

Progress in Photocathode DC Gun at the compact ERL



JAEA

N. Nishimori, R. Nagai, S. Matsuba, R. Hajima



KEK

M. Yamamoto, T. Miyajima, Y. Honda



Hiroshima U.

H. Iijima, M. Kuriki



Nagoya U.

M. Kuwahara



FEL 2013 | Manhattan, USA

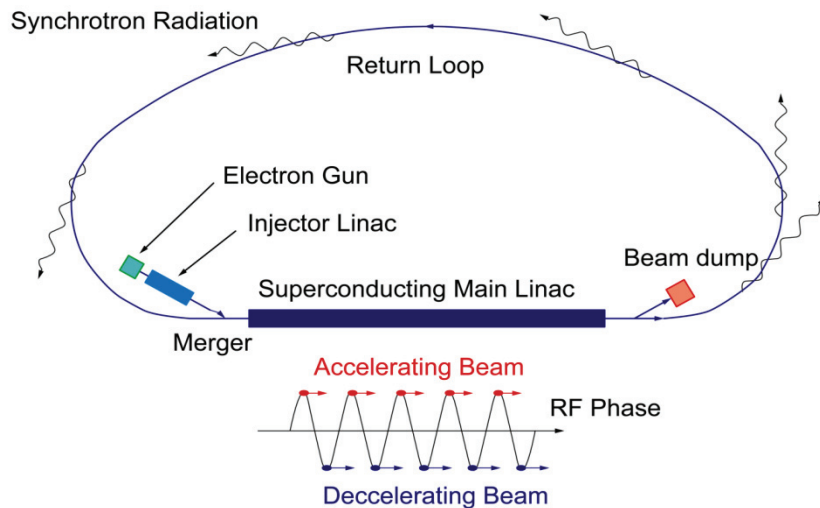
35th International Free-Electron Laser Conference
August 26-30, 2013

Outline

- Introduction
- Discharge problems in DC gun
- 500keV beam generation
- Operation at the compact ERL
- Summary

The next generation ERL light sources

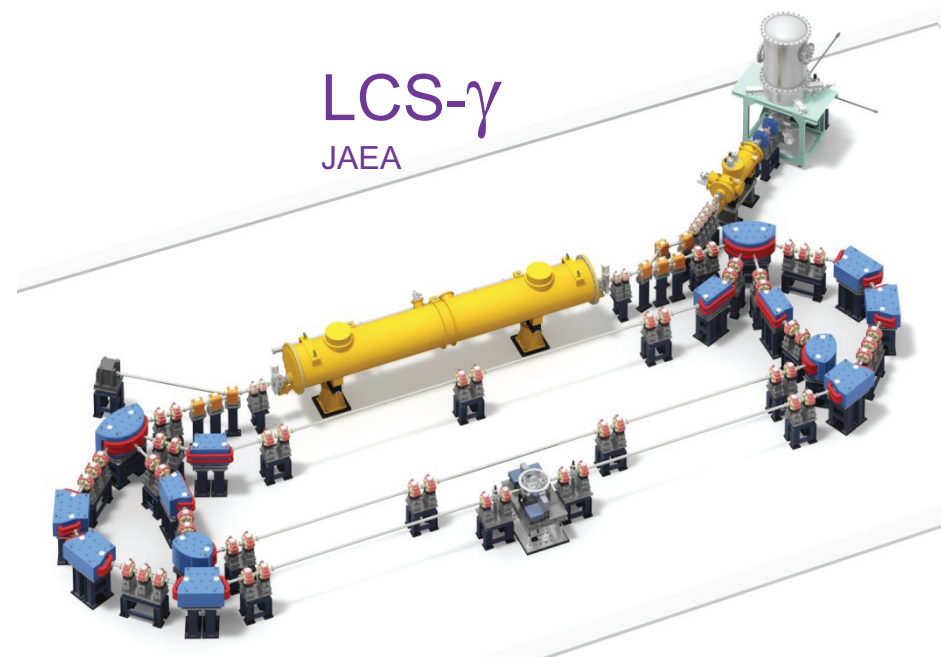
- Diffraction limited X-ray
- Short pulse X-ray (sub-pico seconds)
- XFELO ($\Delta\omega/\omega = 10^{-6}$ - 10^{-8} XFEL: 10^{-3})



- Laser Compton Scattering γ -ray source (flux of $> 10^6$ of conventional sources)

Nondestructive assay of spent nuclear fuels or melt nuclear fuels

LCS- γ
JAEA



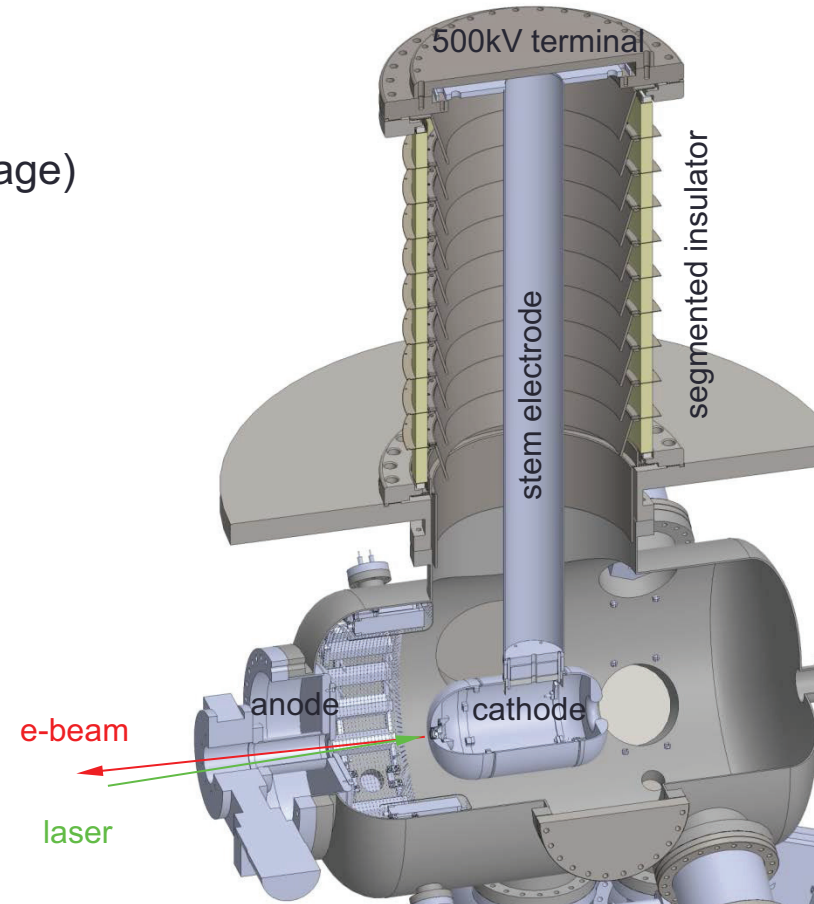
Requirements for the gun parameters for the ERL light sources

Generate low emittance and high current beam

- Suppress emittance degradation downstream (high voltage)
- Suppress emittance degradation on cathode (high field)
- Generate high intensity X, g-ray (high current)

Gun parameters	Requirements
High voltage	500kV
Field on photocathode	$>5\text{MV/m}$
Beam current	100mA
Normalized emittance	$0.1\text{-}1\ \mu\text{mrad}$

Operational voltage of photo-gun has been limited to 350kV since the first proposal of the 500kV photo-gun in 1991.
The high voltage issue is our first priority.

