EUROPEAN
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SOURCE

Beam requirement for target design

ESS Target station Group

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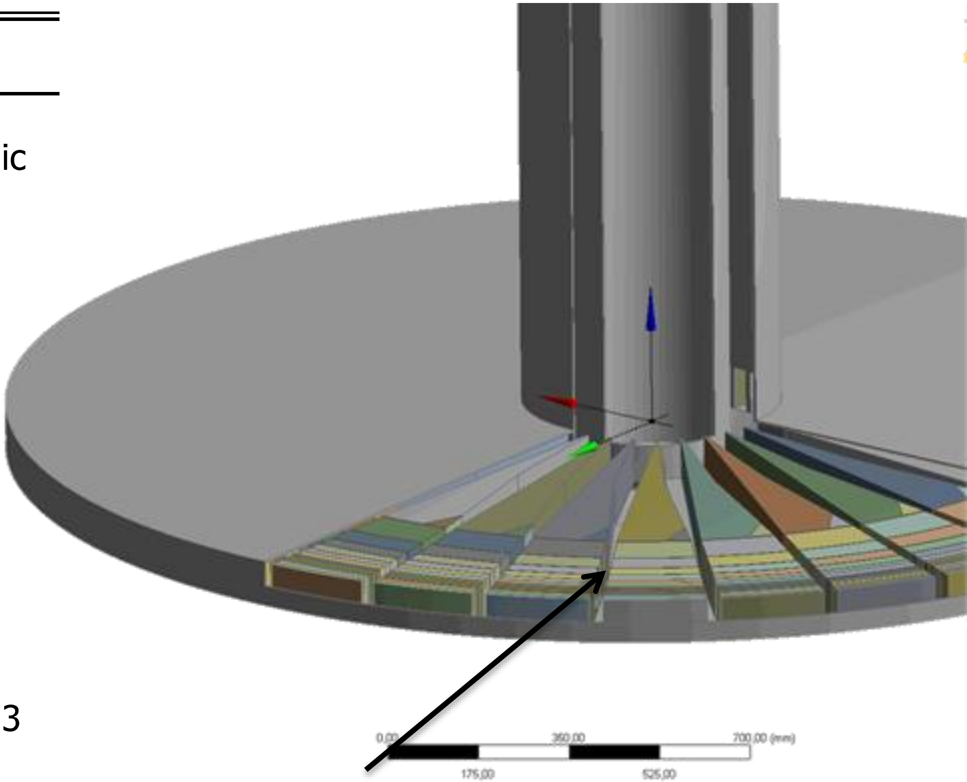
Outline

- Main parameters
- Design of the target
- Beam profile influence

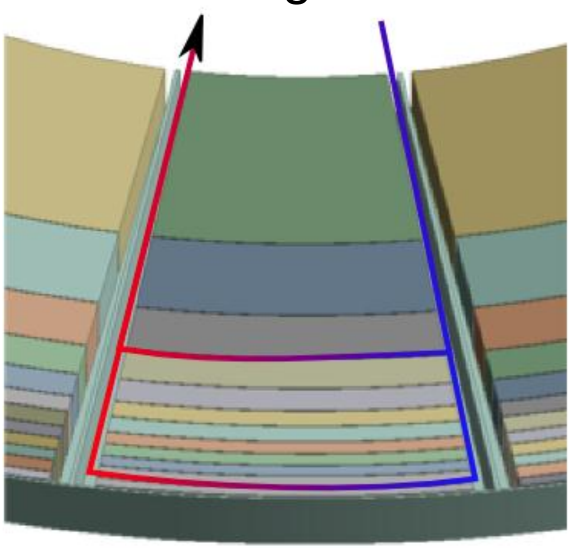
ROTHETA main parameters

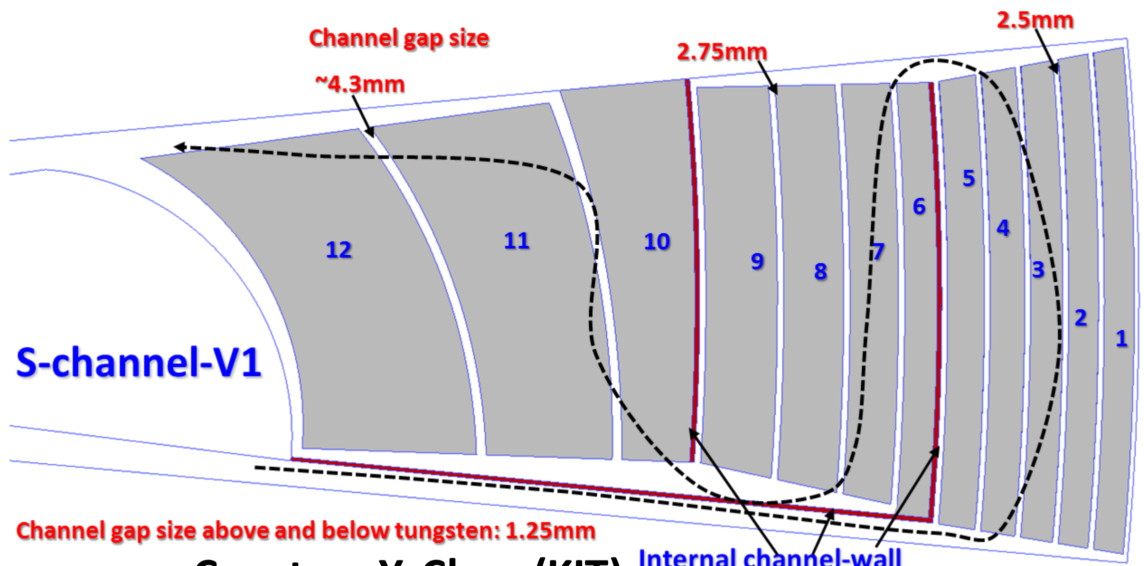
Parameter	Units	Value
Beam Energy	GeV	2.5
Beam Profile	-	Parabolic
Beam width	cm	14
Beam height	cm	5
Peak current density	$\mu A.cm^{-2}$	64
Peak power density (“stationary”)	$kW.cm^{-3}$	4.8
Peak power density (corrected)	$W.cm^{-3}$	154
Average current	mA	2
Average beam power	MW	5
Beam repetition rate	Hz	14
Pulse length	ms	2.86
Wheel outer diameter	m	2.5
Rotation speed	RPM	~25
Number of sectors	-	33
Radiation damage lifetime	dpa/FPY	~2.4 – 3
Target lifetime	Year	~5


