MKI-Cool RF Damper Cooling: Interlock Strategy

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Acknowledgements

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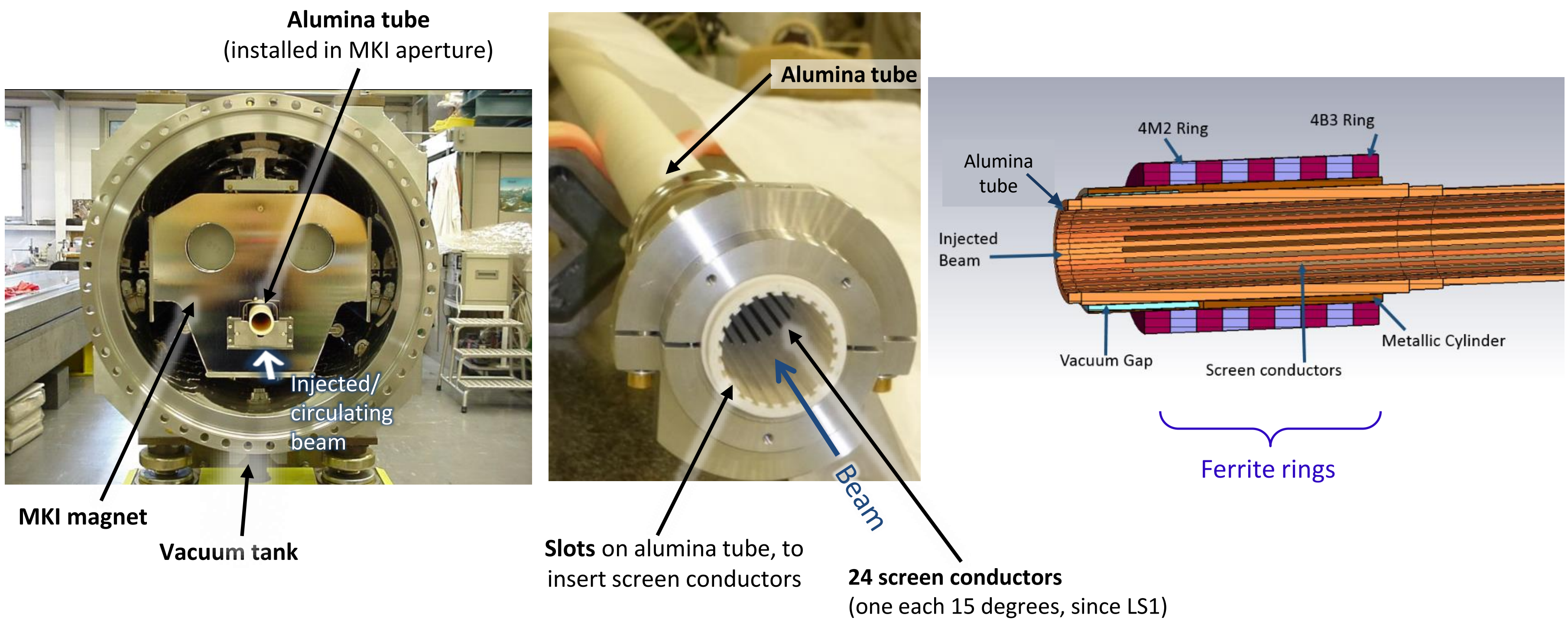
Beam Induced Heating - Reminder

- To reduce beam induced heating, MKIs refurbished during **LS1** have 24 screen conductors (c.f. 15 before LS1), inserted in slots on the inside of an alumina tube
- An alumina tube is installed in the aperture of each MKI kicker magnet
- A set of ferrite rings is installed on each end of the alumina tube

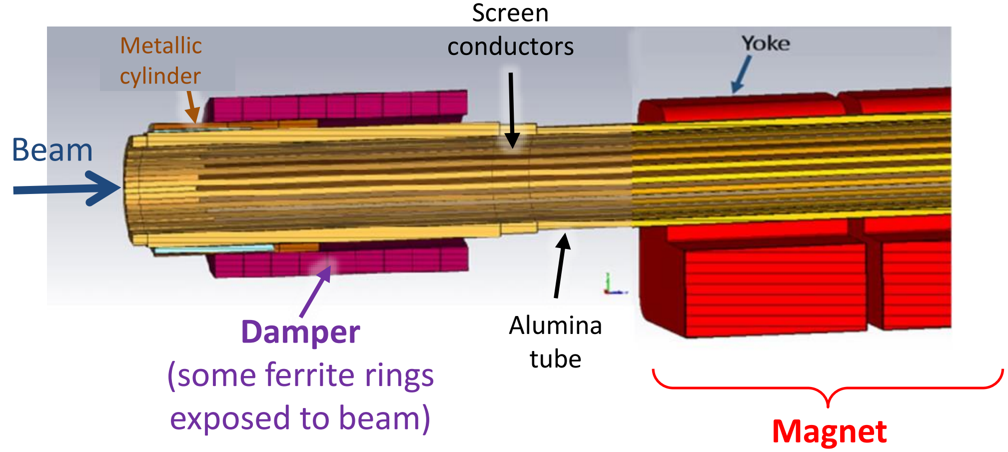


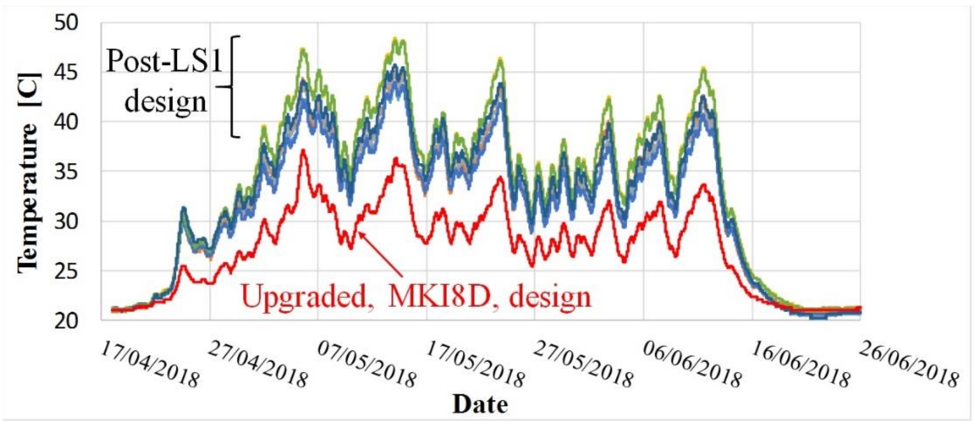
- Highly non-linear beam induced power deposition in the ferrite yoke of an MKI
- With HL-LHC type beams, the RF damper and part of the ferrite yoke would reach its Curie temperature (temporary loss of magnetic properties)

