

SRF guns at BNL: First beam and other commissioning

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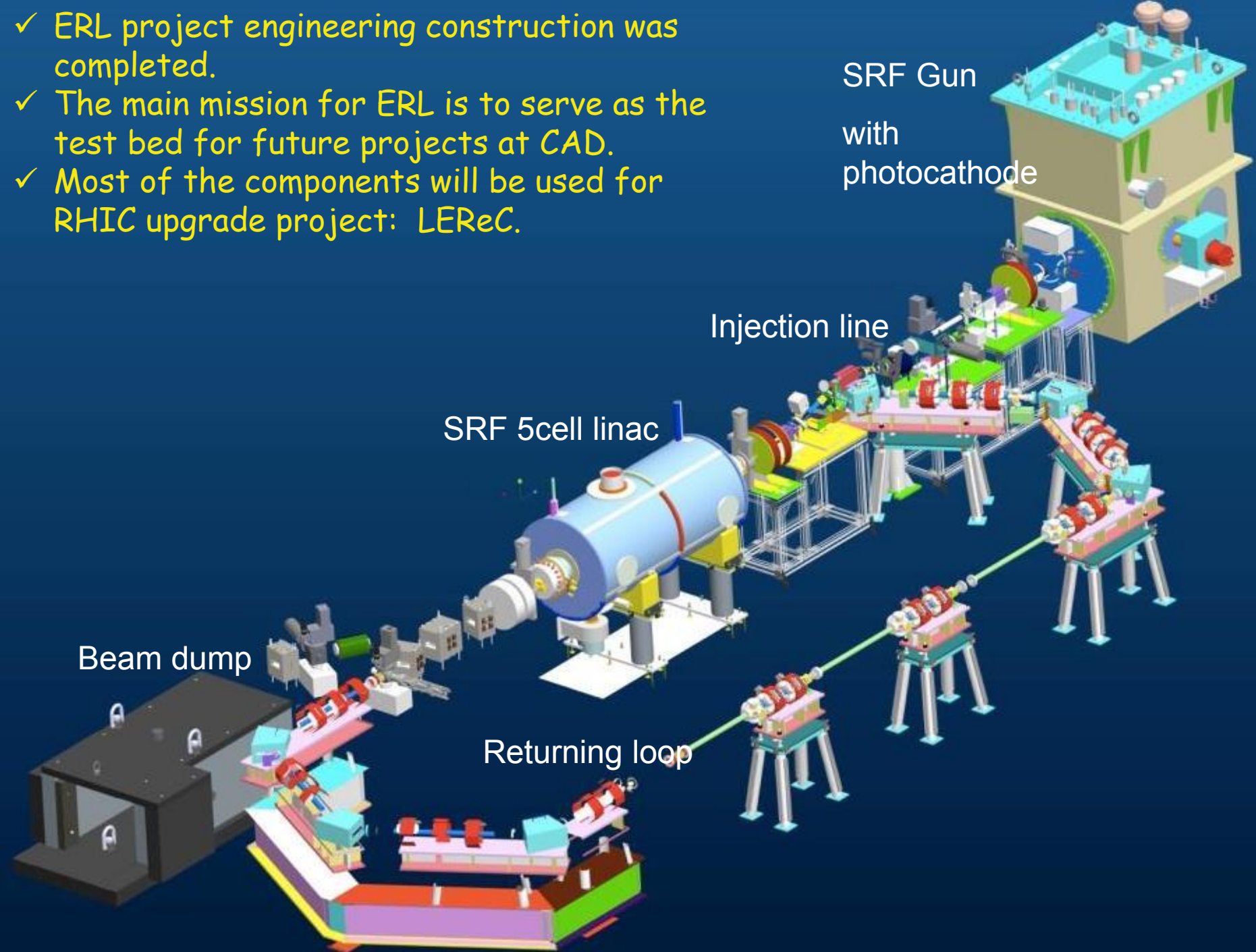
Outline

- 704 MHz half-cell SRF gun for R&D ERL
 - ✓ Brief introduction of R&D ERL and SRF gun;
 - ✓ First beam commissioning with Cu-substrate cathode stalk;
 - ✓ Design and commissioning of the new Ta-substrate cathode stalk;
 - ✓ Beam commissioning with Ta-substrate cathode stalk.

- 112 MHz QWR SRF gun for Proof-of-Principle Coherent Electron Cooling (POP CEC).
 - ✓ First beam commissioning results

- Summary

- ✓ ERL project engineering construction was completed.
- ✓ The main mission for ERL is to serve as the test bed for future projects at CAD.
- ✓ Most of the components will be used for RHIC upgrade project: LEReC.

