



- Schladming , 11.+12. März 2010

# ***Integrative Optimierung von Spritzgußbauteilen***

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***Multidisziplinäre Gestaltoptimierung unter  
Berücksichtigung des Herstellprozesses***

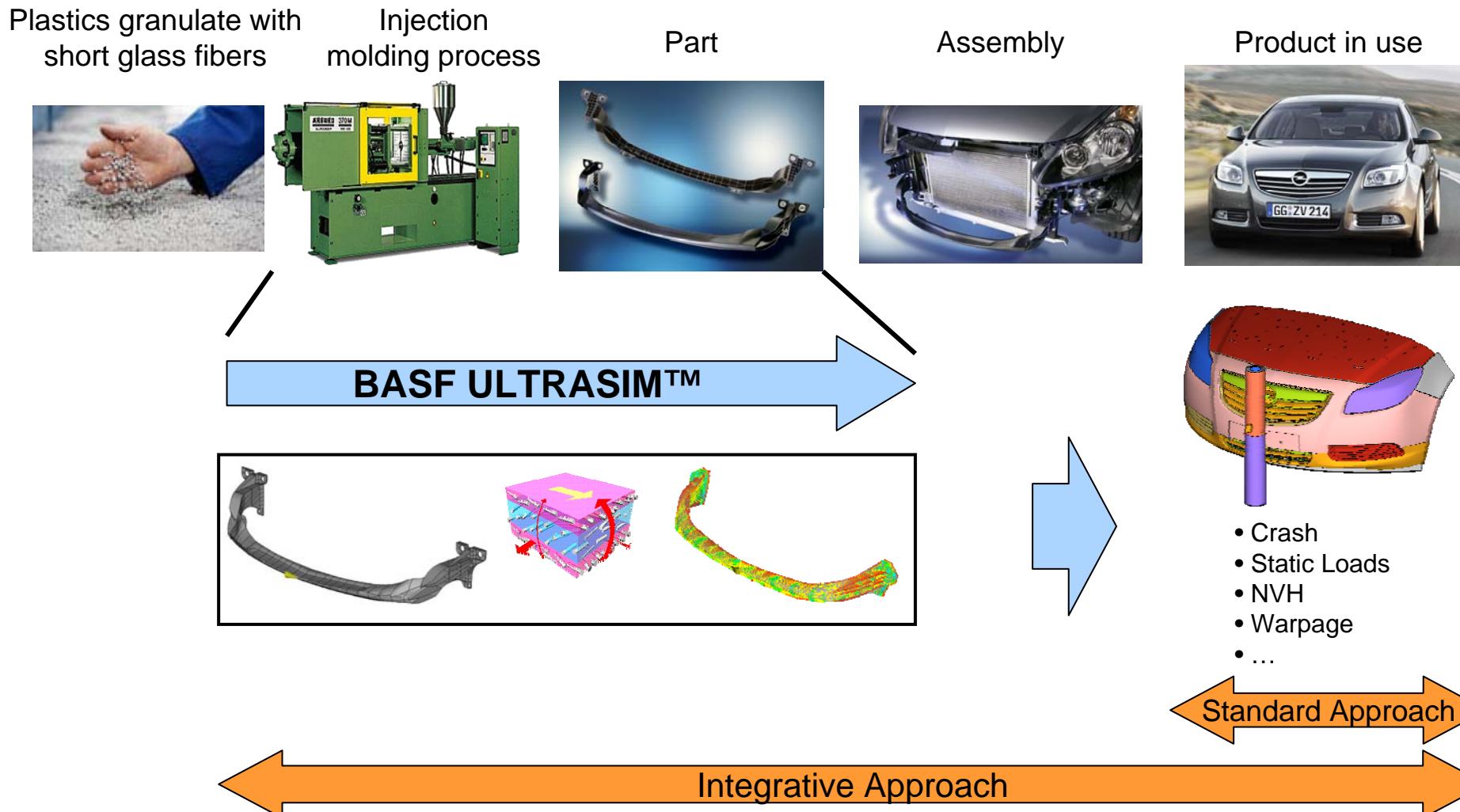
BASF – E-KTE/AE F206  
67056 Ludwigshafen  
[andreas.wuest@basf.com](mailto:andreas.wuest@basf.com)

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The Chemical Company

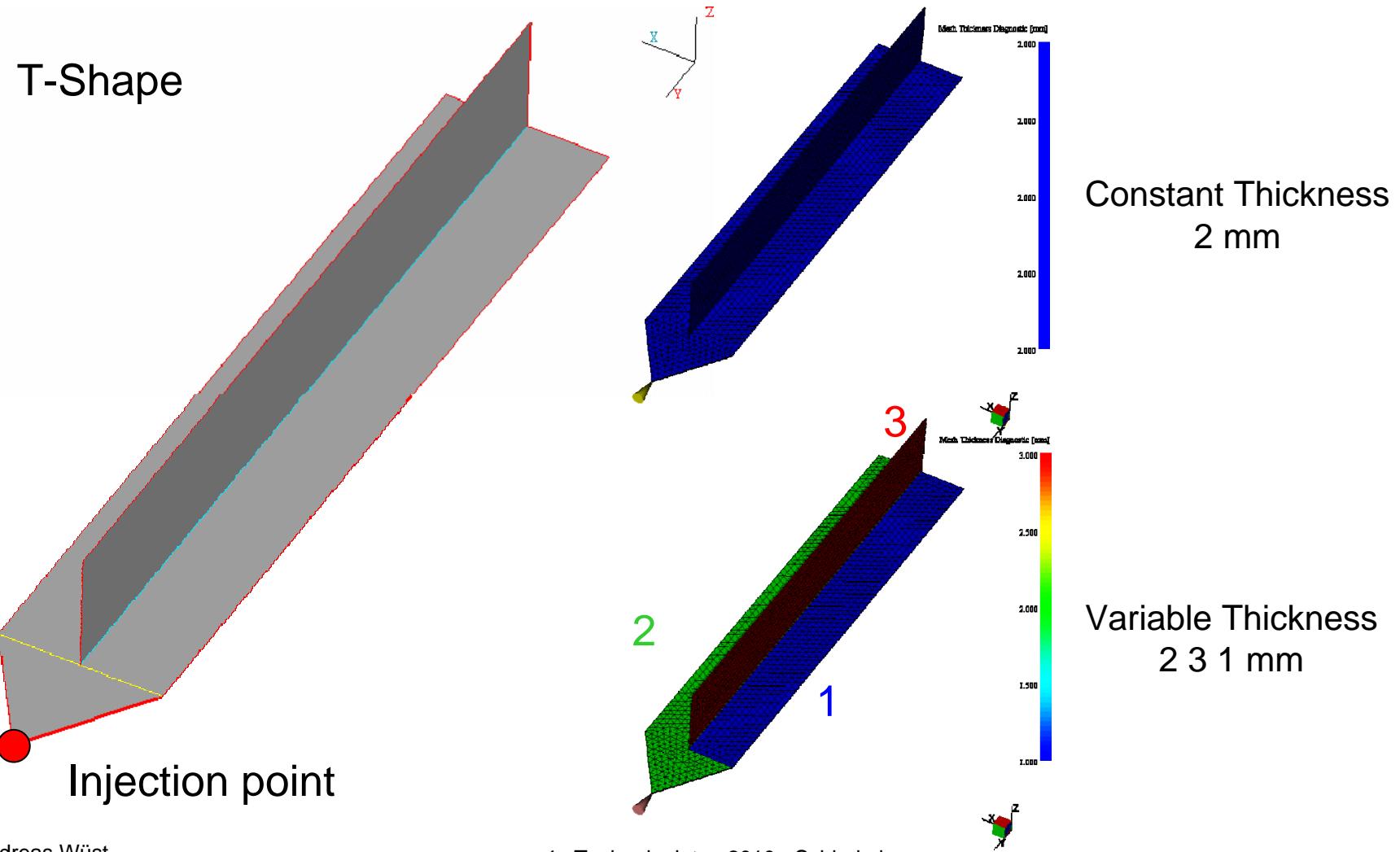
- Motivation → Integrative Approach
  - Process Induced Part Properties → ULTRASIM™
  - ULTRASIM™ Examples
  - State of the Art Optimization Example
- Influence of Integrative Approach on the Optimization Workflow
- Example
  - Injection molded plastic part with manufacturing, shape, thickness parameters
- Summary
- Outlook and Vision

# Motivation

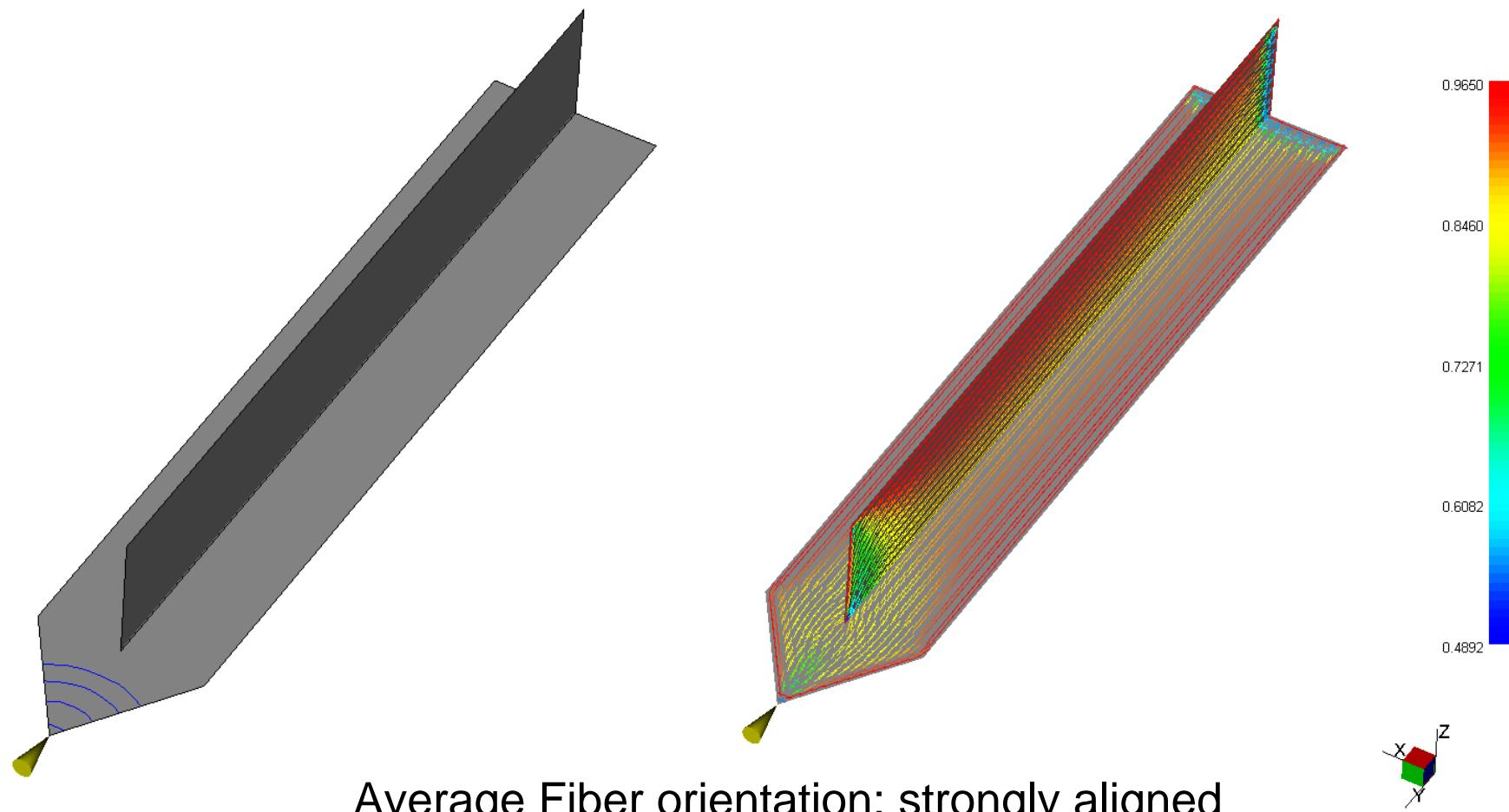
## Standard Optimization and Integrative Approach



