Multiple resort effects on Cu bump technology

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The objectives of this presentation

- This presentation is intended to:
  - Present the Cu bump resort effect;
  - Present our current understanding of the issue and its impact;
  - Seek help from the probing industry to find a solution for this effect;
- This presentation is not about:
  - Cu bump probing process development;
  - Other Cu bump probing challenges.

Outline

- Introduction: TV and product Cres measurements
- The Cu bump multiple probing effect on Cres: TVs and logic products
- The hypotheses explaining the observed effect
- Impact of the multiple resort effect – system correlation and tool IQ methodology
- Summary

☞ Introduction

Cres: A key measurement for process dev and HVM monitoring

- **Test vehicle (TV) Cres for process dev:**
  - ✓ Special Cres measurement test vehicles (TV) are used during probing process development;
  - ✓ All tester IO channel resources can be used for Cres measurements (measuring path resistance and deducing Cres);
  - ✓ Both the single channel max (addresses product IO concerns) and die mean (addresses device power delivery) Cres are used as key responses.
- **Product Cres for HVM monitoring:**
  - ✓ Product IO ESD protection diodes used for Cres estimation;
  - ✓ Product Cres monitored through on-line and off-line PCS systems.

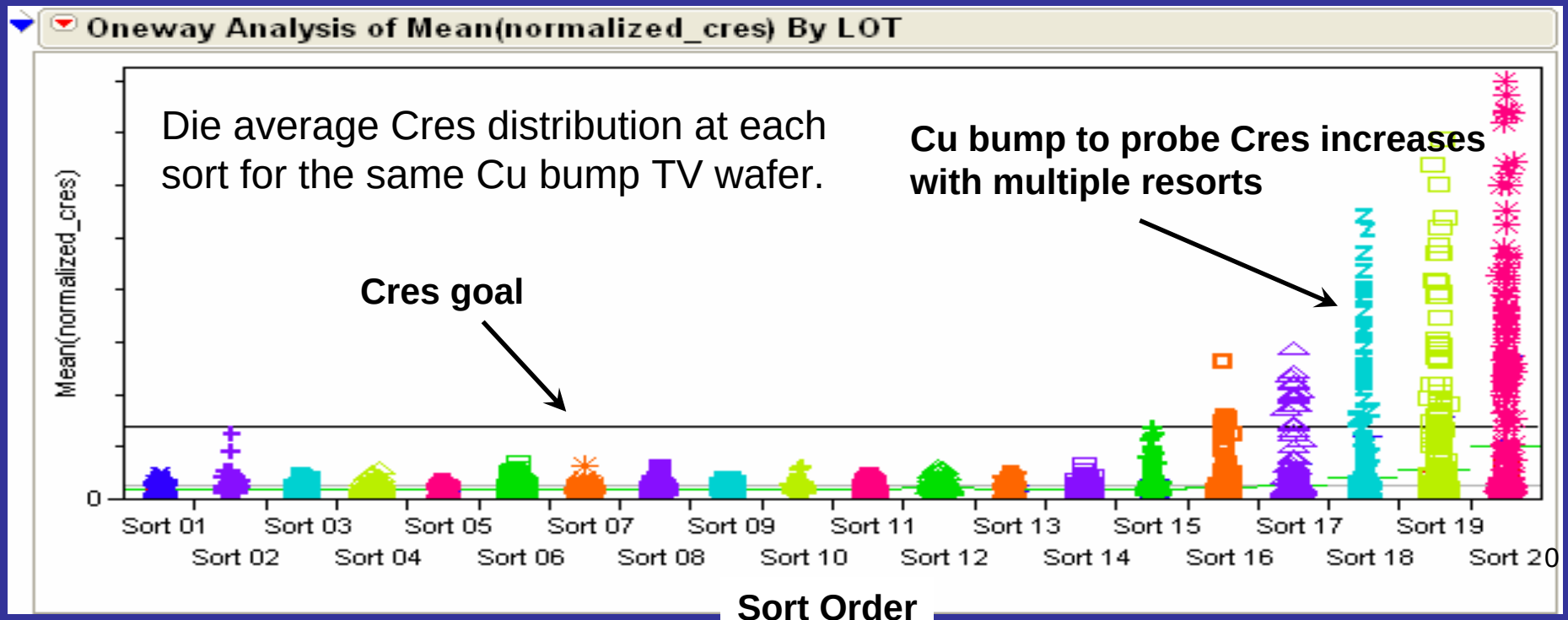
HVM Cu bump probing technology requirements

- Must meet electrical performance requirements for a broad range of products;
- Must achieve a low and stable probing Cres in a production environment;
- Consistent performance over probe card lifetime;
- Consistent performance across multiple probe cards and modules;
- Adequate process margin to overcome variations in Cu bump characteristics;
- Consistent performance under repeated probing (multiple probing).