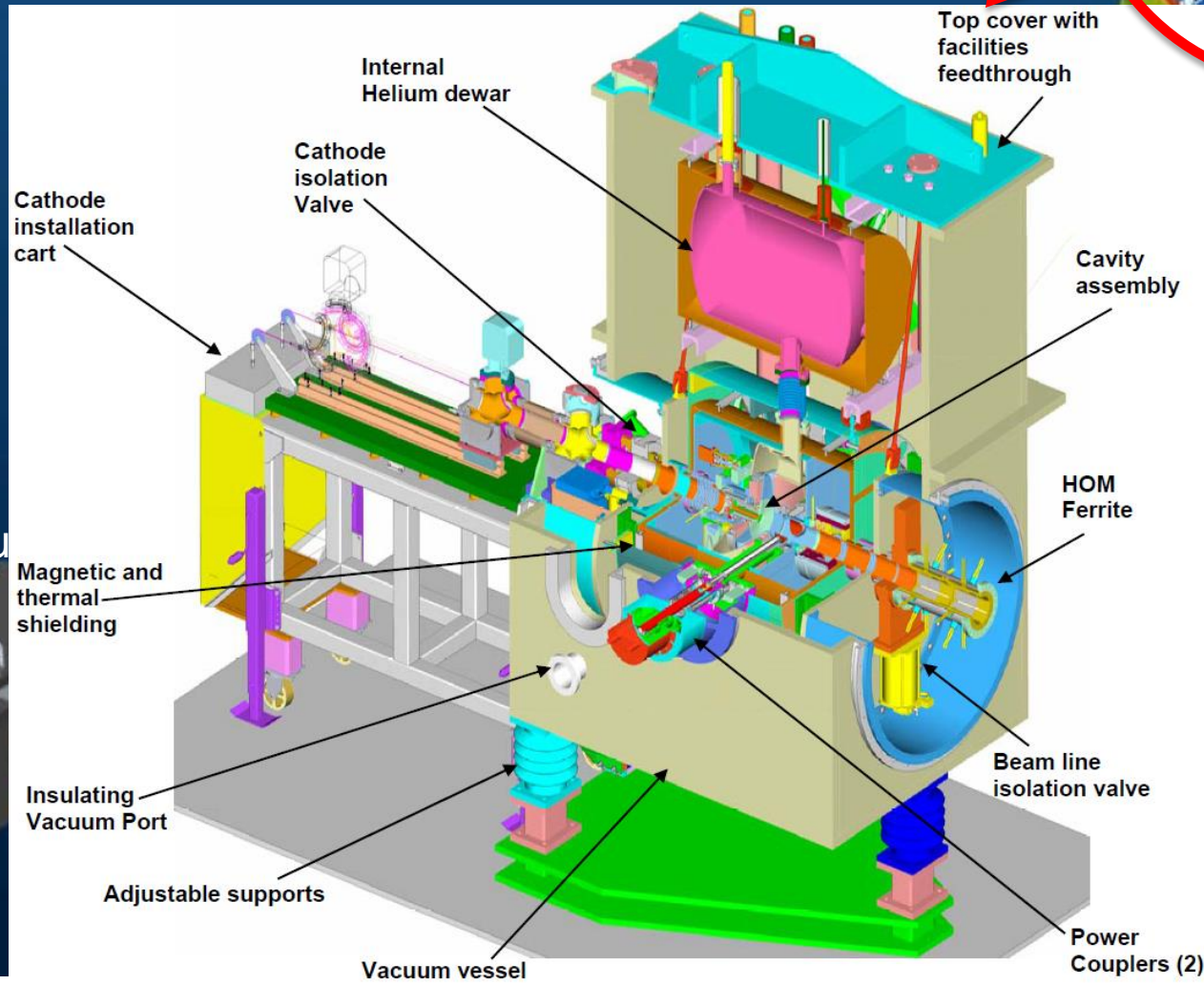


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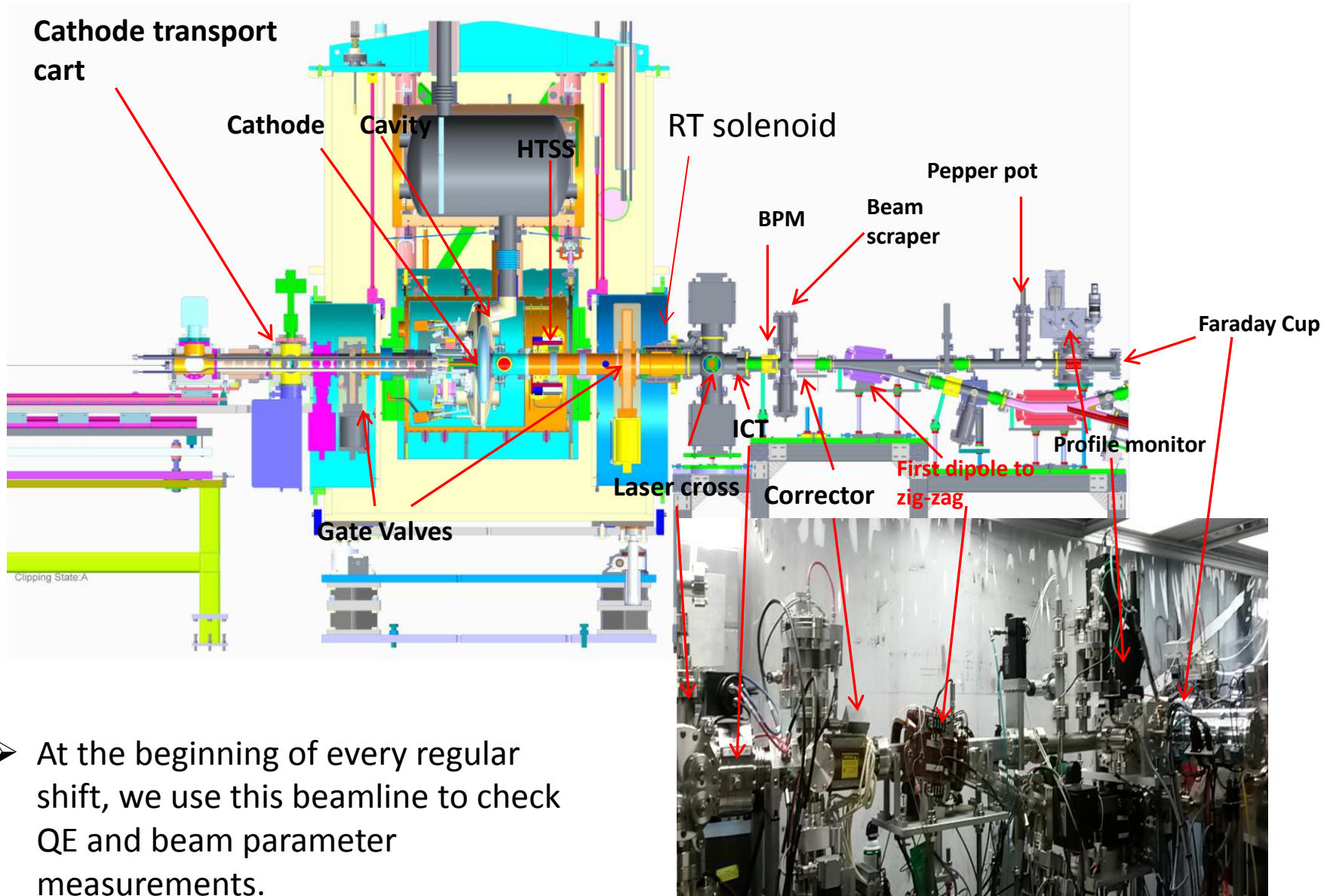
SRF Gun
with
photocathode



Beam du



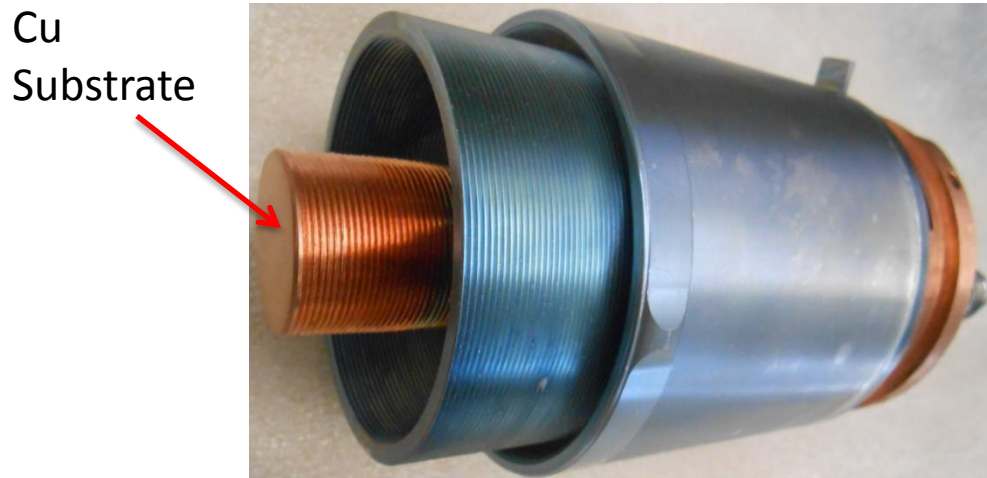
First beam commissioning (Nov. 2014)



- At the beginning of every regular shift, we use this beamline to check QE and beam parameter measurements.

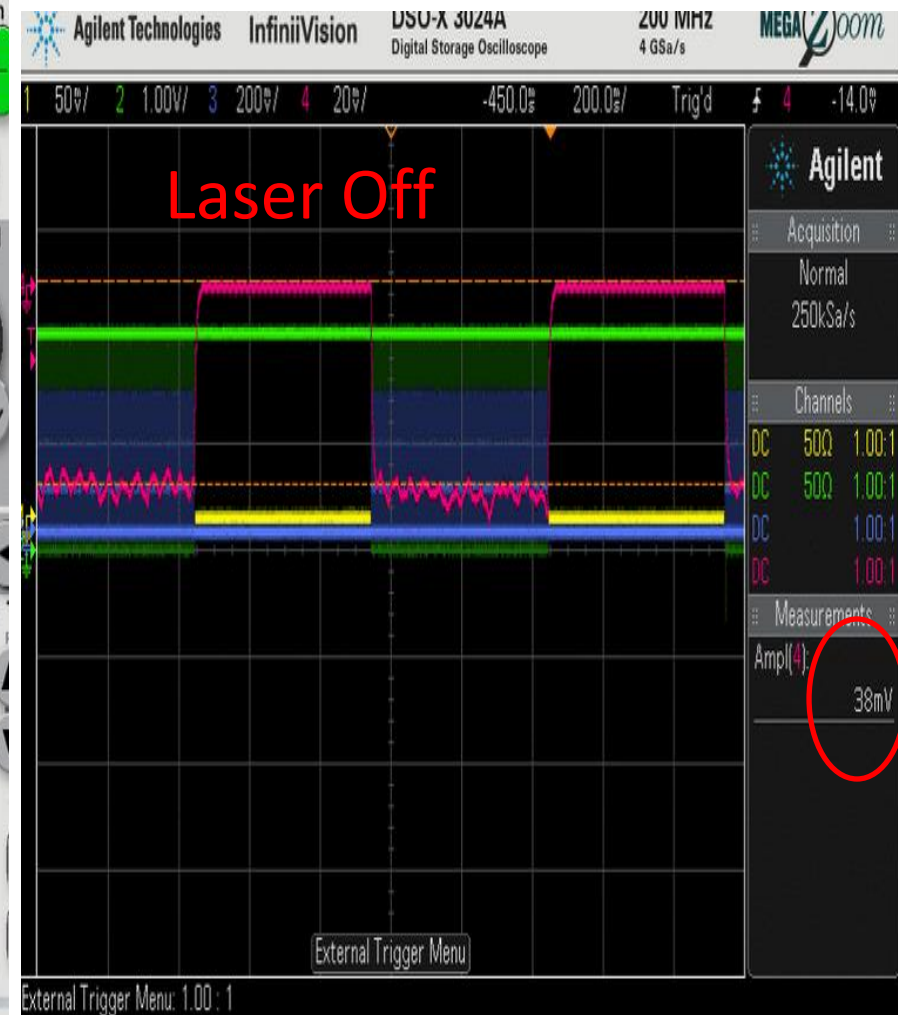
First beam commissioning: Nov, 2014

- Cathode stalk: Cu substrate.



