Tests of a 3D-Printed BPM With a Stretched Wire and With a Particle Beam

Nicolas DELERUE

Didier AUGUSTE, Julien Bonis, Frederick Gauthier, Stéphane Jenzer, Alexandre Moutardier

LAL

CNRS and Université Paris-Saclay

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.

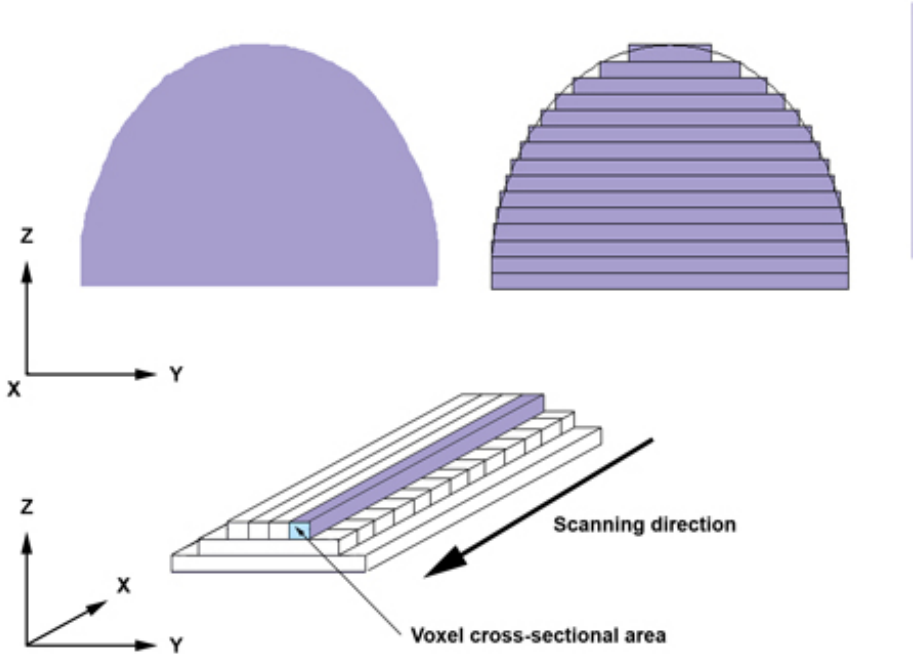


Image source: wikipedia

How additive manufacturing works?

