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Precision and surface roughness of the AM-built RFQ prototype

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M. Vedani, Politecnico di Milano
N. Delerue, IJCLab
T. Otto, TalTech

iFAST

IPAC 2022

AM technology

Additive Manufacturing is a primary shaping process

"Fabrication of a solid body from a shapeless material through cohesion"

... or simply...

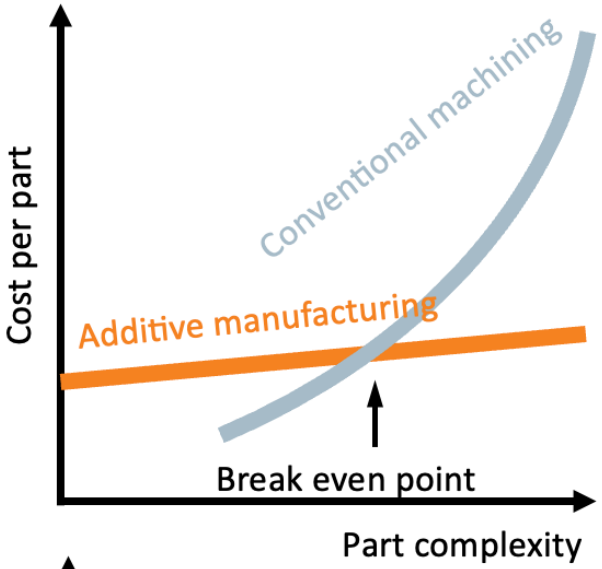
"...a process in which 3D bodies are manufactured in a layer-wise fashion"

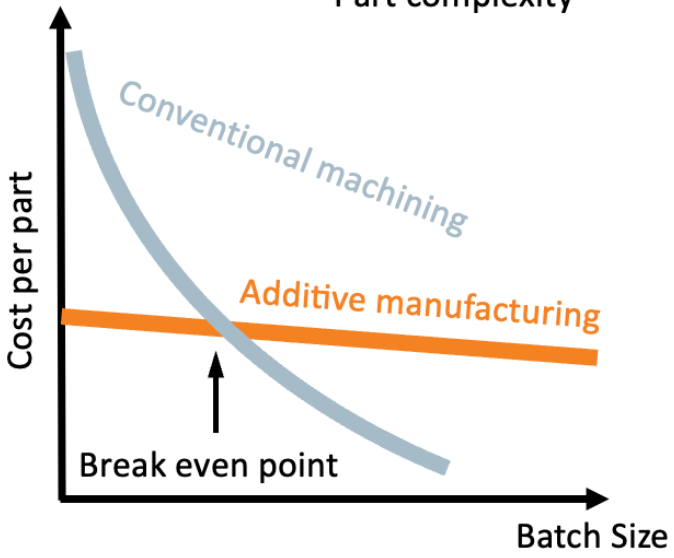
Lukas Stepien @ I.FAST AM workshop '22

AM technology solutions

+ From micro to macro
+ Multilaterals
+ Economic production of complex parts
+ High material utilization
+ Individualization
+ Optimization and redesign
+ In-situ monitoring
+ Density up to 99.99 %

– **Geometrical accuracy** - close to net-shape
– **Surface roughness**
– Sensitive process chain
– Anisotropic material properties
– Support structures needed
– Fabrication speed is comparatively low - productivity ~ 20 - 170 cm^3/ h
– Build size 800 x 400 x 500 mm^3 (l x w x h)





AM in accelerator community

Guntis Pikurs @ I.FAST AM workshop ‘22

Challenges within accelerators

Vacuum, cryo, RF: leak tightness, outgassing rate, porosity, electrical conductivity

Size limitations of machines and available simulation tools

Materials: ultra-clean, chemical purity – still limited avaliability, flow properties

Accuracy: surface roughness, tolerances, geometry precision

Radiation impact and activation

AM technological specificities an optimisation to end requirments (RF, cryo, etc.)

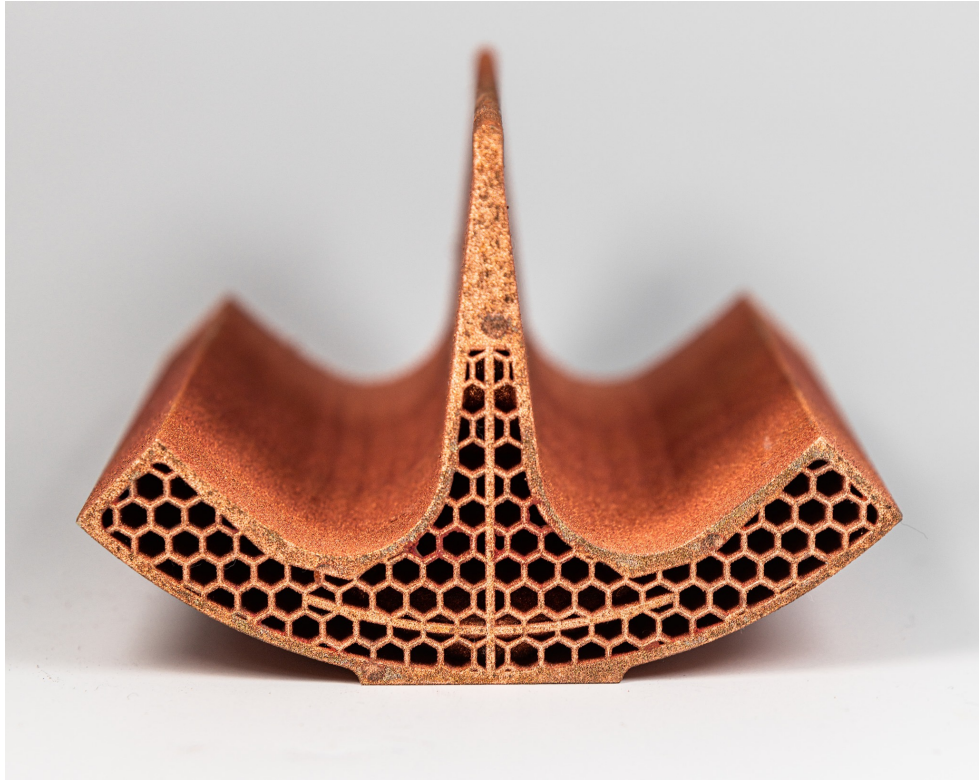
Microstructure uniformity, residual stresses, inclusions, voltage holding

