CFRP chopper discs: state of the art and long term perspective

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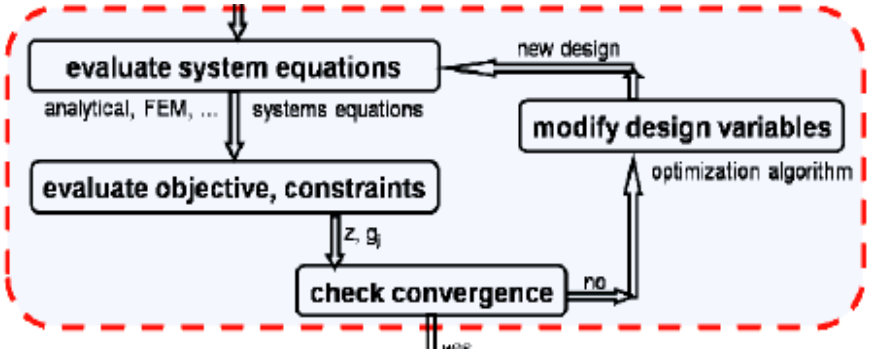
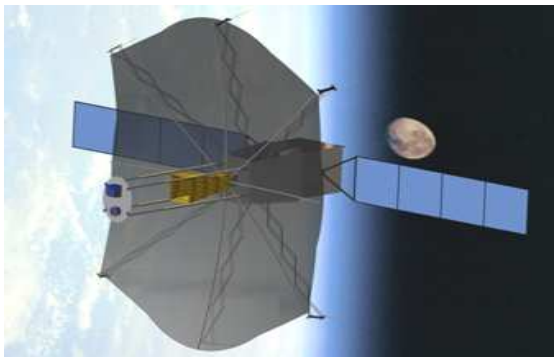
Research areas at LLB / TU München

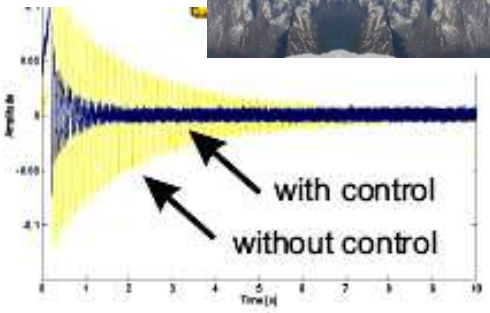
Multidisc. Structural Optimization



Large membrane structures



Smart Structures



Dyn. load allev.

Fiber composites / hybrid mat. structures

Infrastructure LLB

Computer cluster

- **CAD, FEM, Design Optimization**
- **Materials, thermo-mechanics**
- **Aeroelasticity**
- **Dynamic Systems (Matlab/Simlulink)**

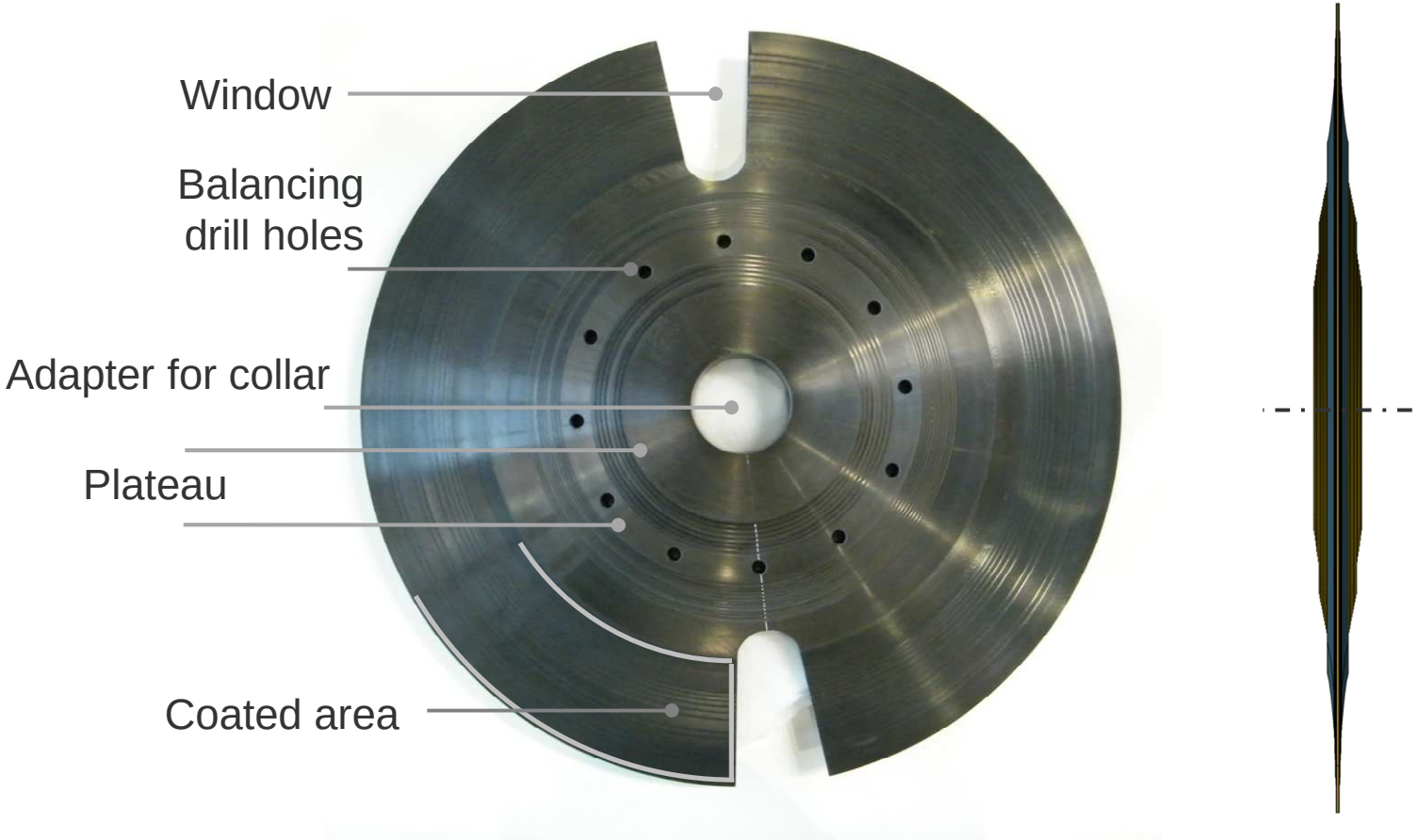
Lab for large scale testing

- **metal & fiber composite workshop**
- **extensive test and measurement techniques (incl. high precision)**
- **mech. + (extreme) environmental loads**
- **NDI methods**
- **Data processing tools**

