This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

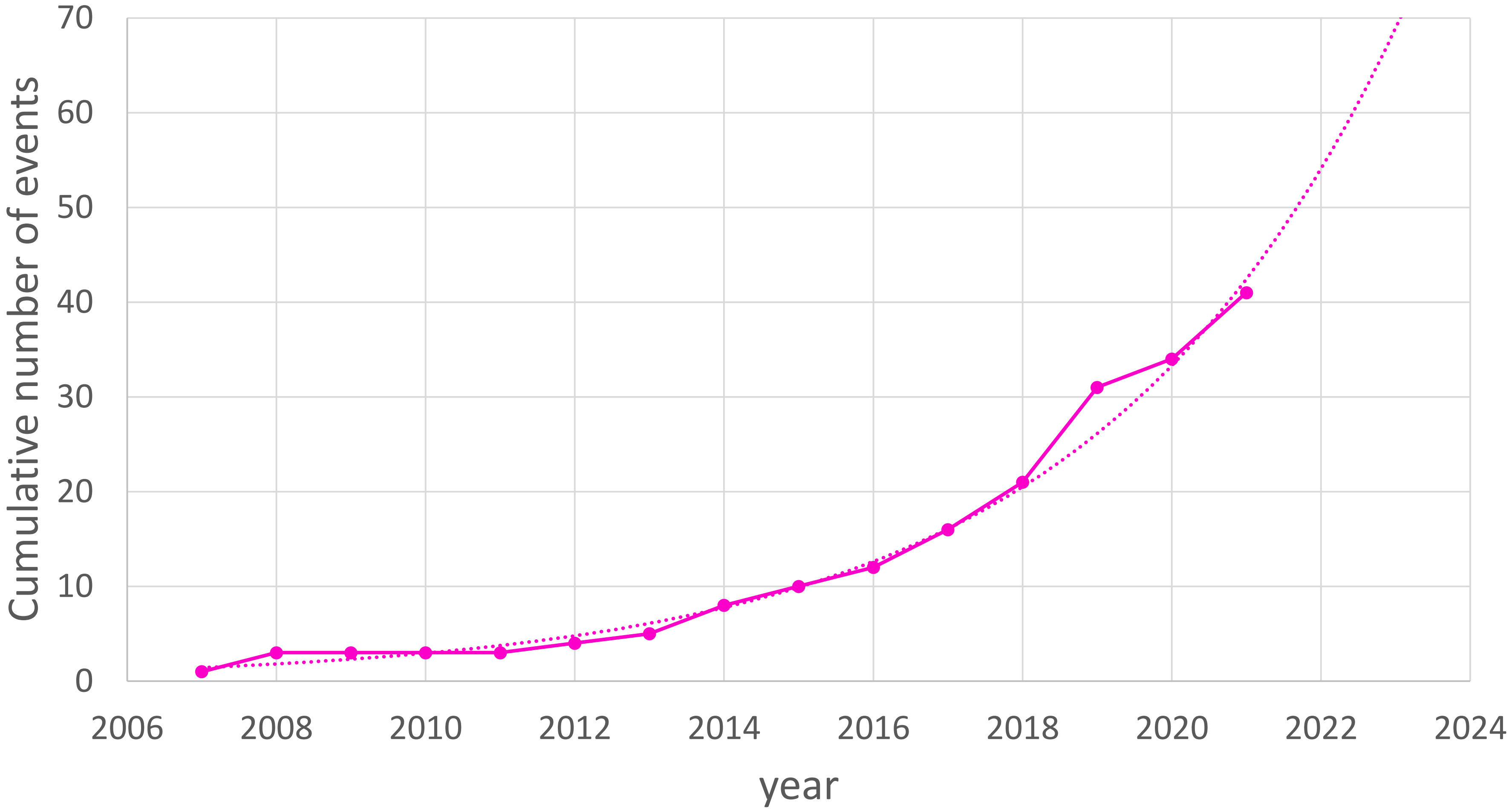
Additive Manufacturing applied to Particle Accelerators

9th meeting of the I.FAST WP10 18/03/2022, Paris

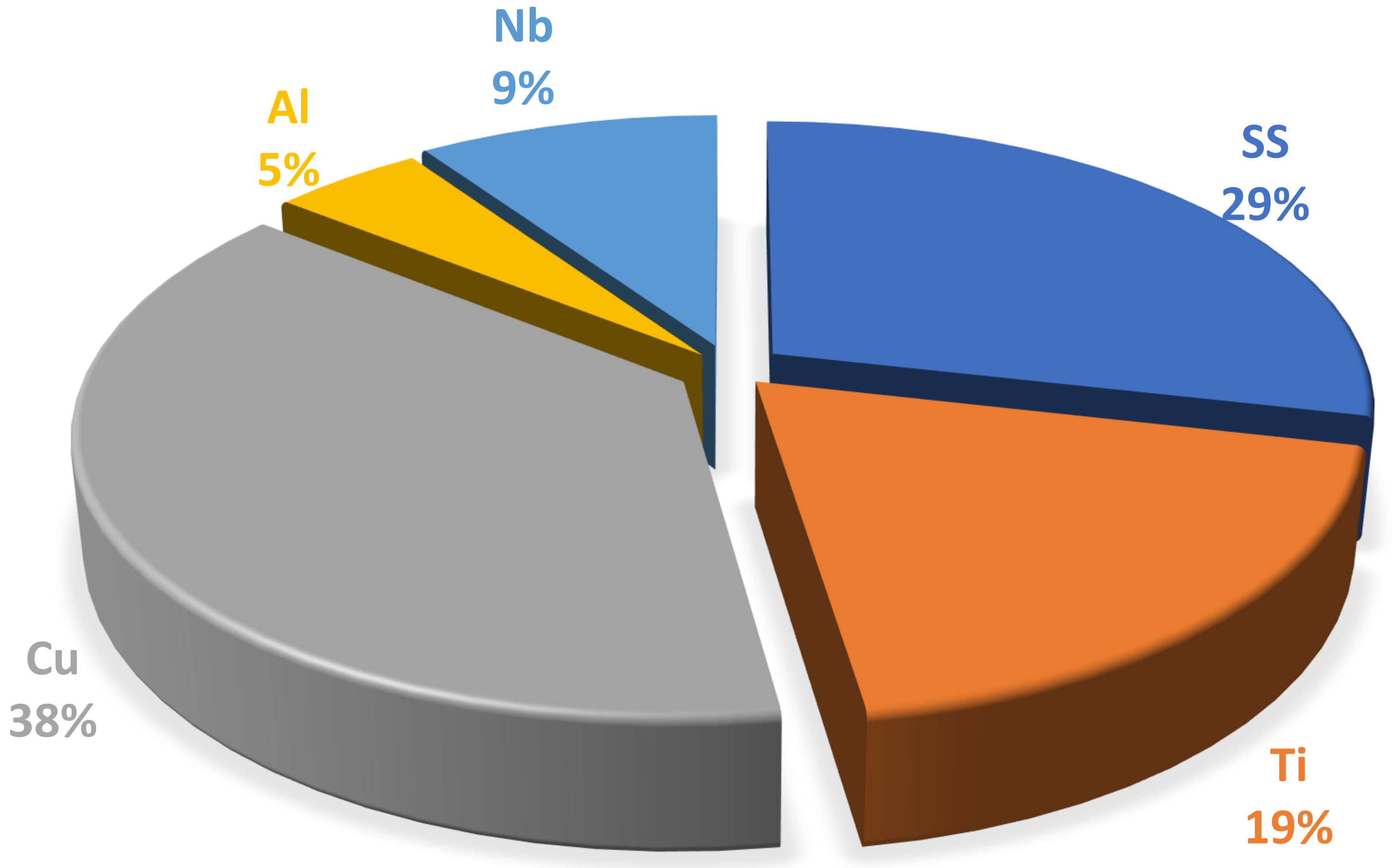
PhD student Guntis Pikurs(RTU)

