QSK (CXRS) - Kühlkonzept AEA21

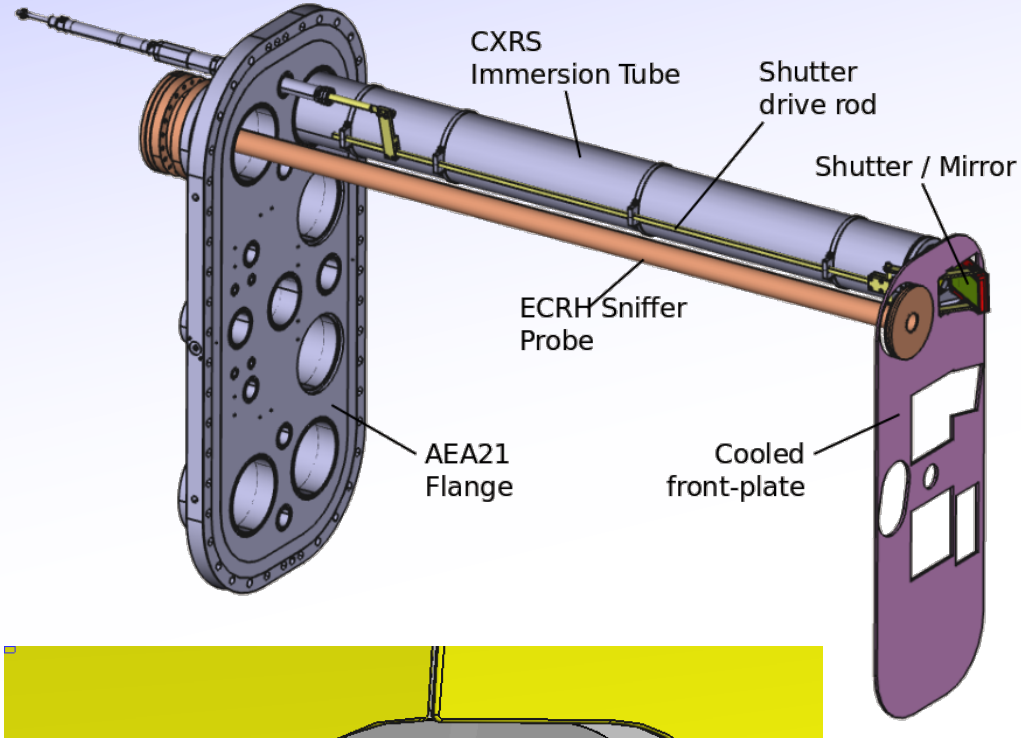
(Ladungsaustauschspektroskopie am Neutralheizstrahl)

Design Review Board 13.09.2019

O. P. Ford[1], M. Steffen[1], C. Biedermann[1]

1: Max-Planck Institut für Plasmaphysik, Greifswald/Garching, Germany

AEA21

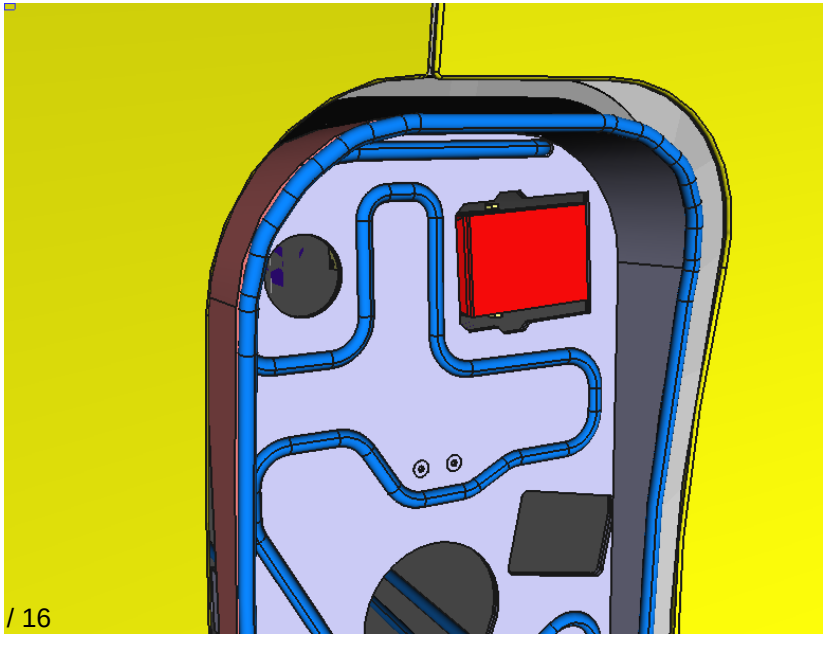


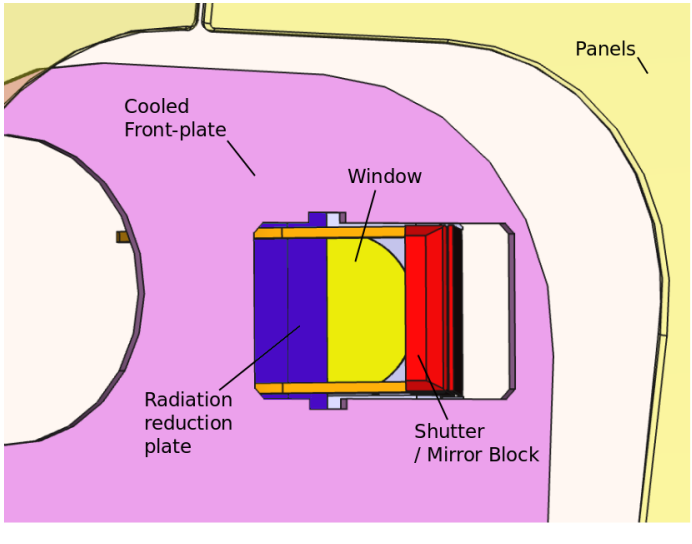
- Cooled front plate provides protection of port wall and most diagnostics parts [QMR2]

- Front plate design finalisation required for thermal calculation and QMR2 DDR.
--> Need to confirm QSK cooling concept.

- QSK Shutter only open during NBI operation ~20seconds.

- Shutter contains aluminium (RSA905) mirror and must remain < 350°C.

