DOE in a Production Environment: Flexibility With JMP® Scripting

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R&D / Mathematical Simulation

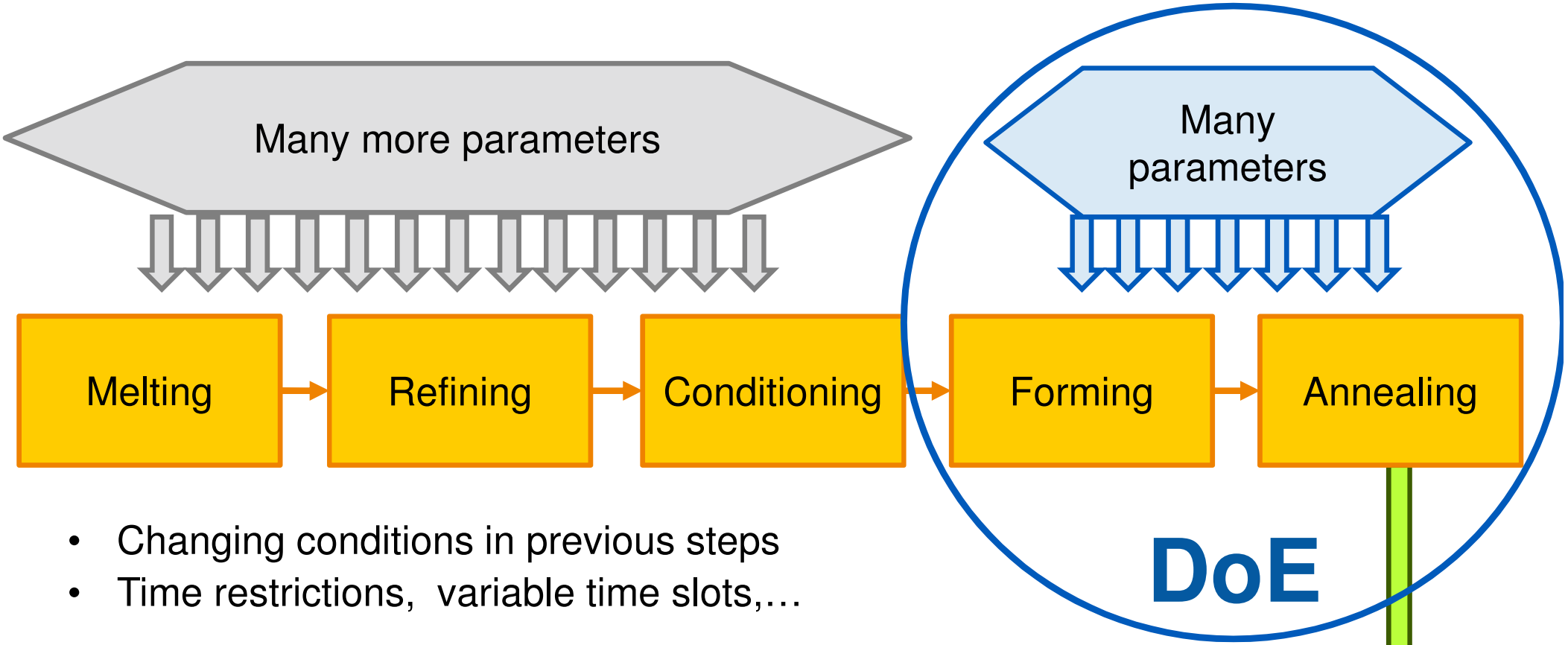
Dr. Katharina Lankers; March 24, 2015

Outline

- Introduction to the problem
- Idea and Solution
- Demo in JMP

A Glass Hot Forming Process

Optimal Setting?
Main influences?



- Changing conditions in previous steps
- Time restrictions, variable time slots,…

„Flexible“ design of experiments ??

Specification:
- Geometry
- Chemical / Physical / Optical Properties

Product

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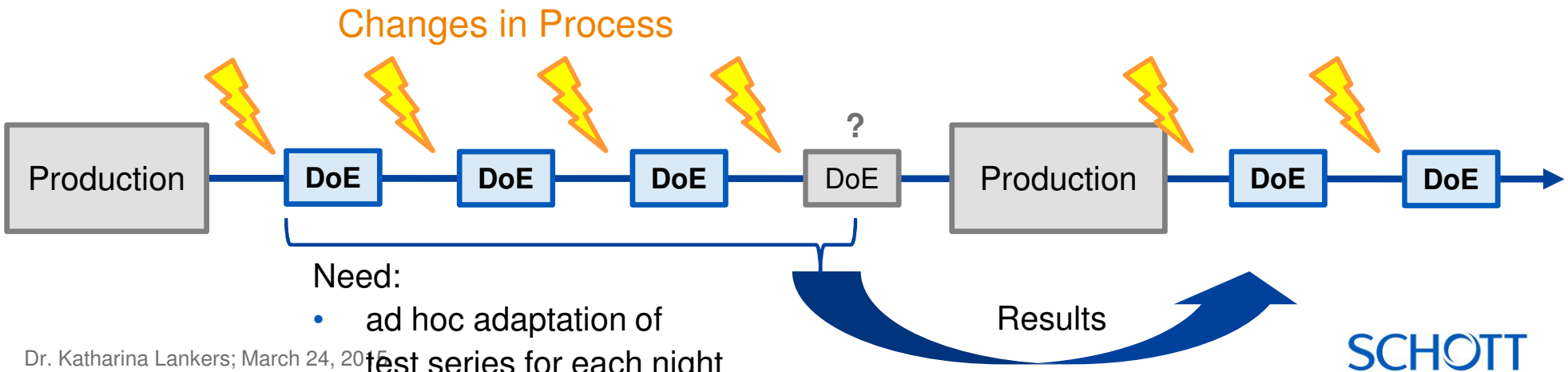
Task

