-plane coupling.

MIA does not trust the BPM accuracy – MIA figures out BPM gain and cross coupling errors.

MIA brought LER working tune to near half integer and fixed the large beta beat and the linear coupling which allowed PEP-II reached its record single-bunch luminosity



Without MIA, previously we were unable to bring LER to near half integer working tune because of linear coupling and large beta beat as shown in the top plot.



Both LER and HER have been brought to work at near half integer working tunes since May 2003. The right figure shows a typical current LER optics characteristics --- beta beat is small, linear coupling is fine, IP tilt angle is fine.

Future Plan (FY 2004, 2005)

- Design lattices with lower momentum compaction factor to reduce bunch length for PEP-II to improve luminosity. Start to consider lattices for the next generation colliders.
- Continue the MIA work to improve the machine optics for the PEP-II and implement vertical dispersion as additional fitting data and reduce it in the machine
- Simulate the beam-beam luminosity and lifetime in a self-consistent way and study the beam-beam effects such as flip-flop, saw-tooth phenomenon at extreme beam intensity

Collective Effects Group

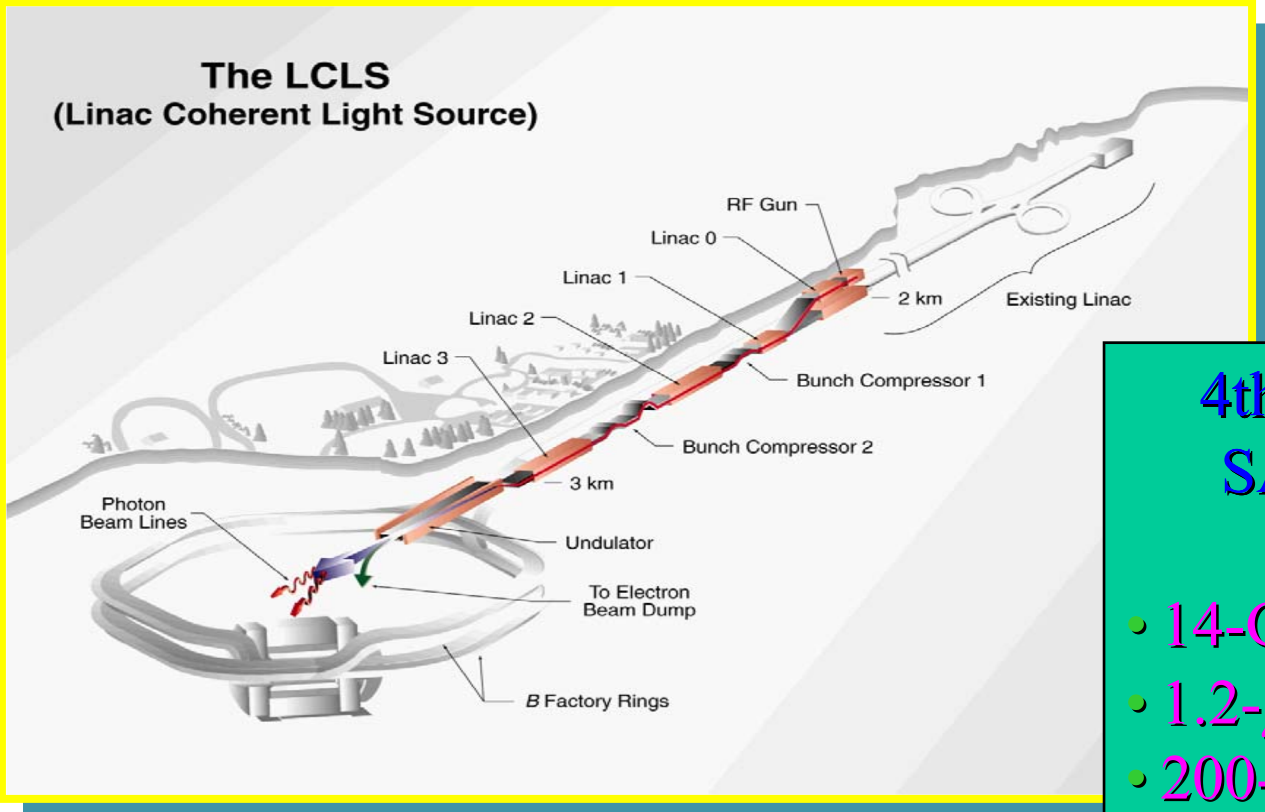
- Gennady Stupakov
- Karl Bane
- Alex Chao
- Paul Emma
- Zhirong Huang
- Sam Heifets
- Sam Krinsky
- Boaz Nash
- Bob Warnock

Breakout session "Accelerator – Beam Dynamics" by G. Stupakov
Thursday June 3, 2004 2:00PM

Recent and current topics of research

- Broad expertise in many areas: lattice design, collective effects, electron cloud, beam-beam interaction, FEL physics.
- Support of all major projects in the lab: PEP-II, NLC, LCLS.
  - Generation of short X-ray pulses in LCLS
  - Laser heater for LCLS
  - Dark currents in NLC structures
  - MIA analysis
  - Simulation of beam-beam interaction for PEP-II
  - Electron cloud effects in PEP-II

Linac Coherent Light Source (*LCLS*)



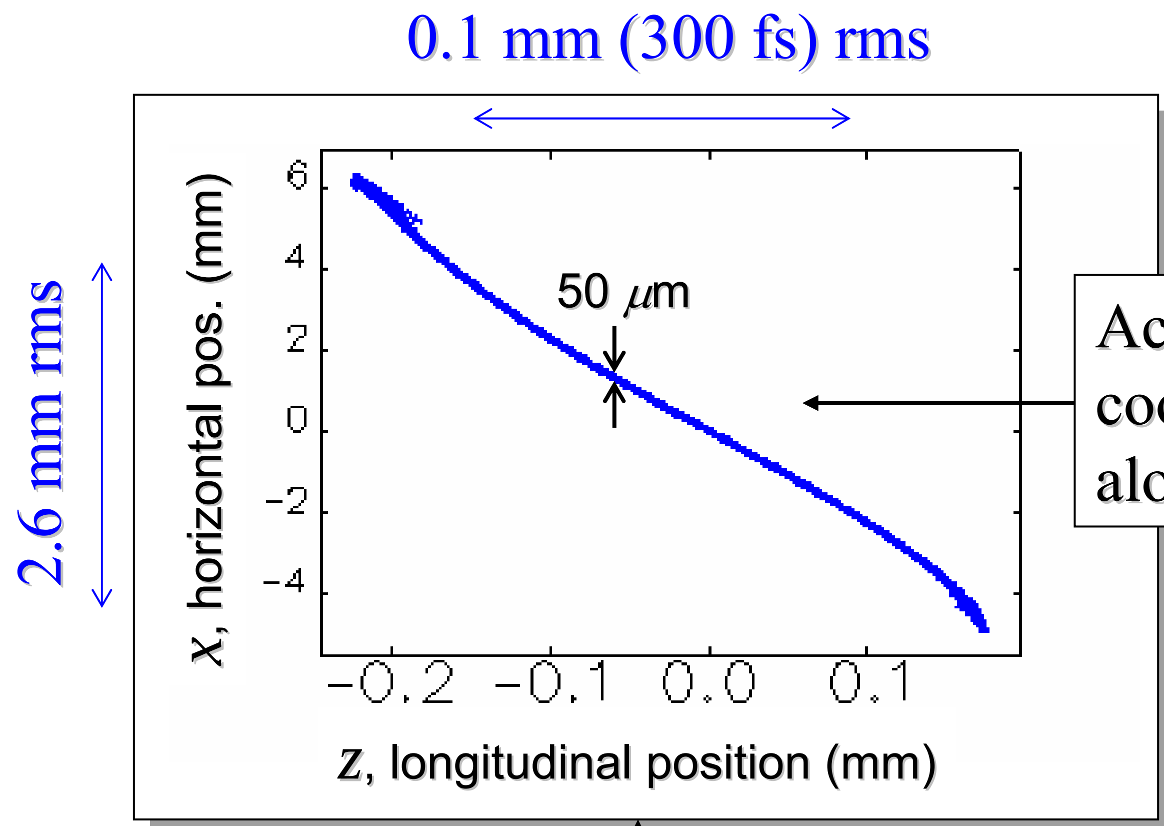
4th-Generation *X*-ray SASE FEL Based on *SLAC* Linac

- 14-GeV electrons
- 1.2-μm emittance
- 200-fsec FWHM pulse
- 2×10^{33} peak brightness*

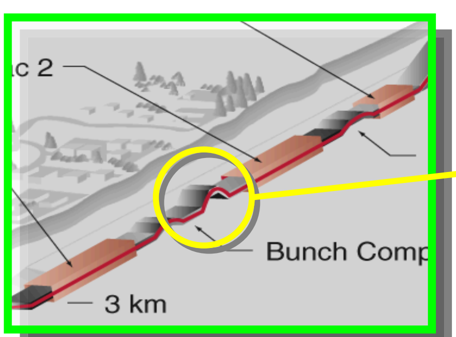
There is a strong interest from future users in shorter pulses of X-rays.

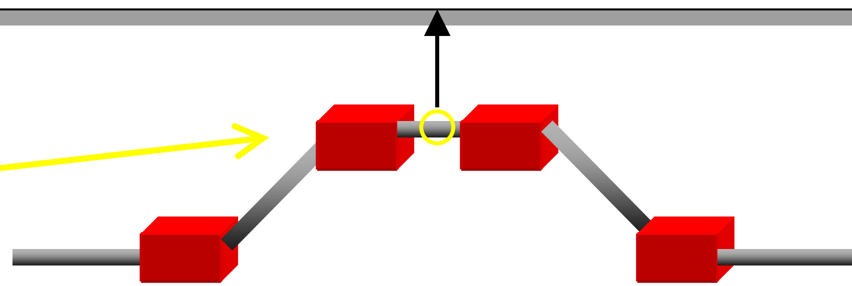
P. Emma, M. Cornacchia, K. Bane, Z. Huang, H. Schlarb (DESY), G. Stupakov, D. Walz, ***PRL, vol. 92, 2004.***

Exploit *Position-Time* Correlation on e^- bunch at Chicane Center



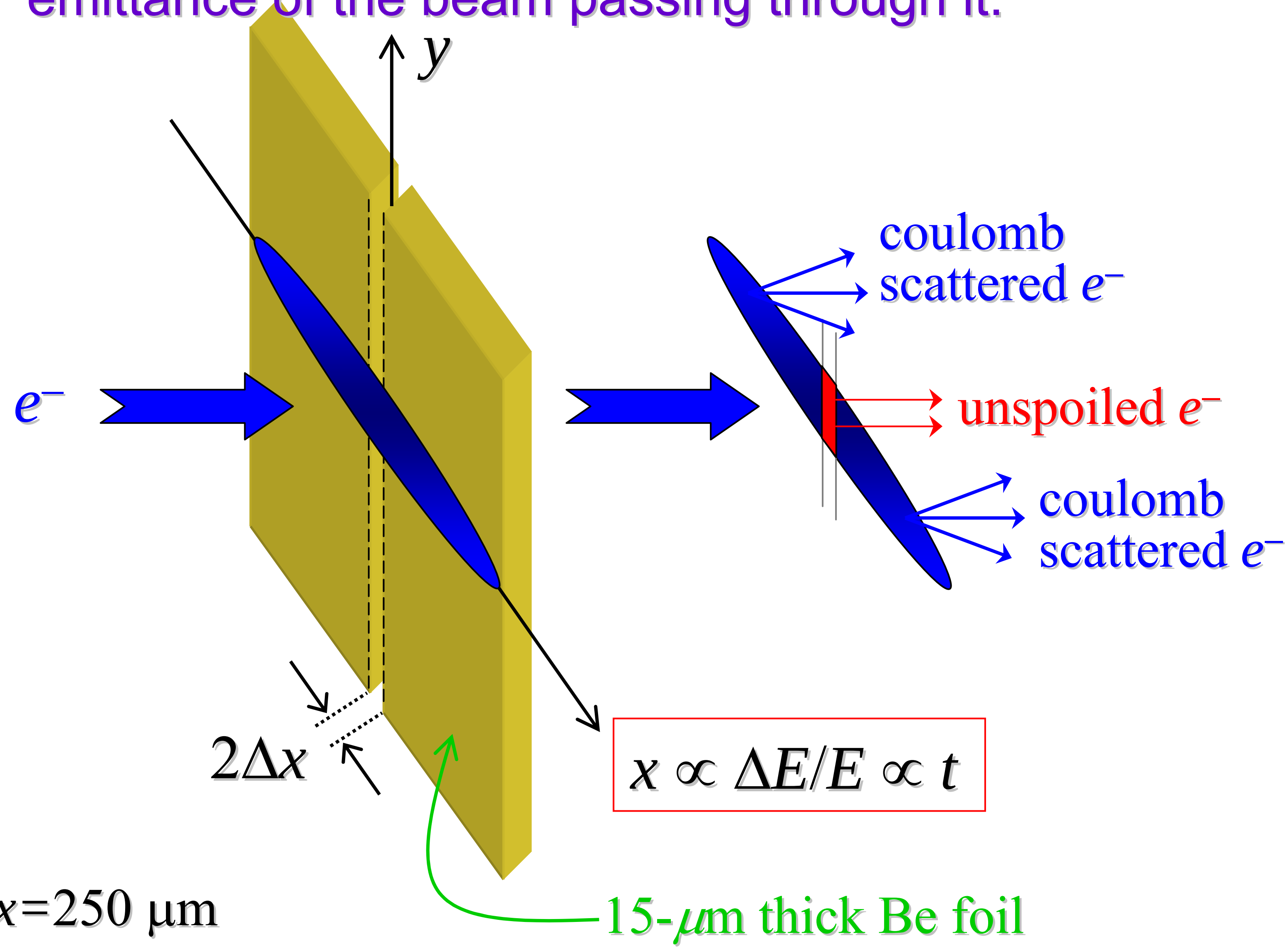
Access to *time* coordinate along bunch





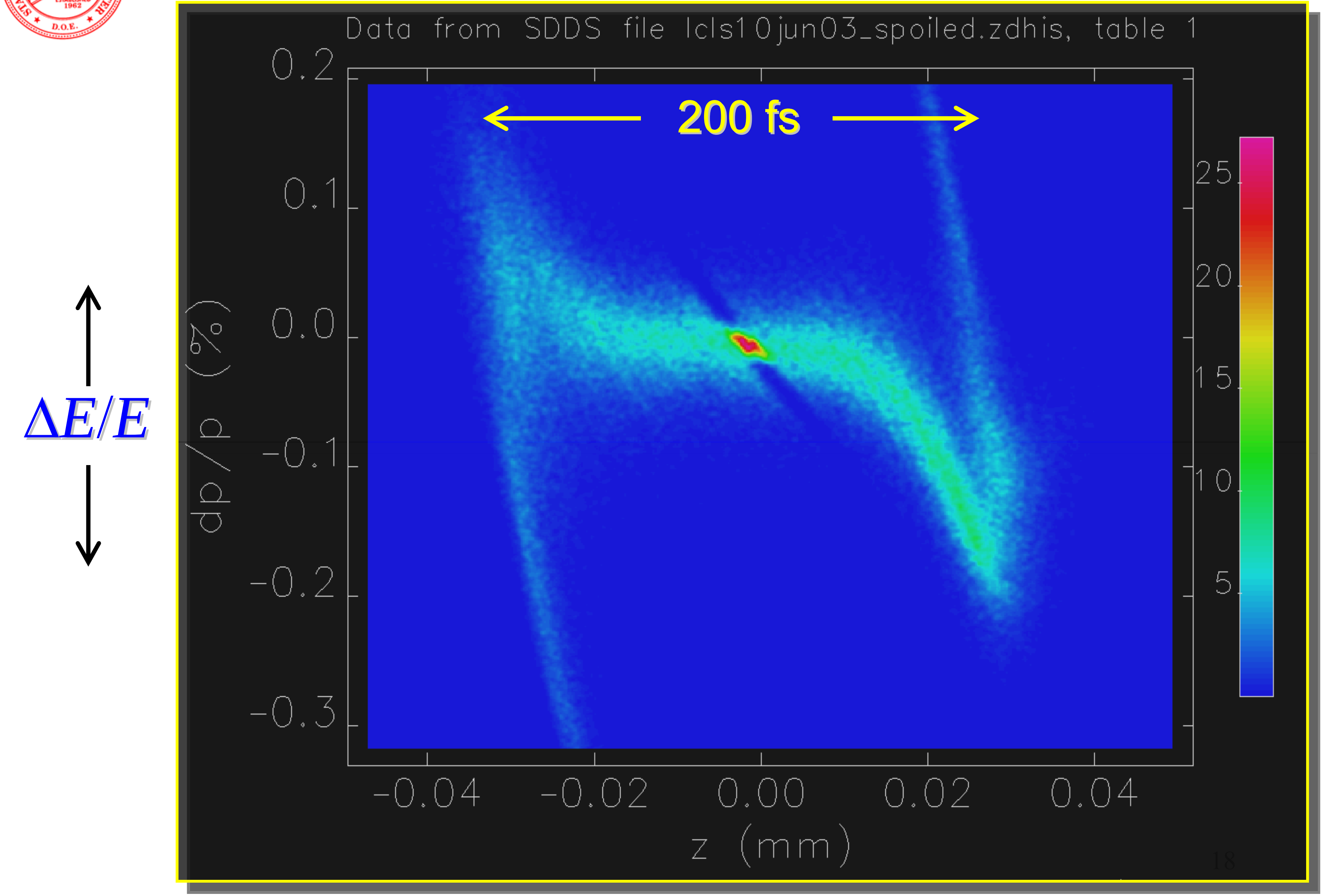
LCLS BC2 bunch compressor chicane (similar in other machines)

Add thin slotted foil in center of chicane. The foil "spoils" emittance of the beam passing through it.



