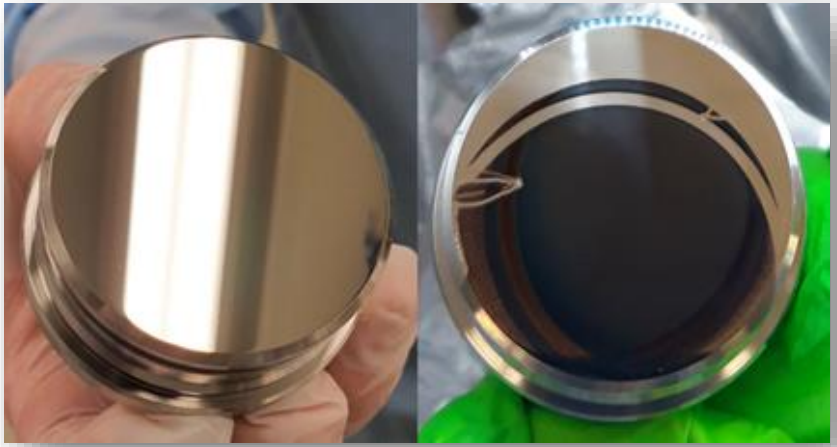

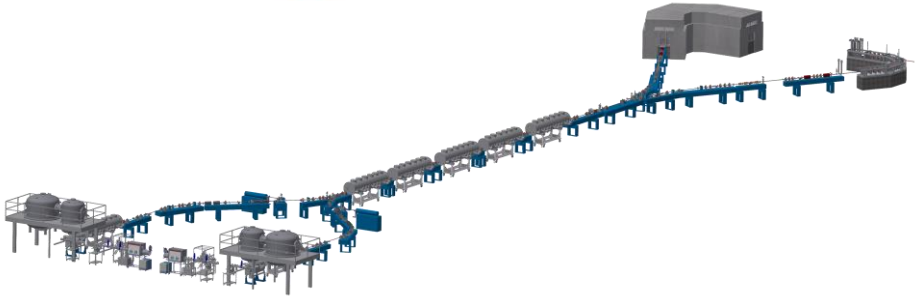

CsK_2Sb-photocathodes for application in an industrial accelerator

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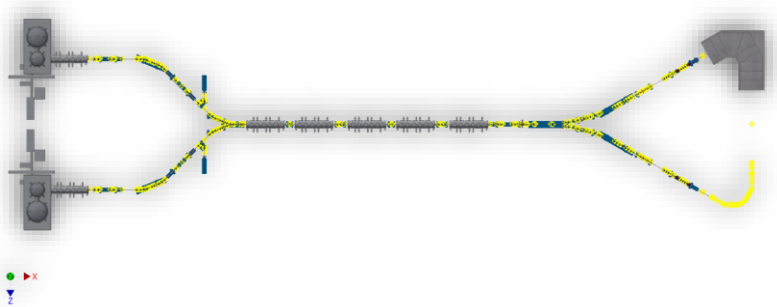
20.09.2022, EWPAA 2022 Milano

Lighthouse Project

- Project of IRE (Institut National des radioéléments, Belgium) to produce radioisotopes (Mo-99) for nuclear medicine imaging
- Two injectors with 350 kV DC photogun
- 40 mA, cw
- Operation 23h/7 days a week



Energy	75 MeV
Current	40 mA
Bunch Frequency	1.3 GHz CW
Beam Power	3 MW

Beam Test Facility

Test all sub-systems of injector

- Laser
- HV
- Photocathode preparation and automated transport
- First diagnostics
- Control system

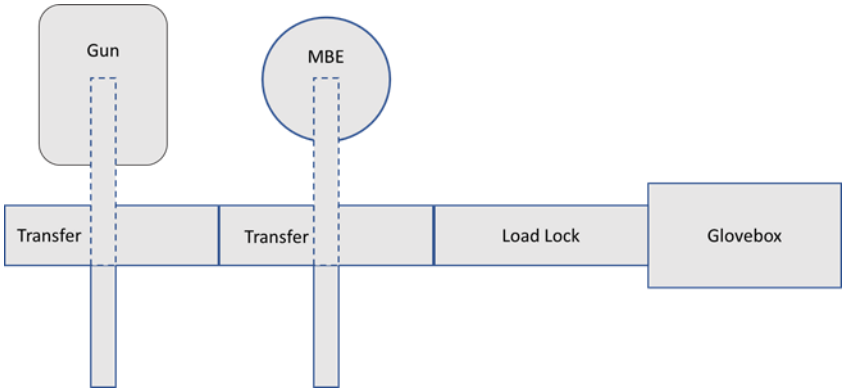
Photocathode preparation and automated transport

