

Initial Experience with Injector Commissioning

P. Emma, et al.

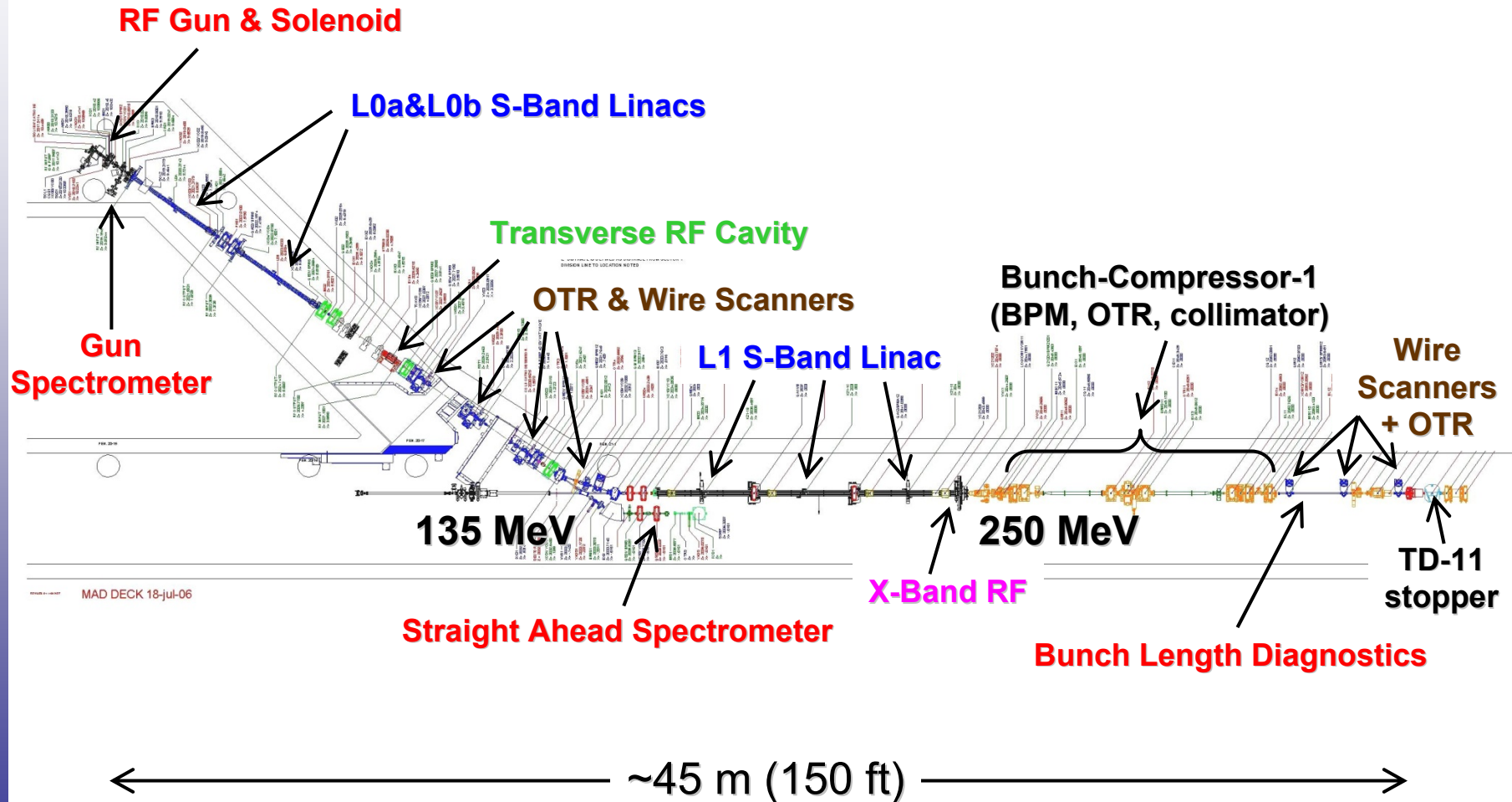
Facilities Advisory Committee Meeting

April 16, 2007



<http://www-ssrl.slac.stanford.edu/lcls/internals/commissioning/index.html>

LCLS Injector Through BC1



Electron Beam Transported to All Injector Areas

- **April 5:** First photo-electrons from gun
- **April 5:** First beam to gun spectrometer
- **April 8:** First beam to inj. spectrometer
- **April 9:** First beam in linac, to TD11 dump
- Up to ~300 pC of charge (300 μ J laser)
- 10 Hz beam & 30 Hz RF (30 Hz e^- possible)
- Gun RF feedback running well (+ water)

Pre-Beam Tunnel Check List Almost Complete

40 pages – all DONE (except many screens)

QA12 (ET quadrupole magnet):
QUAD:LI21:161

- Z-location = 26.33 m
- SLAC bar-code 000427 (ser. #016)
- beam-direction arrow OK
- polarity OK (Fig. 7)
- name-label visible on or near device
- field responds to controls
- quadrupole field
- power connections tight and clear
- power cables labeled for polarity

BPMA12 (QA12 BPM):
BPMS:LI21:161

- Z-location = 26.33 m
- Ser. SA-380-514-01-02
- Installation orientation OK (Fig. 13)
- polarity color-coding OK
- feed-through on upstream end
- name-label visible on or near device

XCA12 (type-1s QA12 x-steering coil):
XCOR:LI21:165

- Z-location = 26.79 m
- SLAC bar-code 001036
- beam-direction arrow OK
- polarity OK (Fig. 1)
- name-label visible on or near device
- field responds to controls
- dipole field
- power connections tight and clear
- power cables labeled for polarity

YCA12 (type-1s QA12 y-steering coil):
YCOR:LI21:166

- Z-location = 26.79 m
- SLAC bar-code 001036
- beam-direction arrow OK
- polarity OK (Fig. 2)
- name-label visible on or near device
- field responds to controls
- dipole field
- power connections tight and clear
- power cables labeled for polarity

YC21203 (type-4 y-steering coil):
YCOR:LI21:203

- Z-location = 28.79 m
- SLAC bar-code ?

Handwritten notes in the form include: "002003", "Pin-3 up (40k)", "added", "002006", and "PC".

Polarity conventions

Field type (quad dipole)

Serial numbers

Installation orientation

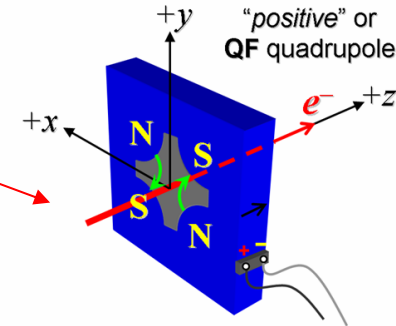


Figure 7. A "positive" normal quadrupole magnet (above) focuses electrons in x (a 'QF' quadrupole).

