Design and certification of the chopper disks for the NEAT II TOF spectrometer: A lesson learned

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- New hub design
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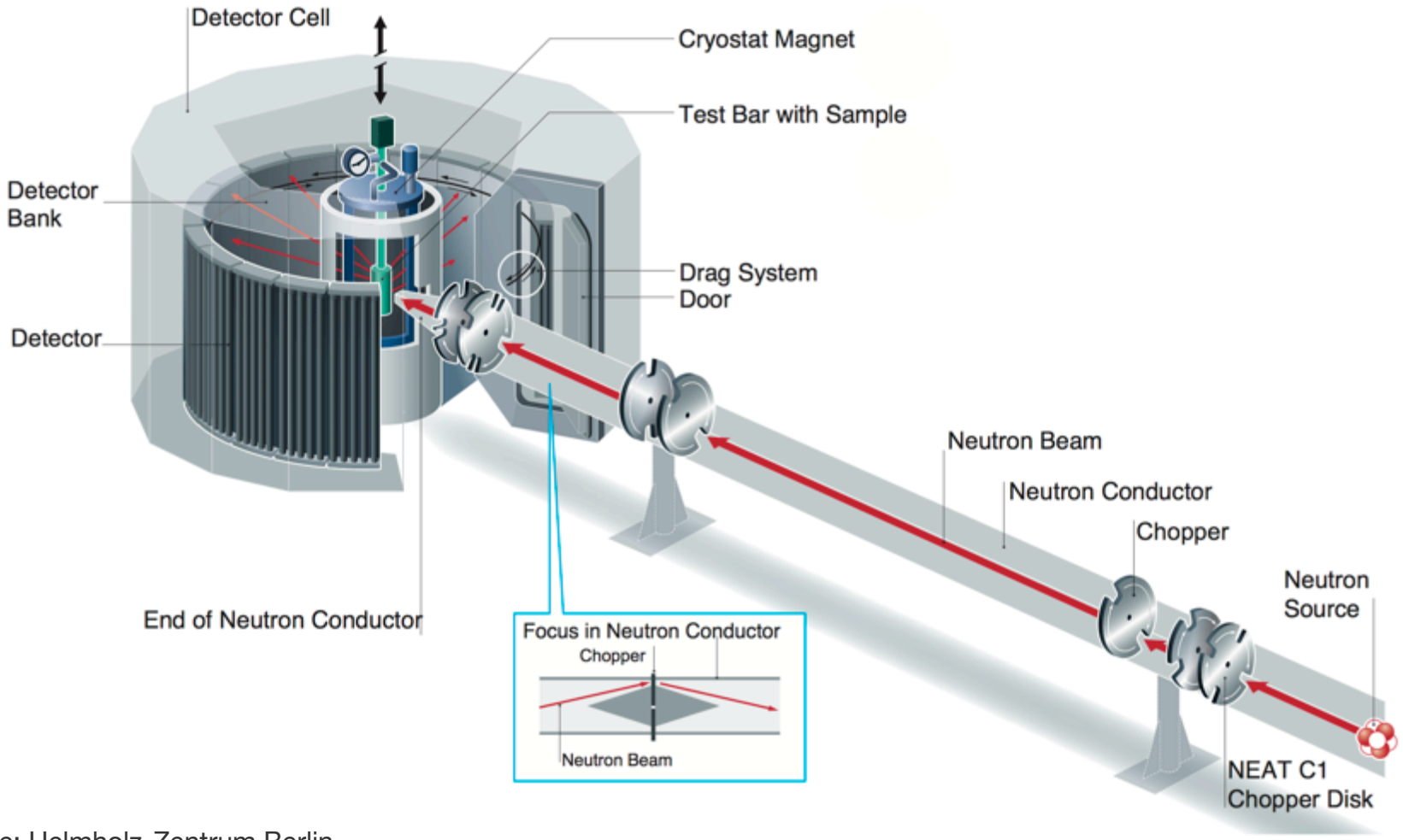
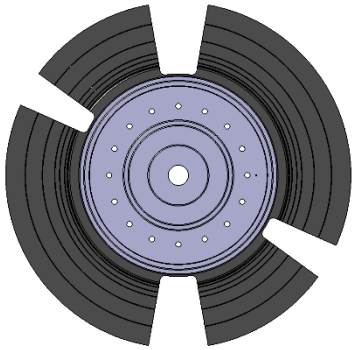
NEAT II Time of flight spectrometer

