Progress on FACET Commissioning

U. Wienands

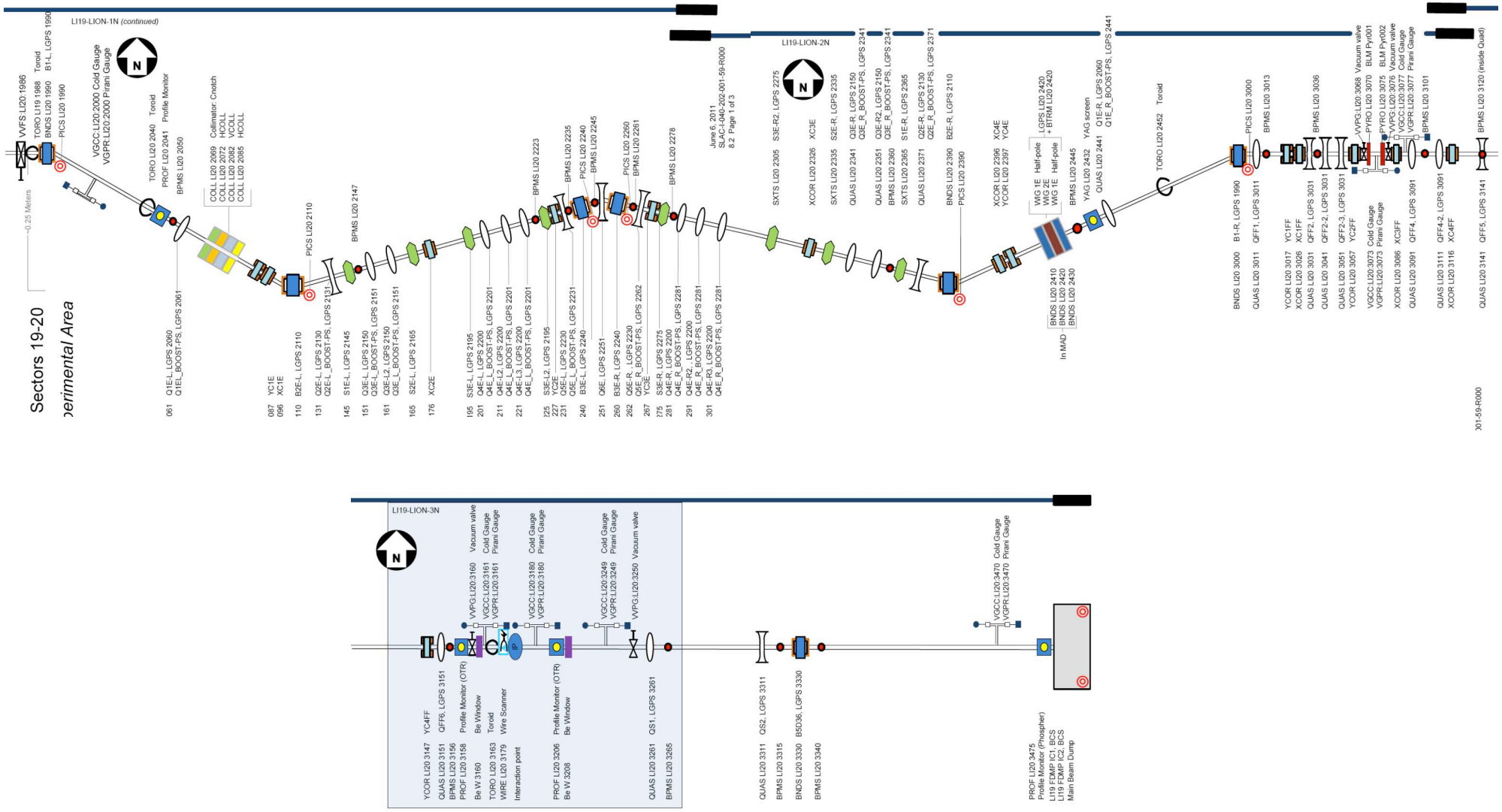
Director, Linac S0-20 Division

for the FACET Commissioning Team

Outline

* Introduction to FACET
* Hardware commissioning
* Beam commissioning
* Operational issues
* FACET Commissioning Workshop
* Plan ahead
* Summary

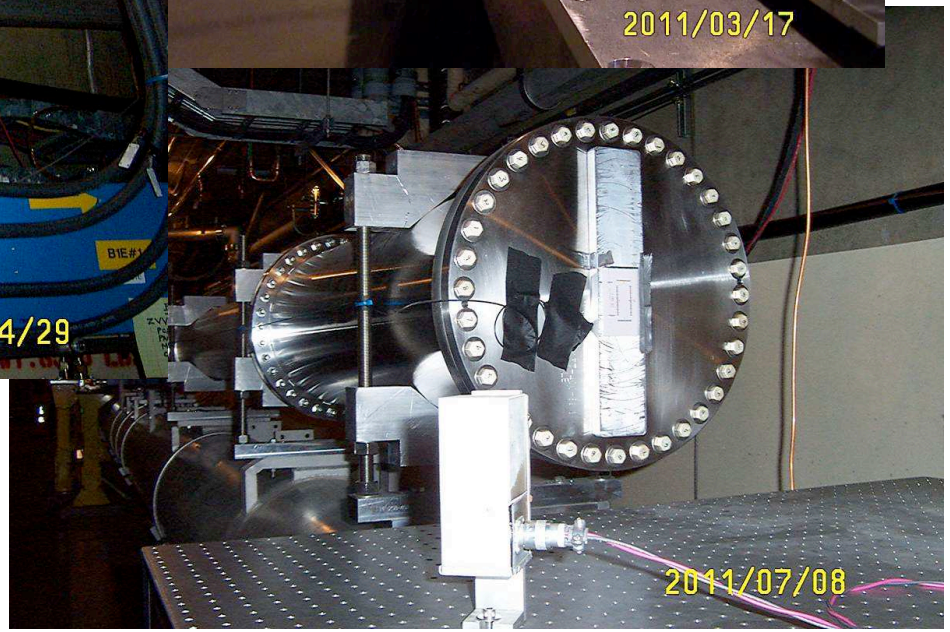
FACET Beamline Map



FACET Design Parameters

Energy	23 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+
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
Momentum dispersion at IP (η and η')	$\eta < 10^{-5}$ m

FACET Installation



FACET Hardware Commissioning

* FACET Readiness Review on 6-May-11
  - most Action Items as expected
* Magnet power supply commissioning
  - verify configuration
  - check polarity
  - fix issues & retest
* Controls Commissioning
  - run supplies through SCP
  - check vacuum controls
  - check diagnostics controls
* Complete safety barriers
* Complete ALARA shield wall at dump table

Early Beam through FACET

on FACET Dump

on Exit Window

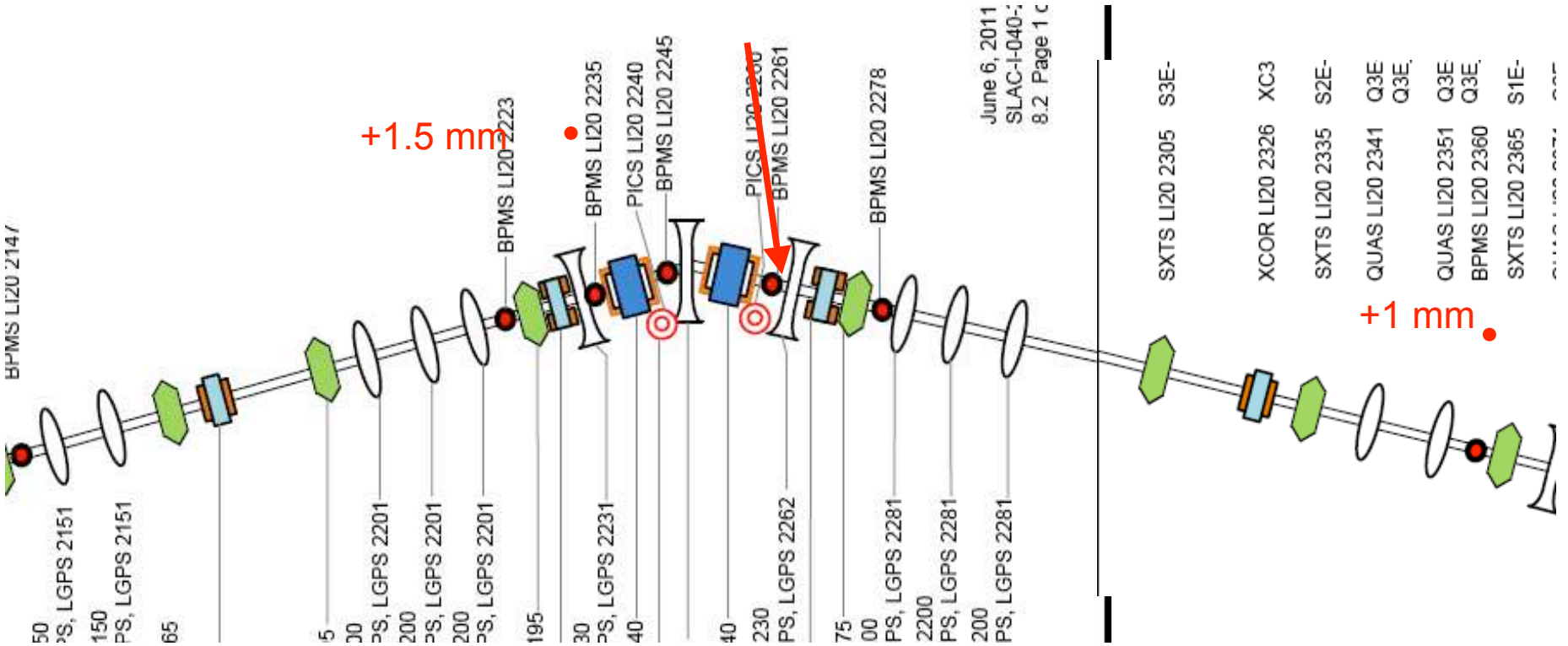
Hardware Issues

* PS:
  - Breakers popped
  - B1,B2,B3 Zero flux transductors/bitbus ground loop
  - MCORs reversed voltage
  - all soon fixed (but a B3 mystery remains)
* BPMs and Toroids
  - TMITs not consistent for BPMs
  - Toro TMIT seem ~25% low in comparison with linac toroids: 9-turn versus 13-turn?
  - Rotation, orientation, PCMM: fixed in 2nd week (or so
  - Missing two BPMS,
  - smaller than necessary beam pipe, misaligned beam pipe
  - much improved, but work remains
* Moving Wire causes vacuum gauge glitch (fixed)

