Dry-ice (CO_2-snow) Cleaning

- **Motivation**
- **Cleaning mechanism, technique & apparatus**
- **Nb cavity results**
- **Copper rf gun cleaning**
- **Summary, open topics + next steps**

Detlef Reschke, Arne Brinkmann

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HELMHOLTZ ASSOCIATION

DESY

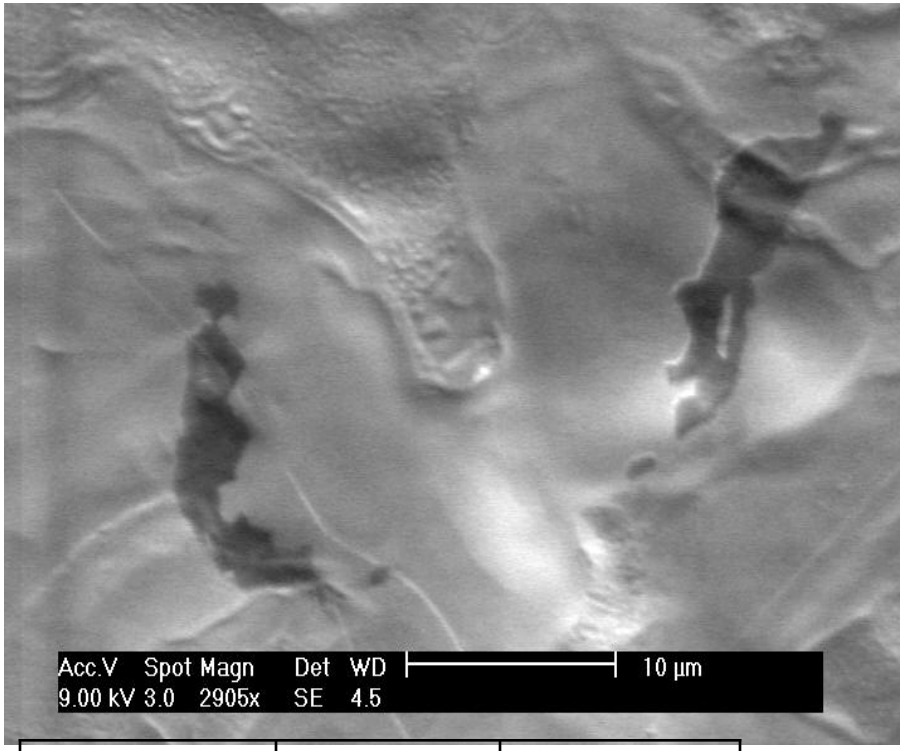
Motivation for dry-ice cleaning

- High cleaning potential for removal of particles + field emission by dry-ice cleaning proven on samples
  => publications by Univ. Wuppertal (e.g. SRF Workshops, …)

- **Additional cleaning option:**
  no replacement of high pressure water rinse !

- advantages of dry-ice cleaning:
  - **Effective removal of particulate and film contamination**
  - **Dry cleaning process**
    => horizontal cleaning option of Nb cavities
    => final cleaning just before string assembly
    => all applications unsuitable for water
    e.g. application to Cu gun cavity
    => no drying procedure necessary

Effect of DIC on a flake-like emitter (courtesy Univ. Wuppertal)



emitter of ~ 20 µm size destroyed by DIC
remnants emitting at higher E_{on}!

EDX: no foreign element detected
(probably oxide of Nb)

emitter	HPR	HPR+DIC
E_{on} (MV/m)	54.3	62.8
$\beta_{\uparrow}$	67.4	35.4
$\beta_{\downarrow}$	51.2	38.0
$S_{\uparrow}$ (m^2)	$2 \cdot 10^{-17}$	$8.3 \cdot 10^{-13}$
$S_{\downarrow}$ (m^2)	$1.2 \cdot 10^{-15}$	$2.4 \cdot 10^{-13}$

