Science & Technology Facilities Council
ASTeC

Performance of the ALICE ERL photoinjector photocathode gun

Boris Militsyn

On behalf of the ALICE team

Accelerator Science and Technology Centre

STFC Daresbury Laboratory

Alice
Accelerators and Lasers
In Combined Experiments

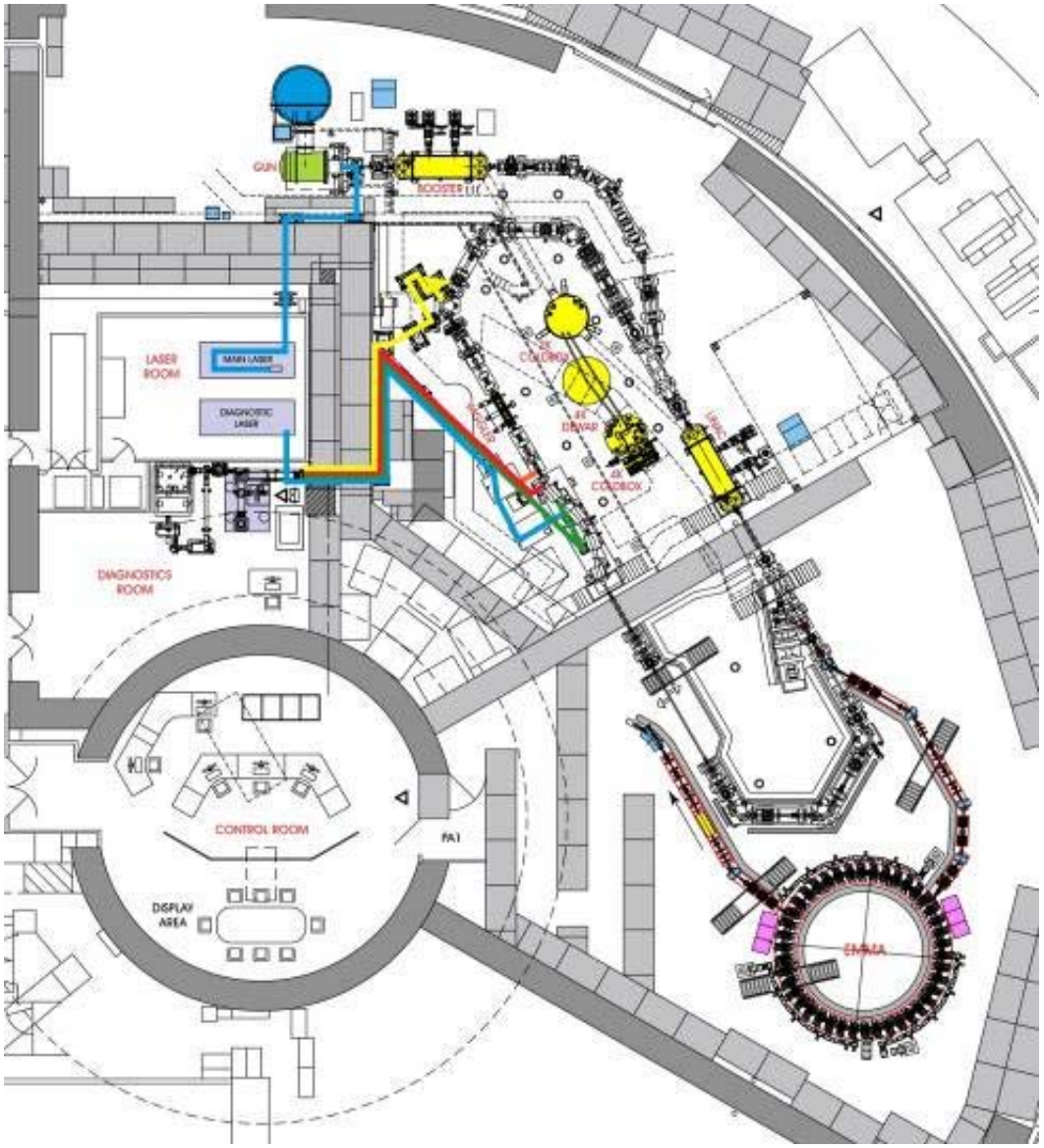
ERL 2011

Outline

- ALICE Energy Recovery Linac overview
- ALICE photoinjector
- Photocathode gun design
- Gun operation and lessons learned
- Photocathode performance in the gun
- Gun upgrade status

