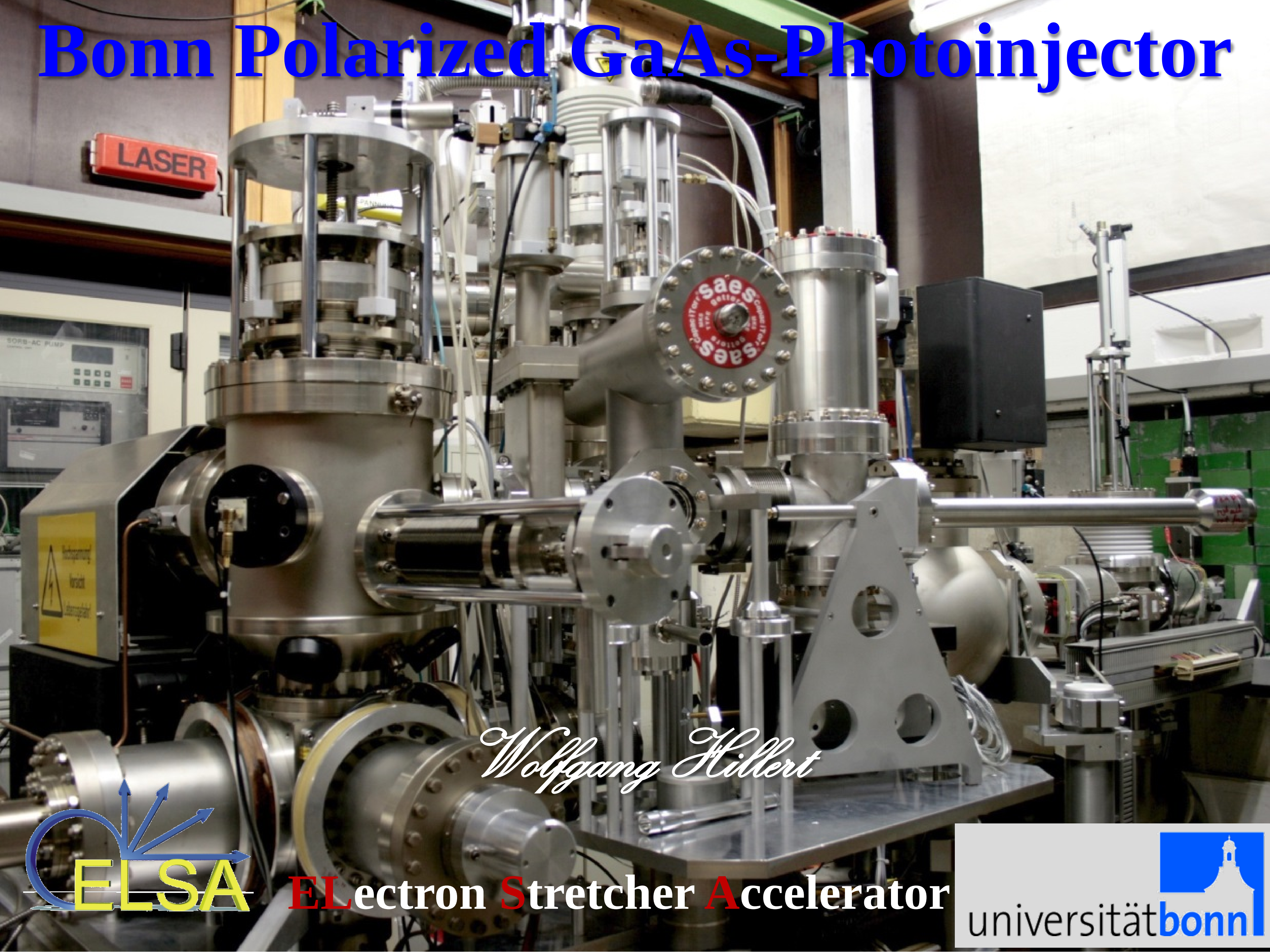
Bonn Polarized GaAs-Photoinjector



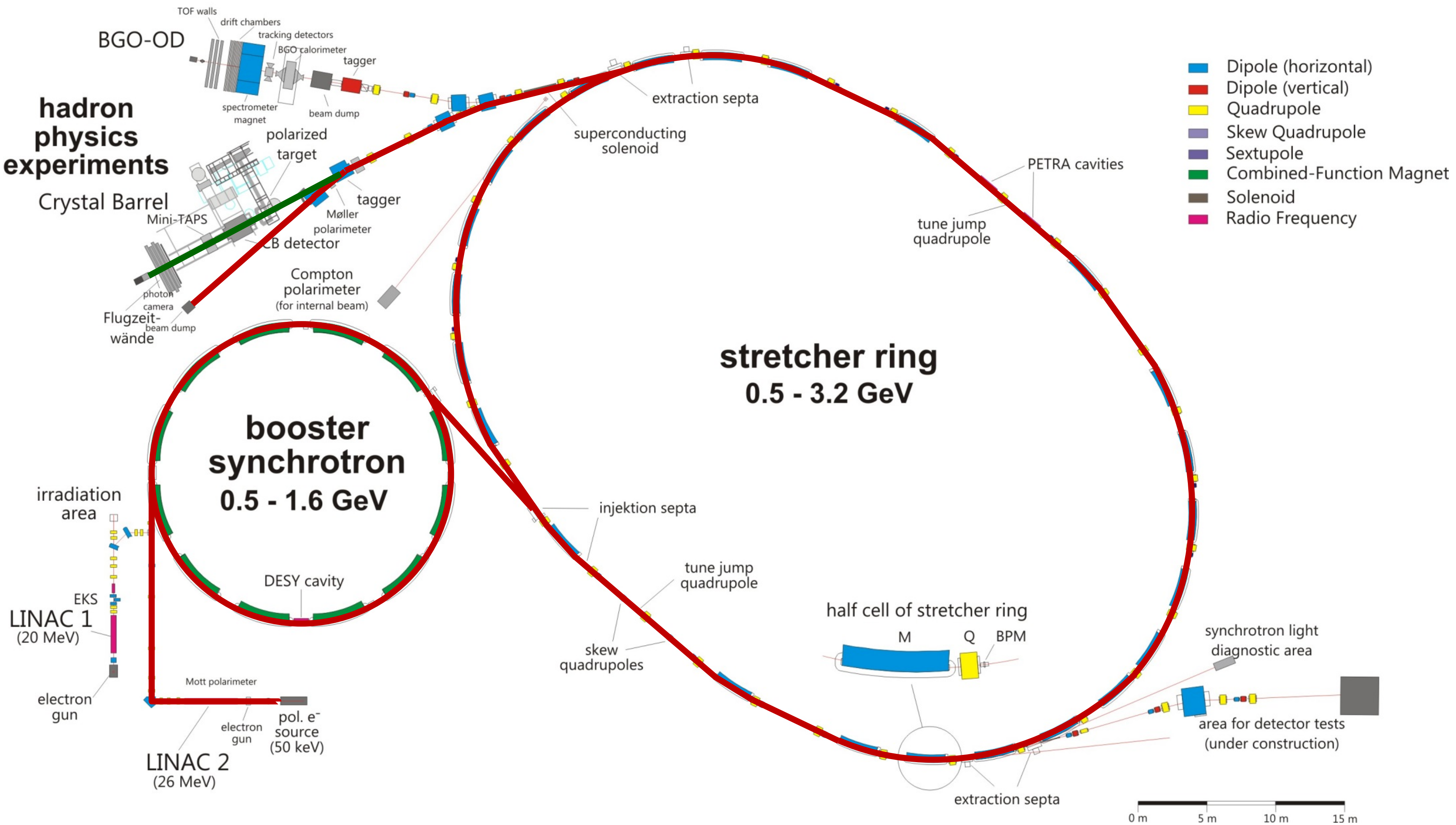
Wolfgang Hillert

ELSA

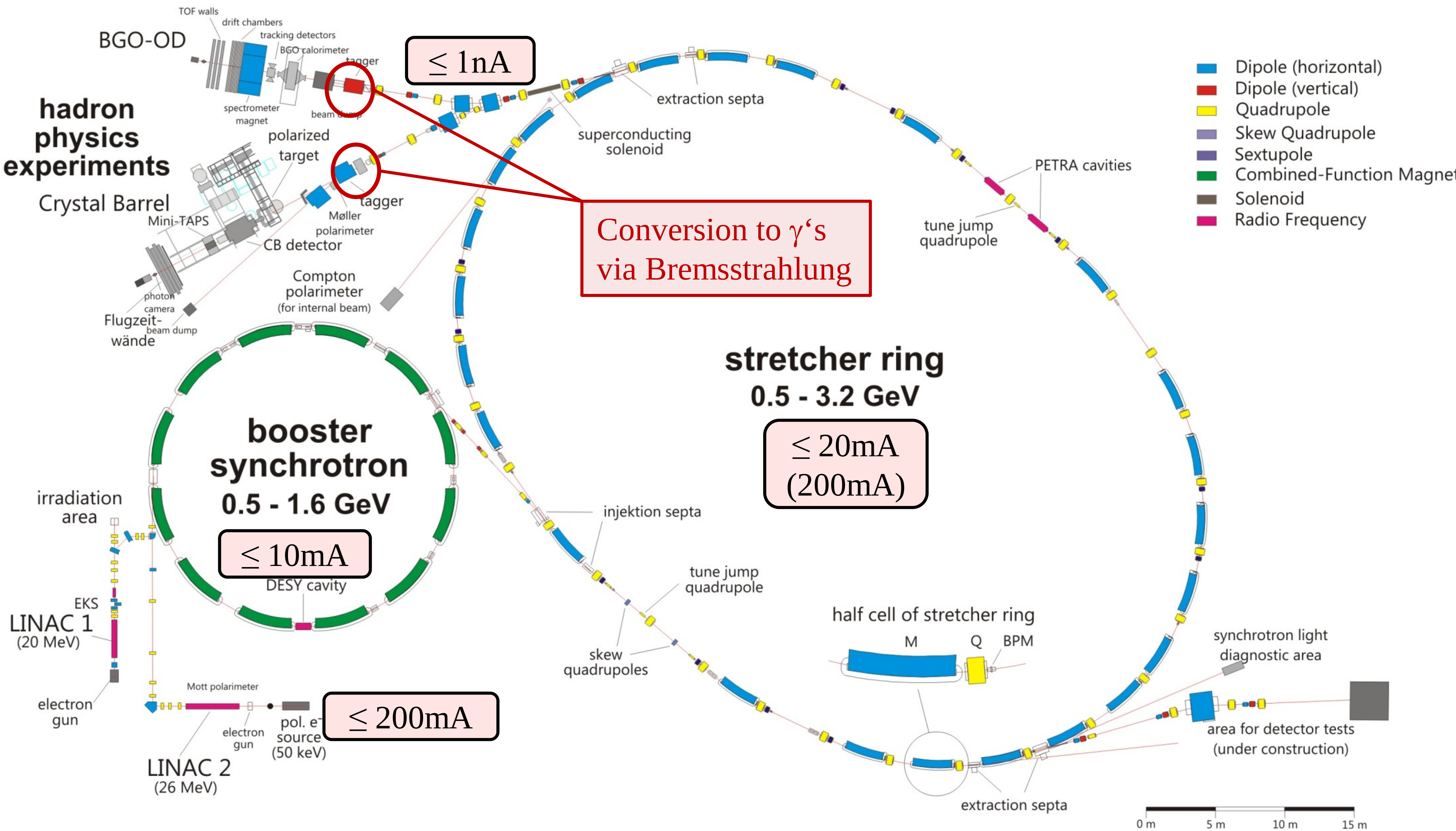
ELectron Stretcher Accelerator

universitätbonn

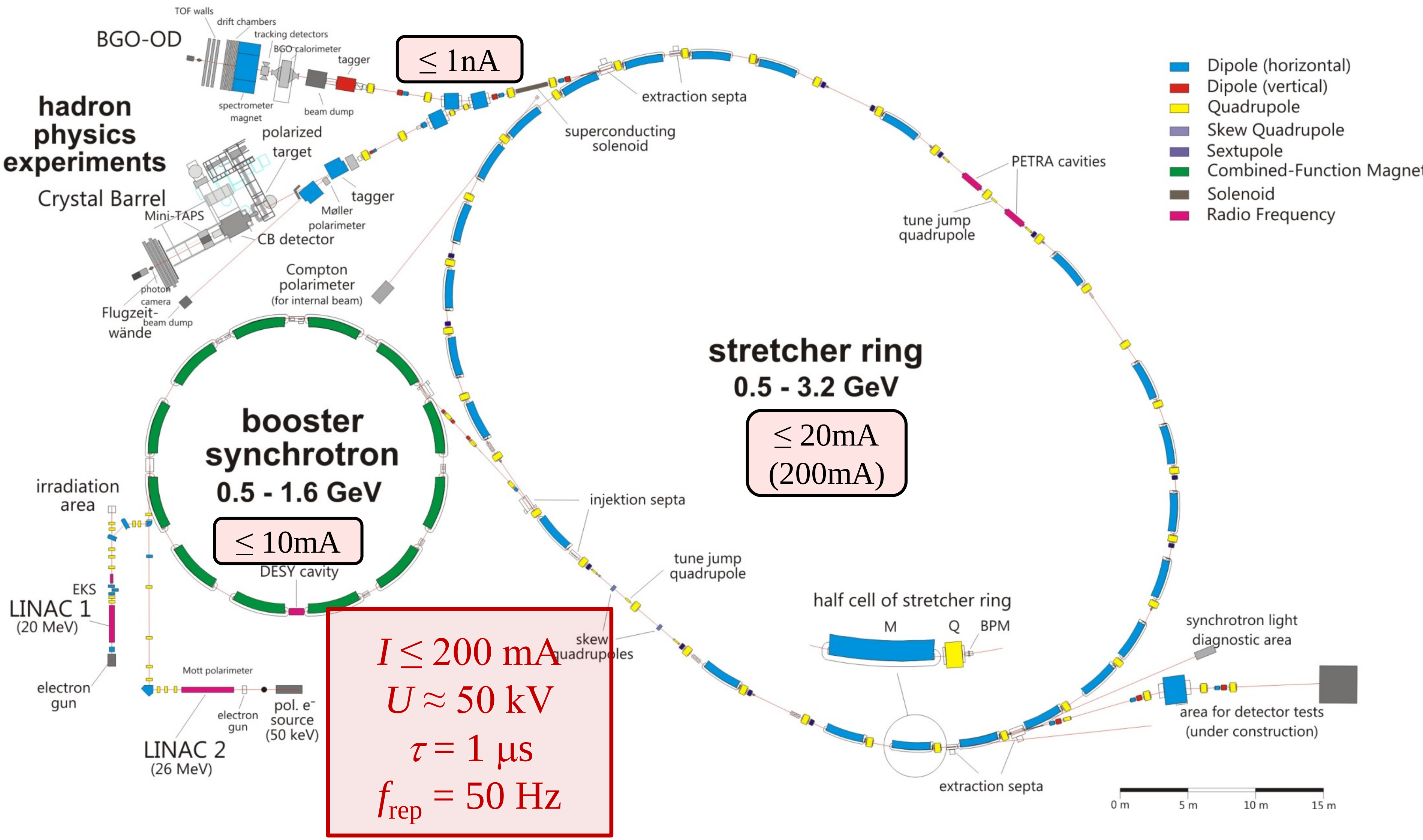
Electron Stretcher Accelerator (ELSA)



