Additive manufacturing for particle accelerators

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Additive manufacturing (AM)

- Colloquially called “3D printing”
- Made by adding droplets of melted material on top of each other.
- Allows great flexibility in the design of mechanical components.
- Allows topological optimisation.
- Studies on-going to see which metals can be 3D printed.
- => potential applications to accelerators

What is additive manufacturing?

- In additive manufacturing an object is built layer by layer.
- This is by opposition with traditional manufacturing where material is usually removed.
- Additive manufacturing allows to produce a large variety of shapes some of which are difficult to produce by conventional manufacturing.

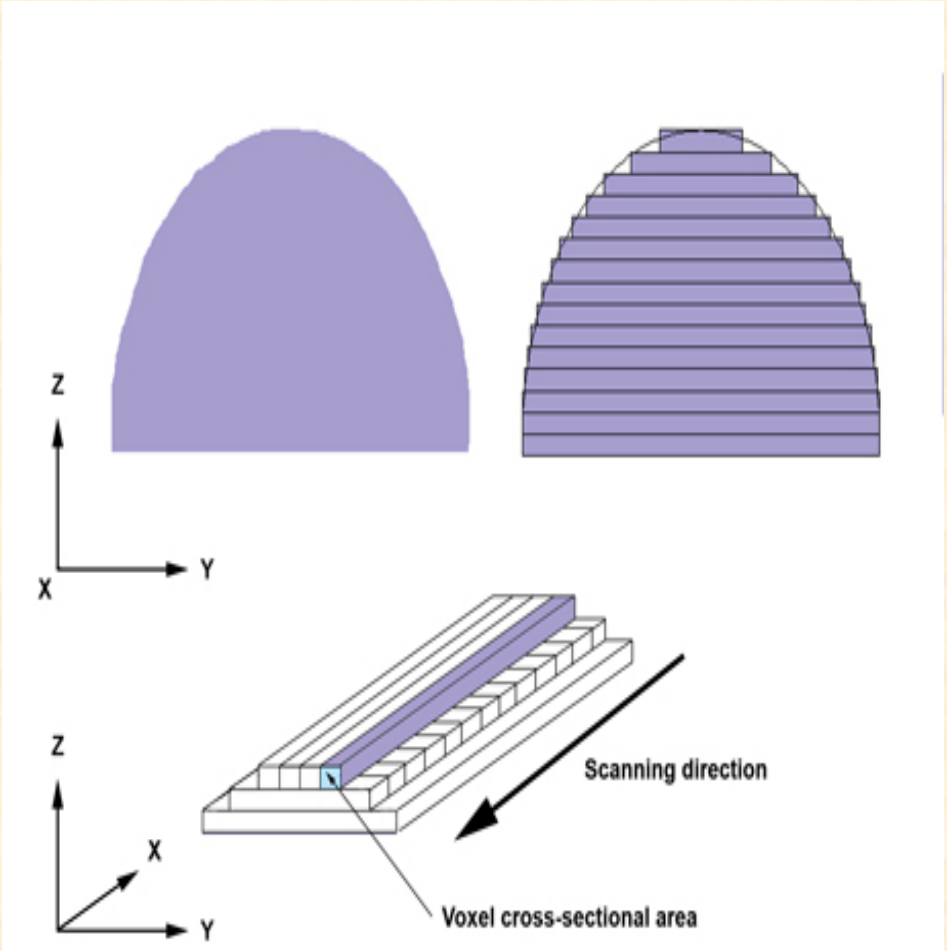
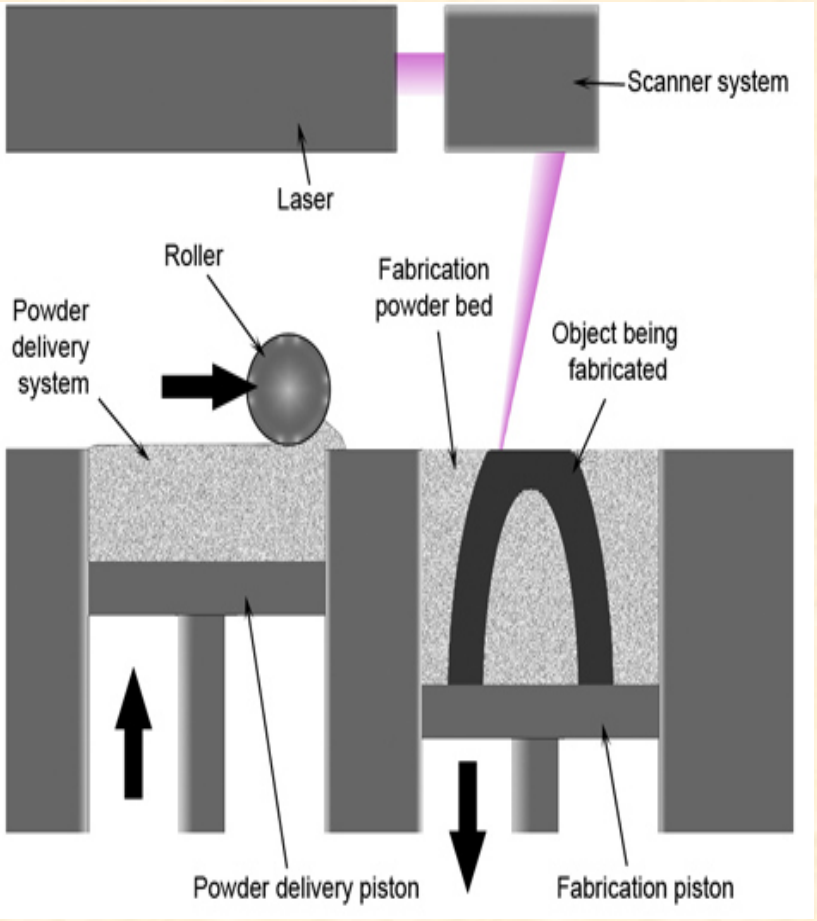


