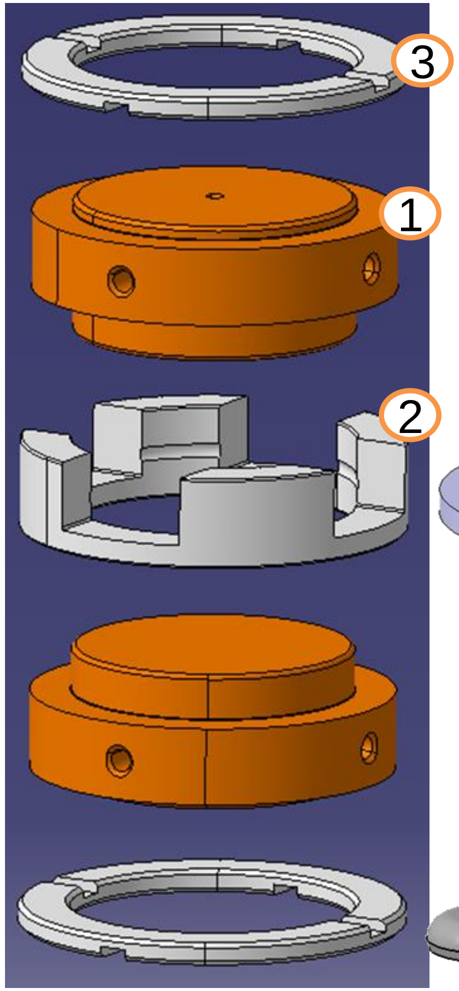
CERN

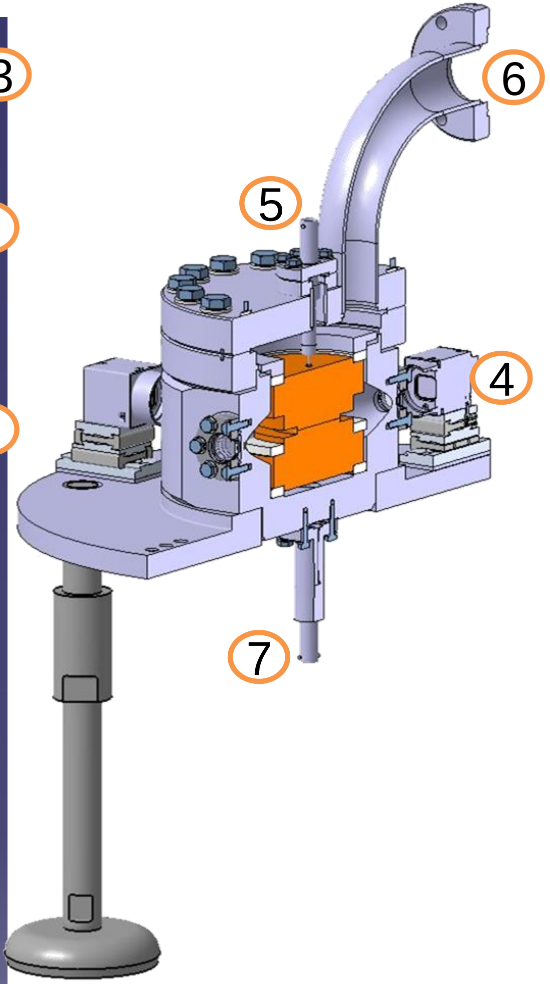
Breakdown testing: benefits CLIC <-> other projects

Sergio Calatroni

Pulsed DC Large Electrode System Chamber

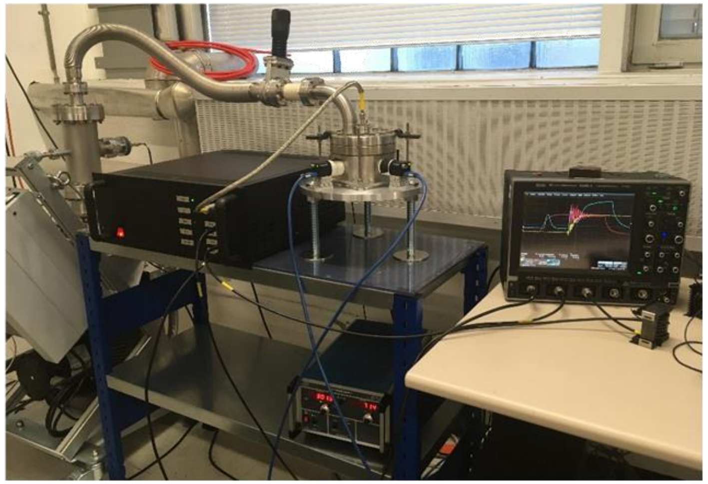
- Configuration
  1. 2 high precision machined electrodes (1µm tolerances)
  2. High tolerance ceramic spacer between electrodes providing a gap of 20µm, 40µm, 60µm, or 100µm
  3. Ceramic spacers to isolate electrodes from the chamber
  4. 4 Windows and 2 perpendicular cameras
  5. High voltage feed though
  6. Vacuum pump output (5x10^-9)
  7. Connection from the bottom electrode to ground (outside of system)