iFAST

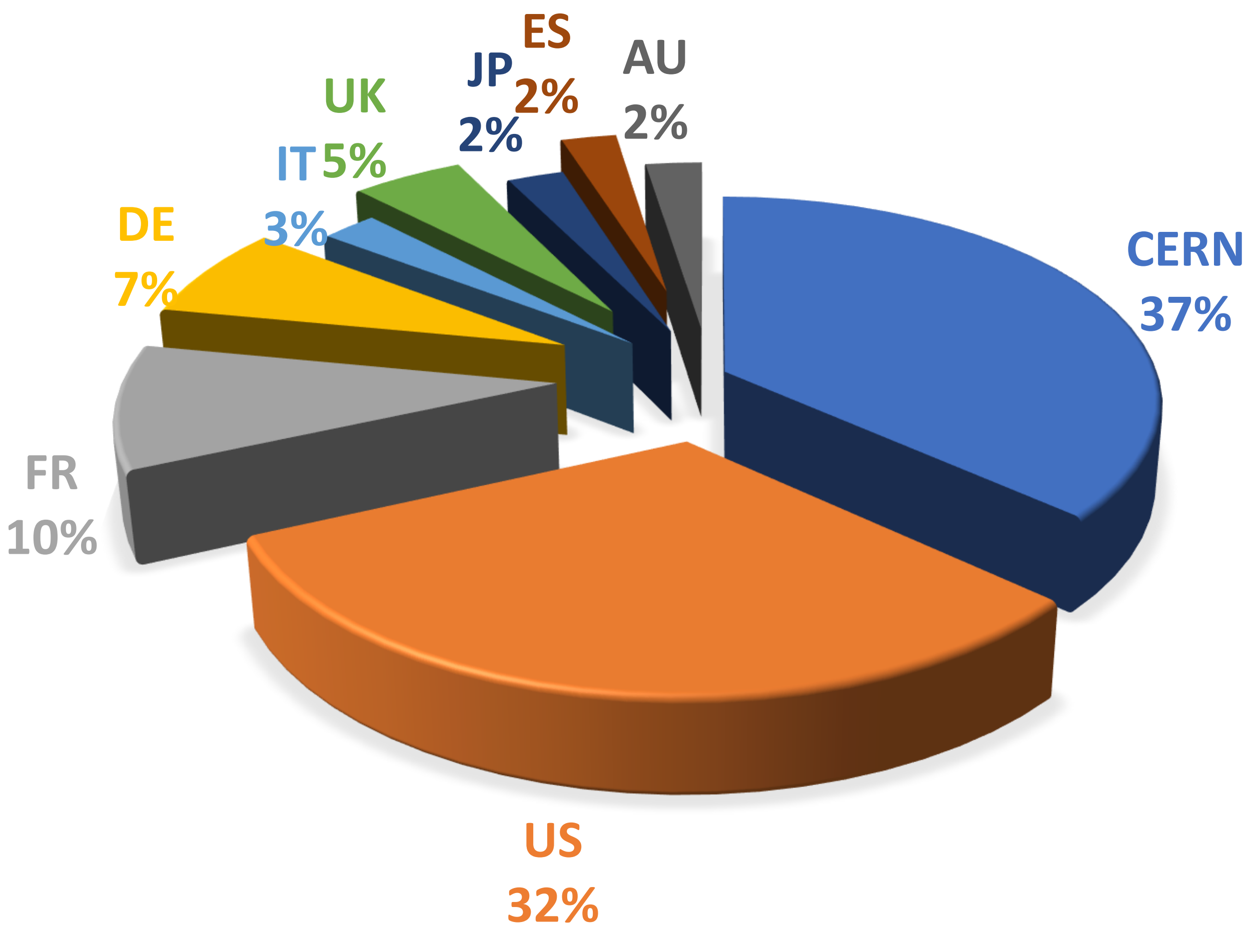
Recognized metal additive manufacturing activities within accelerator community



Materials used for accelerator parts



Distribution among countries



Europe:

CERN(CH)

LAL, CNRS/IN2P3(FR)

INFN(IT)

University of Nottingham(UK)

FAU(DE)

US:

SLAC

NCSU

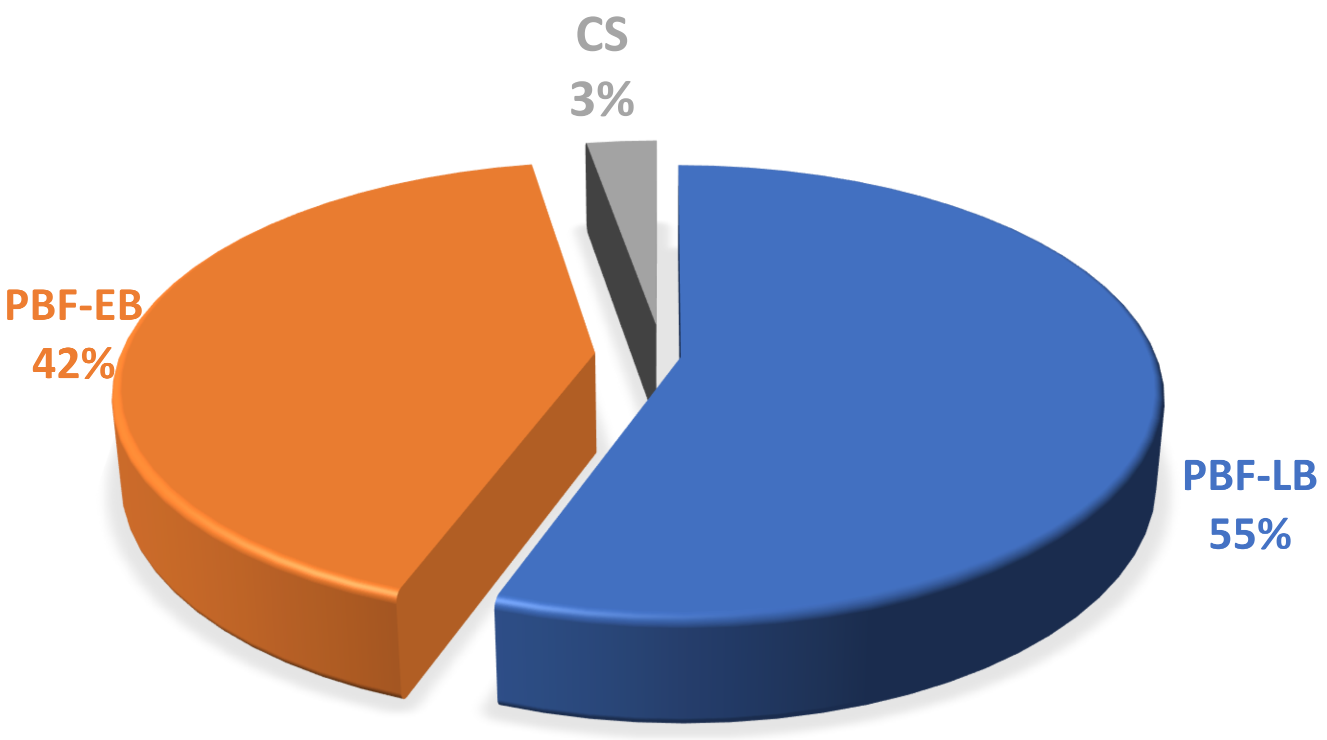
LLNL

RadiaBeam

Asia:

JEOL

Applied AM technologies for accelerators



Applied metal AM technologies:

- PBF-LB
- PBF-EB
- Cold spray

Most often used AM machines:

- GE Arcam
- EOS
- SLM
- Renishaw
- Trumpf
- GE Concept Laser

Collage of metal AM parts within accelerators

Reference links to each of pictures in further slides

Ultra-high vacuum chamber below 10^{-10} mbar (UK)

Material: pre-alloyed, gas atomized AlSi10Mg powder from TLS Technik GmbH;
Grain size:10 µm to 100 µm;
Machine: Renishaw AM250
Process: PBF-LB/M/AlSi10Mg
Process parameters:

- 200W fiber laser@ 1064nm wavelength;
- 180°C bed temperature;
- layer thickness 25 µm;
- hatch spacing of 80 µm;
- point distance of 70 µm;
- exposure time of 220 µs;
- an effective scanning speed of 318mm/s;
- chequerboard pattern and 67° rotation after each layer.

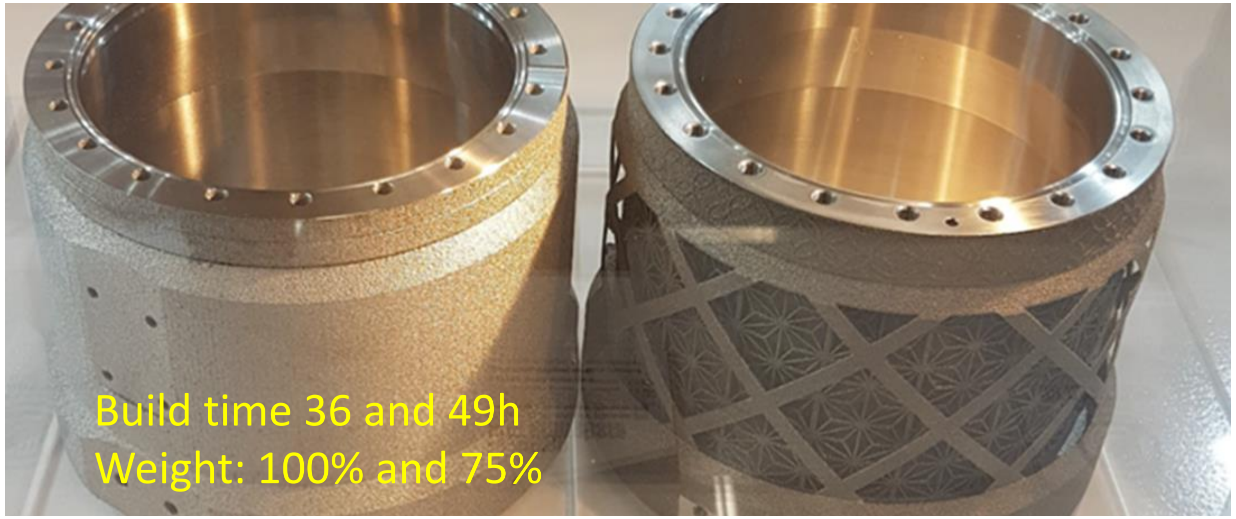
Postprocessing: furnace cooling, EDM, bed blast, thermal treatment.

