Development of an electron gun for an ERL based light source in Japan

N. Nishimori, R. Nagai, H. Iijima, R. Hajima
Japan Atomic Energy Agency (JAEA)
Y. Honda, T. Muto
KEK
M. Kuriki
Hiroshima university
M. Yamamoto, S. Okumi, T. Nakanishi
Nagoya univiersity

Oct. 2, 2008.

Outline

- Introduction: future light sources
- Status of 250 kV 50 mA gun development
- Design of 500 kV 10 mA gun
- Summary

Photon Science resolves urgent issues of nuclear research and industry

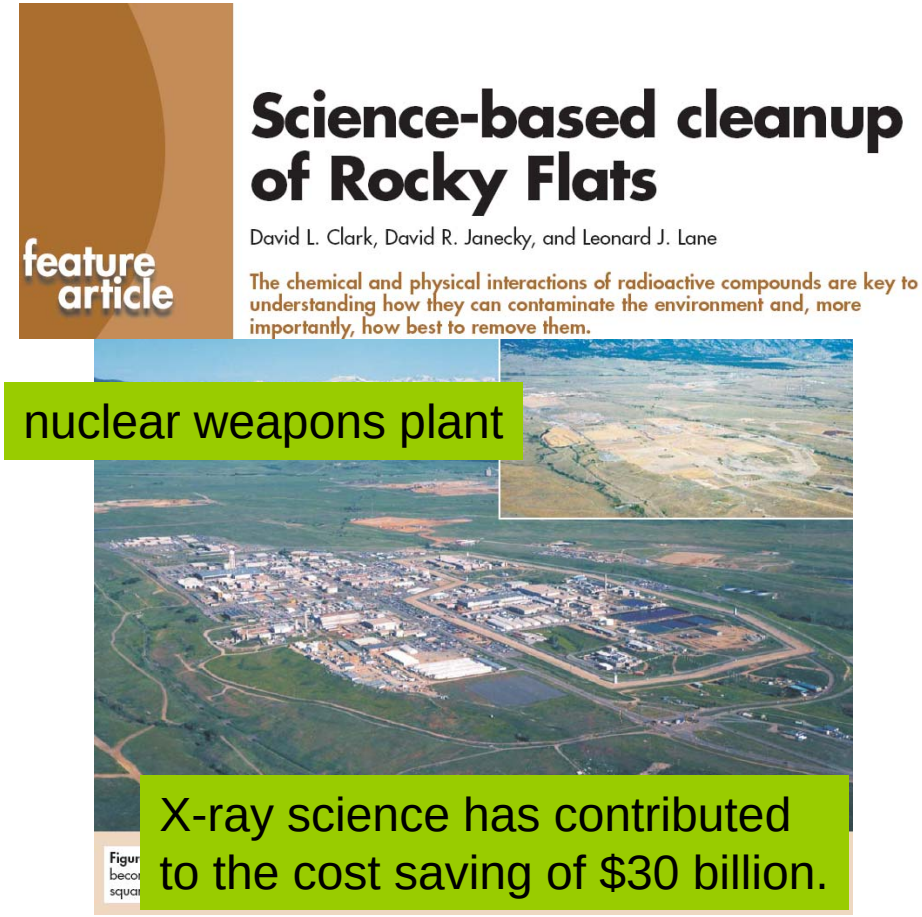
Radioactive waste in JAEA

cleanup of all the waste in JAEA costs $20 billion and 80 years.

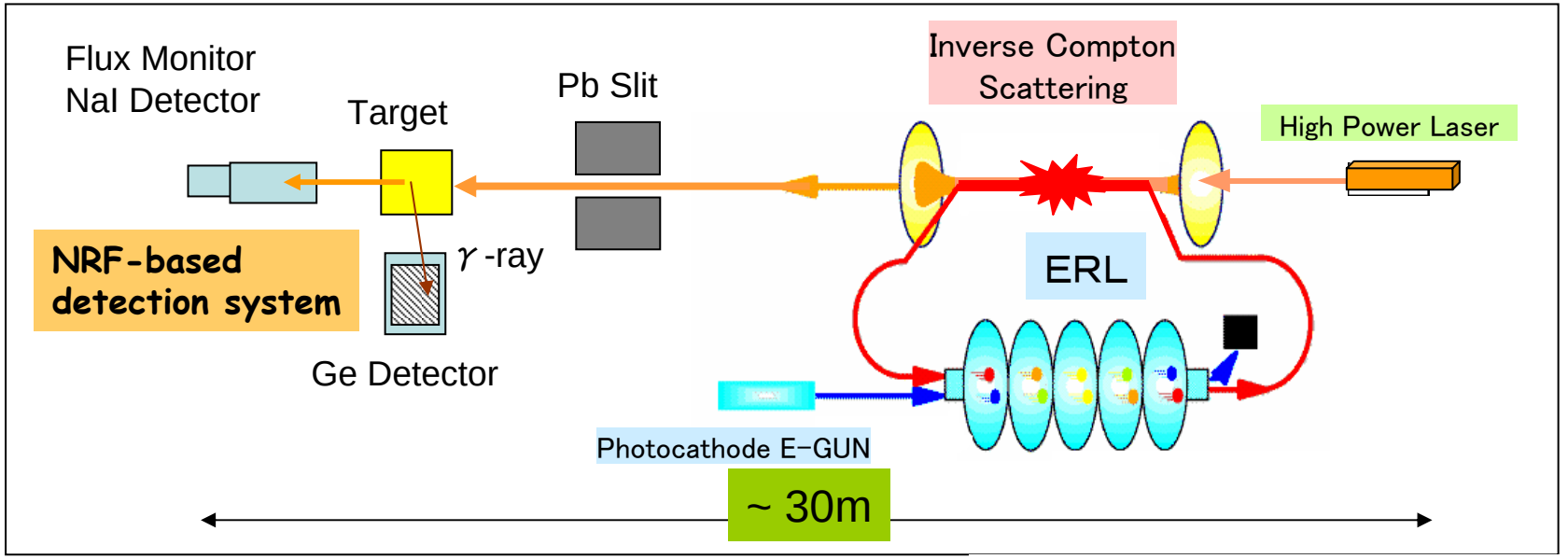
⇩

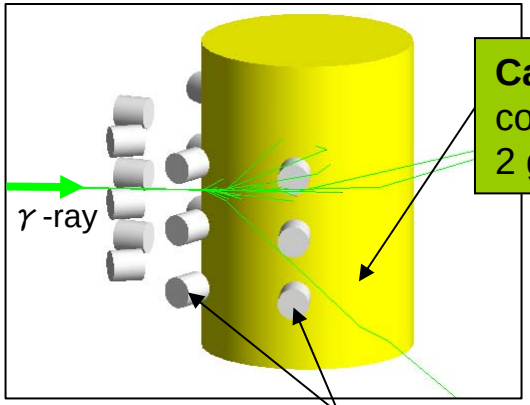
the most urgent issue !

Physics Today, Sep. 2006.



