IPPAT

1862

RIGA TECHNICAL UNIVERSITY

VPP
Valsts pētījumu programma

Participation in Accelerator Projects

Andris Ratkus

Accelerator Technology Group Leader

11.10.2023

Accelerator Technology Team

1862
RIGA TECHNICAL UNIVERSITY

Institute of Particle Physics and Accelerator Technologies

Accelerator Technology Team

- Prof. Toms Torims
- Guntis Pikurs PhD student
- Dr. Andris Ratkus

- Luca Piacentini PhD student*
- Lazar Nikitović PhD student*
- Kristaps Paļskis PhD student*
- Tobia Romano (PoliMi/ RTU) PhD student*

- *Vincenzo Alberto Sansipersico PhD student**
- Aurēlija Viņķe Bachelor student
- Dairis Rihards Irbe Bachelor student

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* RTU/UL Particle Physics and Accelerator Technologies study programme

Accelerator Technology Team

Graduates

– Ekaterina Tskhay	MSc student	2021	
– Dagnija Kroģere	MSc student	2022	
– Viesturs Lācis	MSc student	2023	

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Accelerator projects

iFAST

HITRI plus
Heavy Ion Therapy Research Integration

nimms

IPPAT

Innovation Fostering in Accelerator Science and Technology (I.FAST)

- **WP1: Management, coordination and dissemination**
  – Task 1.2: Information Flow Management and Cross-coordination (Task Leader RTU)

- **WP10: Advanced Accelerator Technologies** (Coordinator RTU)
  – Task 10.1: Coordination and Communication (Task Leader RTU)
  – Task 10.2: Additive Manufacturing - Survey of applications and potential developments
  – Task 10.3: Refurbishment of accelerator components by AM technologies (Task Leader RTU)

- **WP12: Societal Applications**
  – Task 12.1 sub task 3: Environmental applications of electron beam

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  - Task 10.1: Coordination and Communication (Task Leader RTU)
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  - Task 10.3: Refurbishment of accelerator components by AM technologies (Task Leader RTU)

- **WP12: Societal Applications**
  - Task 12.1 sub task 3: Environmental applications of electron beam

Student theses

- **Guntis Pikurs PhD thesis**: **Follow his talk @11:30 (link)**

Research on performance improvement of accelerator and detector components by additive manufacturing

- **Tobia Romano PhD thesis**: **Follow his talk @12:15 (link)**

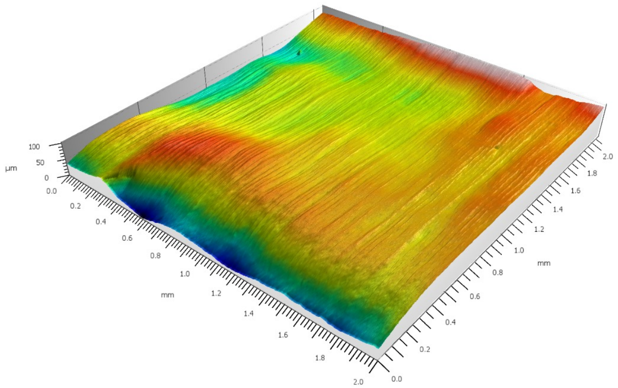
Investigation on the sintering behaviour of pure copper processed via additive manufacturing

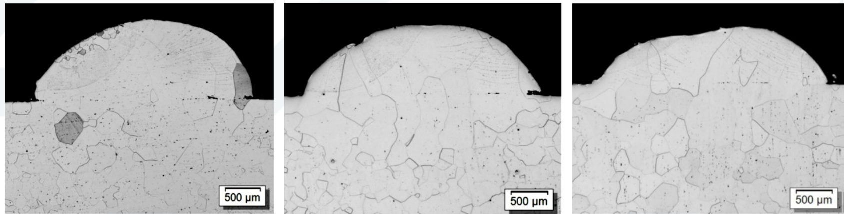
- **Dagnija Krogere MSc thesis (Defended)**:

Research of additive manufacturing applications and strategies for repairing particle accelerator components

- **Viesturs Lacis MSc thesis (Defended)**: **Was @poster Session**

Laser Polishing of Additively Manufactured RFQ Prototype





Results so far

- **Task 10.3 Deliverable was submitted and approved**
  Reported about:
  – AM state of the art in the accelerator community
  – Possible AM repair strategies for accelerators


I.FAST
Innovation Fostering in Accelerator Science and Technology
Horizon 2020 Research Infrastructures GA n° 101004730

DELIVERABLE REPORT

Survey of AM applications and strategies for repairing components by AM

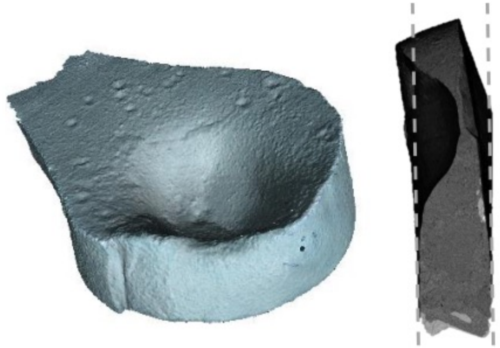
DELIVERABLE: D10.2

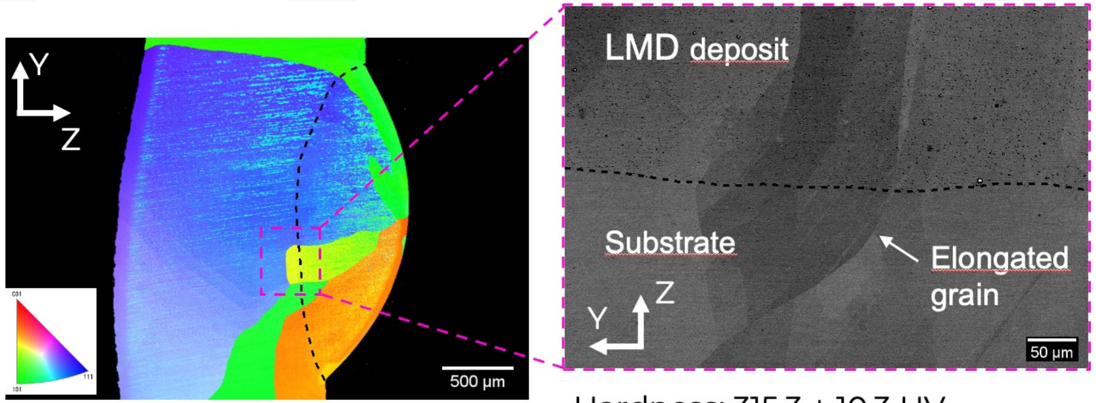
POLITECNICO MILANO 1863
Fraunhofer IWS
TANiOBIS inspiring metal evolution
RIGA TECHNICAL UNIVERSITY
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

IPPAT

Results so far

- **Task 10.3 Deliverable was submitted and approved**
  Reported about:
  - AM state of the art in the accelerator community
  - Possible AM repair strategies for accelerators
  - Case study: Ta cathodes repair by two AM technologies





Hardness: 315.3 ± 10.3 $HV_{0.05}$

I.FAST
Innovation Fostering in Accelerator Science and Technology
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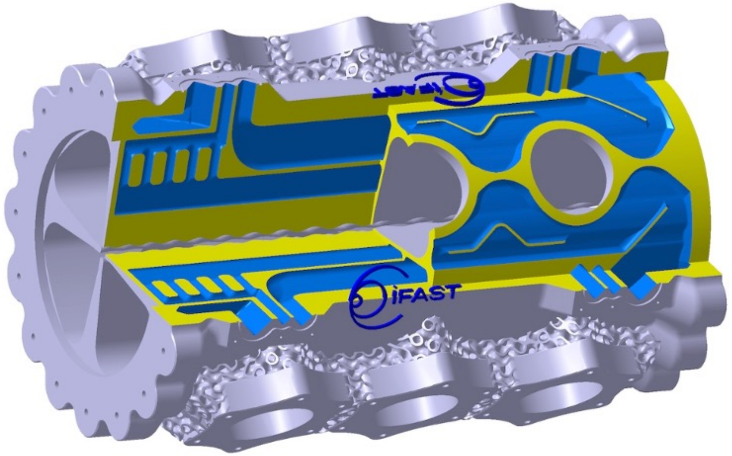
Results so far

- Pure Cu (Cu-ETP) RFQ prototypes manufactured by AM

¼ RFQ L= 95 mm

Results so far

- Pure Cu (Cu-ETP) RFQ prototypes manufactured by AM



L= 250 mm

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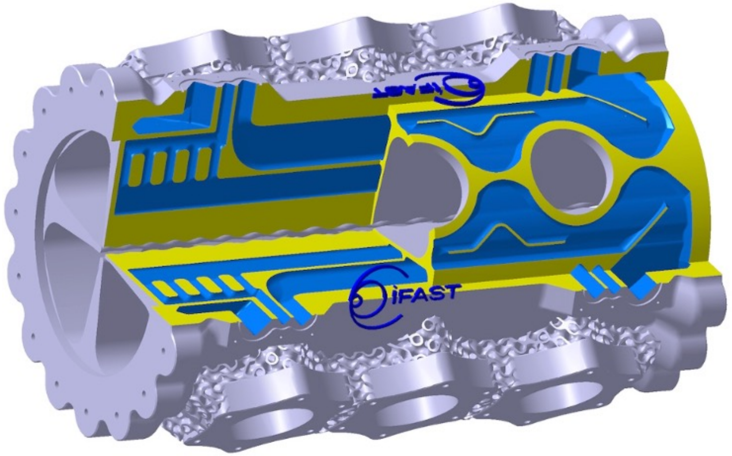

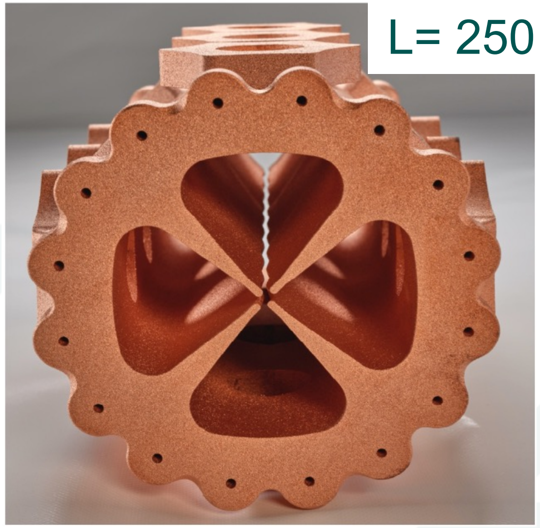

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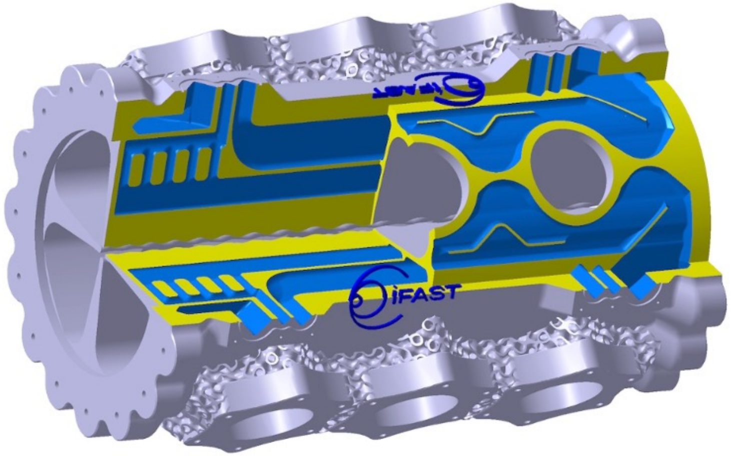

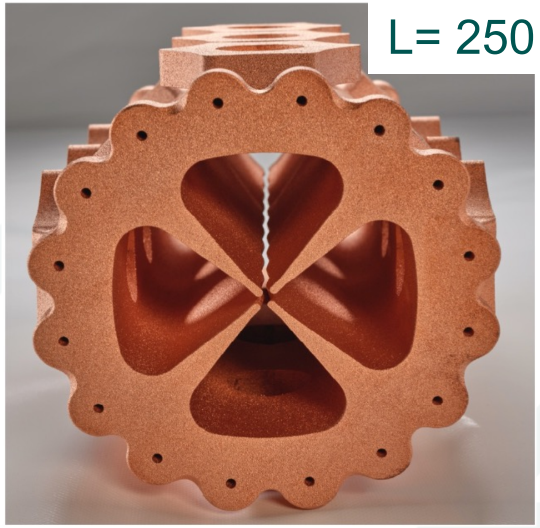

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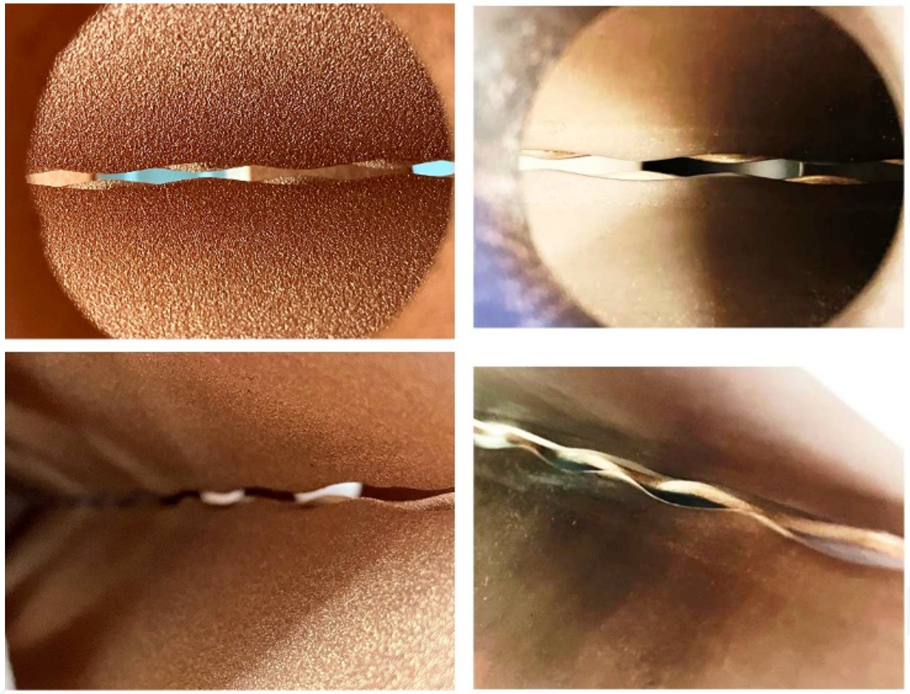

Before After

Post-procesing

CERN · RÖSLER finding a better way ... · POLITECNICO MILANO 1863 · RIGA TECHNICAL UNIVERSITY 1862 · TRUMPF · Fraunhofer IWS · IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis · CERN EN · EN/MME MATERIALS & METROLOGY

IPPAT

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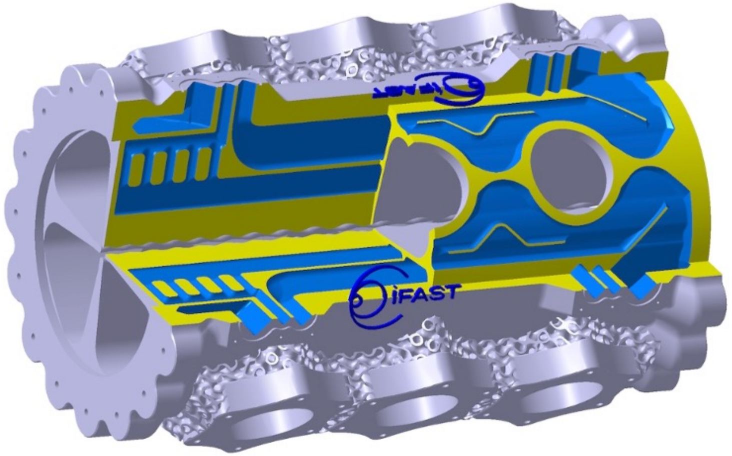

