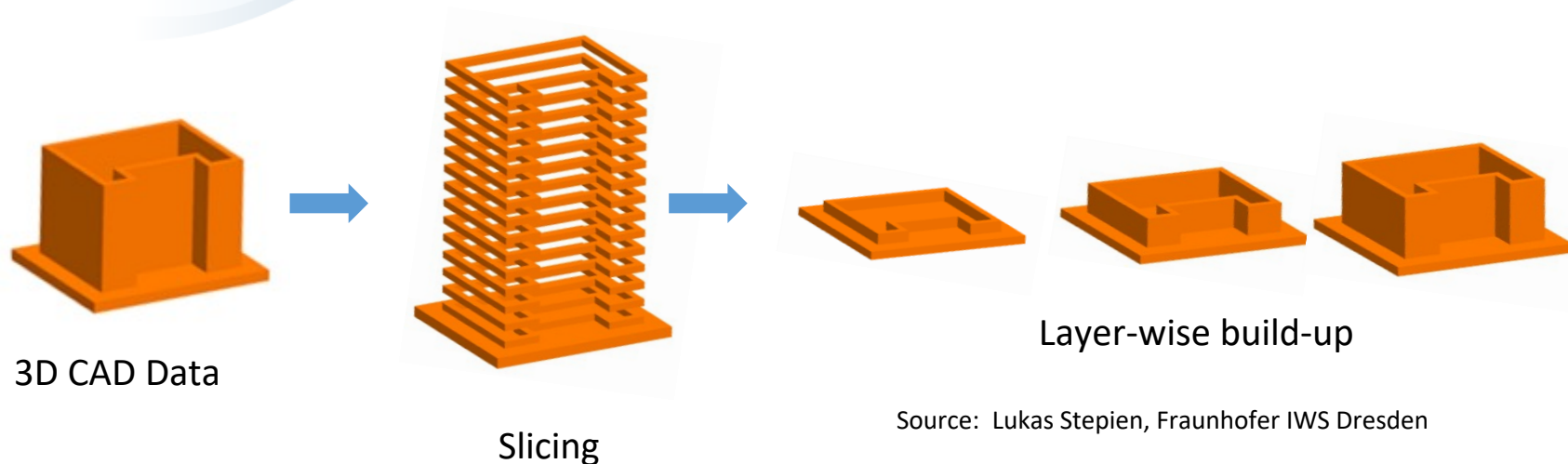


Additive manufacturing applied to accelerators

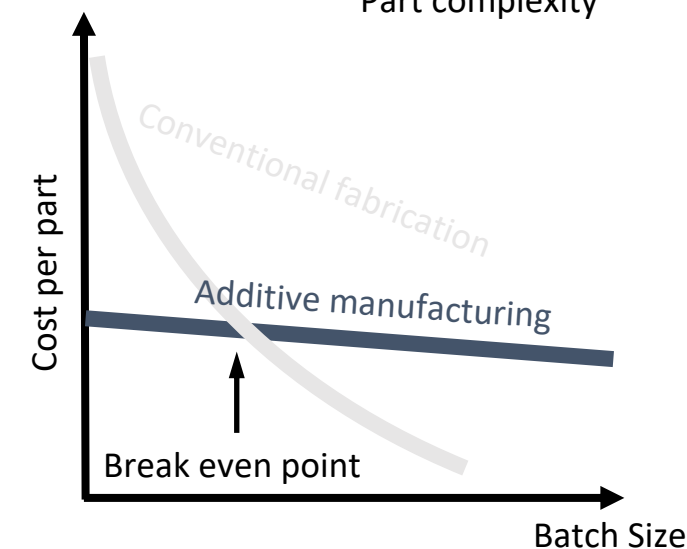
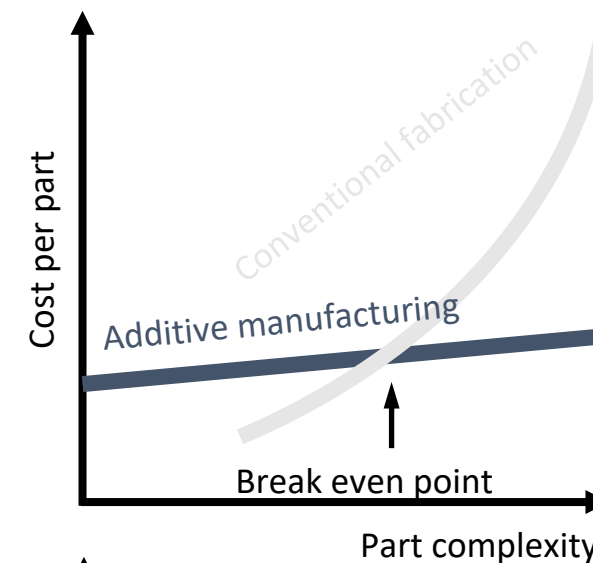
Nicolas Delerue



What is additive manufacturing?