Potential post-processing and eventual hybrid-machining

Yet most importantly: **traditionalism, lack of knowledge, and scepticism on AM compliance with the stringent accelerator requirements**

¼ RFQ prototype

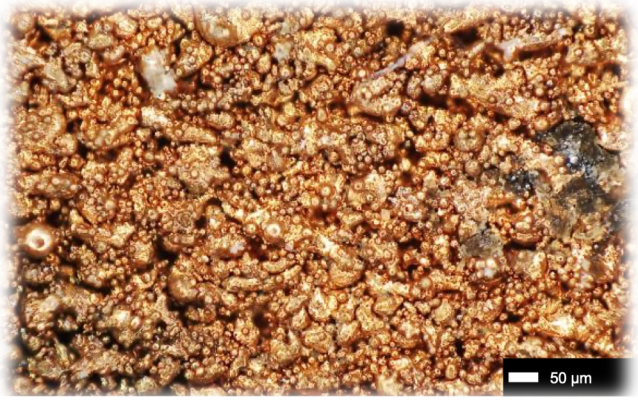
The first prototype by AM pure-copper RFQ



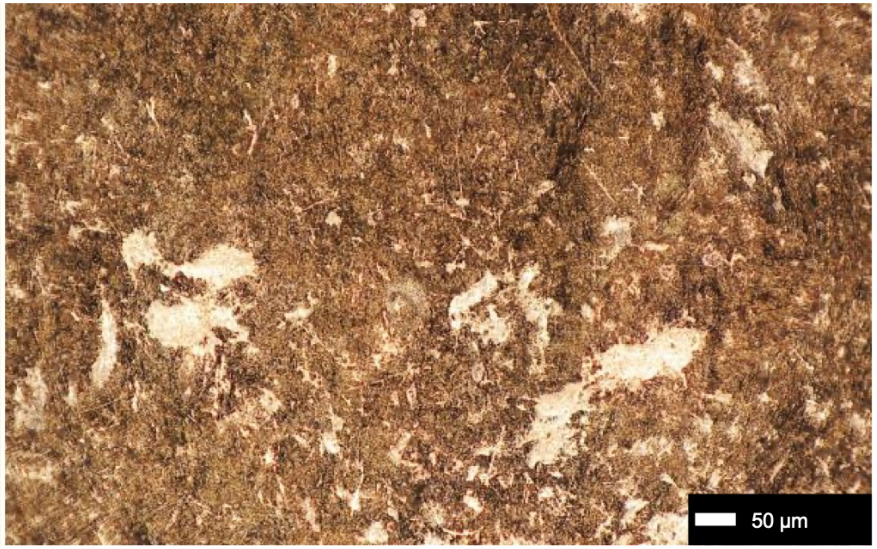
- AM design and optimisation
- Manufacturing – July 2021
- Measurements:
  - ⇨ geometrical precision
  - ⇨ surface roughness
- Results published – Nov 2021
- Post-processing – Mar/Apr 2022
- measurements after post-processing – Apr 2022

Post-processing of ¼ RFQ

1. Conventional surface mass finishing
2. Chemically assisted surface finishing
3. High precision surface finishing with MMP TECHNOLOGY®

