# Initial Experience with Injector Commissioning

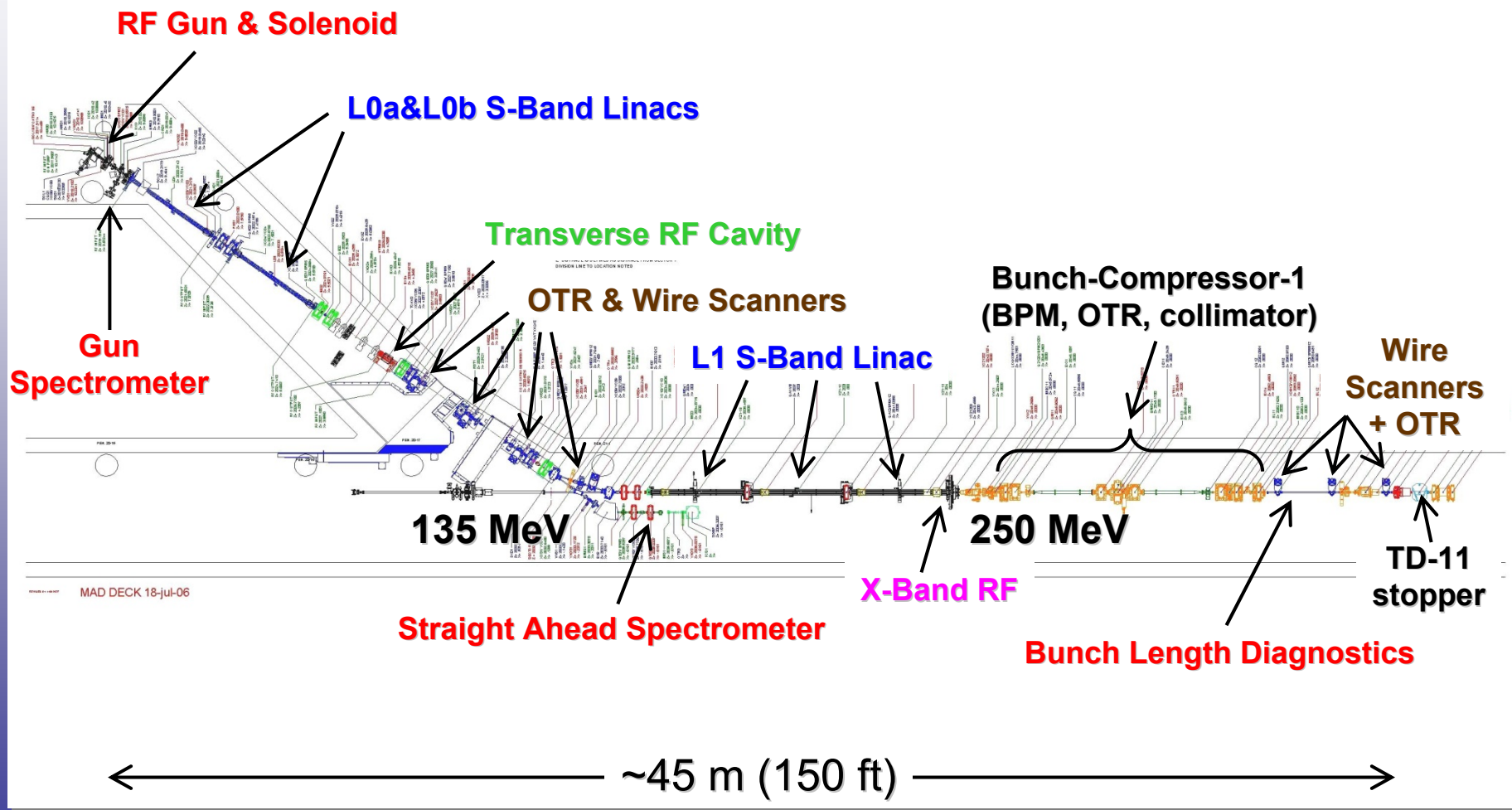
**P. Emma, *et al.***

***Facilities Advisory Committee Meeting***

April 16, 2007


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

# *LCLS* Injector Through BC1





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# 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 μJ 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)

Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

**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 ?

Polarity conventions

Field type (quad, dipole)

Serial numbers

Installation orientation

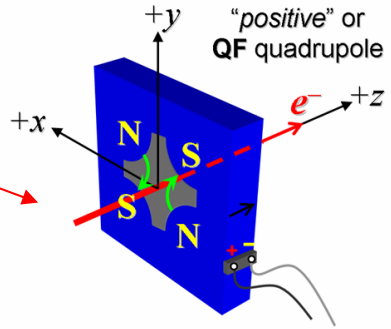



**Figure 7**. A "*positive*" normal quadrupole magnet (above) focuses electrons in $x$ (a '**QF**' quadrupole).

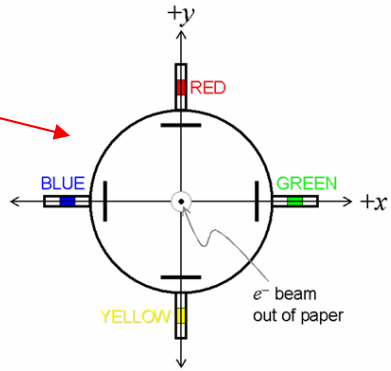
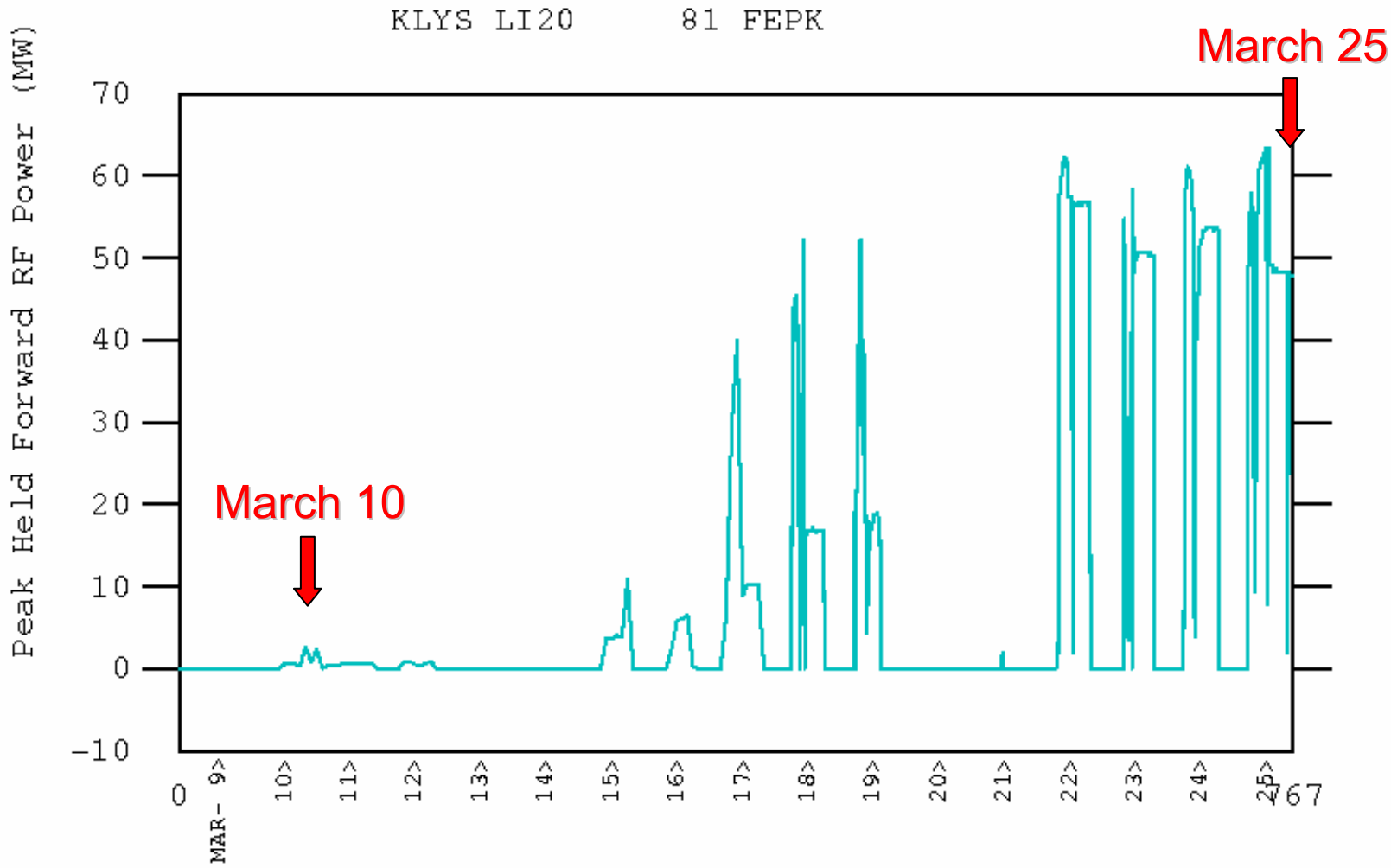