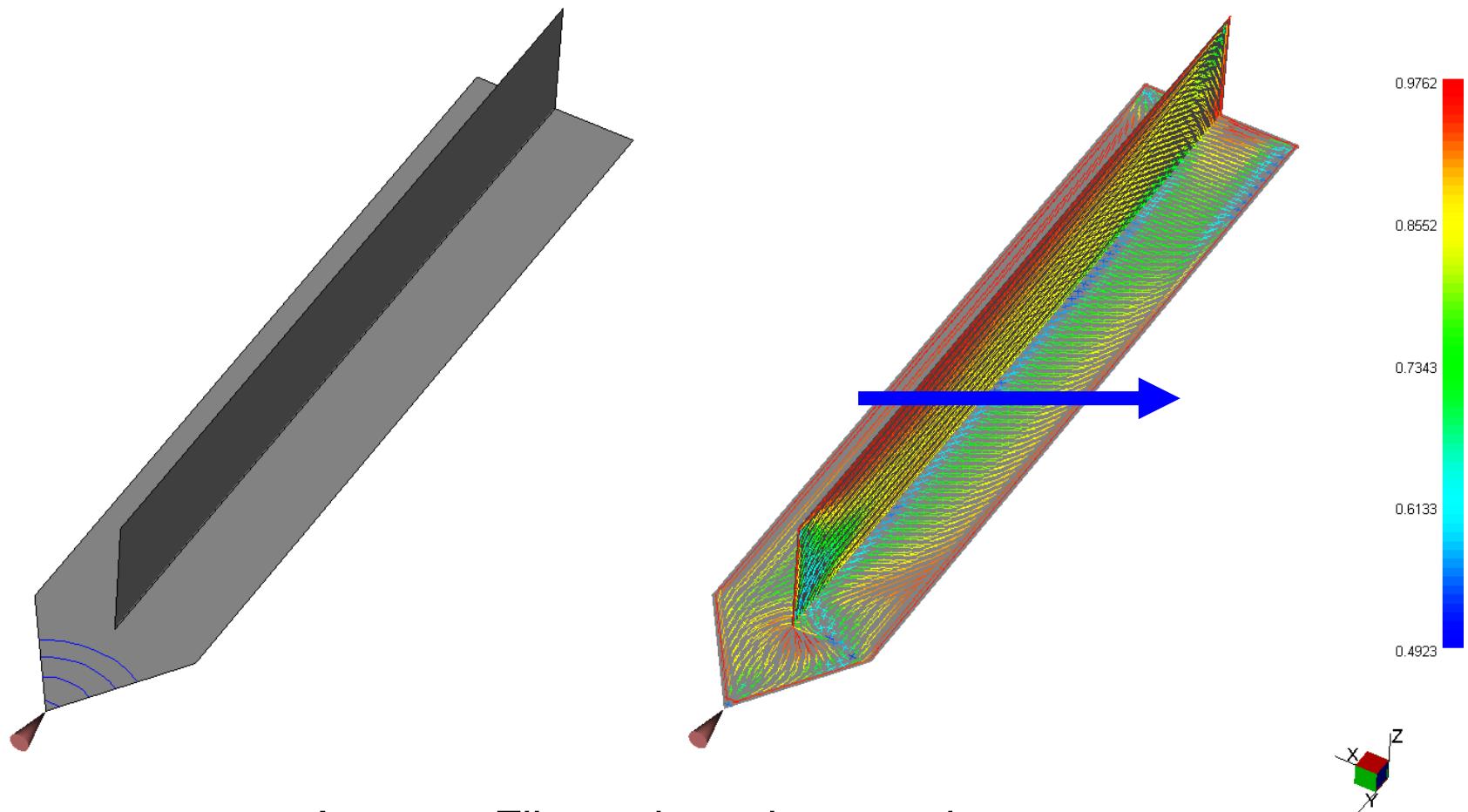
# Injection molding



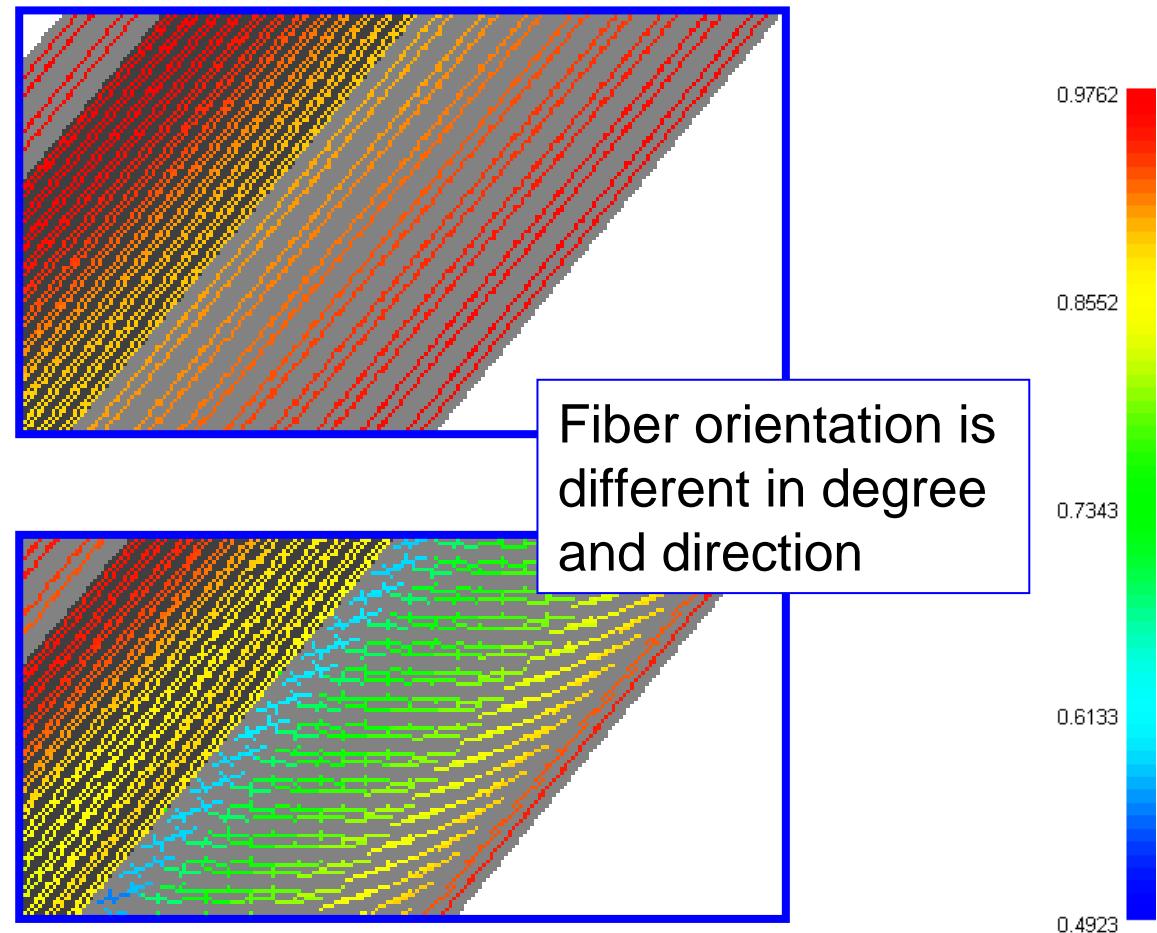
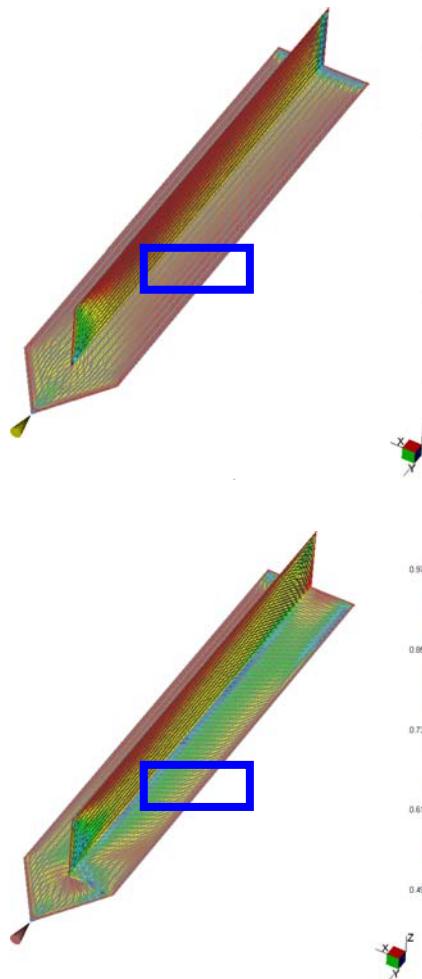
# Injection molding – T-Shape Constant thickness



# Injection molding – T-Shape Variable thickness

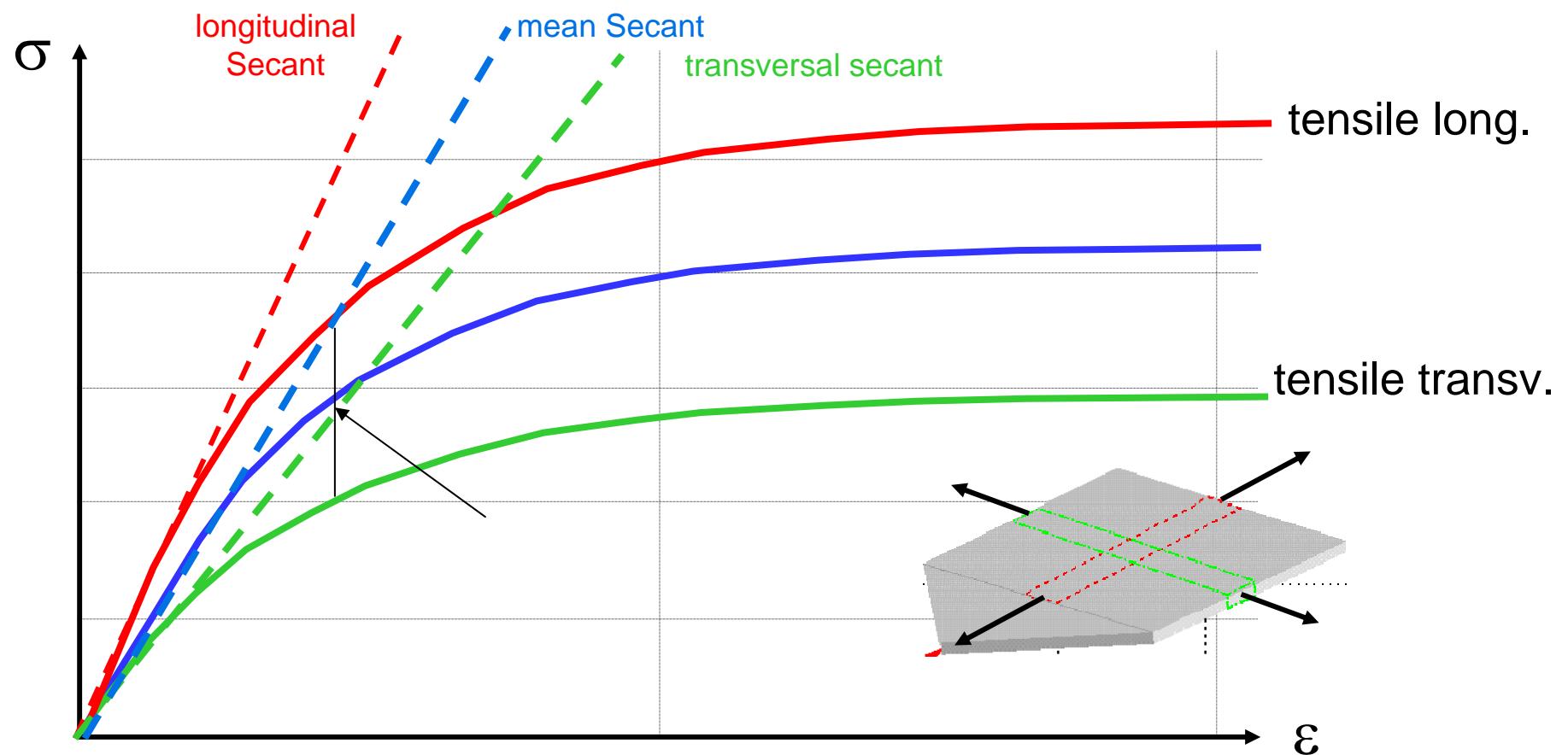


# Fiber Orientation



# Influence of Fiber Orientation on mechanical behaviour

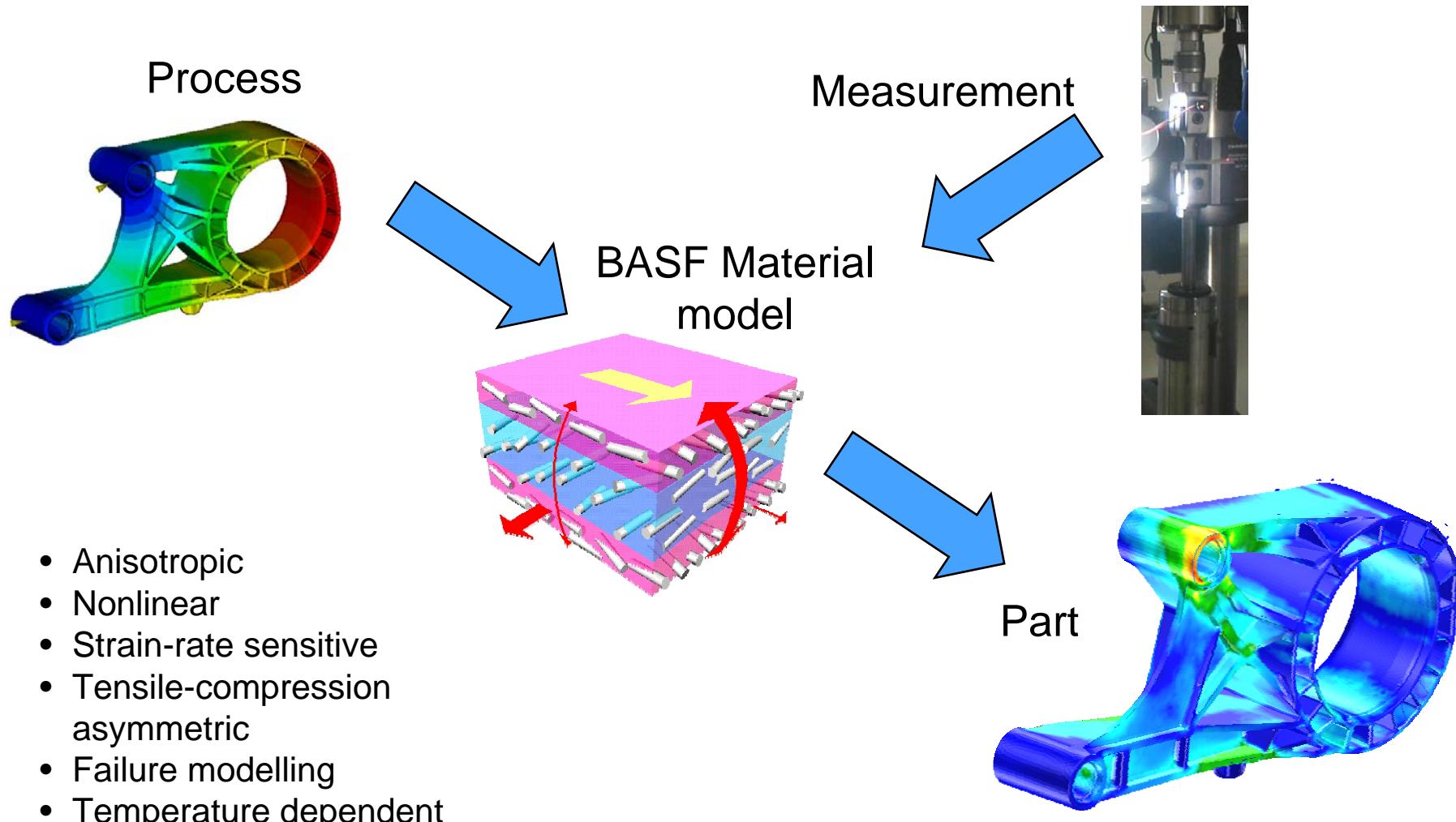
Anisotropy due to fiber orientation



# Integrative Simulation ULTRASIM™

for short fiber reinforced thermoplastics

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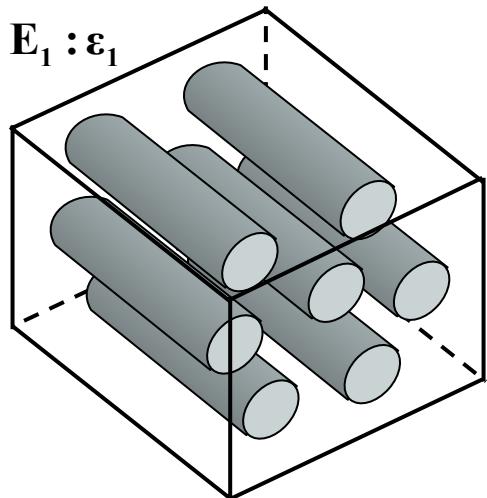
# Homogenization of fibers and polymer

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## Mean Field Theory

$$\sigma_0 = E_0 : \varepsilon_0$$

$$\sigma_1 = E_1 : \varepsilon_1$$

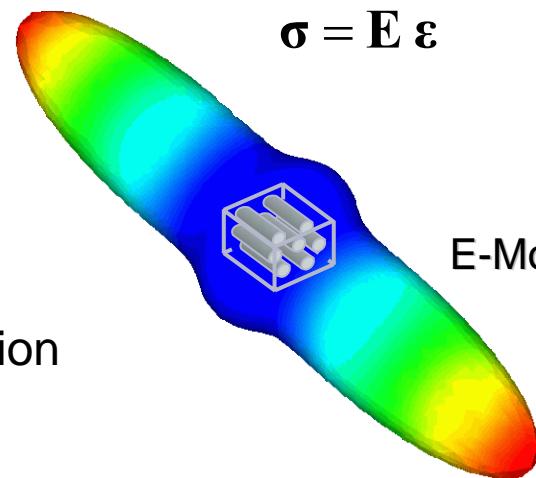


(Mori and Tanaka, Tandon and Weng)