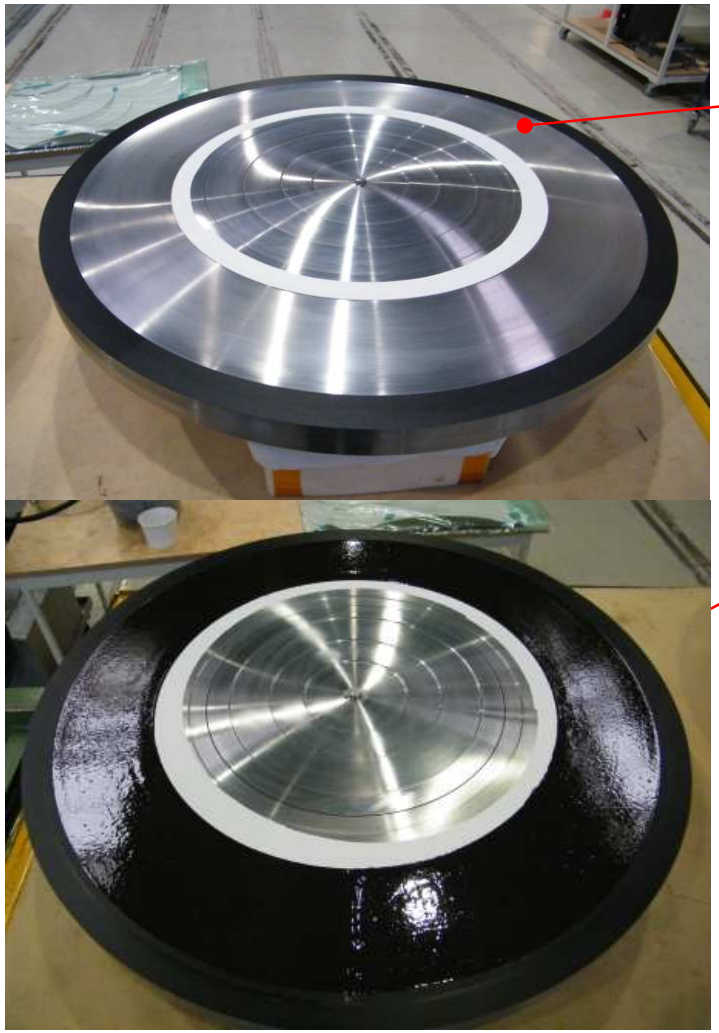
Work at LLB on Chopper discs

- Long experience in design and manufacturing CFRP chopper discs
- Production of (up to) 20 CFRP chopper discs /year
- Diameter up to 750 mm
- Operational speed (up to) 22000 rpm
- Ultimate speed 28000 rpm (destructive testing)
- Various types of windows

CFRP Chopper disc (TOF-TOF at FRM II)



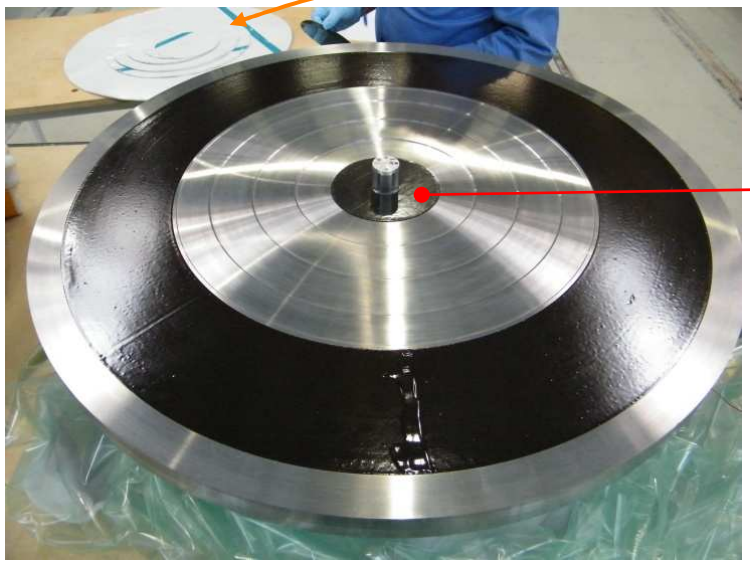
Manufacturing



Two symmetric steel moulds

Boron coating

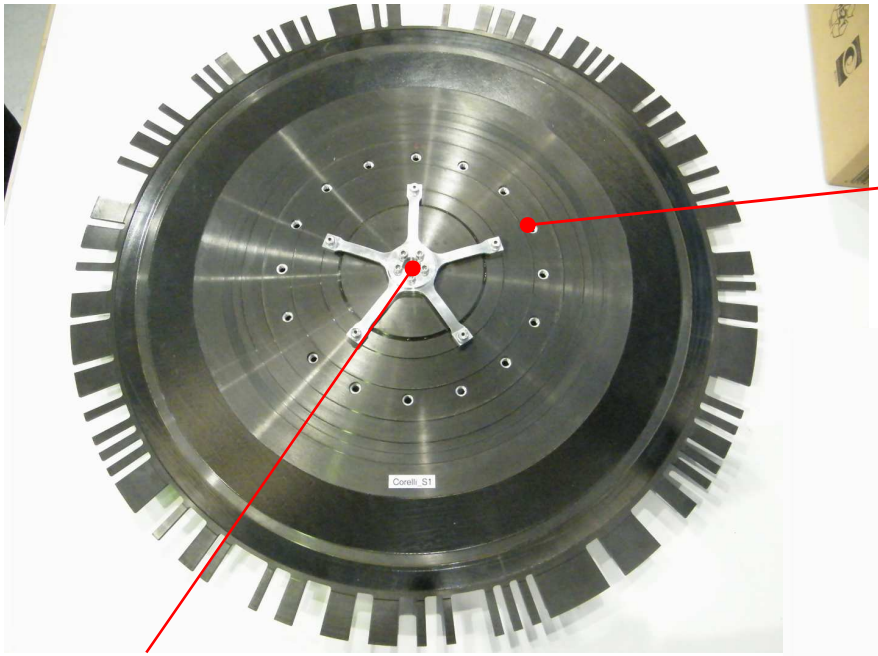
Manufacturing cont.



