RĪGAS TEHNISKĀ UNIVERSITĀTE

Research on design improvement of accelerator components by additive manufacturing

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VPP Valsts pētījumu programma

2022

IFAST

About accelerators

- More than 35’000 accelerators are operating around the world;
- Only ~1% of them are large size machines used for fundamental researches;
- Medicine with its ~35% have largest application field;

- Expensive, complex geometry, high precision parts;
- Obvious need for advanced, reliable, less expensive manufacturing technology;
- AM could be future technology for accelerators

Objective

- to proof that the additive manufacturing technology is viable solution for the production of complex particle accelerator components and that AM technology is able to reach the stringent requirements which are set to accelerator components

2D
- Superfish
- Parmteq

3D
- CAD modeling(Catia)
- Simulations(Ansys)

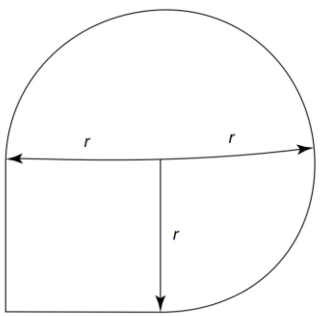
AM build
- Magics
- Manufactring

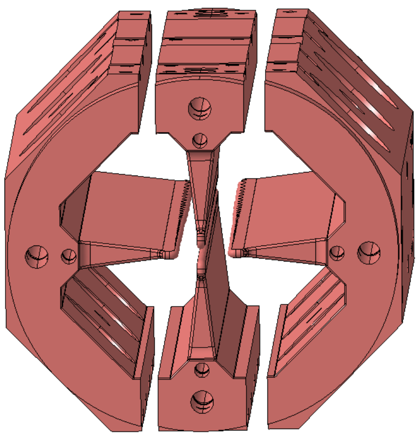
Metrology
- Geometry
- Surface quality

Postprocessing
- Mechanical
- Chemical +mechanical

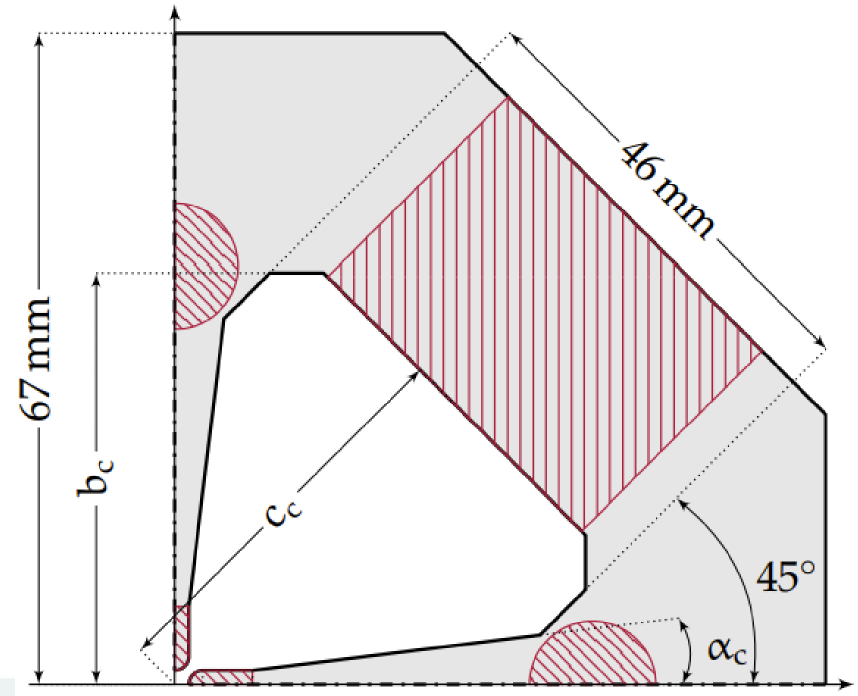
RFQ 2D Cavity design as starting point

Ideal cavity shape





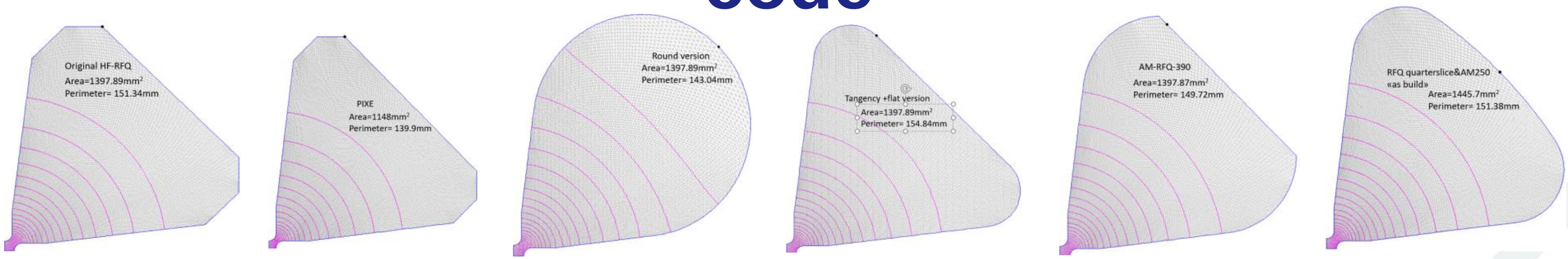
Traditionally manufacturable shape(PIXE)



