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PHOTOCATHODE R&D FOR HIGH AVERAGE CURRENT ERL PHOTOINJECTORS AT STFC ASTEC

B.L. Militsyn on behalf of the ASTeC photoinjector development team

Accelerator Science and Technology Centre
Science & Technology Facility Council, UK

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs

Outline

- General remarks
- Ultimate demands to high brightness high average current emitters
- Physics of photoemission from high current photocathodes
  - Preparation of the high average current photocathodes
  - Investigation of energy distribution of electrons, emitted from the photocathodes
  - High voltage emittance and response time
  - Operation at high currents, dark and operation lifetime
- Development of the electron injectors for ongoing and future projects:
  - Photocathode design
  - Photocathode transport system
  - ALICE photoinjector upgrade
  - Operation of the ALICE photoinjector (see Tuesday talk)

Production of high average current electron beams

- Emission
  - Thermal emission (medium brightness, difficult controllability)
  - Field emission (high brightness, poor controllability)
  - Photoemission (medium brightness, good controllability)
- Acceleration
  - DC gun (low field, highly stable, acceptable environment for photocathodes, high repetition rate)
  - NC RF guns (high field, medium stability, low repetition rate)
  - SRF guns (medium field, high repetition rate)
- Beam manipulation

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Demands on the emitted electron beams for light sources

$$\varepsilon_{n,rms} = \beta\gamma \frac{\lambda}{4\pi}$$

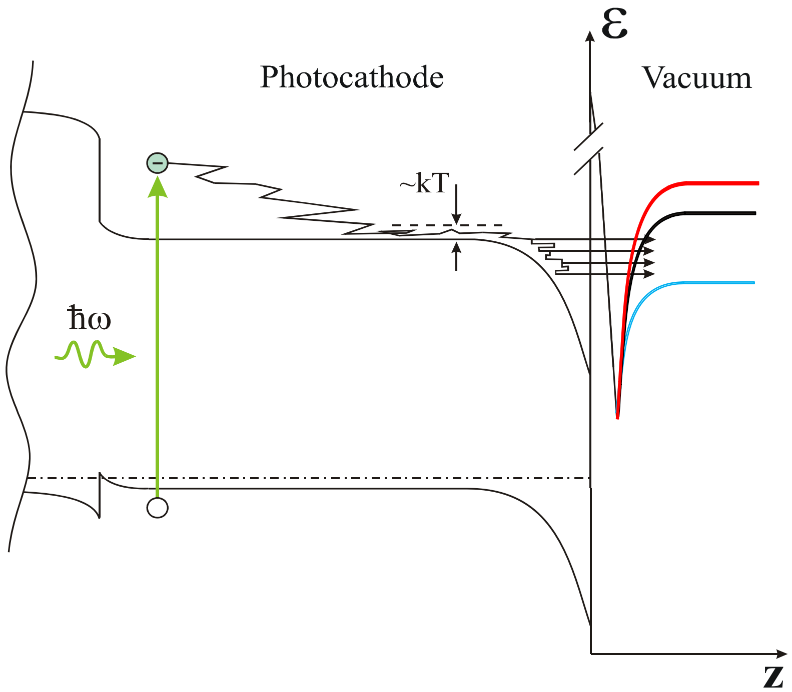
$$\varepsilon_{n,rms} = \sqrt{\overline{x^2}\,\overline{x'^2} - \overline{x \cdot x'}^2} = \sigma_{\perp}\sqrt{\frac{2E_i}{3mc^2}}$$

$$\sigma_{\perp} = \frac{1}{2}\sqrt{\frac{q}{\pi\varepsilon_0 E_c}}$$

$$E_i = 1 \quad eV$$

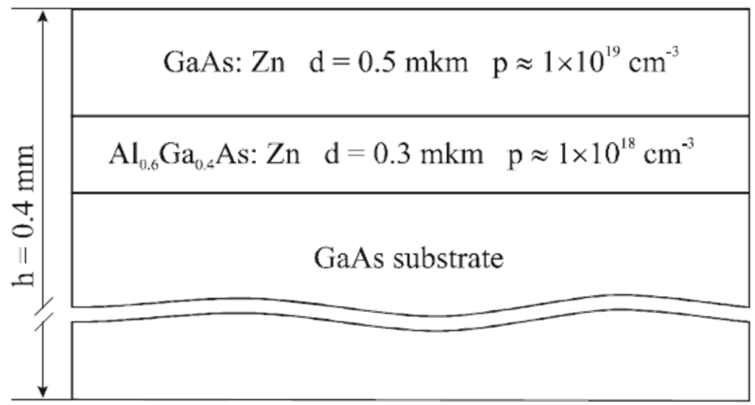
Field strength	Technology	0.01 nC	0.1 nC	1.0 nC
10 MV/m	DC gun	0.11	0.34	1.08
20 MV/m	VHF gun	0.08	0.24	0.77
50 MV/m	L-band gun	0.05	0.15	0.48
100 MV/m	S-band gun	0.03	0.11	0.34

