

Depth sensing for automatic detector construction and quality control

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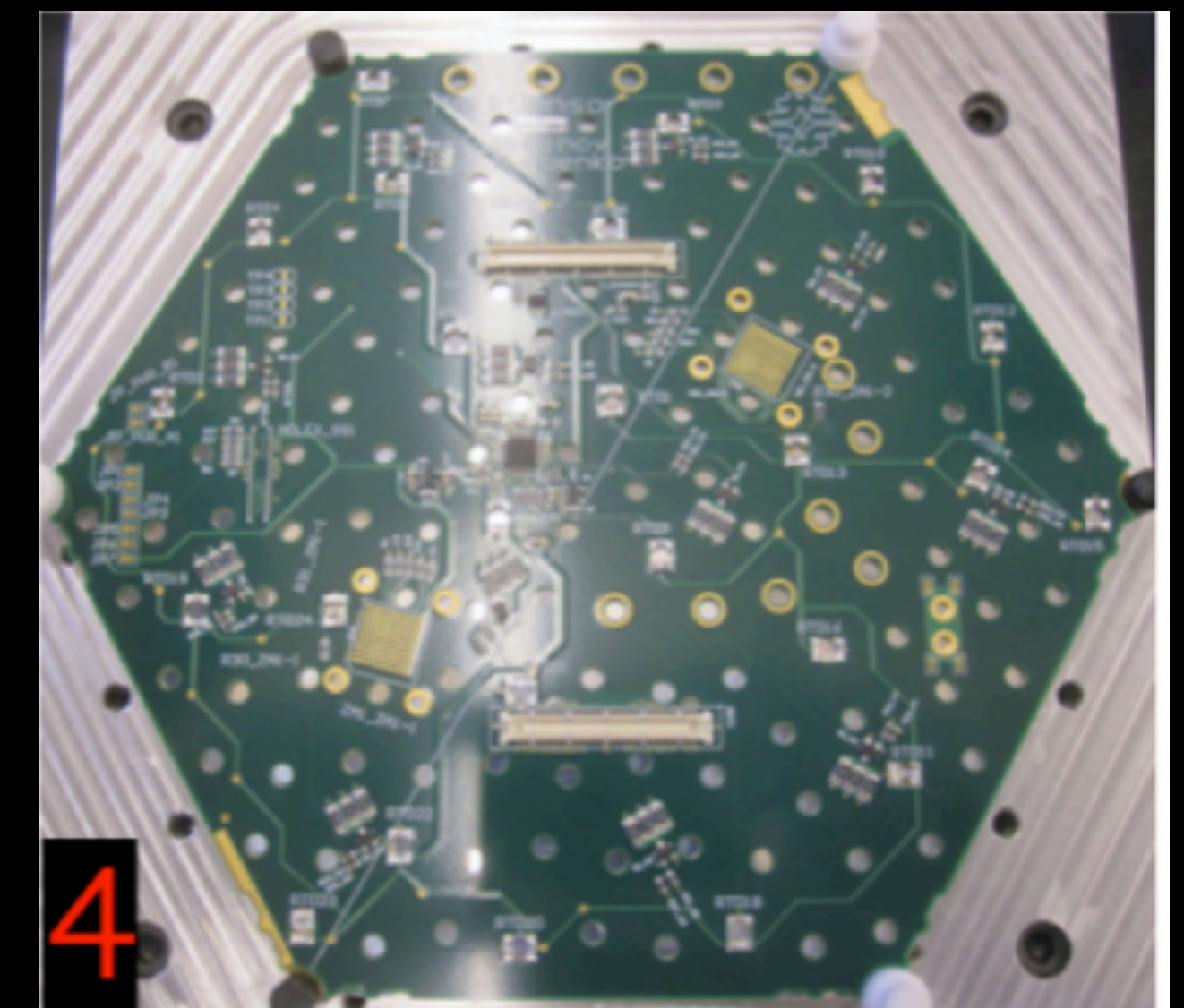
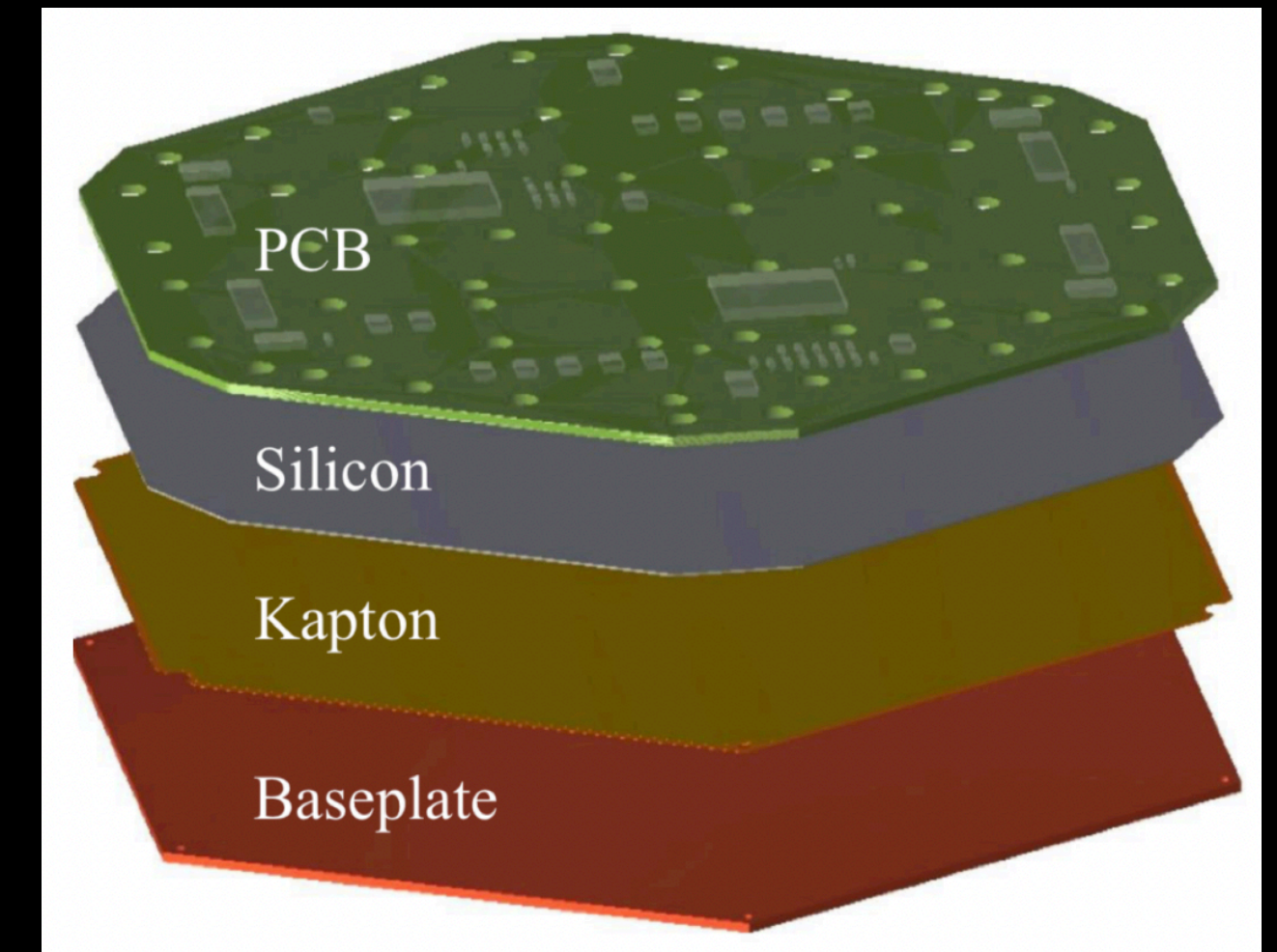
Introduction



