RHIC Electron Lens Commissioning

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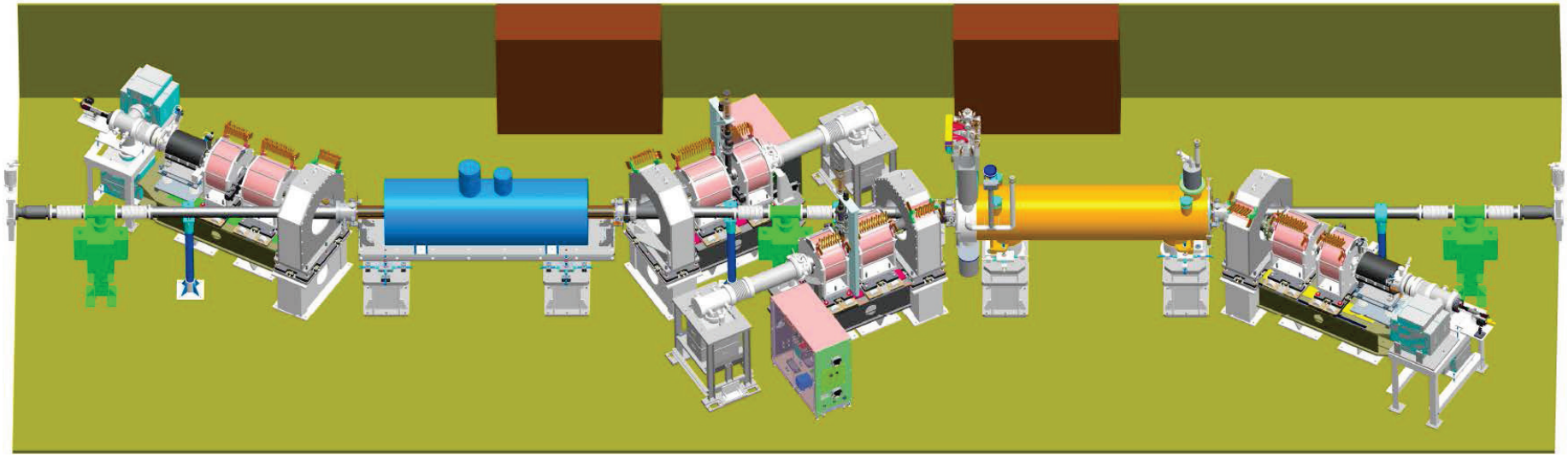
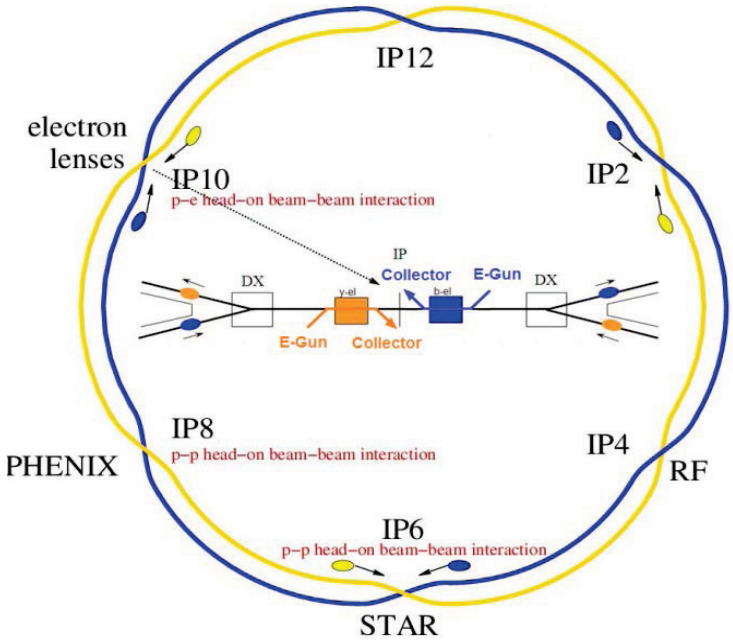
Sep. 29 ~ Oct. 4, 2013, NA-PAC'13.

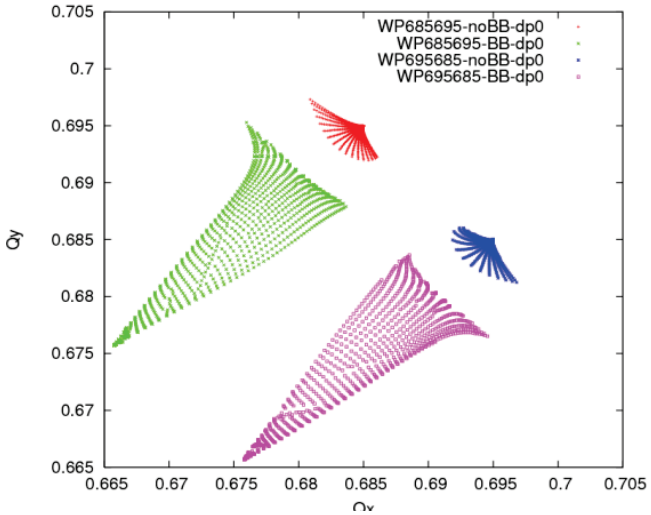


Outline:

- Motivation (1), Requirements (1)
- E-lens Hardware Introduction (2)
- Test Results with e-beam and p-beam (7)
- Summary (1)

Motivation -- Luminosity





RHIC proton intensity threshold:

1 During 2013 RHIC run, intensity threshold [1]:
- 2.2E11 for Blue (beam-beam)
- 2.0E11 for Yellow (longitudinal stability)

2 By Beam-Beam Tracking, intensity threshold [2]:
If intensity >2.0E11, there is no enough space for large beam-beam tune spread

Electron lenses (e-p):

Increase bunch Intensity threshold
=>up to 2 × luminosity

Coherent Instability:

Transverse bunch by bunch damper
Larger beta* (beam size)

[1]V.H. Ranjbar, et al. "RHIC Polarized Proton Operation for 2013". IPAC2013, Shanghai, China, May 12-17, 2013, pp. 1544-1546 (2013).
[2]Y. Luo, et al., "6-D weak-strong simulation of head-on beam-beam compensation in the Relativistic Heavy Ion Collider". Phys. Rev. ST Accel. Beams 15, 051004 (2012).

