FACET Design & Exp. Facilities Beam-Commissioning Status

U. Wienands

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for the FACET Teams

FACET History

* After PEP-II termination in 2008, the first 2 km of the SLAC linac became available as LCLS uses only last km.
* > Proposal to resume PWFA experiments in Sec. 20
  – > FACET: Facility for Advanced aCcelerator Experimental Tests
* Funded Summer 2010, ≈1 y construction & installation
  – "FFTB in Sector 20"
* Subsequently a proposal process was implemented to facilitate other proposals.
* Will become a "National User Facility" later this year.

Overall Thrust of FACET

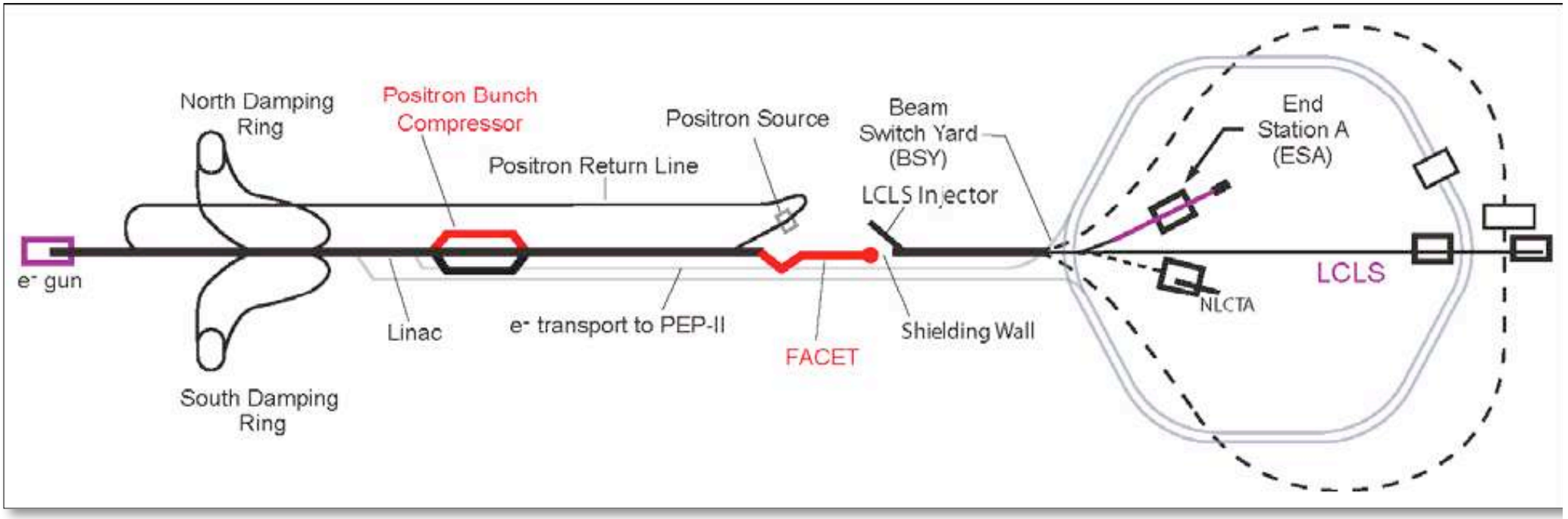
* The primary goal of FACET is proof in principle that plasma acceleration can accelerate a bunch
  - characterize the mechanism under beam loading
  - estimate parameters of the accelerated (witness-) bunch
  - estimate the efficiency and gradient reachable in practice
  - demonstrate acceleration of a positron bunch
* Beyond that, FACET will provide a facility to explore other accelerator physics issues
  - Dielectric Laser Acceleration
  - Wakefield measurements (ILC, CLIC)
  - Matter in extreme fields
  - New Beam-diagnostic methods (THz, S.-P. radiation etc.)
  - new radiation sources
* Short, small bunches, extreme peak intensity.

FACET Design Parameters

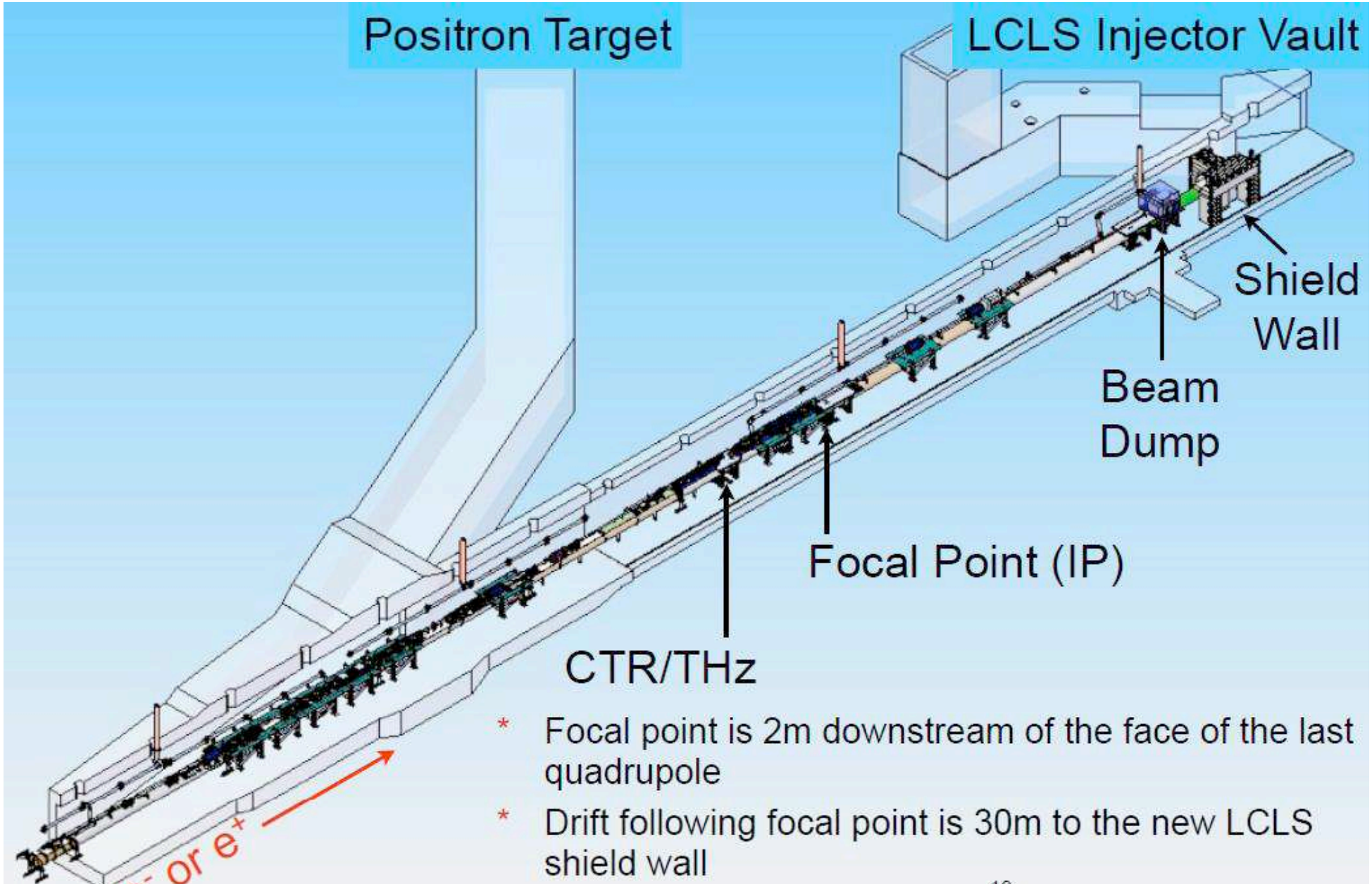
Energy	23 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+
Peak current	20 kA
Pulse length at IP (σ_z)	15 – 40 μm
Typical spot size at IP ($\sigma_{x,y}$)	10 – 20 μm
Repetition rate	1 – 30 Hz
Momentum spread	4 – 0.5% full width

The FACET Facility

* new compressor chicane and exp. area in Sec. 19-20.
* driven by first 2/3rd of the SLAC 2-mile linac
* new compressor chicane in Sec. 10 for e^+, being installed
* e^- now and later also e^+

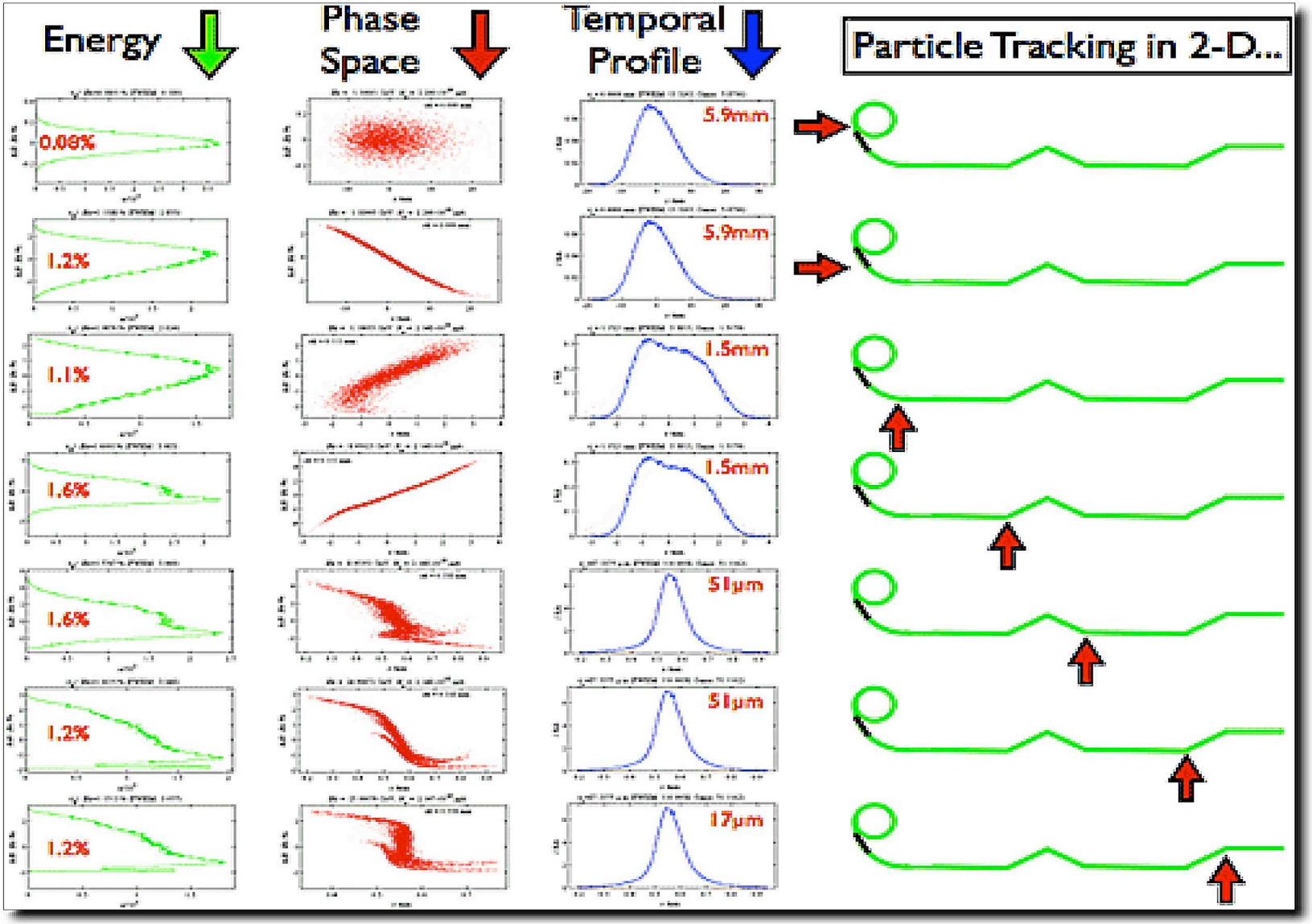


Iso Rendering of FACET in S20



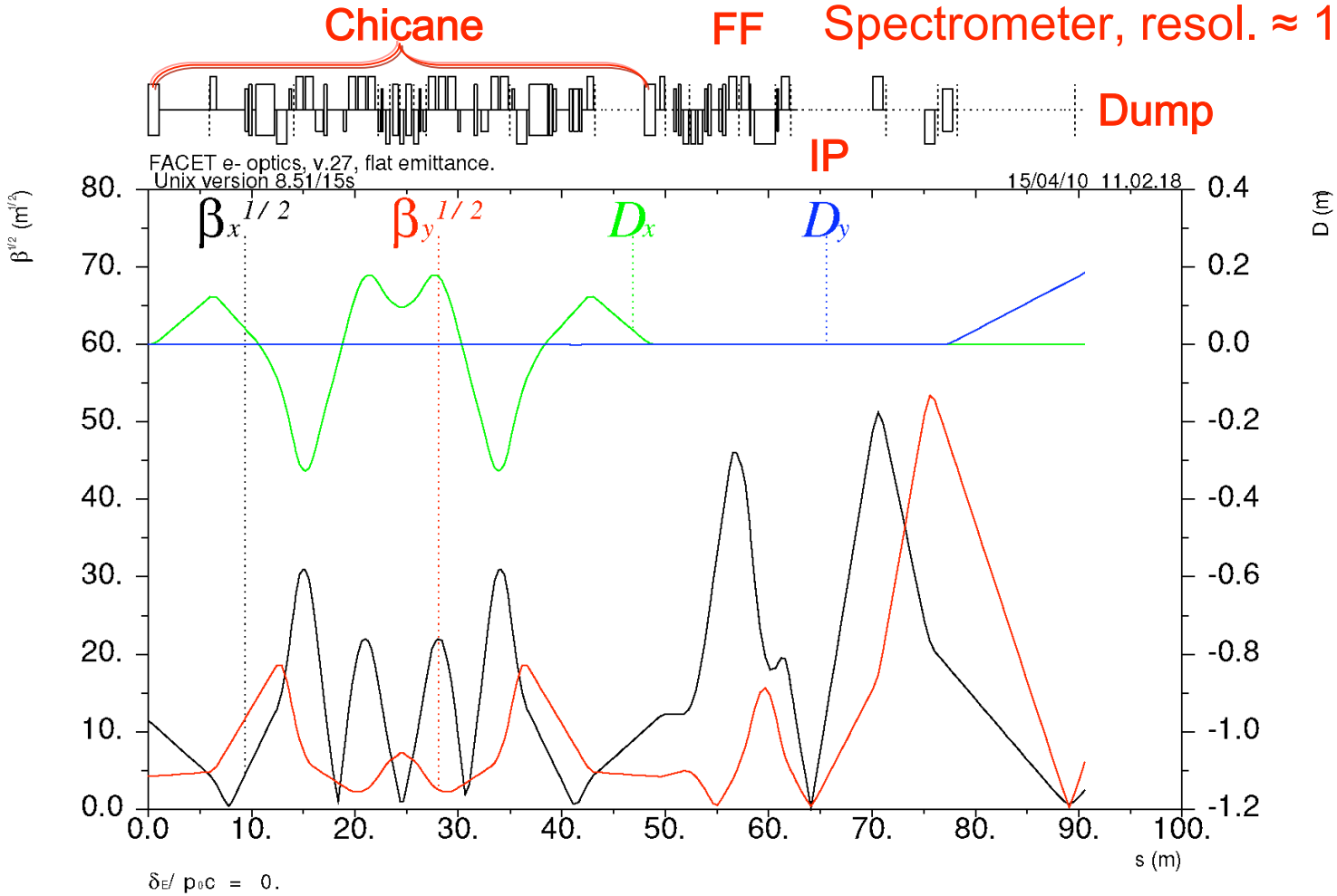
* Focal point is 2m downstream of the face of the last quadrupole
* Drift following focal point is 30m to the new LCLS shield wall