First pre-preg layer

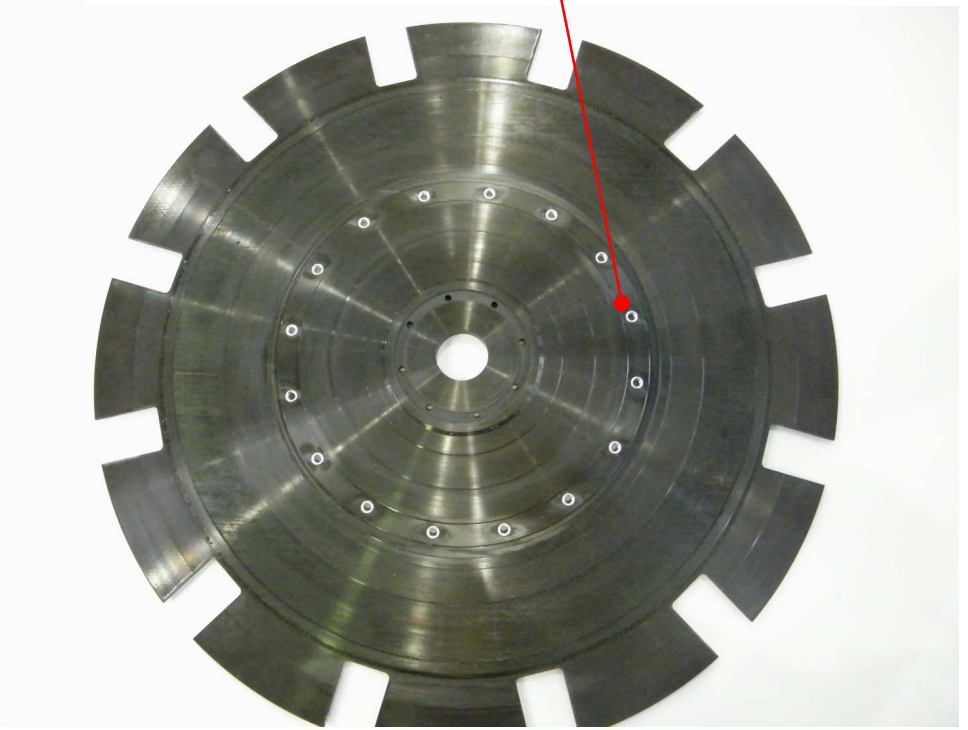
Ready for trimming

Small cut-outs

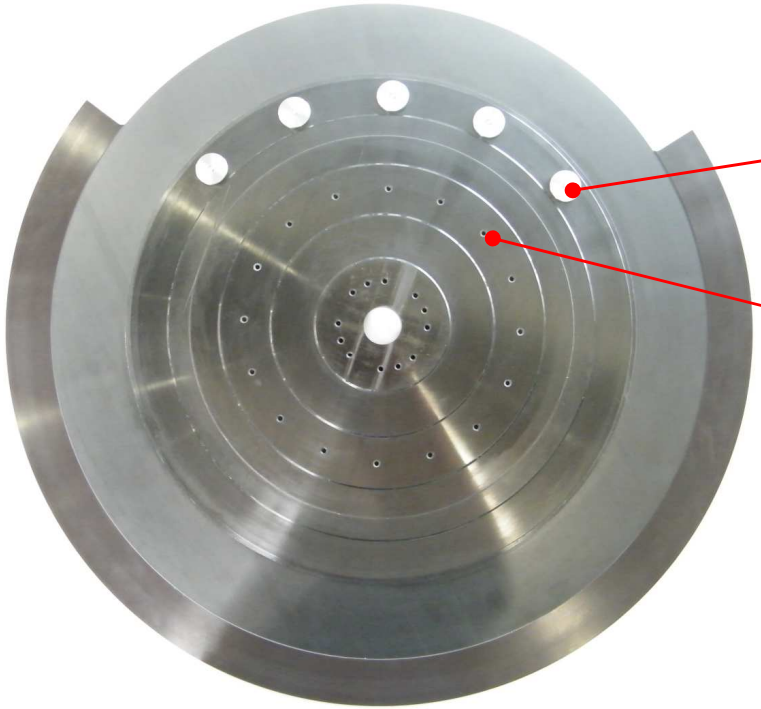


Hub

Balancing weights



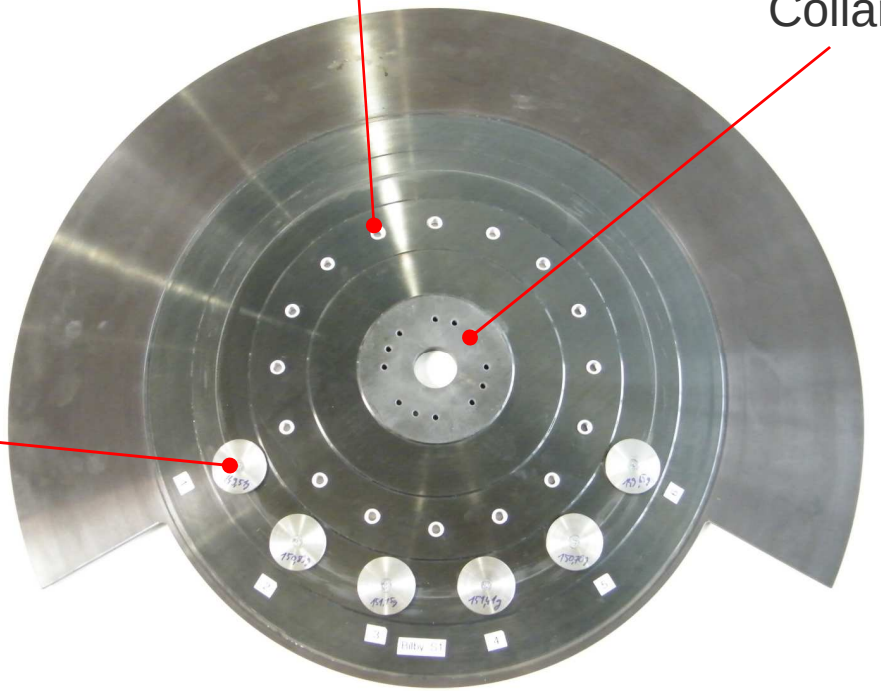
Asymmetric window



Steel weights to compensate for the missing mass of the window

Holes for balancing weights

Collar



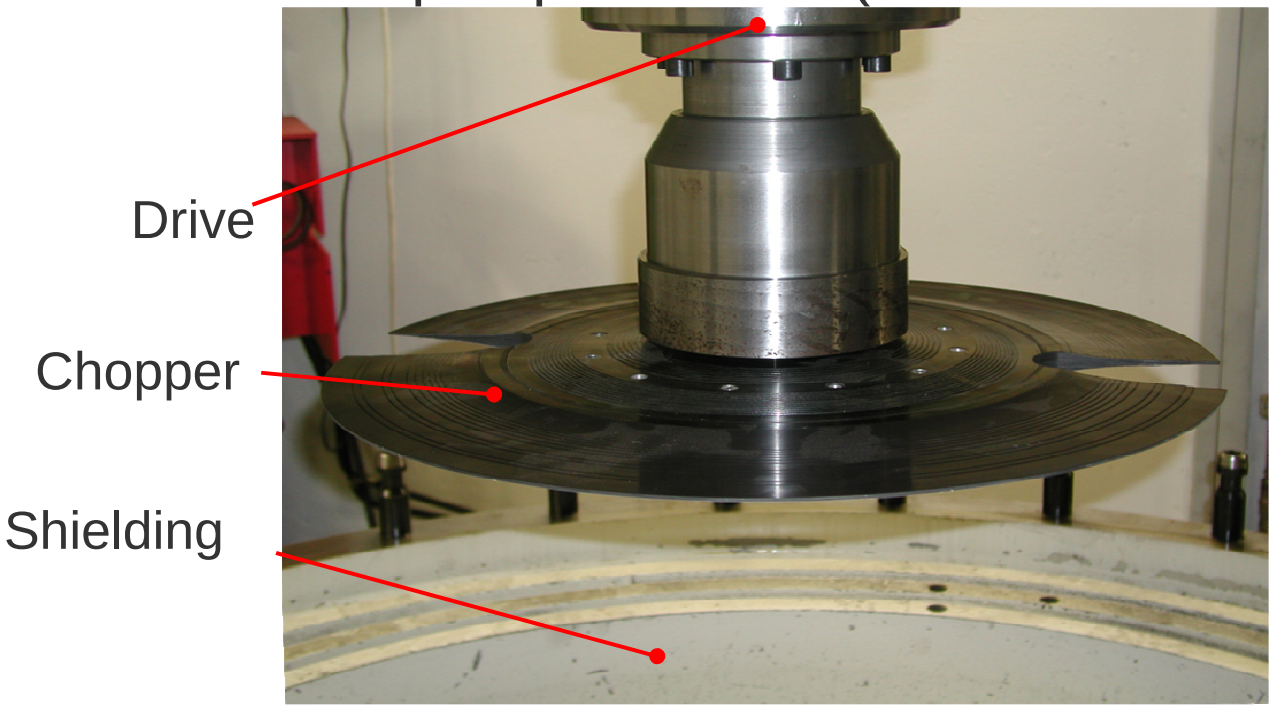
High density (17 g/cm^3) weights to compensate for the window

