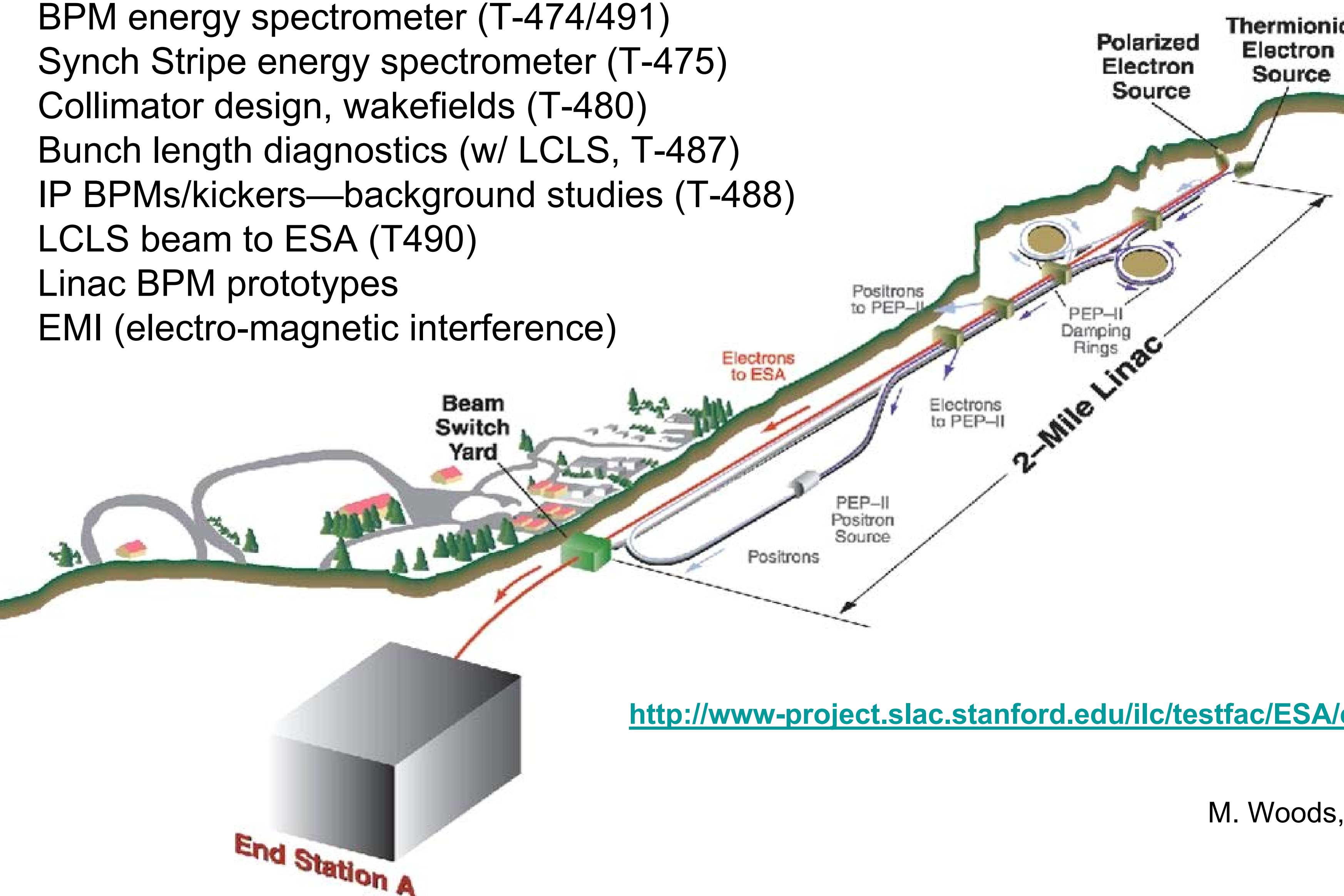
ILC Beam Tests in End Station A

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)
- Energy spectrometer prototypes (T-474/491 and T-475)
- IR background studies for IP BPMs (T-488)
- EMI studies

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:

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

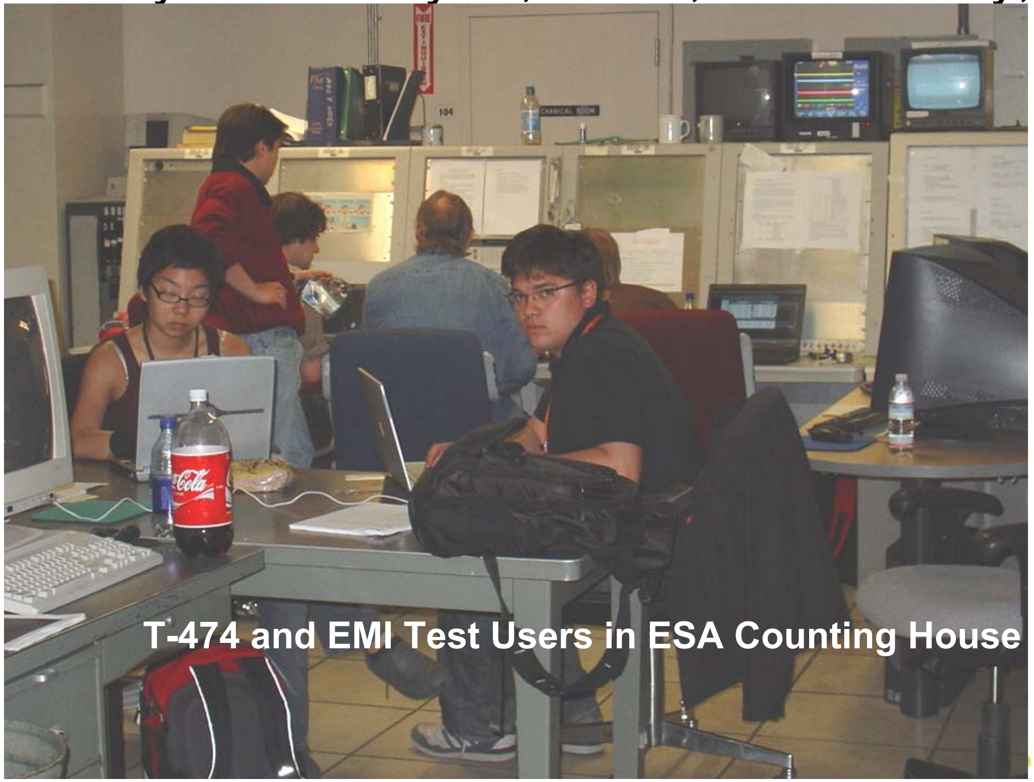
ILC Beam Tests in End Station A

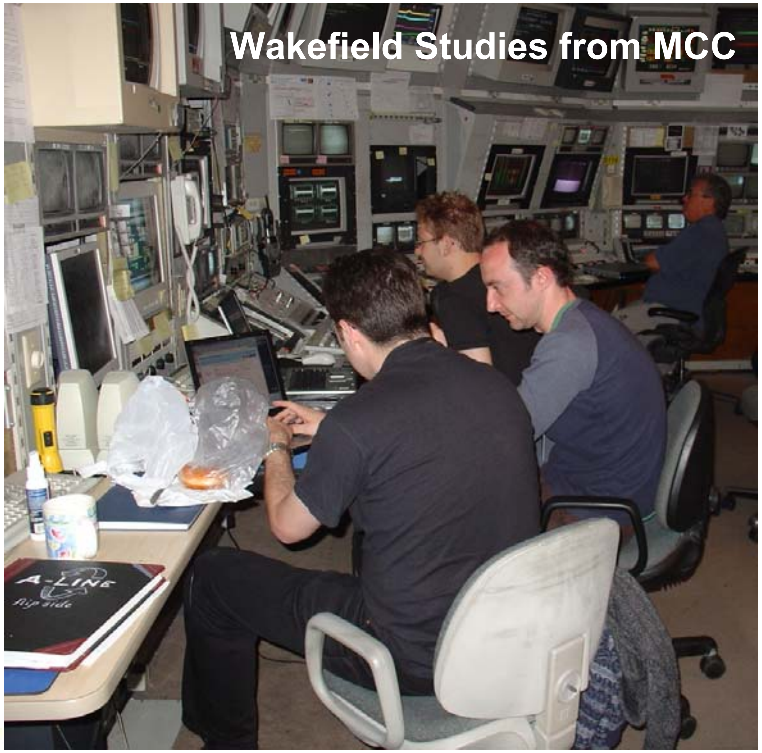
50 Participants at SLAC in 2006 for this program

