MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Intense electron pulses for HITRAP from a robust GaAs photocathode using UV pulse irradiation

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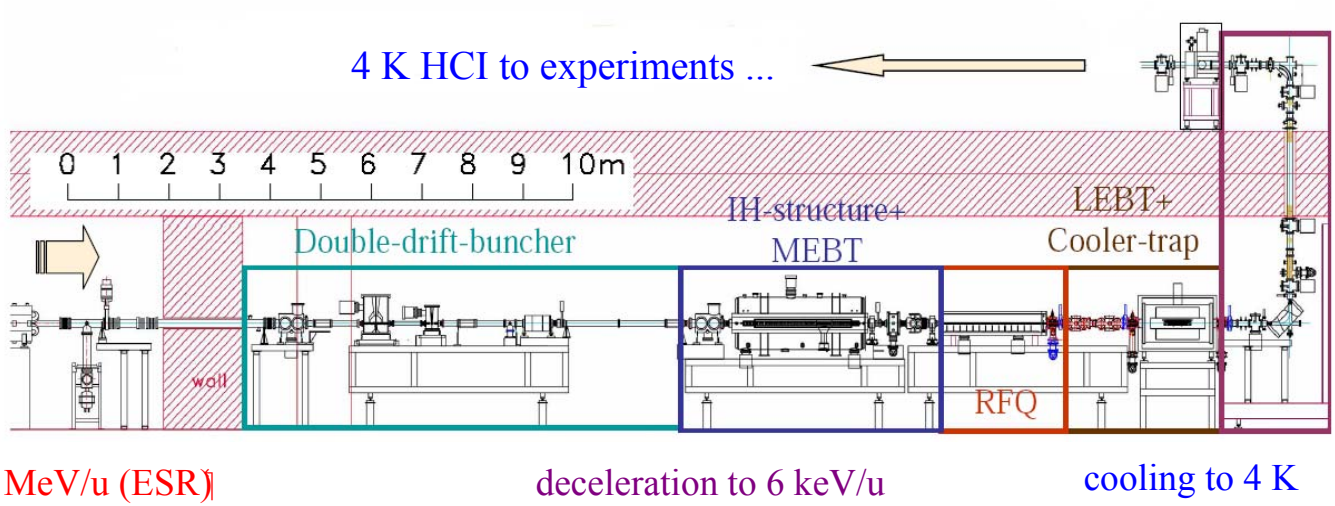
Overview

- HITRAP
  - Electron cooling in a Penning trap
- Photoelectron source
  - Basic requirements
  - Mechanical design
  - Photocathode
- e-gun prototype at MPIK
  - Photocathode stability
  - Operational tests

