DC Photoemission Gun Development for the compact ERL

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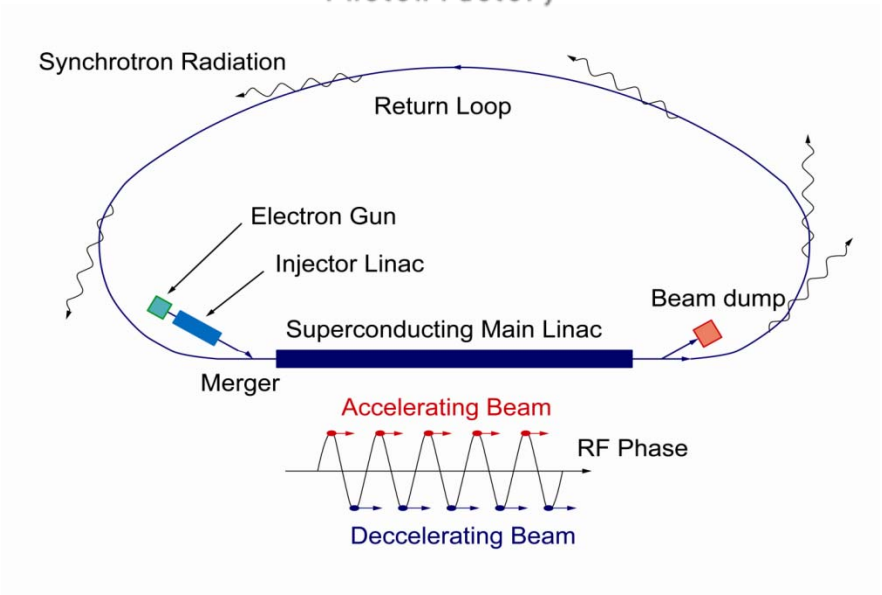
Outline

- 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}）

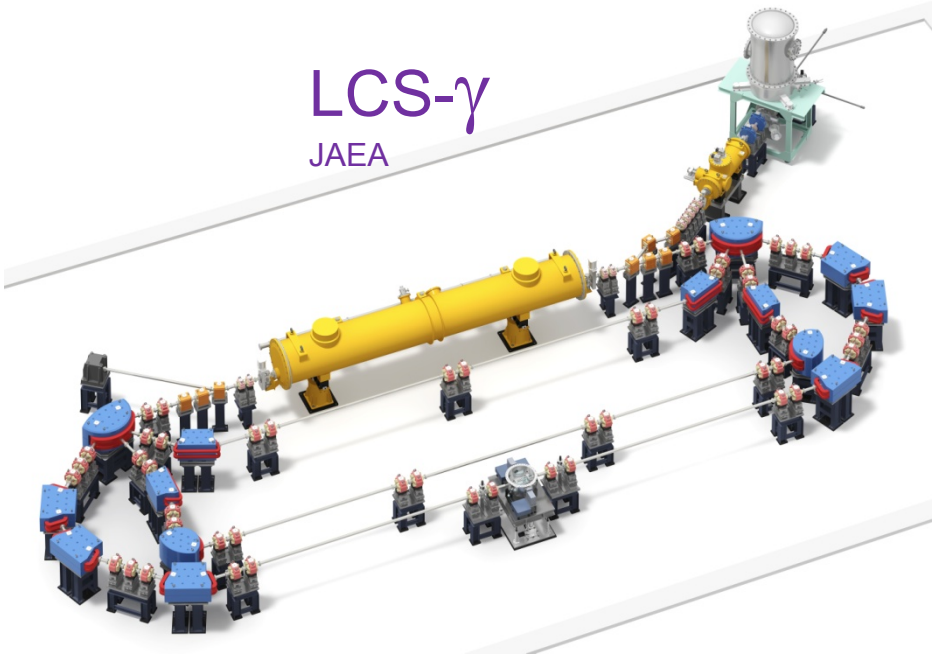
PEARL
Photon Factory



- 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

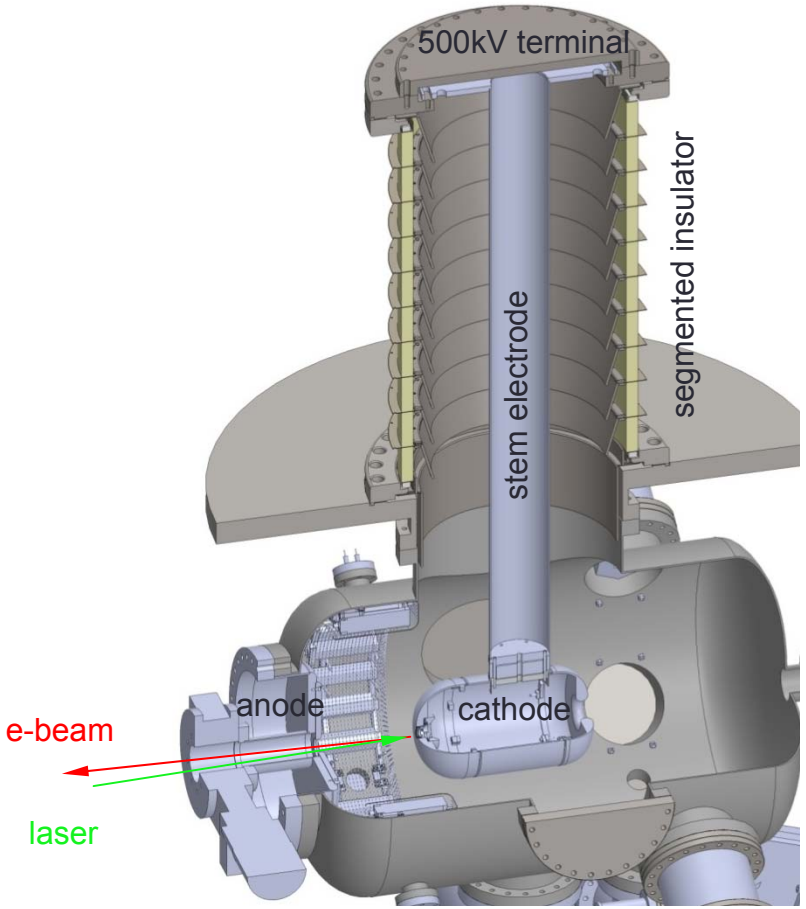


Requirements for the gun parameters for the ERL light sources

Generate low emittance and high current beam

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

Gun parameters	Requirements
High voltage	500kV
Field on photocathode	>5MV/m
Beam current	100mA
Normalized emittance	0.1-1 μmrad