Image source: wikipedia

How additive manufacturing works?



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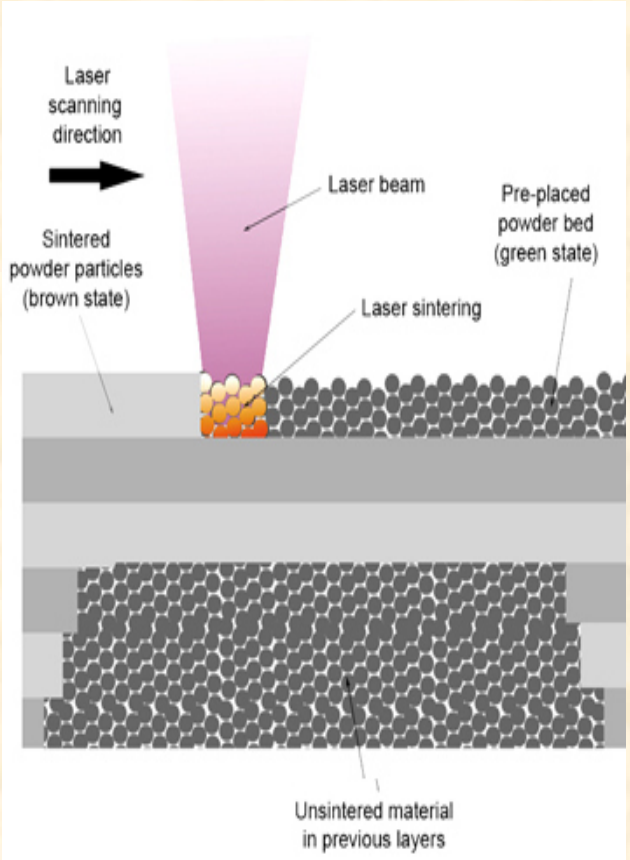
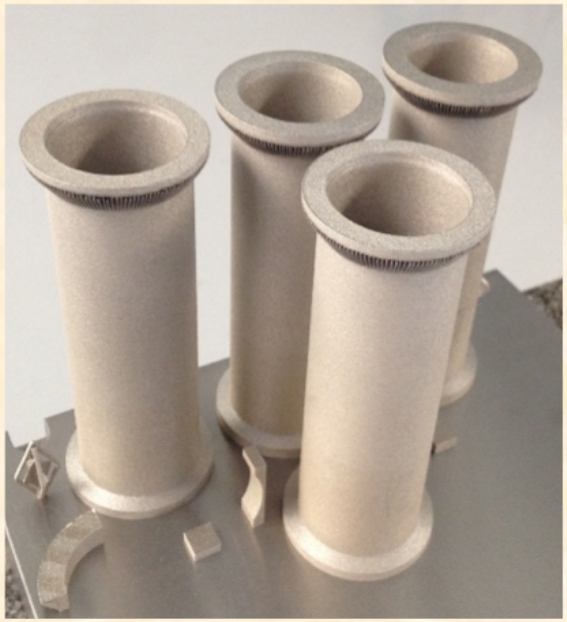