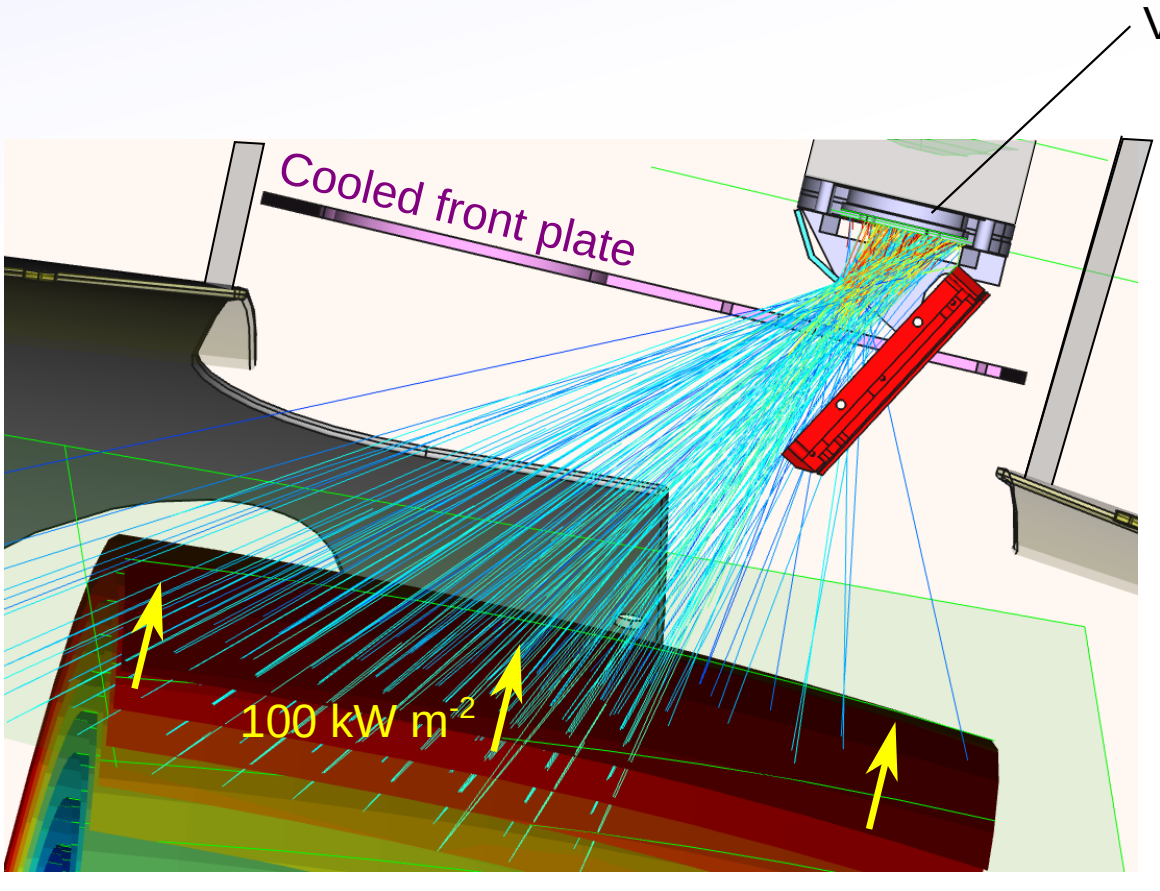


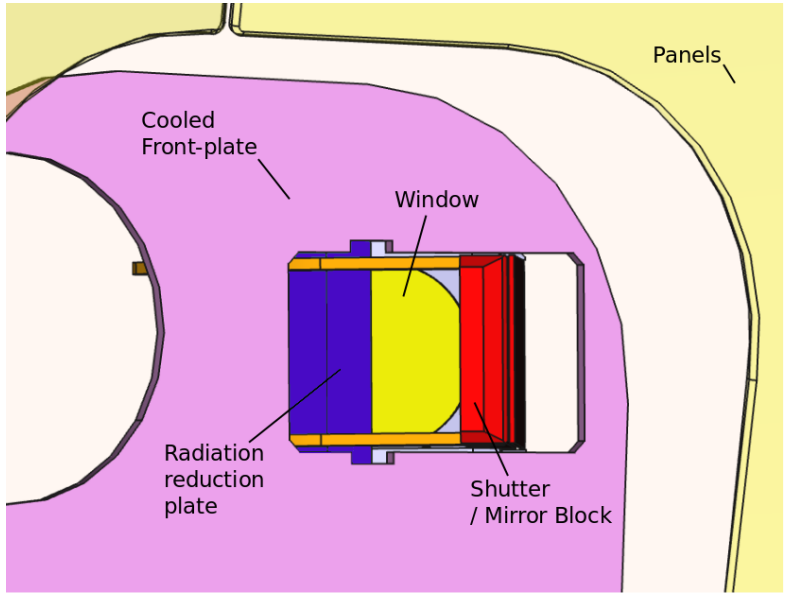


AEA21 - Vacuum window

- Vacuum window only exposed during **20s** open period.
- Shutter, cooled front plate and added structure limit exposure to **40W.**
- Cycle time of NBI ~20 min - enough time to cool by conduction through weld to CF flange.

- *Possible to add 'sacrificial window' (glass plate) in front of vacuum window.*

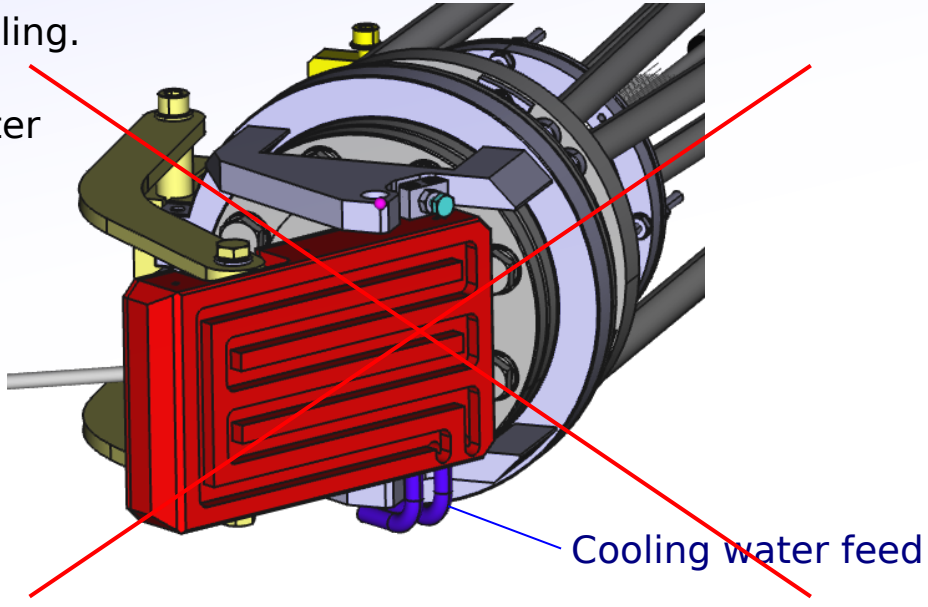




AEA21 - Shutter - Water cooling?

Back side of shutter exposued to full 100kW m^{-2} x 30min.
Shutter hold RSA905 aluminium mirror --> requires cooling.

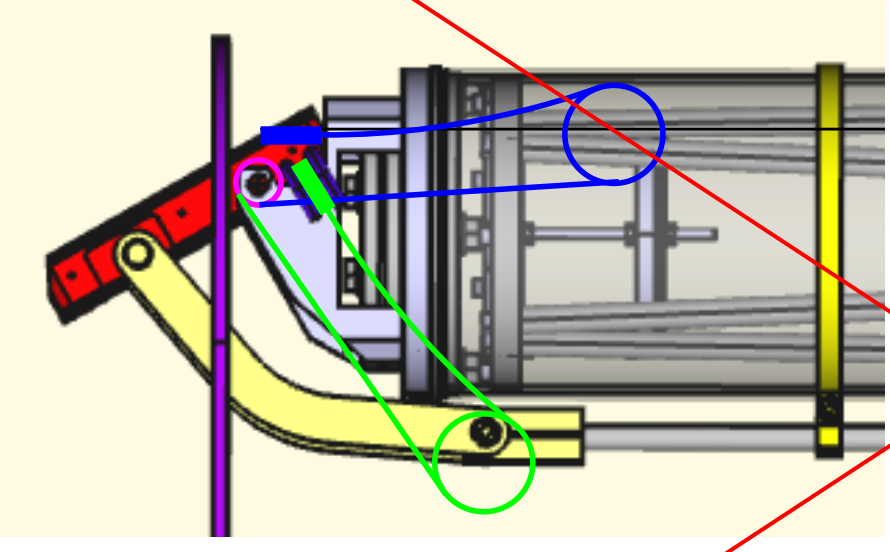
Originally planned to add flexible cooling tubes to shutter but space is too limited.
+Involves risks of water leak.



AEA21 - Shutter

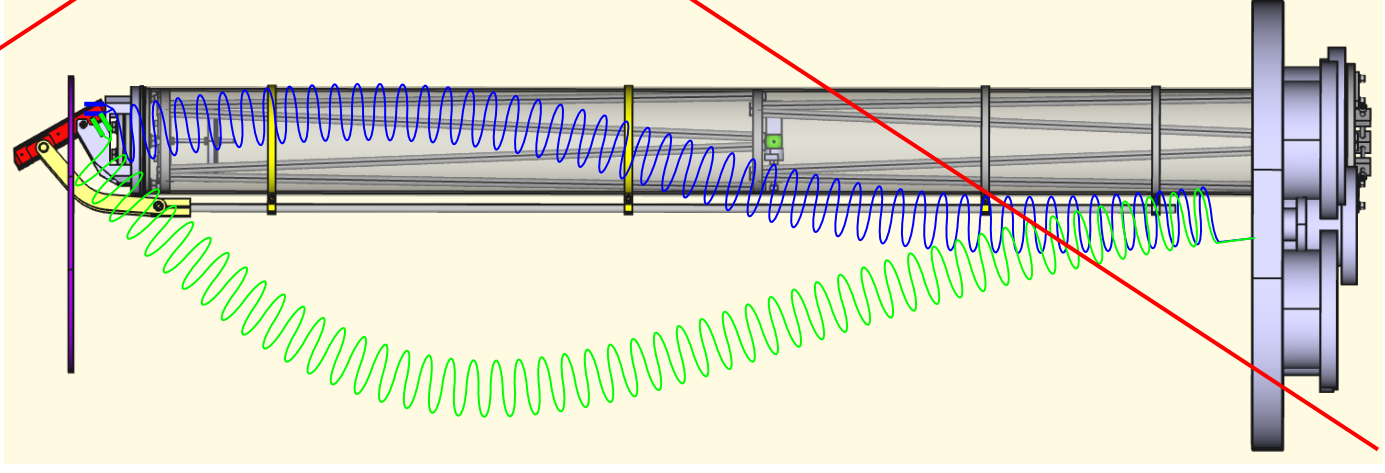
1) Machine water channels into mirror block and add flexible cooling tubes to mirror.

Mirror pivots by 60° and shifts by a few cm - difficult to allow sufficient movement to water cooling pipes.



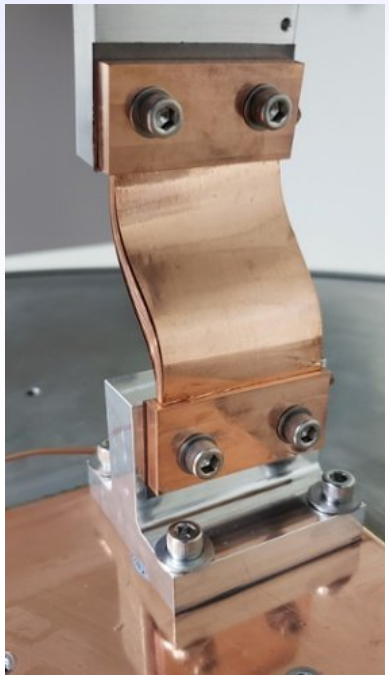
Two coils of pipe required to deal with offset as well as rotation.