- 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

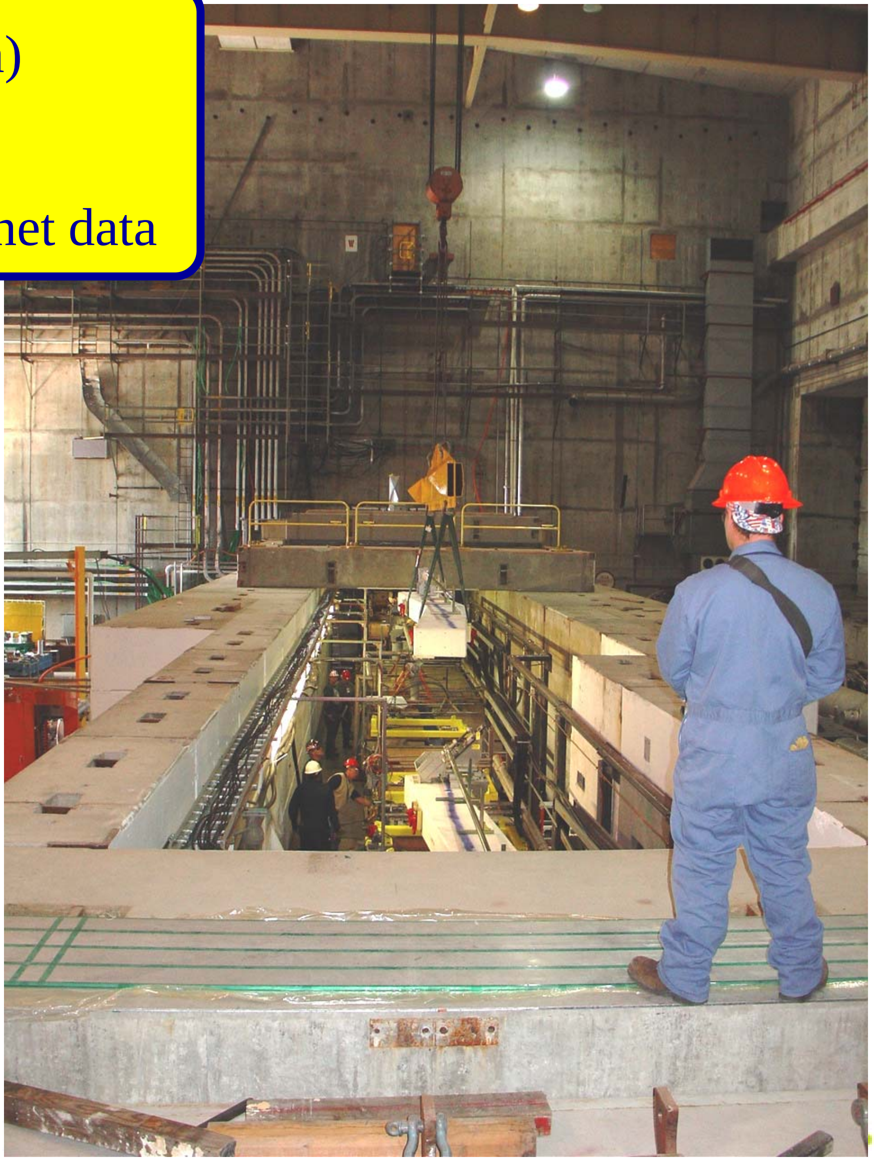
Beam Parameters at SLAC ESA and ILC

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

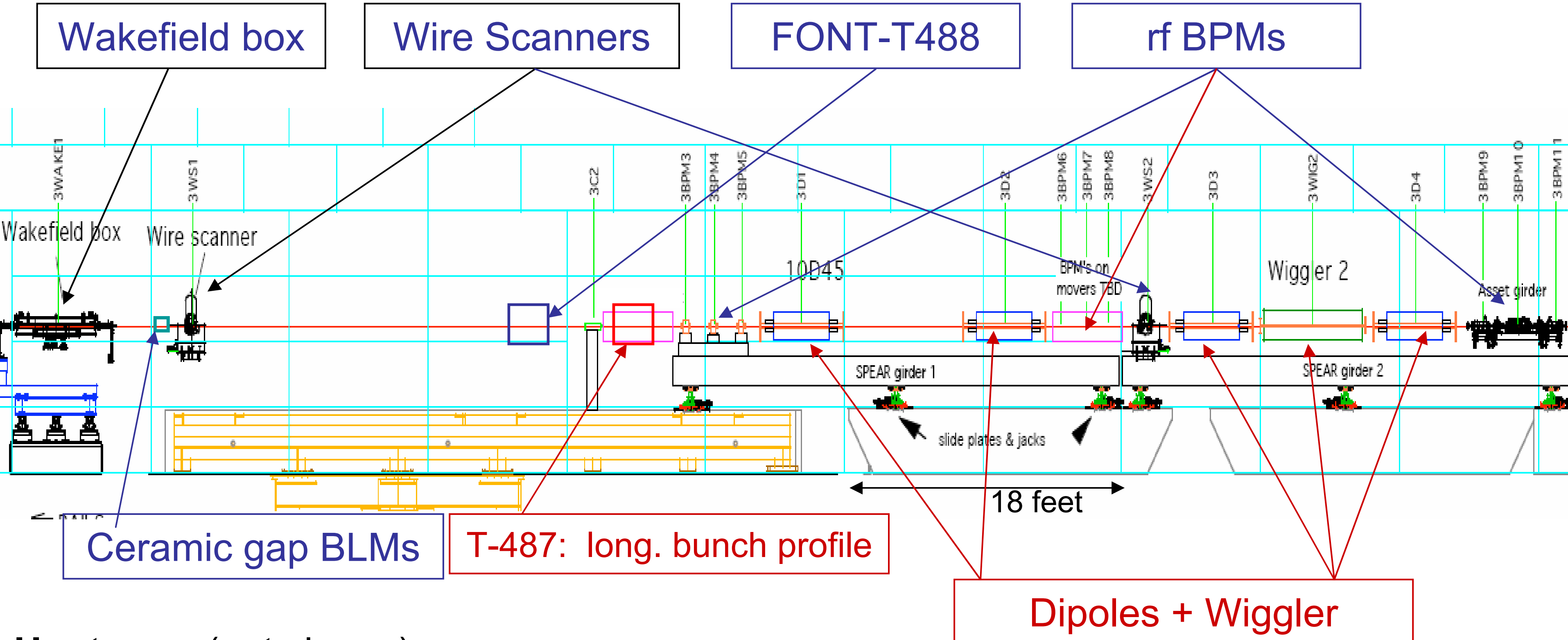
End Station A (ESA)

- ESA is large (60m x 35m x 20m)
- 50/10 t crane
- Electrical power, cooling water
- DAQ system for beam and magnet data



ESA Equipment Layout

blue=FY06
red=new in FY07



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

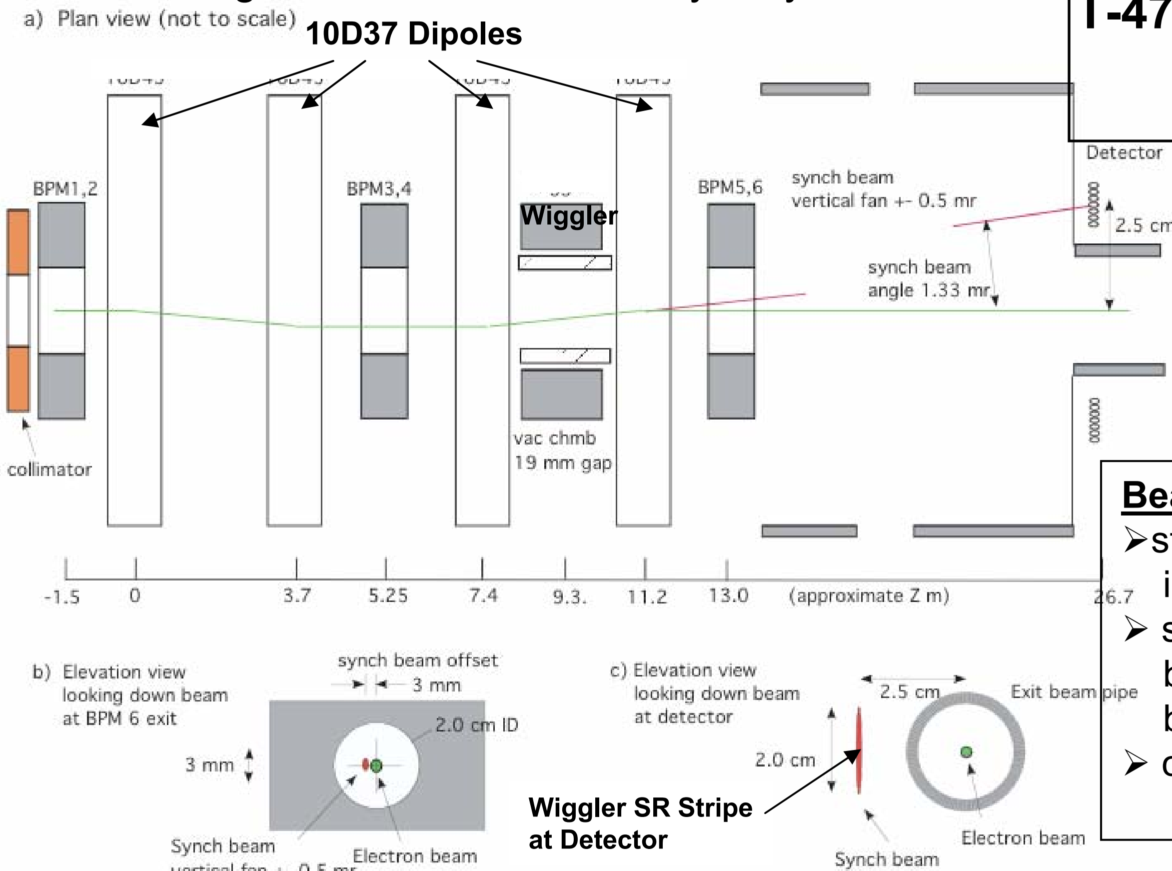
T-474, T-475: Energy Spectrometers

(see talk by S. Boogert)

