ERL09 WG1
DC-Gunに関するレビュー

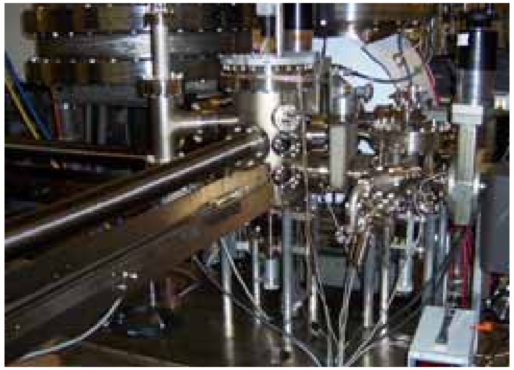
山本 将博
KEK

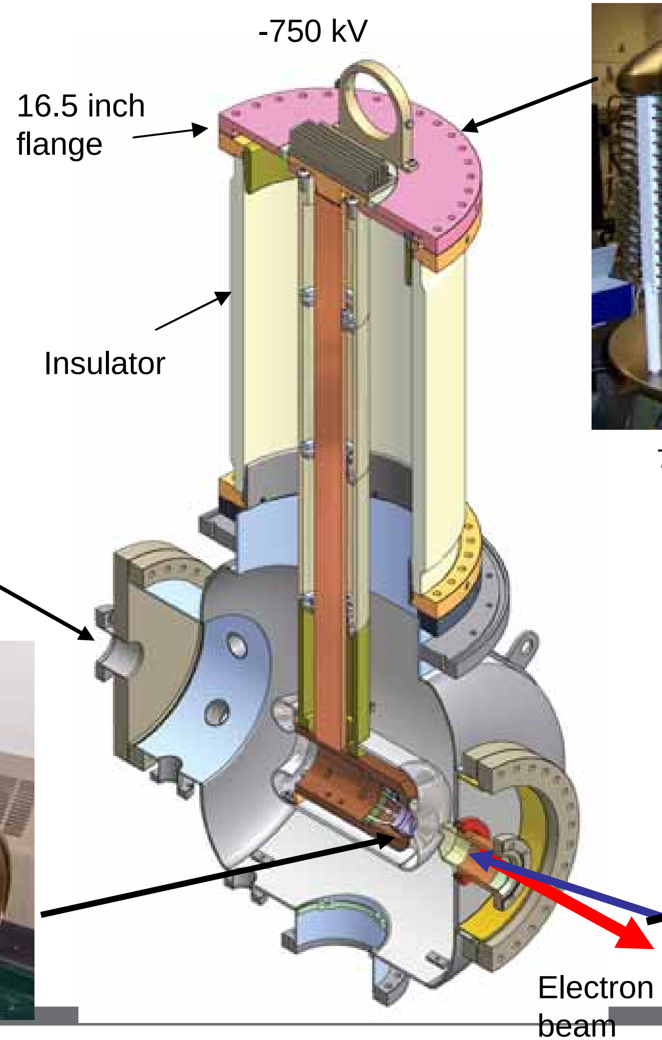
Cornell
JLAB CEBAF
JAEA
JLAB FEL
Daresbury

Cornell Gun

DC Photocathode Gun

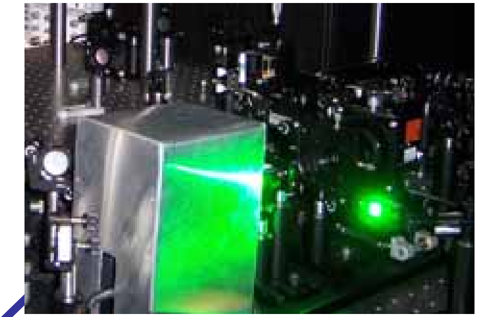
Cathode Preparation and Load Lock





750 kV, 100 mA HVPS

Drive Laser



Focusing electrode,
Cathode support

HV Power Supply

Kaiser

-750kV, 100mA

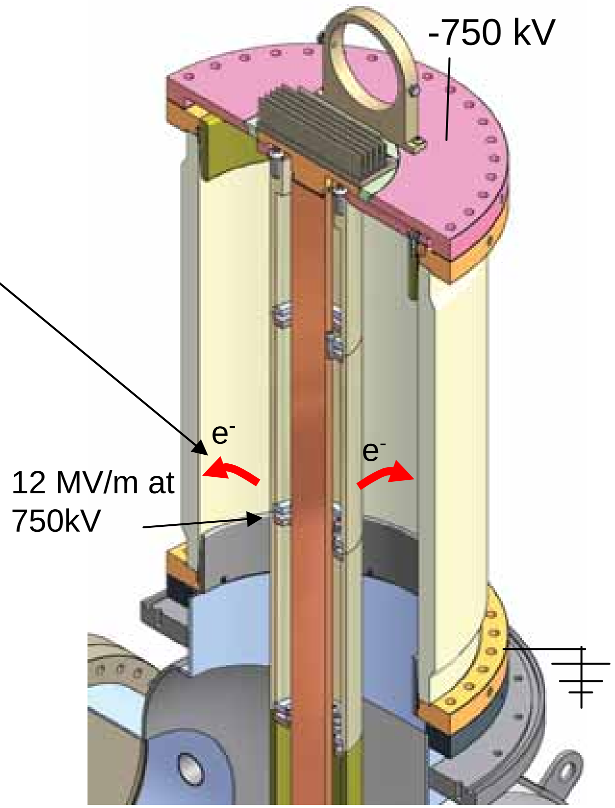
Glassman

-500kV, 10mA

- We typically run well below the maximum power, thus the controls are not very reliable.
- Added a load resistor in parallel with the gun so that we always draw current to help with control stability
- Processing – another supply would be better
- Gas processing

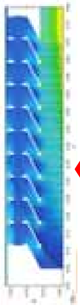
DC Gun - Insulator

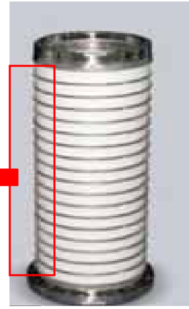
- Large size to keep field gradients low
- Field emitted electrons can build up on the insulator and punch thru
- External SF_6
- High mechanical stresses due to SF_6 pressure and bakeouts
- Difficult to find suppliers
- Braze difficulties due to large size



Braze and punch-thru problems limit us to 250kV for now

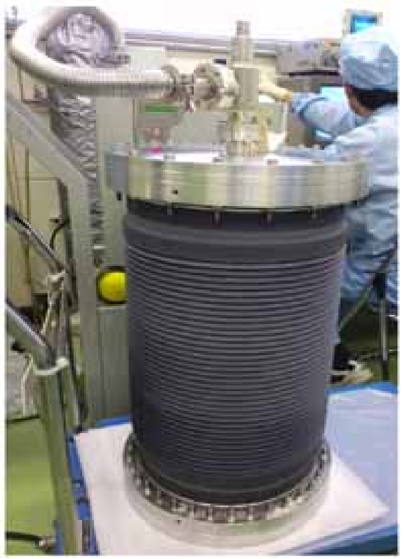
DC Gun - Insulators





Multi-segmented

(KEK, Cornell)



'New' Insulator design collaboration

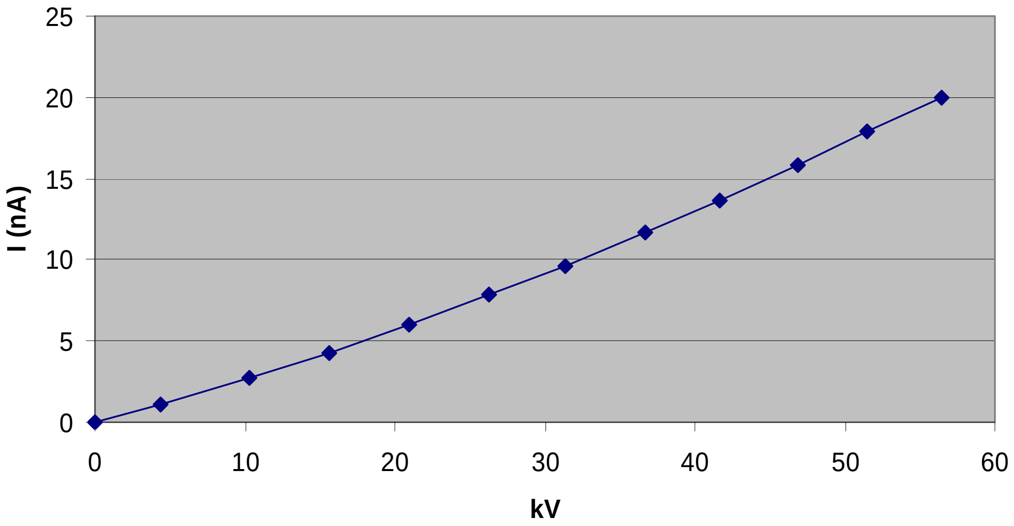
Conductive alumina with improved braze joint

(Daresbury, Jlab, Cornell)

Adapting Industrial tube designs ('inverted')

(Jlab, Cornell)

Insulator resistance



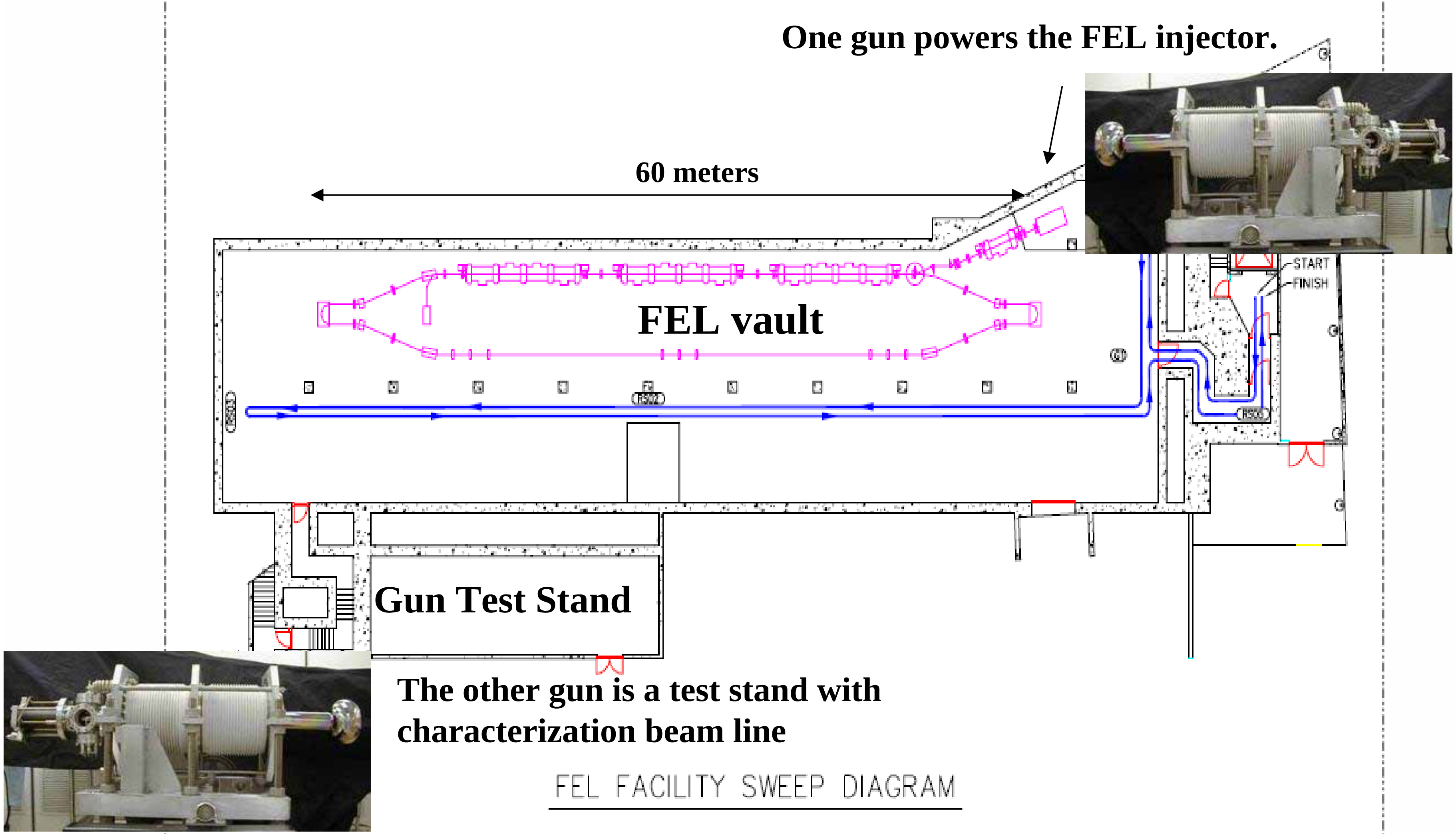
Morgan AL970CD sample

Rectangular piece 0.12x0.14x2.3 inches

Resistivity of 6.5e10 Ohm-cm

In line with Daresbury measurement of 20 uA at 500kV -> resistivity is roughly linear with voltage

