Commission results of the compact ERL High voltage DC gun

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ERL17

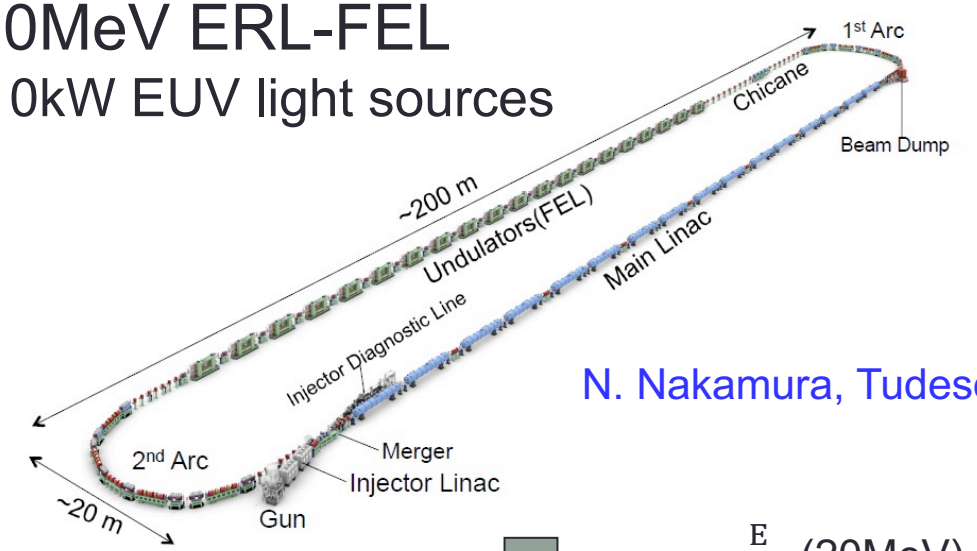
Outline

- Introduction
- Development of a 500kV DC gun at JAEA
- 1mA operation at the compact ERL KEK
- 450 kV operation
- Summary

The next generation ERL light sources

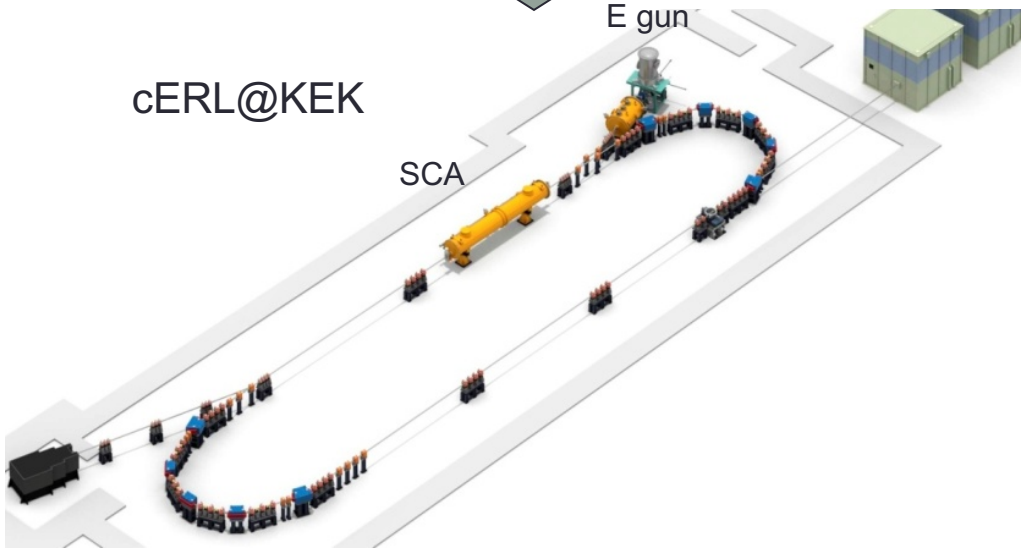
800MeV ERL-FEL

- 10kW EUV light sources



N. Nakamura, Tudesday Talk

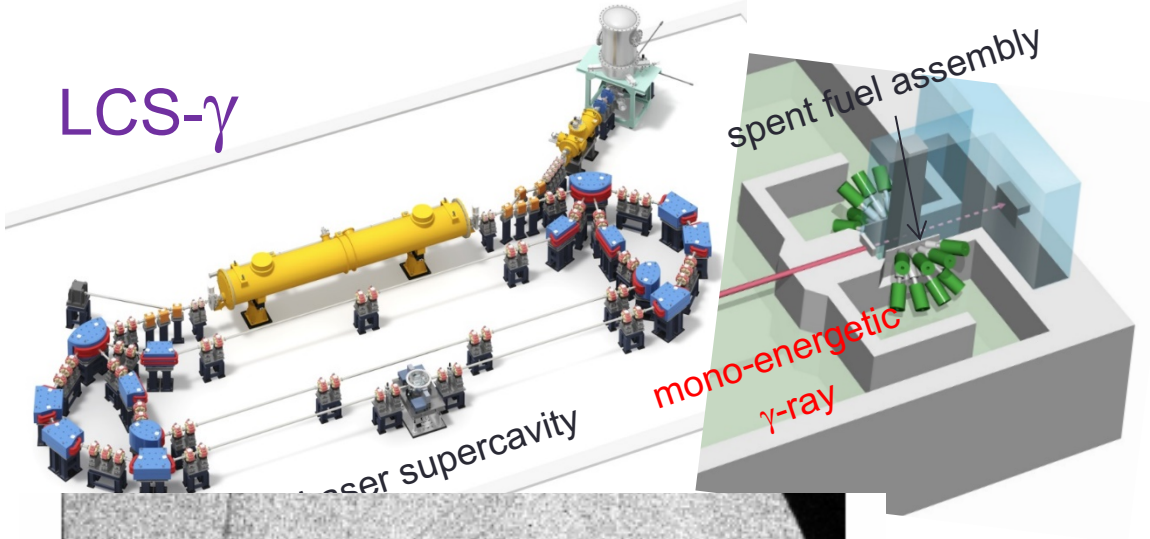
$\frac{E}{40}$ (20MeV)

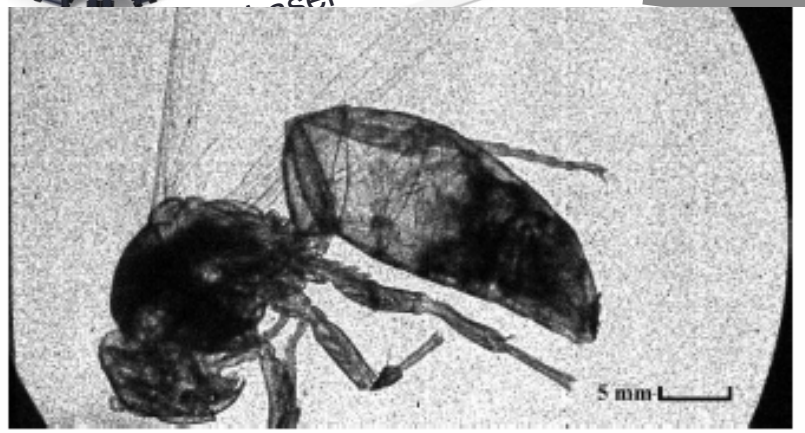


350MeV ERL LCS γ-ray source

LCS: laser Compton scattering

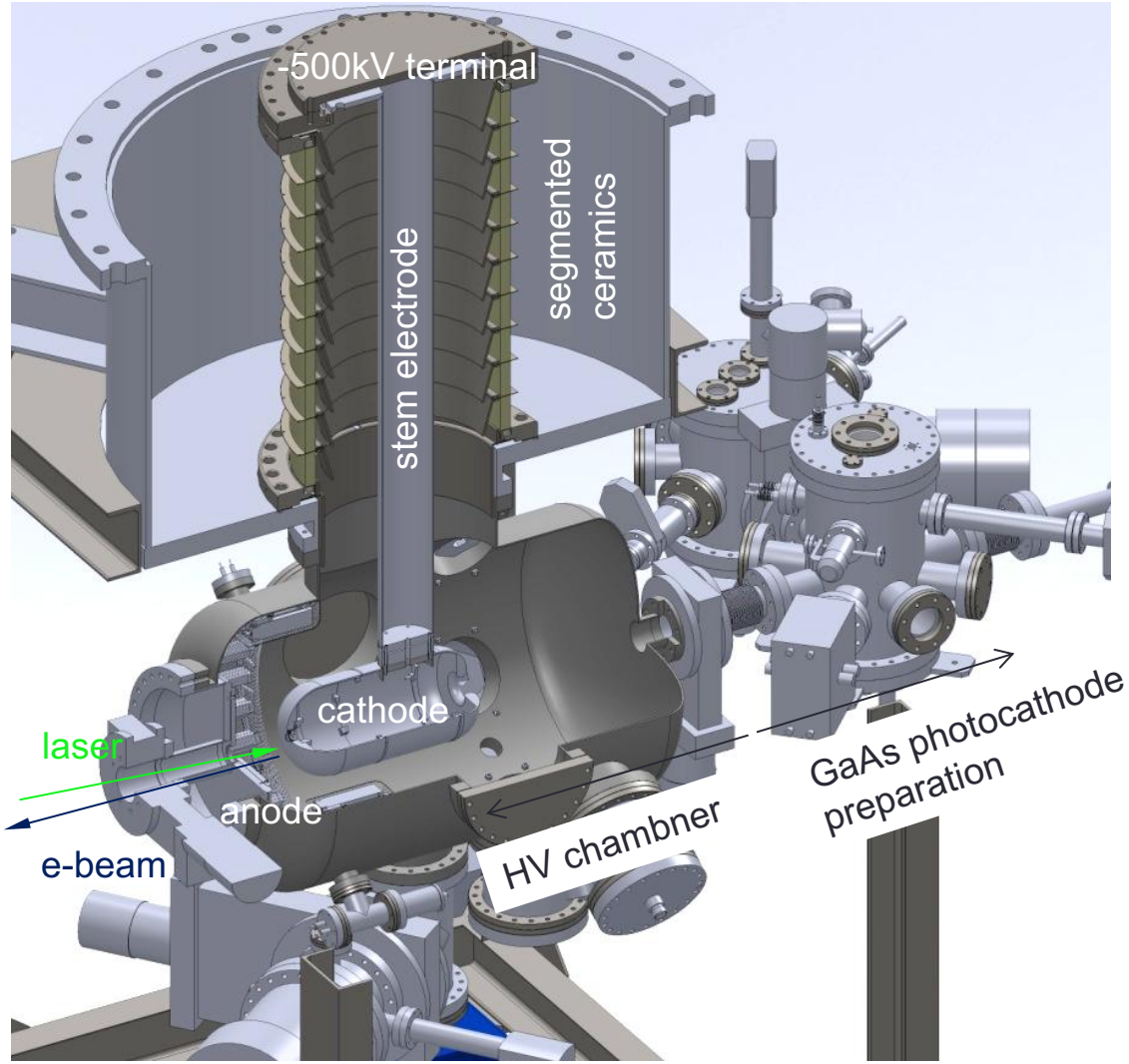
- flux of > 10^6 of conventional sources

