IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Identification, analysis and control of high temperatures on wafer test probing processes

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Overview

Joint Cooperation & Motivation

Temperature Influence on Probing

Experimental data

Results & Future Work

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Results & Future Work

NXP Testcenter Europe

- Engineering site for high performance mixed signal products, automotive and identification business.

- Applications with very high multisite factors and small pad pitch.
- Capability to collect high temperature probing data within production like automated environment

NXP Motivation

- High temperature probing becoming more challenging due to increasing requirements (e.g. 200 °C), mostly driven by the automotive market.
- Smaller pad libraries of advanced processes require higher accuracy to the probe to pad alignment (PTPA).
- Probing process analysis was made inhouse in the past. Evaluation of external tools was needed.
- Review and optimization of existing NXP production process settings for soaktimes and PTPA
- Standardization of probing process analysis needed in NXP.

Rudolph Technologies Motivation

- **Validate new wafer sort process capabilities**
- **Collaborative partnership with industry leader**
- **Positive feedback for product development**

WaferWoRx Process Analysis

- **KGD critical markets**
  - Automotive
  - Medical
  - TSV & Stacked packaging
- **Rapid data analysis and review**
  - High temperature applications
  - Low temperature applications
  - All probe card technologies
- **Multiple data review options**
  - Normalized single variable
  - Vector view
  - User selectable

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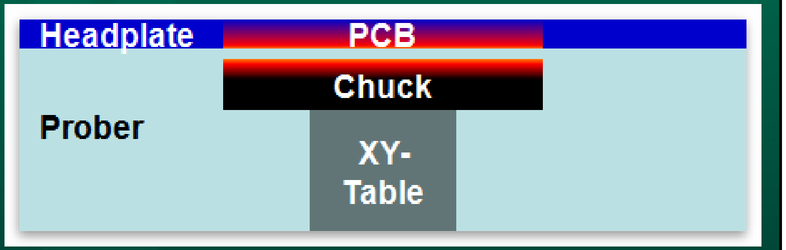
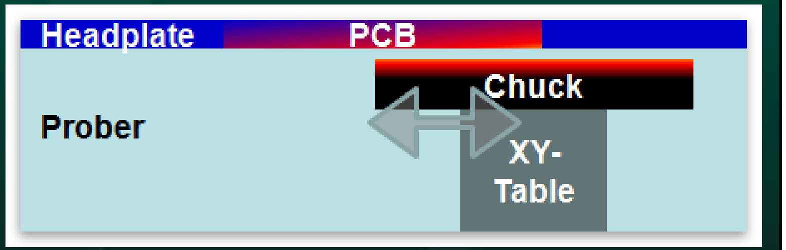
PTPA stress influence

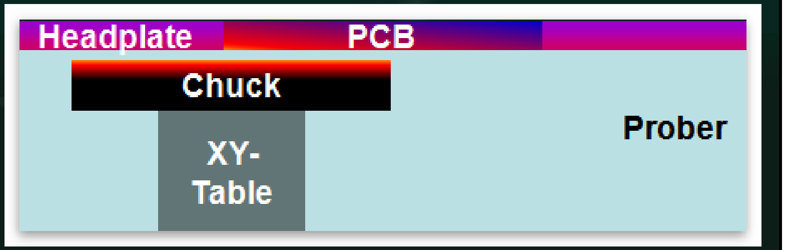
- **Main mechanical stress factors**
  - Test head docking depending on interface design
  - Probe card fixture and landing in probe card changer
  - PCB Stiffner fixture
  - Probe head fixture (for replaceable heads)
- **Main thermal stress factors**
  - Thermal gradient in probe card
  - PCB stiffness
  - Thermal expansion of head plate and probe card changer
  - Moving chuck → continuous stress, no saturation
  - Chuck distance (clearance) to probe card

Continuous thermal stress by moving chuck

- **Wafer start up**
  - Fast heating of PCB
  - Head plate slow temp. change
- **Moving chuck**
  - Change of thermal gradient in PCB
  - Depends on size and thickness
- **Long term status**
  - Headplate warms up
  - Continuous change of thermal gradient in PCB







Solutions to limit thermal stress

- **Preventive Probe card solutions**
  - Probe card construction/materials
    - Schaefer et al SWTW2009
    - Breinlinger – SWTW2010
  - Probe card shielding to reduce heating
    - Wegleitner et al – SWTW2006
  - Probe card heater to harmonize temperature gradient
    - Molinari et al – SWTW2010
    - Wegleitner et al – SWTW2006
- **Online Process solutions**
  - Soak times to avoid big movements at wafer start
  - Probe to pad realignments to compensate continuous stress by moving chuck
  - Find ideal stepping pattern

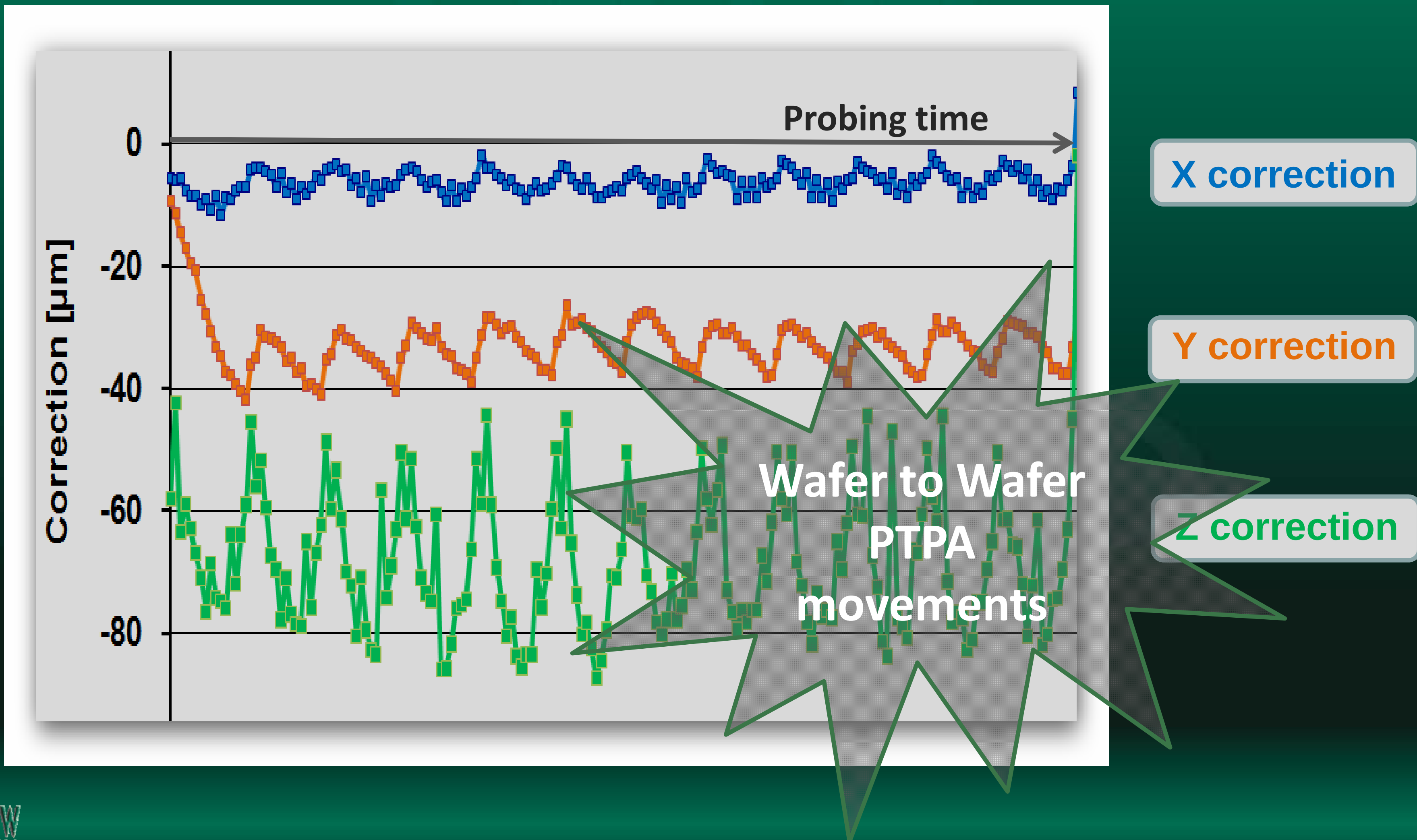
Online Realignment - pros & cons

- **Manual probe mark inspection and realignment by operator (2D)**
  - \+ Flexible use, no equipment automation needed
  - – Difficult use for large probe arrays and multiple touchdowns
  - – Slow, expensive and inaccurate if realignment frequency is too high
- **Automated probe mark inspection and realignment (2D)**
  - \+ Faster because of 2-dimensional analysis only
  - – Not usable for second or further test stages due to multiple probe marks
  - – Some probe technology/pad technology combinations have invisible probe marks
  - – No probe height correction.
- **Automated needle position inspection and realignment (3D)**
  - \+ Usable for multiple test stages
  - \+ Direct needle height measurement
  - – Not fast enough if too many probes inspected
  - – Depends on prober and camera alignment accuracy (probecard/wafer alignment)

NXP Solution

Production data example

Prober needle realignment log data for 12 tested wafers (2,5h/wafer @ 125°C)



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Overview DOE‘s

- **In total 6 experiments including 45 wafers with 60 different settings were prepared**
- **DOE 1 Tool Comparison**
  – 10 wafers were prepared in order to compare inhouse solution to WaferWoRx
- **DOE 2 Stepping pattern optimization**
  – 5 wafers were used
- **DOE 3 Realignment Optimization**
  – 17 wafers were analysed with a large temperature range and different realignment/soaktime settings