Electron Stretcher Accelerator (ELSA)



Electron Stretcher Accelerator (ELSA)



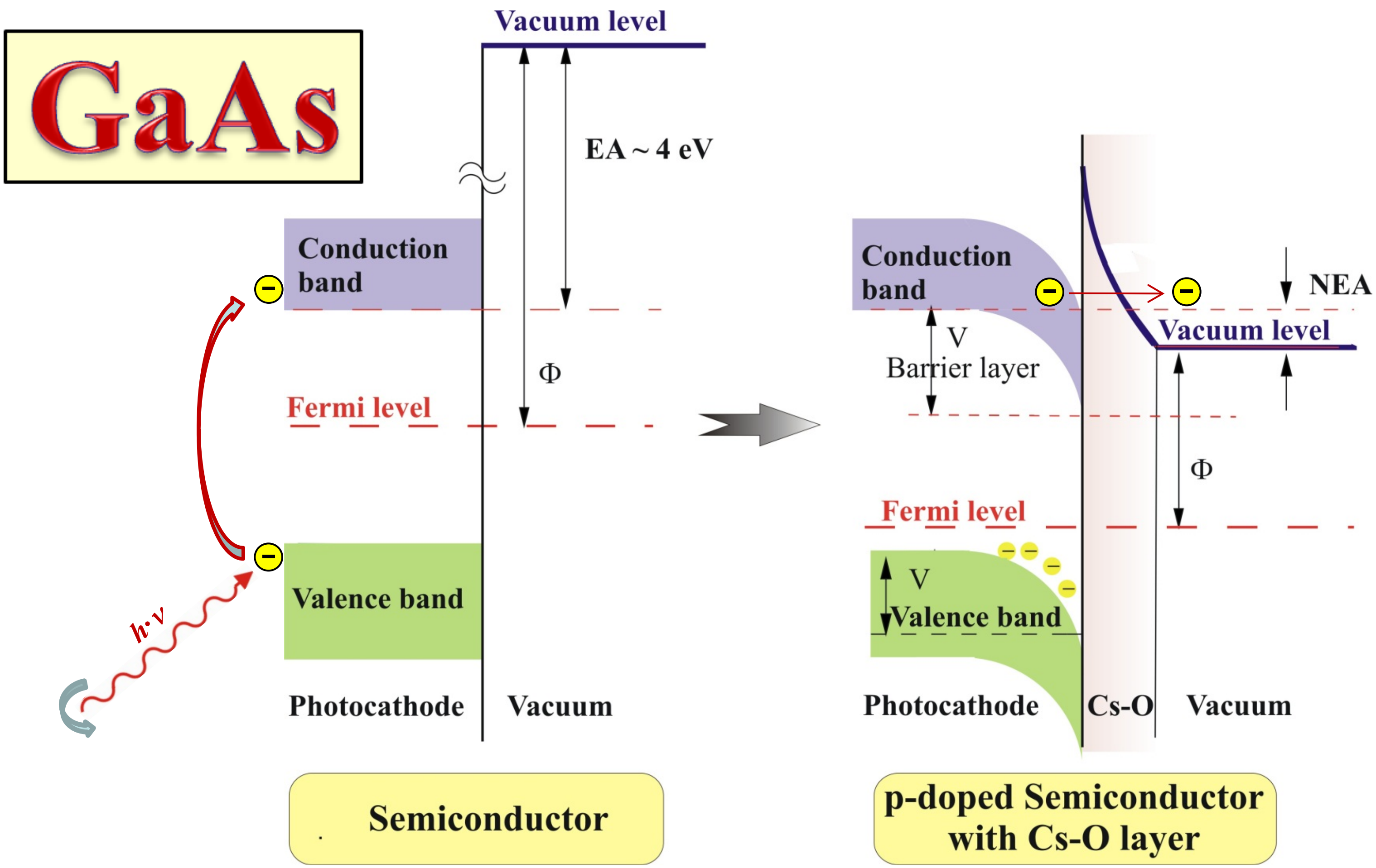
$I \leq 200$ mA

$U \approx 50$ kV

$\tau = 1\ \mu$s

$f_{rep} = 50$ Hz

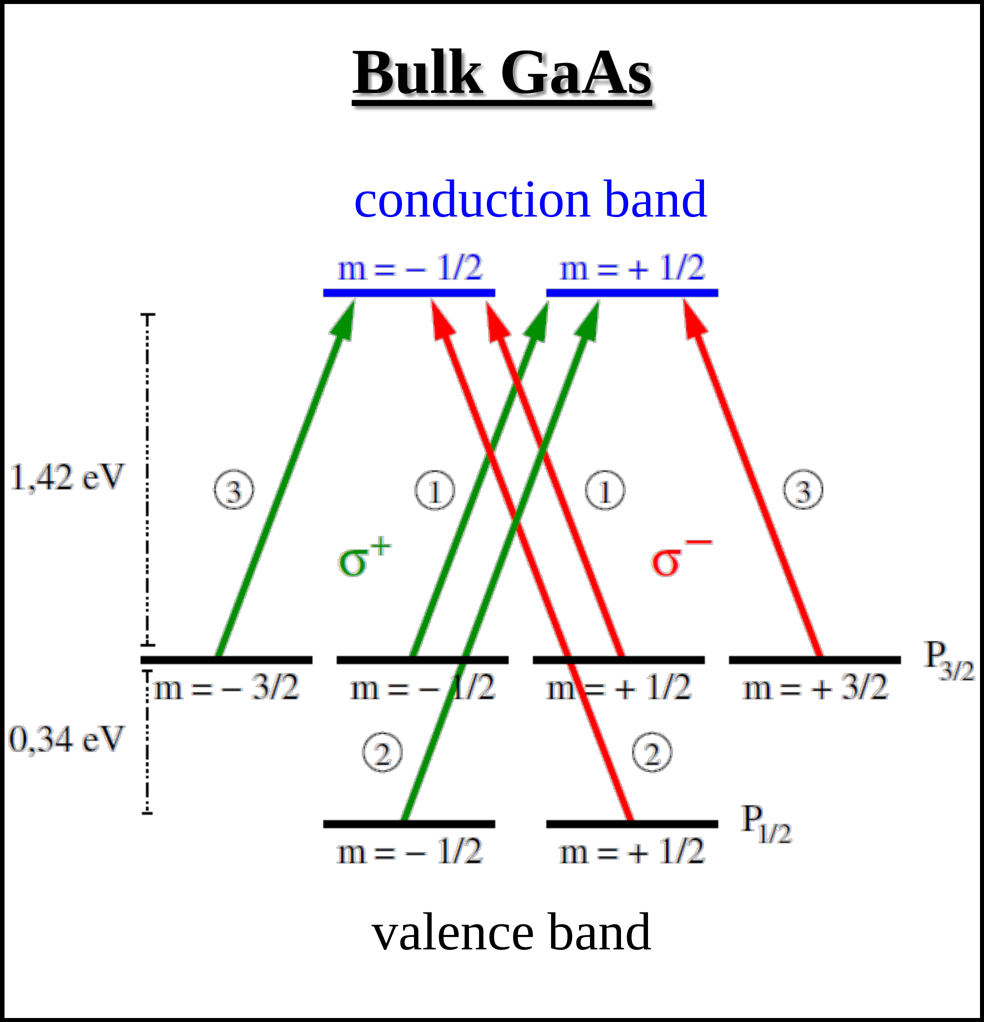
Generation of Polarized Electrons

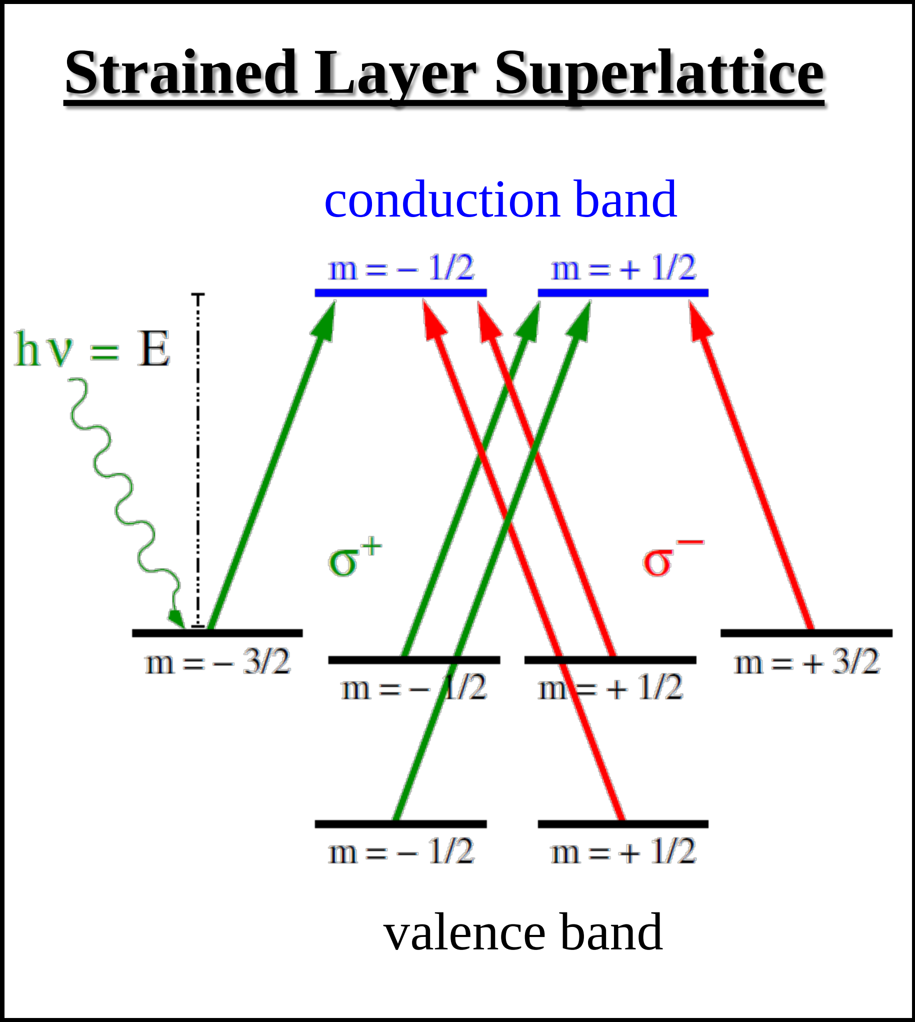


Operation, heat cleaning and activation in extreme UHV

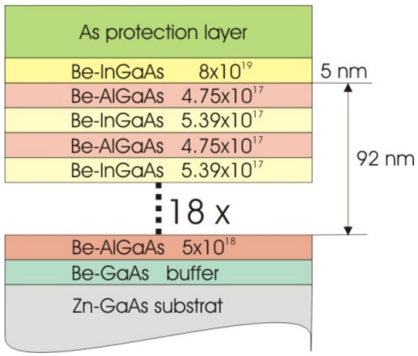
Lifetime 1000 h ↔ P (H_2O, CO_2) < 10^{-13} mbar