The FEL operates two similar DC photoemission guns

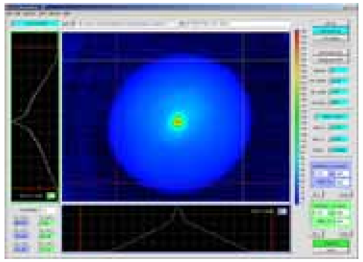


JLAB FEL Gun

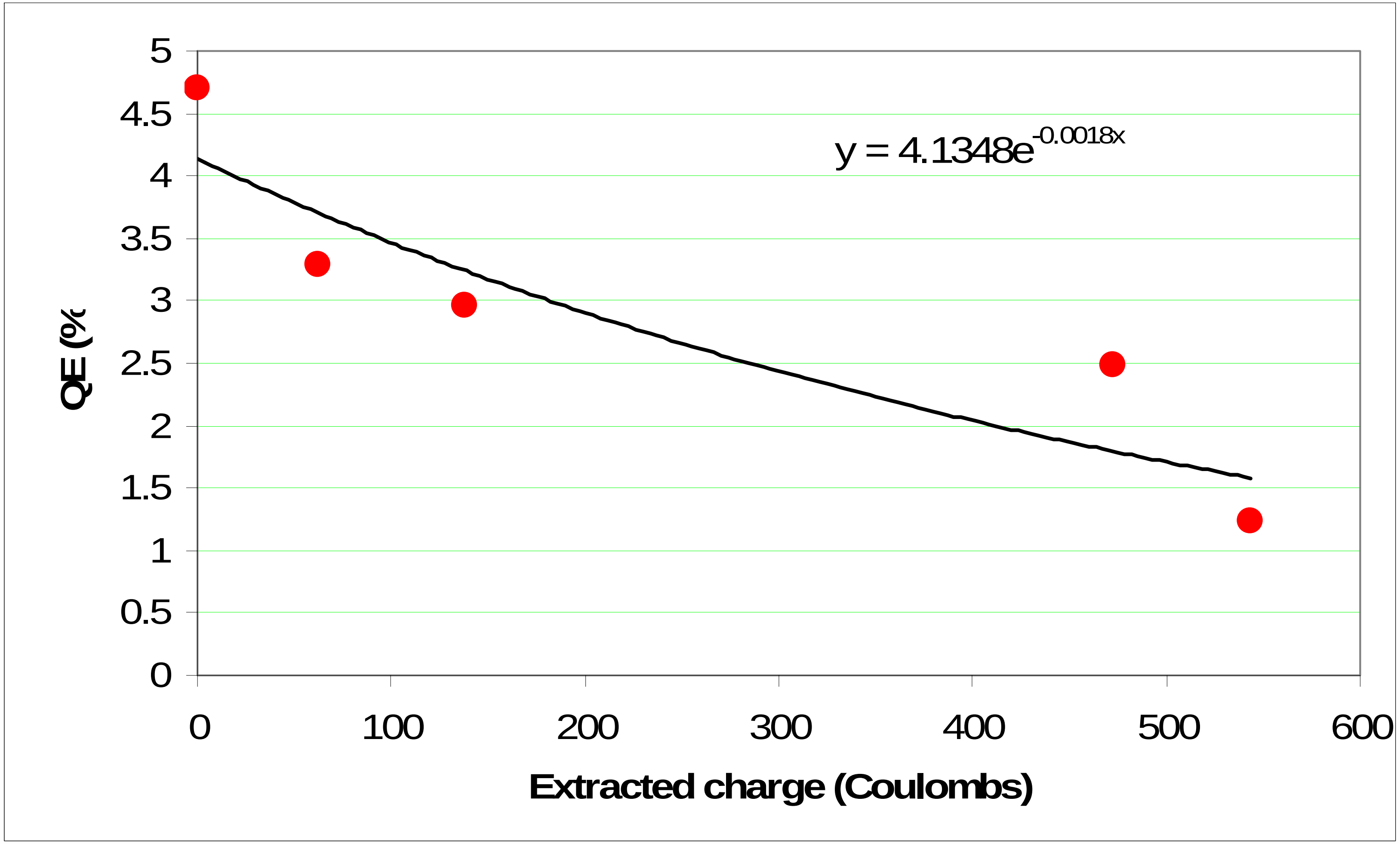
FEL DC Gun status

Date	Event
May 2007	Conclusion of 3 years of operations at **<u>350</u>** kV with a single GaAs wafer delivering over ***<u>7000 Coulombs and 900 of CW beam time</u>***. Opened flange leak at 405kV while testing gun for higher charge studies
Mar. 2008	Punctured insulator at 398kV during conditioning of refurbished gun
Sept. 2008	Rebuilt gun with new insulator, but observed >100 uA of F.E. at 150kV
Oct. 2008	Krypton processed to 375 kV, but too much F. E. from cathode
Nov. 2008	Replaced cathode, F. E. reactivated at 320 kV after gun bake, Kr proc. again
Dec. 2008	No F. E. from cathode, but field emitter re-activated after cathode heat clean.
Up to date	Gun operational at 350kV but with few uA of F. E., lifetime ~10 operational hours. Motorized cathode retraction system cut down re-cesiation time from 3 to 0.5 hours

Gun Test Stand status

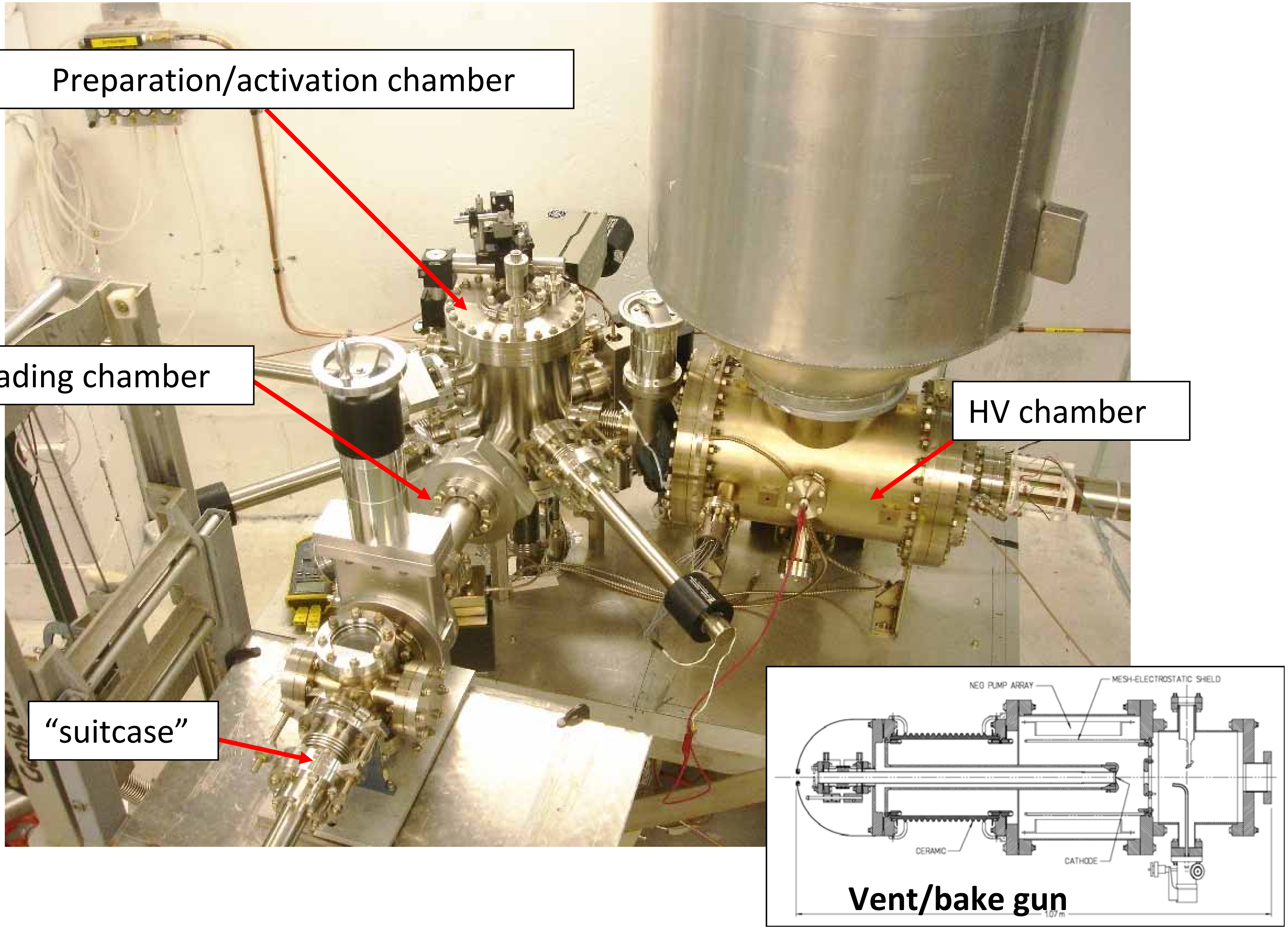
Date	Event
12/06/2007	Started HV conditioning, achieved 85 kV the first day
02/01/2008	Achieved 485 kV after **528 processing-hours**. At 486kV punched-through ceramic insulator
02/28/2008	Fixed ceramic leak and ensured gun performance at **460 kV**. Declared HV conditioning done
03/14/2008	First beam at 300kV 
Spring 2008	Extracted beam up to 375 kV and observed indications of surface charge limit
2009	Multi-slit, second solenoid, kicker cavity ready for installation in expanded diagnostic beam line

The best FEL 1/e photocathode lifetime was 550 Coulombs or ~ 30 hr. at 5 mA CW



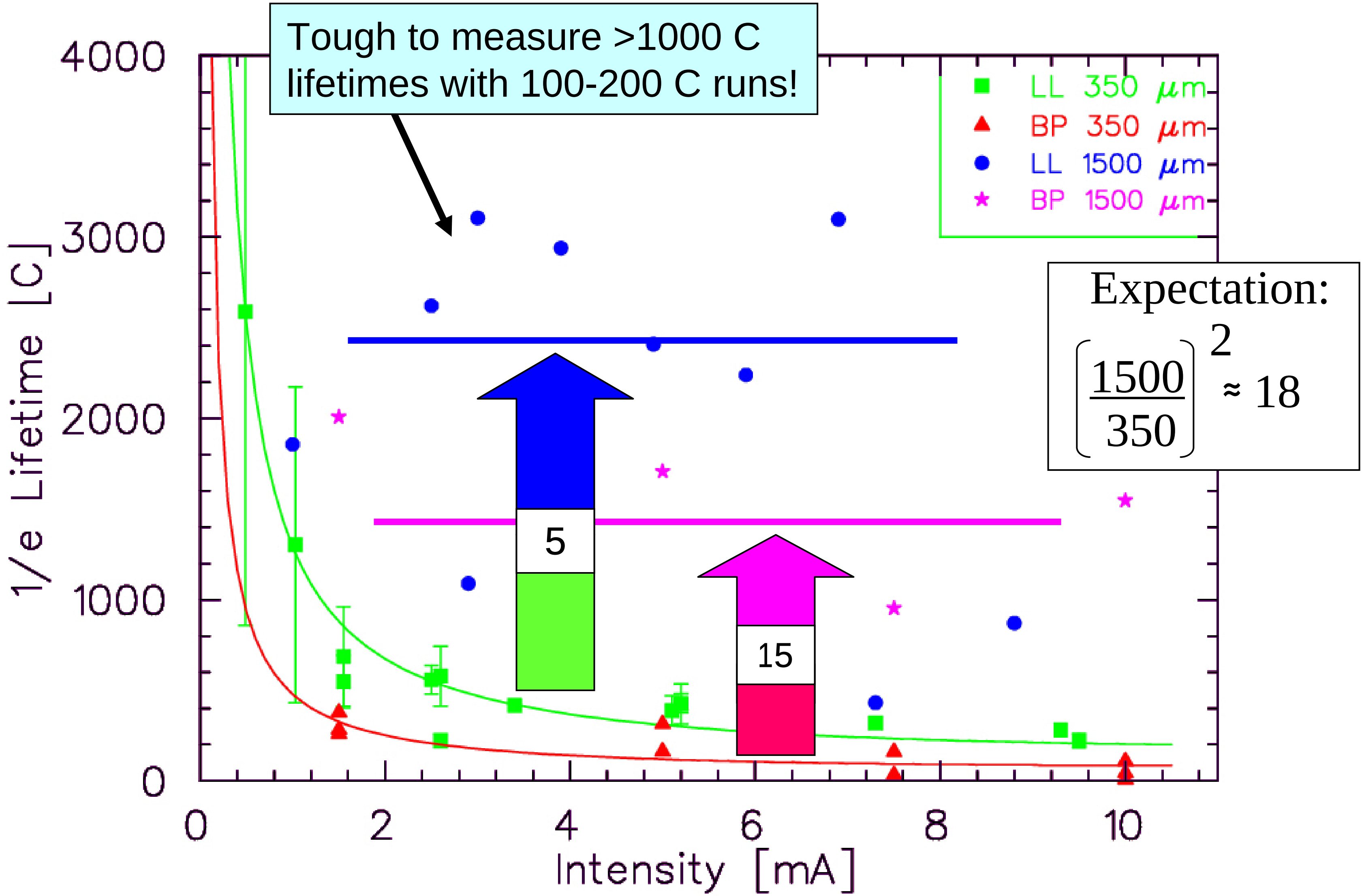
JLAB CEBAF Gun

New CEBAF load-locked gun



Vent/bake gun

Lifetime with Large/Small Laser Spots



“Further Measurements of Photocathode Operational Lifetime at Beam Current > 1mA using an Improved 100 kV DC High Voltage GaAs Photogun,” J. Grames, et al., Proceedings Polarized Electron Source Workshop, SPIN06, Tokyo, Japan

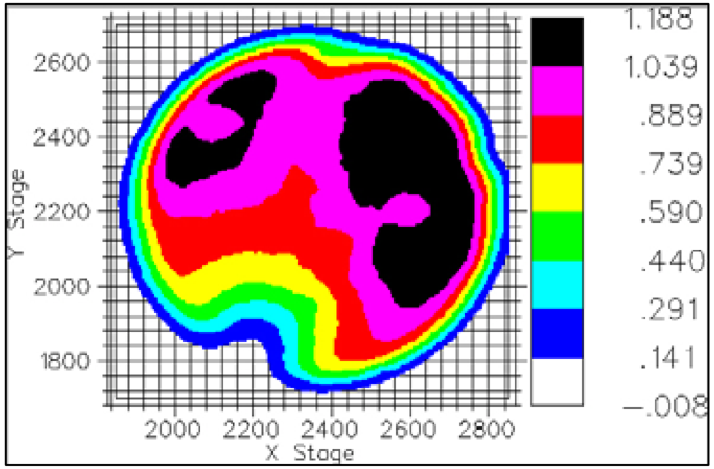
1mA at High Polarization*

Parameter	Value
Laser Rep Rate	499 MHz
Laser Pulselength	30 ps
Wavelength	780 nm
Laser Spot Size	450 mm
Current	1 mA
Duration	8.25 hr
Charge	30.3 C
Lifetime	210 C
#How long at 1mA?	10.5 days