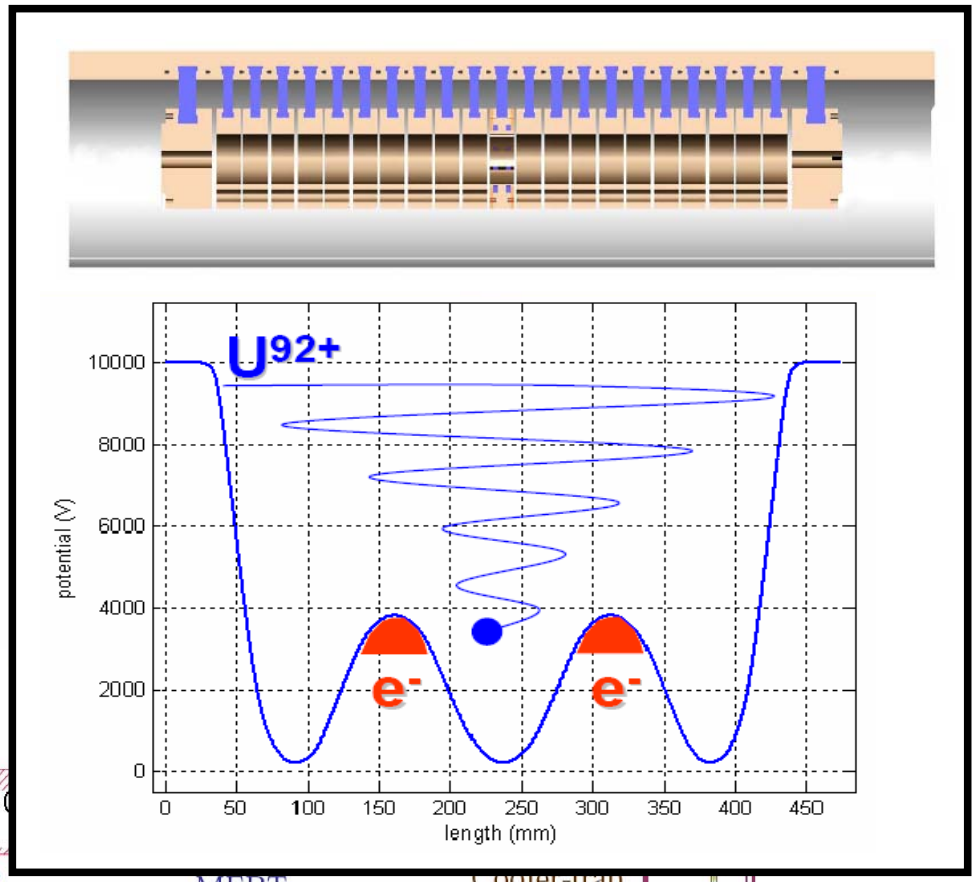
HITRAP

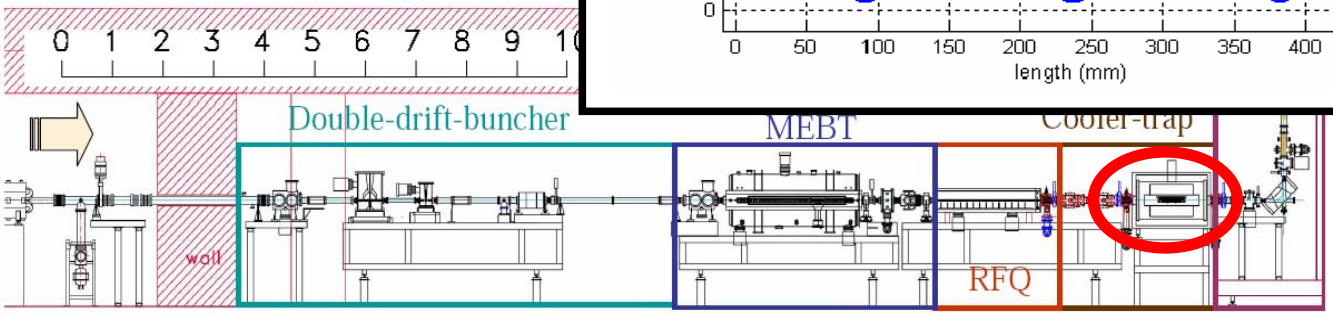
- Decelerator / cooler trap at GSI
  - Input: Highly charged ion beam from ESR @ **4 MeV/u**
  - Output: **4 K cold** HCI bunch to subsequent experiments
  - Design goal: **10^5 U^{92+} every 10 s**



HITRAP

- Cooler trap
  - Multi-ring Penning trap, B = 6...8 T
  - Stores e and ions simultaneously ("nested traps")
  - Cold electrons are buffer gas for ions (**"electron cooling"**)

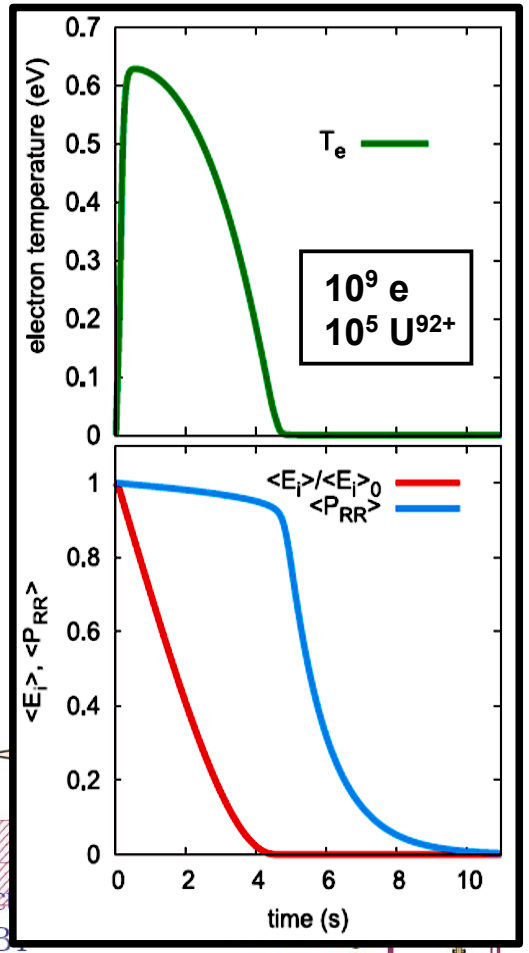




cooling to 4 K

HITRAP

- Ion bunch is cooled by ...
  - ... **e-cooling**
    down to $k_B T = 10$ eV
    (to avoid recombination)
  - ... **resistive cooling**
    to $T = 4$ K