- The LHC at CERN is going to be upgraded to the HL-LHC.
- Increased luminosity will produce a more challenging environment to the detectors.
- TTU HEP group will build ~5k (of the ~30k) silicon modules for the new CMS calorimeter.
- Each module involves laminating components with high precision and bonding ~700 wires.
- The limited timelines generate a need for robust and efficient automation tools.

High Granularity Calorimeter

- HCAL will be upgraded to HGCAL.
- HL-LHC radiation level will be 10x higher than the current CMS design.
- HGCAL has two active materials: silicon (Si) and plastic (Sc)
- 75-100 μm of glue between layers

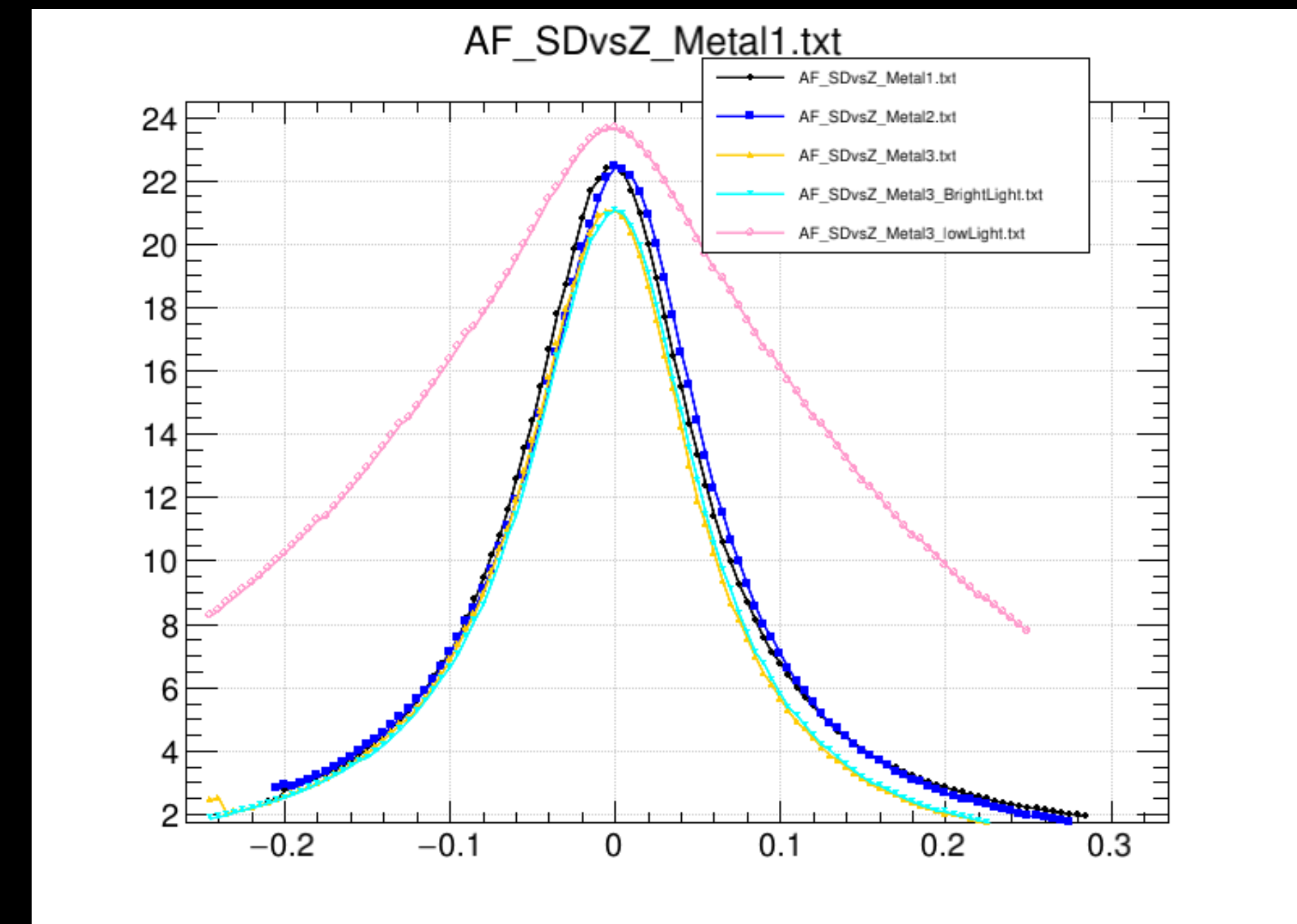


Depth sensing

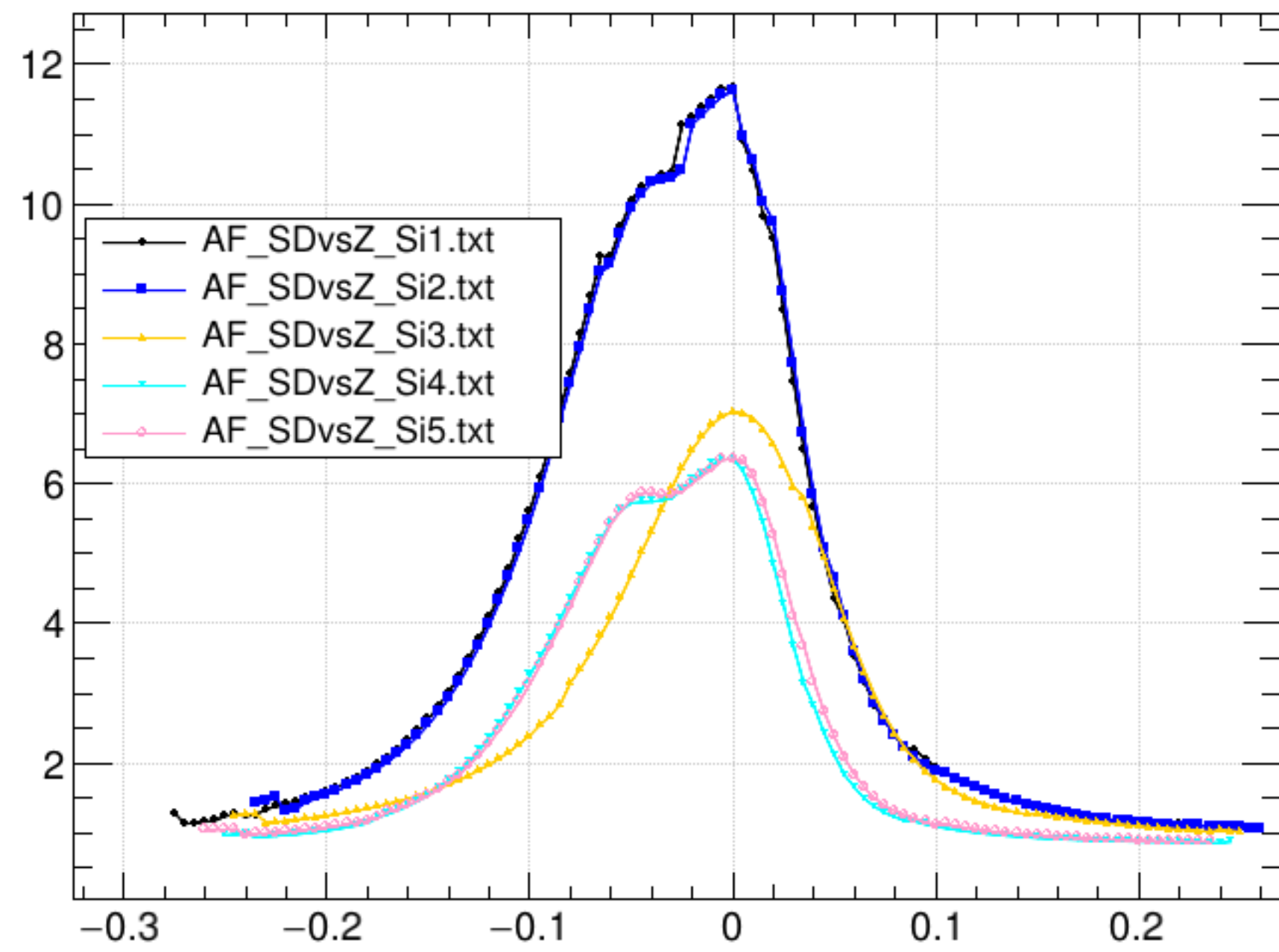
- Needed for high precision assembly and quality control.
- Idea: how can we use a camera for it?
- Relate the sharpness of the image with the distance from the camera (or position recorded by the gantry)