- Building an object by the addition of successive layers of materials (by opposition to traditional manufacturing where material is removed).
- Originally made for rapid prototyping but now extended to the production of fully functional objects.
- For more details, see, for example, the talk by Lukas Stepien given during the I.FAST collaboration meeting:
<https://indico.cern.ch/event/1143029/>





What is additive manufacturing?

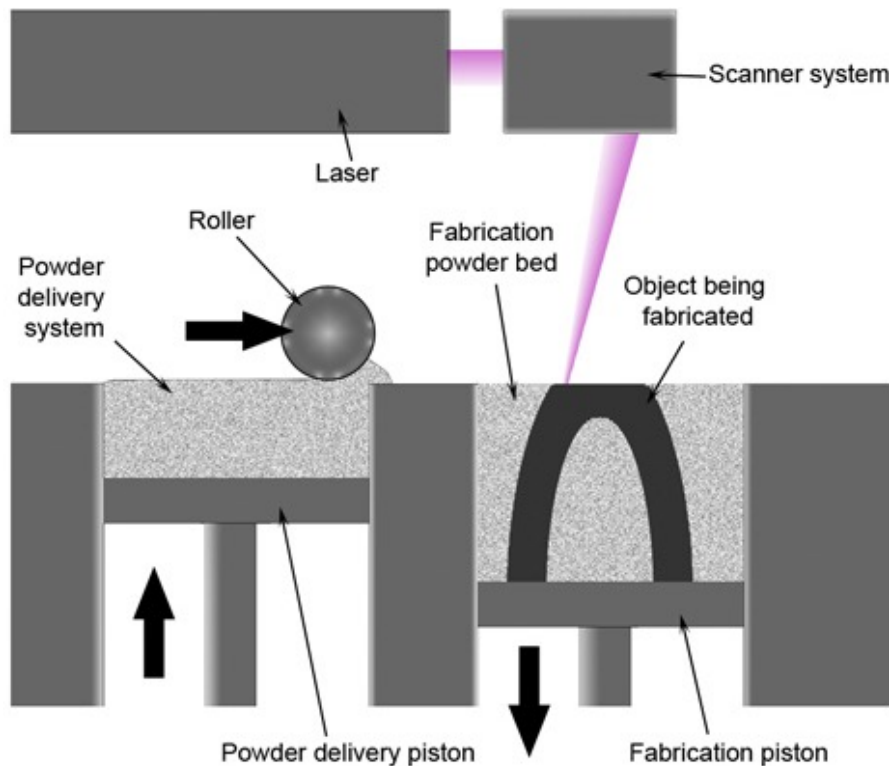
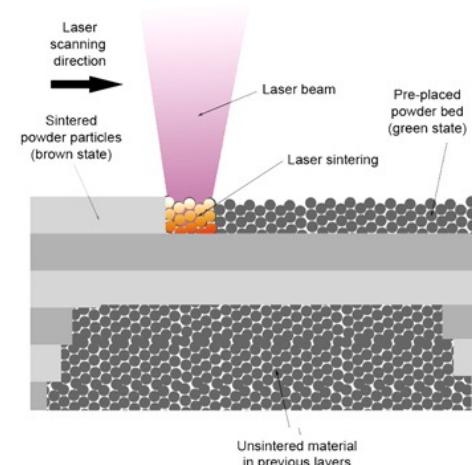


Image source: wikipedia



- Easier with polymers but possible with a large range of materials (including metals).
- Wide range of technologies. For metals, it is necessary to melt powder or a thin wire of the metal. Can be done with a laser or an electron beam.
- More advantageous for small series of complex parts.
- The surface of additively manufactured part is often very rough.