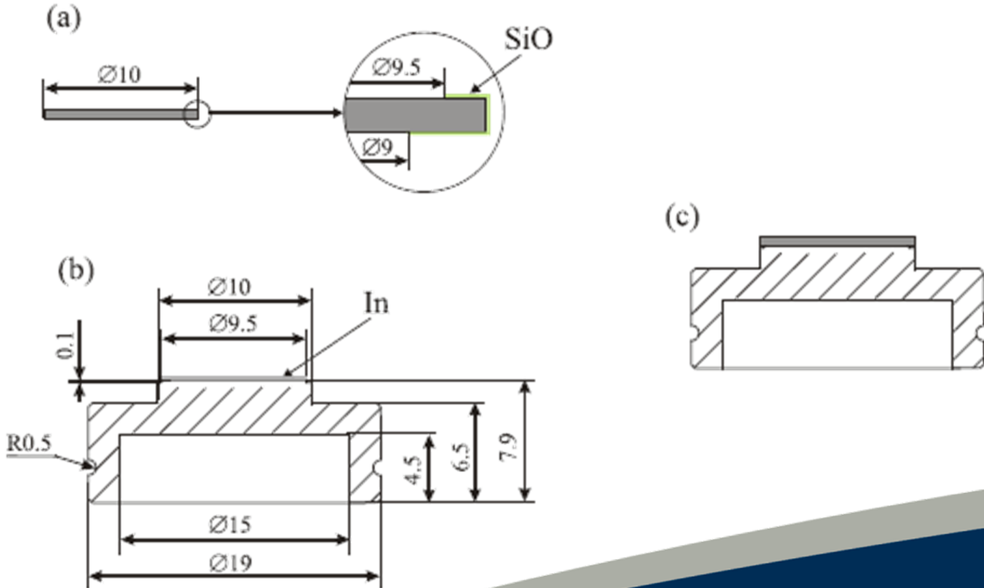
High average current GaAs photocathodes



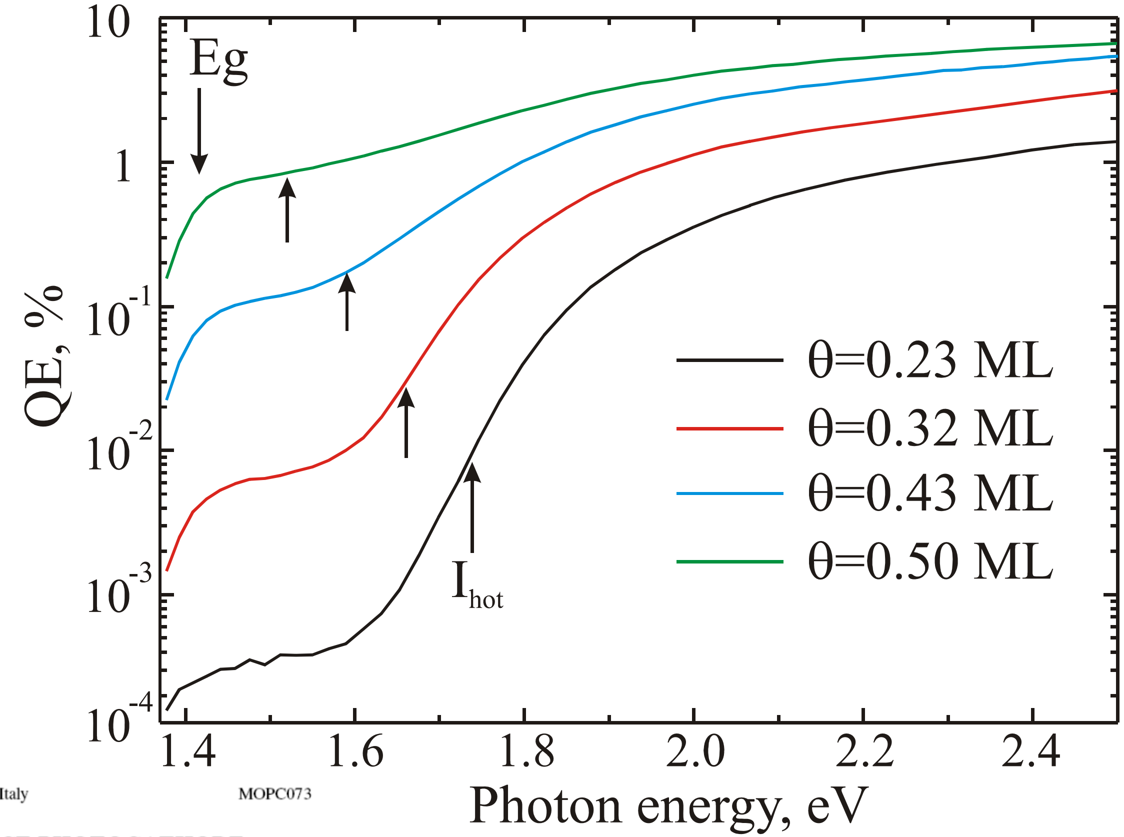
$$\chi > kT \qquad E_i = h\nu - E_g - \chi$$

