FACET Design & Exp. Facilities Beam-Commissioning Status

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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

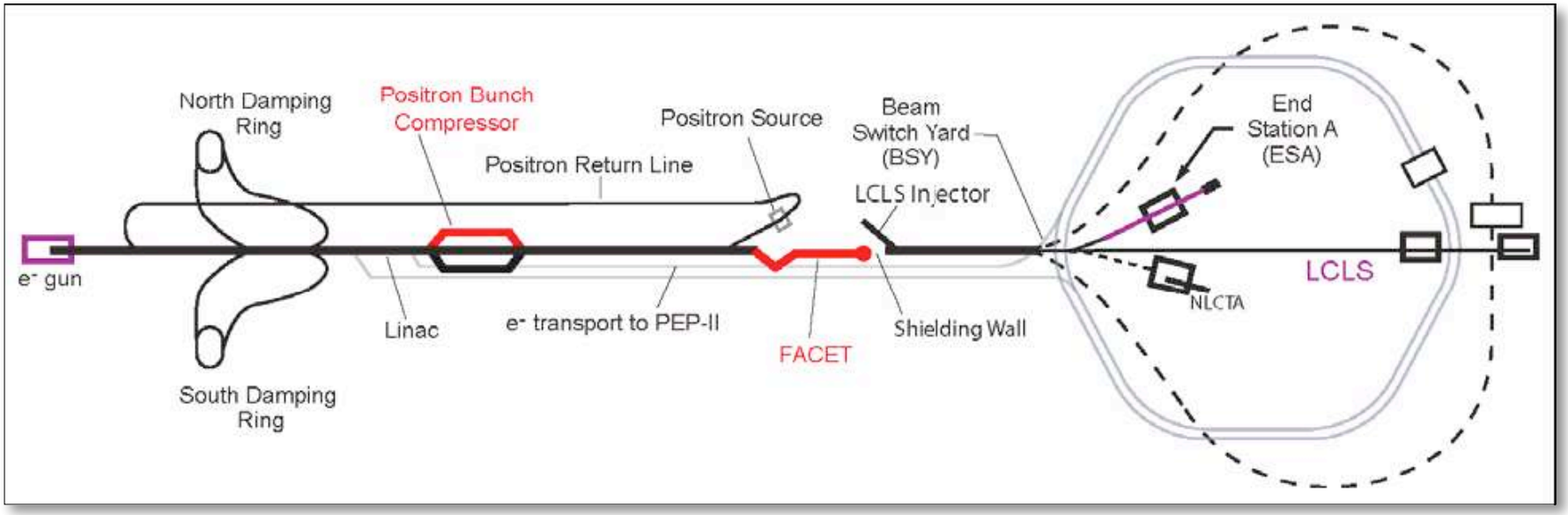
* The primary goal of FACET is proof in principle that plasma acceleration can accelerate a bunch
  - characterize the mechanism under beam loading
  - estimate parameters of the accelerated (witness-) bunch
  - estimate the efficiency and gradient reachable in practice
  - demonstrate acceleration of 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

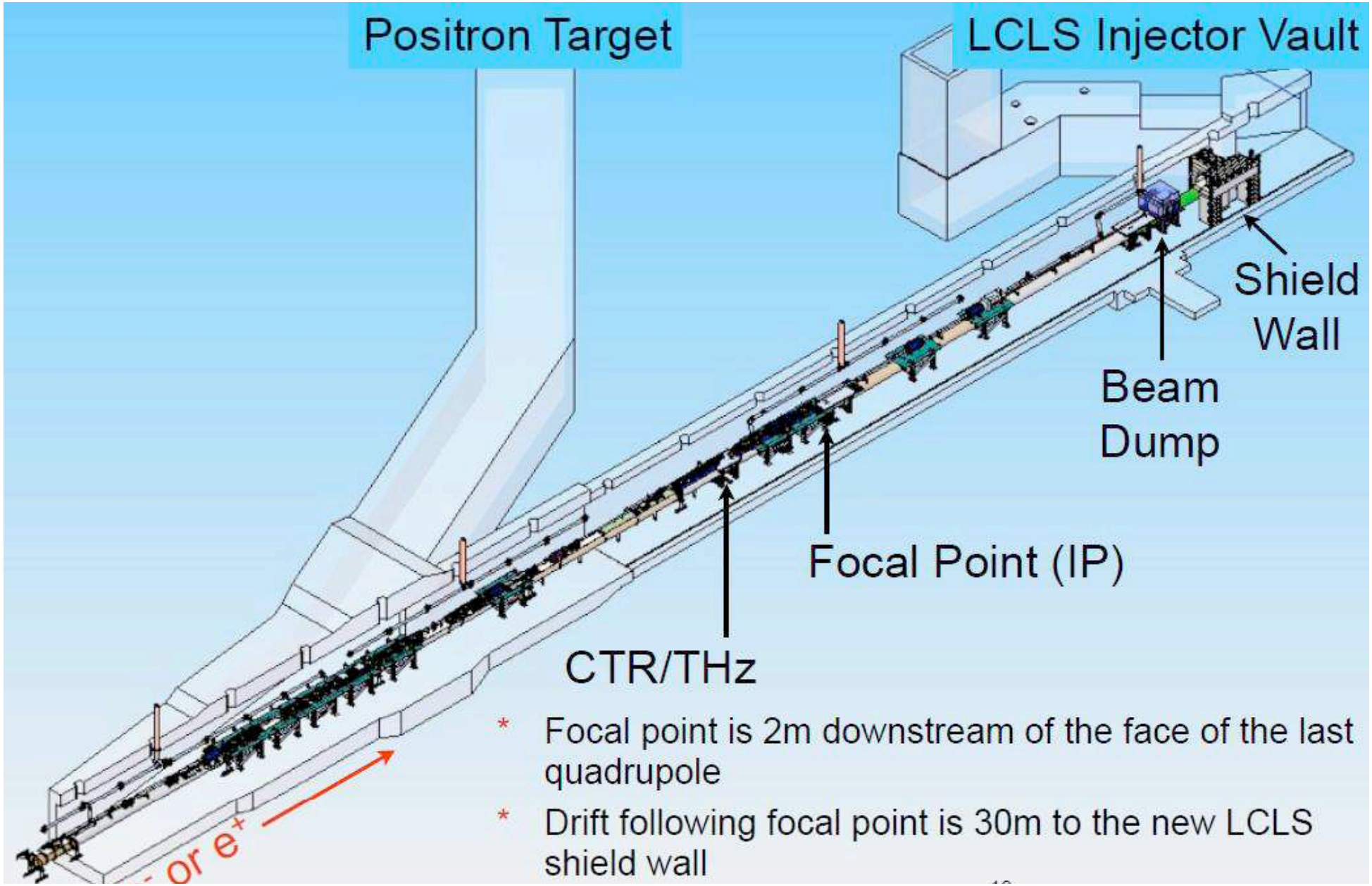
Energy	23 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+
Peak current	20 kA
Pulse length at IP (σ_z)	15 – 40 μm
Typical spot size at IP ($\sigma_{x,y}$)	10 – 20 μm
Repetition rate	1 – 30 Hz
Momentum spread	4 – 0.5% full width