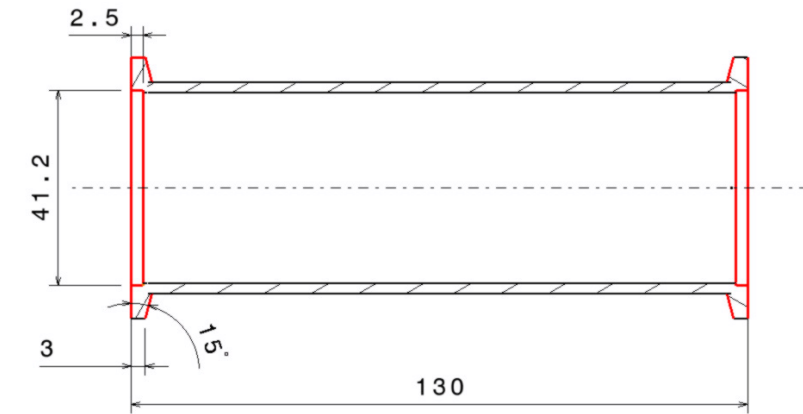


- For accelerators several metals are of interest:
 - Aluminum and Stainless steel are well under control
 - Copper is more difficult because of its reflectivity (see separate slide)
 - Niobium is difficult because of the high melting point.
- Melting copper with an infra-red laser is difficult because of the high reflectivity of Copper at that wavelength
- Several strategies exist:
 - Use more laser power
 - Use a laser with different wavelength (eg: green)
 - Add an additive to the powder to make it absorb the laser power
- Some attempts we did were unsuccessful as the copper produced had too much porosity.
- However this is strongly dependant on the settings of the machine used. More experience needed to understand the acceptable range of machine settings.

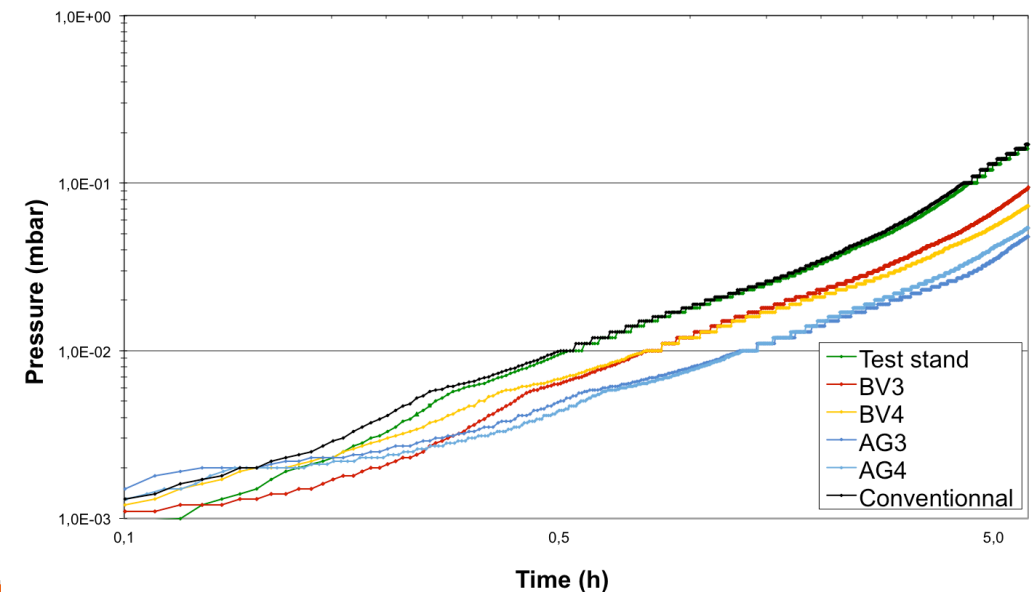




- Beyond the use of polymer AM parts as support, one of the first challenge to address was Ultra-High Vacuum compatibility.
- The rough surface of the stainless steel parts produced was source of concern.
- Several UHV tubes were manufactured and measured by our vacuum group (as well as a conventional tube from a regular supplier).
- It was demonstrated that surface roughness is not an issue (except for the flanges).
- UHV Performances of both types of tubes were similar.

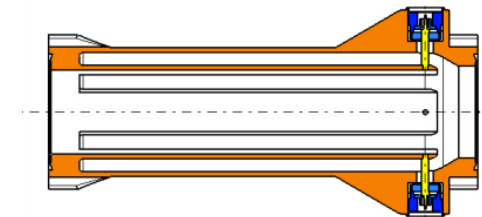
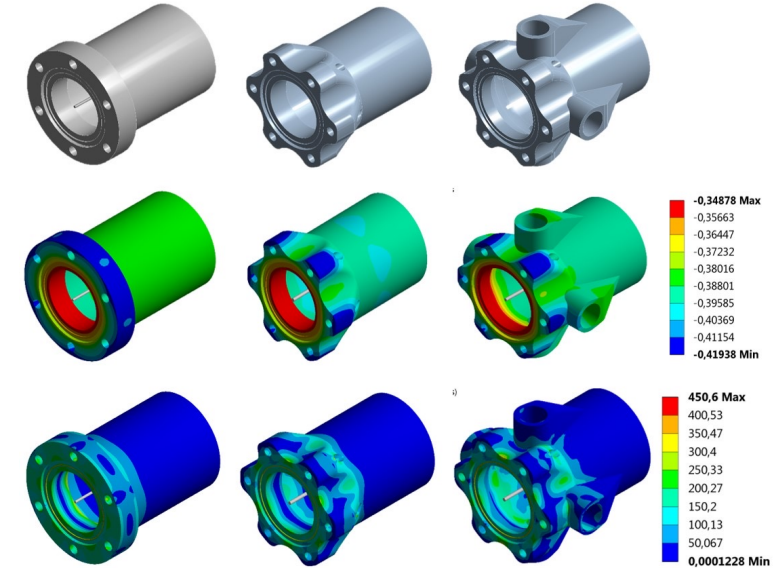