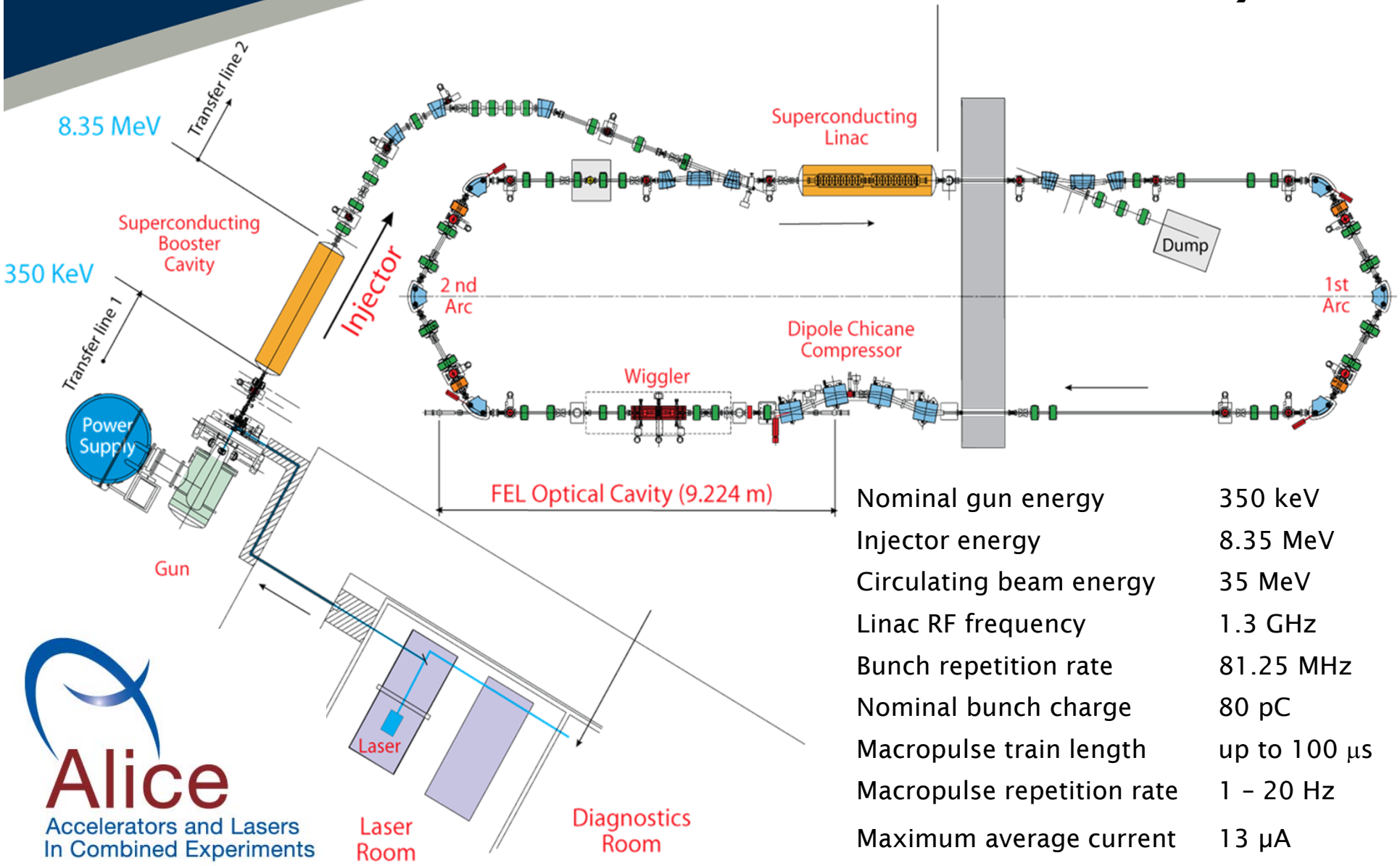
Science & Technology Facilities Council
ASTeC