Homogenization

$$\bar{\sigma} = \bar{E} \bar{\varepsilon}$$

E-Modul



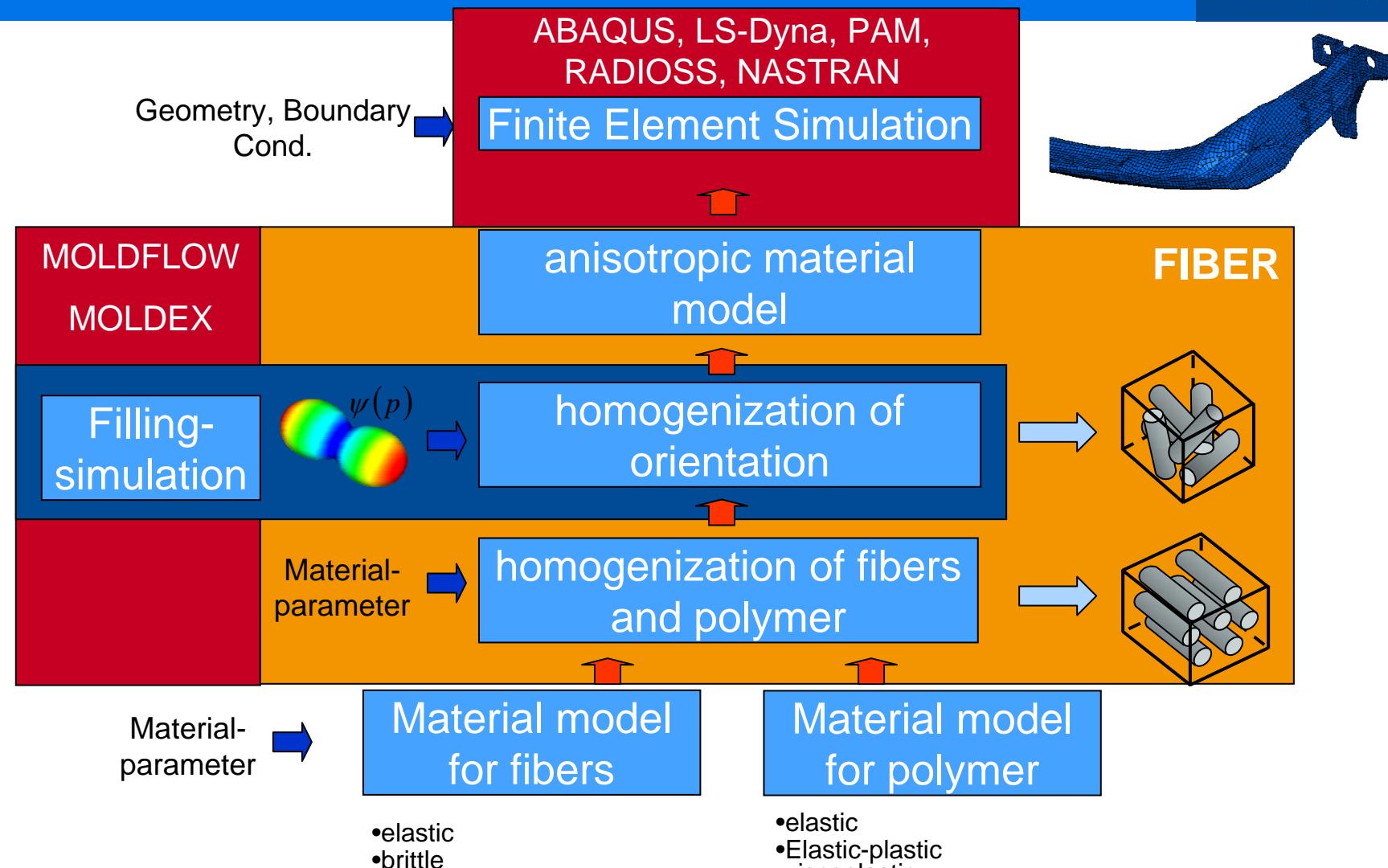
$$\bar{E} = [c_1 E_1 : B^\varepsilon + (1 - c_1) E_0] : [c_1 B^\varepsilon + (1 - c_1) I]^{-1}$$

$$B^\varepsilon = (I + \mathcal{E}_{(I,\omega)} : [E_0^{-1} : E_1 - I])^{-1} \quad \mathcal{E}_{(I,\omega)} : \text{Eshelby Tensor}$$

# Integrative Simulation ULTRASIM™

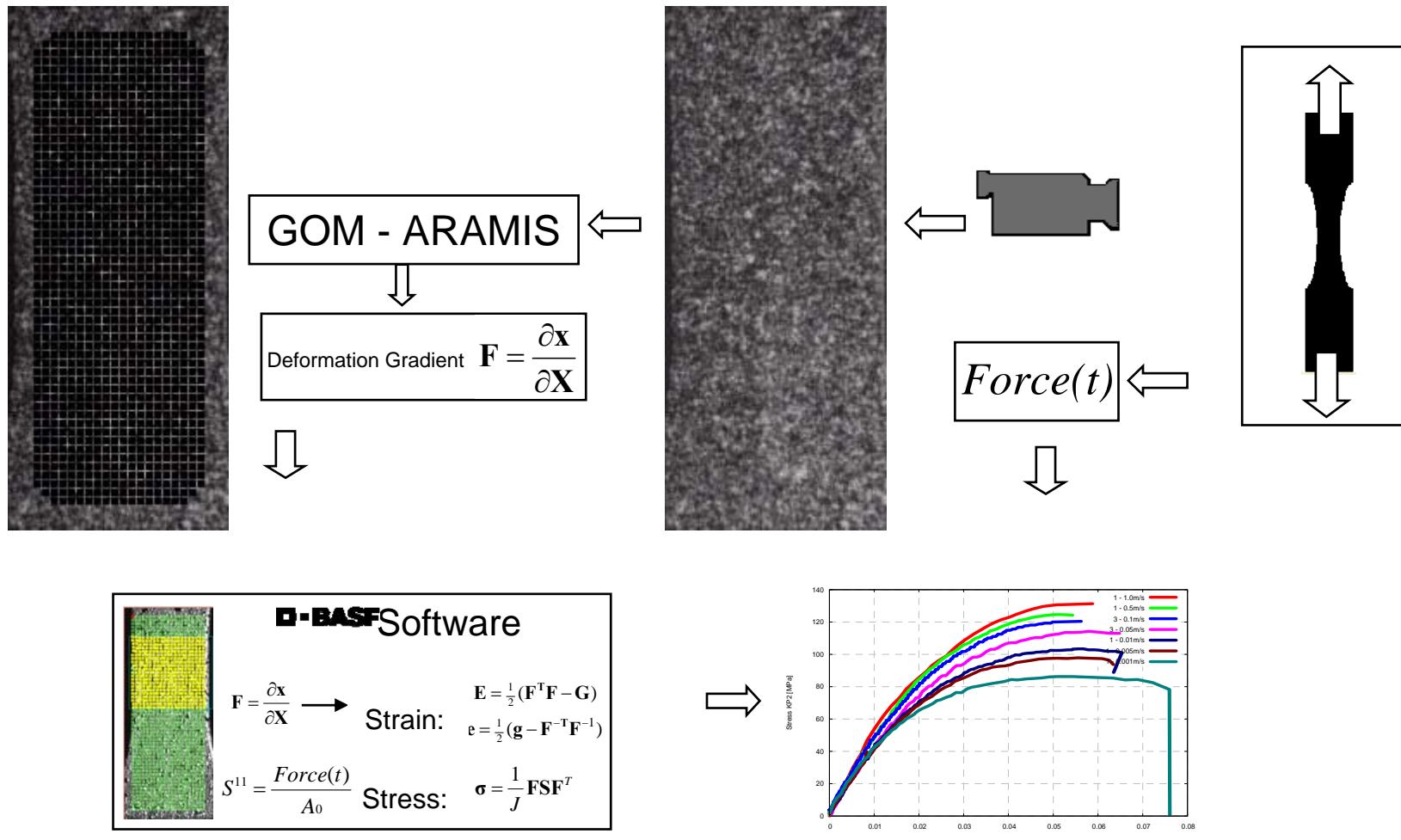
## Data flow structure

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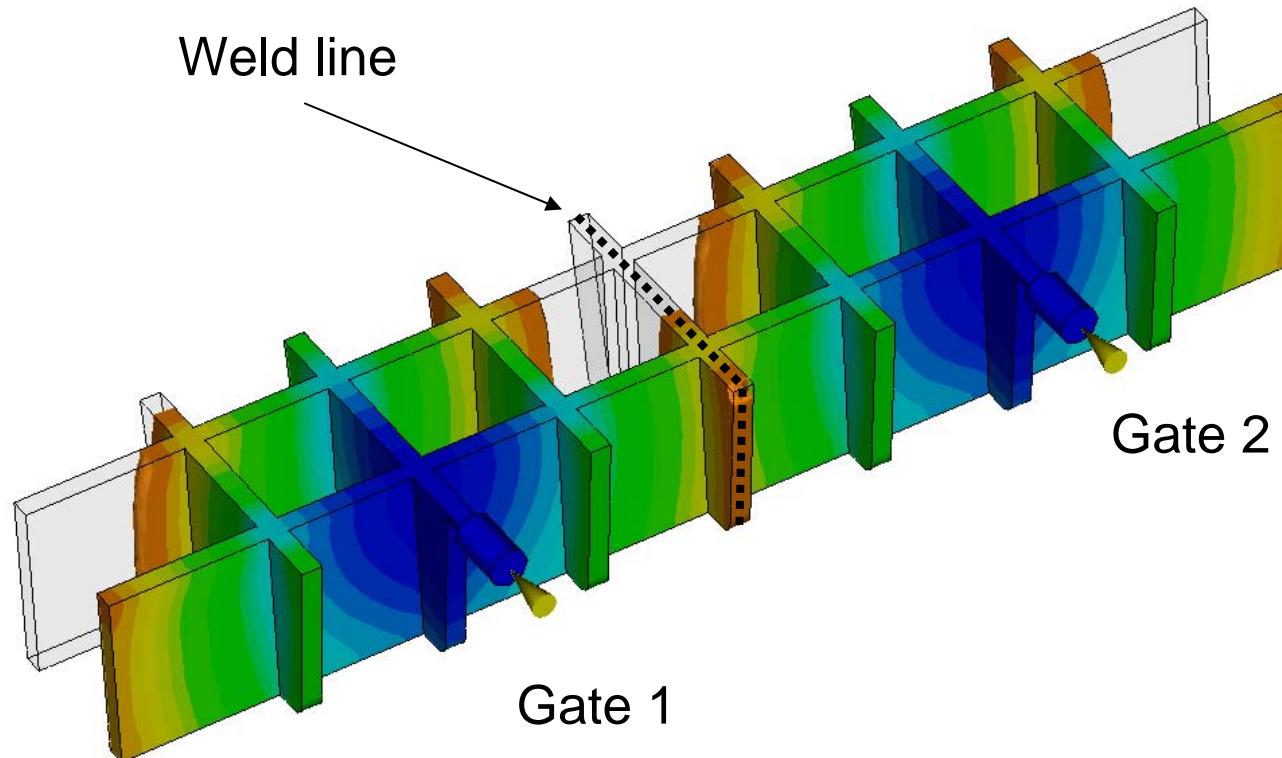


# Material Measurements

## Data Flow

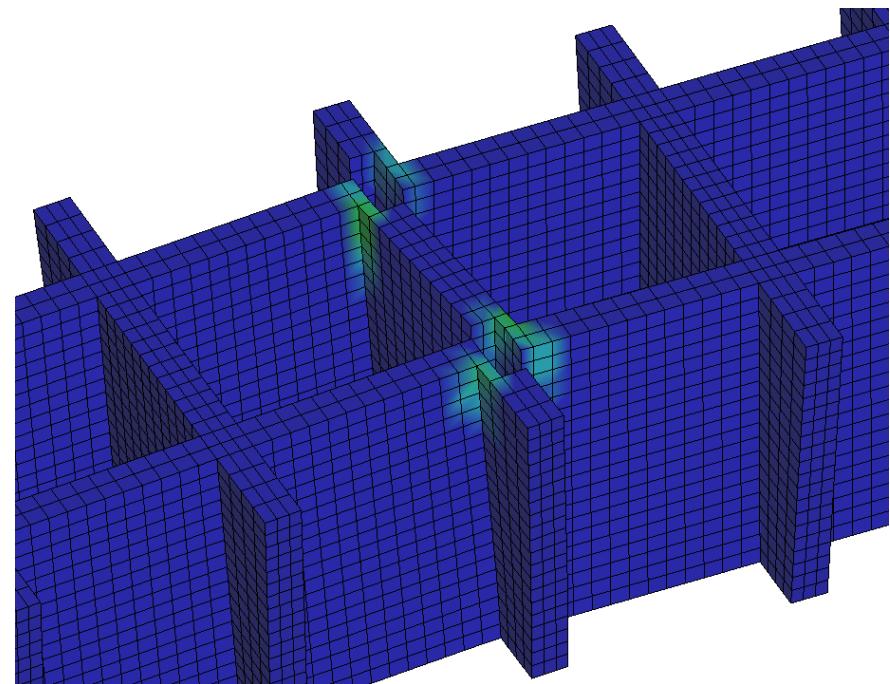
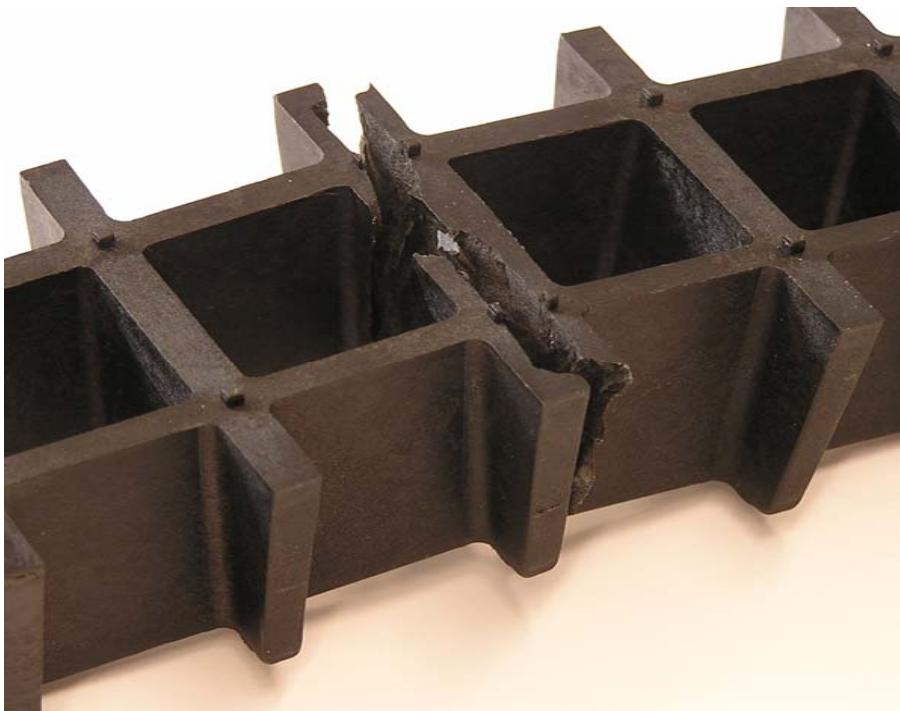


