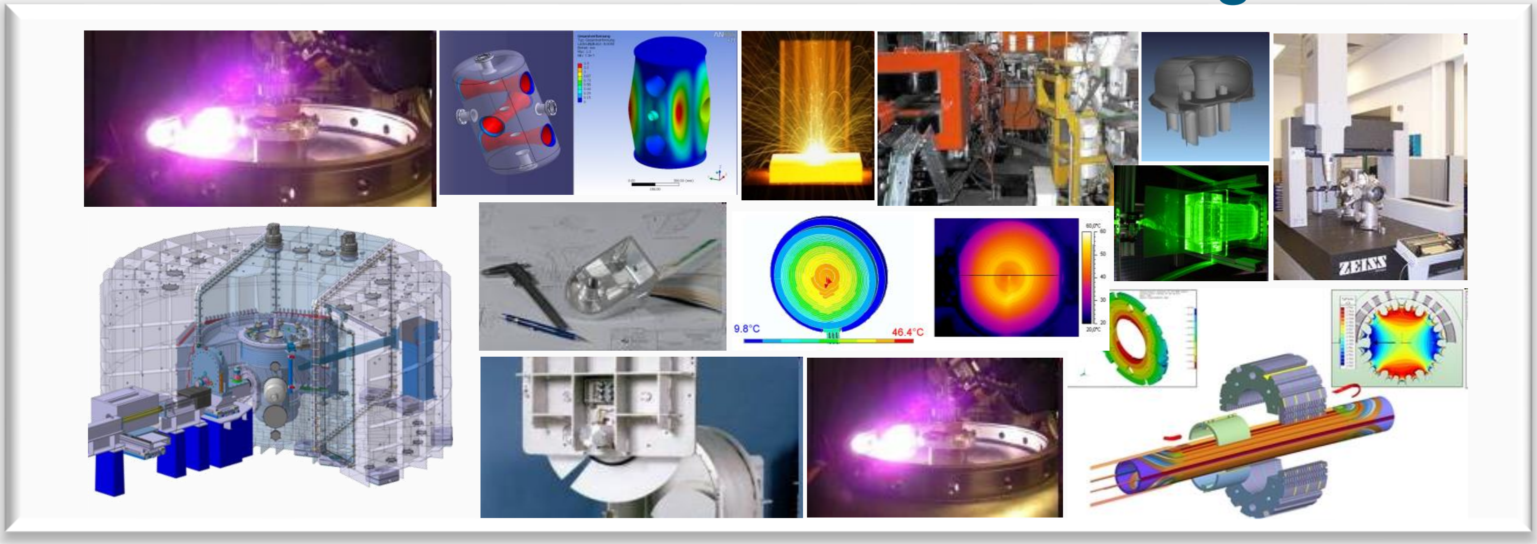
QUALITY-START-UP LECTURES
9th -13th September 2019

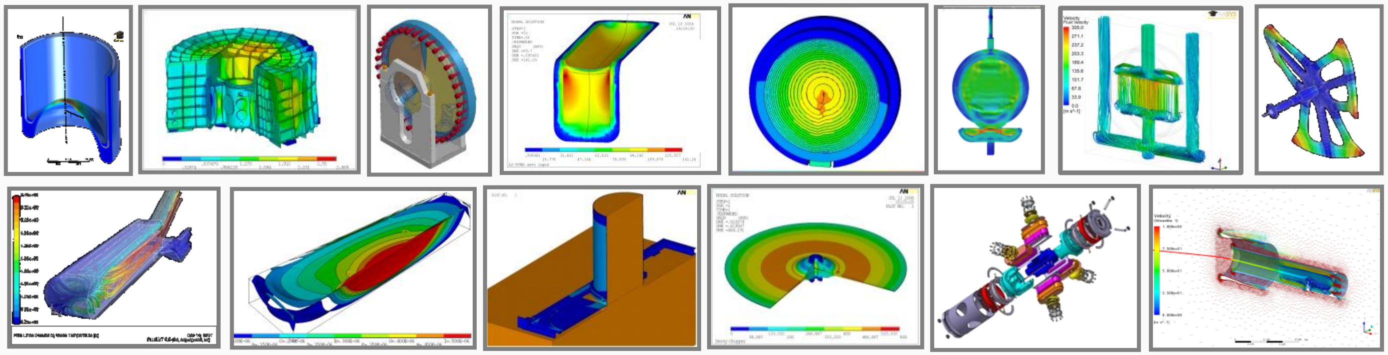
Georgian-German ScienceBRIDGE
CONNECTING PEOPLE AND KNOWLEDGE

JÜLICH
FORSCHUNGSZENTRUM

J. Wolters: Numerical Simulations and Design Calculations



typical applications at ZEA-1



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Central Institute for Engineering, Electronics and Analytics

ZEA-1 – Engineering und Technology

Central Institute for Engineering, Electronics and Analytics | ZEA

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Engineering und Technology | ZEA-1
Technology for World-Class Research

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.

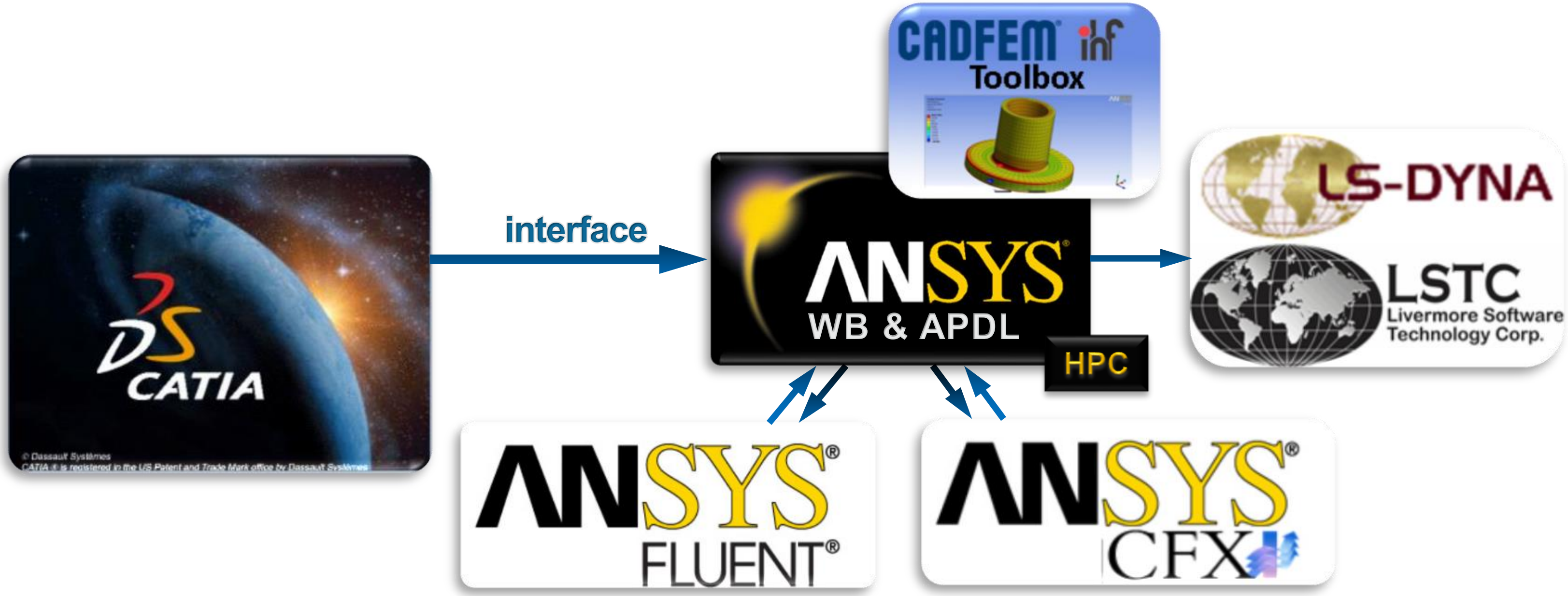
The Benefit of Modern Simulation Tools

- 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
- minimization/optimization of 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)



Ampere / Magneto
INTEGRATED ENGINEERING SOFTWARE

Opera
Cobham

Rifest Plus
IMA DRESDEN

DIMy
DRUCKGERÄTE-DIMENSIONIERUNG

Maplesoft
command the brilliance

Mathcad® 15.0

Microsoft® Excel

HPC Hardware at ZEA-1

- 8 compute nodes
- 80 cores
- 10 Gbit/s Ethernet network
- 464 GB main memory
- storage cluster Skylake1 as file server

- 10 compute nodes (+ 3 nodes for login / service)
- 48 cores / node = 480 cores
- 100 Gbit/s InfiniBand network
- 4608 GB main memory

GPFS storage cluster

Fields of Competence

fields of competence

- thermo-mechanical calculations
- collapse & buckling
- fatigue / fracture mechanics
- Vibrations, modal analyses & rotordynamics
- dynamics & crash simulations
- optimization
- CFD / thermal-hydraulics
- magneto-hydrodynamics (MHD)
- magnetic / electromagnetic calculations
- thermo-electric calculations

FEM

FEM = Finite Element Method

- numerical method

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

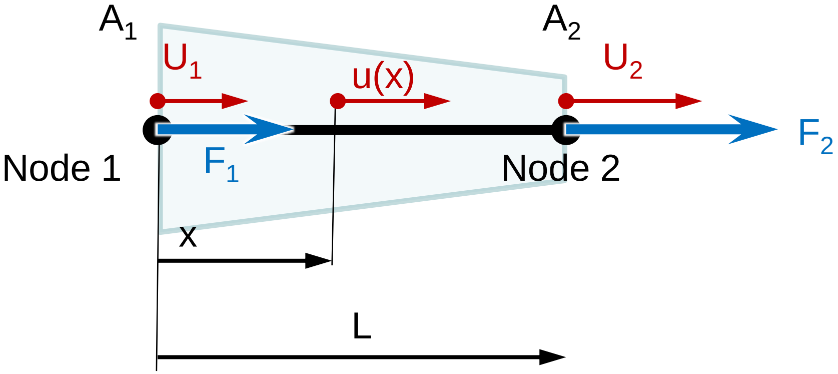
- applicable for differential equations for almost all technical problems

FEM - Theory

↳ degrees of freedom and shape functions

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

example: linear bar element



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

Element strain given by derivative with respect to x:

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

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

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

[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

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

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

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

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

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

FEM - Theory

↳ potential energy function for linear elastic materials

The system is at a stable/stationary position when an infinitesimal variation from such position (discrete values {U}) involves no change in the total potential energy:

example: linear bar element

$$\left\{\frac{\partial \Pi}{\partial U}\right\} = \left\{\begin{matrix}\dfrac{\partial \Pi}{\partial U_1}\\[2ex] \dfrac{\partial \Pi}{\partial U_2}\end{matrix}\right\} = \left\{\begin{matrix}\dfrac{\partial\left(\frac{1}{2}\cdot\frac{E\cdot A_m}{L}(U_2-U_1)^2 - F_1\cdot U_1 - F_2\cdot U_2\right)}{\partial U_1}\\[3ex] \dfrac{\partial\left(\frac{1}{2}\cdot\frac{E\cdot A_m}{L}(U_2-U_1)^2 - F_1\cdot U_1 - F_2\cdot U_2\right)}{\partial U_2}\end{matrix}\right\} = \{0\}$$

$$\Rightarrow \left\{\begin{matrix}\frac{1}{2}\cdot\frac{E\cdot A_m}{L}\cdot 2(U_2-U_1)\cdot(-1) - F_1\\[2ex] \frac{1}{2}\cdot\frac{E\cdot A_m}{L}\cdot 2(U_2-U_1)\cdot(1) - F_2\end{matrix}\right\} = \{0\}$$

$$\Rightarrow \underbrace{\underbrace{\frac{E\cdot A_m}{L}}_{bar\ stiffness}\begin{bmatrix}1 & -1\\ -1 & 1\end{bmatrix}}_{stiffness\ matrix\ [K]}\begin{Bmatrix}U_1\\ U_2\end{Bmatrix} = \begin{Bmatrix}F_1\\ F_2\end{Bmatrix}$$

general formulation

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

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

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

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

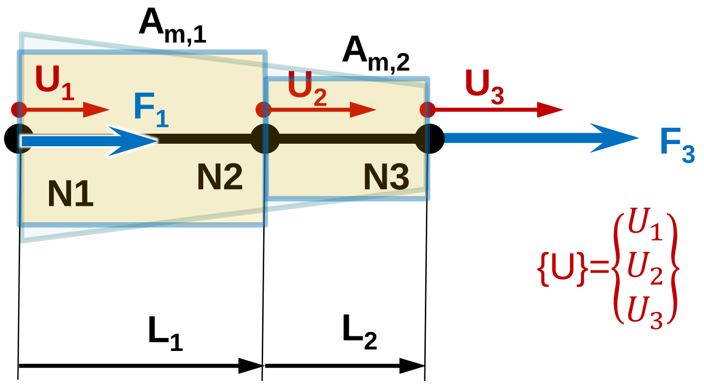
$$\Rightarrow [K]^{(e)}\{U\}^{(e)} = \{F\}^{(e)}$$

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

FEM - Theory

connecting elements

example: linear bar element



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

Expanding element set of equations

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

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

general formulation

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

Superposition

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

$$\begin{bmatrix} \frac{E_1\cdot A_{m,1}}{L_1} & -\frac{E_1\cdot A_{m,1}}{L_1} & 0 \\ -\frac{E_1\cdot A_{m,1}}{L_1} & \frac{E_1\cdot A_{m,1}}{L_1}+\frac{E_2\cdot A_{m,2}}{L_2} & -\frac{E_2\cdot A_{m,2}}{L_2} \\ 0 & -\frac{E_2\cdot A_{m,2}}{L_2} & \frac{E_2\cdot A_{m,2}}{L_2} \end{bmatrix}\begin{Bmatrix}U_1\\U_2\\U_3\end{Bmatrix} = \begin{Bmatrix}F_1\\0\\F_3\end{Bmatrix}$$

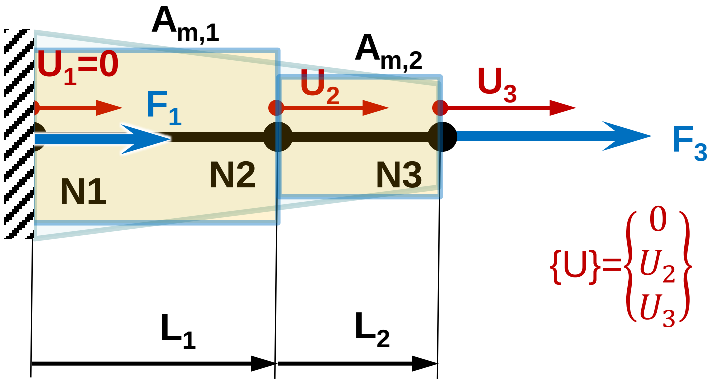
$$\Rightarrow [K]\{U\} = \{F\}$$

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

FEM - Theory

↳ fixed degrees of freedom

Fixed degrees of freedom will reduce the set of equations



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

example: linear bar element

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

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

Solving reduced set of equations:

$$\Rightarrow U_2=\frac{F_3\cdot L_1}{E_1\cdot A_{m,1}}; U_3=\frac{F_3\cdot L_2}{E_2\cdot A_{m,2}}+\frac{F_3\cdot L_1}{E_1\cdot A_{m,1}}$$

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

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:

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

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

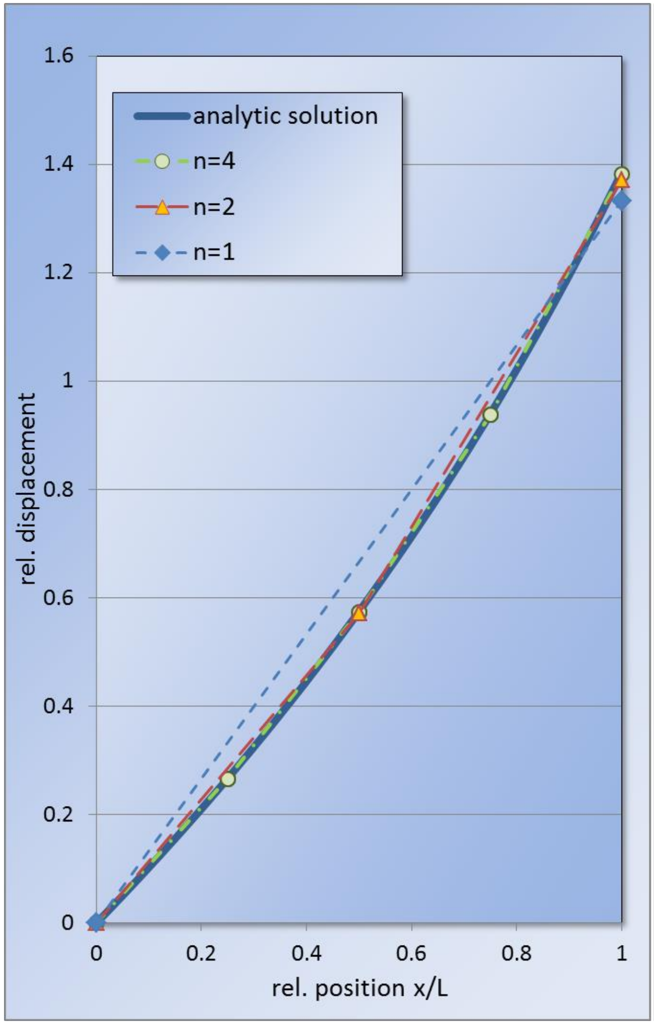
Analytic solution:

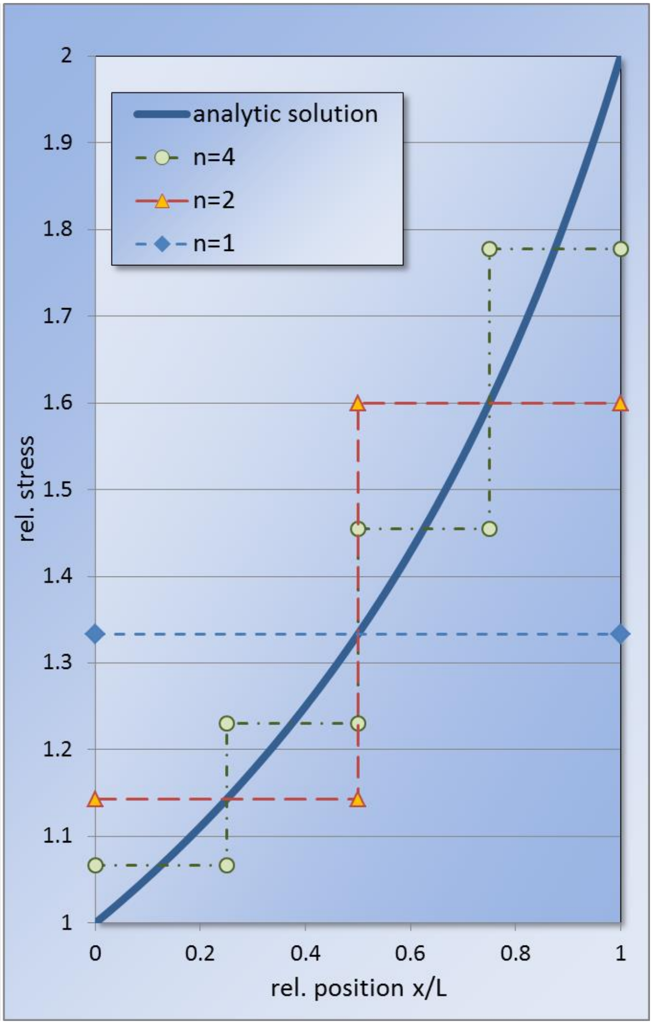
$$u_r(x) = \frac{u(x)}{\frac{F\cdot L}{A_0\cdot E}}$$

