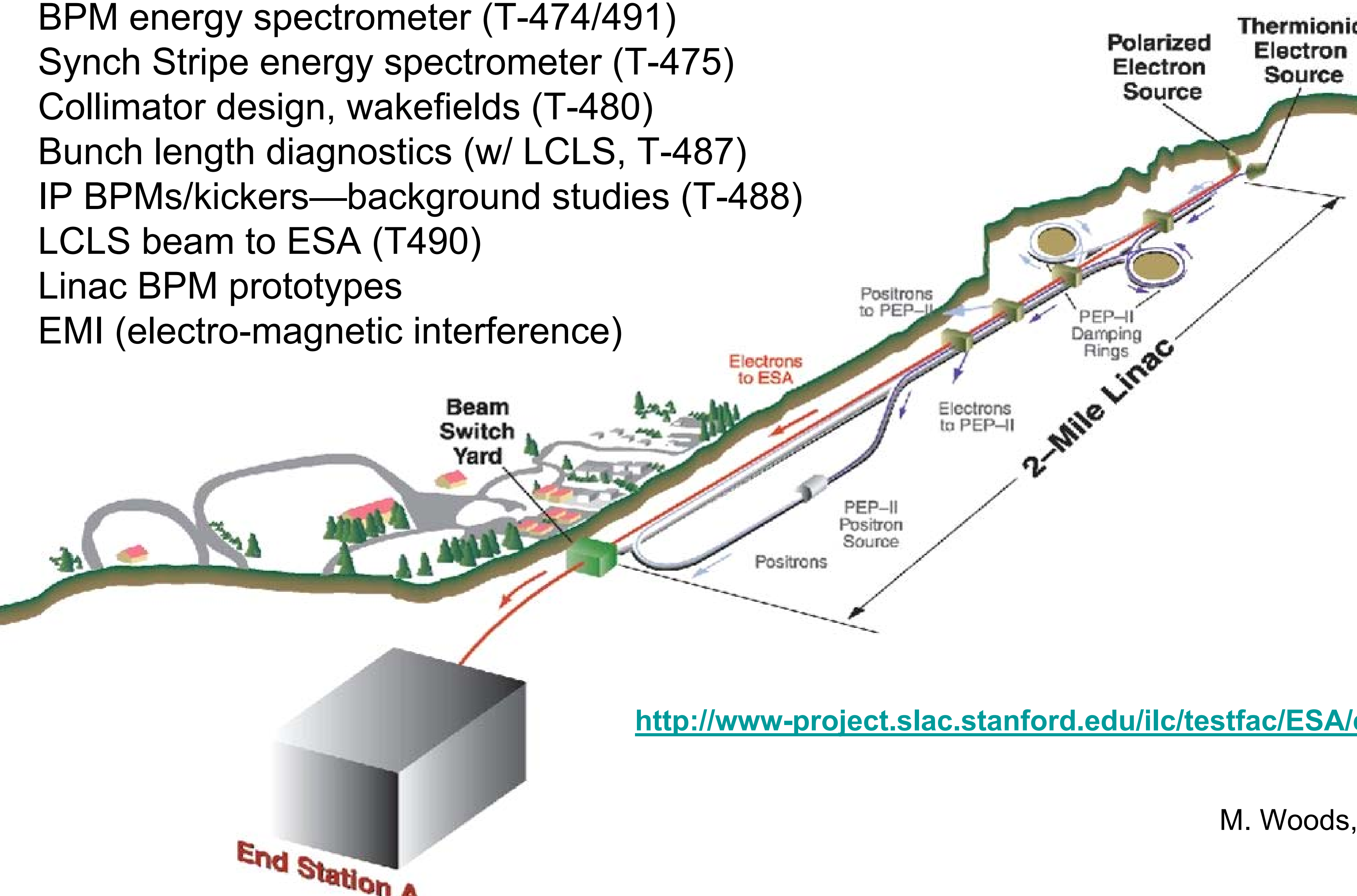
ILC Beam Tests in End Station A

ILC Detector Test Beam Workshop @ Fermilab
January 18, 2007

BPM energy spectrometer (T-474/491)
Synch Stripe energy spectrometer (T-475)
Collimator design, wakefields (T-480)
Bunch length diagnostics (w/ LCLS, T-487)
IP BPMs/kickers—background studies (T-488)
LCLS beam to ESA (T490)
Linac BPM prototypes
EMI (electro-magnetic interference)



http://www-project.slac.stanford.edu/ilc/testfac/ESA/esa.html

M. Woods, SLAC

ESA Program and the ILC

Machine-Detector Interface at the ILC

- ❖ Impact of ILC Parameters on Detector design and Physics reach
- ❖ Impact of Detector designs on ILC design and parameters
  - (L,E,P) measurements: Luminosity, Energy, Polarization
  - Forward Region Detectors
  - Collimation and Backgrounds
  - IR Magnets, Crossing Angle
  - EMI (electro-magnetic interference) in IR