# Filling pattern and weld line



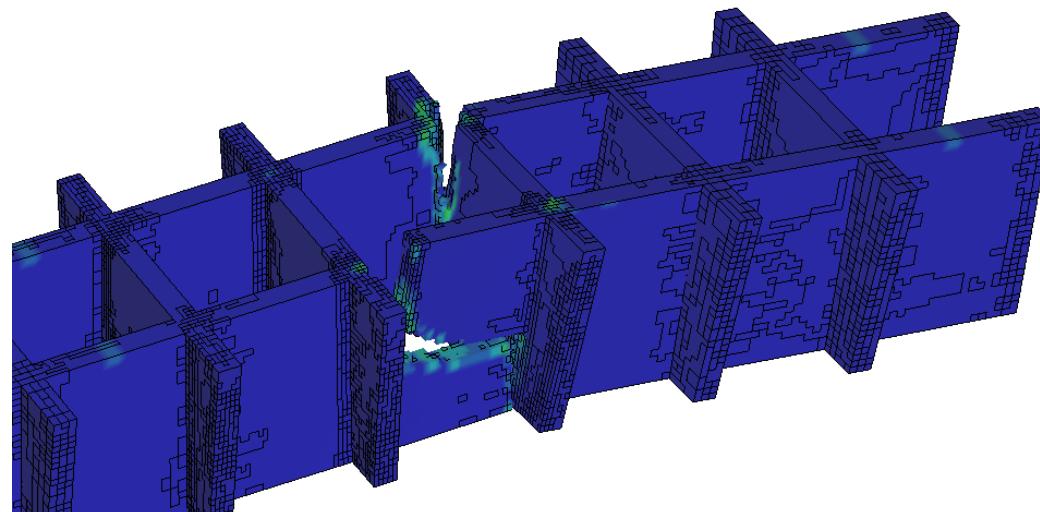
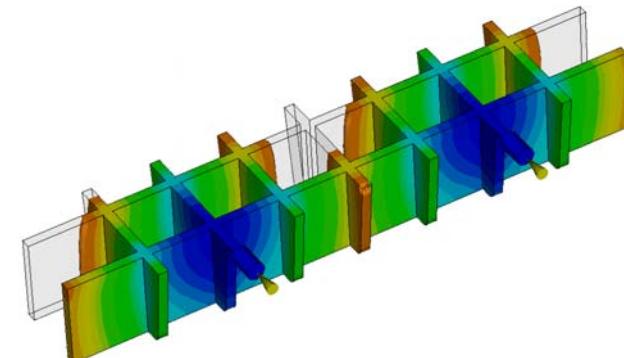
# Failure in weld line - symmetric bending

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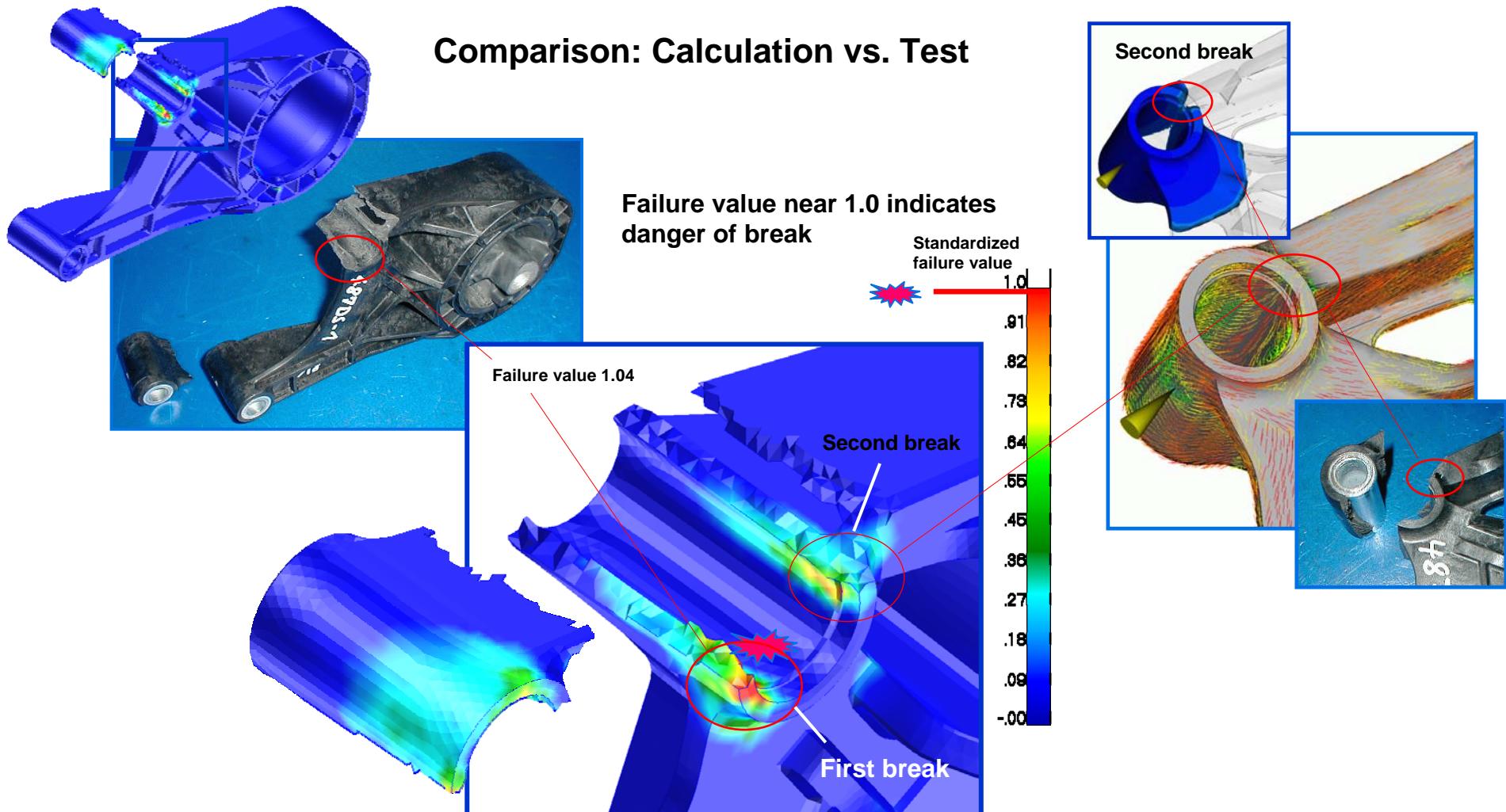
# Complex Material behaviour

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# Precise Forecast of Failure through Integrative Simulation ULTRASIM™

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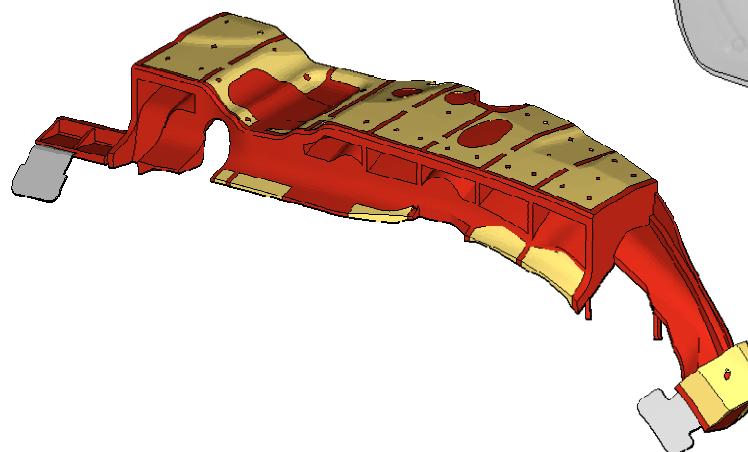


# Structural Insert PSA 308 SW

Serial Application since 01/2008



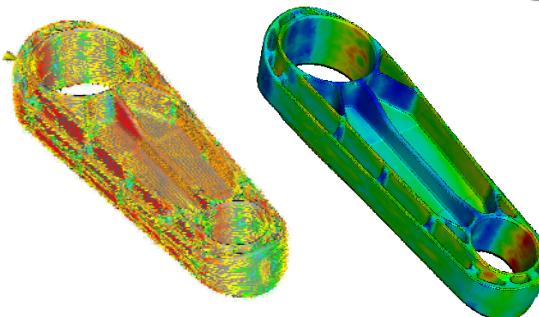
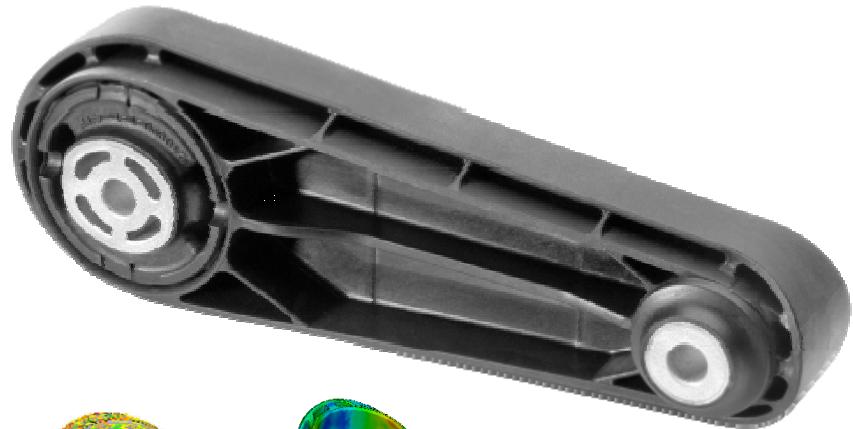
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# Panamera S / Turbo: Torque Mount

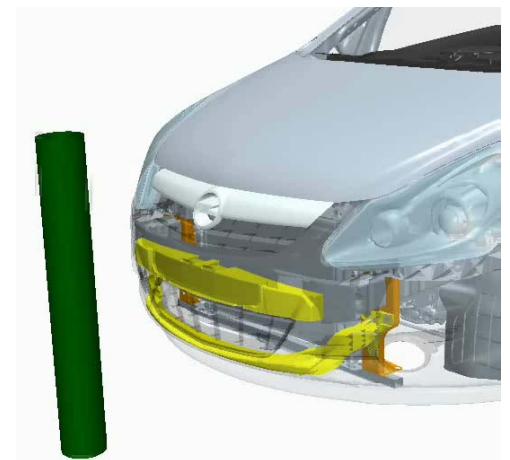
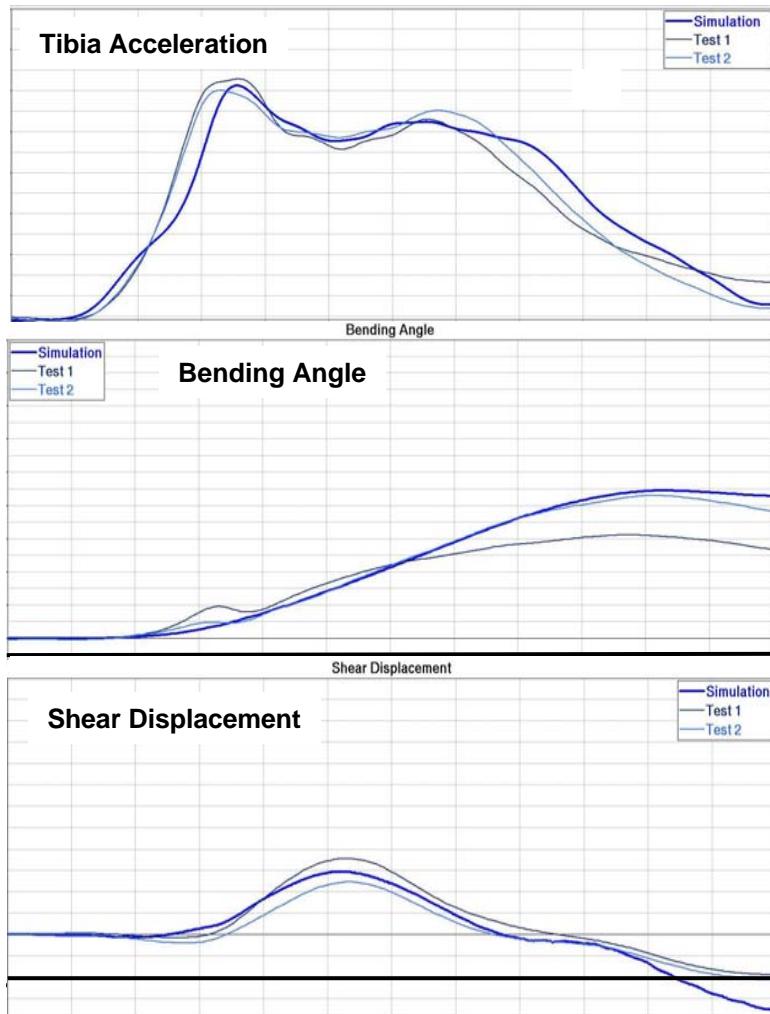
SOP 9/2009

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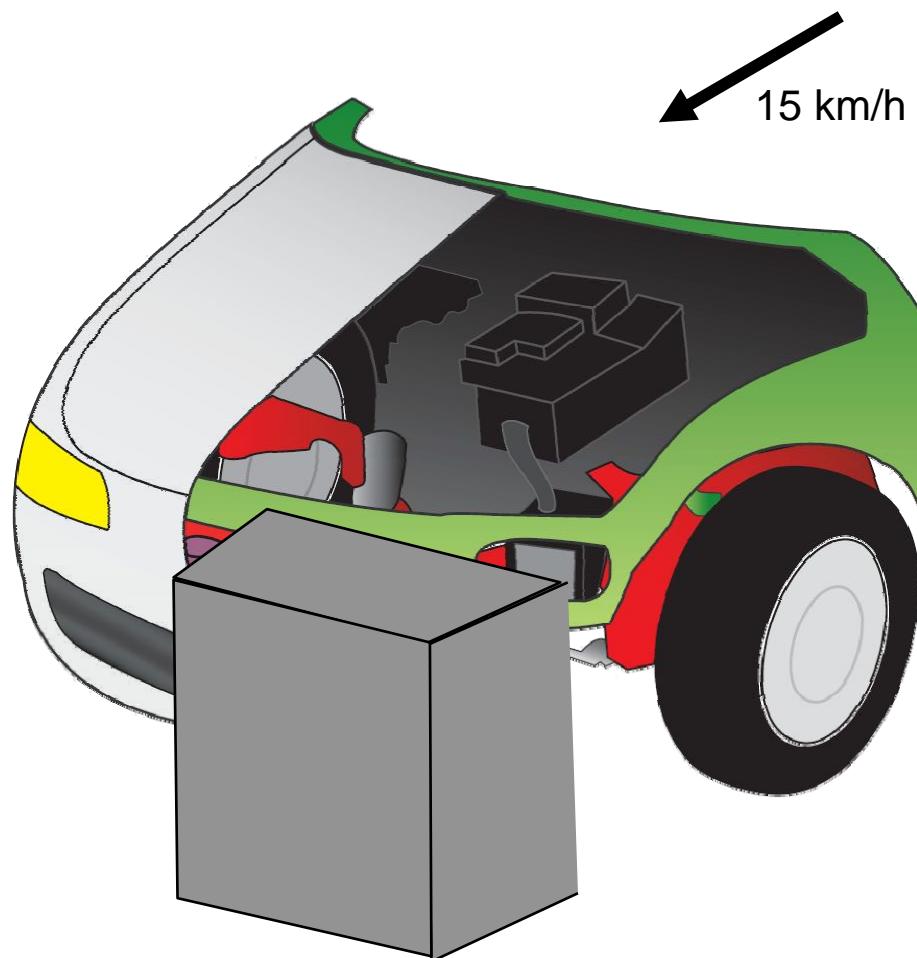
# Leg Impact Correlation to Test:

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# AZT-Test for insurance classification

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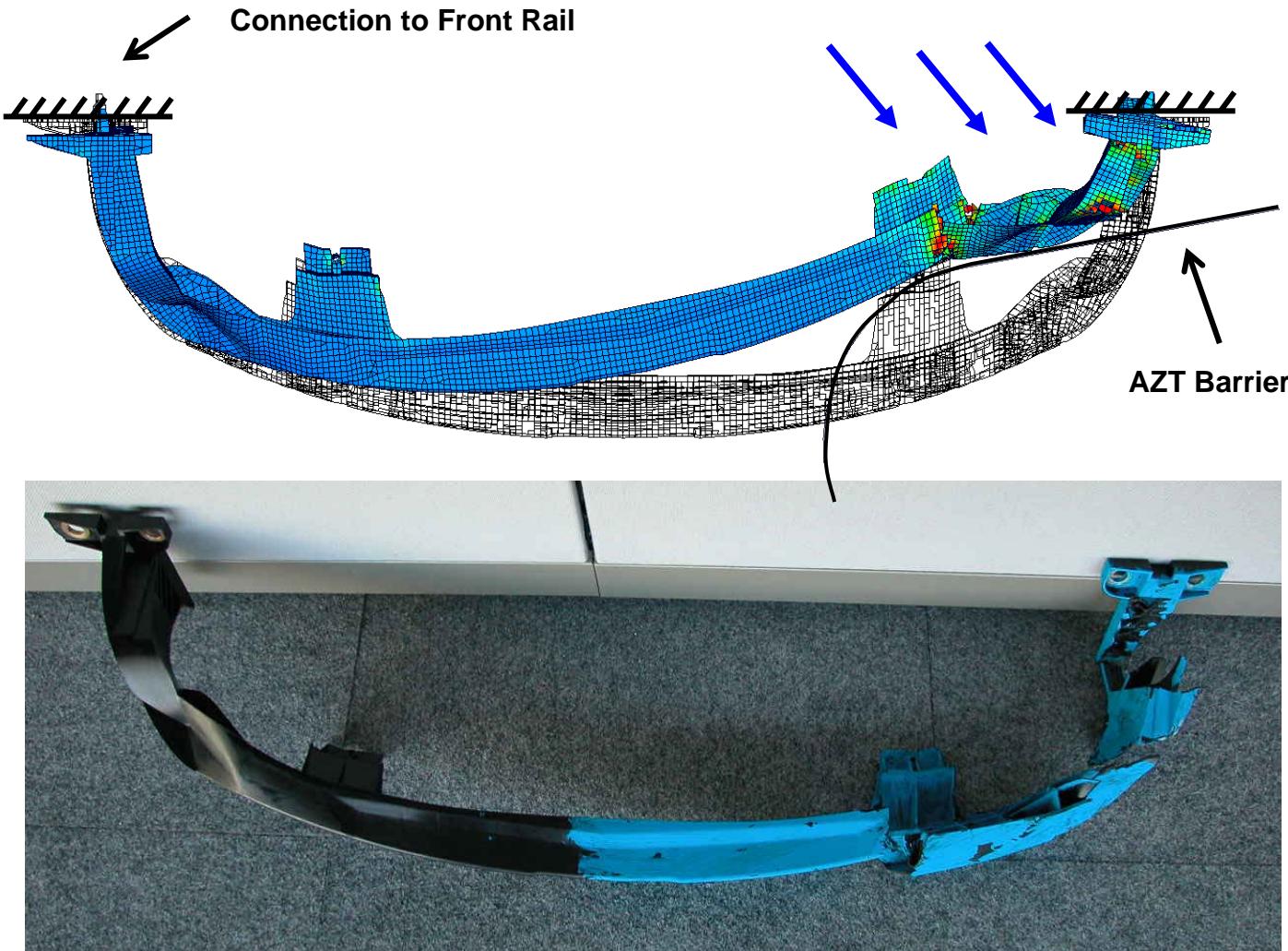
**Source Opel**

Upper support  
structure

# Vehicle Performance AZT Test

Source: Opel

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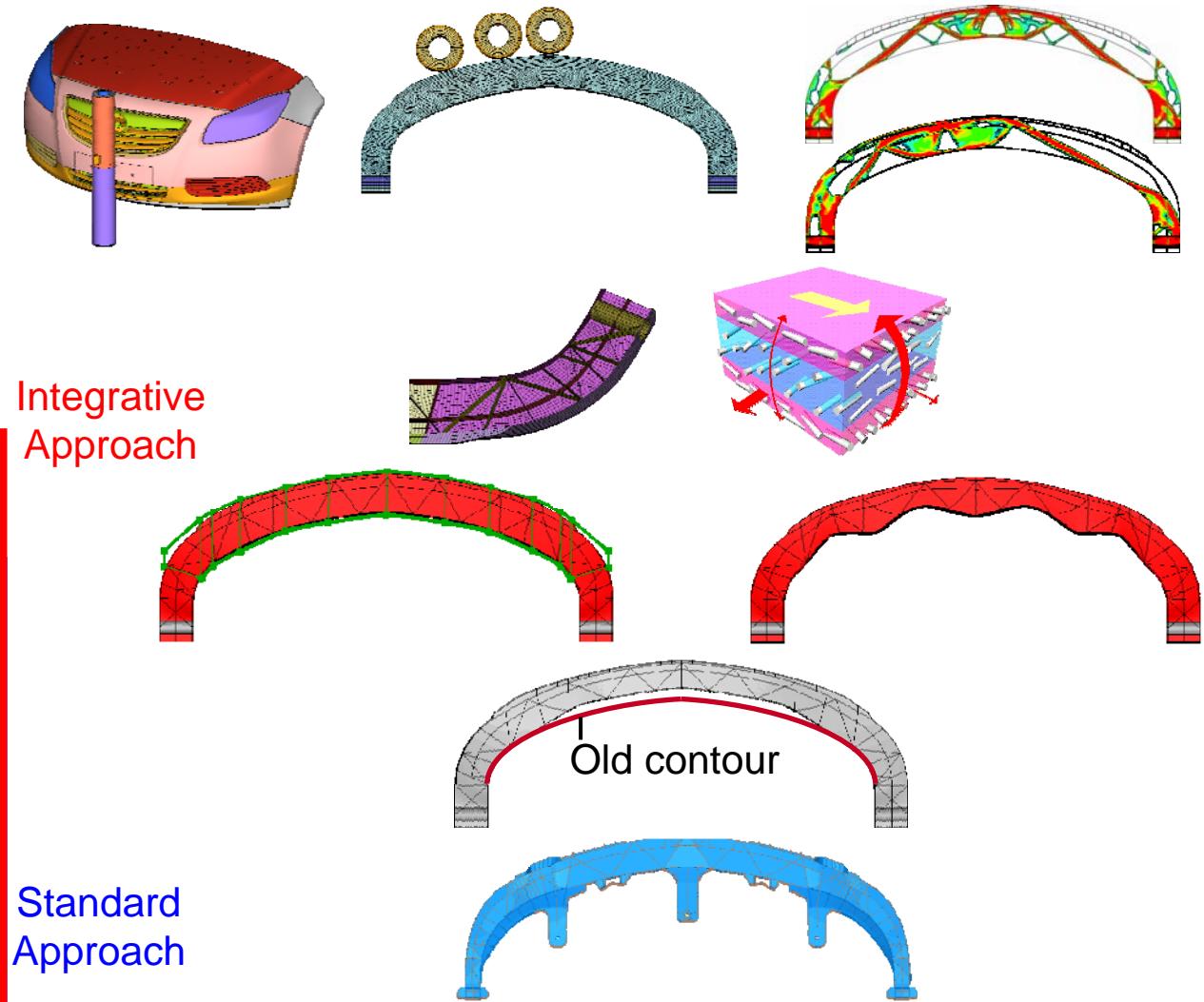
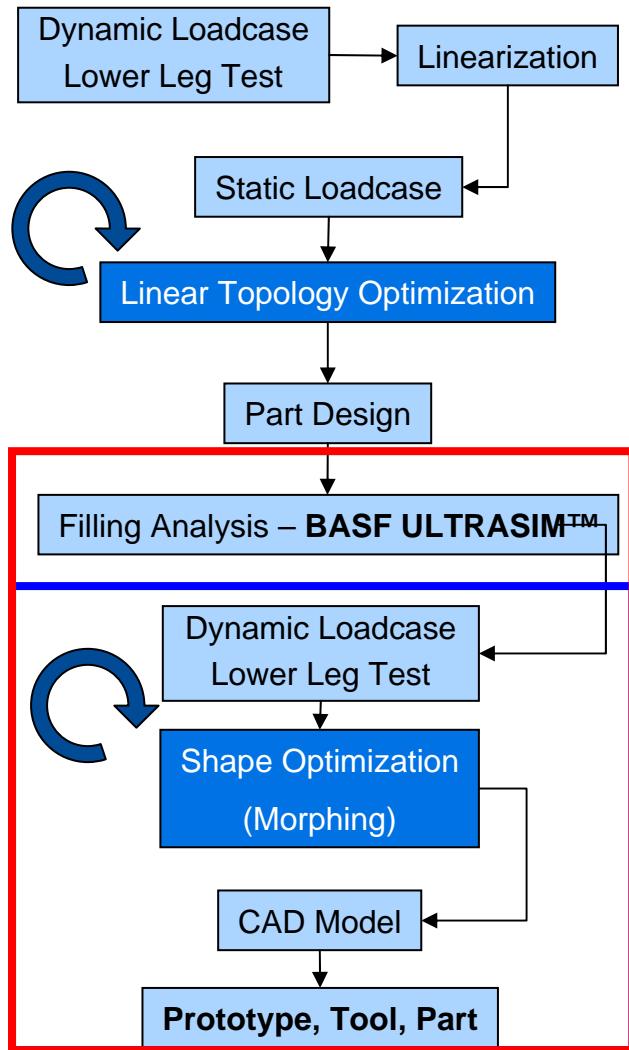


AZT Simulation  
(vehicle removed  
for visualization)

LBS after AZT  
test

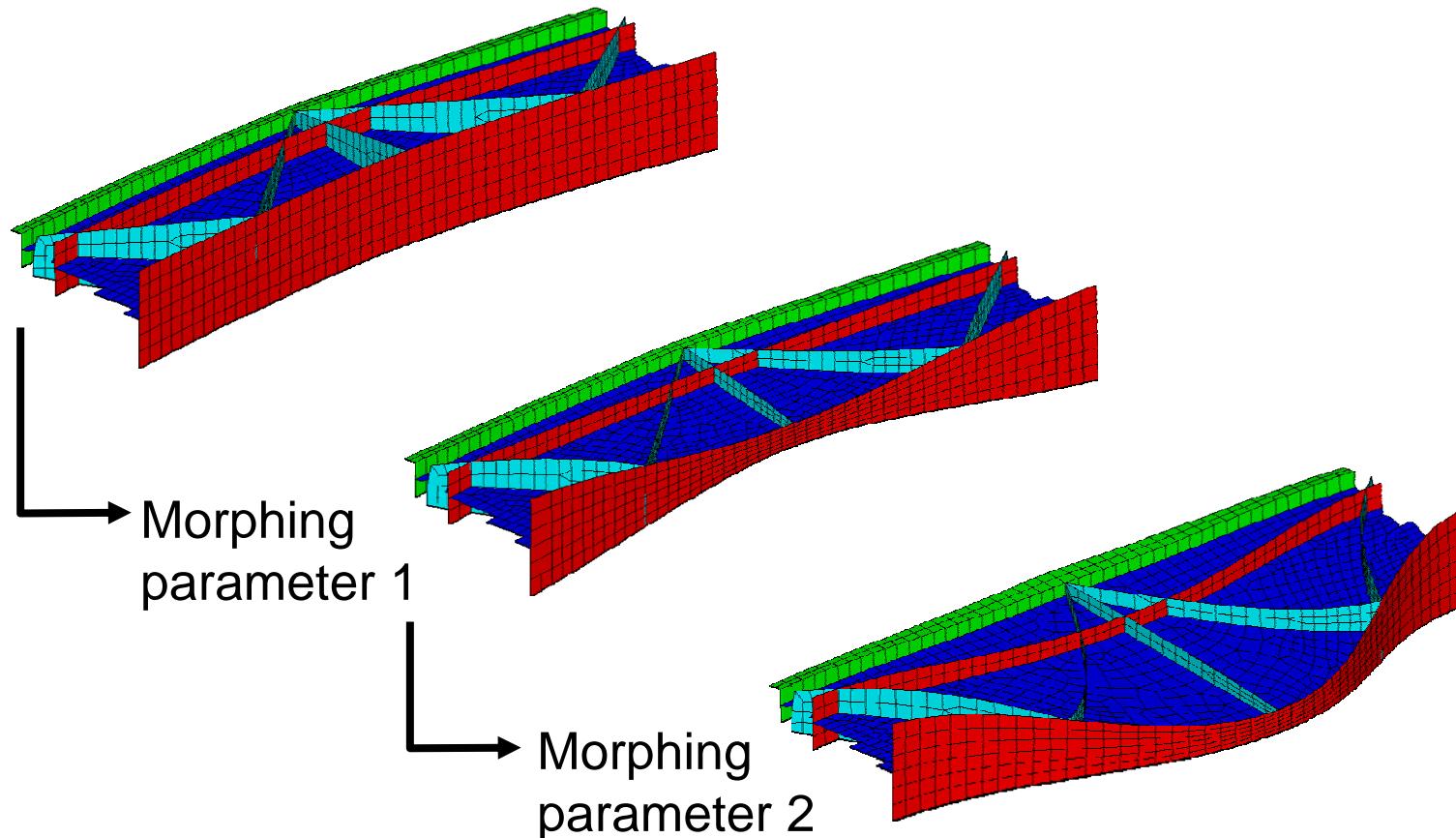
# LBS Optimization using ULTRASIM™

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# Shape Optimization using Morphing

Goal: reduce weight without significantly losing performance



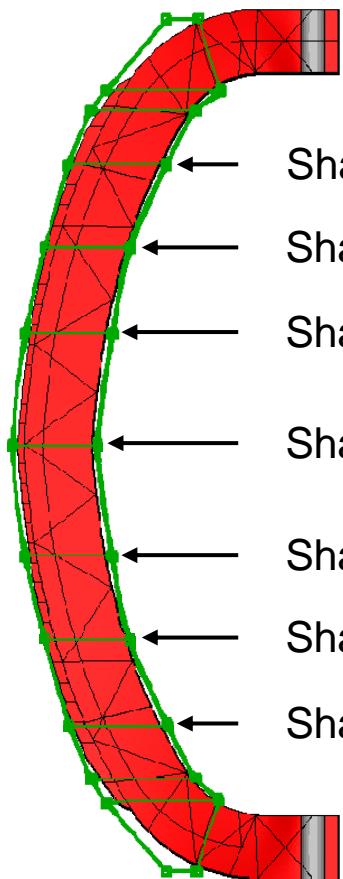
# Optimization in CAE

## Nonlinear Shape Parameter Optimization

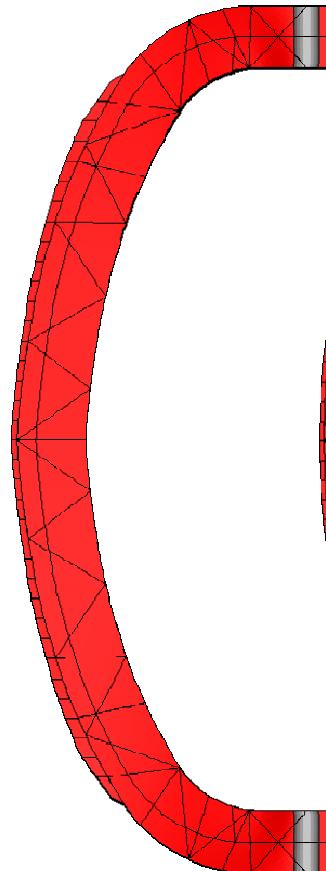
Morphing of the part's rear edge: selected shape combinations