Find main influences for hot forming / annealing to adjust product property

Parameters: Temperatures / Temperature profiles

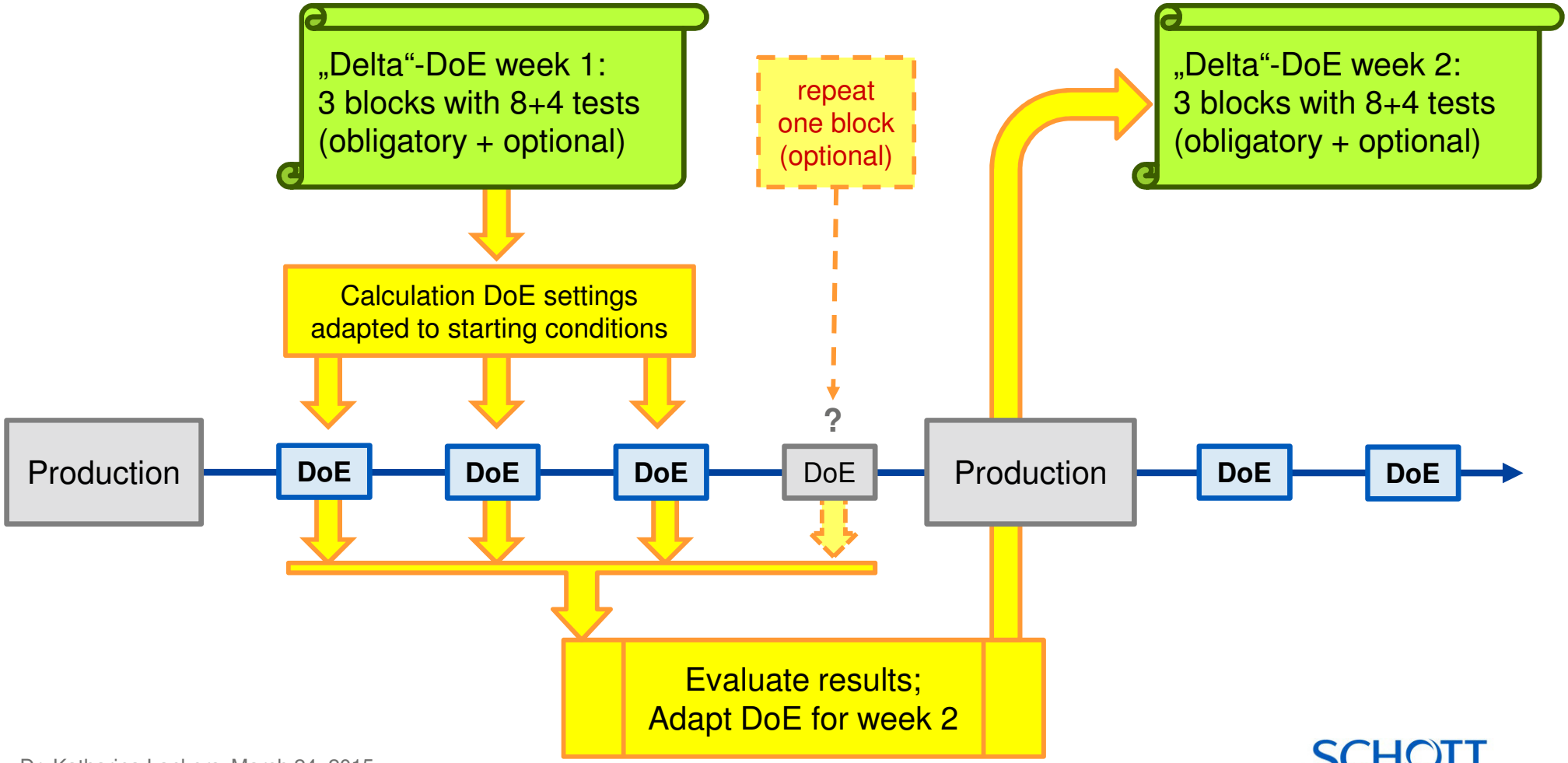
Boundary conditions:

- All tests within 4 weeks
- Every week 3-4 nights (max. 12 hours) for DoE
  (days needed for other tests, weekends for production)
- 1 test needs 1-1,5 hours (=> 8-12 test per night)
- Every evening slightly different starting conditions
- Results of one week should be used to design tests for next week



Idea

- DoE variations in terms of temperature differences („Delta-Design“)
- Calculation of temperature settings from actual start setting and Delta-Design
- DoE in blocks for different nights
- Each night 8 tests plus 4 optional (extended design)



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Idea

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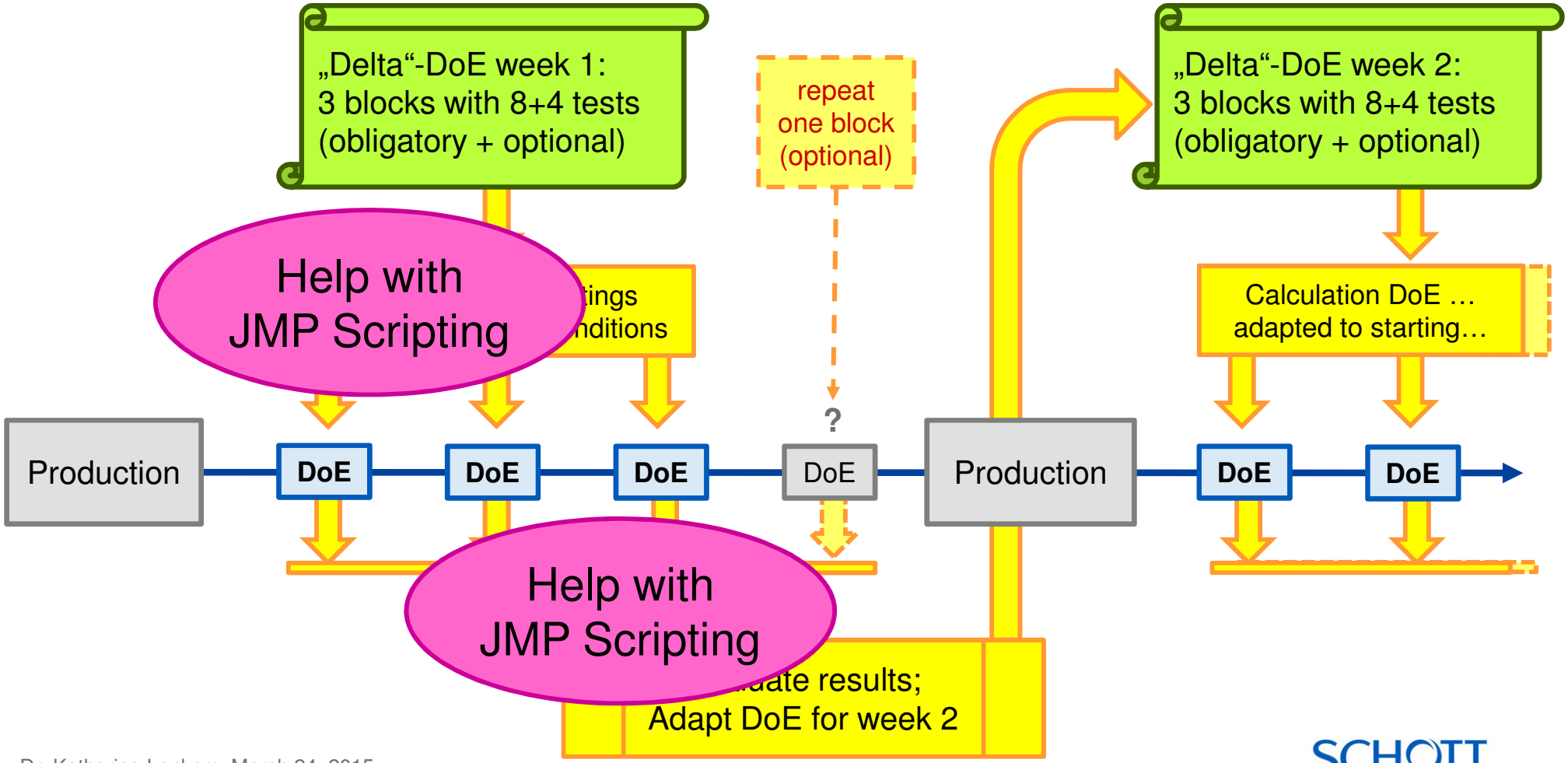