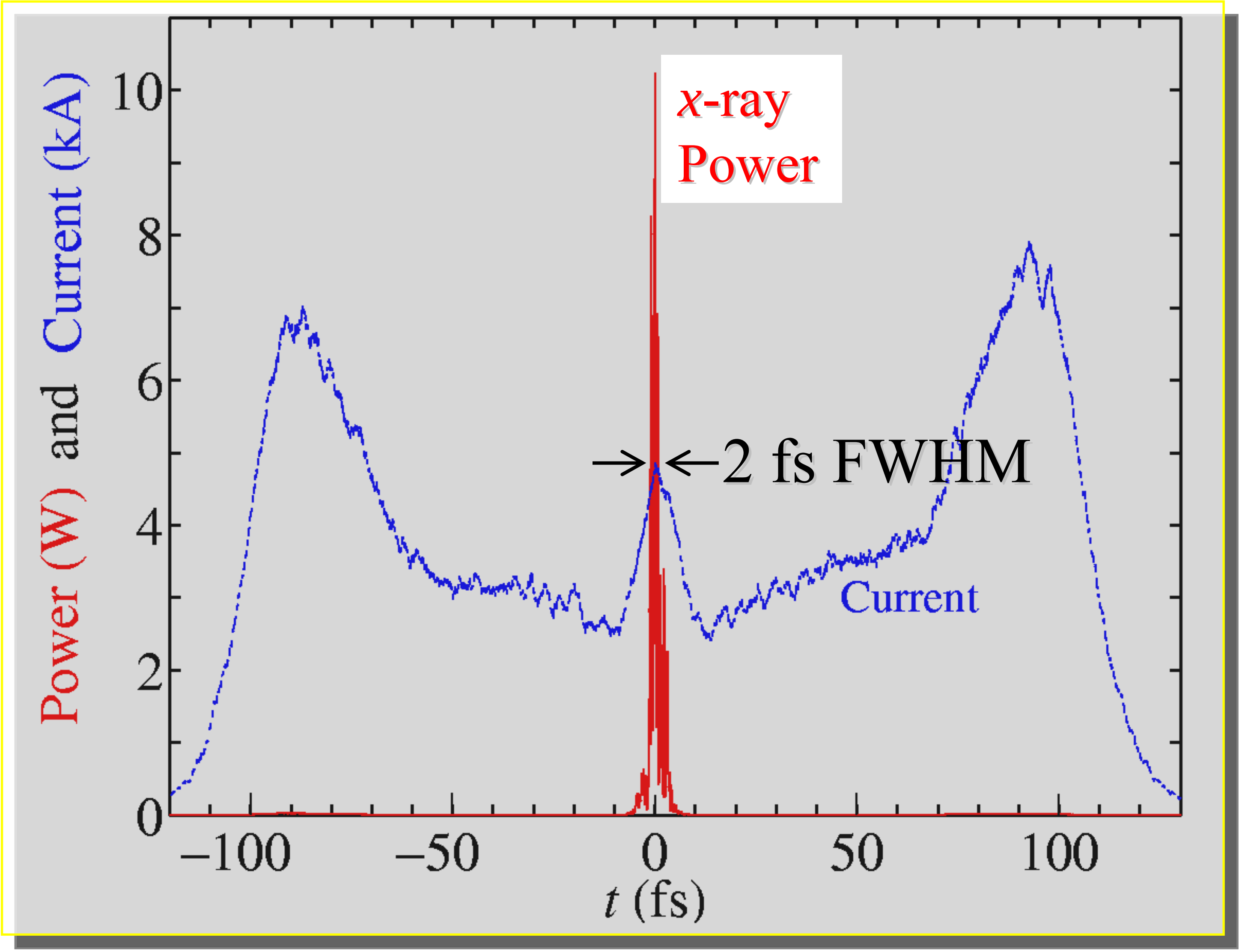
$2\Delta x = 250\ \mu\text{m}$

Track 200k macro-particles through entire *LCLS* up to 14.3 GeV



Genesis 1.3 FEL code

$z \approx 60$ m



Advanced Beam Concepts Group

- Pisin Chen
- John Irwin
- Johnny Ng
- Kevin Reil
- Marina Shmakova
- Kathleen Thompson
- Aleksandr Yashin

Covered in "Particle Astrophysics and Cosmology – Kavli Institute" by R. Blandford
Wednesday June 2, 2004 1:00PM

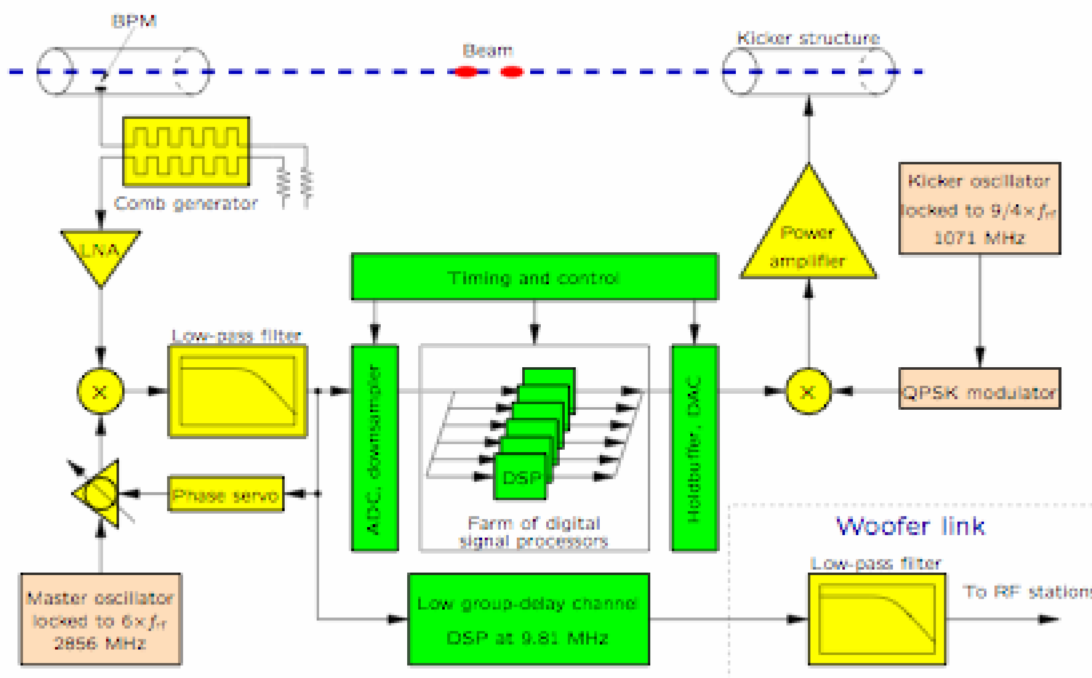
Advanced Electronics Group

- John Fox
- Liane Beckman
- Themistoklis Mastorides
- Dmitry Teytelman
- Daniel Van Winkle
- Yubo Zhou

Breakout session "Accelerator – RF and Electronics" by S. Tantawi
Thursday June 3, 2004 2:00PM

Advanced Electronics - 2004 Overview

The ARDA Advanced electronics group combines interests in accelerator dynamics and instability control with technology expertise in high-speed signal processing. The group does machine physics development of instability control hardware, develops theoretical models of stability and control techniques, and serves to develop special accelerator instrumentation for experiments.

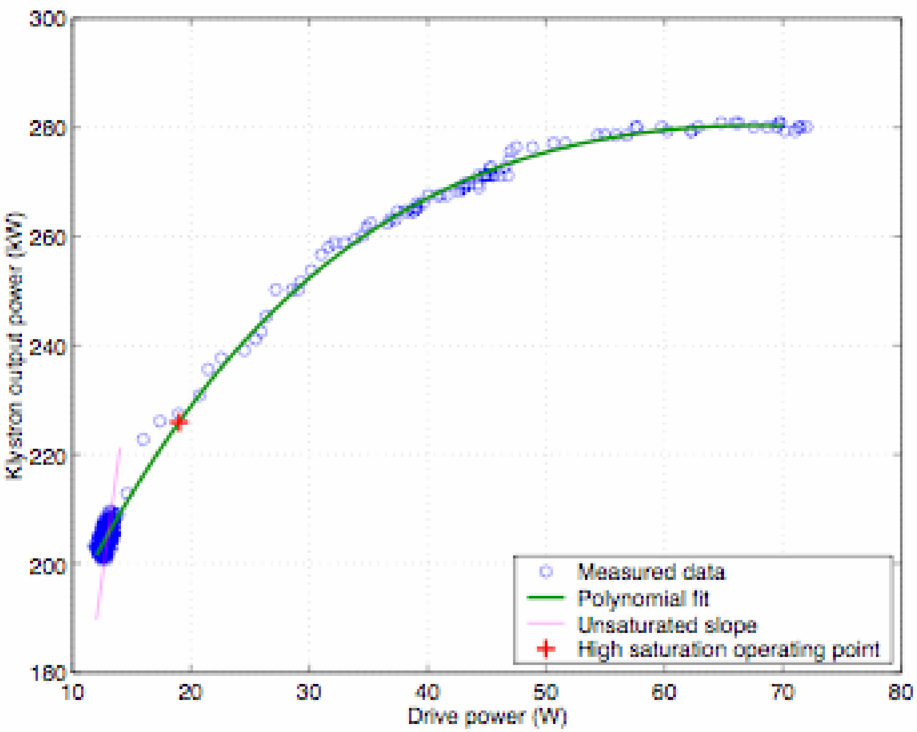


Efforts in 2004 center on high-current stability in PEP-II, plus development of next-generation 1.5 GSample.sec. feedback channels in conjunction with LNF and KEK.

The group comprises SLAC staff and Stanford Ph.D. students in EE/Applied Physics. Last year Dmitry Teytelman won the APS dissertation prize in beam physics for his work applied to PEP-II

PEP-II fast impedance control loops -Limitations of cavity impedance control due to klystron saturation

A major effort by the group involves understanding the high-current instability limits in PEP-II. Our machine physics measurements have led to a better understanding of the limitations of impedance control in the PEP-II RF systems. Due to klystron saturation a linear impedance control model is not applicable.



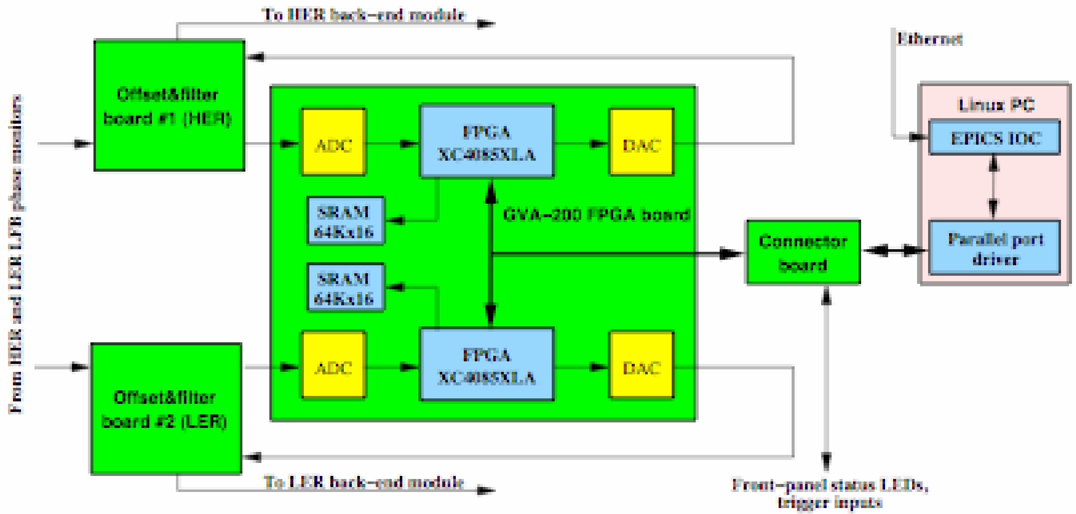
For the HER at 1 A the growth rates rise from linear prediction of 0.12 ms^{-1} to actual 1-1.8 ms^{-1}.

These high growth rates were limiting HER currents above 1380 mA.

We are attacking this limitation through a new RF woofer channel in the longitudinal feedback paths, and a novel klystron linearizer within the low level RF processing

Low group-delay woofer: prototype system

The prototype is based on a off-the-shelf FPGA DSP board. It uses the existing LFB front-end monitor signal and the woofer output is passed to the existing back-end LFB module which drives the RF systems via fiber optic links.



The LGDW prototype implements a 14 tap FIR filter, with a 9.81 MS/s processing rate.Decoupled low-mode and HOM channels allow independent optimization of loop gains and dynamic ranges.

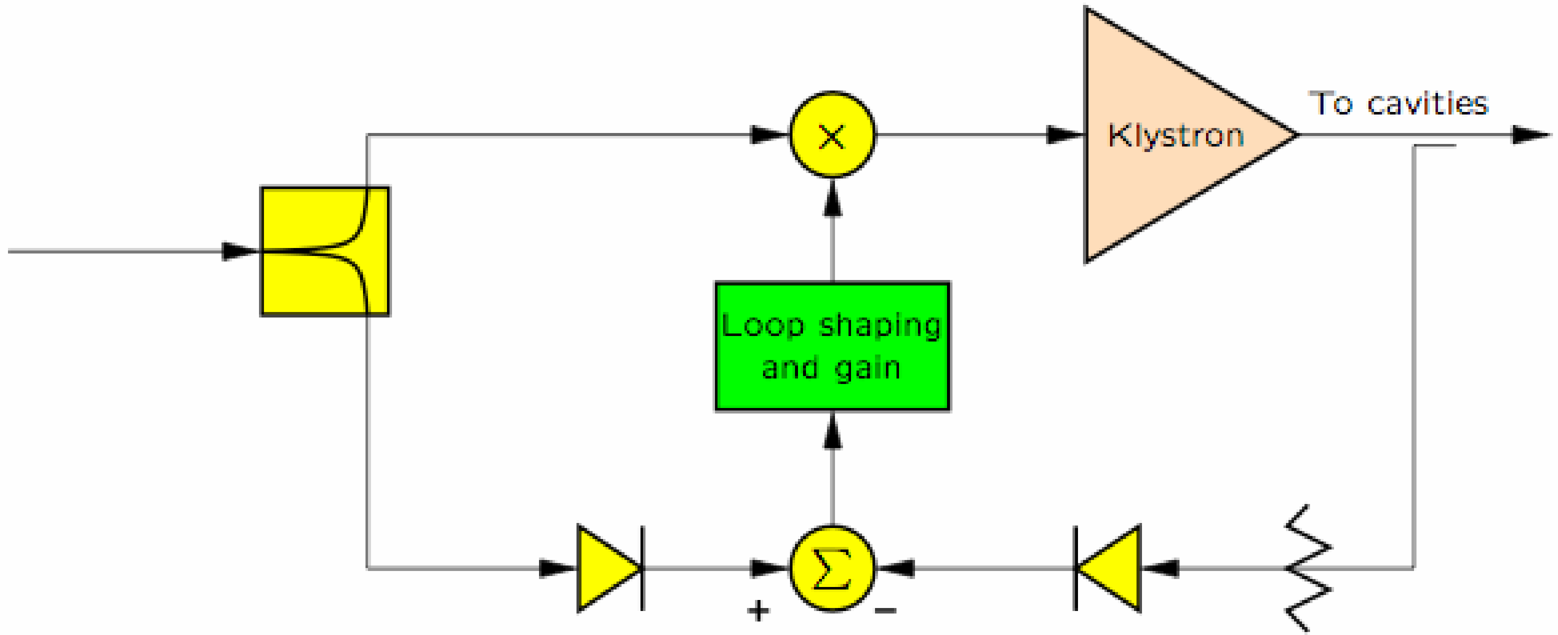
Main advantages: better low-mode damping and overall gain optimization leading to more robust longitudinal stabilization.The low group-delay woofer was tested up to 1550 mA.Prior to this LGDW commissioning we were limited to 1380 mA with very tight operational margins - running with 1 -3 longitudinal aborts per day.