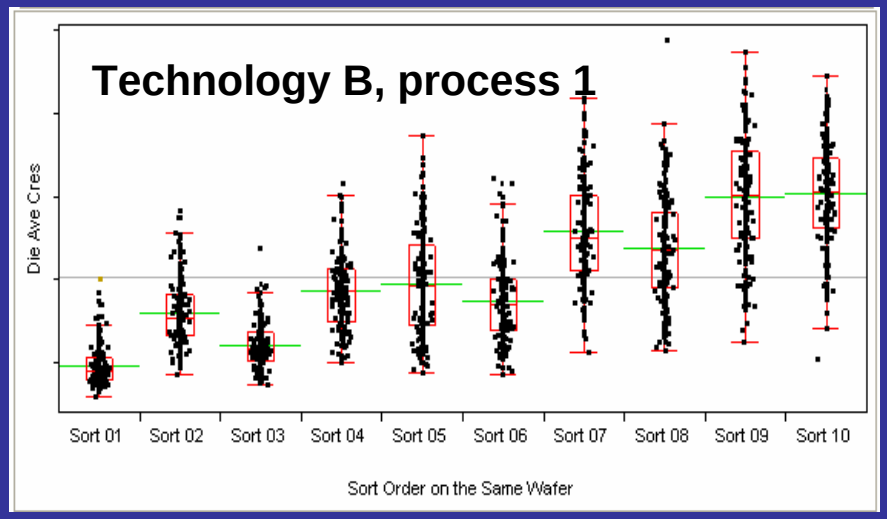
☞ The effect ...

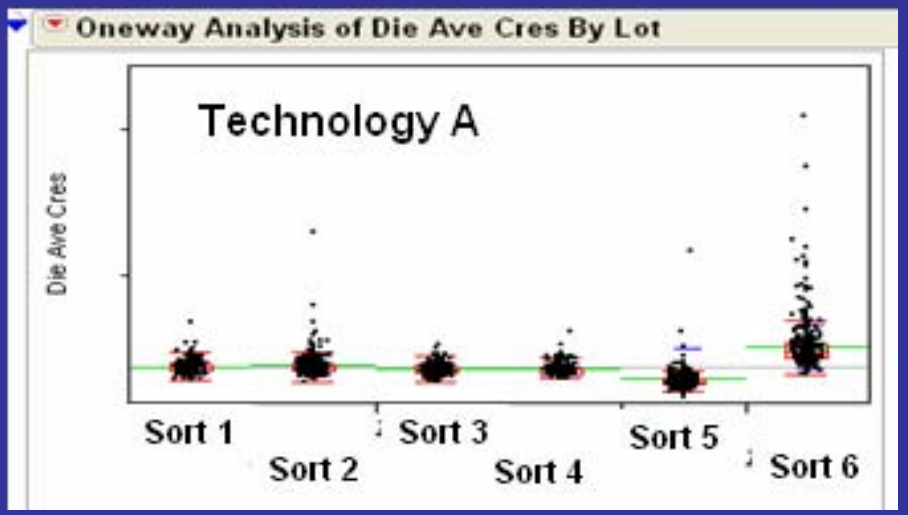
Cu bumps show unique behavior under multiple sorts:

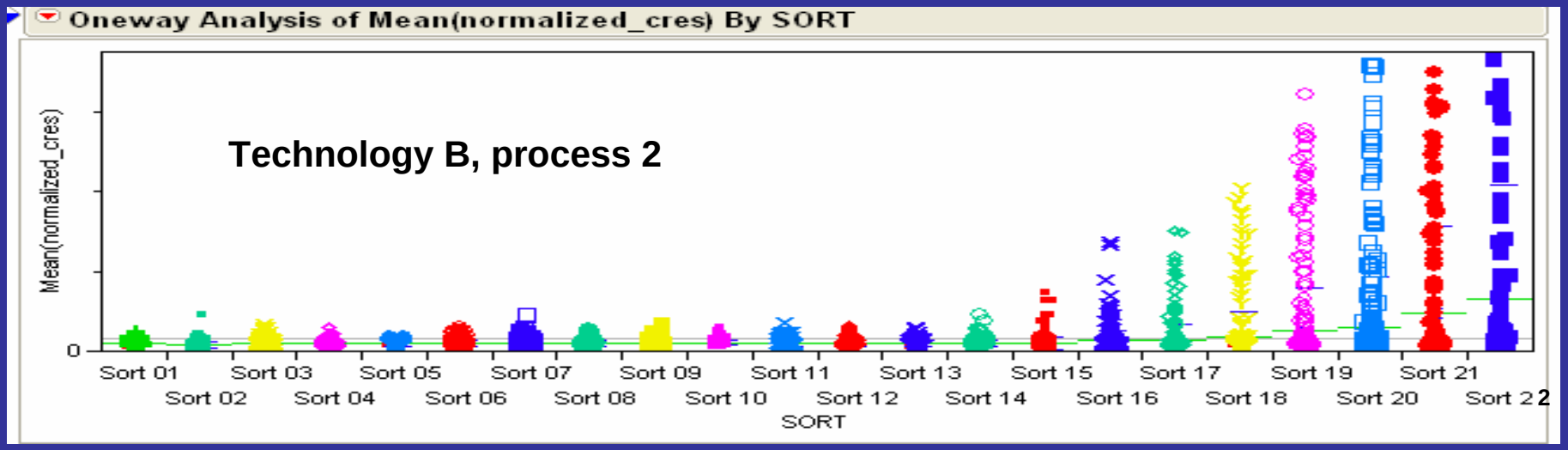
- Probing Cres deteriorates significantly with relatively few repeated tests on the same bumps (wafers);
- The same wafer can only be used to yield reliable results for up to ~ 14 resorts;