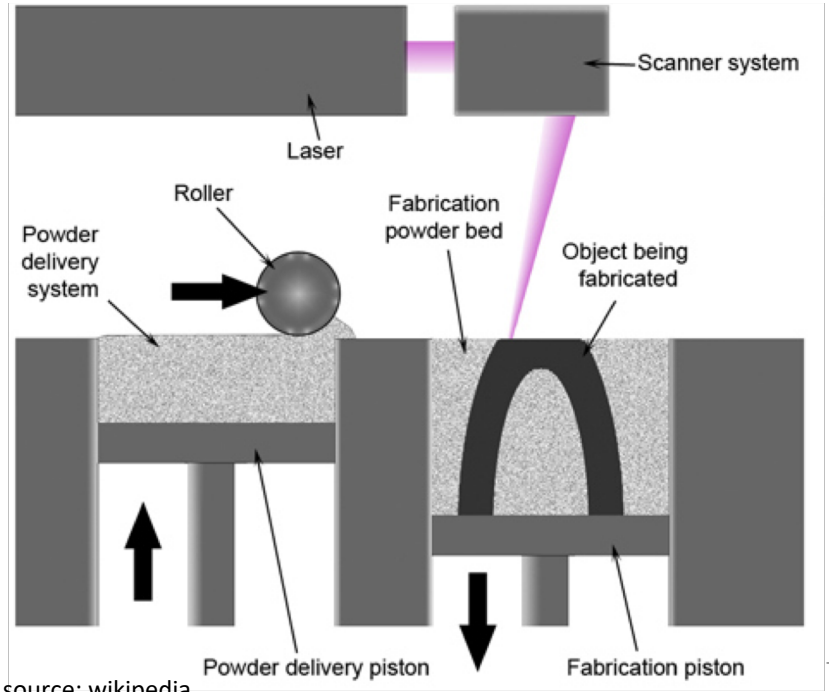


Image source: wikipedia

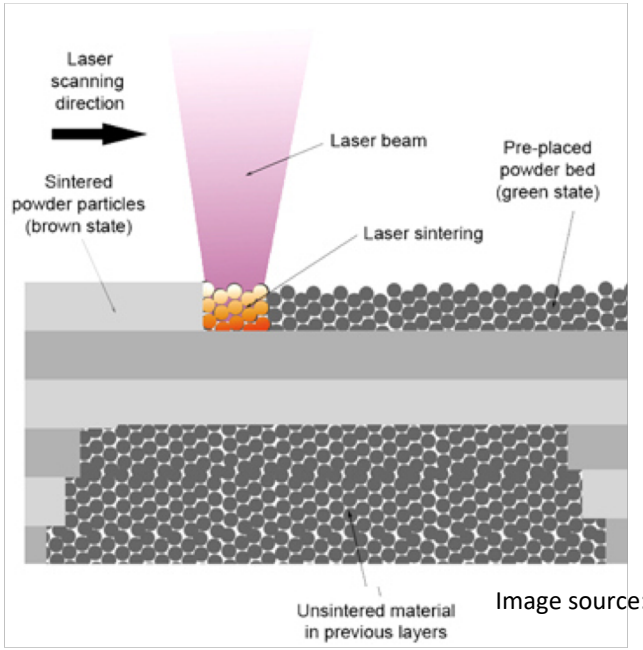
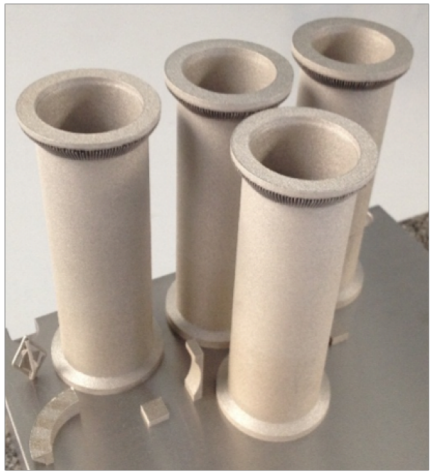


Image source: wikipedia

- 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,…

Can AM be used in accelerators?

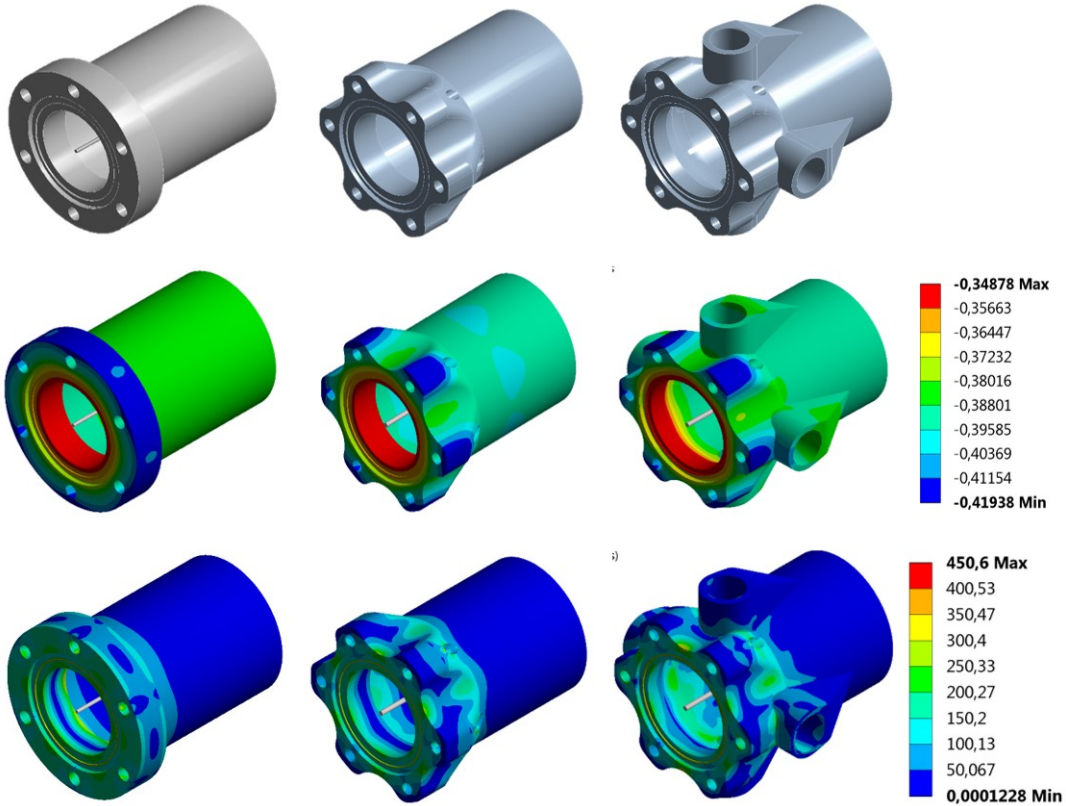
- The capability of AM to make complex shapes is very attractive for accelerators instrumentation.
- However there are several challenges to be addressed:
  - Are additively manufactured part vacuum compatible? *Significant work has been done to address this issue (see Gaël Sattonnay presentation WEXXPLS3).*
  - What is the mechanical strength of these components? *An extensive study campaign is ongoing to address this issue.*
  - What are the electrical properties of AM components? *To test this we decided to build a Beam Position Monitor by AM.*
  - *Cryogenics, RF,…*



More details on the advantages and challenges of additive manufacturing for accelerators: see THPTS008