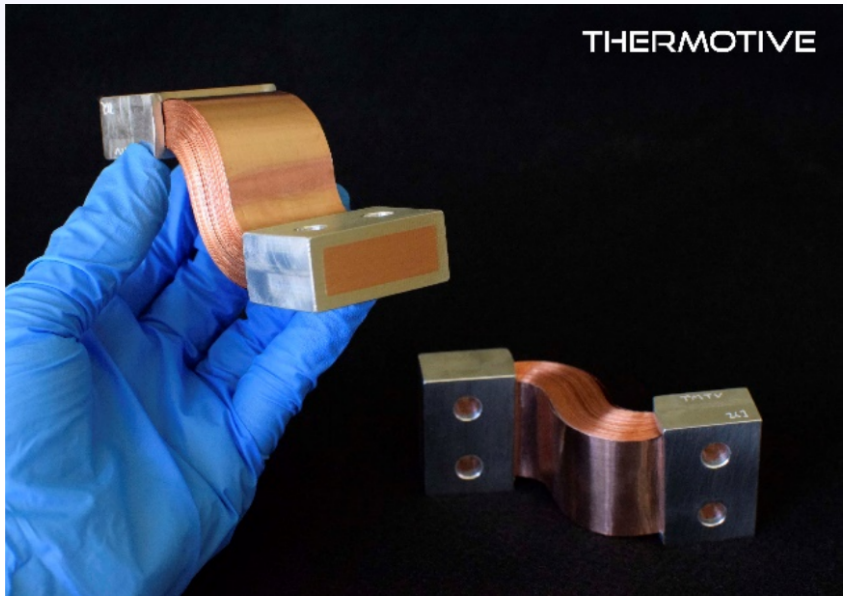
Alternative Idea:
Long coil above/below, using up whole width of port.



AEA21 - Thermal straps

Alternatively, we could use thermal straps:

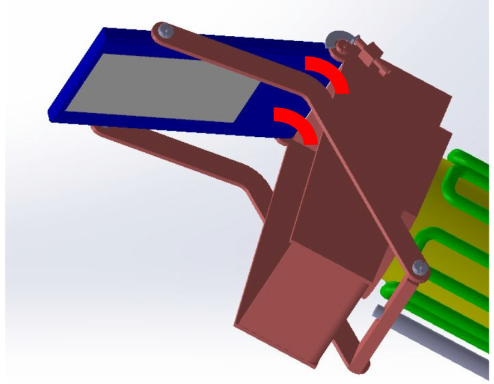




Thermal conductivity:
- Aluminium: 225 $Wm^{-1}K^{-1}$
- Copper: 450 $Wm^{-1}K^{-1}$
- Graphene: 2500 $Wm^{-1}K^{-1}$

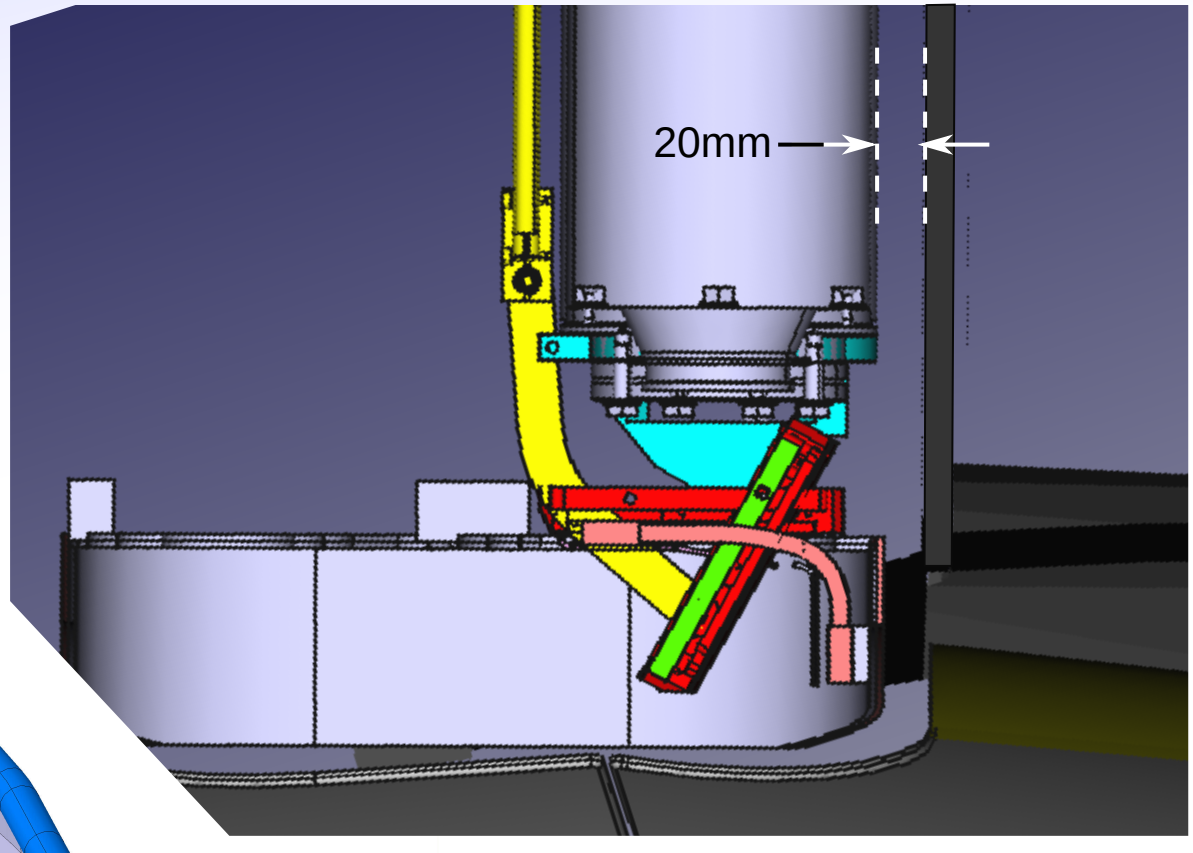
Also planned for Gas Puff Imaging mirror (A. von Stechow)

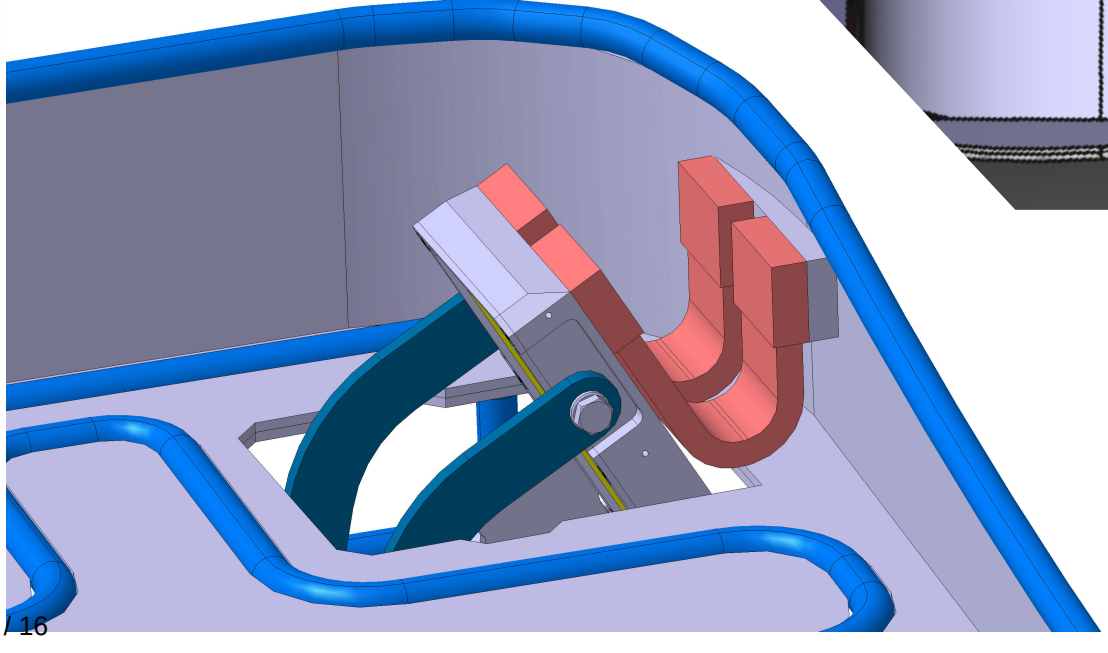
Shutter cooling concept for OP2.0/2.1



AEA21 - Thermal straps

Insufficient space for the thermal strap on the inside of the cooled front plate.