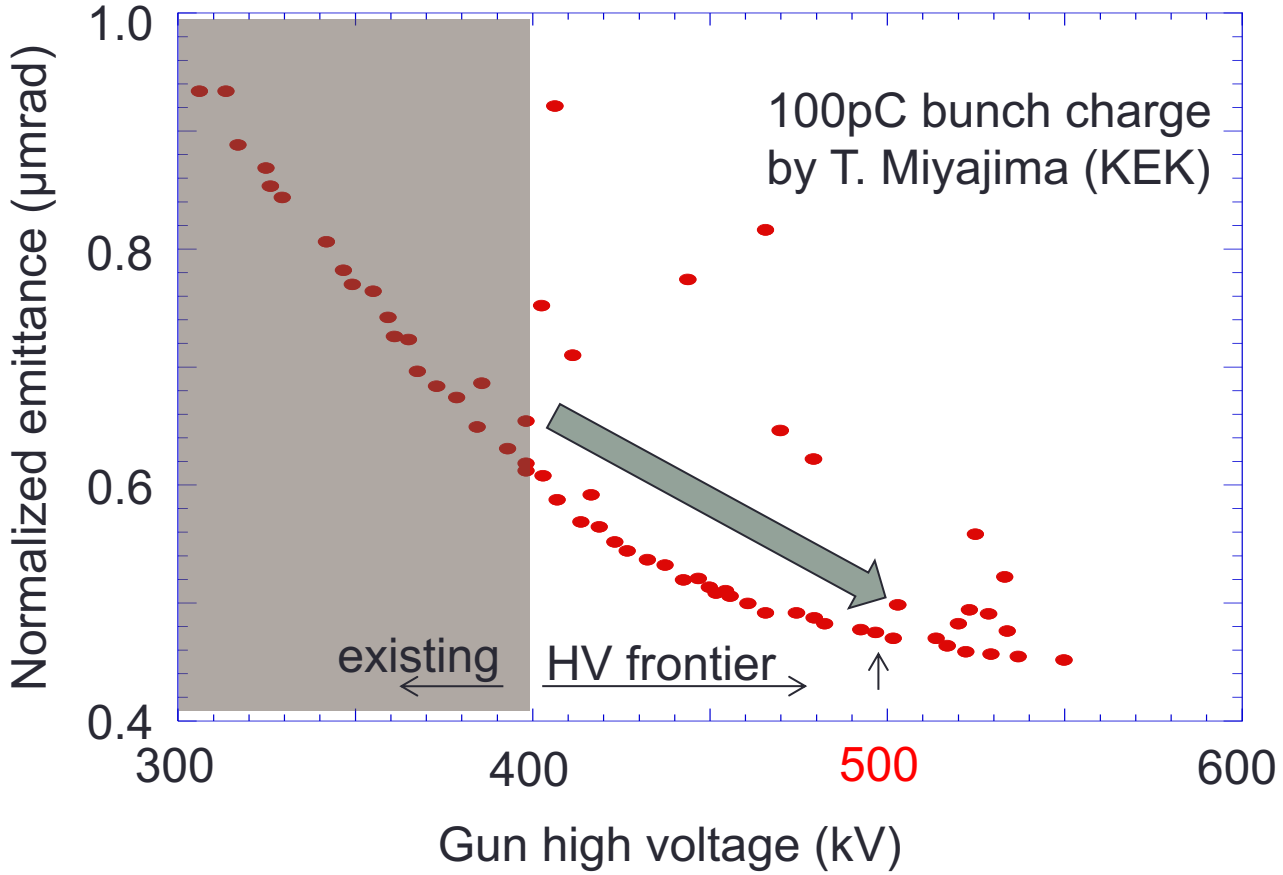




T. Akagi et al., PRAB 19, 114701 (2016)

Development of a 500kV photoemission gun

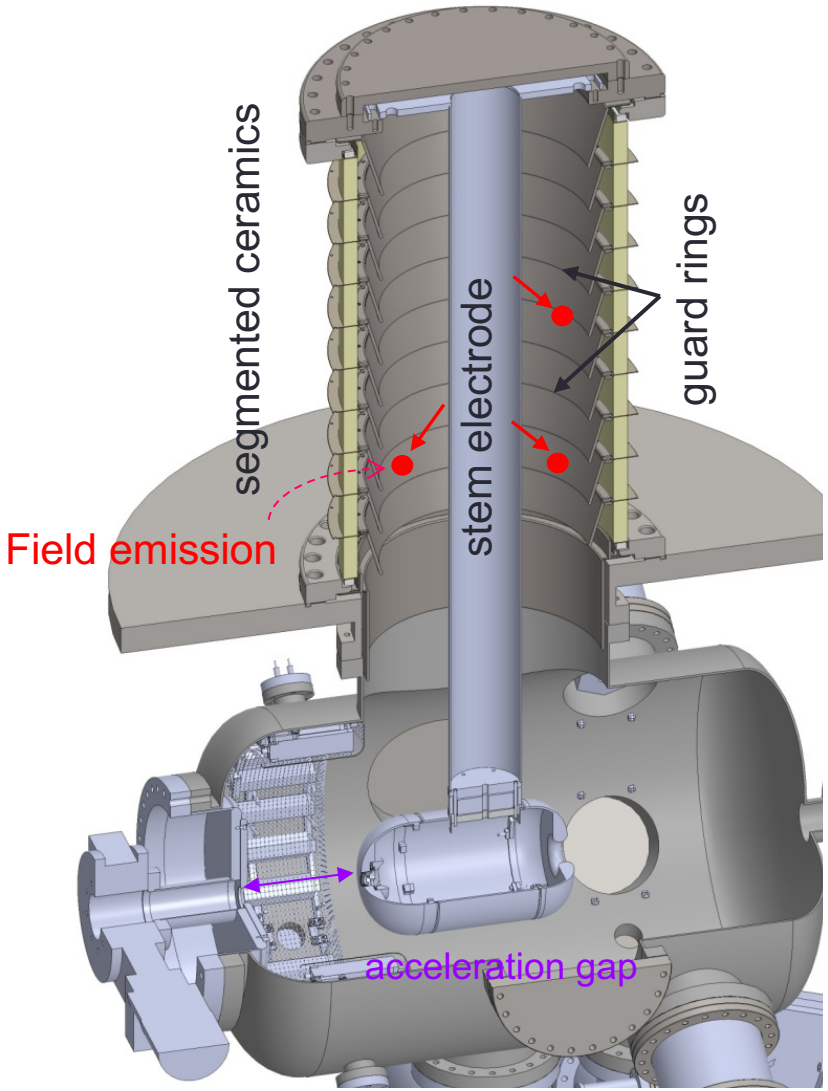




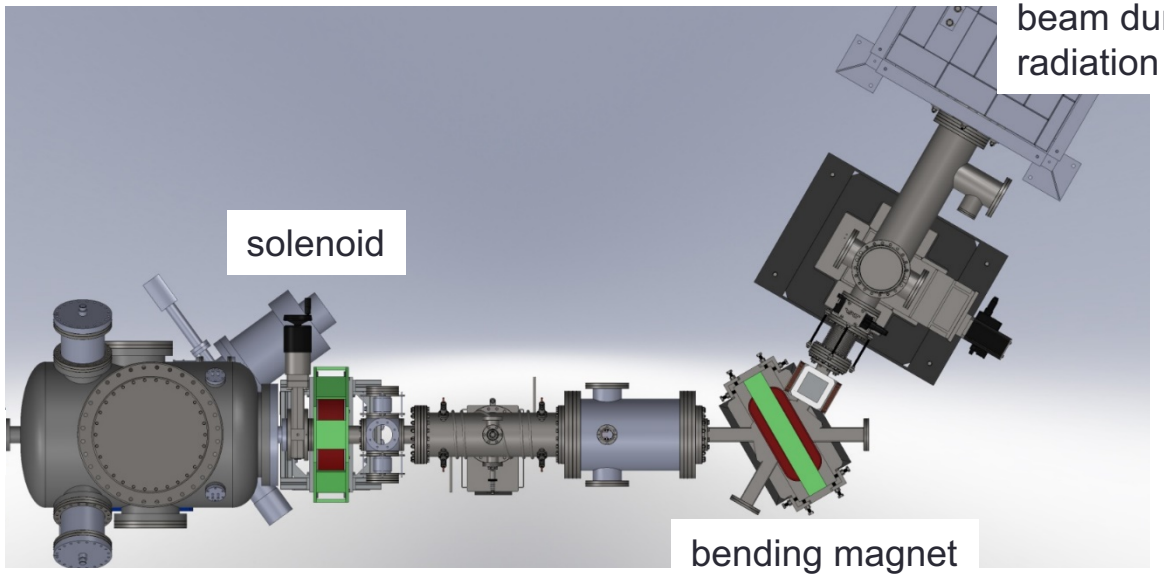
	Requirements
HV	500kV
Photocathode Field	>5MV/m
Current	10mA

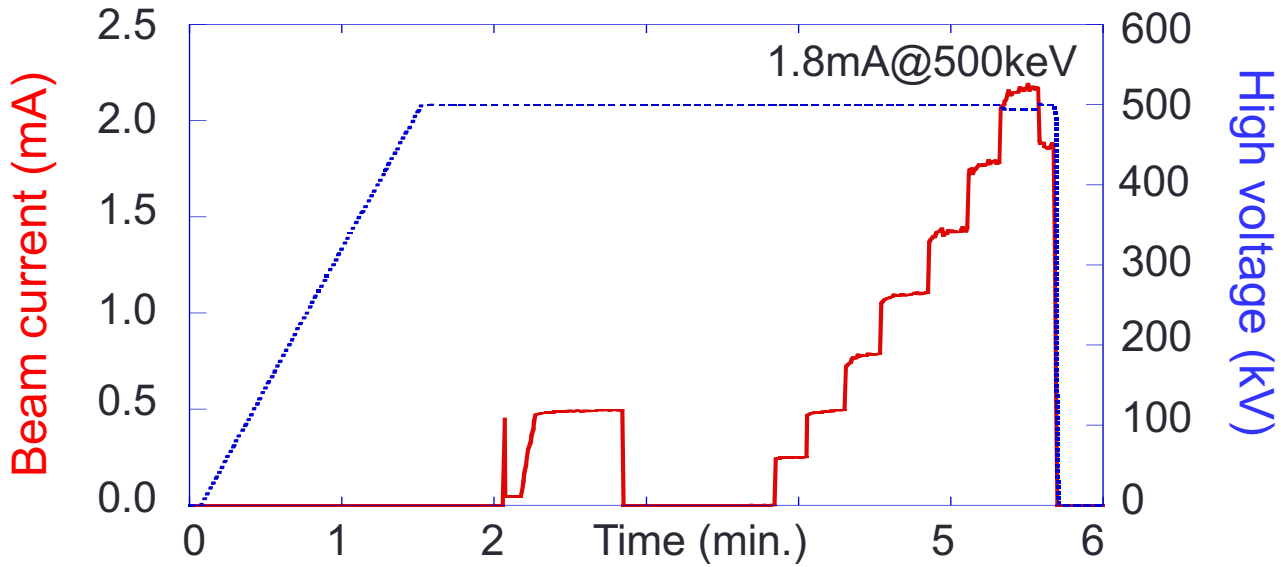
→ Normalized emittance <0.5μm･rad

500keV beam generation at JAEA



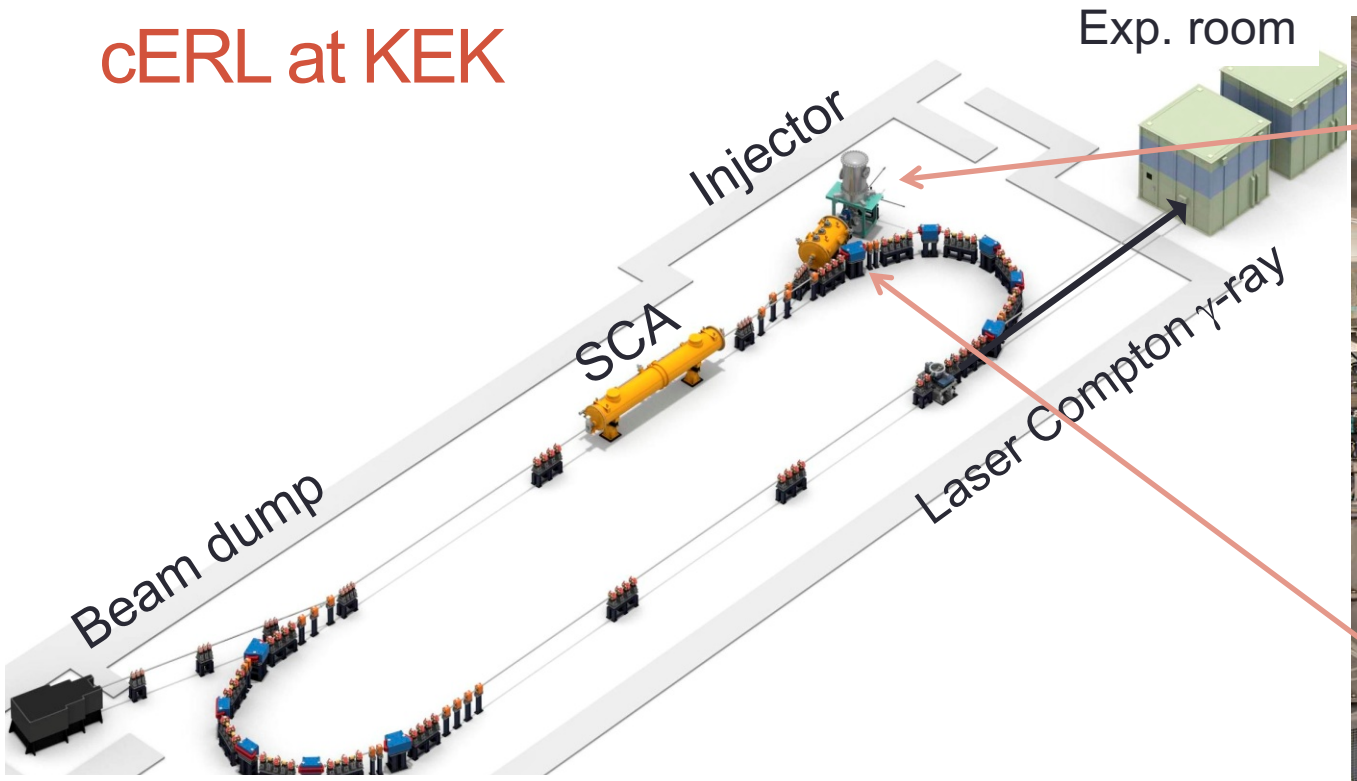
R. Nagai et al., RSI 81, 033304 (2010).
N. Nishimori et al., PRSTAB 17, 053401 (2014).

