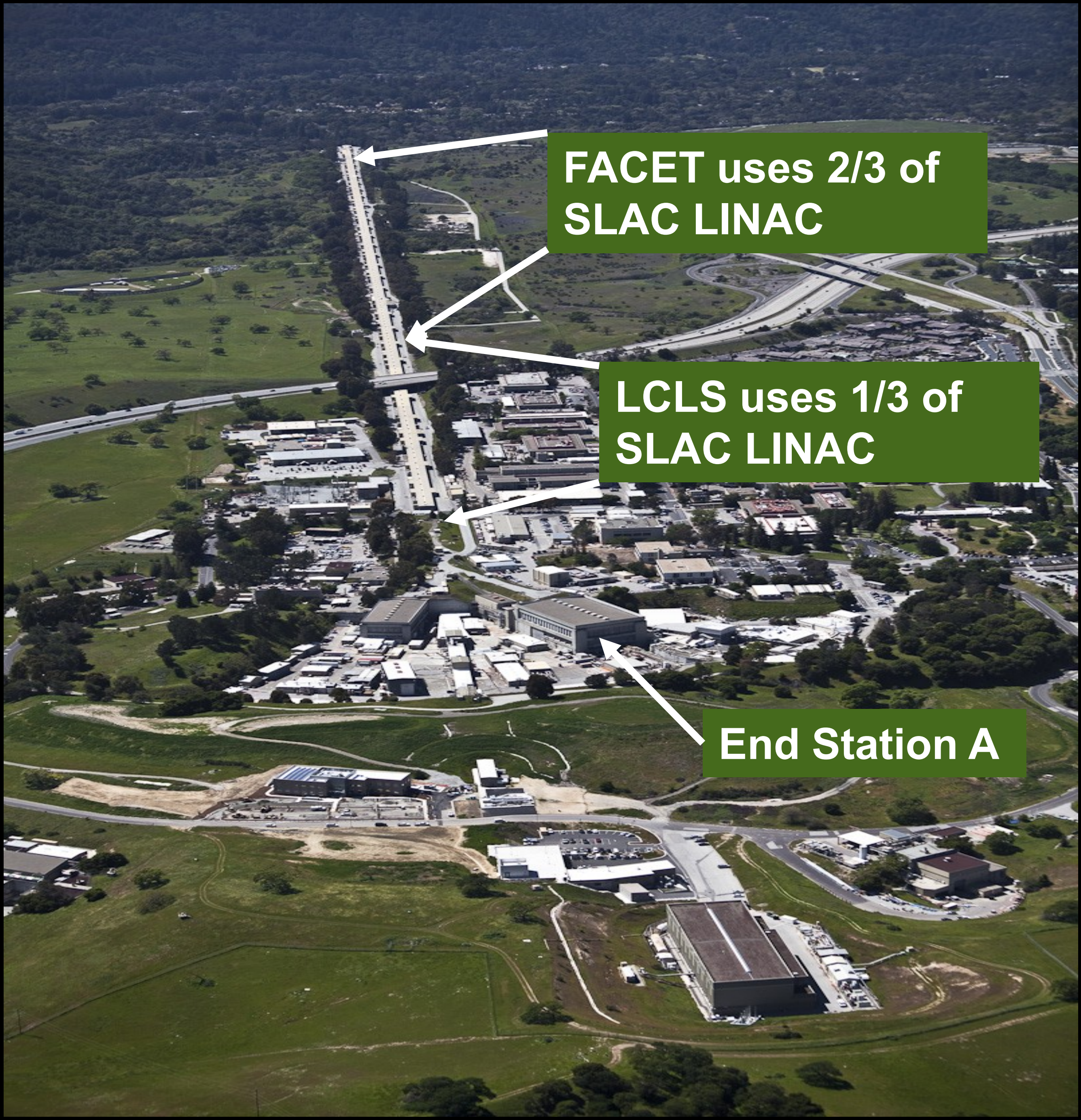
ESTB: End Station A Test Beam

FACET @ SLAC S20

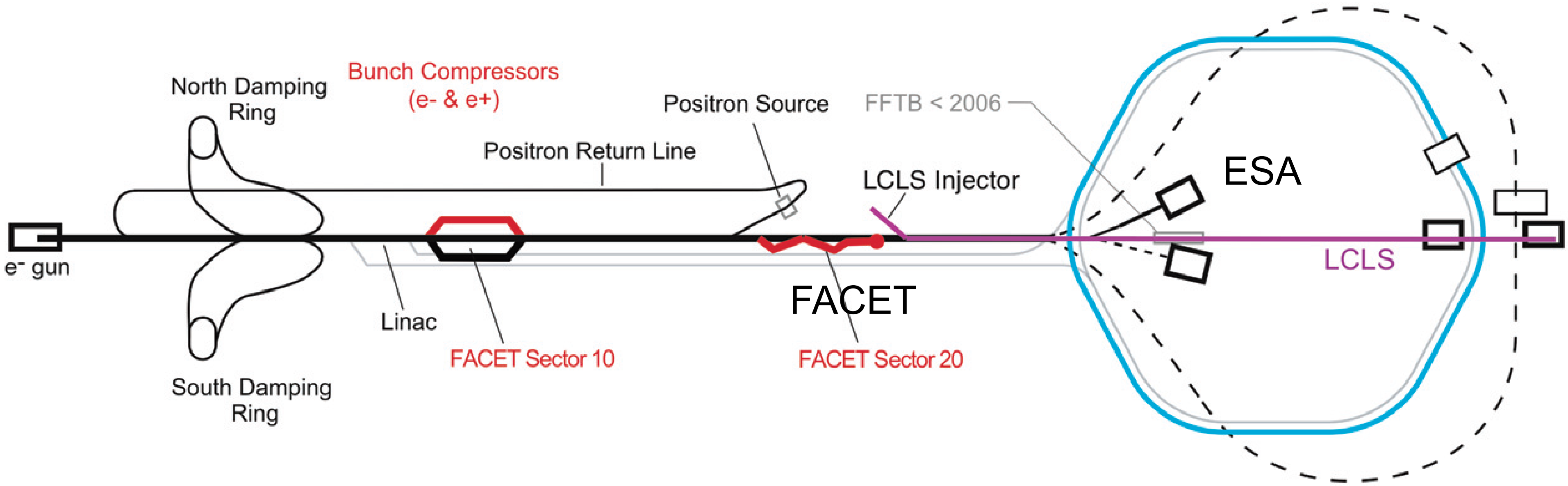
Carsten Hast
SLAC National Accelerator Laboratory

TIPP 2011, Chicago

June 11, 2011


FACET uses 2/3 of
SLAC LINAC
LCLS uses 1/3 of
SLAC LINAC
End Station A

SLAC



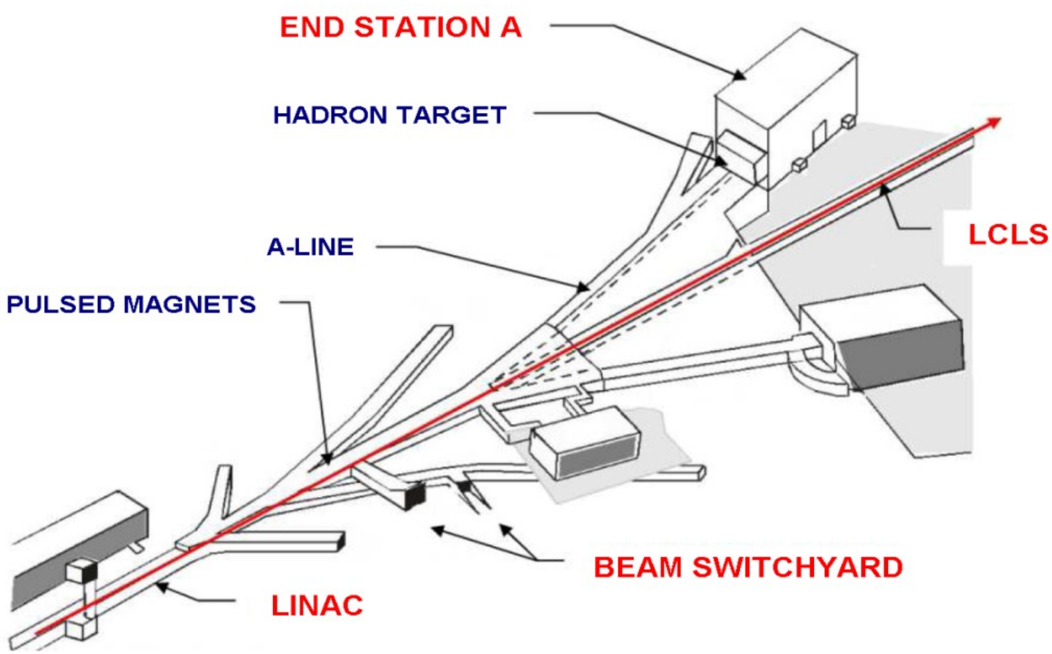
Bunch Compressors
(e- & e+)
North Damping
Ring
Positron Source
FFTB < 2006
Positron Return Line
LCLS Injector
ESA
e⁻ gun
LCLS
FACET
Linac
FACET Sector 10
FACET Sector 20
South Damping
Ring

SLAC End Station A Test Beam (ESTB)

ESTB will be 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
- Secondary hadron beam planned as an upgrade