FACET Beam-Commissioning

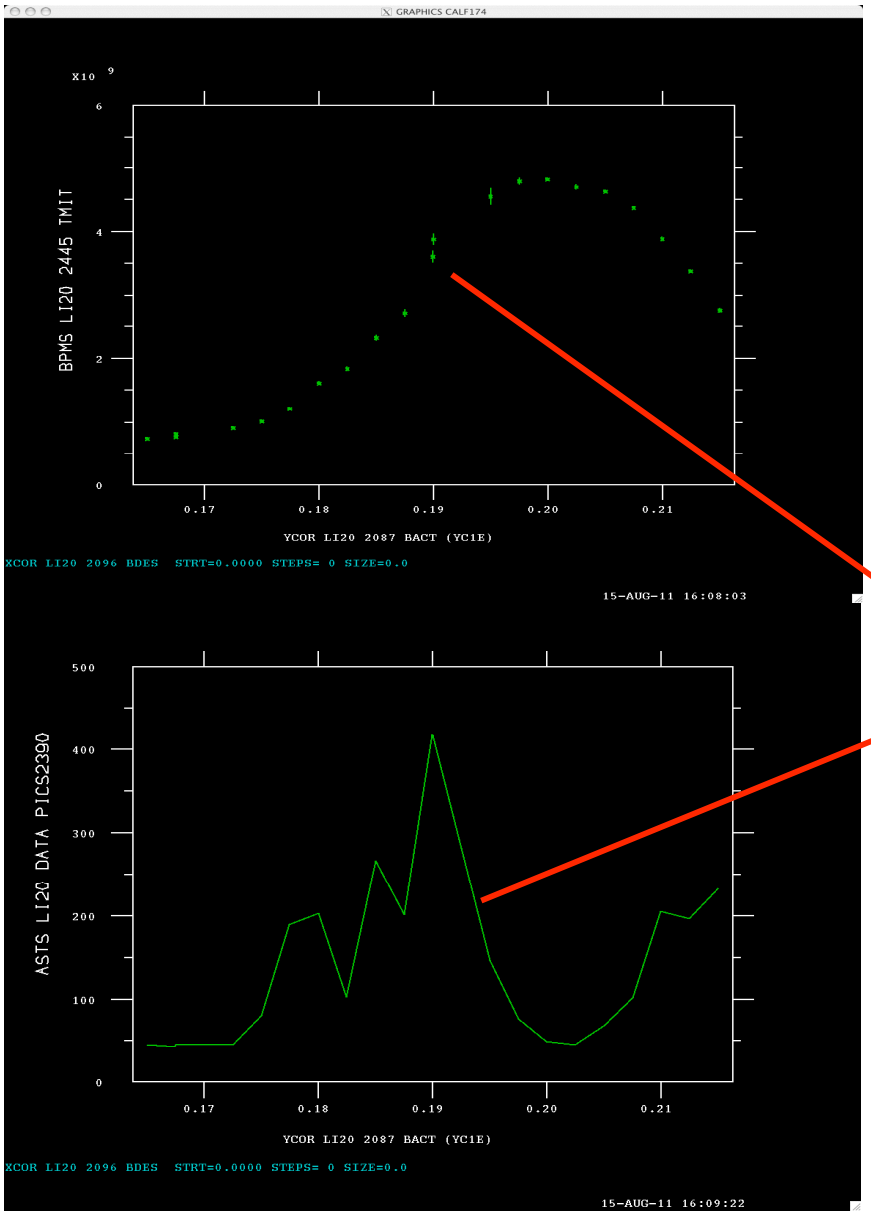
* Beam to dump 23-June
  - immediately clear that dipole calibration was not accurate
  - also, relatively heavy beam loss, not easily tuned out.
* "Relaxed lattice" with much less phase advance in *x*
  - allowed steering, aperture scans, reduction of beam loss
  - revealed serious aperture restriction 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).

* Phase jump across center
  - XCOR 2326 strongly negative
    - again, “shoot beam across pipe”…?
    - but aperture on the + side (1 mm)… not consistent.
      - (xcor 2236 not scanned :-(