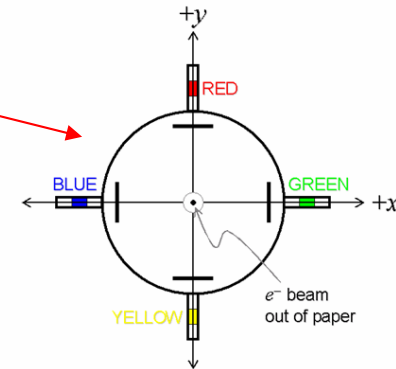
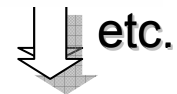
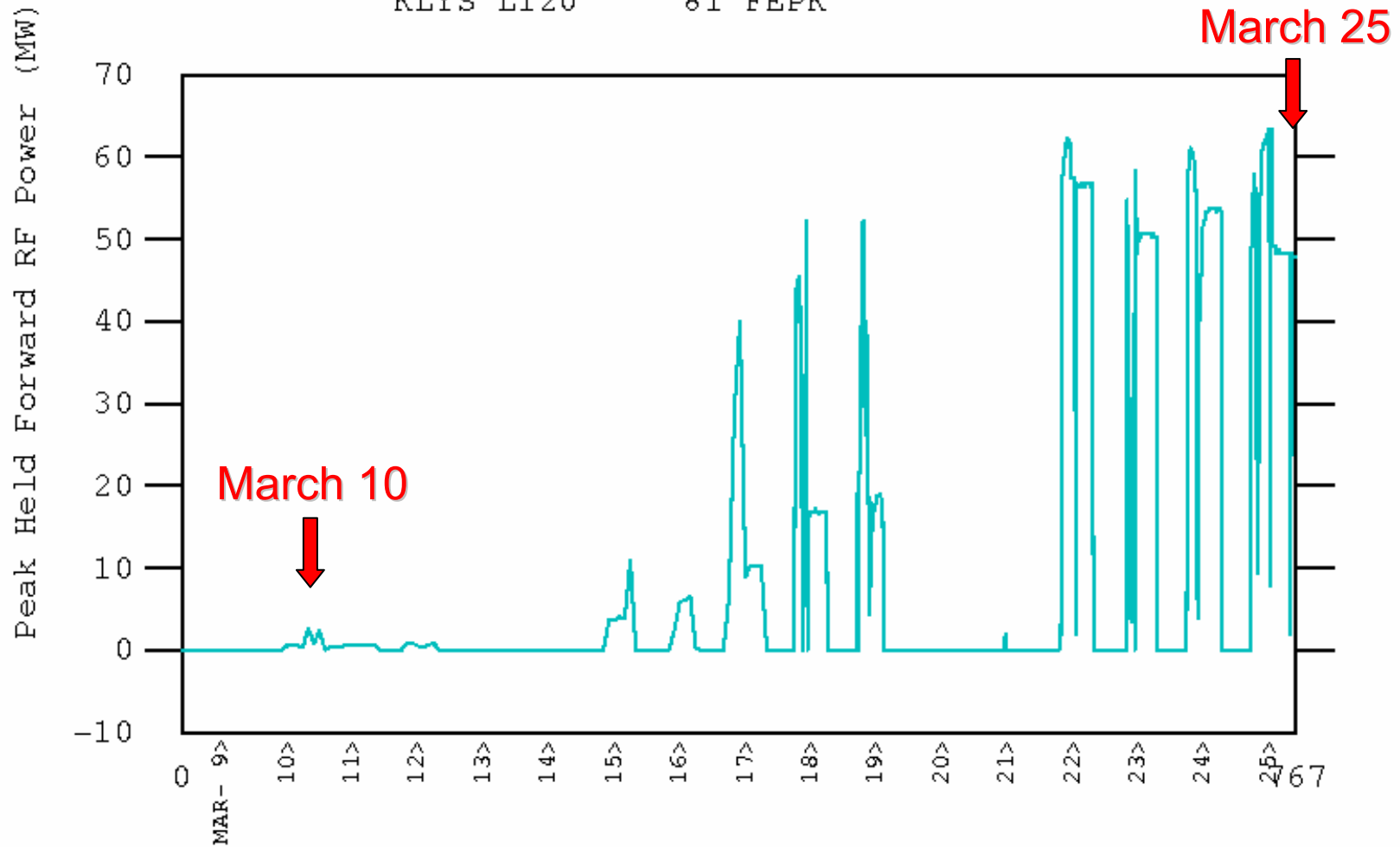


Figure 13. A BPM (above) as seen down its bore with electron beam emerging from paper. The BPM is installed in the upright position ($\theta = 0$). The cable color-coding standard is also illustrated.

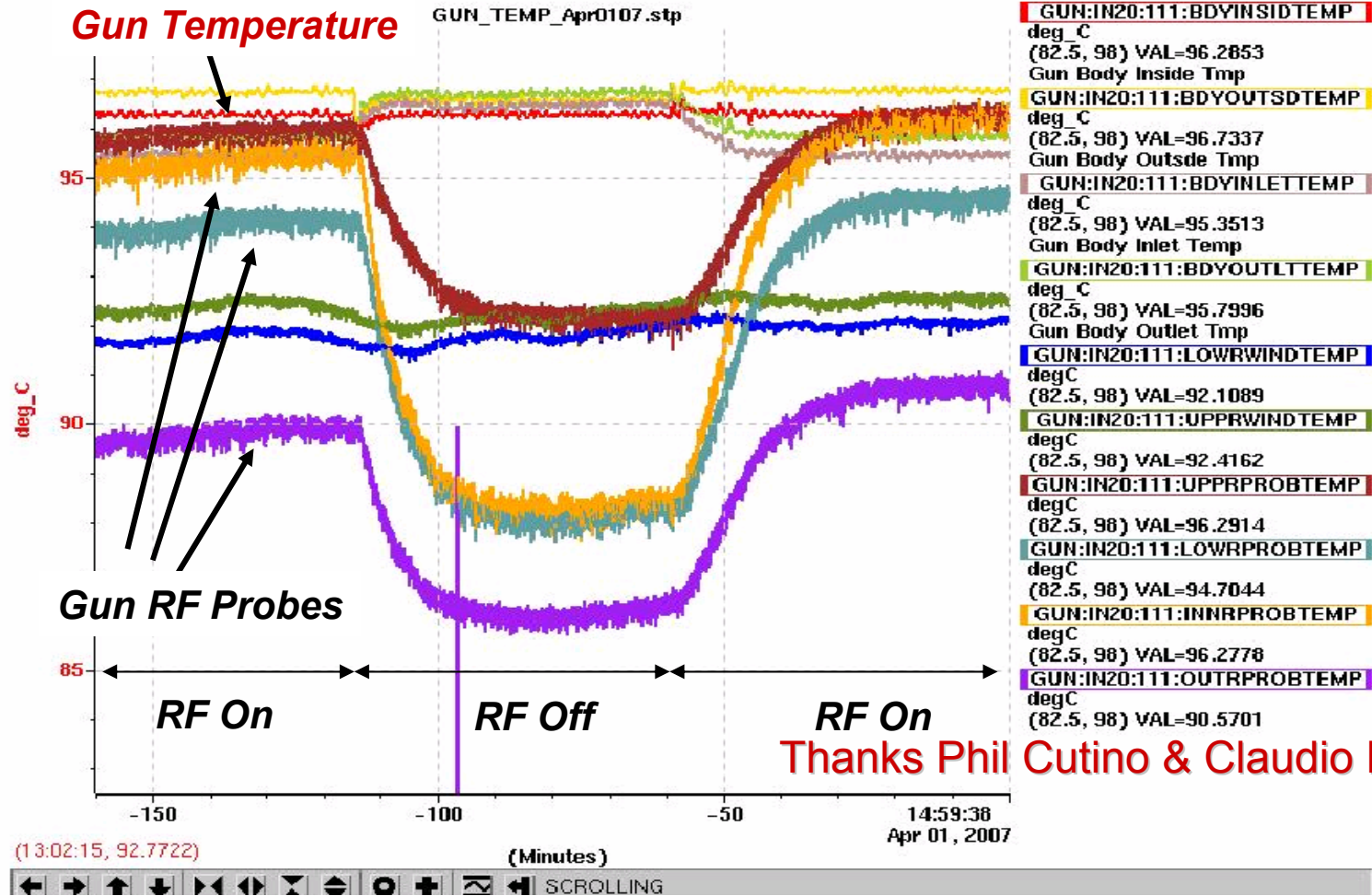


RF Processing of L0b (20-8)