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



LCLS/ESTB Beams

LCLS beam

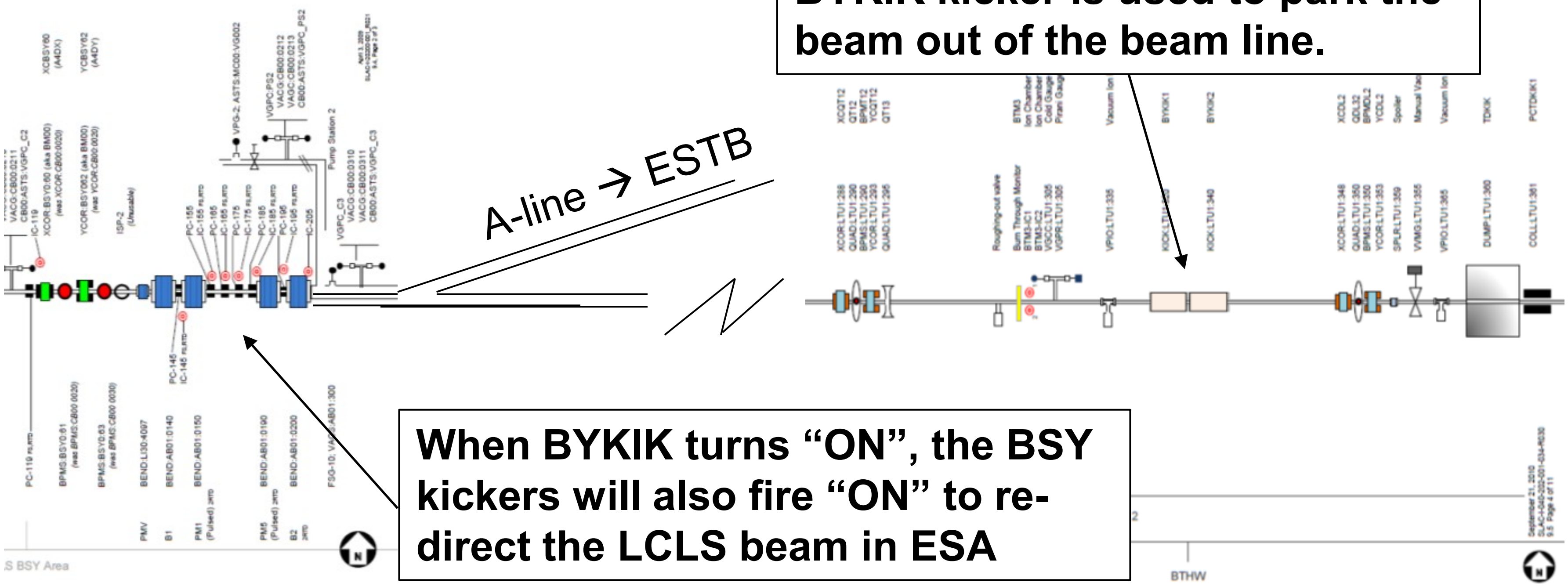
- Energy: **3.5 –13.6 GeV**
- Repetition rate: **120Hz**
- Beam current: 20 to **250 pC**
- 350 pC @ 120Hz has been provided short term
- Beam availability > 95%!

ESTB beam

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

Additional Beam Availability

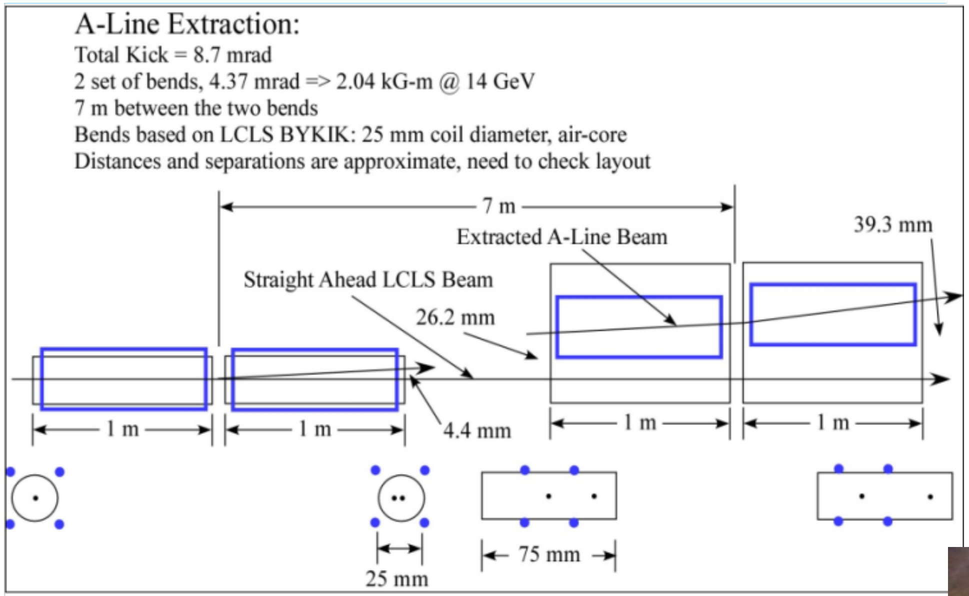
If LCLS experiments don't need full 120 Hz rate, the remaining beam is parked out

