IEEE SW Test Workshop
Semiconductor Wafer Test Workshop


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# Electrical Planarity Characterization of High Parallelism Probe Cards

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Micron®

# Introduction

- Challenge
  - High parallelism (1TD 300mm)
  - Thermal deflection
  - High probe count
  - Shrinking bond pads
- Can we maintain the same probe card planarity specification as 32x to 64x parallelism five years ago??
  - Yes!
- Micron has employed techniques for analyzing optical and electrical planarity data; resulting in…
  - Improved test cell performance
  - Better understanding of high parallelism probe card planarity characteristics
  - Correlation between metrology and test cell tools

# Introduction (2)

- Optical versus electrical… Or, optical + electrical?
  - Optical + electrical
- Electrical first-to-last (EF2L) provides information on potential variance components within the test cell
  - Probe card planarity and tilt
  - Prober chuck curvature, tilt, or deflection
  - System deflection
- Proper analysis of EF2L data allows the user to minimize test cell variance components to achieve the best possible planarity

# Topics

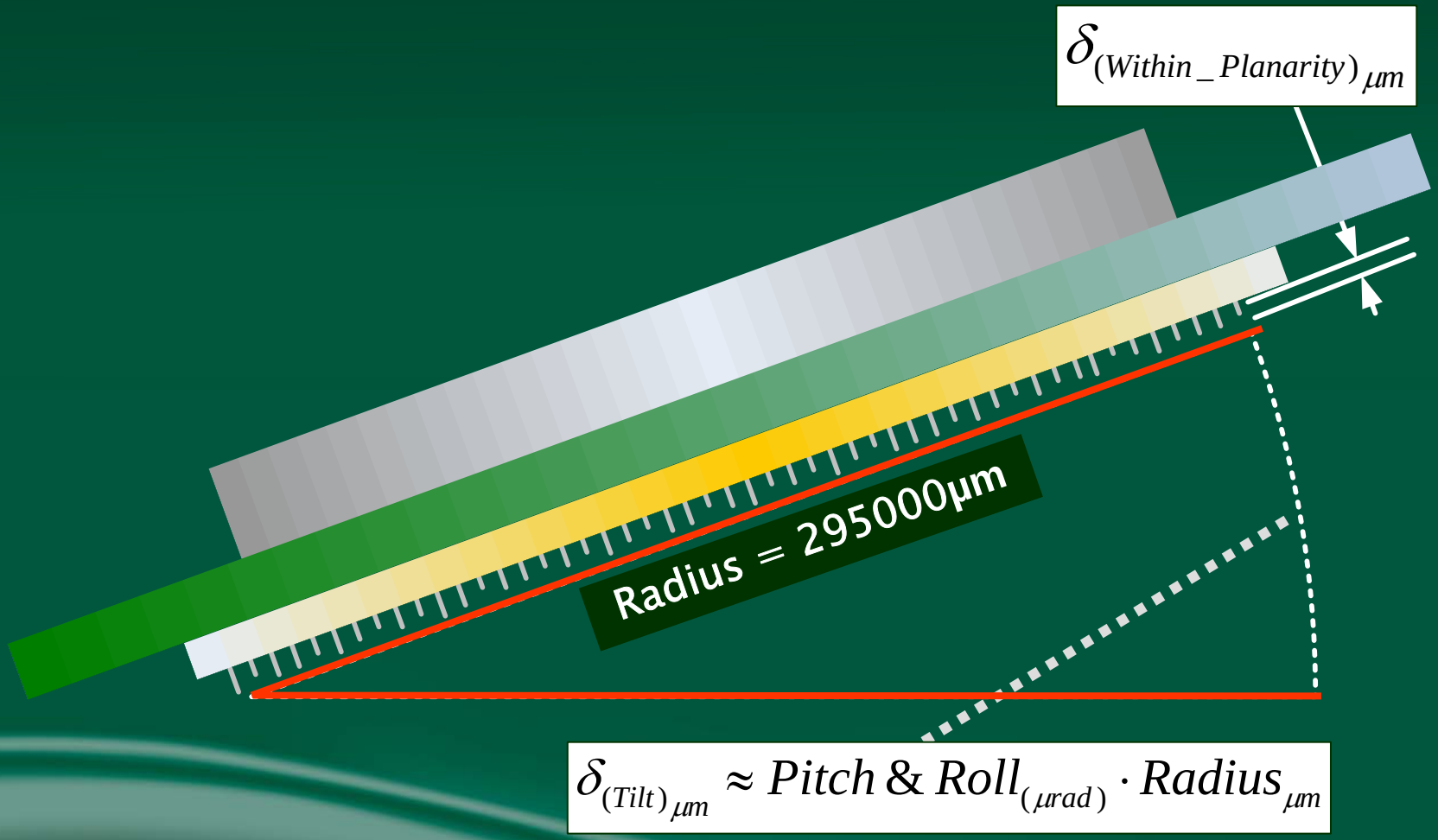
- Pitch and roll
- EF2L Sequence
- EF2L Examples
  1. %Contact by delta-Z
  2. System-to-system planarity & tilt comparison
  3. Test cell stack-up error correction
  4. Optical-to-electrical planarity correlation
  5. Probe card technology benchmark
- Summary

