

# Hybrid Metrology

Ian Dyckes



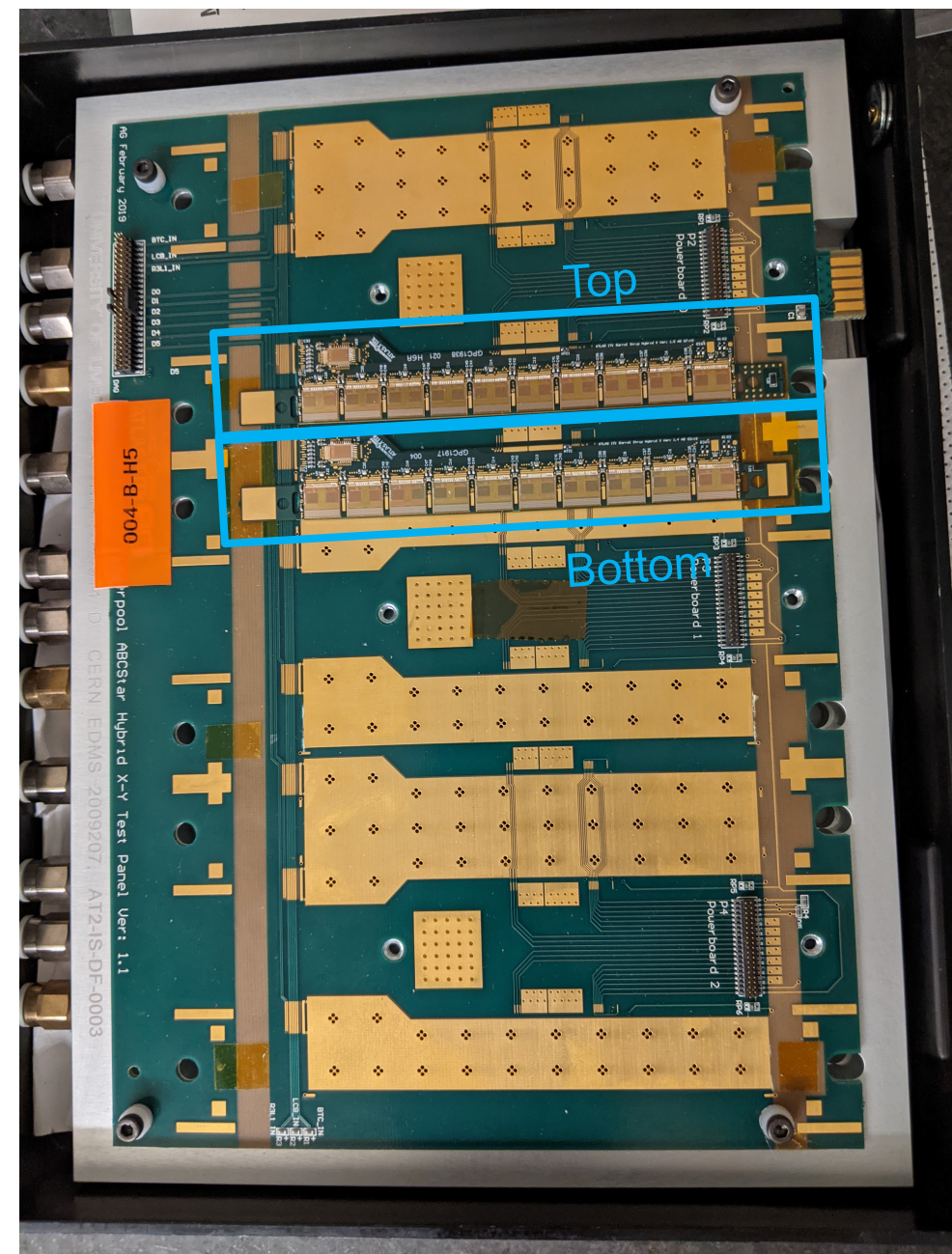
# Introduction

## What I've been doing:

- Working through the hybrid metrology procedures, described [here](#).
  - Part of QC for hybrid assembly.
  - Must demonstrate we can do this for site qualification.
  - Should be performed after gluing ASICs, before wire bonding.
  - Hybrids are under vacuum on test panel.
- Establishing software infrastructure:
  - MeasureMind routines.
  - Python scripts.

## Disclaimers:

- Measured old test hybrids (X-type).
- More concerned about getting reasonable results than being in spec.
- All measurements are optical.
  - No laser measurements.



# Workflow

## Workflow:

1. Perform measurements using SmartScope + MeasureMind software.
  - Produces unformatted raw data.
2. Run python script to reformat data in “common” format.
3. Perform analysis on “common” format data.
  - Create plots and perform required calculations.
4. Eventually upload data and calculations to the database.



## Unformatted Raw Data

```
C:\Part\rt\Ian_hybrid_stretchShrink.RTN 04/07/2021 15:58:42 1
Centroid 3 Pos0
+0.00150009 +0.00100000 +0.00000000 mm +0.00000000
Centroid 7 Pos1
+9.56370857 +0.87258643 -0.06300171 mm +0.00000000
Centroid 8 Pos2
+19.21778876 +0.87113116 -0.17200466 mm +0.00000000
Centroid 9 Pos3
+28.87688594 +0.87467411 -0.23200629 mm +0.00000000
Centroid 10 Pos4
+38.54521007 +0.87071284 -0.22550611 mm +0.00000000
Centroid 11 Pos5
+48.21016346 +0.87075316 -0.21950595 mm +0.00000000
Centroid 12 Pos6
+57.87160225 +0.87429507 -0.18200493 mm +0.00000000
Centroid 13 Pos7
+67.53953107 +0.87683435 -0.14150384 mm +0.00000000
Centroid 14 Pos8
+77.20176163 +0.88137438 -0.05000136 mm +0.00000000
Centroid 15 Pos9
+86.86995139 +0.88491366 +0.03900106 mm +0.00000000
Centroid 16 Pos10
+96.41675528 -0.00100003 +0.07050191 mm +0.00000000
```

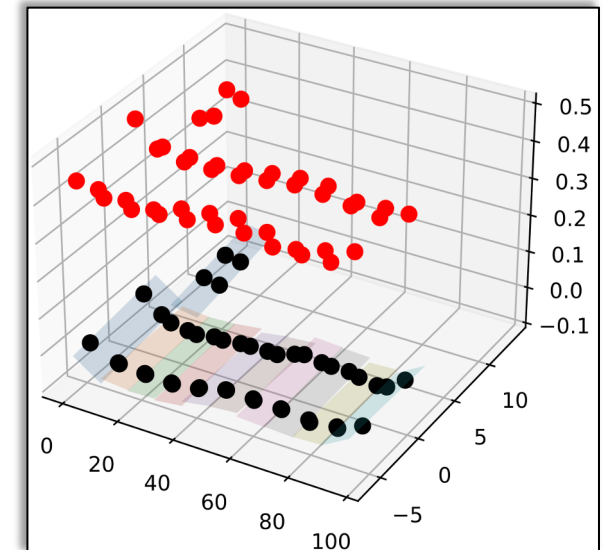


## Raw Data in Common Format

```
#---Header:
EC or Barrel: SB
Hybrid Type: HX
Hybrid Ref Number: None
Measurement Date: 2021-04-07
Measurement Time: 15:58:42
Institute: LBNL
Operator: Ian Dyckes
Instrument Used: OGP Smartscope optic
Test Run Number: 1
Measurement Program Name: Ian_hybrid_stretchShrink.RTN
#---Position Scan:
#Location X [mm] Y [mm]
Pos0 0.002 0.001
Pos1 9.564 0.873
Pos2 19.218 0.871
Pos3 28.877 0.875
Pos4 38.545 0.871
Pos5 48.210 0.871
Pos6 57.872 0.874
Pos7 67.540 0.877
Pos8 77.202 0.881
Pos9 86.870 0.885
Pos10 96.417 -0.001
```



## Plots and Calculations



# Coordinate System

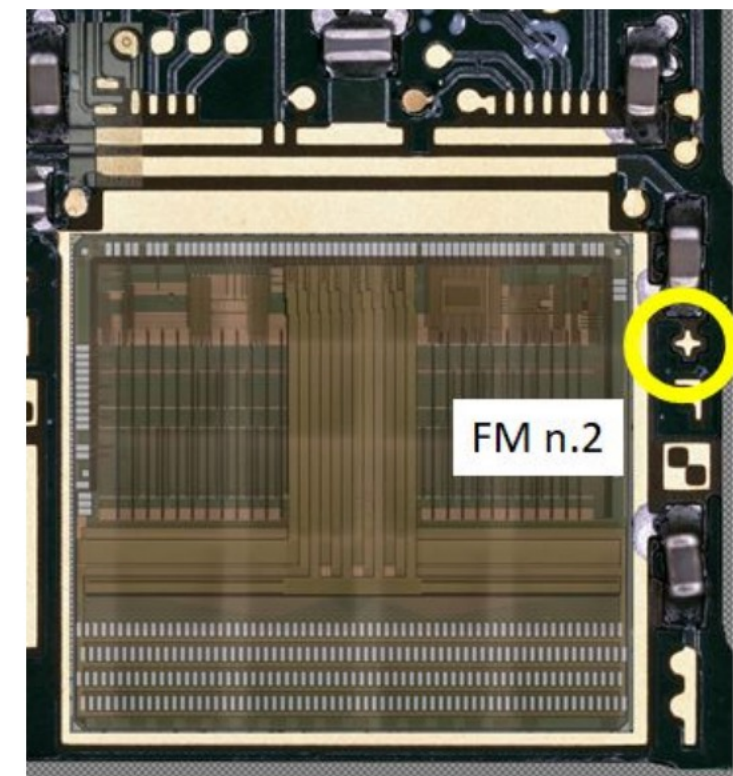
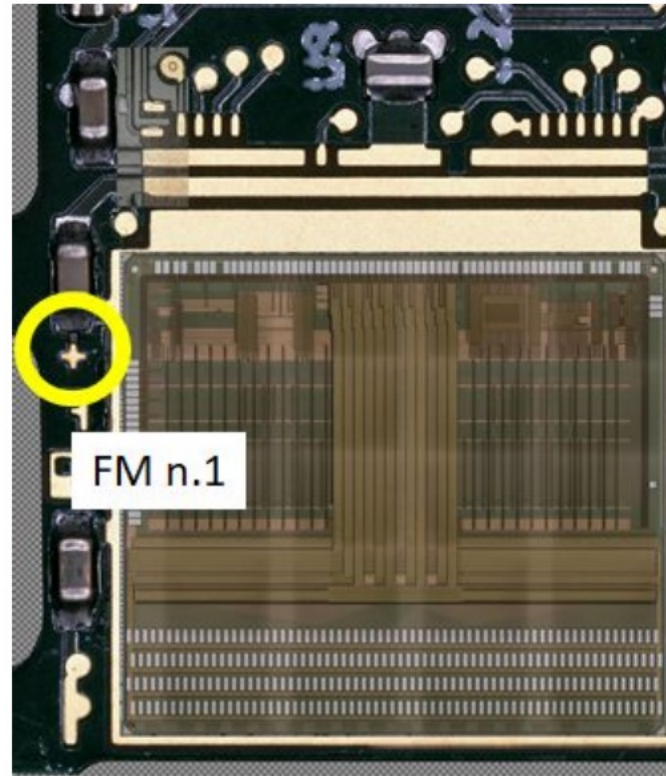
## Coordinate System:

- Use leftmost fiducial (+) as the origin.
- Use rightmost fiducial to define x-axis.
- Define positive y-axis towards HCC.