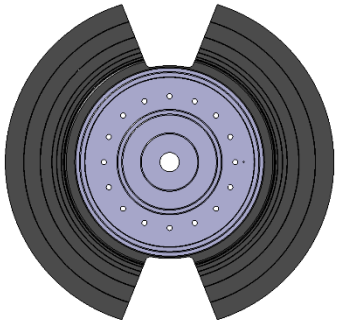


Source: Helmholz-Zentrum Berlin

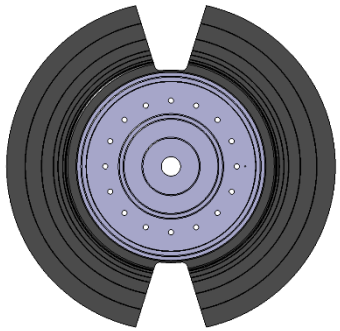
NEAT II chopper disk series: C1 – C7



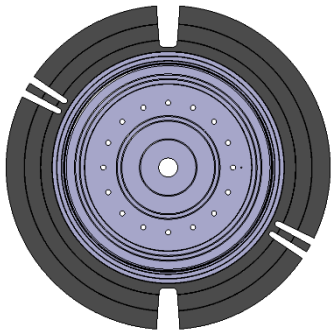
C1 and C2



C3



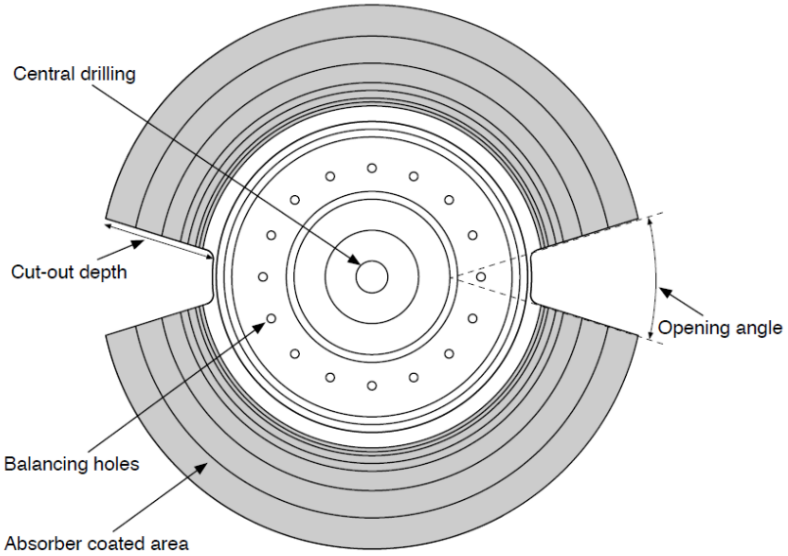
C4 and C5



C6 and C7

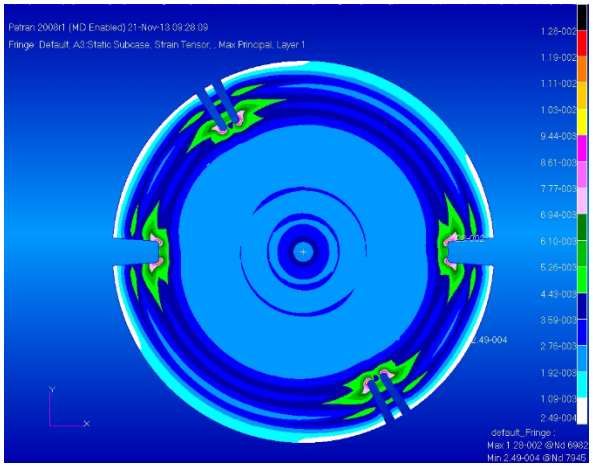
One cross section for all seven disks requires only one mold

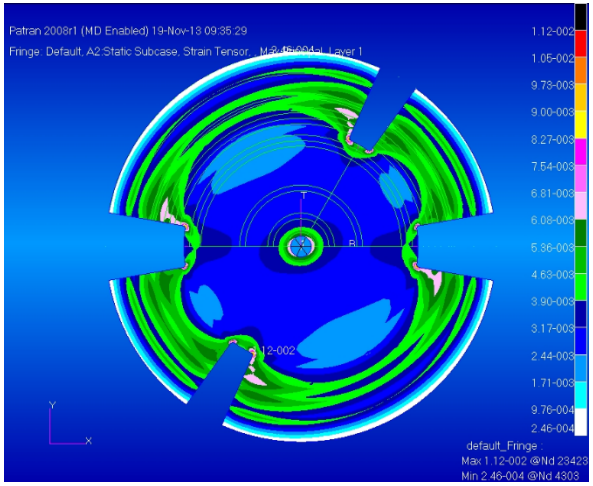
Features of the NEAT II chopper disks



- Diameter: 700 mm
- Cut-out depth: 135 mm
- Operational speed: 20,000 rpm
- Relatively large area with boron coating
- Large opening angle of up to 44°
- Small central drilling
- Unsymmetrical cut-outs (C1/C2)

Design loop


Patran 2008r1 (MD Enabled) 21-Nov-13 09:28:09
Fringe: Default, A3:Static Subcase, Strain Tensor, , Max Principal, Layer 1
default_Fringe :
Max 1.28-002 @Nd 6982
Min 2.49-004 @Nd 7945