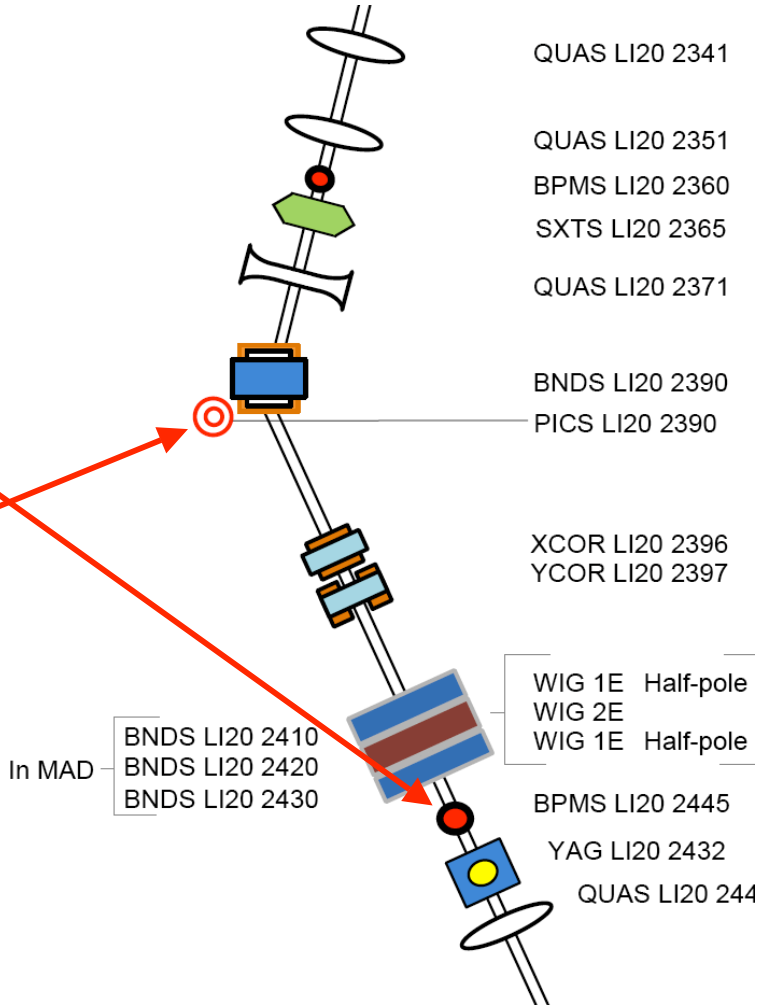


QF5E#2 Chamber Offset

Vertical Aperture

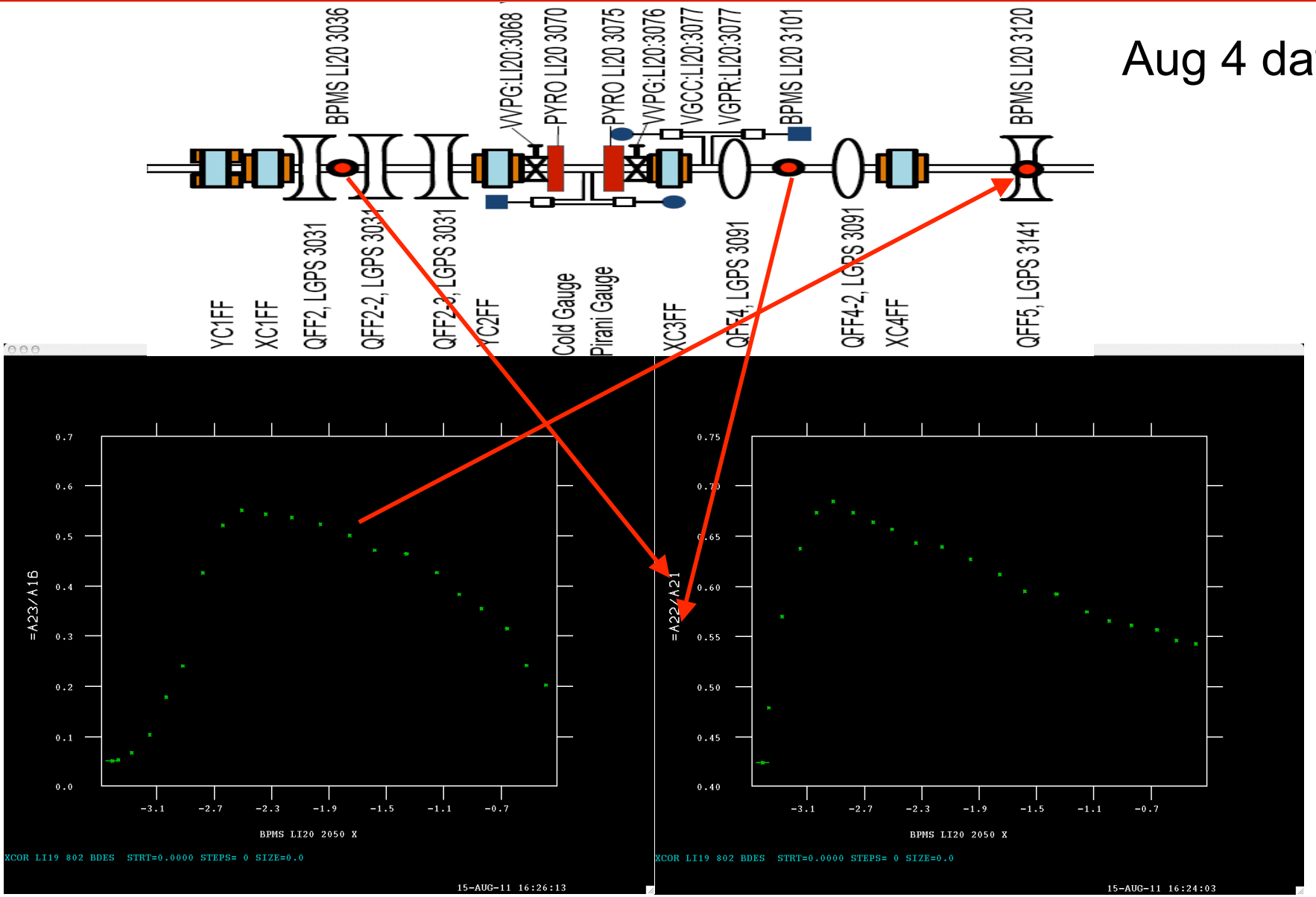


* Aug 4 data



Energy aperture

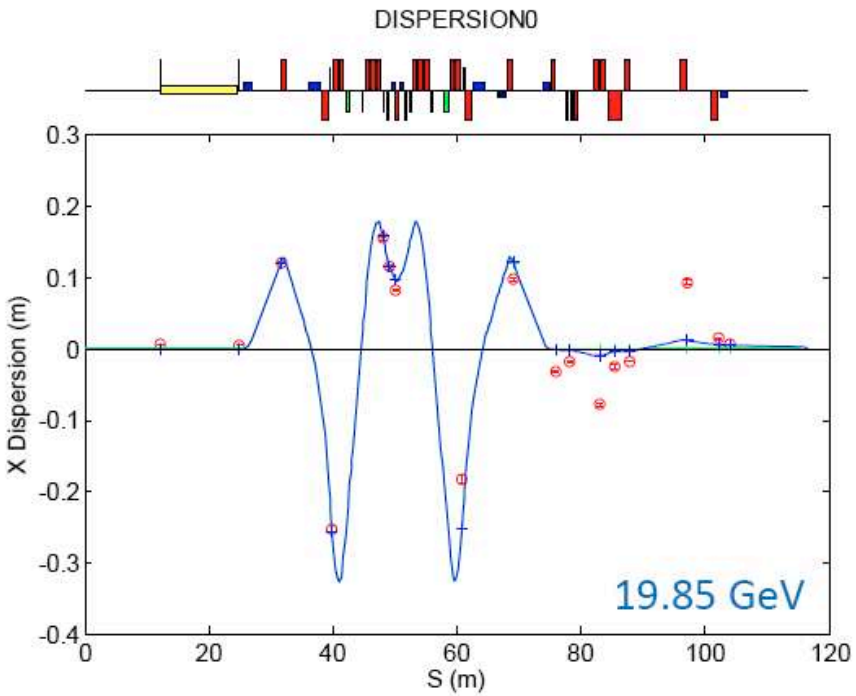
Aug 4 data

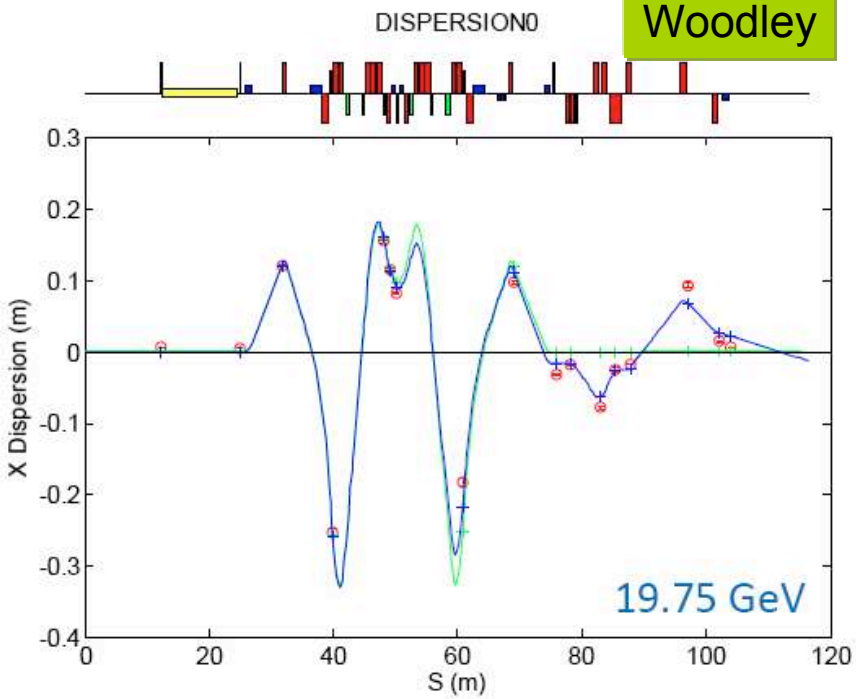


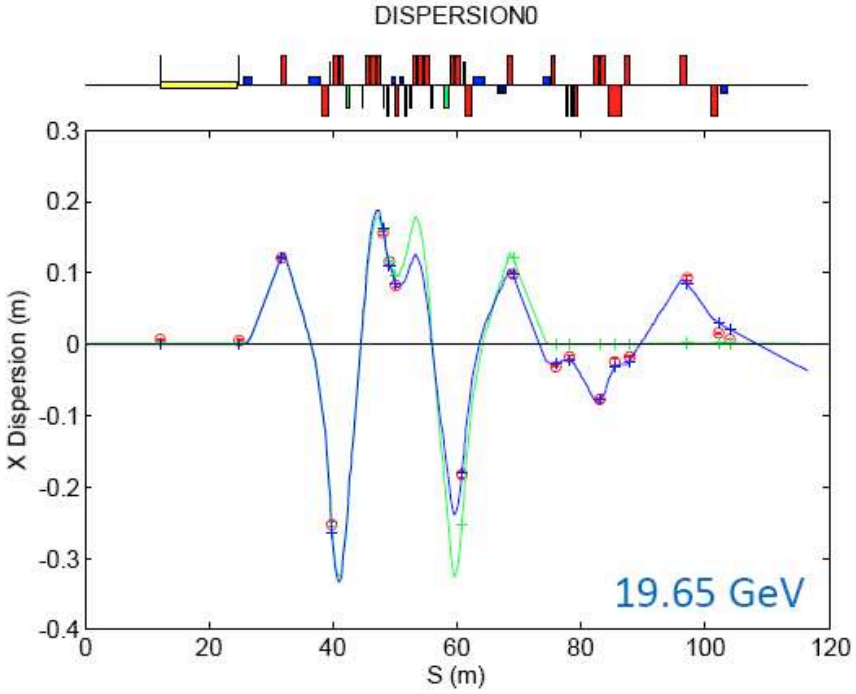
Chicane Lattice Work

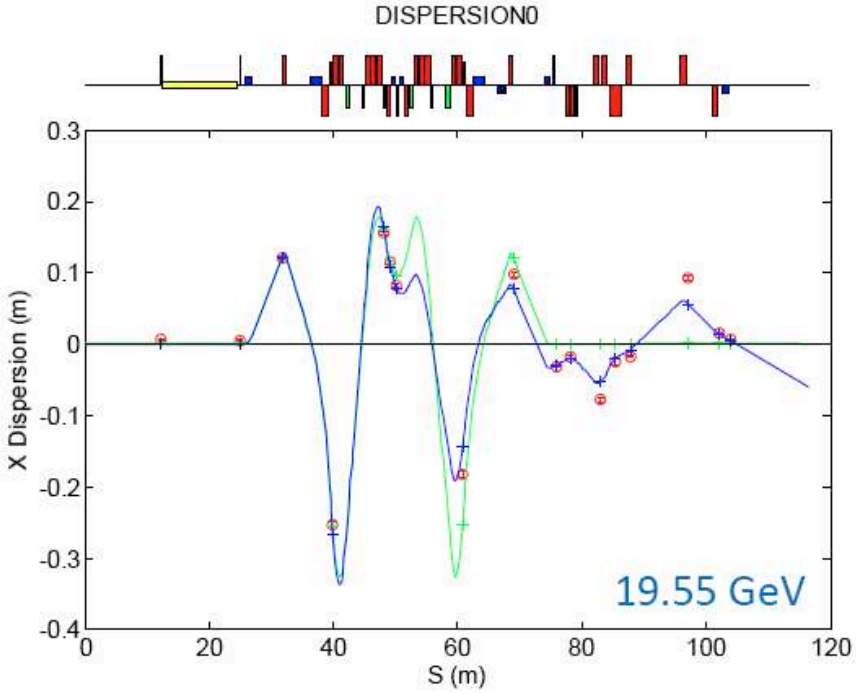
* Response measurements were used to assess the state of the beam optics in the chicane
  - Dispersion: focusing but also the central energy
  - Results in general good agreement with the model prediction
    - Beam energy determined to be 19.65 GeV
  - Dispersion is quite sensitive to even small errors, and even small leakage (≈1 cm) is enough to significantly enlarge the beam size.
  - R_{12}: measures focusing
* BBA is necessary to fully straighten out the beam path
  - The Chicane is challenging due to very strong focusing and not enough correctors or BPMs in the horizontal plane
  - Limits the number of quads/BPMs amenable to straight-forward BBA