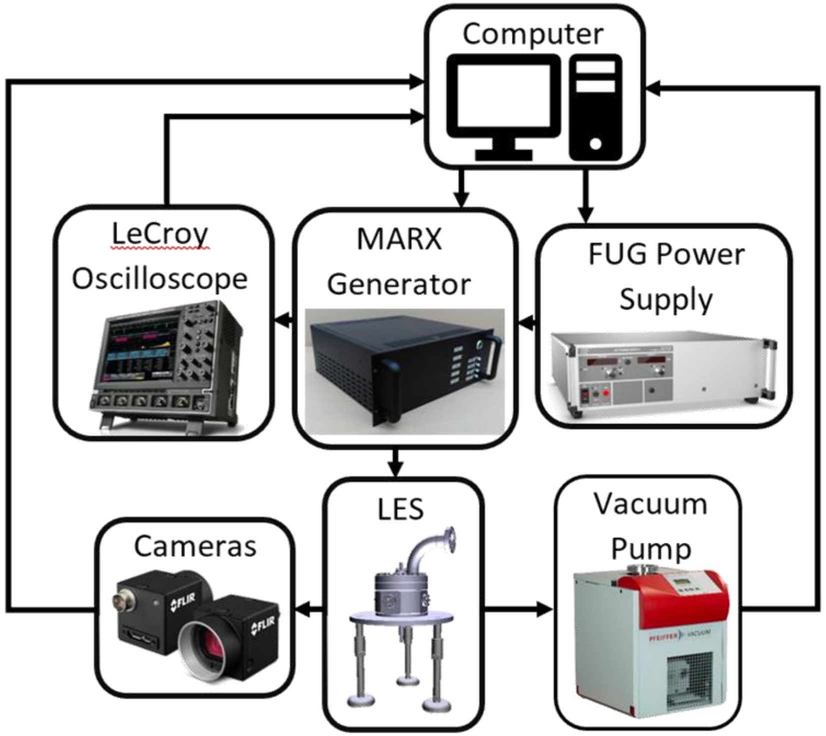
Iaroslava Profatilova, Ruth Peacock

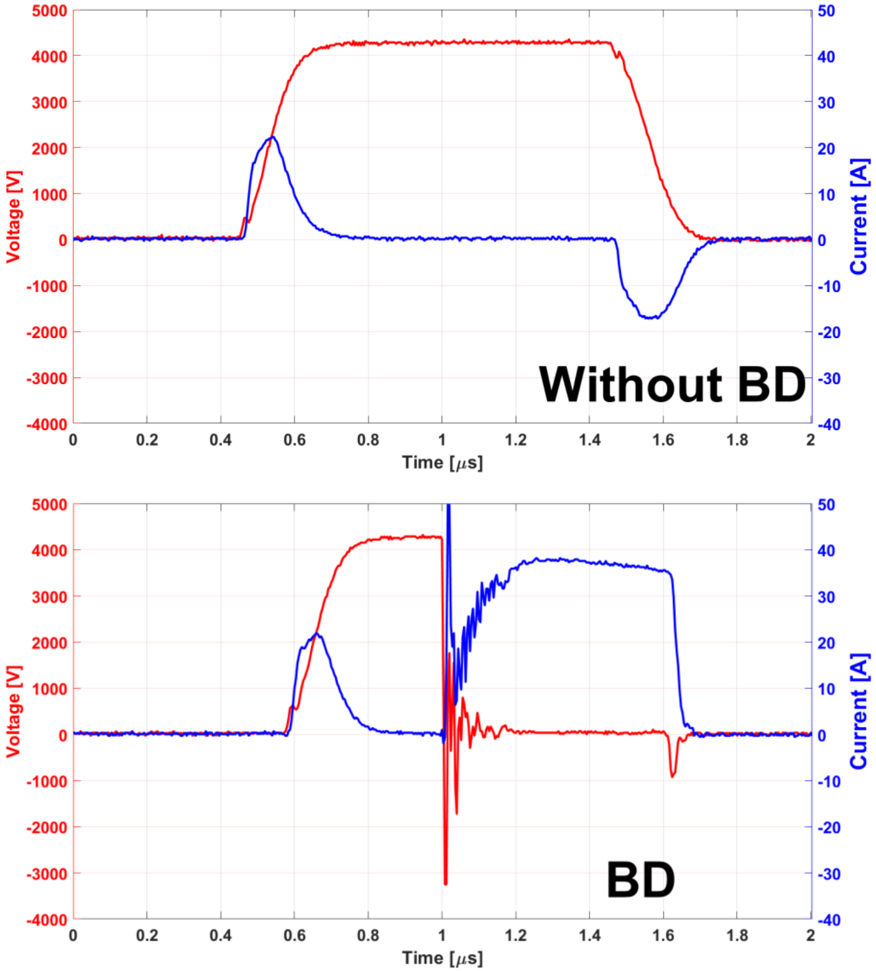
Pulsed DC Large Electrode System Setup



Camera 1

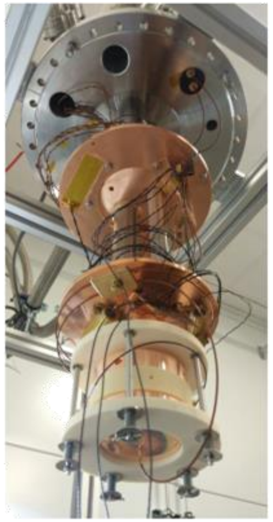
Camera 2

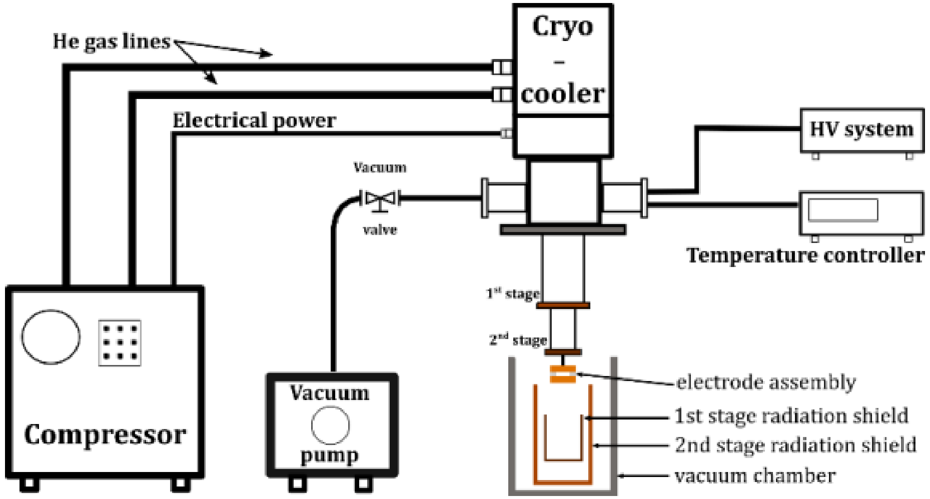


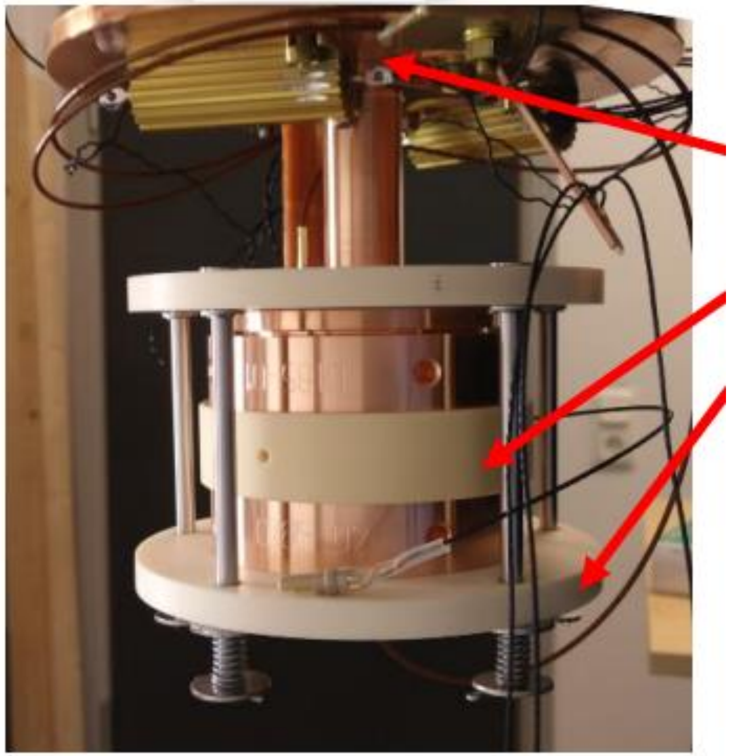


Iaroslava Profatilova, Ruth Peacock

Cryogenic system at Uppsala



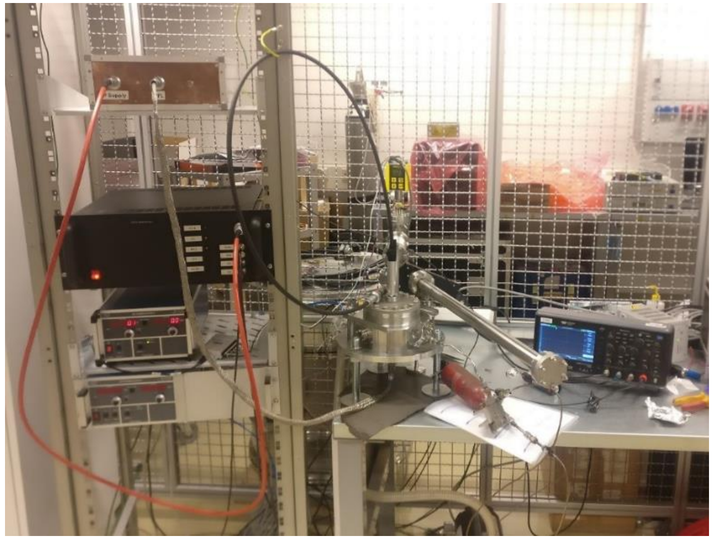


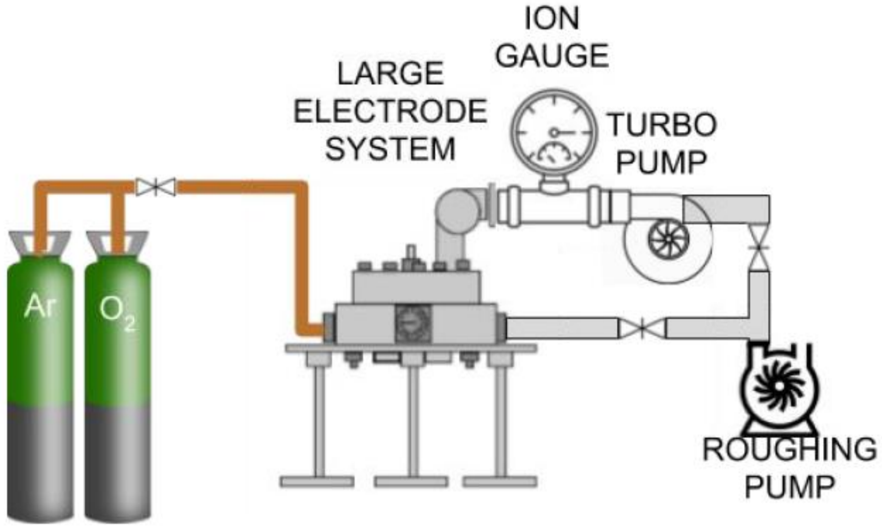


Marek Jacewicz

Room temperature system at Helsinki

- Original motivation was to study dynamic vacuum by optical absorption
- At present: studies of plasma surface cleaning
- Strong collaboration for Molecular Dynamics simulations, plasma simulations, and for materials under extreme environment
- Strong collaboration with Jerusalem University, Tartu University for material analyses, simulations of surface behaviour





Comparison of heat-treated and as-machined copper

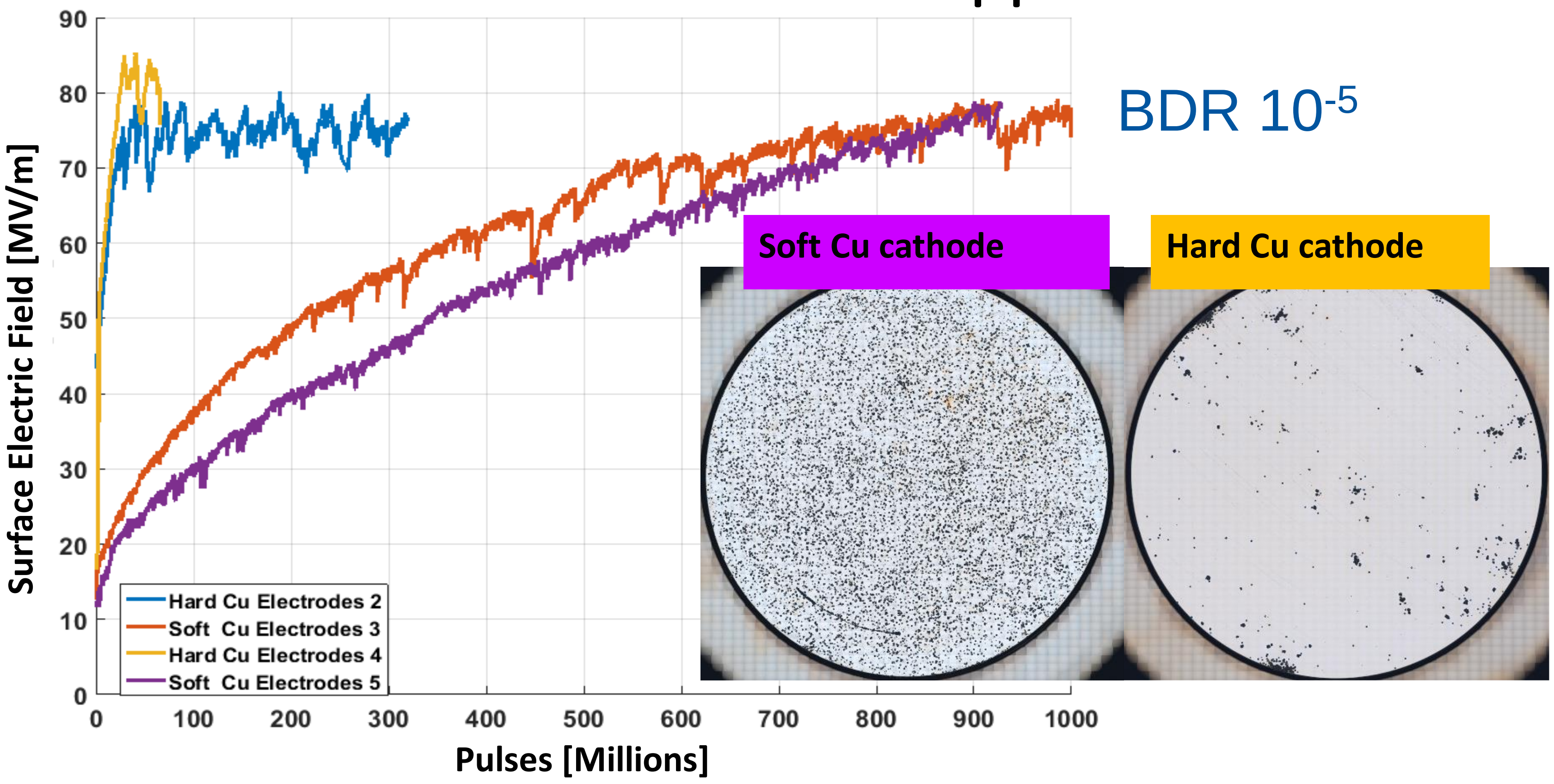
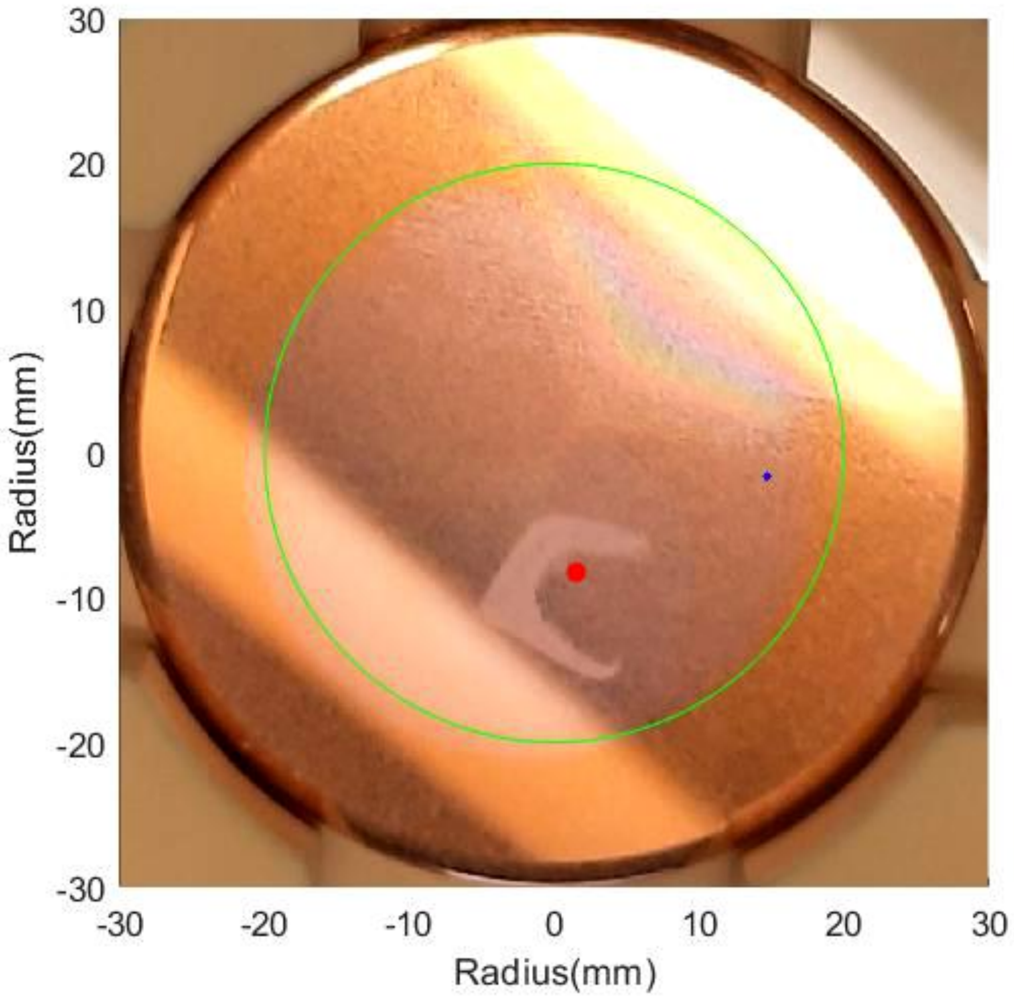
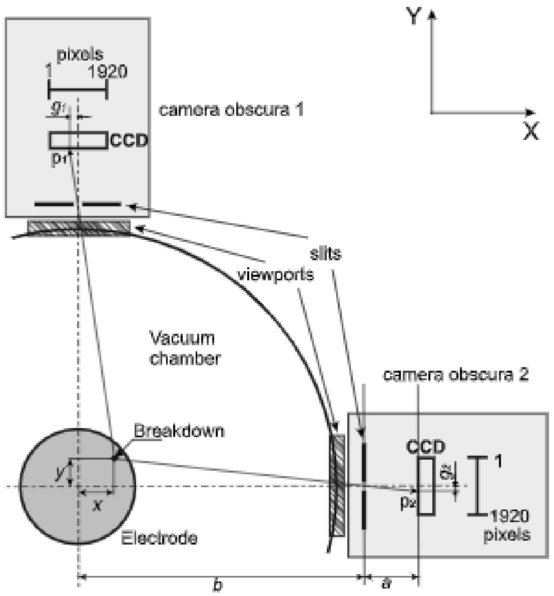
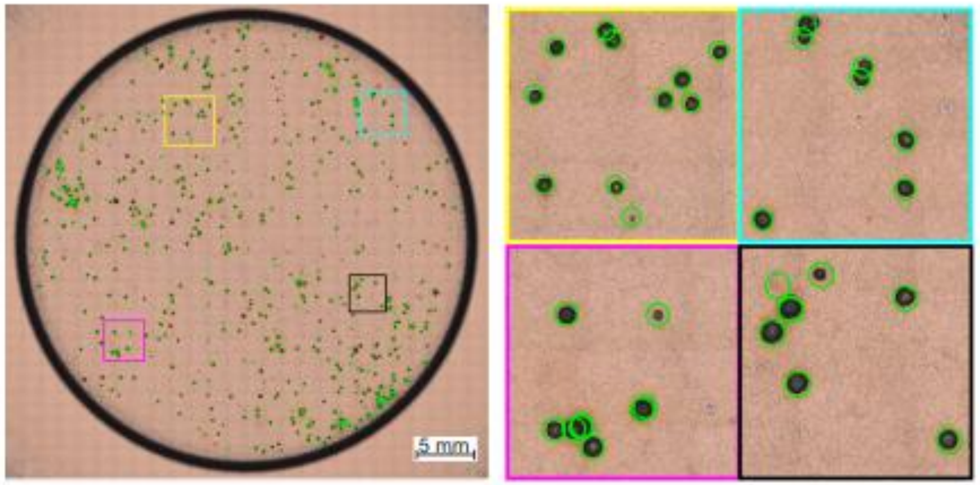


