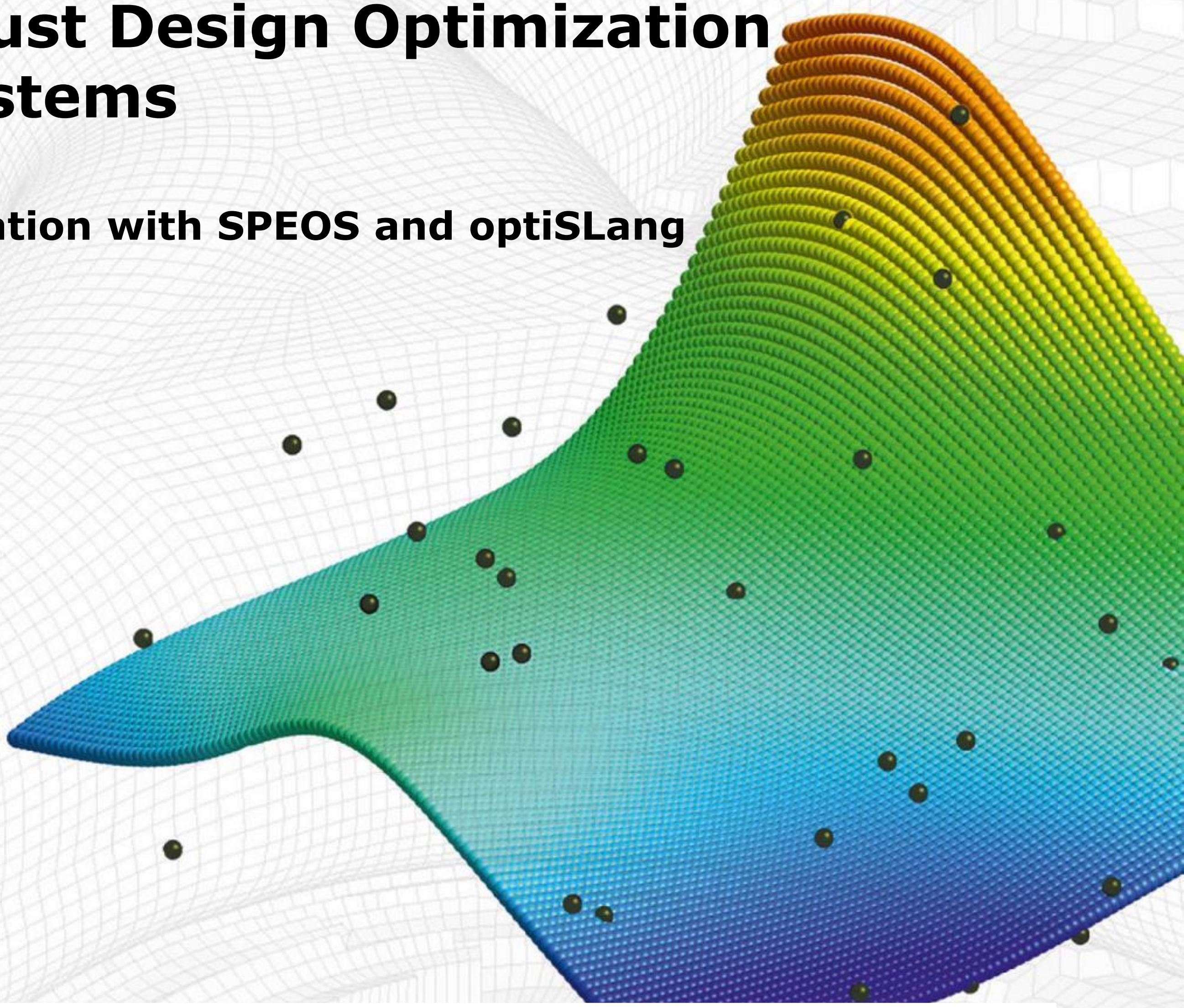
Efficient Robust Design Optimization of Optical Systems

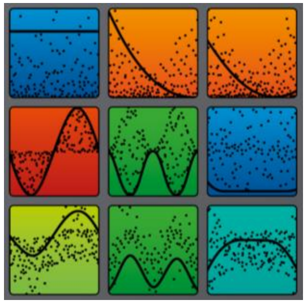
Lightguide Optimization with SPEOS and optiSLang

Stephanie Kunath,
Dynardo GmbH

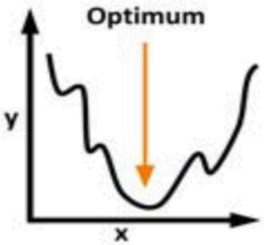


Motivation

- The **optimization of advanced optical designs** is very challenging due to their
  - complexity,
  - nonlinearity,
  - a huge number of input parameters and
  - interactions between them.

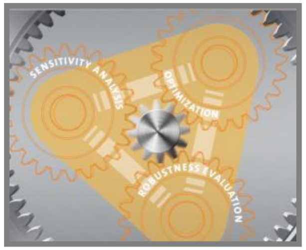


- The demands for the system's **performance** are
  - versatile and
  - very high and even get higher concerning optimization and robustness criteria.



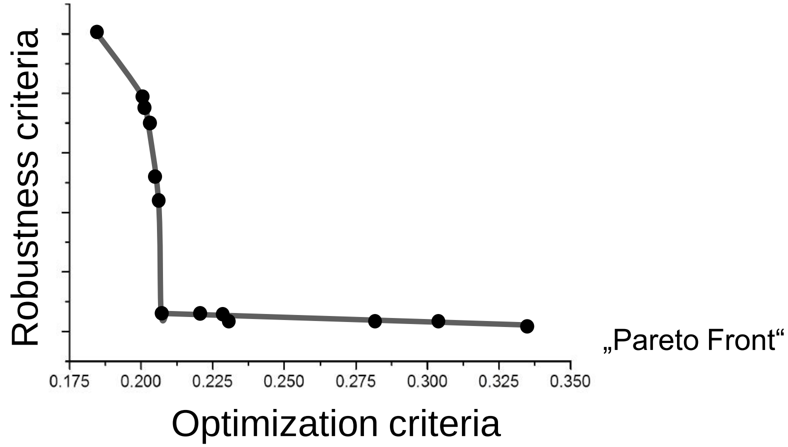
- Furthermore, **totally new developments**, like
  - new materials,
  - manufacturing possibilities and
  - very short product development times,

  simultaneously, require advanced methodologies to develop competitive optical products.

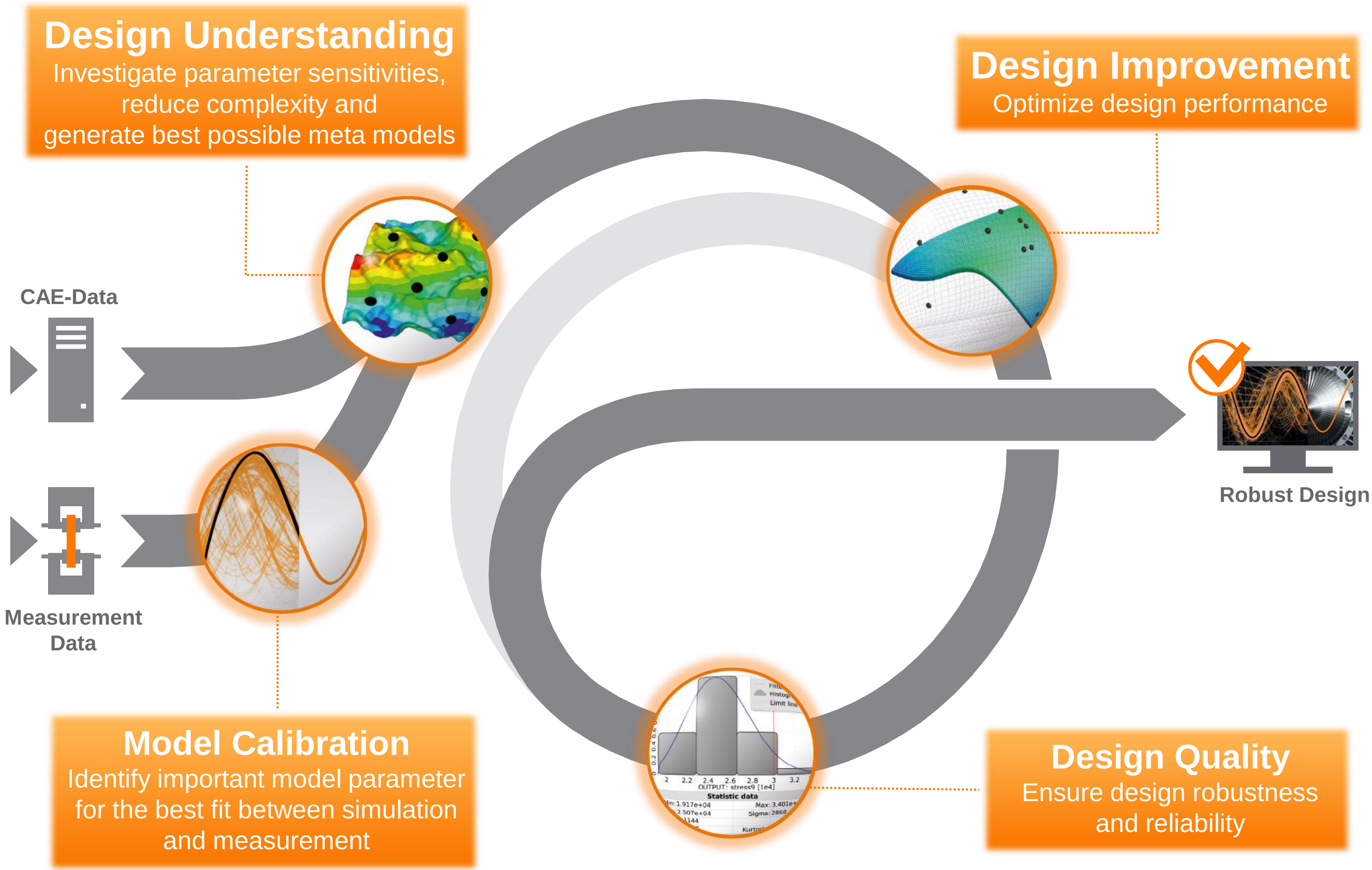


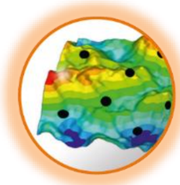
Solution: Software optiSLang

- Dynardo supports the whole virtual product development process with optiSLang. This includes
  - **Process integration** (e.g. SPEOS, VirtualLab, Zemax, Matlab)
  - **Building workflows** (e.g. coupling several physical domains)
  - **Automation**
  - **Robust Design Optimization**