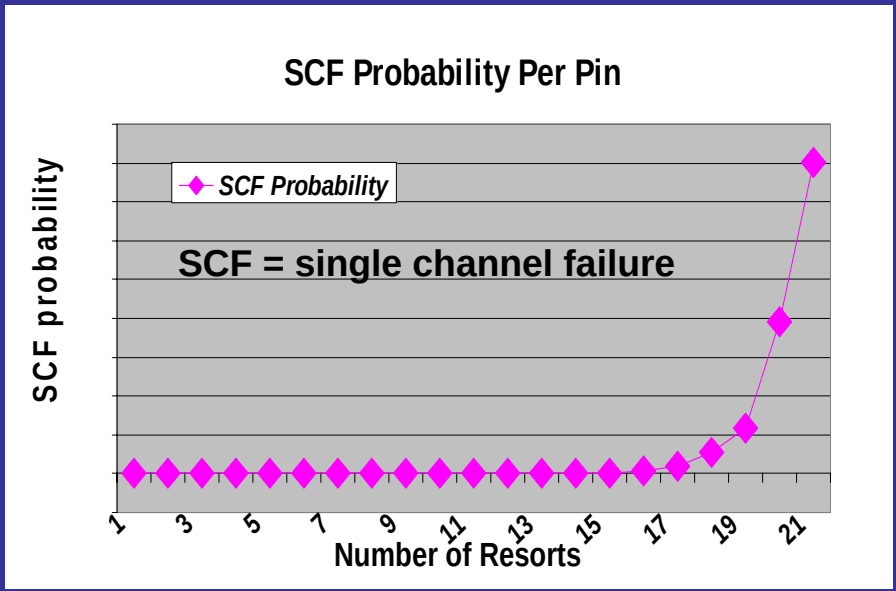
This resort effect with Cu is observed with different probing technologies and processes