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

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

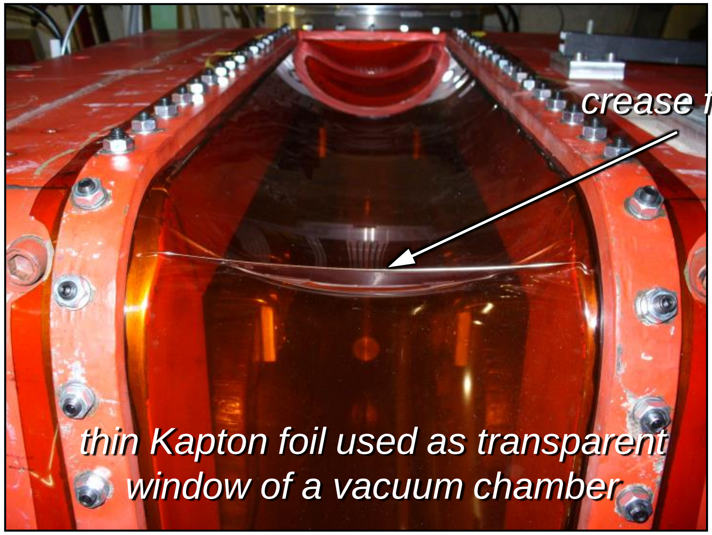
$$\Rightarrow \sigma_r(x) = \frac{1}{1-\frac{x}{2L}}$$





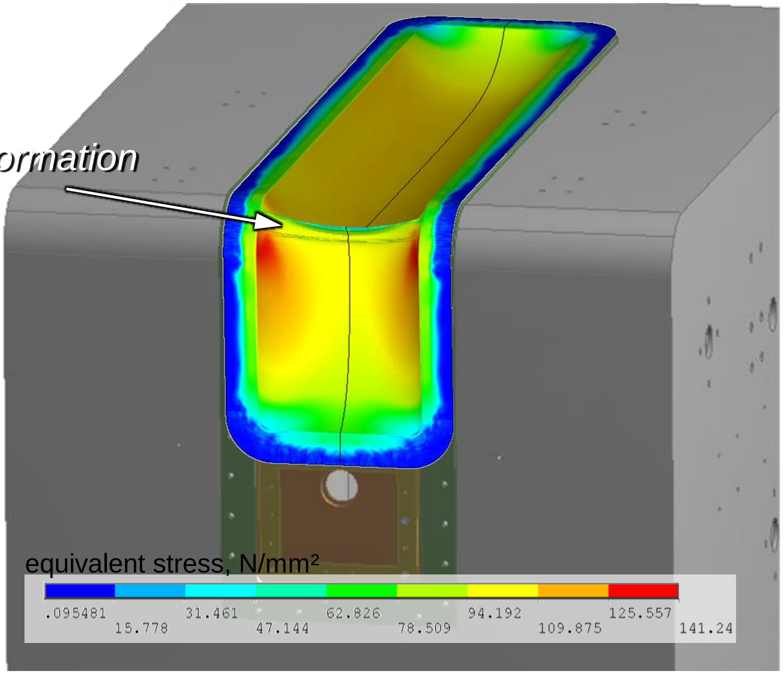
FEM - Theory

↳ nonlinear systems



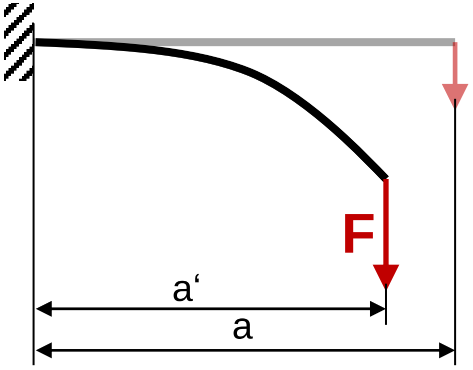
crease formation

thin Kapton foil used as transparent window of a vacuum chamber

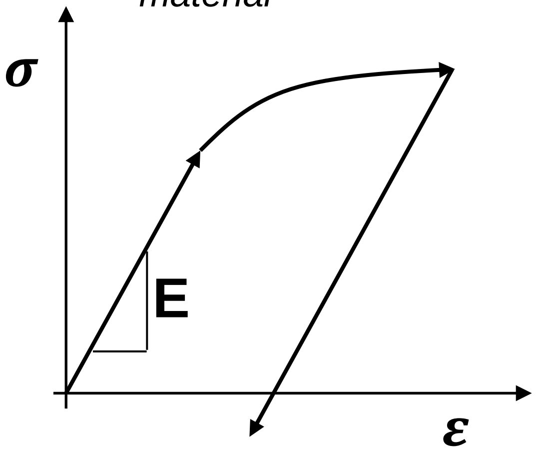


Three types of nonlinearities

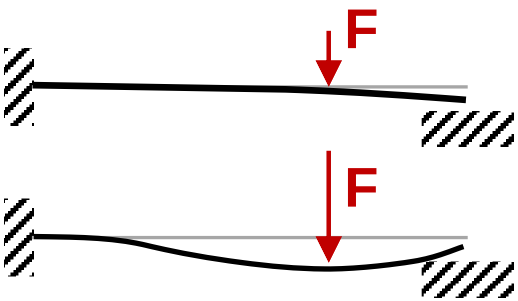
large displacements



material



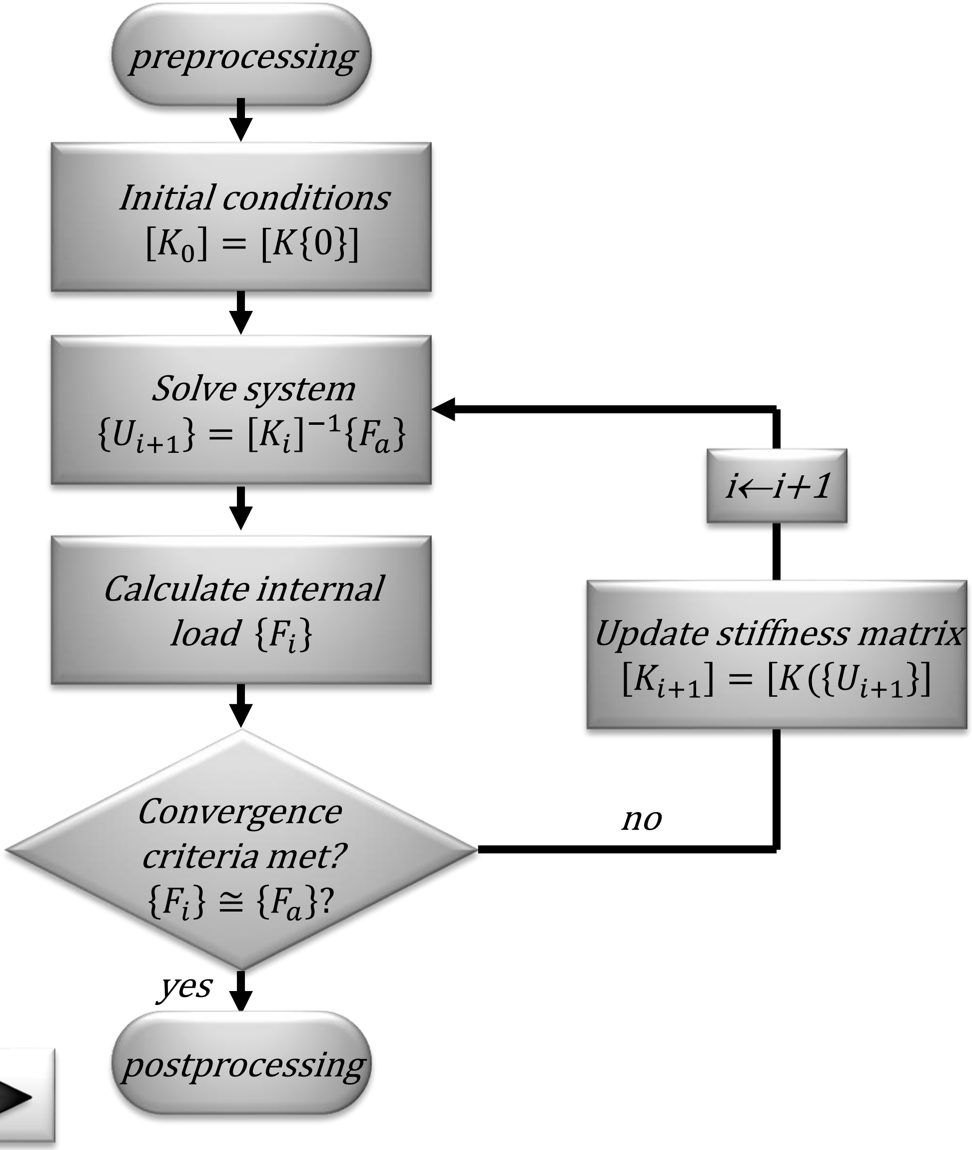
structural (e.g. contact)



FEM - Theory

↳ nonlinear systems

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



preprocessing

Initial conditions
$[K_0] = [K\{0\}]$

Solve system
$\{U_{i+1}\} = [K_i]^{-1}\{F_a\}$

Calculate internal load $\{F_i\}$

Convergence criteria met?
$\{F_i\} \cong \{F_a\}$?

no

Update stiffness matrix
$[K_{i+1}] = [K(\{U_{i+1}\}]$

$i \leftarrow i+1$

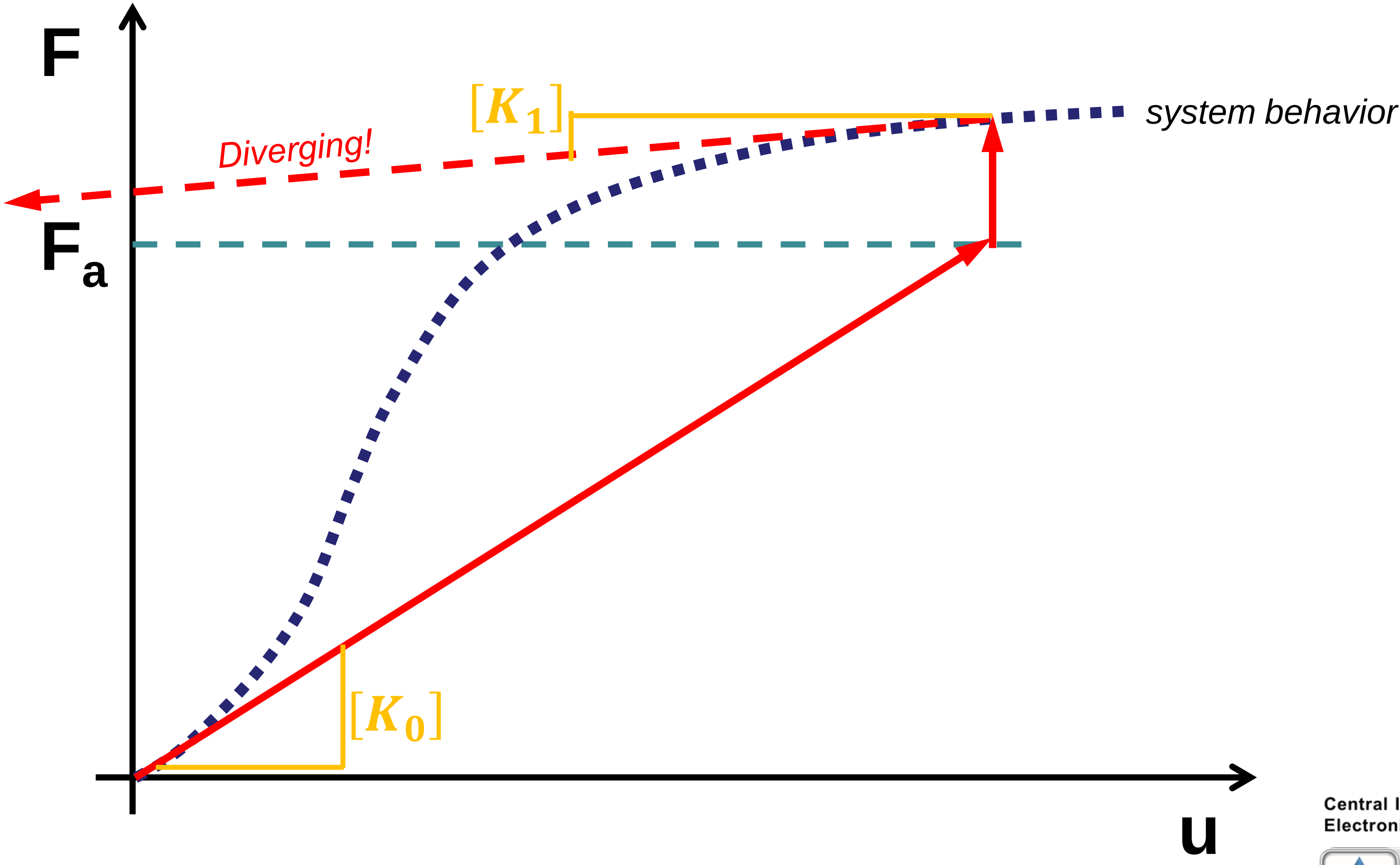
yes

postprocessing

FEM - Theory

↳ nonlinear systems

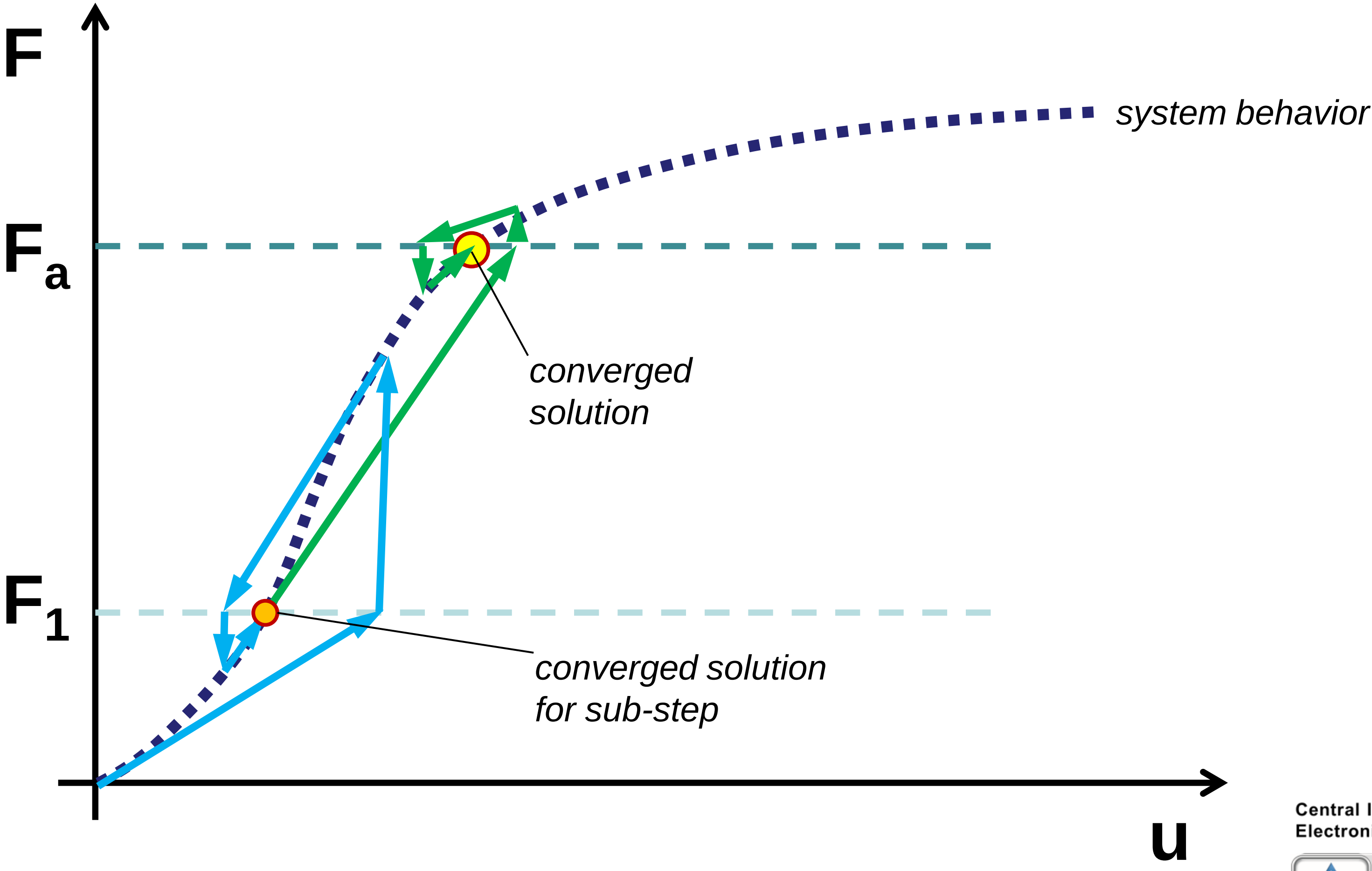
Newton-Raphson Method to solve nonlinear Systems



FEM - Theory

↳ nonlinear systems

Newton-Raphson Method to solve nonlinear Systems



FEM – Theory

↳ further applications

Diffusion: $[D]\{C\} = \{Q\}$

[D]: diffusion coefficient
{C}: concentration
{Q}: sources

Electrostatic: $[\chi]\{\varphi\} = \{Q\}$

[χ]: dielectricity
{φ}: electric potential
{Q}: charge

with damping:

Temperature: $[C]\{\dot{T}\} + [K]\{T\} = \{Q(t)\}$

[C]: heat capacity
[K]: conductivity
{T}: Temperature
{Q}: heat source

Magnetic fields: $[C]\{\dot{A}\} + [K]\{A\} = \{F(t)\}$

[C]: electric conductivity
[K]: magnetic permeability
{A}: vector potential
{F}: current density

with inertia and damping:

Dynamics: $[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = \{F(t)\}$

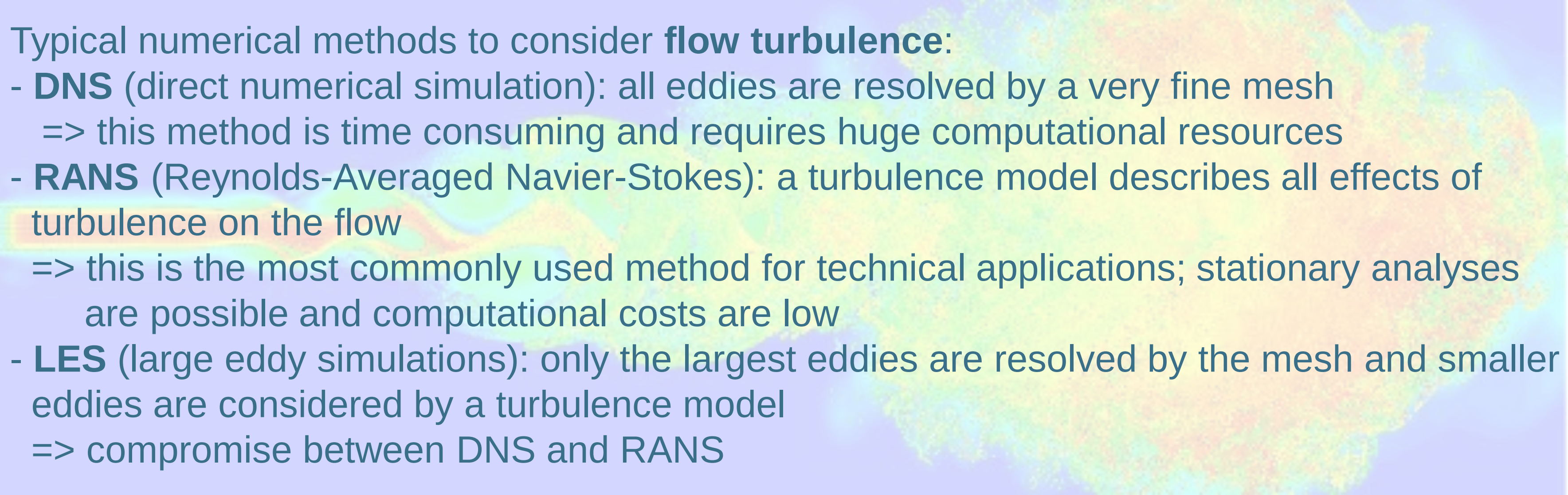
[M]: mass (inertia)
[C]: damping
[K]: stiffness

can also be solved using explicit solvers

CFD - Theory

↳ CFD = computational fluid dynamics

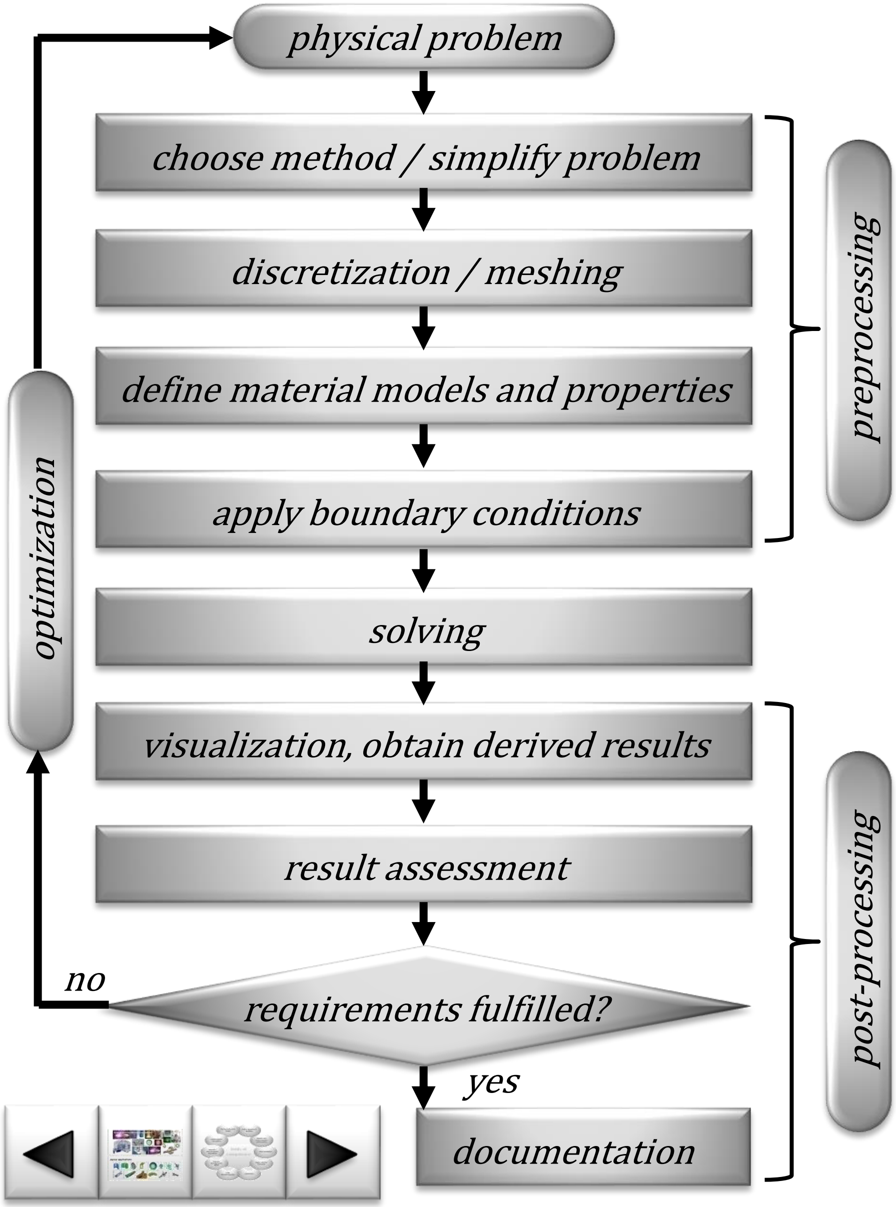
- Numerical method for solving partial differential equations representing conservation laws for **mass, momentum, energy and species** for fluid flows.
- Domain is discretized into a finite set of control volumes or cells. The most commonly used method for CFD is the **Finite-Volume-Method**.
- Control volume balance for a general flow variable ϕ 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

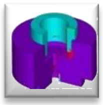
Setting up numerical simulations with FEM/CFD

↳ important aspects for a design engineer

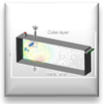


Knowledge and experience of the engineer

- *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?*



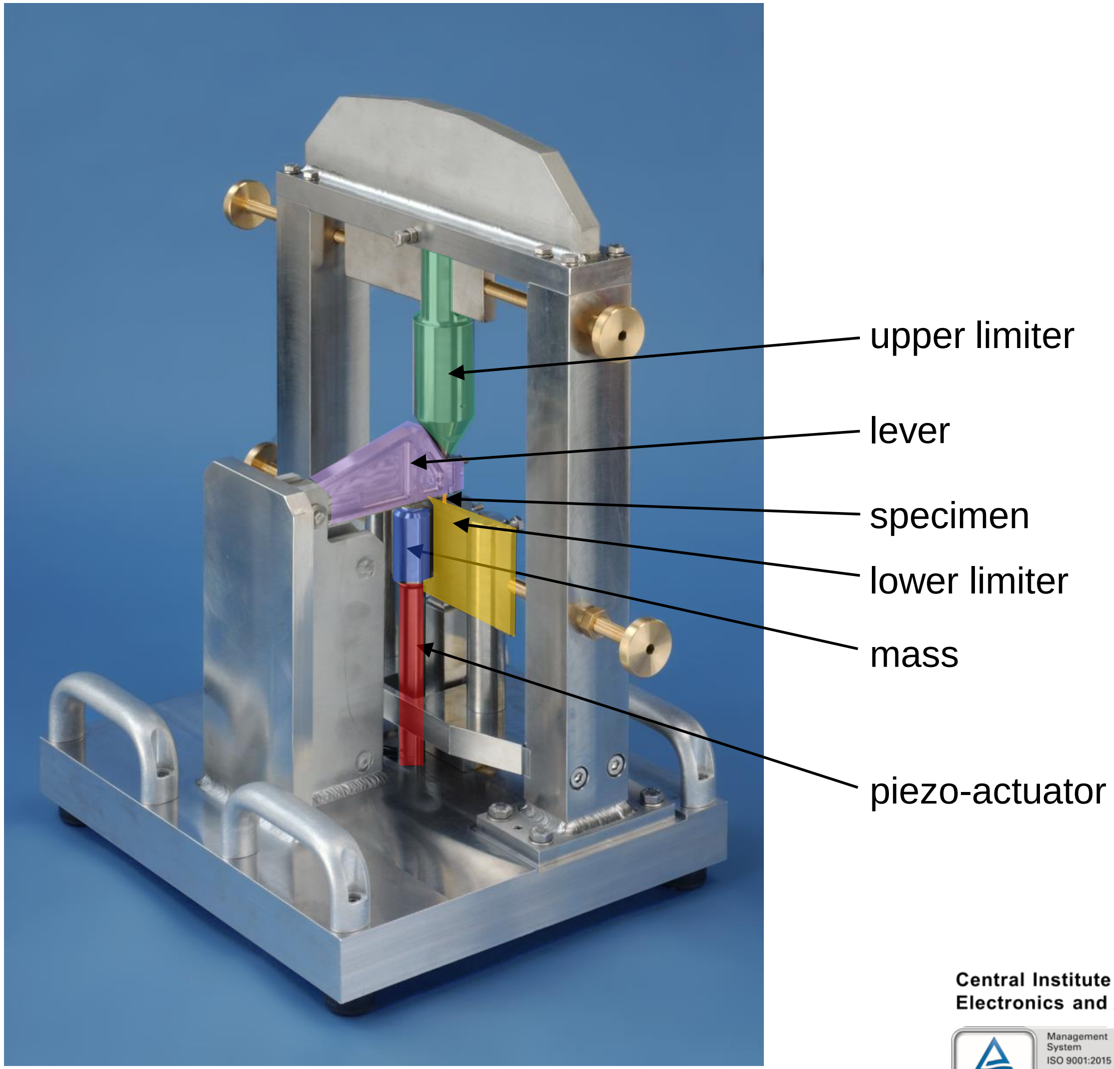
- *which physical effects and details are important?*
- *how can the problem be simplified?*
- *how does the material behave, which material parameters are applicable and proven?*
- *which software is suitable to solve the problem?*
- *implementation of new methods / models necessary?*



- *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!*
- *…*

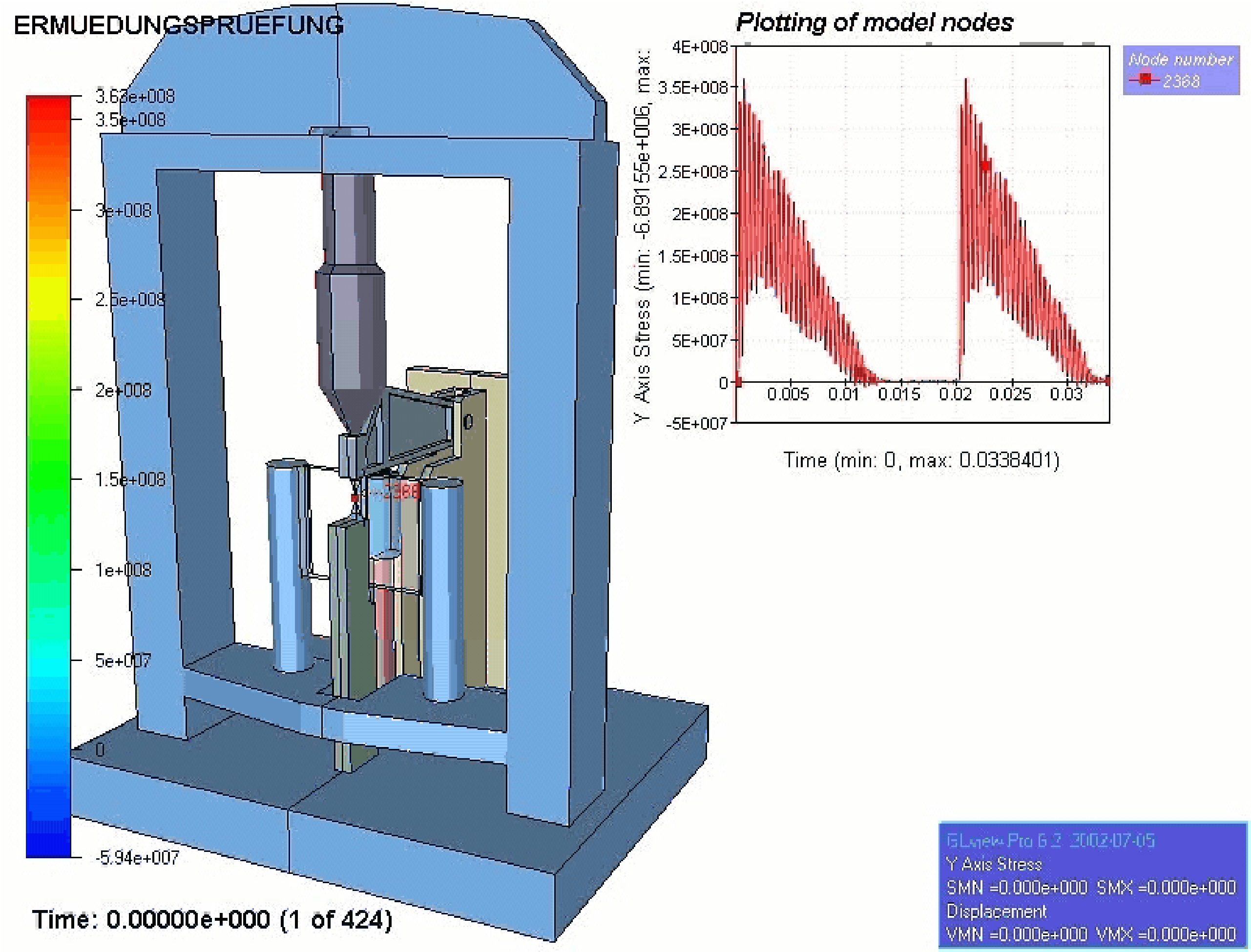
FATIMA – Test Facility

↳ fatigue tests at high strain rates



FATIMA – Test Facility

↳ fatigue tests at high strain rates



Time: 0.00000e+000 (1 of 424)

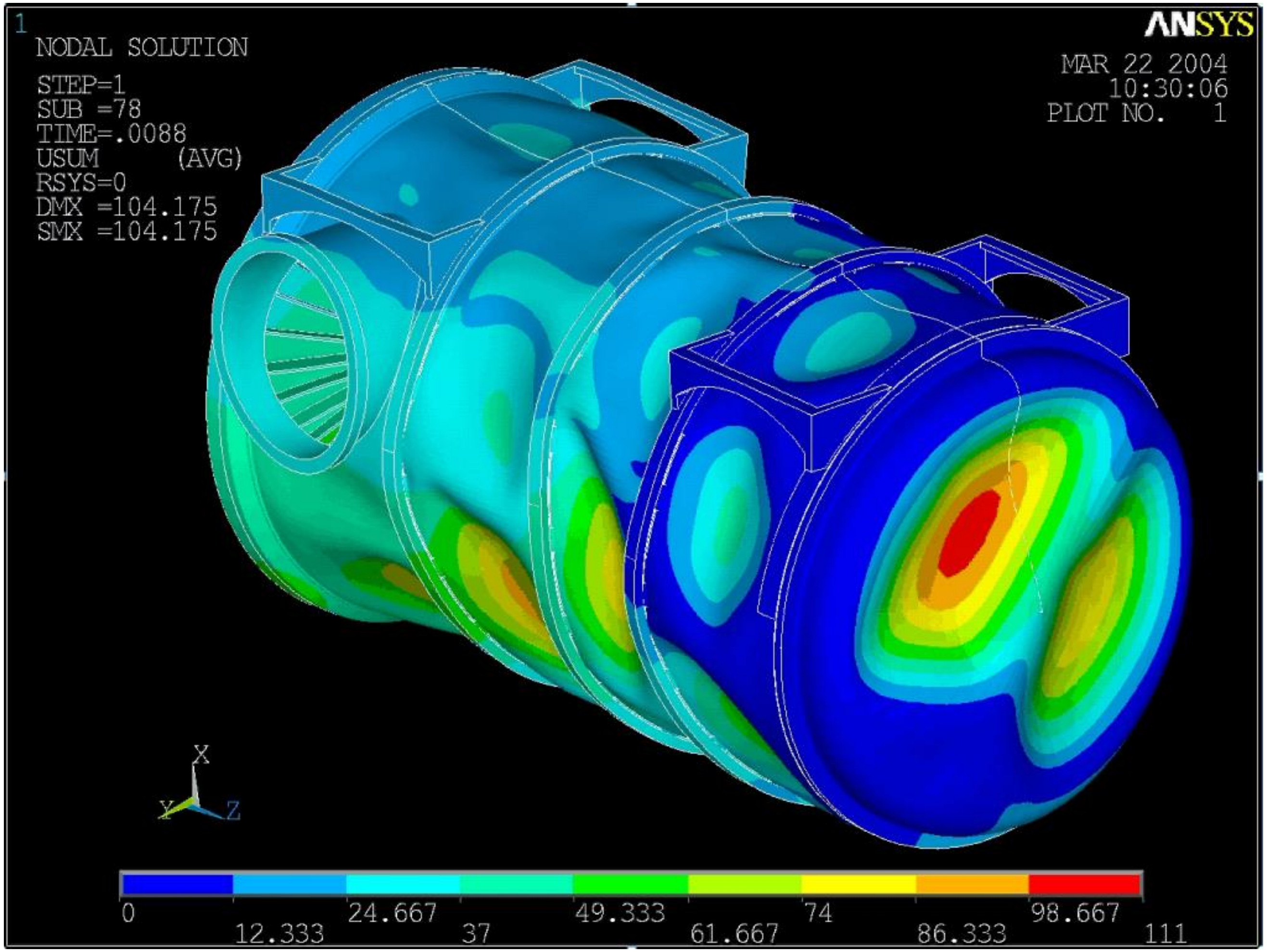
GLview Pro 6.2 2002-07-05
Y Axis Stress
SMN =0.000e+000 SMX =0.000e+000
Displacement
VMN =0.000e+000 VMX =0.000e+000

