
MAX IV

Experience with the Vacuum System for the First Fourth Generation Light Source: MAX IV

Eshraq AL-Dmour, Marek Grabski, Karl Åhnberg

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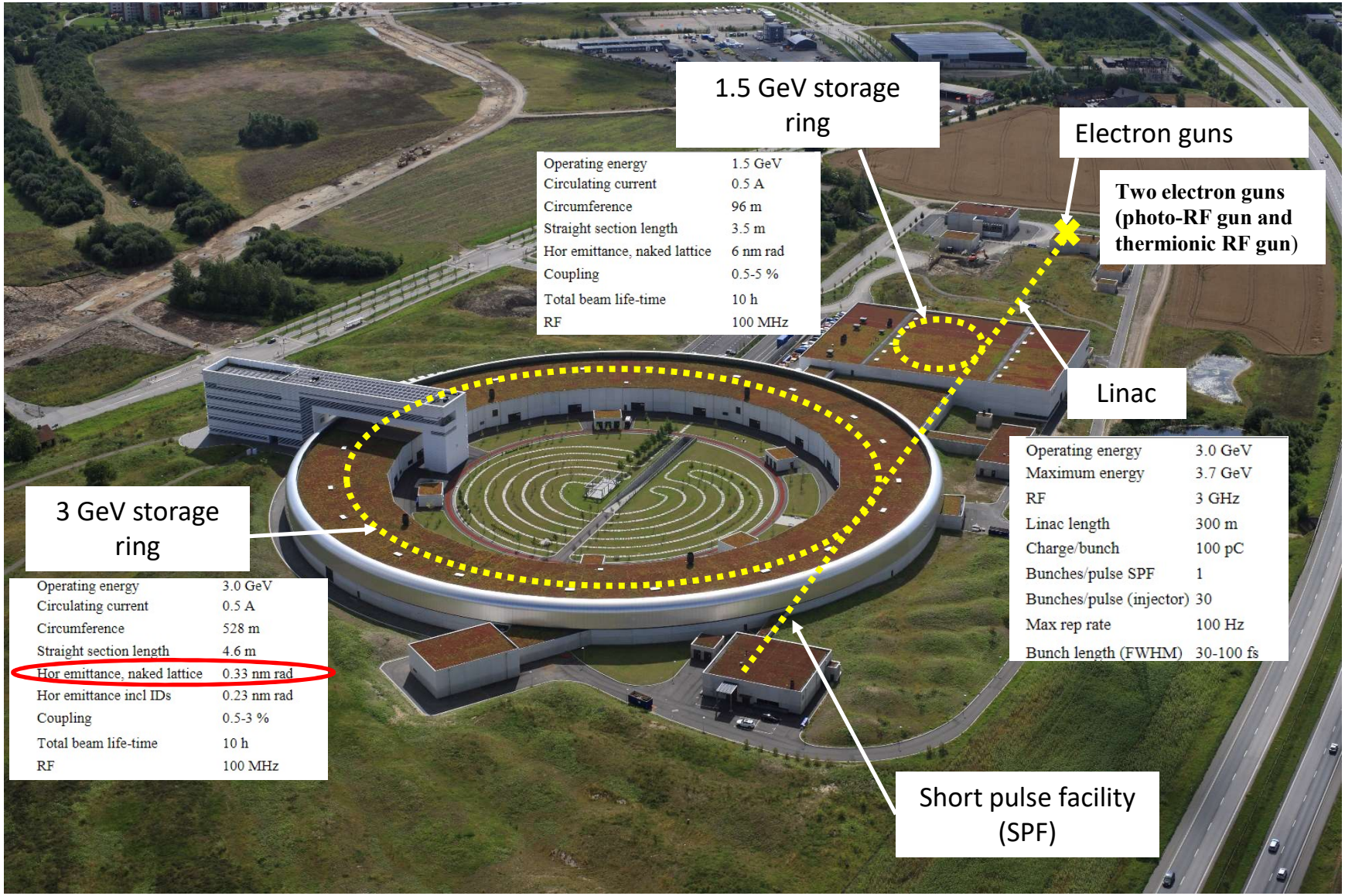
Outline

- MAX IV Facility
- Experience of the vacuum system of the 3 GeV storage ring of MAX IV:
  - Design.
  - Production
  - Installation.
  - Operation.
- Conclusion


The MAX IV facility

The MAX IV facility




3 GeV storage ring vacuum system:
general layout
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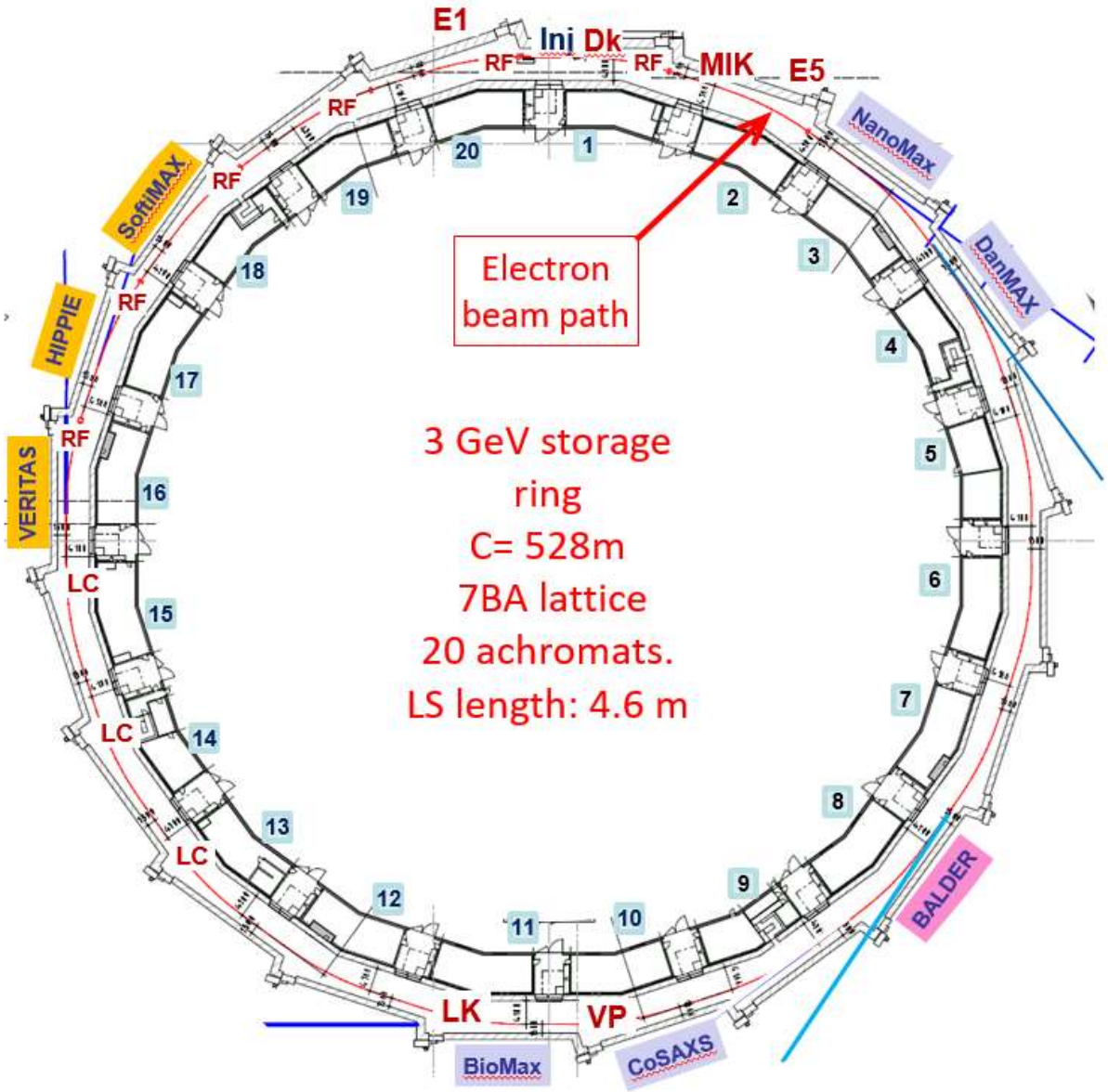
The 3GeV storage ring layout



- Inj: injection straight
- RF: 100 MHz cavities
- LC: 300 MHz Landau cavities
- E1, 5: emittance/diagnostics beamlines.
- DK: dipole kicker.
- MIK: multipole Kicker.
- LK: longitudinal kicker.
- VP: vertical pinger.