[H.Pommerenke 2020]

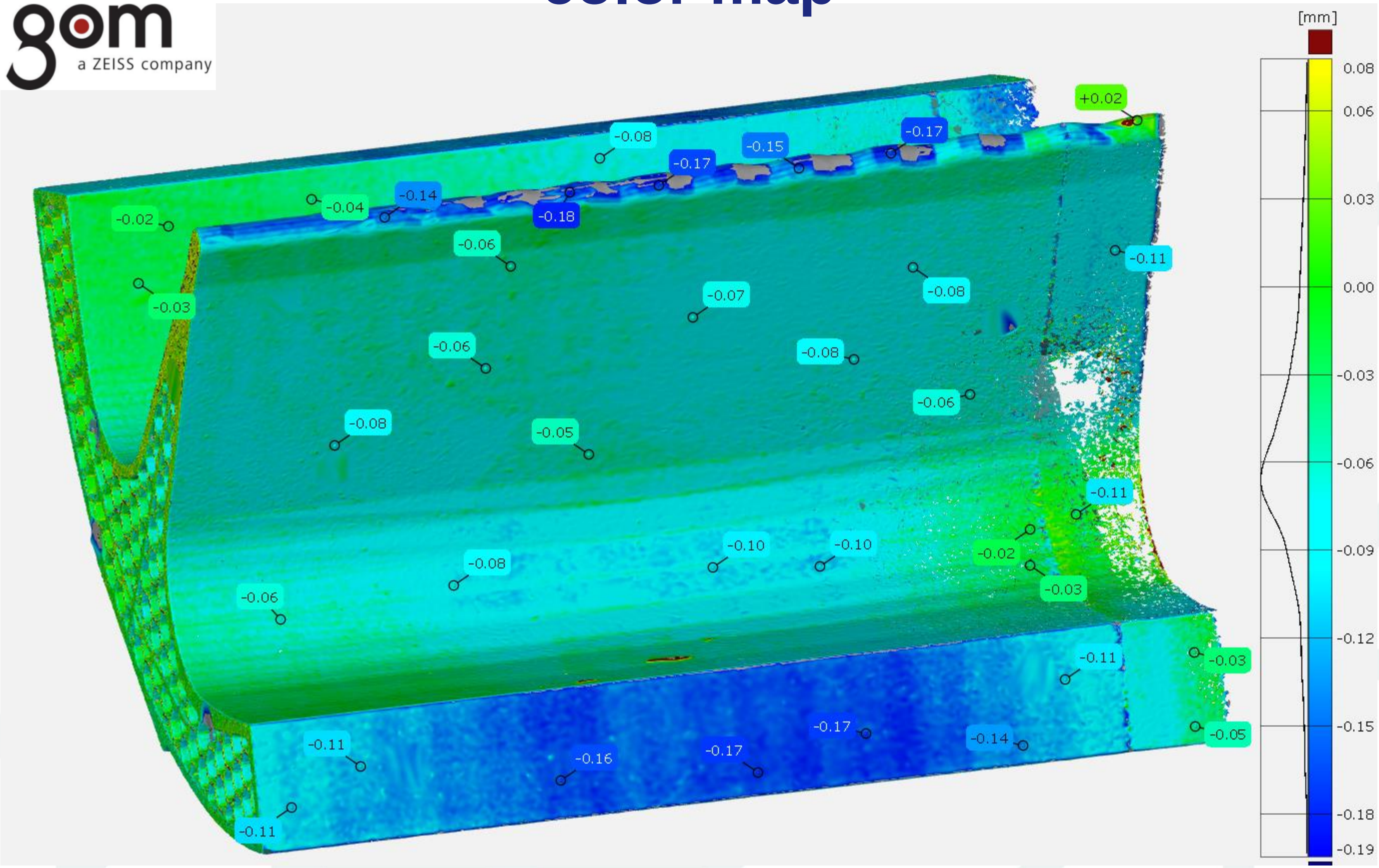
	Challenge	Target
1	Porosity, degassing	vacuum 10^{-7} mbar
2	Manufacturing accuracy	20µm on vane tip, 100µm elsewhere
3	Surface roughness	Ra0.4 for all inner surfaces of quadrupole
4	Electrical conductivity	90% of pure copper
5	Inclusions, voltage holding	80 kV
6	Dimensions	Cylinder ∅100-200 mm, length 200 mm