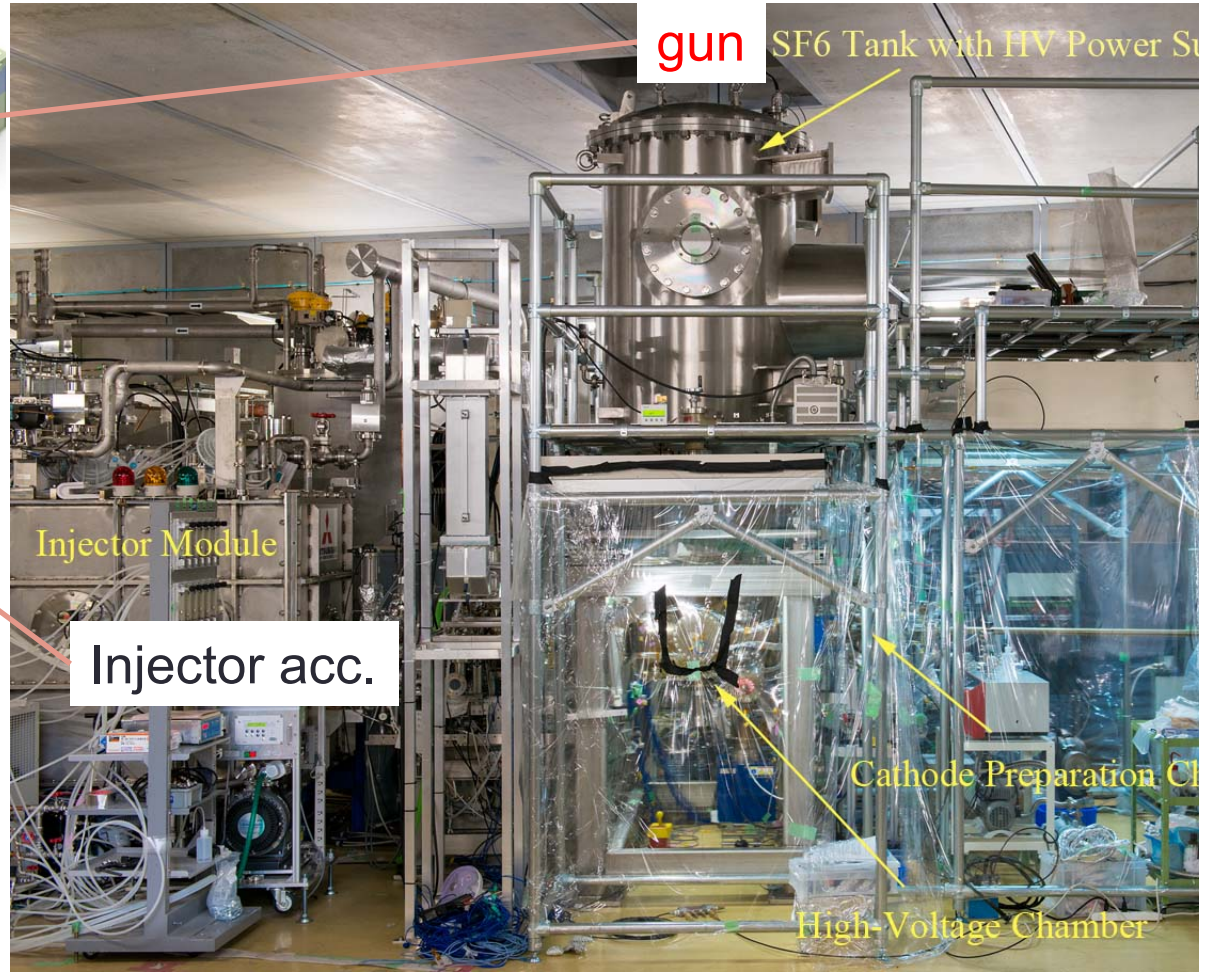




N. Nishimori et al., APL 102, 234103 (2013)

cERL at KEK

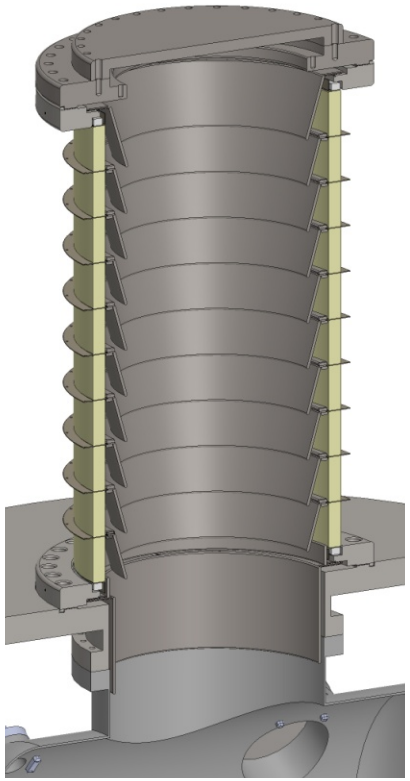


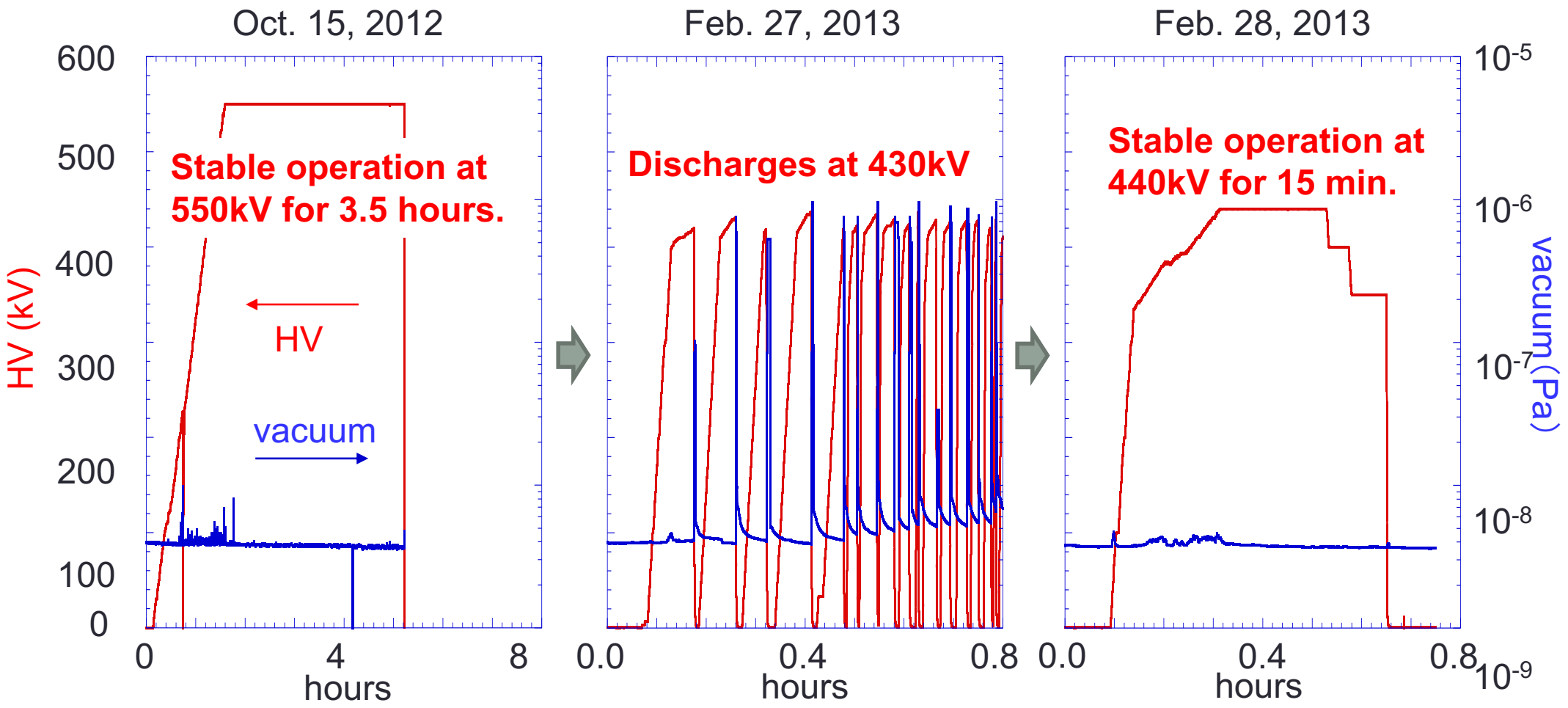


- ✓ Oct. 2012 Transport of gun from JAEA to cERL at KEK
- ✓ Jun. 2013 Injector commissioning 5MeV-0.3μA
- ✓ Mar. 2014 ERL loop commissioning 20MeV-4.5μA
- ✓ Mar. 2015 Laser Compton Scattering (LCS) 20MeV-80μA
- ✓ Mar. 2016 20MeV-1mA operation

Gun voltage is limited to 390kV at cERL until Mar. 2016.

Why 390kV operation ? (experiments with insulator only)



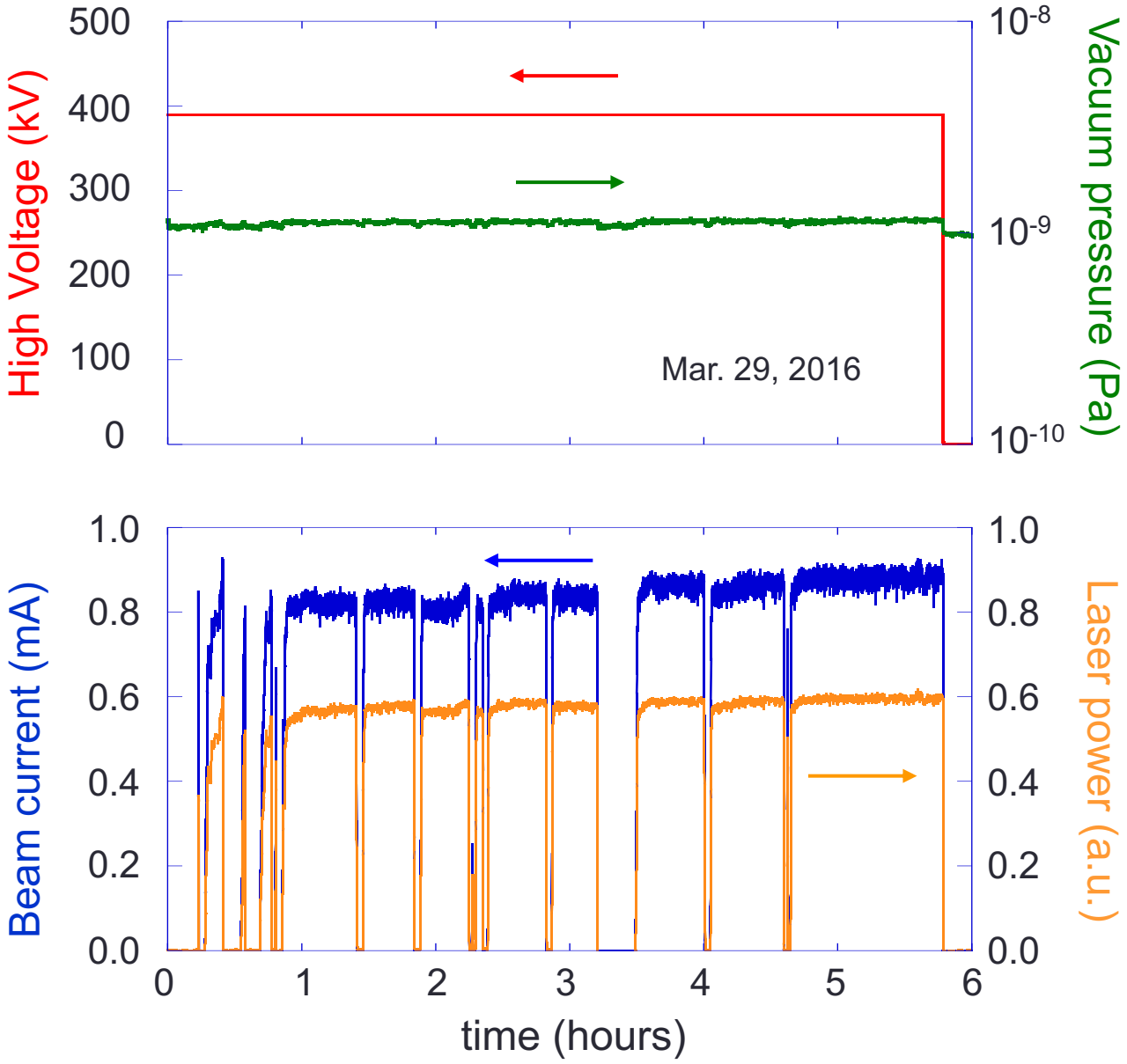


No problem at JAEA

A problem happened at KEK.

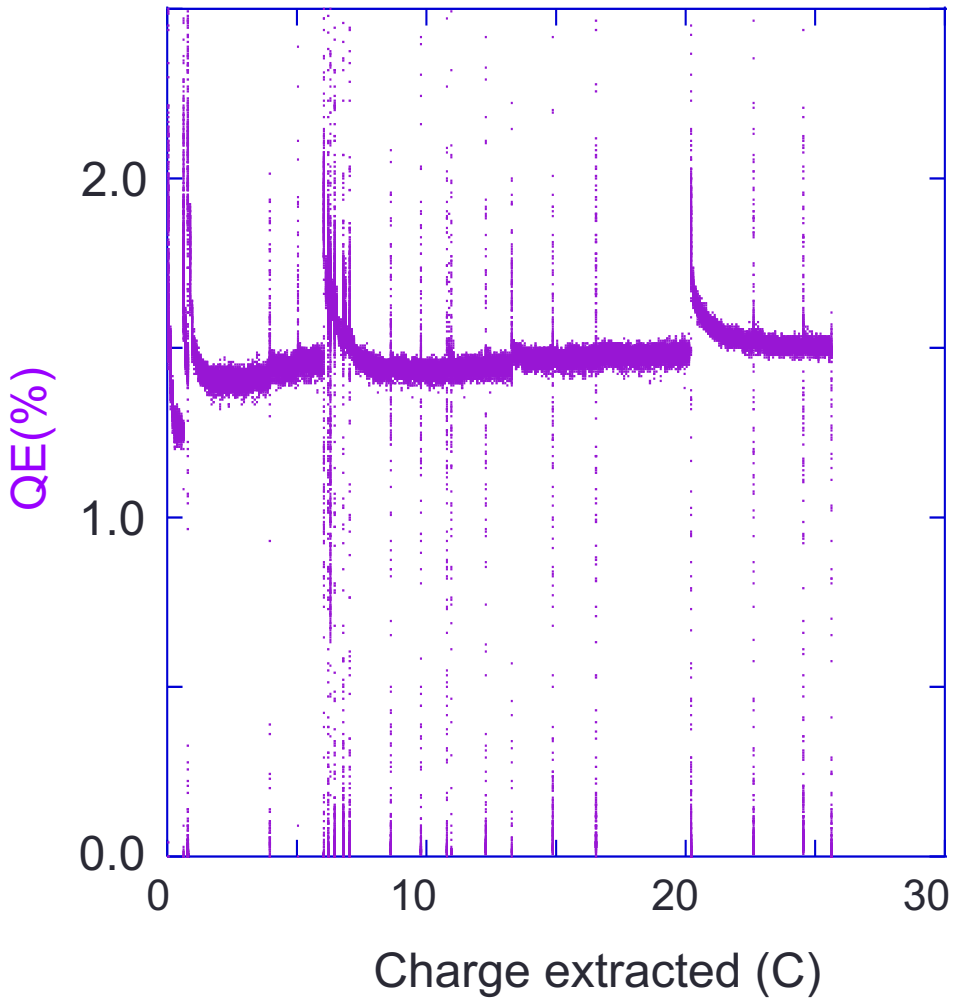
Top and bottom ceramics are short-circuited.
8 segments operation