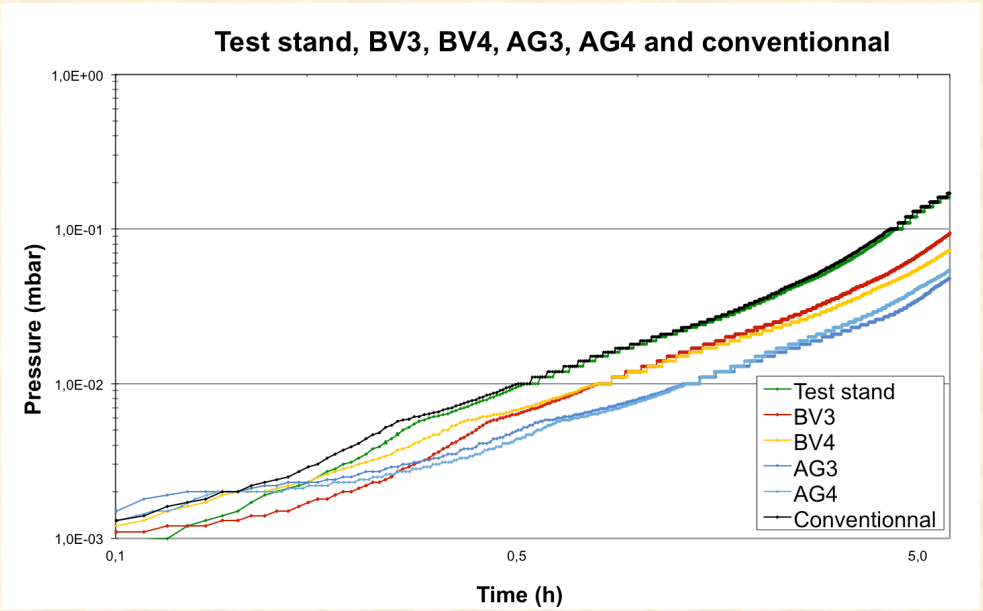
Image source: wikipedia

- Metal additive manufacturing can be done with several technologies.
- One of them is Selective Laser Melting (SLM) where a high power laser melts metal powder to form the object.
- Several metals are available including 316L stainless steel, titanium,…