Woodley


DISPERSION0
X Dispersion (m)
S (m)
19.85 GeV


DISPERSION0
X Dispersion (m)
S (m)
19.75 GeV

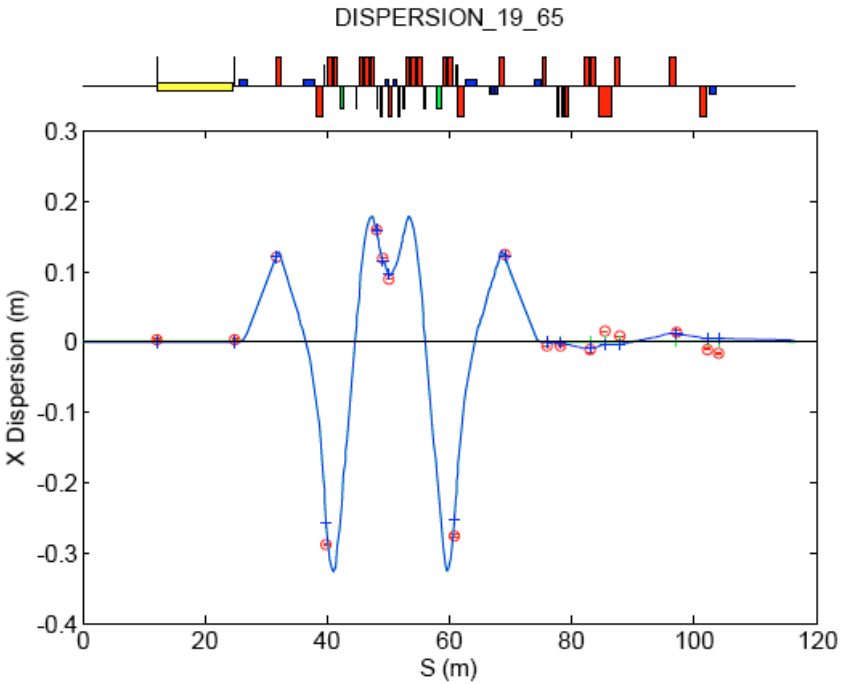

DISPERSION0
X Dispersion (m)
S (m)
19.65 GeV

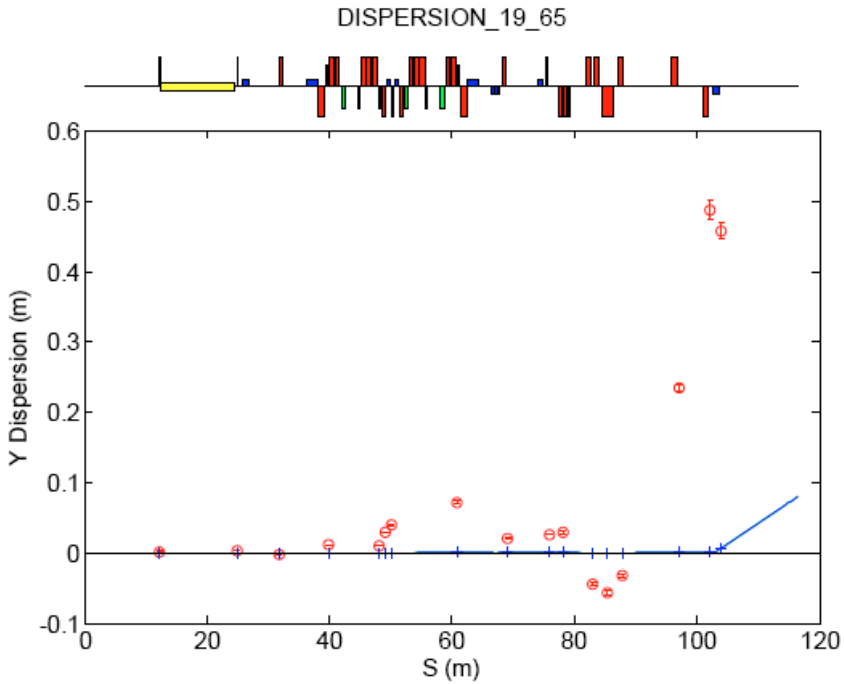

DISPERSION0
X Dispersion (m)
S (m)
19.55 GeV

Dispersion for adjusted Focusing

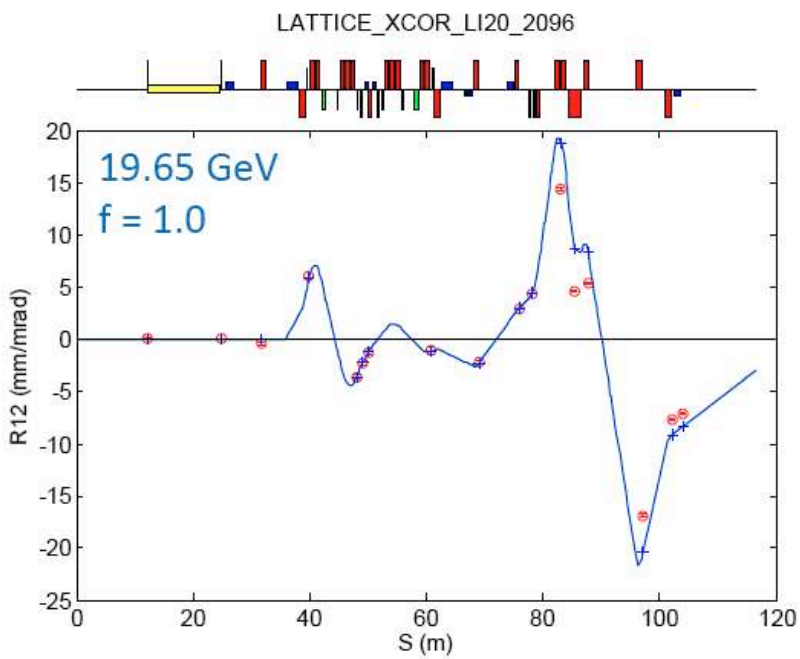
* Note the rather large vertical dispersion.
  – Comparison to MAD results (Nosochkov) indicates S2E

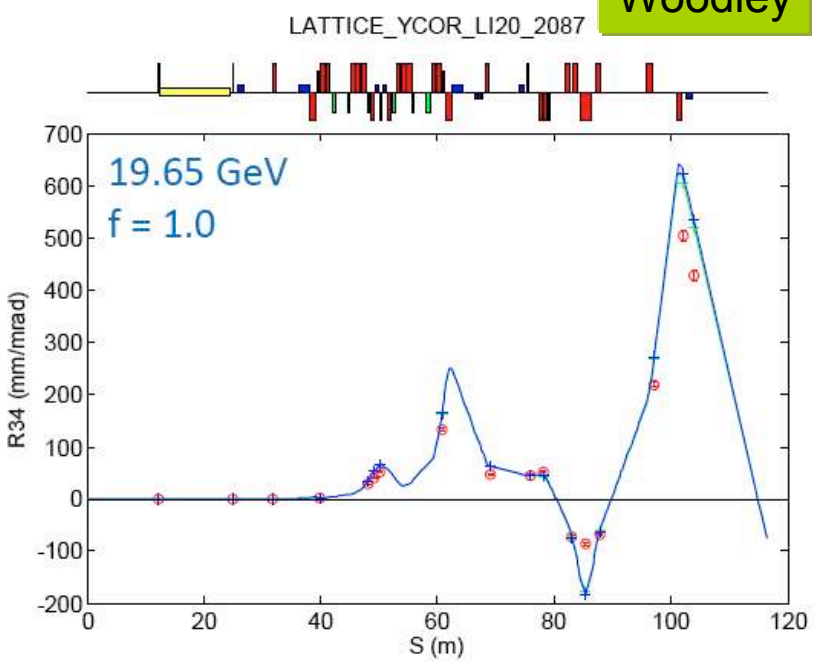
Woodley

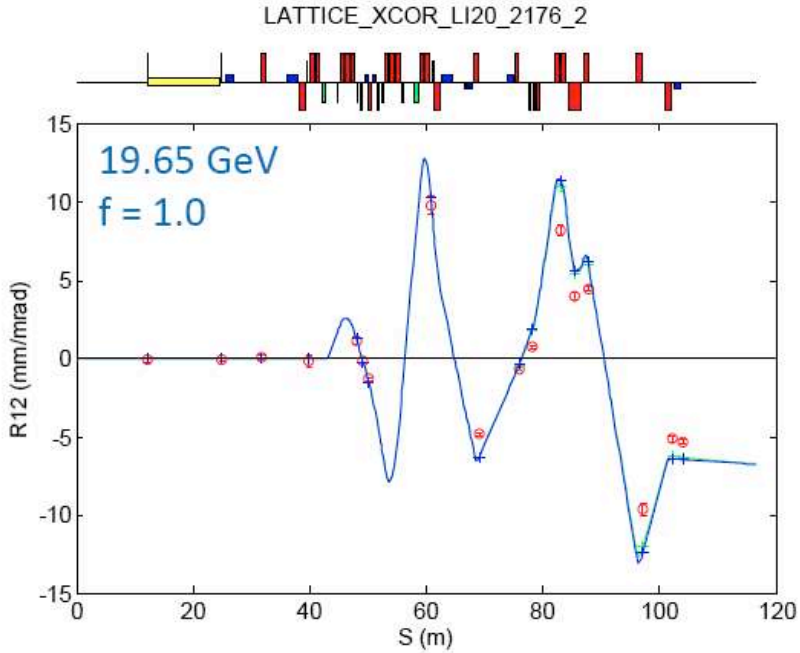


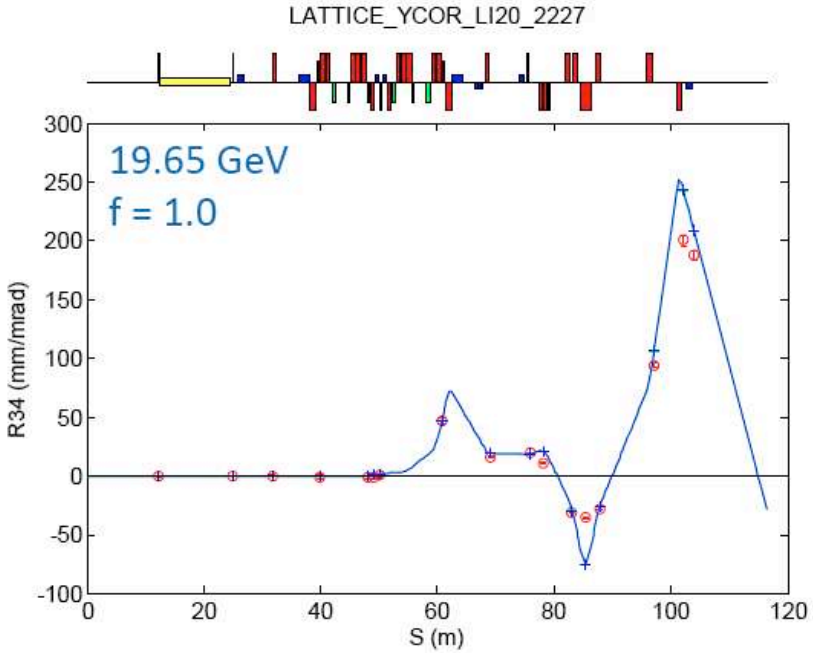


Woodley


LATTICE_XCOR_LI20_2096
19.65 GeV
f = 1.0
R12 (mm/mrad)
S (m)