DOE 1 - Tool Comparison

Comparison of WaferwoRx with NXP solution

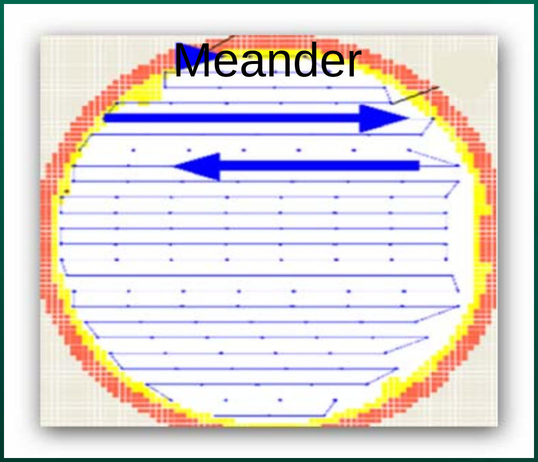
- **10 wafers were probed with intentionally generated, typical production probing errors.**
  - Probe card errors: pitch, role, yaw, etc.
  - Prober errors: Scaling, orthogonality, overtravel, etc.
- **Rudolph WaferwoRx and NXP inhouse inspection solution scanned all wafers**
  - All 10 errors identified by both machines and teams
  - Both machines capable to identify typical production errors, misalignments and maintenance issues

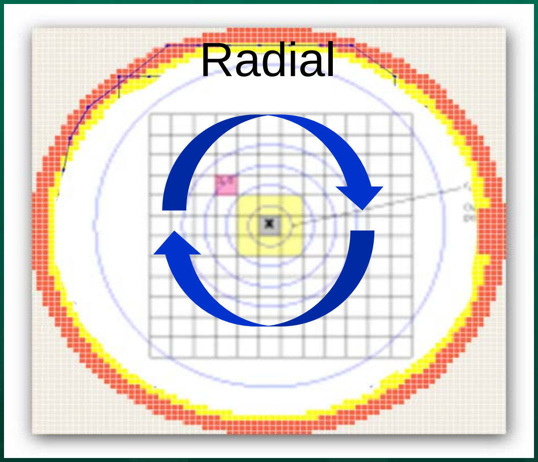
DOE 2 - Stepping pattern optimization

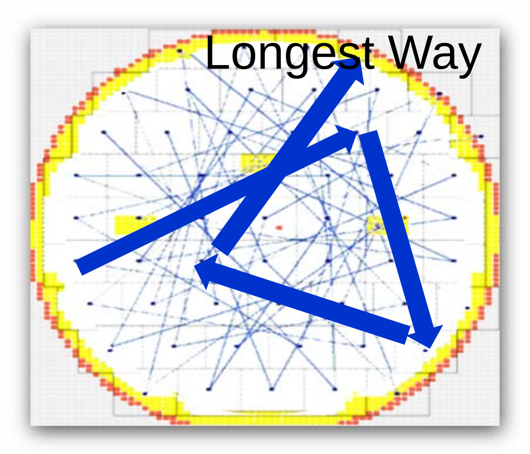
What is the best probing pattern for high temperatures?

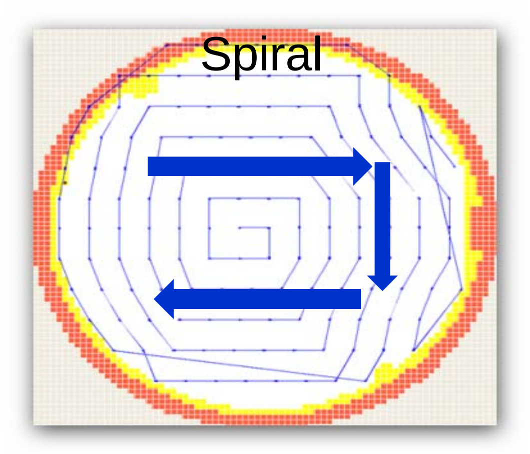
- **5 Wafers were probed with different stepping patterns on wafer**
  - Probing paths created with **MultiSiteOptimizer (MSO) by SPA**
    - Standard meander
    - Radial and spiral starting in the middle
    - Shortest and longest probing path
  - Probed at 125°C without realignment
  - Standard soak time 2min. after direct heating from 30°C to 125°C
- **Probing configuration**
  - Accretech UF3000, Teradyne J750
  - Vertical Probecard, 104 beams
- **Analysis done on WaferwoRx + MS Excel**
  - Additional analysis with Excel 2007 and Pivot Feature

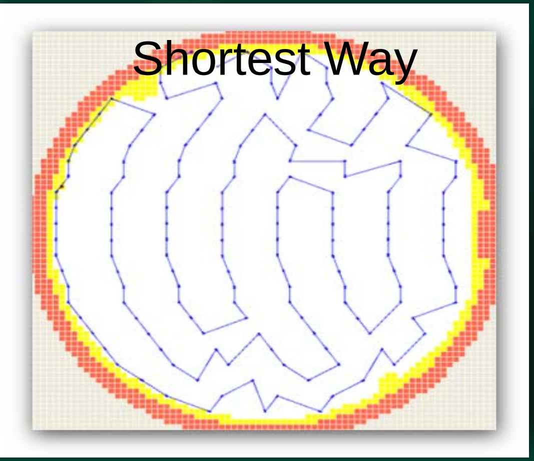
DOE 2 - MSO stepping pattern description