Fig. 5. Conditioning curves from tests at Pulsed DC System taken with HRR circuit, 16.7 µs pulse lengths and 60 µm gap distances.

First tests with LES on irradiated electrode







Ruth Peacock

MeVArc workshops

9th International Workshop on Mechanisms of Vacuum Arcs (MeVArc 2021)

8-12 March 2021
Online
Europe/Zurich timezone

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- Overview
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- Key Dates
- Topics
- Timetable
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- Instruction for oral and poster presentation
- Videoconference Rooms
- Registration
- Participant List

MeVArc 2021 contact

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- flyura.djurabekova@hel...
- marek.jacewicz@physic...
- anton.saressalo@helsin...

Overview

Vacuum arcs are a concern in nearly every vacuum device under electric field; consequently they are present in a very wide range of applications. Sometimes vacuum arcs form the basis for device operation, but all too often they are the primary failure mode.

Understanding the physical processes of a vacuum arc requires expertise from many disciplines – material science, surface physics, and plasma physics. Applications include high-voltage electronics, RF accelerators, electrostatic accelerators and vacuum interrupters. The purpose of this workshop series is to bring together scientists and engineers from many different disciplines and application areas to discuss the latest efforts in understanding vacuum arcs. We cover theory, simulation and experiments.

This year, due to the COVID-19 pandemic, the workshop will be held remotely. The workshop will last 5 days, with a 3-4h session each day, in order to cover all time zones. There will be no participation fee.

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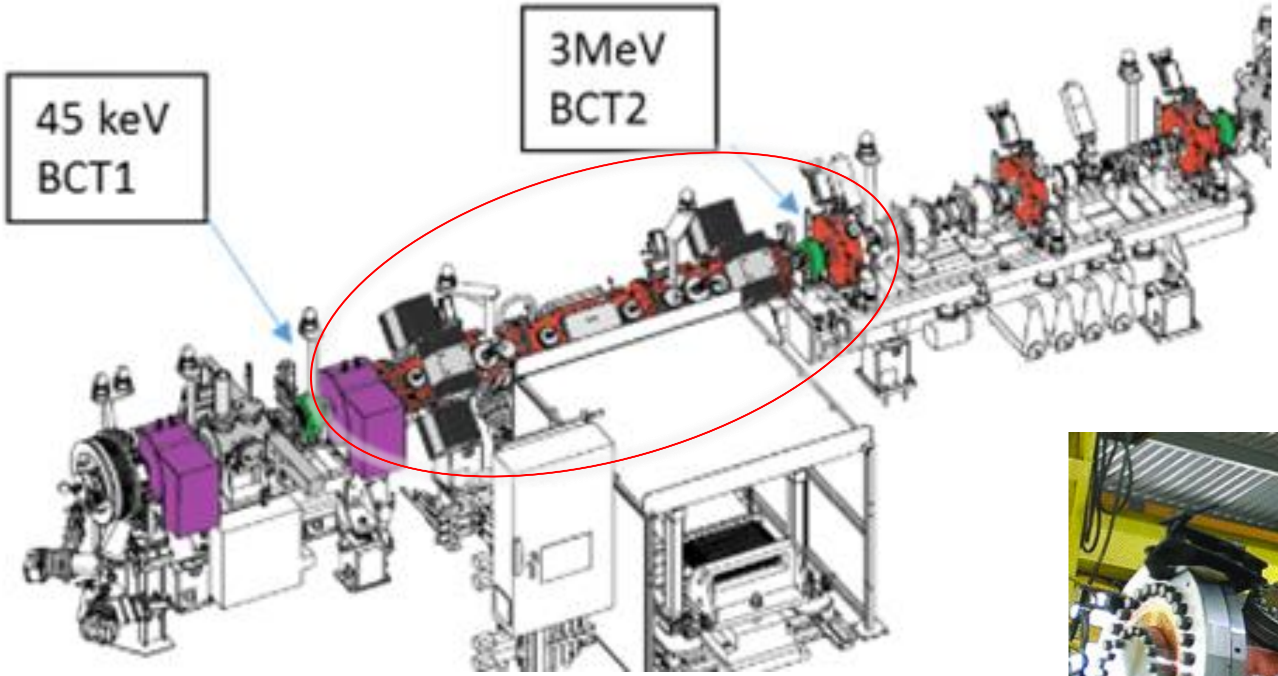
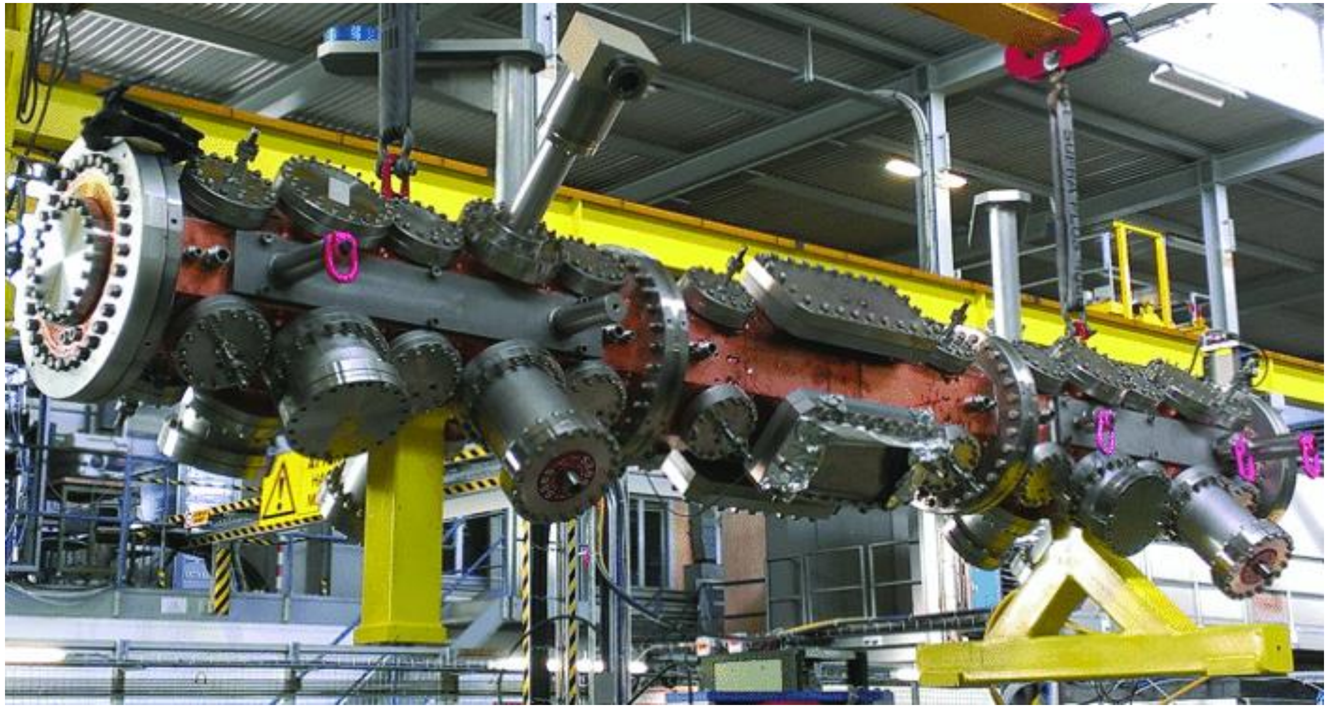
Link

