ESRF | The European Synchrotron

MEDSI 2016

MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

BARCELONA

# THERMAL STABILITY OF THE NEW ESRF EXTREMELY BRILLIANT SOURCE

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1. Permanent static errors from the origin
2. Permanent variable errors (quick effects)
3. Errors triggered by beam operation
4. Long period errors

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**High thermal inertia suspected**
electromagnets, girders, concrete

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**Thermal system**

Heat sources
electromagnets, cables, RF, absorbers

Exterior perturbations
Exp. hall and groundwater temperatures

Cooling systems
air ventilation, water cooling

High thermal inertia suspected
electromagnets, girders, concrete

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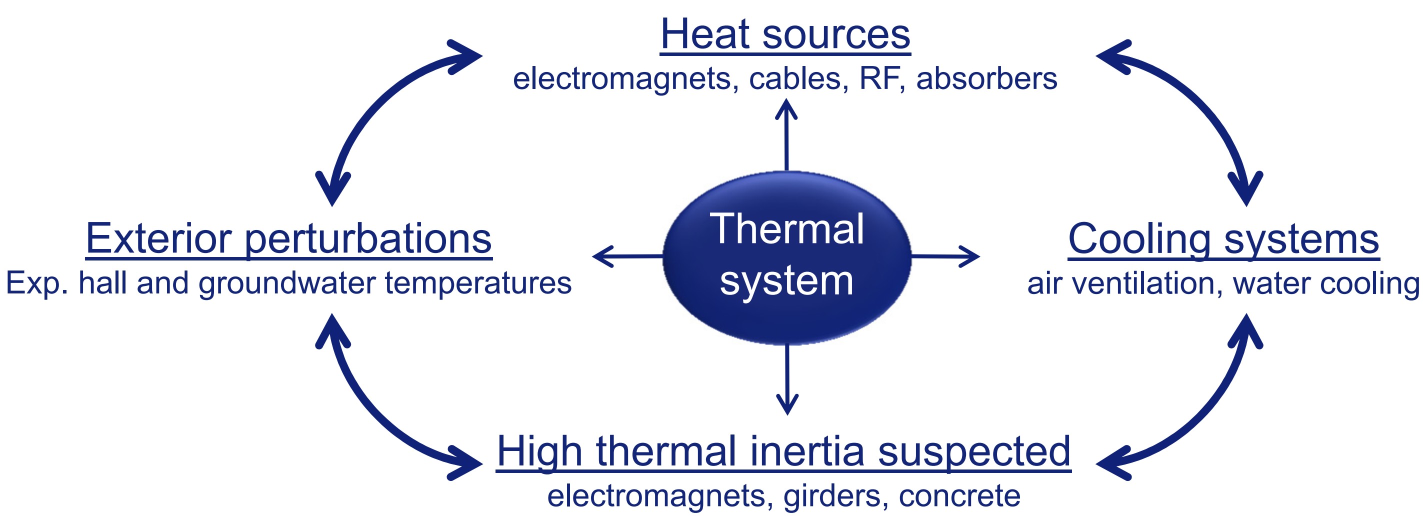

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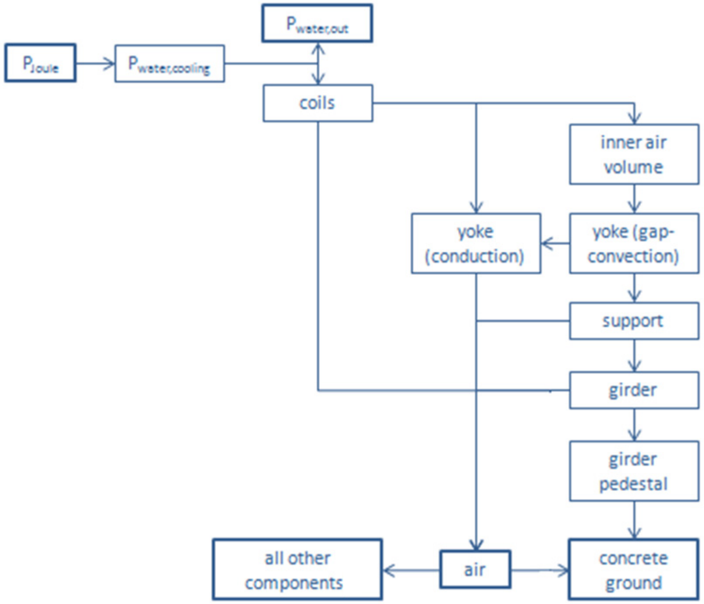

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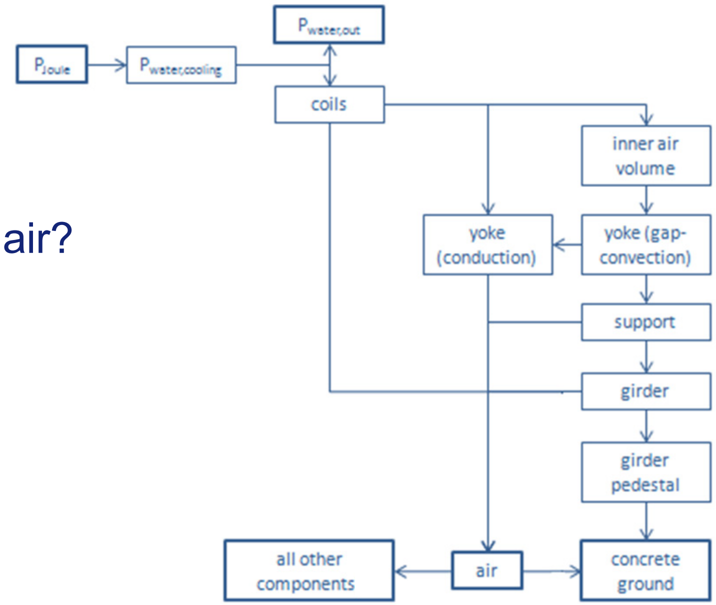

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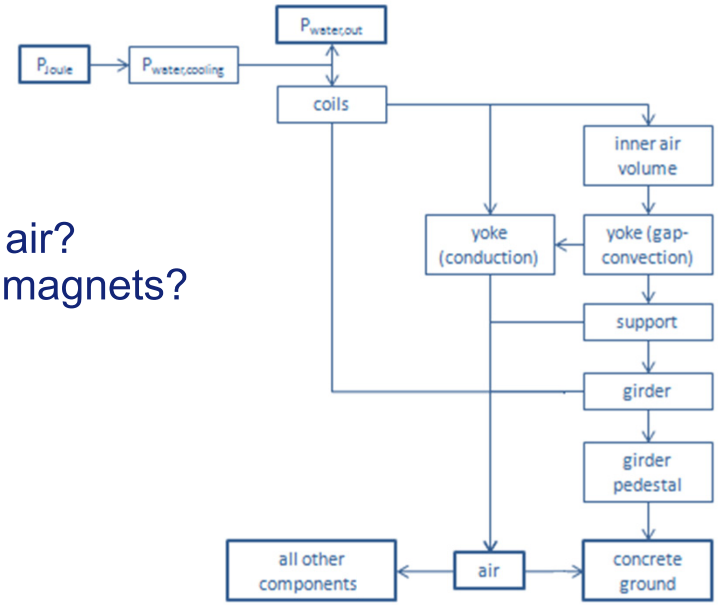

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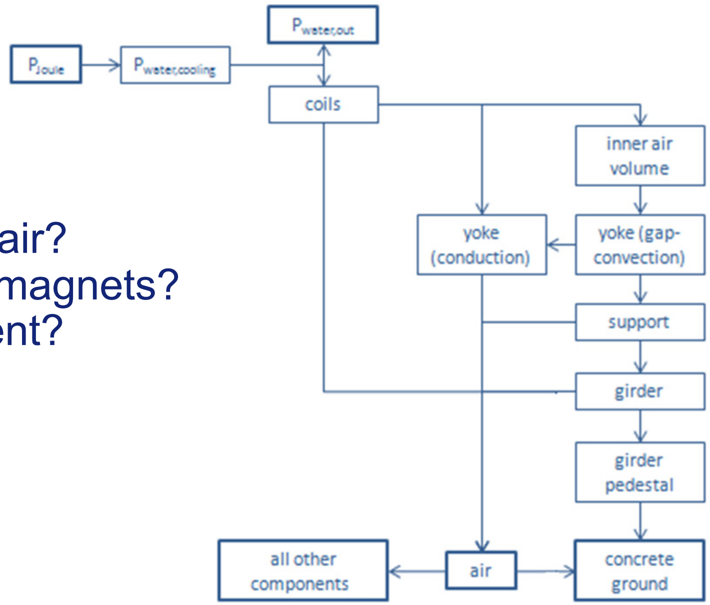


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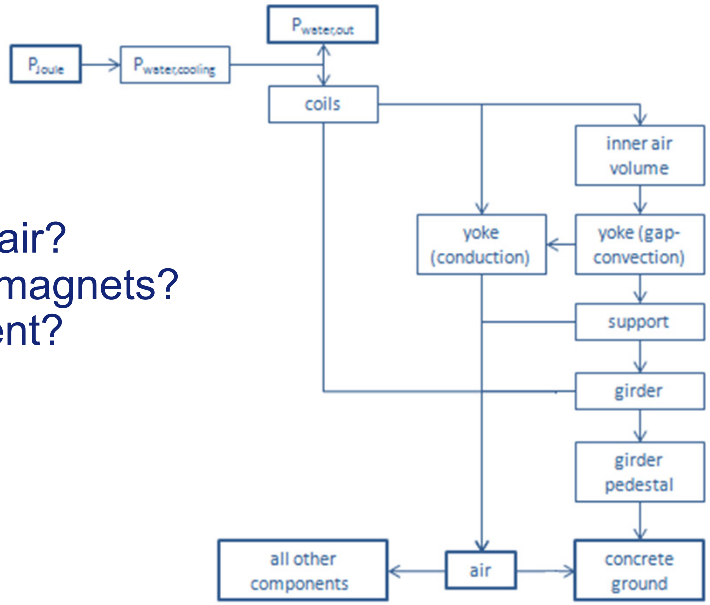


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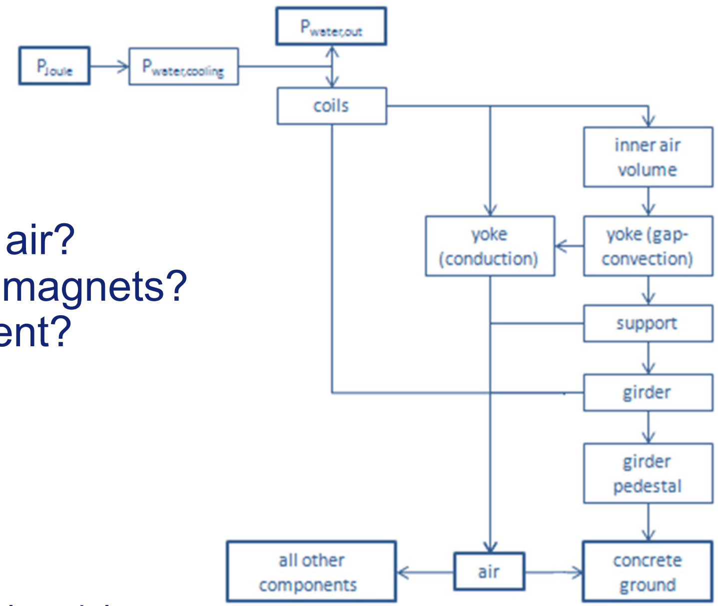