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





GaAs photocathodes. QE and electron affinity



Proceedings of EPAC08, Genoa, Italy MOPC073

DESIGN OF AN UPGRADE TO THE ALICE PHOTOCATHODE ELECTRON GUN

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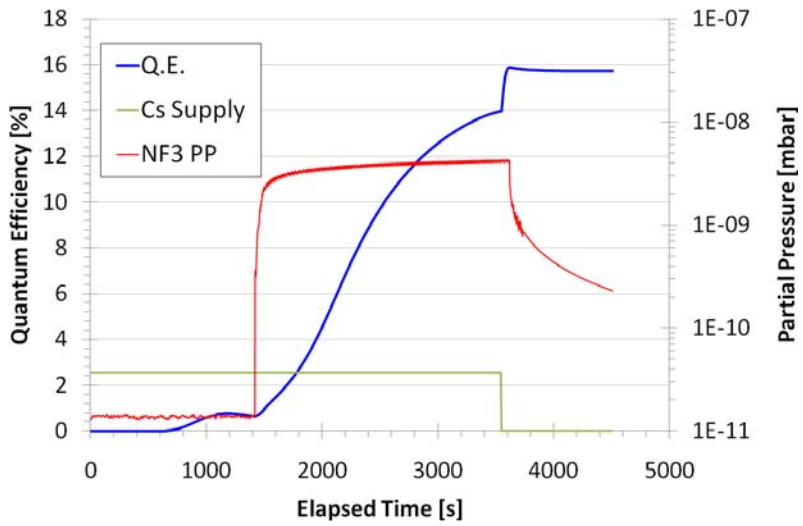
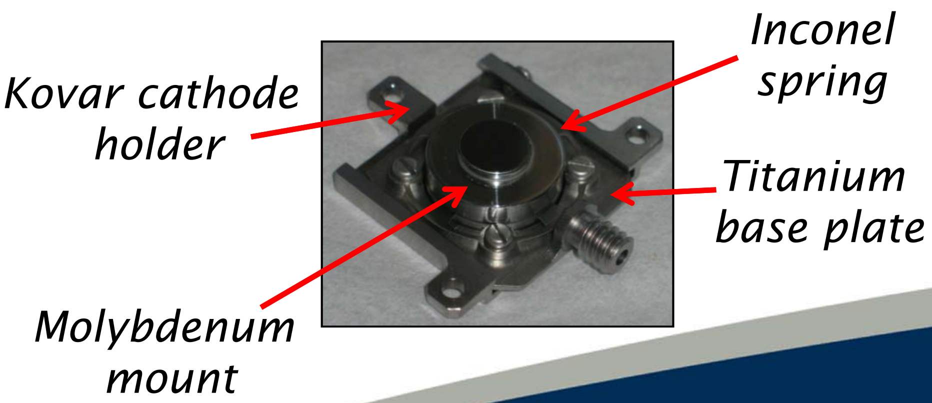
GaAs photocathode preparation facility

K.J. Middleman et al., PESP2010





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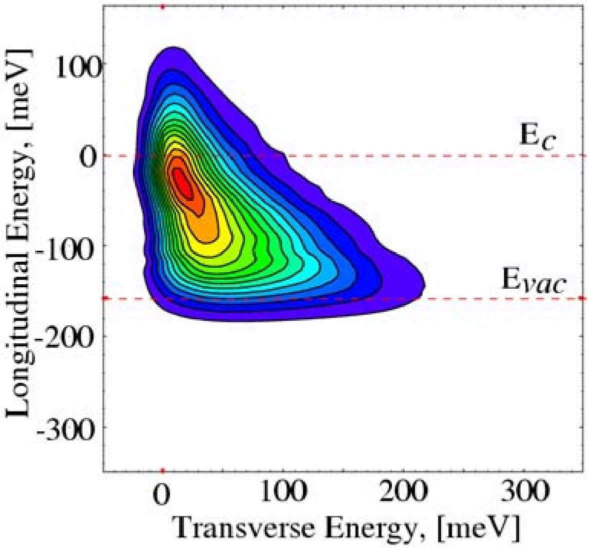
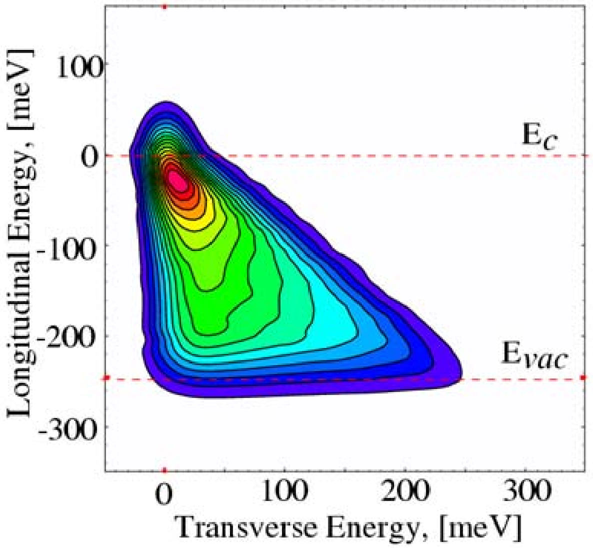
Intrinsic energy of NEA GaAs photocathode