KLYS LI20 81 FEPK

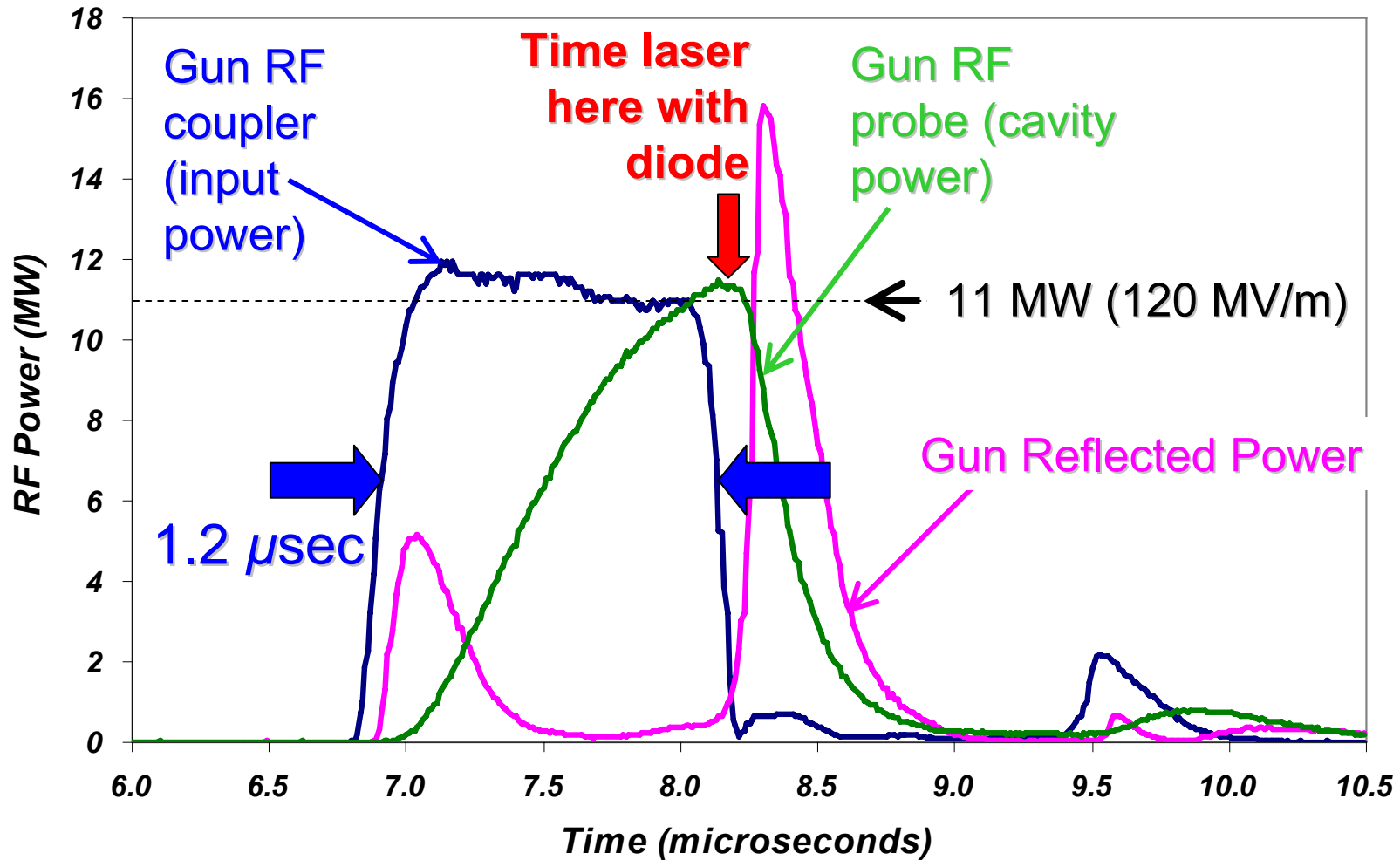


Gun Temperature Feedback Loop

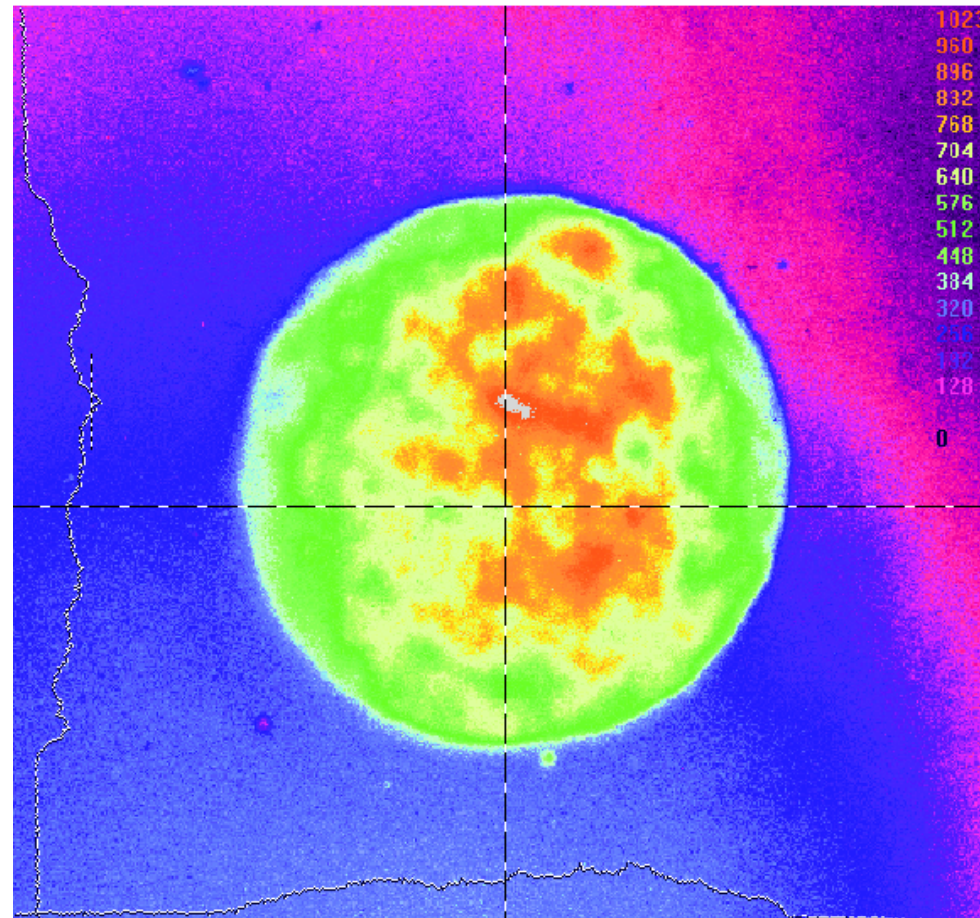


Thanks Phil Cutino & Claudio Rivetta

Gun RF Power (30 Hz)

