SABER

A Facility for Accelerator Physics and Test Beam Experiments

SLAC

Mark Hogan

Advanced Accelerator Concepts Workshop

July 10, 2006

Outline

- What is SABER and Why Does SLAC Want to Build It?
- A Few Highlights of Science at the FFTB
- Some Examples of Future Directions
- Features of SABER
- Timeline
- Summary

The FFTB is Gone!

The Problem:

The Final Focus Test Beam (FFTB) turned off April 10th and has been dismantled to make room for the LCLS.

Strong user demand:

Plasma wakefield acceleration

SPPS

Laboratory Astrophysics

Many other unusual physics and technology measurements

What can be done to replace its functions?

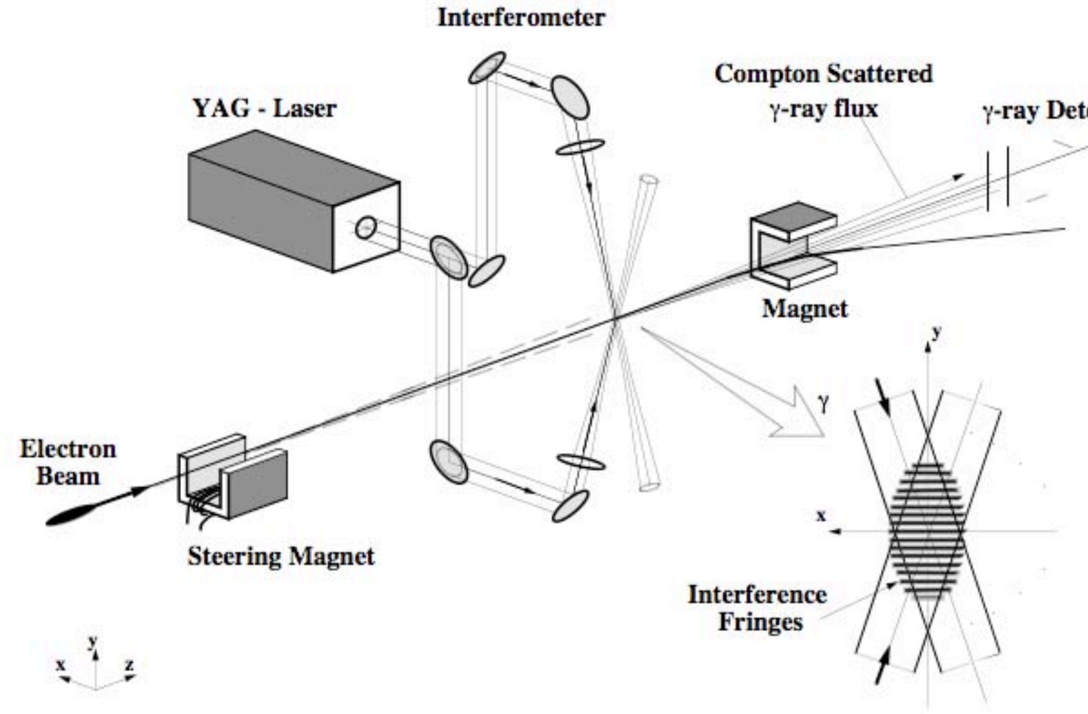
SABER: South Arc Beam Experiment Region

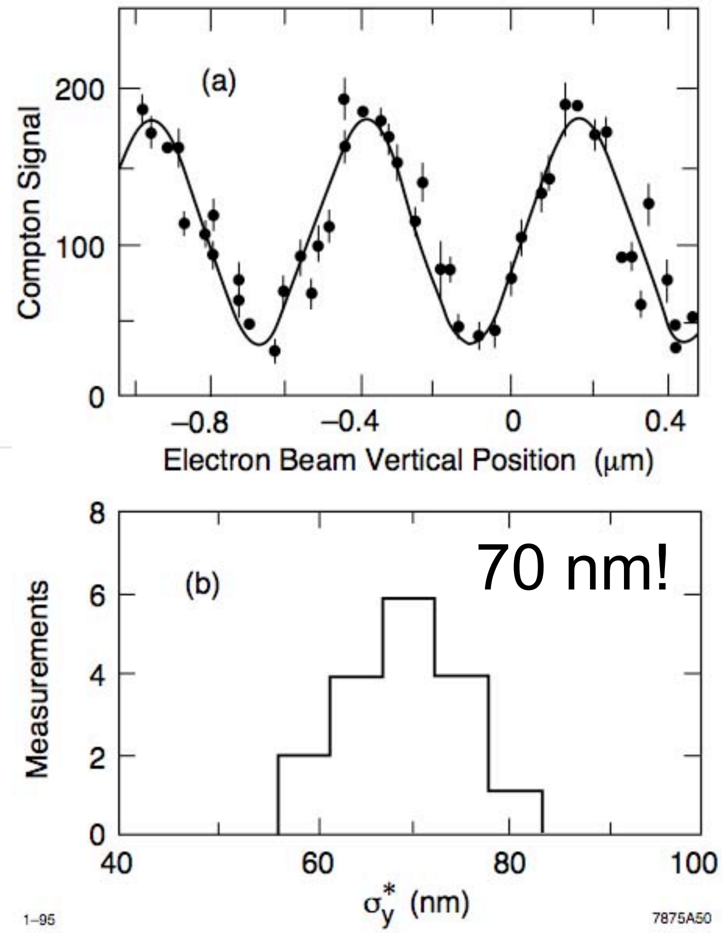
- A proposed facility for experiments requiring compressed, focused, high-energy beams of electrons or positrons.
- To be built in the Instrument Section in the SLC South Arc tunnel.

Description:

- **SABER White Paper (December 2005)** **http://www.slac.stanford.edu/grp/rd/epac/LOI/SABER.pdf**
- **SABER Workshop (March 2006) presentations:** **http://www-conf.slac.stanford.edu/saber/present/default.htm**