2.5-D energy distributions of emitted photoelectrons

300 K



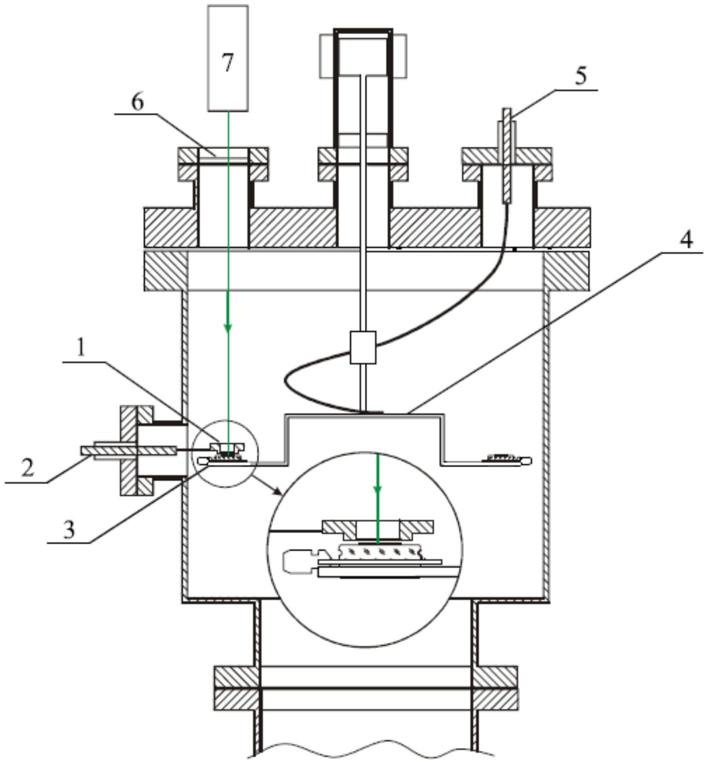
90 K



$$E_{\parallel} + E_{\perp} = E_i = \chi$$

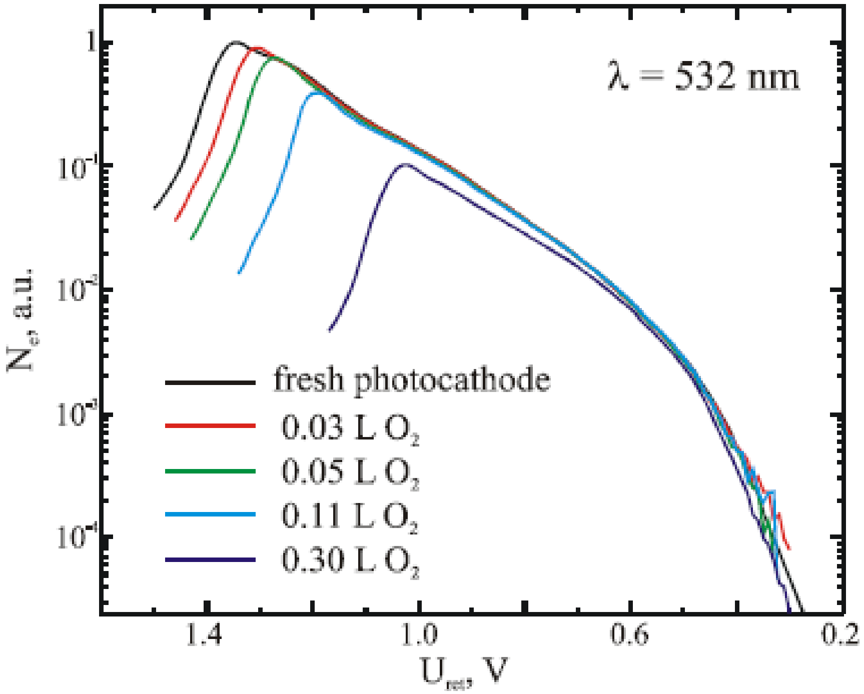
D. A. Orlov et al., Appl. Phys. Lett. 78 (2001) 2721

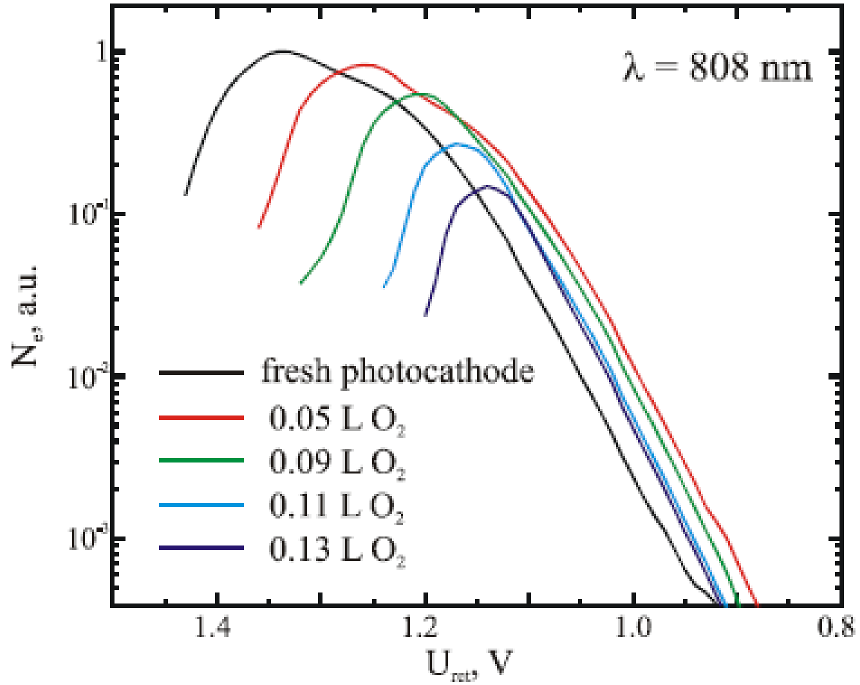
Intrinsic energy of GaAs photocathodes. longitudinal energy distribution I



Measurements of the longitudinal energy distribution in a photocathode preparation chamber

