Progress in SACLA Operation

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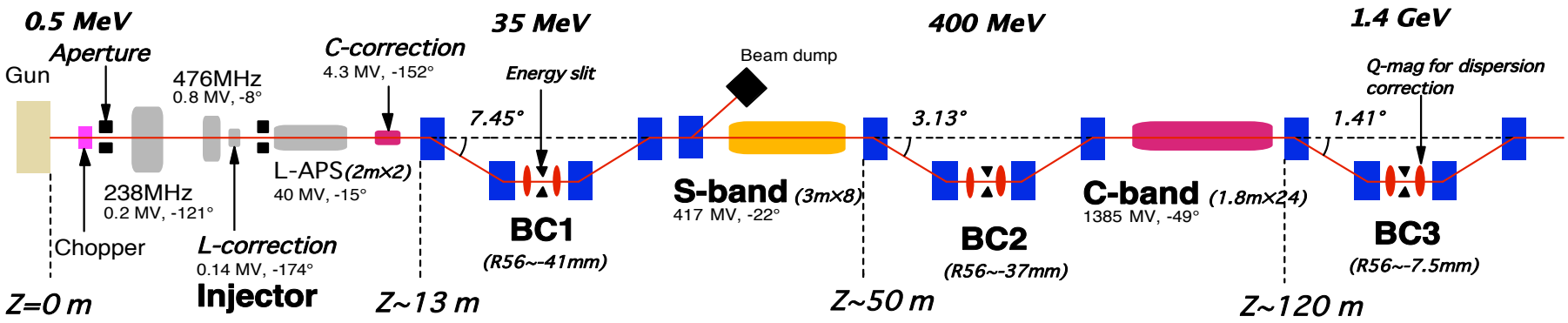
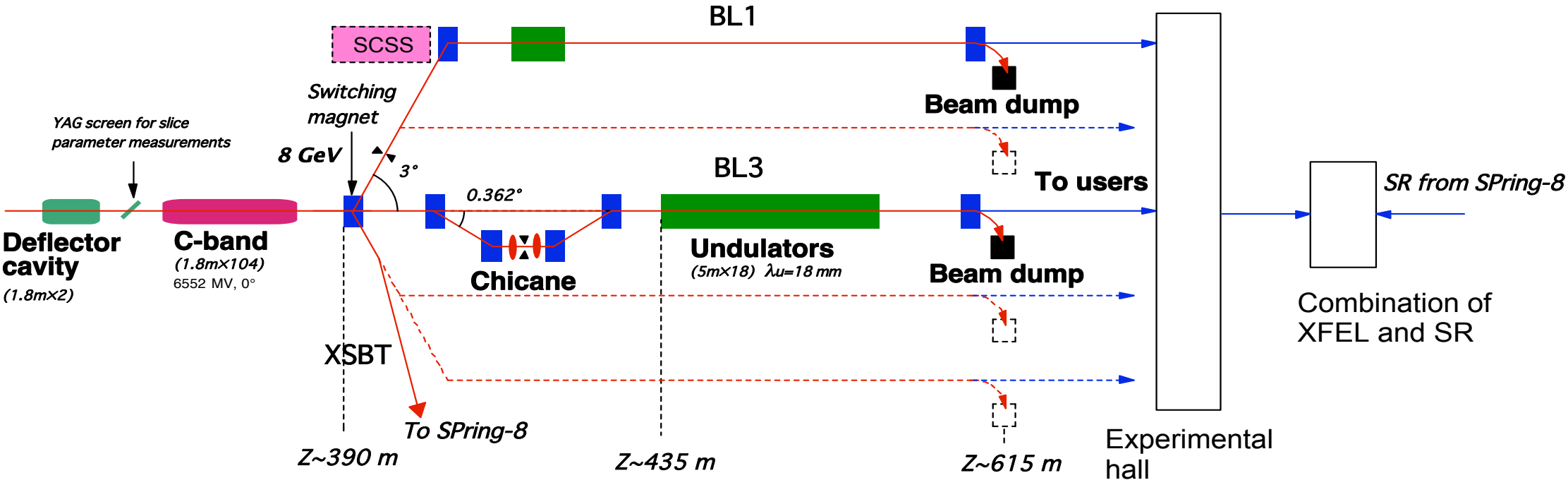
SACLA (SPring-8 Angstrom Compact LAser)

XFEL-SPring-8 experimental facility

SACLA (SPring-8 Angstrom Compact LAser)





Beam tuning and FEL outputs

- Start beam commissioning in February 2011, the first lasing in June.
  - Operation mainly at 7 GeV
  - 30 μJ@10 keV (7 GeV, K=1.8)