Apple undulators

In vacuum undulators

In vacuum wiggler

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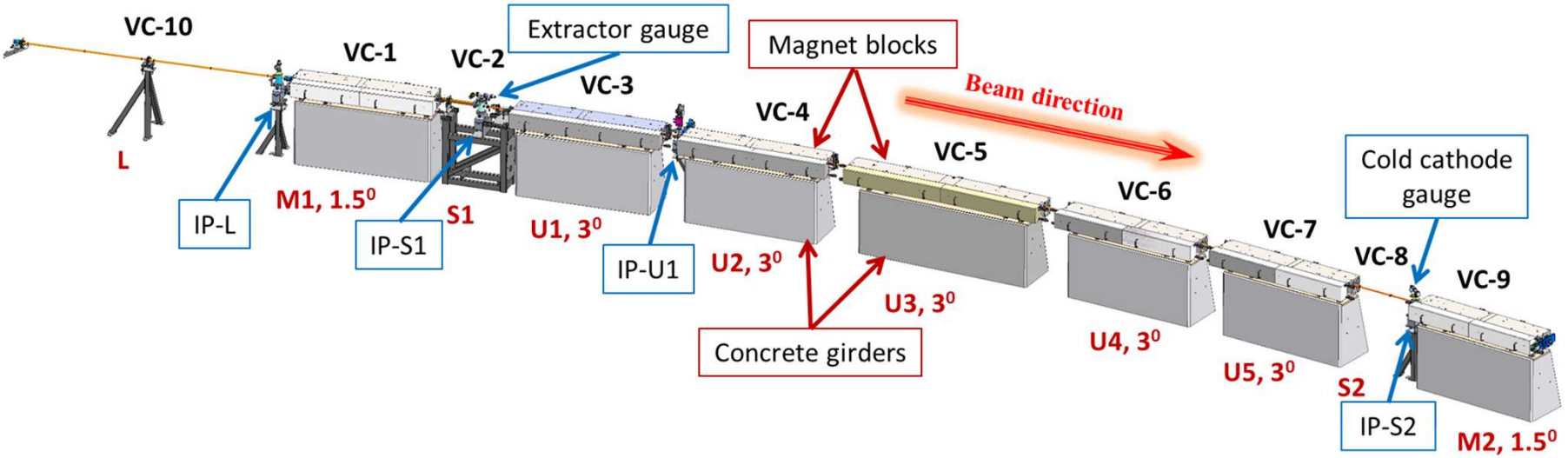
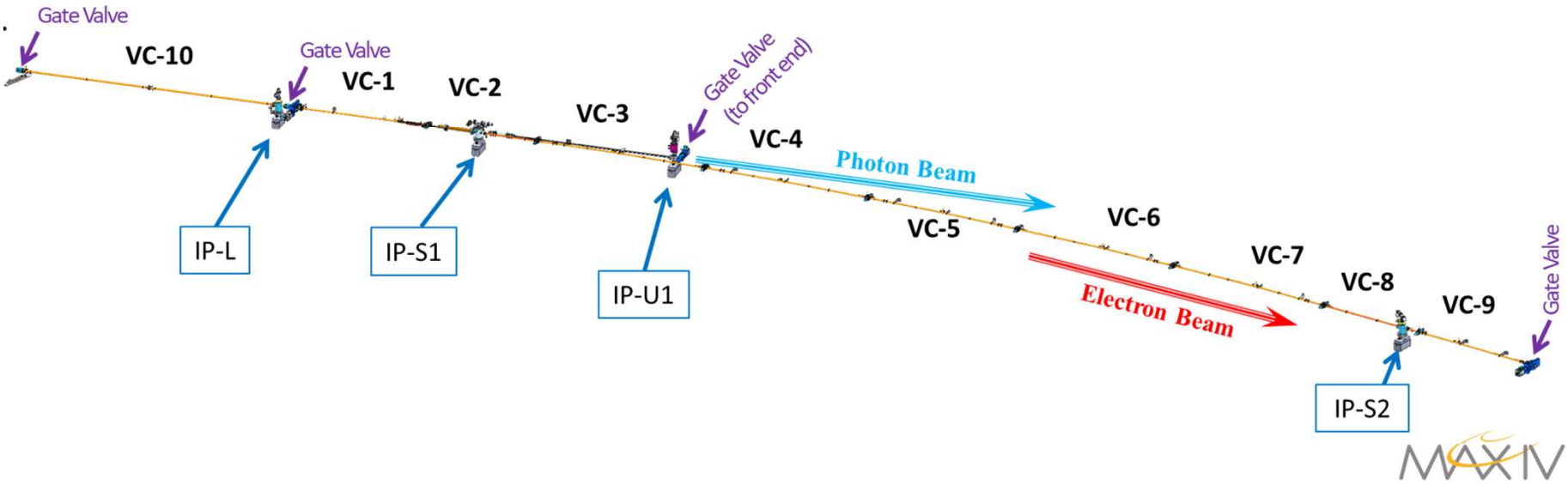
3 GeV achromat layout





3 GeV storage ring vacuum system: **chambers design & production**

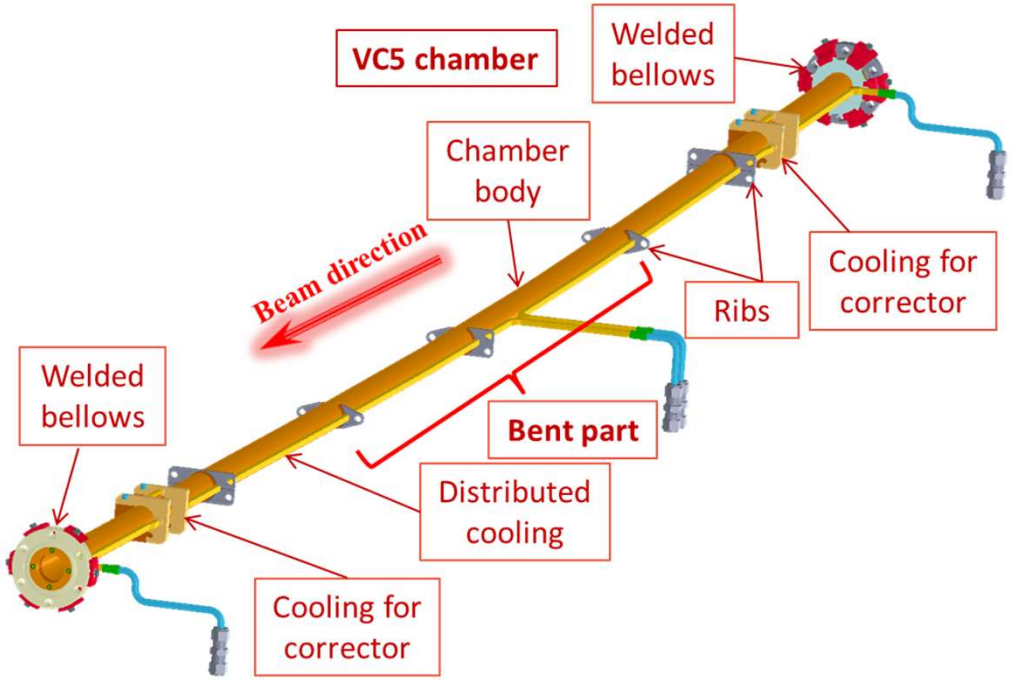
Chambers design

Design challenges:

- Extraction of the photon beam.
- Avoid interferences with other systems.
- Provide cooling for the chambers in tight areas.
- Guarantee the mechanically stability of the BPM.
- NEG coating.
- Installation.
- Standardization.

To overcome the challenges several studies, FEA and prototyping being made.