Robust Design Optimization for Product Development

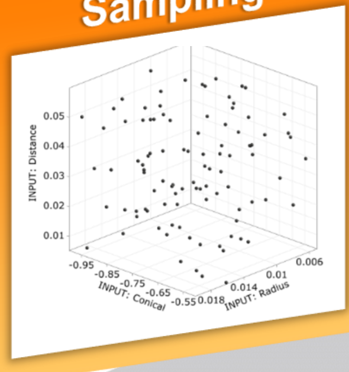

Design Understanding
Investigate parameter sensitivities,
reduce complexity and
generate best possible meta models
Design Improvement
Optimize design performance
CAE-Data
Robust Design
Measurement
Data
Model Calibration
Identify important model parameter
for the best fit between simulation
and measurement
Design Quality
Ensure design robustness
and reliability



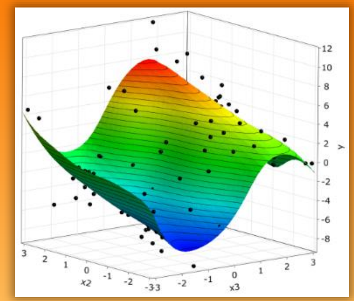
Sensitivity Analysis

Understand the most important input variables!

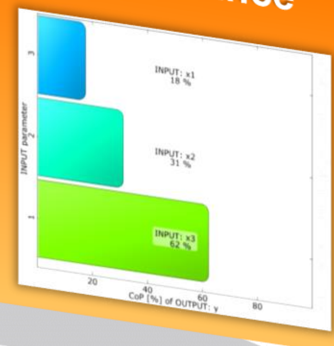
Latin Hypercube Sampling



Metamodel of Optimal Prognosis

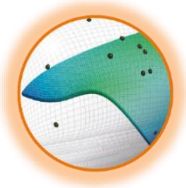


Input parameter importance



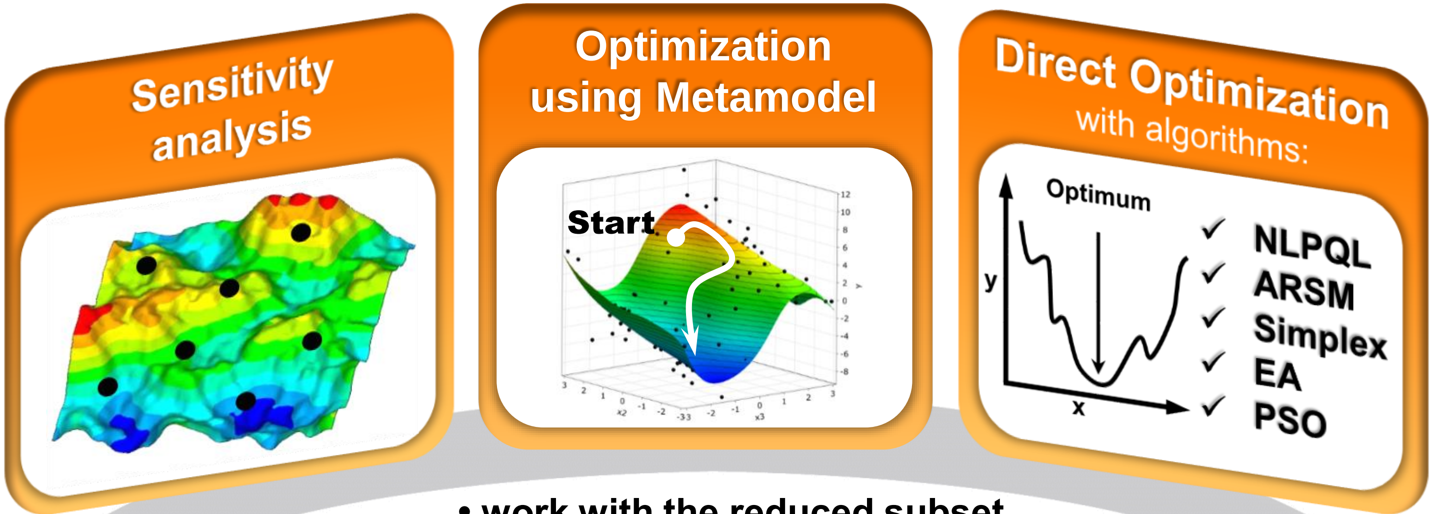
Automatic workflow
with a minimum of solver runs to:

- **identify the important parameters for each response**
- **Generate best possible metamodel for each response**
- **understand and reduce the optimization task**
- **check solver and extraction noise**



Optimization

Optimize your product design!

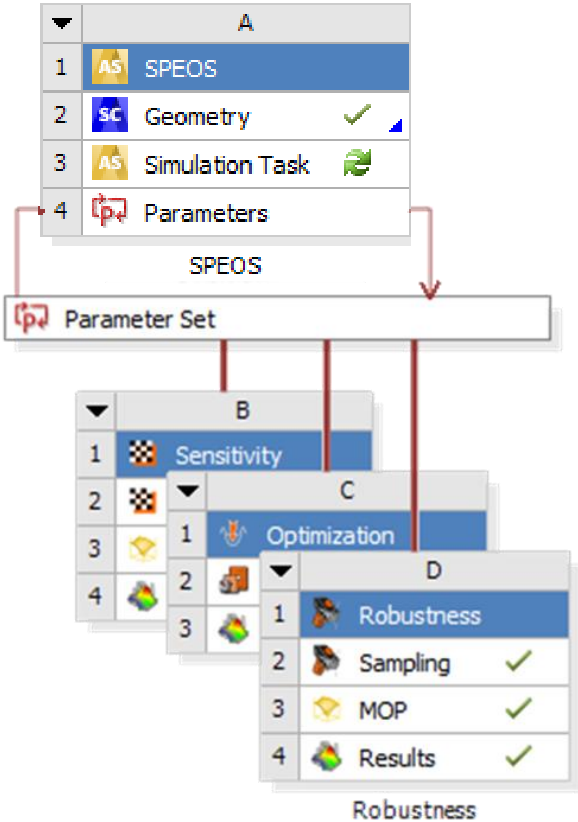


• work with the reduced subset of only important parameters
• pre-optimization on meta model
• optimization with leading edge optimization algorithms
• decision tree for optimization algorithms