1mA operation at 390kV



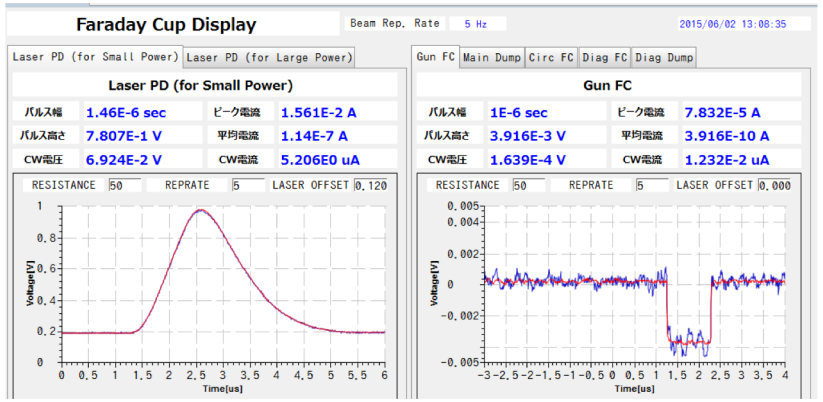
GaAs QE

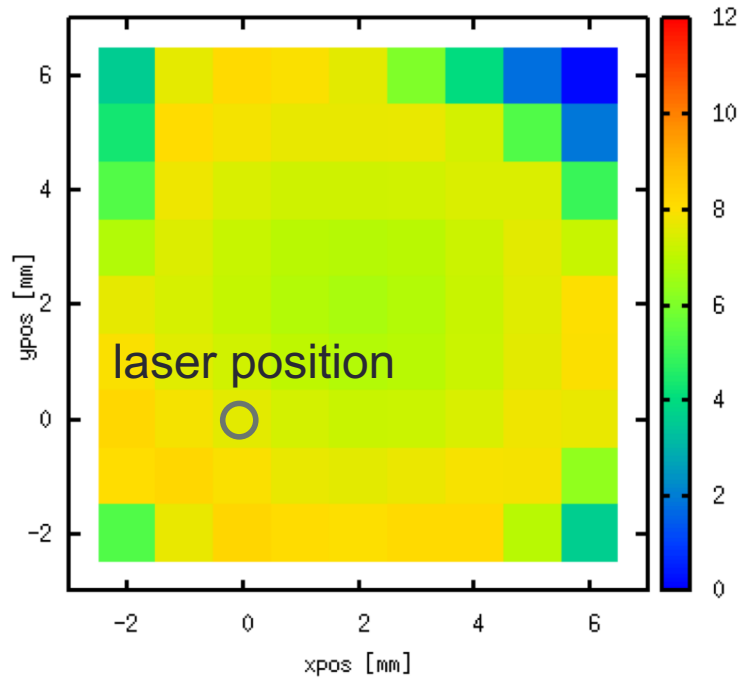
derived from beam dump current and monitor laser power for Mar. 24 to 30 operation in 2016

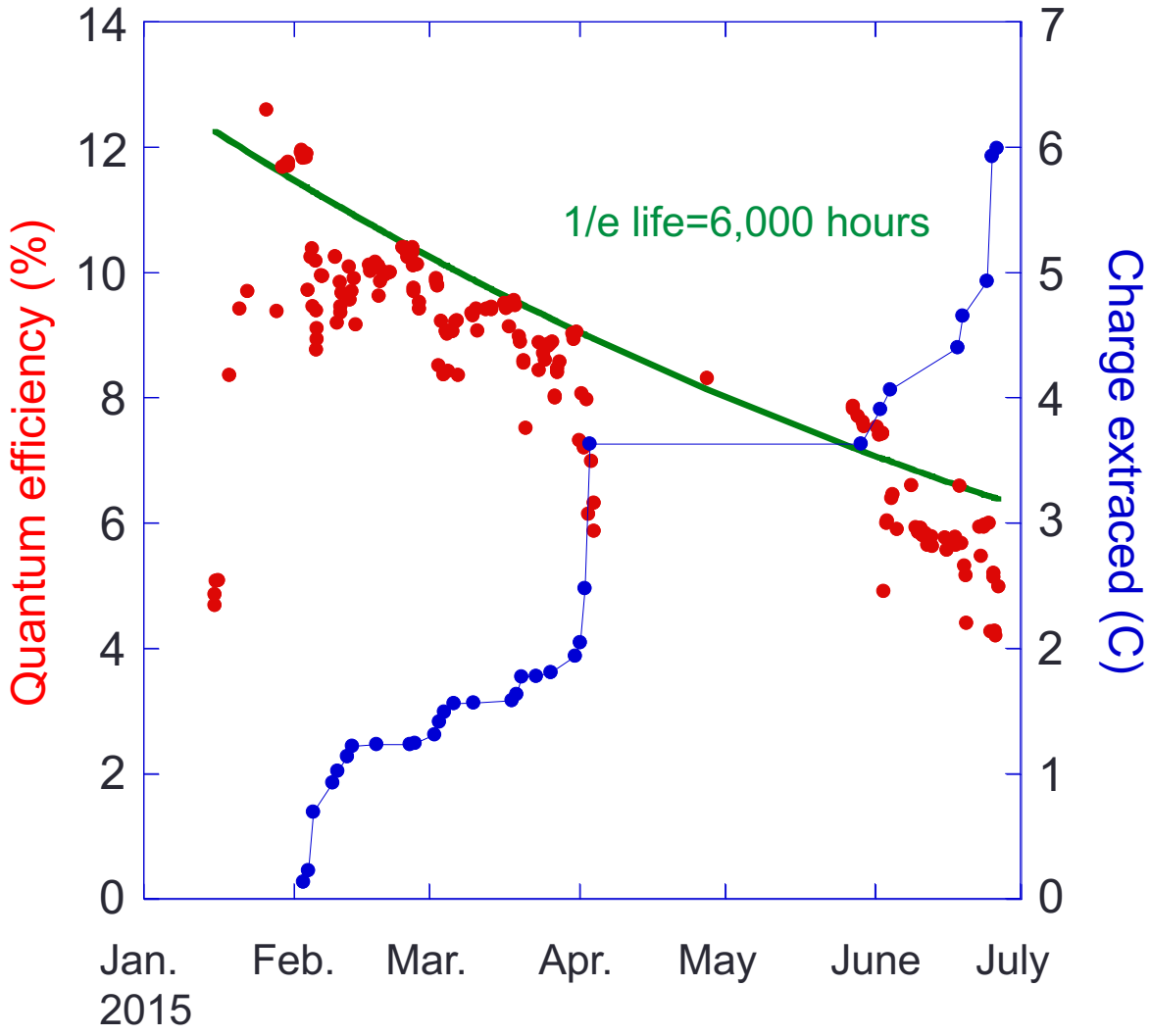


QE looks unchanged during 1mA operation

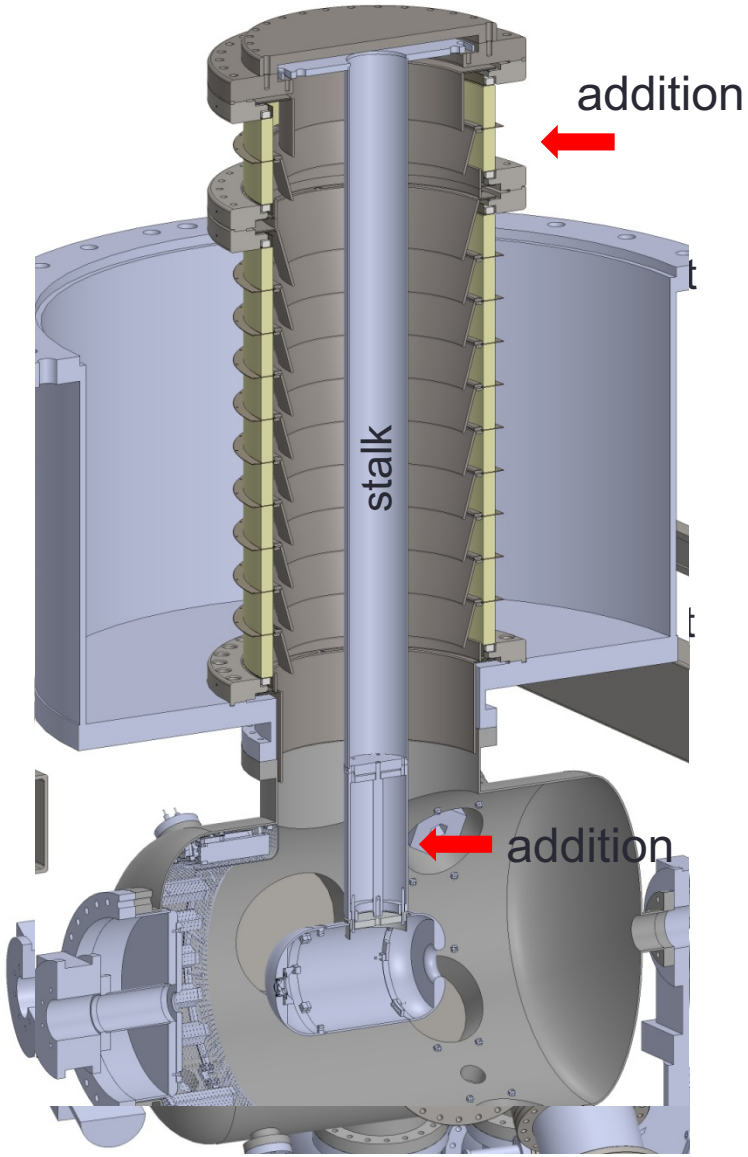
Dark lifetime of GaAs during 0.1 mA operation