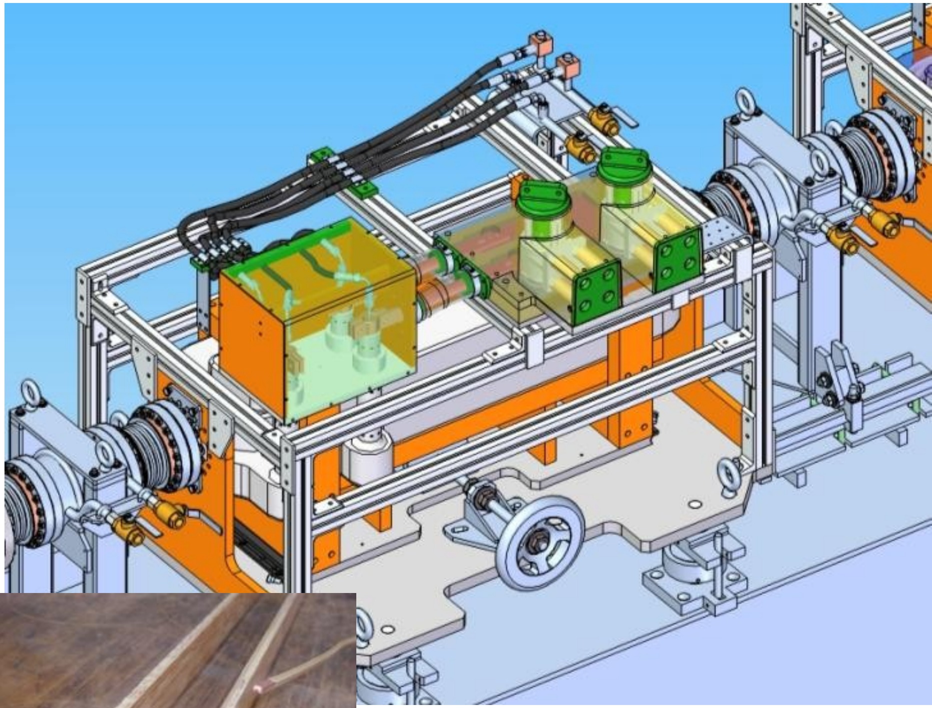


Extra 5% of beam time at 120Hz (!) possible

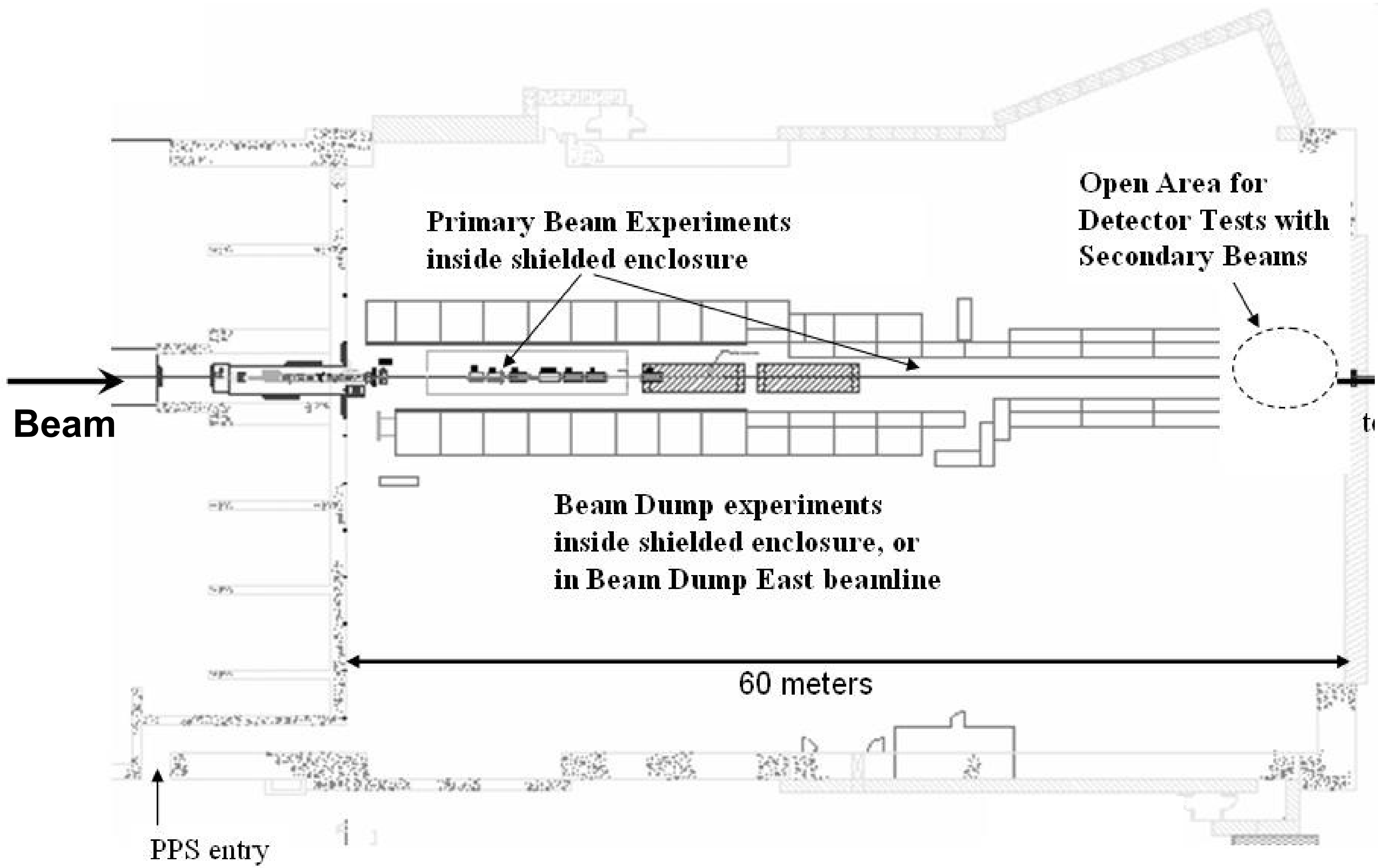
ESTB Hardware Needed

- 4 new kicker magnets including power supplies and modulators, vacuum chambers, collimators are designed and components are being ordered and manufactured
- Build new PPS system and install new beam dump in ESA

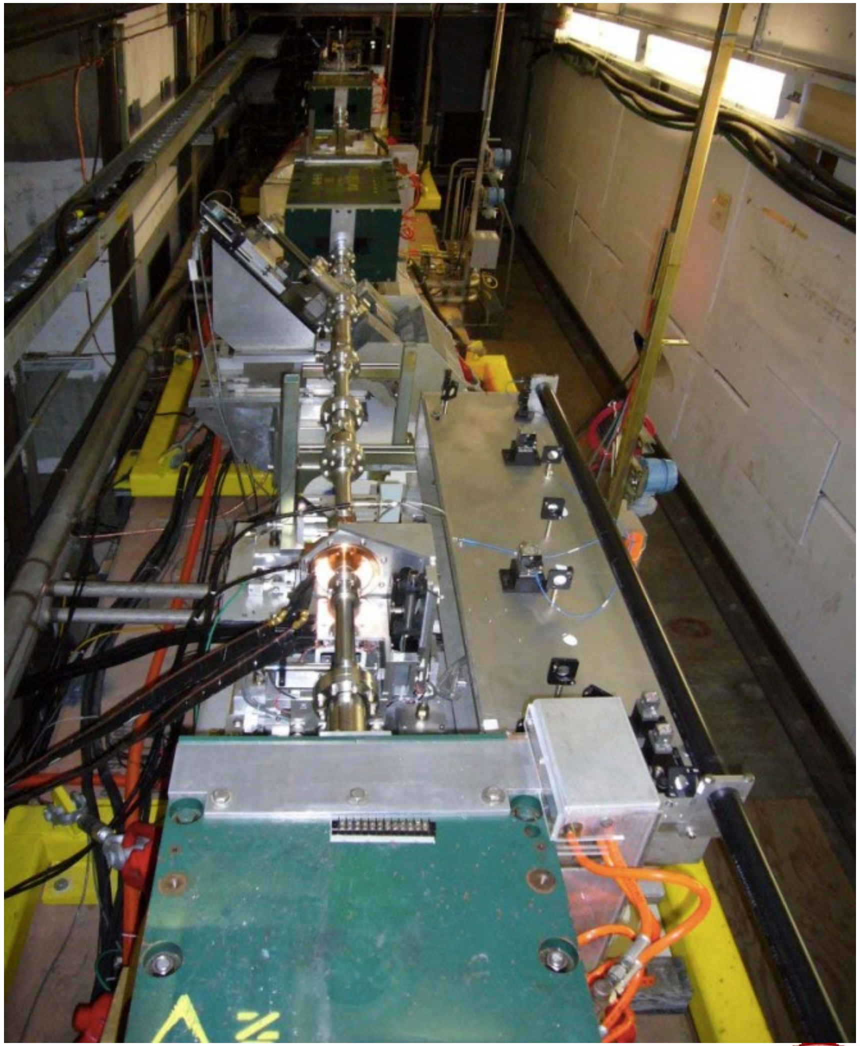




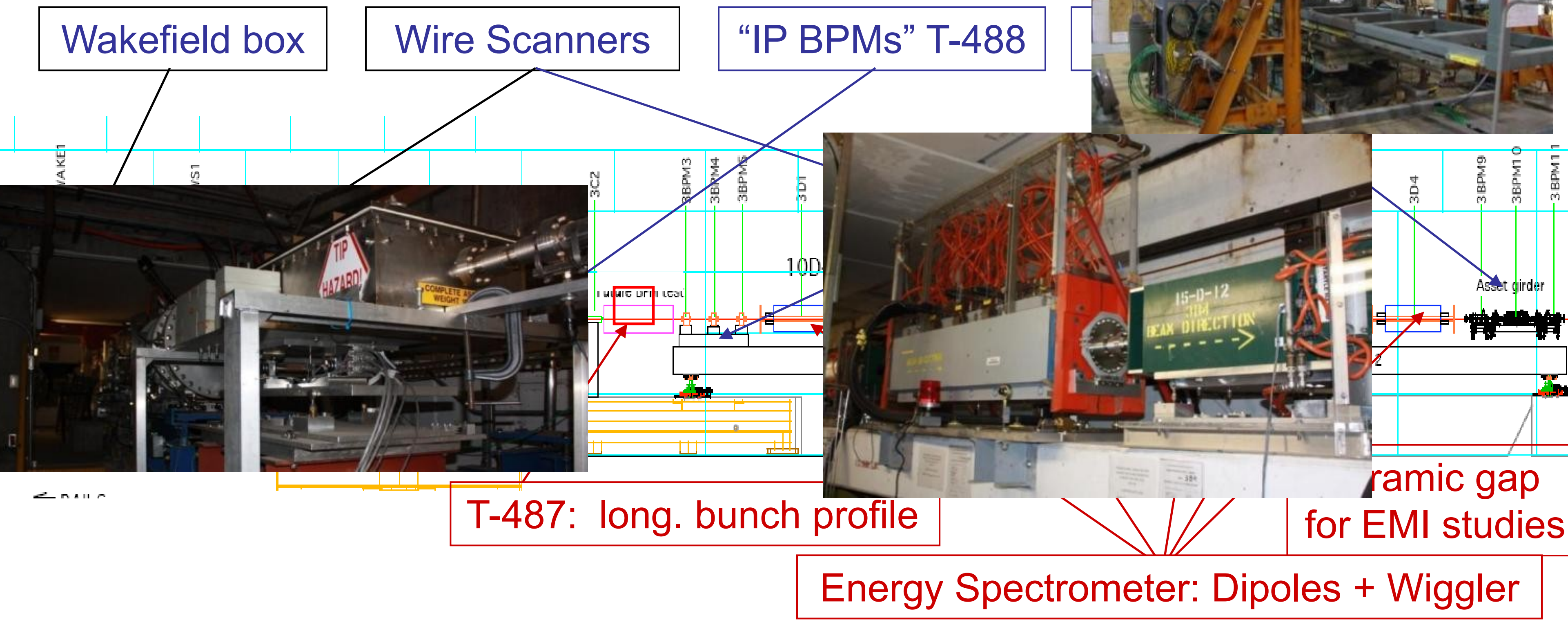
Building 61: ESA



End Station A Experimental Area



ESA Past Experiments



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

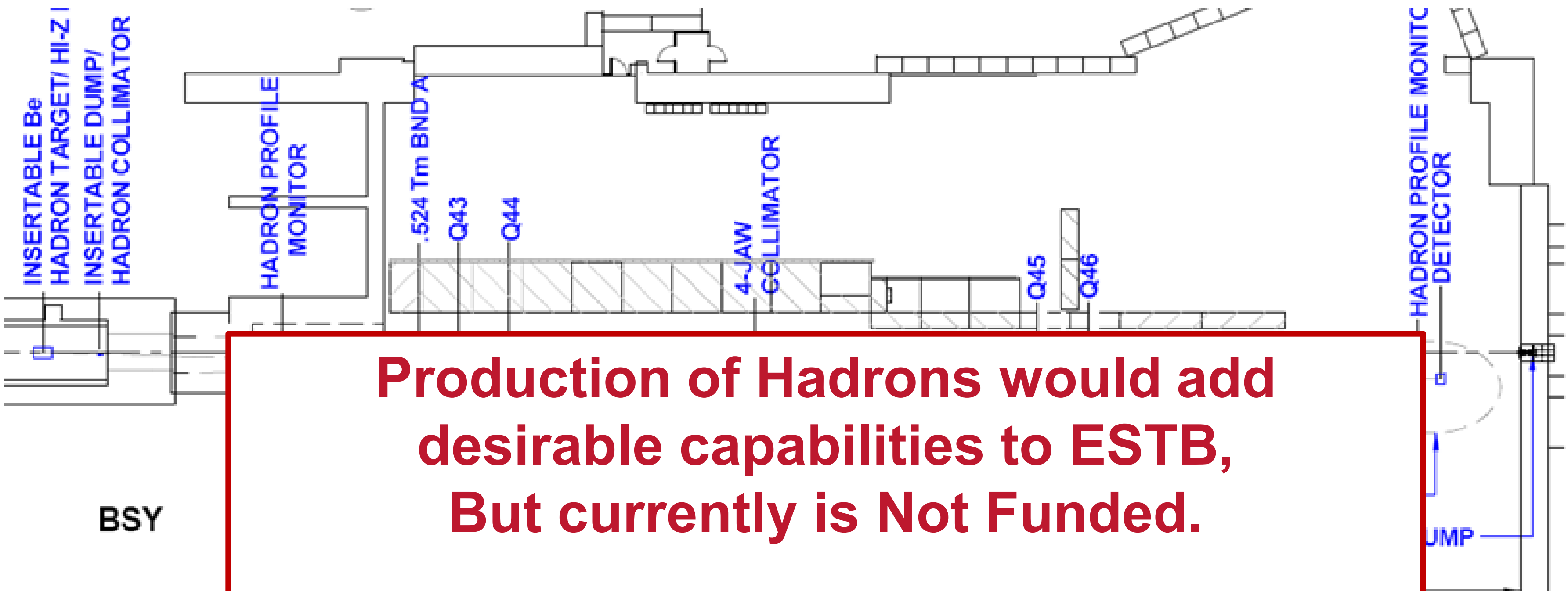
IP BPMs—background studies (T-488)
LCLS beam to ESA (T490)
Linac BPM prototypes
EMI (electro-magnetic interference)
Irradiation Experiments