Staged Bunch Compression

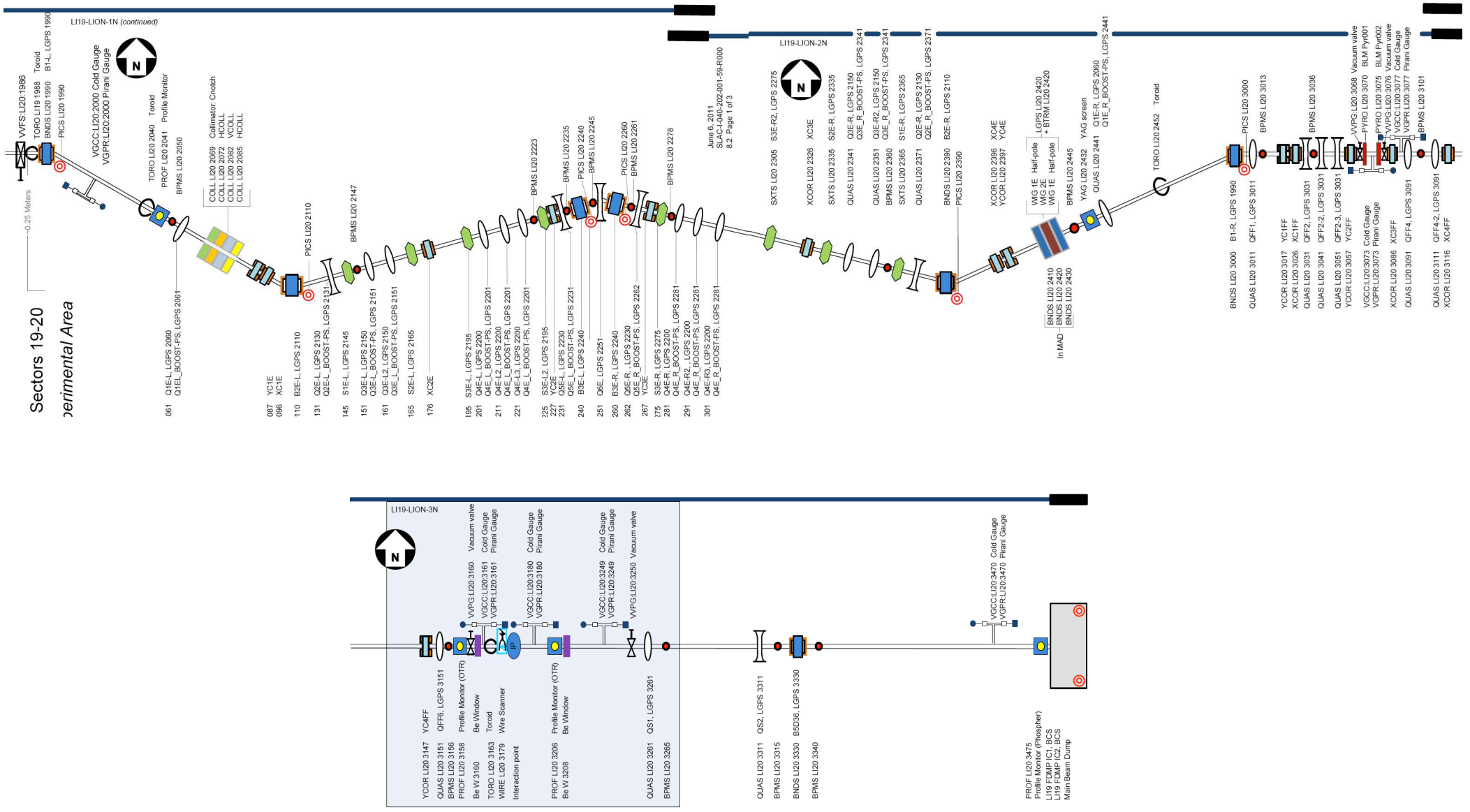


Sector-20 optics functions

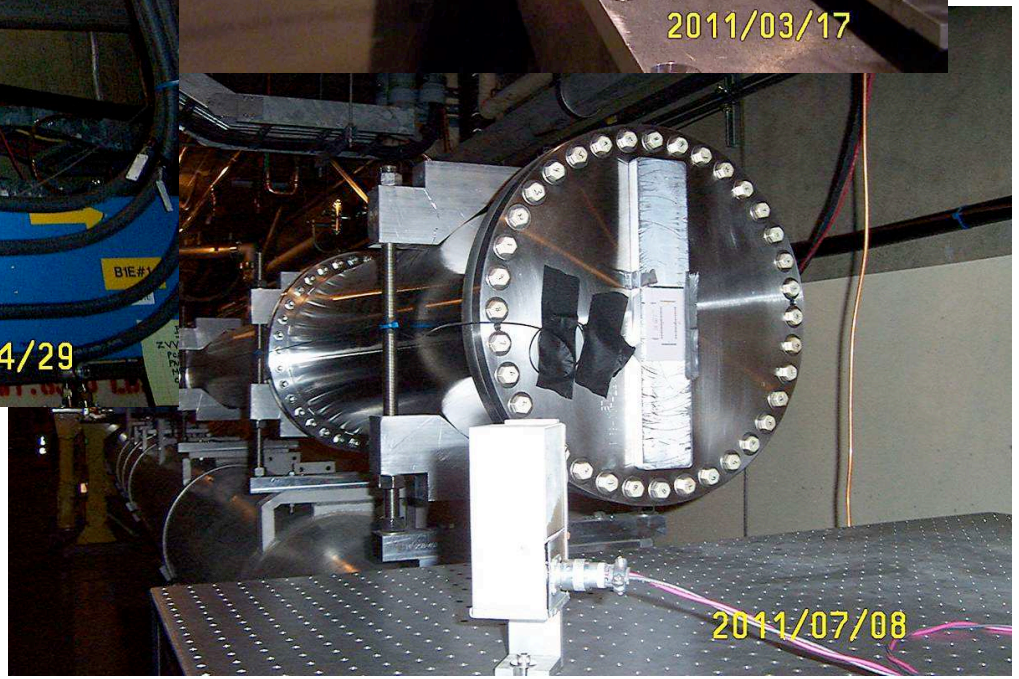
* The Sector-20 optics provides a small round spot at IP with zero dispersion, R_{56} = 4 mm, and it is compatible with the future e+ chicane.
* Incoming emittance and IP β-functions: $\gamma\varepsilon_x/\gamma\varepsilon_y$ = 50/5 μm·rad, β_x/β_y = 1.5/15 cm.



FACET Beamline Map



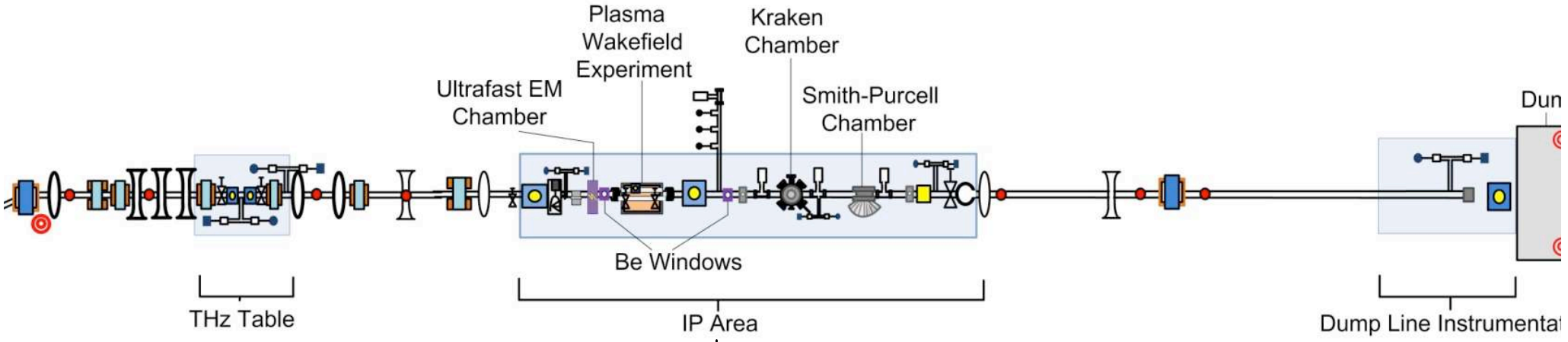
FACET Installation



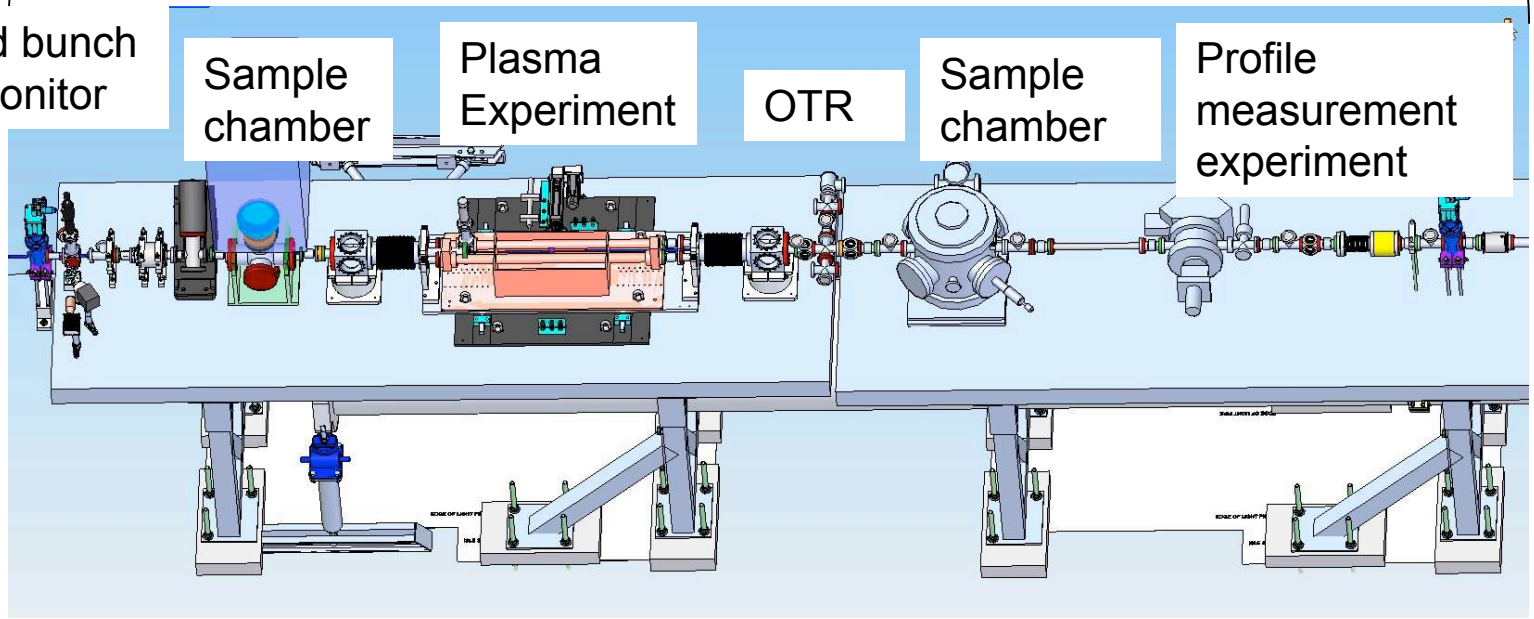
Experimental Facilities

* There are four 8’ optical tables to install experiments
  - upstream IP: THz radiation expt.
  - 2 Tables at IP: PWFA, DLA, Smith-Purcell, magnetic switching.
  - 1 Table at Dump: Cherenkov detectors for spectrometer.
* 4+1 Experiments are installed
* One primary user determines beam parameters (i.e. waist location) etc.
  - max. use of beam time minimizing installation time.
* The IP tables have a windowed vacuum system
  - 2 Be windows, 1 ss window downstream
  - Allow expt. installations that cannot meet linac vacuum specs.
* The 2nd IP table has a universal chamber (“Kraken”)
  - useful for smaller expts.