Concept of a high-flux γ-ray source



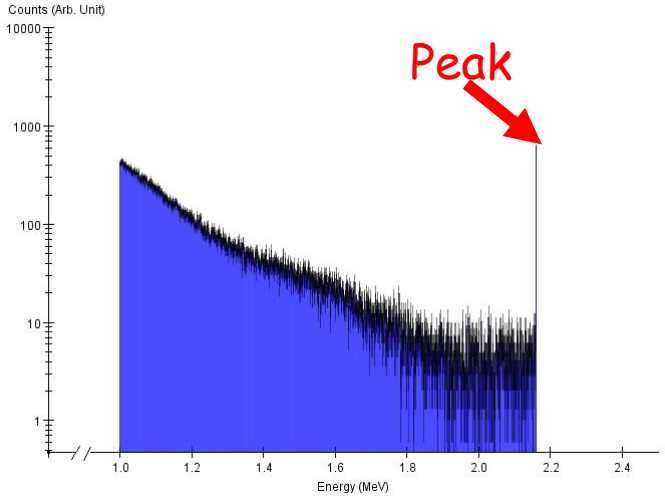


Cask for radioactive waste
concrete + U238
2 g/cm^3 , 1000 Bq/g

N_γ=1x10^9/keV

Ge Detector
ϕ 8.4cm, L=8.6cm

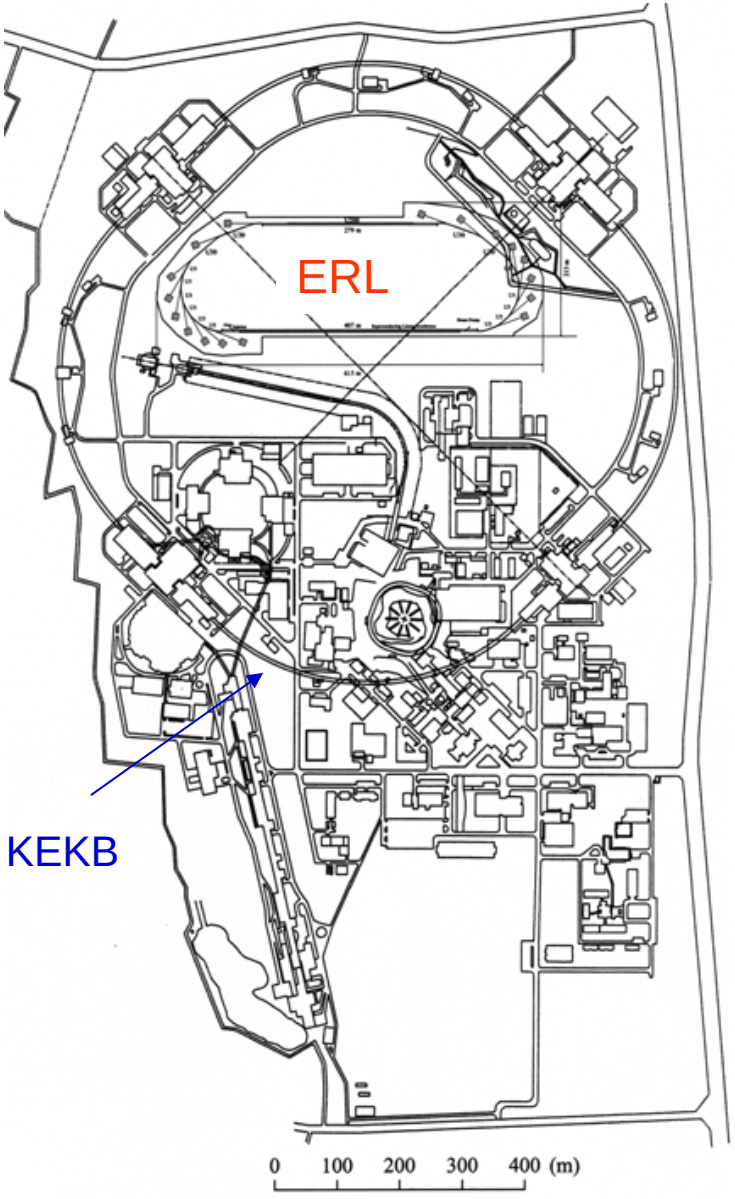
Detection time ~ 0.1 sec.



σ_{NRF} = 28 mbarn·keV @ 2.17MeV

R. Hajima et al., J. Nucl. Sci. and Tech. 45, 441 (2008).

5-GeV ERL plan at KEK



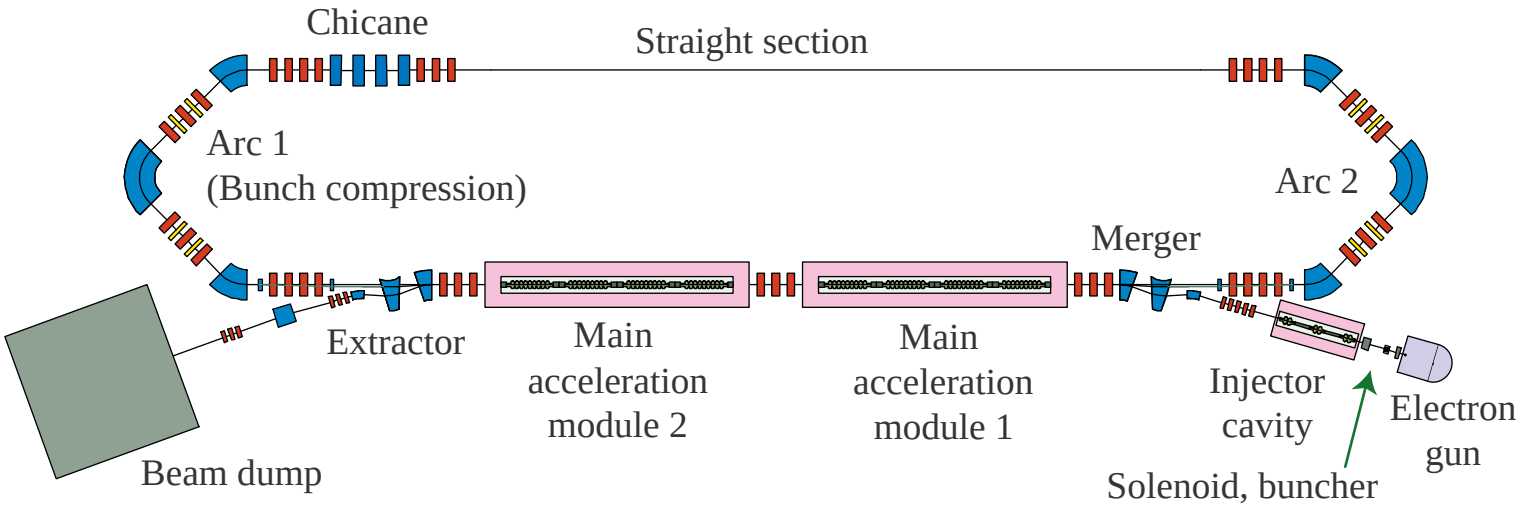
Parameters of the ERL

	Parameter
Beam energy	5 GeV
Average current	10 - 100 mA
Normalized emittance (rms)	0.1 - 1 mm·mrad
Energy spread (rms)	(0.5 - 2) $\times 10^{-4}$
Bunch length (rms)	1 - 3 ps (usual mode) ~ 100 fs (bunch compression)
RF frequency	1.3 GHz

Parameters of the light sources

	Parameter
Spectral range	30 eV - 30 keV
Average brilliance from insertion devices	10^{21} - 10^{23} ph/s/mm^2/mrad^2/0.1%bw
Average flux	> 10^{16} phs/s/0.1%bw
Number of ID's	20 - 30

Compact ERL (test facility)