Welded ribs

Current baseline (v2)

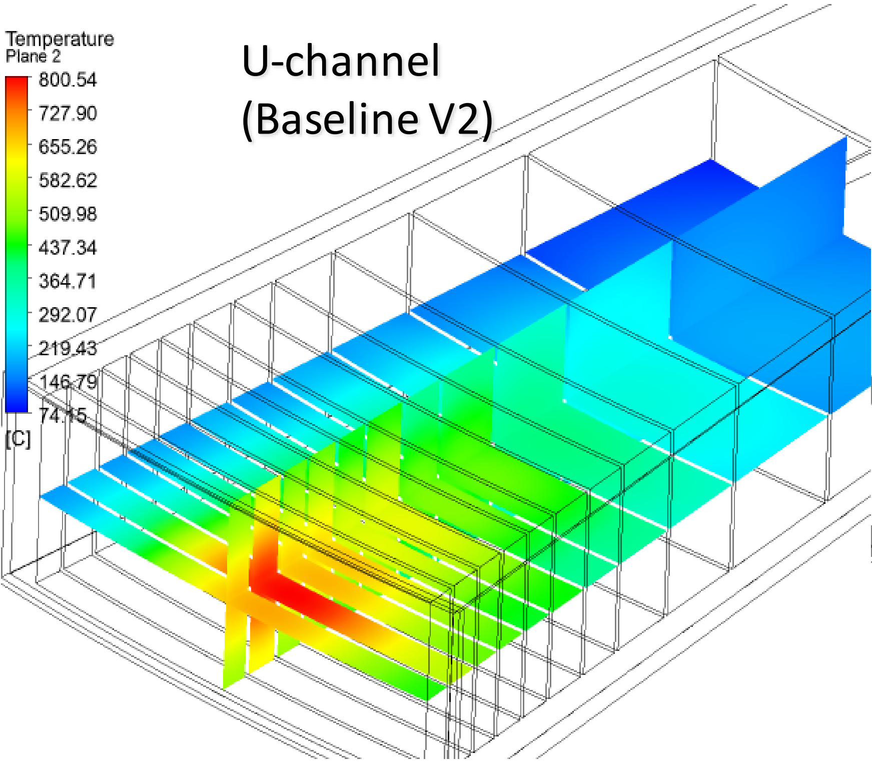
- Baseline flow pattern (U-channel)
  - Flow in tangential direction following a U
  - Cooling channel 2mm
- Alternative flow pattern (S-Channel)
  - Flow in tangential direction but describing a S
  - Channel larger to conserve the ΔP

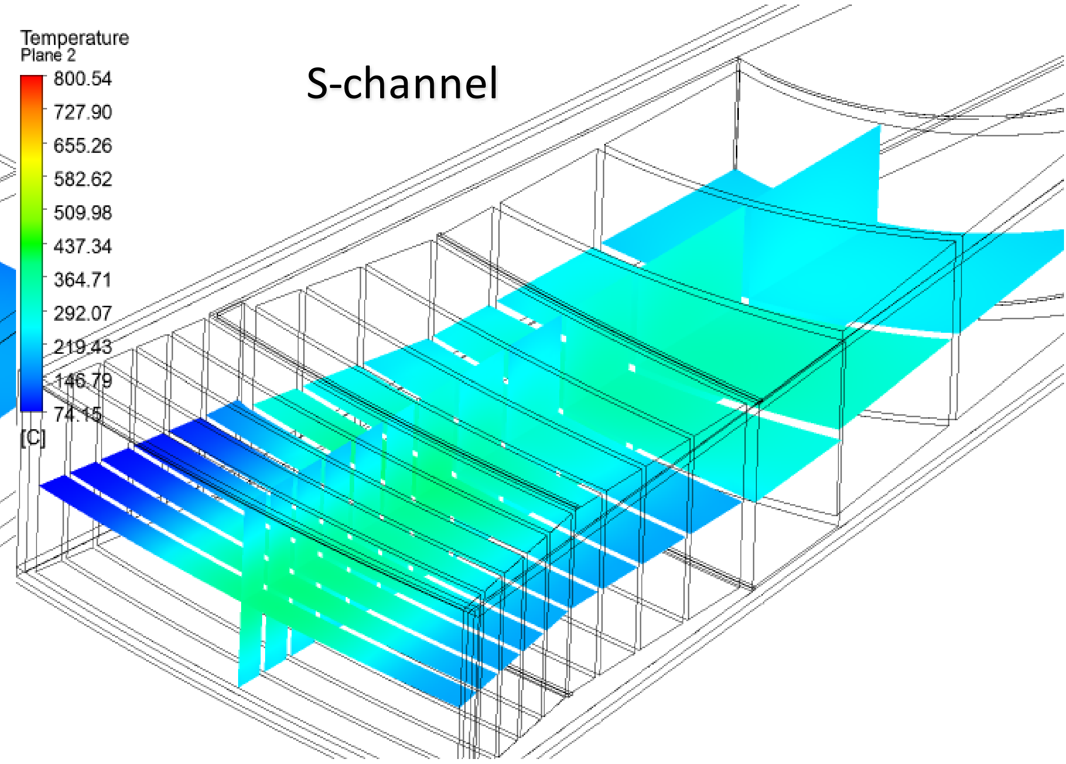




Courtesy Y. Chen (KIT)