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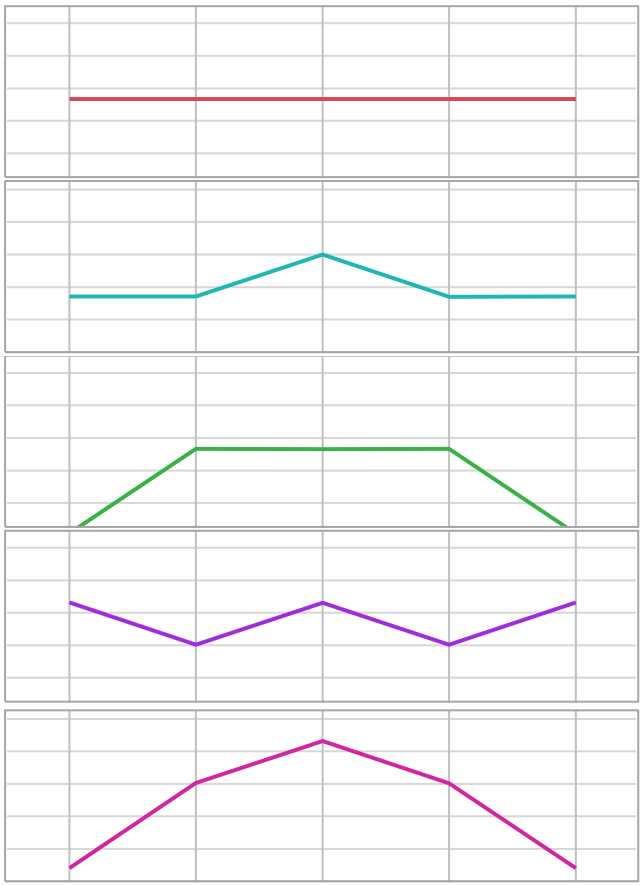
Parameters To Vary (simplified situation)

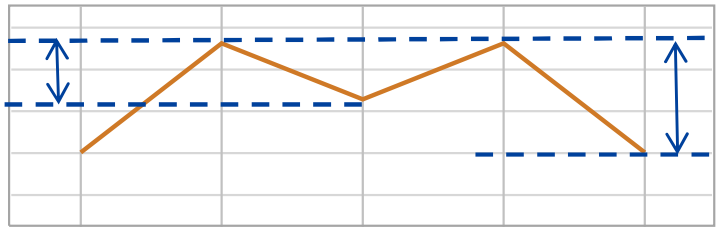
- 40 different temperatures
- Symmetry => 24 different temperatures
- Vary middle temperatures and profiles
  => 10 parameters (factors)

T1 LL	T1 L	T1 M	T1 R	T1 RR
T2 LL	T2 L	T2 M	T2 R	T2 RR
T3 LL	T3 L	T3 M	T3 R	T3 RR
T4 LL	T4 L	T4 M	T4 R	T4 RR
T5 LL	T5 L	T5 M	T5 R	T5 RR
T6 LL	T6 L	T6 M	T6 R	T6 RR
T7 LL	T7 L	T7 M	T7 R	T7 RR
T8 LL	T8 L	T8 M	T8 R	T8 RR

Different profile types:



← 2 profile parameters:



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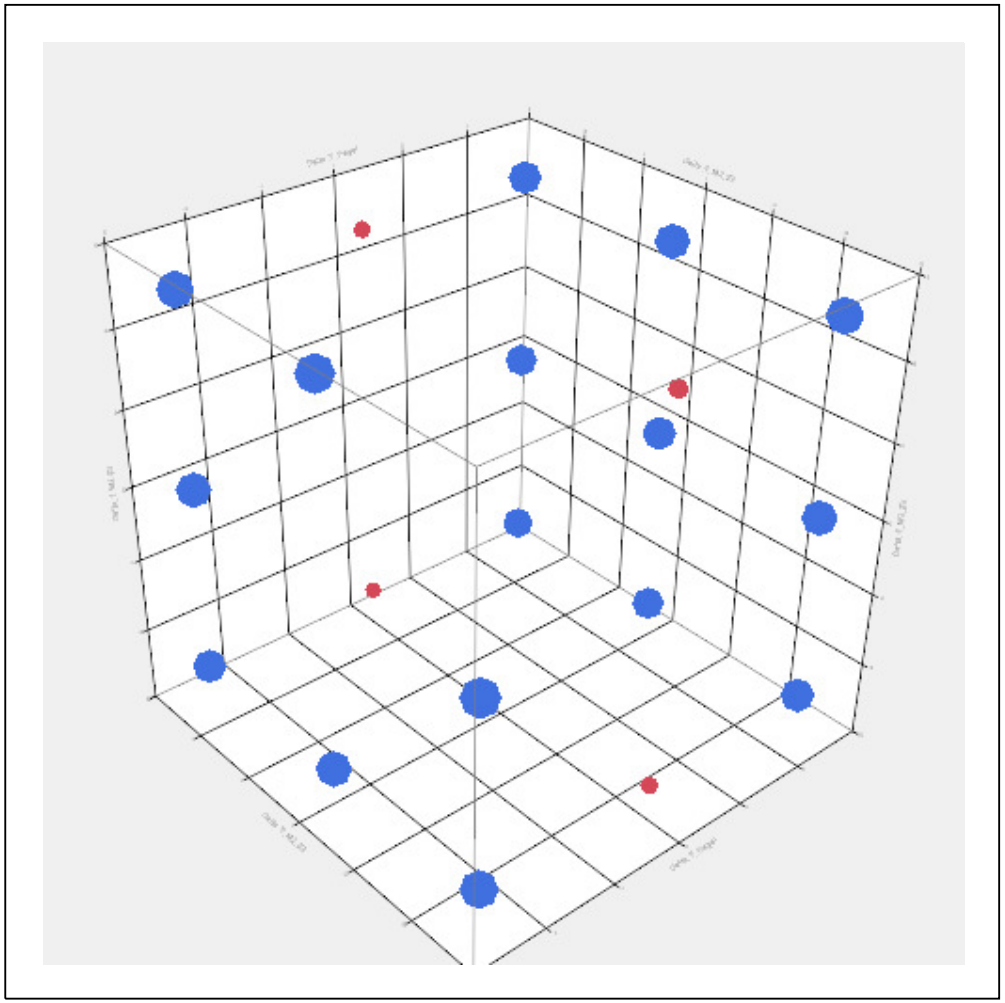
Delta - Design