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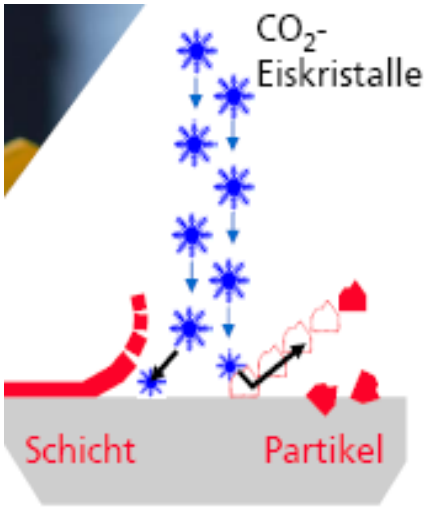
Cleaning mechanism

- dry-ice “snow”: mechanical, thermal + chemical cleaning forces

  - thermo-mechanical: i) embrittling by shock-freezing
    ii) shearing forces by high momentum
    iii) drastic volume increase by sublimation
  - chemical: liquid CO_2 acts as solvent for hydrocarbons + silicone

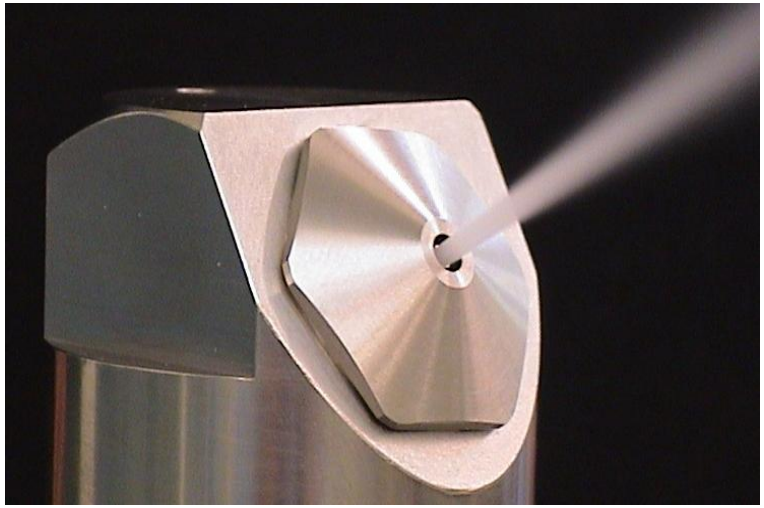
=> embrittling, blasting, shearing, dissolving, washing

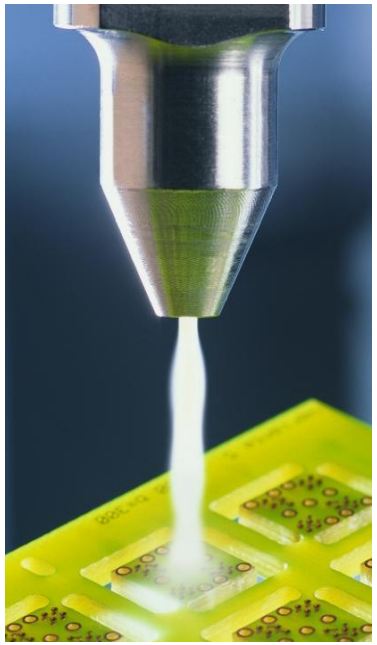


- removal of particles down to < 100nm
- local, dry, without residues
- simple checks with air and surface particle counters possible