Buckling analysis for a vacuum vessel

↳ CRISTA @ GEOPHYSICA

Buckling analysis for a vacuum vessel

↳ CRISTA @ GEOPHYSICA

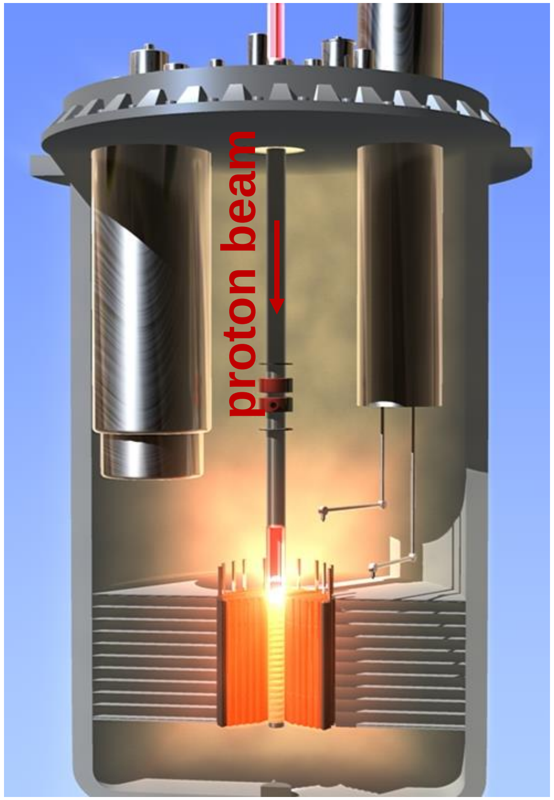


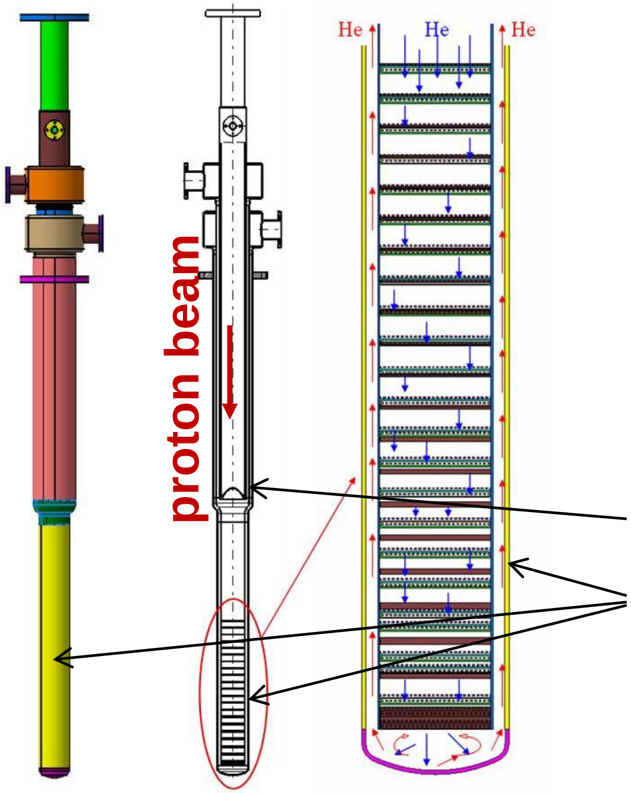
Deformations, mm

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





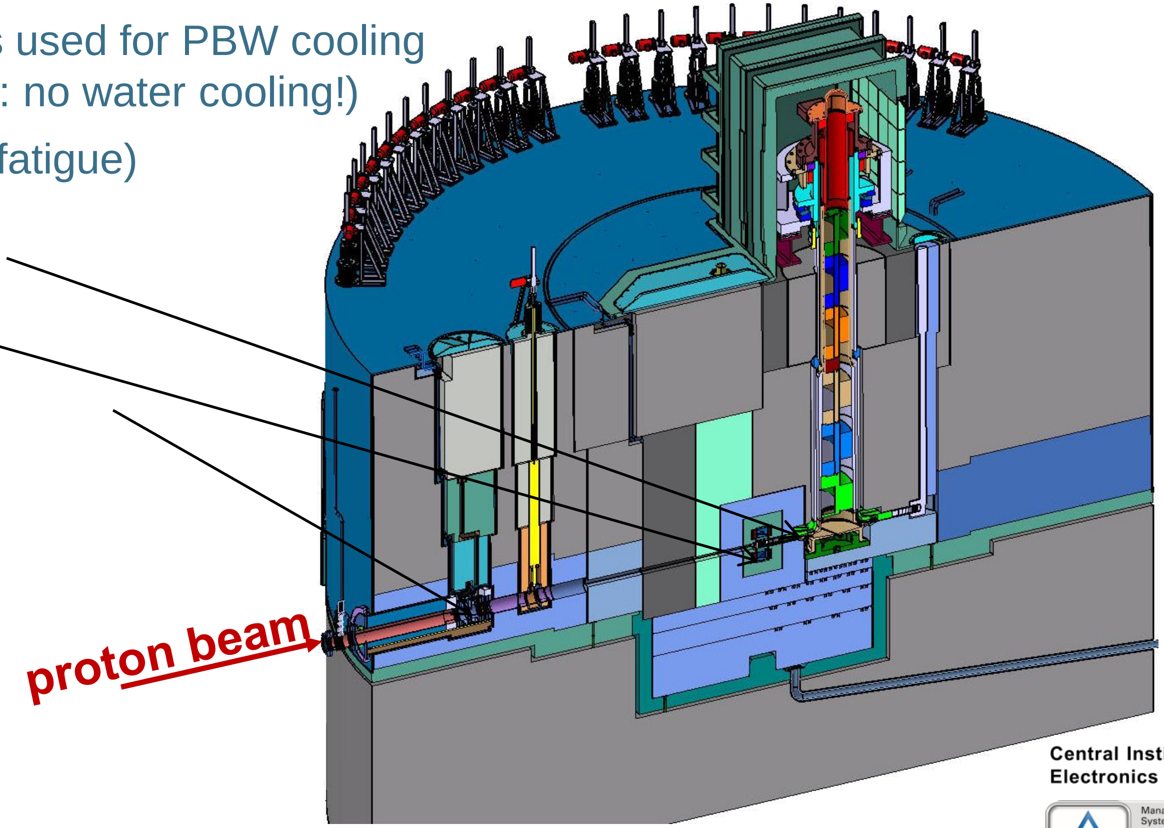
PBW

spallation target

Design of Proton Beam Windows

ESS

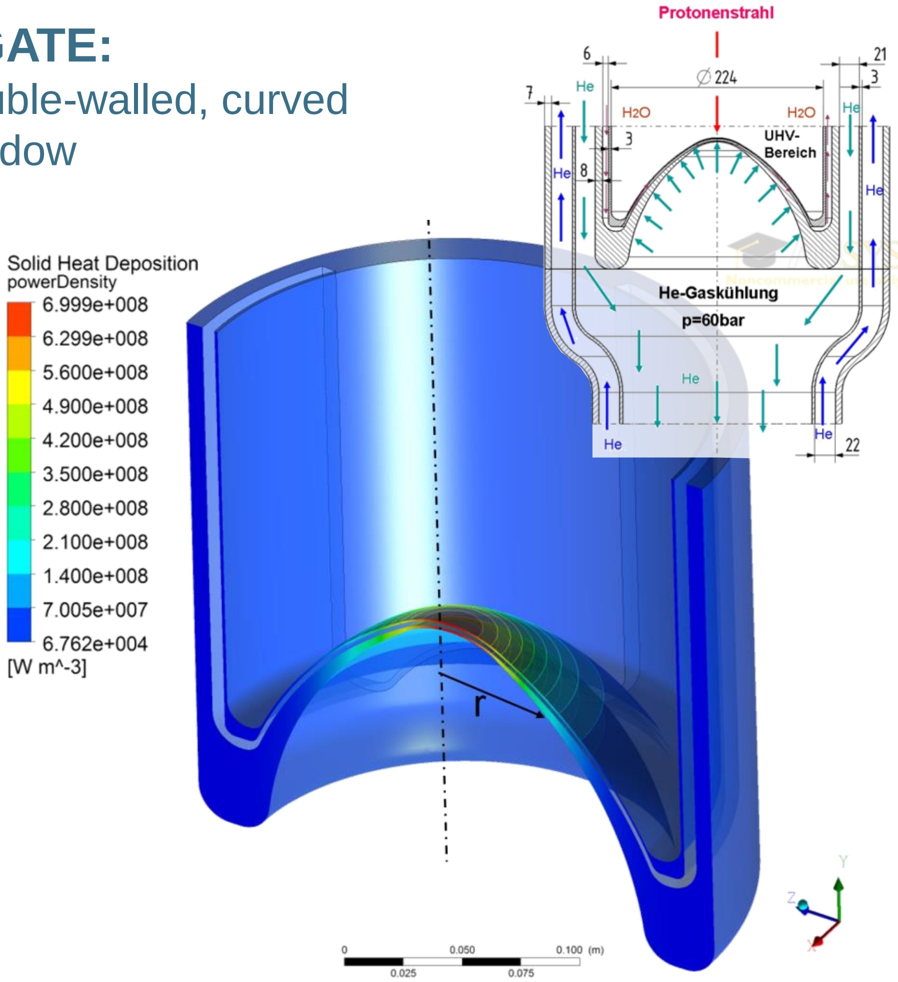
- ESS (European Spallation Source)
- the spallation target serves as neutron source for scientific experiments
- the PBW separates the accelerator vacuum from the helium atmosphere in the target room (1 bar helium)
- helium at 10 bar is used for PBW cooling (customer request: no water cooling!)
- pulsed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



