Georgian-German ScienceBRIDGE
CONNECTING PEOPLE AND KNOWLEDGE

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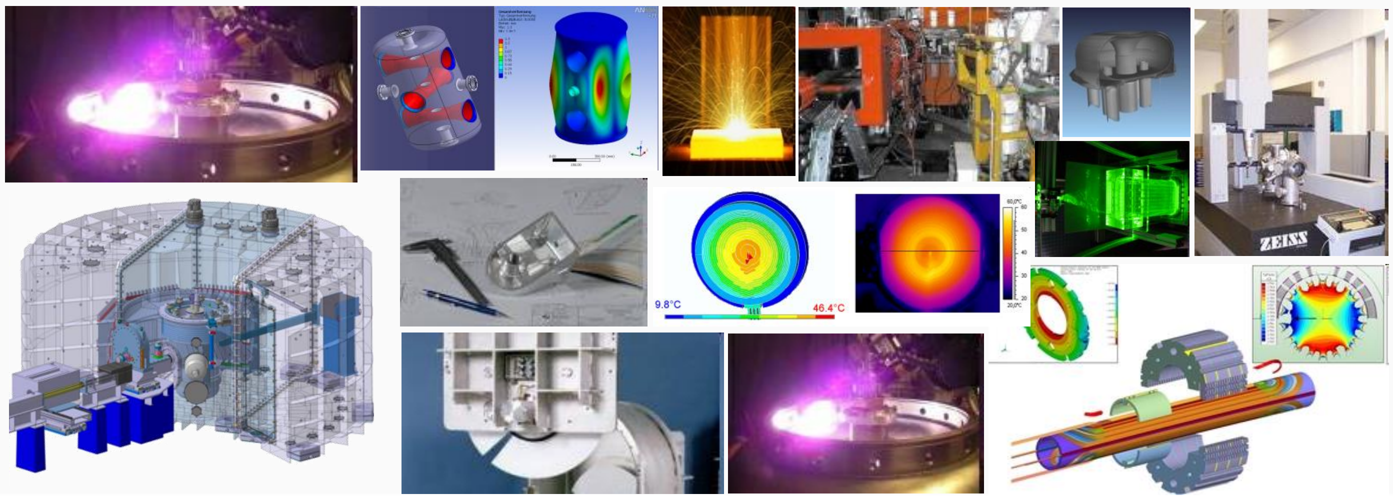
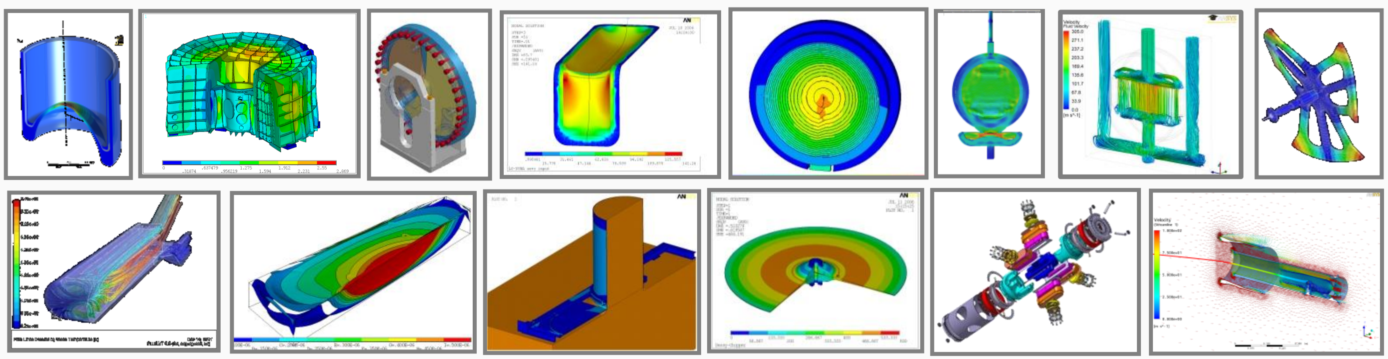
# J. Wolters: Numerical Simulations and Design Calculations



typical applications at ZEA-1



Mitglied der Helmholtz-Gemeinschaft

## Central Institute for Engineering, Electronics and Analytics

ZEA-1 – Engineering und Technology

# ZEA-1 – Engineering and Technology

## guiding principles

- ZEA-1 is a scientific and technical institute supporting the research institutes at Forschungszentrum Jülich as a competent partner.
- We design, develop, and fabricate scientific and technical equipment, instruments, and processes that are not commercially available, both for the institutes at Forschungszentrum Jülich and for third parties.
- We maintain and modify instruments, refine them, provide technology consulting for our customers, and compile feasibility studies.
- With our competence and extensive experience, we meet our customers' and partners' requirements in a quick and flexible manner.
- We extend our expertise and acquire new know-how as and when required by our customers.
- We offer attractive and future-oriented jobs and training.
- Our excellence and our strong emphasis on customer needs play a decisive part in helping Forschungszentrum Jülich achieve its objectives.

# The Benefit of Modern Simulation Tools

- analysis of complex systems possible
- fast and easy design optimization in terms of material stressing, weight, stiffness …
- identification of faulty designs and weak spots in the early development phase
- minimizing/optimizing costly experiments*
- results are available everywhere in the system
- assessment of lifetime

- enhanced product quality
- shortening of development phases
- reduction of development costs

*nevertheless, in most cases experiments are also indispensable in prototype development and only the combination of simulations and experiments will lead to optimal results

# Software at ZEA-1 (FEM / CFD / others)

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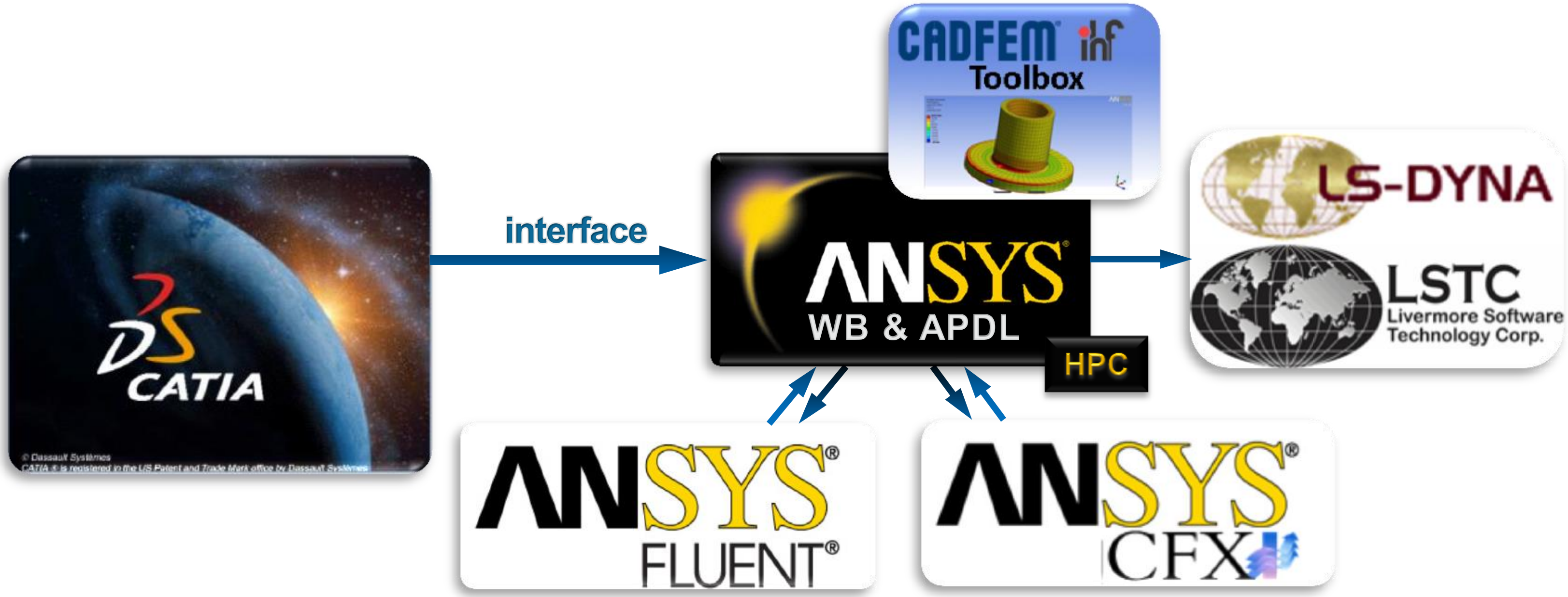


Ampere / Magneto
INTEGRATED ENGINEERING SOFTWARE

Opera
Cobham

Rifest Plus
IMA DRESDEN

DIMy
DRUCKGERÄTE-DIMENSIONIERUNG

Maplesoft
command the brilliance

Mathcad 15.0

Microsoft Excel

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TÜV Rheinland ZERTIFIZIERT
Management System
ISO 9001:2008

# HPC Hardware at ZEA-1


9 compute nodes / 88 cores

3 Nehalem 8-core, 2.93 GHz, 48 GB

5 Westmere 12-core, 2.93 GHz, 96 GB

1 Opteron 4-core, 2.01 GHz, 4 GB as file server

storage cluster Ivybridge1


JUROPA 3z (operation till end of 2018)

16 compute nodes (total 60) / 256 cores
à 2 Intel Xeon E5-2650, 8-core, 2.0 GHz

14 nodes: 128 GB memory (DDR3, 1600 MHz)

2 nodes: 256 GB memory (DDR3, 1600 MHz)


12 compute nodes (+ 2 nodes for login / service)

40 cores / node = 480 cores

10 nodes: 384 GiB; 2 nodes: 768 GiB

JUST storage cluster (GPFS)

# Fields of Competence

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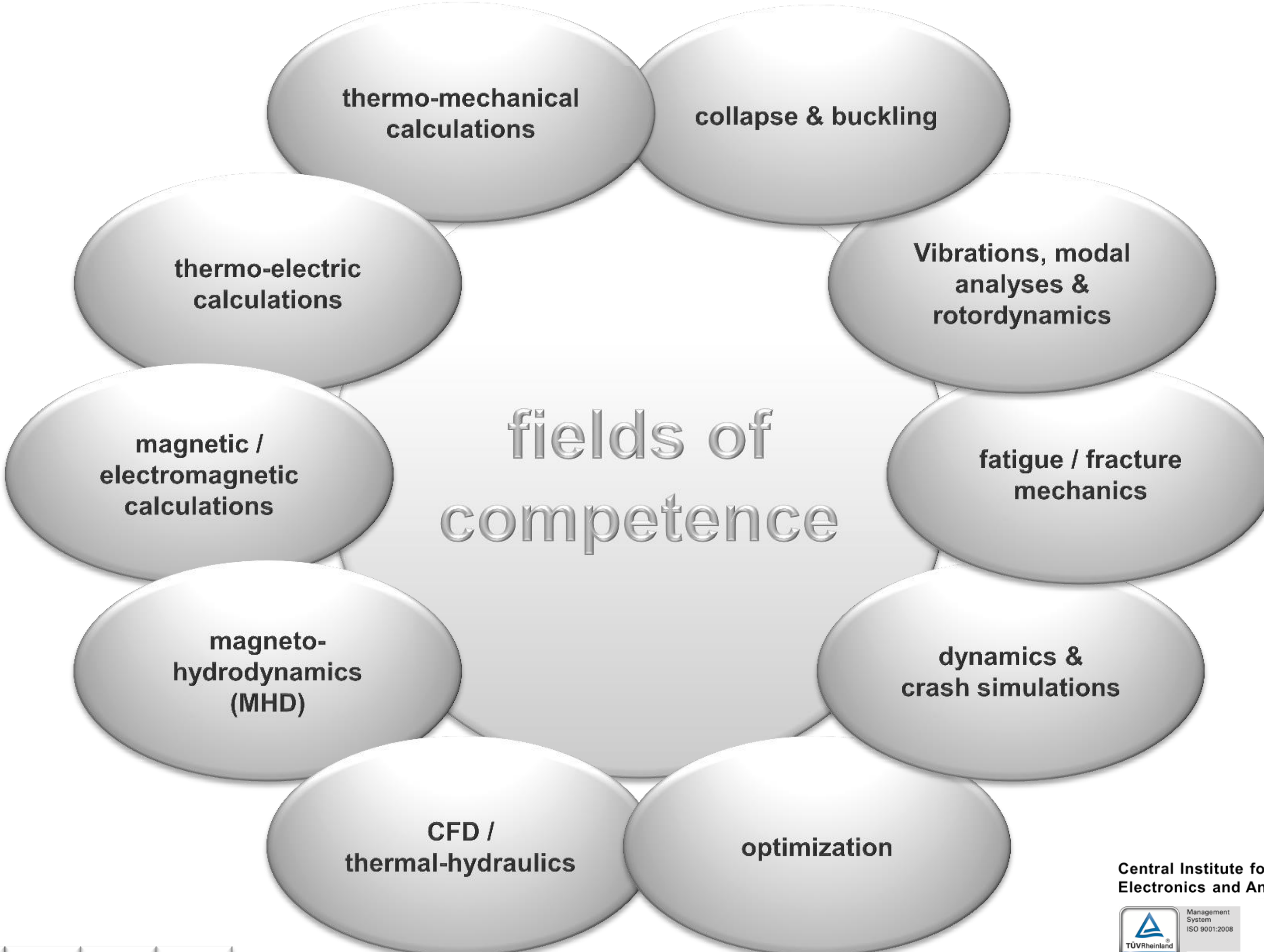


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# FEM

FEM = Finite Element Method

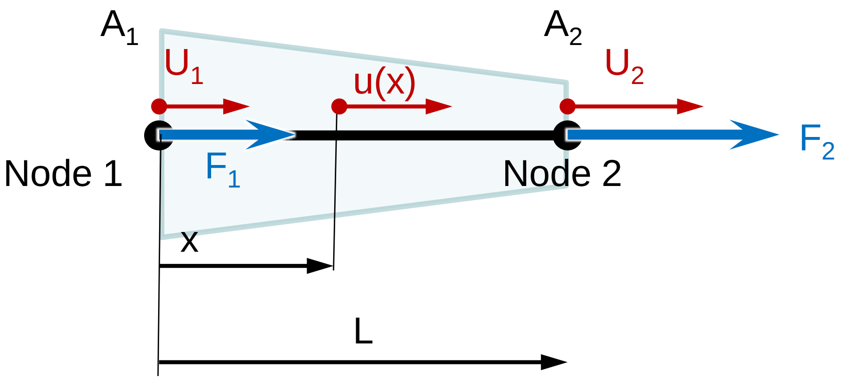
- numerical method

  - partitioning domain into small, non-overlapping subdomains – the finite elements
  - local functions approximate global solution

- applicable for differential equations for almost all technical problems

Shape functions interpolate the element solution between the discrete values obtained at mesh nodes, e.g. displacements

*example: linear bar element*




$$u(x) = \left(1 - \frac{x}{L}\right) \cdot U_1 + \left(\frac{x}{L}\right) \cdot U_2 = N_1 \cdot U_1 + N_2 \cdot U_2$$

*general formulation*

$$\{u\}^{(e)} = [N]^{(e)} \{U\}^{(e)}$$

$[N]^{(e)}$: shape functions of element

$\{U\}^{(e)}$: discrete values at nodes / element degrees of freedom

$\{u\}^{(e)}$: solution within element

*Derived element strain:*

$$\varepsilon(x) = \frac{du(x)}{dx} = \frac{d[N]}{dx}\{U\} = \underbrace{\begin{bmatrix} -\frac{1}{L} & \frac{1}{L} \end{bmatrix}}_{[B]^{(e)}}\{U\} = \frac{(U_2 - U_1)}{L}$$

$$\{\varepsilon\}^{(e)} = [D][N]^{(e)}\{U\}^{(e)} = [B]^{(e)}\{U\}^{(e)}$$

$[D]$: matrix differentiation operator

$[B]^{(e)}$: displacement differentiation matrix

# FEM - Theory

## ↳ potential energy function for linear elastic materials

The total potential energy Π is given by the strain energy U and the work potential W of external loads:

$$\Pi = U + W = \frac{1}{2}\int_V \{\varepsilon\}^T\{\sigma\}dV - \underbrace{\int_V \{u\}^T\{p^V\}dV}_{volumetric\ loads} - \underbrace{\int_S \{u\}^T\{p^S\}dS}_{surface\ loads} - \underbrace{\sum_i \{u\}_i^T P_i}_{concentrated\ loads}$$

*example: linear bar element*

$$\sigma(x) = E \cdot \varepsilon(x) = E \cdot \frac{(U_2 - U_1)}{L}$$

$$\Pi = \frac{1}{2}\int_0^L E \cdot \frac{(U_2 - U_1)^2}{L^2} \cdot A(x)dx - F_1 \cdot U_1 - F_2 \cdot U_2$$

$$= \frac{1}{2}E \cdot \frac{(U_2 - U_1)^2}{L^2} \cdot \int_0^L A(x)dx - F_1 \cdot U_1 - F_2 \cdot U_2$$

$$\Rightarrow \Pi = \frac{1}{2} \cdot \frac{E \cdot A_m}{L}(U_2 - U_1)^2 - F_1 \cdot U_1 - F_2 \cdot U_2$$

*general formulation*

$$\{\sigma\}^{(e)} = [E]^{(e)} \cdot \{\varepsilon\}^{(e)} = [E]^{(e)}[B]^{(e)}\{U\}^{(e)}$$

$$\Pi = \frac{1}{2}\int_V \left([B]^{(e)}\{U\}^{(e)}\right)^T [E]\left([B]^{(e)}\{U\}^{(e)}\right)dV$$

$$- \int_V ([N]\{U\})^T\{p^V\}dV - \int_S ([N]\{U\})^T\{p^S\}dS$$

$$- \sum_i ([N]\{U\})_i^T P_i$$

$[E]^{(e)}$: elasticity matrix

## potential energy function for linear elastic materials

The system is at a stationary position when an infinitesimal variation from such position involves no change in the total potential energy:

*example: linear bar element*

$$\left\{\frac{\partial \Pi}{\partial U}\right\} = \left\{\begin{matrix}\dfrac{\partial \Pi}{\partial U_1}\\ \dfrac{\partial \Pi}{\partial U_2}\end{matrix}\right\} = 0 \Rightarrow \underbrace{\underbrace{\frac{E \cdot A_m}{L}}_{bar\ stiffness} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}}_{stiffness\ matrix\ [K]} \left\{\begin{matrix}U_1\\U_2\end{matrix}\right\} = \left\{\begin{matrix}F_1\\F_2\end{matrix}\right\}$$

*general formulation*

$$\left\{\frac{\partial \Pi^{(e)}}{\partial U^{(e)}}\right\} = 0$$

$$\Rightarrow \int_V [B]^{(e)^T}[E]^{(e)}[B]^{(e)}dV\ \{U\}^{(e)} =$$

$$\int_V [N]^T\{p^V\}dV + \int_S [N]^T\{p^S\}dS$$

$$+\sum_i [N]_i^T P_i = \{F\}^{(e)}$$

$$\Rightarrow [K]^{(e)}\{U\}^{(e)} = \{F\}^{(e)}$$

$[K]^{(e)}$: element stiffness matrix

# FEM - Theory

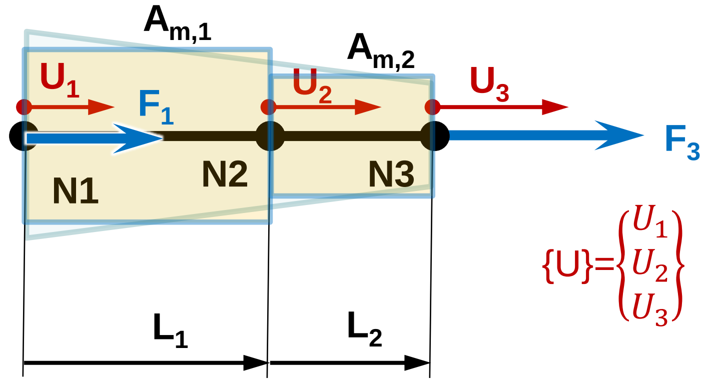
## connecting elements

*example: linear bar element*

Expanding element set of equations

$$\begin{bmatrix} \frac{E_1 \cdot A_{m,1}}{L_1} & -\frac{E_1 \cdot A_{m,1}}{L_1} & 0 \\ -\frac{E_1 \cdot A_{m,1}}{L_1} & \frac{E_1 \cdot A_{m,1}}{L_1} & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} U_1 \\ U_2 \\ U_3 \end{Bmatrix} = \begin{Bmatrix} F_1 \\ F_2^{(1)} \\ 0 \end{Bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & \frac{E_2 \cdot A_{m,2}}{L_2} & -\frac{E_2 \cdot A_{m,2}}{L_2} \\ 0 & -\frac{E_2 \cdot A_{m,2}}{L_2} & \frac{E_2 \cdot A_{m,2}}{L_2} \end{bmatrix} \begin{Bmatrix} U_1 \\ U_2 \\ U_3 \end{Bmatrix} = \begin{Bmatrix} 0 \\ F_2^{(2)} \\ F_3 \end{Bmatrix}$$




$$\{U\} = \begin{Bmatrix} U_1 \\ U_2 \\ U_3 \end{Bmatrix} \qquad \{F\} = \begin{Bmatrix} F_1 \\ 0 \\ F_3 \end{Bmatrix}$$

*general formulation*

$$\sum_{i=1}^{n_{el}} [C]^{(i)^T} [K]^{(i)} [C]^{(i)} \{U\} = \sum_{i=1}^{n_{el}} [C]^{(i)^T} \{F\}^{(i)}$$