- Precision energy measurements, 50-200 parts per million, needed for Higgs boson and top quark mass msmts
- BPM (T-474) & synch. stripe (T-475) spectrometers will be evaluated in a common 4-magnet chicane.
- These studies address achieving the ILC precise energy measurement goals: resolution, stability & systematics

T-474 BPM Energy Spectrometer Collaborators:
U. Cambridge, DESY, Dubna, Royal Holloway, SLAC, UC Berkeley, UC London, U. of Notre Dame

T-475 Synch Stripe Spectrometer Collaborators:
U. of Oregon, SLAC



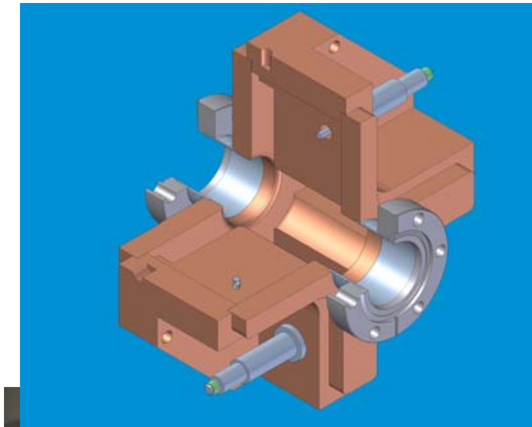
For BPM spectrometer

- **$\delta E/E$=100ppm → δx= 500nm, at BPMs 3-4**
- **Dipole B-field ~ 1kGauss**
- ➢ **these are same as for ILC design**

Beam Tests

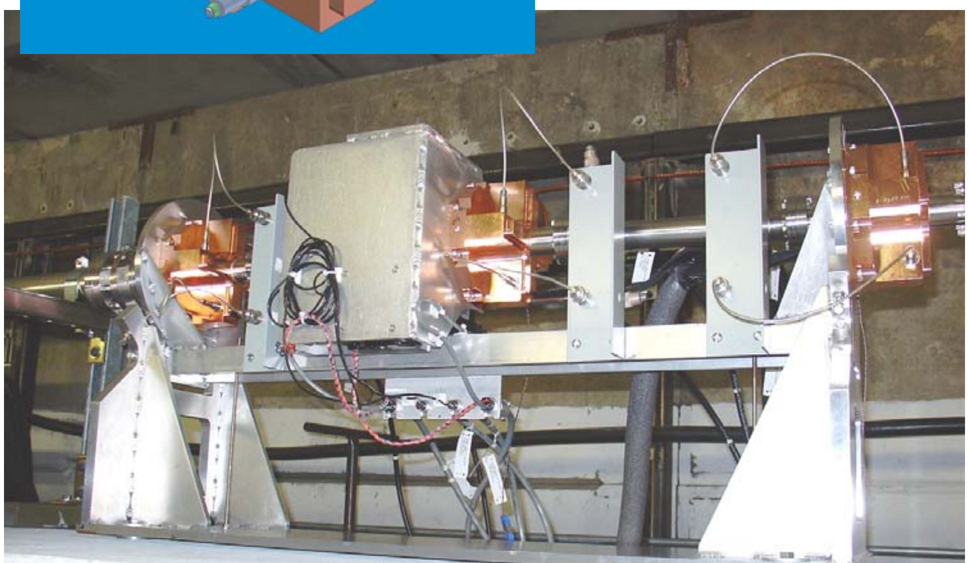
- ➢ study calibration procedure, which includes reversing the chicane polarity,
- ➢ study sensitivity to: beam trajectory, beam tilt, bunch length, beam energy, beam shape, …
- ➢ compare T-474 and T-475 results and compare with A-line energy diagnostics

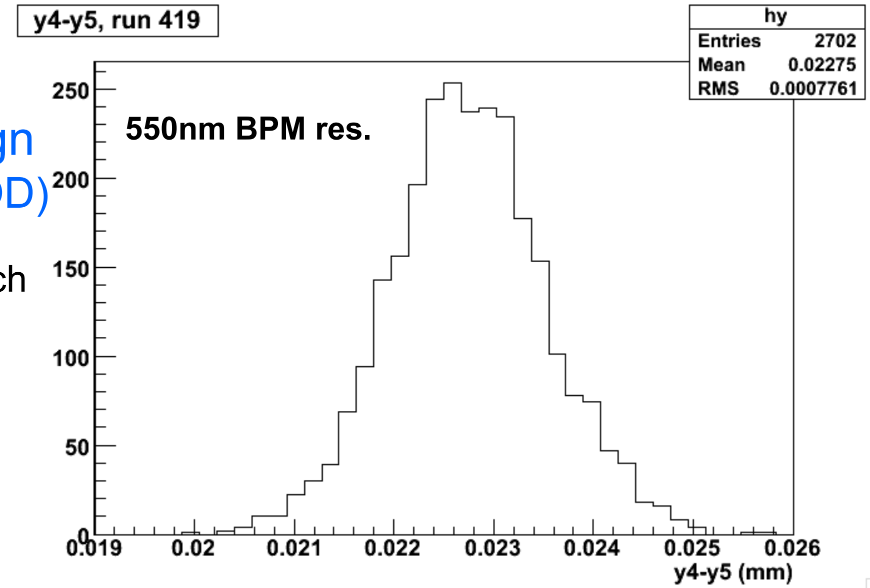
T-474 Run 1 Prelim. Results for Prototype Linac rf BPMs

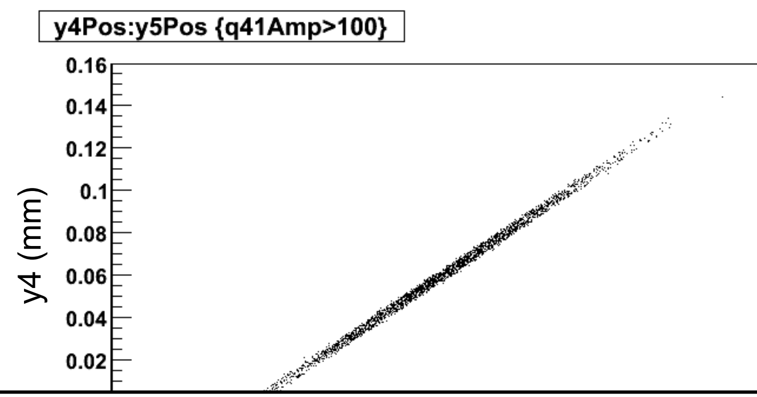


S-Band BPM Design
(36 mm ID, 126 mm OD)

Q~500 for single bunch resolution







New Linac BPM Prototype
(C. Adolphsen, G. Bowden, Z. Li)
→ **used as BPM3-5 for T-474**

Also investigating how T-474 setup can be used to test micron-level stability relevant for ILC Linac quad/bpm modules.

T-475: Preparing for Wiggler Installation

Wiggler location between 3B3 and 3B4

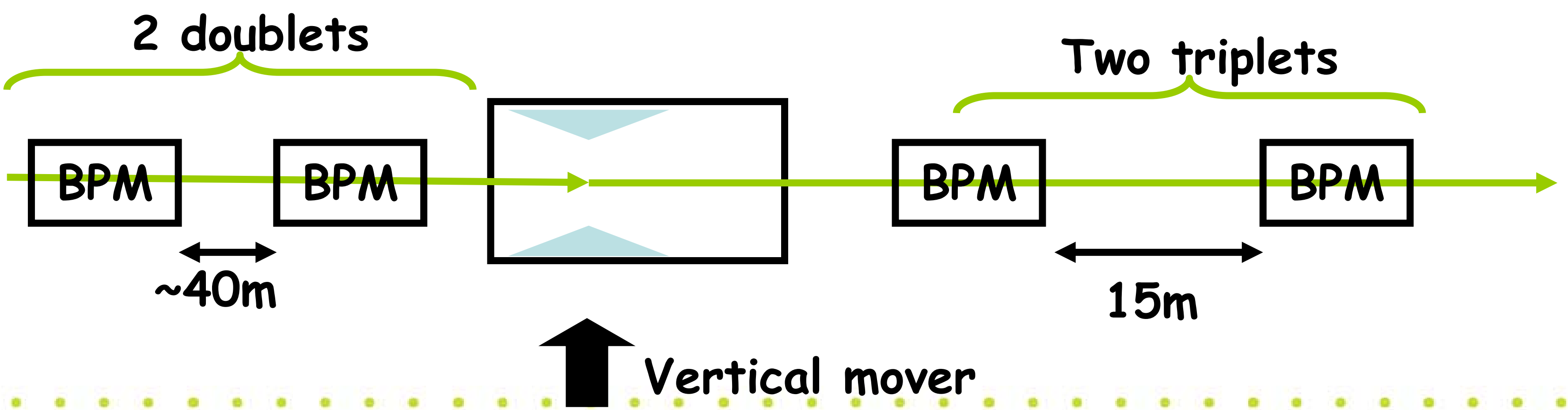

Wiggler w/ steel flux return removed

T-480: Collimator Wakefields

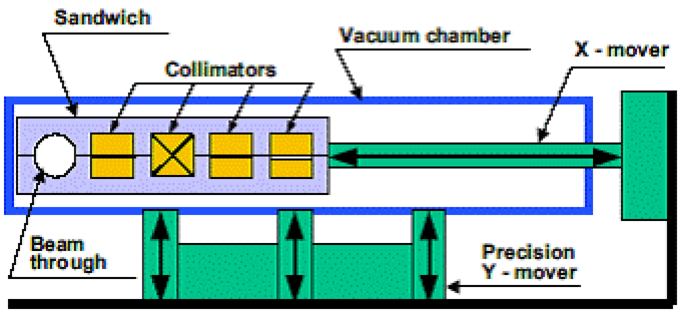
Collimators remove beam halo, but excite wakefields.
Goal: determine optimal collimator material and geometry
→ Beam Tests address achieving ILC design luminosity.