Want: Each night 8 tests plus 4 optional

(Real case: 16 factors)

Customized Design: 24 Runs in 3 blocks (16 factors)
+ Augmented Design 4 Runs in 3 blocks (11 factors)



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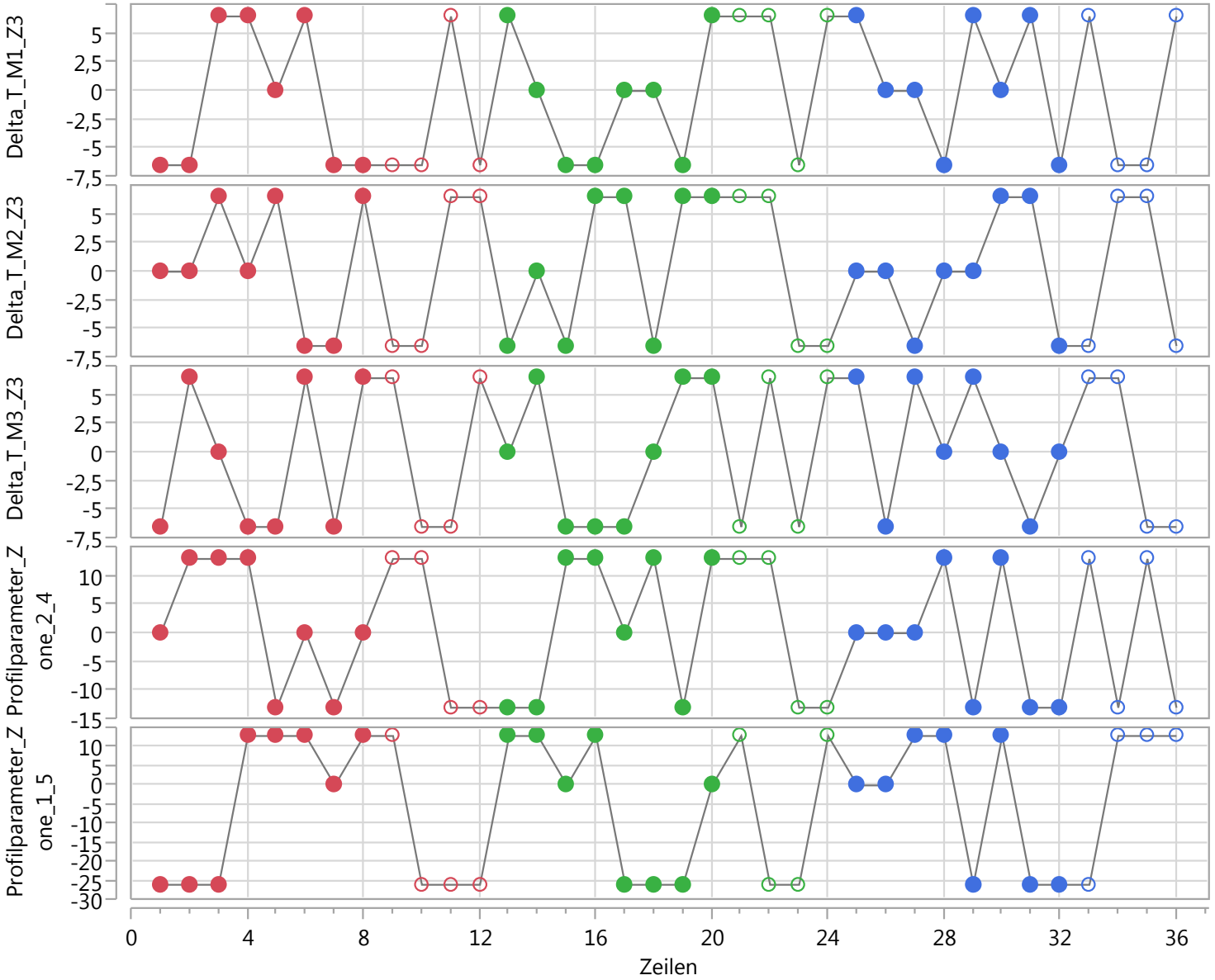
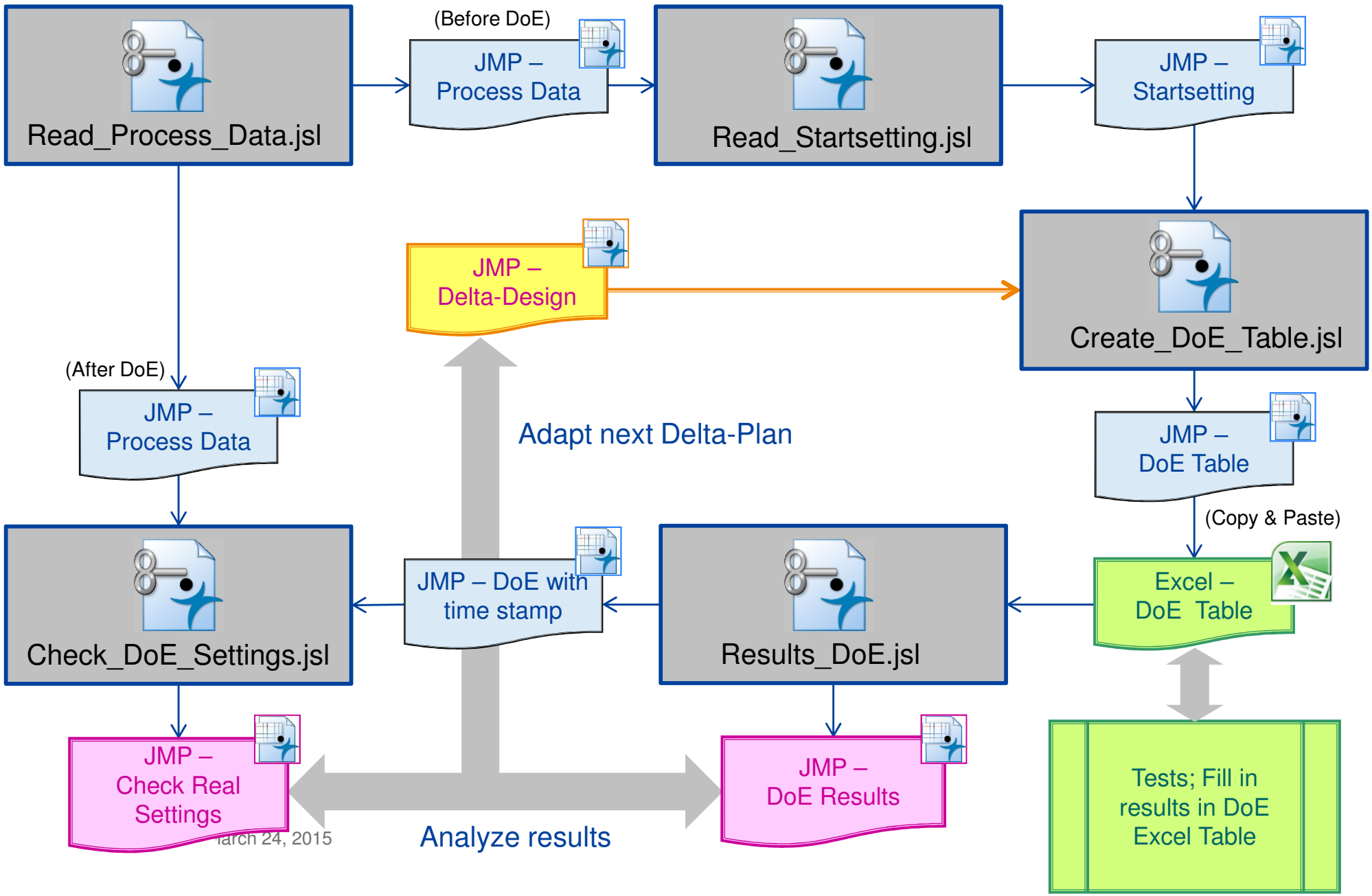
Delta - Design