$[C]^{(i)}$: logic element connection matrix

$$\Rightarrow [K]\{U\} = \{F\}$$

Superposition

$$\begin{bmatrix} \frac{E_1 \cdot A_{m,1}}{L_1} & -\frac{E_1 \cdot A_{m,1}}{L_1} & 0 \\ -\frac{E_1 \cdot A_{m,1}}{L_1} & \frac{E_1 \cdot A_{m,1}}{L_1} + \frac{E_2 \cdot A_{m,2}}{L_2} & -\frac{E_2 \cdot A_{m,2}}{L_2} \\ 0 & -\frac{E_2 \cdot A_{m,2}}{L_2} & \frac{E_2 \cdot A_{m,2}}{L_2} \end{bmatrix} \begin{Bmatrix} U_1 \\ U_2 \\ U_3 \end{Bmatrix} = \begin{Bmatrix} F_1 \\ 0 \\ F \end{Bmatrix}$$

$F_2^{(1)} + F_2^{(2)} = 0$ (inner forces)



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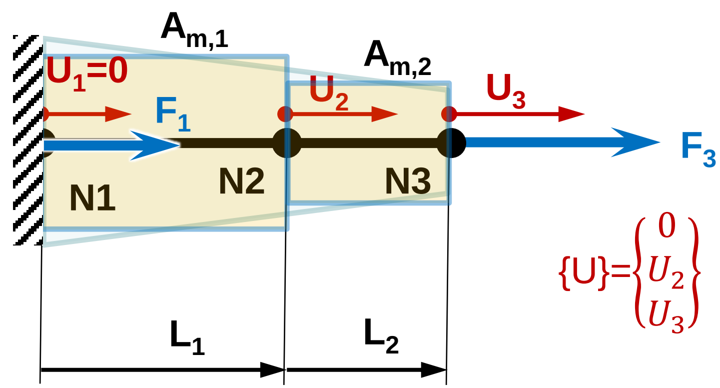
# FEM - Theory

## ↳ fixed degrees of freedom

Fixed degrees of freedom will reduce the set of equations




$\{U\}=\begin{Bmatrix}0\\U_2\\U_3\end{Bmatrix}$ $\{F\}=\begin{Bmatrix}F_1\\0\\F_3\end{Bmatrix}$

*example: linear bar element*

$$\begin{bmatrix} \frac{E_1\cdot A_{m,1}}{L_1} & -\frac{E_1\cdot A_{m,1}}{L_1} & 0 \\ -\frac{E_1\cdot A_{m,1}}{L_1} & \frac{E_1\cdot A_{m,1}}{L_1}+\frac{E_2\cdot A_{m,2}}{L_2} & -\frac{E_2\cdot A_{m,2}}{L_2} \\ 0 & -\frac{E_2\cdot A_{m,2}}{L_2} & \frac{E_2\cdot A_{m,2}}{L_2} \end{bmatrix} \begin{Bmatrix}0\\U_2\\U_3\end{Bmatrix} = \begin{Bmatrix}F_1\\0\\F_3\end{Bmatrix}$$

$$\begin{bmatrix} \frac{E_1\cdot A_{m,1}}{L_1}+\frac{E_2\cdot A_{m,2}}{L_2} & -\frac{E_2\cdot A_{m,2}}{L_2} \\ -\frac{E_2\cdot A_{m,2}}{L_2} & \frac{E_2\cdot A_{m,2}}{L_2} \end{bmatrix} \begin{Bmatrix}U_2\\U_3\end{Bmatrix} = \begin{Bmatrix}0\\F_3\end{Bmatrix}$$

*Solving reduced set of equations:*

$$\Rightarrow U_2=\frac{F\cdot L_1}{E_1\cdot A_{m,1}};\ U_3=\frac{F\cdot L_2}{E_2\cdot A_{m,2}}+\frac{F\cdot L_1}{E_1\cdot A_{m,1}}$$

$$\Rightarrow F_1=-\frac{E_1\cdot A_{m,1}}{L_1}\cdot\frac{F_3\cdot L_1}{E_1\cdot A_{m,1}}=-F_3$$

*general formulation*

reduced set of equations:

$$[K]'\{U\}'=\{F\}'$$
$$\Rightarrow \{U\}'=[K]'^{-1}\{F\}'$$

reaction forces:

$$\Rightarrow \{F\}=[K]\{U\}$$

# FEM - Theory

## accuracy of solution

*example:*

$$A_L = \frac{1}{2} A_0; L_i = \frac{L}{n}; E_i = E$$

$$\Rightarrow A_{m,i} = \frac{4 \cdot n - 2 \cdot i + 1}{4 \cdot n} A_0$$

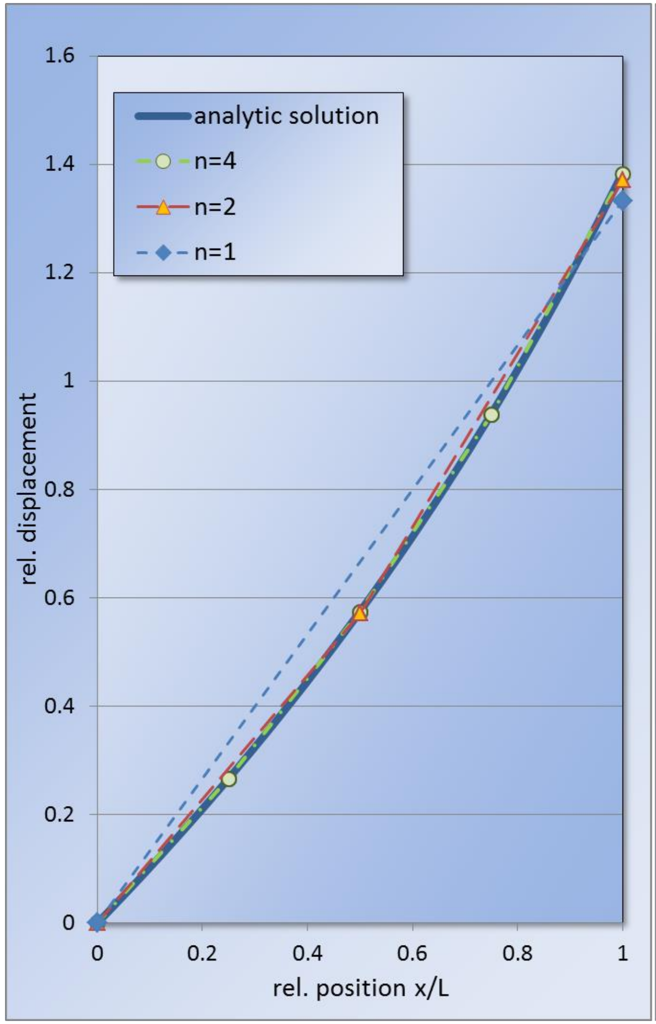
*Analytic solution:*

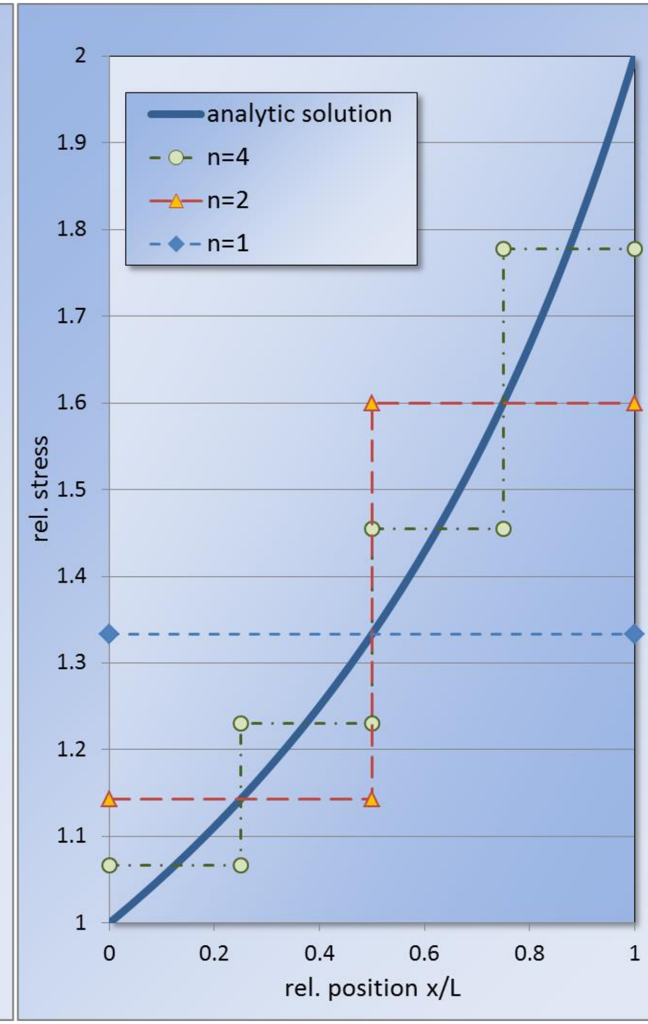
$$u_r(x) = \frac{u(x)}{\frac{F \cdot L}{A_0 \cdot E}}$$

$$\Rightarrow u_r(x) = \ln\left[\left(\frac{1}{1 - \frac{x}{2L}}\right)^2\right]$$

$$\sigma_r(x) = \frac{\sigma(x)}{\frac{F}{A_0}}$$

$$\Rightarrow \sigma_r(x) = \frac{1}{1 - \frac{x}{2L}}$$





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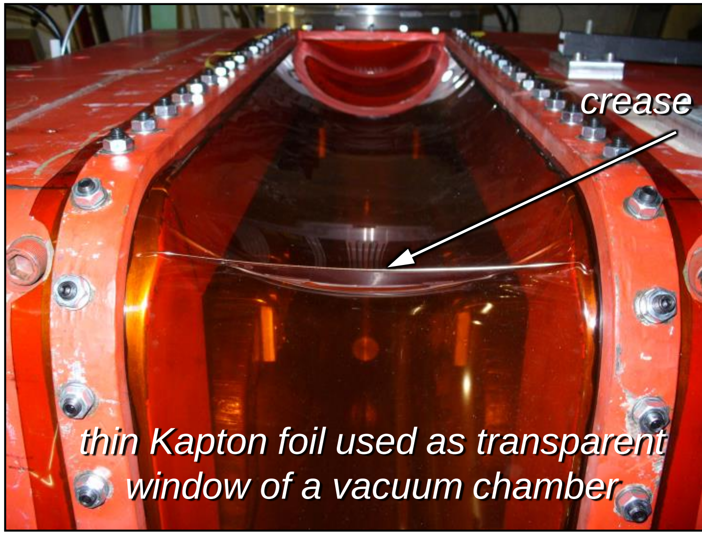
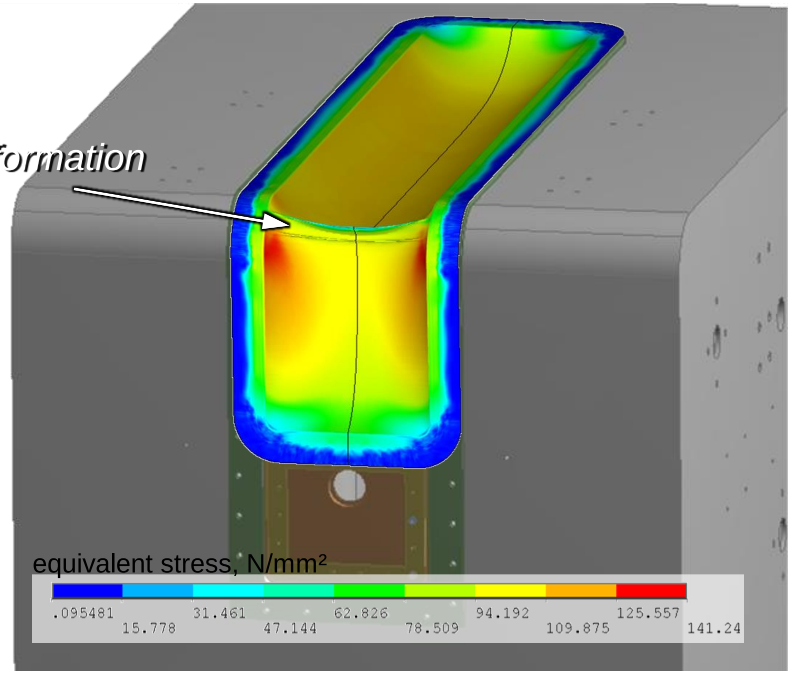
# FEM - Theory

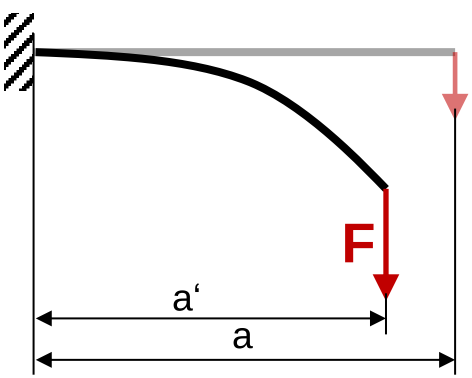
## ↳ nonlinear systems



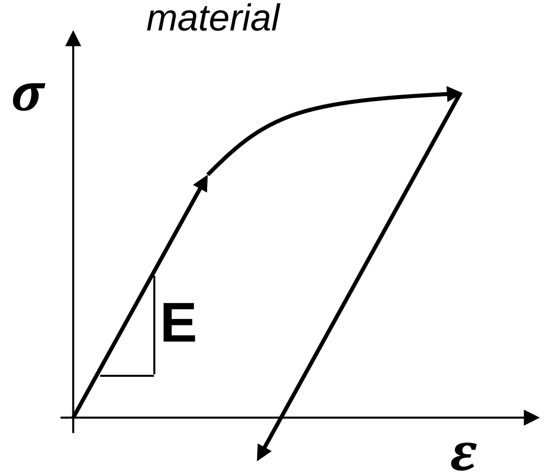




**Three types of nonlinearities**

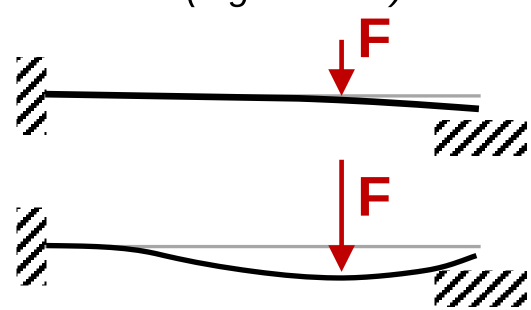
*large displacements*




*material*



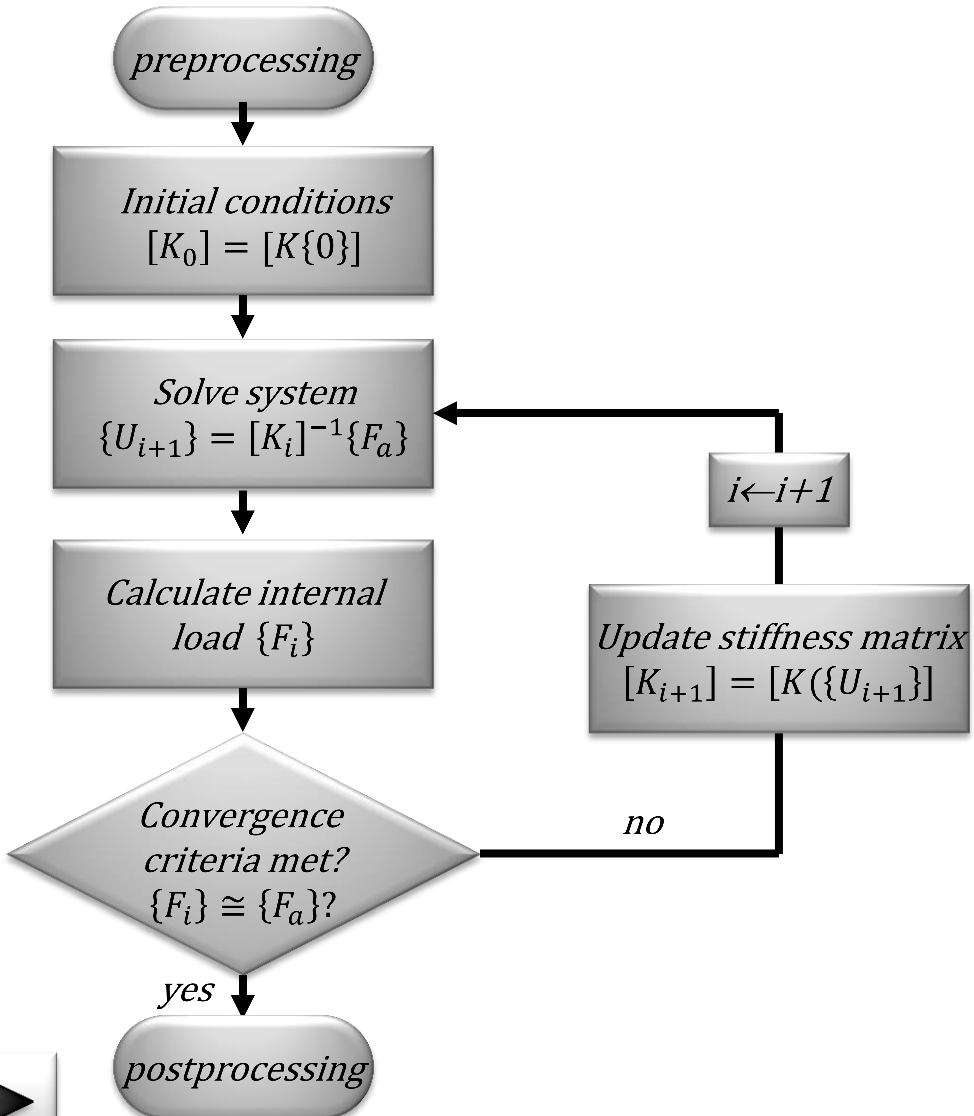

*structural (e.g. contact)*



# FEM - Theory

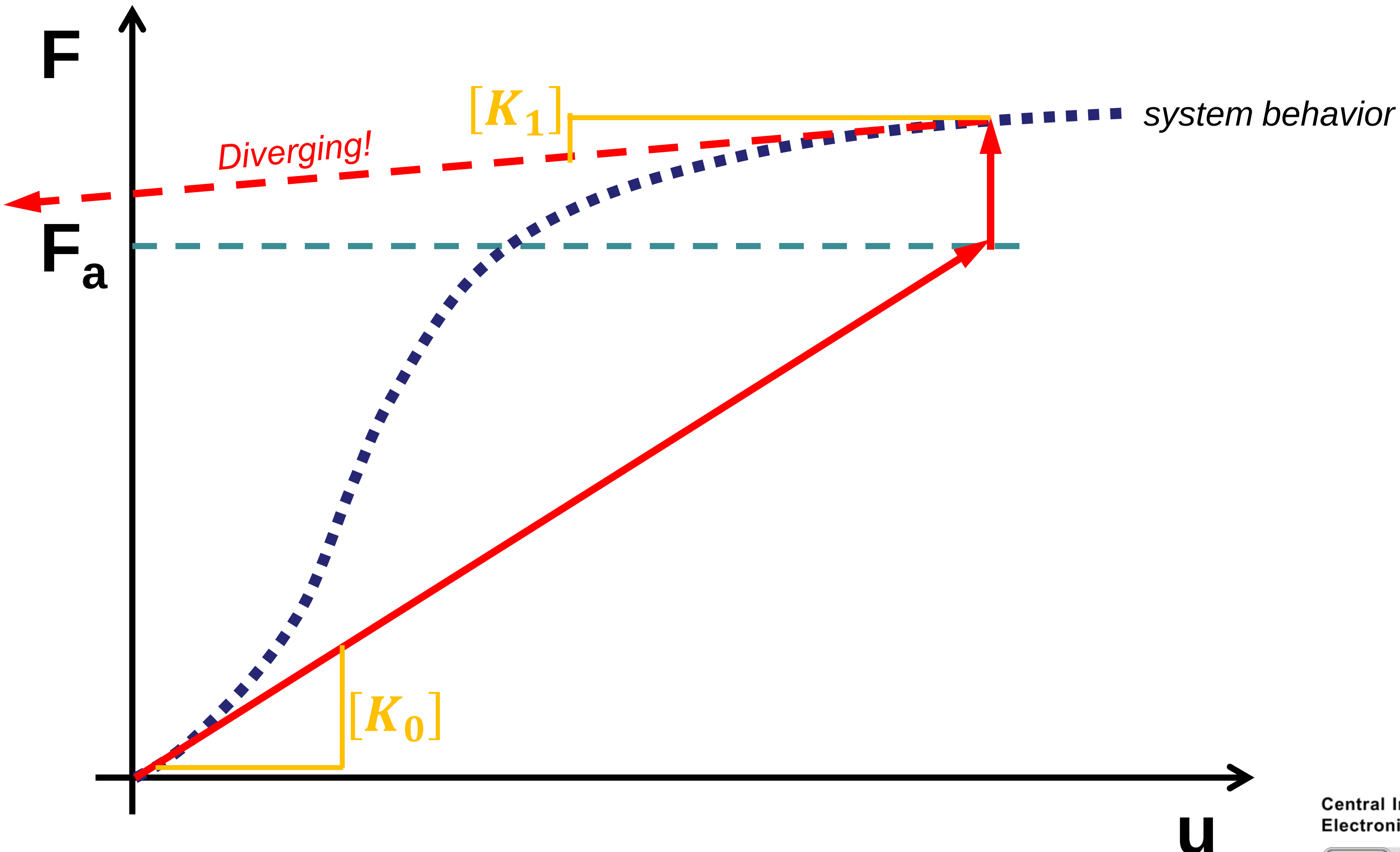
## ↳ nonlinear systems

*If the stiffness matrix depends on deformations* $[K(\{U\})]\{U\} = \{F\}$*, the system has to be solved iteratively:*