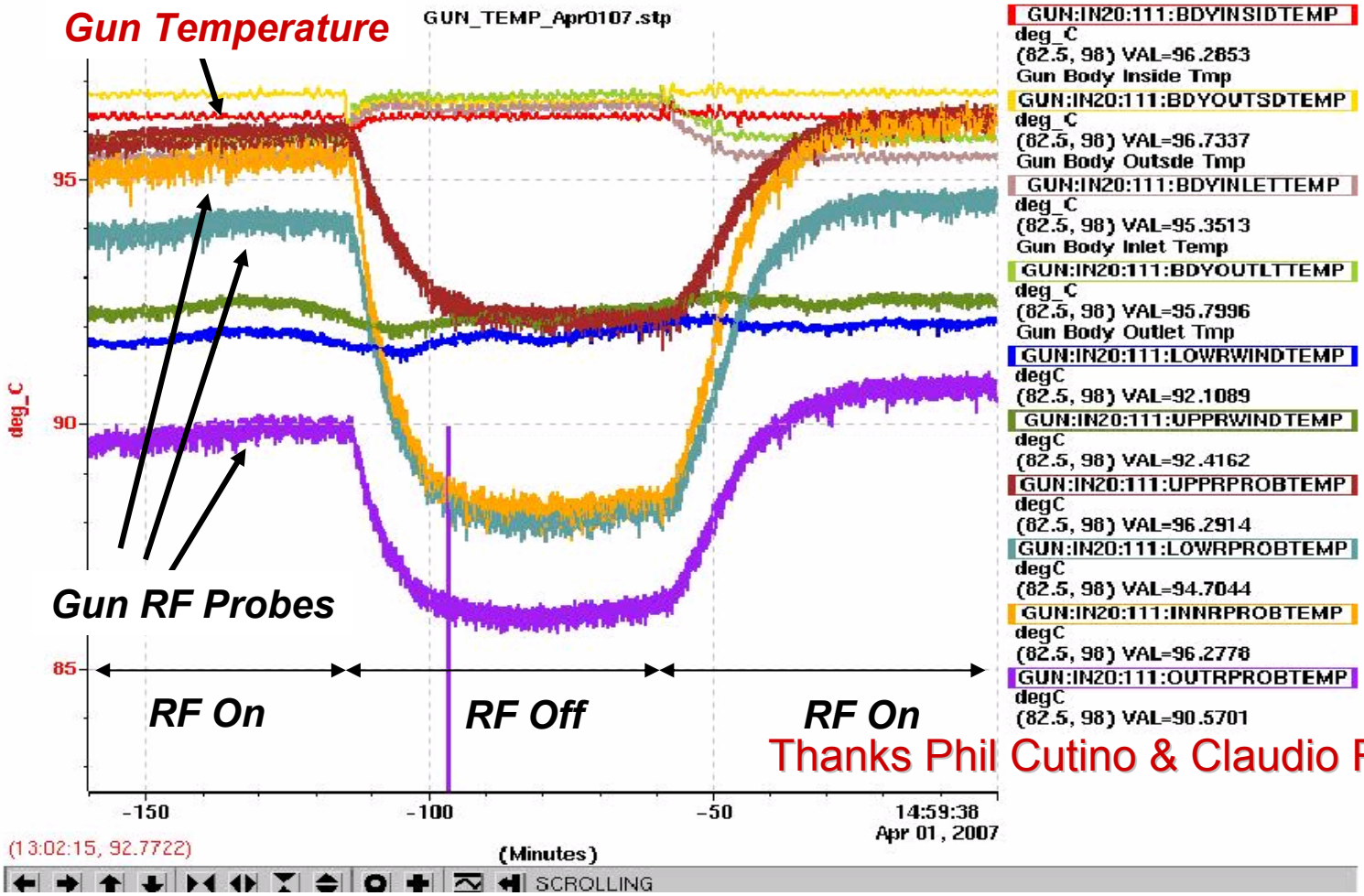

**Figure 13.** A BPM (above) as seen down its bore with electron beam emerging from paper. The BPM is installed in the upright position ($\theta = 0$). The cable color-coding standard is also illustrated.

etc.