Autofocus

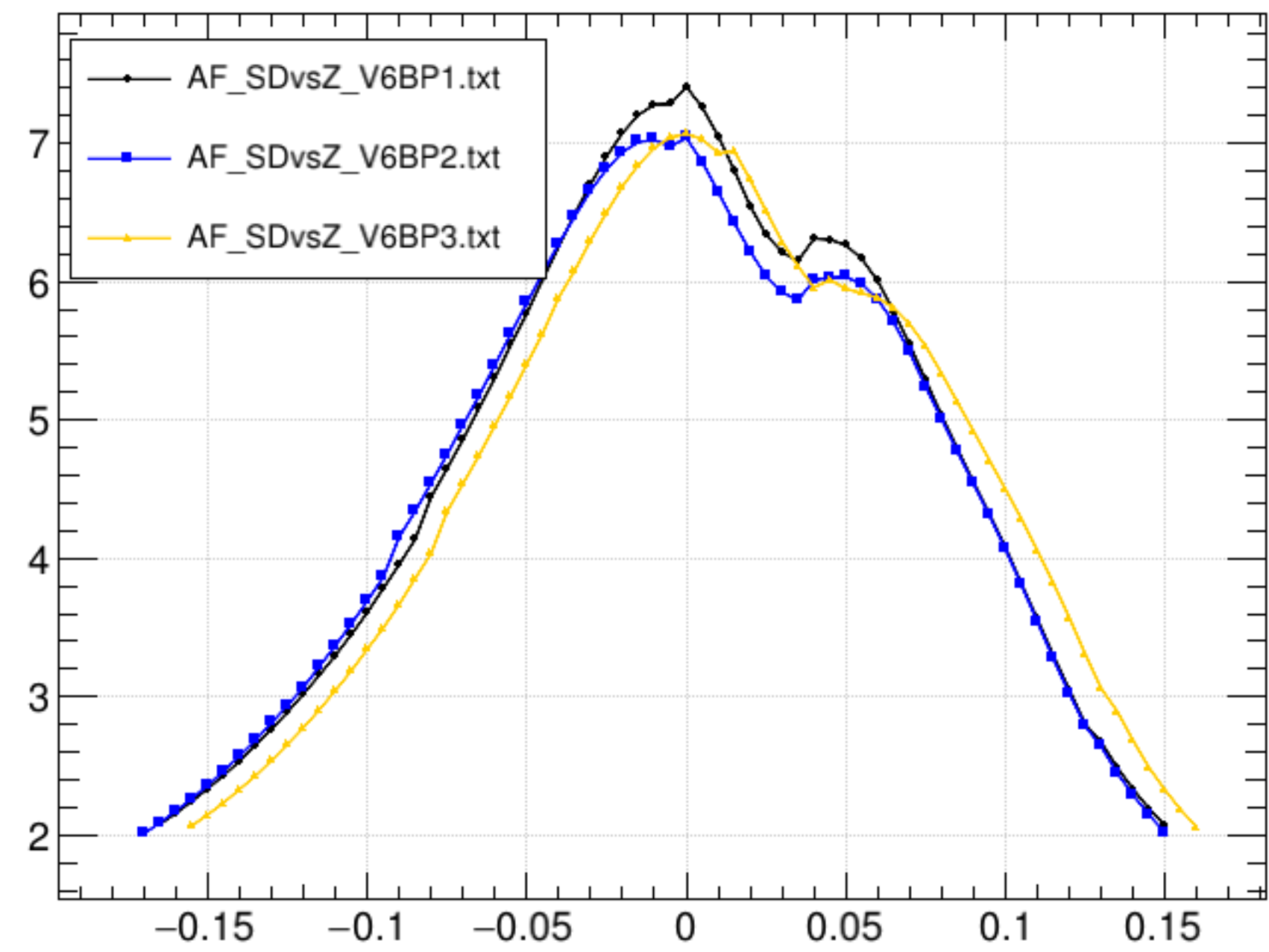
- **Sobel filter:** gradient based method
 - Good for detecting edges
 - Looks for changes in the first derivative of an image
 - A pair of convolution masks
- Find the max. sharpness
- Measure the distance compared to the baseplate