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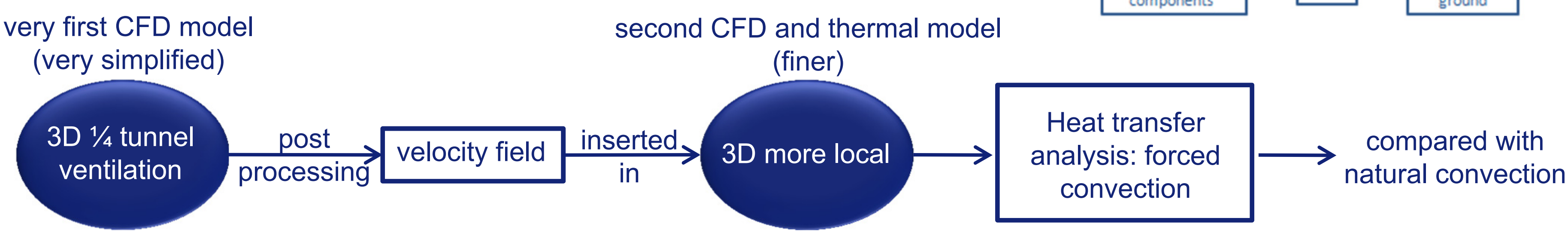

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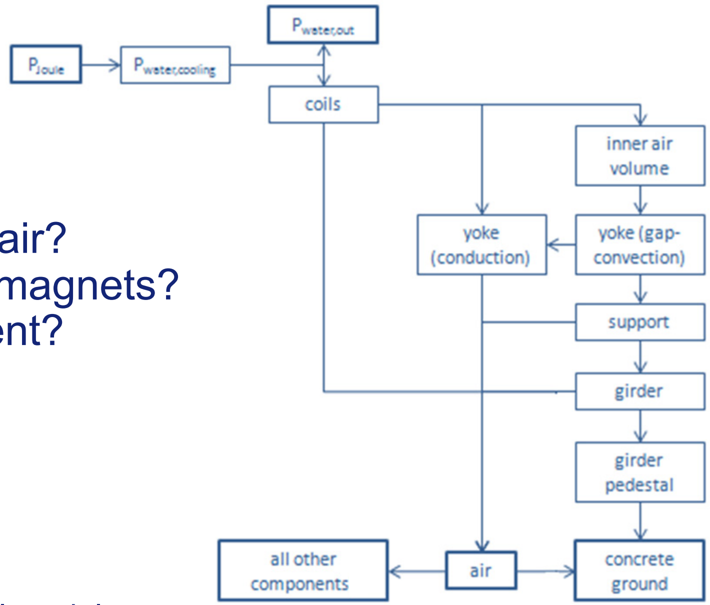


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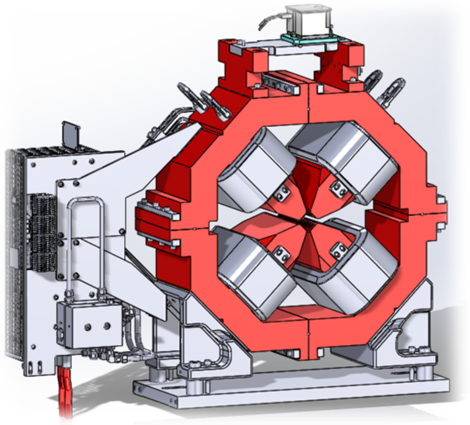
very first CFD model (very simplified)

3D ¼ tunnel ventilation → post processing → velocity field → inserted in → 3D more local → Heat transfer analysis: forced convection → compared with natural convection

second CFD and thermal model (finer)

**Inner volume** of electromagnets: natural convection is predominant

# EBS QUADRUPOLE



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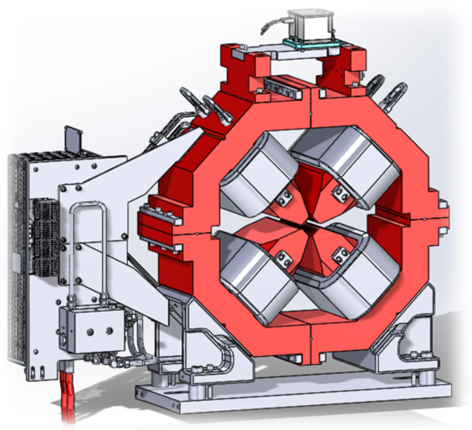

- Each coil dissipates 500W of heat (2000W total)
- Coils are water cooled in parallel

  0.45L/min

  $T_{inlet}$ = 24°C

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- Air: only natural convection is considered

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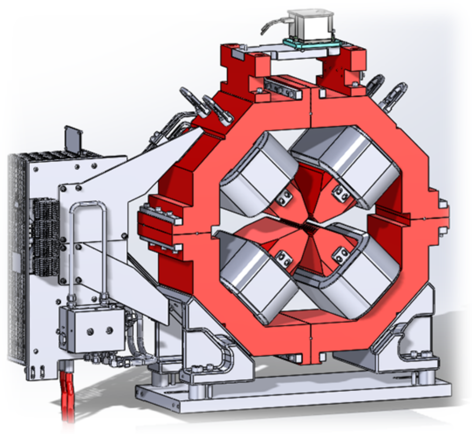

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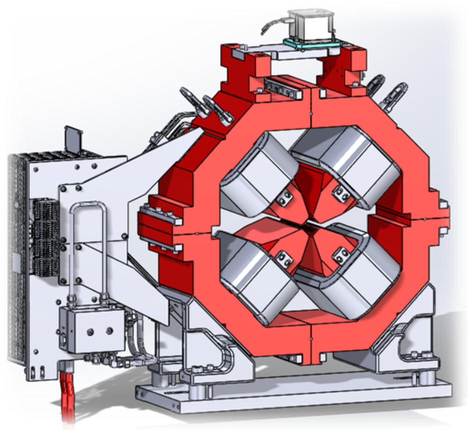

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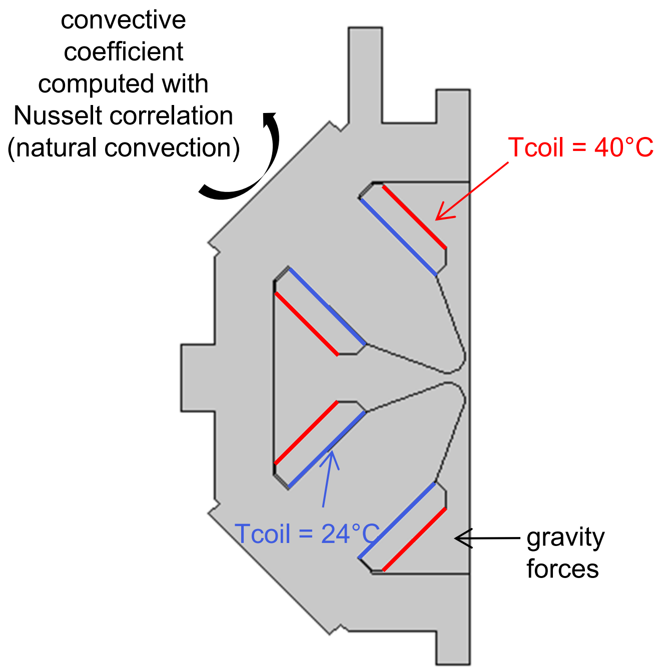

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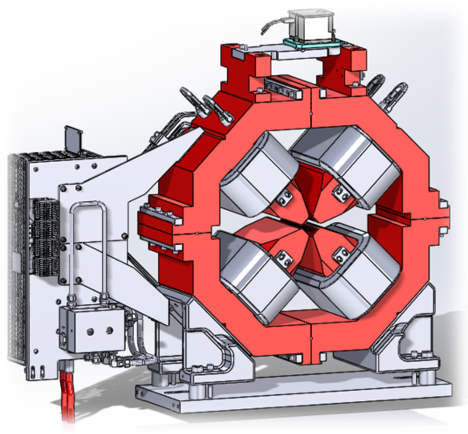

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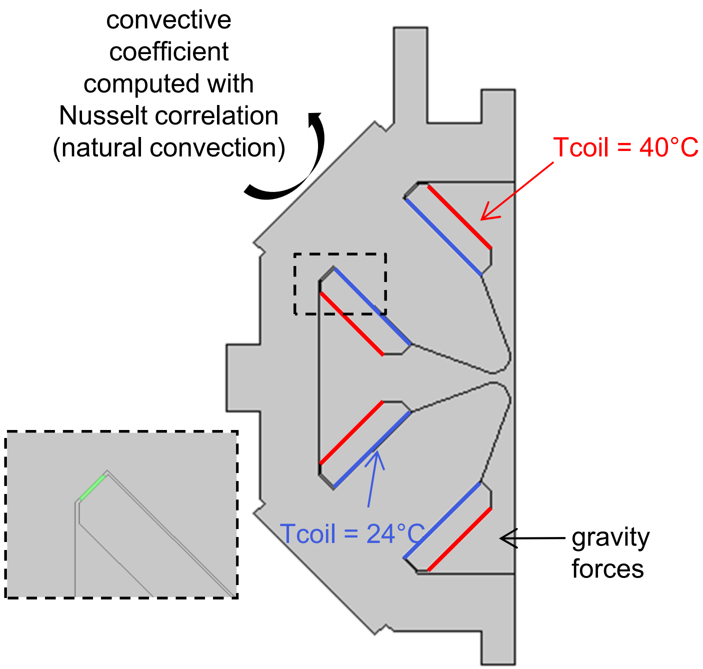

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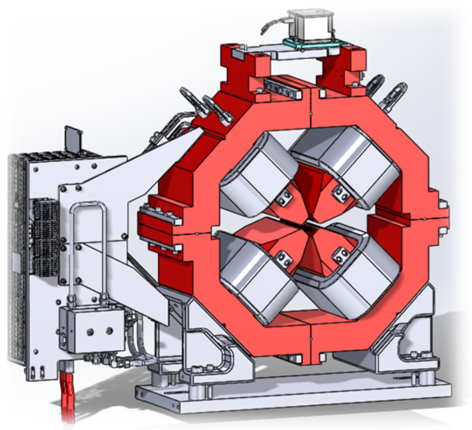

