

# End Station A Test Beam ESTB & CLIC Wakefield Collimation

Mauro Pivi, SLAC National Accelerator Laboratory  
on behalf of ESTB/ESA team

Webex CLIC meeting  
June 09, 2011

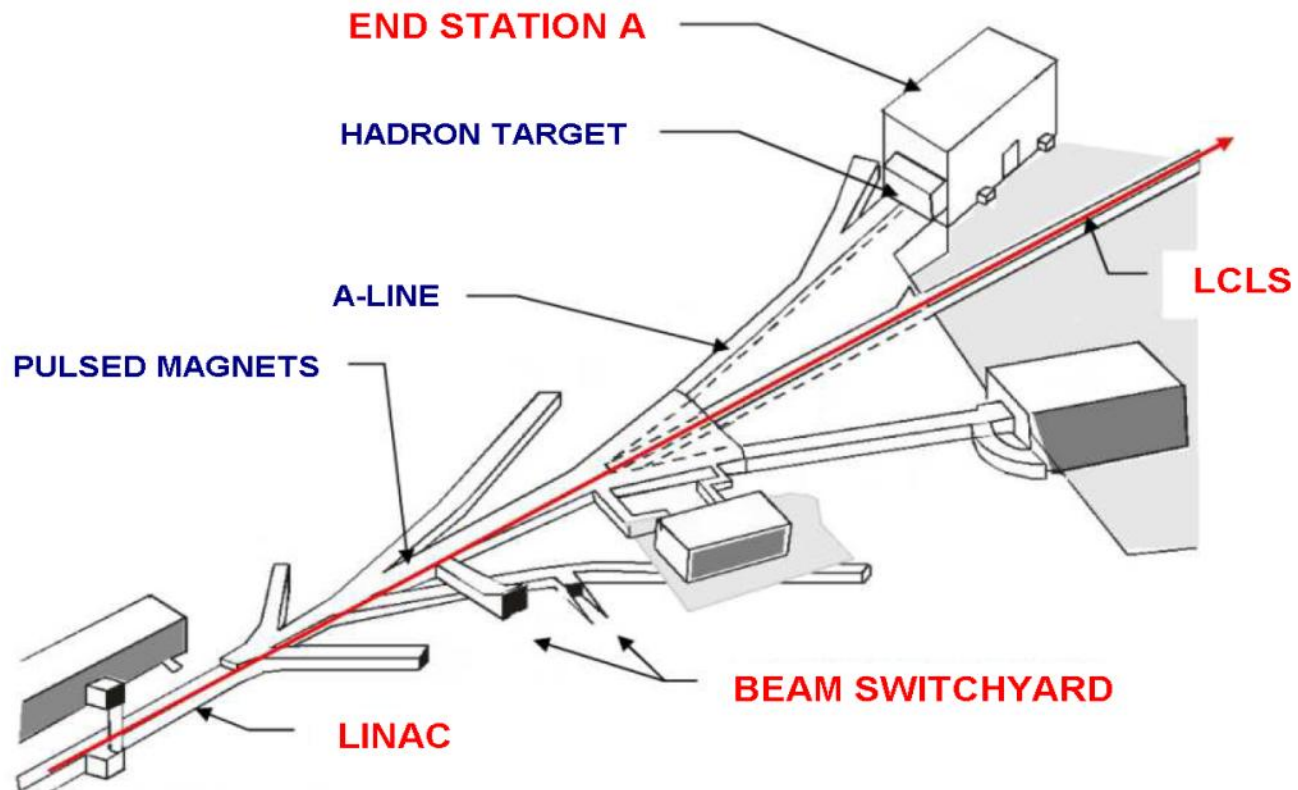
An aerial photograph of the SLAC National Accelerator Laboratory. A long, narrow, light-colored structure, the SLAC Linac, runs vertically through the center of the image. A white arrow points from a green text box to the lower portion of this structure. Another white arrow points from a second green text box to a large, rectangular building complex situated to the right of the linac. The surrounding area includes various other buildings, parking lots, and green fields.