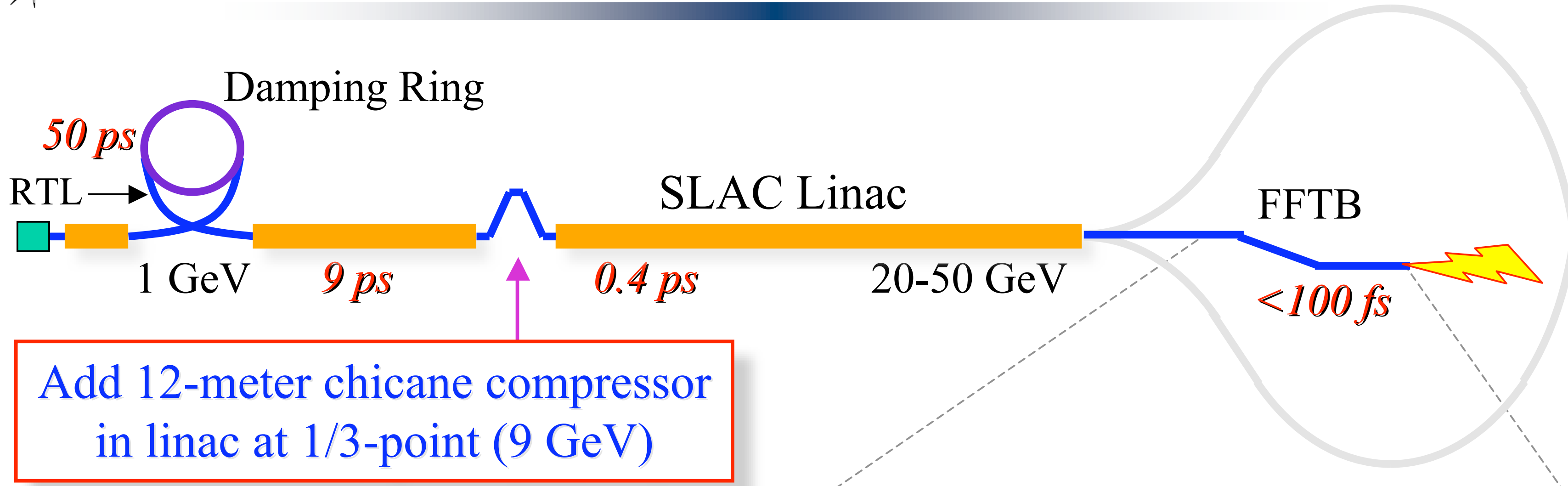
The FFTB's Original Mission



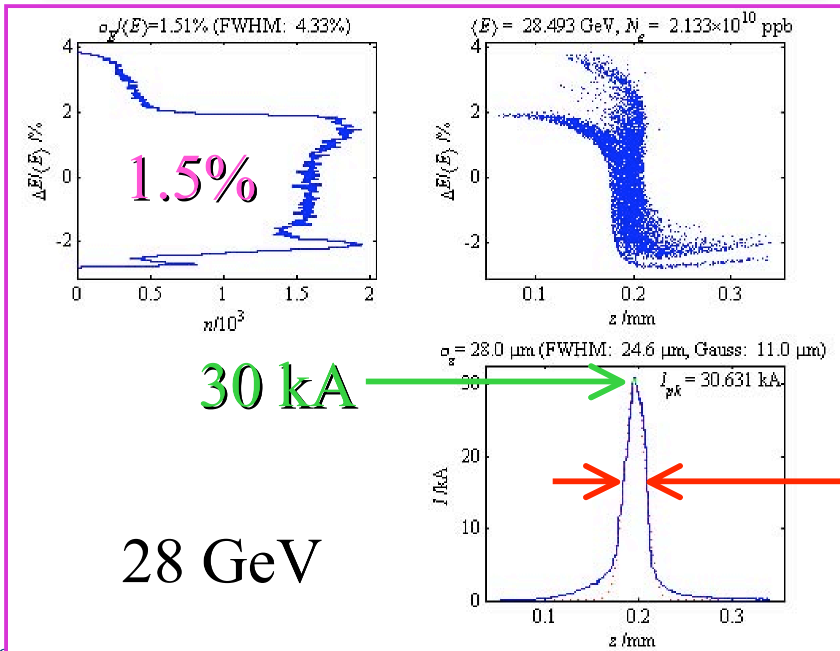


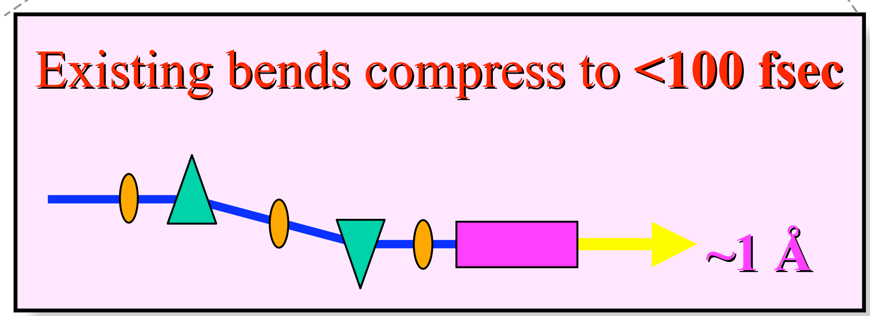
Designed to prove the concepts for the final focus system of a future linear collider (chromatic correction, beam-based alignment…)

Short Bunch Generation in the SLAC Linac

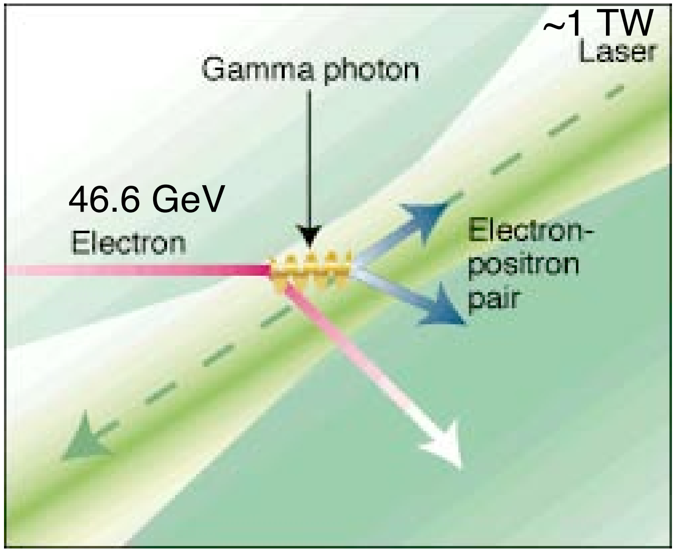


Add 12-meter chicane compressor in linac at 1/3-point (9 GeV)



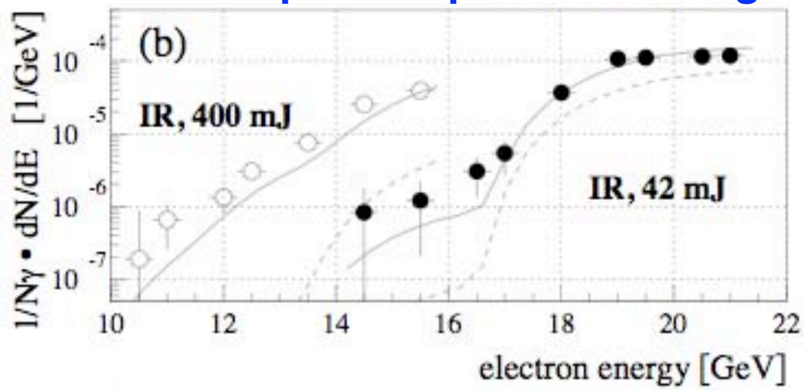


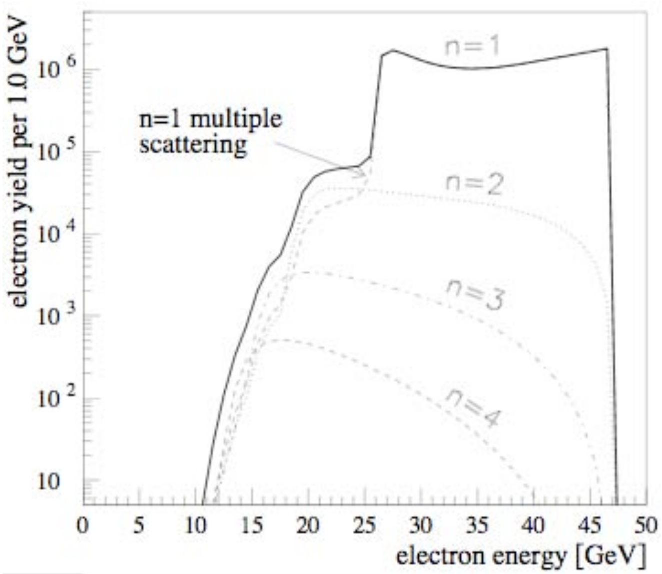
E-144: Matter from Light



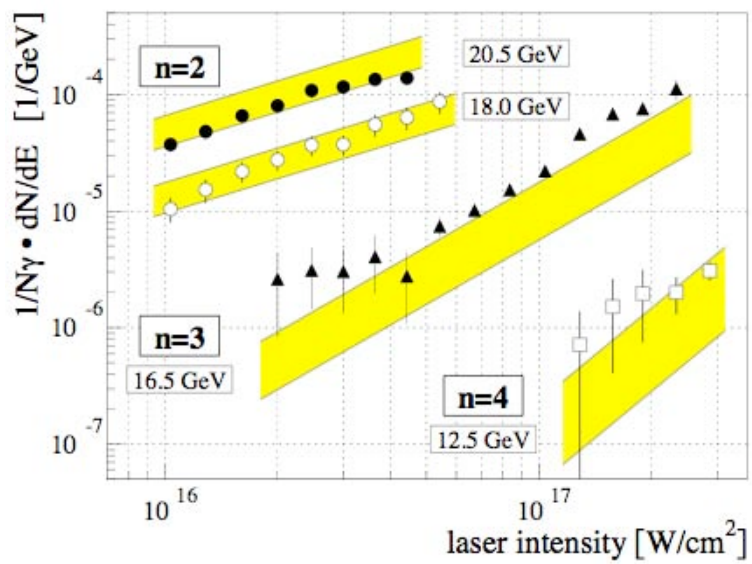
C. Bula *et al.*, Phys. Rev. Lett. **76**, 3116 (1996)

Observation of
Nonlinear (multi-photon) Compton Scattering
***Not* Multiple Compton Scattering**