Patran 2008r1 (MD Enabled) 19-Nov-13 09:35:29
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default_Fringe :
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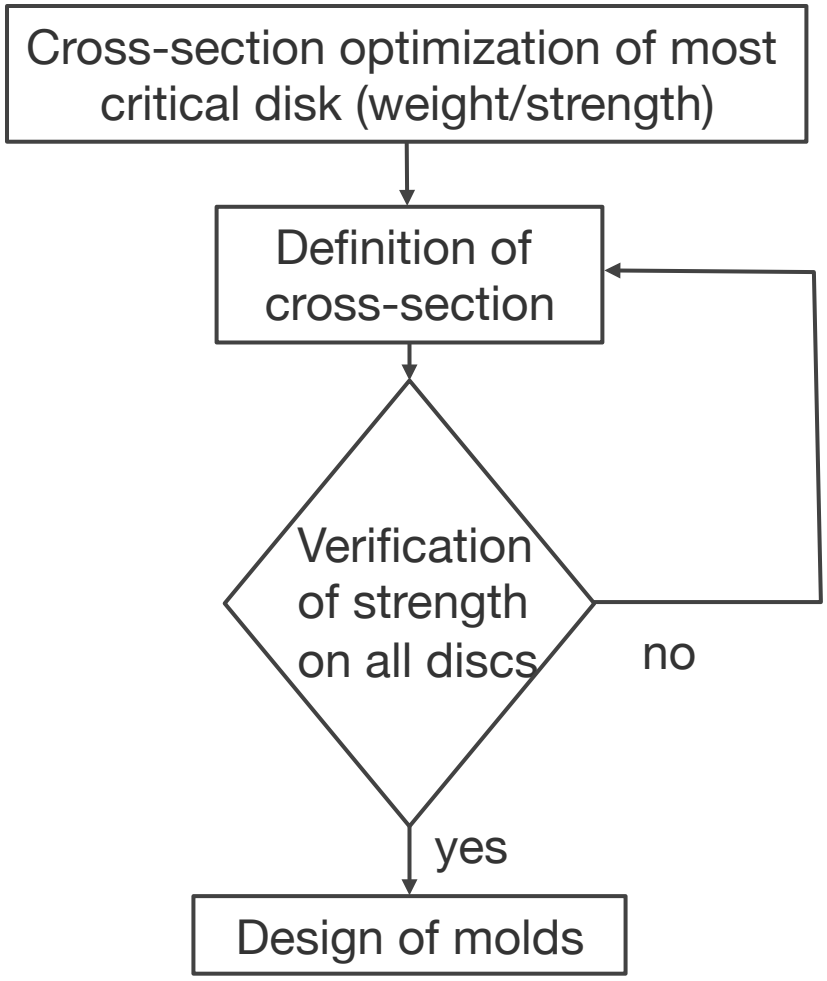
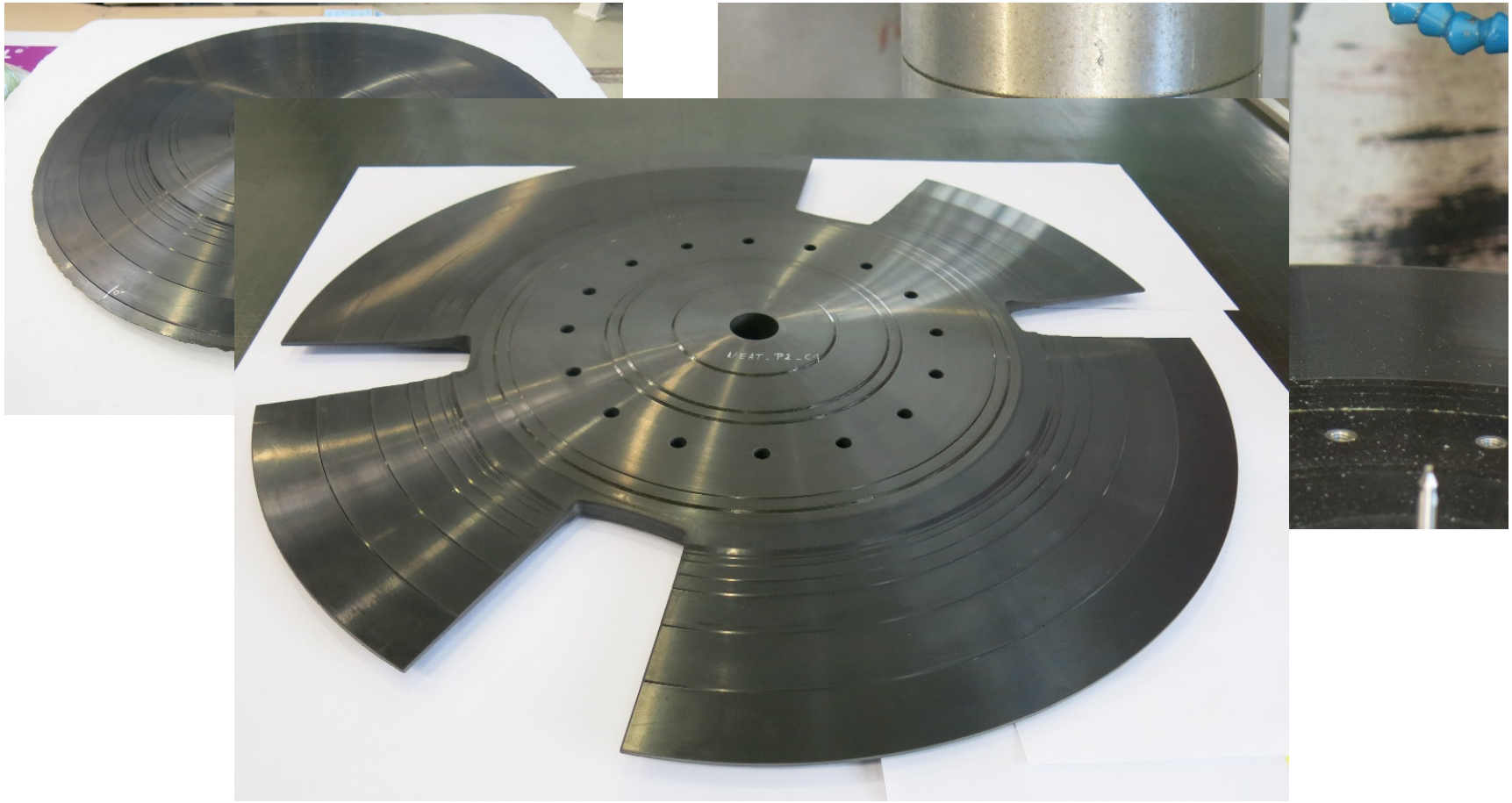
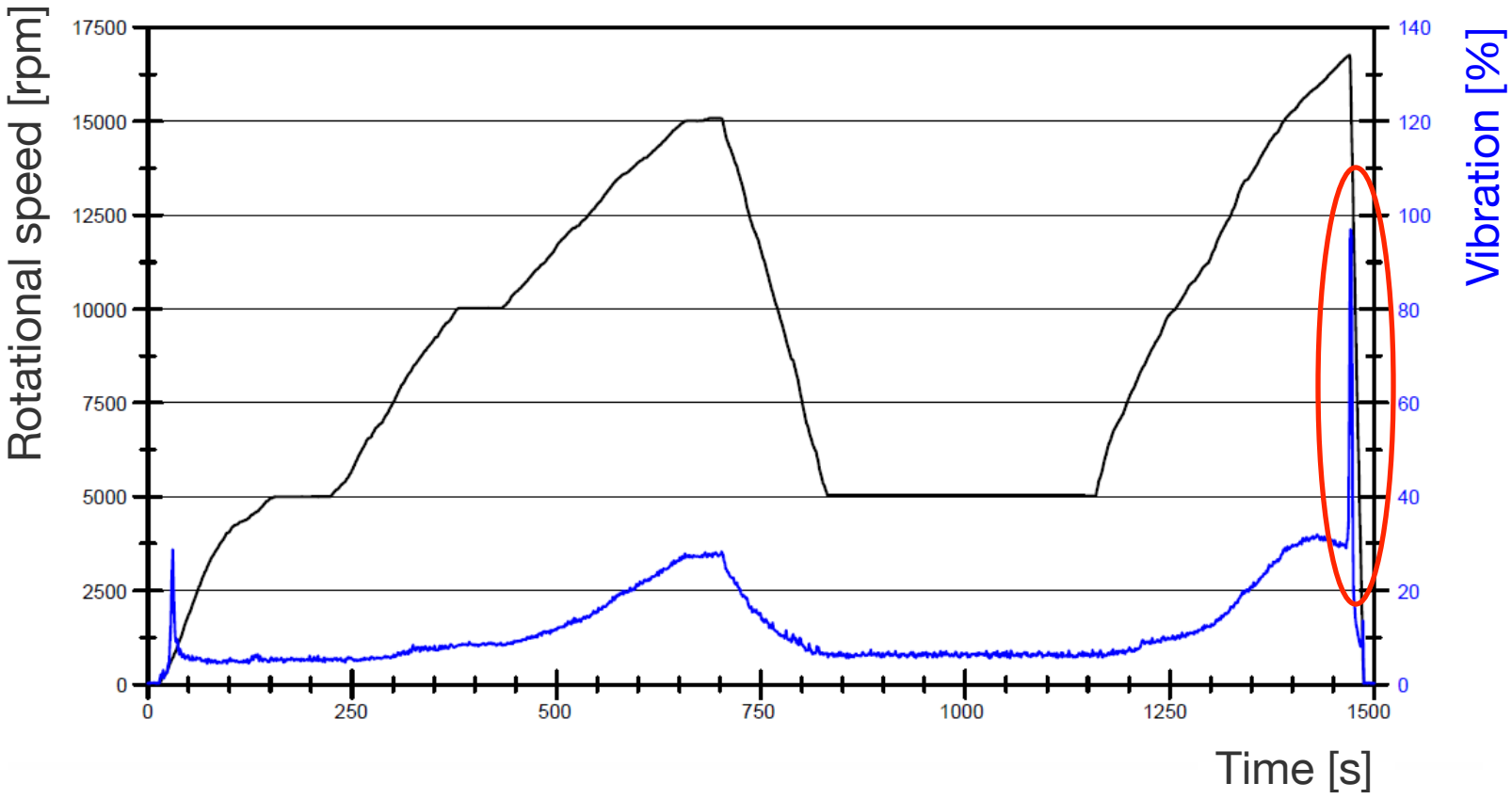
Min 2.46-004 @Nd 4303