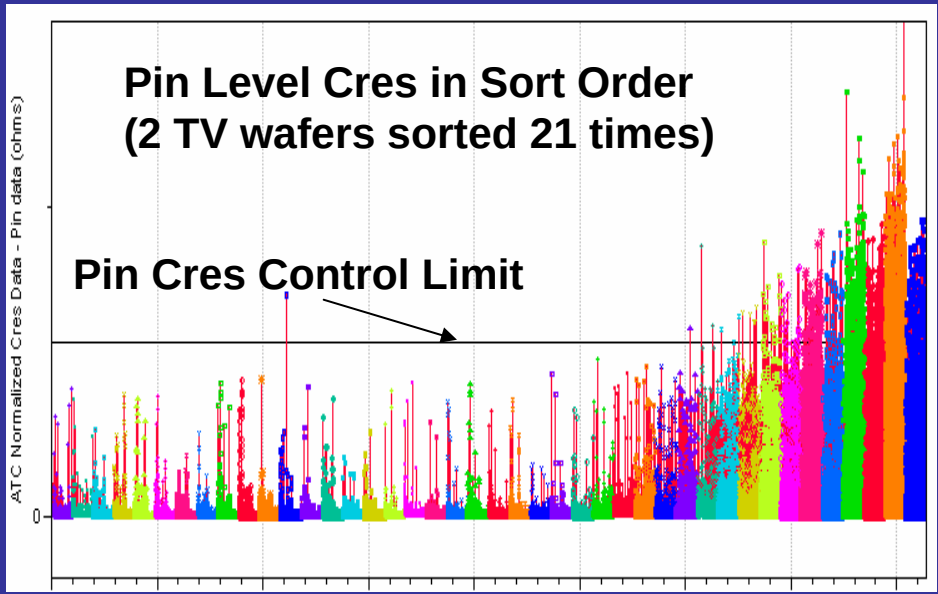






Characteristics of the multiple resort effect

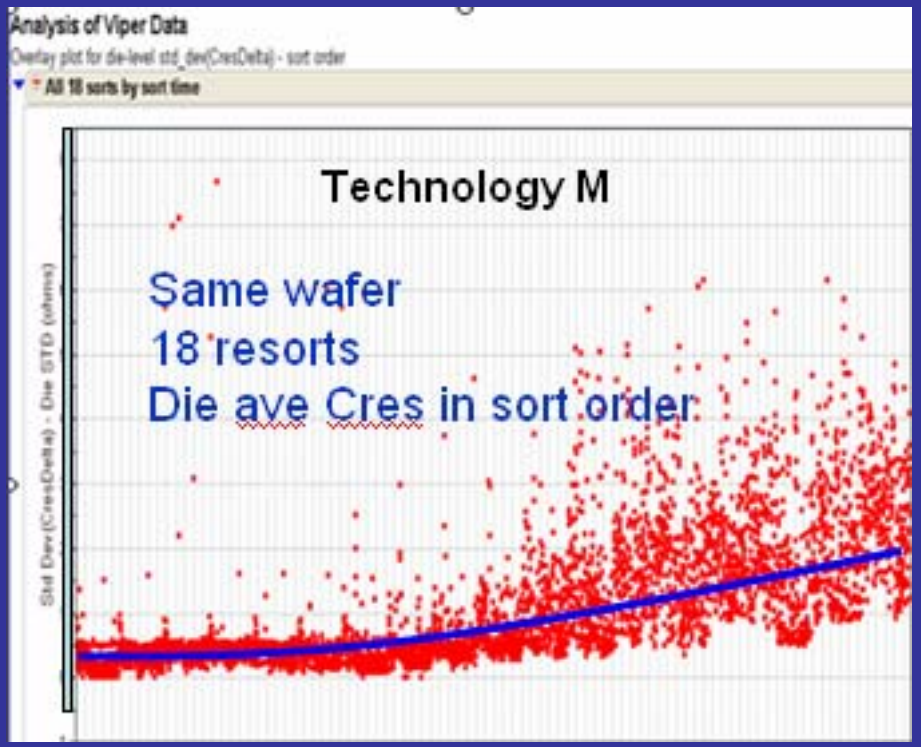


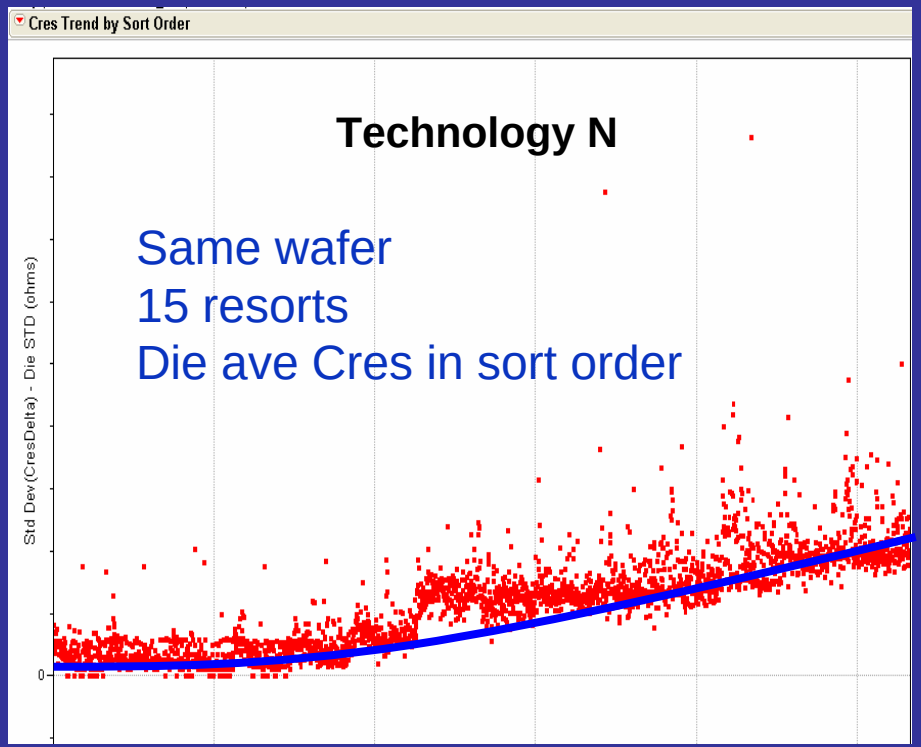


- Uniform Cres increase on all pins on all dies was not observed;
- Probability of pins to have high Cres (SCF rate for pins) increases with the number of resorts;
- The magnitude of the effect depends on probing processes, individual wafers, probe cards and other **random** factors ;
- Was not due to specific probes, bumps;

