SLAC Electron Beam Test Facilities 5 MeV to 20 GeV

FACET • ESTB • NLCTA • ASTA

Carsten Hast, SLAC

SiD Workshop, Oct. 15th, SLAC 2013

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY


20-23 GeV
FACET
5 MeV
ASTA
2-15 GeV
& single e-
ESTB
NLCTA
60-220 MeV

SLAC Beam Test Facilities Overview

Facility	Purpose	Parameters
FACET	Accelerator R&D, Material Science, THz	Very focused and short bunches at 20GeV e+/- 20x20x20 um^3
ESTB	Detector R&D, LC MDI, Radiation Tests	2-16GeV primary LCLS beam or single e-
NLCTA	Accelerator R&D, Medical, Radiation Tests	60 to 220 MeV, small emittance, very versatile infrastructure
ASTA	Gun and RF Testing, RF processing	<50MeV, X- and S-Band RF power

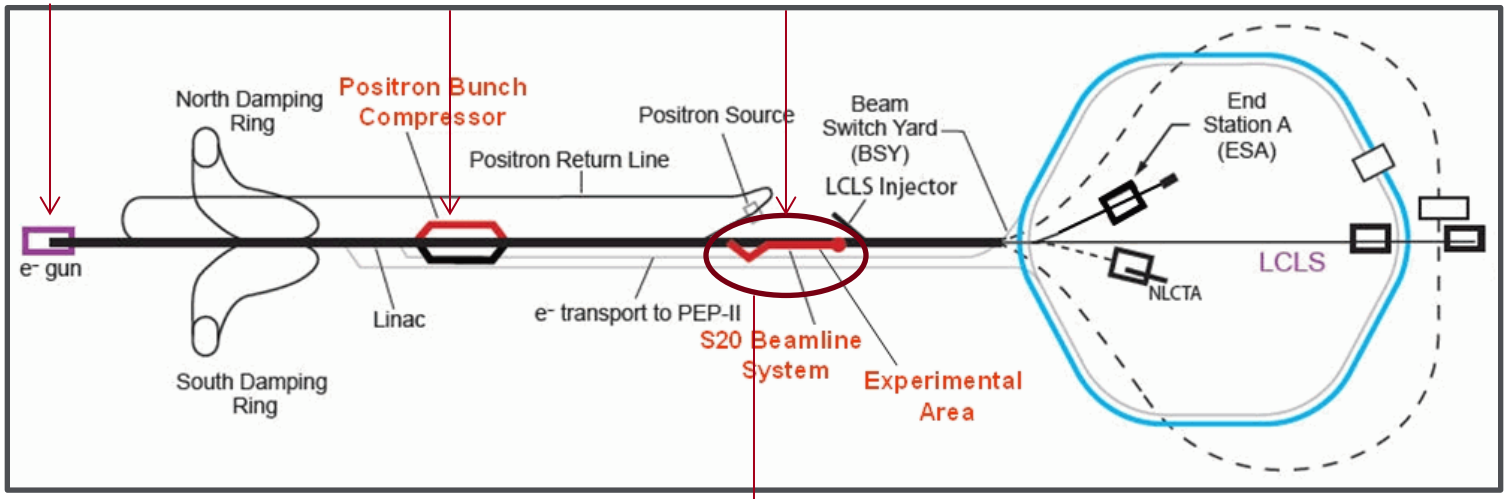
- All supported by SLAC's Test Facilities Department
- https://portal.slac.stanford.edu/sites/ard_public/tfd/Pages/Default.aspx
- http://facet.slac.stanford.edu and http://estb.slac.stanford.edu
- e-mail: hast@slac.stanford.edu
- Google: SLAC FACET or SLAC ESTB

FACET Facility for Advanced Accelerator Experimental Tests

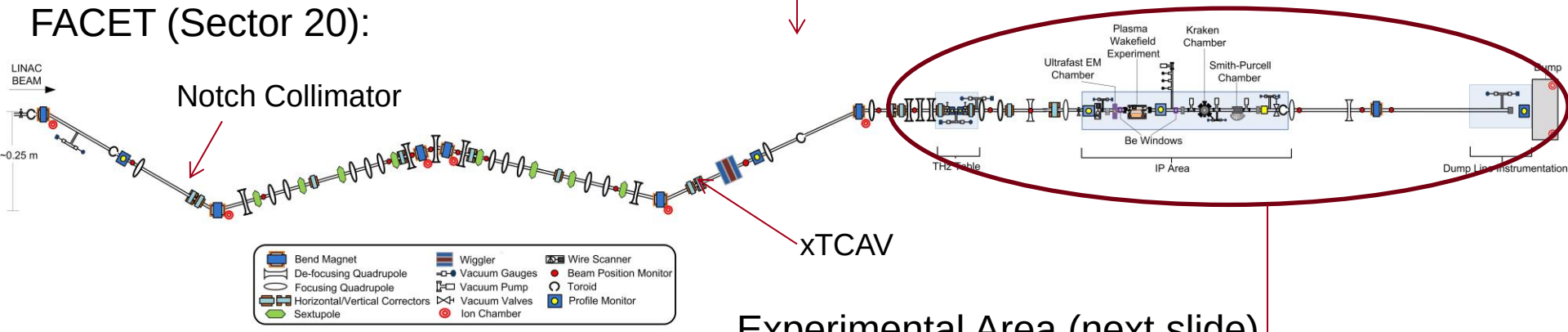
SLAC

- DoE HEP National User Facility

Linac: Sector 0 Sector 10 Sector 20



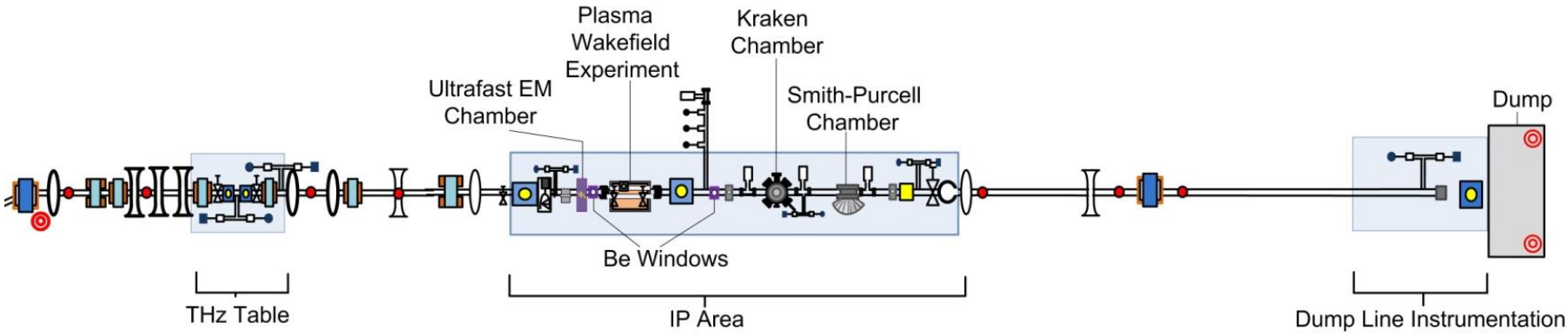
FACET (Sector 20):

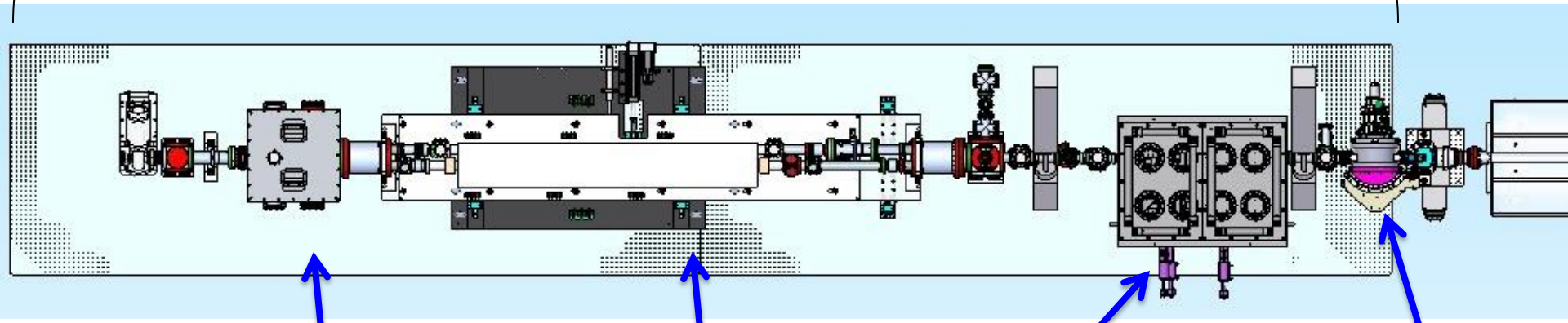


Experimental Area (next slide)