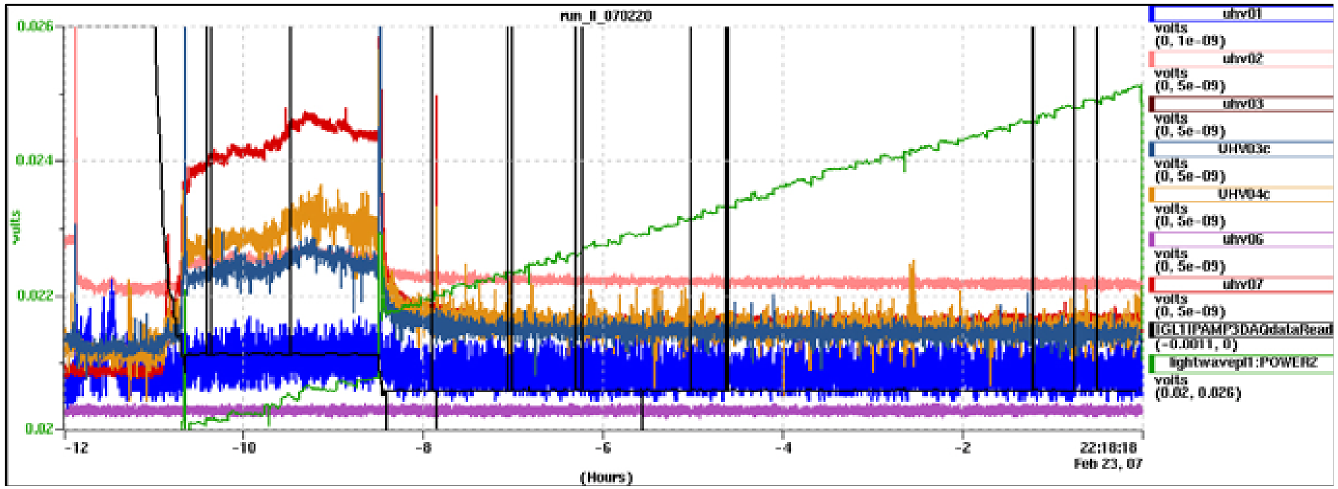
prediction with 10W laser

*** Note: did not actually measure polarization**

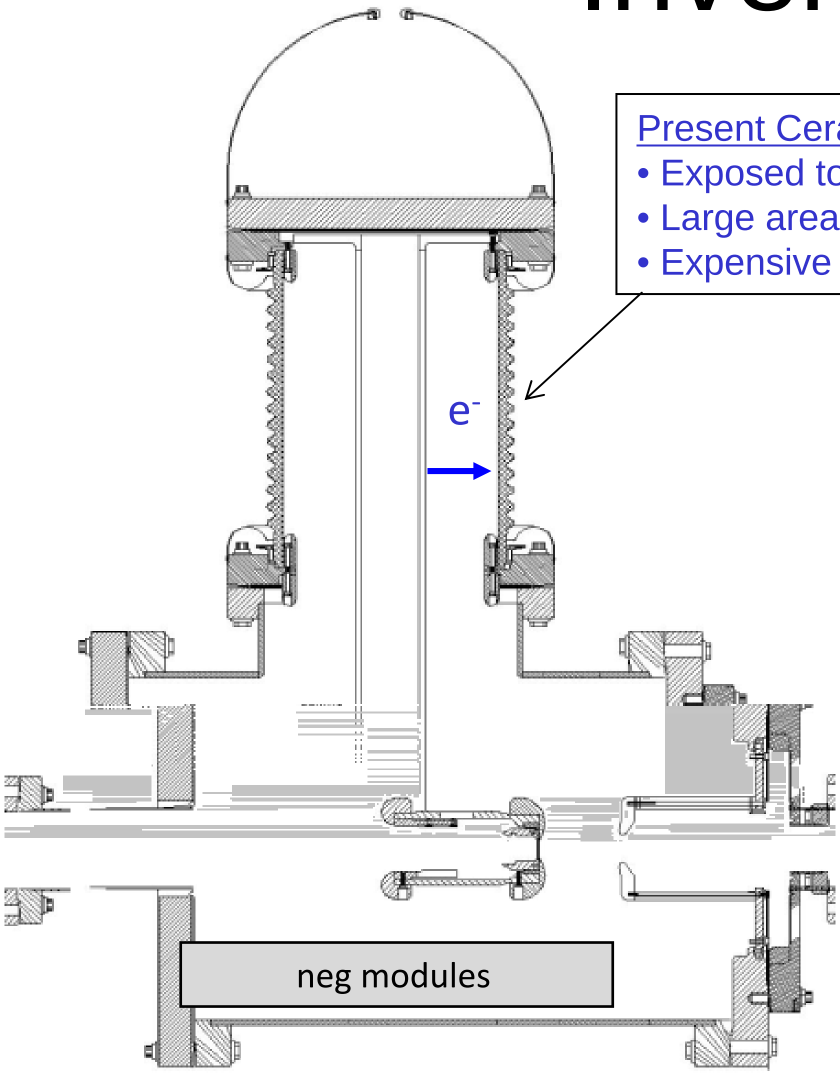
High Initial QE



Vacuum signals
Laser Power
Beam Current



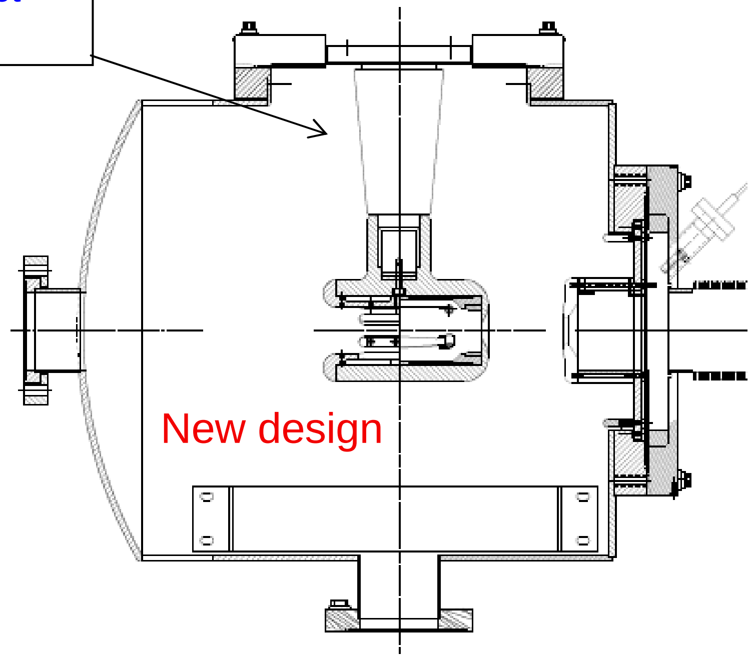
“Inverted” Gun



Present Ceramic
- Exposed to field emission
- Large area
- Expensive (~$50k)

Medical x-ray technology

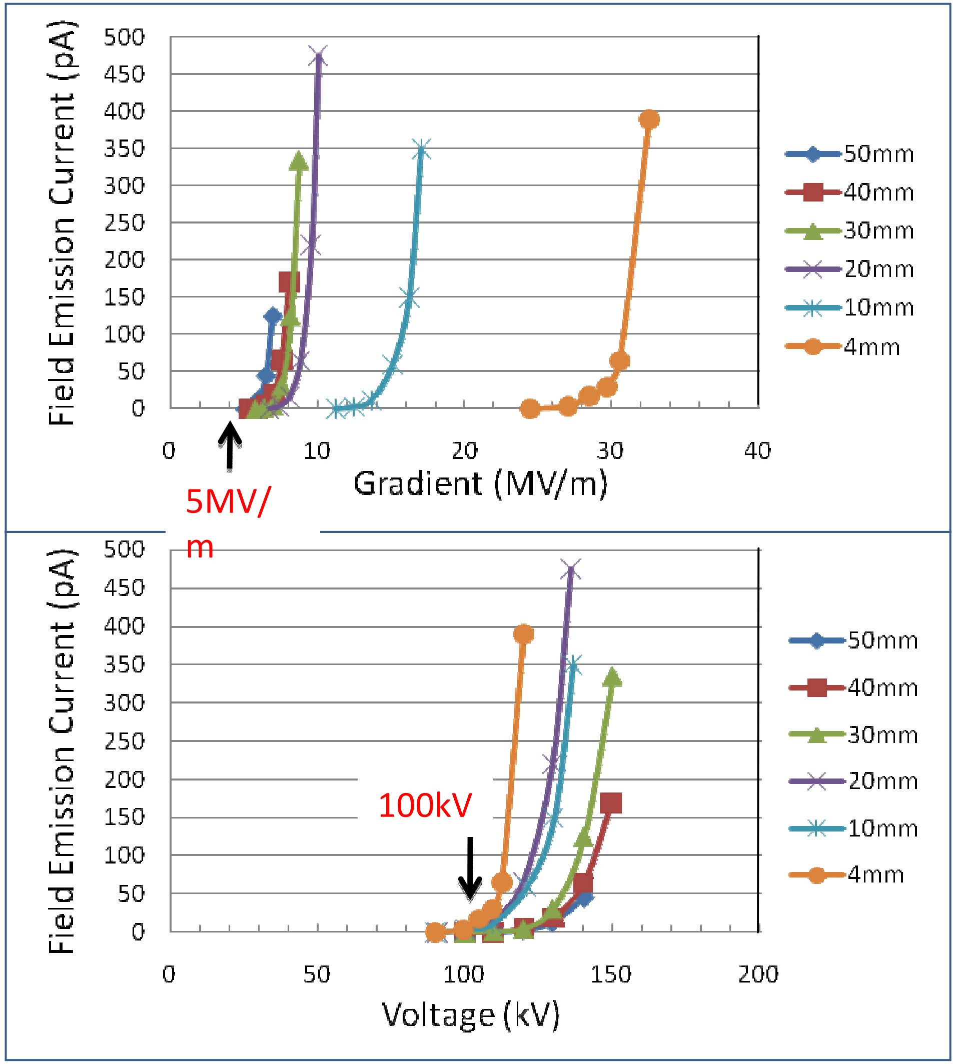
New Ceramic
- Compact
- ~$5k



Move away from “conventional” insulator used on most GaAs photoguns today – expensive, months to build, prone to damage from field emission.

Field Emission – Most Important Issue

Stainless Steel and Diamond-Paste Polishing
Good to ~ 5MV/m and 100kV.

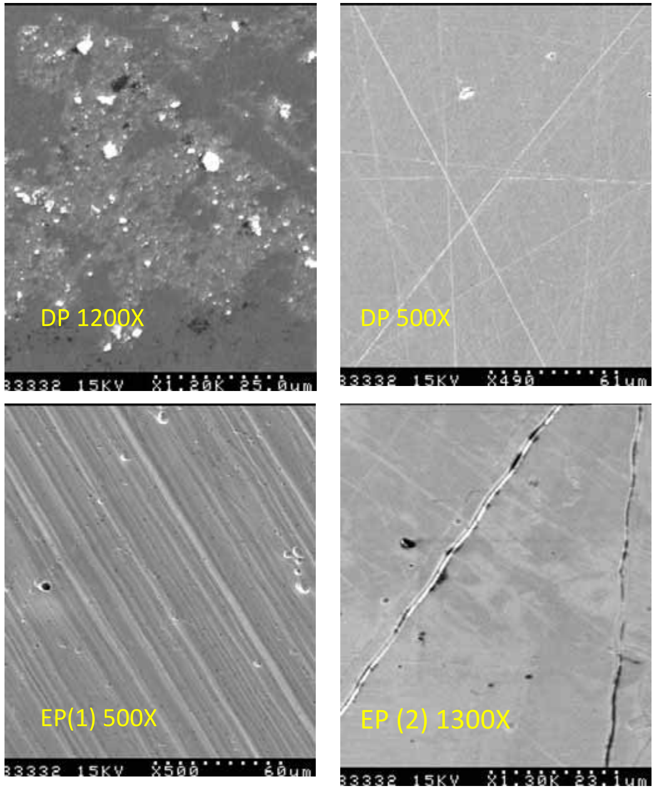


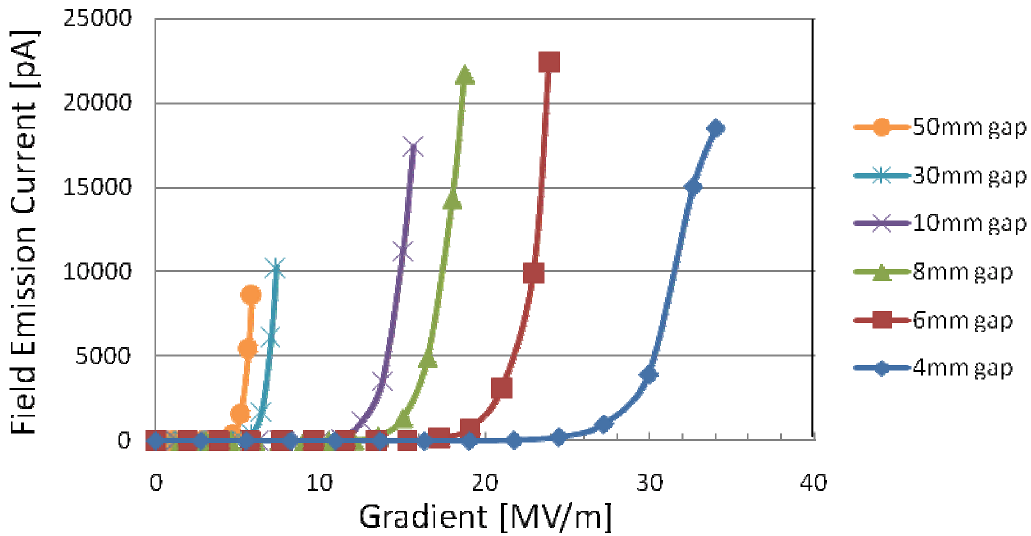
- Flat electrodes and small gaps not very useful
- Want to keep gun dimensions about the same – suggests our 200kV gun needs “quiet” electrodes to 10MV/m

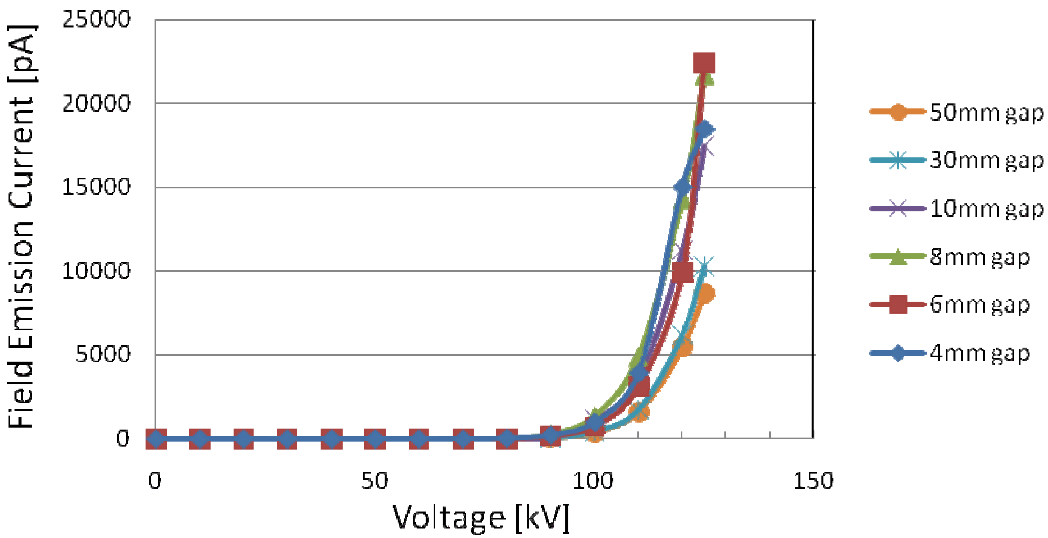
Work of Ken Surles-Law, Jefferson Lab

Electropolished Stainless Steel

- Results similar to diamond-paste polishing: limiting gradient 5MV/m
- Considerable time saving
- Perhaps better results if we start with smoother surface