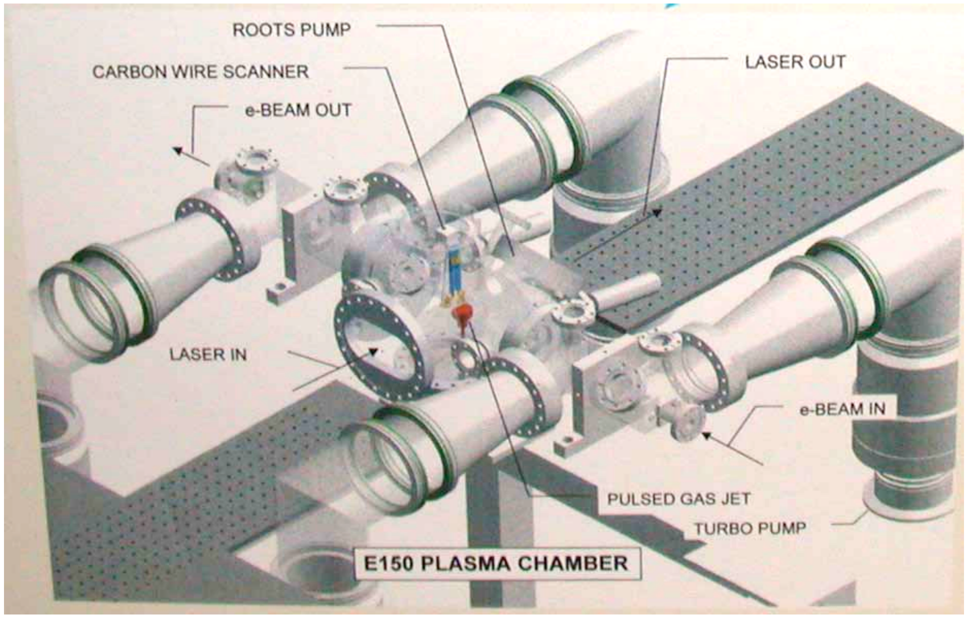




Yield Increases with Laser Intensity

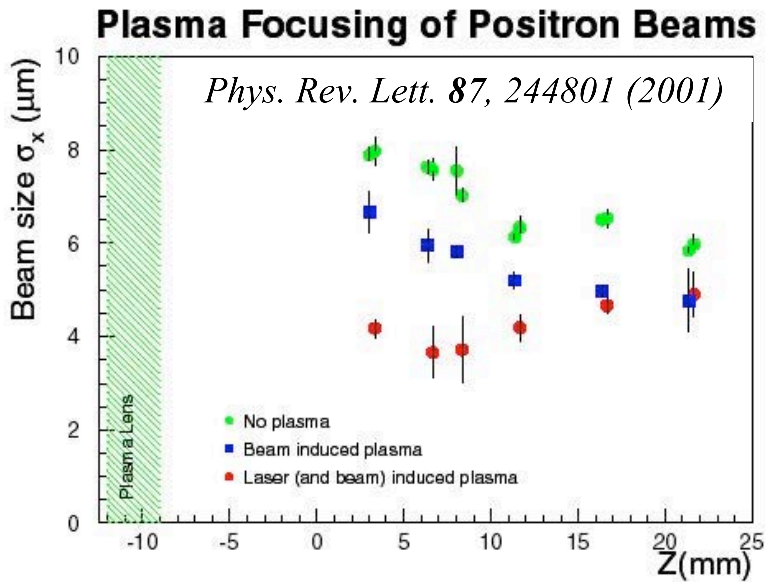


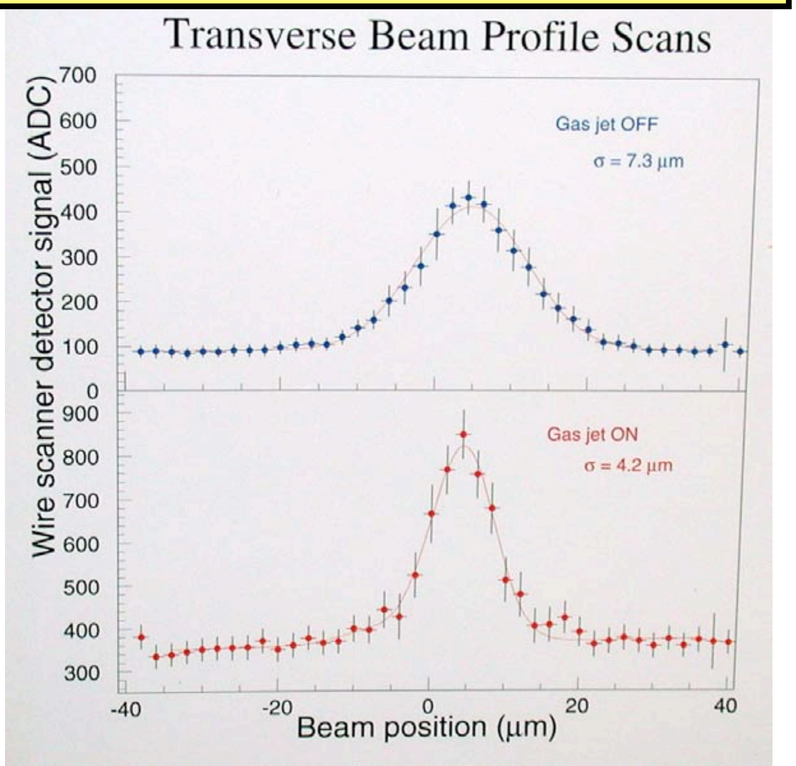
E-150: Plasma Lens for e^- & e^+



Built on early low-energy demonstration experiments in early to mid-nineties with electrons: FNAL (1990), JAPAN (1991), UCLA (1994)…

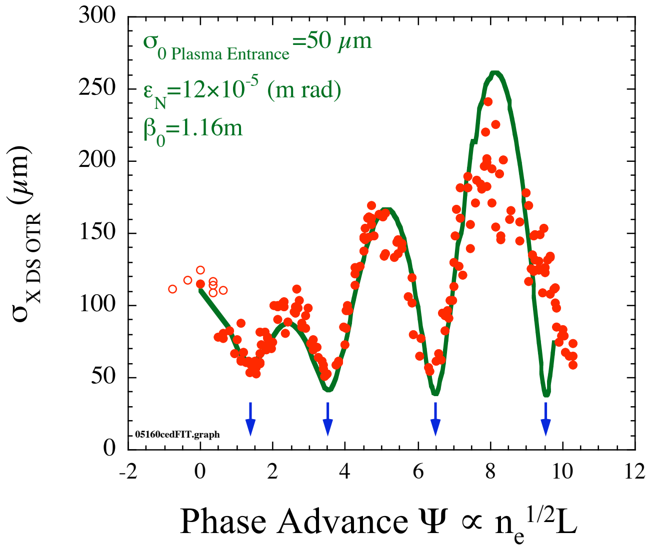
Demonstrated plasma lensing of 28.5GeV electron *and* positron beams





E-157/162/164/164X/167 Beam-Plasma Experimental Results

Focusing e^-

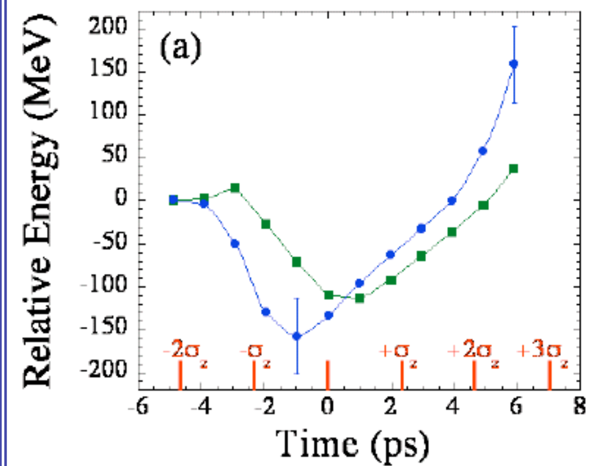


Phys. Rev. Lett. **88**, 154801 (2002)

X-ray Generation

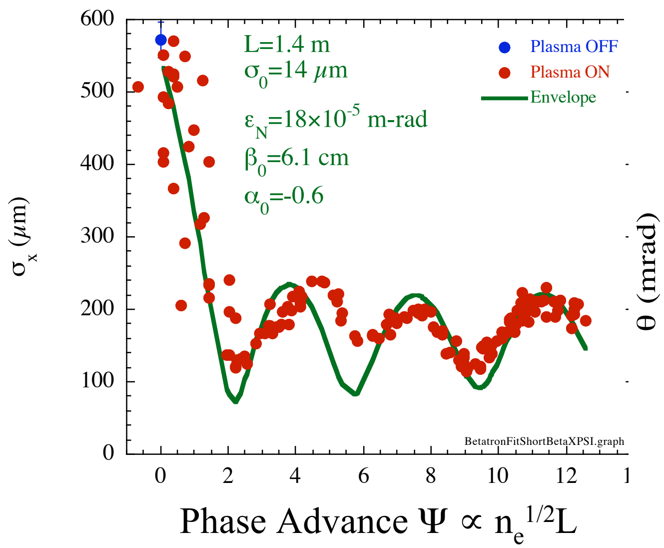
Phys. Rev. Lett. **88**, 135004 (2002)