FACET's Experimental Area

SLAC





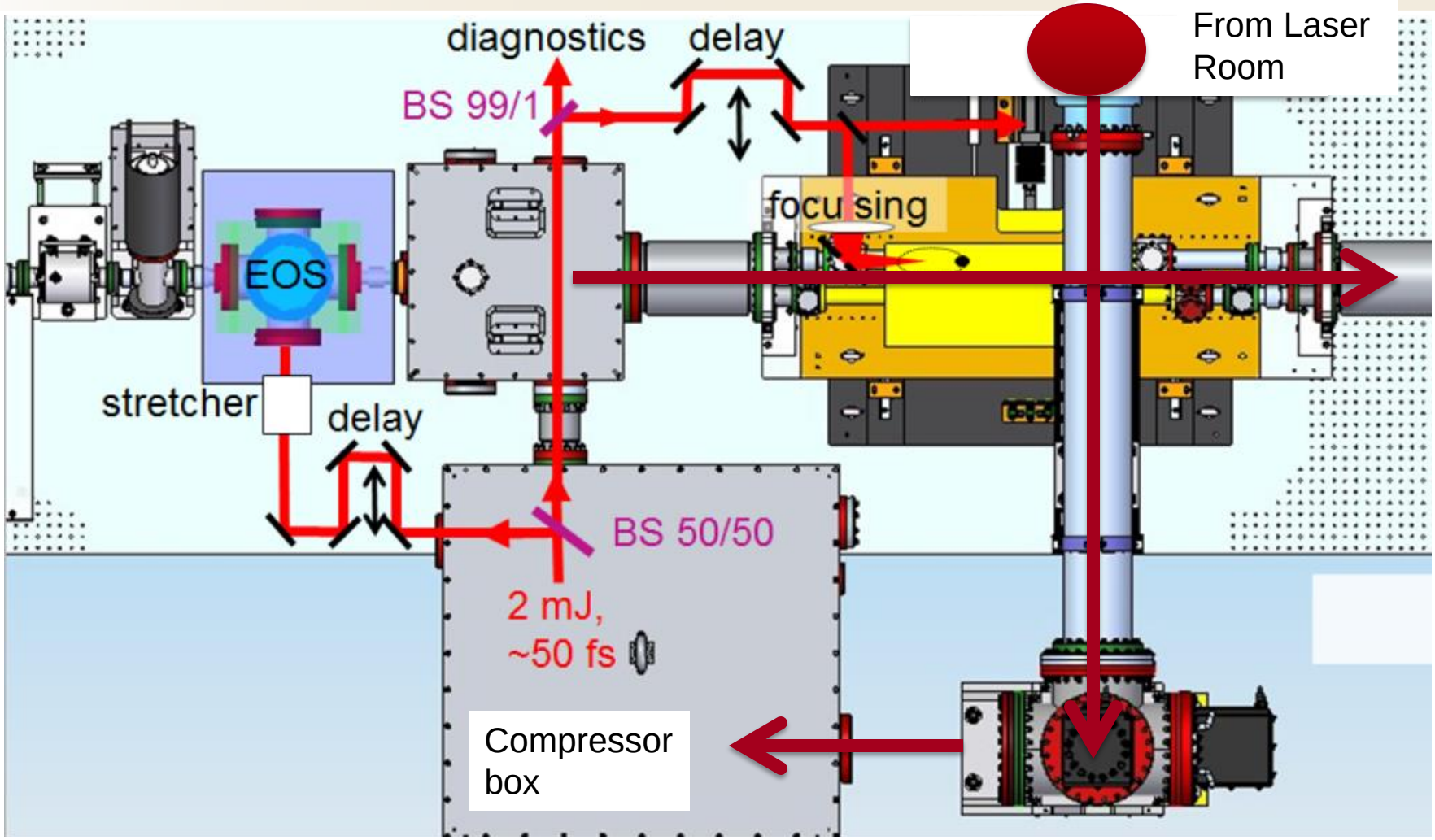
Laser Insertion chamber

Plasma Experiment

Sample chamber

Profile measurement experiment

FACET's New 10TW Laser System



Very Productive User Run at FACET
Every Program Expecting Publishable Results

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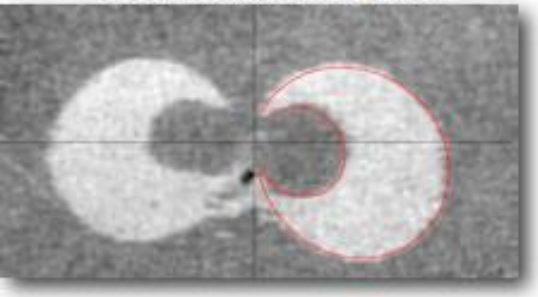
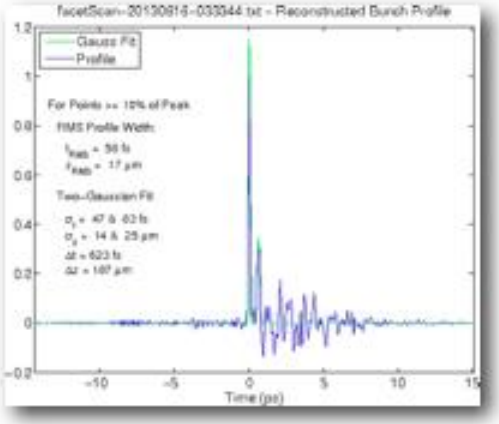
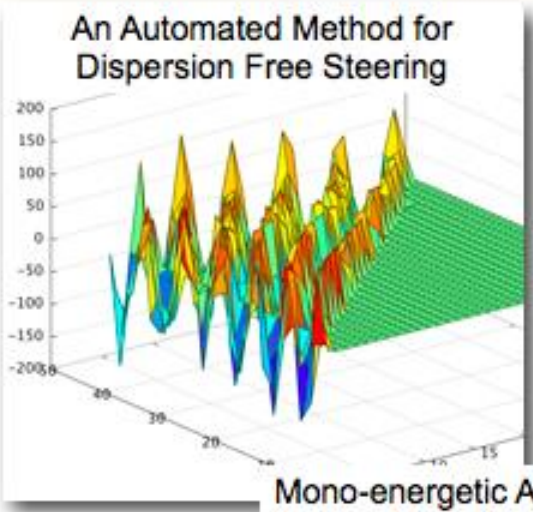
Switching Mechanisms in Ultrafast Electromagnetic Pulses



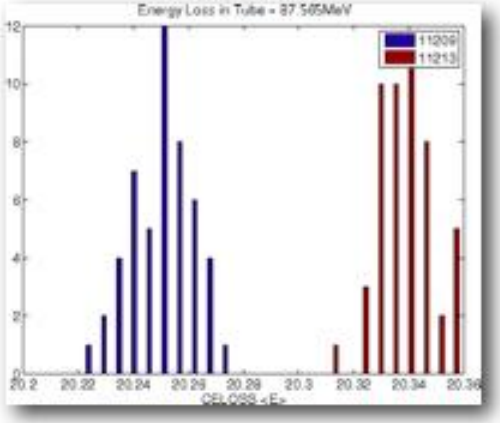
THz Reconstruction of Two-Bunch Profile

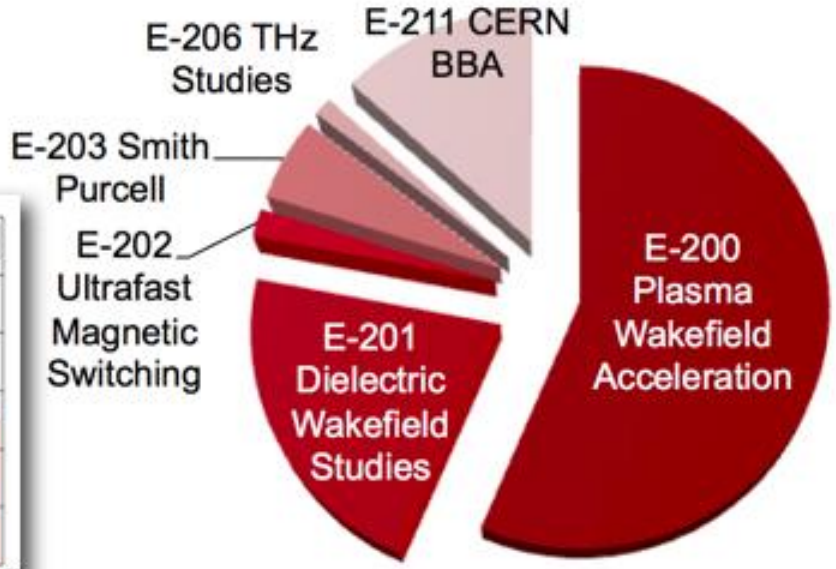


An Automated Method for Dispersion Free Steering

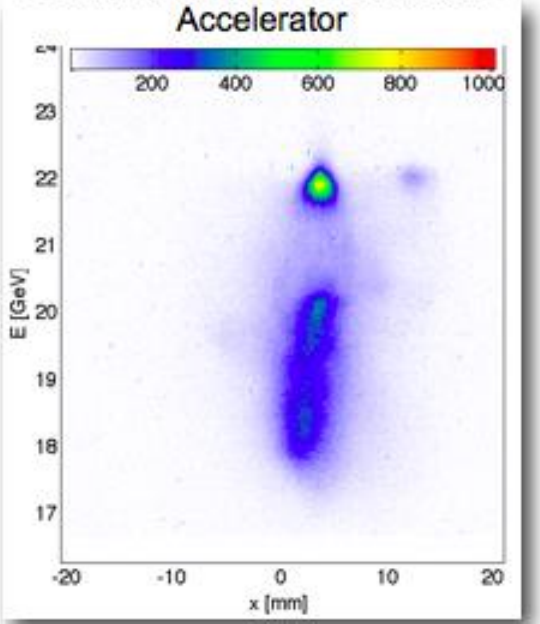


Demonstration of Gigavolt-per-meter Accelerating Gradients in Dielectric Wakefield Accelerating Structures