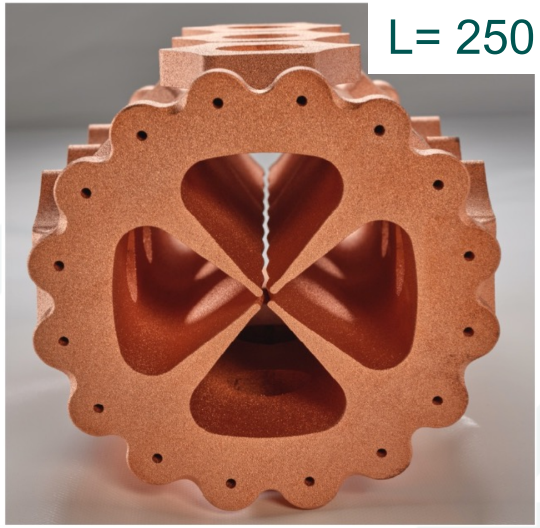

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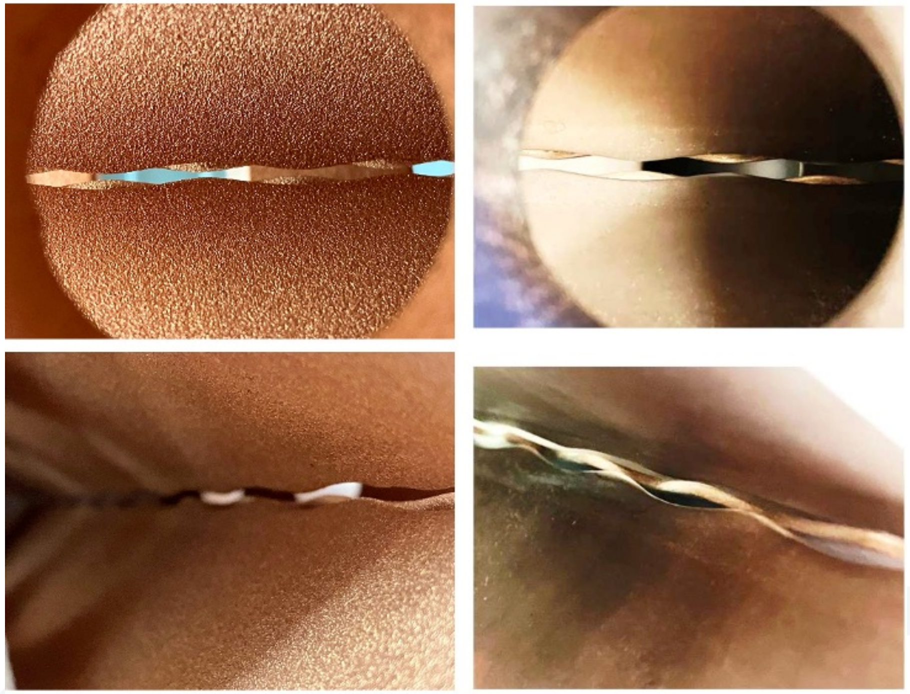

Before

After

Post-procesing

Post-procesed and machined

CERN
RÖSLER finding a better way ...
POLITECNICO MILANO 1863
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MATERIALS & METROLOGY

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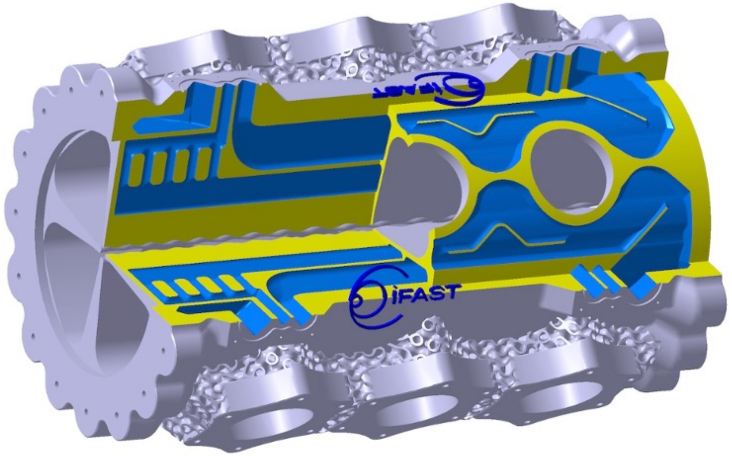

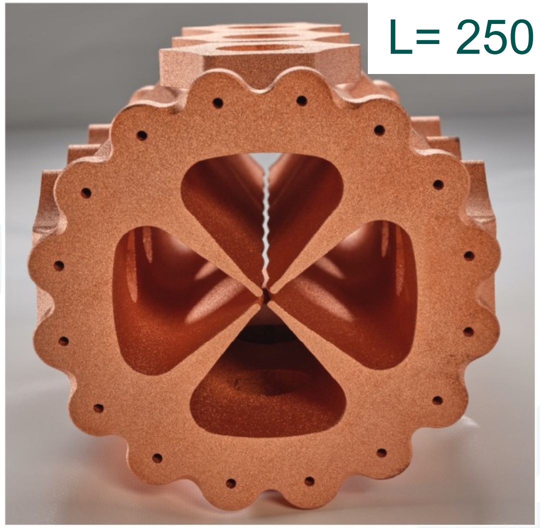

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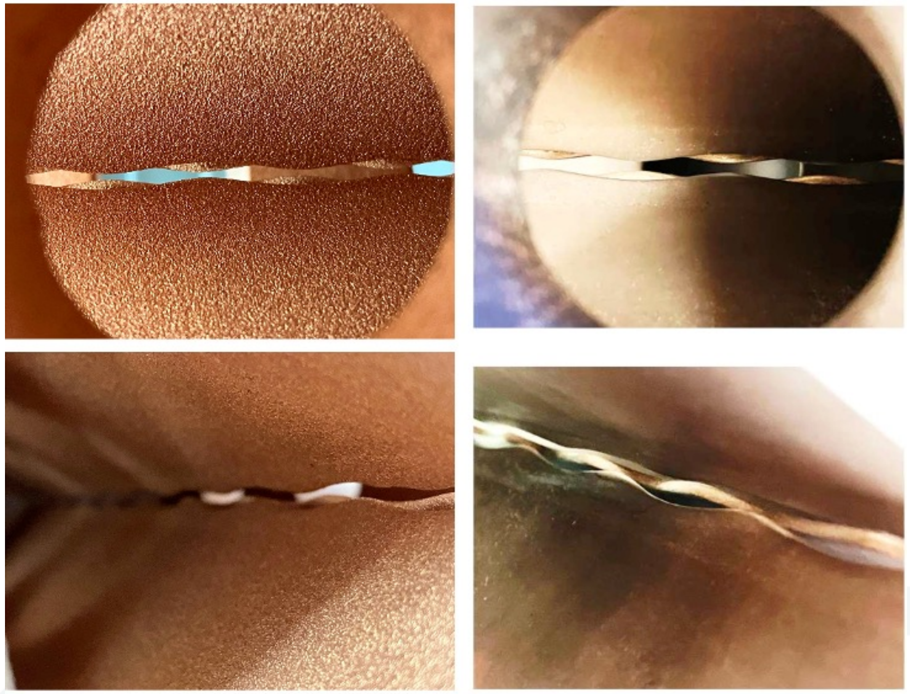


Before

After

Post-procesing

Post-procesed and machined

Vacuum tests at IJCLab (currently)

RF tests at CERN will follow

Accelerator projects

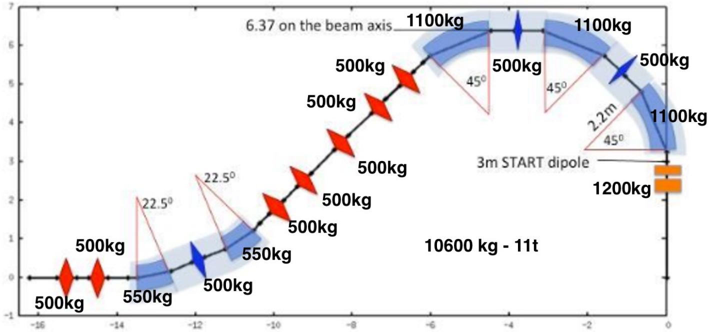
HITRI plus

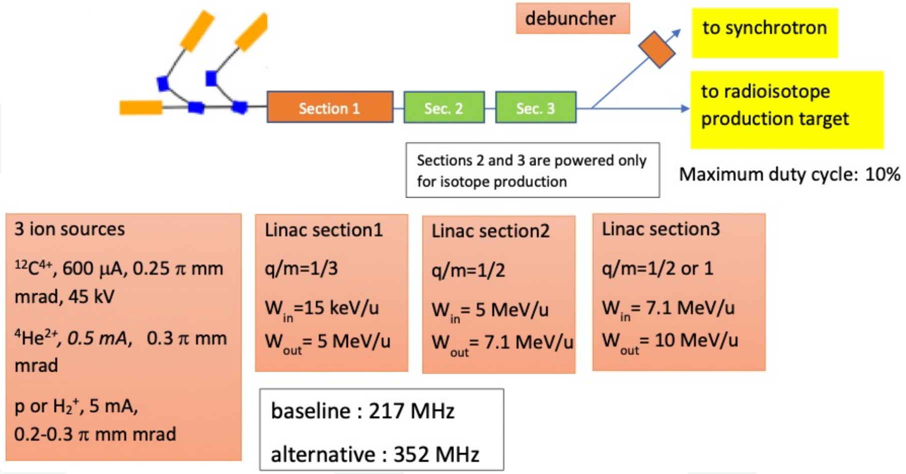
Heavy Ion Therapy Research Integration

IPPAT

Heavy Ion Therapy Research Integration

- **WP 7: Advanced accelerator and gantry design**
  - **Task 7.4:** Injector Linac Design
  - **Task 7.5:** Integration of an innovative superconducting gantry: optics, mechanics, beam delivery





Courtesy: M. Vretenar

HITRI plus
Heavy Ion Therapy Research Integration

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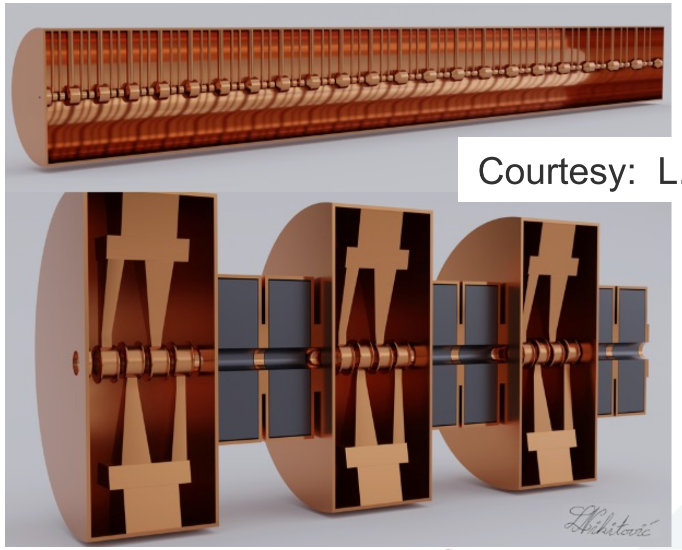
Student theses

- **Lazar Nikitovics PhD thesis:** Was @poster Session

Design study of a high-frequency linear accelerator for the purposes of injection into a therapy synchrotron and parallel production radioisotopes



Courtesy: L. Nikitovic

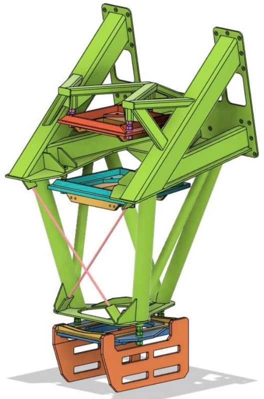
- **Luca Piacentini PhD thesis:** Was @poster Session

Mechanical integration of systems, instruments and components of a carbon ion rotating gantry for medical treatments

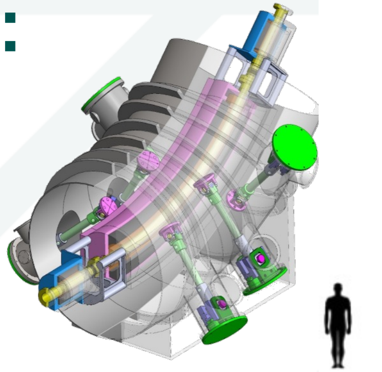
Was @poster Session

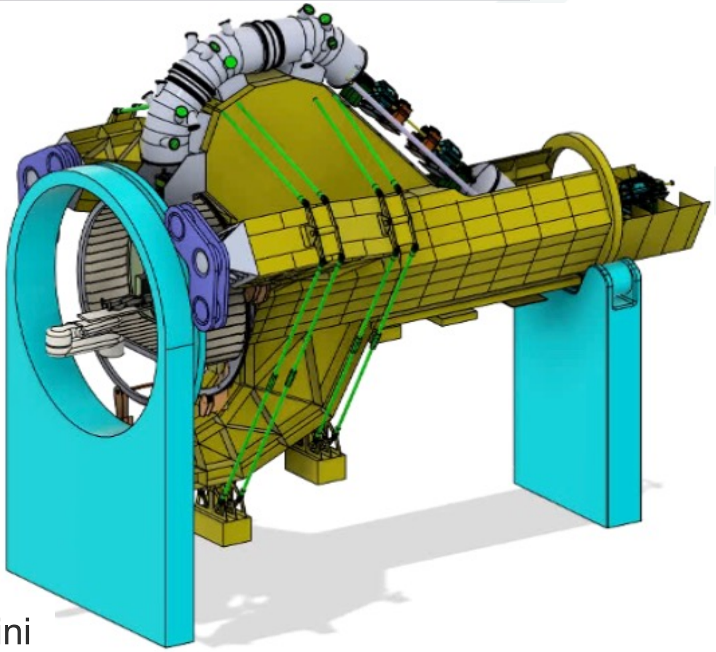
- **Dairis Rihards Irbe Bachelor thesis:**

Designing of gantry mechanical components



Courtesy: D. Irbe





Courtesy: L. Piacentini

HITRIplus Heavy Ion Therapy Research Integration

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Results so far

1 Posters

2 Publications

IPAC’23 Proceedings:
https://www.ipac23.org/preproc/index.html

MDPI Journal Machines:
https://www.mdpi.com/2075-1702/11/10/929

HITRI*plus* Deliverables:
- Task 7.4 (submitted)
- Task 7.5 (work in progress)

COMPARISON OF 352 MHz LINAC STRUCTURES FOR INJECTION INTO AN ION THERAPY ACCELERATOR

L. Nikitovic [1,2], T. Torims [1], M. Vretenar [2]

[1] Riga Technical University, Riga, Latvia
[2] CERN, Geneva, Switzerland

AIMS OF STUDY

- RF design and beam optics studies for comparison of various accelerating structures at 352 MHz for the HITRIplus LINAC:
  - Quasi Alvarez Drift Tube LINAC (QA-DTL);
  - Inter-digital H-mode Drift Tube LINAC (IH-DTL);
  - Separated Inter-digital H-mode Drift Tube LINAC (S-IH-DTL).

WHY DO WE NEED A NEW DESIGN?

- Lower operational costs of accelerators - hence more affordable to society;
- Improved beam optics with high transmission and optimum beam quality, achieving better performance for cancer treatment.

RESULTS

C^{4+} in QA-DTL

QA-DTL

QA-DTL

PROS:
- Higher effective shunt impedance in comparison to a standard DTL;
- Strong beam focusing in transversal plane;
- Klystron can be used as RF power source, at a lower cost per watt than a solid state amplifier.

CONS:
- Higher power dissipation in comparison to a conventional IH-DTL.

S-IH-DTL

PROS:
- Clean FODO beam optics, without the need for KONUS optics.
- Optimised effective shunt impeda-nce - different radius for every tank;
- Different focusing systems can be used (e.g. doublets and triplets);

CONS:
- Higher power dissipation in comparison to a conventional IH-DTL;

S-IH-DTL

DTL
- Standard Alvarez DTL structure has been designed only for the acceleration of He^{2+} and H^{+} ions;
- DTL has been designed as the second and third tank of HITRIplus LINAC.

CONCLUSIONS

STRUCTURES	QA-DTL	S-IH-DTL (doublets)	DTL Cav.1	DTL Cav.2
Designed Ions	C^{4+}	C^{4+}	He^{2+}	H^{+}
L_{total} [m]	5.1	5.9	1.5	1.1
$P_{dissipation}$ [kW]	626	614	181	147
E_{input} [MeV/u]	0.7	0.7	5	7
E_{output} [MeV/u]	5	5	7	10

WHICH LINAC STRUCTURE IS THE "BEST"?
- QA-DTL, designed as the first tank of HITRIplus LINAC, has shown to be a good alternative to conventional IH-DTL for acceleration of C^{4+} ions;
- Standard Alvarez DTL, designed as the second and third tank of HITRIplus LINAC, indicated to be a good choice for acceleration of H^{+} and He^{2+} ions;
- S-IH-DTL showed to be a viable option for acceleration of C^{4+} ions, but not as effective as QA-DTL in terms of both production and operational costs.