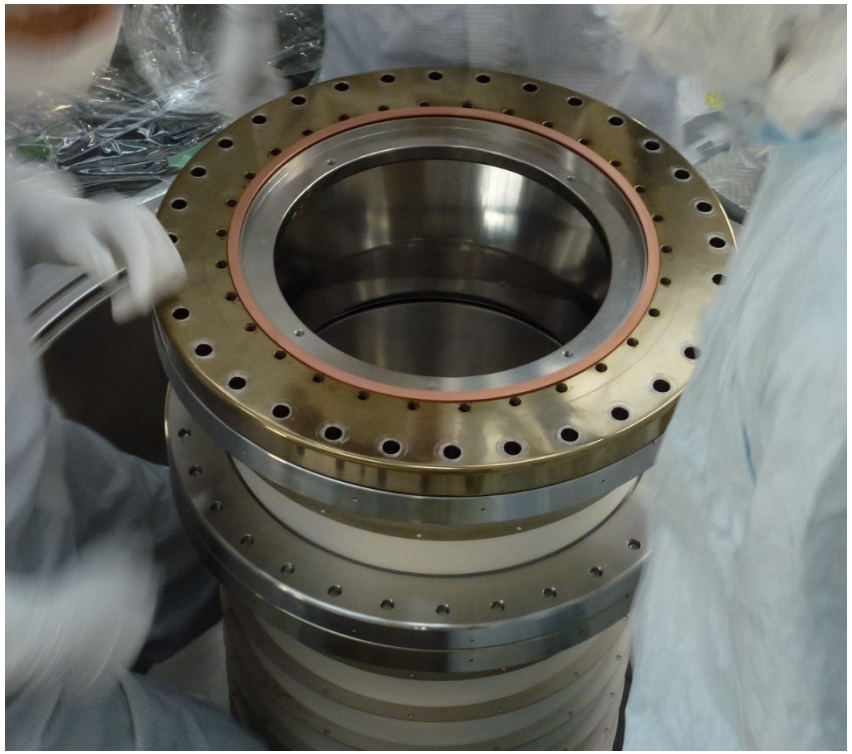






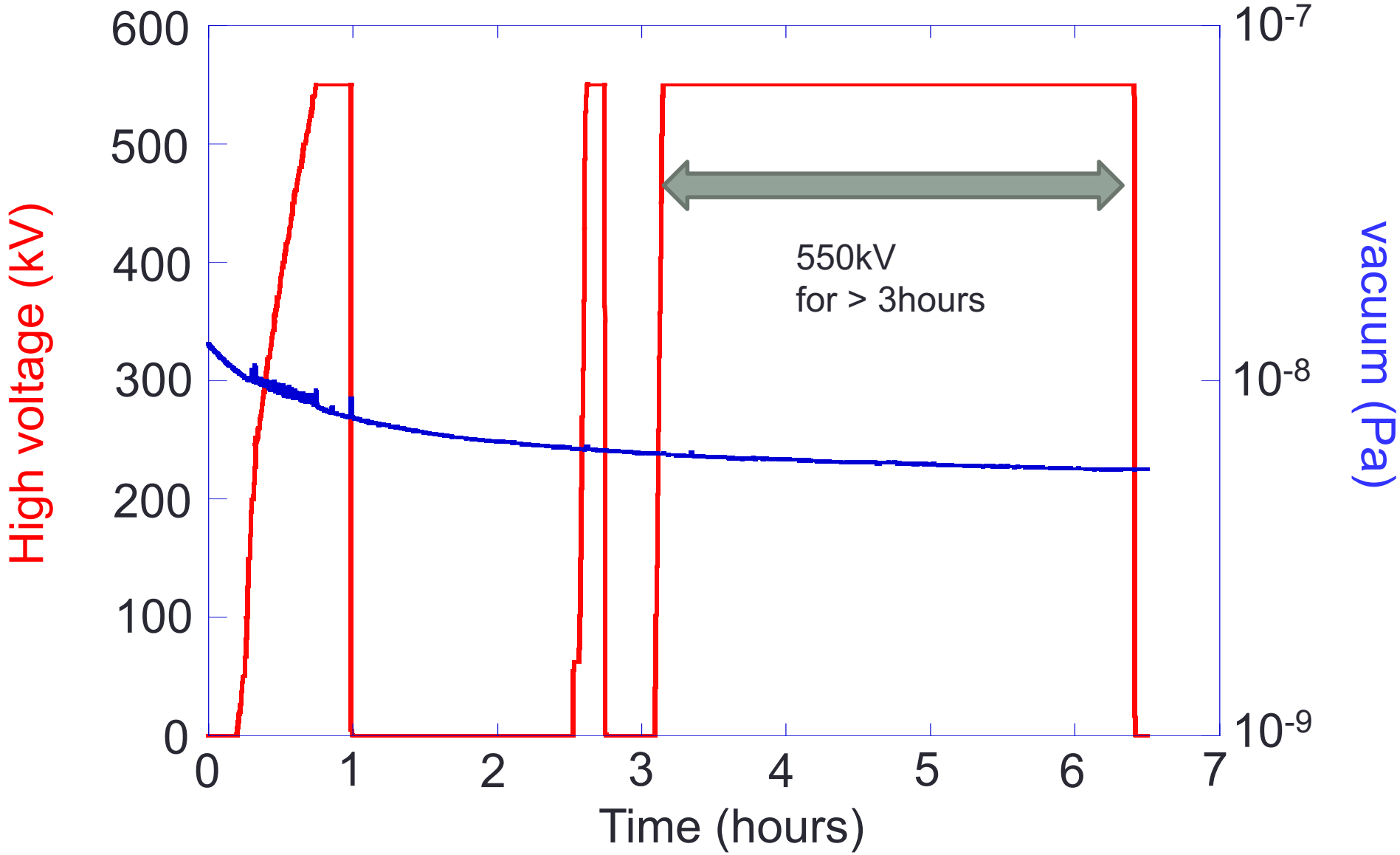
A Plan to 500kV operation at the cERL





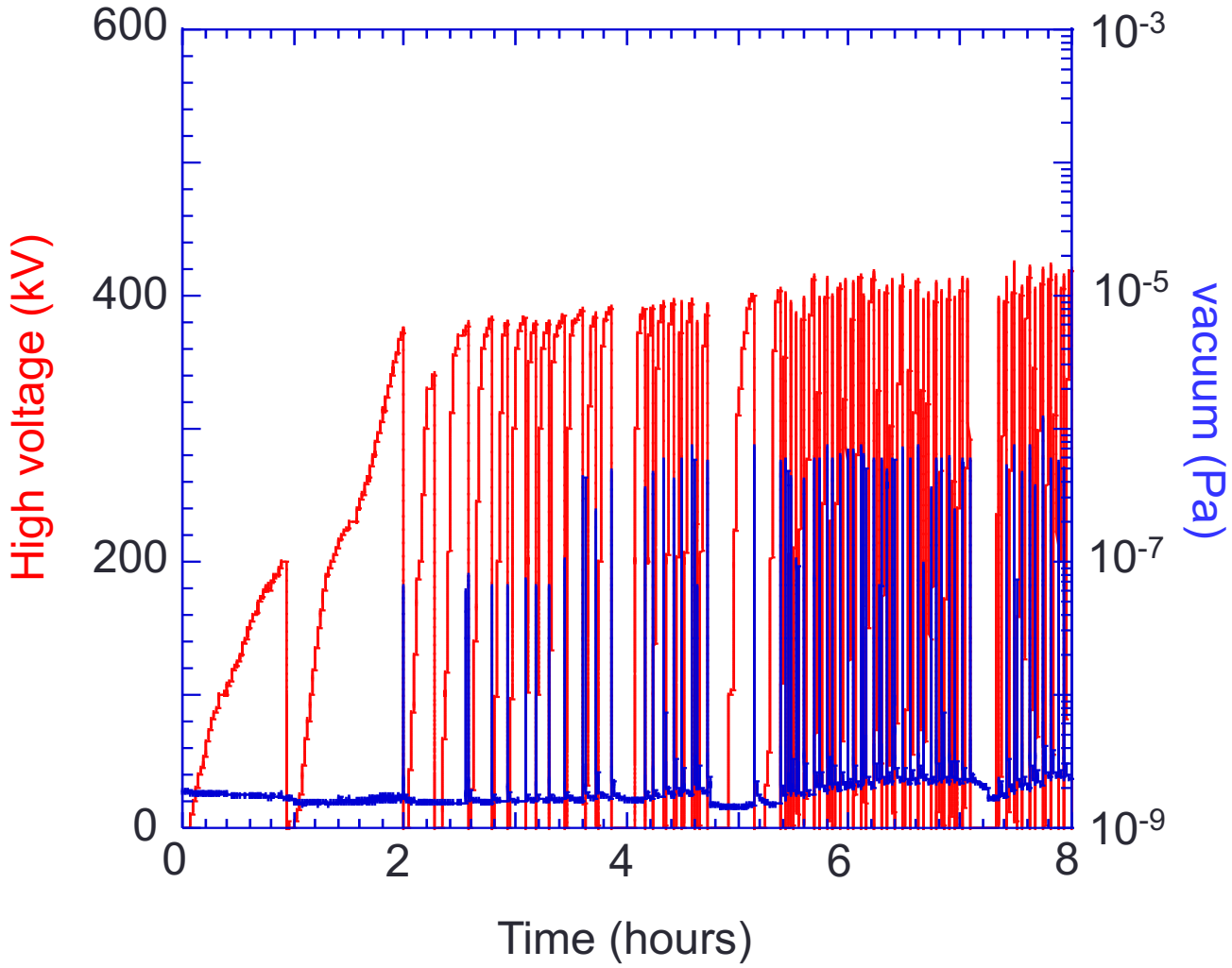
- ✓ Installed an additional ceramics in July 2015
- ✓ Performed HV test up to 550 kV without stalk
- ✓ Installed a cathode electrode in Nov. 2015
- ✓ Performed HV test with cathode electrode in Dec. 2015
- ✓ Performed beam generation in Feb. 2016

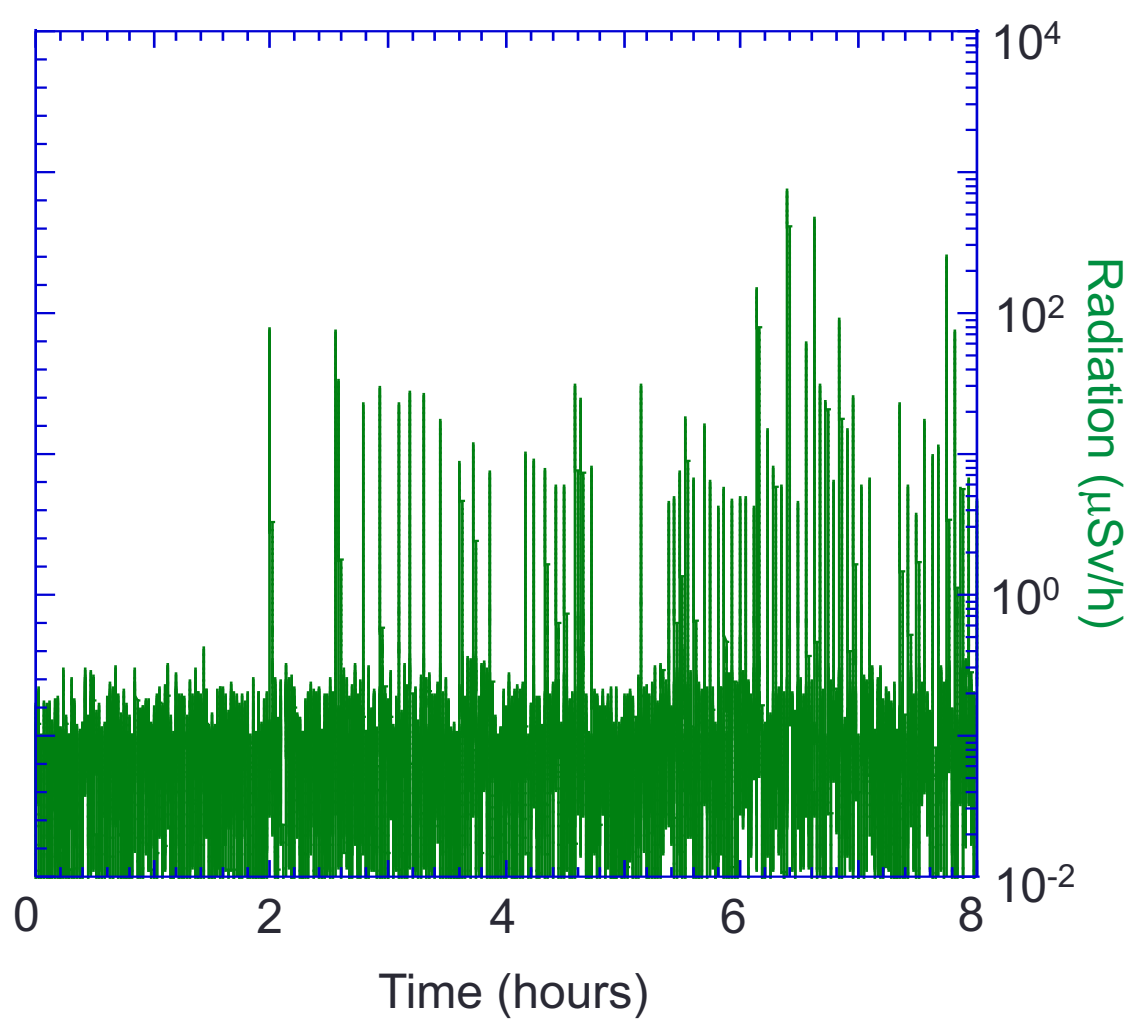
HV test with the additional insulator without stalk



HV test with cathode electrode in place

Started HV conditioning on Nov. 26 2015 and observed discharge event around 400kV.
Reached 550kV after 150 hours conditioning.