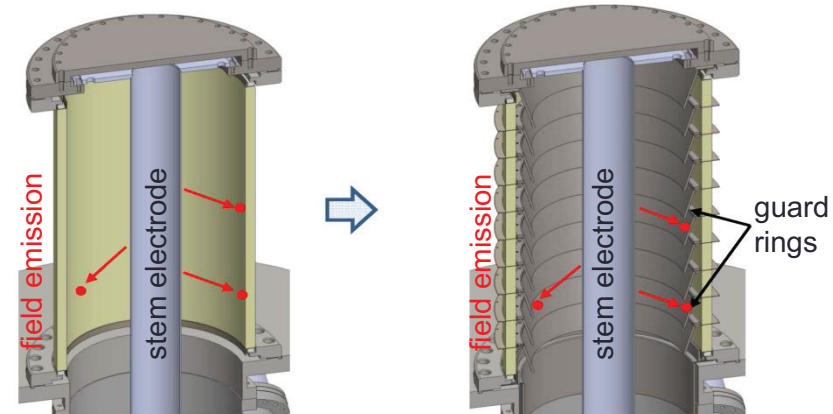


Discharge problems in DC gun

- 1: Discharge on insulator ceramics caused by field emission from a central stem electrode

→ Employ segmented ceramics

R. Nagai, et al., Rev. Sci. Instrum. 81, 033304 (2010)

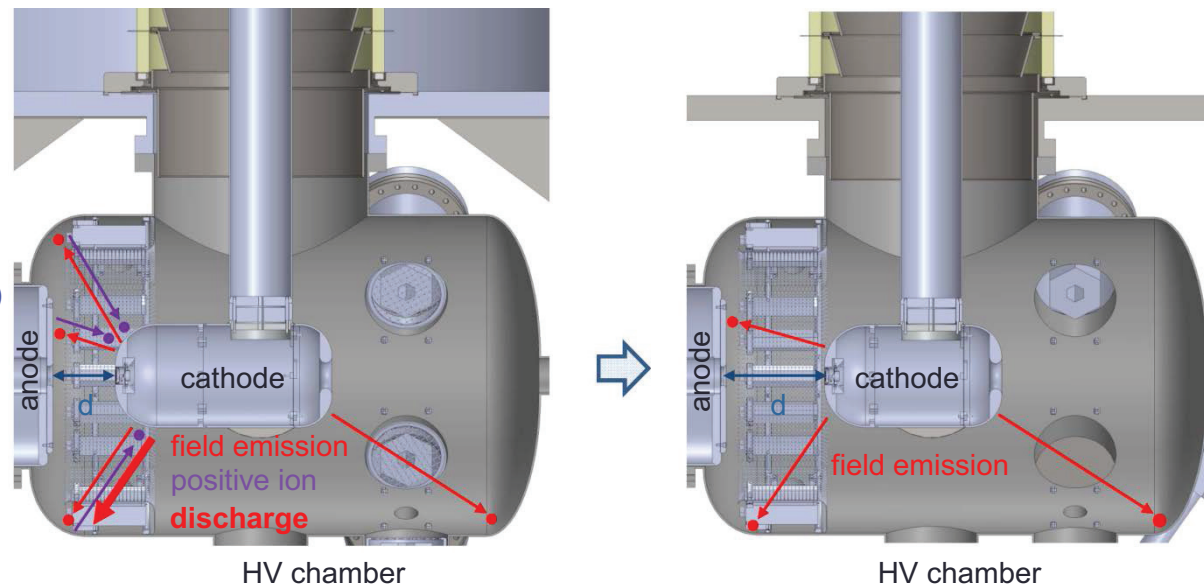


- 2: Discharge between the cathode and HV chamber (anode) which propels microparticles on the HV chamber surface to the cathode. The microparticles serve as a field emission site.

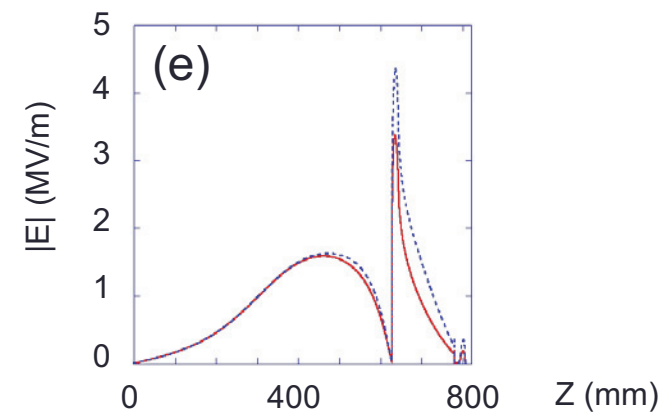
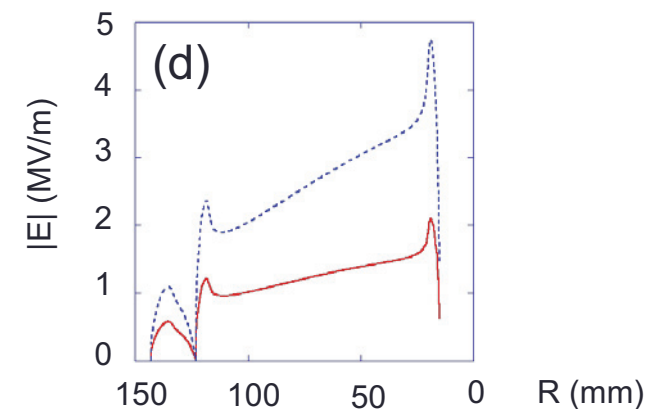
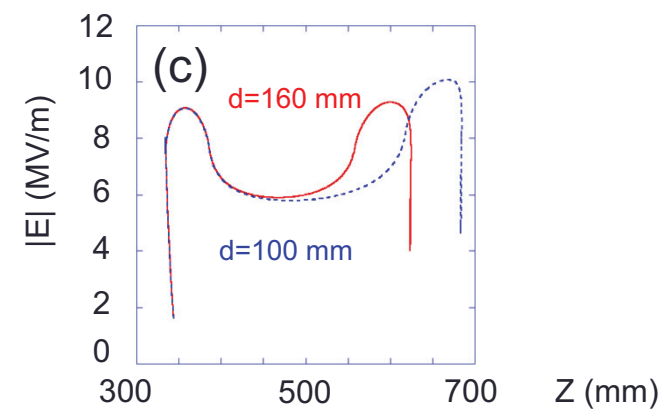
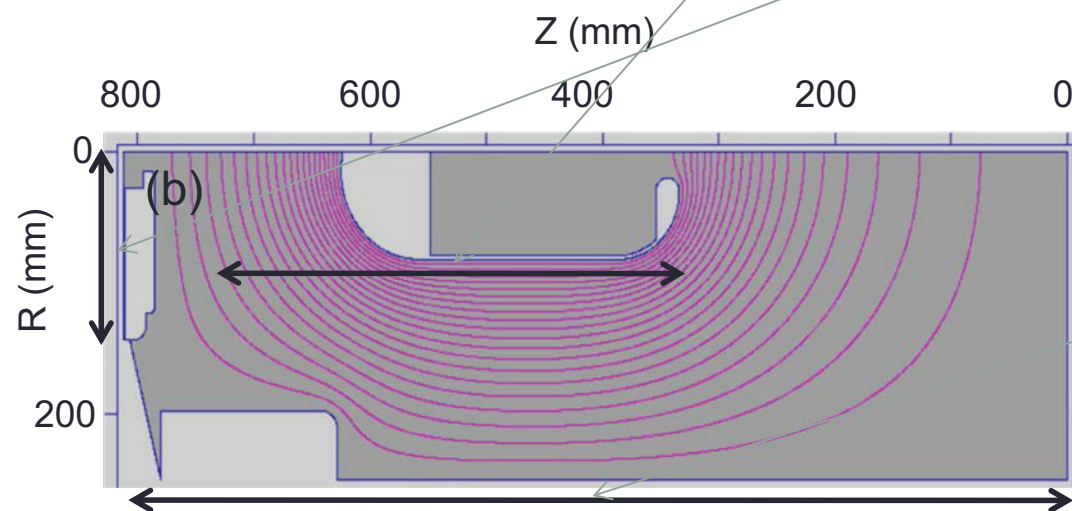
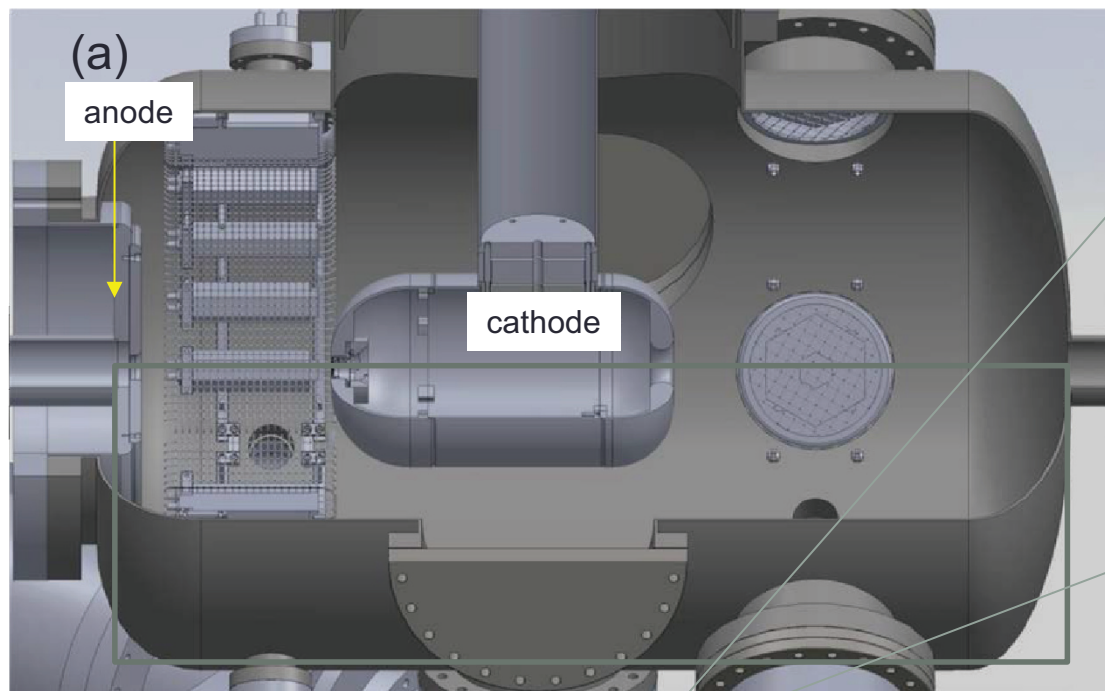
→ Decrease anode field by increasing gap