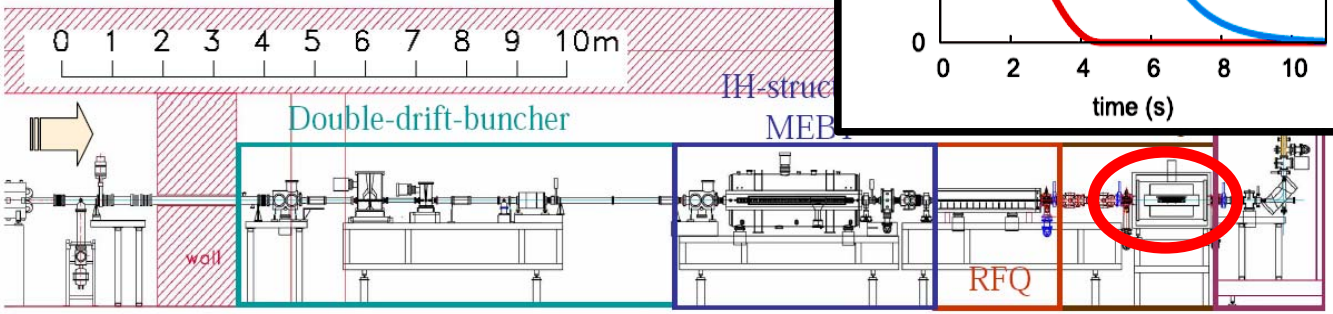


G. Maero, PHD 2008

electron temperature

ion temperature

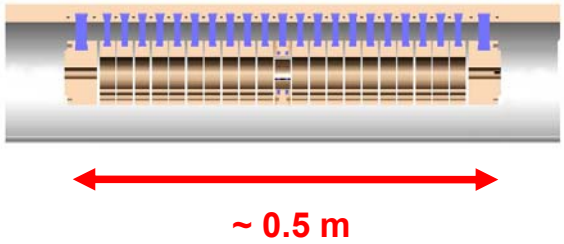
ion survival probability



Photoelectron Source

- Basic requirements:
  - **Round-trip time** in trap $t_{fill} \sim U^{-1/2}$
    Need "short" electron pulses

    e.g. $U = 50$ V: $t_{fill} \sim 240$ ns
    $U = 300$V: $t_{fill} \sim 100$ ns



  - Need ~ **10^9 electrons** to cool 10^5 U^{92+}:
    high peak currents at low voltages
    (i.e. high "gun perveance")