CFD Analysis
Tungsten temperature





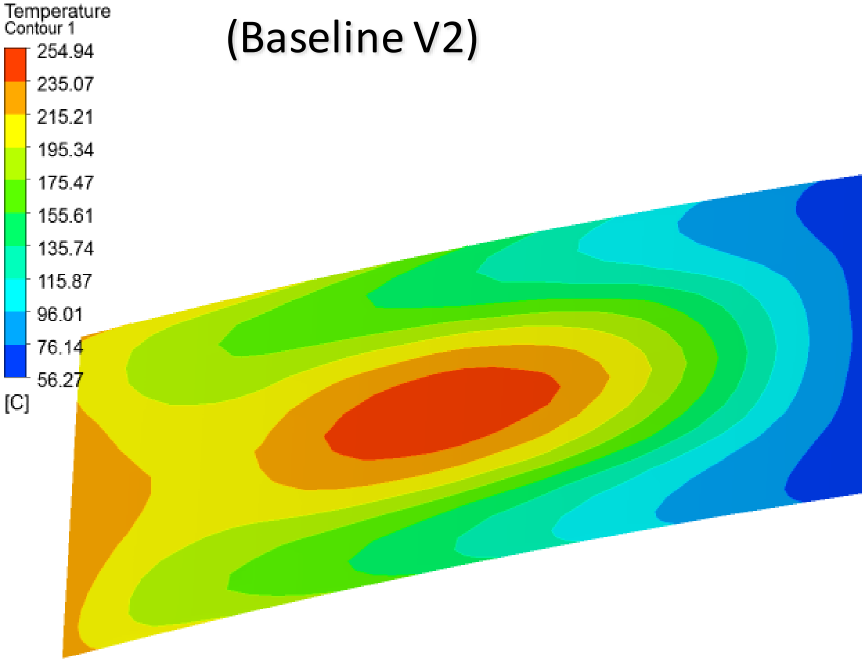
Maximum temperature reduced from 800°C to 394°C **Courtesy to Y. Chen (KIT)**

Pressure drop is increased / further work to reduce the pressure loss

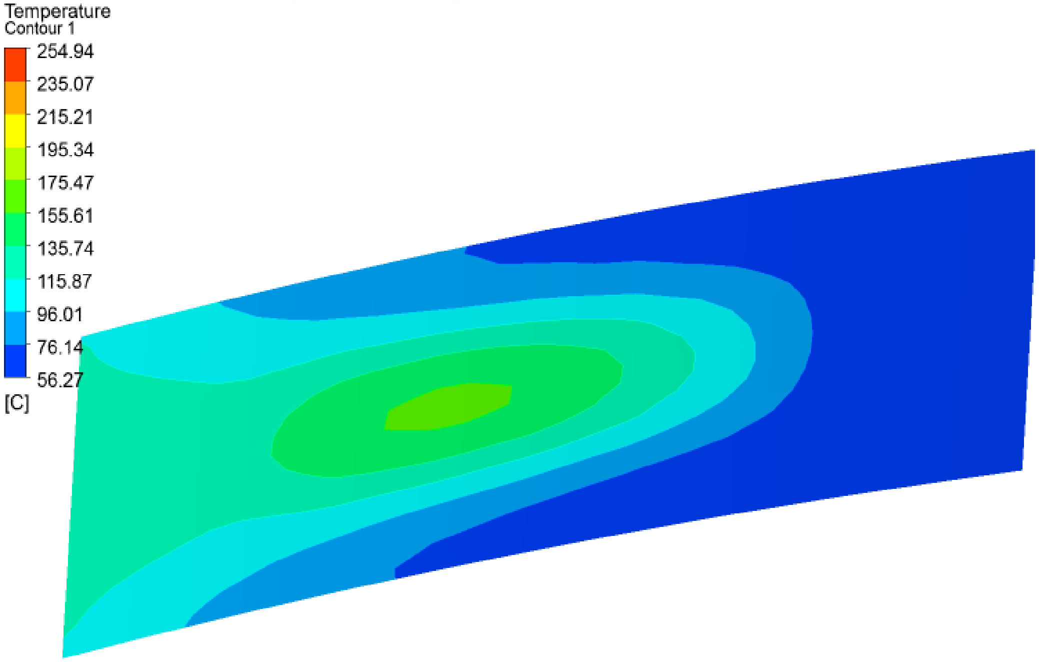
CFD Analysis
BEW temperature

Karlsruhe Institute of Technology

U-channel
(Baseline V2)