## Tests:

- Hybrid stretch/shrinkage.
- ASIC XY position.
- ASIC glue height.
- ASIC tilt.

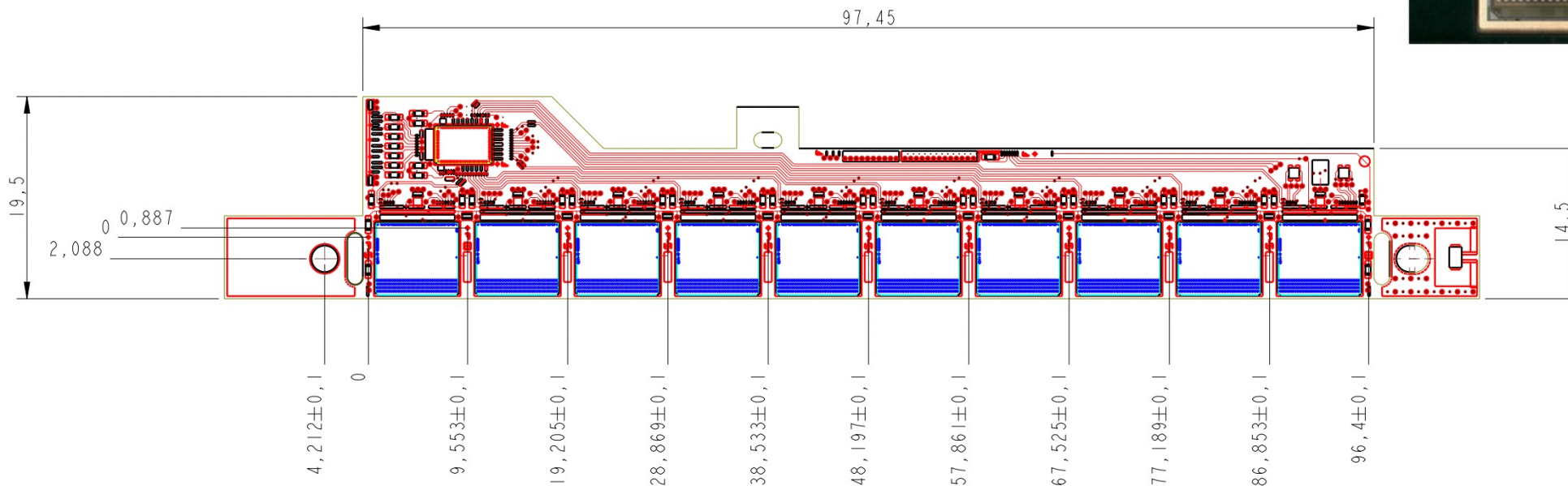
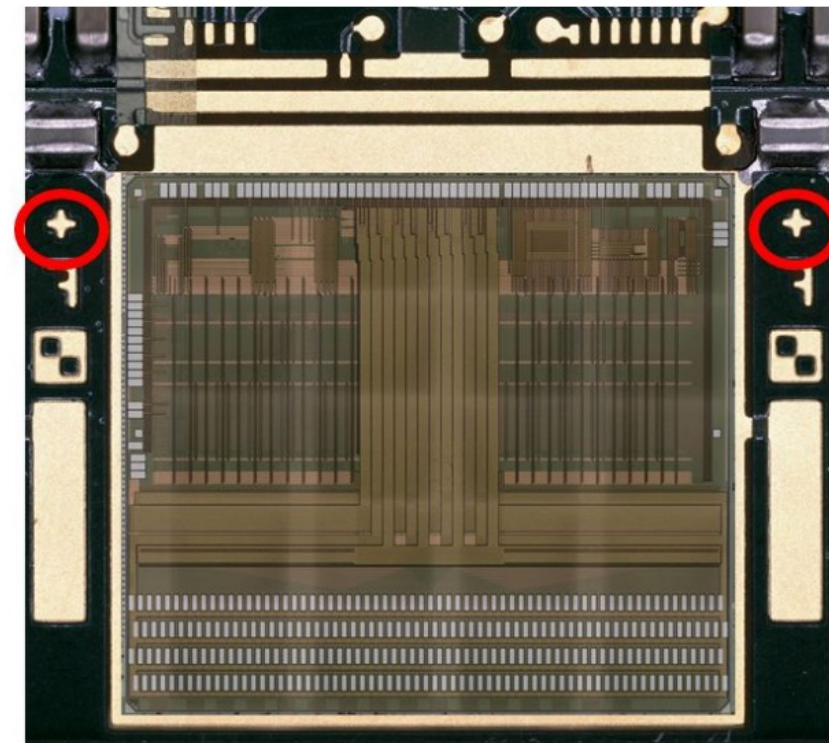
X-type hybrid



# Hybrid Stretch/Shrinkage

## Procedure:

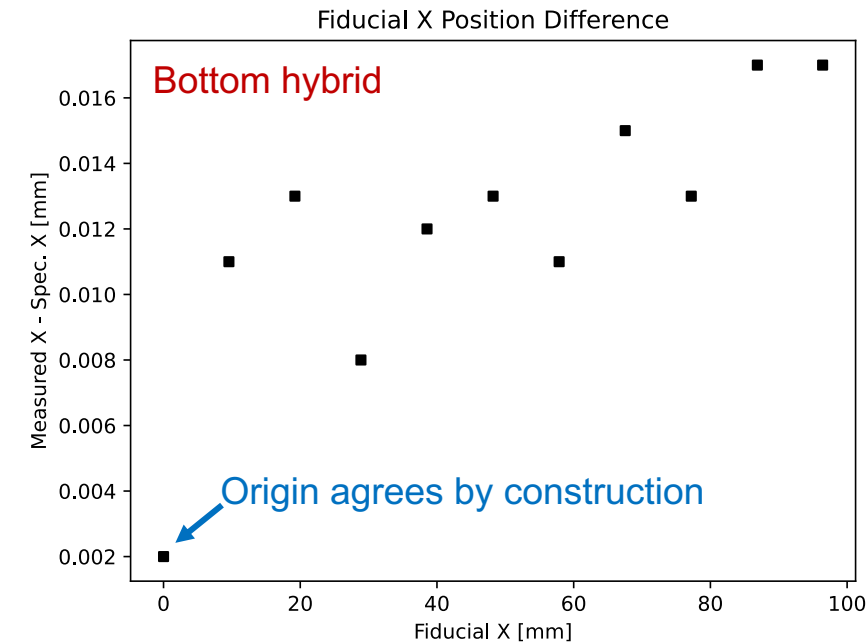
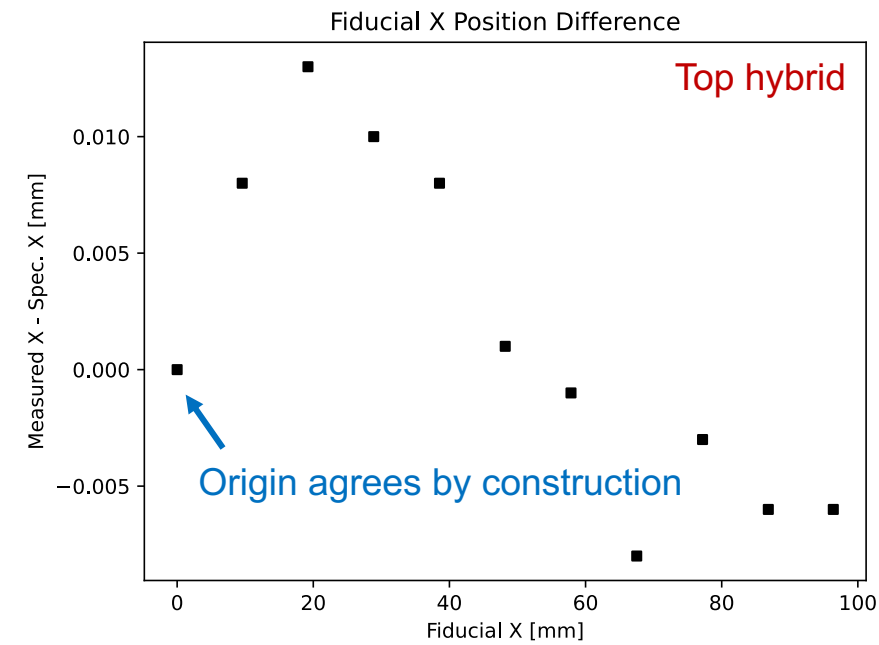
- Measure position of fiducials (+) next to each ABC.
  - Using centroid tool.
- Calculate  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$  for each fiducial.
  - $\Delta x > 0 \rightarrow$  stretch.
  - $\Delta x < 0 \rightarrow$  shrinkage.
- Tolerance on each fiducial position =  $\pm 0.1$  mm.