# FEM - Theory
## ⇘ nonlinear systems

*Newton-Raphson Method to solve nonlinear Systems*



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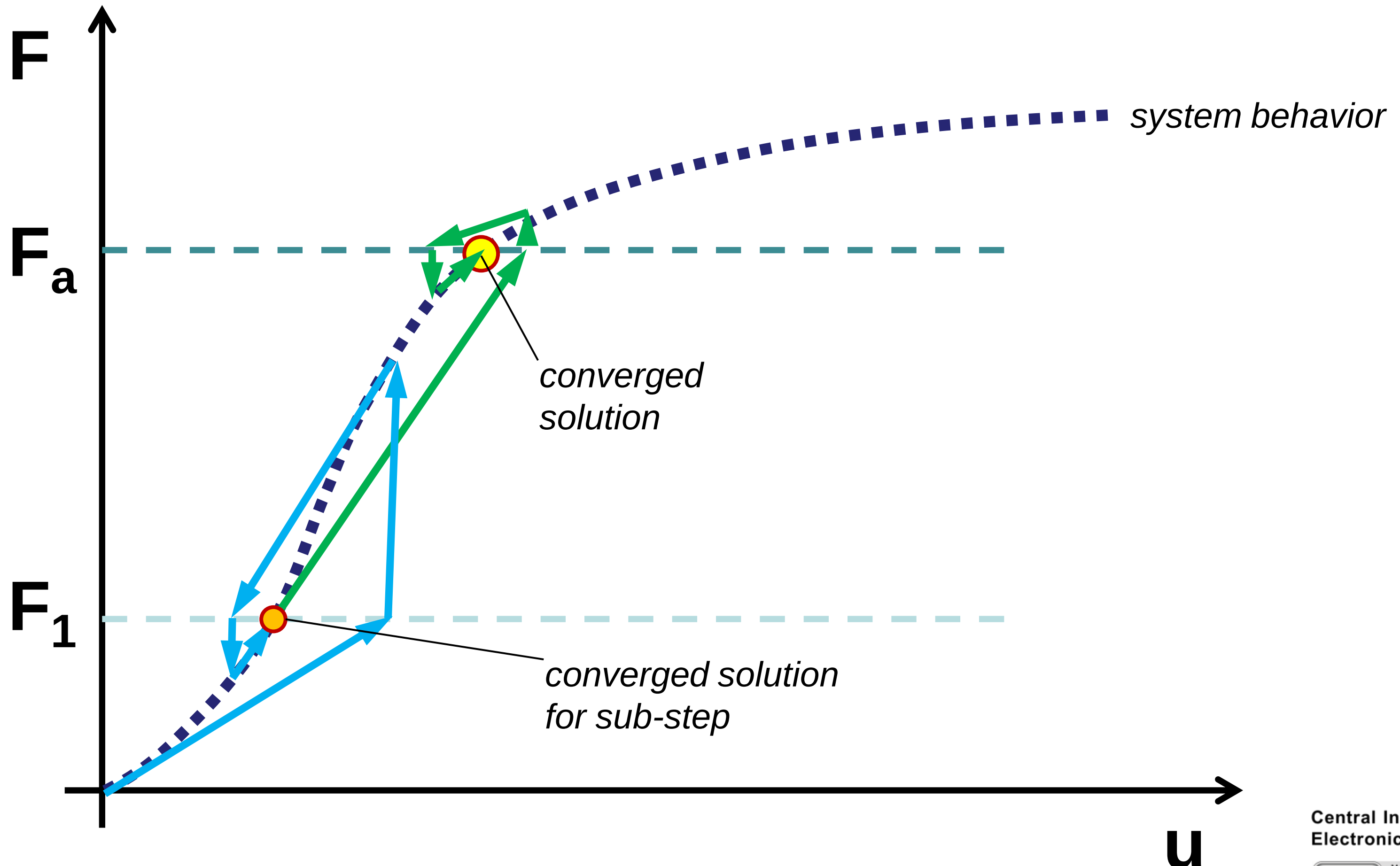
# FEM - Theory

## ↳ nonlinear systems

*Newton-Raphson Method to solve nonlinear Systems*



# FEM – Theory

## ↳ further applications

| | | |
|---|---|---|
| *Diffusion:* | $[D]\{C\} = \{Q\}$ | [D]: diffusion coefficient<br>{C}: concentration<br>{Q}: sources |
| *Electrostatic:* | $[\chi]\{\varphi\} = \{Q\}$ | [$\chi$]: dielectricity<br>{$\varphi$}: electric potential<br>{Q}: charge |

*with damping:*

| | | |
|---|---|---|
| *Temperature:* | $[C]\{\dot{T}\} + [K]\{T\} = \{Q(t)\}$ | [C]: heat capacity<br>[K]: conductivity<br>{T}: Temperature<br>{Q}: heat source |
| *Magnetic fields:* | $[C]\{\dot{A}\} + [K]\{A\} = \{F(t)\}$ | [C]: electric conductivity<br>[K]: magnetic permeability<br>{A}: vector potential<br>{F}: current density |

*with inertia and damping:*

| | | |
|---|---|---|
| *Dynamics:* | $[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = \{F(t)\}$ | [M]: mass (inertia)<br>[C]: damping<br>[K]: stiffness |

*can also be solved using explicit solvers*

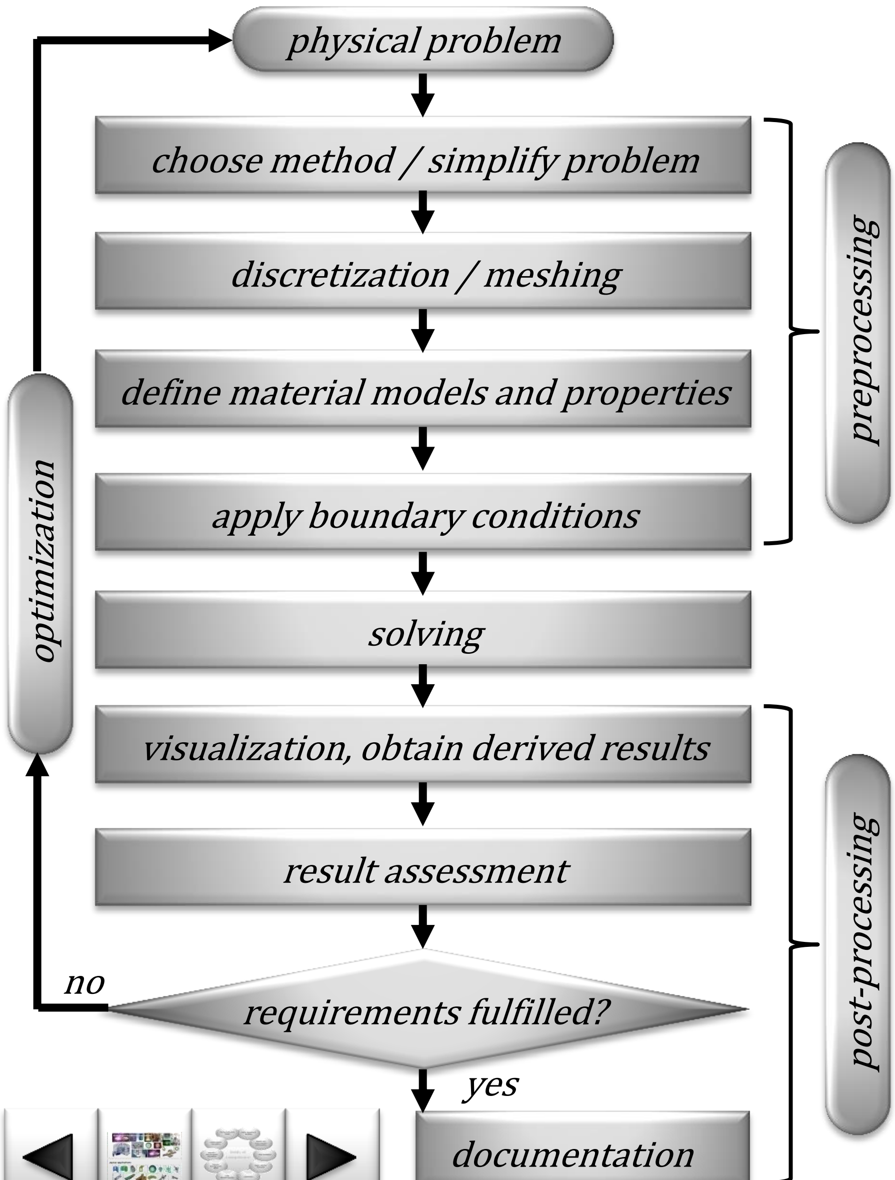
# CFD - Theory

## ↳ CFD = computational fluid dynamics

- Numerical method for solving partial differential equations representing conservation laws for **mass, momentum, energy and species** for fluid flows.
- Domain is discretized into a finite set of control volumes or cells. The most commonly used method for CFD is the **Finite-Volume-Method**.
- Control volume balance for a general flow variable $\phi$ can be expressed by:
  **rate of change = net convective flux + net diffusive flux + net creation rate**
- The **Navier-Stokes equations** are the general form of the equation of motion for a viscous fluid.
- Typical numerical methods to consider **flow turbulence**:
  - **DNS** (direct numerical simulation): all eddies are resolved by a very fine mesh
    => this method is time consuming and requires huge computational resources
  - **RANS** (Reynolds-Averaged Navier-Stokes): a turbulence model describes all effects of turbulence on the flow
    => this is the most commonly used method for technical applications; stationary analyses are possible and computational costs are low
  - **LES** (large eddy simulations): only the largest eddies are resolved by the mesh and smaller eddies are considered by a turbulence model
    => compromise between DNS and RANS

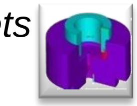
# Setting up numerical simulations with FEM/CFD

## ↳ important aspects for a design engineer

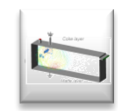



*Knowledge and experience of the engineer*

- *which design rules have to be applied?*
- *what are the requirements of the design rules, what are the safety-related acceptance targets and criteria, what are the limits?*

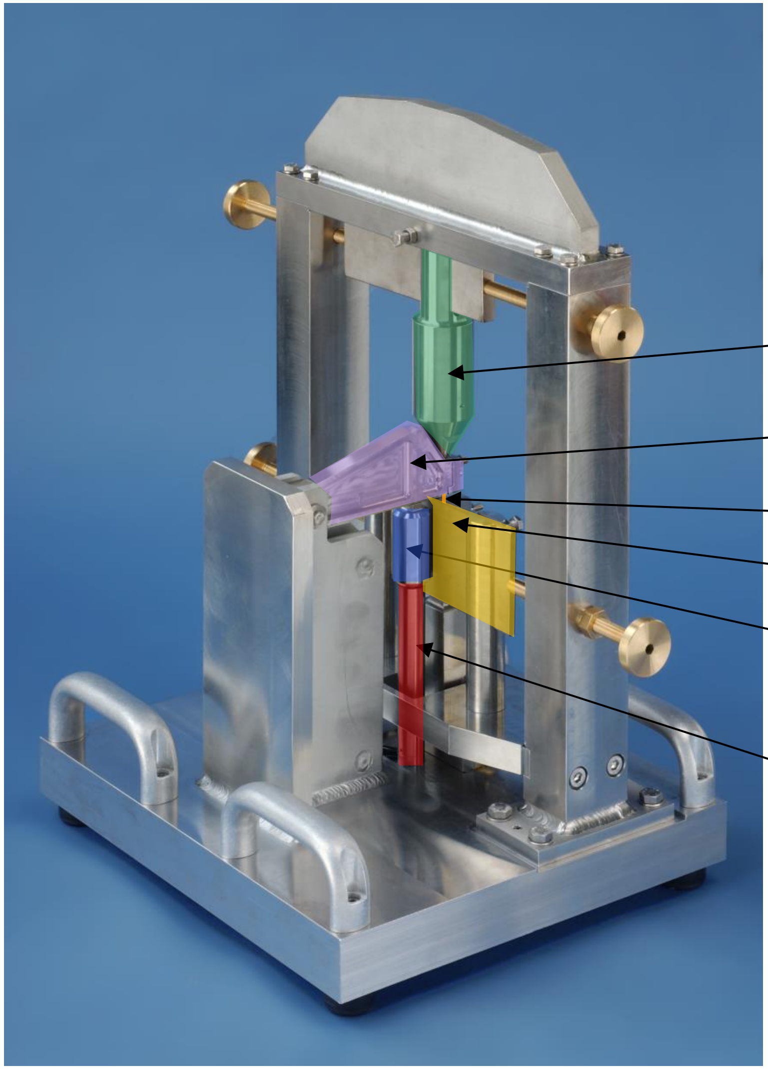


- *which physical effects and details are important?*
- *how can the problem be simplified?*
- *how does the material behave, which material parameters are applicable and proven?*
- *which software is suitable to solve the problem?*
- *implementation of new methods / models necessary?*



- *how big is the error due to the meshing, where is a mesh refinement necessary?*
- *how to model the boundary conditions, how to cover uncertainties in the boundary conditions?*
- *chose appropriate solvers, solver settings, load steps and convergence criteria!*
- *estimate necessary computational resources!*
- *validate model!*
- *assess results according to design rules!*
- *…*

# FATIMA – Test Facility
## ↳ fatigue tests at high strain rates



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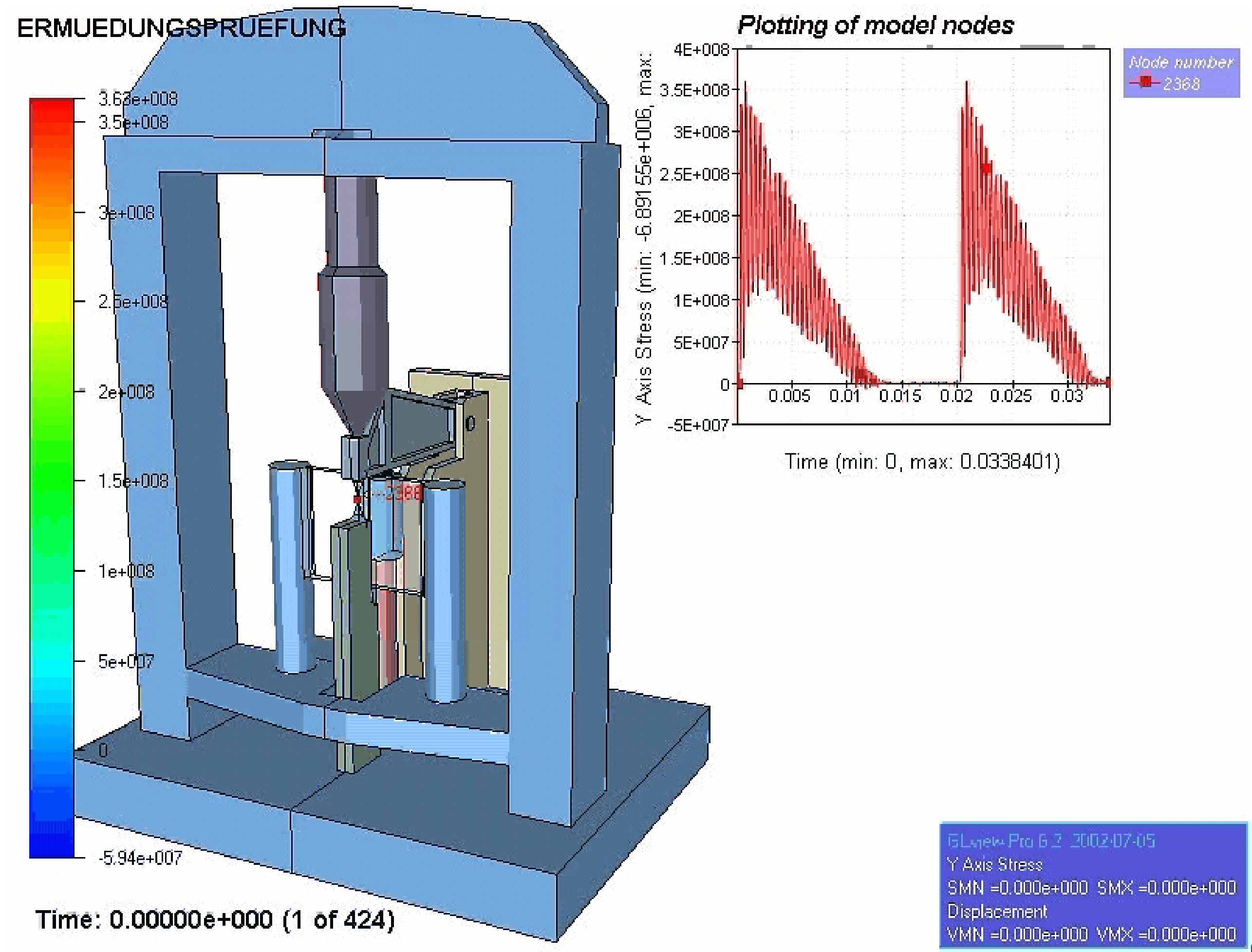
# FATIMA – Test Facility
## ↳ fatigue tests at high strain rates

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# Buckling analysis for a vacuum vessel
## ↳ CRISTA @ GEOPHYSICA





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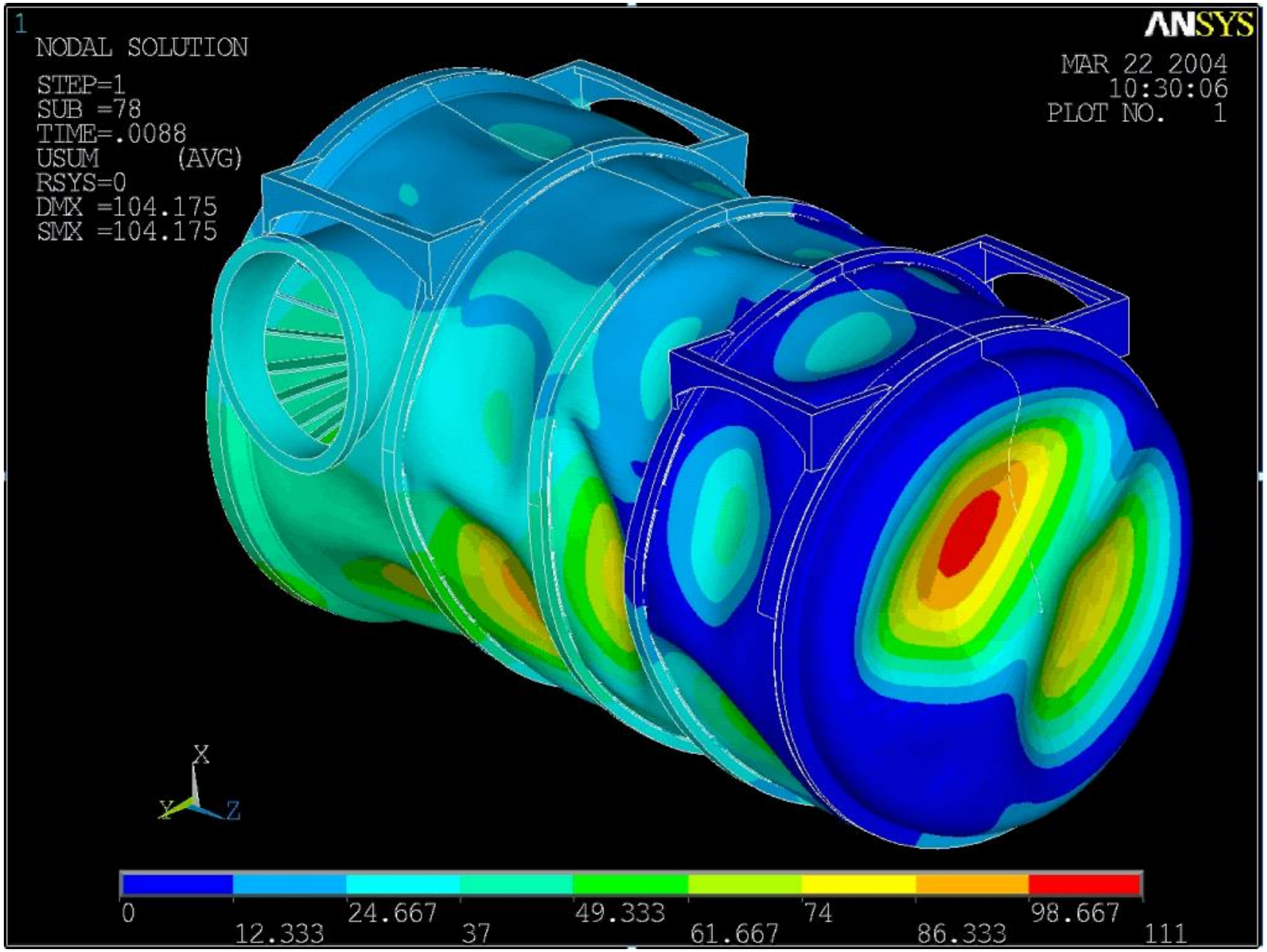
# Buckling analysis for a vacuum vessel