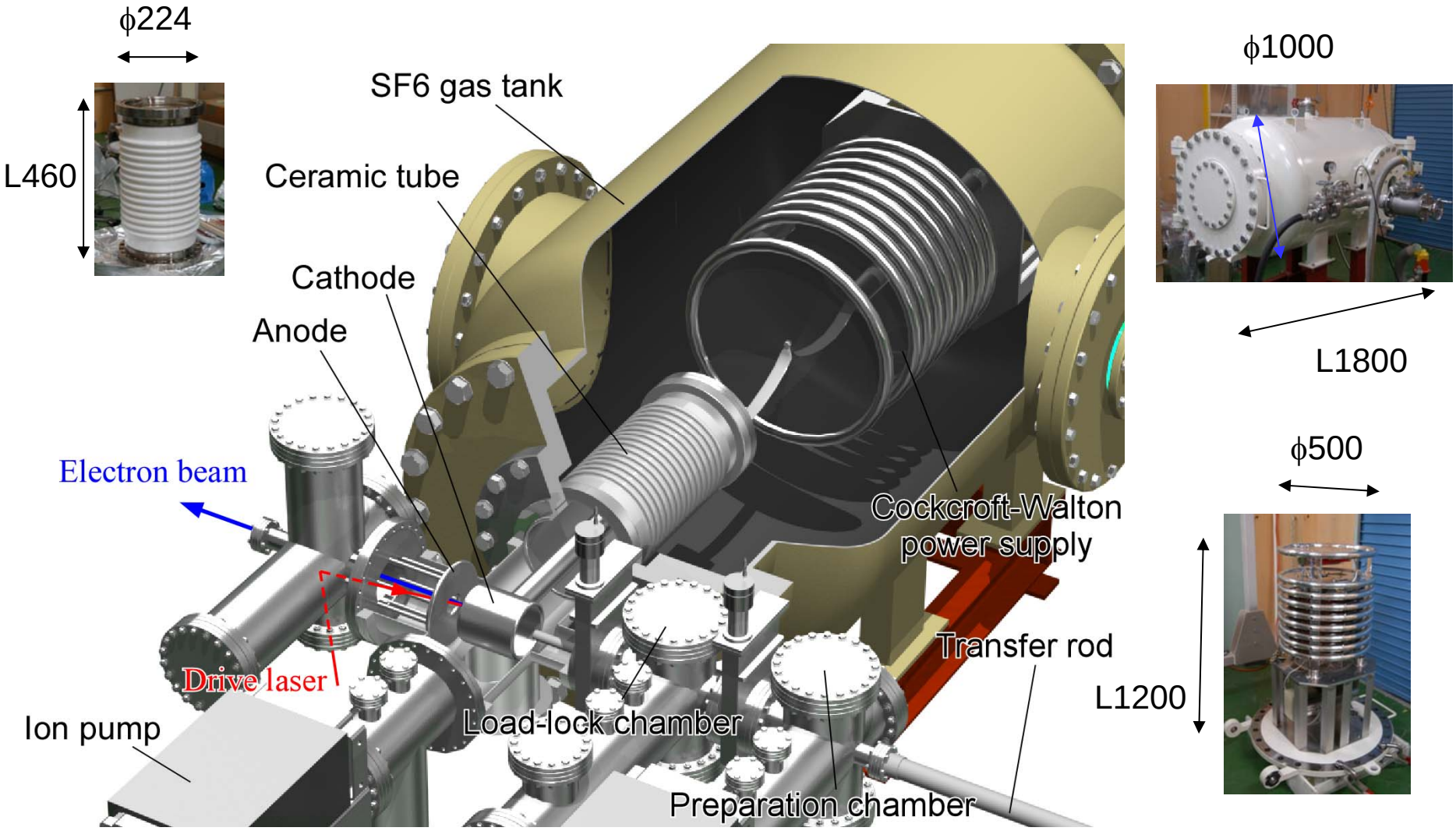
Principal parameters

Beam energy	60 – 85 MeV（max. 200 MeV）
Beam current	10 – 100 mA
Normalized emittance $\varepsilon_n = \varepsilon/(\gamma\beta)$	1 mm·mrad (77 pC/bunch) 0.1 mm·mrad (7.7 pC/bunch)
Energy spread（rms）	$< 3 \times 10^{-4}$
Bunch length (rms)	1 – 3 ps (non compress.) 100 fs (bunch compression) *

* With some emittance growth due to CSR

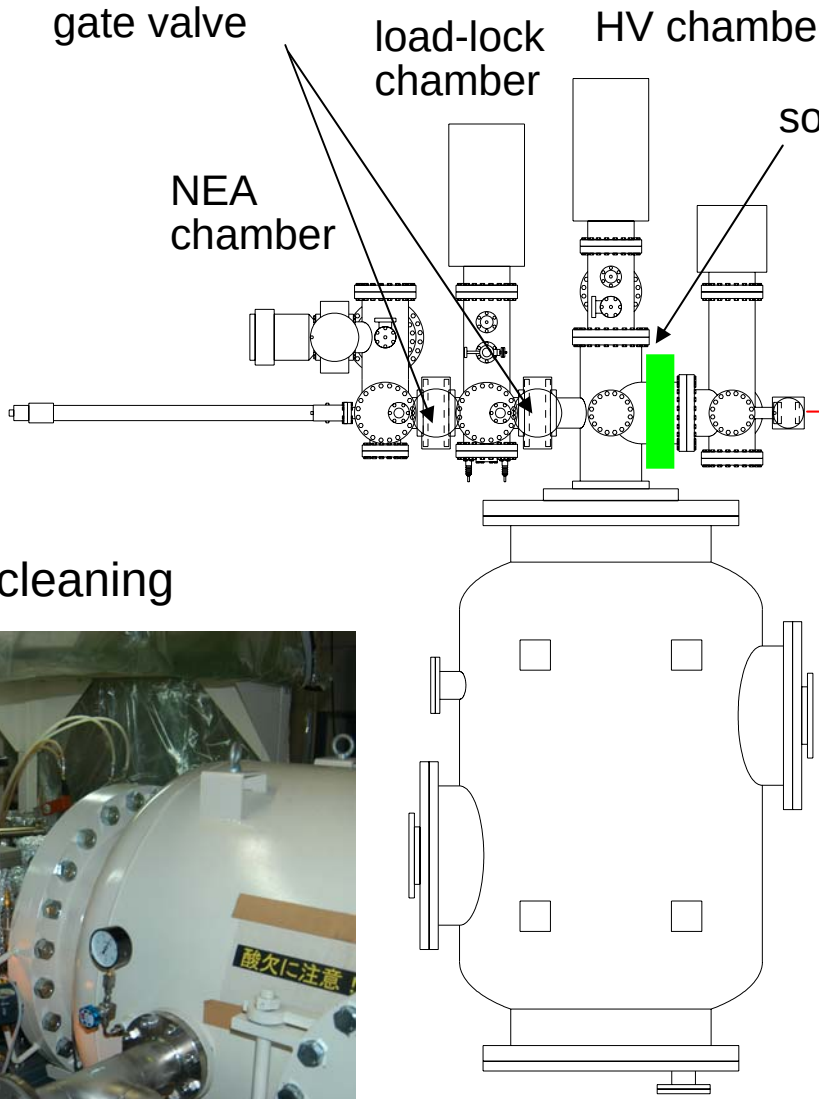
Conceptual design report:
KEK Report 2007-7/
JAEA-Research 2008-032

250kV prototype electron gun

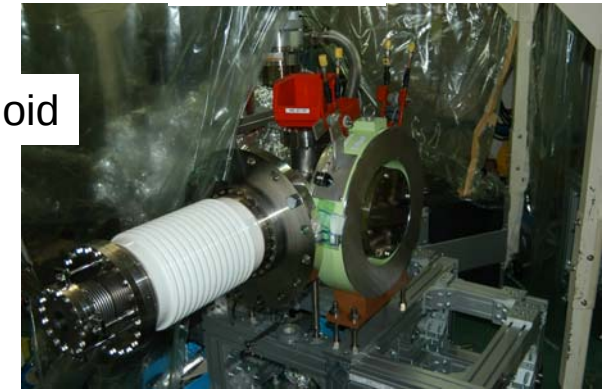


250kV max.
50mA max.