MKI8D: upgraded MKI

Upgraded MKI installed, in Point 8, during **YETS 2017/18** (MKI8D):

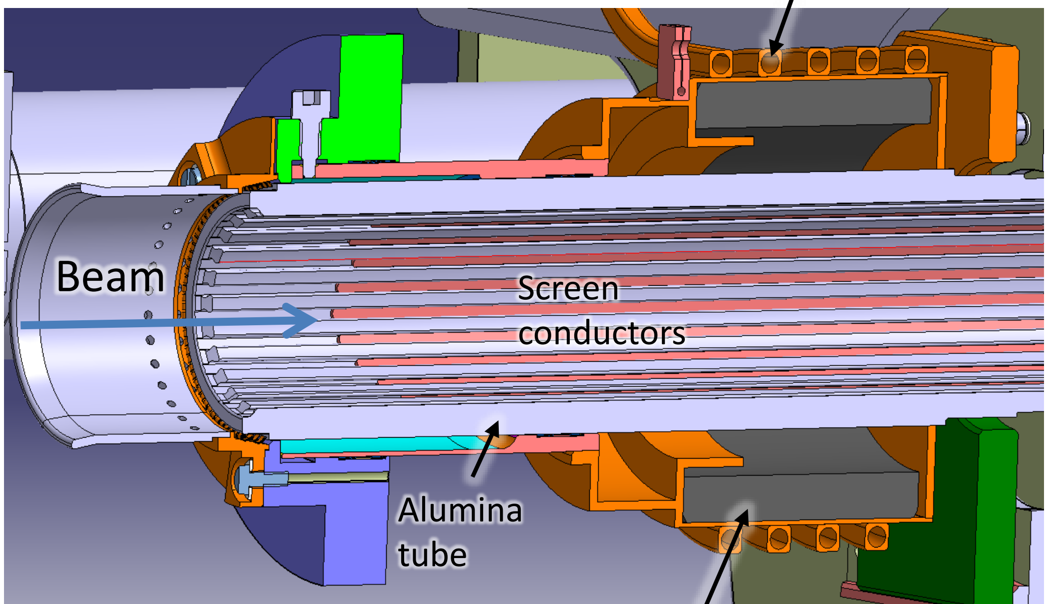
- Redesigned ferromagnetic rings (damper), on the upstream end of the alumina tube, outside of the magnet aperture, **relocates beam induced power from the ferrite yoke to the damper**
- **RF damper is not at pulsed high voltage**
- Reduced yoke temperature w.r.t. LS1 MKI's – but still need to further reduce temperatures for HL-LHC type beams