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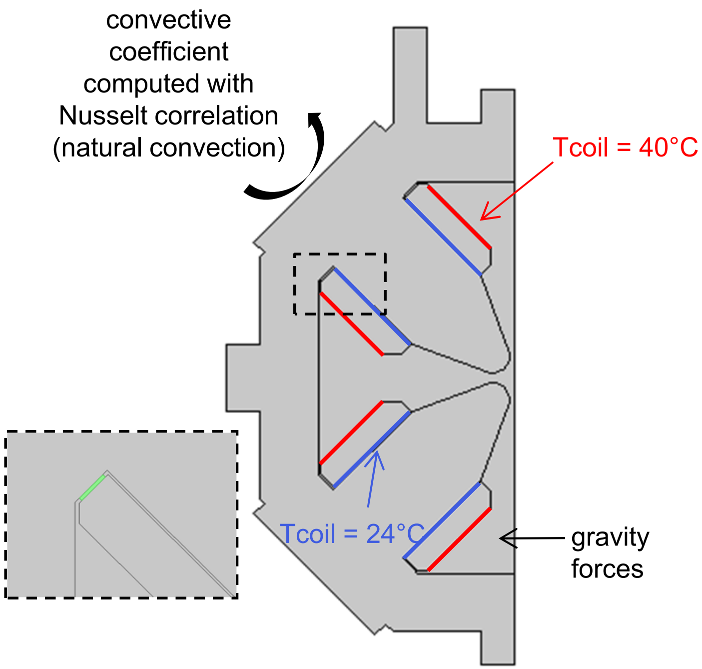
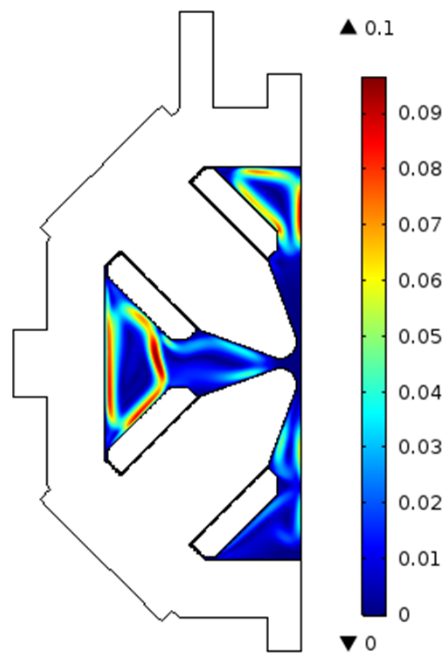



velocity field (m/s) - steady state



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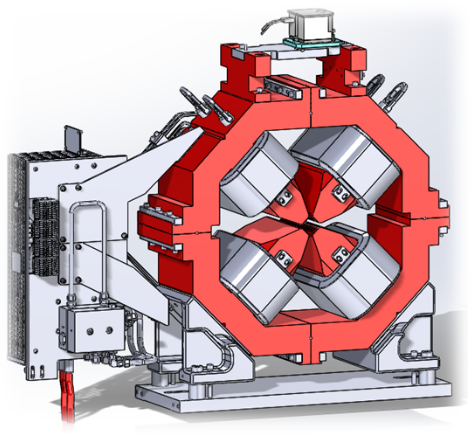

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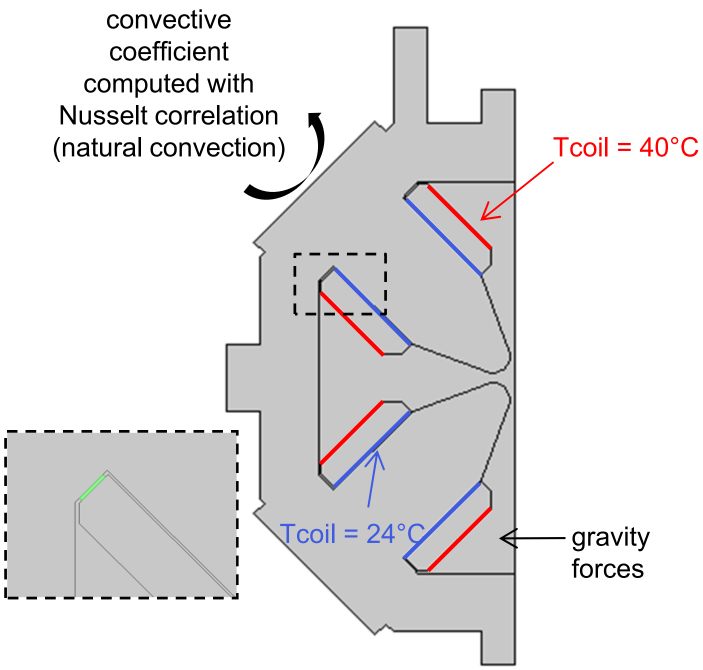


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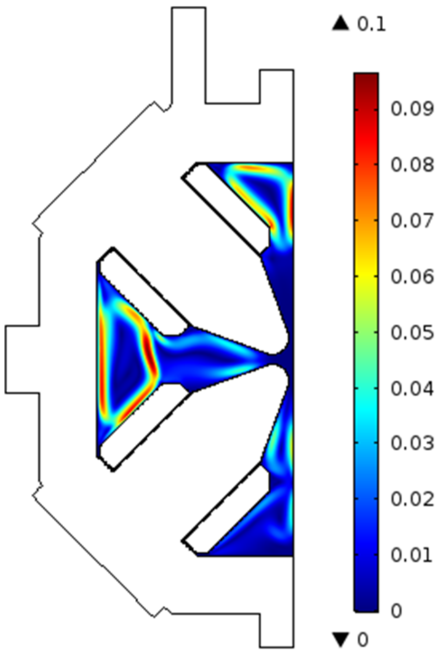


➡ local convective coefficients computed all along inside surfaces of the quadrupole

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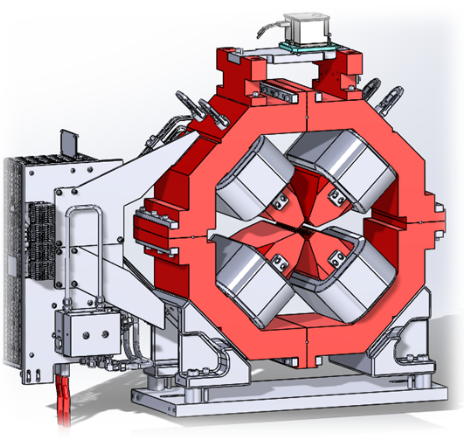

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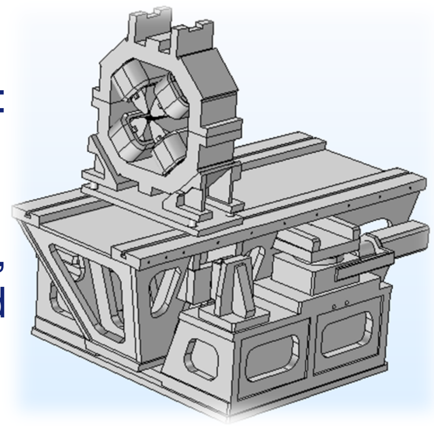

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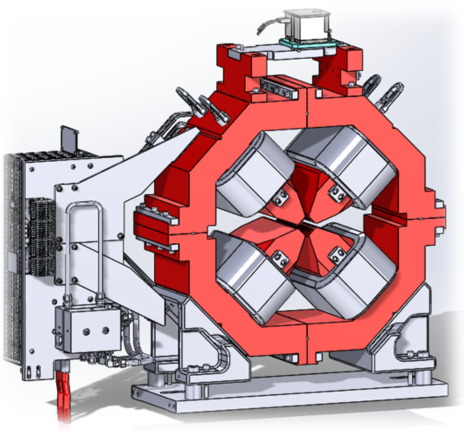

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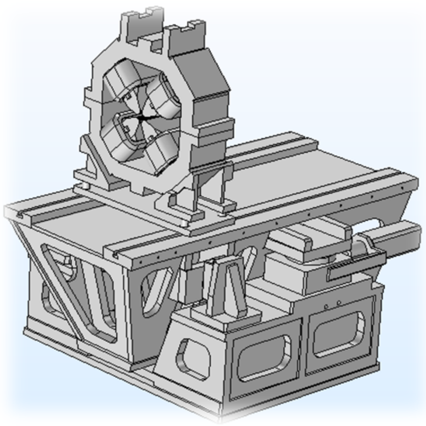
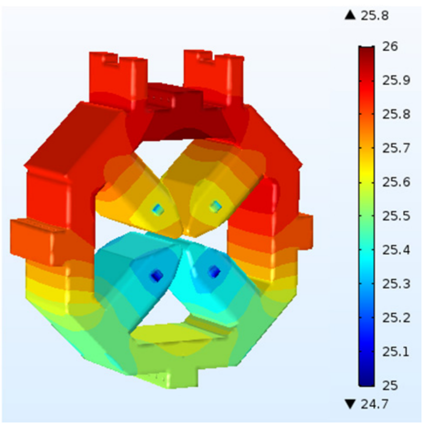


Temperature field [°C]

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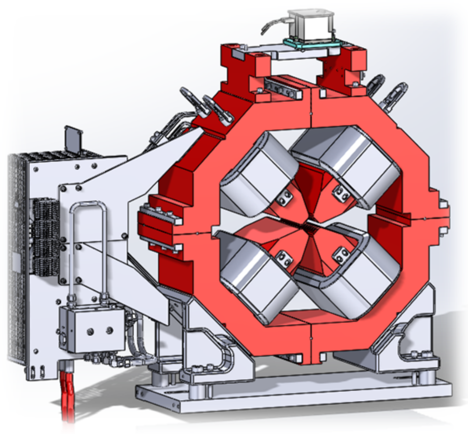

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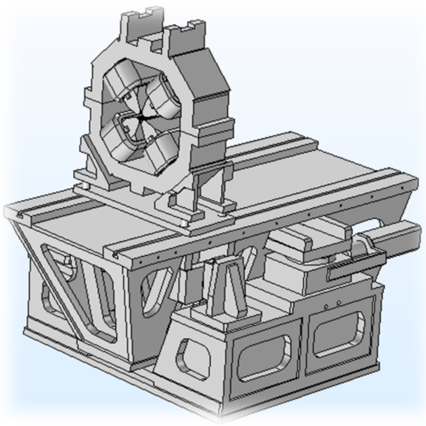

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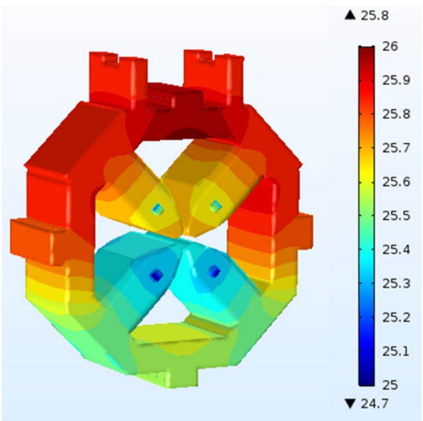


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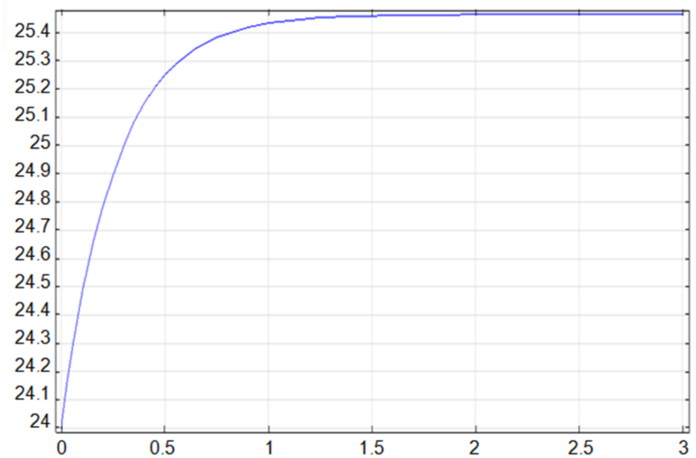
Average temperature (yoke & poles) [°C] against time [d]