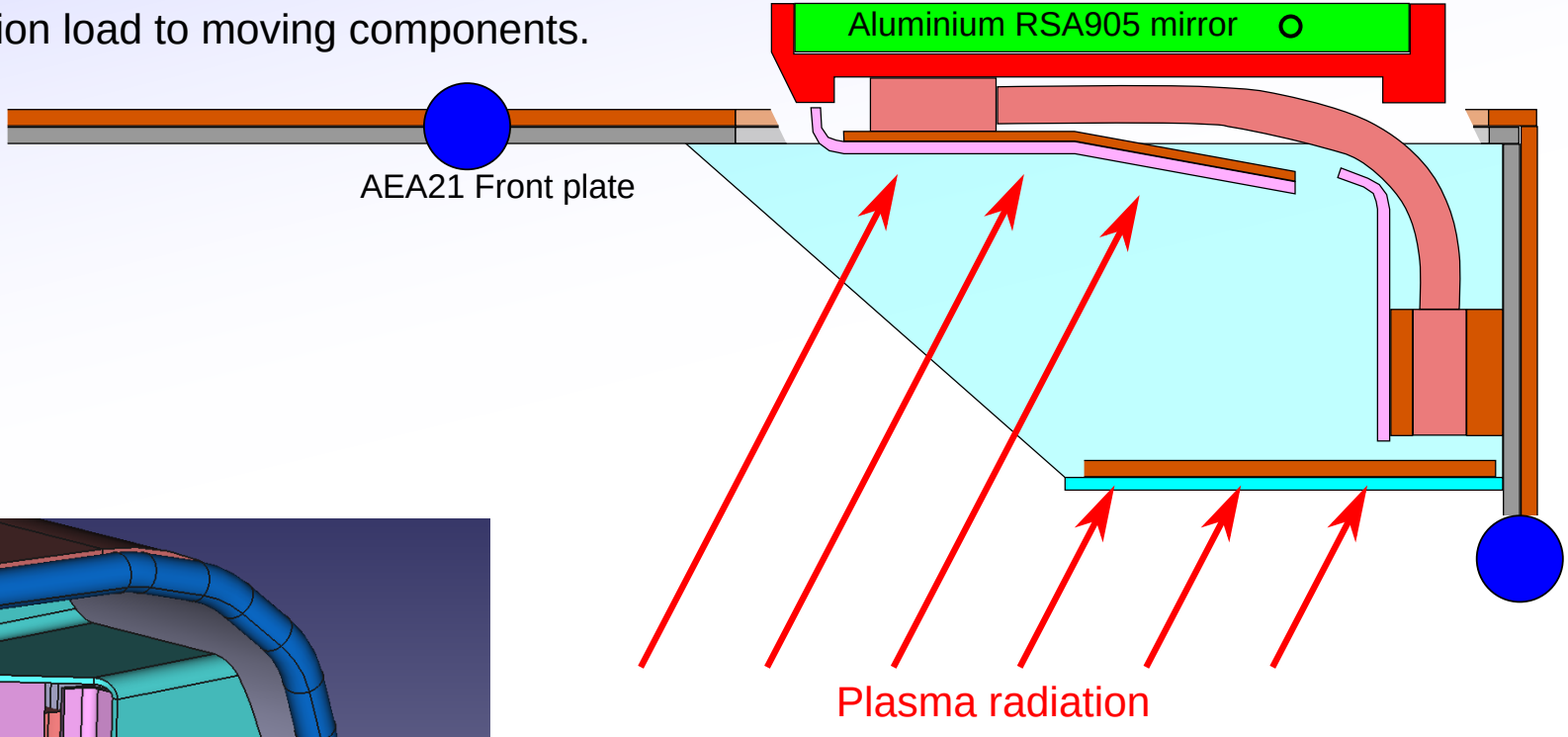


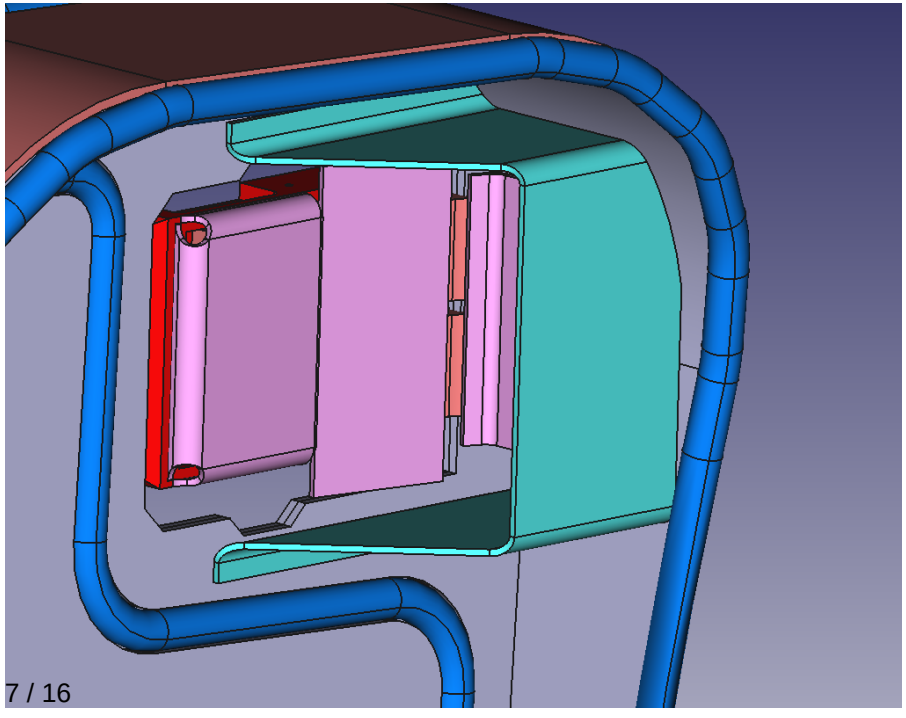


Sufficient space to attach on outside of cooled front plate, but copper straps exposed to plasma.

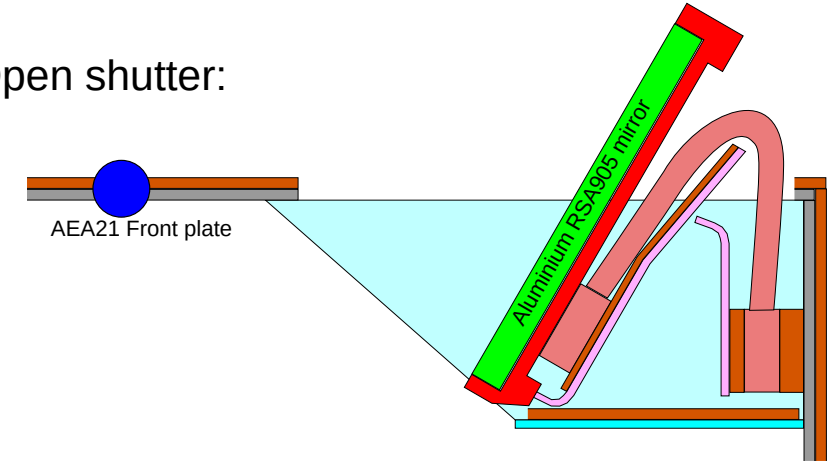
AEA21 - Concept

Copper straps to be shielded from plasma exposure, also reducing radiation load to moving components.



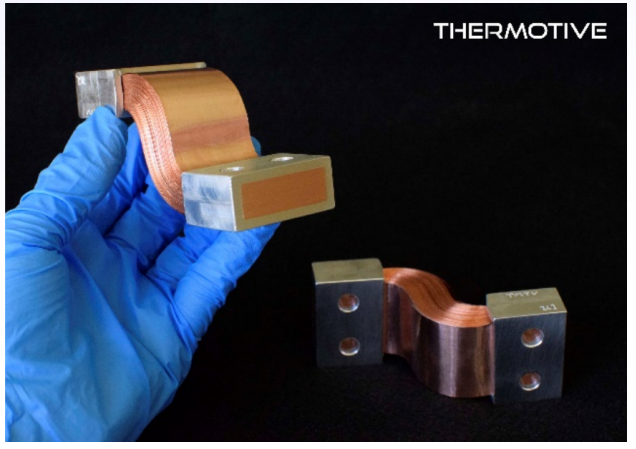


Open shutter:



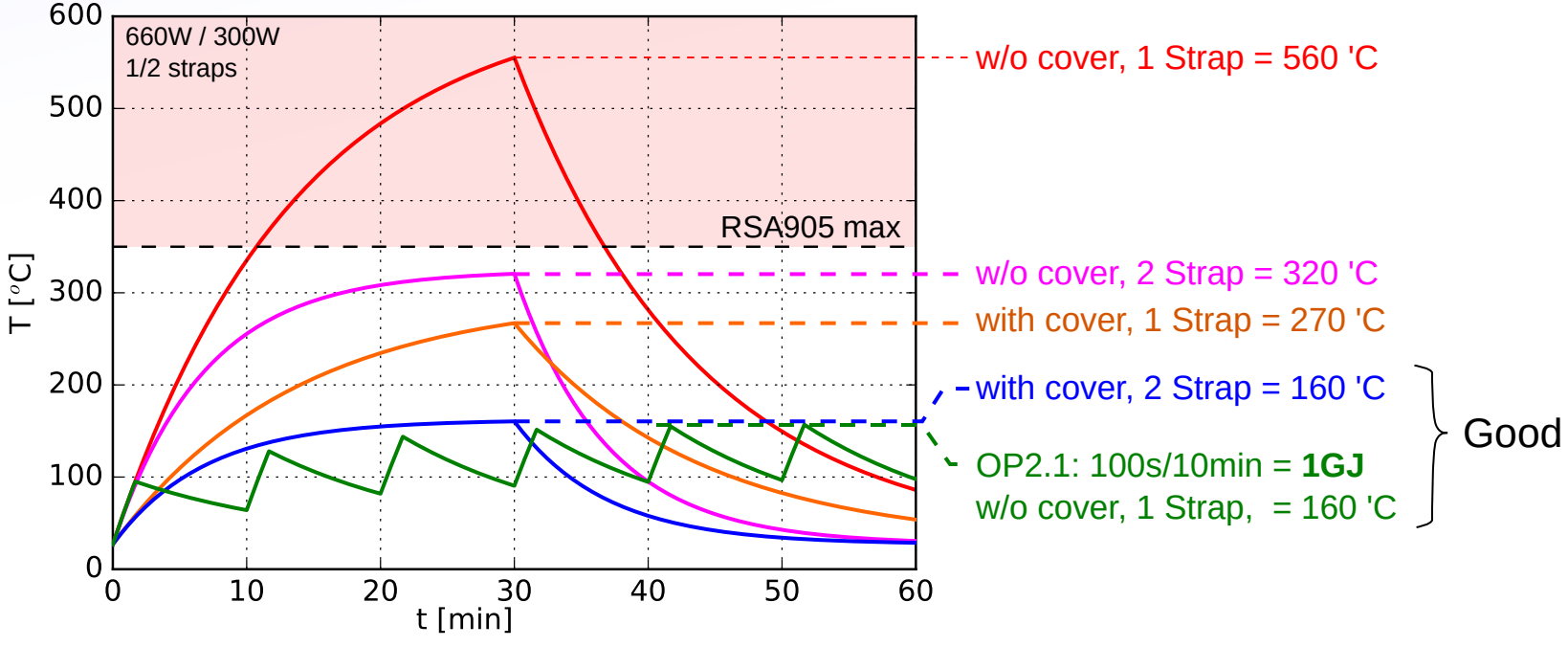
AEA21 - Thermal strap

Ray-traced loads to shutter from 100kW m^{-2} at plasma boundary.
Without cover: 660W
With cover: 300W



Largest copper strap has 111/L W/K conductance.

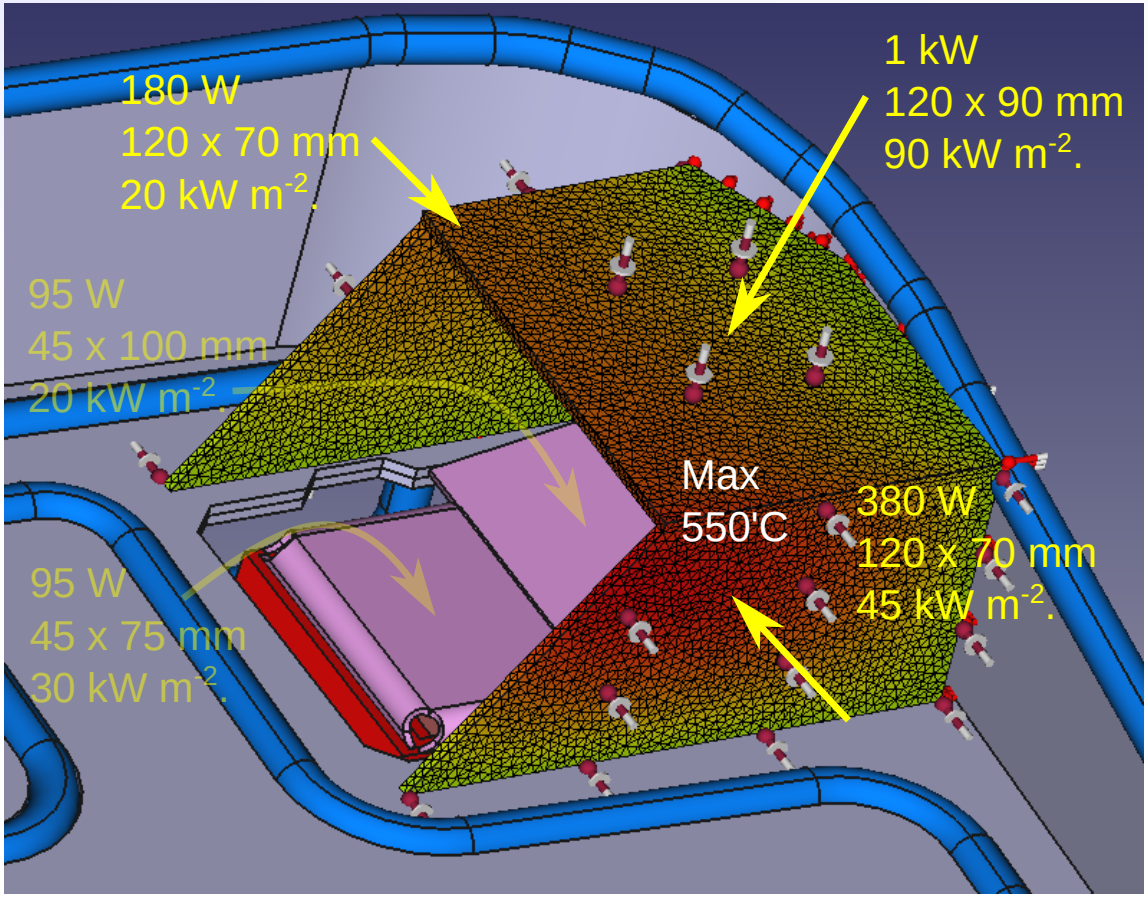
Direct performance calculation:

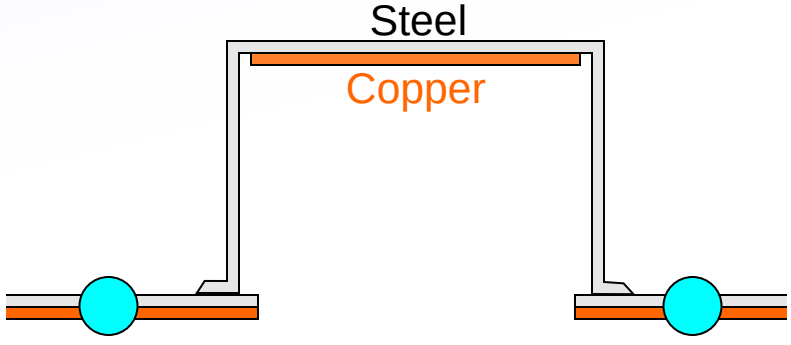


1) With 2 straps and cover, 18GJ is OK by x2
2) 1GJ is OK even with no cover and only 1 strap

AEA21 - Cover

Ray traced 100kW m^{-2} at plasma boundary to cover.