MDI-related Experiments at SLAC's End Station A

- Collimator Wakefield Studies (T-480) ⇨ Talk by A. Sopczak
- Energy spectrometer prototypes (T-474/491 and T-475)
- IR background studies for IP BPMs (T-488) ⇨ Talk by M. Hildreth
- EMI studies ⇨ Talk by C. Clarke

Beam Instrumentation Experiments in ESA

- Rf BPM prototypes for ILC Linac (part of T-474)
- Bunch length diagnostics for ILC and LCLS (includes T-487)

ILC Beam Tests in End Station A

6 test beam experiments approved: T-474, T-475, T-480, T-487, T-488, T-490

2006 Runs:

i. January 5-9 commissioning run
ii. April 24 – May 8, Run 1
iii. July 7-19, Run 2

2007 Runs (dates tentative):

i. March 7-26, Run 3
ii. July 5-8, T490 w/ LCLS beam
iii. July 9-22, Run 4

+ requesting two 2-week runs in FY08

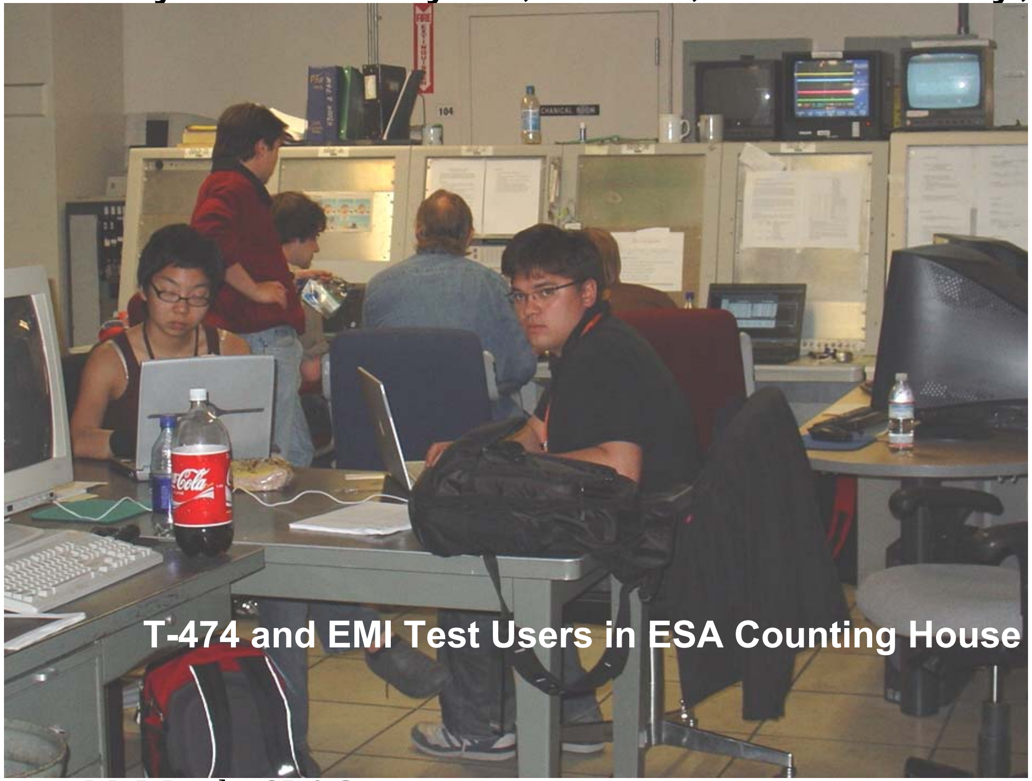