Klystron linearizer: block diagram

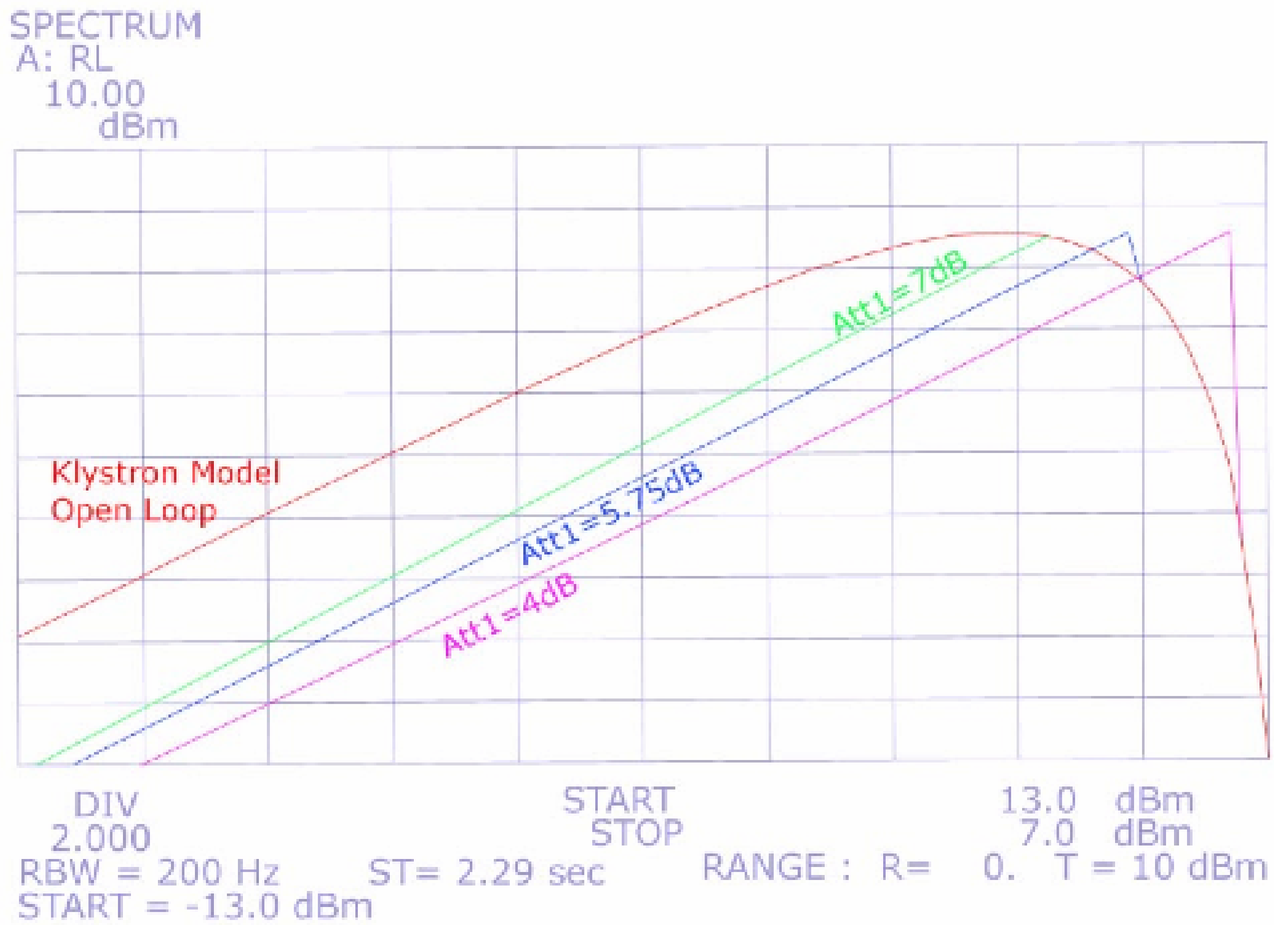
We have started a study to develop a technique to improve the impedance control

Compare the input of the klystron and the output, use amplitude modulator to make the two match. Linearizes the klystron so that large- and small-signal gains are identical. Feedback does increase the effective klystron delay.

Has been simulated, currently testing a bench prototype. We plan to test this idea on one of the PEP-II LER stations before the shutdown.



Dc power levels - klystron model and linearized output



RF Structures Group

- Juwen Wang
- Nicoleta Baboi
- Gordon Bowden
- Roger Miller
- Roger Jones
- Jim Lewandowski

See also "Linear Collider – NLC R&D" by D. Burke
Thursday June 3, 2004 8:30AM

Breakout session "Accelerator – NLC Tour in ESB"
Thursday June 3, 2004 2:00PM

Mission for RF Structures Group

Mission

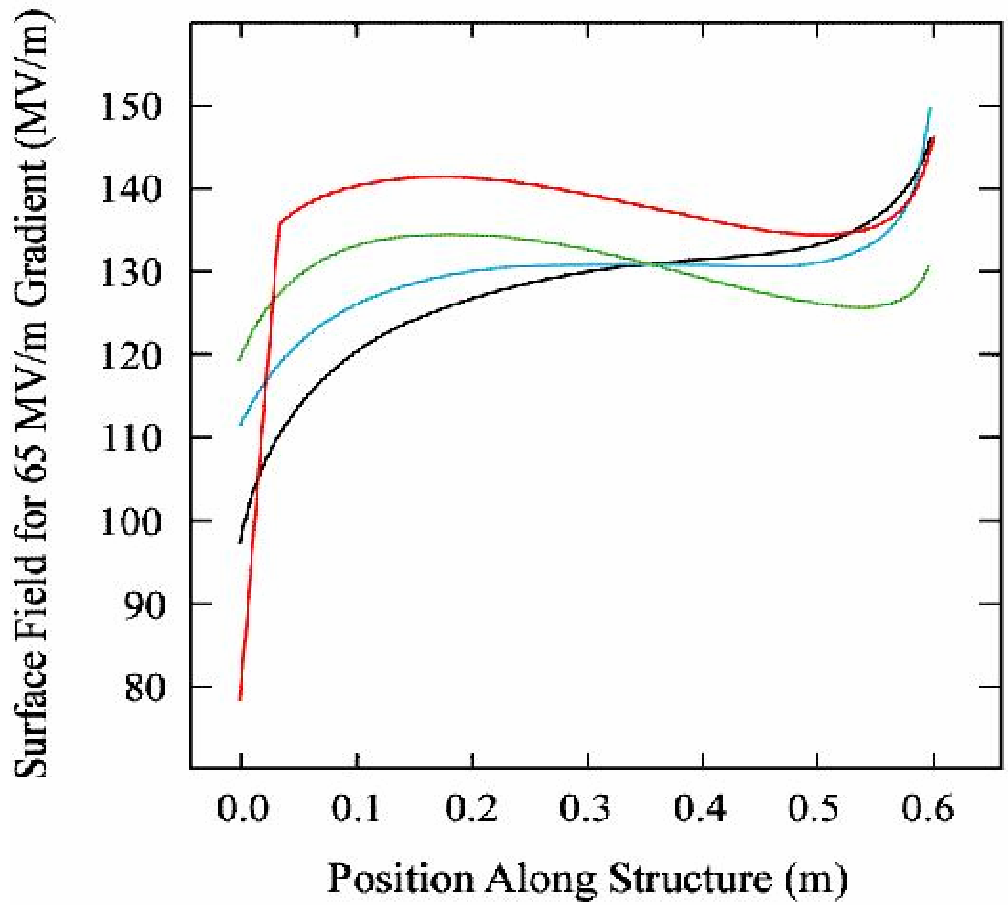
We design, engineer and test accelerator structures for future linear colliders operating under extremely high gradient conditions with superior properties in higher modes suppression.

The activities

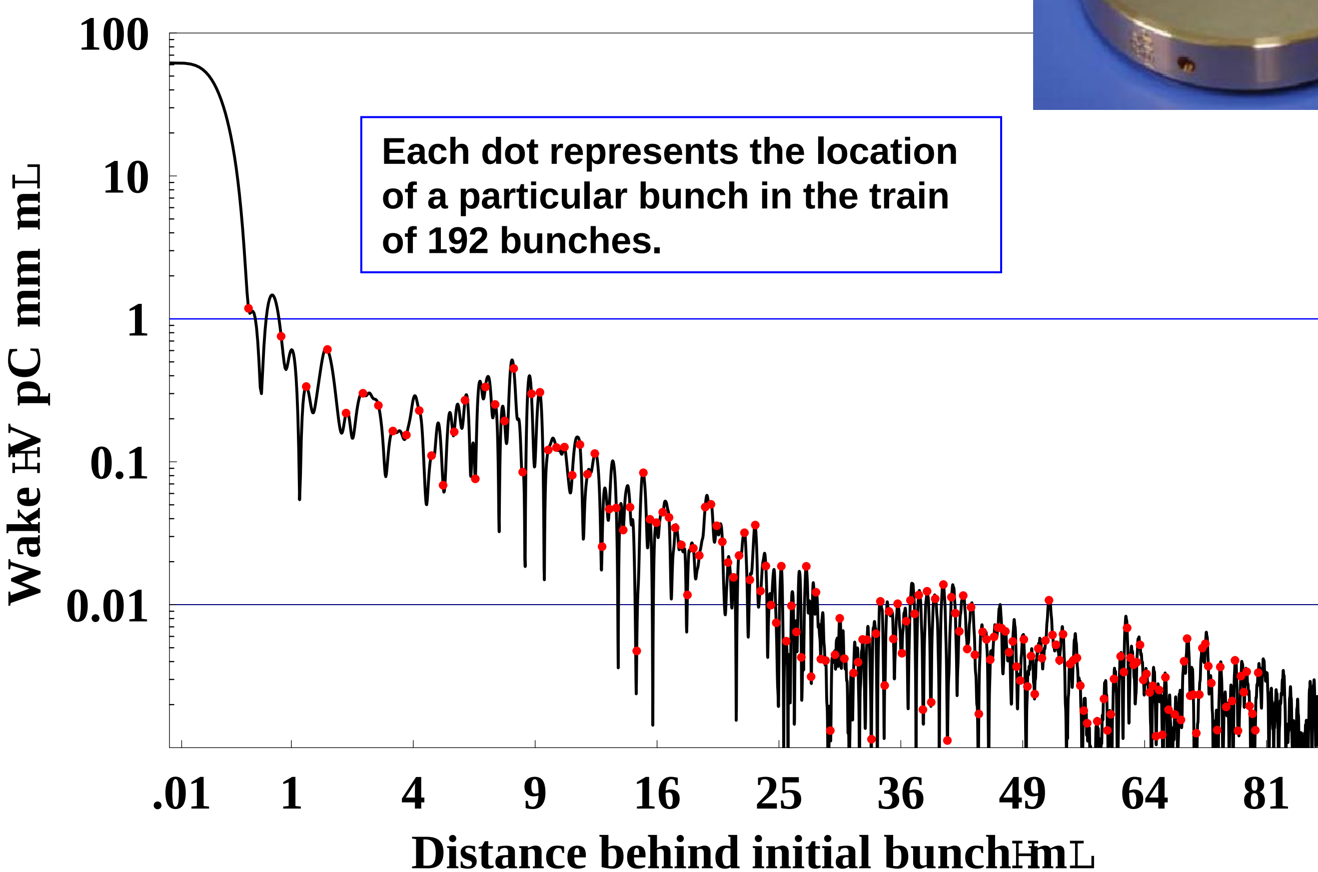
- Accelerator Theoretical Studies.
- Simulation and Computer Aided Accelerator Design.
- Mechanical Design.
- Fabrication Technologies Studies.
- Microwave Characterization.
- High Power Experiments.

Structure Design Optimization for Efficiency and High Gradient Performance

Comparison of maximum iris surface field for different structure designs at an unloaded gradient of 65 MV/m. The red curve is for H60VG3N (a/λ=0.18), which has rounded shaped irises – the others have elliptical shaped irises, which lowers the peak field. This structure also has a reduced field in the first several cells. The green curve is for H60VG3S18 (a/λ=0.18), which shows the effect of the elliptical shaped irises. The light blue curve is for H60VG3S17



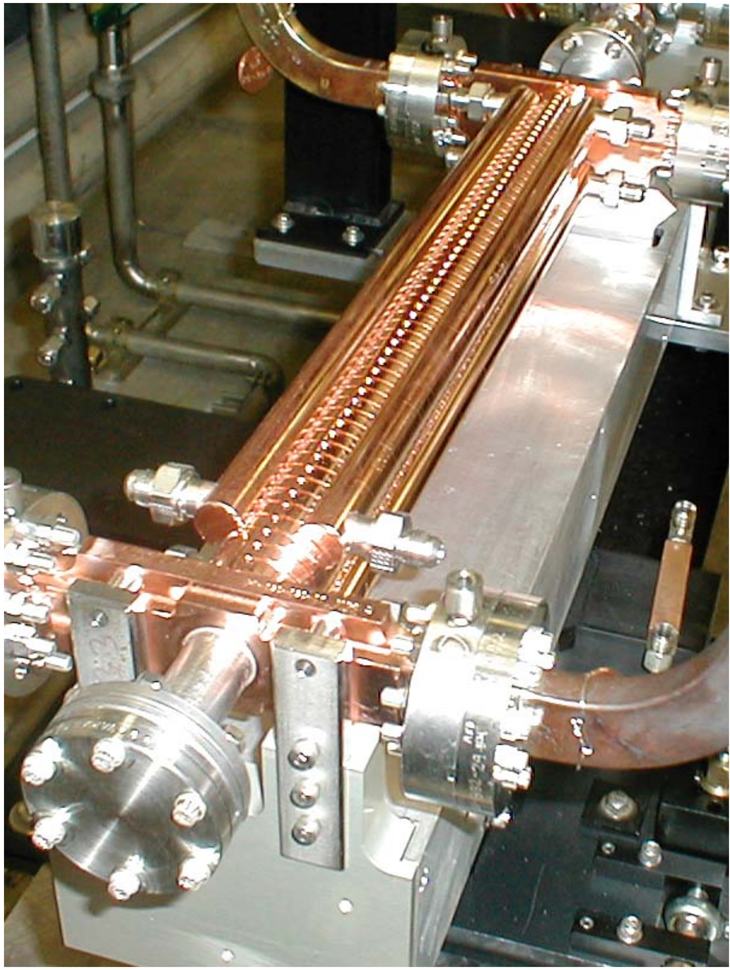
Envelope of Wake for Four-Fold Interleaving of GLC/NLC X-Band Accelerating Structures



High Gradient Structure Development

- Designed, fabricated and tested 34 structures with over 20,000 hrs of high power operation.
- Improved structure preparation procedures - includes various heat treatments and avoidance of high rf surface currents.
- Found lower input power structures to be more robust against rf breakdown induced damage.
- Developed 'NLC/GLC Ready' design with required wakefield suppression features – it is 33% as long (60 cm) and requires 40% of the power of the 1.8 m design.