Summer shutdown

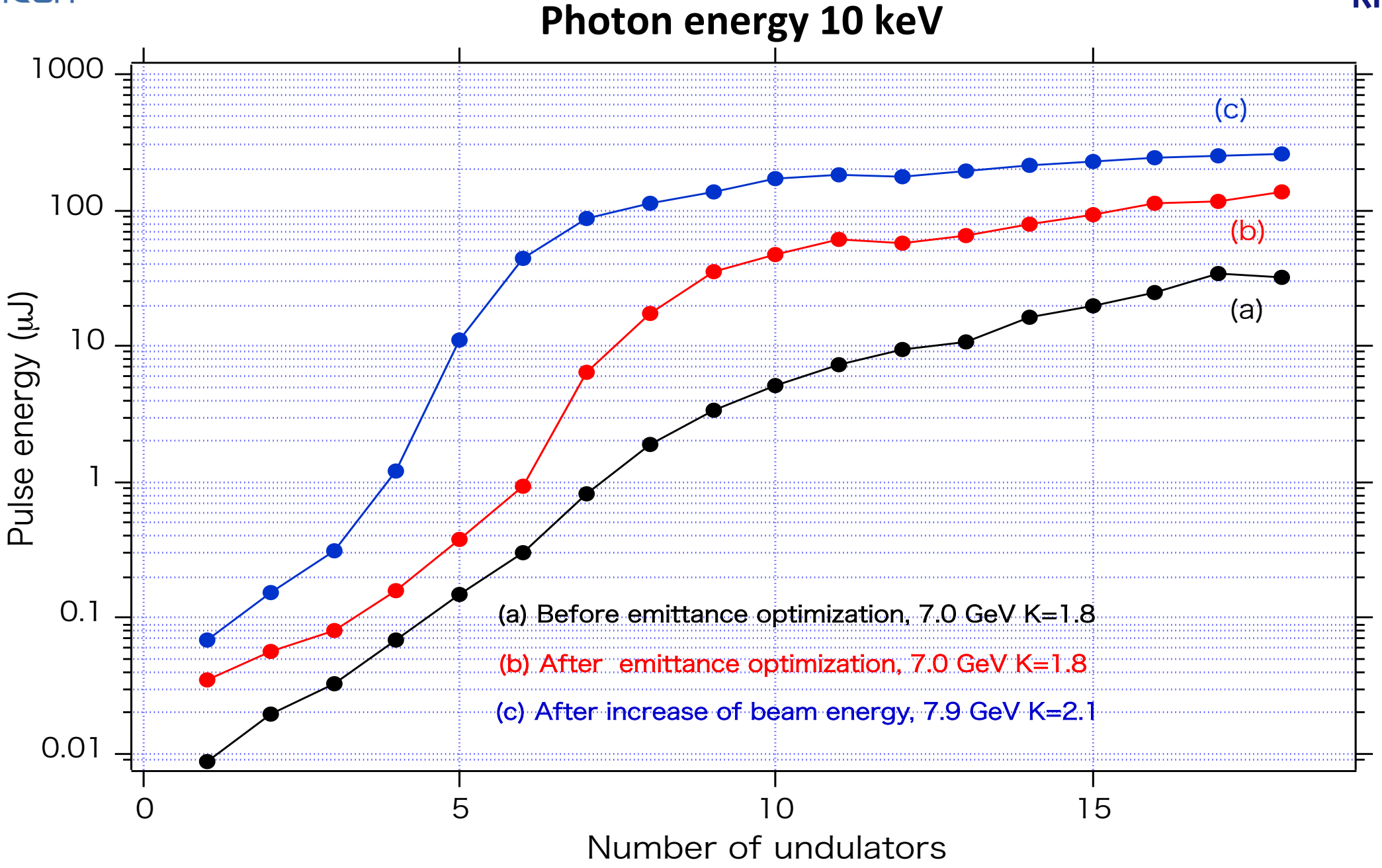
- Improvement of projected emittance
  - 120 μJ@10 keV (7 GeV, K=1.8)

Winter shutdown

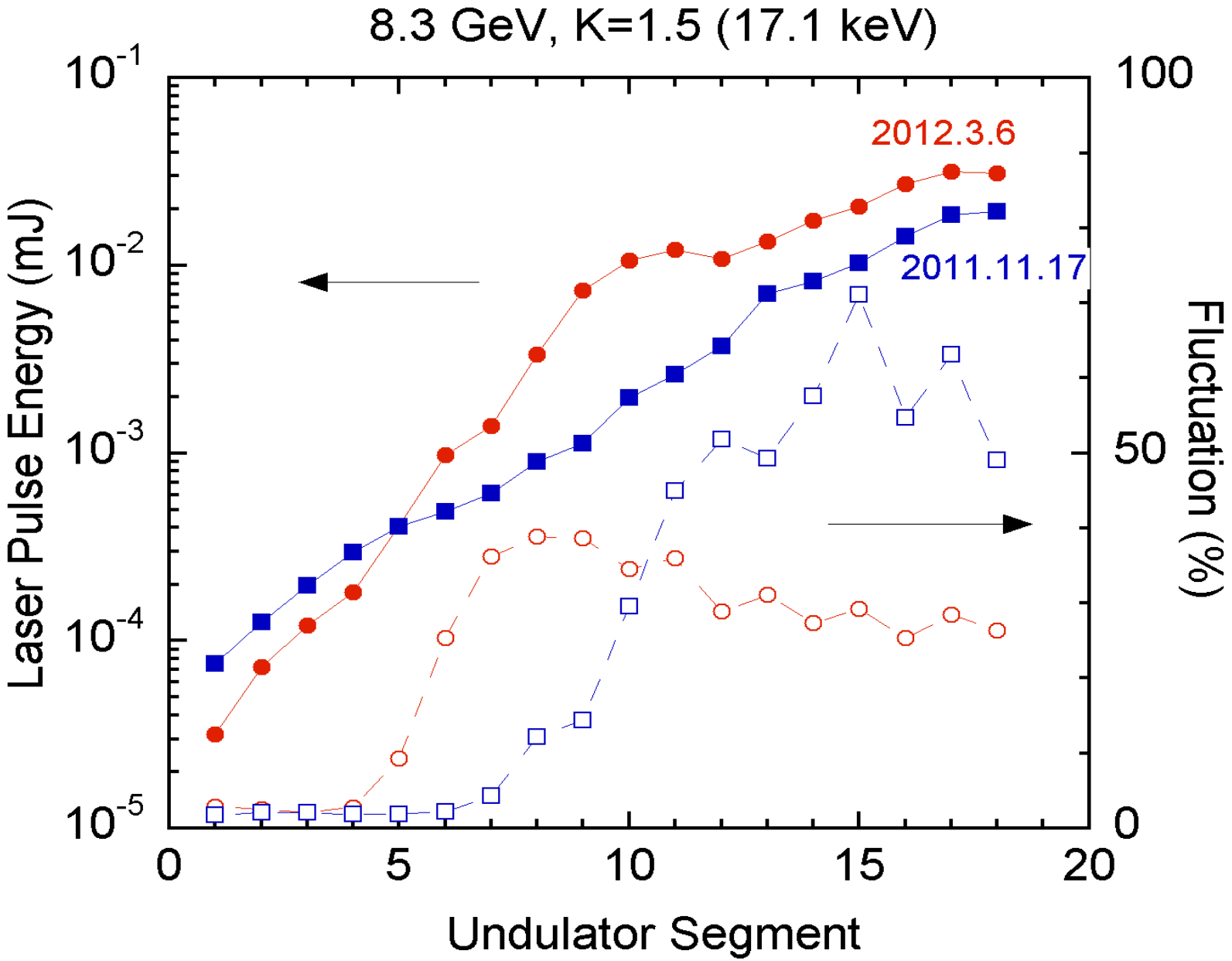
- Cathode replacement, smaller slice emittance, higher beam energy and K-value
  - Operation at 8 GeV, maximum energy 8.5 GeV
  - 250 μJ@10 keV (7.9 GeV, K=2.1)

- SACLA is open to public users in March 2012.