# RF Processing of L0b (20-8)

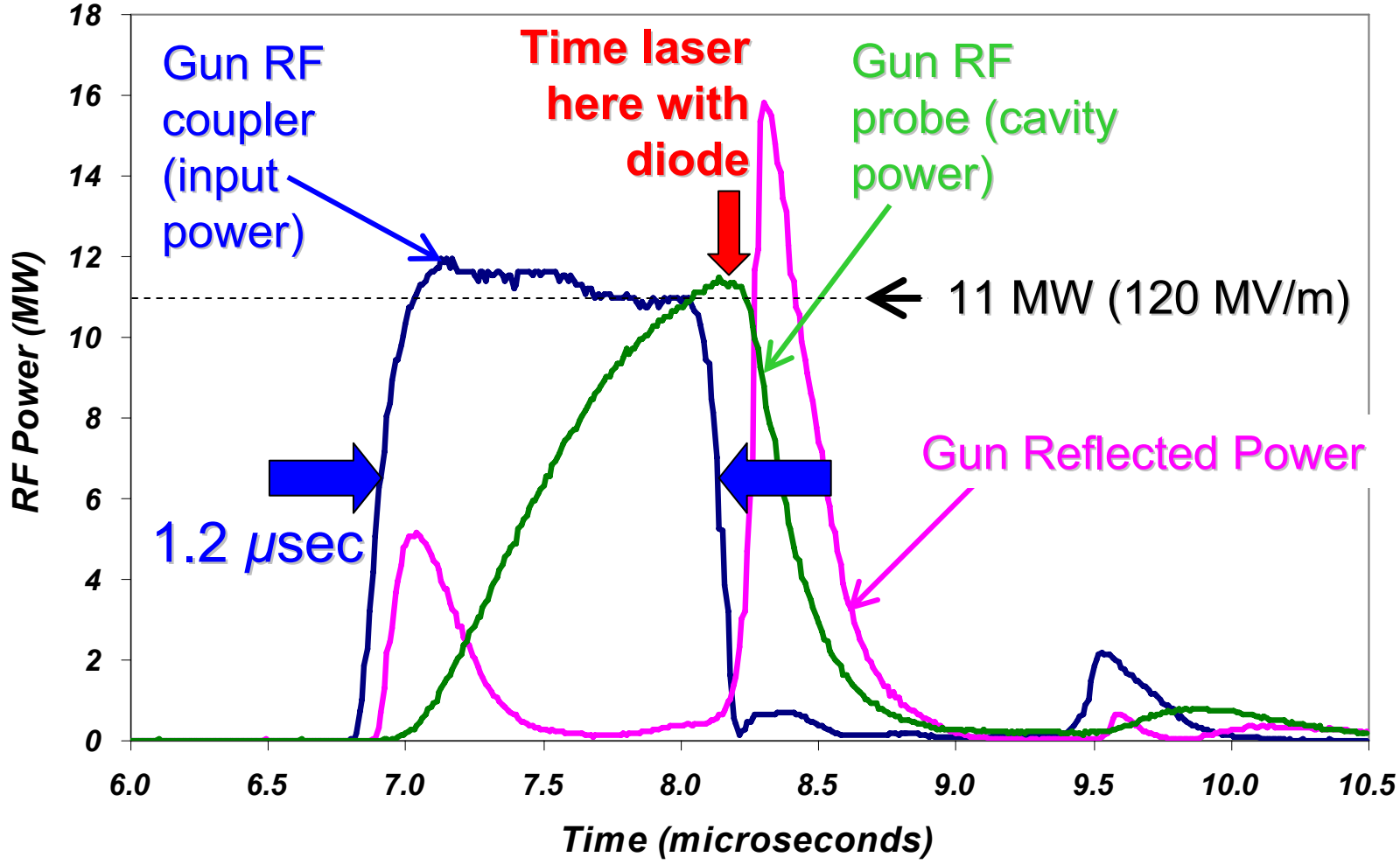


# Gun Temperature Feedback Loop




Thanks Phil Cutino & Claudio Rivetta

# Gun RF Power (30 Hz)





Thanks Arnold Vlieks
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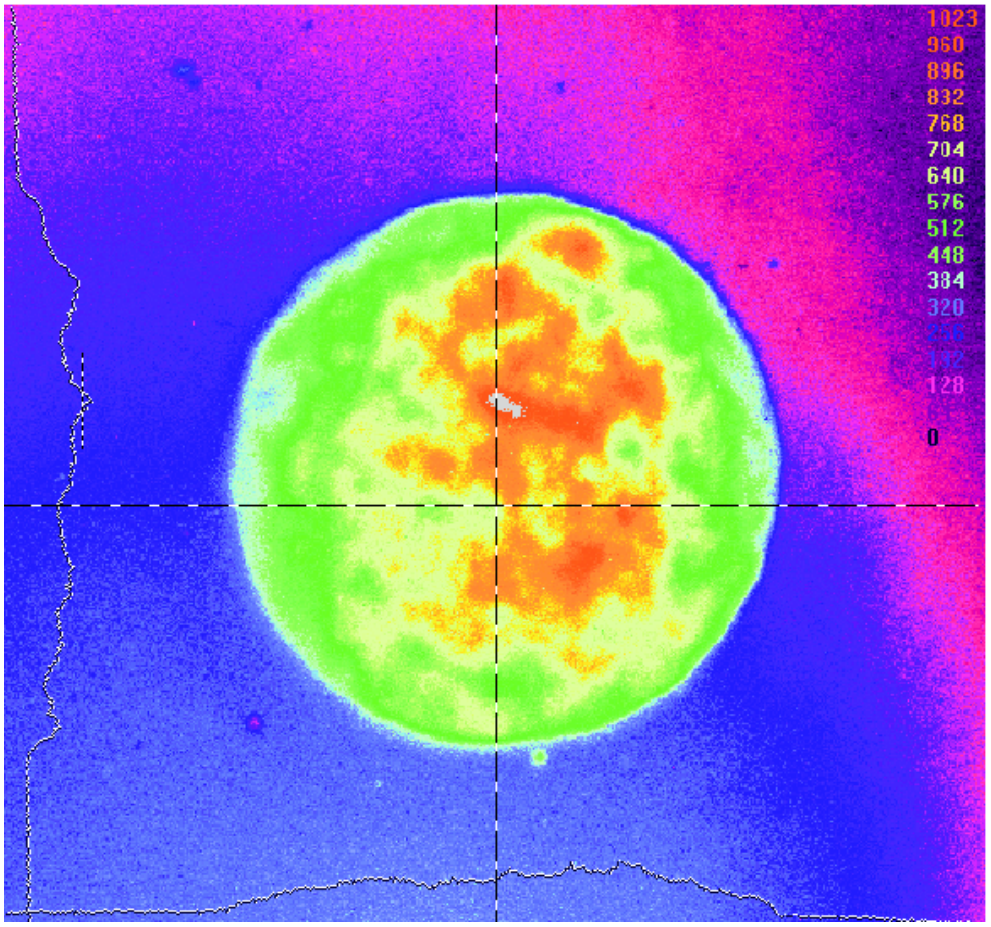
# Virtual Cathode (optical image of laser spot on cathode)





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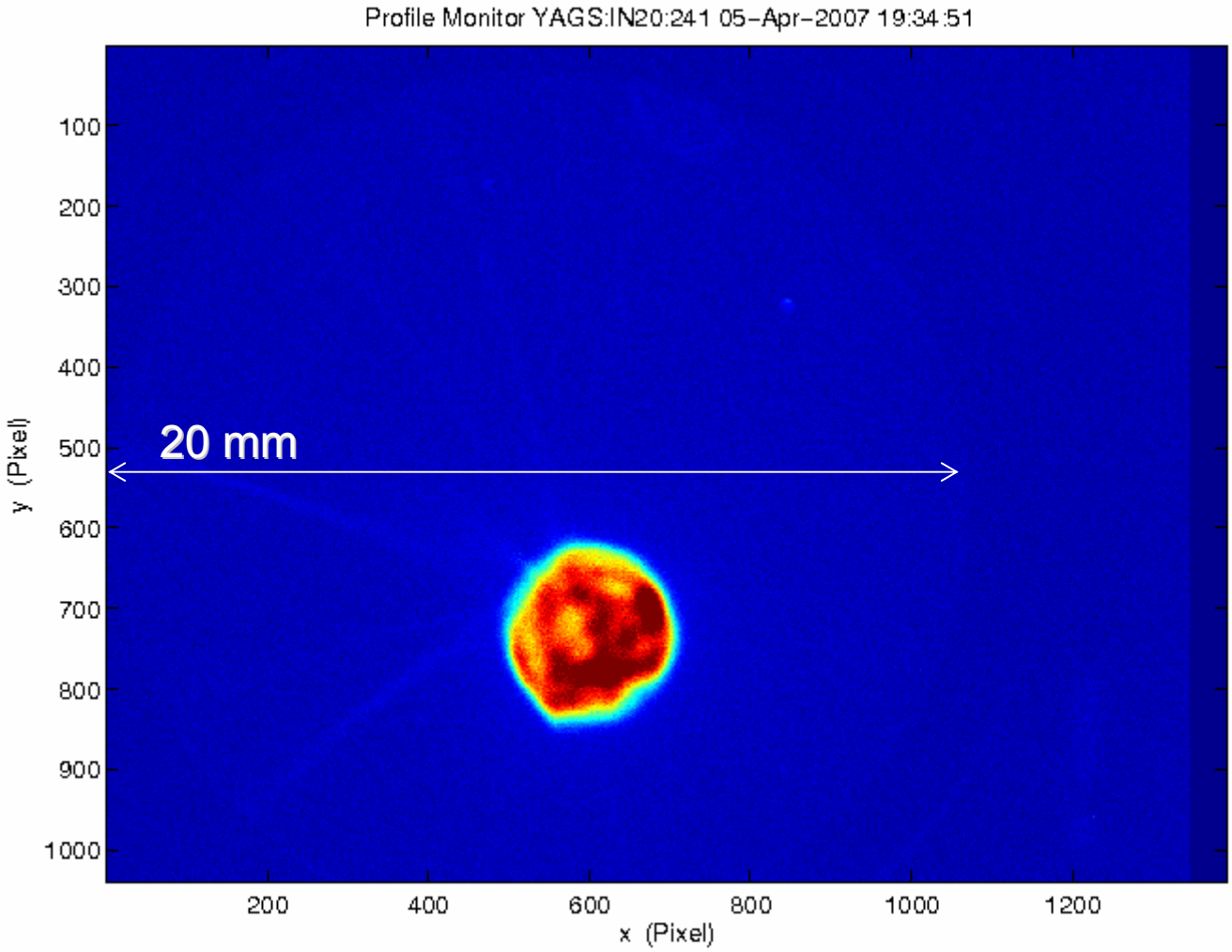
# Beam on YAG02 (80 cm from gun)





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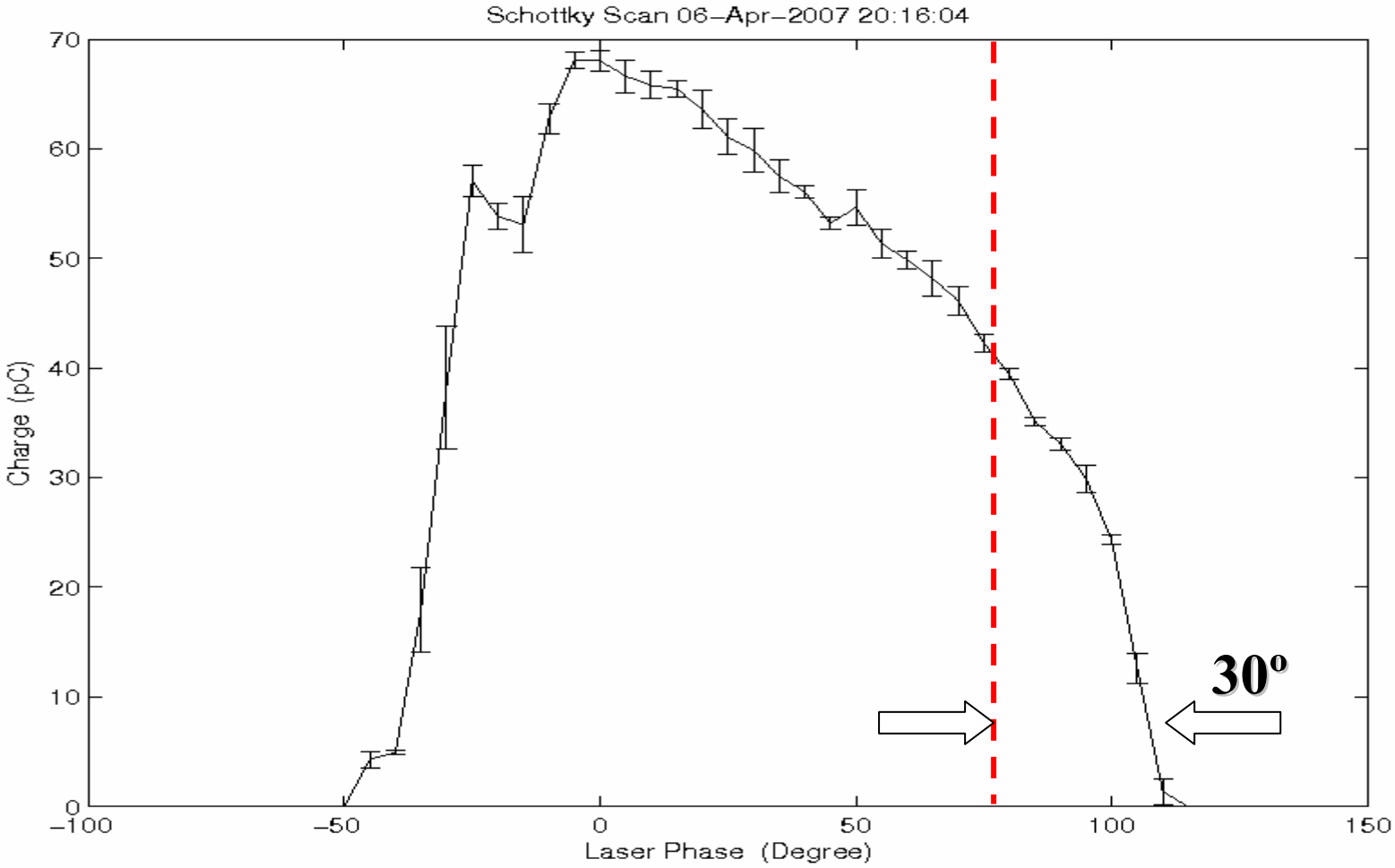
# Laser Phase (Shottky) Scan