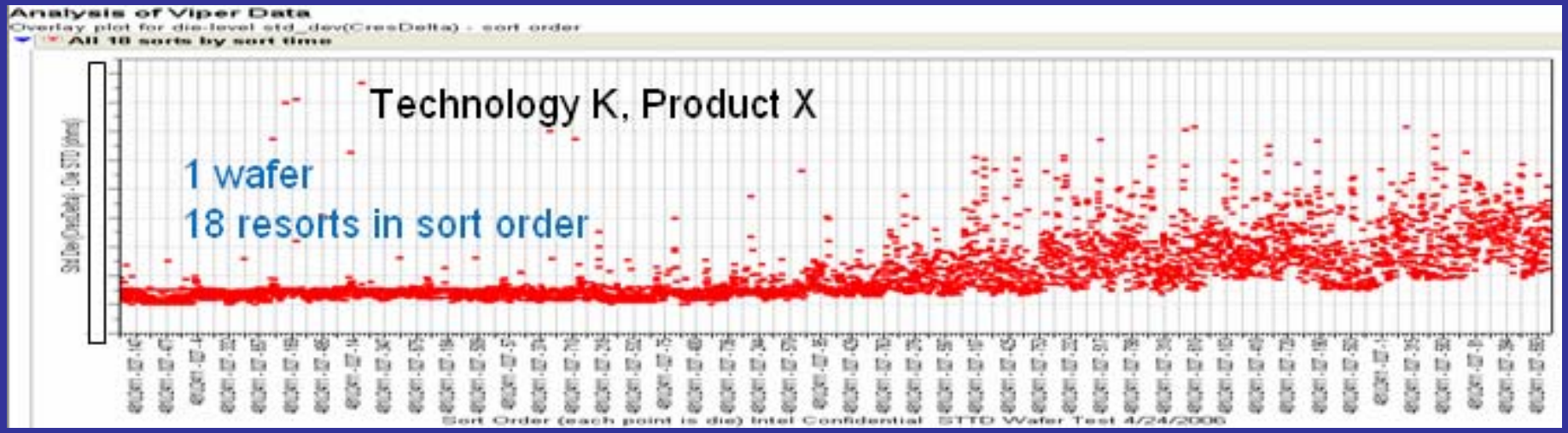
Product Cres change vs multiple resorts

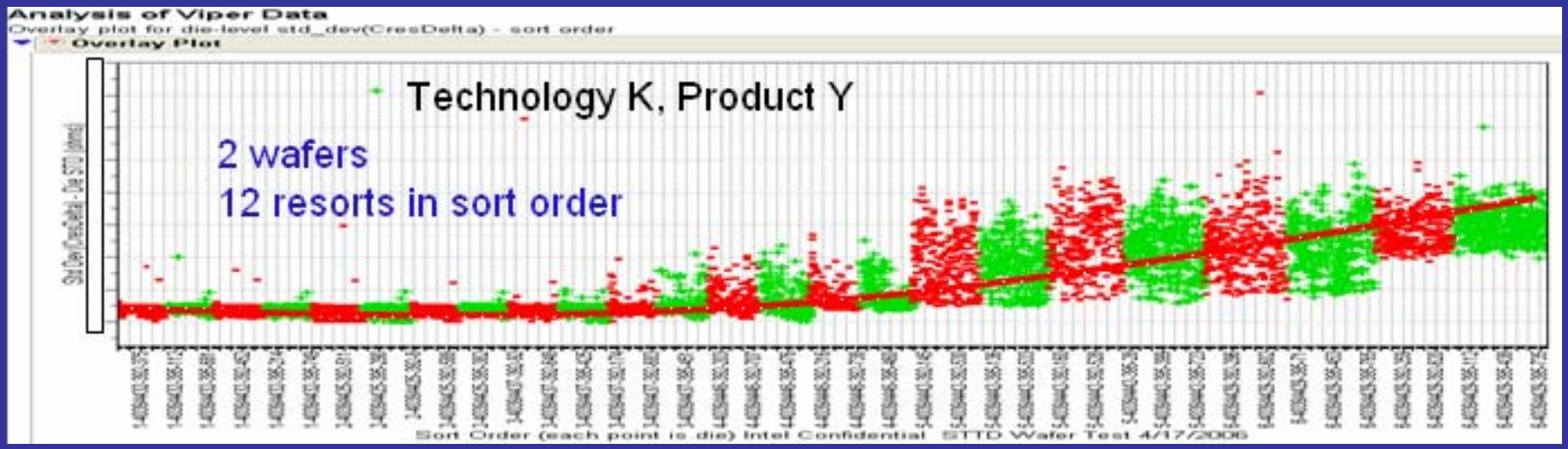
- Similar trend on product Cres observed on different probing technologies;
- The die average std Cres increases with multiple resorting.





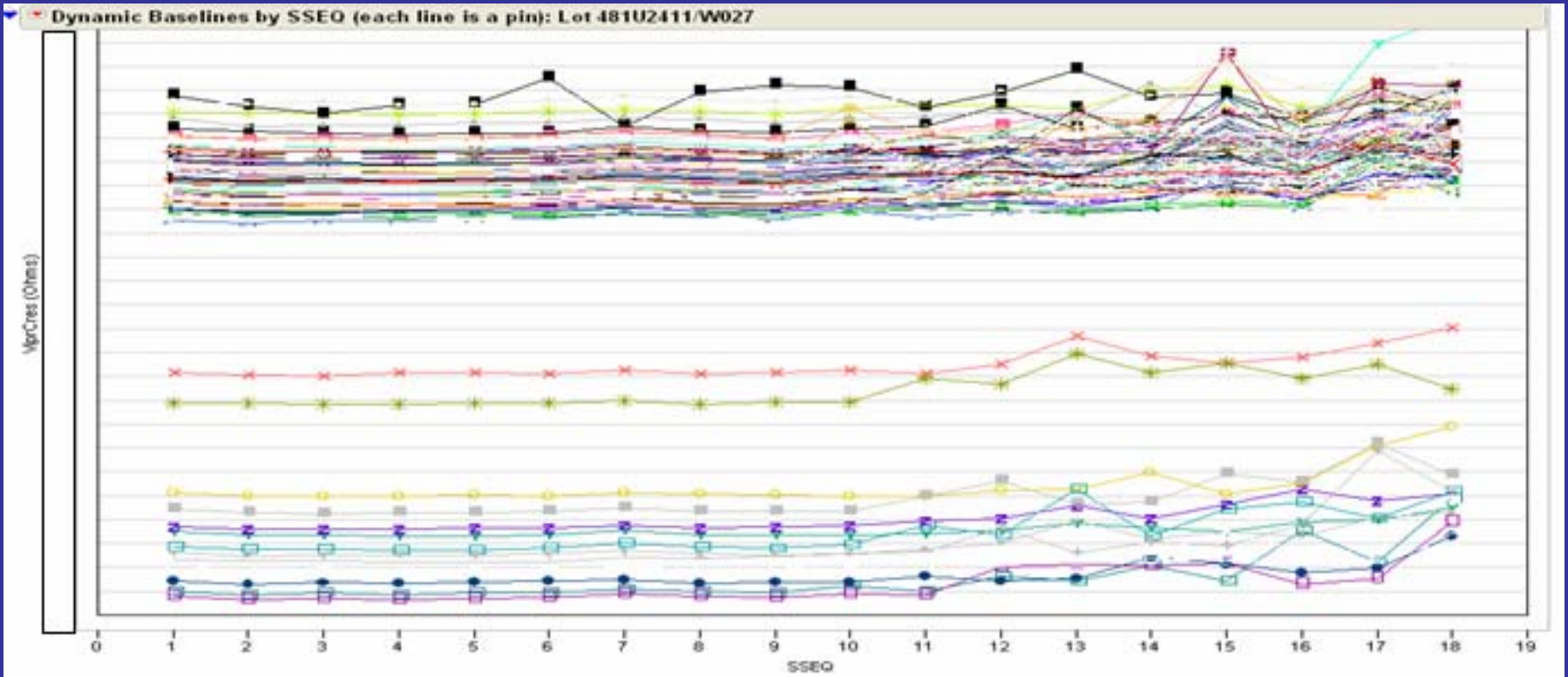
Product Cres change vs multiple resorts: Same technology but different products