RFQ cavity 2D shape study by SUPERFISH code

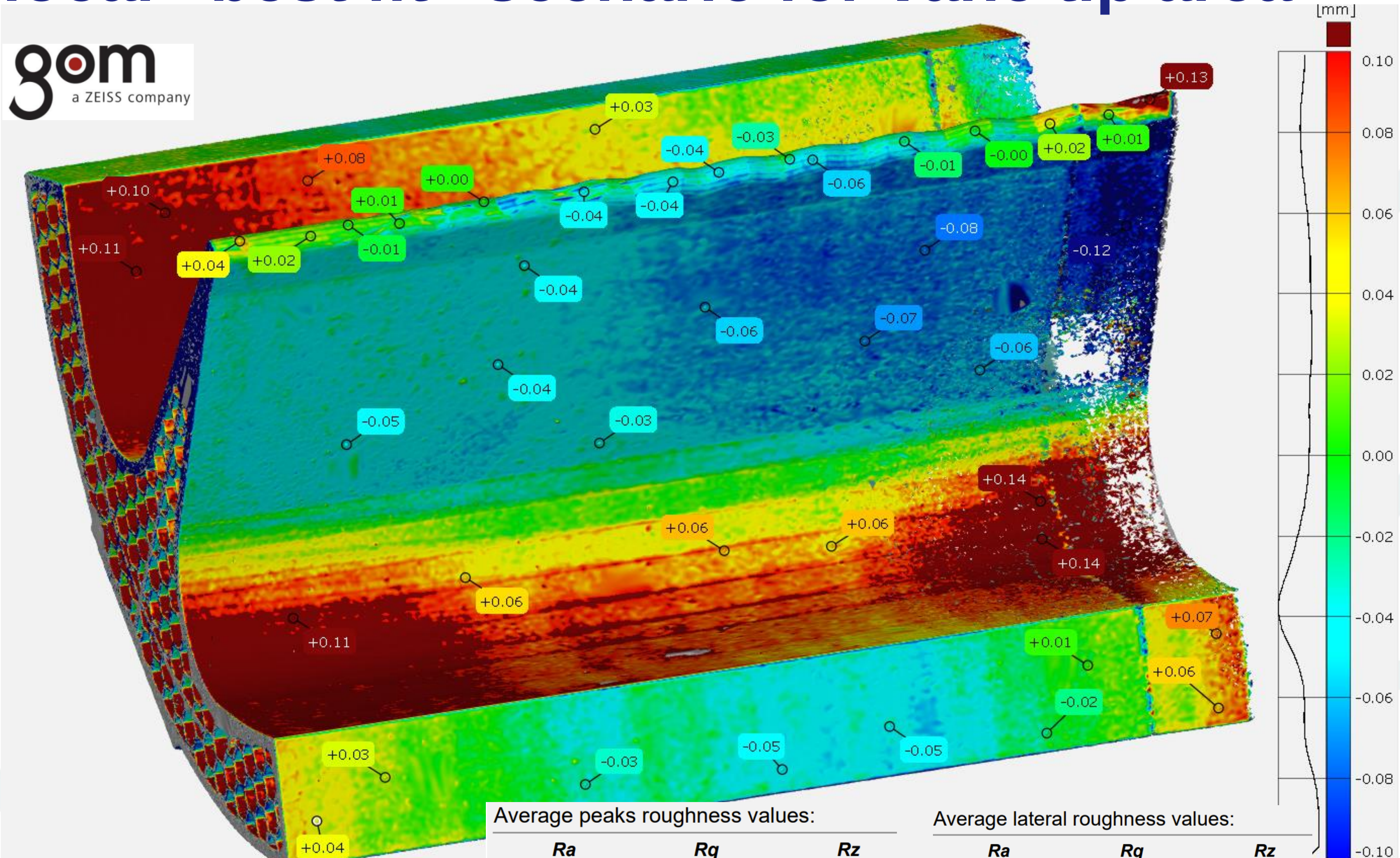


Cavity design	Perimeter, mm	Area, mm^2	Frequency, Hz	Q-value	Tip radiuss, mm	Aperture radiuss, mm	Shunt impedance, MΩ/m	Stored energy, $*10^{-5}$J/cm
HF-RFQ	151.34	1397.89	716.56	8028.51	1.504	1.935	6303.894	6.8775
PIXE	139.9	1148	728.97	7156.49	1.439	1.439	6286.239	6.87484
Carbon HF-RFQ	142.15	1202	709.78	7273.45	1.411	1.411	6620.685	6.87443
Round design	143.04	1397.89	714.75	8608.20	1.504	1.935	6737.561	6.91407
Tangency + flat	154.84	1397.89	716.59	7811.74	1.504	1.935	6133.634	6.90091
AM390	149.72	1397.87	716.44	8138.77	1.504	1.935	6388.894	7.55072
AM250&QS	151.38	1445.7	703.25	8254.51	1.504	1.935	6578.903	4.49217
AM250&QS-200µm	152.1	1475.2	736.70	8569.27	1.304	2.135	6574.460	4.36554

Pointcloud and CAD model surface deviation «best fit» alignment for «as build» part 3 sigma color map