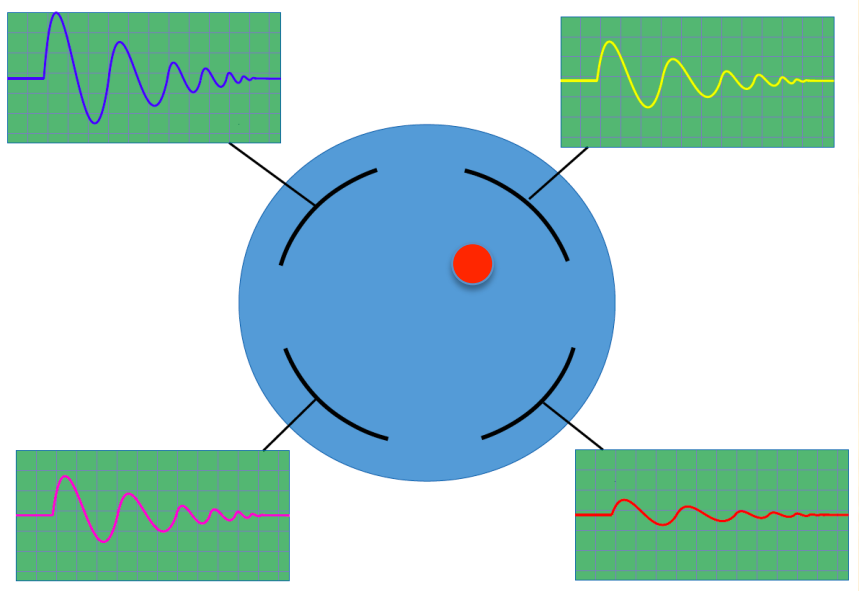
AM and Ultra High Vacuum (UHV)

- We built UHV beam pipes by AM and compared them with conventional ones.
- Surface roughness was not good, however UHV performances were good.





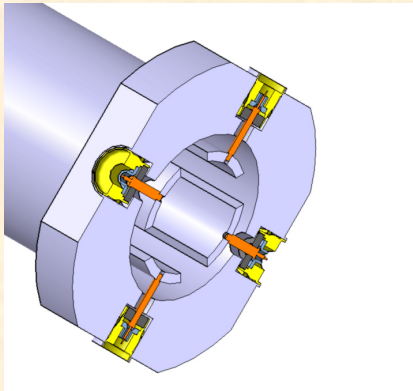
One step further:
Beam Position Monitor (BPM)

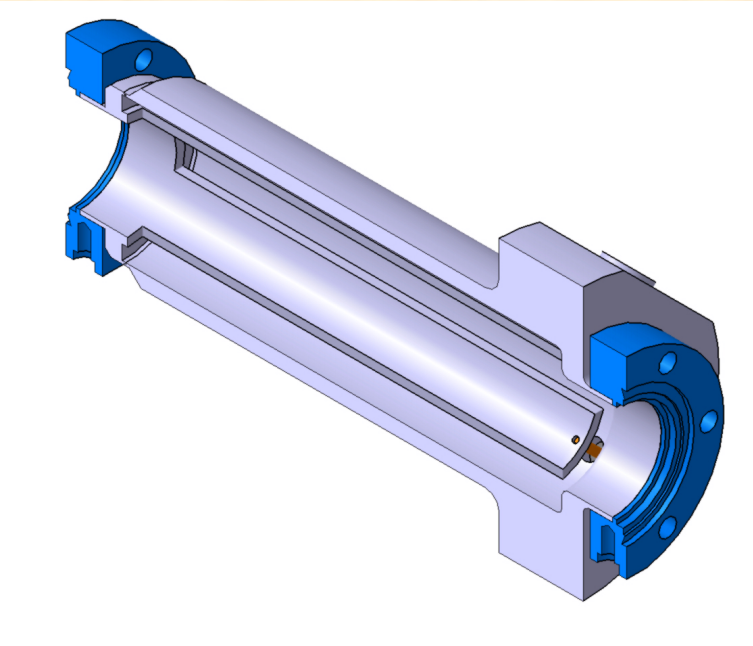


- A BPM is a common device in accelerators.
- Traditional manufacturing is labor intensive => simplfication using AM