LCLS uses 1/3 of  
SLAC LINAC

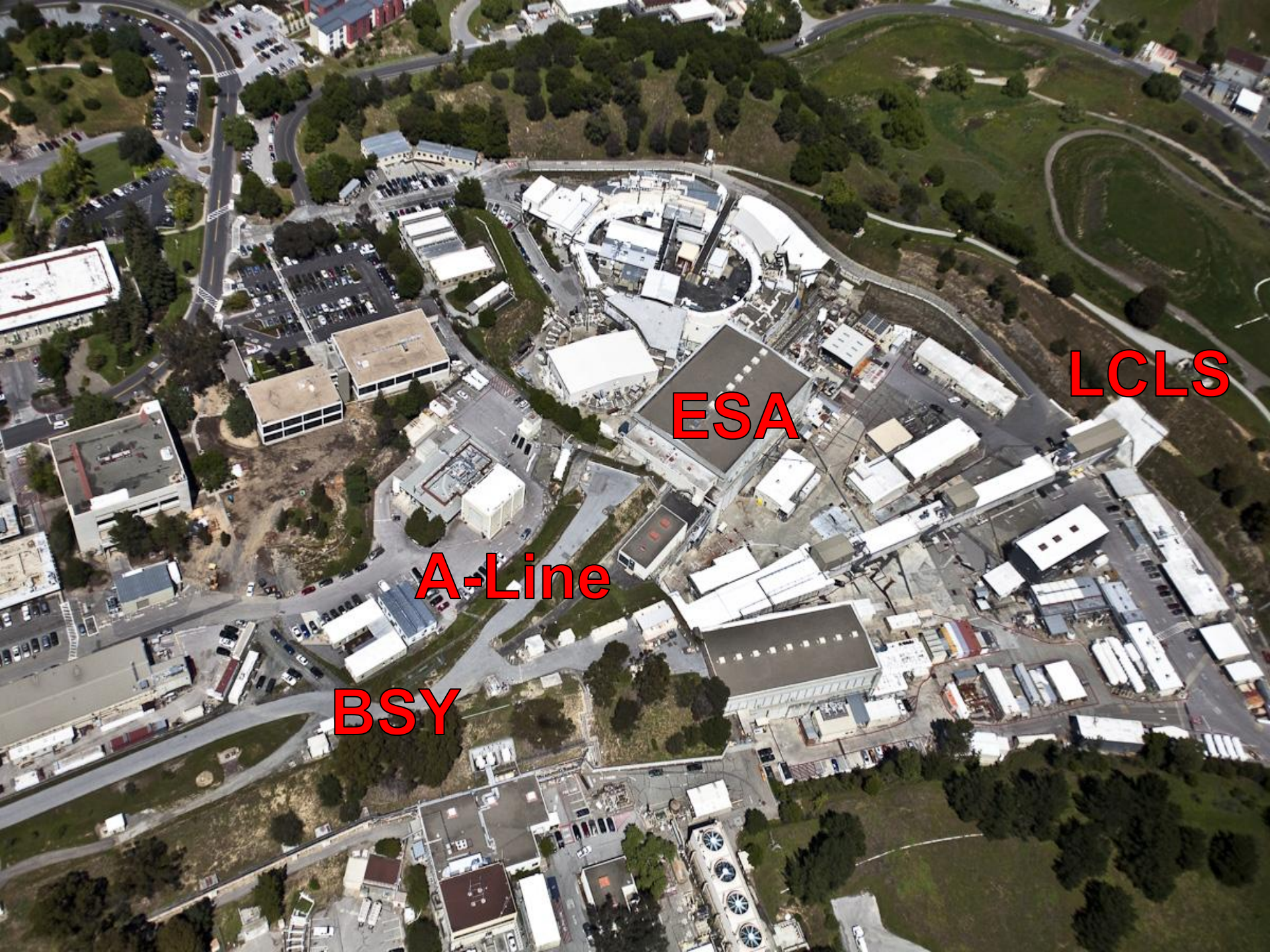
End Station A

# LCLS and ESA

Use pulsed magnets in the beam switchyard to send LCLS beam to End Station A (ESA)







LCLS

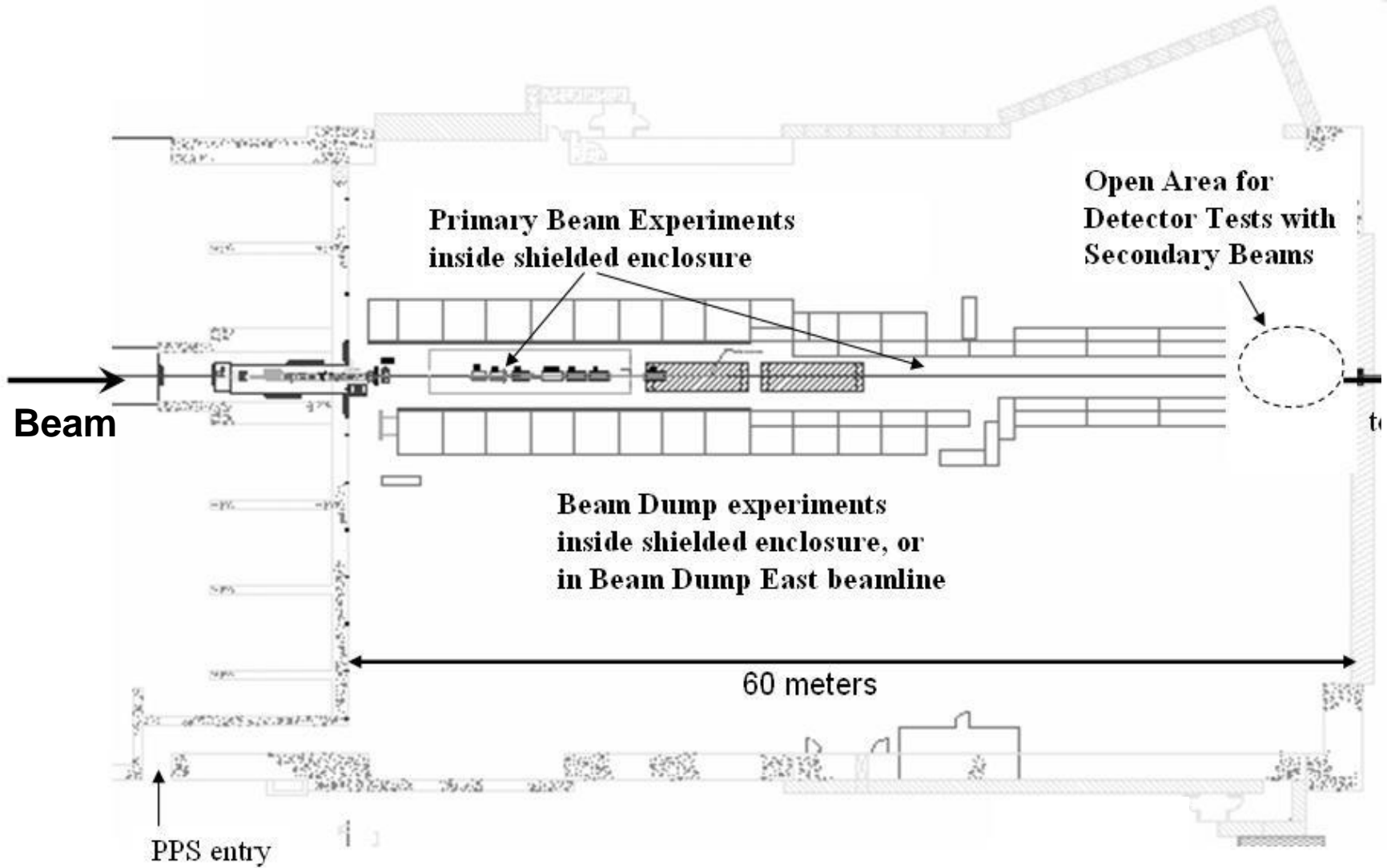
ESA

A-Line

BSY



# Building 61: ESA



# LCLS/ESTB Beams

## LCLS beam

- Energy: **3.5 –13.6 GeV**
- Repetition rate: **120Hz**
- Beam current: 20 to **250 pC**
  - 150 pC preferred by LCLS Users these days
- 350 pC @ 120Hz has been provided
  - This is the current upper limit for the present cathode
  - **Radiation Safety approved 600 pC running!**
- Beam availability > 95%!