«As build» pointcloud vs CAD model local «best fit» scenario for vane tip area



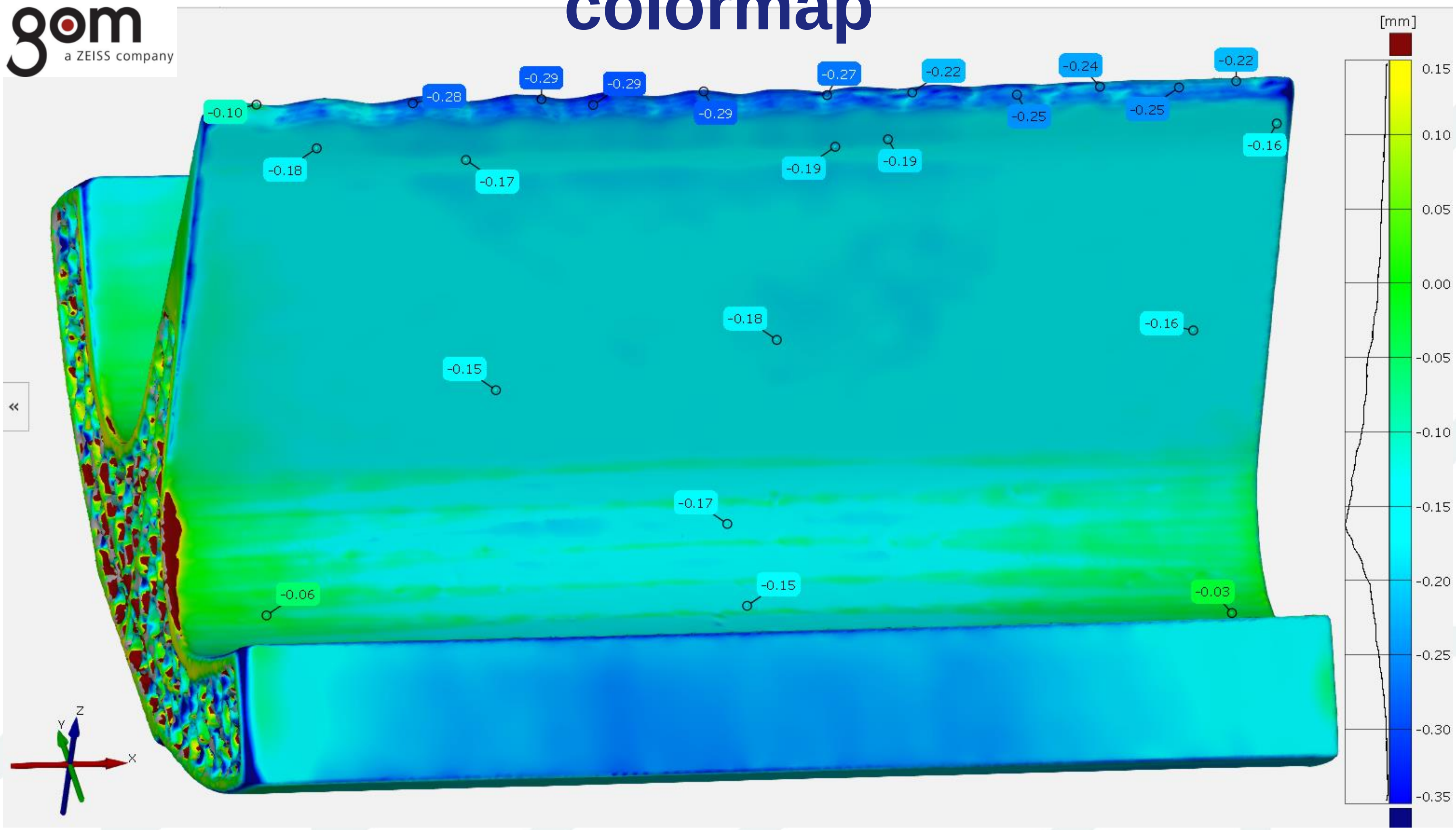
Average peaks roughness values:

Ra	Rq	Rz
µm	µm	µm
10,4 ± 2,7	13,1 ± 0,9	65,2 ± 3,9

Average lateral roughness values:

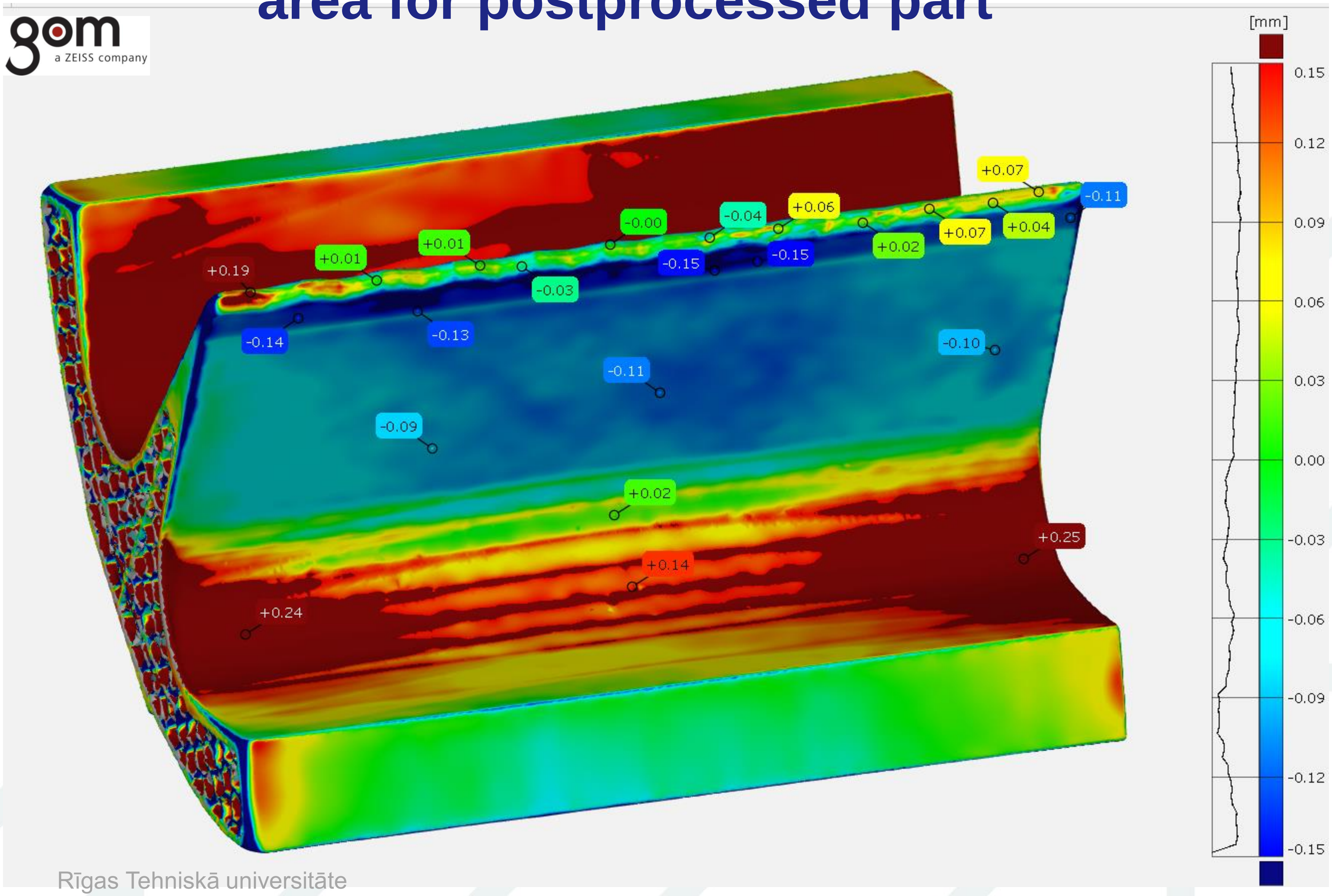
Ra	Rq	Rz
µm	µm	µm
12,4 ± 0,3	15,7 ± 0,2	98,2 ± 4,6

Postprocessed part «best fit» alignment applied to whole whole part 3sigma colormap

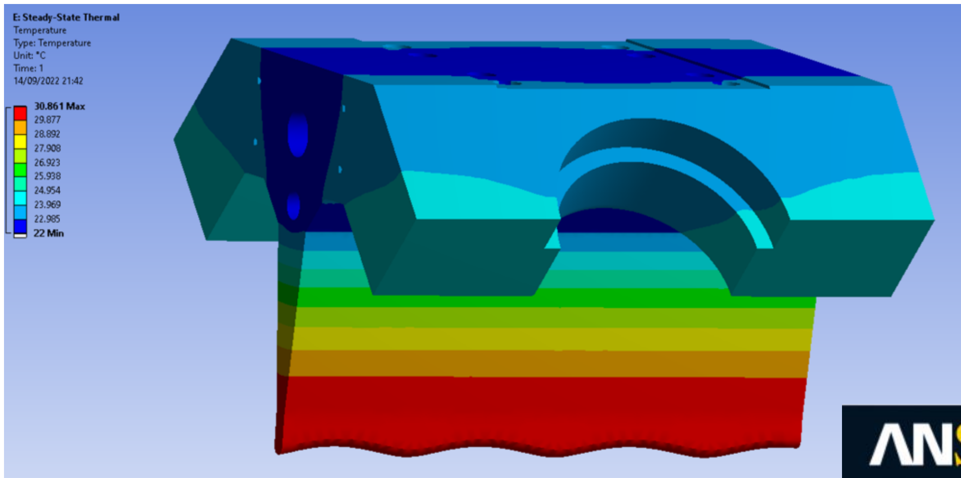


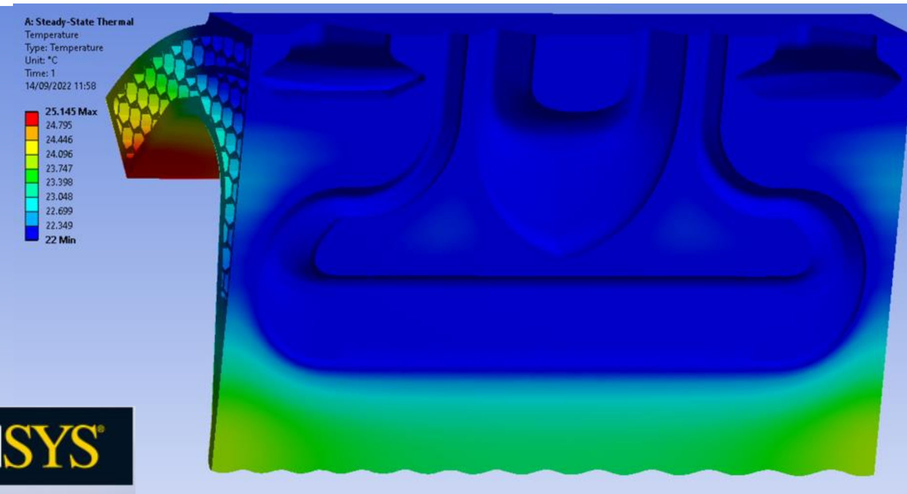
On vane tip area Ra=0.1...0.4 measured at CERN EN-MME