ThomX's BPM

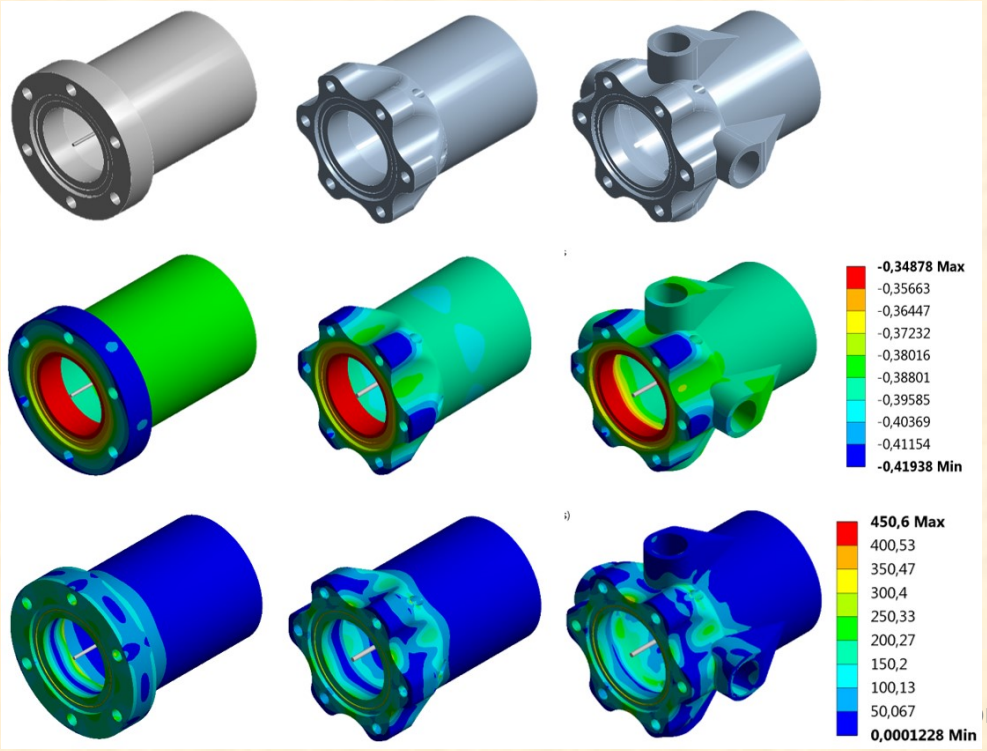
- Several BPMs have been produced at LAL for the ThomX project.