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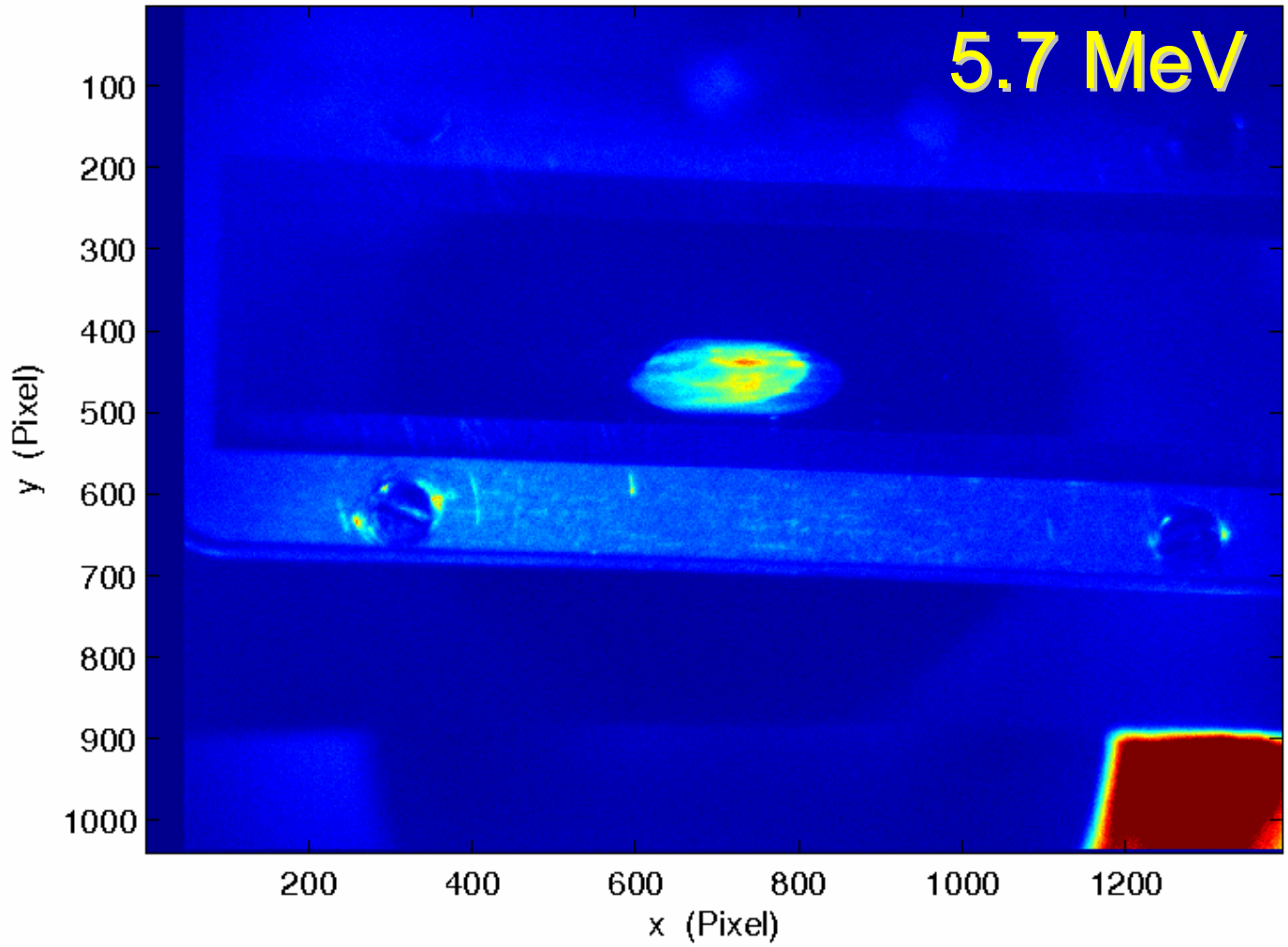
# Beam on Gun Spectrometer





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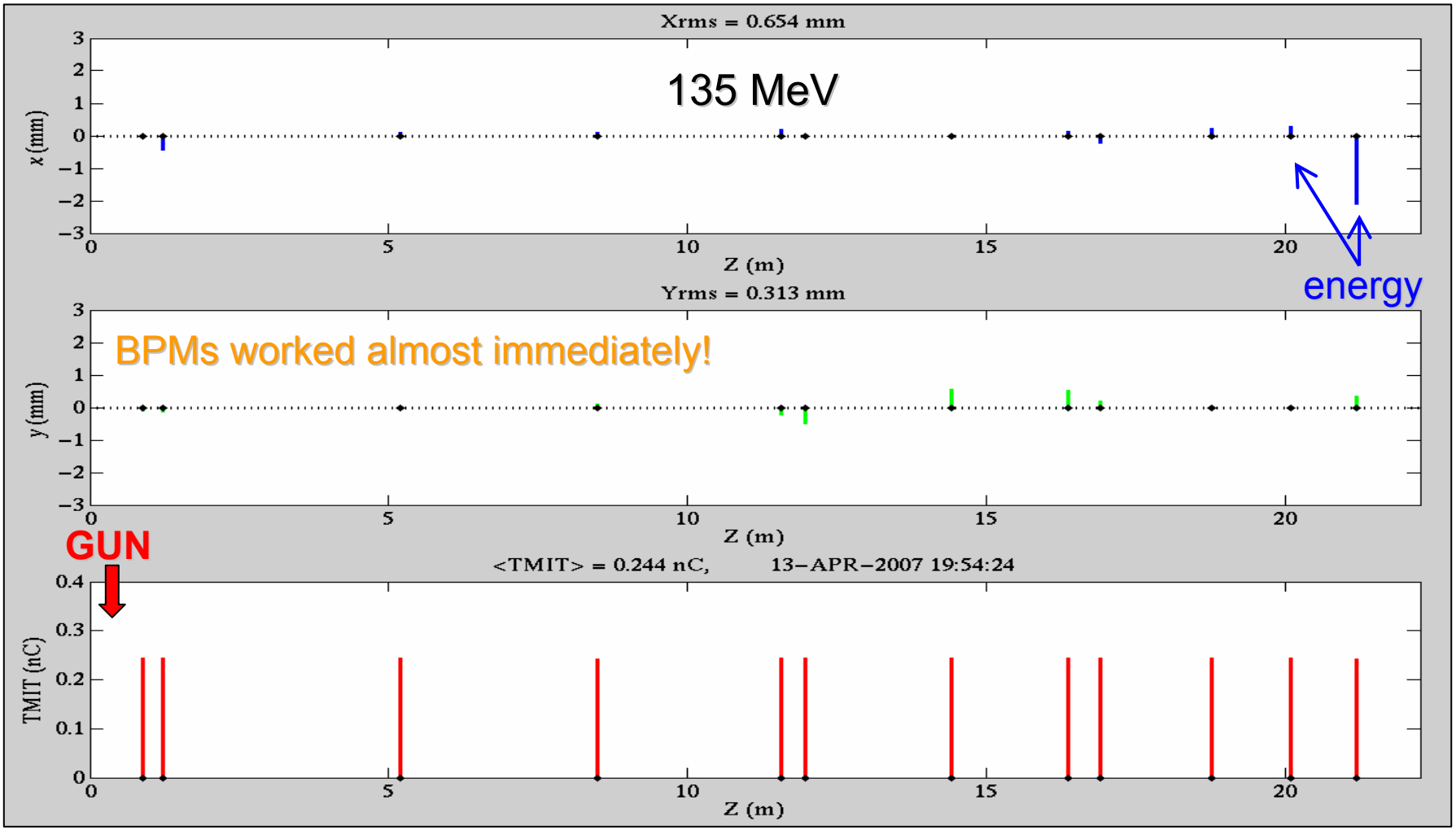
# Beam to Injector Spectrometer