ILC Beam Tests in End Station A

50 Participants at SLAC in 2006 for this program

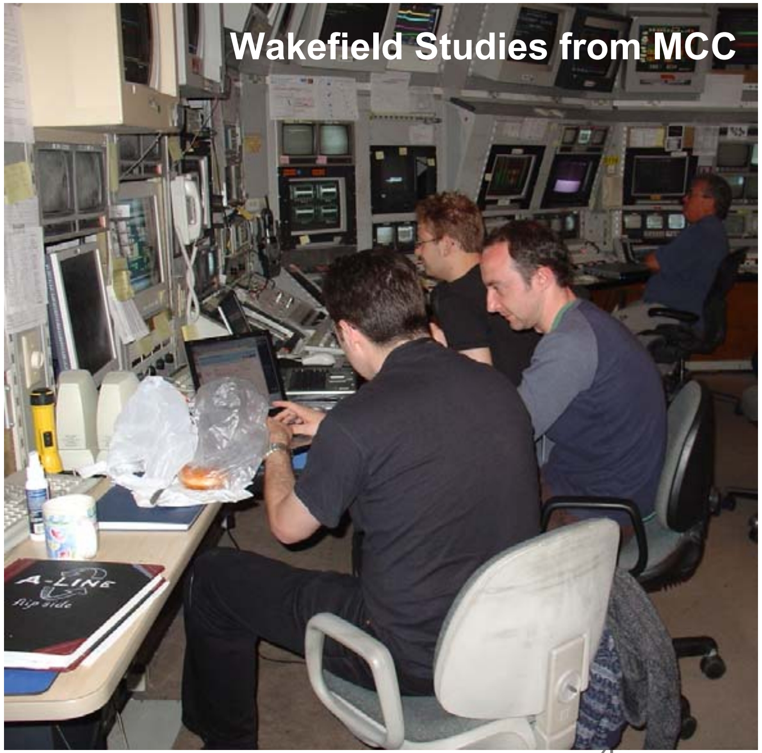
- 18 from SLAC + 32 users

18 Institutions participated in 2006 beam tests and measurements

Birmingham U., Cambridge U., Daresbury, DESY, Dubna, Fermilab, KEK, Lancaster U., Leland H.S., LLNL, Manchester U., Notre Dame U., Oxford U., Royal Holloway U., SLAC, UC Berkeley, UC London, U. of Oregon



T-474 and EMI Test Users in ESA Counting House



Wakefield Studies from MCC

Beam Parameters at SLAC ESA and ILC

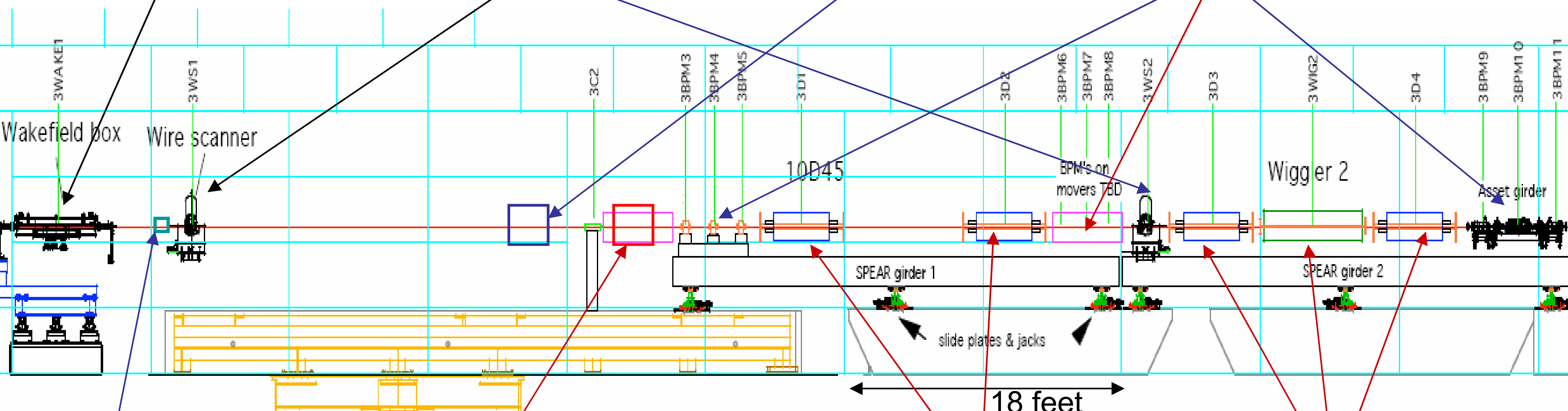
Parameter	SLAC ESA	ILC-500
Repetition Rate	10 Hz	5 Hz
Energy	28.5 GeV	250 GeV
Bunch Charge	2.0×10^{10}	2.0×10^{10}
Bunch Length	300-500 μm	300 μm
Energy Spread	0.2%	0.1%
Bunches per train	1 (2*)	2820
Microbunch spacing	- (20-400ns*)	337 ns