Vacuum Chambers Design



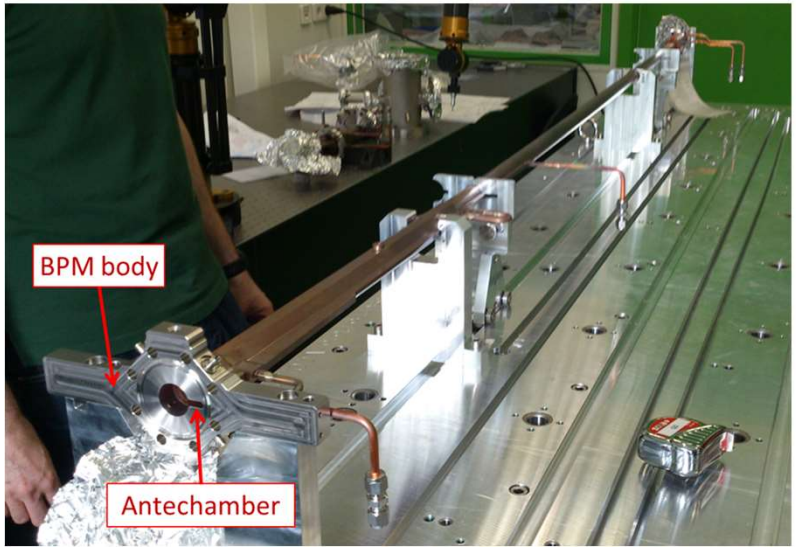
Material: oxygen-free silver-bearing copper

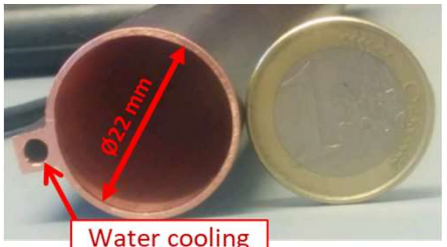
Inside diameter:	**22 mm,**
Wall thickness:	**1 mm**
chamber length:	**2.5 m,**

Bent part

Arc length:	**1 m,**
Bending angle:	**3^0,**
Bending radius:	**19 m.**

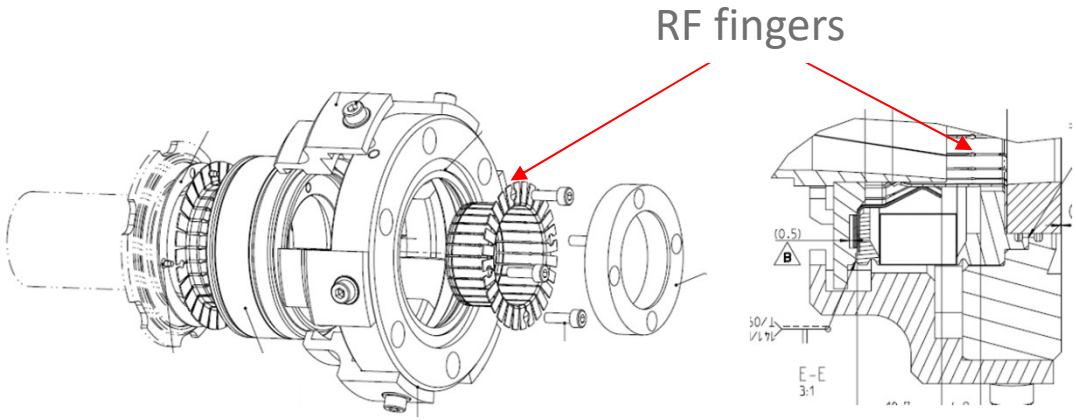
NEG-coated.

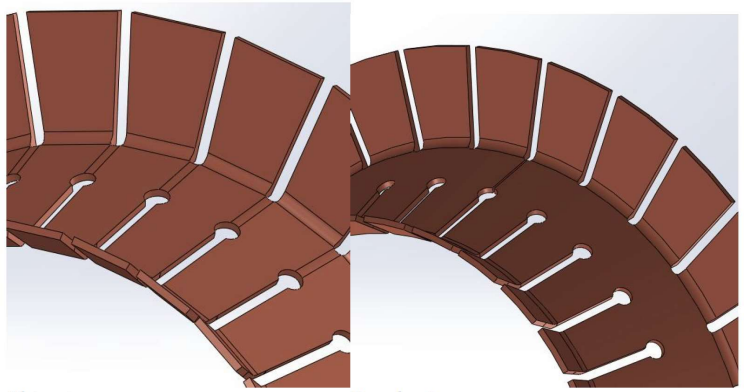




Example of FEA during design stage:

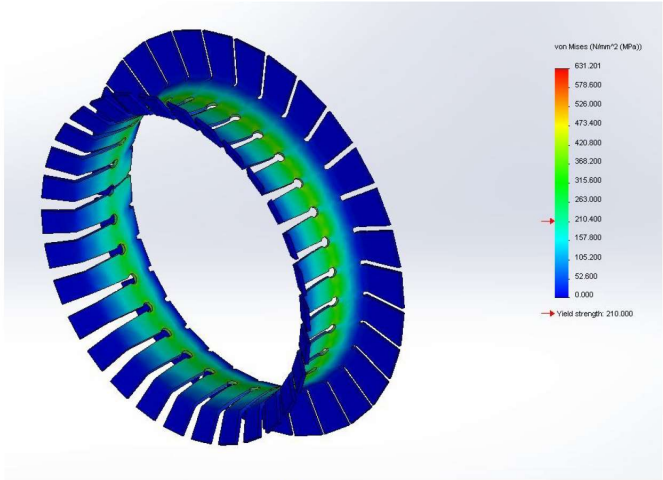
optimization of the RF fingers: shape, number and pre-stress force.





Flat springs *Round springs*

Spring configuration	Pre-stress displacement [mm]	Pre-stress force [N]	Stress [MPa]
30 spring finger, flat	0.1	0.8-1	252
	0.25	2.0-2.7	630
	0.4	3.9-4.3	1000
15 spring finger	0.1	1.4-1.6	307
	0.25	3.4-4.1	767
	0.4	5.5-6.5	1230
30 spring finger curved	0.1	1.1-1.6	290
	0.25	2.7-4.0	730
	0.4	4.4-6.4	1170



0,25mm pre stress resulting in 630MPa

Courtesy: Karl Åhnberg

Chamber production and coating

- Production was done by one supplier.
- NEG coating was done by the chamber's supplier and at CERN and the ESRF.
- Several production processes were included:
  - **Machining** of the chamber parts: flanges, bellows, bellows sleeves, ribs, BPM blocks, cooling tubes …etc.
  - **Vacuum brazing** of stainless steel flanges to transition copper sleeves of the bellows, brazing of the stainless steel ribs to copper transition…etc.
  - **TIG welding**: flanges to the chamber body, ribs assembly to the chamber body…etc.
  - **Electron beam welding** of the cooling tubes to the chamber body.
  - **Bending** of chambers body to the correct radius of curvature.
  - **Vacuum cleaning.**
  - **Visual inspection and dimensional check.**
  - **Cooling and vacuum testing.**
  - **NEG coating**