LATTICE_YCOR_LI20_2087
19.65 GeV
f = 1.0
R34 (mm/mrad)
S (m)


LATTICE_XCOR_LI20_2176_2
19.65 GeV
f = 1.0
R12 (mm/mrad)
S (m)


LATTICE_YCOR_LI20_2227
19.65 GeV
f = 1.0
R34 (mm/mrad)
S (m)

The Linac

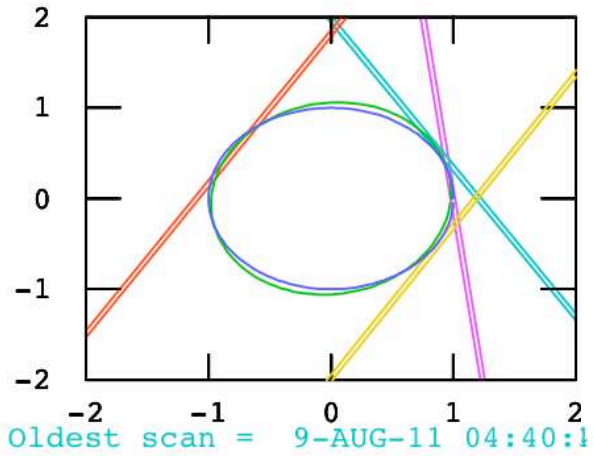
* Re-commissioning of front-end and NDR
  - lots of hardware issues, but no show stoppers
  - largest time-sink was TIU problems
* Beam emittance initially quite large, significant tuning effort
  - fix correctors so local bumps actually work
  - match issue in S02 resolved.
  - nowadays we get 3 by 0.3 in S02 with little mismatch fairly routinely
* S10 chicane recommissioned without much trouble
* Linac emittance in S11 still relatively large

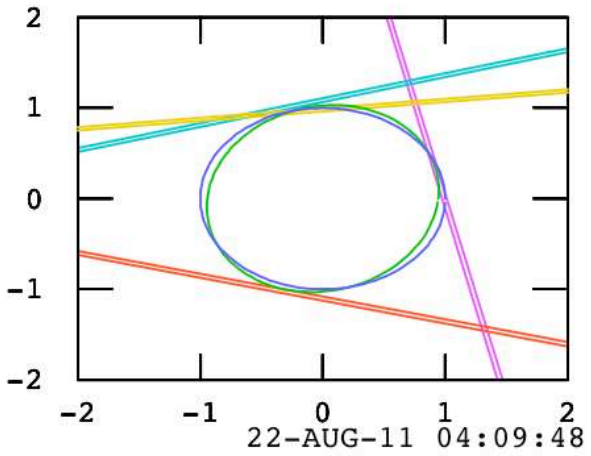
* Linac beam into chicane not yet what we need

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

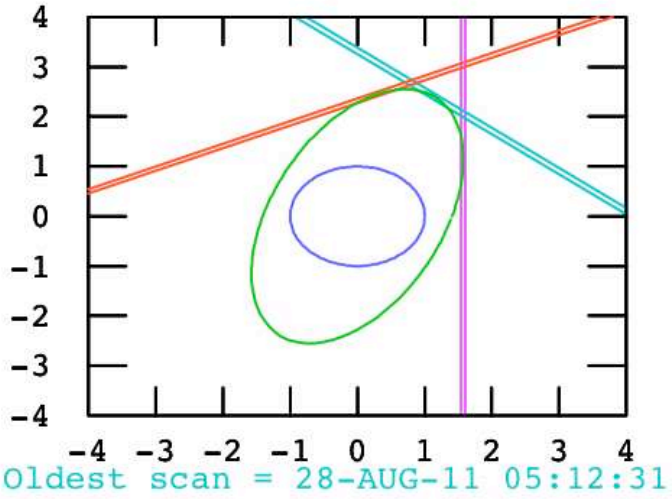


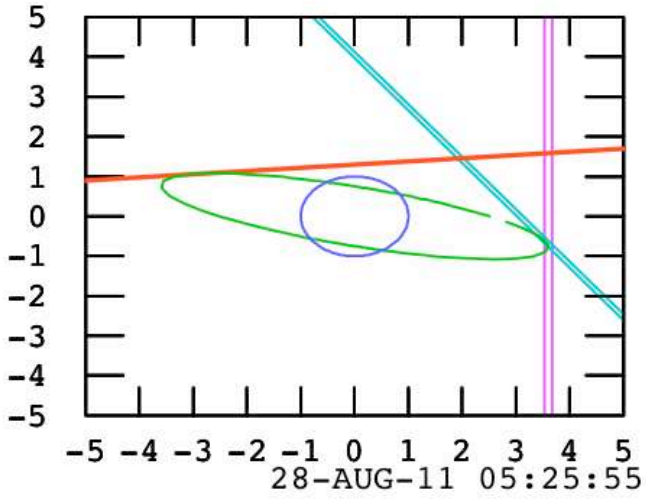


Sector 11 Emittance Scan

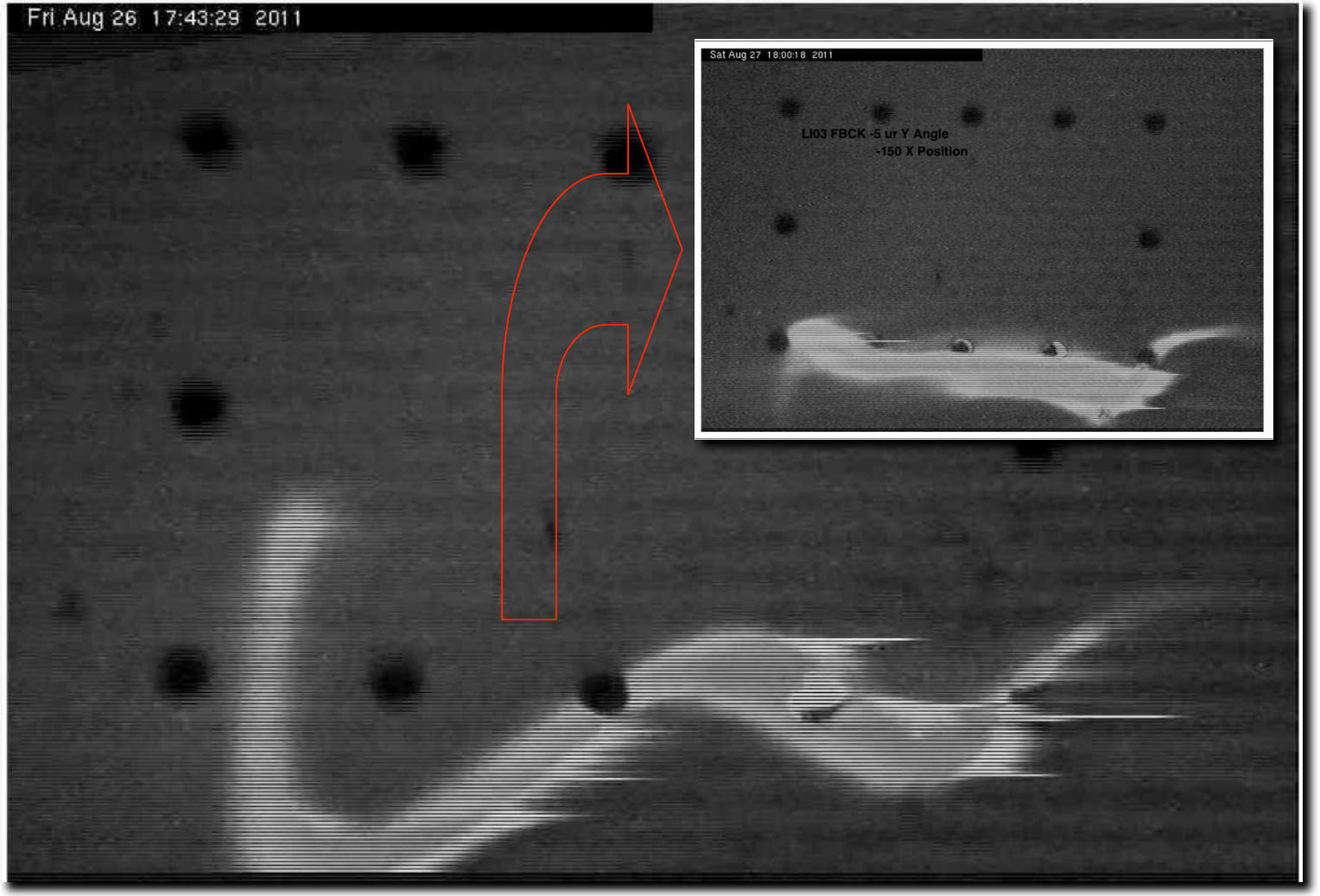
SLC 2-DIMENSIONAL PHASE SPACE ANALYSIS

LI11 X-PLANE ELEC		LI11 Y-PLANE ELEC
10.786+- 0.393 (3.000)	EMITTANCE(mE-5)	0.813+- 0.164 (0.300)
13.513+- 0.322 (3.000)	BMAG*EMIT(mE-5)	2.124+- 0.069 (0.300)
1.253+- 0.044 (1.000)	BMAG	2.611+- 1.972 (1.000)
-0.449+- 0.023 (0.000)	BMAG_COS	0.836+- 0.016 (0.000)
-0.402+- 0.042 (0.000)	BMAG_SIN	0.393+- 0.047 (0.000)
29.812+- 0.980 (43.150)	BETA (m)	46.903+-36.065 (9.785)
-2.121+- 0.109 (-2.341)	ALPHA	3.361+- 2.832 (0.487)
421.929+- 8.439 (267.712)	SIG(344)(um)	145.342+- 2.907 (40.314)
242.355+- 4.847 (93.588)	SIG(444)(um)	217.595+- 4.352 (88.886)
481.915+- 9.638 (228.109)	SIG(614)(um)	51.399+- 1.028 (39.676)
2.348+- 0.205	INTENSITY	1.805+- 0.717
0.000000	CHISQ/DOF	0.000000
-0.235+- 0.203	ASYM(344)	-0.497+- 0.147
-0.374+- 0.057	ASYM(444)	-0.479+- 0.071
0.075+- 0.041	ASYM(614)	0.384+- 0.150