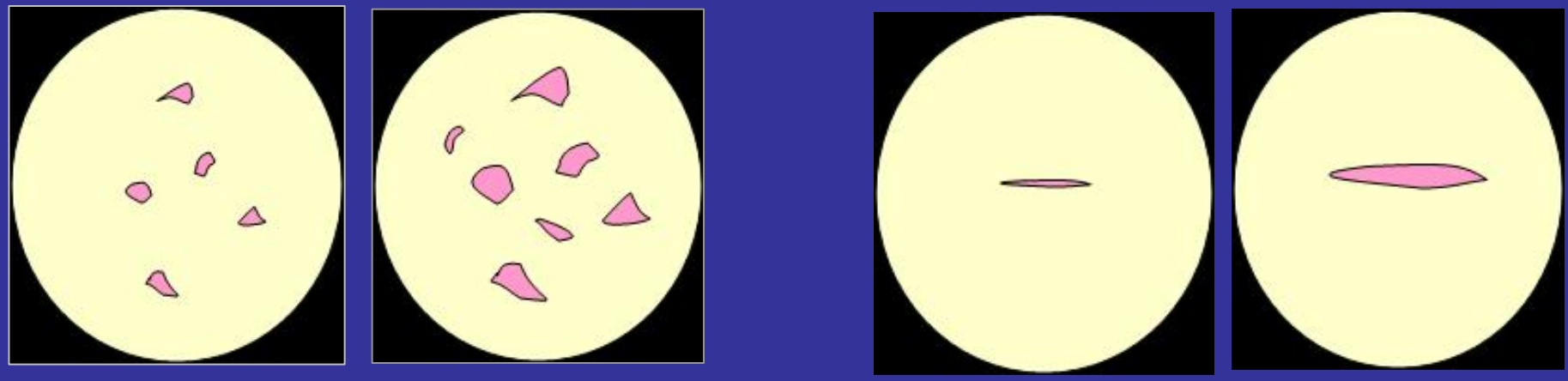
Product IO channel resistance change vs the number of resorts

- Some channels were more sensitive to the number of resorts;
- But the overall trend does exist for all channels.



☞ The hypotheses ...

What causes the multiple probing effect?



1st probing multiple probing

Flat probes

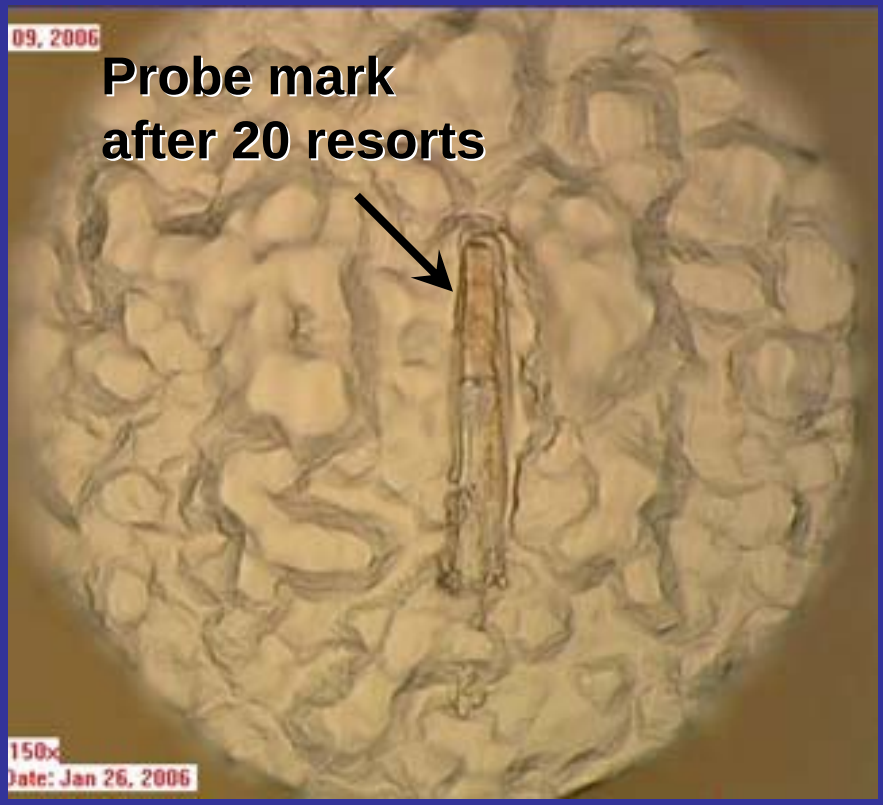
1st probing multiple probing

Wedge/Blade probes

Probe Mark Observations:

- More flat areas on the bump surface after multiple probing with flat probes;
- Wider and deeper probe marks after multiple probing with wedge / blade probes;

Probe mark examples



What causes the multiple probing effect (cont'd)?