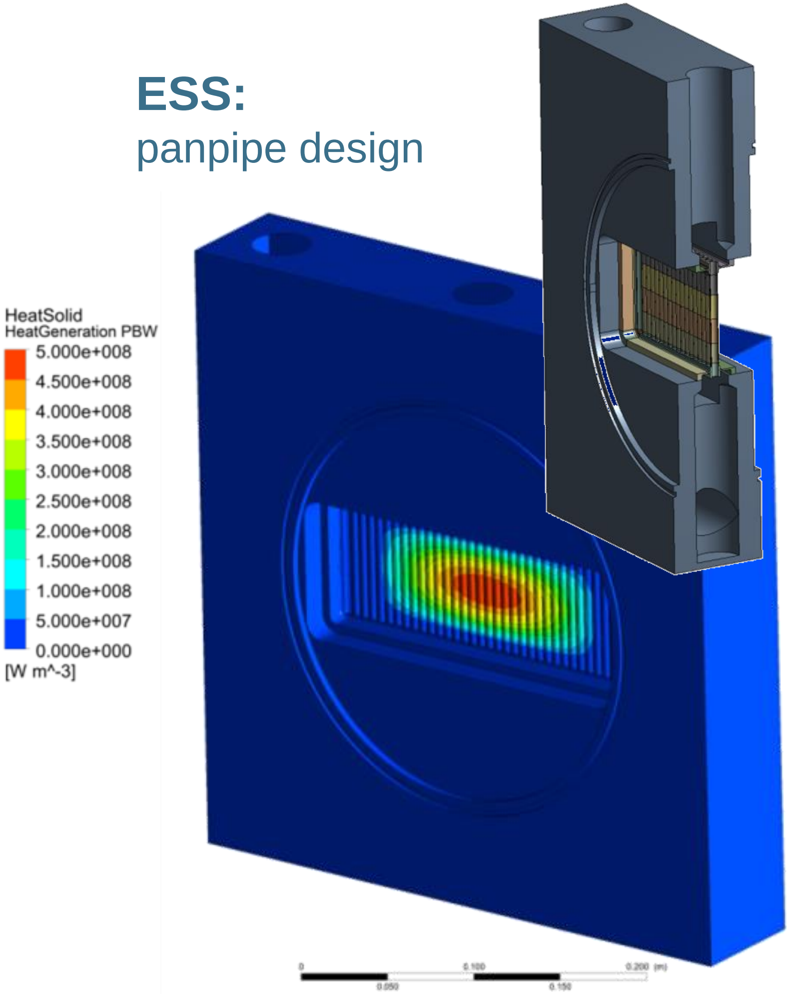
Design of Proton Beam Windows

↳ design concepts for different boundary conditions

AGATE:
double-walled, curved window



ESS:
panpipe design

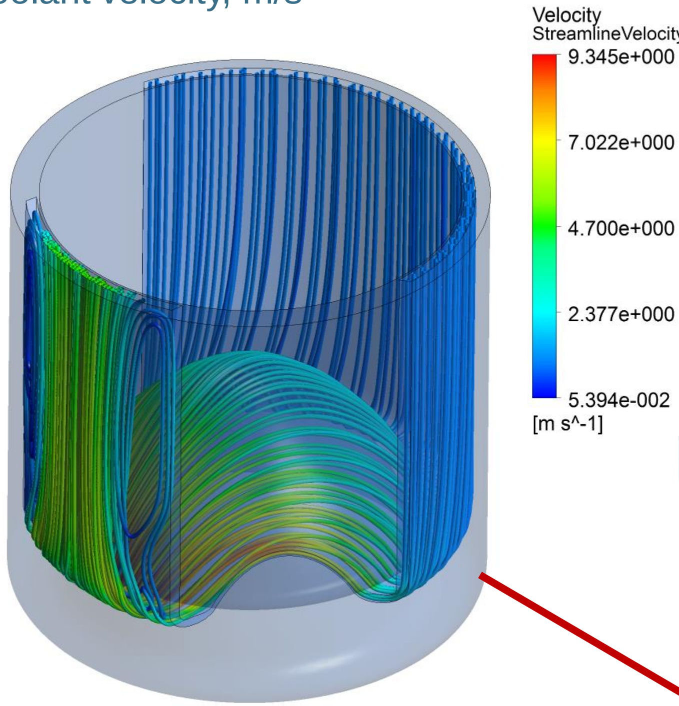


Al6061-T6

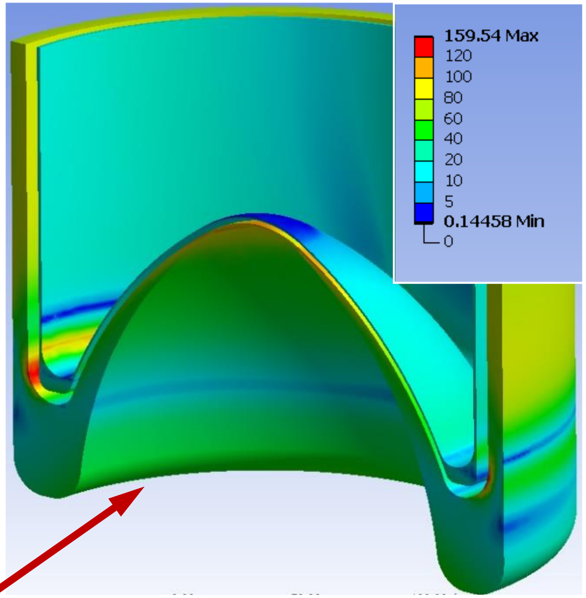
Design of Proton Beam Windows

↳ design details for AGATE

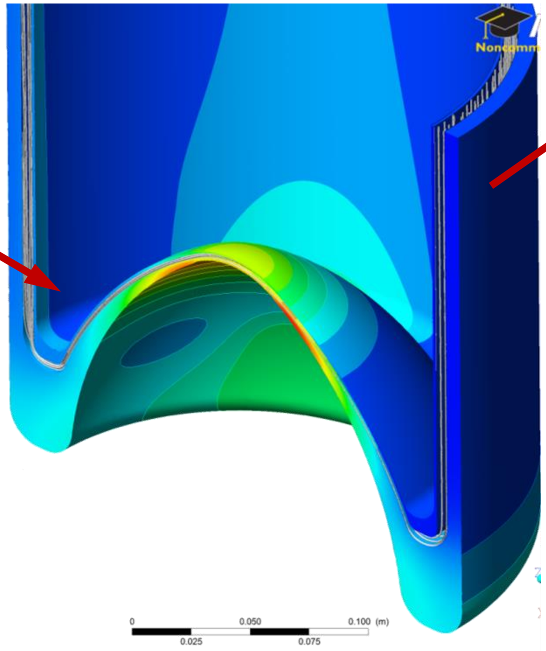
coolant velocity, m/s



equivalent stress, MPa

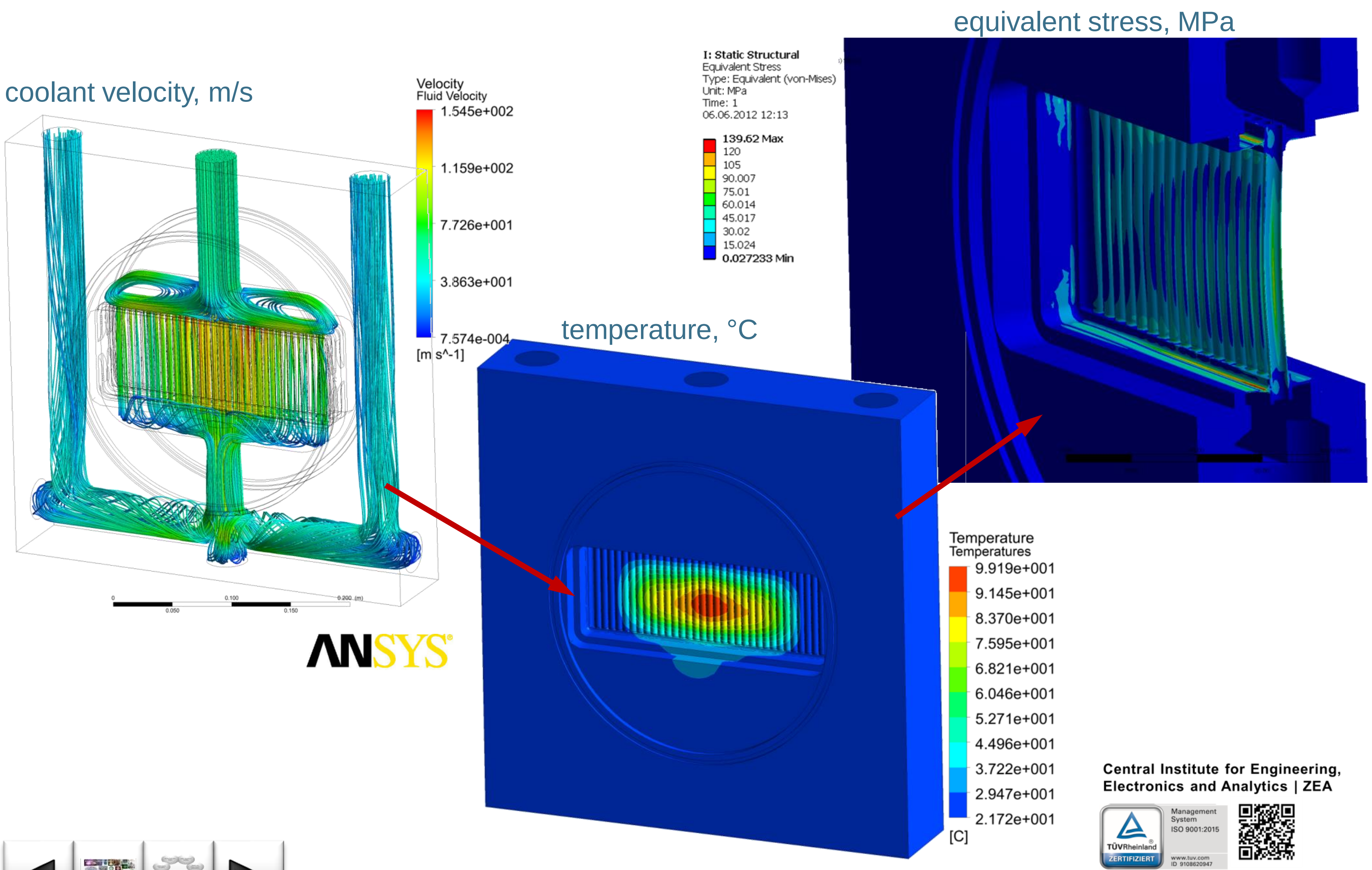


temperature, °C



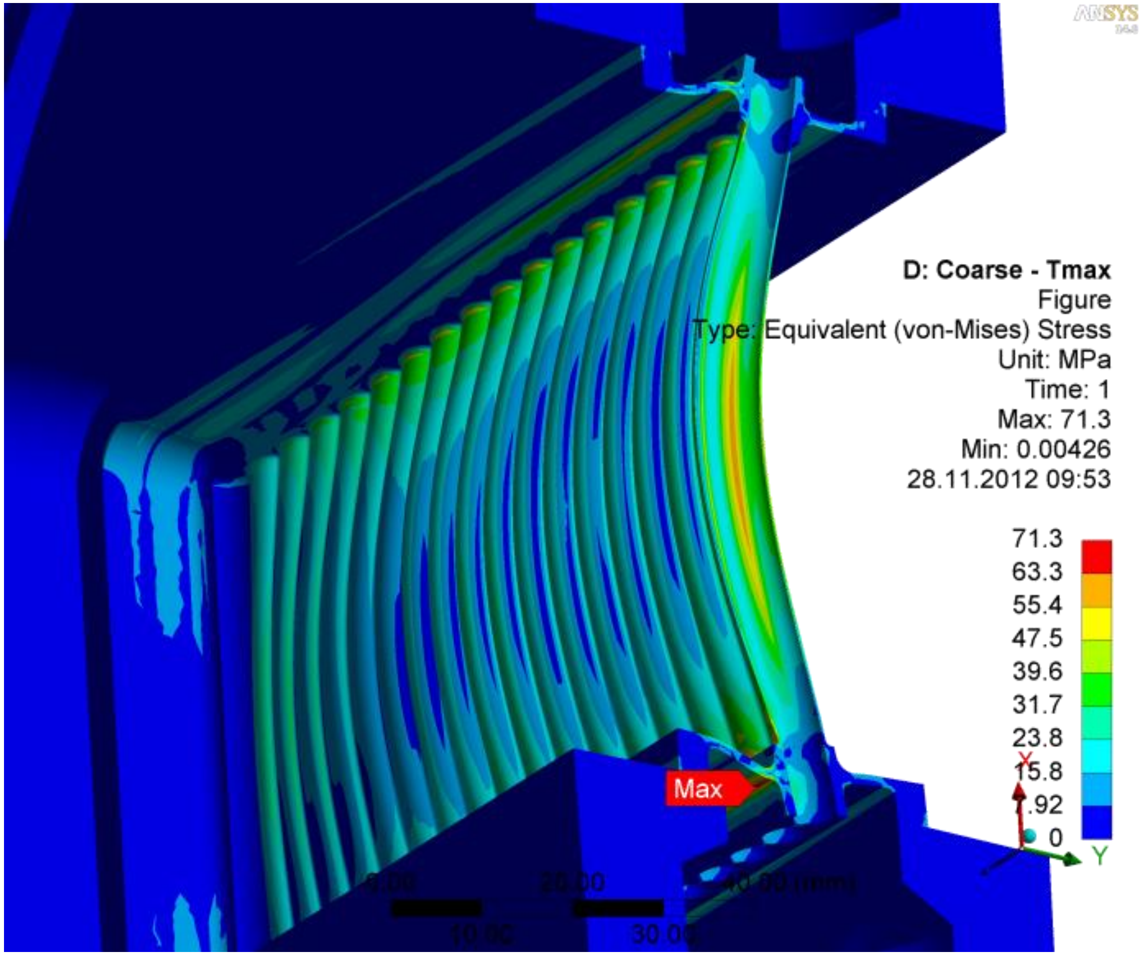
Design of Proton Beam Windows

↳ design details for ESS

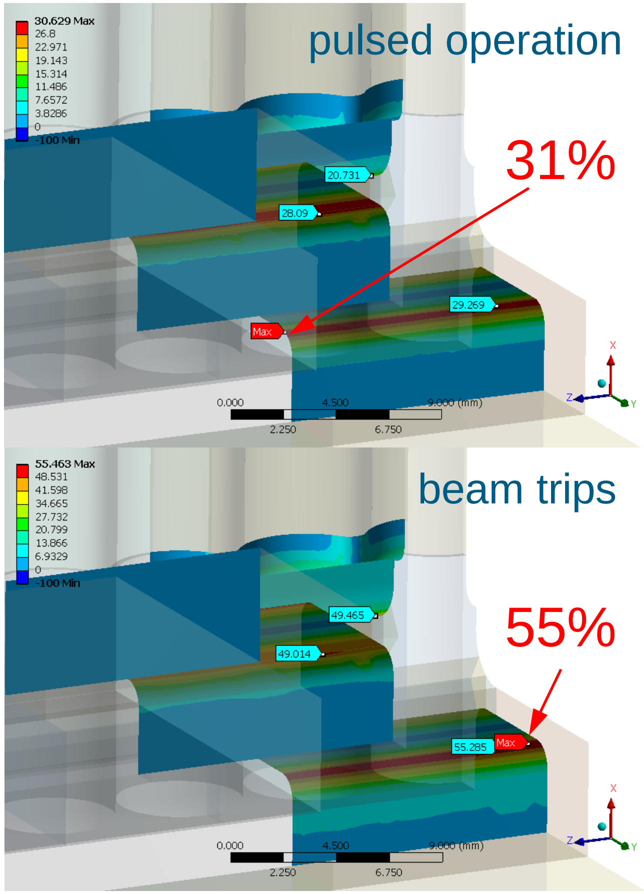


Design of Proton Beam Windows

↳ design against fatigue for ESS



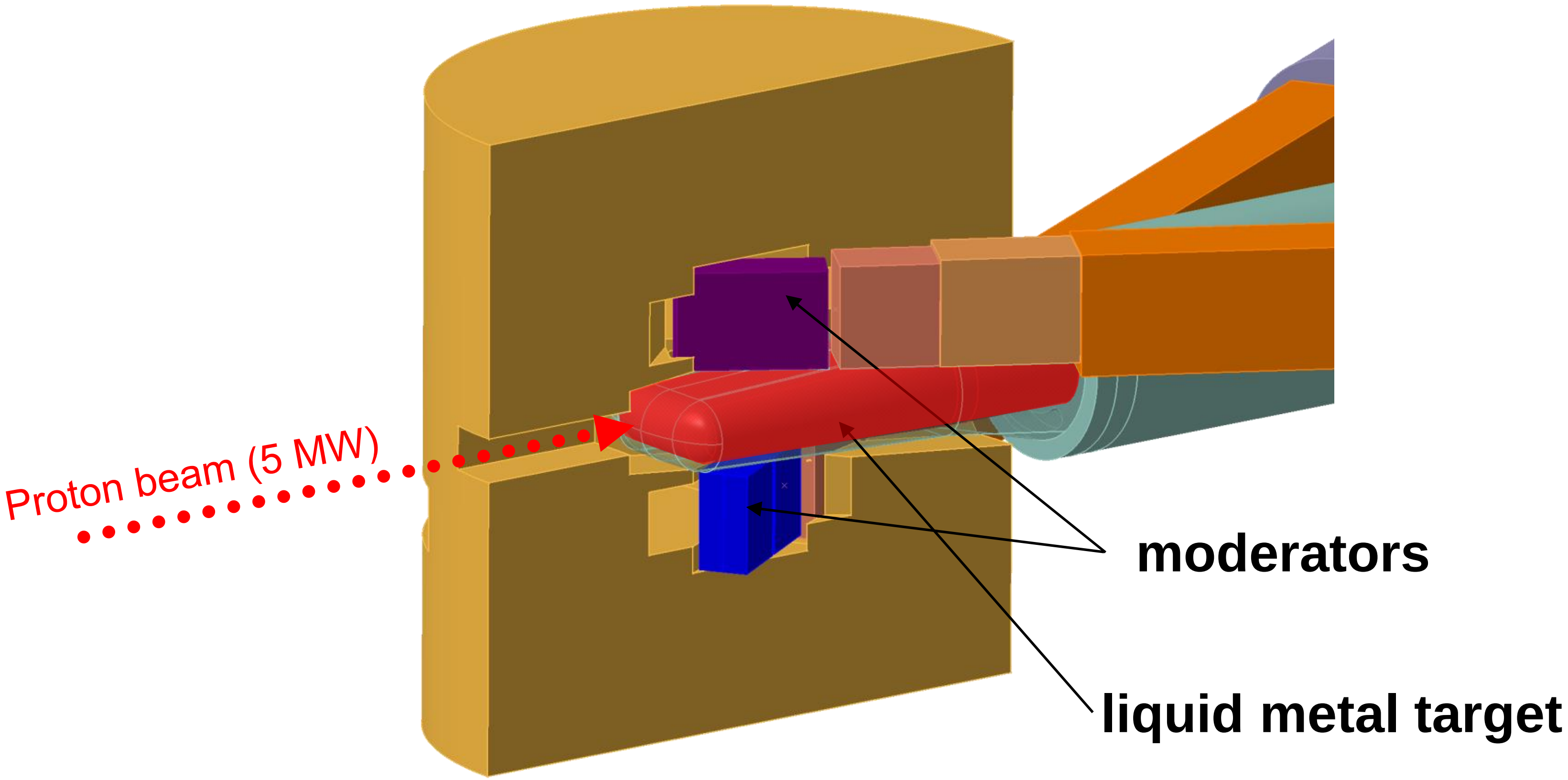
resultant stresses due to thermal and mechanical loading



calculated utilization factors

Design of ESS Mercury Target

↳ configuration



Design of ESS Mercury Target

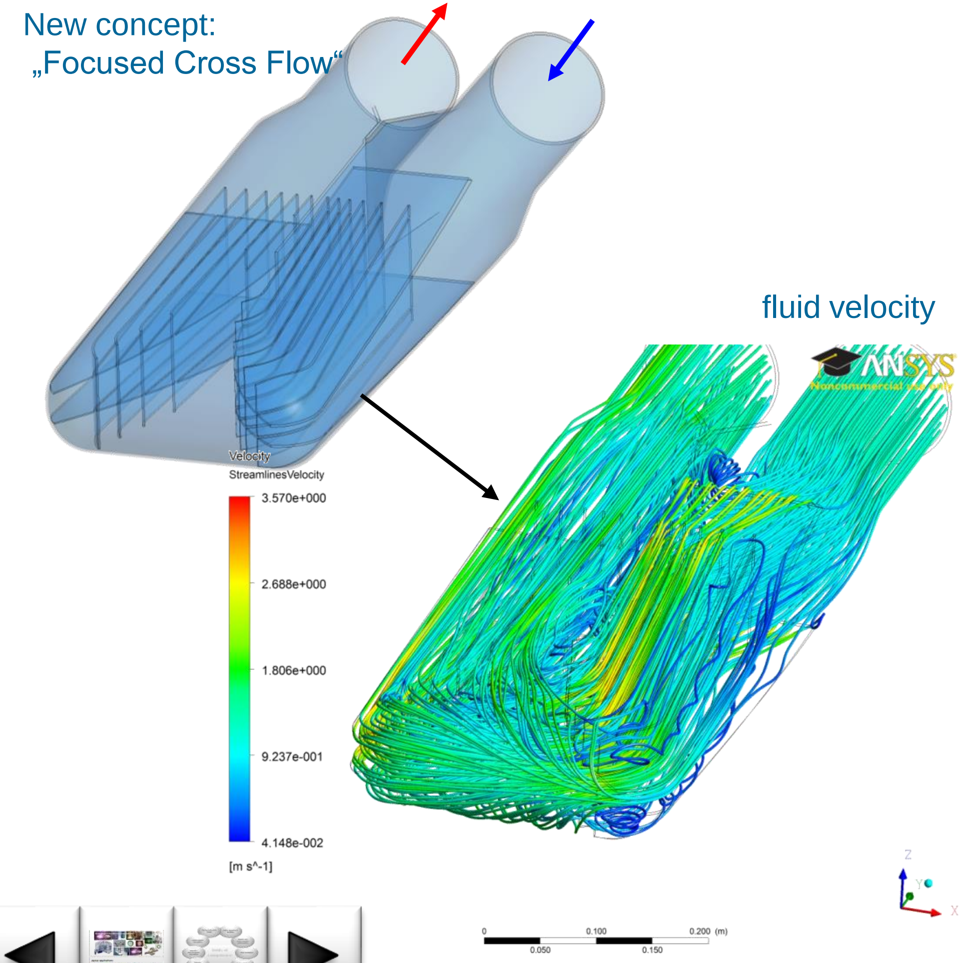
⇘ thermal hydraulic design

JÜLICH FORSCHUNGSZENTRUM

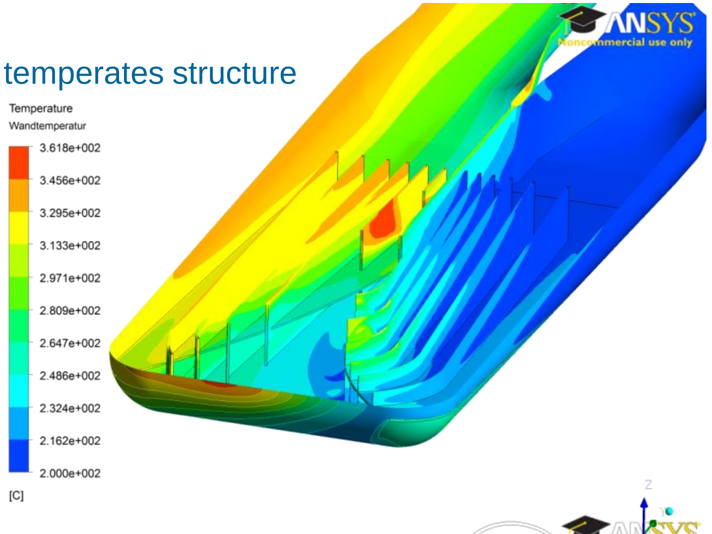
Focus on:

- ➢ cooling of beam entrance window
- ➢ heat removal capacity

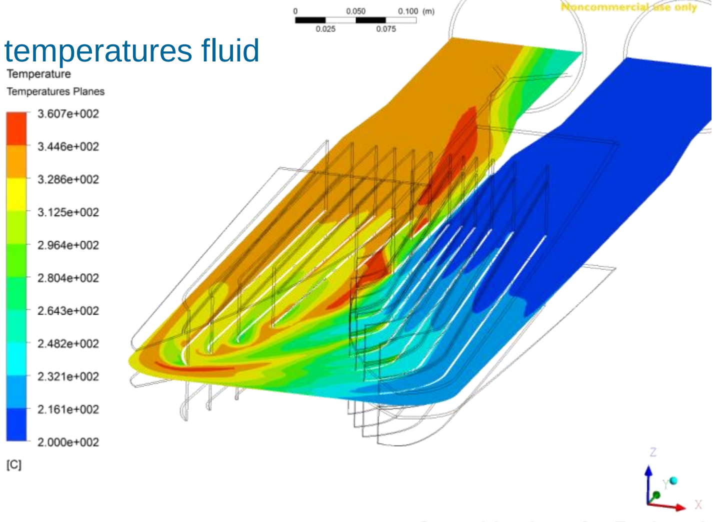
New concept:
„Focused Cross Flow“


fluid velocity

temperates structure



temperatures fluid



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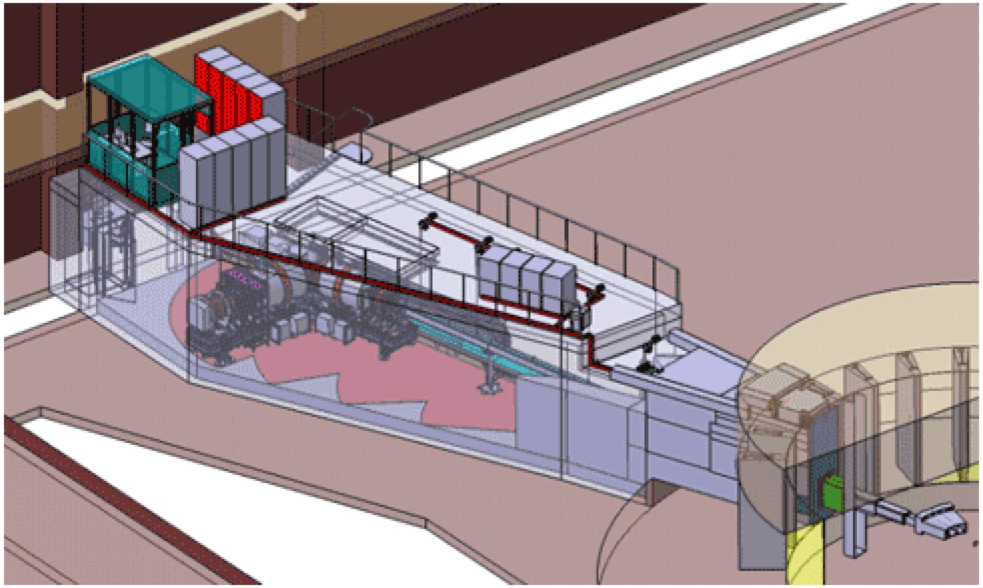
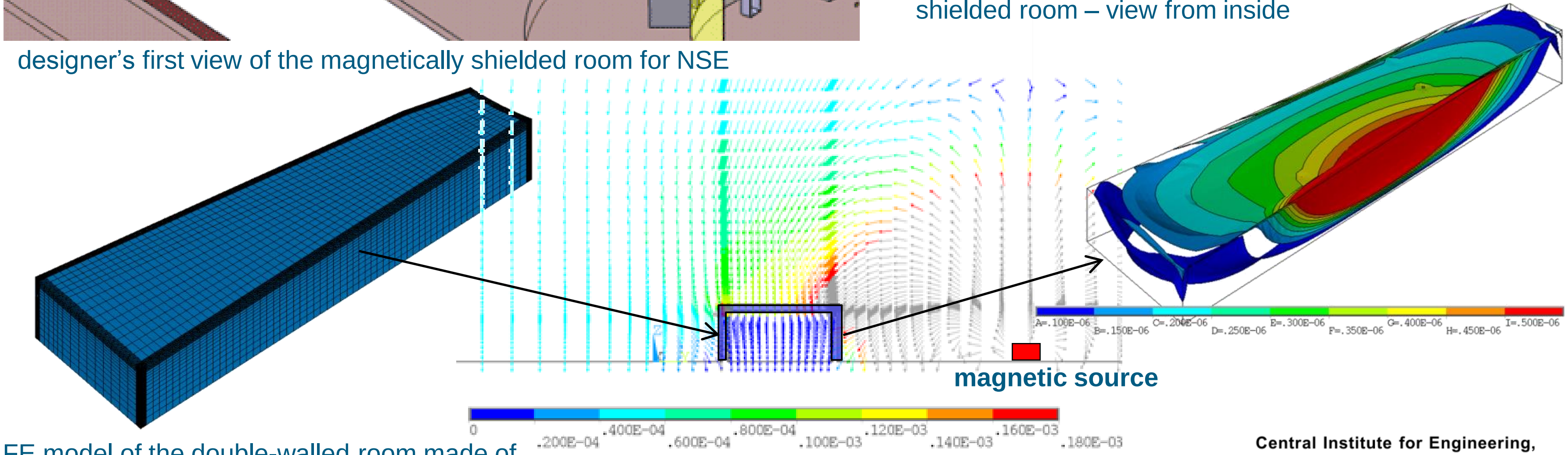
Design of Magnetic Shielded Room

↳ for neutron spin echo spectrometer @SNS



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

shielded room – view from inside



magnetic source

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

magnetic flux density calculation for an external magnetic source

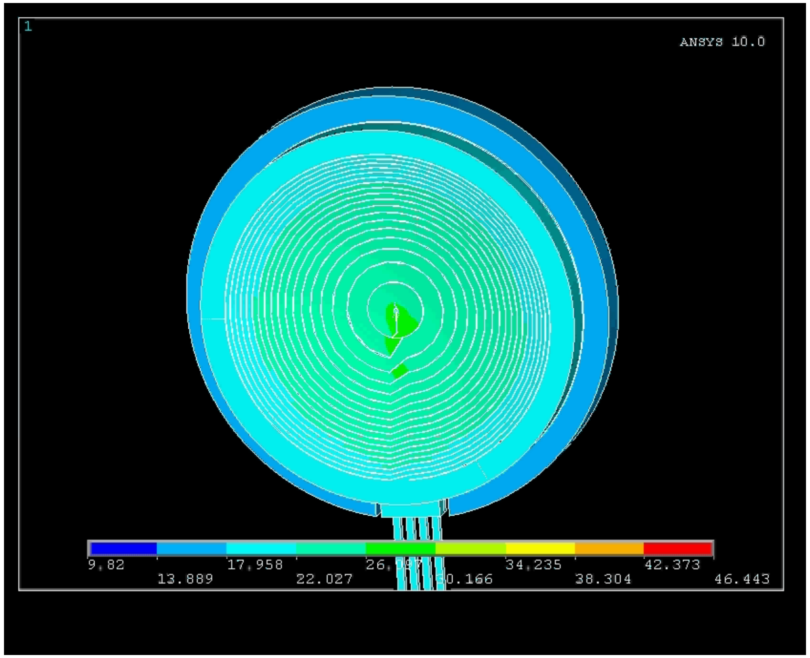
Thermal Design of Correction Coils

↳ for neutron spin echo spectrometer @SNS

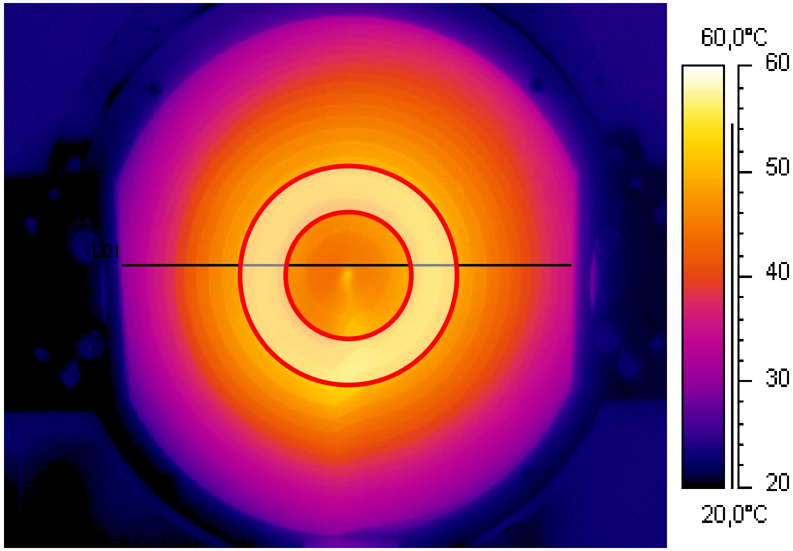
- current density in the coil was calulated
- thermal load due to high current modeled
- cooling by bonded cooling plate was considered