Gain curve before and after summer shutdown



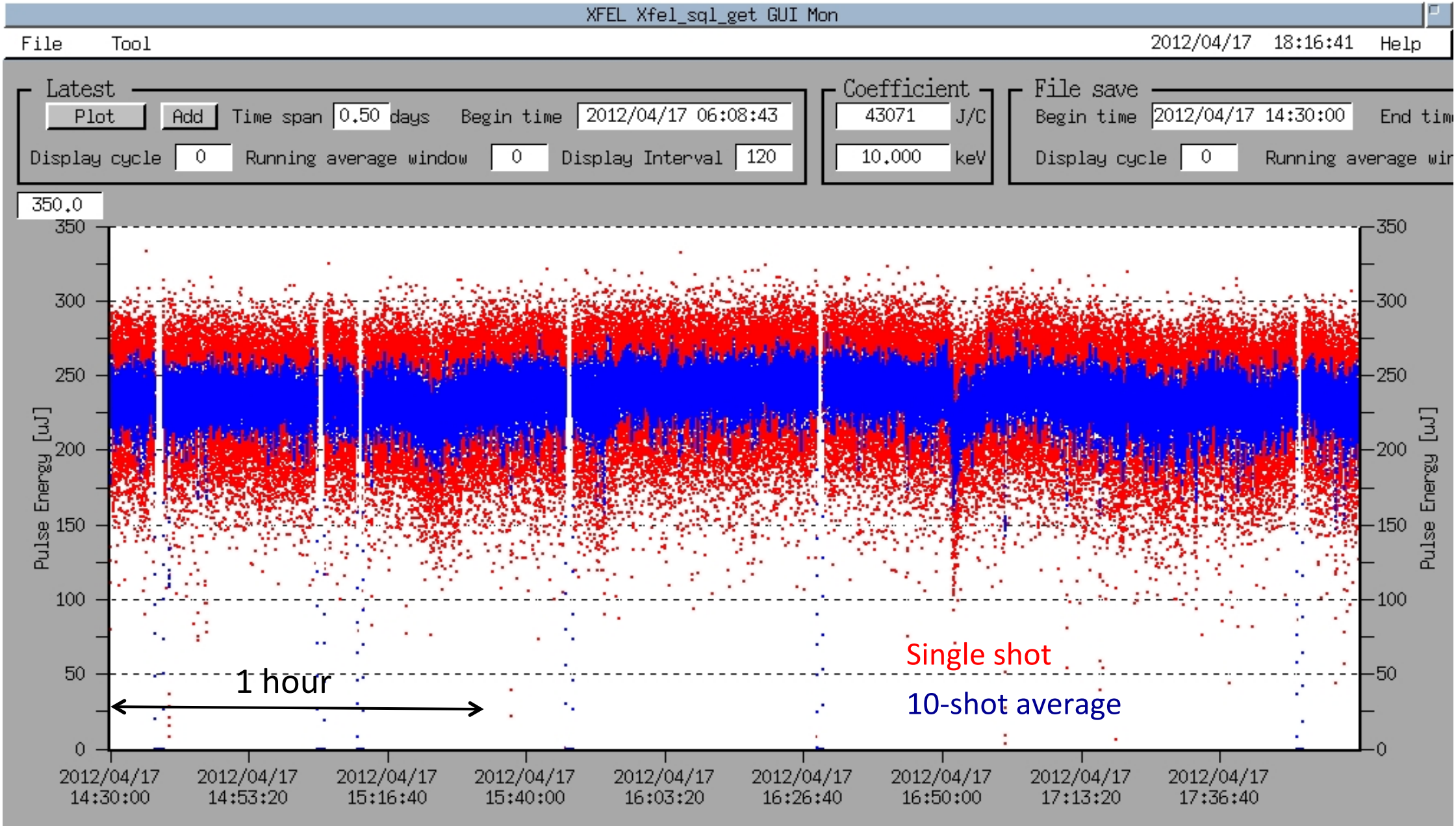
Gain curve before and after winter shutdown