*possible, using undamped beam

ESA Equipment Layout

blue=FY06
red=new in FY07

Wakefield box | Wire Scanners | FONT-T488 | rf BPMs



Ceramic gap BLMs | T-487: long. bunch profile

Dipoles + Wiggler

Upstream (not shown)

4 rf BPMs for incoming trajectory
Ceramic gap w/ rf diode detectors (16GHz, 23GHz, and 100GHz) and 2 EMI antennas

Downstream (not shown)

Ceramic gap for EMI studies
T475 Detector for Wiggler SR stripe

Installation of Beamline Components for 2006 Runs

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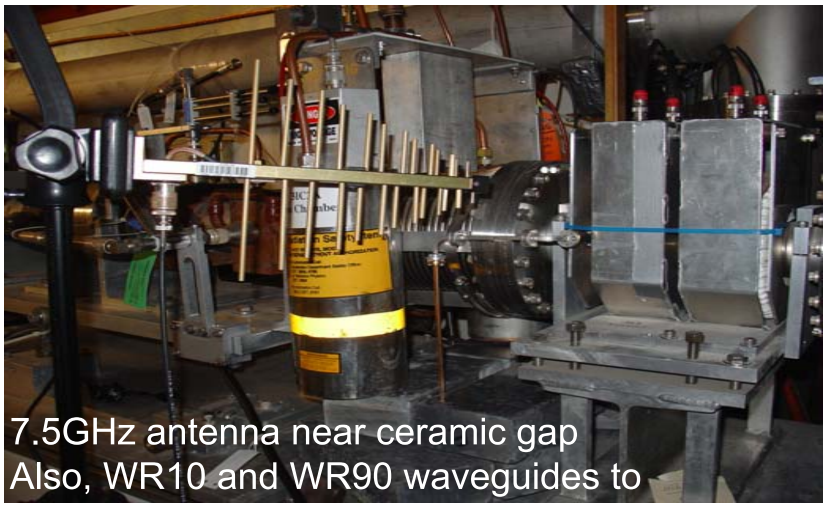
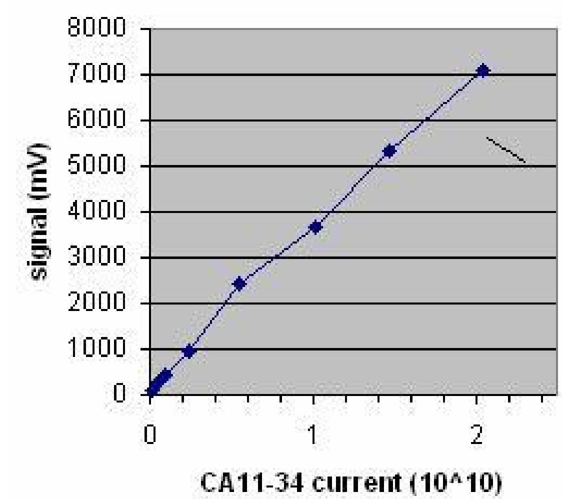
EMI Studies in ESA

US-Japan funds; Y. Sugimoto (KEK),
G. Bower (SLAC), N. Sinev (U. of Oregon)

- ❖ Characterized EMI along ESA beamline using antennas & fast 1.5GHz scope
- ❖ Measured dependence of EMI antenna signals on bunch charge, bunch lengt





- ➢ waveform insensitive to beam conditions and bunch length (only see dependence on bunch length with 100GHz diode and pyroelectric detectors)
- ➢ amplitude has linear dependence on bunch charge
- ➢ data taken at different beamline locations; timing studies done to look for different sources
- ➢ dominant source is exposed ceramic gap; smaller source from upstream toroid

→ ***Reproduced and studied failure mode observed with SLD's vertex detector***

- quantified failure rate at different EMI levels, varying geometry and shielding of electronics

→ ***Important to develop EMI standards in IR Region for Detector and Accelerator***

Bunch Length Studies

Collaborative effort with LCLS
Collaborators: P. Emma, J. Frisch, R. Iverson, D. McCormick, S. Molloy, M. Ross, S. Walston, M. Woods

❖ **LCLS bunch length after BC-1 is 200μm rms, similar to 300μm ILC bunch length**

- commission + study high frequency diode and pyroelectric detectors to view radiation emitted at a ceramic gap -- detectors for future use at LCLS
  (ex. to use for phase feedbacks on Linac klystrons and sub-boosters)
- provide necessary diagnostics to characterize ESA beam
  (ex. bunch length info is needed for T-480 collimator wakefield study)

Use A-line as a bunch compressor:

- R_{56} = 0.465m (large)
- 700μm rms bunch length at end of Linac with small chirp;
- Sector-10 chicane off