Microdischarges on the anode are suppressed.

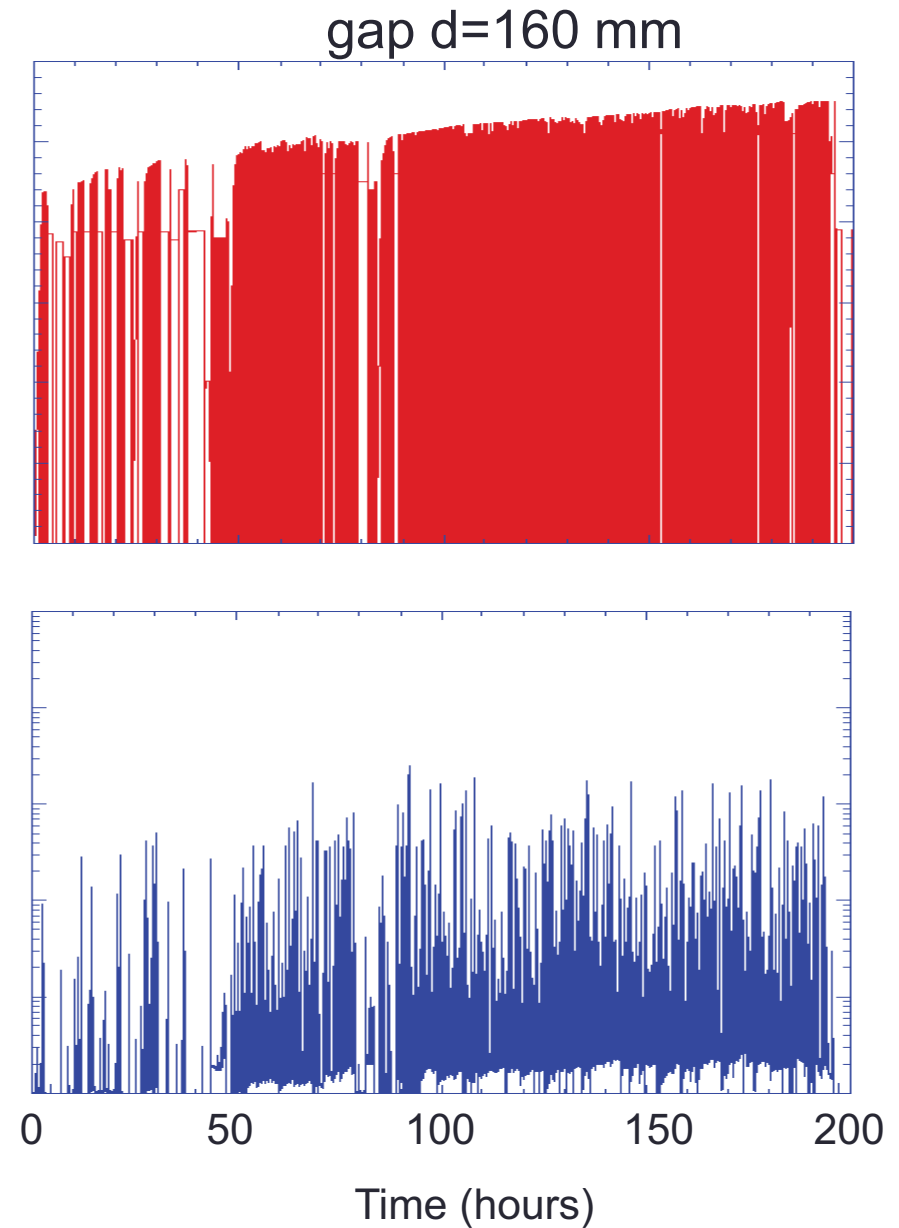
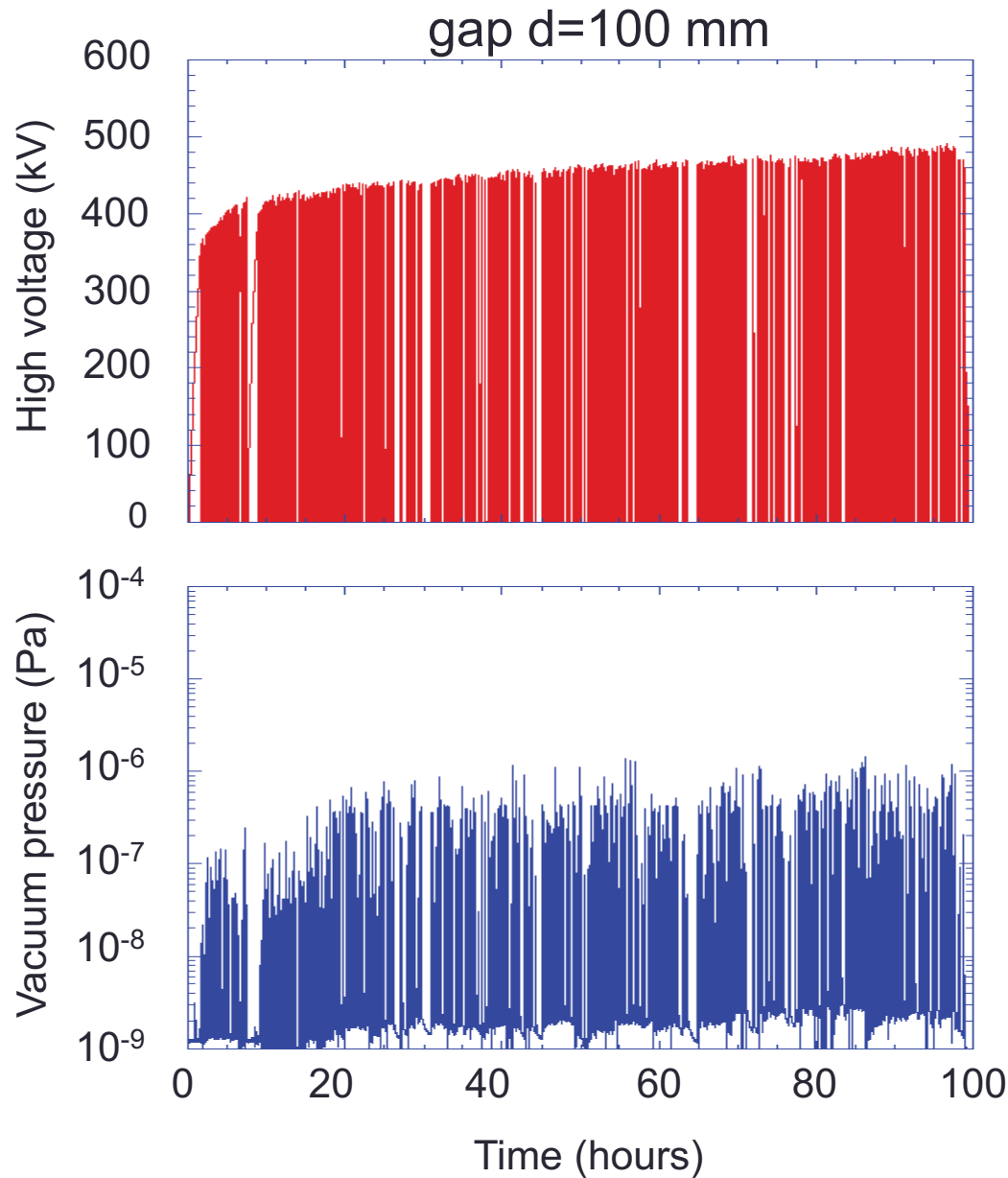
N. Nishimori, et al., Appl. Phys. Lett. 102, 234103 (2013)