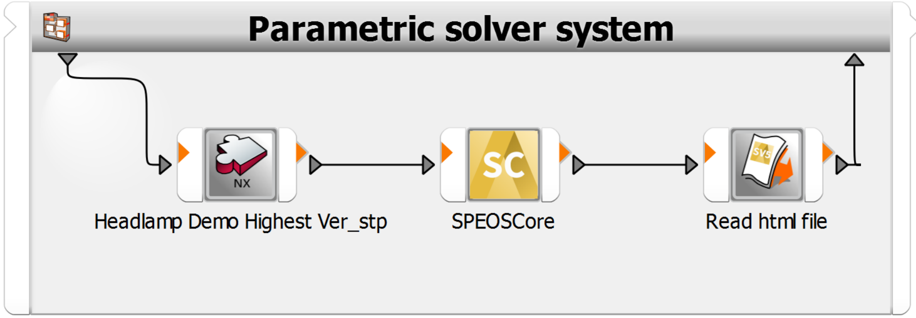
SPEOS Integration

Process Integration: ANSYS SPEOS

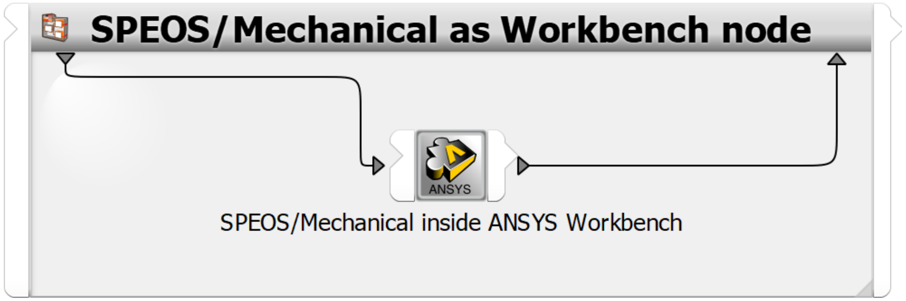
A) optiSLang inside Workbench



B) Direct integration via scripts

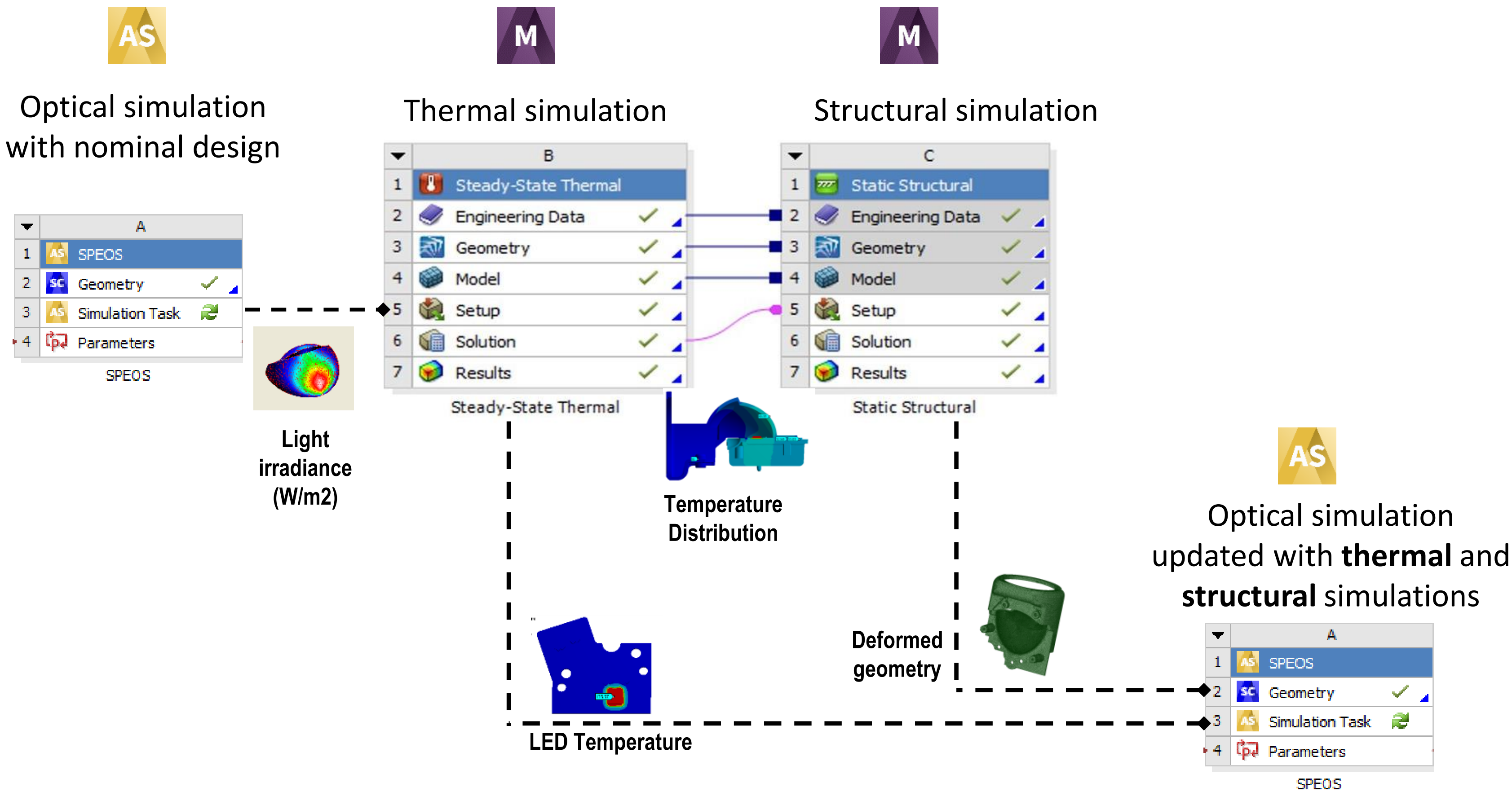


C) Workbench inside optiSLang



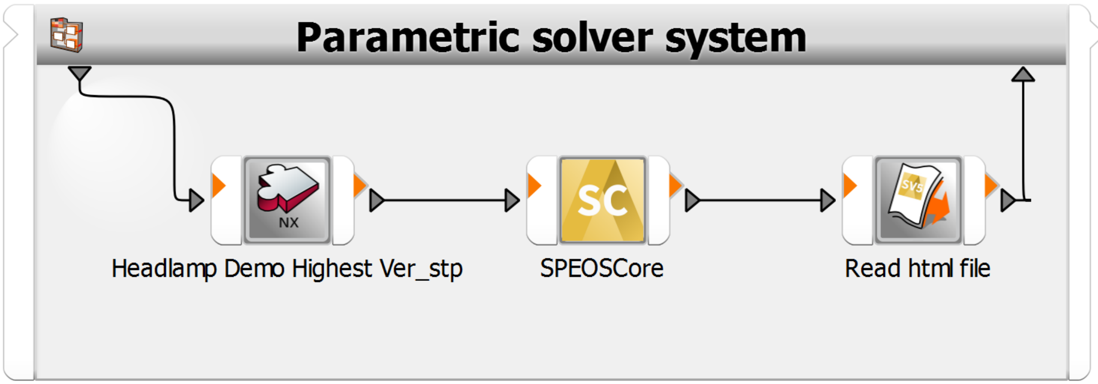
ANSYS SPEOS and Mechanical

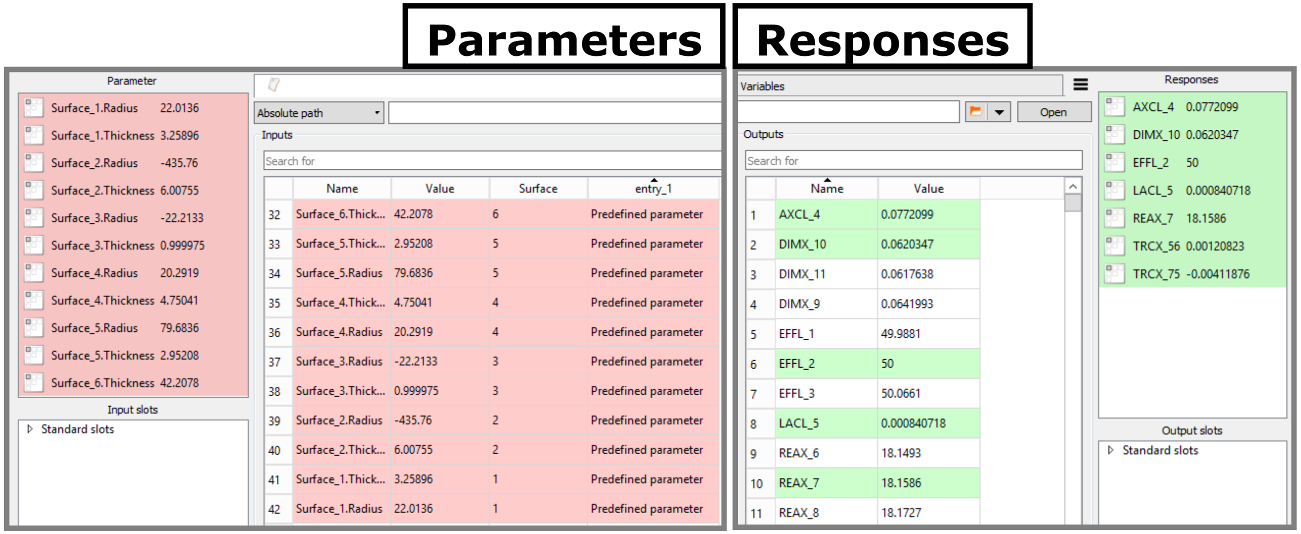
- Optomechanical design studies with SPEOS and Mechanical



Process Integration: SPEOS for CAD

- SPEOS for NX and CATIA



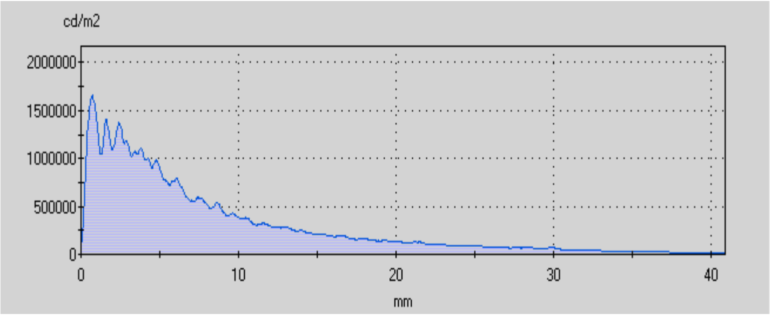


Example: Lightguide Optimization

Lightguide Optical Shape Design Optimization

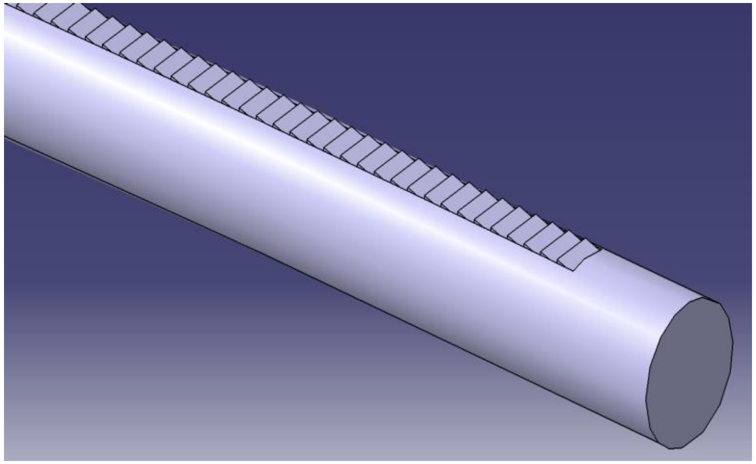
- Lightguide optimization of an automotive headlamp
- Obtain an homogeneous lit appearance, maximize average luminance
- Homogeneity is represented by RMS contrast