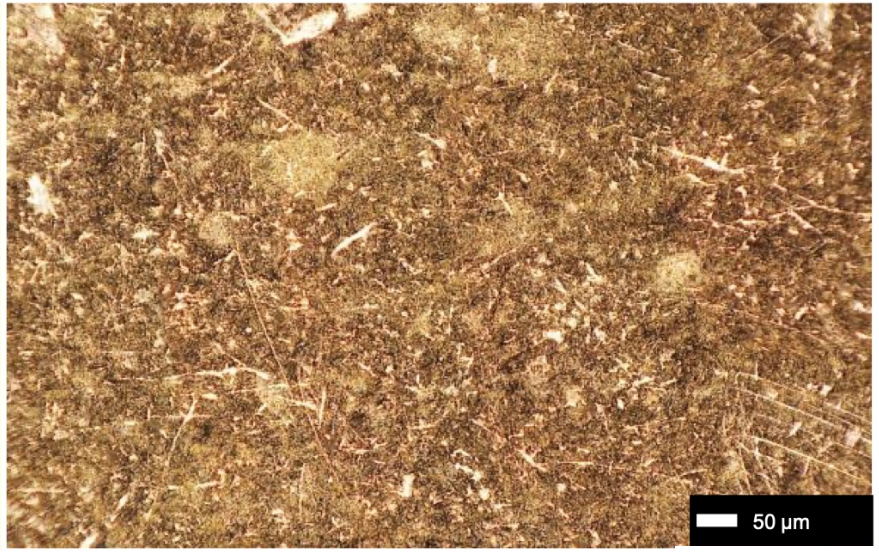


#1: mechanical treatment



Ra (µm)
0,28 ± 0,12
Rz (µm)
2,09 ± 0,89

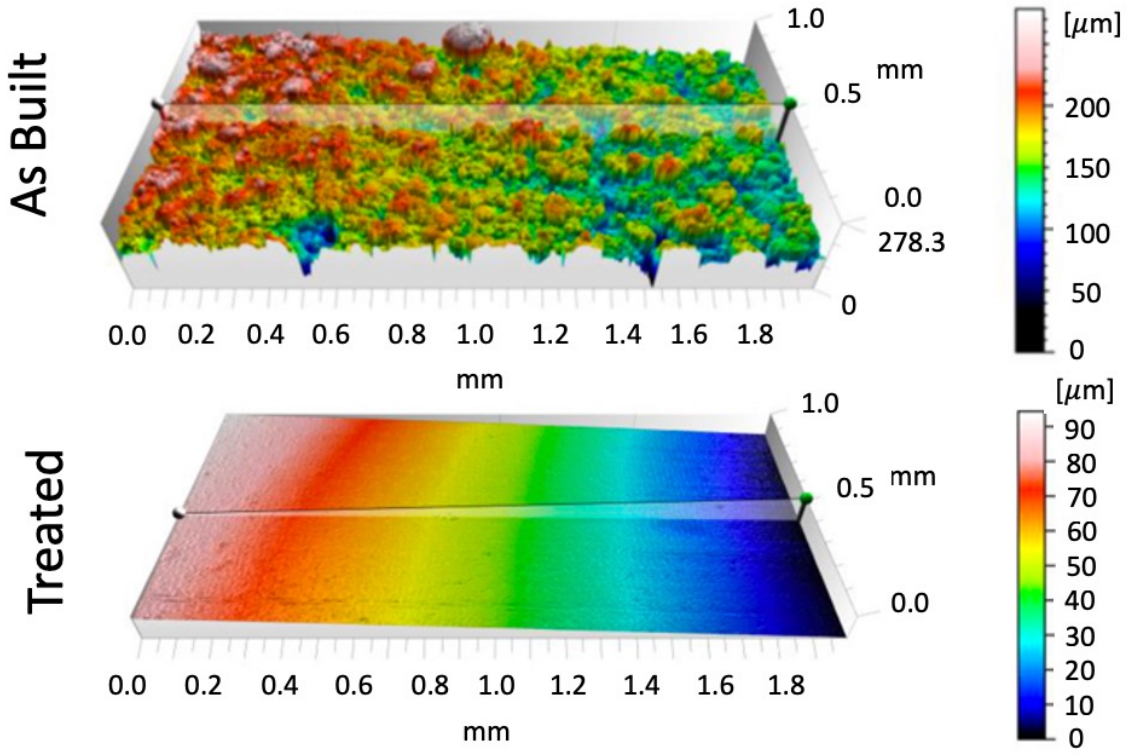
#2: chemically assisted process



Ra (µm)
0,28 ± 0,09
Rz (µm)
1,56 ± 0,50

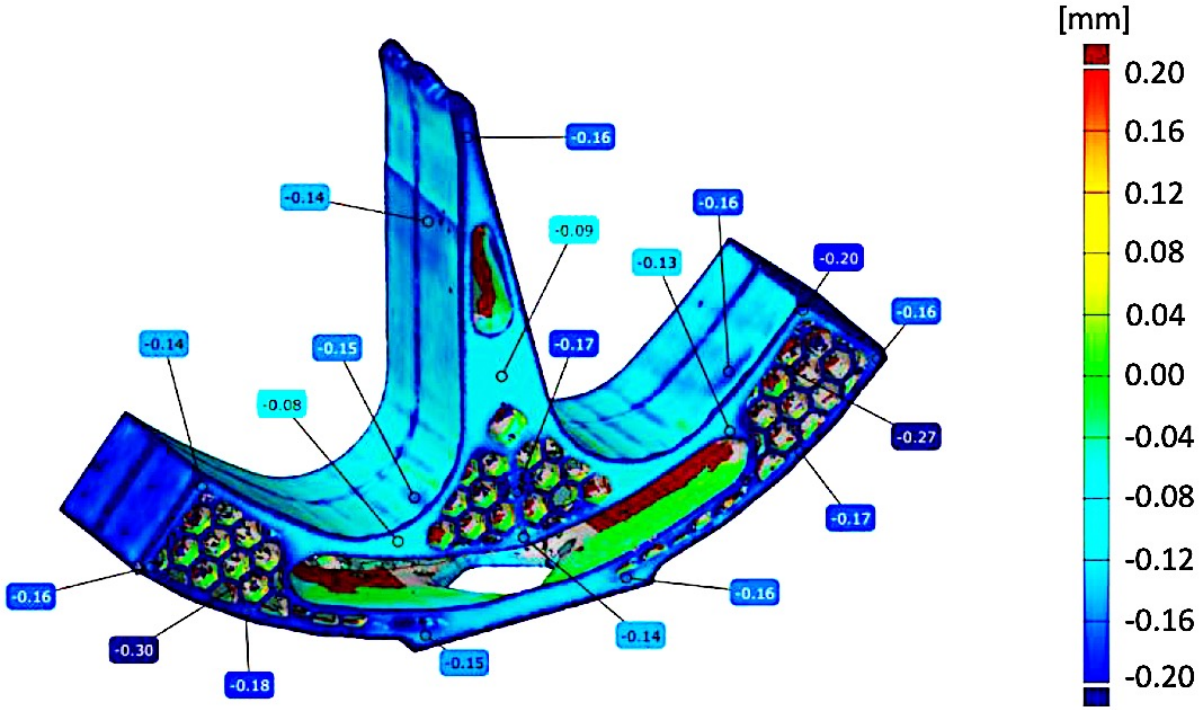
Surface roughness before and after post-processing