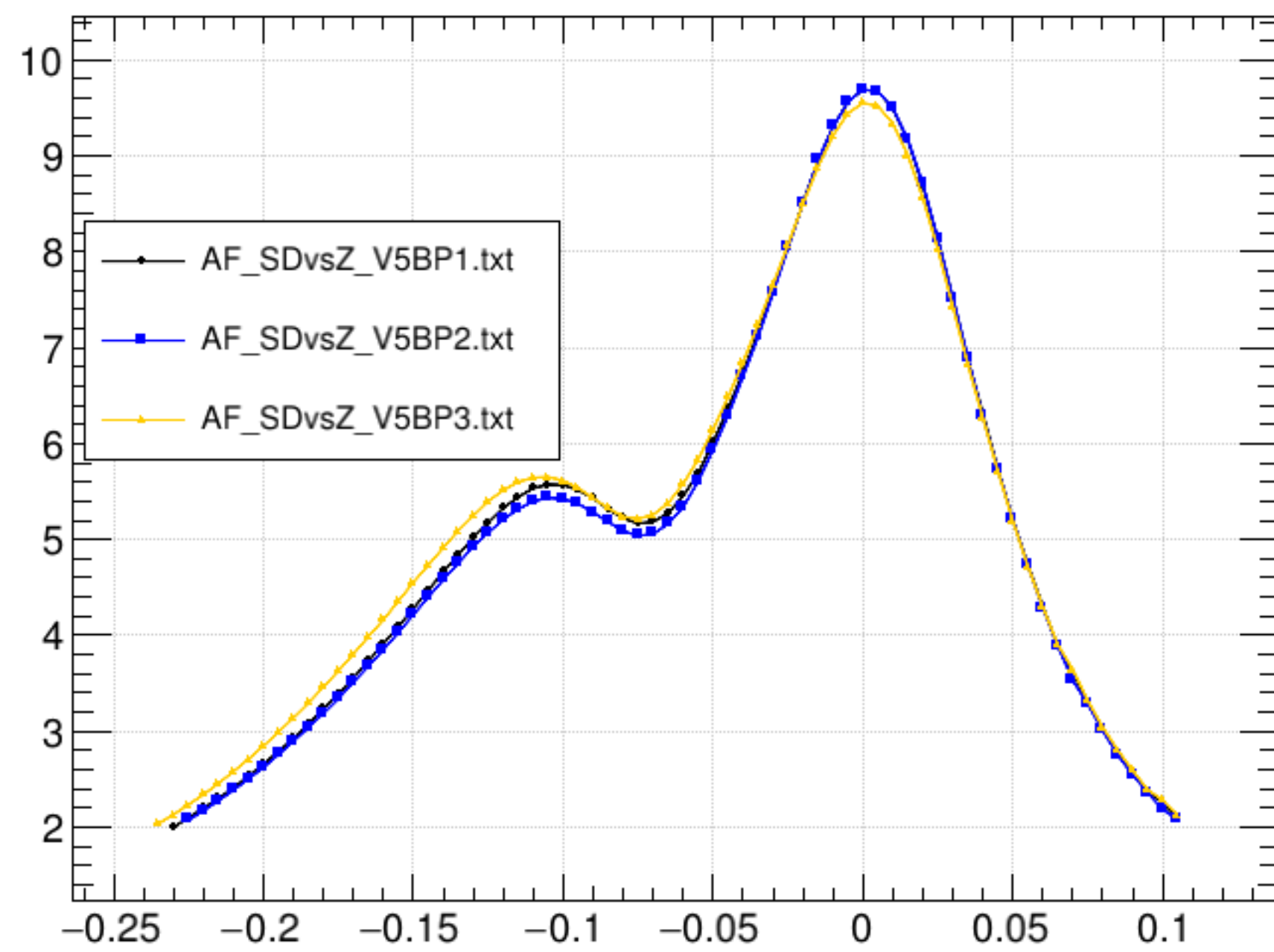
AF_SDvsZ_Si1.txt



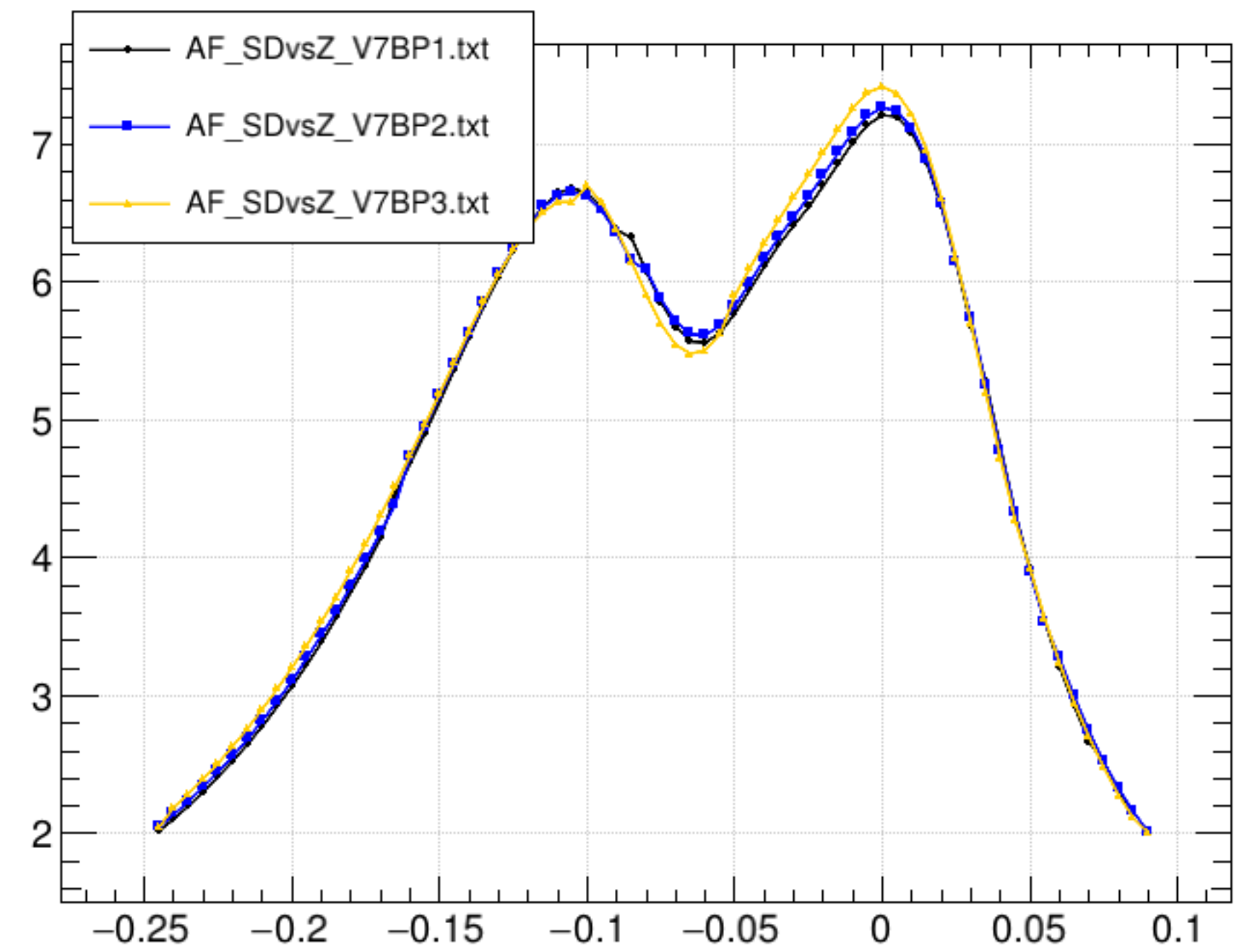
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