Basic design requirements

- Operational speed
- Outer diameter
- Number and dimension of the window(s)
- Hub diameter
- Maximum weight
- Design is often based on strength (→no stiffness requirement) unless restriction in minimal first eigenfrequency

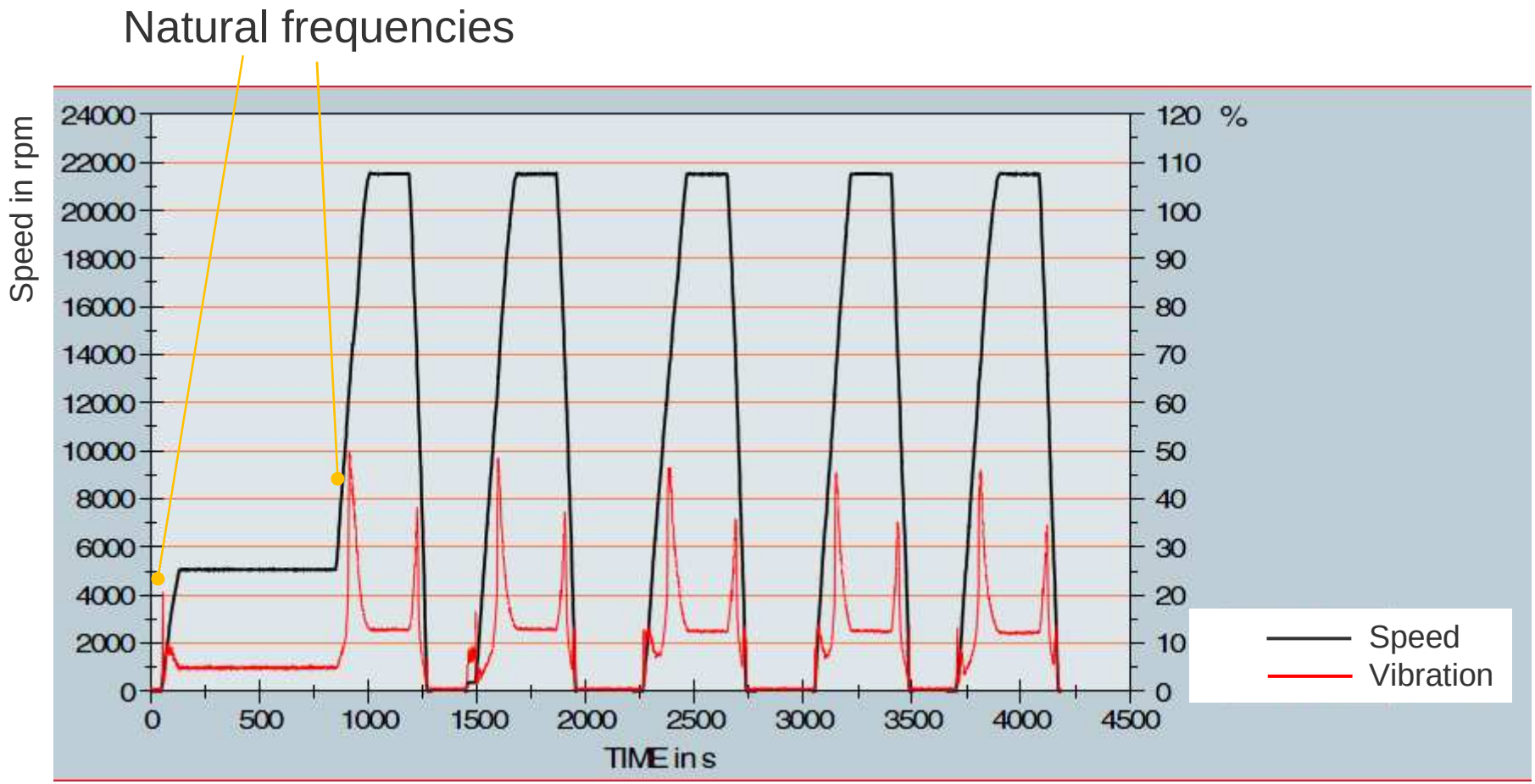
Qualification test

- Test in vacuum chamber
- Accelerometer on axle to measure vibrations
- Test speed increased in steps up to failure (destructive test)