Requirements

1. Electron beam size in the main solenoid and current

   RMS beam size: 0.3 mm - 0.8 mm (issue: relatively small), 0.85A

2. Gaussian shape of electron beam

   good fit to 2.8 σ (issue: cathodes have limited size)

3. Straightness of magnetic field in main solenoid

   target of ± 50 mm after correction (issue: good overlap of e and p beam)

4. Steering electron beam in e-lens

   maximum shifting : ± 5 mm in X and Y planes

   maximum angle : 0.1 mrad

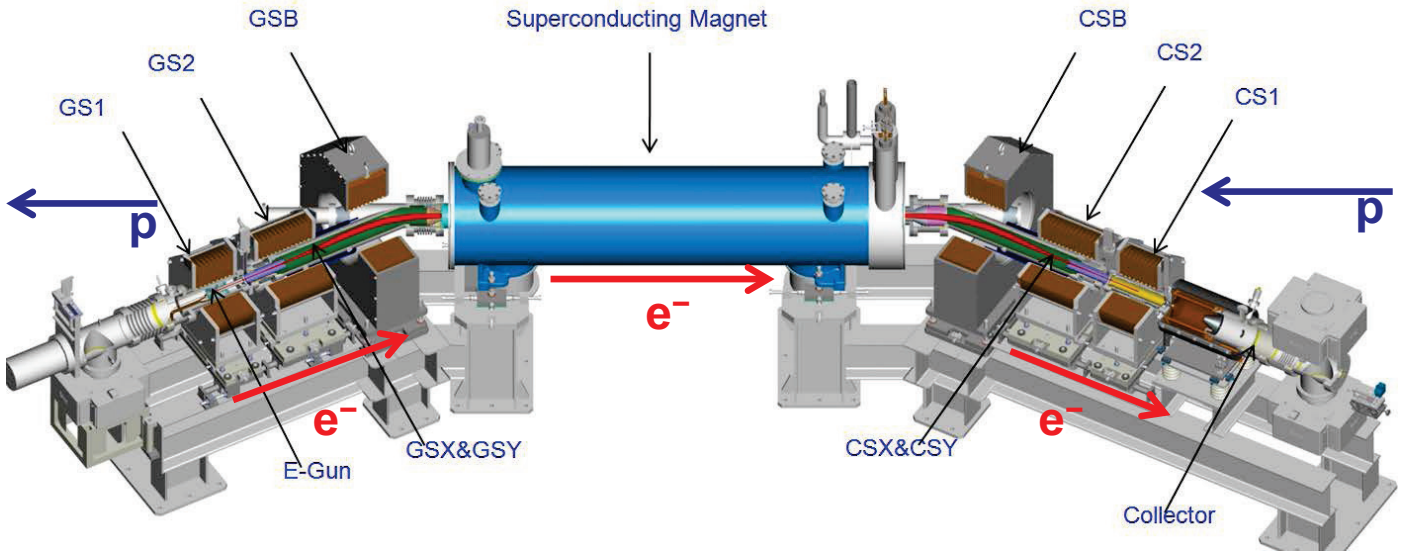
5. Stability of electron current

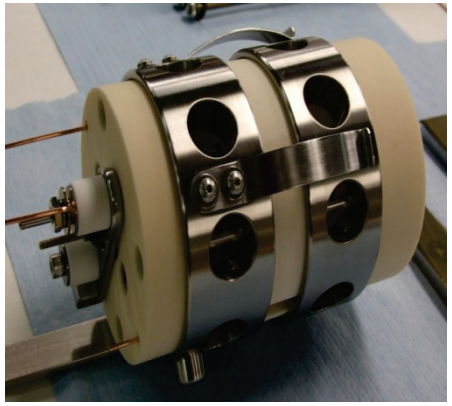
   power supplies stability better than 10-3

6. Overlap of electron and proton beams

   robust real-time measurement with resolution better than 100 mm

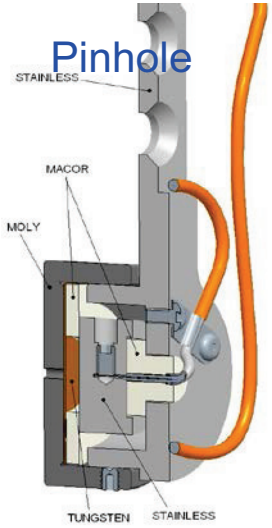
Layout and hardware (one e-lens)

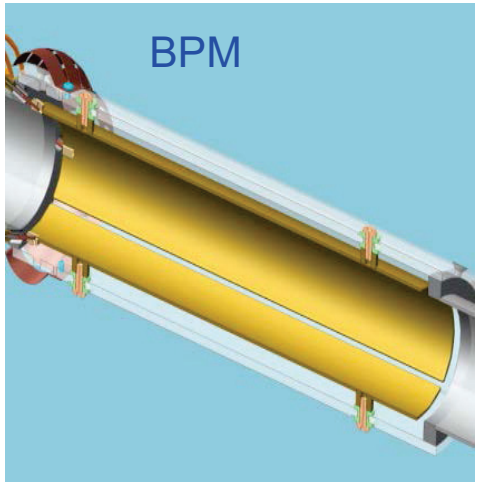


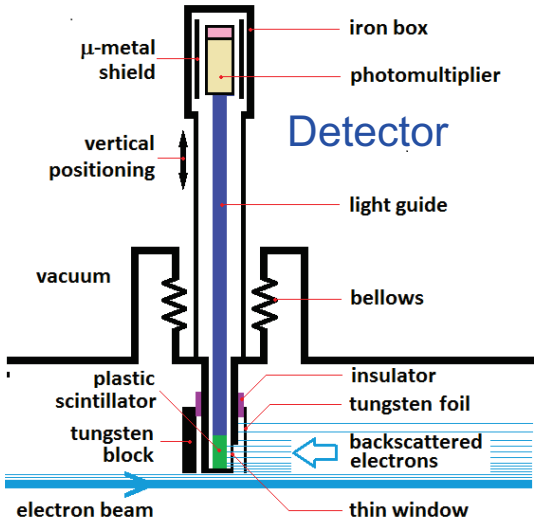


1. **Main Solenoid: 6T, Beam size and coherent instability.**
2. **Superconducting Correctors: proton beam alignment and field straightness**