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

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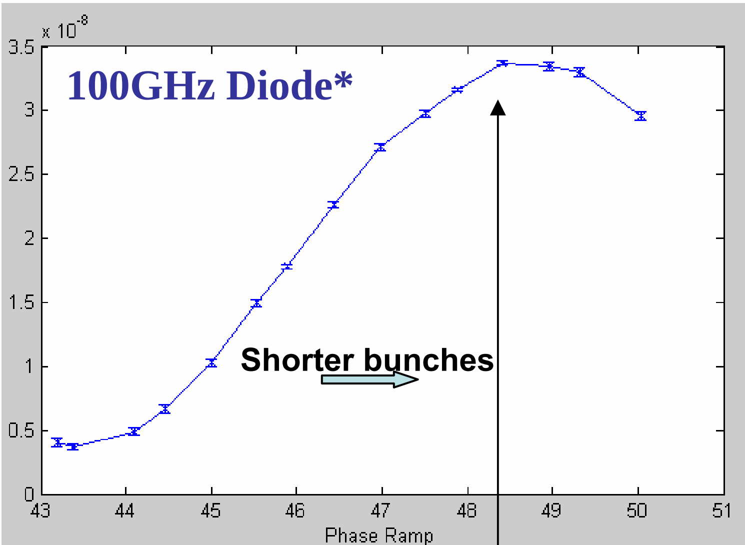
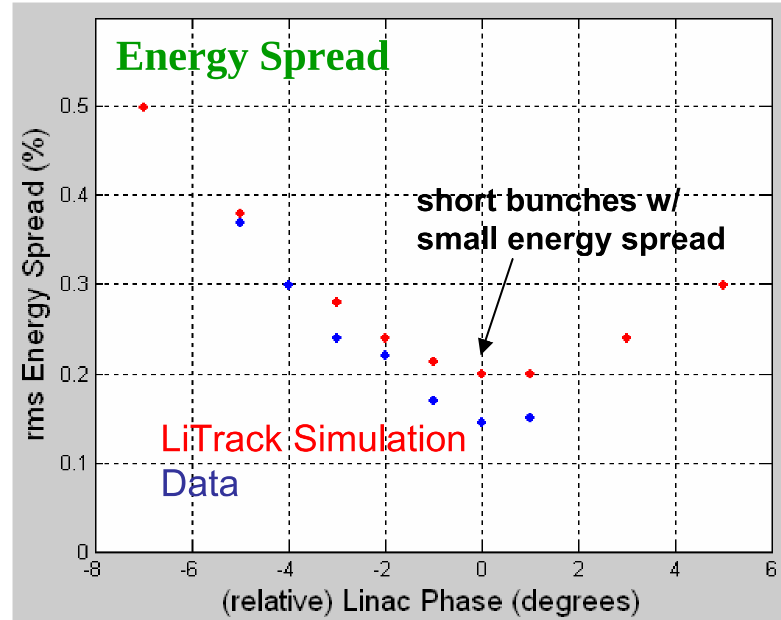
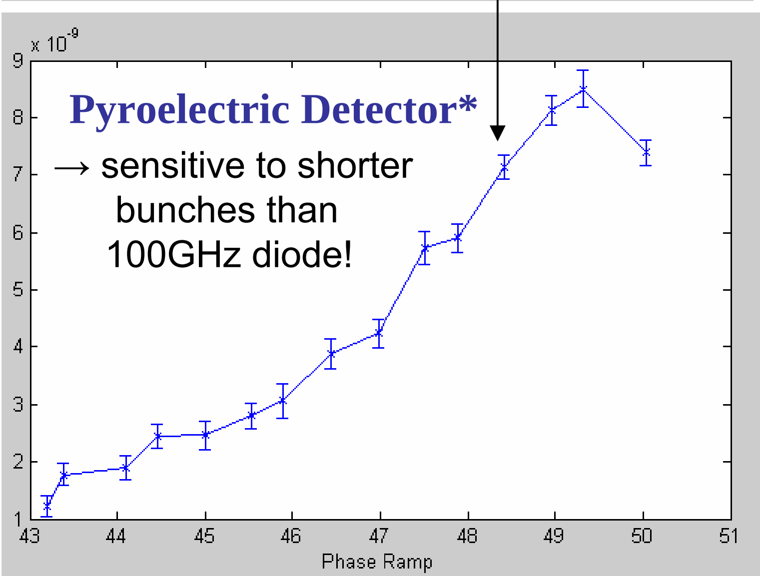
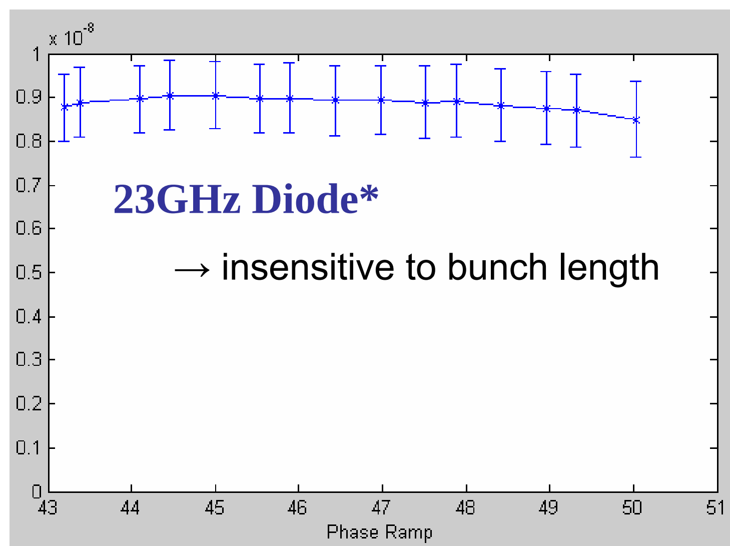
Bunch Length Measurements vs Linac rf Phase