# Hybrid Stretch/Shrinkage

## Result:

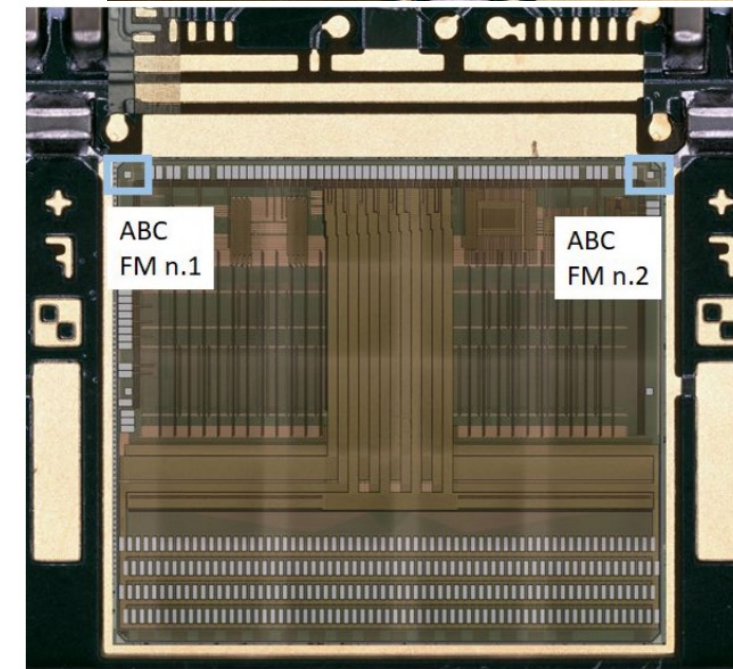
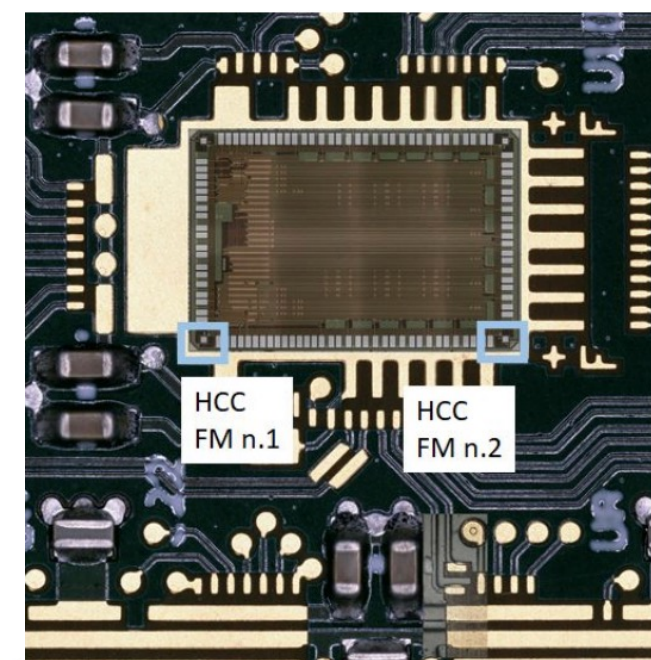
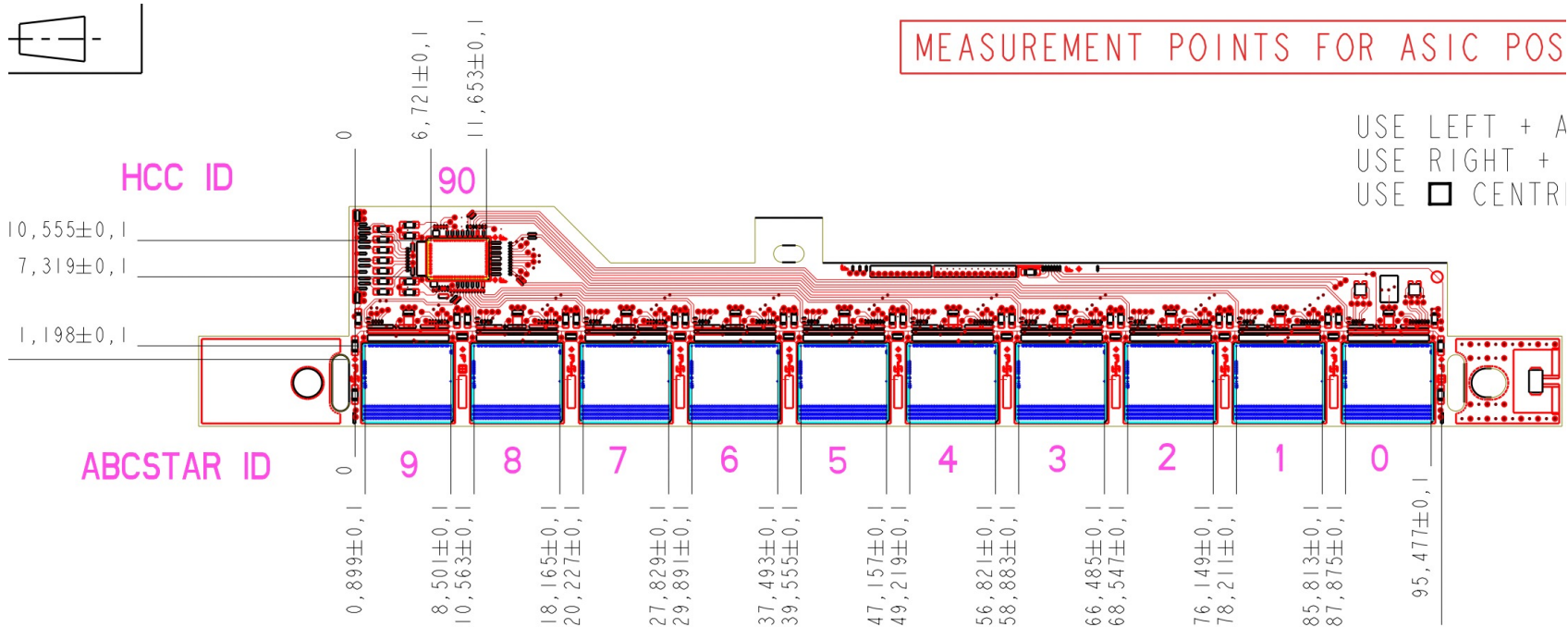
- Plotting  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$  for each fiducial.
  - Resolution: few  $\mu\text{m}$ .
  - All fiducials well within tolerance of 100  $\mu\text{m}$ .
- Top hybrid:
  - Rightmost fiducial (farthest from origin) is 5  $\mu\text{m}$  closer than spec.
- Bottom hybrid:
  - Rightmost fiducial is 17  $\mu\text{m}$  beyond spec.



# ASIC XY Position

## Procedure:

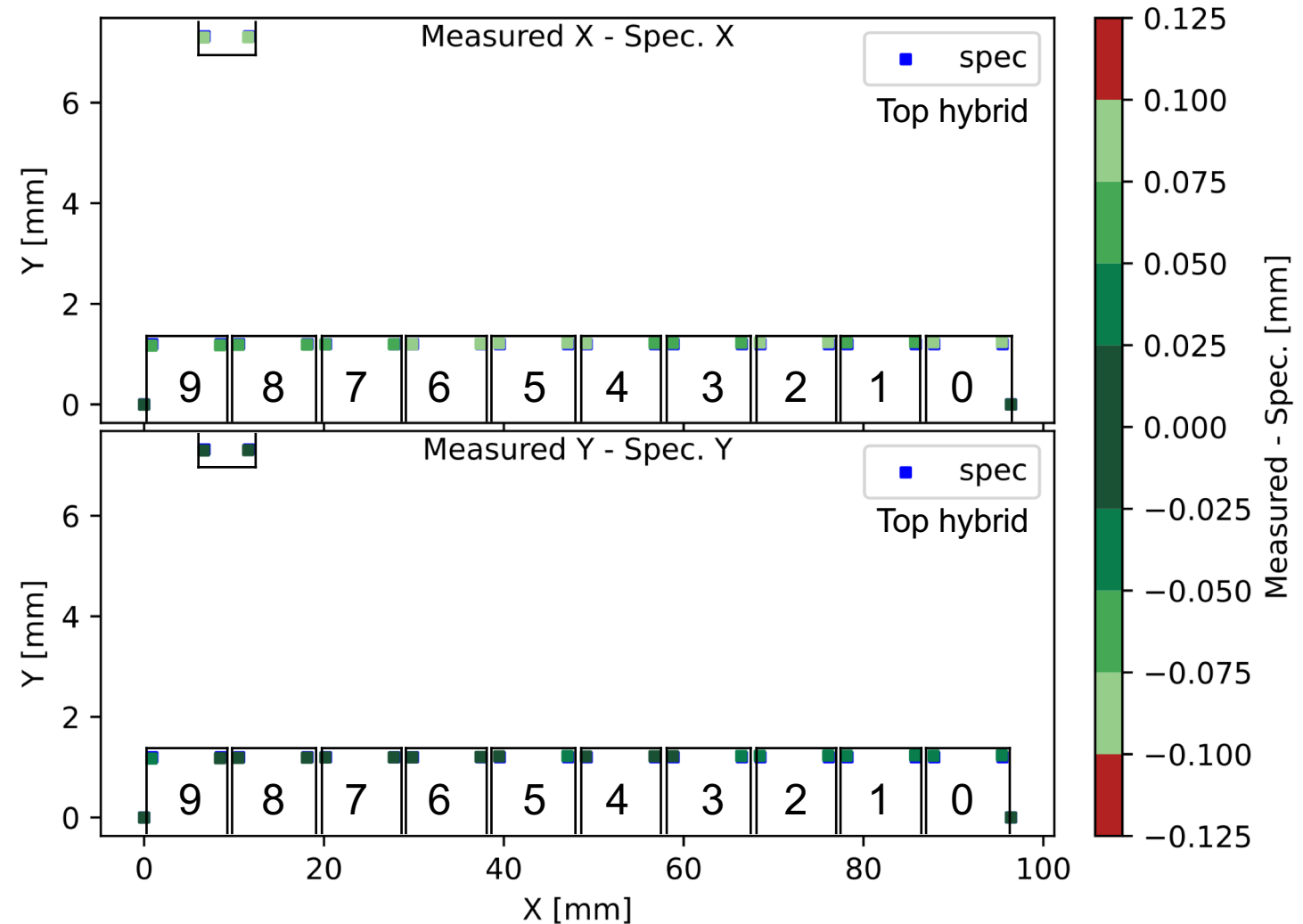
- Measure position of two fiducials (■) on each ASIC.
  - Using centroid tool.
- Calculate  $\Delta x$  and  $\Delta y$  compared with spec. for each fiducial.
  - Tolerance =  $\pm 0.1$  mm.



# ASIC XY Position (Top Hybrid)

## Results:

- Plotting XY position of **measured** points and **spec**.
  - Zoom to see **spec** underneath.
- Color of measured points  $\rightarrow$  offset from spec.
  - Top panel:  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$ .
  - Bottom panel:  $\Delta y = y_{\text{measured}} - y_{\text{spec}}$ .
- Plot primarily for quick tolerance check.
  - All points within the tolerance of  $\pm 0.1$  mm.
- But ASICs appear systematically shifted in x.