Schematic of a 250 kV-50mA DC gun



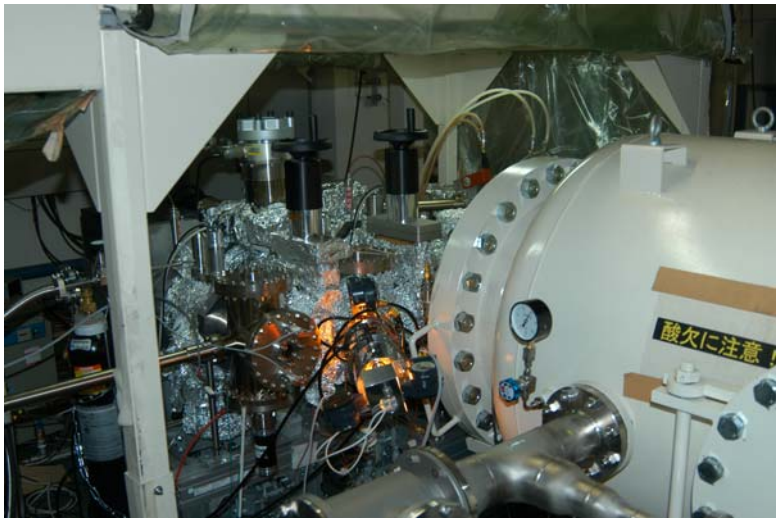
solenoid



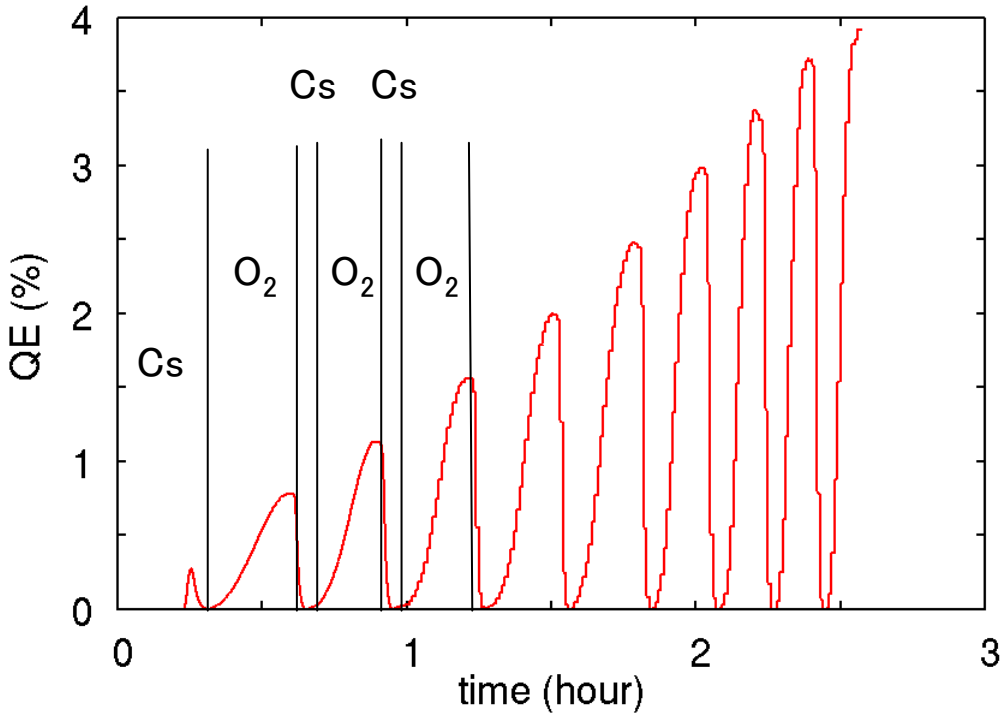
e-beam

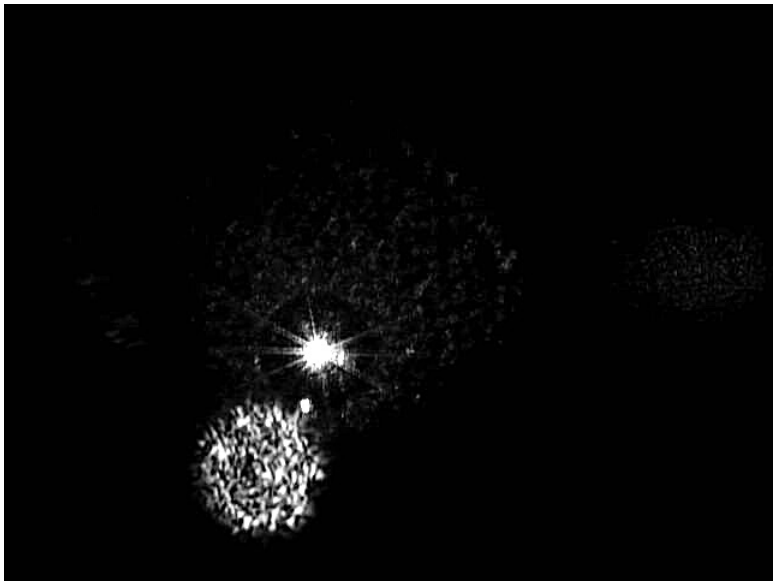
GaAs cathode

IR heater cleaning



NEA activation and beam generation

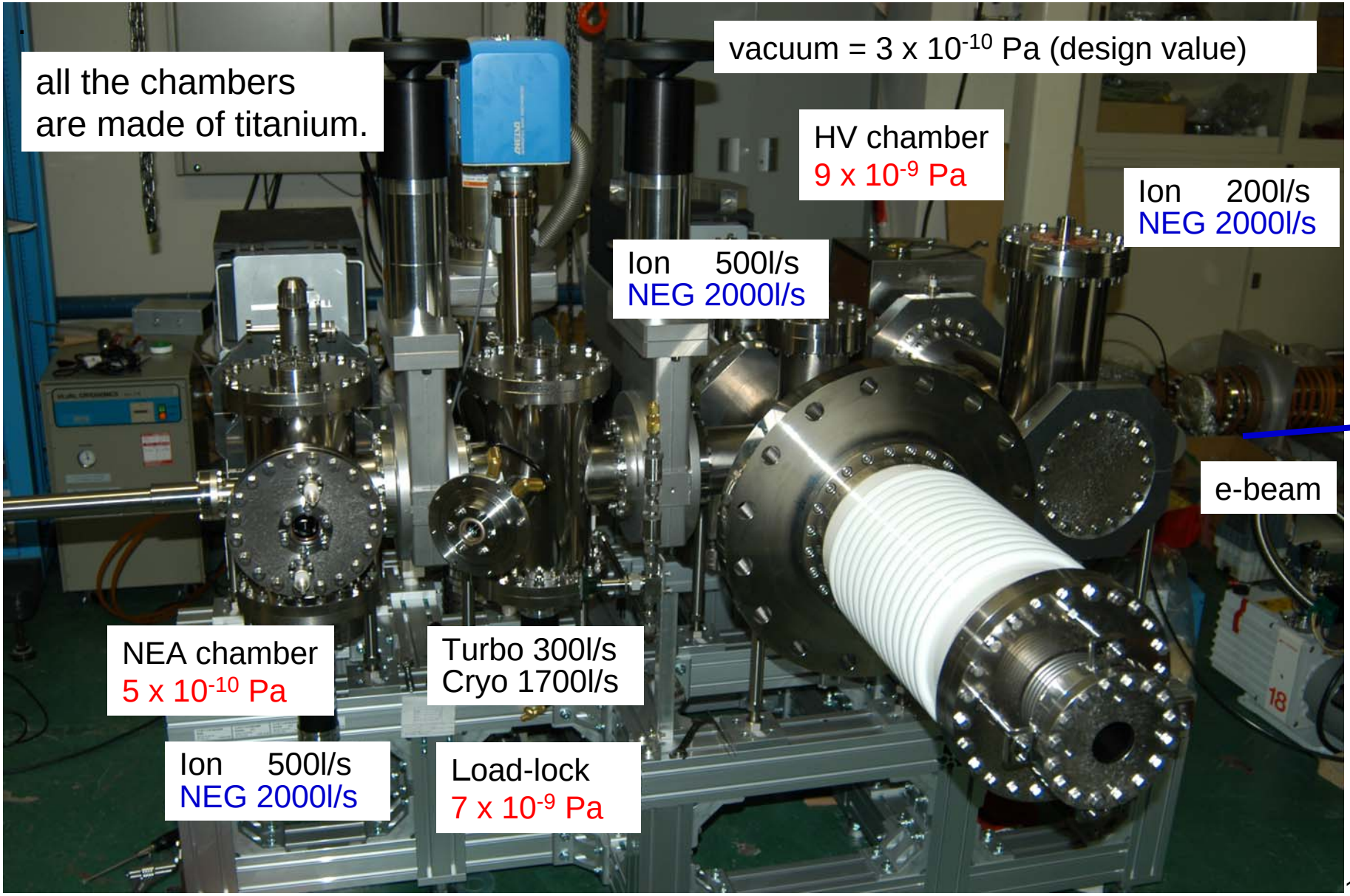




Generation of 150 kV、1μA beam
using He-Ne laser 2.4 mW.
Laser spot size is 1mm.

Ti:sapphire laser	Spectra-Physics Tsunami
Wavelength	780nm
Repetition rate	83.3MHz
Average power	500mW
Bunch length	2ps

Gun vacuum

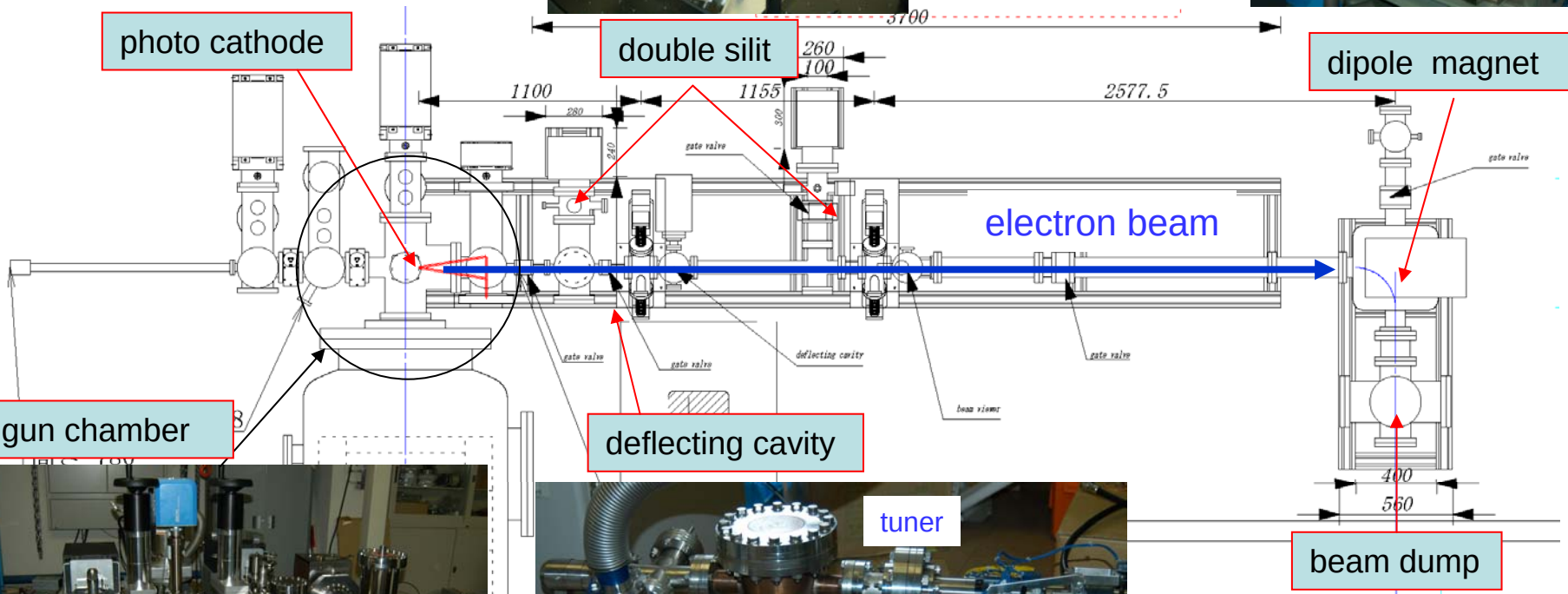

all the chambers
are made of titanium.
vacuum = 3 x 10-10 Pa (design value)
HV chamber
9 x 10-9 Pa
Ion 200l/s
NEG 2000l/s
Ion 500l/s
NEG 2000l/s
e-beam
NEA chamber
5 x 10-10 Pa
Turbo 300l/s
Cryo 1700l/s
Ion 500l/s
NEG 2000l/s
Load-lock
7 x 10-9 Pa