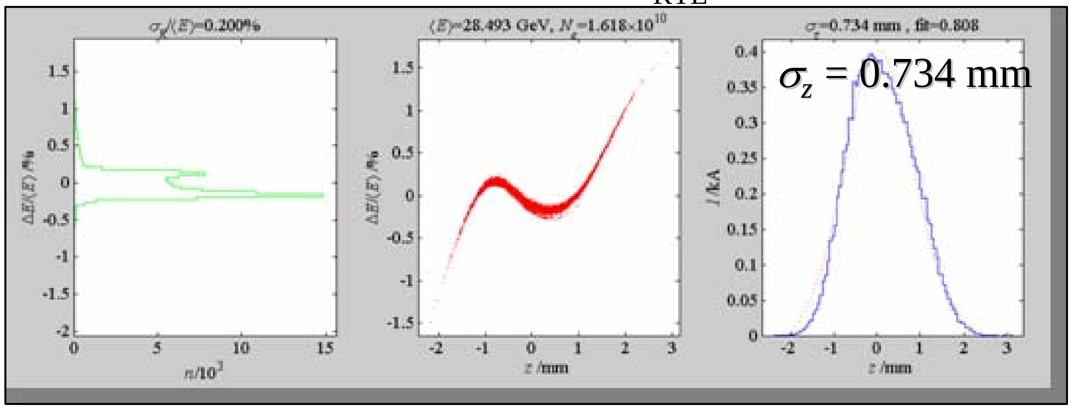
*normalized to toroid

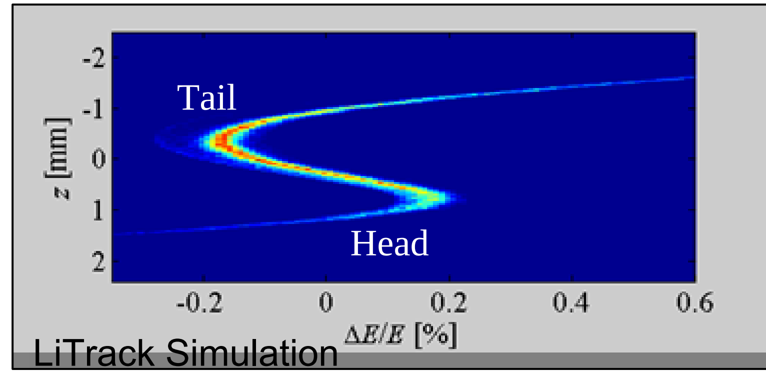
International Linear Collider
at Stanford Linear Accelerator Center