Lit appearance

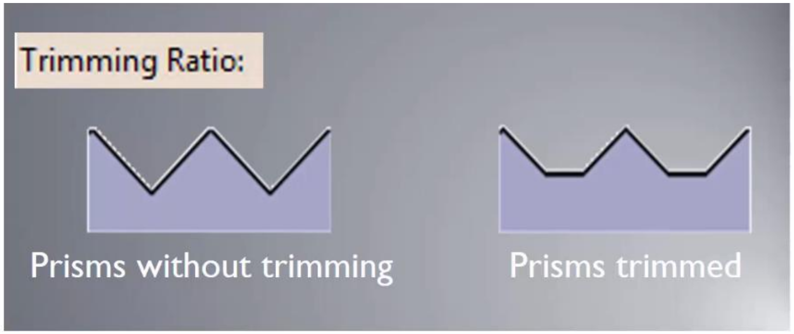


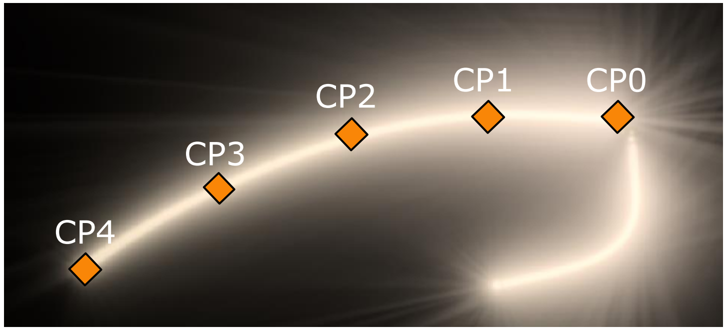
Cross section

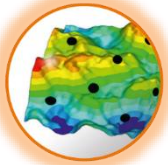
Lightguide Parametrization



- **Inputs**: 5 trimming ratio control points of prisms on the lightguide
  -> control efficiency of each prism
- **Outputs** (Luminance):
  - RMS contrast
  - Average [cd/m²]
  - Minimum [cd/m²]
  - Maximum [cd/m²]
- **Objective**:
  Minimize *RMS contrast*
  Maximize *average luminance*



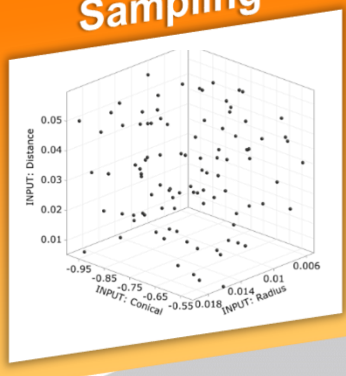




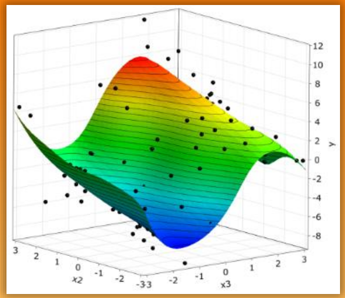
Sensitivity Analysis

Understand the most important input variables!

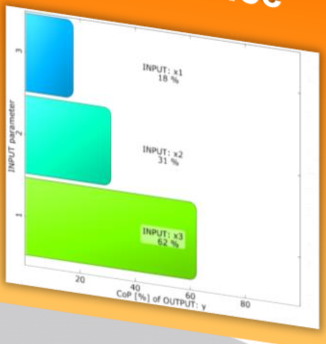
Latin Hypercube Sampling



Metamodel of Optimal Prognosis



Input parameter importance



Automatic workflow
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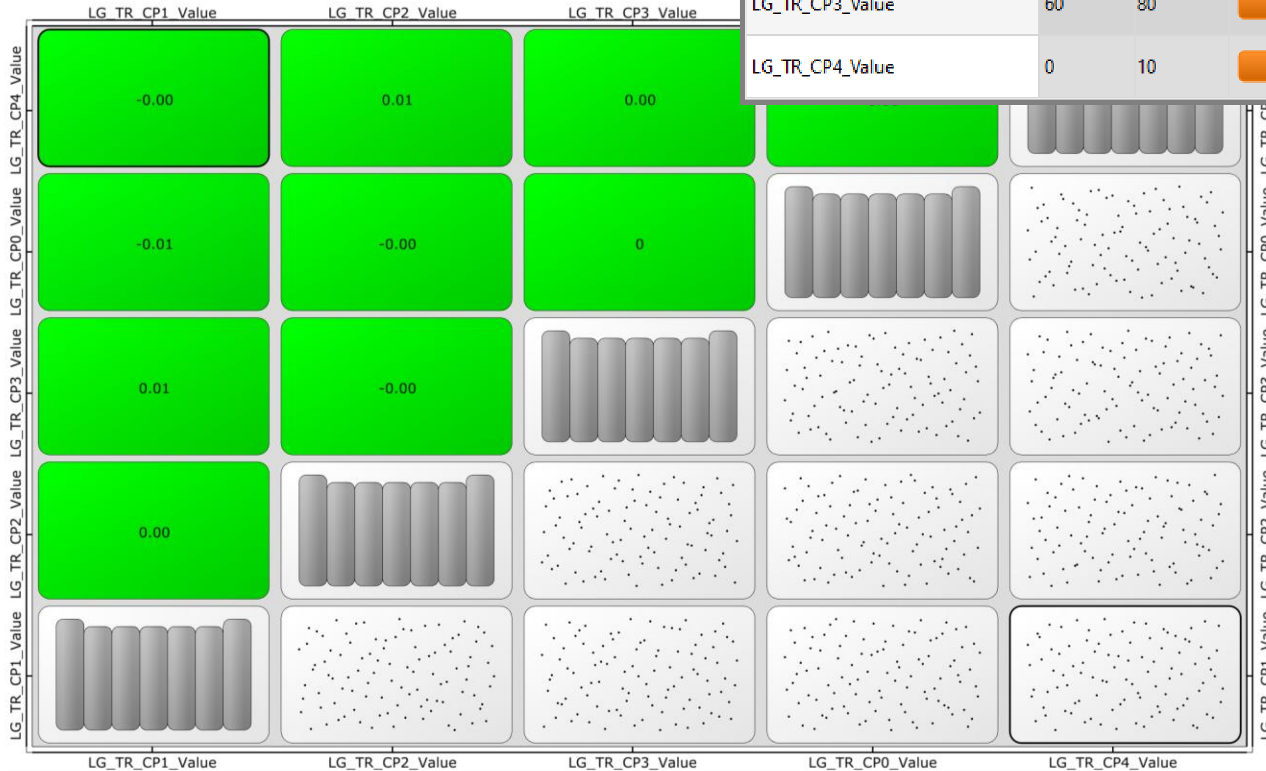
Sensitivity Analysis Sampling

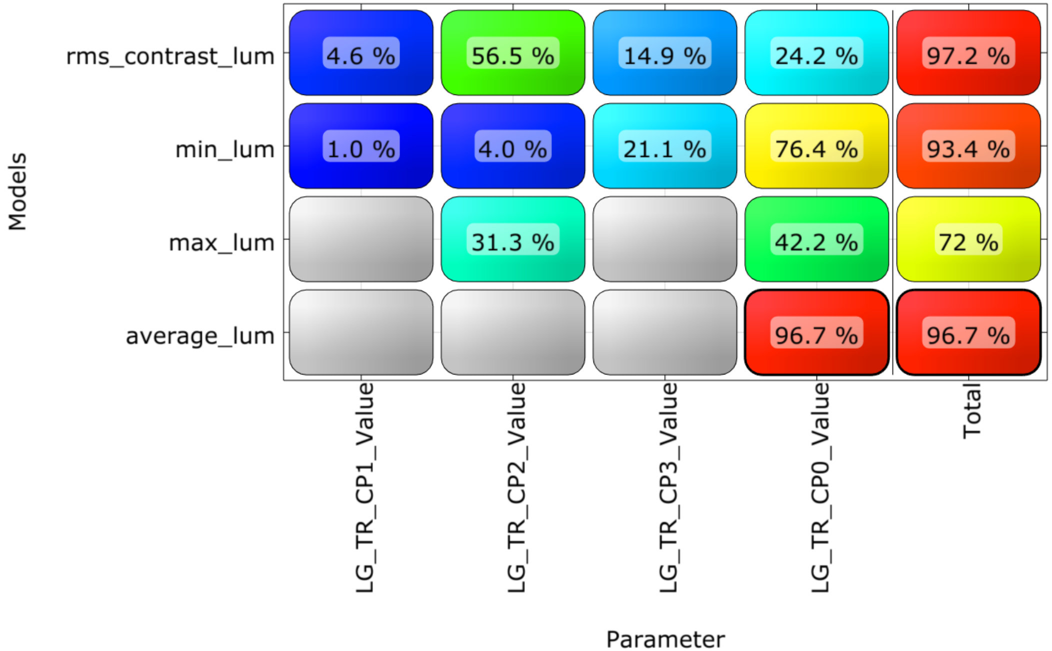
- Latin Hypercube Sampling with 100 designs
- Input ranges and correlation matrix of inputs:

Name	Range		Range plot
LG_TR_CP0_Value	90	100	
LG_TR_CP1_Value	85	90	
LG_TR_CP2_Value	75	85	
LG_TR_CP3_Value	60	80	
LG_TR_CP4_Value	0	10	