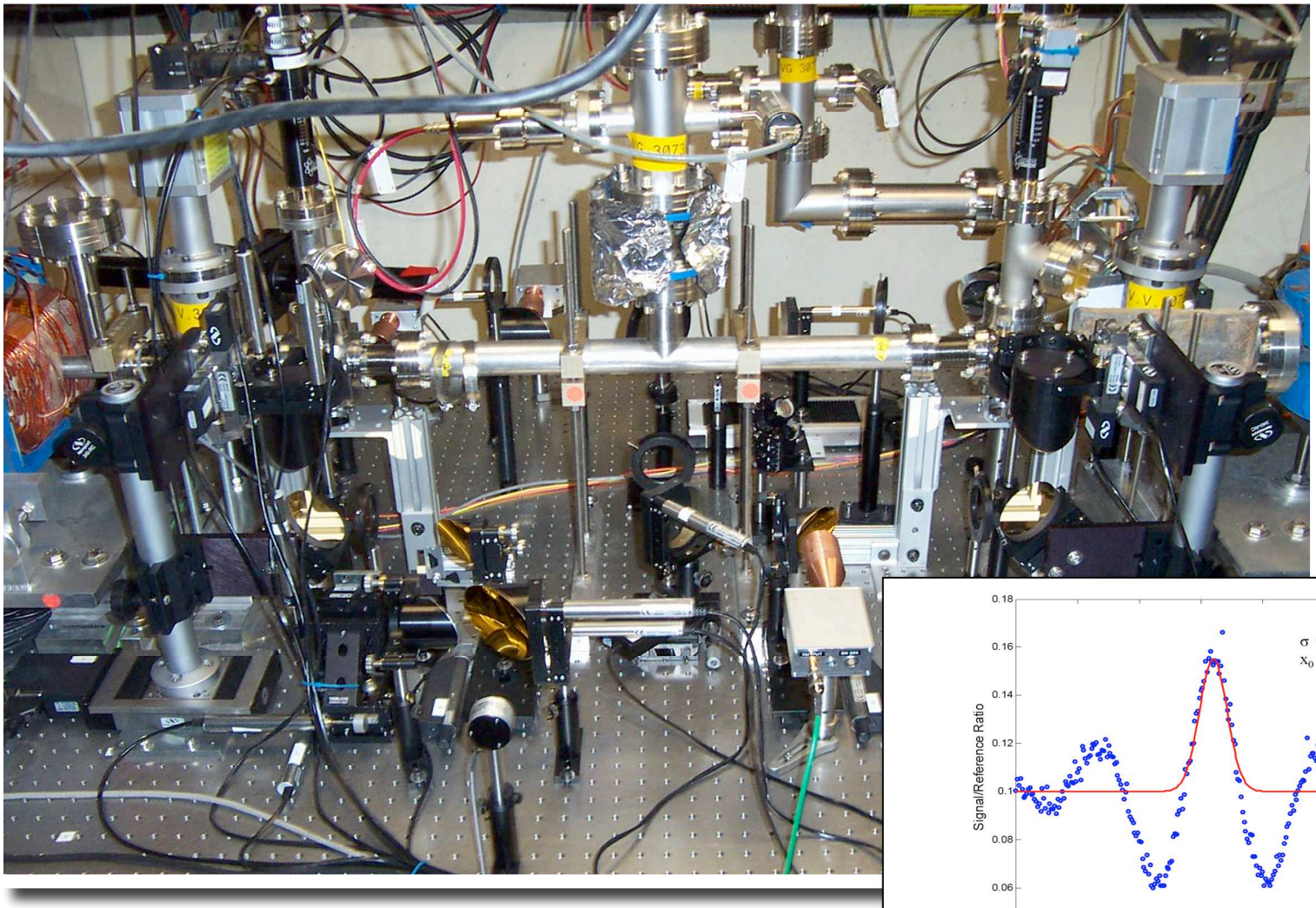
Experimental Installation

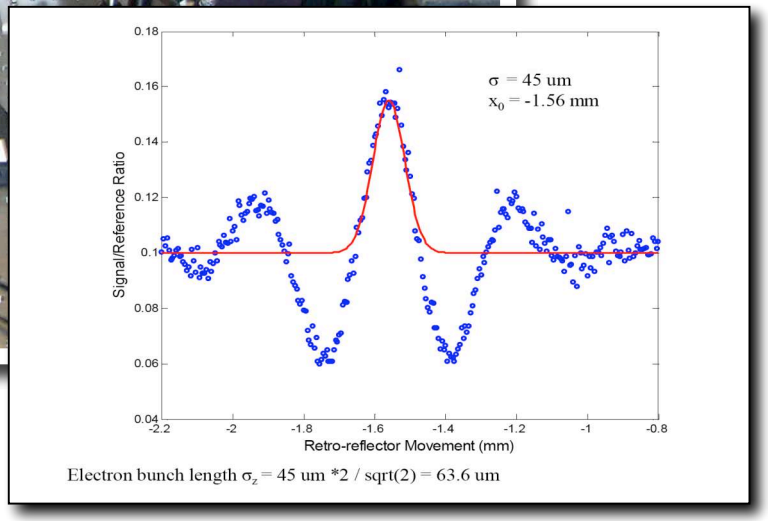


OTR and bunch length monitor



THz table with Michelson Interferometer

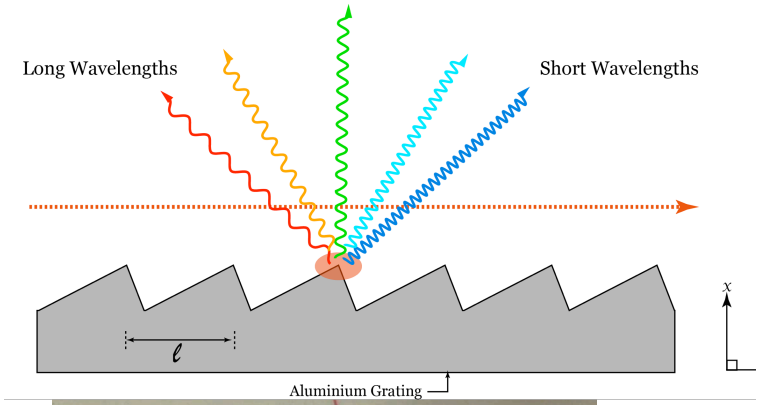


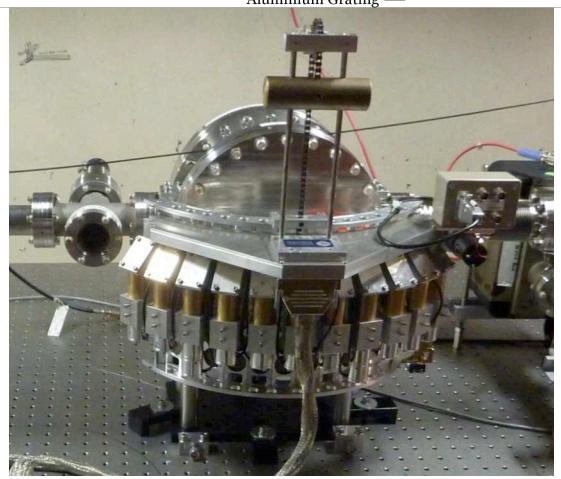


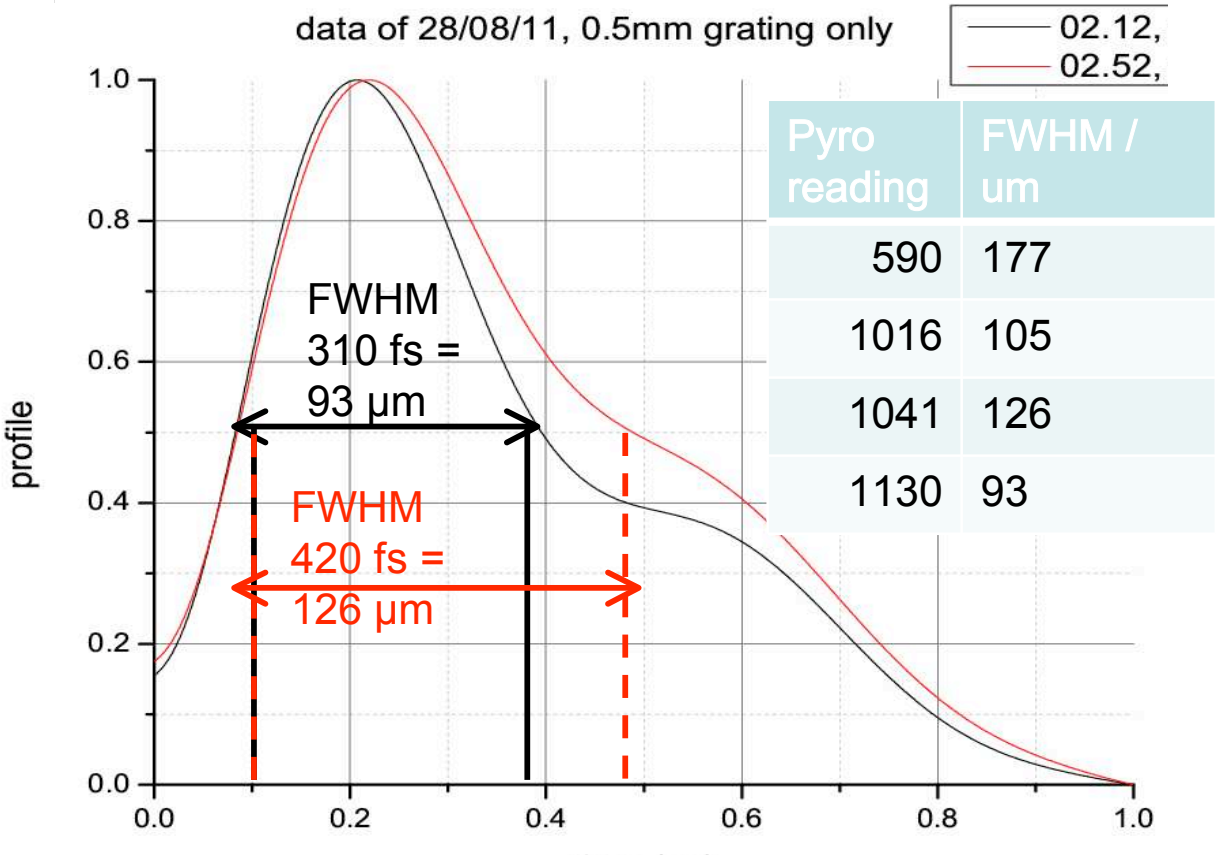
Electron bunch length σ_z = 45 um *2 / sqrt(2) = 63.6 um

E-203 Smith Purcell

- Bunch Time Profile measurements with Coherent Smith-Purcell Radiation
- Over 30 hours of beam-time during User-Aided Commissioning
- Big success: made longitudinal profile measurements in new realm
- Beam requirements very relaxed but they do want to measure down to 50 fs
- Eventually, we would like to integrate this into suite of FACET diagnostics