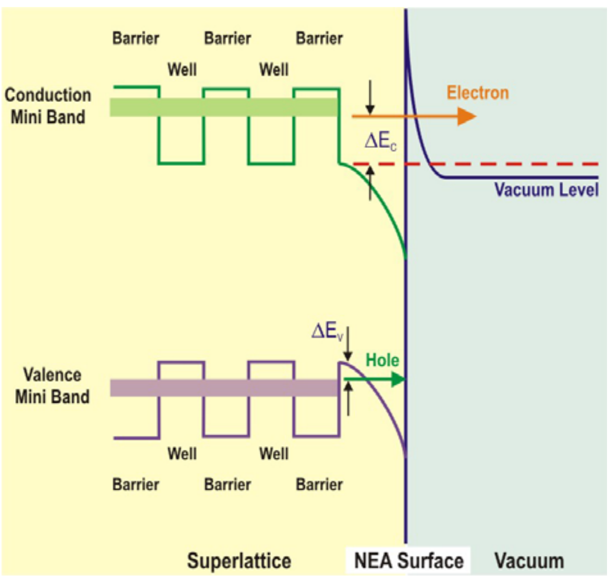
Highest Polarization



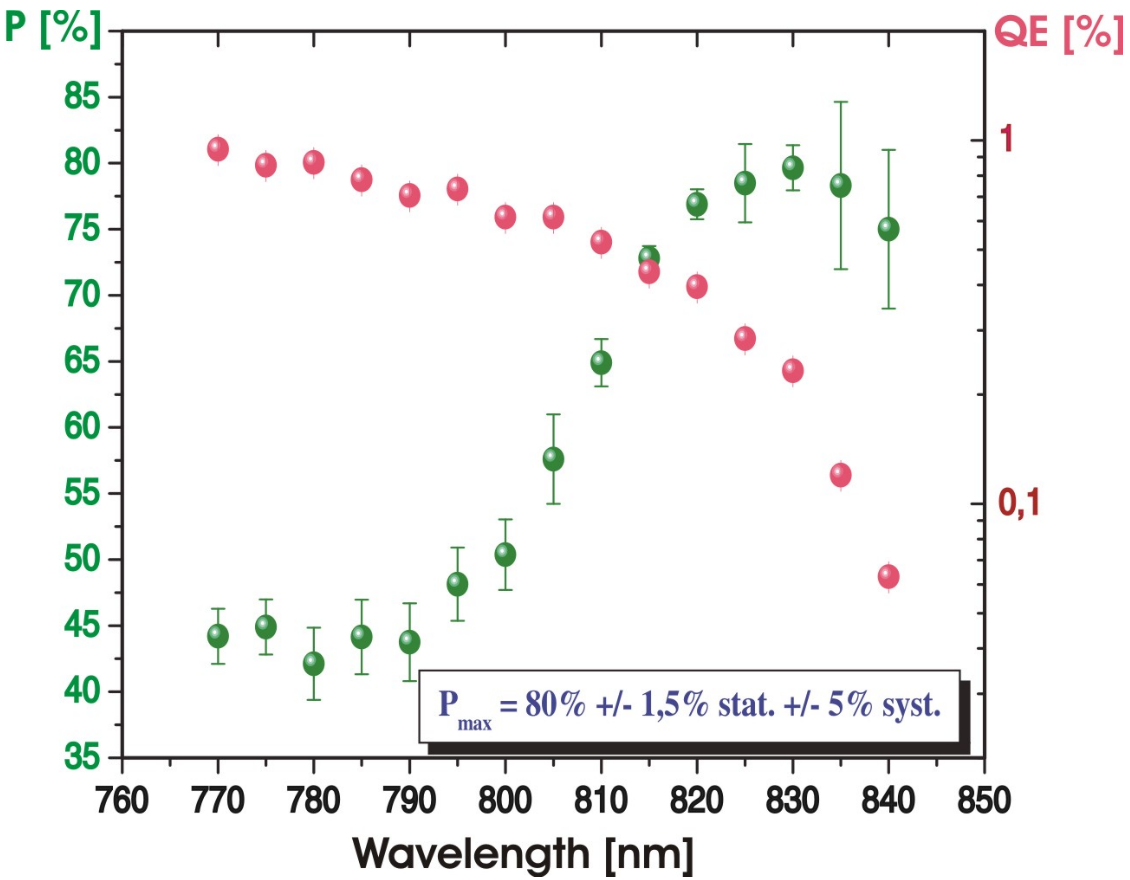


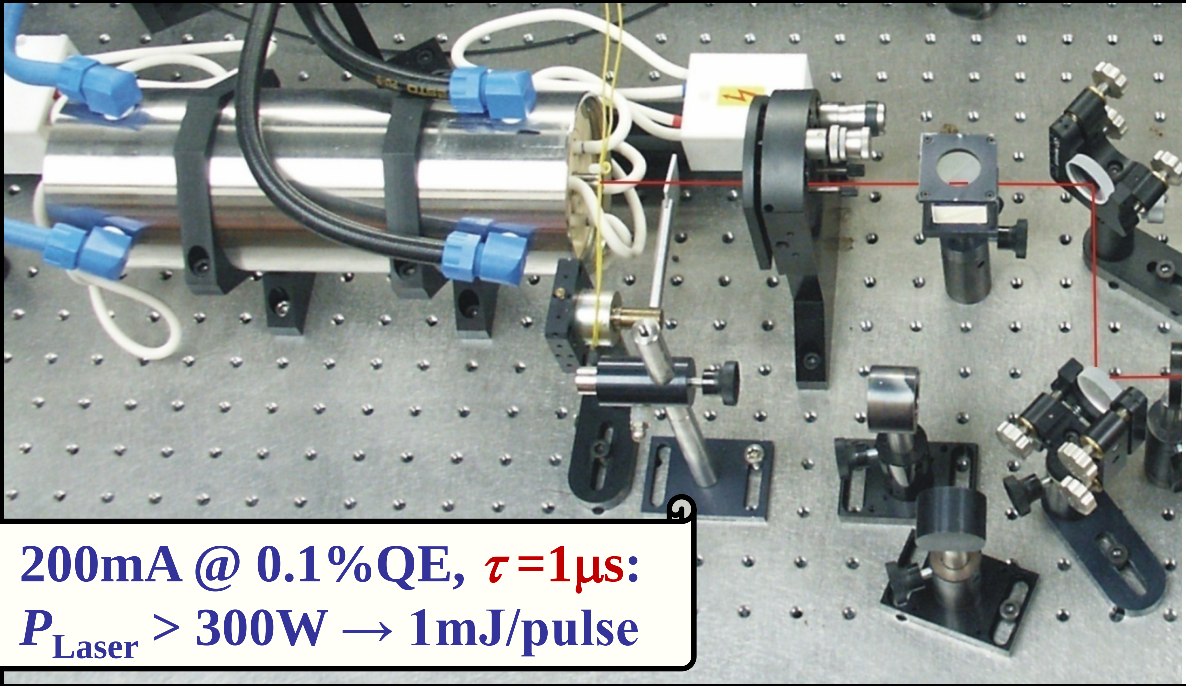
Typ. Photocathode Performance



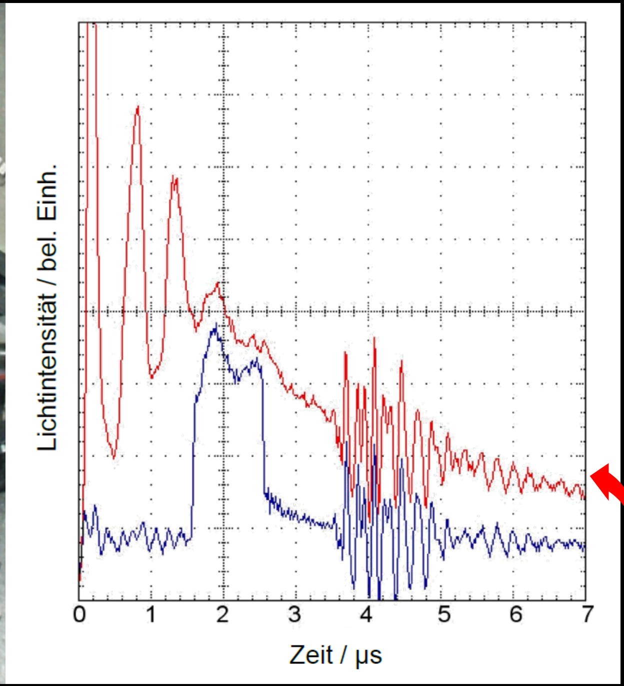


Be-InGaAs/AlGaAs Superlattice

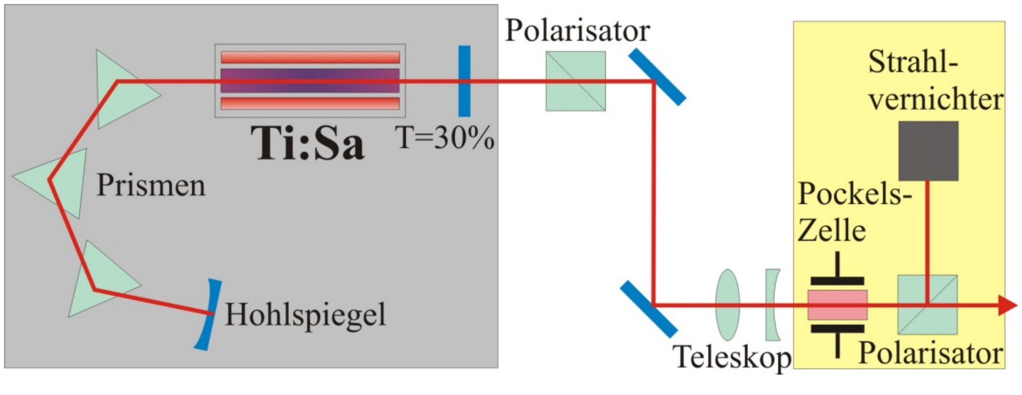




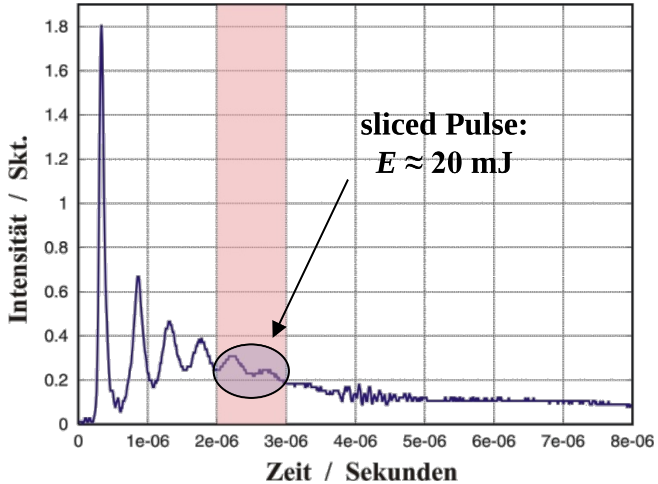
200mA @ 0.1%QE, τ=1µs:
P_{Laser} > 300W → 1mJ/pulse



Titanium-Sapphire-Laser



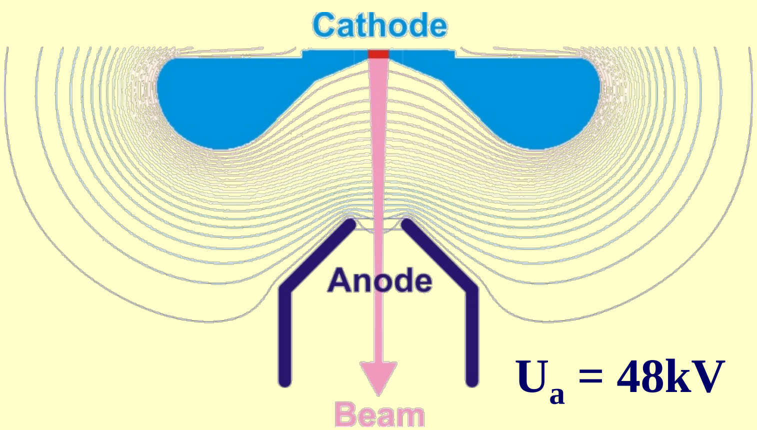
available light pulse

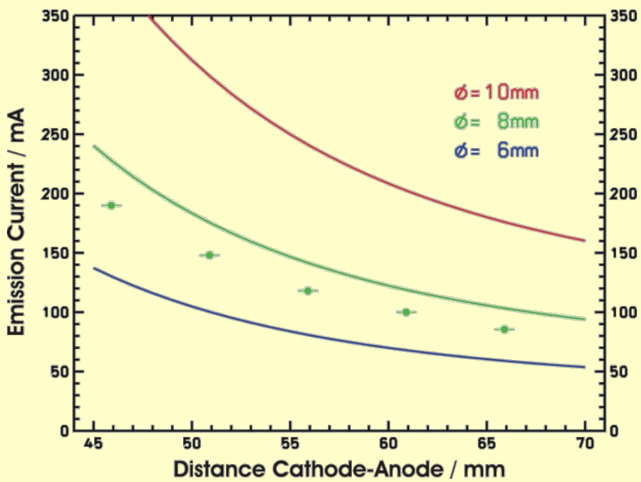


max. energy: 200mJ / pulse

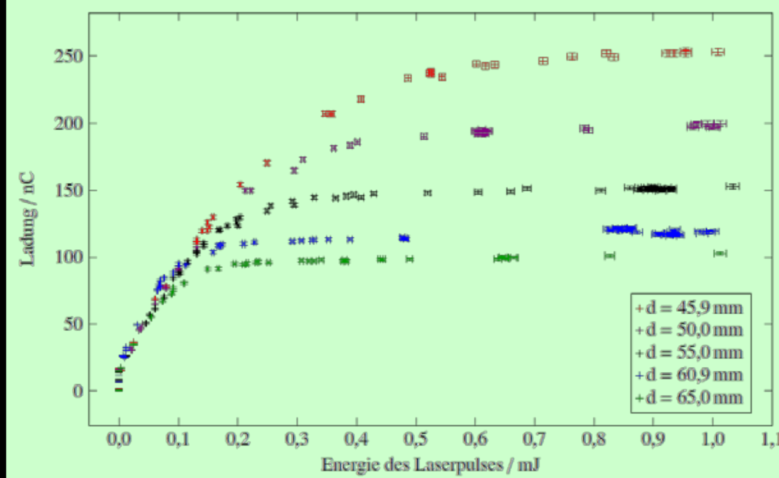
Space Charge Limited Emission

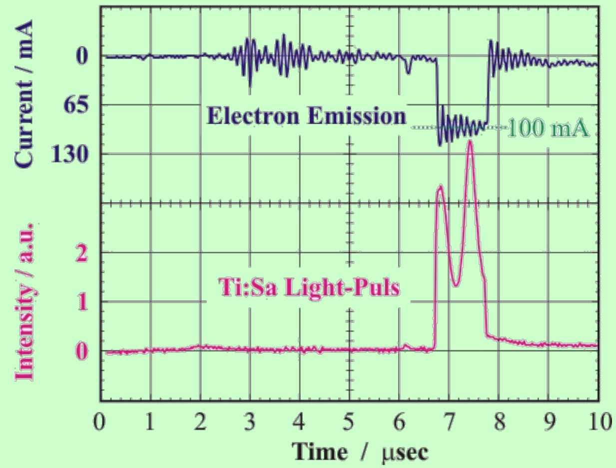
EGUN-Simulations:

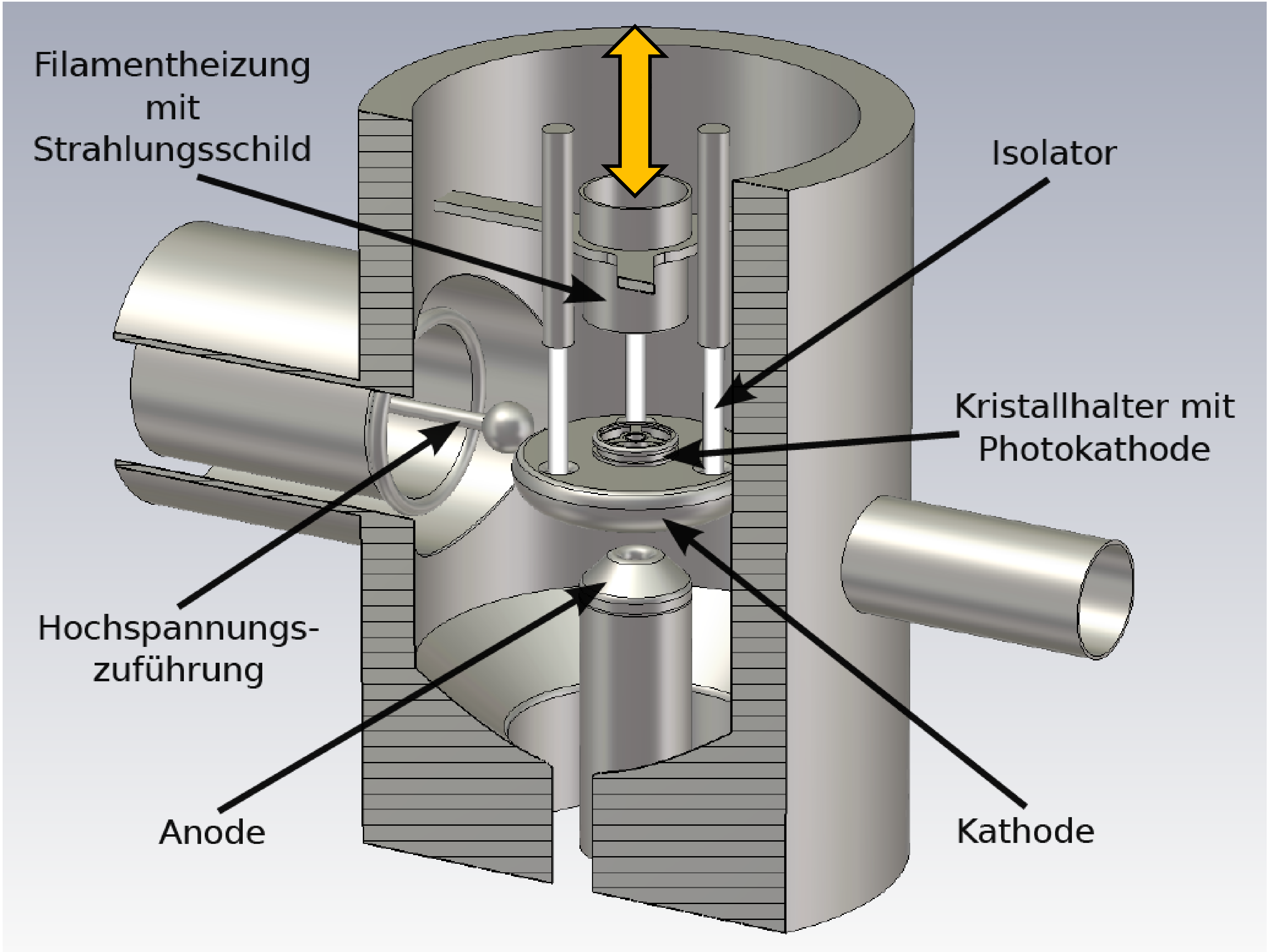




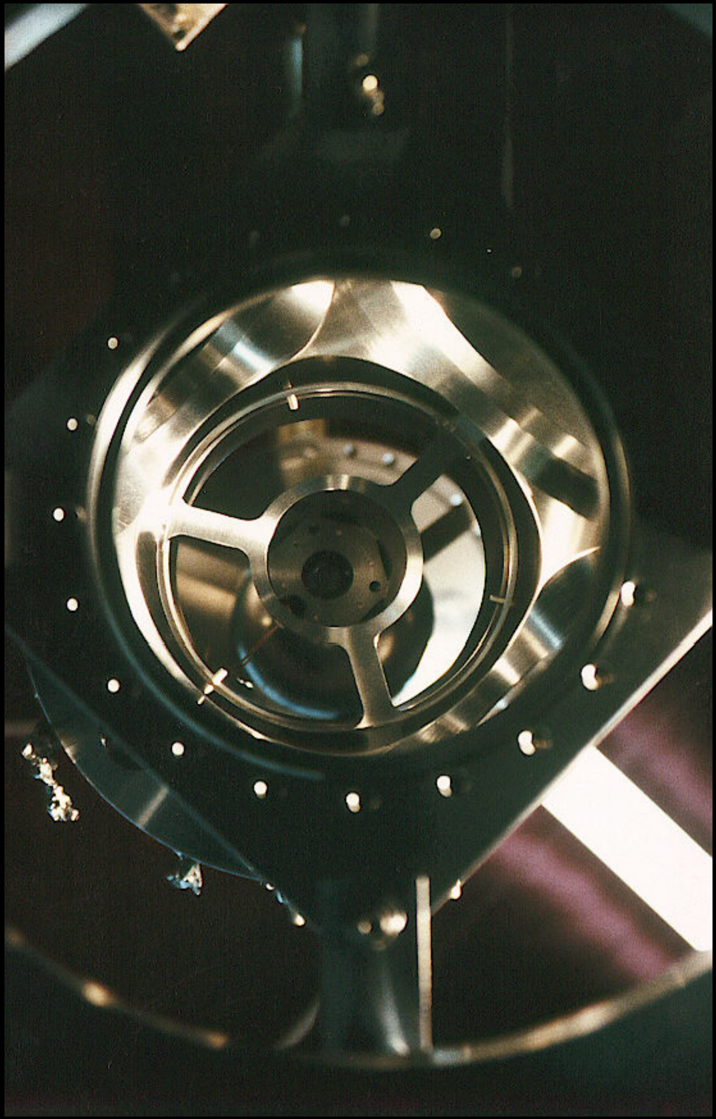
Measurements:

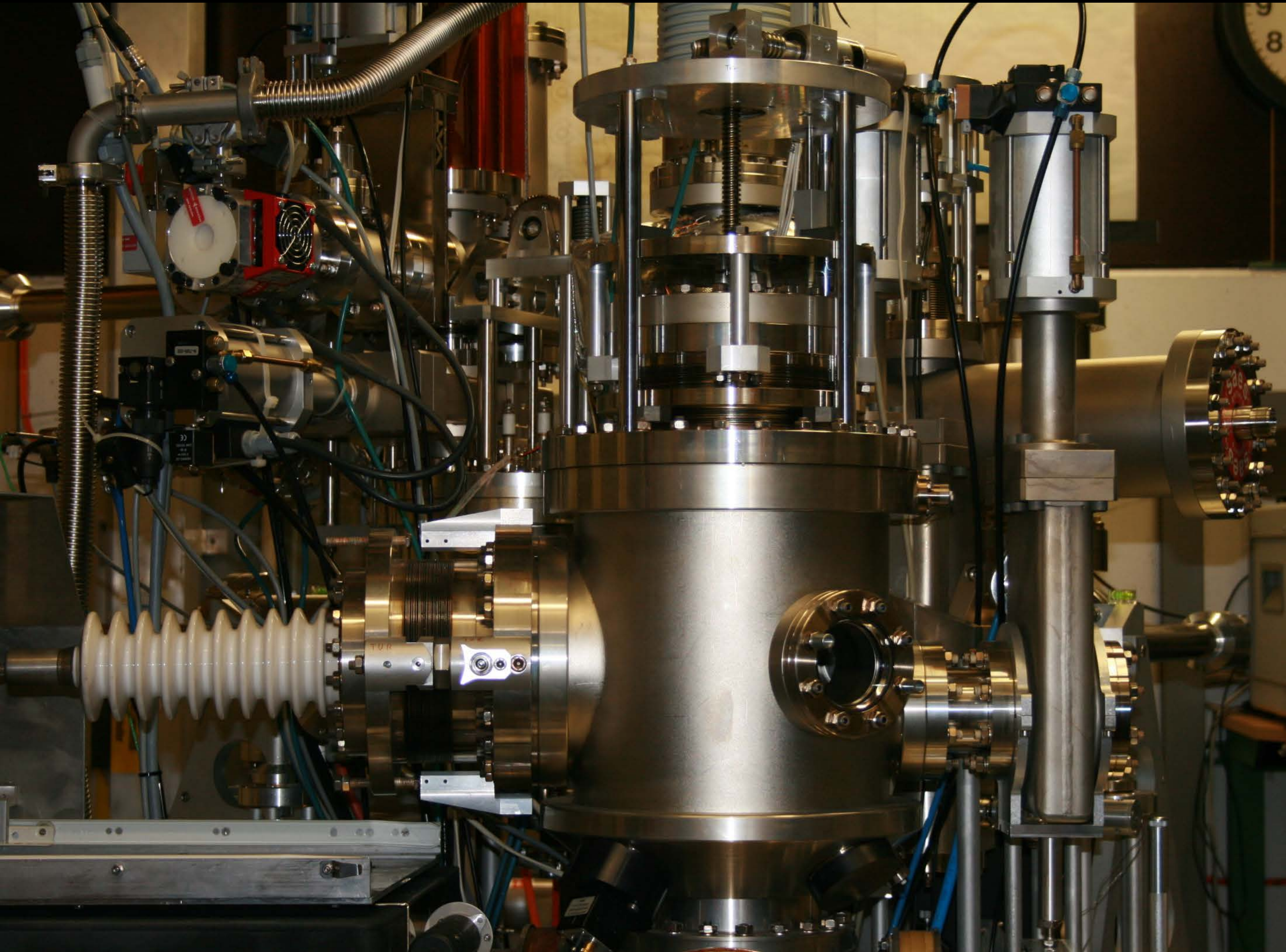




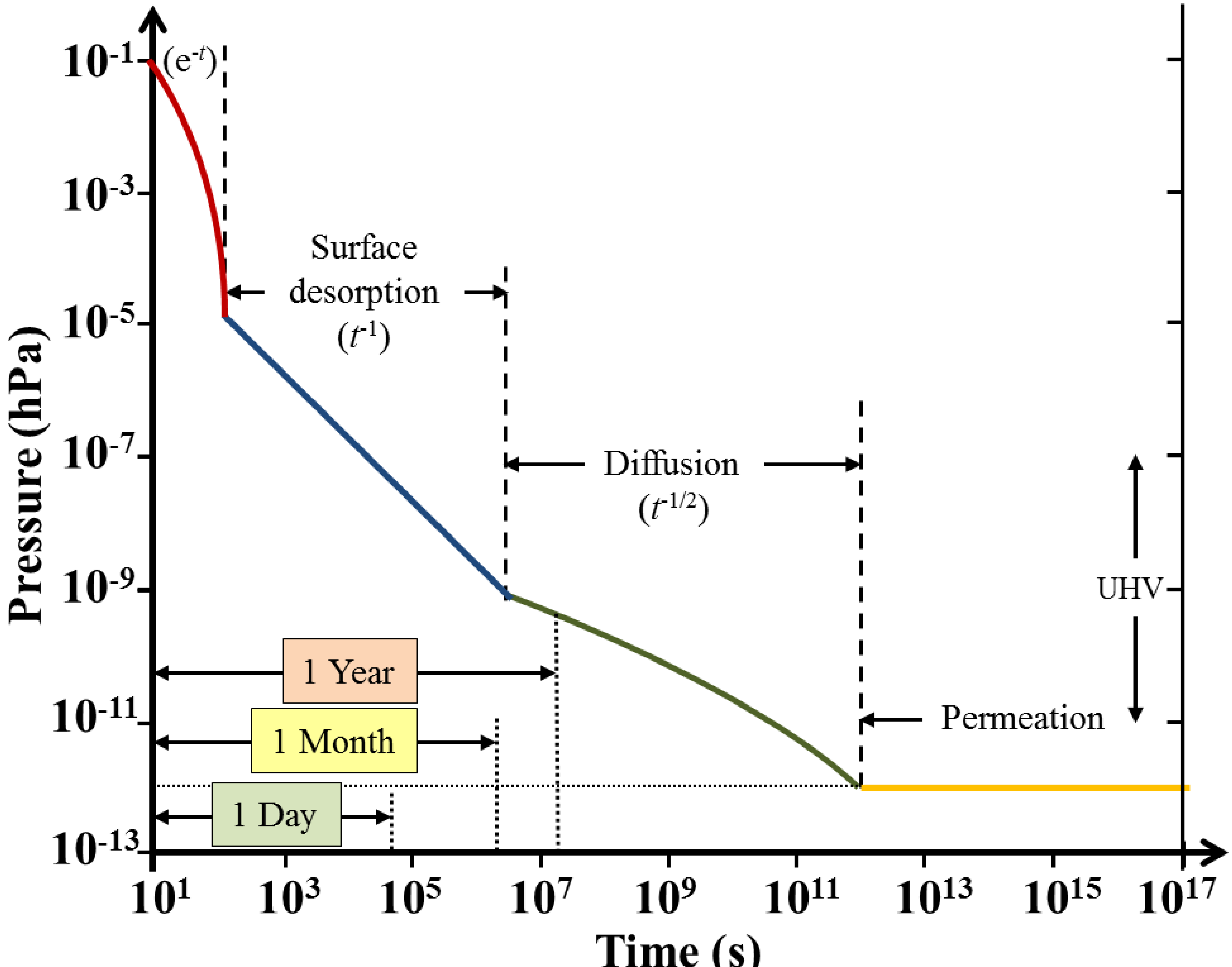

Filamentheizung
mit
Strahlungsschild
Isolator
Kristallhalter mit
Photokathode
Hochspannungs-
zuführung
Anode
Kathode

Assembly

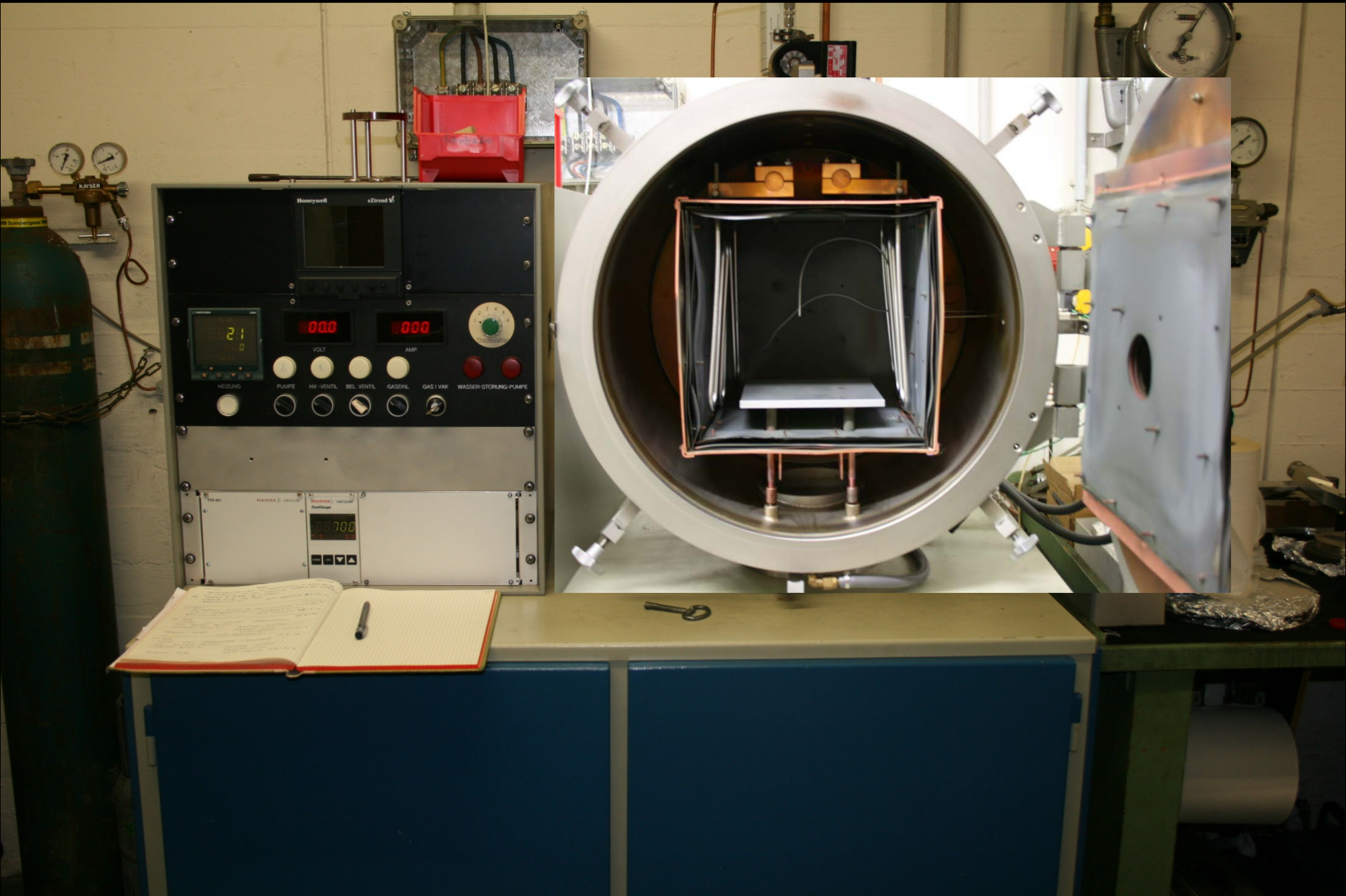




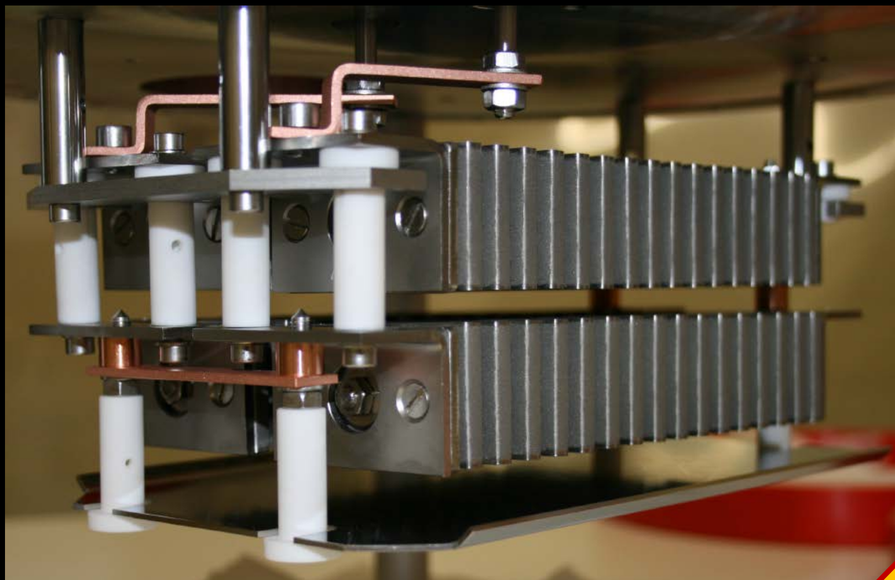
The way to 10^{-12} mbar



Key to Success: H-Firing!