Beam Incoming (PMON)



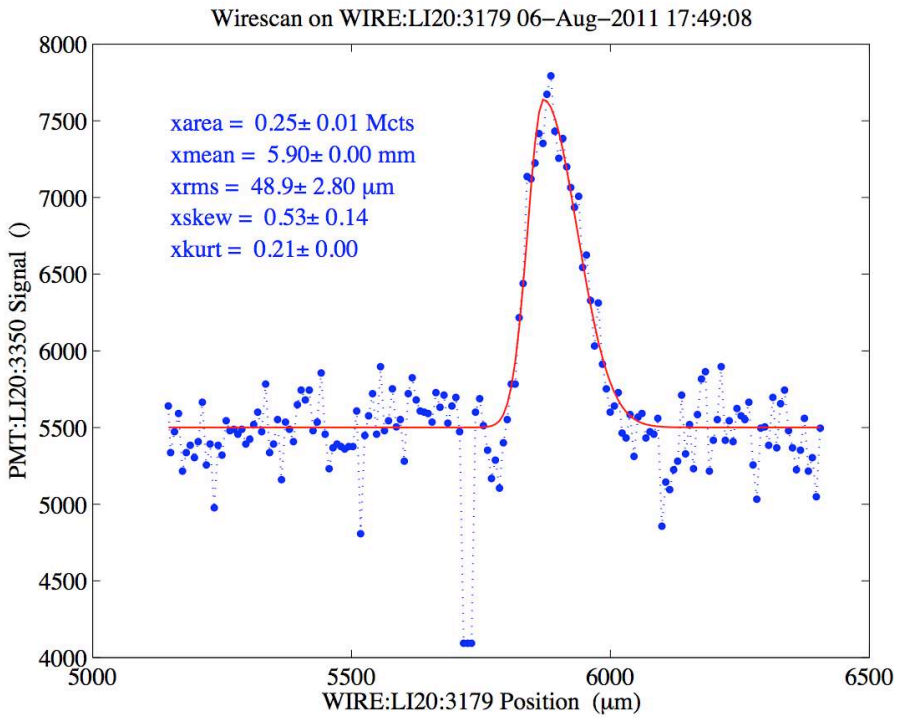
Understanding FACET Beam Sizes

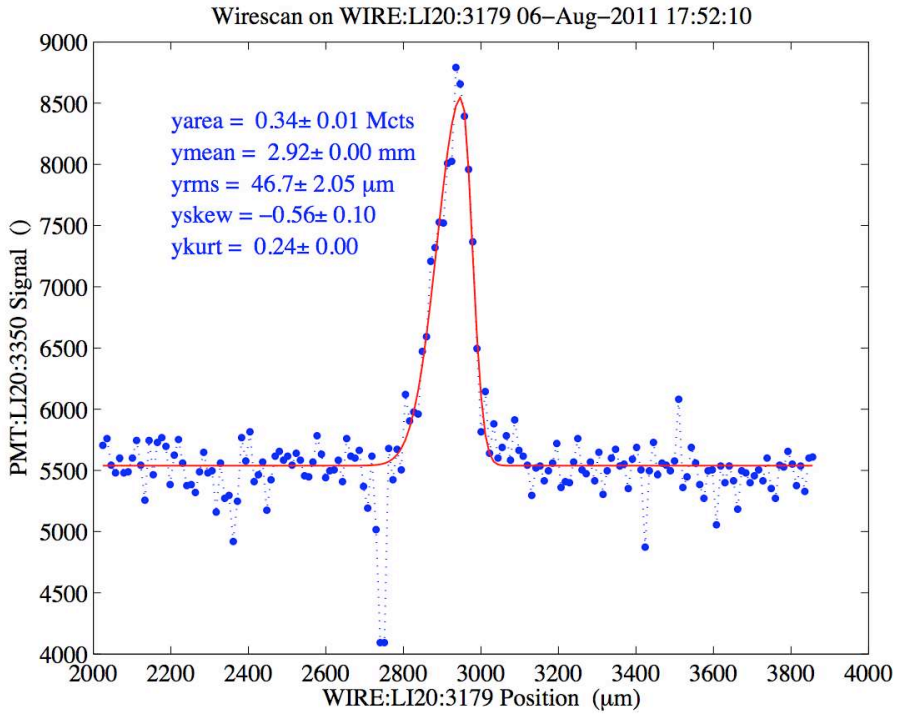
* Best emittance: ≈ 7 by 1 μm-rad (meas in S11)
* $\sigma_{E/E} \approx 1$ % (SYAG, PR185)
* $\eta_x \approx 0.015$ m; $\eta_y \approx 0.015$ m (measured)
* [$\beta_x \approx 0.03$ m; $\beta_y \approx 0.3$ m (design)]

* So the dispersive beamsize alone ≈ 150 μm(!)
  - we have seen beamsizes considerably smaller than this
    - down to 30 by 32 μm @ IPWIRE
  - likely the tuning reduces the dispersion leakage (zero crossing)
* Longitudinal
  - THz indicates bunch length may be near 65 μm.
  - E203 has little signal for 50 μ grating => bunch >> 17 μm long
  - Wakeloss scans about 120 MeV: consistent with SppS data.

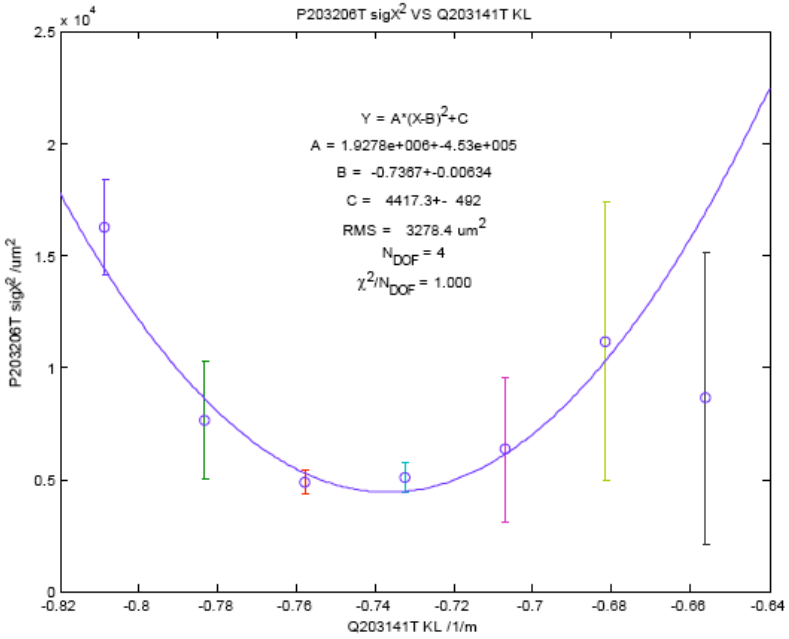
Wirescans @ IP

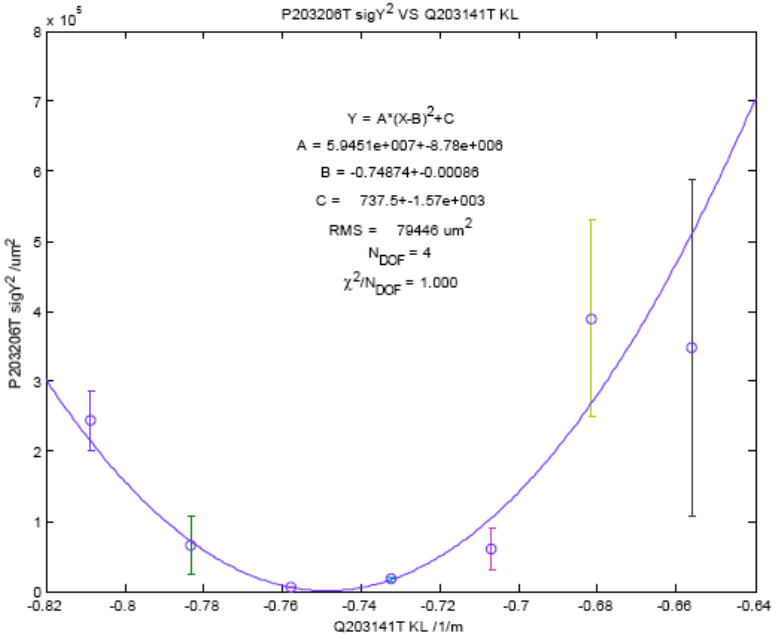
* Note: the best ones were 30 μm by 32 μm
  – some inconsistency to nearby BPMs, but WS calibration checked with dial gauge => WS should be correct.