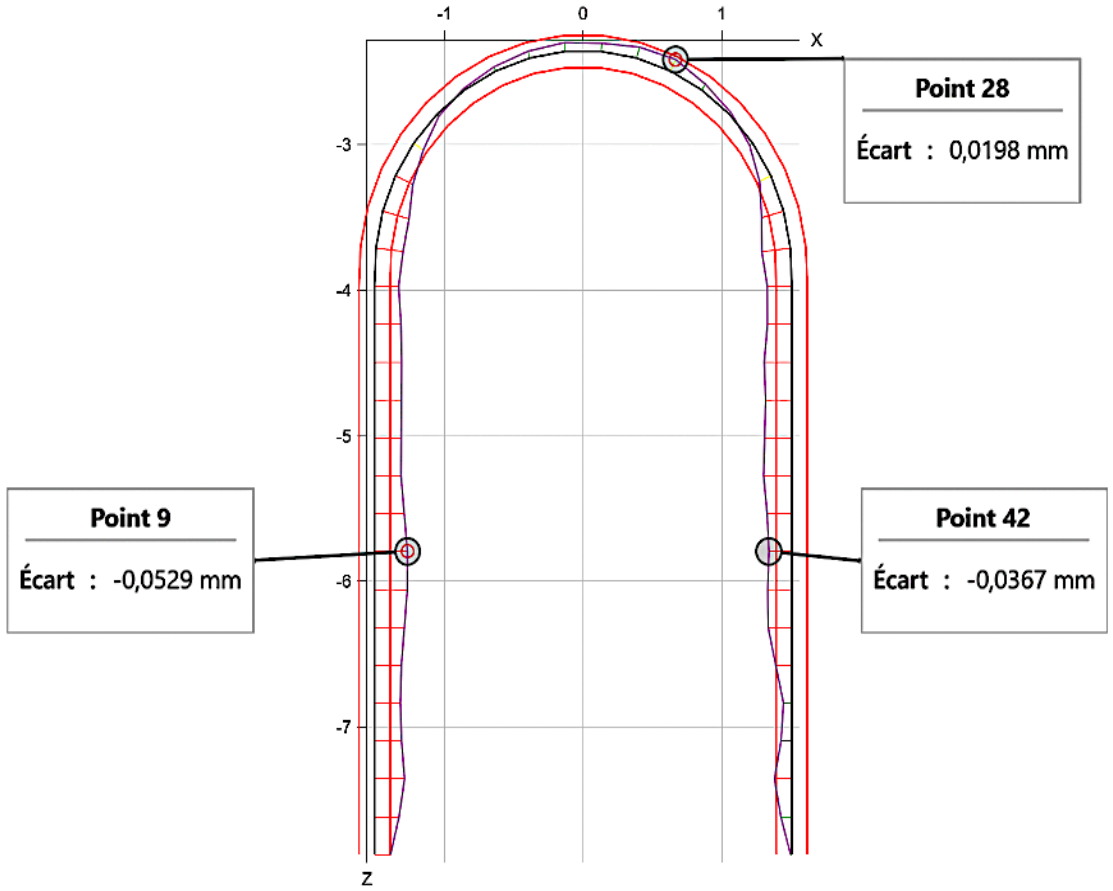
Post processing method	Side	R_a, µm	R_z, µm
Before post-processing		13.82	48.86
Trad. mass finishing	A	0.09	0.83
	B	0.07	0.58
Chemically assisted	A	0.07	0.67
	B	0.12	0.97
MMP TECHNOLOGY®	A	0.30	3.24
	B	0.11	1.03
Target roughness		0.4	not set