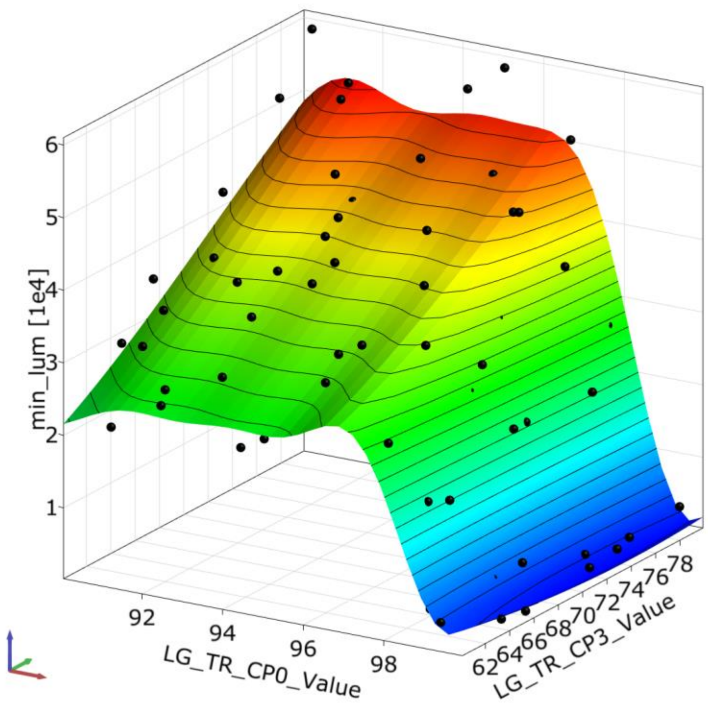
Sensitivity Analysis Results

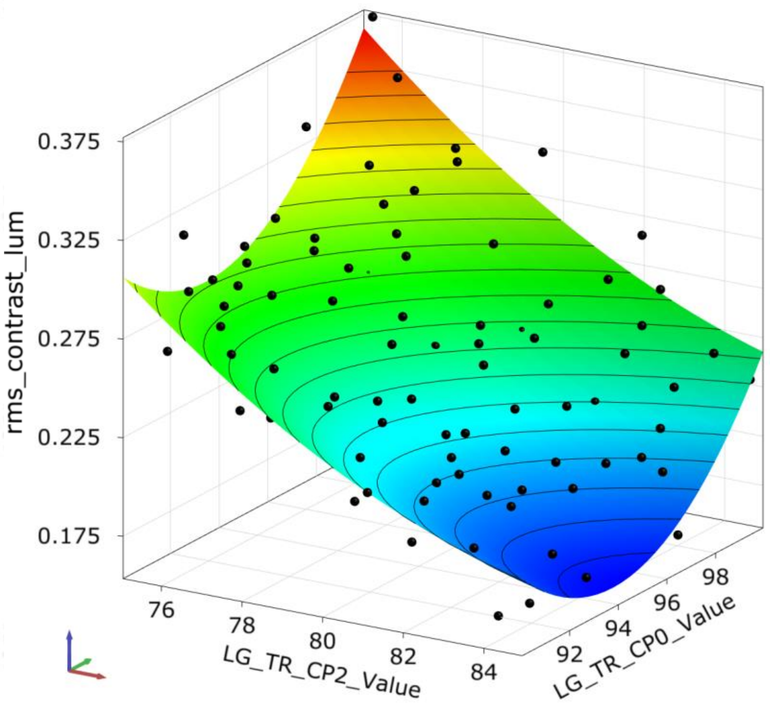
- **Metamodelling**: CoPs over 70% for non-linear effects!
- Dominant parameters over all responses is the value of the trimming ratio (TR) of the control point (CP) at position 0 (LG_TR_CP0_Value) of the and at position 2 (LG_TR_CP2_Value)
- No effect of trimming ratio at CP4 detected



Sensitivity Analysis Results

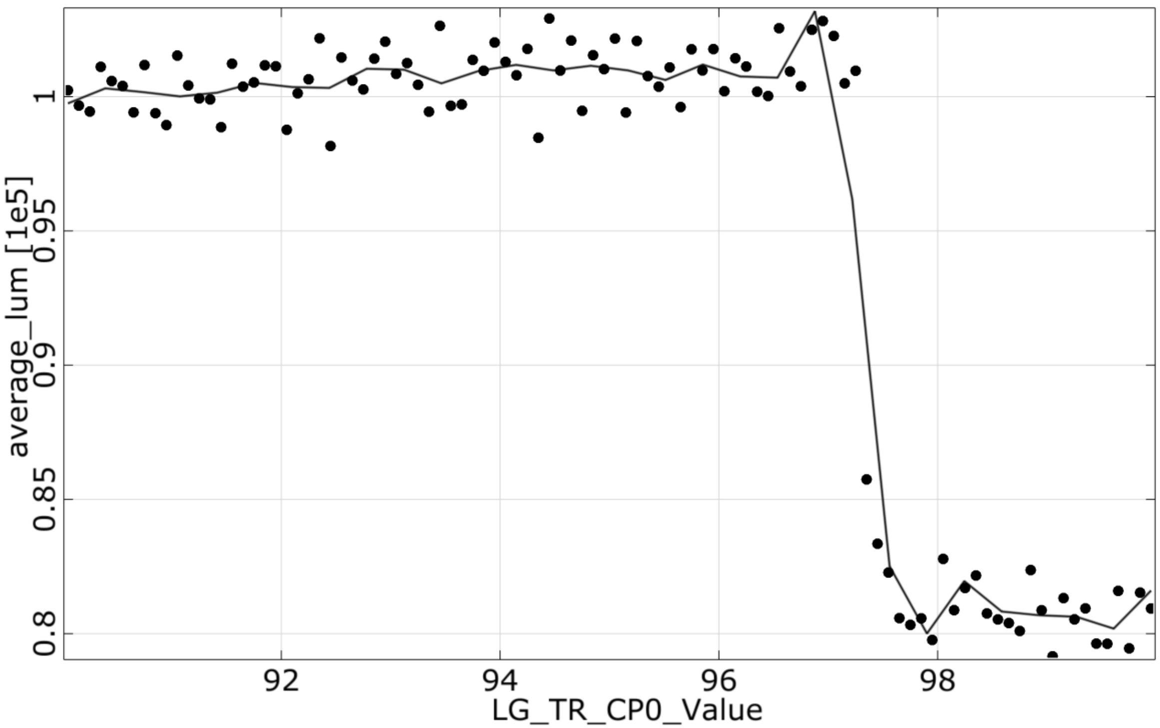
- **Metamodelling**: *Minimum luminance* is mainly effected by trimming ratio at CP0 and CP3
- *RMS contrast* is mainly effected by trimming ratio at CP0 and CP2