Traveling-Wave Structure



High Power RF Group

- Sami Tantawi
- Christopher Nantista
- Valery Dolgashev
- Perry Wilson
- David Farkas
- Zhiyu Zhang
- Yasser Hussein
- Jiquan Go

See also "Linear Collider – NLC R&D" by D. Burke
Thursday June 3, 2004 8:30AM

Breakout session "Accelerator – RF and Electronics" by S. Tantawi
Thursday June 3, 2004 2:00PM

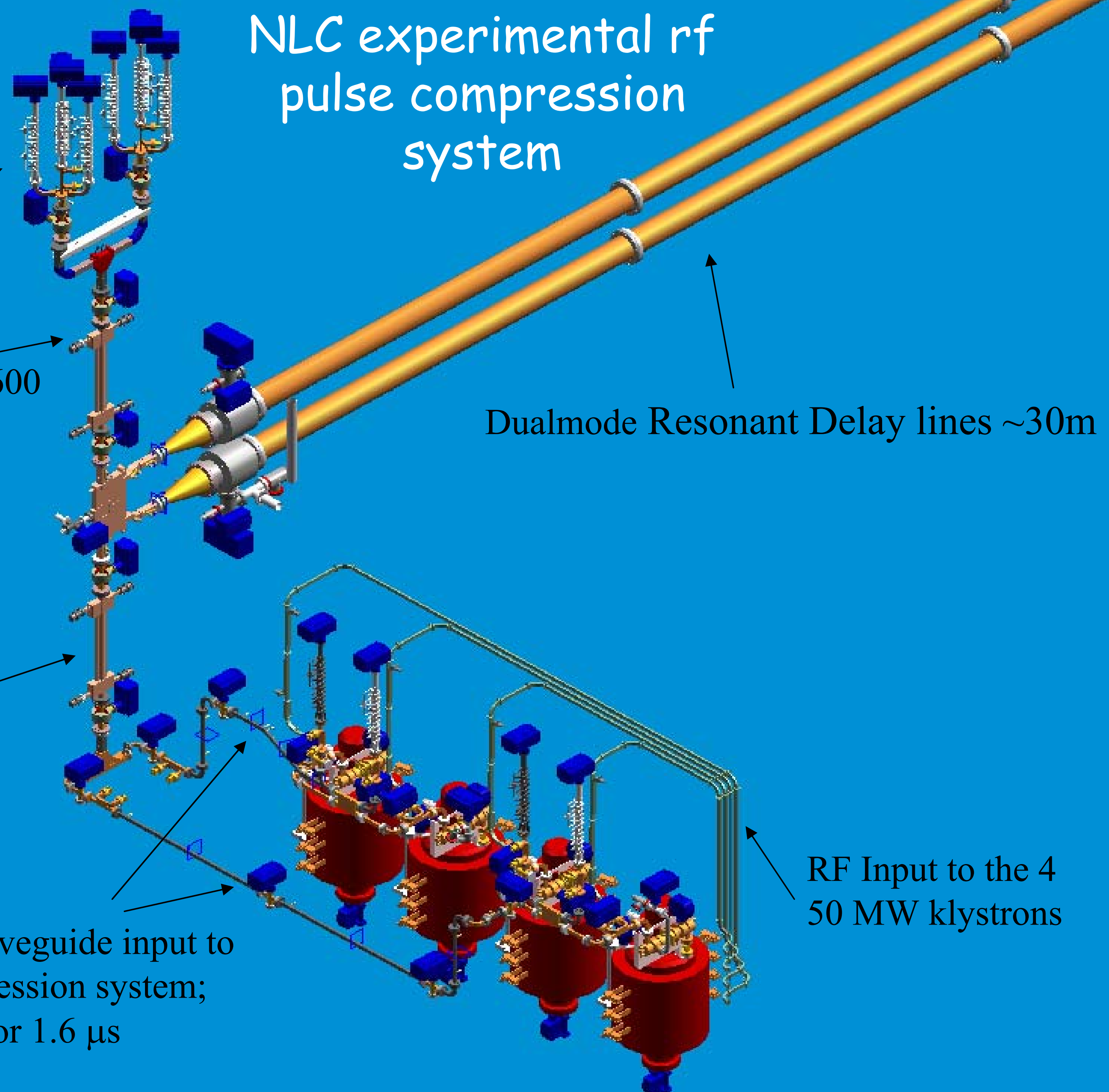
Breakout session "Accelerator – NLC Tour in ESB"
Thursday June 3, 2004 2:00PM

Group Goal: Advance the State of the Art of High-Power RF Components and Sources

Research Areas:

1. Ultra-High-Power RF components at X-band frequencies and higher
2. Passive Pulse compression systems
3. Active RF components
4. Active Pulse compression systems
5. RF components and analysis codes for microwave tubes
6. RF components and analysis codes for Accelerator structures
7. Experimental and theoretical studies of RF breakdown phenomenon in high vacuum structure.

NLC experimental rf pulse compression system



- Dual-mode rf pulse compression system achieved peak power of about 580 MW; 130% of NLC spec.
- Dual-moding reduce delay-line length by 50%.
- Modular multimode components allow multiple pulse compression configurations.
- Overmoded components keep electric field < 49 MV/m and Magnetic Field < 0.17 MA/m at power levels of 600 MW.
- The system had 14 trips due to the overmoded system after 39 million pulses at 400 ns and above 500 MW.

[1]Sami G. Tantawi et al, "Ultra-High-Power Multimode X-Band RF Pulse compression and Distribution System," to be submitted to Physical Review Special Topics-Accelerators and Beams.

[2] S. G. Tantawi, "Multimoded reflective delay lines and their application to resonant delay line rf pulse compression systems," Phys. Rev. ST Accel. Beams 7, 032001 (2004)

[3] S.G. Tantawi, *et al.*, "A Multimoded RF Delay Line Distribution System for the Next Linear Collider," Phys.Rev.ST Accel.Beams, vol. 5, March 2002.

[4] Sami G. Tantawi, et. al. "The Generation Of 400-MW RF Pulses At X Band Using Resonant Delay Lines,", IEEE Trans. on Microwave Theory and Techniques, Vol 47, No. 12, December, 1999, p. 2539-2546

Last year

Our development of ultra-high-power RF components and pulse compression systems lead to the a successful demonstration of an RF system suitable for NLC

This year

1- Continue our development of RF compnents for NLC by adding a distribution system to the current RF pulse compression system

2- Converting two of the NLCTA station into dual-moded pulse compression system

3- We are performing a series of experiments on active RF components which we expect to push the state of the art of semiconductor rf switches and nonreciprocal Ferrite switches by a few orders of magnitude

4-We are performing a series of experiments on *single cell Traveling wave* accelerator structures to understand the breakdown phenomenon and the role of materials in determining the limits on high gradients.

Main Directions of the ARDB Program

Laser Acceleration of Electrons

A program to investigate the technical and physics issues of vacuum laser accelerators, with the ultimate goal of building a high energy linear collider.

Experiments: LEAP, E163

Plasma Wakefield Acceleration

A program to investigate the physics of beam-driven plasma wakefields with the ultimate goal of doubling the energy of a linear collider.

Experiments: E157, E162, E164, E164X

ARDB

Laser Acceleration
LEAP/E163

**E. R. Colby, B. M. Cowan, M. Javanmard, R. J. Noble,
D. T. Palmer, R. H. Siemann, J. E. Spencer, D. R. Walz, N. Wu**
Stanford Linear Accelerator Center

R. L. Byer, T. Plettner
Stanford University

J. B. Rosenzweig
University of California Los Angeles

T. I. Smith, R. L. Swent
Hansen Experimental Physics Laboratory

Y.-C. Huang
National Tsing Hua University, Taiwan

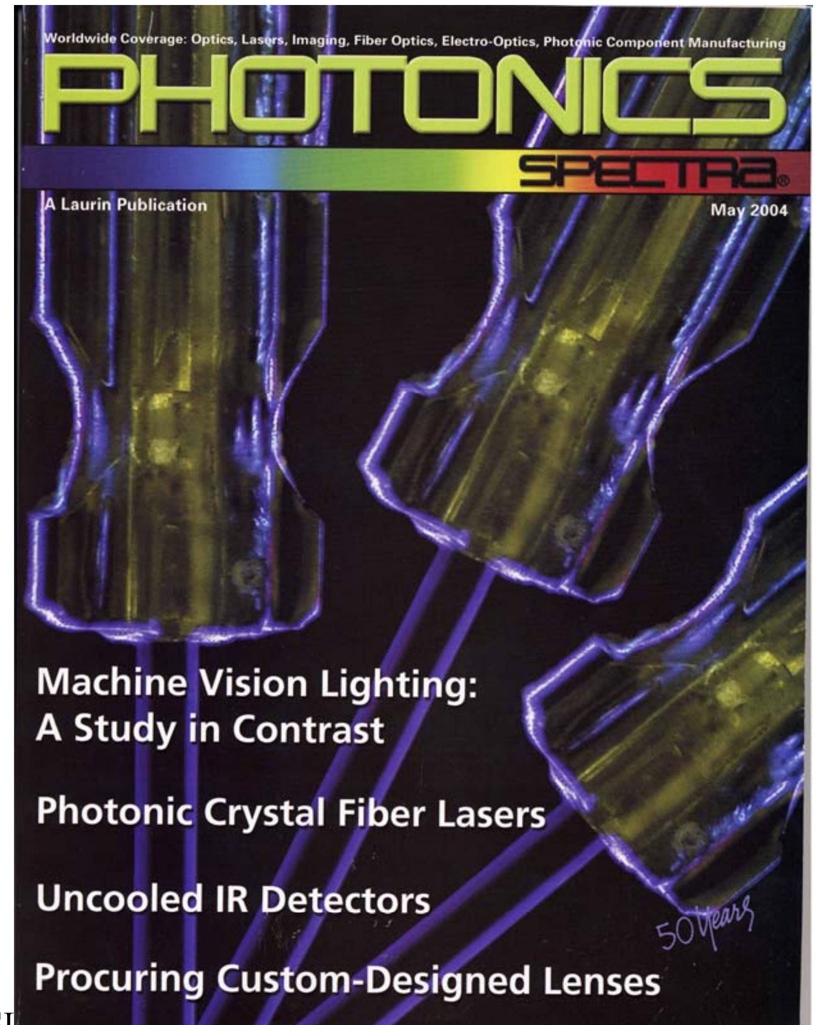
L. Schächter
Technion Israeli Institute of Technology

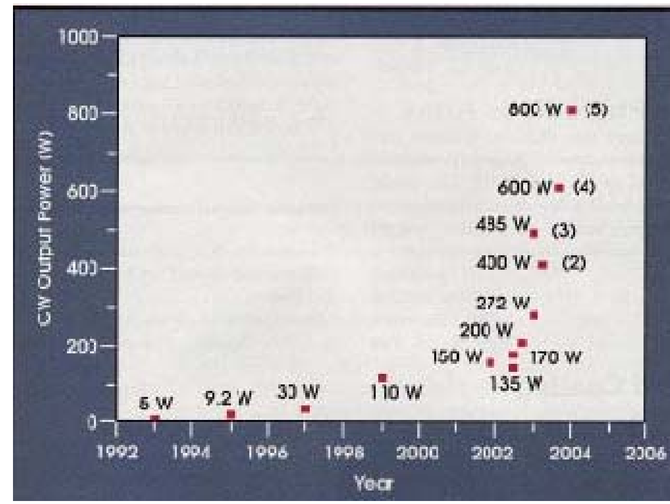
Breakout session "Accelerator – Laser Acceleration Structures" by E. Colby
Thursday June 3, 2004 2:00PM

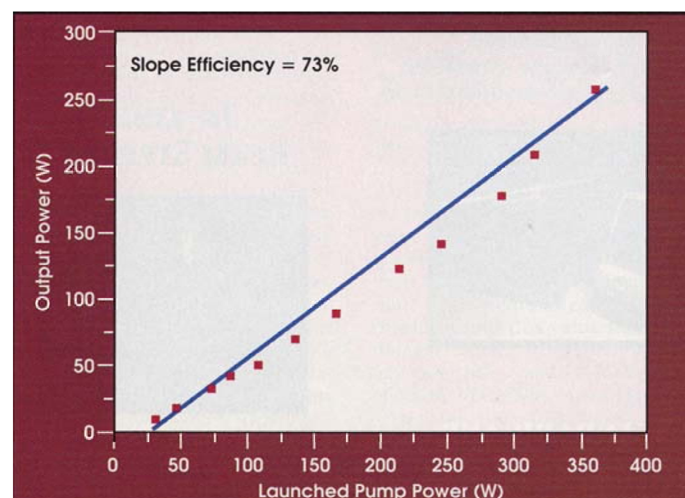
ARDB

Vacuum Laser Acceleration
LEAP & E163
Motivation For This Research

J. Limpert *et al*, “Scaling Single-Mode Photonic Crystal Fiber Lasers to Kilowatts”







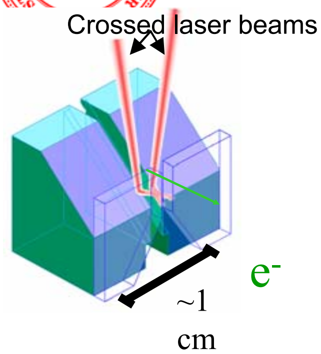
Laser Acceleration: LEAP

[Breakout Presentation by Eric Colby this afternoon]

Laser Electron Acceleration Project (LEAP)

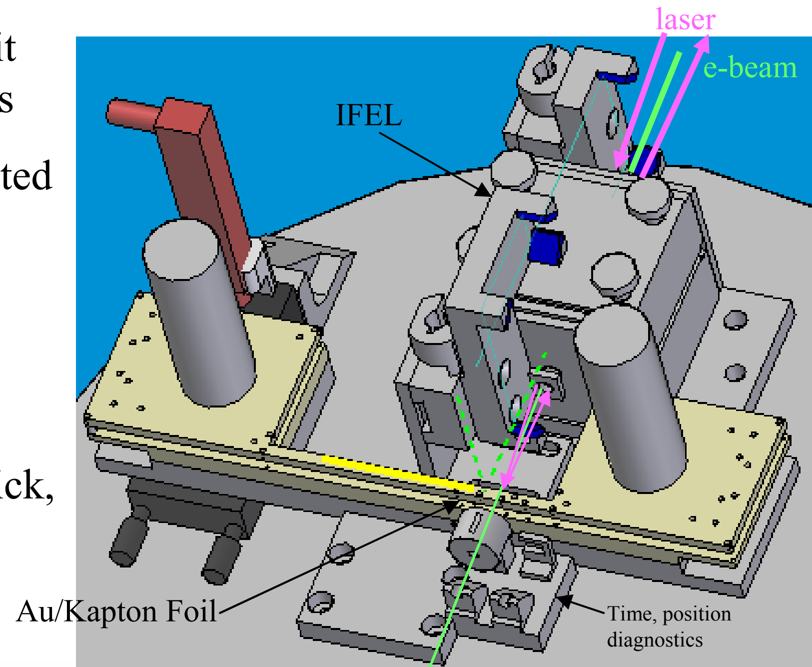
- Last experimental run June 2002, *will run off-resonance IFEL and ITR experiments at HEPL this summer*
- Continuing work on laser phase locking; *carrier-phase detection achieved!*
- Substantial photonic band gap structure development underway
    - Planar structures developed (suitable for semiconductor lithography)
        - EM simulations, shunt impedance studies *complete*
        - Particle tracking studies underway
    - Fiber structures developed (suitable for fiber bundle drawing)
        - EM simulations, shunt impedance studies *complete*
        - 3000 x scale model (w-band) measurements underway
        - Wakefield simulations underway