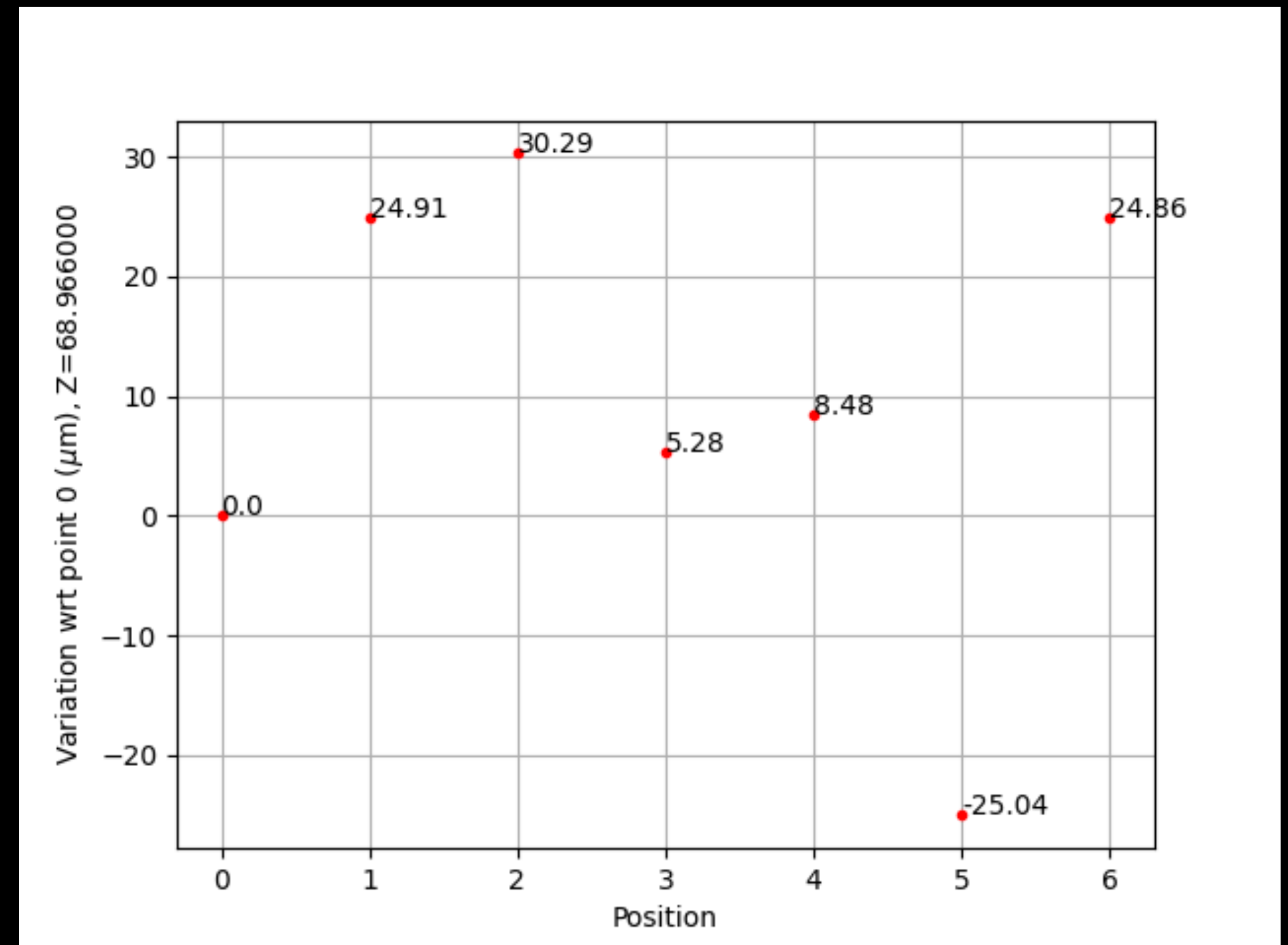
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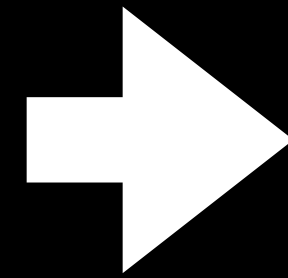
AF_SDvsZ_V7BP1.txt