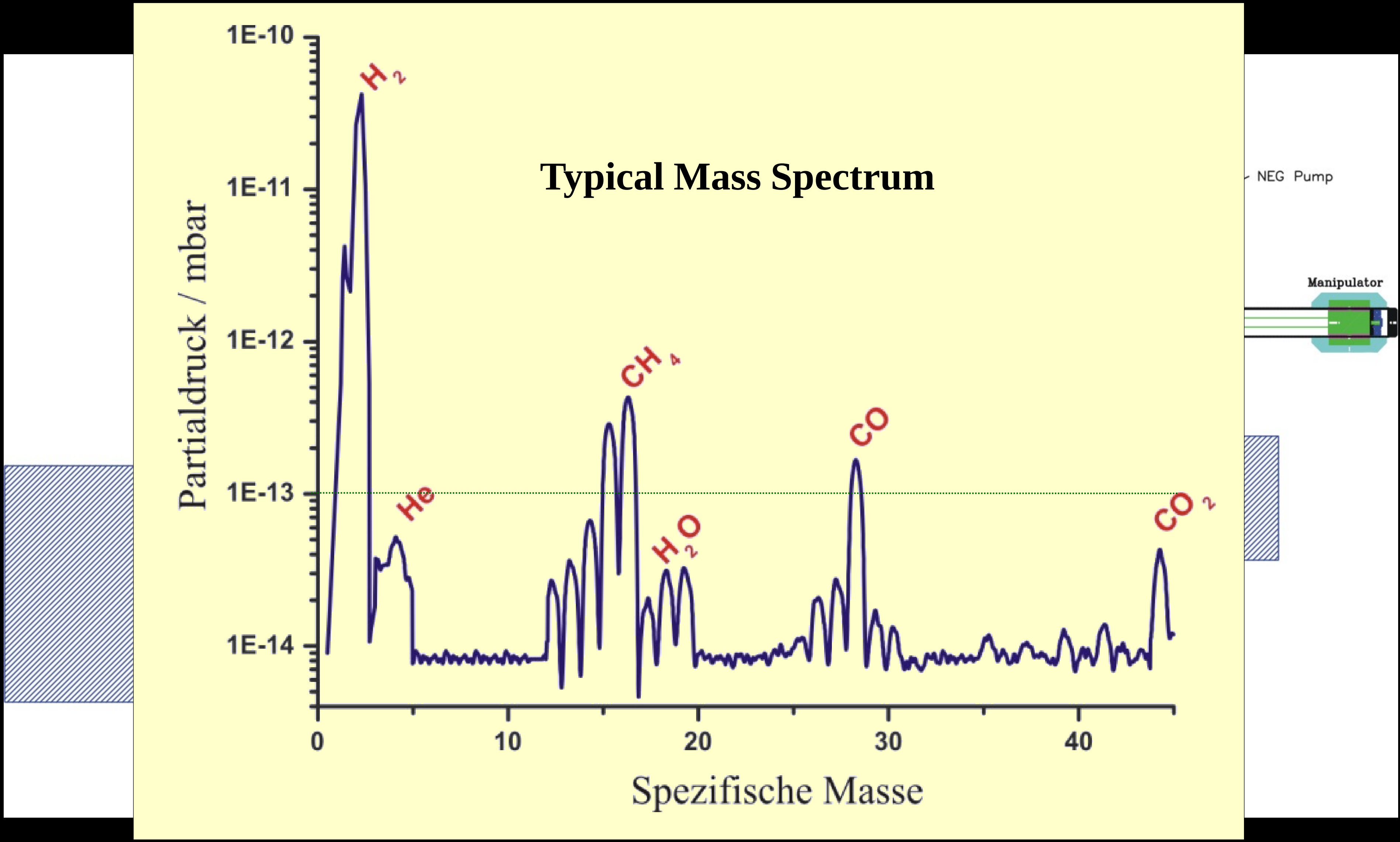


Vacuum in the Storage Chamber



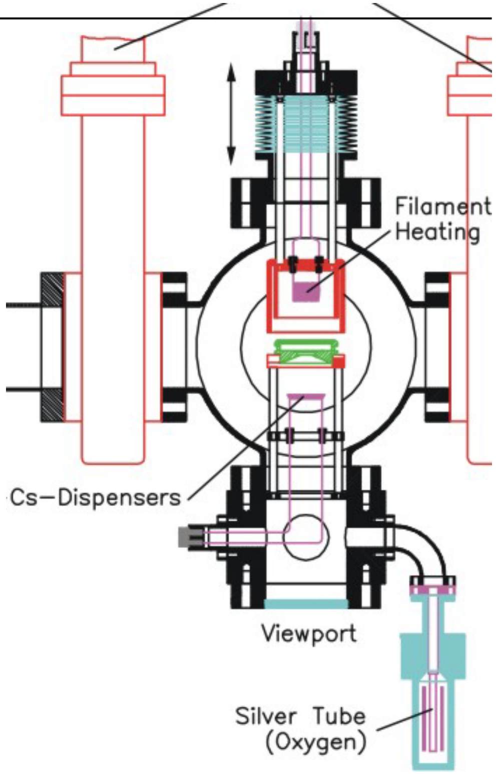
important!

Electron Gun

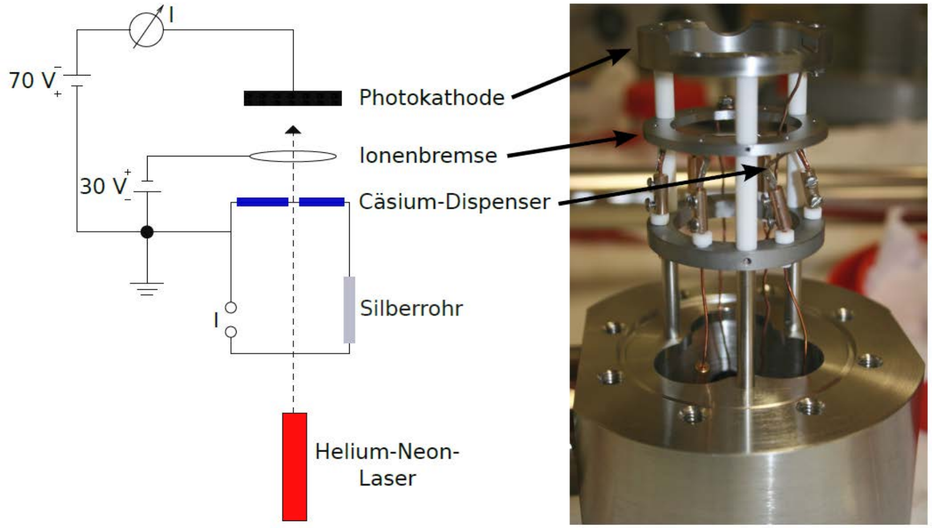


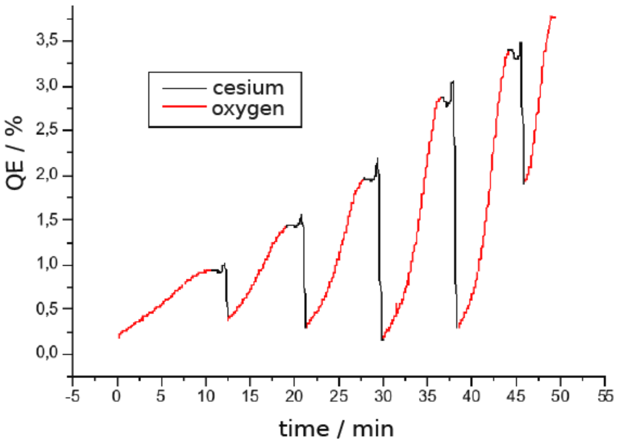
Photocathode Preparation

- **Cleaning of the PC's surface:**
  - **heat cleaning at ~550°C:**
    200°C: AsO
    350°C: As (from $As_2O_3 + 2GaAs \rightarrow$ **Ga_2O_3** $+ 2As\uparrow$)
    500°C: Ga_2O
  - **addition of atomic H:**
    $Ga_2O_3 + 4H \rightarrow Ga_2O\uparrow + 2H_2O\uparrow$