3 GeV storage ring vacuum system:
Installation
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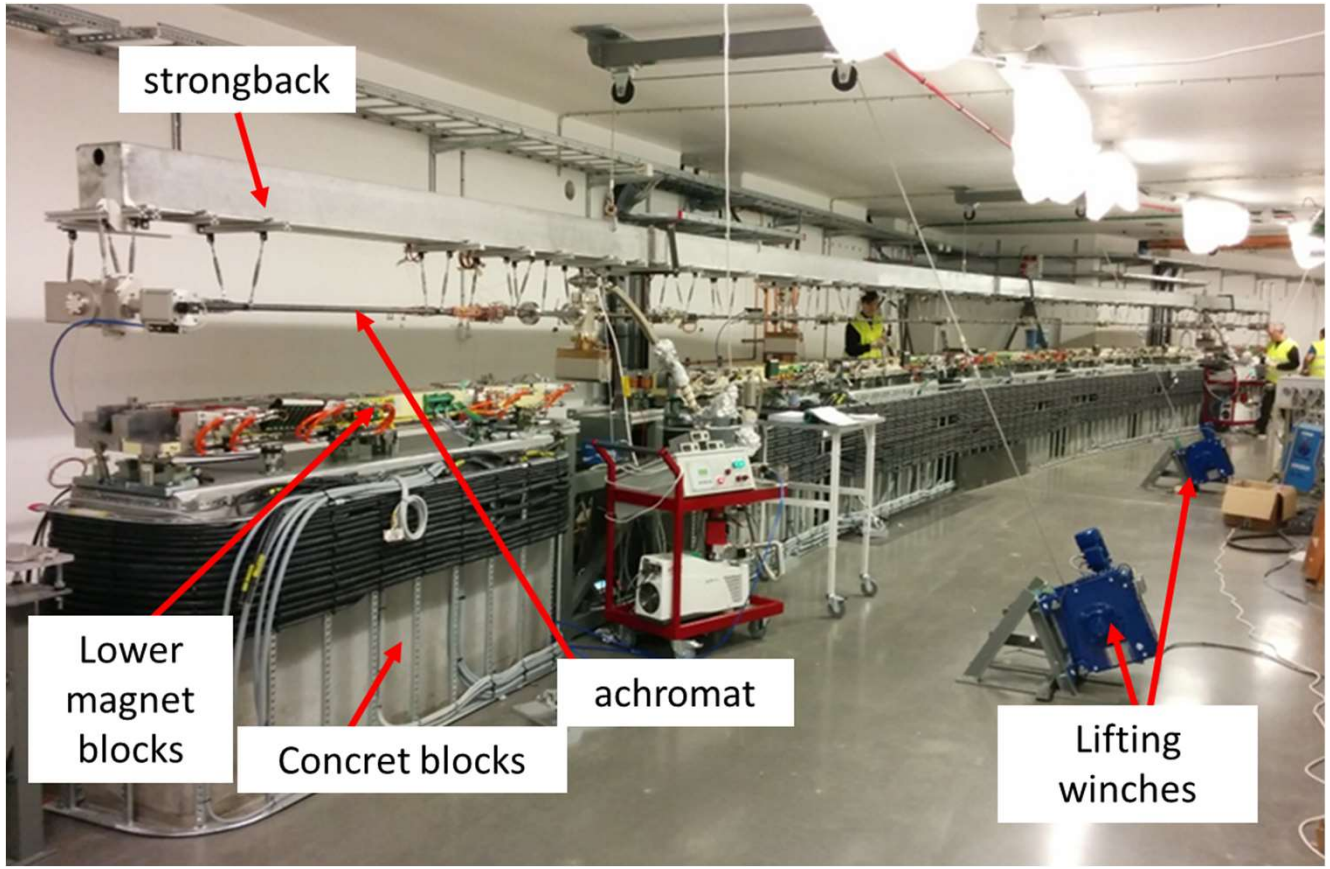
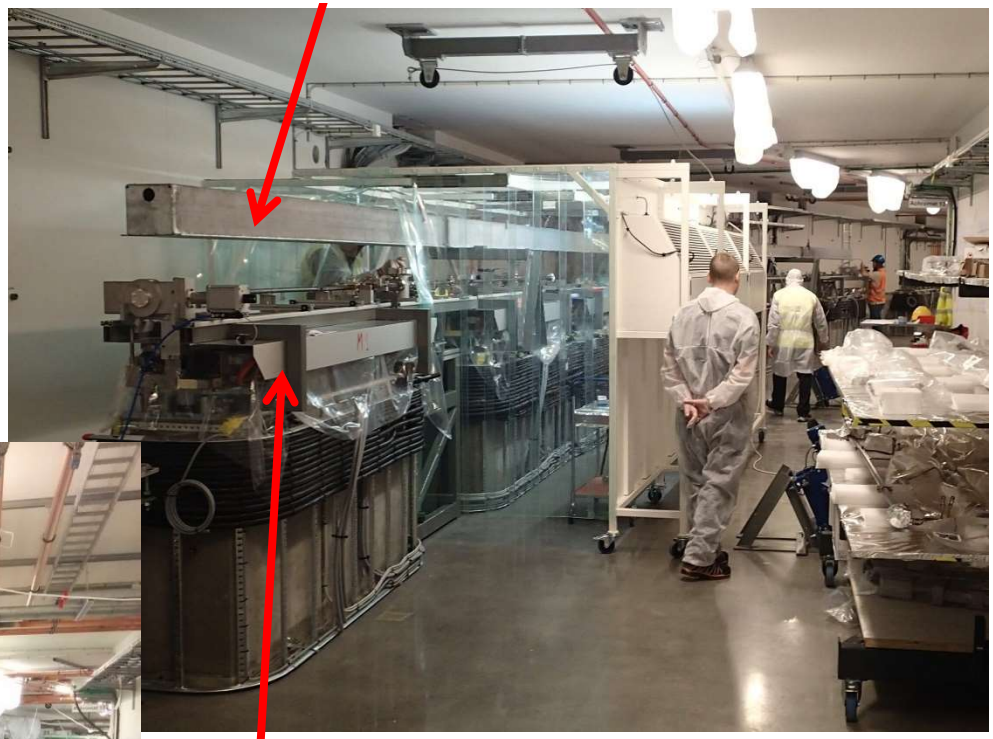
Installation

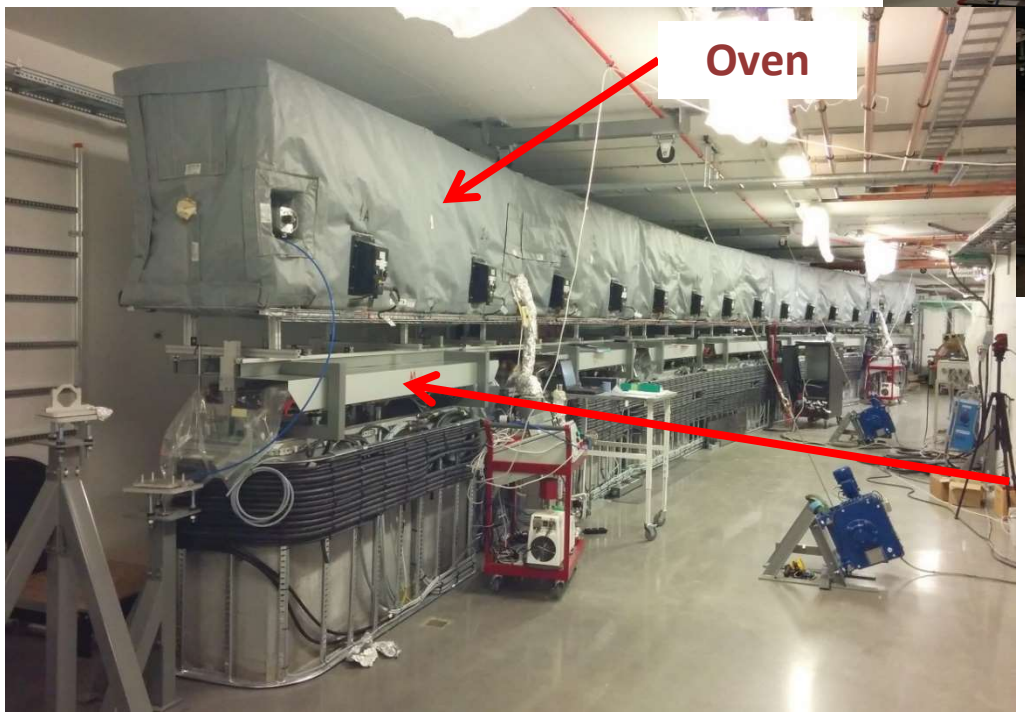
- Ring installation was tested and rehearsed by installing and activating mockup achromat
- Two teams.
- 6 months for the whole ring.
- Installation tools:



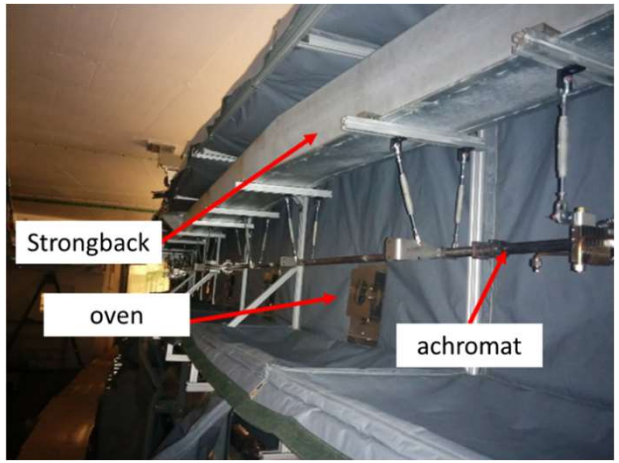
Installation procedure

- Magnet top halves removed,
- Installation of assembly tables.
- Assembly of vacuum chambers
- Pump down and testing,
- Lifting chamber up,
- Installation of bakeout oven
- Baking (1 day), activation (1 day),