ALICE ERL. Overview



Science & Technology Facilities Council
ASTeC

ALICE ERL. Layout

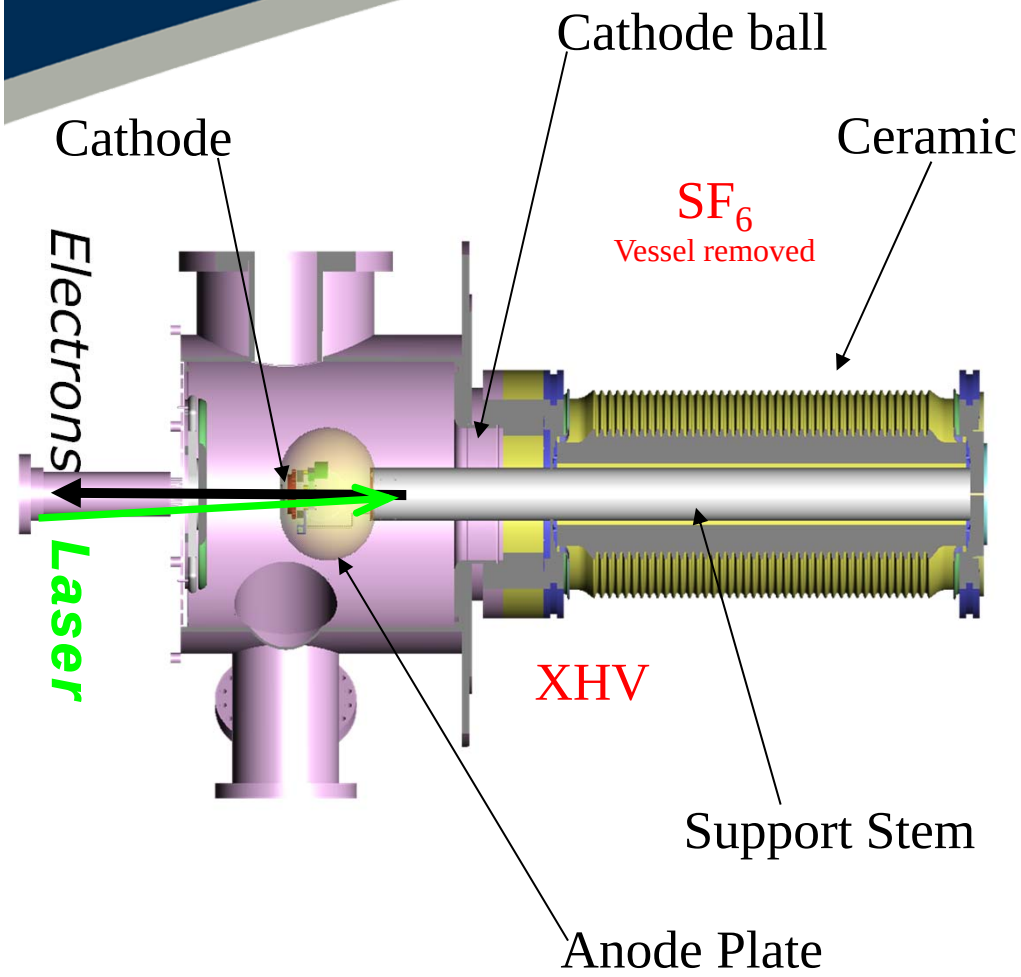


Alice
Accelerators and Lasers In Combined Experiments

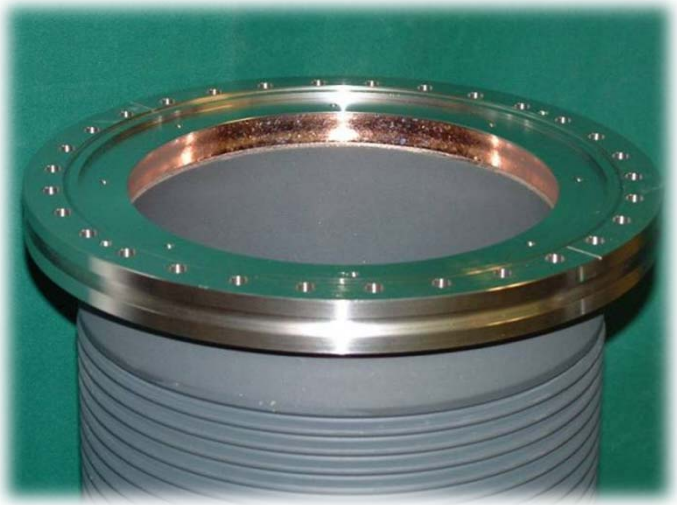
Nominal gun energy	350 keV
Injector energy	8.35 MeV
Circulating beam energy	35 MeV
Linac RF frequency	1.3 GHz
Bunch repetition rate	81.25 MHz
Nominal bunch charge	80 pC
Macropulse train length	up to 100 μs
Macropulse repetition rate	1 – 20 Hz
Maximum average current	13 μA

Science & Technology Facilities Council
ASTeC

ALICE photocathode gun



- Uses Cs:GaAs photocathode
- 500 kV DC power supply
- Single bulk-doped ceramic
- Good electrical performance
- Poor mechanical performance