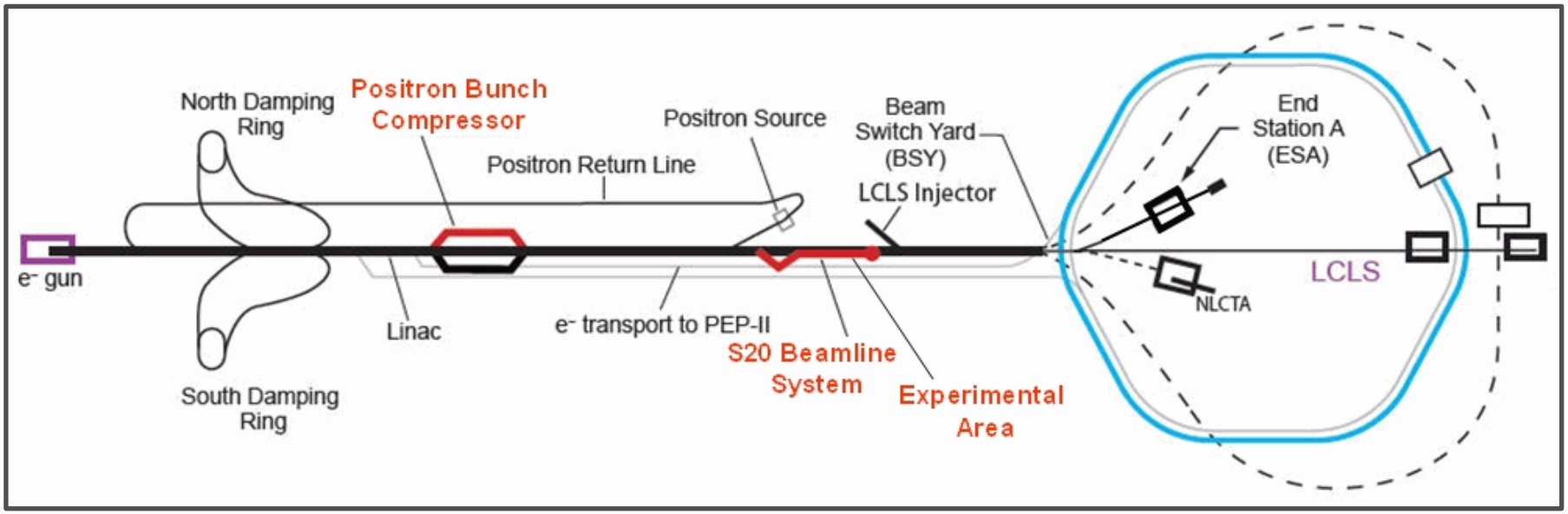




Mono-energetic Acceleration in a Beam-driven Plasma Wakefield Accelerator



ESTB End Station (A) Test Beam

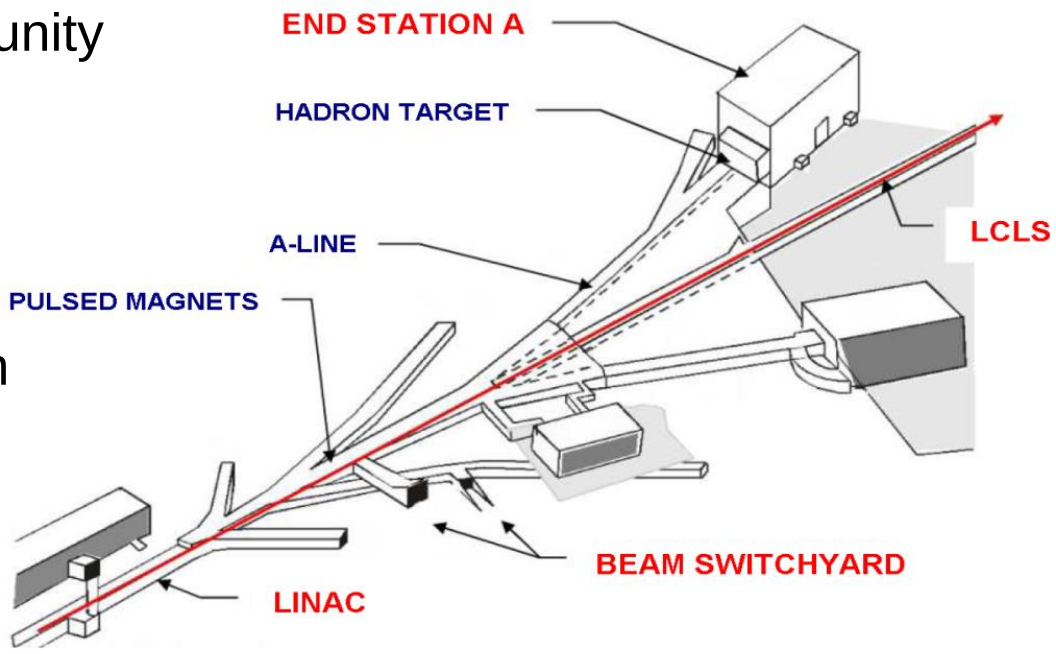


ESTB Mission and Layout

ESTB is a unique HEP resource

- World's only high-energy primary electron beam for large scale Linear Collider MDI and beam instrumentation studies
  - Exceptionally clean and well-defined primary and secondary electron beams for detector development
  - Serves a broad User community

Pulsed magnets in beam switch yard to send LCLS beam to ESA



LCLS and ESTB Beams

SLAC

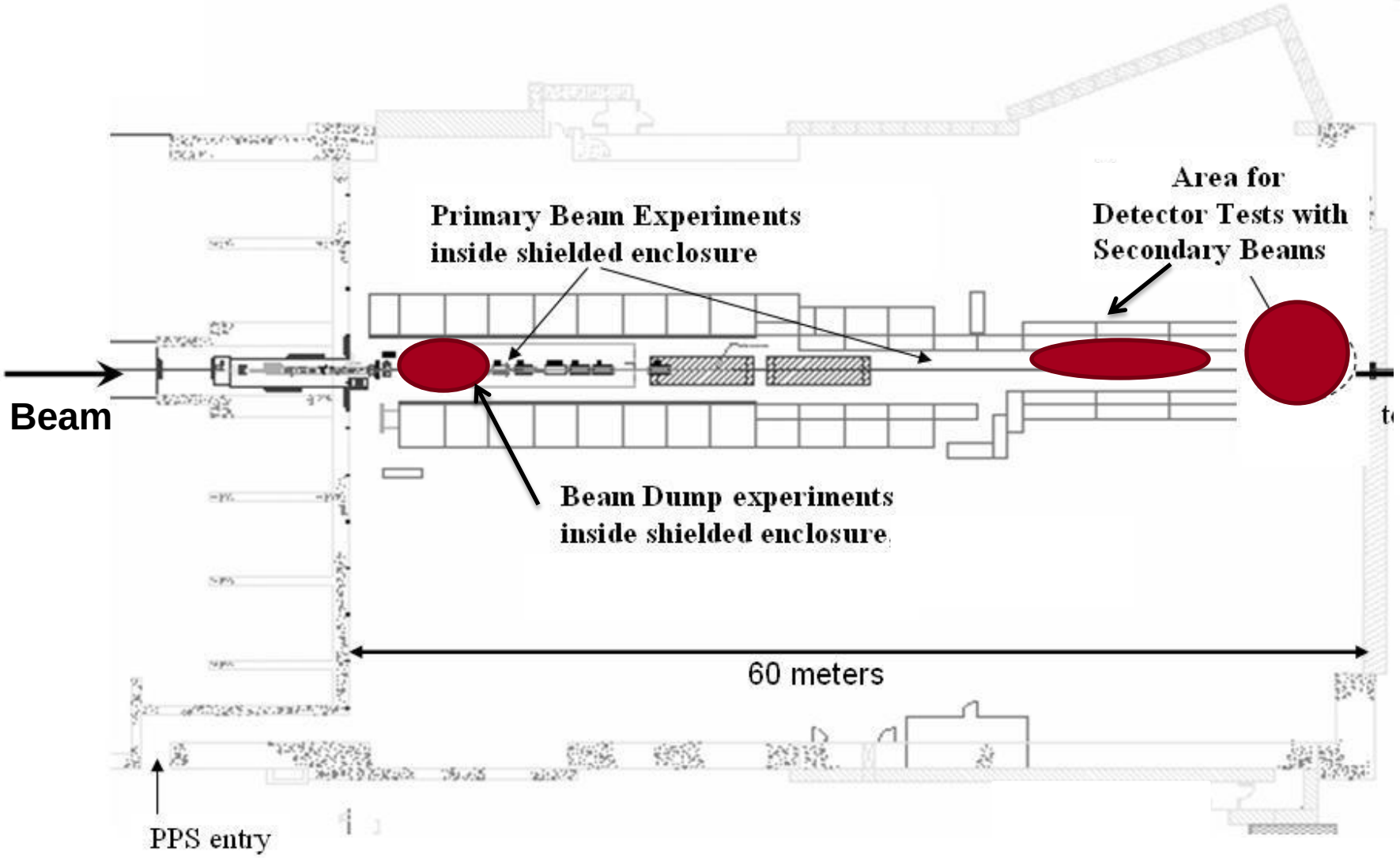
LCLS beam

- Energy: 2.2 –16.0 GeV
- Repetition rate: 120Hz
- Beam charge: 20 to 250 pC (150pC typically)
- Beam availability > 95%!