Test stand, BV3, BV4, AG3, AG4 and conventionnal



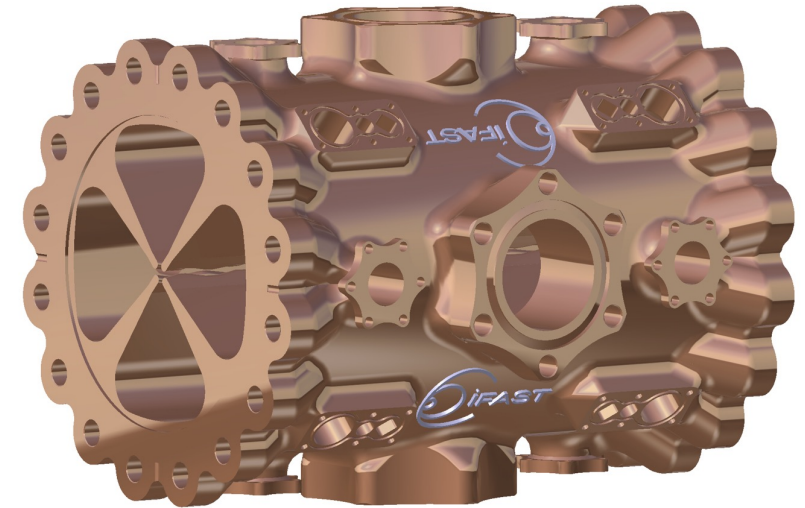


- The next step was to produce a working accelerator part.
- The choice was to build a beam position monitor as it is mechanically complex.
- Topological optimization was used to improve the design.
- The use of additive manufacturing allowed to have thinner electrodes (and thus a better impedance matching).
- After production the BPM was validated by our vacuum group and then installed on our photo-injector next to two conventional BPMs.
- All measurements showed no difference in behaviour between the three BPMs.
- Note: At the moment the electrical feedthrough are still sourced externally and note additively manufactured (R&D on this is in progress).



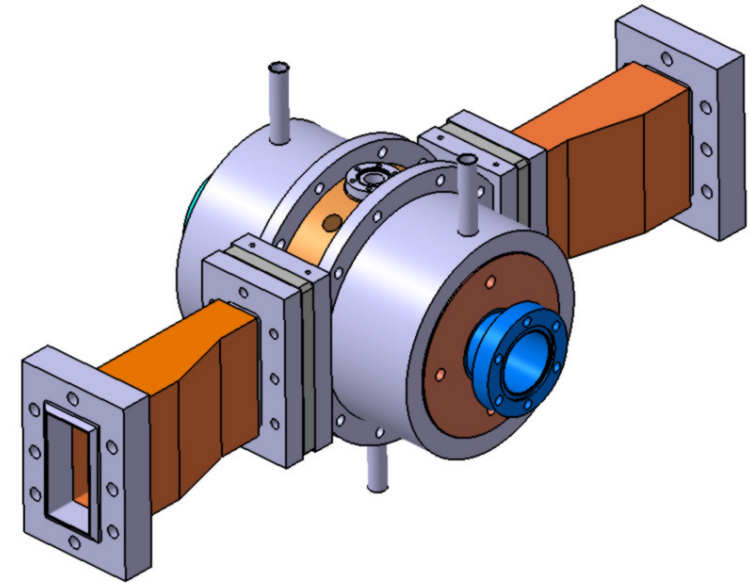


- In the European project I.FAST, Work Package 10 is partly dedicated to the applications of additive manufacturing to accelerators.
- WP 10 involves Riga Technical University, CERN, Politecnico University of Milano, IWS Fraunhofer, INFN Padova, Tallinn Technical University, Trumpf and CNRS.
- The collaboration has worked on the design of a segment of RFQ made of copper.
- Validation tests are in progress.





- We have started internal R&D to produce an accelerating section using additive manufacturing.
- Aim: qualify a copper accelerator component with high power RF and then with an electron beam.





Outlook:

- Additive manufacturing has several advantages for accelerators:
 - Shapes can be closer from specifications
 - Possibility to add cooling channels as close as possible to heat source
 - Faster and/or cheaper production (for complex parts).
- Some challenges still to be addressed:
 - UHV electrical feedthrough
 - High power RF
 - Accelerating a particle beam with an AM component
 - (not addressed here) Application to cryogenics