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^+

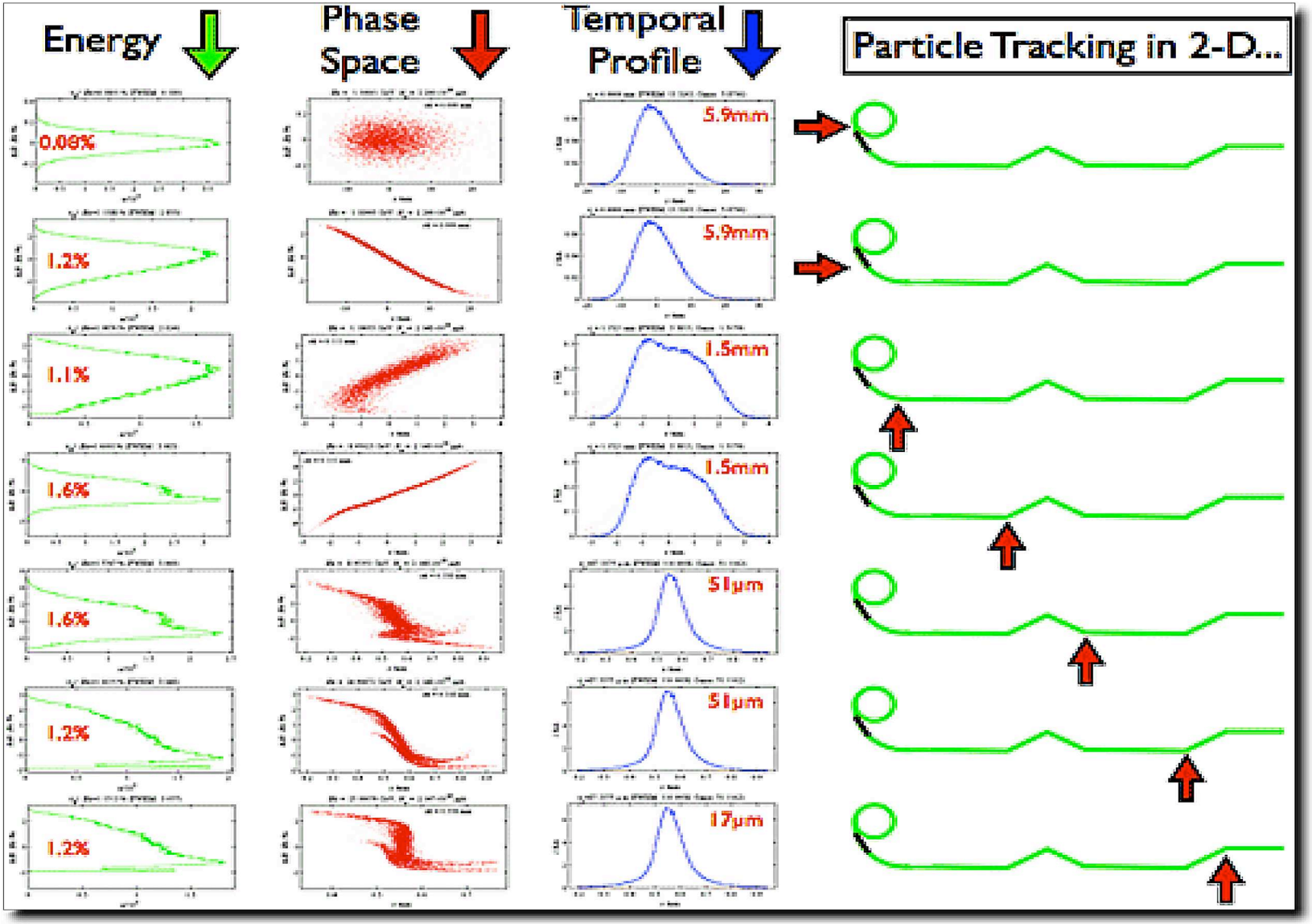


Iso Rendering of FACET in S20



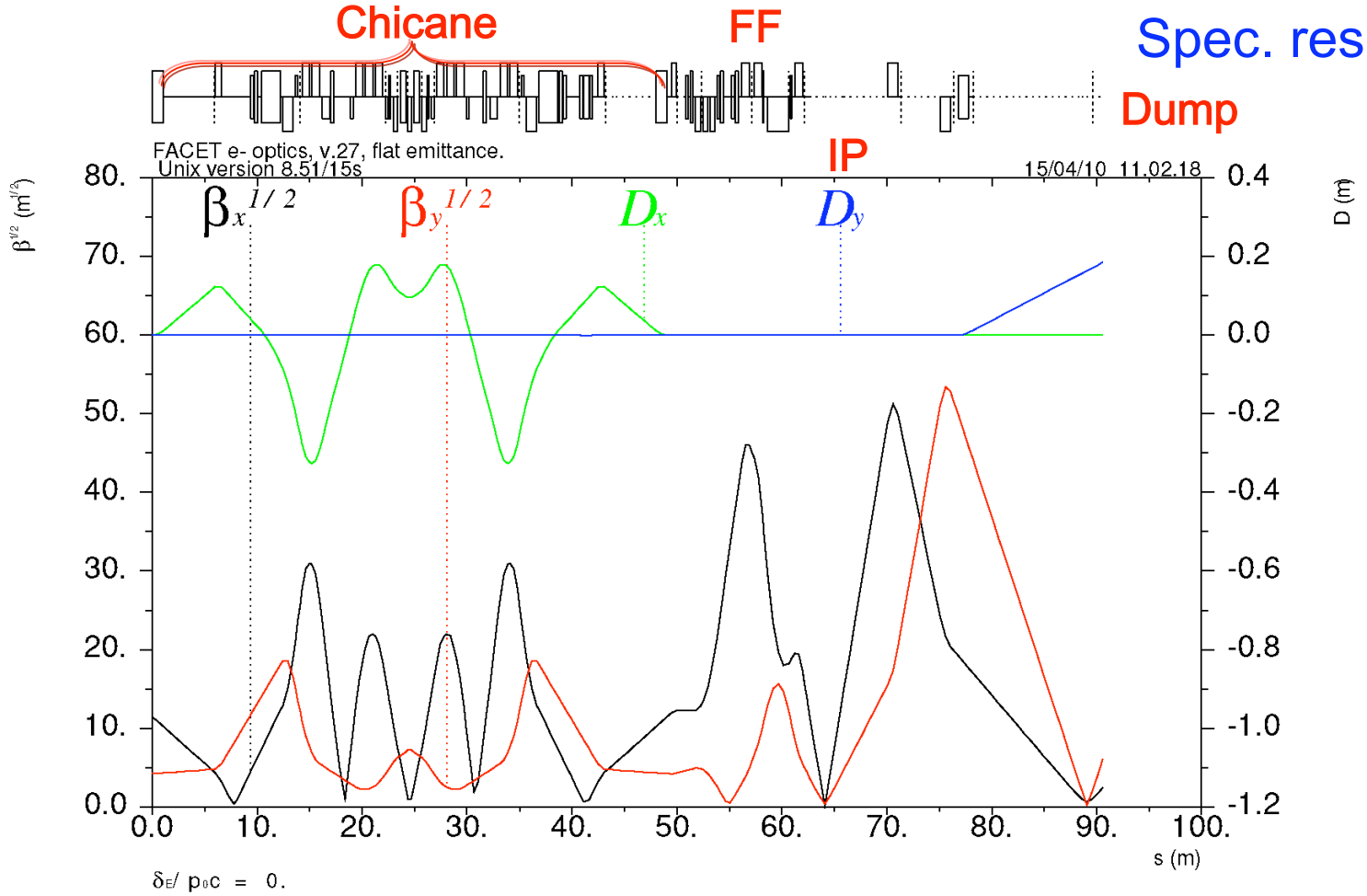
* Focal point is 2m downstream of the face of the last quadrupole
* Drift following focal point is 30m to the new LCLS shield wall

Staged Bunch Compression

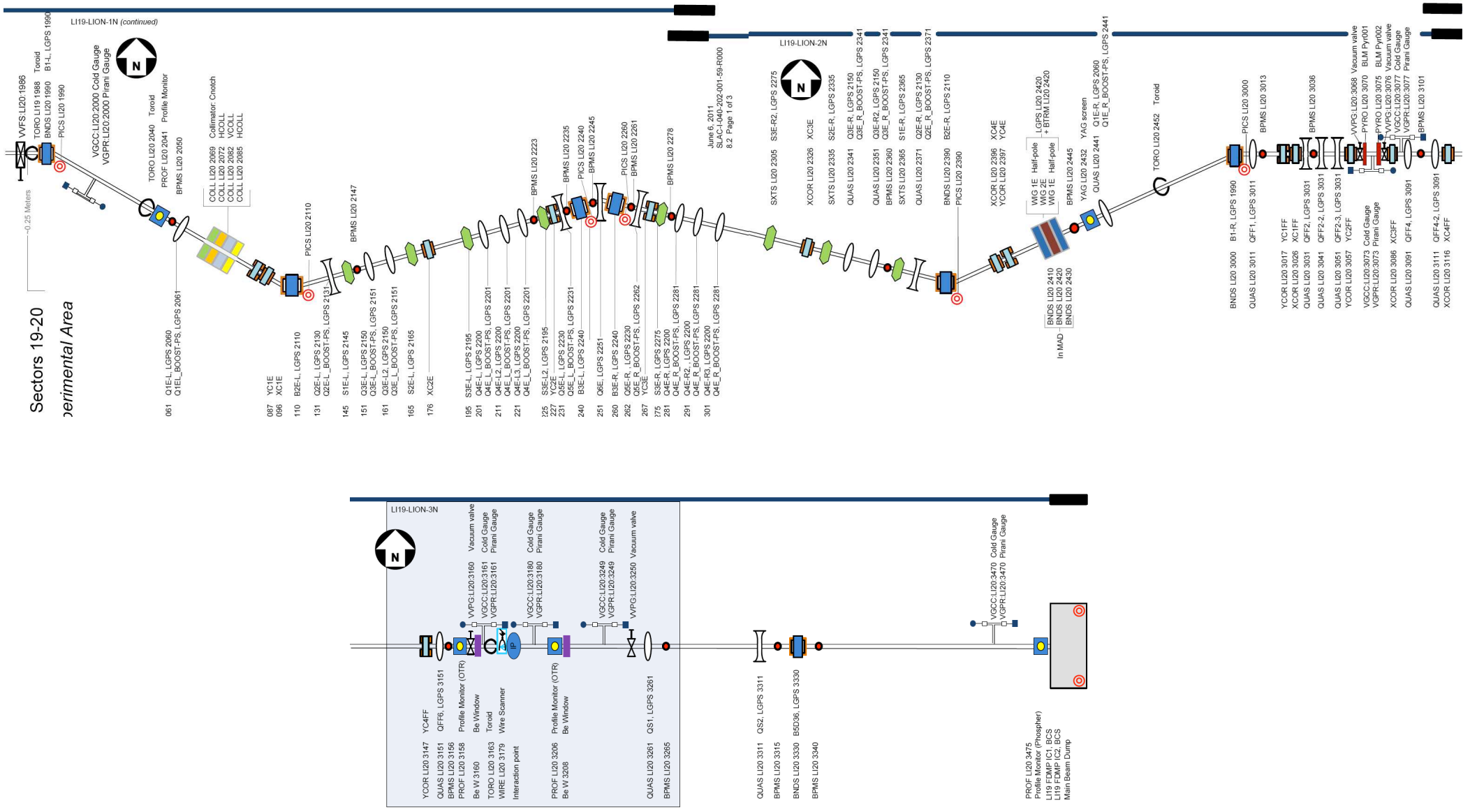


Sector-20 optics functions

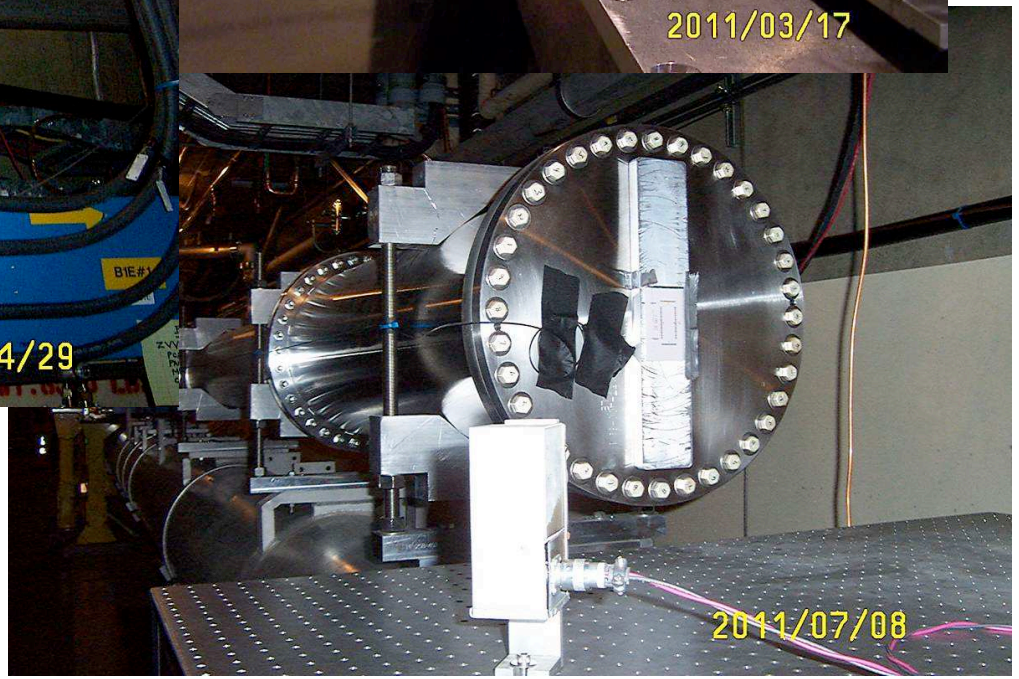
* The Sector-20 optics provides a small round spot at IP with zero dispersion, R_{56} = 4 mm, and it is compatible with the future e+ chicane.
* Incoming emittance and IP β-functions: $\gamma\varepsilon_x/\gamma\varepsilon_y$ = 50/5 μm·rad, β_x/β_y = 1.5/15 cm.