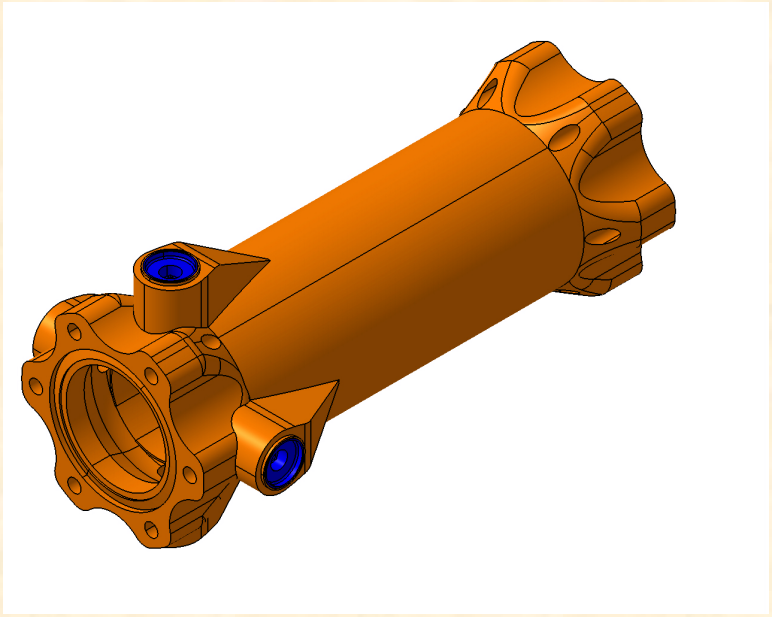




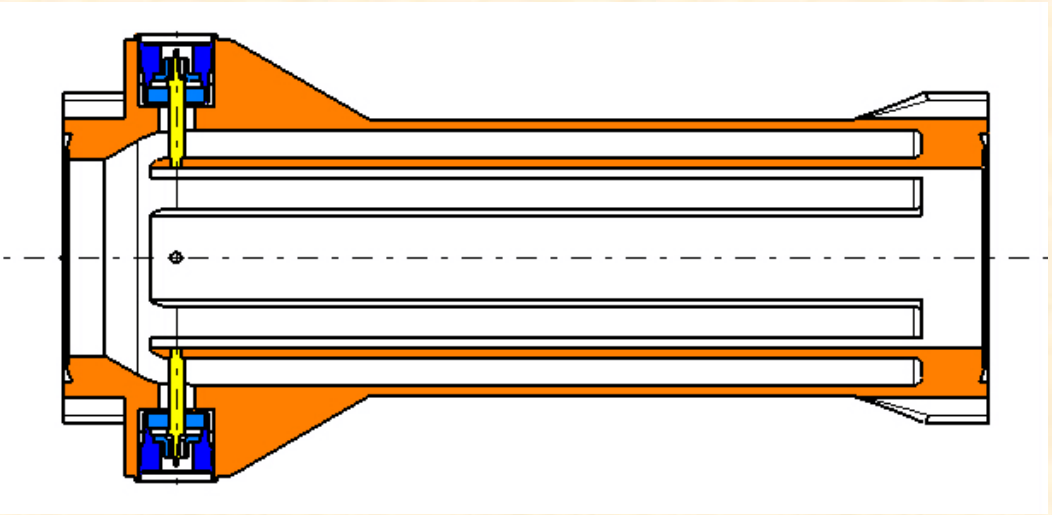
Topological optimisation

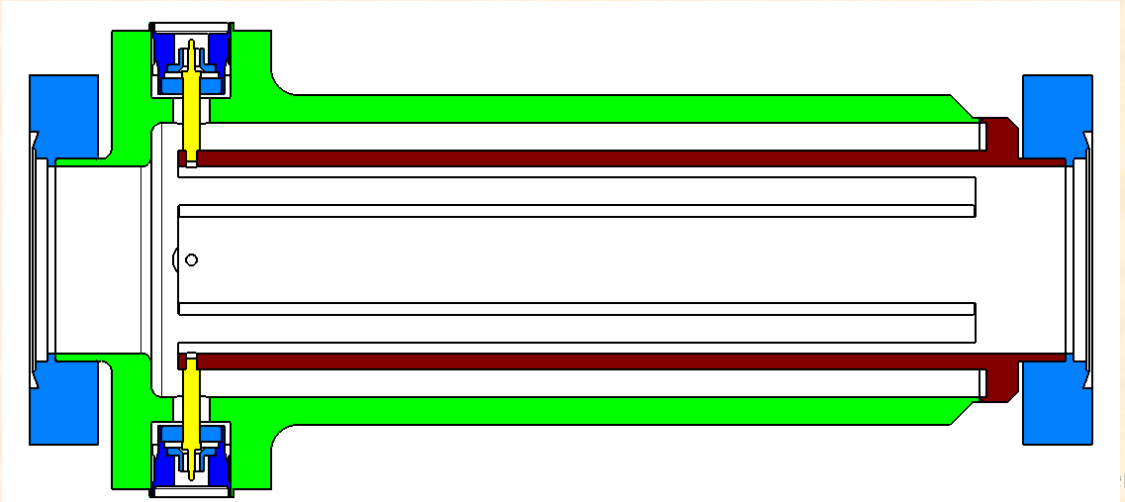
- The ThomX design has been topologically optimized.