ESTB Stage I: Primary and Secondary beams

- **Primary e- Beam operations**
  - Full intensity, 4 - 14 GeV, LCLS beam into ESA
- **Secondary e^- beams**
  - 4 - 13 GeV, up to 10^{-4} momentum resolution
  - 1 GeV (maybe) and 2 GeV (most likely)
  - Adjusting 2 collimators: 0.1 - 10^9 electrons/pulse
- **Tagged photon beams**
  - developing the needed infrastructure

ESTB Stage II: Hadron Production

- Add Be target, beam dump, analyzing magnet, momentum slit, and quadrupole doublets to produce a secondary hadron beam
- Production angle = 1.35^{O} and Acceptance = 10 μsr



Production of Hadrons would add desirable capabilities to ESTB, But currently is Not Funded.

We need User requests!

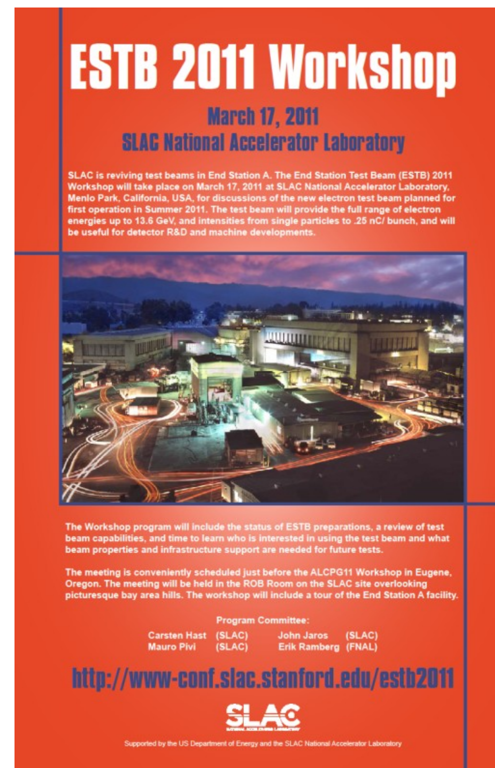
- Protons and Kaons at ~ 0.02 / 250 pC

ESTB Workshop at SLAC

1st ESTB User Workshop in March 2011

- 50 participants from 16 institutions and 5 countries
- 13 short presentations for proposed test beam uses
- 8 requests received (already before the workshop)

Underlines the broad interest by the community



Proposals

- Test of the SSD Electronics for STAR HFT Upgrade
- Pixel Sensors for ATLAS Upgrades
- STAR Pixel Detector
- Fermi Large Area Telescope
- LC detector: Silicon-Tungsten Calorimeter
- Super B R&D
- **Energy Spectrometry**
- **CLIC Wakefield Collimator Studies**
- Radiation Physics Beam Tests
- Beamcal Radiation Damage Study
- Geosynchrotron Radio Emission from Extensive Air Showers
- SuperB DCH
- Askaryan Effect in High Energy Showers

Howard Matis, LBNL (*)

Philippe Grenier, SLAC (*)
Leo Grenier, LBNL (*)
Elliott Bloom, SLAC (*)
Ray Frey, University of Oregon (*)
Jerry Va'Vra, SLAC
Mike Hildreth, Notre Dame University (*)
Roger Jones, Cockcroft/Manchester U
Mario Santana, SLAC
Bruce Schumm, UC Santa Cruz
Konstantin Belov, UCLA

Mike Rooney (*)
Peter Gorham, Hawaii U. (*)

(*) proposal received

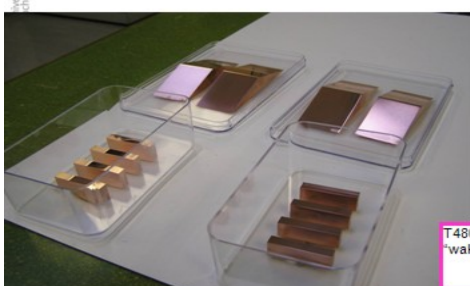
Collimator Wakefield Measurements

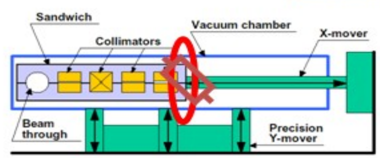
R.M. Jones, D. Schulte, R. Tomas, W. Wuensch for the CLIC team

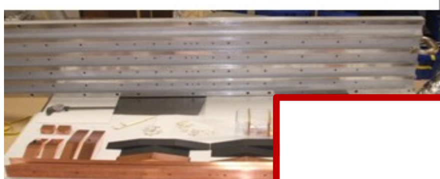
Motivation

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

Collimator Hardware







R.M. Jones (University of Manc

- Bunch length [partially hidden]
optic bunch le[partially hidden]
- Need BPM resolution in the 100 nm level (partially contributed by CERN)

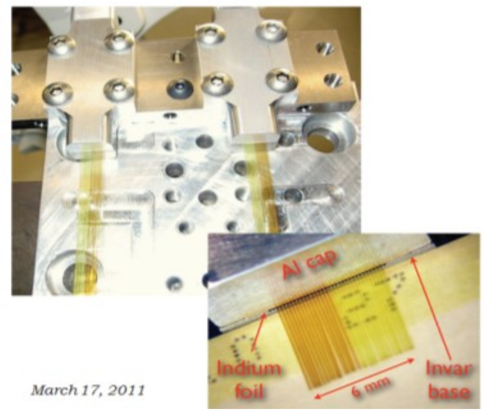
Energy Spectrometer Tests at End Station A

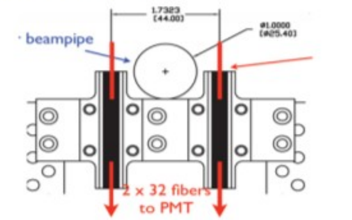
Mike Hildreth

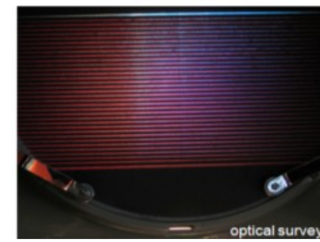
New SR Stripe Detector

E. Torrence (Oregon), SLAC

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

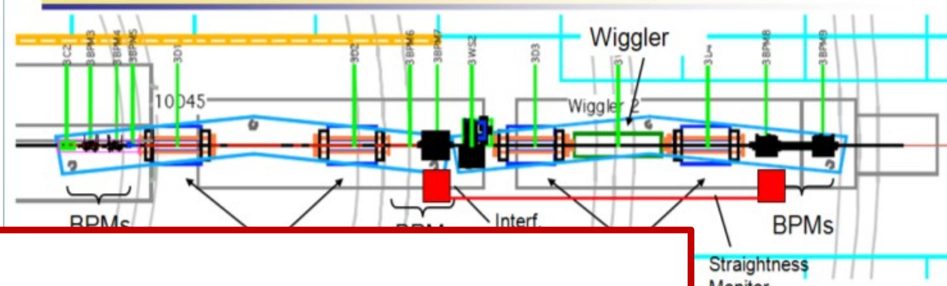






March 17, 2011

Next Steps for ESA

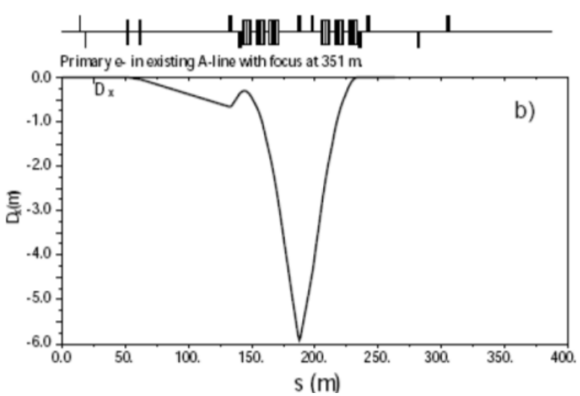


[partially hidden]lution
- more new hardware/electronics for better resolution/stability
- aim for 1×10^{-4} relative measurement, cross-calibration
- Finish what we started!