## ↳ CRISTA @ GEOPHYSICA




**Deformations, mm**

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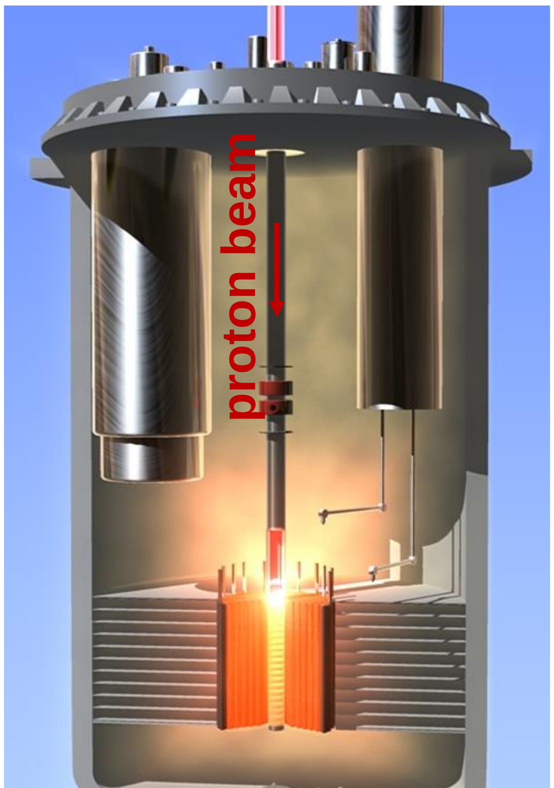
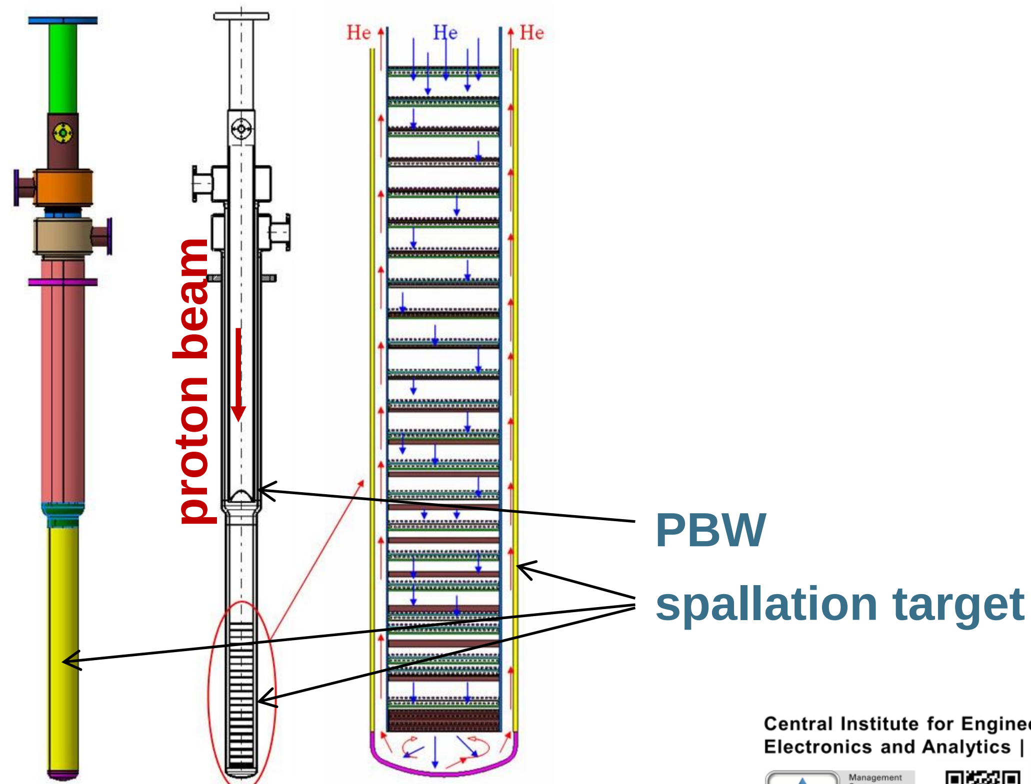
# Design of Proton Beam Windows

## ↳ AGATE

- AGATE (Advanced Gas-cooled Accelerator-driven Transmutation Experiment)
- the spallation target serves as continuous neutron source for a subcritical reactor
- the PBW separates the accelerator vacuum from the target coolant (60bar helium)
- water at 3 bar is used for the PBW cooling

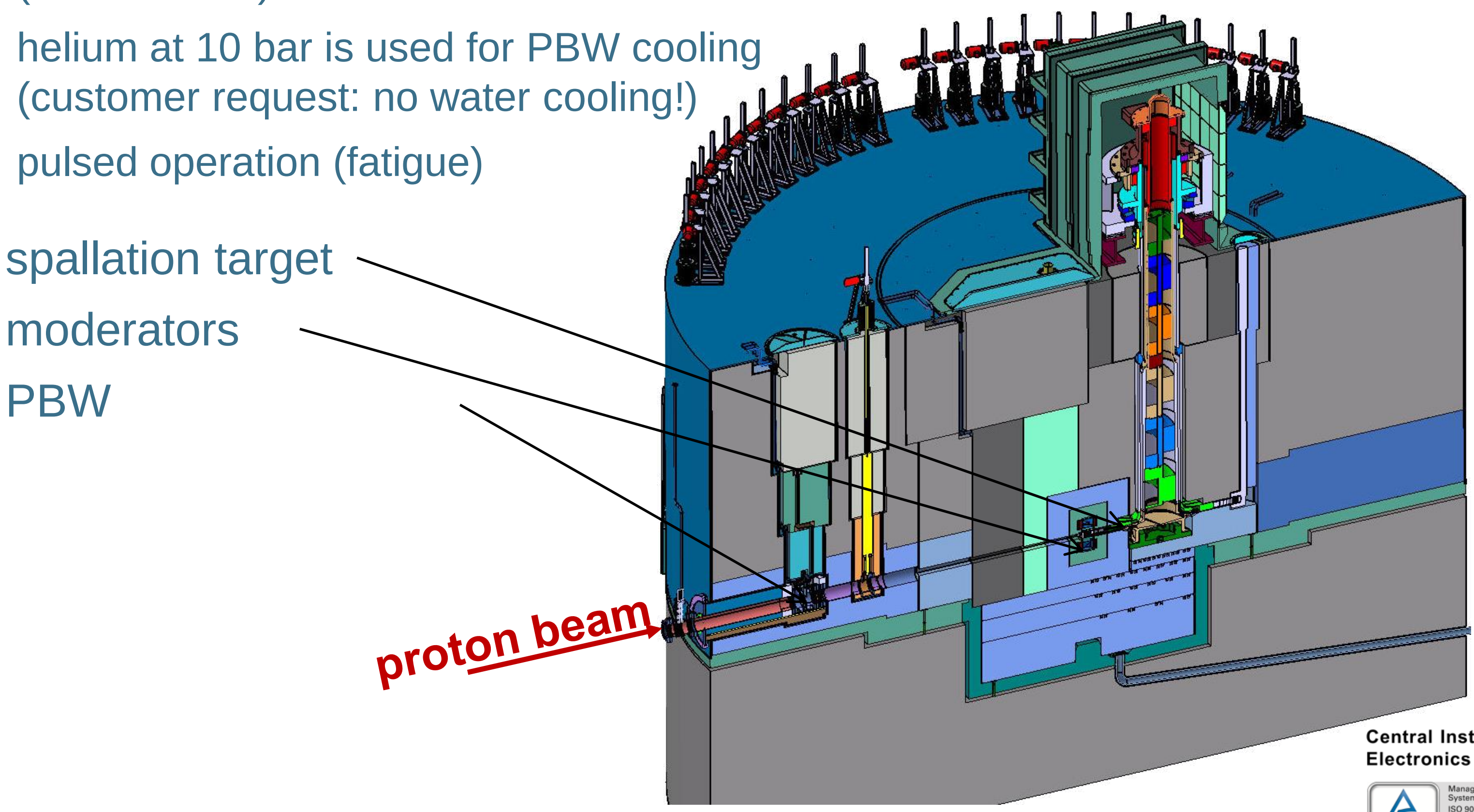


# Design of Proton Beam Windows

## ESS

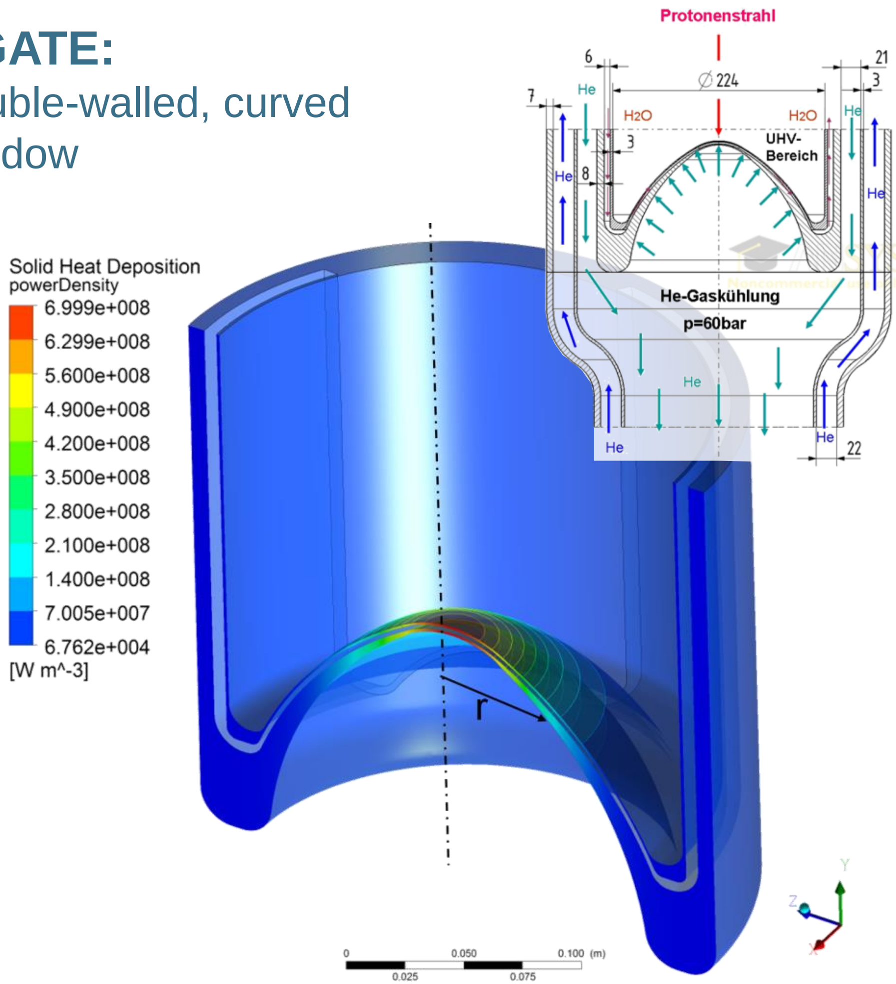
- ESS (European Spallation Source)
- the spallation target serves as neutron source for scientific experiments
- the PBW separates the accelerator vacuum from the helium atmosphere in the target room (1 bar helium)
- helium at 10 bar is used for PBW cooling (customer request: no water cooling!)
- pulsed operation (fatigue)



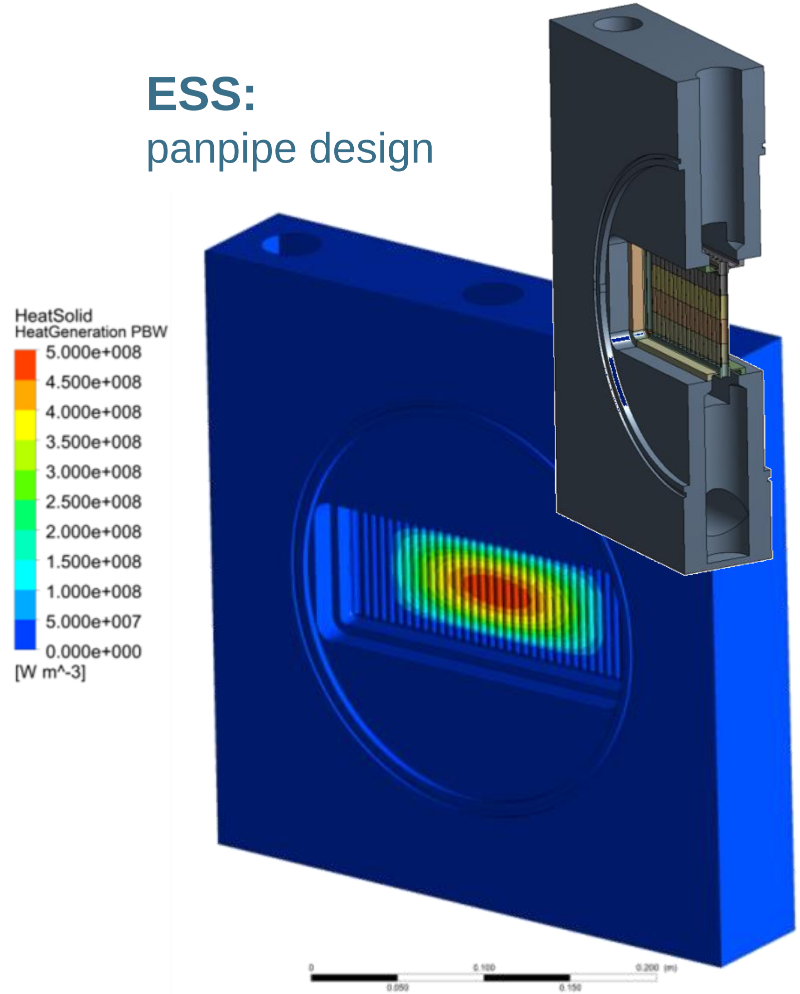
# Design of Proton Beam Windows

## ↳ design concepts for different boundary conditions

**AGATE:**
double-walled, curved window




**ESS:**
panpipe design

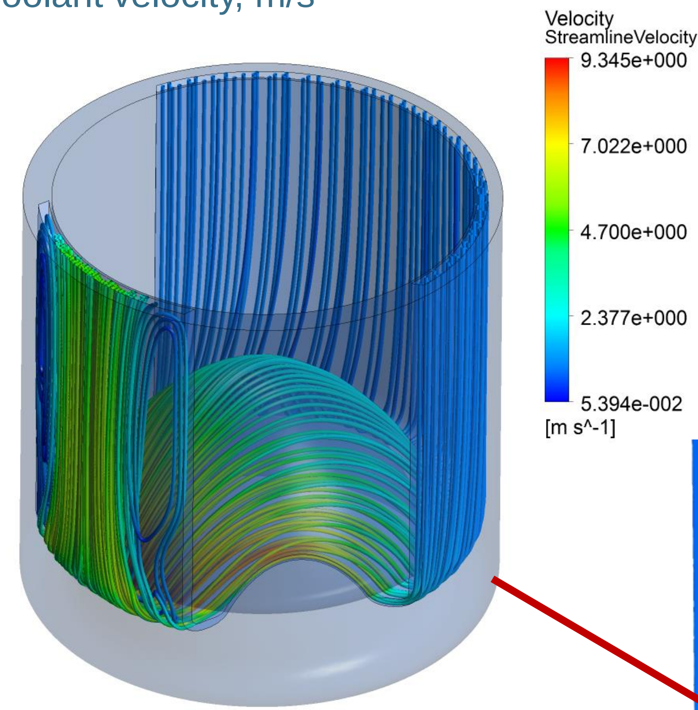



**Al6061-T6**

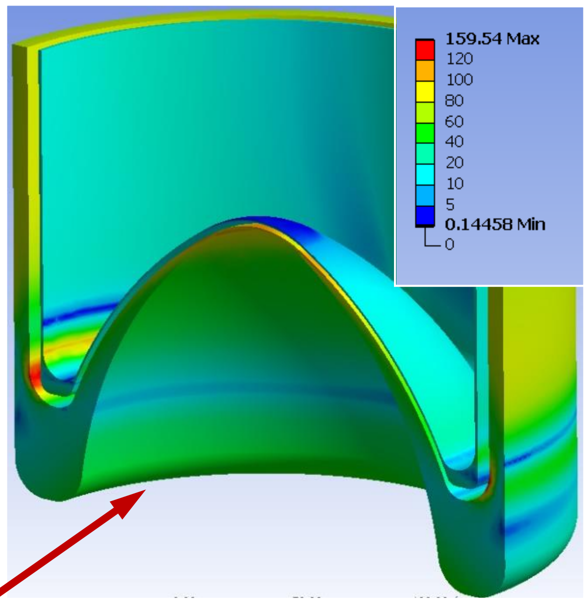
# Design of Proton Beam Windows

## ↳ design details for AGATE

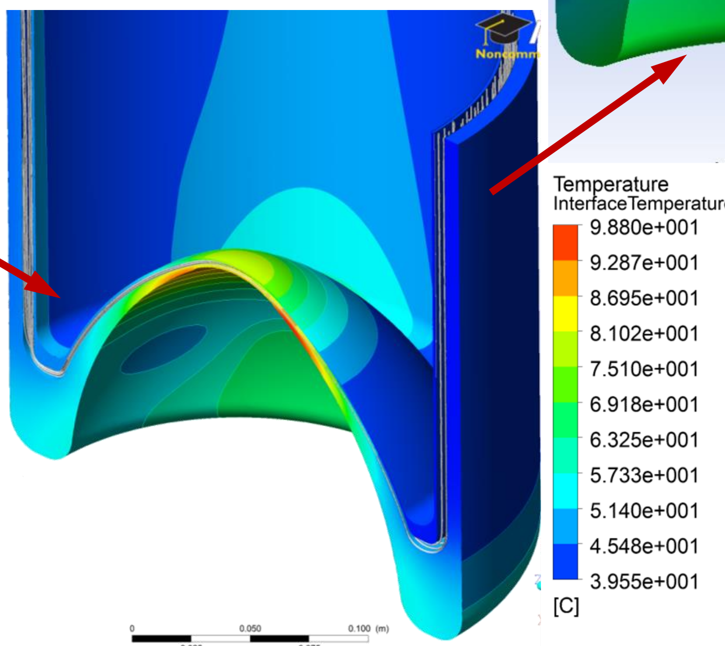
coolant velocity, m/s




equivalent stress, MPa




temperature, °C




ANSYS

# Design of Proton Beam Windows

## ↳ design details for ESS

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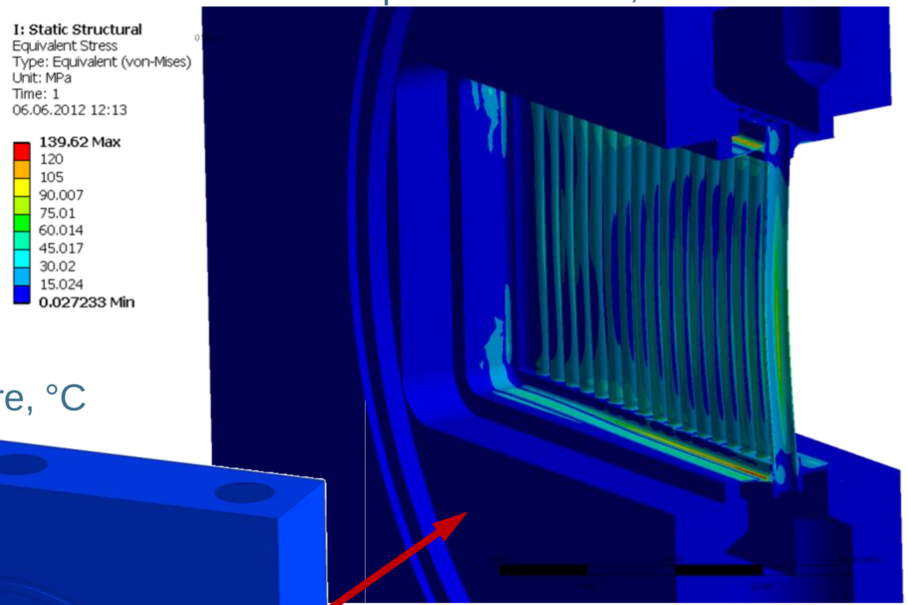
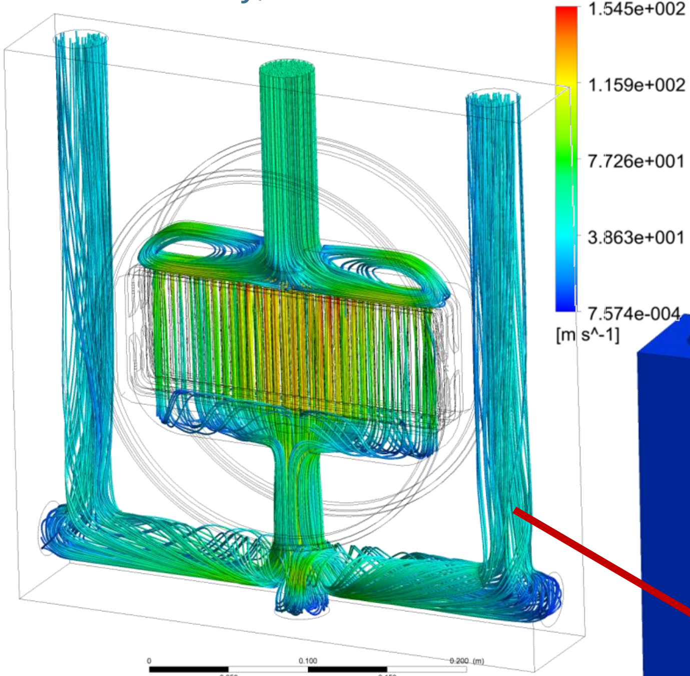
equivalent stress, MPa