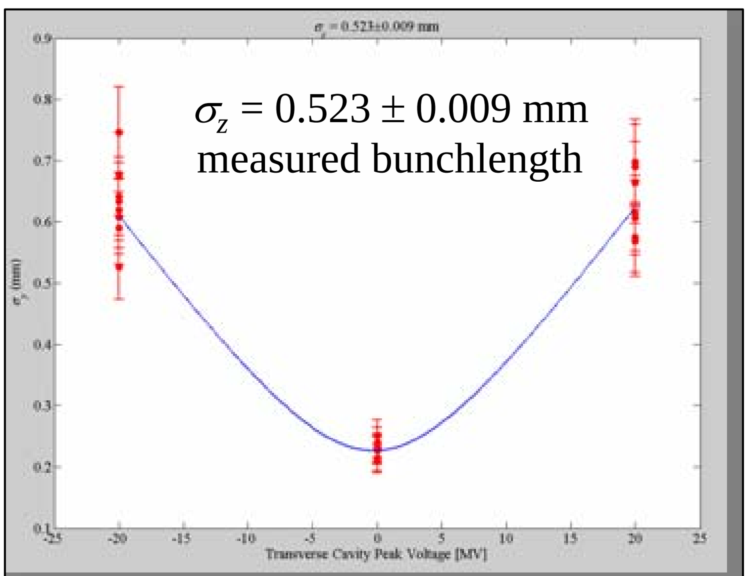
Bunchlength + Energy-Z correlation Measurements at end of Linac with Transverse "LOLA" cavity

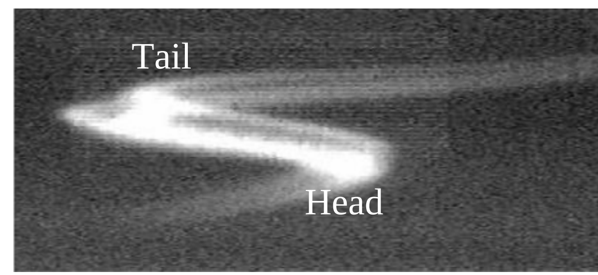
2006 Results (Preliminary)

LiTrack Simulation: Linac RF phase = -10 deg, N = 1.6E10, V_{RTL} = 38.5 MV









A-Line Synchrotron Light Monitor signal w/ LOLA on. 1-m dispersion for horizontal axis. Calibrated vertical scale to be 0.32mm/deg; 1deg at S-band ~300um.

→ **first measurement of E-z correlation, using this technique!**
Technique will be used by LCLS.

T487 (in FY07)
Longitudinal Bunch Diagnostics for the ILC

PI: G. Doucas (Oxford U.),
Collaborating Institutions: U. of Oxford, Rutherford Appleton Lab,
U. of Essex, Dartmouth College, SLAC

Goal: non-invasive determination of longitudinal bunch profile

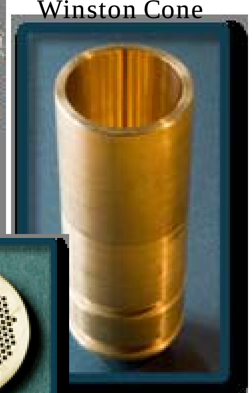
- Fundamental beam quantity; important for beam-beam effects.

Carousel of Gratings

Technique: Use Coherent Smith-Purcell radiation, emitted when a beam passes close to a periodic structure (metallic grating)

- Grating produces dispersion of the wavelengths according to the angle of observation.
- Wavelength distribution of emitted coherent radiation depends on the temporal profile of the bunch
- has previously been tested at lower energies w/ longer bunches and lower bunch charges

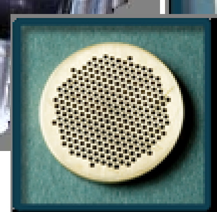
Winston Cone



Simple experimental set-up:

- 'Carousel' of 3 gratings with different periodicities.
- Array of 11 room temperature pyroelectric detectors covering angular range 40 – 140° w.r.t. the beam direction.

Front View



Waveguide Array Plate Filter

T-490 in FY07
LCLS Beam to ESA

PI: M. Woods
SLAC Collaborators: R. Arnold, P. Emma, T. Fieguth, C. Hast, M. Woods

Goals:

- investigate capabilities for test beam experiments in ESA using the LCLS beam
- commission accelerator safety systems for beam containment (BCS) and machine protection (MPS) when the LCLS injector is used.
- characterize the transverse and longitudinal emittance of the beam in ESA.

Apparatus:

- same as for the ILC-ESA tests (T-474 etc.)
- install wire cards with 25-micron wires (rather than current 75-micron wires) in the 2 ESA wire scanners for spotsize and emittance measurements.
- use quad scans and wire scans for transverse emittance measurements.
- use the transverse rf cavity LOLA, the A-Line synch lite monitor and ESA bunch length diagnostics for longitudinal emittance measurements and to measure E-z correlation

Schedule: Tentative run dates are July 5-8, 2007 just prior to Run 4

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Future for continuing this ILC Test Beam Program?