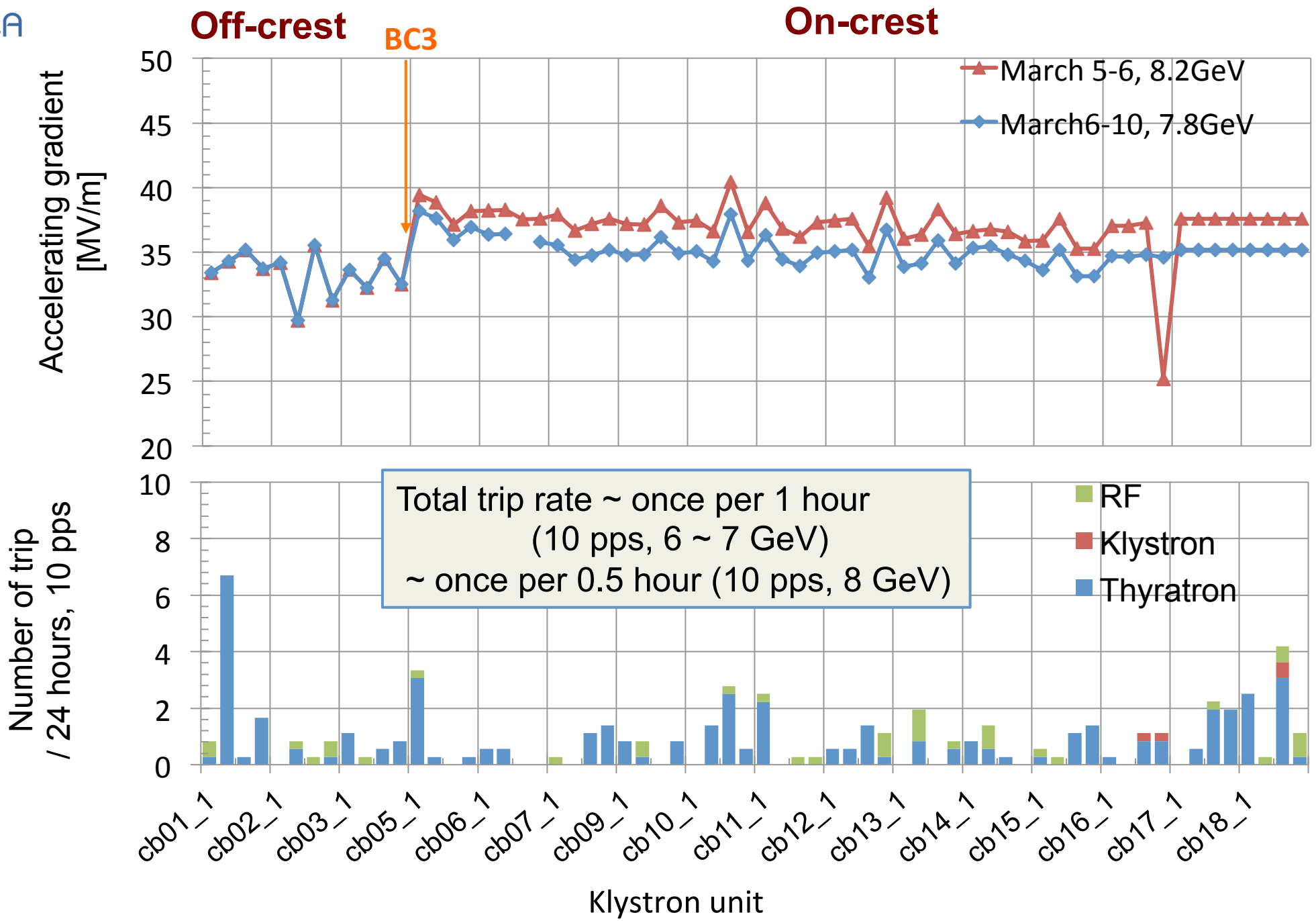
Current operation

- Stability of the accelerator
  - SASE fluctuation 10-20 %(σ), central wavelength 3×10^{-4}(σ)
  - Orbit fluctuations due to injector will be improved.
- Photon beam availability 90-95%, 7000 hours operation planned in 2012
  - Time loss is mainly due to RF faults (discharges and thyratron misfires).
  - Interlock logic changed for quick recovery from thyratron misfires.
  - Pulse-tag recorded for thyratron misfires for data analysis of user experiments.
- Stable operation of C-band accelerators at 35-40 MV/m

Stability of FEL pulse energy
(10 keV, 7.9 GeV, K=2.1)