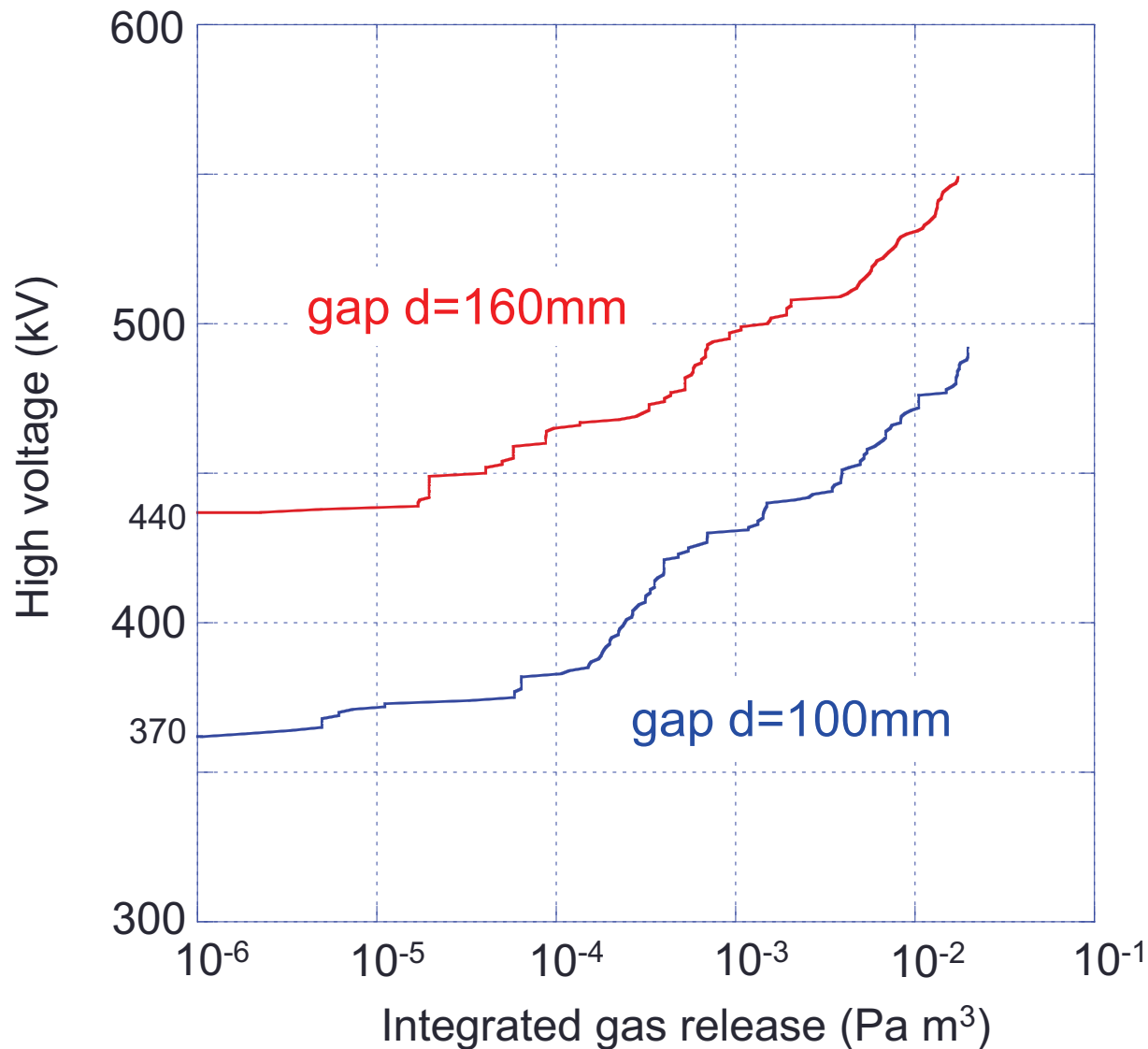
Surface electric fields for 160 mm gap



HV conditioning



High voltage as a function of gas desorption



Discharge initiation voltage V_I can be defined as

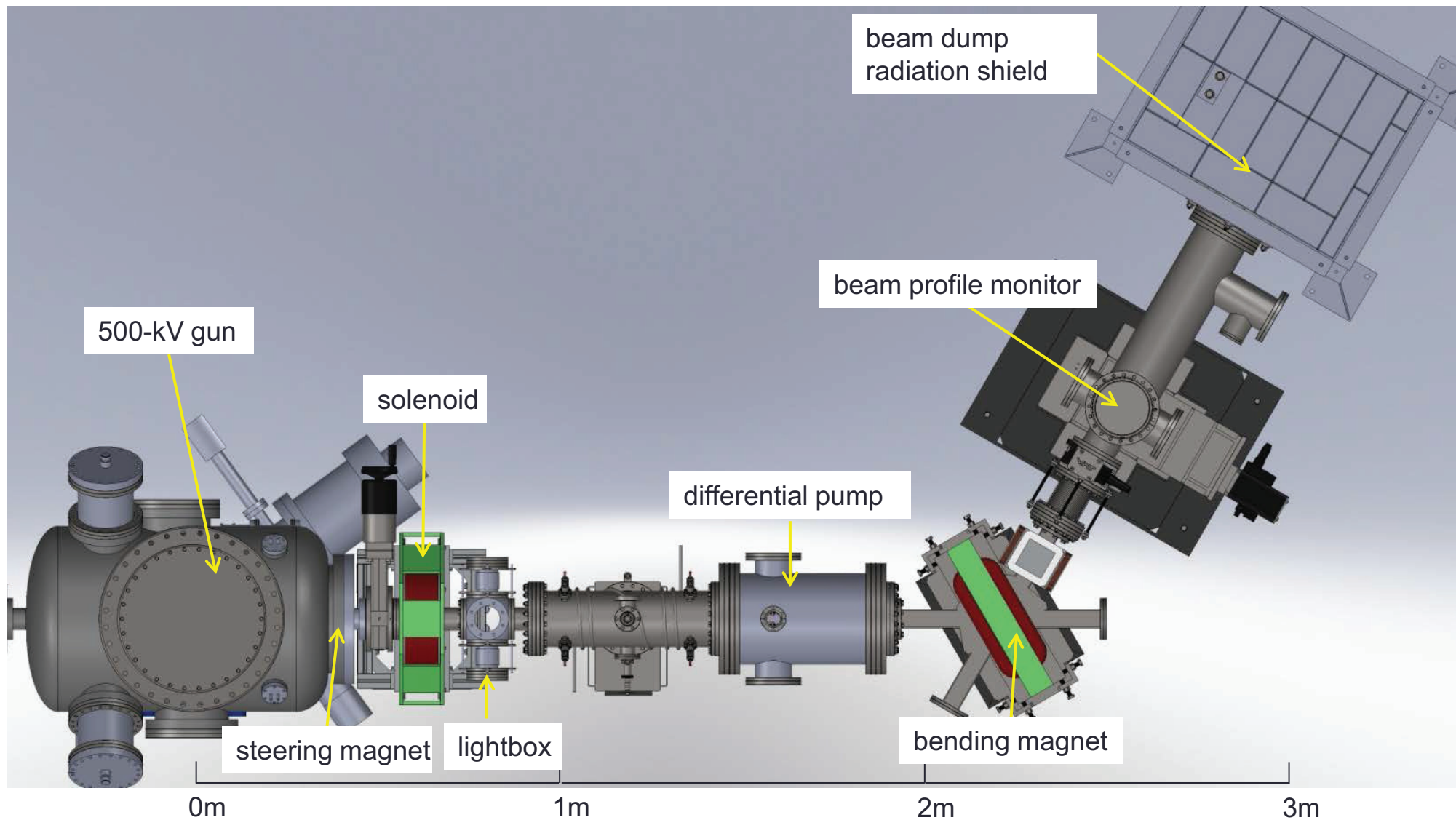
$$V_I = 67d^{0.37},$$

in units of V_I in kV and d in mm.
Breakdown voltage V_B can be obtained under assumptions that $V_B \propto d^{0.37}$ and that $V_B=500\text{kV}$ for $d=100\text{mm}$.

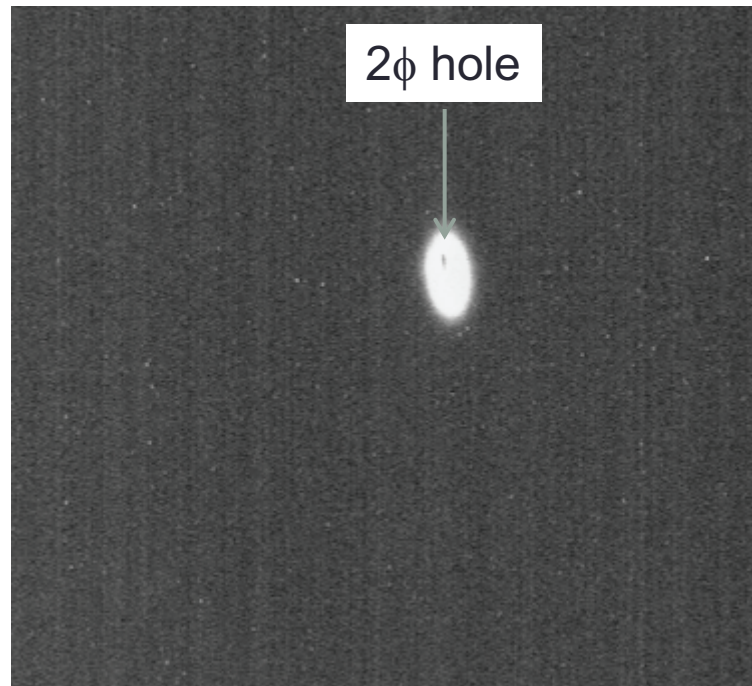
$$V_B = 91d^{0.37}.$$

This suggests $V_B=600\text{ kV}$ for $d=160\text{mm}$.