# Pitch and Roll

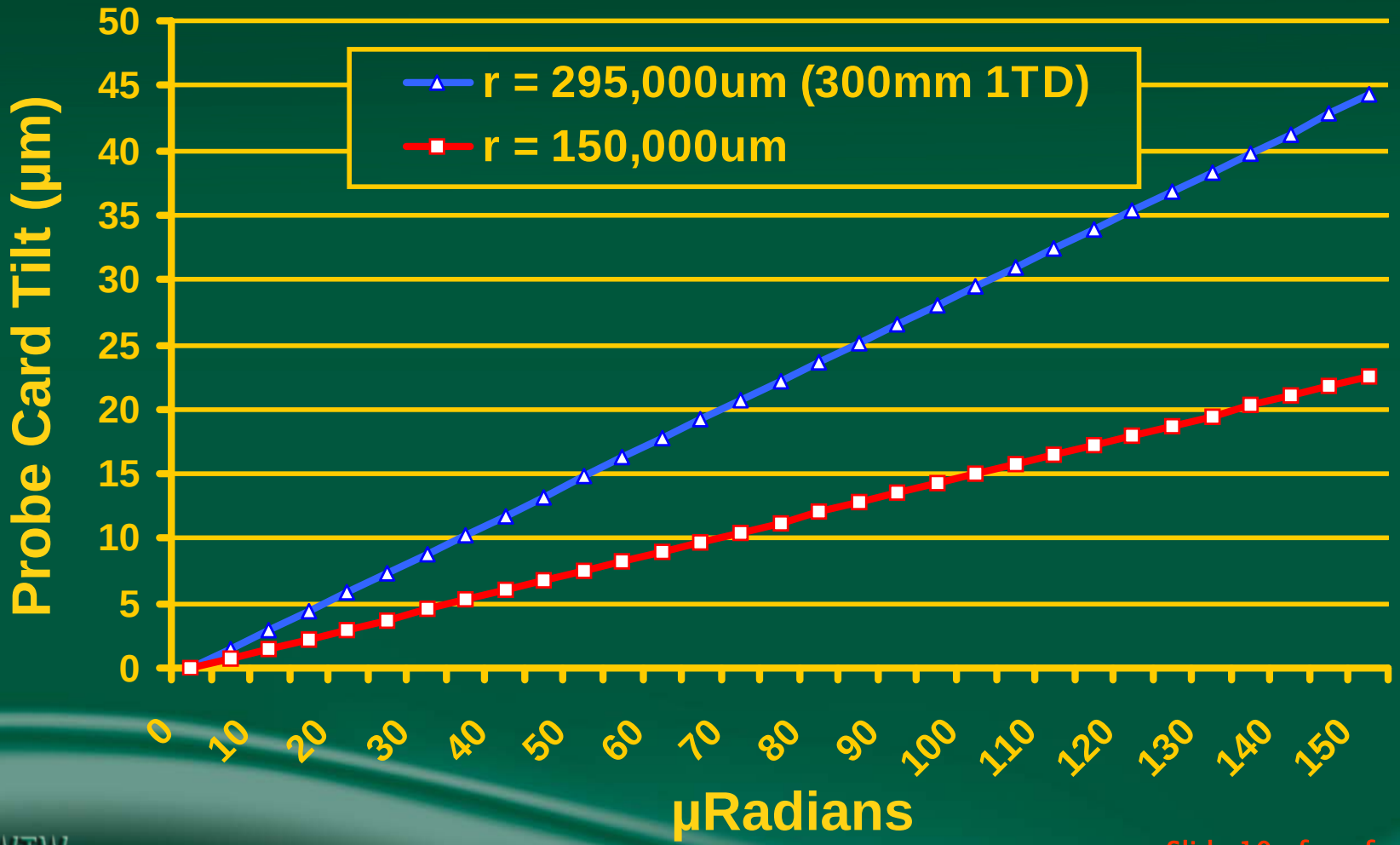
# Pitch and Roll

- Pitch and roll is. . .
  - A metric that represents probe card tilt when installed in metrology systems and/or test cells
  - A relative comparison from one system to another when characterizing the same probe card
  - Estimated by best-fit linear plane and represented in terms of µRadians
  - Not a metric that was invented by Micron or used exclusively by Micron (data analysis methods vary)