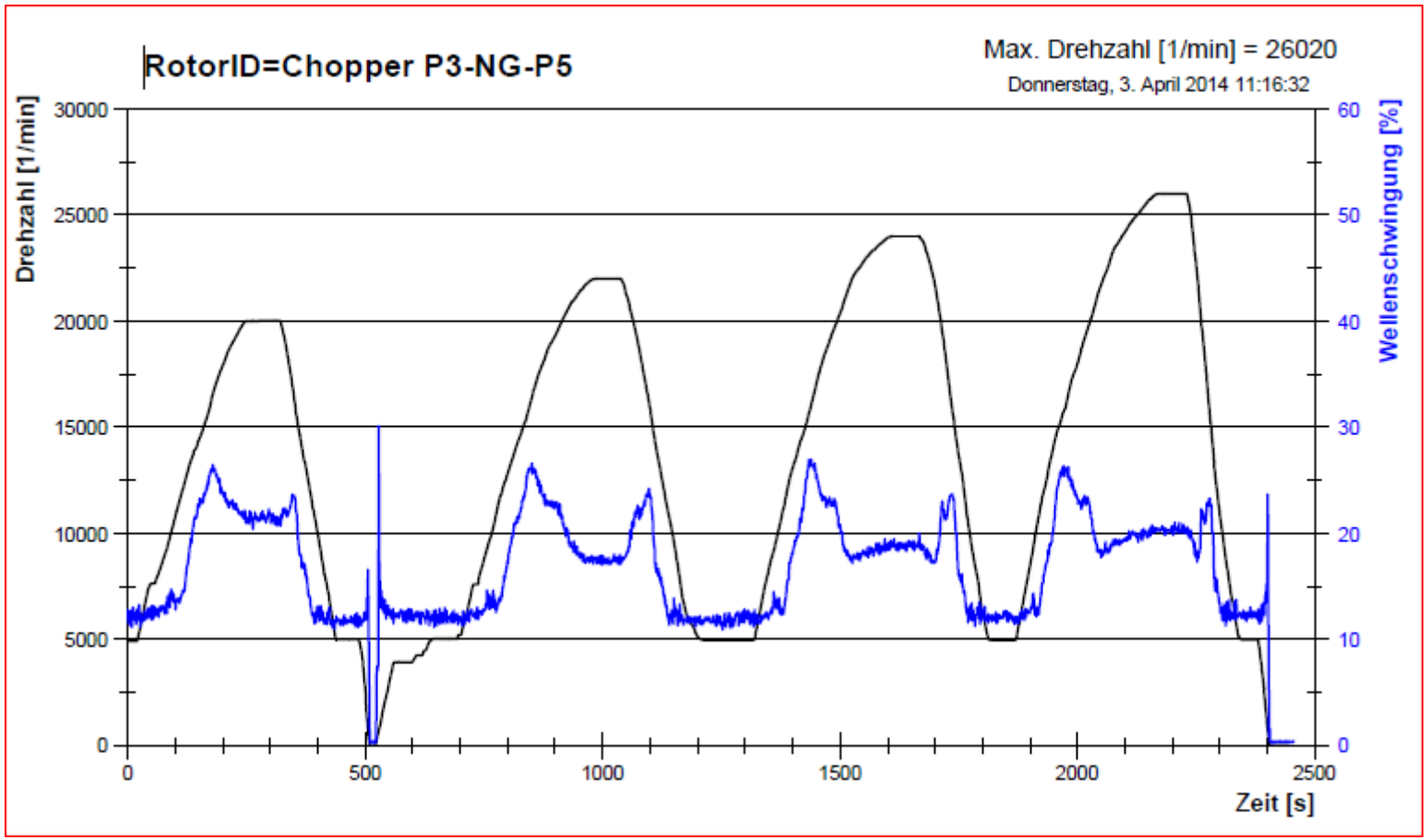


Test set-up at MTU

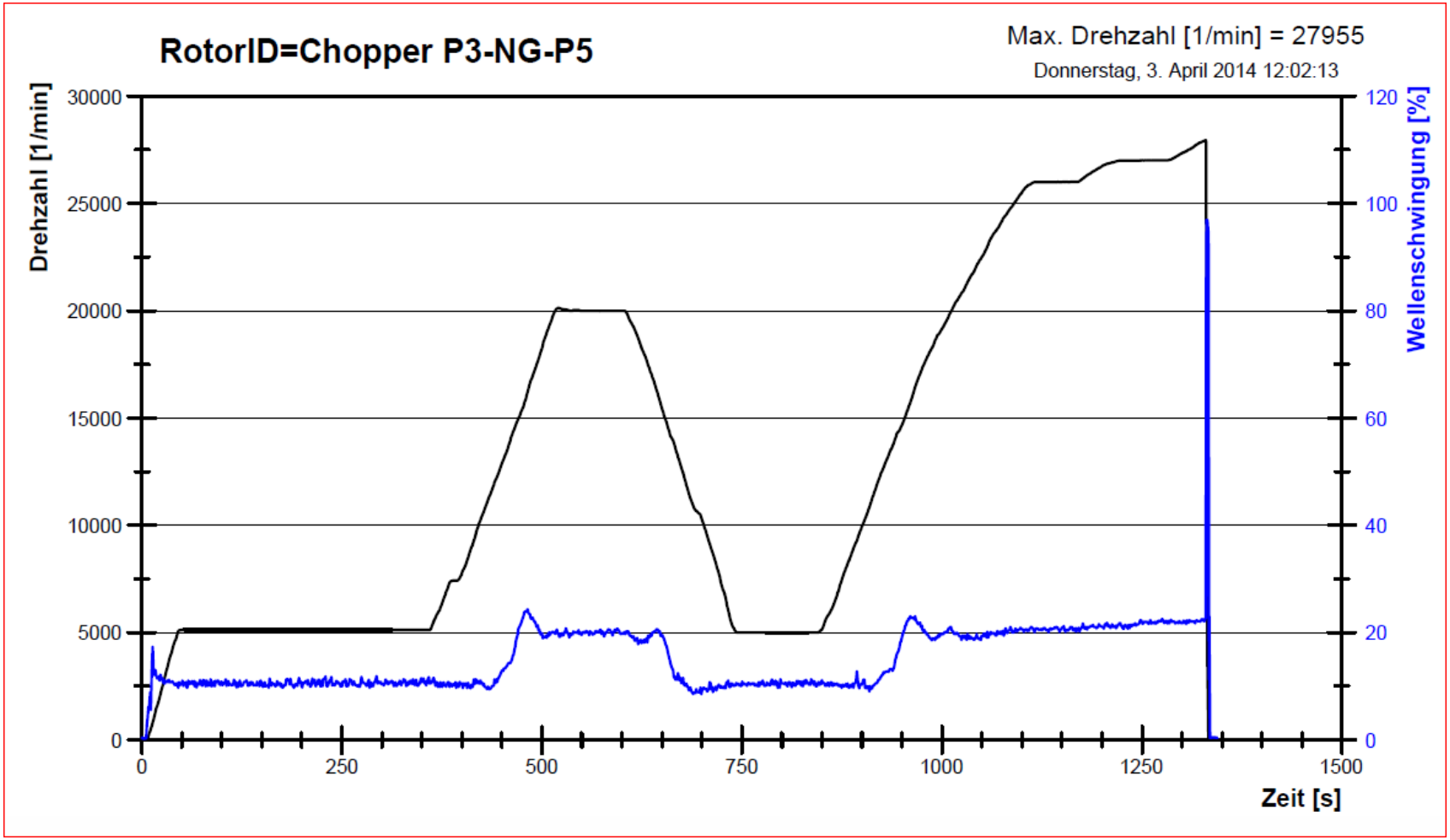
Qualification test



Ultimate speed test (first part)



Ultimate speed test (second part)