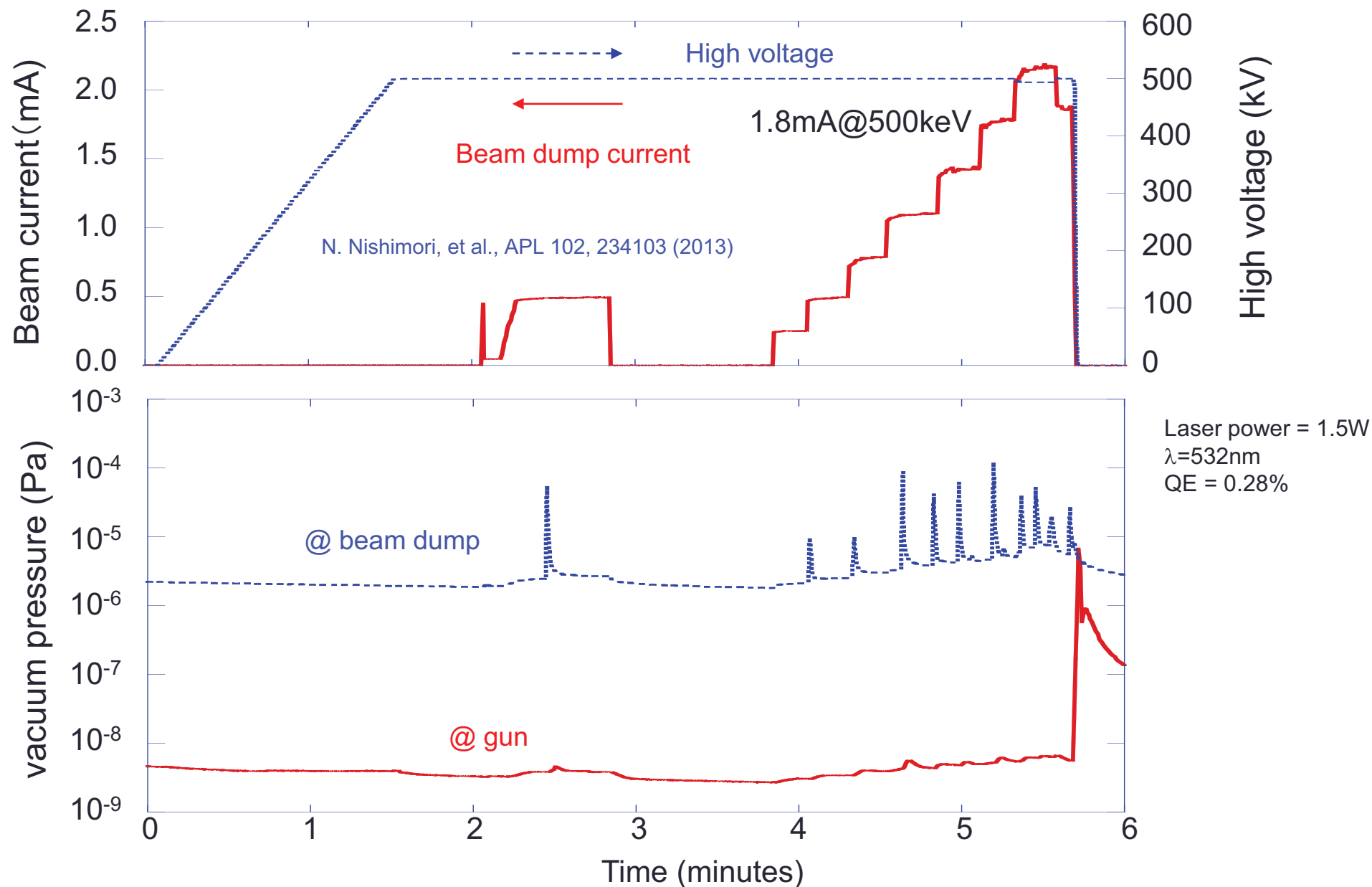
Beam line for the DC gun at JAEA



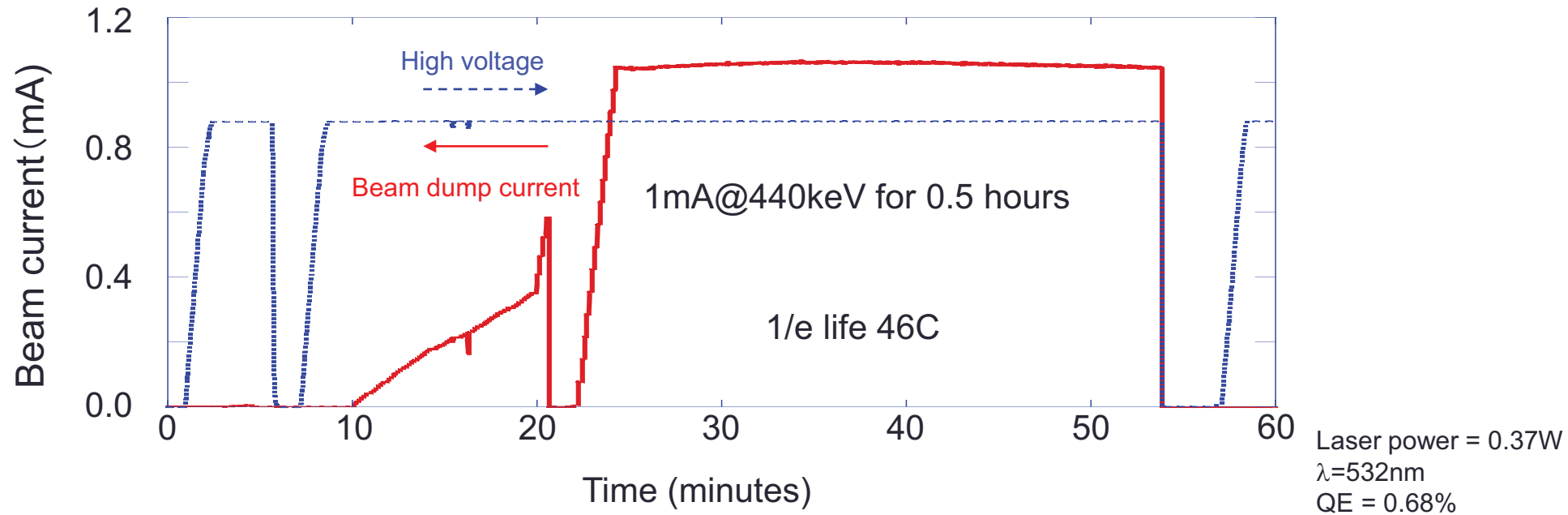