This study was (partially) supported by the European Union's Horizon 2020 research and innovation programme under grant agreement no. 101008548 (HITRIplus)

For questions contact: lazar.nikitovic@cern.ch

Scan for additional information

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HITRI*plus* Heavy Ion Therapy Research Integration

Courtesy: L. Nikitovic

HITRI*plus* Annual meeting and Workshop

https://indico.cern.ch/event/1246177/

Workshop: Clinics and research: considerations to create a novel particle therapy center (within HITRIplus Event)

Wednesday 28 Jun 2023, 10:00 → 15:45 Europe/Riga

Domus auditorialis, Zunda krastmala 8

https://indico.cern.ch/event/1256528/

Accelerator projects

nimms

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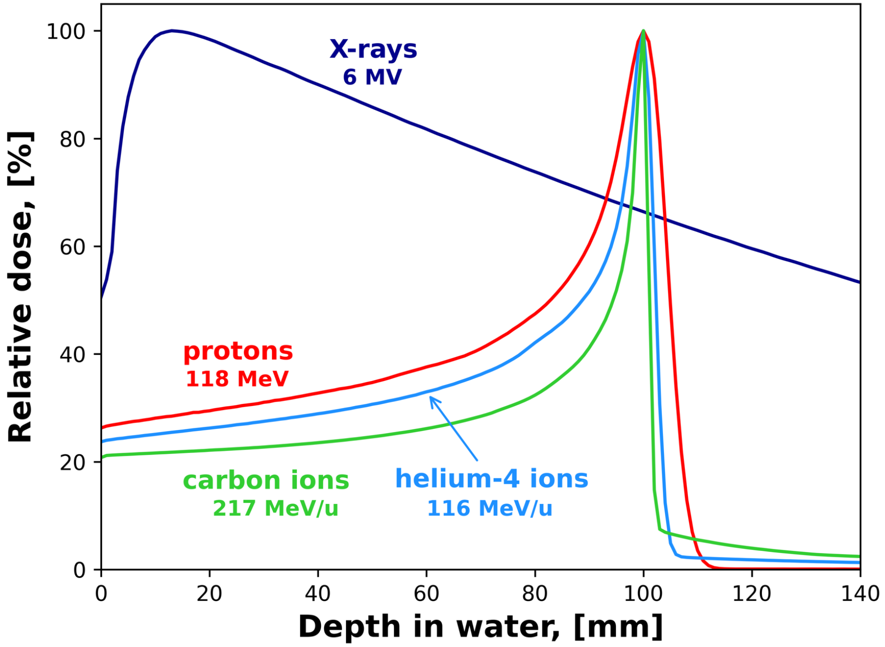
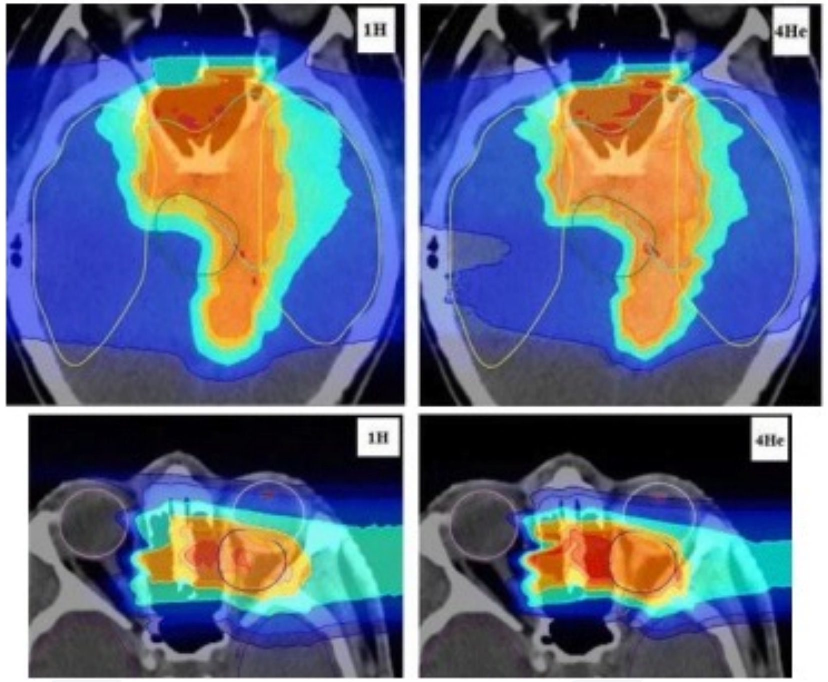
Next Ion Medical Machine Study

- Developing new technologies for the future generation of accelerators for cancer therapy





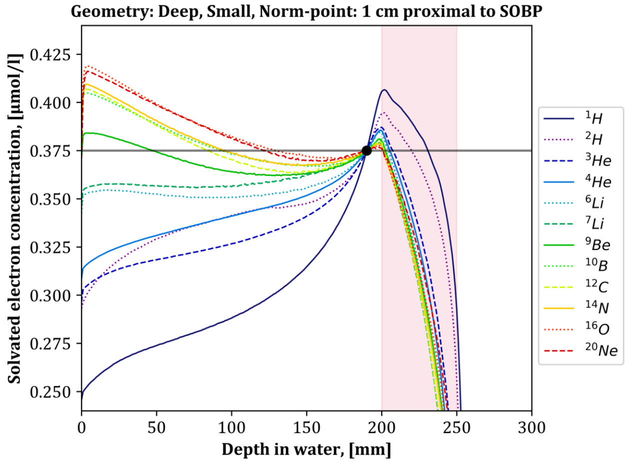
Courtesy: K. Palskis

Student theses

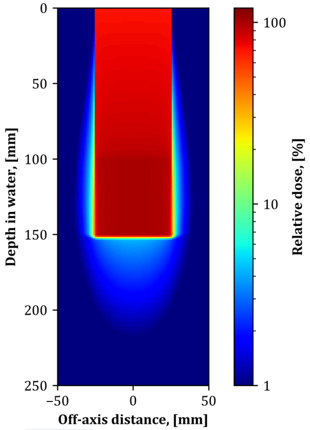
- **Kristaps Paļskis PhD thesis:** Studies of different ion types and their use for radiation therapy, *FLASH* therapy aspects. Optimization of ion beam parameters for very high dose rate (FLASH) radiotherapy
  Presented @9:55 (link)

- **Vincenzo Alberto Sansipersico PhD thesis:** Optimization and Integration of a $^{4}He^{2+}$ Synchrotron for Cancer Therapy

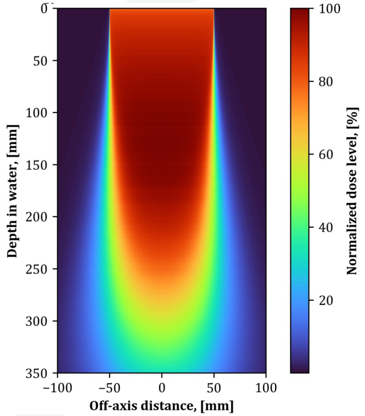
- **Aurēlija Viņķe Bachelour thesis:** Studies of proton radiography



FLASH effect modeling for Ions



SFUD field



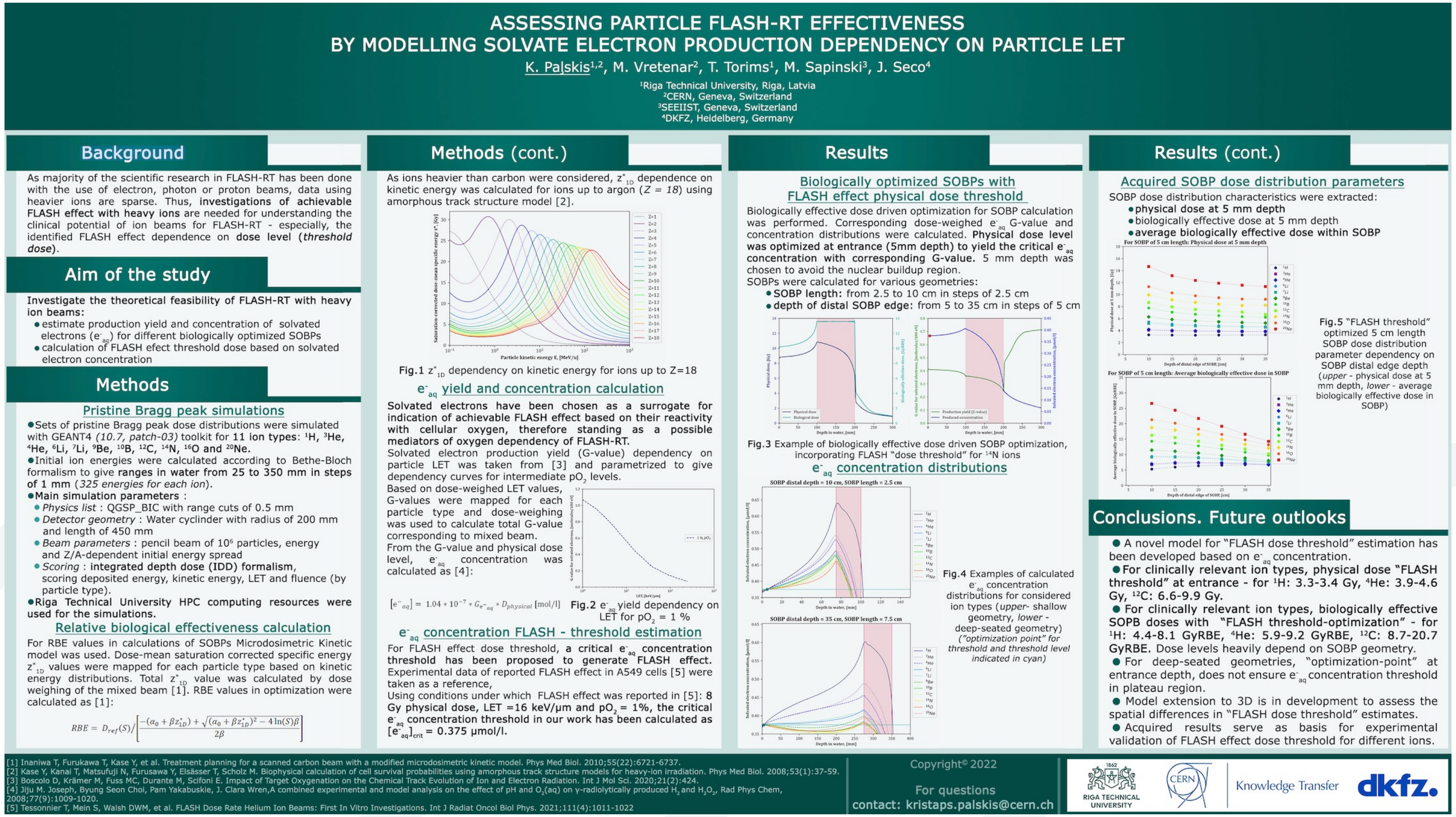
VHEE field

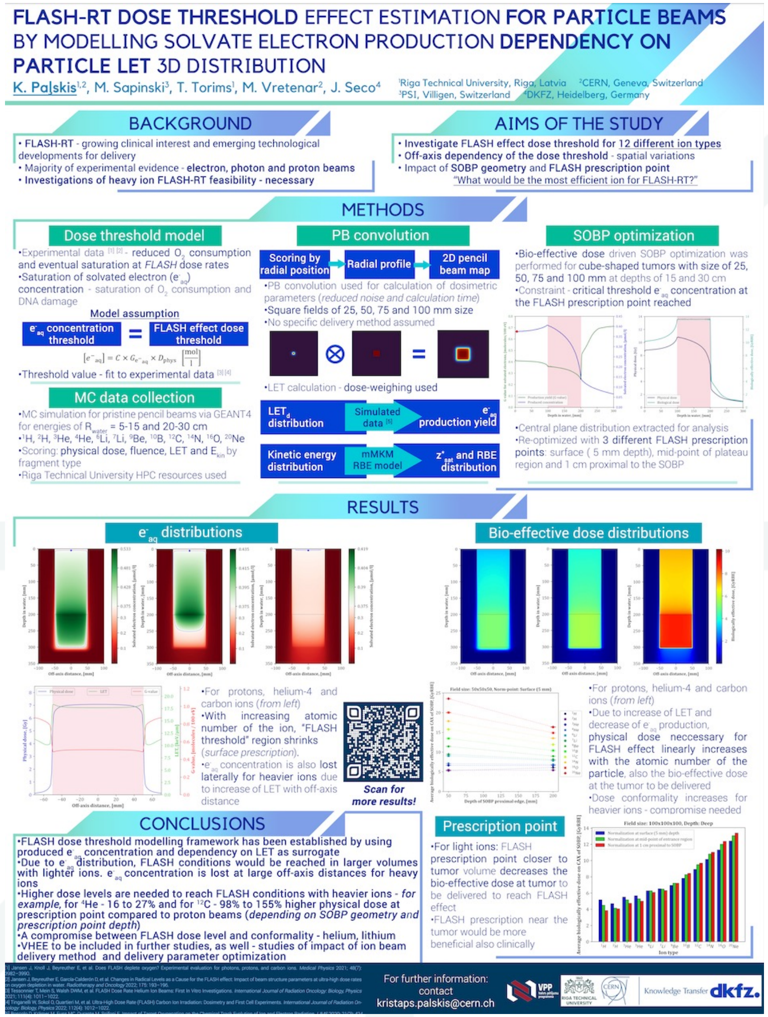
Courtesy: K. Palskis

Results so far

2 Posters

1 Publications





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Courtesy: K. Palskis

Other activities

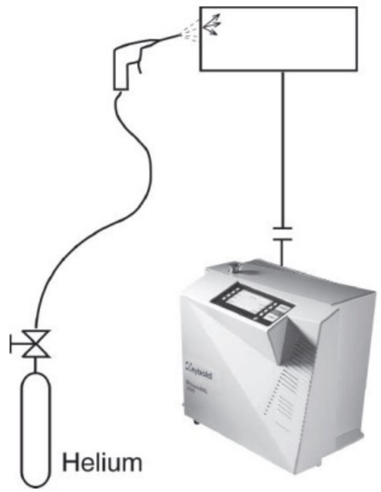
IPPAT

CERN TE-VSC

Primarily concerned with two Additive Manufacturing (AM) technologies

FUTURE CIRCULAR COLLIDER

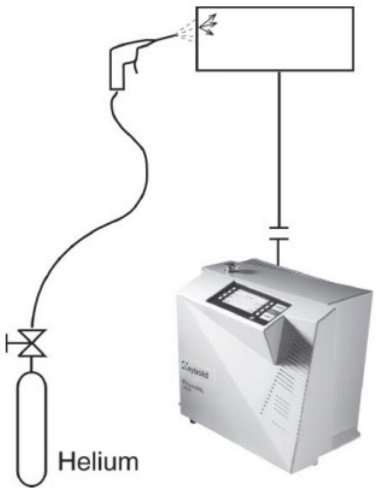
CERN TE-VSC



Primarily concerned with two Additive Manufacturing (AM) technologies

IPPAT

CERN TE-VSC



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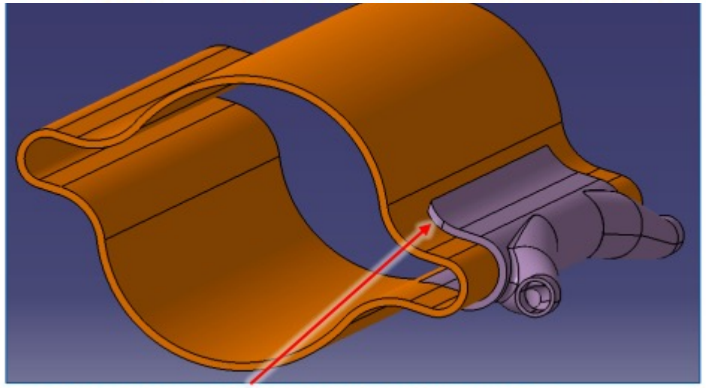
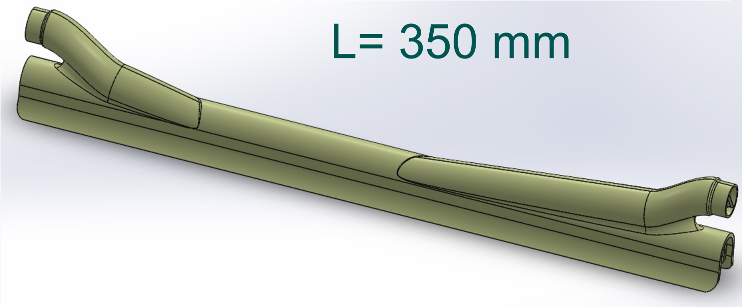
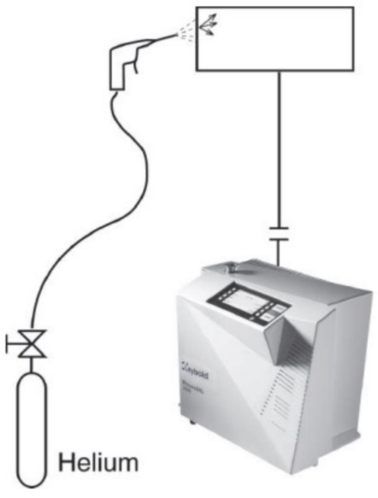