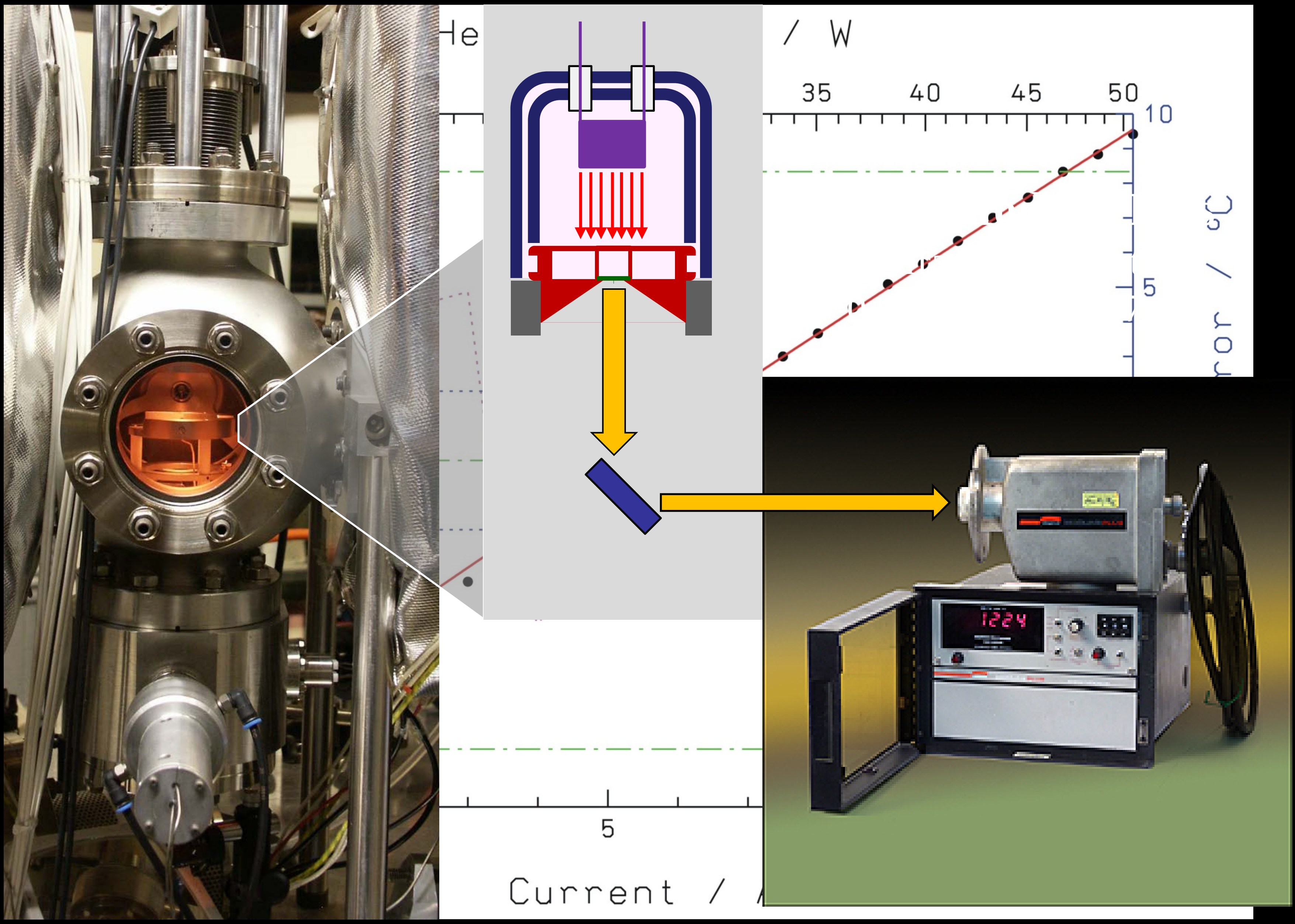


- **Activation with Cesium and Oxygen:**

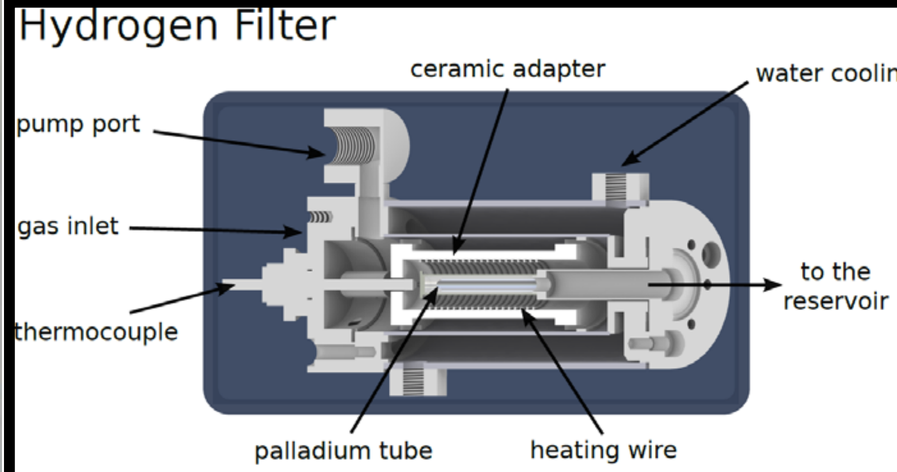


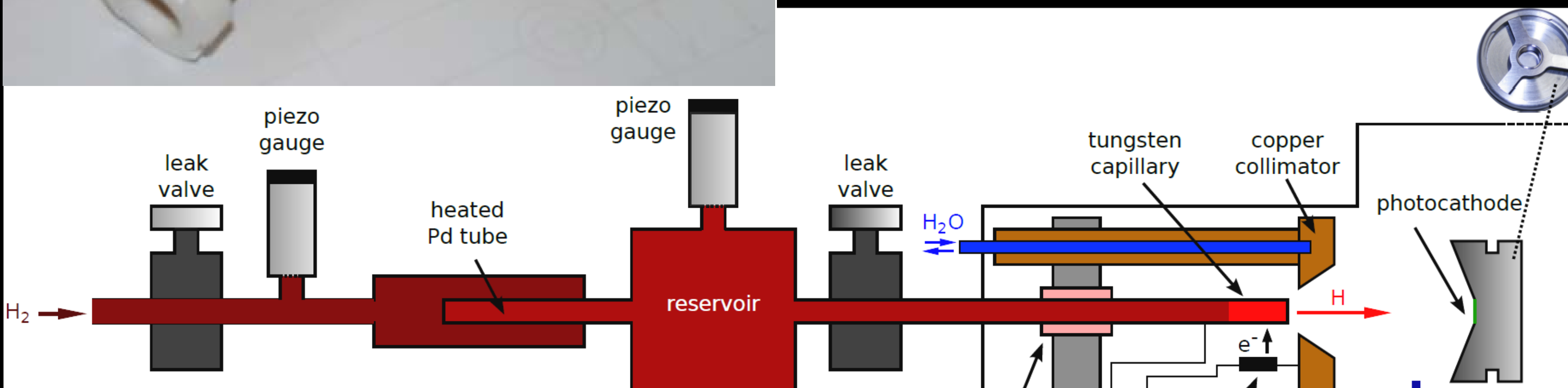


Heat Cleaning



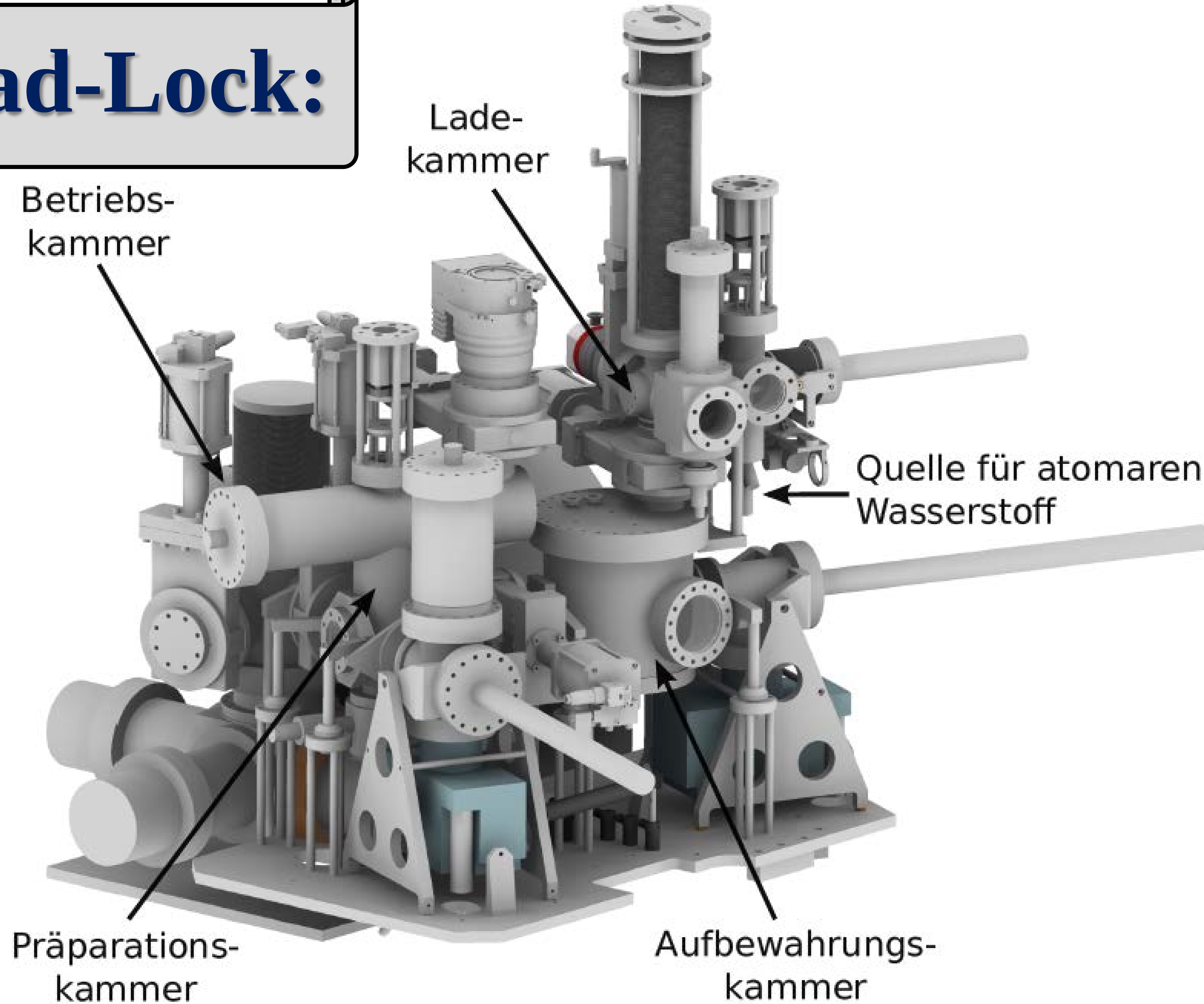
Hydrogen Cleaning





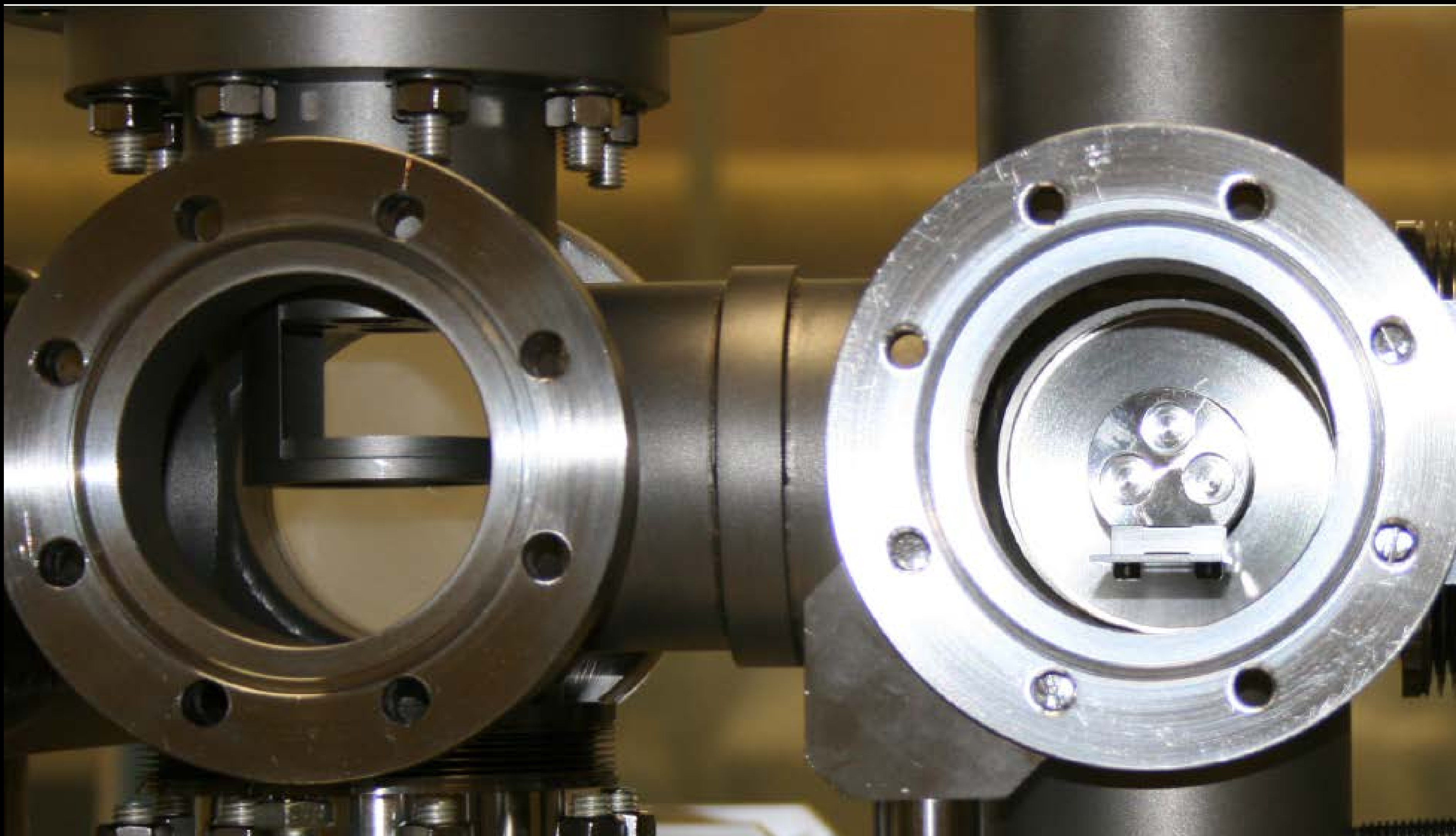
- Highly purified molecular hydrogen (99.9999%) from a gas bottle flows through a leak valve towards the heated palladium tube. The pressure is measured with a piezo gauge.
- Because only hydrogen passes through heated palladium, hydrogen without any impurities accumulates on the baked-out vacuum side of the tube. The pressure in this reservoir is measured with a piezo gauge.
- A calibrated leak valve is used to adjust the hydrogen flow through a capillary heated by electron bombardement up to 2000 K. There it is cracked into atomic hydrogen and is directed to the photocathode.

Load-Lock:

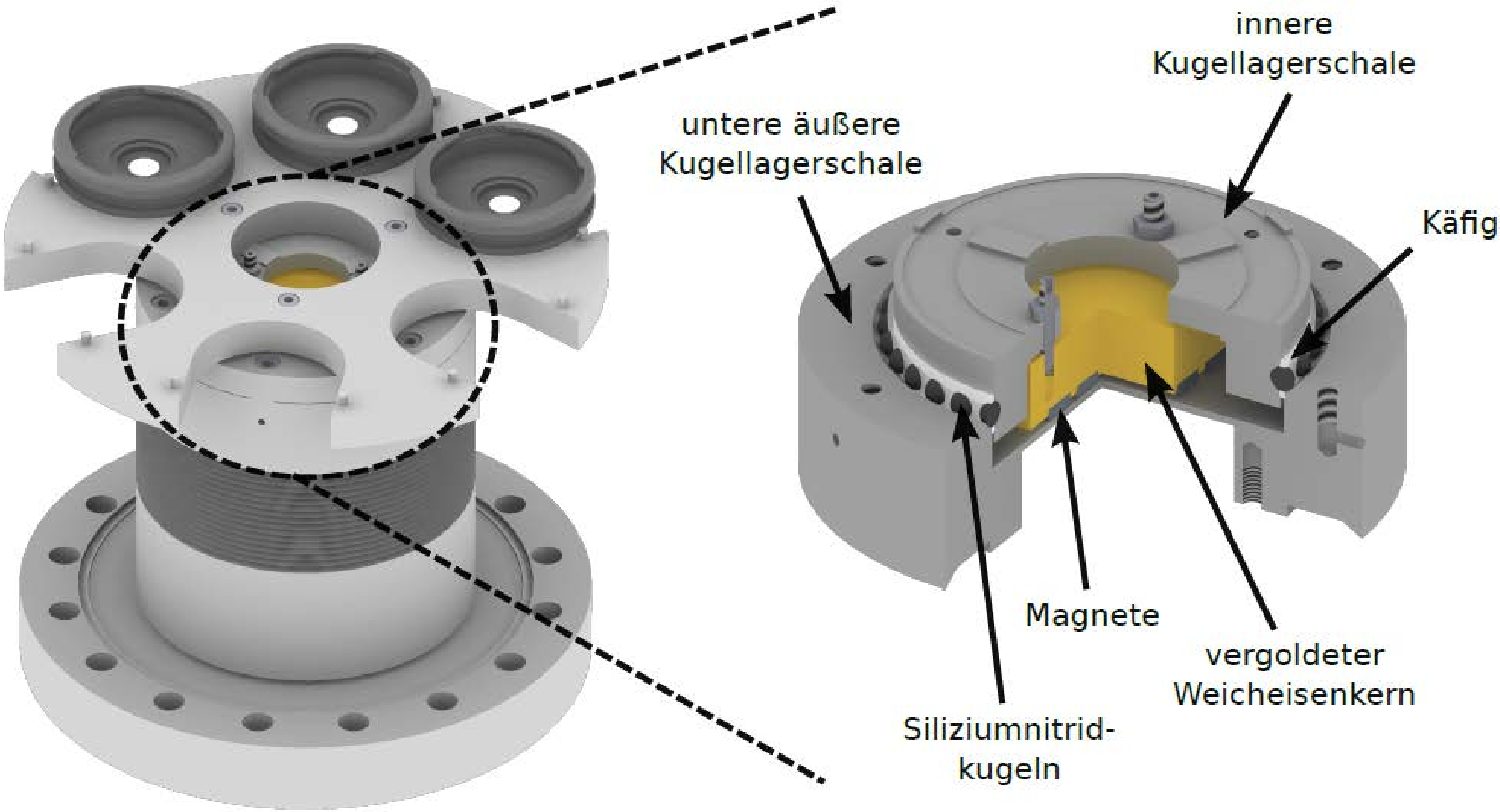


Betriebs-
kammer
Lade-
kammer
Quelle für atomaren
Wasserstoff
Präparations-
kammer
Aufbewahrungs-
kammer