Acceleration gradient and RF trip of C-band accelerators

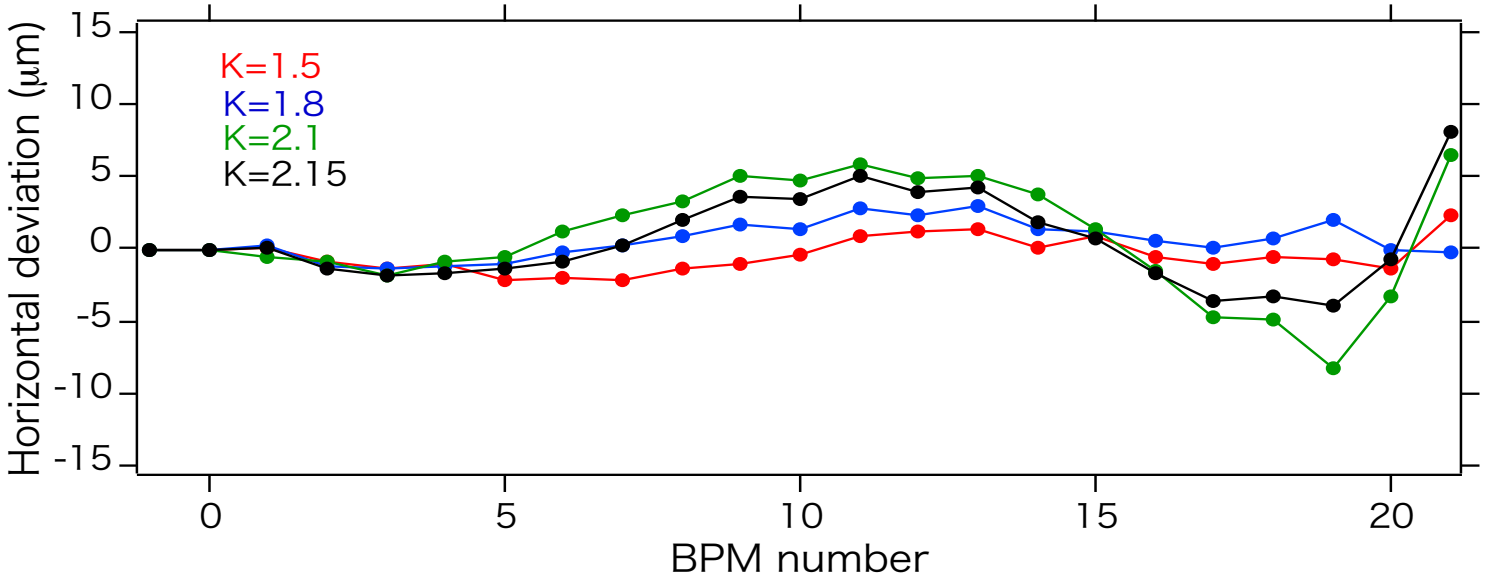


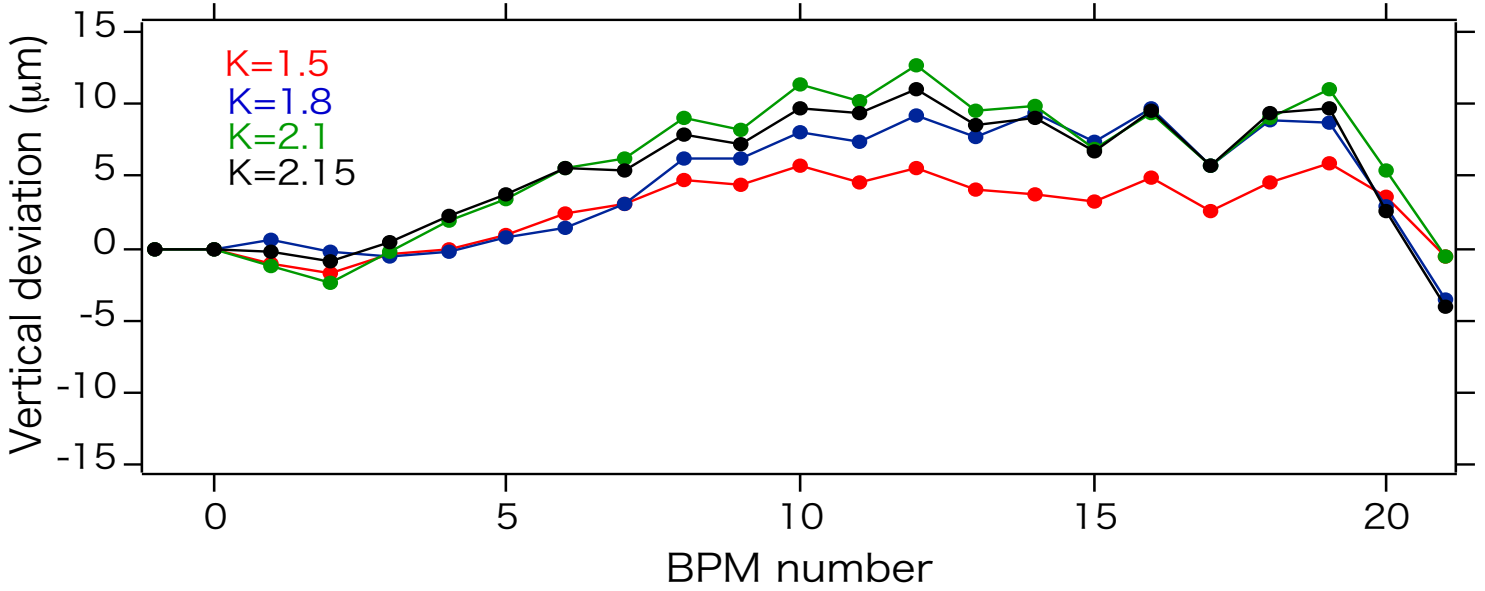
Current operation

- Photon energy change by undulator gap
  - Users can freely adjust photon energy by simply setting K-value, then undulator taper and phase shifters are automatically optimized.
- Photon energy range
  - User operation in 5-15 keV.
  - Photon energy adjustment by undulator gap within several seconds.
  - Photon energy change by beam energy within 10-15 mins by operators.

THPD38, K. Togawa et al., “Laser wavelength tuning by variable-gap undulators in SACLA”.

Accuracy of current ID feed-forward table

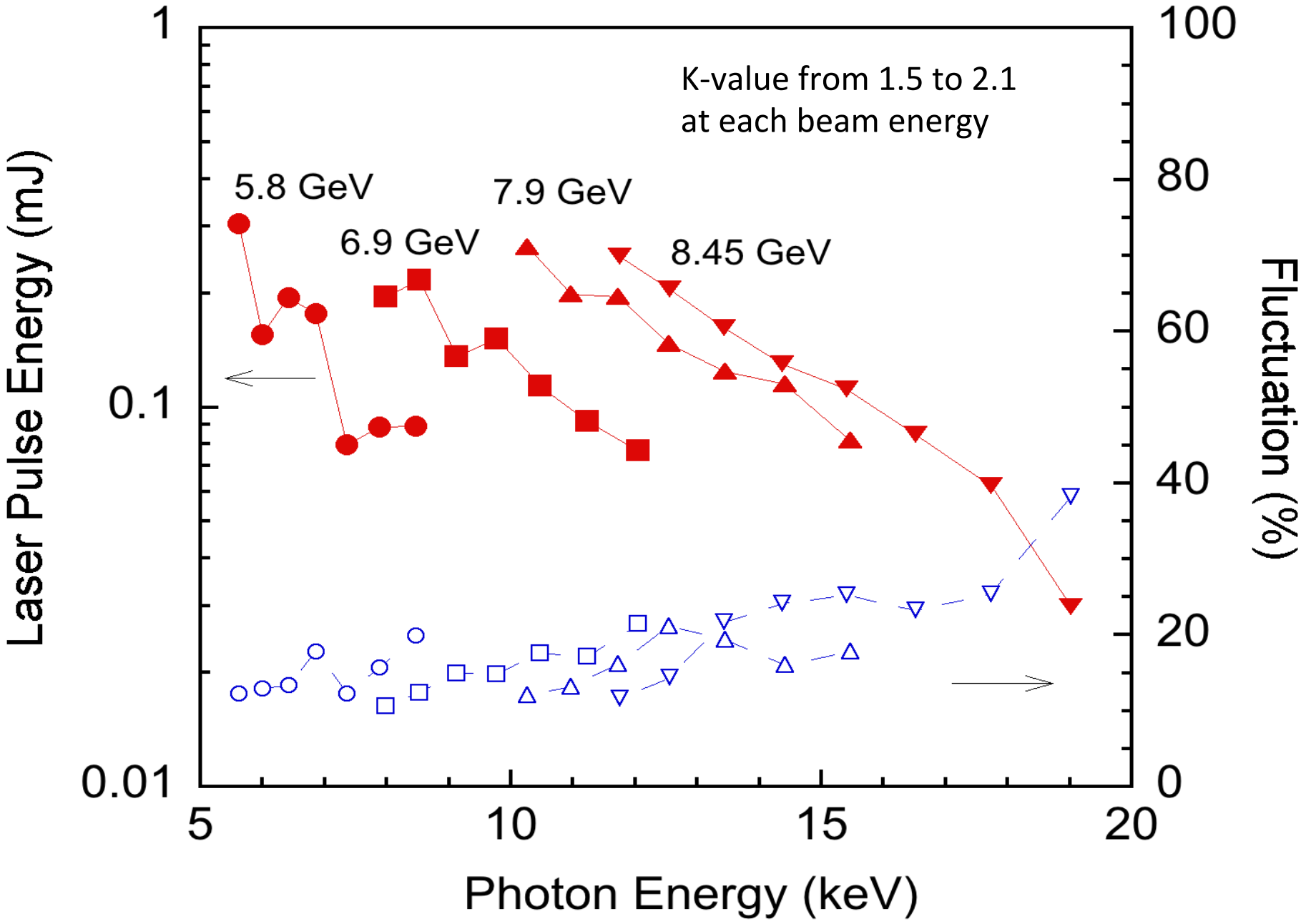




Orbit deviation with respect to 10 mm gap reference.