X-band klystron output cavity with micro-cooling channels and accelerator cavity

Material: OFE-Cu;
Machine: Arcam S12
Process: PBF-EB/M/OFE-Cu;

https://www6.slac.stanford.edu/sites/www6.slac.stanford.edu/files/image1-2-side-by-side.jpg

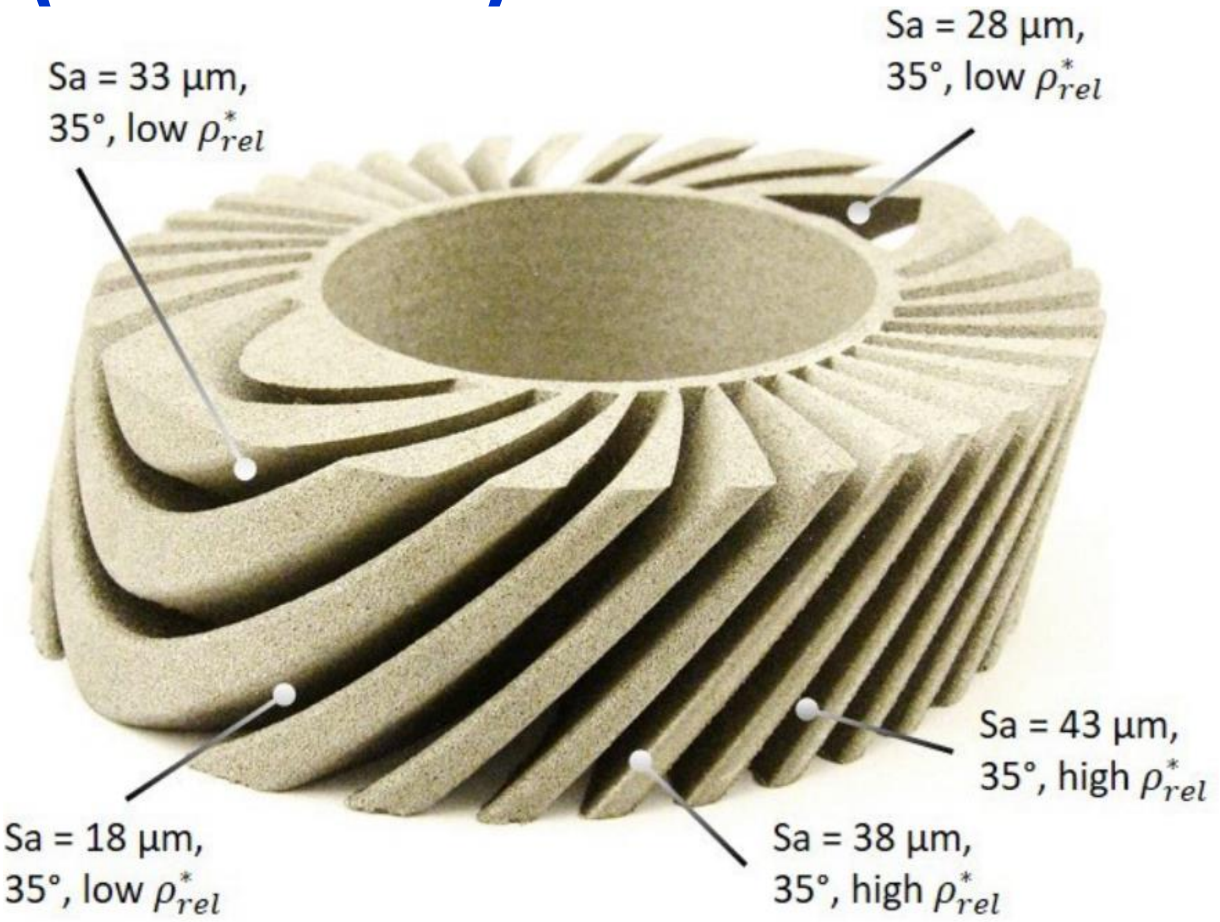
Electron gun and UHV chambers (JEOL)



Material: Ti-6Al-4V (grade23)
Machine: JEOL EBM
Process: PBF-EB/M/Ti6Al4V
Electron beam 1.2kW

Photos from exhibition FORMNEXT’2021, by G.Pikurs

Winding former of superconducting solenoid coil (ETH Zurich)