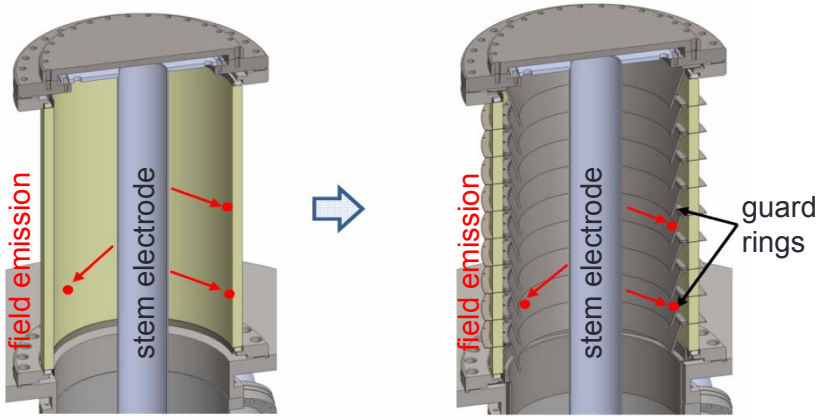
Operational voltage of photo-gun has been limited to 350kV since the first proposal of the 500kV photo-gun in 1991.
The high voltage issue is our first priority.

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)

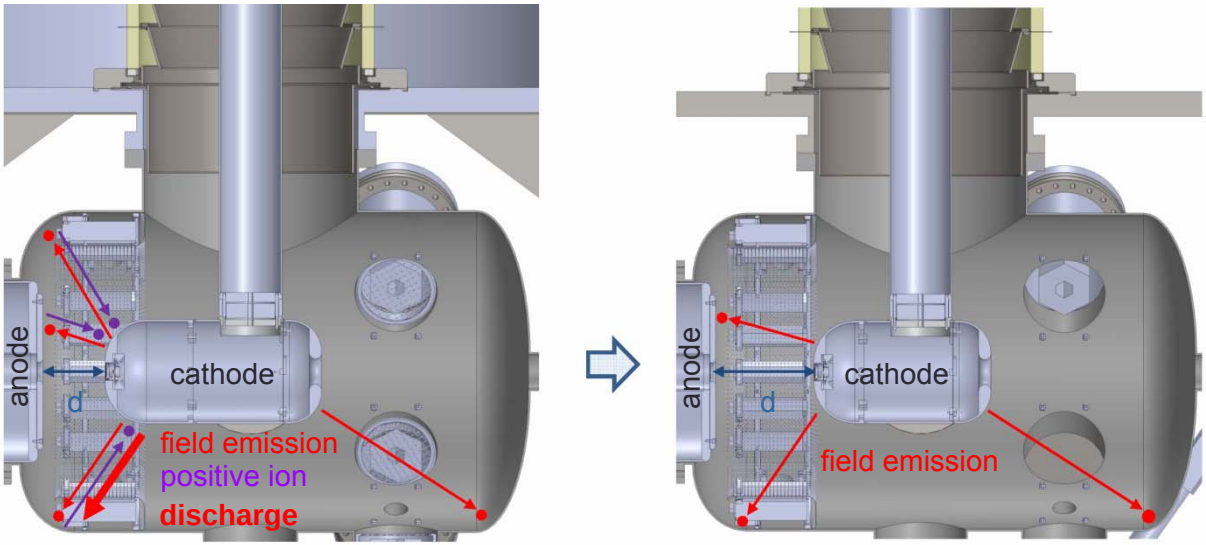


2: Discharge between the cathode and HV chamber (anode) which propels microparticles on the HV chamber surface to the cathode. The microparticles serve as a field emission site.

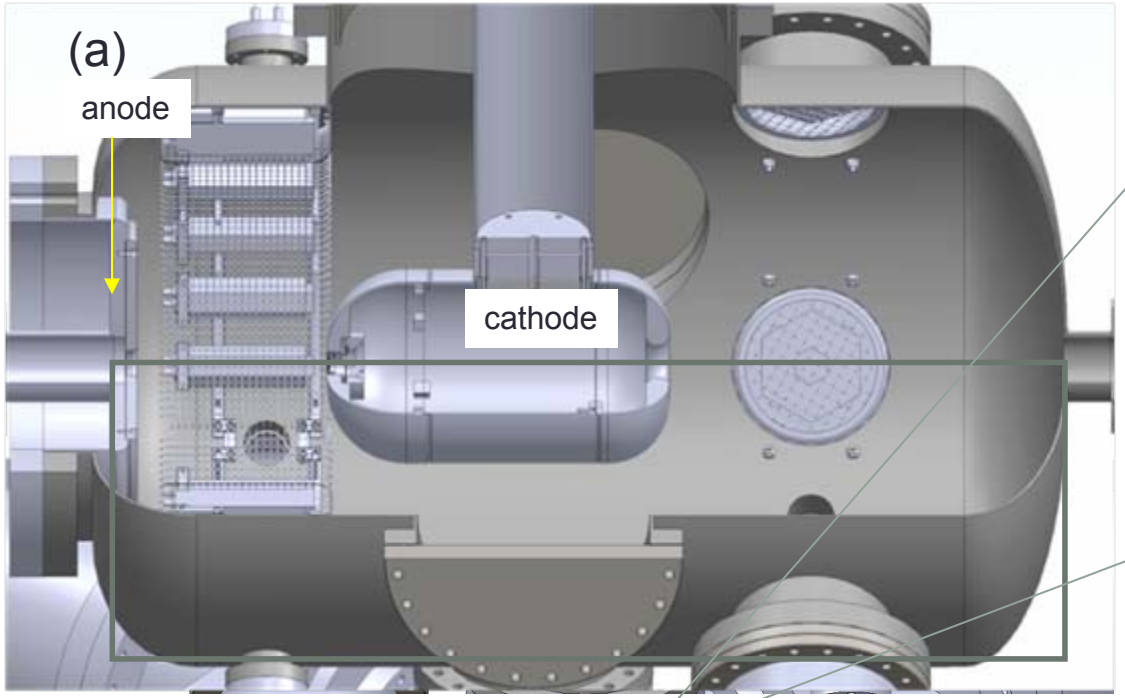
➡ Decrease anode field by increasing gap