ESTB beam

- Kick the LCLS beam into ESA @ 5 Hz
  - Potential for higher rates when LCLS doesn't need full rate
- Primary beam 2.2 -16.0 GeV
  - Determined by LCLS
  - <1 x 10^9 e^-/pulse (150 pC)
- Clean secondary electrons
  - 2 GeV to 15 GeV, 1 e^-/pulse to 10^9 e^-/pulse
  - Momentum resolution way better than 1%

Building 61: End Station A



ESA Infrastructure

- Beam height: 6’10”=208cm
  - 20” above optical table
  - 48” at radiation area
  - Very large open area
- HV for PMTs etc.
- NIM electronics
- Remote scopes
- ADCs
- Signal patch cables
- Beam triggers
- Ethernet
- Cooling water
- House air, technical gases
- Multiple remote x/y stages
- Cameras
- Crane and forklift

- Homegrown silicon telescope for tracking

Test of a RICH-Prototype Based on CsI-GEMs for an Electron-Ion Collider (T-507)

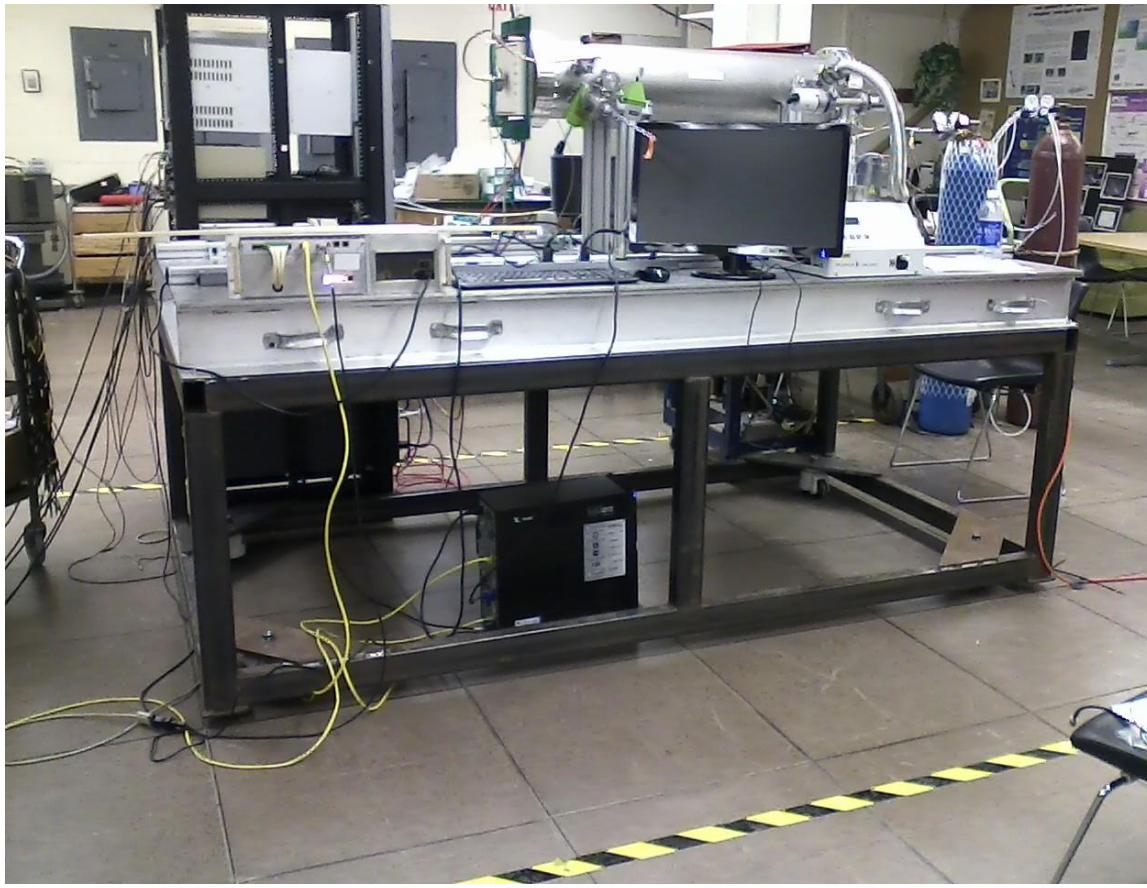
Principal Investigator: T. Hemmick
Institution: Stony Brook University
(6 Users)

Beam parameters
- Single electrons @ 5 Hz
- Energy: 9 GeV
- Various GEM HV settings

Scheduled for May 13th
After the coil incident on 5/15 rescheduled for 5/30 but SLAC had a side wide power outage …

Finally had 4 consecutive 24h days from 5/31 to 6/03

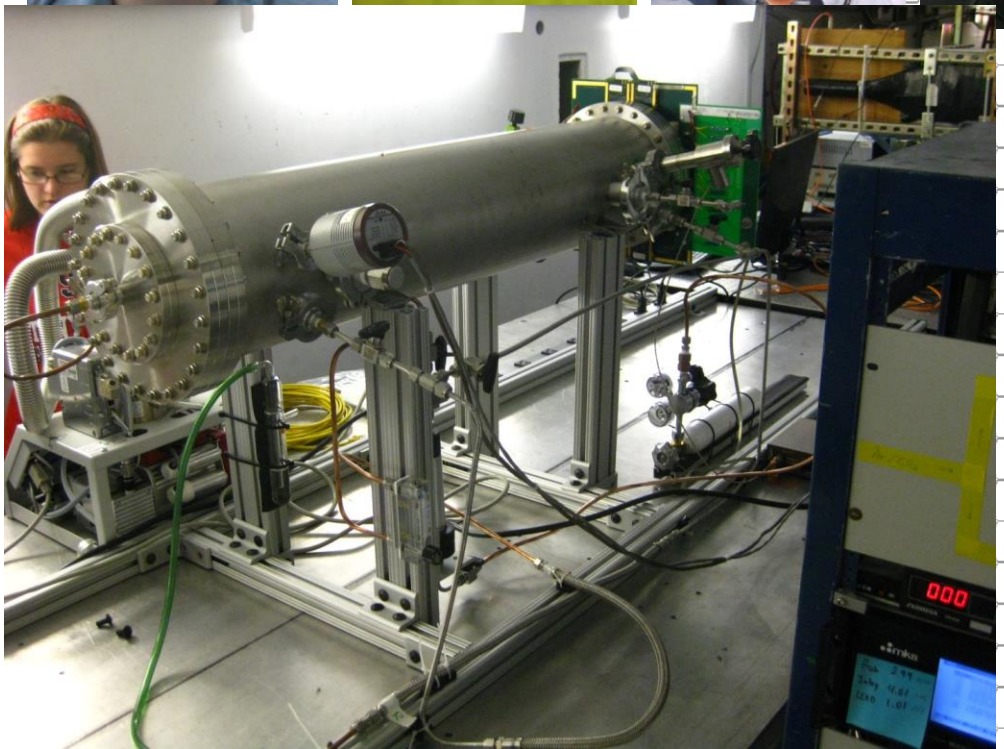
- Recorded 1.4 million triggers
- Ran for 84% of wall clock time
- 13 hours total downtime in 4 days
  - Includes accesses and time between data runs