# Within Planarity vs. Tilt

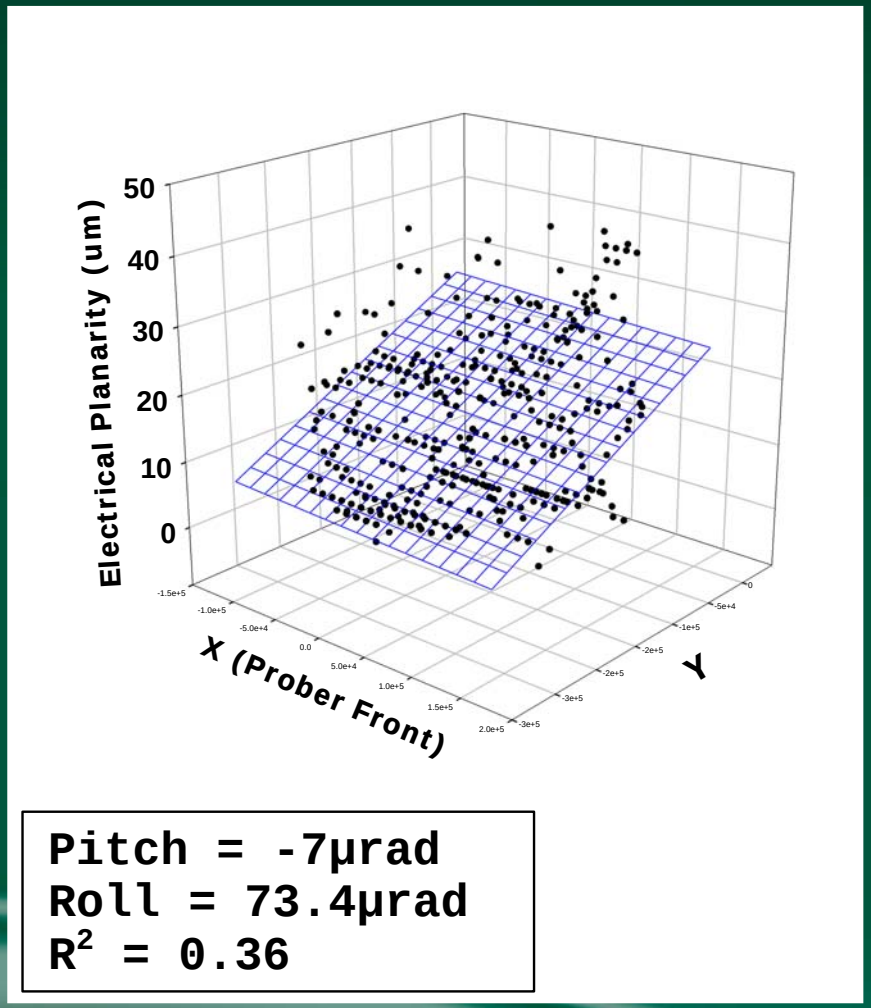


# µRadians to µm



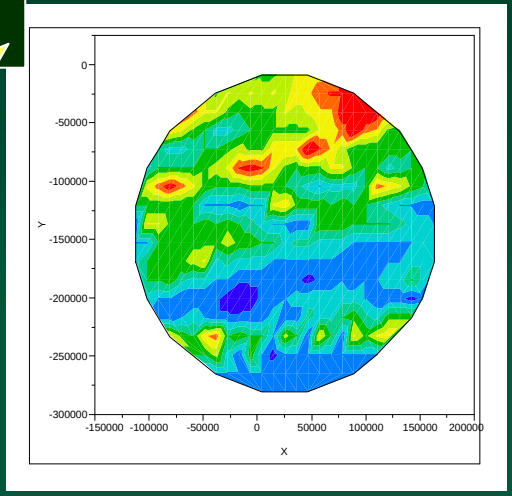

Slide 10 of conference proceedings

# Estimating Pitch and Roll

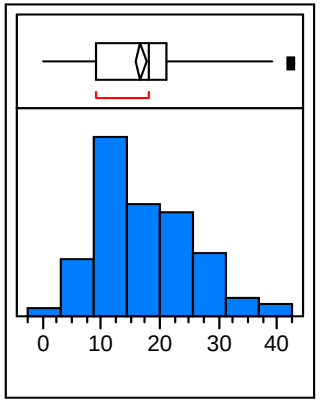



**Pitch = -7µrad**
**Roll = 73.4µrad**
**$R^2$ = 0.36**

TILT




**Planarity (um)**



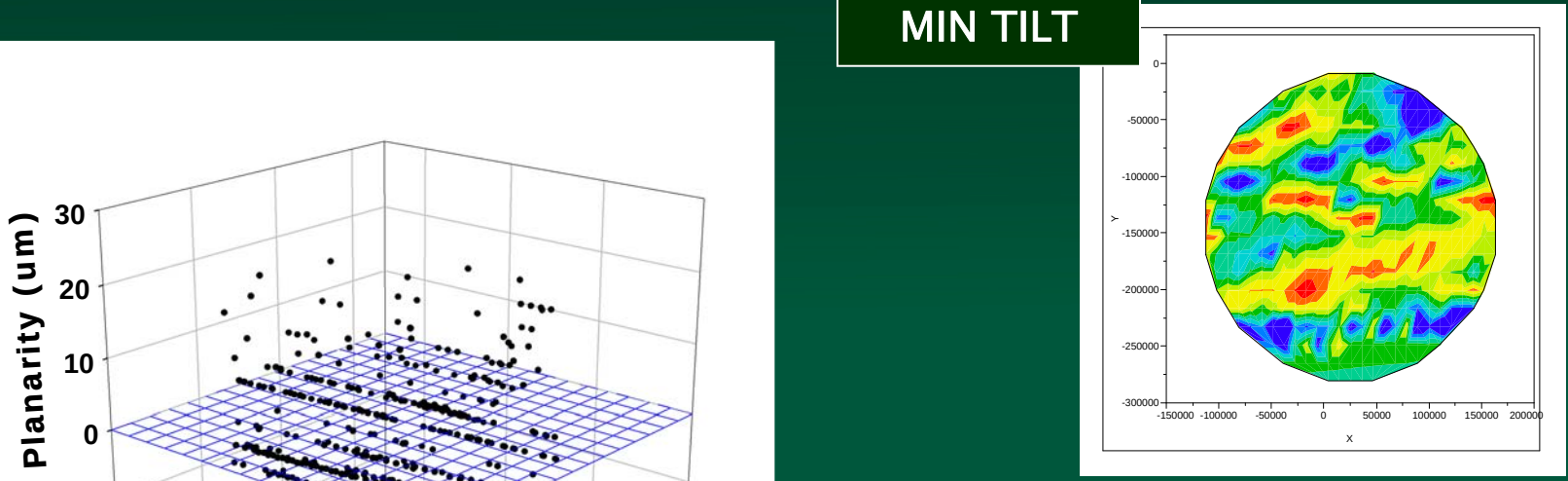

**Quantiles**

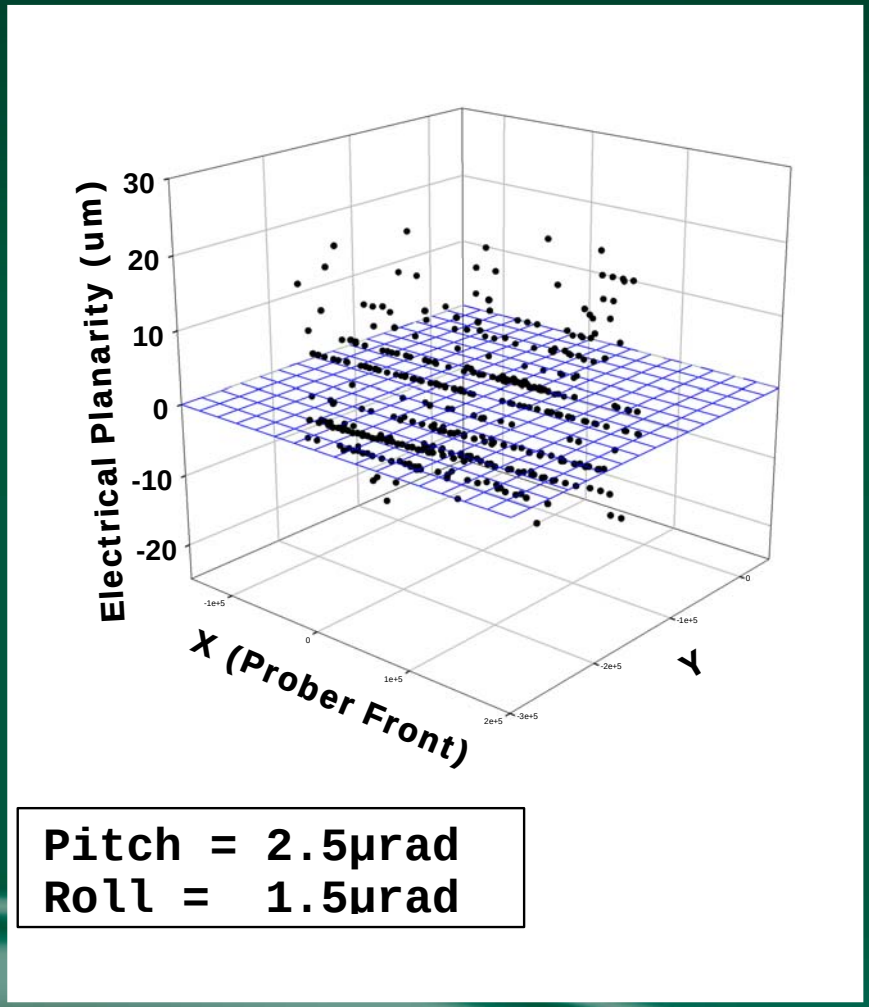
| | | |
|---|---|---|
| 100.0% | maximum | 42.000 |
| 99.5% | | 42.000 |
| 97.5% | | 38.625 |
| 90.0% | | 28.500 |
| 75.0% | quartile | 21.000 |
| 50.0% | median | 18.000 |
| 25.0% | quartile | 9.000 |
| 10.0% | | 6.000 |
| 2.5% | | 6.000 |
| 0.5% | | 2.475 |
| 0.0% | minimum | 0.000 |

**Range = 42µm**

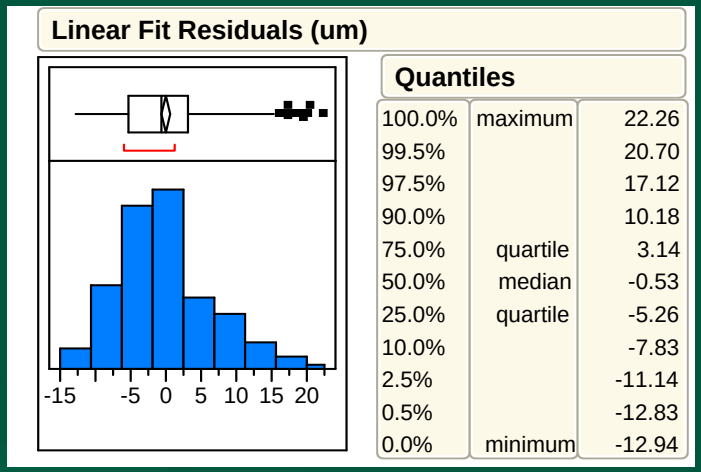
# Residual Plot (Within Planarity)