SR Absorber to be laser welded along outer profile



FUTURE CIRCULAR COLLIDER

CERN TE-VSC



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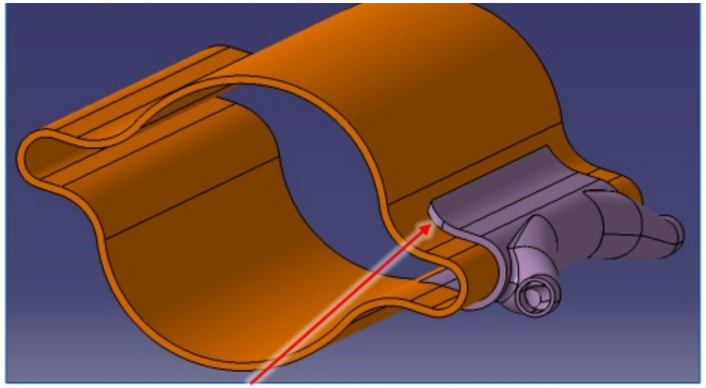

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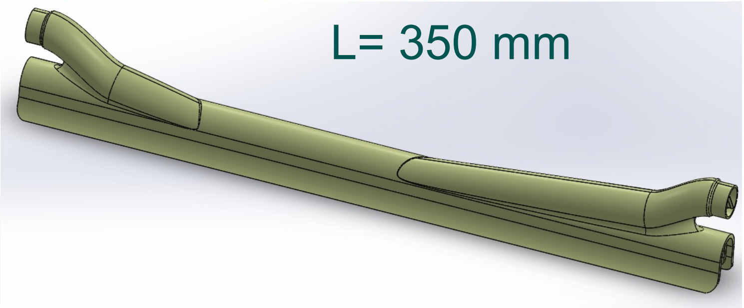

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Fraunhofer IWS

International
MUON Collider
Collaboration

The Memorandum of Understanding has been signed by RTU

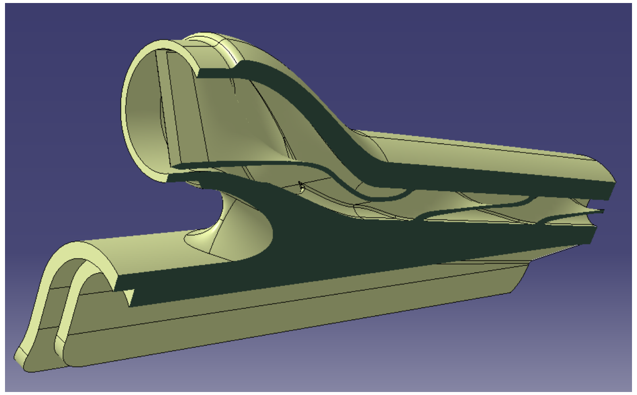
IPPAT

CERN Summer Student Programm

CERN Summer Student Programm

Student: Kristupa Seskauskaite (KTU) tasks:

- AM component and surface characterisation
- Measurements
- Design evaluation
- Continuation with Bachelor thesis



SR Absorber test sample (95 mm)

CERN Summer Student Programm

FUTURE CIRCULAR COLLIDER

RIGA TECHNICAL UNIVERSITY 1862

ktu kaunas university of technology 1922

CERN

Was @poster Session

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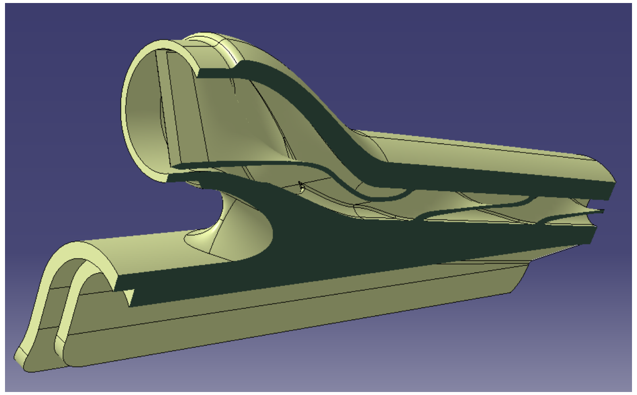

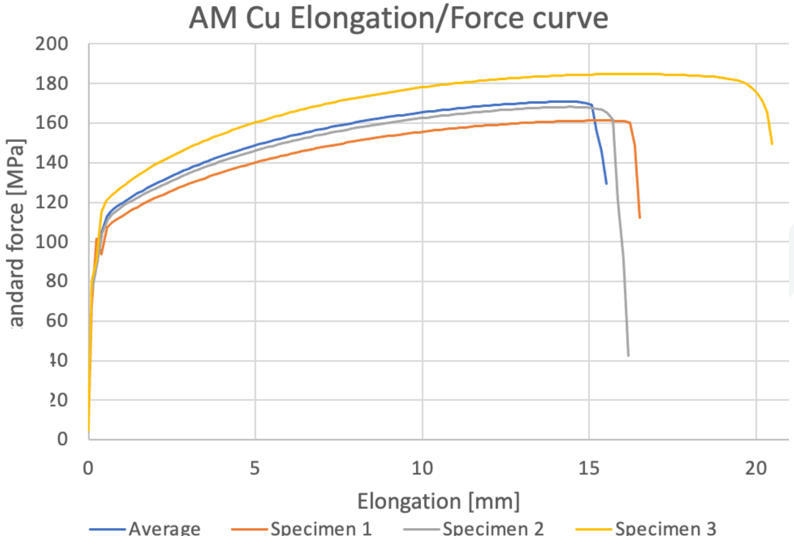

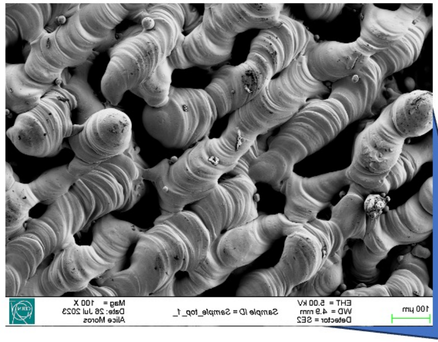

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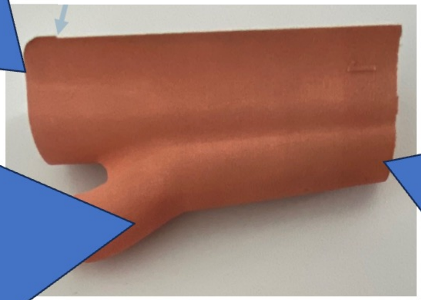
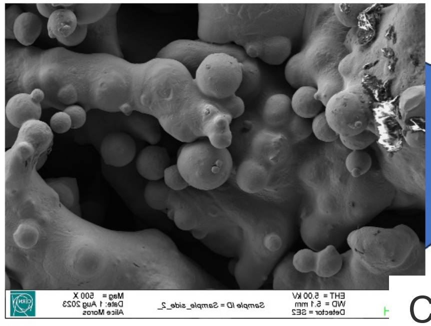
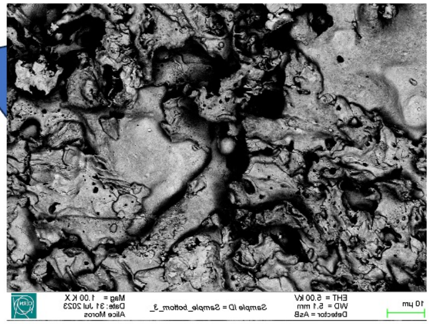






Material/Property	AM Cu	AM CuCrZr [1-3]	Cu10100 [4]
Yield strength, MPa	100	204-361	69-360
Young's modulus, GPa	137,6	114	115
Hardness, HV	71,2-73,8	88,185	51-127
Density, %	96-99	90-99	100
Roughness, µm	18,01	8-18	N/A

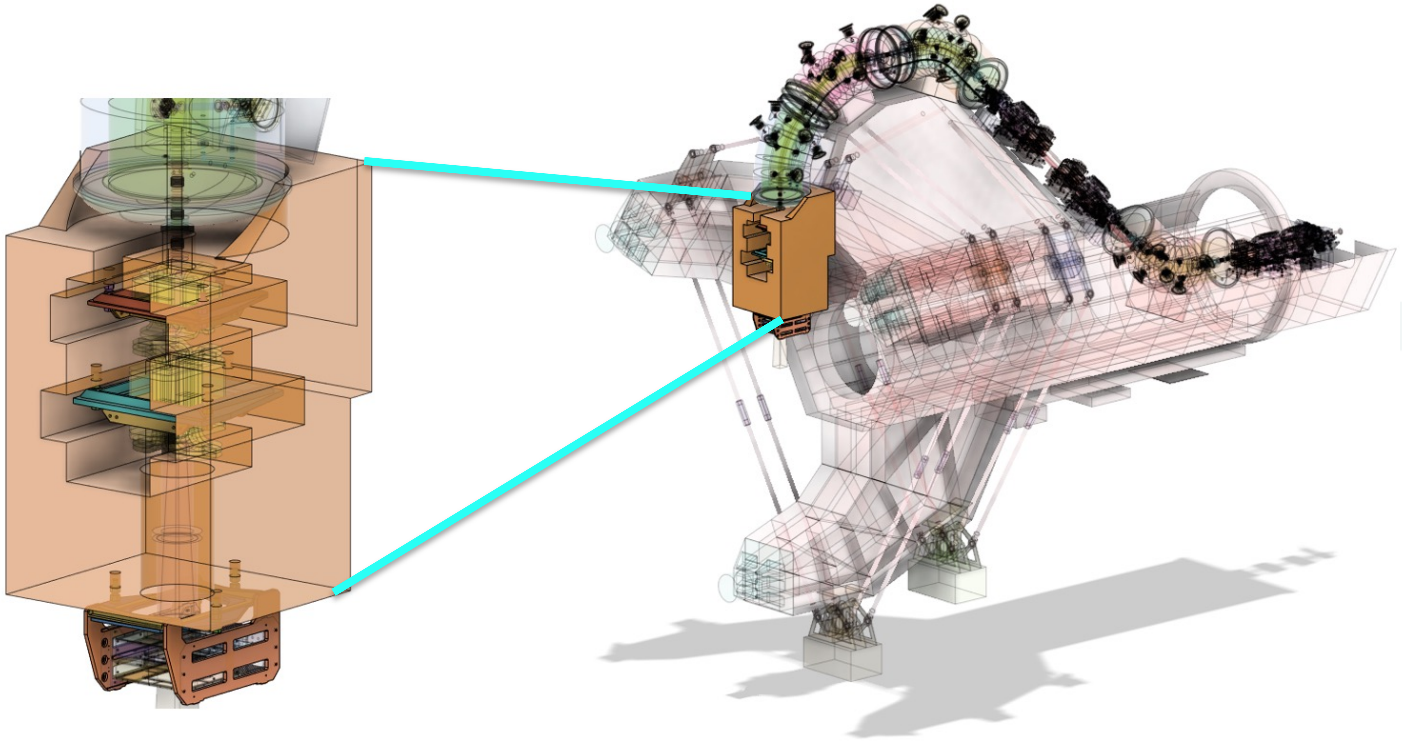
Courtesy: K. Seskauskaite

IPPAT

CERN Summer Student Programm

Student: Dairis Irbe (RTU) tasks:

- Design of support structure for nozzle components
- Evaluation of design
- Continuation with Bachelor thesis



Courtesy: D. Irbe

CERN Summer Student Programm

Heavy Ion Therapy Research Integration

Was @poster Session

Student: Dairis Irbe (RTU) tasks:

- Design of support structure for nozzle components
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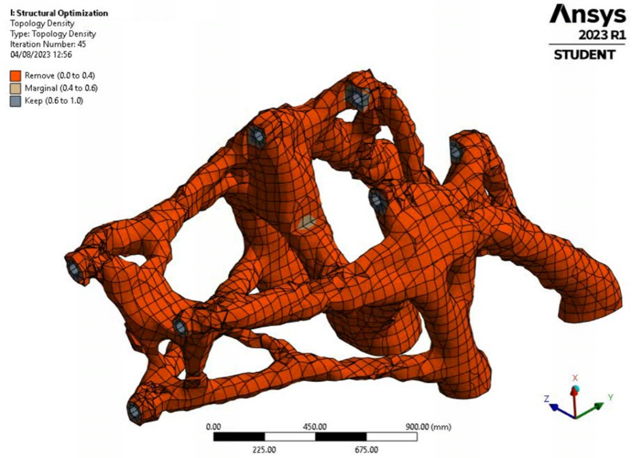
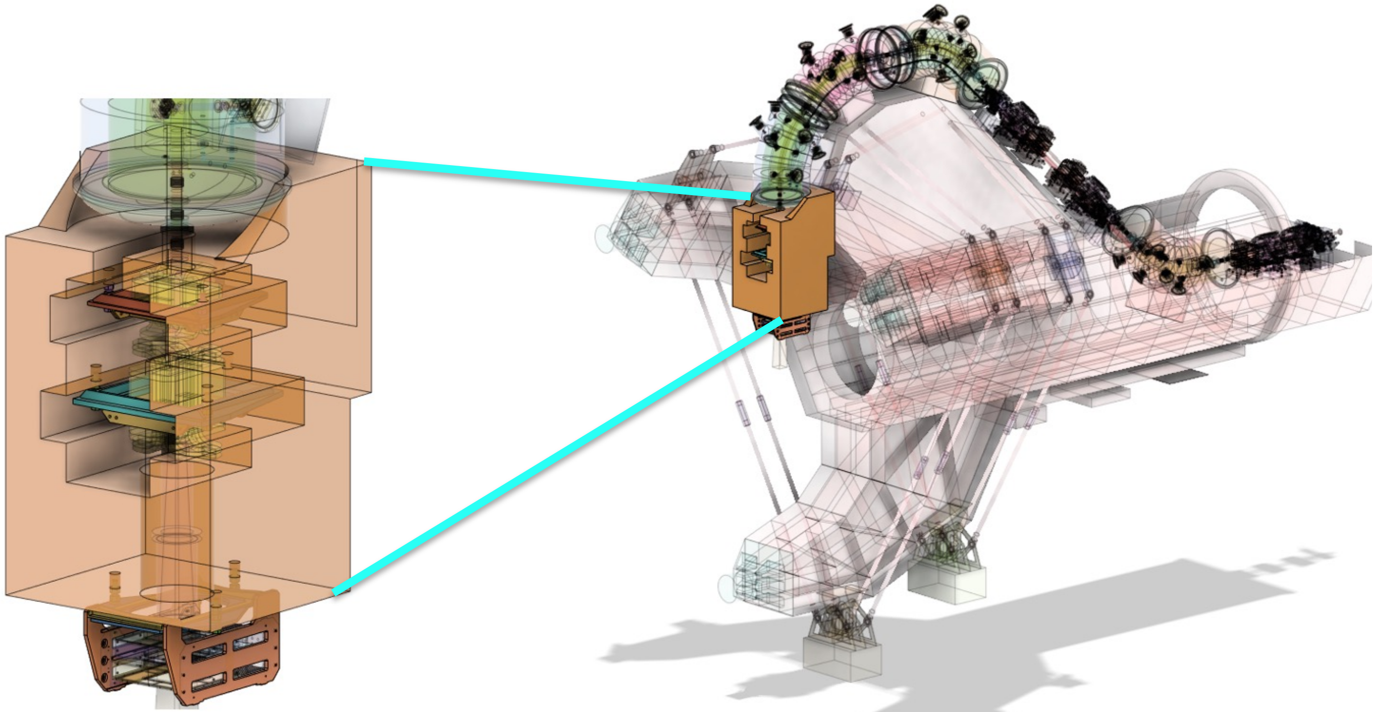
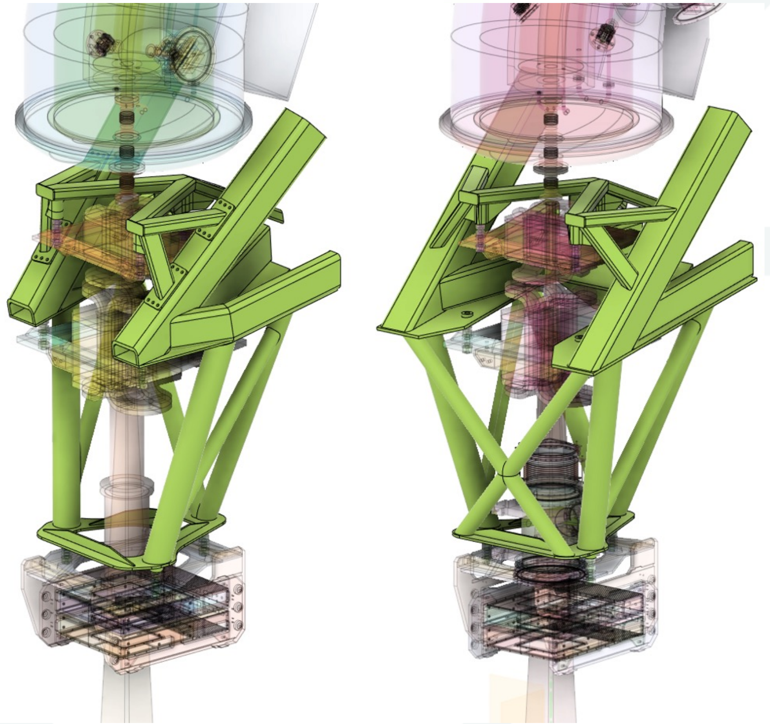
- Continuation with Bachelor thesis