Wakefield Acceleration e^-



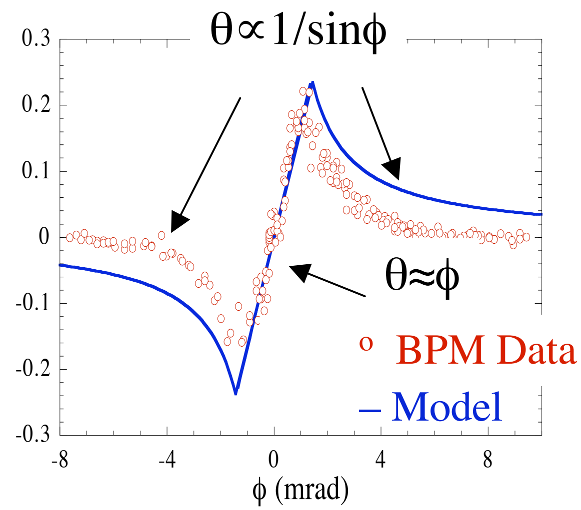
Phys. Rev. Lett. **93**, 014802 (2004)

Matching e^-



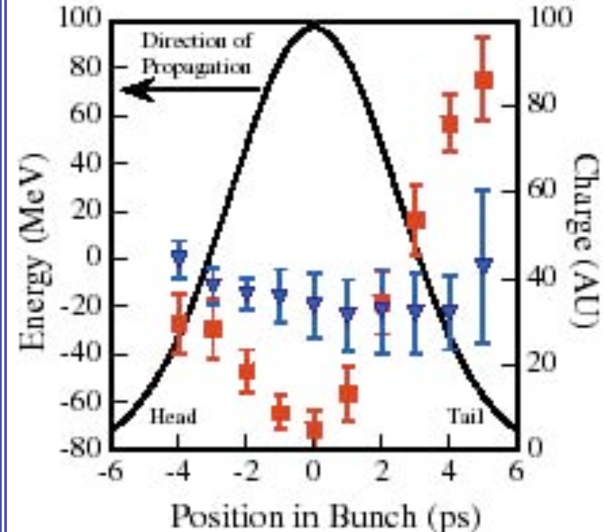
Phys. Rev. Lett. **93**, 014802 (2004)

Electron Beam Refraction at the Gas–Plasma Boundary



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

Wakefield Acceleration e^+



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

Future Directions for Beam Plasma Experiments

Sorry - This figure is part of a submission to a journal with a strict embargo policy against online posting prior to publication.

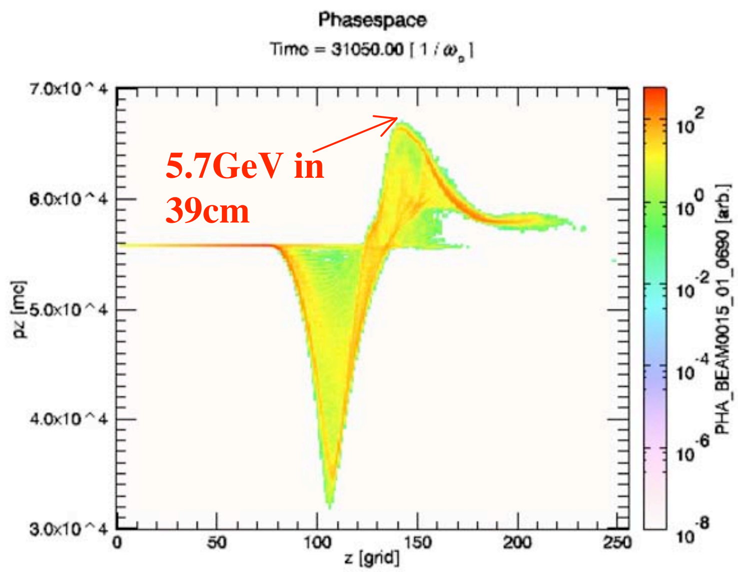
As you saw in the previous talk, still more interesting work to be done with electron beams
- Push past head erosion limit
- Accelerate a distinct second bunch
- Understand effects of trapped particles

…but the real frontier is compressed positrons.

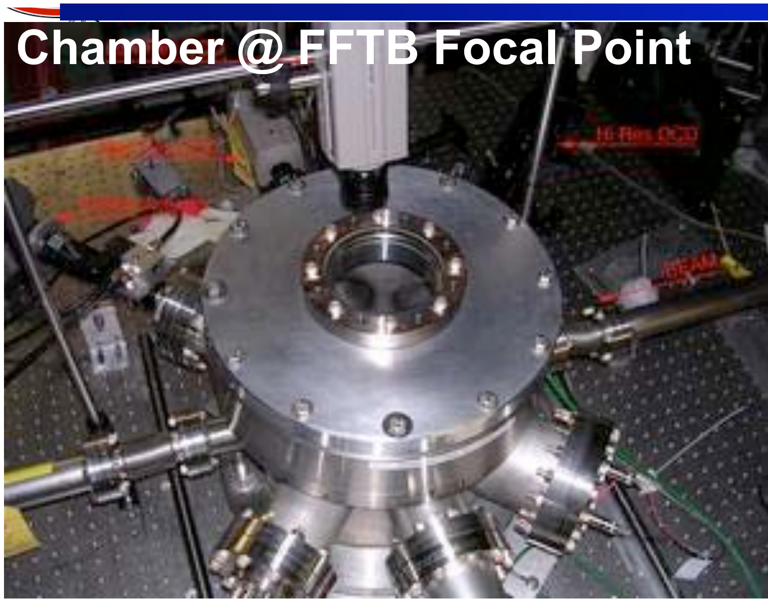
Can the large amplitude wakes measured for electrons be created and sustained for a positron drive beam?

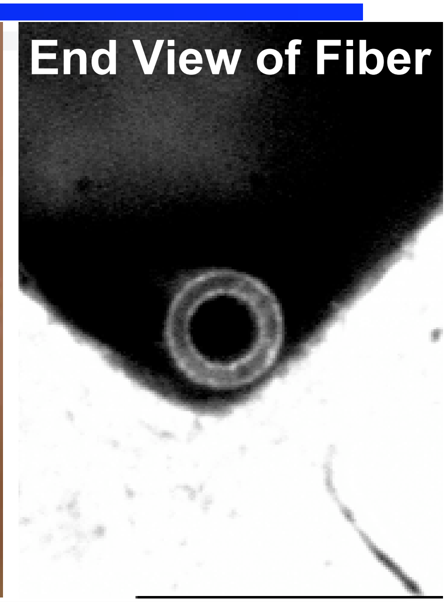
Evolution of a positron beam/wakefiled and final energy gain in a **self-ionized** plasma

$$N_b = 8.79\times10^9, \sigma_r = 11\mu m,\ \sigma_z = 19.55\mu m,\ n_p = 1.8\times10^{17} cm^{-3}$$