FACET Beamline Map



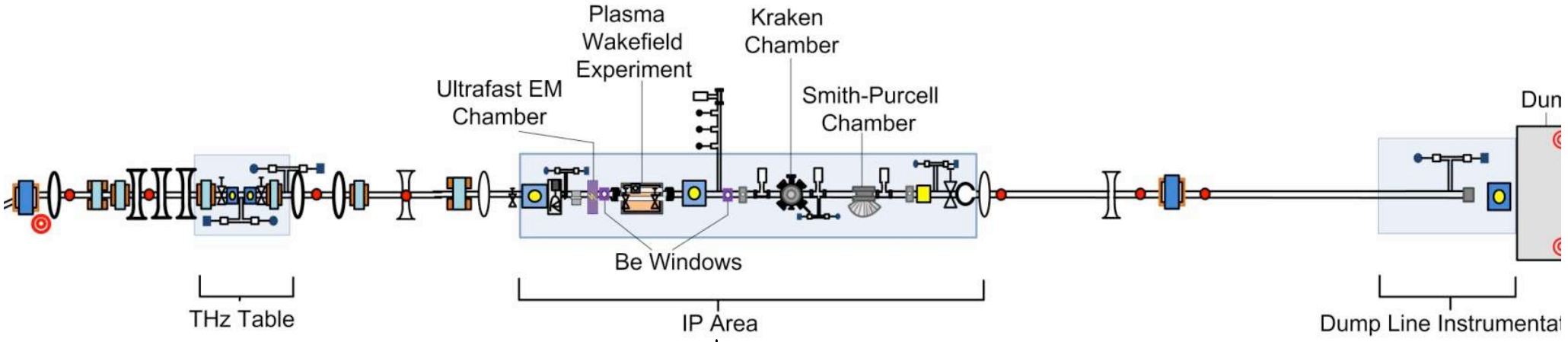
FACET Installation



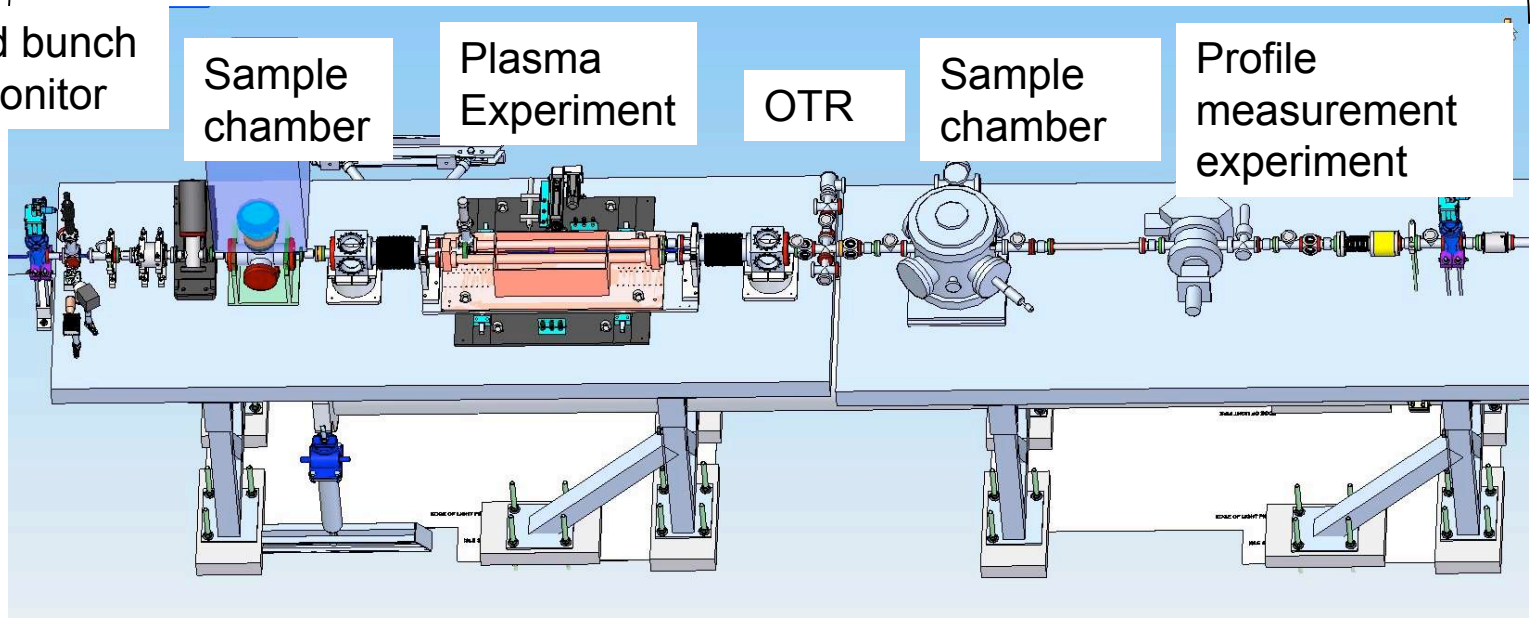
Experimental Facilities

* 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.