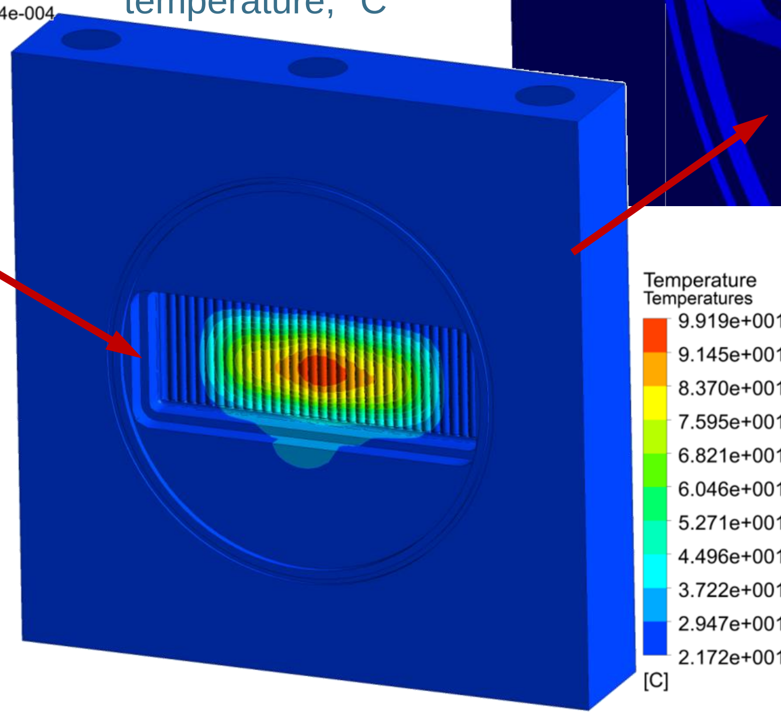



coolant velocity, m/s




ANSYS

temperature, °C

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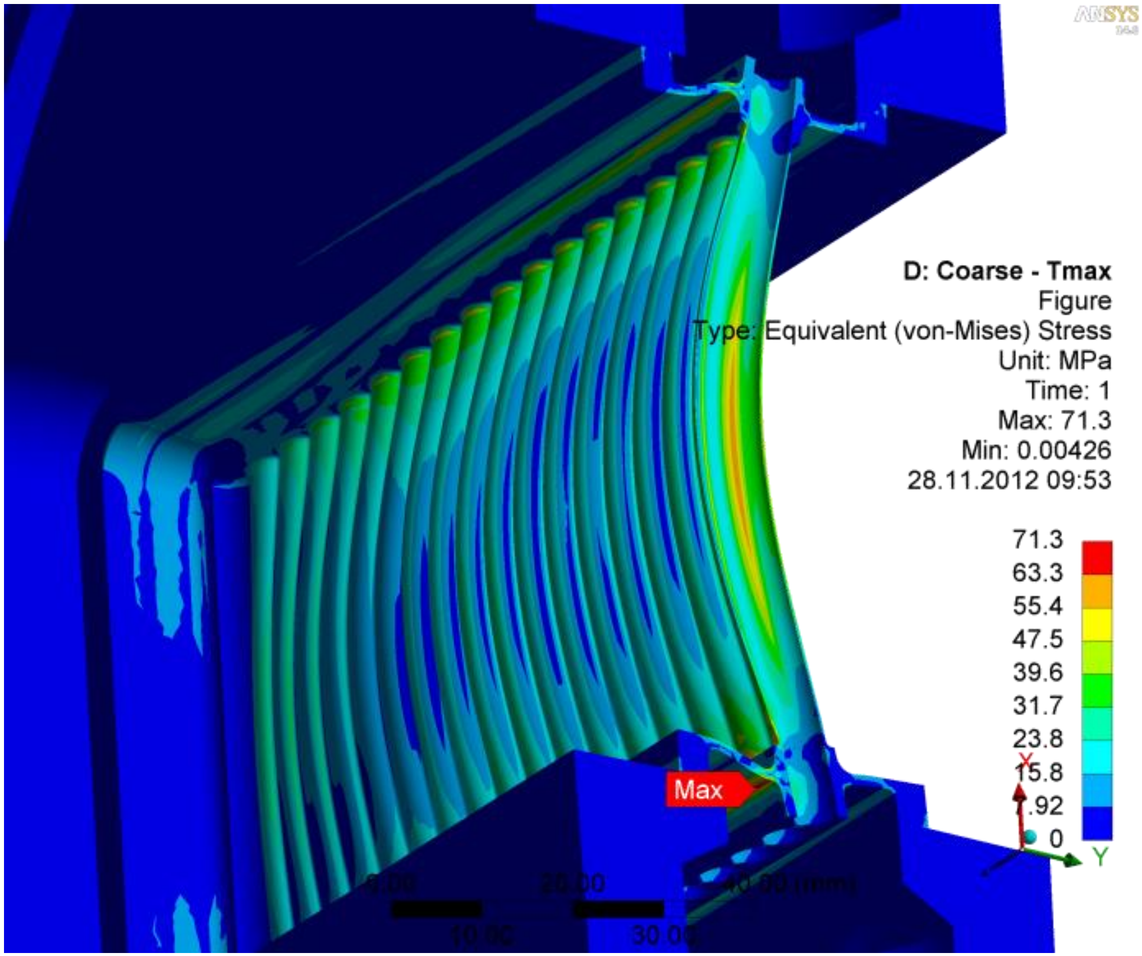
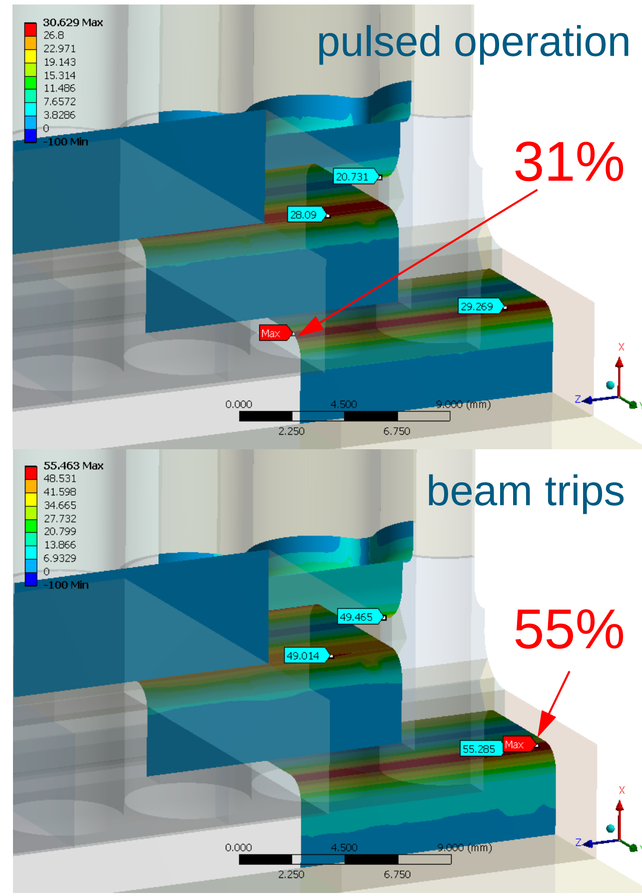
# Design of Proton Beam Windows

## ↳ design against fatigue for ESS




resultant stresses due to thermal and mechanical loading




calculated utilization factors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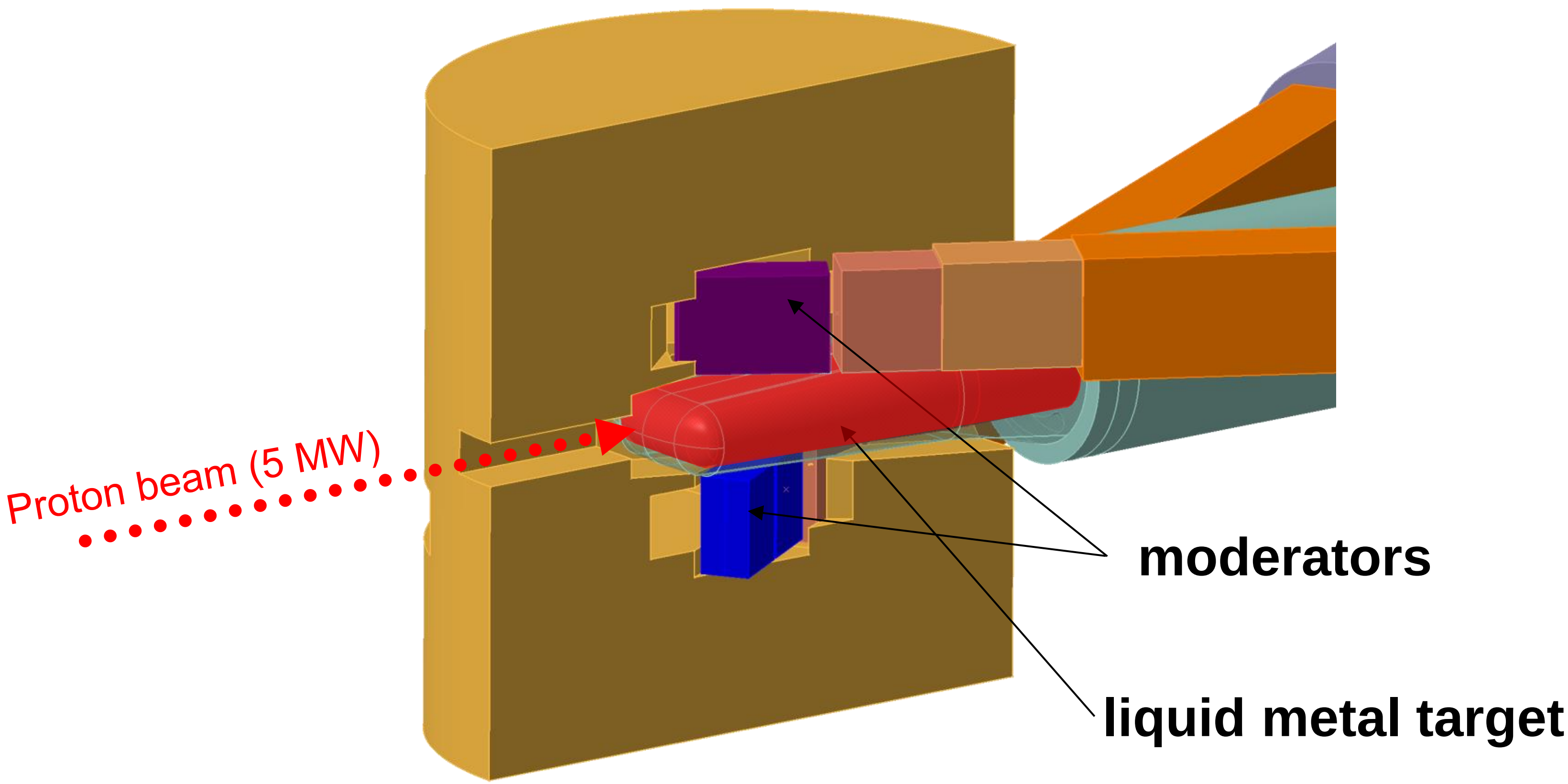
# Design of ESS Mercury Target

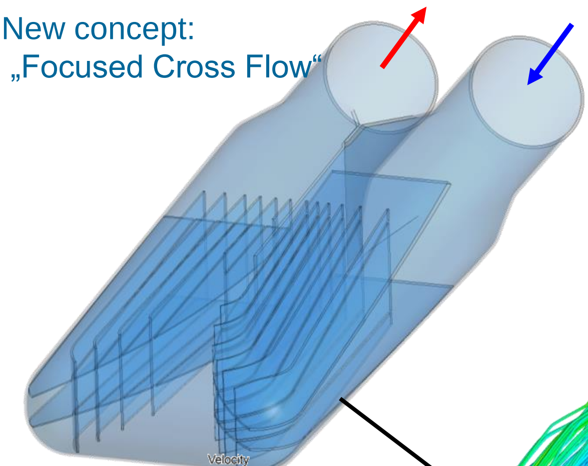
## configuration



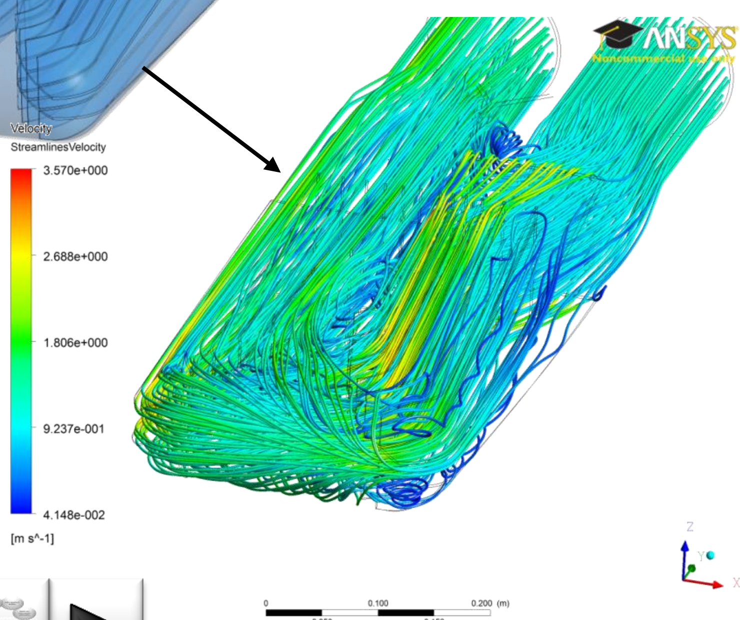
# Design of ESS Mercury Target
## ↳ thermal hydraulic design

Focus on:
- ➢ cooling of beam entrance window
- ➢ heat removal capacity

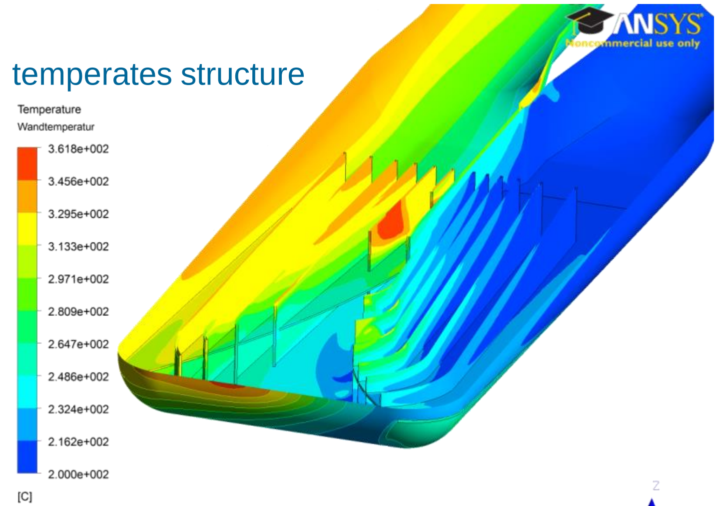
New concept:
„Focused Cross Flow“



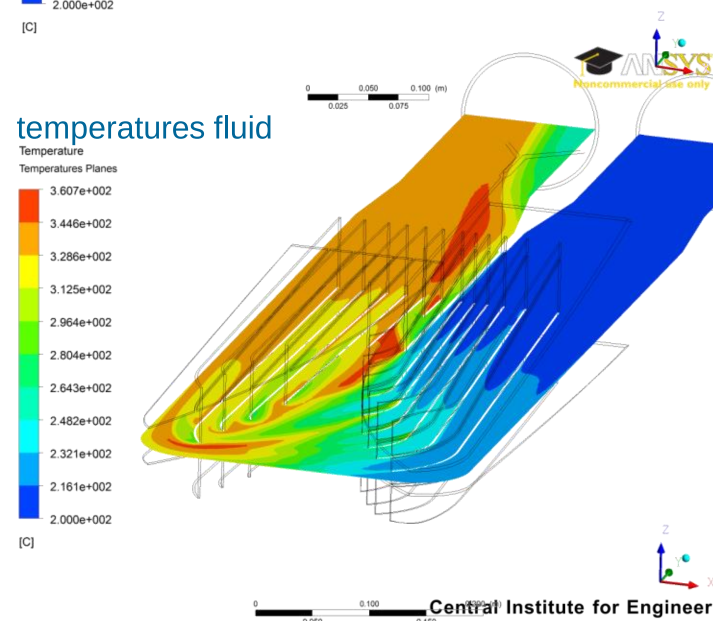
fluid velocity




temperates structure

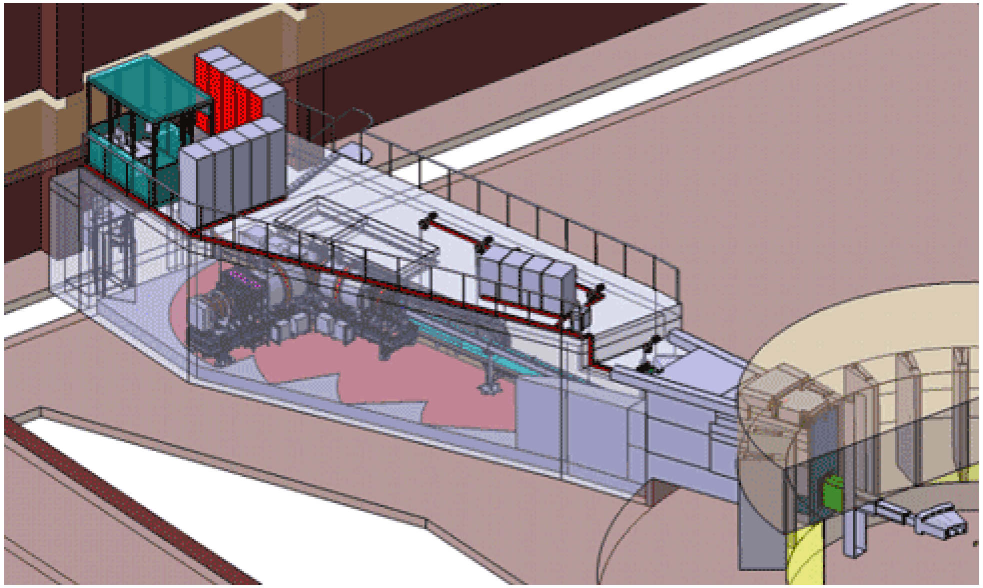



temperatures fluid



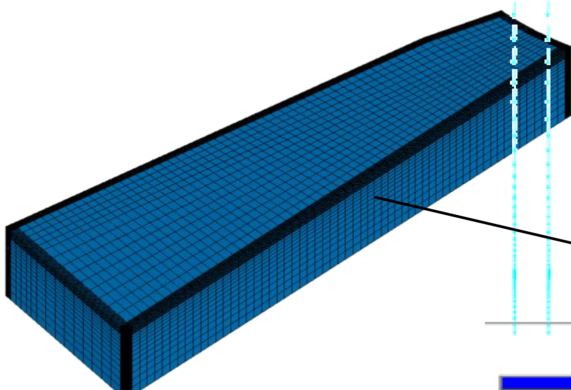
# Design of Magnetic Shielded Room

## ↳ for neutron spin echo spectrometer @SNS

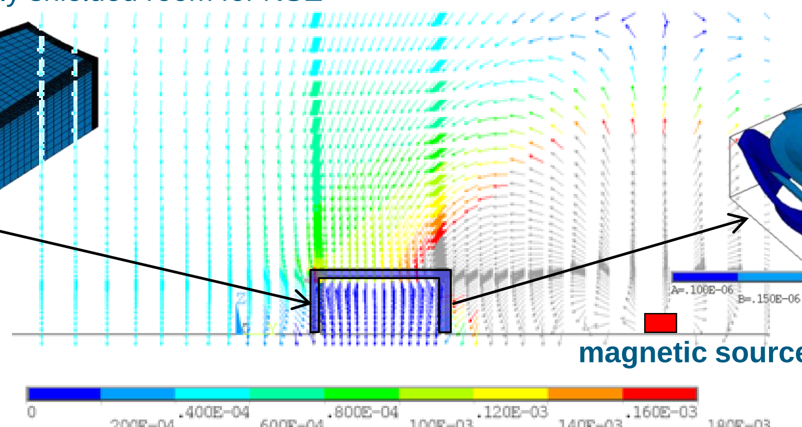


designer's first view of the magnetically shielded room for NSE

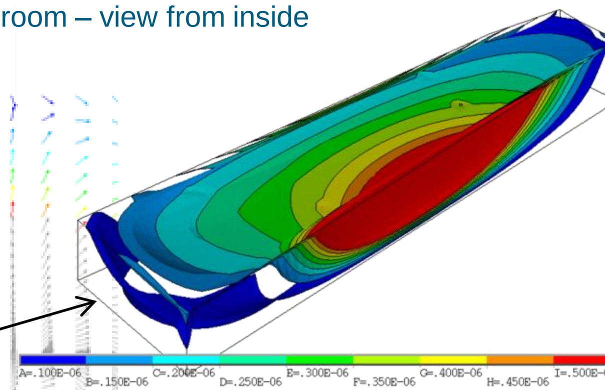
shielded room – view from inside



FE model of the double-walled room made of µ-material




magnetic flux density calculation for an external magnetic source

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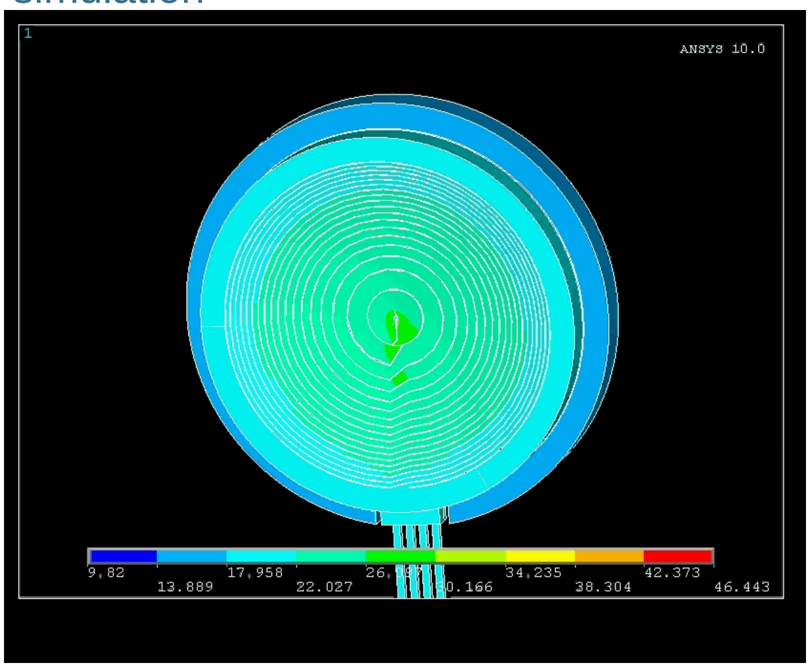
# Thermal Design of Correction Coils