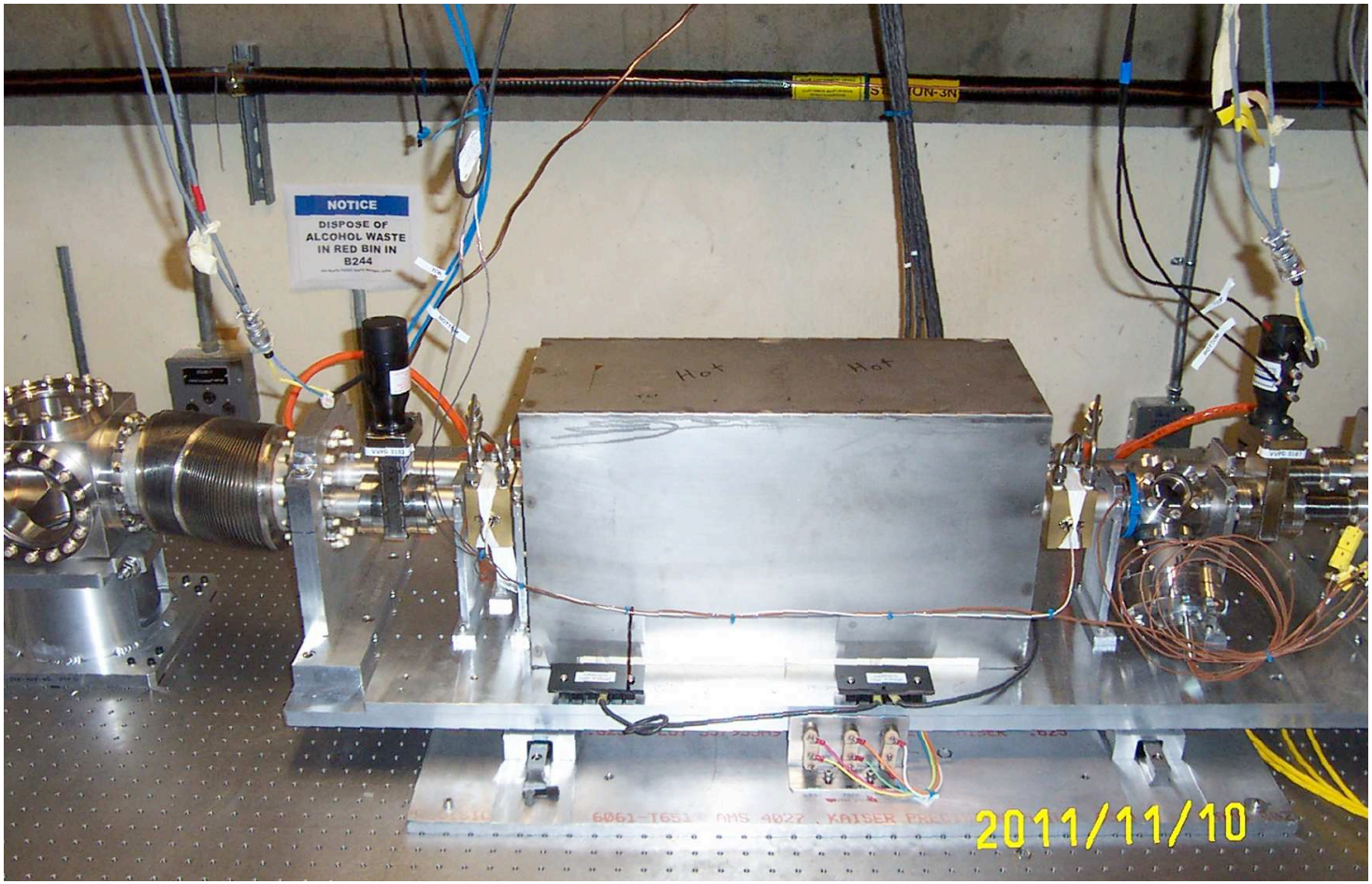




Pyro reading	FWHM / um
590	177
1016	105
1041	126
1130	93

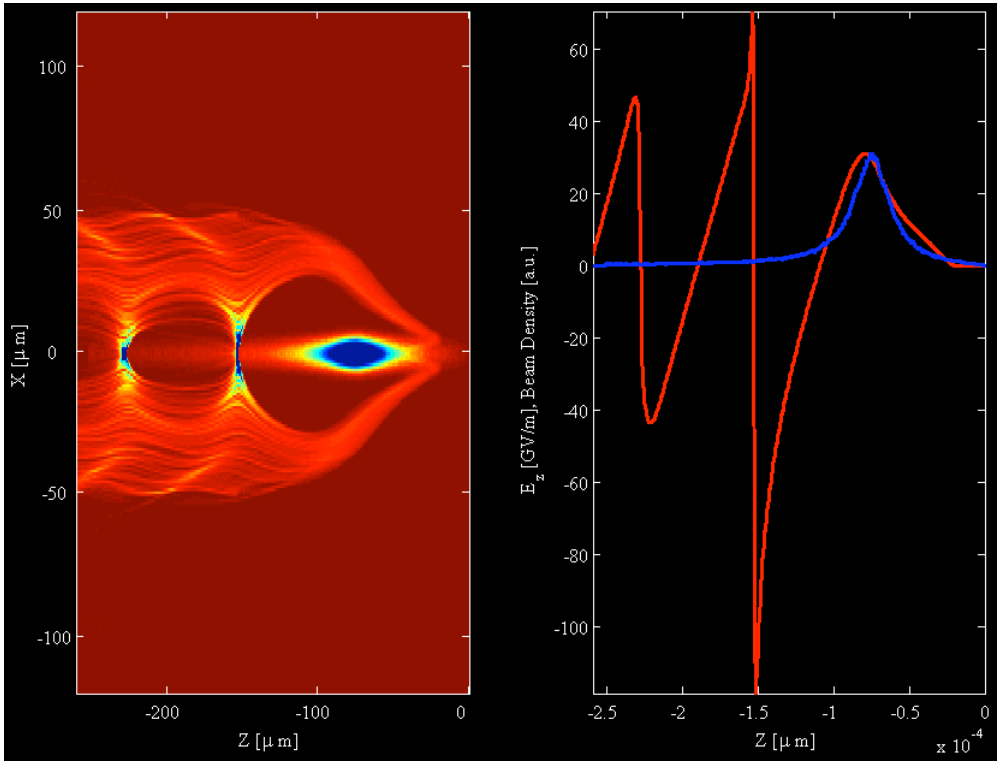
E200 PWFA

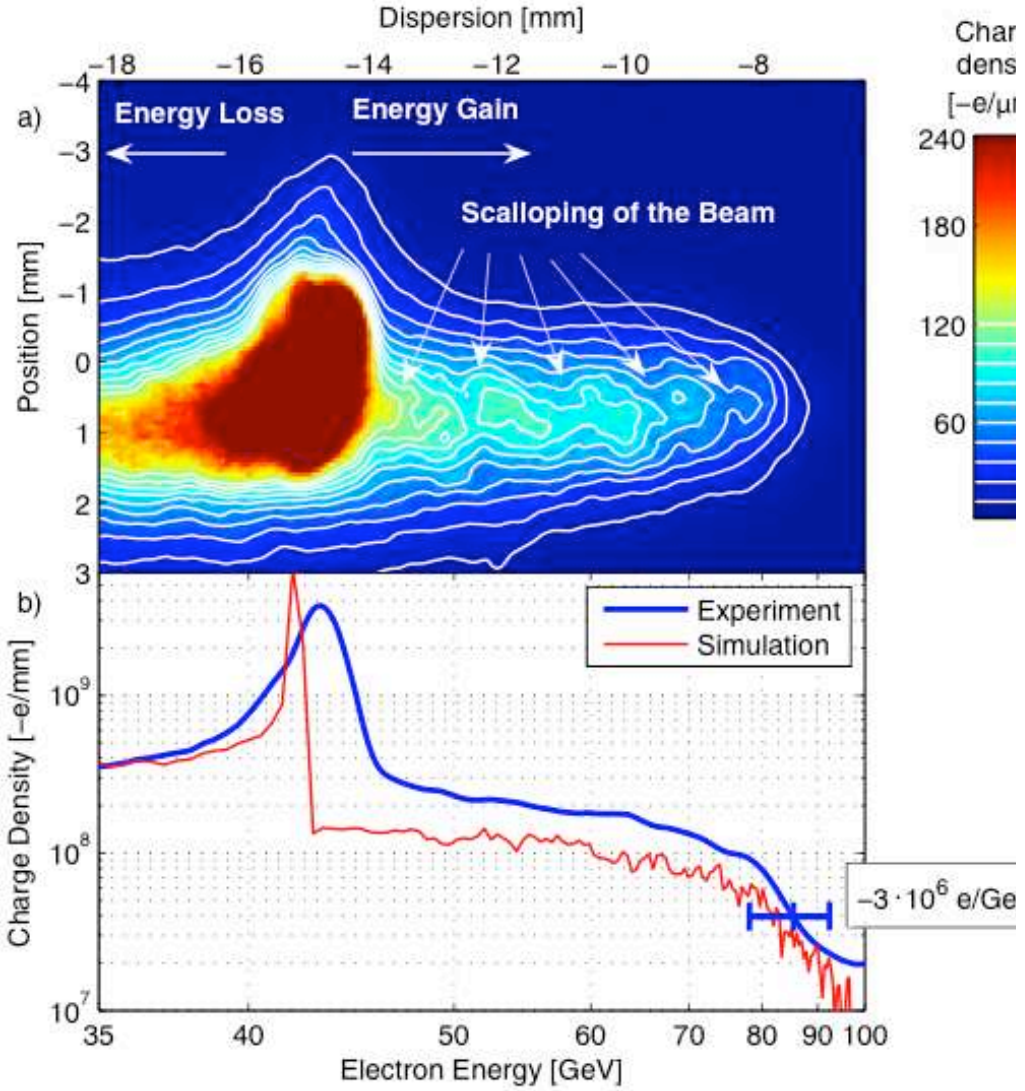
* Engineering run this summer
  – Experimental setup commissioned



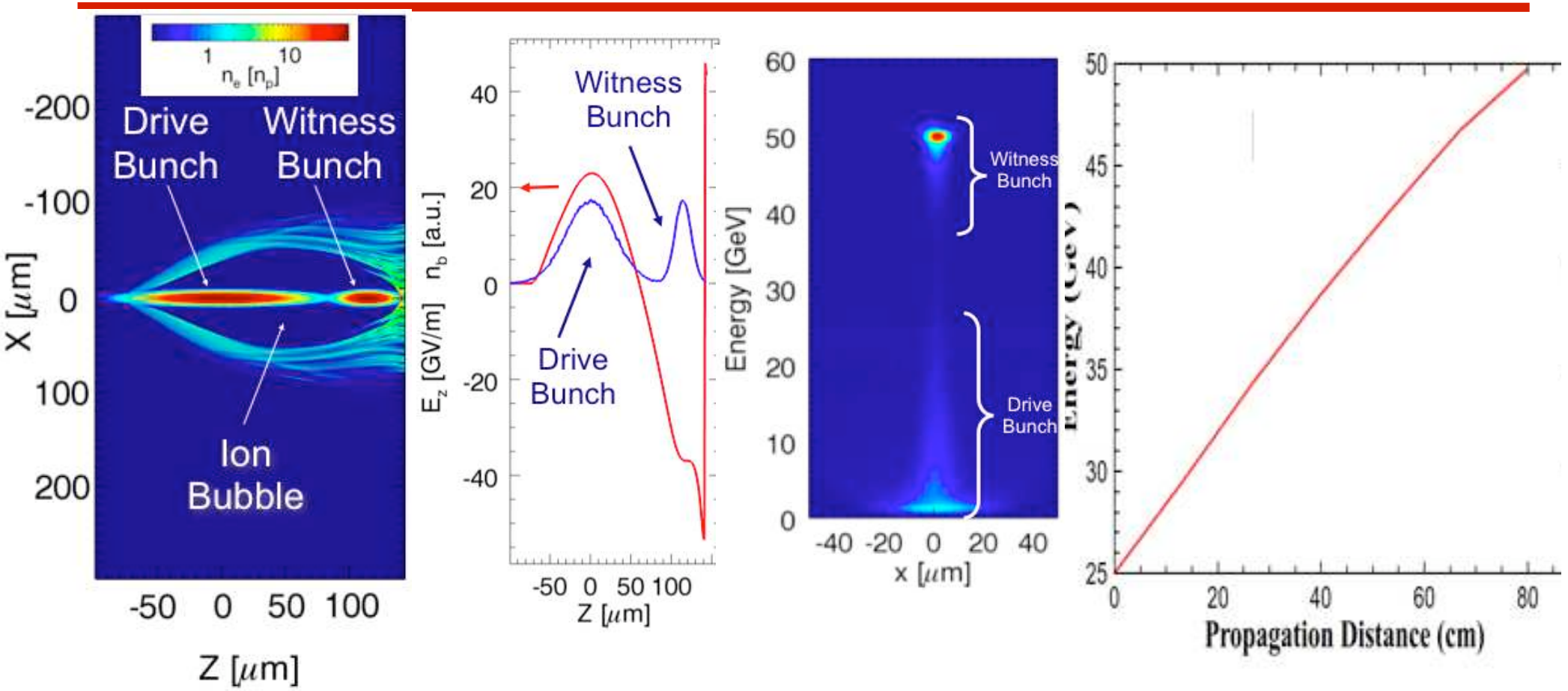
Plasma Wakefield Acceleration

* E-167: Acceleration Gradients of ~50GeV/m (3,000 x SLAC)
  – Doubled energy of 45 GeV electrons in 1 meter plasma
* Single Bunch



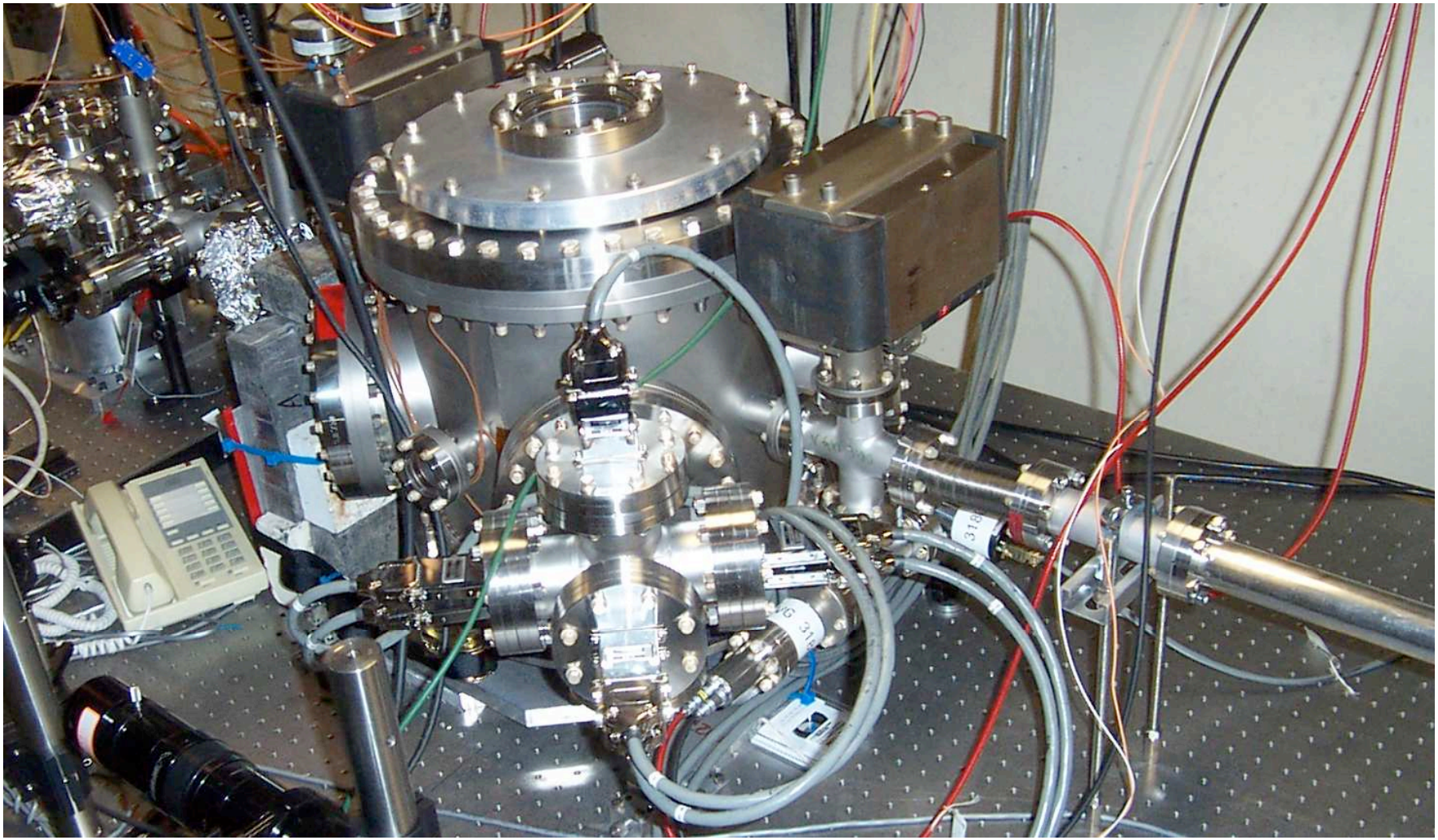


PWFA with "witness bunch"