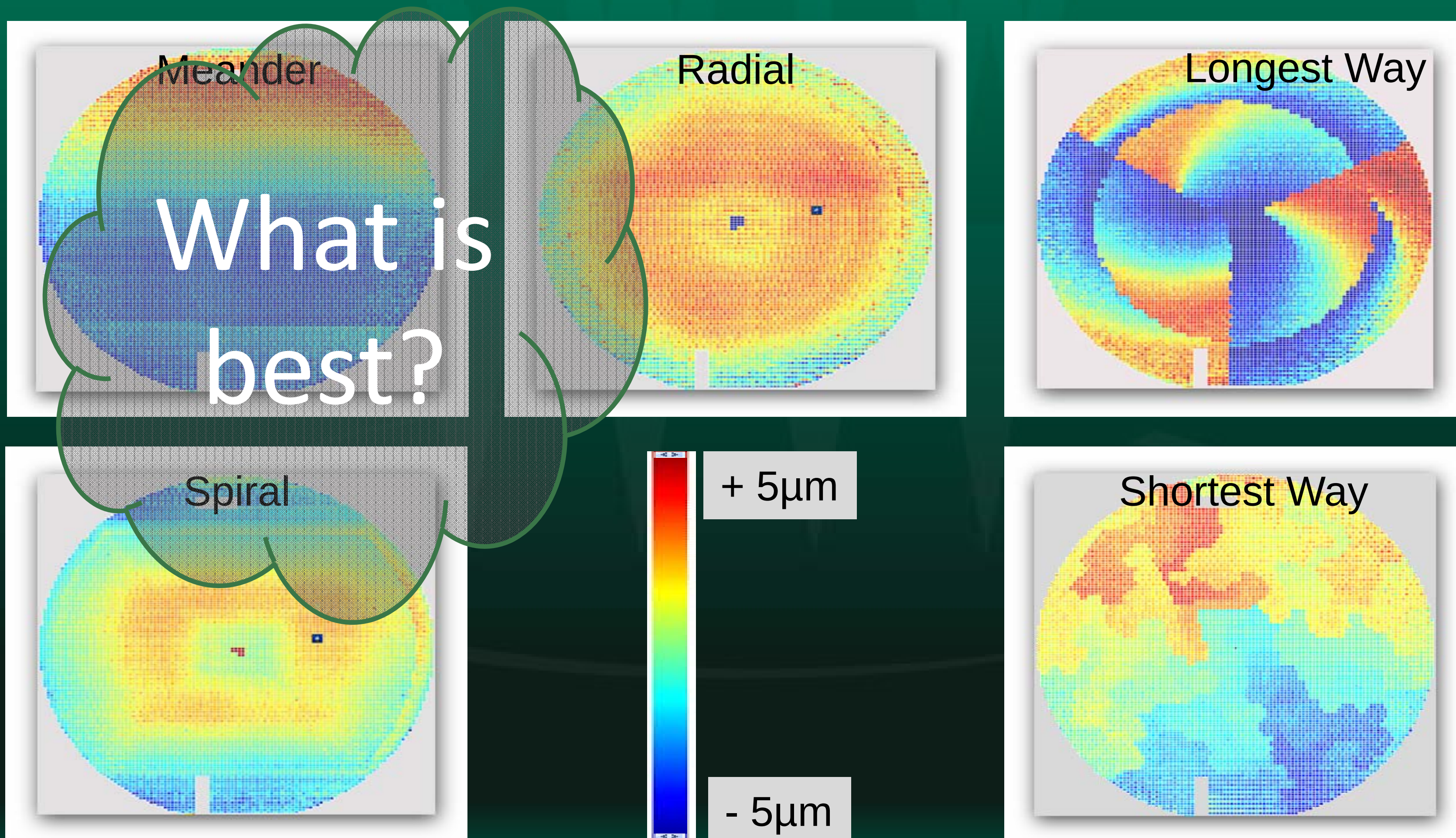




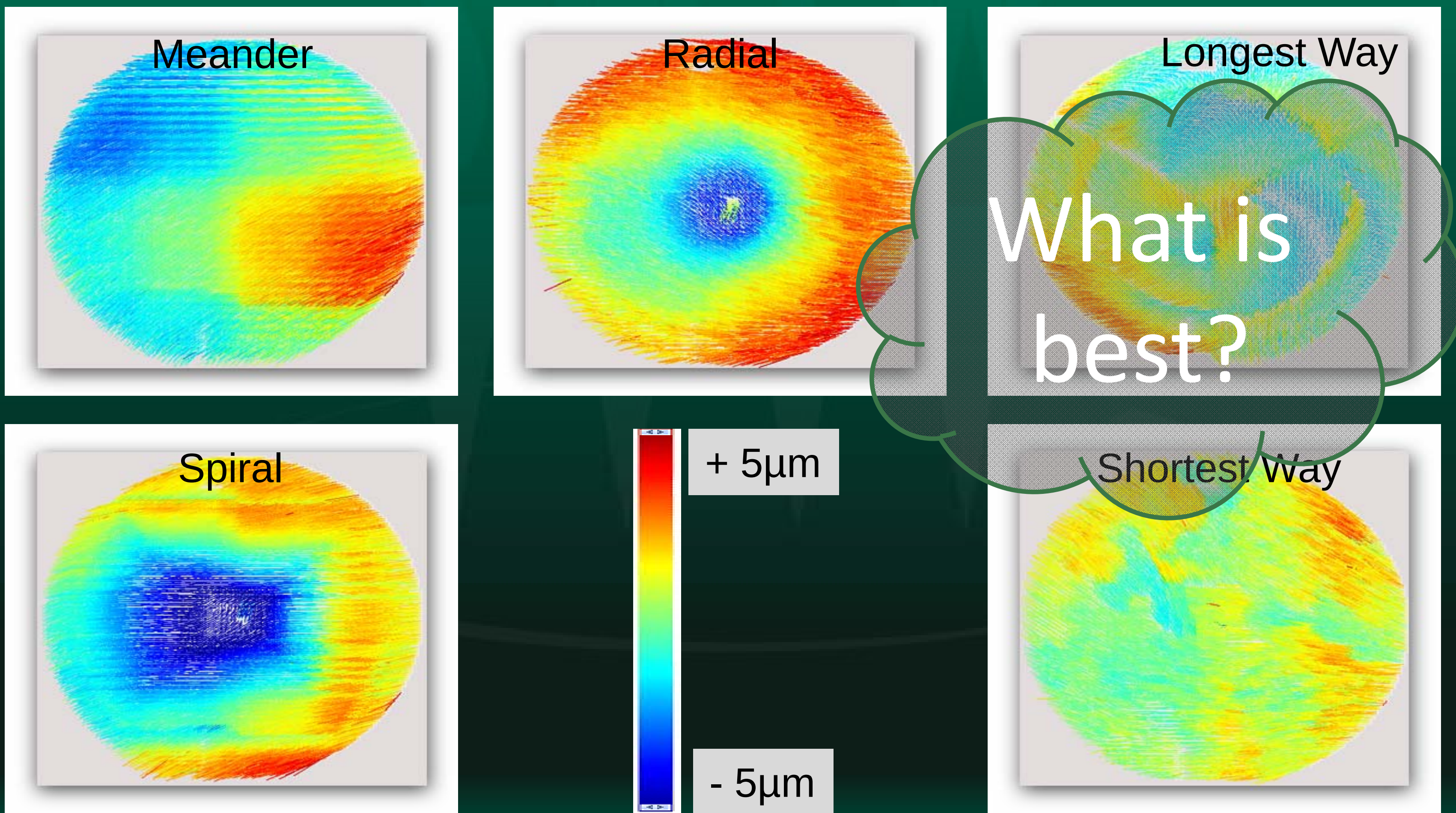




DOE 2 - WaferWoRx
Y Scrub Position



DOE 2 - WaferWoRx
Vector View



DOE 2 - Conclusion from WaferWoRx view

- Stepping Pattern recognized in plots
- Estimation possible on favorable pattern

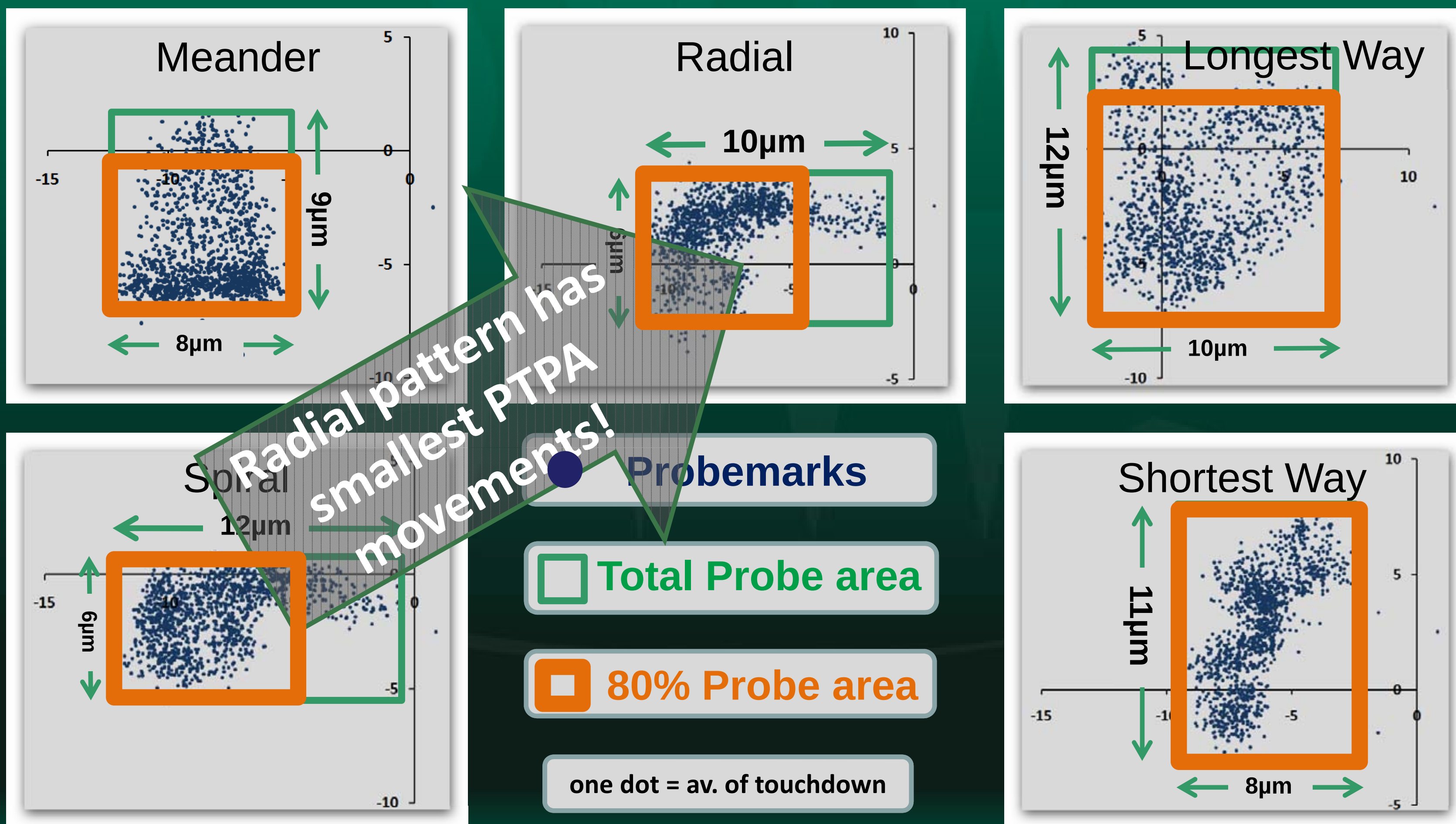
How do I…

- get the probing time aligned with my analysis data?
- compare wafer results in one graph?
- get more flexibility to experiment with probemark data?

→Additional analysis with Excel 2007 and Pivot Feature

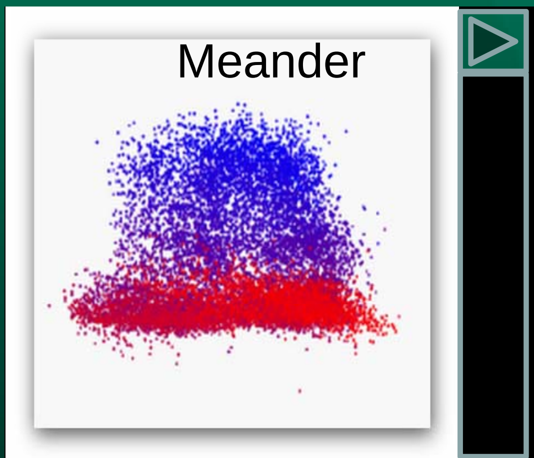
DOE 2 - Total probe area

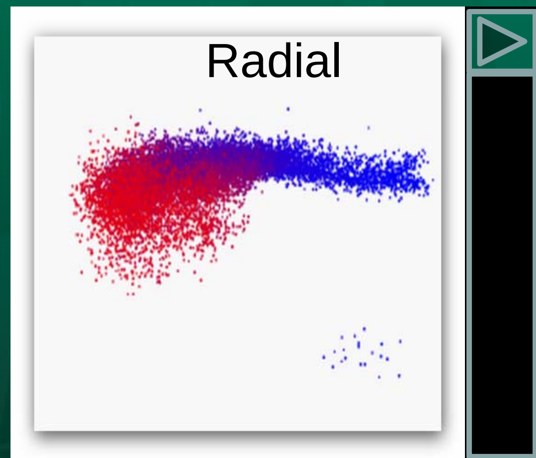
Comparison of stepping patterns regarding probe area