Temperature distribution in the coil

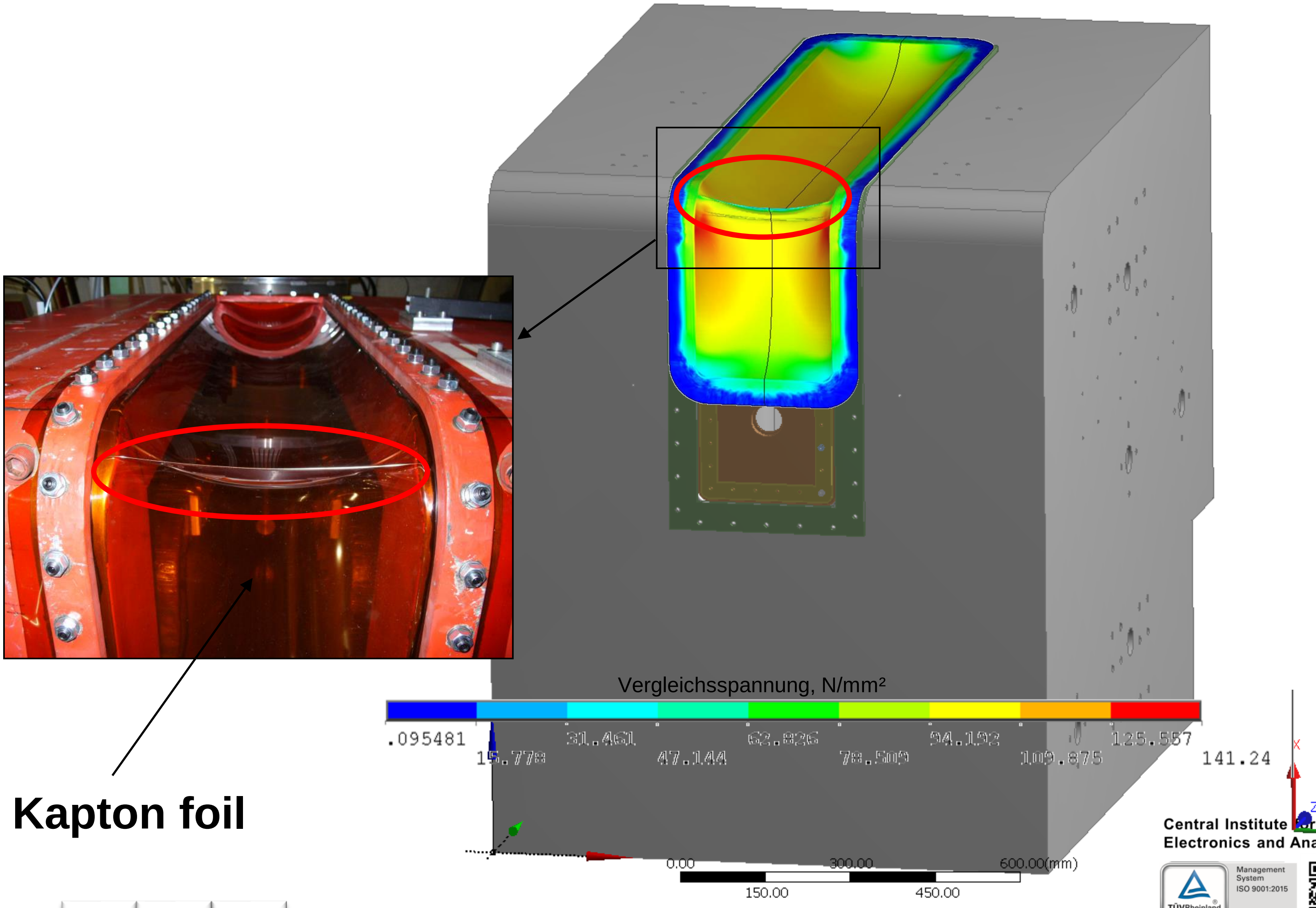
simulation



measurement



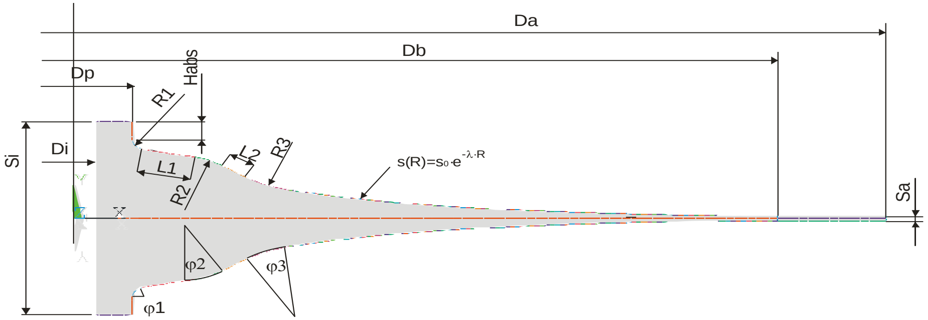
Kapton foil window for a vacuum chamber



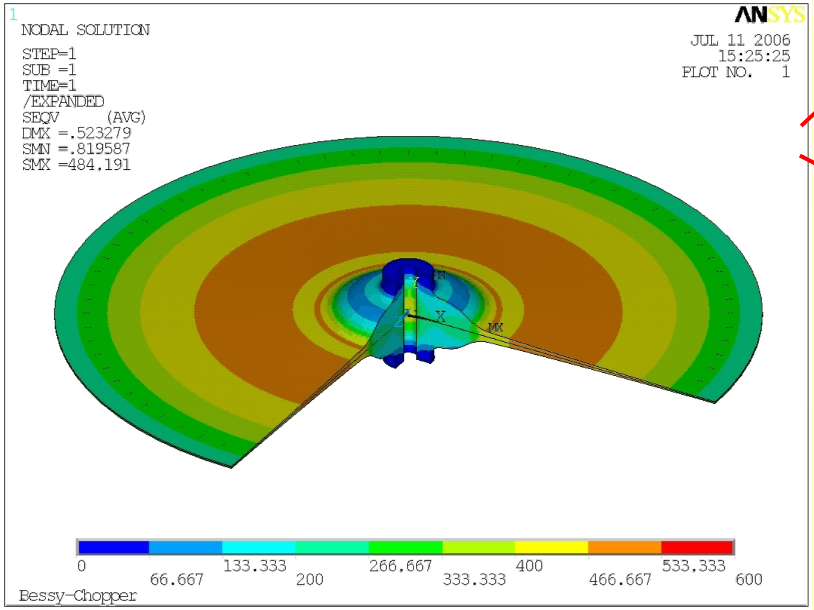
Kapton foil

Optimization of the chopper disk contour

parameterized model



Optimization process in ANSYS



1

NODAL SOLUTION

STEP=1
SUB =1
TIME=1
/EXPANDED
SEQV (AVG)
DMX =.523279
SMN =.819587
SMX =484.191

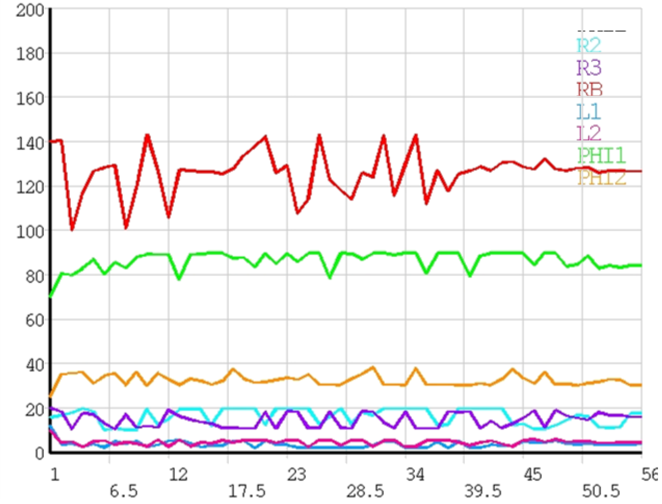
ANSYS

JUL 11 2006
15:25:25
PLOT NO. 1

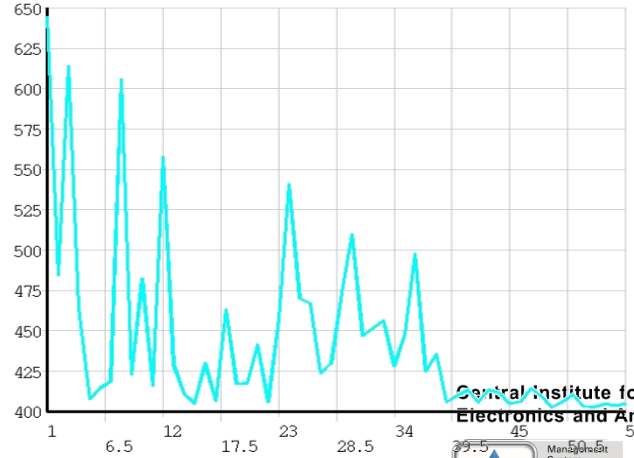
0 66.667 133.333 200 266.667 333.333 400 466.667 533.333 600

Bessy-Chopper

Variation of parameters



Max. equivalent stress [MPa]



Lysimeterpress

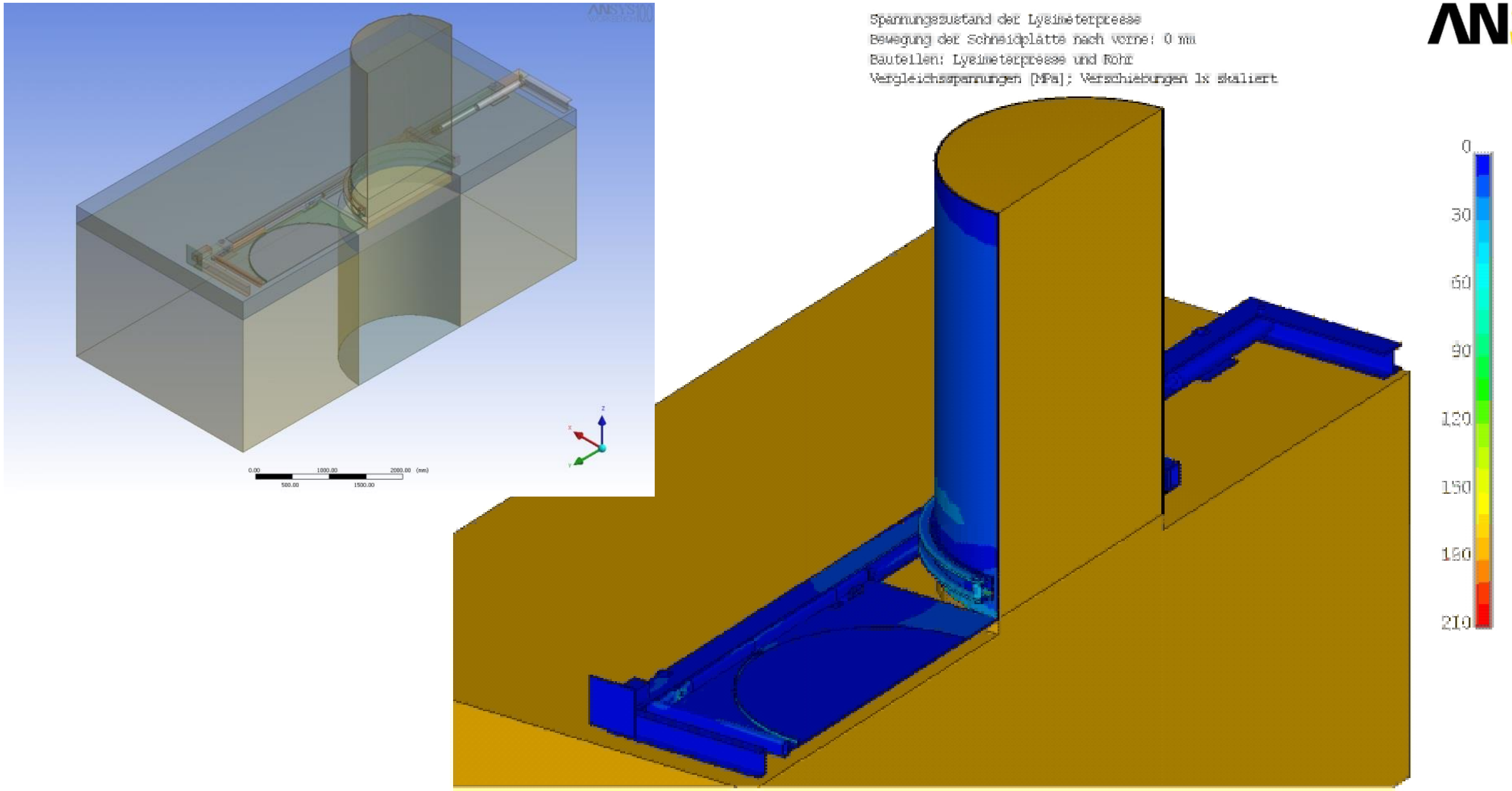
introduction

- 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

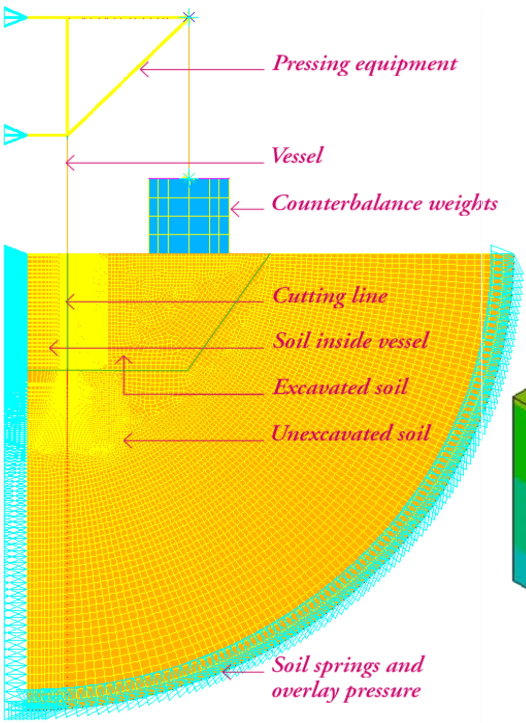
- Project start: typical engineering task -> optimization of design

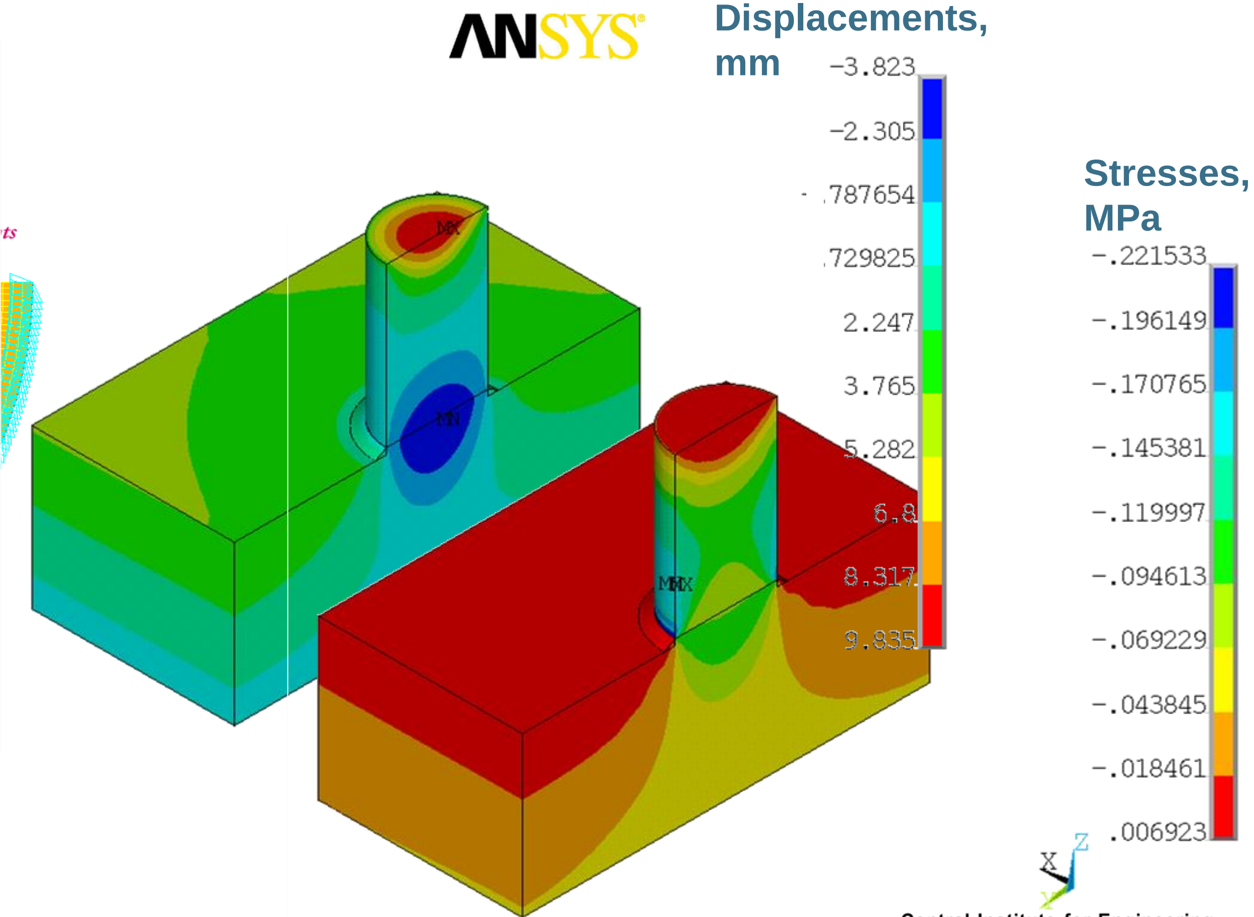


Lysimeterpress

↳ optimization of lysimeterpress

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



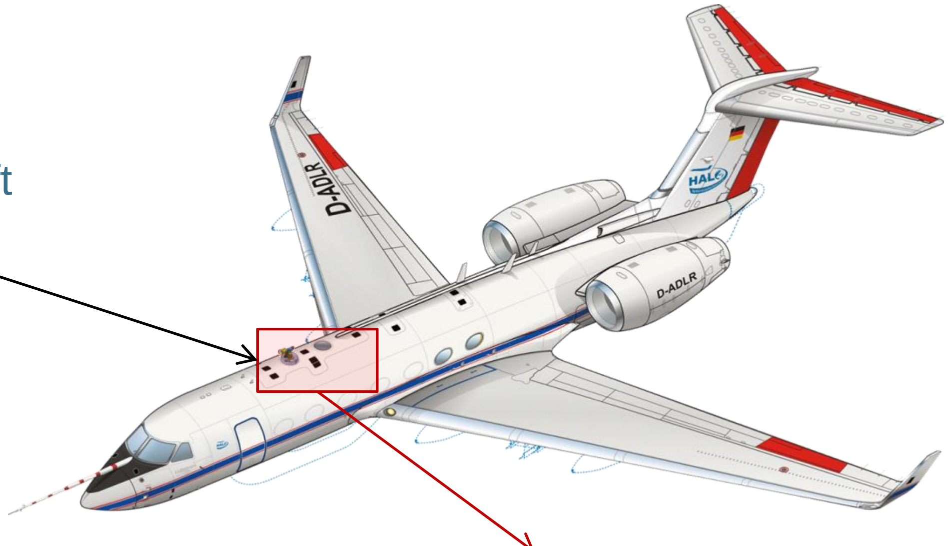


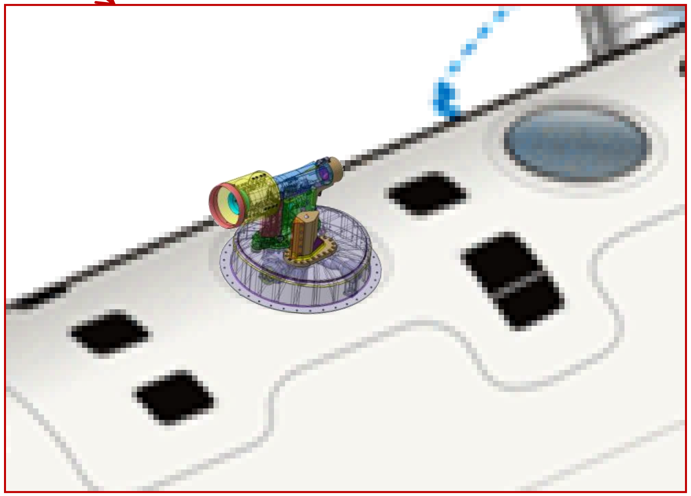
- Some important conclusions could be drawn with respect to the influence of the lysimeter design on the soil state