Local «best fit» alignment applied to vane tip area for postprocessed part



Temperature distribution and Max total deformation for design versions(SteadyState Thermal +Static Structural)





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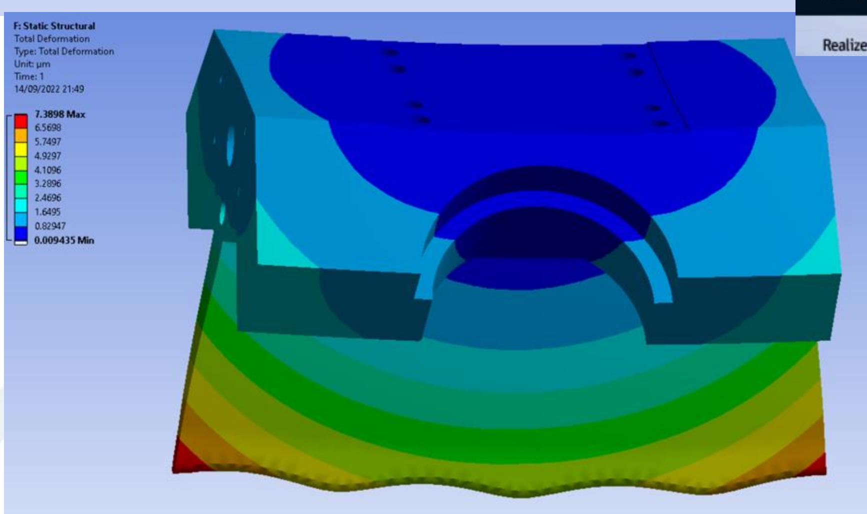
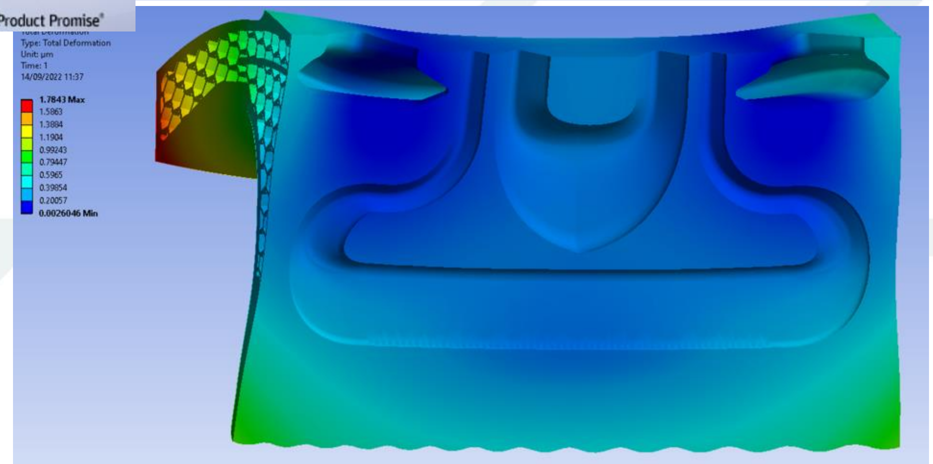
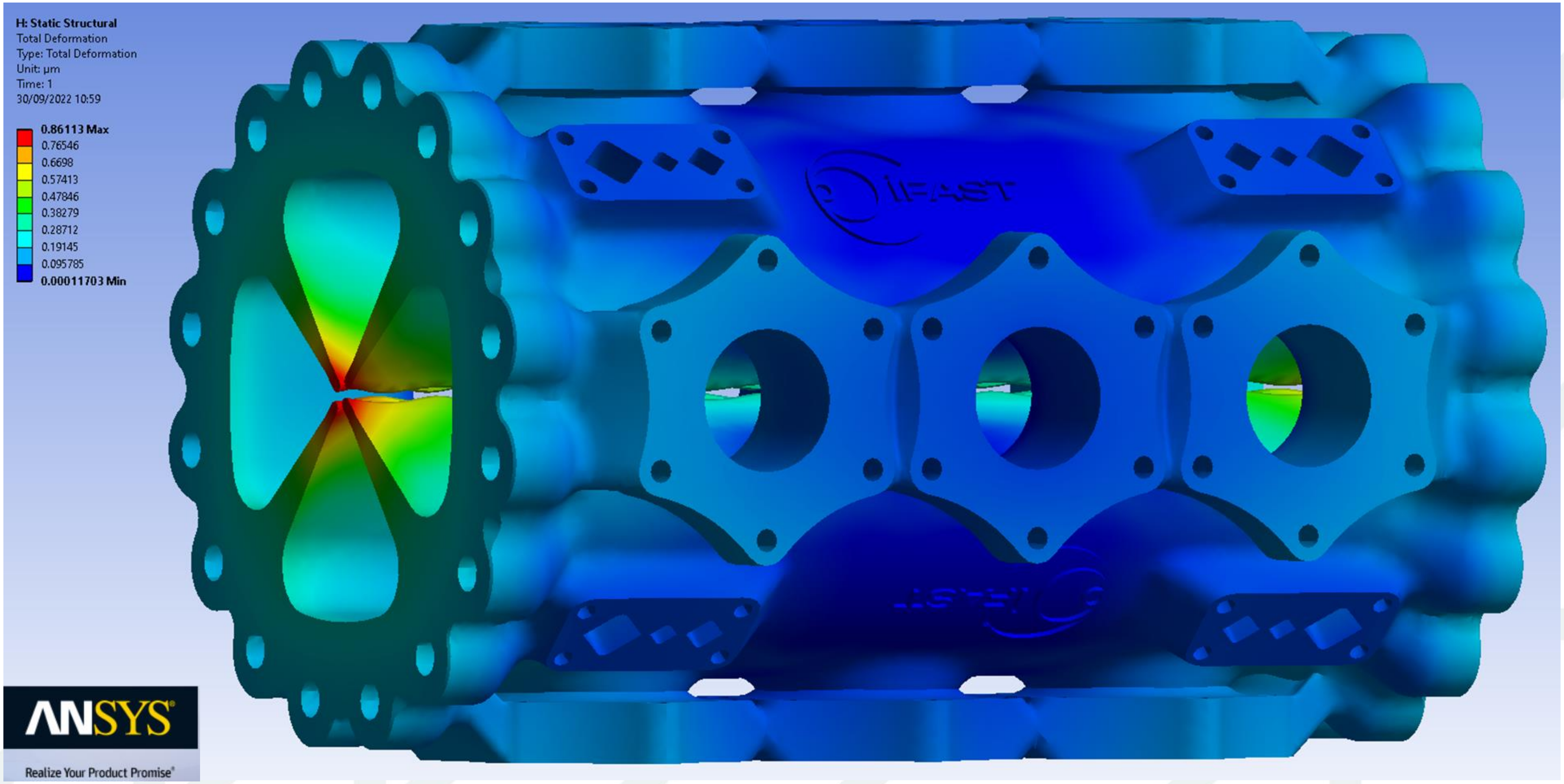
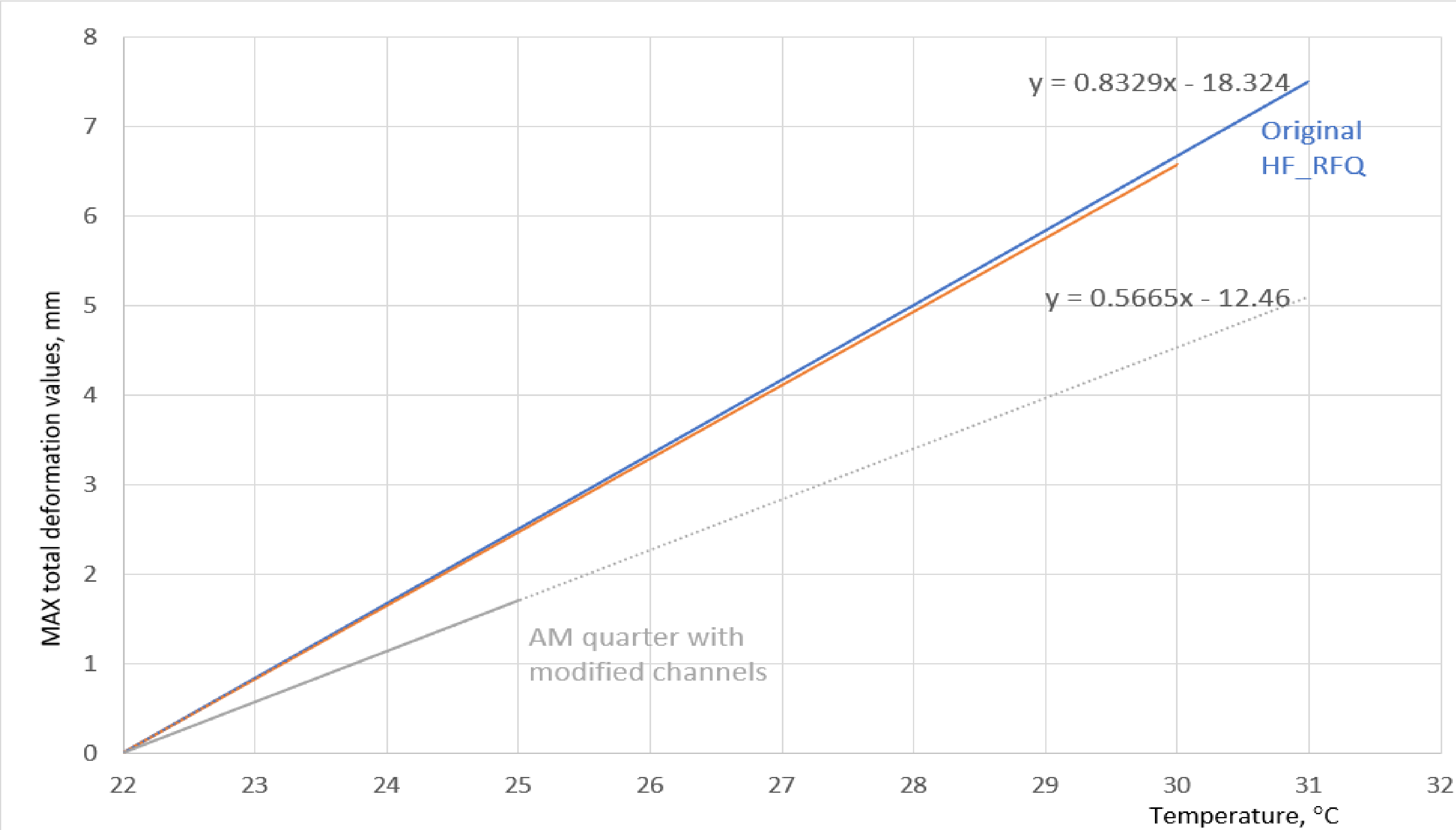