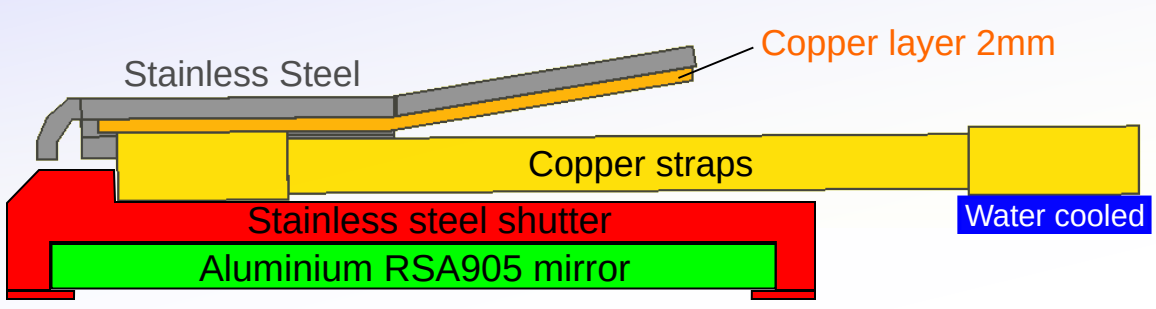


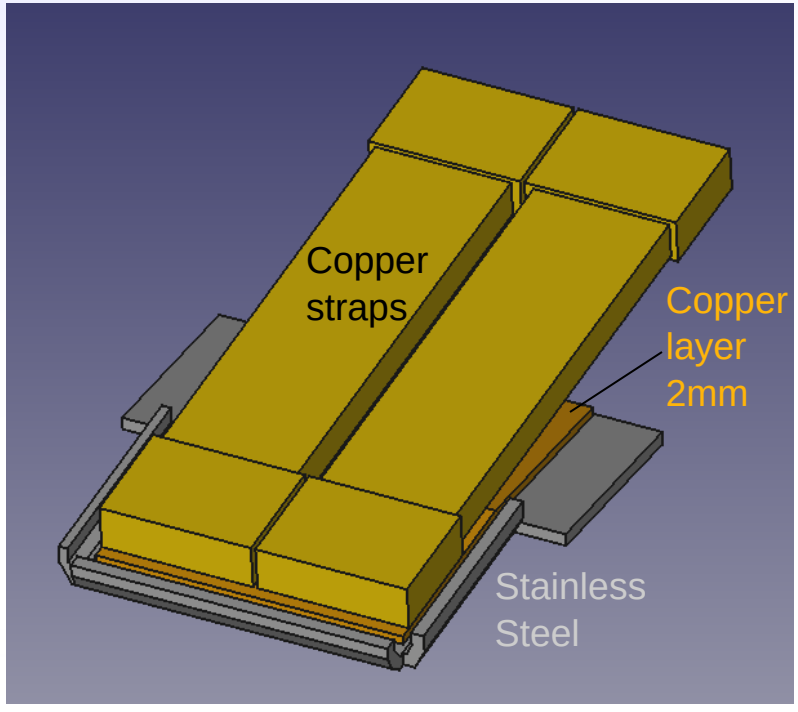
Only 3mm Stainless steel --> 1200°C

With 3mm copper layer on inside of top cover --> 550°C

AEA21 - Mirror block cap

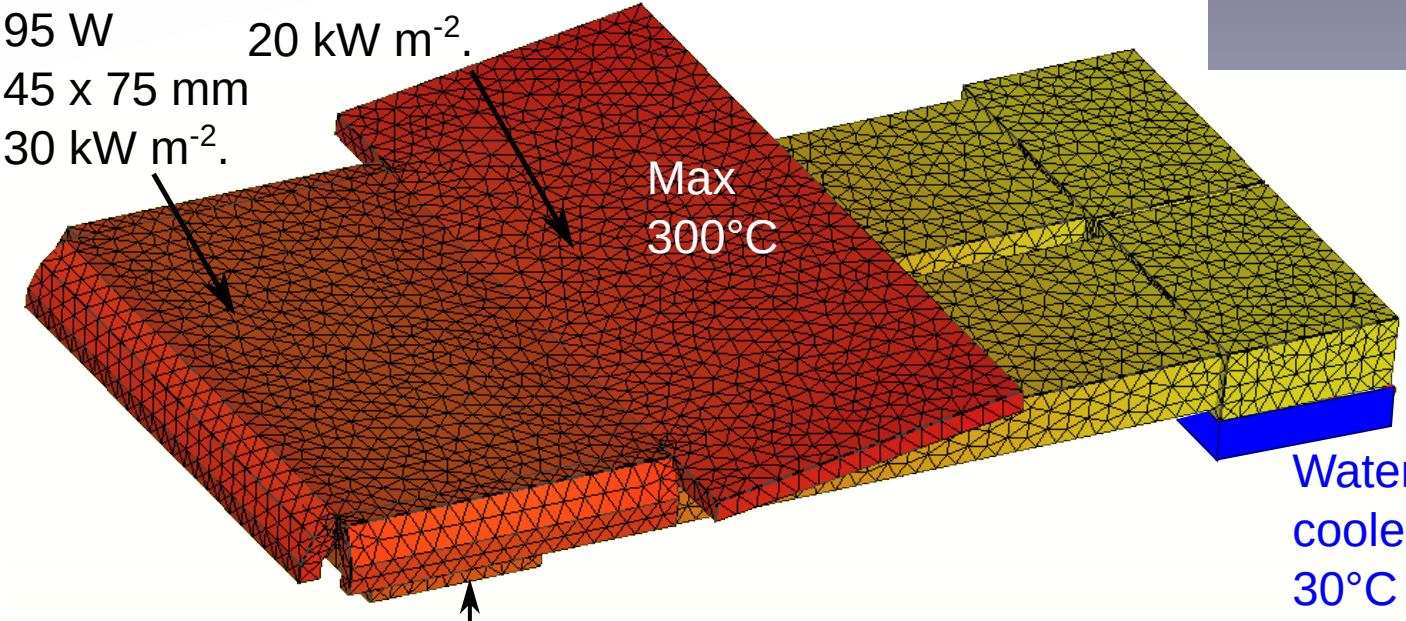
Heat loads to mirro block cap still significant and requires copper plating for full 18GJ.





95 W
45 x 100 mm
20 kW m^{-2}.

95 W
45 x 75 mm
30 kW m^{-2}.



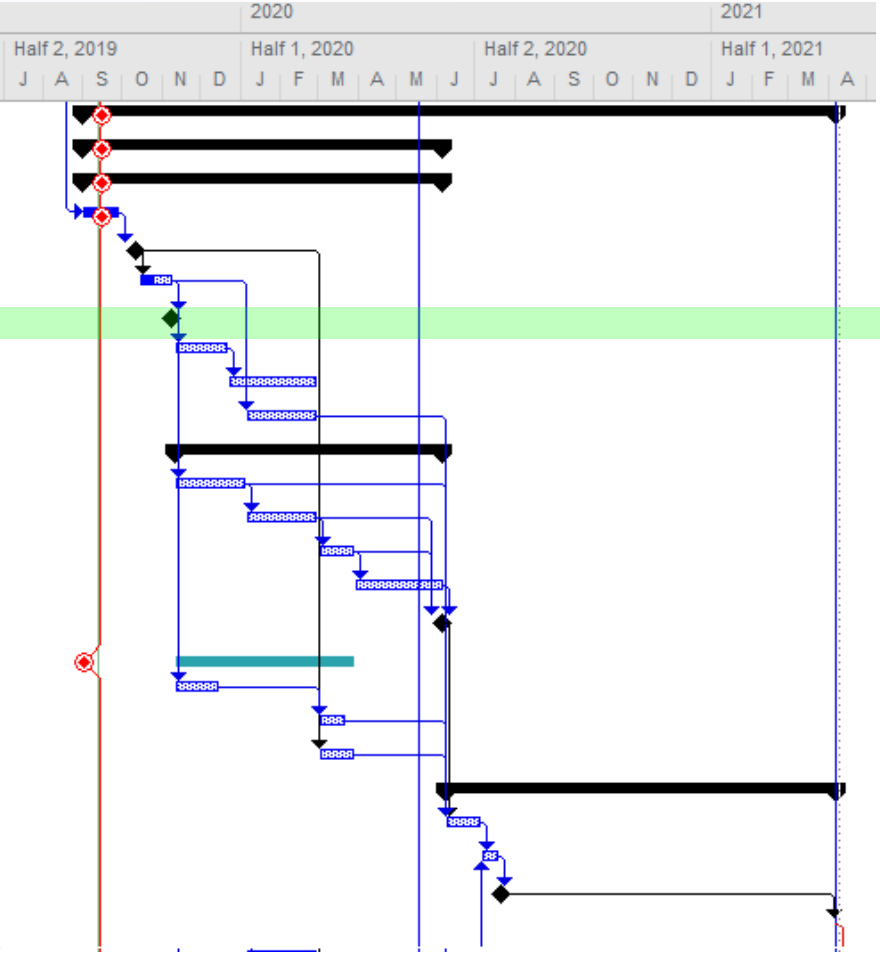
Mirror block connected to straps at < 300°C.
Direct radiation < 50W

QSK AEA21 Cooling - Planning

Funding: 7k€ of 20k€ requested from contingency for QSK hardening.

WBS:

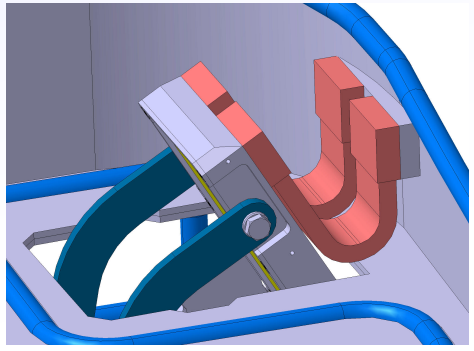
Vorgangsname	abgeschlossen in %	Duration	Start
K2: AEA21-O	**7%**	**417 d?**	**Sun 01/09/19**
OP2 Upgrade	**8%**	**200 d?**	**Sun 01/09/19**
QSK-K2 Hardening	**8%**	**200 d?**	**Sun 01/09/19**
Calculation for required cooling AEA21	100%	4 w	Sun 01/09/19
DRB QSK OP2 AEA21	0%	2 w	Mon 30/09/19
Design straps, caps and cover	50%	4 w	Mon 14/10/19
Design ready for finalisation of front-plate (QMR2)	0%	0 d	Fri 08/11/19
Thermal calculations by EN (QMR2)	0%	6 w	Mon 11/11/19
Manufacturing cover and cap. Copper plating.	0%	10 w	Mon 23/12/19
Modification/manufacture shutter AEA21	0%	8 w	Mon 06/01/20
Thermal straps	**0%**	**150 d**	**Mon 11/11/19**
Purchase thermal straps	0%	8 w	Mon 11/11/19
Heat transfer qualification	0%	8 w	Mon 06/01/20
Flexibility qualification	0%	4 w	Mon 02/03/20
Mistral tests ECRH thermal straps	0%	10 w	Mon 30/03/20
Thermal strap qualification complete	0%	0 d	Fri 05/06/20
Cooling monitoring / control	**0%**		
Design work for the thermocouples	0%	5 w	Mon 11/11/19
Thermocouples	0%	3 w	Mon 02/03/20
DAQ / Control interface to CoDAC	0%	4 w	Mon 02/03/20
OP2 Preparation	**0%**	**217 d**	**Mon 08/06/20**
Reassembly plug-in into AEA21 port flange	0%	4 w	Mon 08/06/20
Funtional testing, alignment internal optics	0%	2 w	Mon 06/07/20
QSK-AEA21o ready for handover of AEA21 to AS	0%	1 d	Mon 20/07/20
Calibration during AEA21 flange installation	0%	1 d	Tue 06/04/21



QSK AEA21 Cooling - Summary

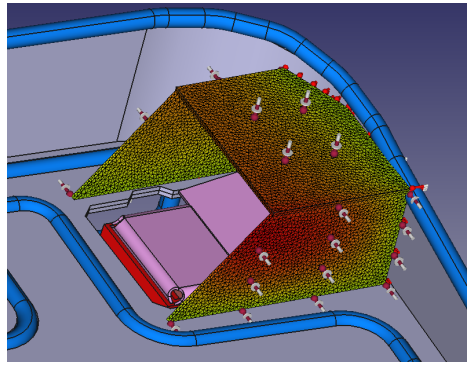
Proposed concept for cooling of CXRS plug-in AEA21:

- Vacuum windows and mirror protected by only 20s exposure to plasma.