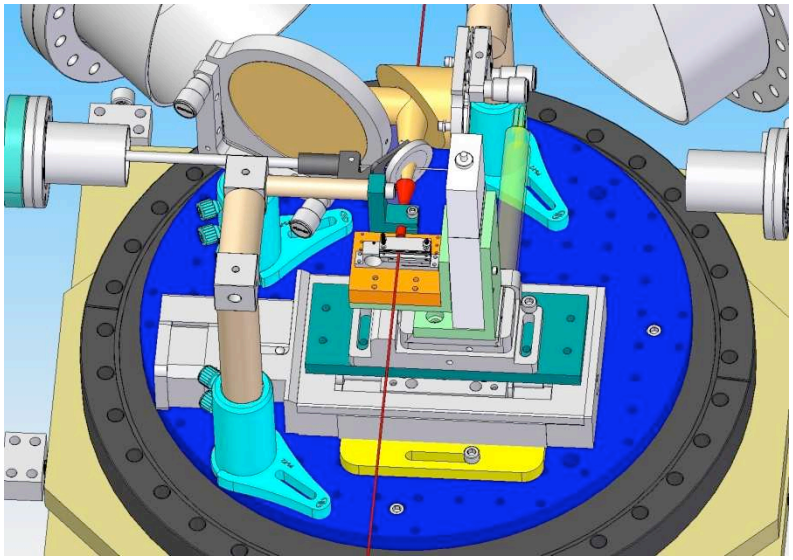


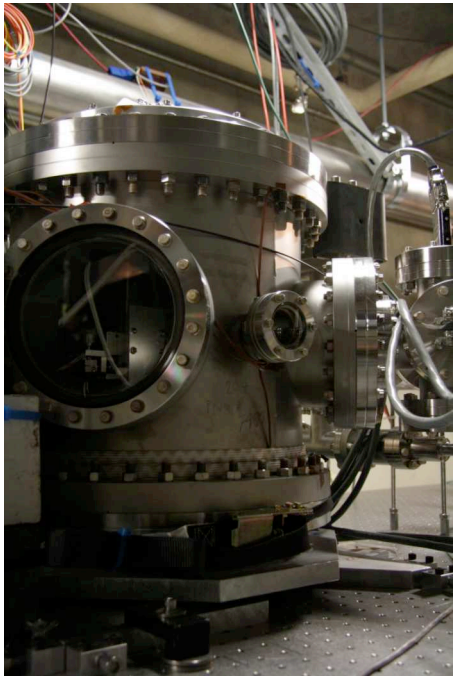
* Beam loading at 37GeV/m (z = 0)
* After 80cm plasma, gain 25GeV with 3% ΔE/E
* Wake evolution due to bunch head erosion, but no dephasing
* Wake evolution "bends" energy gain but preserves low ΔE/E
* Drive to witness Energy transfer efficiency ~ 30%

"Kraken" Chamber



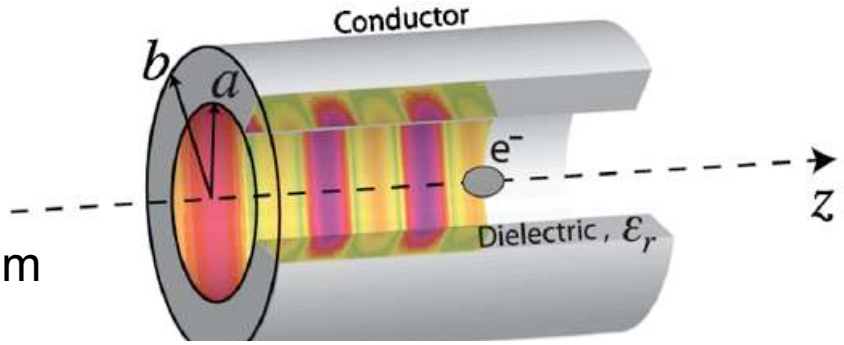
E-201 and E-205 Wakefield Acceleration in Dielectric Structures





* The FACET beam is sent through prototype dielectric wakefield acceleration structures
* For 2012, they will make parametric breakdown studies and lifetime effects
* They will install variable structures (dimensions, materials etc)
* With the use of the notch collimator, they can use drive and witness bunches to observe acceleration
* There is an alignment procedure that was successful at FFTB to ensure the beam passes through the structures with ID 100um

a = 100um to 800um

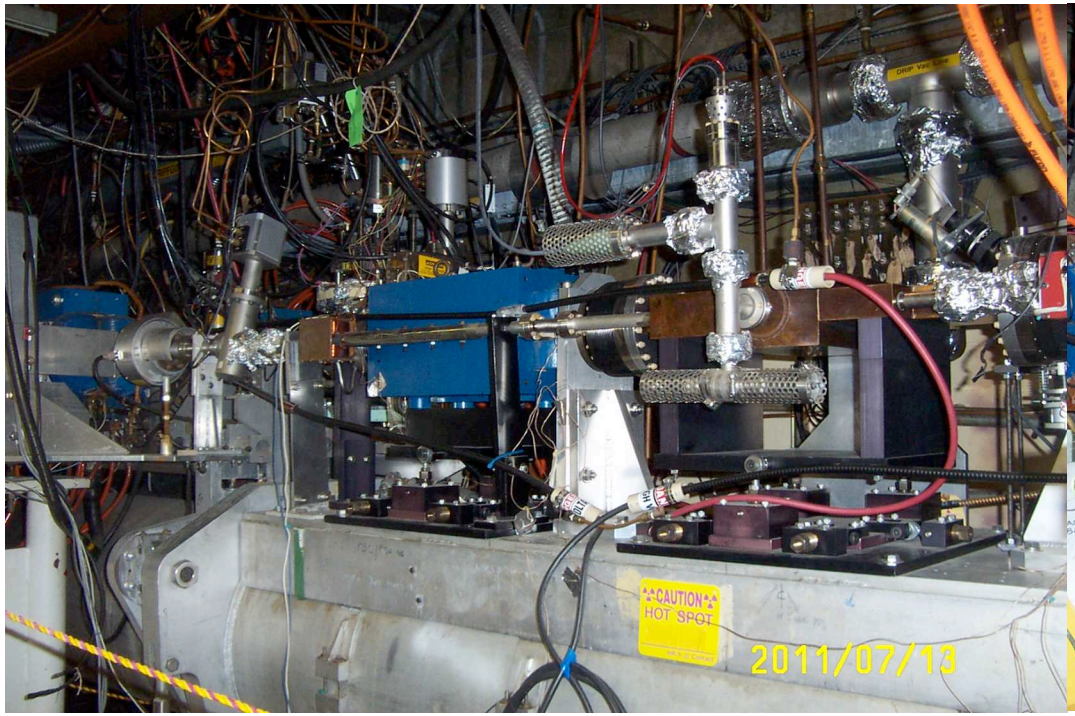


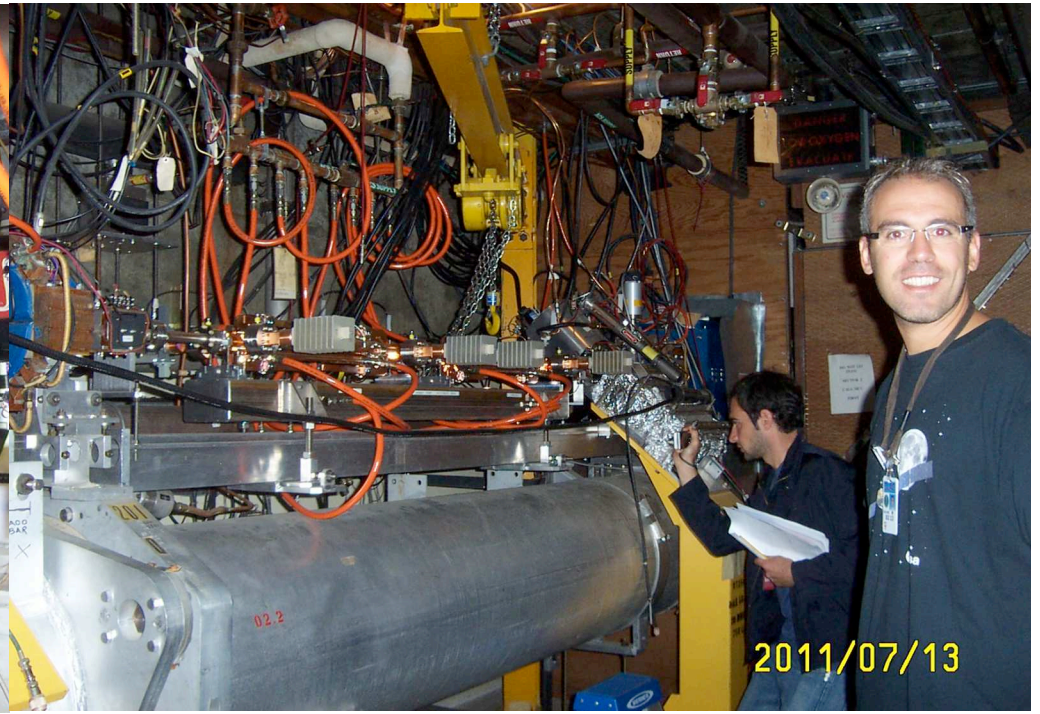
Other Expt. Possibilities

* The ASSET facility for wakefield measurements will be recommissioned
  - proposal to analyse CLIC accel. structures
* We are working with the CTF team to test steering algorithms in the linac
  - could be interesting for FACET operation
* Desire to bring the THz radiation out of the housing
  - allow convenient access to THz for users
  - ≥ 0.6V/Å, brightest source of THz radiation in existence
* Low emittance beam
  - > low-divergence beam (O(1 μr)) is possible (esp. in vertical plane)
* e^- and e^+ beams have very similar characteristics

ASSET

* One bunch (e+) excites wakefields
* 2nd bunch (e–) samples the fields
  – vernier timing between the two
  – use *n* BPMs downstream to increase sensitivity/reduce meas't noise.





FACET Early Beam-Commissioning

* Beam to dump 23-June
  - immediately clear that dipole calibration was not accurate
  - also, relatively heavy beam loss, not easily tuned out.
* “Relaxed lattice” with much less phase advance in *x*
  - allowed steering, aperture scans, reduction of beam loss
  - revealed serious aperture restriction near center of “W”
* Survey of center of “W” found vac. chamber in Q5E-R dislocated by ≈1/2 inch (7-July).
  - supported properly => this restriction no longer present.
* Back to full-strength lattice
  - Some beam loss showed up again; getting about 90% through.
* More work on dipole settings
  - PCD did find issues with the transductor electronics, fixed the BACT–BMON diff (28-July).

Early Beam through FACET

1st beam on June 23 (these pix were taken later)