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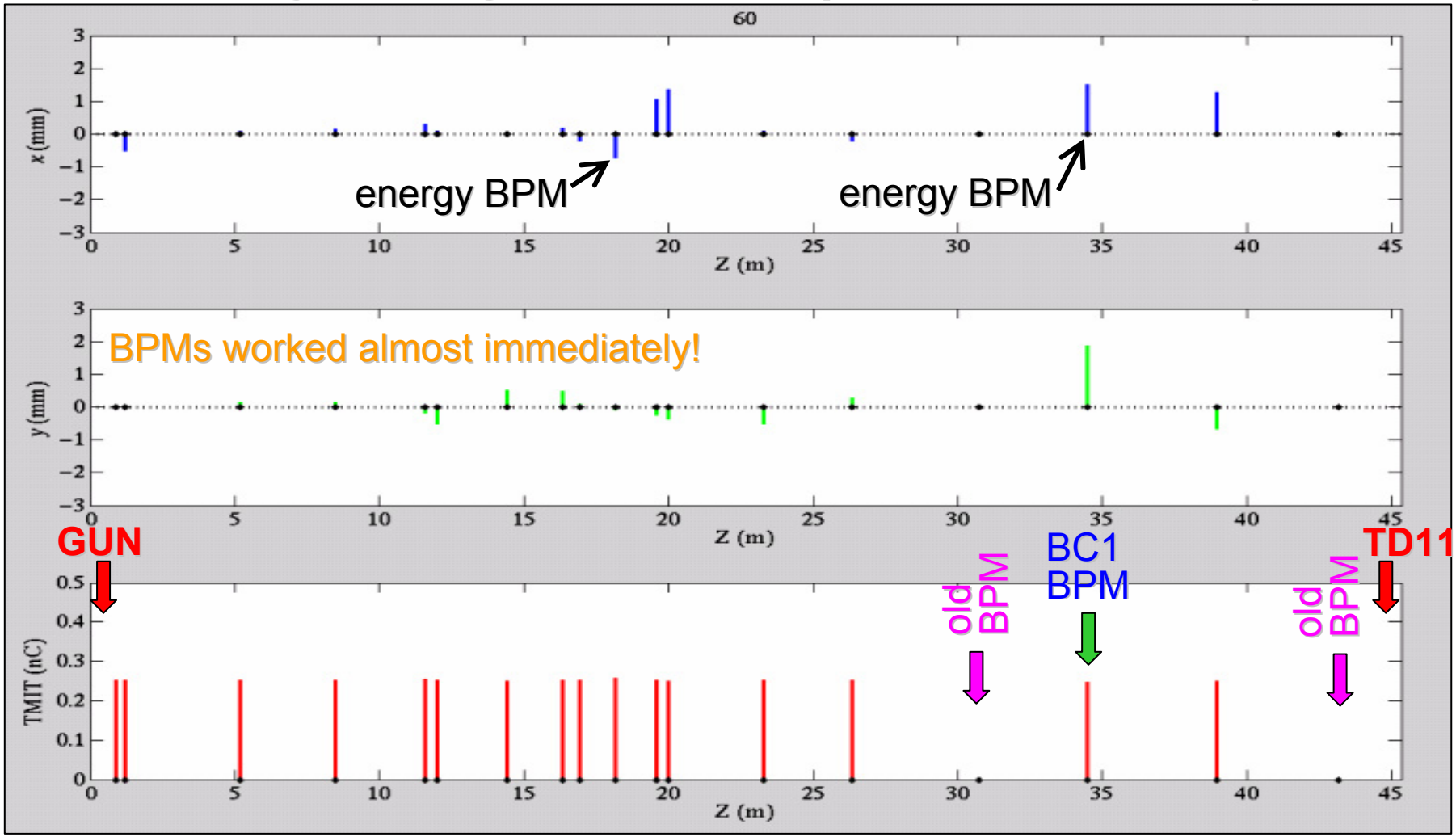
# Trajectory to TD11 (in main linac)





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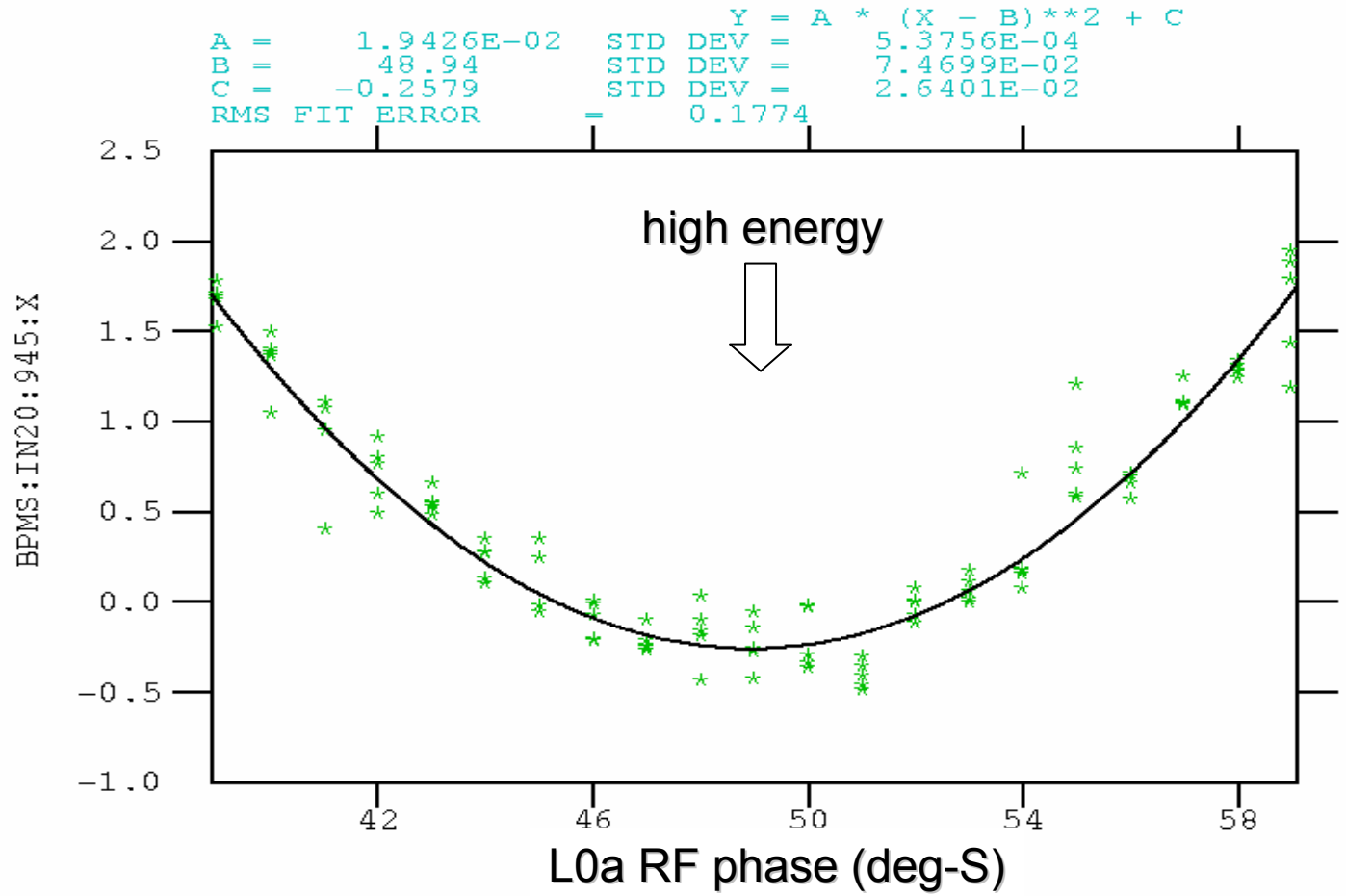
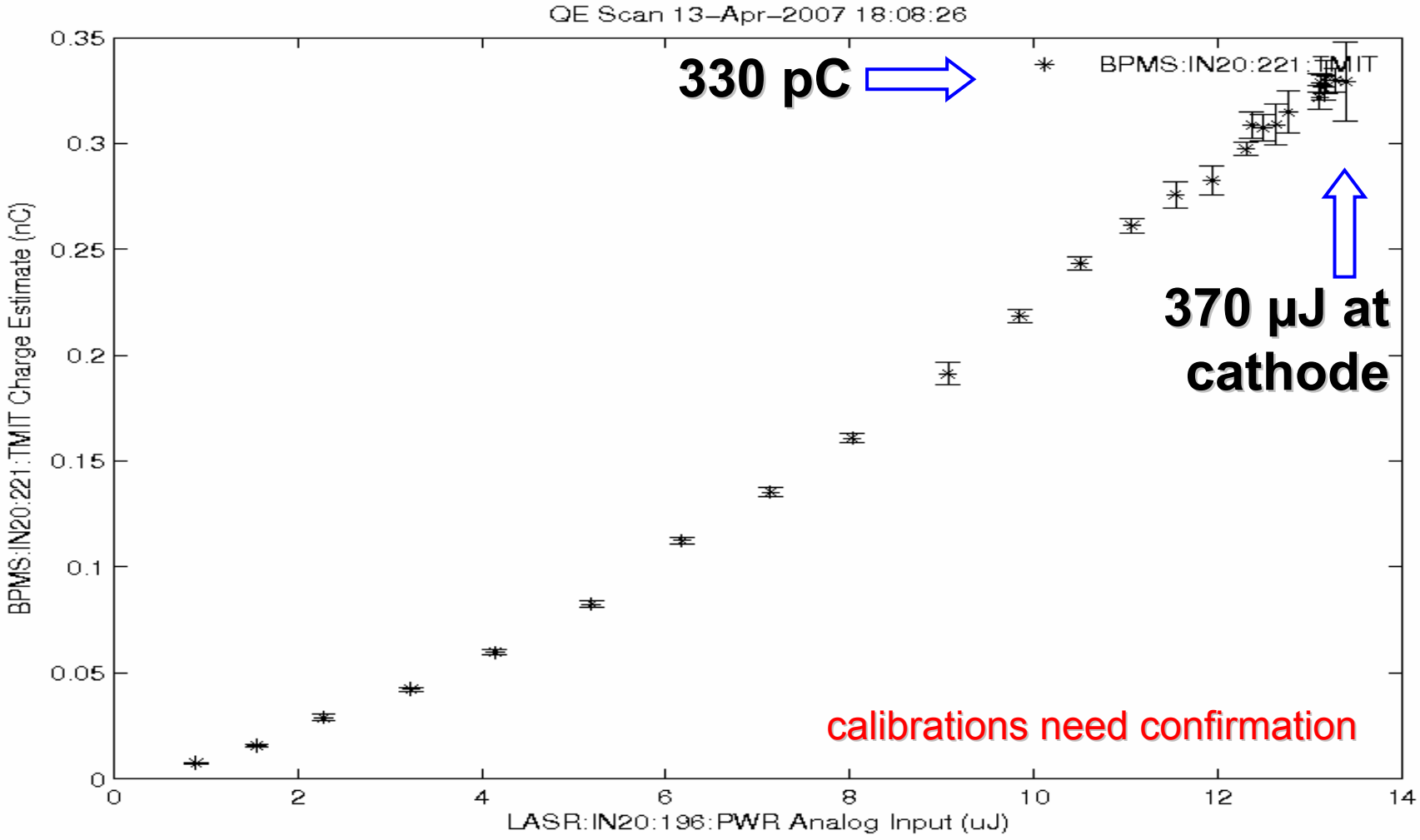
# L0a RF Phase Scan on Dispersed BPM *X*