Steady state reached after: 5τ ~1.5days
Time constant τ ~0.3day

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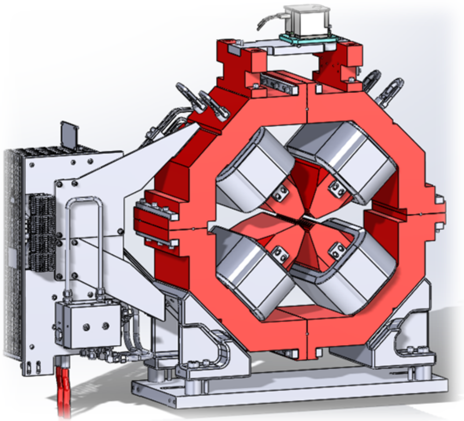

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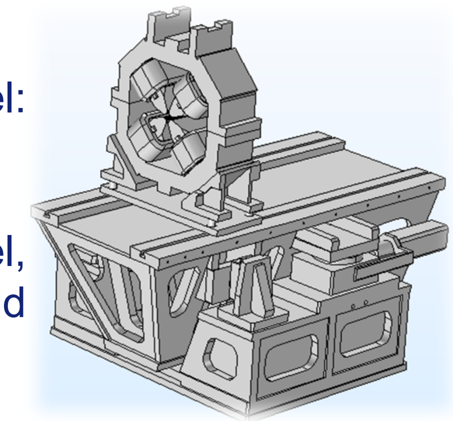

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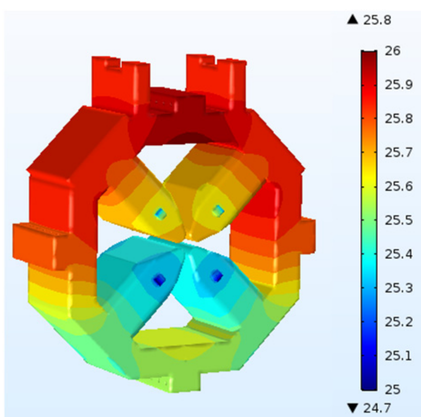


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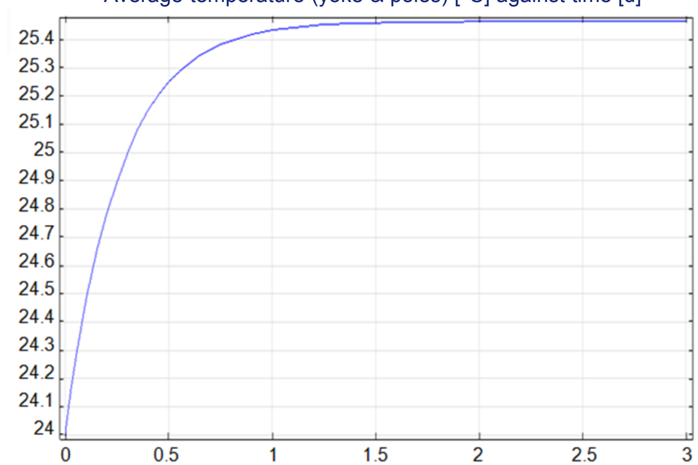


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→ time constant of ~0.3day

→ temperature increase by ~1°C

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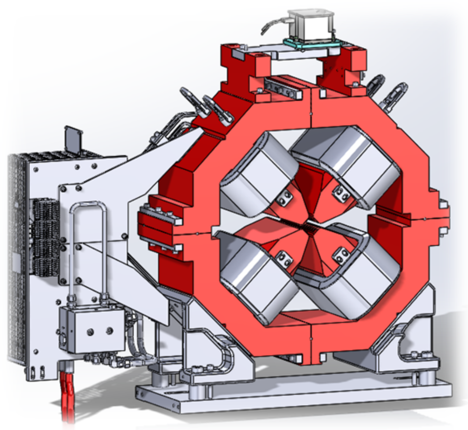

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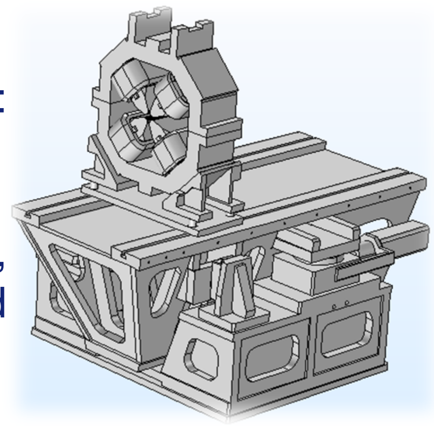

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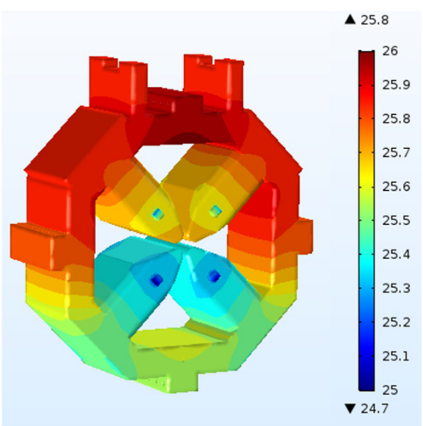


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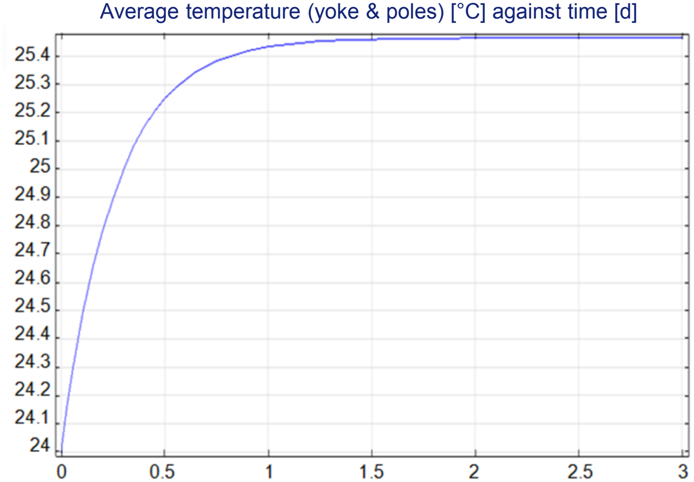


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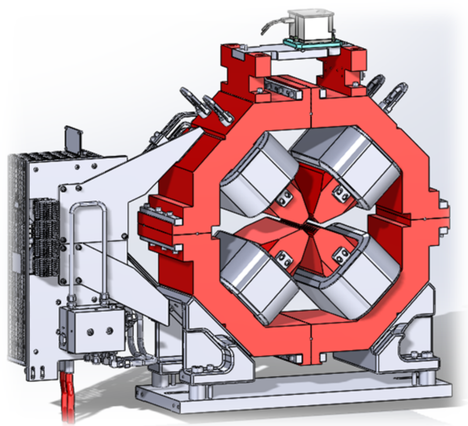

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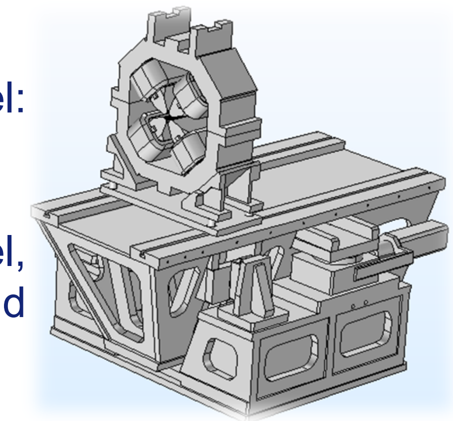

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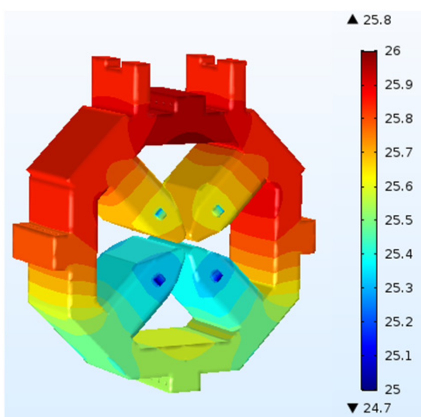


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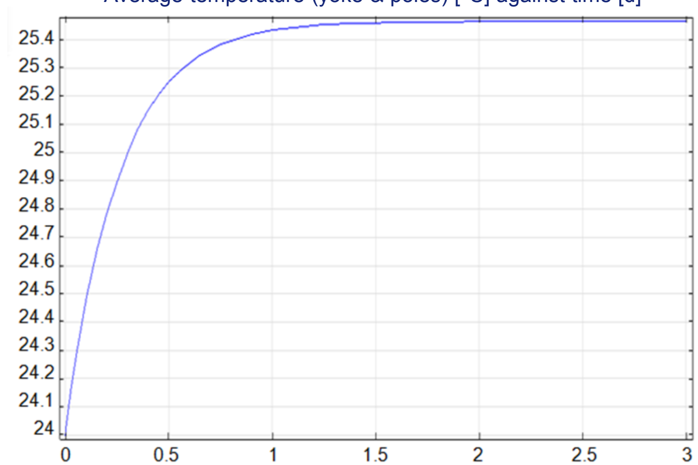
Average temperature (yoke & poles) [°C] against time [d]