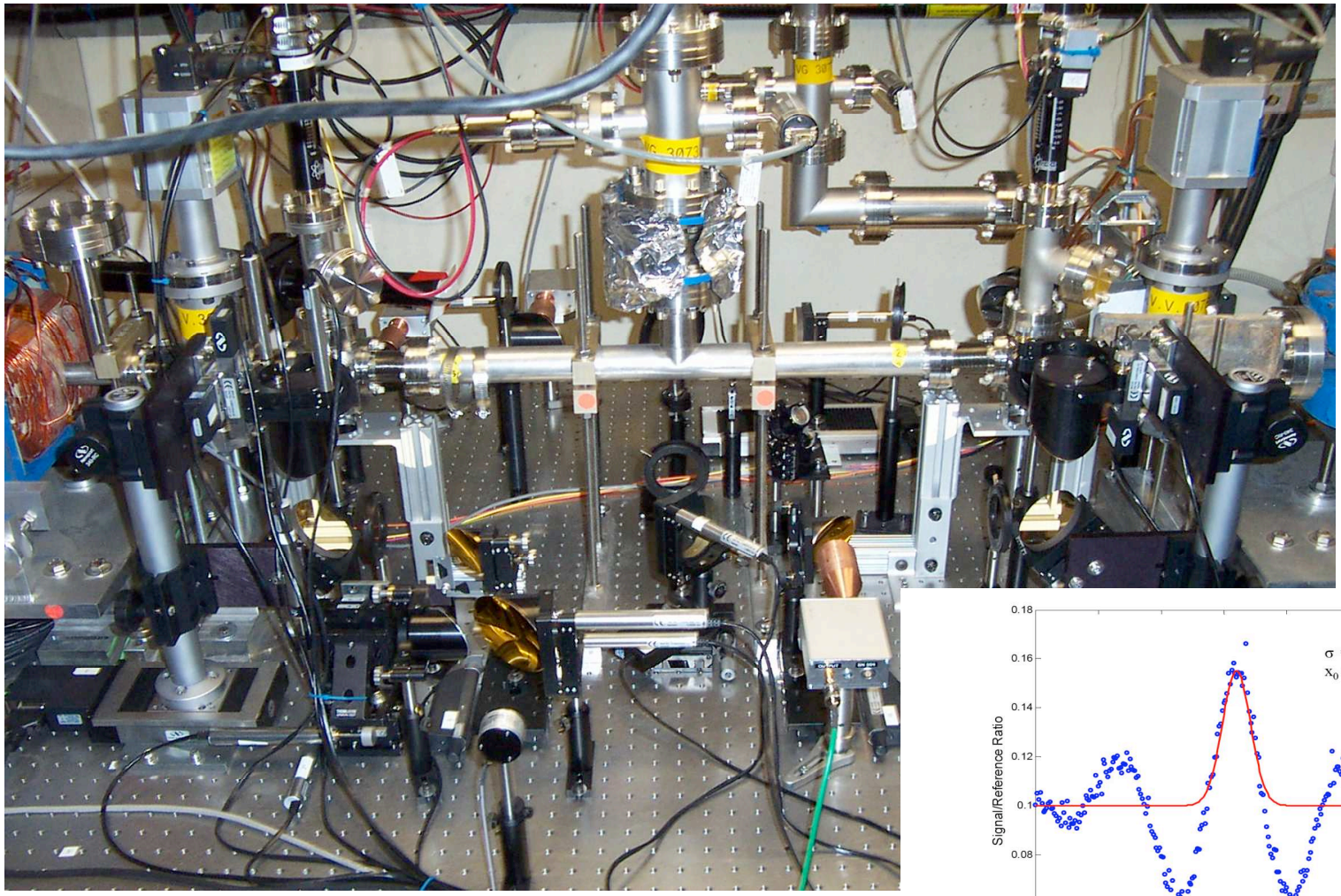
Experimental Installation



OTR and bunch length monitor



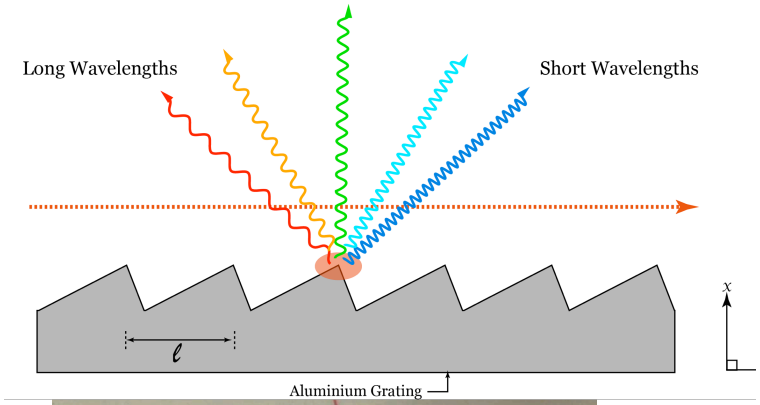
THz table with Michelson Interferometer

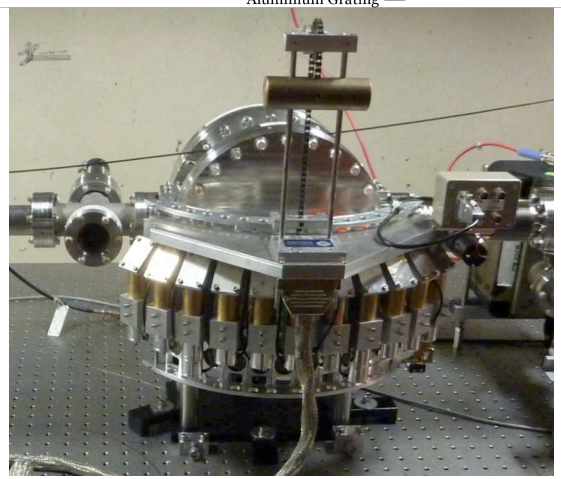


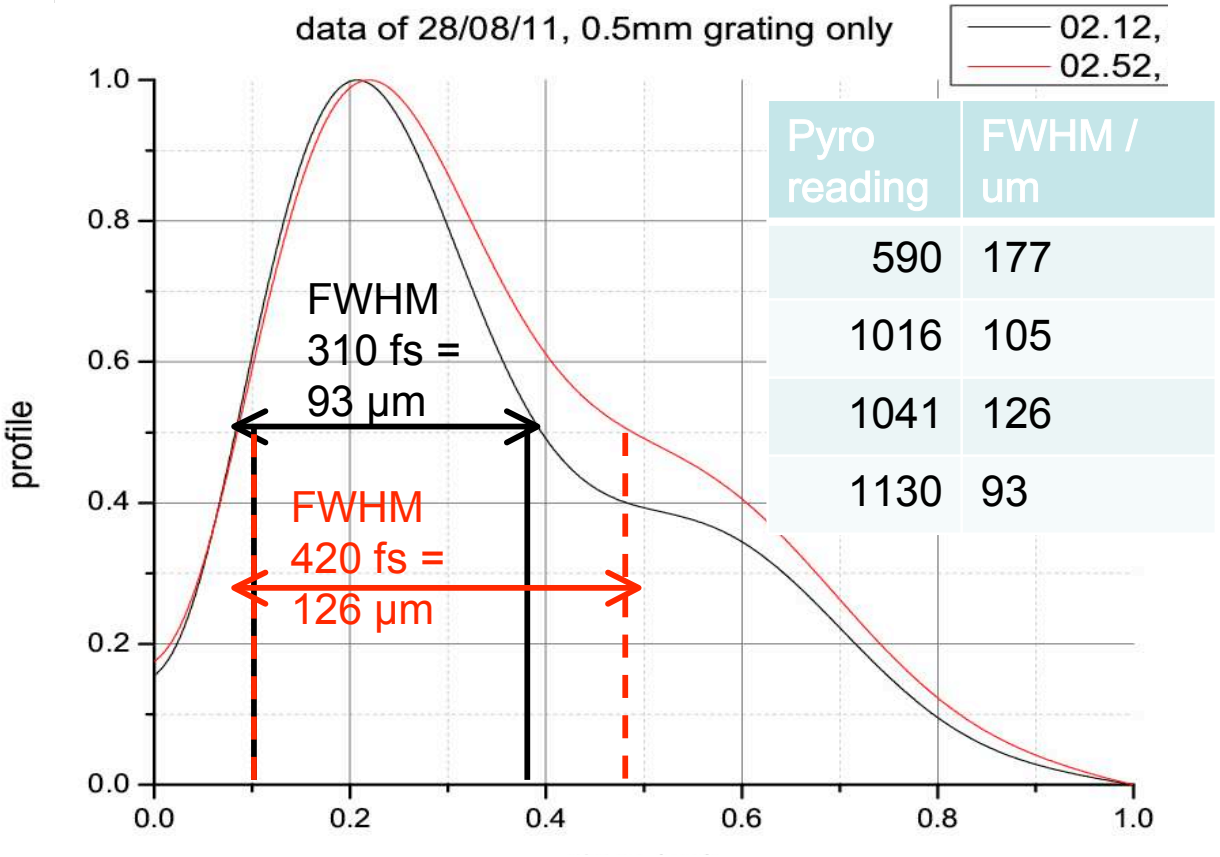
Electron bunch length σ_z = 45 um *2 / sqrt(2) = 63.6 um

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



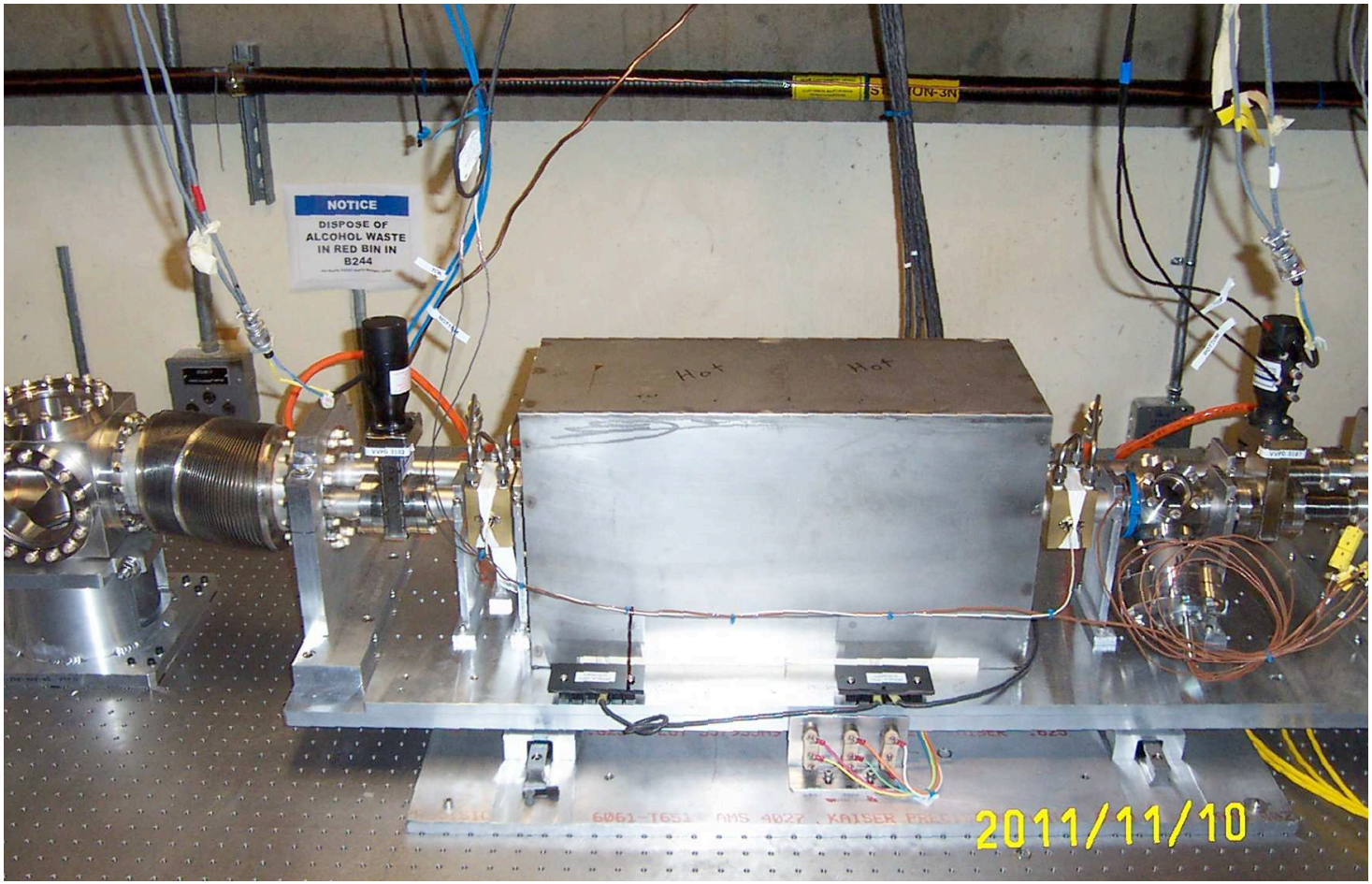




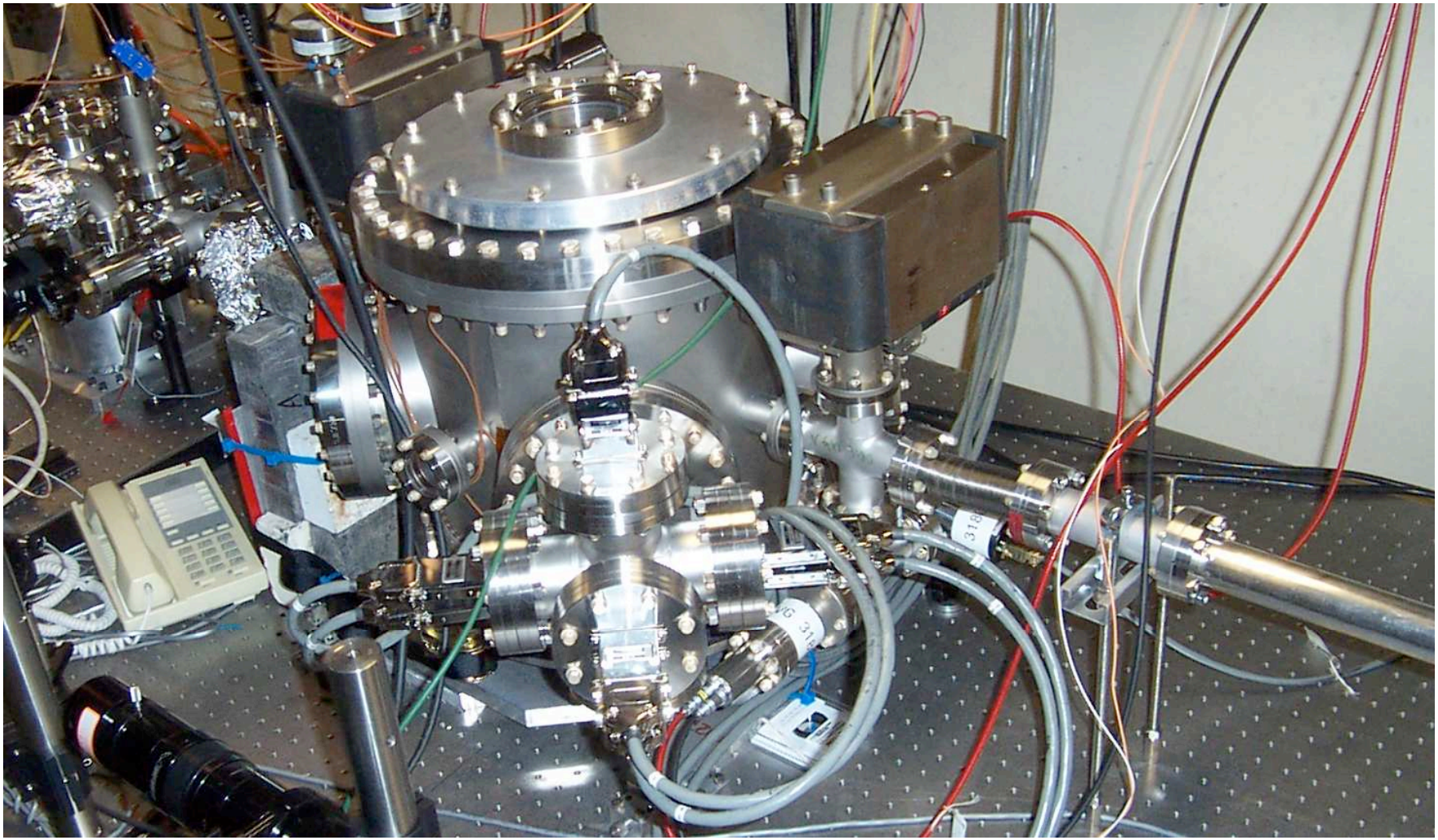
Pyro reading	FWHM / um
590	177
1016	105
1041	126
1130	93