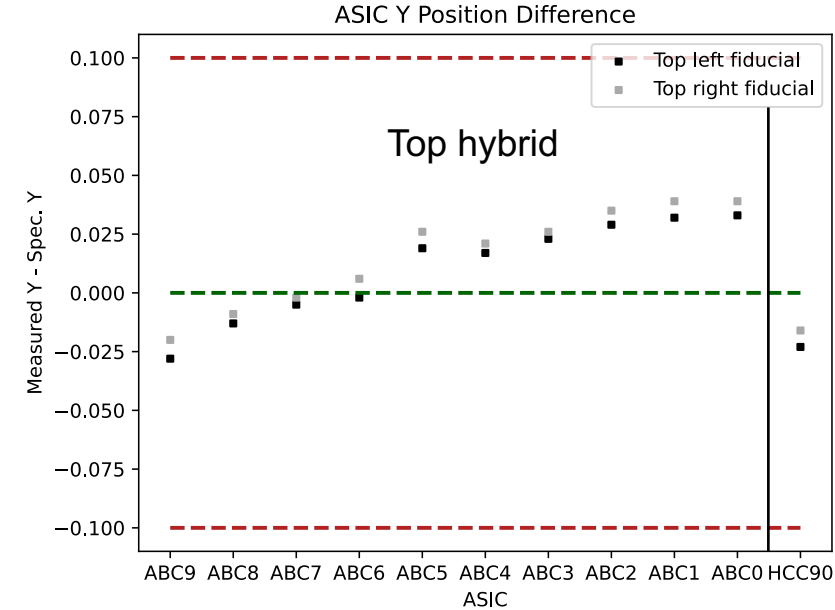
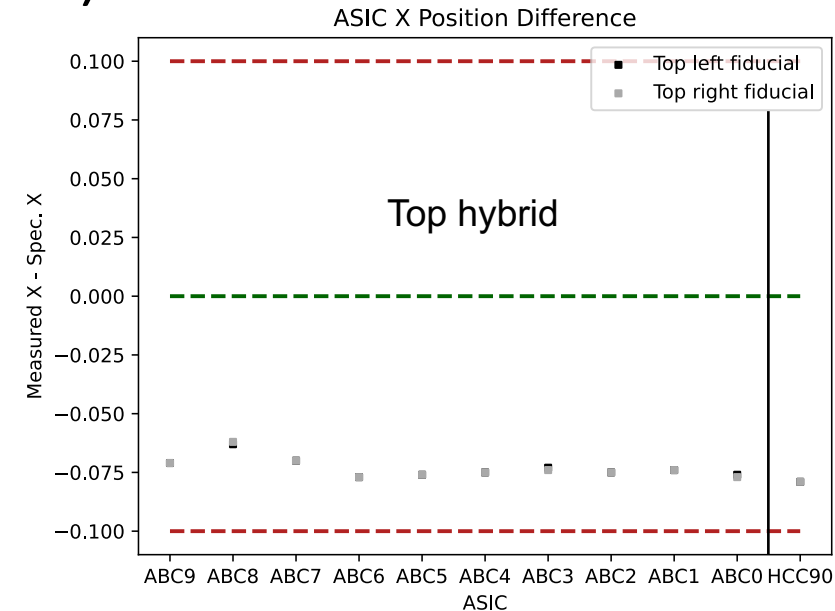




# ASIC XY Position (Top Hybrid)

## Results:

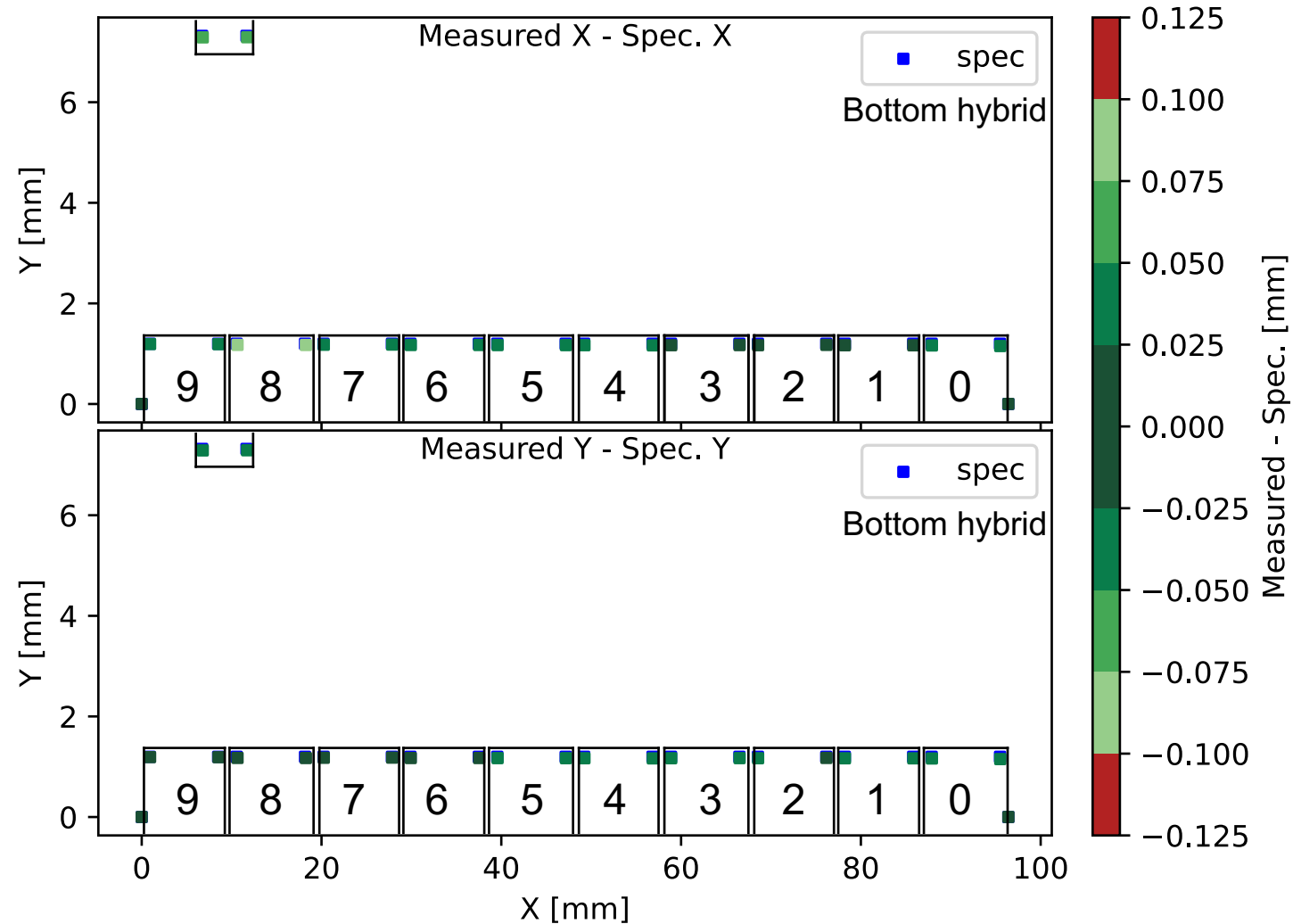
- Plotting XY position of **measured** points and **spec.**
  - Zoom to see **spec** underneath.
- Color of measured points → offset from spec.
  - Top panel:  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$
  - Bottom panel:  $\Delta y = y_{\text{measured}} - y_{\text{spec}}$
- Plot primarily for quick tolerance check.
  - All points within the tolerance of  **$\pm 0.1$  mm**.
- But ASICs appear systematically shifted in x.
  - To the left by  $\sim 0.075$  mm.



# ASIC XY Position (Bottom Hybrid)

## Results:

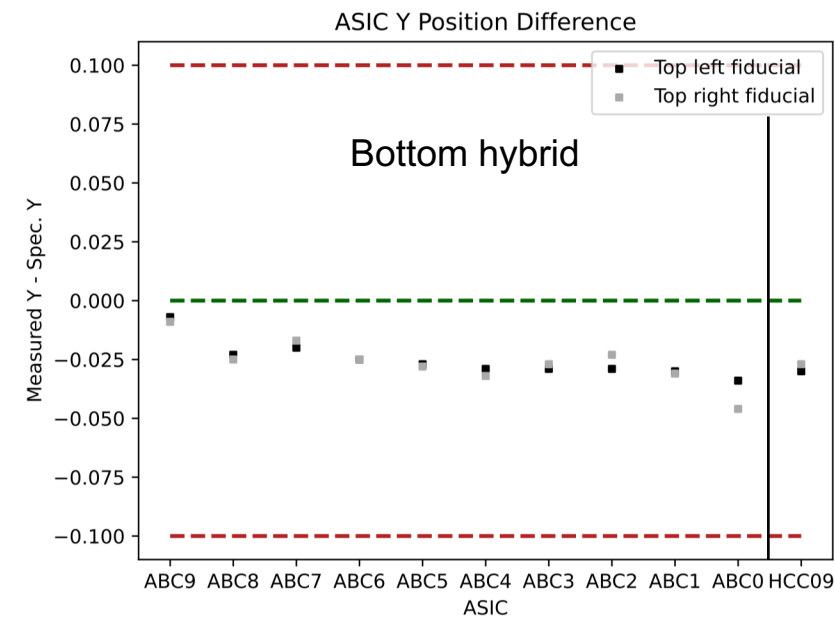
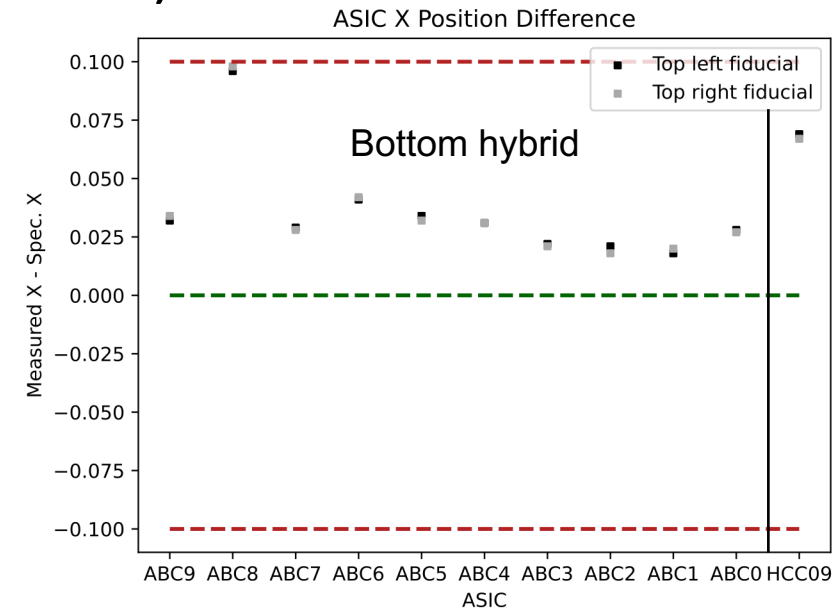
- Plotting XY position of **measured** points and **spec**.
  - Zoom to see **spec** underneath.
- Color of measured points  $\rightarrow$  offset from spec.
  - Top panel:  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$ .
  - Bottom panel:  $\Delta y = y_{\text{measured}} - y_{\text{spec}}$ .
- Plot primarily for quick tolerance check.
  - All points within the tolerance of  $\pm 0.1$  mm.
- HCC and ABC8 are close to limit for  $\Delta x$ .