Diagnostic beam line for prototype gun

photo cathode

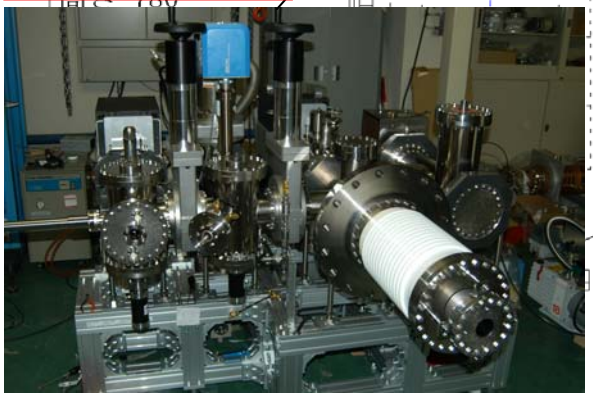
double silit

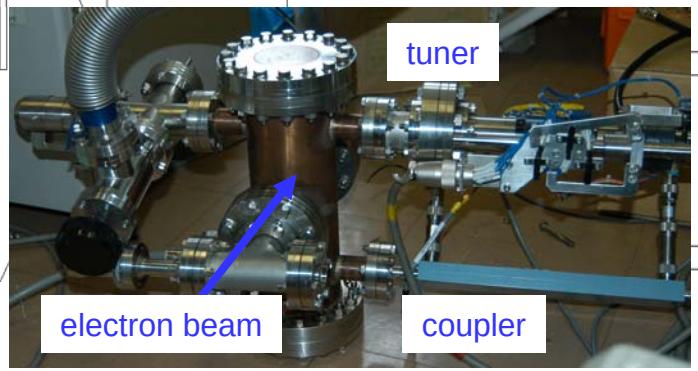
dipole magnet



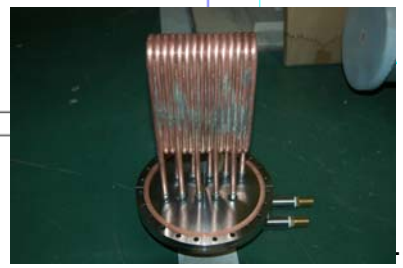
gun chamber

deflecting cavity

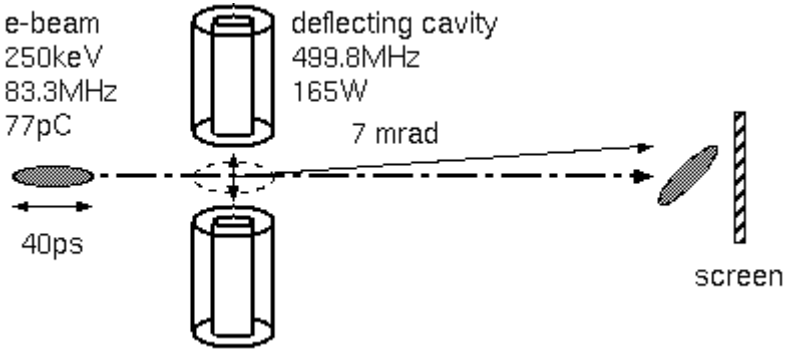


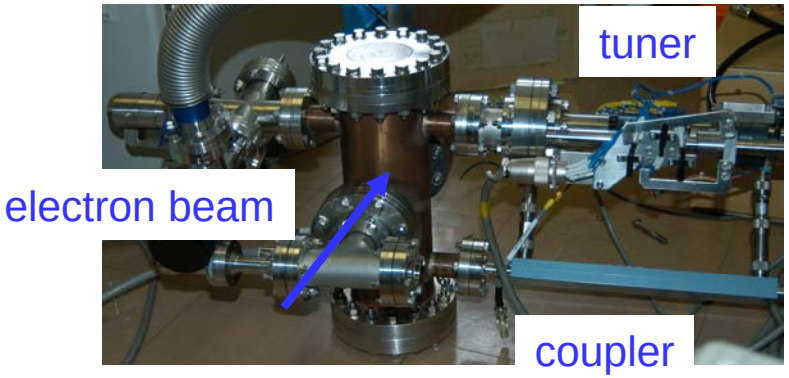


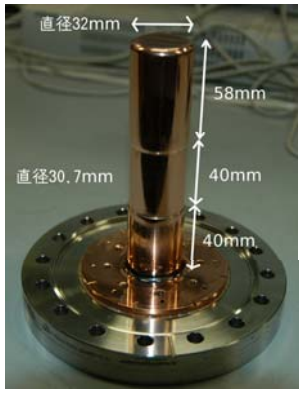
beam dump

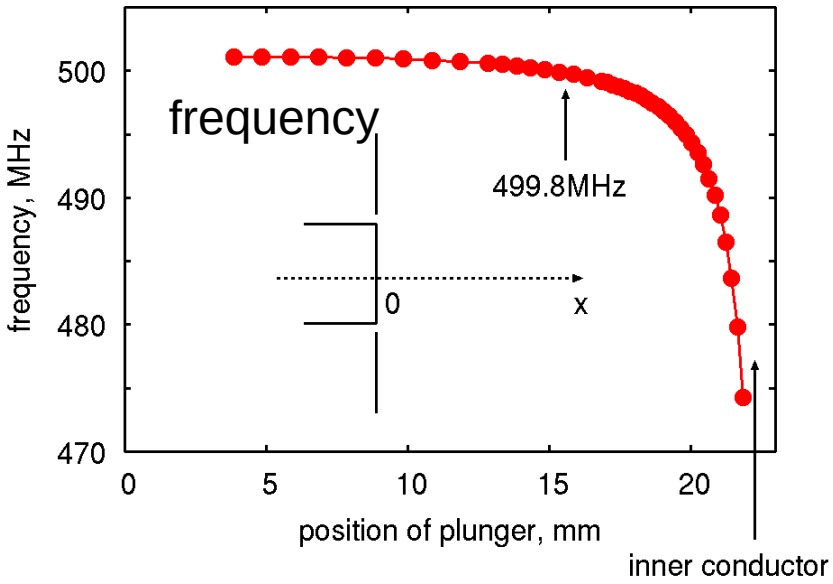


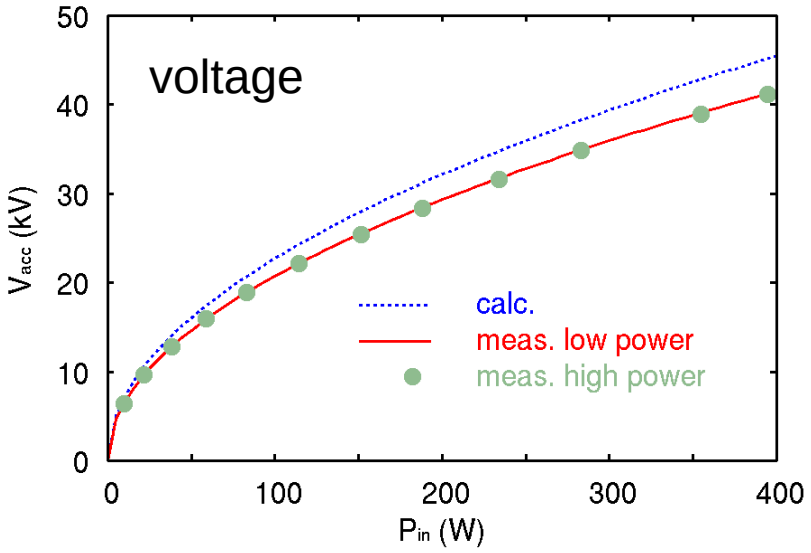
499.8MHz deflecting cavity











Design of a 500kV electron gun

Goals of FY2008 are

- 500kV high voltage processing
- preparation of NEA GaAs cathode

  - ✓ 500 kV high voltage power supply
  - insulator tube
  - SF6 tank
  - ➢ NEA GaAs cathode preparation system