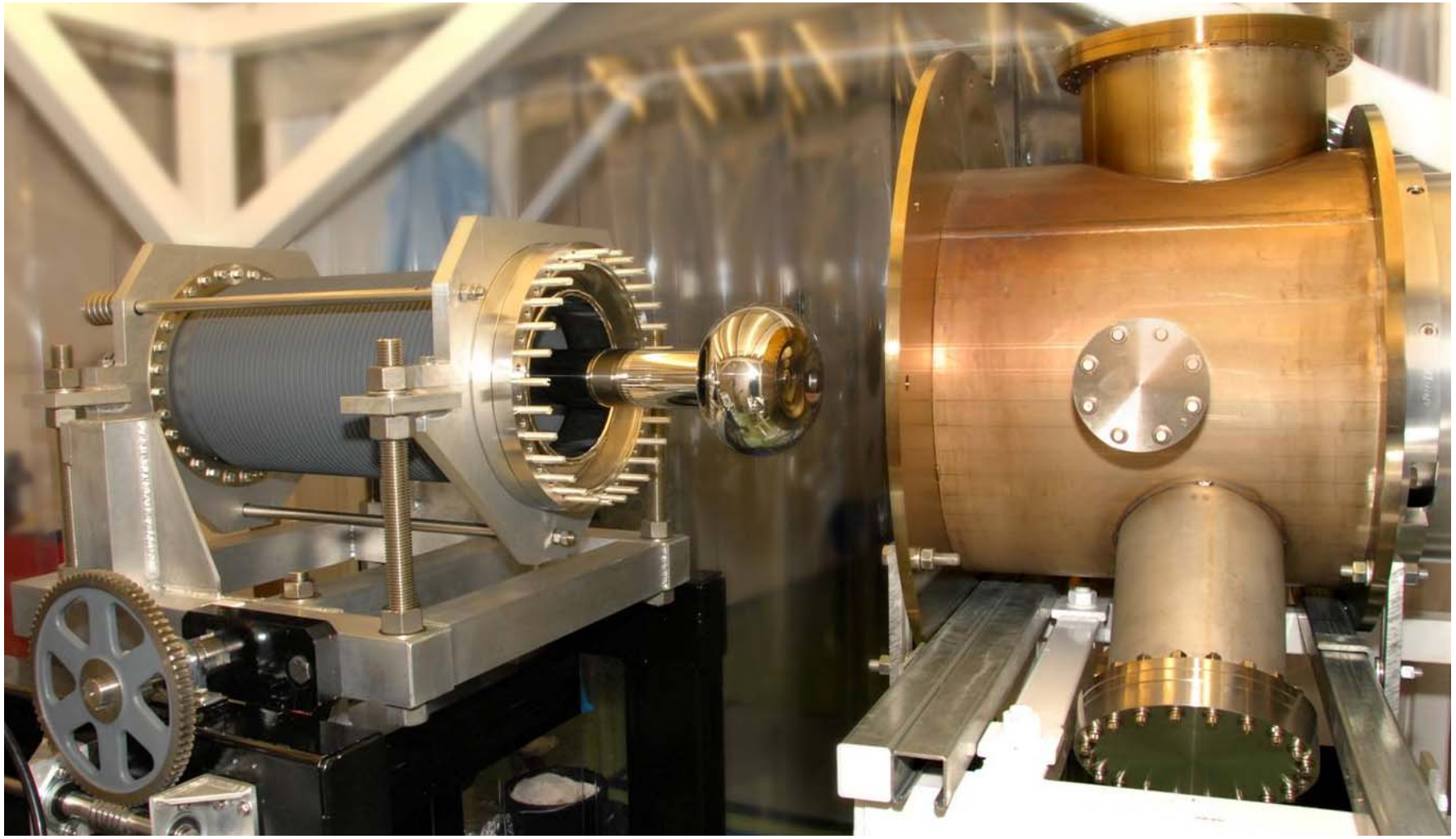


× Repeated failure of ceramic forced use of spare 2-piece ceramic

× Operating voltage limited to 230 kV

Science & Technology Facilities Council
ASTeC

Photocathode gun. Assembly stage

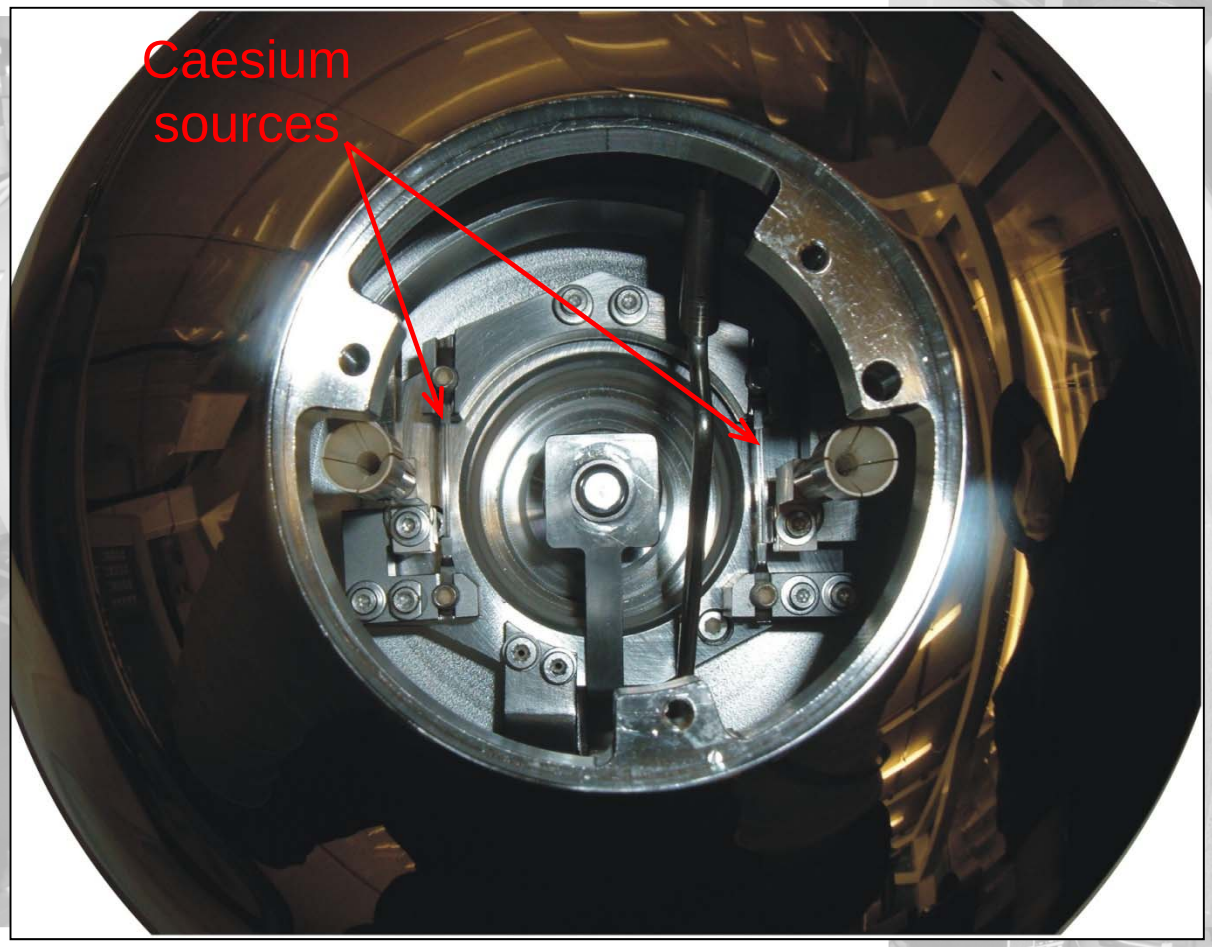


Science & Technology Facilities Council
ASTeC

Photocathode gun. 500 kV power supply

Science & Technology Facilities Council
ASTeC

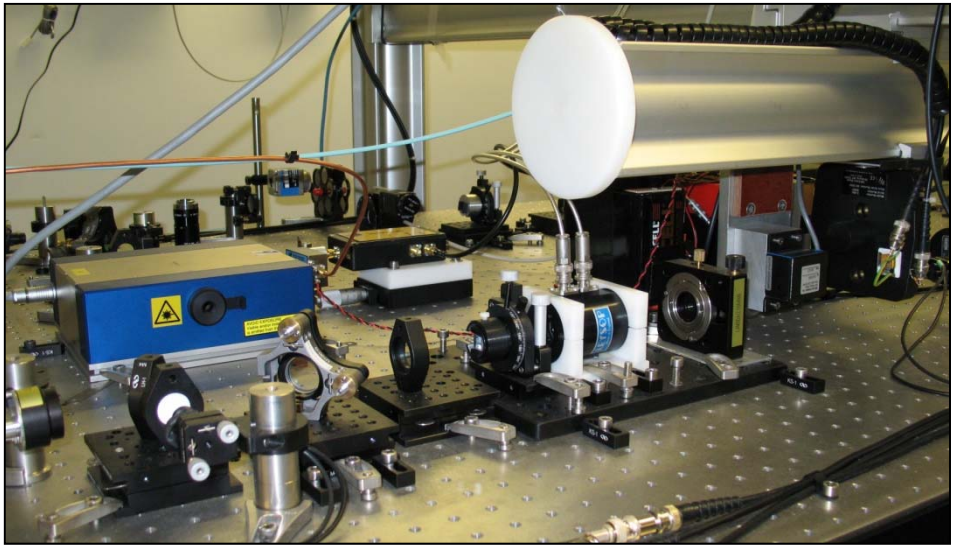
Photocathode gun. Cathode electrode and cathode stem



Science & Technology Facilities Council
ASTeC

Photocathode gun. Drive laser

- 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: up to 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