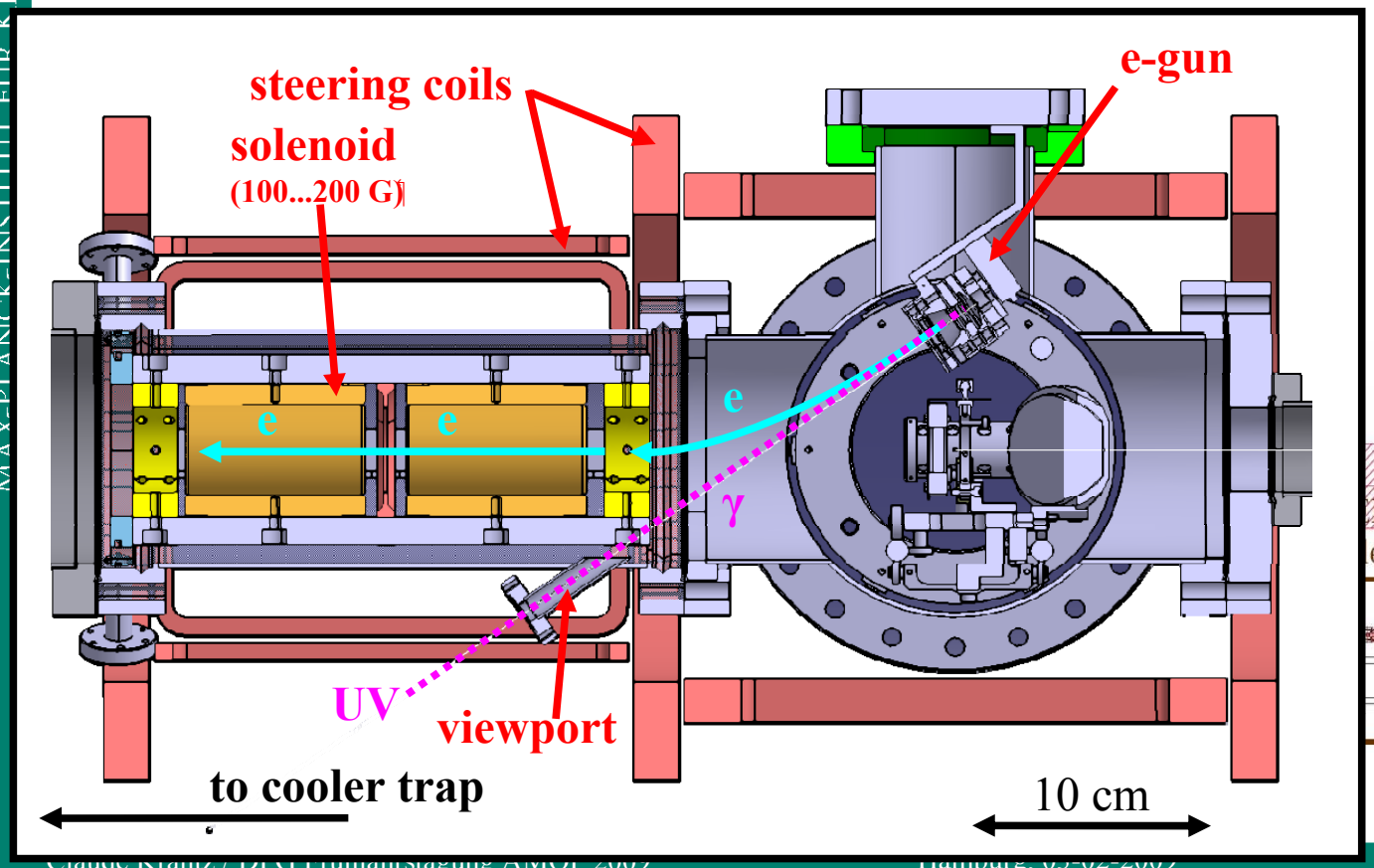
    e.g. for $U = 50$ V: $I_{max} \geq 0.67$ mA
    → perveance $\boldsymbol{P \geq 2}$ **µPerv**

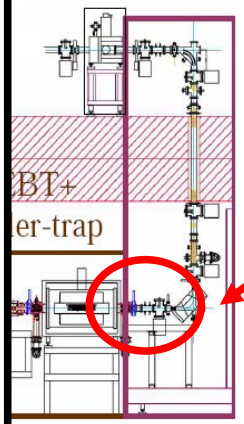
$$I_{max} = PU^{3/2}$$

Photoelectron source driven by pulsed light source

Photoelectron Source

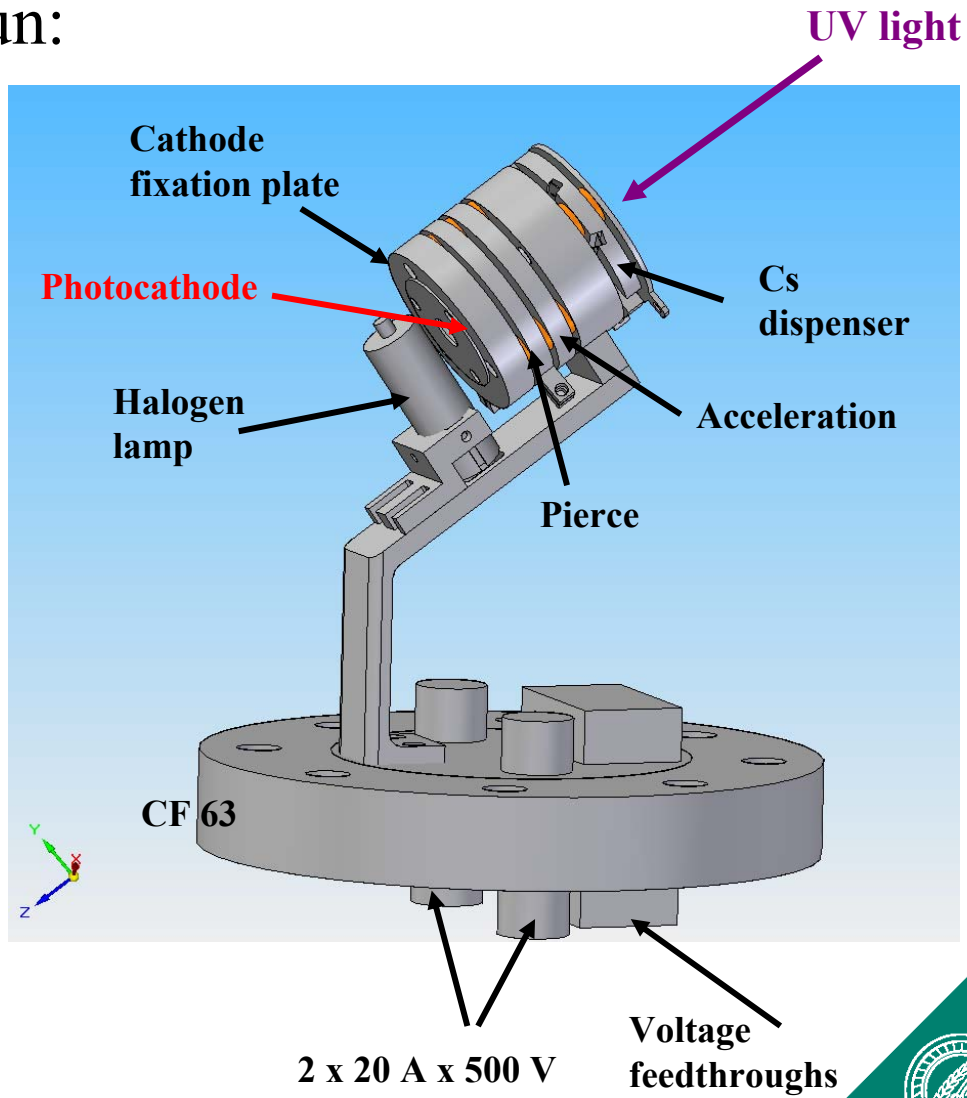
- Mechanical design of e-gun:
  - ... must be **compact** to fit into beam diagnostic chamber
  - ... must stay **off-beam** axis