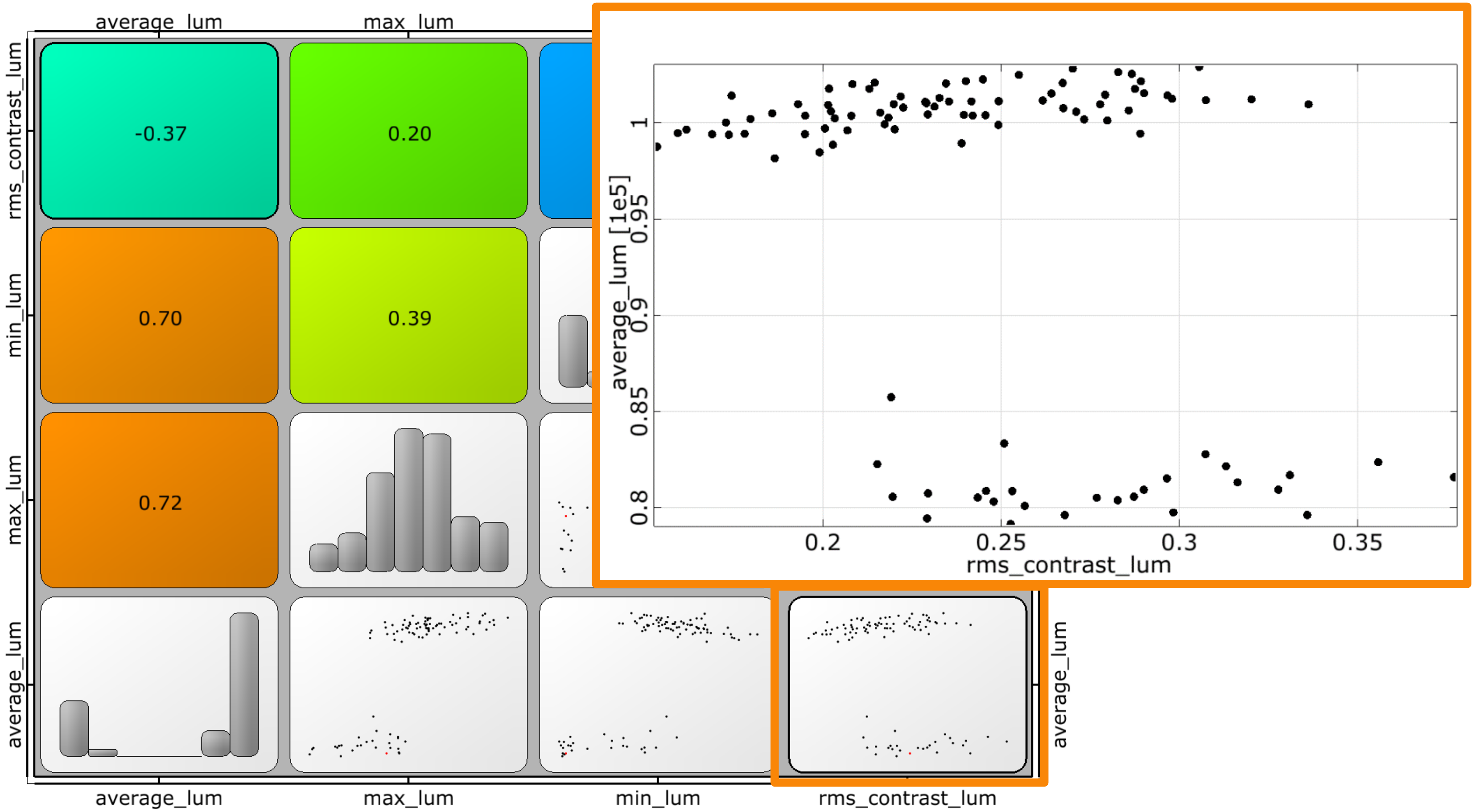
Sensitivity Analysis Results

- **Metamodelling**: *Average luminance* only depends on trimming ratio at CP0



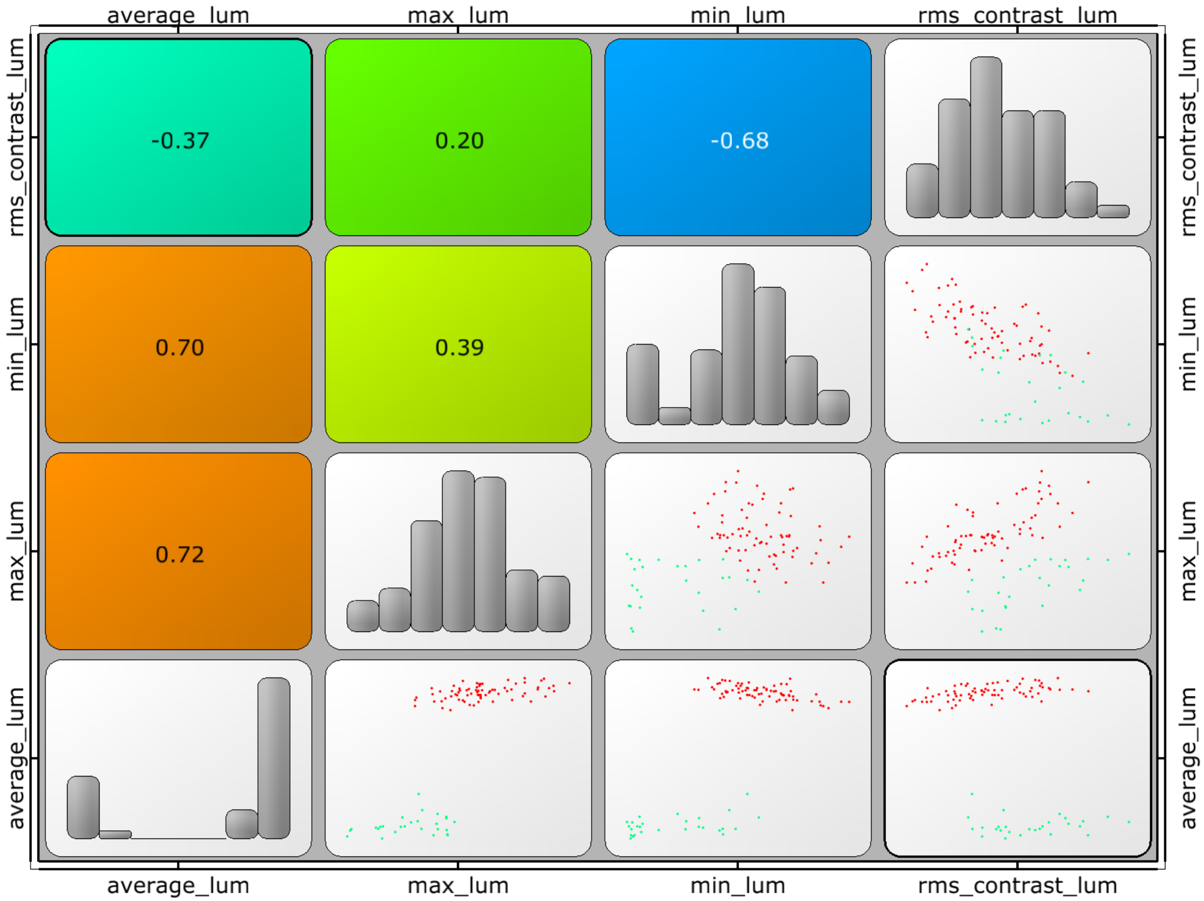
Sensitivity Analysis Results

- Correlation analysis: 2 clusters for *average luminance* get visible



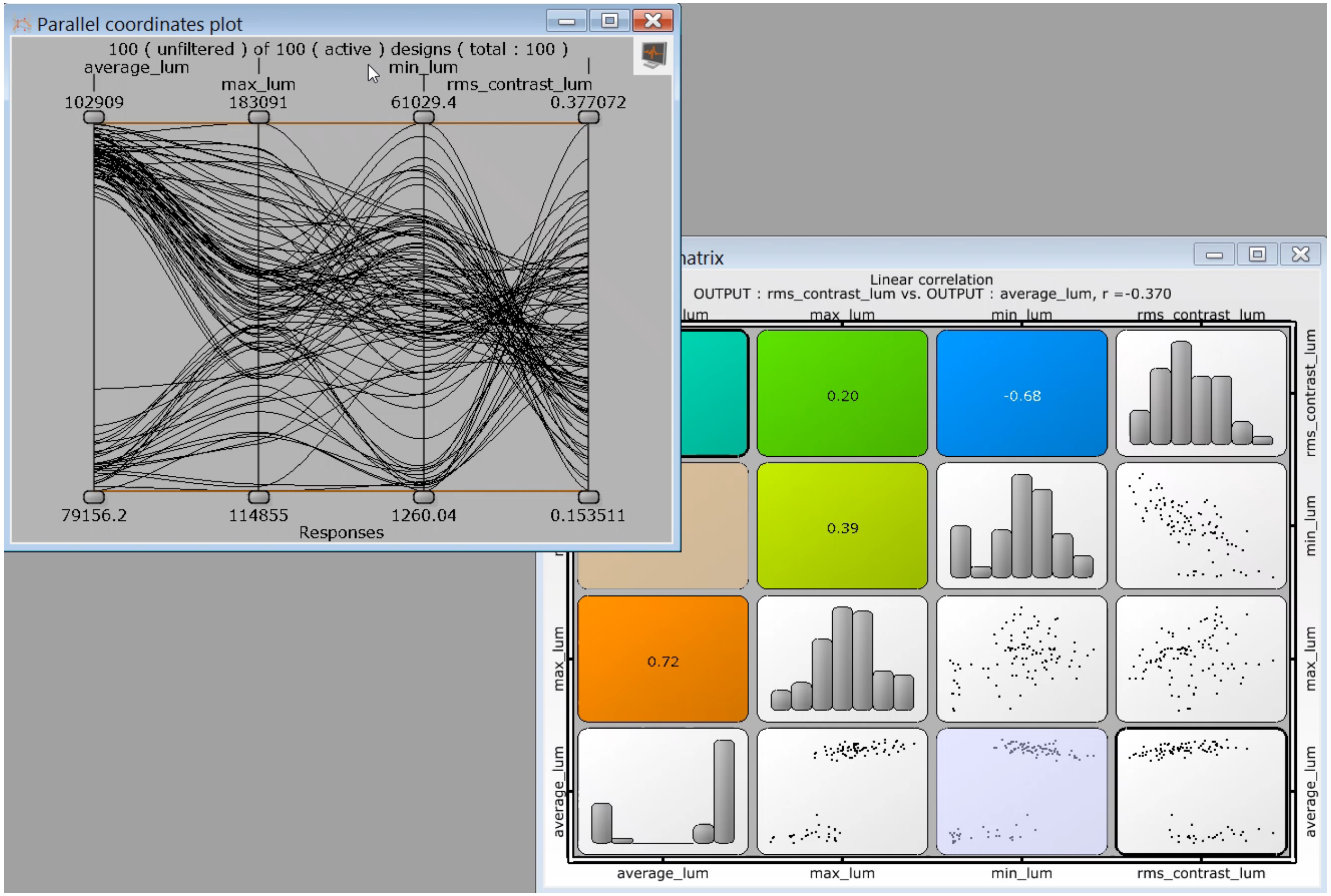
Sensitivity Analysis Results

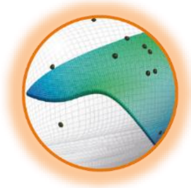
- Correlation analysis and cluster analysis



Sensitivity Analysis Results

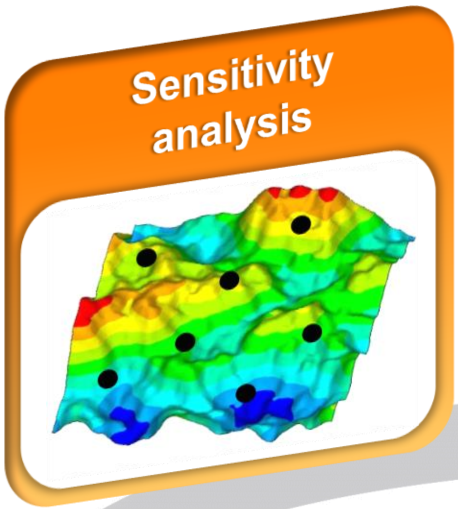
- Correlation analysis and cluster analysis

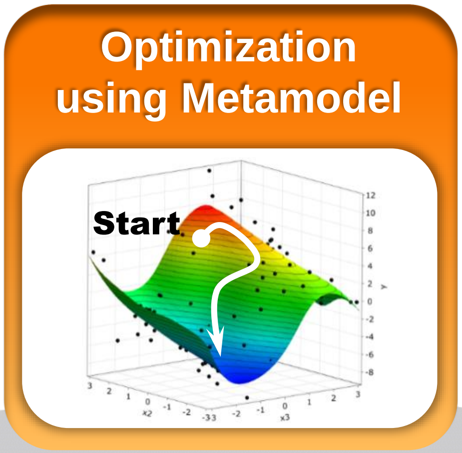


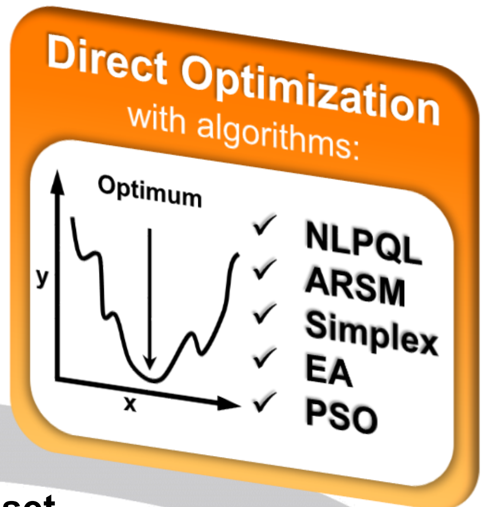


Optimization

Optimize your product design!