Cleaning technique

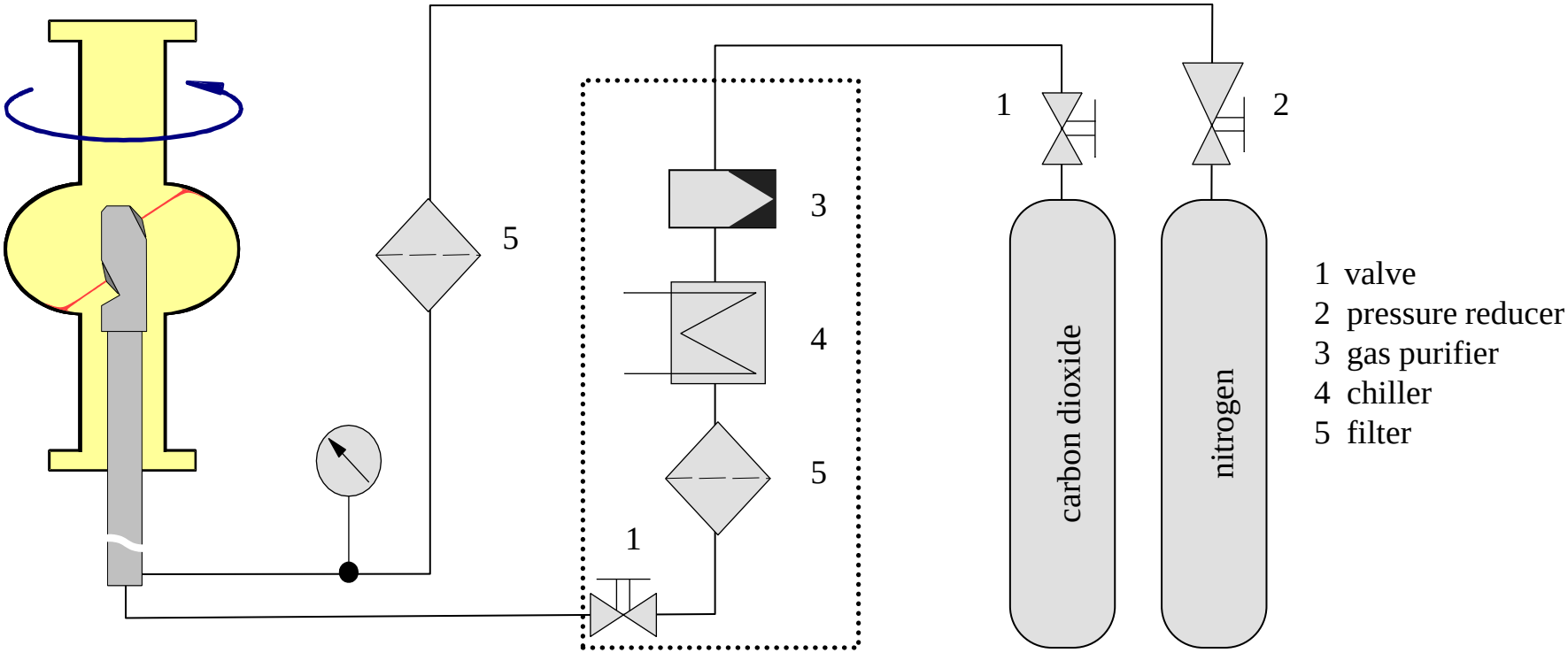
- patent-registered nozzle design for CO_2 surrounded by nitrogen designed by Fraunhofer IPA, Stuttgart, Germany
- spontaneous formation of snow/gas mixture by relaxation of liquid CO_2
  - app. 40-45% snow at -78,9 C; ~50-55 bar
- surrounding supersonic nitrogen gas (20 C; (12-18)bar)
  => accelerating + focussing of jet
  => (partially) avoidance of condensation of humidity