S-channel

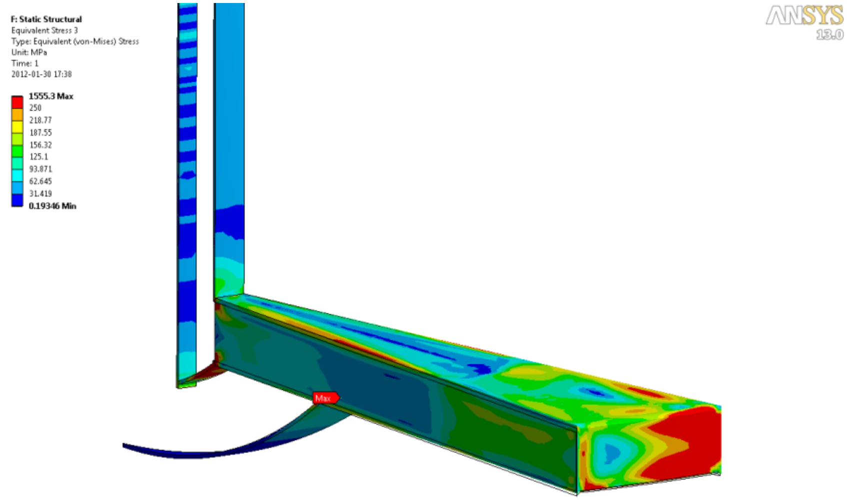


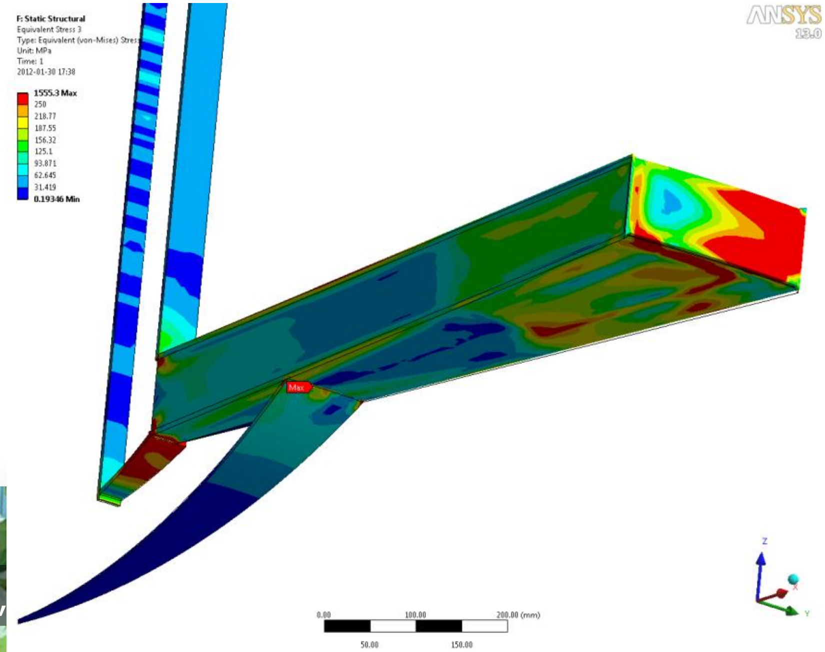
Maximum temperature reduced from 255°C to 170°C

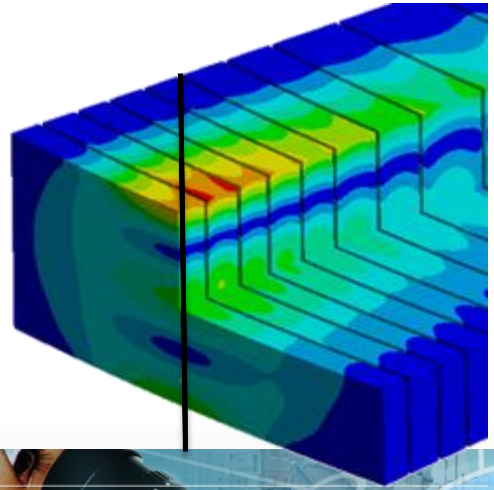
Courtesy to Y. Chen (KIT)

Thermo-mechanical Analysis

- Results
  - First approach (von Mises stress around 250-300MPa): improvement paths identified
  - Limits defined by standards
  - Tungsten stress: max 412 MPa ($Rp_{0.2}$=462MPa), plates can be cut







Conclusion

- Deposition in the BEW not visible (stress, temperature) → 2^{nd} order importance
- However, very important to minimize its impact in order to increase the margin for other influence (cooling)

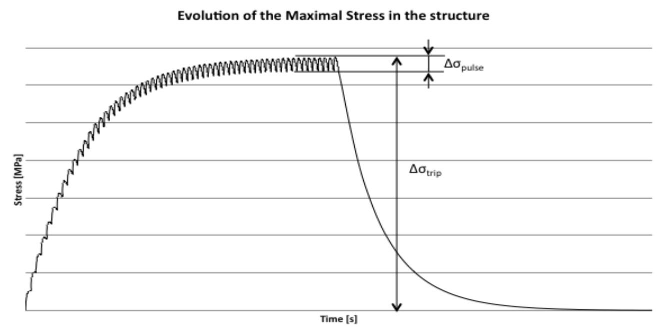
Beam profile influence

- Parameter study to define tolerance envelope: only energy deposited in the BEW considered
- Beam envelope: 14cm x 5cm (worst case for study)
- 3 profiles studied:
  - Theoretical parabolic shape
  - Gaussian shape
  - Flat shape

Beam profile influence

- Method:
  - Parabolic taken as the reference
  - Same energy deposited for all 3 shapes
  - Peak values calculated by Maxima
  - Import of calculated values into ANSYS → Stress analysis
  - Post processing according to RCC-MRx design standard