## ESTB beam

- Kick the LCLS beam into **ESA @ 5 Hz**
- Primary beam 3.5 -13.6 GeV
  - Determined by LCLS
  - $<1.5 \times 10^9$  e-/pulse (250 pC)
- Clean secondary electrons
  - 1 GeV to 13.6 GeV, 0.1 e-/pulse to  $10^9$  e-/pulse

# ESTB parameters

Table 1.1.1. ESTB primary electron beam parameters and experimental area at the BSY and in ESA

Parameters	BSY	ESA
Energy	4-13.6 GeV	4-13.6 GeV
Repetition Rate	5 Hz	5 Hz
Charge per pulse	0.25 nC	0.25 nC
Energy spread, $\sigma_E / E$	0.058%	0.058%
Bunch length rms	10 $\mu\text{m}$	280 $\mu\text{m}$
Emittance rms ( $\gamma\varepsilon_x, \gamma\varepsilon_y$ )	(1.2, 0.7) $10^{-6}\text{m-rad}$	(4, 1) $10^{-6}\text{m-rad}$
Spot size at waist ( $\sigma_{x,y}$ )	-	< 10 $\mu\text{m}$
Drift Space available for experimental apparatus	-	60 m
Transverse space available for experimental apparatus	-	5 x 5 m



# ESTB Hardware Needed

- 4 kicker magnets including power supplies, modulators and vacuum chambers are being manufactured
- Build new PPS system and install new beam dump

## A-Line Extraction:

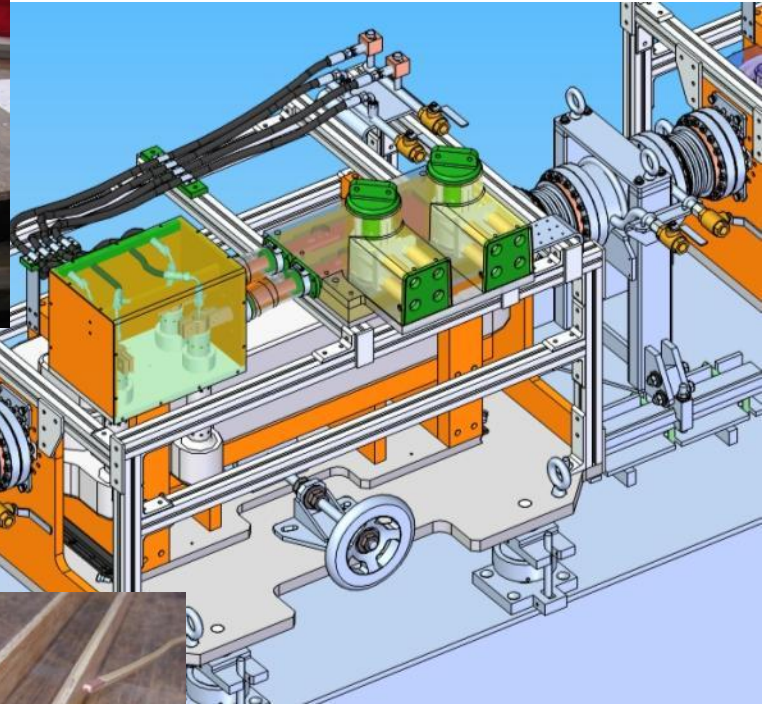
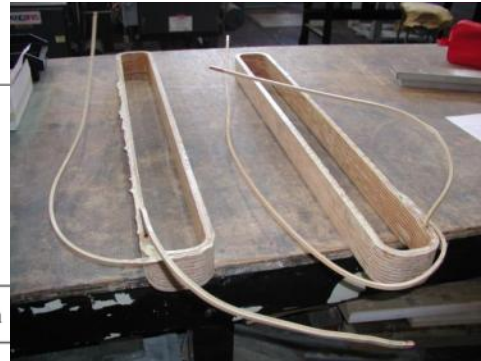
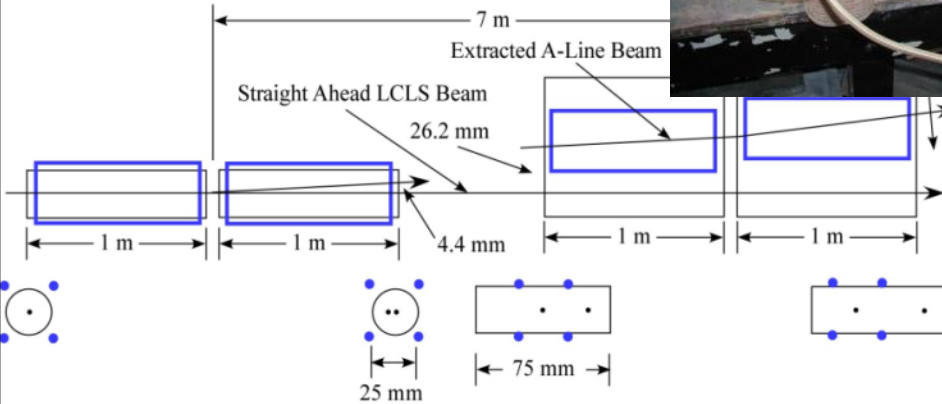
Total Kick = 8.7 mrad