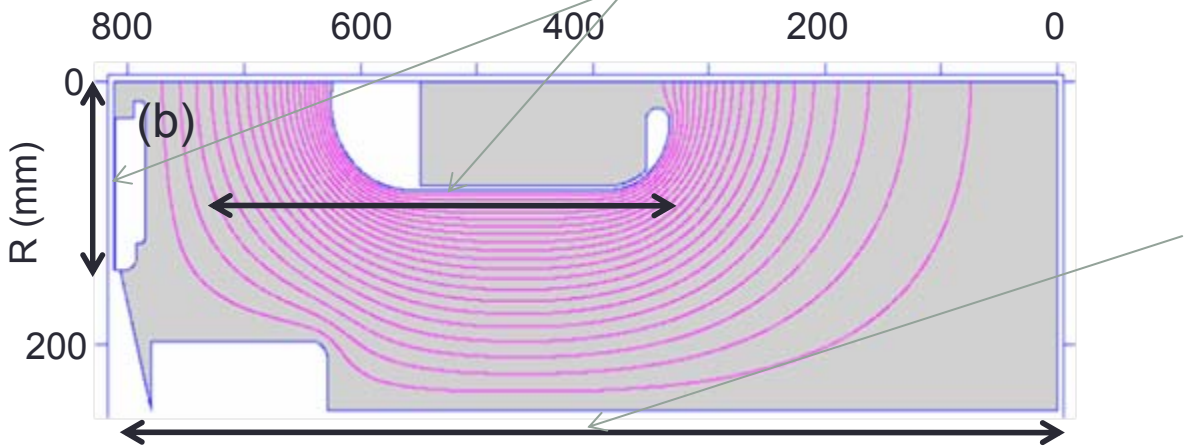
Microdischarges on the anode are suppressed.

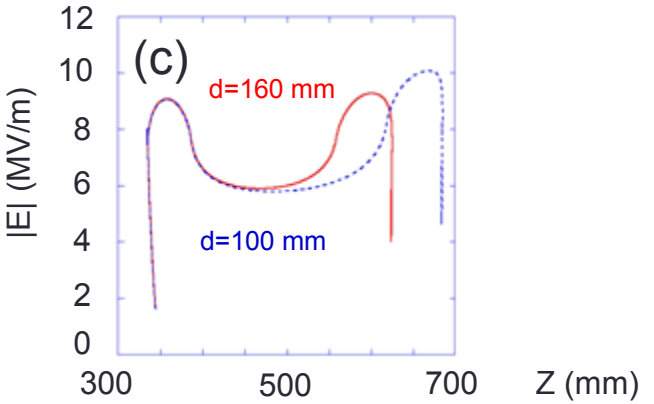
N. Nishimori, et al., Appl. Phys. Lett. 102, 234103 (2013)