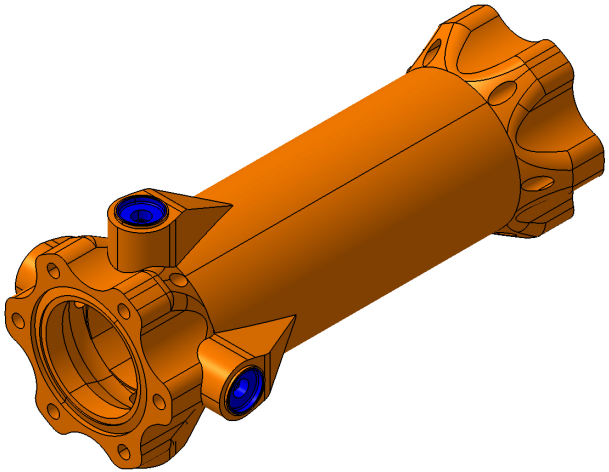
Designing a BPM for additive manufacturing

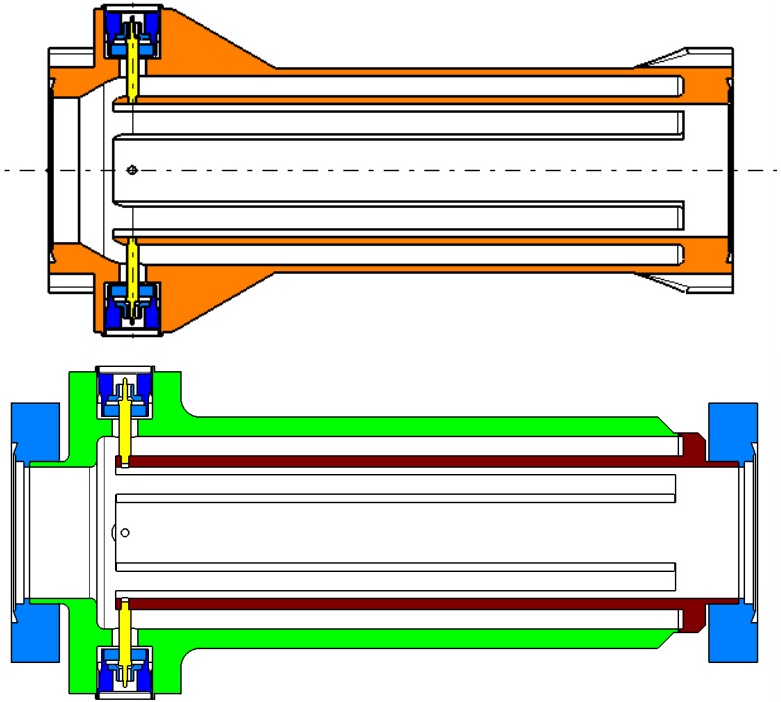
- Additive manufacturing allows topological optimisation of the shape.
- It also sets constraints on overhanging surfaces.
- Topological optimisation allows a lighter flange with similar functionalities.



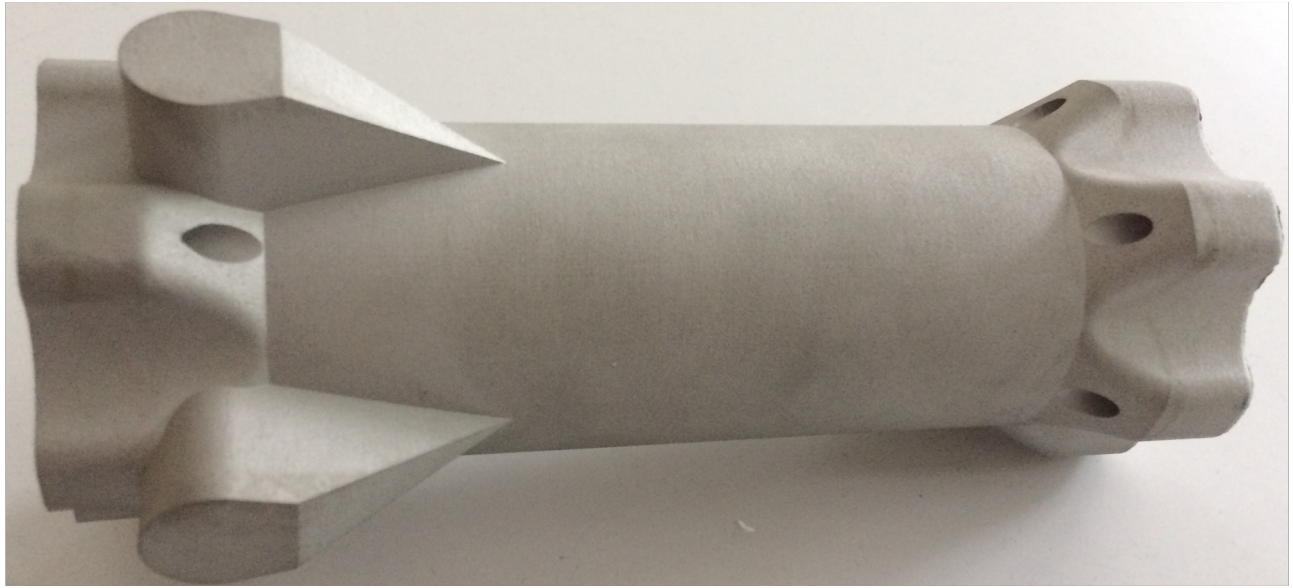
Designing a BPM for additive manufacturing (2)