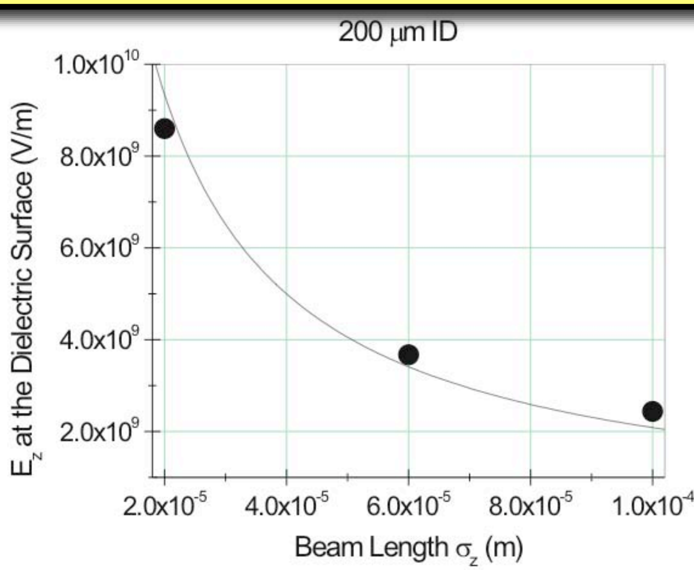


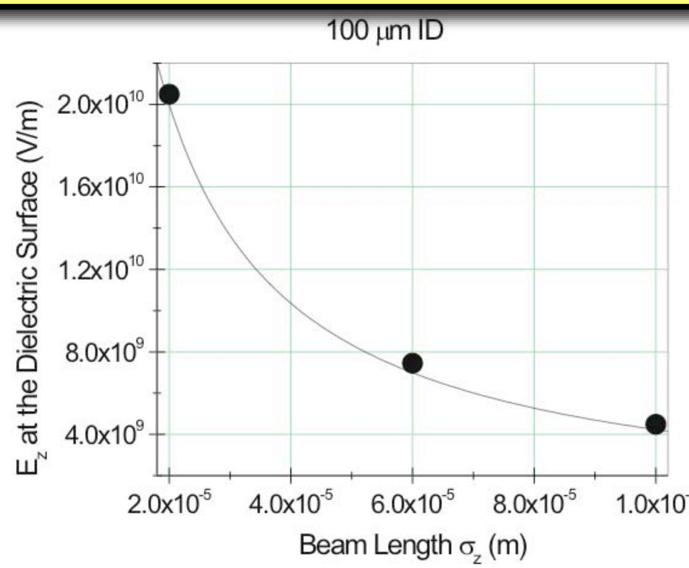
T-481: LLNL/UCLA/SLAC Ultra-High Gradient DWA





Study Breakdown As a Function of Bunch Length and Fiber Diameter



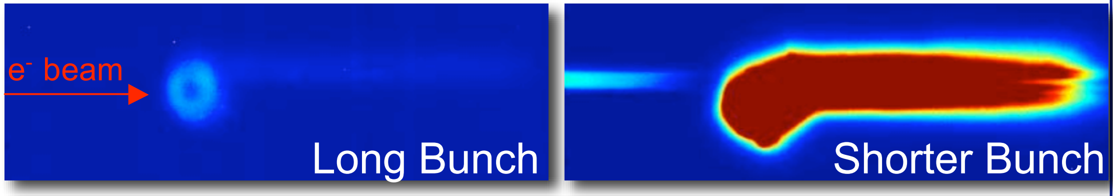


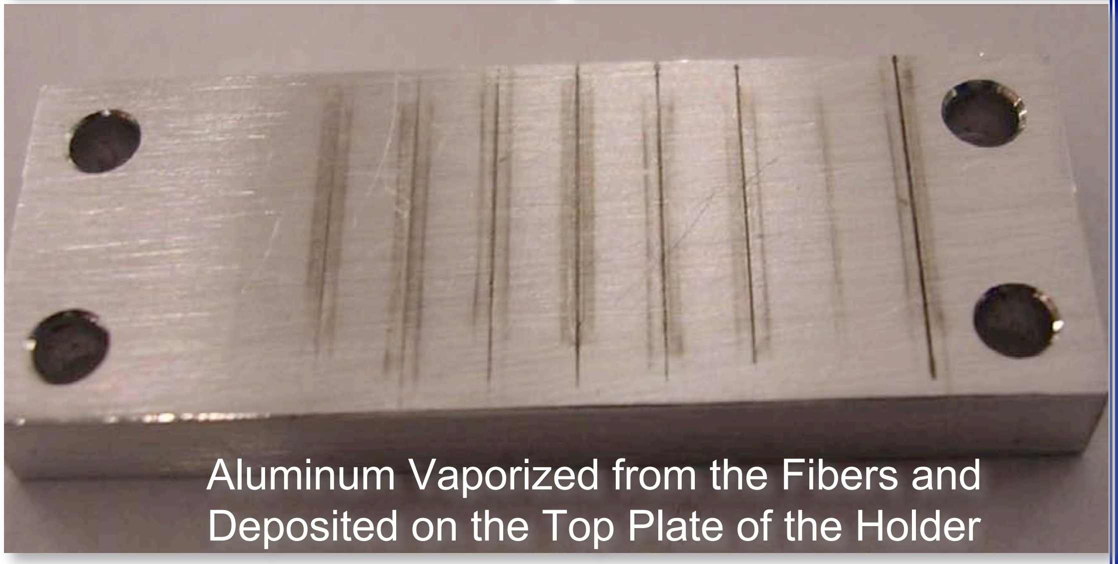
Observations & Plans For SABER

The first run of the experiment occurred in Aug 2005. The objective of the run was to examine breakdown thresholds.

Major Observations:

- A sharp increase in visible emission from the capillaries near the mid-range of beam current, probably indicating breakdown.
- Principle form of damage to the dielectric wake structures appear to be vaporization of the aluminum cladding. The fused silica appeared substantially intact.





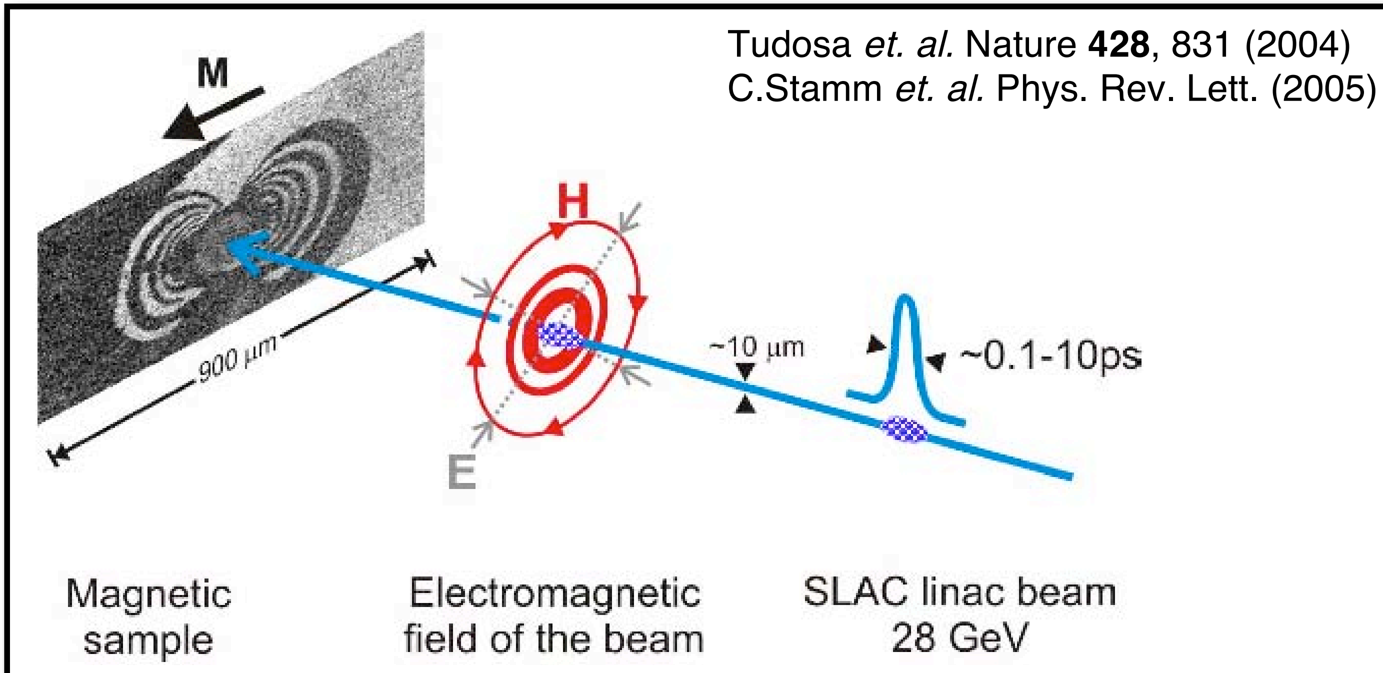
Aluminum Vaporized from the Fibers and Deposited on the Top Plate of the Holder

Next experiments will extend the dielectric length, measure e^- & e^+ for same conditions and look for CCA as direct measure of wake amplitude

Speed Limit for Magnetic Switching

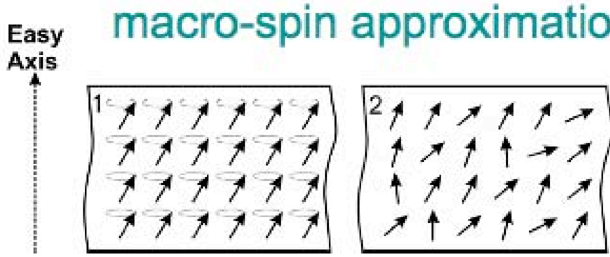
Magnetic Recording Requires Ever Smaller Bits and Faster Magnetic Switching
FFTB Experiments Demonstrated ps Speed Limit to Precessional Switching

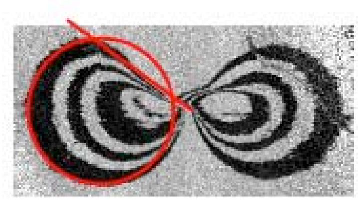
Tudosa *et. al.* Nature **428**, 831 (2004)
C.Stamm *et. al.* Phys. Rev. Lett. (2005)



Magnetization fracture, breakdown of the macro-spin approximation

Magnetic equation of motion in question!