- Works like a charm for small field of view
- For bigger field of view other methods are needed



- Assembly in the gantry
- Wire bonding
- Quality control



All use different equipment

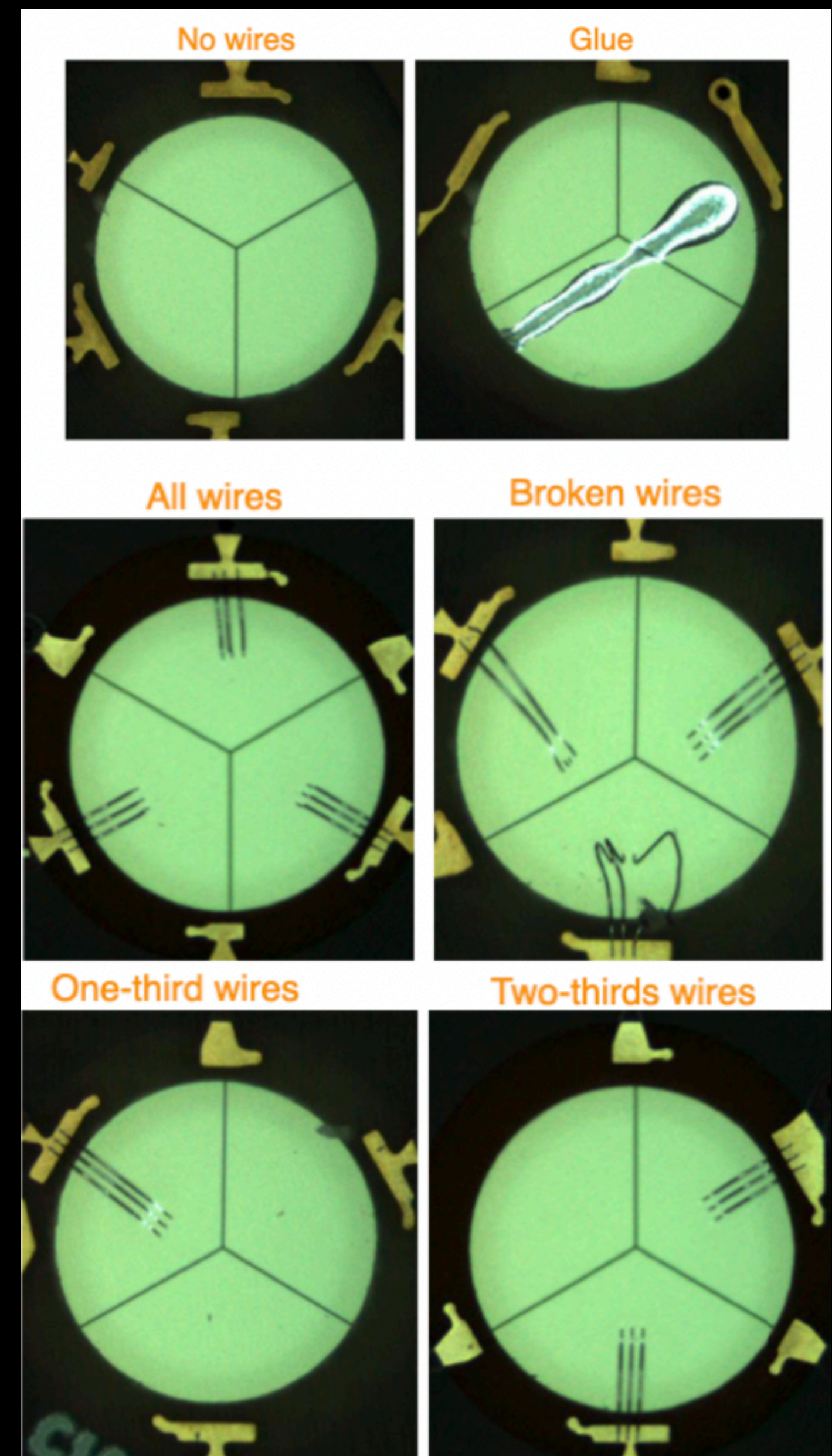
Solution:

Integrate all processes in the gantry

Wire-bond Quality Control

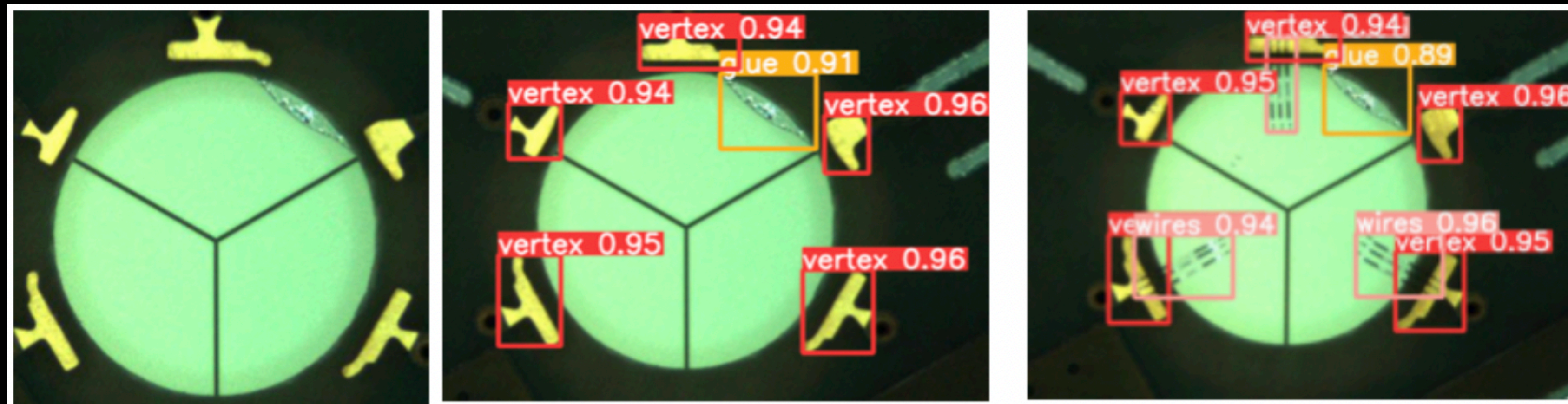
- Key to producing high-performance detectors
- The number of wire-bonds and the dimensions of the wires (~25um) make it unpractical to inspect it manually
- Autofocus depth sensing helps
- Computer vision techniques based on deep learning algorithm

- Holes are checked before and after wire-bonding
 - presence of glue
 - count the wires and identify the broken ones



Object detection

- YOLO - you only look once
 - class & location
 - in principle we don't want any glue, but depending on the location it is still possible to wire-bond



Results

- Precision: $TP/TP+TN$
- Recall: $TP/TP+FN$

Class	Labels	Precision	Recall
All	764	0.992	0.951
Wires	420	0.981	1
Broken	96	0.999	0.917
Glue	192	0.988	0.885
FooBar	56	1	1

Summary

- Depth sensing algorithm works for precise measurements in a small field of view.
- Optimize it.
- Object detection with YOLO is working well with accuracy >95%.
- Next: use YOLO to find the wholes and make the whole QC automatic.

Thanks!

Gracias!