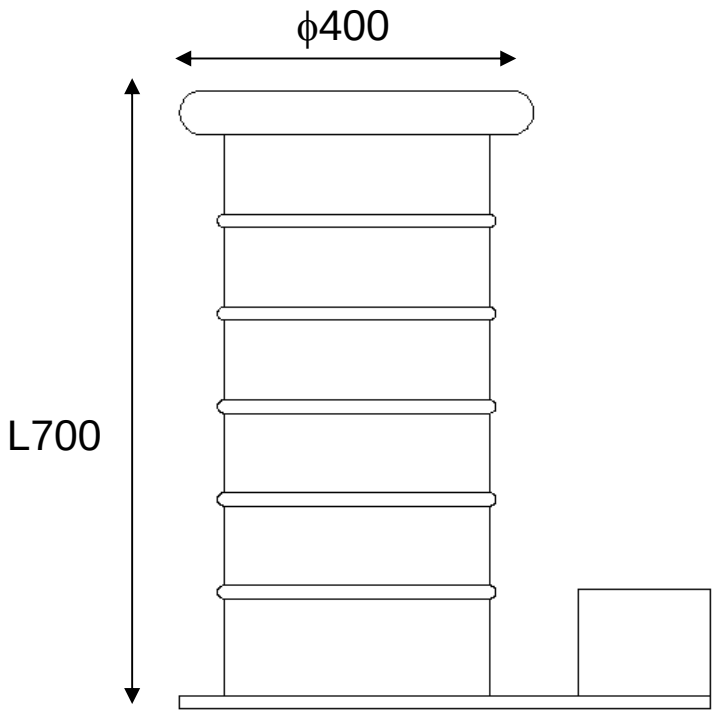
Goal of FY2009 is

- generation of 500kV electron beam

  - ➢ High voltage chamber

500kV high voltage power supply

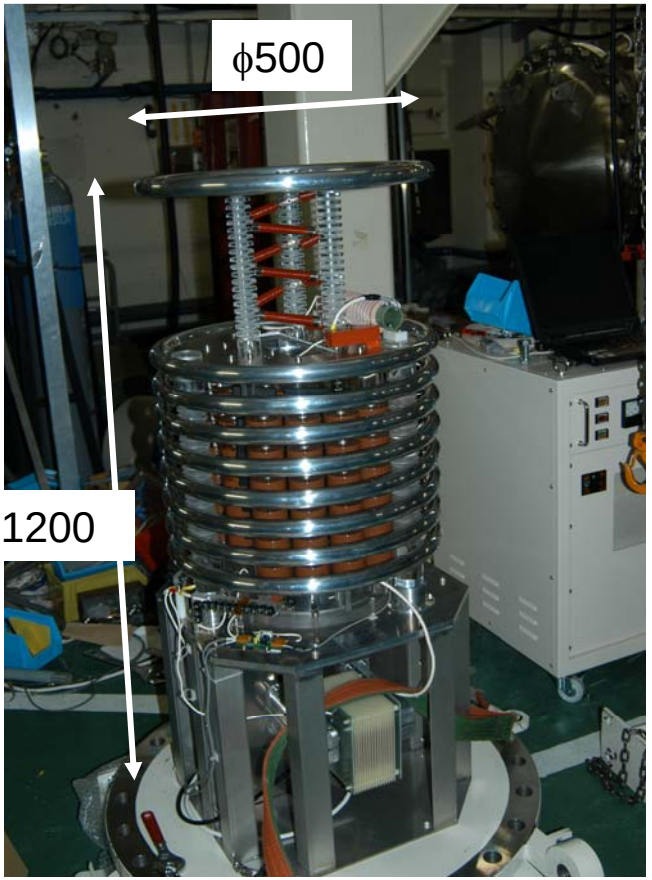
500kV high voltage power supply



- −500kV (−550kVmax.)
- ripple < $1x10^{-4}$
- 10mA max.

placed an order.

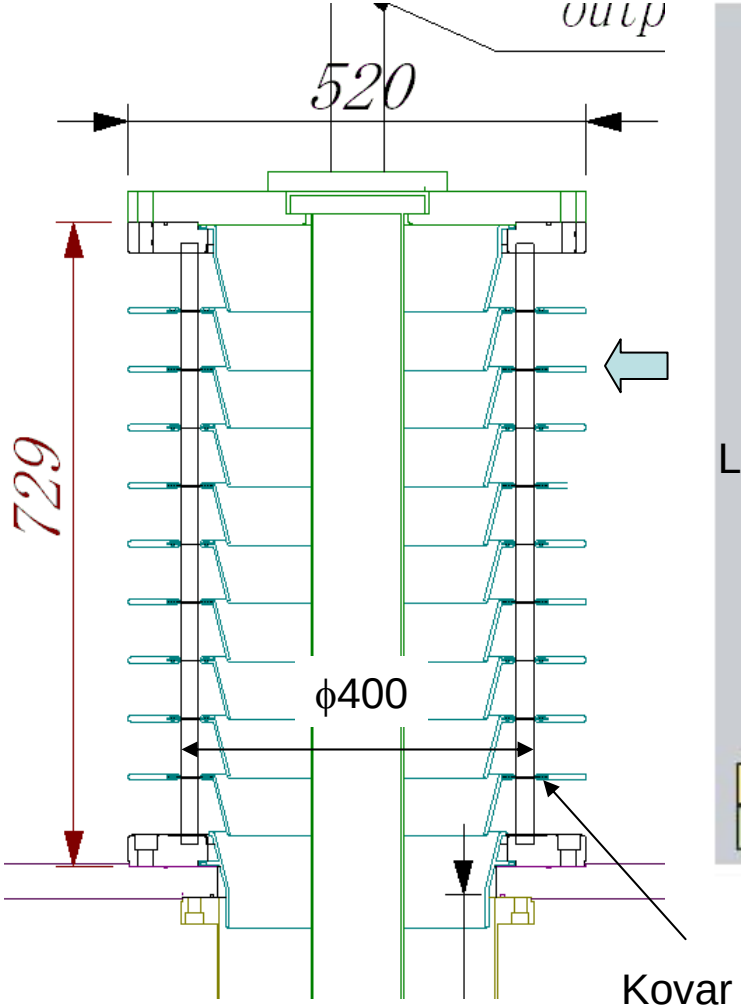
250kV high voltage power supply



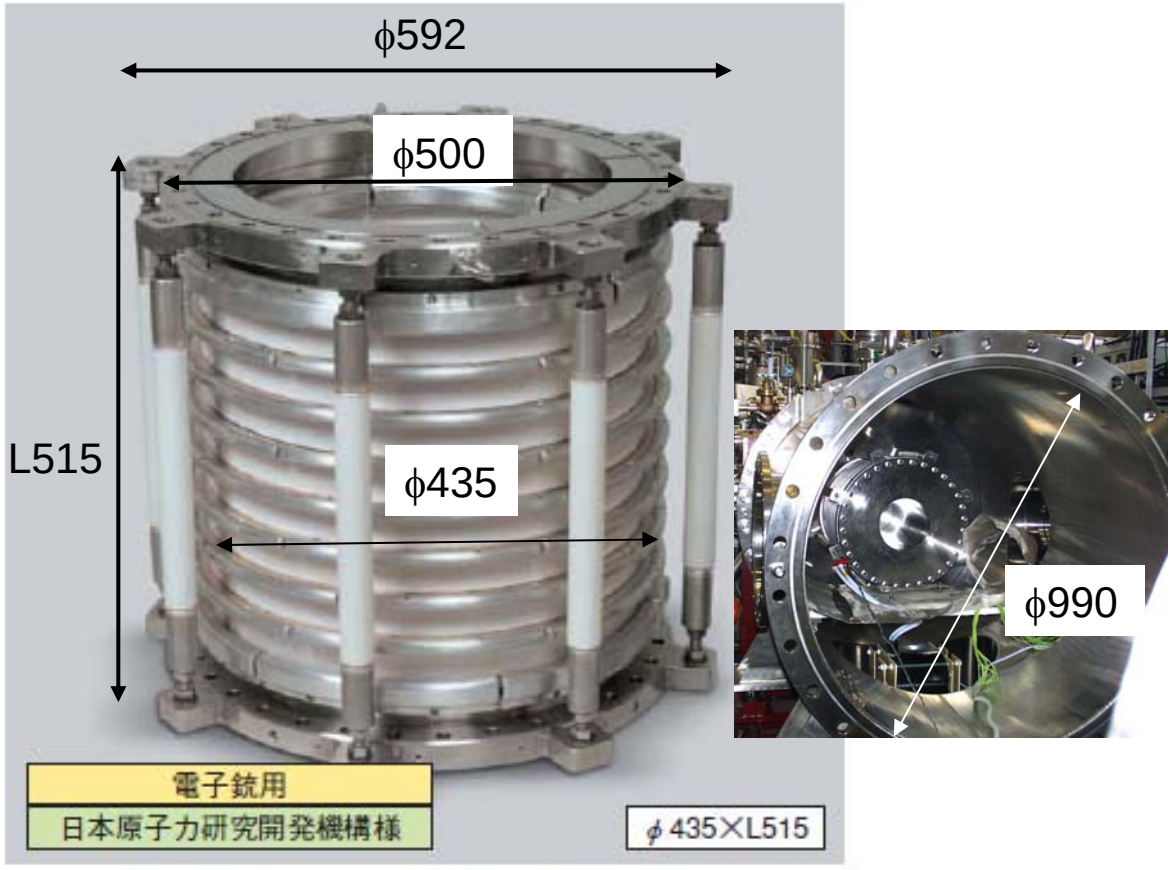
- −250kV max.
- ripple < $1x10^{-4}$
- 50mA max.