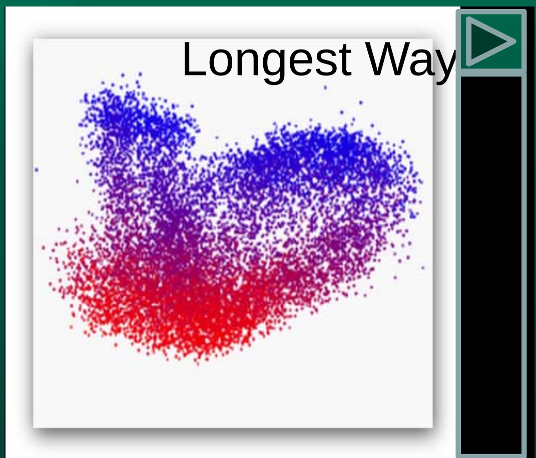


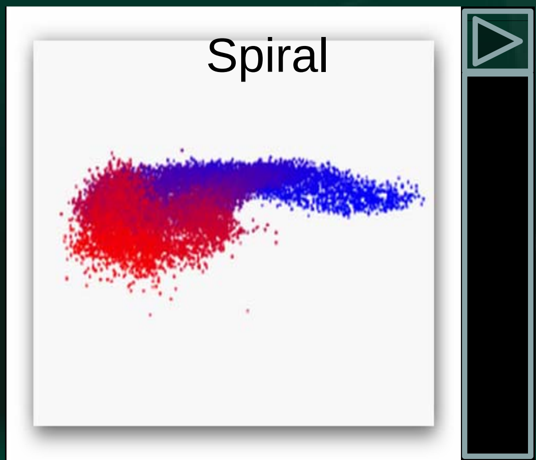
DOE 2 - PTPA development

Development of probe mark position resp. probing time

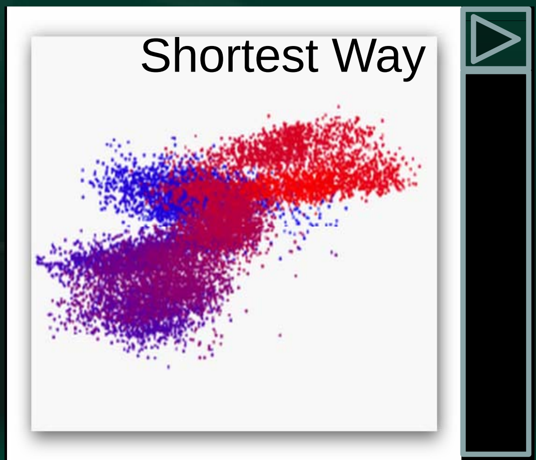






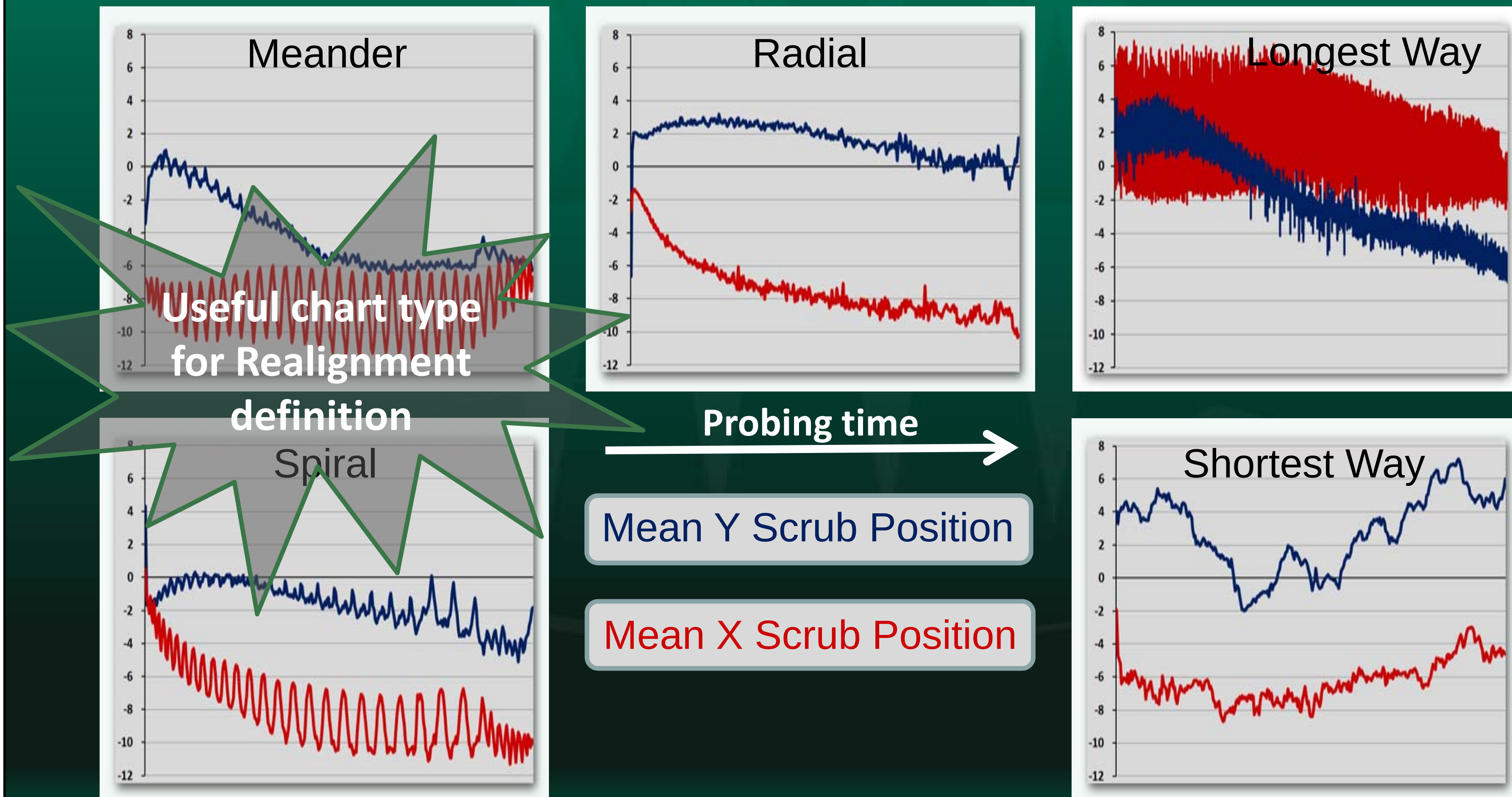


Time to PTPA Position Videos, very powerful!