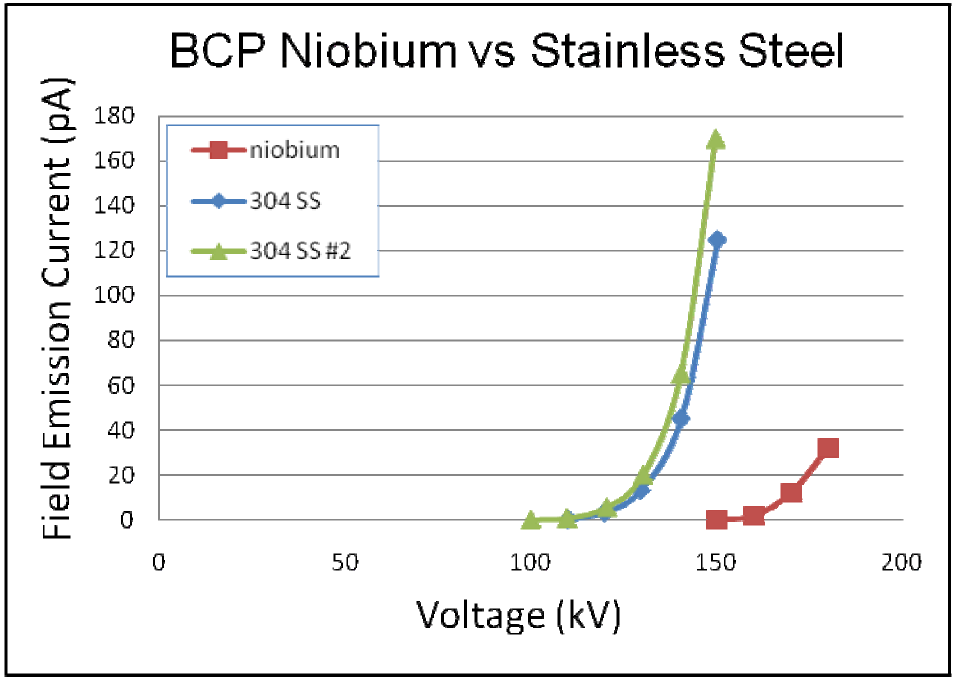






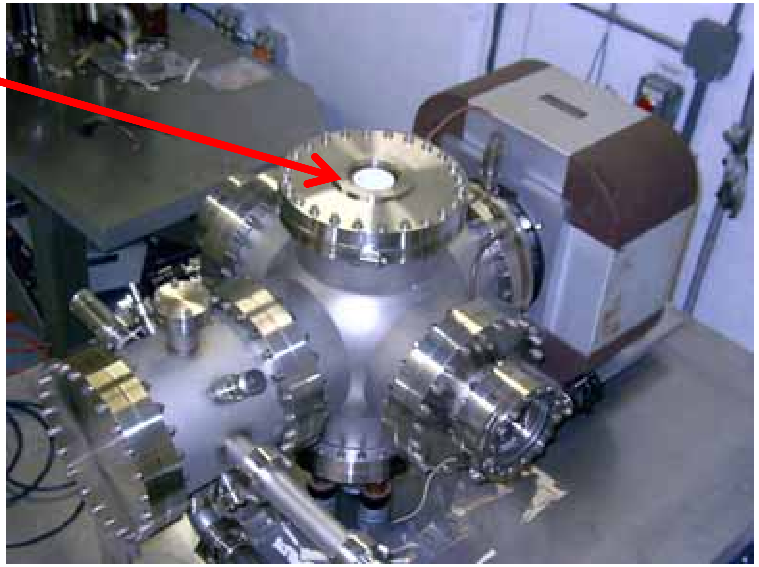
Work of Ken Surles-Law, Jefferson Lab

Single Crystal Niobium:
- Capable of operation at higher voltage and gradient
- Buffer chemical polish (BCP) much easier than diamond-paste-polish

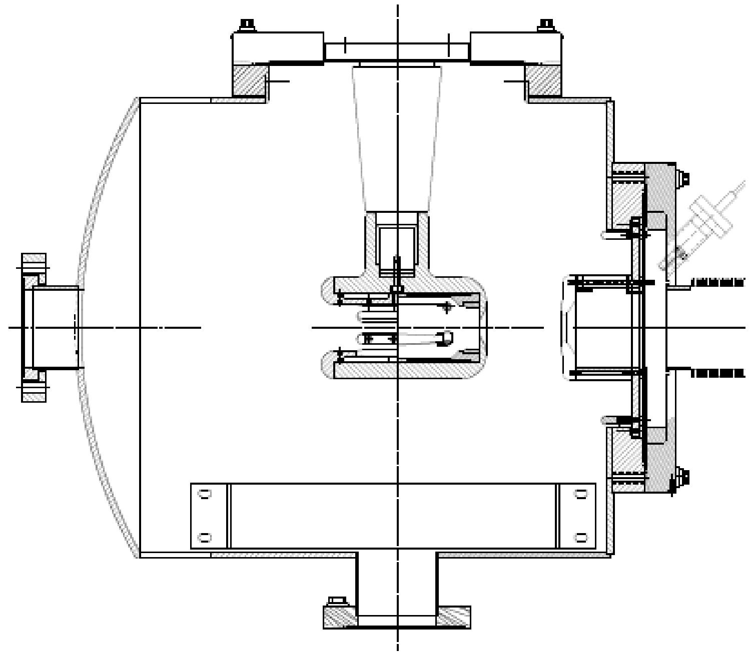


Conventional geometry: cathode electrode mounted on metal support structure

Replace conventional ceramic insulator with "Inverted" insulator: no SF6 and no HV breakdown outside chamber

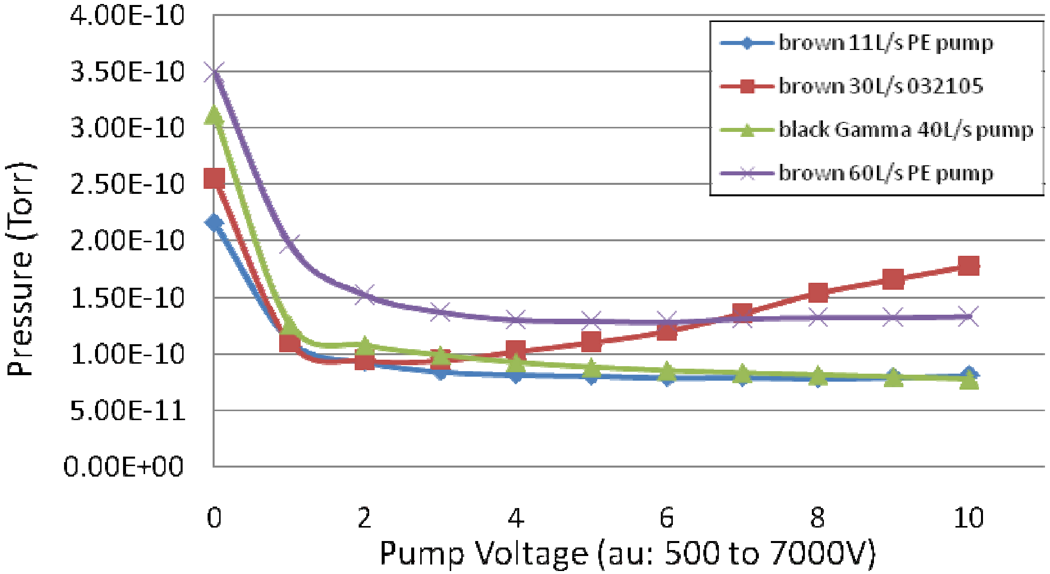


Work of Ken Surles-Law, Jefferson Lab

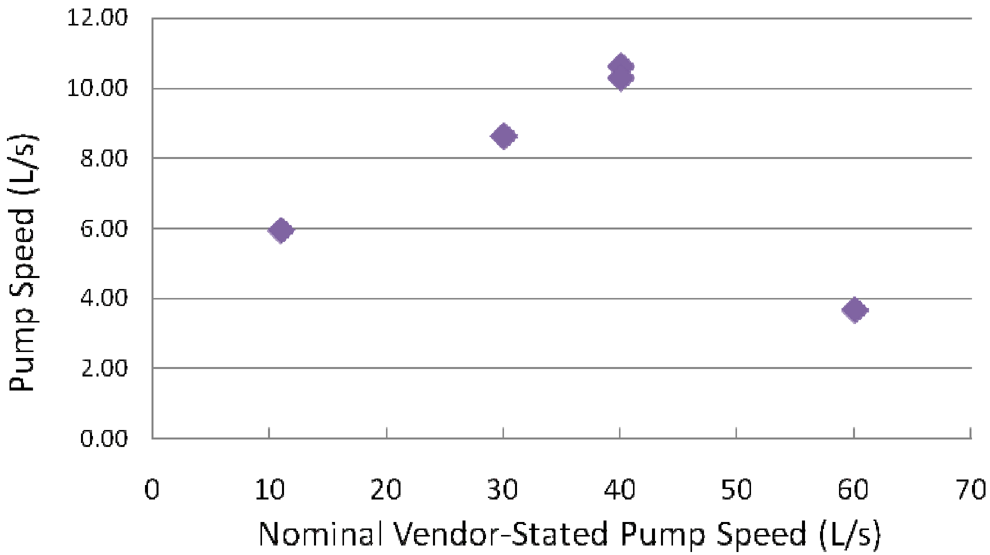



Ion Pumps and 10^{-12} Torr Vacuum

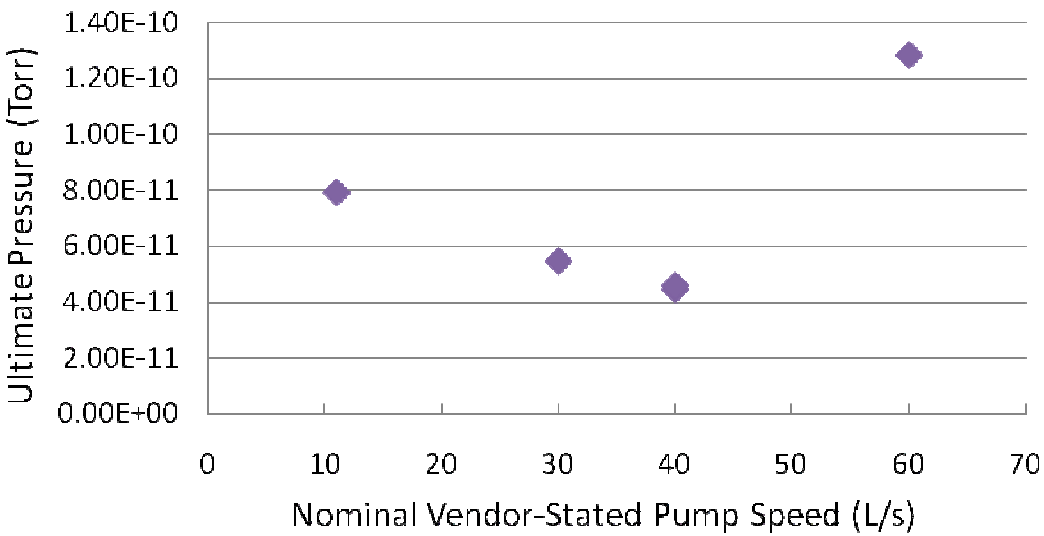
- Mount different Ion Pumps on BeCu chamber with Leybold Extractor gauge and leak valve
- Bakeout, then measure “Ultimate Pressure vs Bias Voltage” and “Ion Pump Current vs Pressure”
- Known Outgassing Rate provides pump speed at Pult
- Admittedly, outgassing rate of BeCu chamber disappointing



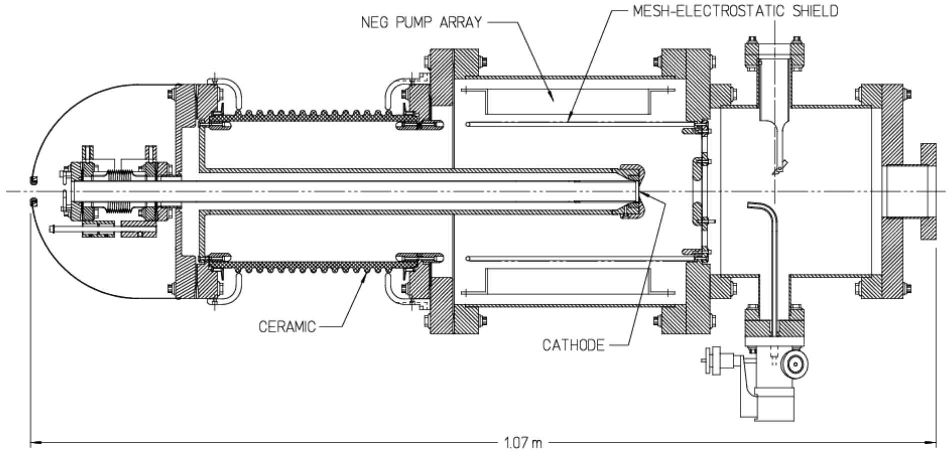
Ion Pumps and 10^{-12} Torr Vacuum



- Would pressure extend to –12 Torr on chamber with smaller load?
- Bigger Ion Pump not necessarily better



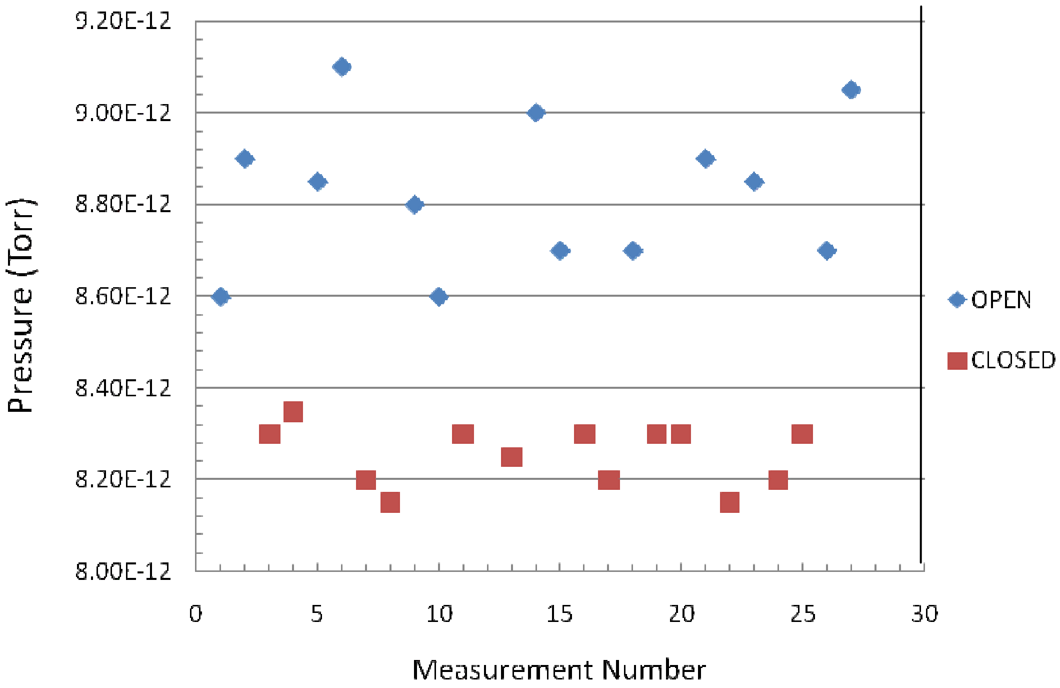
Vacuum Studies: Ion Pump Limitation?