- With additive manufacturing a more compact design is possible.
- The impedance of the 3D-printed BPM is closer to 50 Ohms (thinner electrodes).





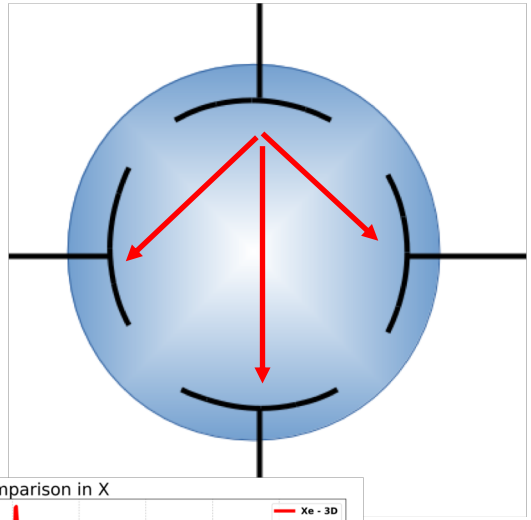
Designing a BPM for additive manufacturing (3)

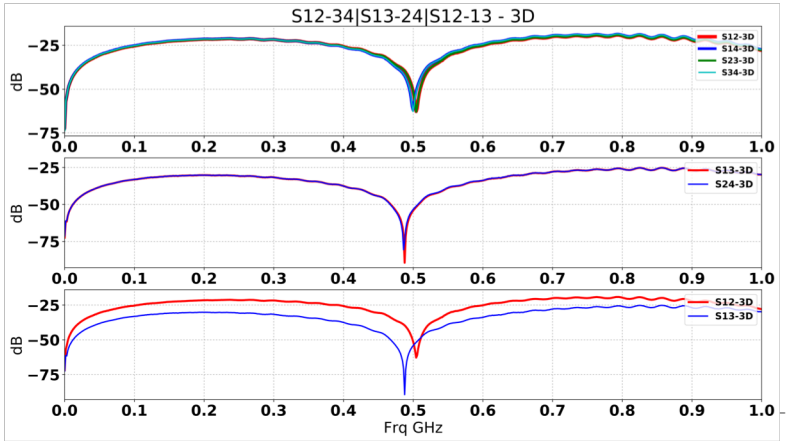


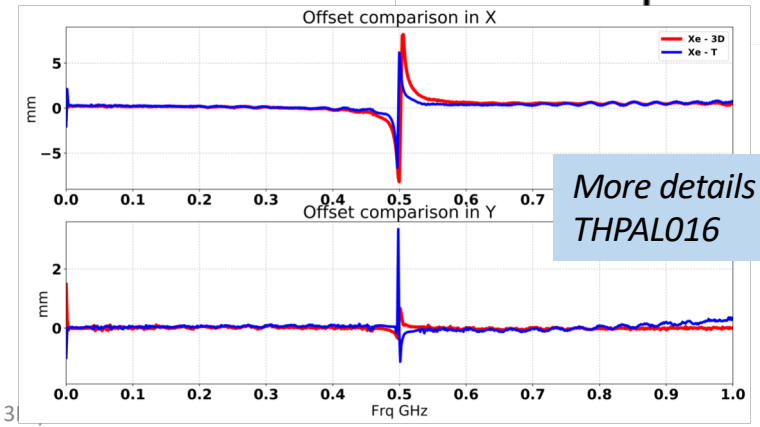
- After printing the BPM add to be post-processed:
  - Cut the knife edges for UHV CF Flanges.
  - Weld the electrodes feedthrough.

Lambertson measurements

- The first step to qualify the BPM was the measure of the electrodes coupling and misalignment using the Lambertson method (with a network analyser).
- In the Lambertson method the coupling between the electrodes is measured by injecting a signal on one electrode and reading it on one the others.
- This gives information on coupling and misalignment.
- The properties measured by that method were found to be similar or better than with traditional manufacturing.