Beam profile



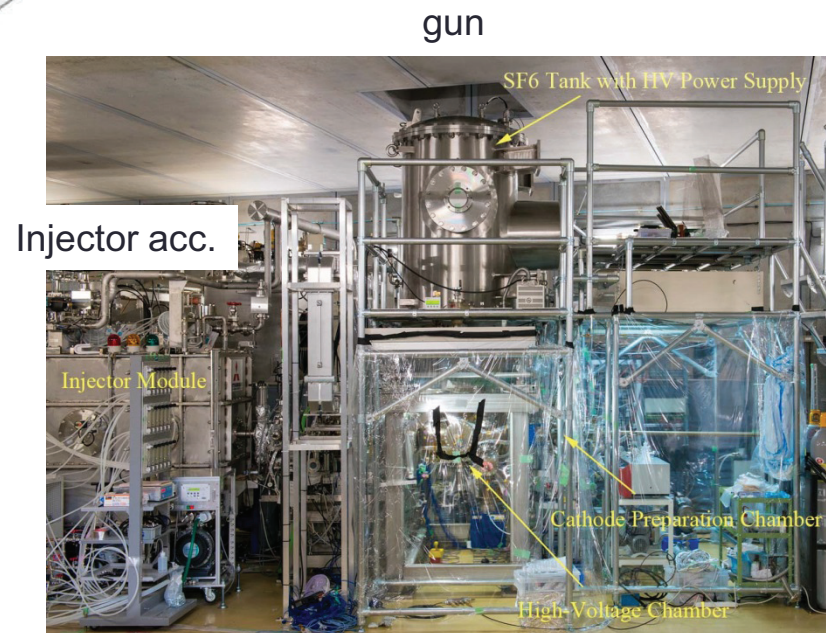
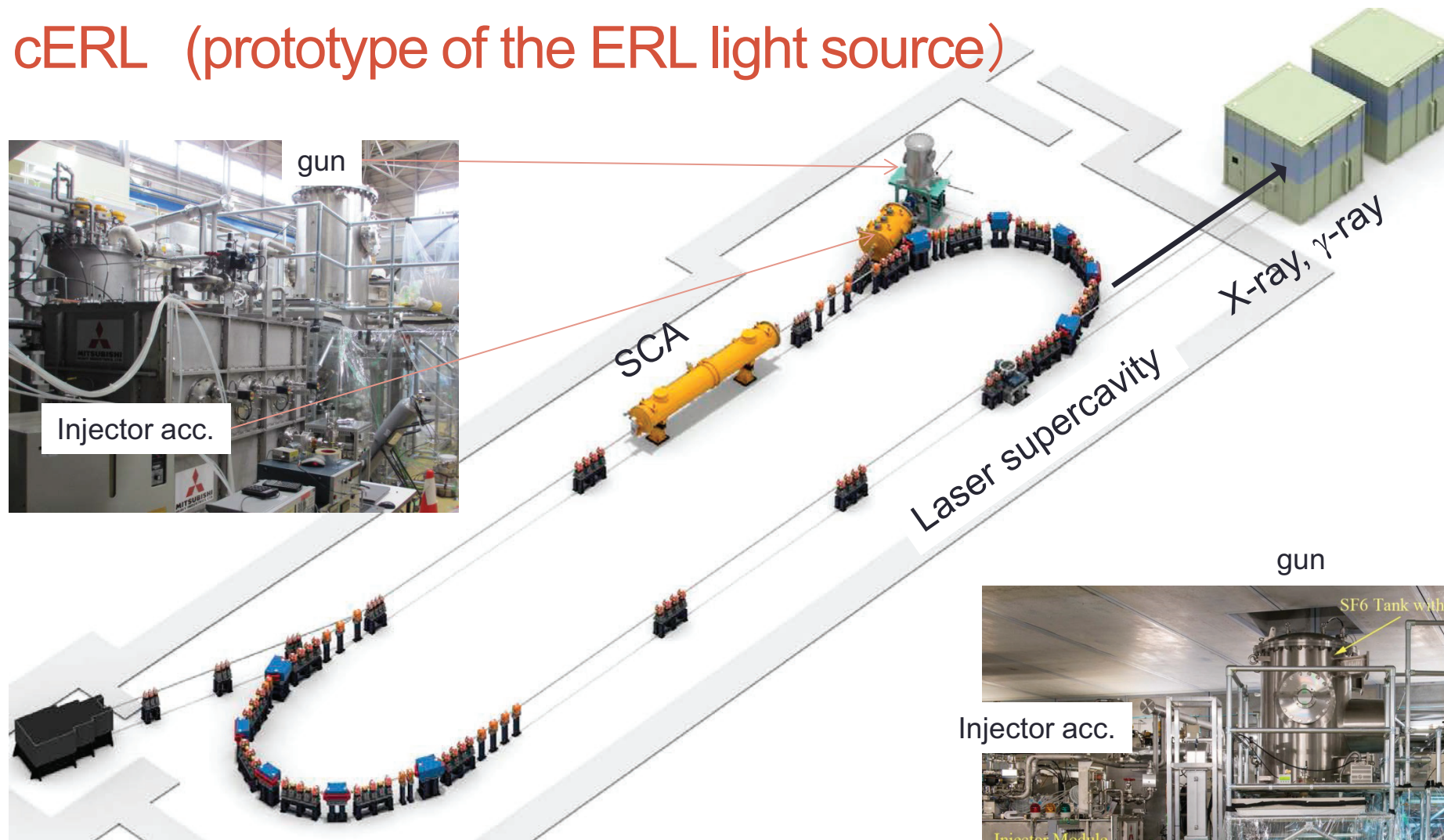
500keV beam generation