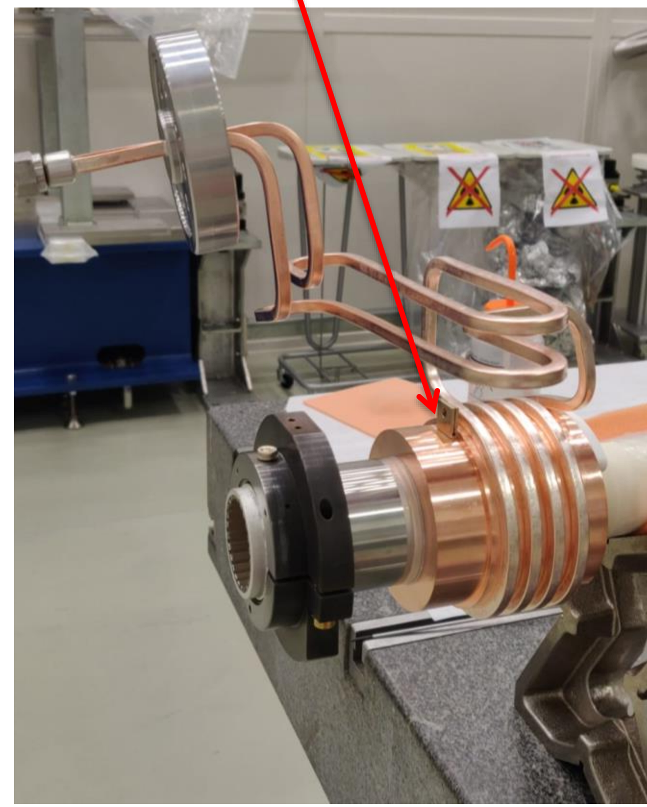




RF Damper of MKI-Cool

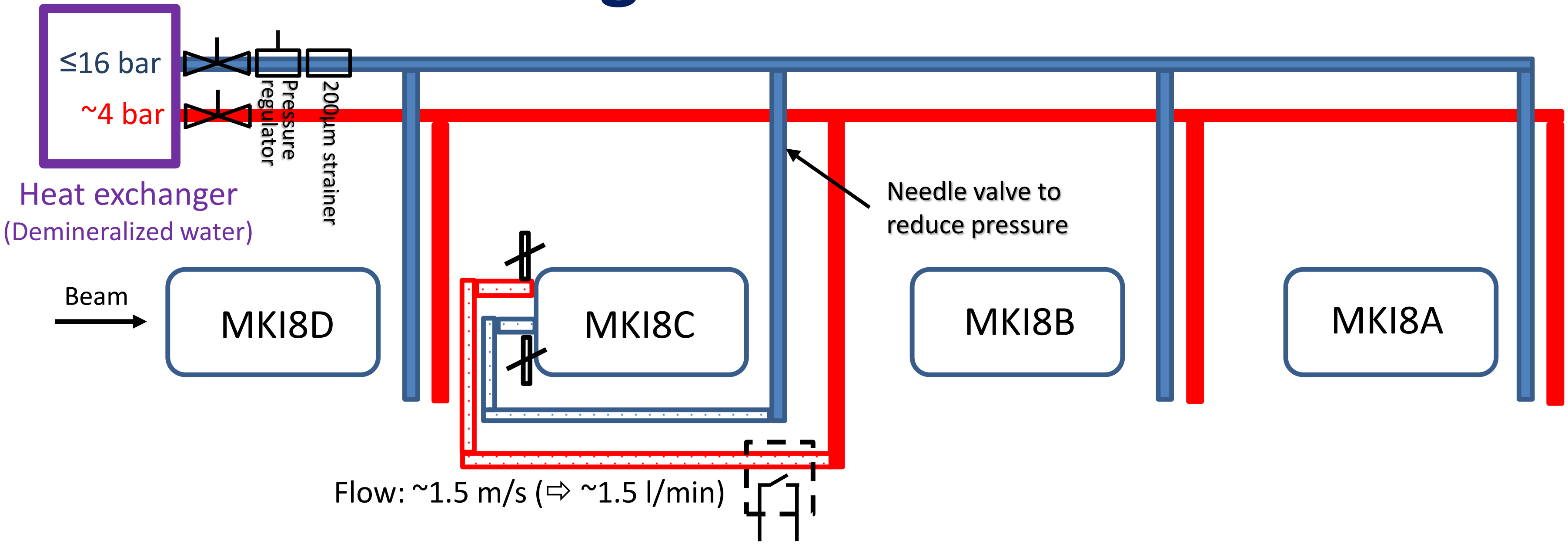
<u>MKI cool</u> = RF <u>damping</u> element + water <u>cooling</u>





- ✓ **MKI-Cool is expected to be significantly below the ferrites Curie temperature for HL-LHC type beams.**

MKI-Cool **cooling circuit**



Eletta **flow monitor** (with direct reading dial): with independently adjustable upper and lower flow alarm (**μ-switches**):

- Status of low-flow micro-switch (dry contact) to be readback by SY-ABT
- Status of high-flow monitor micro-switch to be readback by SY-ABT

2*PT100 on cooling pipes (outside MKI vacuum tank)

PT100 on RF damper (previous slide)

'Turbine' (analogue signal) to be installed to readback analogue signal α flow-rate (radiation resistant)

MKI-Cool Additional Interlocks (c.f. 'regular' MKIs)

Interlocks:

The low-flow micro-switch (dry contact), from the Eletta flow-monitor, will be used as an interlock:

- Prevent injection if water flow is too low (use few *s* time-constant);
- Request a beam dump if water flow is to low (to prevent possible boiling of water in cooling pipe and resulting high pressure): use few *s* time-constant. The low-flow micro-switch will be cabled to an SY-ABT PLC for requesting a beam-dump to the BIS
- The upper flow alarm will be used as a **warning**;
- Request a beam dump if RF Damper Temperature (Tube_Up) exceeds X°C e.g. 50°C (~34°C max expected): use few *s* time-constant. This temperature interlock will be implemented in the ABT PLC (a Beam dump will be requested through the BIS). Since the temperature data will be in a FESA class, it is available, in the future, to also implement as an interlock in SIS.

Note: input and output water temperatures, water flow-rate, and PT100s within MKI vacuum tank to be logged (WinCC and NXCALS).

Thank you for your attention

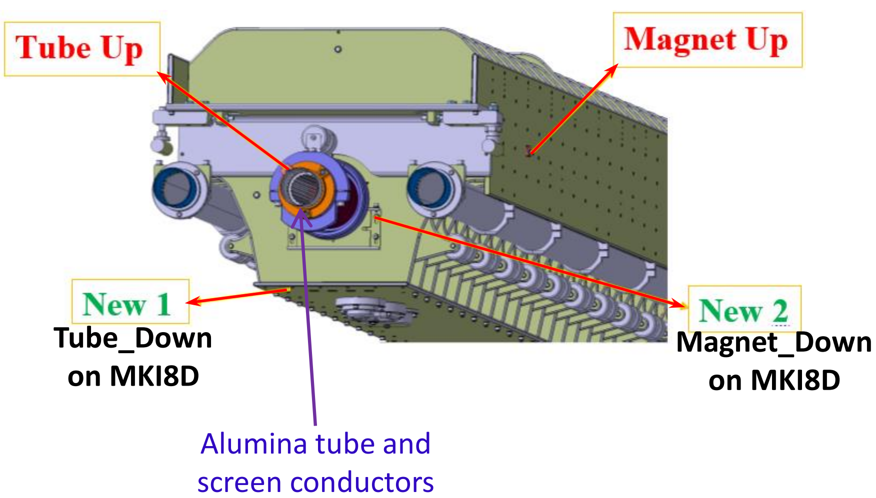
Backup Slides

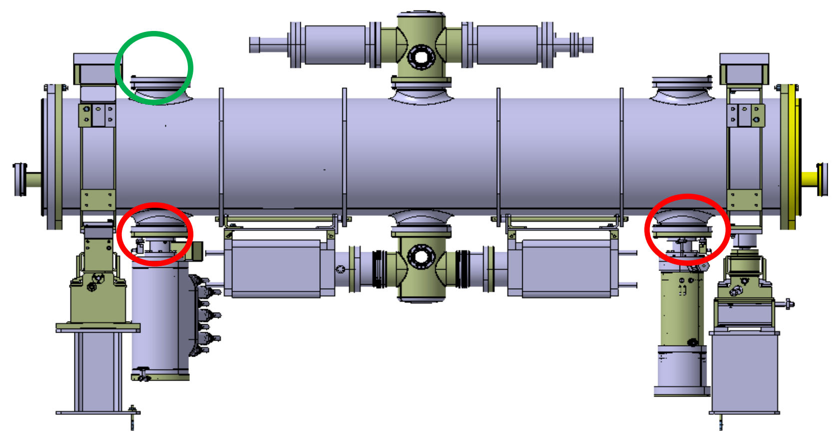
PT100 locations in MKIs

MKIs refurbished during LS1 have four PT100s under vacuum:

- Magnet_Up and Magnet_Down (on side plates)
- Tube_Up and Tube_Down (close to ferrite rings on alumina tube)

The MKI8D (MKIMA04-T09) and MKI Cool (MKIMA08-T11 -> MKI8C) have two additional PT100s installed under vacuum.