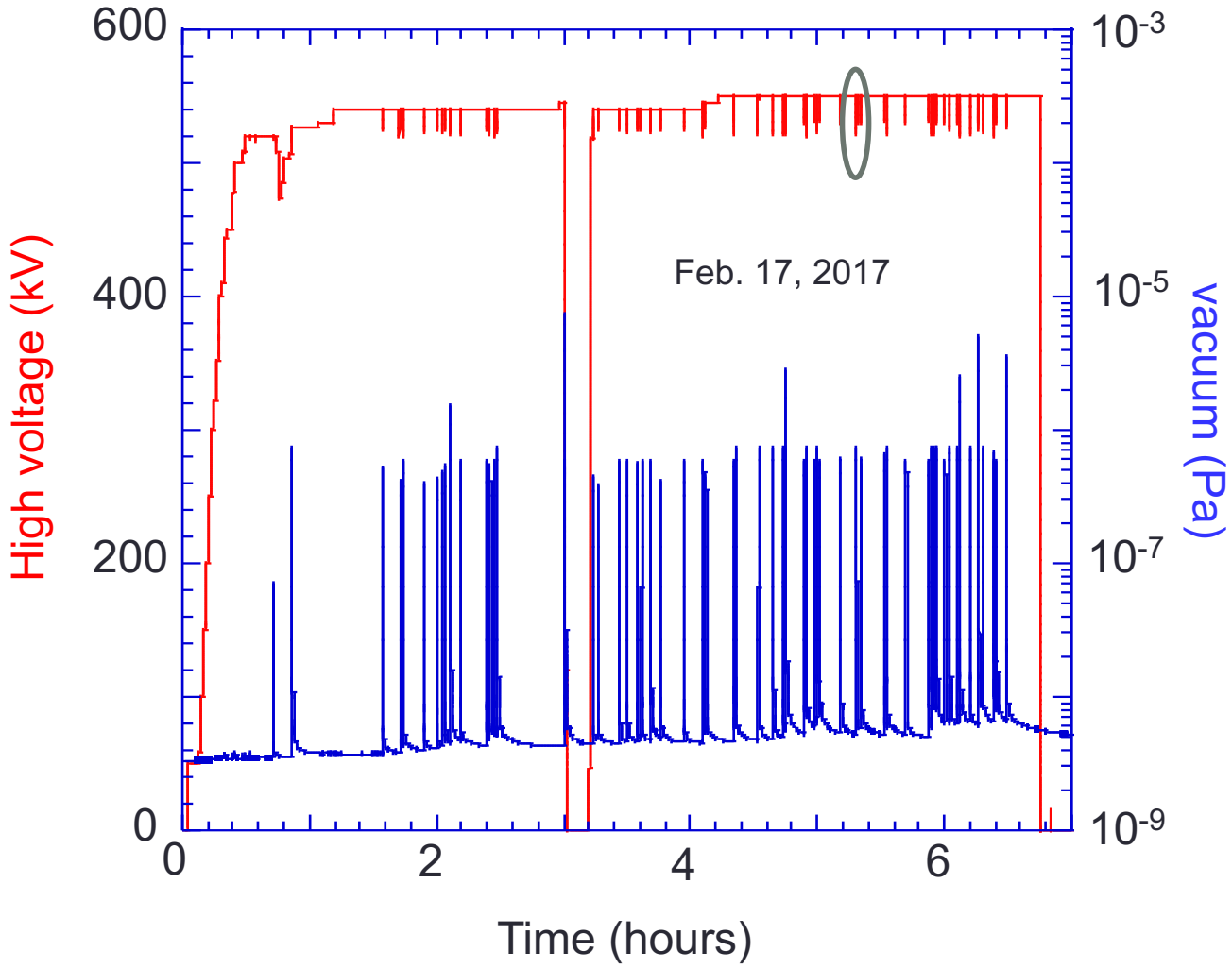


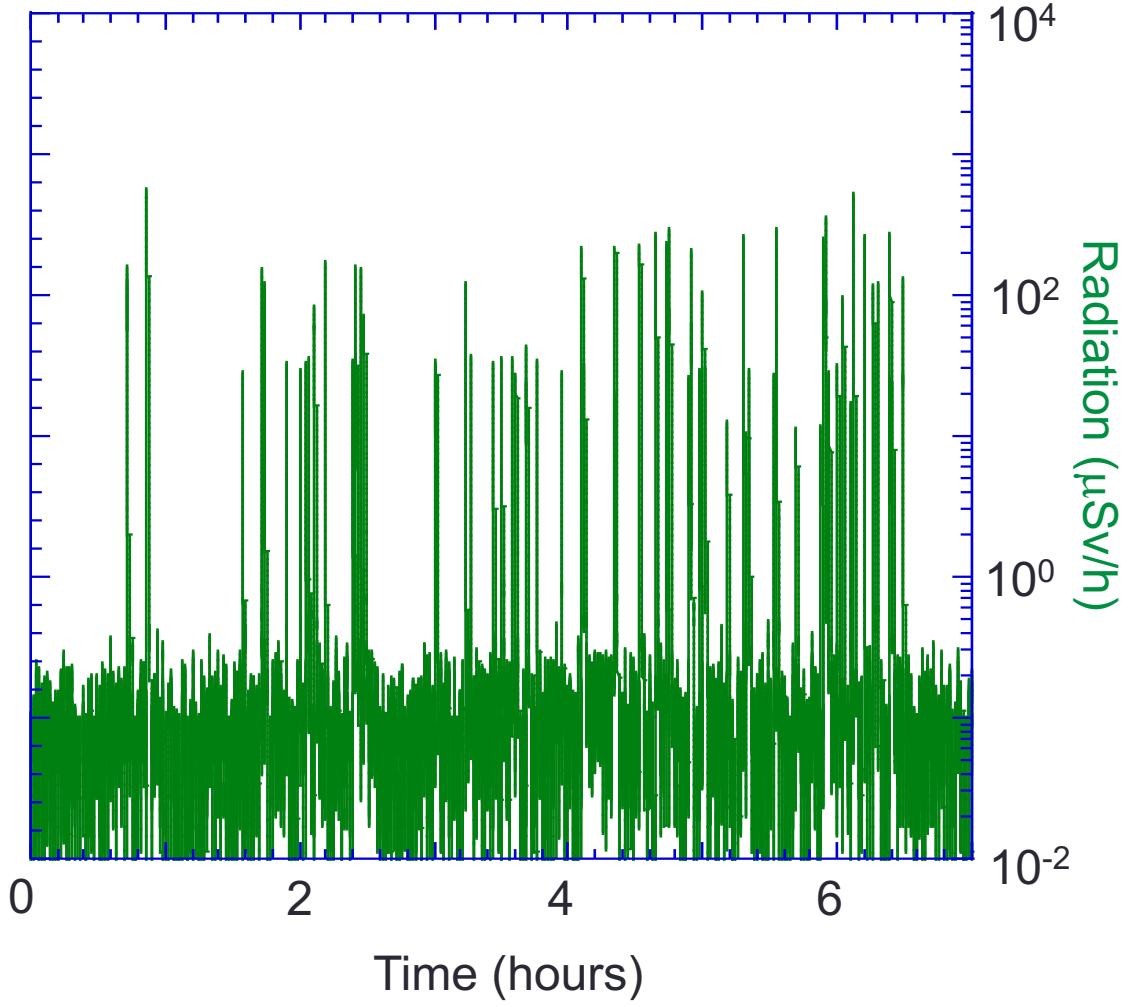


High voltage threshold for stable operation in a dc electron gun

Focused on discharge stop voltages

M. Yamamoto and N. Nishimori, APL 109, 014103 (2016)





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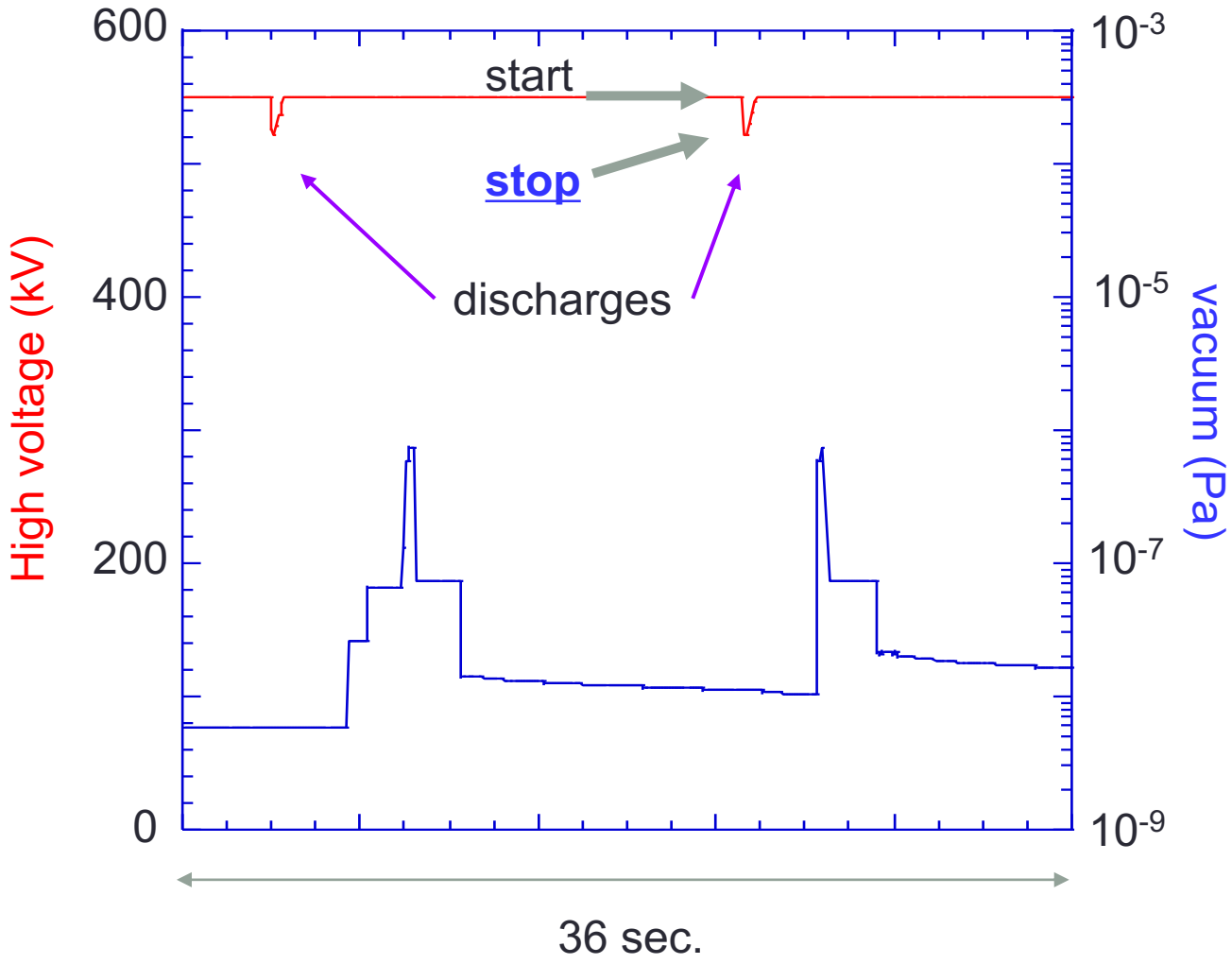