Cross-section optimization of most critical disk (weight/strength)
Definition of cross-section
Verification of strength on all discs
no
yes
Design of molds

P1 – First prototype (C1 design)



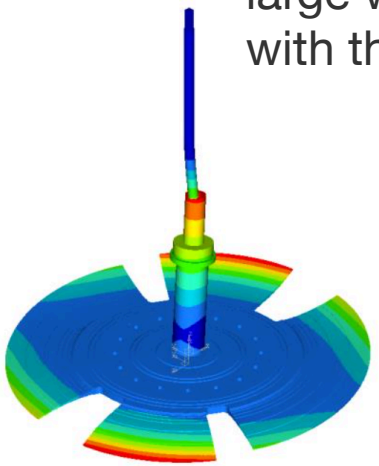
Spin test of P1



Possible causes of vibration peak

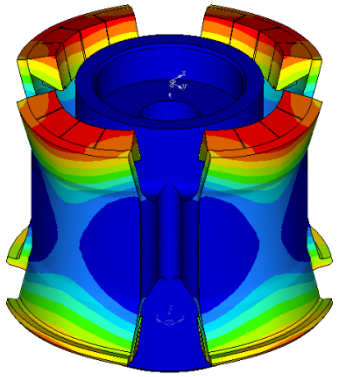
Disk

- Natural frequencies of the disk get triggered by rotational speed
- Coupling effects of the large wings of the disk with the shaft