2 set of bends, 4.37 mrad  $\Rightarrow$  2.04 kG-m @ 14 GeV

7 m between the two bends

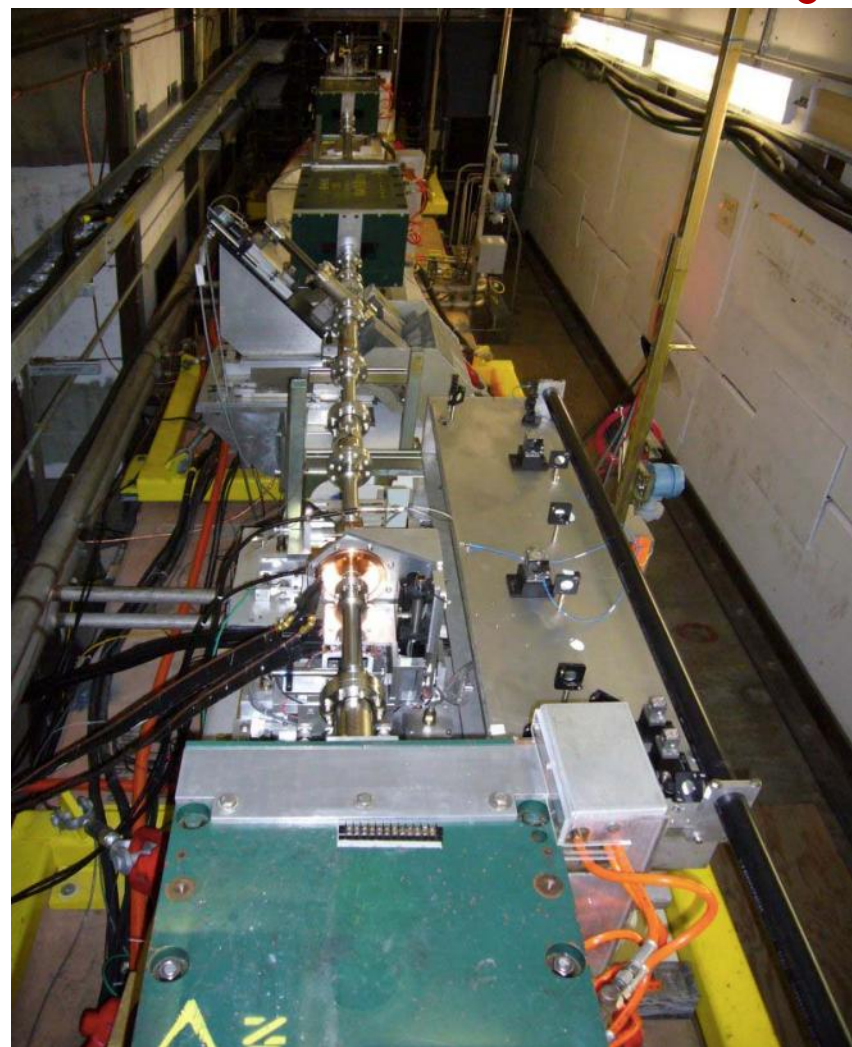
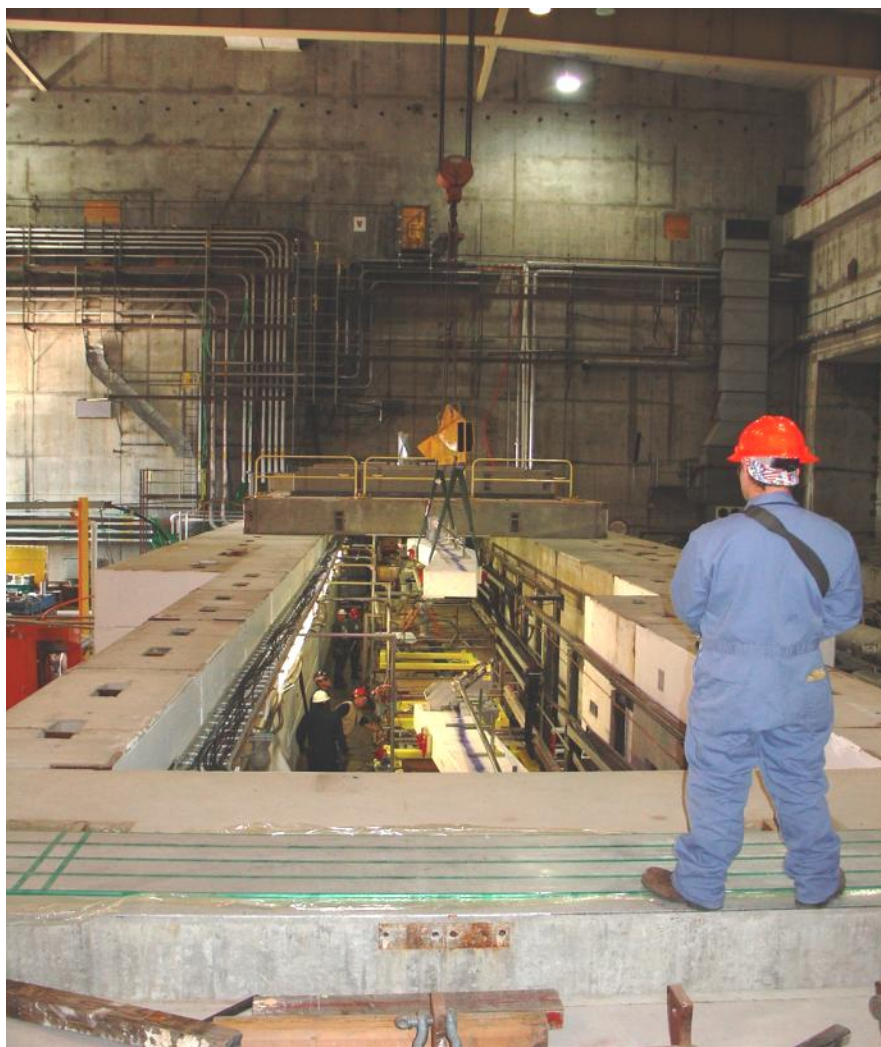
Bends based on LCLS BYKIK: 25 mm coil diameter, air-core