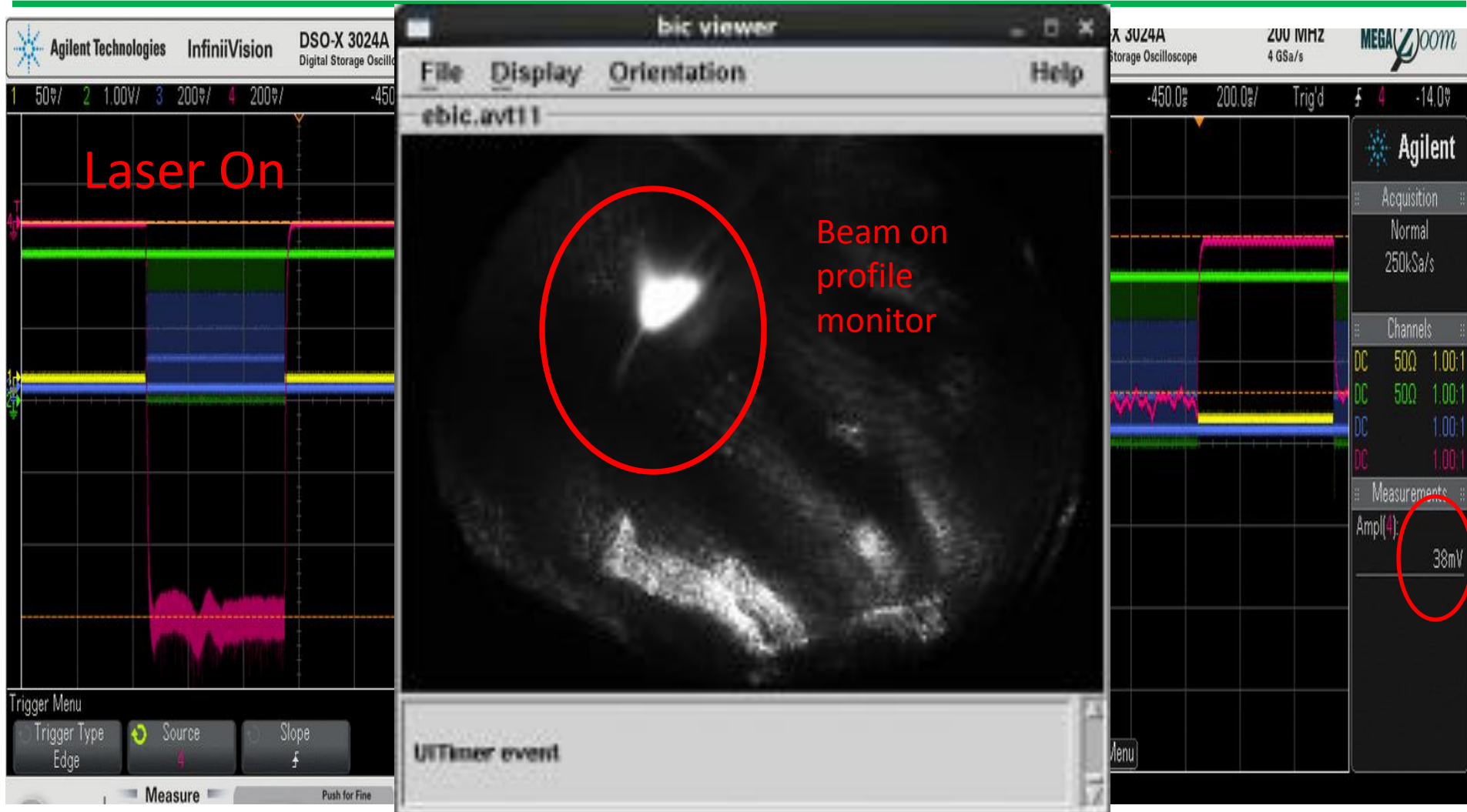
- Cathode: Cs_3Sb photocathode, $2.75\text{E-}3$ of QE on the fresh cathode and decayed to $3.5\text{E-}4$ before inserting into the gun for beam test.
- RF: 1.2 MV, in pulse mode.

1 μ A Beam



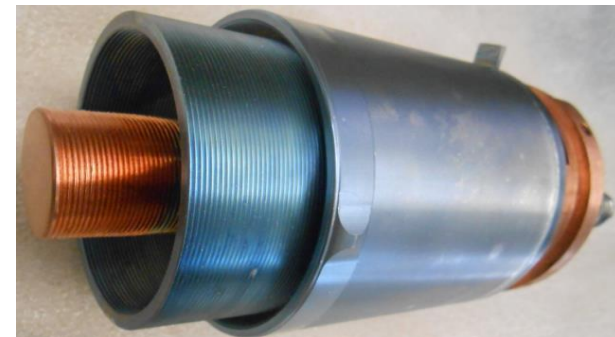
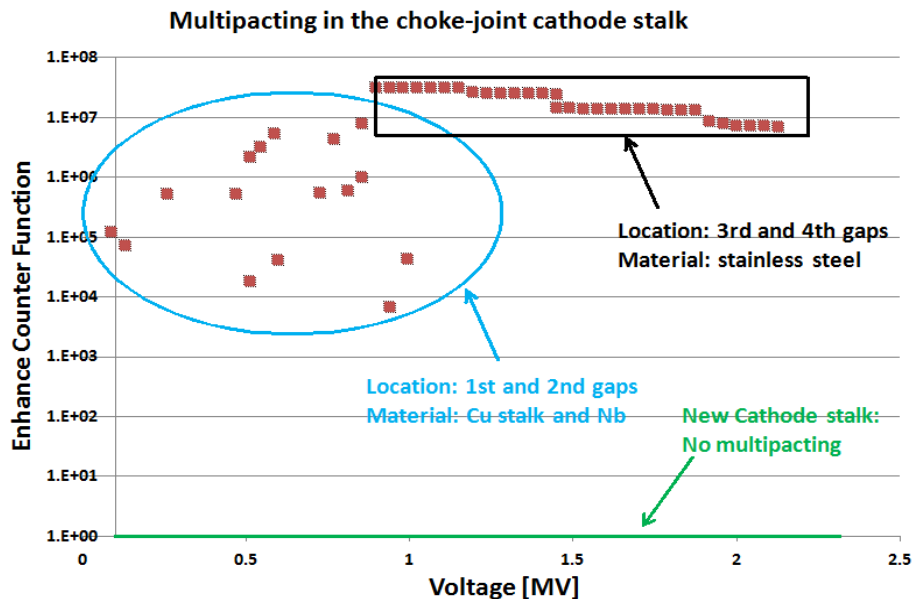
- Parameters: Laser: 6.08 Watt; RF: 1.2 MV, 500 ms;
- Beam: bunch charge: 7.7 pC, photoemission current 1 μ A, dark current: 38 nA;
- Focusing the beam with RT solenoid.

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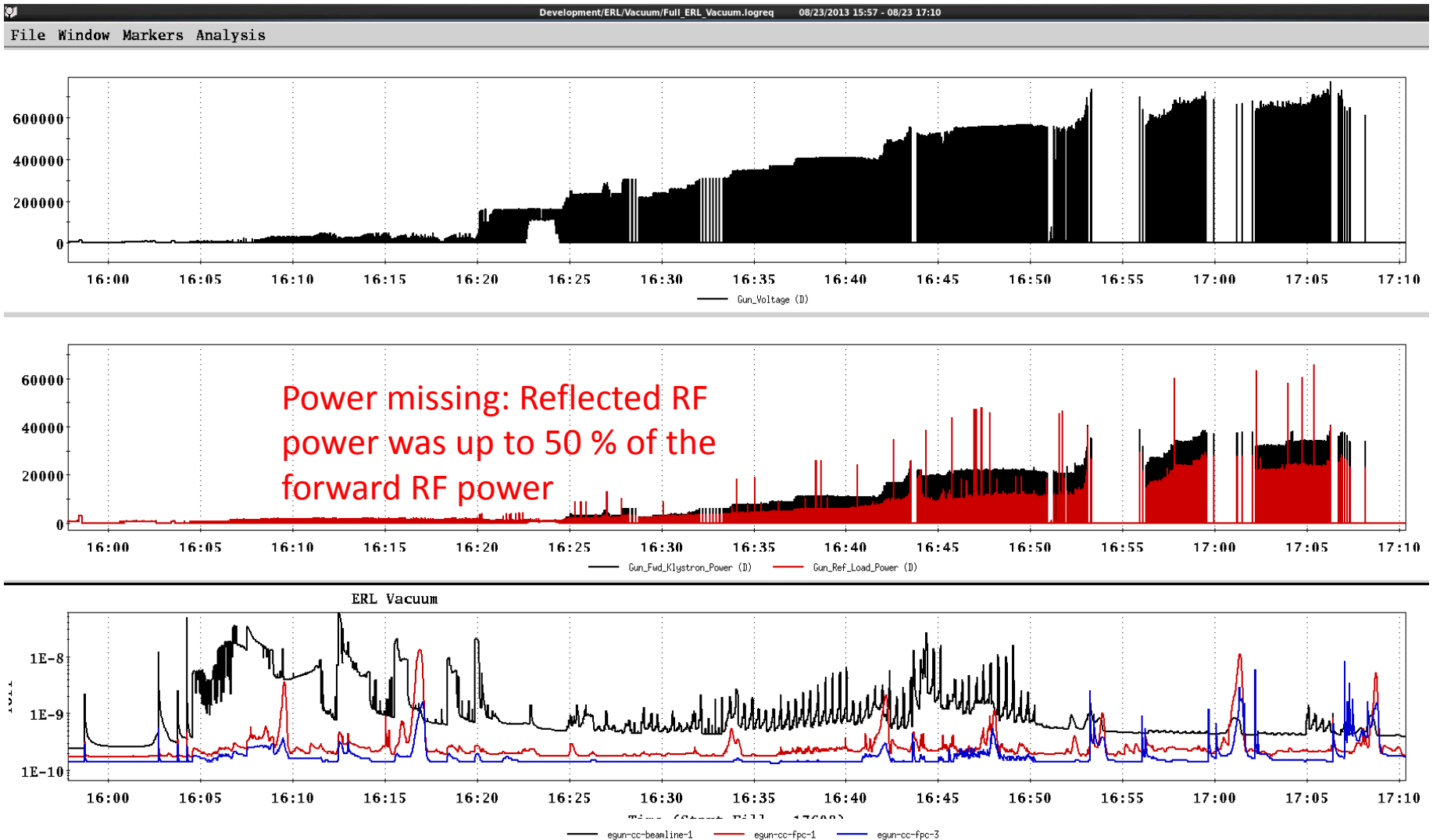
Design and commissioning of the new cathode stalk



Three reasons for new cathode stalk:

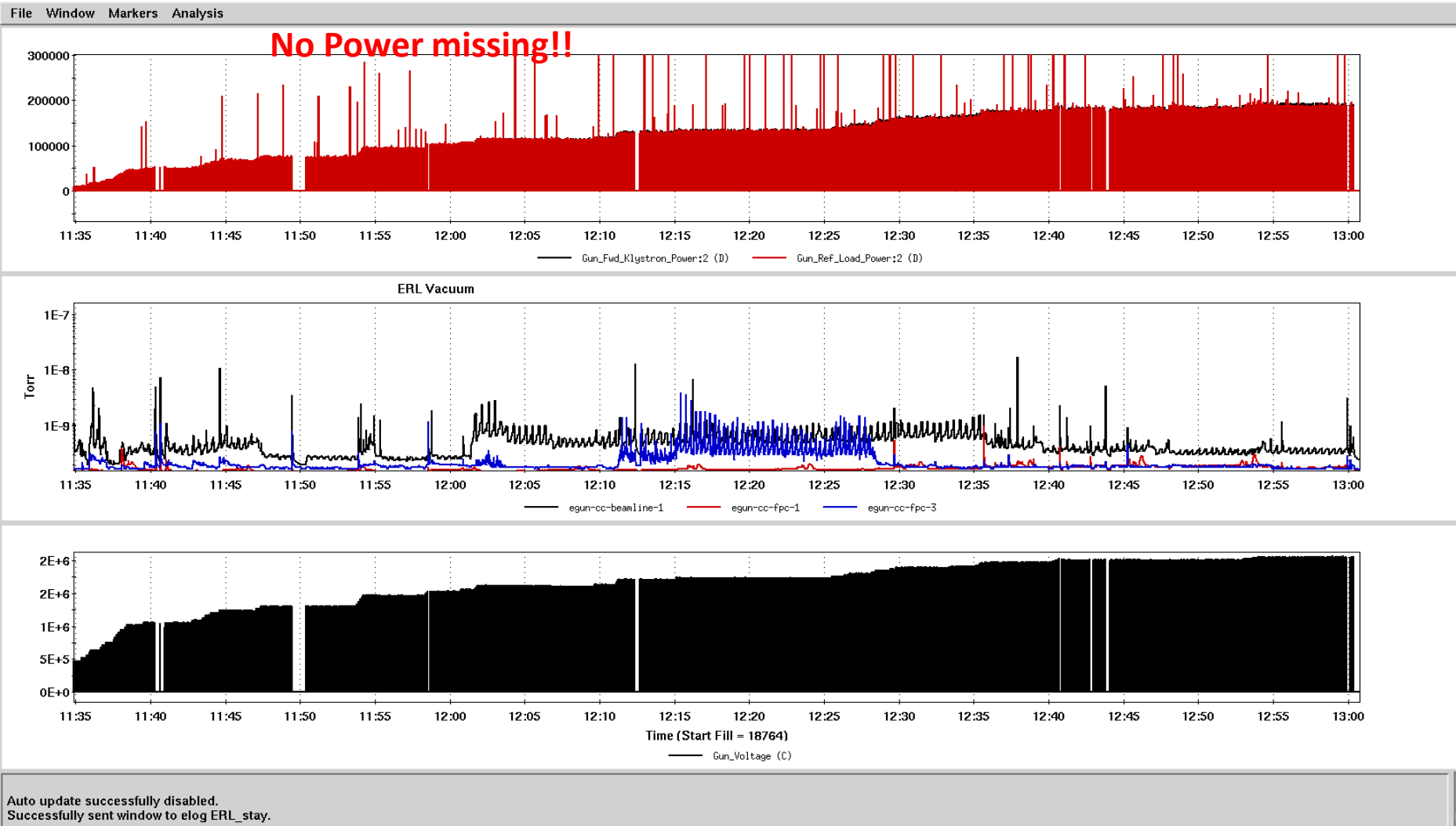
- **Strong multipacting occurred at various field levels in the choke-joint cathode stalk.**
=> Design a multipacting-free cathode stalk for reduction of conditioning time.
=> CW operation.
- **To replace Cu substrate with Ta.**
=> High QE for high charge/current operation.
=> Reserve the cathode lifetime.
- **To reduce cathode stalk heat loading**
=> Improve the LN2 cooling .

Multipacting in the Cu cathode stalk



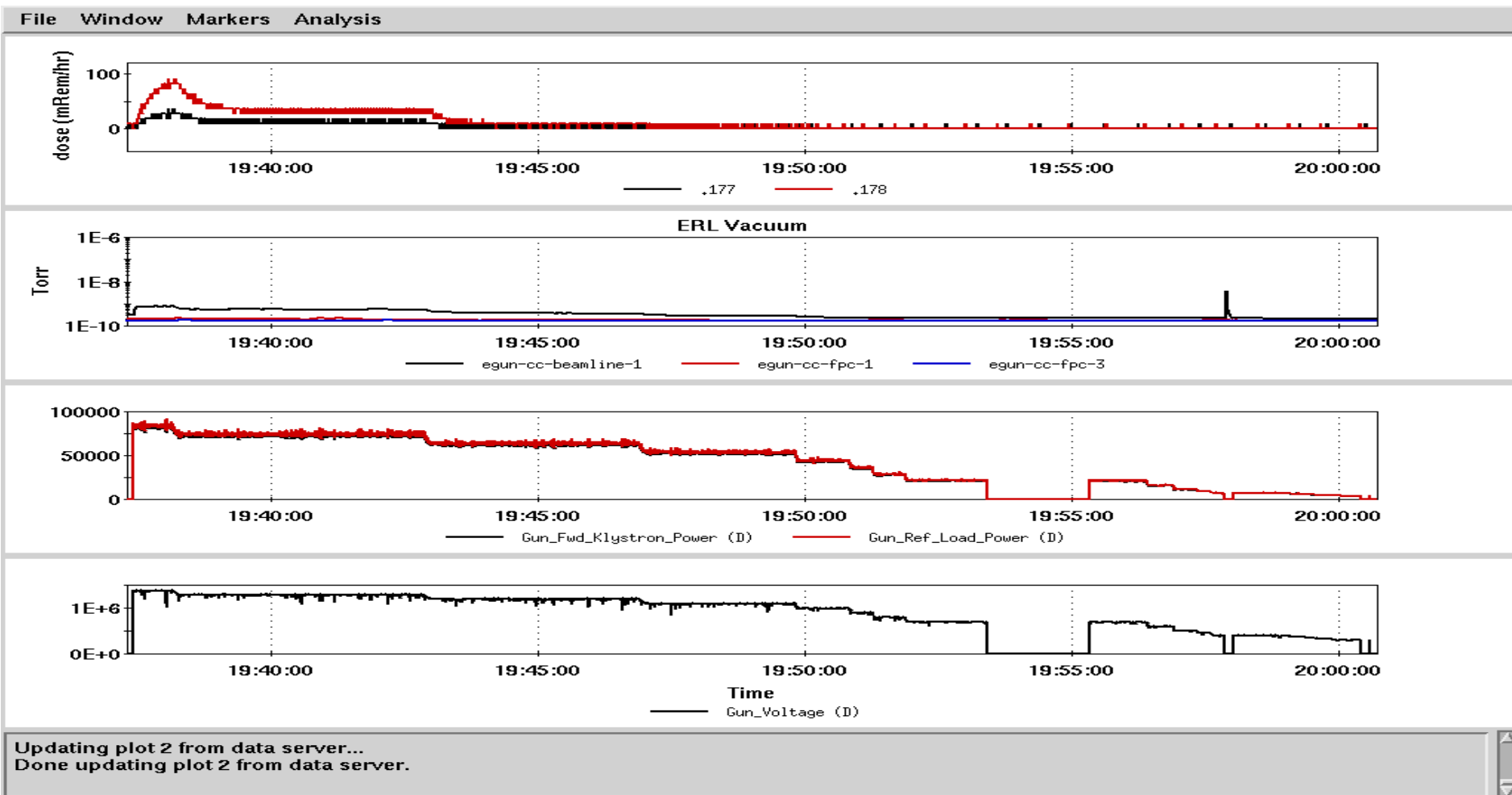
- After conditioning for 7 days and average 10 hours per day, the gun reached 1.85 MV with 18% of duty factor.

Multipacting-free Ta cathode stalk test results



➤ Within the first 1.5 hours, the cavity voltage goes up to 2 MV in pulse mode without multipacting.

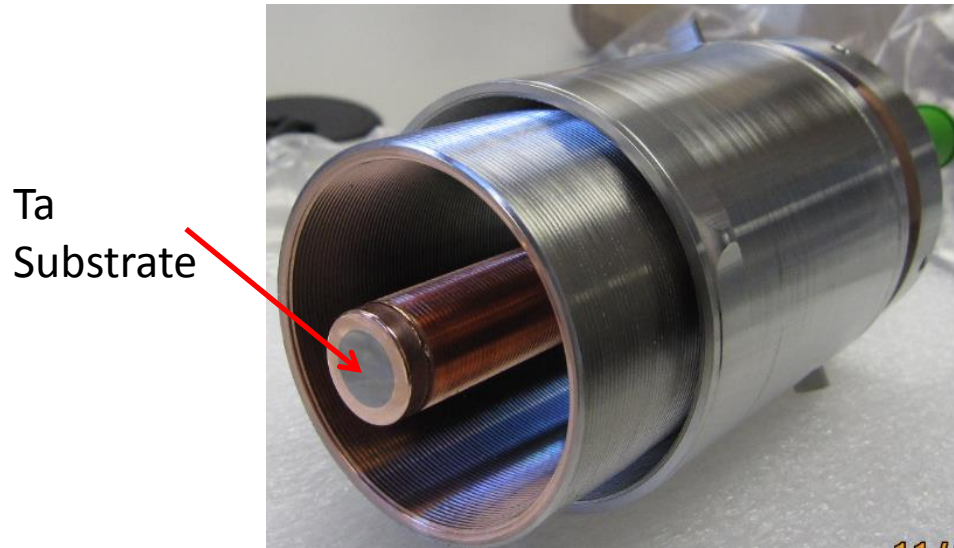
Multipacting-free cathode stalk test results (CW)



- After **less than 10 hrs** conditioning, it is **stable CW operation from 0.4 MV to 1.3 MV CW**.
- Above 1.4 MV, field emission started. We decided to use this cathode stalk for beam test as the field is good enough for initial beam tests.