Customized Design: 24 Runs in 3 blocks (16 factors)
+ Augmented Design 4 Runs in 3 blocks (11 factors)

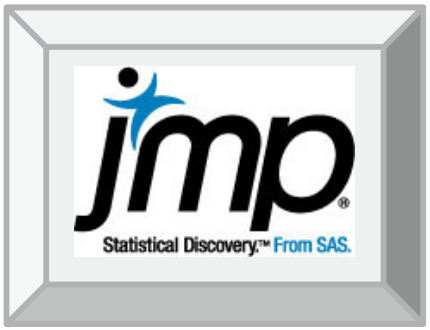
- Middle temperatures of 3 modules
- 2 profile parameters



Process Flow around DoE-Nights: Scripts and Analyses



Demo



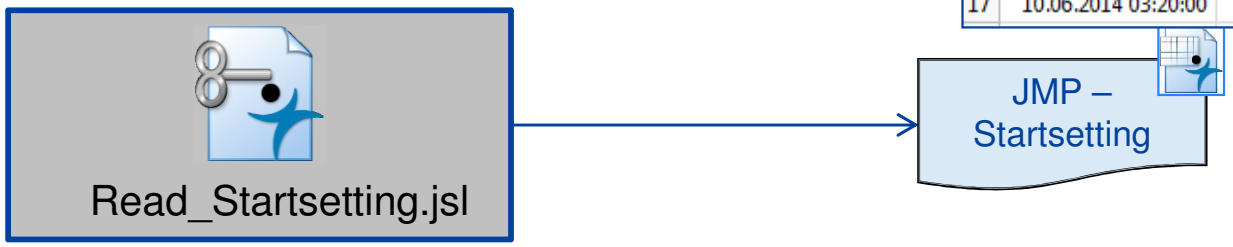
(Example: 5 factors)

Step 1: Determine actual Startsetting

Read process data; take a subset from process data representative for start setting (e.g. the last hour)

	Zeit								
1	10.06.2014 02:00:00	1040	1039,5	1027,1	1027	1000,6	1001	1001	1001
2	10.06.2014 02:05:00	1040	1039,5	1027,1	1027	1000,6	1001	1001	1001
3	10.06.2014 02:10:00	1040	1040,1	1027,1	1027	1000,7	1001	1001	1001
4	10.06.2014 02:15:00	1040	1040,1	1027,1	1027	1000,7	1001	1000,9	1001
5	10.06.2014 02:20:00	1039,9	1040,1	1027,1	1026,9	1000,7	1001	1000,9	1001
6	10.06.2014 02:25:00	1039,9	1039,1	1027	1026,9	1001	1001	1000,9	1001
7	10.06.2014 02:30:00	1039,9	1039,1	1027	1026,9	1001	1001	1001,5	1001
8	10.06.2014 02:35:00	1040	1039,1	1027	1027	1001	1001	1001,5	1001
9	10.06.2014 02:40:00	1040	1040	1027	1027	1001,5	1001	1001,5	1001
10	10.06.2014 02:45:00	1040	1040	1027	1027	1001,5	1001	1000,4	1001
11	10.06.2014 02:50:00	1040	1040	1027	1027	1001,5	1001	1000,4	1001
12	10.06.2014 02:55:00	1040	1039,7	1027	1027	1000,9	1001	1000,4	1001
13	10.06.2014 03:00:00	1040	1039,7	1027	1027	1000,9	1001	1001,3	1001
14	10.06.2014 03:05:00	1040				1000,9	1000,9	1001,3	1001
15	10.06.2014 03:10:00	1040				1000,9	1000,9	1001,3	1001
16	10.06.2014 03:15:00	1040				1000,9	1000,9	1001,3	1001
17	10.06.2014 03:20:00	1040				1000,9	1001	1001,3	1001

Determine Startsetting



Messstelle	Wert
T_M1_Z1	1040
T_M1_Z2	1040
T_M1_Z3	1040
T_M1_Z4	1040
T_M1_Z5	1040
T_M2_Z1	1027
T_M2_Z2	1027
T_M2_Z3	1027
T_M2_Z4	1027
T_M2_Z5	1027
T_M3_Z1	1001
T_M3_Z2	1001
T_M3_Z3	1001
T_M3_Z4	1001
T_M3_Z5	1001