MIN TILT



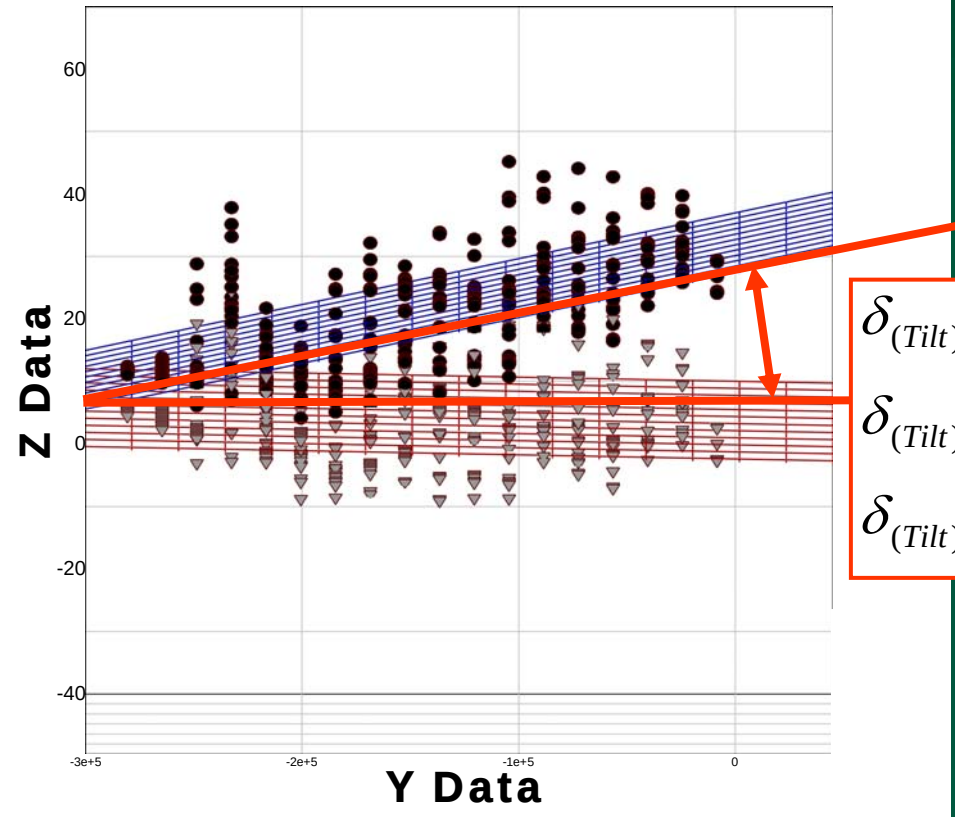




**Pitch = 2.5µrad**
**Roll = 1.5µrad**




**Range = 35µm**

# ~73µrad Doesn't *Really* Add ~21µm To Planarity Window

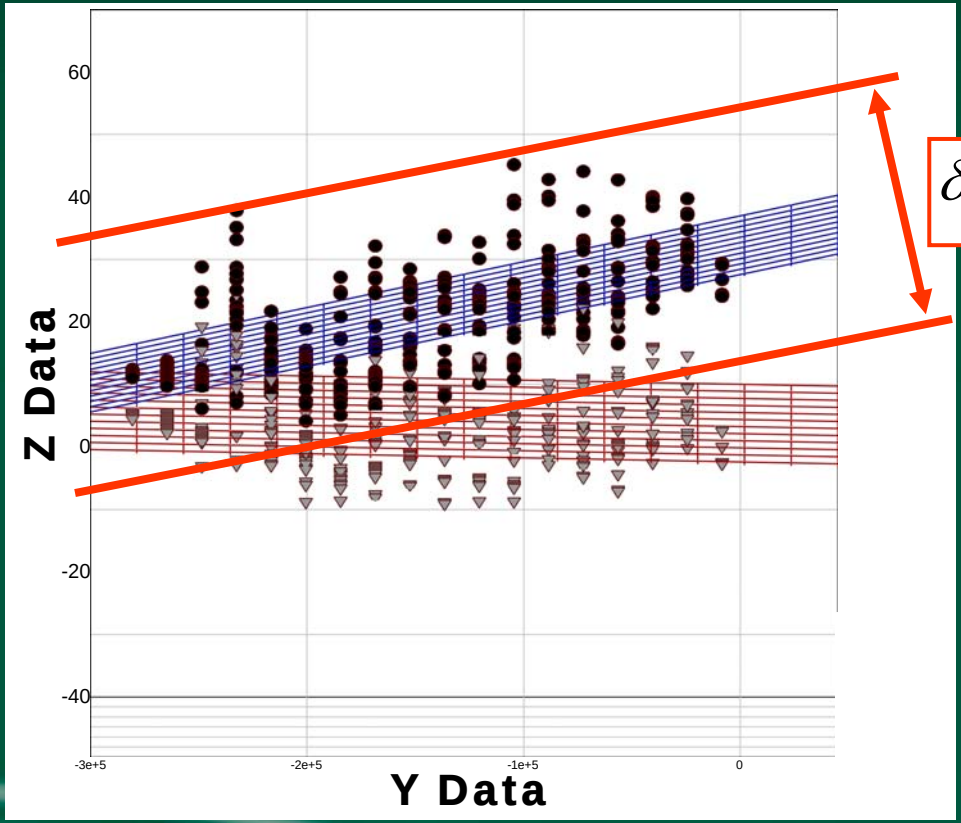



$$\delta_{(Tilt)\,\mu m} \approx Pitch\ \&\ Roll_{(\mu rad)} \cdot Radius_{\mu m}$$

$$\delta_{(Tilt)\,\mu m} \approx 73.4_{\mu rad} \cdot 295{,}000_{\mu m}$$

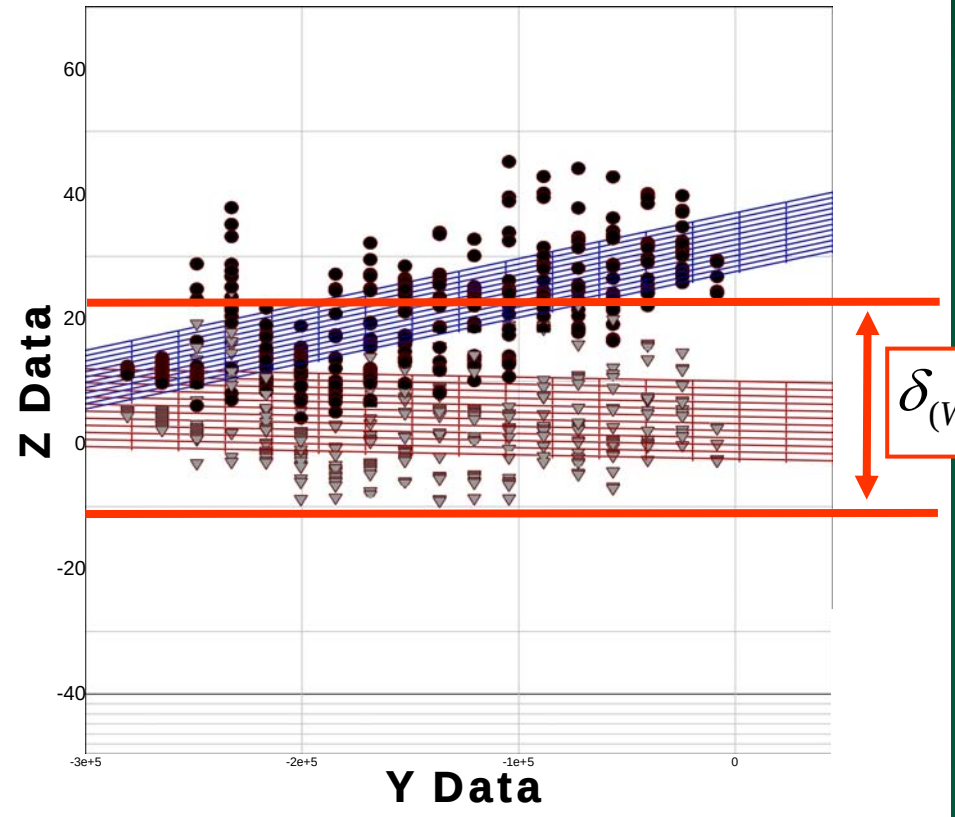
$$\delta_{(Tilt)\,\mu m} \approx 21.7_{\mu m}$$