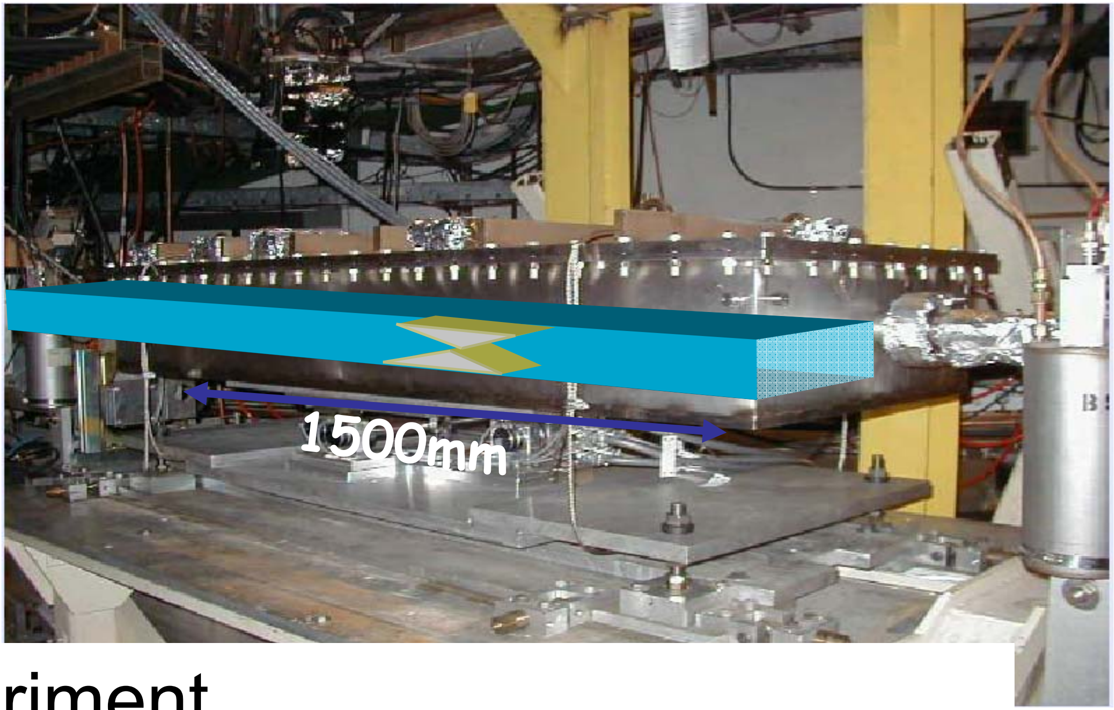
PIs: Steve Molloy (SLAC), Nigel Watson (U. of Birmingham)
Collaborating Institutions: U. of Birmingham, CCLRC-ASTeC + engineering, CERN, DESY, Manchester U., Lancaster U., SLAC, TEMF TU

Concept of Experiment

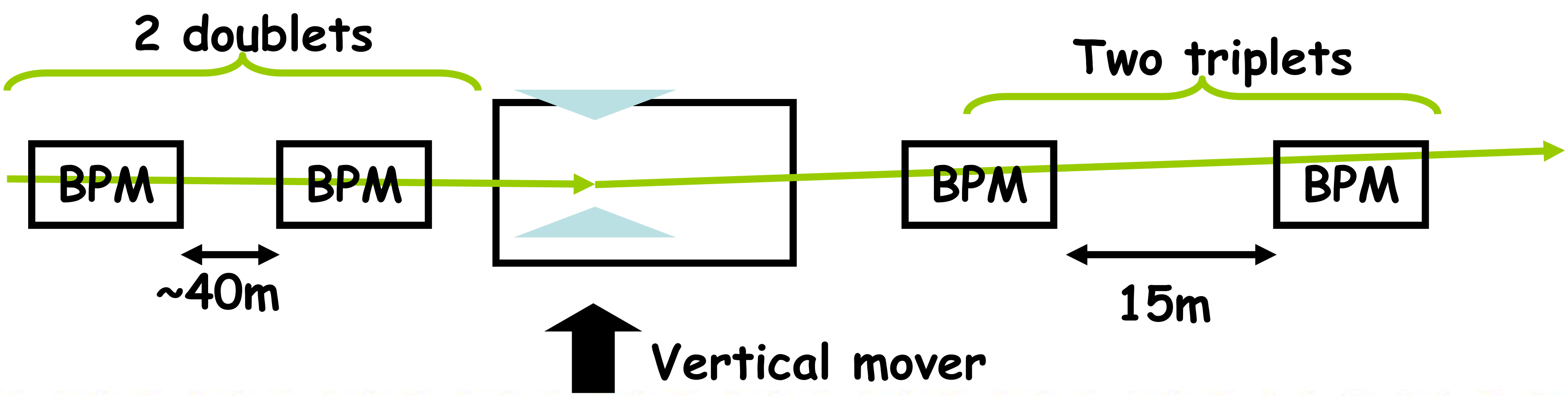


T-480: Collimator Wakefields



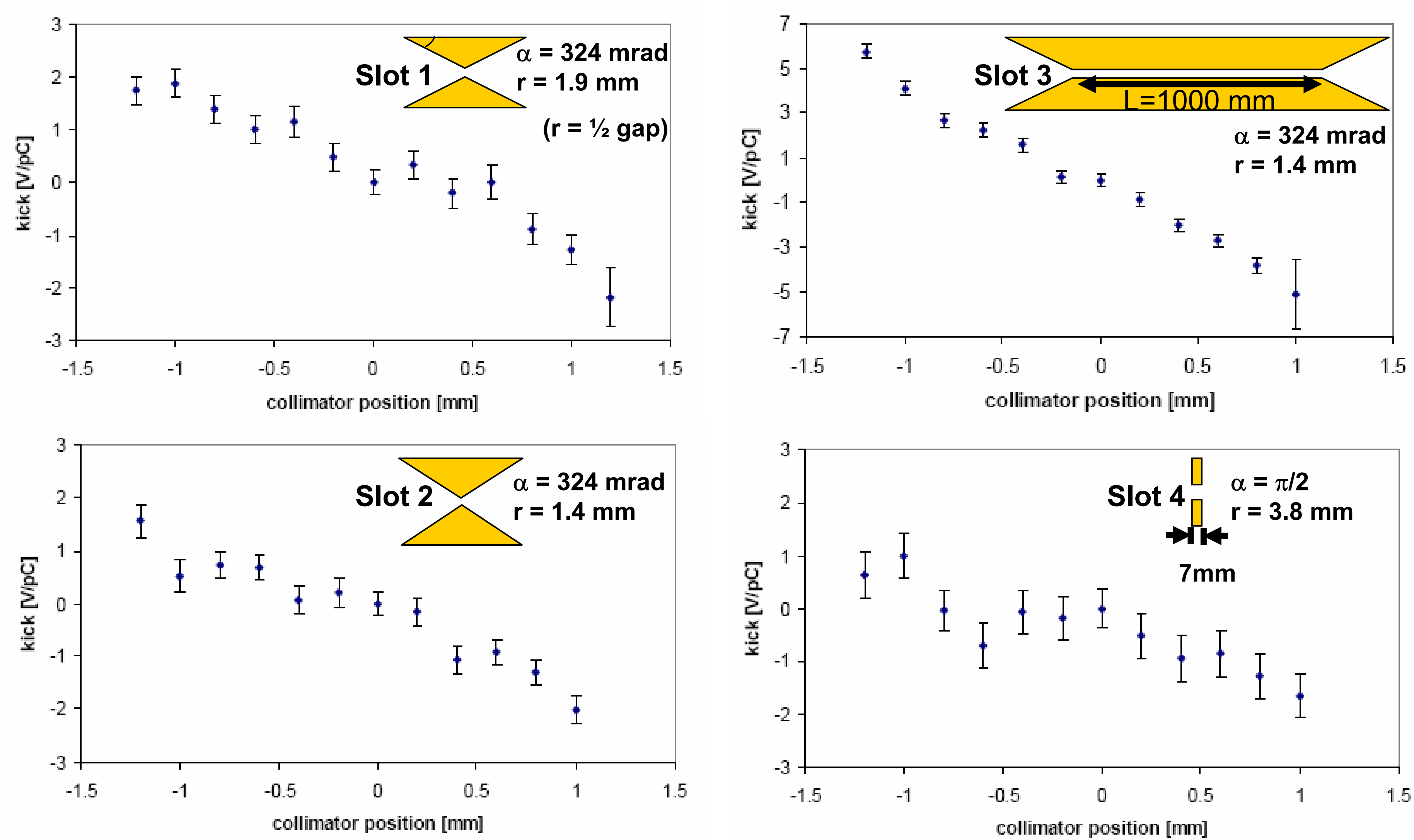


Concept of Experiment



T-480 Preliminary Results from 2006 Data

Sandwich 1 Collimators:



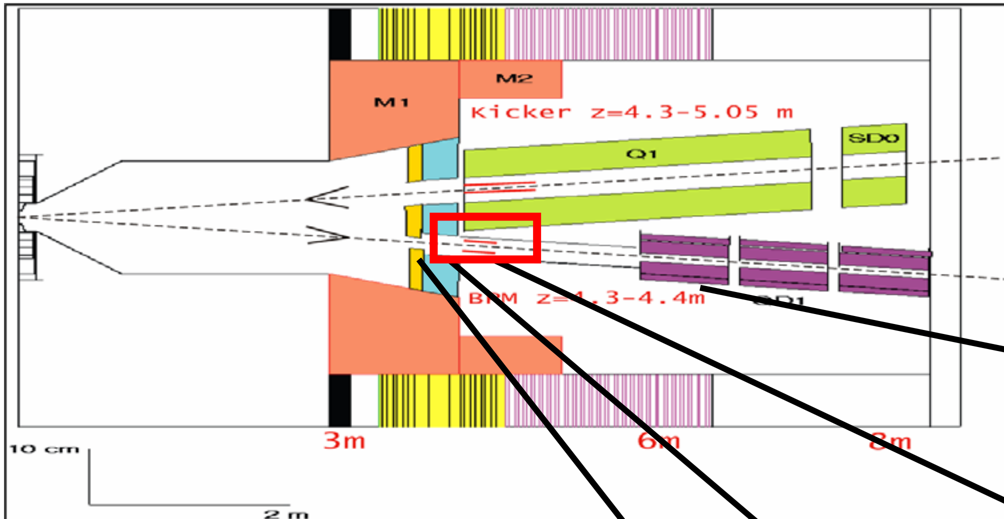
T-480 Preliminary Results from 2006 Data

Collimator	Measured[4] Kick Factor V/pc/mm (χ^2/dof) Linear fit	Measured[4] Kick Factor V/pc/mm (χ^2/dof) Linear + Cubic Fit	Analytic Prediction[1] Kick Factor V/pc/mm	3-D Modelling Prediction[2] Kick Factor V/pc/mm
1 (Sand1,Slot1)	1.4 ± 0.1 (1.0)[3]	1.2 ± 0.3 (1.0)	1.1	1.7
2 (Sand1,Slot2)	1.4 ± 0.1 (1.3)	1.2 ± 0.3 (1.4)	2.3	3.1
3 (Sand1,Slot3)	4.4 ± 0.1 (1.5)	3.7 ± 0.3 (0.8)	6.6	7.1
4 (Sand1,Slot4)	0.9 ± 0.2 (0.8)	0.5 ± 0.4 (0.8)	0.3	0.8
5 (Sand2,Slot1)	1.7 ± 0.3 (2.0)	1.7 ± 0.3 (2.2)	2.3	2.4
6 (Sand2,Slot2)	1.7 ± 0.1 (0.7)	2.2 ± 0.3 (0.5)	2.3	2.7
7 (Sand2,Slot3)	0.9 ± 0.1 (0.9)	0.9 ± 0.3 (1.0)	2.4	2.4
8 (Sand2,Slot4)	3.7 ± 0.1 (7.9)	4.9 ± 0.2 (2.6)	2.3	6.8

[1]Assumes 500-micron bunch length
[2]Assumes 500-micron bunch length, includes analytic resistive wake; modelling in progress
[3]Kick Factor measured for similar collimator described in SLAC-PUB-12086 was (1.3 ± 0.1) V/pc/mm
[4]Still discussing use of linear and linear+cubic fits to extract kick factors and error bars

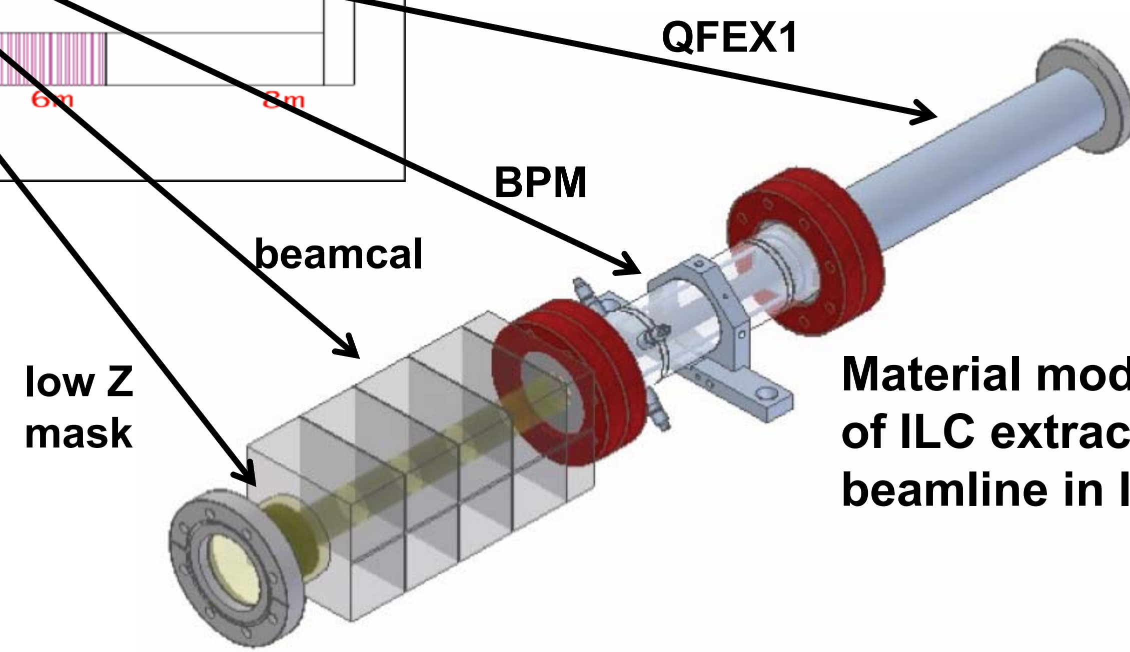
→ Goal is to measure kick factors to 10%

T-488: IR Mockup for FONT IP BPM studies



IR Extraction Line

PI: Phil Burrows, U. of Oxford
Collaboration: U. of Oxford, Daresbury Lab, SLAC



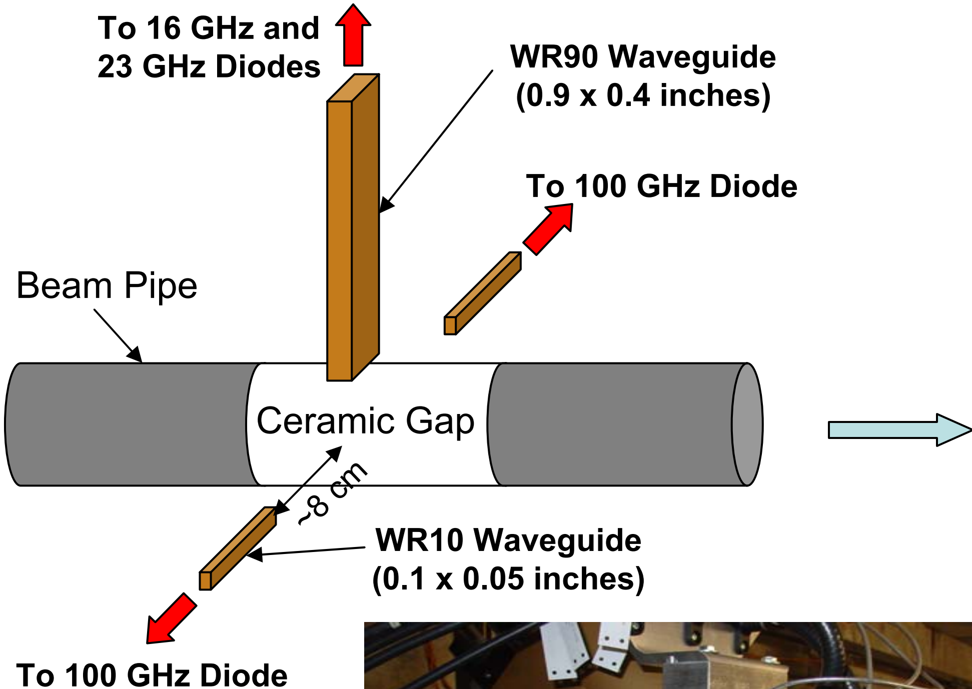
Material model of ILC extraction beamline in IR