The RFQ of LINAC4



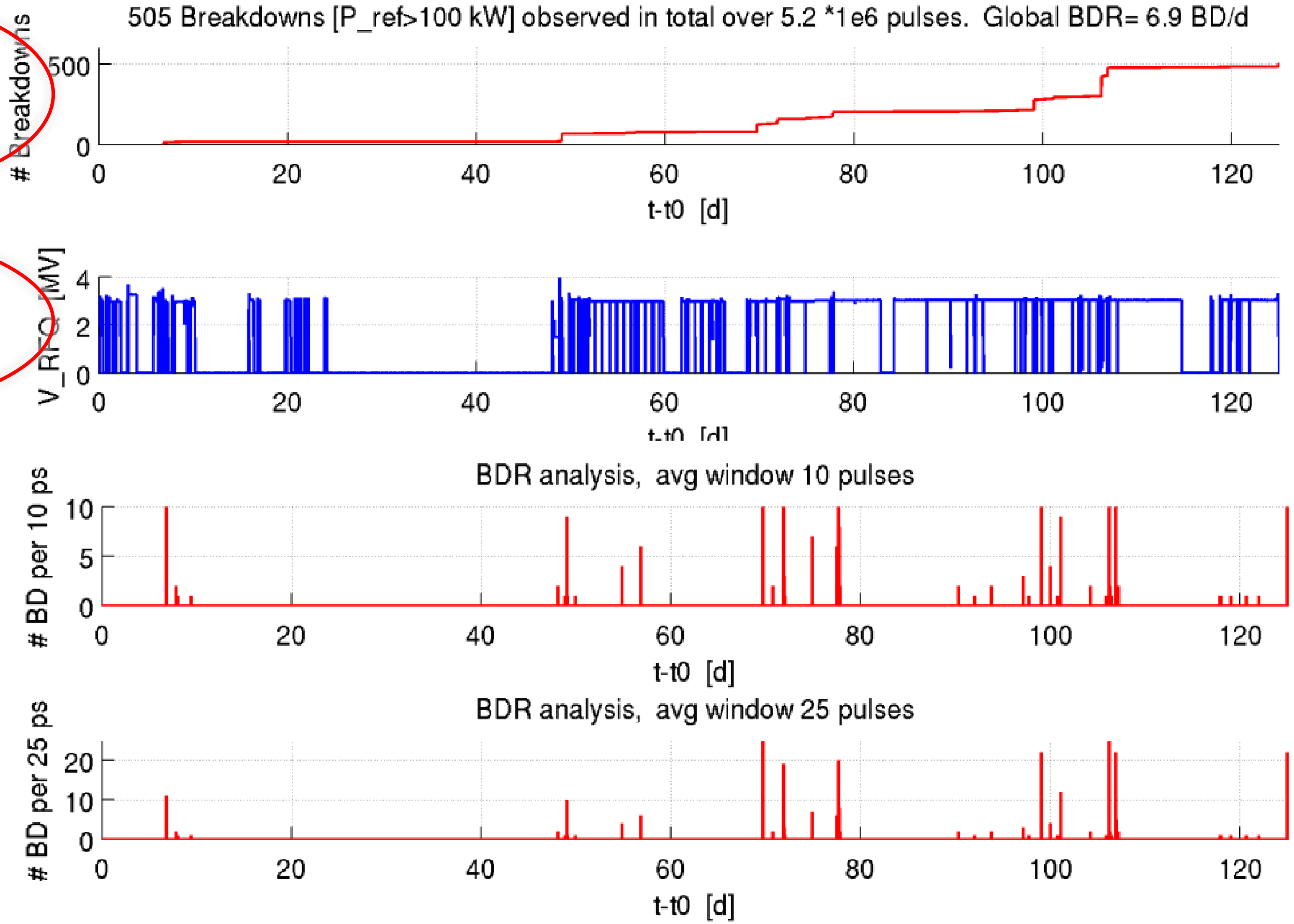


Breakdown rate (BDR) in RFQ

BDR: ~10^{-4}

Surface field: ~35 MV/m

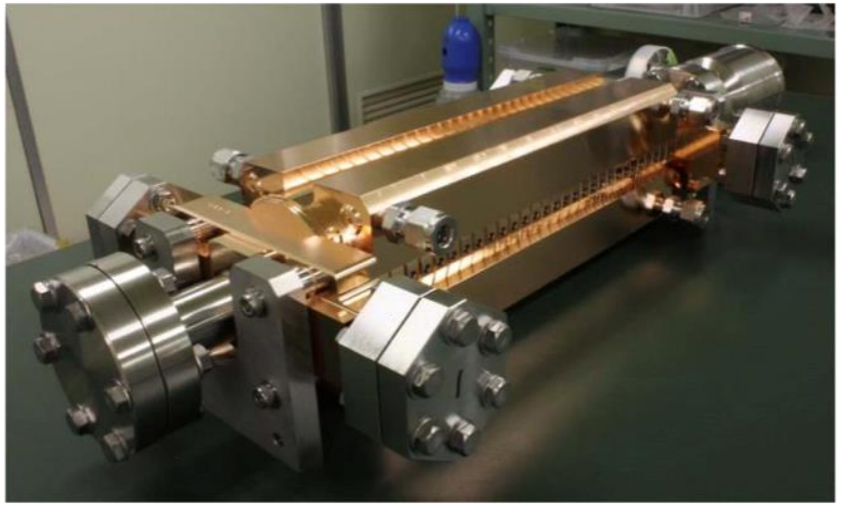
RF pulse 1 ms
Rep rate 1 Hz

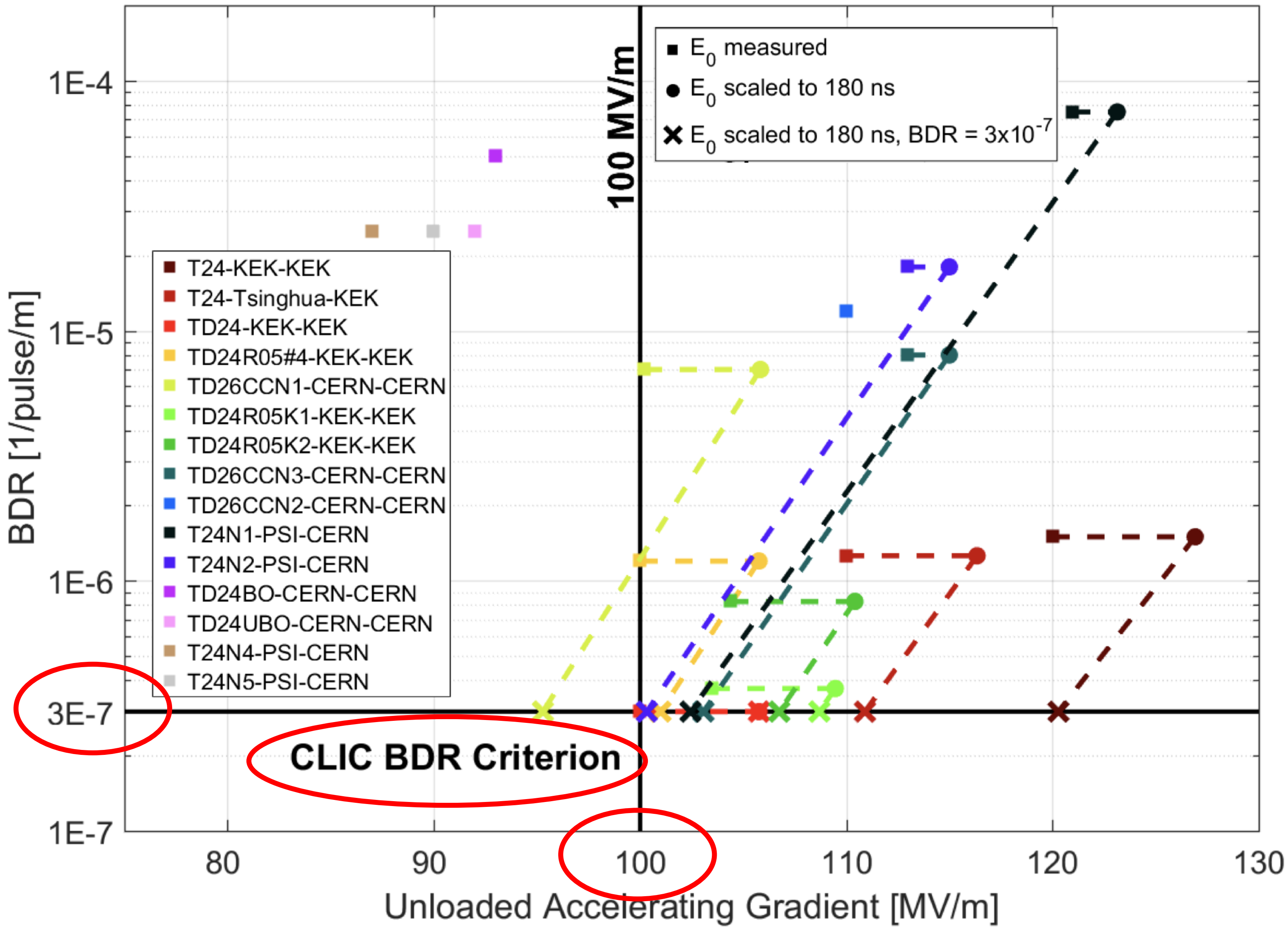


Rolf Wegner

BDR in CLIC accelerating structures, a comparison

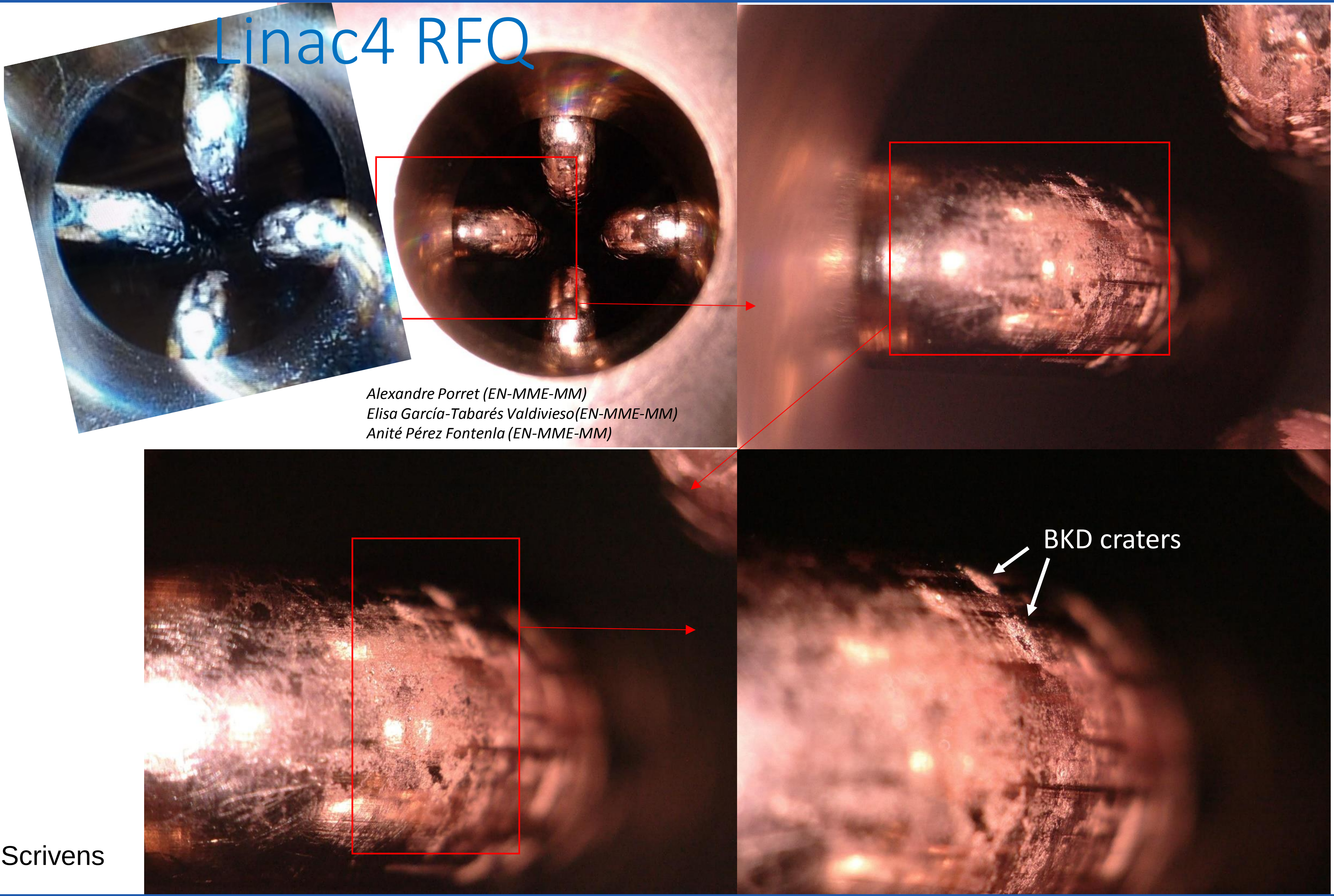
RF pulse 230 ns
Rep rate 50 Hz





W. Wuensch, S. Stapnes

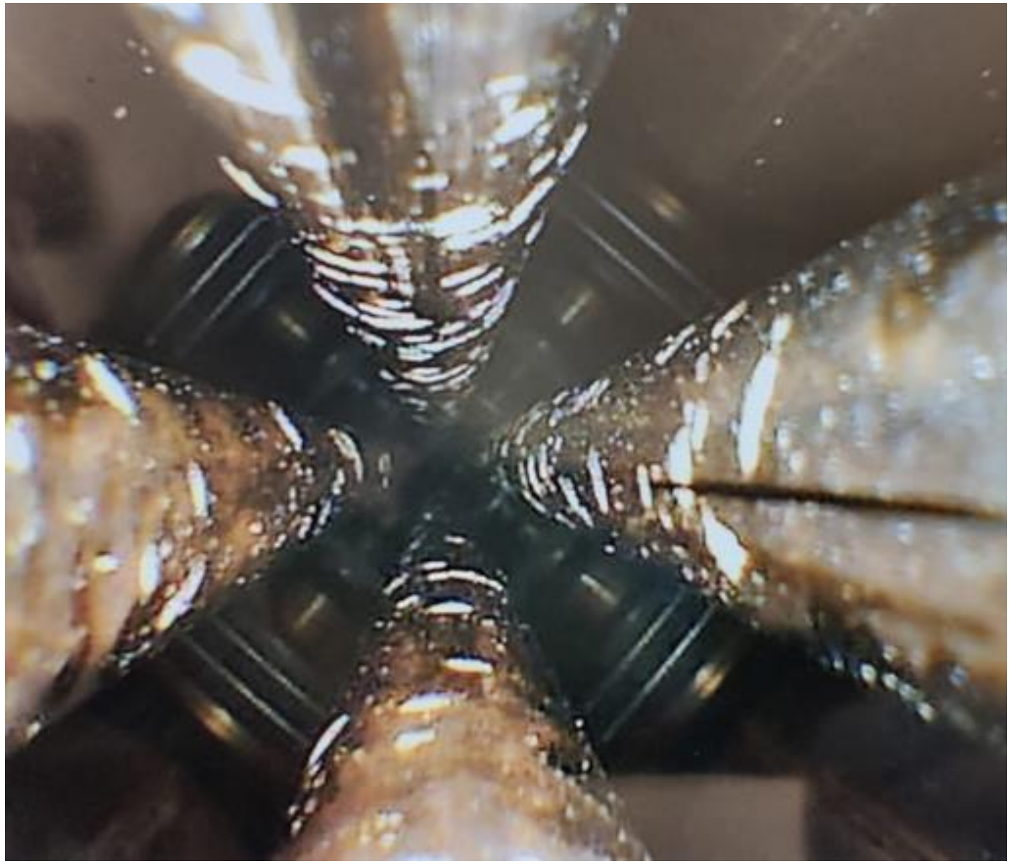
Entrance of RFQ



Alexandre Porret (EN-MME-MM)
Elisa García-Tabarés Valdivieso(EN-MME-MM)
Anité Pérez Fontenla (EN-MME-MM)
Nicolas Thuas (TE-VSC) plus TE-MSC and EN-HE

Richard Scrivens

Downstream

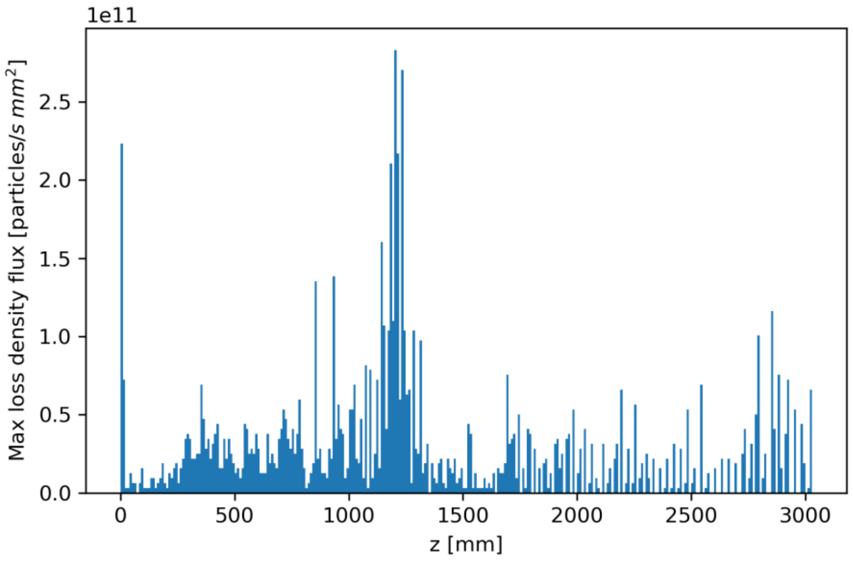


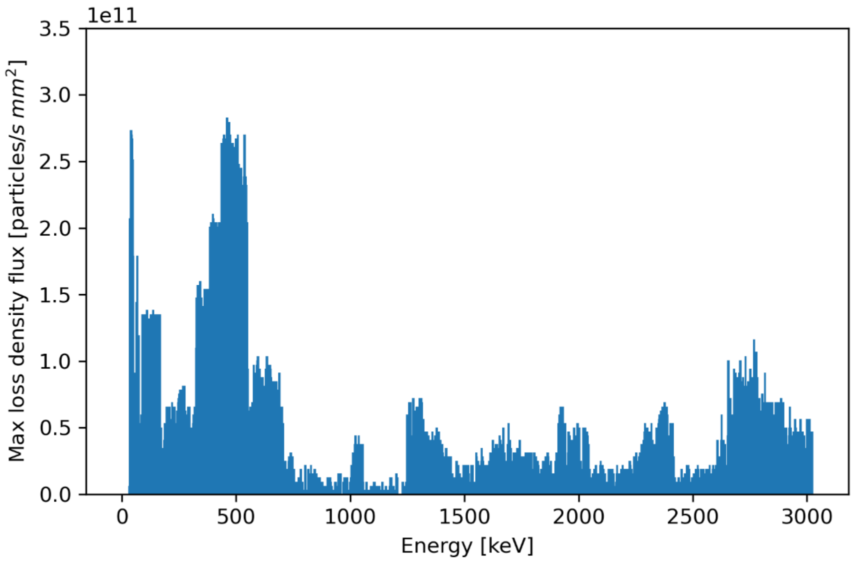
- Need to understand origin of enhanced breakdown rate, and find a mitigation

- Could breakdowns be correlated with beam losses ?

Density calculations per second

The maximum value of particles/mm2*s and the resulting power loss can be calculated along the RFQ