440keV beam generation for 0.5 hours

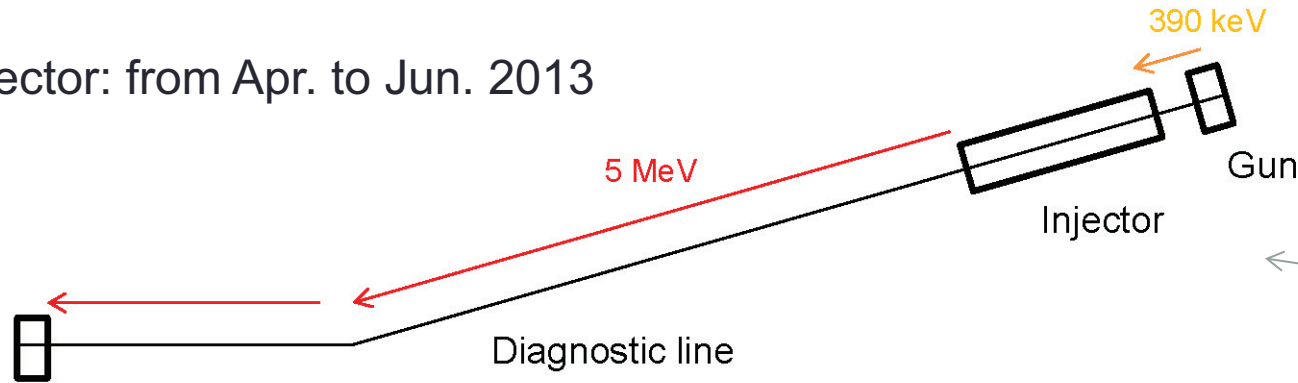


cERL (prototype of the ERL light source)

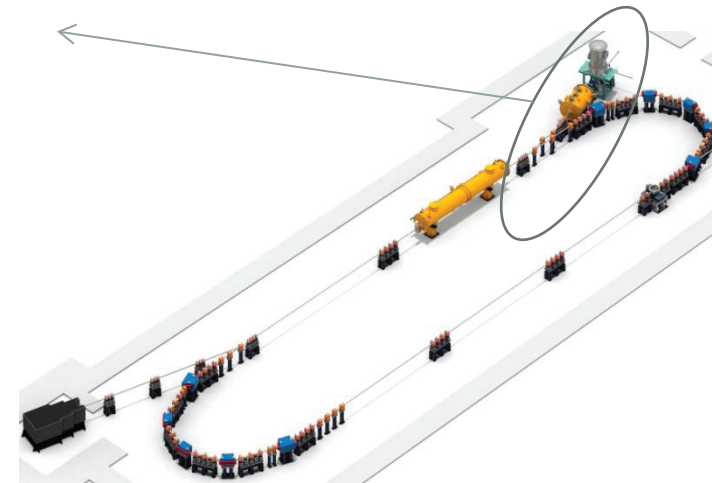
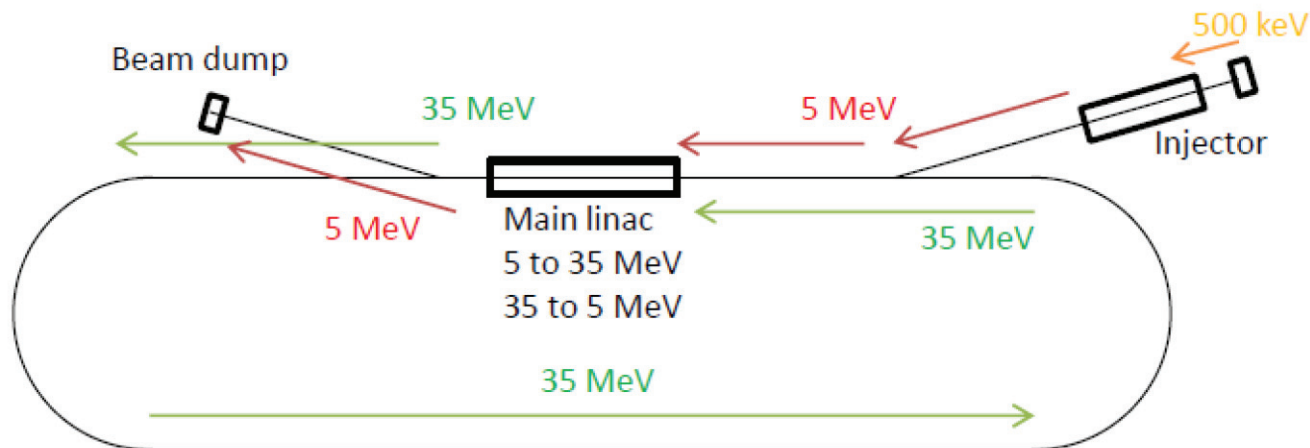


Commissioning of cERL

Injector: from Apr. to Jun. 2013



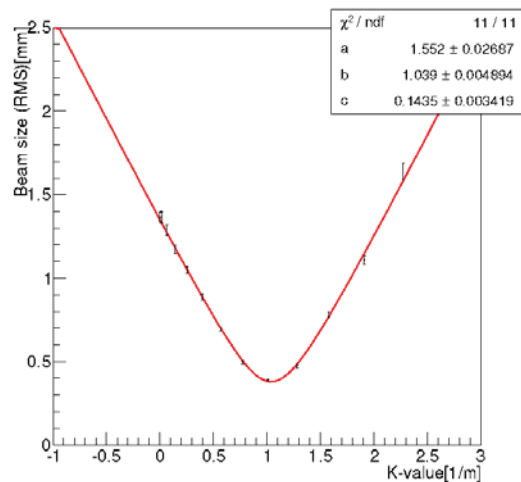
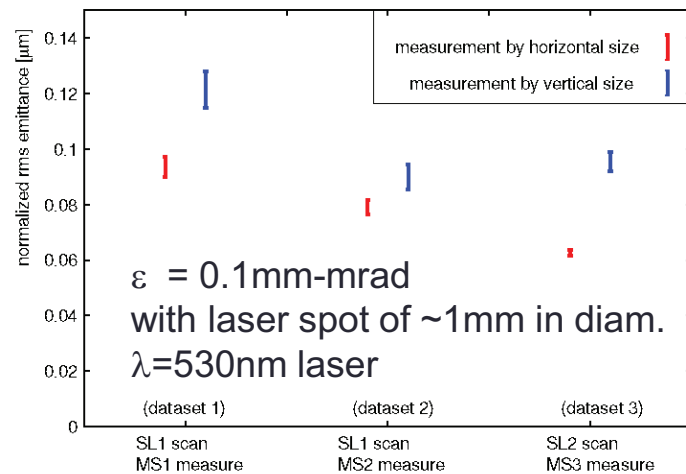
Loop: from Dec. 2013



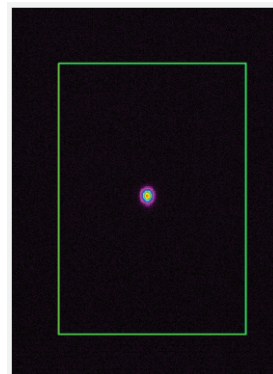
Preliminary emittance measurements

Y. Honda, T. Miyajima, et al., "Transverse Beam Performance Measurement at compact-ERL Injector", 10th Meeting of Particle Accelerator Society of Japan, SUP011, (2013).