E200 PWFA

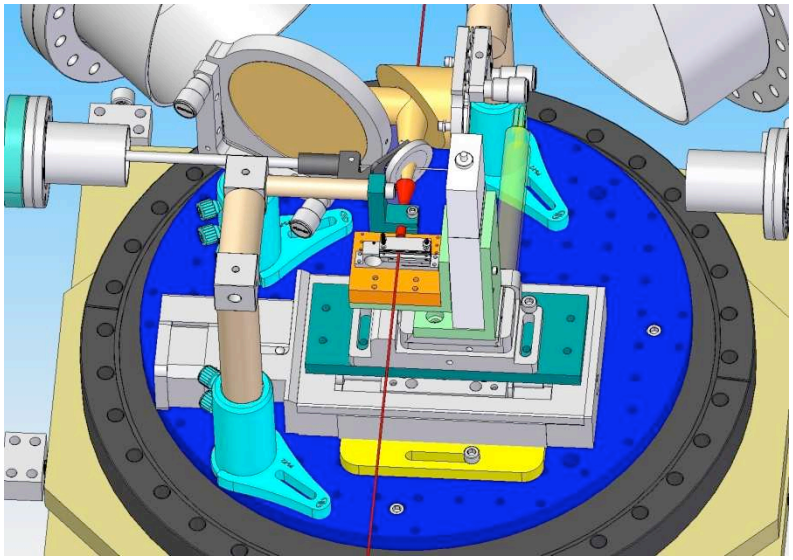
* Engineering run this summer
  – Experimental setup commissioned

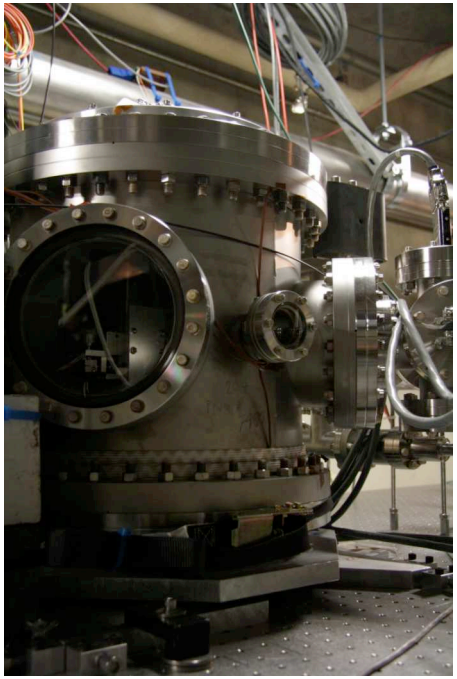


"Kraken" Chamber



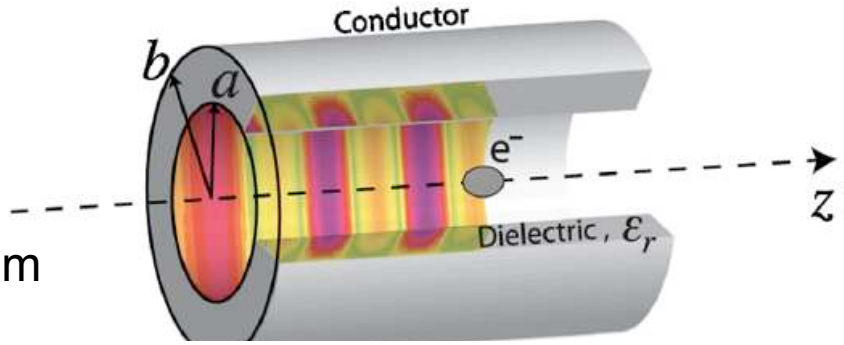
E-201 and E-205 Wakefield Acceleration in Dielectric Structures





* 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

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)

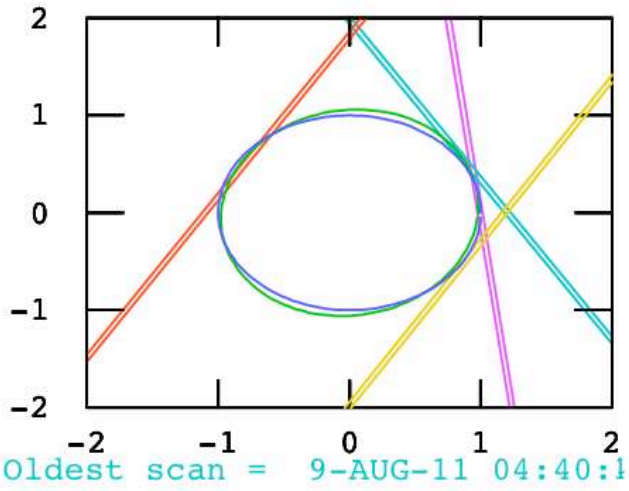
on FACET Dump

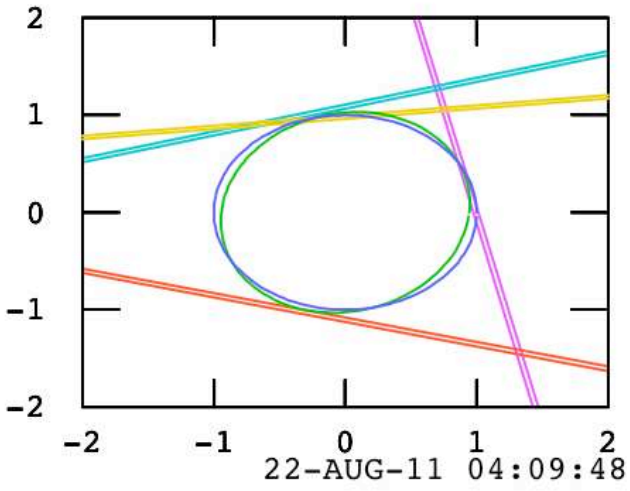
on Exit Window

Sector 02 Emittance

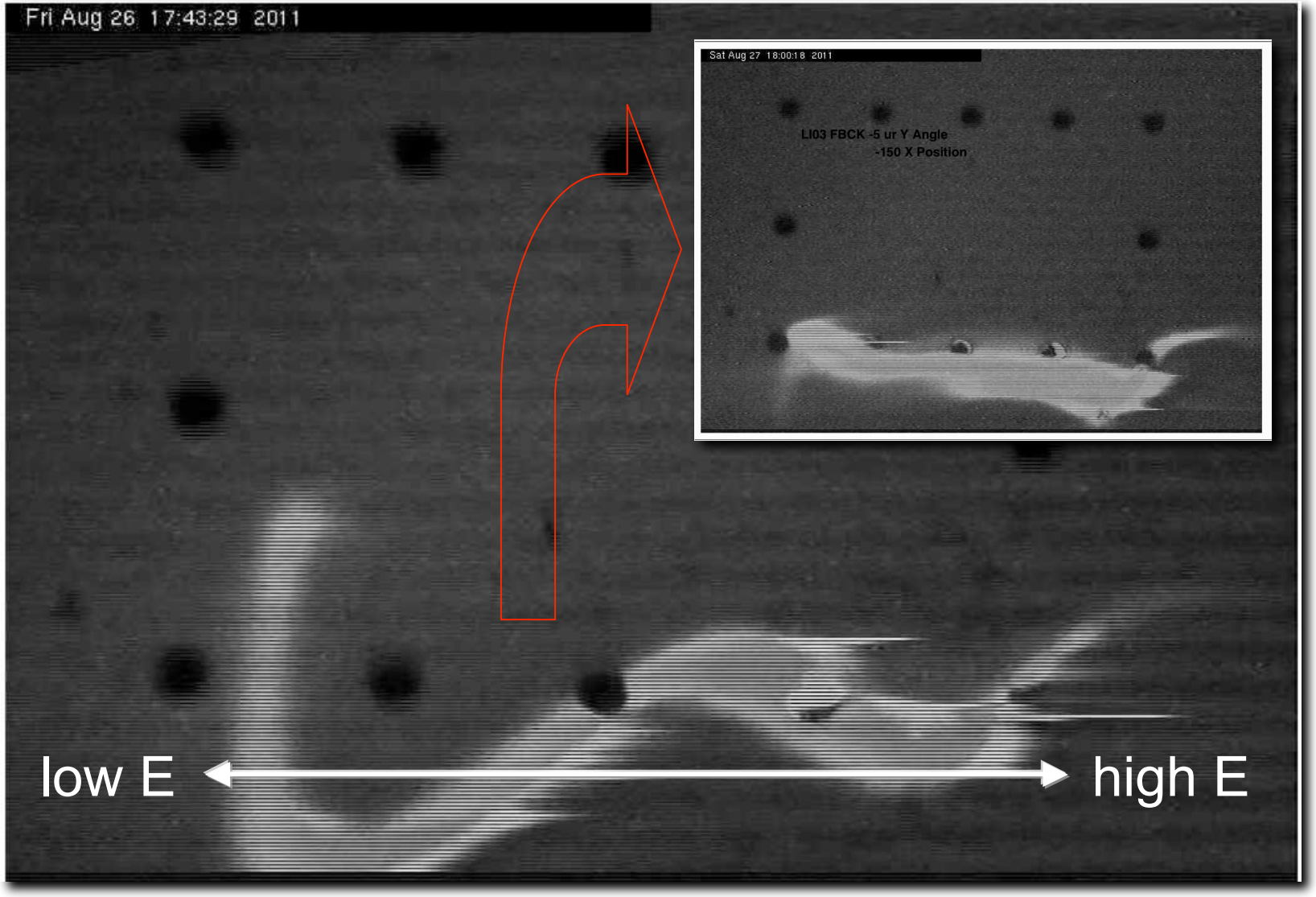
SLC 2-DIMENSIONAL PHASE SPACE ANALYSIS

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





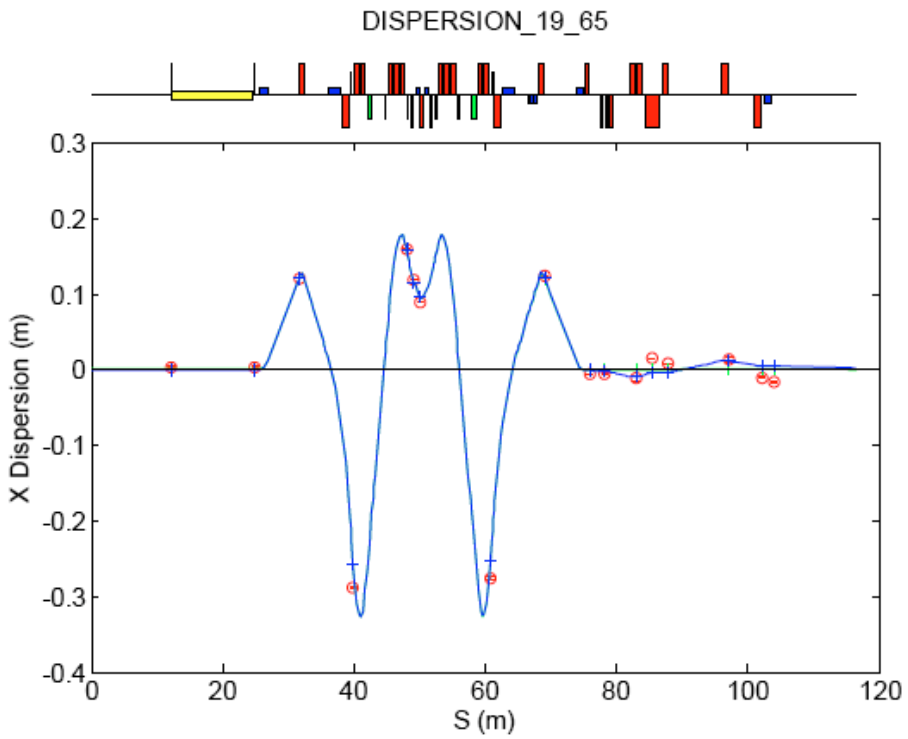
Beam Incoming (PMON)