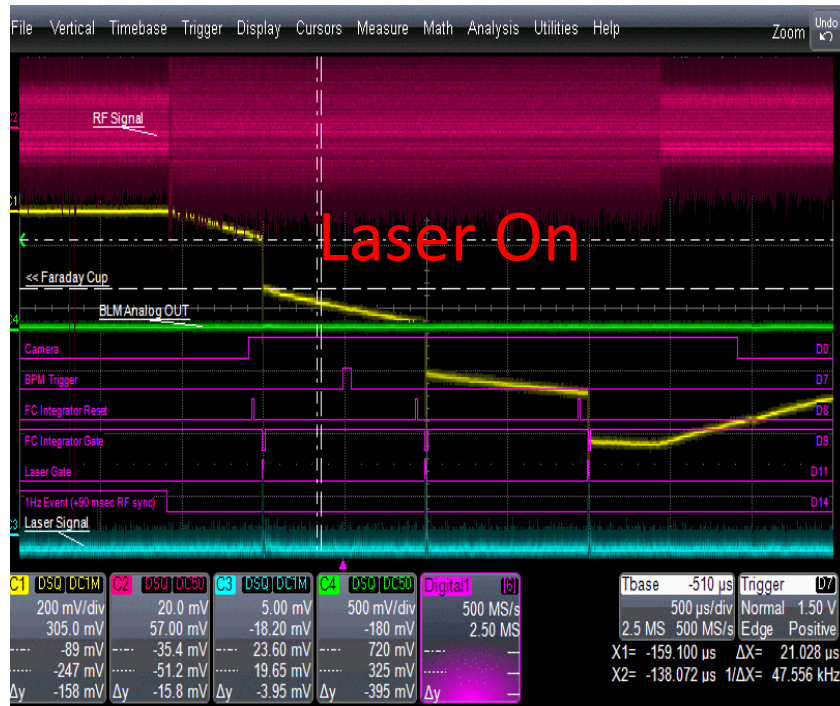
Beam commissioning with new stalk

- Cathode stalk: multipacting-free cathode stalk with Ta tip.

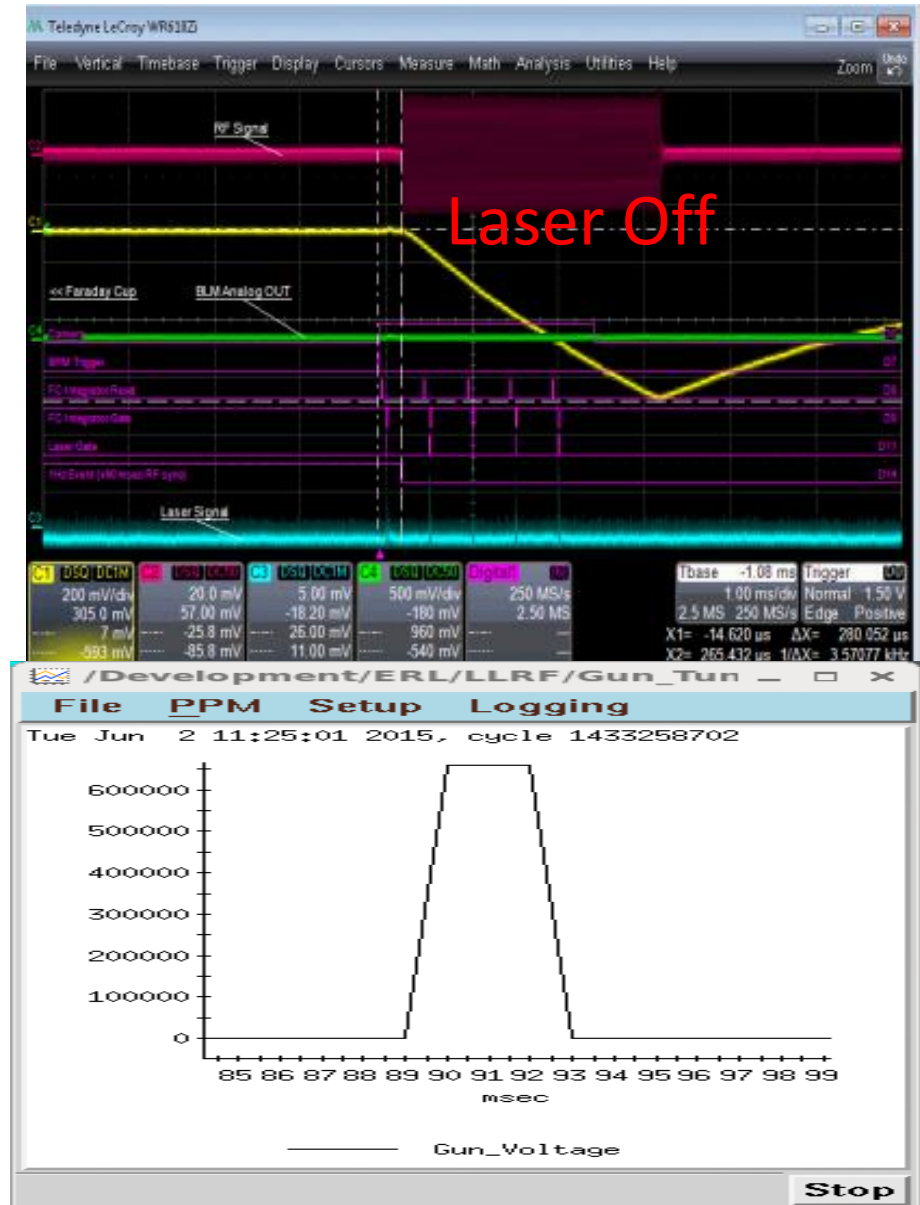


- Cathode: K_2CsSb photocathode, 3.8% of QE on the fresh cathode stalk and stay the same up before inserting into the gun.
- It was used for beam test since June 1 to present, the initial QE was 1%.
- After that, the QE stays at 0.03%~0.05% for months, which is “good” (safe) for machine tuning.
- No significant additional heatload on the cathode stalk.

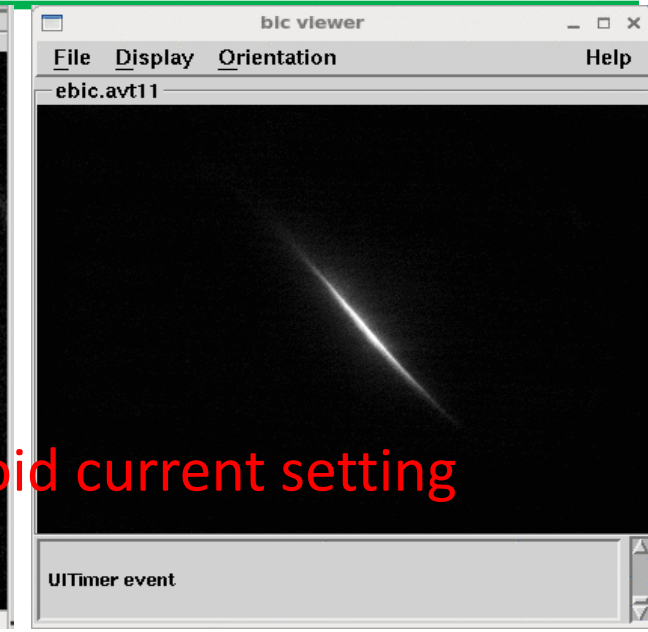
Beam on Faraday cup



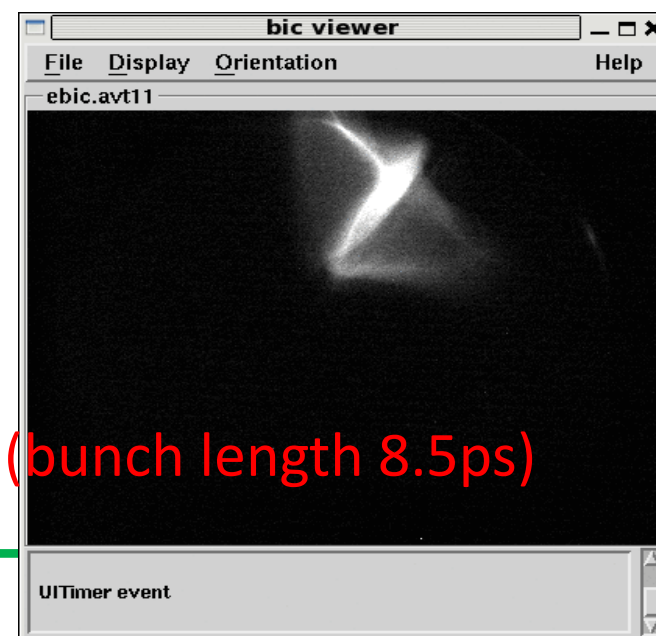
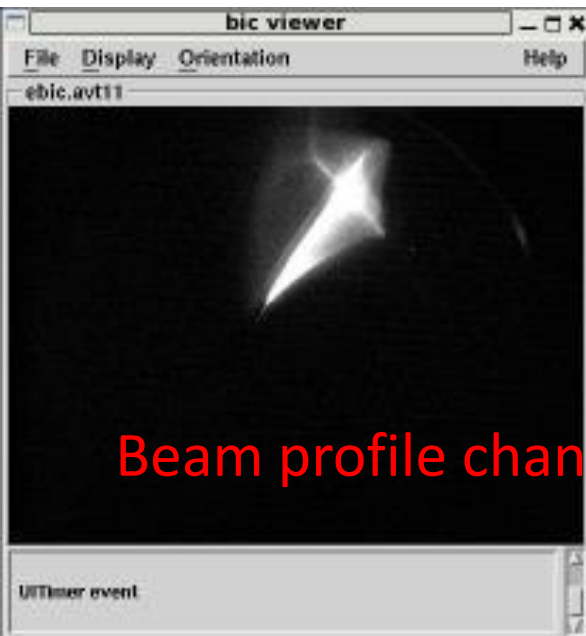
- Laser: 0.044 W, 5 μ sec, 9.38MHz rep rate.
- RF: 0.65 MV, 3 ms;
- Photocurrent: 17pC per pulse or 159 μ A within macro laser pulse.
- Dark current: 4 μ A