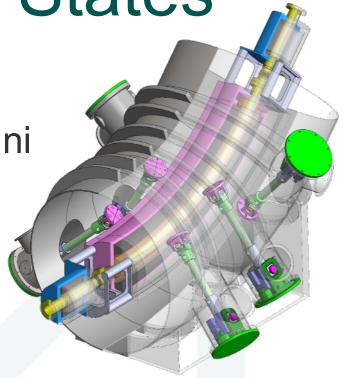
IPPAT

Courtesy: D. Irbe

Building the expertise in Accelerator Technologies

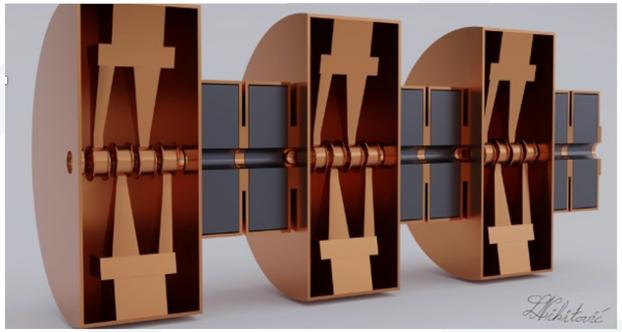
- Project initiative: Advanced Particle Therapy center in the Baltic States

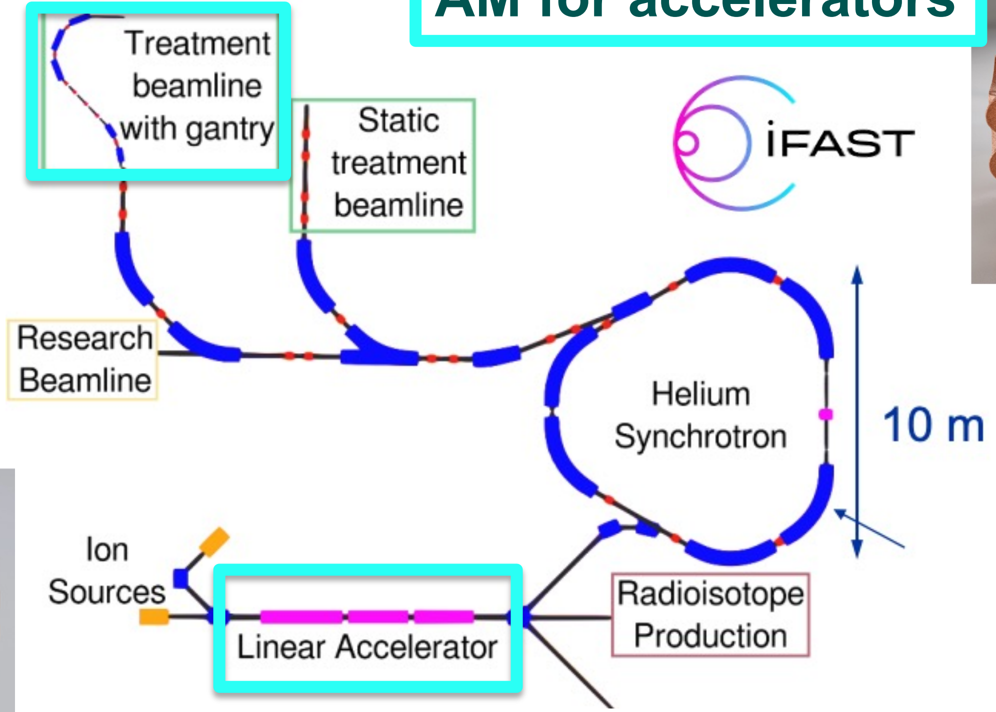
Courtesy: L. Piacentini



HITRIplus
Heavy Ion Therapy Research Integration

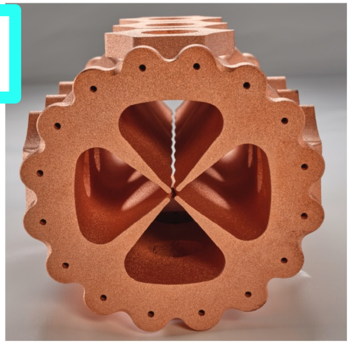
Courtesy: L. Nikitovic



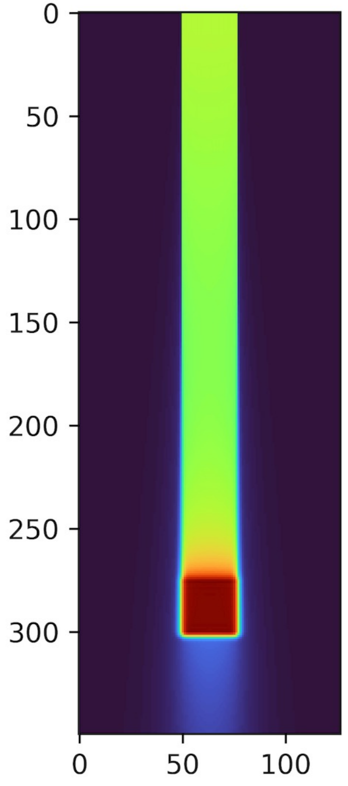


Source: M. Vretenar et al., IPAC2022

AM for accelerators



CERN Baltic Group



Courtesy: K. Palskis

FLASH therapy

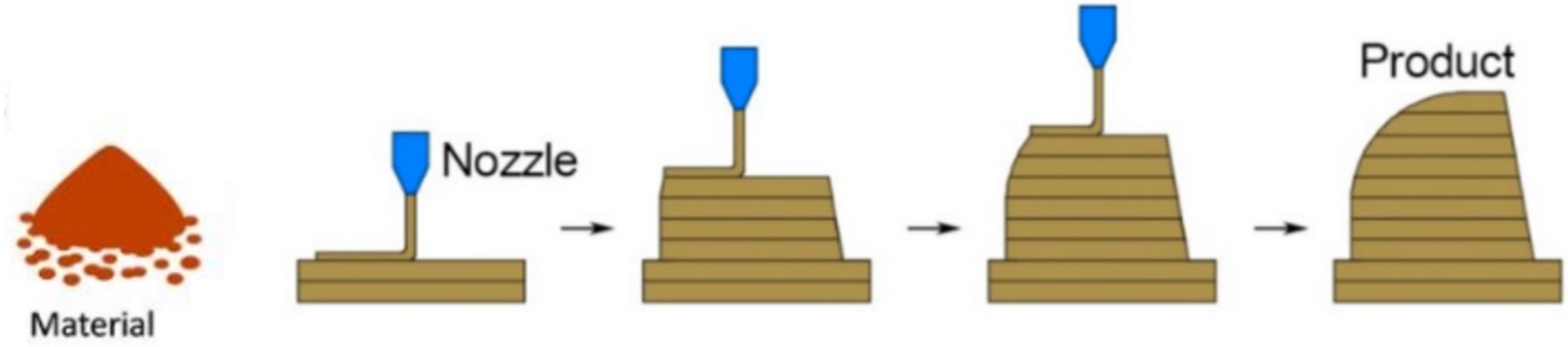
Examination of AM for accelerator applications

Andris Ratkus

Accelerator Technology Group Leader

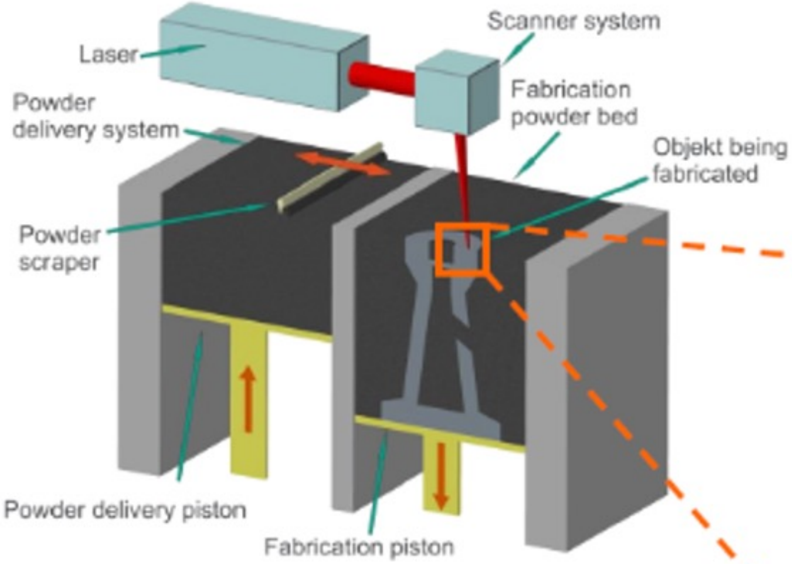
11.10.2023

AM Technology



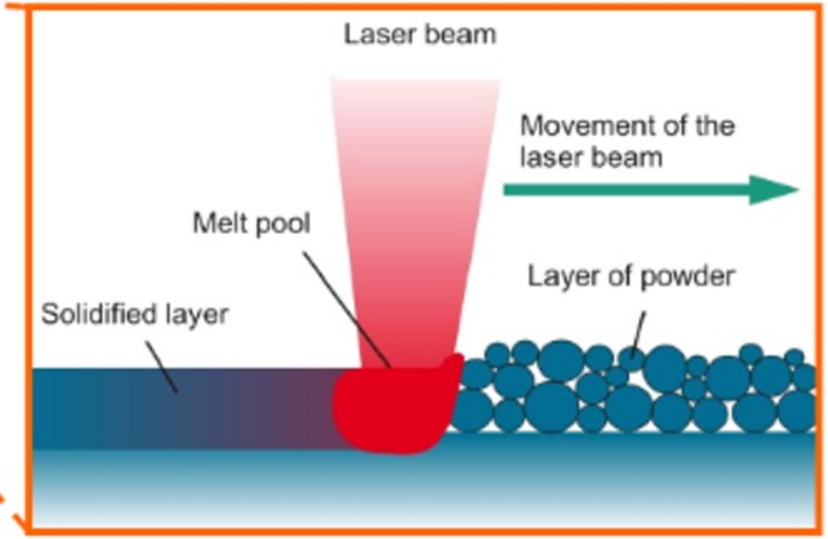
AM Technology

Powder Bead Fusion



Principle sketch of a laser melting machine

Source: Fraunhofer IWU



Schematic diagram of laser beam melting

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Accelerator Requirements

Requirement	Target value
Geometrical accuracy	20 µm on vane tip, 100 µm elsewhere
Surface roughness	Ra = 0,4 µm for all inner surfaces
Vacuum	10^{-7} mbar
Electrical conductivity	90% IACS
Peak electric field on surface	≈ 40 MV/m

**RFQ Requirements*

IPPAT

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**RFQ Requirements*

P (Torr)	λ	Regime
760	70 nm	Atmosphere
1	50 µm	Rough vacuum
10^{-3}	5 cm	Medium vacuum
10^{-7}	500 m	High Vacuum
10^{-10}	500 km	Ultra High Vacuum
10^{-12}	50,000 km	Extreme High Vacuum

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Ultra High Vacuum design for BIDs

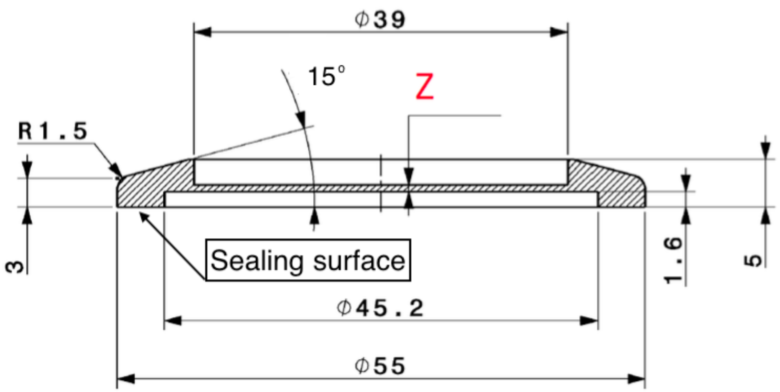
Vacuum criteria

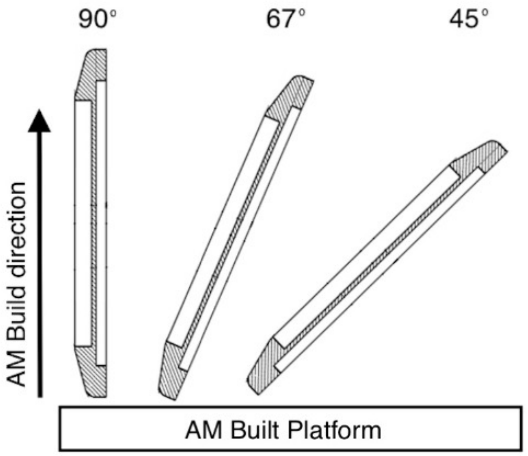
- **Leak tightness** (e.g. $1 \cdot 10^{-10}$ mbar·l·s^{-1})
- **Contamination** (hydrocarbons, CO/CO_2, higher Z – from cleaning or poor design)
- **Outgassing** (from internal components) (e.g. threshold 10^{-7} mbar·l·s^{-1})
- **Virtual leaks** (e.g. trapped pockets of gas) (< $5 \cdot 10^{-9}$ mbar·l·s^{-1})

He leakage test

First test for Ultra High Vacuum applications

The aim of this research is **to find the minimum pure copper AM wall thickness limits applicable for UHV** by using **specially designed test membranes**





Z = 2.5; 2; 1.5; 1; 0.75; 0.5 mm

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Thanks to CERN TE-VSC and Cedric GARION

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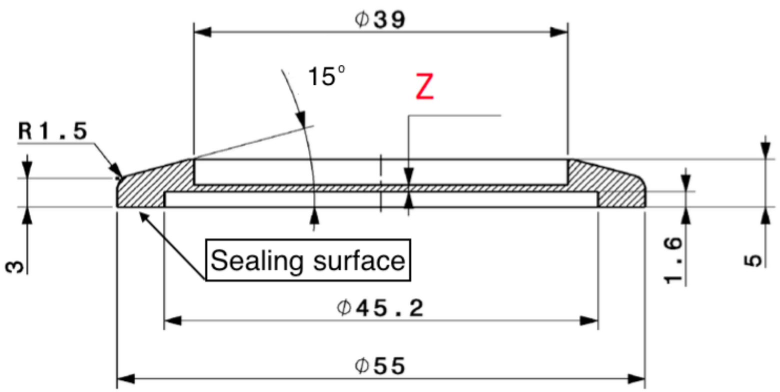