## ↳ for neutron spin echo spectrometer @SNS

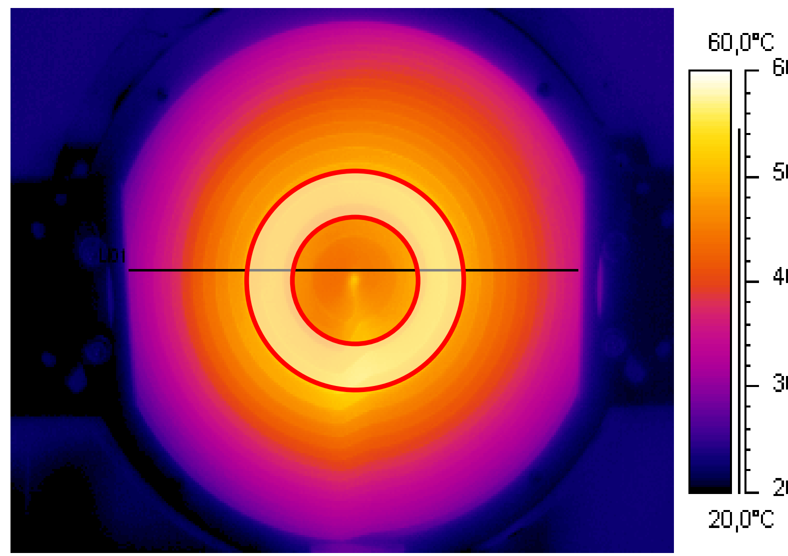
- current density in the coil was calulated
- thermal load due to high current modeled
- cooling by bonded cooling plate was considered

## Temperature distribution in the coil

simulation




measurement

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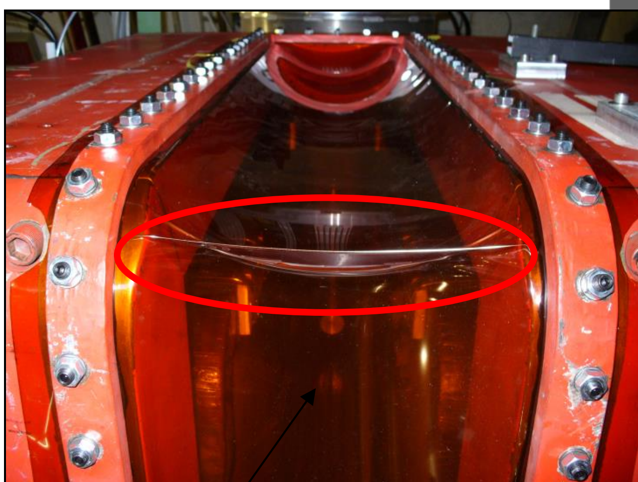
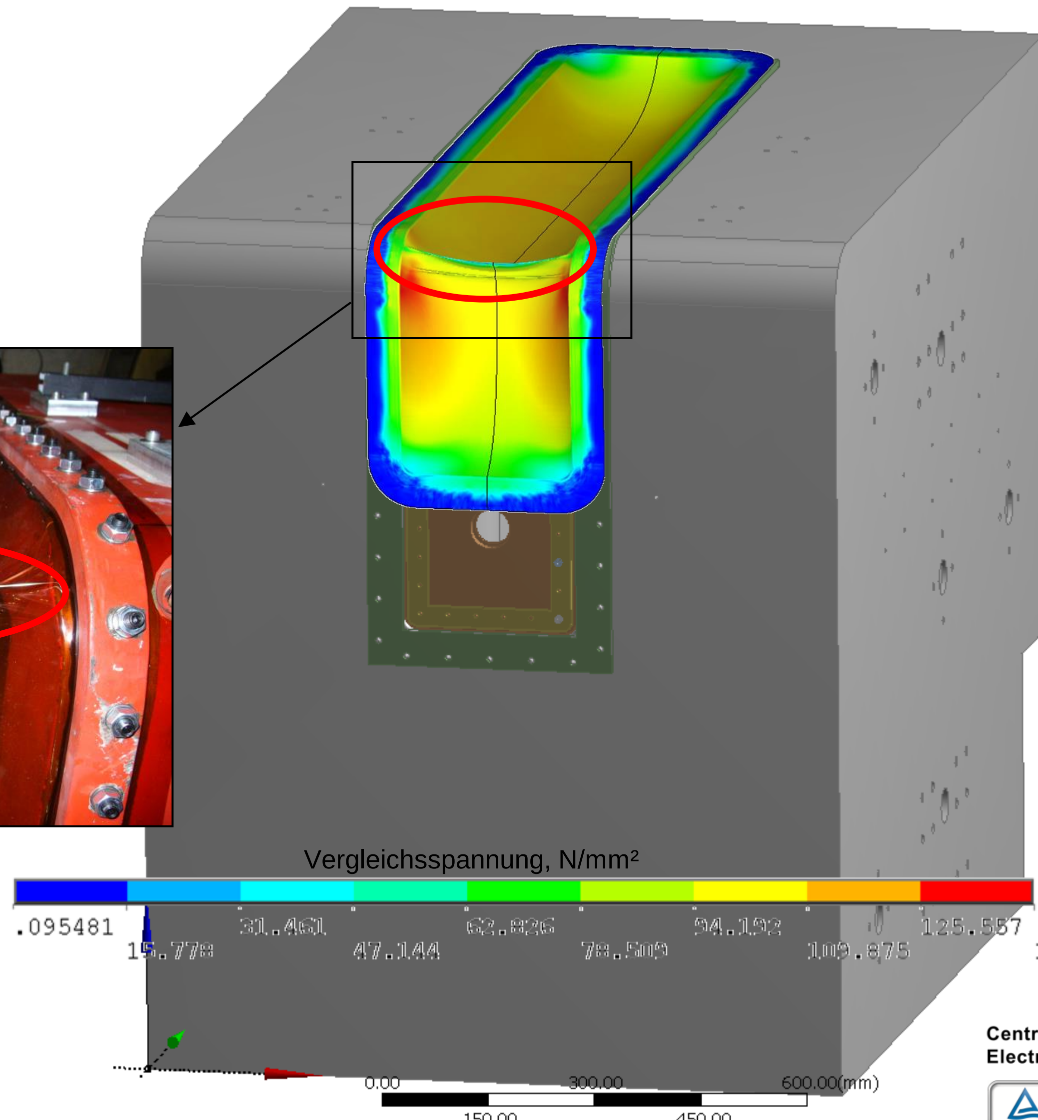
# Kapton foil window for a vacuum chamber






**Kapton foil**

# Optimization of the chopper disk contour

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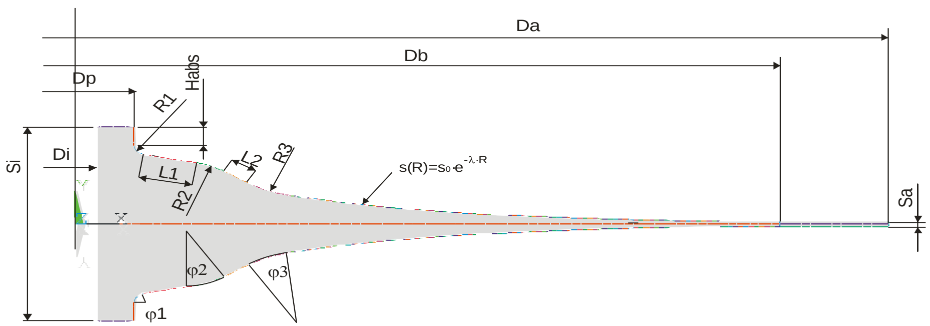
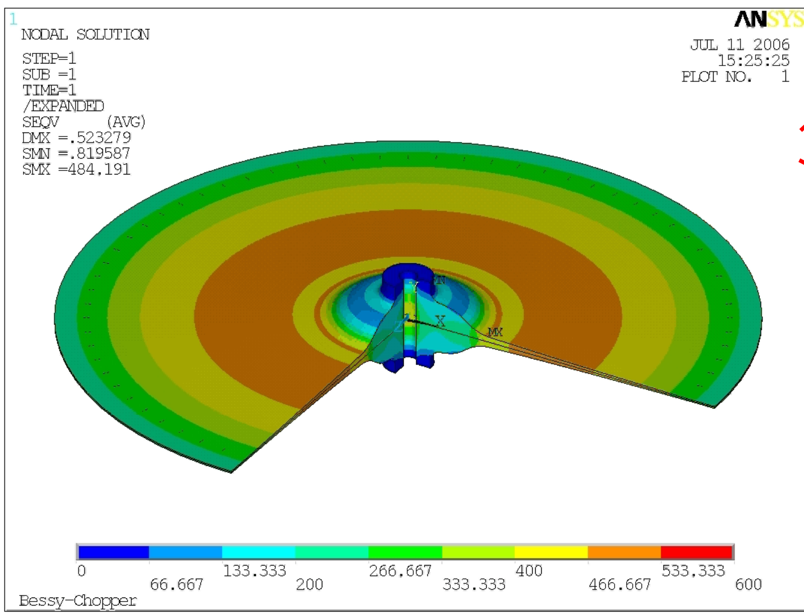
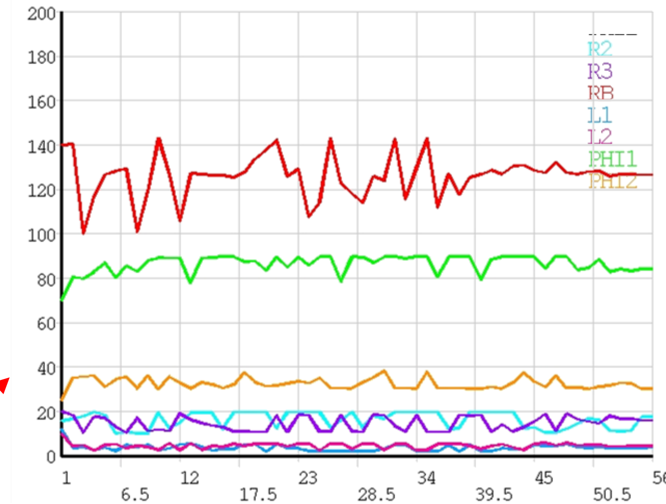
## parameterized model



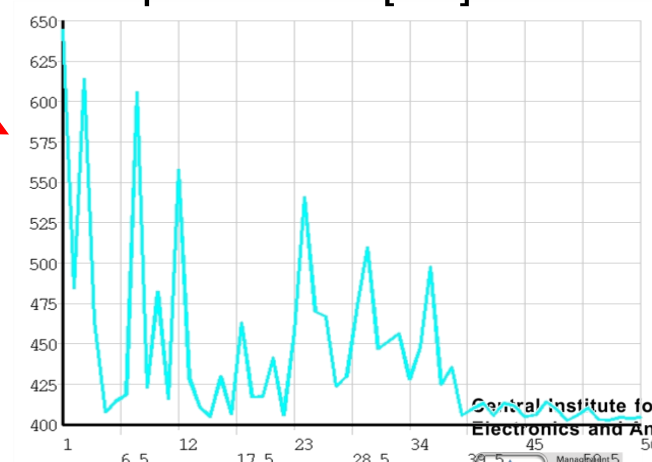

## Optimization process in ANSYS




## Variation of parameters




## Max. equivalent stress [MPa]



# Lysimeterpress

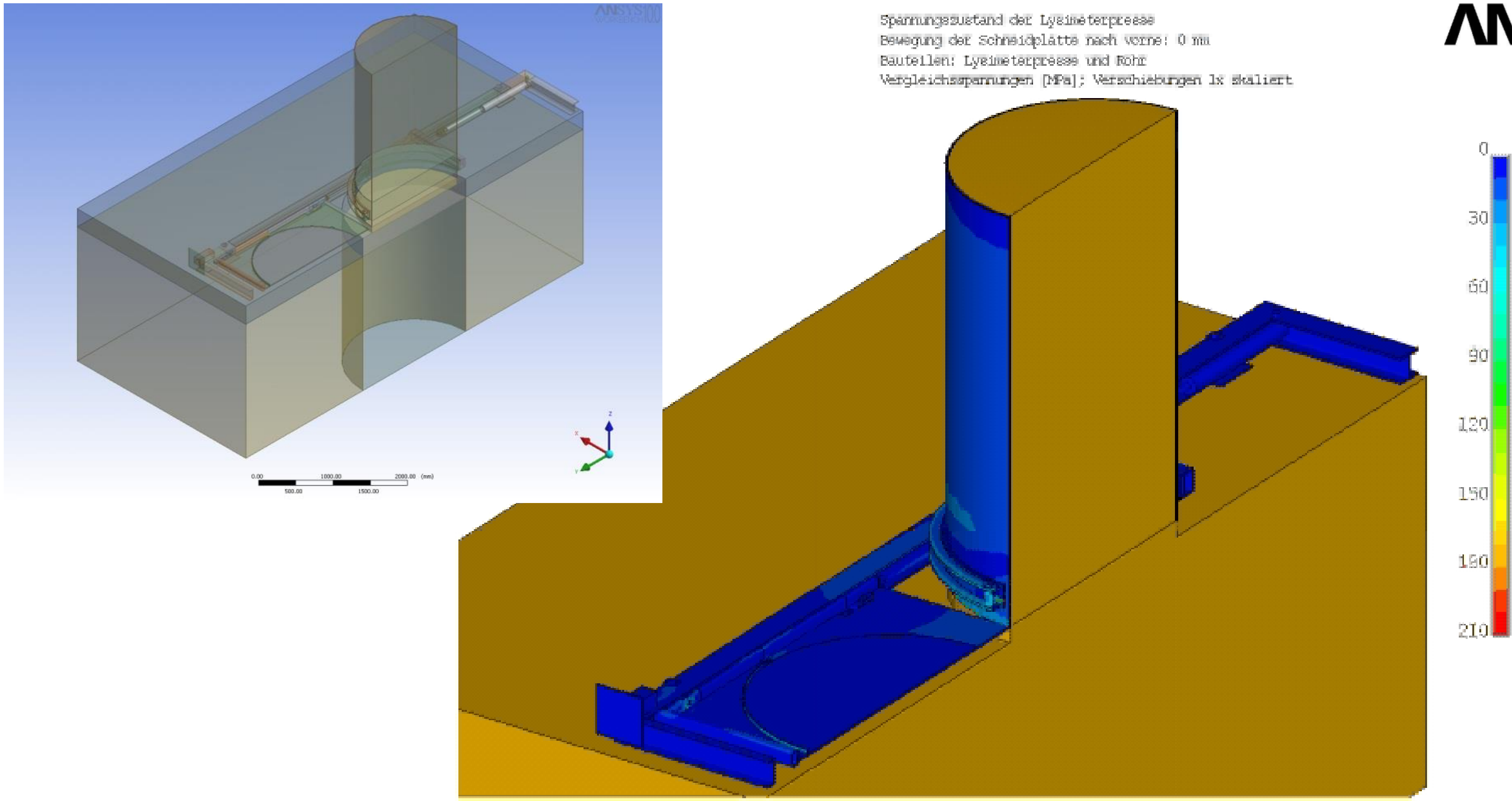
## introduction

- Lysimeters are tubes containing soil samples for scientific experiments in the field of agricultural and environmental research
- The tubes are pressed into the soil and afterwards excavated
- A sintered metal plate is used to cut the soil column and to seal the lysimeter


# Lysimeterpress

## ↳ optimization of lysimeterpress

- Project start: typical engineering task -> optimization of design




ANSYS



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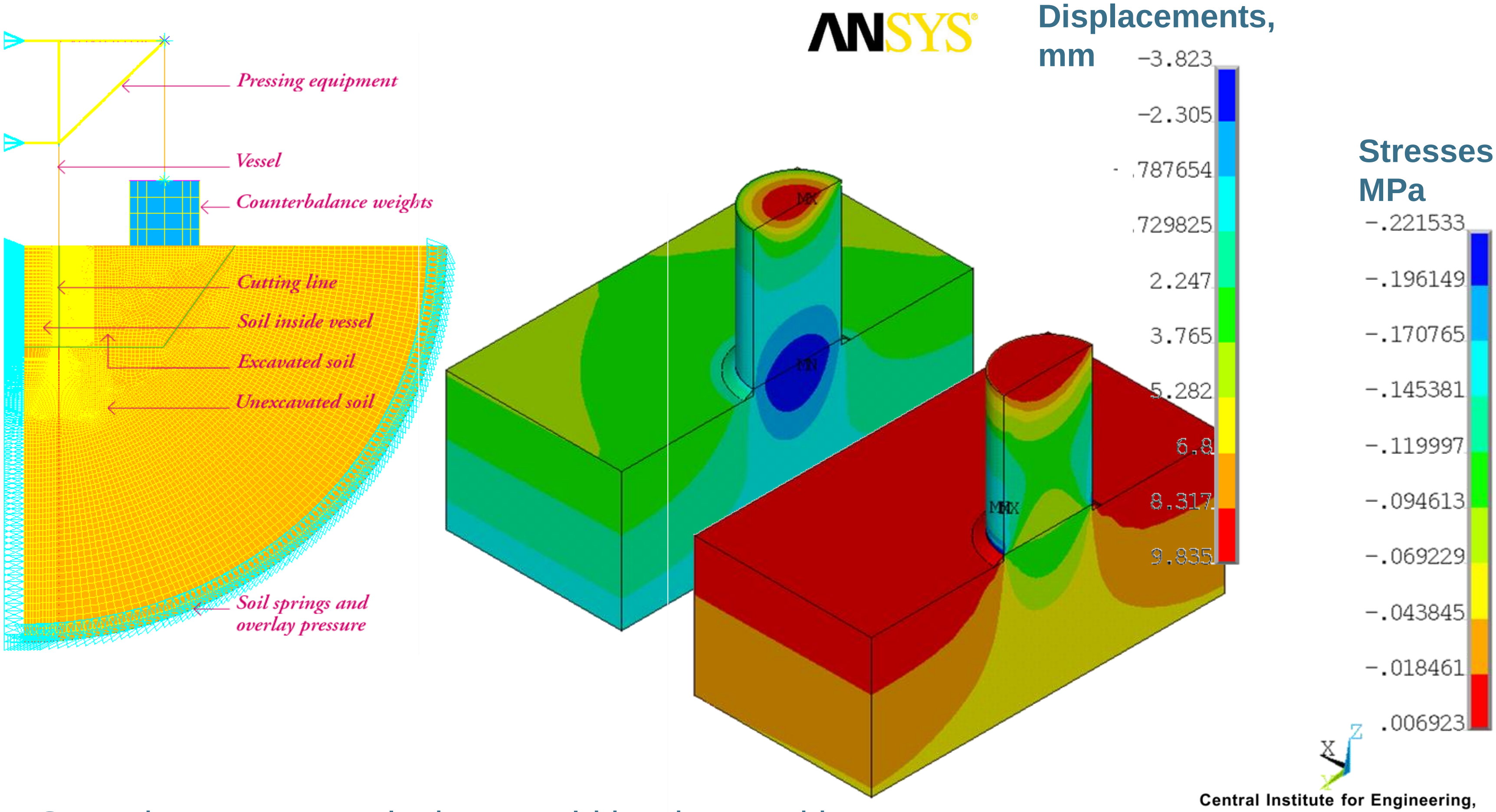
# Lysimeterpress

## ↳ optimization of lysimeterpress

- Project progress: scientific aspect -> soil state in lysimeter

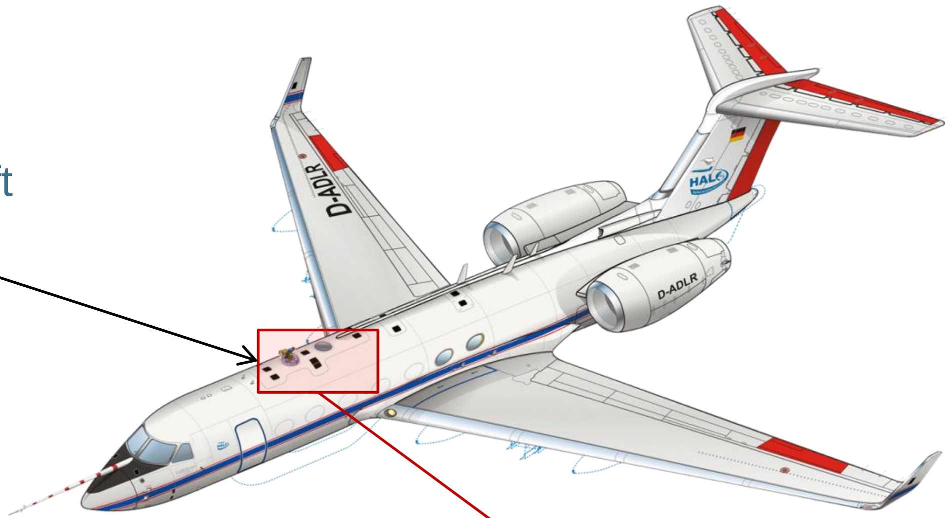



- Some important conclusions could be drawn with respect to the influence of the lysimeter design on the soil state