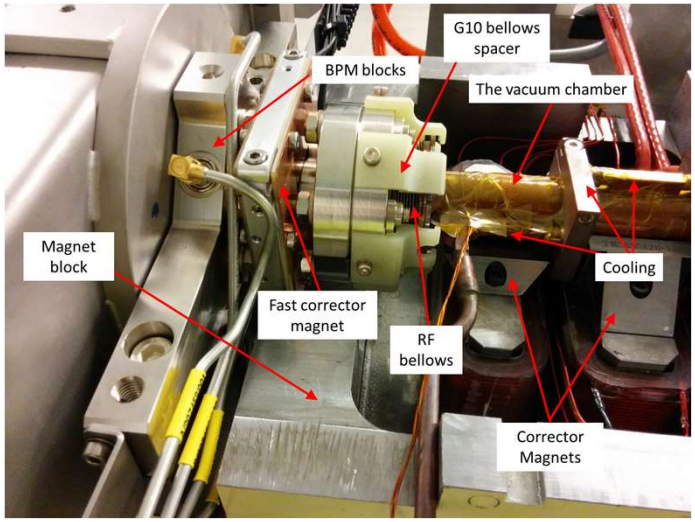


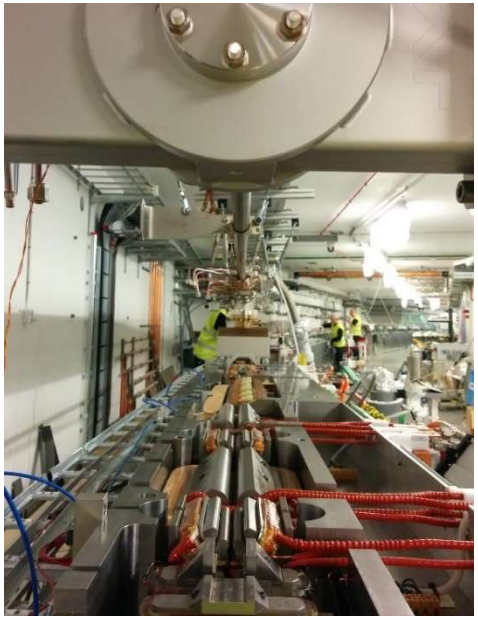
Assembly tables

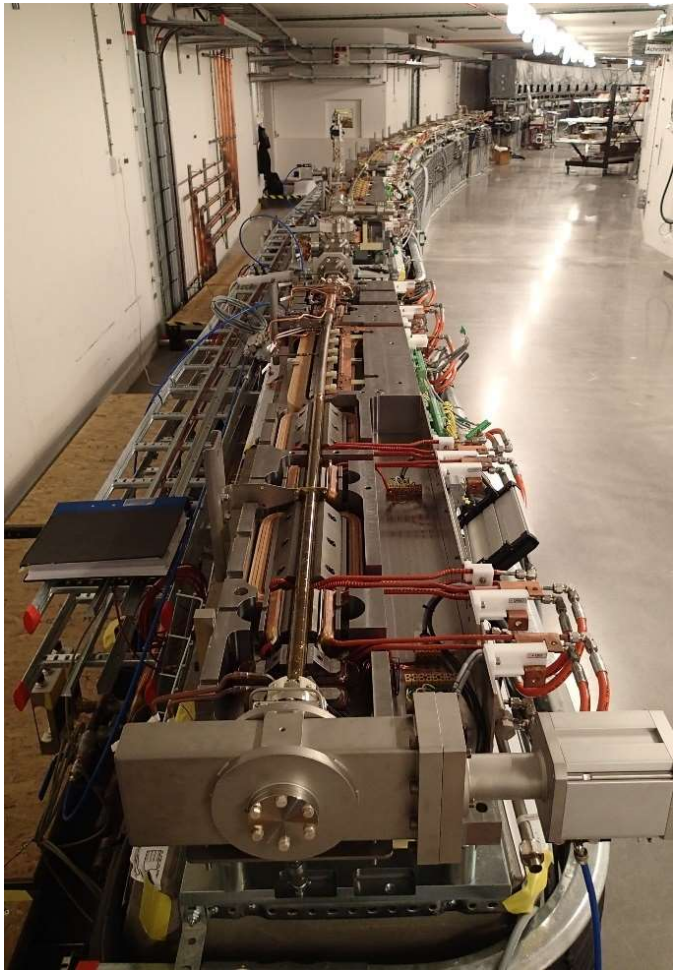


Installation procedure

- Installation of final equipment (supports, BPM cables),
- Lowering to the bottom magnet half.
- closing magnet blocks.

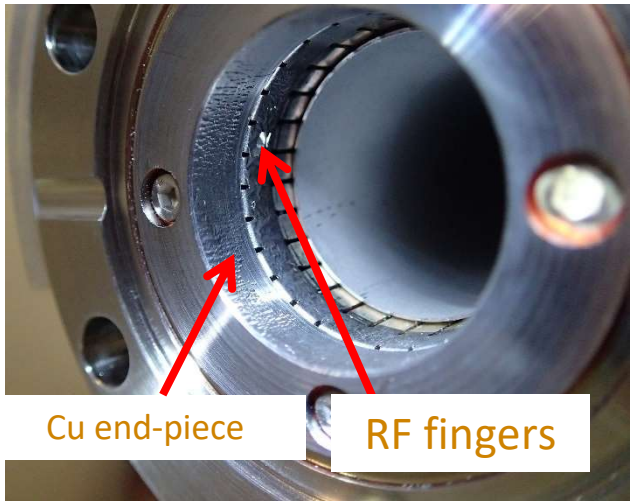


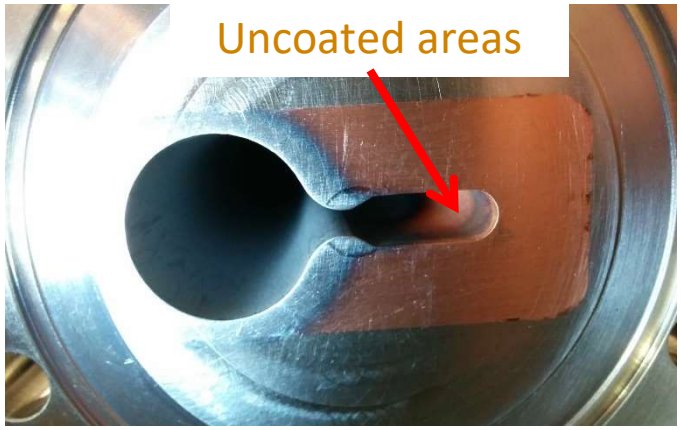




Installation issues:

Coating peeling-off





Damage of bellows
during manipulation


3 GeV storage ring vacuum system:
Operation
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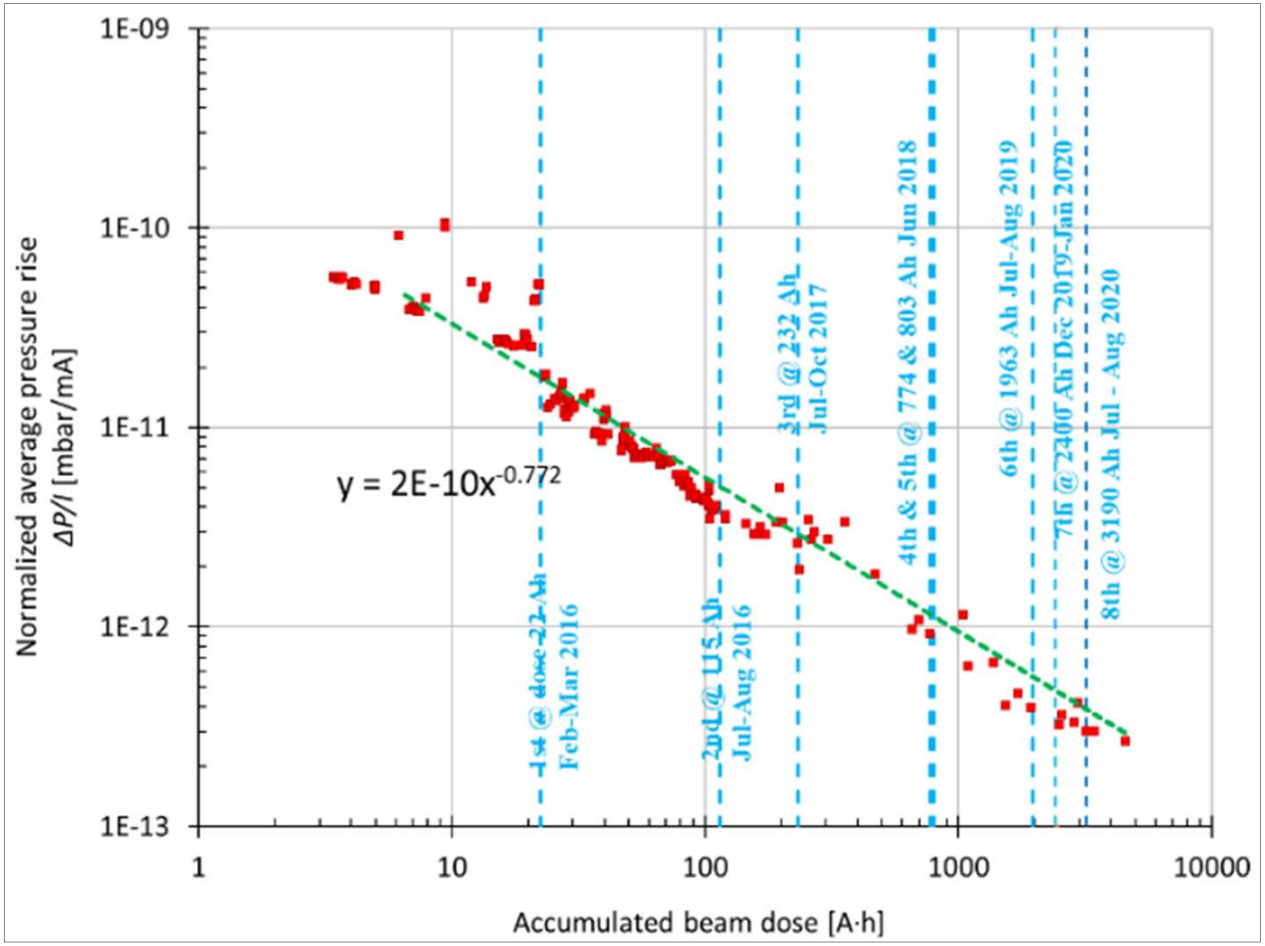
Operation

- Average base pressure: 2.10^{-10} mbar (extractor gauges)
- Accumulated beam dose (1st July 2021): 4620 Ah
- Max. stored current: 500 mA.
- Standard delivery to beamlines is at 300 mA with top-up every 10 minutes.
- Total beam lifetime: 16 h.
- Eight operational beamlines.
- During 2020 vacuum related beam dumps counted to 2.7% of the total machine beam dumps.