Photoelectron Source

- Mechanical design of e-gun:
  - Fits on a single **CF-63**.
  - Statically mounted **GaAs(Cs) photocathode**.
  - Operated in **reflection** mode.
  - Allows in-vacuum cathode **refreshing**.

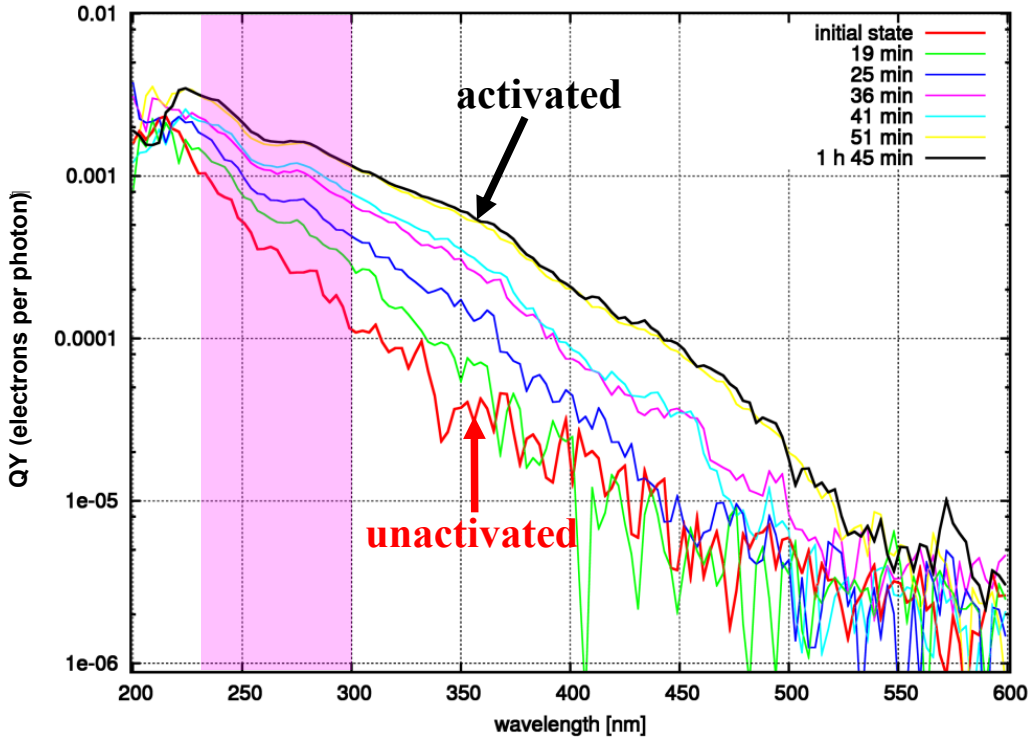


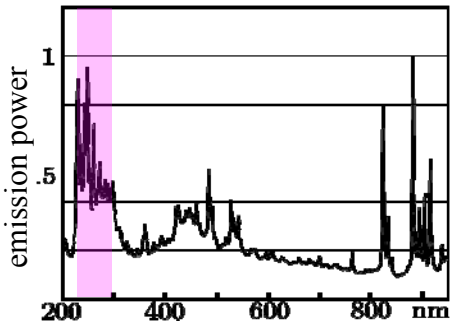
Photoelectron Source

- GaAs photocathode:
  - "minimally" activated **GaAs(Cs)** cathode.
  - **QY > 0.1%** for 230 nm ≤ λ ≤ 300 nm
  - UV efficiency low, but **robust** (and still higher than e.g. metal)
  - UV light provided by *Hamamatsu L9455* **Xe flashlamp**.