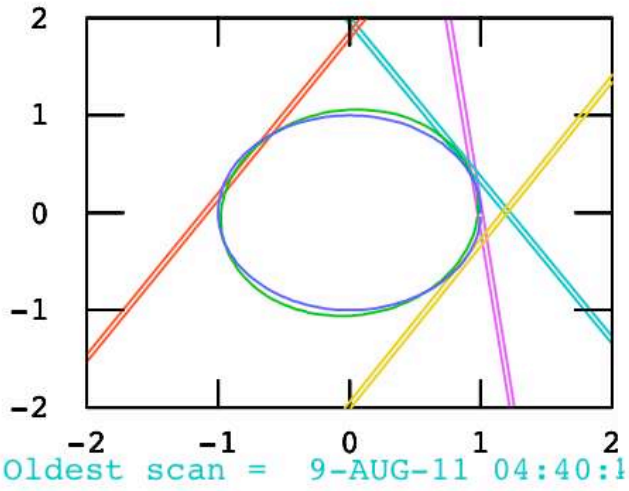
on FACET Dump

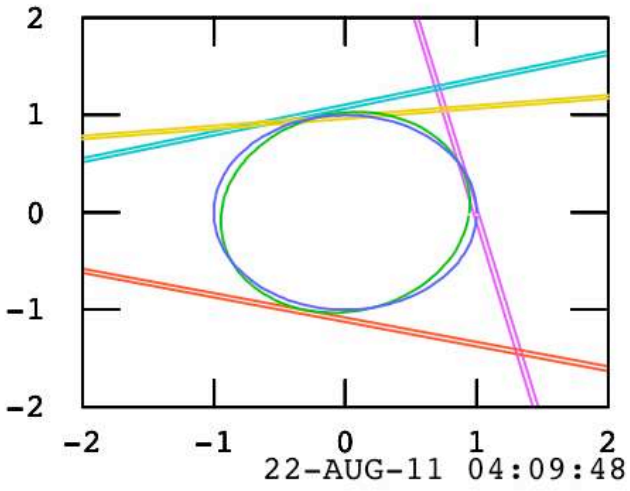
on Exit Window

Sector 02 Emittance

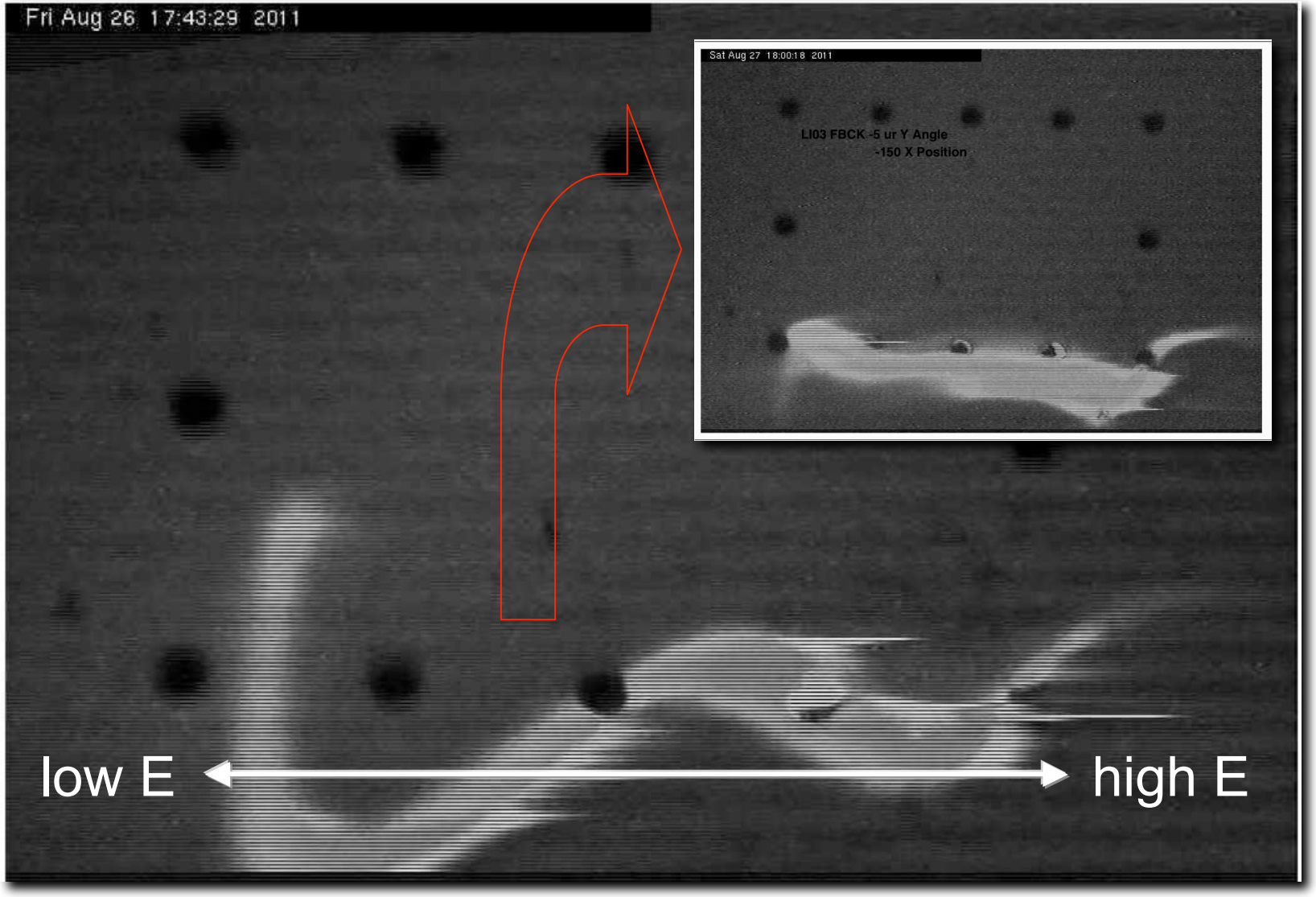
SLC 2-DIMENSIONAL PHASE SPACE ANALYSIS

LI02 X-PLANE ELEC		LI02 Y-PLANE ELEC
3.106+- 0.167 (3.000)	EMITTANCE(mE-5)	0.292+- 0.009 (0.300)
3.122+- 0.186 (3.000)	BMAG*EMIT(mE-5)	0.294+- 0.007 (0.300)
1.005+- 0.010 (1.000)	BMAG	1.008+- 0.010 (1.000)
-0.080+- 0.091 (0.000)	BMAG_COS	-0.086+- 0.034 (0.000)
-0.060+- 0.026 (0.000)	BMAG_SIN	-0.091+- 0.066 (0.000)
14.130+- 1.340 (15.282)	BETA_(m)	6.616+- 0.199 (7.179)
-3.176+- 0.291 (-3.369)	ALPHA	0.394+- 0.076 (0.526)
352.077+- 7.042 (356.827)	SIG(125)(um)	131.046+- 2.621 (135.393)
237.070+- 4.741 (230.382)	SIG(209)(um)	117.754+- 2.355 (112.551)
129.225+- 2.584 (137.319)	SIG(239)(um)	47.598+- 0.952 (44.427)
376.869+- 7.537 (371.774)	SIG(339)(um)	39.229+- 0.785 (40.285)
1.860+- 0.029	INTENSITY	1.964+- 0.025
3.445268	CHISQ/DOF	5.839703
0.000+- 0.012	ASYM(125)	-0.303+- 0.048
-0.055+- 0.021	ASYM(209)	0.103+- 0.012
0.004+- 0.016	ASYM(239)	0.202+- 0.012
0.046+- 0.024	ASYM(339)	0.019+- 0.020





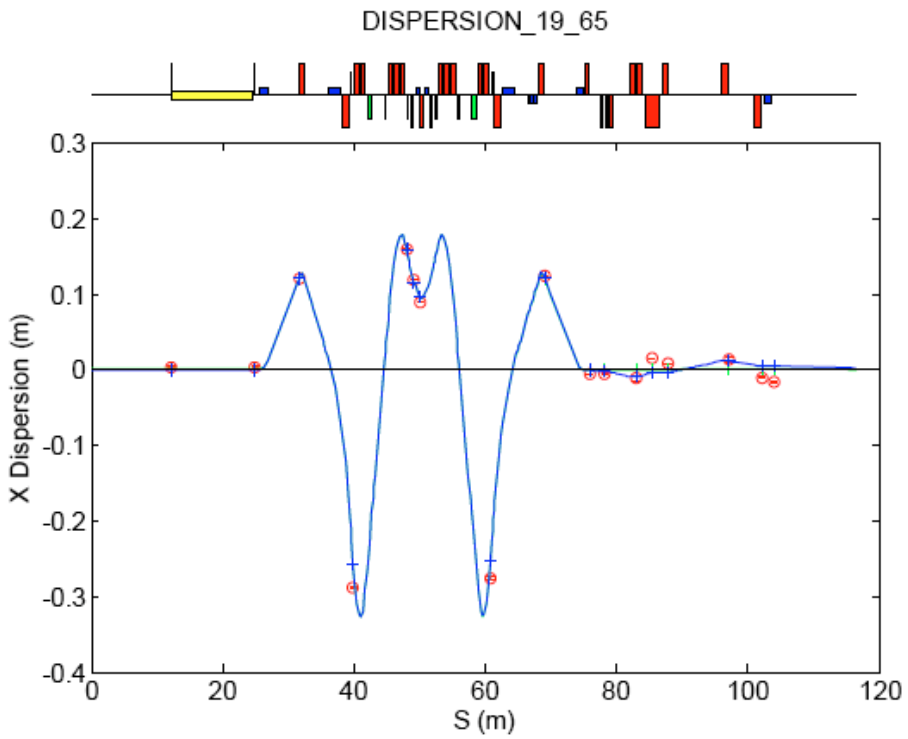
Beam Incoming (PMON)

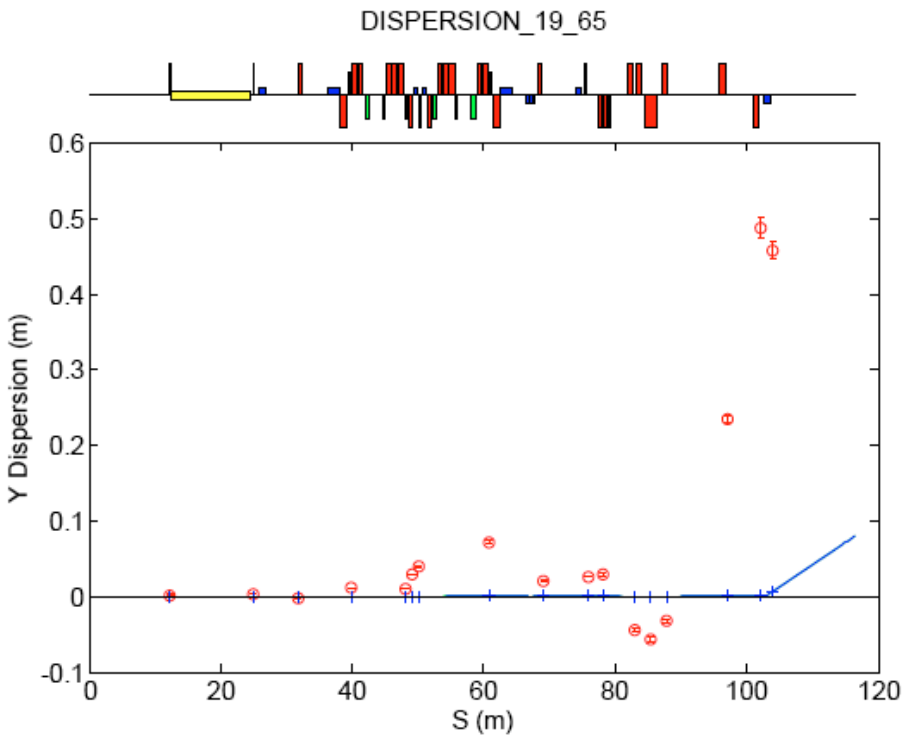


Dispersion for adjusted Focusing

* Note the rather large vertical dispersion.
  – Comparison to MAD results (Nosochkov) indicates S2E