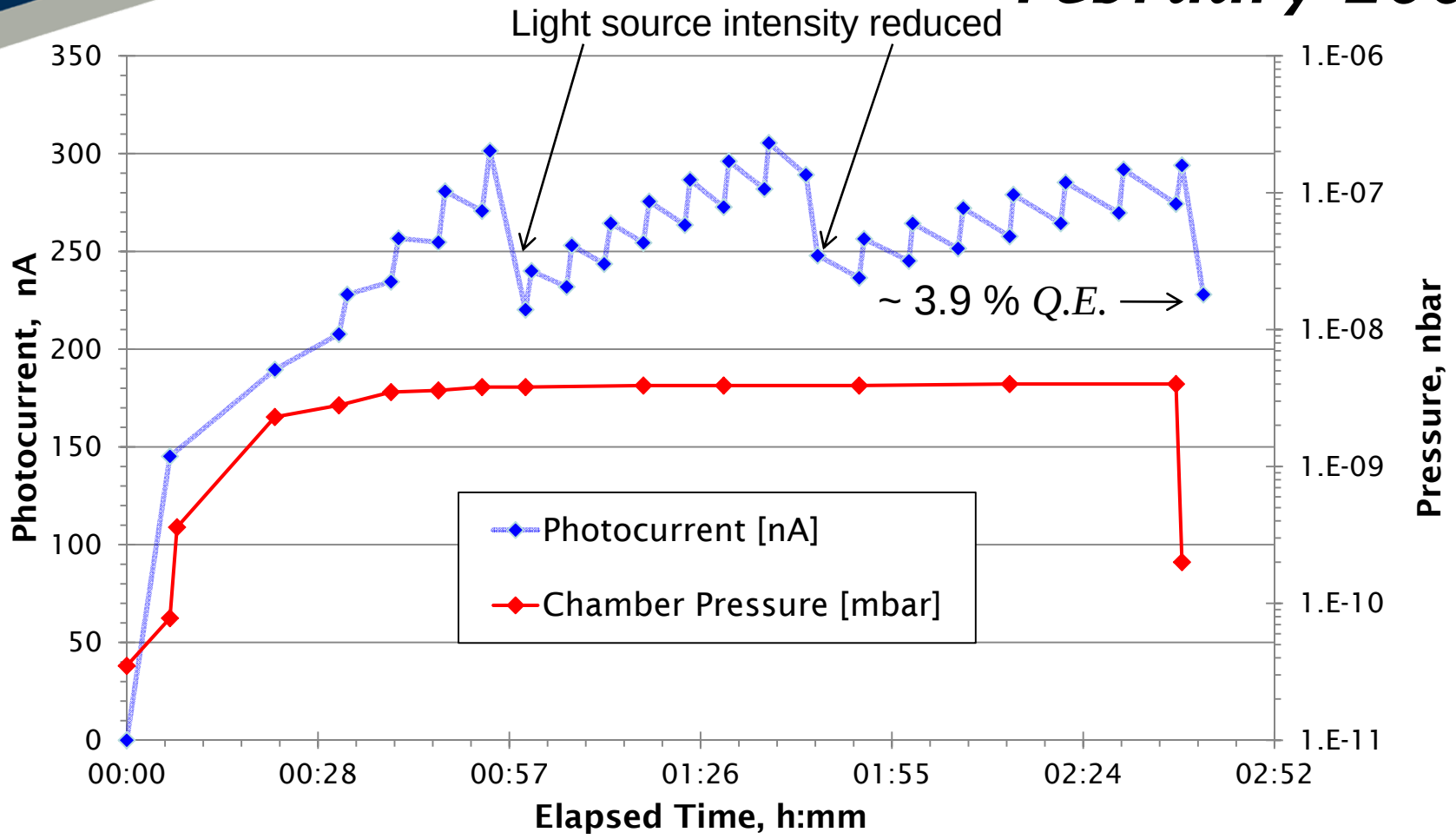
Science & Technology Facilities Council
ASTeC

Photocathode gun. Operation modes

Gun operation mode	Gun voltage, kV	Micropulse charge, pC	Micropulse repetition rate, MHz	Train length, μs	Train repetition rate, HZ
Single pulse ERL mode	230	Up to 200	81.25	Single micropulse	Up to 10
FEL Mode	230	60	16.25	100	10
THz mode	230	60	40.125	100	10
EMMA injection mode	230	40	81.25	Single micropulse	5