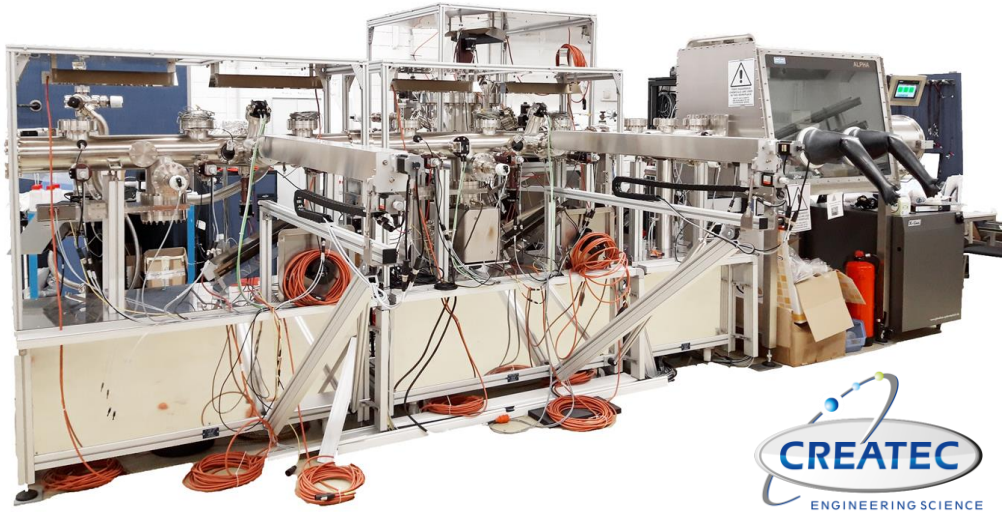
- Test recipes
- Reach **QE ≈ 4-7%**
- Lifetime tests (shelf/operation)

350 kV
40 mA
1.3 GHz CW
< $5x10^{-10}$ mbar
24h beam operation

Photocathode Transport and Preparation

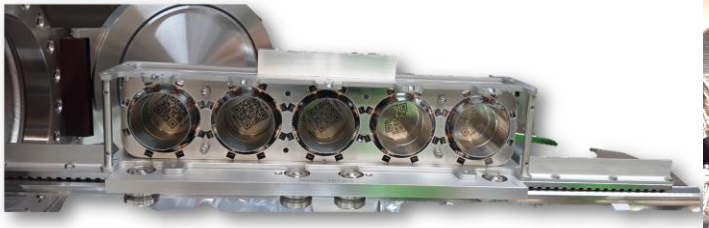
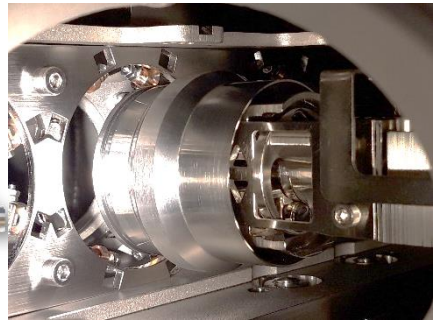
- Glovebox, Load Lock, MBE chamber, 2x Transfermodul, gun chamber
- All puck/PC transfers automated
- Trolley for 5 pucks (size 2”)
- MBE chamber with thermal effusion cells

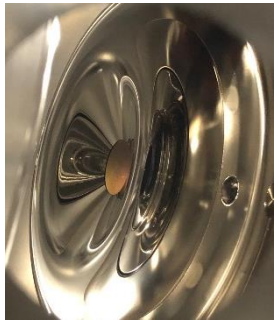




Cathode transfer

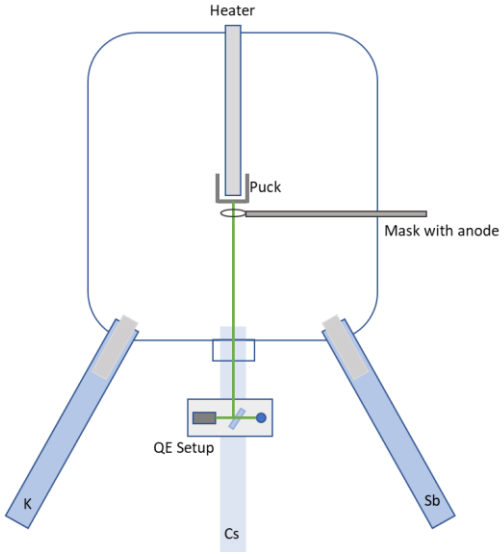
- Glovebox and load lock for dust, oxygen and water “free” insertion of fresh pucks
- Rail system in linear transfer line
- Motorized transfer rods for grabbing pucks and transfer into MBE and gun chamber
- QR code scanner for puck identification