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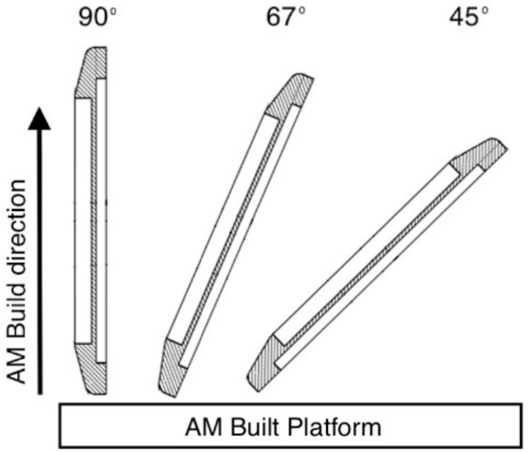

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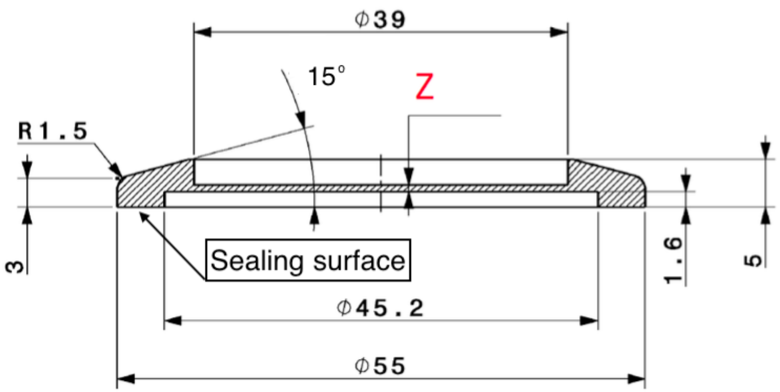

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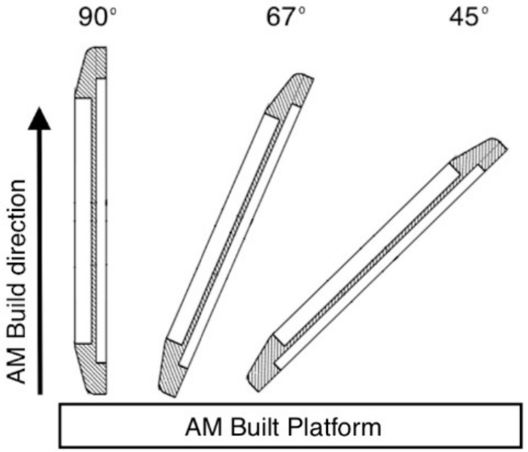

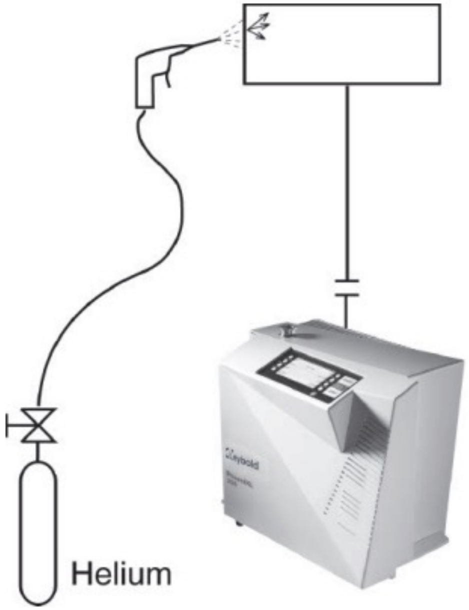

During the test vacuum level of **10^{-3} mbar** was provided

Thanks to CERN TE-VSC and Cedric GARION

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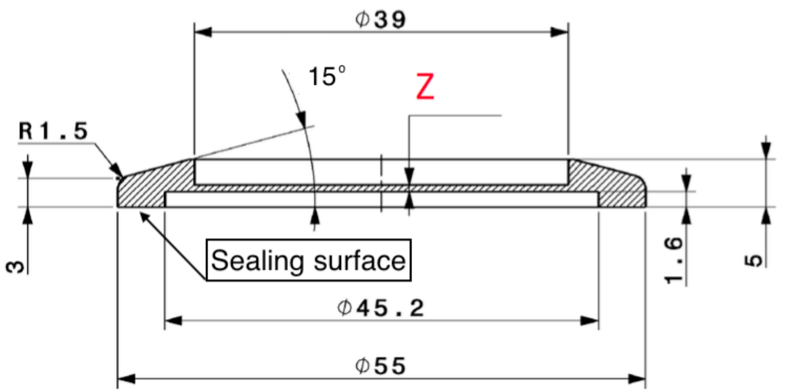

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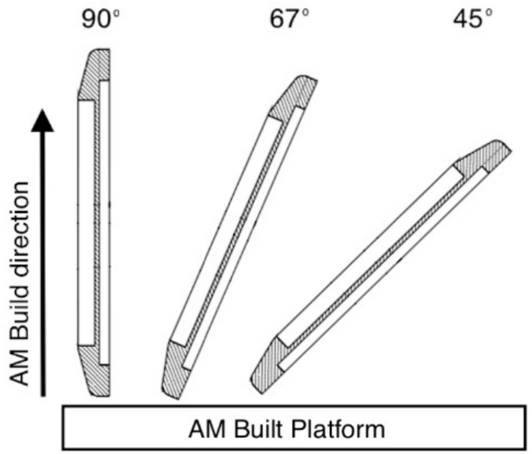


Results

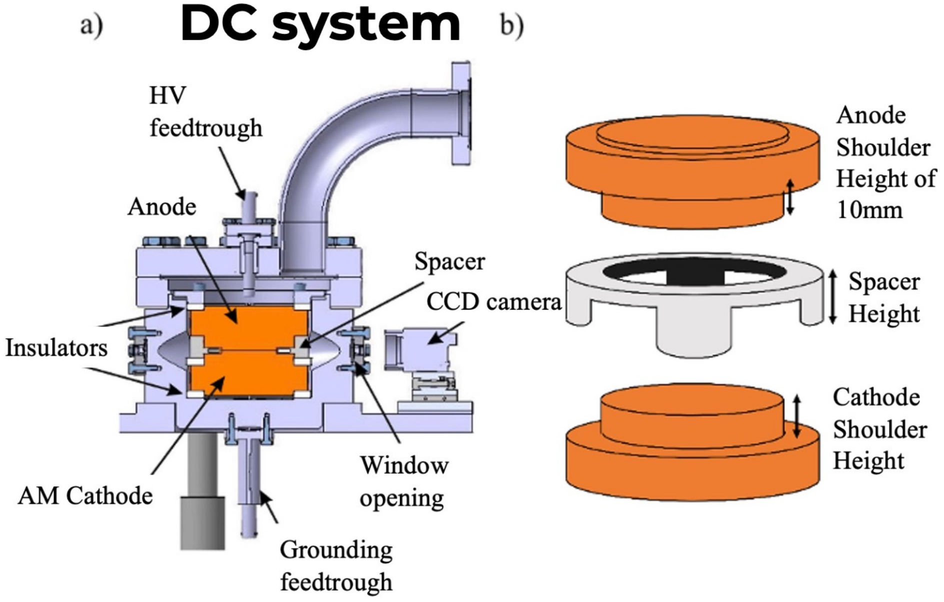
The leak detector threshold value is set at **$1 \cdot 10^{-10}$mbar·l·s^{-1}**

Thickness Z (mm)	Angle/Result (mbar/l/s^{-1})		
	45°	67°	90°
2.5	PASS	PASS	PASS
2	PASS	PASS	PASS
1.5	PASS	PASS	PASS
1	PASS	PASS	PASS
0.75	PASS	PASS	$1 \cdot 10^{-6}$
0.5	PASS	$2.5 \cdot 10^{-3}$	$5 \cdot 10^{-2}$

Thanks to CERN TE-VSC and Cedric GARION

High voltage holding test

CERN's pulsed high-voltage DC system



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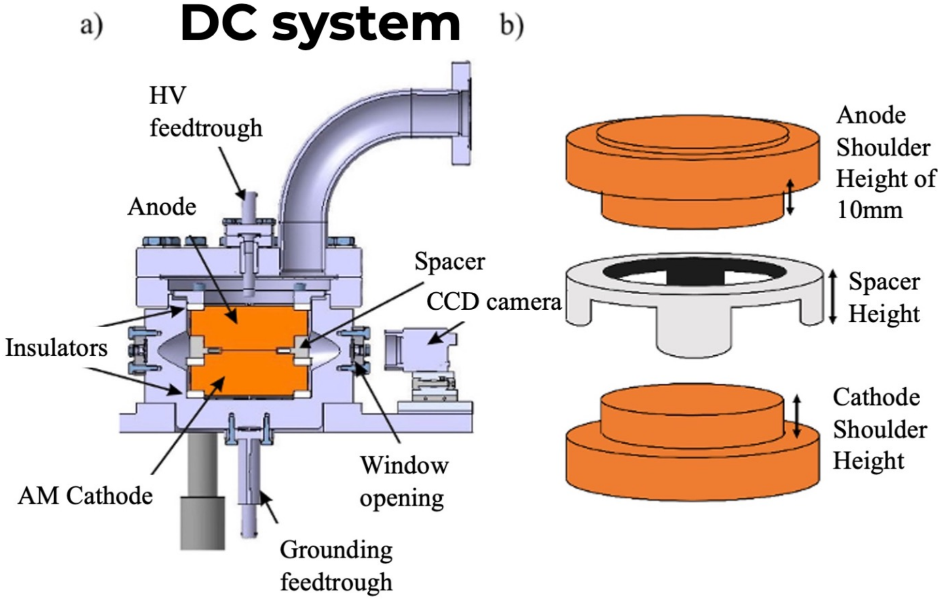
Thanks to CERN SY-RF team and Walter WUENSCH

High voltage holding test

HV characteristics are related to surface roughness values and chosen material, therefore, the aim is to clarify AM pure copper **surfaces performances in as-built conditions**.

CERN's pulsed high-voltage DC system



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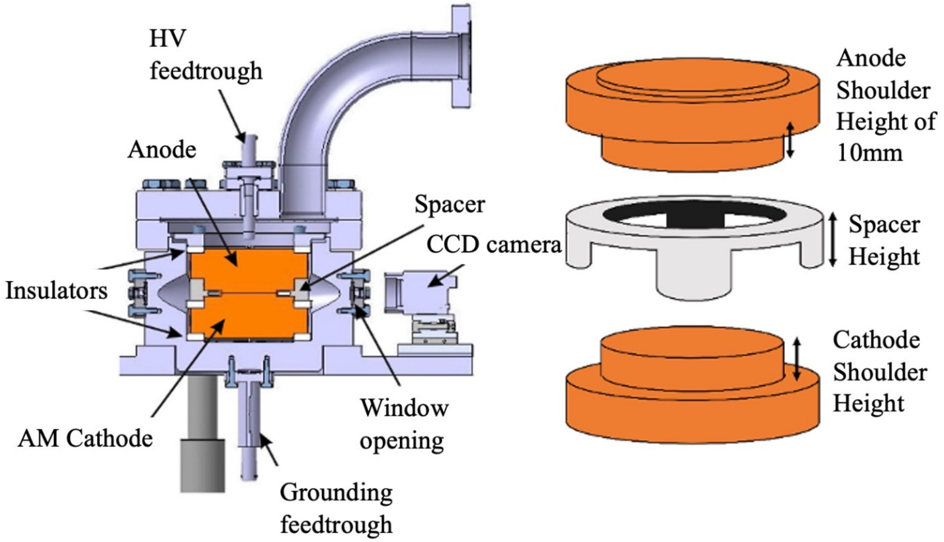
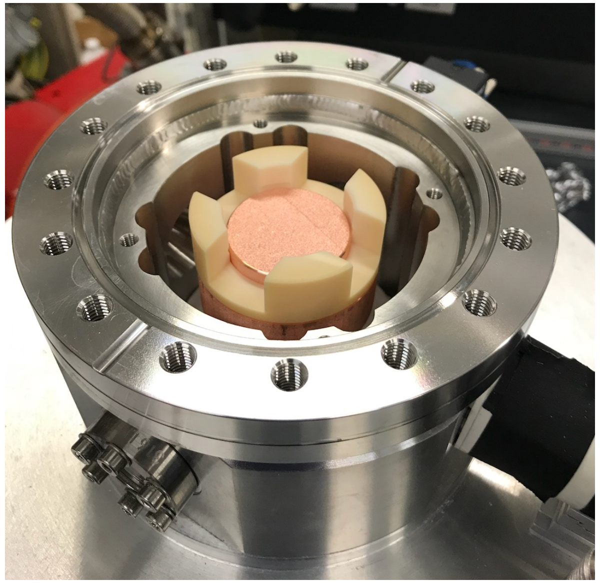
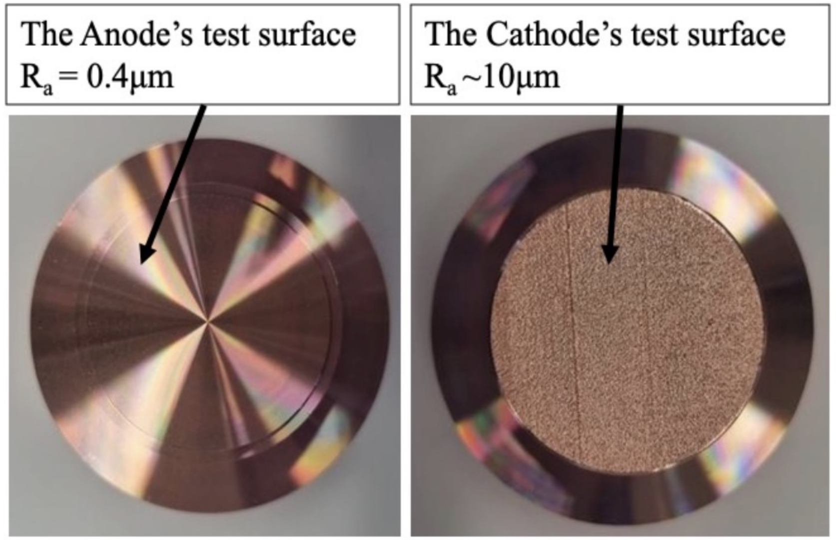
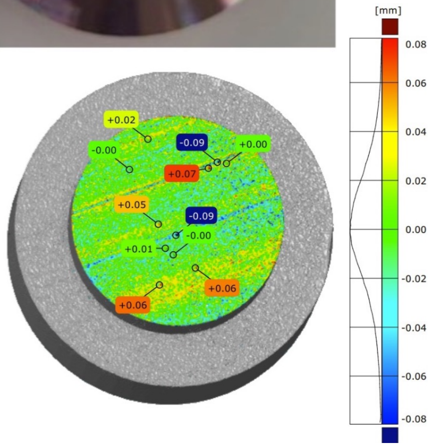






Ra = **8.28** ± 0.89 and **10.67** ± 1.16 µm
Rz = **42.10** ± 5.33 and **52.76** ± 7.56 µm
(two perpendicular measurements)



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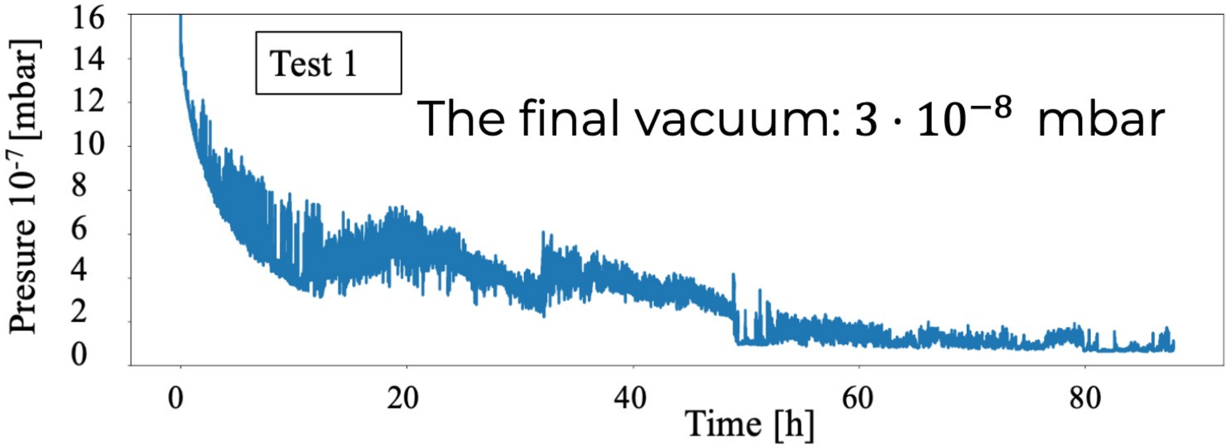
Thanks to CERN SY-RF team and Walter WUENSCH