Test Beam Experiments in FFTB

T-447	Single Pulse Damage in Materials (Sept 2000)
T-448	Magnified Optical Transition Radiation Test (Oct 2000)
T-450	Damage Test in Diamond for LCLS (Oct 2000)
T-451	High Energy Neutron Spectra Measurement (March 2001)
T-452	STAR Endcap Calorimeter Detector Prototype Test (Jan 2001)
T-453	Radiation Damage in Diamond for LCLS (April 2001)
T-454	Measurement of Neutron Spectra (June 2001)
T-455	Measurement of the Calorimeter for the Local Polarimeter at Phenix/RHIC (Aug 2001)
T-456	Magnetization Dynamics in Magnetic Films (Sept 2001)
T-457	Measurement of Neutron Energy Spectra Using Bonner Multi-Sphere Spectrometer (June 2002)
T-460	Characterization of Askaryan Effect in Rock Salt (June 2002)
T-461	High Atmosphere Air Fluorescence (June 2002)
T-462	Magnetization Dynamics of Soft-Magnetic Films (June 2002)
T-464	Correlation of Linac Transverse Deflection Cavity with FFTB Streak Camera (June 2002)
T-465	Magnetization Dynamics in the Sub-picosecond Time Scale (May 2003)
T-466	UCLA Electromagnetic Calorimeter (EMC) Prototype (May 2003)
T-467	Measurement of FFTB Backgrounds for E166 (Jan 2004)
T-468	Diamond Detector Response (July 2003)
T-470	DASH: Diamond Detectors for FLASH (June 2004)
T-471	Incoherent Radio Emission from Showers (July 2004)
T-472	Neutron Energy Spectra Measurements (June 2004)
T-473	Diamond Detector Response (July 2004)
T-478	Magnetism with Ultrashort Magnetic Field Pulses
T-481	Ultra-high Gradient Cerenkov Wakefield Acceleration (August 2005)
T-482	XTR as an Electron Beam Diagnostic (August 2005)

Recipe for Success in the FFTB

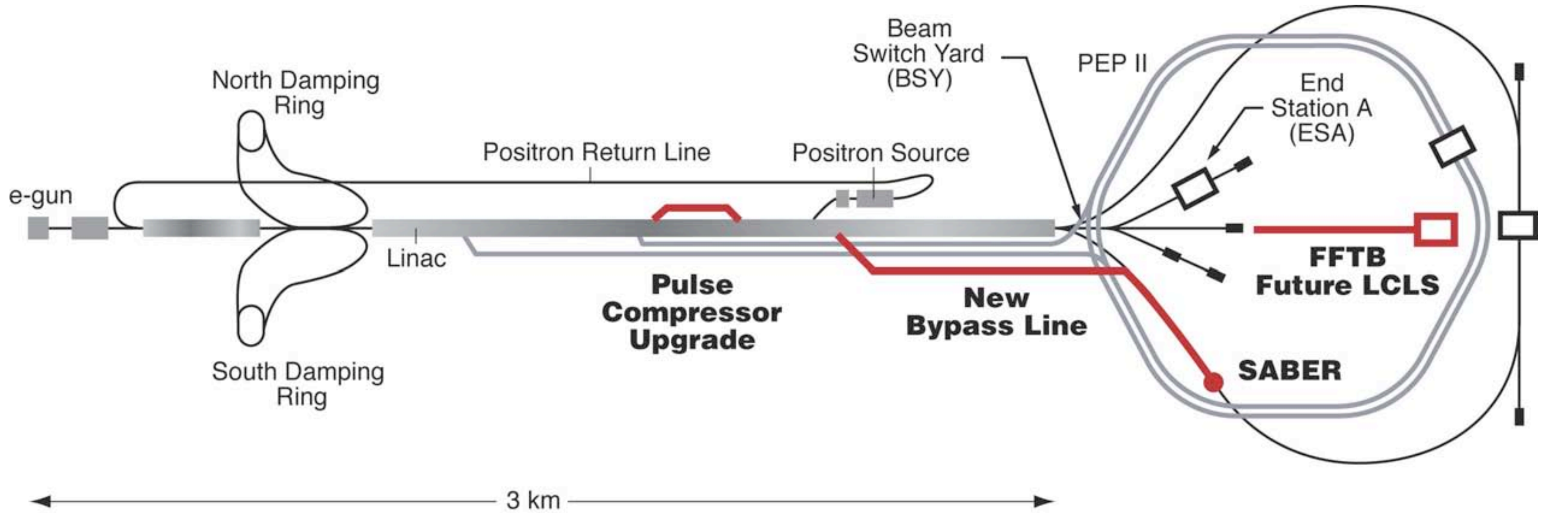
University–National Lab Collaborations

- The FFTB:
  - BINP/DESY/FNAL/KEK/Max-PlanckInst/Orsay/SLAC
- E-144:
  - Princeton/Rochester/SLAC/Tennessee
- E-150:
  - FNAL/Hiroshima/SLAC/LLNL/SLAC/Tennessee/UCLA
- E-157/162/164/164X/167
  - LBL*(E-157 only)*/SLAC/UCLA/USC
- T-462/478
  - Seagate/SimonFraserUniv/SFIT/SLA
- T-481
  - LLNL/SLAC/UCLA/USC

- Universities Bring Expertise and Ideas in Wide Range of Disciplines
- SLAC Brings Expertise in Accelerators and Unique Facilities With Stable, Well Diagnosed Beams

SLAC Overview with SABER

- LCLS injector will be installed at Sector 21, downstream of existing positron source.
- LCLS transport system and undulator will displace the FFTB.

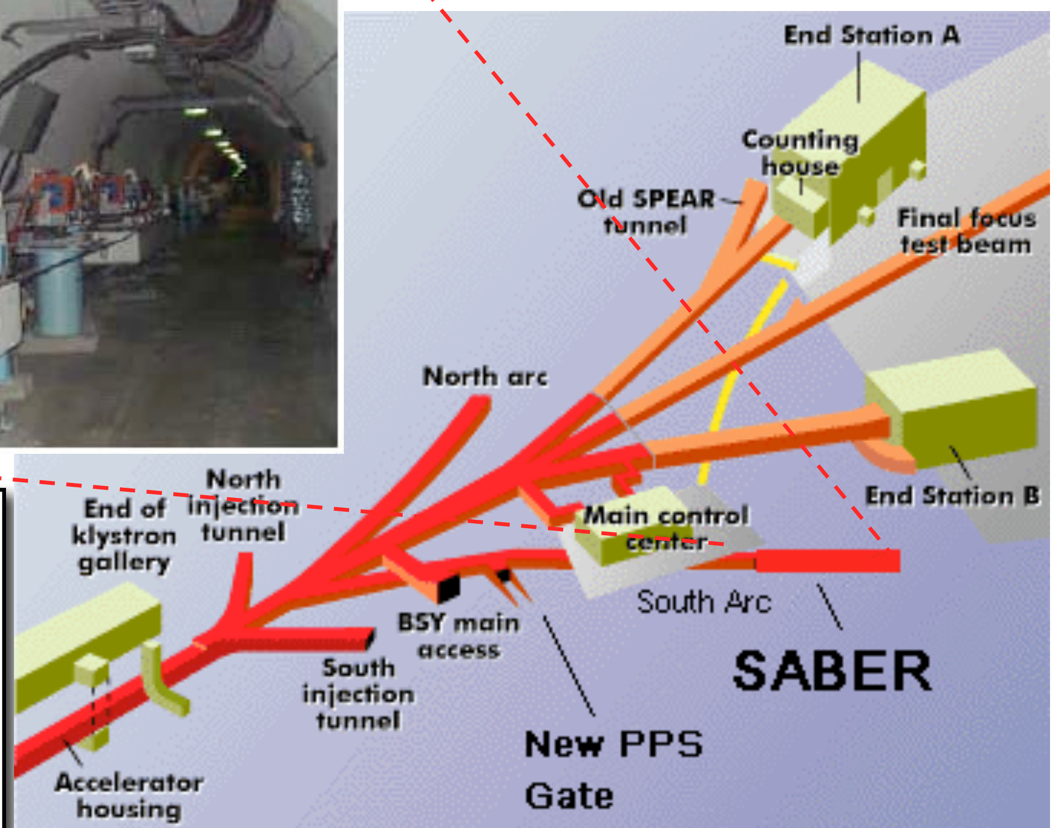


SABER consists of three main components:

1. Experimental area with final focus and beam dump in SLC South Arc tunnel.
2. Linac Pulse Compressor upgrade to compress positron bunches.
3. Bypass Line to deliver e^- or e^+ beams to SABER, bypassing the LCLS.