Hub

- Low bending stiffness
- Detachment from disk
- Low contact pressure



Optimization of thickness distribution

- Blue: Design space
- Gray: Non-design space (boron coating)

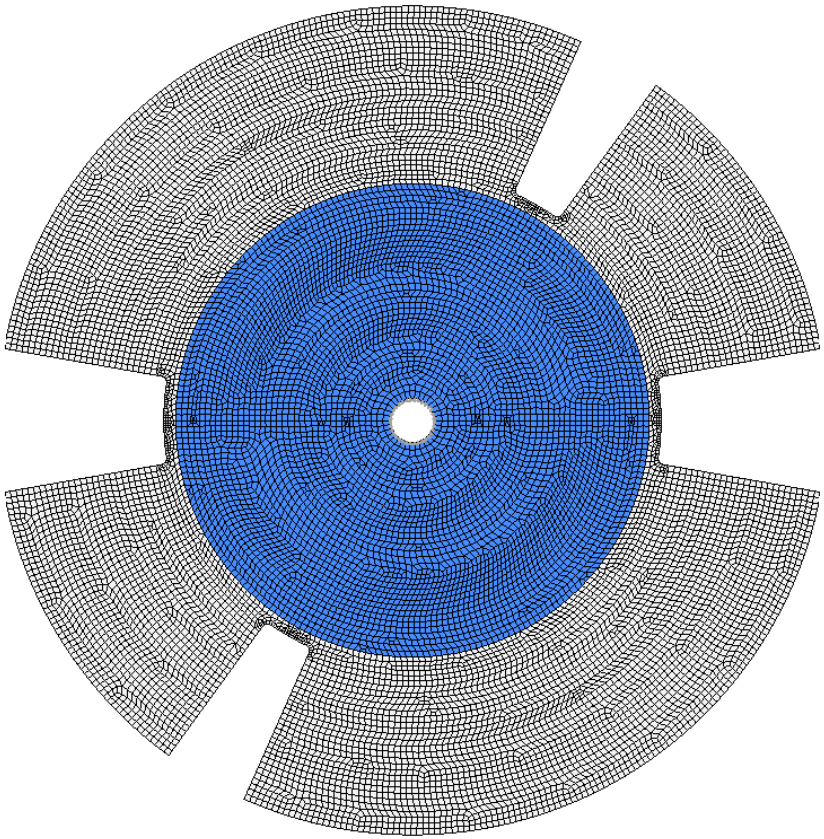
$$\min\{z(H) \,|\, g_1(H) \leq 0 \,|\, g_2(H) \leq 0\}$$

Objective function: $z = -\sum_{i=1}^{3} f_{e_i}(H)$ Natural frequency

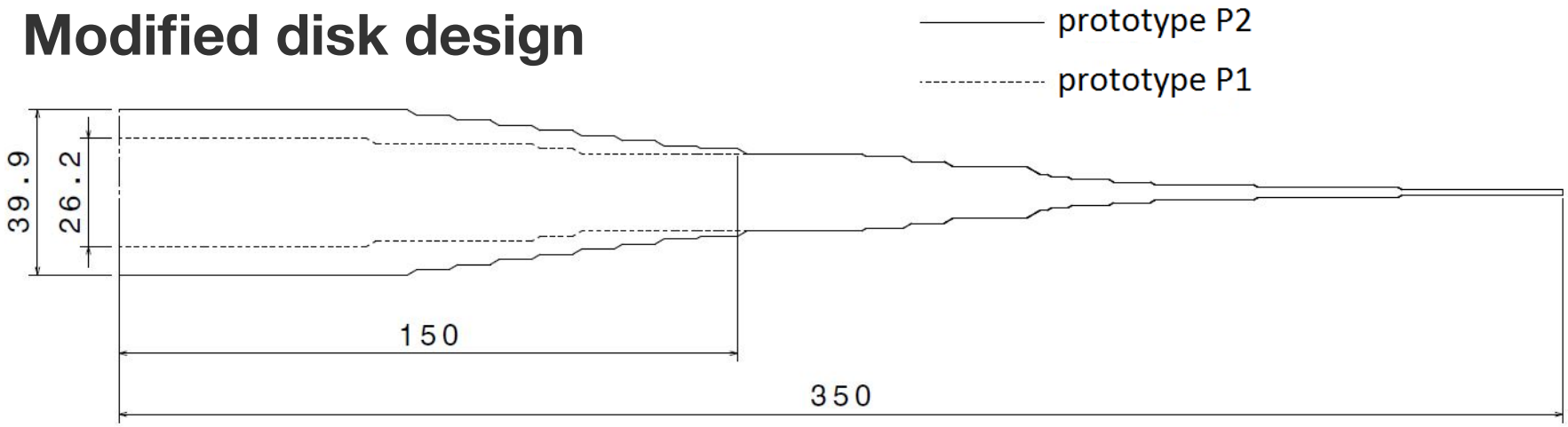
Constraints: $g_1 = \frac{m(H)}{m_{max}} - 1 \leq 0$ Mass

$g_2 = \frac{FI}{0.8} - 1 \leq 0$ Failure index

Design domain: $H \in [1.28; H_{max}]$ Element thickness



Modified disk design



Additional CFRP layers in the central area in order to:

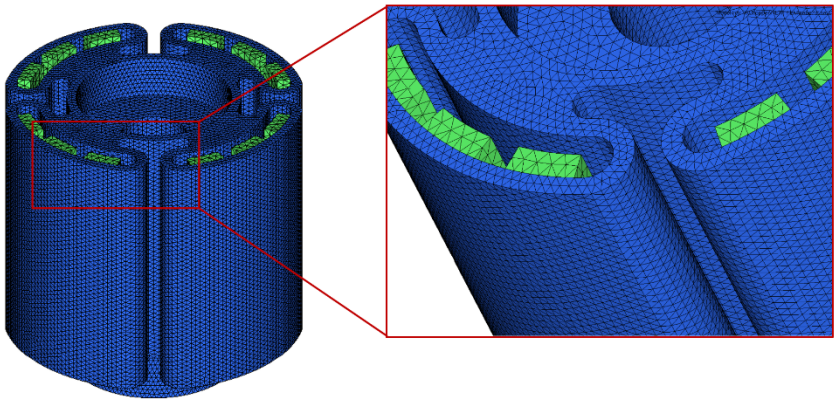
- Stiffen the disk
- Reduce the widening of the central drilling

But:

- 20 % weight increase

New design of a hub with single curved wings

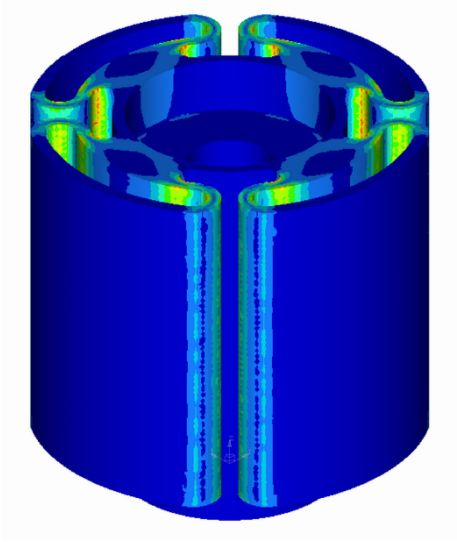
FE model:

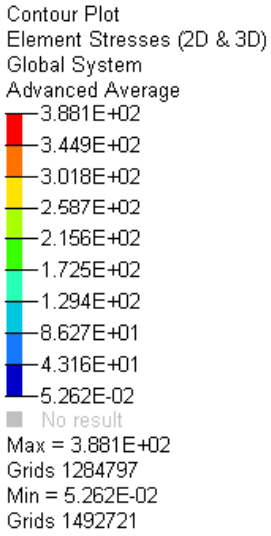


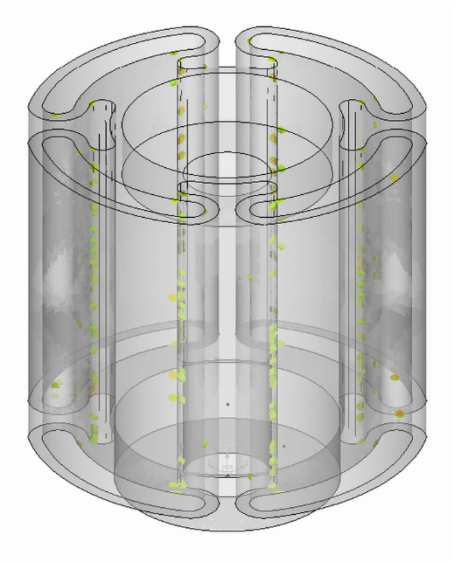
DOF:	1.7 m.
Elements:	CTERTA, Solid 2. order
Constraint:	Inertia relief

Avoiding plastic deformation after cold pressing-in

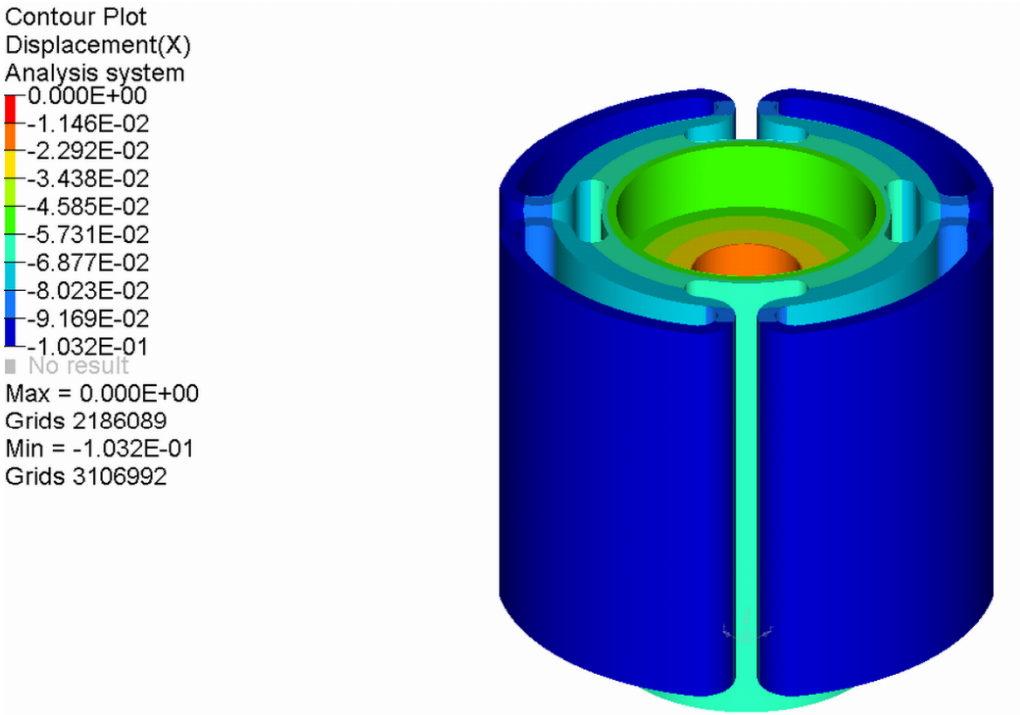
- Stress peaks up to 390 MPa caused by numerical elements (CETETRA)
- Elements with stress > 250 MPa