Used old gun as test bed: "flapper" valve installed between gun and ion pump

Conventional wisdom says:
Ion pumps required for gasses not pumped by NEGs – but might be limiting our ultimate pressure. Our next test at Test Cave…

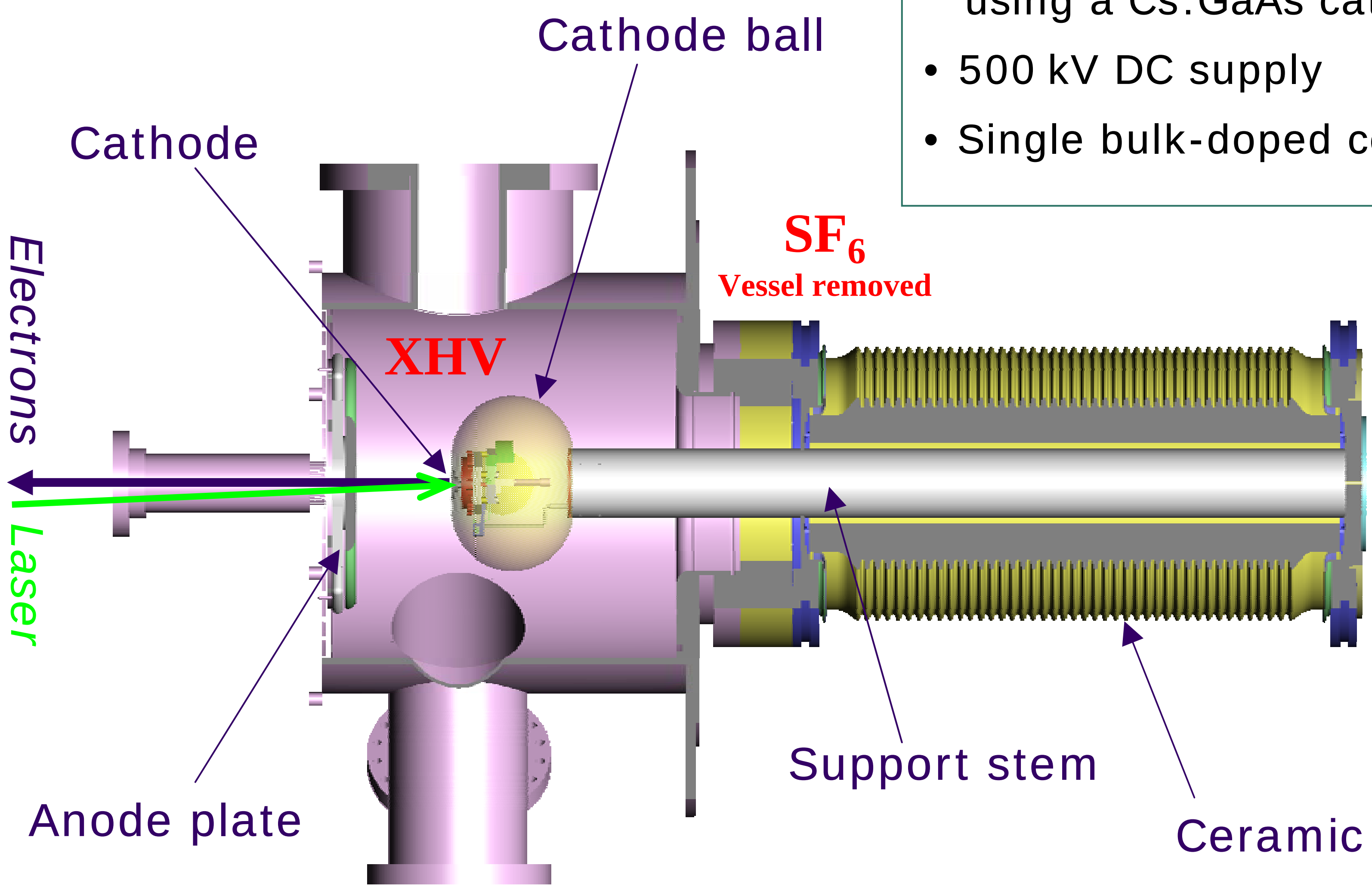
Valve to Ion Pump Open/Closed



Daresbury Gun

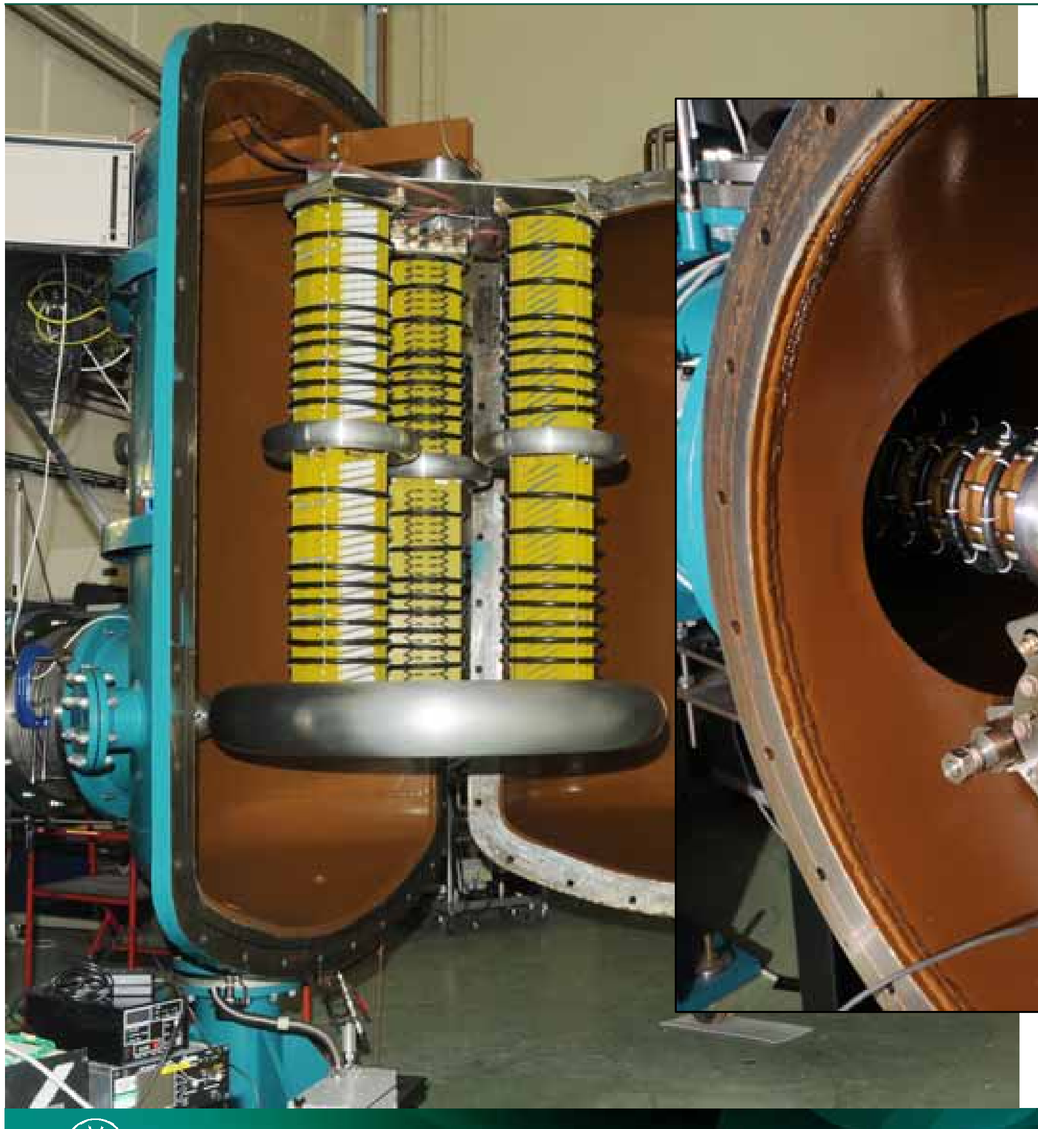
ALICE ERL: Gun assembly

- Based on the JLab IR-FEL gun using a Cs:GaAs cathode
- 500 kV DC supply
- Single bulk-doped ceramic

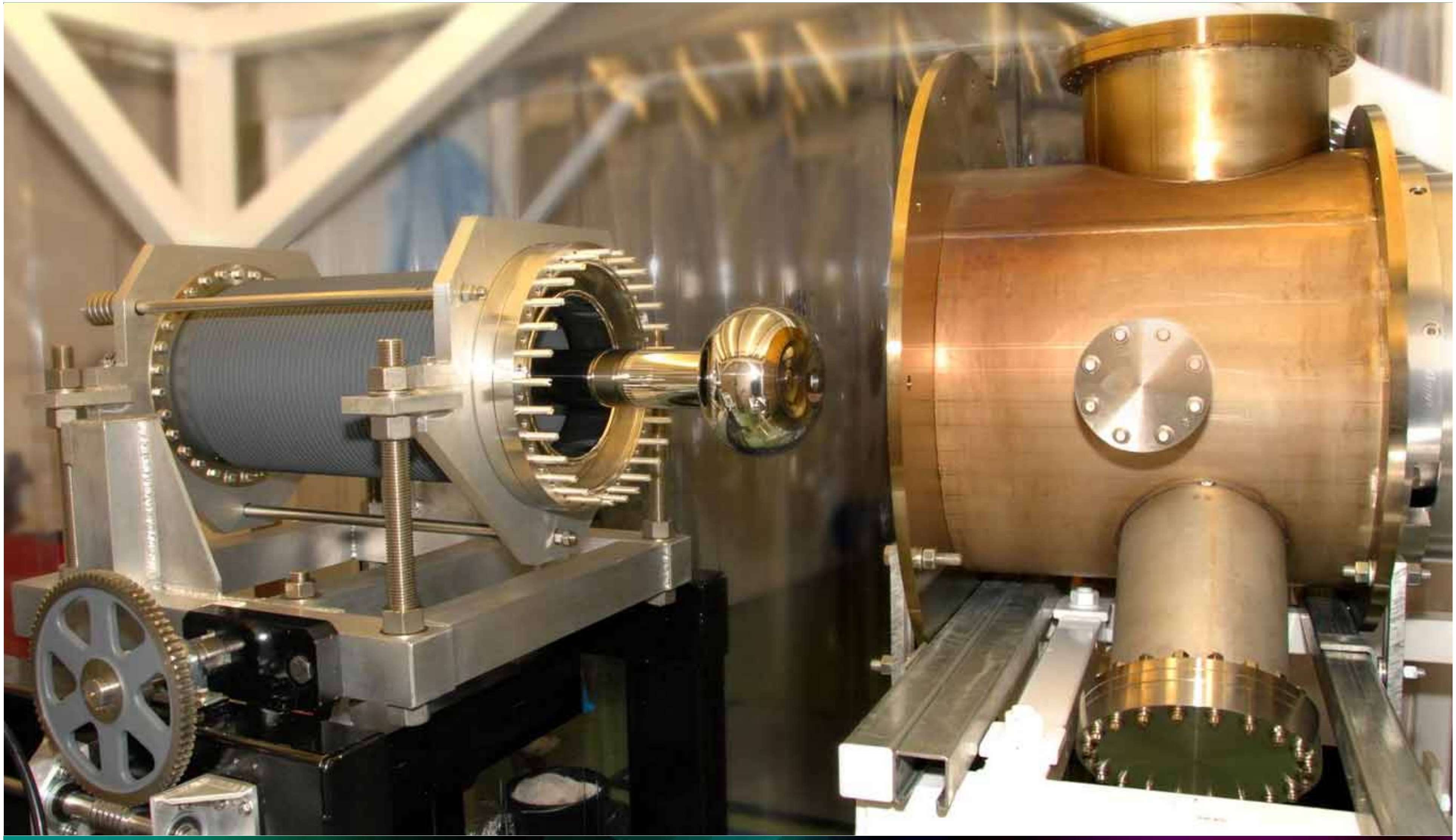


Gun 500 kV power supply

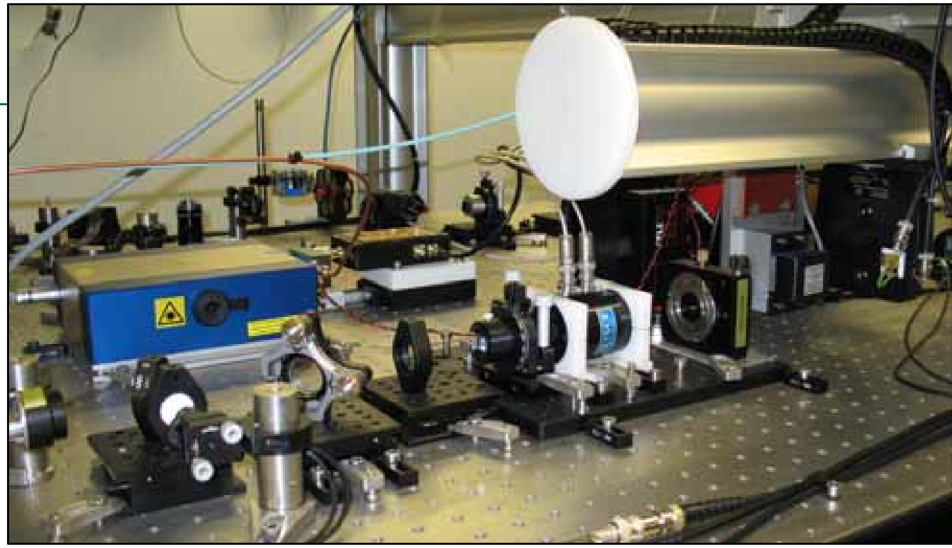
Gun 500 kV power supply



Cathode ball, insulating ceramic & vacuum vessel



Drive laser: Summary

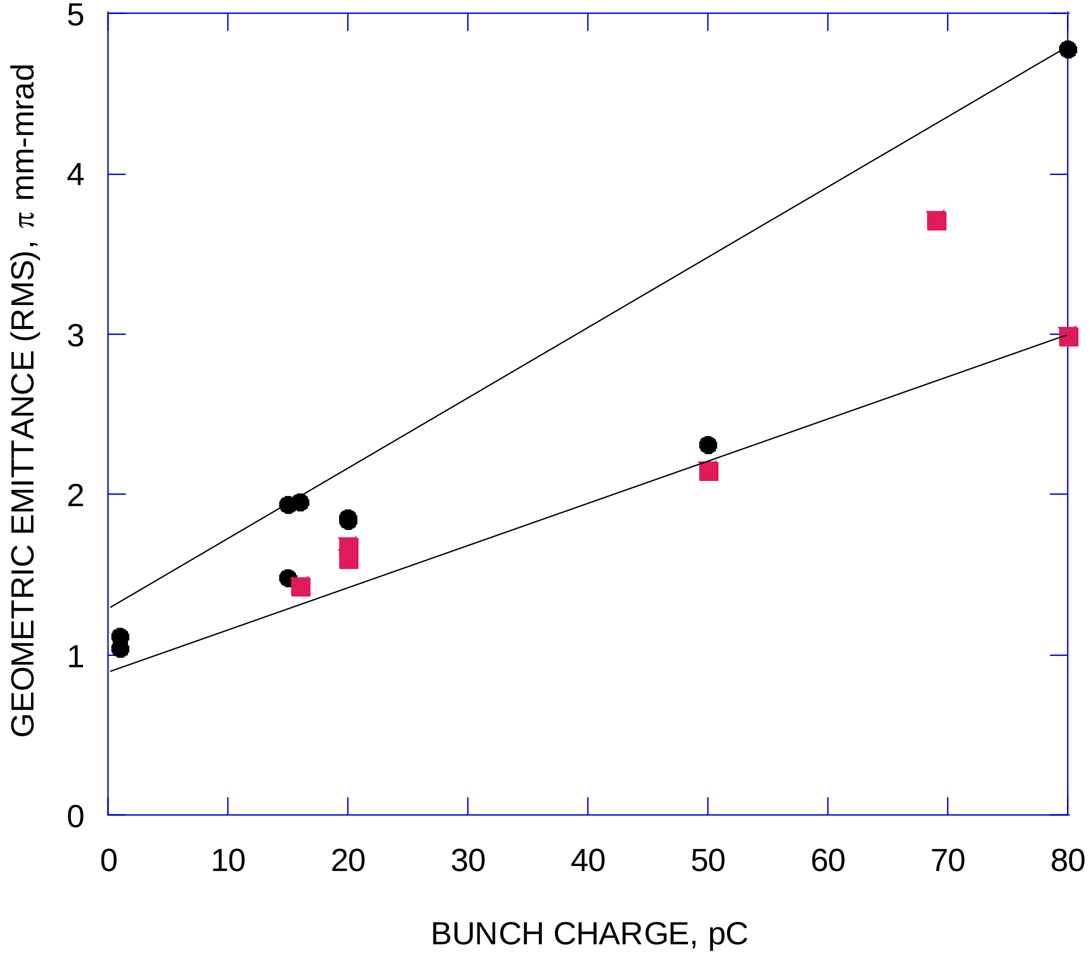


- Diode-pumped $Nd:YVO_4$
- Wavelength: 1064 nm, doubled to 532 nm
- Pulse repetition rate: 81.25 MHz
- Pulse duration: 7, 13, 28 ps FWHM
- Pulse energy: up to 45 nJ (at cathode)
- Macropulse duration: 100 μs @ 20 Hz