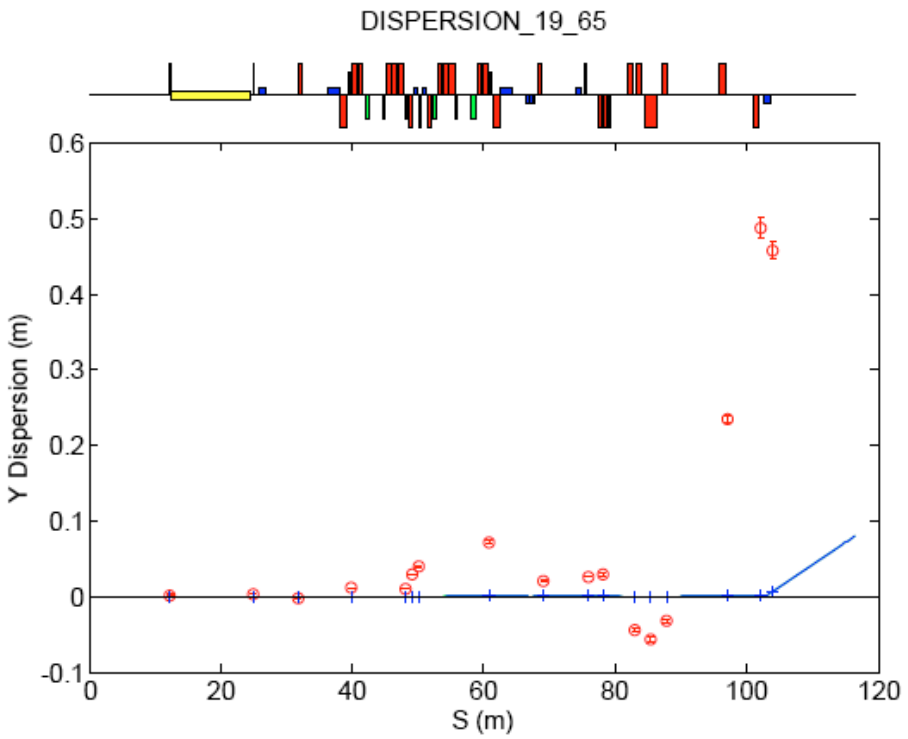


Dispersion for adjusted Focusing

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

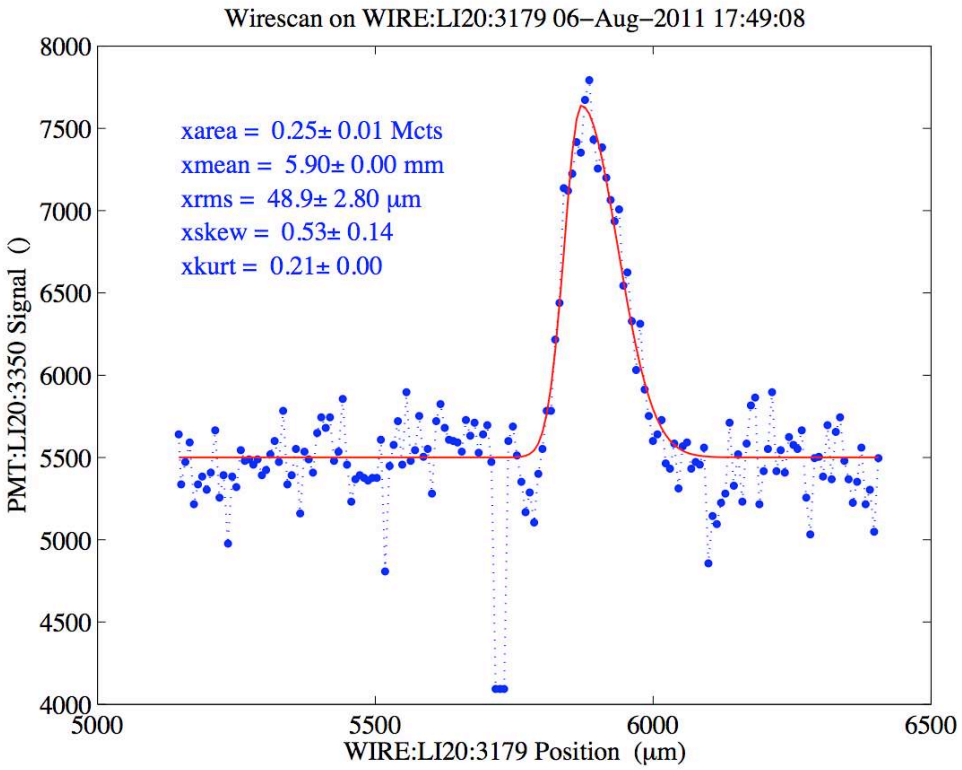
Woodley

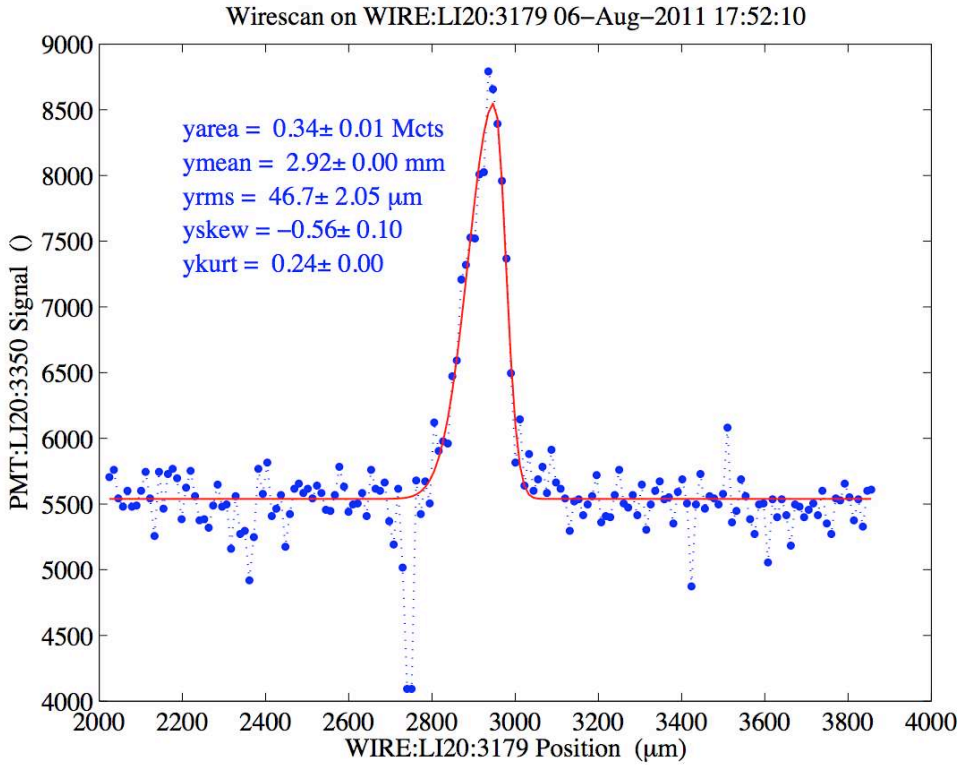




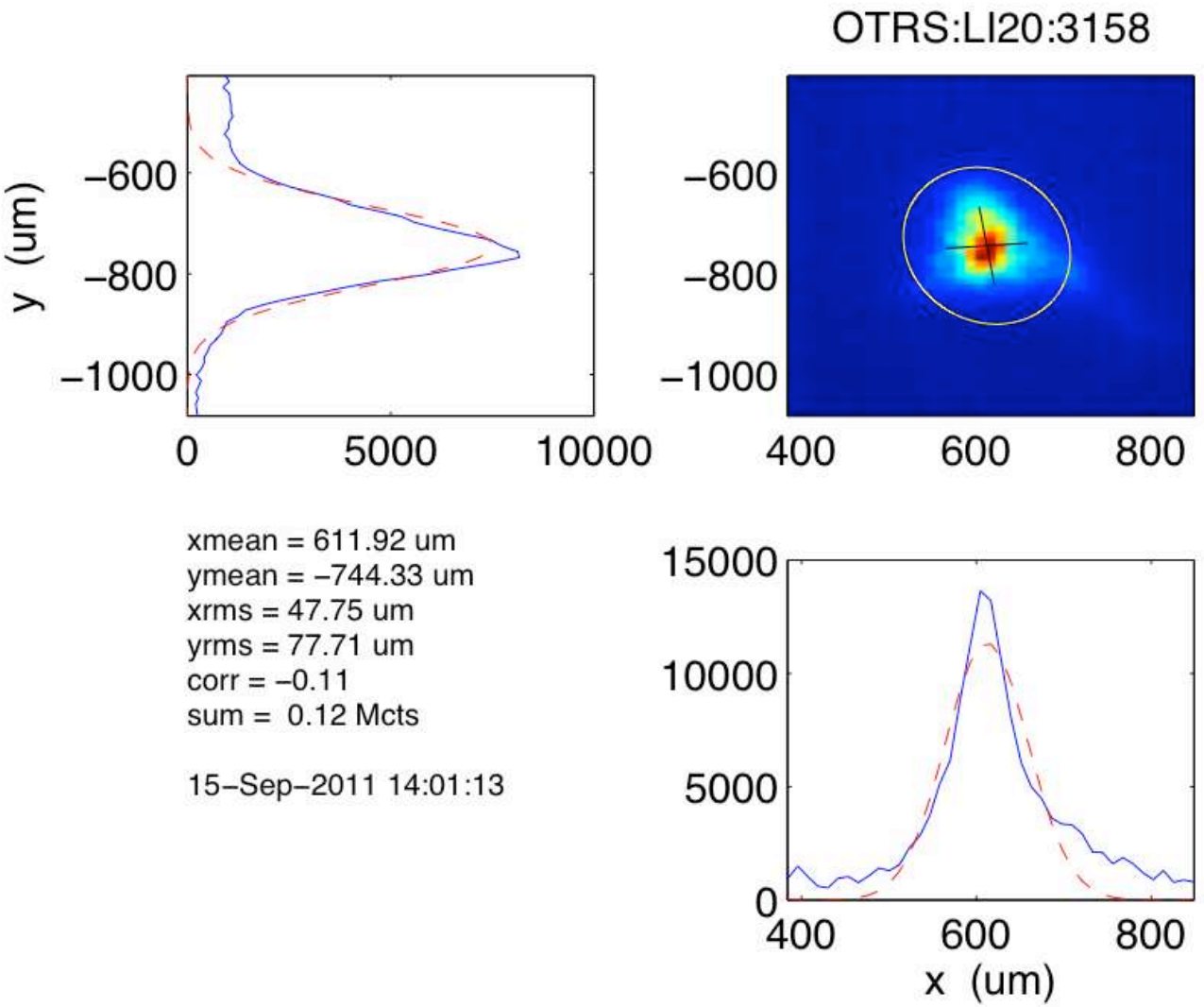
Wirescans @ IP