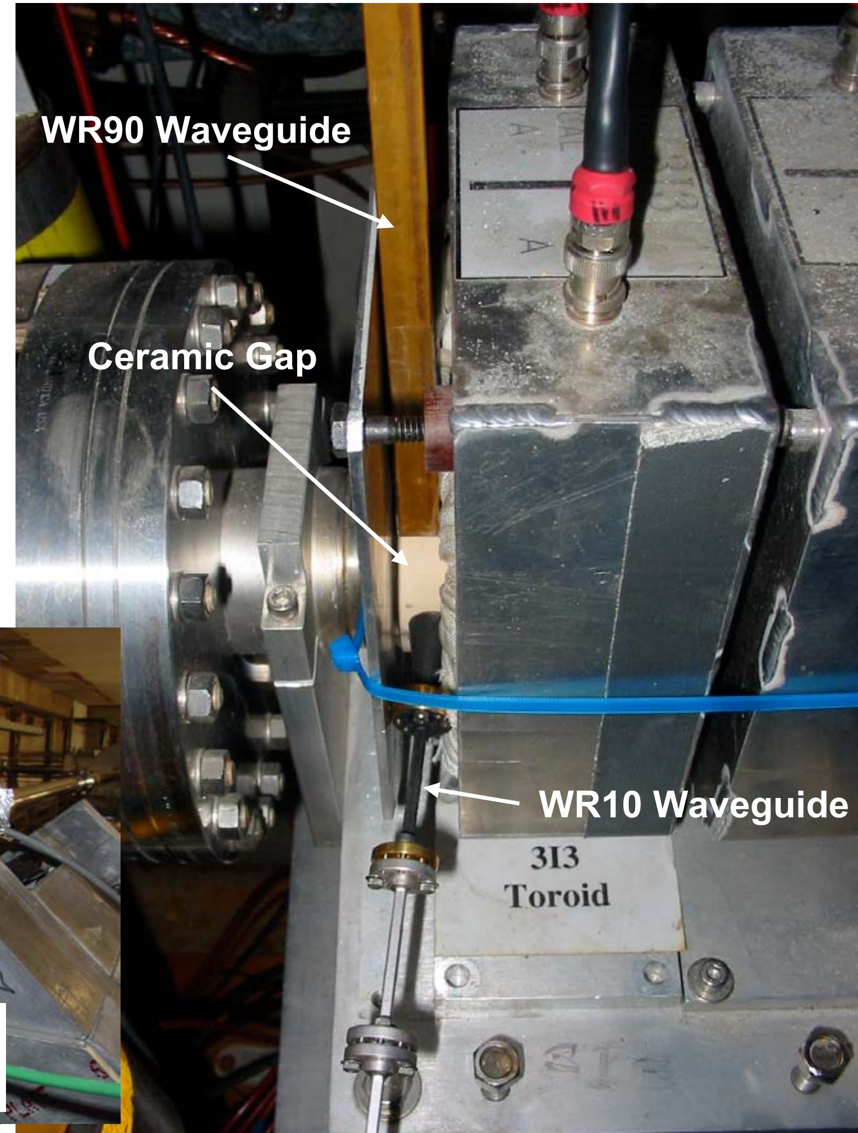
Beam Test

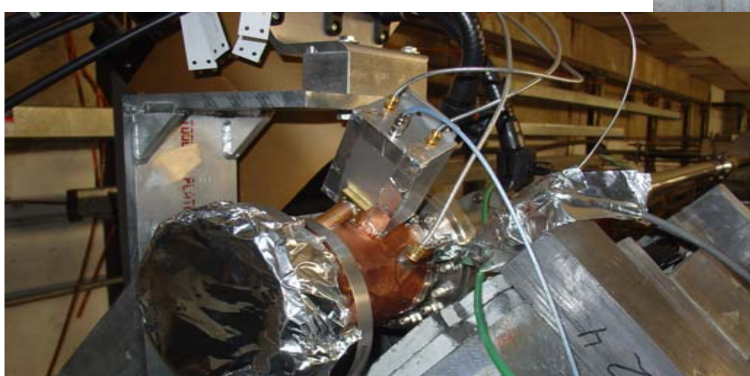
- simulate ILC pairs hitting components in forward region of ILC Detector near IP bpms, exceeding maximum ILC energy density of 1000 GeV/mm^2 by up to factor 100

RF Bunch Length Detectors in ESA

Collaborating Institutes: Livermore, SLAC

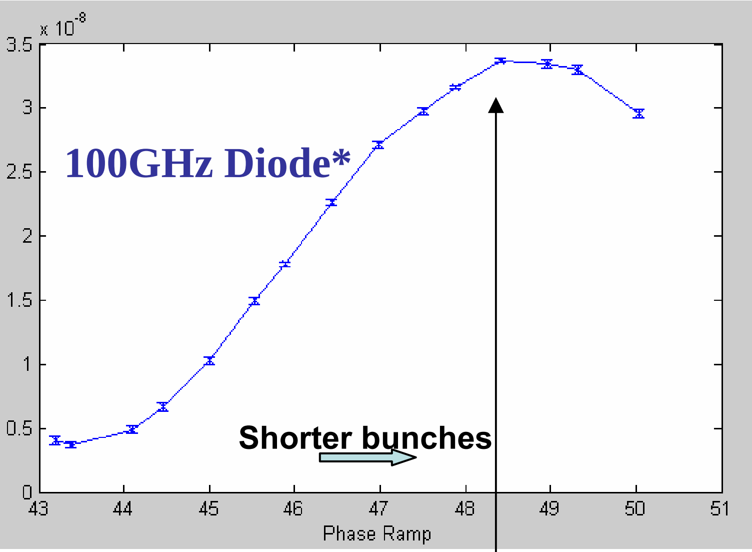


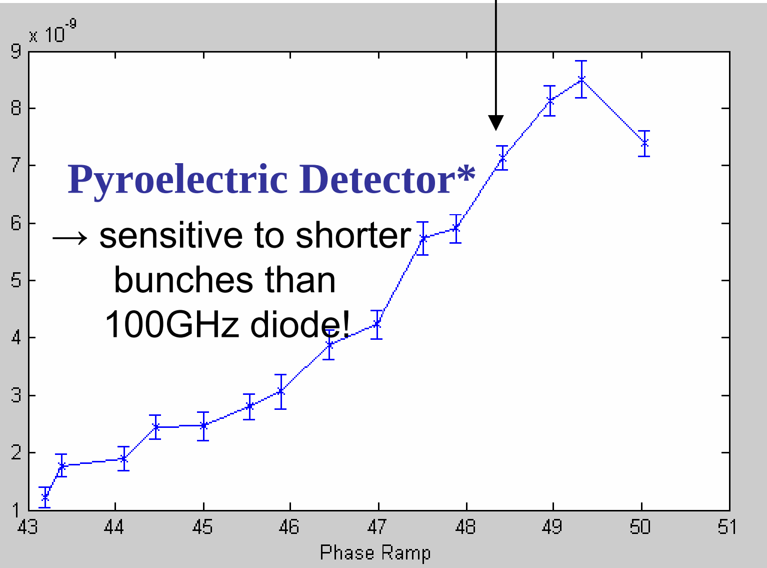




(shielded) Pyroelectric Detector at (shielded) ceramic gap

Bunch Length Measurements vs Linac rf Phase





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

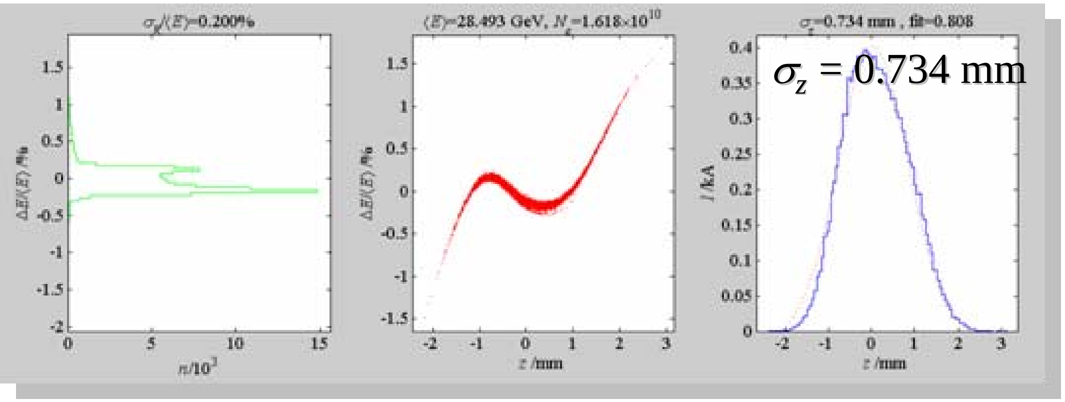
23GHz Diode was insensitive to bunch length

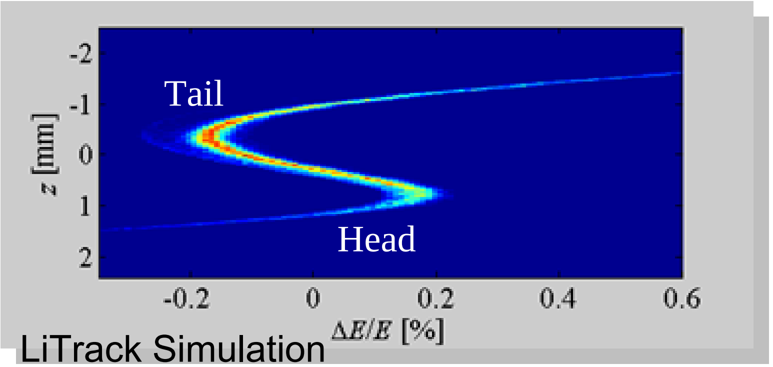
(phase ramp determines relative timing of beam wrt accelerator rf)