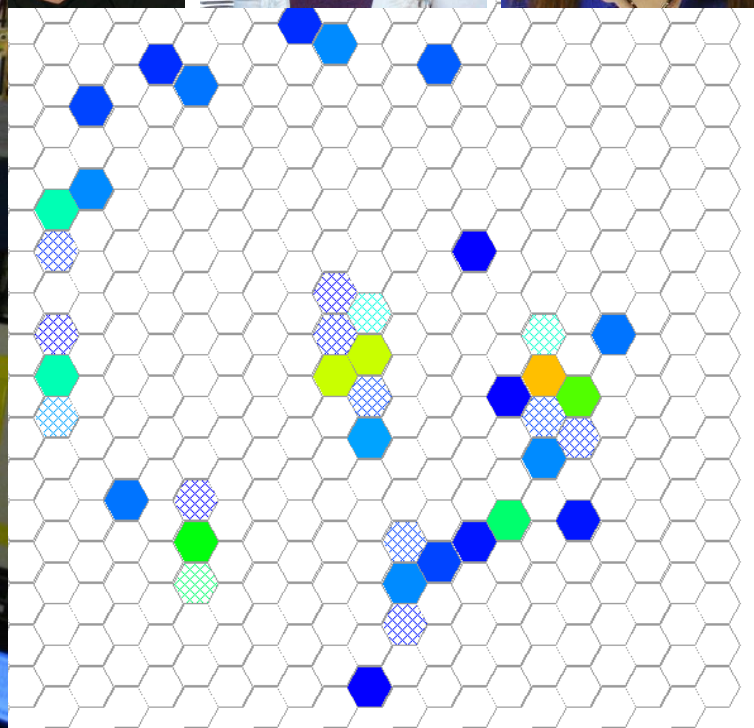


Test of a RICH-Prototype Based on CsI-GEMs for an Electron-Ion Collider (T-507)

SLAC

Tom Hemmick	Abhay Deshpande	Klaus Dehmelt	Nils Feege	Stephanie Zajac	Marie Blatnik





HERA-B e-Cal modules beam test for $G_{Ep}(5)$ at J- Lab (T-508)

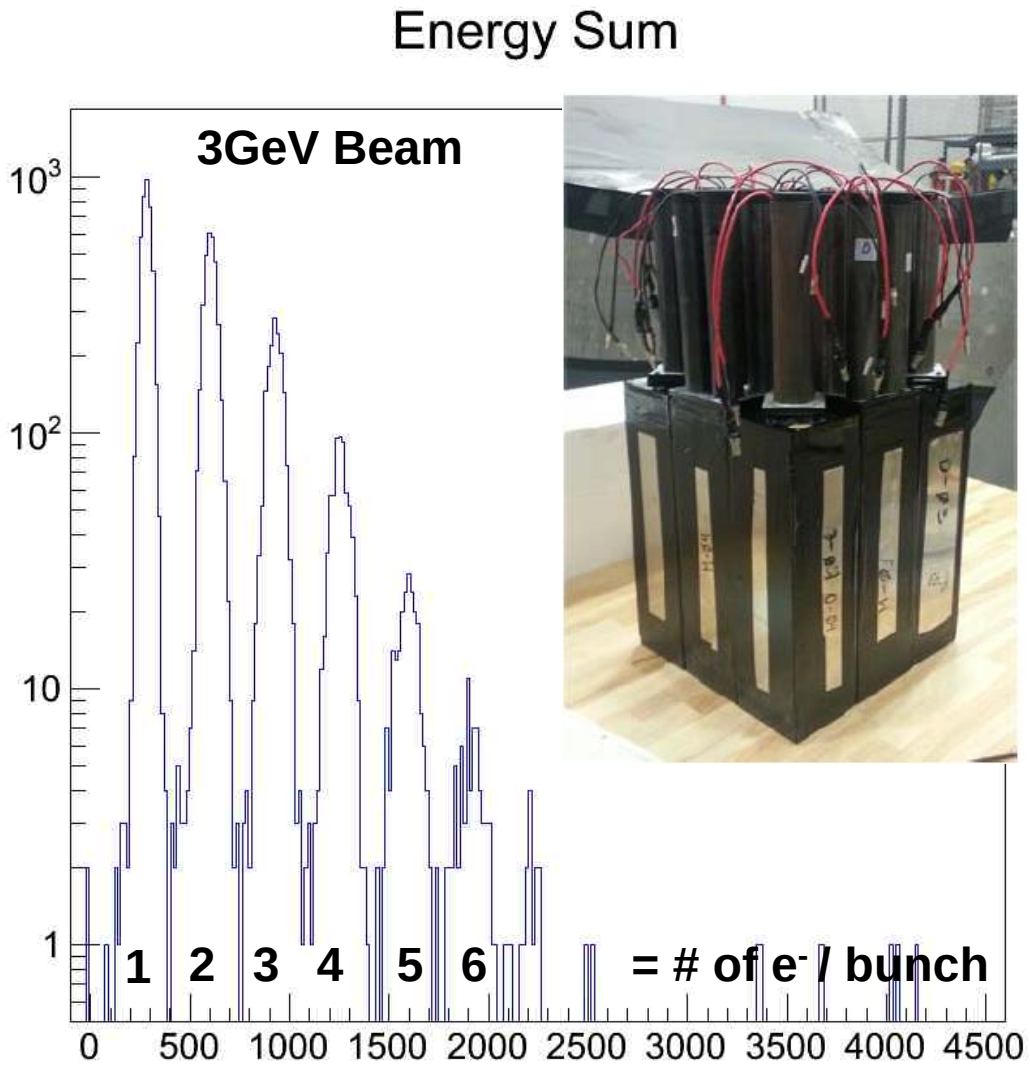
Principal Investigator: Ed Brash
Institution: Christopher Newport University / J-Lab (5 Users)

Physics goal: Measure the ratio of the proton elastic form factors G_{Ep}/G_{Mp}

Calibration of 9 “Shashlik” style lead/scintillating fiber calorimeter modules from Hera-B

Beam parameters
- Single electrons @ 5 Hz
- Energy: 3, 9, 12 GeV
- Various incident angles

Run Times: 6/6 until 6/11



Electromagnetic Shower Damage to Silicon Diode Sensors (T-506)

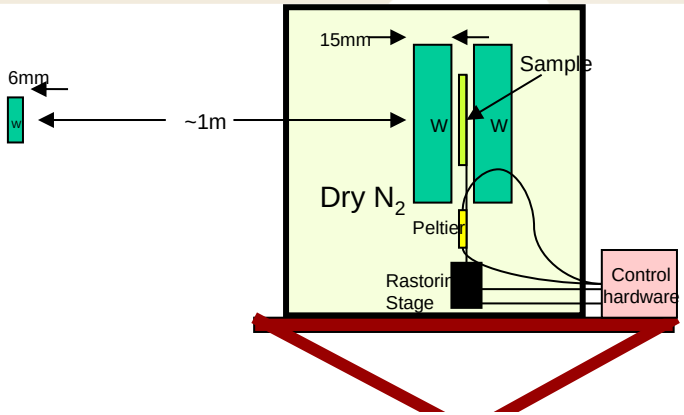
Principal Investigator: Bruce Schumm
Institution: UCSC (9 Users)

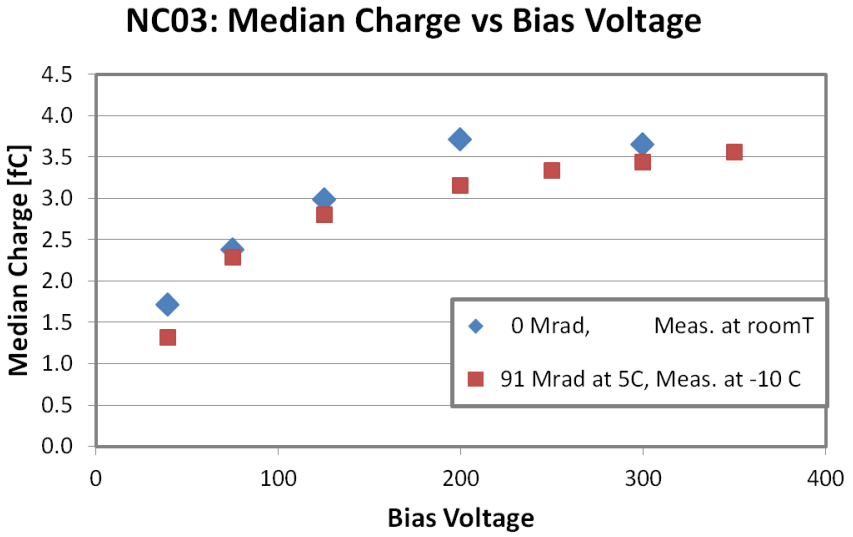
Physics goal: Evaluate the radiation damage in silicon diode sensors in a most realistic experimental setting with e-beams. Needed for ILC beam calorimeter, which is at very small angles and sees about 100Mrad/year.