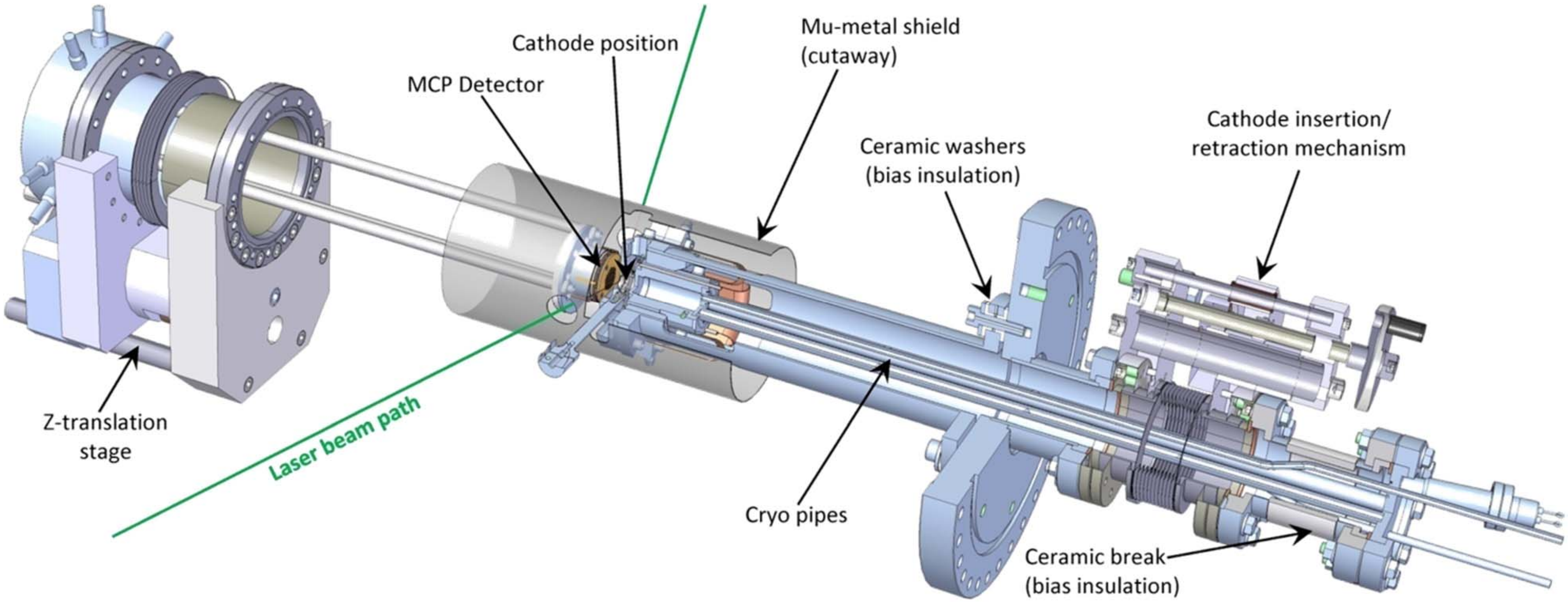
Intrinsic energy of GaAs photocathodes. longitudinal energy distribution. Preliminary results





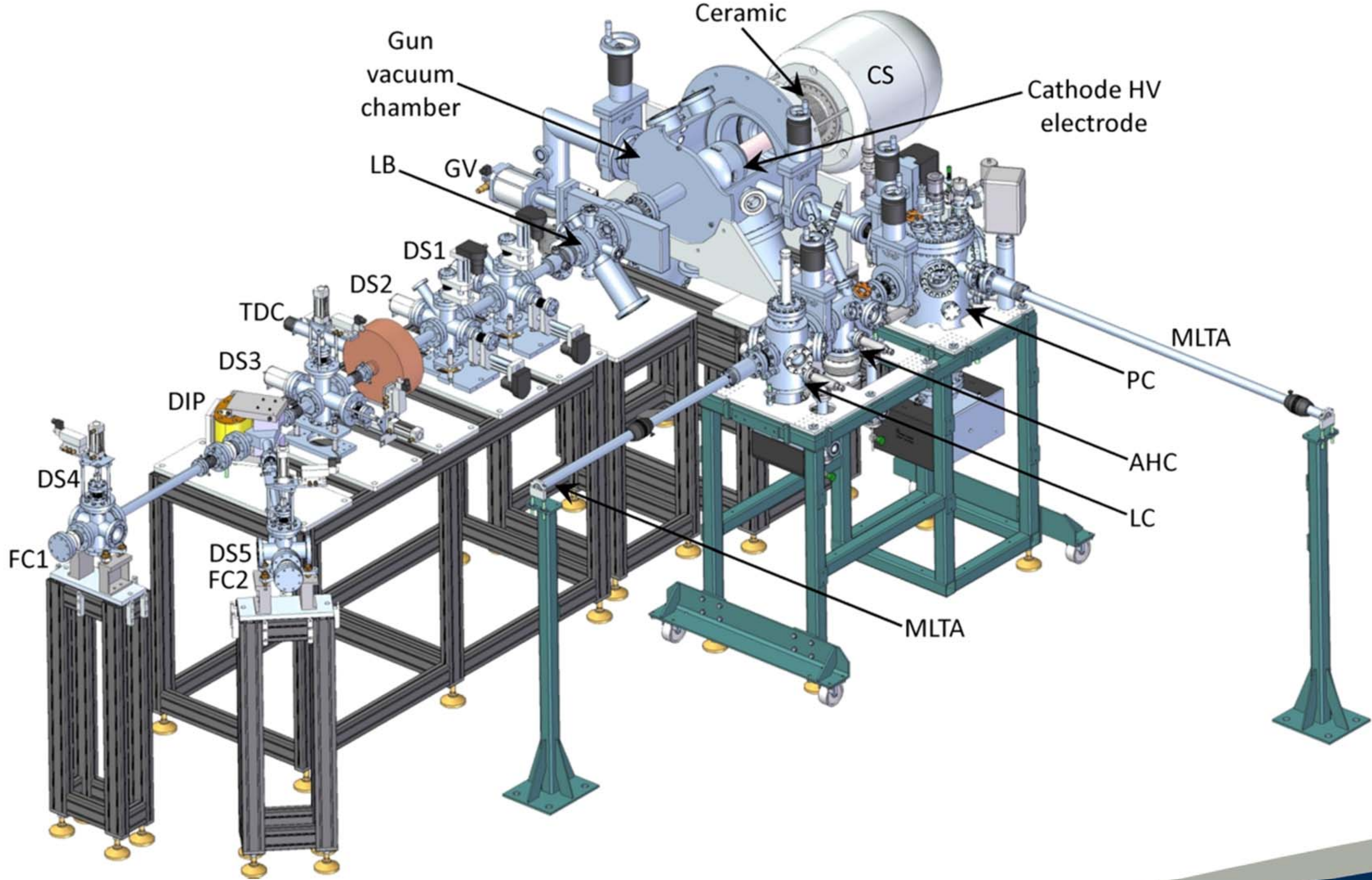
Degradation of the photocathodes with initial QE of 20% at 650 nm