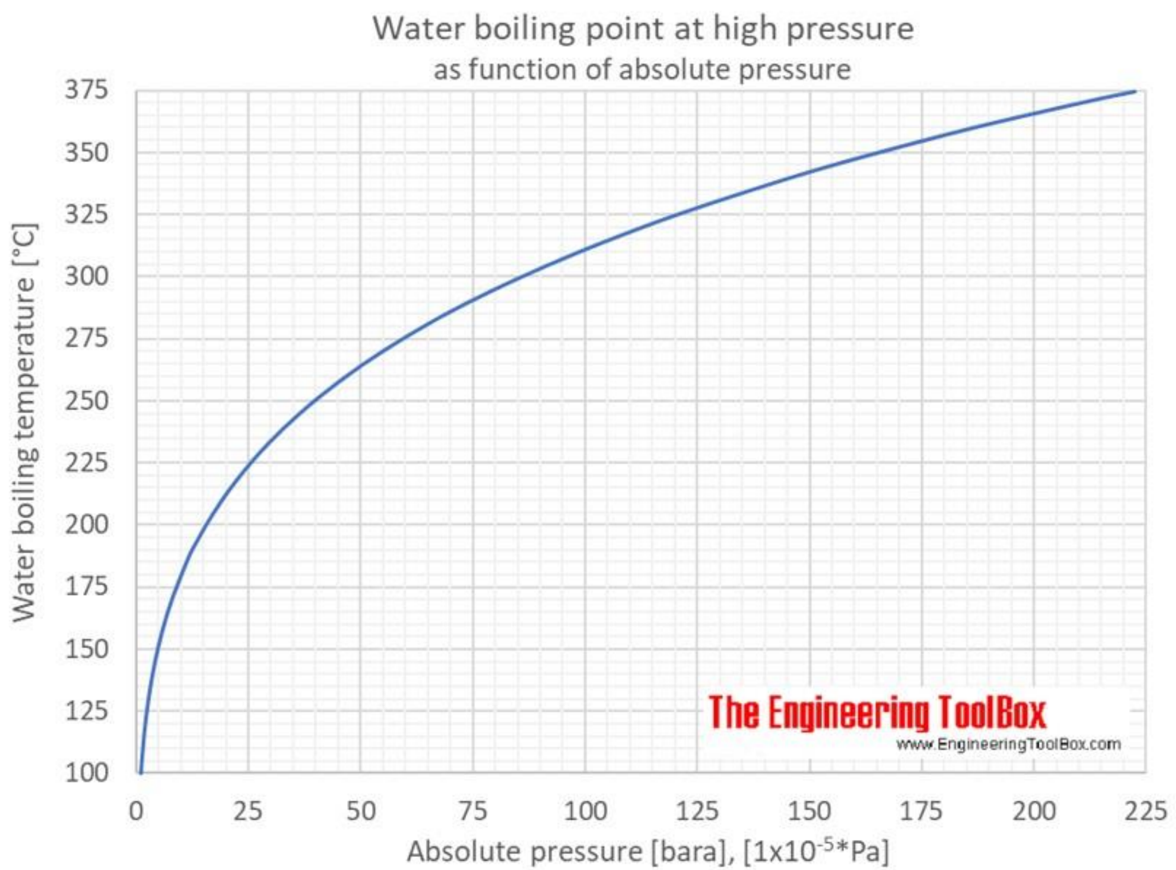




For MKI8D: measurements of only 4 PT100s could be readback/logged. 8 additional wires to UA are required for reading back of other 2 under vacuum PT100s.

MKI-Cool Readback

- 8 additional wires required to readback all PT100s under vacuum
- 8 additional wires required to readback both PT100s outside vacuum (cooling water temperature)
- 5 additional wires required to readback status of flow micro-switches
- 2 additional wires for readback of analogue flow-rate


Water boiling point at high pressure
as function of absolute pressure
375
350
325
300
275
250
225
200
175
150
125
100
Water boiling temperature [°C]
0
25
50
75
100
125
150
175
200
225
Absolute pressure [bara], [1x10-5*Pa]
The Engineering ToolBox
www.EngineeringToolBox.com

Selected Comments on https://edms.cern.ch/document/2010448/1.1

Accepted with Warning by WENNINGER Jorg (BE-OP)
Ok - clearly an important component test

I am however surprised to discover a SIS interlock that was never discussed before with OP. As an interlock that is supposed to dump the beam after passing through many SW layers, there is a significant risk of false dumps due to controls issues. Such an interlock requires a lot of precautions in the implementation, in particular timeout periods that should typically be set to 20 seconds, possibly with fail-unsafe logic in case of signal absence. It is not clear from the document whether this is consistent with the requirements.