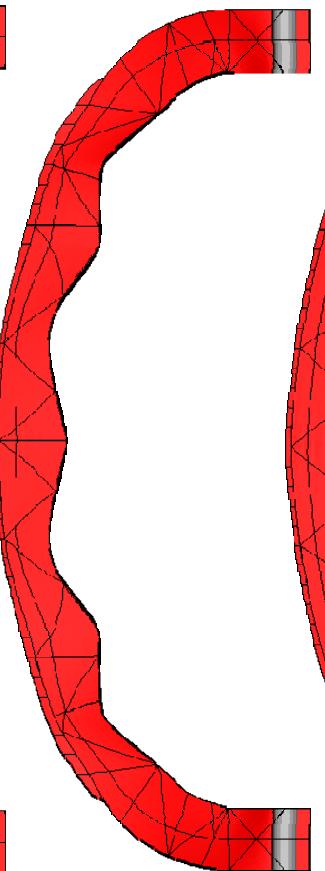
Shape: 1 – 2 – 3 – 4 [mm]



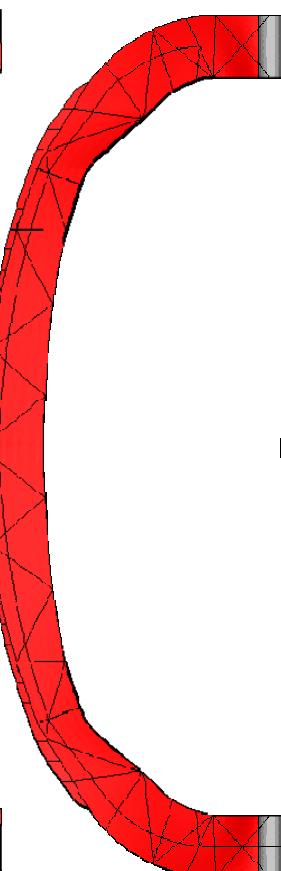
0-0-0-0



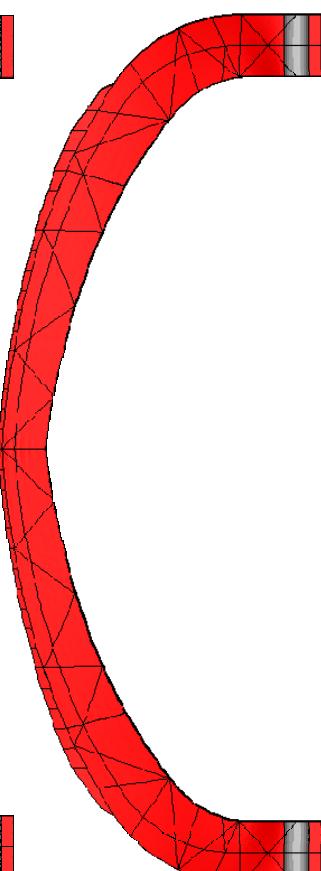
0-40-0-40



10-20-30-40



40-30-20-10



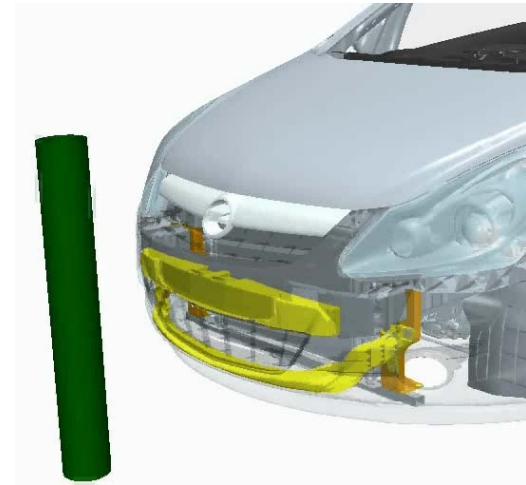
# Optimization in CAE

## Optimization procedure summary



Successive Response Surface Method  
Linear Response Surface  
D-Optimal Sampling with 4 Shapes results in 8 Jobs per Iteration / per Loadcase = 24 Runs per Iteration

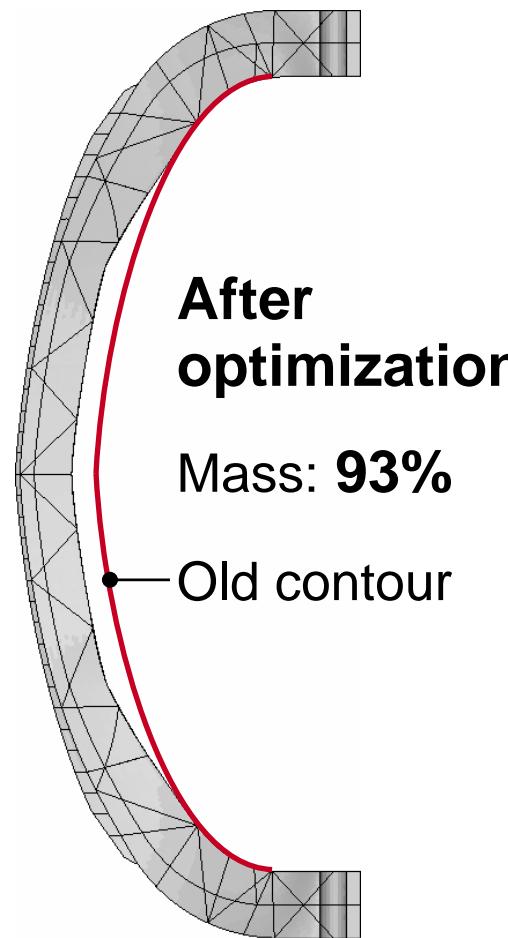
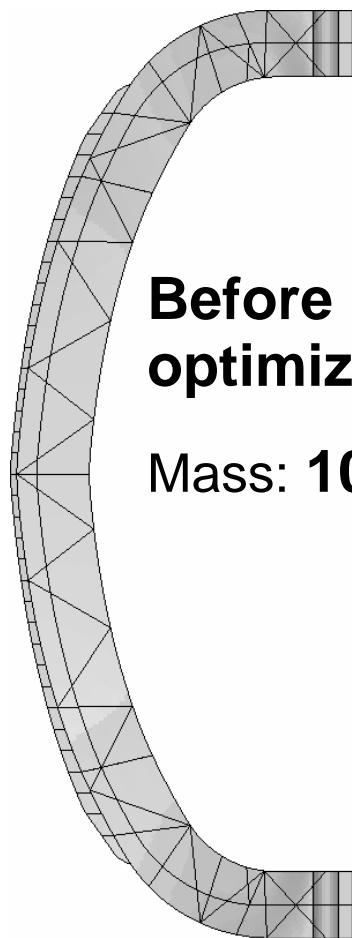
6 Iterations needed = 144 Runs



CPU time per loadcase: 3h on 8 Linux Opteron Processors  
 $3h \times 144 = 432 h$   
3 Jobs in parallel → Total time 144 h = 6 days

# Optimization in CAE

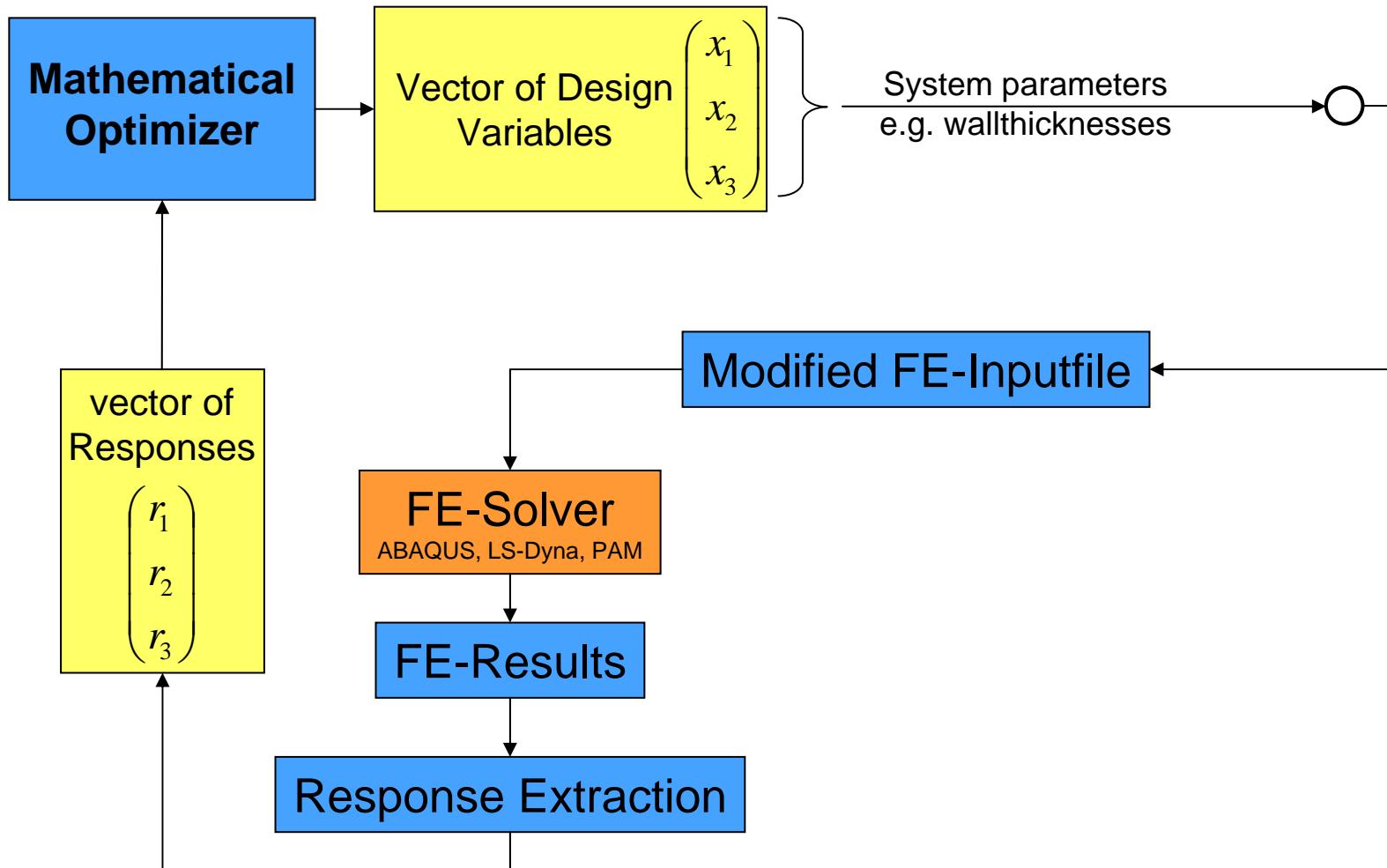
## Nonlinear Shape Optimization - Result



Shape Results  
(0-40 mm)

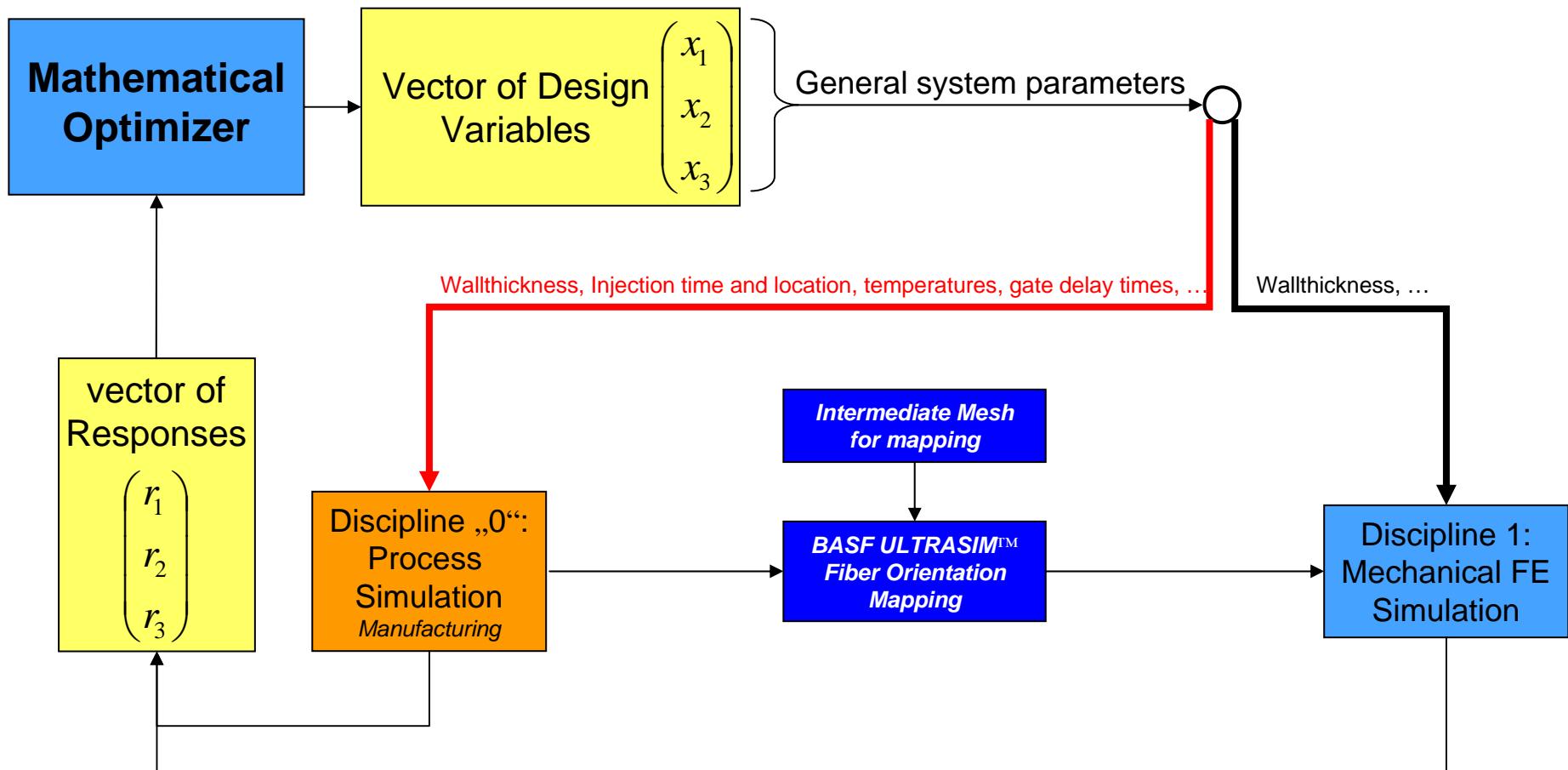
- 1: 31.0 mm
- 2: 30.5 mm
- 3: 32.0 mm
- 4: 10.1 mm