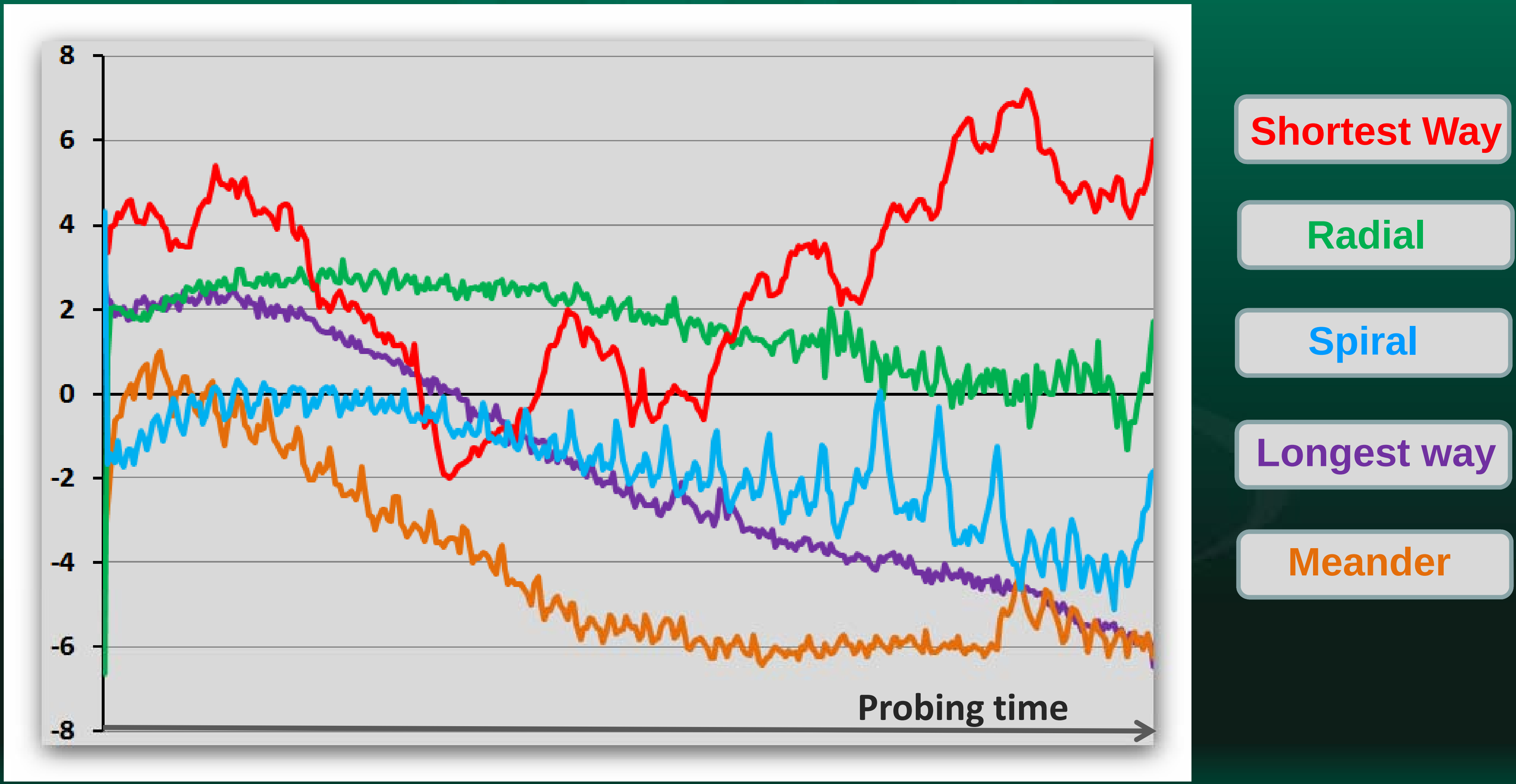
DOE 2 - X/Y Position change

X/Y Postion [µm] over time (~1hour) for different stepping pattern



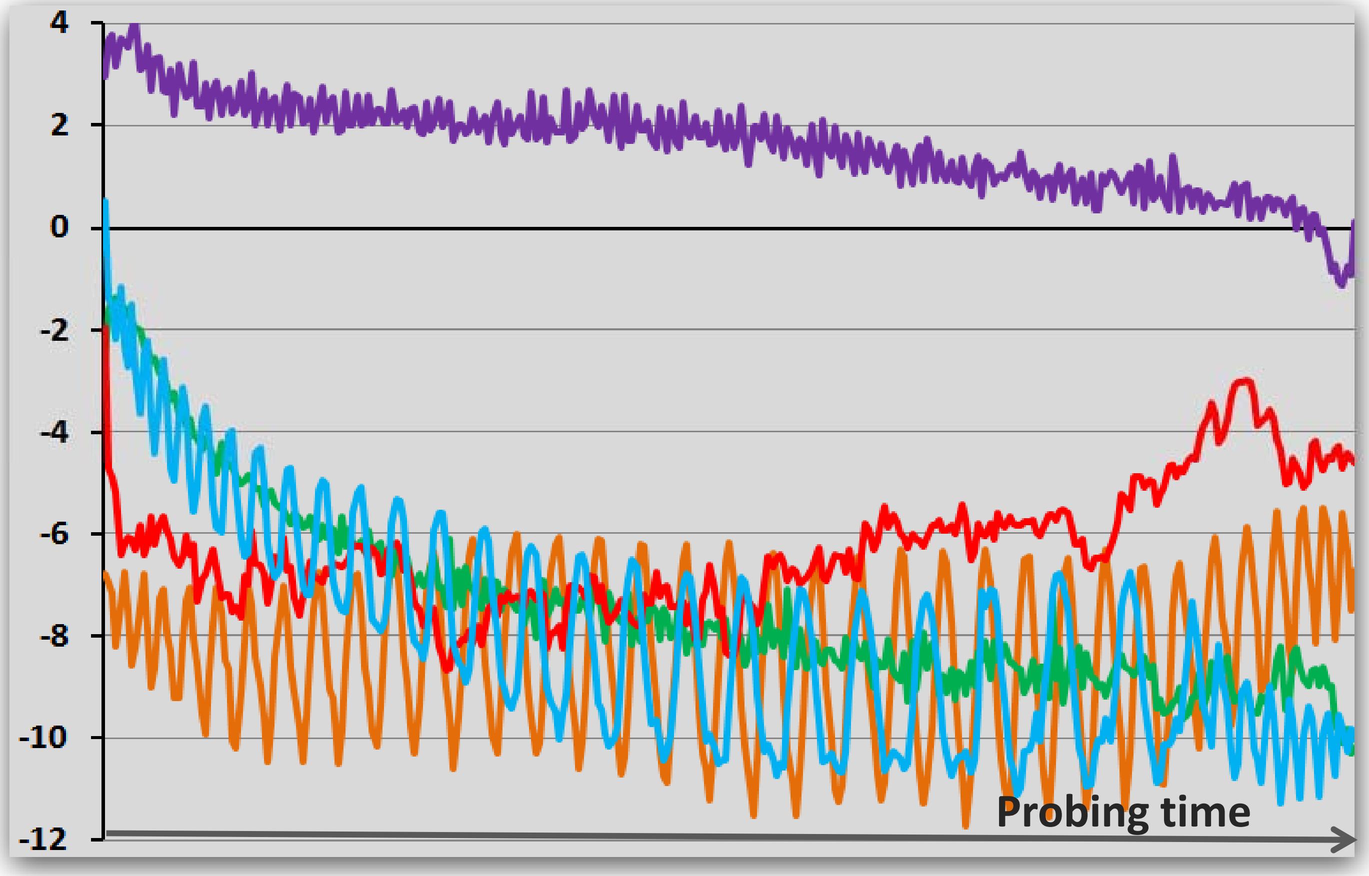
DOE 2 – Comparison Y Position

Y Position [µm] over time (~1hour) for different stepping pattern



DOE 2 – Comparison X Position

X Postion [µm] over time (~1hour) for different stepping pattern



Shortest Way

Radial

Spiral

Longest way

Meander

DOE 2 - Results

What is the best probing pattern for high temperatures?

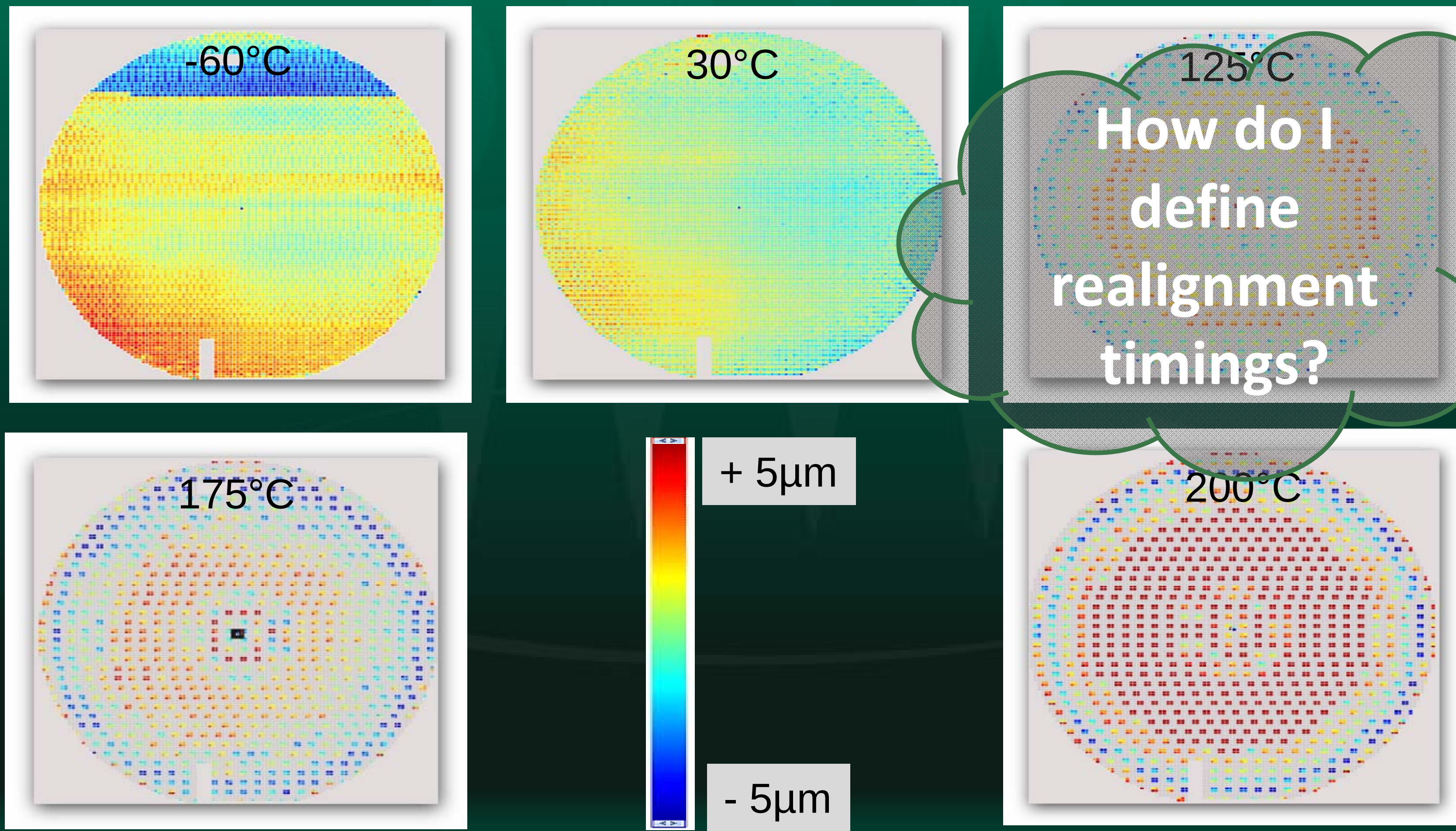
- **Significant probe to pad movement at 125°C**
  - All pattern need minimum one realignment
  - Smallest movements with radial/spiral pattern
  - Shortest and longest way unexpected large movements
  - Longest way expensive – very large index times
- **WaferwoRx improvement proposals**
  - Time resolution 2D charts
  - Data comparison of several wafers in one graph
  - Time resolution scatter plots
  - Video scatter plots

DOE 3 – Realignment Optimization

What are the best realignment settings for extreme temperatures?

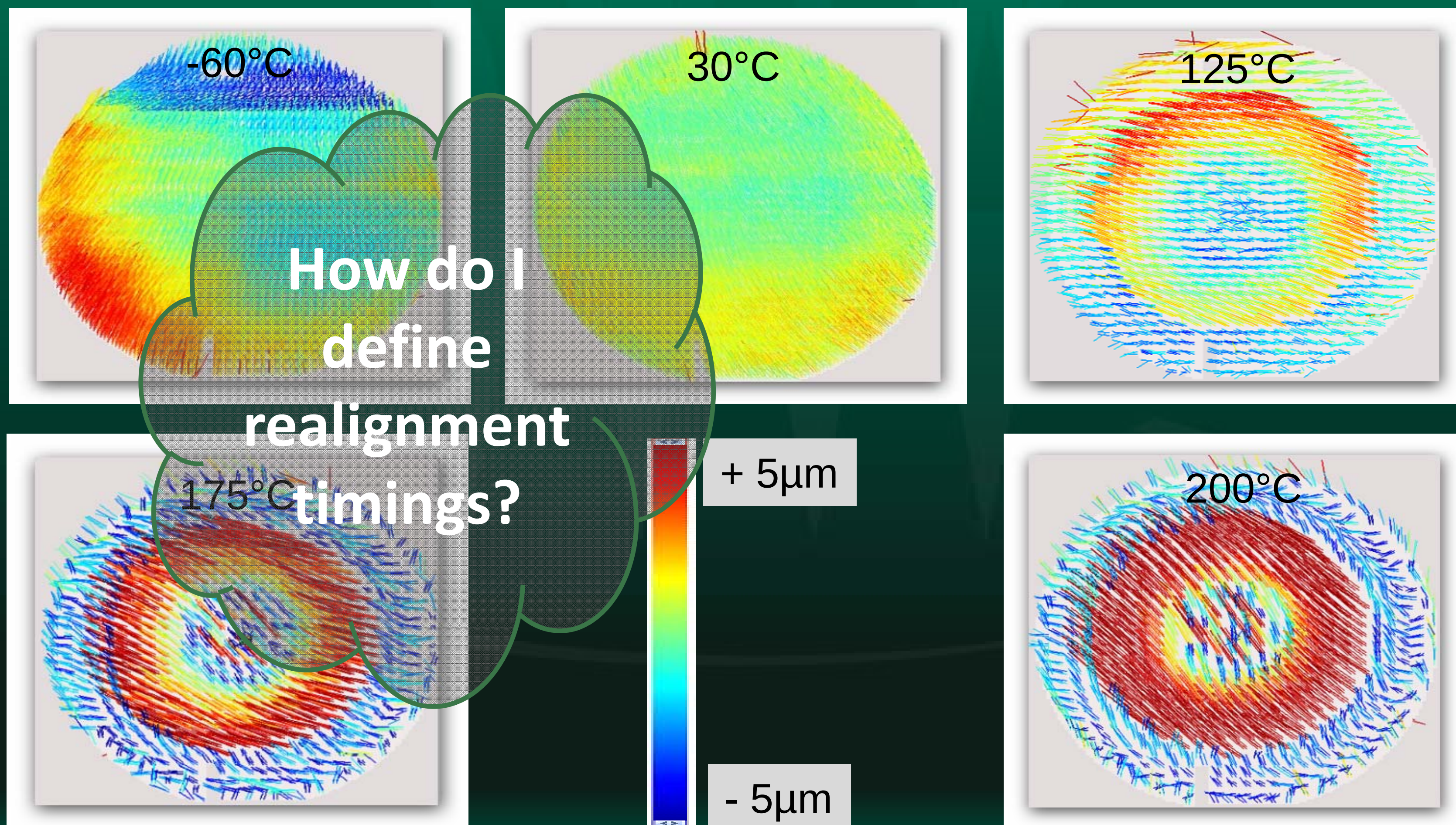
- **17 Wafers were probed with different temperatures/realignment/soaktime settings**
  - Cold, ambient, hot (-60°C, 30°C, 125°C, 175°C, 200°C)
  - Meander and Radial probing pattern for high temperatures
  - Soaktime 2min and NXP std. realignment
- **Probing configuration**
  - Accretech UF3000, Teradyne J750
  - Vertical Probecard, 104 beams
- **Analysis done on WaferwoRx + MS Excel**
  - Additional analysis with Excel 2007 and Pivot Feature