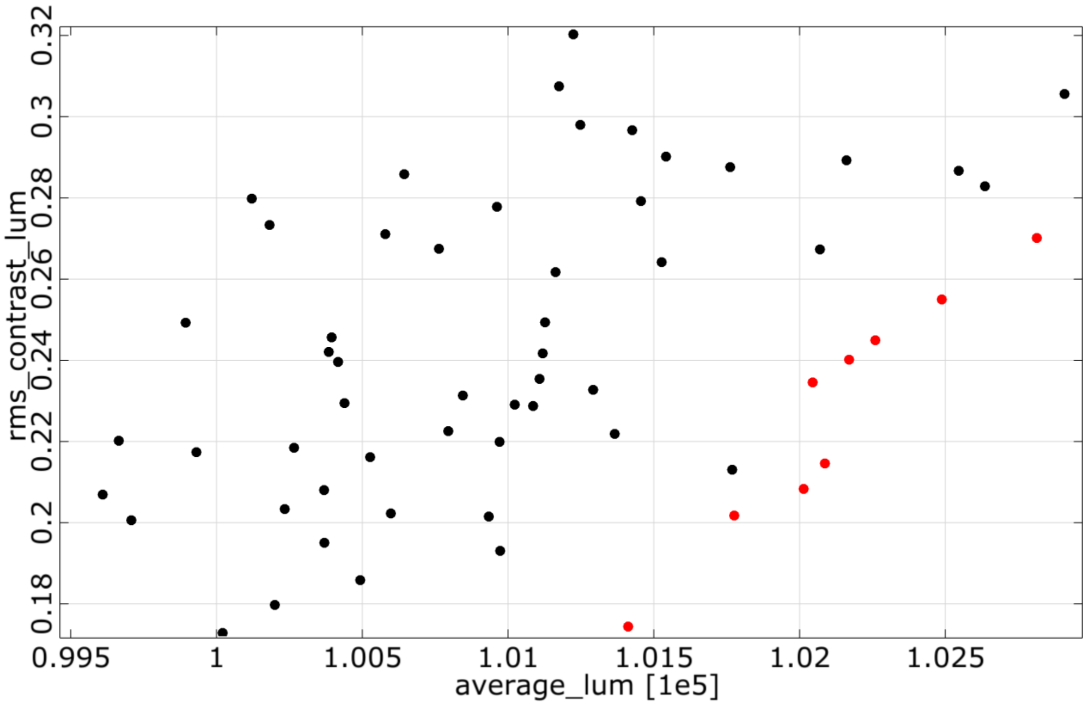
- work with the reduced subset of only important parameters
- pre-optimization on meta model
- optimization with leading edge optimization algorithms
- decision tree for optimization algorithms

Definition of Objectives

- Visualization of objectives using designs from sensitivity analysis
- Trade-off between *RMS contrast* and *average luminance*

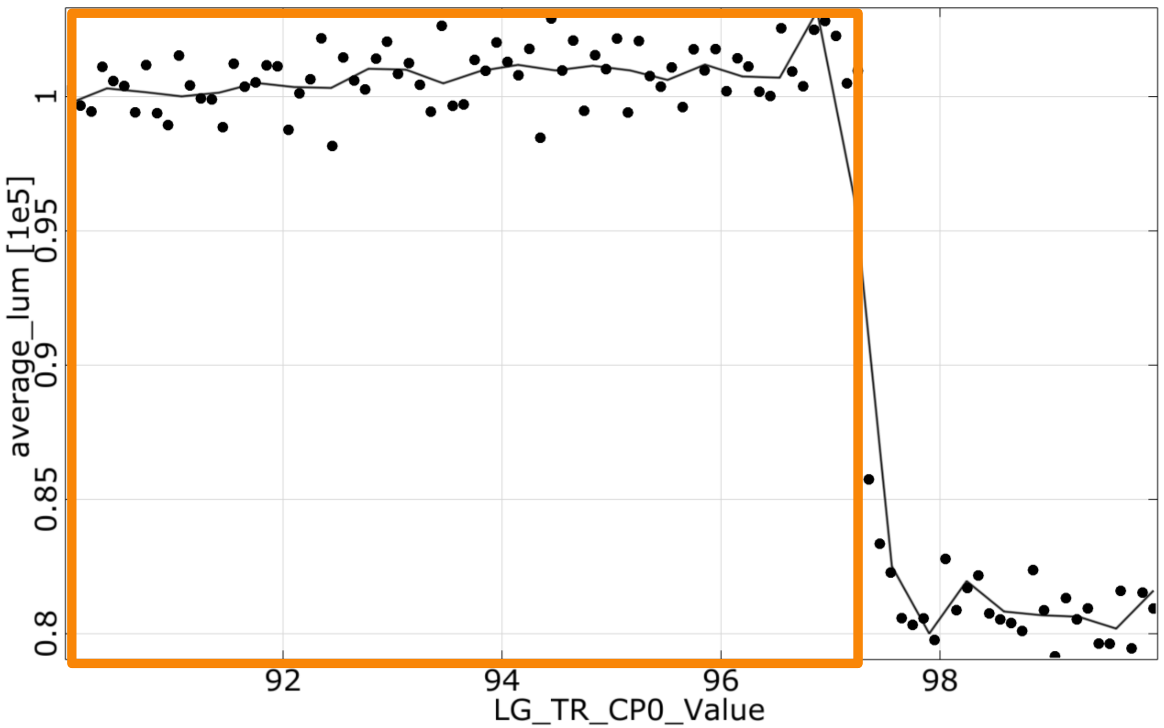
-> Pareto optimization (2 separate objectives):

- Minimize RMS contrast
- Maximize average luminance



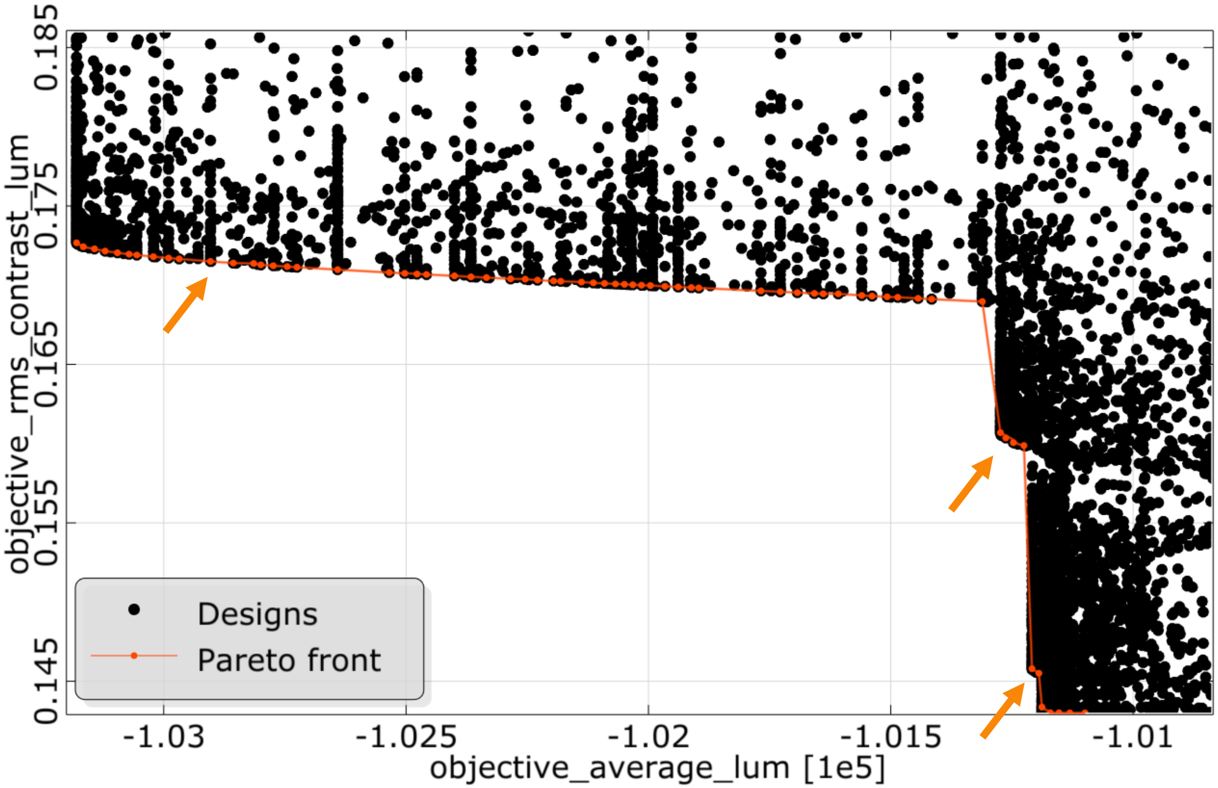
Definition of Input Range

- Limit the range of trimming ratio at CP0 to [90;97.3] to increase *average luminance*