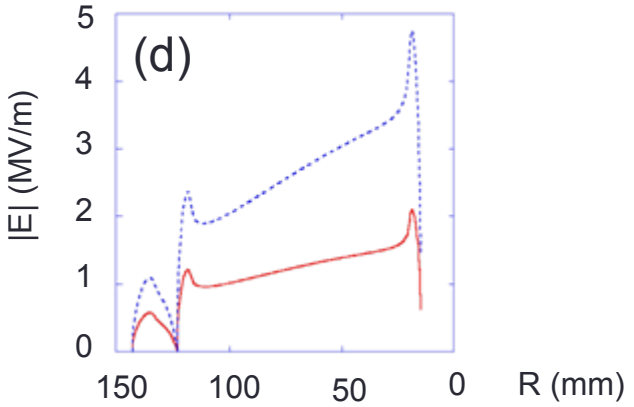


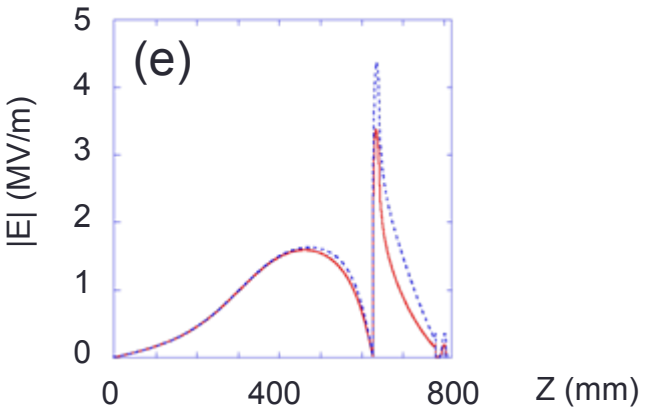
Surface electric fields for 160 mm gap



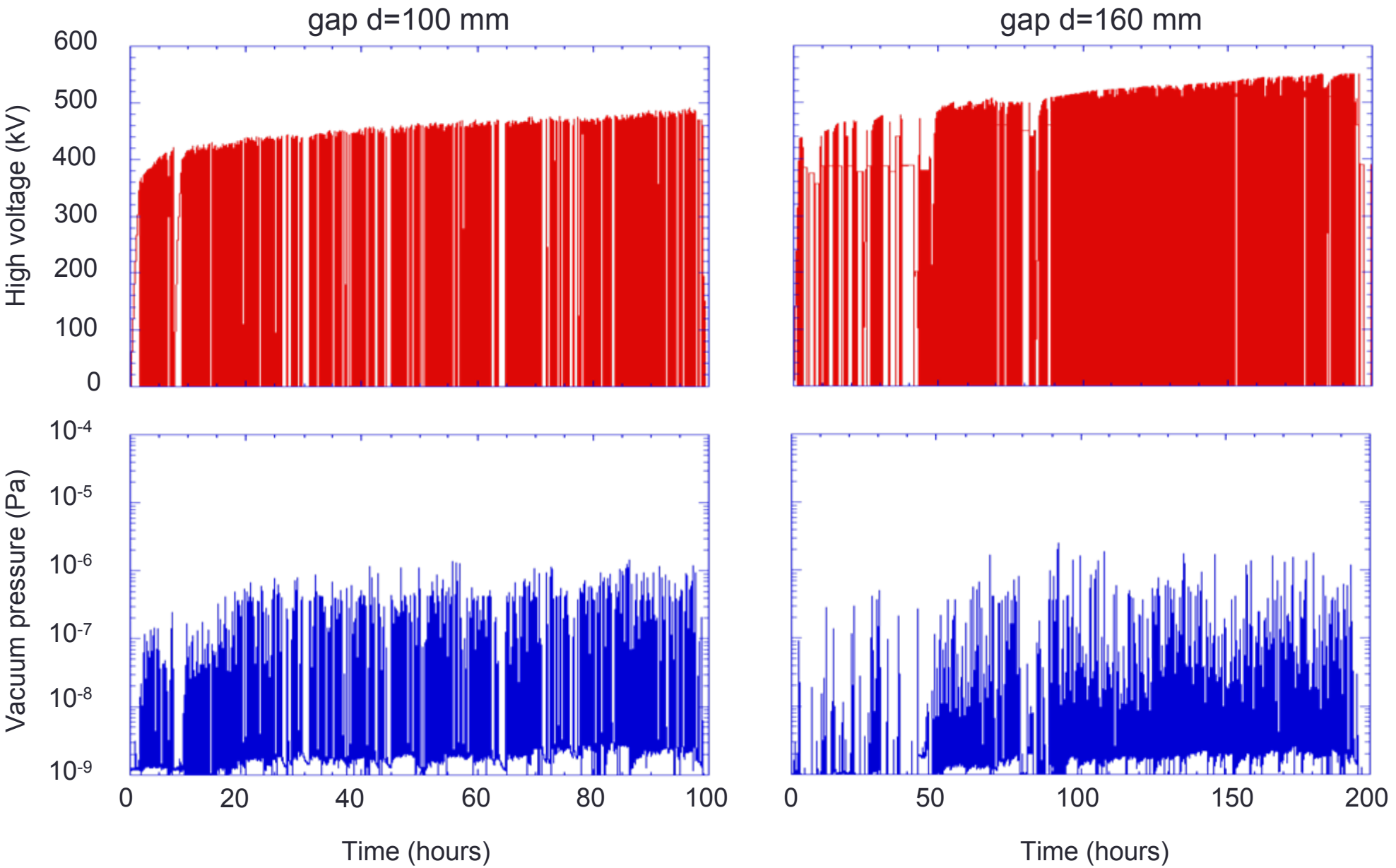




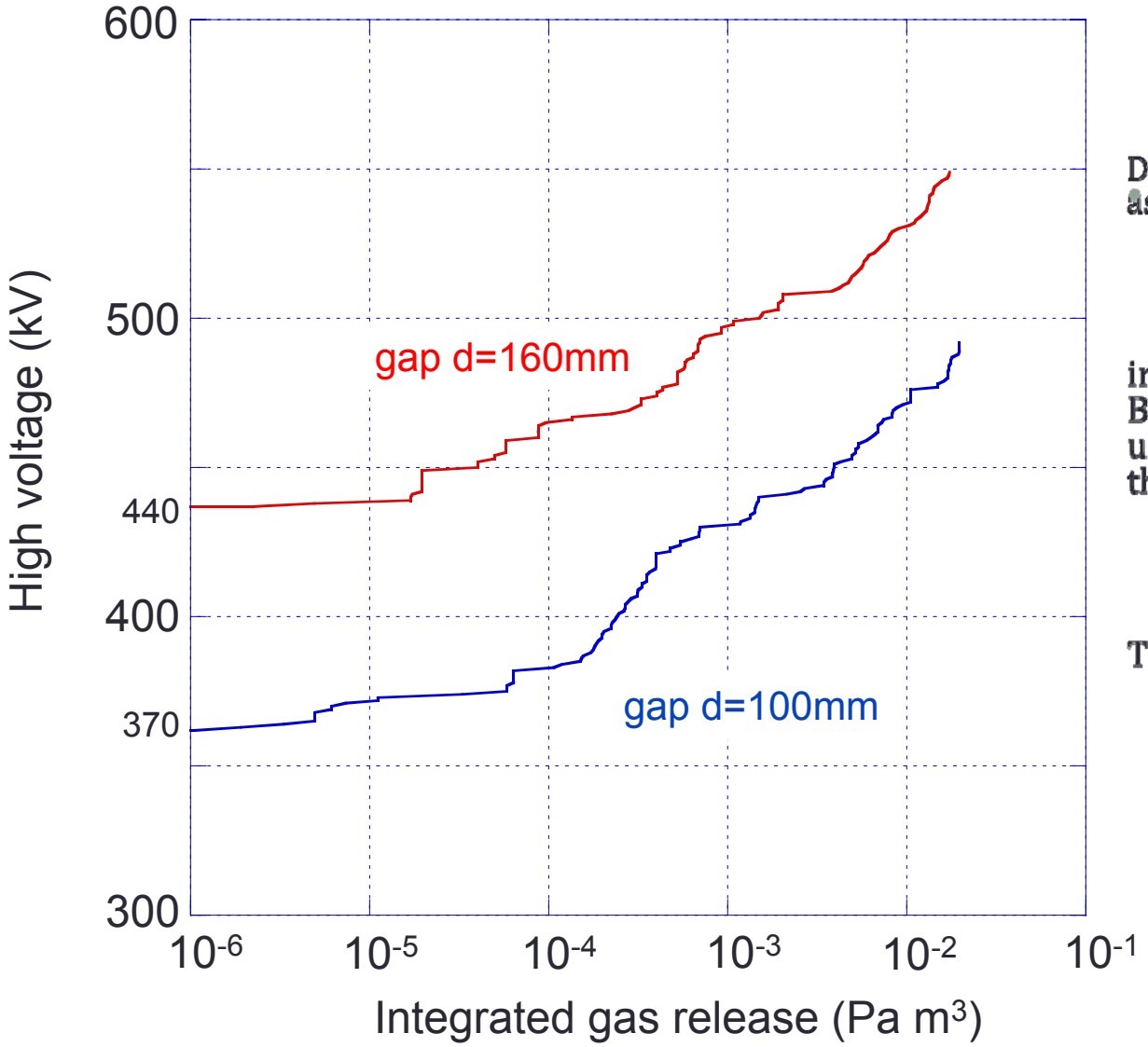




HV conditioning



High voltage as a function of gas desorption