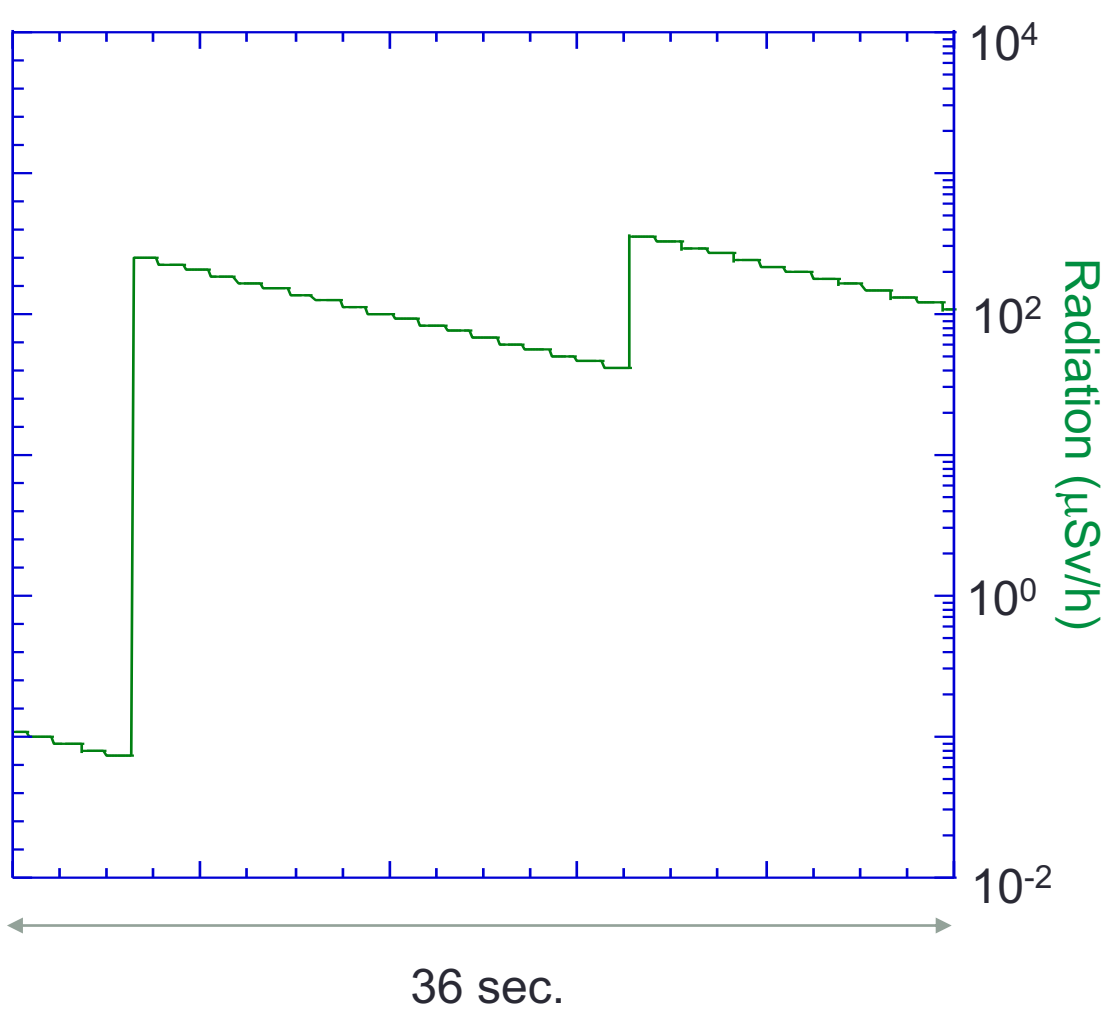

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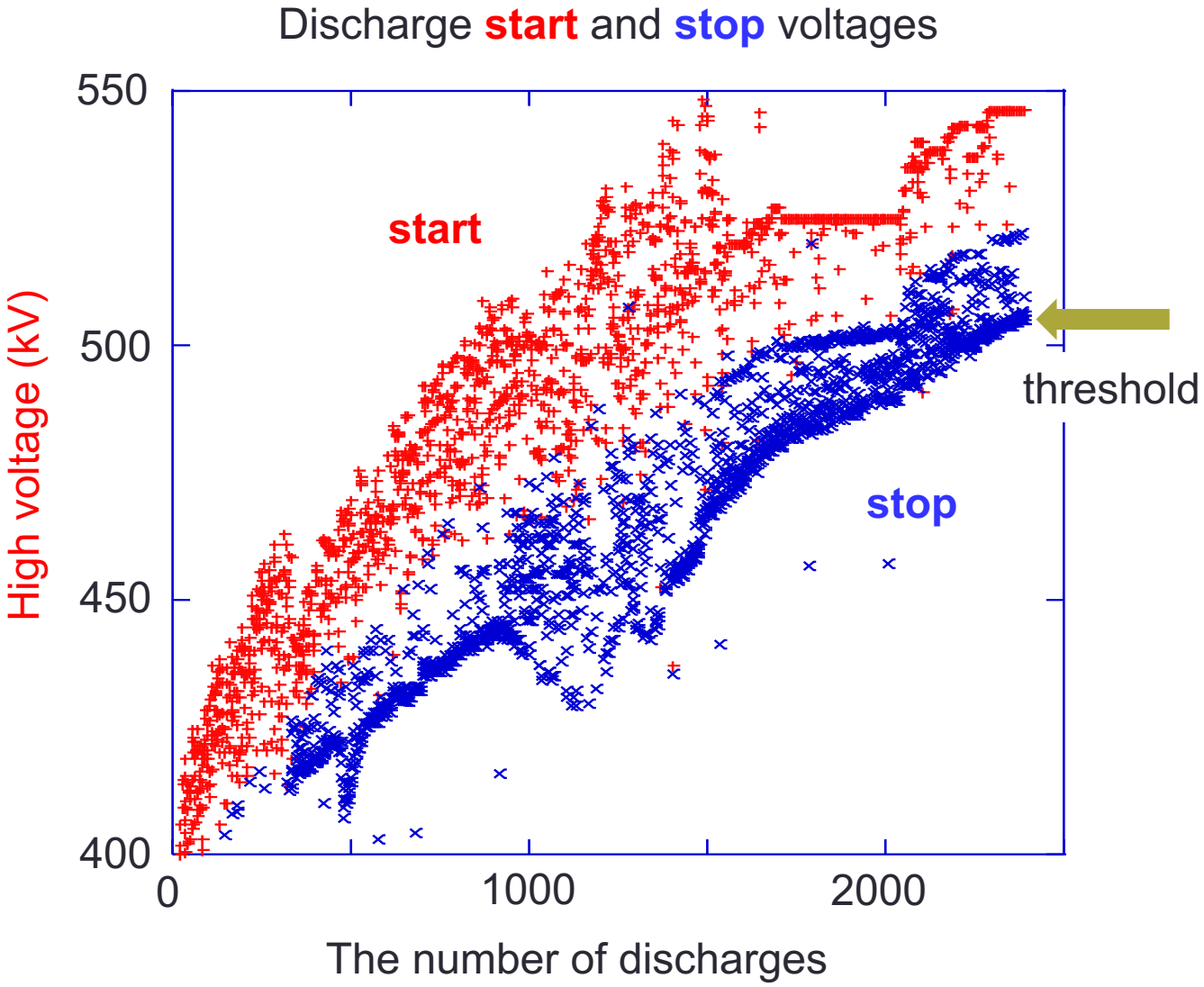
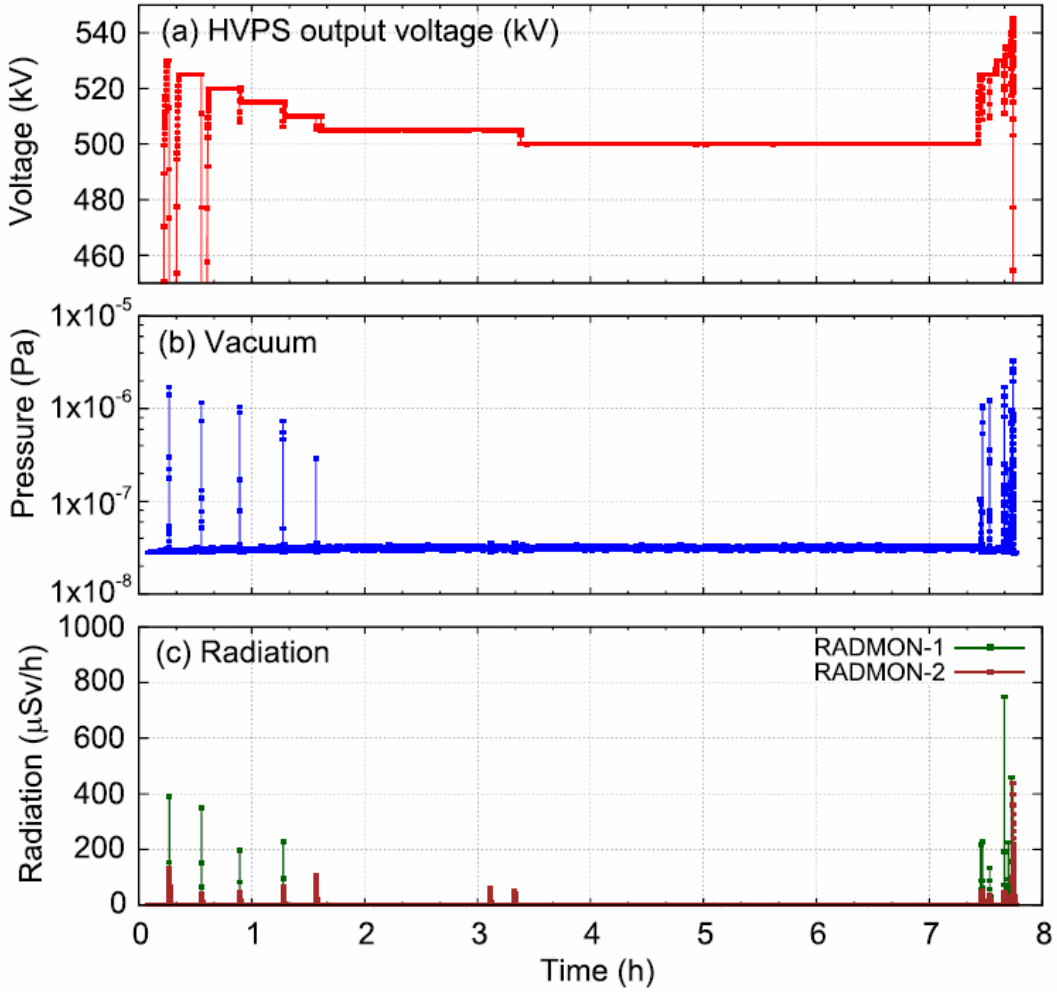


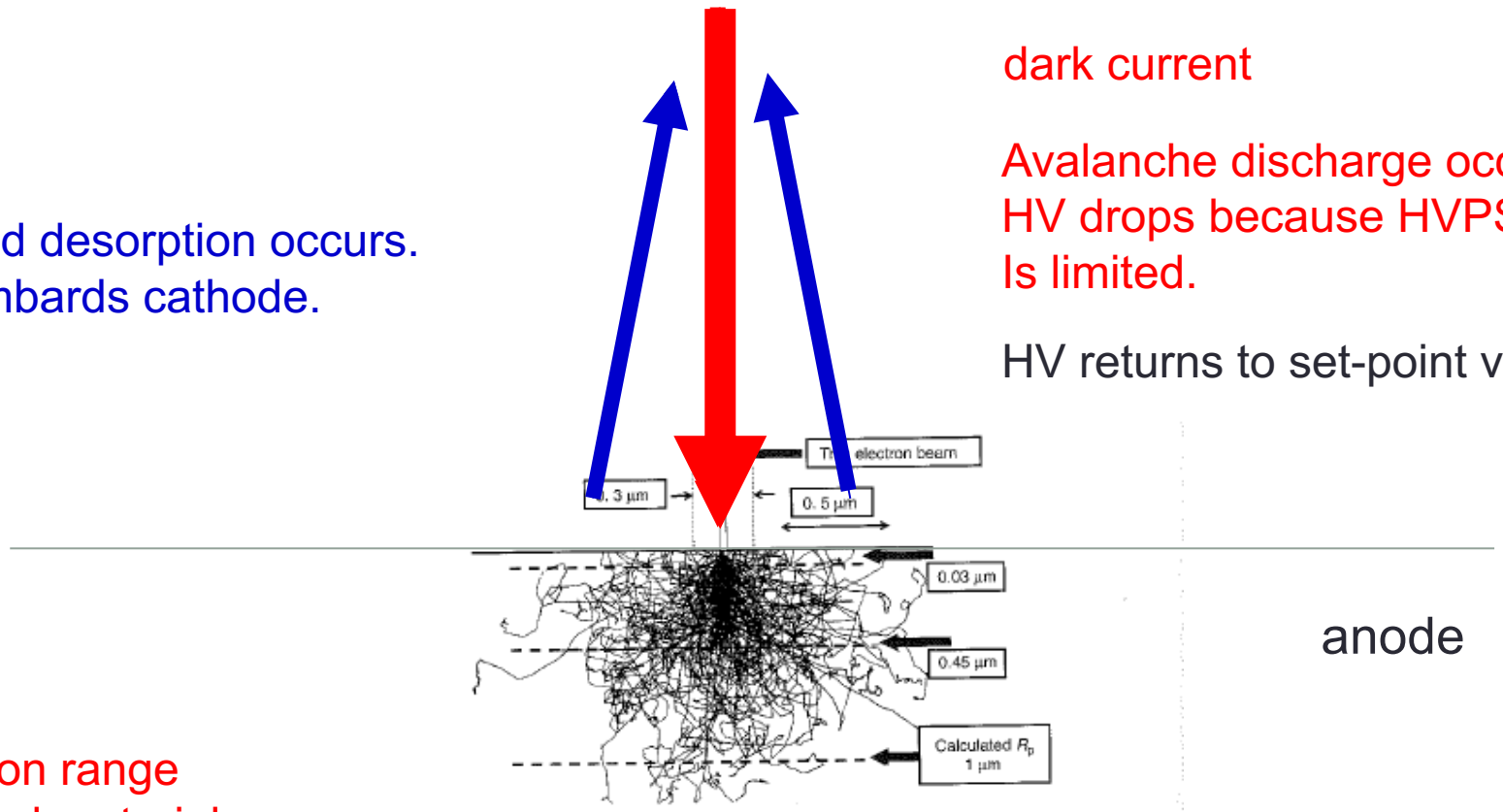


M. Yamamoto and N. Nishimori, APL 109, 014103 (2016)

Discharge mechanism

See poster for details M. Yamamoto and N. Nishimori at ERL17

cathode



anode

dark current

Avalanche discharge occurs.
HV drops because HVPS capacity
Is limited.

HV returns to set-point value.

Electron stimulated desorption occurs.
Fractional ion bombards cathode.

Electron penetration range
depends on HV and material

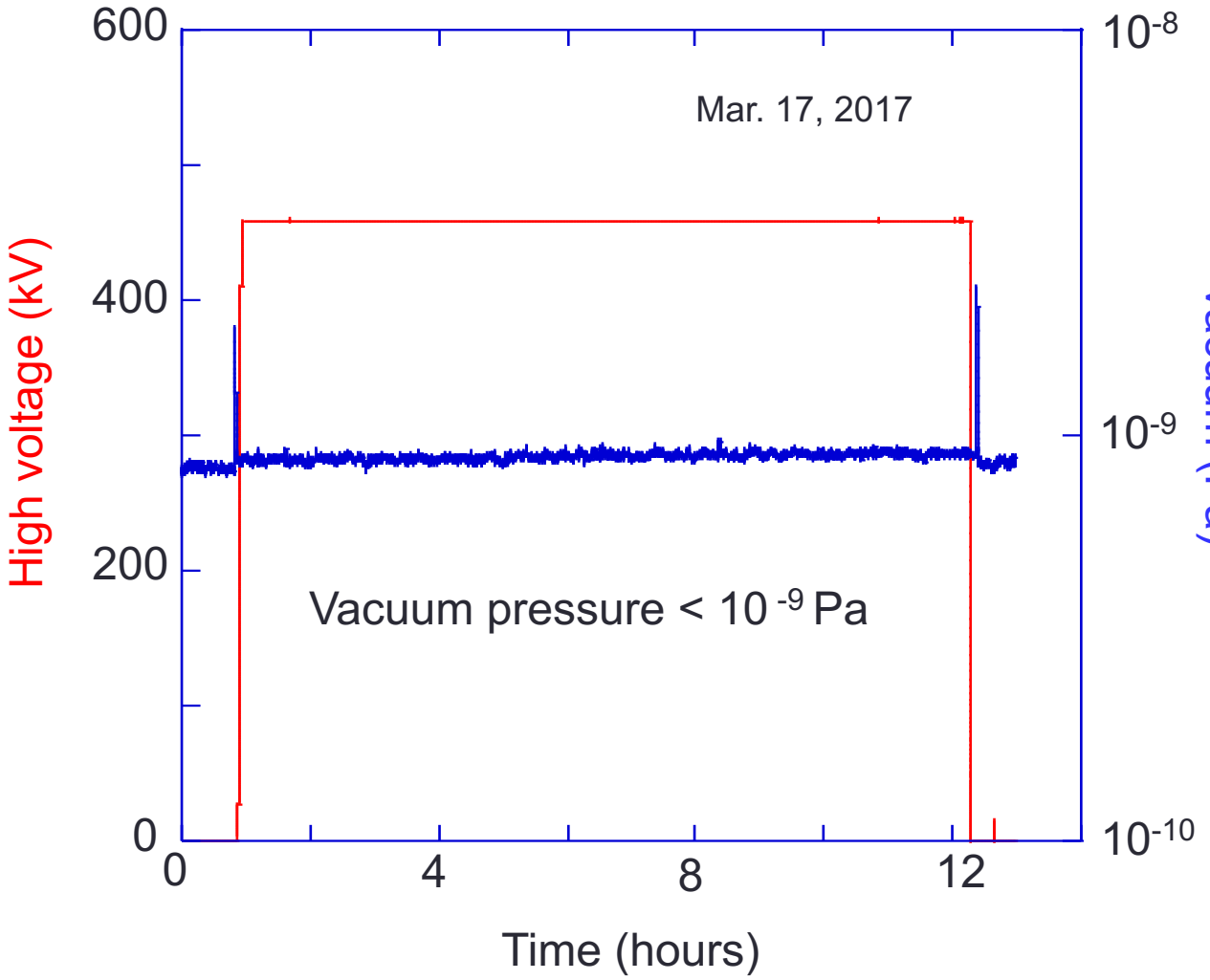
FIGURE 1.49 Monte-Carlo simulation of a thin, 20 keV electron beam at normal incidence on to an Fe anode [84].