Distances and separations are approximate, need to check layout





# End Station A Experimental Area





# Collimator Wakefield Measurements

R.M. Jones, D. Schulte, R. Tomas, W. Wuensch for the CLIC team

## Motivation

- Collimator wakefields may limit CLIC performance
- CLIC parameters sit close to limit of formulae applicability
- Previous experiments in ESA (T-480)<sup>a</sup> show discrepancies with model (is the lack of bunch length measurement the culprit?)
- Non-linear components?

**Collimator Hardware**

Manchester 2011

The Cockcroft Institute of Accelerator Science and Technology

Sandwich, Collimators, Vacuum chamber, X-mover, Precision Y-mover, Beam through

T480 "wakefield box"

ESA beamline

R.M. Jones, University of Manchester/Cockcroft Inst. on behalf of CLIC

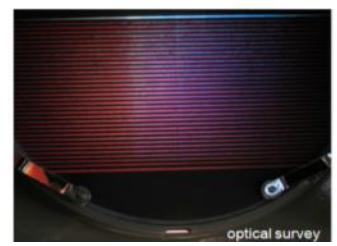
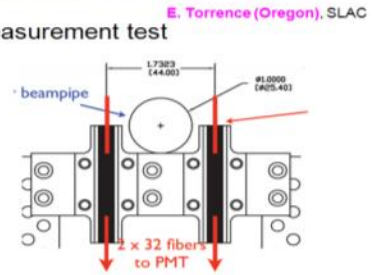
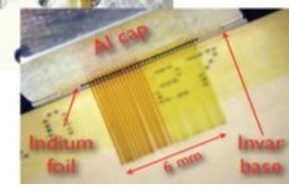
- Bunch length measurement is critical . New electro-optic bunch length instrumentation (CLIC CDR)
- Need BPM resolution in the 100 nm level (partially contributed by CERN)

# Energy Spectrometer Tests at End Station A

Mike Hildreth

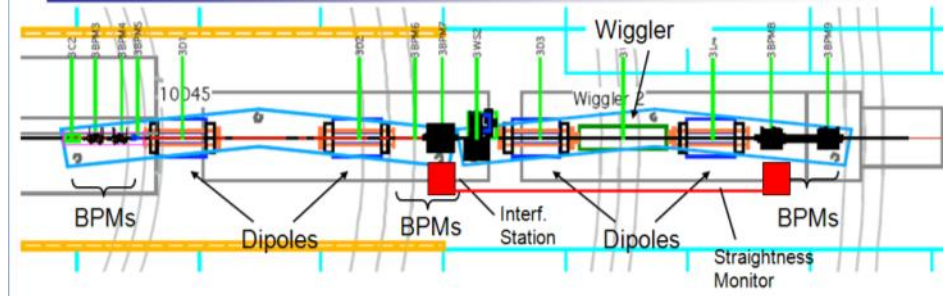
## New SR Stripe Detector

- Next-generation prototype for Energy Measurement test
  - schedule advanced in anticipation of ESA closure/hiatus due to LCLS



March 17, 2011

## Next Steps for ESA



- Cross check of spectrometer energy measurements
  - Commission SR-Stripe setup
  - Previous chicane measurements limited by BPM resolution
    - LCLS2 BPMs? (under negotiation)
  - more new hardware/electronics for better resolution/stability
  - aim for  $1 \times 10^{-4}$  relative measurement, cross-calibration
  - Finish what we started!

# Collimator Wakefield “Box” in ESA

- Installed and tested in 2007-'08
- Different jaw apertures, coll. lengths
- Tests: optimal materials and geometry to minimize wakefields
- T-480, see papers S. Molloy *et al.*

Slot	Side view	Beam view	
1	<p><math>\alpha</math> <math>r=1/2</math> gate</p>	<p>38 mm <math>h=38</math> mm</p>	$\alpha=335\text{mrad}$ $r=1.9\text{mm}$
2			$\alpha=335\text{mrad}$ $r=1.4\text{mm}$
3	<p><math>L=1000</math> mm</p>		$\alpha=335\text{mrad}$ $r=1.4\text{mm}$
4	<p>7 mm</p>		$\alpha=\pi/2\text{rad}$ $r=3.8\text{mm}$



- “Wakefield box” allows swapping of collimators and adjusting jaw aperture
- measured wakefield kick to the beam by downstream BPMs