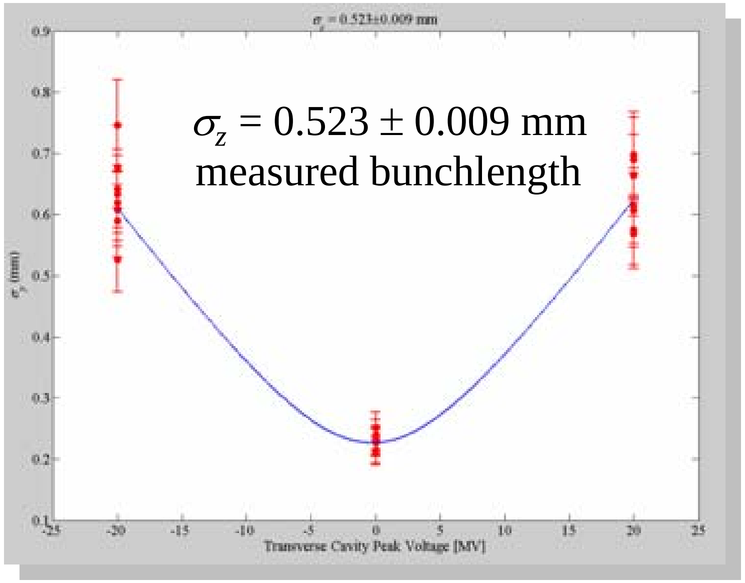
Bunchlength + Energy-Z correlation Measurements at end of Linac with Transverse "LOLA" cavity

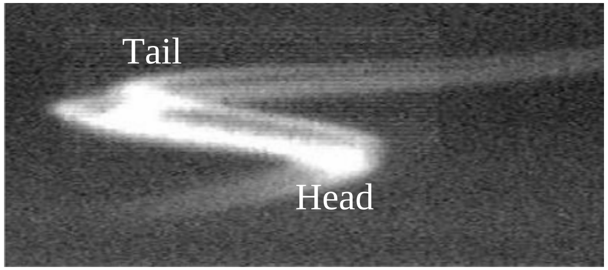
2006 Results (Preliminary)

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







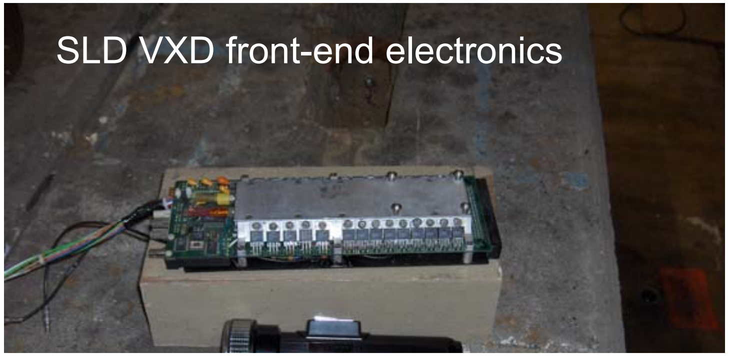


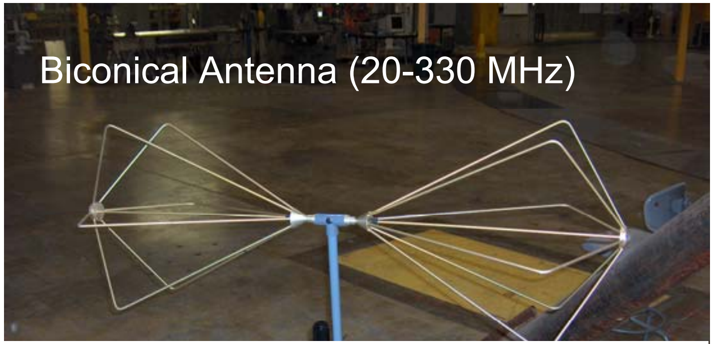
A-Line Synchrotron Light Monitor signal w/ LOLA on. 1-m dispersion for horizontal axis. Calibrated vertical scale to be 0.32mm/deg; 1deg at S-band ~300um.

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

EMI Studies at SLAC ESA

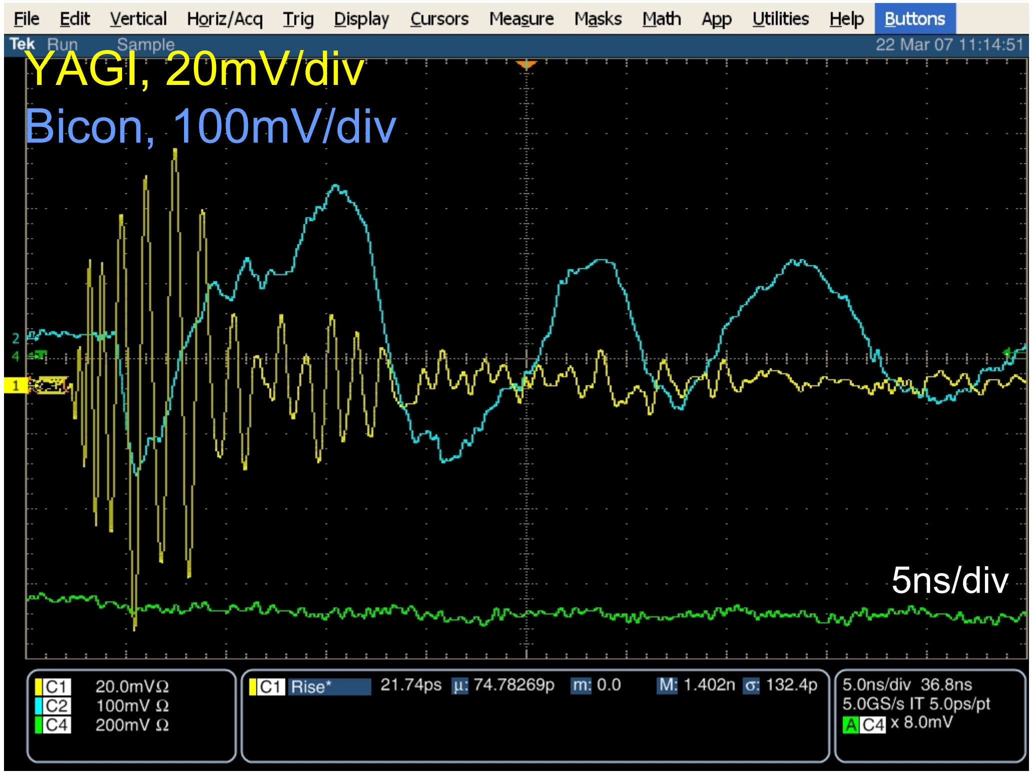
G. Bower (SLAC), N. Sinev (U. Oregon), Y. Sugimoto (KEK)

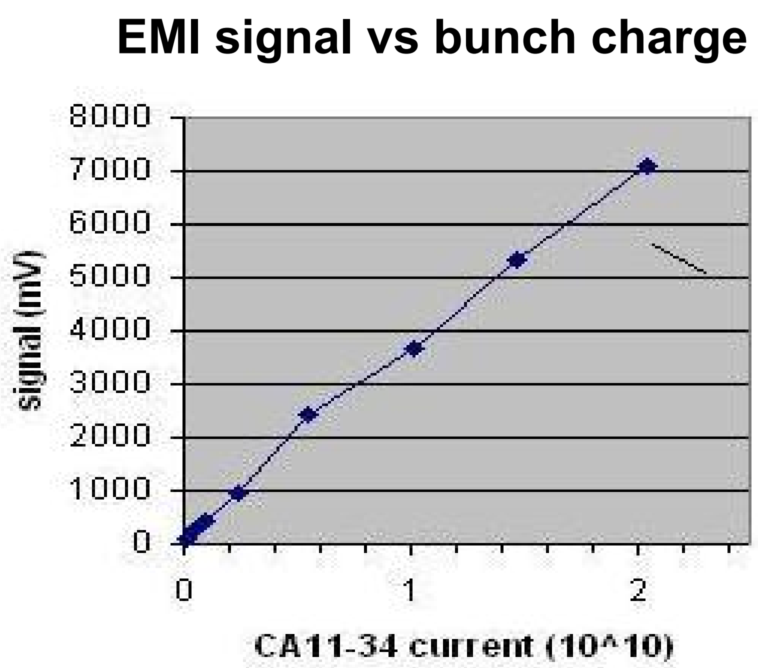




- EM fields within the beam pipe are contained by the small skin depth.
- But dielectric gaps emit EM radiation out of the beam pipe.
- Common “gaps” are camera windows, BPM feedthroughs, toroid gaps, etc.

EMI Measurements near ceramic gap





- Antennas placed near (~1 m) gaps observed EMI up to ~20 V/m.
- Pulse shapes are very stable over widely varying beam conditions, indicating they are determined by the geometry of beam line elements.
- Pulse amplitudes varied in proportion to the bunch charge but were independent of the bunch length. Observe ~1/r dependence on distance from gap.

VXD electronics failures: observations

EMI Shielding Tests, July 2006

- Placing just the SLD VXD board inside an aluminum foil shielded box stopped the failures.
- Covering the gap also stopped failures.
  - ➢ failures not due to ground loops or EMI on power/signal cables
  - ➢ failures are due to EMI emitted by gap
  - ➢ what frequencies are important?