Beam profile influence



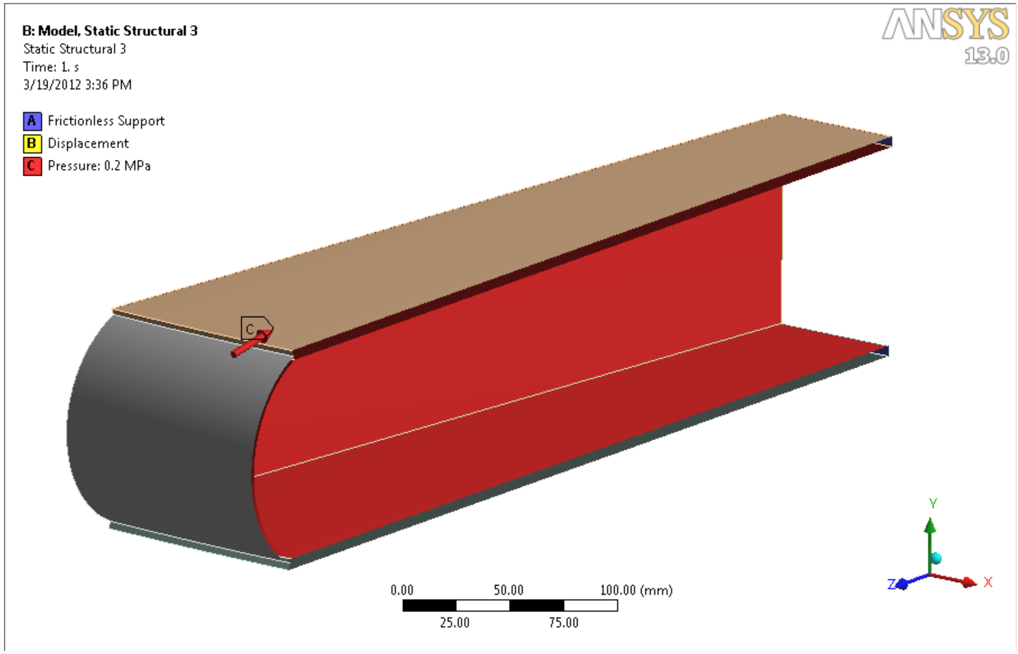
$$\sigma_{Total} = \sigma_{P} + \sigma_{Th_1} + \sigma_{Th_2} + \sigma_{Th_3}$$

σ_P : stress due to pressure

σ_{Th1} : stress due to ΔT from time averaged energy deposition

σ_{Th2} : stress due to ΔT from instantaneous energy deposition (considered negligible compared to σ_{Th1})

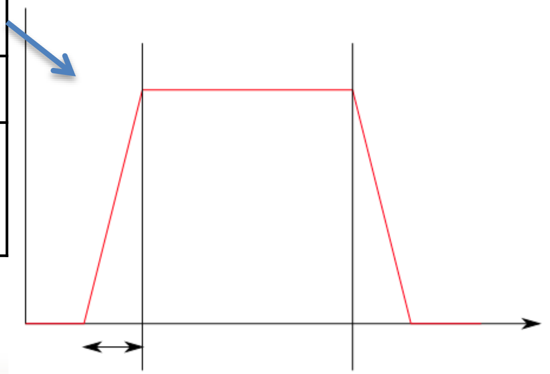
σ_{Th3} : stress due to heat transported by the coolant (neglected in that analysis, but very high contribution)



Beam profile influence

- Input parameters:

Shape	Input	min	max	Units
All	Peak density (time averaged)	2.4	64	μA/cm^2
	Peak density (instantaneous)	60	1600	μA/cm^2
	Tail (% of peak)	0	10	%
	Vertical error	-1	1	cm
	Horizontal error	-2	2	cm
Flat	edge sharpness	0	2	cm
Gaussian	Vertical sigma	0.5	2	cm
	Horizontal sigma	1	6	cm