- Duty cycle: 0.2% (maximum)
- Timing jitter: < 1 ps (specified)
  < 650 fs (measured)
- Spatial profile: Circular top-hat on photocathode
- Laser system commissioned at Rutherford Laboratory in 2005, then moved to Daresbury Laboratory in 2006

L.B. Jones, Status of the ERLP Photoinjector driver laser, ERL '07 proceedings

RMS Geometric emittance (function of bunch charge)



RMS geometric emittance as a function of bunch charge:

- Horizontal (●)
- Vertical (■)

ALICE ERL target was specified as 1·π mm-mrad by ASTRA for Q = 80 pC

Some factors are missing from the ASTRA model [1,2]

[1] I.V. Bazarov *et al.*, Proceedings of PAC'07, Albuquerque, 2007, pp. 1221-1223.
[2] F. Zhou *et al.*, Phys. Rev. ST - AB **5**, 094203, 2003.

Design criteria demonstrated so far ……

Y.M. Saveliev *et al.*; Proc. EPAC '08, 208-210; MOPC062

Y.M. Saveliev *et al.*; Proc. EPAC '08, 210-212; MOPC063

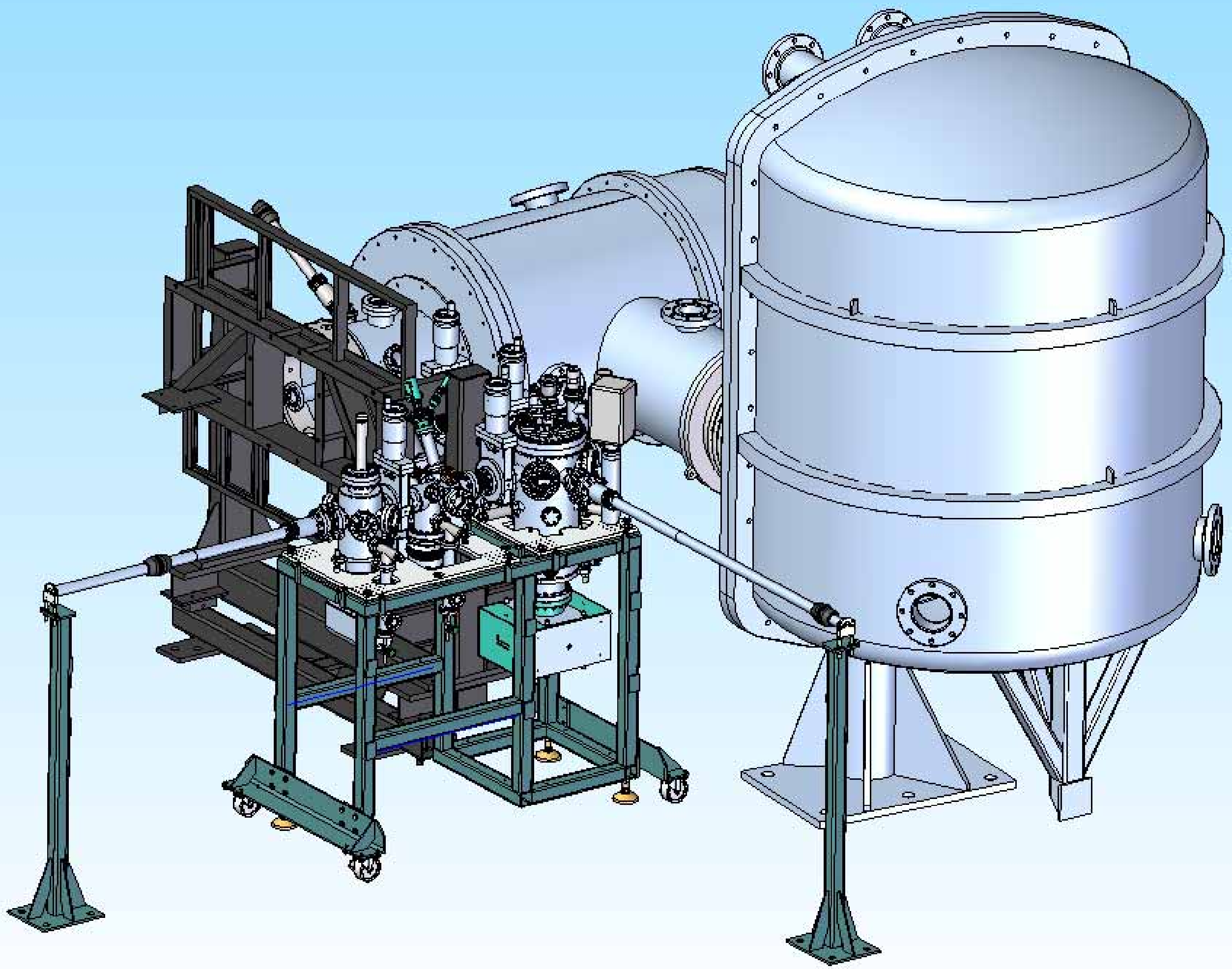
- Beam energy: **350 keV** ✓
- Bunch charge: **> 80 pC** ✓
- Quantum Efficiency (*Q.E.*):

  4.0% with 1/e lifetime nearing 900 hours ✓

- Bunch train length: **Single 7 ps pulse to 100 μs** ✓
- Train repetition rate: **Operated up to 20 Hz** ✓

3-Stage photocathode preparation system

Courtesy B.L. Militsyn, DL



3-Stage photocathode preparation system

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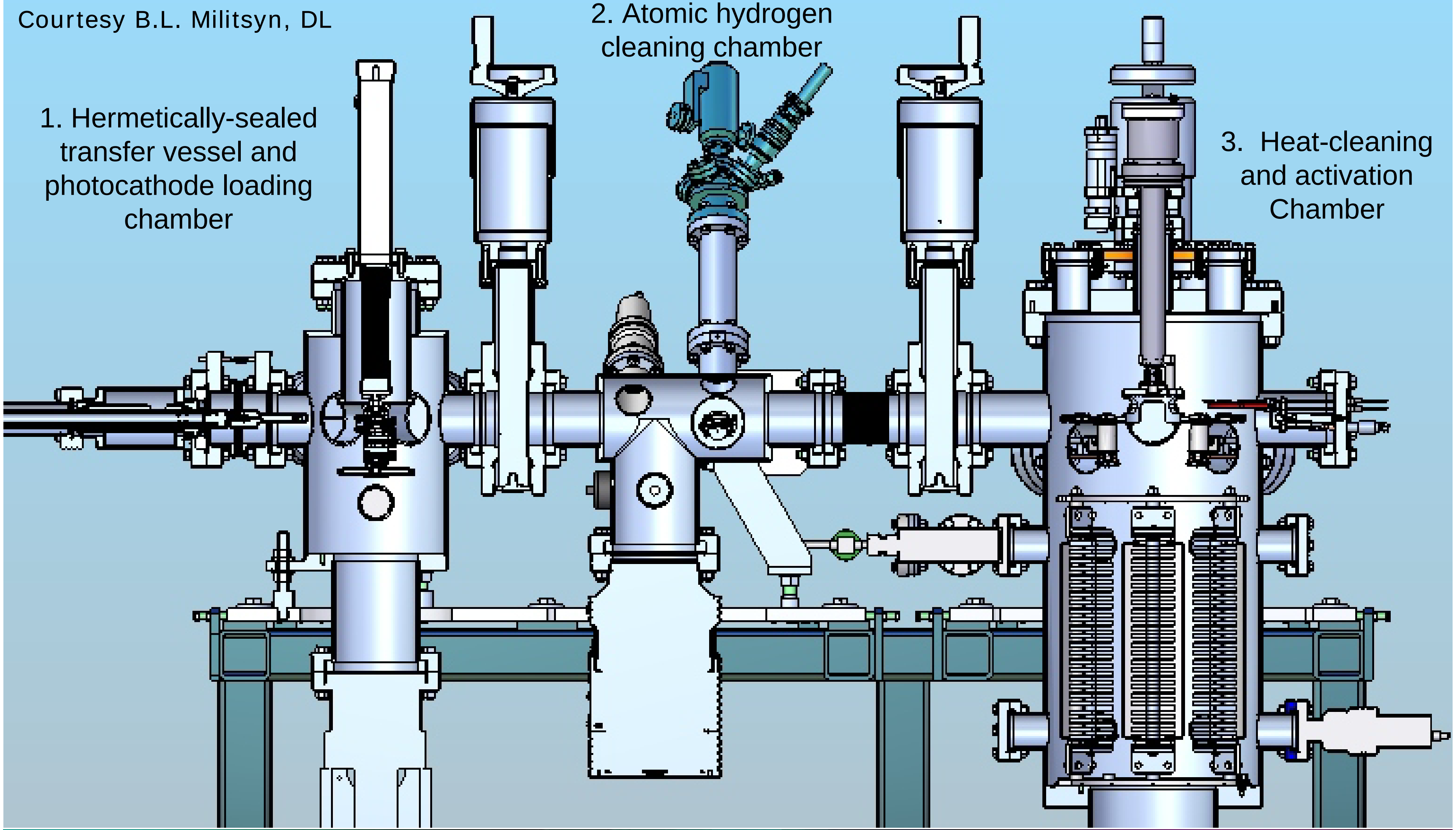
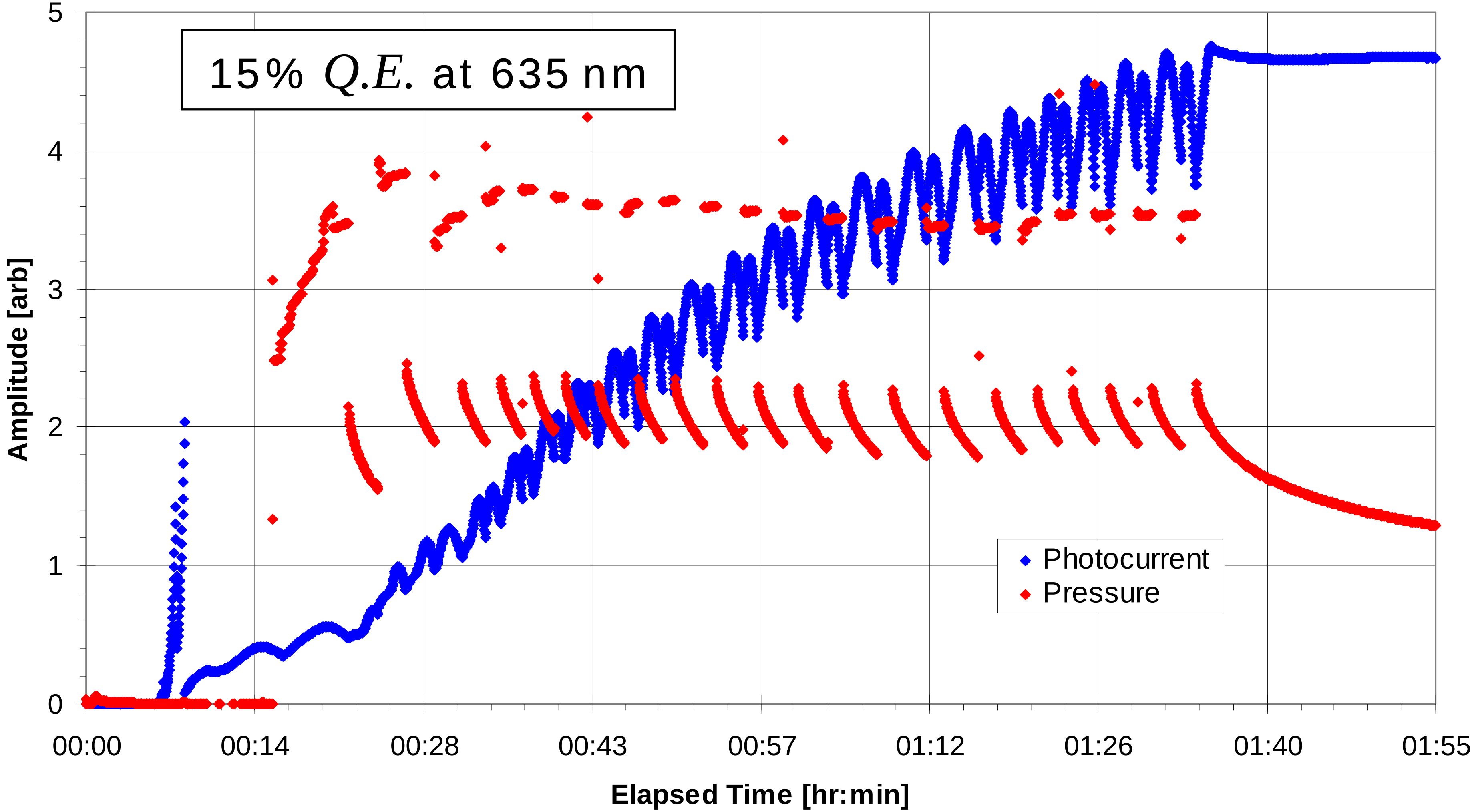