# ~73µrad Doesn't *Really* Add ~21µm To Planarity Window




$$\delta_{(Within\_Planarity)\,\mu m} = 42\,\mu m$$

# ~73µrad Doesn't *Really* Add ~21µm To Planarity Window




$$\delta_{(Within\_Planarity)\,\mu m} = 35\mu m$$

# EF2L Sequence

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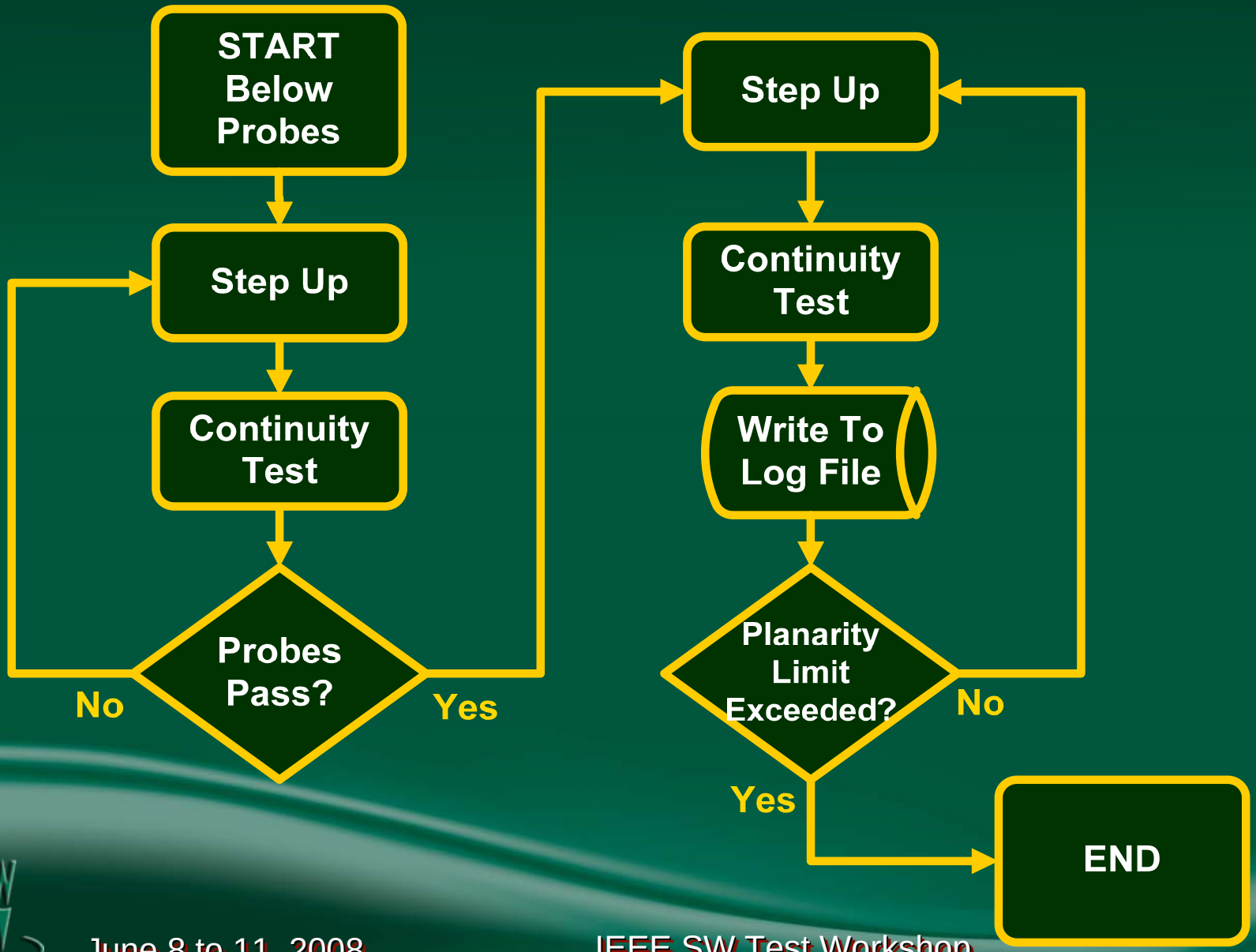
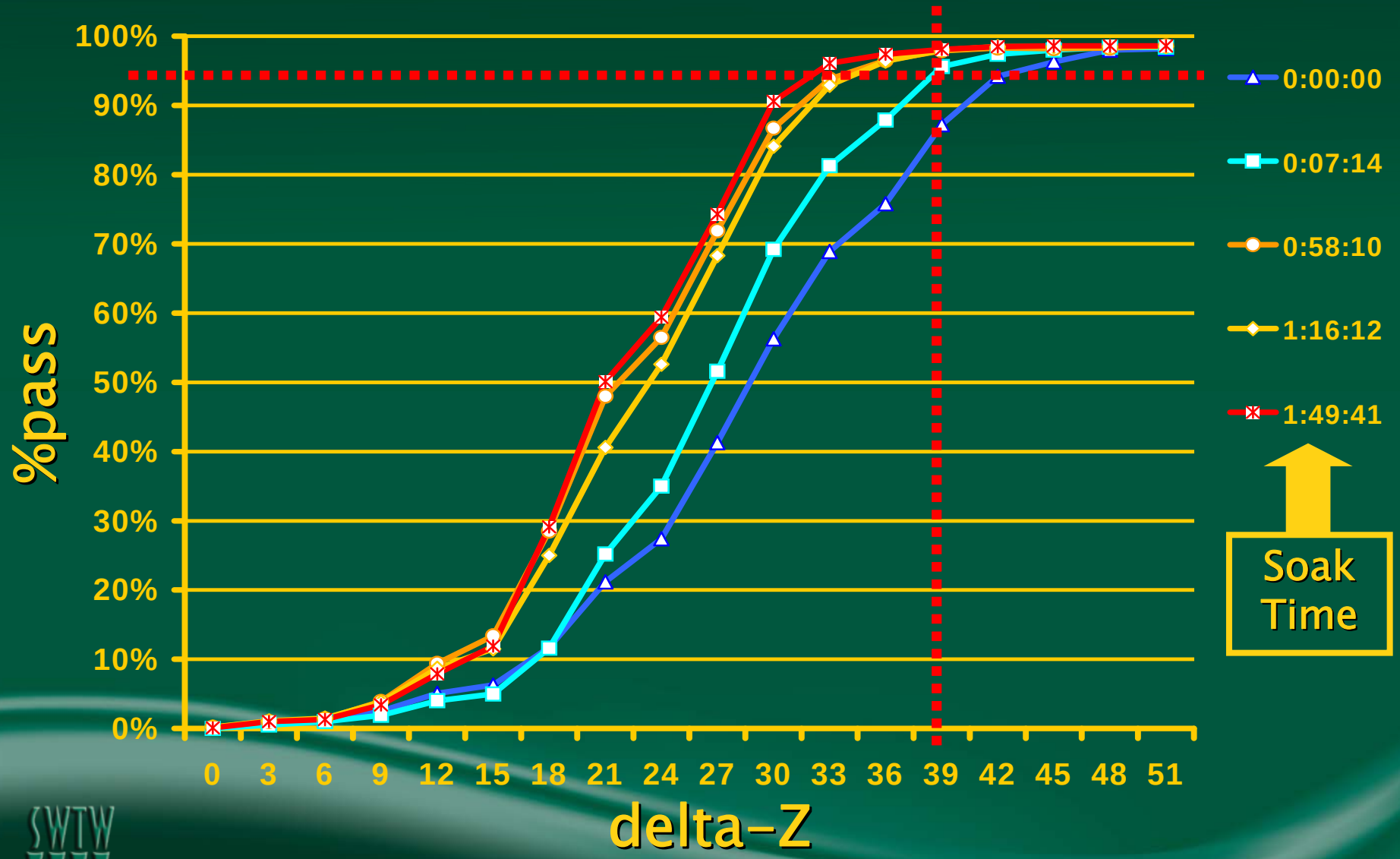