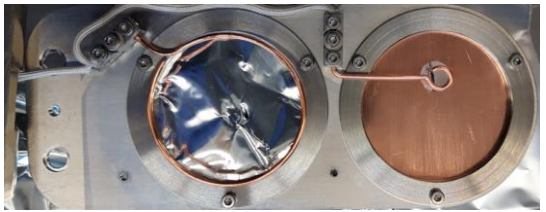





MBE chamber

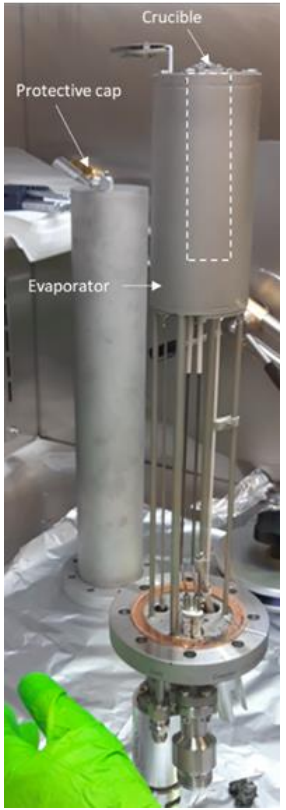
- Pressure < $5x10^{-10}$ mbar
- Automated transfer from transfer tunnel into MBE
- Manipulator with cooling and two thermocouples for puck temperature
- Water cooled PBN heater for puck heating
- Two different masks with ring anodes
- Quartz micro balance
- QE-setup with green laser (520 nm)
- Three thermal evaporators (Sb, K, Cs)
  - Cracker Cell (41g Sb)
  - Low-Temp. Cell 1 (2g K + 39.8g In)
  - Low-Temp. Cell 2 (2.5g Cs + 47.5g In)





Effusion cells

- Filling inside of glovebox in Ar-atmosphere
- Use In-K and In-Cs alloy to reduce reactivity and increase evaporation temperatures of alkali metals
  - Safe transport through air
  - Bakeout at 175°C possible