# Bunch Charge vs. Laser Energy





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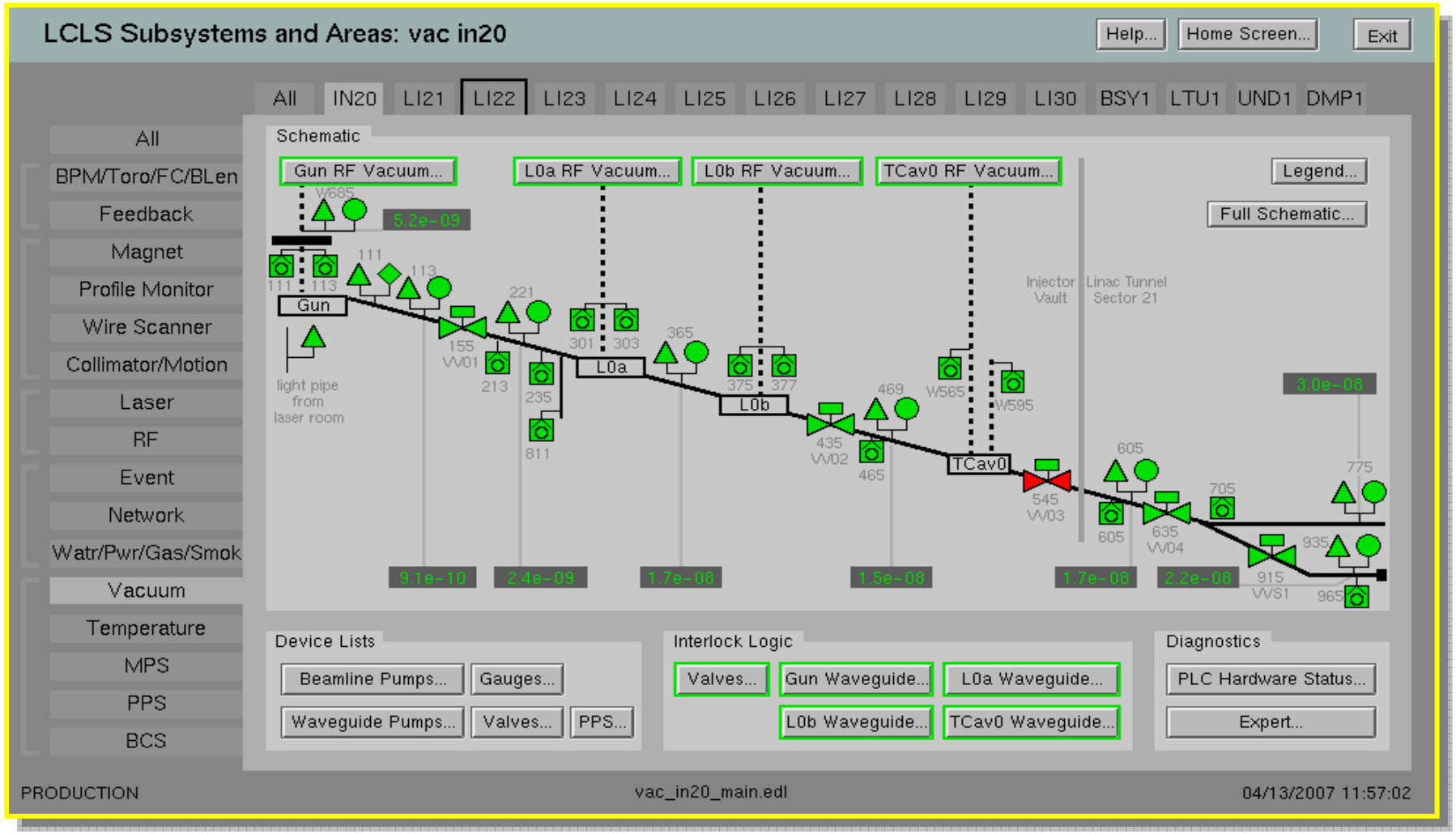
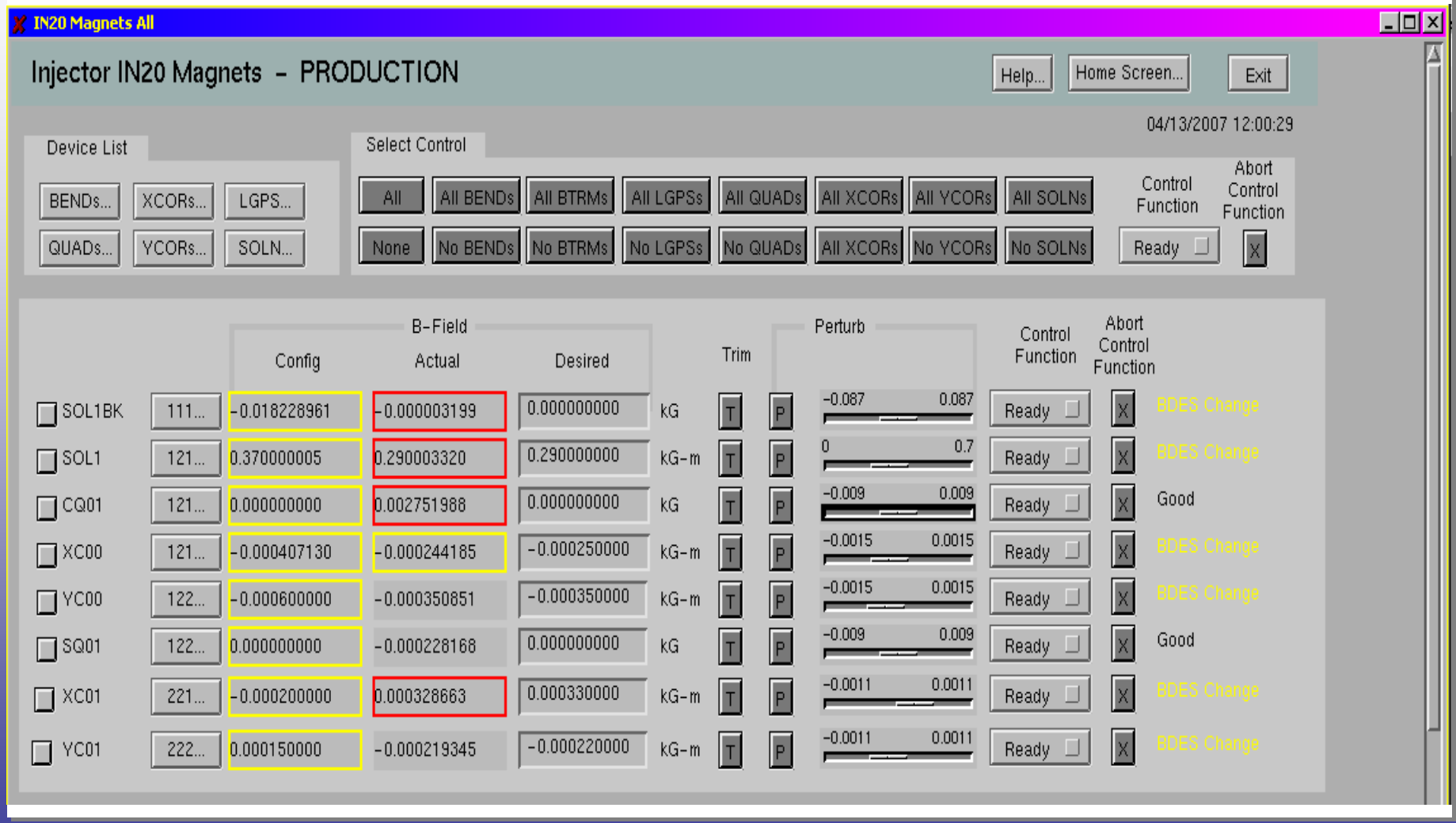
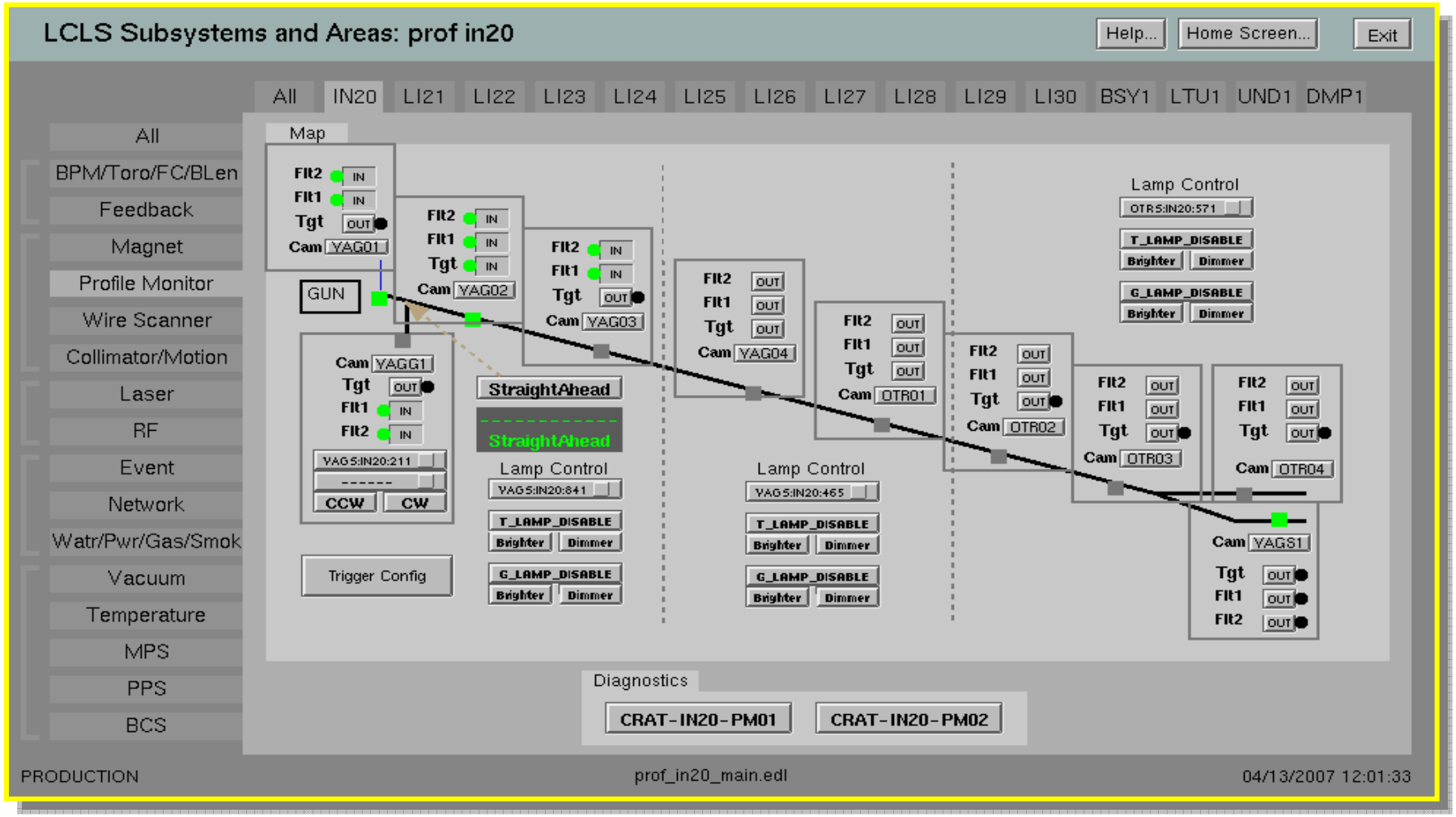