Bunch profile on the YAG screen



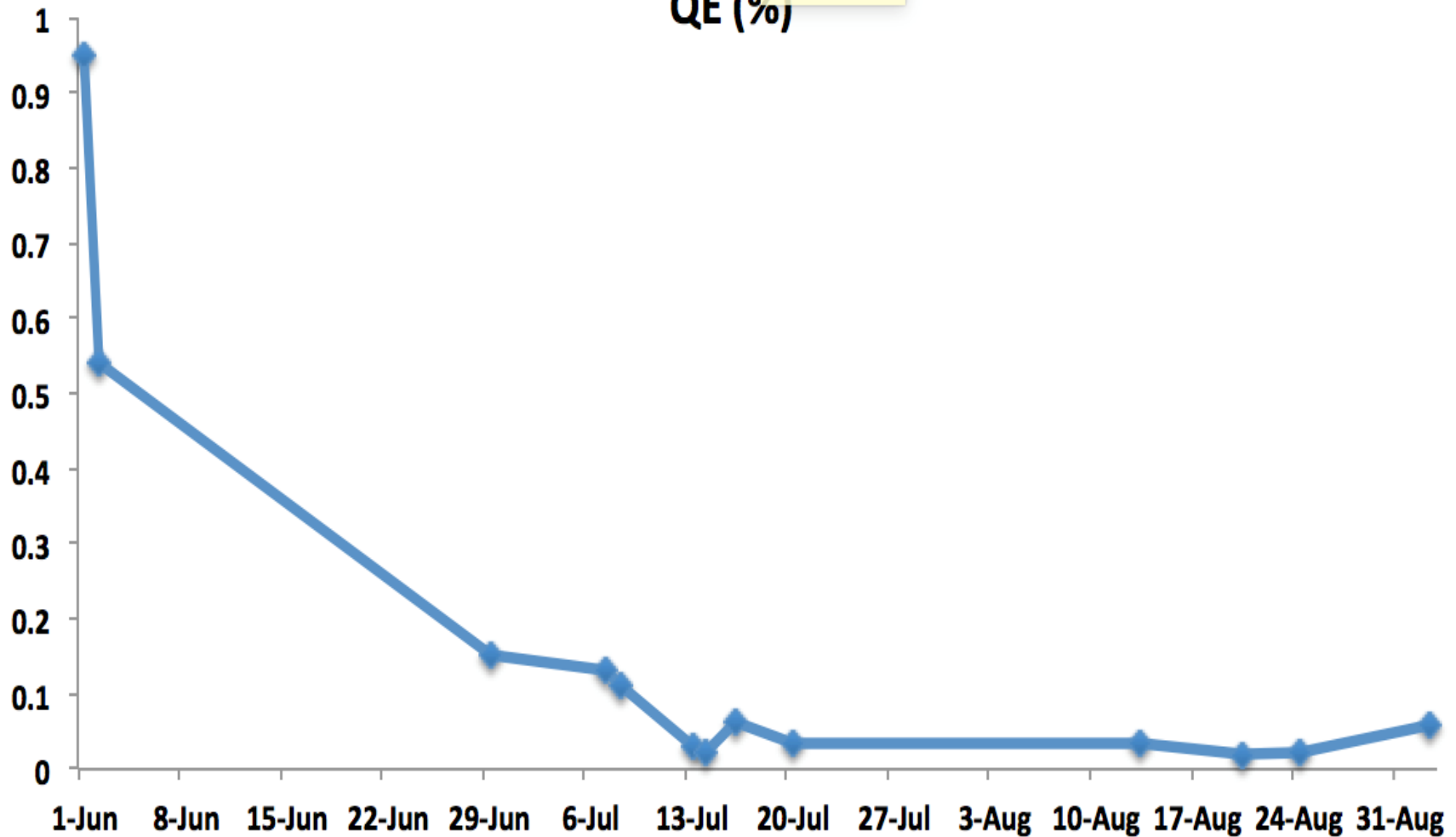
Beam profile changes with different RT solenoid current setting
(bunch length 23 ps)



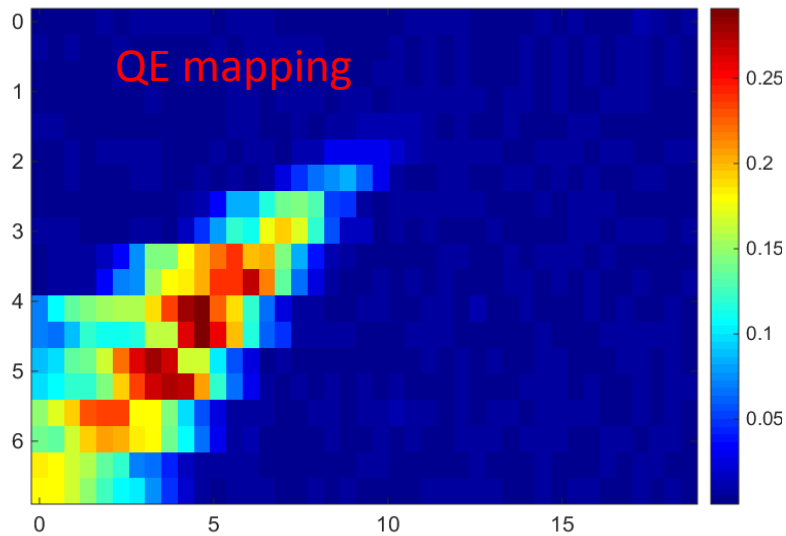
Beam profile changes with waving RF phase (bunch length 8.5ps)

New cathode stalk: high QE, long lifetime

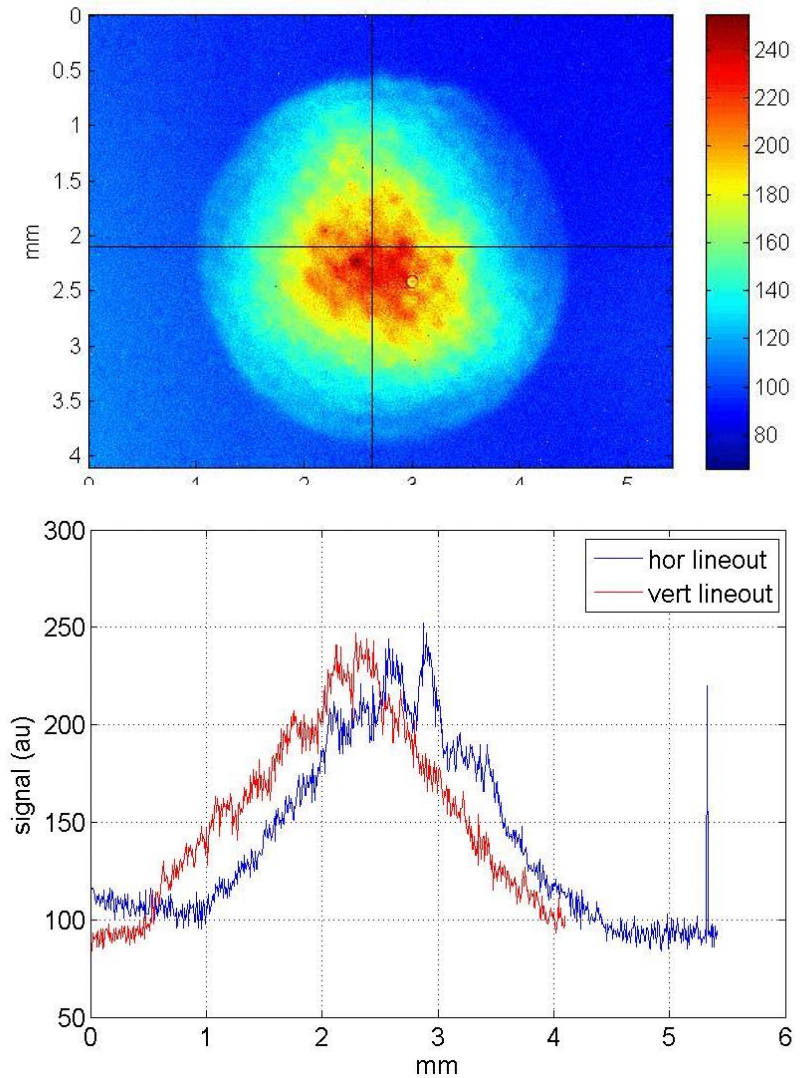
QE (%)