(calculates means of relevant process data as starting values for DoE)

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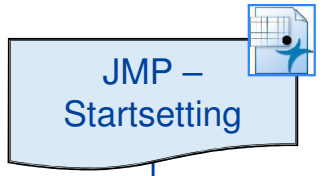
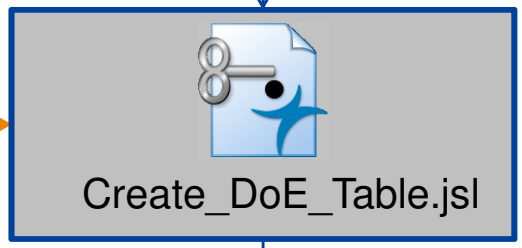
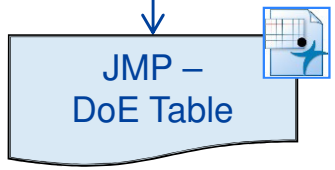
Step 2: Create DoE Table

... from Delta Design and Startsetting



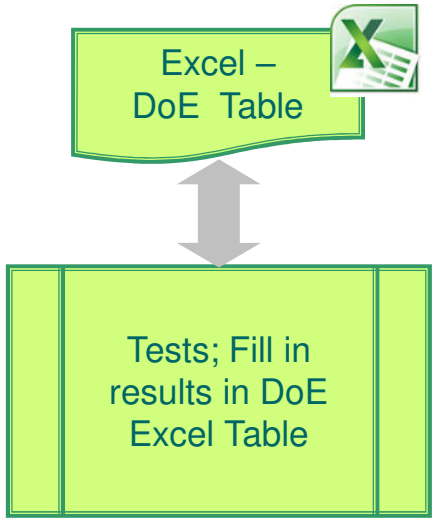


	Setting	Block	Versuch_ Nr	Delta_T_M1 _Z3	Delta_T_M2 _Z3	Delta_T_M3 _Z3	Profilparameter _Zone_2_4	Profilparameter _Zone_1_5
1	Plan	1	1_01	-6,5	0	-6,5	0	-26
2	Plan	1	1_02	-6,5	0	6,5		-26
3	Plan	1	1_03	6,5	6,5	0		-26
4	Plan	1	1_04	6,5	0	-6,5		13
5	Plan	1	1_05	0	6,5	-6,5		13
6	Plan	1	1_06	6,5	-6,5	6,5		13
7	Plan	1	1_07	-6,5	-6,5	-6,5	-13	0
8	Plan	1	1_08	-6,5	6,5	6,5	0	13
9	Erweiterung	1	1_09	-6,5	-6,5			
10	Erweiterung	1	1_10	-6,5	-6,5			
11	Erweiterung	1	1_11	6,5	6,5			
12	Erweiterung	1	1_12	-6,5	6,5			
13	Plan	2	2_01	6,5	-6,5			
14	Plan	2	2_02	0	0			
15	Plan	2	2_03	-6,5	-6,5			
16	Plan	2	2_04	-6,5	6,5			



Block	Versuch _Nr	Setting	T_M1_Z1	T_M1_Z2	T_M1_Z3	T_M1_Z4	T_M1_Z5	T_M2_Z1	T
1	1_00	Startsetting	1040	1040	1040	1040	1040	1027	
1	1_01	Plan	1007,5	1033,5	1033,5	1033,5	1007,5	1001	
1	1_02	Plan	1020,5	1046,5				1014	
1	1_03	Plan	1033,5	1059,5				020,5	
1	1_04	Plan	1072,5	1059,5				1053	
1	1_05	Plan	1040	1027				033,5	
1	1_06	Plan	1059,5	1046,5				033,5	
1	1_07	Plan	1020,5	1020,5	1033,5	1020,5	1020,5	1007,5	
1	1_08	Plan	1046,5	1033,5	1033,5	1033,5	1046,5	1046,5	
1	1_09	Erweiterung	1059,5	1046,5	1033,5	1046,5	1059,5	1046,5	
1	1_10	Erweiterung	1020,5	1046,5	1033,5	1046,5	1020,5	1007,5	
1	1_11	Erweiterung	1007,5	1033,5	1046,5	1033,5	1007,5	994,5	
1	1_12	Erweiterung	994,5	1020,5	1033,5	1020,5	994,5	994,5	
1	1_13	Startsetting	1040	1040	1040	1040	1040	1027	
2	2_00	Startsetting	1040	1040	1040	1040	1040	1027	
2	2_01	Plan	1046,5	1033,5	1046,5	1033,5	1046,5	1020,5	
2	2_02	Plan	1040	1027	1040	1027	1040	1027	
2	2_03	Plan	1046,5	1046,5	1033,5	1046,5	1046,5	1033,5	
2	2_04	Plan	1059,5	1046,5	1033,5	1046,5	1059,5	1059,5	
2	2_05	Plan	1014	1040	1040	1040	1014	1007,5	

Step 3: Fill in Excel Table



- Copy & paste data from DoE table to Excel Template
- Carry out DoE tests
- Fill in results in Excel table

DoE Template for Staff

Versuch_Nr	Bediener_1	Bediener_2	Datum der Einstellung	Zeit der Einstellung	Datum der Probennahme	Zeit der Probennahme
1_00						
Startsetting						

Vorgaben für Versuchseinstellungen:

	Z1	Z2	Z3	Z4	Z5
M1	1040	1040	1040	1040	1040
	1027	1027	1027	1027	1027
M3	1001	1001	1001	1001	1001
M4	0	0	0	0	0
M5	0	0	0	0	0
M6	0	0	0	0	0
M7	0	0	0	0	0
M8	0	0	0	0	0

DoE Settings

Ergebnisse:

Results from DoE

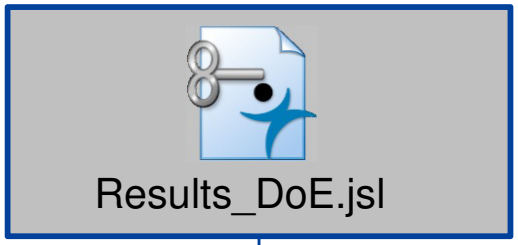
Sample 1	
Sample 2	
Sample 3	
Sample 4	

additional measurement 1	
additional measurement 2	
additional measurement 3	

gelb markierte Felder: Eingabe durch Bediener

Step 4: Analyse DoE Results

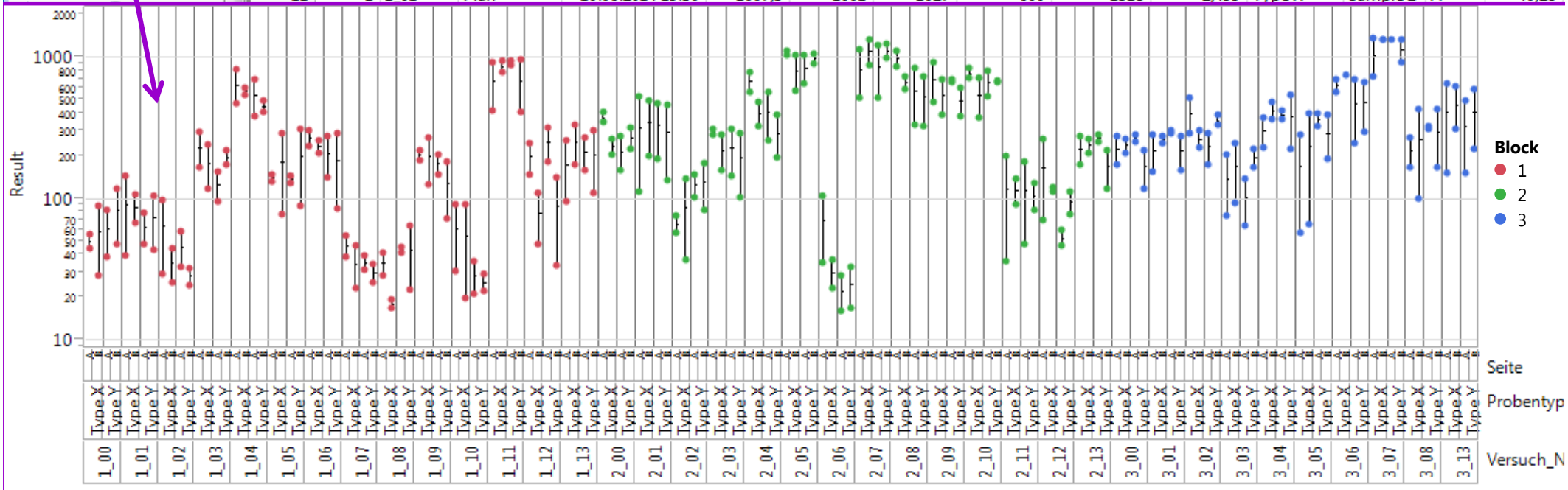
… from Excel Table



Versuchseinstellungen_...
Quelle
Übersicht Ergebnisse
Screening Result
Spalten (30/0)
Block
Versuch_Nr
Setting
Zeit Probennahme

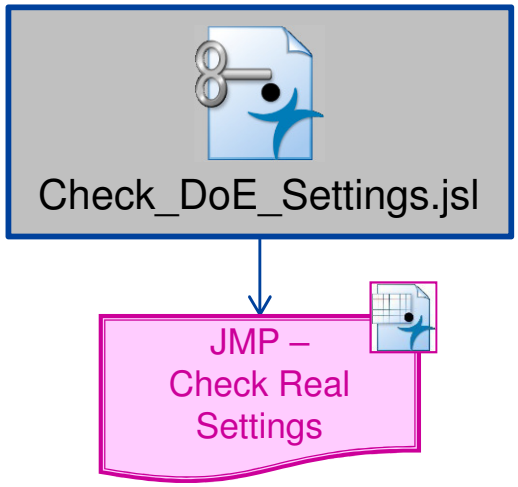
	Block	Versuch_Nr	Setting	Zeit Probennahme	T_M1_Z5	T_M2_Z1	T_M2_Z2	additional measurement 1	additional measurement 2	additional measurement 3	Probentyp	Probe	Seite	Result
4	1	1_00	Startsetting	10.06.2014 18:35	1040	1027	1027	600				Sample 2	B	91,69
5	1	1_00	Startsetting	10.06.2014 18:35	1040	1027	1027	600				Sample 3	A	39,856
6	1	1_00	Startsetting	10.06.2014 18:35	1040	1027	1027	600				Sample 3	B	119,144
7	1	1_00	Startsetting	10.06.2014 18:35	1040	1027	1027	600				Sample 4	A	84,217
8	1	1_00	Startsetting	10.06.2014 18:35	1040	1027	1027	600				Sample 4	B	48,654
9	1	1_01	Plan	10.06.2014 19:30	1007,5	1001	1027	600				Sample 1	A	145,591
10	1	1_01	Plan	10.06.2014 19:30	1007,5	1001	1027	600	1518	2,499	Type X	Sample 1	B	68,635
11	1	1_01	Plan	10.06.2014 19:30	1007,5	1001	1027	600	1518	2,499	Type X	Sample 2	A	40,28