Segmented insulator tube

Design of 500kV insulator tube



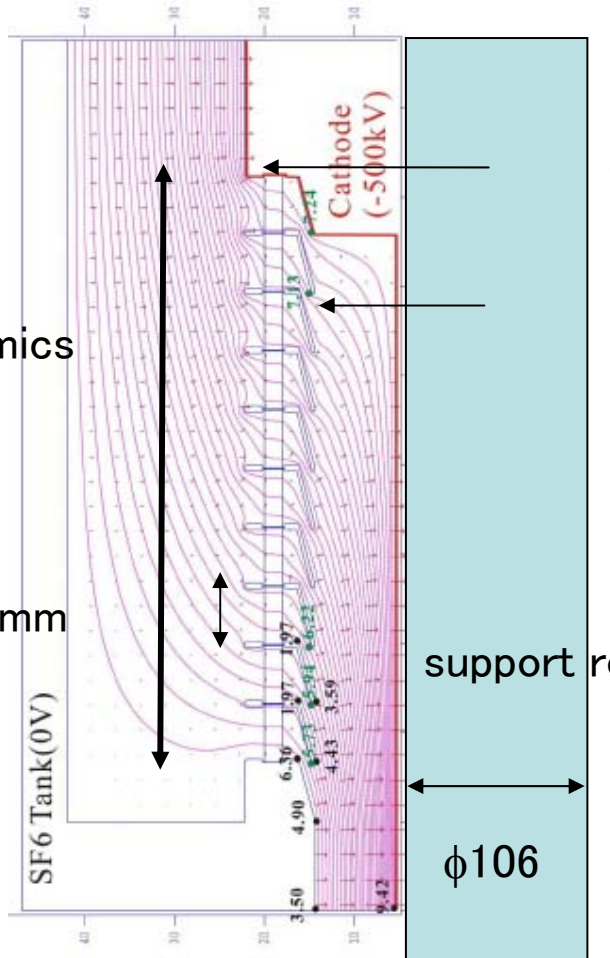
250kV insulator tube for JAEA thermionic cathode gun



by courtesy of Japan Atomic Energy Agency
Application: Electron Gun

Kyocera home page
http://global.kyocera.com/

Design of support rod and guard ring



729 mm
for 10 ceramics

50kV /65mm

ϕ400 outer diameter of ceramic

ϕ288 inner diameter of guard ring

Guard rings suppress secondary electron emission from ceramics by preventing field emitted electrons from reaching ceramics.

support rod

ϕ106

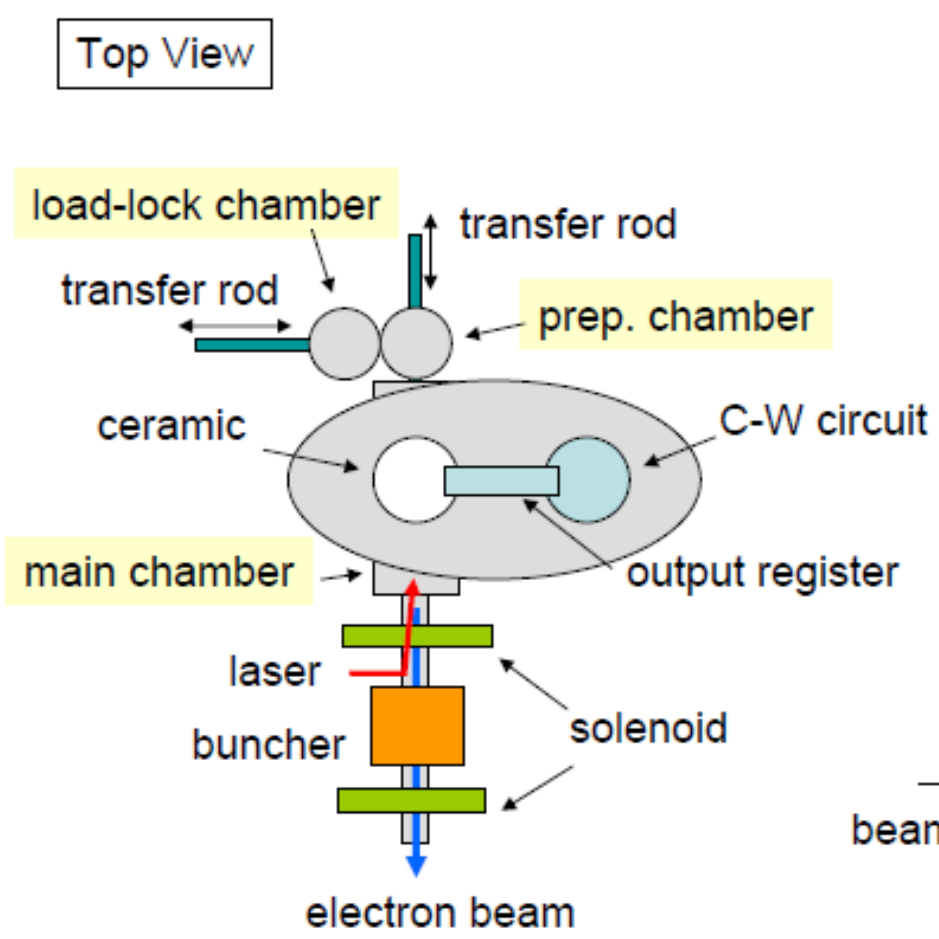
Optimization of guard rings and support rod limits the highest field to less than 10 MV/m.

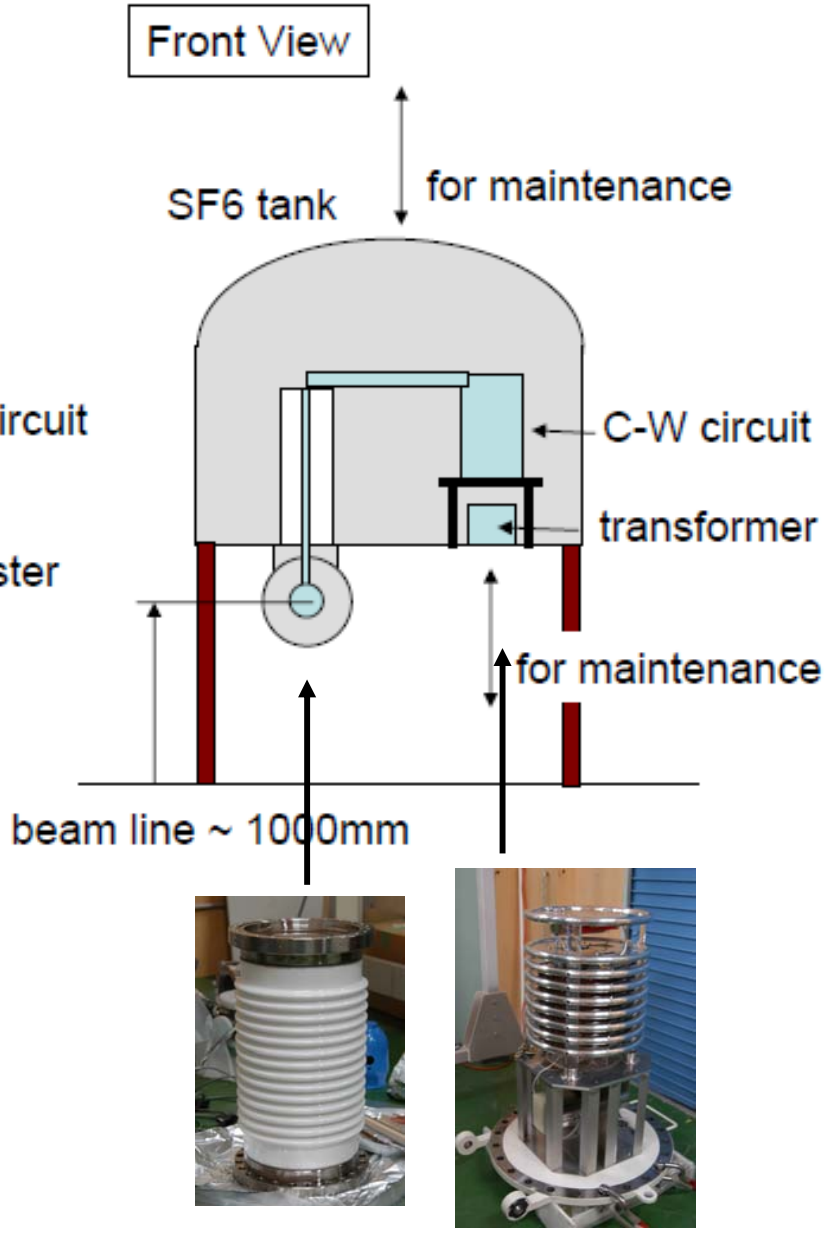
cathode (−500kV)