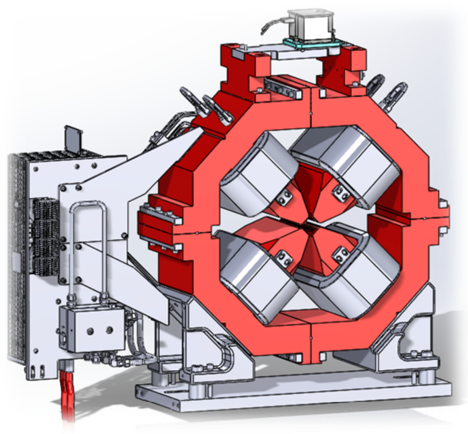


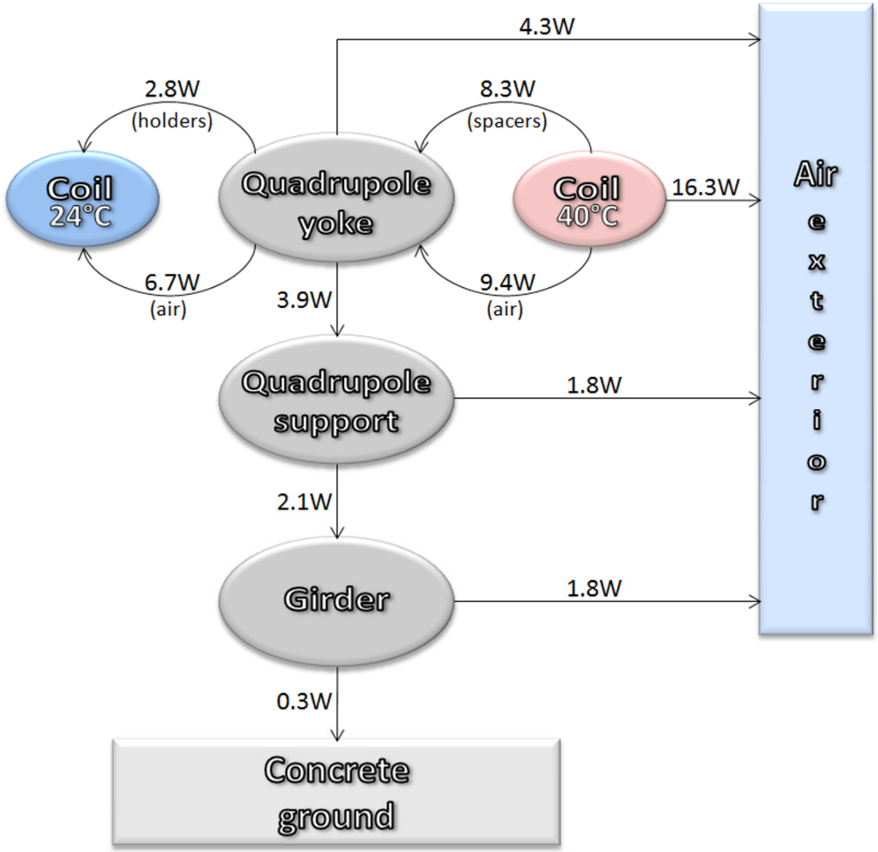

Steady state reached after: 5τ ~1.5days
Time constant τ ~0.3day

➡ time constant of ~0.3day observed experimentally ☺

➡ temperature increase by ~1°C not observed experimentally ☹ (actually it is +3°C)

# EBS QUADRUPOLE – HEAT BALANCE





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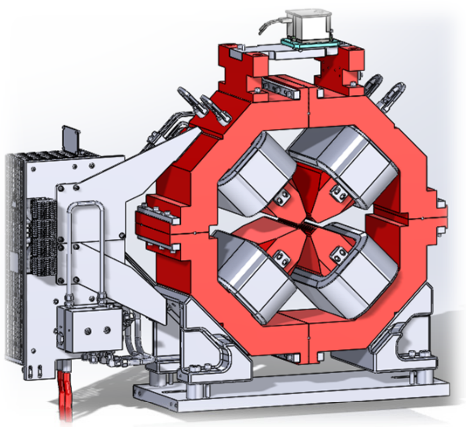

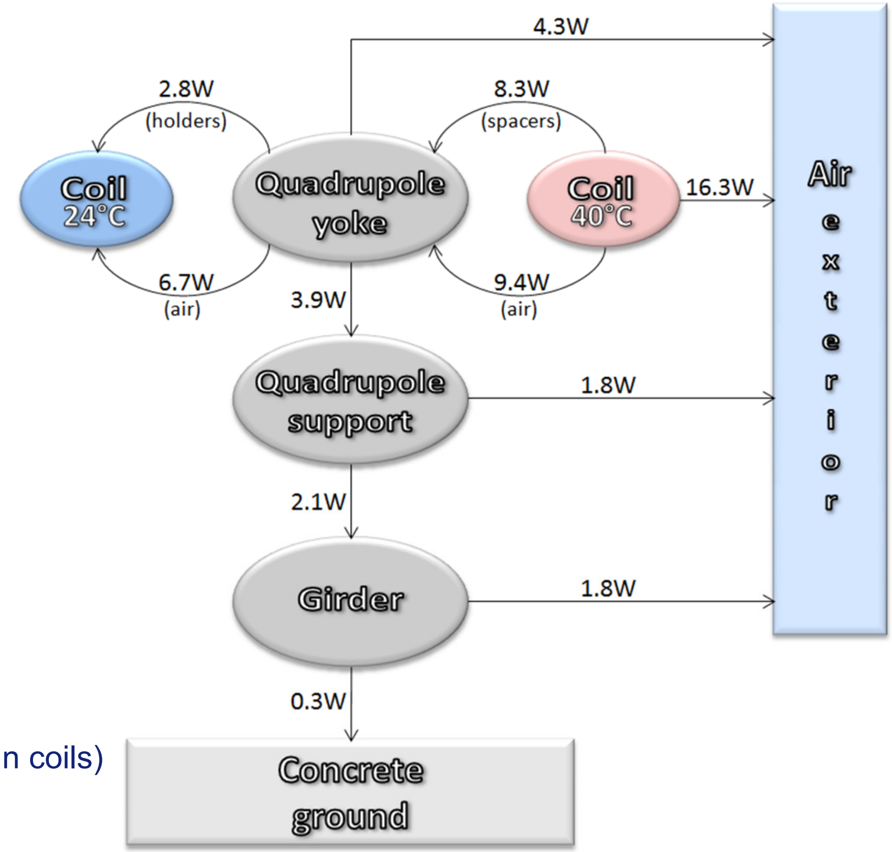


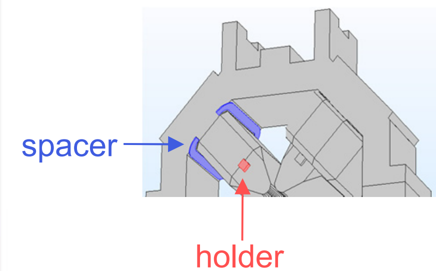


- Coils⟷Quadrupole:
  17.7W in
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    - *- 53.1% from air*

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    - *- 29.5% from holders*
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- 24.2W in air (1.2% of the total heat in coils)
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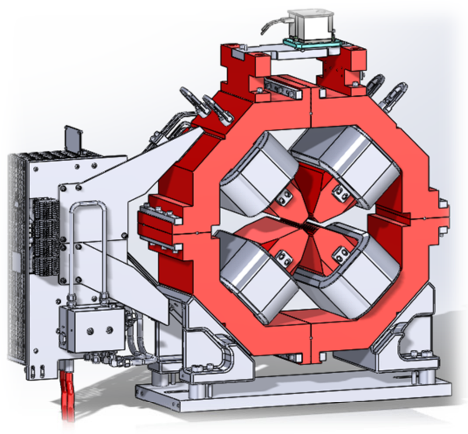

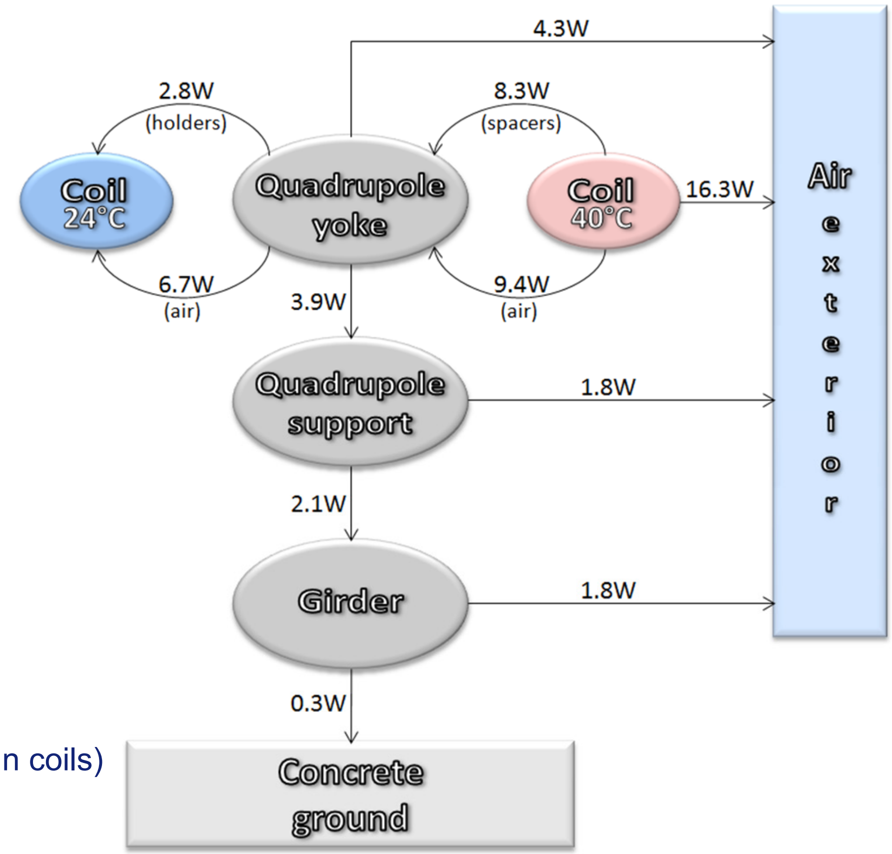


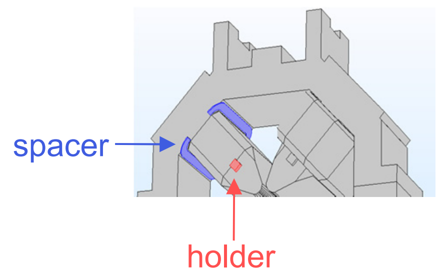


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| FEA | EXP. |
|---|---|
| Tav. +1°C | Tav. +3°C |

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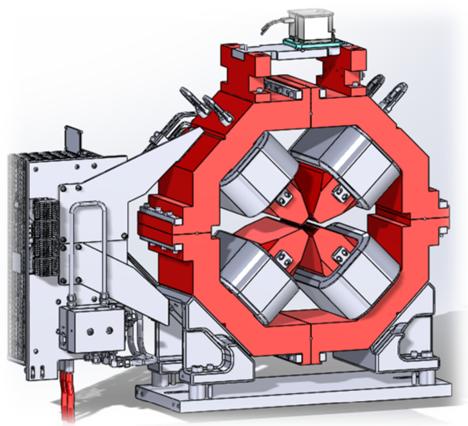