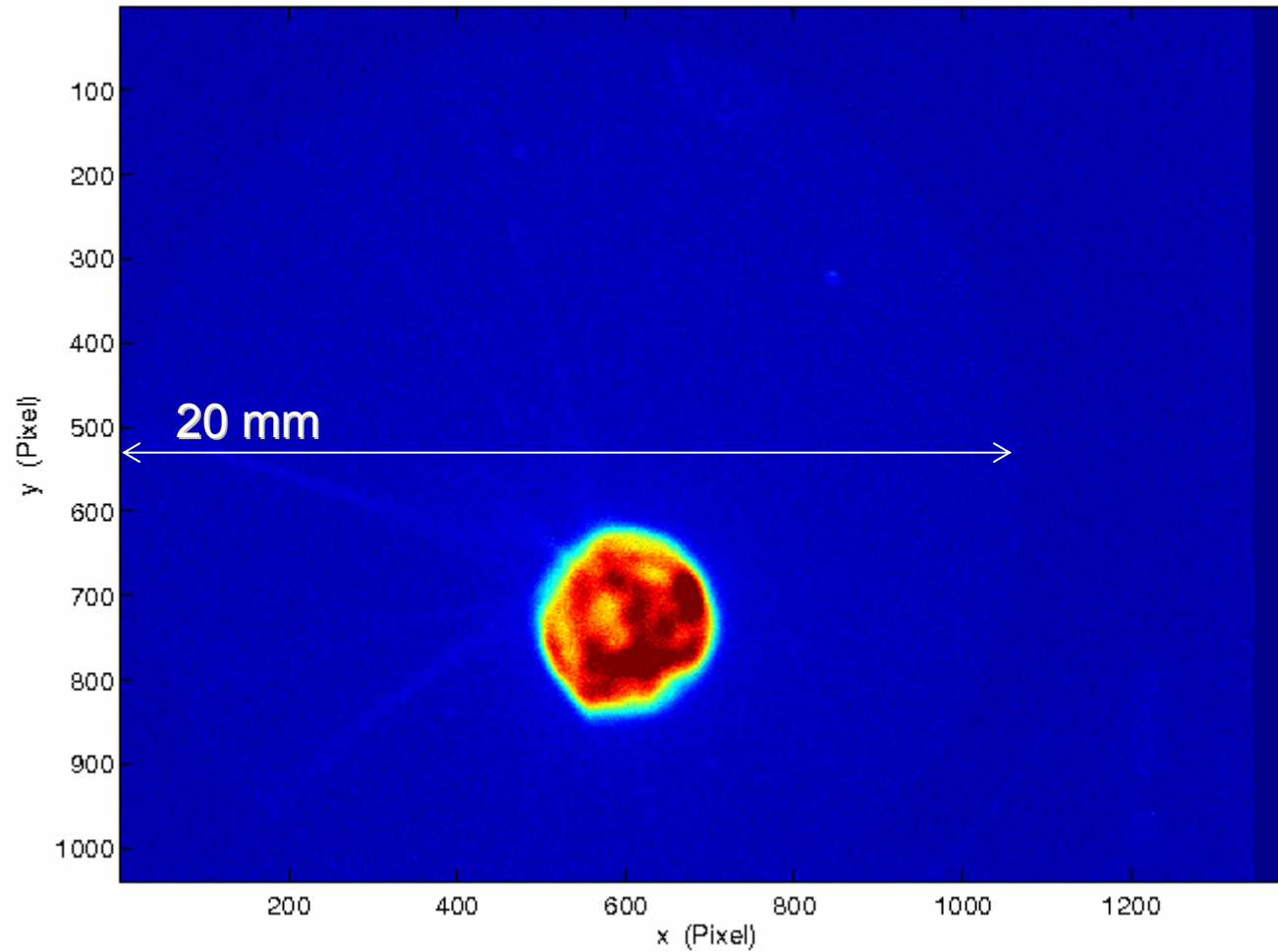


Virtual Cathode (optical image of laser spot on cathode)

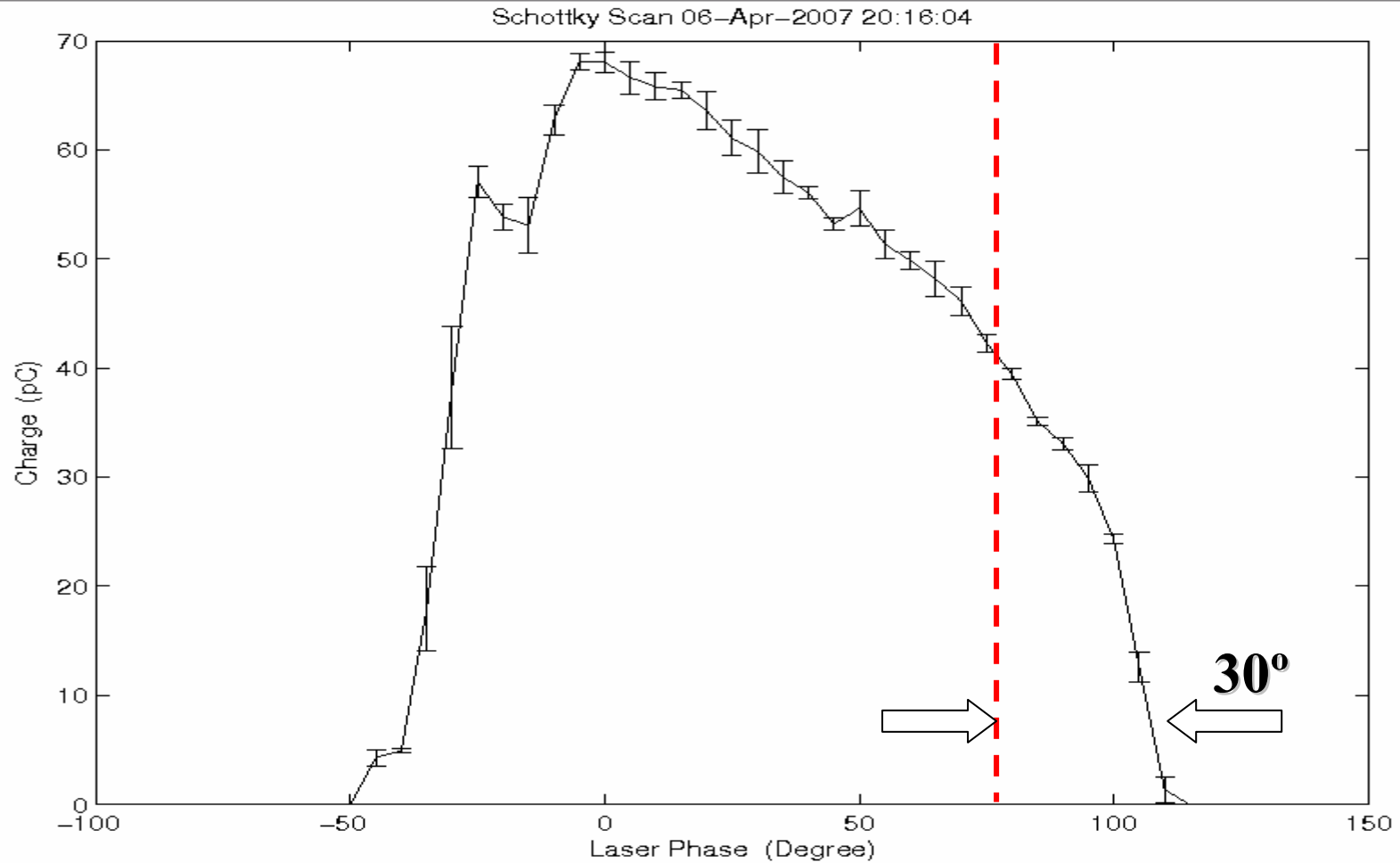


Beam on YAG02 (80 cm from gun)

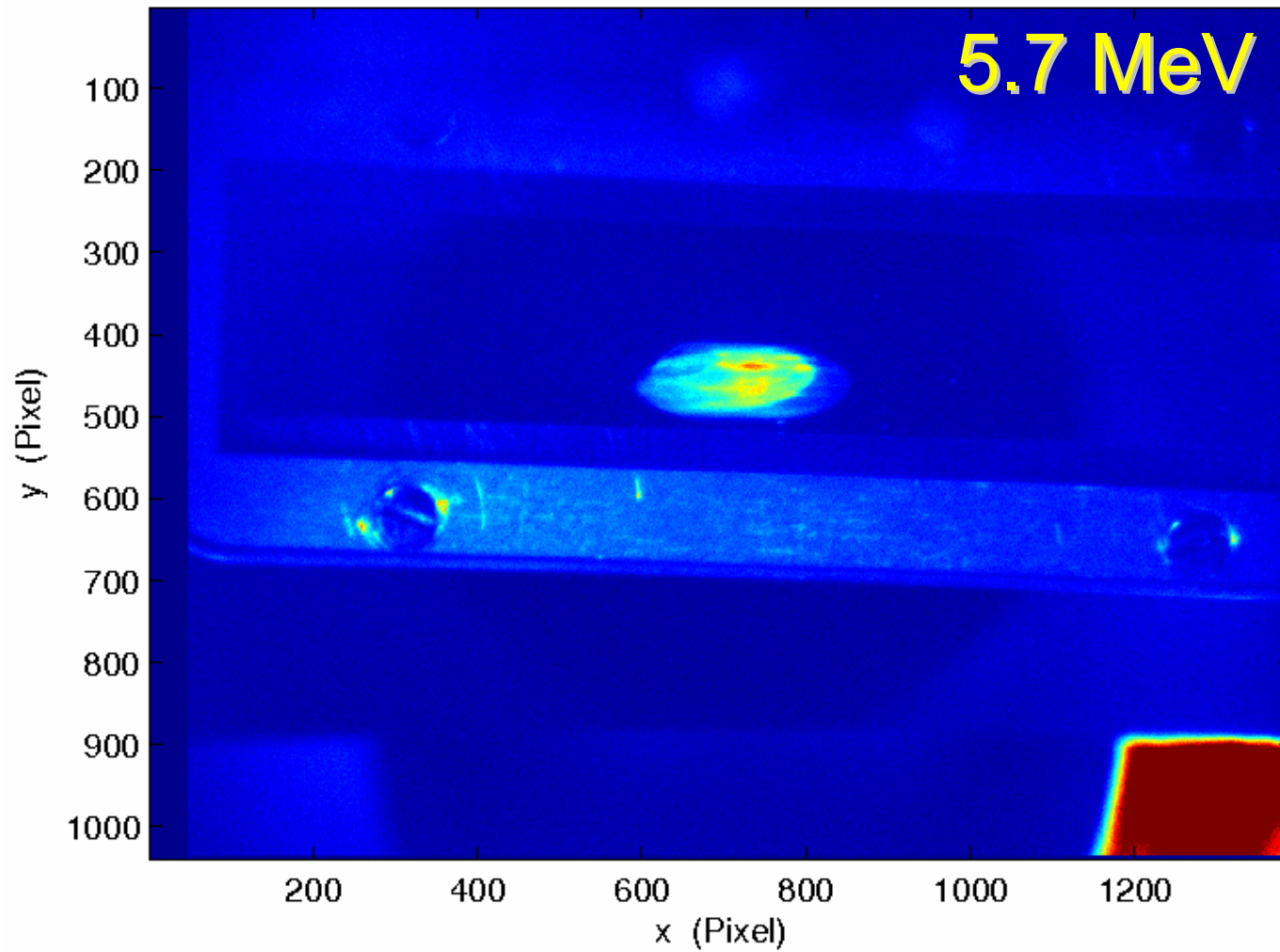
Profile Monitor YAGS:IN20:241 05-Apr-2007 19:34:51