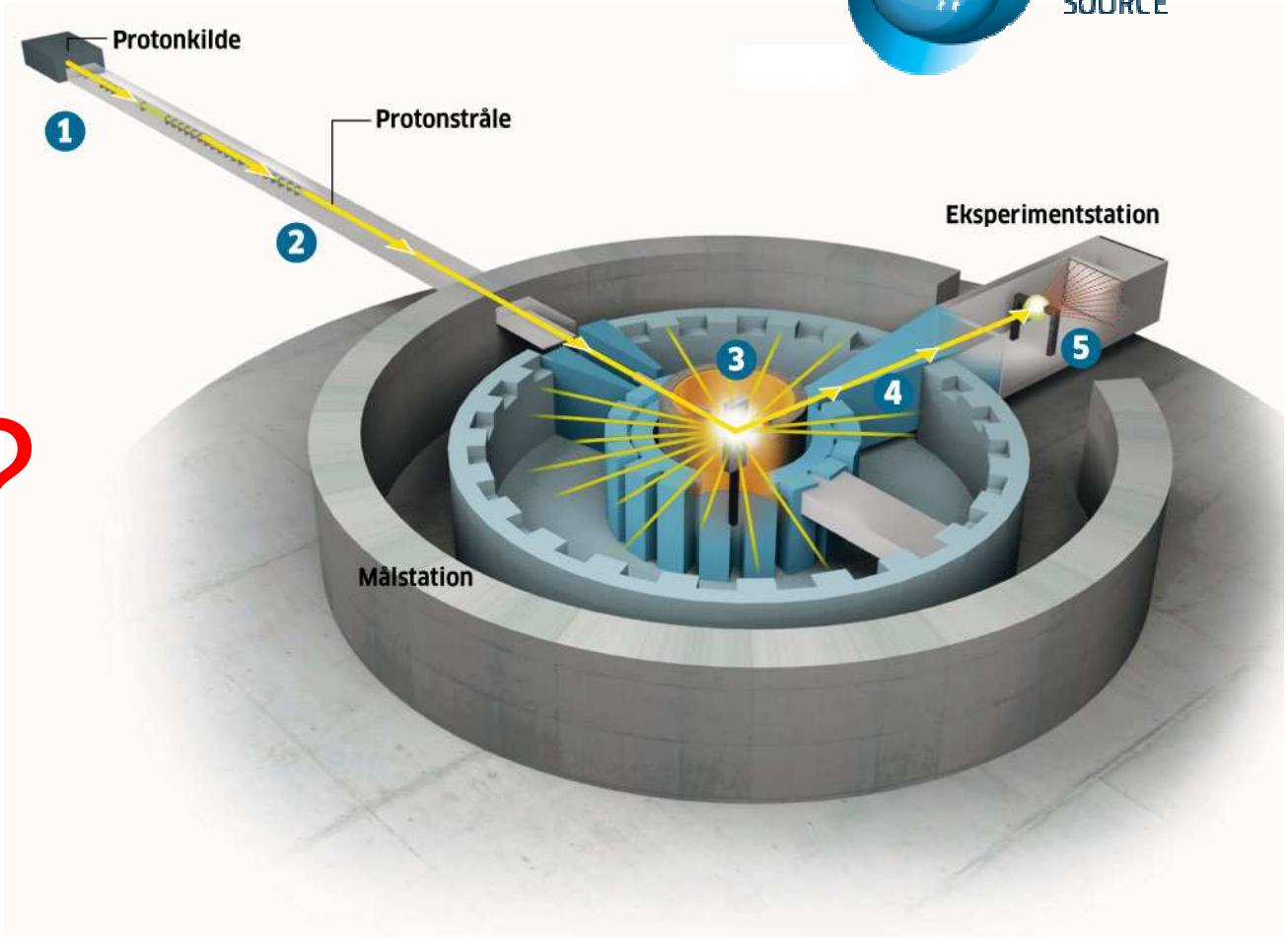


Motivation

EUROPEAN SPALLATION SOURCE

Large
Fast
Slow
Light
Stable
Small windows
Large windows

?!?



Parameter Study

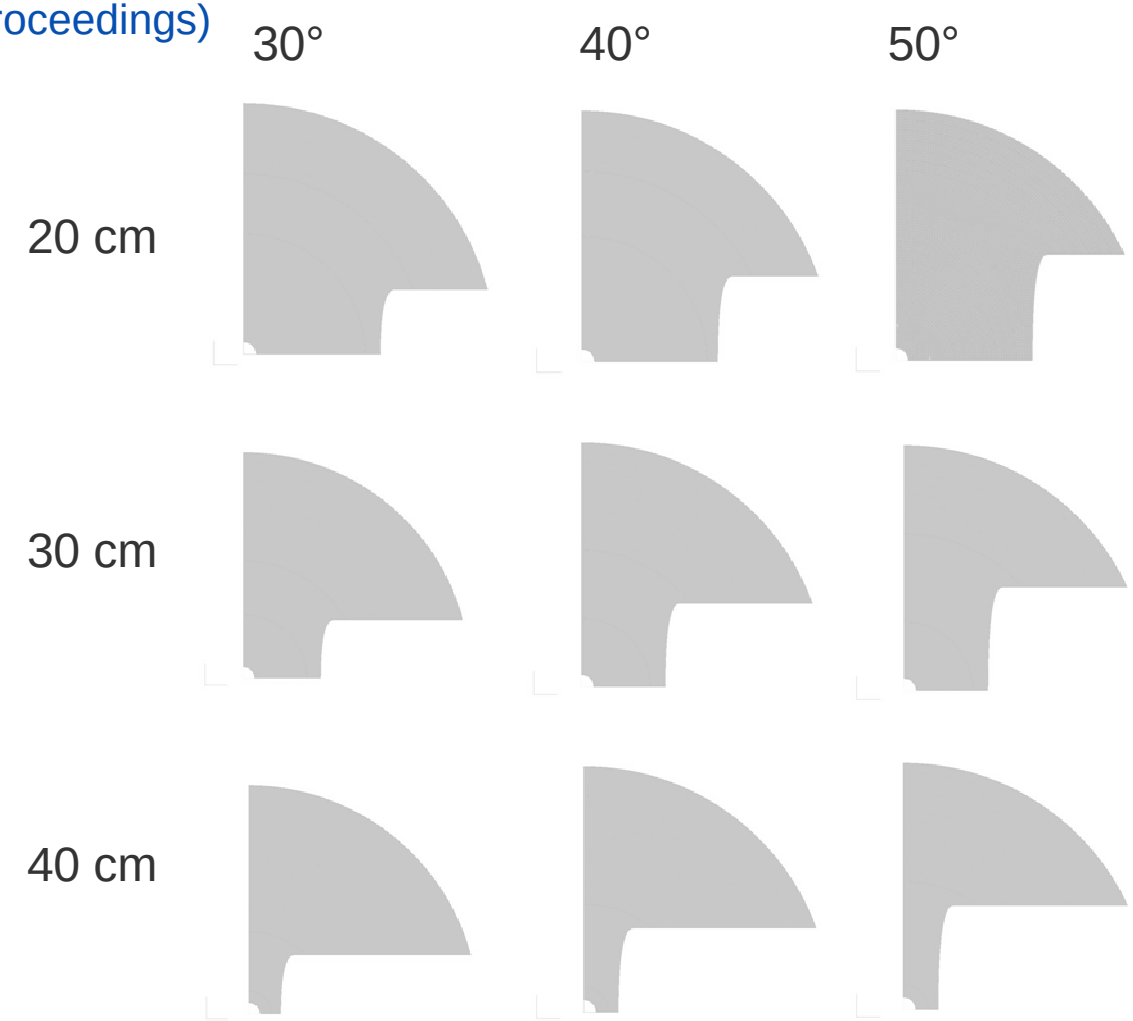
(FRM-II - published in ICCM 19 proceedings)