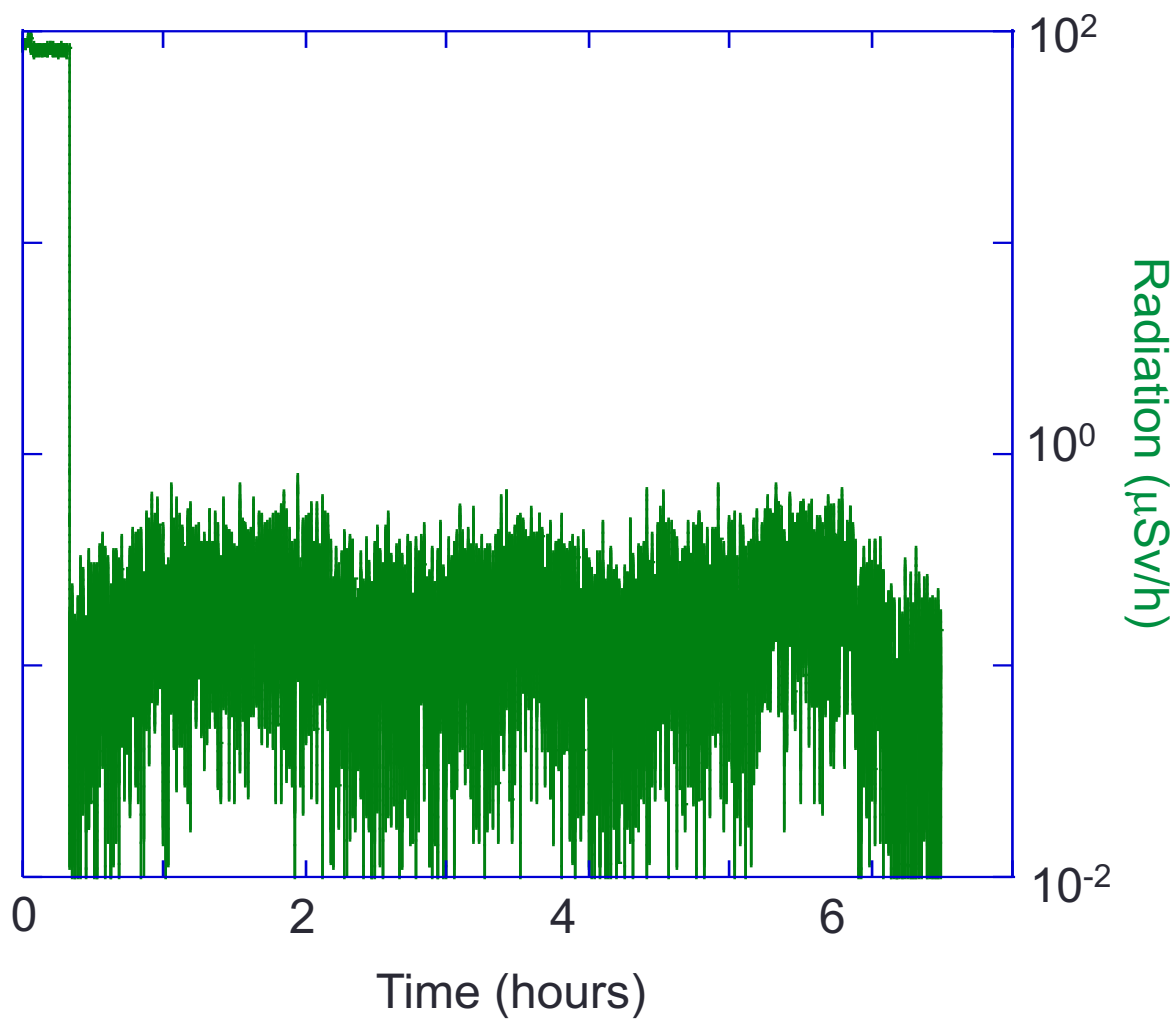
URE 1.49 Monte-Carlo simulation of a thin, 20 keV electron beam at normal incidence on t
de [84].

P. G. Slade “The Vacuum Interrupter” CRC press 2008

450kV operation for high bunch charge mode

140 hours operated at 450 kV without any trouble in Mar. 2017.



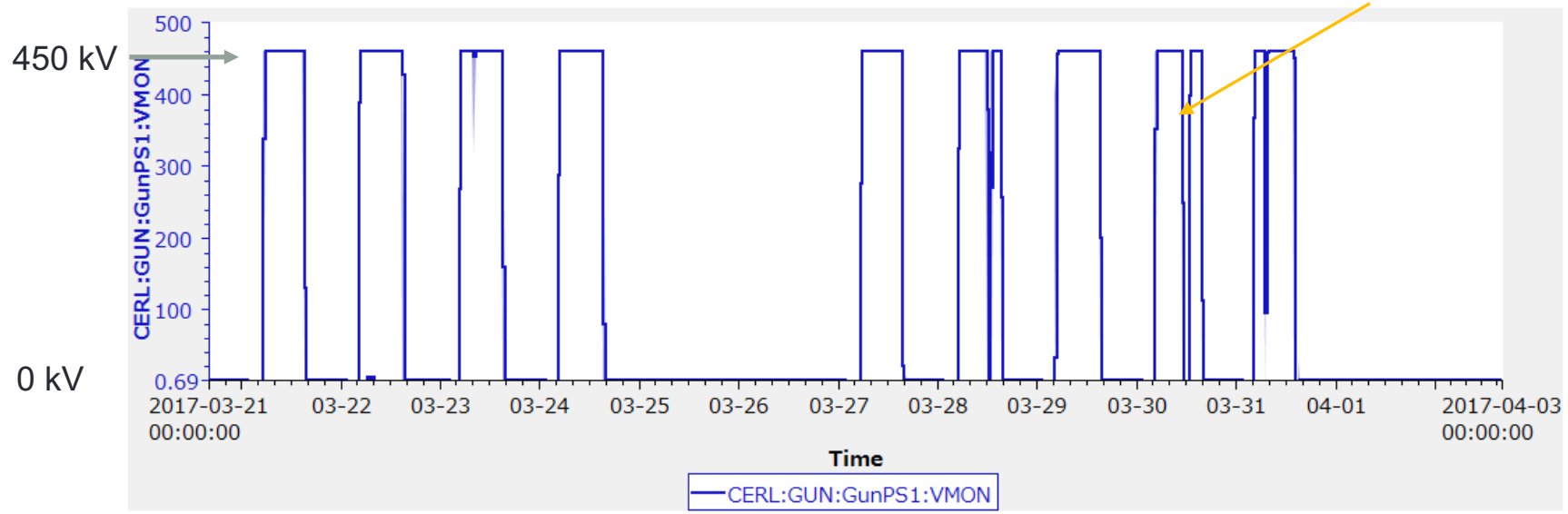


Gun operational status for two weeks

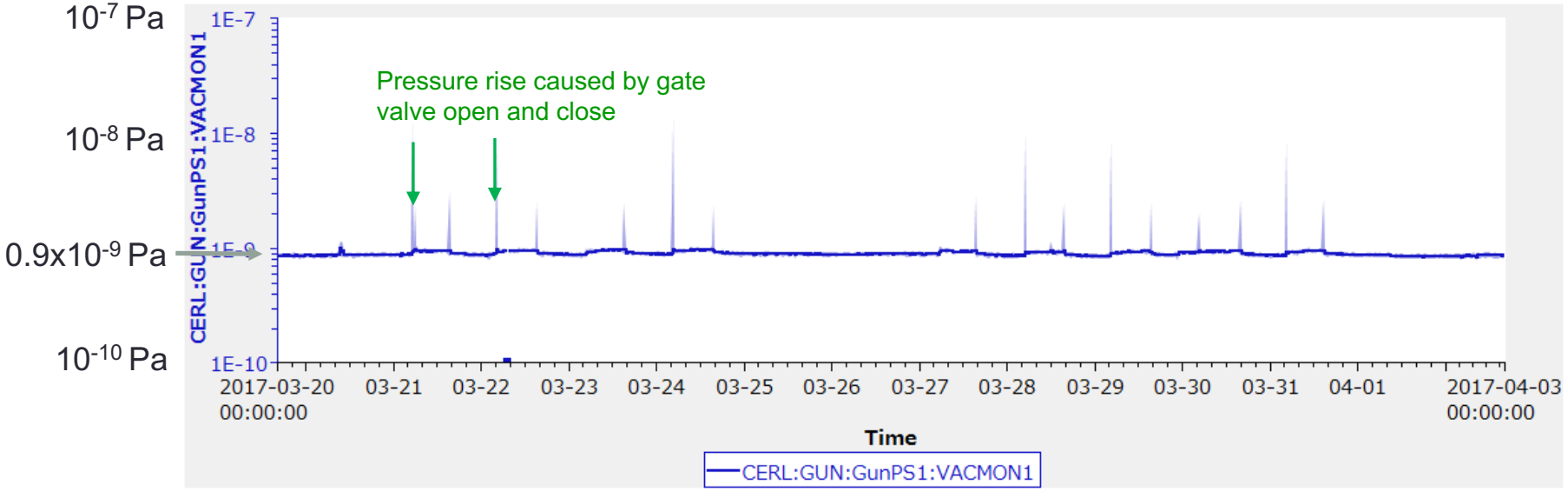
Cathode voltage

Stable operation

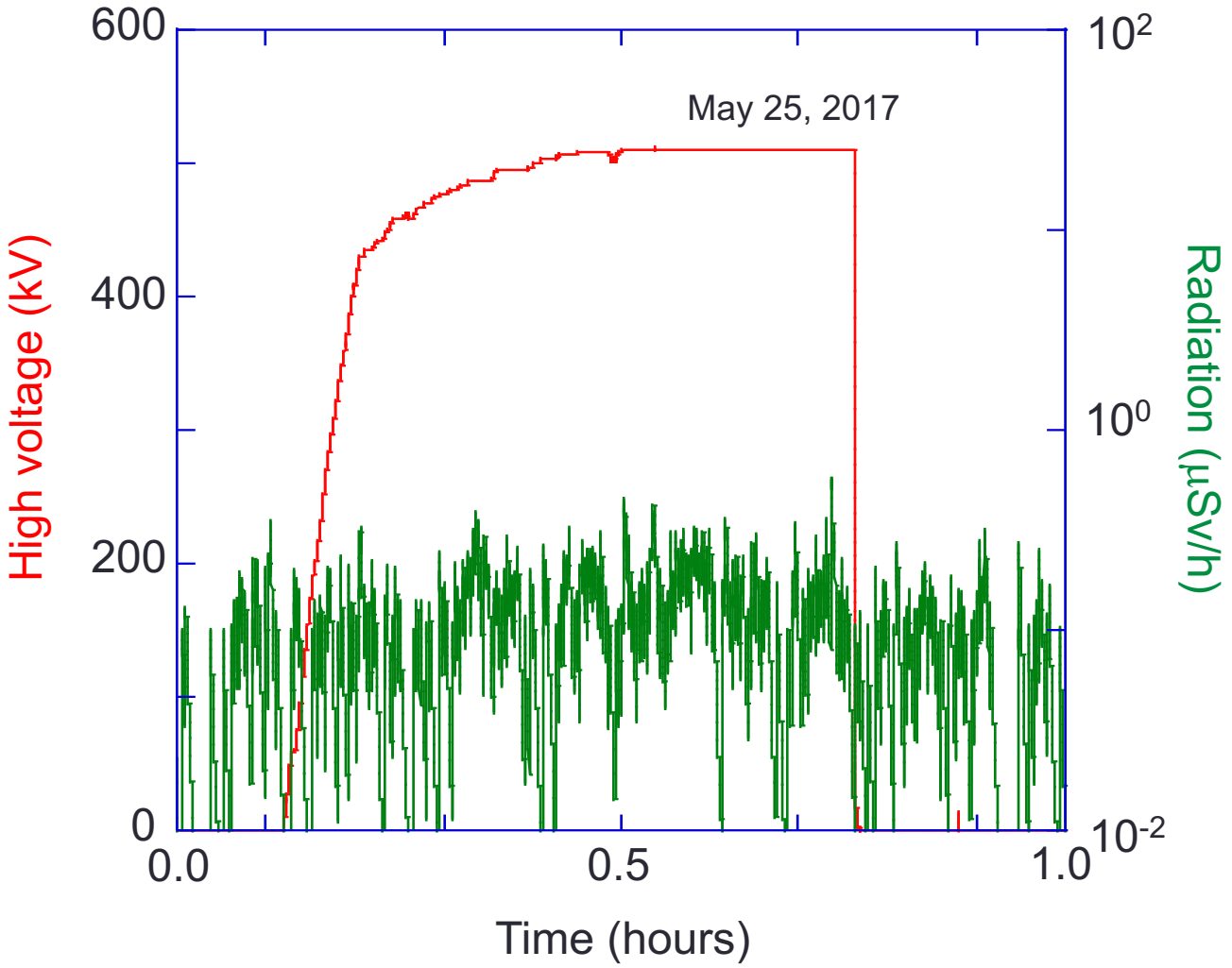
Interruption to enter the acceleration hall



Vacuum pressure



Preparation for 500kV operation



- Why 450 kV ?
- Because dark current from GaAs puck was observed above 450 kV.
- We recently replaced the GaAs wafer with new one and obtained good result.
- Radation is background level.
- We will perform beam test at 500 kV in July

Summary

✓ Delivered 390keV beam stably for more than 4 years at the cERL.
✓ Delivered 1mA-390keV beam with extraction charge > 30 C from GaAs cathode.
✓ Successfully installed an additional ceramic insulator.
✓ Performed high voltage conditioning upto 550 kV.
✓ Found high voltage threshold for stable operation in a dc electron gun.
✓ Delivered 450keV beam stably for more than 140 hours.

Future work

- Perform 500 kV operation at the cERL

Acknowledgement
This work is partially supported by
JSPS Grants-in-Aid for Scientific Research in Japan (15H03594,16K05385).