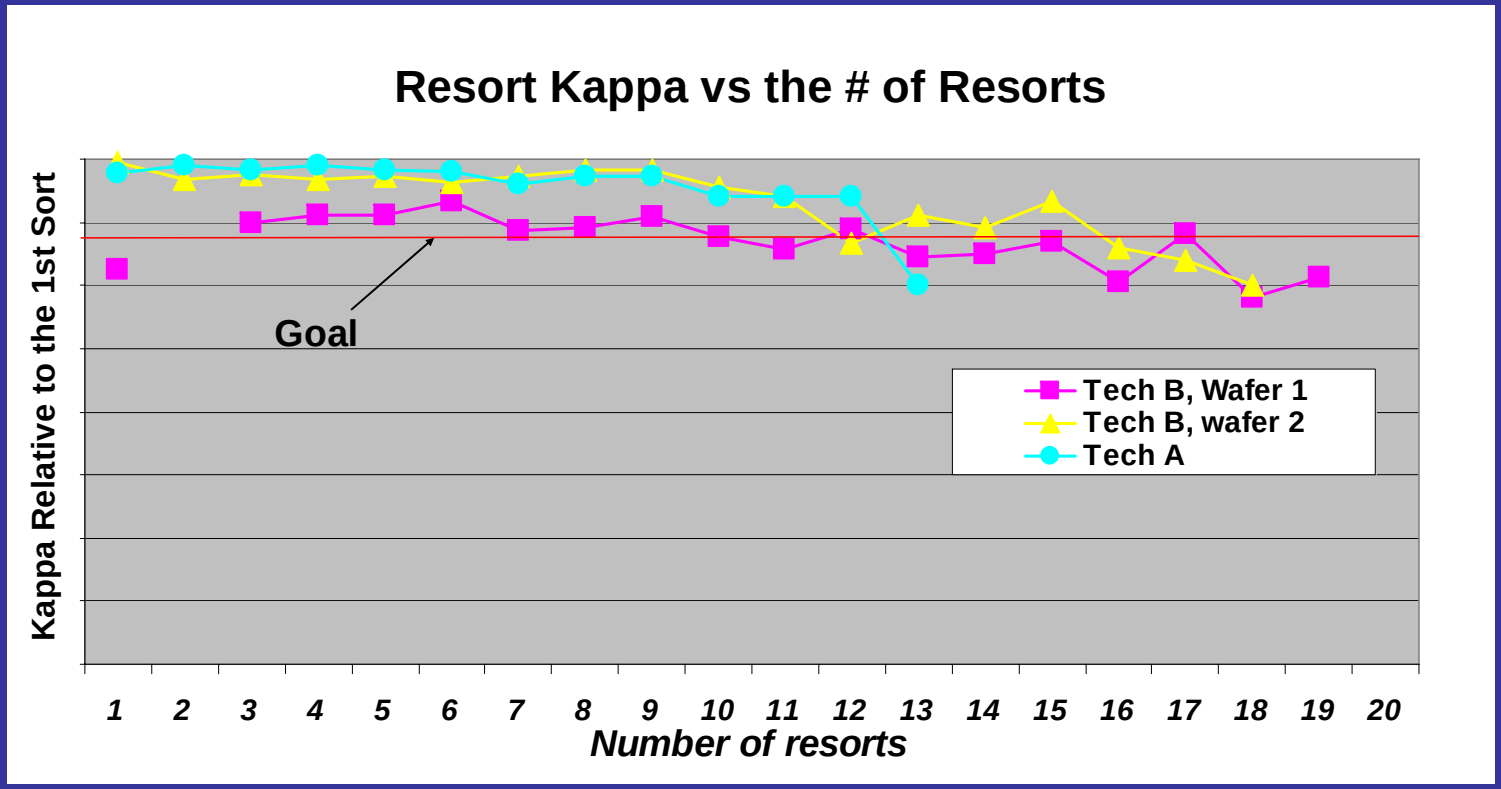
- **Hypothesis I:**
  - ✓ A minimum pressure is needed to overcome the copper oxide layer (a few nm) for good contacts.
  - ✓ Multiple probing increases the "contact" area, reduces the contact **pressure**, resulting in poor contacts;
- **Hypothesis II:**
  - ✓ Multiple probing smoothes the bump surface on a micro-scale;
  - ✓ The probes sometimes may **slide** on the smooth Cu surface, resulting in poor contacts;
- **Hypothesis III:**
  - ✓ The Cu bumps act as a polisher for probes, and the accumulated **debris** may cause poor contacts;

☞ The impacts ...