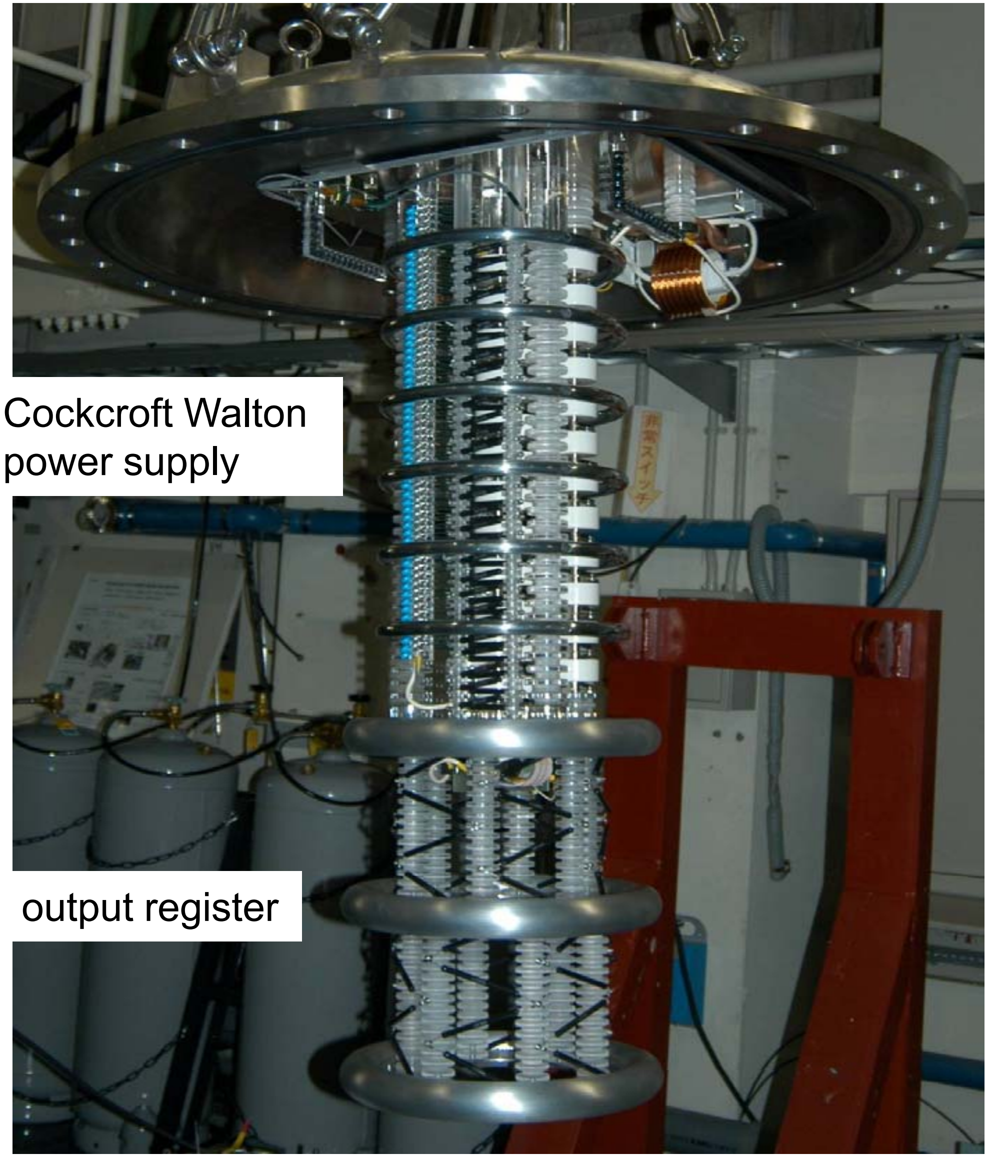
Photocathode preparation system: *1st Result* ☺

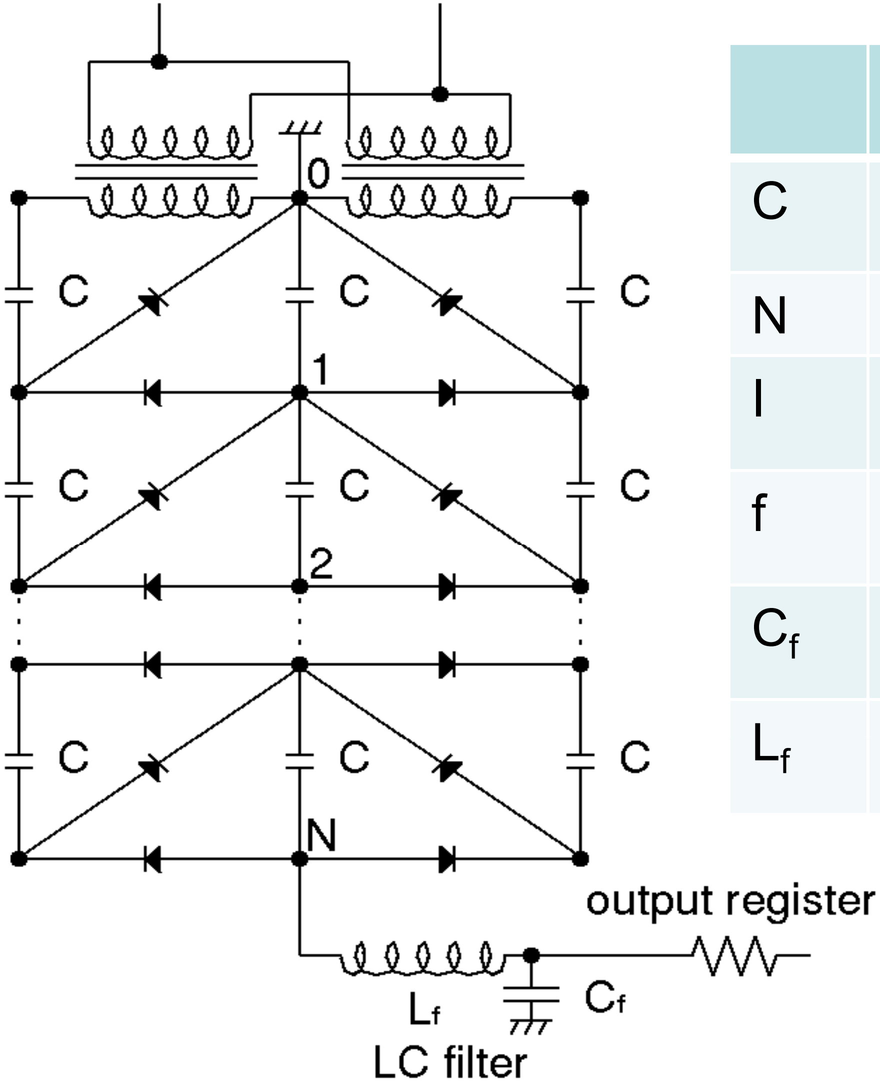


Courtesy B.L. Militsyn, DL

JAEA Gun

High voltage power supply

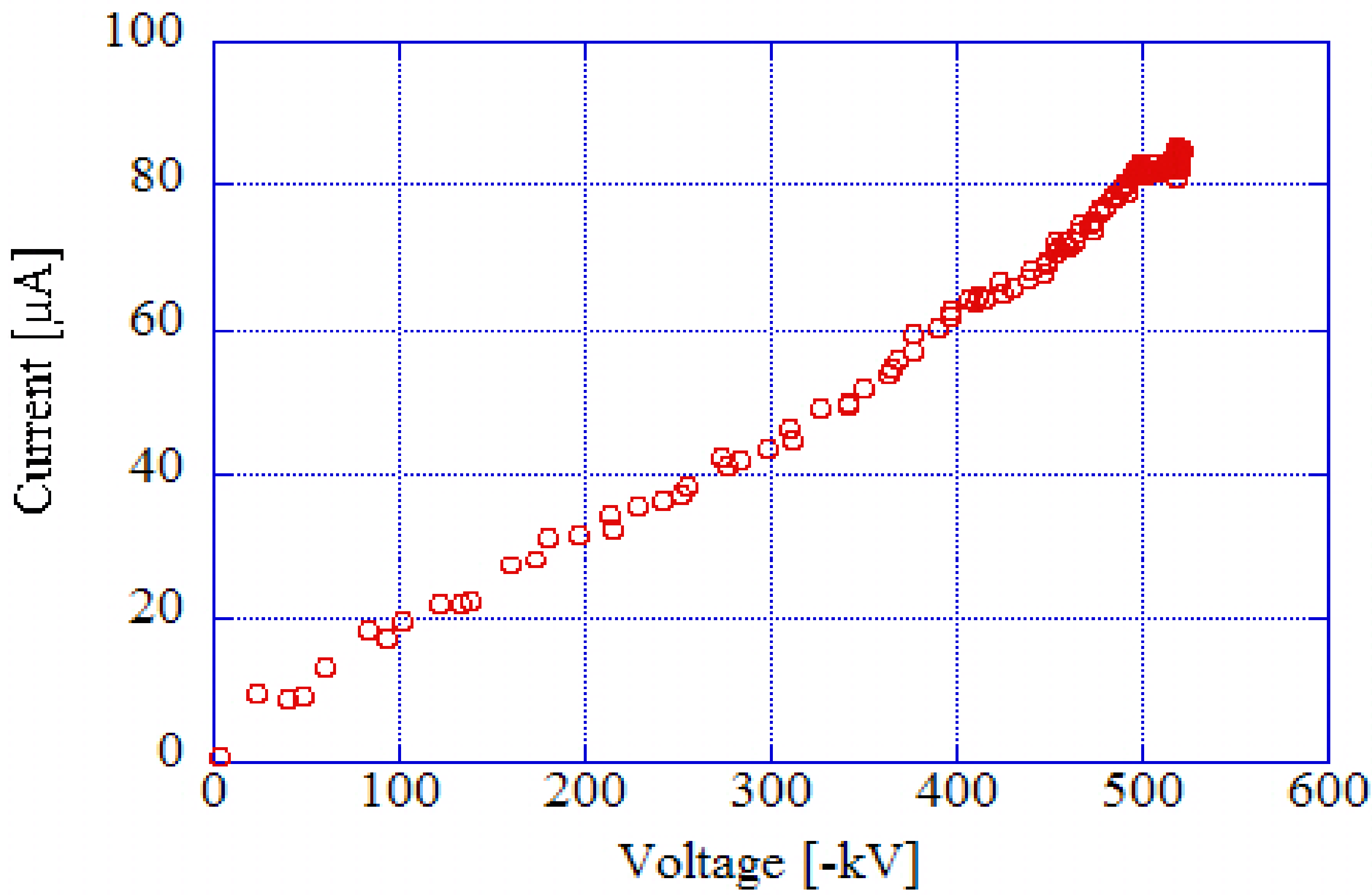




	value
C	2.4nF
N	12
I	10mA
f	40kHz
C_f	0.2nF
L_f	2.0H

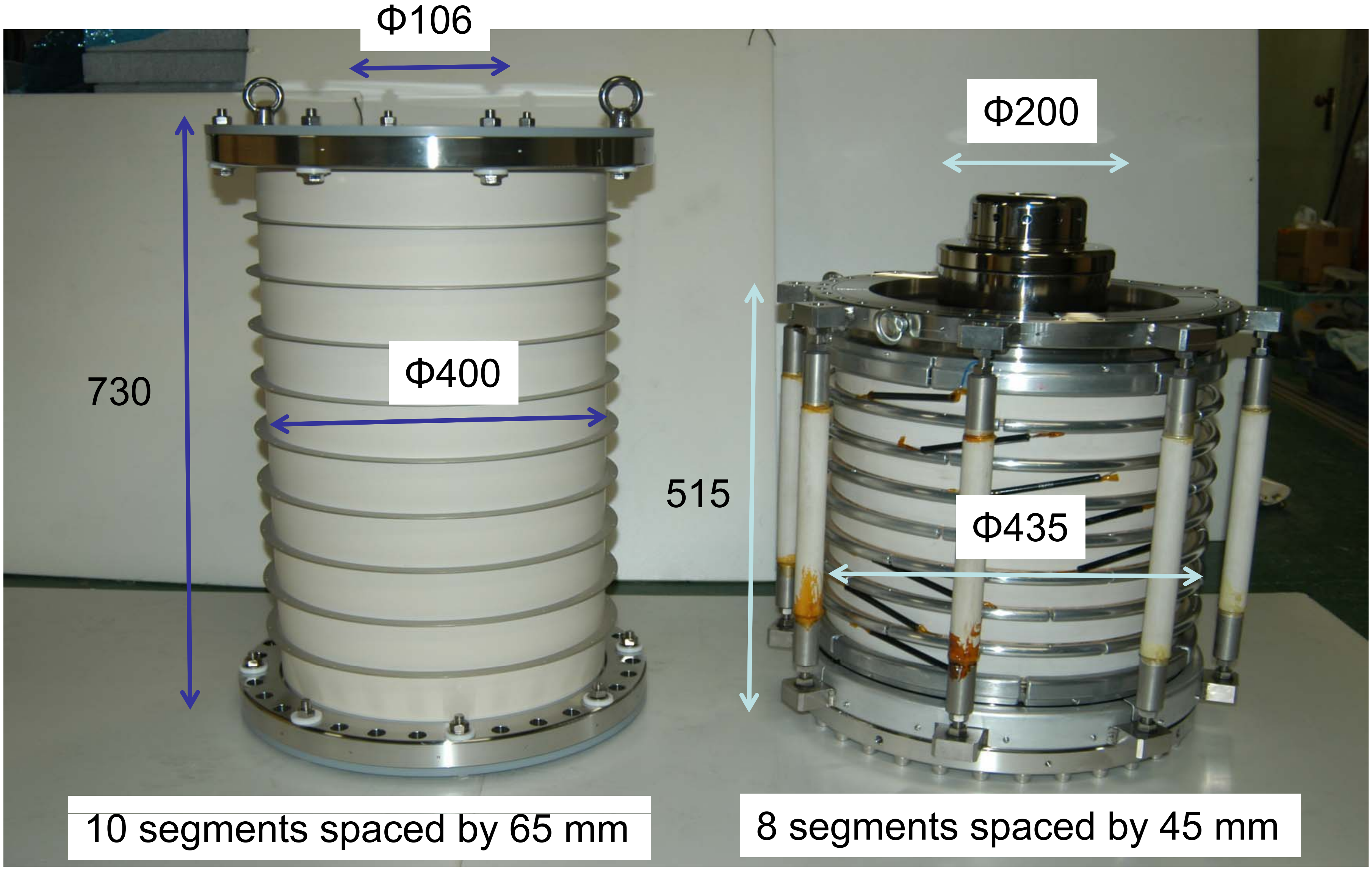
$$\text{ripple} = NI/(8\pi^2 f^3 C\, C_f L_f) = 25\ \text{V}$$

High voltage power supply



A high voltage test to -550 kV was done.
Frequency of transformer of power supply is lowered from 40 kHz to 25 kHz because of temperature increase of IGBT.
The voltage ripple is 8 times greater than design.
The IGBT (SKM 300GB125D) will be replaced with a different one (SKM 300GB063D).