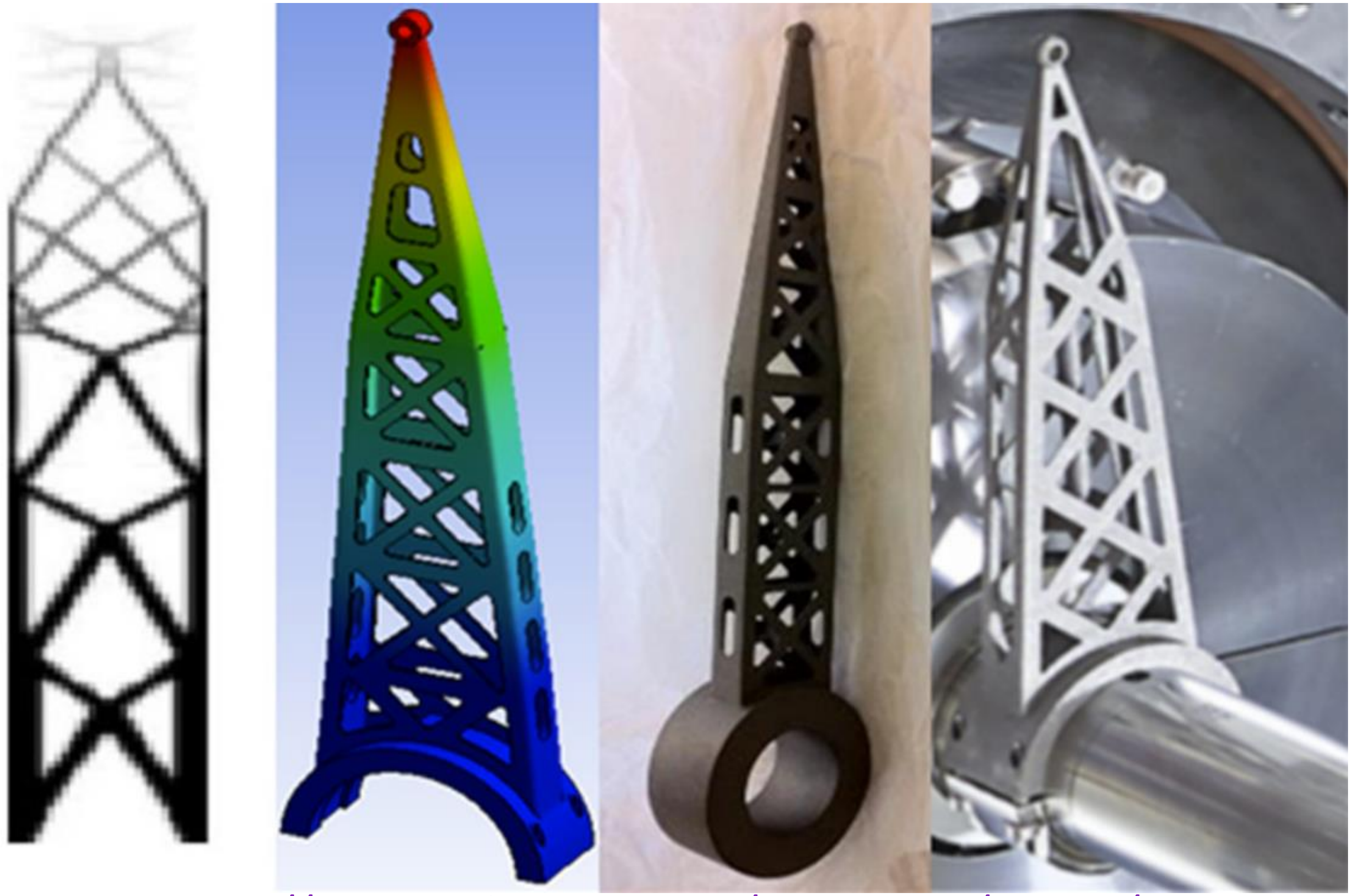


Material: 316L;
Layer: 30 µm;
Machine: Mlab Cusing R (GE Additive)
Process: PBF-LB/M/316L;
Yb:YAG fiber laser 1070 nm;
Focal diameter of 50 µm;
Max power 100W

Research is focused on manufacturing parameter optimization for different overhangs

https://doi.org/10.3929/ethz-b-000514979

Fork for fast Beam Wire-Scanner (CERN)



Material: Ti6Al4V;
Powder: ~30 µm;
Machine: SLM 280HL
Process: PBF-LB/M/Ti6Al4V;
400W IPG fiber laser@ 1070nm wavelength;
Wall thickness 0.4mm

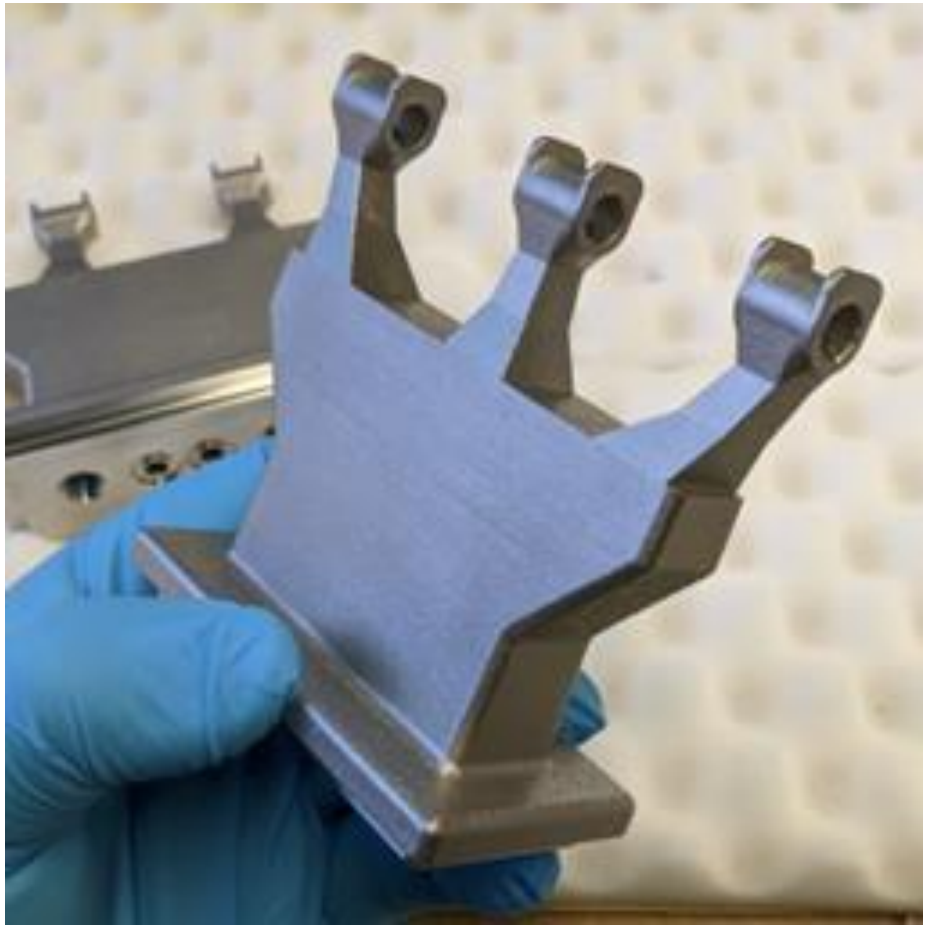
https://accelconf.web.cern.ch/medsi2018/papers/tuph36.pdf

Highly efficient beam dump prototype for SPES LNL INFN

Material: Cu OFHC;
Layer: 30 µm;
Machine: SISMA Mysint100 PM
Process: PBF-LB/M/CuOFHC;
Fiber laser, 1070nm;
Spot size of ~30 µm;
Max power 200W;
Printed volume: 88392 mm^3
Printing height Z of 32mm
Print job of ~75 hours
Reached relative density of 98.1 %

https://www.pd.infn.it/eng/infn-proposal-ranked-among-the-best-technology-transfer-projects-selected-by-the-regione-veneto/

3D printed girder-drifttube structure including the integrated cooling channels



Material: 1.4404;
Vacuum, outgassing: 2.97×10^{-6} mbar was achieved after about 100 hrs of pumping
Cavity size:221x206x261 mm
Developed at:
Goethe University, Frankfurt a. M.