# EPICS Controls - Vacuum



# EPICS Controls - Magnets



# EPICS Controls – Profile Monitors





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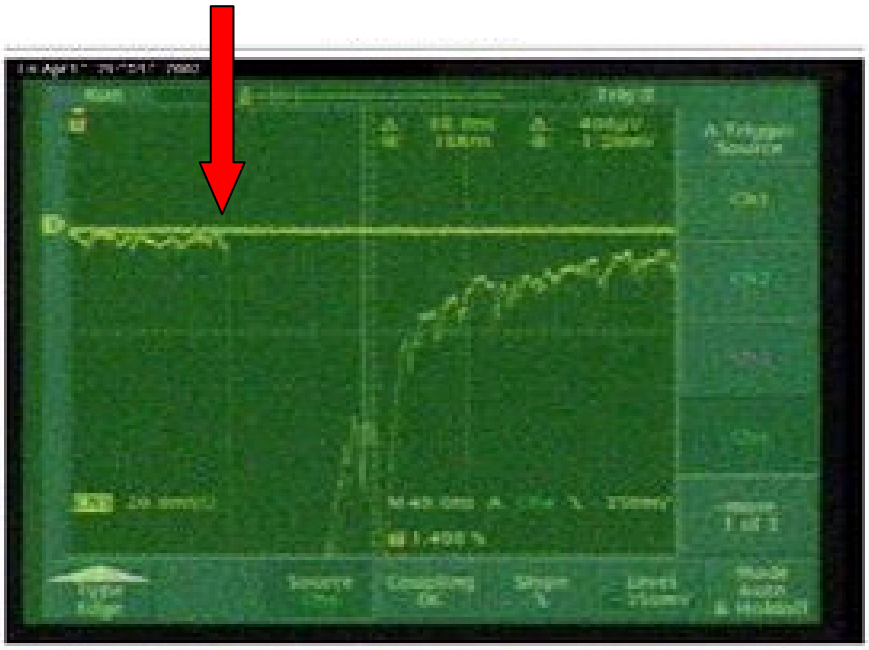
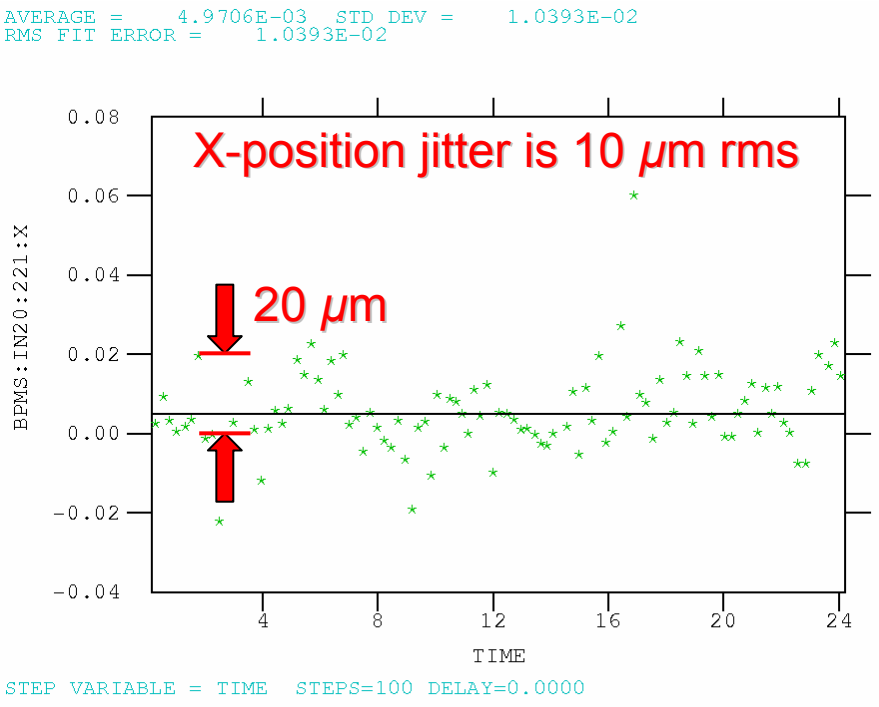
# Long Ion Chamber Along Full Accelerator