We need rf BPMs possibly LCLS-II type

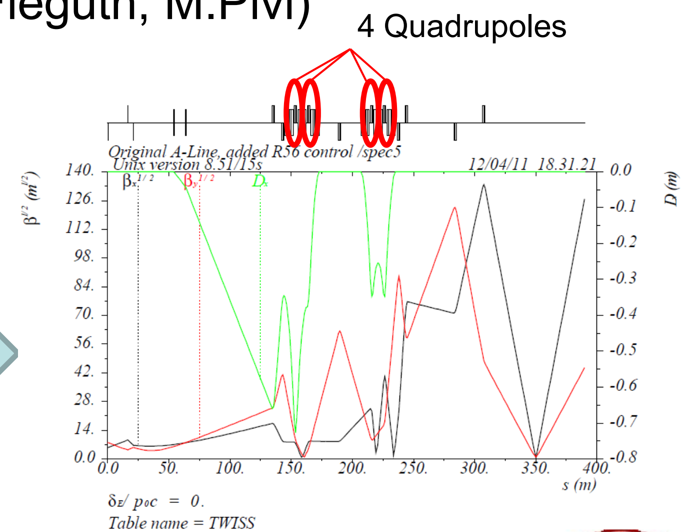
Development: Short bunch length

- Interest for short bunches ~50μm (CLIC, accel. R&D.)
- LCLS beam: 10 μm and smaller
- In A-line, bunch length increases to 280 μm due to 24.5° bend, large dispersion and large R56
  - Reduce LCLS beam σ_E~0.02% (Z. Huang) →100 μm
  - Install 4 QUADs in A-line to reduce R56 (T. Fieguth, M.Pivi)
  - **bl = 50 μm or shorter in ESA**

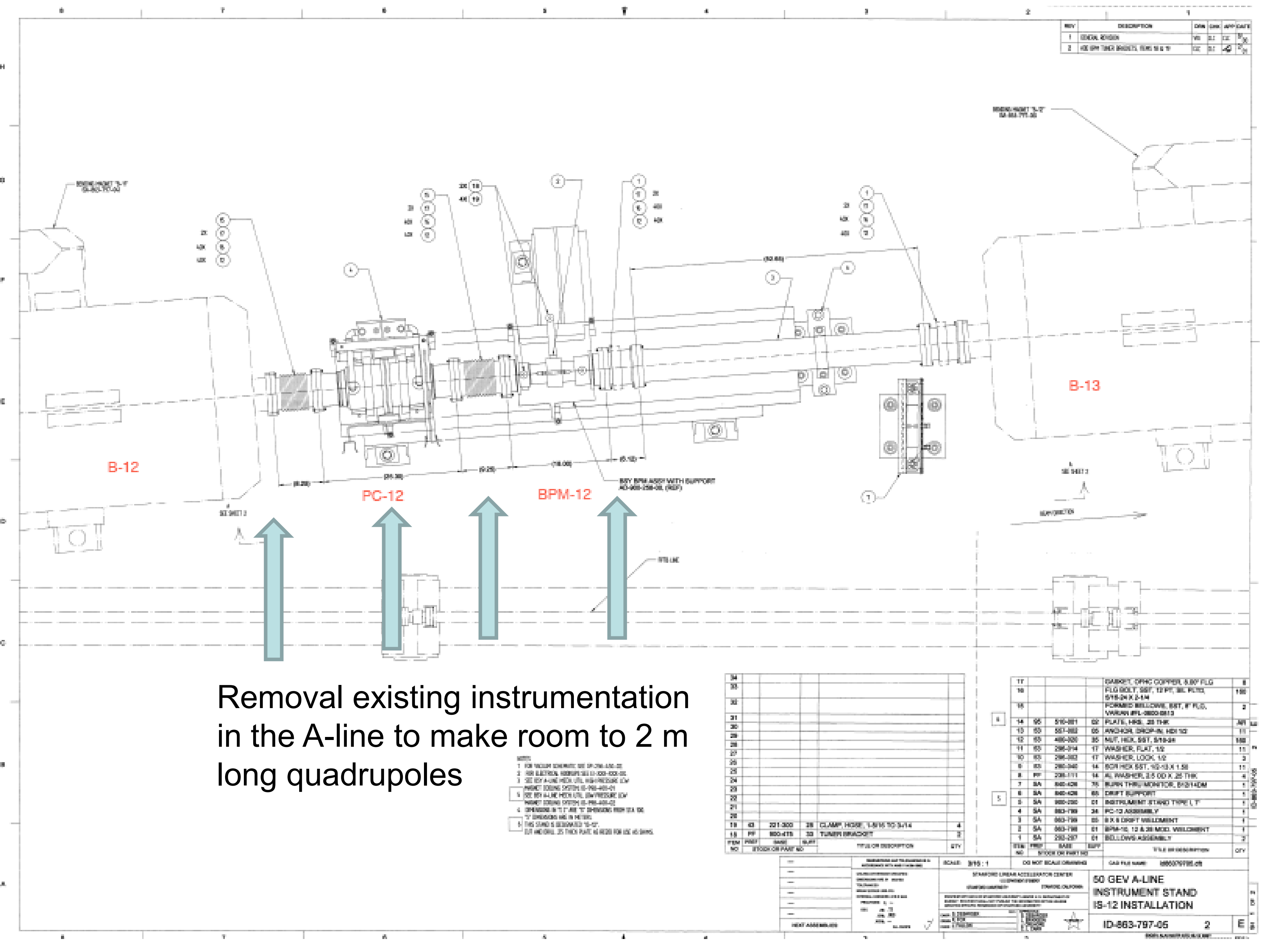


Existing optics

R56~0.46



R56<0.1



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

ESTB Schedule

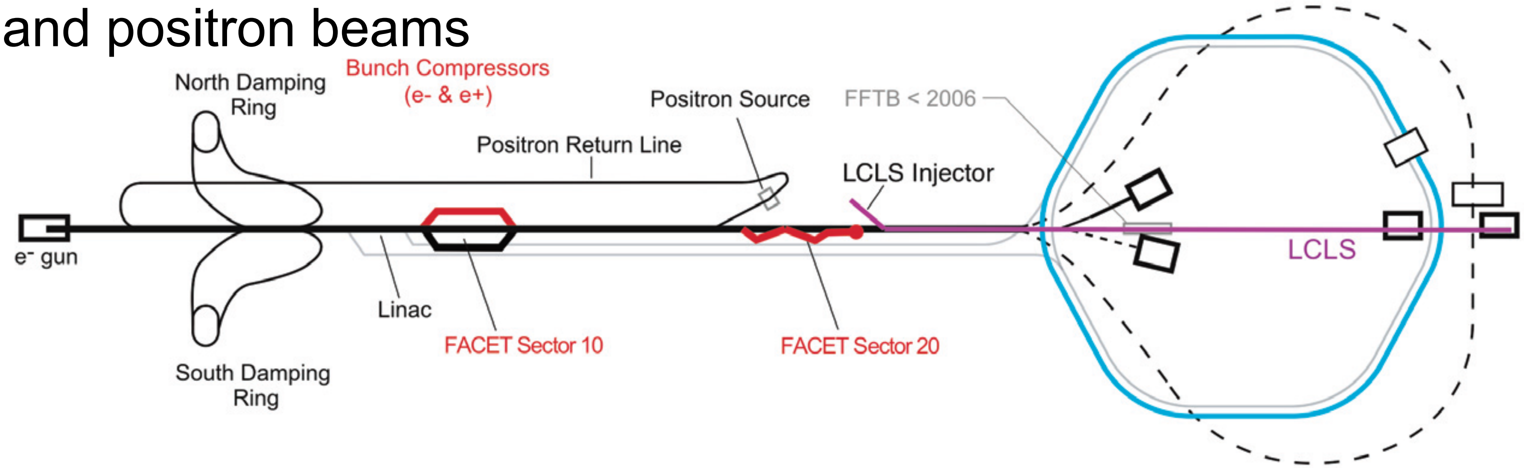
- July install one kicker in BSY
- August ESTB can do first test of kicking a 4GeV beam into A-line
- ESA PPS becomes available this summer
  - 4GeV primary beam to ESA
  - 4-14GeV secondary electron beam to ESA
- Commissioning of ESA infrastructure September/October
- Oct 25th – Nov 1st install 4 BSY kicker magnets with ceramic chambers
- ESTB commissioning run in November and December
- LCLS off from Christmas to end of January
- ESTB running starts February 2012
- SLAC downtimes are in Aug/Sept and over Christmas for the next years