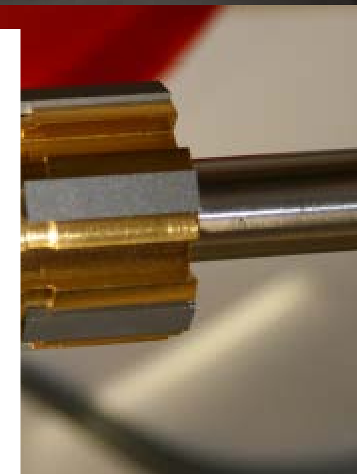
Loading Chamber



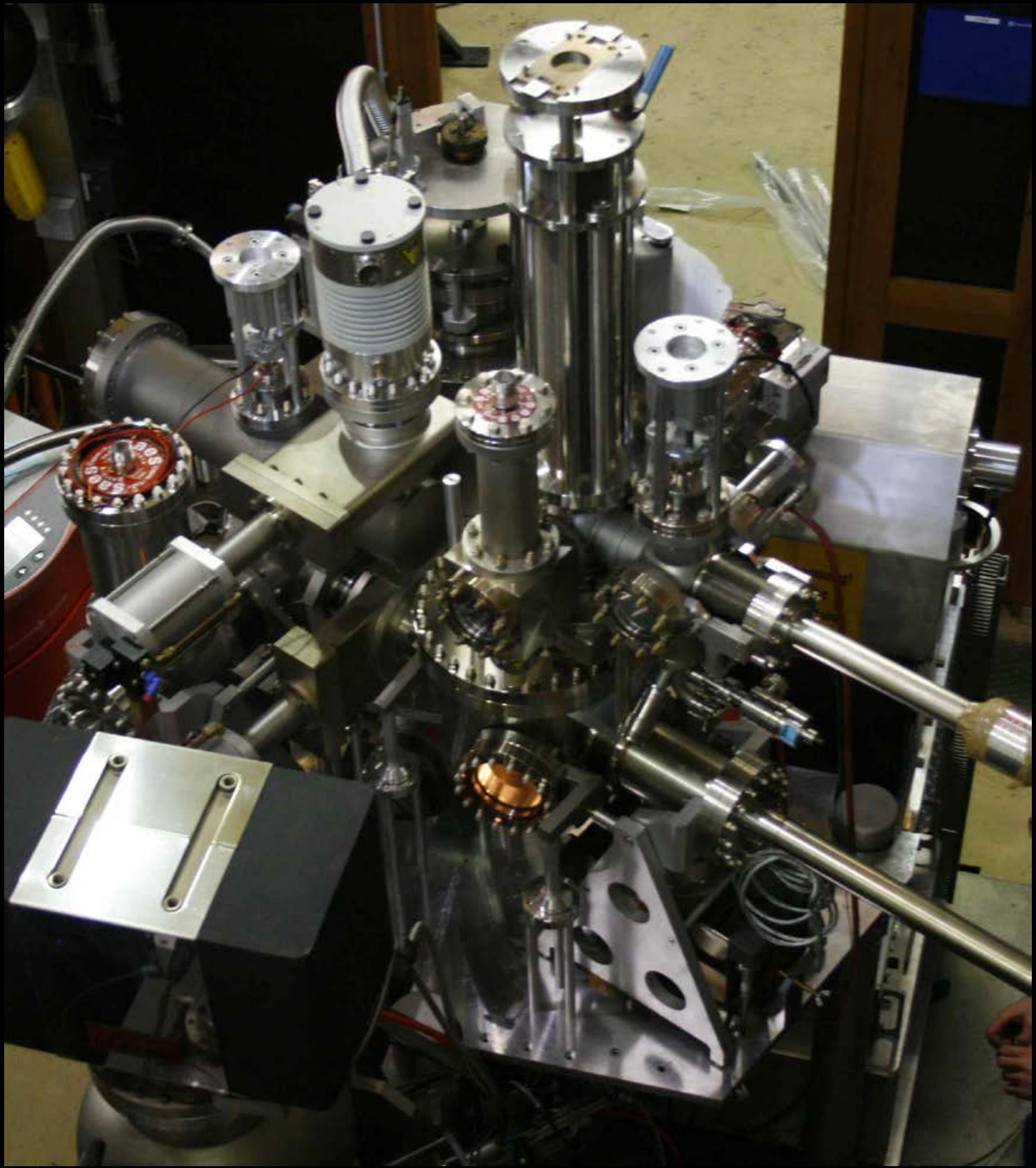
Storage Chamber



Storage Chamber



Source of Polarized Electrons

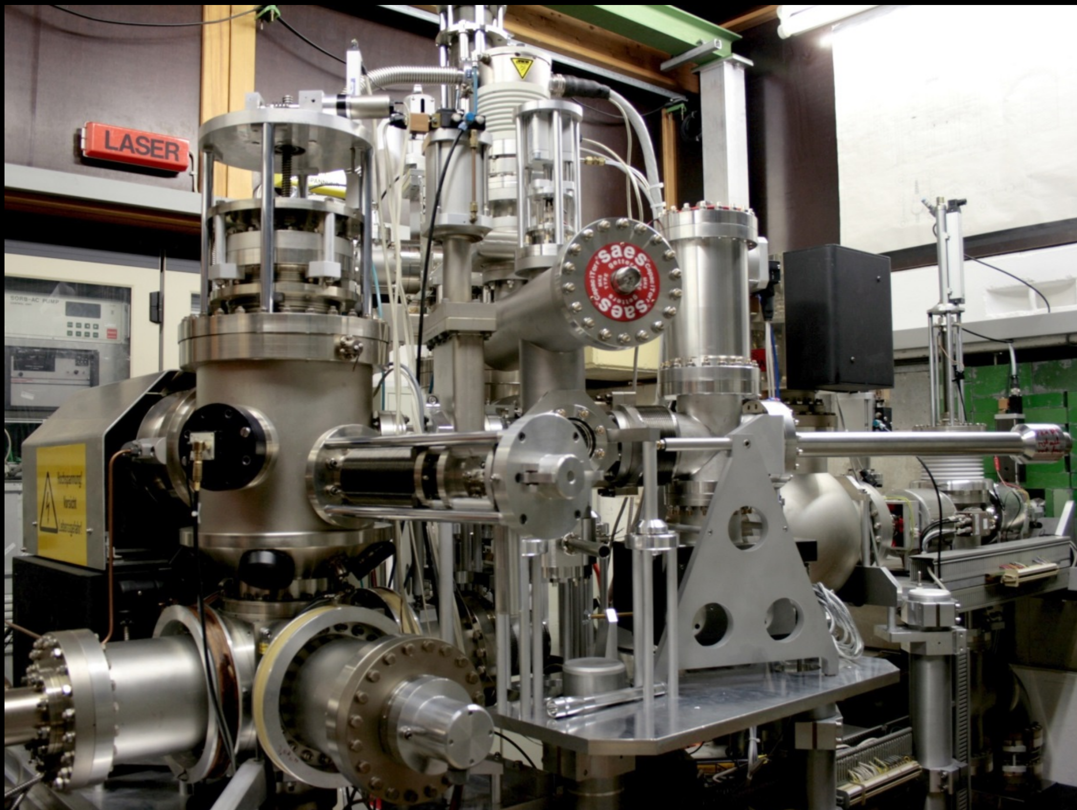


Specific features:

- inverted HV geometry
- adjustable perveance
- full load lock system
- H-cleaning
- P > 80% @ E = 48 keV
- I = 200 mA @ τ = 1µs
- QE-lifetime > 1000 h

Photocathode holder:

Source of Polarized Electrons



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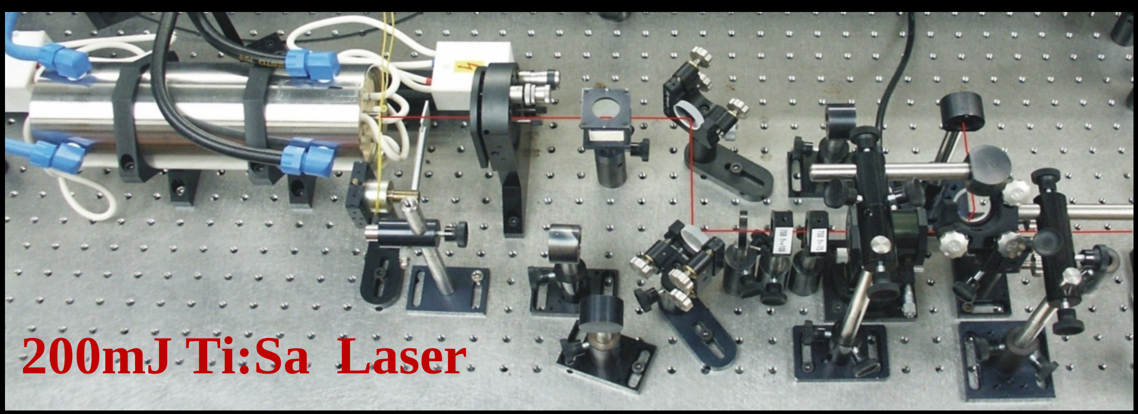
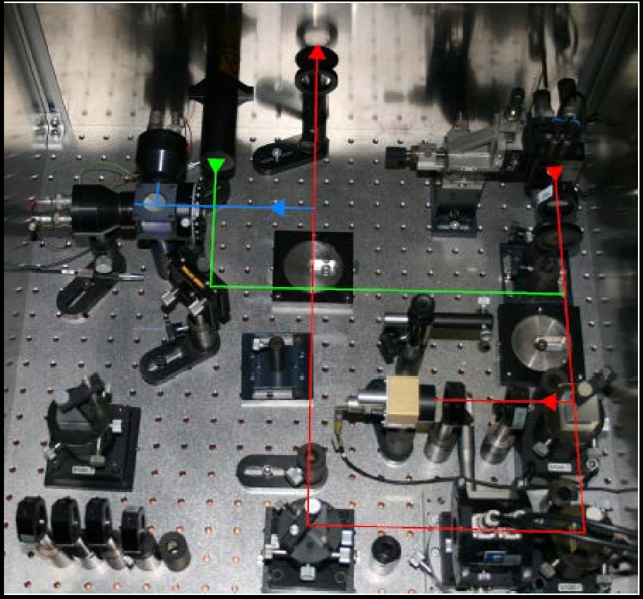
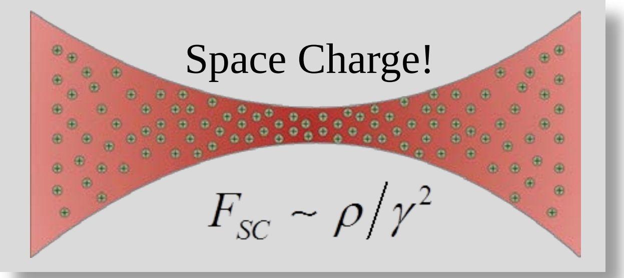
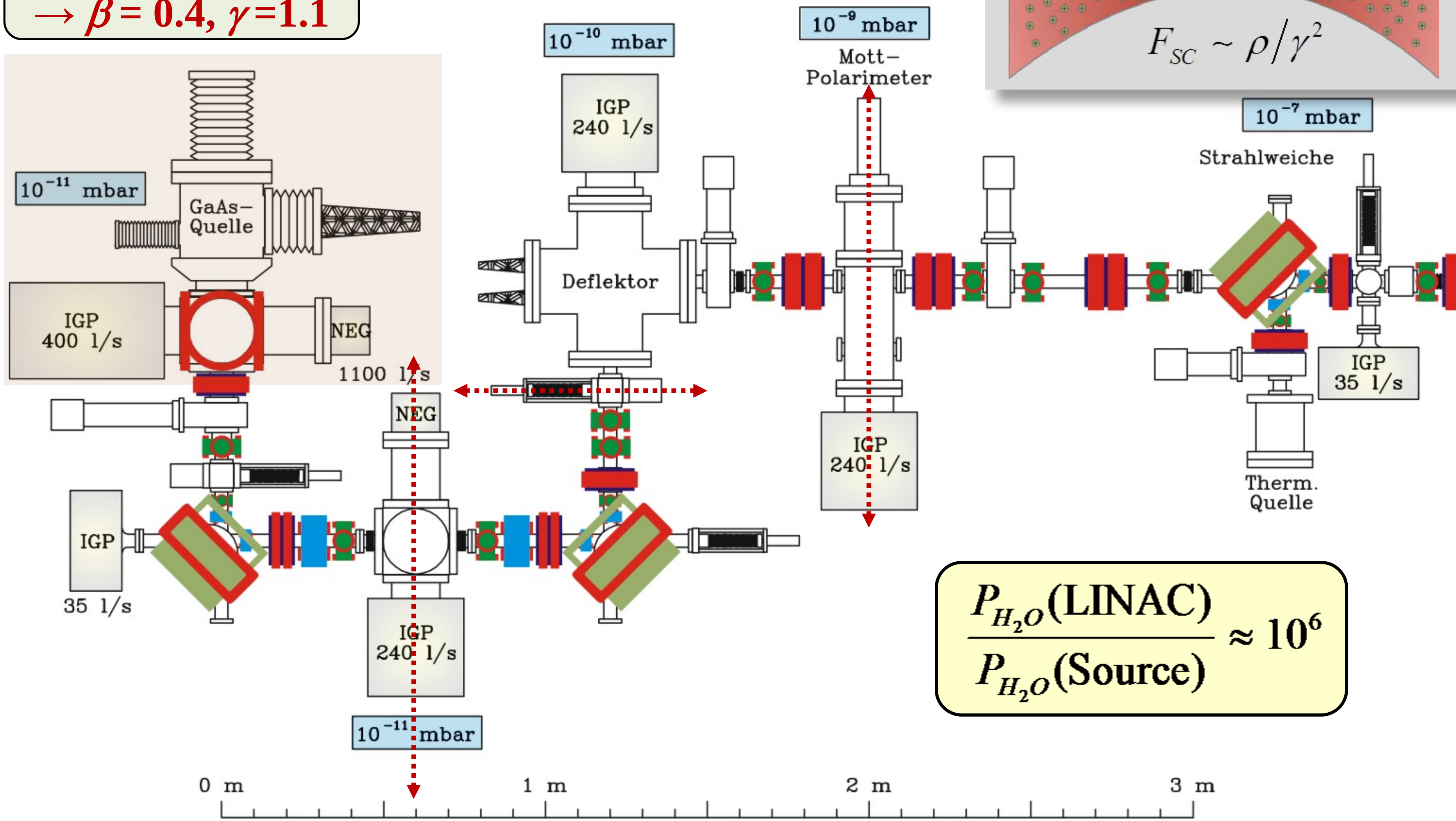