EMI Shielding Tests, March 2007

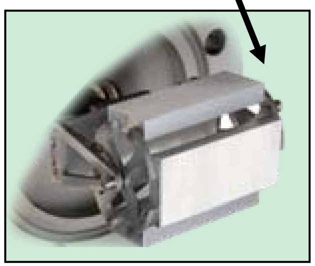
- A single layer of common 5mil aluminum foil was placed over the ceramic gap and clamped at both ends to provide an image current path.
- The antenna signal amplitude was reduced by >x10.
- EMI from upstream sources limited the resolution.
- The aluminum foil gap cover stopped VXD failures.
- A 1 cm x 1 cm hole in the gap foil cover emitted enough EMI to cause about 50% VXD failure rate at ~1m distance. (With no foil rate would be 100% at this distance.)
- There was no failure with a 0.6 cm x 0.6 cm hole.

T487: 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

Carousel of 3 gratings and ‘blank’

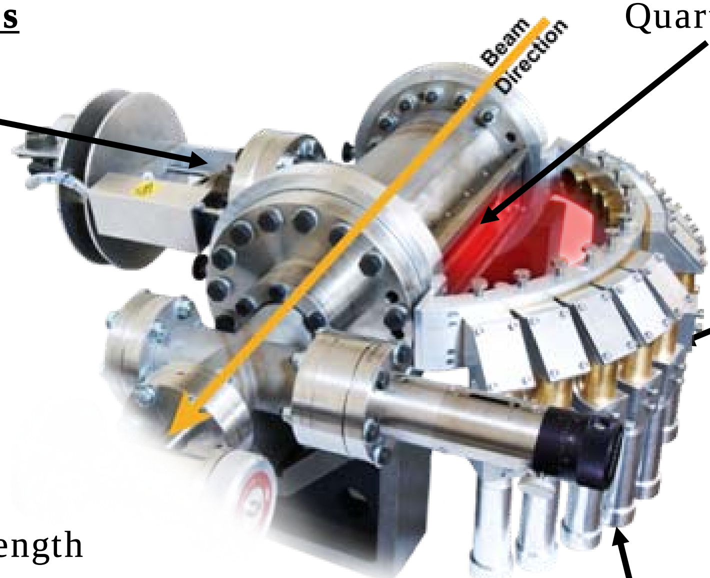


•Expands observable wavelength range.

• Quick measurement turnaround.

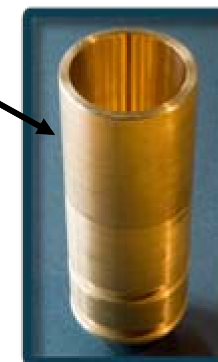
• Allows ‘**true**’ SP signal to be found (i.e. ‘*grating – blank grating*’ signal = true SP signal).

Quartz Window



Winston Cone

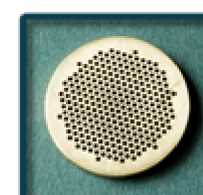
• Collects and concentrates the light seen.



11 **Pyroelectric Detectors**

•Inexpensive, room temperature detectors.

Waveguide Array Plate Filter



•Far infrared filter, designed to reject non- SP wavelengths.

G. Doucas

T-490: 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: July 5-8, 2007 just prior to Run 4

Future for continuing ILC-ESA Test Beam Program?

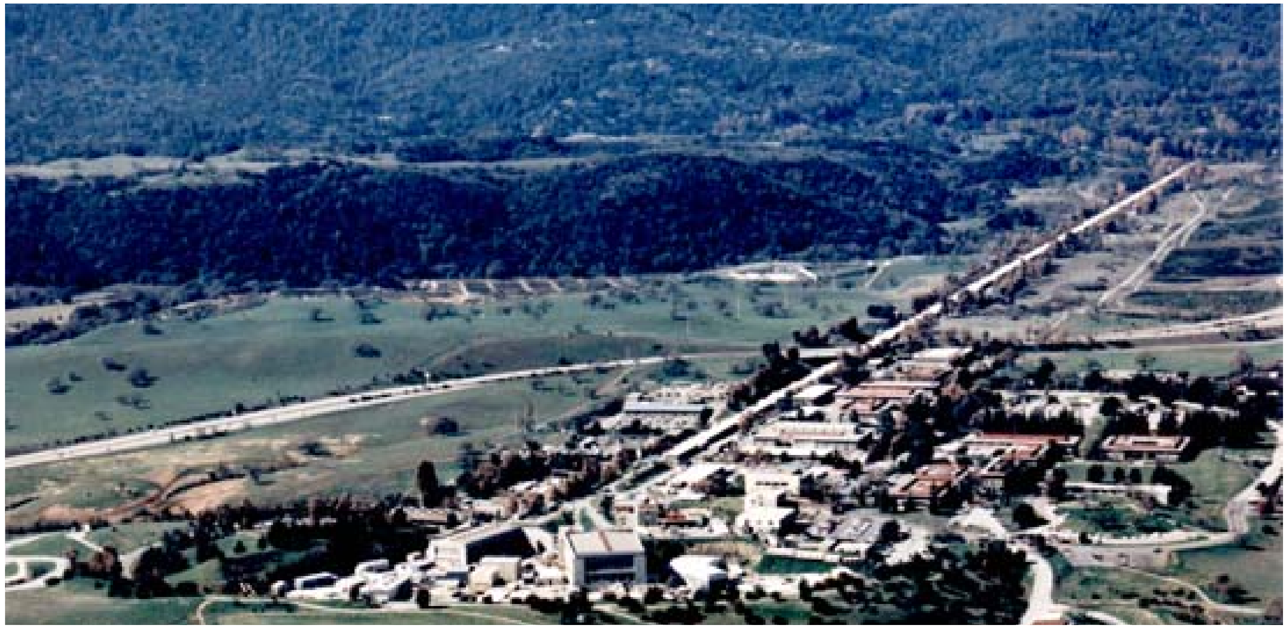
FY08 → continue program in ESA, requesting 4 weeks of Beam Tests
→ beam scheduling more difficult: priority for LCLS
→ reduced funding available from SLAC, but major installations are complete

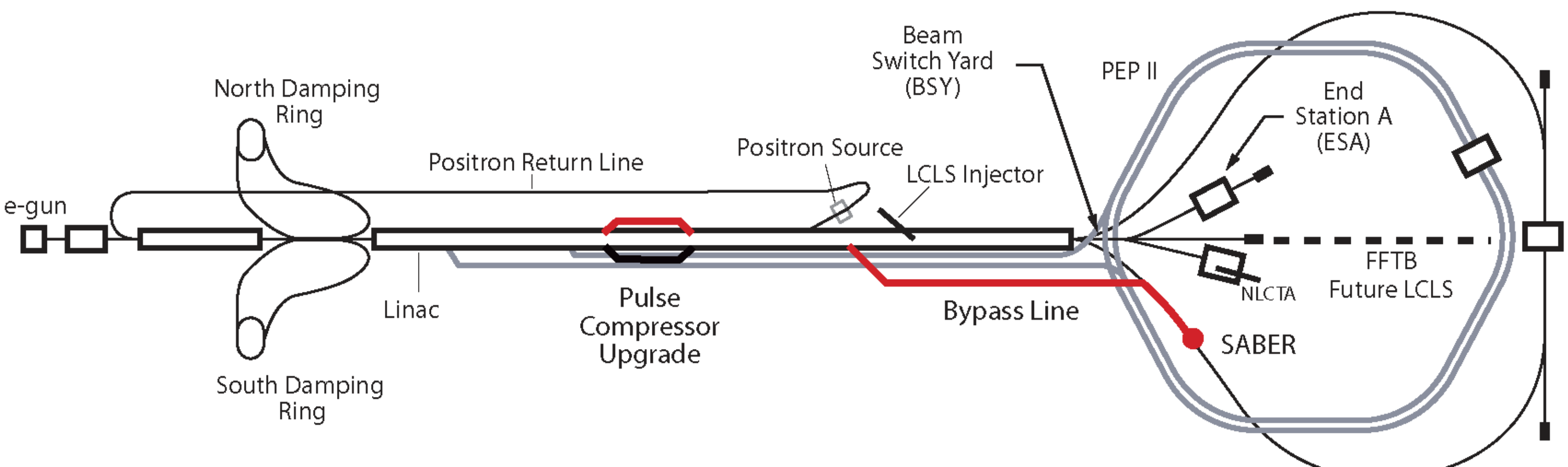
FY09 and beyond (LCLS era, parasitic operation with PEP-II ends at end of FY08)
→ ESA PPS upgrade needed for continued ESA operation
→ ILC beam instrumentation tests in proposed SABER (South Arc Beam Experimental Region) facility possible
→ Study group looking at SLAC test beam capabilities with primary and secondary beams for Detector and MDI-related R&D – discussed at 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, ii) extend SABER bypass line to ESA, 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, iv) pulsed magnets in BSY using 10Hz LCLS beam and BSY production collimator,

Test Beams at SLAC





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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

FY08 → continue program, requesting 4 weeks of Beam Tests
→ beam scheduling more difficult: priority for LCLS commissioning
→ reduced funding available from SLAC, 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: internal report submitted to HEP Director at SLAC last week