Key impacts of the effect

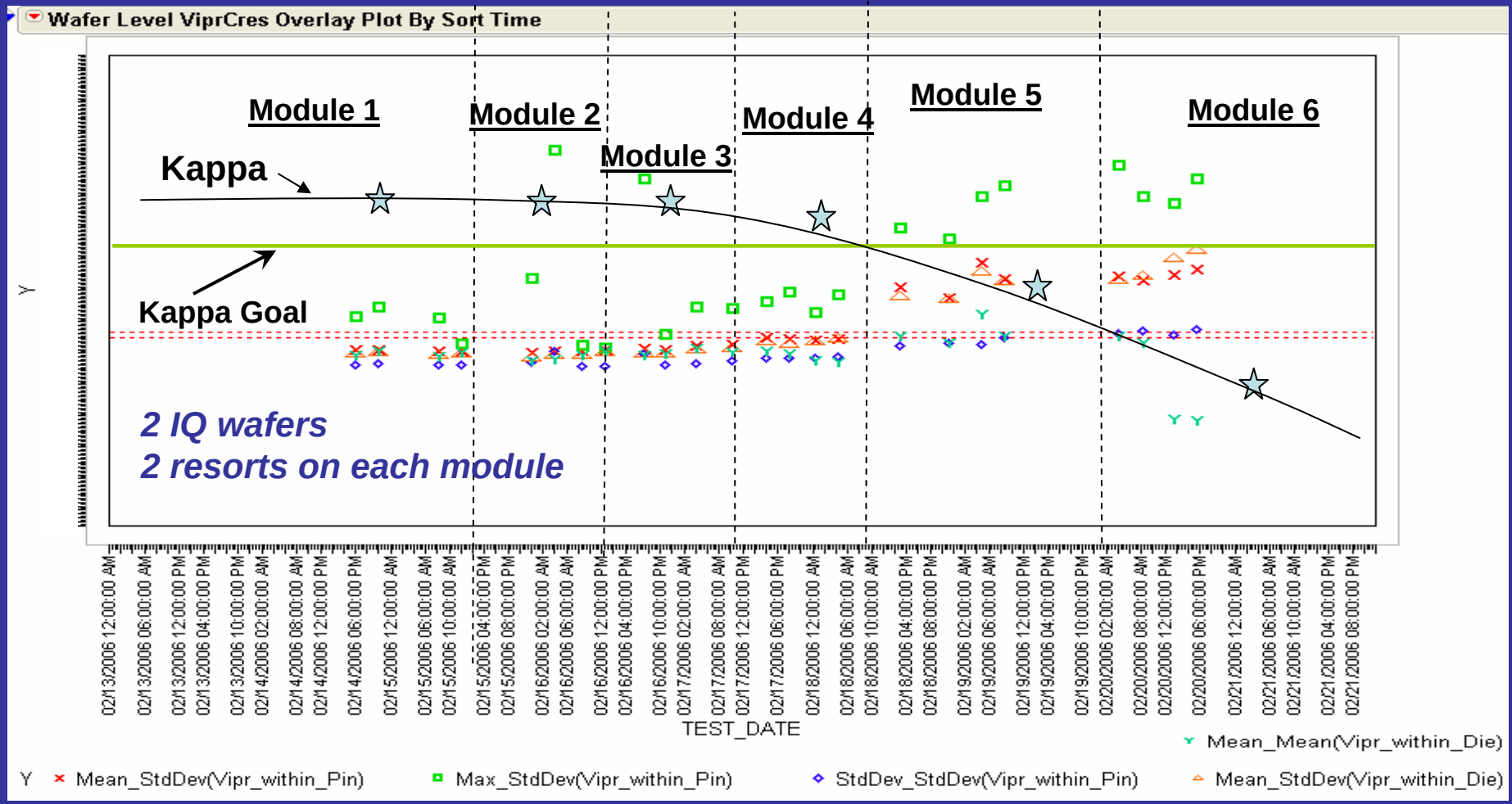
- Sort module “golden” correlation methodology
  - ✓ Cu correlation wafer lifetime is reduced compared to that of PbSn wafers;
  - ✓ Bin switches (Kappa) is sensitive to this effect;
- Sort module IQ methodology
  - ✓ Cu IQ wafer lifetime is reduced compared to that of PbSn wafers;
  - ✓ Parametric reproducibility and kappa are both affected by the increased Cres after multiple resorts;
  - ✓ It is difficult to qualify a whole fleet of tools when the wafers you are using as “standards” could not yield reproducible results after small number of testing.

Corr wafer lifetime example: Bin switches (Kappa) vs. number of resorts for logic products



- Kappa deteriorates after multiple resorts;
- The rate of deterioration is not consistent;
- Potential factors impacting deterioration rate: 1. Probing technology; 2. Individual SIU; 3. Probing process; 4. Material

IQ wafer lifetime example: Kappa, Cres vs resorts



Potential Solutions

- Further probing process optimization to minimize the effect;
- Alternative correlation wafer methodology;
  - ✓ Revisit system correlation usage cases;
  - ✓ Alternatives to “golden” corr methods;
- Alternative tool IQ methodology;
  - ✓ Optimize IQ wafer usage;
  - ✓ Revisit IQ test parameters and their success criteria;
- New advances in probing technology for Cu;
  - ✓ Innovative correlation / module matching solutions;
  - ✓ Alternative probe tips may increase corr / IQ wafer lifetime;

Summary

- The Cu bump multiple resort effect was observed on both TV and products, and on different probing technologies;
- The magnitude of the effect depends on probing technologies/processes, individual wafers, probe cards and other random factors;
- We believe the effect is due to the micro-scale surface condition changes on the probing area: **pressure, sliding** and **debris** are the three main hypotheses.
- Both the system correlation and IQ methodologies are being challenged by the effect. Innovative solutions are needed to increase corr/IQ wafer lifetime.