South Arc Tunnel

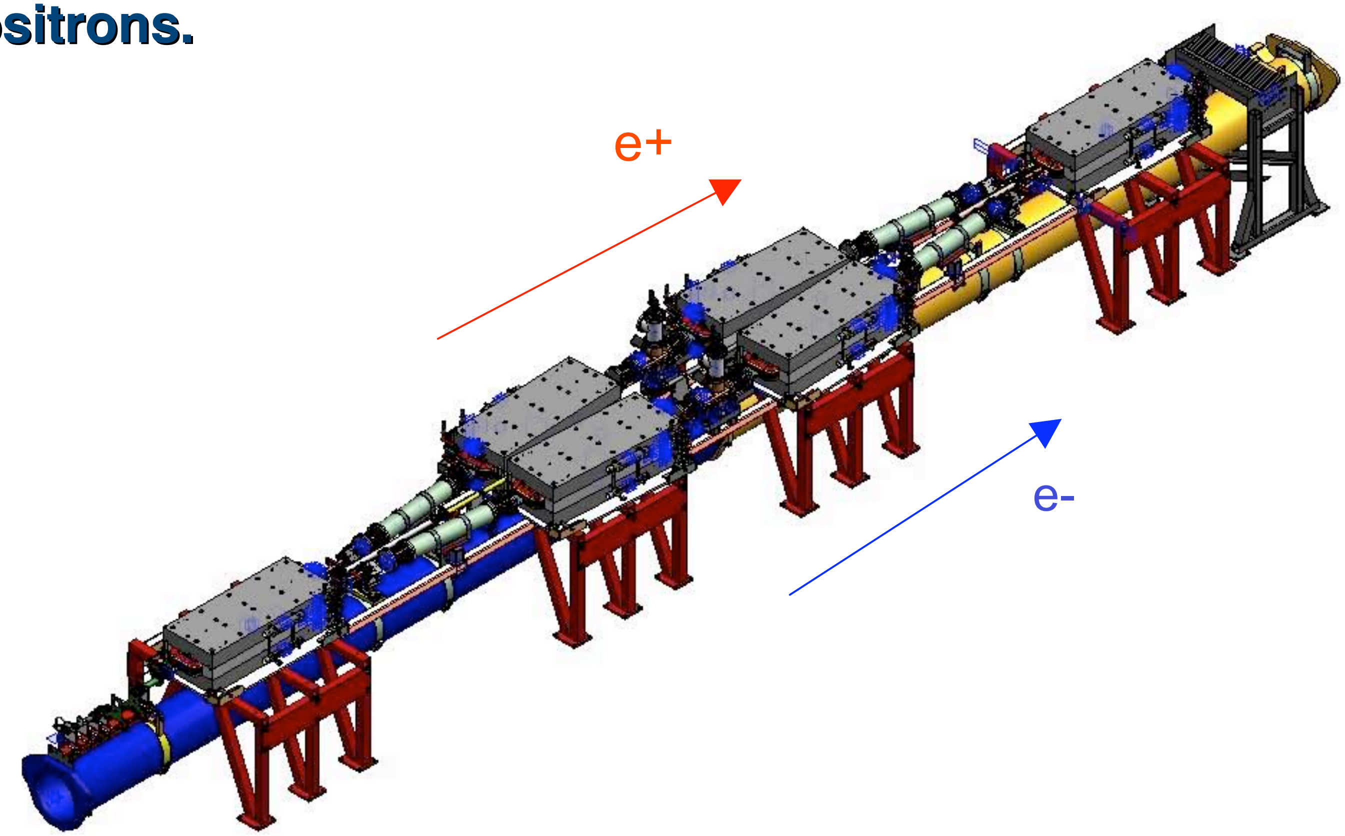
- **People can work safely in the South Arc tunnel, Independently of PEP-II or LCLS operations.**
- **Radiation safety issues are easier than in FFTB (SABER is deep underground).**



SLC Ran until June 1998
- South Arc & Instr. Section well maintained
  - Plumbing & Magnets in good shape
  - Vacuum Integrity Good
  - Control System Functioning
  - Quads & correctors powered up
- Some Systems Require Attention
  - PPS, DC busing, Hoses…

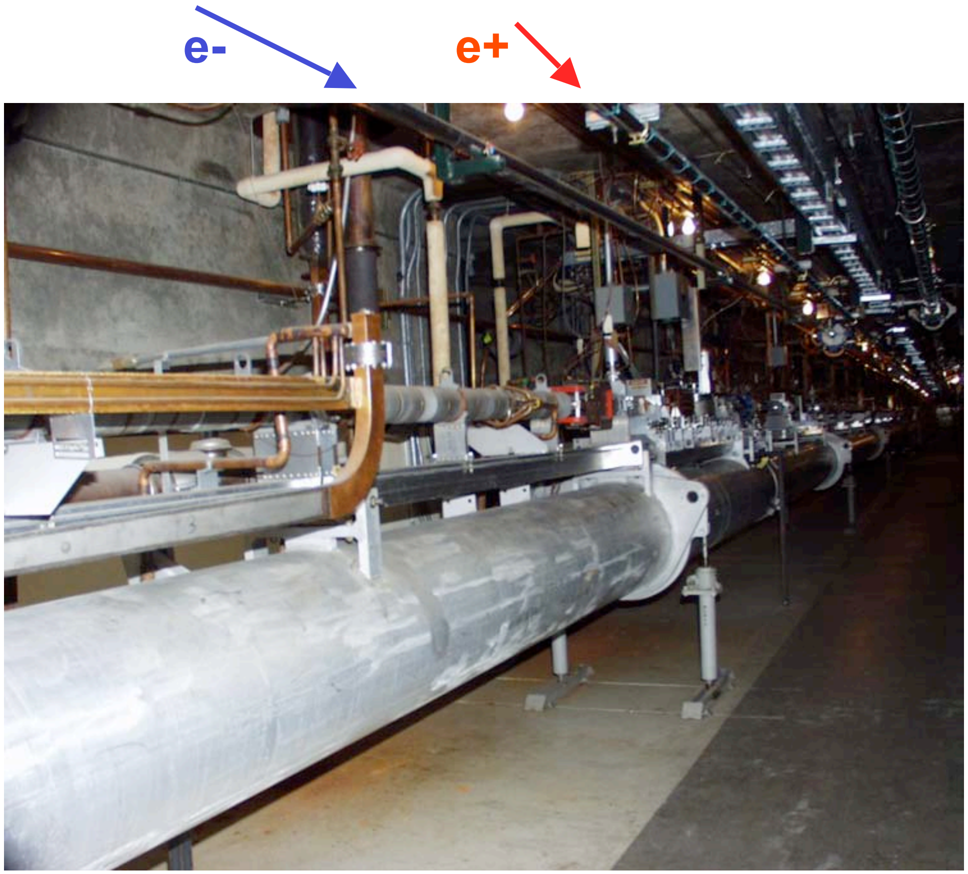
Positron Compressor Chicane

- Sector 10 compressor chicane has been used successfully for several years, but cannot be used with positrons (because electrons are required to make the positrons, and only one charge can pass through the present chicane).
- Chicane can be modified to be symmetric for electrons and positrons.



Bypass Line

- A Bypass Line from Sector 20 will allow delivery of 30 GeV electrons to BSY without passing through last third of linac.
- SABER will then be independent of LCLS operations.
- Cost could be significantly reduced by converting one of the PEP-II injection transport lines for this purpose.