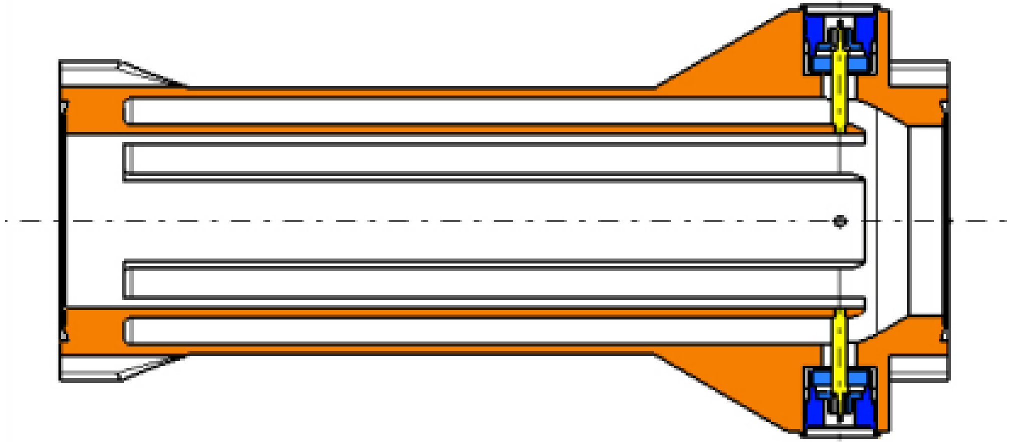
https://accelconf.web.cern.ch/ipac2021/papers/mopab194.pdf

Ultra high vacuum tubes(IN2P3/CNRS)

https://accelconf.web.cern.ch/ipac2017/papers/wepva043.pdf

Material: 316L;
Vacuum test: (1.2×10^{-5} mbar; 9.6×10^{-6} mbar);
Size: 130 mm long DN40KF;
Build time:
30h for 4piece buildjob at 40µm layer thickness(BV Proto);
60h for 4piece buildjob at 20µm layer thickness(AGS Fusion);
As build surface roughness:
Ra = 8.5µm to 10µm for BV Proto;
Ra = 6µm to 7.5µm for AGS Fusion
Manufactured at:
BV Proto (http://bvproto.eu/);
Fusion AGS (https://www.ags-fusion.fr/)
Work supported by a grant from IN2P3/CNRS, program I3D metal.

Beam Position Monitor (LAL, TomX)



Material: 316L;
Technology: PBF-LB/M/316L
Developed at: LAL, TomX project
Advantages over traditional machining method:

- 60% of original weight;
- Cost reduction by 50%;
- Manufacturing time reduced by 2/3;

I.FAST WP10.4. RF cavities (INFN DIAM)

Material: Cu OFHC;
Process: PBF-LB/M/CuOFHC;
Postprocessing at: Rossler Italiana S.R.L.

Additively manufactured HOM Coupler (CERN)

Courtesy of P.Trubacova (CERN EN-MME)

Process: PBF-LB/M/Ti6Al4V;
Postprocessed at: **BINC Industries**,
MMP average material removal **85.5 ± 23.9µm**
Final Ra0.02…0.03µm

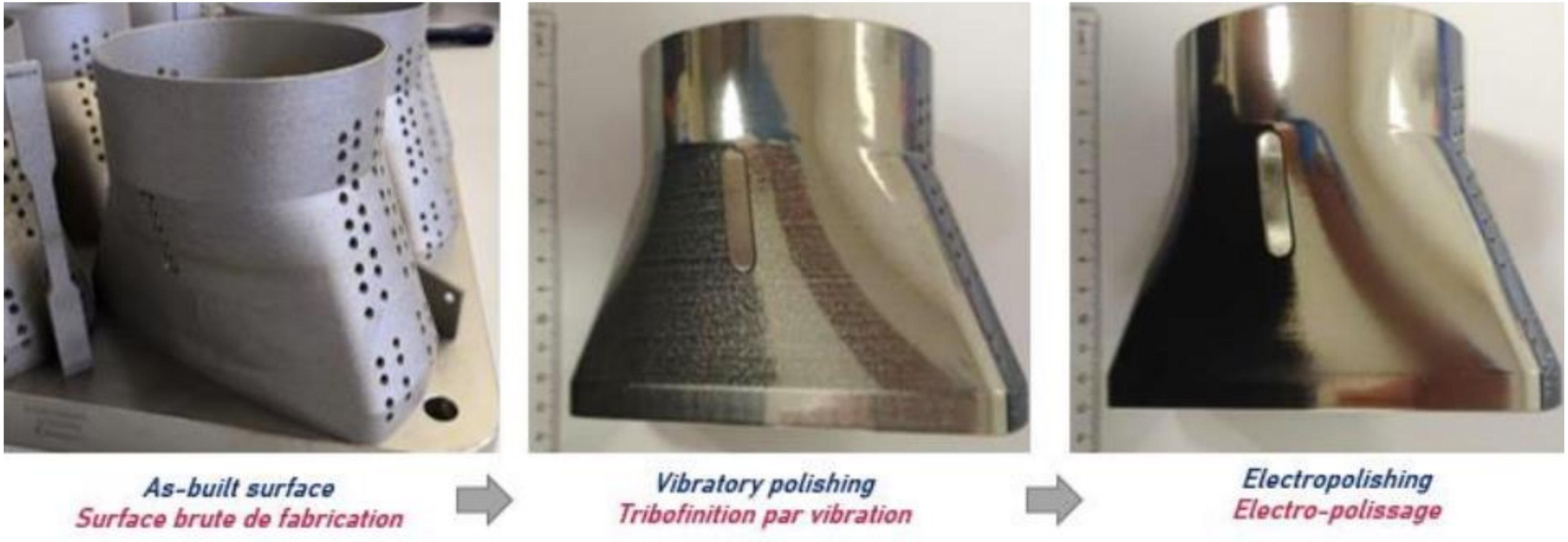
https://indico.cern.ch/event/708160/contributions/2907448/attachments/1659769/2658741/MMP_development_RD_-_SRF_workshop.pdf

SRF single-cell cavity (RadiaBeam)

Material: 316L; Nb
Technology: PBF-EB/M
Machine: Arcam AB
Developed at: RadiaBeam,
Vacuum:

https://accelconf.web.cern.ch/srf2015/papers/thpb042.pdf)