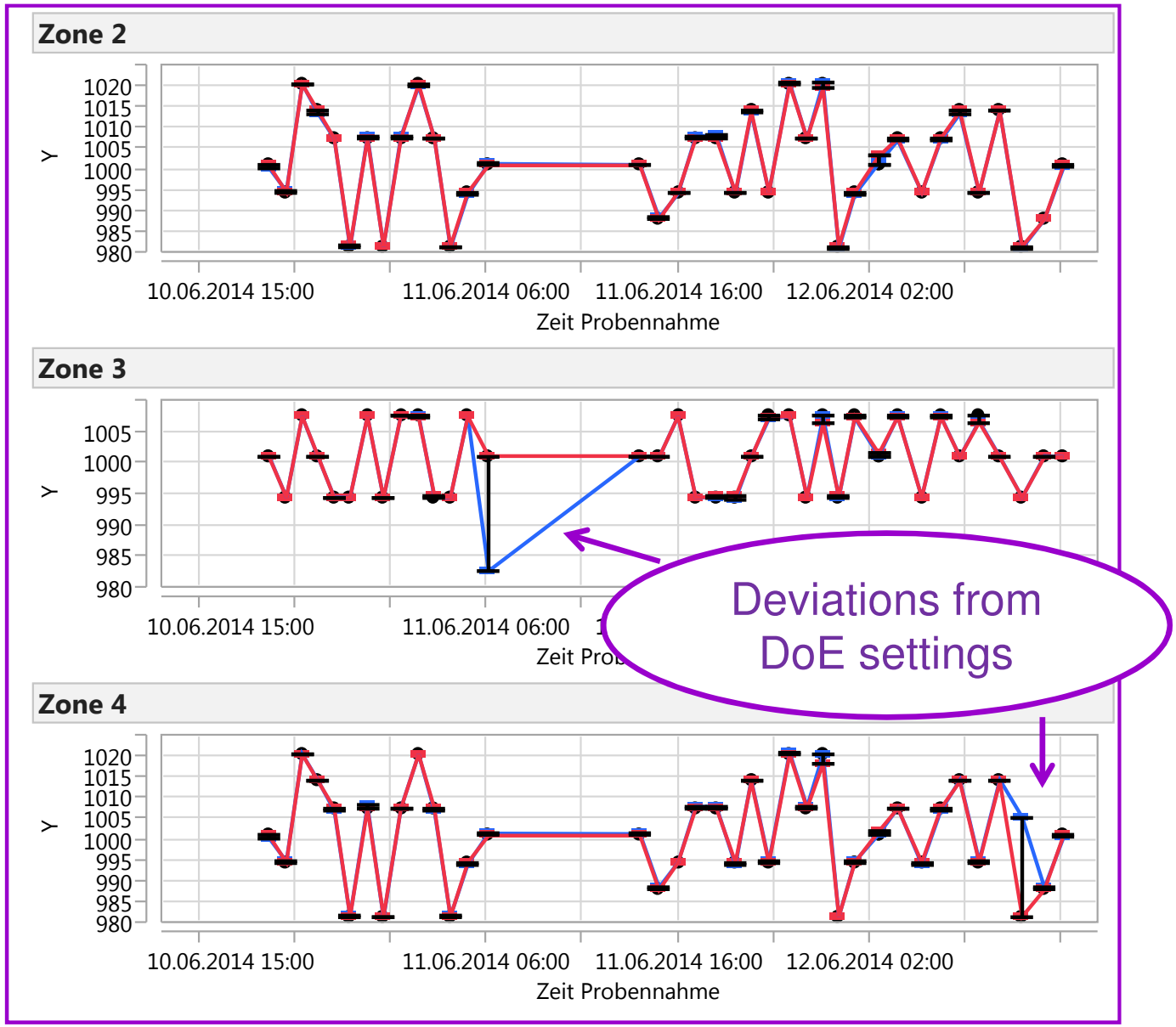
JMP – DoE Results



Step 5: Check Realization of DoE Settings

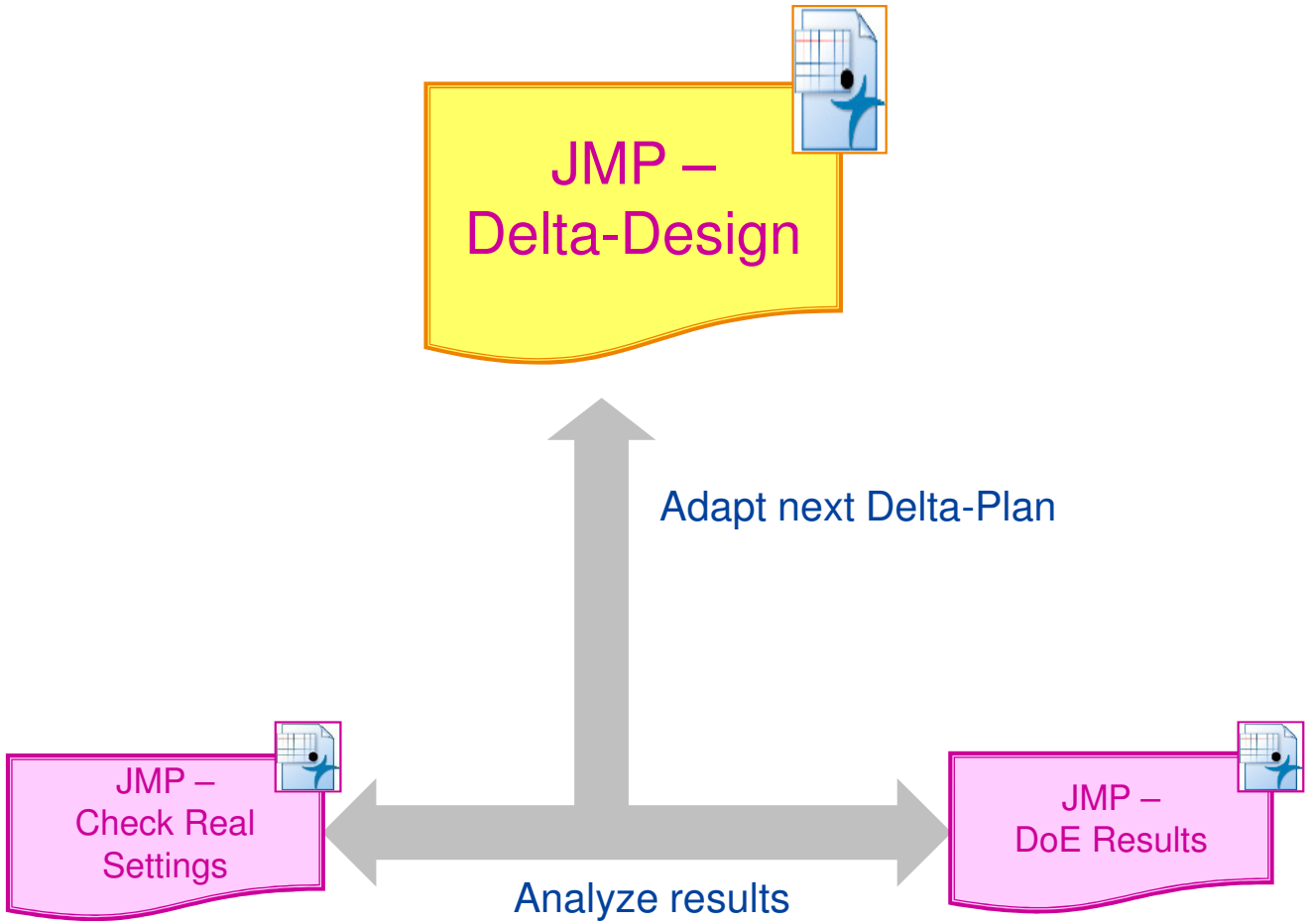
Read process data during tests, compare with suggested settings from DoE design





Black: Required settings from DoE
Blue: Real values side A
Red: Real values side B

Step 6: Analyse and Adapt New Delta Design



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Summary

- DOE important for understanding correlations and finding best settings
- Flexibility needed for production requirements:
  - Settings have to be adapted quickly
  - Analyses have to be fast and easy
- JSL scripts allow for
  - rapid setup changes in experiments,
  - compatibility with Excel templates for production staff
  - comfortable data visualisation and analyses.

Thank you!

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