Irradiate silicon sensors to various levels of radiation (1h – 12h = 0.1-100Mrad)

Beam parameters
- Primary Beam @ 5 Hz
- Energy: < 10 GeV

Run Times: 6/20 until 7/15



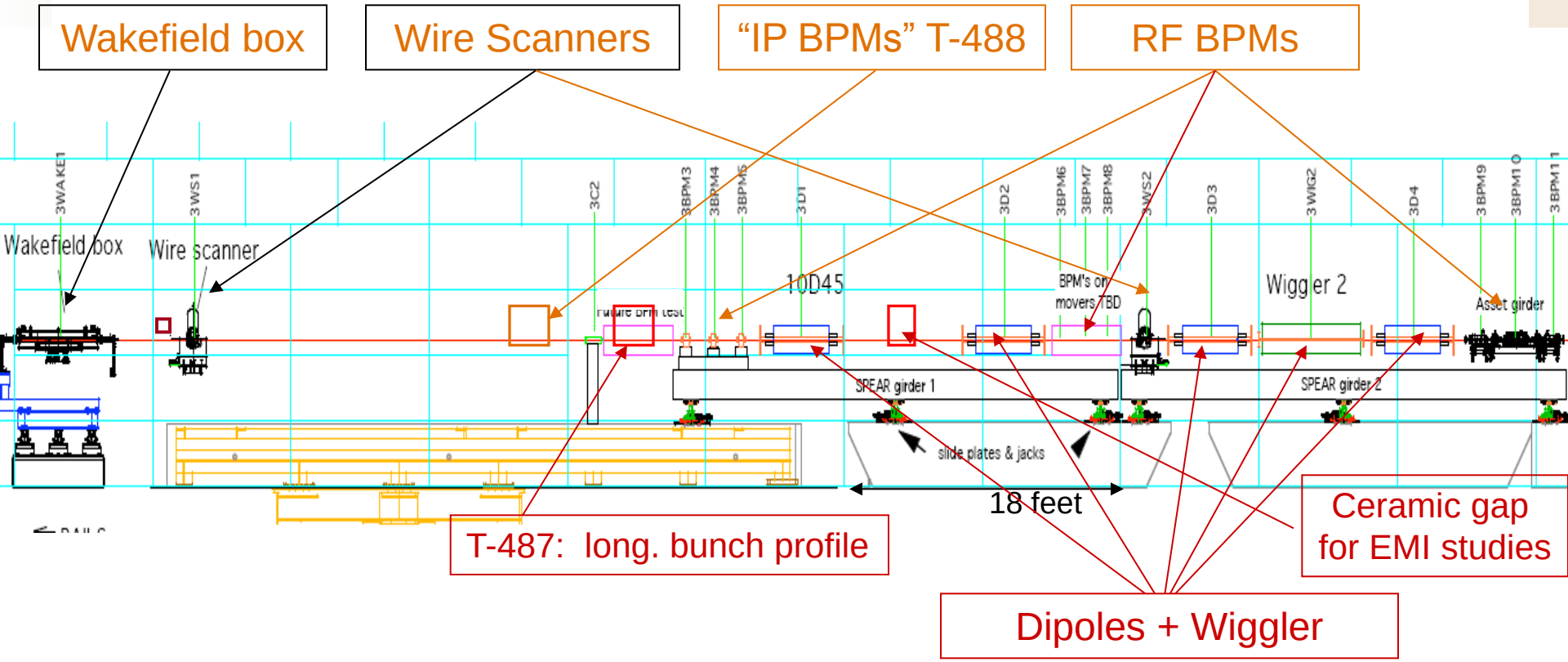


- N-Type magnetic Czochralski sensor shows low degradation of the charge collection efficiency
- But leakage current goes up quite a bit (not shown)

ESA has a lot of space…

T-510 Anita: Geosynchrotron radio emission from extensive air showers (in Jan/Feb)

ESA Primary Beam Layout

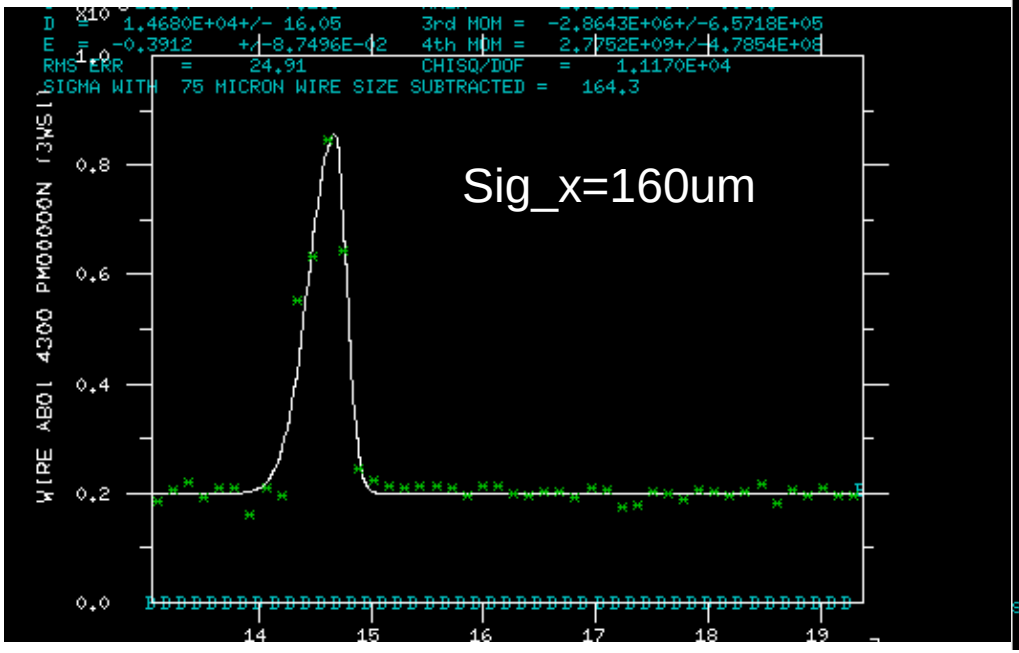


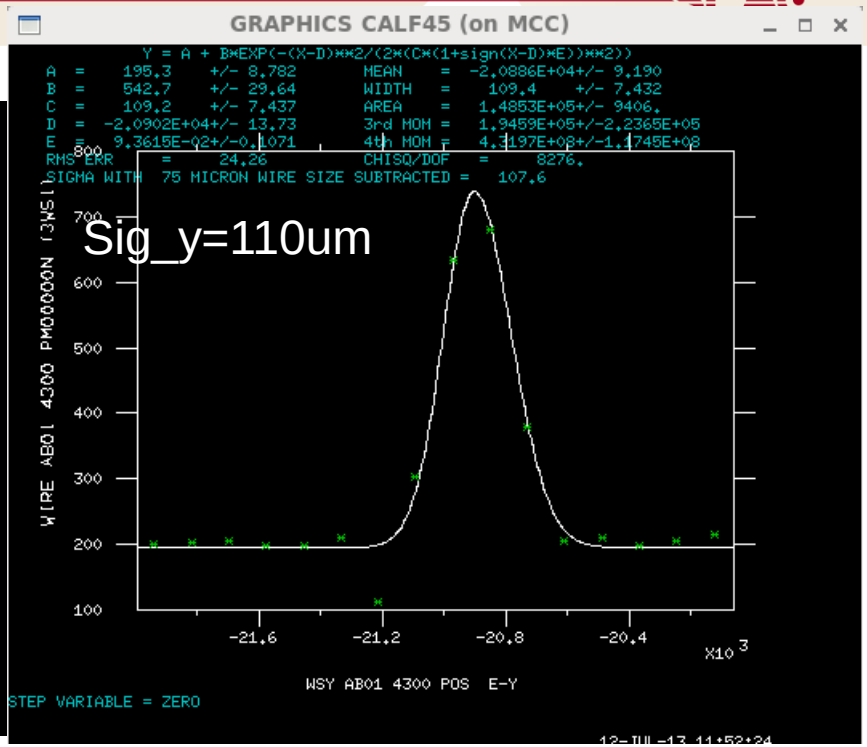
BPM energy spectrometer (T-474/491)
Synch Stripe energy spectrometer (T-475)
Collimator design, wakefields (T-480)
Bunch length diagnostics (T-487)
Smith-Purcell Radiation

IP BPMs—background studies (T-488)
LCLS beam to ESA (T490)
Linac BPM prototypes
EMI (electro-magnetic interference)

Until 2008, End of PEP II

Primary Beam





- With new optics expect 30 to 40 micron spots in ESA
- T-513 Crystal channeling (next month)
- Proposal from Valencia/CERN/Darsbury for revisiting the collimator-wakefield measurements

ESTB Proposals and Run Time

Had a successful 1st User run from May to July 2013

- ✓ T-505: Tests of 3D silicon pixel sensors for ATLAS, P. Grenier, SLAC
- ✓ T-506: EM Shower Damage to Si Diode Sensors, Bruce Schumm, UCSC
- ✓ T-507:Test of a RICH-Prototype Based on CsI-GEMs for an Electron-Ion Collider, T. Hemmick, Stony Brook University
- ✓ T-508: HERA-B ECal modules beam test in ESTB at SLAC for $G_{Ep}(5)$ at Jefferson Lab, E. J. Brash, Christopher Newport University
- ✓ T-511: Test of a Silicon-Tungsten Electromagnetic Calorimeter for the ILC SiD, R. Fry, Univ. of Oregon