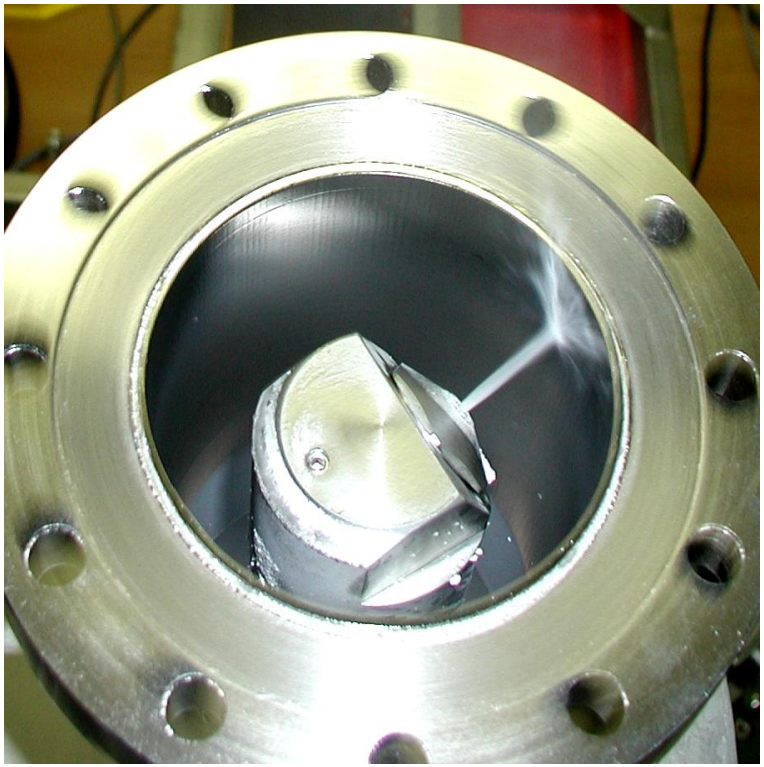


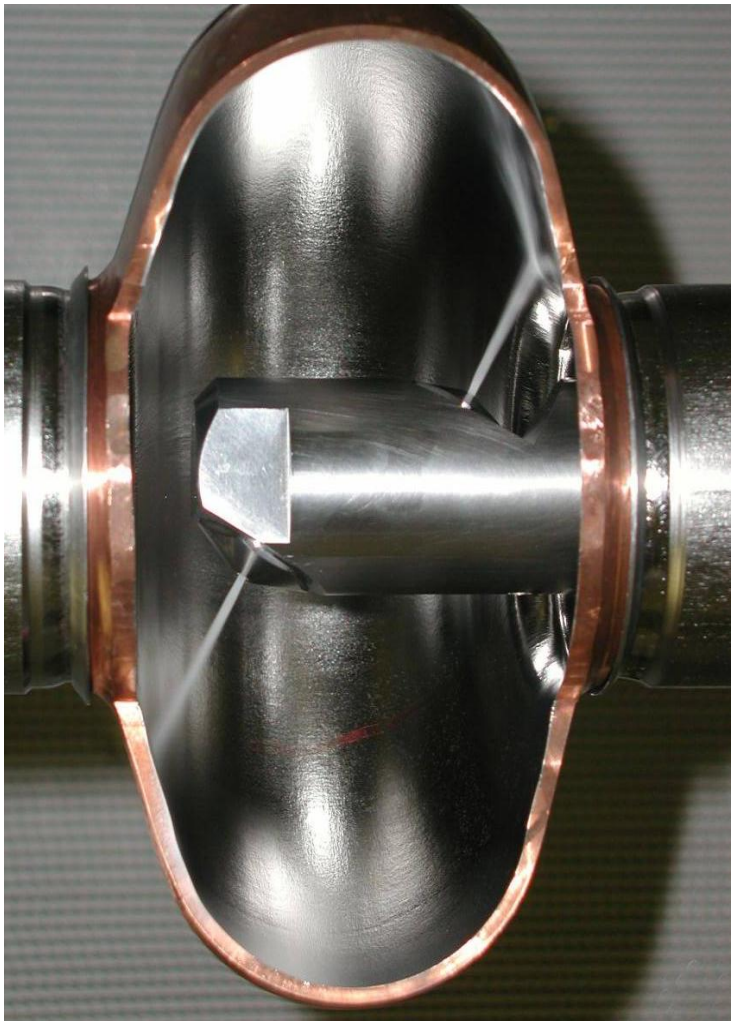
Apparatus: General

- schematic of dry-ice cleaning set-up



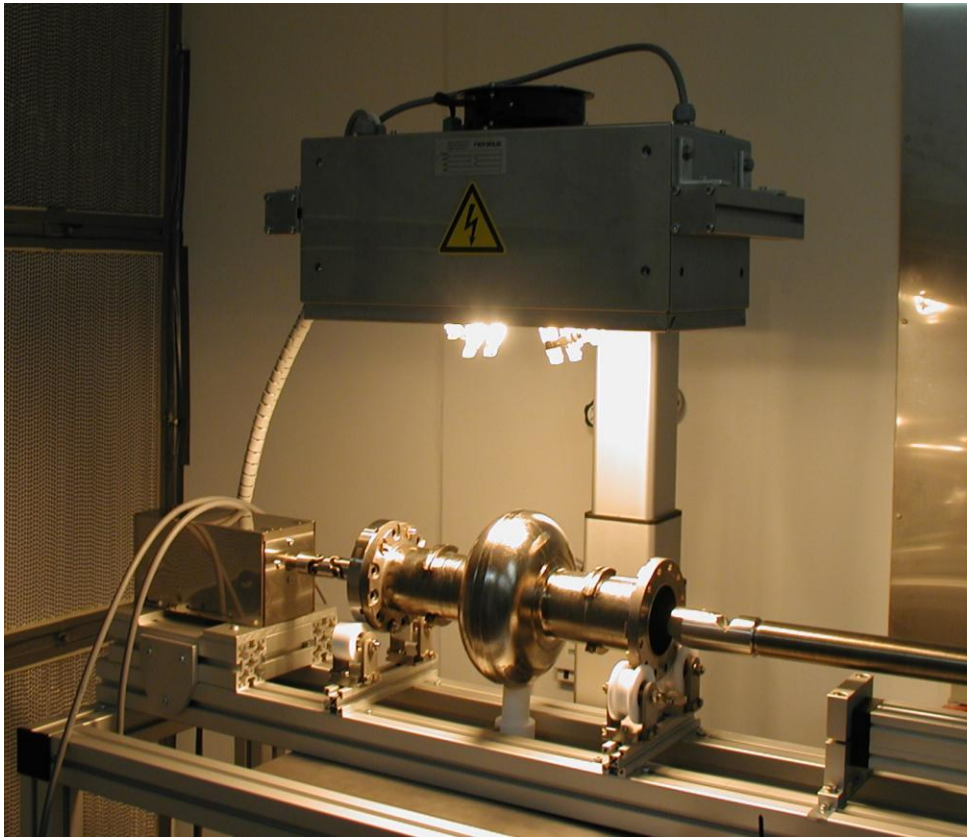
Apparatus: key components + operation

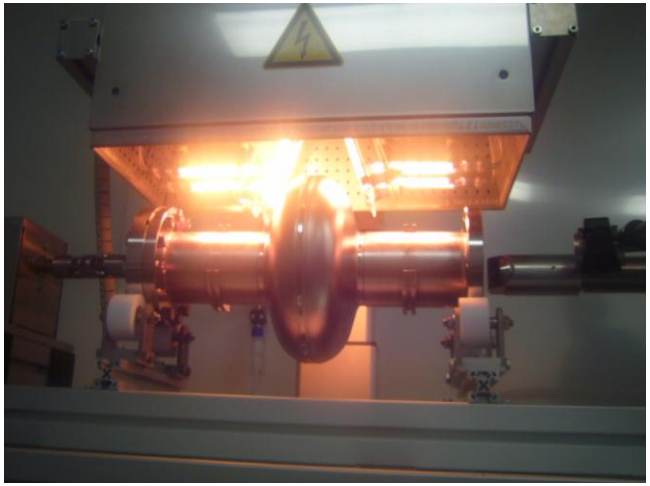




Apparatus: key components + operation