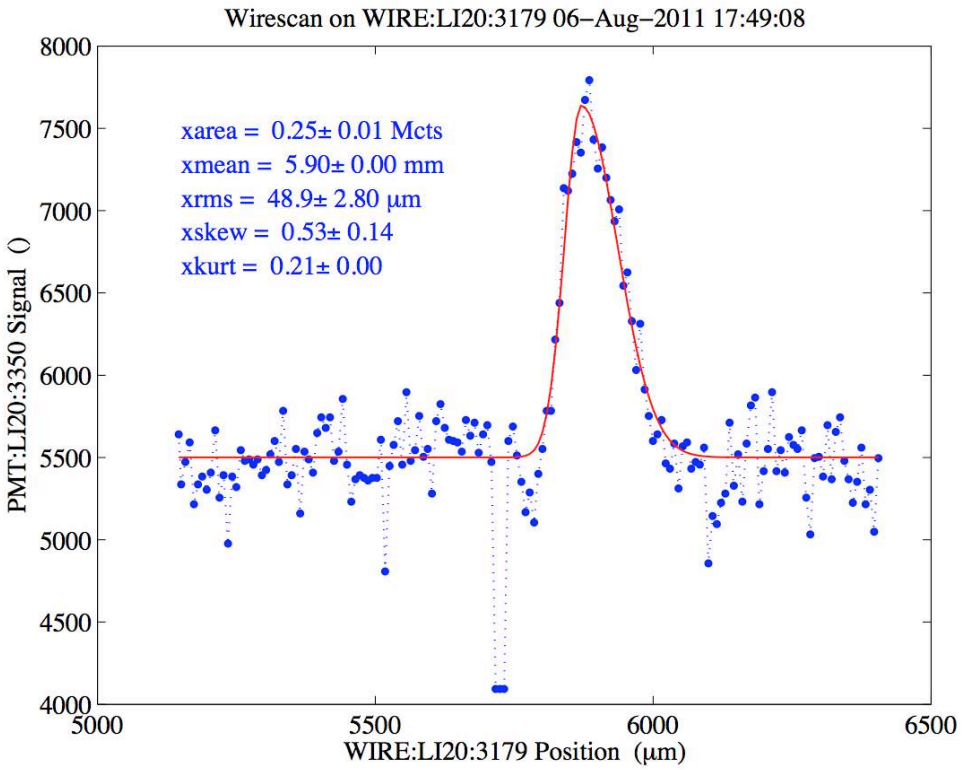
Woodley

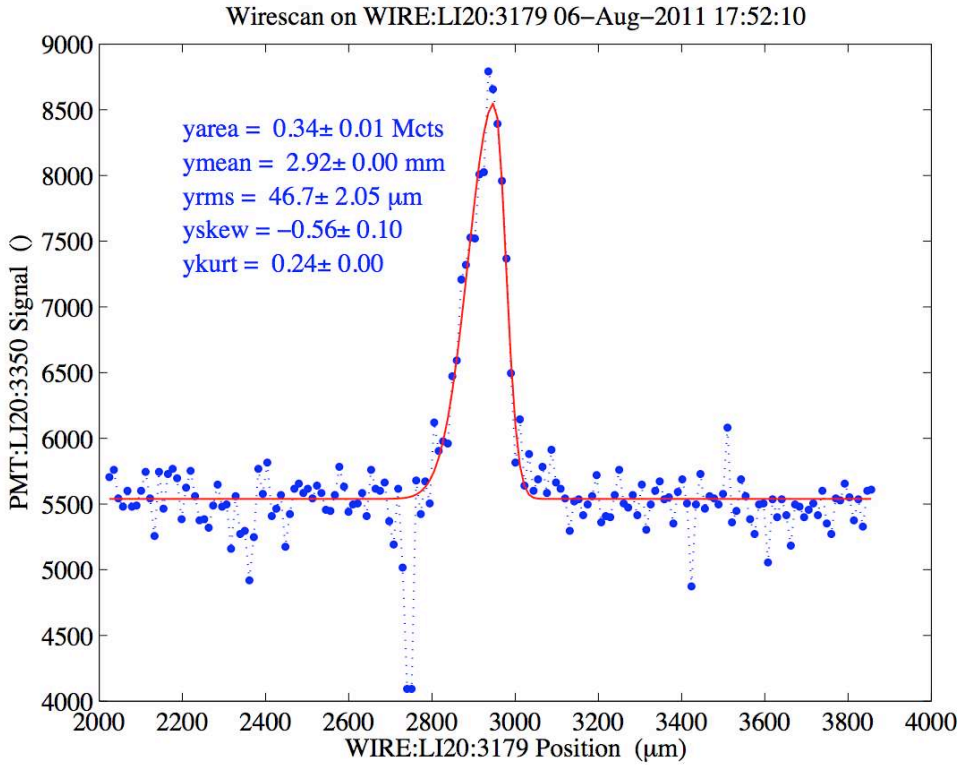




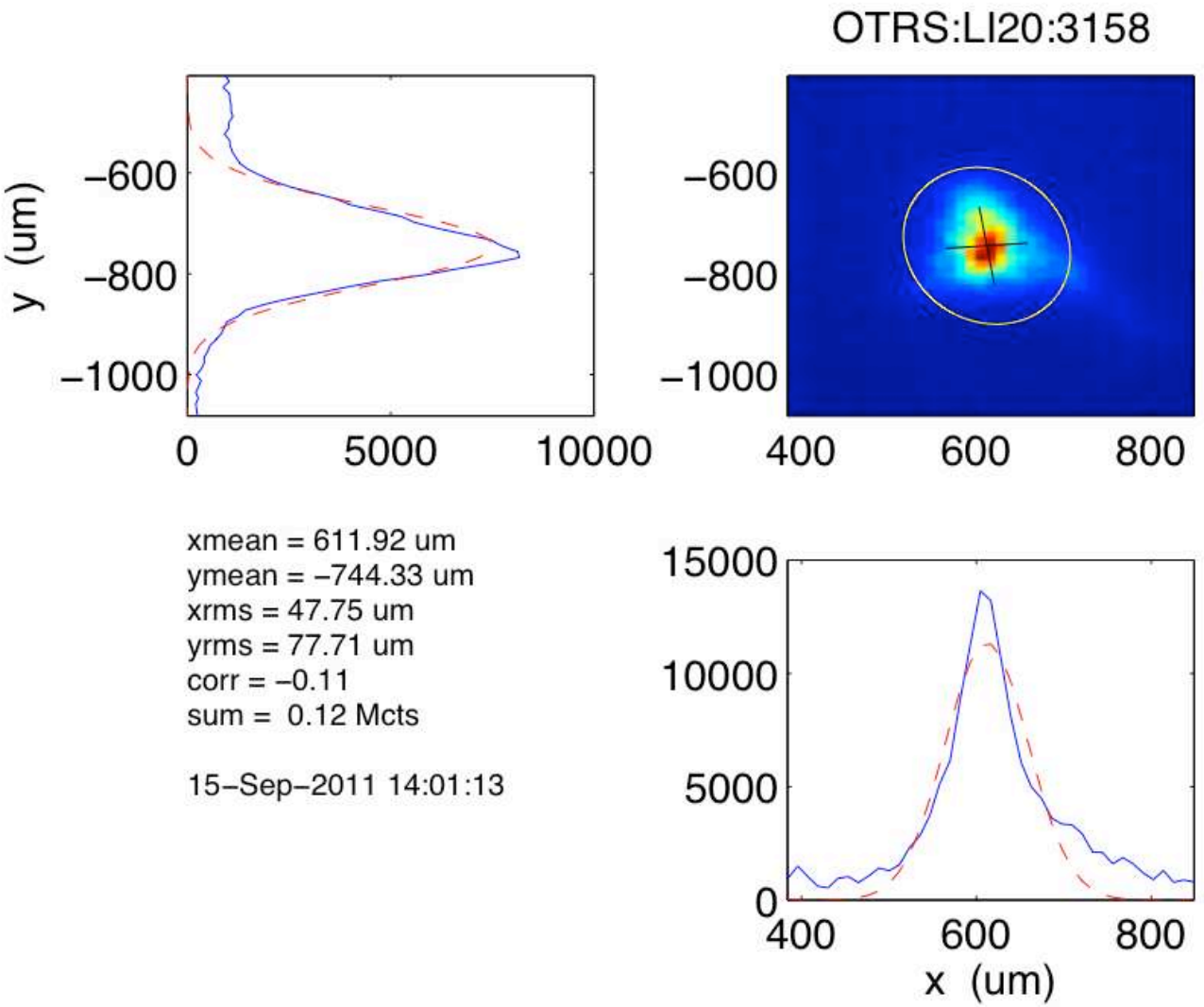
Wirescans @ IP

* Note: the best ones were 30 μm by 32 μm

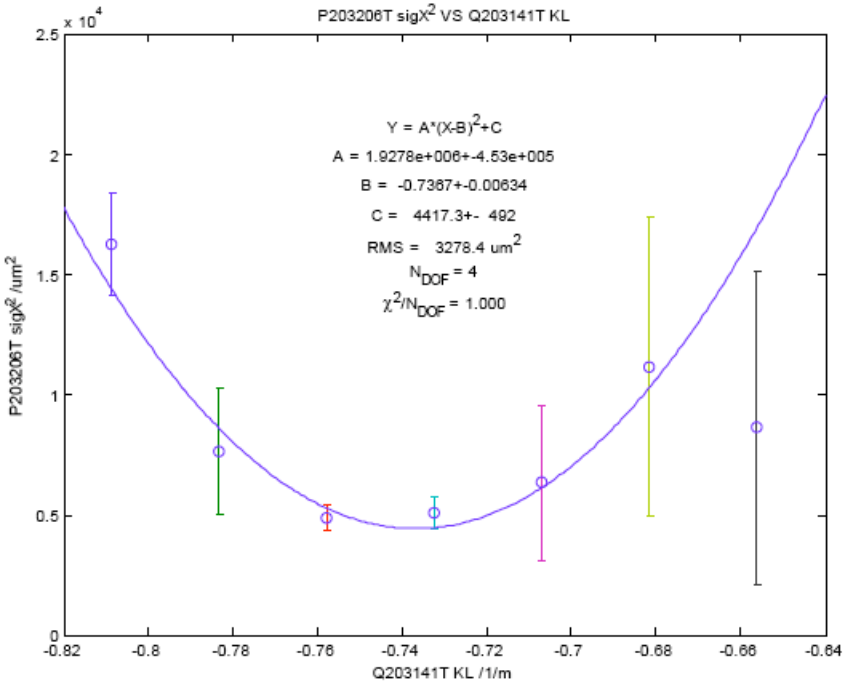


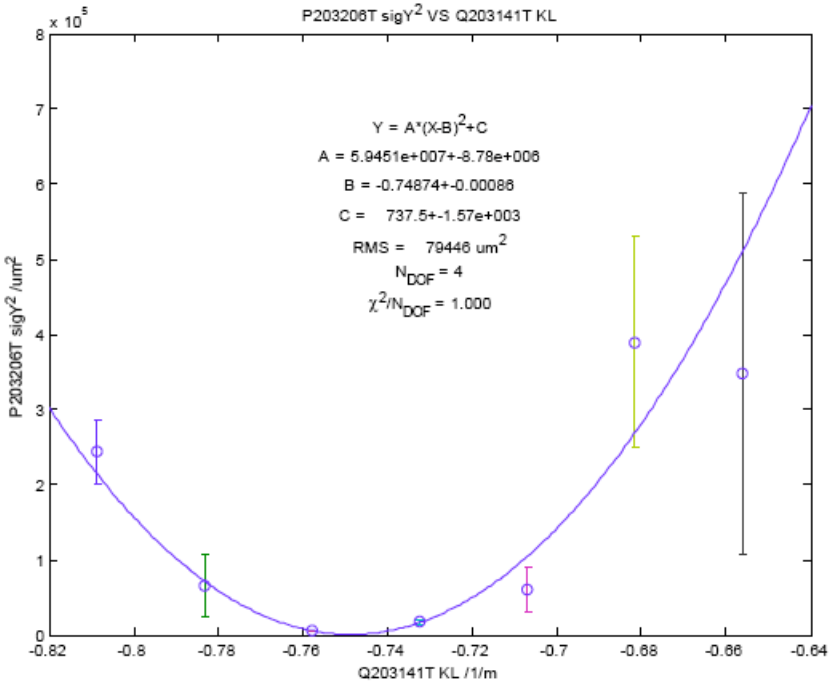


US OTR Readout



Beam emittance in S20 (DSOTR)





asymmetric

asymmetric

X emittance parameters at upstream end of Q203141T

THICK LENS

energy	=	19.650			GeV	
emit	=	1.323e-008	+-	1.465e-009	m	
emitn	=	5.088e-004	+-	5.635e-005	m	
emitn*bmag	=	2.550e-001	+-	4.949e-002	m	
bmag	=	501.094	+-	57.302		(1.000)
bmag_cos	=	-1.000	+-	0.000		(0.000)
bmag_sin	=	-0.010	+-	0.000		(0.000)
beta	=	23.594	+-	3.049	m	(875.749)
alpha	=	6.836	+-	0.925		(442.991)

Y emittance parameters at upstream end of Q203141T

THICK LENS

energy	=	19.650			GeV	
emit	=	2.659e-009	+-	3.253e-009	m	
emitn	=	1.022e-004	+-	1.251e-004	m	
emitn*bmag	=	4.196e-003	+-	7.290e-004	m	
bmag	=	41.047	+-	56.188		(1.000)
bmag_cos	=	-0.965	+-	0.000		(0.000)
bmag_sin	=	0.261	+-	0.000		(0.000)
beta	=	240.468	+-	326.489	m	(167.548)
alpha	=	-94.309	+-	127.861		(-73.175)

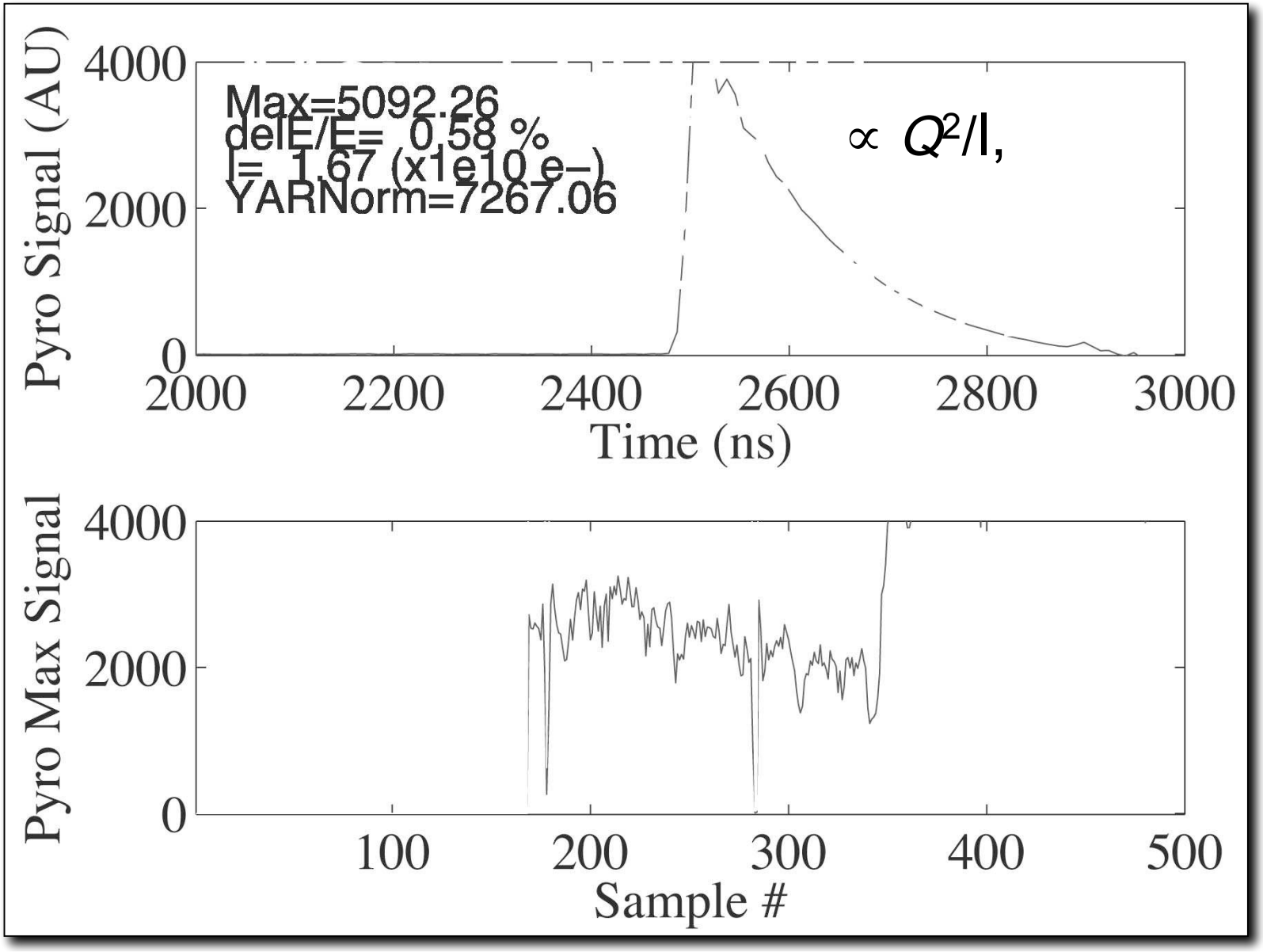
Tracking Performance (Design)

* Elegant, 23 GeV, $\varepsilon_{x,y}$=50 by 5 μmr, β^*=1.5 by 15 cm.
  - blue, green numbers include tails

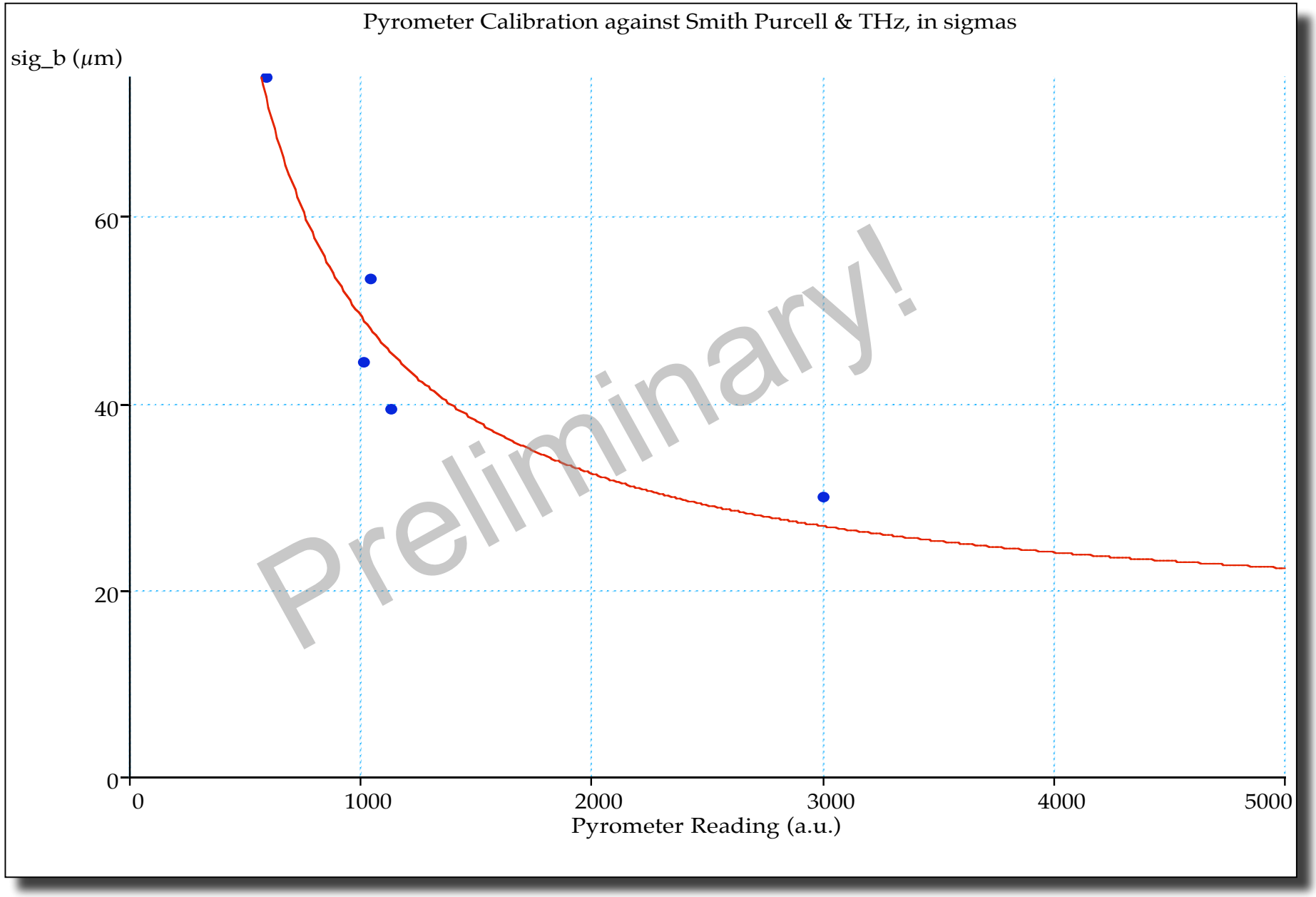
			No SR and Δ p/p = 0 (sext geometric)	No SR (chrom + sext geom)	+ISR	+ISR + CSR
Gaussian fit rms	σ_x	μm	4.4	8.2	11.6	15.0
	σ_y		4.1	7.0	7.1	7.1
Full rms	σ_x	μm	4.7	16.0	17.1	19.9
	σ_y		4.1	19.4	19.3	19.2
	$\gamma\varepsilon_x$	μm-rad	54.2	176.6	194.8	246.0
	$\gamma\varepsilon_y$		5.1	30.2	30.0	30.1