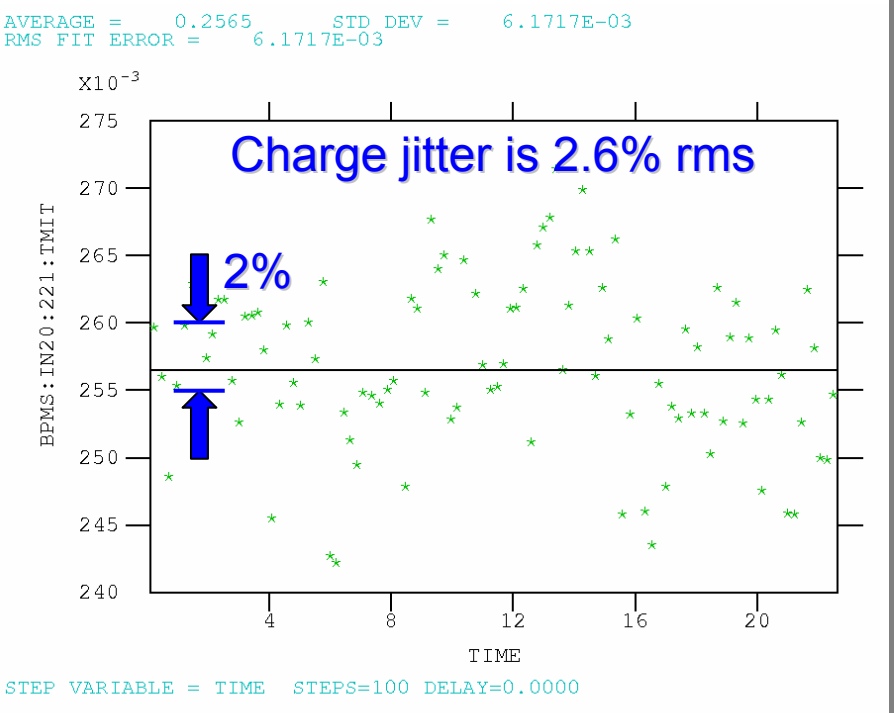
YAG03 inserted



YAGS2 inserted

# Charge and Position Jitter – Shot to Shot




**100 shots at 10 Hz using BPM immediately after gun**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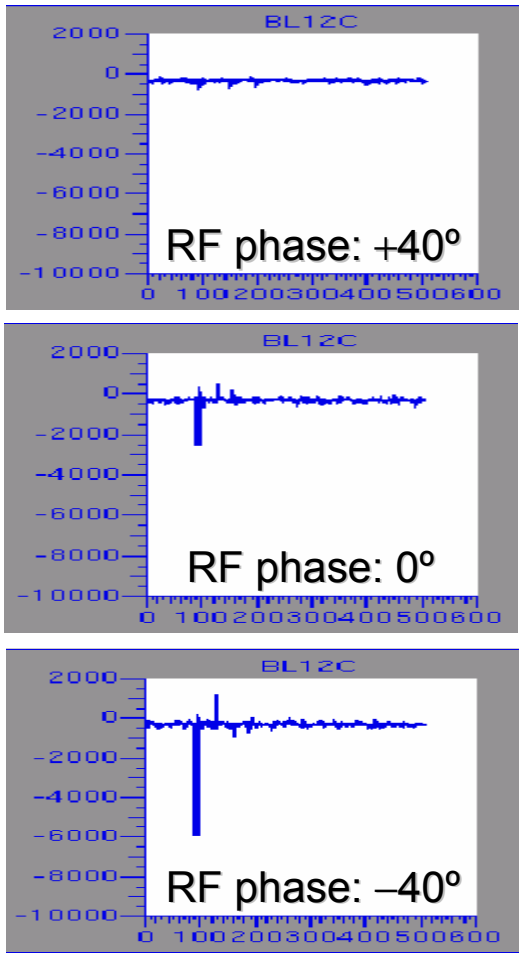
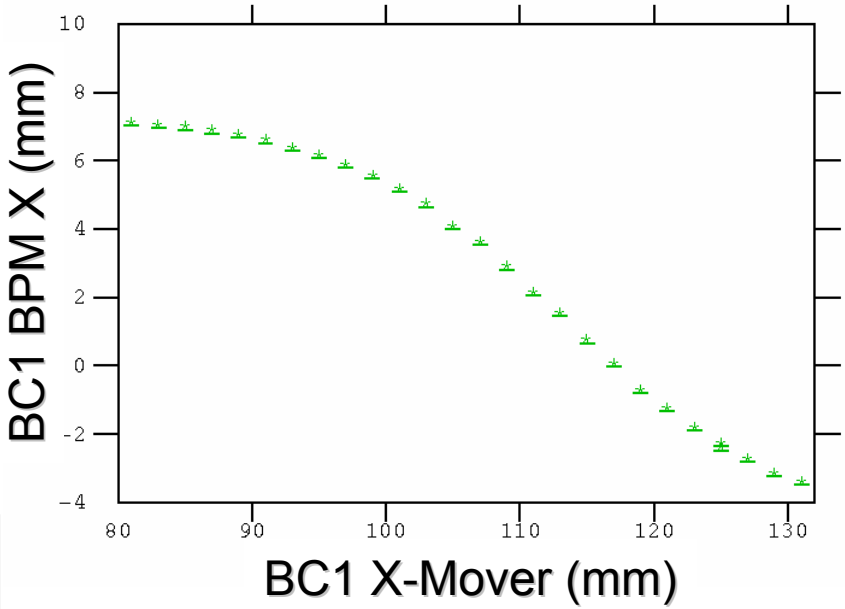
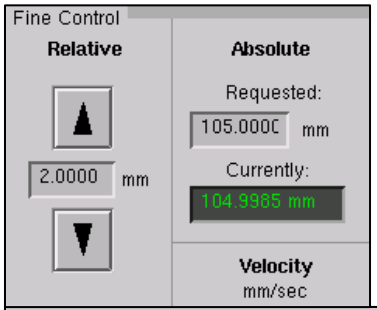
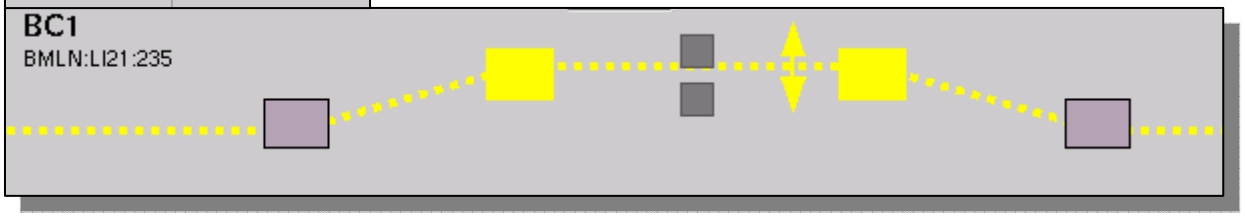
# BC1 Chicane Control and Compression

## Ceramic Gap Bunch Length Monitor




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)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# 2007 Injector Commissioning Goals

http://www-ssrl.slac.stanford.edu/lcls/internals/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. | DONE |
| 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). | DONE |
| 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. | DONE |
| 4) The electron bunch will also have been transported to the injector and gun spectrometers with minimal beam loss. | DONE |
| 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. | STARTED |
| 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. | ~DONE |
| 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). | NOT STARTED |
| 8) (*The bunch length after BC1 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-BC1 bunch length measurement is not a rigid goal.*) | 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**


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