FY08 → continue program in ESA, requesting 4 weeks of Beam Tests
→ beam scheduling more difficult: priority for LCLS, also for SABER
→ reduced funding available (?) from SLAC and ILC, but major installations are complete

FY09 and beyond (LCLS era, parasitic operation with PEP-II ends at end of FY08)
→ ESA PPS upgrade needed for continued ESA operation
→ ILC beam instrumentation tests in SABER are possible
→ Study group looking at SLAC test beam capabilities with primary and secondary beams for Detector and MDI-related R&D – need input from Fermilab ILC test beam workshop

SABER
- assume SABER exists with bypass line and operational for beam tests by 2010
- parameters for primary beam can be similar to ILC for bunch charge, energy spread, bunch length. 28.5 GeV energy.
- limited space and infrastructure
- should be able to carry out small scale tests, ex. tests for BPMs, bunch length detectors
- unlikely to continue T-474/T-475 here; T-480 may be possible, but difficult
- need to investigate capability for low-intensity secondary beams for ILC detector R&D

ESA
- several possibilities exist for primary and secondary beams to ESA in LCLS era; most require PPS upgrade and some require pulsed magnets in Beam Switchyard
- primary beam modes: i) high energy beam when LCLS not running, iii) extend SABER bypass line to ESA (expensive), iii) interleaved 10Hz running using LCLS beam with pulsed magnets,
- secondary beam modes: i) high energy beam when LCLS not running, ii) parasitic operation with LCLS using beam halo and production collimator in BSY, iii) extend SABER bypass line to ESA (expensive), iv) pulsed magnets in BSY using 10Hz LCLS beam and BSY production collimator,

Summary

Very successful program in 2006!

- 4 weeks of beam tests for 7 experimental programs
- 50 participants from 18 institutions

T-480 Collimator Wakefield Study

- Results essential for ILC collimator design
- Minimize risk for emittance degradation to IR and for achieving design luminosity

T-474 and T-475 Energy Spectrometer Prototypes

- Experimental results needed to demonstrate ability to meet design goals for precise energy measurements for the ILC physics program.

FY07 → strong program, with 5 weeks of Beam Tests planned

FY08 → continue program, requesting 4 weeks of Beam Tests
→ beam scheduling more difficult: priority for LCLS commissioning, also for SABER
→ reduced funding available (?) from SLAC and ILC, but major installations are complete

FY09 and beyond (LCLS era, parasitic operation with PEP-II ends at end of FY08)
→ ESA PPS upgrade needed for continued ESA operation
→ ILC beam instrumentation tests in SABER possible; secondary electron beam possible
→ Study group looking at SLAC test beam capabilities with primary and secondary beams for Detector and MDI-related R&D (need input from this workshop for user needs)

Additional Material

DRAFT of one summary table being prepared for a SLAC study on future of SLAC test beams beyond FY08

Table 1: Summary of Test Beam Requirements and Facility Capabilities using Primary Beams

Parameter	Test Beam Requirement	SABER	ESA
Energy	5-30 GeV	5-30 GeV	5-30 GeV
Charge/bunch	$(0.2 - 2.0) \cdot 10^{10}$	$(0.2 - 3.5) \cdot 10^{10}$	$(0.2 - 3.5) \cdot 10^{10}$
Repetition Rate (Hz)	10Hz	10-30 Hz	10-30 Hz
rms Pulse Length	(100-1000) μm	(30-1000) μm	(300-1000) μm[1]
$\gamma\varepsilon_x$, $\gamma\varepsilon_y$ (mm-mrad)	as low as possible; $\gamma\varepsilon_x$, $\gamma\varepsilon_y$ <(300, 20) acceptable	50,10	15,10 w/ LCLS beam, 300, 15 w/ SABER beam
rms (x,y) Spotsize	<1mm; (5-20) μm for some tests	(10 μm, 10 μm) at focal point	0.5mm,[1] 100μm
rms Energy Spread	<(0.5-1)%	0.2% uncompressed, 1% w/ full compression	<0.5%[1]
Momentum precision	(100-1000) ppm for some tests	?	1000ppm absolute, 100ppm relative
x,y,z space required	0.5m, 0.5m, (0.5-30)m	0.5m, 0.5m, 5m	2m, 2m, 40m
Instrumentation needs	Q, x, y, x',y', σ_x, σ_y, σ_z, E, σ_E	Q, x, y, x',y', σ_x, σ_y, σ_z, E	Q, x, y, σ_x, σ_y, σ_z, E, σ_E
Crane requirements	Up to 15 tons	No crane	50 tons

[1]shorter bunches and smaller energy spread are possible if LCLS beam is used.

(also have other summary tables for individual BI, MDI, Detector tests)