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

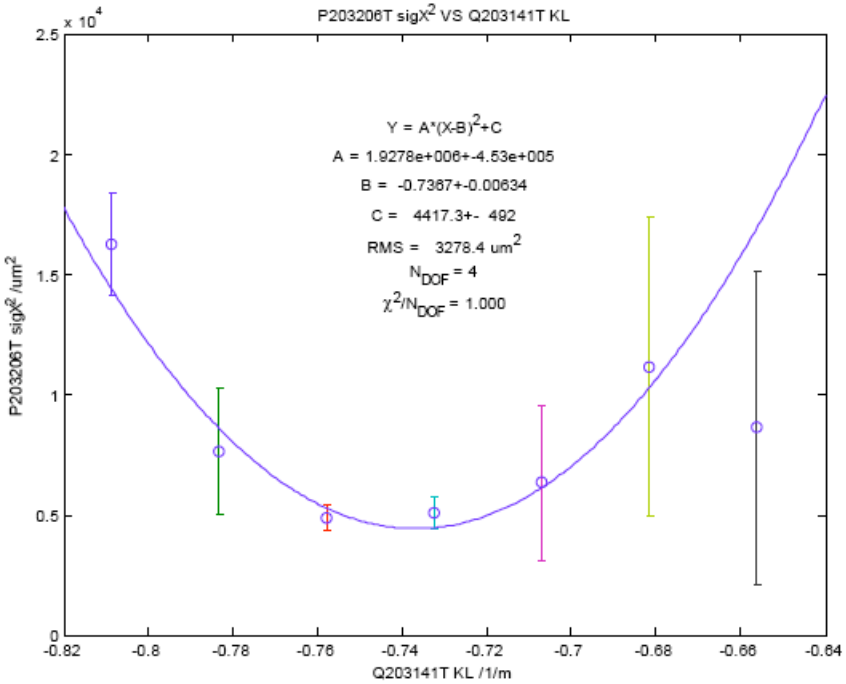


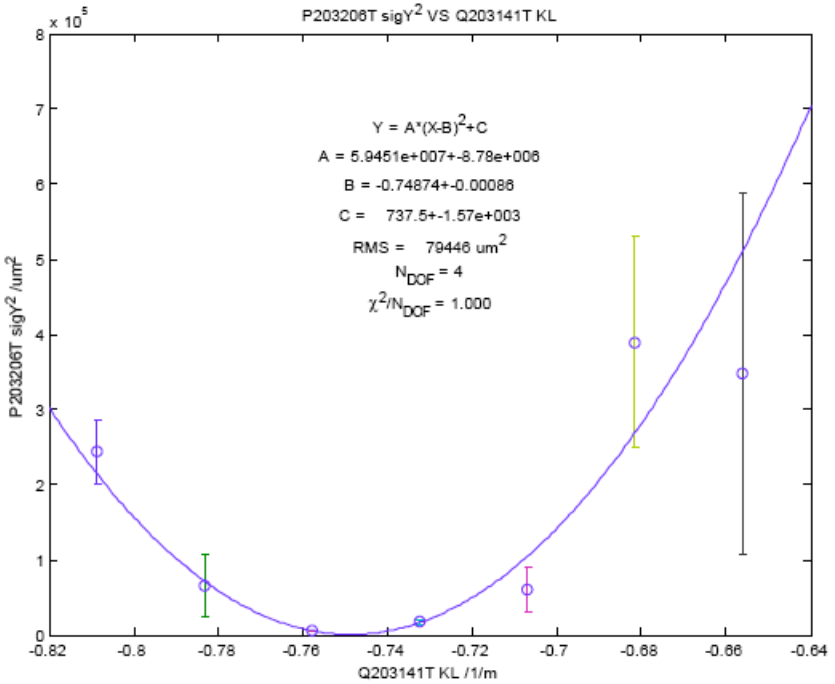


US OTR Readout



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)

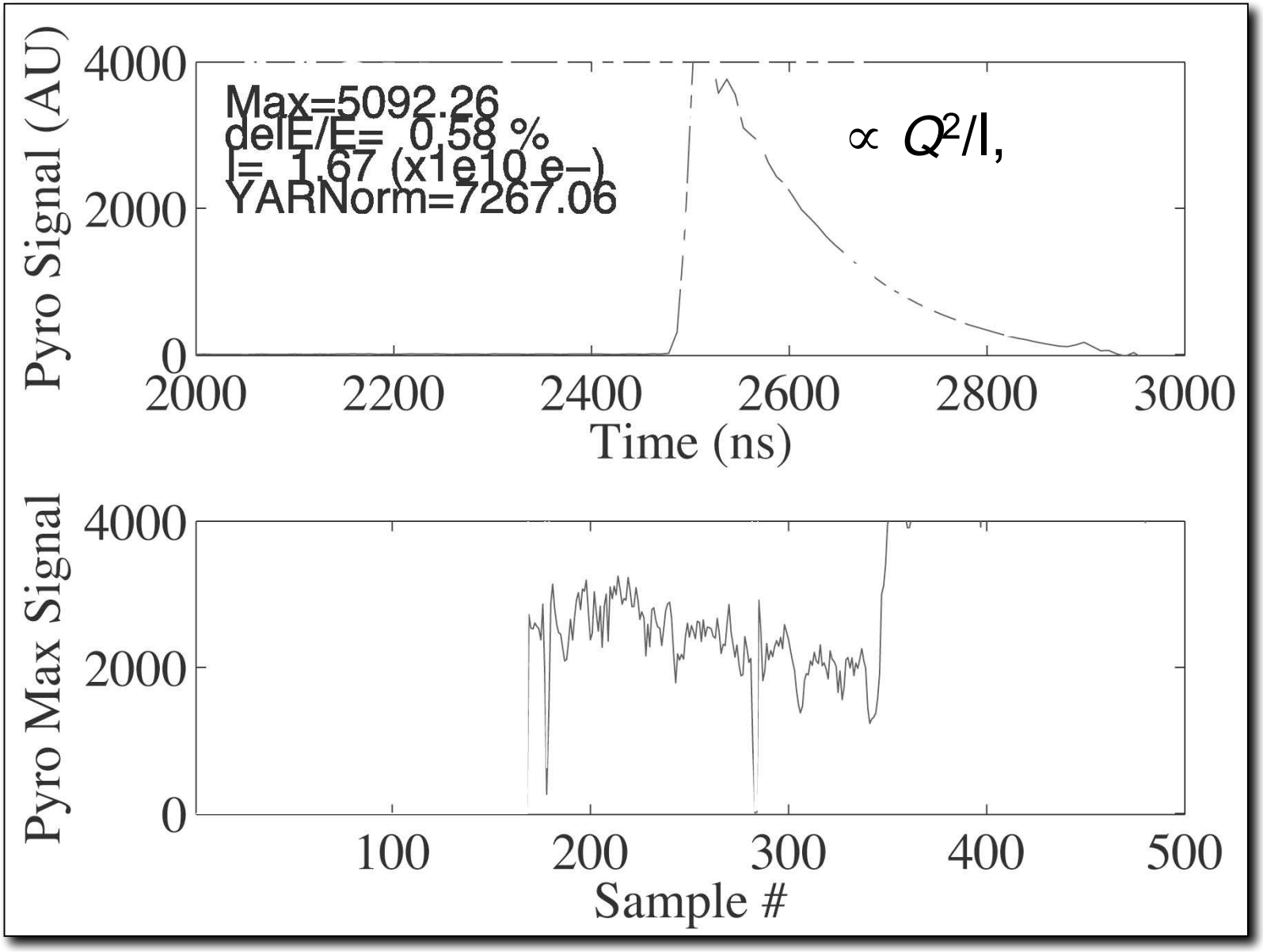
Tracking Performance (Design)