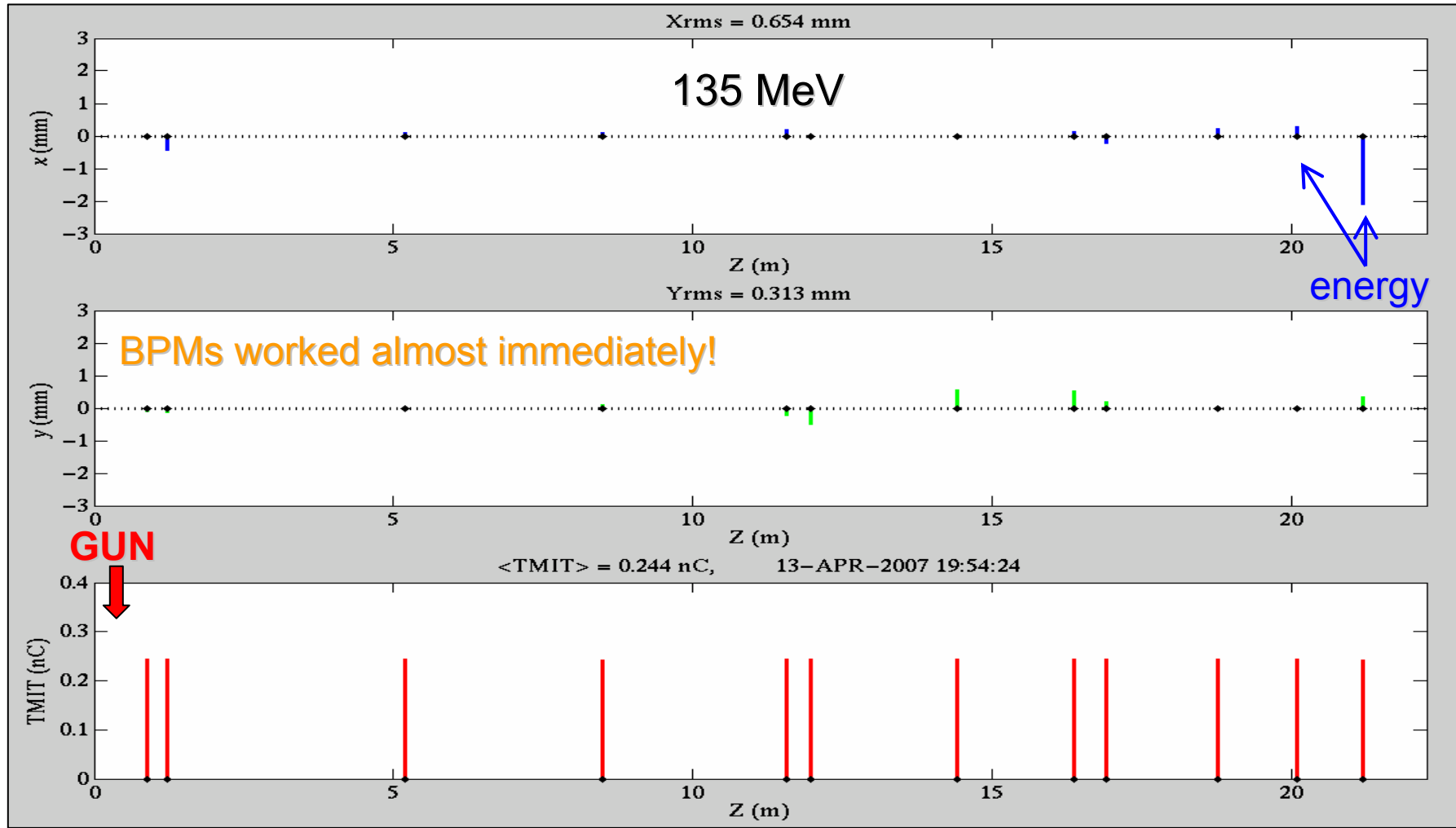
Laser Phase (Shottky) Scan



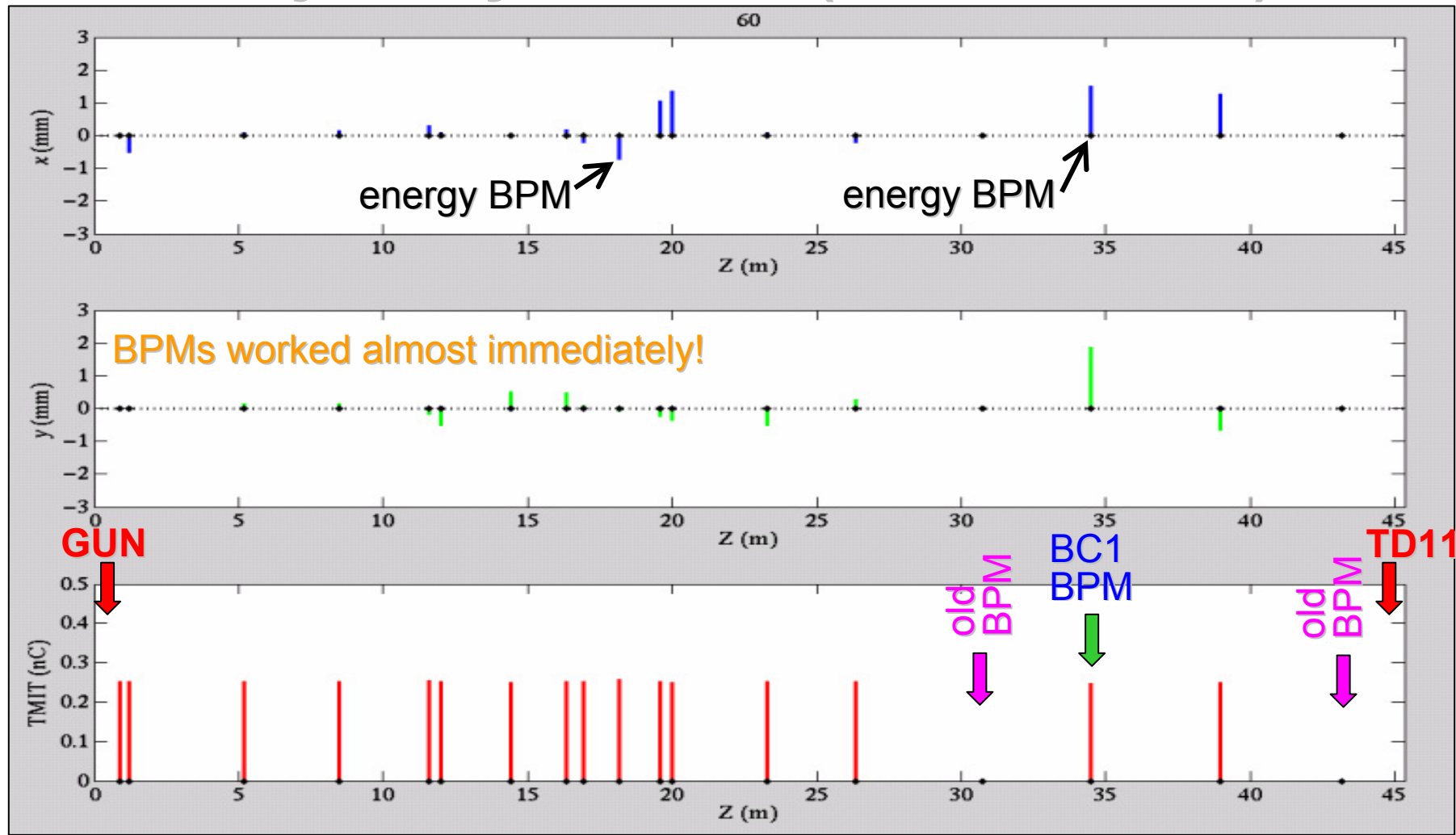
Beam on Gun Spectrometer



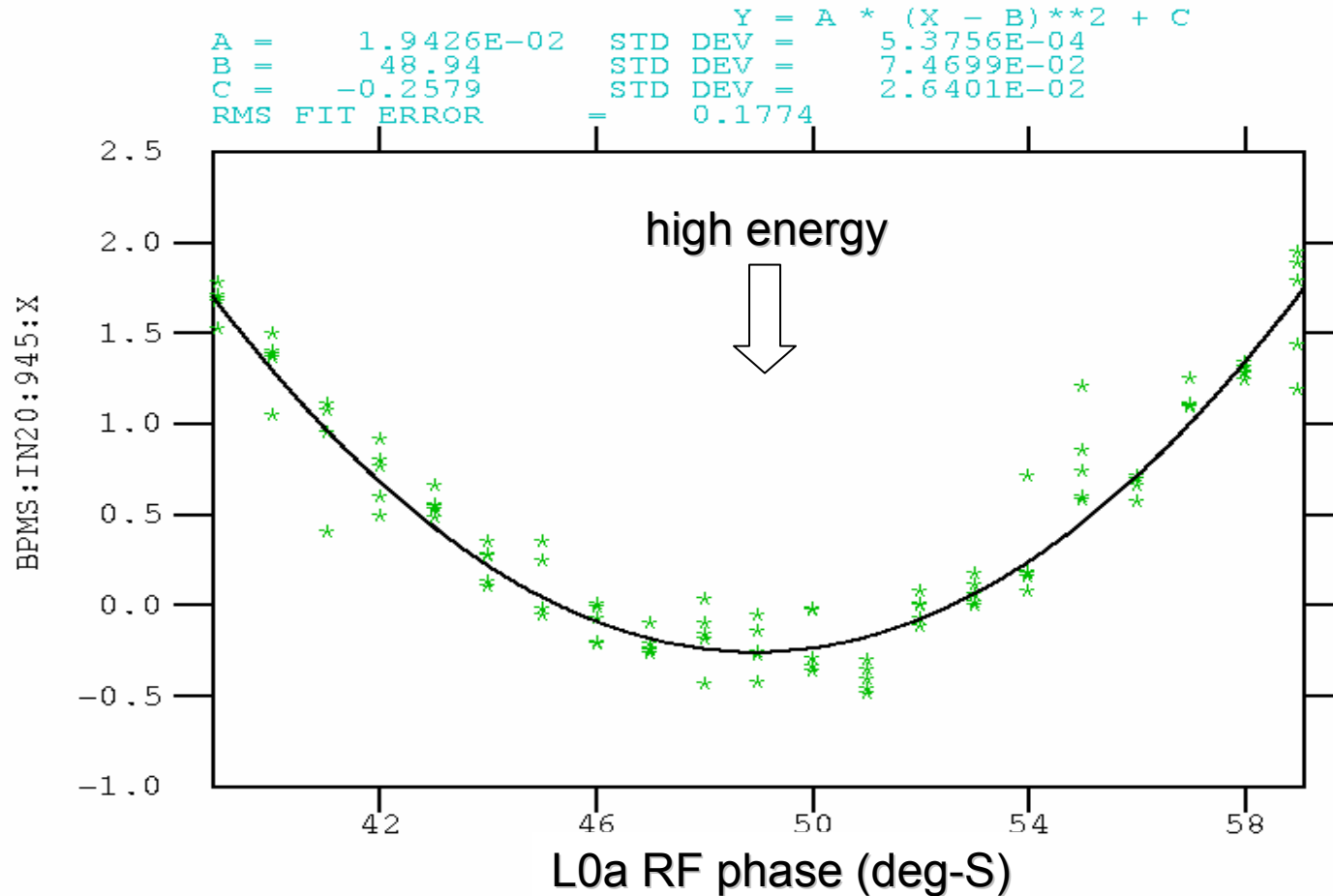
Beam to Injector Spectrometer



Trajectory to TD11 (in main linac)