Oversize of the hub

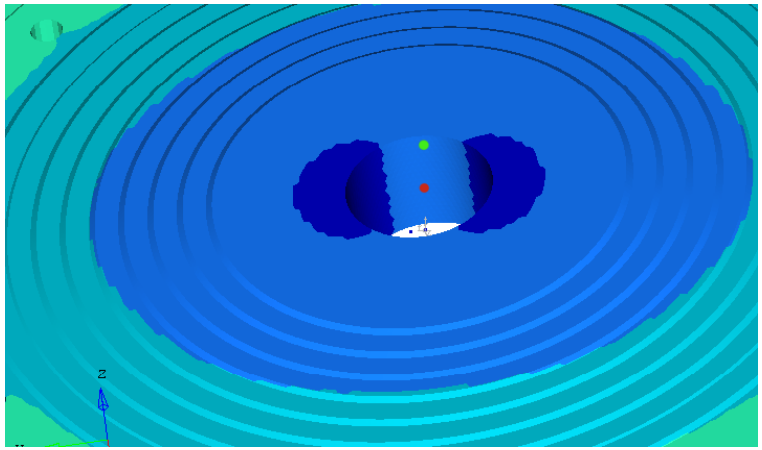


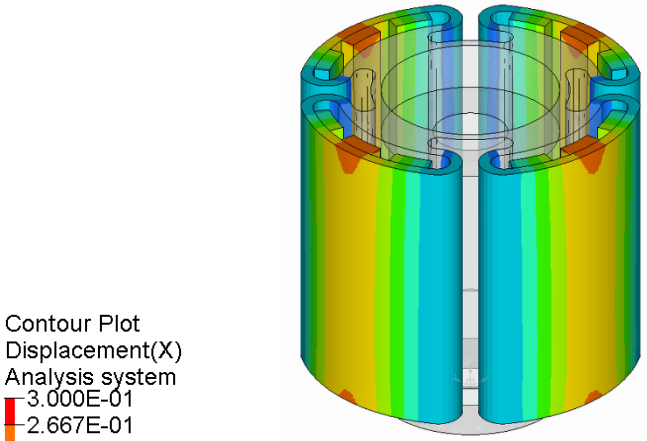
Radial contraction (ΔT = -180 K):
Δr = - 0.1 mm

Ø Drilling disk P2:	**50,07 mm**
Ø Hub at 20 °C:	**50,27 mm**
Ø Hub at -160 °C:	**50,07 mm**

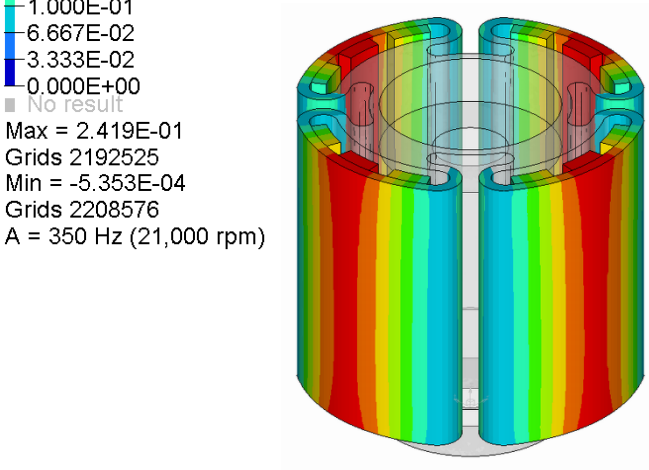
Radial widening during rotation

- Oval widening of the central drilling
- Calculating contact area for operational speed and design speed with respect to the prestrain