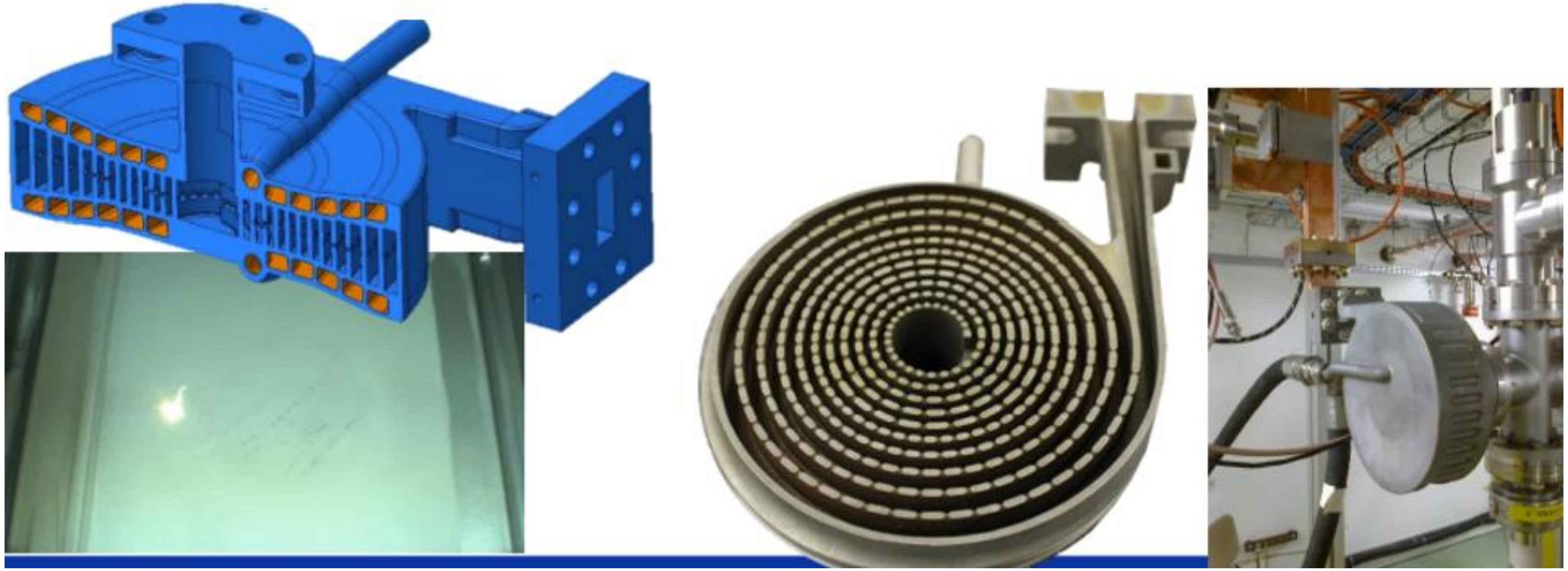
SPS pumping port shielding (CERN)



Courtesy of R. Gerard - CERN EN-MME - Foselev

https://indico.ijclab.in2p3.fr/event/7055/contributions/22436/attachments/16682/21653/R%20GERARD%20-%20La%20Fabrication%20Additive%20me%CC%81tal%20au%20De%CC%81partement%20d%27inge%CC%81nierie%20du.pdf

CLIC RF spiral load

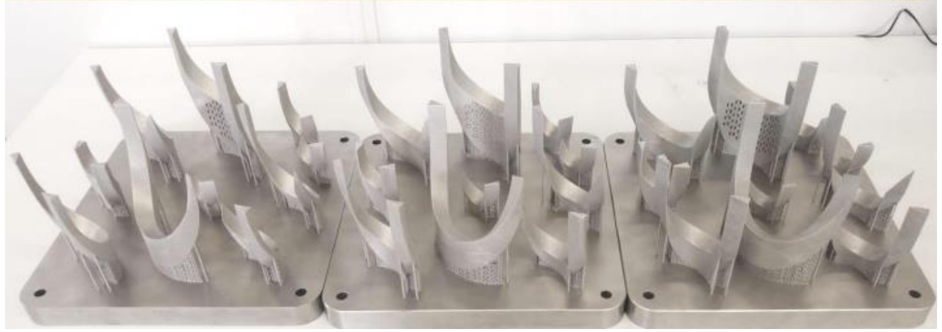


https://indico.ijclab.in2p3.fr/event/7055/contributions/22436/attachments/16682/21653/R%20GERARD%20-%20La%20Fabrication%20Additive%20me%CC%81tal%20au%20De%CC%81partement%20d%27inge%CC%81nierie%20du.pdf

6GHz cavity, PBF-LB/M/Nb

https://indico.cern.ch/event/725106/contributions/2982999/attachments/1639125/2618793/additive_Manufacturing_2.pptx

Separators for 15T dipoles (Fermilab)



https://indico.ijclab.in2p3.fr/event/4990/contributions/16695/attachments/13619/16418/I3DMetal_-_AMCERN.pdf

Compact X-band RF loads

LIEBE: Heat Exchanger Lead-Bishmut/Water

https://indico.cern.ch/event/567462/contributions/2293345/attachments/1353055/2044352/PS_DUMPREVIEW_Metal_Additive_Manufacturing_RG.pdf

Linac2 solenoid housing

https://indico.ijclab.in2p3.fr/event/4990/contributions/16695/attachments/13619/16418/I3DMetal_-_AMCERN.pdf

Our experience on OFE-Cu RFQ ¼ sector

Material: m4p™ PureCu gas-atomised spherical shaped powder;

Powder size: 19.5 … 34.9 µm;

Machine: Trumpf TruPrint1000 Green Edition (500W disc laser@515nm wavelength);

Process: PBF-LB/M/OFE-Cu

Process parameters:

Layer thickness 30µm;

Print job: 16h 29min

Trumpf predefined scanning pattern;

Manufactured at: Fraunhofer IWS

Postprocessing at: Rosler Italiana S.R.L.