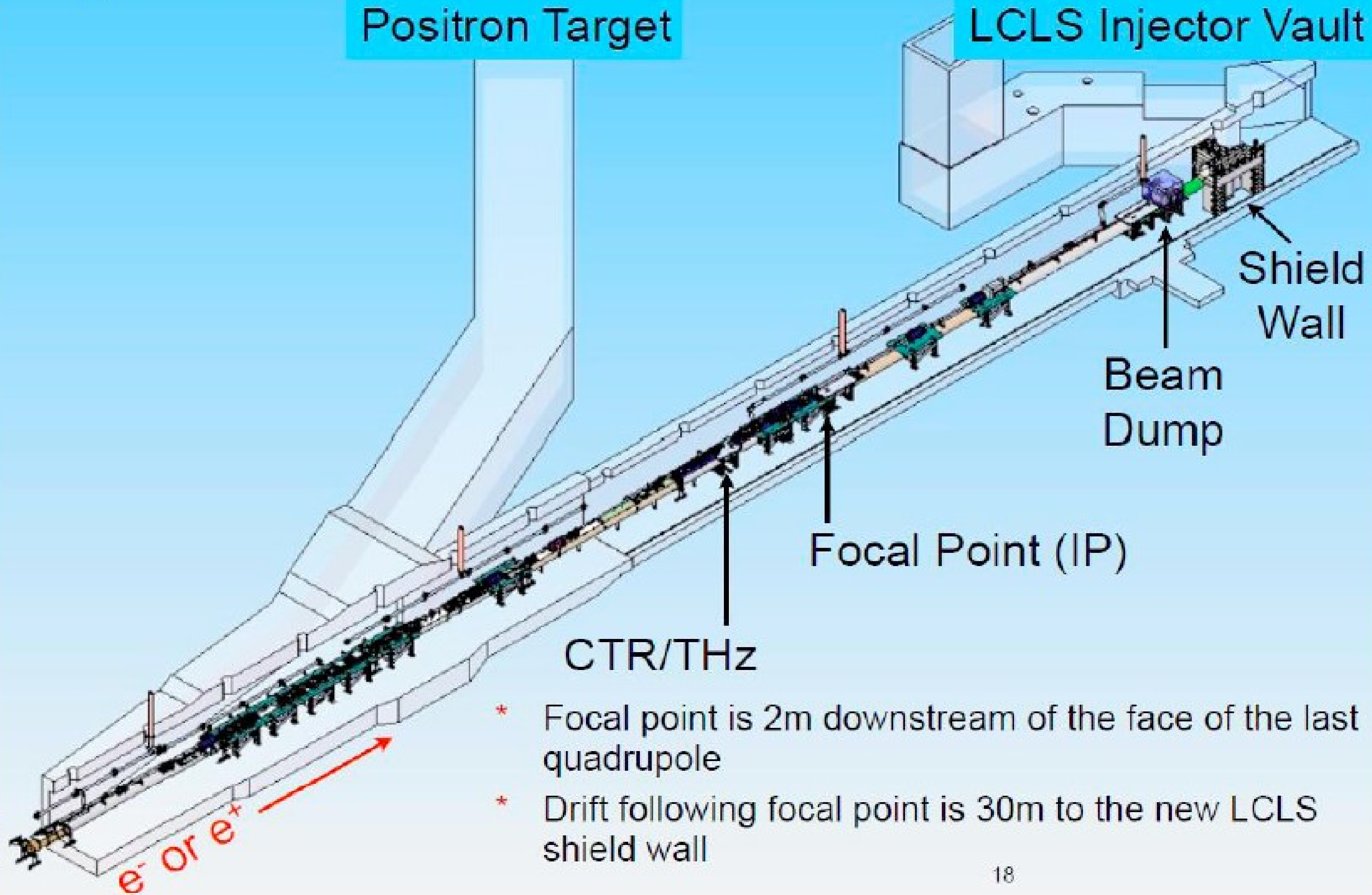
- For MDI proposal we tie into the FACET Review process (October 2011)

FACET at Sector 20

- FACET uses the first two-thirds of the SLAC Linac
- Energy = 23 GeV
- Charge 3.2 nC
- Sigma x = 14 μm
- Sigma y = 6 μm
- Sigma z = 14 μm minimum (20 μm typical)
- Bunch length can be increased up to a factor of 3
- Electron and positron beams

} At IP (Sigma x, Sigma y, Sigma z)



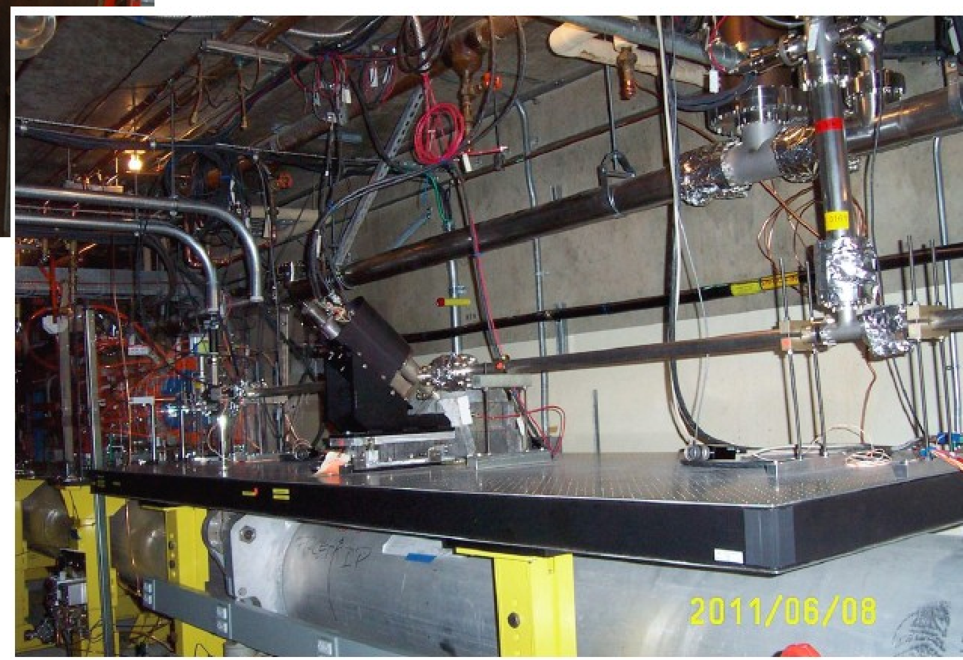


* Focal point is 2m downstream of the face of the last quadrupole
* Drift following focal point is 30m to the new LCLS shield wall

THz and IP Optical Tables

THz Table (looking east towards dump)

IP Table



Magnets installed meanwhile...

SLAC Test Facilities

- FACET, Sec. 20, dedicated linac beam
- ESTB, ESA, LCLS beam
- NLCTA, 0.5 GeV, dedicated accelerator
- ASSET, ≈2 GeV, Sec. 2, long (1.5 mm) bunches

	FACET	ESA (ESTB)
Energy	23 GeV	4 – 13.6 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+	0.15 x 10^{10} e^-
Pulse length at IP (σ_z)	15 – 40 µm	100 μm (44 µm)
Typical spot size at IP ($\sigma_{x,y}$)	10 – 20 µm	$\gamma\varepsilon$ = 4 pm-rad by 1 pm-rad
Repetition rate	1 – 30 Hz	5 Hz
Momentum spread	4 – 0.5%	0.06 – 0.02% (?)
Momentum dispersion at IP	$\eta < 10^{-5}$ m	0 (?)

FACET Schedule

- June 16th start of beam operation
- July 7th (or so) installation of experiments (one week or so)
- Mid July to July 31st more beam tuning
- August 1st to 31st "User Assisted Commissioning"
  - We will have 4 experiments installed
    - Plasma Wakefield Acceleration
    - Smith Purcell
    - Magnetic Switching
    - Wakefield acceleration in dielectric structures
- FACET User Meeting August 29/30
- Call for proposals in October
- 1st User Run February to March 2012 and May/June

Summary

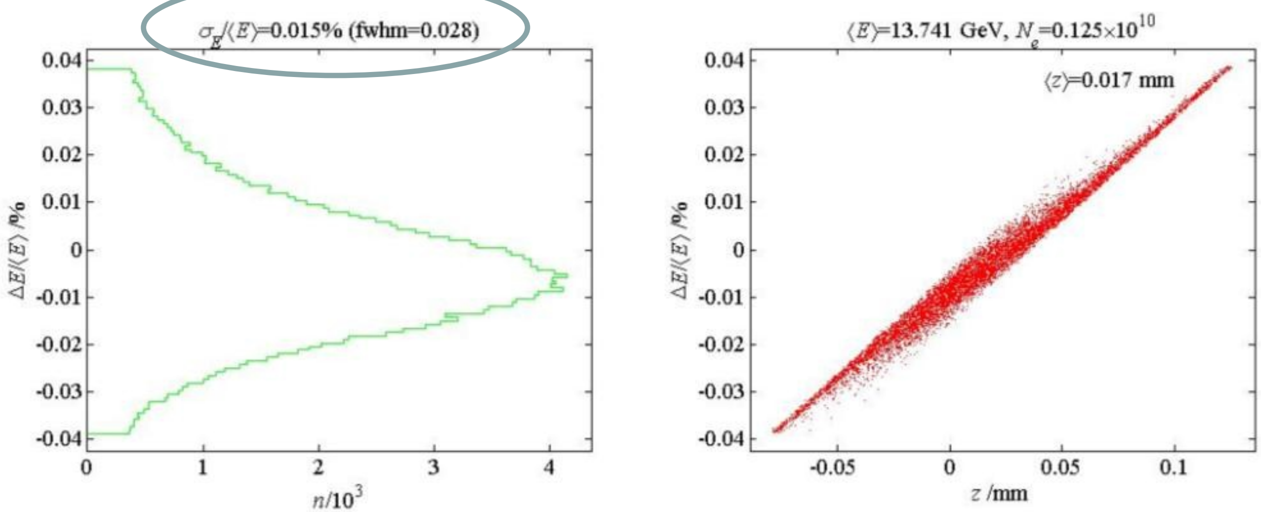
We are excited (and slightly overworked…)

- To start FACET this month
- To re-start ESA test beams later this year
- Unique high energy electron (positron) beam lines in the US
- With plenty of infrastructures and SLAC support for Users

Keep Your Proposals Coming

Back-up

Using LiTrack: example

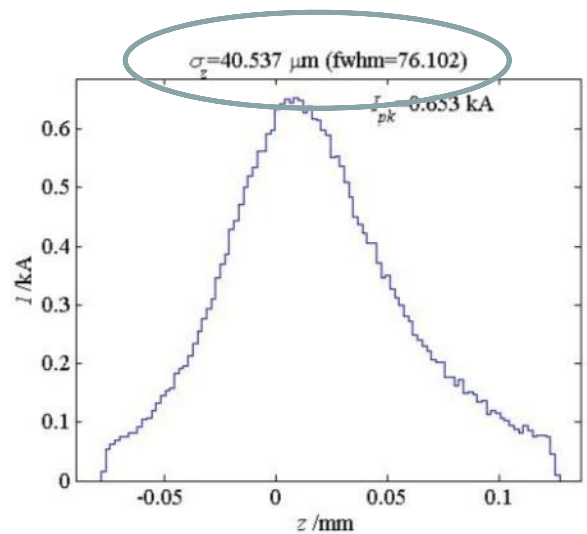


LiTrack simulations (Z. Huang):