Instrumentations and Modulator

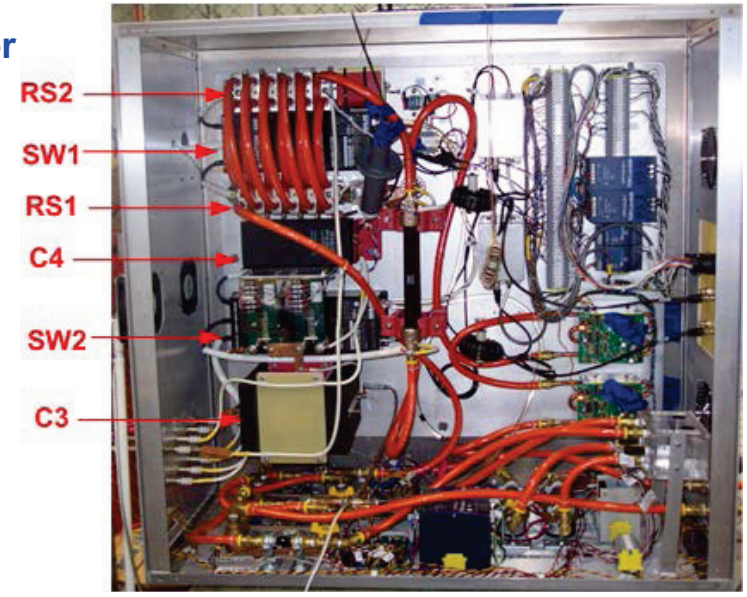




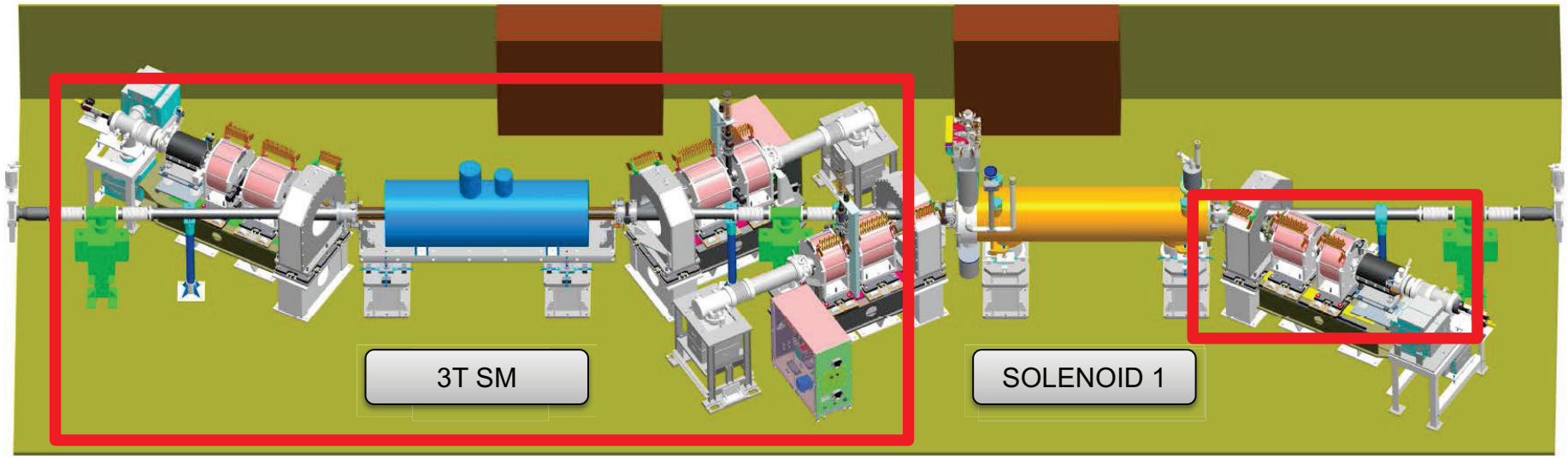


1. YAG and Pinhole Scanner are for beam profile measurement.
2. BPMs and Backscattering Detector are used for e-p beam alignment.

- Provides Voltage on anode (gun)
- Operation Modes: Single, Pulse, 78k Hz,DC
- Frequency: DC – 80kHz
- Pulse Width: 500ns – DC
- Pulse Mode: positive and inverted
- Voltage: 15kV. Presently we are using 10kV
- Rise time and fall time: < 50ns
- Water cooled Behlke switches