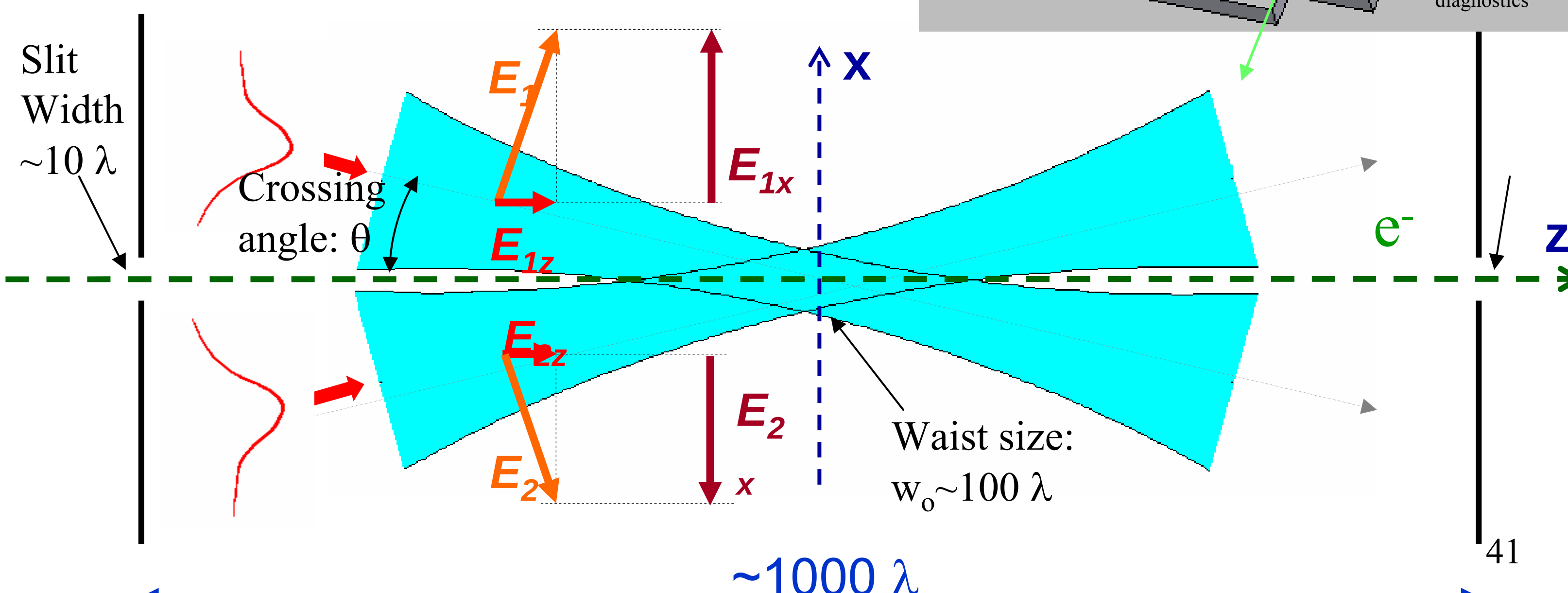
Crossed Laser Beam Accelerator



Original LEAP cell design

- Original LEAP cell redesigned to permit above-damage threshold ITR experiments
- Disposable transition radiator is Au coated kapton tape, advanced for each shot
- Expected interaction strength: 50 keV (w_0=40 μm, 0.5 mJ per pulse)
- Will test IFEL in non-resonant regime (γ_{res}=120, γ_{test}=70). Expect 57 keV rms kick, will permit precise timing of e/γ.





0.8 μ IFEL/Chicane Microbuncher

ARDB

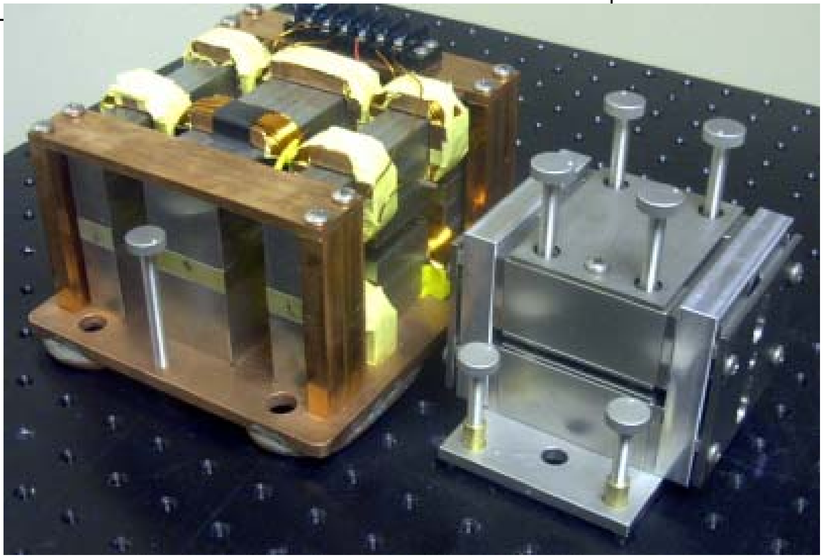
• 0.8 μm optical prebuncher has been designed, simulated, and initial magnetic measurements completed

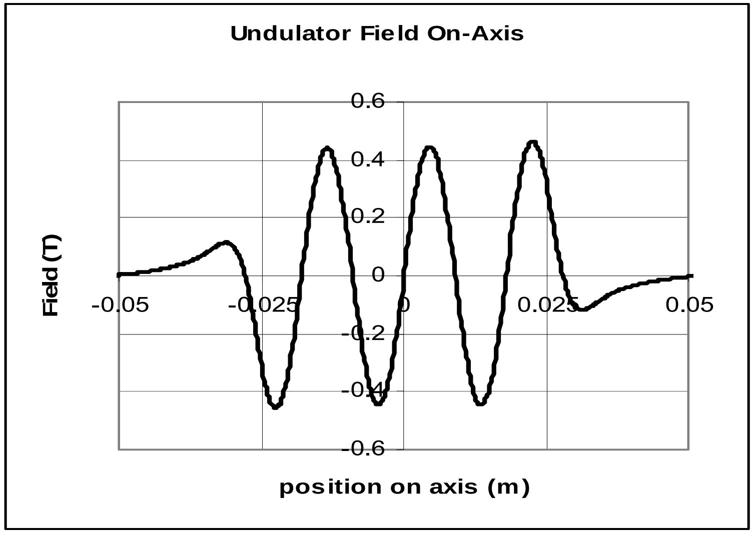
•IFEL modulates a 1 ps electron pulse at 800 nm; chicane turns energy modulation into longitudinal density modulation

•In conjunction with short RF linac, serves as optical injector for laser acceleration experiments at E-163

•IFEL interaction only ~0.15% energy modulation; kept small to avoid washing out acceleration signal

•Hardware adjustable (gap height/field strength) for flexibility in resonant wavelength, beam energy, modulation strength, etc.

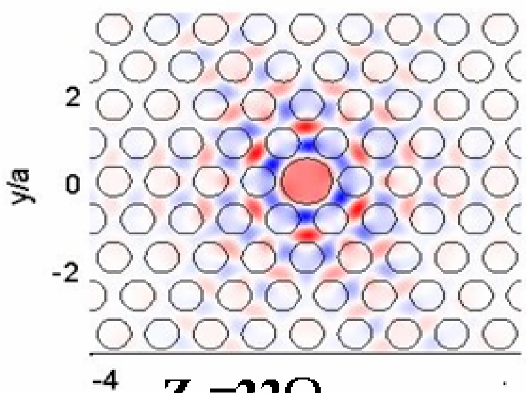




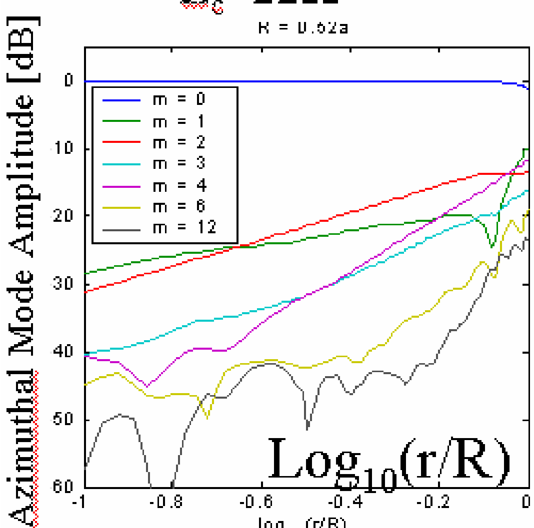
2D Fiber Structures

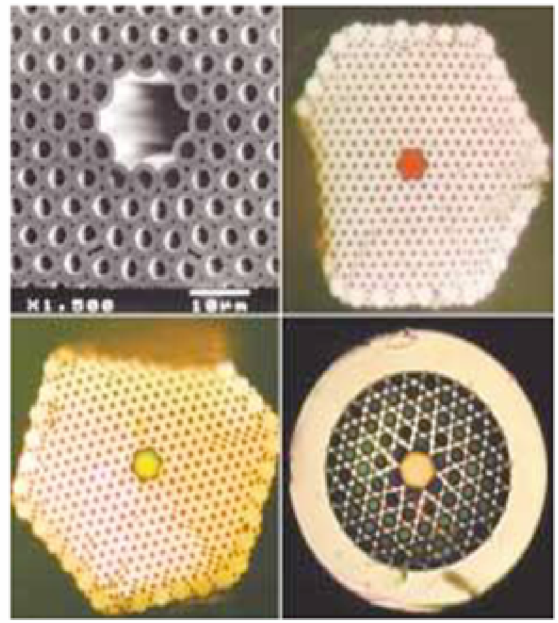
ARDB

Defect radius R = 0.52a



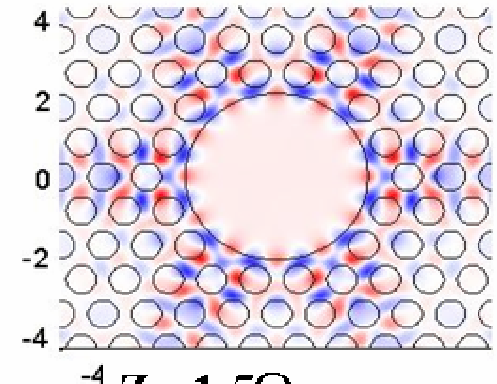
Z_c=22Ω



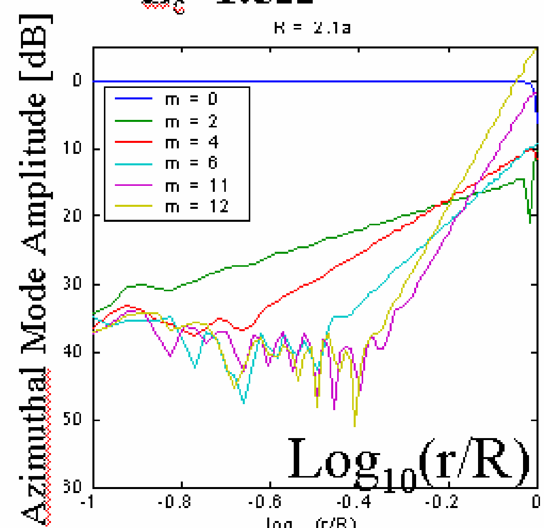


P. Russell, "Holey fiber concept spawns optical-fiber rennaissance", *Laser Focus World*, Sept. 2002, p. 77-82.

Defect radius R = 2.1a



Z_c=1.5Ω

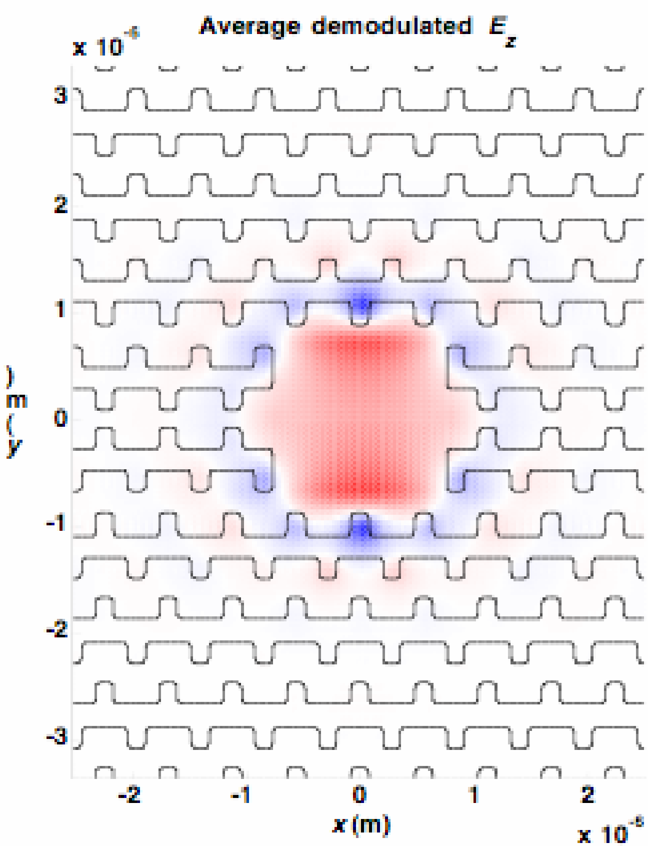


Mehdi Javanmard, ARDB, SLAC

This geometry is designed for the fiber drawing process.

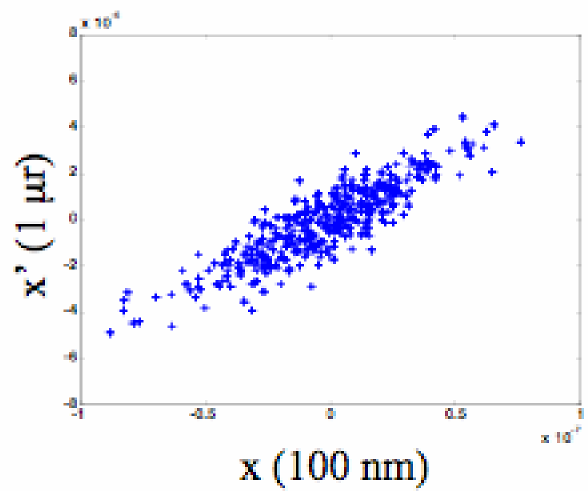
3D Structures: Detailed Simulation

- Accelerating mode in "woodpile"-based PBG waveguide



Field normalized to E_{acc} = 1

- "Woodpile" lattice has omnidirectional band gap
- Structure uses optical fields to focus particle beam
- Beam dynamics simulations demonstrate particle stability
- Structure can be fabricated using wafer-fusion technique

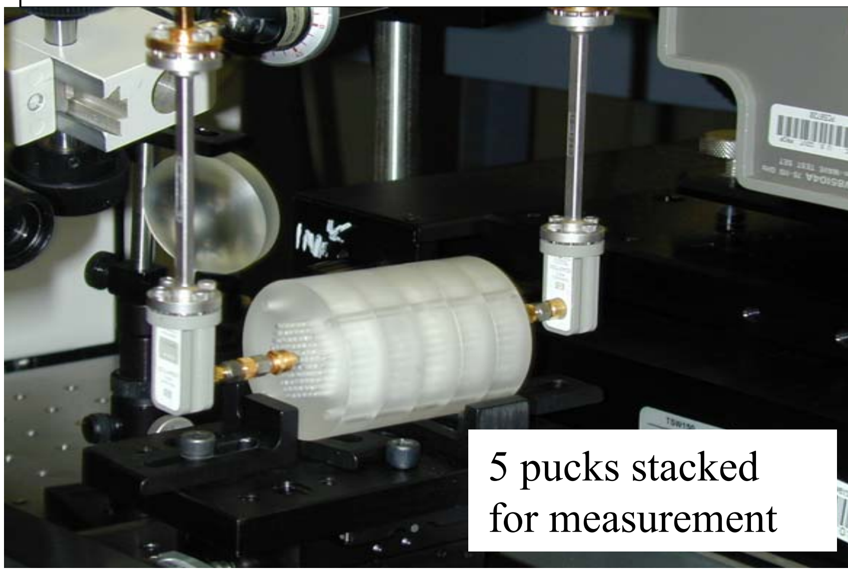


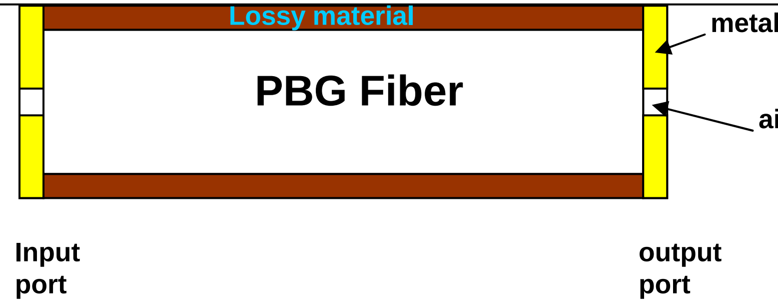
Particle tracking studies through 2.9×10^6 λ (2.33 m) of structure show good emittance preservation

PBG Fiber Scaled-Model Tests & Simulations

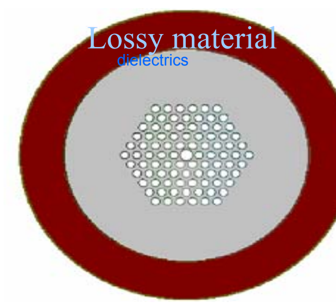
ARDB

- For proof of concept, experiments conducted at W-band due to ease of fabrication and the ability to measure field profiles.
- Fabricated by stacking and pinning "pucks" adjacently as shown below.