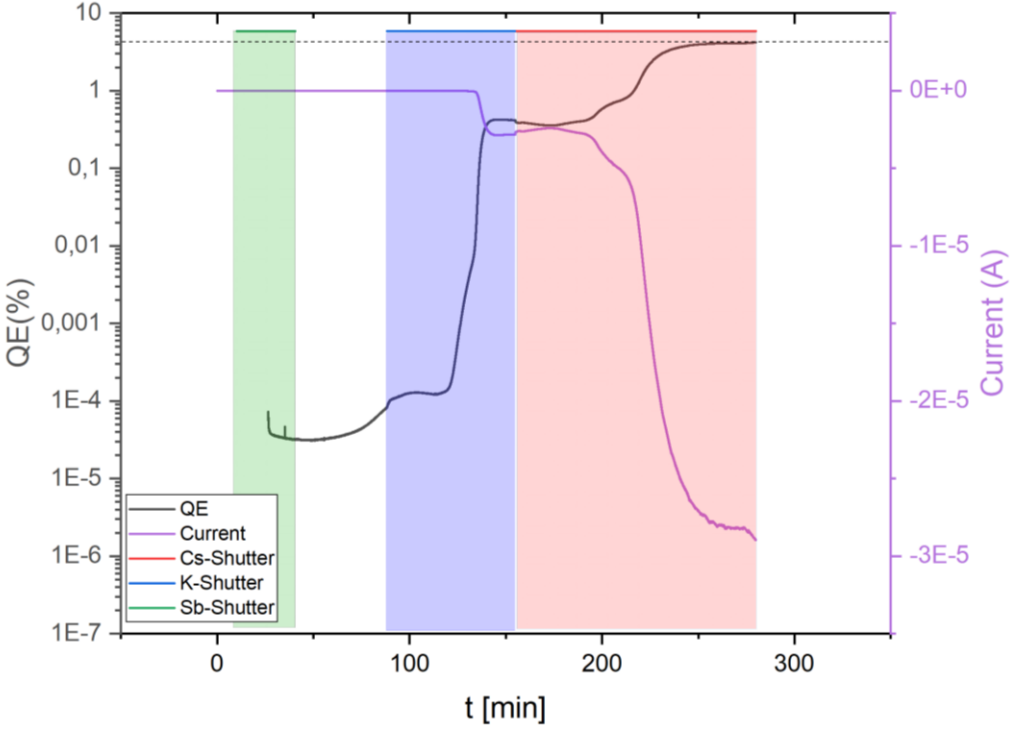


Recipe

1. Polish Mo or SS substrate to Ra< 5 nm
2. Puck heated to **500°C** for **8h**
3. Puck temperature is reduced to **100°C** and kept constant for the processes.
4. Heat up Sb to 520°C (EC)/ 670°C (HL)
5. Deposit **20 nm Sb** onto the puck.
6. Heat K evaporator to 300°C
7. Close shutter of K evaporator when a plateau in quantum efficiency (QE) is reached.
8. Heat up Cs evaporator to 305°C
9. Evaporate Cs until a plateau is reached in the QE
10. Stop heating the puck
11. Wait until a puck temperature of <75°C is reached
12. Close shutter of Cs-evaporator.
13. Cool the puck to room temperature.

Results

- First nine cathodes QE between 4 and 7% (routinely 4%)
- Recipe highly reproducible
- No measurable degradation during transfer in gun chamber
- First e^- beam in electron gun with 120 kV



Outlook

- Lifetime tests (shelf and operation)
- Test other recipes
- Beam operation with 350kV, 40 mA, cw for 23h

Acknowledgement

research instruments

Lighthouse Project

research instruments

Reactor based

Non-proliferation

Uranium target production

50 year old reactors

Reactor irradiation

Nuclear waste

Uranium target processing

running out of operation

Superconducting e- Accelerator based

Not radio-active

^{100}Mo target production

Innovative accelerator

Accelerator irradiation

Negligible waste

^{99}Mo processing

^{99}Mo → ^{99m}Tc (66 hrs)

Generator

^{99m}Tc → 141 keV (6 hrs)

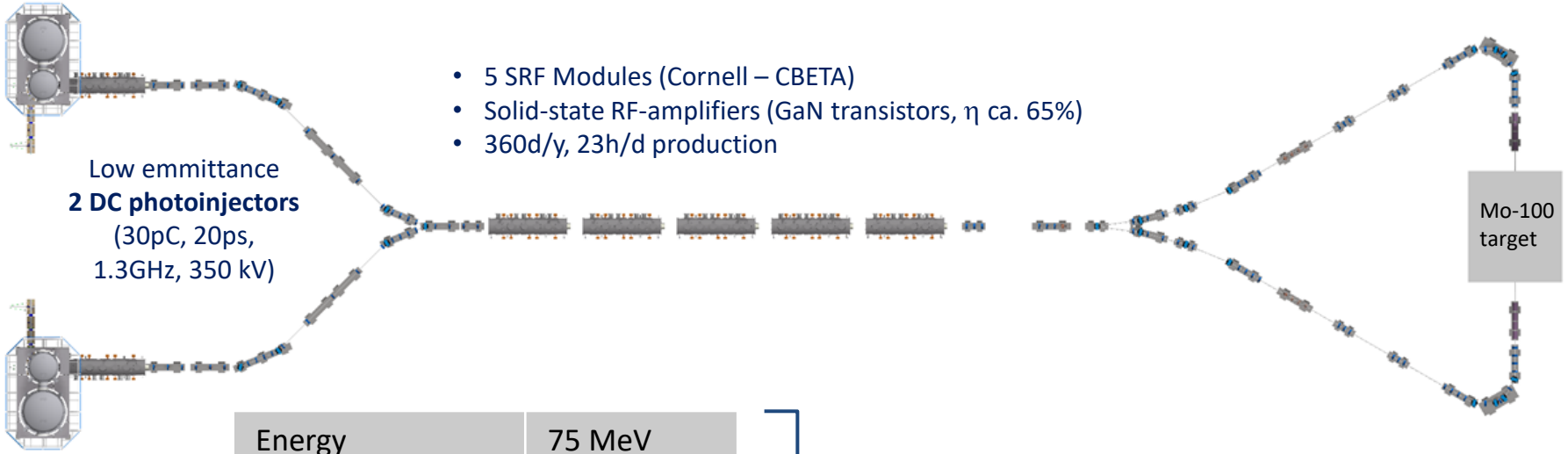
Radio-Pharmacy / Hospital

SPECT scan

High levels of ^{99m}Tc in pelvis and axilla (red) showing areas of cutaneous T-cell lymphoma.

~ 60 million procedures world wide p.a.

Lighthouse Project



- 5 SRF Modules (Cornell – CBETA)
- Solid-state RF-amplifiers (GaN transistors, η ca. 65%)
- 360d/y, 23h/d production

Energy	75 MeV
Current	40 mA
Bunch Frequency	1.3 GHz CW
Beam Power	3 MW

On target