Inlet System for HALO

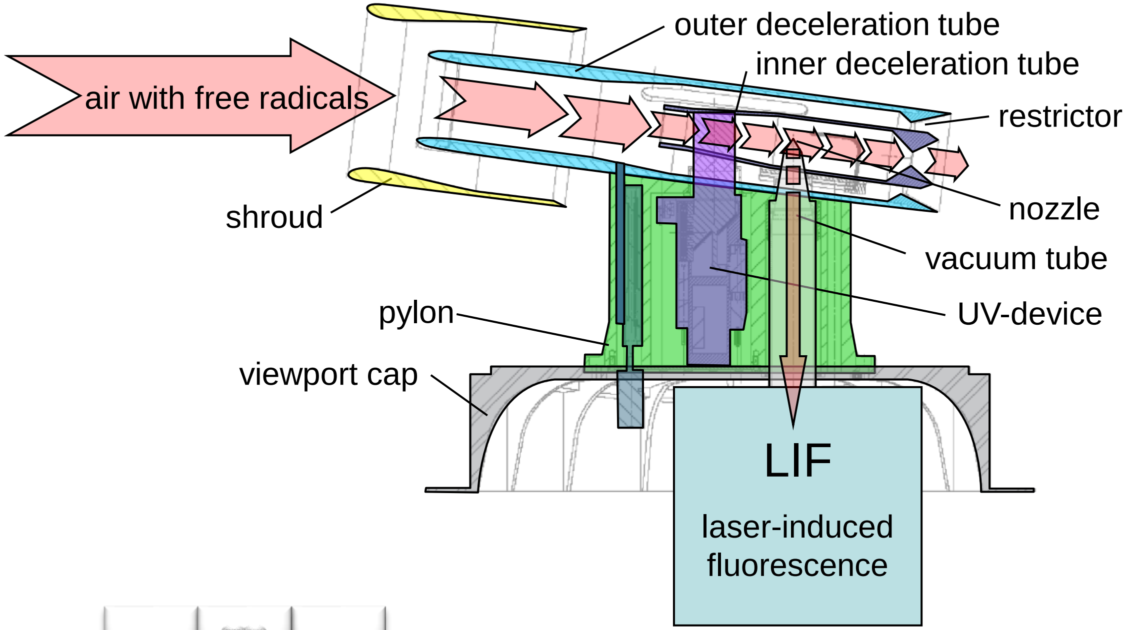
↳ introduction

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



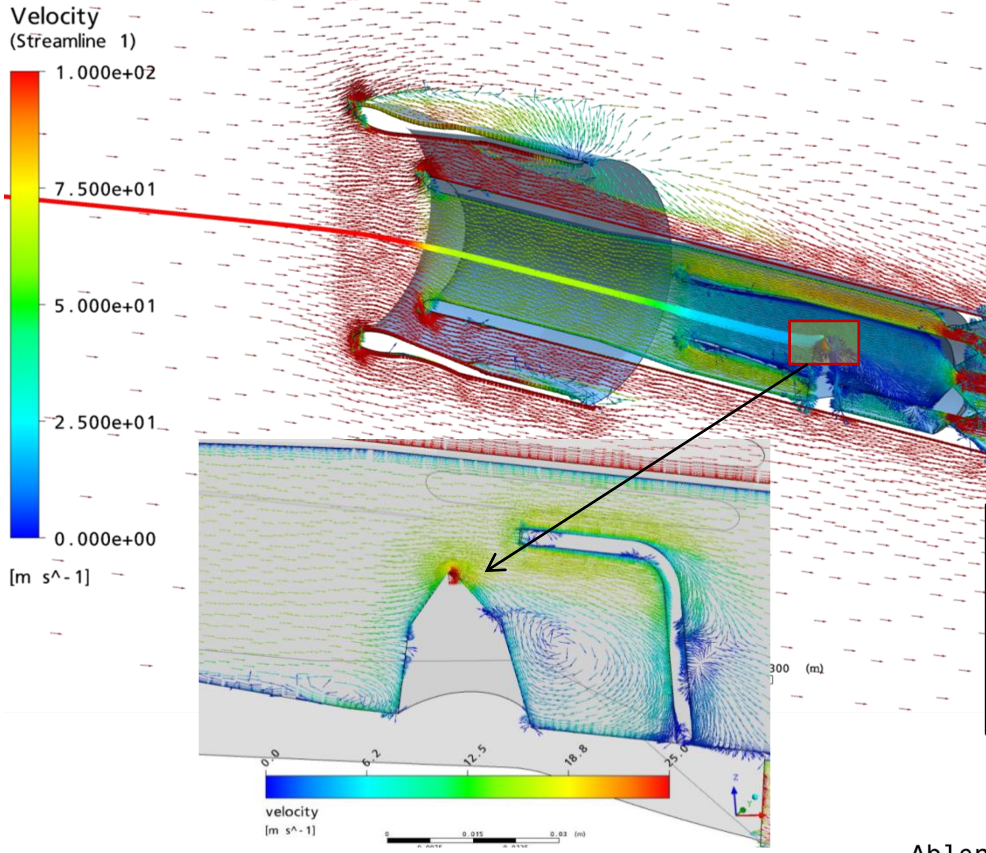


principle set-up:



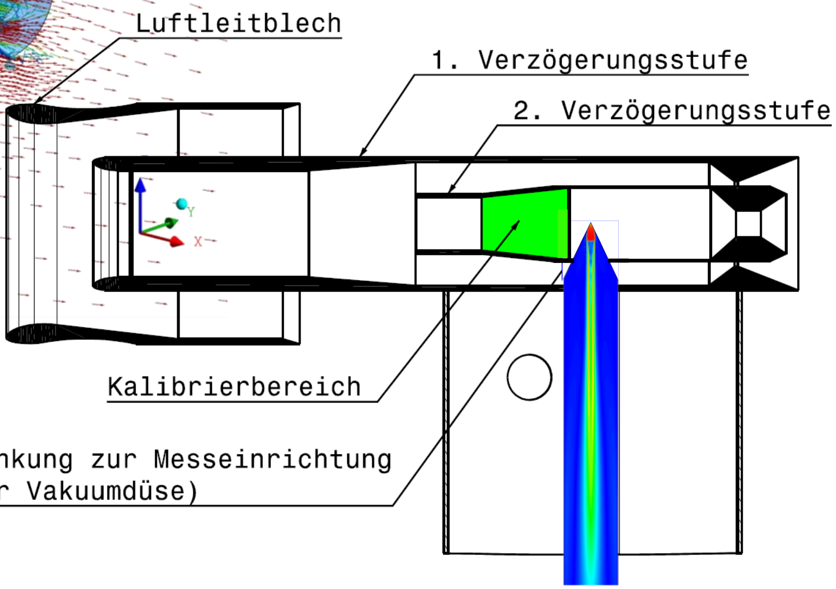
Inlet system for HALO

↳ 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

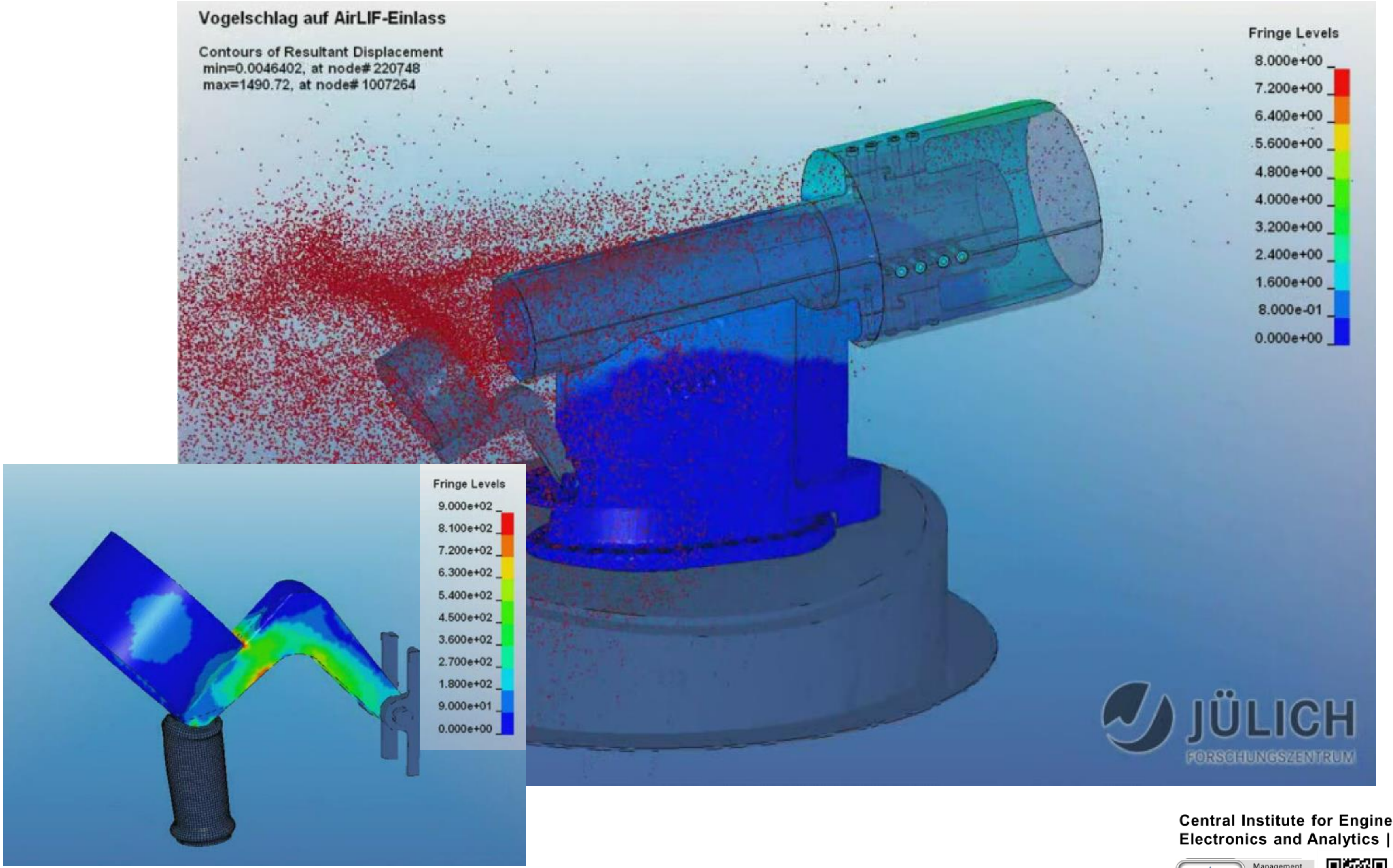
Inlet System for HALO

↳ 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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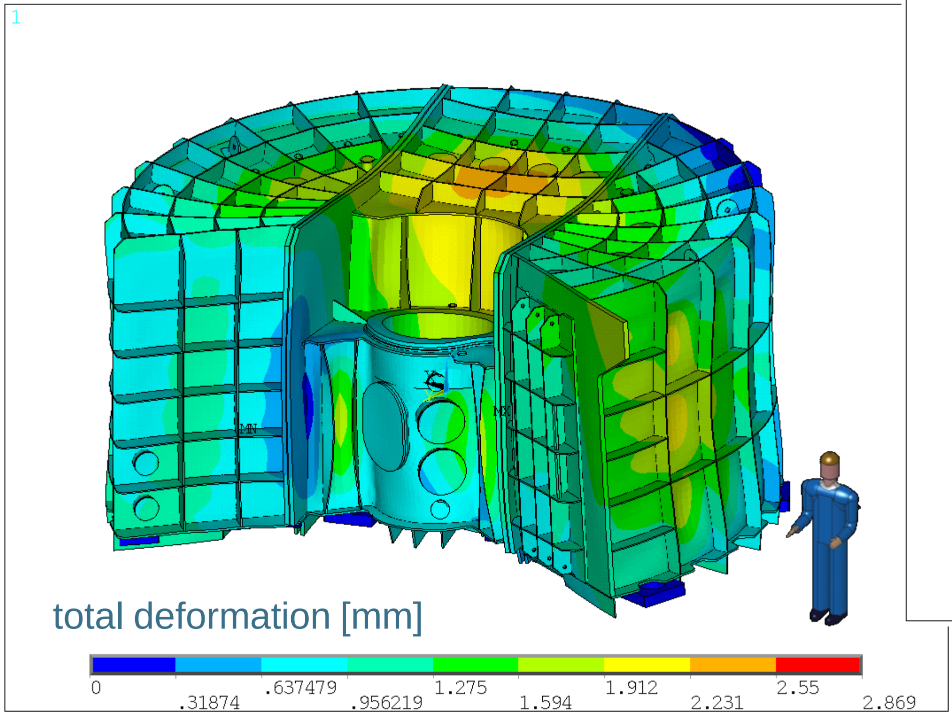
Inlet system for HALO

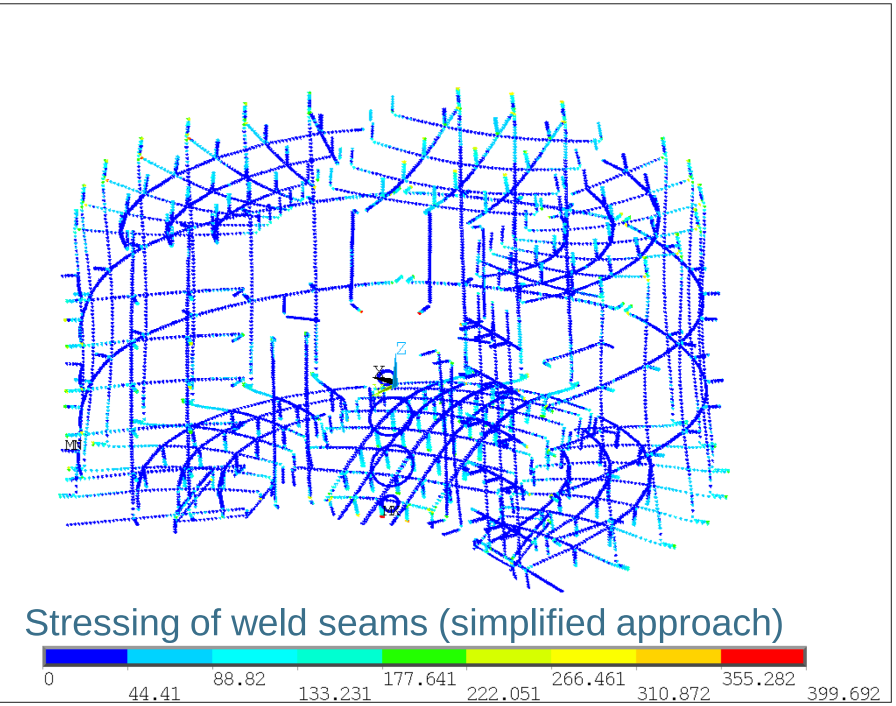
↳ bird strike test

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.