# ASIC XY Position (Bottom Hybrid)

## Results:

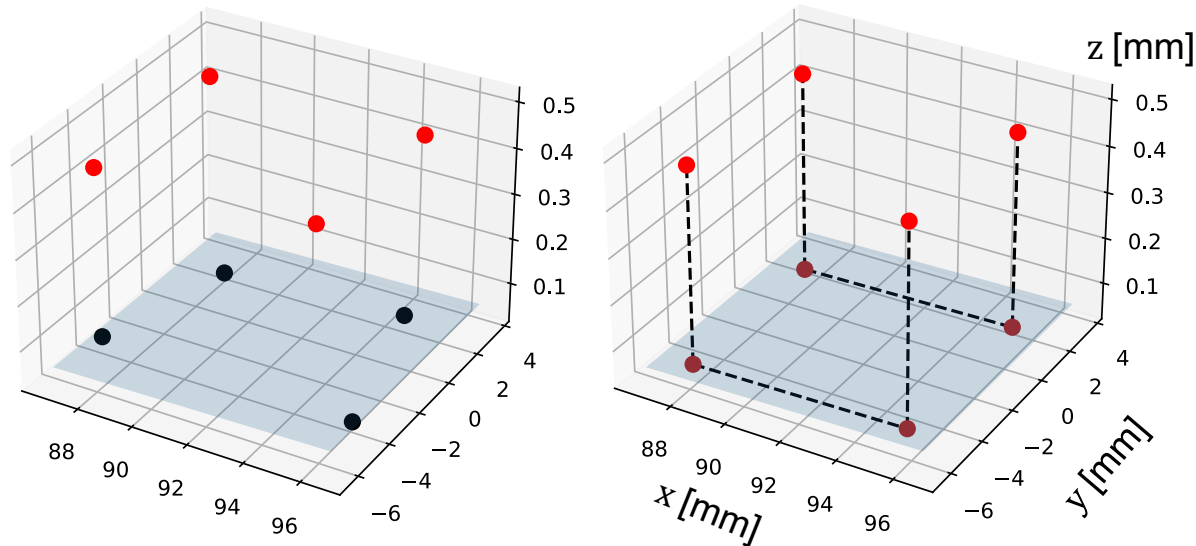
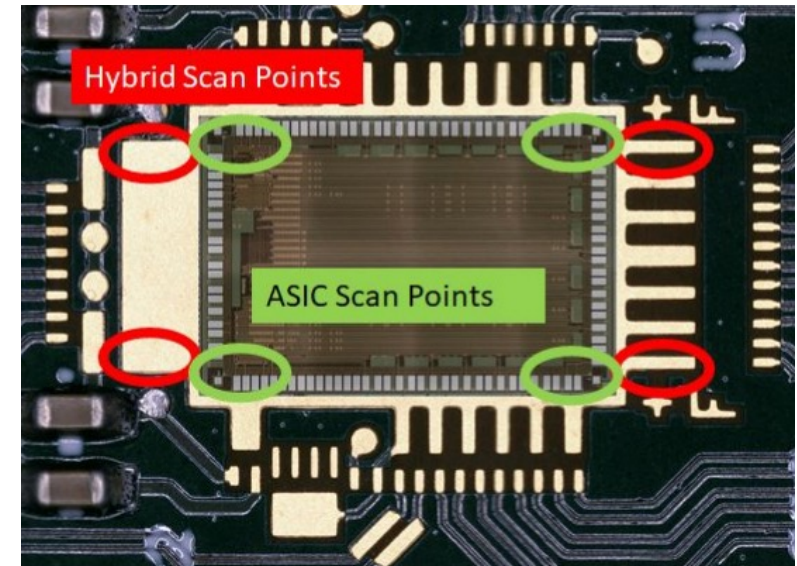
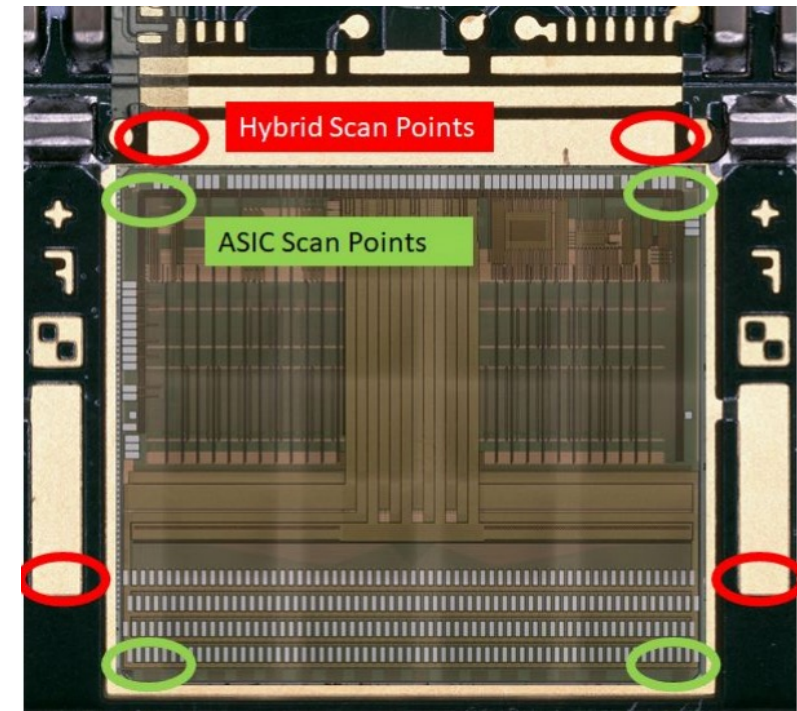
- Plotting XY position of **measured** points and **spec.**
  - Zoom to see **spec** underneath.
- Color of measured points → offset from spec.
  - Top panel:  $\Delta x = x_{\text{measured}} - x_{\text{spec}}$
  - Bottom panel:  $\Delta y = y_{\text{measured}} - y_{\text{spec}}$
- Plot primarily for quick tolerance check.
  - All points within the tolerance of  **$\pm 0.1$  mm**.
- HCC and ABC8 are close to limit for  $\Delta x$ .



# Glue Height

## Procedure:

- Measure  $(x, y, z)$  of four points on each ASIC near the corners.
- Measure  $(x, y, z)$  on four points on hybrid surrounding each ASIC.
- Fit plane to hybrid points.
- Calculate ASIC point height relative to hybrid plane.
- Subtract ASIC thickness ( $300 \mu\text{m}$ ) from ASIC height  $\rightarrow$  glue height.
  - Report average glue height for each ASIC.
- Spec =  $120 \pm 40 \mu\text{m}$ .