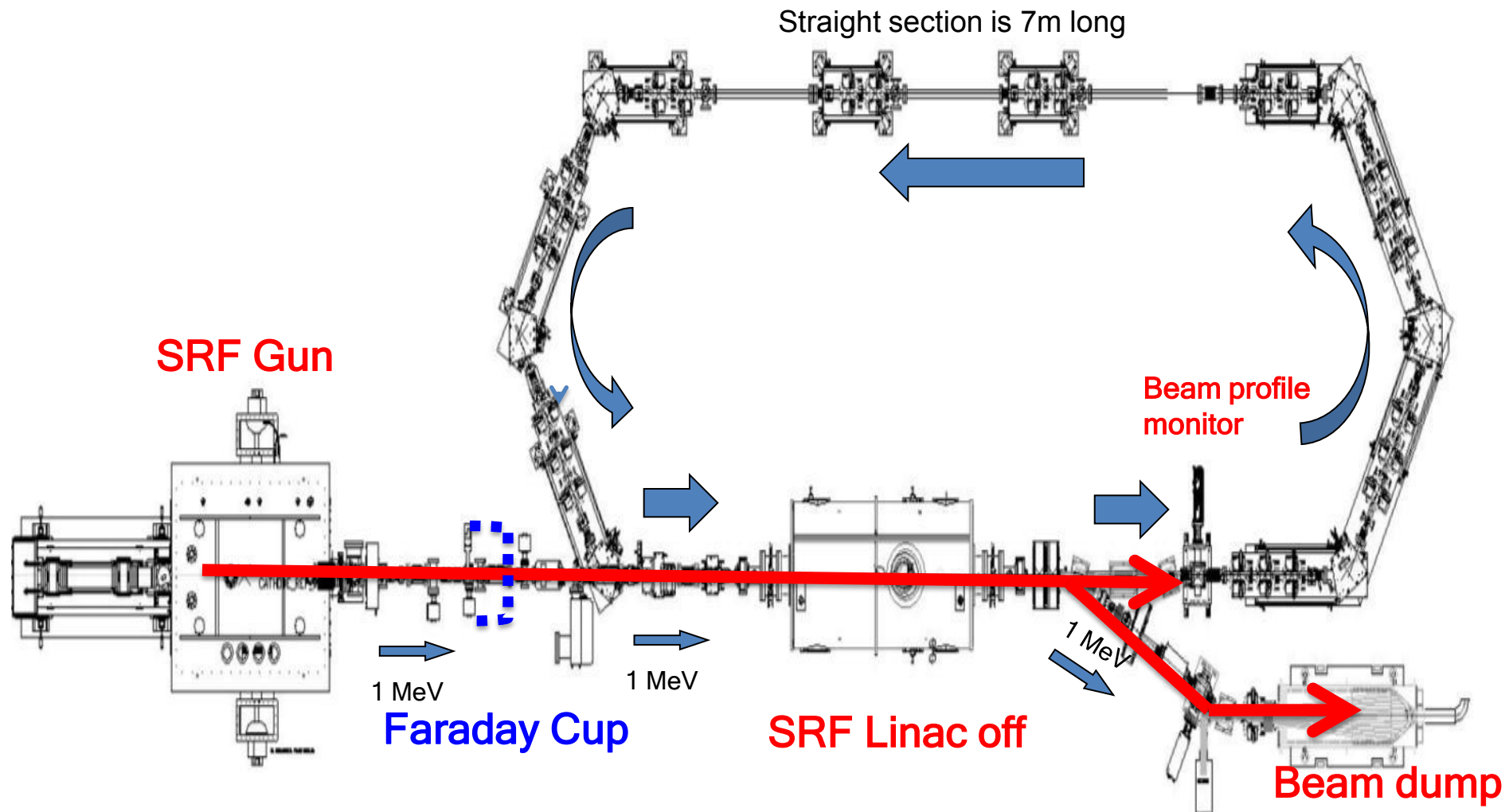
QE mapping



QE mapping is still under developing now and it is semi-automatic now.



ERL Commissioning status: GuntoDump



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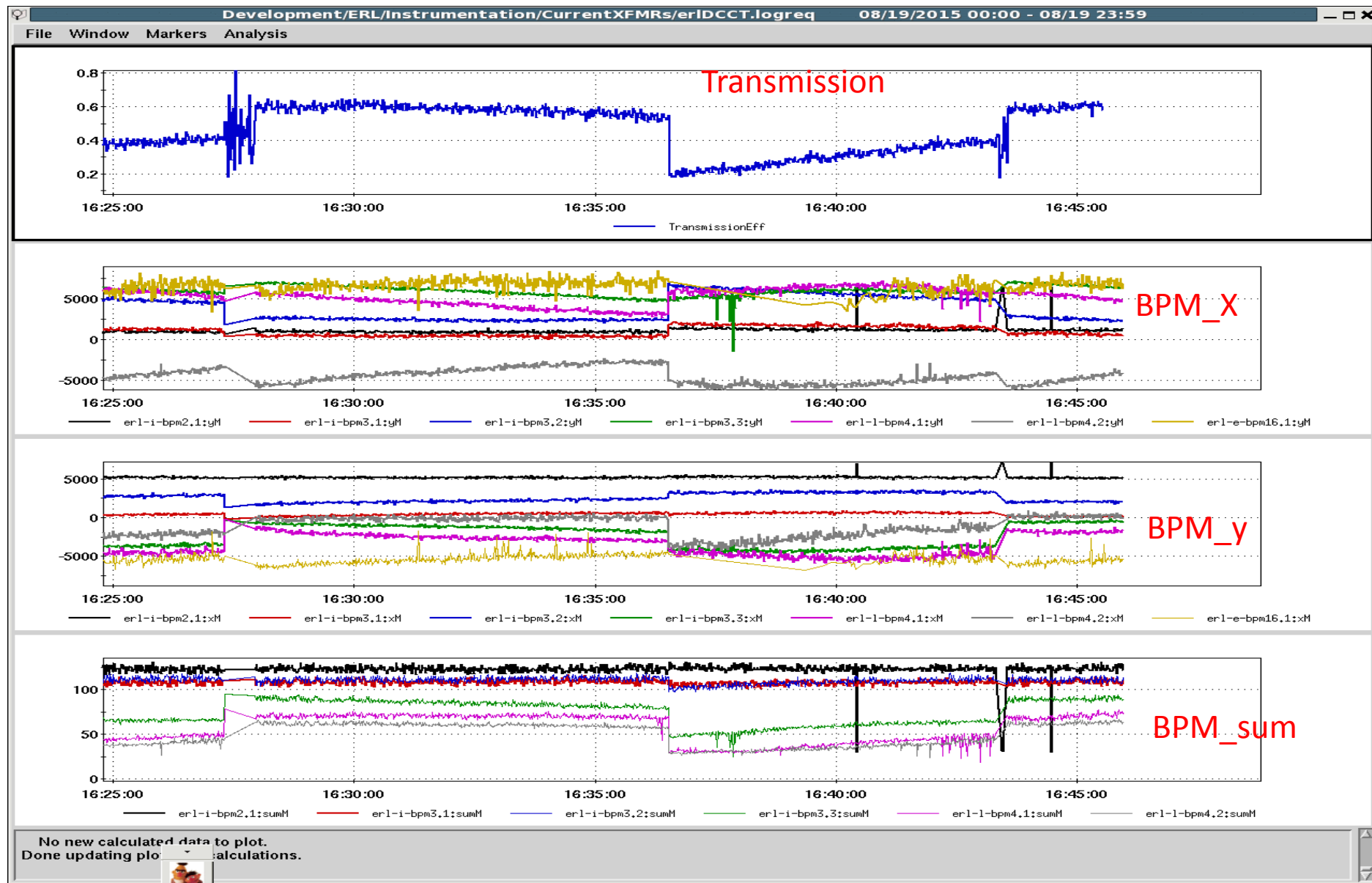
SRF Gun

Beam profile monitor

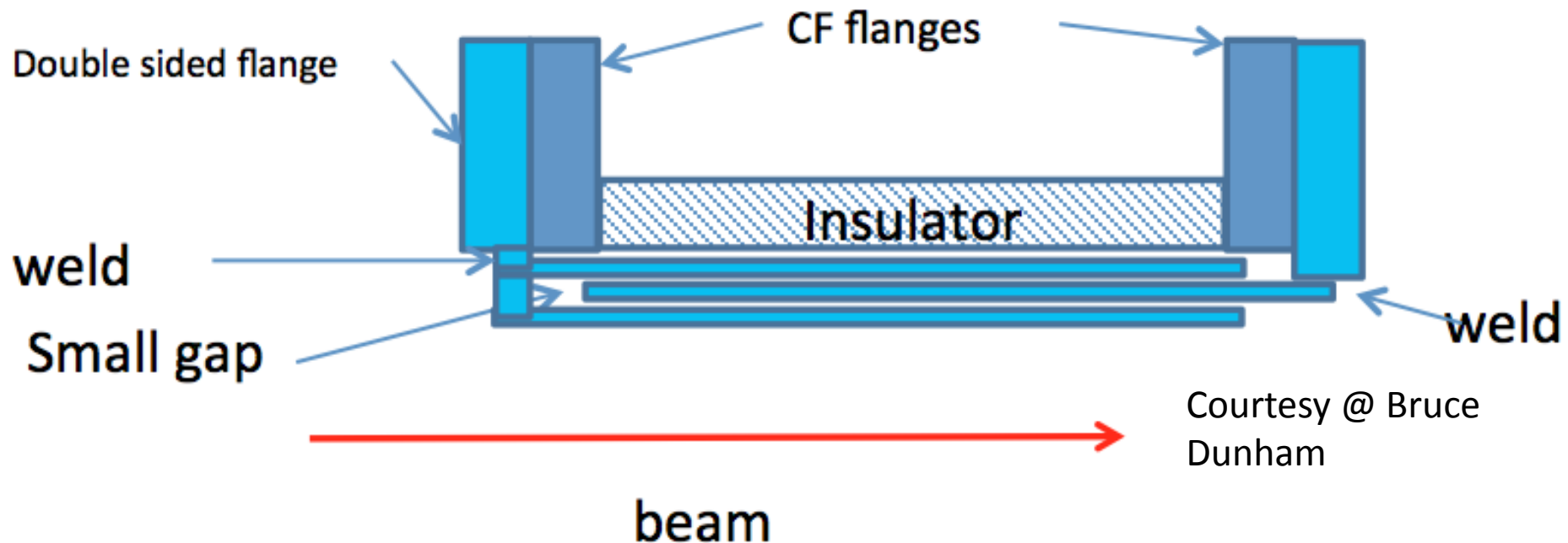
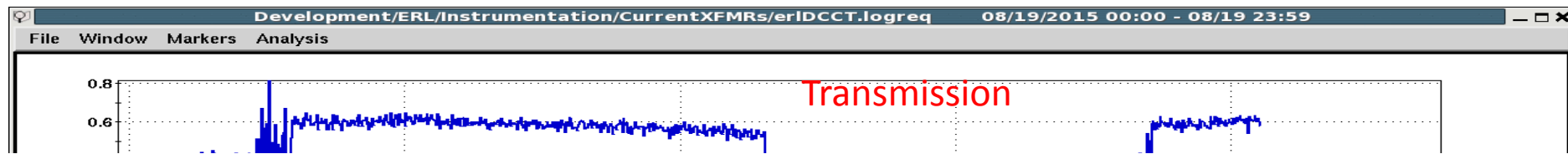
Transmission