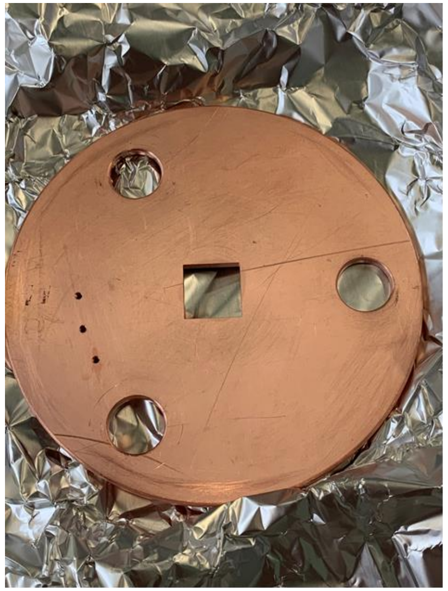


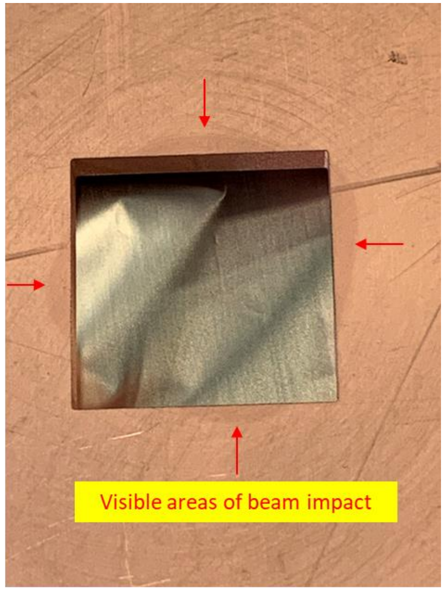


Assuming that this picture doesn't evolve in time, in one year (100 days) of RFQ operation the maximum dose locally deposited would be:

~2E11 p/s/mm^2 x 1E7s = 2E18p/mm^2

Preliminary test: collimator irradiation





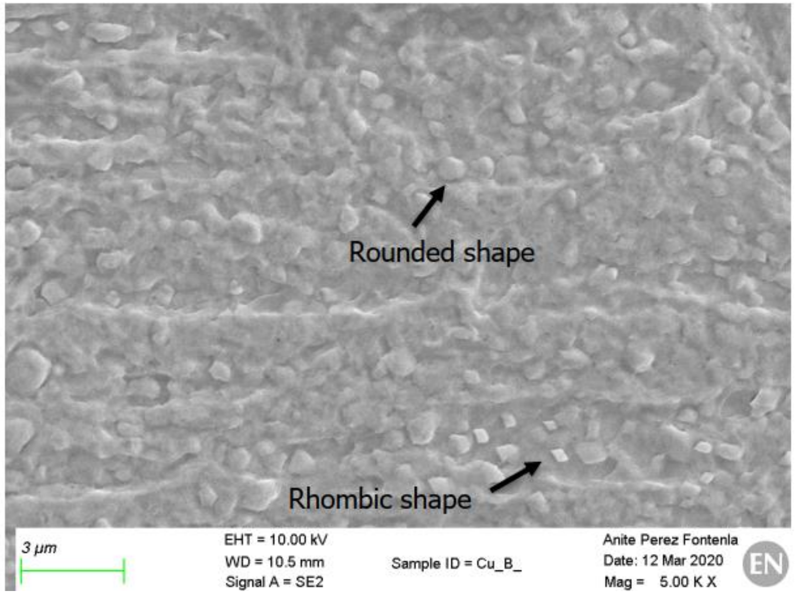
Evidence for blistering on copper upon H^- irradiation at 45 keV (penetration 300 nm)

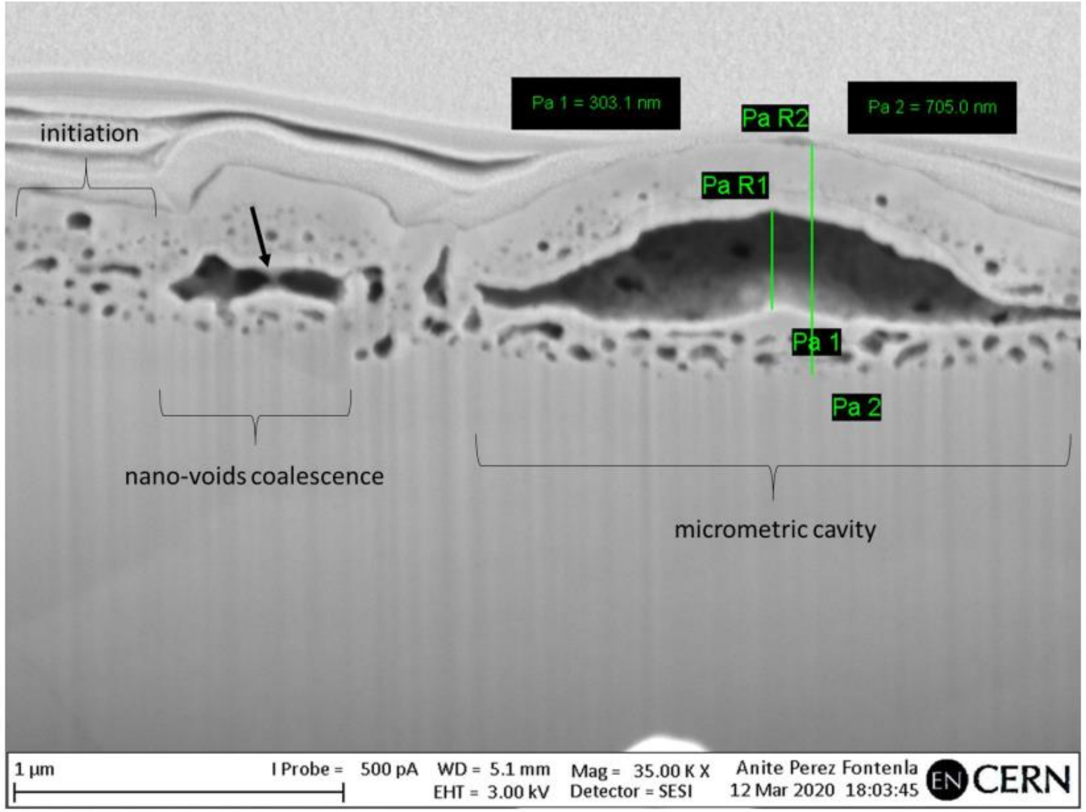
Preliminary tests at LINAC4 test source (collimator 1) and confirmed in literature

Edgar Mahner,
Anité Perez Fontenla

3 mm thick Cu-OFE
Aperture 15 x 15 mm^2

Beam time≈ 12 days
E= 45 keV H^-
I≈ 35 mA
Ions Impacting Total= 1.7 $x10^{19}$
Dose: ~$7x10^{18}$ H^-/cm^2





Project work plan (highlights)

- Design a new RFQ (RFQ3) with better expected performance in terms of beam acceptance and breakdown resistance and beam loss resilience than the present L4-RFQ.