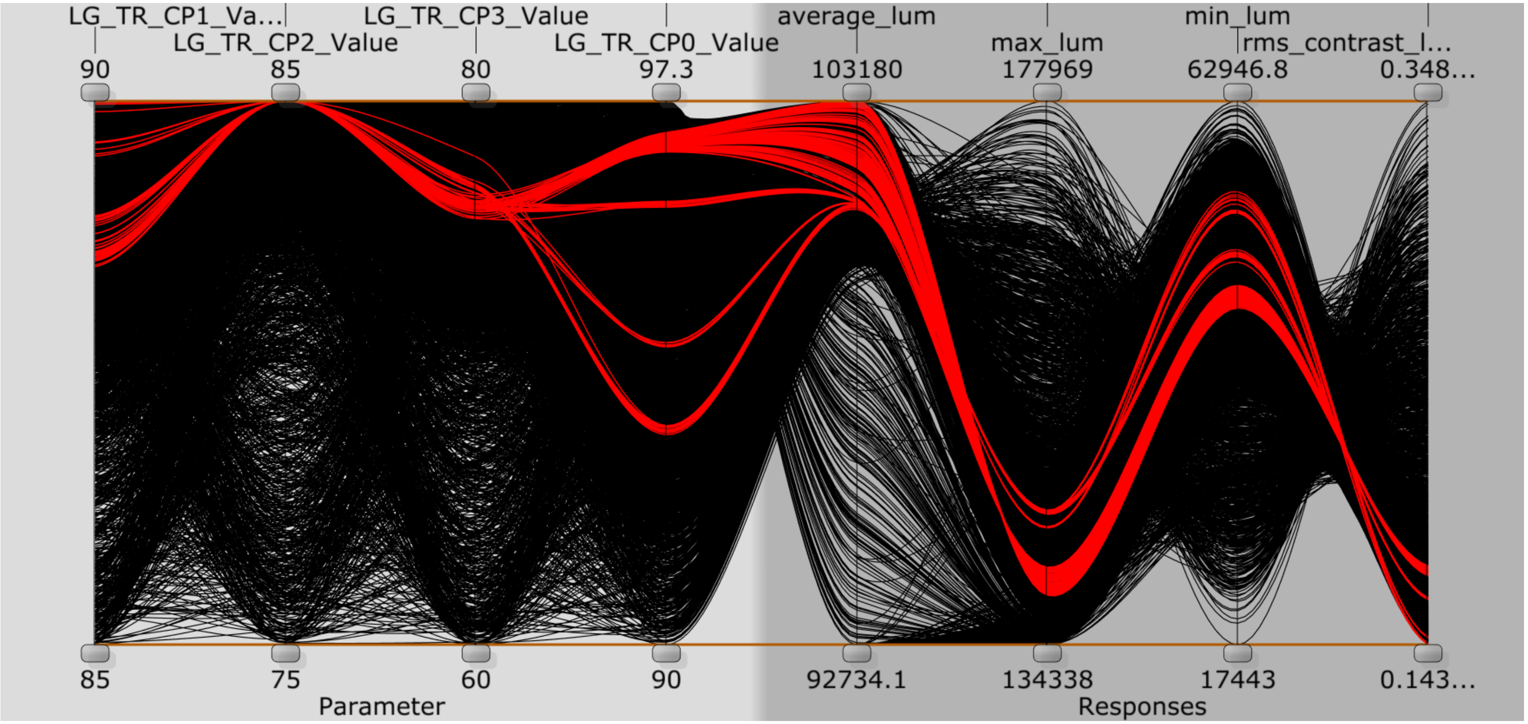
Pareto Optimization on Metamodel

- **Pareto front designs** illustrate trade-off between the objectives
- Best design can be chosen from the Pareto front and used as start design for further direct optimization



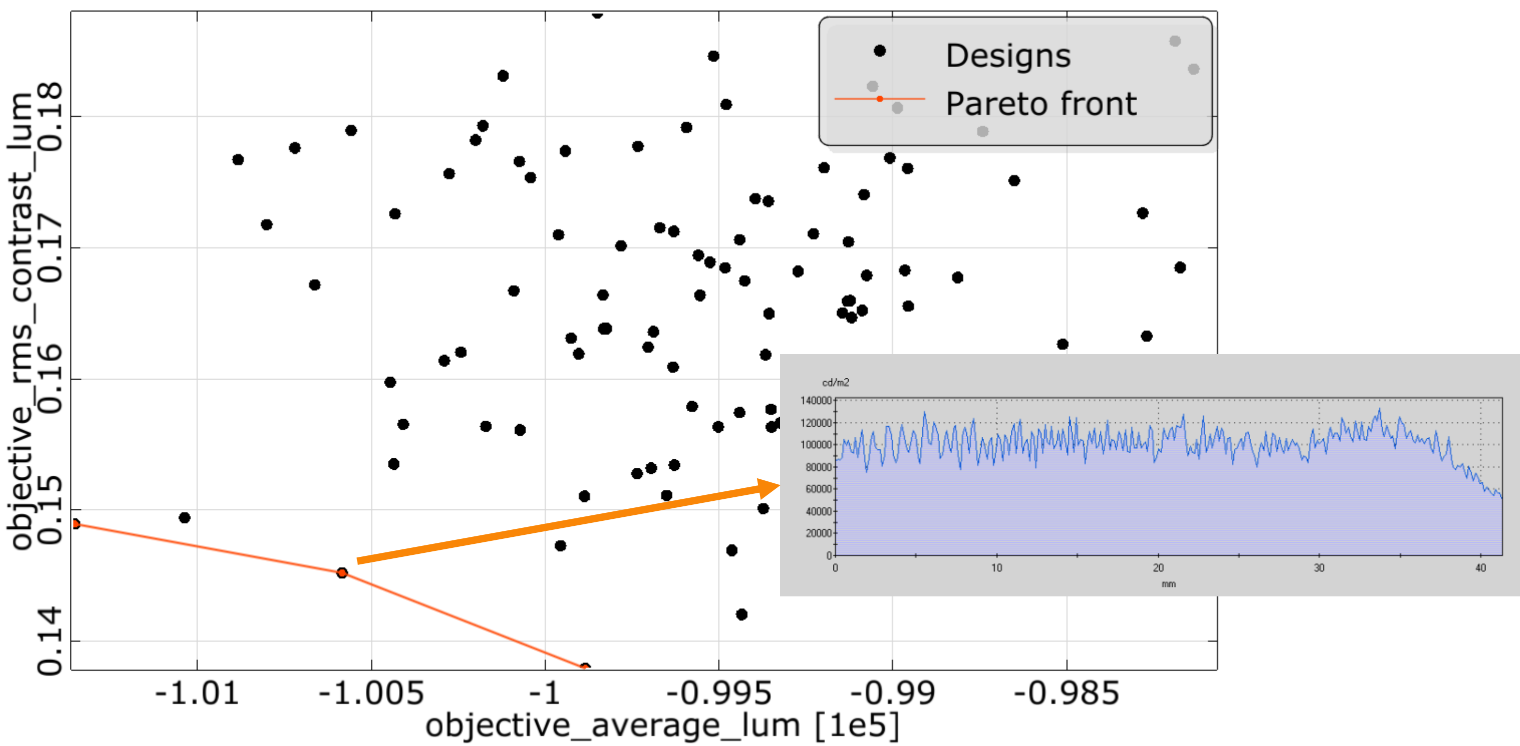
Pareto Optimization on Metamodel

- Further analysis of the **Pareto front designs** with Parallel Coordinates Plot
- Data ranges of all inputs are strongly limited within the optimization space -> further reduction of input space possible



Direct Optimization with SPEOS

- Validation of Pareto front designs of optimization on metamodel (=best designs) with SPEOS
- Use these designs as start design for subsequent direct optimization with SPEOS

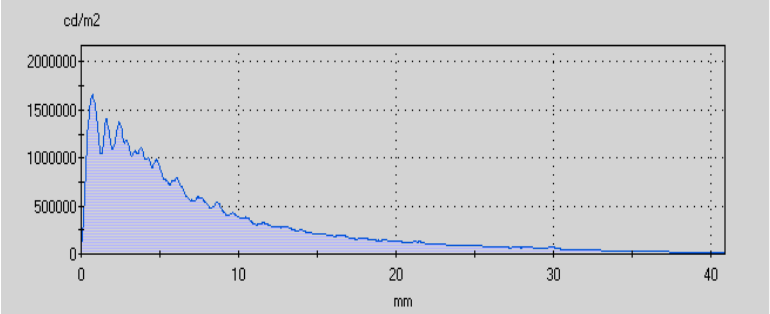


Summary and Next Steps

- optiSLang-SPEOS integration
- Design understanding and definition of optimization problem with sensitivity analysis
- Efficient pre-optimization on metamodel
- Direct optimization with SPEOS

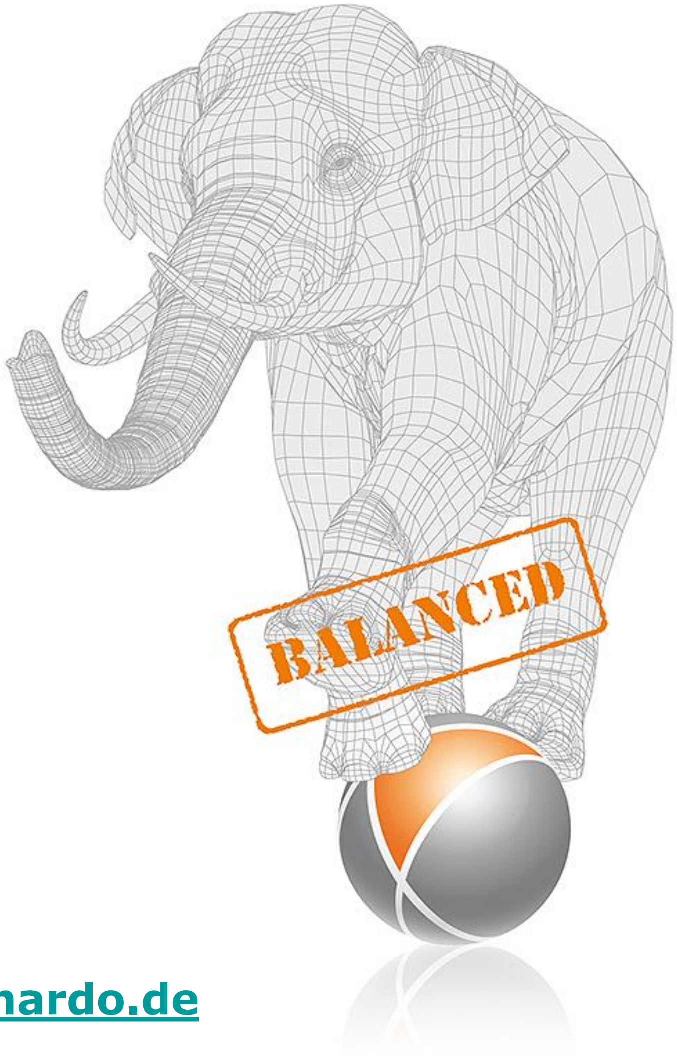
- Next steps:
  - Consideration of more input parameters and meet the regulation
  - 2D (signal) data analysis for further understanding and improved optimization results

Lit appearance



Cross section

Thank you for your attention!



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