Thermal emittance at the gun at E=390keV

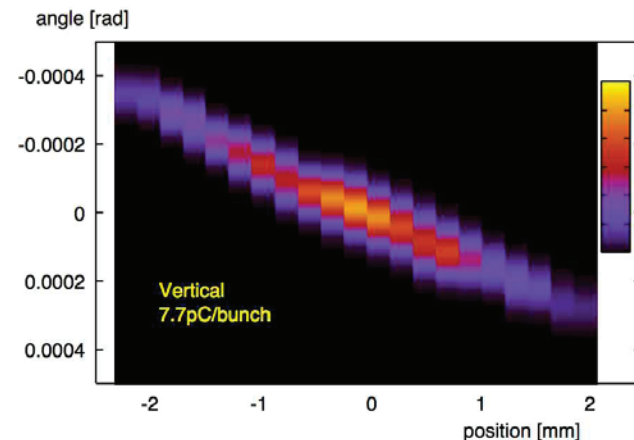
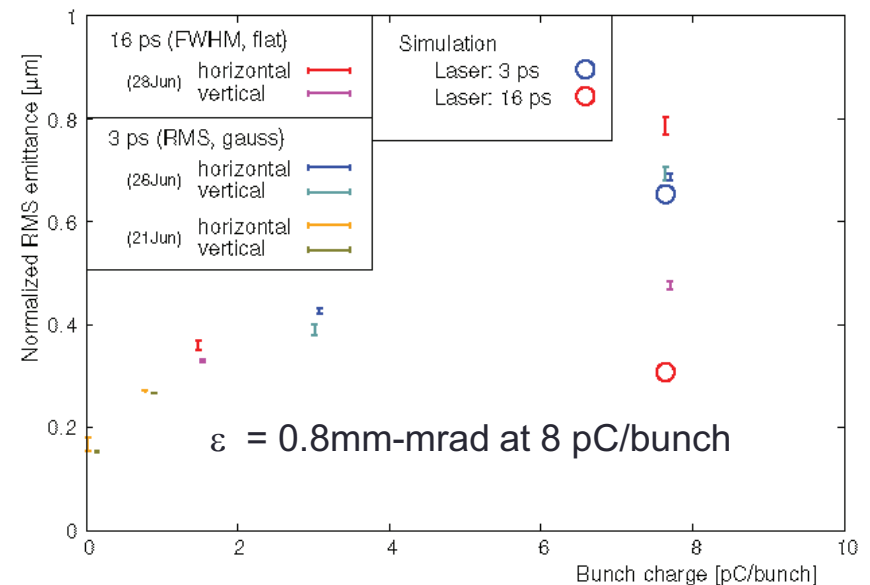


Solenoid scan



Beam profile on YAG screen

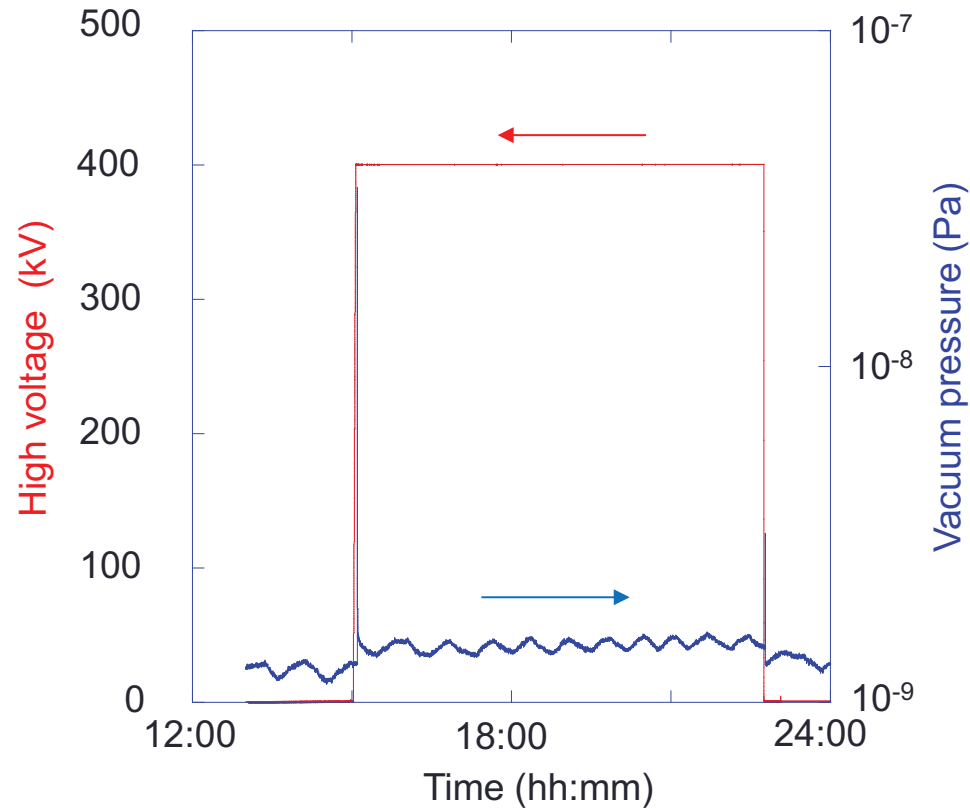
Emittance at the injector at E=5MeV



Phase space distribution measured with a slit scan

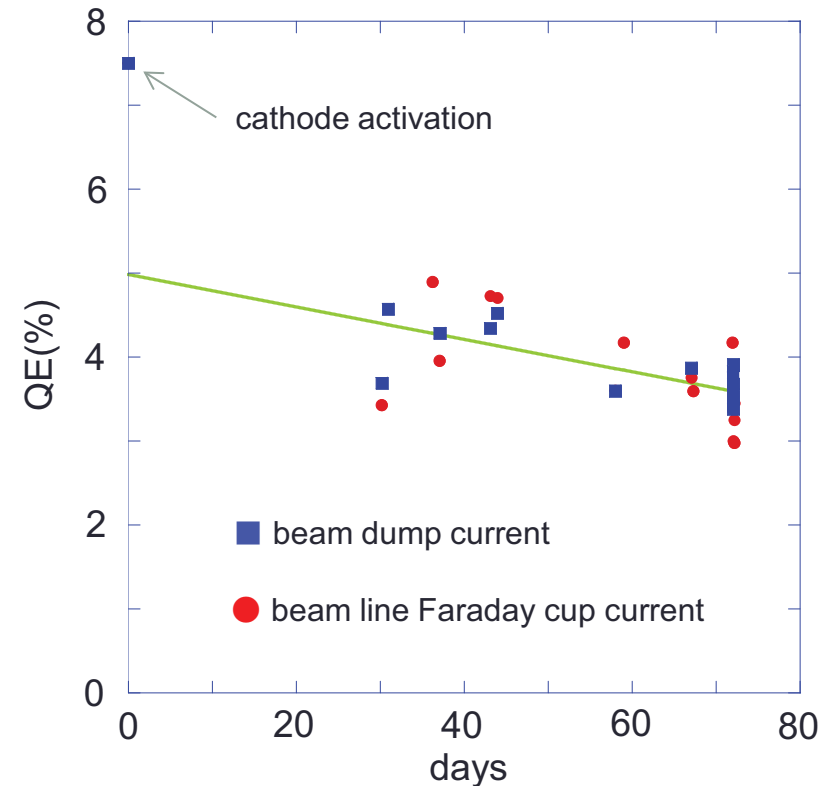
Gun operation during injector commissioning

Stability of gun HV



- Stable operation at 390kV for 200 hours
- Vacuum pressure of 1.4×10^{-9} Pa (connected to the downstream beam line)

QE of GaAs cathode during commissioning



- 1/e life 5000 hours (7 months)
- Good for commissioning with low current beam

Summary

Results at JAEA

- ✓ Applied 500kV with 5.8 MV/m on the photocathode center
- ✓ Generated 500keV electron beam from the photo-gun with current up to 1.8mA

Results at cERL

- ✓ Provided 390keV beam stably for the injector commissioning
- ✓ 1/e life of GaAs cathode is 7 months
- ✓ Preliminary thermal emittance of 0.1mm-mrad with a 530nm laser of spot size of about 1mm in diam.
- ✓ Preliminary emittance of 0.8mm-mrad with bunch charge of 8pC

Future work

- ❑ Address the problem of our high voltage power supply for 500kV-10mA operation
- ❑ Address the problem of our segmented ceramics (8 segments -> 10 segments)
- ❑ Develop a photocathode appropriate for high current operation