Discharge initiation voltage V_I can be defined as

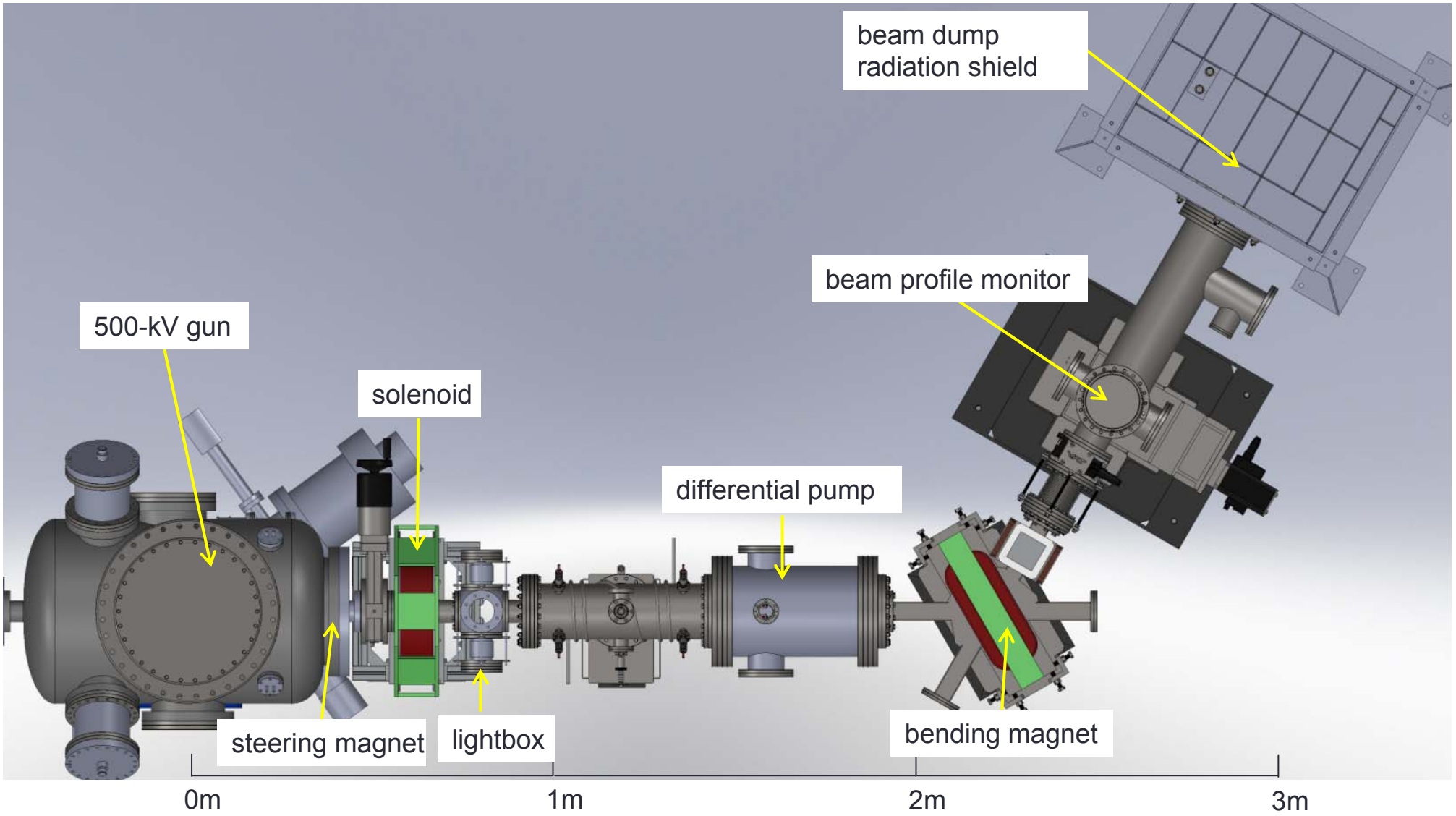
$$V_I = 67d^{0.37},$$

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=500kV for d=100mm.

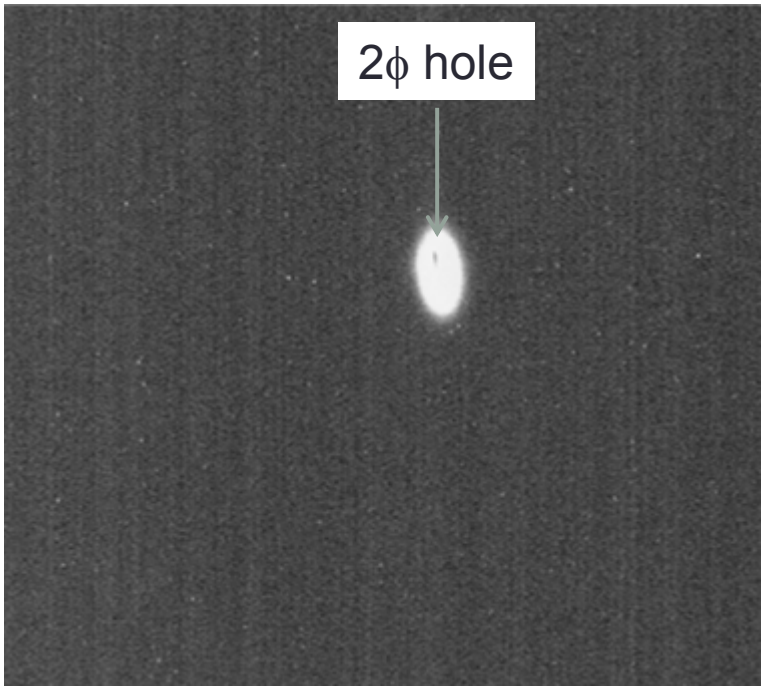
$$V_B = 91d^{0.37}.$$

This suggests V_B=600 kV for d=160mm.