- Hypothesis: blistering from beam losses as triggers for breakdowns

  - Finding a new material for RFQ fabrication with better performance than annealed OFE-Cu in terms of high electric field strength and beam loss resilience
  - Design of an RFQ based on a new material (if found) with higher surface E-field limit and/or high acceptable beam loss limit

Synergies with CLIC

- Leverage expertise developed within CLIC high gradient studies
  - Study Cu and new materials with LES system, to measure BDR as a function of H irradiation
  - Material analyses with SEM and FIB on LES electrodes and other irradiated samples.
- Benefit from know-how developed on conditioning of RF structures (Xboxes, etc.)
  - Note, RFQ has different conditions: 1 ms pulse, 1 Hz rep rate, 35 MV/m surface field
- Leverage collaboration with Helsinki University
  - Material irradiation with ion implanter (500 keV) and Tandem (5 MeV)
  - Expertise of materials for nuclear fusion
  - Simulation of H bubbles formation and coalescence

How to limit hydrogen bubble formation

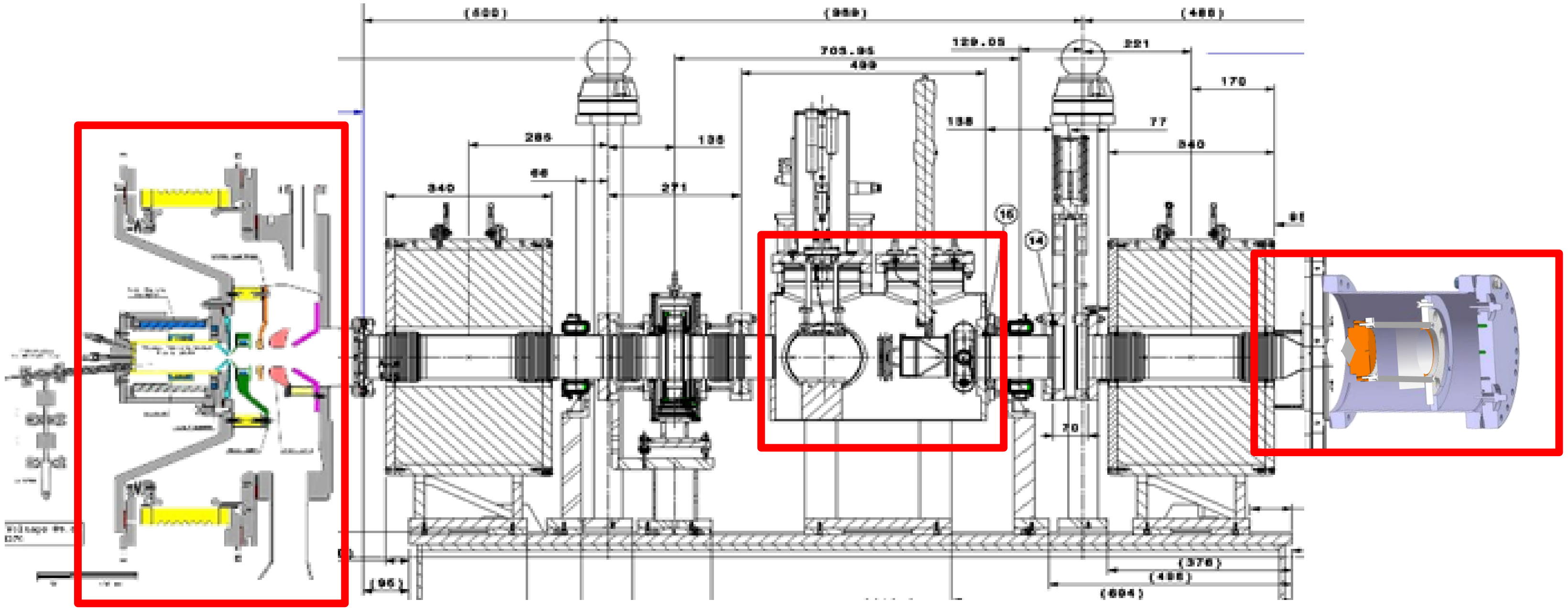
- Criteria for material choice I:
  - Hydrogen solution must be energetically favorable
  - Hydrogen must have high diffusivity at room temperature
  - Hydrogen solubility limit must be high

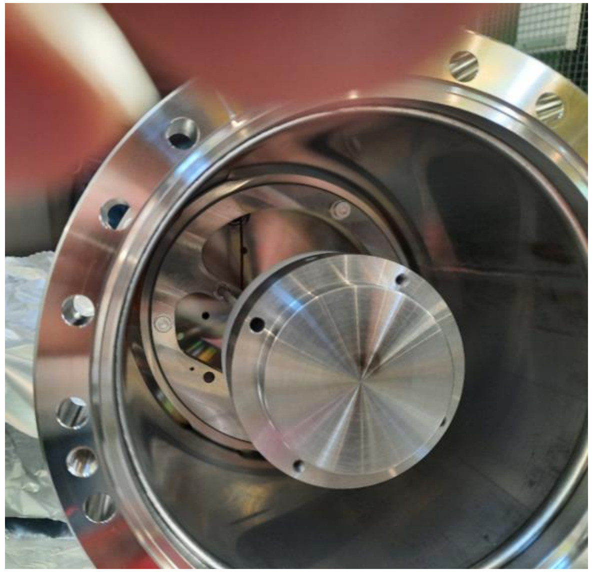
- Criteria for material choice II:
  - Material strength larger than copper
  - Reduced dislocation movement
  - Presence of trapping centers for hydrogen to prevent coalescence

- This is a problem of hydrogen in metals: VSC core business

- Selected material candidates:
  - Cu-OFE, CuCr1Zr, CuBe, Nb, β-Ti6Al4V, Ta
  - (electrical conductivity is not a primary concern for RFQ vanes)