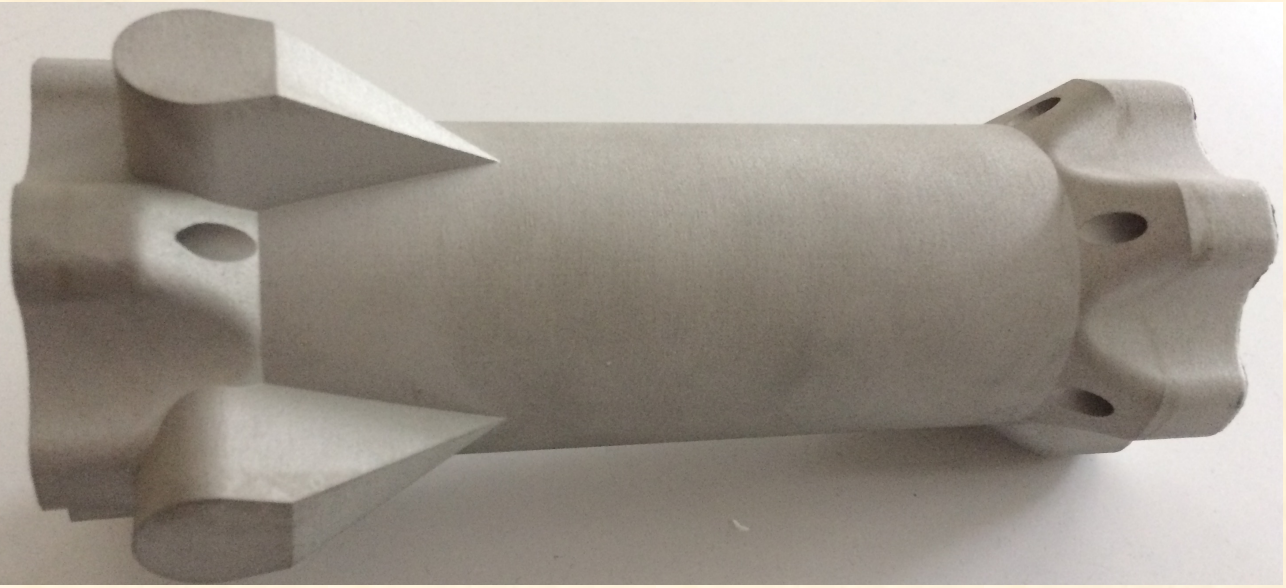
Savings with 3D printing





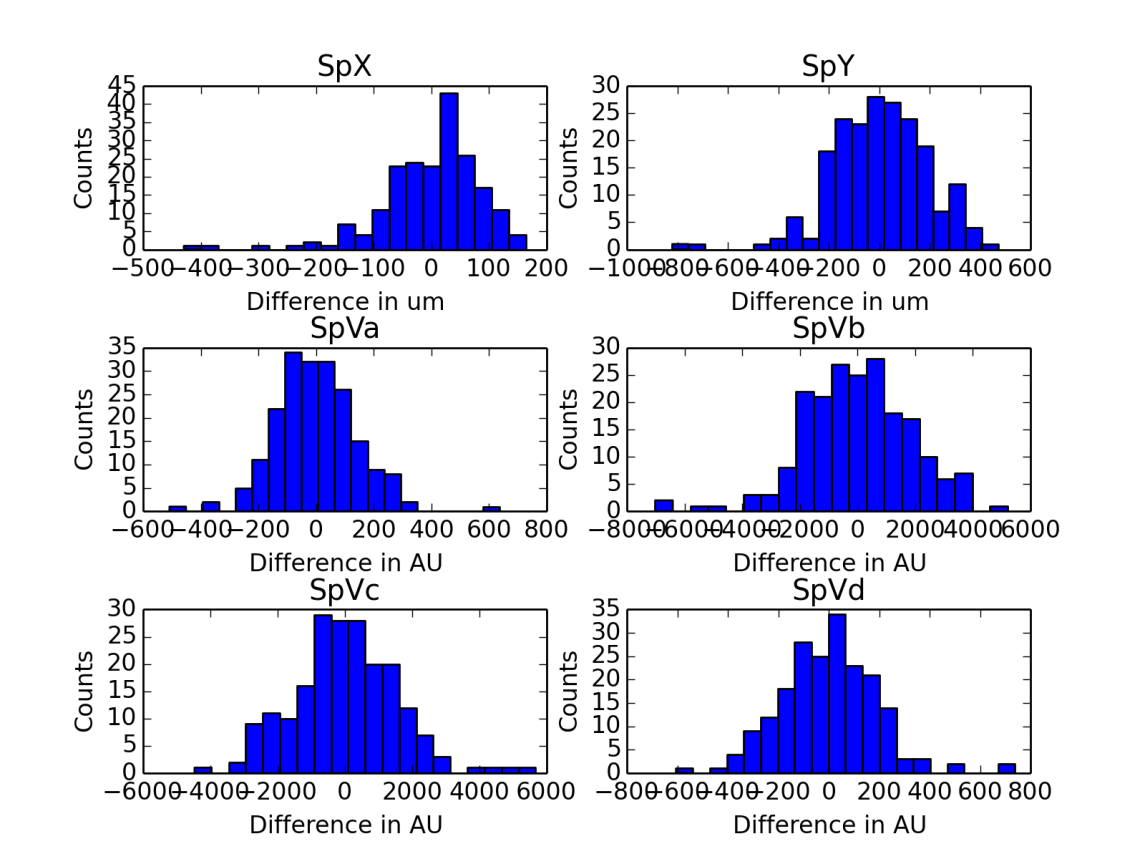
- Topological optimisation allows to build a shorter BPM with the same functionality.
- Cost reduction: 50%
- Production time: 2 weeks instead of 6 weeks.
- Better mechanical accuracy (some shapes were impossible with traditional manufacturing).
- 60% of the original weight.

The 3D printed BPM



- Postprocessing:
  - Electrical feedthrough (including an insulator) were welded after.
  - The flanges'knifedge had to be machined.

Beam tests on a particle accelerator



- Very low residual => no significant issues.
- AM BPM is validated!

Next steps

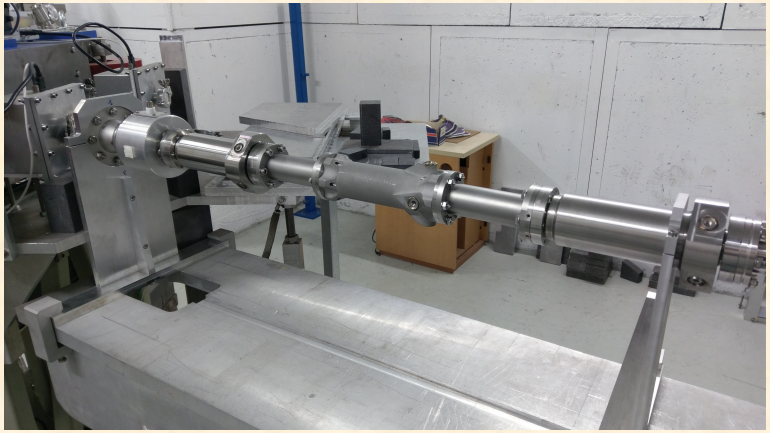
- A network dedicated to AM has been created at CNRS.
- The European project on accelerators innovation IFAST has a work package on additive manufacturing.
- Locally a project has recently being submitted to attempt to build a superconducting cavity with AM.
- Looking forward to new developments.

Open questions

- Copper is used widelly in accelerators.
  - Can we use pure copper in AM? Difficulties created by Cu's reflectivity.
  - What is the conductivity of Cu after AM?
- For superconductivity we use Niobium.
  - How to produce and handle ultra-pure Niobium powder?
  - How does AM affect superconducting properties?
- …

Outlook

- Additive manufacturing can change our way to produce accelerator components.
- Still several technical issues to be solved.
- Significant work at national and European level to address these challenges.



References

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