Outer diameter: 1 m
Inner diameter: 50 mm

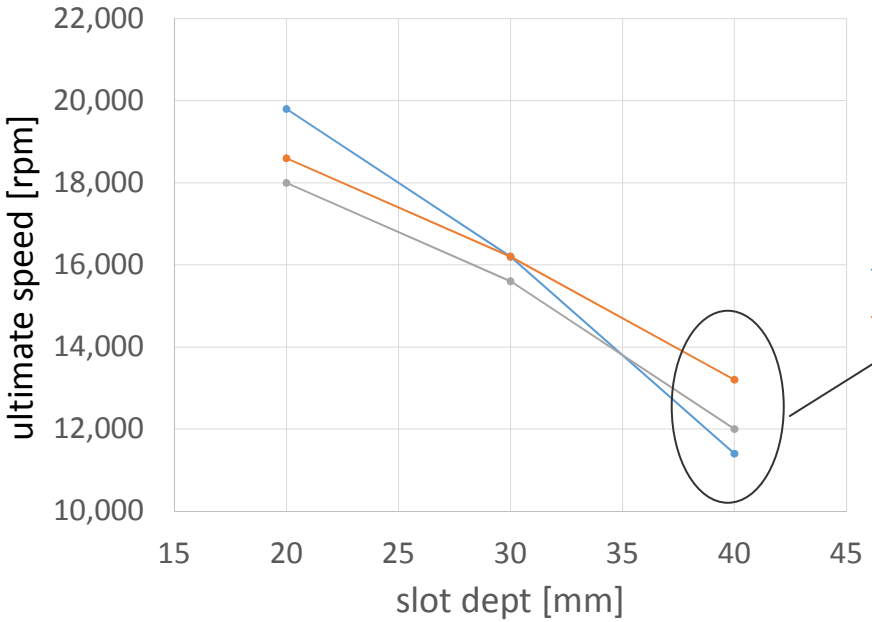
Max weight: 10 kg

2 symmetrical windows

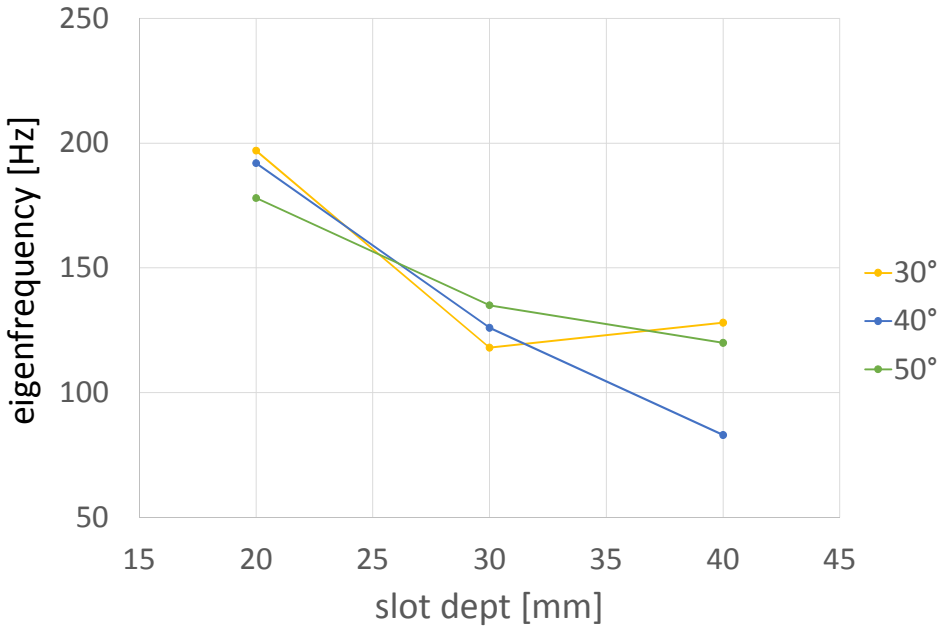
Material M30SC
(medium stiffness –
high strength carbon fibre
and epoxy resin)