Photocathode energy distribution. 2.5-D energy distribution experiment



Operation at room and LN_2 temperature

160 kV research gun for photocathode emittance and responce time investigation



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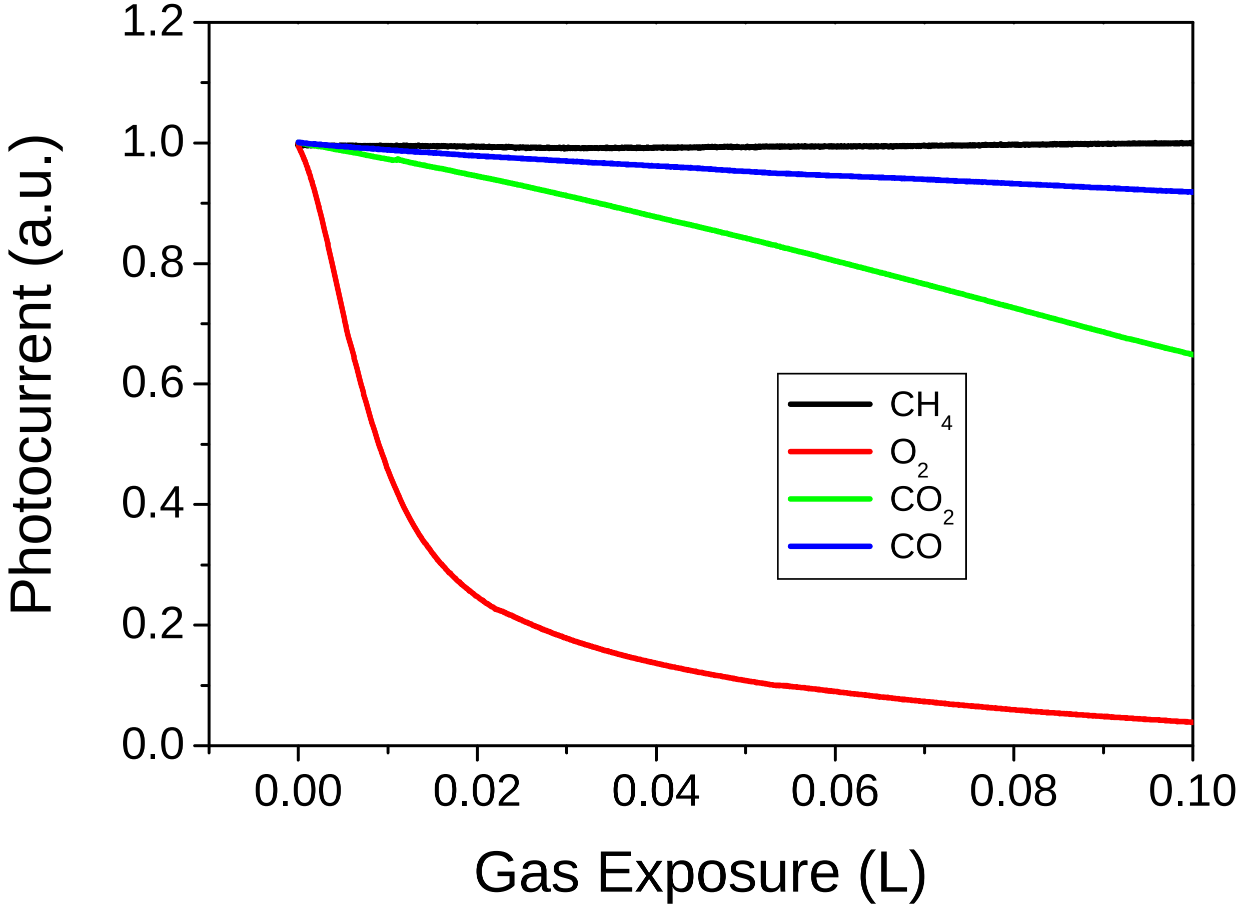
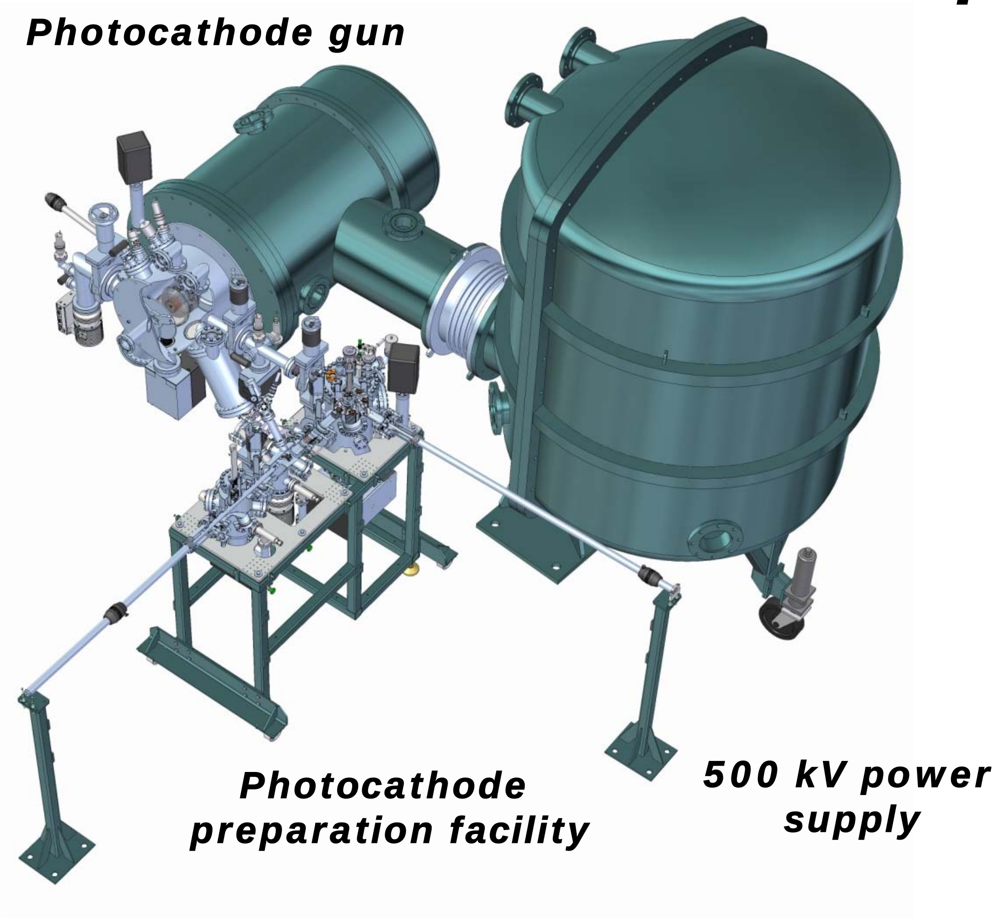
GaAs photocathodes. Dark life time