High voltage holding test

Initial results: Test 1 (Gap 270μm)

Vacuum pumdown



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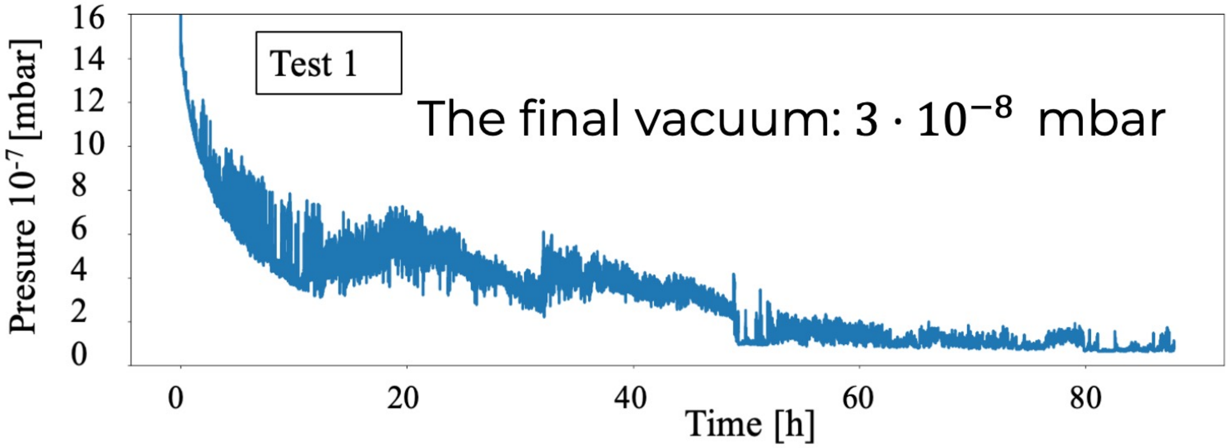
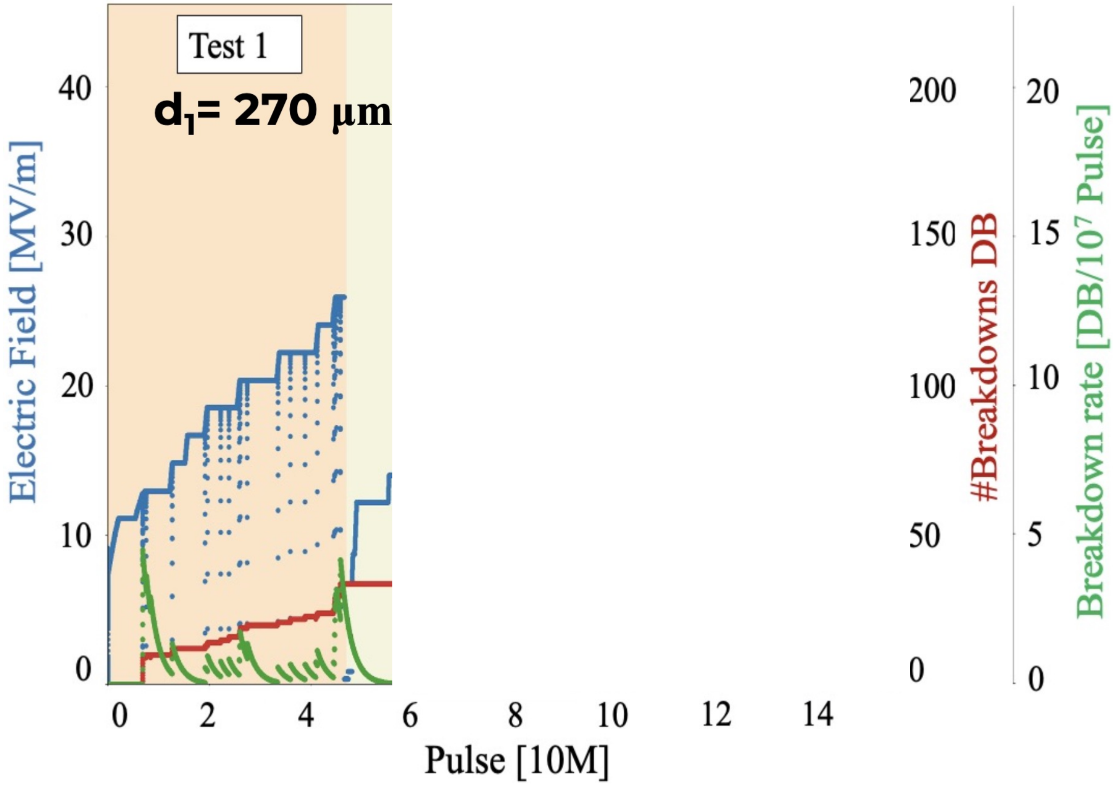


HV holding test



Test 1 reached a stable **26 MV/m** (equivalent to the system maximum voltage of 7 kV)

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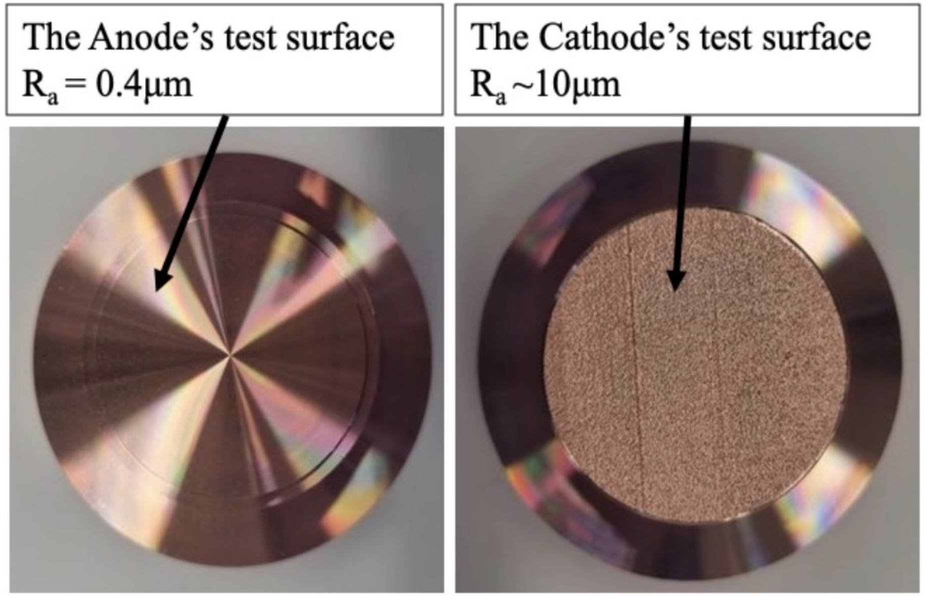
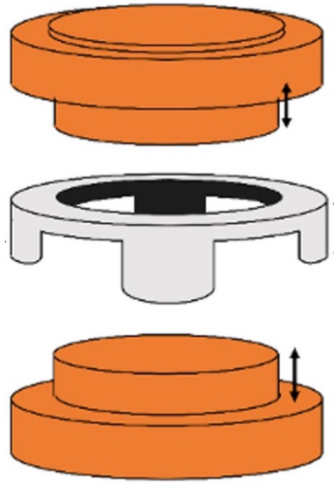
Thanks to CERN SY-RF team and Walter WUENSCH

High voltage holding test

Initial results: Test 2 (Gap 115μm)

Gap reduction by remachining shoulder hight





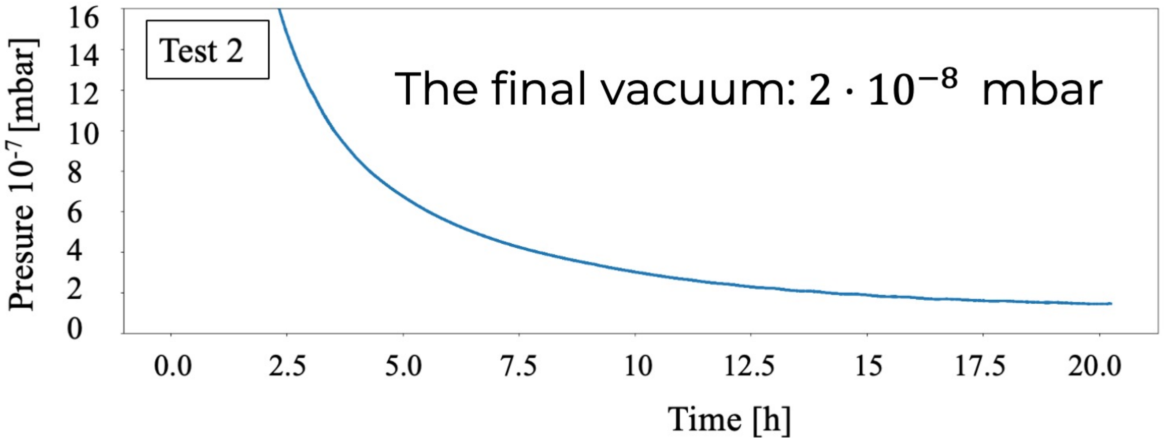
The same preconditioned cathode and anode were used for test 2

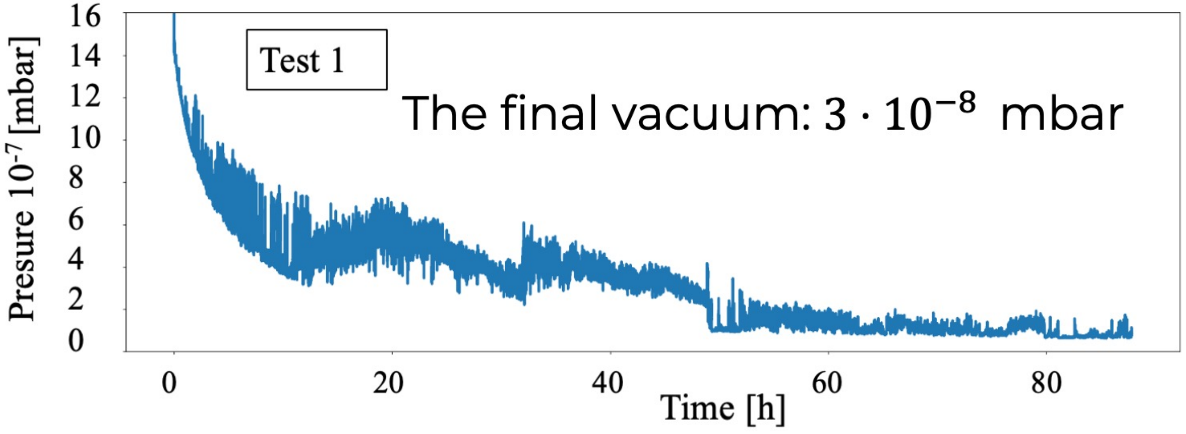
Thanks to CERN SY-RF team and Walter WUENSCH

High voltage holding test

Initial results: Test 2 (Gap 115μm)

Vacuum pumdown





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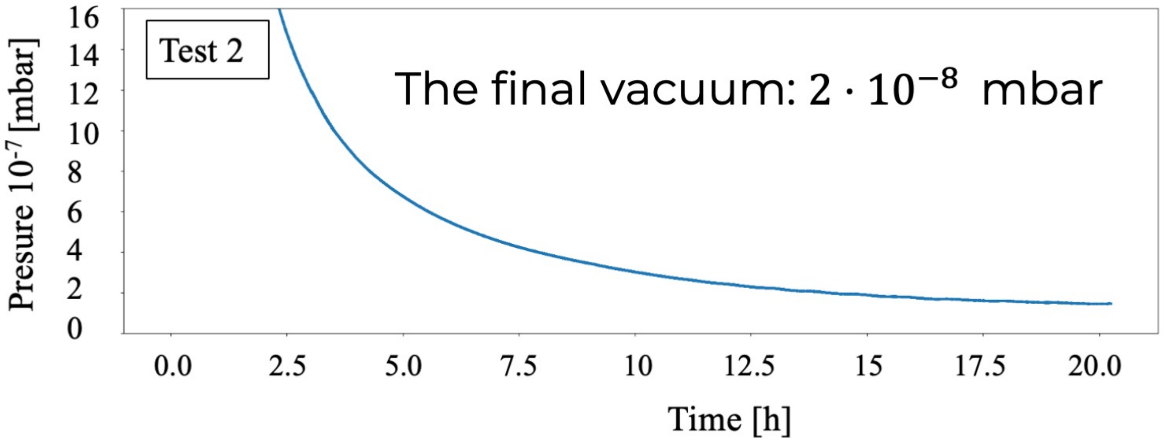
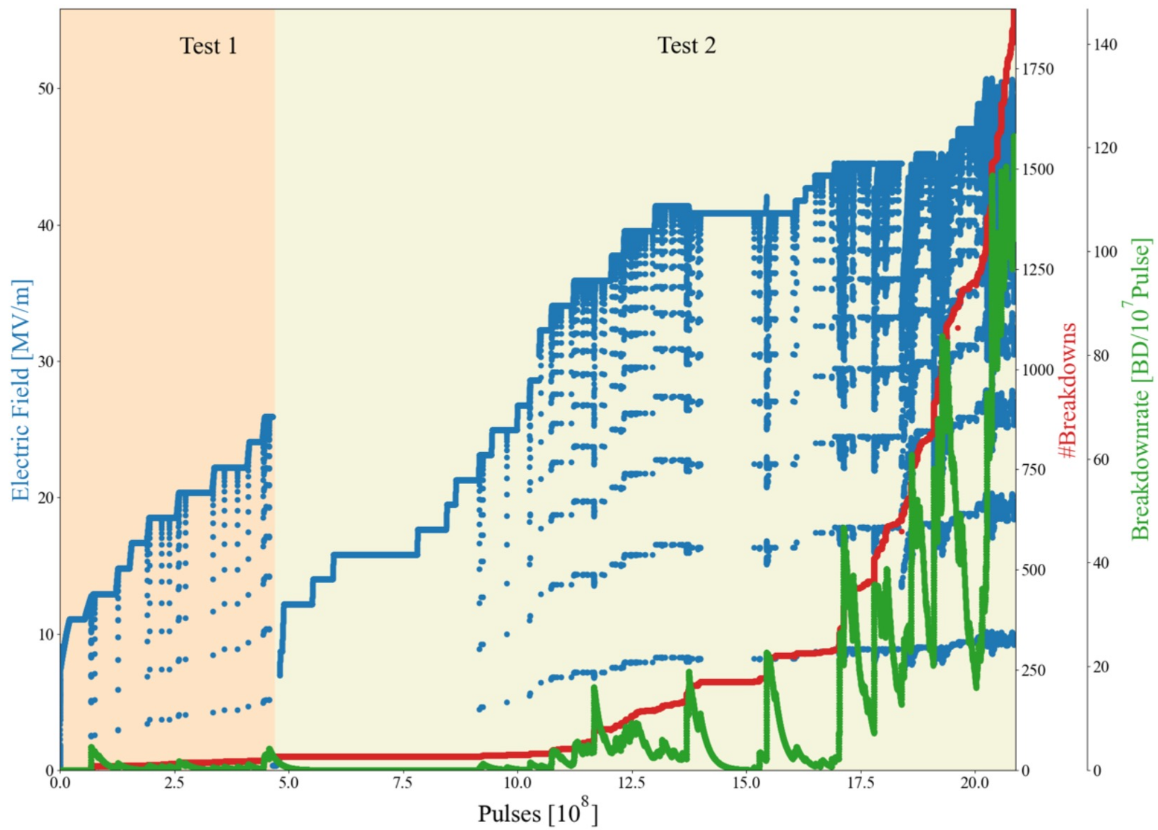