Thermoelectric Pyrometer

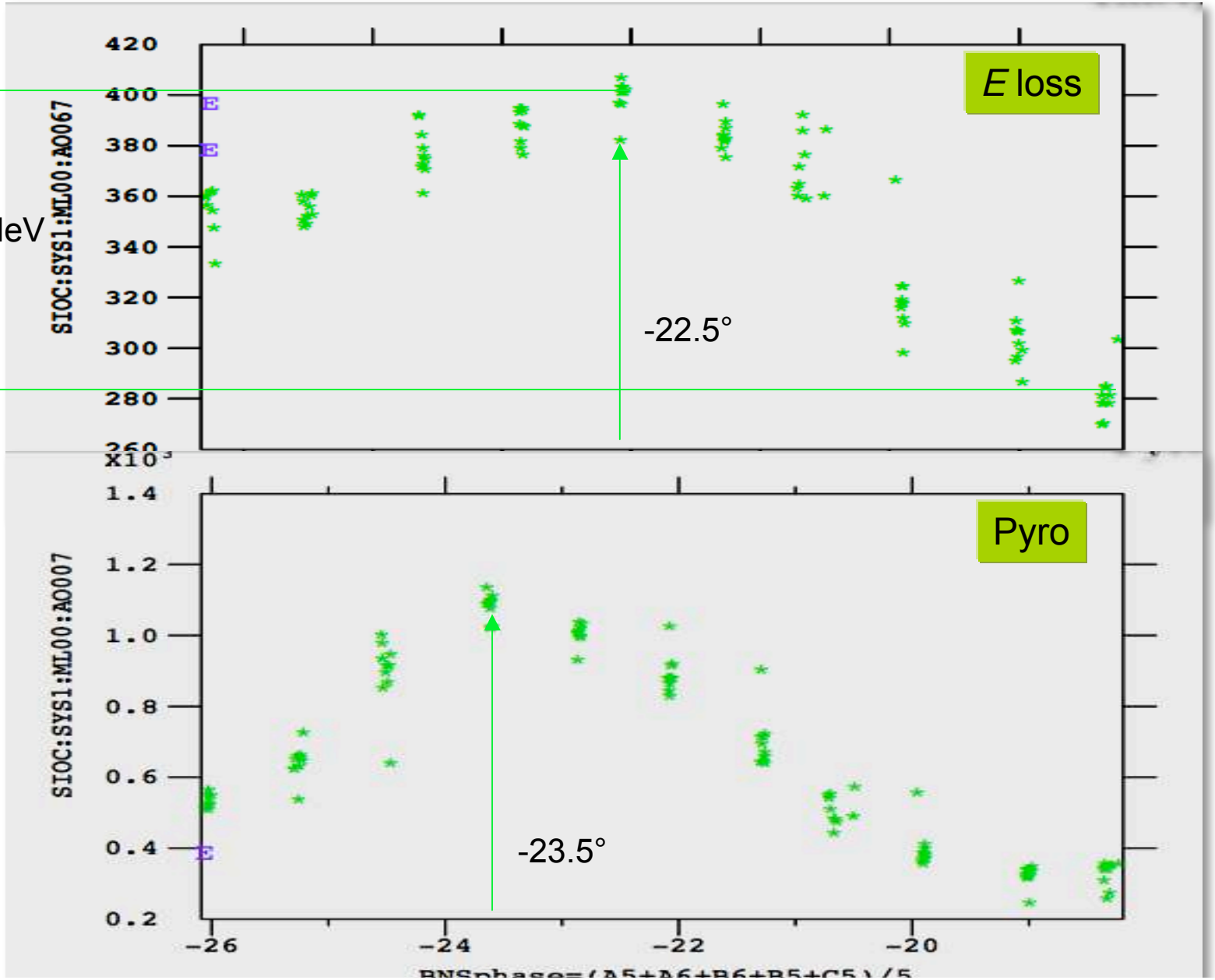
5000≈25μm
(±25%)



Pyrometer Calibration (prelim)



Wake loss Scan



FACET Beam Parameters Achieved to Date

SLAC NATIONAL ACCELERATOR LABORATORY

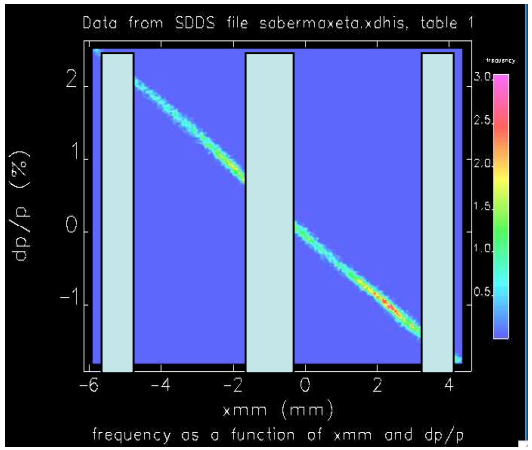
after about 2.5 months of beam commissioning		achieved
Energy	23 GeV	20.8 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+	2.0 x 10^{10} e^-
Pulse length at IP (σ_z)	15 – 40 μm	≈25 μm (THz), wakeloss similar to FFTB
Spot size at IP ($\sigma_{x,y}$)	10 – 20 μm	30…50 μm compressed 16 by 35 μm low Espread
Repetition rate	1 – 30 Hz	10 Hz (ALARA)
Momentum spread	4 – 0.5%	3% fw PR185, SYAG
Momentum dispersion at IP (η and η')		$\eta \approx 0.004$ m

Performance Upgrades

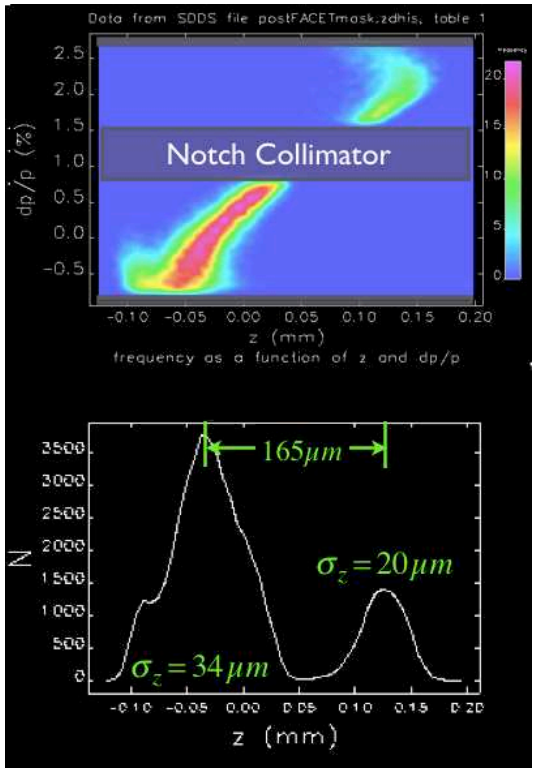
* Presently installing e+ chicane in S10
  - e^- or e^+ through Chicane, but not both
* Project to install a transverse X-band cavity for direct bunch length & distribution measurement
* Install wirescanner & BLM in linac S18
  - also separate power for 4 quads for ε scans & improving match.
* Provide movers for S2E sextupoles
  - use extant FFTB units, want BPMs there as well
* Add more toroids to improve accuracy of charge meas't.

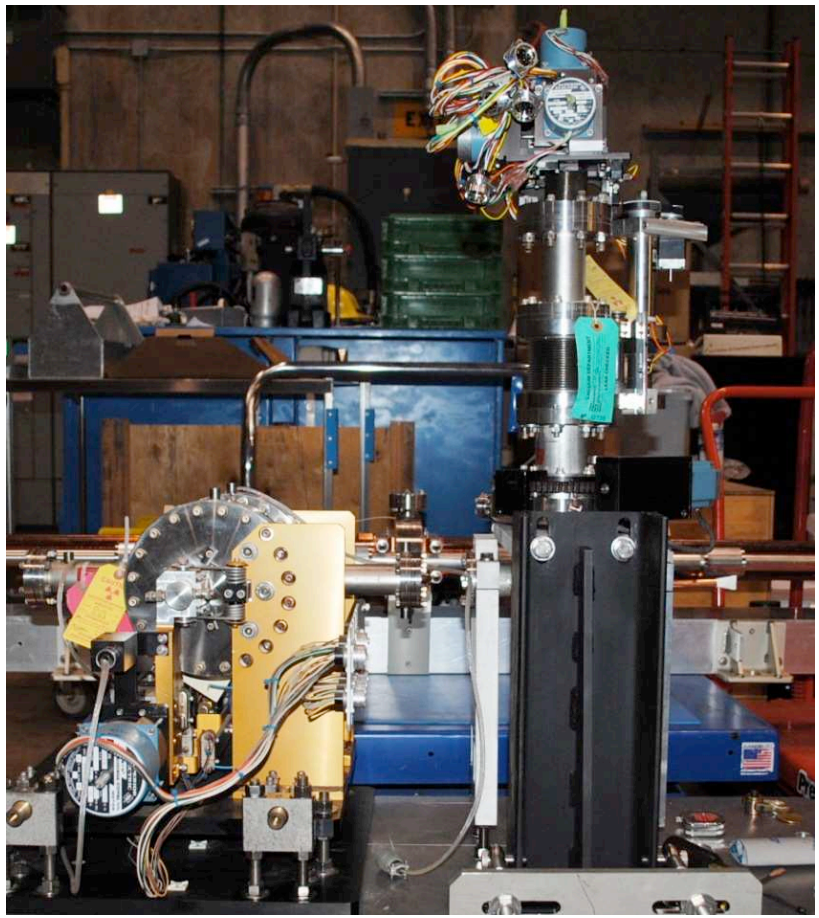
E-200 Notch and Jaw Collimator

* Used at FFTB, the Notch Collimator can “chop” the beam into two bunches and the Jaw Collimator can shape it
* This will be installed this downtime
* 2012 E-200 beam-time will commission the collimators
* The Notch and Jaw Collimators can be used by most experiments at FACET



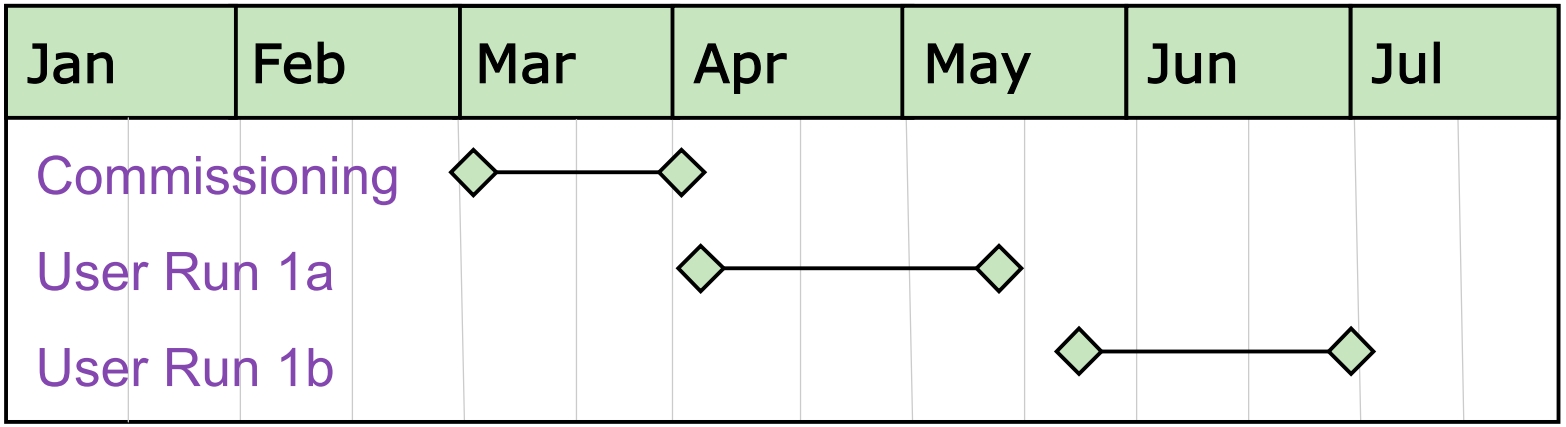
Selectively collimate in first leg of chicane





2012 Schedule

* 5 weeks of commissioning + 10 weeks of User run time
* An installation period will separate two User Runs to give the opportunity to install newly approved experiments and instrumentation
  – TCAV to be installed in this installation period in 2012
* We will have access at least one day a week (every Wednesday)
  – Need to change-over E-202 samples every week (4-5 hours)
* Some experiments will require daily accesses
* Machine Development periods initially every week
* Tuning will occur as a part of experimenter shifts



Out Year Running

* We are asking for sufficient funds to run 4 months/year
  - "User Facility" status will help with funding
* We need to commission the positrons
  - in 2012 not sufficient funds to do this without compromising electron operation
  - in 2013 the e^+ will likely get higher priority
* Yearly proposal cycle will continue
  - Proposals due mid-October, SAREC review late January
* Further upgrades will be pursued
  - e.g. increase intensity to 4E10/bunch
  - e^+ "Sailboat" chicane in S20 (pending funding)
* At present, FACET has a projected lifetime of 5 years
  - in 2017, LCLS II may claim the middle km of the linac
  - We will be ready with a proposal for "FACET II" in S09 of the linac…

Conclusion

* FACET has had a good startup
  - Close to desired beam parameters after a shortened commissioning period
* 1st round of experiments is installed, received beam
  - some already have physics data & are writing papers
* 2012 Run has been scheduled
  - 5 wks startup & beam commissioning, then physics running
* New proposals (≈ 5) will be reviewed at the end of January
  - to be scheduled as machine time and readiness permit.
* For more info re. proposal process, contact
  - Christine Clarke (cclarke@slac.stanford.edu), FACET User Mgr.
  - or yours truly (uli@slac.stanford.edu)

FACET is Open for Business!