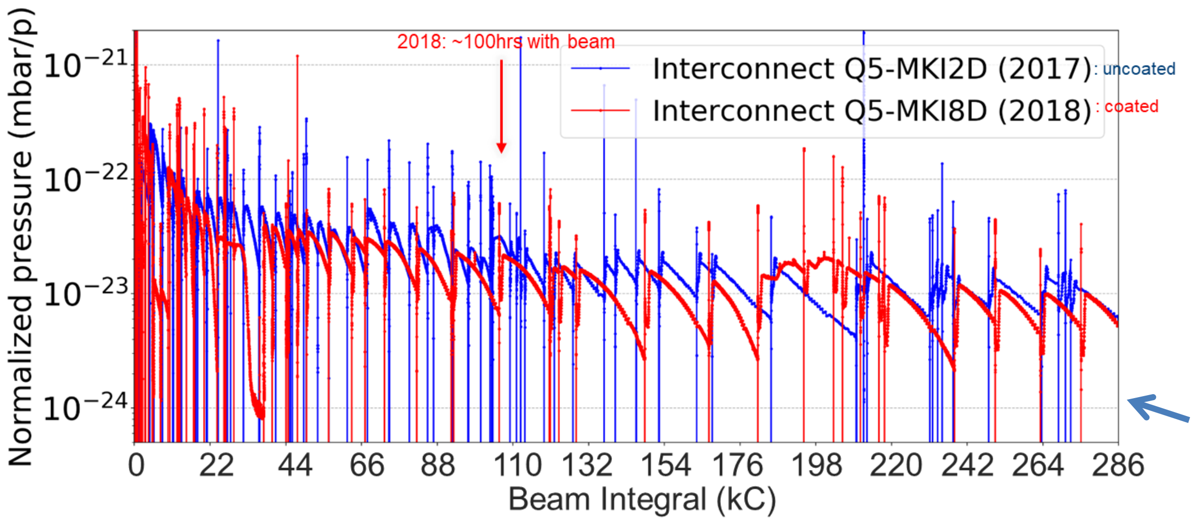
In reply to the comment from Jorg Wenninger:
Thanks for your comment.
A FESA class will be created to push the temperature data to NXCALS. Hence, the temperature interlock on the RF damper will be implemented in the ABT PLC and we will request a Beam dump from the PLC (through the BIS). In any case, this is a ¿secondary interlock¿ as the primary interlock is the water flow.
Since the temperature data is in the FESA class, it is available if, in the future, we want to implement the interlock in SIS.

In reply to **Markus ZERLAUTH**:
Thanks for your comments and corrections.
Impedance wise the foreseen 3-4 intensity steps should be sufficient to qualify the expected performance of the MKI cool. However, even though the alumina tube is coated internally with Cr2O3 (as per the MKI8D exchanged during YETS 2017/2018) dynamic vacuum could initially limit the intensity ramp up. Lotta METHER gave a summary of the MKI8D beam conditioning at the 29th SPS MPC (in the context of beam conditioning the low impedance MKP-L). Her presentation is here:
https://indico.cern.ch/event/1208316/contributions/5081442/attachments/2526205/4345060/SPS_MPC_20221011_SPS_scrubbing_2023.pdf

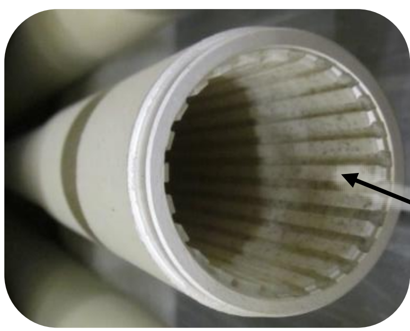
Comment from Impedance Working Group:
As already stated in the previous version of this document, the Impedance Working Group supports the installation of the MKI-COOL.

Transverse beam dynamics studies were performed by Nicolas Mounet and showed that the impact of the MKI-COOL on transverse stability is expected to be negligible (https://indico.cern.ch/event/881273/). This point and its reference should be added to the document in Chapter 5. Measurements of the transverse impedance were not performed on this modified MKI-COOL, but they will be performed on the next MKI-COOL to be modified in the upcoming weeks

Cr_2O_3 coating in MKI8D, installed in YETS 2017/2018



- Before YETS:
  Pressure in MKI8D interconnect used to be a factor of ~3 (2012, 2015 and 2017) and ~12 (2016) higher than that of Q5-MKI2D
- After YETS:
  This factor is not observed anymore.
  No other vacuum modifications were done, so pressure reduction is attributed to Cr_2O_3 coating 👍