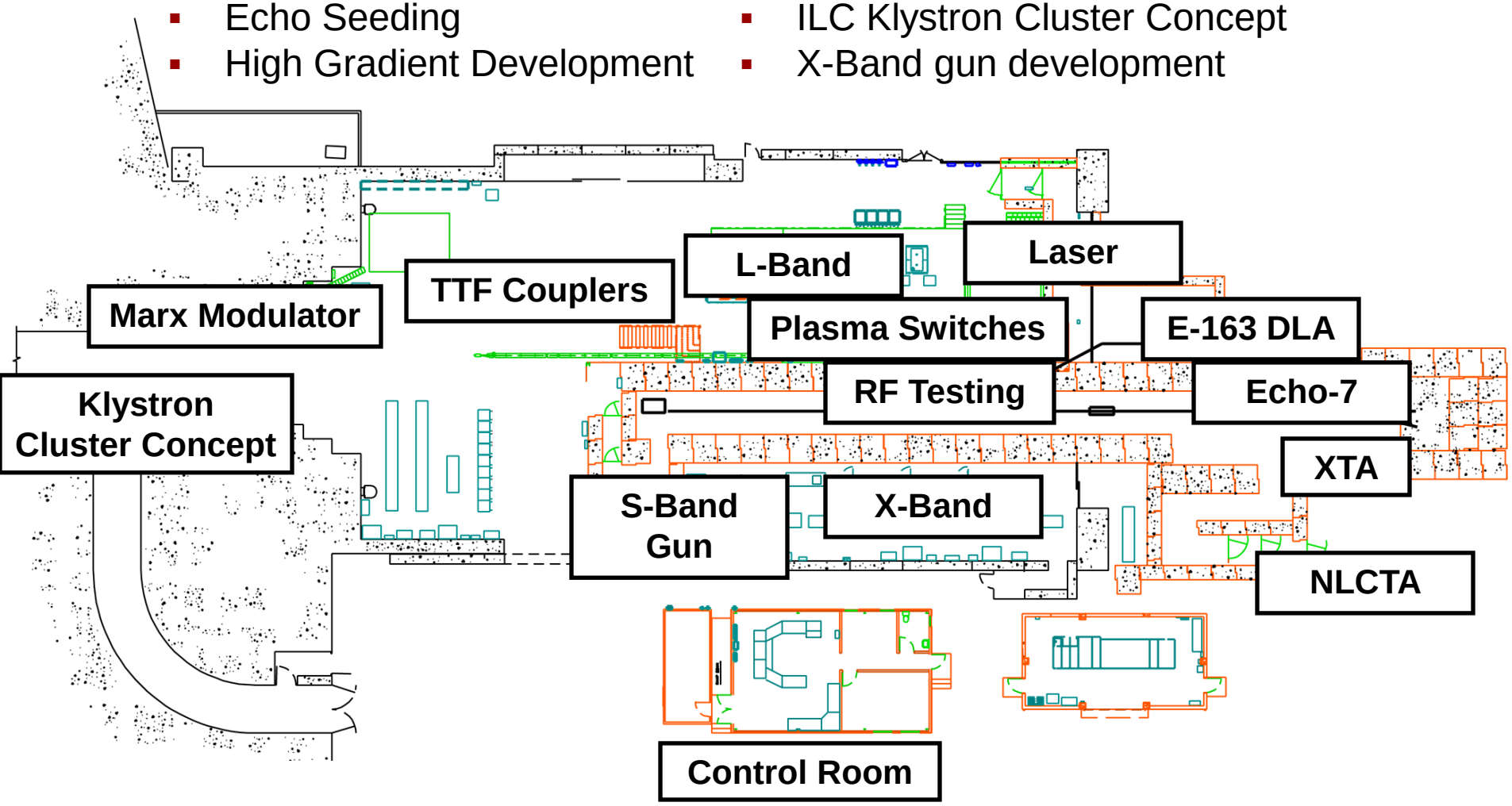
Starting 2nd User run now until early July 2014

- T-505: Tests of 3D silicon pixel sensors for ATLAS, P. Grenier, SLAC
- T-512: Calibration of the g-2 calorimeter, D. Hertzog, Univ. of Washington
- T-509: Develop a Neutron Beam Line for Calibration of Dark Matter Detectors, J. Va'Vra, SLAC
- T-513: Crystal Channeling, U. Wienands, SLAC
- T-514: Heavy Photon Search Silicon Irradiation
- T-510: Geosynchrotron radio emission from extensive air showers to detect ultra-high energetic neutrinos at Antarctica, K. Belov, UCLA
- T-511: Test of a Silicon-Tungsten Electromagnetic Calorimeter for the ILC SiD, R. Fry, Univ. of Oregon

- Will receive the ATLAS Silicon Telescope in March 2014 for 1/2 year
  - Several Atlas R&D proposals in draft form plus T-505 (1 week of commissioning and 3 weeks of experiments)
- Radiation Physics experiments by: CERN/SLAC and KEK/SLAC (in preparation)
- Performance confirmation of Belle II imaging Time of Propagation prototype counter, G. Varner, Univ. of Hawaii (in discussion)

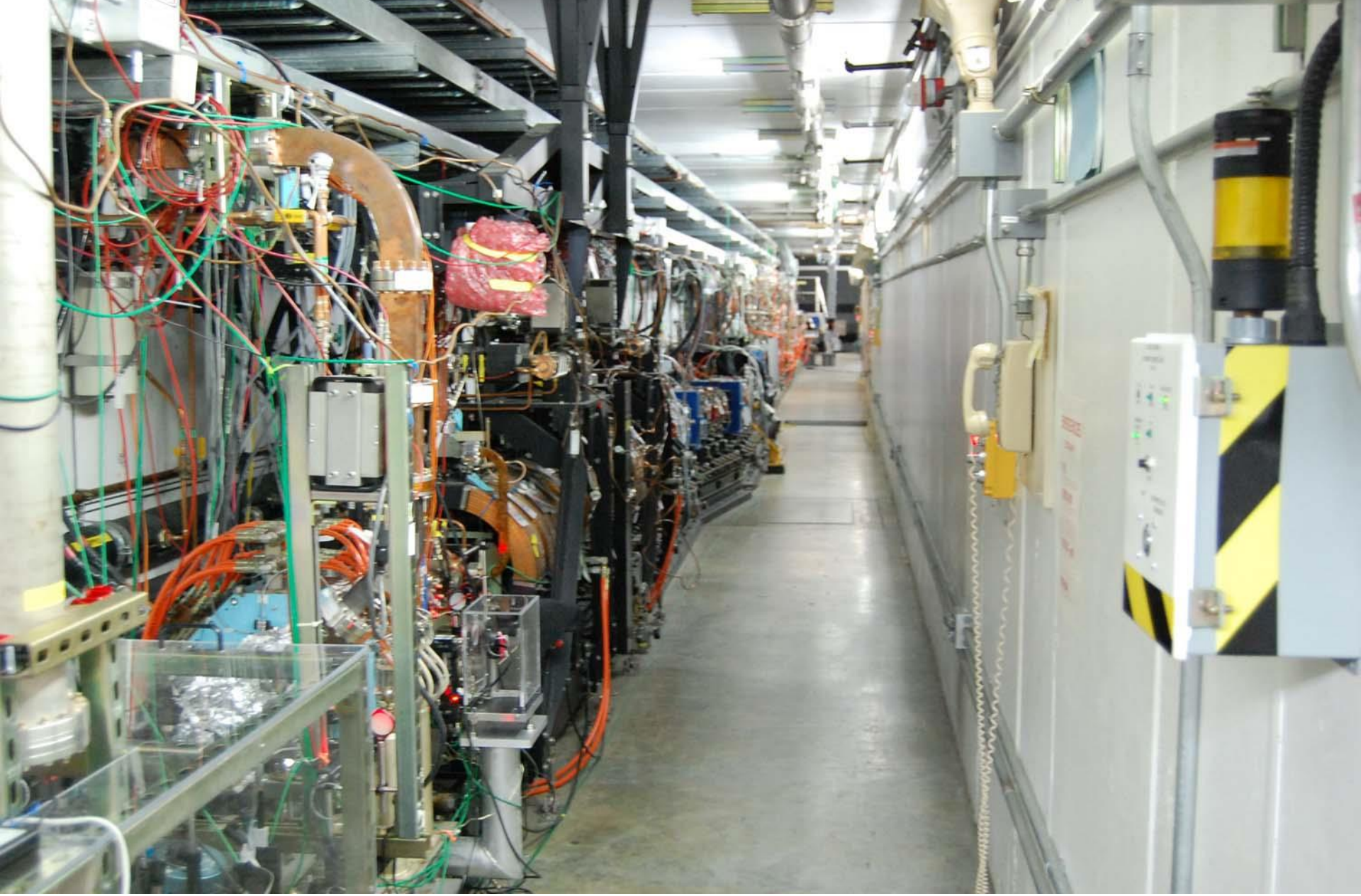
End Station B and NLCTA

- Direct Laser Acceleration
- Echo Seeding
- High Gradient Development
- ILC Modulator Development
- ILC Klystron Cluster Concept
- X-Band gun development