K=2.15 roughly corresponds to 3.5 mm gap.

Current photon energy range of SACLA



Current operation

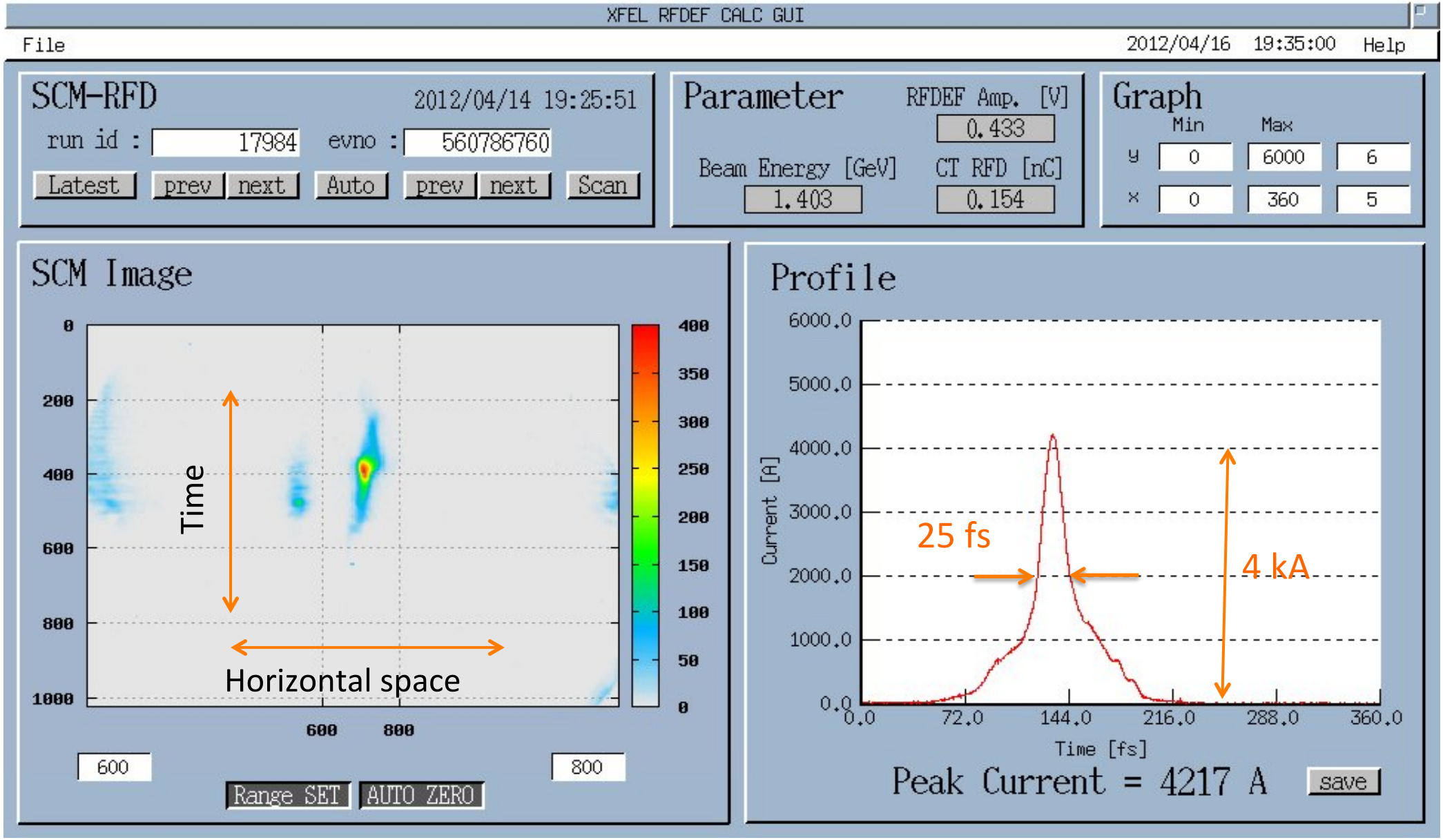
- Electron bunch length about 25 fs (FWHM) with 4 kA
  - Photon pulse length about 10-15 fs from the measurement of single-shot spectral spike widths.
  - Short photon pulse down to 5 fs is confirmed by increasing bunch compression, but lower pulse energy.
- Photon beam divergence
  - Important to match BL optics.
  - Electron beam orbit fluctuation is still large.
- Electron beam orbit alignment at undulator section
  - The floor of the undulator hall still moving by 50 μm in two months.
  - Beam orbit alignment using synchrotron radiation axes, every two weeks.
  - Adjustment of gun emission, every one month.

THOCI01, T. Tanaka, "X-ray based undulator commissioning in SACLA".

Bunch profile measured by RF-deflector

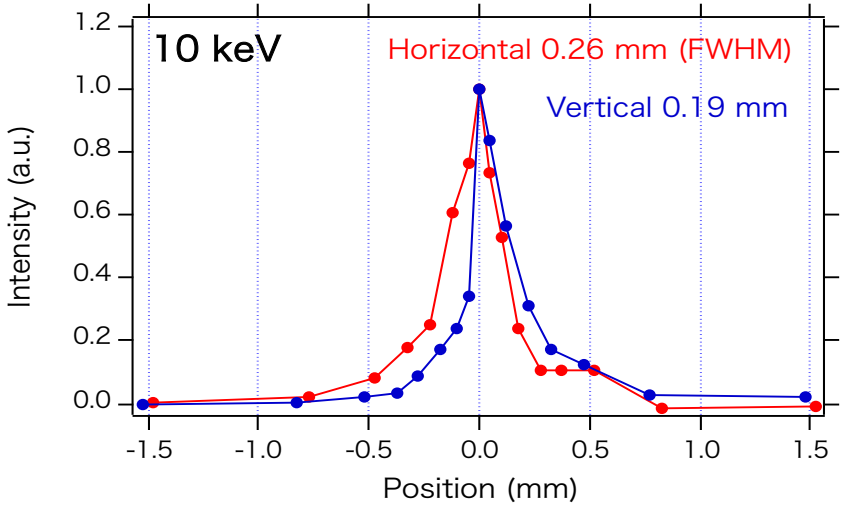
Compression factor more than 3000,
VB x20, BC1 x5, BC2 x10 and BC3 x3.