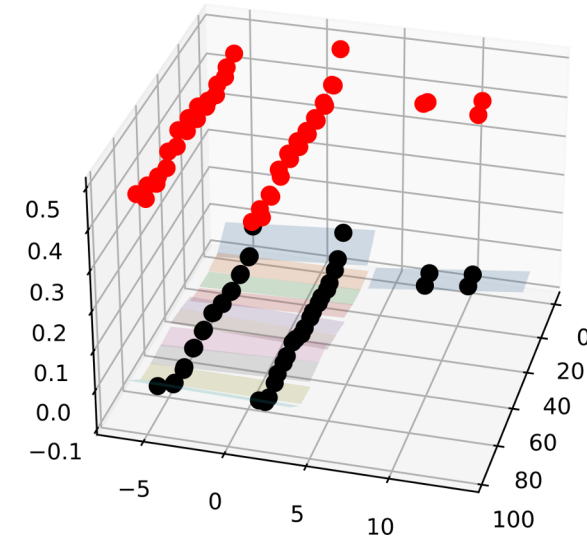
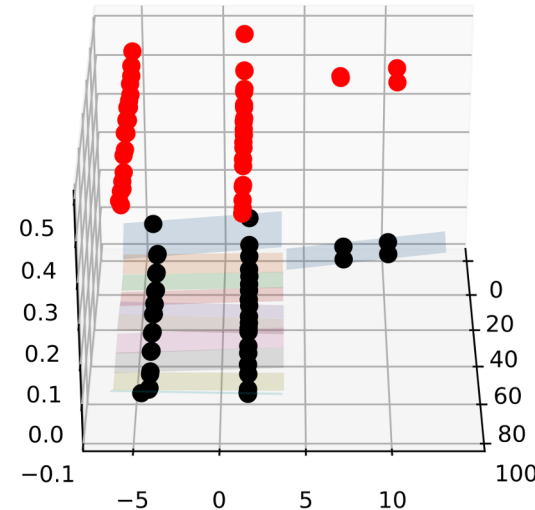
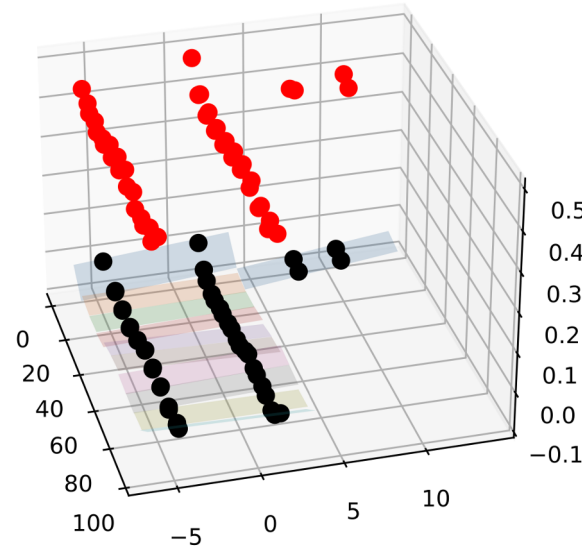
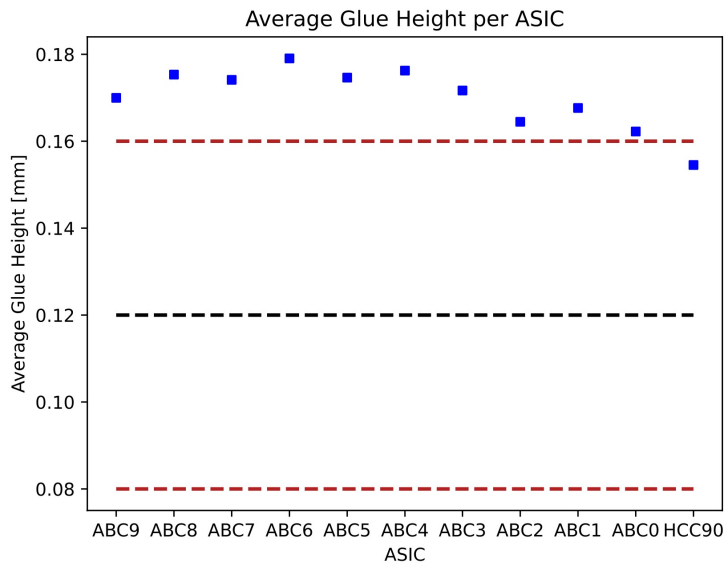
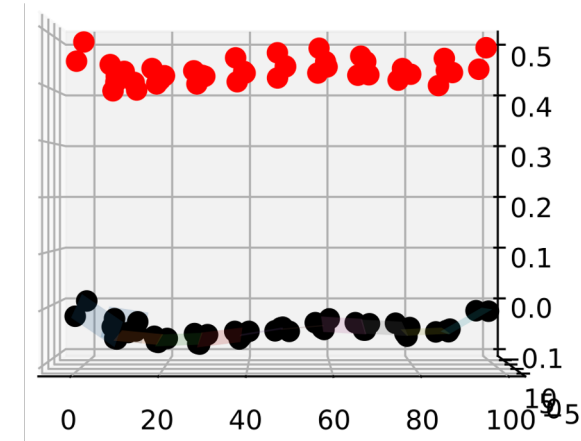
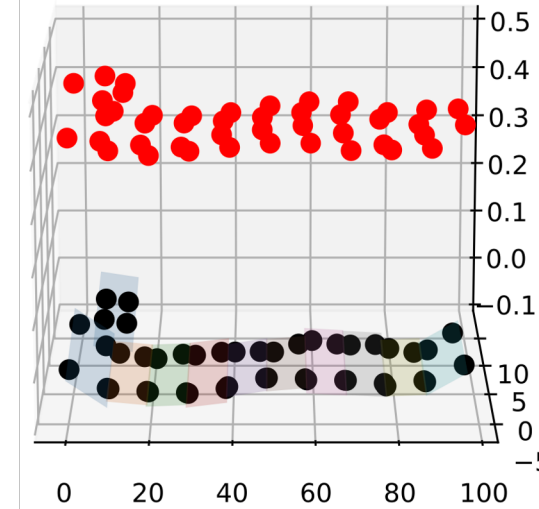
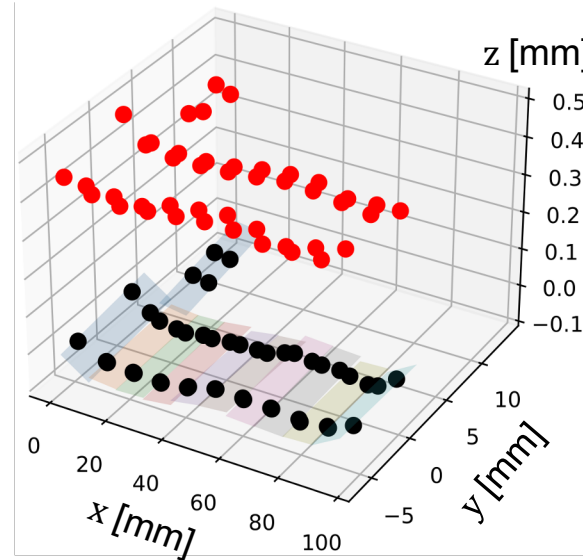
- Hybrid points.
- ASIC points.
- ASIC points projected on hybrid plane.

# Glue Height (Top Hybrid)

- Hybrid points.
- ASIC points.

## Results:

- Very different scales on axes.
- Glue heights above tolerance.
  - Though spec not finalized.
  - ABC thickness may vary by  $20\ \mu\text{m}$  ([ABC spec](#)).

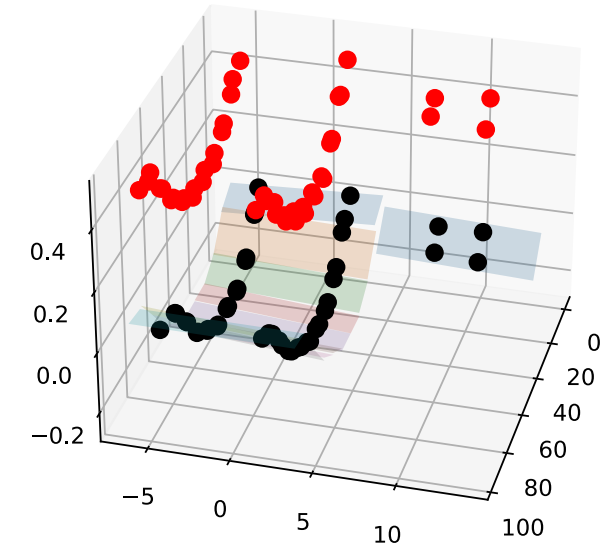
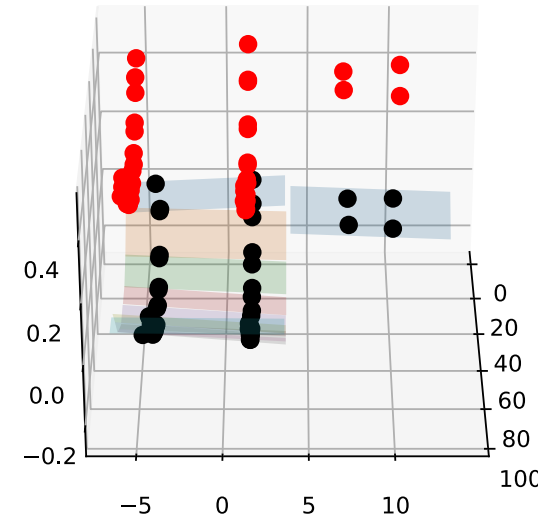
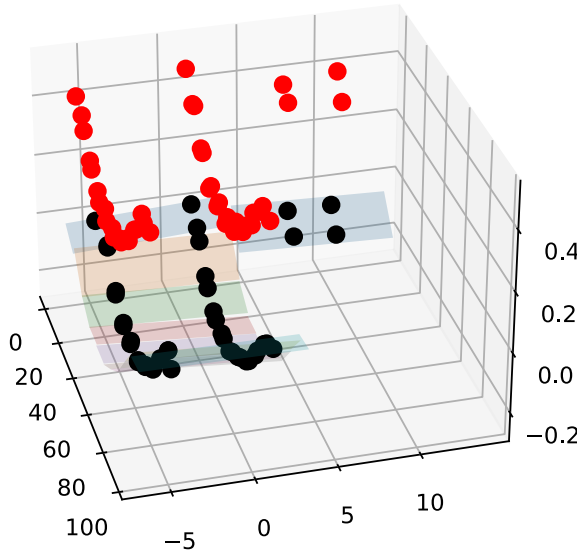
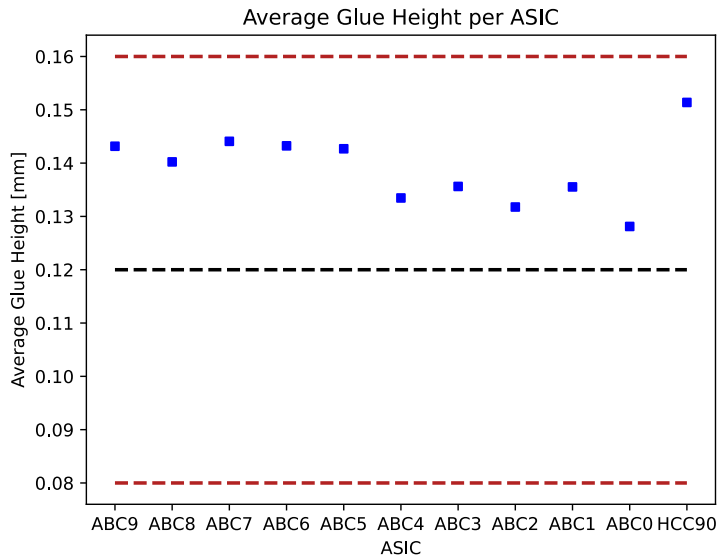
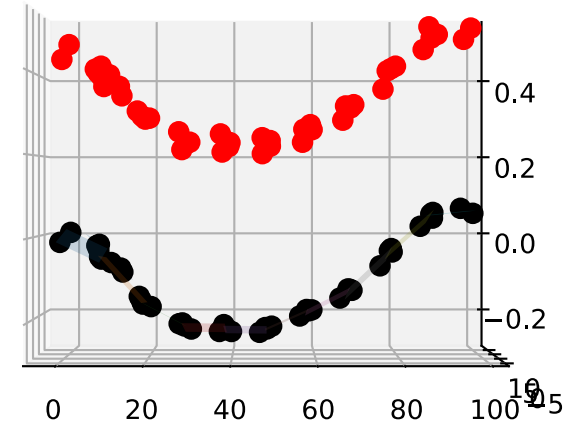
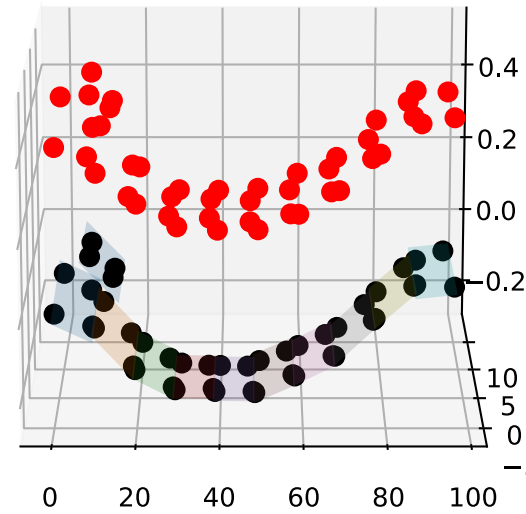
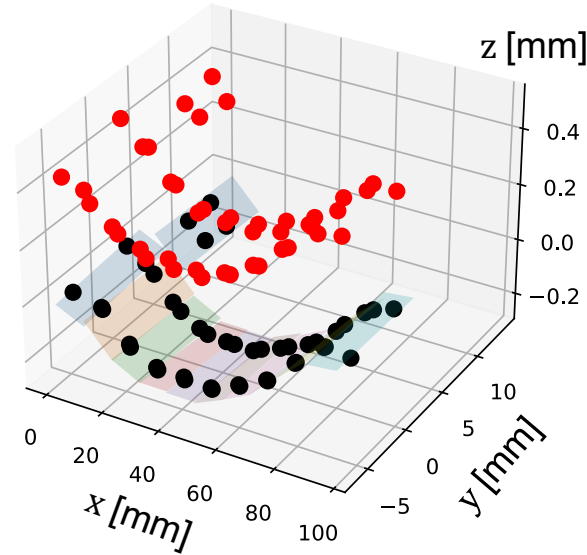


# Glue Height (Bottom Hybrid)

- Hybrid points.
- ASIC points.