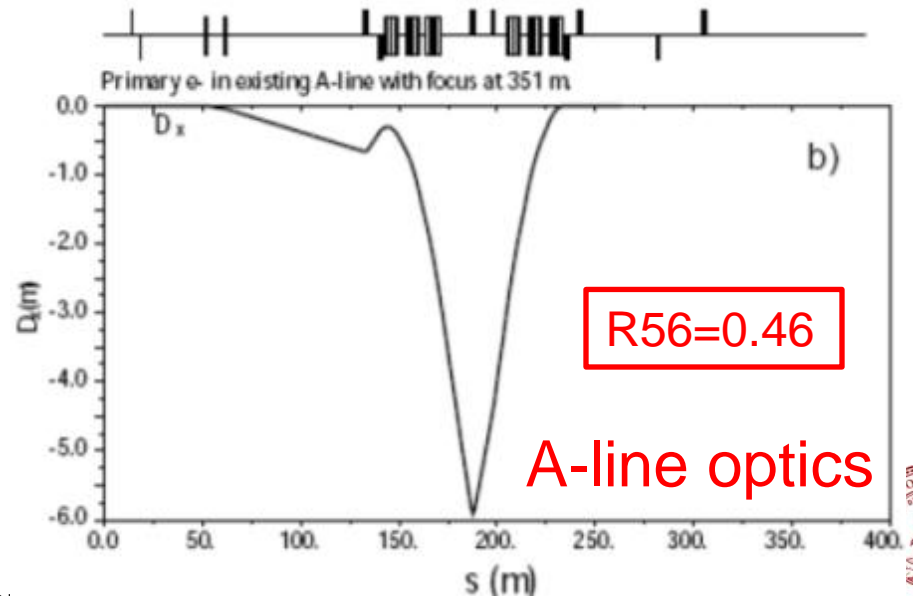


# CLIC collimation wakefield

- CLIC bunch length  $44 \mu\text{m}$
- LCLS beam:  $10 \mu\text{m}$  and smaller
- To first order: bunch length  $\sigma_z = \delta_{uE} \times R56$ .
- In the A-line, bunch length increase due to  $24^\circ$  bend, large dispersion (6m!) and large R56.

at nominal  $\delta_{uE}=0.06\%$  and  
 $R56 = 0.46$ :

$$\sigma_z = \delta_{uE} \times R56 = 280 \mu\text{m}$$



# CLIC collimation wakefield

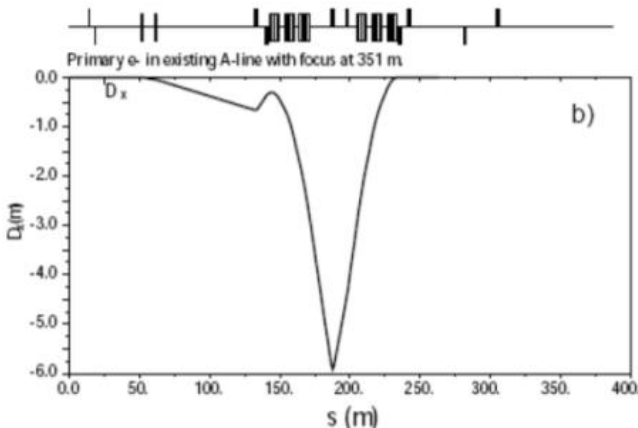
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- It is possible to reduce  $\delta_E \sim 0.02\%$  (Z. Huang)
- Bunch lengths of 100  $\mu\text{m}$  are possible.
- For smaller bunch length we would need to modify the optics and reduce R56.

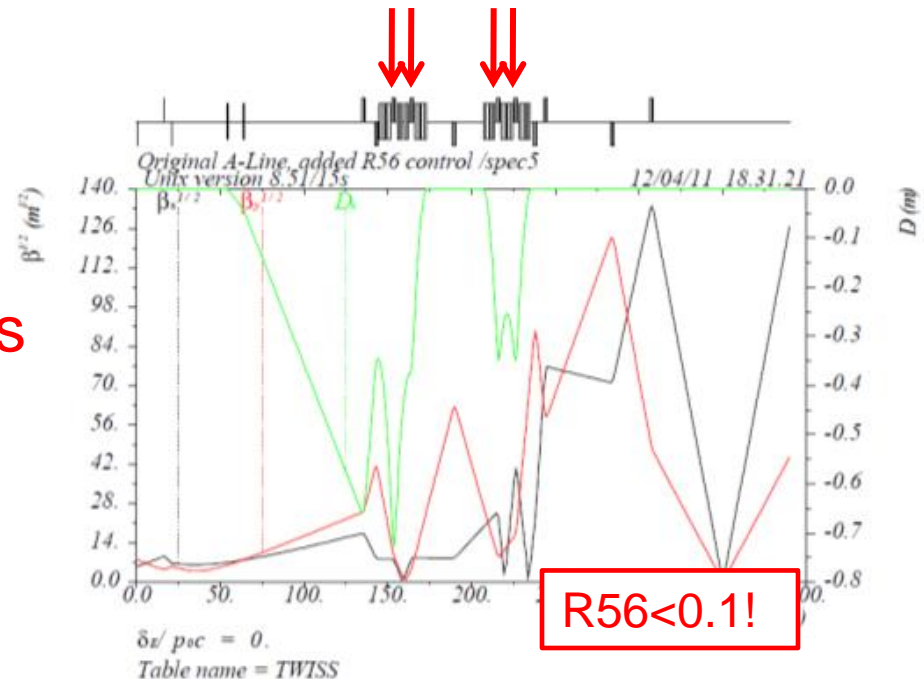
# CLIC collimation wakefield

- Solution: installation of 4 available QUADs to reduce dispersion at bends locations:

- reduce R56  $\sim 0.1$  (Ted Fieguth, M. Pivi)
- with LCLS beam  $\delta_E \sim 0.02\%$  (Z. Huang)
- $\sigma_z \leq 44 \mu\text{m}$  in ESA