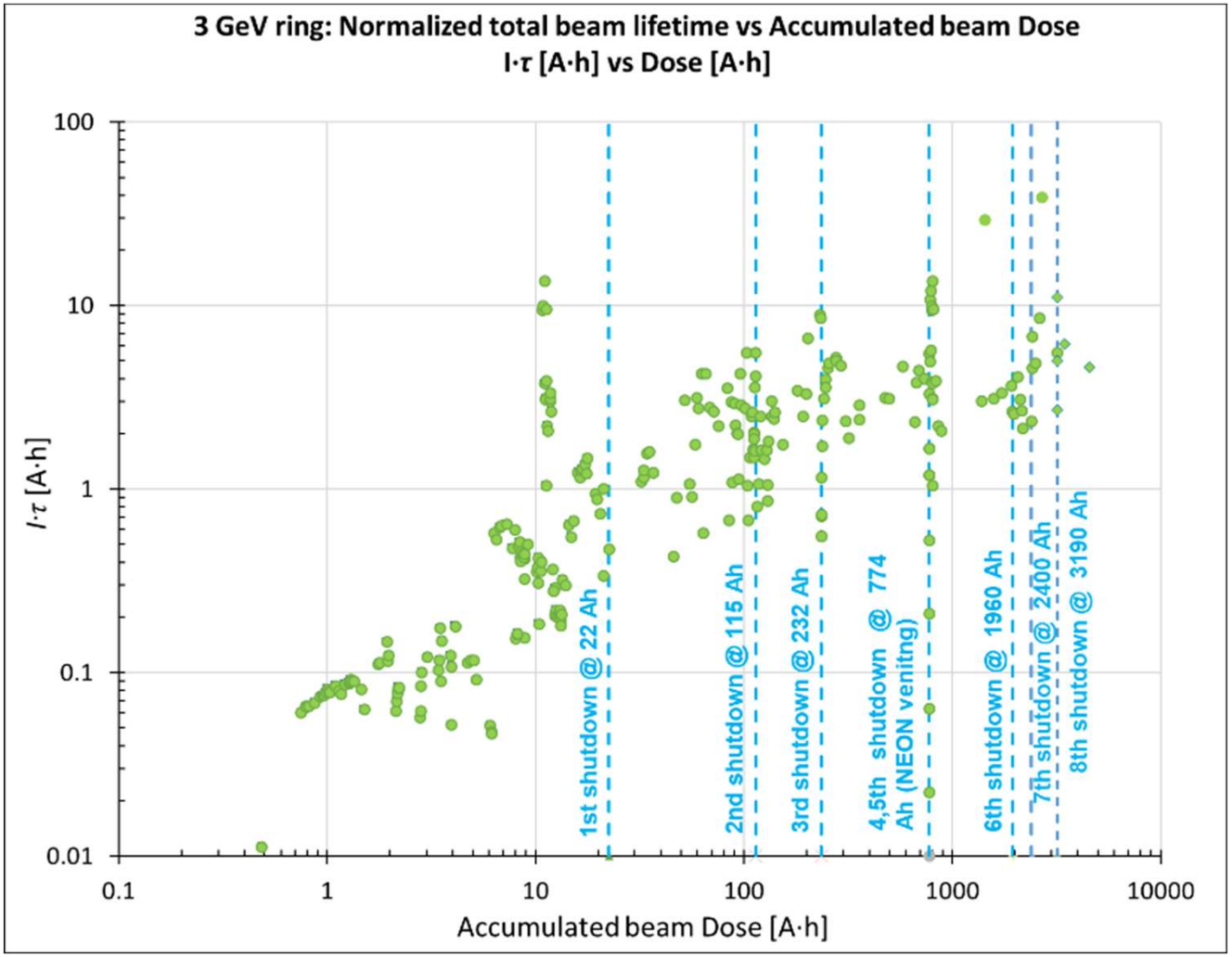
Operation

Normalized average pressure rise vs. beam dose



Operation

Normalized beam lifetime vs. beam dose



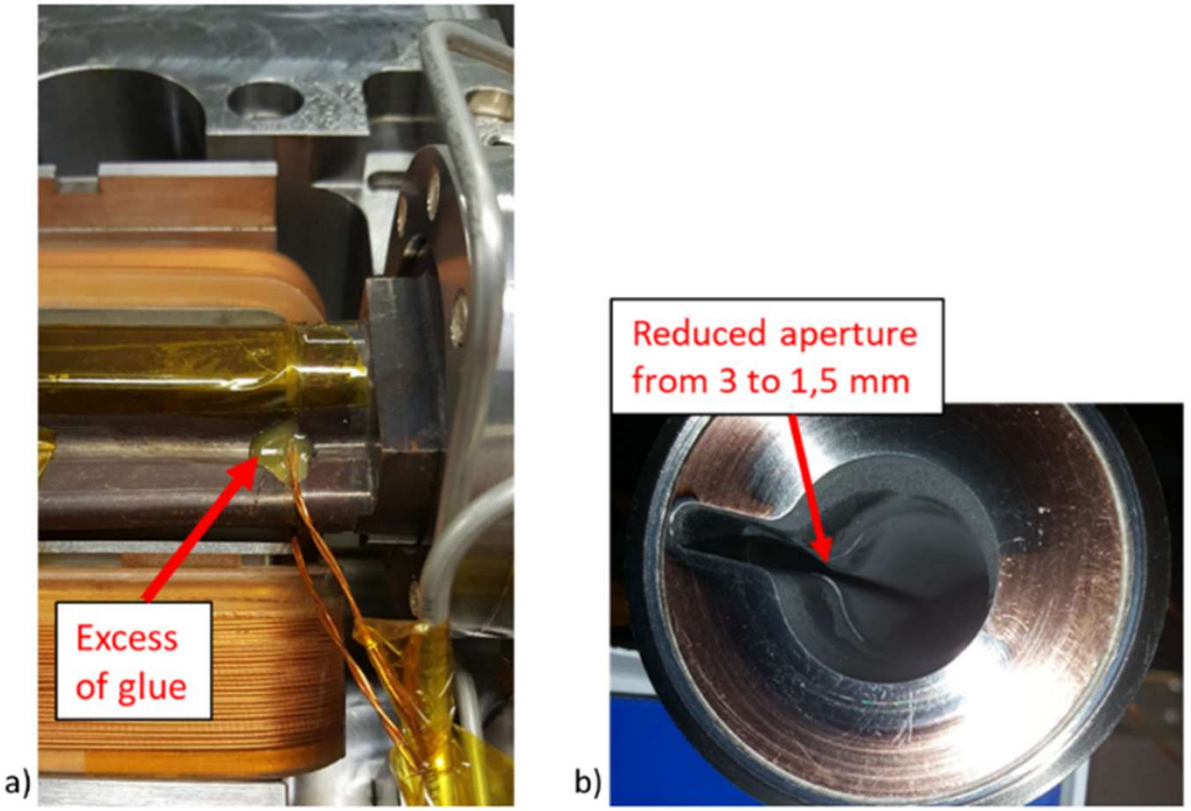
Operation

Operational issues: hot spots

- Around 30 thermocouples installed on the chambers/achromat.
- Purpose: assure the beam hit at the designated areas and no missteering issues.
- Readings from thermocouples over the interlock limit will dump the beam.
- at the start of operation few thermocouples were reading higher than what FEA simulated.
- Hot spots causes:
  - **Positioning** of the vacuum chambers due to geometrical non-conformity, or deformation.
  - **Chamber non-conformities**
  - **Deformed chambers during installation**