FWHM: 300 ... 500 ns
few µJ in UV
rate 0 ... 150 Hz
"cheap"

Cs activation:

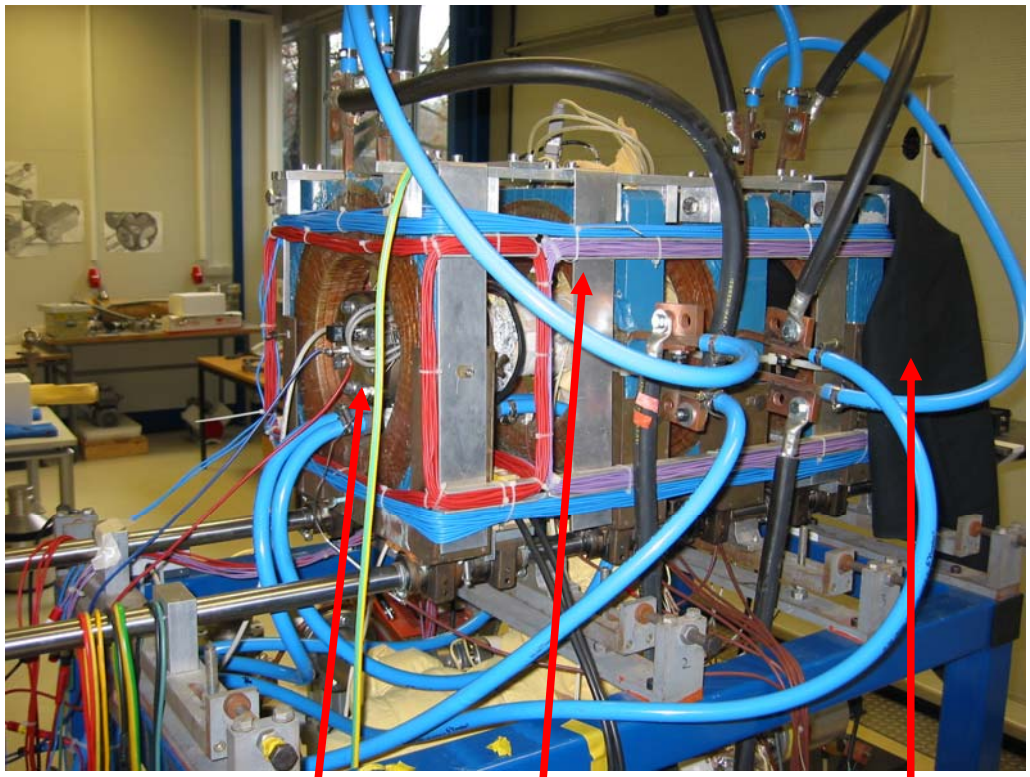




E-gun prototype at MPIK

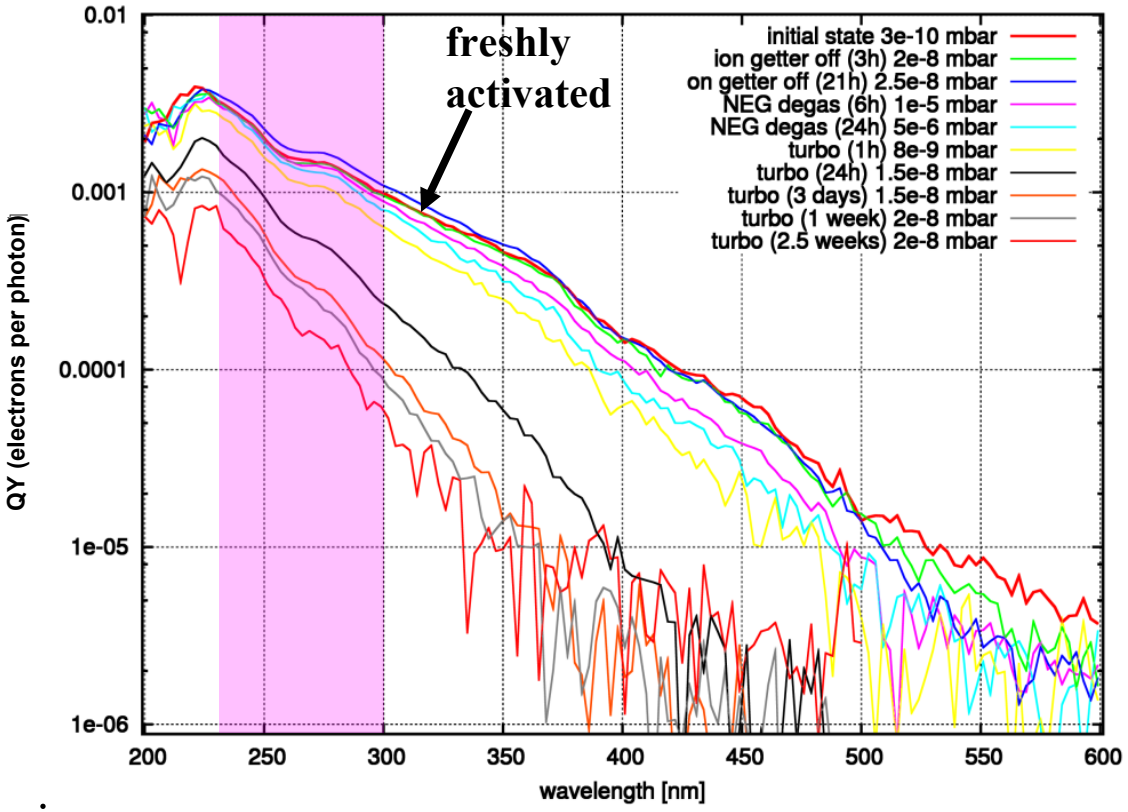
E-gun prototype

Test setup:



E-gun prototype at MPIK

- Cathode stability:
  - 3-week-test showed **little or no "natural" degradation** of the cathode QY.
  - Cs layer proved **robust** even against "artificial" vacuum degradation.
  - Degraded cathode can be **easily reactivated** using built-in Cs-dispenser.

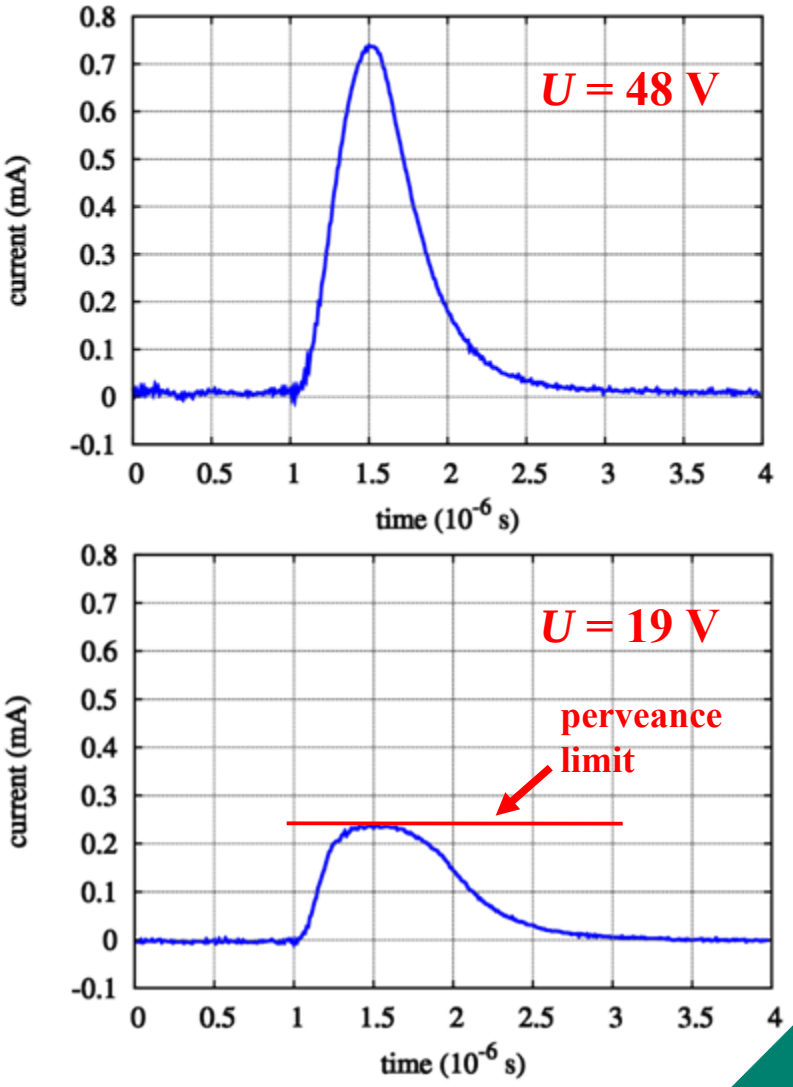


E-gun prototype at MPIK

- Operational tests

work in progress!