- system for **horizontal cleaning** of (1-3)-cell cavities in stable operation



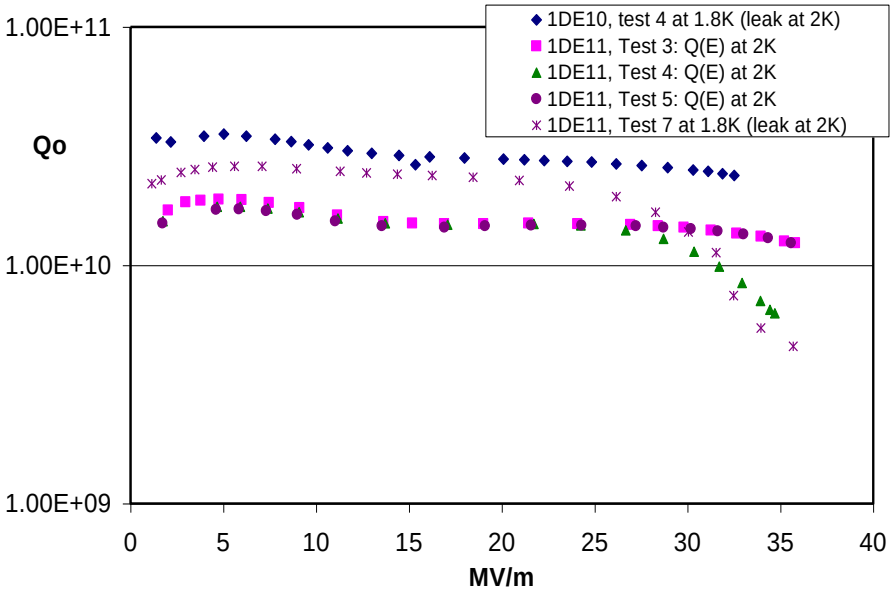


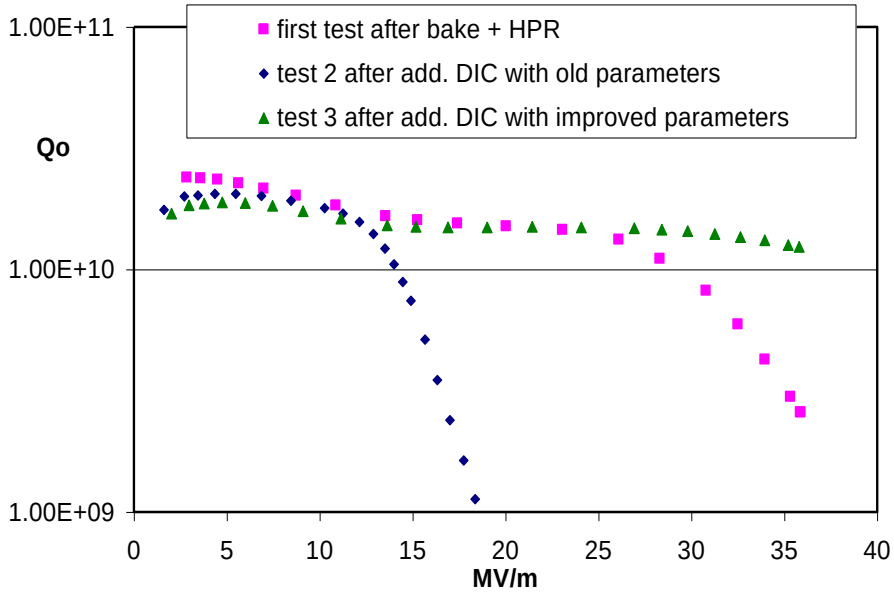
Single cell Nb cavity results

- Results with actual cleaning parameters:

=> 3 of 5 tests show no fieldemission up to 35 MV/m; 2 tests with moderate FE

- Potential to remove HPR resistant field emitters ??





Copper rf gun cavity cleaning

- Task: cleaning of the copper rf gun cavity of the photo injector for FLASH and European XFEL
- Goal:
  effective removal of particles => low dark current with no oxidation of Cu