- Shutter cooled with copper thermal straps connected to front plate.

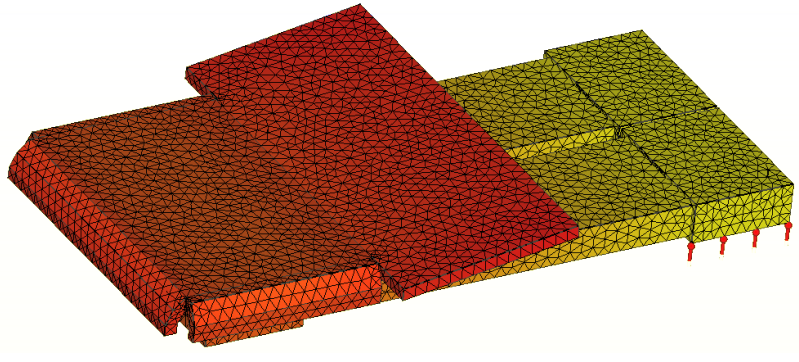
- Cover welded to front-plate to reduce load to shutter and straps.
  With copper layer, remains < 550°C for full radiating 18GJ.



- Straps protected by steel plate above shutter.
  With copper layer, remains < 300°C for 18GJ.

- Shutter and aluminium mirror remain < ~200°C for 18GJ.
  (To be measured with thermocouples).

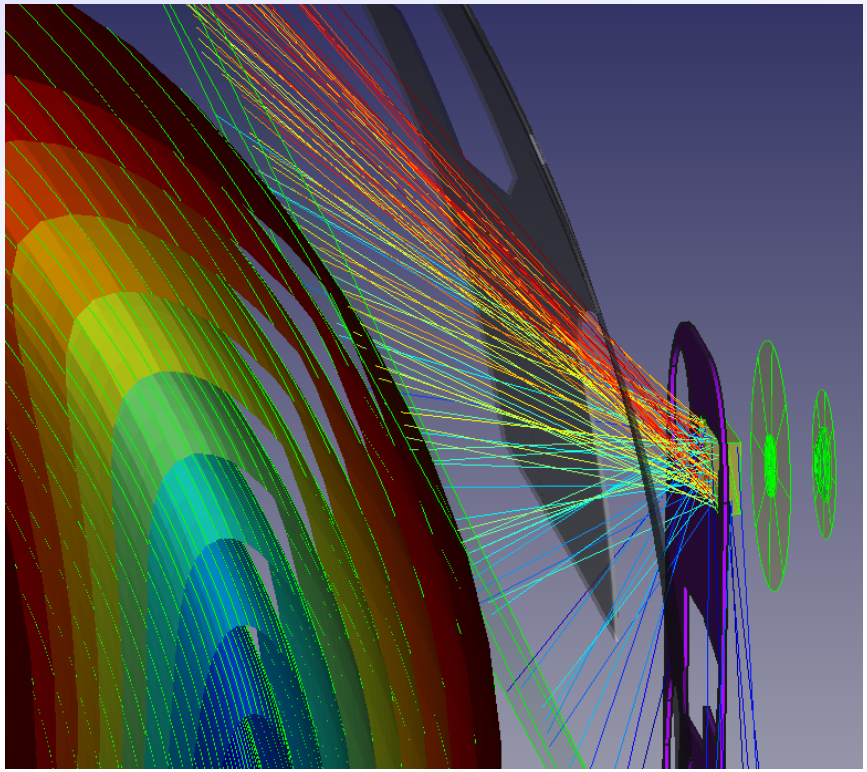
- All temperatures insignficant for 1GJ (OP2.0 / 2.1)

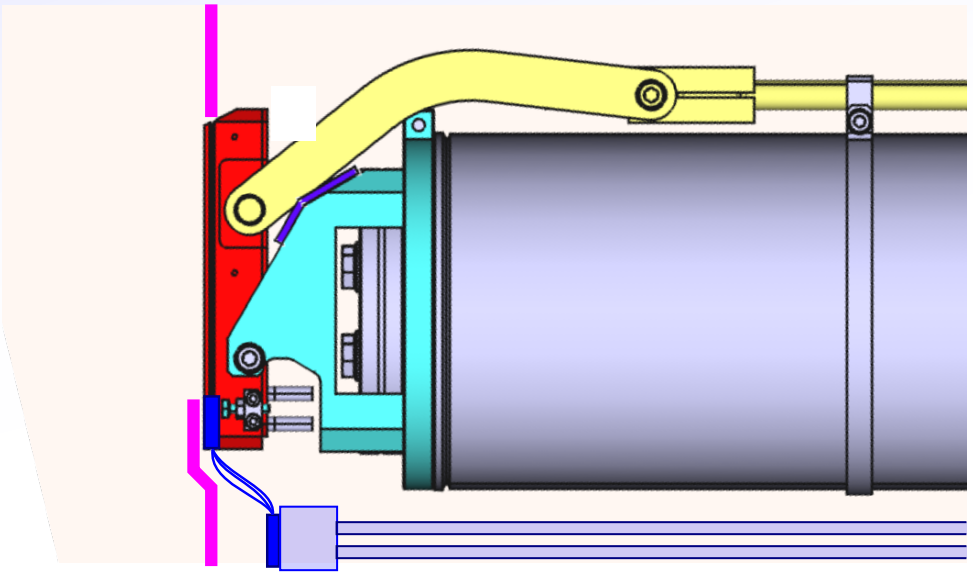


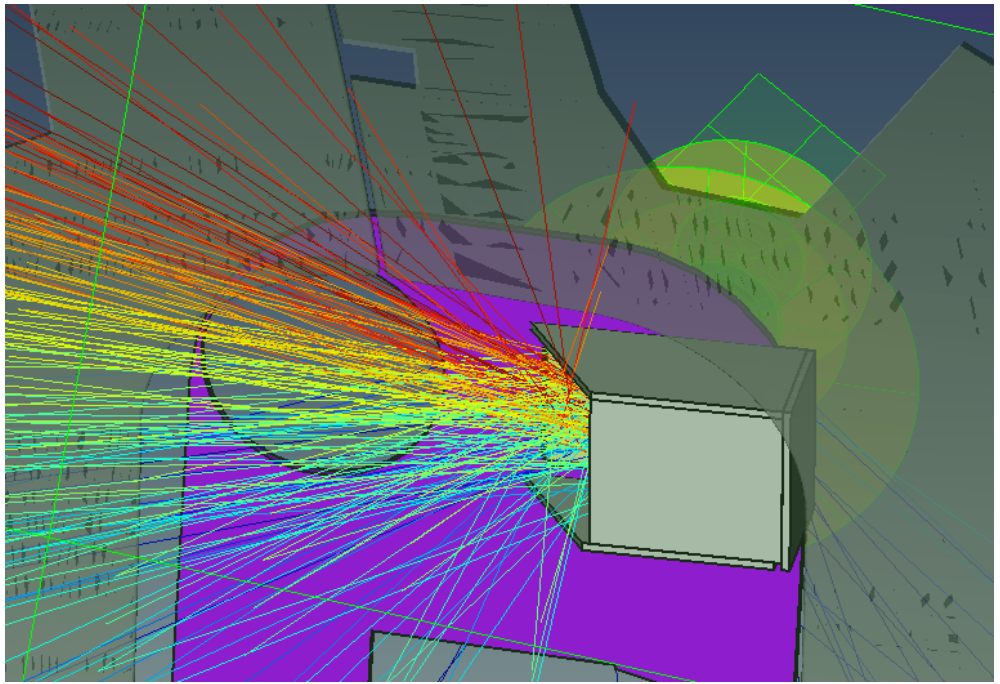
Concept advantages:
+ No water in moving parts in vessel
+ No KKL needed for QSK at AEA21.
+ No modification to AEA21 flange (feedthroughs etc)
+ No break of QSK plug-in vacuum barriers.

AEA21 - Heat load (closed)