Attained geometrical accuracy

Target values:
- 20 µm on vane-tip
- 100 µm elsewhere





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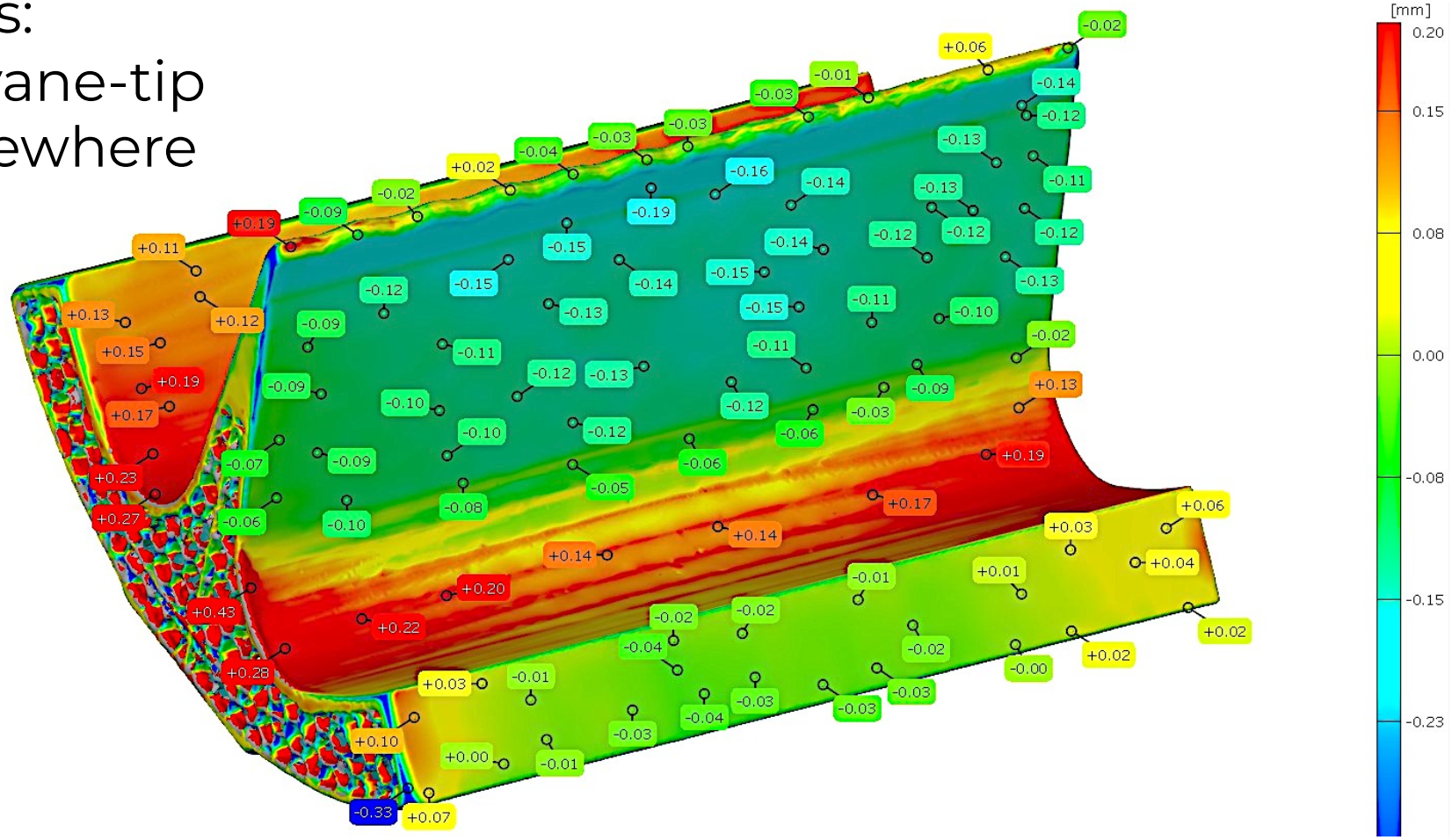
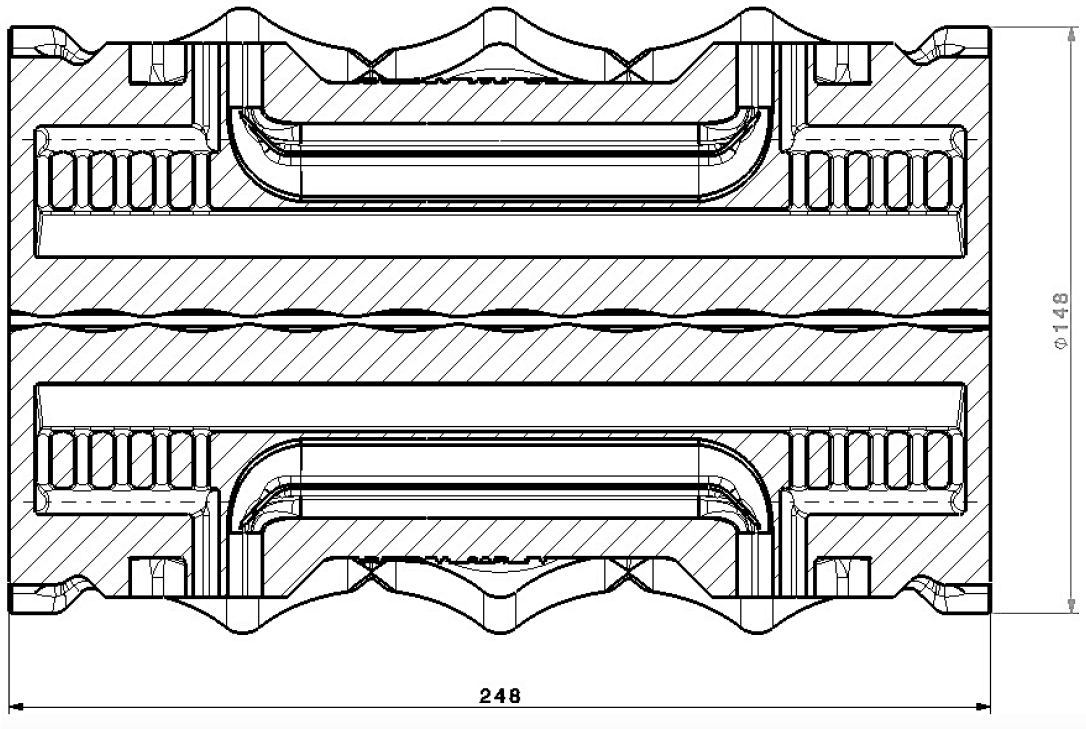
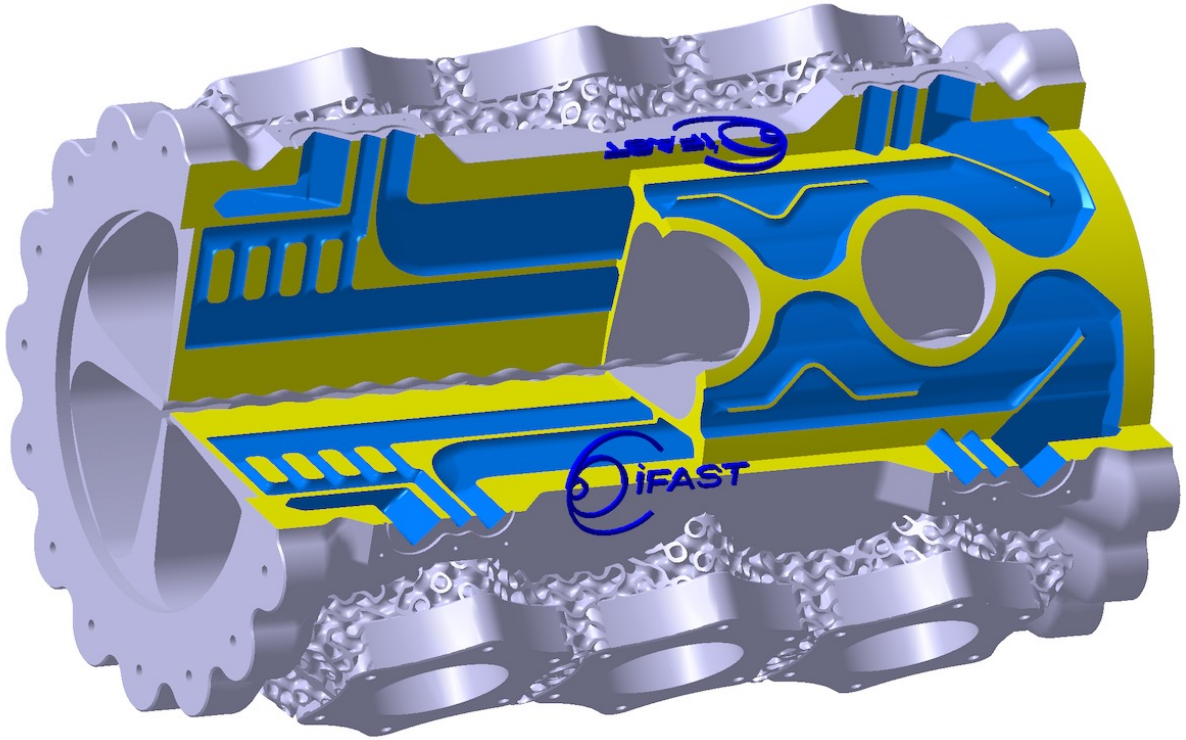