  - **Pulsed operation** with Xe flashlamp **works**.
  - **≈ 3·10^9 e / pulse**
    FWHM ~ 400 ns
    (defined by τ of lamp)
  - e-gun perveance:
    ***P* ~ 3 µPerv**
    (enough for 1 mA @ 50 V)

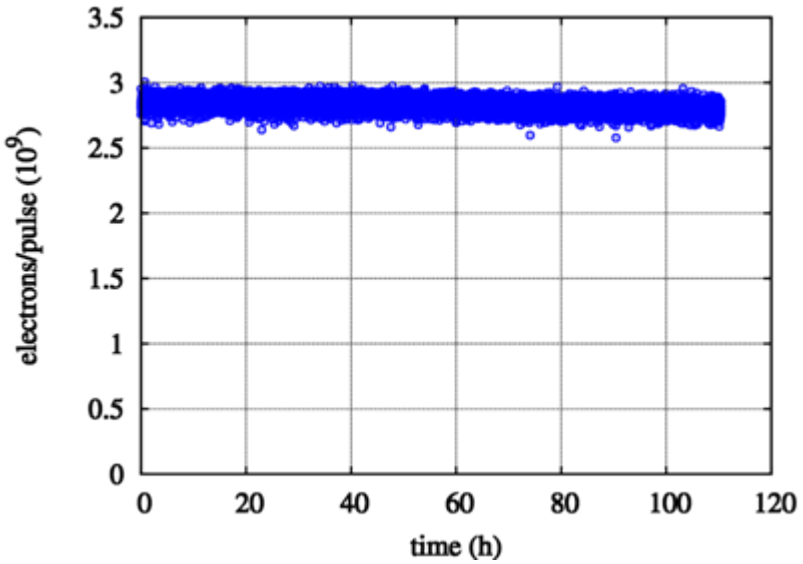


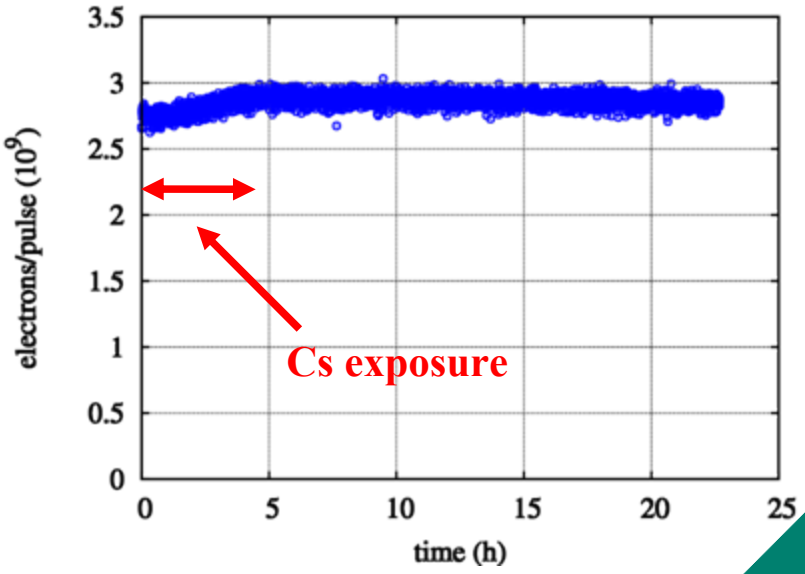
E-gun prototype at MPIK

- Operational tests

work in progress!

  - > 4-day-long pulsed operation at **rate 0.2 Hz**
  - **good stability** of pulse intensity
    (τ = several months)
  - Possible to **re-activate** cathode **in operation** by Cs-exposure.





Conclusions and Outlook

- A UV-driven, pulsed photoelectron source for the HITRAP Cooler trap has been developed.
- The pulse intensity meets the 10^9 electrons/pulse required for efficient filling of the trap.
- The stability of the photocathode source allows months of operation.
- Upcoming work: Study electron velocity distribution in pulse.
- Outlook: Mount electron gun at HITRAP. Do trap-filling and ion cooling tests.

Thank you!

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