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)
chisq/N	=	1.000			
min(sig)	=	66.4		um	

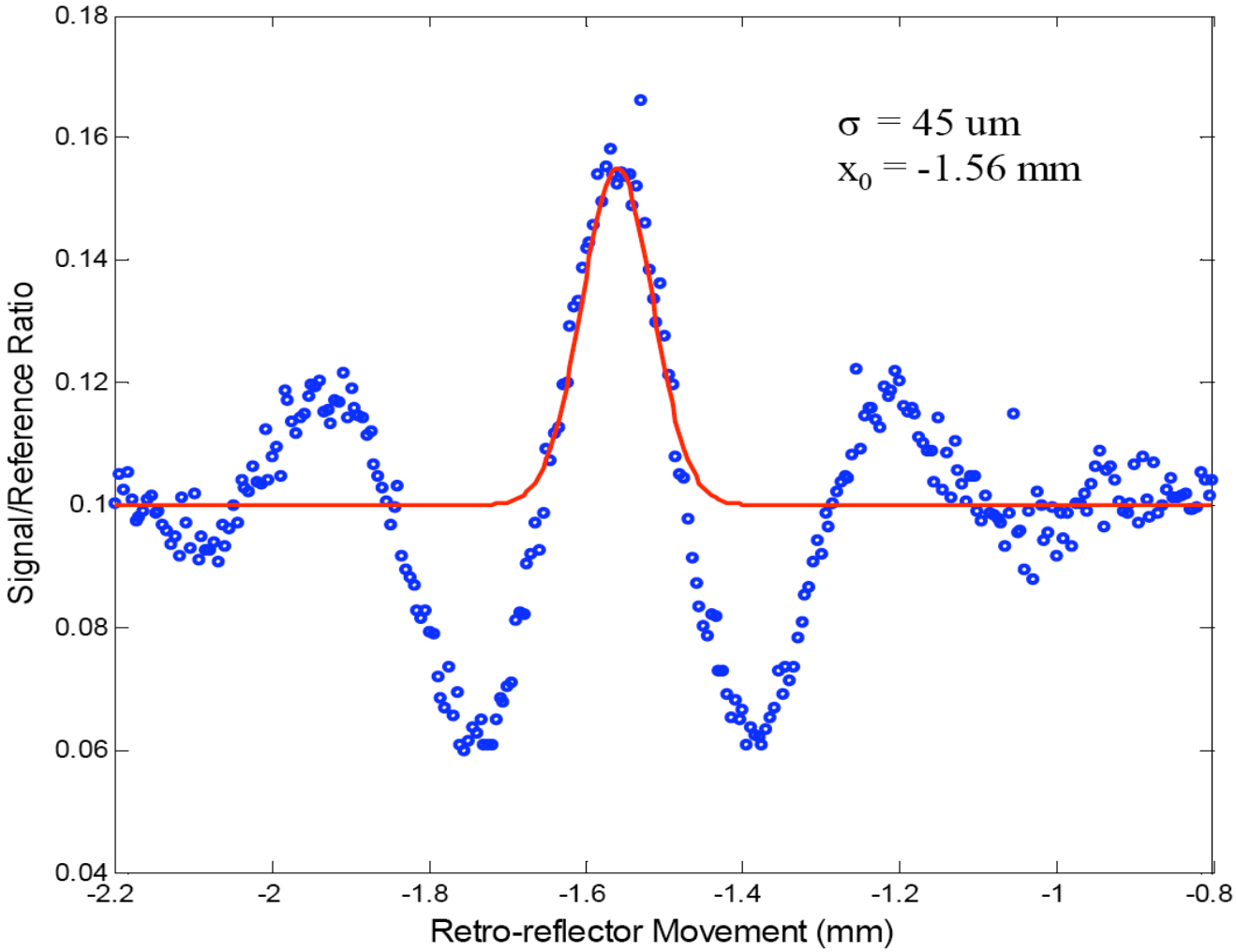
Y emittance parameters at upstream end of Q203141T

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)
chisq/N	=	1.000			
min(sig)	=	27.2		um	

Michelson Interferometer

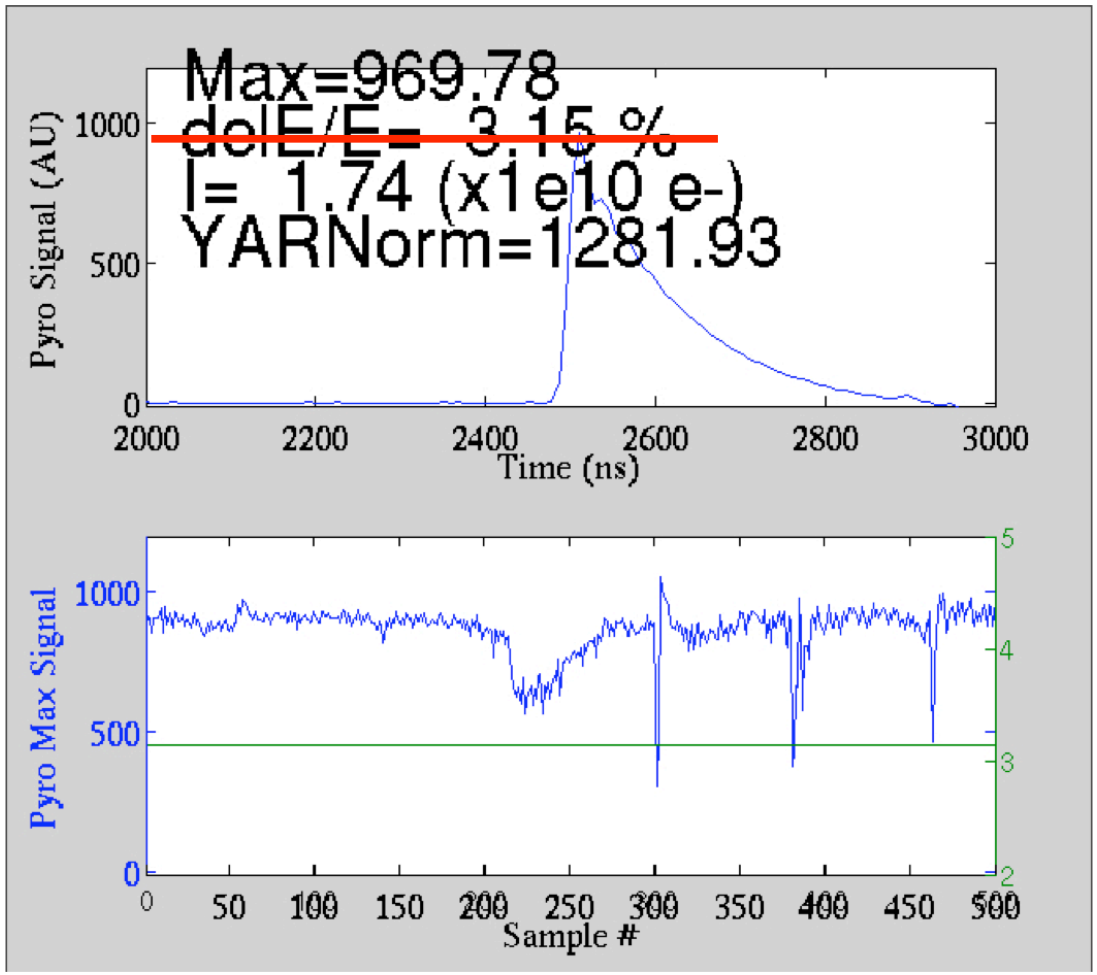
Z. Wu



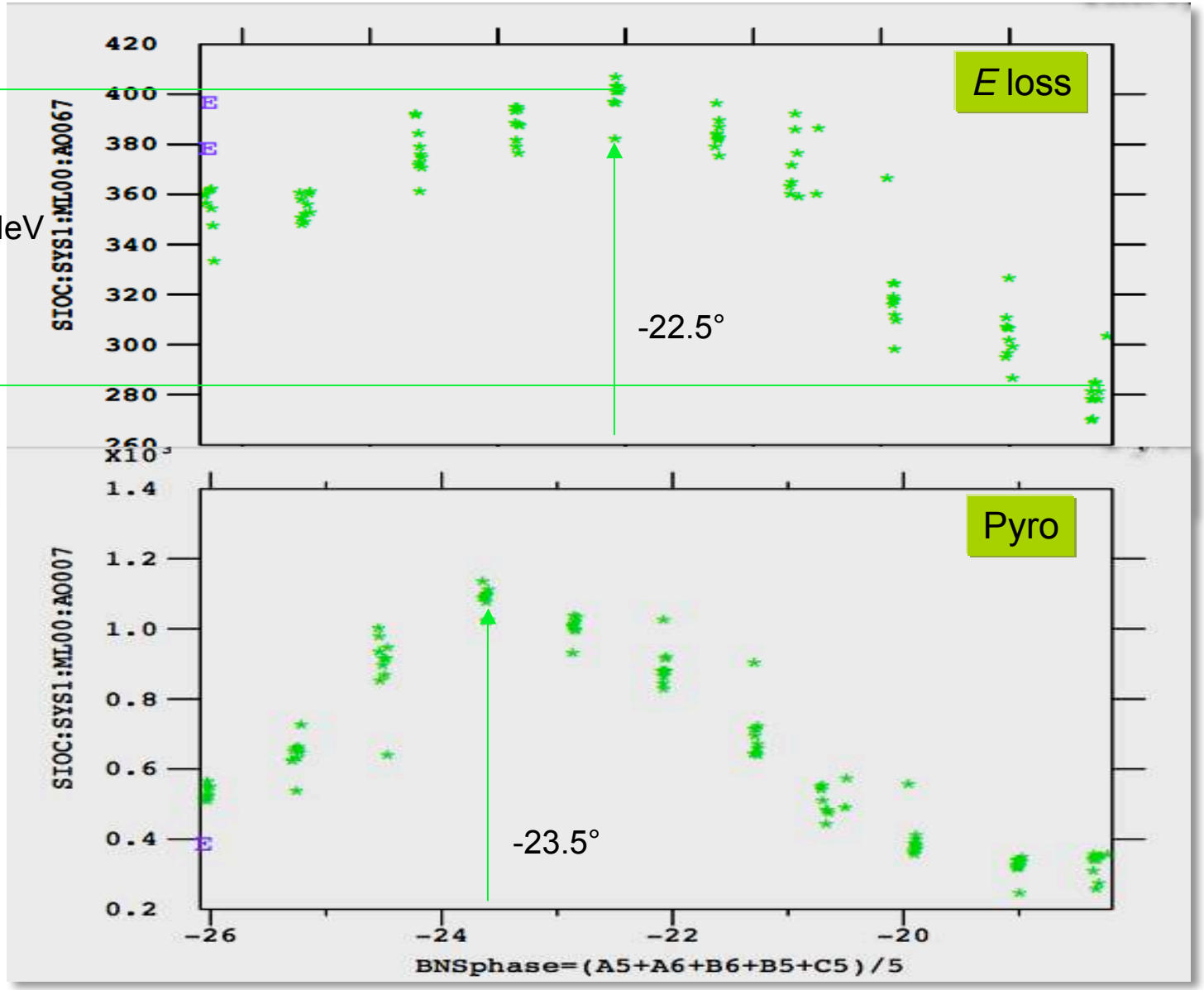
Electron bunch length σ_z = 45 um *2 / sqrt(2) = 63.6 um