Operation

Example of hot spots



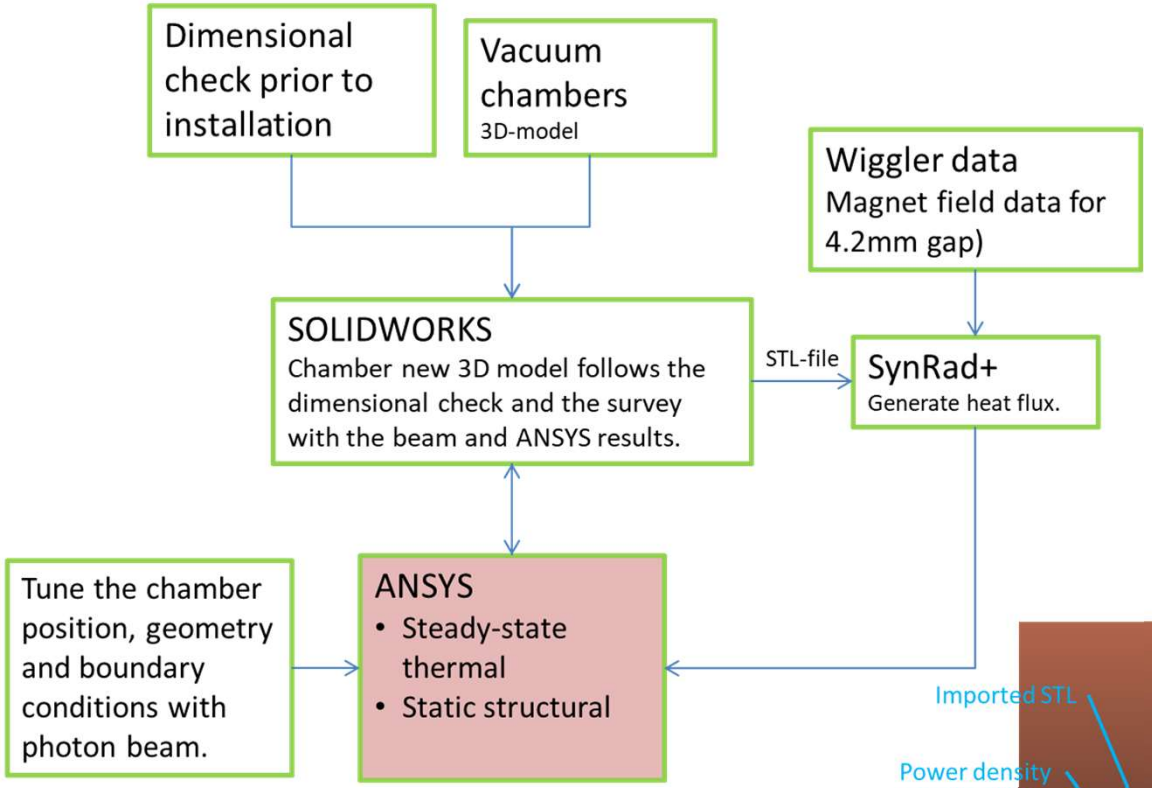
New vacuum chambers were designed and produced.

Meanwhile we have to defined the operational conditions within the safe limits for the damaged chambers.

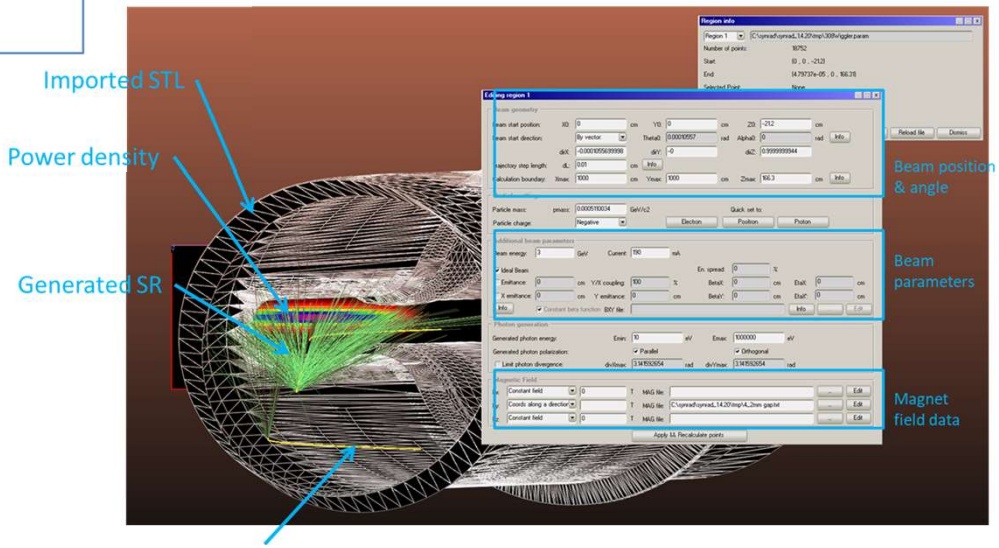
Operation

Operational issues: hot spots

Work flow:



SynRad+

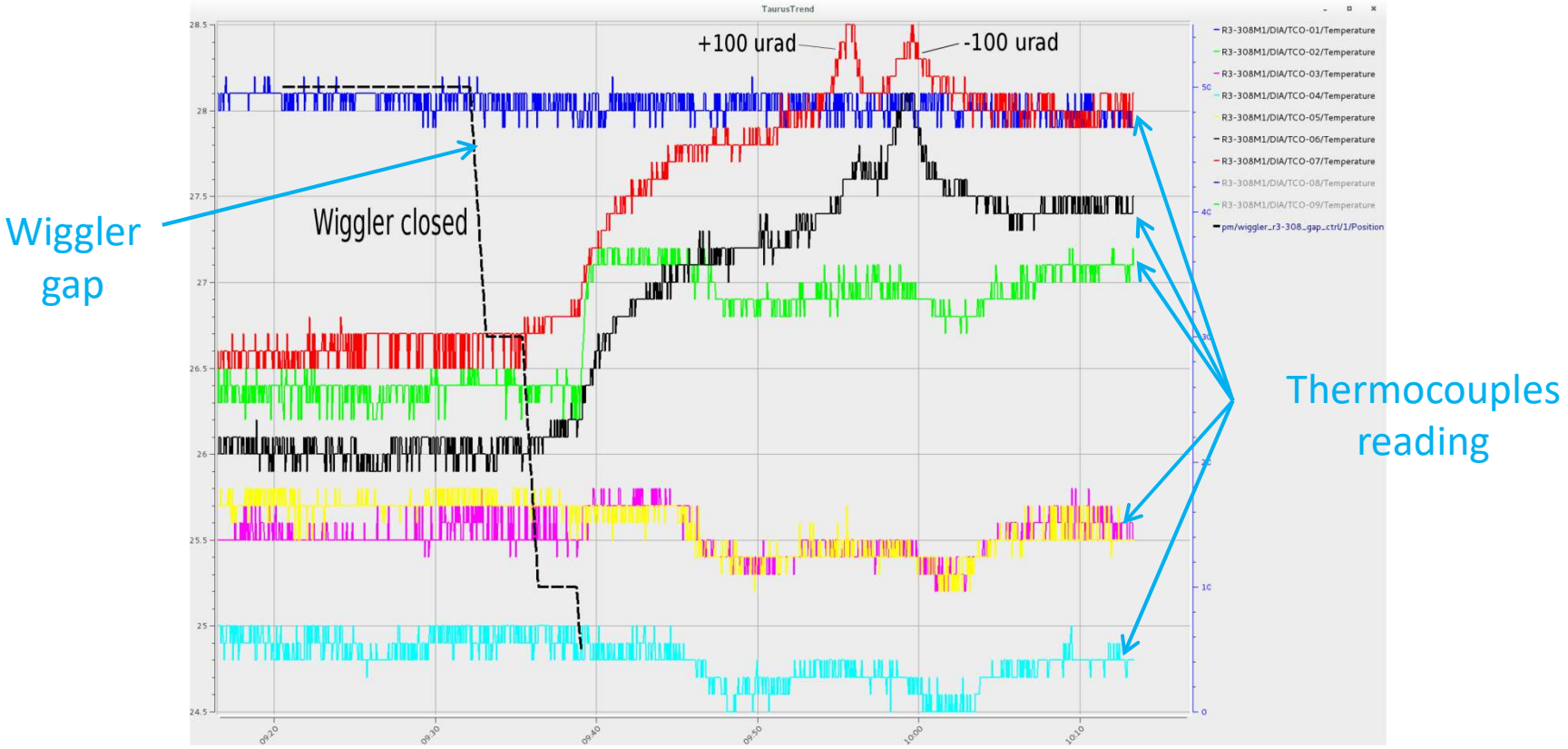


Courtesy: Karl Åhnberg

Operation

Operational issues: hot spots

Scanning the beam to tune in the position of the beam and define the boundary conditions :