# Workflow for Standard Optimization Approach



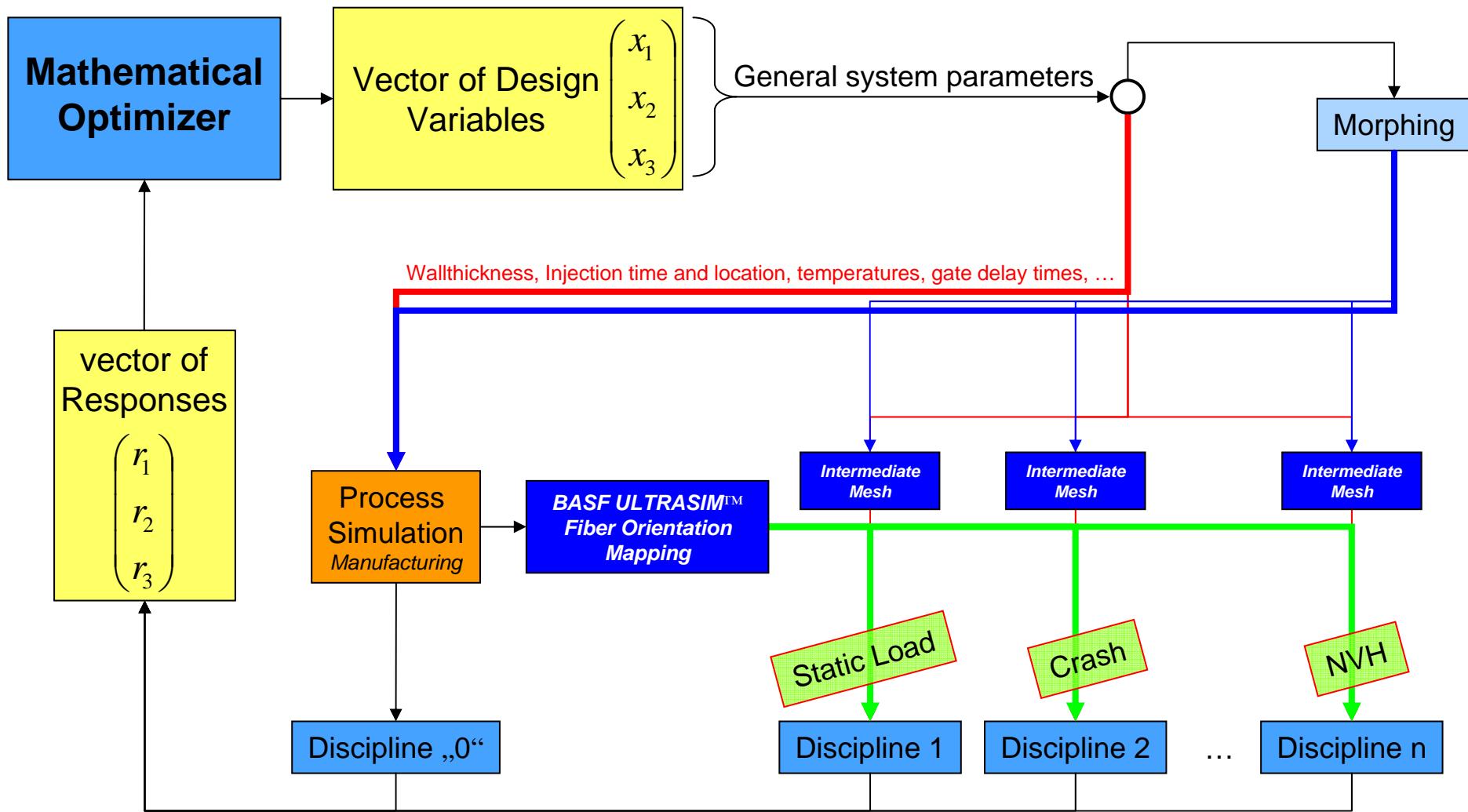
# Workflow for Integrative Optimization Approach

## Single disciplinary (without morphing)



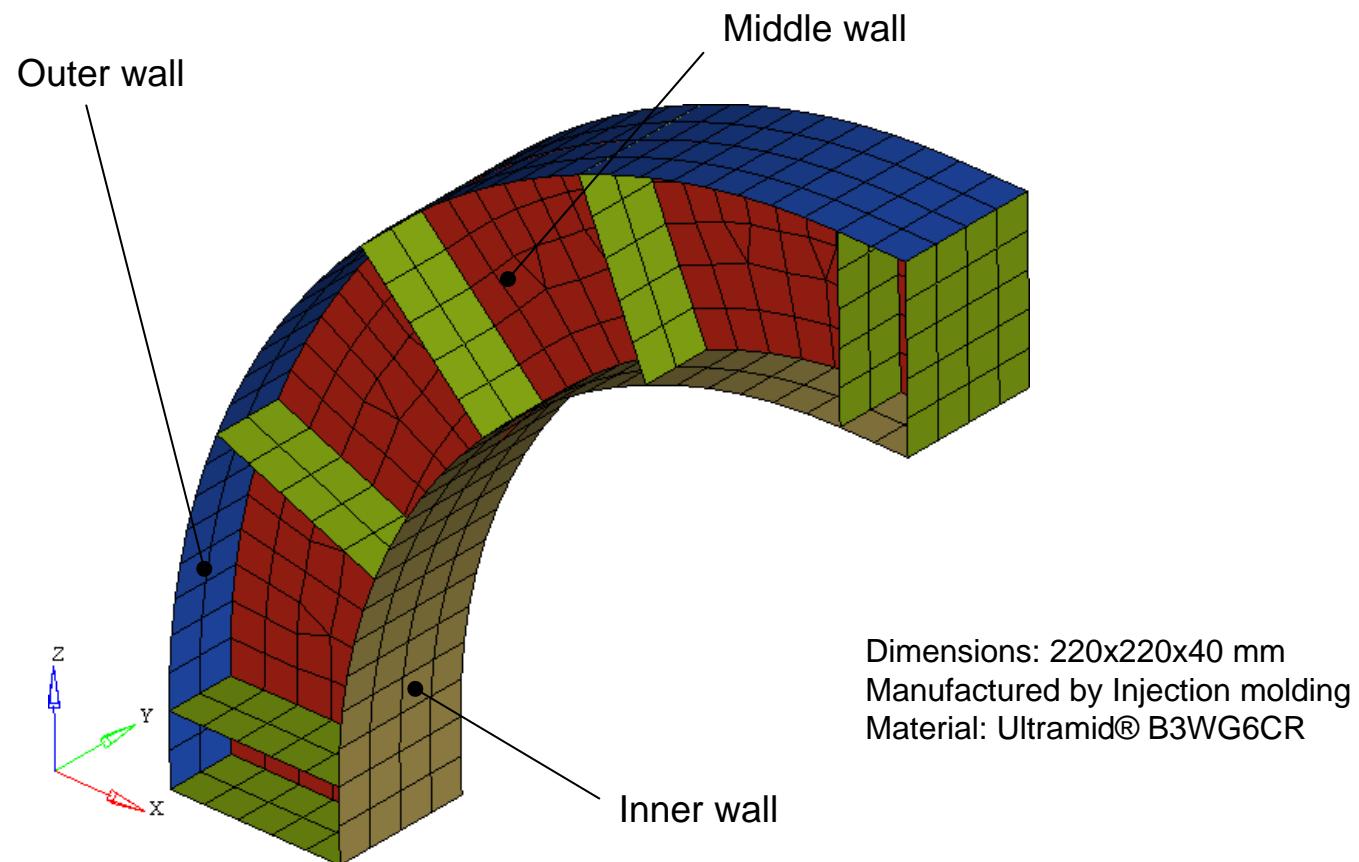
# Workflow for Integrative Optimization Approach

## Multi disciplinary (with morphing)



# Example

## Test geometry for Integrative Approach



# Optimization Setup – Integrative Approach

## Disciplines + Design Variables

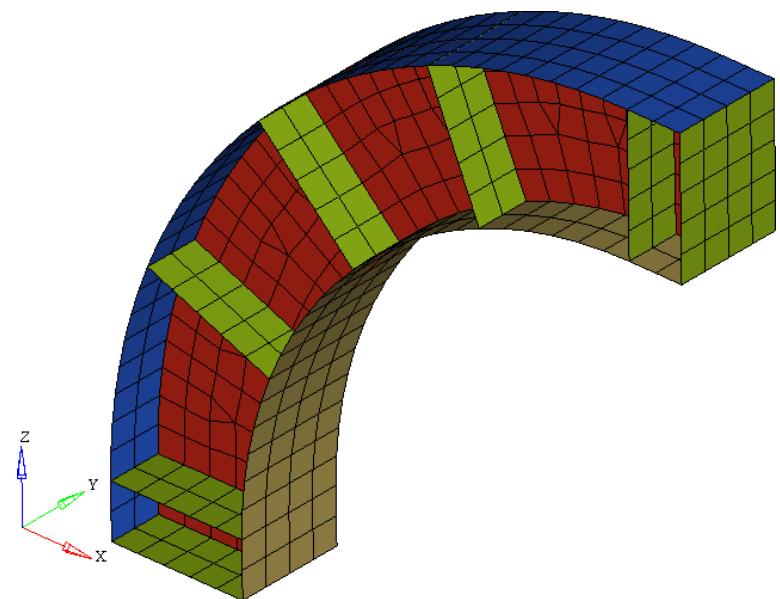


- A: Filling Study      MOLDFLOW
- B: Warpage Simulation      MOLDFLOW
- C: Impact Analysis      LS-Dyna

Possible Design Variables

Manufacturing Variables

- Inner wall thickness
- Outer wall thickness
- Middle wall thickness
- Morph Shape
- Gate location
- Injection Time
- Melt temperature
- Tool temperature



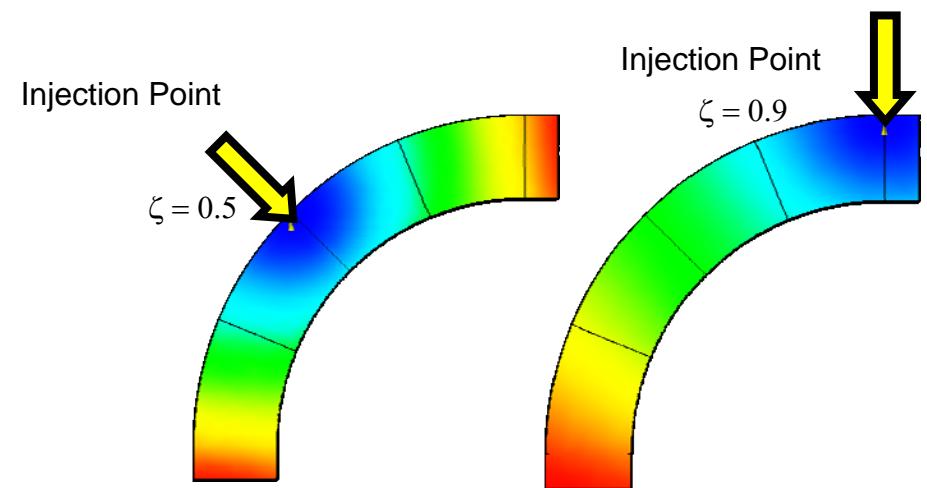
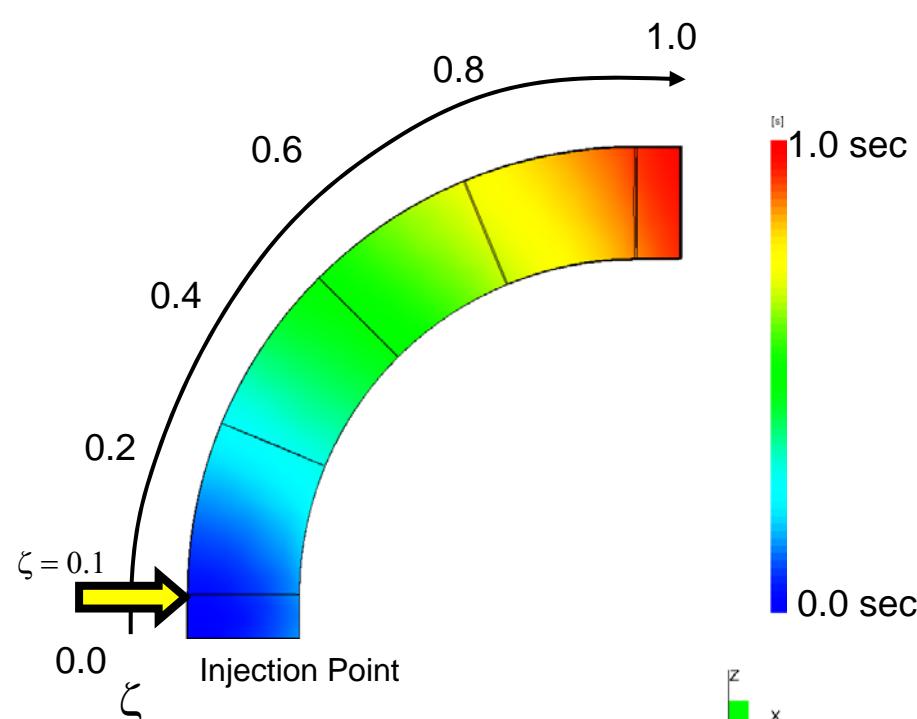
# Design Variable: Injection location

## Parametric Definition of Injection Point



Material: Ultramid® B3WG6CR

Colours indicate the fill time



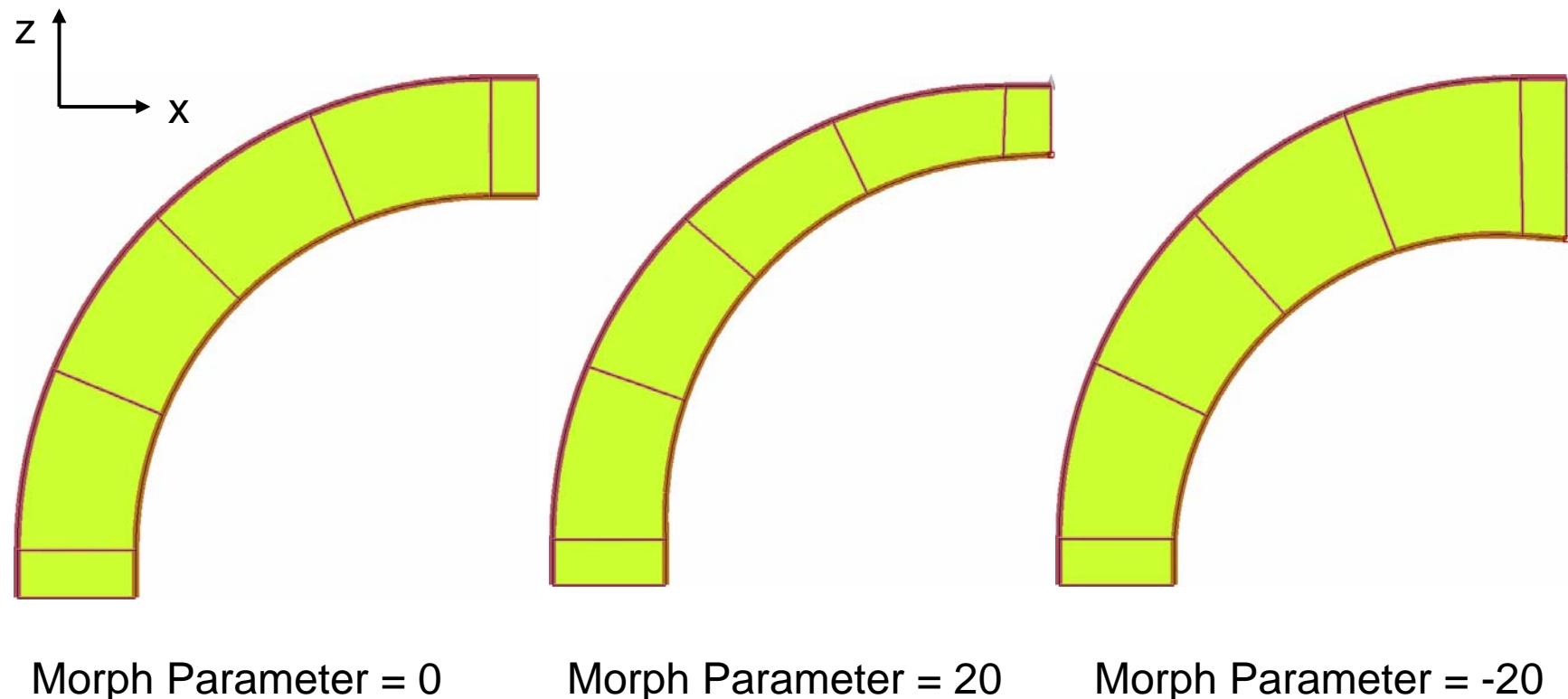
Parameter value  $\zeta$  is mapped onto node list

Additional process DVs which could be used in Filling Simulation:  
Melt temperature, tool temperature, injection time, injection location, ...