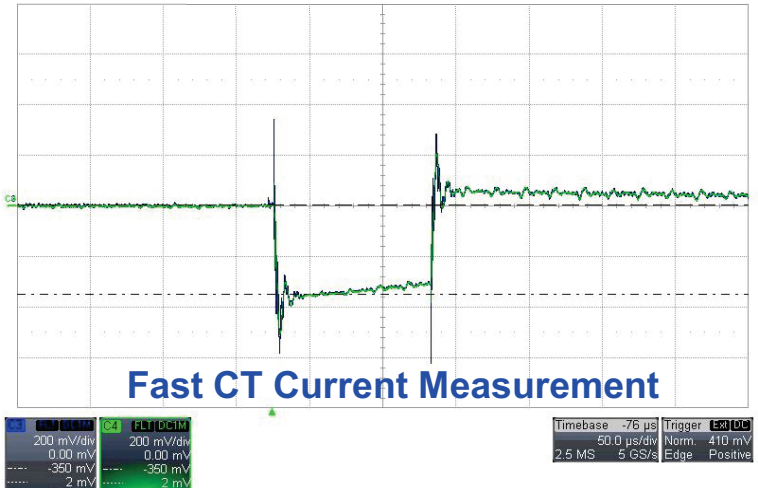


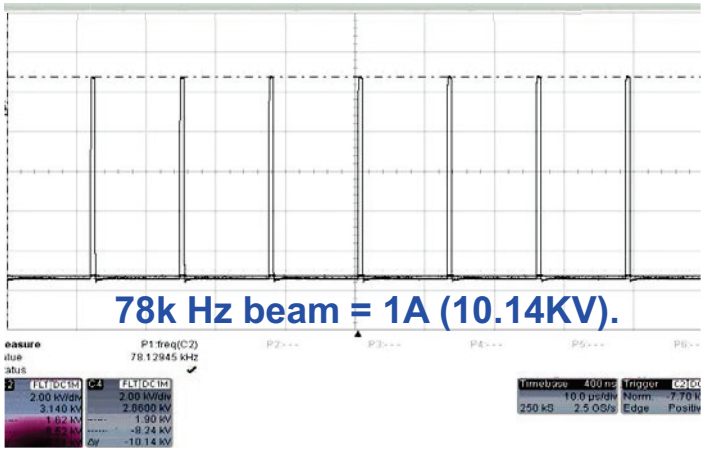
Test with e and p beam

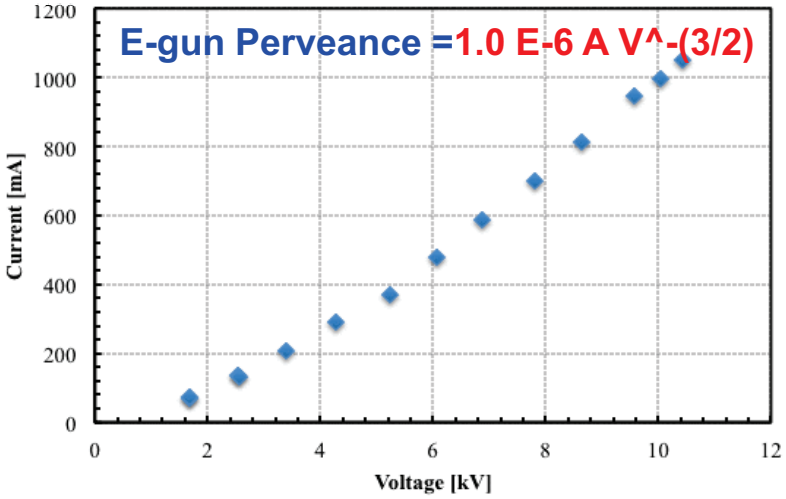


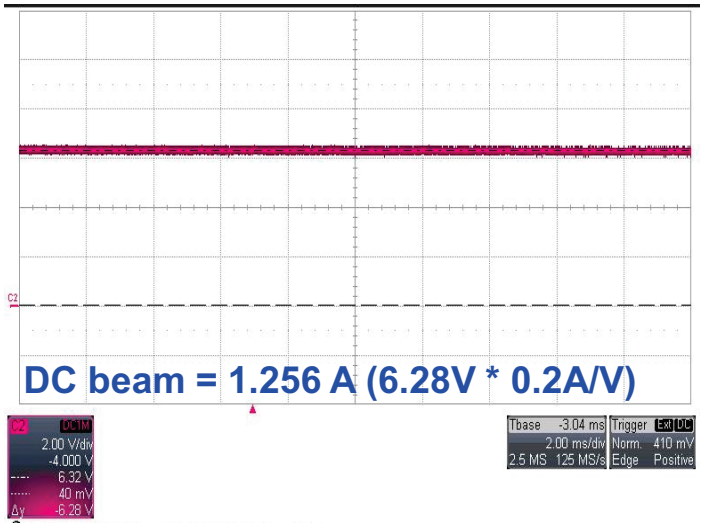
1. Two e-lenses: The blue e-lens is on the left and yellow on the right.
2. E-gun is put in center.
3. Blue e-lens system (hardware and software) commissioning was done.
4. Solenoid #2 was replaced with a 3T superconducting magnet.
5. Yellow warm solenoids were tested. Detectors are not ready.

Beam Propagation and E-gun Performance





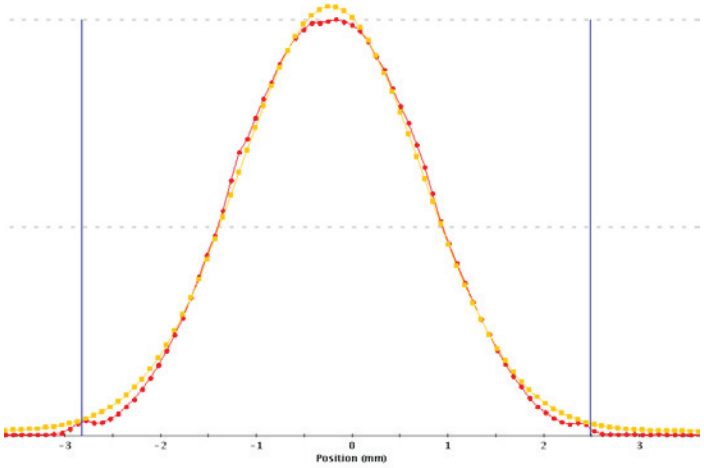


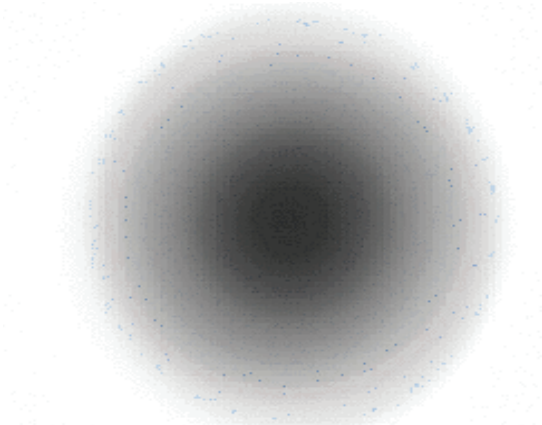


1. Electron beam was propagated from gun to collector
2. Perveance is high enough with 10kV modulator voltage. (Needs 0.85A)
3. High duty (78k Hz and DC) beam was tested with more than 1A beam.