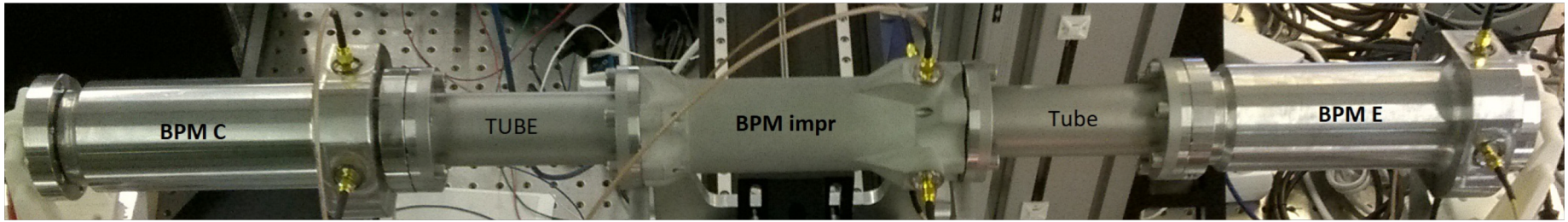




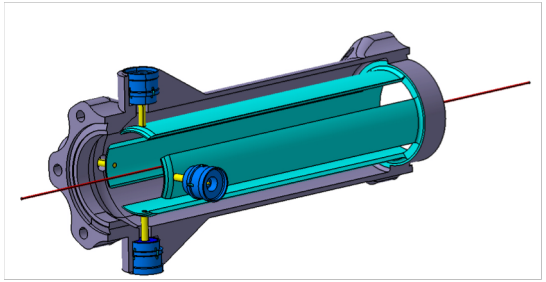
More details at IPAC'18 THPAL016

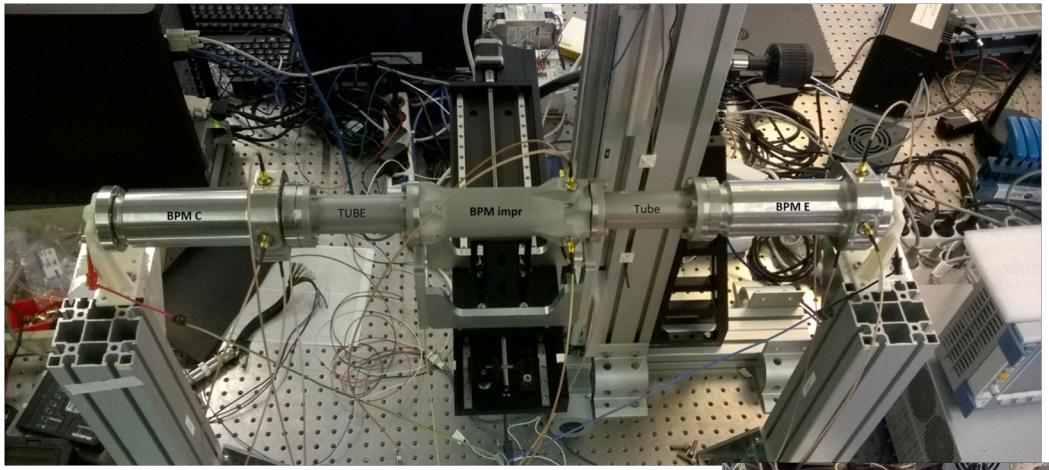
Comparison with traditional BPMs

- To qualify the AM BPM we mounted it on a triplet with two BPMs made by conventional methods.
- This allows direct comparison of the performances of the three BPMs.