# EF2L Examples

# Example: %pass Data

| delta-Z | #PASS | DELTA-PASS | %PASS |
|---|---|---|---|
| 0 | 6 | 6 | 0.2% |
| 3 | 12 | 6 | 0.4% |
| 6 | 18 | 6 | 0.6% |
| 9 | 28 | 10 | 0.9% |
| 12 | 146 | 118 | 4.8% |
| 15 | 443 | 297 | 14.6% |
| 18 | 695 | 252 | 23.0% |
| 21 | 1403 | 708 | 46.4% |
| 24 | 2016 | 613 | 66.7% |
| 27 | 2315 | 299 | 76.6% |
| 30 | 2720 | 405 | 89.9% |
| 33 | 2914 | 194 | 96.4% |
| 36 | 2953 | 39 | 97.7% |
| 39 | 2967 | 14 | 98.1% |

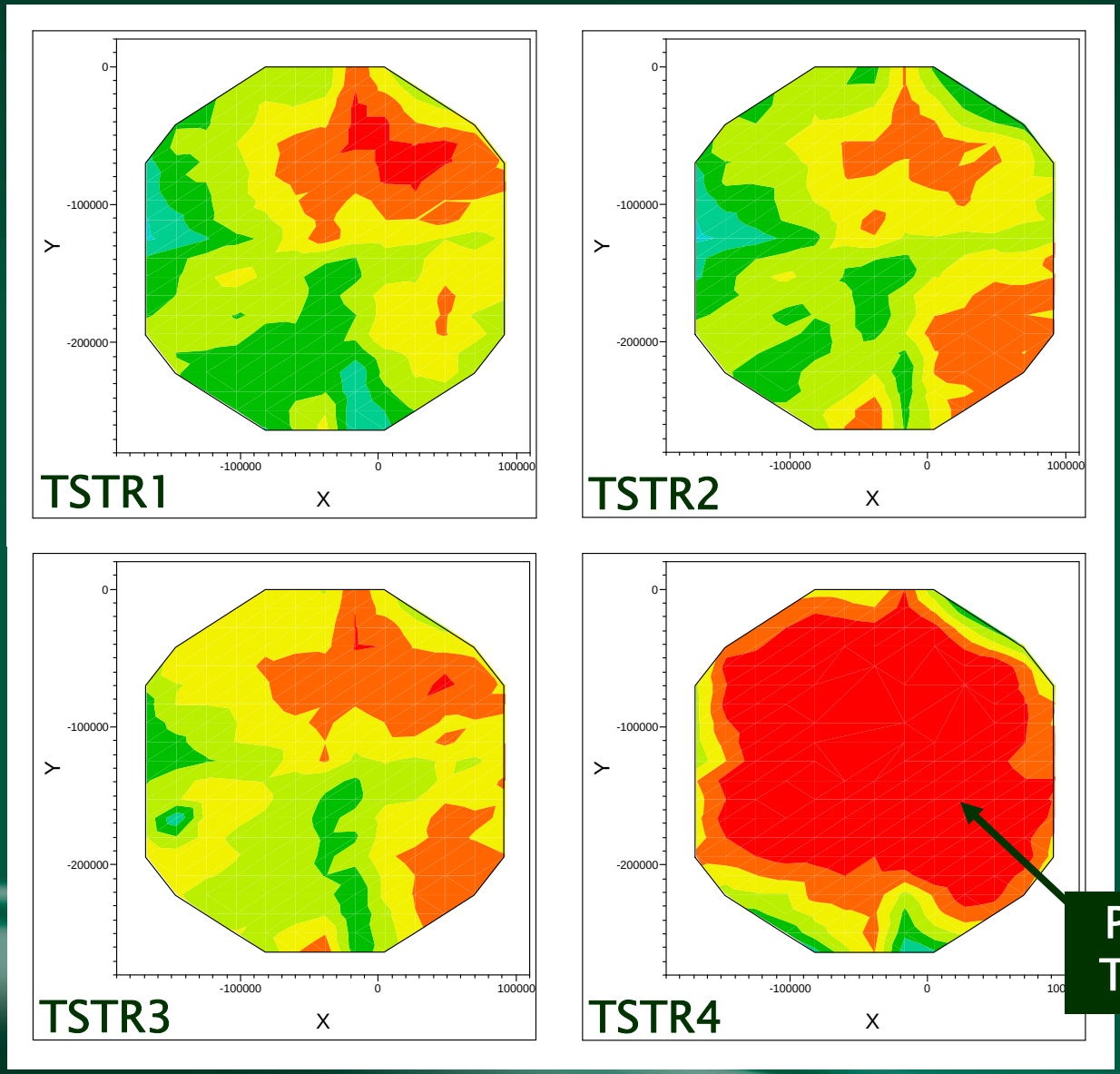
# %pass by delta-Z



# Example: Pin Height

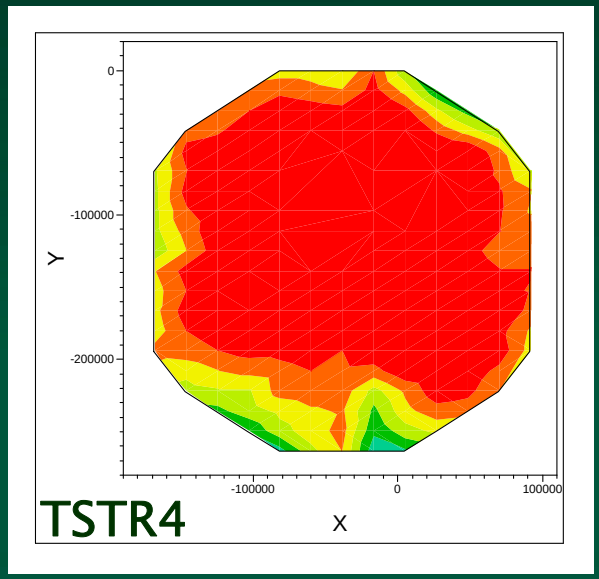
| TESTER DUT | X-COORD (um) | Y-COORD (um) | PROBE# | PIN_HEIGHT (um) |
|---|---|---|---|---|
| 0 | -59903 | -235432 | 1 | 15 |
| 0 | -59903 | -235432 | 2 | 18 |
| 0 | -59903 | -235432 | 3 | 18 |
| 0 | -59903 | -235432 | 4 | 15 |
| 0 | -59903 | -235432 | 5 | 18 |
| 0 | -59903 | -235432 | 6 | 18 |
| 0 | -59903 | -235432 | 7 | 15 |
| … | … | … | … | … |
| … | … | … | … | … |