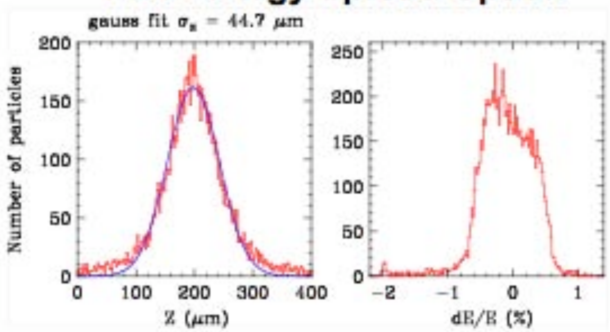


"Nominal" SABER Beam Parameters

- **Energy:**
  - **28.5 GeV with PEP-II or LCLS with bypass line.**
  - **Up to 30 GeV with full linac (but not with bypass line).**
- **Charge per pulse:**
  - **2 x 10^{10} e^- or e^+/pulse with full compression.**
  - **3.5 x 10^{10} e^- or e^+/pulse without compression.**
- **Pulse length:**
  - **σ_z = 33 µm (r.m.s.), 19 µm Gauss Fit to core**
  - **Ipk = 20 kAmps**
- **Spot size at IP:**
  - **10 µm nominal;**
  - **$\sigma_{x,y}$ = 5.2 x 5.4 µm achieved in computer simulations.**
- **Momentum spread:**
  - **4% full width with full compression.**
  - **< 0.5% full width without compression.**
- **Momentum dispersion at IP:**
  - **η = 0.**
  - **η' = 0.**

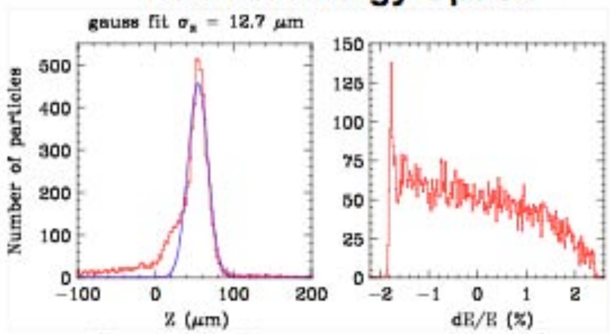
Other Potential Running Modes @ SABER

Low Energy Spread Option



σ_z = 45 μm
I_{pk} = 20 kA

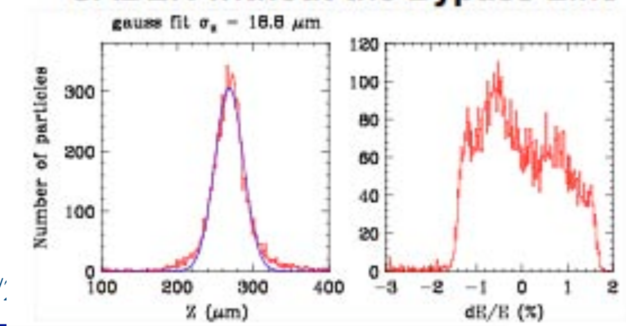
Low DR Energy Option



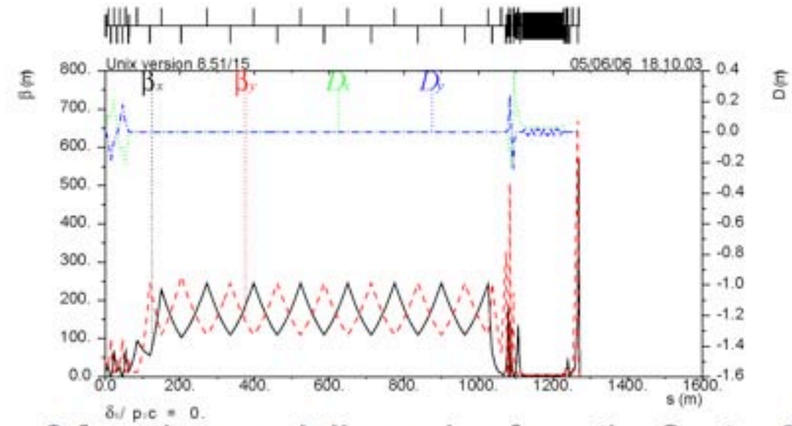
σ_z = 13 μm
I_{pk} = 30 kA

Damping Ring energy reduced from 1.19 GeV to 0.9 GeV.

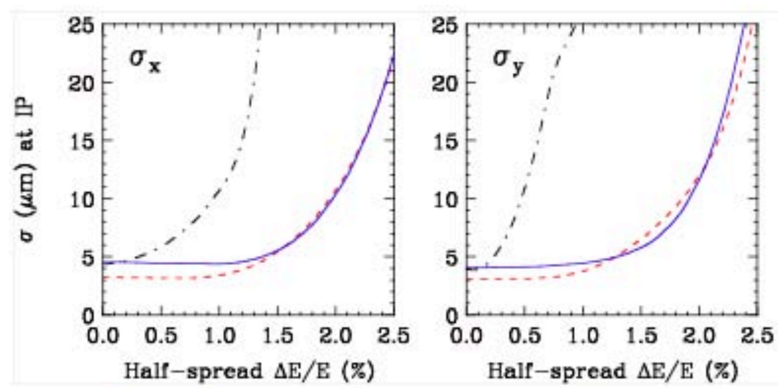
SABER without the Bypass Line



σ_z = 19 μm
I_{pk} = 21 kA



β functions and dispersion from the Sector 20 extraction point to the final focus IP.



Beam Size vs energy spread with:
- **sextupoles and synch rad (solid line),**
- **sextupoles but no synch rad (dashed line),**
- **SR but no sextupoles (dash-dotted line).**

Proposed Schedule

- Refurbishment work in BSY; tie in with PPS: August – October 2006.
  First electrons to the SLC Instrument Section in early 2007.
- First useful beam – positrons or compressed electrons through the full linac, interleaved with PEP-II injection pulses, to a dump in the SLC Instrument Section – in mid-2007.
- Installation of positron compressor chicane in linac: Sept – Oct 2007.
- Positron beam, fully compressed and focused in 2008.
- Bypass line in 2009.
- SABER experimental programs can coexist with PEP-II and LCLS programs.
- This schedule depends on the availability of engineering manpower and other resources.

SABER Safety Issues

- **Radiation**

  Beam energy and power are substantially less than SLC, which ran successfully from 1986 to 1998. The Sector 10 positron compressor chicane will be a mirror image of the electron compressor, and will incorporate the same safety features.

- **Electrical**

  Magnet voltages in the South Arc will be less than 30 volts, but conductors will be covered or interlocked.

- **Non-ionizing Radiation**

  No new RF sources involved with SABER. Some future experiments may involve lasers, but these will be reviewed when they are proposed.

- **Seismic Hazard**

  Existing South Arc tunnel will be used. No new civil construction. The walls of the SW Adit ramp are being reinforced.

Summary

- We have seen a constant demand for electron and positron beams in the FFTB from a wide variety of users, but the FFTB has recently been dismantled to make room for the Linac Coherent Light Source (LCLS).
- A new facility to replace the FFTB will be constructed in the SLC South Arc tunnel. A proof-of-principle study shows that low emittance, compressed bunches can be delivered to users.
- The electron bunch compressor chicane in the linac will be modified to compress positron bunches, opening up new areas of physics.
- A Bypass Line from Sector 20 to the BSY can be built to deliver beams to SABER, independent of LCLS.
- SABER will be a unique facility delivering high-energy, high peak current, electron and positron beams.
- Open to both existing collaborations as well as new collaborations and proposals

Acknowledgements

Special thanks to:

- **Roger Erickson for his coordination of these many efforts**
- **Yuri Nosochkov, who has developed optical solutions for SABER.**
- **Karl Bane, who has been investigating wake field effects and demonstrated bunch compression in the South Arc.**
- **Lynn Bentson, who has done the preliminary engineering studies and cost estimates.**
- **Paul Emma, who did initial optics and tracking simulations for the FFTB and has helped in exploring other options.**
- **Mark Woodley, who has assisted with design and tracking studies.**
- **Patrick Krejcik, who revived our interest in the South Arc option and demonstrated its feasibility.**
- **Ted Fieguth, whose dedication to SLAC's test beam activities has kept these programs alive and who has provided invaluable advice and perspective.**
- **John Seeman, who has consistently supported and encouraged these studies.**
- **Al Baker, Martin Berndt, Alex Chao, Scott DeBarger, Rick Iverson, Paul Miller, Alyssa Prinz, Mike Saleski, and the MFD and CPE staff members who have been helping assess the feasibility of SABER.**