- δ_E~0.015%
- applied 10% energy cut
- R56 = 0.23 m (not 0.1 yet!)
- got σ_z =40 um

Source: lcls_200pC_6MeV_560um.zd

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

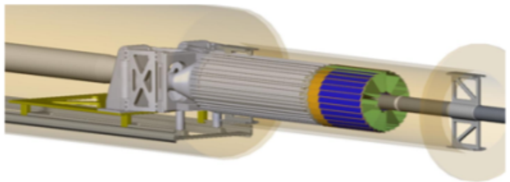


LiTrack (SLAC)

STAR Pixel Detector

A MAPS based vertex detector for STAR

Short description of the detector and why we need test beam



LBNL
Leo Greiner, Eric Anderssen, Howard Matis, Thorsten Stezelberger, Joe Silber, Xiangming Sun, Michal Szelezniak, Chinh Vu, Howard Wieman

UTA
Jo Schambach

IPHC Strasburg
Marc Winter CMOS group

LC Detector: Silicon-Tungsten Electromagnetic Calorimeter R&D Collaboration

M. Breidenbach, D. Freytag, N. Graf, R. Herbst, G. Haller, J. Jaros, T. Nelson
SLAC National Accelerator Center

- KPiX readout chip
- downstream readout
- mechanical design and integration

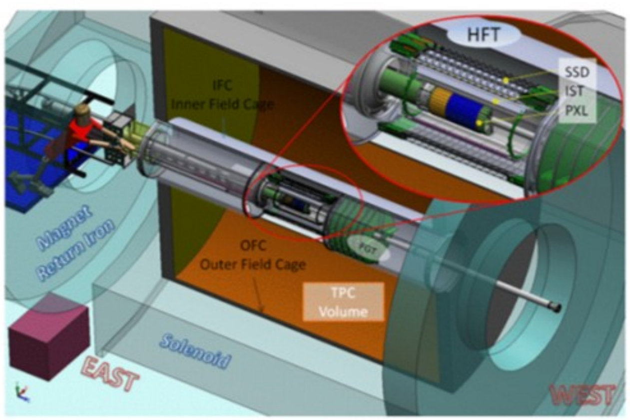
J. Brau, R. Frey, D. Strom, P. Radloff (grad student), undergraduates
U. Oregon

- detector development
- readout electronics

B. Holbrook, R. Lander, M. Tripathi, M. Woods (grad student)
UC Davis

- cable development
- bump bonding

Inner Detector Upgrades



TPC – Time Projection Chamber (main tracking detector in STAR)
efficiency and spatial resolution sensors

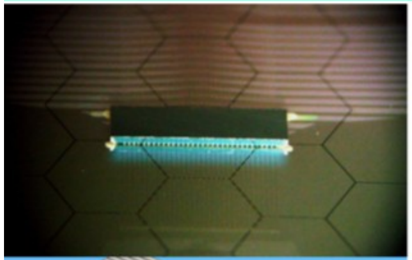
HFT – Heavy Flavor Tracker
- SSD – Silicon Strip Detector
  - r = 22 cm
- IST – Inner Silicon Tracker
  - r = 14 cm
- PXL – Pixel Detector
  - r = 2.5, 8 cm

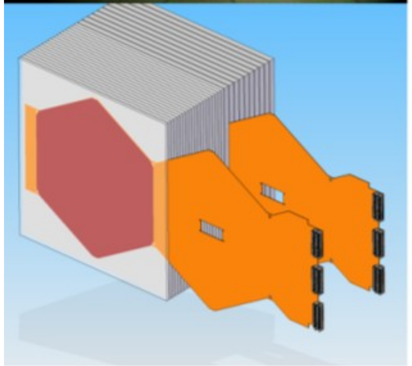
We track inward from the TPC with graded resolution:

TPC → ~1mm → SSD → ~300µm → IST → ~250µm → PXL → <30µm → vertex

Solenoid Tracker at RHIC: search qg plasma.

Silicon-Tungsten R&D and test beam module





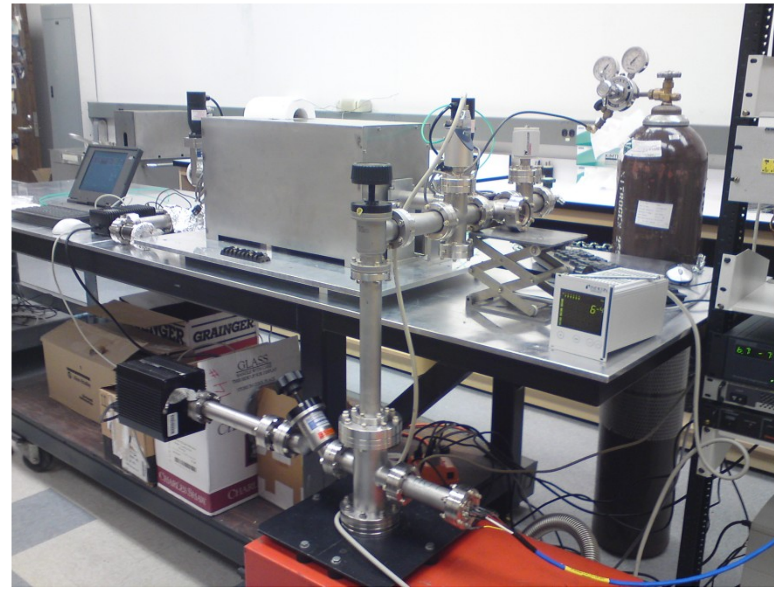
- 15 cm silicon sensors
  - 13 mm2 pixels
- 1024-channel KPiX readout chip
  - Bump-bonded to sensor
  - One digital output
  - Large dynamic range
  - Power pulsing

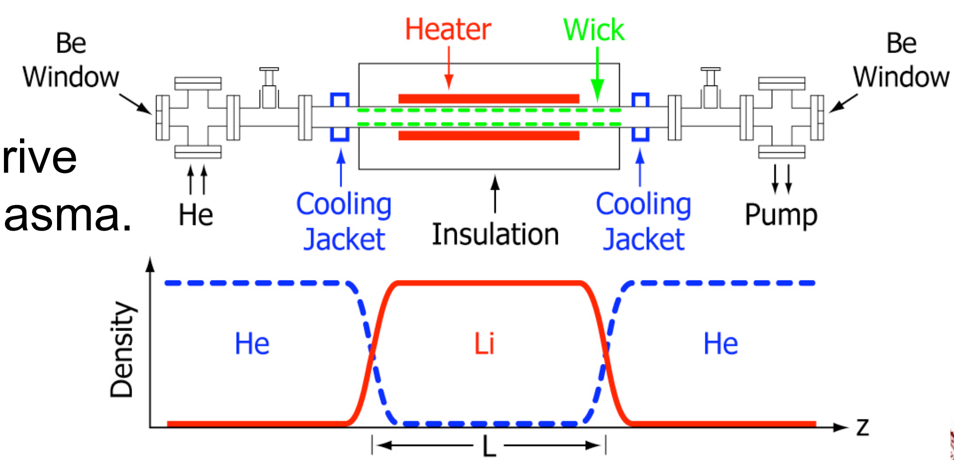
R&D project goal: Produce full-depth (30 layer) module which uses appropriate technologies for a collider detector (and test it).

(expect it to be ready ~ summer)

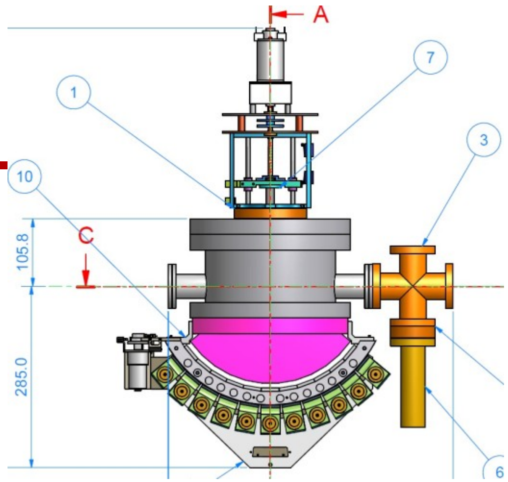
Plasma Wakefield Acceleration

- Continuation of very successful FFTB experiments
- Heat-pipe oven to be installed this July
- Lithium metal vaporized at 800ºC
- Length of plasma controllable by controlling heaters and pressure of helium buffer gas
- Phase One: Begin with single electron bunch in field ionized lithium plasma.
- Phase Two: Single bunch in field ionized cesium plasma.
- Phase Three: Use Notch Collimator.
- Phase Four: Two electron bunches (drive and witness) in field ionized cesium plasma.
- After first year, pre-ionized plasma, positrons, positrons and electrons.