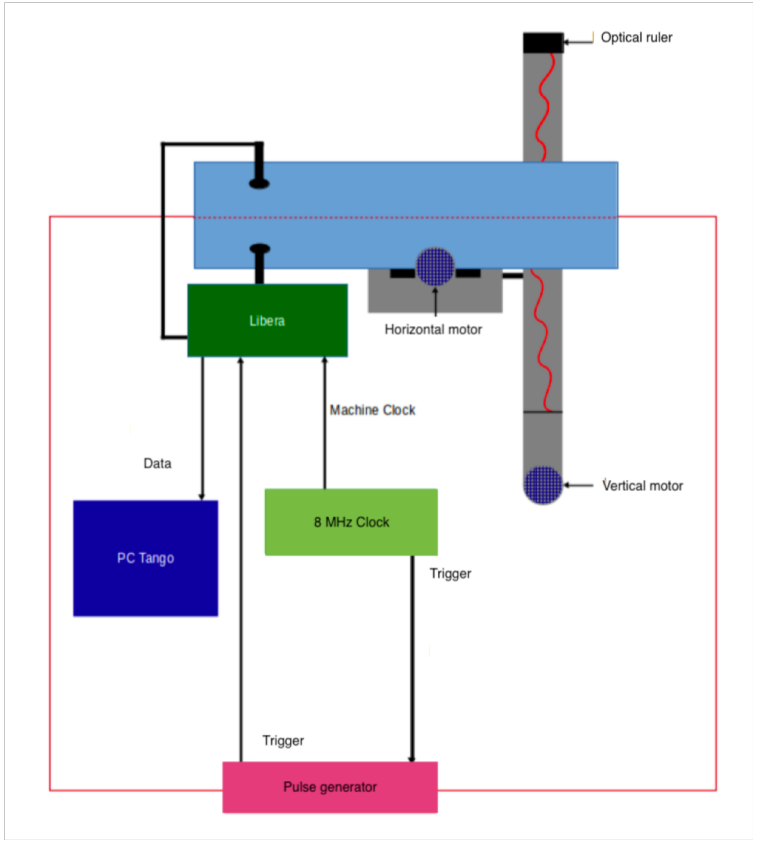
Stretched wire tests

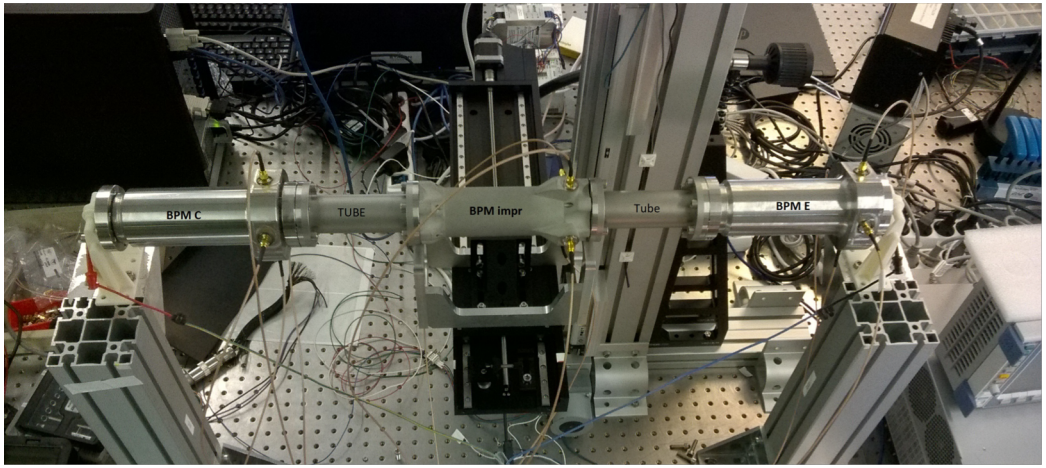




- The stretched wire method allows to measure the response of a BPM to a displacement of the wire.
- A wire is stretched across the BPM triplet which is mounted on translation stages.
- To avoid vibration problems we decided to move the BPMs, not the wire.

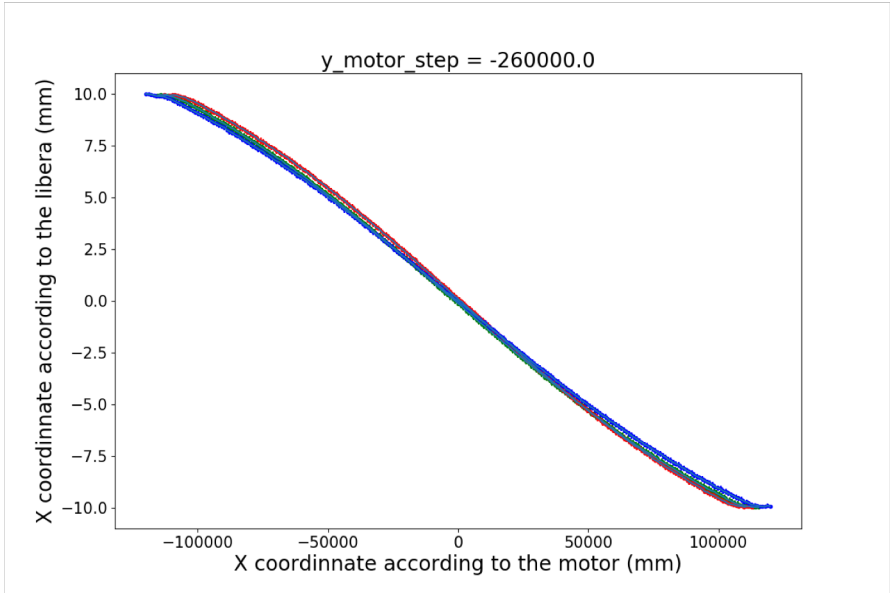
Stretched wire tests (2)