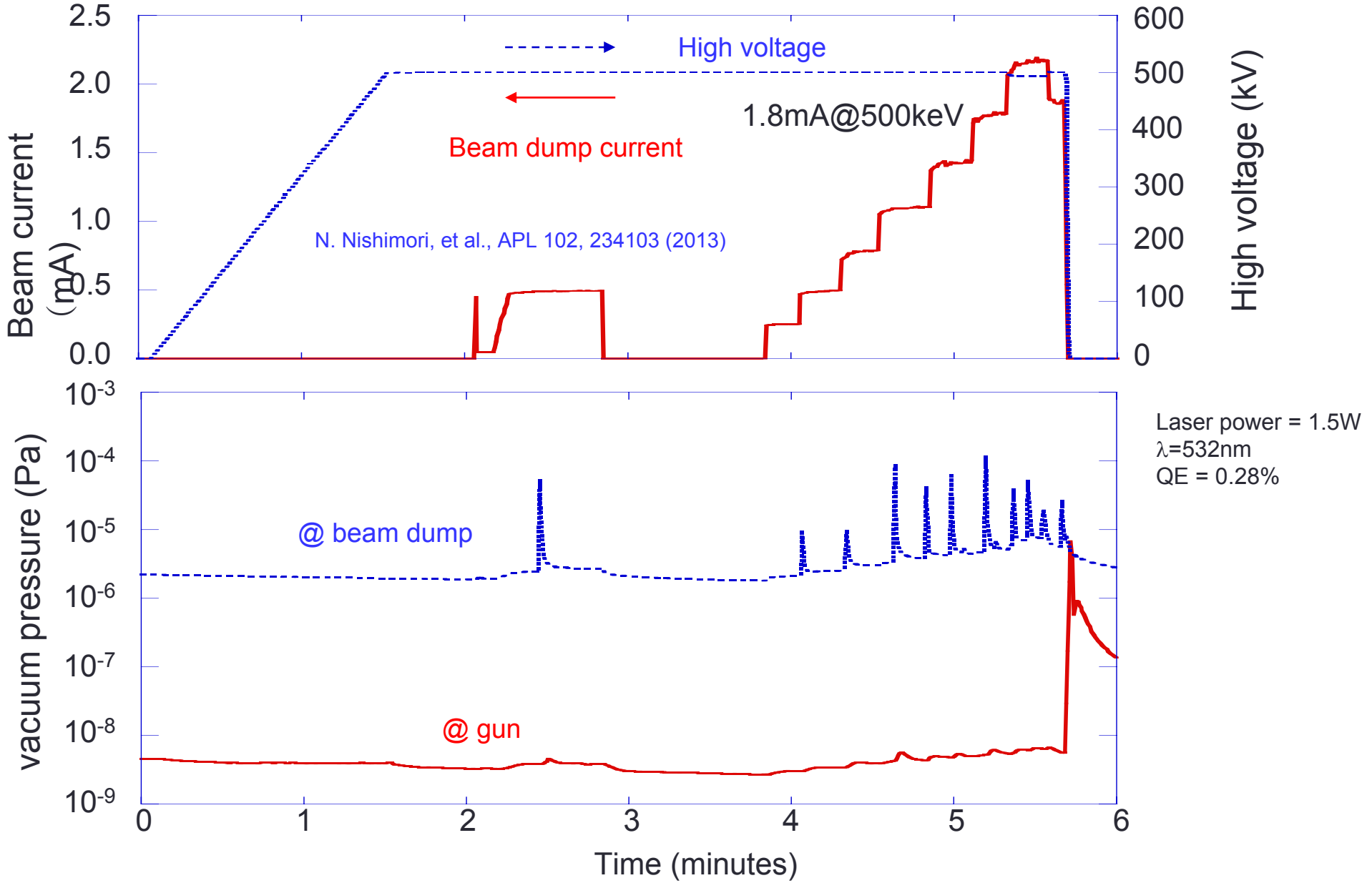
Beam line for the DC gun at JAEA



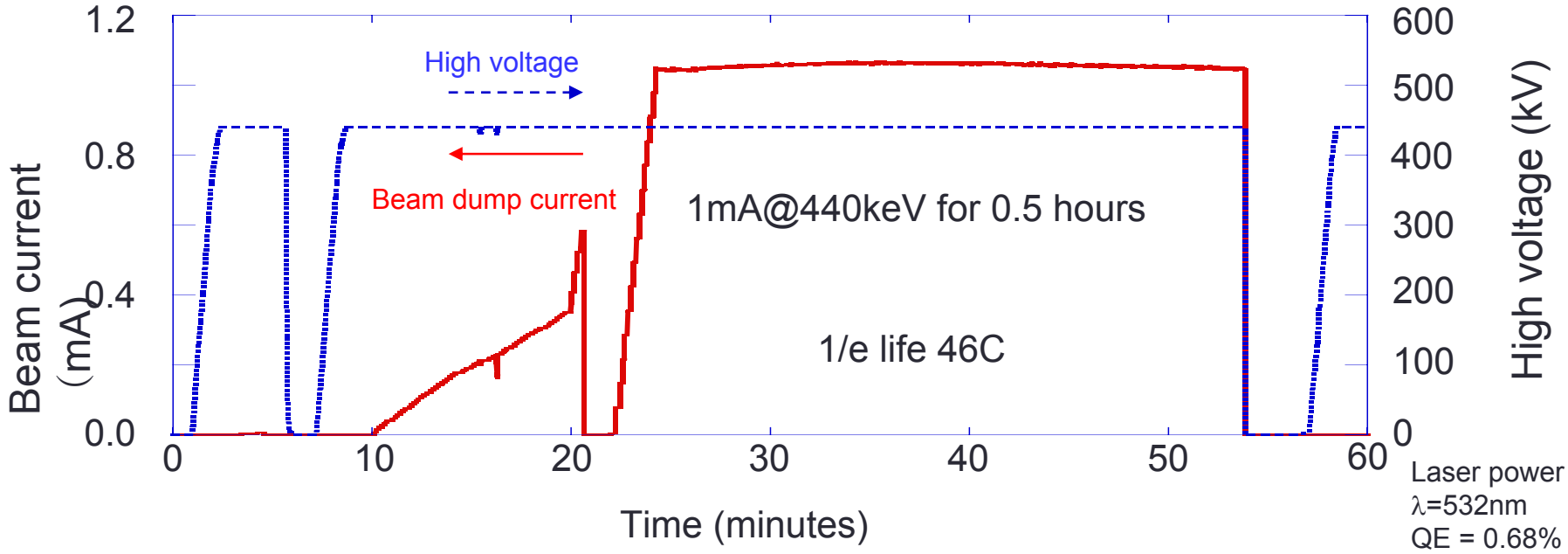
Beam profile



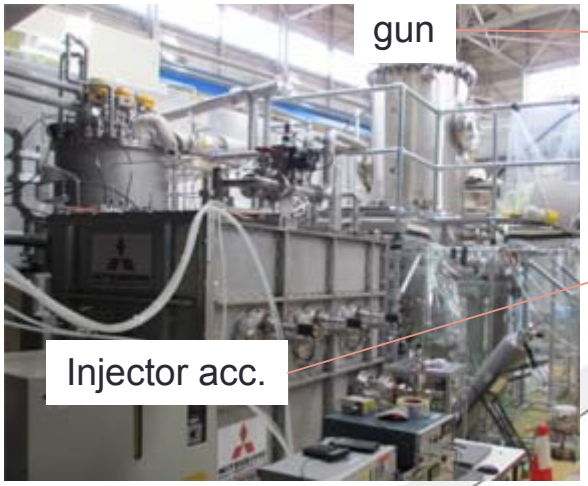
500keV beam generation



440keV beam generation for 0.5 hours

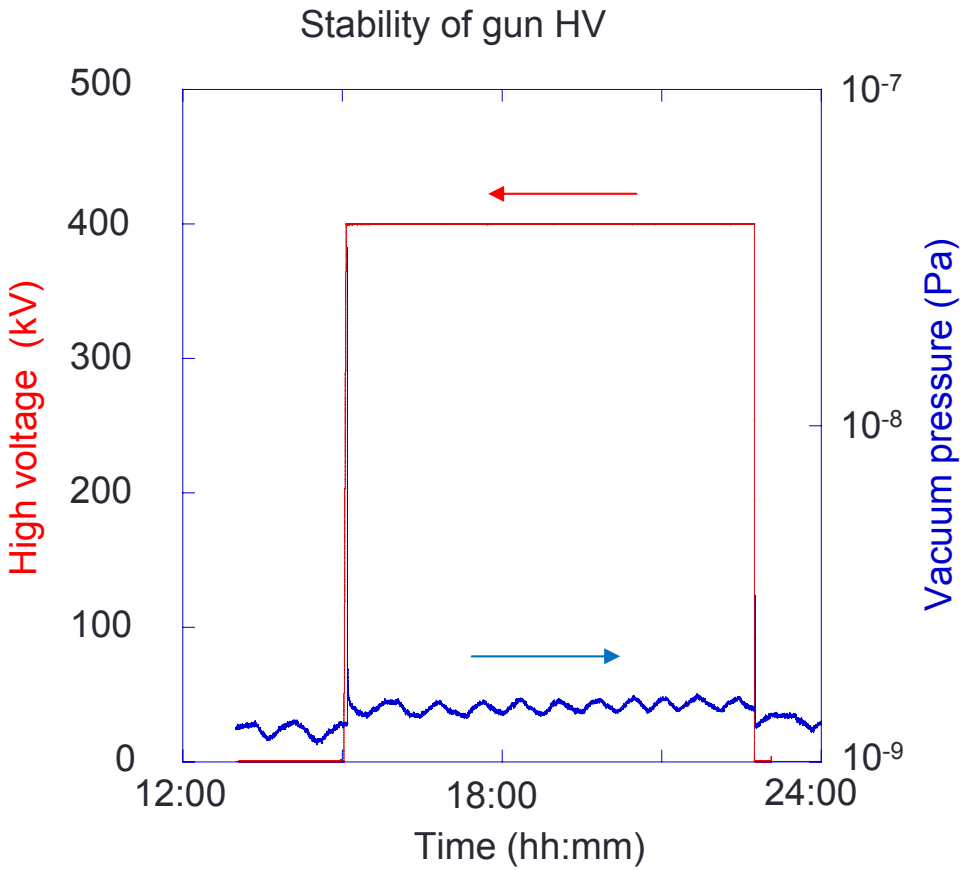