## Results:

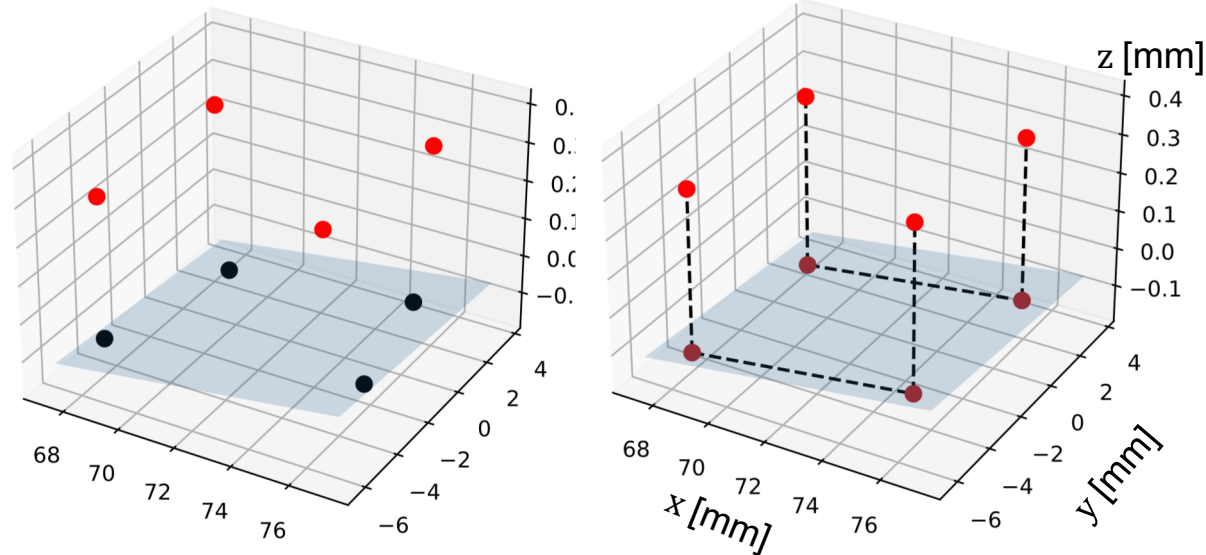
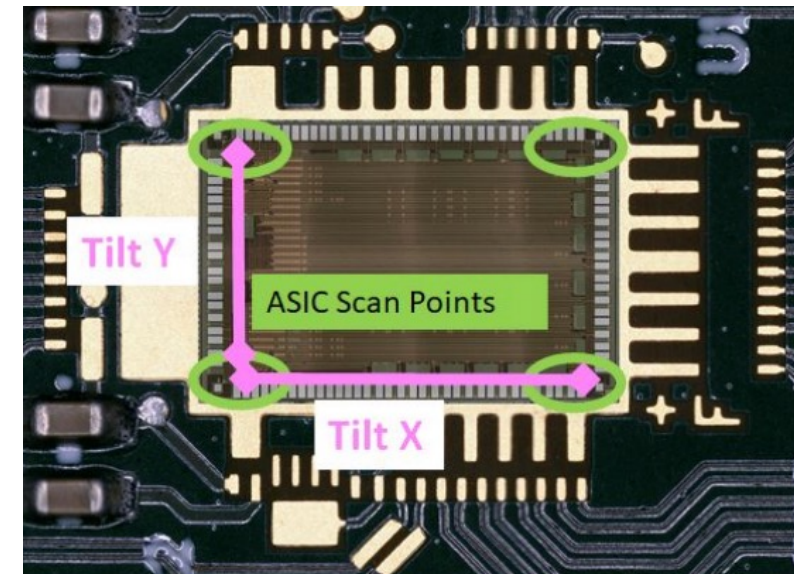
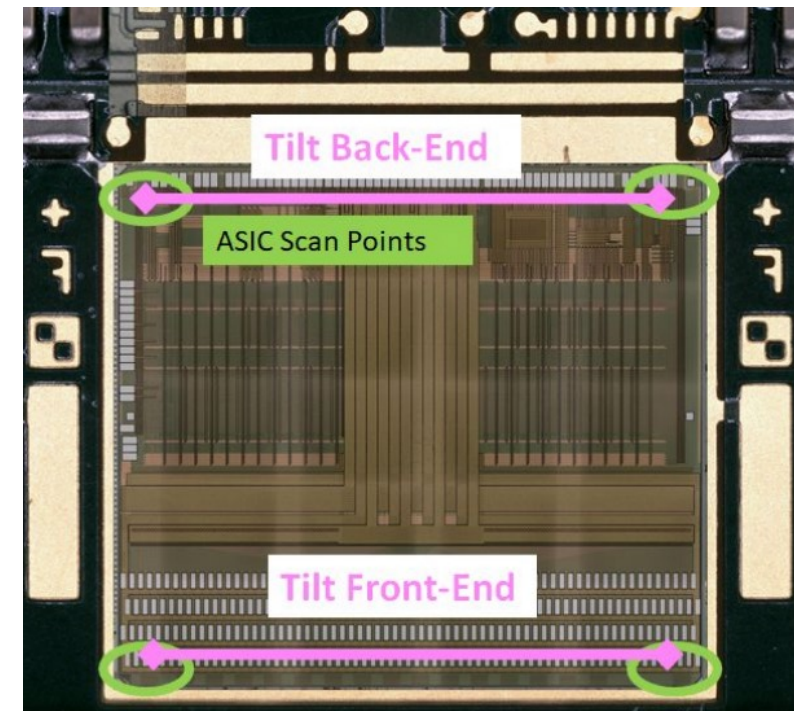
- Bowing of hybrid under vacuum.
- Exaggerated by scale differences between axes.
- Glue heights within tolerance.



# ASIC Tilt

## Procedure:

- Using same  $(x, y, z)$  measurements from glue height calculation.
- For ABCs, calculate tilt along front-end and back-end of chip.
- For HCC, calculate tilt along  $x$  and  $y$  directions.



- Hybrid points.
- ASIC points.
- ASIC points projected on hybrid plane.

# ASIC Tilt

- ASIC points.
- ASIC points projected on hybrid plane.

## Calculation:

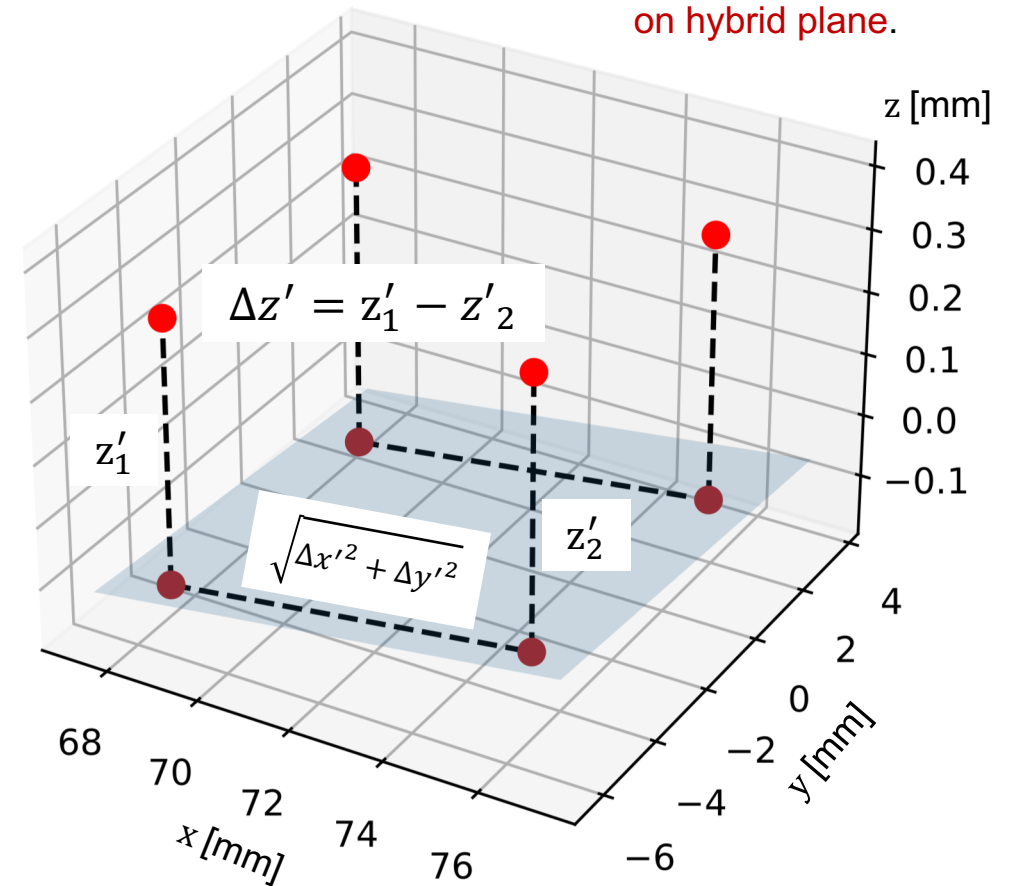
- Plane fitted to hybrid points defines  $z' = 0$  ( $x'y'$ -plane).