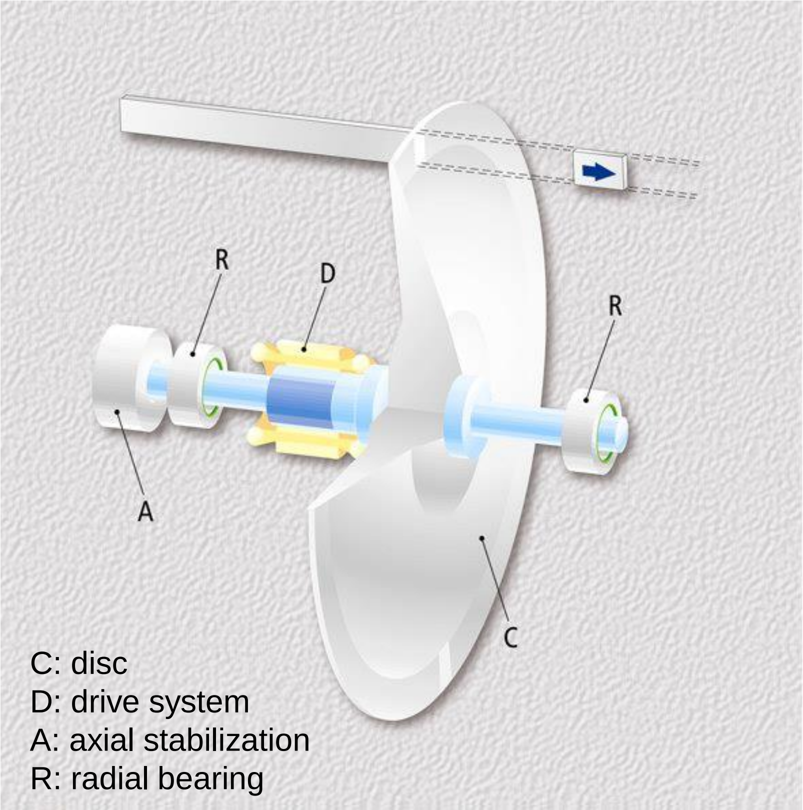

total deformation [mm]


Stressing of weld seams (simplified approach)

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



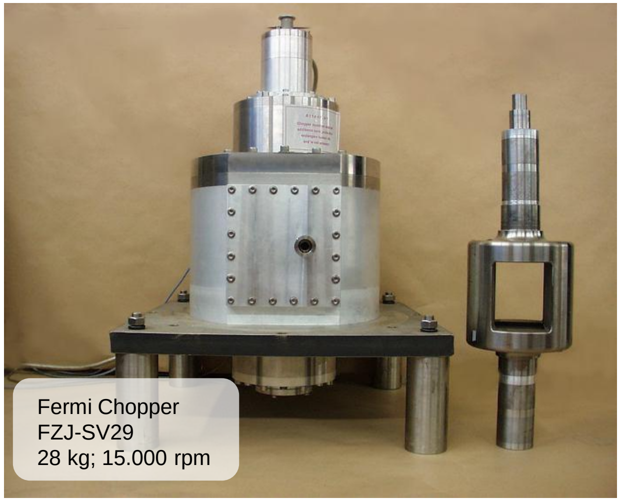
C: disc
D: drive system
A: axial stabilization
R: radial bearing

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

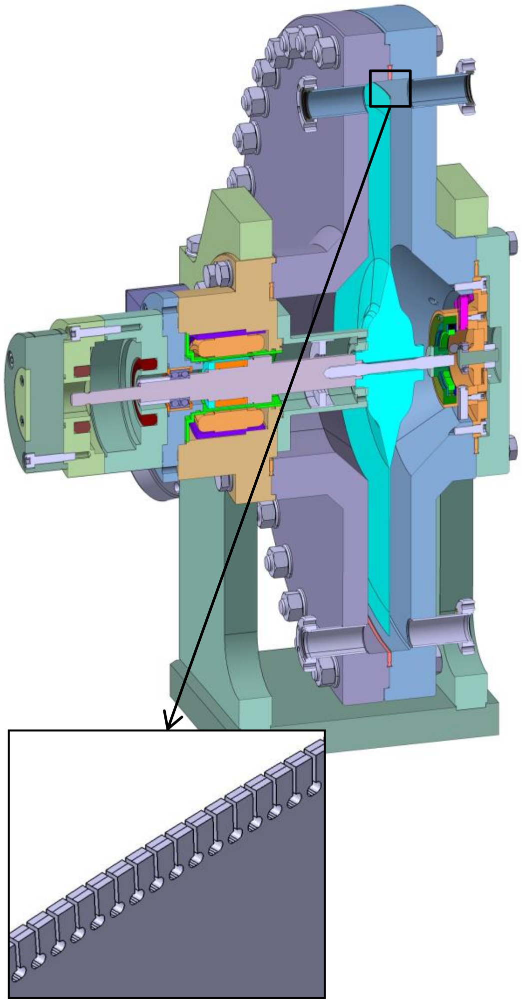
Chopper Cascade
ILL-IN5 TOF
6 disks; max. 8 kg;
20.000 rpm

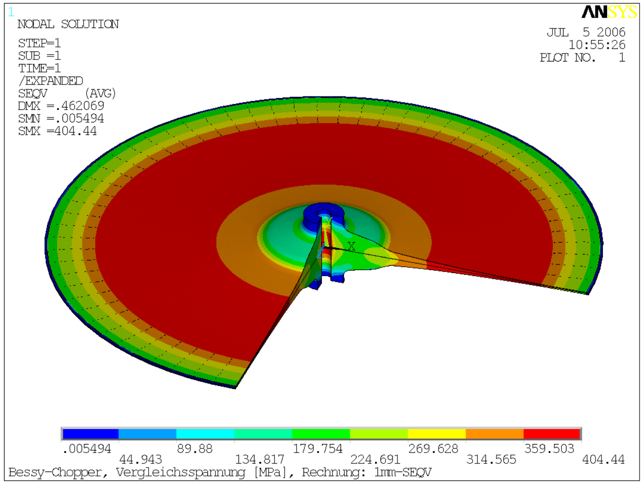
SNS-NSE
4 disks
7 kg; 3600 rpm

PST-Chopper
diameter 1280mm
4800 rpm

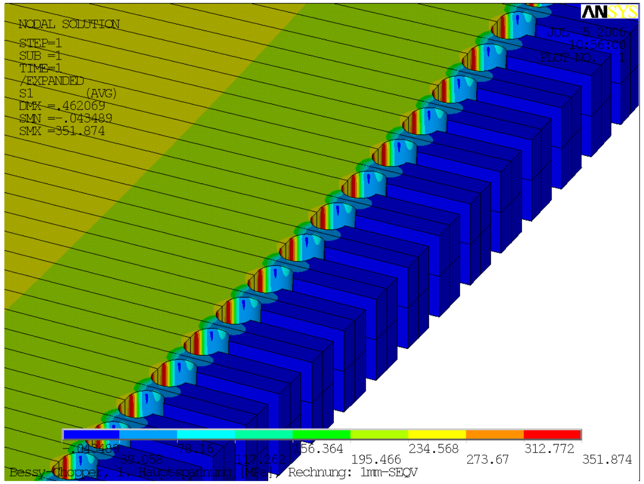
Chopper Design

↳ mechanical design of chopper disc (here: BESSI)

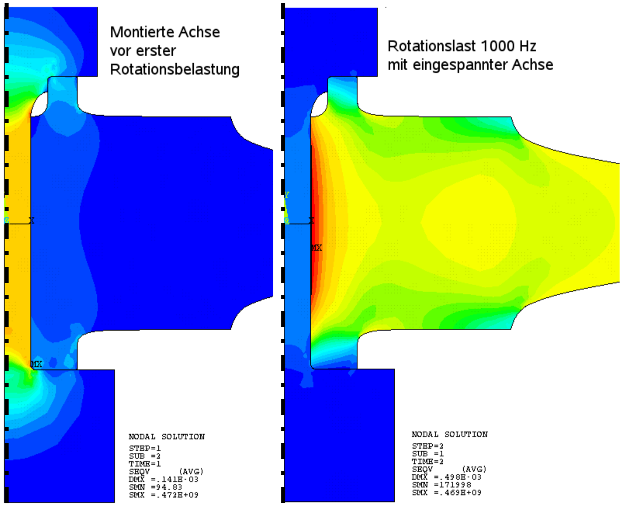




optimization of disc contour



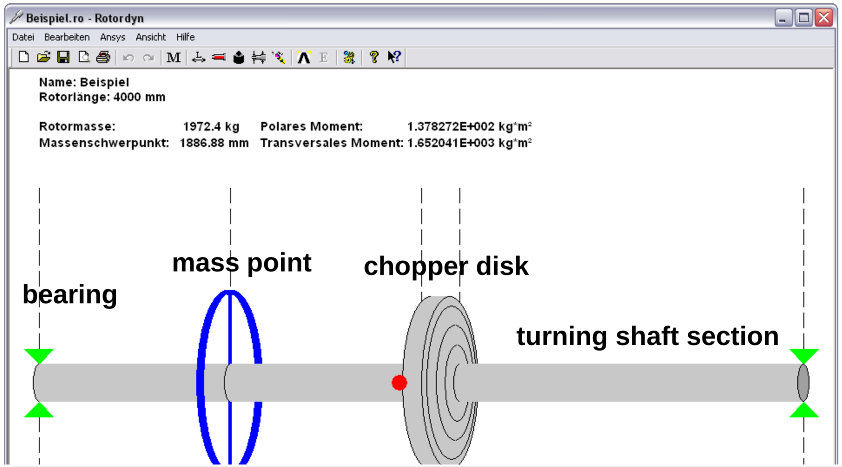
optimization of slit contour



investigation of clamping

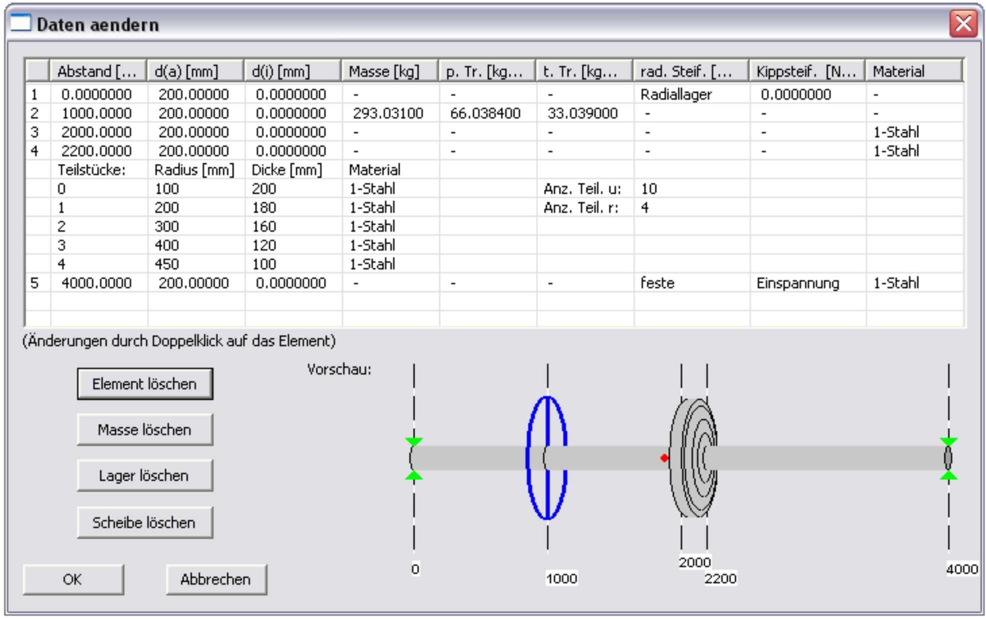
Chopper Design

rotor-dynamic design



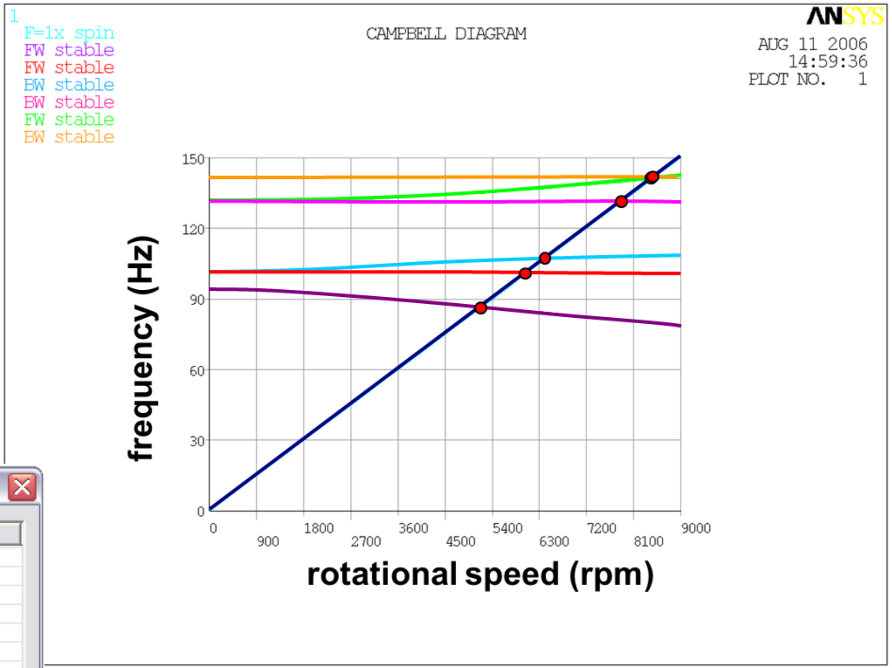
Name: Beispiel
Rotorlänge: 4000 mm

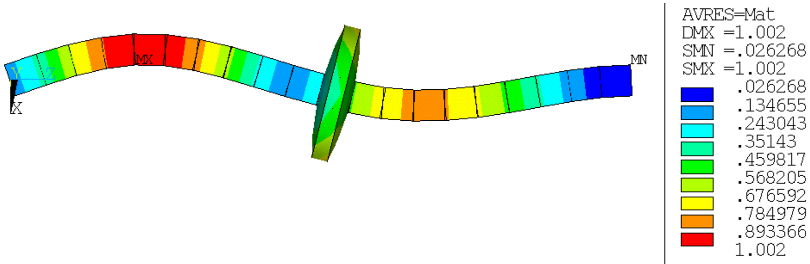
Rotormasse: 1972.4 kg Polares Moment: 1.378272E+002 kg*m²
Massenschwerpunkt: 1886.88 mm Transversales Moment: 1.652041E+003 kg*m²



	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

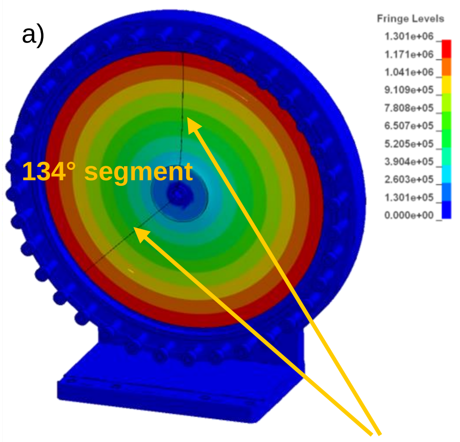
(Änderungen durch Doppelklick auf das Element)



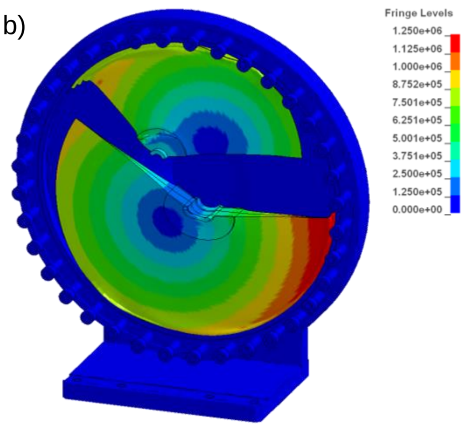


Chopper Design

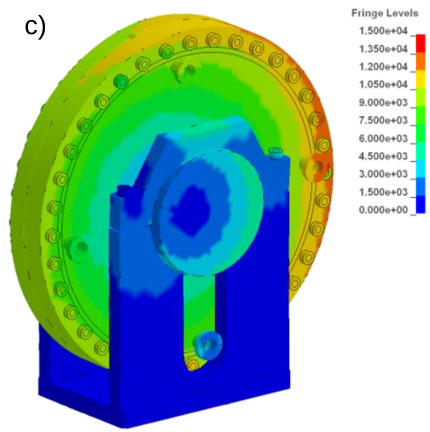
↳ safety case for housing



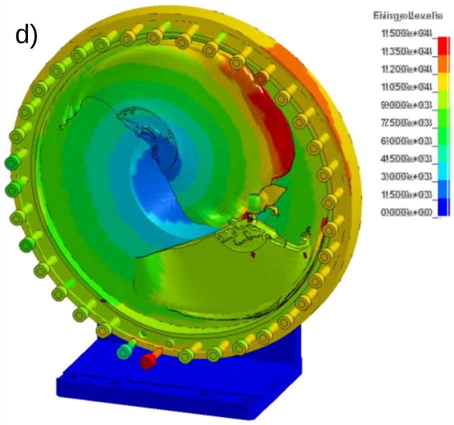
0 ms: initial conditions – disc with crack



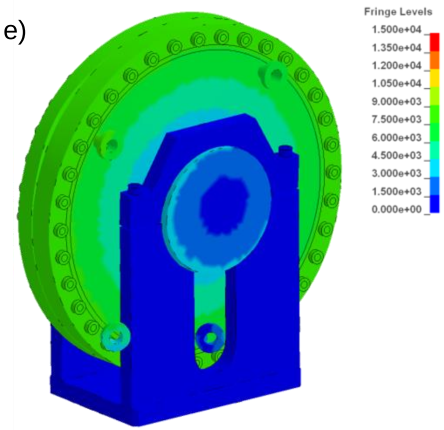
0.2 ms: disc crash on housing, housing starts to rotate in its bearings



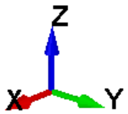
2,3 ms: first adapter shears-off due to rotation of housing



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

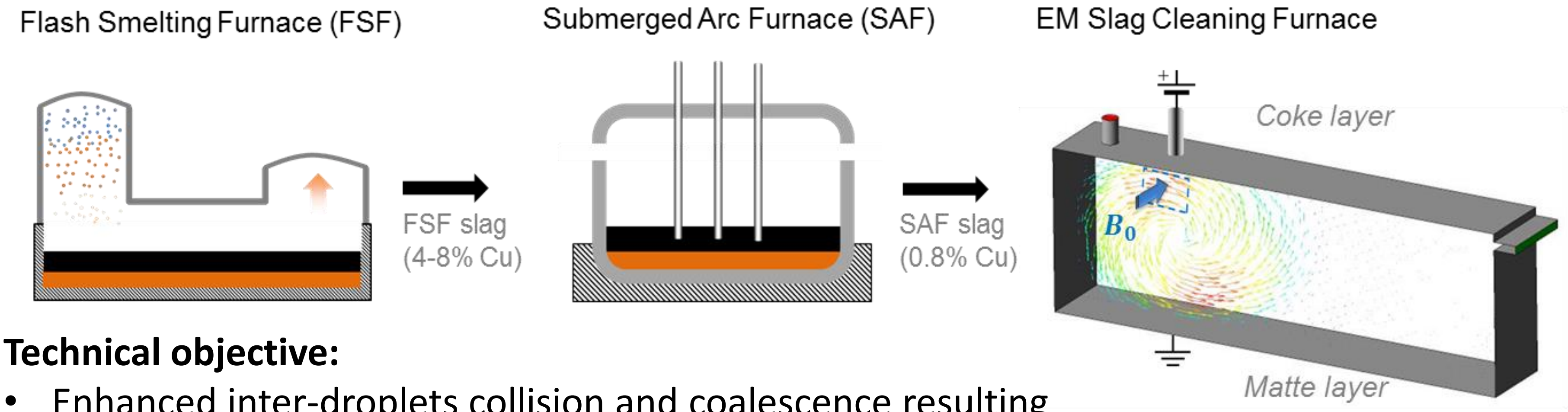


20 ms: end of simulation – the housing is still rotating but the remaining kinetic energy is less than 1% of the initial energy



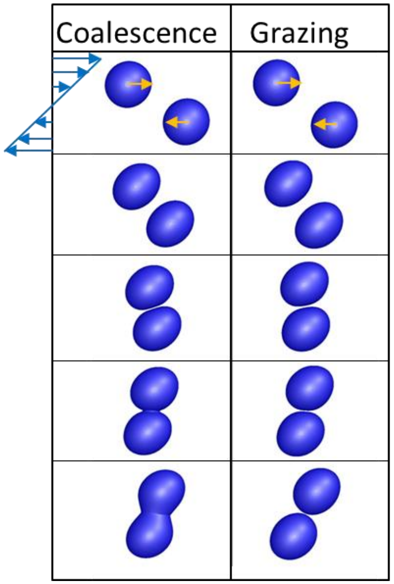
Copper Slag Cleaning Process

↳ electromagnetic stirring to intensify the cleaning process



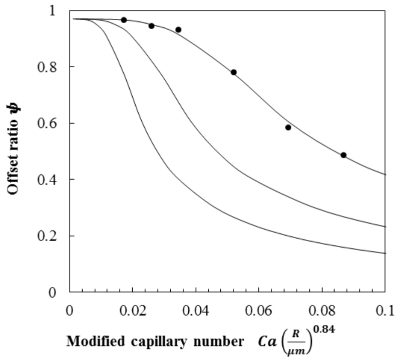
Technical objective:

- 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