NLCTA

- 45m long bunker for e-beams and RF processing
- 4 X-band RF stations capable of > 100 MW each
- Beam energy 60 - 120 MeV (going to 220 MeV in 2014)
- Bunch charge 10 pC - 1 nC
- Bunch length 0.5 psec
- xy-emittance 1 to few microns
- Momentum resolution $dp/p \leq 10^{-4}$
- X-Band transverse cavities for bunch length measurements
- LCLS 1st generation style S-band injector
- Multiple laser systems for E-163, Echo-7, and XTA
  - GW-class Ti:Sapphire system (800nm, 2.5 mJ, 1ps)
    - BBO/BBO tripler for photocathode (266nm, 0.25 mJ)
    - 100 MW-class OPA (1200-3000 nm, 80-20 μJ)
    - 5 MW-class DFG-OPA (3000-10,000 nm, 1-3 μJ)
  - 100 GW-class Ti:Sapphire system (800nm, 4 mJ, 30fs)
  - Active and passive stabilization techniques
- Rich beam diagnostics and experimental infrastructure
- Skilled operations group with significant in-house capabilities

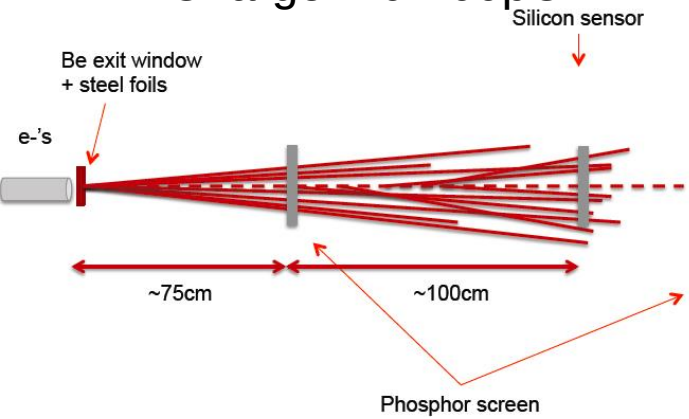


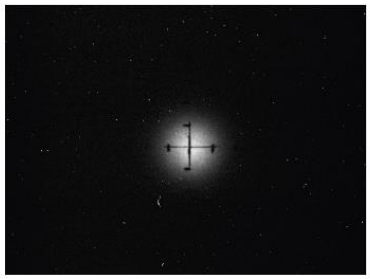
T-515: Radiation Test at NLCTA for Heavy Photon Search at JLAB

SLAC

- Radiation damage to silicon strips
- Expect up to 10^6 electrons/ strip / 40usec
- Spot size is ~0.32cm width

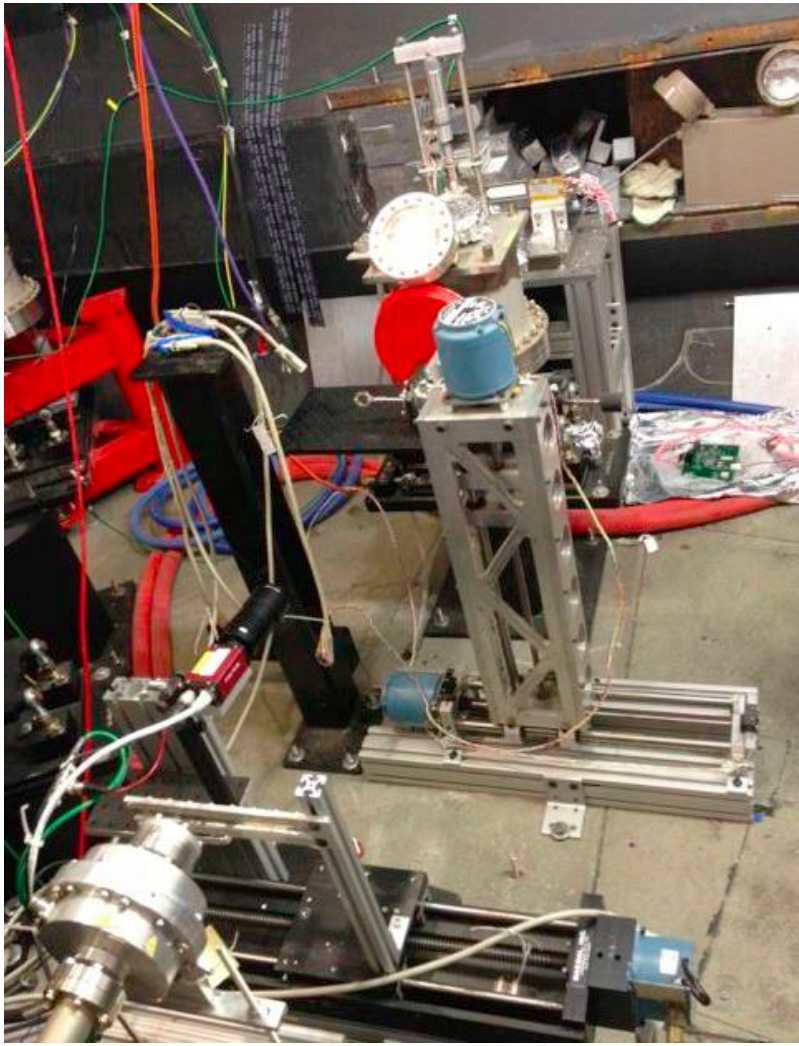
- NLCTA can do that nicely!
- E_e = 60-200MeV
- Charge=10-100pC





Spot size
about 5 mm

- …and indeed fried the detector…



Accelerator Structure Test Area (ASTA)

Small bunker (10’ by 28’)

Maximal beam energy 50 MeV

2 X-Band RF Stations

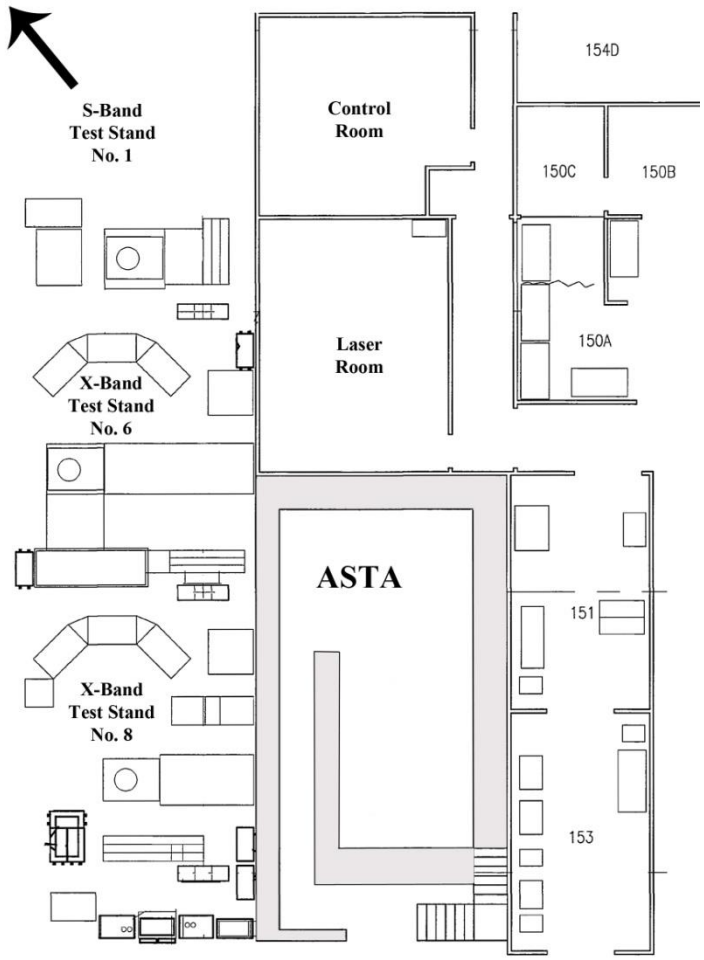
- 50 MW each
- Variable length pulse compressor that can produce up to 500 MW

1 S-Band RF station

New laser

Very flexible infrastructure allows combination of the X- and S-Band sources

Quick turn around for experimental changes



ASTA

SLAC

High Gradient RF Developments

- Geometrical Studies
  - Standing wave accelerator structures
  - Photonic band gap Structures
- Material Studies
  - Pulsed heating effects
  - Hard materials
  - Mixed materials
  - Low temperature accelerators
- Full Length Accelerator Structures

Gun Test Lab

- Cathode and gun development with focus on LCLS
  - In situ cathode QE and e-beam emittance measurements
  - Cathode performance studies with different laser conditions
  - Develop laser cleaning methodologies
  - Load lock system development and hot spare for LCLS

Start soon CLIC acceleration structure testing

Summary

- ASTA-NLCTA-ESTB-FACET span a broad spectrum
  - e^- energy between a few MeV to 20 GeV, and positrons at FACET
- Together they cover broad research themes
  - Novel and better acceleration techniques
    - RF, X-Band, WFA, DLA, GTL, Seeding
  - BDL/MDI for Linear Colliders
  - Detector R&D
- User and technical support is via Test Facilities Department
- Formal proposal review processes in place for all facilities
  - Please submit your proposals

Need Electrons? Come to SLAC !