$$\text{Tilt} = \frac{|\Delta z'|}{\sqrt{\Delta x'^2 + \Delta y'^2}}$$

## Tolerance:

- Max possible  $|\Delta z'| = 80 \mu\text{m}$  (glue height tolerance x2).
- Lowest separation of points on ASIC =  $3236 \mu\text{m}$ .
  - HCC length in y-direction.
- So require:

$$\text{tilt} \leq 80 \mu\text{m} / 3236 \mu\text{m} \approx 0.025$$





# ASIC Tilt

## Calculation:

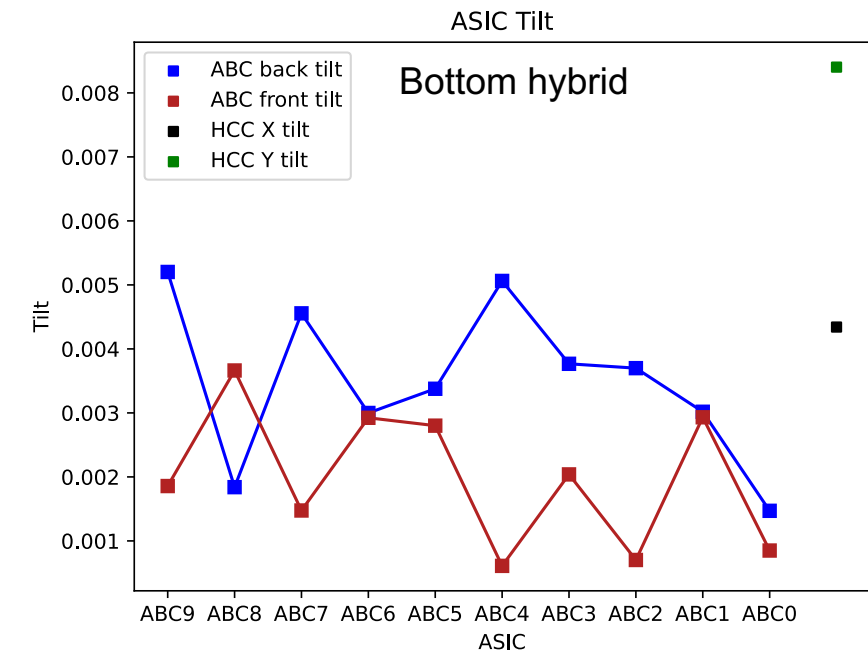
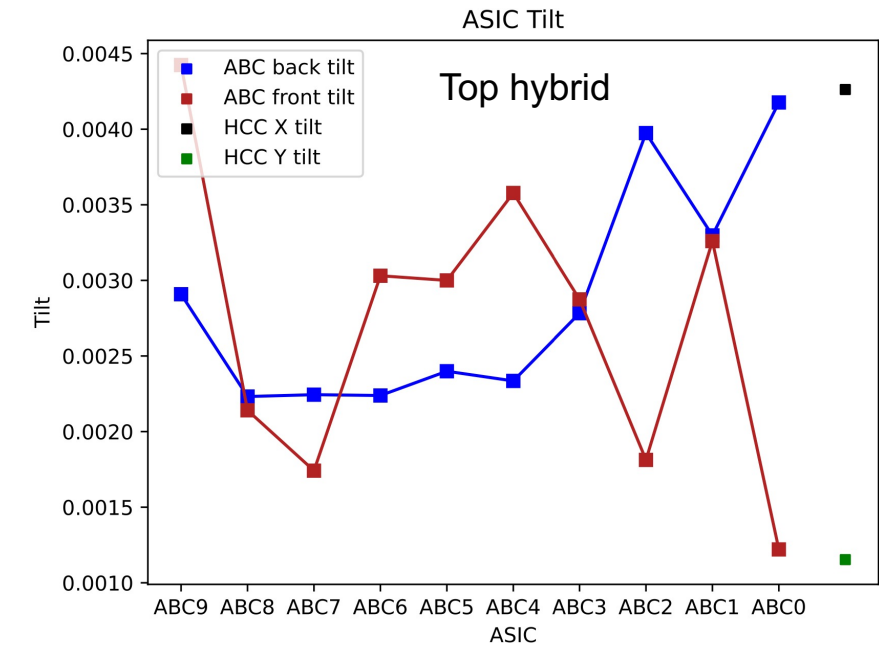
- Plane fitted to hybrid points defines  $z' = 0$  ( $x'y'$ -plane).

$$\text{Tilt} = \frac{|\Delta z'|}{\sqrt{\Delta x'^2 + \Delta y'^2}}$$

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  - HCC length in y-direction.
- So require:

$$\text{tilt} \leq 80 \mu\text{m} / 3236 \mu\text{m} \approx 0.025$$



# Summary

## Summary:

- Showed preliminary results for hybrid metrology.
- Reasonable results for measurements and calculated values.
- Software infrastructure in place.

## Next Steps:

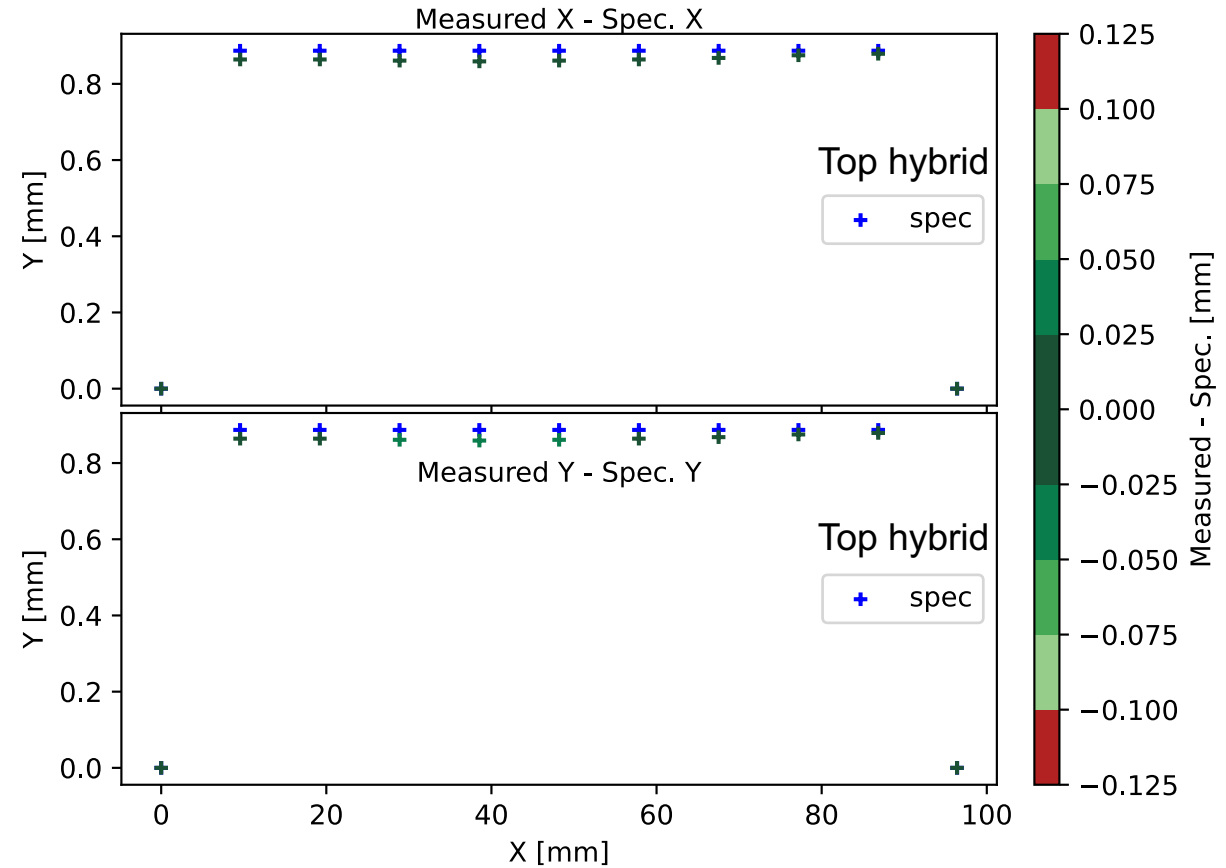
- Output calculations in JSON format → upload to database using API.
  - Test not defined in database yet.
- Document procedure for site qualification.
- Start module metrology.

# Backup

# Hybrid Stretch/Shrinkage

## Result:

- Plotting  $(x, y)$  of each fiducial (measured and **spec**).
  - For top hybrid only.
- Top panel:
  - Color  $\rightarrow \Delta x = x_{\text{measured}} - x_{\text{spec}}$ .
- Bottom panel:
  - Color  $\rightarrow \Delta y = y_{\text{measured}} - y_{\text{spec}}$ .
- Quick check to see if any fiducials out of tolerance.

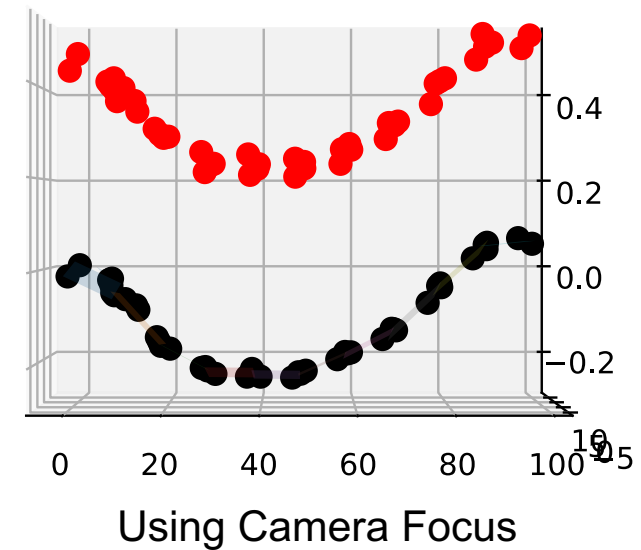
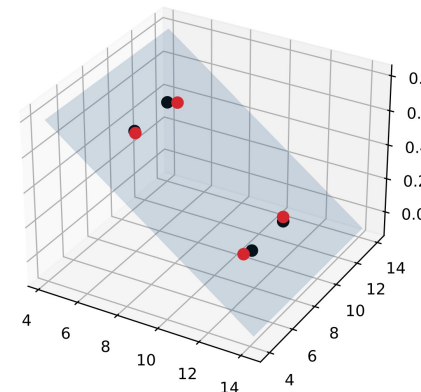


# Laser Issues

## Laser measurements:

- Tried to use laser for ASIC and hybrid height measurements.
  1. Find target on hybrid using camera, then use laser to focus on target.
  2. Stage moves to center target under laser. Laser lowers to focus, then raises.
  3. Stage returns to original location. Target is centered on camera.
    - But target out of focus! And Z measurement differs by  $200\ \mu\text{m}$ .
- Don't care about absolute Z, only differences, so proceed with height measurements.
  - Points on left side of ASIC seem fine but...
  - Points on right side of ASIC are very low in Z, similar to hybrid points  $\rightarrow$  very large tilt.
    - Clearly something wrong.
- Suspect X calibration is off, and stage moves such that the laser is too far too the right.
  - Left ASIC points fine since still on ASIC.
  - Right ASIC points move off ASIC and onto hybrid.
    - Maybe on gold pad, maybe not.

- Hybrid points.
- ASIC points.



Using Laser Focus