Bunch Length Signals

* Pyro ∝ Q^2/l, YARNorm = Pyro/Q^2 ∝ 1/l

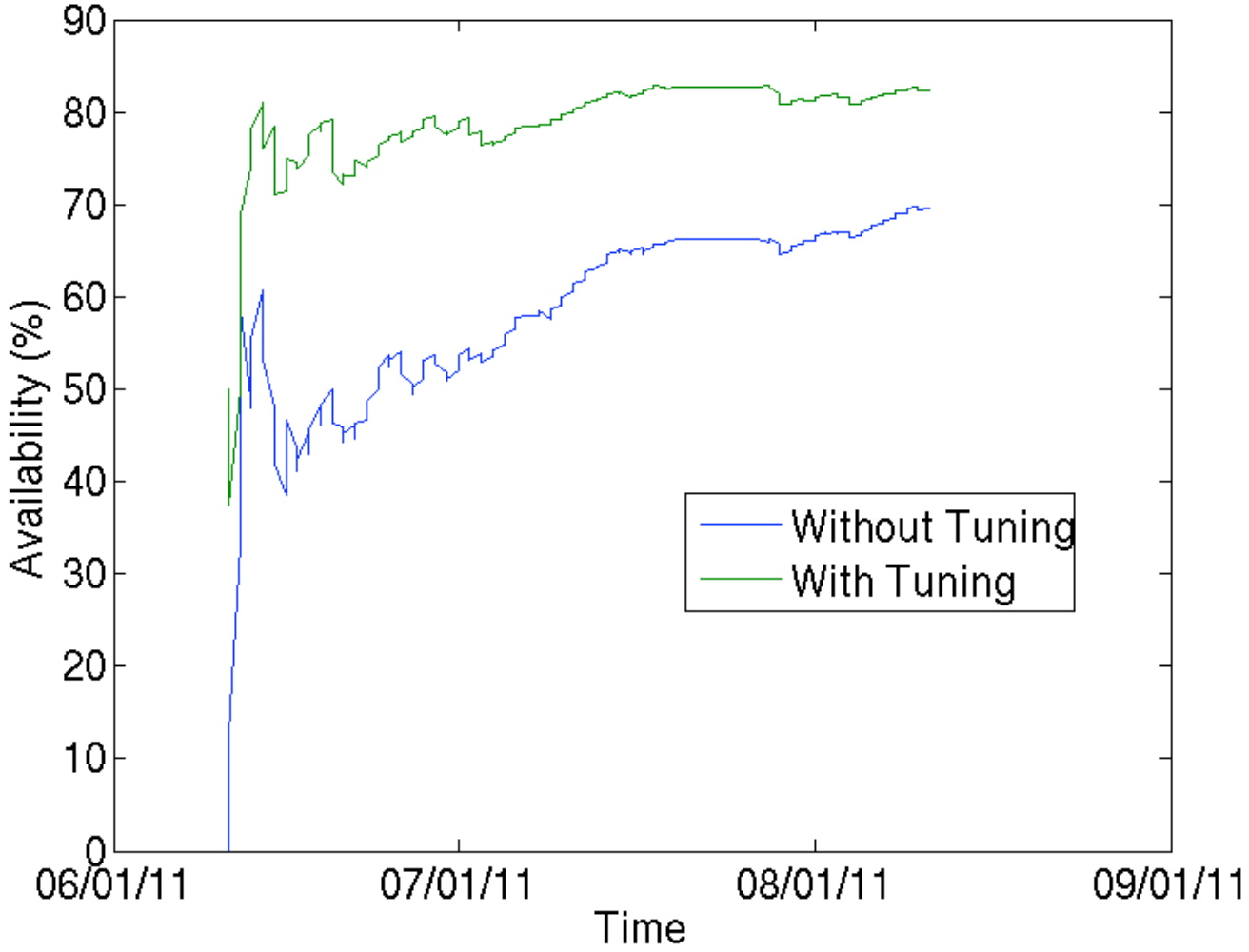


Wake loss Scan



Availability

Colocho



Operational Issues

* One (dedicated) operator/shift
  - initially mostly the ones with SLC experience,
  - now bringing in younger ones as well, cross training
  - during quieter times operate near LCLS => better integration
  - some EOIC's spend time @ FACET beyond their direct shifts
* A set of SOPs is being generated (Schuh, Stanek, Yocky)
  - "Save-the-(FACET-)World" macro
  - Standard characterizations to be done at beginning of shift
  - Tuning & measurement procedures (e.g. wakeloss scan, front-end tuning, etc.)
  - Configurations for different experiments, knobs for waist shifts

Commissioning "mini Workshop"

* On 16-Aug, we used a 3-day exp. installation period to take a step back & look at what we have achieved & where we are going => half-day "mini workshop"
  - Open workshop
  - Invited guests not usually much involved in FACET commissioning
    - Emma, Seeman, Raubenheimer, Safranek, Colby, England, Cai, Iverson, Corbett, Frisch, Hast, Erickson, …
  - Presentations, discussions, suggestions
  - Web site: https://slacspace.slac.stanford.edu/sites/s0-20facetcore/startup/FACET%20Commissioning%20Mini%20Workshop/default.aspx?InstanceID=1

Agenda

Time	Title	Speaker	Duration
9:00	System and acticities overview	Wienands	0:15
9:15	Lattice work and BBA results	Woodley/Decker	0:20
9:35	Aperture scans	Wienands	0:15
9:50	**Discussion**	**all**	**0:15**
10:05	Front-end & DR tuning & performance	Yocky	0:15
10:20	Beam size tuning	Decker (Sheppard)	0:15
10:35	Compression tuning, e-loss scans	Yocky	0:15
10:50	**Discussion**	**all**	**0:15**
11:05	Diagnostics/Controls	tbd	0:15
11:20	Hardware issues	Sheppard	0:15
11:35	Operations report & uptime	Schuh/Stanek	0:15
11:50	Plan for the remaining commissioning time	Wienands	0:10
12:00	**Discussion**	**all**	**0:30**
12:30	Adjourn.		

Workshop Outcome

- 50 Action Items
- A number of commissioning activities suggested:
  - "pencil beam" studies
  - "standard operating procedures"
  - Importance of 2nd- and higher-order aberrations
    - ways to study sextupole issues
  - more structured planning
  - look-ahead planning for downtime
  -
  -
  -

FACET Beam Parameters Achieved to Date

SLAC NATIONAL ACCELERATOR LABORATORY

		achieved
Energy	23 GeV	19.65 GeV
Charge per pulse	0.5 – 2.0 x 10^{10} e^- or e^+	2.0 x 10^{10} e^-
Bunch length at IP (σ_z)	15 – 40 μm	≈65 μm (THz), wakeloss similar to FFTB
Typical spot size at IP ($\sigma_{x,y}$)	10 – 20 μm	>30-50 μm on IPWIRE
Repetition rate	1 – 30 Hz	10 Hz
Momentum spread	4 – 0.5%	3% fw PR185, SYAG
Momentum dispersion at IP (η and η')	η < 10^{-5} m	η ≥ 0.014 m

The Plan Ahead

* I have asked to extend the commissioning run until 15-Sept.
  - I am optimistic this will come through
  - Focused on beam commissioning but will allow for some user time as well.
* We operate under a “Rolling 7-day Plan” that facilitates planning without being unduly inflexible.
  - introduced after the mini workshop
* Beam commissioning will continue to focus on reducing the beam size in all dimensions:
  - Transverse: linac emittance, FACET “final focus”, IP dispersion, 2nd- and higher order effects, diagnostics
  - Longitudinal: reliable and quantitiative bunch length measurement, linac tuning, vary R_{56} in chicane (?)

Details

* Linac tuning for PMON image & FACET spot size interleaved with user shifts (present)
* Low-energy spread “pencil beam” studies
  - discussed at mini workshop
  - requires setup time, incompatible with user shifts
  - expect to be in this mode for up-to 3 days
    - questionable whether e.g. IPWIRE can see this beam
* Sextupole effects study (coupling, aberrations)
  - compare with simulations
* Reduce beam loss
  - activation is a real issue, potentially increasing cool-down time
  - already we attempt to minimize the charge going through FACET
* BBA program not yet complete, esp. at center of “W”
* Calibration of diagnostics (e.g. IPWIRE, OTRs)

Goals (Sept. 14)

* Beam size: 25 by 25 μm or less (IPWIRE or OTR)
* BLEN: ≥ 2000
* Calibrate BLEN/Q2 & wakeloss in μm (vs THz)
* Resolve IPWIRE calibration issues

Downtime work

* We will be down mid-September until ≈ mid February
  - Install Sector 10 e^+ chicane
    - AIP Project now under L. Bentson's leadership
  - Ready e^+ system
    - e^+ source, PRL etc.
    - SDR
    - Work to begin Oct. 1st
  - Identified need for several improvements in the linac:
    - S19 wirescanner + quad supply to facilitate quad emittance scans
    - S11 bunch-length monitor
    - S02 bunch-length monitor
  - Various software upgrades
* There was an expectation to upgrade the PPS for a dedicated S20 zone
  - Cost estimate came in @ M$ 1.4...☹ (not incl. dark-current stoppers)
  - Need to regroup & see how this can be done.
  - Actual impact less than might be thought
    - 1-hr cool-down will remain independent of this

Summary

* FACET commissioning has been a challenging experience
* The chicane optics we believe is mostly understood
  – dispersion, aberrations still need work
* We are “re-learning” how to minimize wakefield effects in the linac
  – will be continuing challenge
* The frontend, incl. NDR, produce the required intensity & phase-space density
* As we continue making progress with beam sizes and halo, beam loss in the chicane will diminish
* e^+ next year will provide additional challenge

Thank You to all Involved in getting FACET off the Ground!

FACET Construction Mgt. Team:

N. Phinney, J. Q. Chan, J. Sheppard, U. W.

Commissioning team: *next page*

Commissioning team

- G. Yocky
- N. Lipkowitz
- F.-J. Decker
- J.C. Sheppard
- M.D. Woodley
- T. Smith
- W. Colocho
- S.P. Weathersby
- P. Schuh
- M. Stanek
- J. Nelson
- J. Turner
- H.V. Smith
- U. Wienands
- C. Clarke
- S. Kalsi

plus AARD-PWFA members:

M. Hogan

S. Li

E. Adli

S. Gessner

J. Frederico