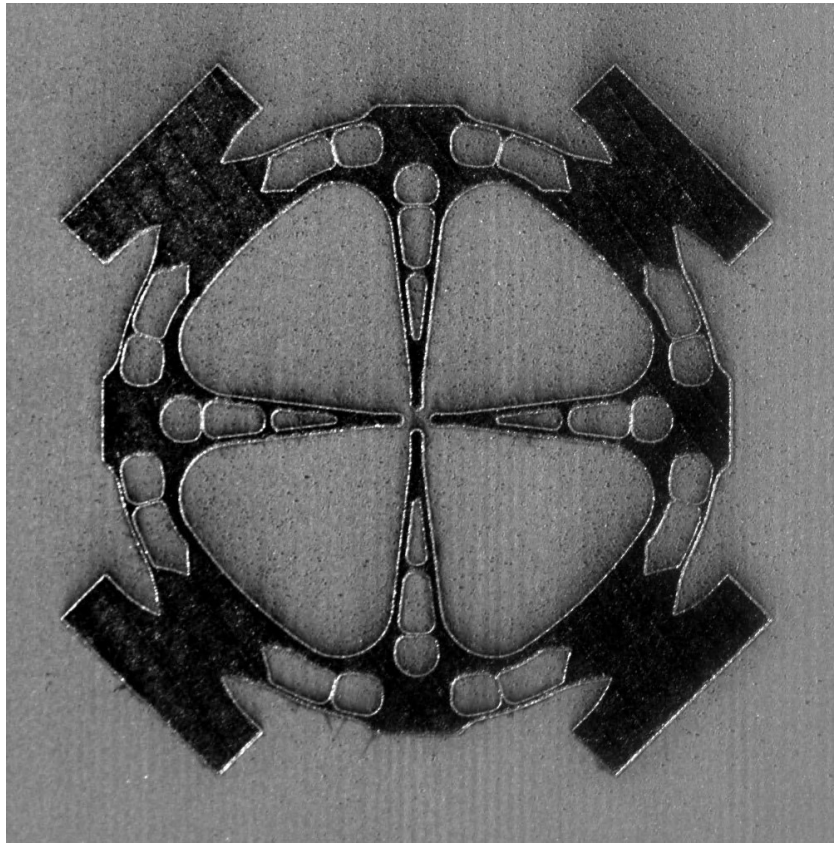
AM produced full-size RFQ module

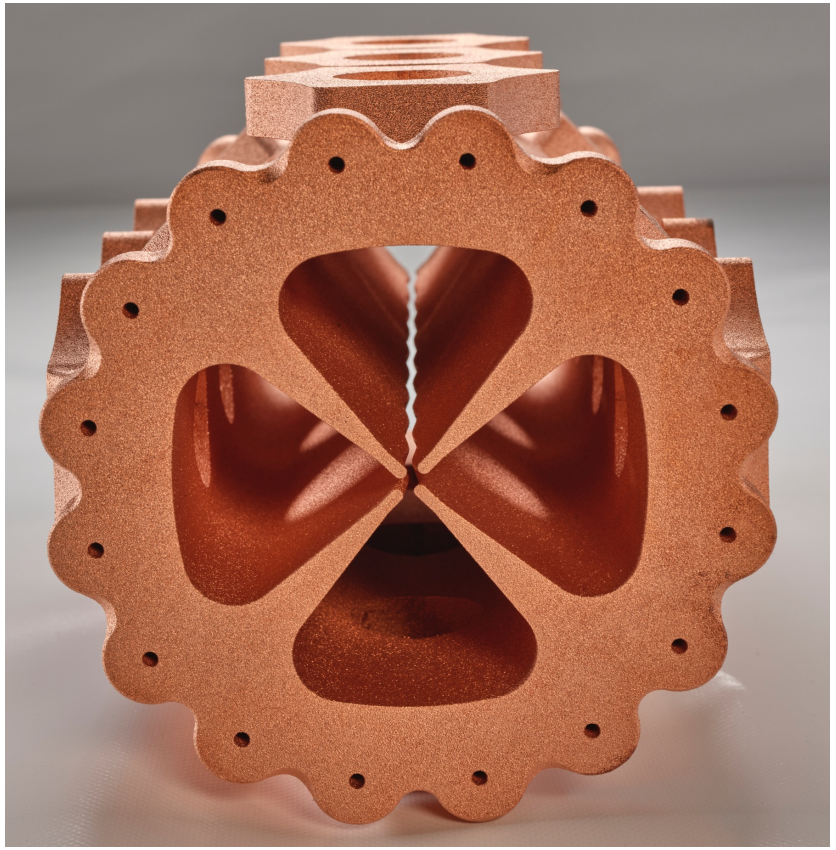
Optimisation of design - thanks to AM





Enabling complex designs





AM produced full-size RFQ module

- Manufacturing – May 2022
- Measurements – June 2022

Next steps

Tests of the full RFQ module