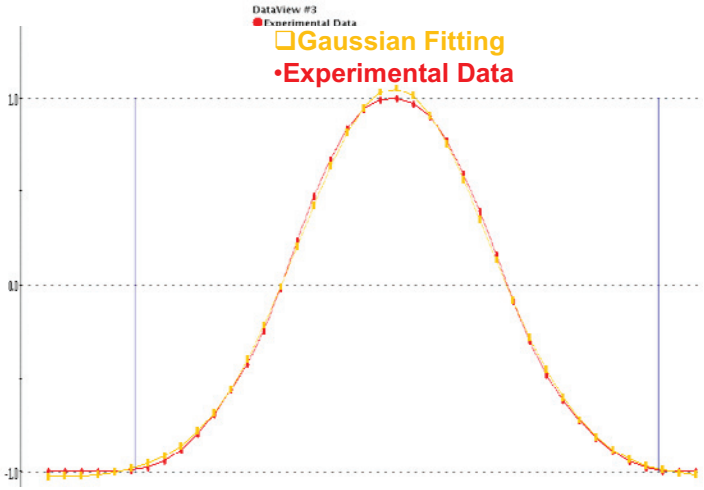
Beam Profile Measured via YAG & Pinhole

YAG image 70mA beam



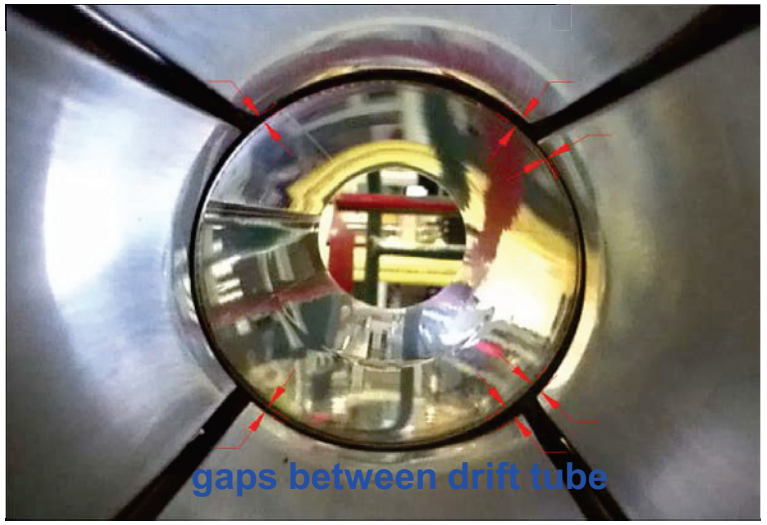


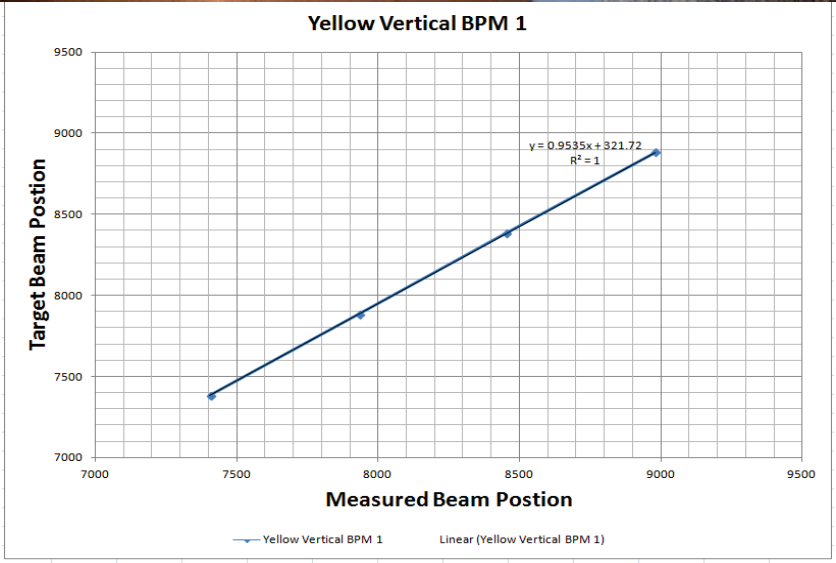
Pinhole image (1150mA beam)

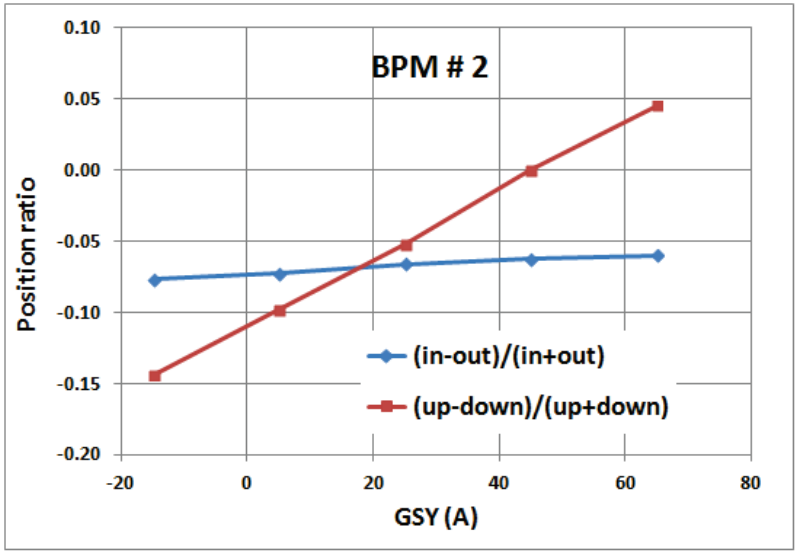


1. Gaussian beam with small flat top for both YAG and Pinhole results.
2. Radius/Sigma=2.76 and it should be 2.8 from model.