Electron beam

anode

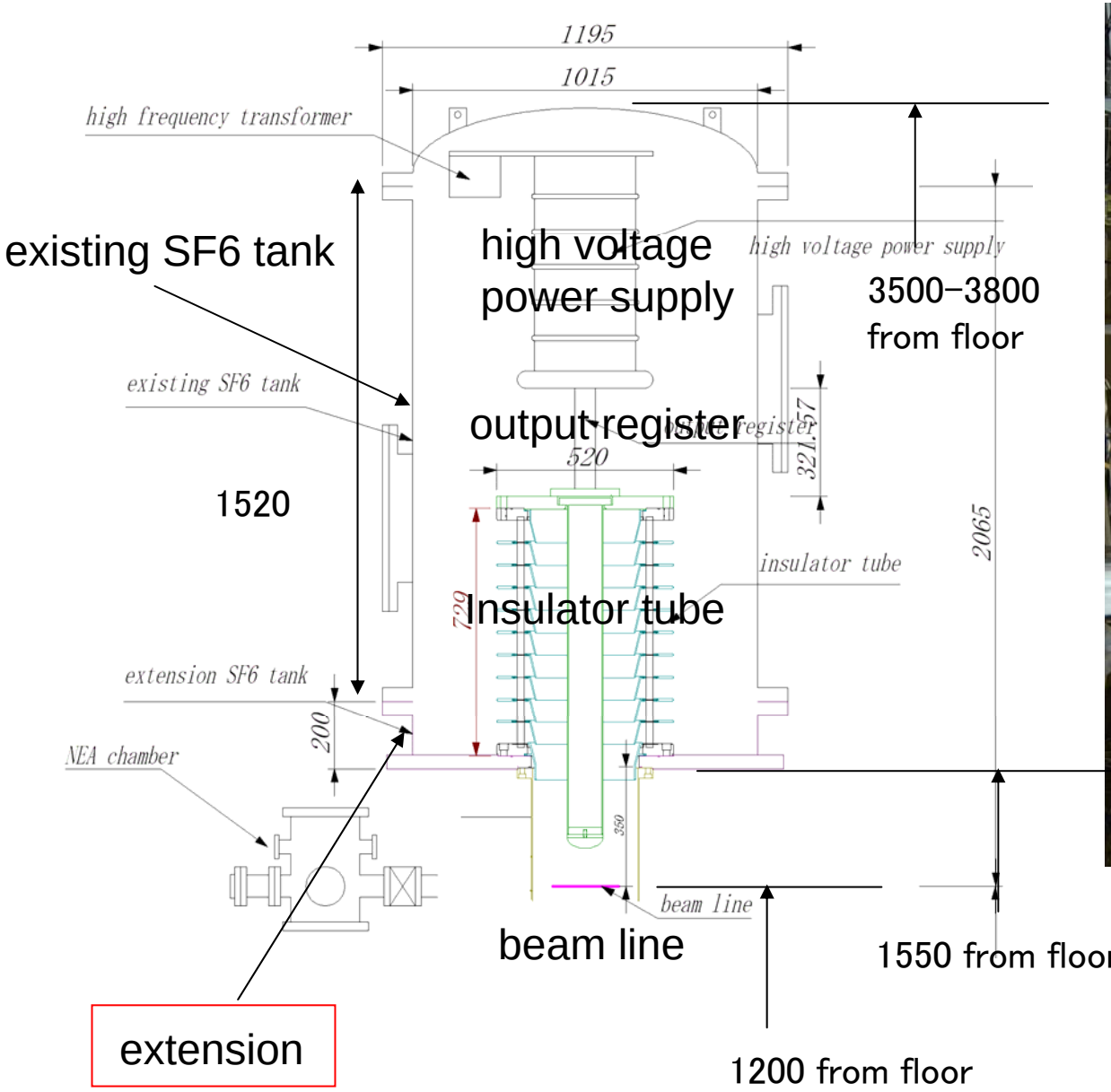
SF6 tank (plan A)





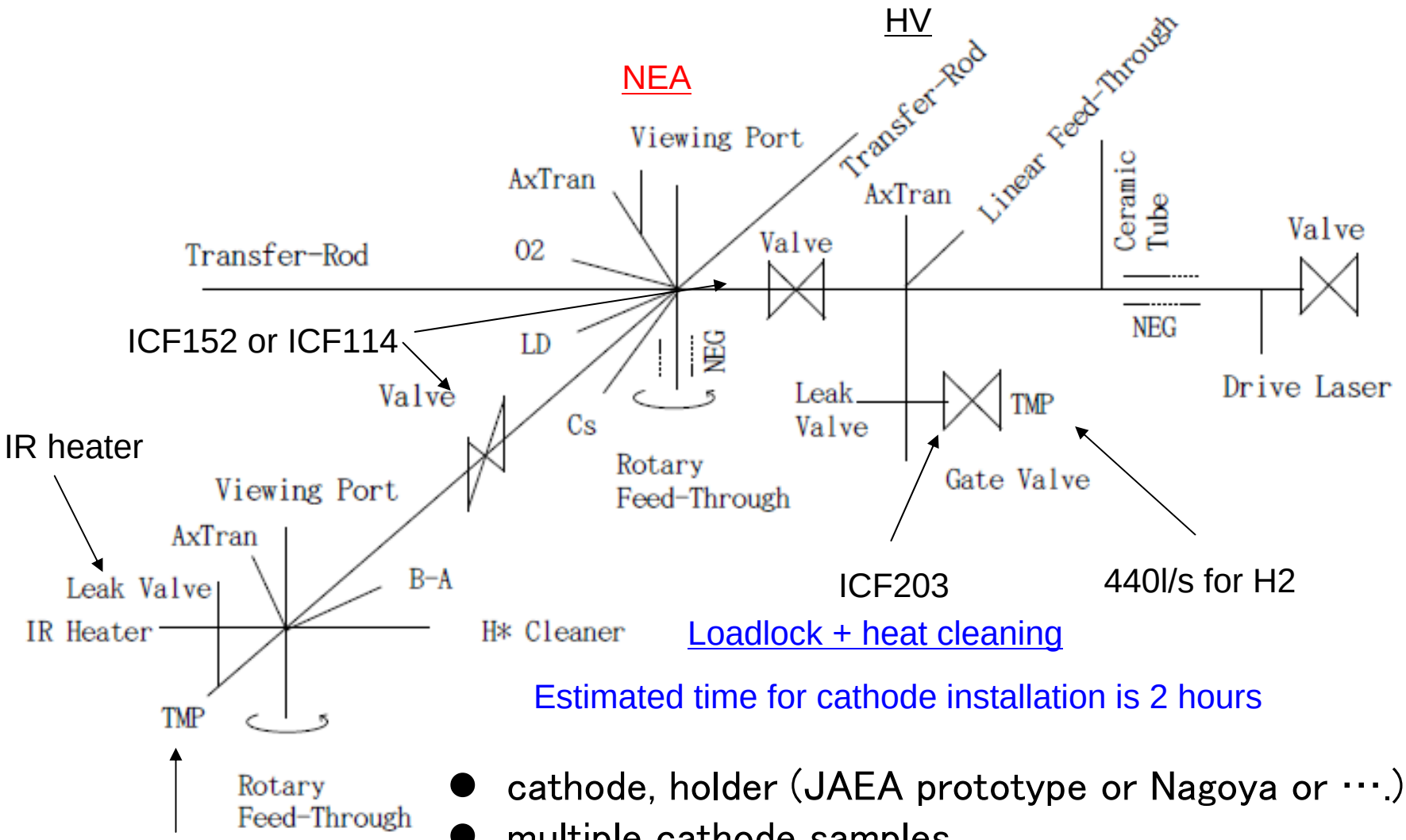
similar to Cornell tank.

SF6 tank (plan B)



SF6 tank for JAEA
thermionic cathode gun

Plan of cathode preparation system



Loadlock + heat cleaning

Estimated time for cathode installation is 2 hours

- cathode, holder (JAEA prototype or Nagoya or ….)
- multiple cathode samples
- sample transfer system

Summary

- Developed a 250kV photocathode DC gun.
- Generated 150keV 1μA beam.
- Under construction of diagnostic beam line for 250 kV prototype gun.
- Designed 500 kV segmented insulator tube with guard rings and a SF6 tank with symmetrical configuration.
- Design and construct cathode preparation system for 500 kV gun this fiscal year.