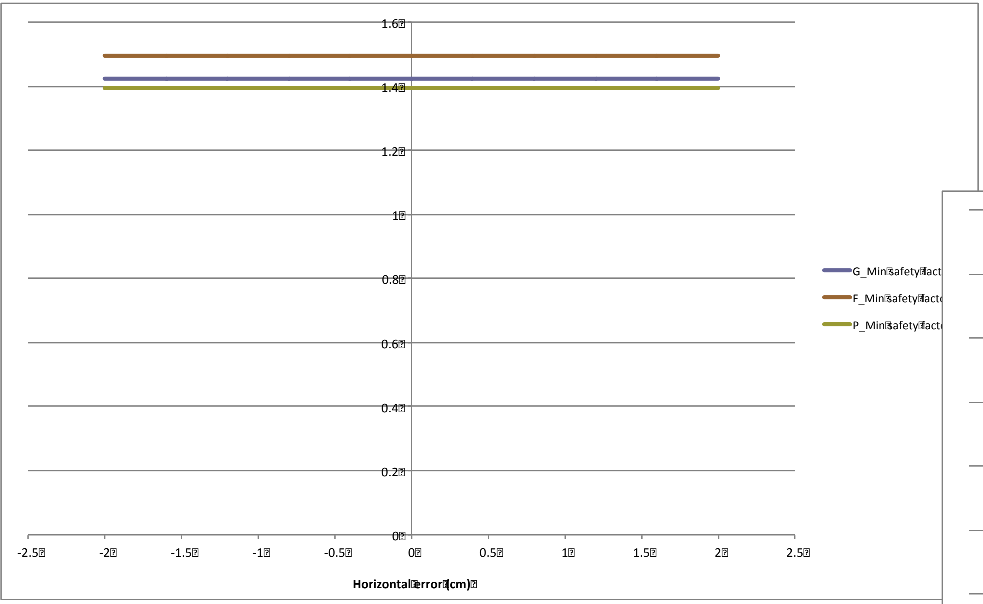


Beam profile influence

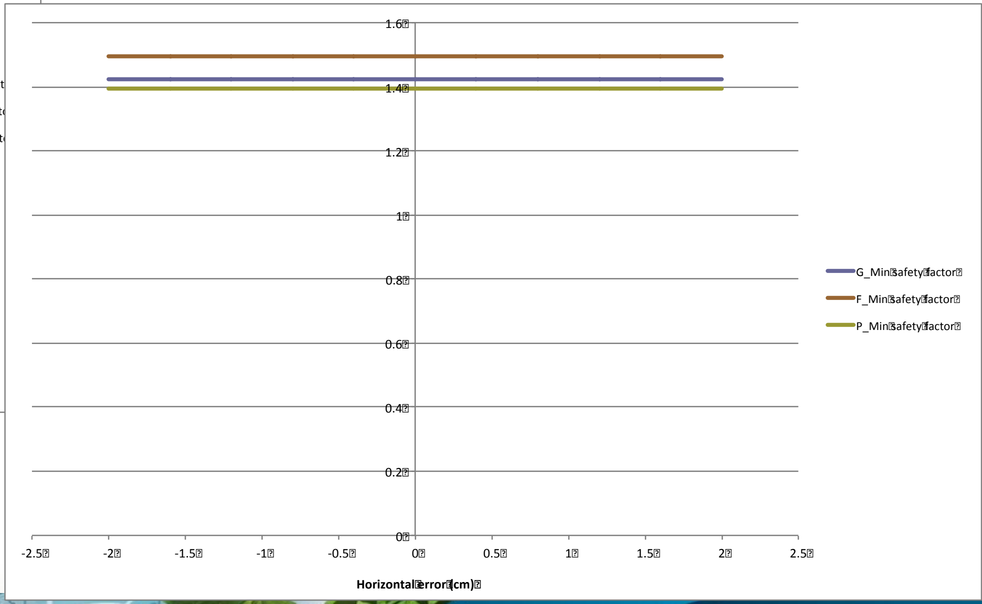
- Output parameters:
  - Minimum safety margin for P damages for all 3 profiles
  - S damages have been investigated but not considered as an issue

Beam profile influence

- Results: alignment error

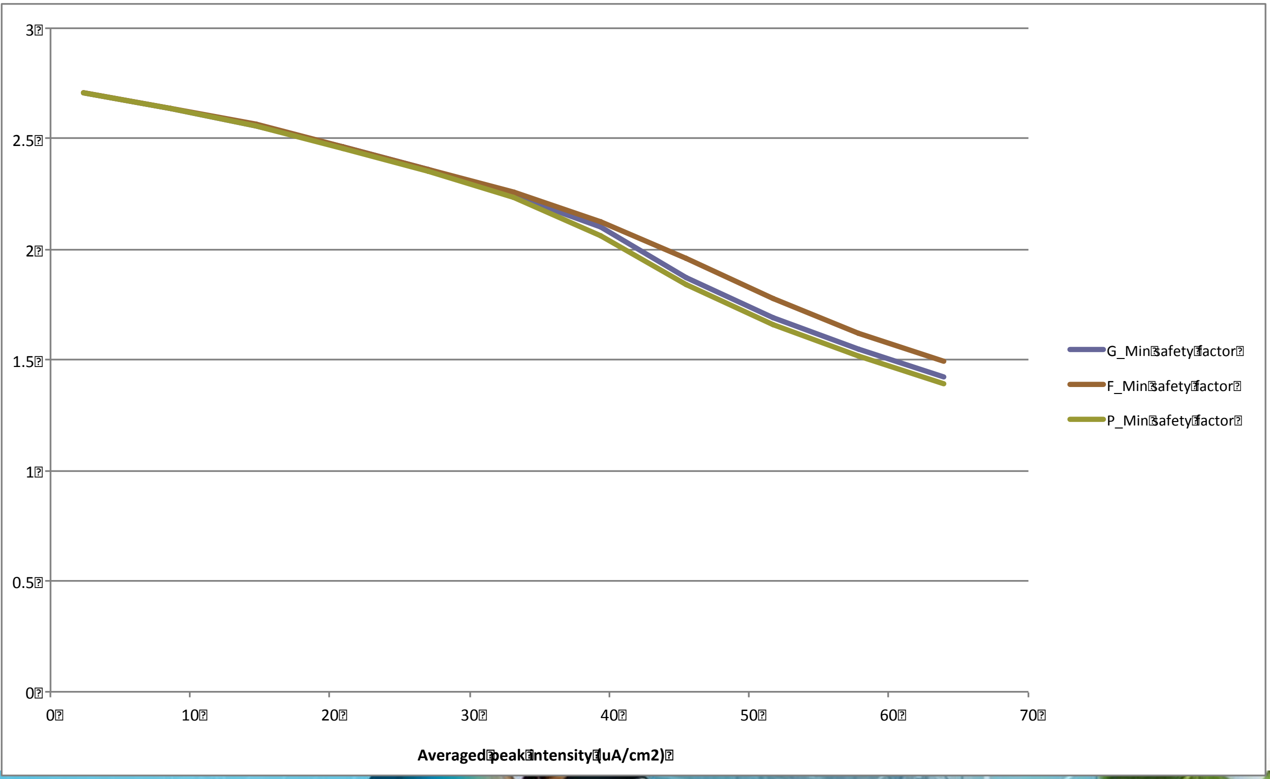


No influence!