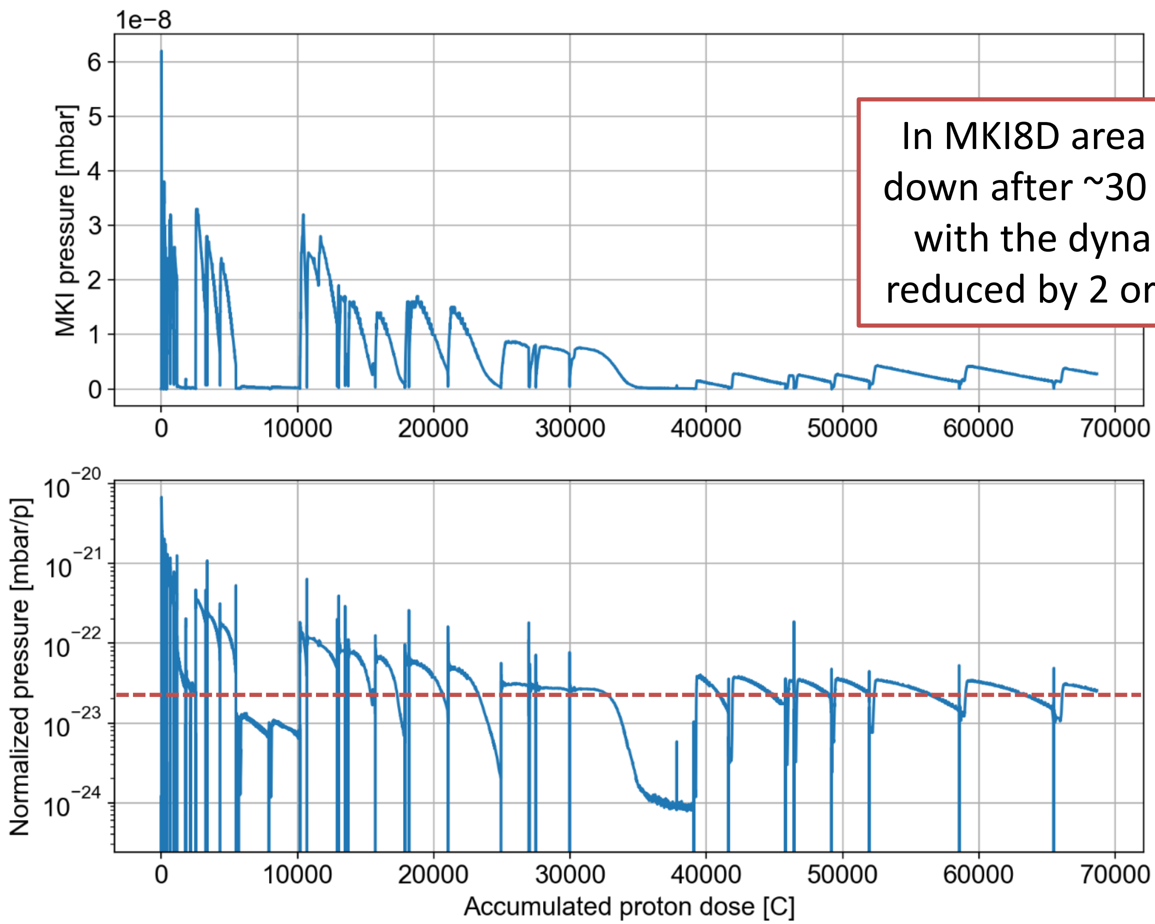


Alumina tube with **Cr_2O_3 coating** on the inside

Expected conditioning of coated alumina tube

From: https://indico.cern.ch/event/1208316/contributions/5081442/attachments/2526205/4345060/SPS_MPC_20221011_SPS_scrubbing_2023.pdf

- With current MKP-L, no evident conditioning after installation in 2014, nor after LS2
- Cr_2O_3 coated alumina also used in MKI8D, installed in LHC during YETS 17/18
  - Clear conditioning visible after installation in 2018

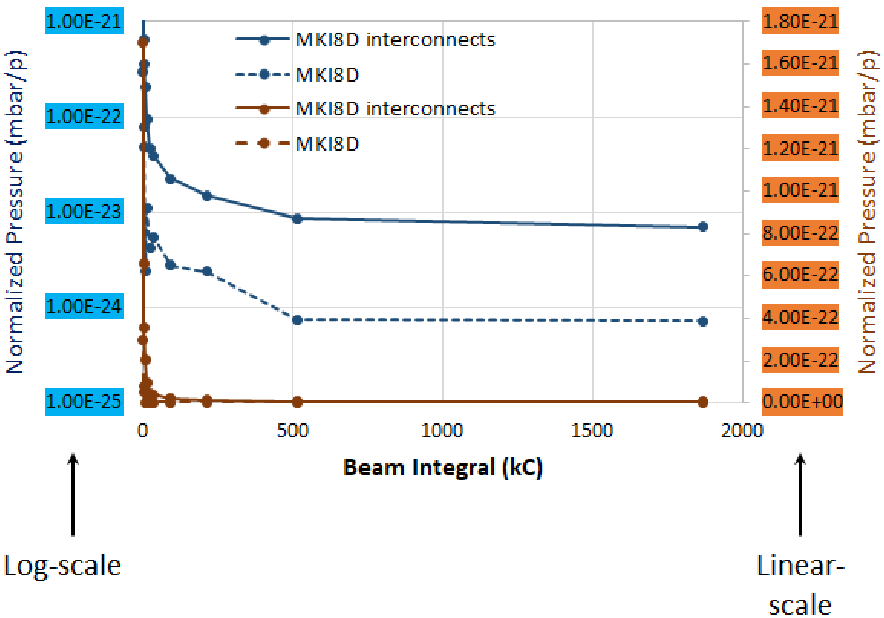


In MKI8D area scrubbing slowed down after ~30 kC of proton dose, with the dynamic pressure rise reduced by 2 orders of magnitude

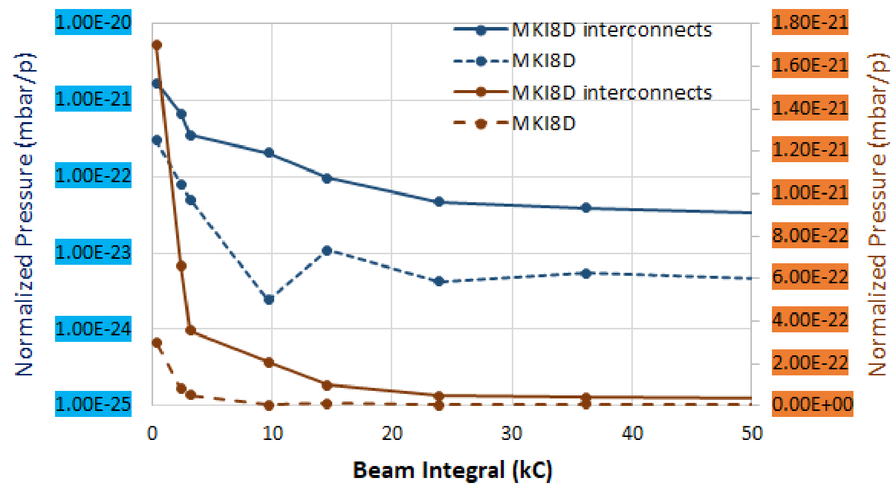
From: https://indico.cern.ch/event/1195594/contributions/5086753/attachments/2524482/4341538/MKICool-Conditioning_LIBD_11102022.pdf

Normalized pressure for MKI8D interconnects during 2018

Following plots use the maximum of the interconnects on both sides of MKI8D:



- In general, the **MKI8D magnet normalized pressure is approximately an order of magnitude below the interconnect pressure.**
- **Very rapid initial on MKI8D (order of magnitude reduction of interconnect normalized pressure with 10kC)**



From: https://indico.cern.ch/event/1195594/contributions/5086753/attachments/2524482/4341538/MKICool-Conditioning_LIBD_11102022.pdf

From "Injection Considerations for Scrubbing Run"

Prior to Scrubbing:

- Request that VSC increase "digital interlock" of Penning gauge, on each MKI tank, as follows:

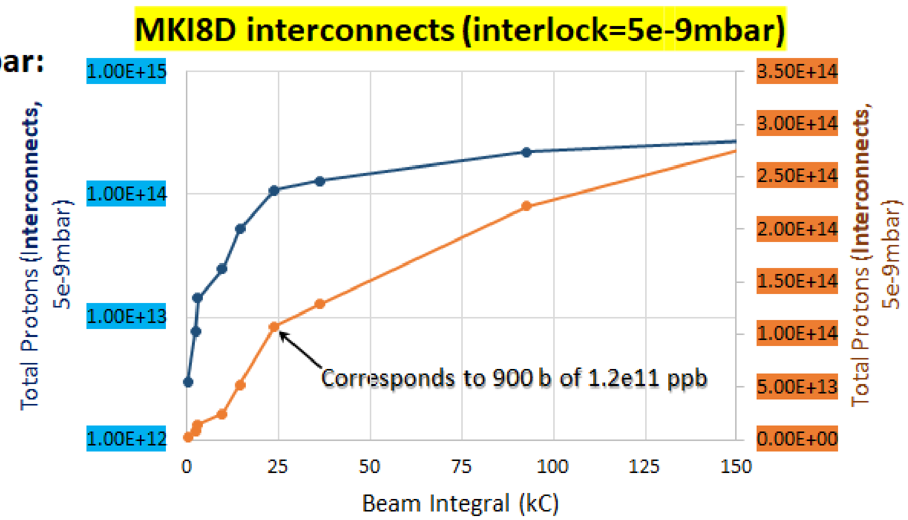
Seuil Bas : 1e-8 mbar ⇨ 4e-8 mbar

Seuil Haut: 2e-8 mbar ⇨ 5e-8 mbar

During Scrubbing:

- Controlled increase of SIS interlock thresholds for MKI **interconnects**, from **5e-9 mbar** to **5e-8 mbar** (maximum)
- Controlled increase of SIS interlock thresholds for MKI **tanks**, from 2e-9 mbar to **5e-9 mbar** (maximum)

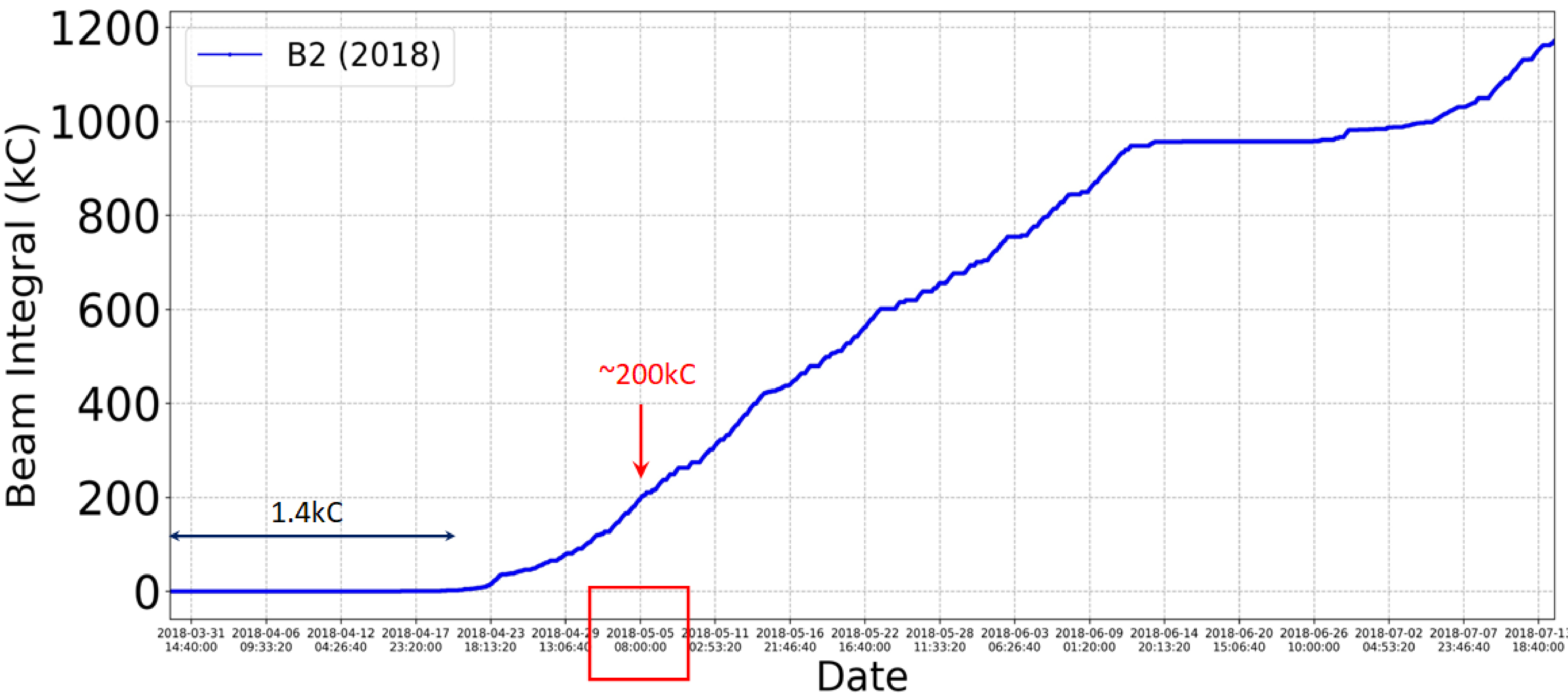
Plot based on interlock level of 5e-9mbar:



From: https://indico.cern.ch/event/1195594/contributions/5086753/attachments/2524482/4341538/MKICool-Conditioning_LIBD_11102022.pdf