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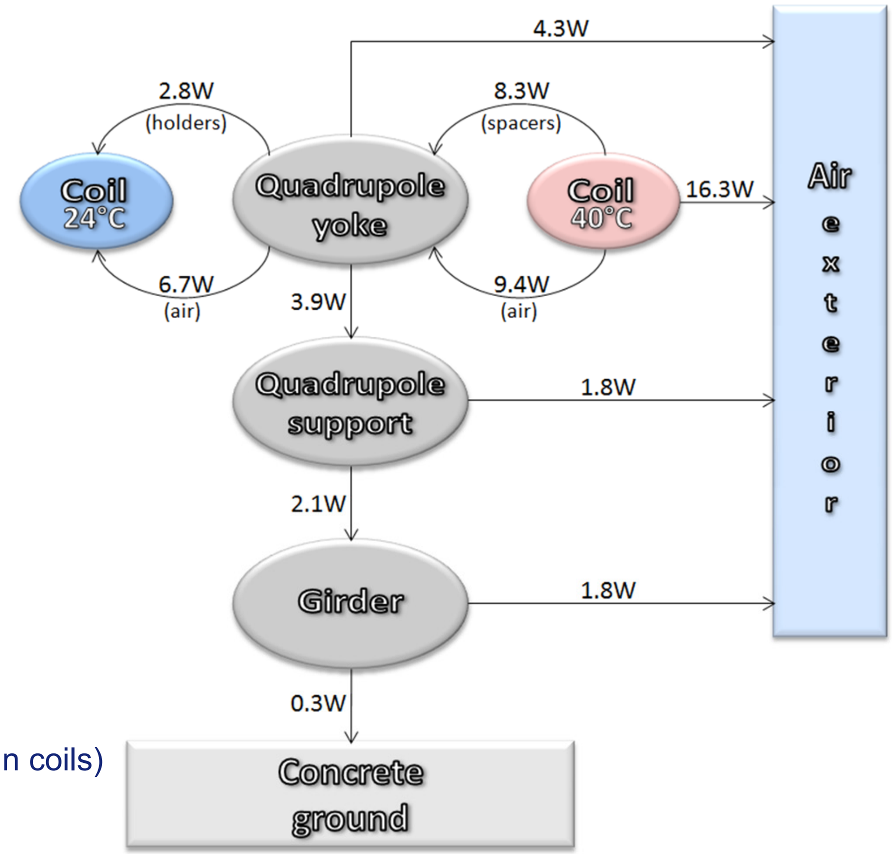


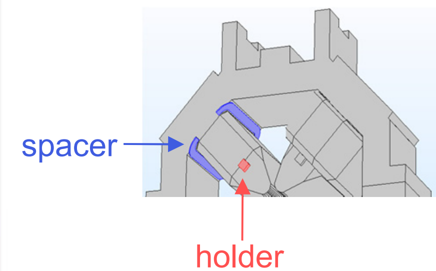


| FEA | EXP. |
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| Tav. +1°C | Tav. +3°C |
| 1% of heat in air | 4% of heat in air |

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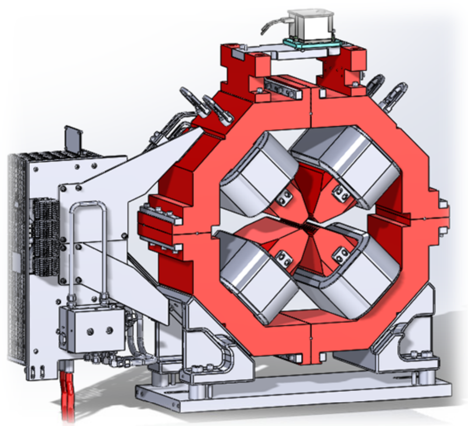

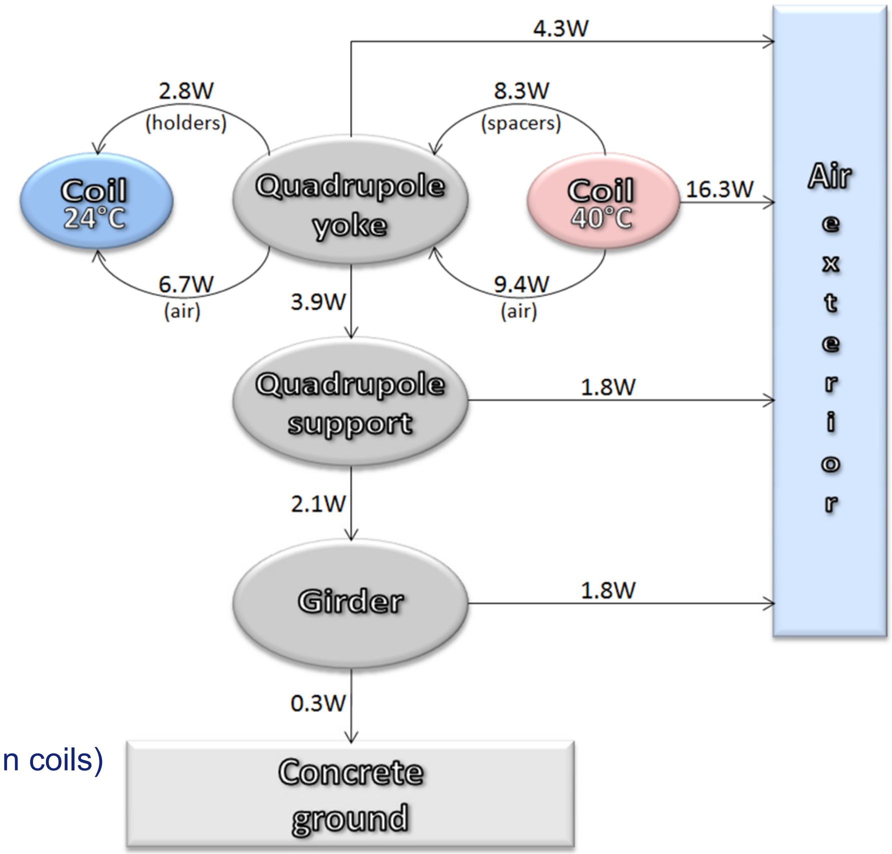


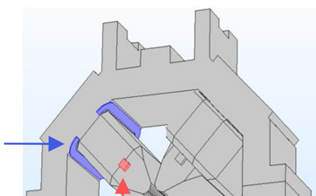


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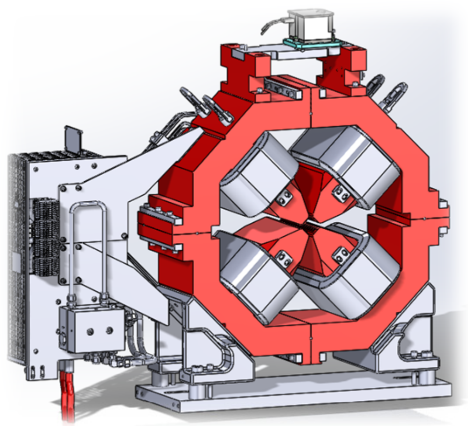

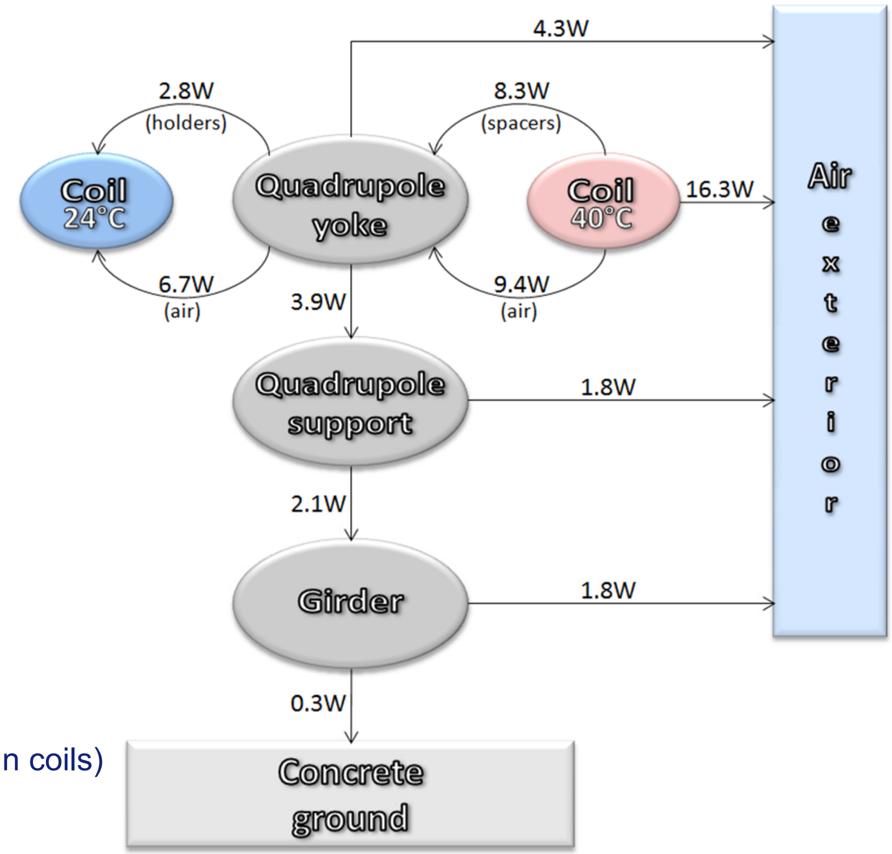


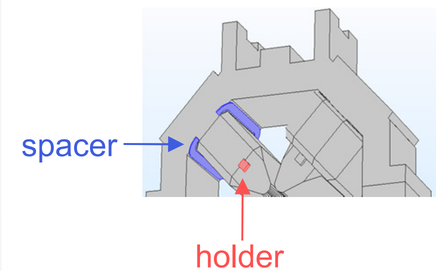


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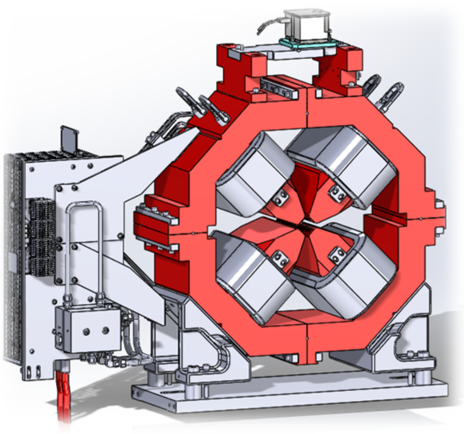
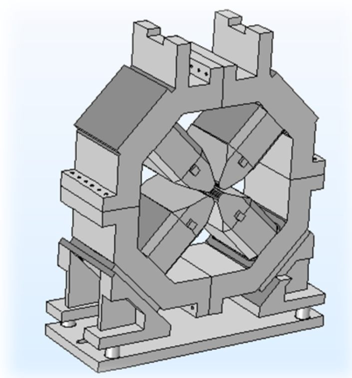
→ **EXP. magnet more than twice as deep as the FEA one**

→ more heat added to quadrupole
more investigations to do

# EBS QUADRUPOLE – THERMOMECHANICAL DISPLACEMENTS





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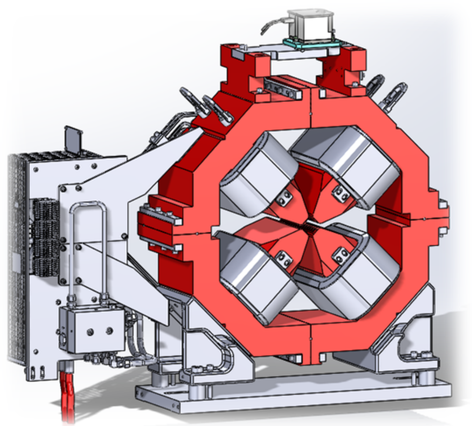
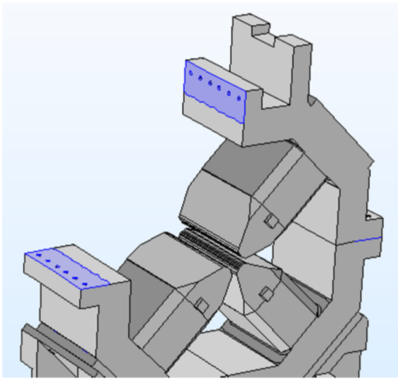
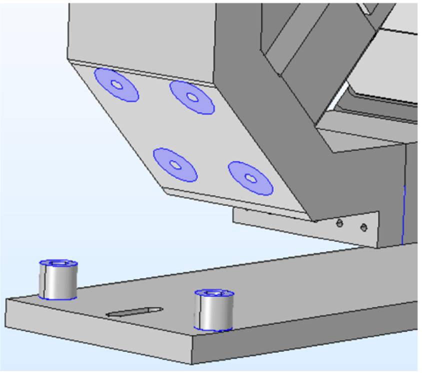
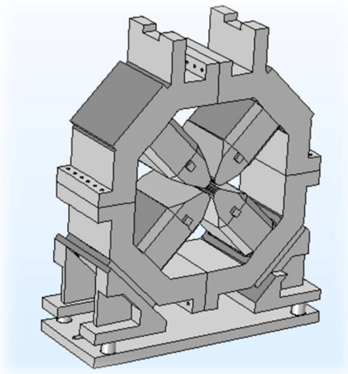