5 pucks stacked for measurement

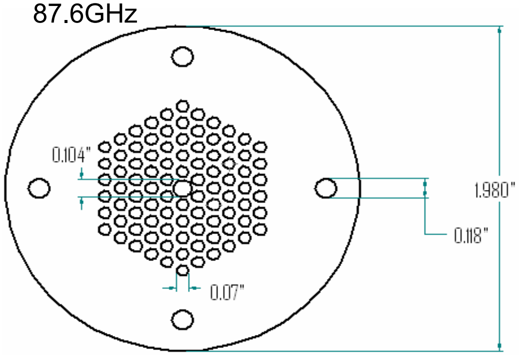


- Originally designed with the MIT Photonic Bands code
- Time-domain GdfidL simulations of the w-band model are being developed for comparison purposes and to gain understanding of the simulation and measurement processes
- Input power coupler studies are underway



PBG Fiber

Bandgap Theoretically centered at 87.6GHz



Test "puck" made of rexolite n=1.59, at 3000x scale.

Laser Acceleration: E163

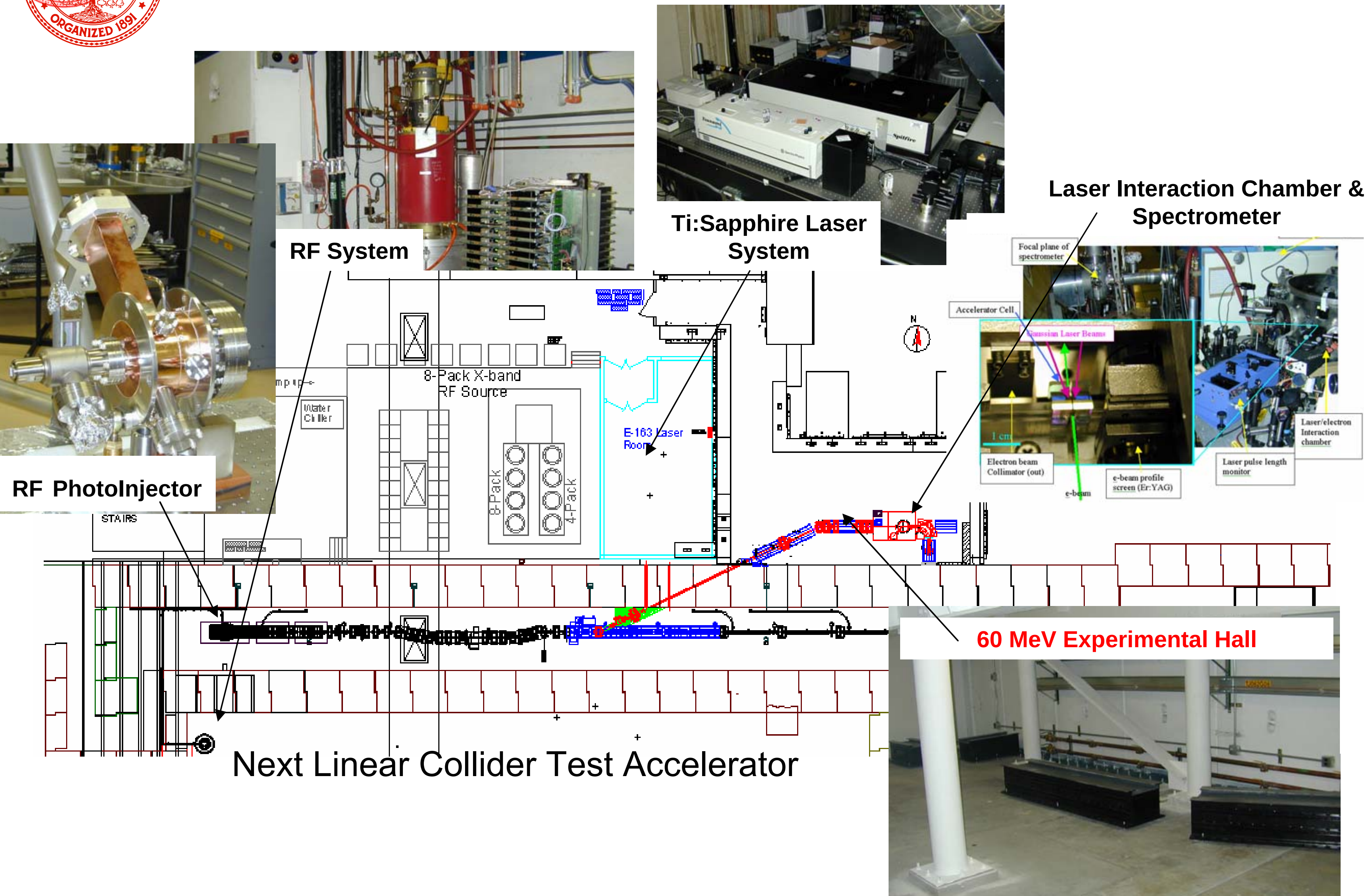
E163: Laser Acceleration at the NLCTA

➔ *Future home of the LEAP experiment*

- Substantial infrastructure completed:
  - Electron gun, experimental hall construction, s-band rf system, laser system, gun solenoid *completed*
  - Electron gun power-tested at production gradient
- Optical prebuncher (IFEL & compressor chicane) components *completed*
- Complete by fall this year:
  - Laser cleanroom and experiment control room
  - Beamline magnets
- Work on controls, diagnostics, personnel and machine protection systems will begin this summer
- *Expect start-of-science near end of FY2005*

E163 – Laser Acceleration Experiment

ARDB



Plasma Wakefield Group

C.E. Barnes, C. O'Connell, F.J. Decker, P. Emma, M.J. Hogan, R. Iverson*
P. Krejcik, R.H. Siemann, and D. Walz
Stanford Linear Accelerator Center

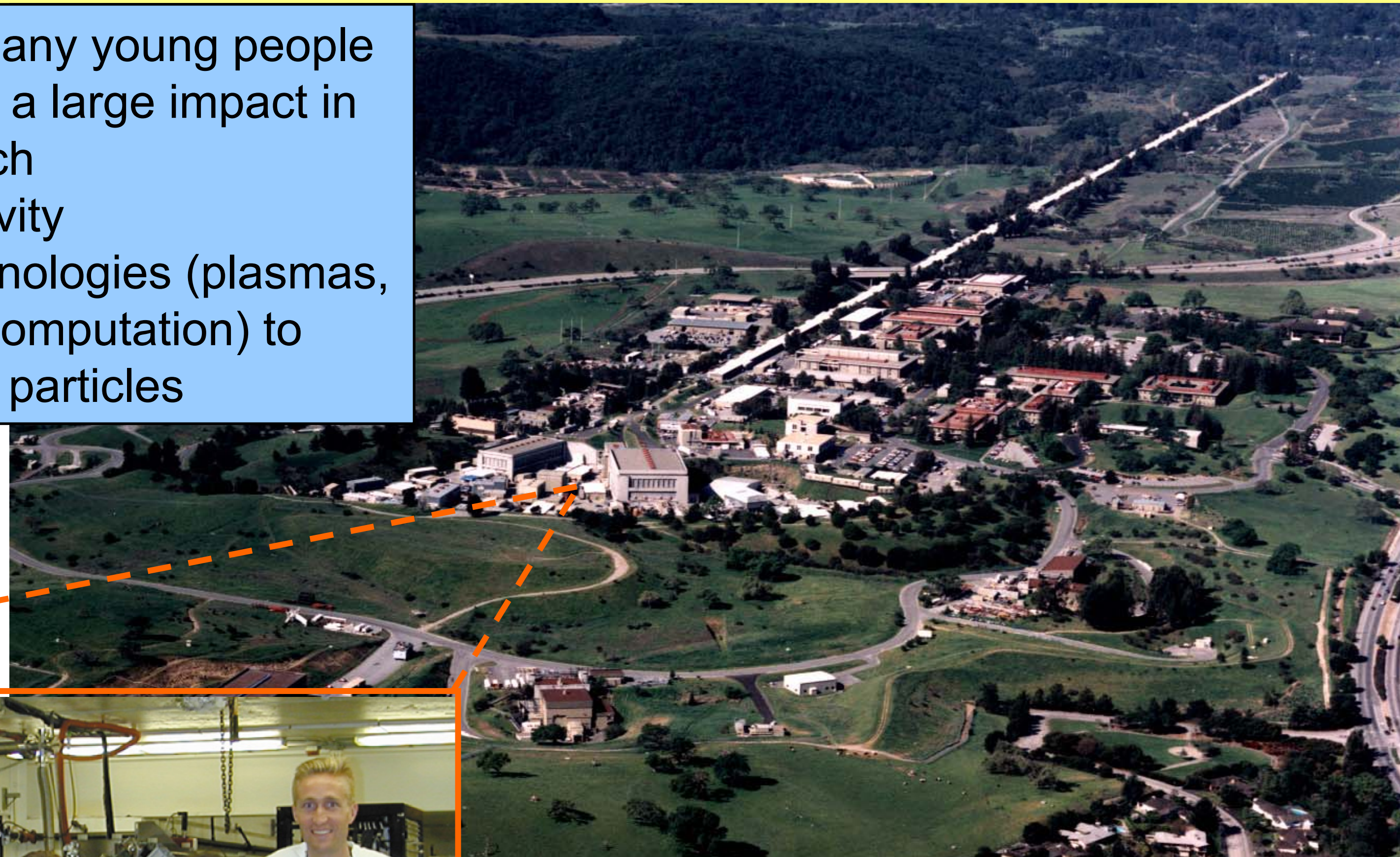
C. E. Clayton, C. Huang, D. K. Johnson, C. Joshi, W. Lu*
K. A. Marsh, and W. B. Mori
University of California, Los Angel*es*

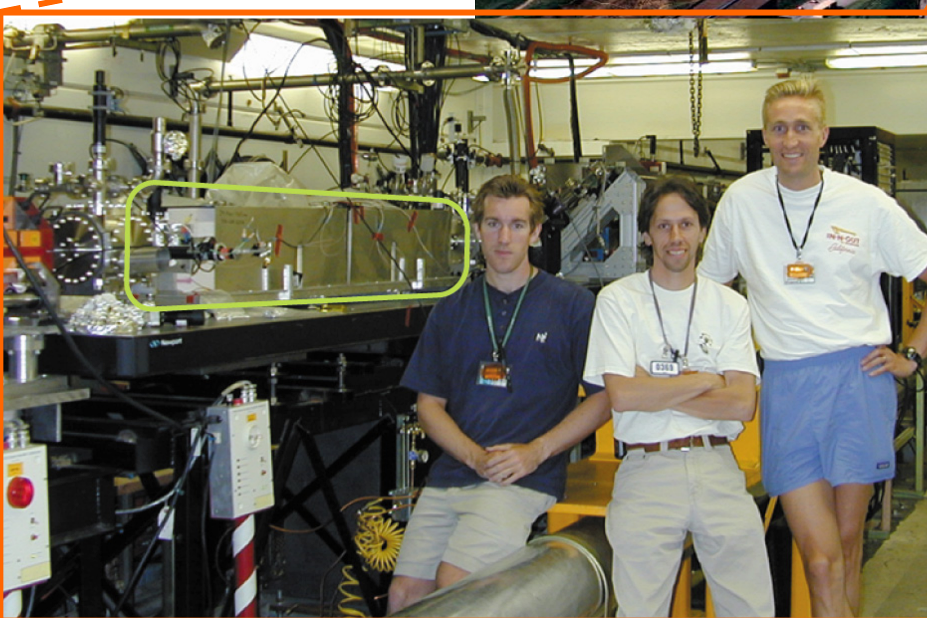
S. Deng, T. Katsouleas, P. Muggli and E. Oz*
University of Southern California

Breakout session "Accelerator – Recent Plasma Acceleration Results" by M. Hogan
Thursday June 3, 2004 2:00PM

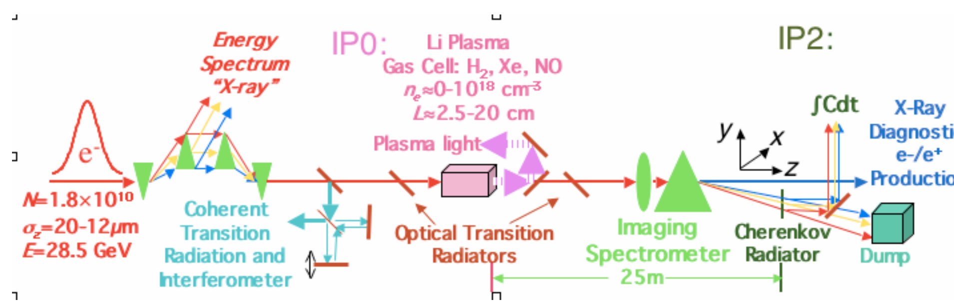
Plasma Wakefield Acceleration: Who We Are & What We Do:

Small group with many young people
➔ individuals have a large impact in all areas of research
- Premium on creativity
- Apply various technologies (plasmas, lasers, advanced computation) to accelerate & focus particles



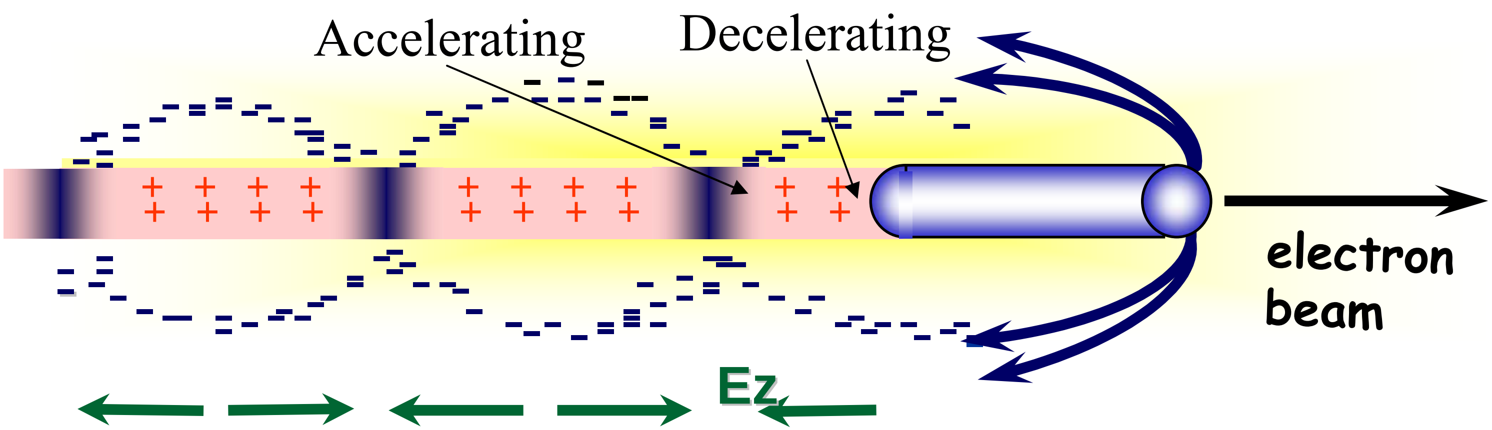


E-162 (complete) & E-164 (w/SPPS)