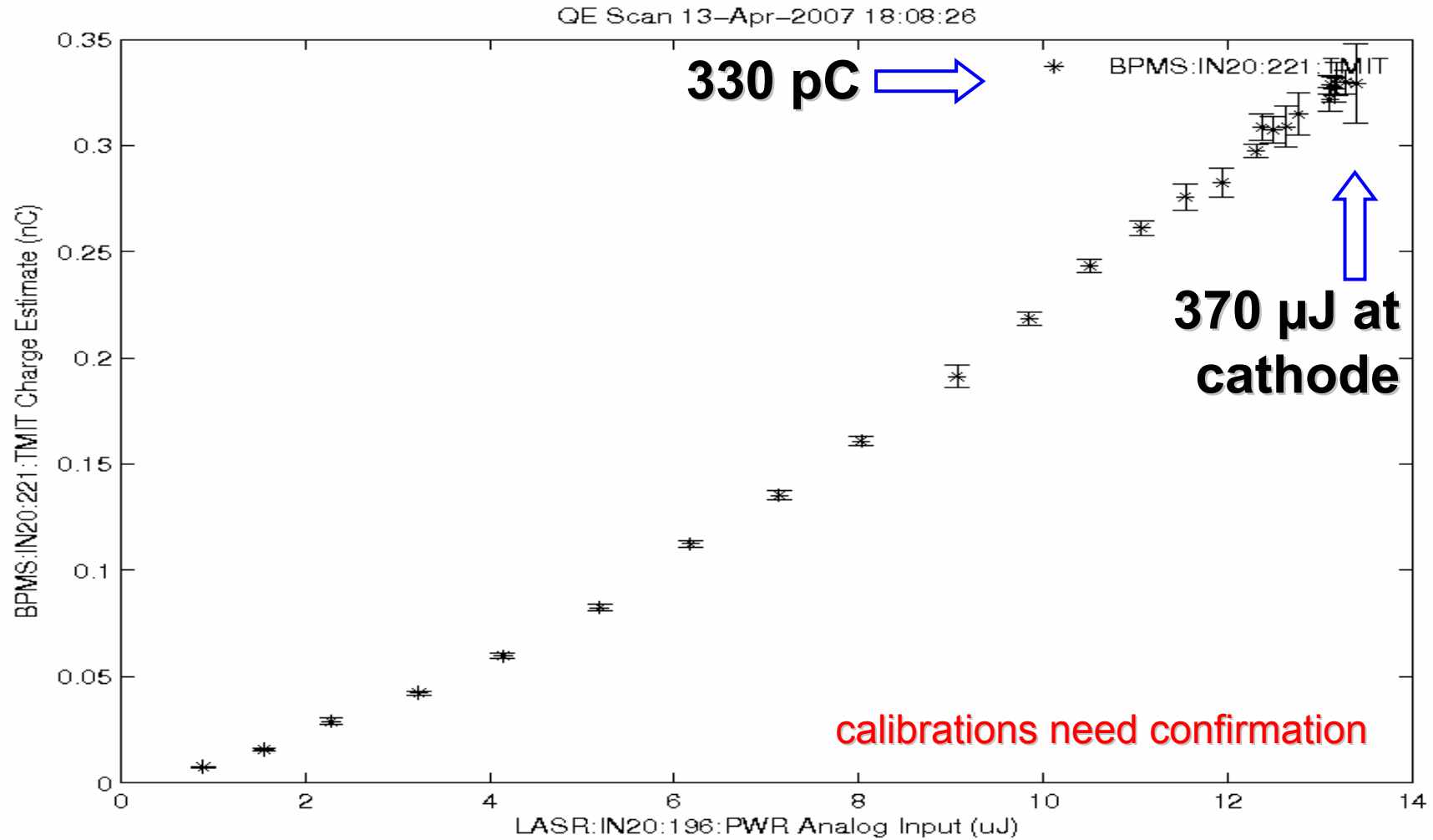
L0a RF Phase Scan on Dispersed BPM X



MATLAB:5.VAL STRT=39.000 STEPS= 21 SIZE=1.0000
STEP VARIABLE = TIME STEPS=5 DELAY=0.0000

12-APR-07 10:24:58

Bunch Charge vs. Laser Energy



EPICS Controls - Vacuum

LCLS Subsystems and Areas: vac in20

Help... Home Screen... Exit

All IN20 LI21 LI22 LI23 LI24 LI25 LI26 LI27 LI28 LI29 LI30 BSY1 LTU1 UND1 DMP1

All
BPM/Toro/FC/BLen
Feedback
Magnet
Profile Monitor
Wire Scanner
Collimator/Motion
Laser
RF
Event
Network
Watr/Pwr/Gas/Smok
Vacuum
Temperature
MPS
PPS
BCS

Schematic

Gun RF Vacuum... L0a RF Vacuum... L0b RF Vacuum... TCav0 RF Vacuum...

Gun

light pipe from laser room

Injector Vault Linac Tunnel Sector 21

3.0e-08

5.1e-10 2.4e-09 1.7e-08 1.5e-08 1.7e-08 2.2e-08

Device Lists

Beamline Pumps... Gauges...
Waveguide Pumps... Valves... PPS...

Interlock Logic

Valves... Gun Waveguide... L0a Waveguide...
L0b Waveguide... TCav0 Waveguide...

Diagnostics

PLC Hardware Status...
Expert...

Legend... Full Schematic...

PRODUCTION vac_in20_main.edl 04/13/2007 11:57:02

EPICS Controls - Magnets

IN20 Magnets All

Injector IN20 Magnets - PRODUCTION Help... Home Screen... Exit

04/13/2007 12:00:29

Device List

BENDs... XCORs... LGPS...
QUADs... YCORs... SOLN...

Select Control

All All BENDs All BTRMs All LGPSs All QUADs All XCORs All YCORs All SOLNs
None No BENDs No BTRMs No LGPSs No QUADs All XCORs No YCORs No SOLNs

Control Function Ready

Abort Control Function X

	Config	B-Field		Trim	Perturb	Control Function	Abort Control Function	
		Actual	Desired					
<input type="checkbox"/> SOL1BK	111...	-0.018228961	-0.000003199	0.000000000	kG	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change
<input type="checkbox"/> SOL1	121...	0.370000005	0.290003320	0.290000000	kG-m	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change
<input type="checkbox"/> CG01	121...	0.000000000	0.002751988	0.000000000	kG	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	Good
<input type="checkbox"/> XC00	121...	-0.000407130	-0.000244185	-0.000250000	kG-m	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change