# Design Variable: Morphing Shape

## Visualization of shape changes by morphing (ANSA)

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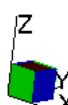
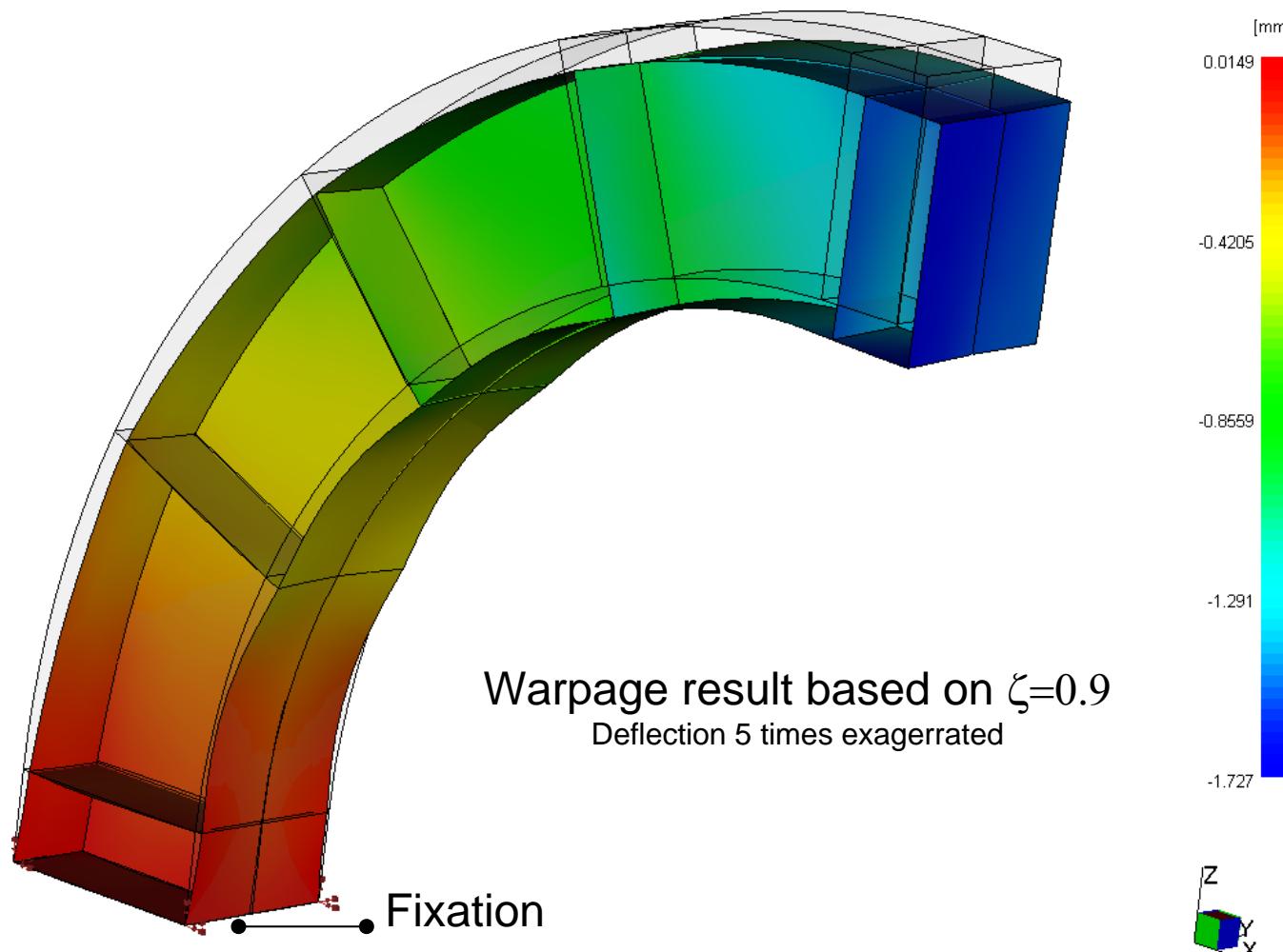
Morph Parameter = 0

Morph Parameter = 20

Morph Parameter = -20

# Example

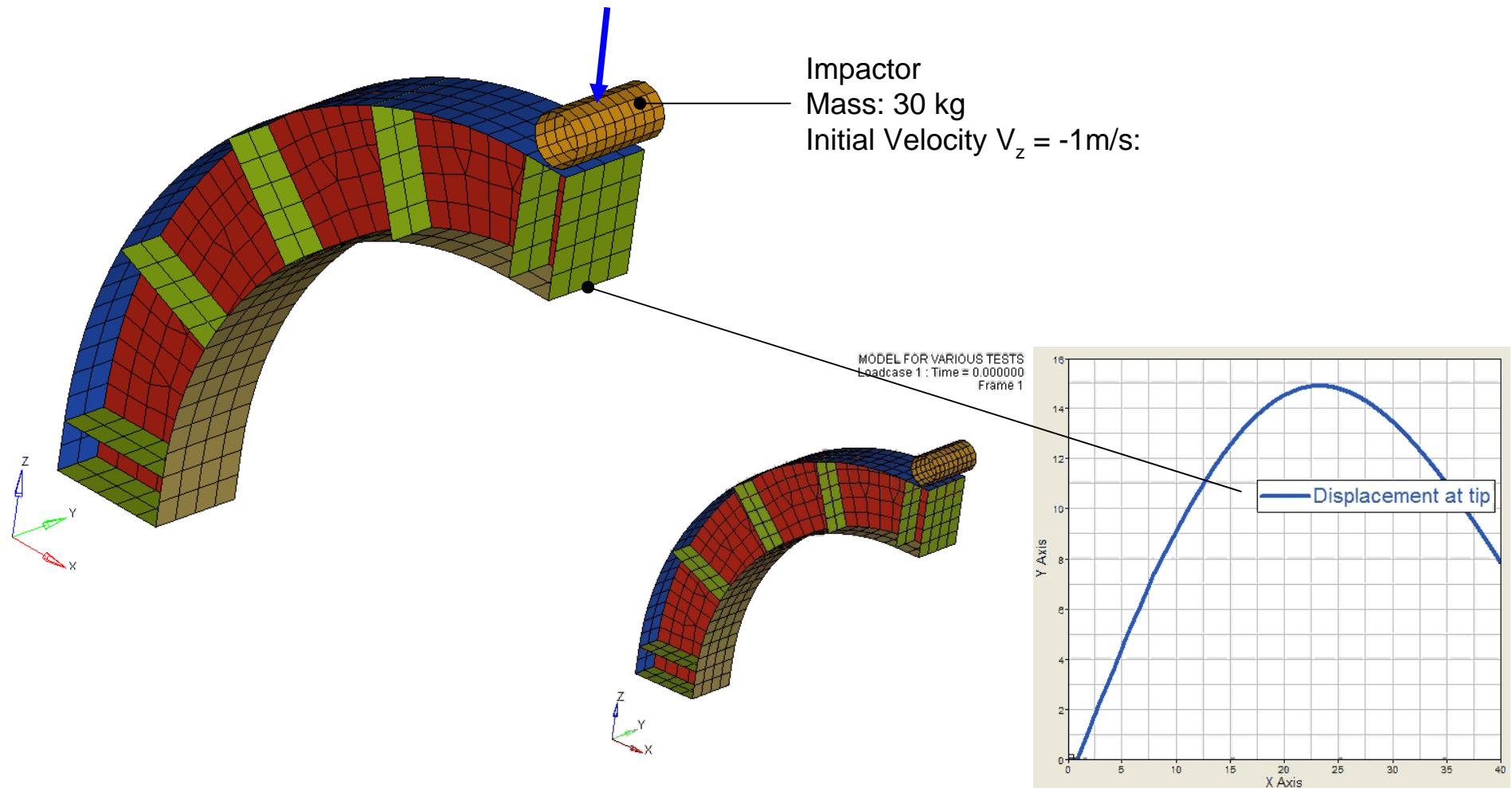
## Discipline B: Warpage Simulation with MOLDFLOW



# Example

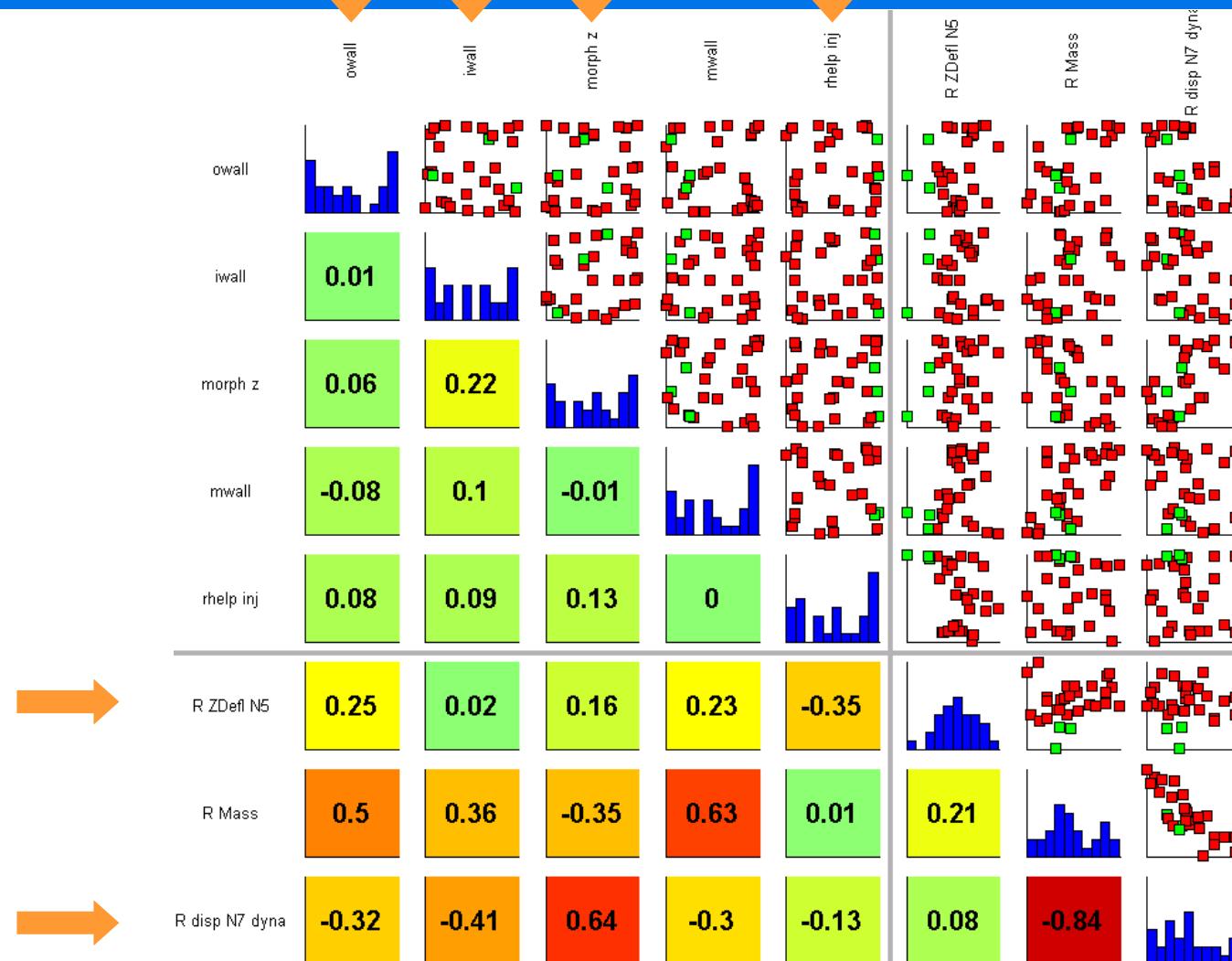
## Discipline C: Impact Simulation with LS-Dyna Impactor guided in z-direction

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# Example

## ScreeningPhase - Anthill Correlation Plot



# Example - Optimization Setup in LS-OPT

Metamodel Based Design Optimization, Radial Basis Functions

Sampling: Space Filling 8 Jobs/Iteration



Objective: Minimize Mass

Constraints: Warpage Deflection in Discipline B < 1.0 mm  
Displacement at tip in Discipline C < 14.0 mm

Design Variables:

Convergence after 13 Iterations

Inner wall thickness

2-5 mm → 2.0 mm

Outer wall thickness

2-5 mm → 3.49 mm

Middle wall thickness

Morph Shape

-35 to +25 mm → -18.8 mm

Gate location

0.1 – 0.9 → 0.9

Injection Time

Melt temperature

Tool temperature

# Summary



- *Integrative Approach* means that manufacturing influences are taken into account during optimization. Here → Injection molding
- Manufacturing Simulation is a preprocessing step for all other disciplines as well as an own discipline in itself
- Integrative Approach affords changes in the optimization workflow
- Injection molding Example was given which contains
  - Manufacturing Design Variables (→ Injection location)
  - Shape Design Variables (→ Morphing shape)
  - Standard Design Variables (→ Wallthickness)
- Example could be handled with a high amount of user scripting
- Improvements are necessary!

- Optimization software must be able to model a whole process structure
  - Not isolated disciplines → dependent disciplines
  - Several preprocessing steps have to be handled (Morphing, Mapping, ..)
- Manufacturing software
  - has to be ready for stable batch processing
  - MOLDFLOW – Optimization Interface needed
  - Crossover of Operating Systems (Windows/LINUX)
- Preprocessing (Morphing) Software needs
  - Stable link to Optimization software
  - Tools to validate possible morphing shapes **before** optimization runs
  - Batch mode