K.J. Middleman et al., PESP2010

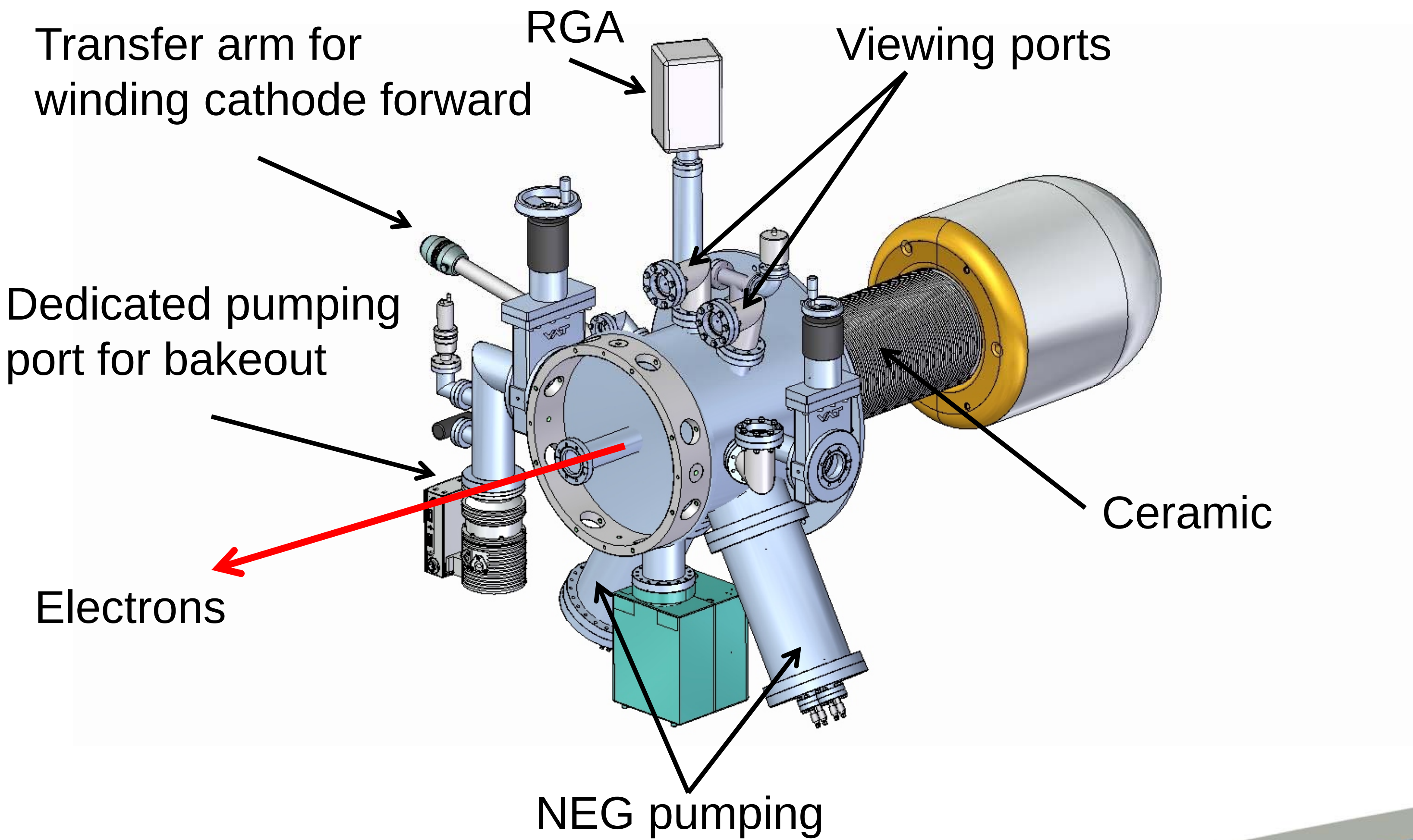
ALICE DC photocathode gun upgrade



Upgrade of the gun allows

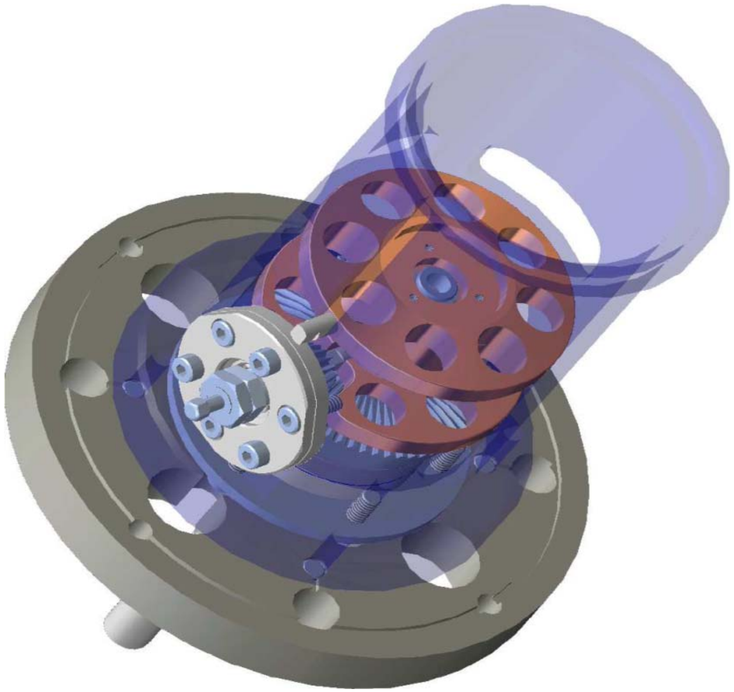
- Reduce the down time required for activation of the photocathode and allows ALICE for operation with higher bunch charge.
- Remove activation/caesiation procedure out of the gun
  - Improve vacuum in the gun
  - Reduce contamination of the high voltage electrodes with Cs and other products of photocathode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

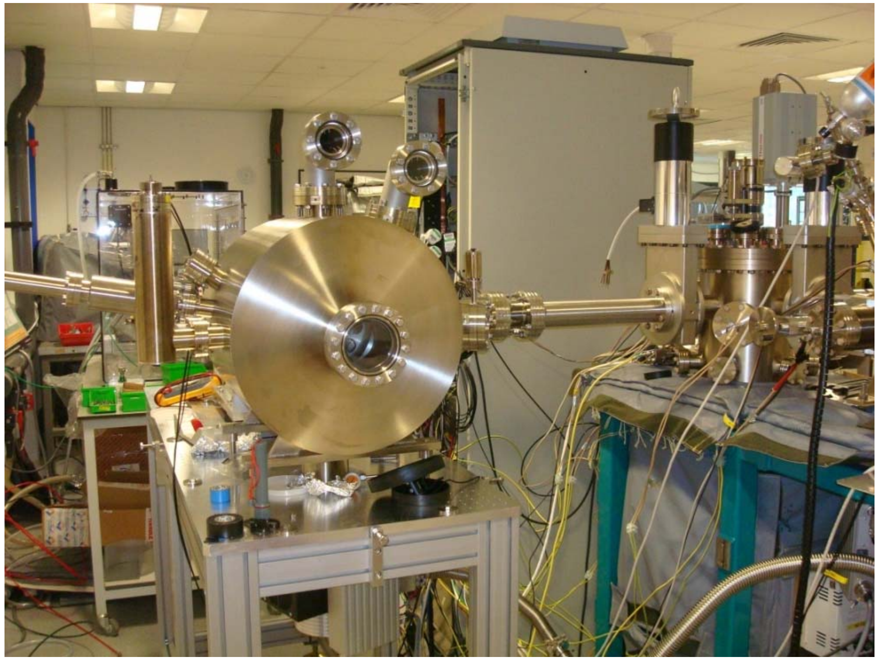
ALICE gun upgrade. New gun chamber



PPF. Ball Mechanism and Prototype Gun

Cathode ball mechanism based a bevel gear for winding the cathode forward and backward





Mock gun built to test the cathode transfer mechanism. Without bake out the system has worked well

Conclusion

- ASTeC is successfully leading experimental work in the development of high current, high repetition rate photocathodes and photoinjectors
- High current GaAs and GaAsP photocathode technology has been successfully developed and implemented at ASTeC in collaboration with Institute of Semiconductor Physics, Novosibirsk
- Photocathodes designed for 4GLS and ALICE have been manufactured and their activation technology developed to reach quantum efficiencies as high as 20%
- An ALICE gun upgrade utilising GaAs and GaAsP has been designed and manufactured. The gun chamber is now undergoing commissioning
- Further efforts are concentrated on physics of photoemissinon in particular on investigation of energy spread and time response of III-V photocathotes at both room and cryogenic temperatures

Acknowledgements

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