Beam dump

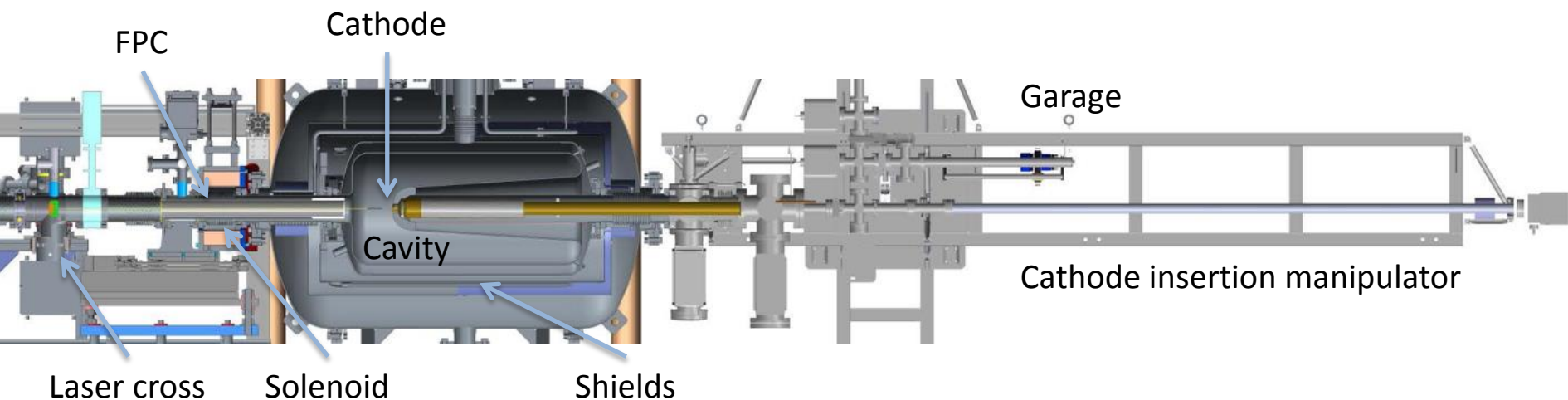
Orbit shift and jump: due to ceramic charging and discharging



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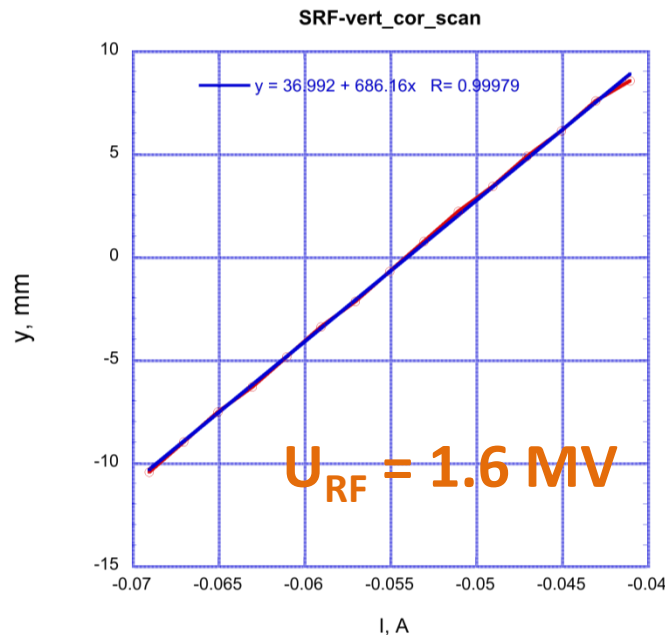
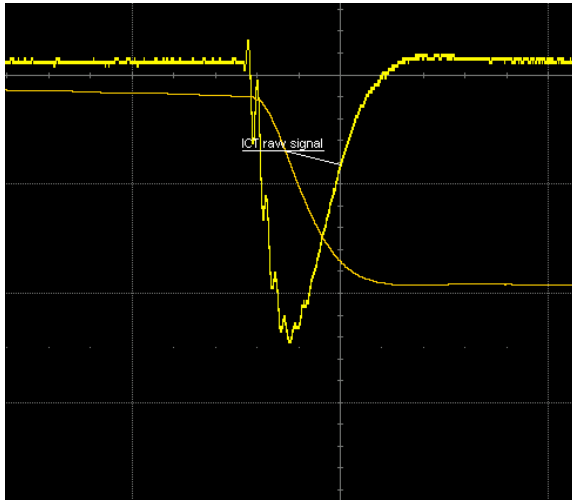
112 MHz QWR SRF gun



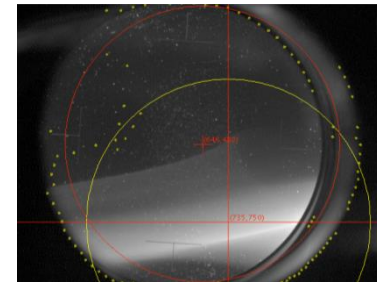
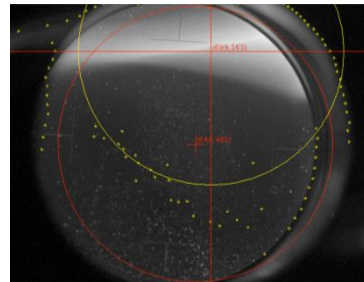
- Quarter-wave cavity
- 4 K operating temperature
- Manual coarse tuner
- Fine tuning is performed with FPC
- 2 kW CW solid state power amplifier
- CsK₂Sb Cathode is at room temperature
- Cavity field pick-up is done with cathode stalk (1/2 wavelength with capacitive pick-up)
- Up to three cathodes can be stored in garage for quick change-out
- Design gradient 22.5 MV/m

Thursday's Poster THPB058

112 MHz QWR SRF GUN: First beam observation



- First beam was observed in June 2015, with integrating current transformer during phase scan. The charge was 0.5 nC.
- Found that beam charge is limited by space charge forces.
- After 50% laser spot size increase we were able to observe 3 nC charge.
- We have increased pulse repetition rate from few Hz to 5 kHz (laser max) and observed 15 μA current.
- Were able to see beam on the first profile monitor 2.77 m downstream.



Summary

- 704 MHz ERL SRF gun observed first beam in Nov, 2014, with Cu substrate cathode stalk.
- The new cathode stalk suppresses multipacting, reduces the 2K heat load and provides high QE, long lifetime photocathode.
- With new cathode stalk, ERL is under Gun-to-Dump commissioning. We are working on stabilizing the beam orbit first.
- 112 MHz CEC gun generated the first beam in June, 2015 and demonstrated 3nC (maximum charge) electron beam.

Acknowledge

ERL Team: Zeynep Altinbas, Dana Beavis, Sergey Belomestnykh, Ilan Ben-Zvi, Paul Bergh, Suresh Deonarine, Jesse Fite, David Gassner, Lee Hammons, Ramesh C. Gupta, Harald Hahn, Chung Ho, James Jamilkowski, Stephen Jao, Prerana Kankiya, Dmitry Kayran (shift leader), Robert Kellermann, Nikolaos Laloudakis, Robert Lambiase, Edward Lessard, Vladimir Litvinenko, George Mahler, Leonard Masi, Gary McIntyre, Wuzheng Meng, Robert Michnoff, Toby Allen Miller, Michiko Minty, John Morris, Igor Pinayev, David Phillips, Vadim Ptitsyn (shift leader), Triveni Rao, Pablo Rosas, Thomas Roser, Scott Seberg, Thomas Seda, Brian Sheehy, Loralie Smart, Kevin Smith, Victor Soria, Andrew Steszyn, Roberto Than, Erdong Wang, Andreas Warkentien, Daniel Weiss, Huamu Xie, Alex Zaltsman....

Thanks Igor Pinayev and Vladimir Litvinenko to provide slides on 112 MHz SRF gun.