DOE 3 - WaferWoRx
Y Scrub Position



How do I define realignment timings?

DOE 3 - WaferWoRx
Vector View



DOE 3 - Conclusion from WaferWoRx view

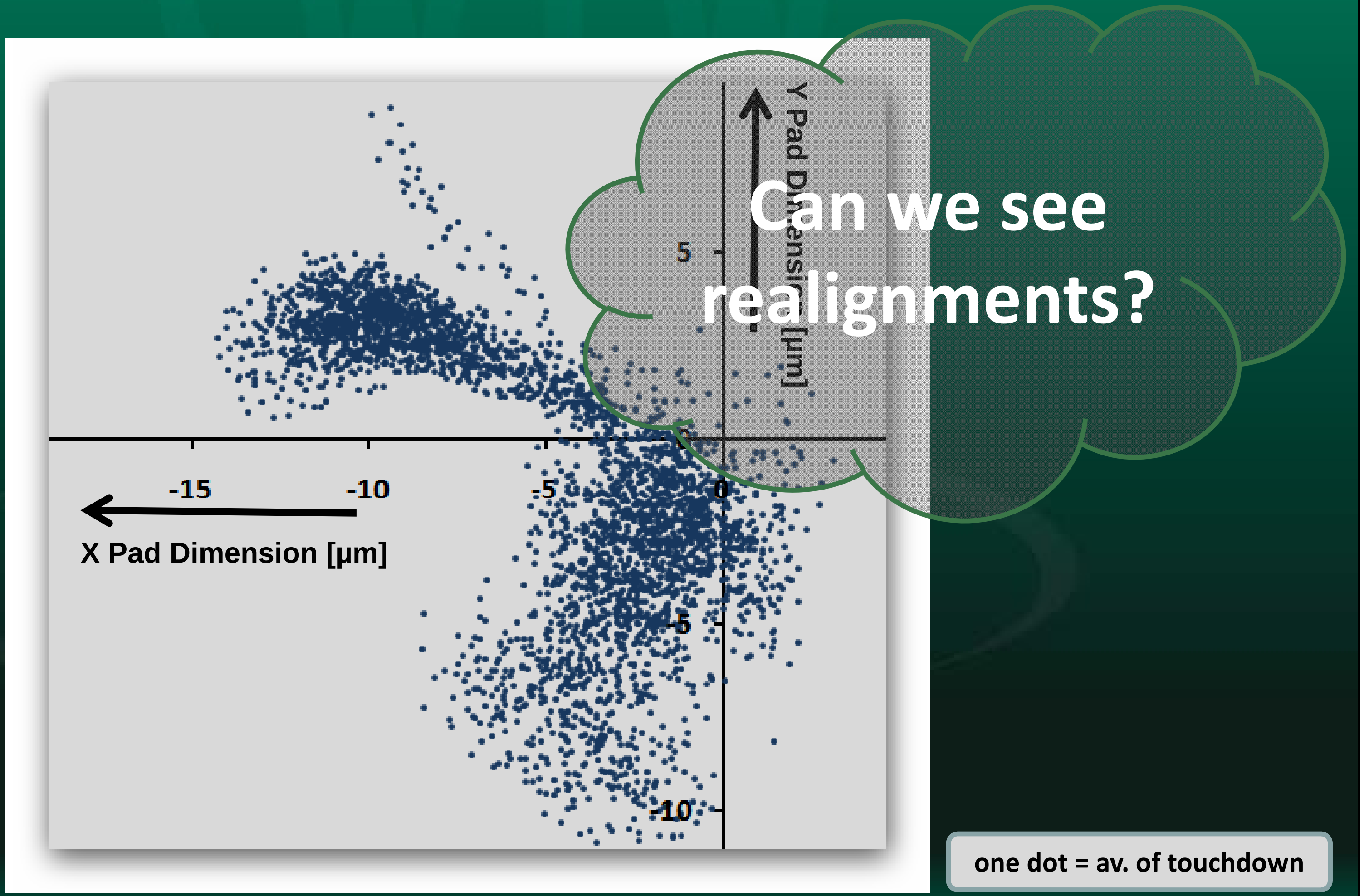
- Expected temperature difference recognized in plots
- Realignment positions visible
- Estimation of optimized realignment settings difficult

How do I…

- get the probing time aligned with my analysis data?
- include prober needle realigment data?
- get more flexibility to experiment with data?