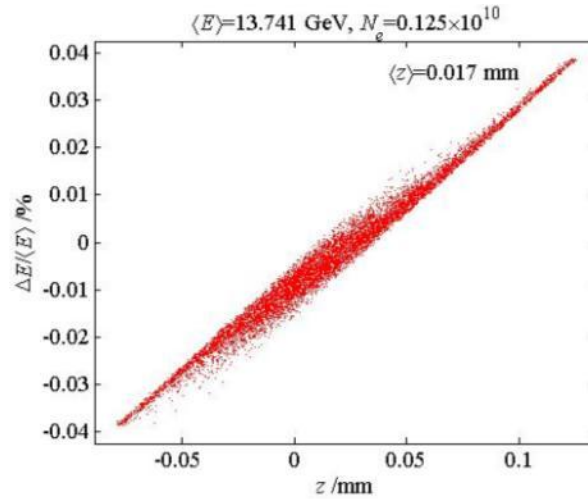
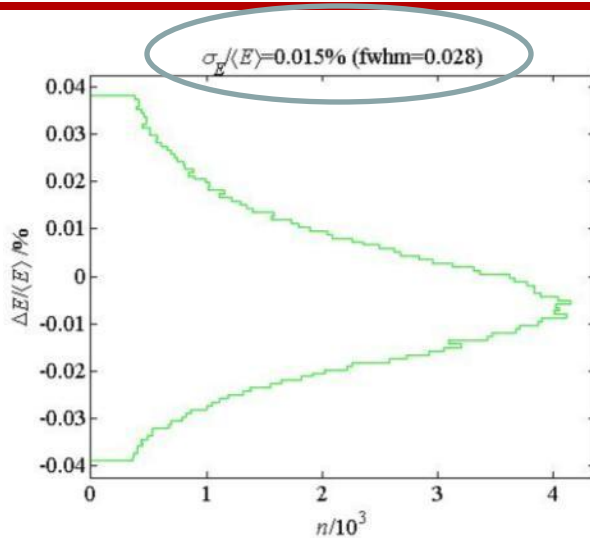


+ 4 Quads





# Using LiTrack: example

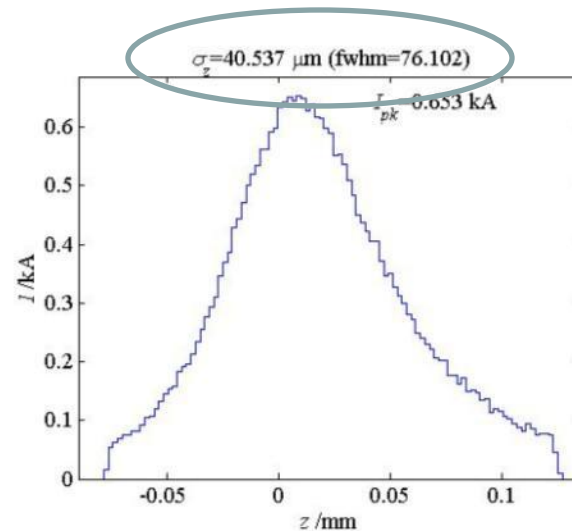


LiTrack simulations (Z. Huang):

- $\delta_E \sim 0.015\%$
- applied 10% energy cut
- R56 = 0.23 m (not 0.1 yet!)
- got  $\sigma_z = 40$   $\mu\text{m}$

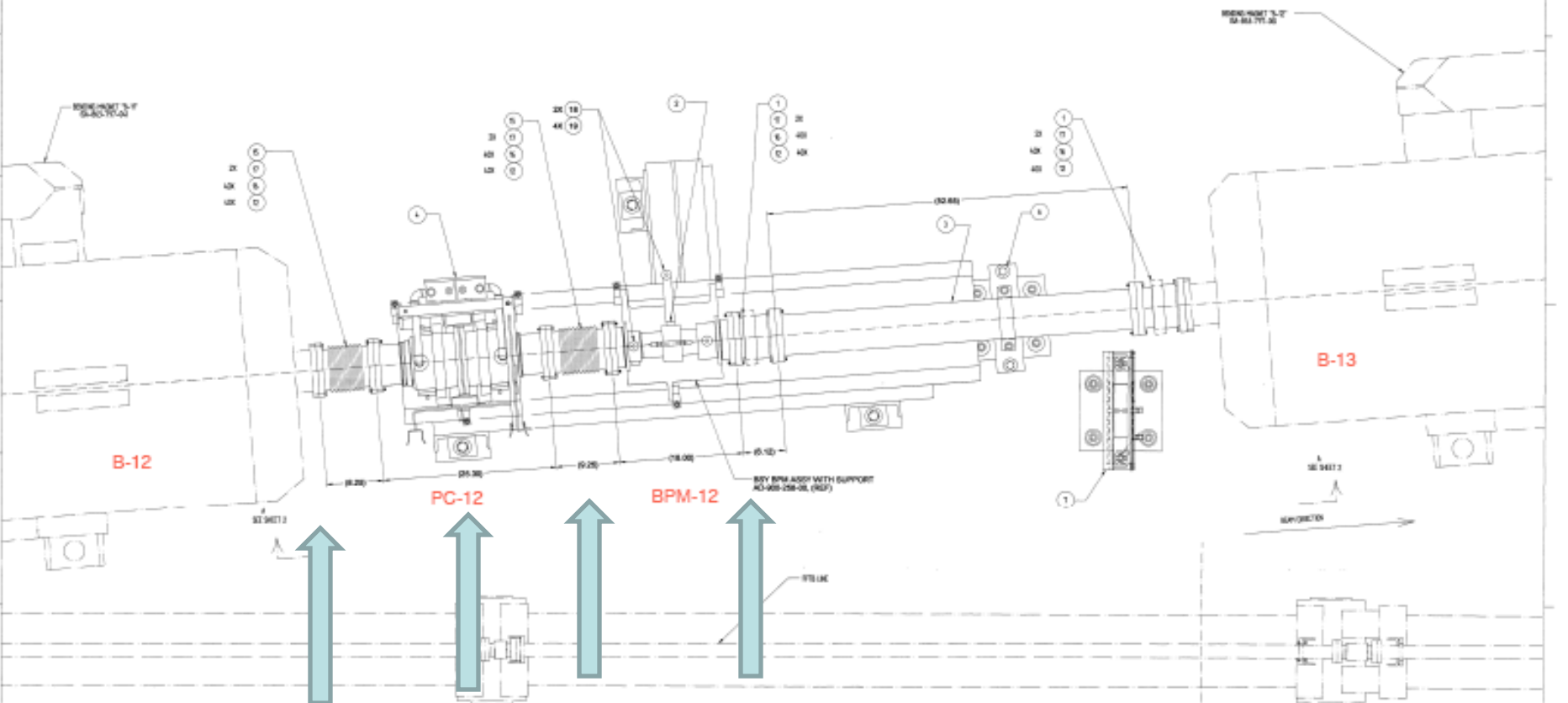
source: lcls\_200pC\_6MeV\_560um.zd

Elegant (MADX?!) simulations of whole beam line on the way



LiTrack (SLAC)