Irradiation setup – LINAC4 source test stand





H^- Source 45 keV

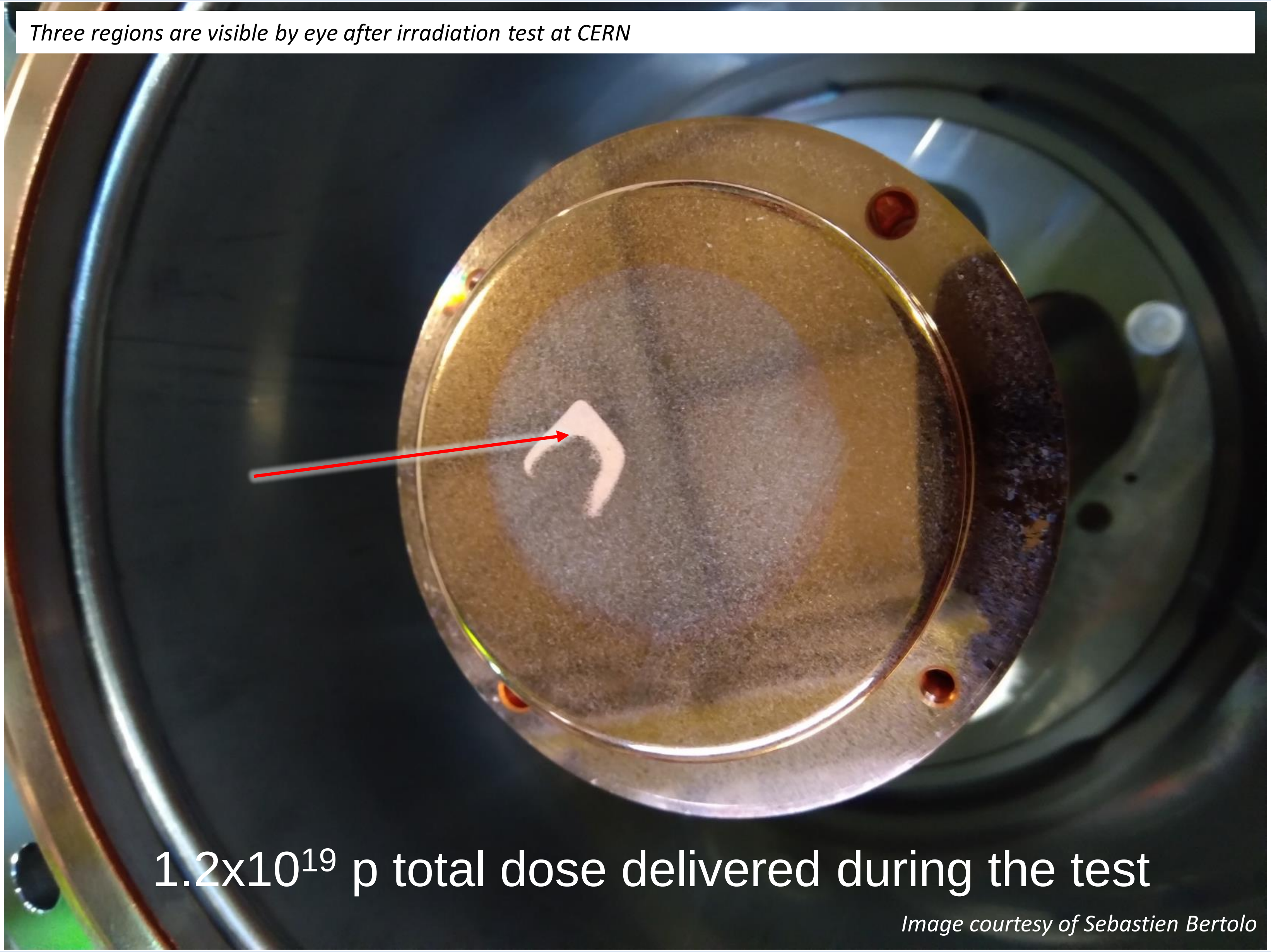
Low-energy beam transport

2 Steerers, 2 Solenoids

Sample holder

Alessandra Lonbardi

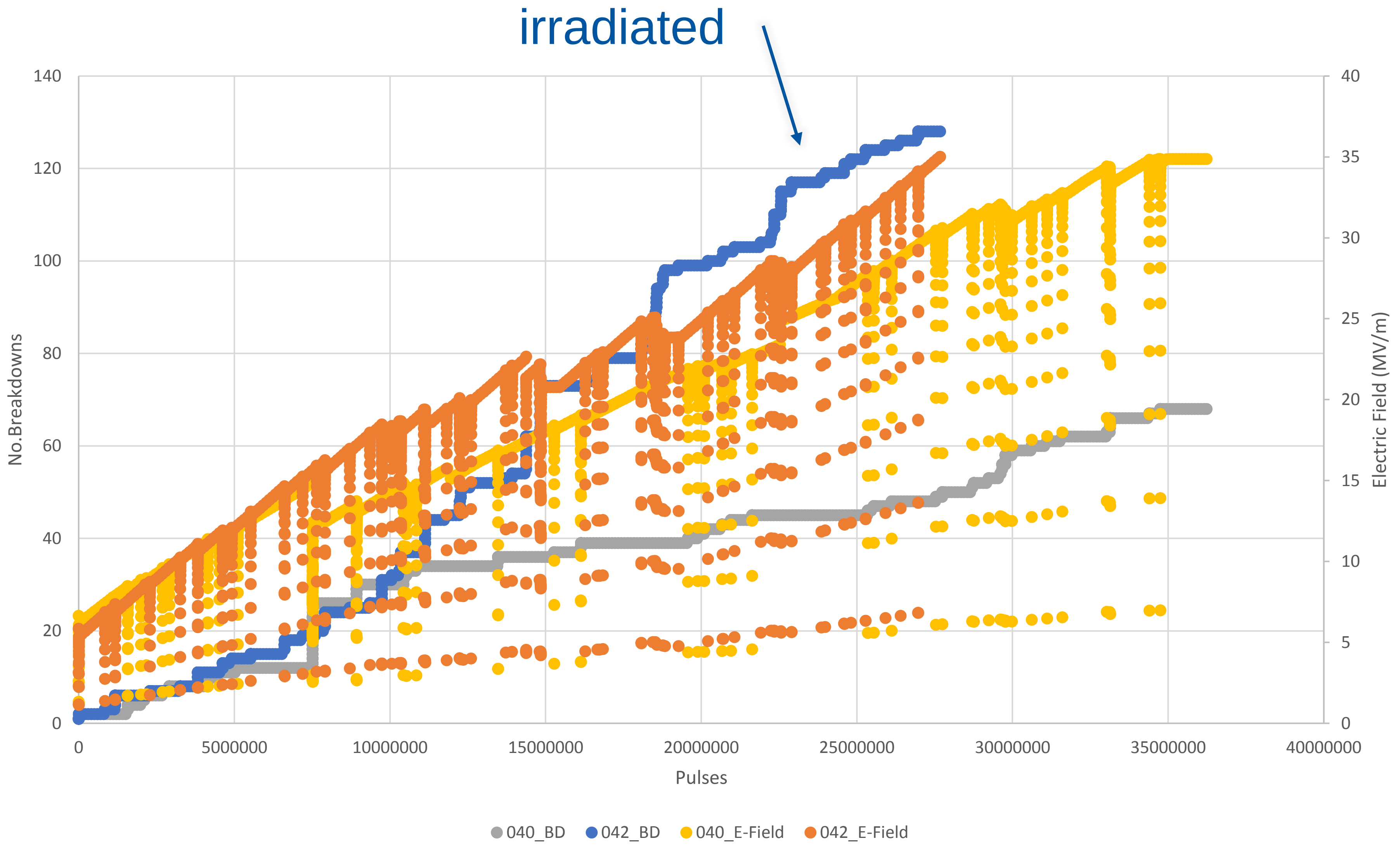
First irradiated sample – LINAC 4 source at 45 keV



Nb sample
CuCrZr sample

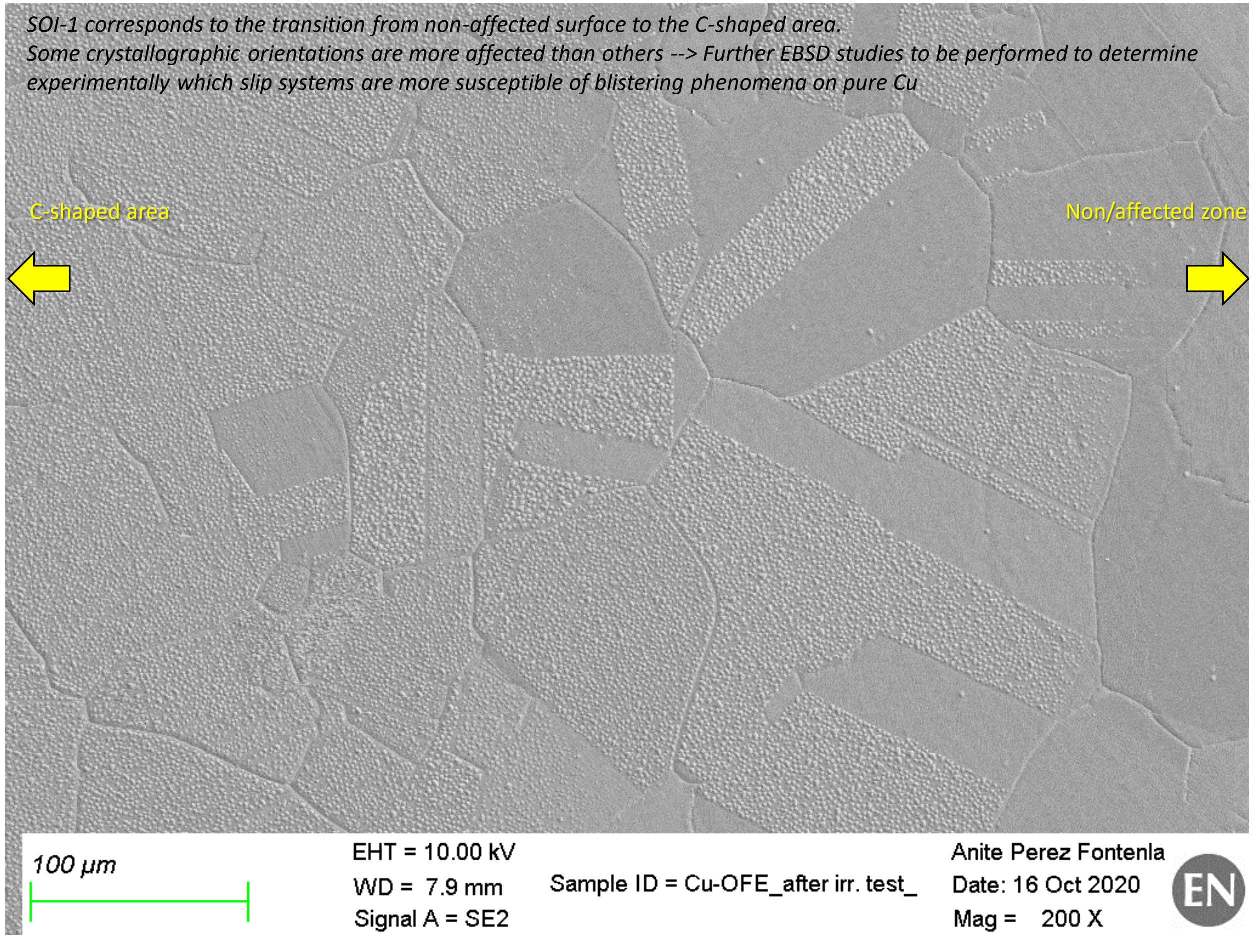
Also irradiated in the last weeks

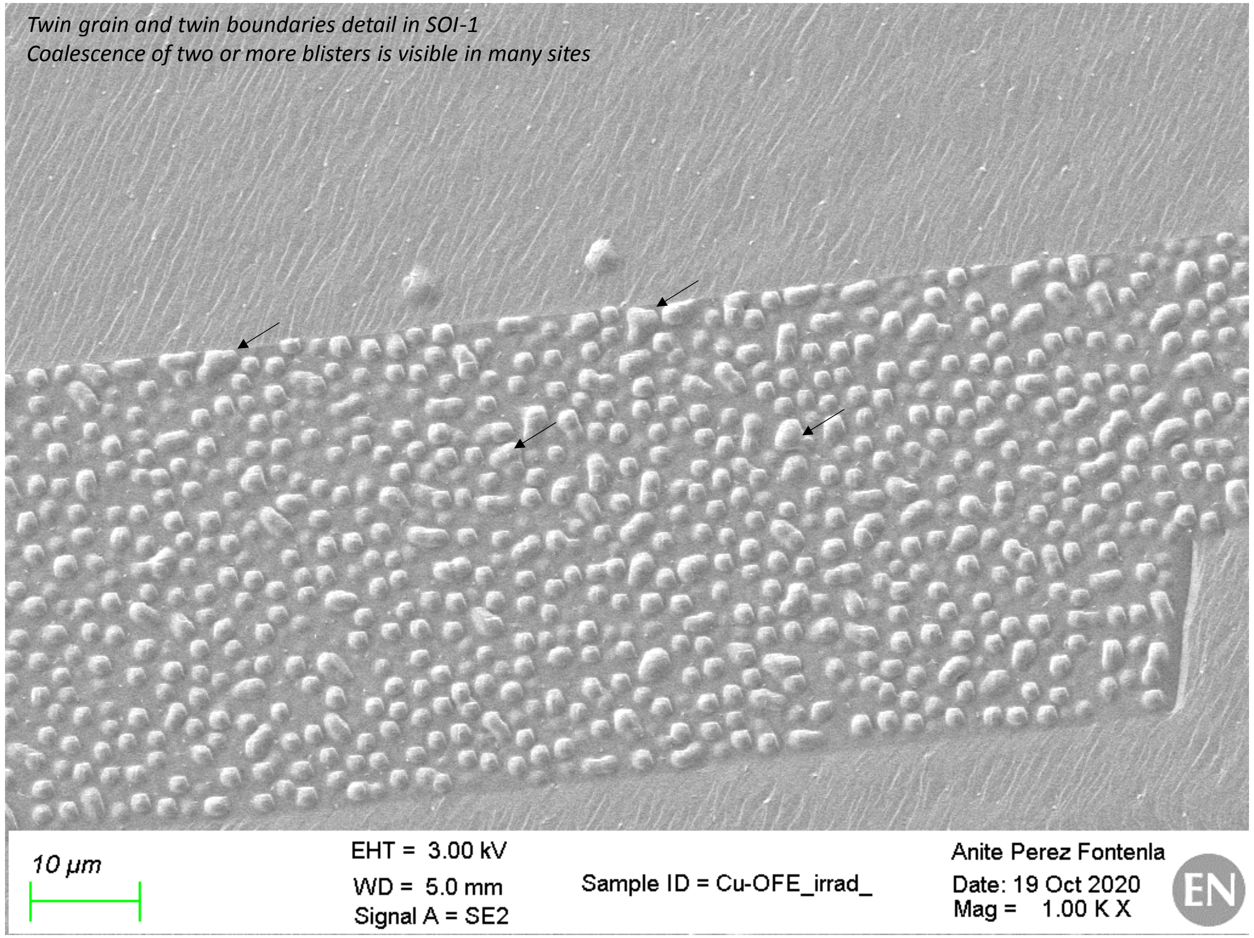
Comparison of first conditioning: copper after brazing cycle