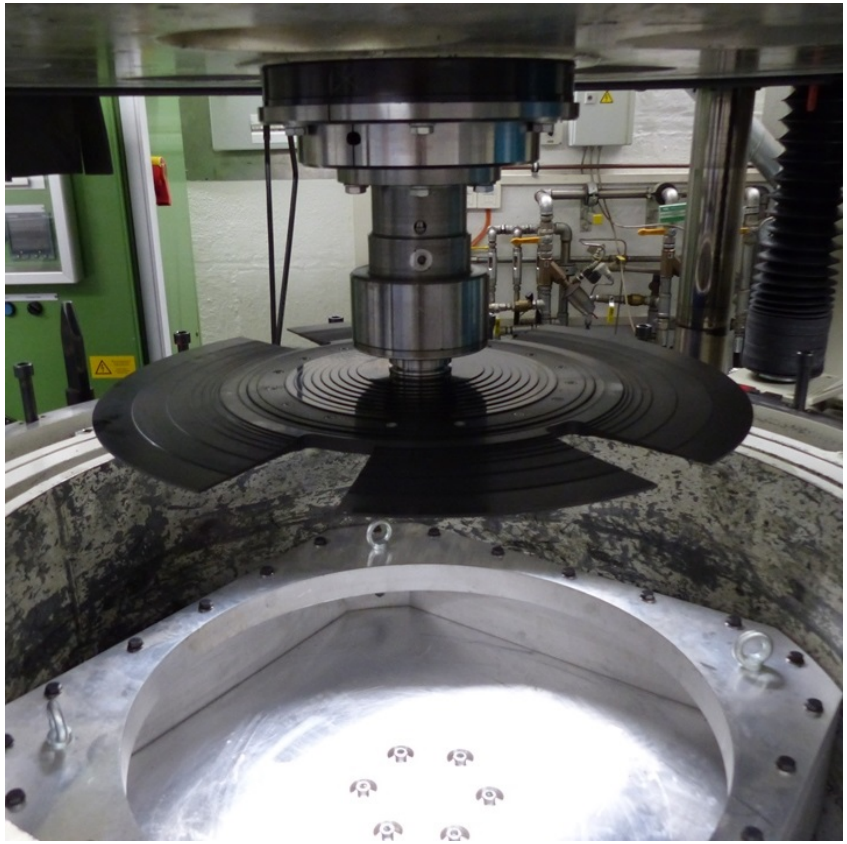


350 Hz (21.000 rpm)



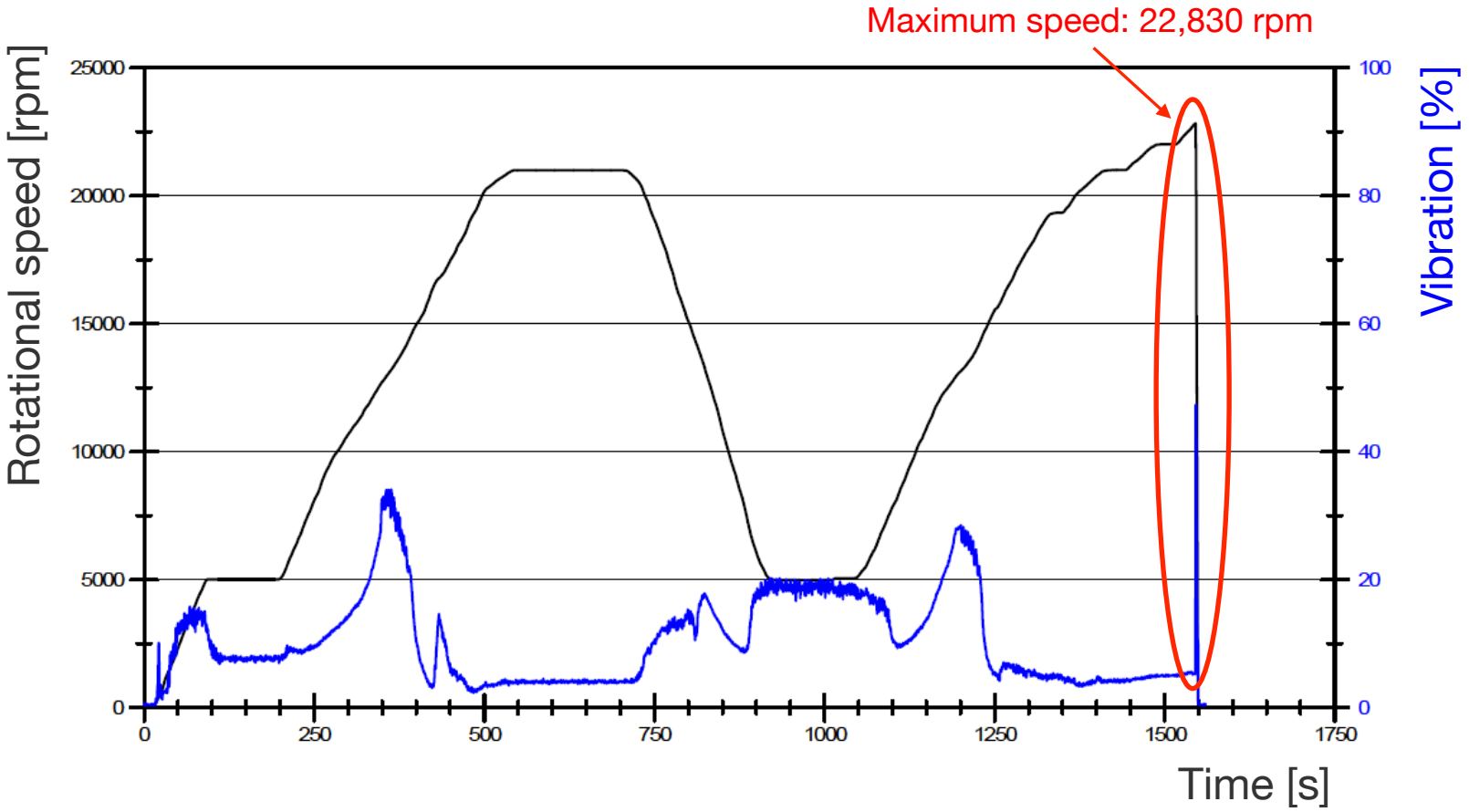
384 Hz (23.000 rpm)

Overspeed test prototype P2 with new hub design



Operational speed:	333 Hz (20,000 rpm)
Certification speed:	350 Hz (21,000 rpm)
Design speed:	380 Hz (22,800 rpm)

Overspeed test of P2



P2 after overspeed test

Conclusions

- Chopper disk series NEAT II is “non-standard”
  - Large diameter
  - Deep windows
  - Unsymmetrical geometry
  - High rotational speed
- Many small problems added up and delayed the project
- New hub system is developed with high bending stiffness and low radial stiffness

Thank you for your attention

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