REV	DESCRIPTION	CHK	APP	DATE
1	ISSUE DESIGN	MS	ST	22/01/04
2	REV BY THE DESIGN, REV 1 & 2	AC	ST	22/01/04



Removal existing instrumentation in the A-line to make room to 2 m long quadrupoles

- NOTES
- FOR MOUNTING DIMENSIONS SEE IS-12-100-01
  - FOR ELECTRICAL CONNECTIONS SEE IS-12-100-02
  - SEE REF A-LINE MECH UTIL. HIGH-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW
  - SEE REF A-LINE MECH UTIL. LOW-PRESSURE SW

ITEM NO	QTY	DESCRIPTION	UNIT	
18	43	201-300	28 CLAMP HOSE, 1.815 TO 3.174	4
19	PP	800-475	33 TURNER BRACKET	3
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				

ITEM NO	QTY	DESCRIPTION	UNIT	
1	1	1 SA 250-287	01 BELLOW ASSEMBLY	1
2	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
3	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
4	4	4 SA 363-788	24 PC-12 ASSEMBLY	1
5	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
6	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
7	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
8	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
9	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
10	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
11	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
12	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
13	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
14	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
15	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
16	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
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18	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
19	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
20	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
21	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
22	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
23	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
24	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
25	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
26	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
27	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
28	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
29	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
30	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
31	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
32	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
33	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
34	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
35	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
36	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
37	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
38	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
39	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
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44	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
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47	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
48	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1
49	1	1 SA 363-788	01 BIP-10, 12 & 20 MOD. WELDMENT	1
50	1	1 SA 363-788	05 18 X 8 DRIFT WELDMENT	1

SCALE: 3/16" = 1"

STANDARD LINEAR ACCELERATOR CENTER

50 GEV A-LINE INSTRUMENT STAND IS-12 INSTALLATION

ID-863-797-05 2 E

# CLIC collimation wakefield

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- 4 quadrupoles 2 meter long, aperture 8cm available at SLAC.
- Installation: need removal of existing instrumentation, new stands, power supplies (upgrade), pulling cables, cooling water channels, radiation physics calculations, designers, etc.
- \$1.0M+ estimate for 4-quad installation and infrastructures



# Schedule

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- Oct 25<sup>th</sup> – Nov 1<sup>st</sup> install 4 BSY kicker magnets
- First ESTB run in November and December (need commissioning time)
- LCLS off from Christmas to end of January
- ESTB running resumes February 2012
- SLAC downtimes are in Aug/Sept and over Christmas for the next years

# Summary

- We are excited to re-start ESA/ESTB test beams!
  - Unique High energy test beam line in the US, with plenty of infrastructures and SLAC support for Users
- Beam parameters determined by LCLS. Availability 5Hz +.
- Installation of the full 4 kicker system by end October
  - First ESTB run in November / December 2011
- CLIC collimation wakefield:
  - Wakefield “box” tested/ready for use in ESTB
  - In principle bunch lengths 100 um are possible in ESTB
  - Possible optics upgrade need funding (!) for  $\sigma_z \leq 44\text{um}$ .
  - ESTB allows sensitivity studies scanning bunch length.
  - Need better bunch length instrumentation + BPMs (UK colleagues!)

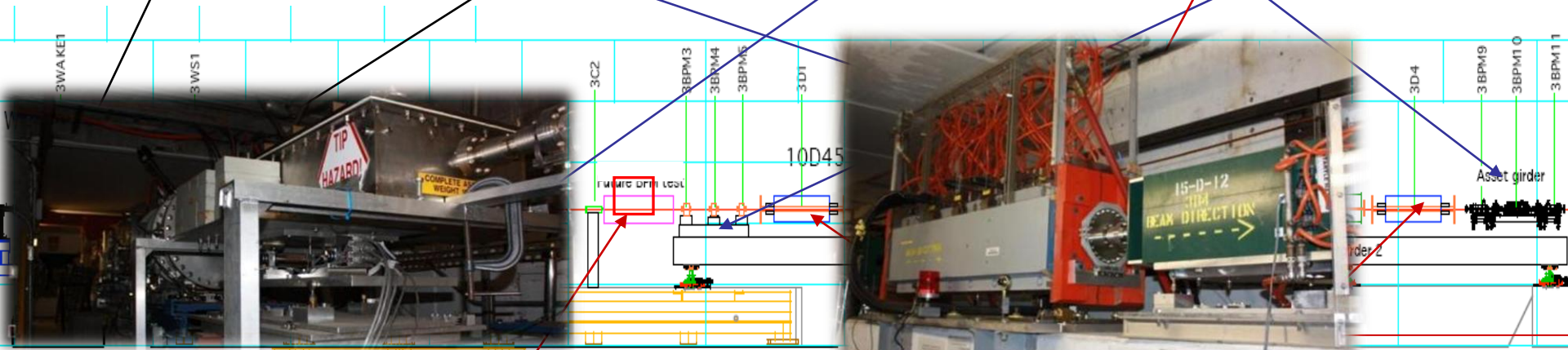
# ESA Past Experiments

Wakefield box

Wire Scanners

“IP BPMs” T-488

rf BPMs



T-487: long. bunch profile

Ceramic gap for EMI studies

Energy Spectrometer: Dipoles + Wiggler

BPM energy spectrometer (T-474/491)

IP BPMs—background studies (T-488)

Synch Stripe energy spectrometer (T-475)

LCLS beam to FCA (T499)

Collimator de

Bunch length

Smith-Purcell

**We need rf BPMs possibly LCLS-II type**