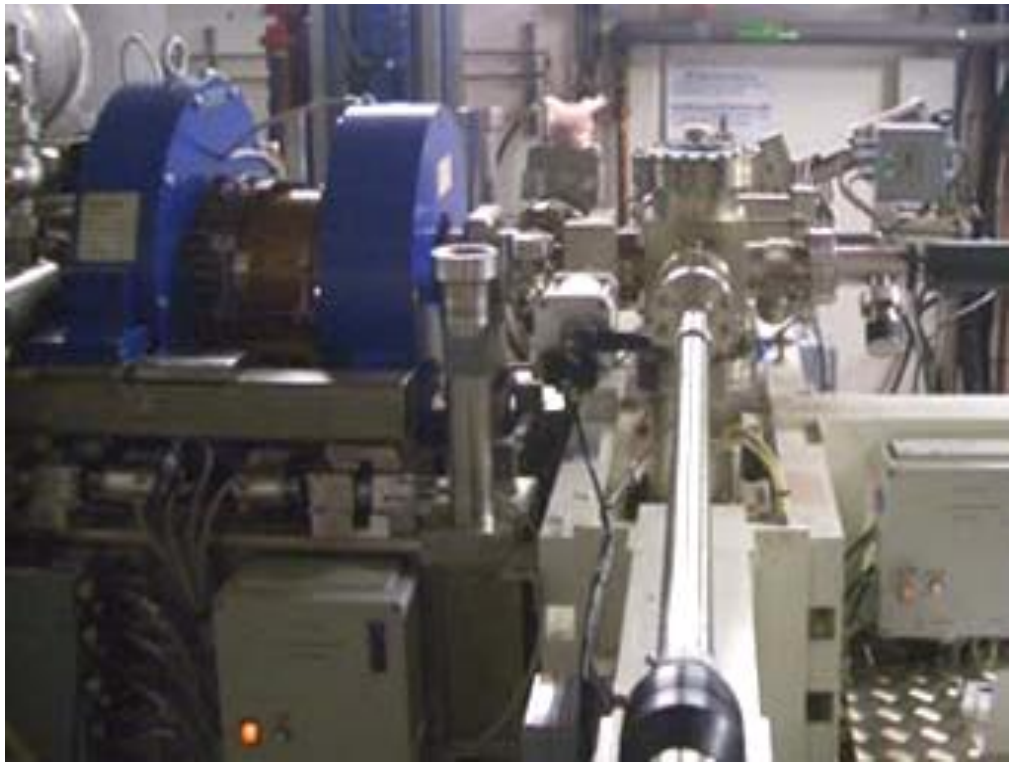
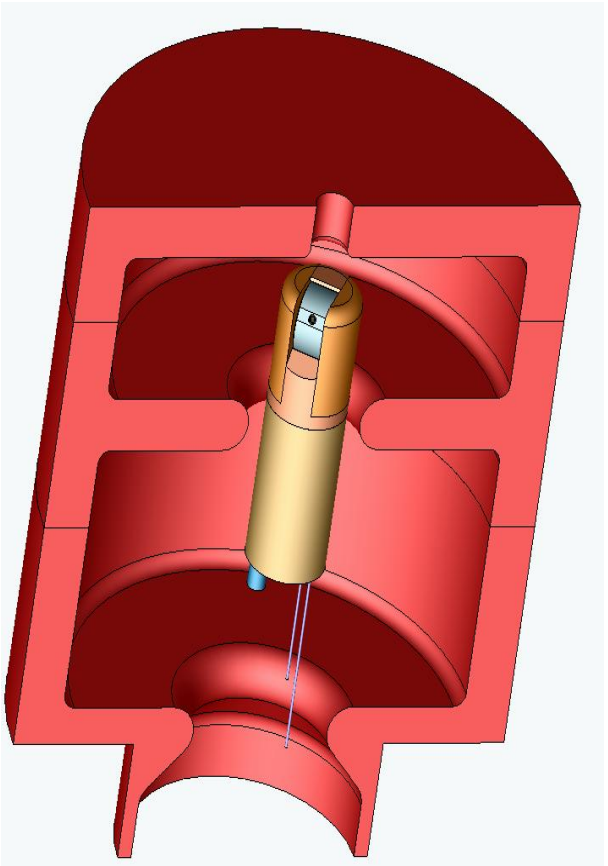