<input type="checkbox"/> YC00	122...	-0.000600000	-0.000350851	-0.000350000	kG-m	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change
<input type="checkbox"/> SQ01	122...	0.000000000	-0.000228168	0.000000000	kG	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	Good
<input type="checkbox"/> XC01	221...	-0.000200000	0.000328663	0.000330000	kG-m	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change
<input type="checkbox"/> YC01	222...	0.000150000	-0.000219345	-0.000220000	kG-m	<input type="checkbox"/> Ready	<input checked="" type="checkbox"/> X	BDES Change

EPICS Controls – Profile Monitors

LCLS Subsystems and Areas: prof in20

Help... Home Screen... Exit

All IN20 LI21 LI22 LI23 LI24 LI25 LI26 LI27 LI28 LI29 LI30 BSY1 LTU1 UND1 DMP1

All
BPM/Toro/FC/BLen
Feedback
Magnet
Profile Monitor
Wire Scanner
Collimator/Motion
Laser
RF
Event
Network
Watr/Pwr/Gas/Smok
Vacuum
Temperature
MPS
PPS
BCS

Map

The diagram shows a beamline layout with the following components and controls:

- GUN**: Accelerator gun.
- Cam YAG01, YAG02, YAG03, YAG04, YAGG1, YAGS1**: YAG laser cameras.
- FI2, FI1, Tgt**: Filter and target stations.
- OTR01, OTR02, OTR03, OTR04**: Output Target Radiators.
- OTR5:IN20:571**: Output Target Radiator 5.
- Lamp Control**: Includes buttons for **T_LAMP_DISABLE**, **Brighter**, **Dimmer**, and **G_LAMP_DISABLE**.
- StraightAhead**: Beamline section with a **StraightAhead** indicator.
- YAG5:IN20:211**, **YAG5:IN20:841**, **YAG5:IN20:465**: YAG laser input addresses.
- CCW**, **CW**: Counter-clockwise and clockwise buttons.
- Trigger Config**: Configuration button.
- Diagnostics**: Includes **CRAT-IN20-PM01** and **CRAT-IN20-PM02**.

PRODUCTION prof_in20_main.edl 04/13/2007 12:01:33

Long Ion Chamber Along Full Accelerator

YAG03 inserted

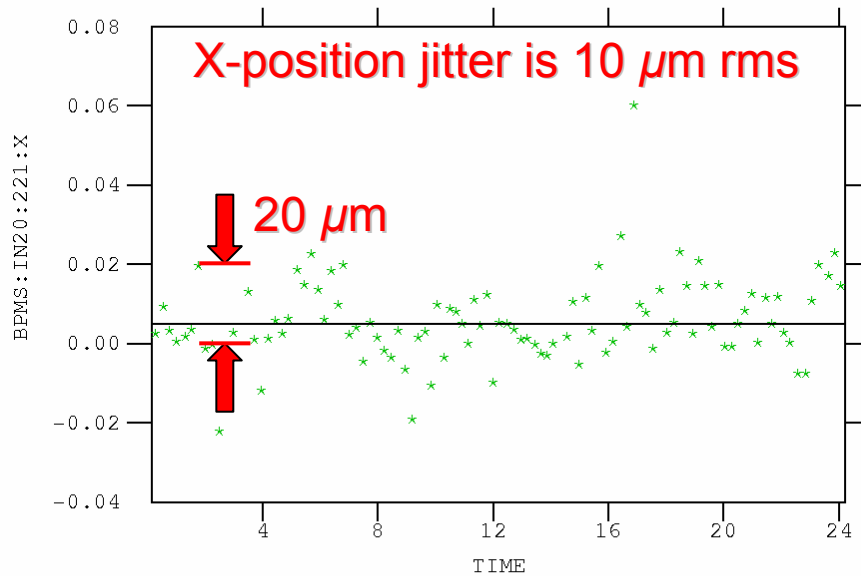


YAGS2 inserted



Charge and Position Jitter – Shot to Shot

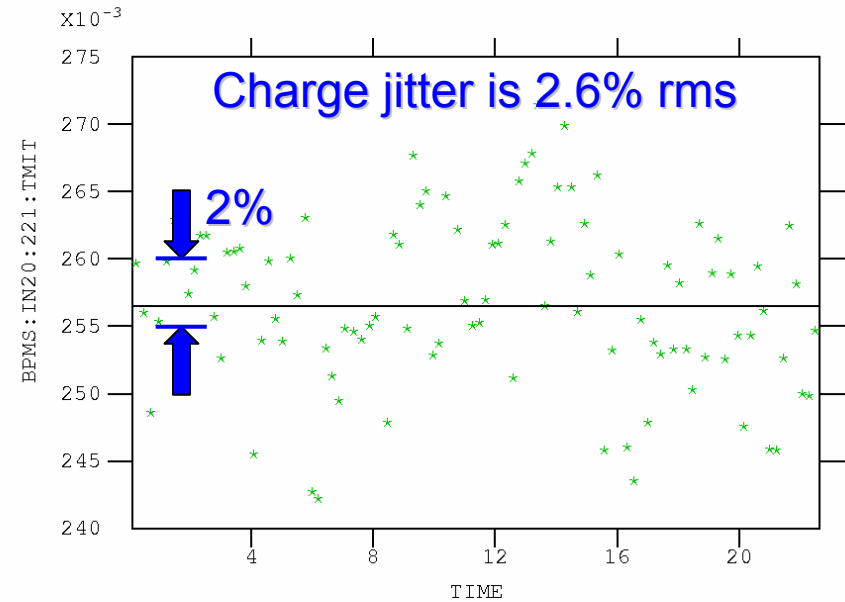
AVERAGE = 4.9706E-03 STD_DEV = 1.0393E-02
RMS FIT ERROR = 1.0393E-02