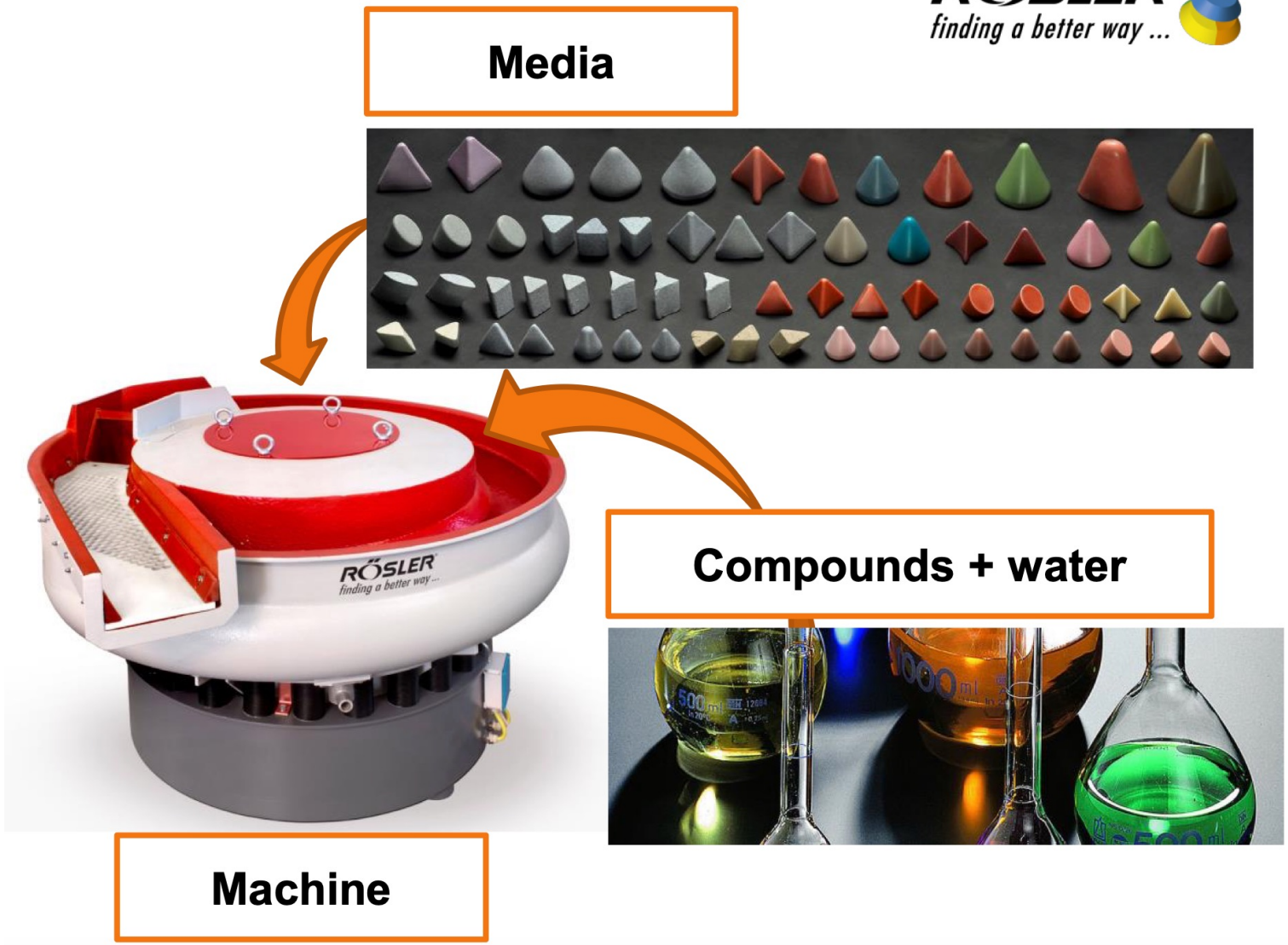
- Comprehensive geometrical accuracy and surface roughness measurements @ CERN
- Vacuum, watertightness, and RF tests at IJCLab
- RFQ module has been designed and equipped with the flanges and orifices enabling these tests

Post-processing of full RFQ

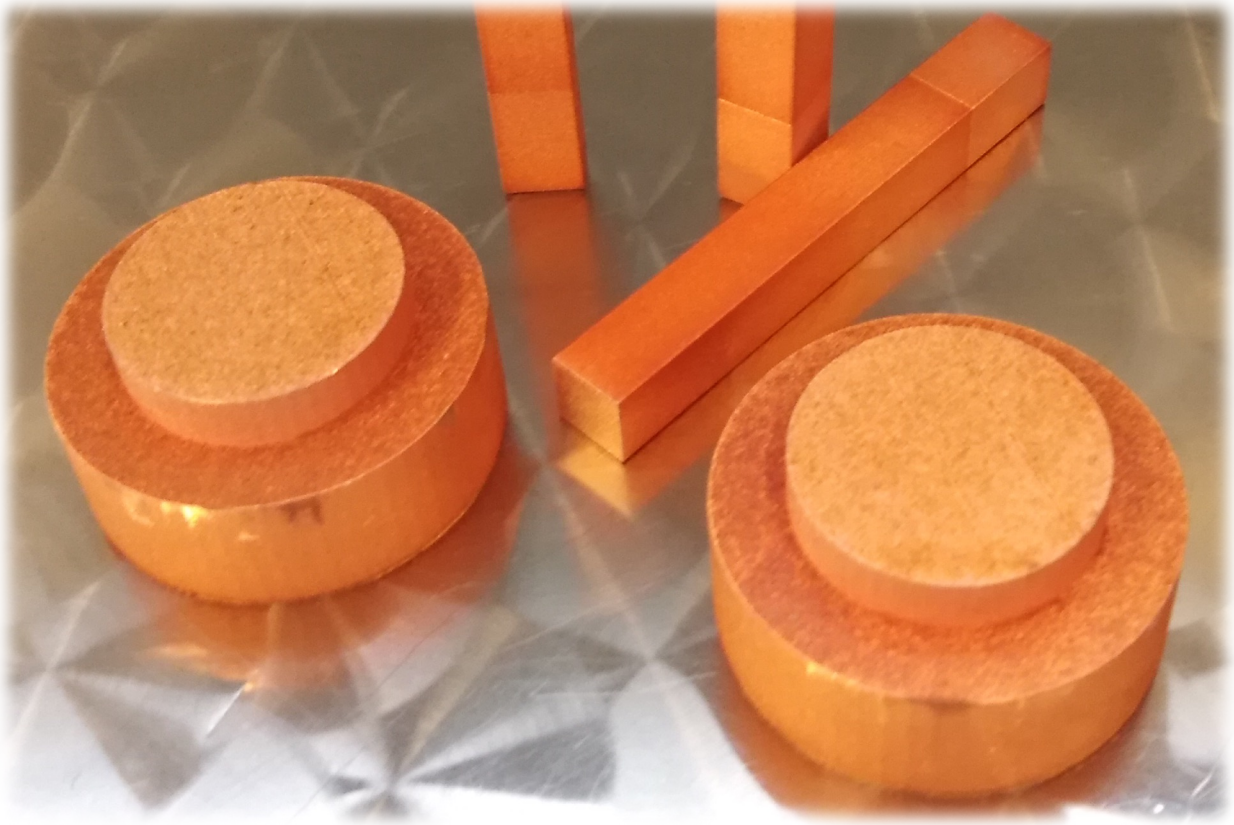
Surface engineering:

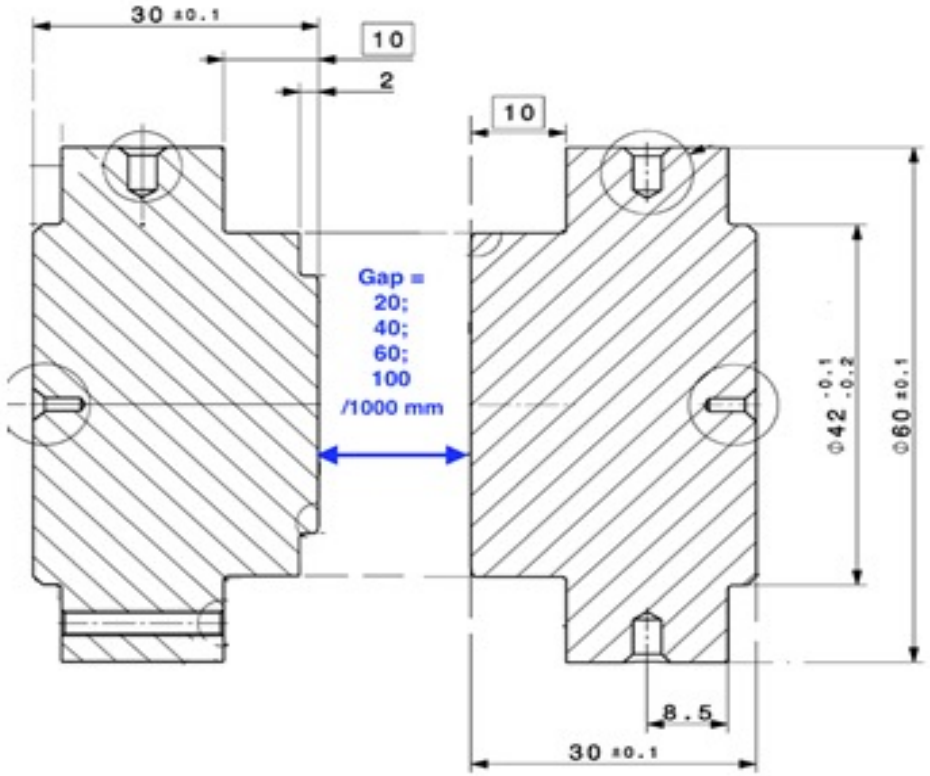
1. Conventional surface mass finishing
2. Chemically assisted surface finishing
3. High precision surface finishing

With subsequent full set of measurements



High Voltage Holding tests @ CERN

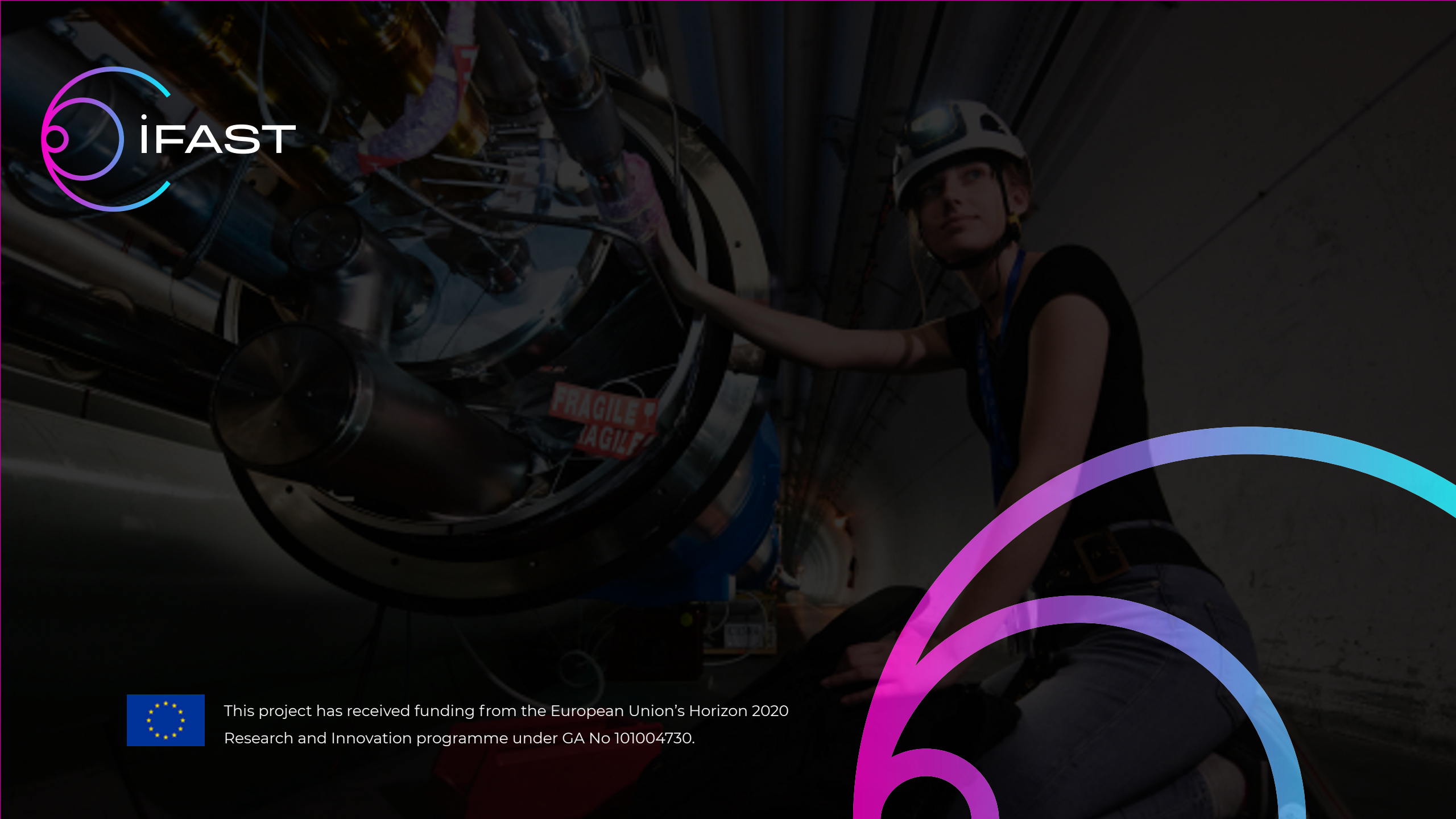




Anode Cathode

AM change of paradigm

- Our community is having new design opportunities
- e.g. RFQ braze-less manufacturing
- Multi-materials are possible
- Hybrid machining options
- Is vastly used by other communities and industries
- Ideal for small quantities high complexity and precision
- Technology is developing rapidly and is accessible



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