→Additional analysis with Excel 2007 and Pivot Feature

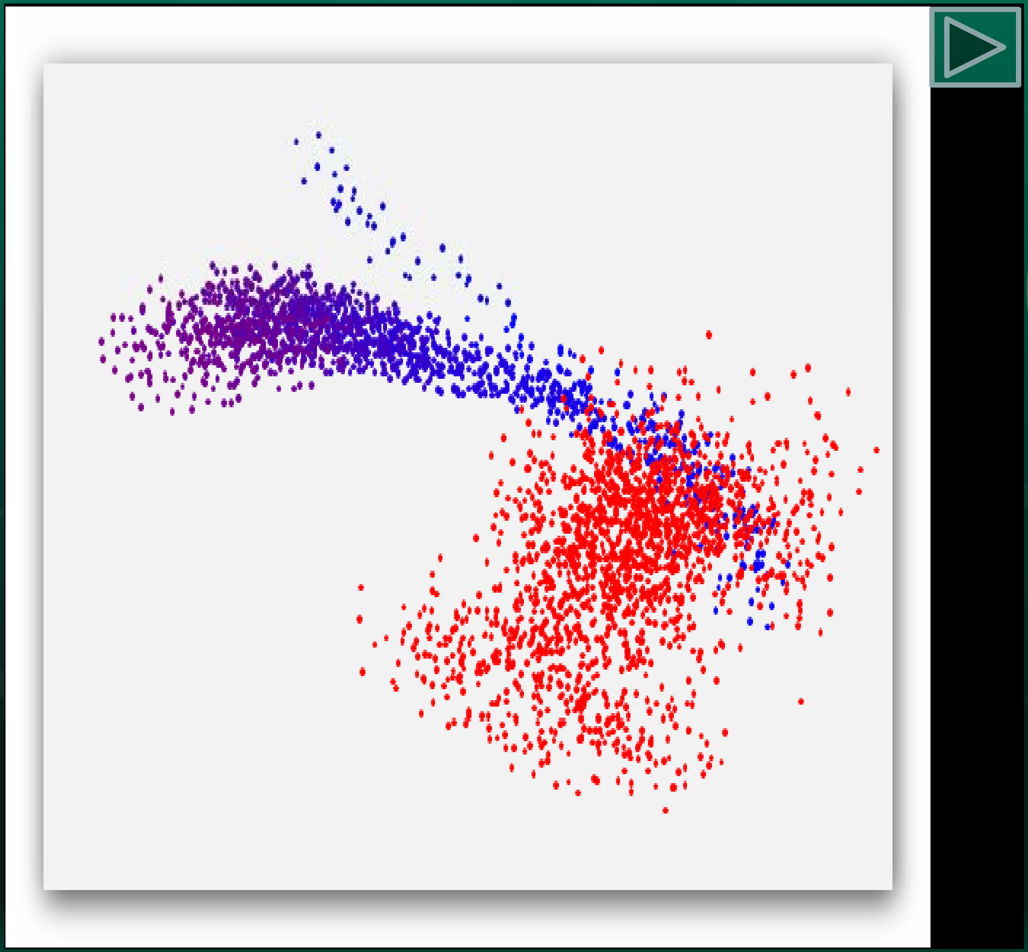
200°C Probemark Distribution



one dot = av. of touchdown

200°C Probemark Distribution

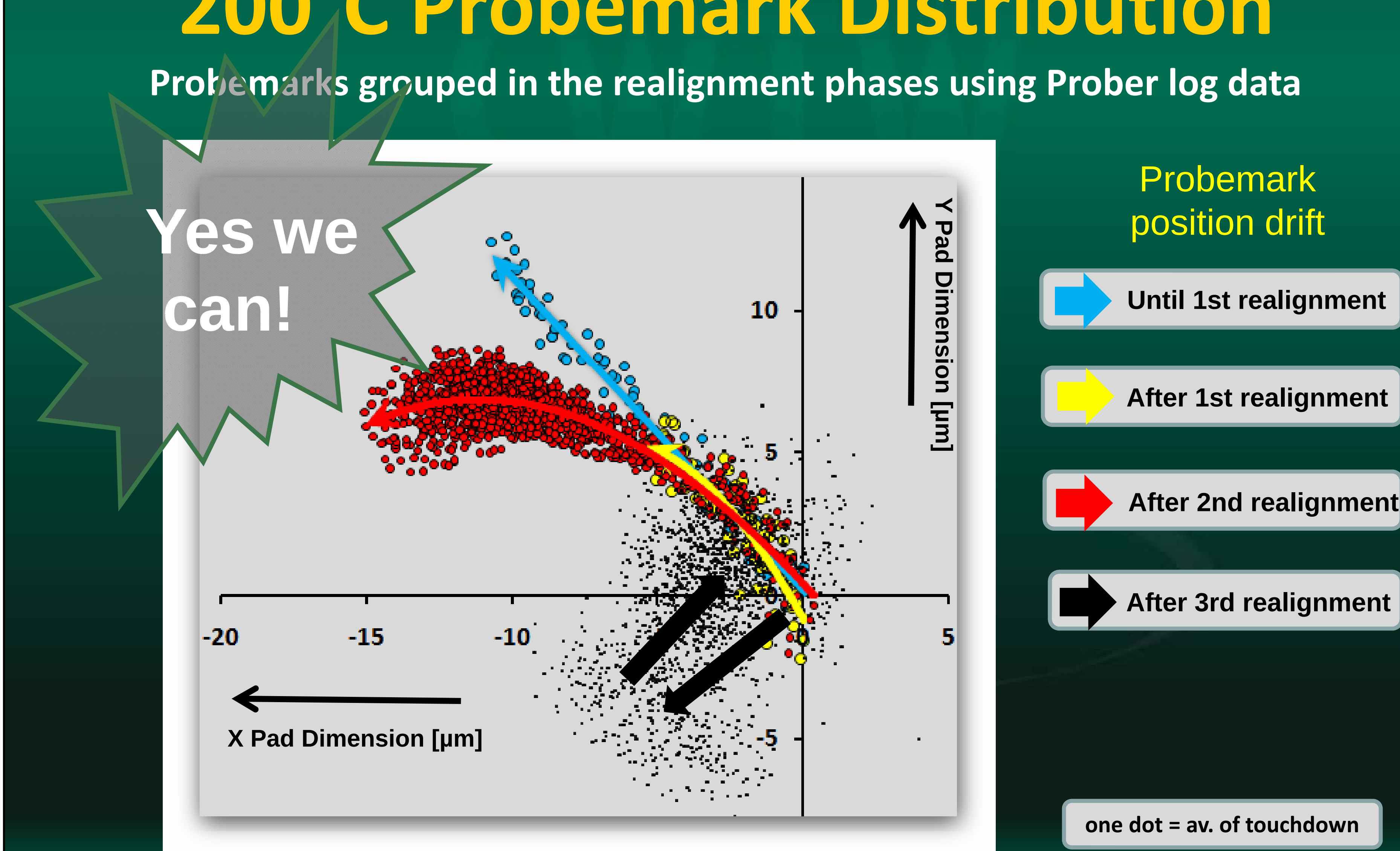
Development of the probe position in time



We're getting there…

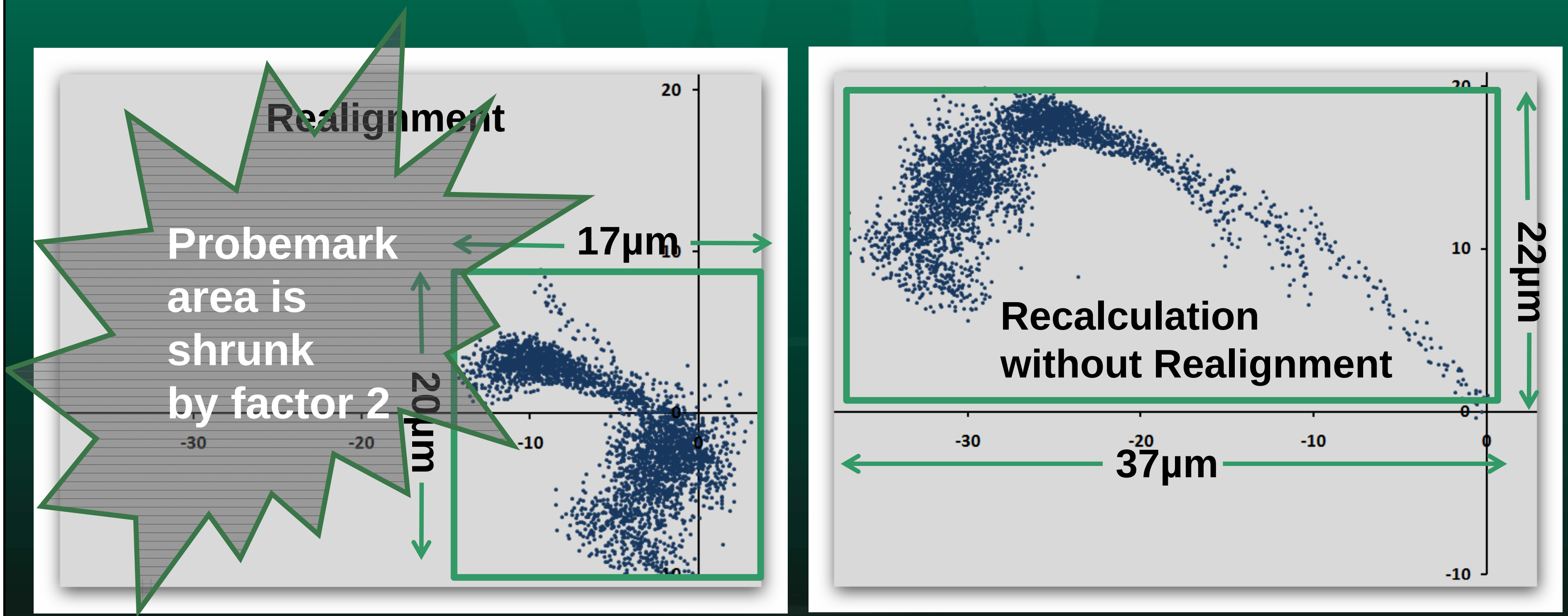
200°C Probemark Distribution

Probemarks grouped in the realignment phases using Prober log data



200°C Probemark Distribution

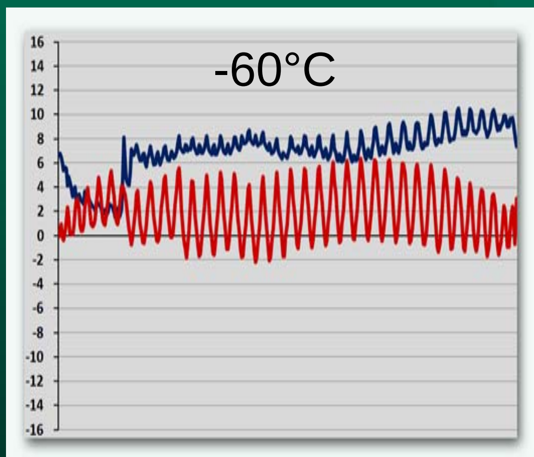
Significance of realignment visible by comparing total probe area