Beam profile influence

- Results: Peak density

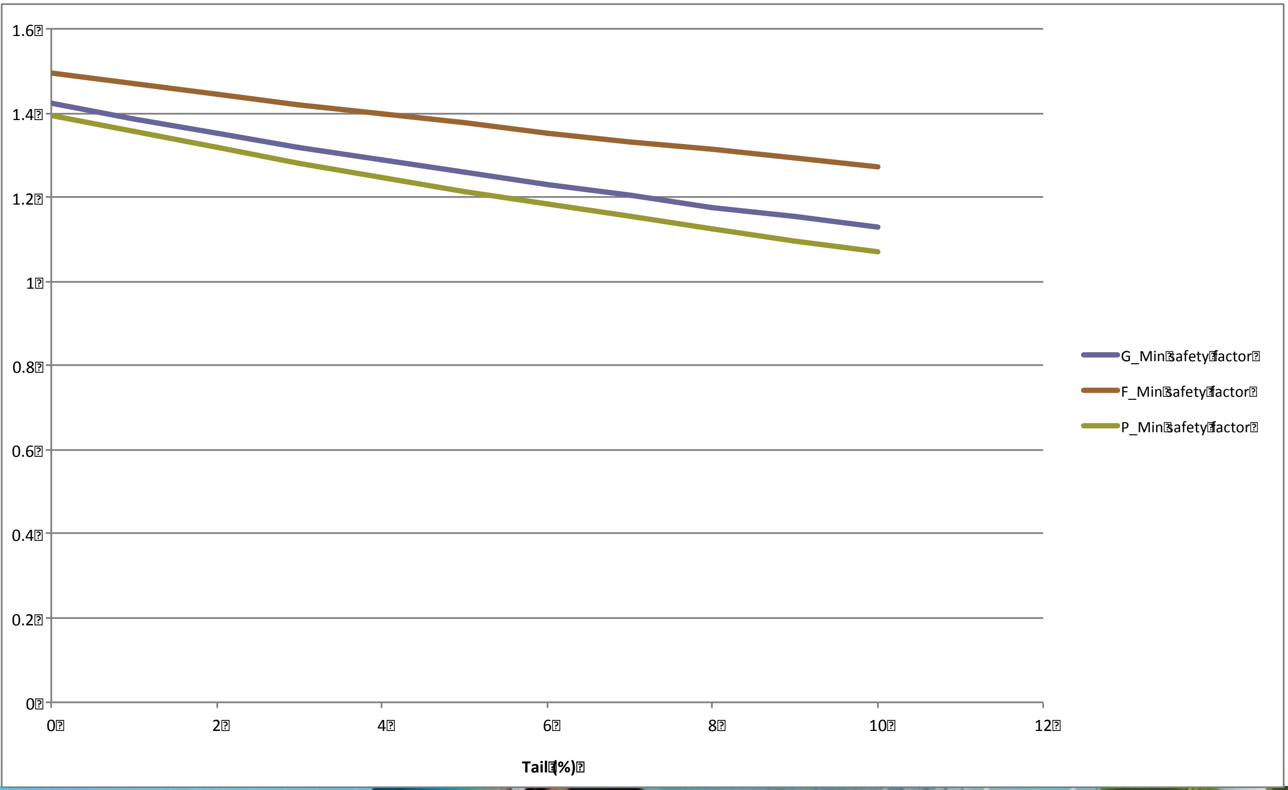


Strong influence!

Peak density should be reduced as much as possible. But 2mA must be kept (neutronic performances)