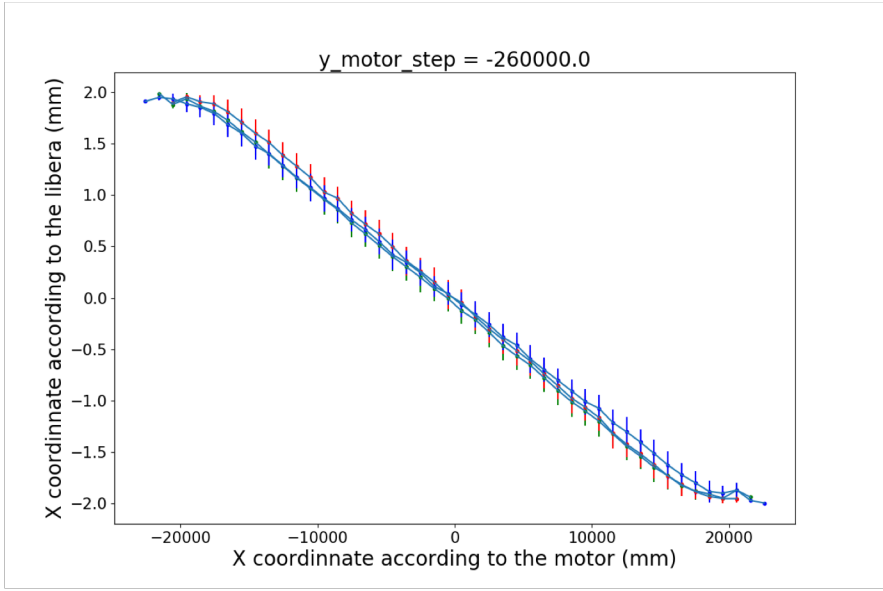




- Electrical pulses are sent across the wire and are read on the BPM electrodes.
- We used a Libera Billiance+ to read the signal on the electrodes.
- Data acquisition was done through Tango.

Stretched wire tests results

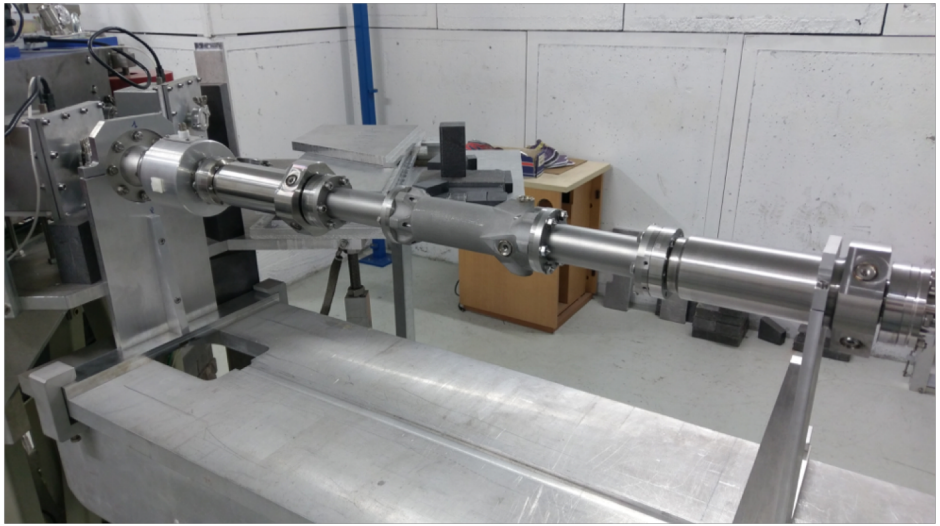




- A very good correlation was observed between the expected and measured position for the three manufactured BPMs.
- The residual error with a linear fit is similar to that of the other BPMs (and can be explained theoretically).