Continuity







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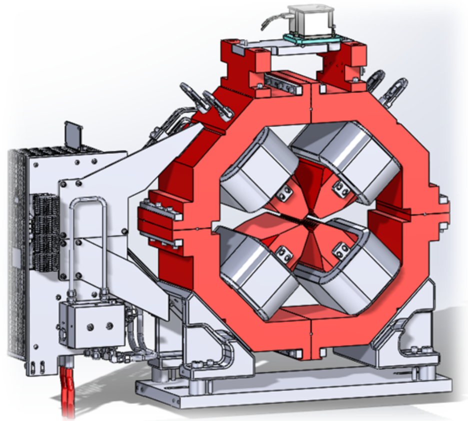

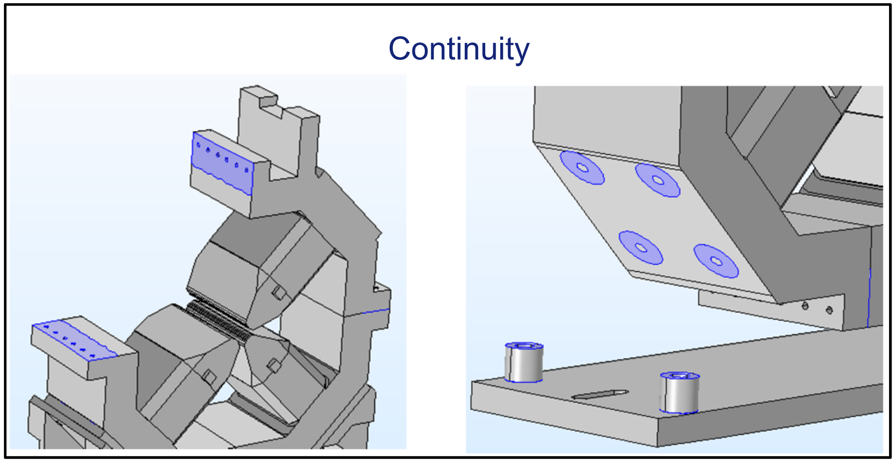


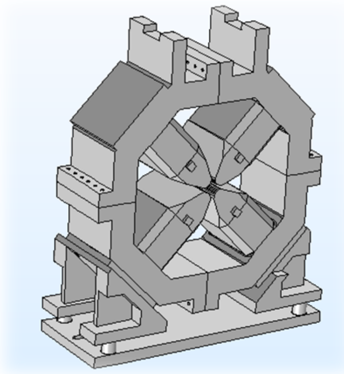

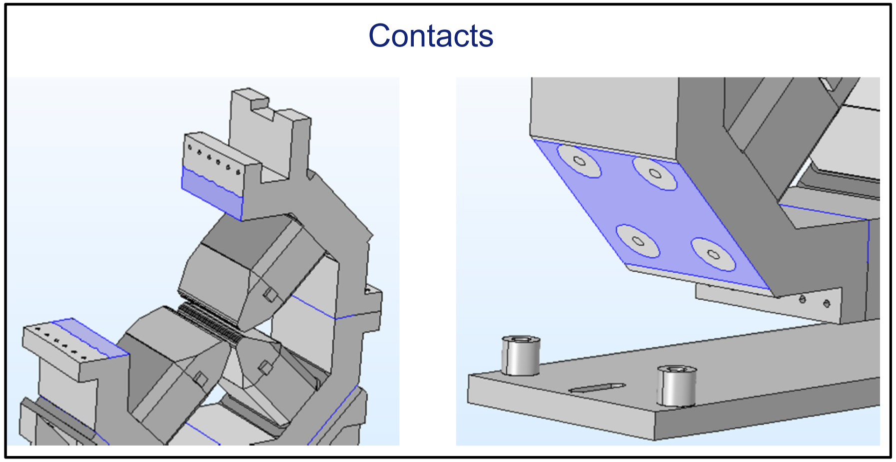

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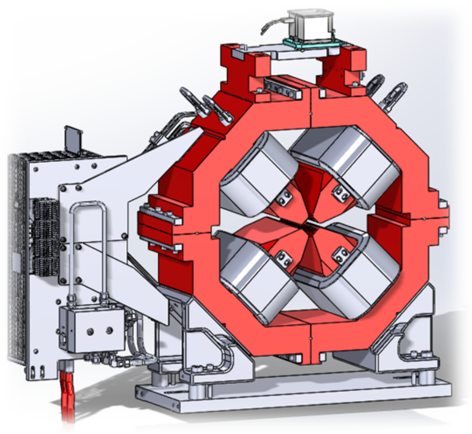

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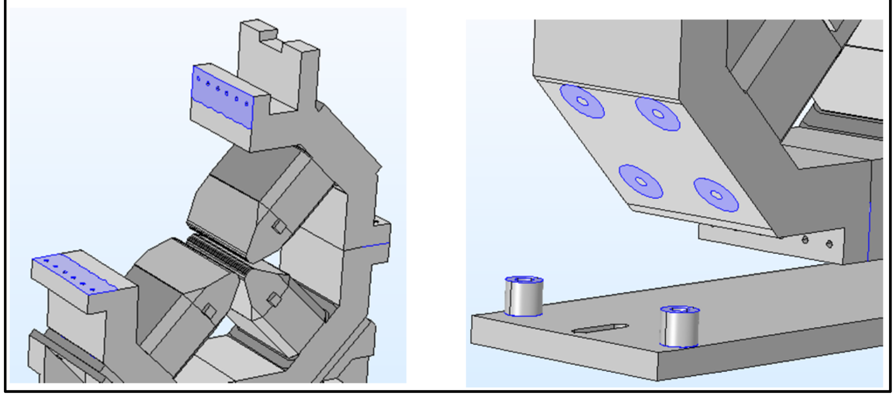
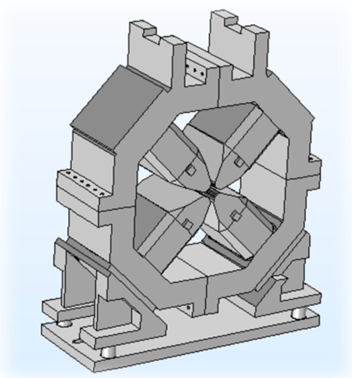
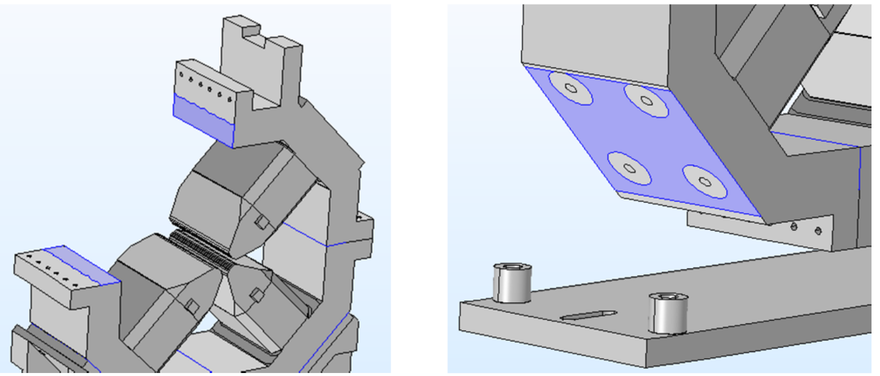
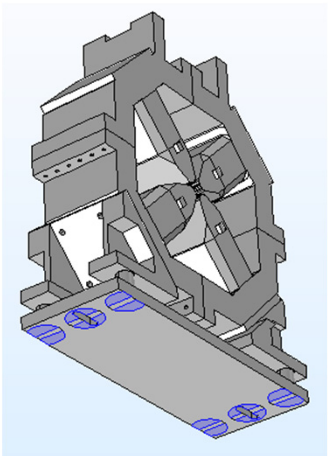




Contacts



Displacement = 0



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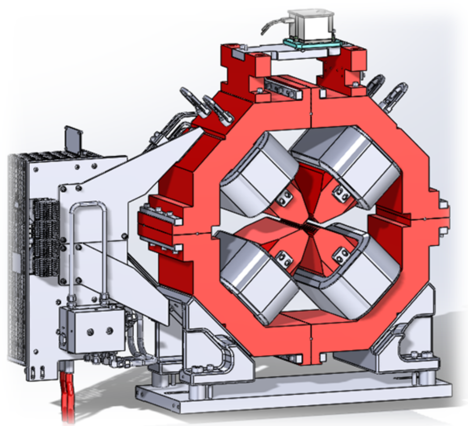

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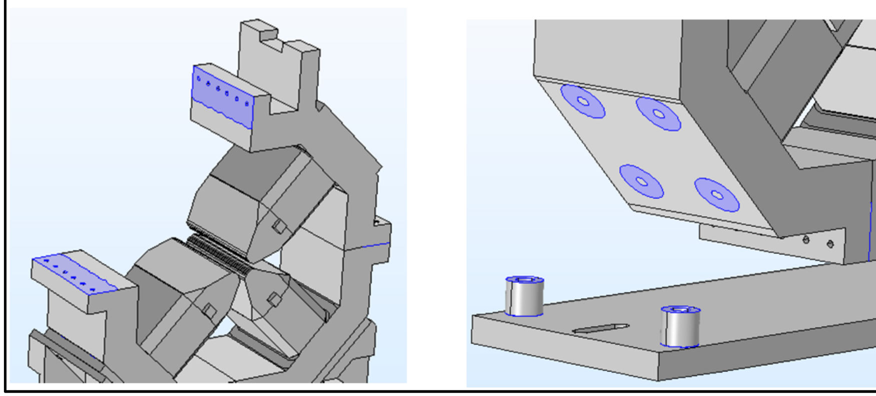