Calculation of heat load to closed shutter from 100kW m^{-2} at LCFS is 660W



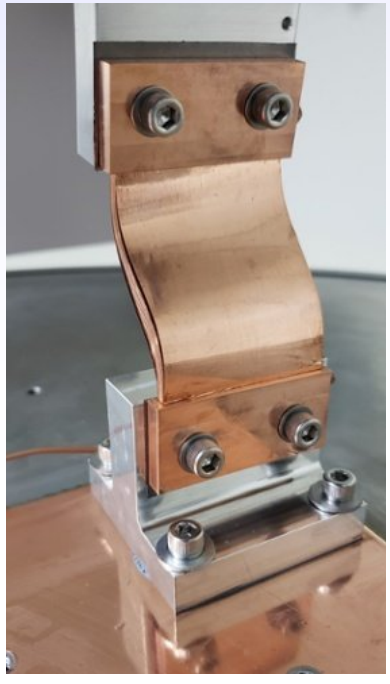


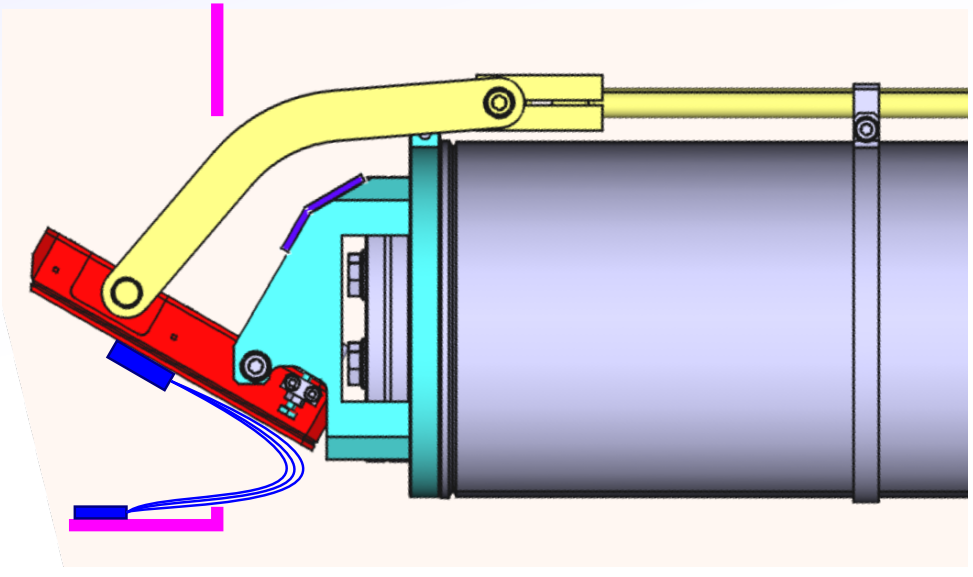


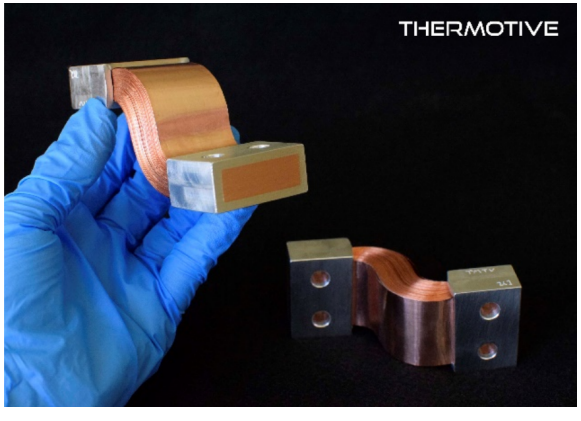
Including an outer cover as part of the front plate reduces this to 250 W

AEA21 - Shutter

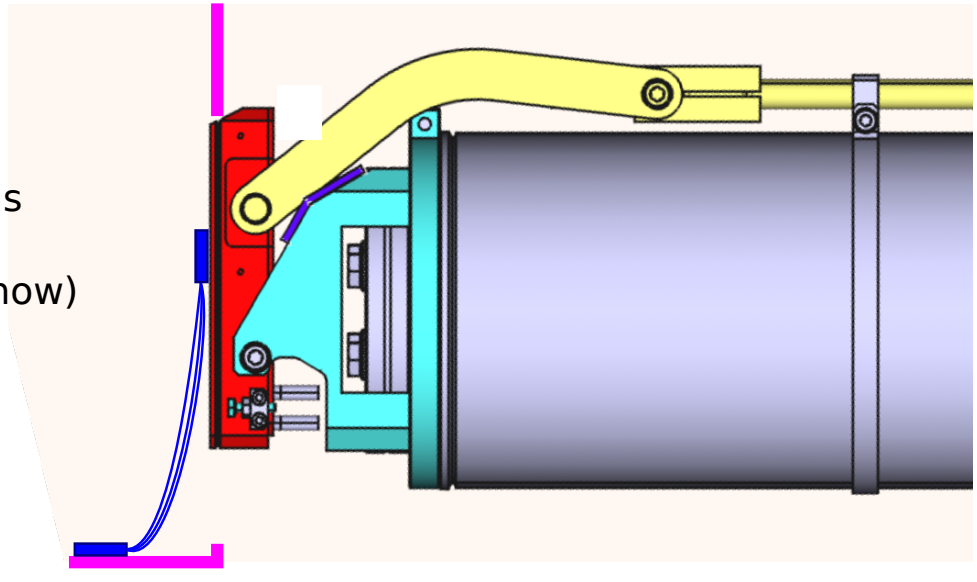
Alternatively, we could use a thermal strap:







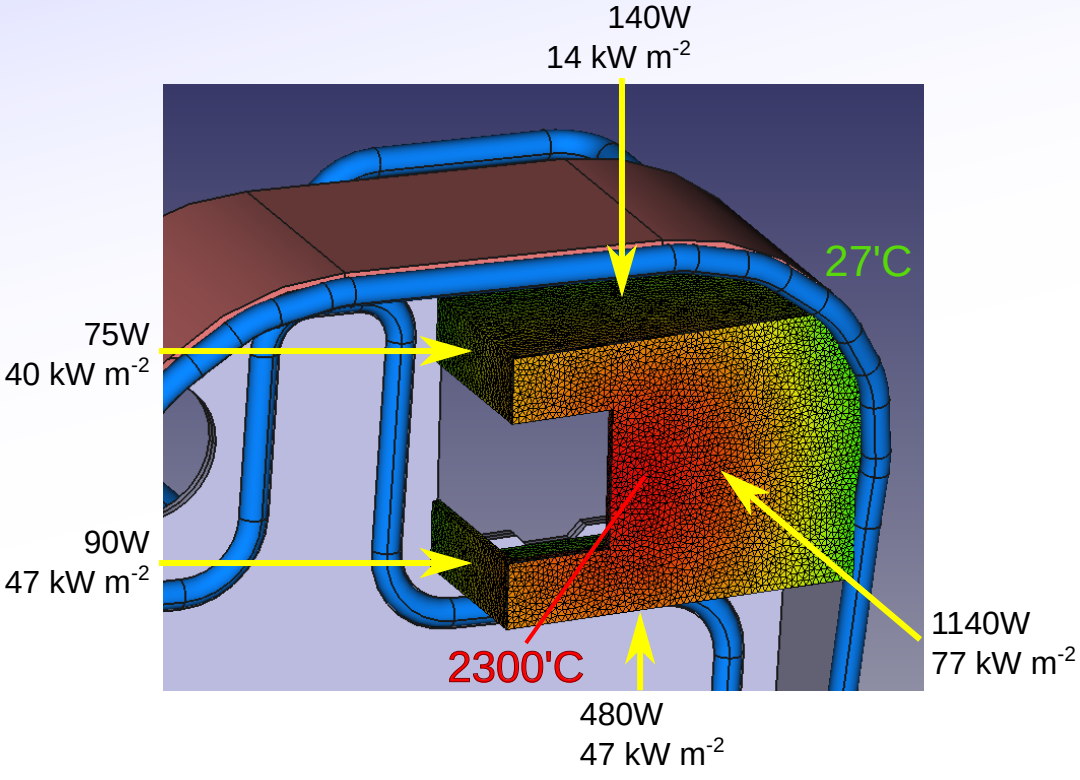
Also planned for Gas Puff Imaging mirror (A. von Stechow)

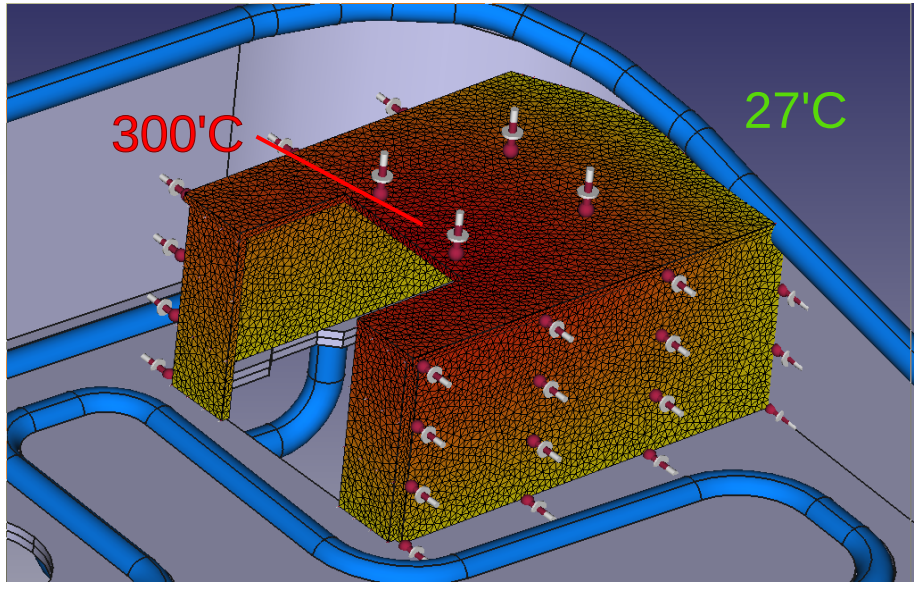


Thermal conductivity:
- Aluminium: 225 $Wm^{-1}K^{-1}$
- Copper: 450 $Wm^{-1}K^{-1}$
- Graphene: 2500 $Wm^{-1}K^{-1}$

AEA21 - Cover

Ray traced 100kW m-2 at LCFS to cover.
FEM model for 3mm thick SS --> Too hot, needs some kind of copper layer or water pipes.





3mm SS: 43 W m^{-1} K^{-1} --> 2300'C

3mm Copper: 300 W m^{-1} K^{-1} --> 300'C