STEP VARIABLE = TIME STEPS=100 DELAY=0.0000

13-APR-07 20:16:

AVERAGE = 0.2565 STD_DEV = 6.1717E-03
RMS FIT ERROR = 6.1717E-03



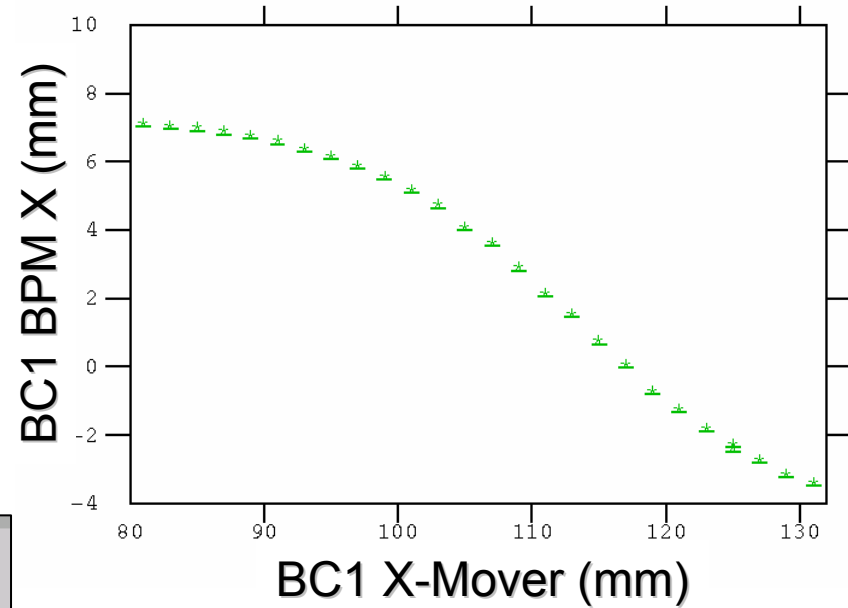
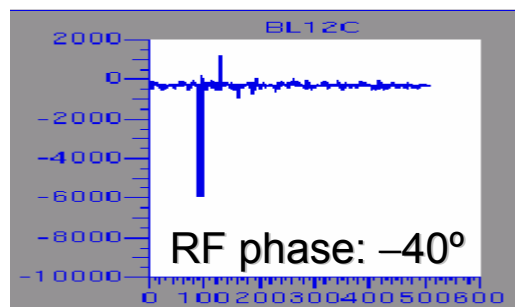
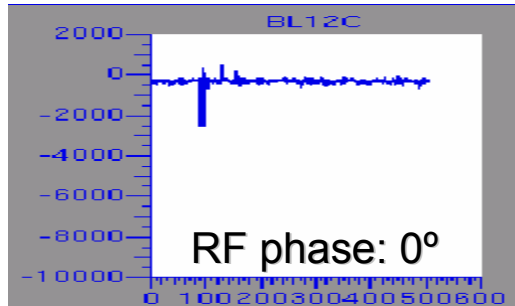
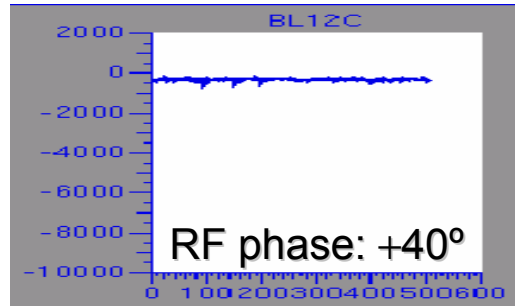
STEP VARIABLE = TIME STEPS=100 DELAY=0.0000

13-APR-07 20:10

100 shots at 10 Hz using BPM immediately after gun

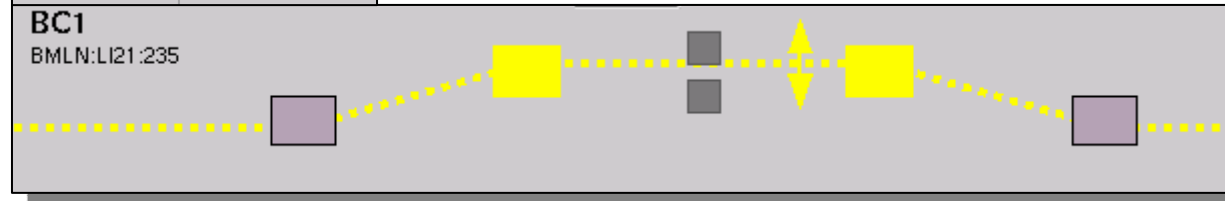
BC1 Chicane Control and Compression

Ceramic Gap Bunch Length Monitor



Fine Control

Relative	Absolute
▲	Requested: 105.000C mm
2.0000 mm	Currently: 104.9985 mm
▼	Velocity mm/sec



OTR screen still needs camera

Problems/Issues

- Gun Faraday cup broken (pneumatic error)
- Gun toroid shorted during installation
- Gun z-position not right yet (7.5-mm interference)
- YAG screens not setup before installation (hard-stops)
- Still need to install cameras and air lines for 7 screens
- No toroids working yet (1 shorted, 3 left to install)
- BC1 motion control limited (300 mm \Rightarrow 260 mm)
- QE about 4-times lower than design (to be verified)
- Some controls tools late (orbit displays & fitting)

2007 Injector Commissioning Goals

<http://www-ssrl.slac.stanford.edu/lcls/interals/commissioning/documents/lclsinjector-commissioninggoals.doc>

- 1) The drive laser pulse will be transported to the gun cathode with at least 0.25 mJ of energy in a 10-ps pulse length at a repetition rate of at least 10 Hz.
- 2) The RF-Gun will operate with a peak cathode field of at least 110 MV/m at a repetition rate of at least 10 Hz (demonstrated in the hot-test, prior to installation).
- 3) The electron bunch will be transported from gun through first bunch compressor to the TD11 stopper at 250 MeV with at least 200 pC of charge and minimal beam loss at a repetition rate of at least 10 Hz.
- 4) The electron bunch will also have been transported to the injector and gun spectrometers with minimal beam loss.
- 5) All relevant beamline components (magnets, BPMs, screens, toroids, wire-scanners, RF-structures) will be operationally verified (with beam) in terms of polarity, calibration, function, timing, reasonable alignment, and motion-control, where relevant. Basic control system functionality will be validated simultaneously and as a consequence of this verification process.
- 6) All machine protection (MPS) and beam containment systems (BCS) will be operationally verified early in the commissioning cycle to ensure safe operation for both personnel and hardware. PPS checkout is not part of commissioning.
- 7) The electron bunch will be characterized, and tuning sensitivities demonstrated, with regard to energy, energy spread, trajectory, charge, emittance, beta function, bunch length, and centroid coordinate stability in all six dimensions. These measurements need to be made both before and after the bunch compressor (with the possible exception of the bunch length measurement – see next point below).
- 8) *(The bunch length after BCI is best measured in an absolute sense using the transverse RF deflecting structure located in sector-29, requiring beam transport through the full linac during the 2007 commissioning cycle. This capability is not yet guaranteed so the post-BCI bunch length measurement is not a rigid goal.)*

DONE

DONE

DONE

DONE

STARTED

~DONE

NOT STARTED

NOT STARTED

Summary

- Beam transported to all areas (no trouble)
- No obstructions or 'backwards' components, etc (but no *systematic* checkout yet)
- Controls still developing, but working well and improving fast – great cooperation and effort
- Communication with laser group excellent
- Screens and toroids late, but installation continues
- Some quality control issues with a few components
- Thanks to all – **First indications are very positive**