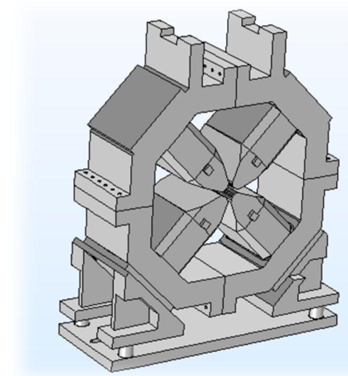

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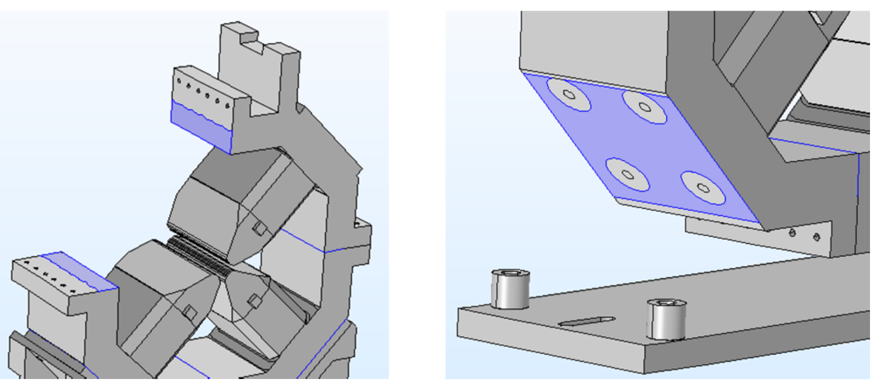

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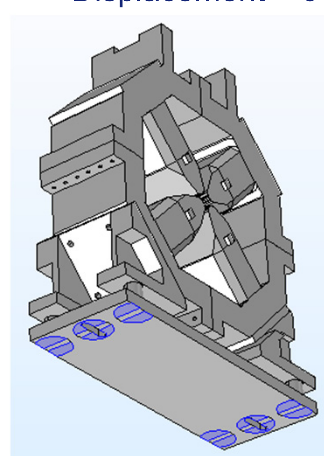
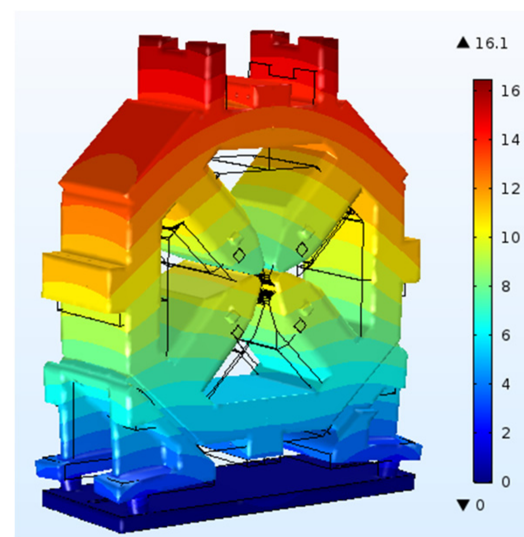


Total displacements [µm]



# GIRDER MOCK-UP

Full scale mock-up girder prototype with power cables inside

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Full scale mock-up girder prototype with power cables inside

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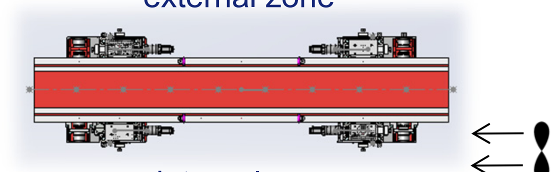
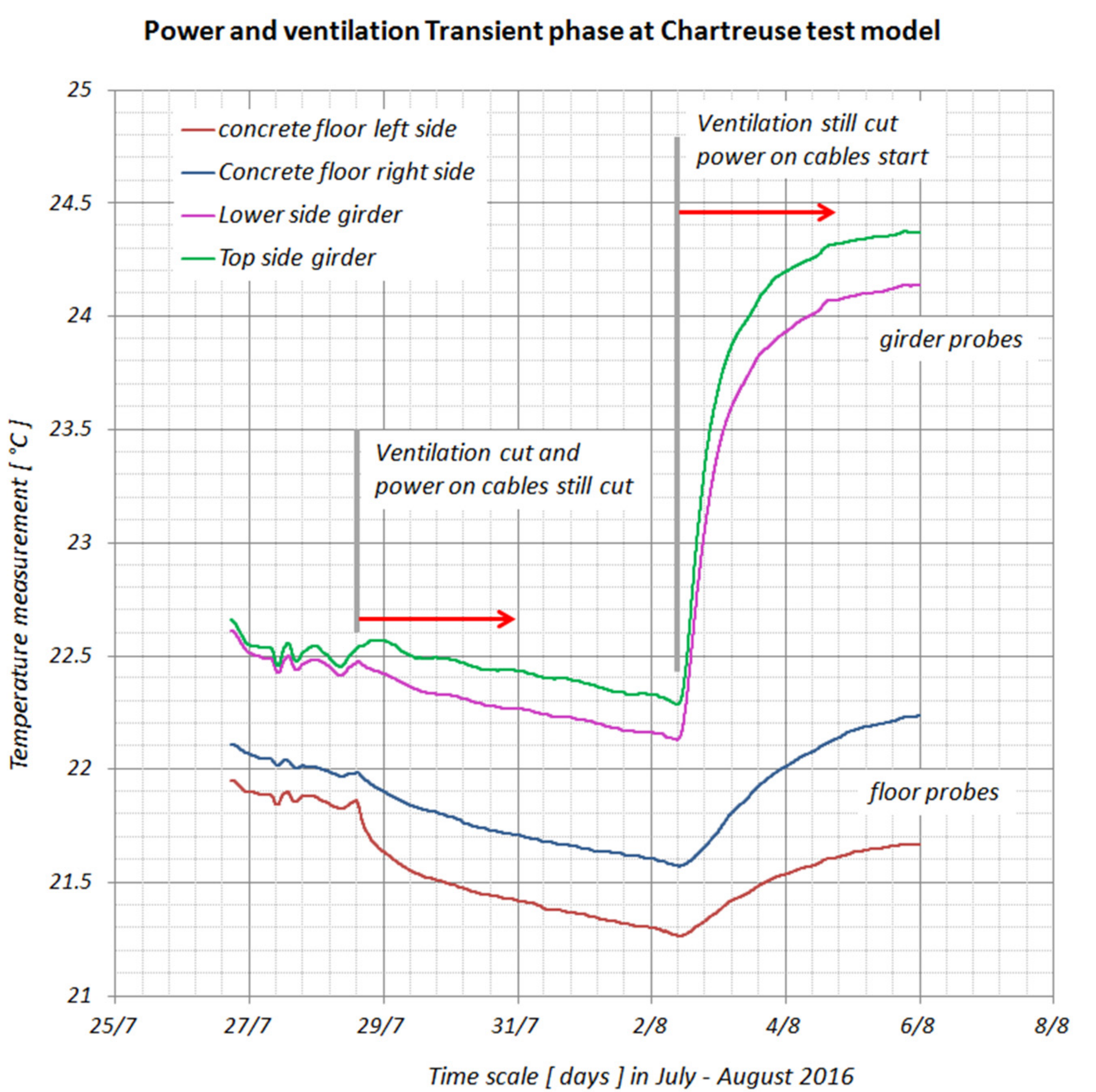
<u>Mock-up</u>:
- probed with several PT100
- girder is isolated by walls and ceiling to reproduce a cell of the storage ring
- fan is integrated

external zone



internal zone

# GIRDER MOCK-UP – TEMPERATURE PROBES



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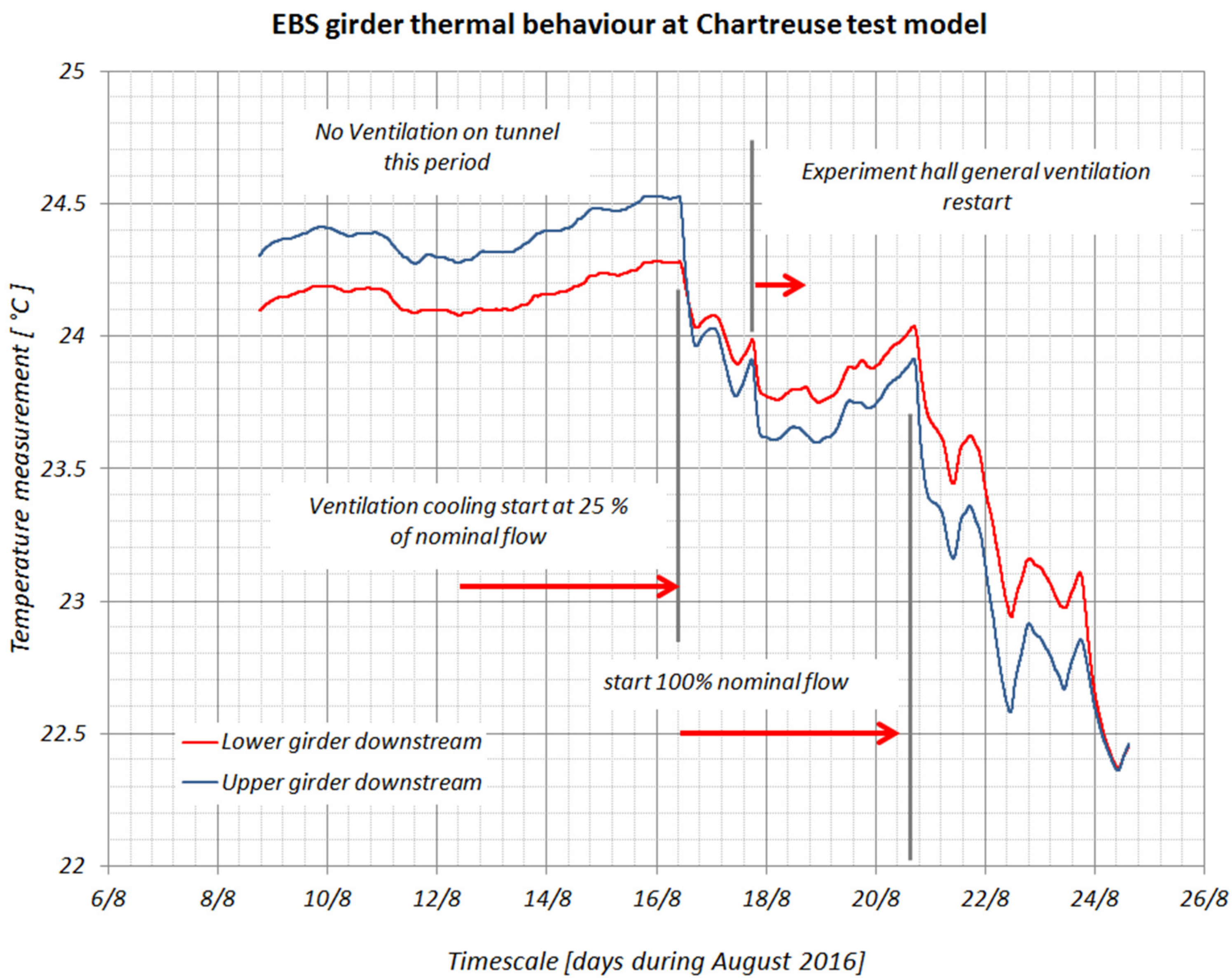

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## THANK YOU FOR YOUR ATTENTION