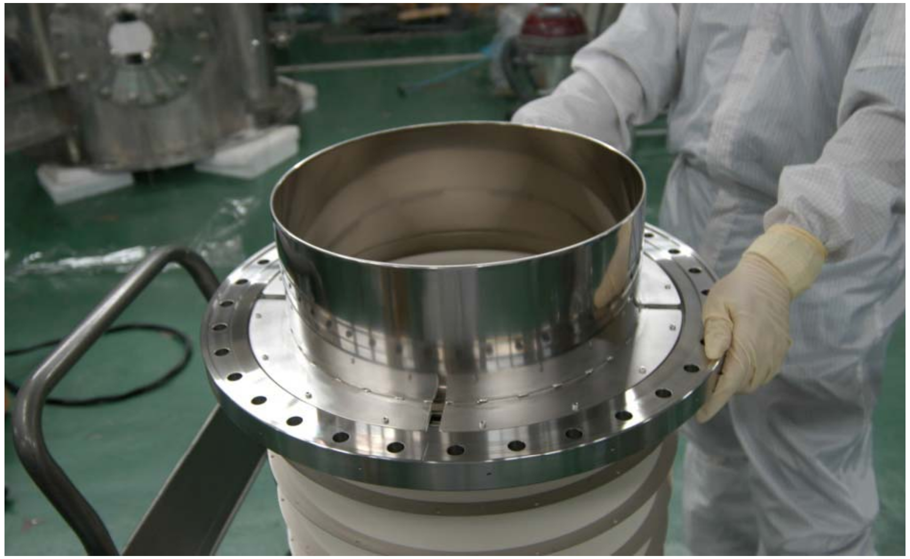
Insulator

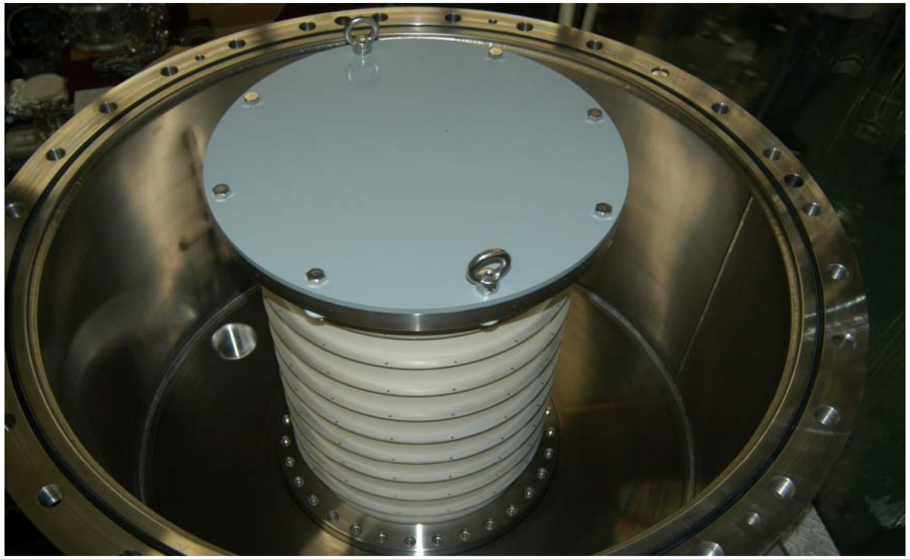


for a 500 kV gun

for a therminoic gun for JAEA FEL

Plan for HV test

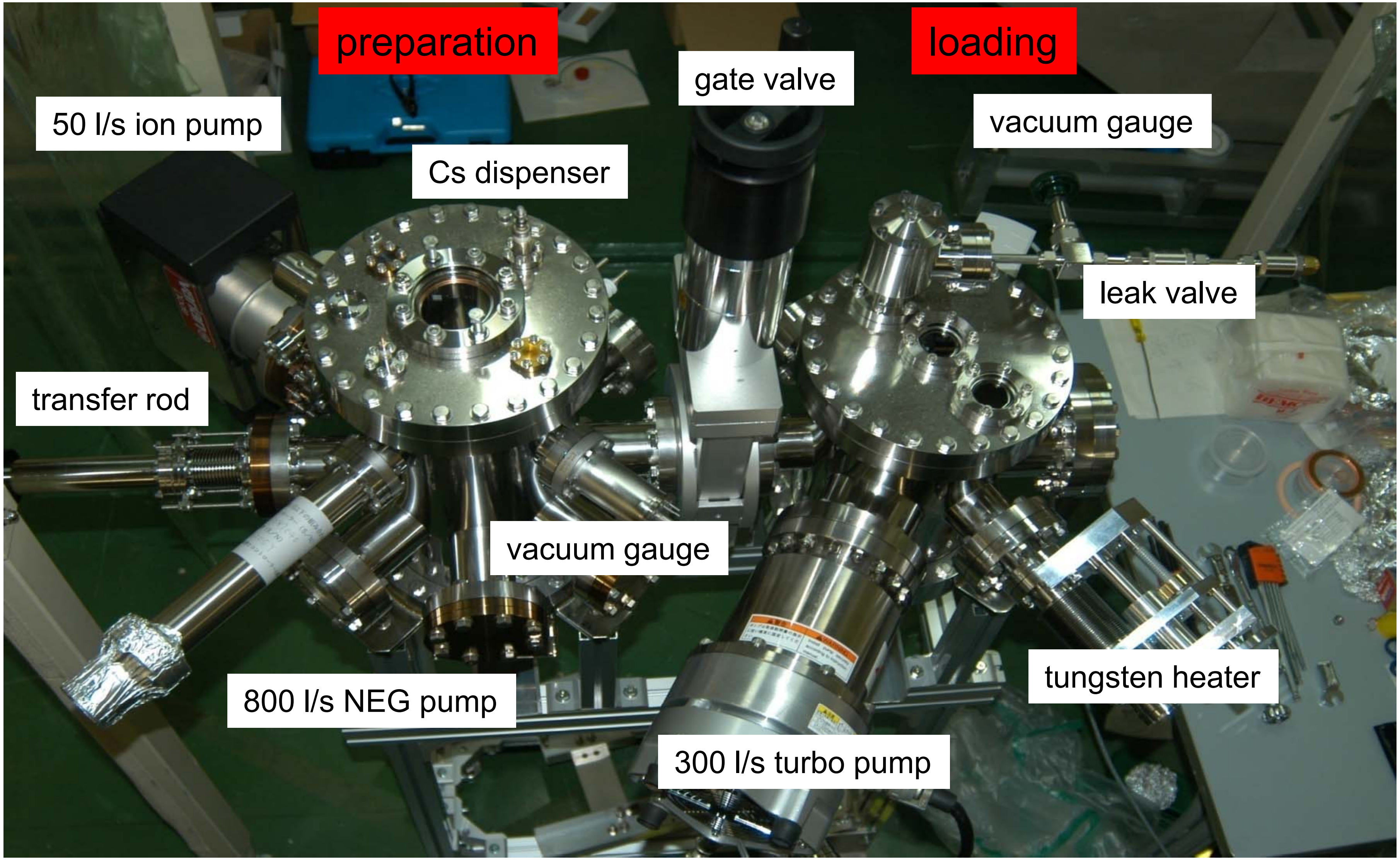




1. Assembly of guard rings and HV chamber.
2. HV test of the insulator with a guard ring but without a support rod.
3. HV test of the insulator with a support rod.
4. If we face any problem, we can reverse the guard ring.

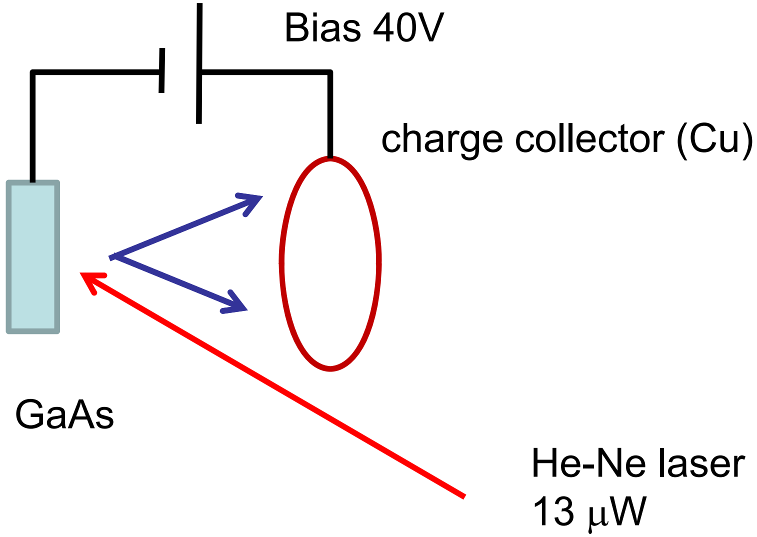
- A 1000 l/s turbo pump will be used for the HV tests.
- A NEG pump unit for the HV chamber will be installed after August.

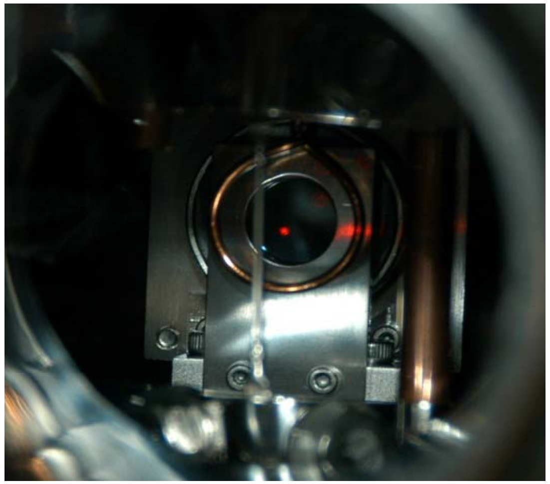
Cathode preparation system



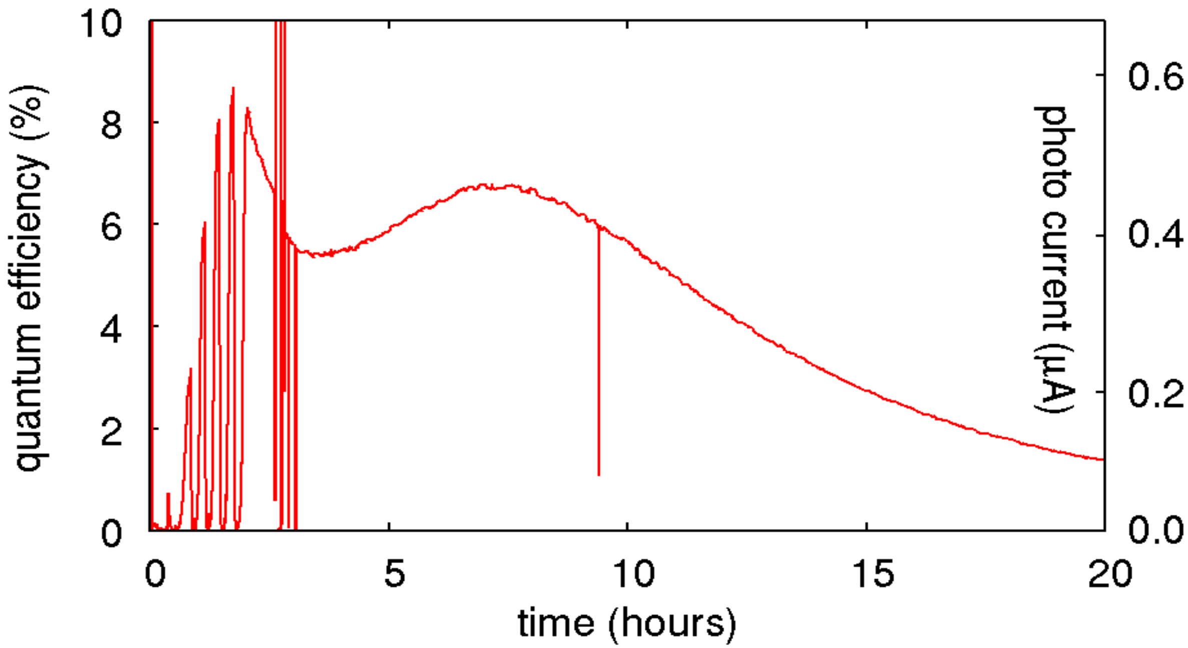
- JLab polarized gun is the model of our chamber system.
- Vacuum: 4.5 x 10^{-9} Pa at preparation, <5.0x10^{-8} Pa at loading.

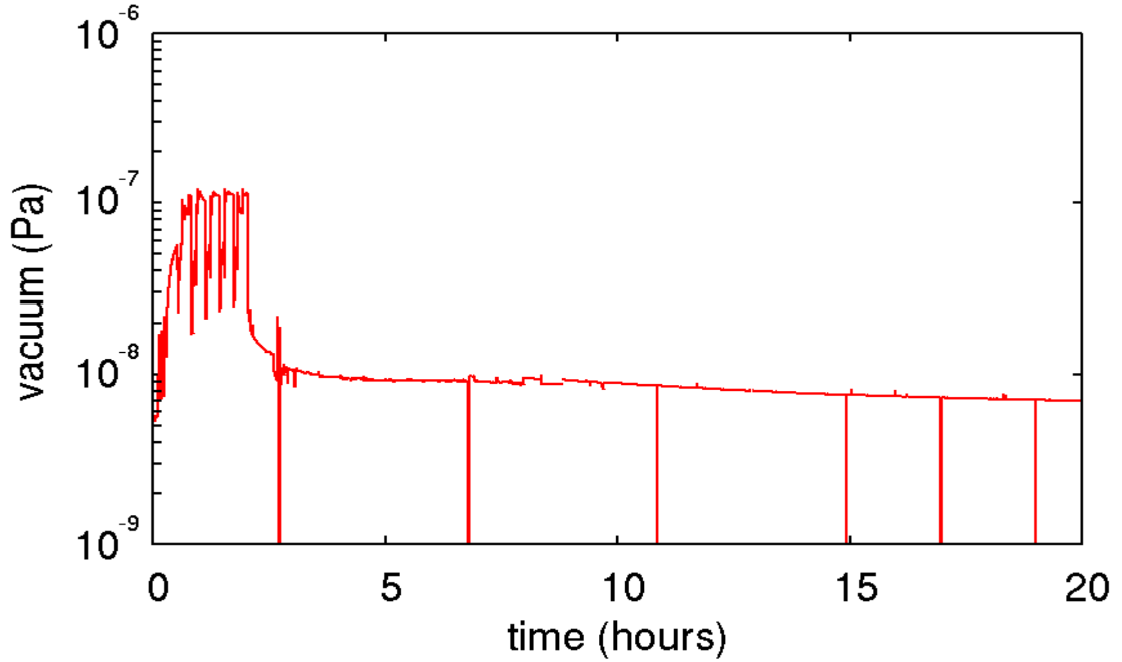
QE measurement





- The base pressure is 6.5×10^{-9} Pa.
- The life time needs to be improved.





WG1全体に関するまとめは、最終日のレポート

Report From Working Group 1 - Injectors, Guns, & Cathodes

DC-gunに関しては、西森氏

SRF-gunにかんしては、John Lewellen氏

のスライドをご参照ください。