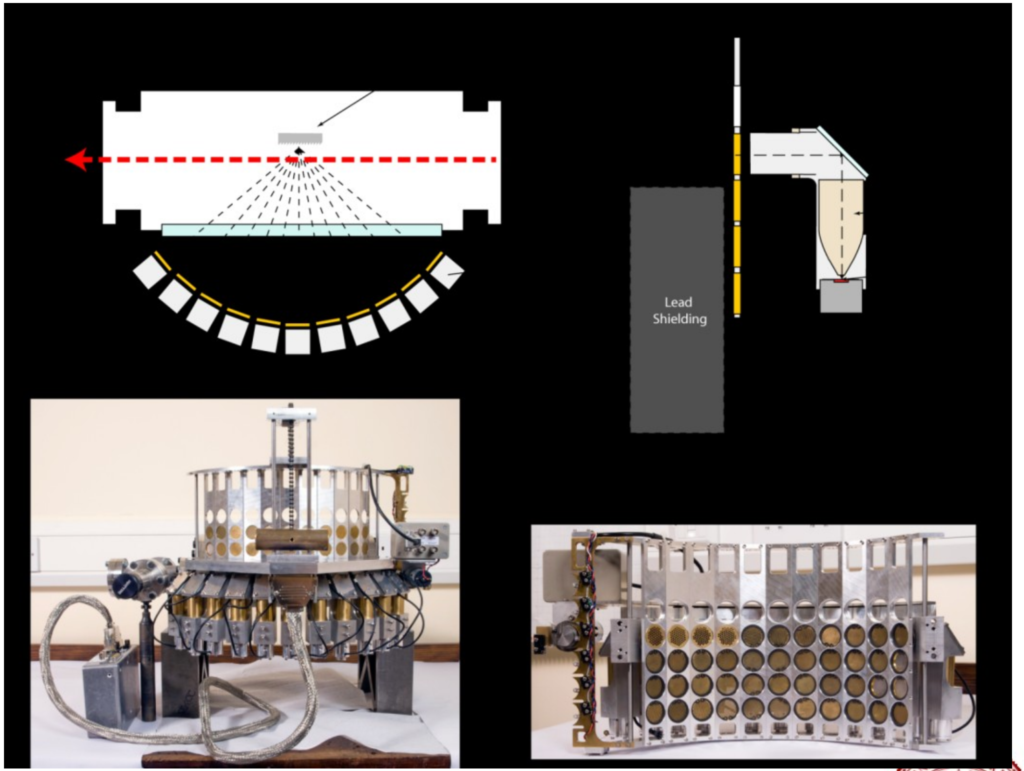




Smith Purcell

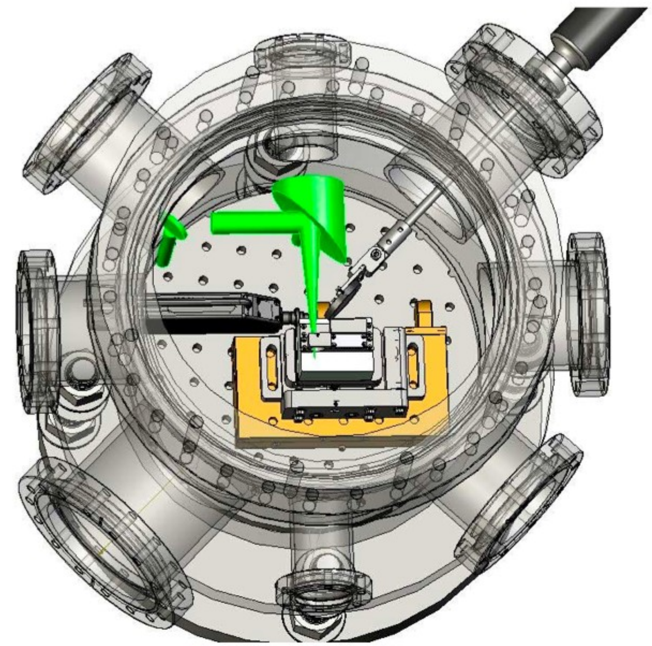


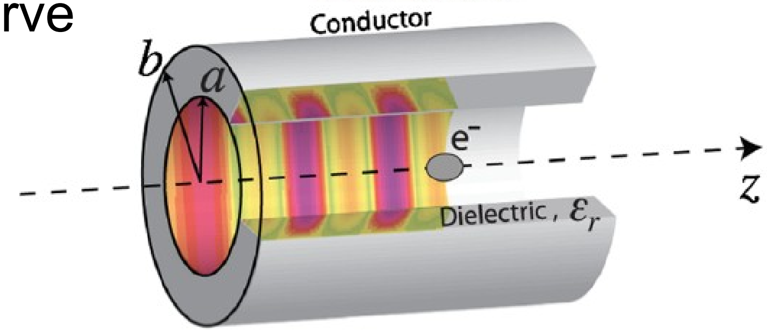
- Bunch Time Profile measurements with Coherent Smith-Purcell Radiation
- Moderate band-width terahertz
- Beam passes by grating which has a dispersive effect
- Continuation of experiment at ESA
- Not sensitive to beam spot size (will be situated upstream of IP).
- Non-destructive (parasitic running).



Wakefield Acceleration in Dielectric Structures

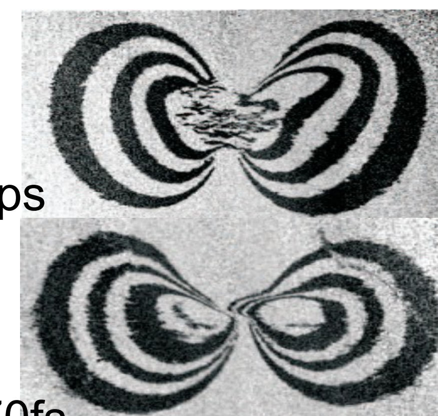
- GV/m class DWA for use in linear colliders and future light sources.
- Previous work at FFTB/SLAC, UCLA, BNL.
- High gradient regime at FACET.
- FACET beam sent through prototype dielectric wakefield acceleration structures.
- Parametric breakdown studies and lifetime effects.
- Vary structures (dimensions, materials etc).
- Use drive and witness bunches to observe acceleration.
- Use coherent Cerenkov radiation
- Next year, use protons.





Ultrafast Magnetic Switching

- Continuation of FFTB work.
- Change in magnetization of a sample on ultrafast timescales
- Change pulse-lengths with constant Q - do longer pulse-lengths have more energy deposition?
- Expose sample to electron bunch
- Then image with spin-sensitive scanning electron microscope.
- Different patterns on same film indicate different physical processes.
- Chaos cannot be explained
- Need to rule out experimental artefacts.



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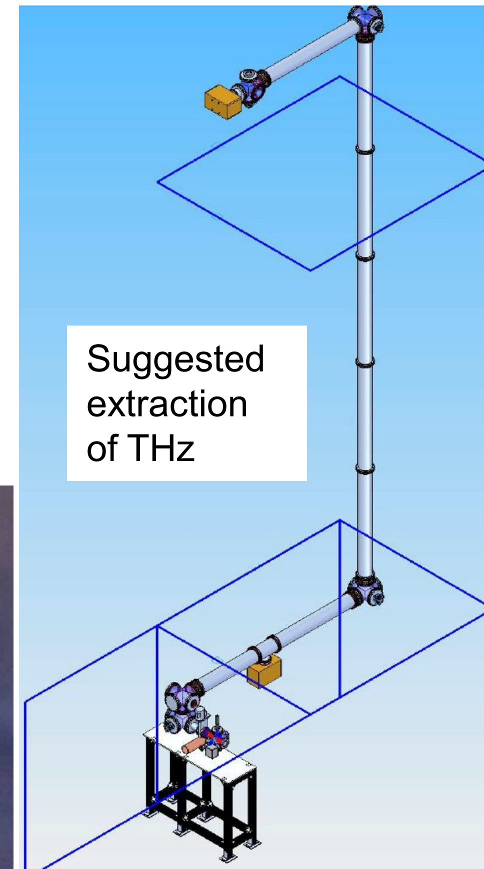
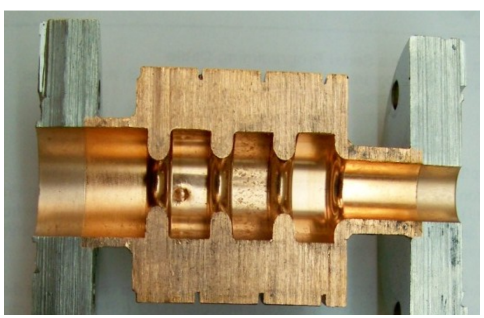
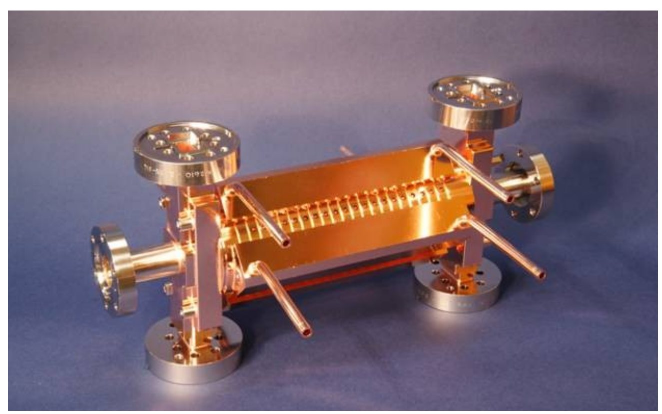
Additional Experiments

- Metallic Periodic Structures (Accepted Proposal)
  - Short-pulse, high fields to study breakdown physics.
- High gradient dielectric wakefield measurements (Accepted Proposal)
  - dielectric based collimating systems
- CLIC Studies (letter of intent)
  - Dispersion-free steering
  - Accelerating structure Wakefield Studies
  - Collimator Wakefield Studies
- THz extraction (expression of interest)
  - Extract radiation to an experimental area




Short Metallic Accelerating Structure


30cm High Power test structure (CLIC Studies)