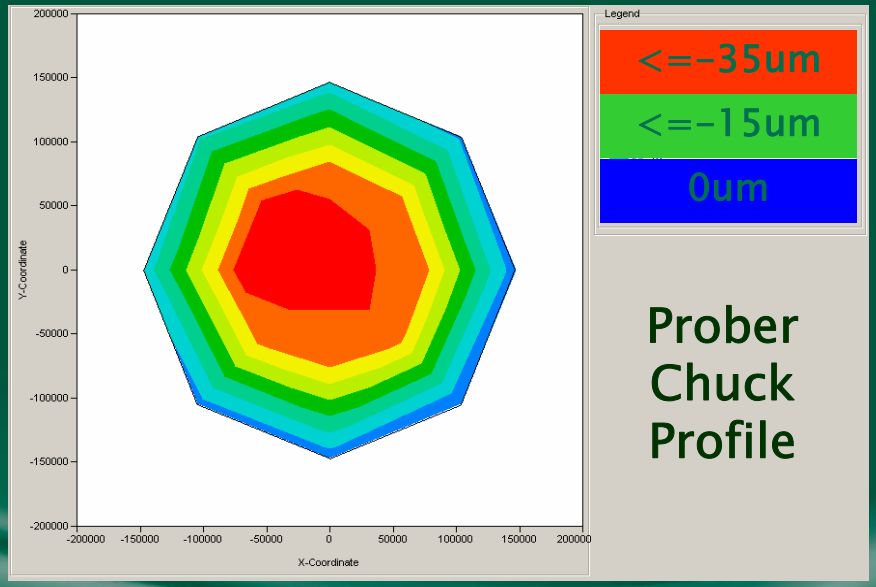
# System-to-System Planarity Correlation



# Test Cell Problem Resolution

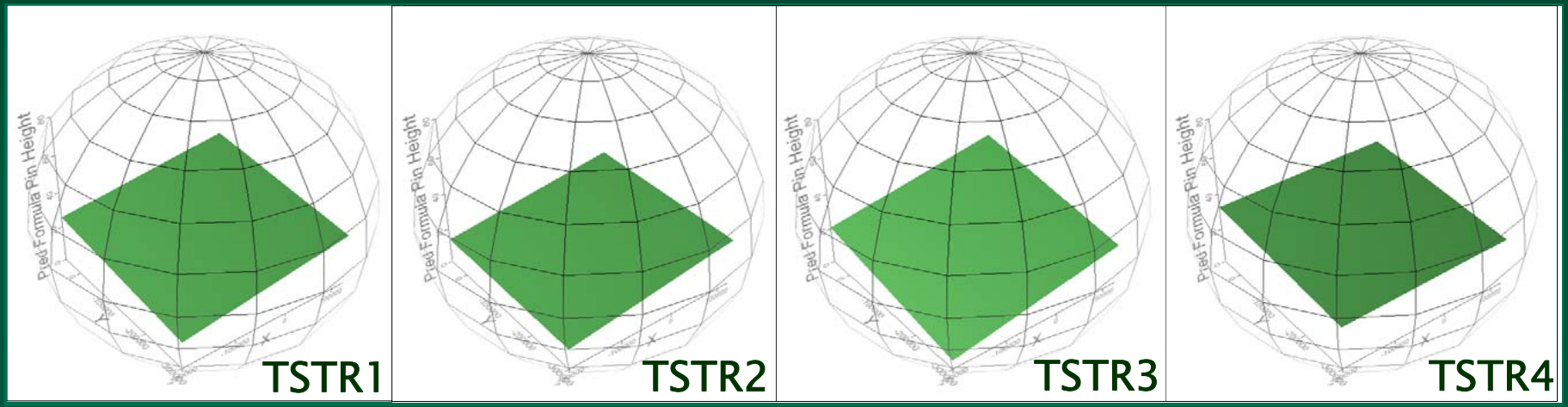
- Planarity signature: Inverted bowl
- Root cause: Prober chuck curvature
- Solution: Replaced prober chuck