E-164X:
A new regime for PWFA

LINEAR PWFA SCALING



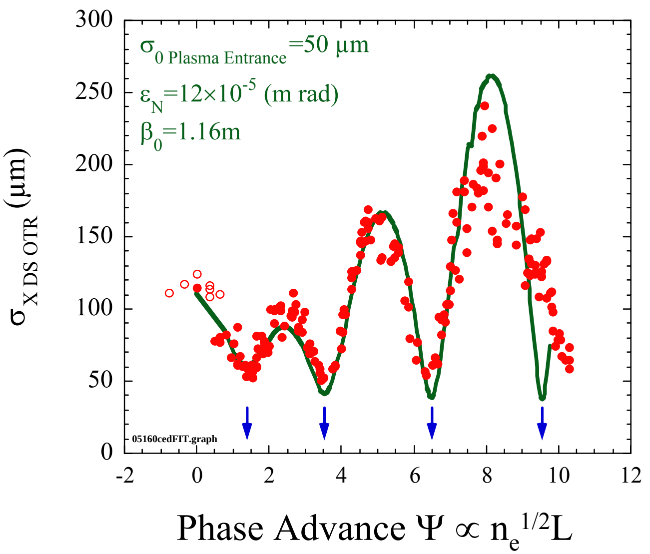
- $E_{z,linear} \propto \frac{N}{\sigma_z^2}$ Short bunch!
- For $k_p \sigma_r << 1$ and $k_p \sigma_z \cong \sqrt{2}$ or $n_p \propto \frac{1}{\sigma_z^2}$

E_z: accelerating field
N: # e⁻/bunch
σ_z: gaussian bunch length
k_p: plasma wave number
n_p: plasma density
n_b: beam density

- However, when $n_b > n_p$, non-linear□□□□ or "blow-out" regime
- Scaling laws valid?

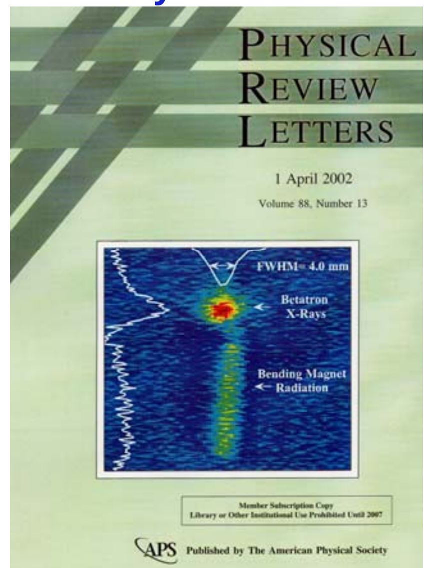
Beam-Plasma Experimental Results (6 Highlights) *ARDB*

Focusing e^-



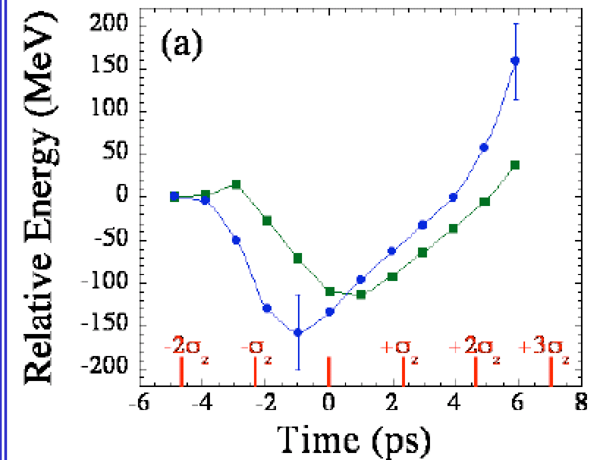
Phys. Rev. Lett. **88**, 154801 (2002)

X-ray Generation



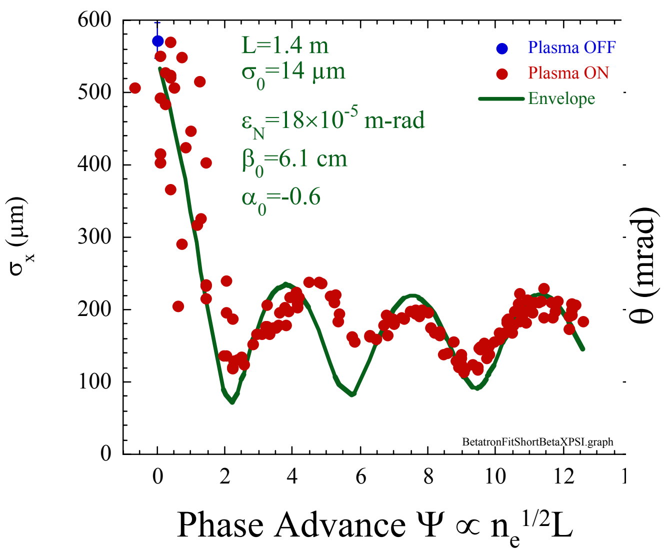
Phys. Rev. Lett. **88**, 135004 (2002)

Wakefield Acceleration e^-

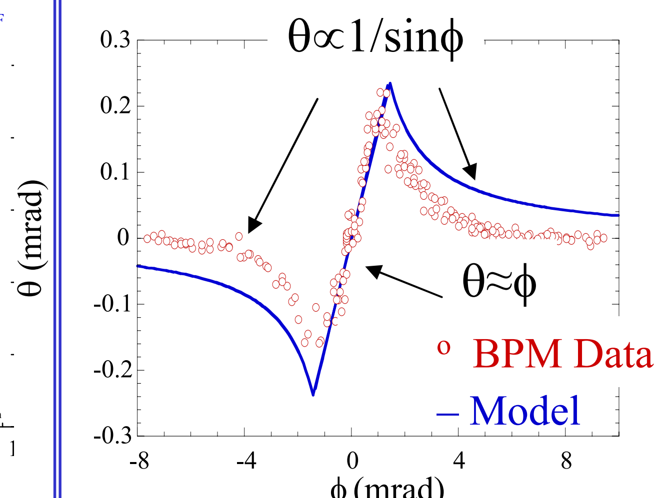


Accepted Phys. Rev. Lett. (2004)

Matching e^-

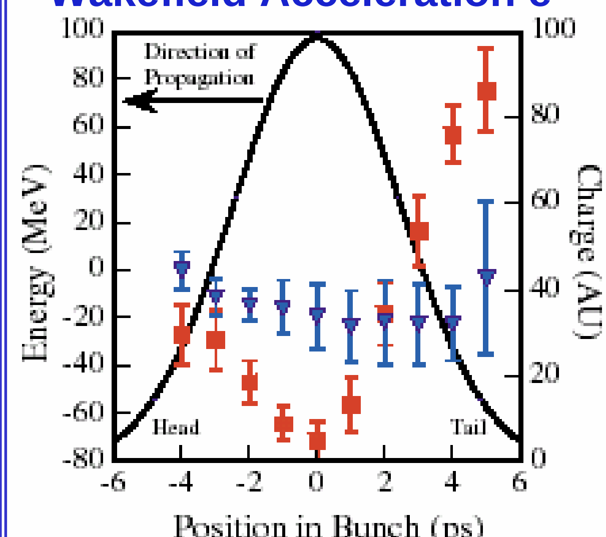


Electron Beam Refraction at the Gas Plasma Boundary



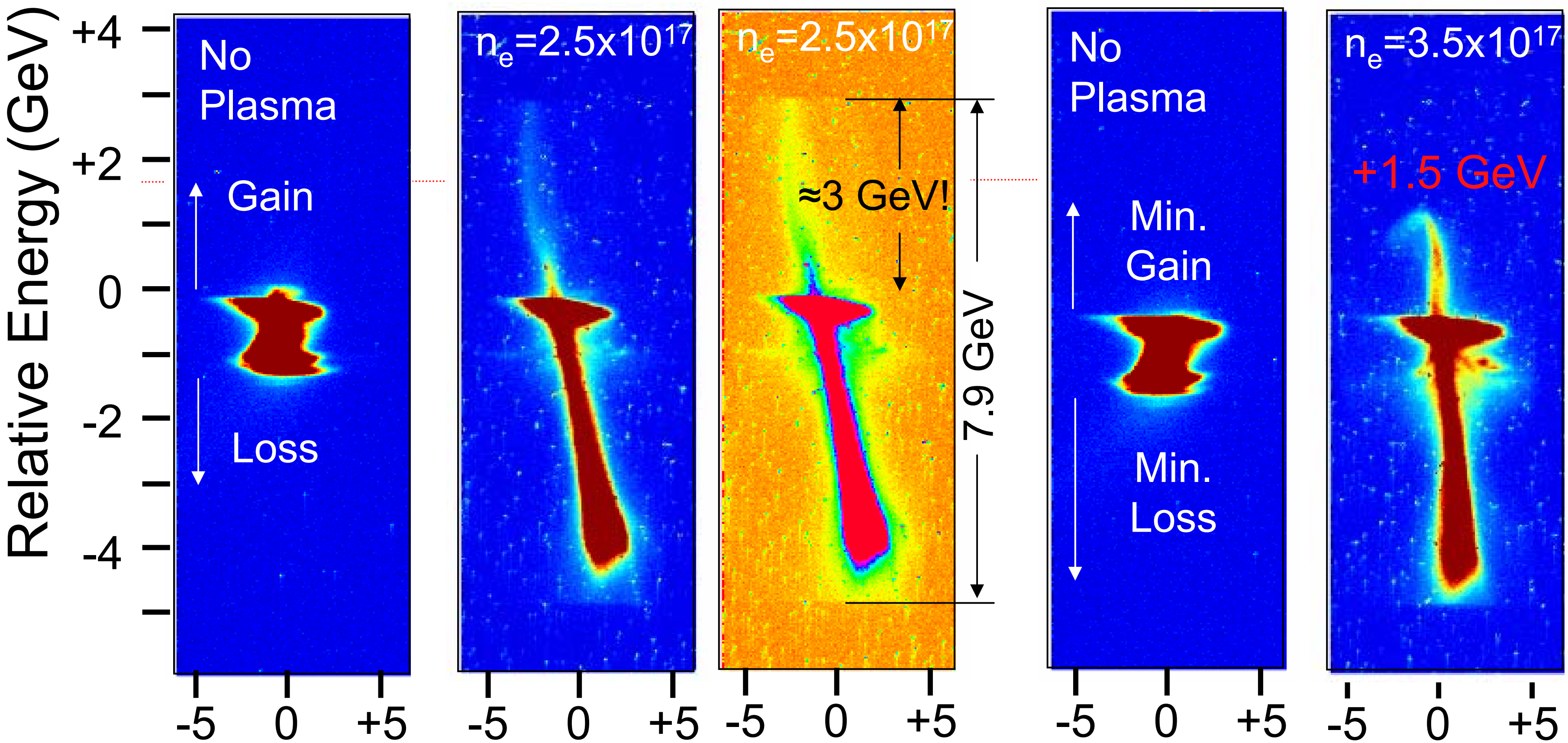
Nature **411**, 43 (3 May 2001)

Wakefield Acceleration e^+



Phys. Rev. Lett. **90**, 214801 (2003)

Accelerating Gradients ~ 30 GeV/m! Sustained over 10cm

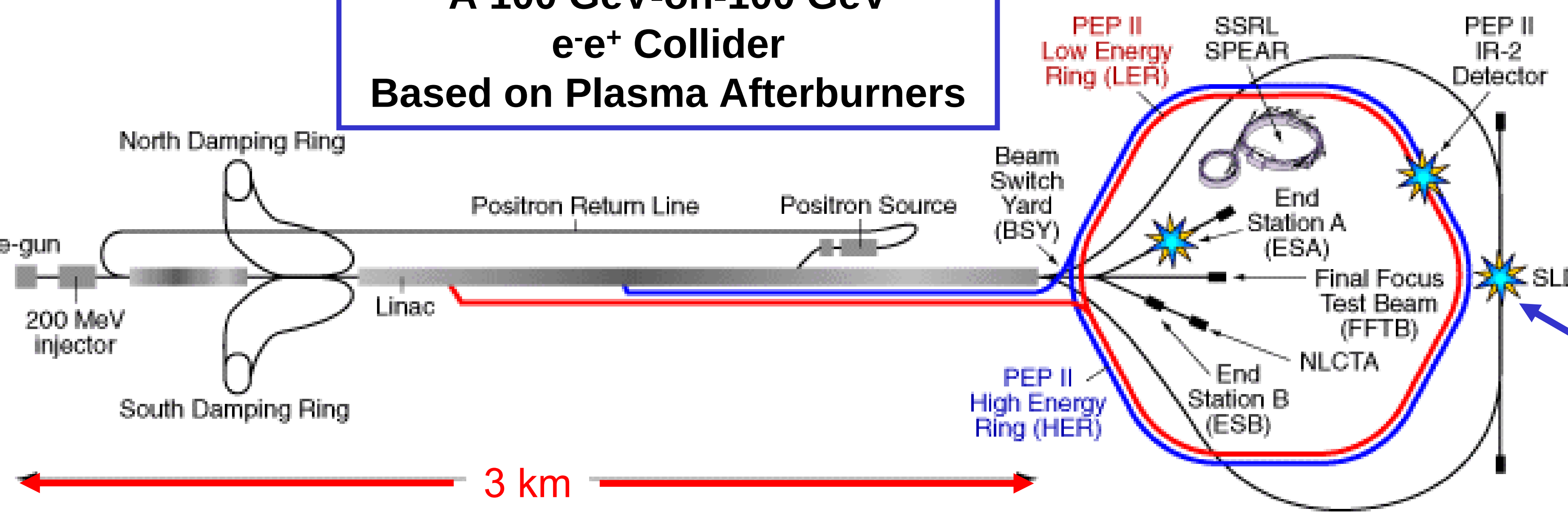


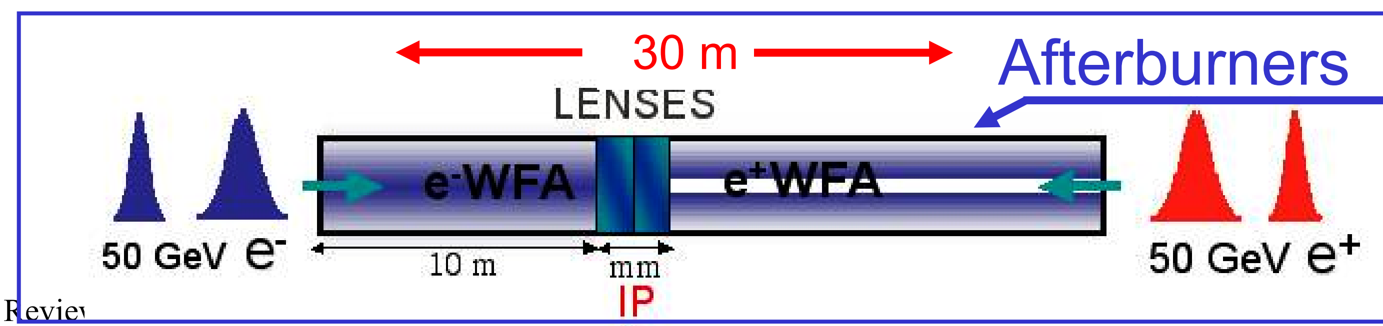
- Charge Fraction at $E > E_0$: 6.8-7.9% of total charge!
- Acceleration with significant charge: 1.5-3 GeV above Max E_0