Science & Technology Facilities Council
ASTeC

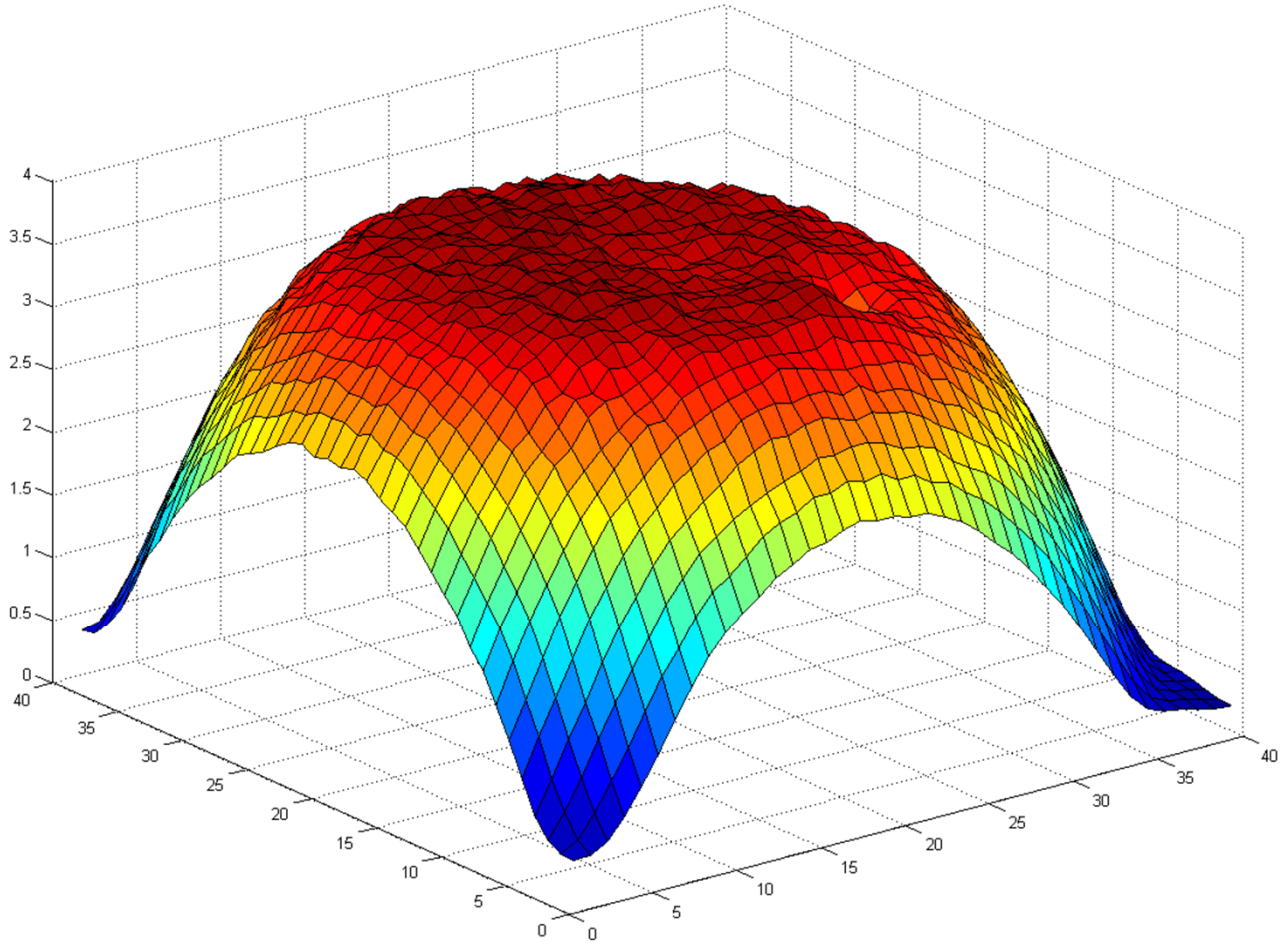
Photocathode. NF_3 activation in the gun in February 2009



2nd activation of a VGF wafer supplied by Mateck GmBH (Julich)

Science & Technology Facilities Council
ASTeC

Photocathode. NF_3 activation in the gun in February 2009

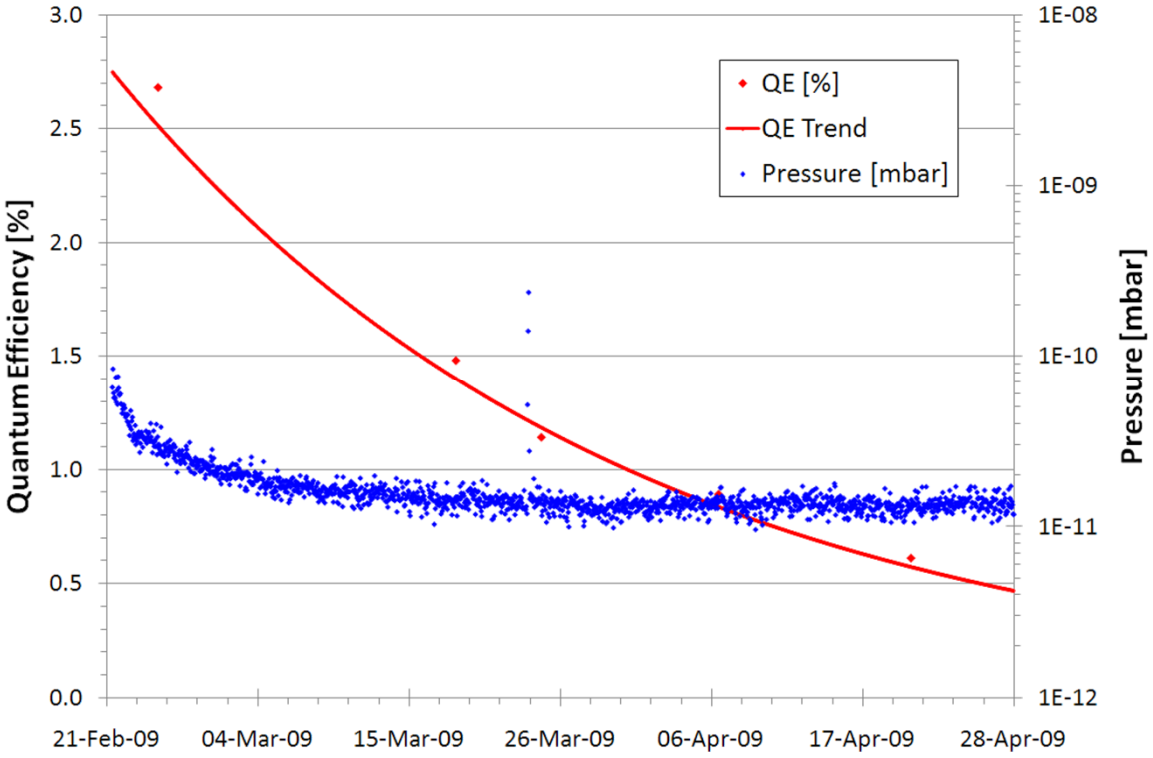


Peak *Q.E.* ~ 3.9 % at 532 nm

Science & Technology Facilities Council
ASTeC

Photocathode. Dark lifetime

1/e dark lifetime ~ 900 hours for NF_3 activation (1st re-caesiation), despite a minor vacuum incident



Process	Date	Initial *Q.E.*	$^1/_e$ Lifetime	Life [hrs]	Final *Q.E.*
Activation	12/02/09	3.9	~ 200	156	0.3
Re-Cs # 1	21/02/09	3.4	~ 900	2,280	0.05
Re-Cs # 2	01/06/09	2.2	270	215	0.63
Re-Cs # 3	10/06/09	2.0	50	28	1.1