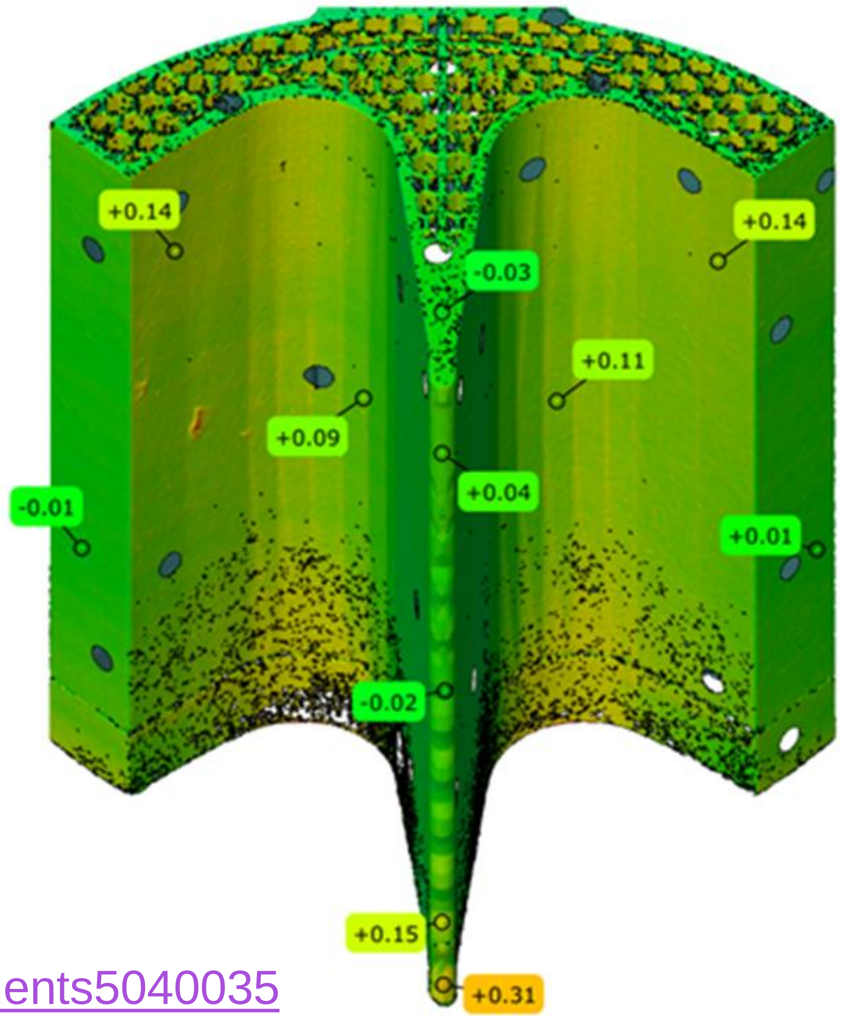
Lessons learned:

Successes:

- Good machining performance in terms of geometrical accuracy.

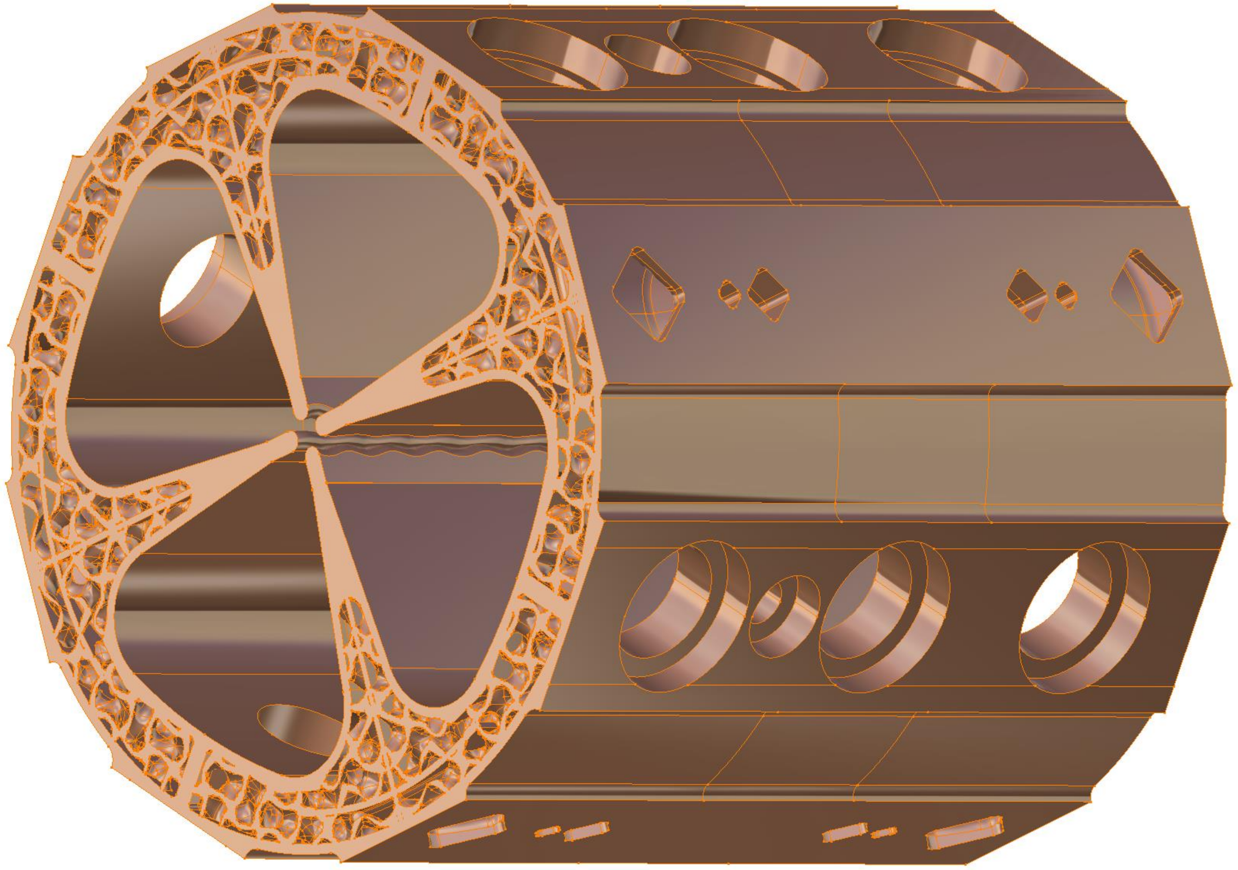
Issues to solve in future:

- STL model was not targeted and prepared for best result;
- Surface roughness is still challenge and definitely will need multi-step postprocessing;
- Circumstantial machine bed failure, due to powder bed sealing issue.



https://doi.org/10.3390/instruments5040035

Next step: full sector RFQ



Material: OFE-Cu;
Size~120x120x125mm
Material volume~415.4cm^3
Weight~3.714kg
Layer: 30 µm;
Machine: Trumpf 5000 Green eddition?
Process: PBF-LB/M/OFE-Cu;
Green Disc laser, wavelength 515nm?;

iFAST

Thank you for attention!

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.