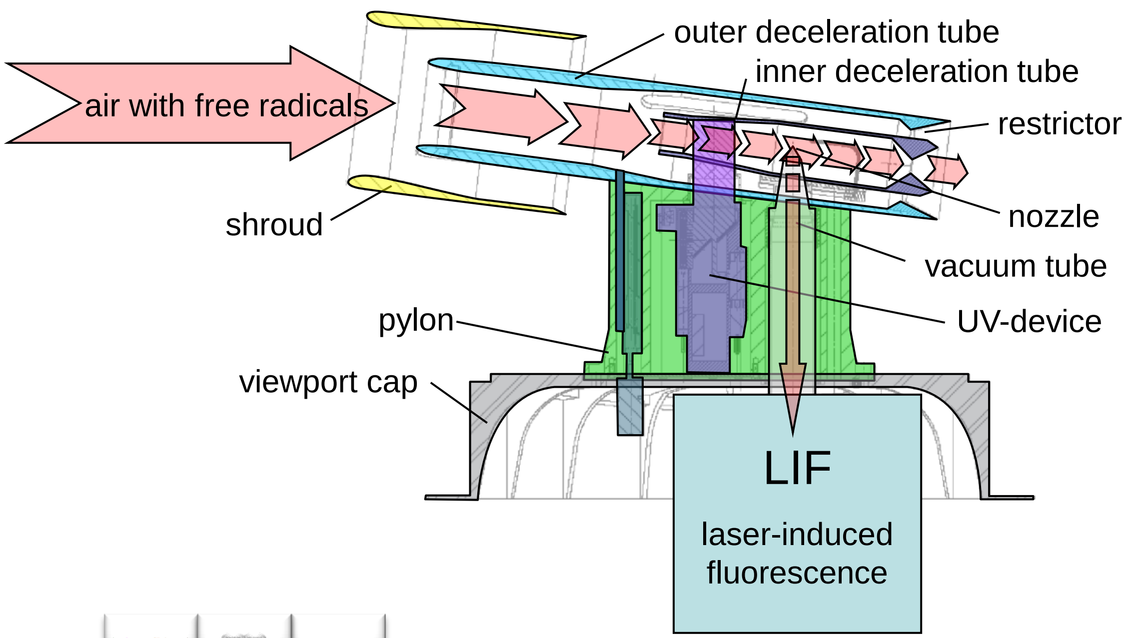
# Inlet System for HALO

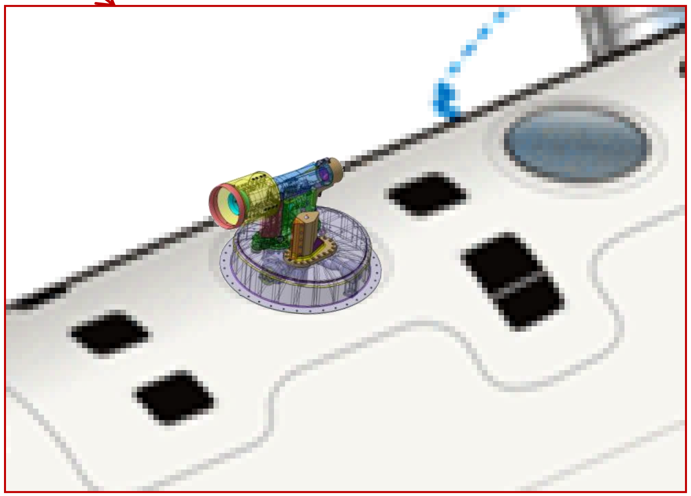
## introduction

- HALO = high altitude and long range research aircraft
- Inlet system for LIF device (measuring radicals)




principle set-up:

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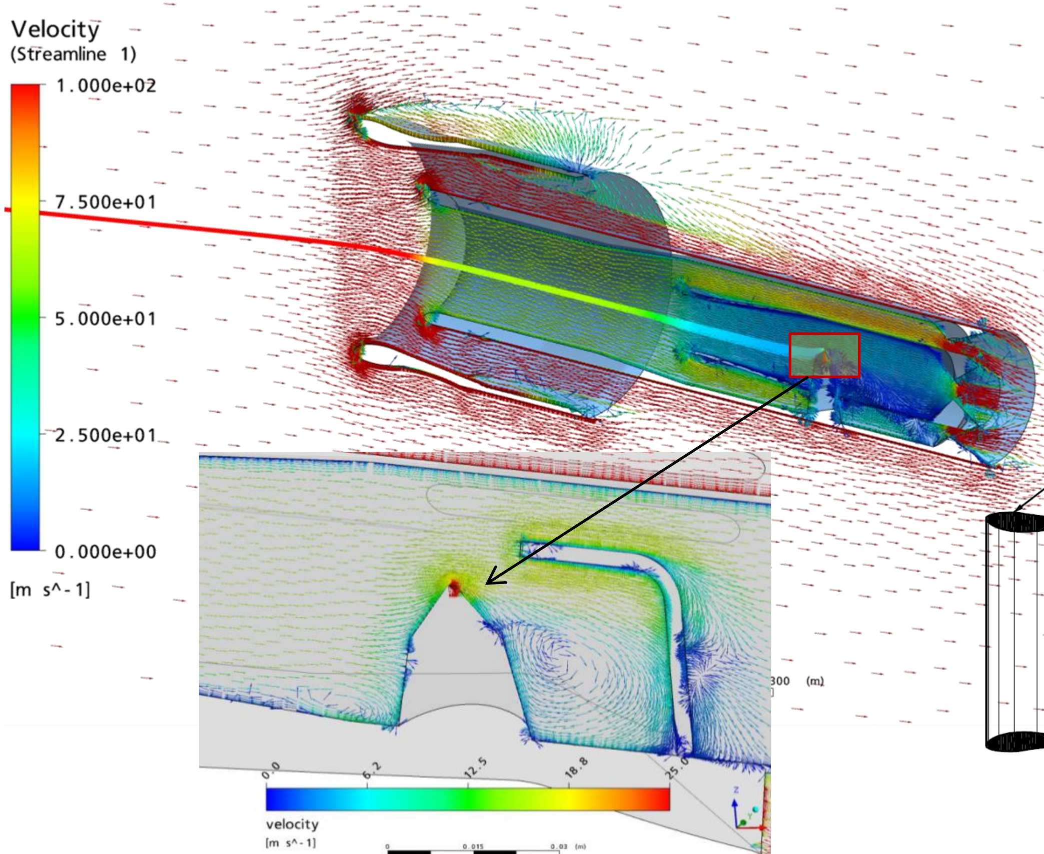
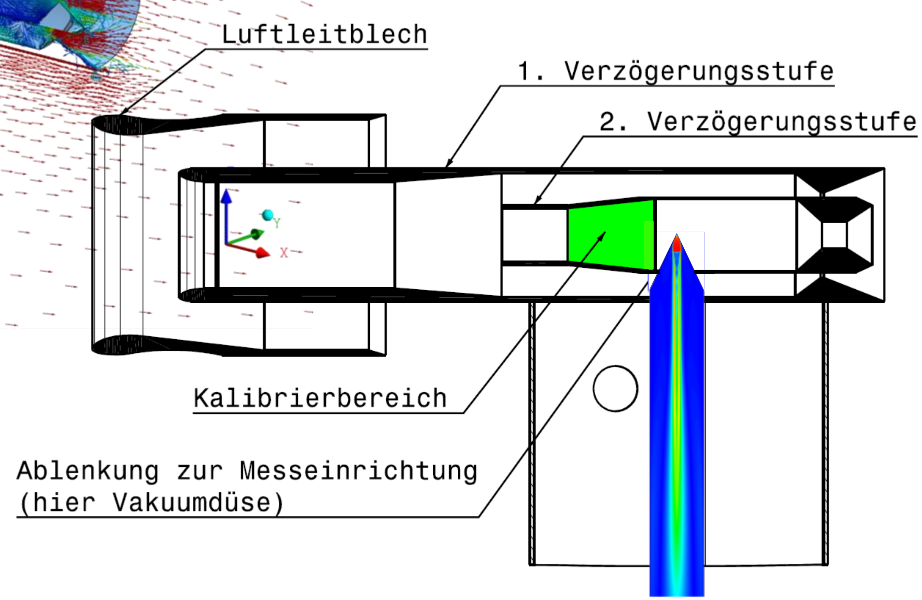
# Inlet system for HALO

## ↳ aerodynamic design




Typical question to answer

- influence of scaling
- design of restrictors
- influence of angle of attack
- risk of wall contact
- reduction of turbulence intensity

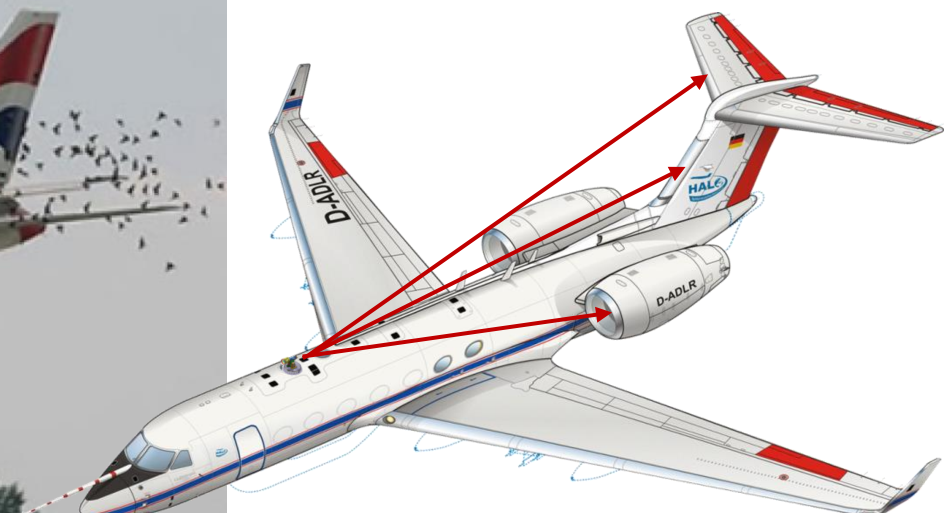



- design of the nozzle
- jet formation
- maximum distance to the LIF unit

# Inlet System for HALO

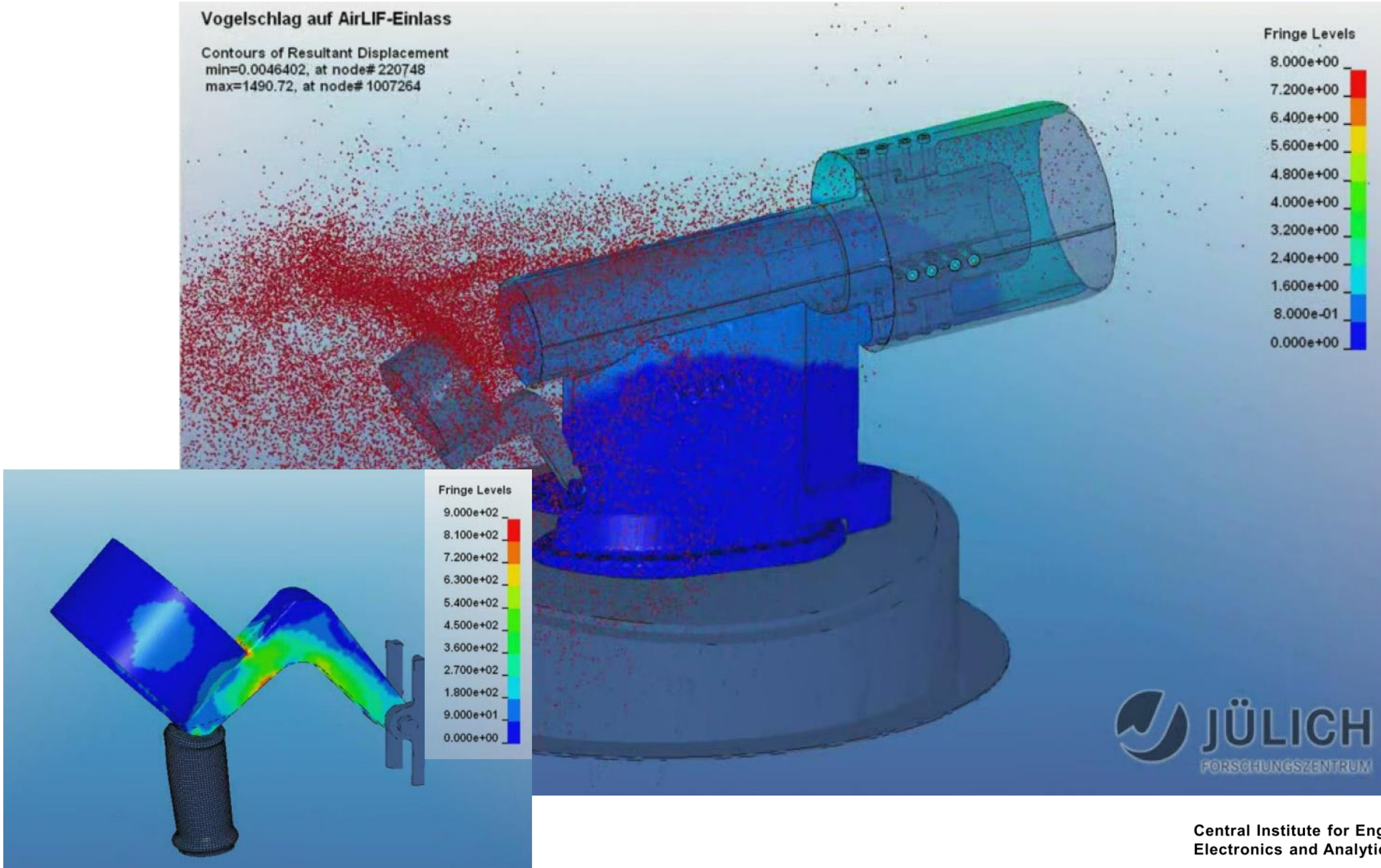
## bird strike event

- the ‘Bird strike’ load case is a critical design issue for the inlet system and has to be investigated (requirement of the Federal Office of Civil Aeronautics)
- the inlet system must be robust enough to avoid impact of broken-off parts into the engines or the tail assembly
- but if the inlet system is too stiff and totally ‘captures’ a bird (this would be the case if the restrictor is fixed to the inlet tubes) the aircraft shell can be seriously damaged



# Inlet System for HALO

## bird strike simulation





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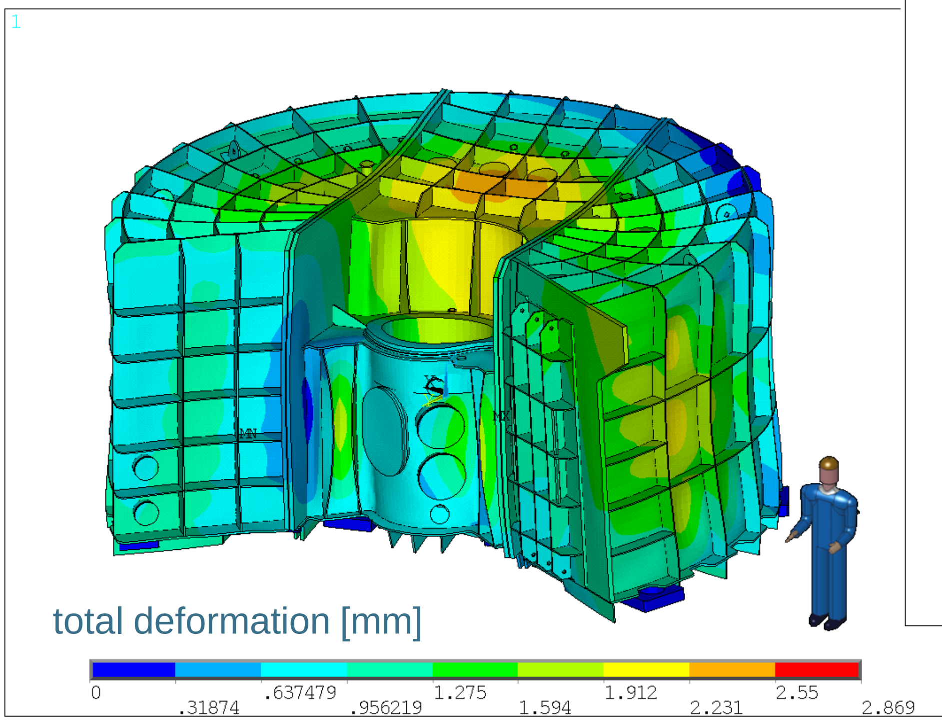
# Inlet system for HALO

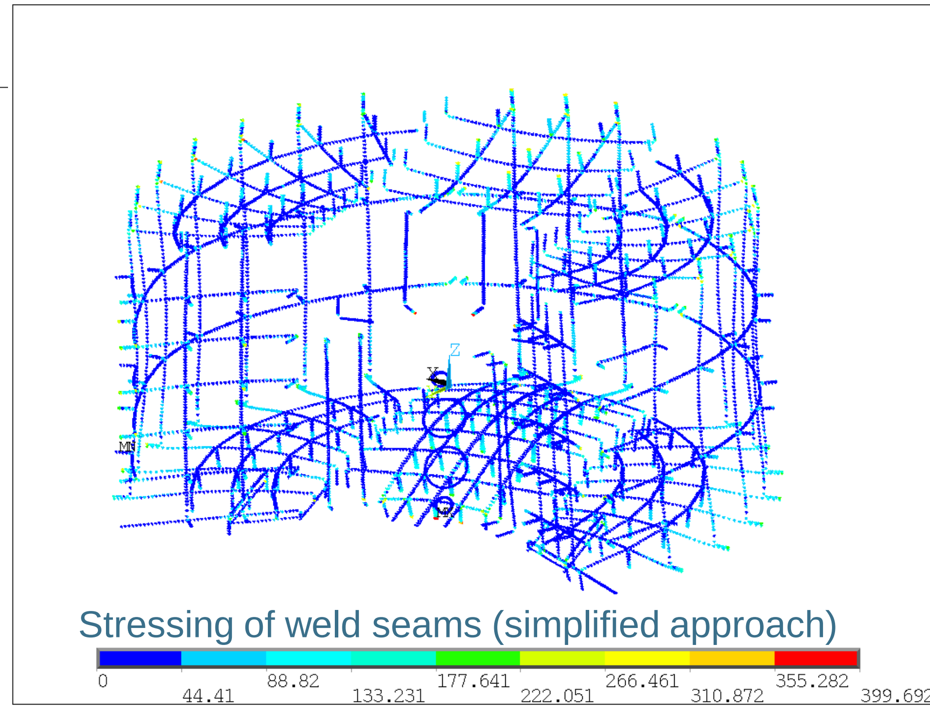
## ↳ bird strike test

# Mechanical Design of Vacuum Chambers

## ↳ weld seam design for the TOPAS vacuum chamber

- The TOPAS vacuum chamber was designed to withstand the outer pressure of 1 bar
- Weld seams could not be modeled in detail in the global model, therefore a simplified contact approach was used to determine critical regions..
- For the critical regions a sub-model was investigated in detail.