Science & Technology Facilities Council
ASTeC

Photocathode. Performance in the ALICE gun

- Current photocathode is in operation since 2008
- Best photocathode performance (highest *Q.E.* and best dark lifetime) have been achieved using the Cs-NF_3 activation, however, activation success with NF_3 has been inconsistent (no first-peak photocurrent response seen in some activations, prompting a switch to O_2)
- NF_3 requires a higher partial pressure than O_2, typically a decade higher with O_2 in the mid 10^{-10} mbar and NF_3 in the mid 10^{-9} mbar. This leads to a longer vacuum recovery
- The dark lifetime has not been specifically monitored since 2008, though gun base pressure has improved significantly since.
- O_2 is used as the default oxidant due to health & safety considerations
- Re-caesiation take place typically every 7 to 12 days, having extracted ~ 0.3 C charge
- External connection to Cs source for *fast re-caesiation* (no SF_6 extraction required)

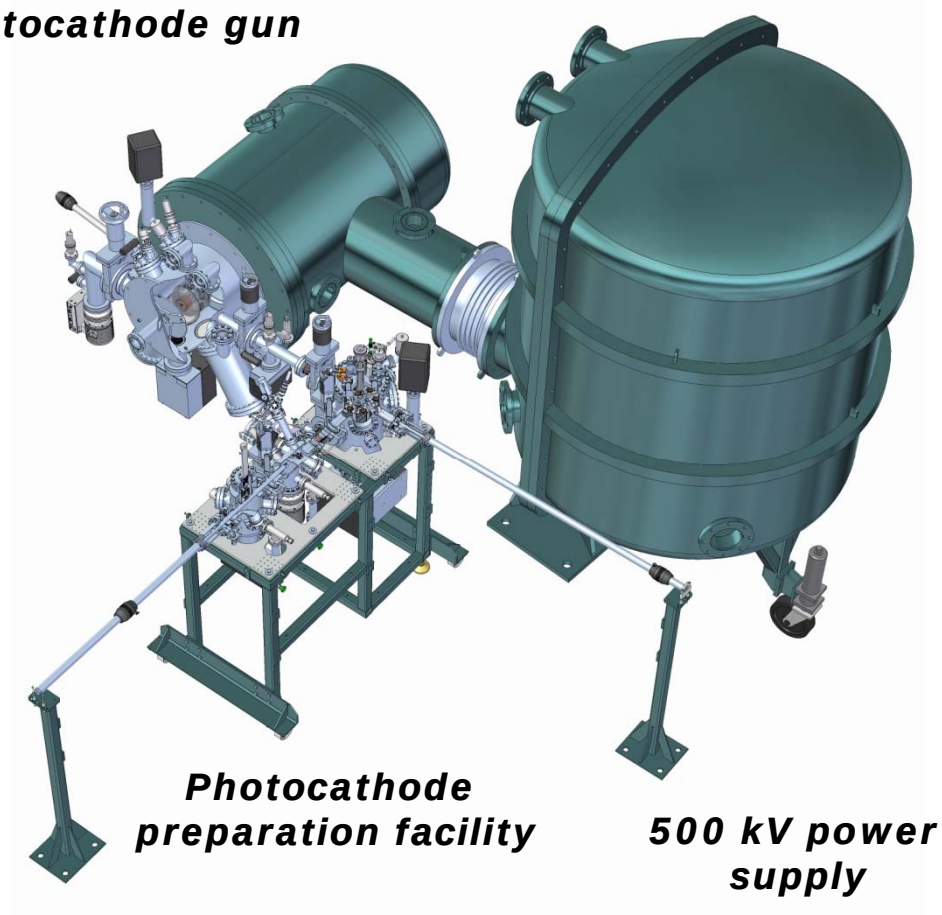
Science & Technology Facilities Council
ASTeC

Status of the ALICE gun upgrade

Upgrade of the gun allows

- Reduce the down time required for activation of the photocathode and allows ALICE for operation with higher bunch charge.
- Remove activation/caesiation procedure out of the gun
  - Improve vacuum in the gun
  - Reduce contamination of the high voltage electrodes with Cs and other products of photocathode preparation
- Make photocathode activation more controllable
- Allows for experiments with different types of photocathodes