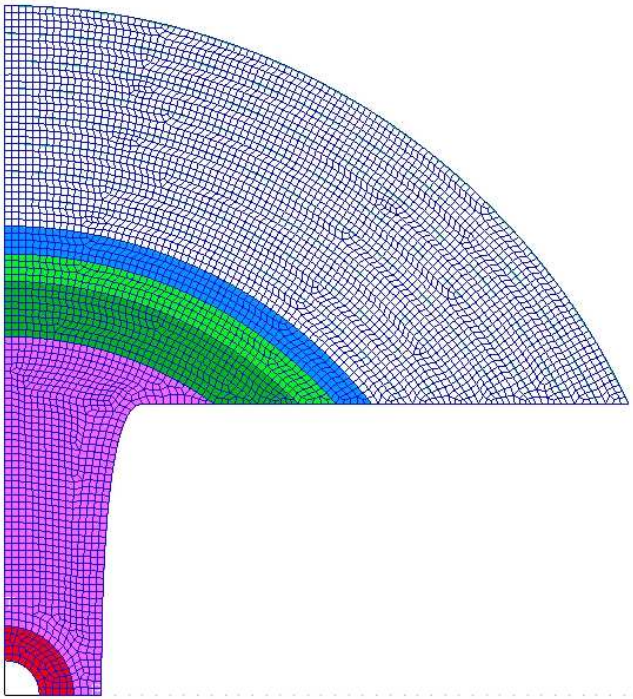
Results: strength and stiffness

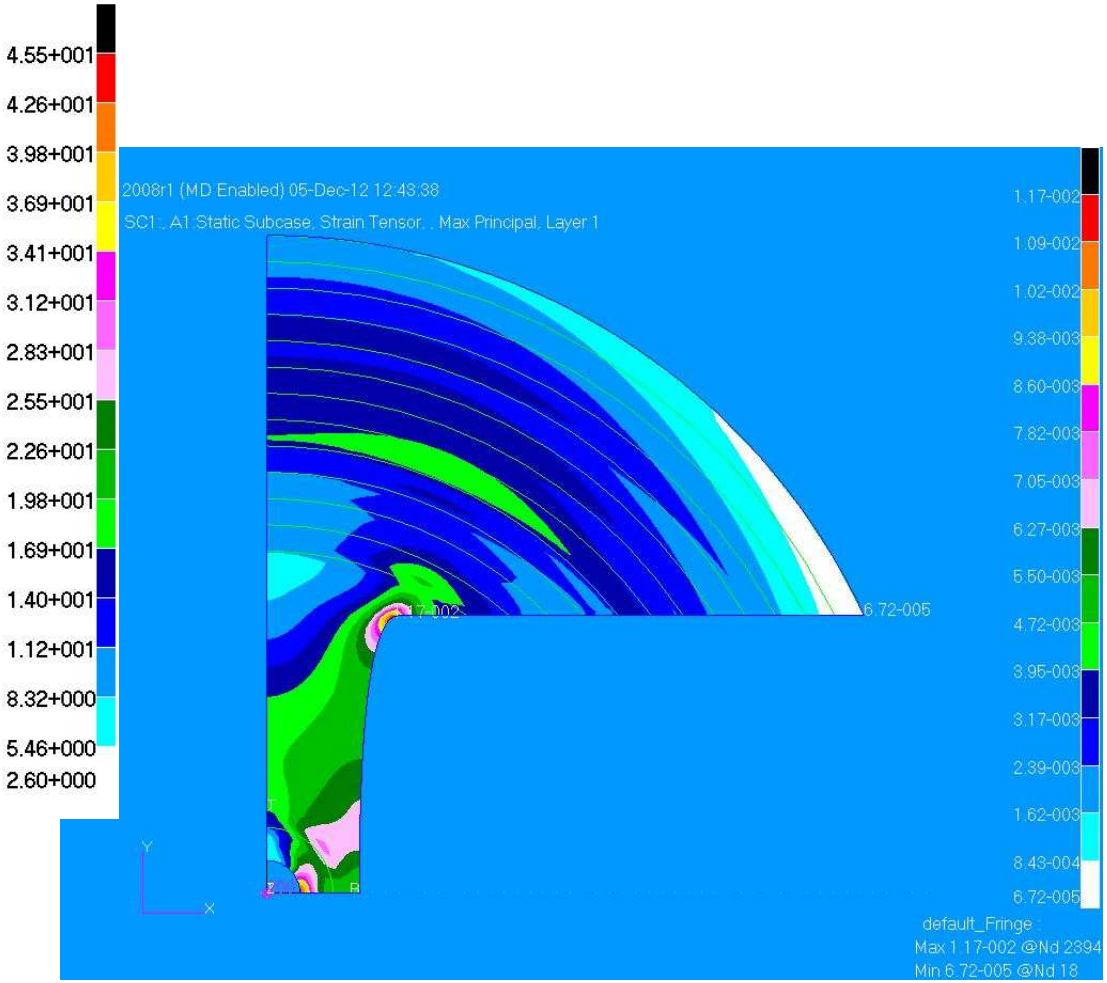


The windows with larger opening angle are lighter



Results: manufacturability

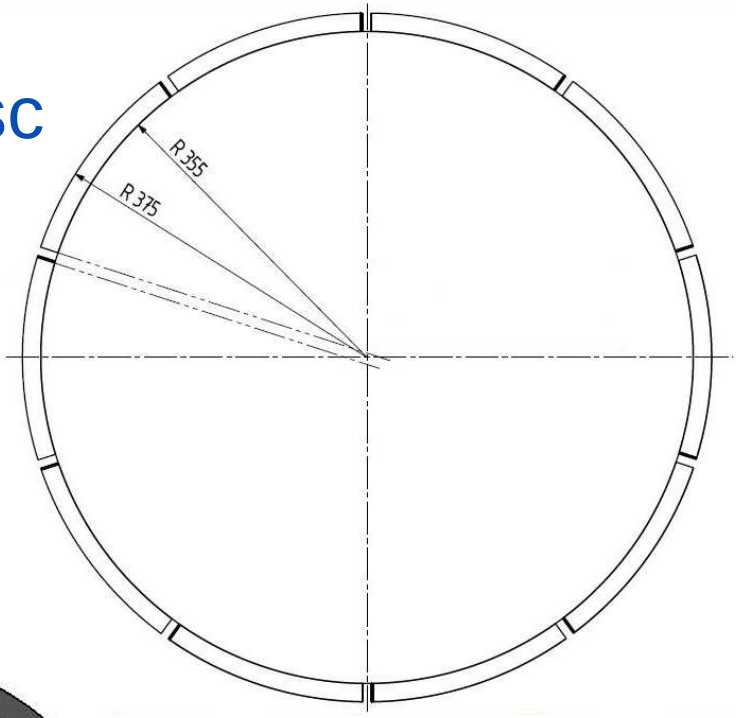




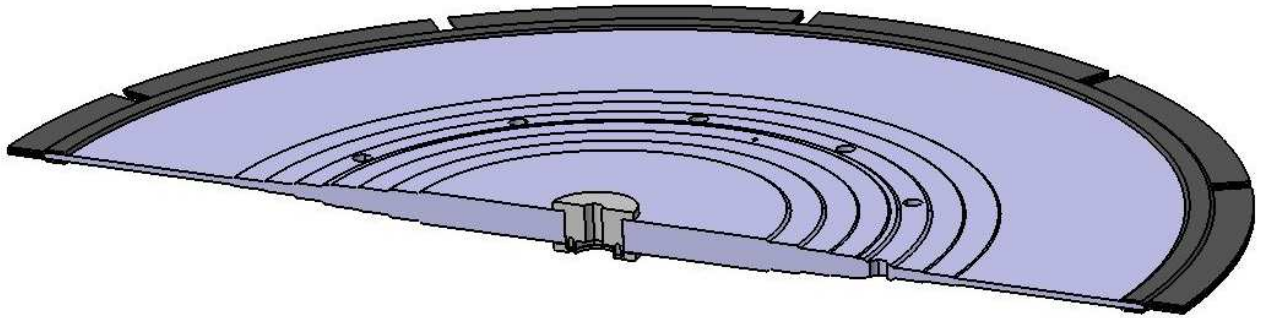
Conclusions

- The analyses have shown the feasibility of large chopper discs with large windows.
- For very deep apertures, a larger diameter might be considered
- There is not a large difference between triangular or rectangular window shapes
- A harder restriction in weight does not greatly influence the ultimate load, but reduces the first natural frequency
- The natural frequencies of the discs are lower than the ultimate speed. This might play an important role for such large devices and should be further investigated in a later design phase

Case study: Powtex chopper disc



- Large diameter (750 mm)
- Low operational speed (12,000 rpm)
- Small windows

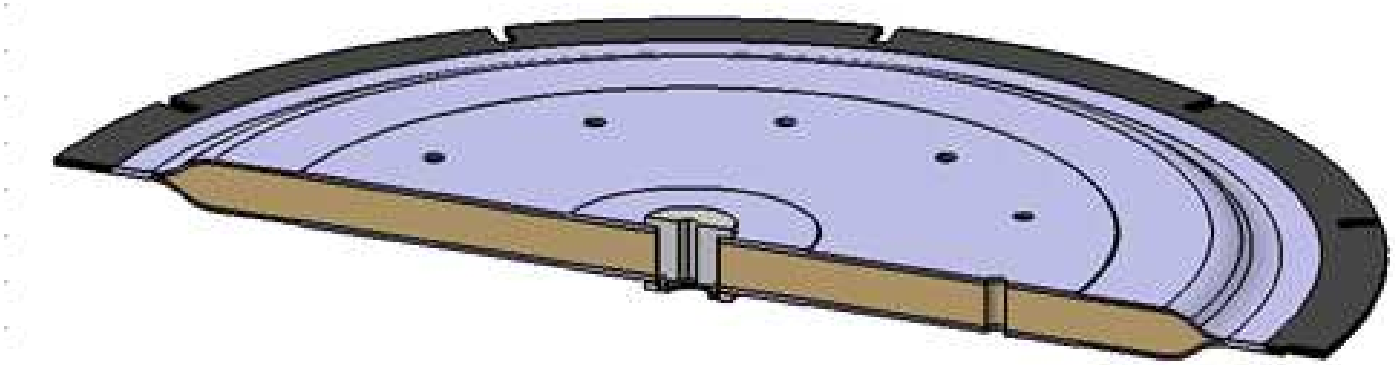


Weight:	2 kg	→ 4.5 kg
Maximum thickness:	6 mm	→ 19.5 mm
Critical frequency:	33 Hz	→ 130 Hz

Sandwich design

(Julich - published in ICCM 20 proceedings)

- Same amount of CFRP as in original design
- Solid laminate in window area (for structural reason and to guarantee accuracy of measurements)



Disc	Weight	Critical Frequency
Ultra-light CFRP	1.98 Kg	33.41 Hz
Solid CFRP	4.56 Kg	130.10 Hz
Sandwich	3.38 Kg	351.92 Hz

Conclusions

- Choppers with a operational speed of 25,000 rpm are already feasible
- Many possibilities to extend the boundaries in the design of new choppers
- Development time has to be taken into account when designing new instruments