Photo injector area with rf gun cavity at FLASH

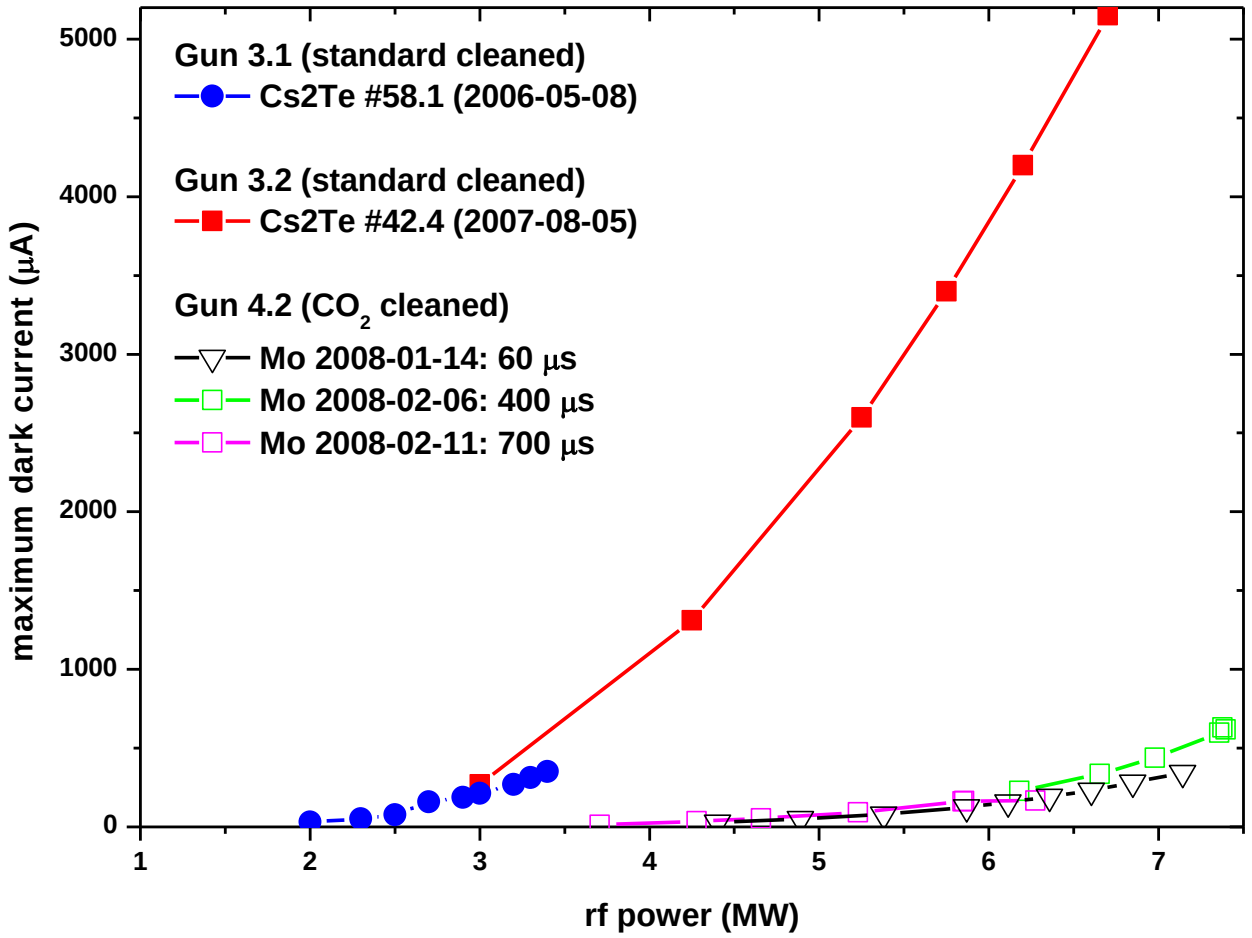
Copper rf gun cavity cleaning (ctd.)

- new vertical cleaning stand with modified **movable** nozzle



Copper rf gun cavity cleaning: first result

- three guns cleaned
  example: gun cavity 4.2 conditioning at PITZ
  => dark current during gun processing app. factor 20 reduced



Open topics + ideas

- Further optimisation of cleaning parameters:

  reduced CO_2-capillary size, cleaning speed
  => reduce consumption of CO_2
  => reduce/avoid moisture condensation
  => avoid heating ??

- What is the “better” nozzle head:

  One movable nozzle vs. two fixed nozzles? (angle of nozzles?)

- Heating of cavity or inert gas atmosphere ??

- Improved drive system of cavity

Summary + Outlook

- In operation:
  - horizontal cleaning of (1-3) cell cavities => successful
  - cleaning of 1.3 GHz Cu gun cavity with movable nozzle => successful
- Future:
  - Cleaning of **REGAE** (Relativistic Electron Gun for Atomic Explorations)
  - Regular cleaning of 1.3 GHz gun cavities for FLASH and European XFEL
  - Cleaning of water sensitive special parts
- Options:
  - Extension to Nb nine-cell accelerator cavities ?
  - Cleaning of full accelerator modules ???