Plasmas Have Extraordinary Potential

Investigating the physics and technologies that could allow us to apply the enormous fields generated in beam-plasma interactions to high energy physics via ideas such as:

A 100 GeV-on-100 GeV
e^-e^+ Collider
Based on Plasma Afterburners





Summary of Plasma Experiments In the FFTB

- A rich experimental program in plasma physics ongoing at SLAC
- Primarily looking at issues associated applying plasmas to high energy physics and colliders
- Built on E-157 & E-162 which observed a wide range of phenomena with both electron and positron drive beams: focusing, acceleration/de-acceleration, X-ray emission, refraction, tests for hose instability…
- E-164X in progress
  - o Compressed bunches field ionize neutral vapor and create the plasma
  - o Accelerating gradients of 30 GeV/m over 10cm
  - o Energy Gains > 1 GeV (1st time in a plasma accelerator!)
  - o Limited by energy acceptance of FFTB dumpline

Advanced Accelerator R&D Synopsis

ARDA

•Lattice Dynamics

MIA work to improve PEP-II, Tevatron; electron cloud and beam-beam interaction calculations for PEP-II and Super-B

•Collective Effects

CSR microbunching instability, including screening; collective effects in PEP-II upgrades; SPPS experiment; LCLS improvements;

•Advanced Beam Concepts

FLASH, Laboratory Astrophysics, Gravitational Lenses, Early Universe Simulation Code

•Advanced Electronics

PEP-II high-current commissioning, Quadrupole Mode Control Studies, GBoard Processing Channel

•RF Structures

Prototype Structures for NLC, Compact HOM Damping Structures, Develop Automated RF QC and Tuning Systems

•High Power RF

8-Pack; high power circulators; RF breakdown phenomenon; active pulse compression system; highly multimoded delay lines; DLDS

ARDB

•Laser Acceleration

Laser pulse and phase locking; photonic band gap structure design and testing; E163 construction and commissioning

•Plasma Wakefield Acceleration

Demonstration of high gradient acceleration (30 GeV/m) over 10cm with total energy gain > 1 GeV

Advanced Computations Department (ACD)

- Formed in 2001, ACD now consists of 3 groups with 13 staff members, 3 grad students, 1 undergrad, 3 visitors *(Multidisciplinary):*

  Accelerator Modeling *- V. Ivanov, A. Kabel, K. Ko, M. Kowalski, Z. Li, C. Ng, L. Xiao*

  Computational Mathematics *- S. Chen, L. Ge, R. Lee, K. Shah, R. Uplenchwar*

  Computing Technologies *- N. Folwell, A. Guetz, J. He, N. Loebner, G. Schussman*

  Visitors *– G. Golub (Stanford), L. Stingelin (PSI), J. Varner (Genencor)*

- Support derived from base program and Lab projects, SciDAC program (HEP and ASCR), 2 SBIR grants, and 1 CRADA project

- SciDAC collaborations in comp. science and applied math. involve 3 national labs and 6 universities:

  LBNL *- E. Ng, P. Husbands, X. Li, A. Pinar*

  LLNL *- L. Freitag, D. Brown, K. Chand, B. Henshaw, D. White*

  SNL *- P. Knupp, T. Tautges, K. Devine*

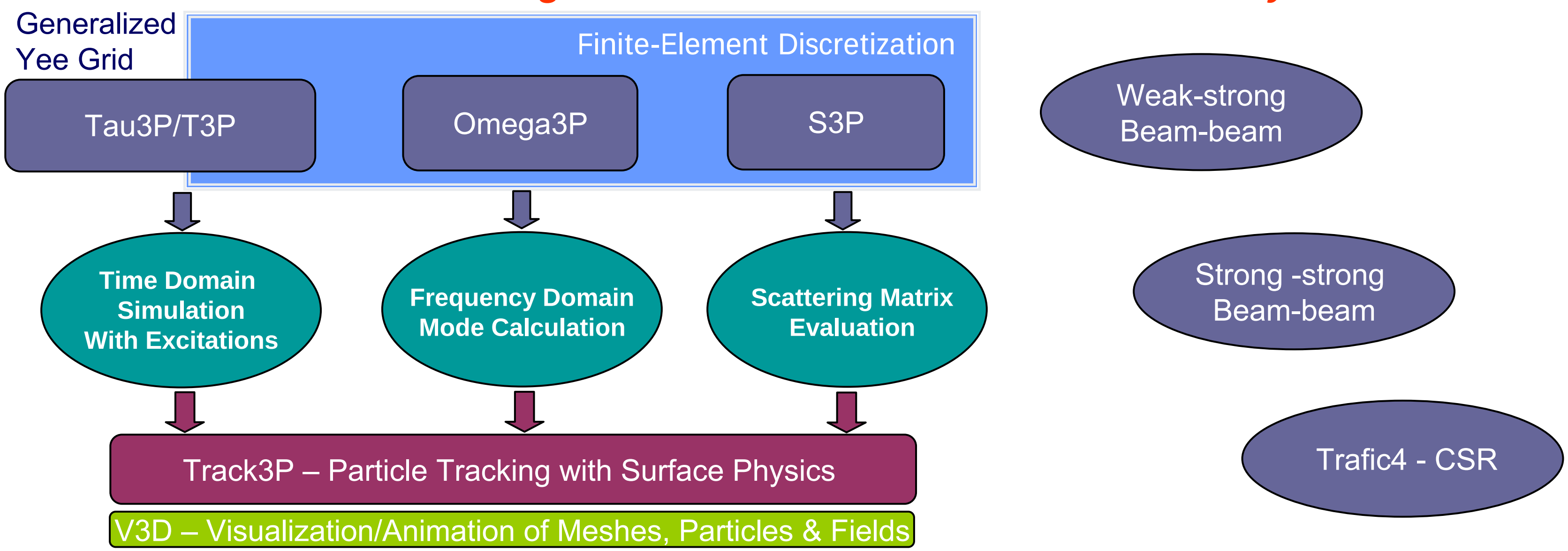
  Stanford *– G. Golub;* ***UCD*** *– K. Ma, H. Yu;* ***RPI*** *– M. Shephard, Y, Luo;*

  Columbia *– D. Keyes;* ***Carnegie Mellon U*** *– O. Ghattas,* ***U. of Wisconsin*** *– H. Kim*

Code Development, Collaborations & Applications

- SciDAC supports development of parallel tools to enable *Large-scale accelerator simulations* on DOE's flagship supercomputers

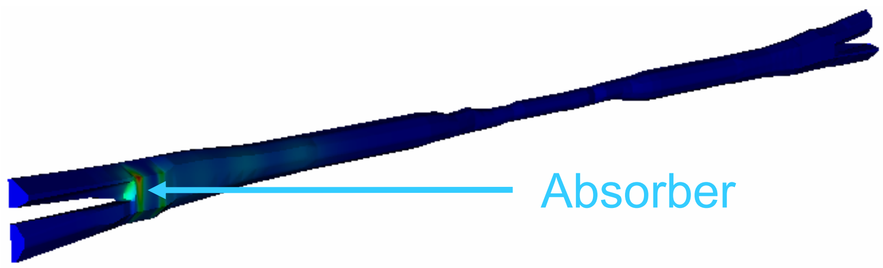
"Electromagnetics" *"Beam Dynamics"*

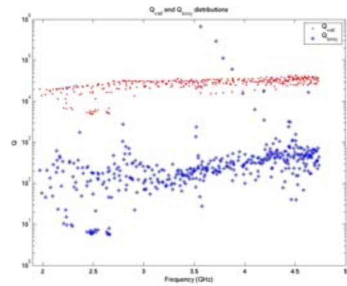


- SciDAC collaborations are *maximizing code capability/performance* through new algorithms and advances in computational science (mesh refinement, partitioning, visualization, etc..)
- Codes are applied to *improve existing accelerators* (PEP-II, Tevatron), and to *design planned and future facilities* (LCLS, NLC)

Parallel Electromagnetic Modeling

- **PEP-II** – Omega3P/Tau3P are being used to study beam heating in the Interaction Region and absorber design for damping trapped modes



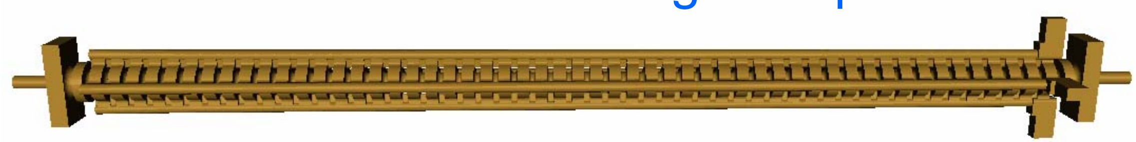


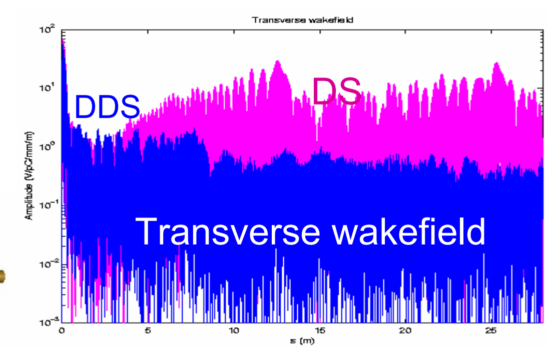
Wall Loss Q

Damped Q

QuickTime™ and a
MS-MPEG4v2 Video decompressor
are needed to see this picture.

- **NLC** – Tau3P provided 1st ever direct beam calculation of wakefields in an entire DDS structure that includes all higher dipole bands





QuickTime™ and a
MS-MPEG4v2 Video decompressor
are needed to see this picture.

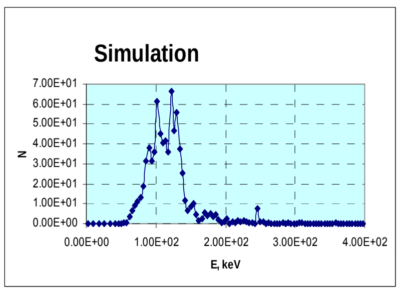
ACD ADVANCED COMPUTATIONS

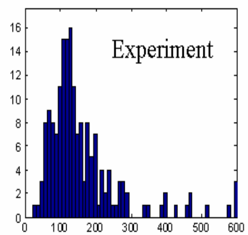
SciDAC Scientific Discovery through Advanced Computing

Progress in Computational Science

➢ Dark Current Simulation

Track3P benchmark against high power test data on **NLC** waveguide bend. Simulation of 30-cell and 55-cell **NLC** structures in progress.





QuickTime™ and a MS-MPEG4v2 Video decompressor are needed to see this picture.

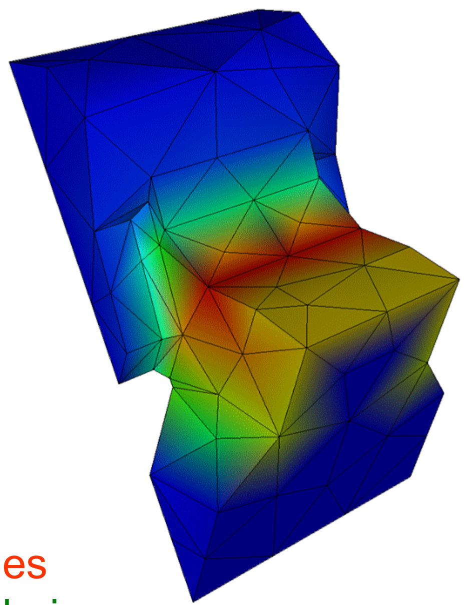
Primaries

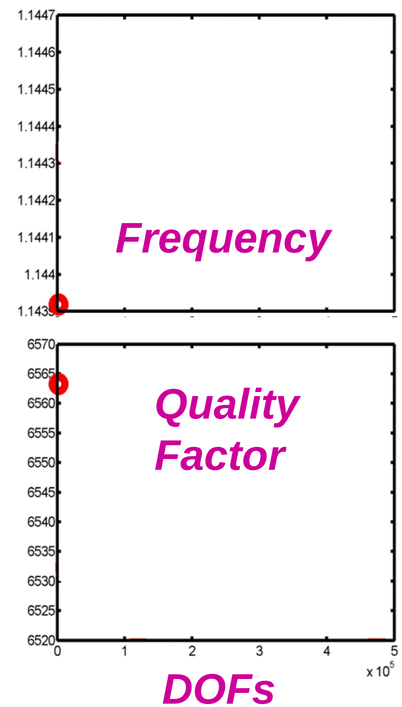
Secondaries

➢ Adaptive Mesh Refinement

Omega3P with AMR uses ***1/18*** of the DOFs previously needed to achieve same accuracy in calculating **NLC/DDS** cell's frequency and quality factor.

Joint work with RPI



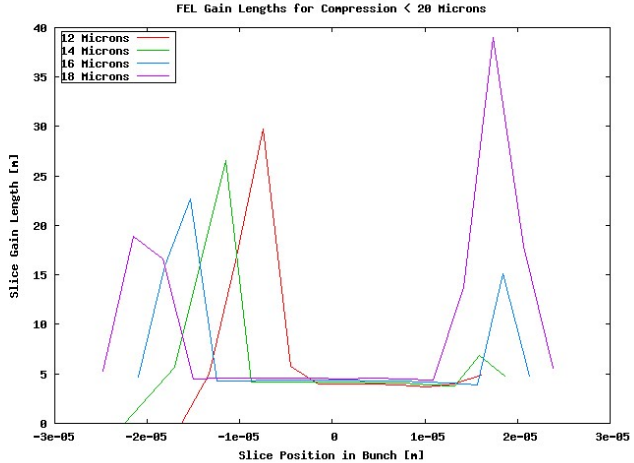


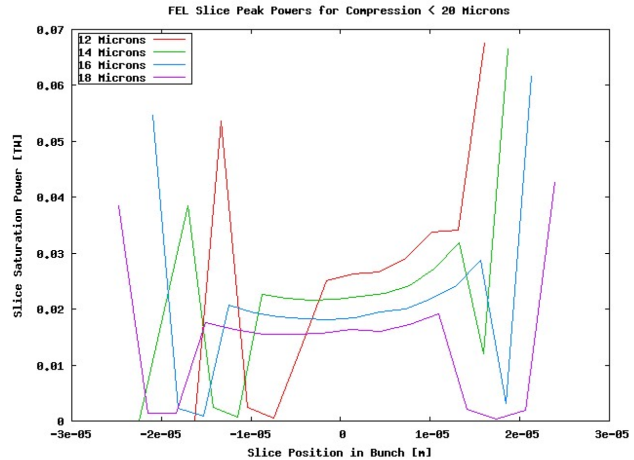
ACD ADVANCED COMPUTATIONS

SciDAC Scientific Discovery through Advanced Computing

Parallel Beam Simulations

- **LCLS** - Self-Consistent *CSR simulations* for bunch compression show potential for shorter bunches/higher FEL performance

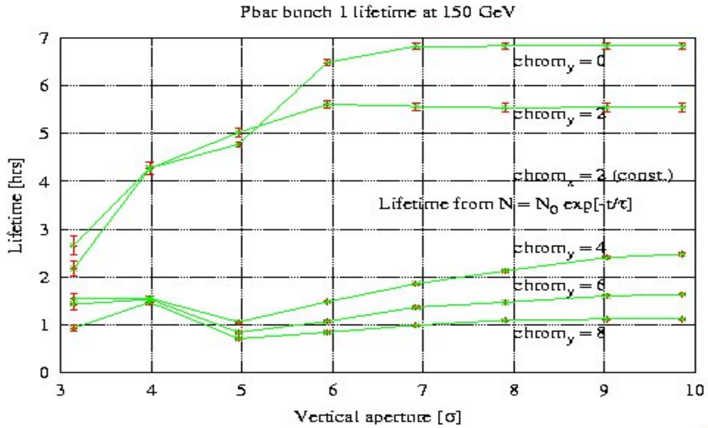




- **Tevatron** – *Beam-beam simulations* predict beam lifetimes

Simulations aid in choices of optimal operation parameters:

- Chromaticity
- Helix openings
- Beam currents
- Beam emittances
- Bunch train schemes



ACD ADVANCED COMPUTATIONS

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