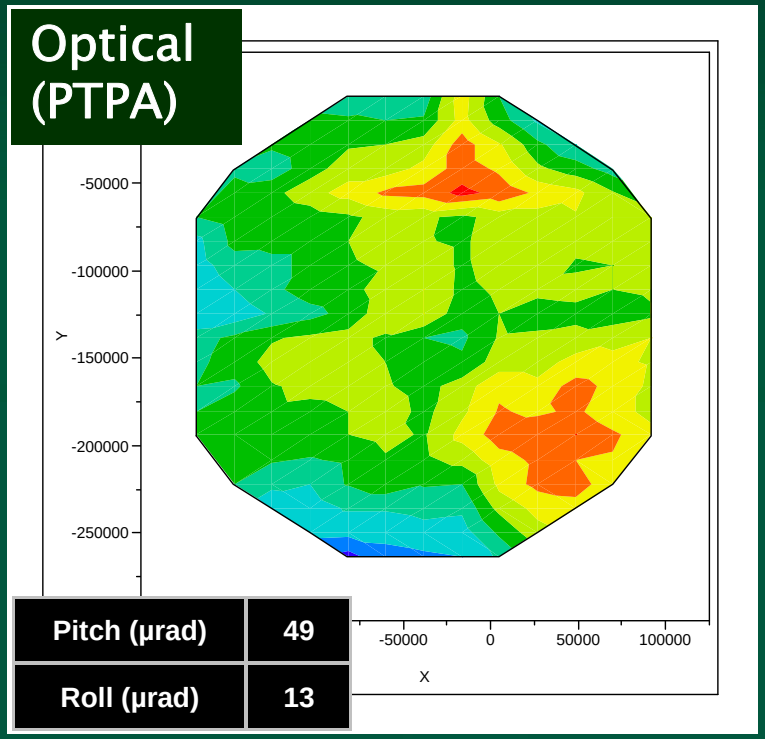
# System-to-System Tilt Correlation

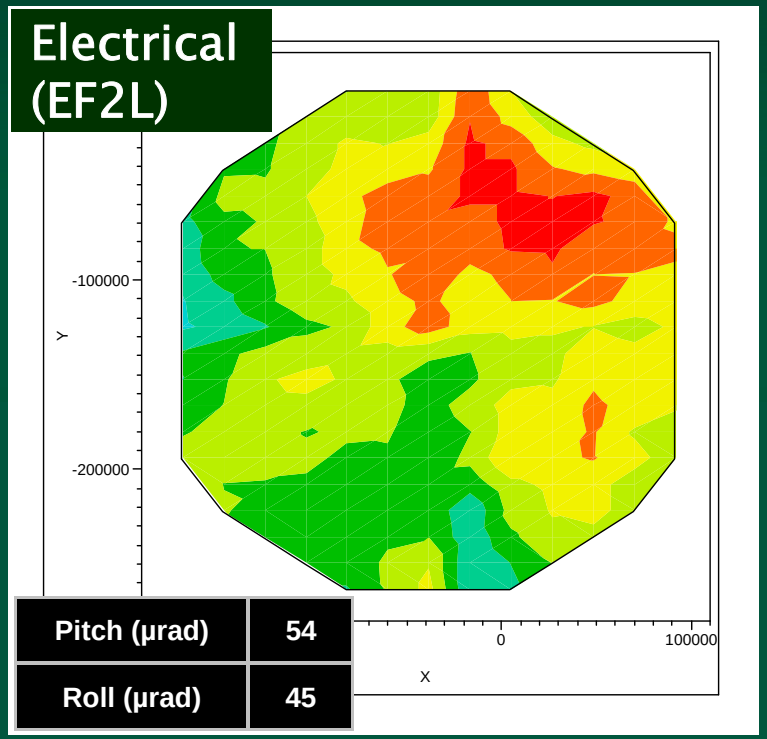
## Best Fit Linear Plane

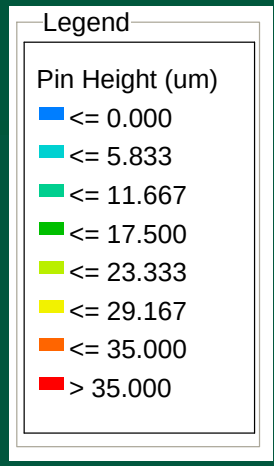



| | TSTR1 | TSTR2 | TSTR3 | TSTR4 | Range |
|---|---|---|---|---|---|
| Pitch (µrad) | 41 | 42 | 53 | 5 | 48 |
| Roll (µrad) | 30 | 5 | 44 | 24 | 39 |

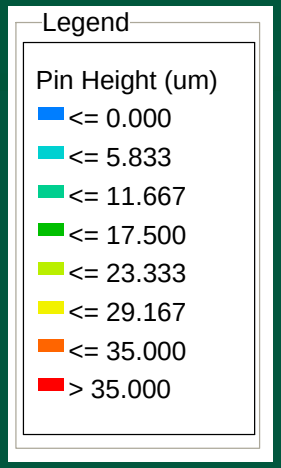
# Optical-to-Electrical Correlation

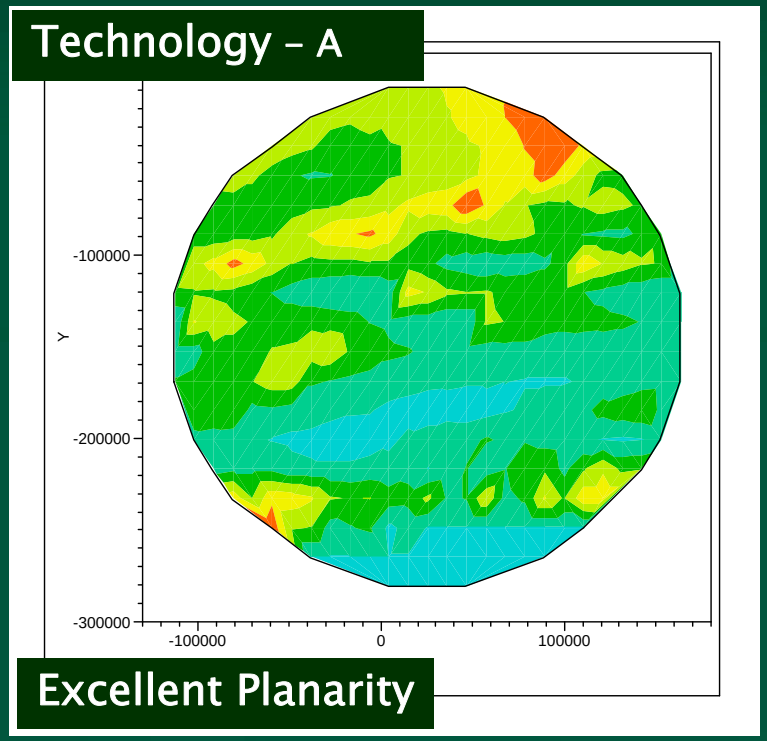


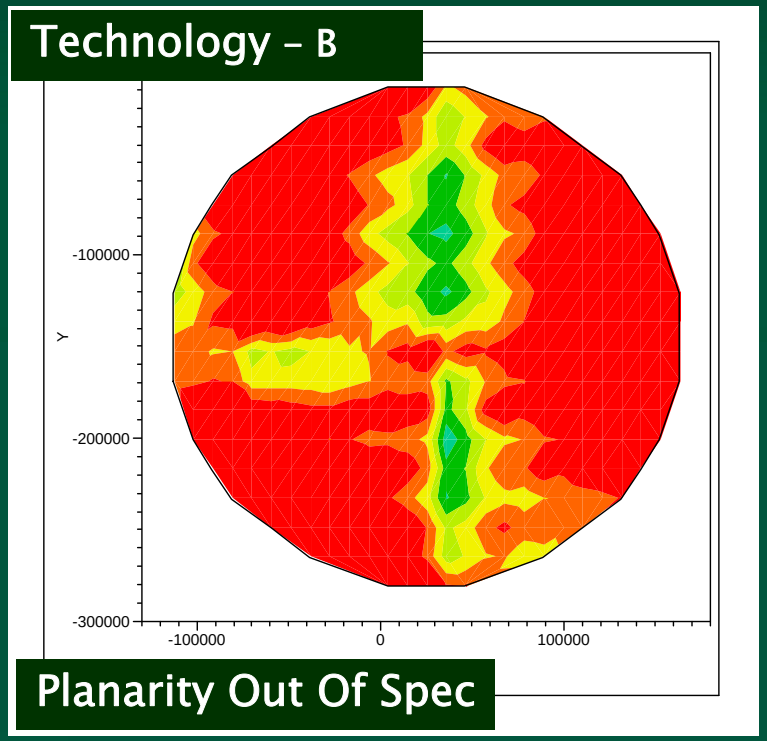



# Probe Card Technology Benchmark




*Both probe cards 1TD 300mm

# Summary

- **Meeting the challenge**
  - High parallelism (1TD 300mm)
  - Thermal deflection
  - High probe count
  - Shrinking bond pads
- **EF2L is a key component in understanding probe card planarity**
  - Electrical planarity spec validation
  - System-to-system correlation
  - Probe card technology benchmark
  - Thermal profile / soak
  - Identify other test cell issues, such as prober chuck curvature and system deflection

# Thank You!