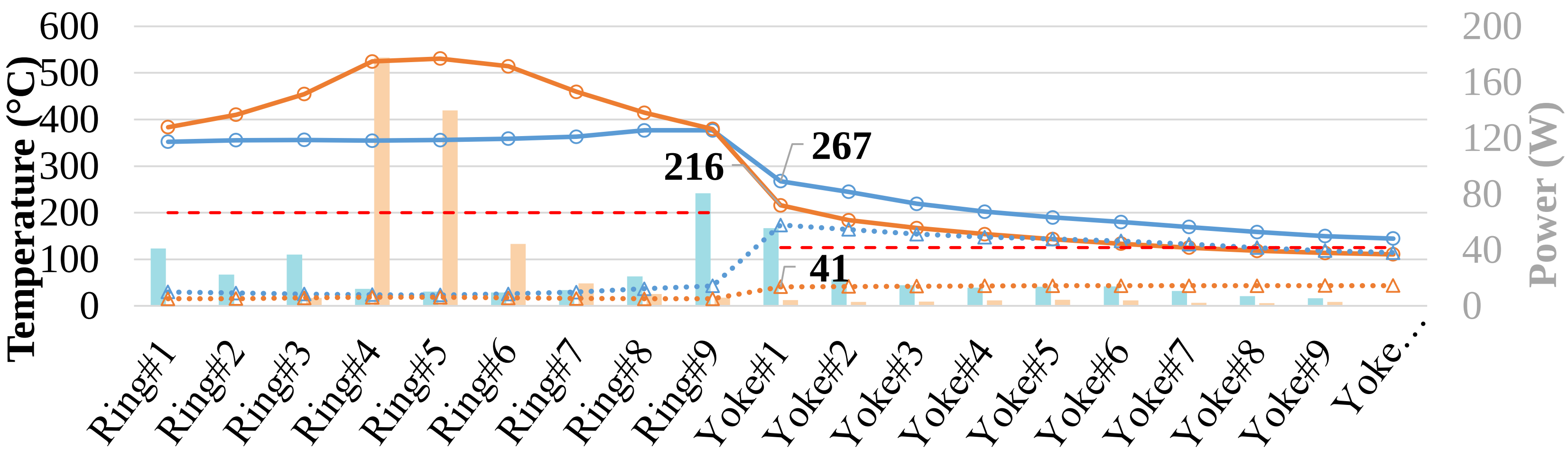
Beam 2 Integral vs. Time for start-up of 2018

MKI2: Start time = 2017-04-29 00:00:00, End time = 2017-10-01 23:59:59, Start/End beam1 elapsed time = 0/1553.8hrs (0kC since 2017-04-29 / 1496.7 kC). Intensity>1e12
MKI8: Start time = 2018-03-30 00:00:00, End time = 2018-07-14 23:59:59, Start/End beam2 elapsed time = 0/1135.5hrs (0kC since 2018-11-02 / 1174.9 kC). Intensity>1e12



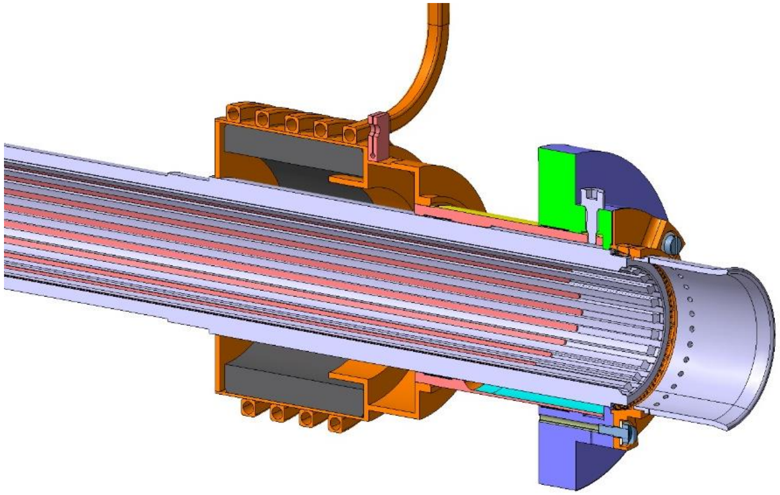
Slide Courtesy of L. Vega Cid (PhD thesis defense: 15/1/2021)

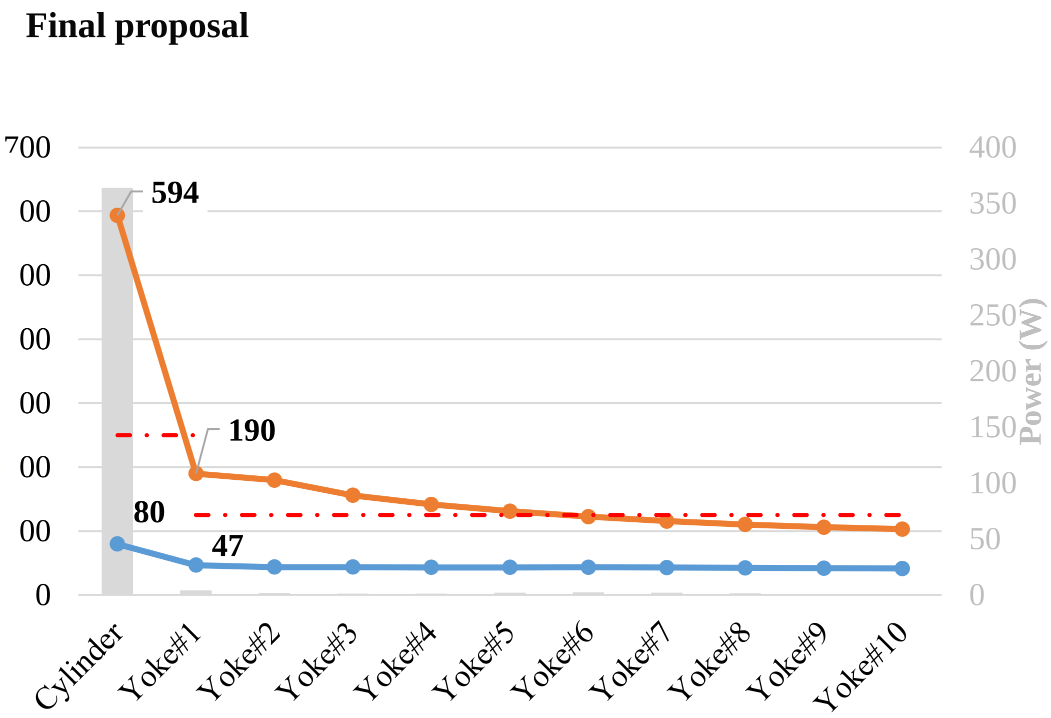
Cooling ferrite rings with reduced overlap length



- **Decision**: Combined solution of reducing the overlap length and installing a cooling system around the rings.

Slide Courtesy of L. Vega Cid (PhD thesis defense: 15/1/2021)





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15/01/2021