cERL (prototype of the ERL light source)

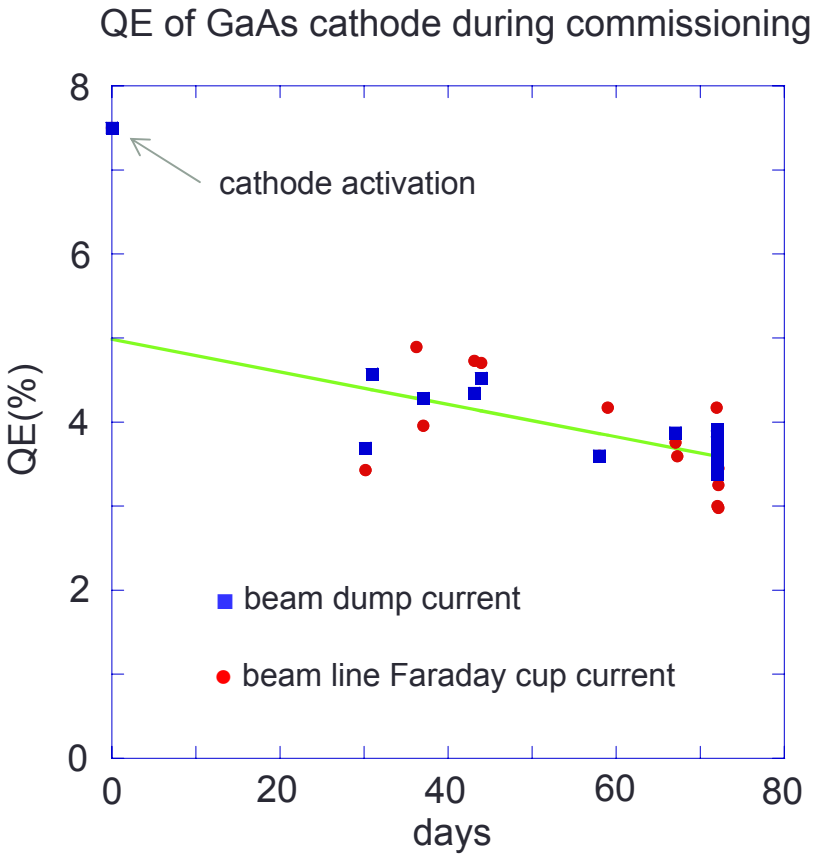


gun

Gun operation during injector commissioning



- Stable operation at 390kV for 200 hours
- Vacuum pressure of1.4x10^{-9}Pa (connected to the downstream beam line)