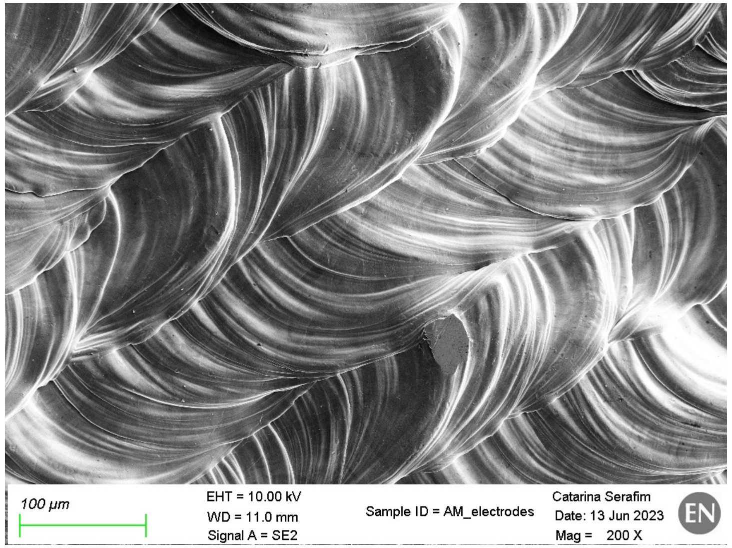
HV holding test

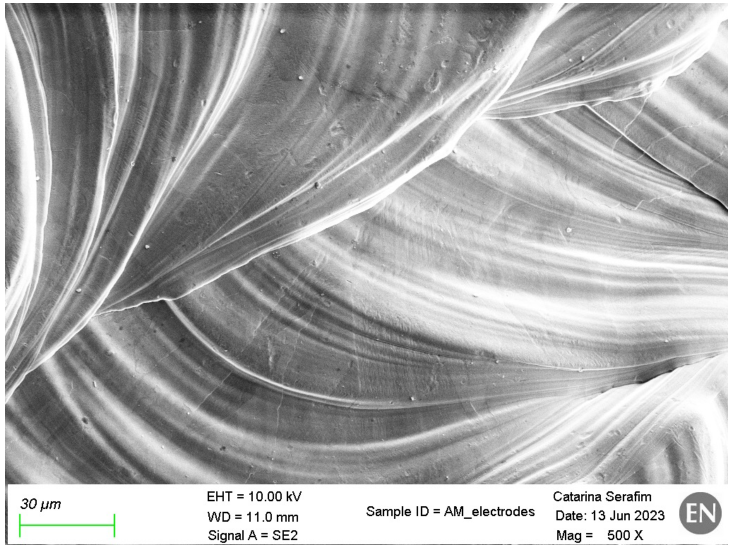


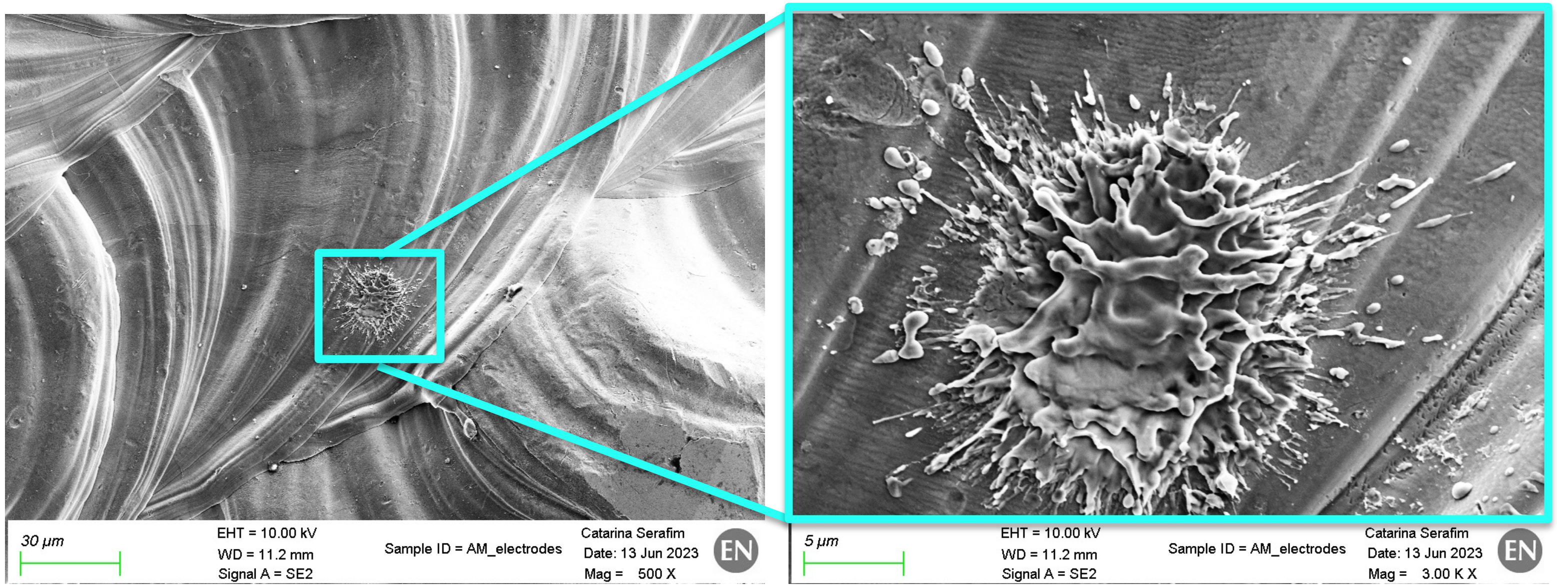
Electrical Field reached a stable **50 MV/m;**
(**40 MV/m** corresponds to the operating conditions of **the compact 750 MHz RFQ design of CERN)**

Thanks to CERN SY-RF team and Walter WUENSCH

High voltage holding test







Courtesy: C. Serafim

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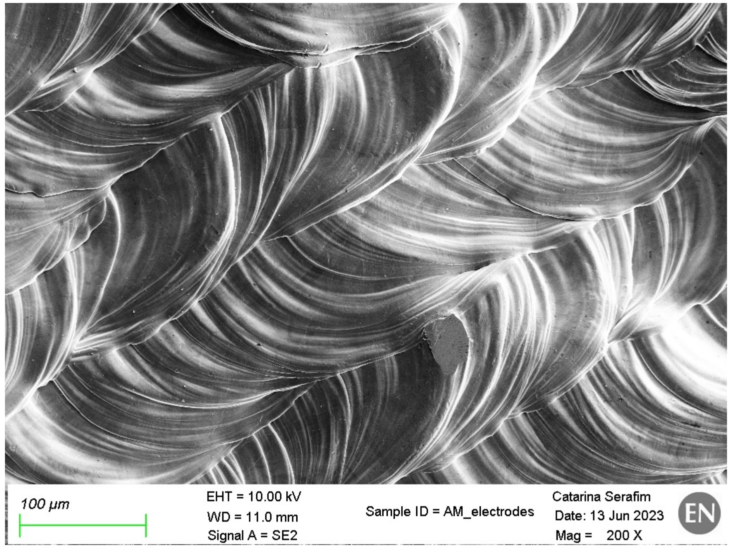
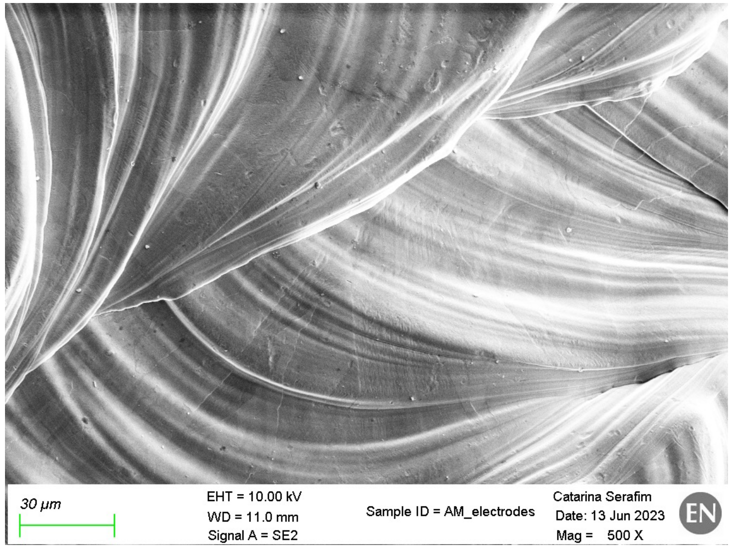
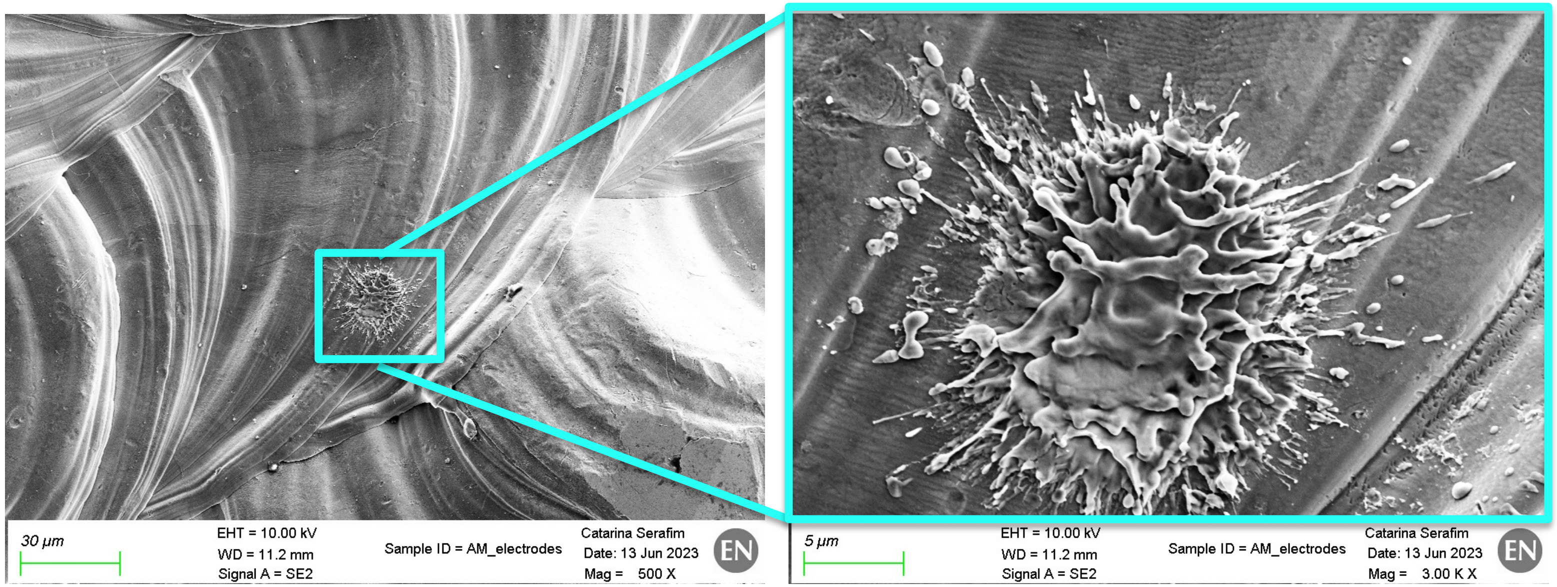
High voltage holding test







Courtesy: C. Serafim

Further tests with:

- Smaller gap height – 60μm;
- HV Tests after surface post-processing;
- Test of built direction and laser source influence

Thanks to CERN SY-RF team and Walter WUENSCH

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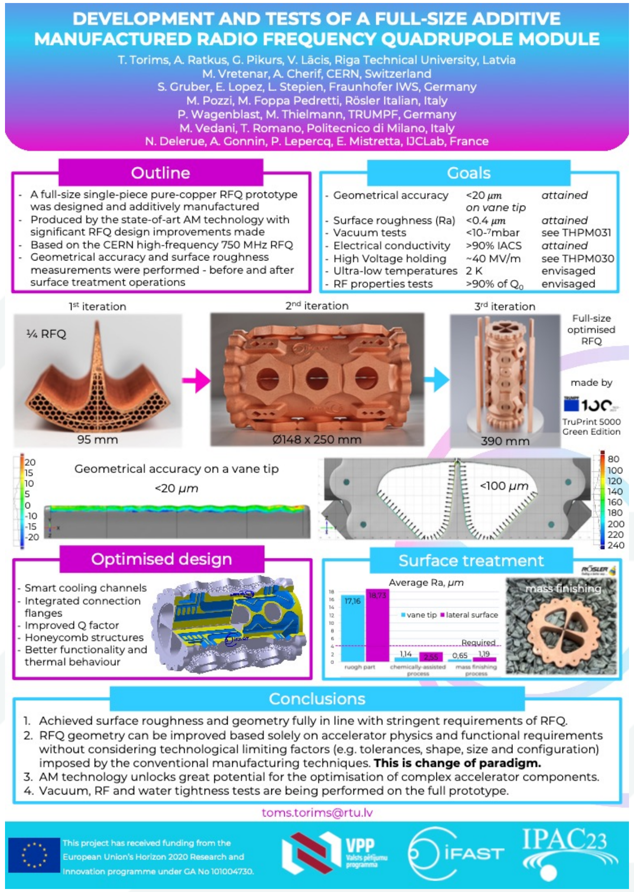
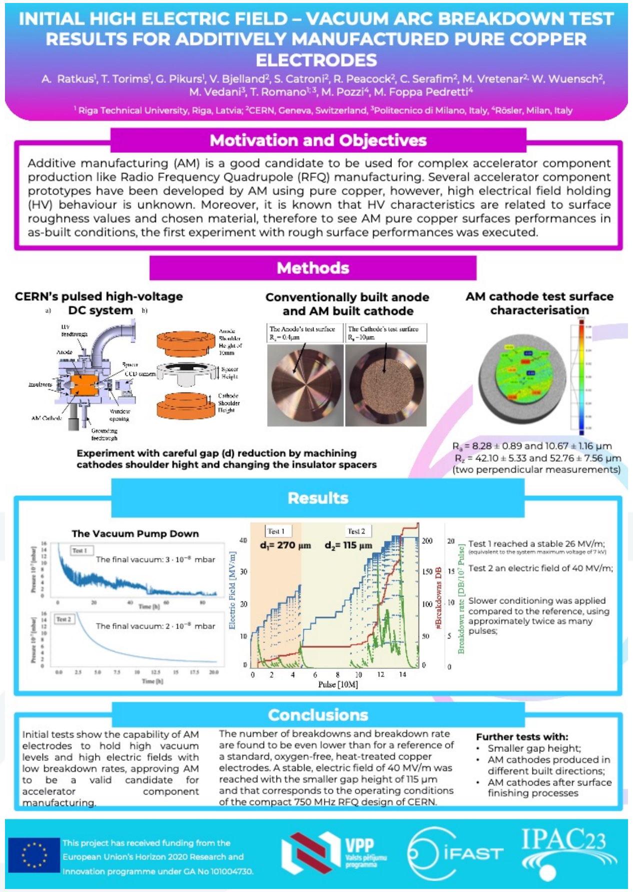
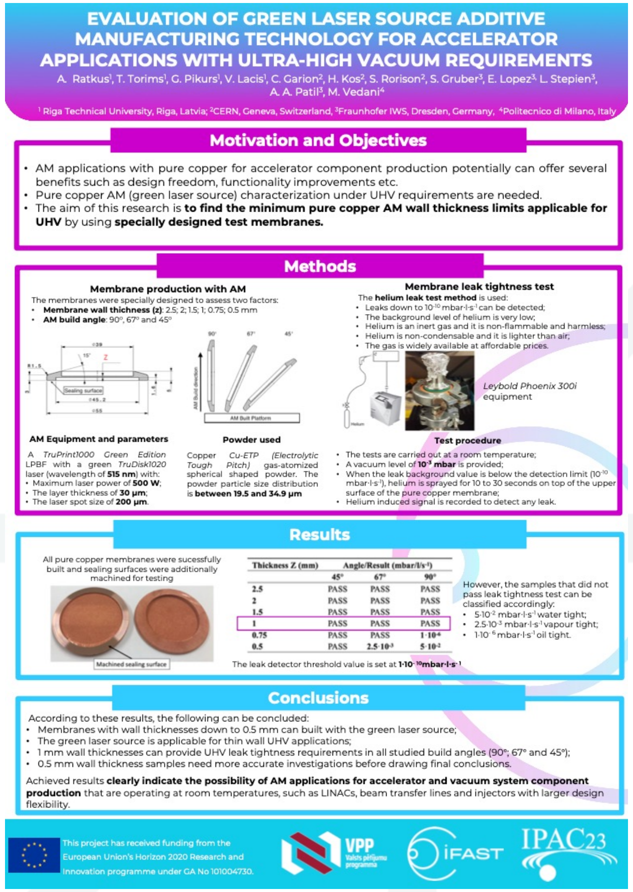
Results

3 Posters

2 Publications







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IPAC'23 Proceedings: https://www.ipac23.org/preproc/index.html

Thank you!