E-lens BPM Test with Proton and Electron

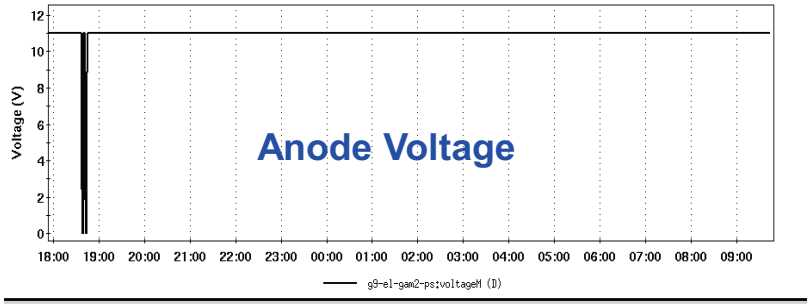




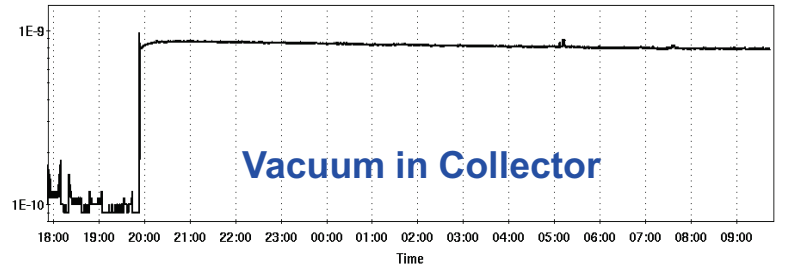


1. Two blue BPMs were tested with proton and electron beam
2. Calibration with proton beam position: linearity is good.
3. Cross-talk between V and H can be improved by re-survey.

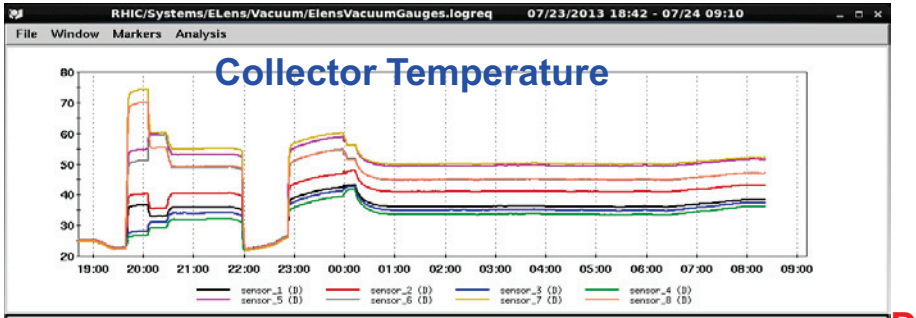
System Reliability and Failure Scenarios