Photocathode gun

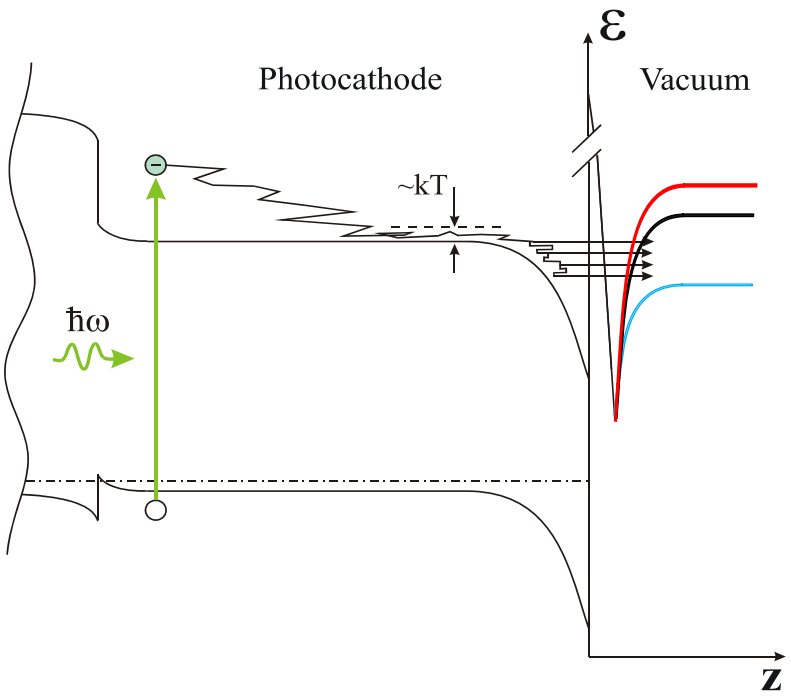


Photocathode preparation facility

500 kV power supply

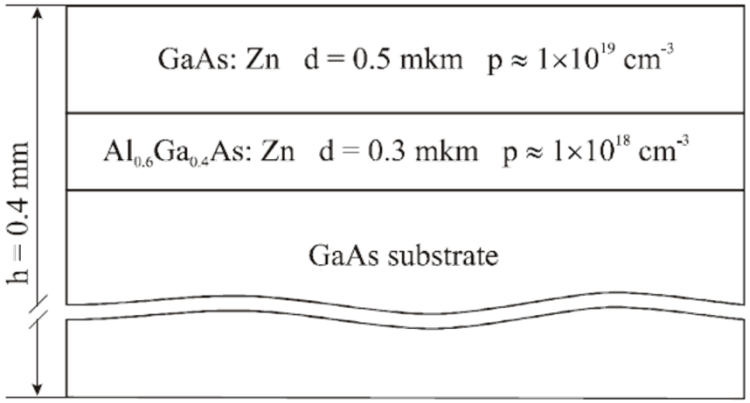
Science & Technology Facilities Council
ASTeC

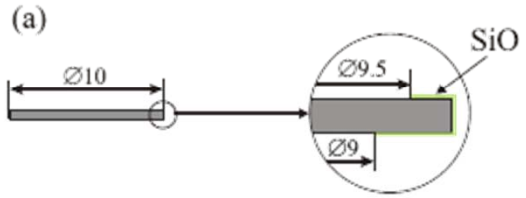
High average current GaAs photocathodes

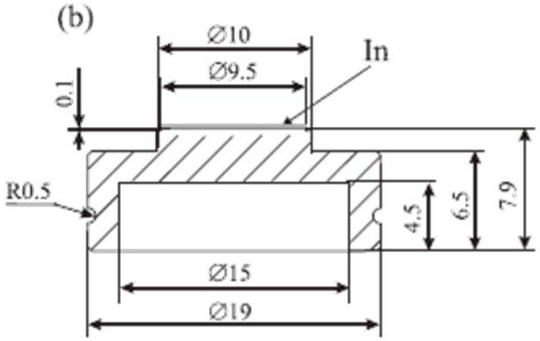


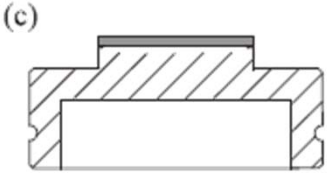
$$\chi > kT \qquad E_i = h\nu - E_g - \chi$$

$$\chi < 0 \qquad E_i = h\nu - E_g - \chi$$





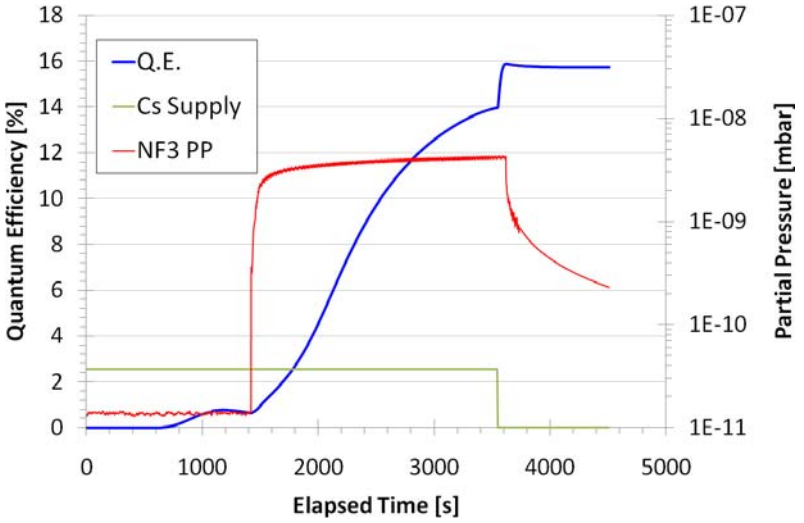


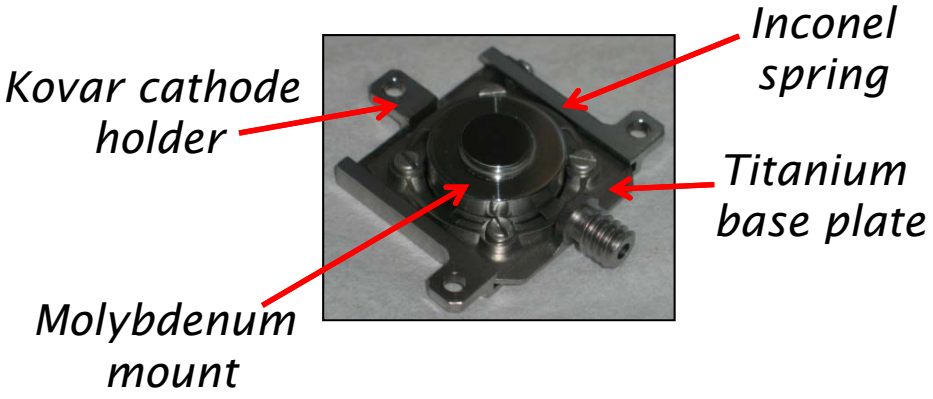


Science & Technology Facilities Council
ASTeC

GaAs photocathode preparation facility

K.J. Middleman et al., PESP2010





Summary

- ALICE photocathode gun is successfully operated since 2008 with “temporary” double ceramic insulator with reduced high voltage of 230 kV in different operation modes
  - Highest photocathode *Q.E.* seen in the ALICE gun when using NF_3 (~3.9 %)
  - Best dark lifetime seen in ALICE gun following re-caesiation of the cathode activated using NF_3 (~ 900 hours)
- During current shutdown the temporary insulator is going to be replaced with a newly brazed single ceramic unit after that the operation voltage of 350 kV is expected.
- Installation of the gun upgrade has been postponed