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

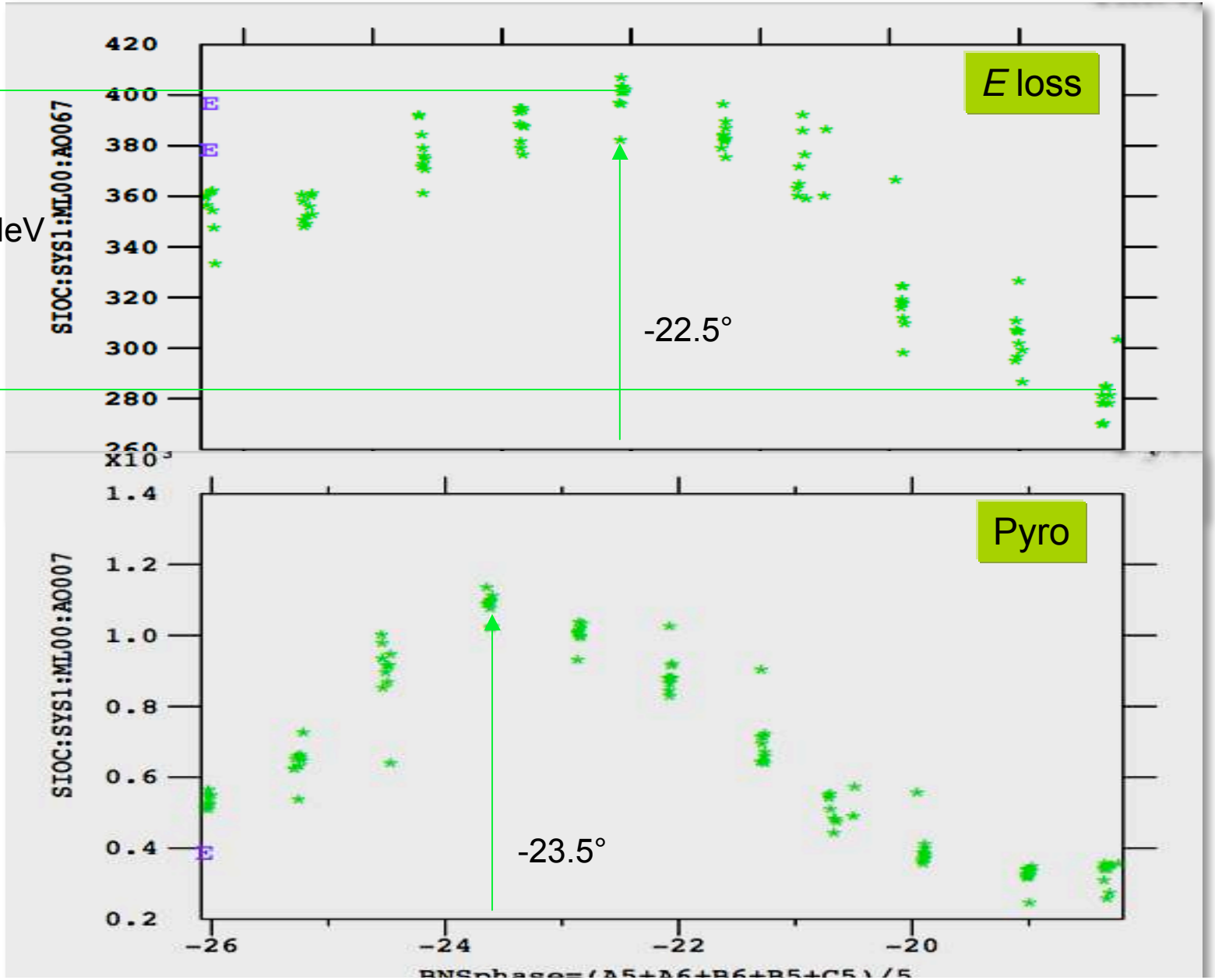
			No SR and Δ p/p = 0 (sext geometric)	No SR (chrom + sext geom)	+ISR	+ISR + CSR
Gaussian fit rms	σ_x	μm	4.4	8.2	11.6	15.0
	σ_y		4.1	7.0	7.1	7.1
Full rms	σ_x	μm	4.7	16.0	17.1	19.9
	σ_y		4.1	19.4	19.3	19.2
	$\gamma\varepsilon_x$	μm-rad	54.2	176.6	194.8	246.0
	$\gamma\varepsilon_y$		5.1	30.2	30.0	30.1

Thermoelectric Pyrometer

5000≈25μm
(±25%)



Wake loss Scan



FACET Beam Parameters Achieved to Date

SLAC NATIONAL ACCELERATOR LABORATORY

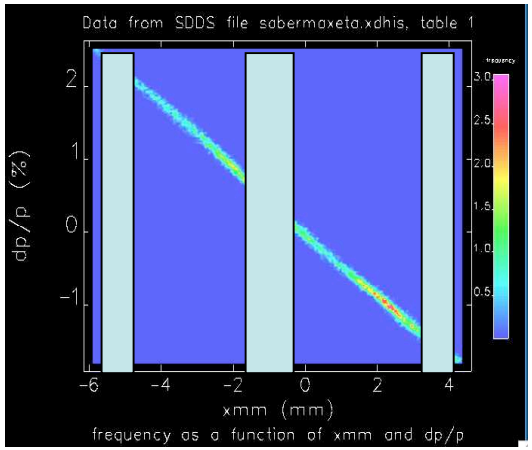
after about 2.5 months of beam commissioning		achieved
Energy	23 GeV	20.8 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+	2.0 x 10^{10} e^-
Pulse length at IP (σ_z)	15 – 40 μm	≈25 μm (prelim), wakeloss similar to FFTB
Spot size at IP ($\sigma_{x,y}$)	10 – 20 μm	30…50 μm compressed 16 by 35 μm low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

Performance Upgrades

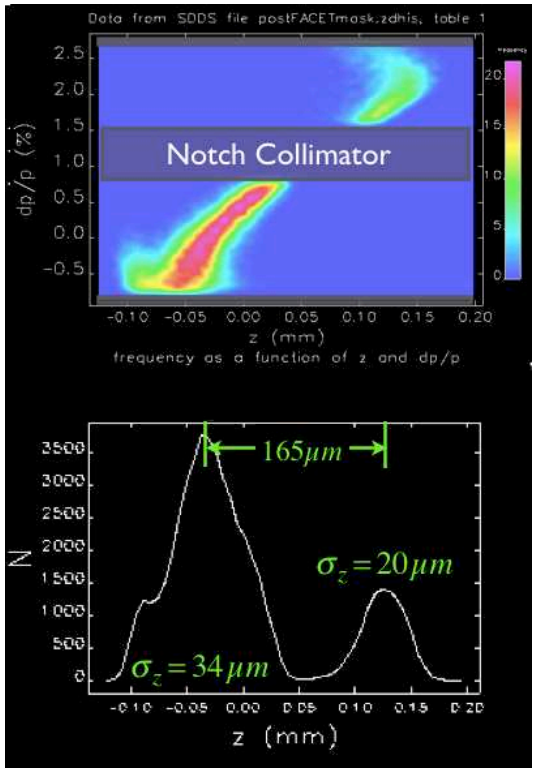
* Install wirescanner & BLM in linac S18
  - also separate power for 4 quads for ε scans & improving match.
* Provide movers for S2E sextupoles
  - use extant FFTB units, want BPMs there as well
* Add more toroids to improve accuracy of charge meas't.
* Presently installing e+ chicane in S10
  - e^- or e^+ through S20 FACET Chicane, but not both
* Install "notch collimator" to create 2 bunches ≈150 μm apart in distance
  - 2nd "witness" bunch to sample plasma wake.
* Project to install a transverse X-band cavity for direct bunch length & distribution measurement

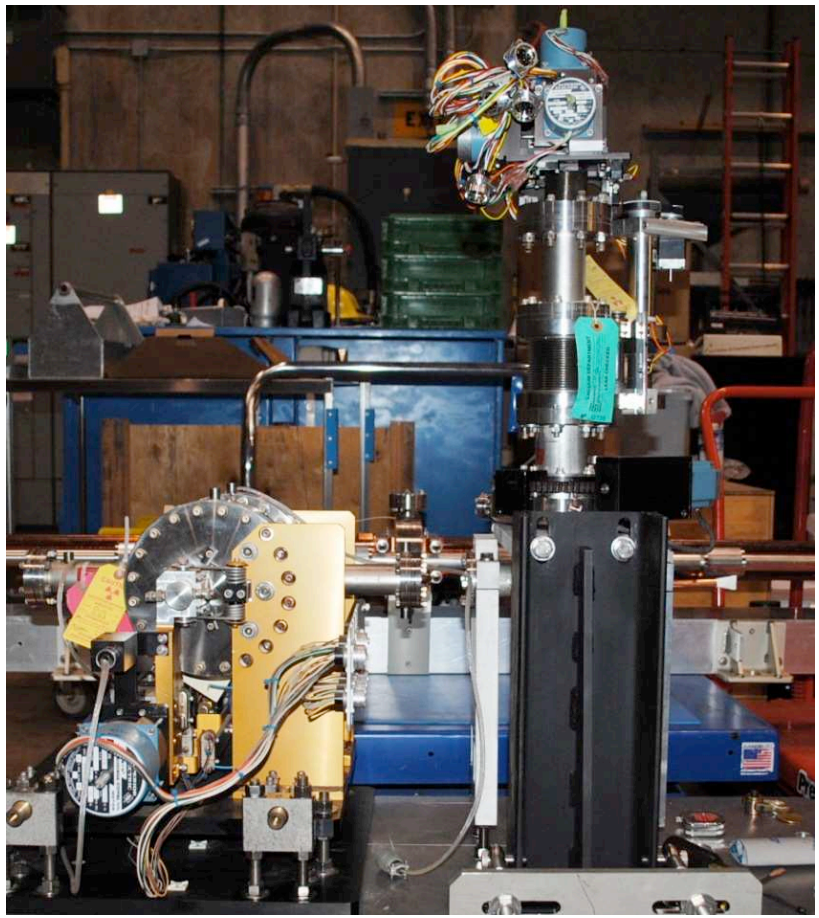
E-200 Notch and Jaw Collimator

* 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



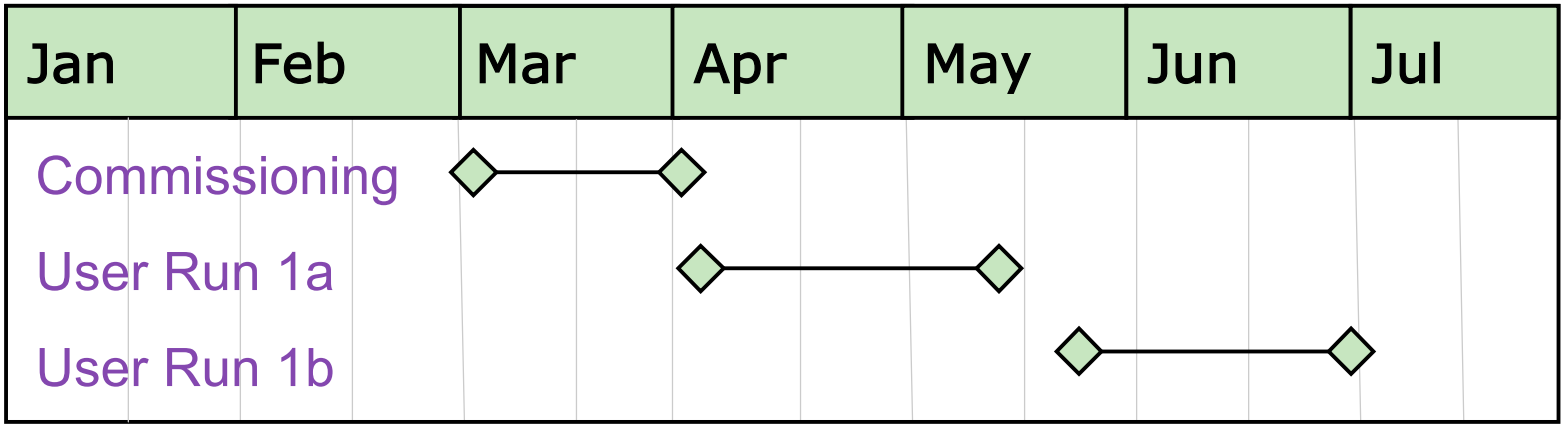
Selectively collimate in first leg of chicane





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 will 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
* 2012 Run has been scheduled
  - finish beam commissioning, 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)

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