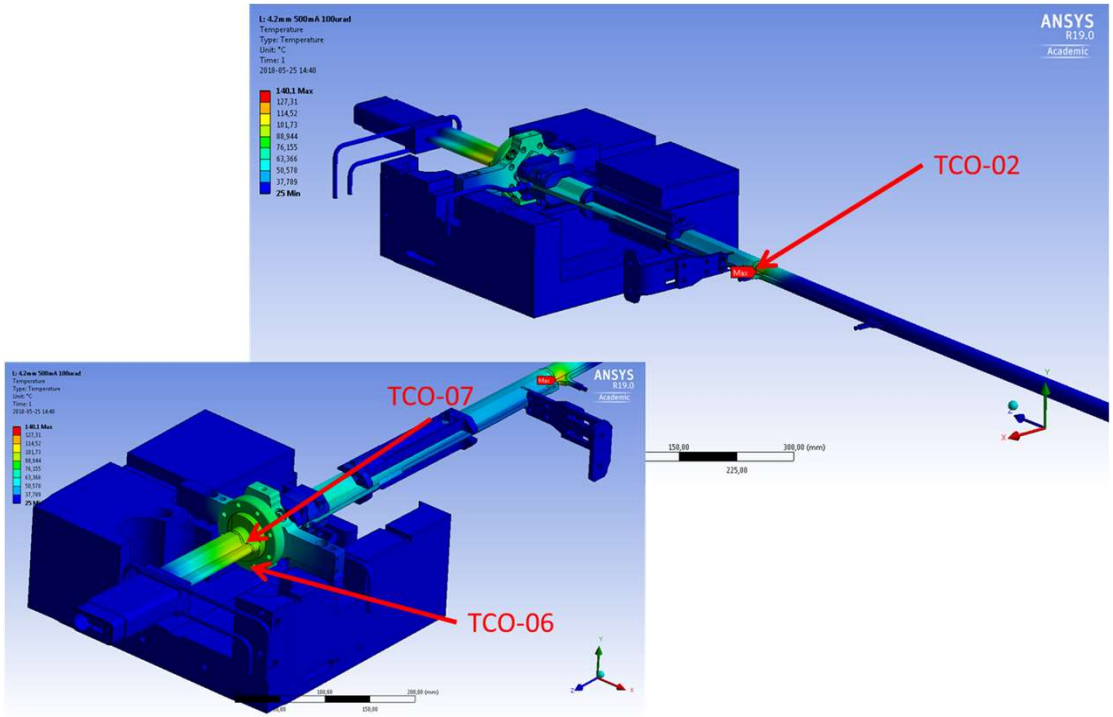


Operation

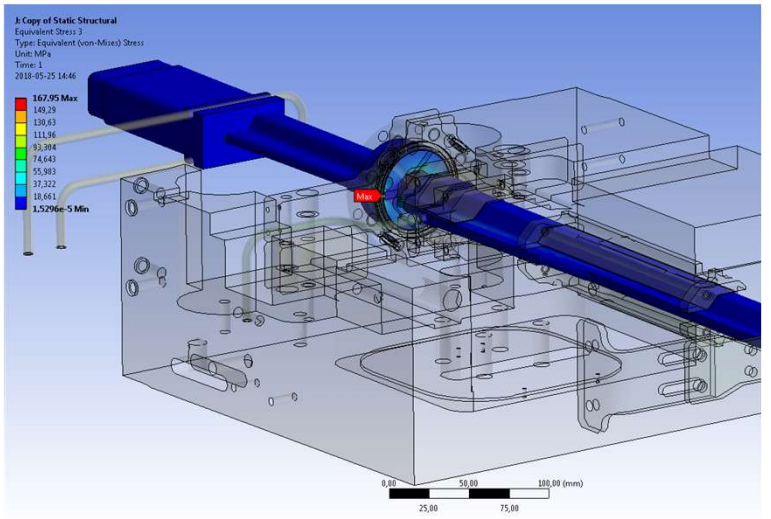
Operational issues: hot spots

	Nominal	Nominal				
	5mm 20mA	4.2mm 190m	4.2mm 250mA	4.2mm 500mA	4.2mm 500mA 70urad	4.2mm 500mA 100urad
Max. temp.	29,60	75,01	89,01	142,05	124,04	140,10
TCO-07	28,93	67,58	78,70	124,91	104,87	93,55
TCO-06	28,94	67,79	79,05	124,75	105,01	93,70
TCO-02	25,52	41,60	46,88	67,78	92,01	102,67
Equivalent Stress				253,12	198,89	167,95
Equivalent Total Strain				0,22%	0,17%	0,16%
VC1 Stress				69,72	68,91	67,57
VC1 Strain				0,068%	0,068%	0,066%

Case wiggler gap at 4.2 mm 500 mA 100 µrad -Temperature



4.2mm 500mA – Stress



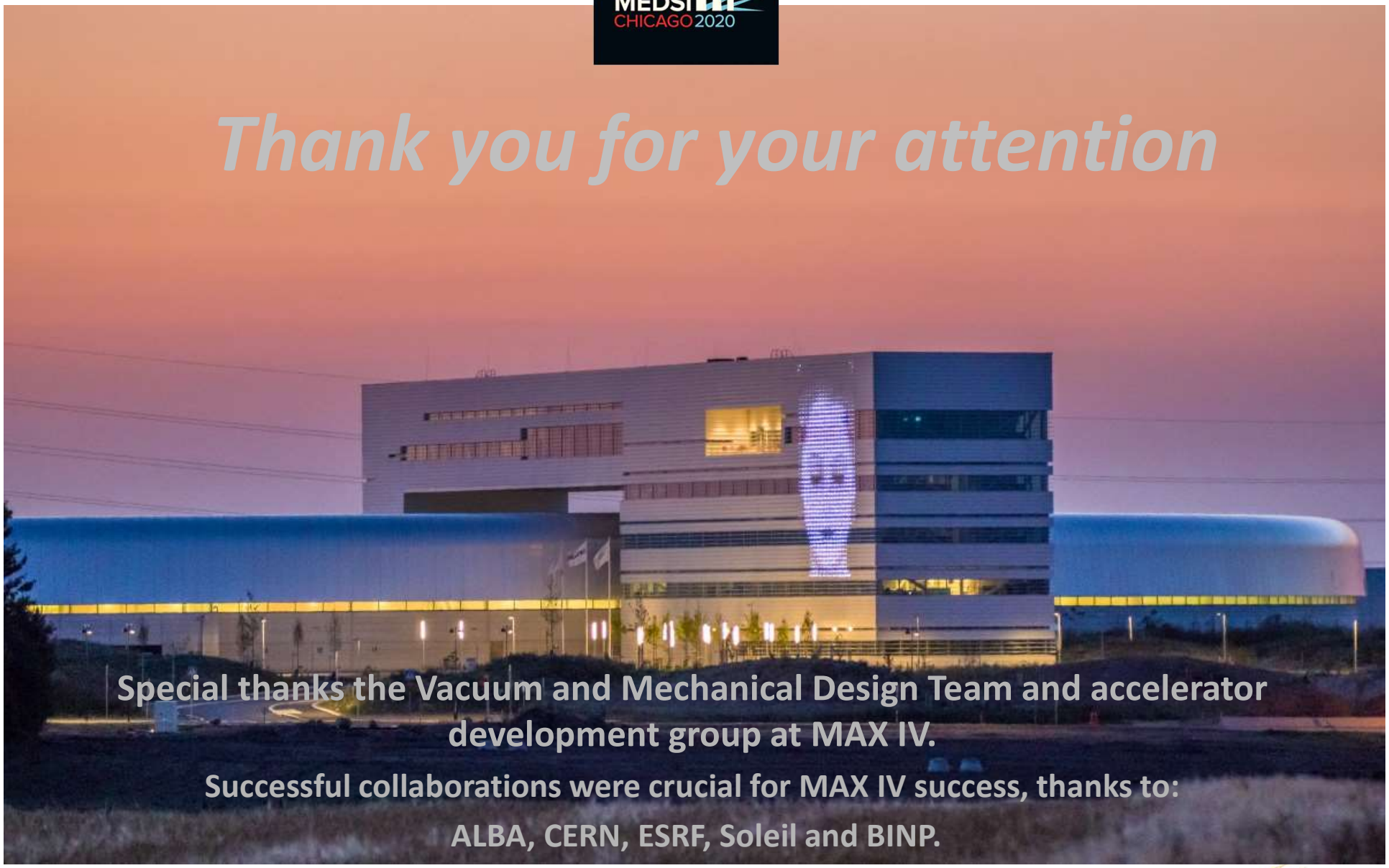

3 GeV storage ring vacuum system:
Conclusion
MAX IV

Conclusions

- MAX IV is the first synchrotron facility which have small aperture fully NEG coated vacuum system for the storage ring.
- Challenges were faced during the design, production, installation and operation.
- Mechanical engineering tools were used to validate design solutions, and trouble shooting during operation.
- The vacuum conditioning as measured by pressure reduction and lifetime increase are proofs of successful operation.

MEDSI CHICAGO 2020

Thank you for your attention



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