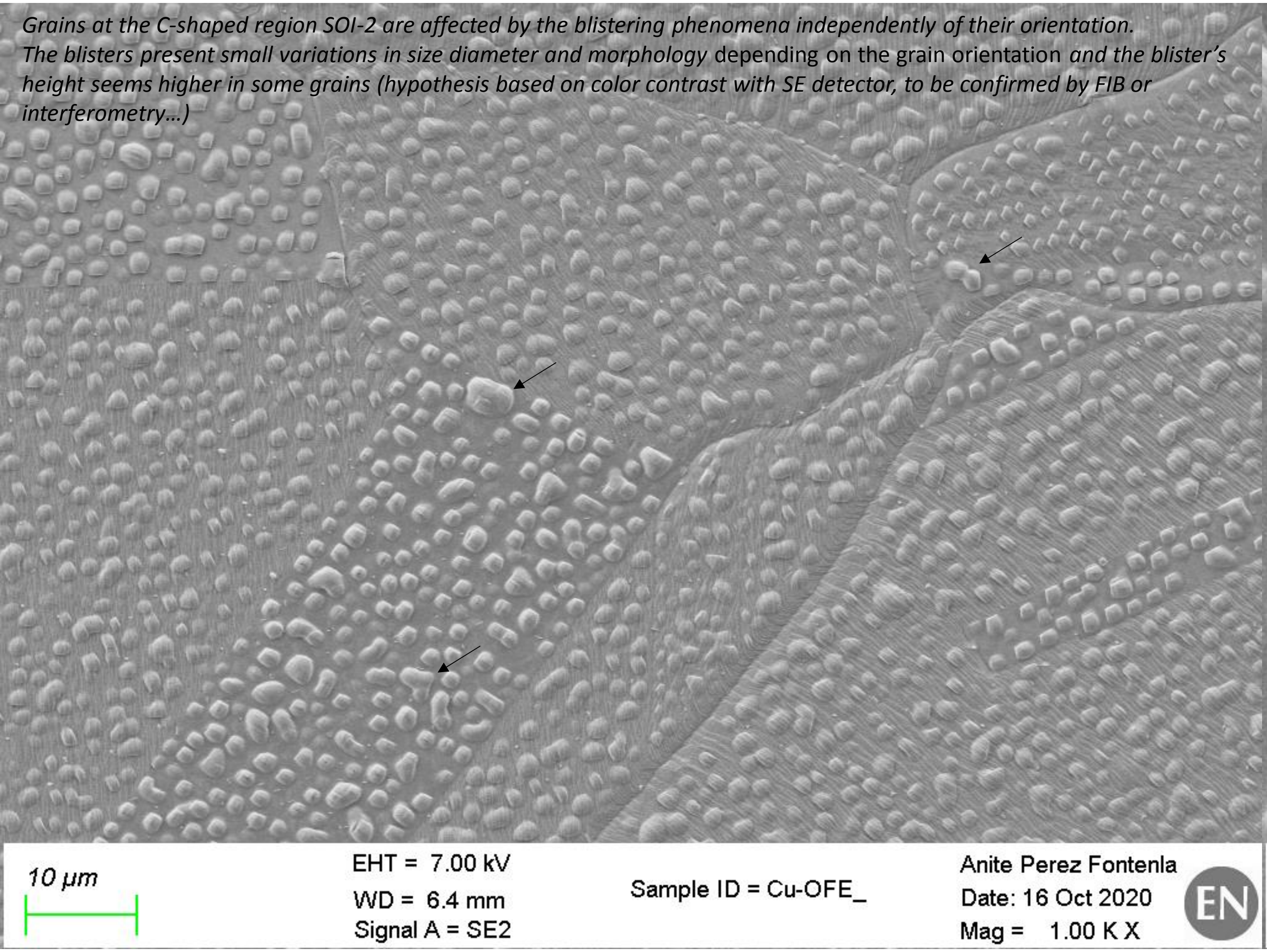
Ruth Peacock

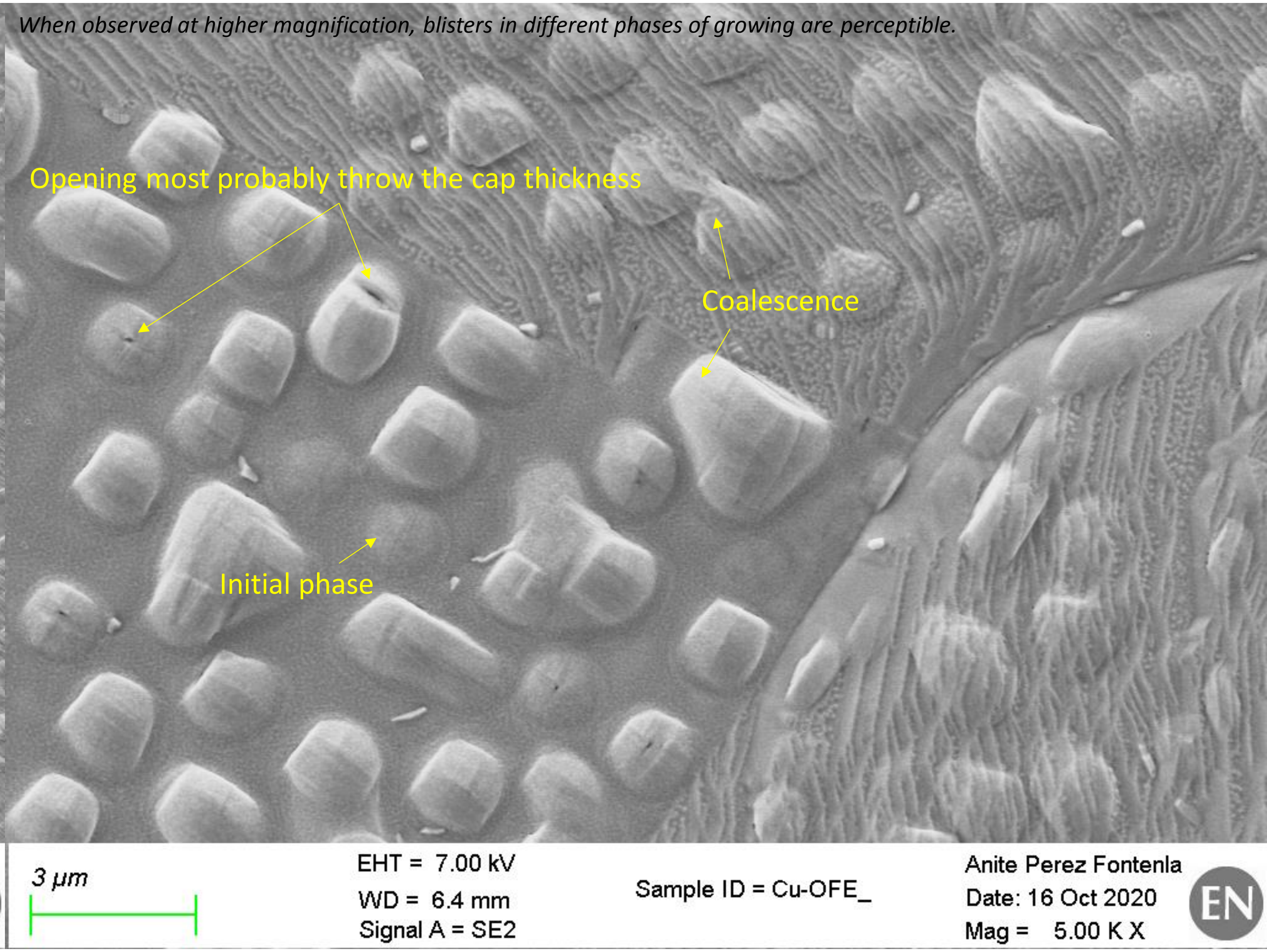
SEM results





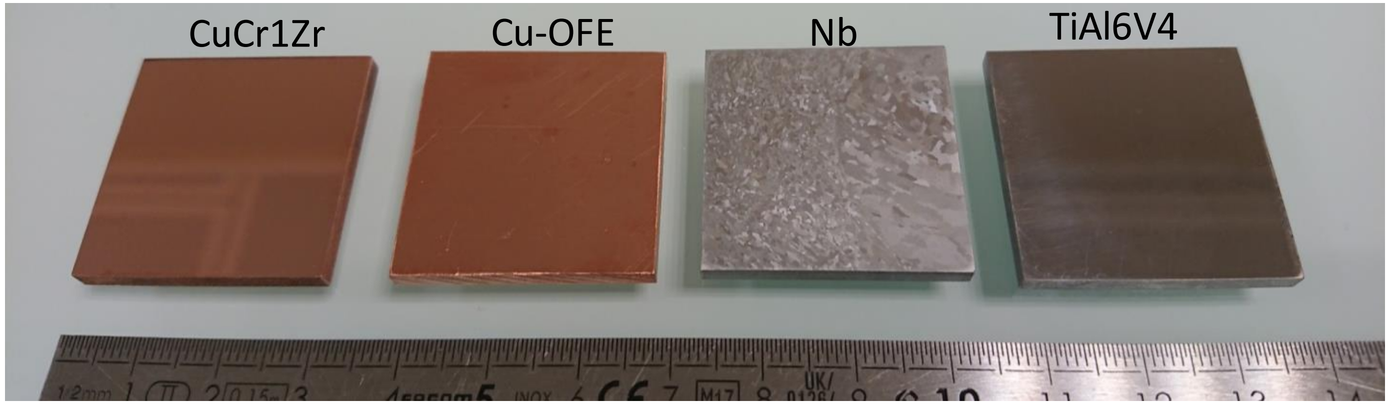
Anité Perez Fontenla

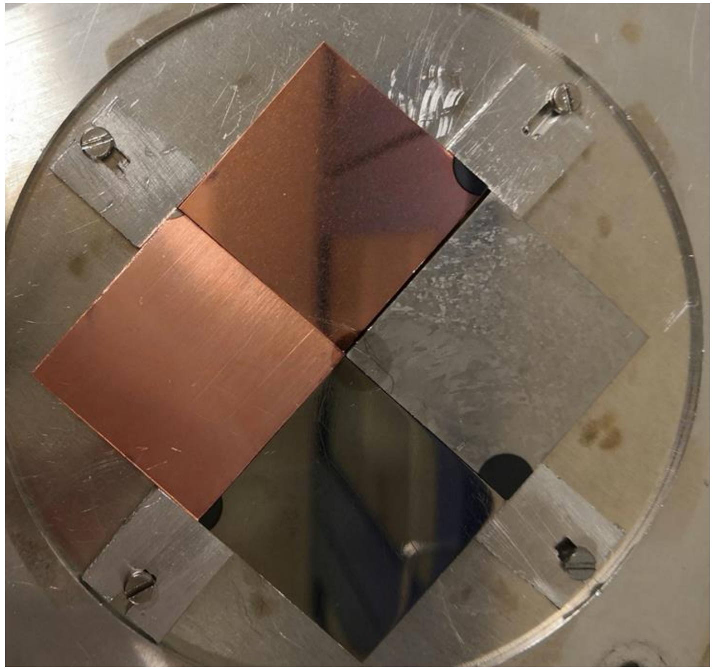




Anité Perez Fontenla

Irradiation in Helsinki





Helsinki's system:

- Particle type H2+, 90 keV
- Normal incidence angle
- Maximum diameter of the sample holder: Ø100 mm → 4 samples of 30 mm x 30 mm can be tested simultaneously

Main goal of this preliminary test was to confirm that is comparable with irradiation test performed at CERN (Cu-OFE collimators EDMS 2356205***)*** → **Cu-OFE** sample (as rolled) equivalent to Collimator's was sent

Three additional samples were sent → **CuCr1Zr**, Nb and TiAl6V4 (manually polished)

	Energy [keV/H]	Dose [1E18p/cm^2]	Beam Current [μA]	Time [h]
First Test	45	4	5	18
Second Test	45	1	5	4.5

Anité Perez Fontenla

Final remarks

- Material selection for new RFQ3, more robust to beam losses
- Work in synergy with CLIC, leveraging expertise of the Collaboration
- Irradiation of samples in Helsinki for physics understanding
- Irradiation experiments at CERN with LINAC 4 source test stand (limited availability)
- BD testing in LES system on electrodes of different materials
- SEM + FIB + EBSD + … material analyses to understand origin of enhanced BDR
- PhD student partly funded from RFQ and CLIC to work on this study, supervised from Helsinki University (Flyura Djurabekova)
- Information gathered could be useful for CLIC and high-gradient technologies in general (effect of beam losses)

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