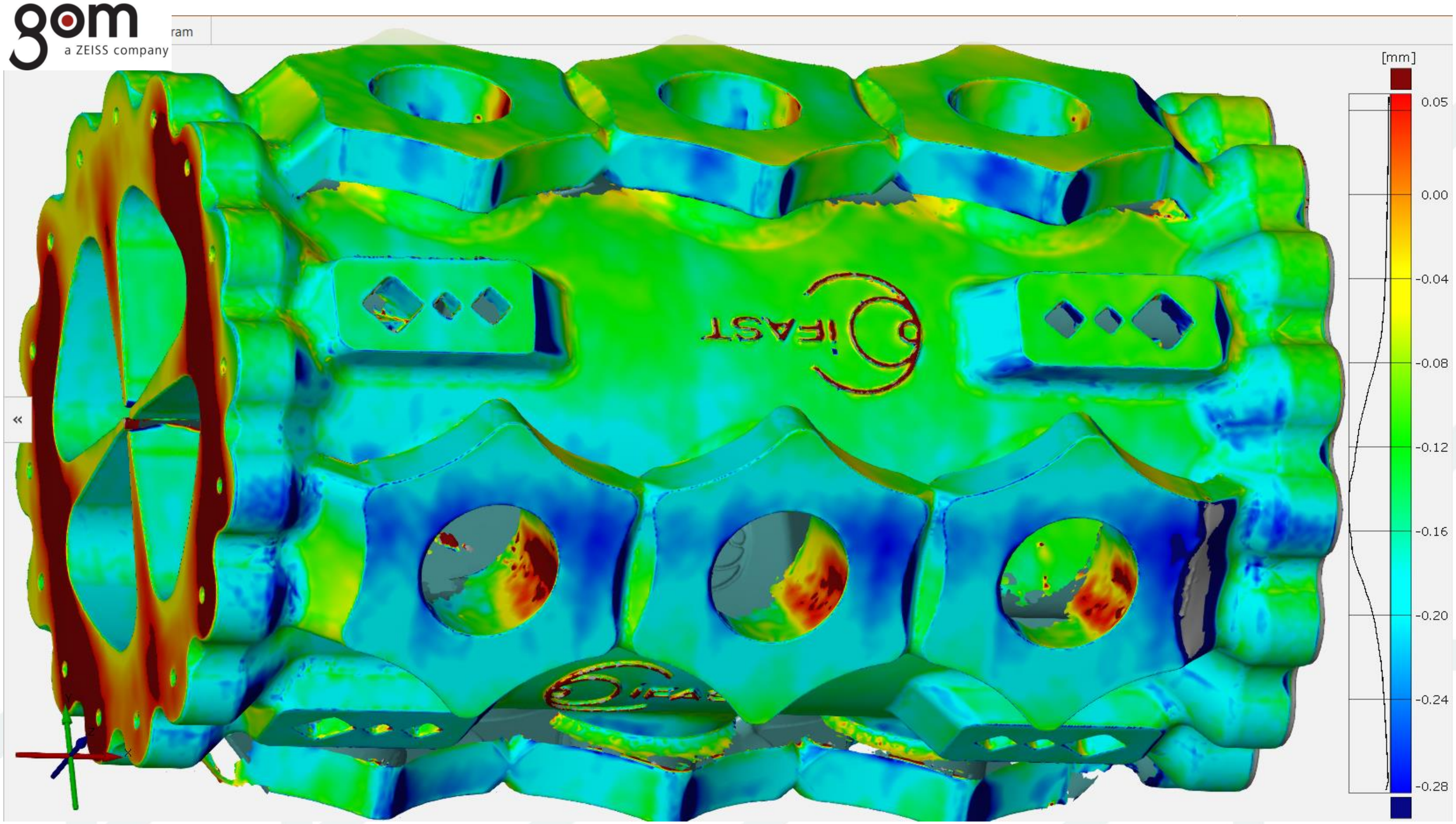
Thermal deformation of 248mm full sector RFQ



Max total deformation as function from temperature



248mm AM-RFQ 1σ color map



Conclusions

- PBF-LB/M additive manufacturing technique have good potential to enter in field of accelerators with high performance design parts;
- Current AM processing and postprocessing achievements in H2020 I.FAST WP10 collaboration looks promissing for further technology development;
- AM manufacturing by itself have less gaps for human errors during manufacturing process

Thank You for Your Time!