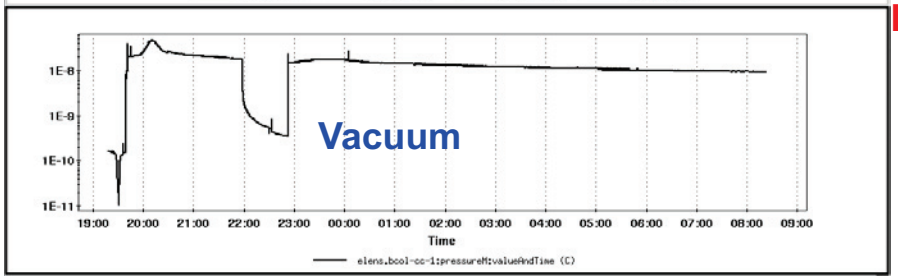


78k Hz, 14 hours

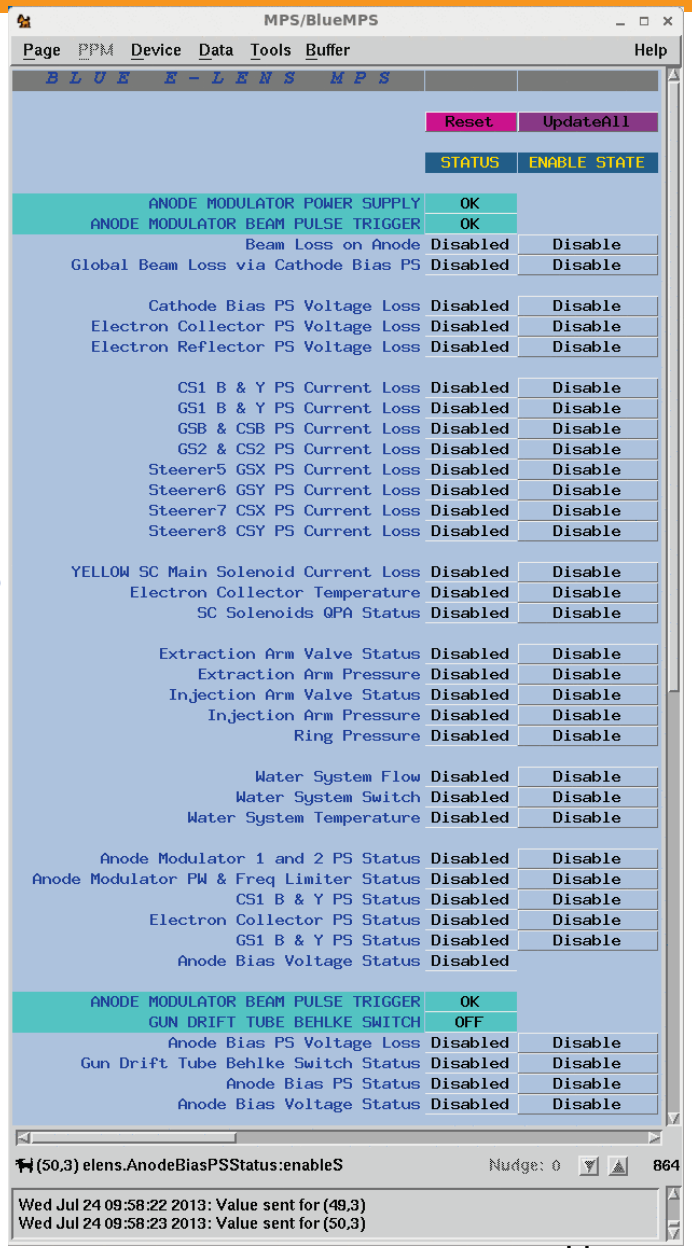


Disable MPS
Run Beam

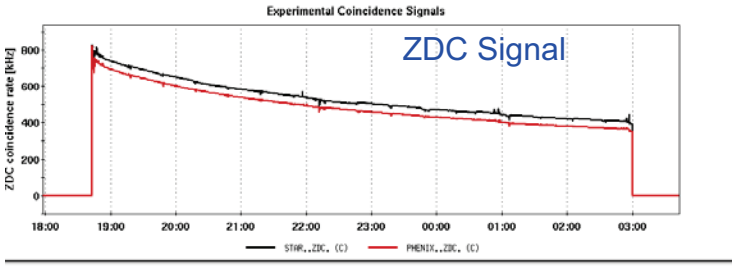


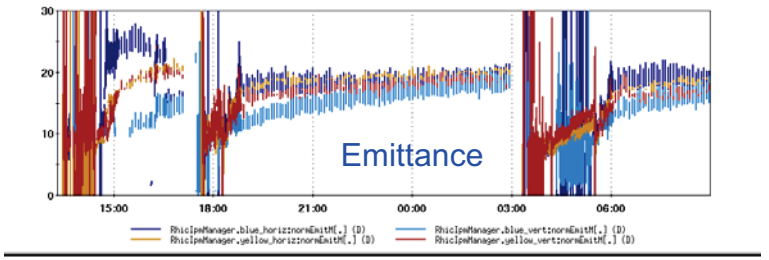


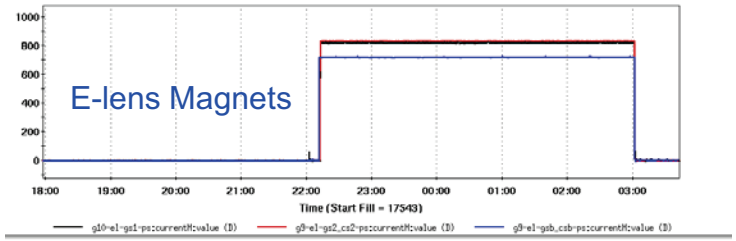
DC, 9.5 hours

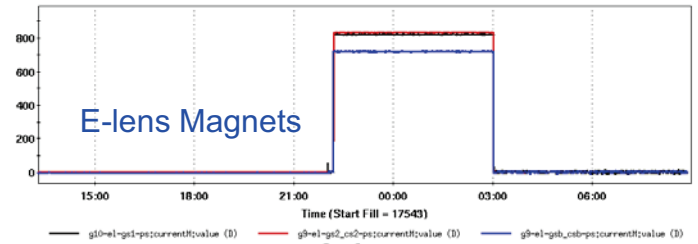


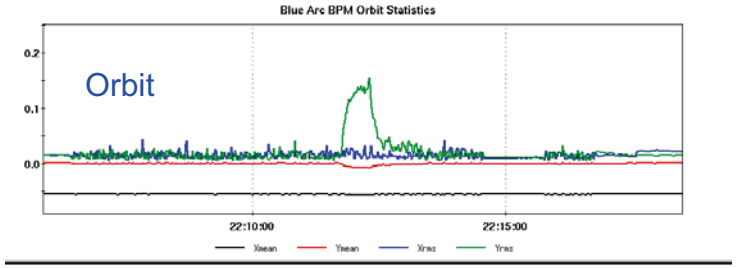
E-lens Warm Magnets & Proton Store

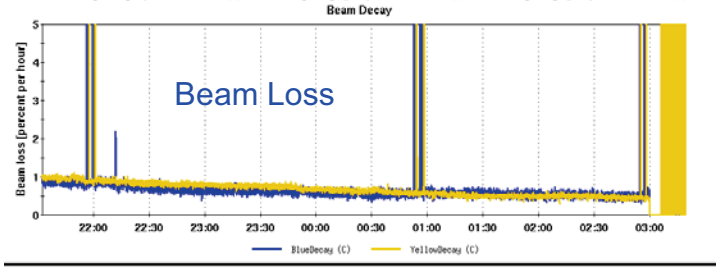


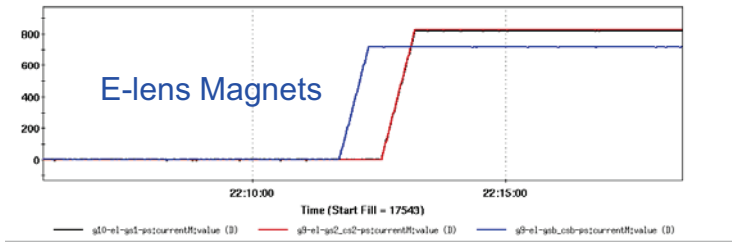


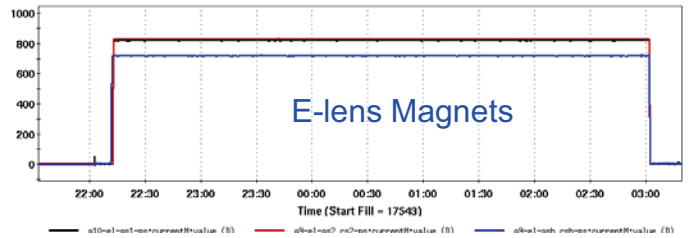






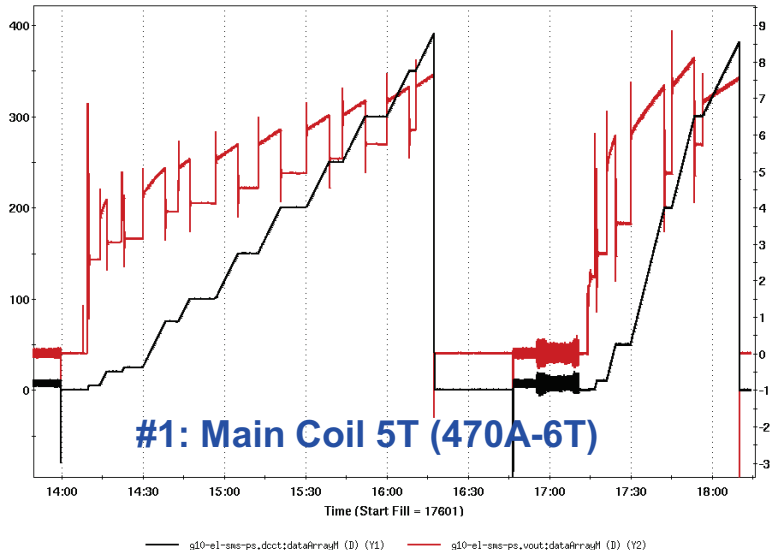


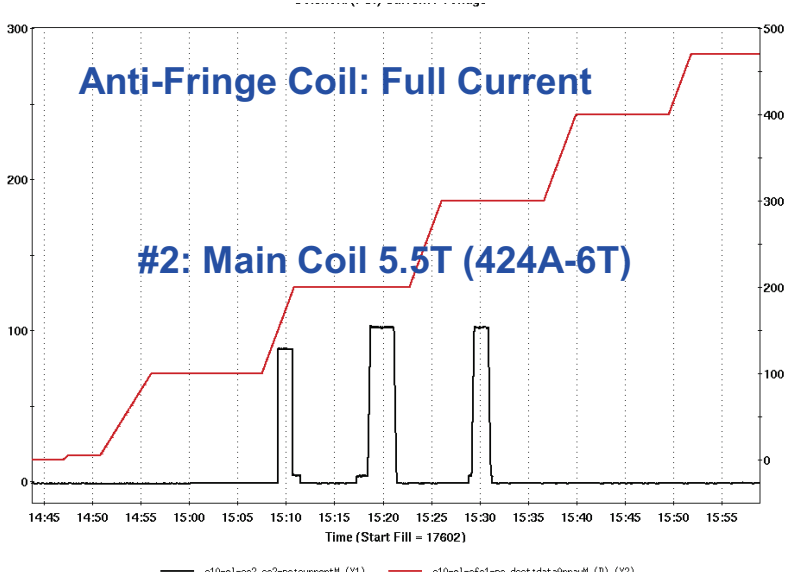


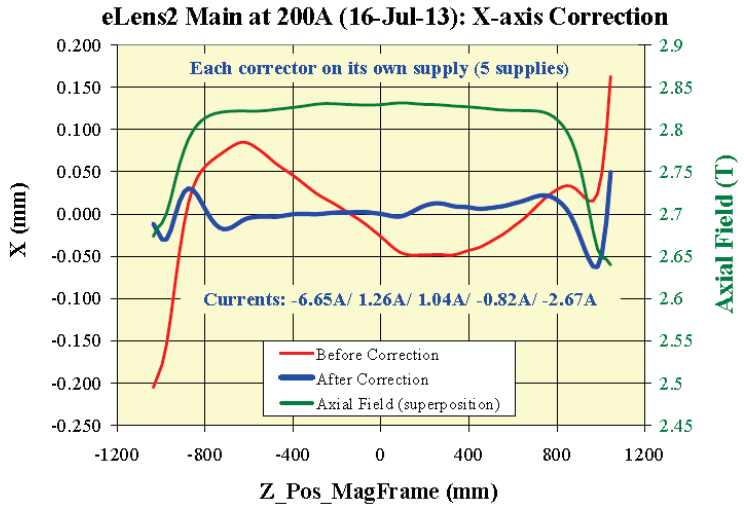


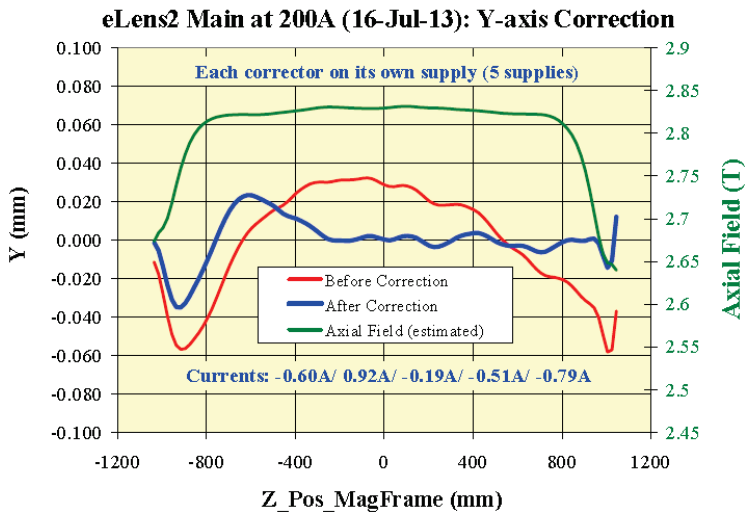
1. Some effects on Y-orbit with warm magnets.
2. Didn't find visible effects on beam with orbit feedback on.
3. No effects with tune & orbit feedback with 0.6T solenoid #1 and 3T EBIS spare.

Solenoid Horizontal Test & Field Measurement









1. Solenoid #1: 5T (Horizontal, 2 quenches), Solenoid #2: 5.5T (5 quenches, vertical)
2. Solenoid #2: +/- 50 um is satisfied in X/Y for about +/-900mm without correctors .

Courtesy of A. Jain

Summary

1. Blue e-lens hardware and software are tested and fully functional, except e-p alignment detector.

2. Electron beam current 1.256A and Gaussian beam profile have been measured.

3. System reliability was tested. Several failure scenarios were also finished.

4. Two solenoids field have been tested to >=5T. Field straightness of solenoid #2 was measured last week.

5. Installation is underway, both e-lenses will be ready for commissioning during 2014 run.

Thank you !

We are grateful for the valuable discussions with the FNAL TEL staffs, in particular with V. Shiltsev, A. Valishev, and G. Stancari.

We would like to acknowledge the help of our instrumentation group, vacuum group and controls group.