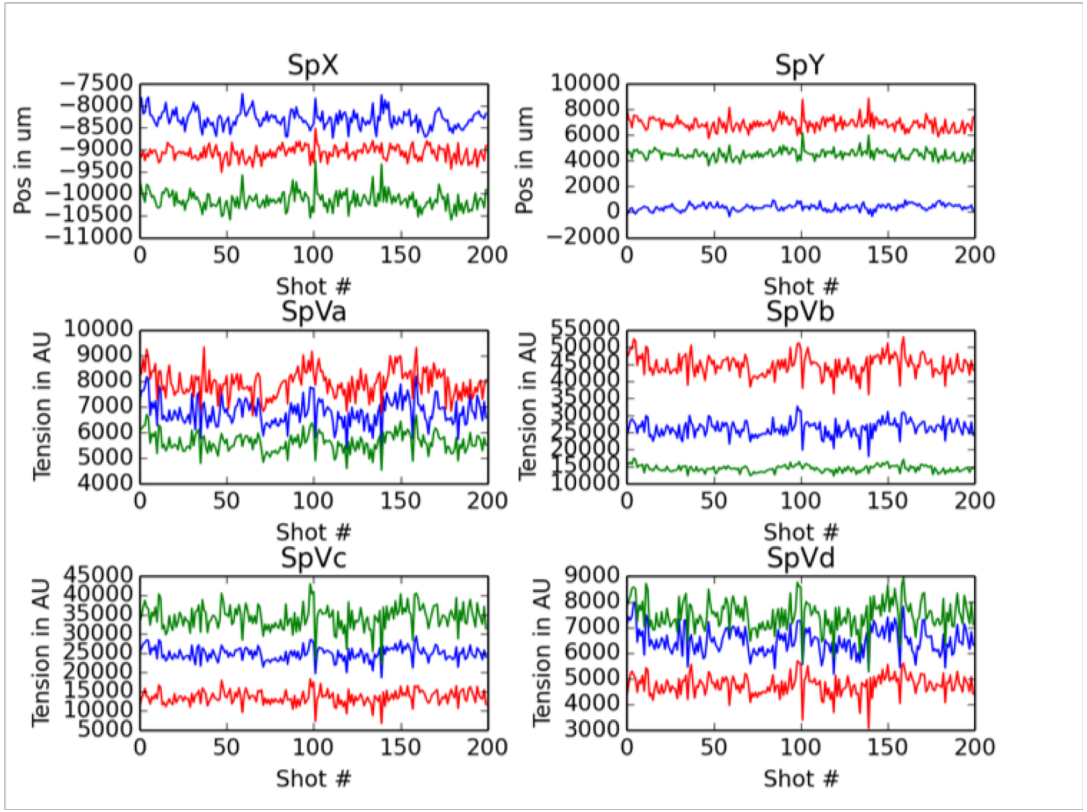
Tests on a photo-injector

- After the measurements with the stretched wire the BPM was installed on the PHIL photo-injector.
- All 3 BPMs were revalidated by the UHV group for installation in the accelerator UHV.
- PHIL can deliver a 3.5MeV, 100pC at 5Hz beam of electrons with a transverse size of a few millimetres.

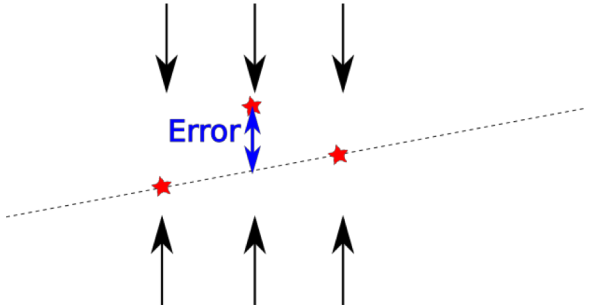


Tests on a photo-injector (2)

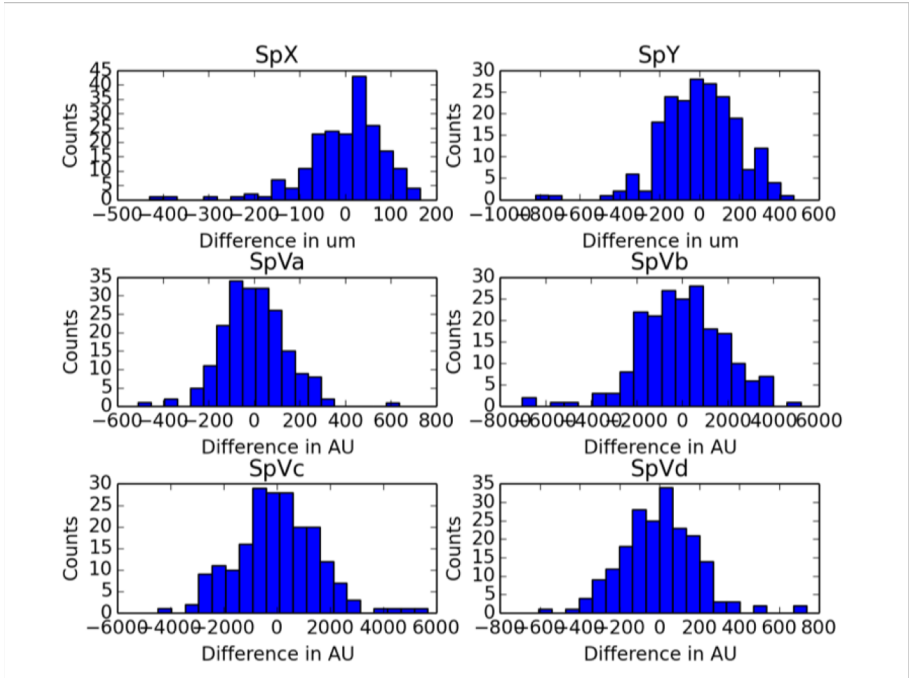
- During the first tests we changed some accelerator settings and looked at the response of each of the electrodes of each BPM.
- The signal on the 3D-printed BPM was higher (before attenuation) because of the better impedance matching.
- We observed that the electrodes had a similar behaviour for the three BPMs.



Tests on a photo-injector (3)



- Looking at the misalignment error between the three BPMs we found 200um (horizontal) and 400um (vertical), that's about 10% of the beam size.
- Reasonable errors for single pass measurements.



Outlook

- We have built a BPM using topological optimisation and additive manufacturing.
- We qualified it, together with two traditionally manufactured BPMs, using the Lambertson method and the stretched wire method.
- In both cases the performances of the 3D-printed BPM were found to be better or equal to those of the other BPMs.
- It was then UHV-qualified and installed on a photo-injector where its performances were within specifications.
- ***The 3D-printed BPM performs at least as well as conventional BPMs.***