Beam profile influence

- Results: Tail

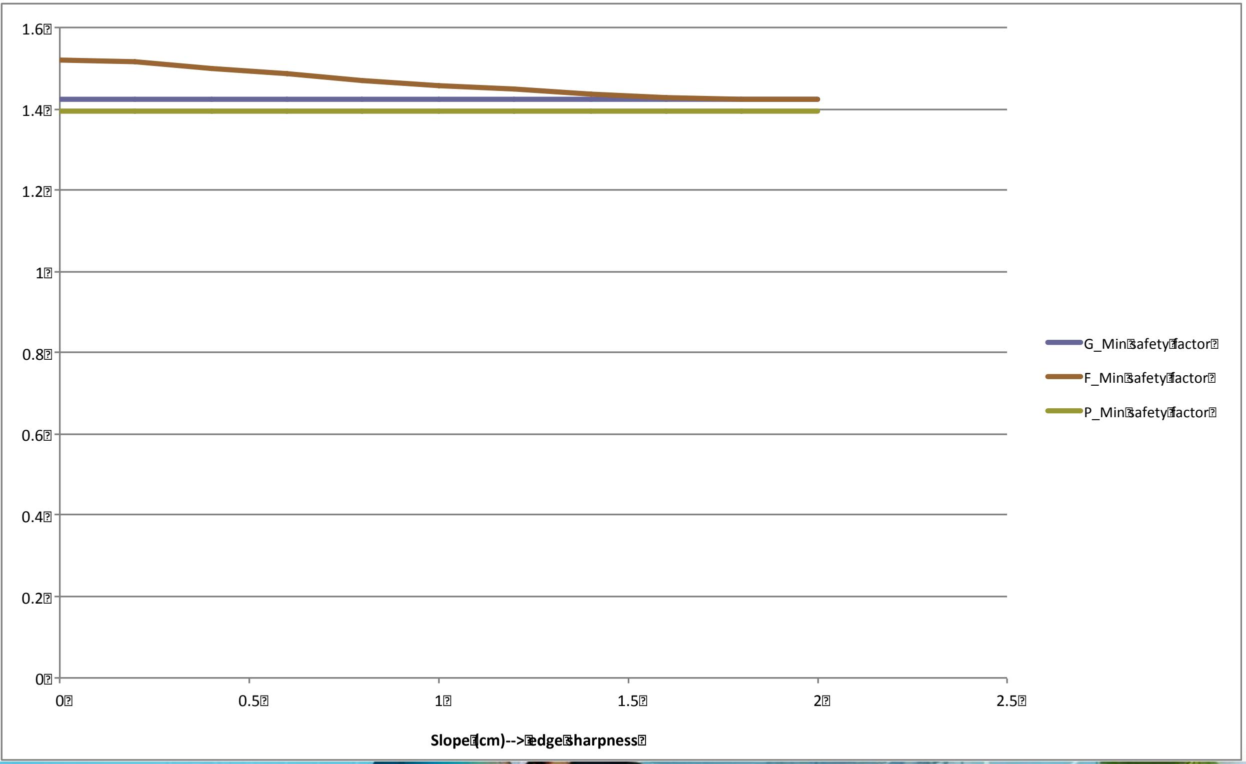


No influence!

No influence at constant power, but could have a large influence by inducing a disequilibrium.

Beam profile influence

- Results: Flat profile, edge sharpness



No influence!

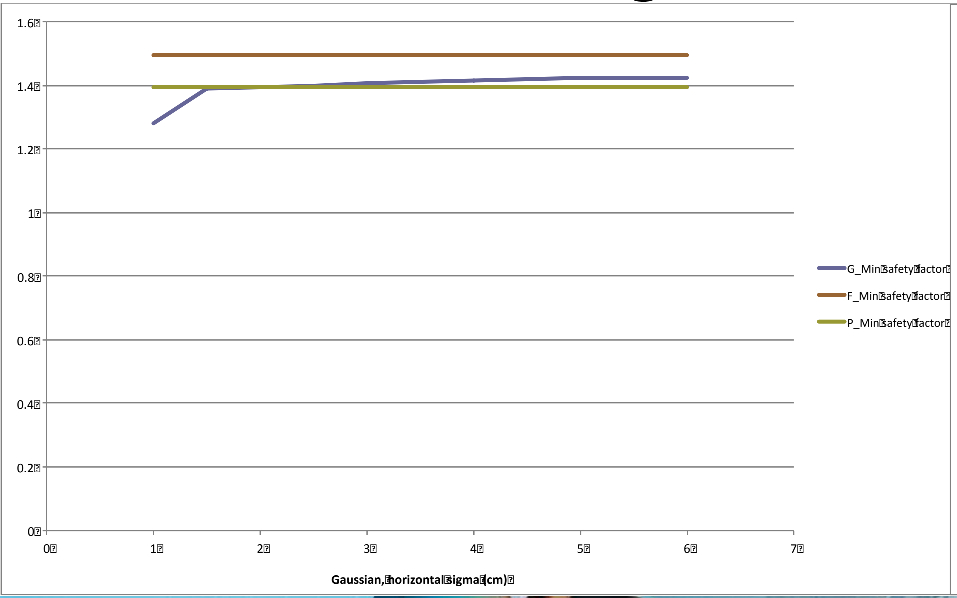
To keep the same total deposited energy, the sharp edge involve less peak. This parameter leads to consider peak density

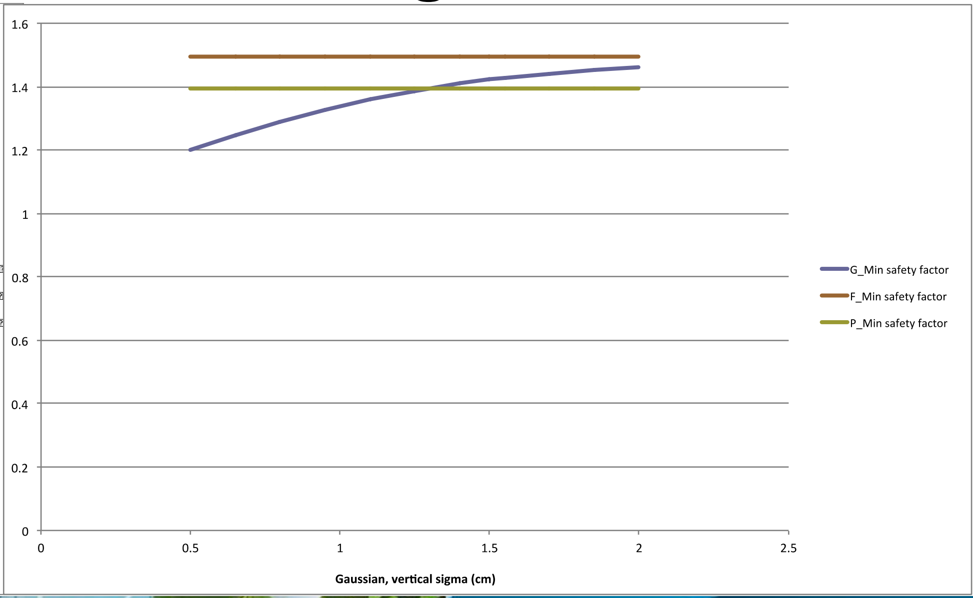
Beam profile influence

- Results: Gaussian profile, hor. & vert. sigma

No influence of horizontal sigma!

Strong influence of vertical sigma!





Beam profile influence

- Conclusion
  - Main parameter: peak density
  - Requirements:
    - Low peak density
    - No tail (if possible)

  → Inside this envelope, no requirement

Investigations continue for PBW and fatigue

Thanks for your attention and to all contributors …