Source and Transfer Line

E = 48 keV
$\rightarrow \beta = 0.4,\ \gamma = 1.1$

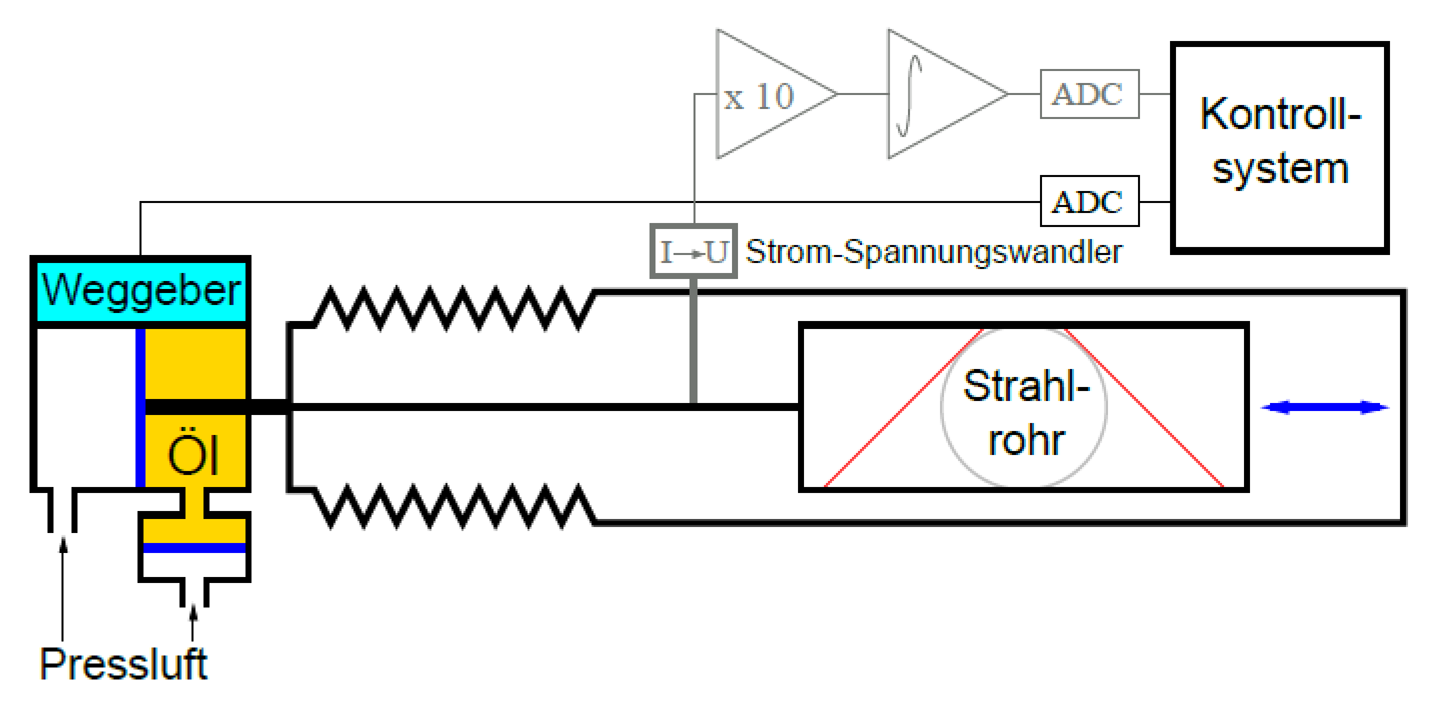


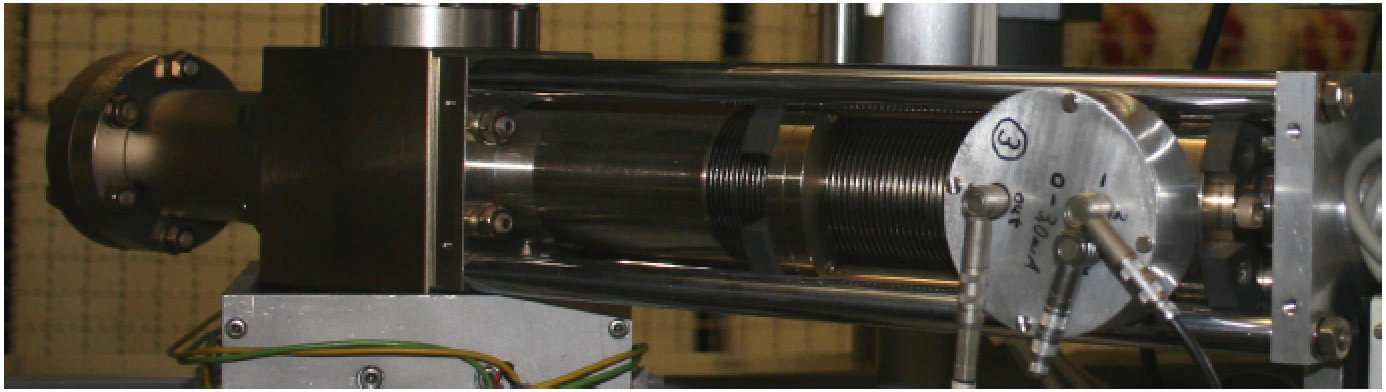


$$\frac{P_{H_2O}(\text{LINAC})}{P_{H_2O}(\text{Source})} \approx 10^6$$

Electrostatic Deflector

Wire Scanner





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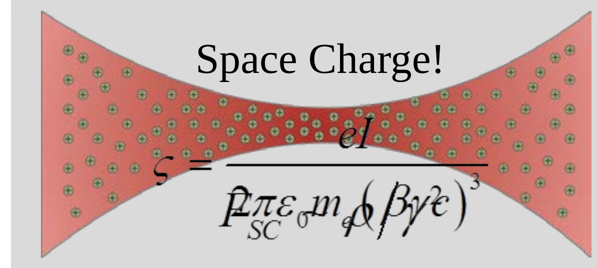
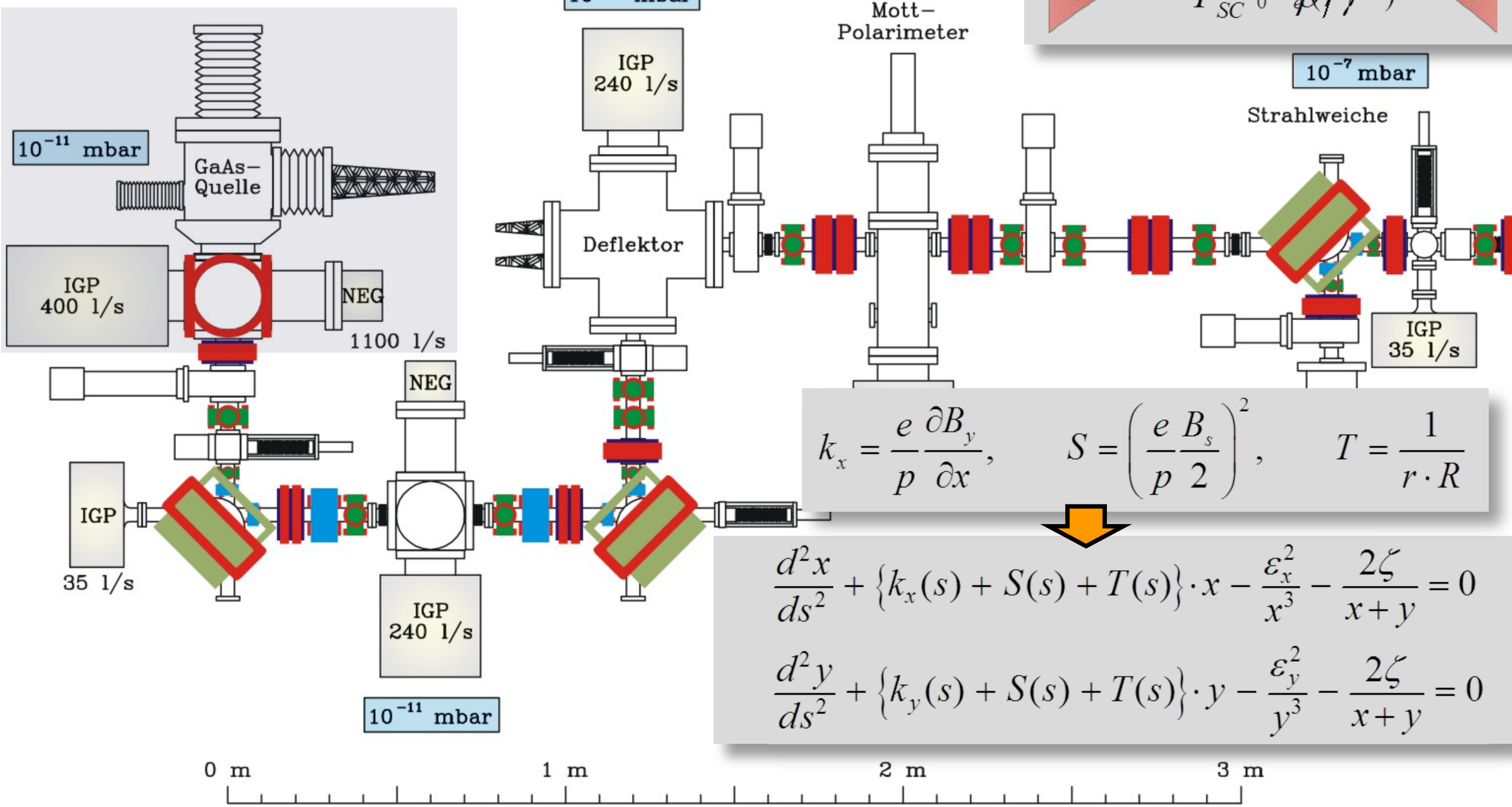


$$\varsigma = \frac{eI}{2\pi\varepsilon_0 m_0 (\beta\gamma c)^3}$$

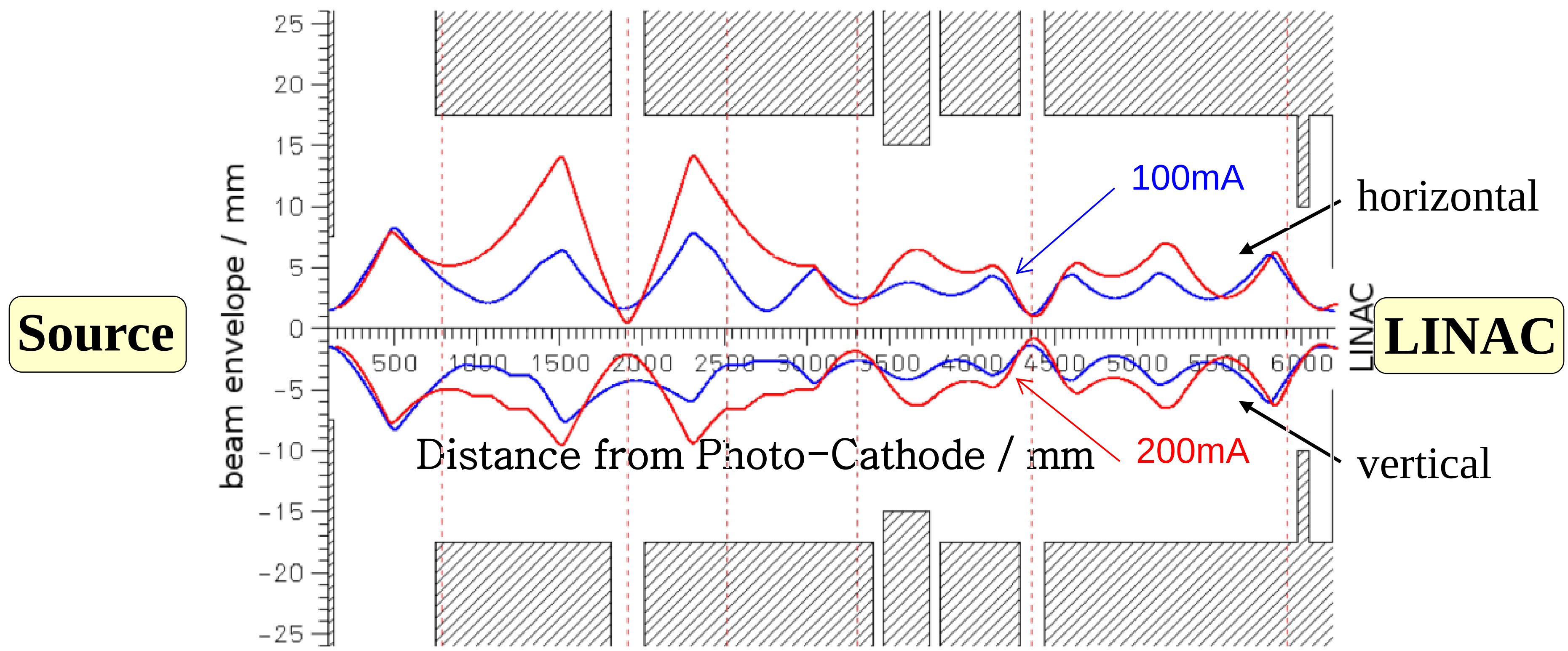


$$k_x = \frac{e}{p}\frac{\partial B_y}{\partial x}, \qquad S = \left(\frac{e}{p}\frac{B_s}{2}\right)^2, \qquad T = \frac{1}{r \cdot R}$$

$$\frac{d^2x}{ds^2} + \{k_x(s) + S(s) + T(s)\} \cdot x - \frac{\varepsilon_x^2}{x^3} - \frac{2\zeta}{x+y} = 0$$

$$\frac{d^2y}{ds^2} + \{k_y(s) + S(s) + T(s)\} \cdot y - \frac{\varepsilon_y^2}{y^3} - \frac{2\zeta}{x+y} = 0$$

Space-Charge dominated Beam Transfer at 48 keV



$$\frac{d^2x}{ds^2} + \left\{k_x(s) + S(s) + T(s)\right\}\cdot x - \frac{\varepsilon_x^2}{x^3} - \frac{2\zeta}{x+y} = 0$$

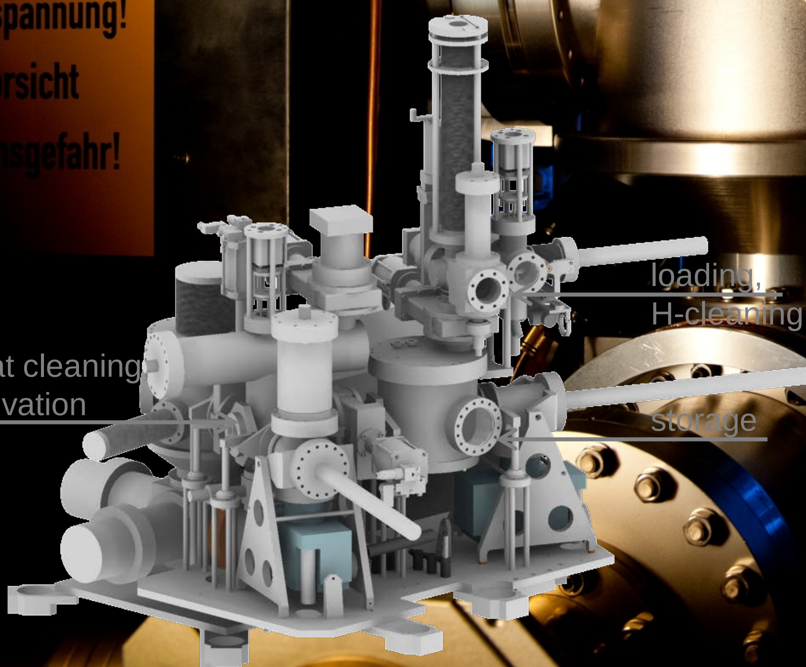
$$\frac{d^2y}{ds^2} + \left\{k_y(s) + S(s) + T(s)\right\}\cdot y - \frac{\varepsilon_y^2}{y^3} - \frac{2\zeta}{x+y} = 0$$

Transfer Efficiency > 99%

Bonn Polarized GaAs-Photoinjector

Workhorse since 2000:

- spin polarization P > 80%
- pulsed beam current I = 100mA
- quantum life time τ > 3000h
- transfer efficiency to LINAC > 99%
- uptime close to 100%



- ➢ **new load-lock with H-cleaning**
- ➢ **upgraded to pulse currents I = 200mA**