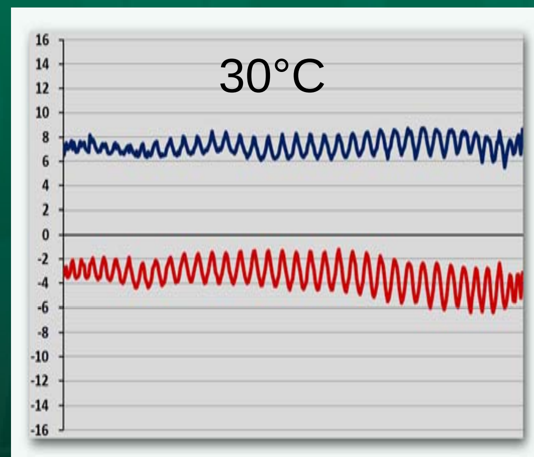


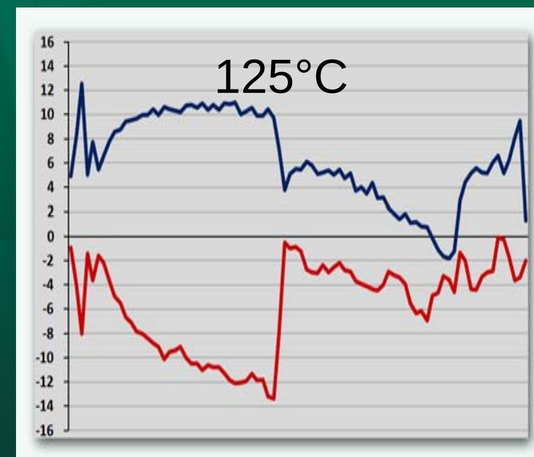
one dot = av. of touchdown

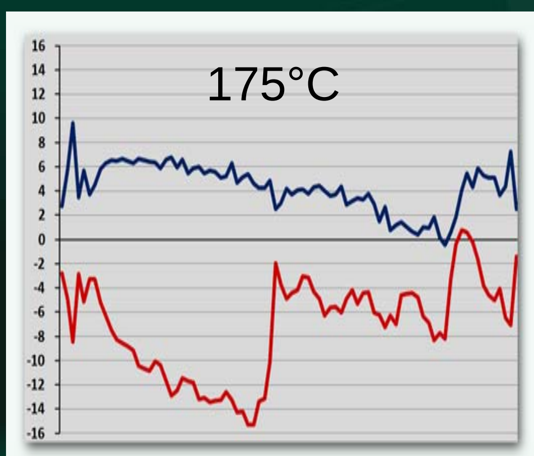
DOE 3 - X/Y Position change

X/Y Postion [µm] over time (~1hour) for different temperatures





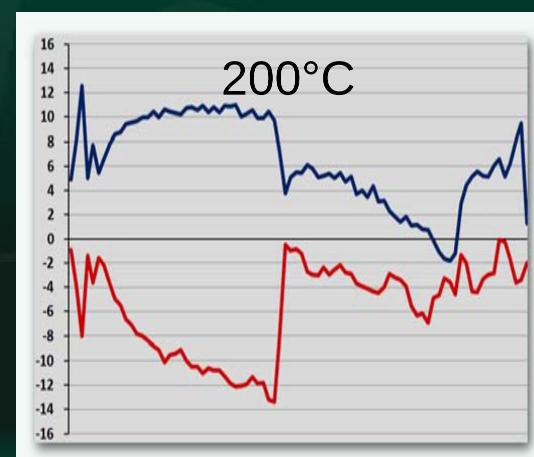




Probing time →

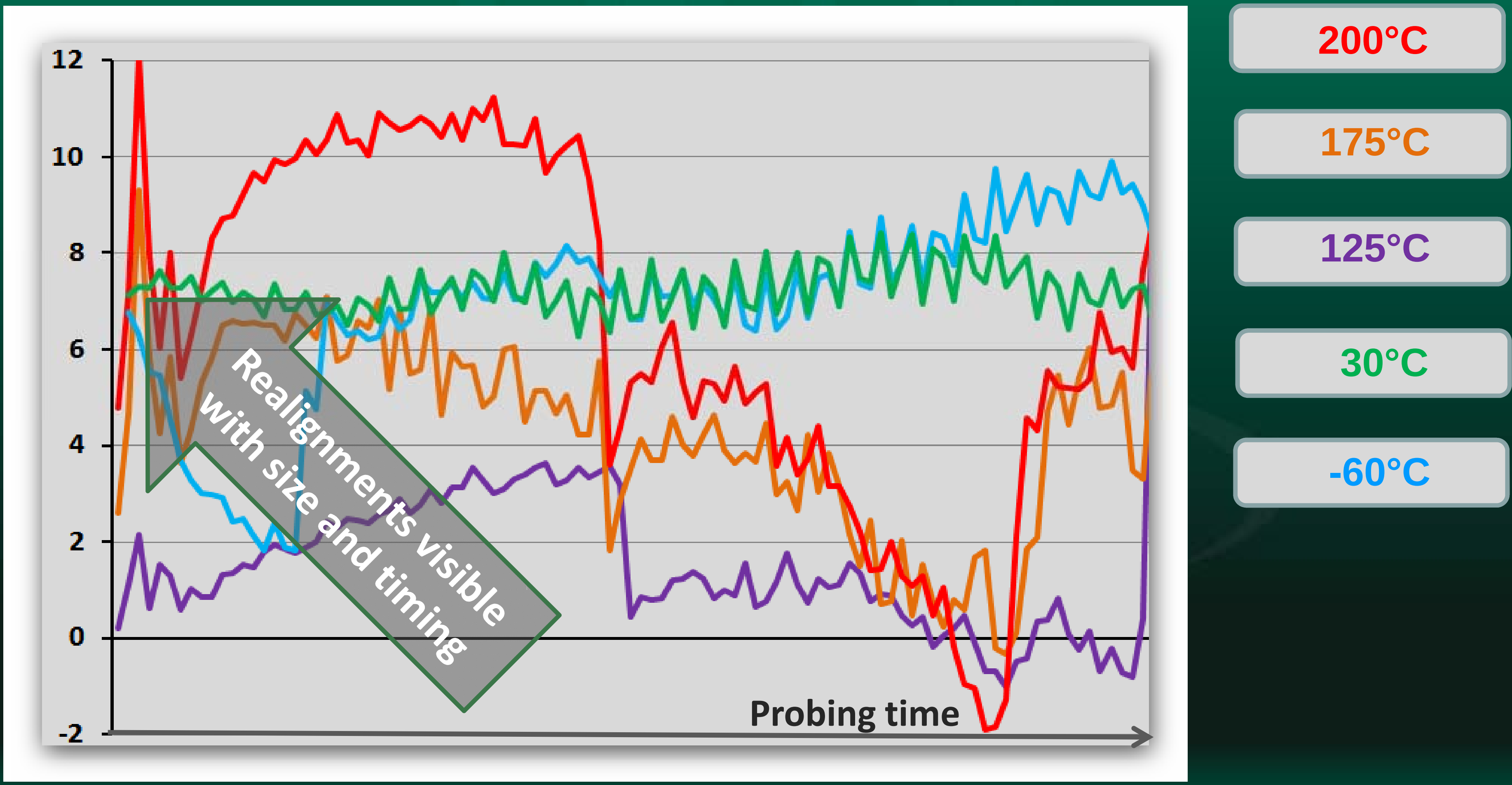
Mean Y Scrub Position

Mean X Scrub Position



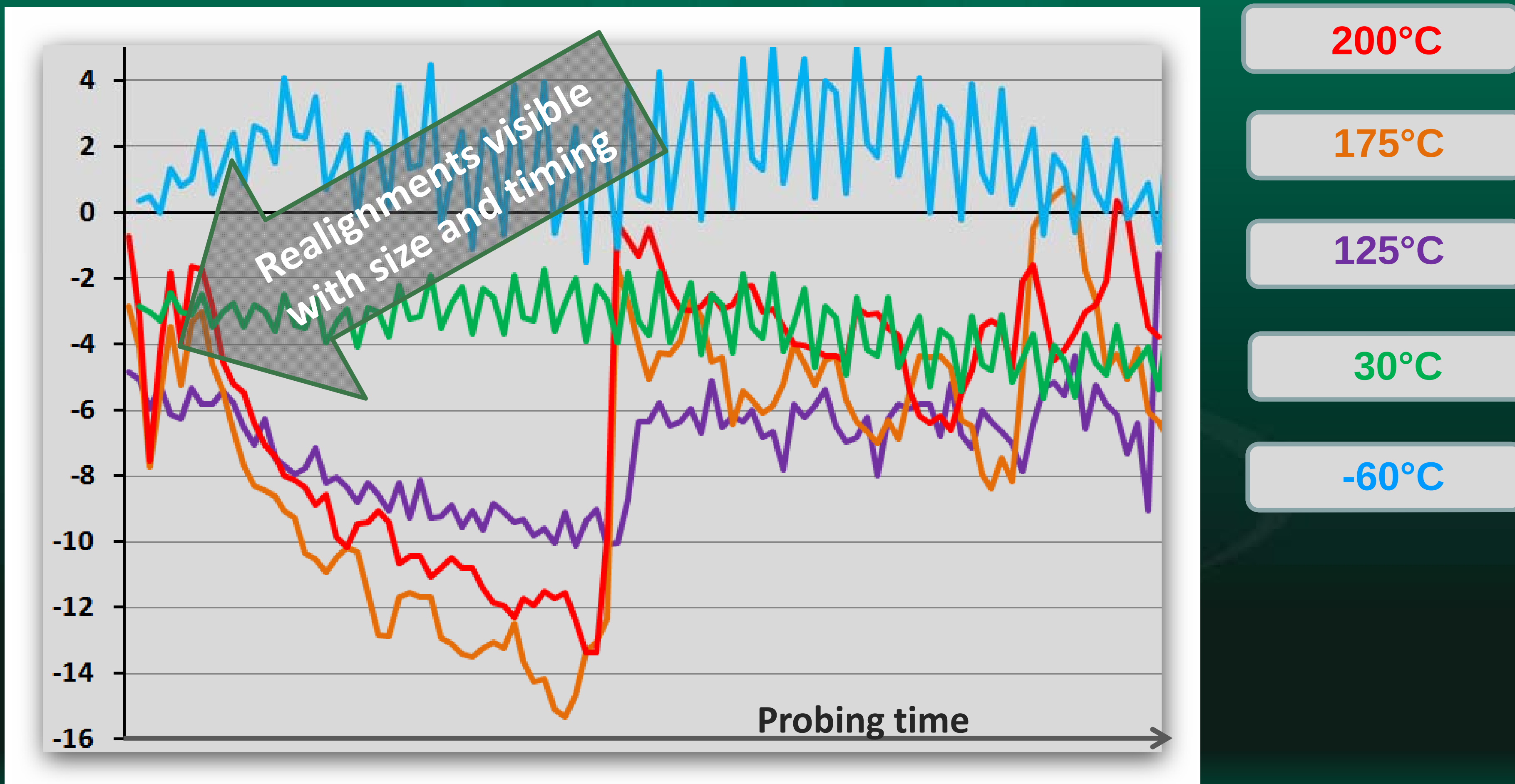
DOE 3 – Comparison Y Position

Y Postion [µm] over time (~1hour) for different temperatures



DOE 3 – Comparison X Position

X Postion [µm] over time (~1hour) for different temperatures



DOE 3 - Results

What are the best realignment settings for extreme temperatures?

- **All hot and cold probing temperatures show significant probe to pad movements**
  - Temperature distance to ambient is main driver
  - 200°C with biggest probe to pad deviations
  - Realignments defined depending on probing temperature
- **WaferWoRx improvement proposals**
  - Probe log data and map data input interface
  - Realignment identification
  - Raw data transformation and modification

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Results & Future Work

Results

- **Successful process optimization**
  - Different stepping patterns evaluated
  - Soak time and realignment settings optimized
  - Up to 200°C tested and recipes defined
- **Evaluation of WaferWoRx to in house tools done. Both are technically comparable.**
  - All standard errors were succesfully identified.
- **Recommendations developed to improve WaferWoRx models and graphical user interface**
  - Temperature analysis needs time resolution GUI
  - Prober log data and map data input interface
  - Raw data transformation and modification needed

Future Work

- Analyze and understand differences of different hardware combinations
- Improve test cell hardware performance to reduce number of needed realignments
- Analysis results and method to be roled out in NXP

Acknowledgements

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  - Darren James
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  - Rex Sandbach
  - Sam Waggoner

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– NXP Semiconductors
  - Thomas Dabelstein
  - Jens Däbritz
  - Swen Mohr

Working on preparation, data acquisition and analysis.

Questions?