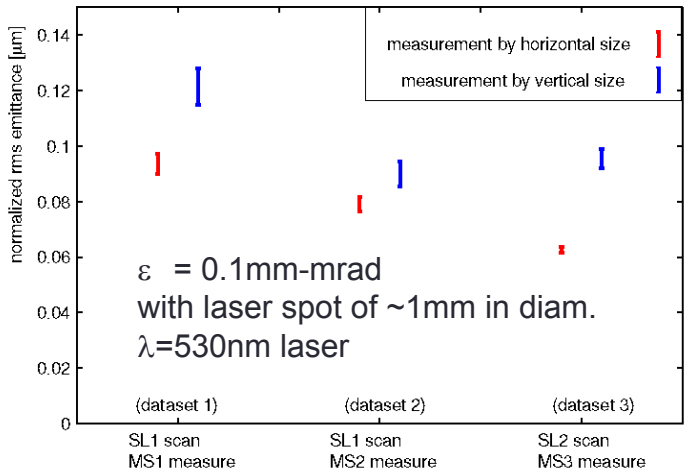


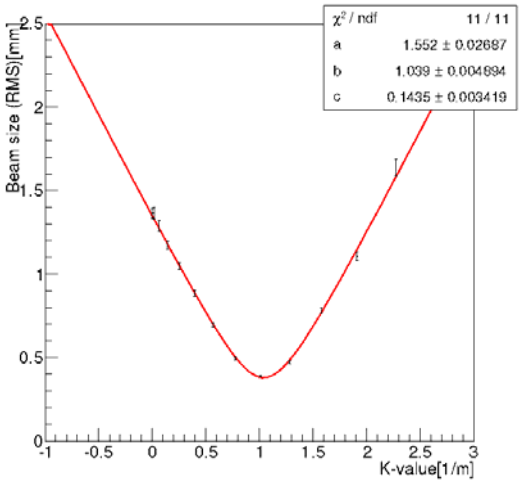
- 1/e life 5000 hours (7 months)
- Good for commissioning with low current beam

Preliminary emittance measurements

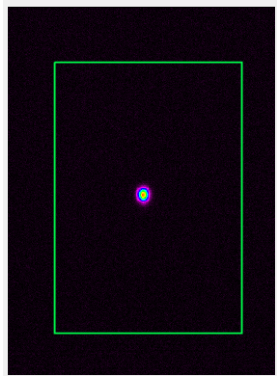
Y. Honda, et al., "Beam Performance Measurement at compact-ERL Injector", PS03, "ERL-2013" (2013).

Thermal emittance at the gun at E=390keV



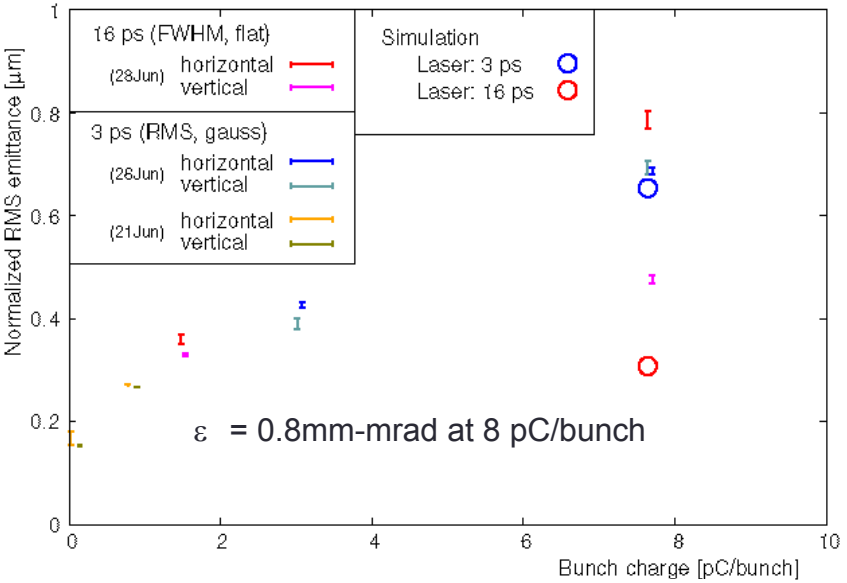


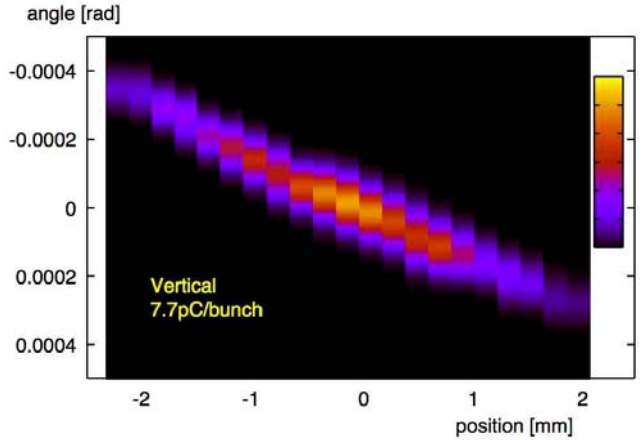
Solenoid scan



Beam profile on YAG screen

Emittance at the injector at E=5MeV





Phase space distribution measured with a slit scan

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.

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