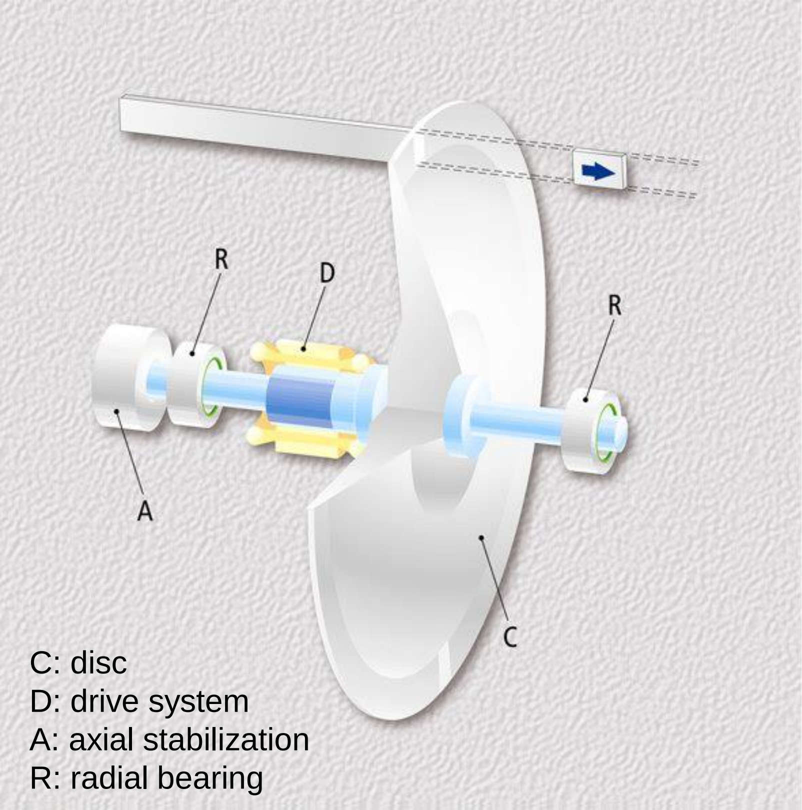


# Chopper Design

## introduction

- Neutron beams are useful probes for studying the arrangement of atoms in materials
- A neutron chopper is essentially a disc rotated at high speed with one or more ‘windows’, which the neutrons can pass unhampered at particular points in time
- By arranging several choppers - one after another - special neutron pulses can be selected
- At ZAT maintenance-free magnetic bearings are used for such chopper systems at high rotational speeds and operating in vacuum.
- Beside neutron choppers ZAT also developed and built neutron, light pulse and x-ray pulse selectors



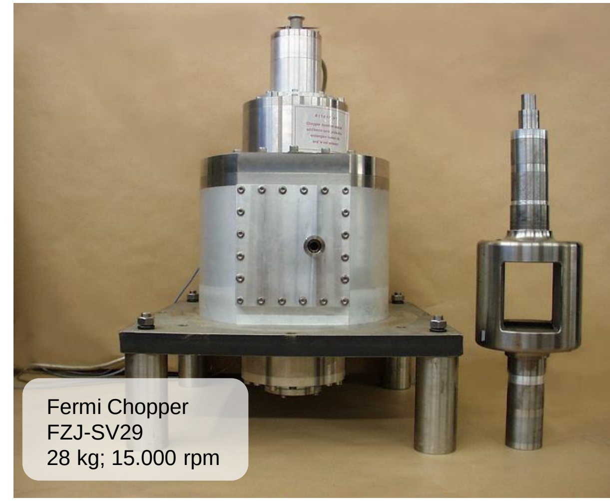

C: disc
D: drive system
A: axial stabilization
R: radial bearing

# Chopper Design

## ↳ typical choppers developed at ZEA-1

X-Ray Chopper
ESRF/ KEK/
Spring-8
1 kg; 60.000 rpm

Chopper Disk of PSI-
MARS Cascade
5 disks; max. 9 kg;
21.000 rpm



Fermi Chopper
FZJ-SV29
28 kg; 15.000 rpm

1.25 MHz Light
Source Pulse Selector
for BESSY, MPI Halle
1 kg; 60.000 rpm

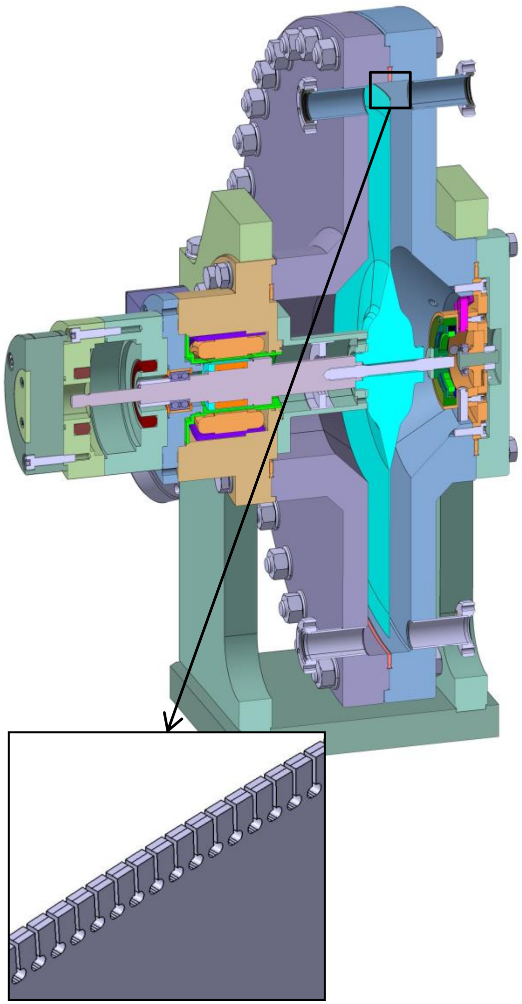
Chopper Cascade
ILL-IN5 TOF
6 disks; max. 8 kg;
20.000 rpm

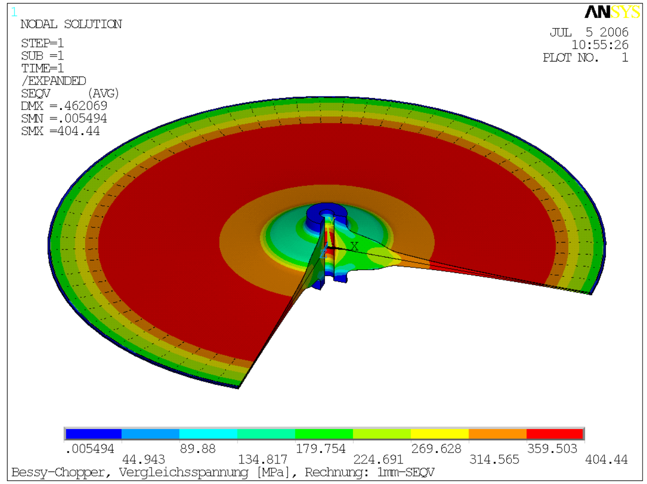
SNS-NSE
4 disks
7 kg; 3600 rpm

PST-Chopper
diameter 1280mm
4800 rpm

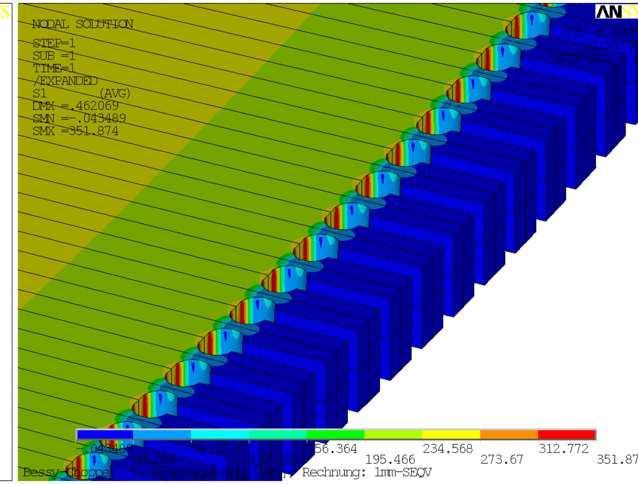
# Chopper Design

## ↳ mechanical design of chopper disc (here: BESSI)

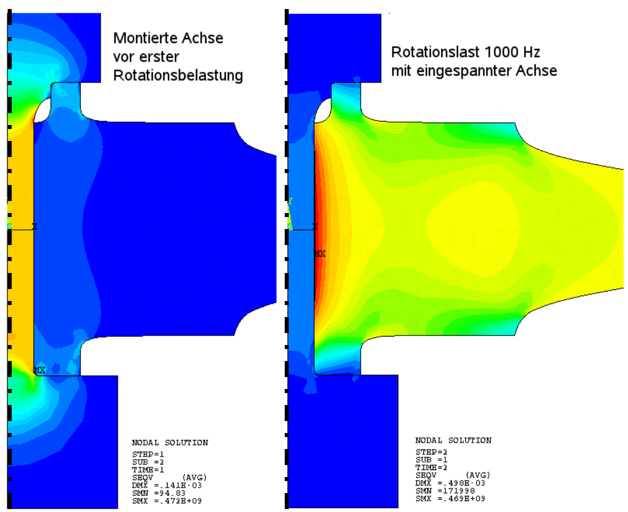





optimization of disc contour



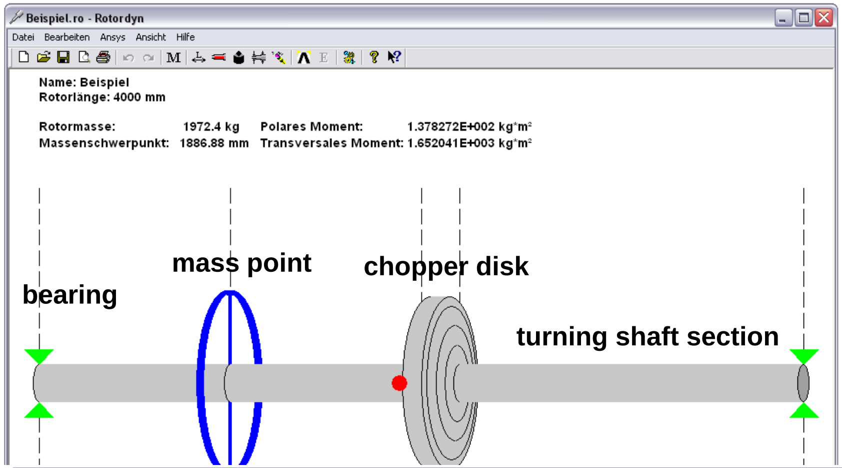

optimization of slit contour

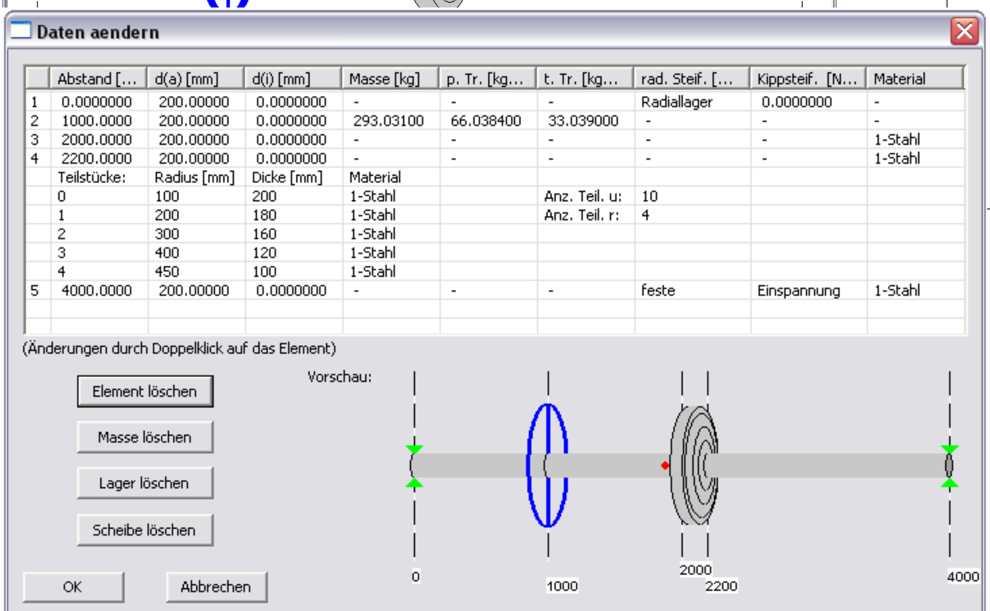



investigation of clamping

# Chopper Design

## ↳ rotor-dynamic design



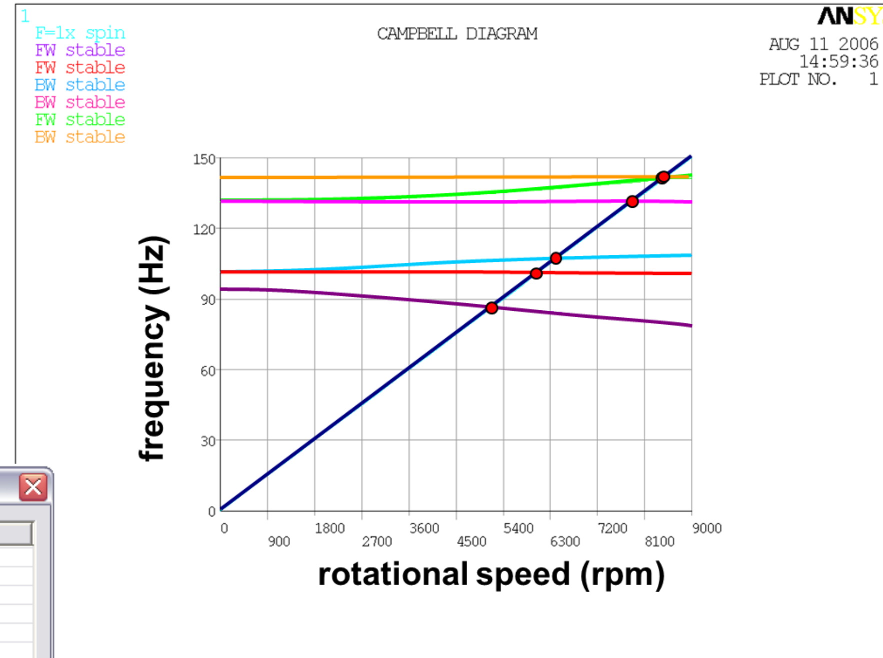


Daten aendern

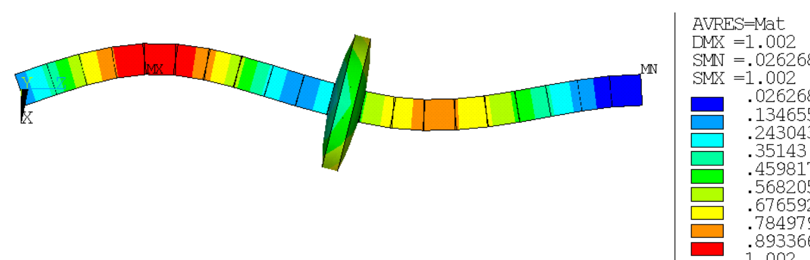
| | Abstand [... | d(a) [mm] | d(i) [mm] | Masse [kg] | p. Tr. [kg... | t. Tr. [kg... | rad. Steif. [... | Kippsteif. [N... | Material |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0000000 | 200.00000 | 0.0000000 | - | - | - | Radiallager | 0.0000000 | - |
| 2 | 1000.0000 | 200.00000 | 0.0000000 | 293.03100 | 66.038400 | 33.039000 | - | - | - |
| 3 | 2000.0000 | 200.00000 | 0.0000000 | - | - | - | - | - | 1-Stahl |
| 4 | 2200.0000 | 200.00000 | 0.0000000 | - | - | - | - | - | 1-Stahl |
| | Teilstücke: | Radius [mm] | Dicke [mm] | Material | | | | | |
| | 0 | 100 | 200 | 1-Stahl | | Anz. Teil. u: | 10 | | |
| | 1 | 200 | 180 | 1-Stahl | | Anz. Teil. r: | 4 | | |
| | 2 | 300 | 160 | 1-Stahl | | | | | |
| | 3 | 400 | 120 | 1-Stahl | | | | | |
| | 4 | 450 | 100 | 1-Stahl | | | | | |
| 5 | 4000.0000 | 200.00000 | 0.0000000 | - | - | - | feste | Einspannung | 1-Stahl |

(Änderungen durch Doppelklick auf das Element)

Element löschen
Masse löschen
Lager löschen
Scheibe löschen
OK
Abbrechen

Vorschau: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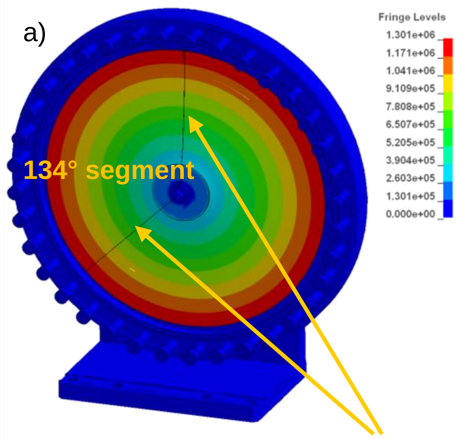
# Chopper Design

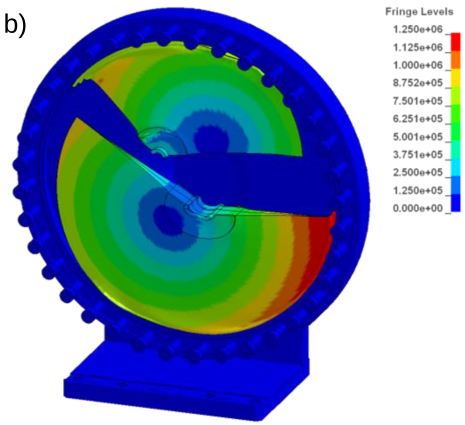
## safety case for housing

a)



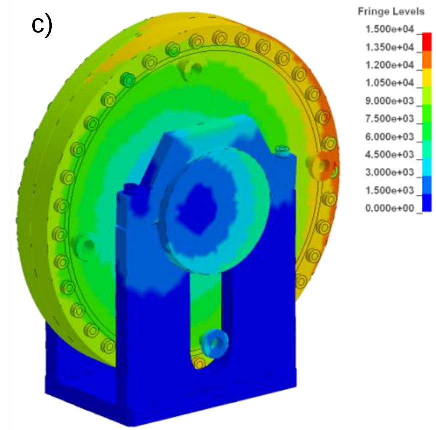

0 ms: initial conditions – disc with crack

b)



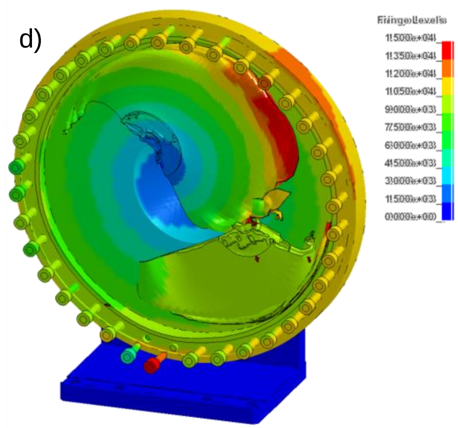

0.2 ms: disc crash on housing,
housing starts to rotate in its bearings

c)



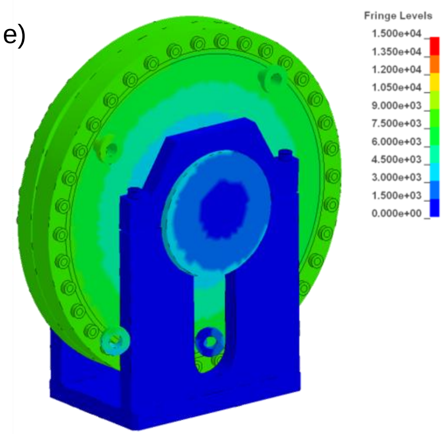

2,3 ms: first adapter shears-off due to rotation of housing

d)

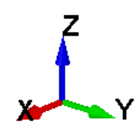


~4 ms: rotational speed of disc
≅ rotational speed of housing
(end of plastic impact)

e)

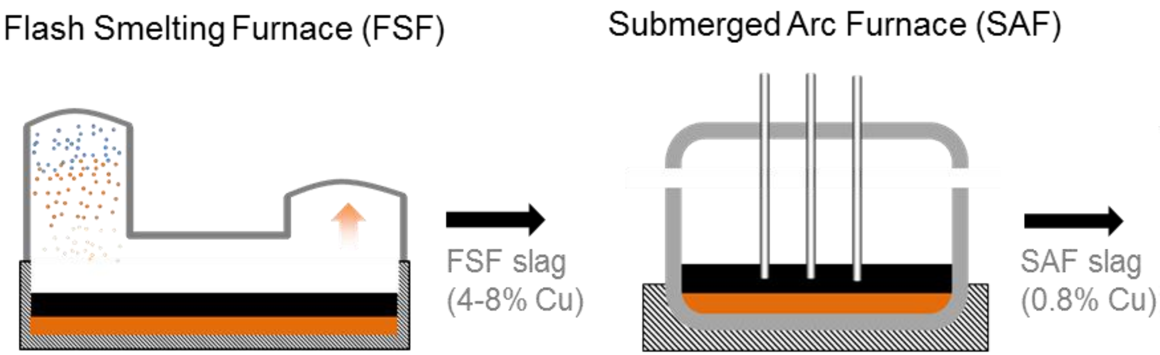


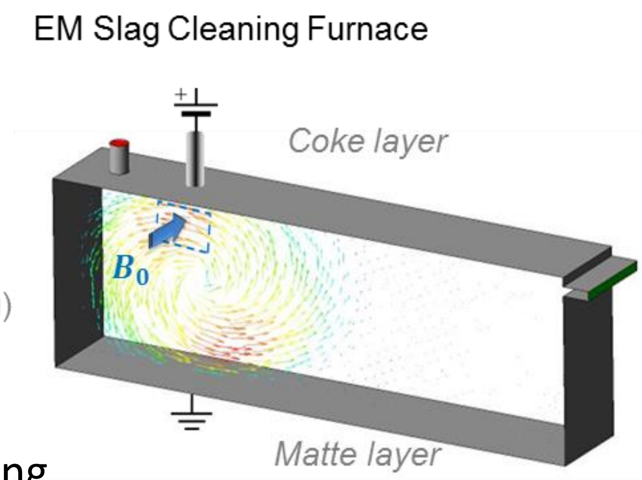

20 ms: end of simulation – the housing is still rotating but the remaining kinetic energy is less than 1% of the initial energy



# Copper Slag Cleaning Process

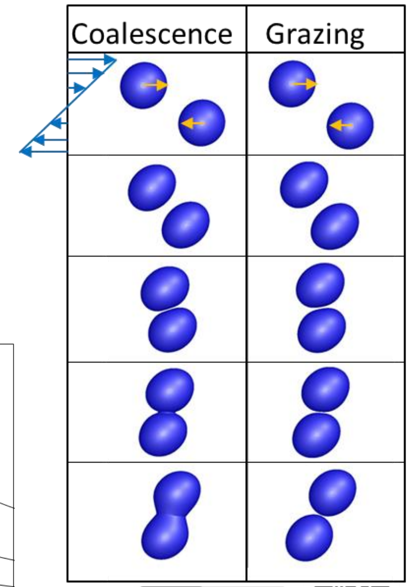
## ↳ electromagnetic stirring to intensify the cleaning process



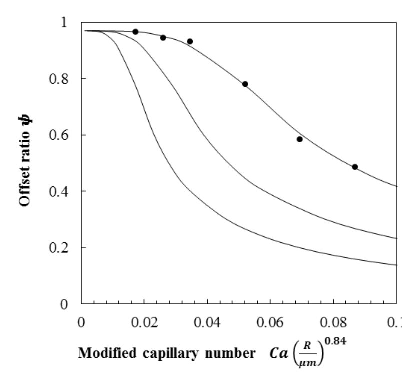

**Technical objective:**

- Enhanced inter-droplets collision and coalescence resulting in higher settling rates
- Significant reduction of copper content in slags up to 0.4%




**Main achievements:**

- Implementation of a mesh independent hybrid collision algorithm
- Using new collision outcome regime map based on VoF calculations
- Cooperation with SMS Group GmbH to share experimental and numerical achievements




# High pressure NPT 1 ½ ´´ - adapter

## ↳ detailed modelling of the thread collapse

Semi-empirical approach to determine required depth of engagement according to design rules not applicable

- pre-stress in conical thread
- flexibility of pipe fitting