Bunch charge 150 pC

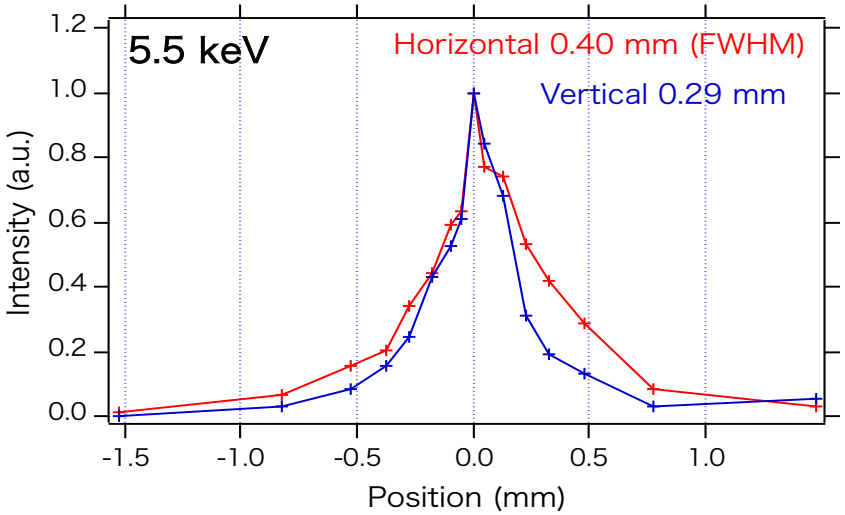


Photon beam divergence

- Averaged photon beam size at 75 m downstream of the last undulator.
  (FE slit scan, each point averaged for 100 shots)



$$\sigma_{r'x} \approx 1.5\mu rad$$
$$\sigma_{r'y} \approx 1.1\mu rad$$



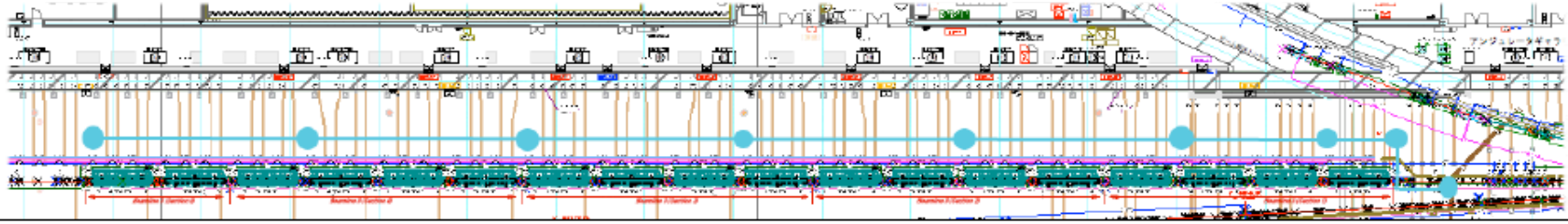
$$\sigma_{r'x} \approx 2.3\mu rad$$
$$\sigma_{r'y} \approx 1.6\mu rad$$

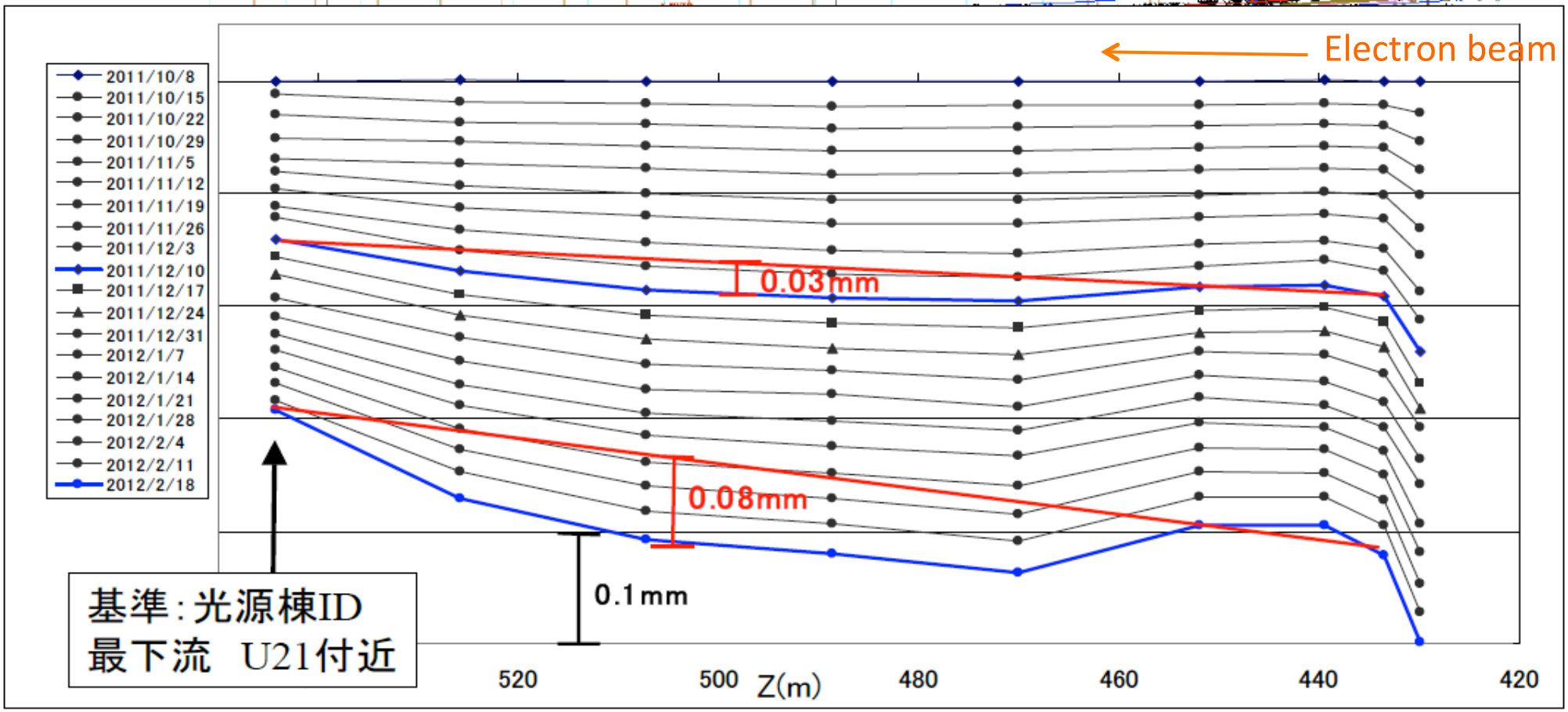
- Roughly two times larger than intrinsic SASE divergence.
- Necessary to stabilize electron beam orbit.

TUPD37, T. Hasegawa et al., "Upgrade of a precise temperature regulation system for the injector at SACLA".
TUPD38, H. Maesaka et al., "Stability improvements of SACLA".

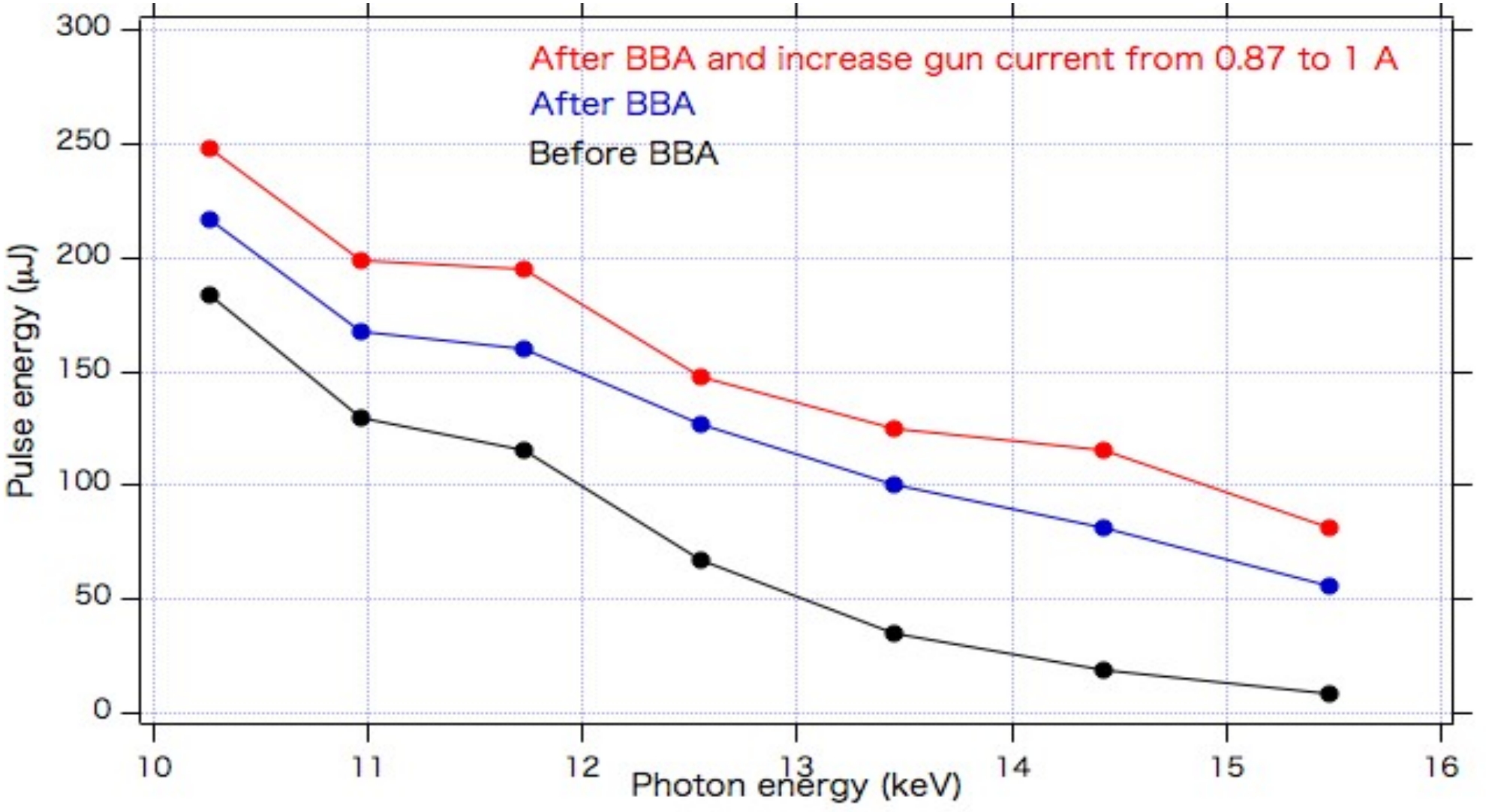
BBA using SR axes of 18 undulators

Change of floor level at undulator hall in 2 months





FEL output after BBA



Beam energy at 7.8 GeV, K-value scanned from 2.1 to 1.5.

Future developments

- Increase FEL output power and photon energy range
  - Installation of additional C-band to reach 9 GeV.
  - Undulator minimum gap reduced from 3.5 mm (K~2.15) to 3 mm (K~2.5).
- Increase repetition rate to from 10 Hz to 20-30 Hz, and 60 Hz.
- Self-seeded FEL in SACLA BL3
  - Move 9th undulator to 19th, and installation of a chicane in this summer.
  - Installation of a single crystal in 2013.
- Reinstallation of SCSS test accelerator to SACLA BL1 as a soft x-ray FEL source.
  - By adding C-band to reach 1.4 GeV.
  - Independent operation from SACLA.
- Development of fast beam distribution system to multi-BLs at 60 Hz.