A. Zandonella :: Vacuum :: Paul Scherrer Institut

Vacuum concept for SLS 2.0

ALERT 2019 workshop

10. - 12.07.2019, Ioannina

Content

Technical aspects

- Vacuum system concept
- Vacuum chamber design
- NEG coating
- SR photon absorbers
- seals, pumps and valves

Planning

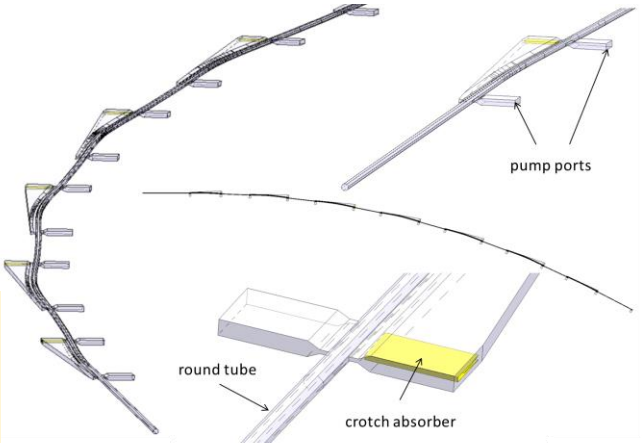
- Vacuum system installation procedures

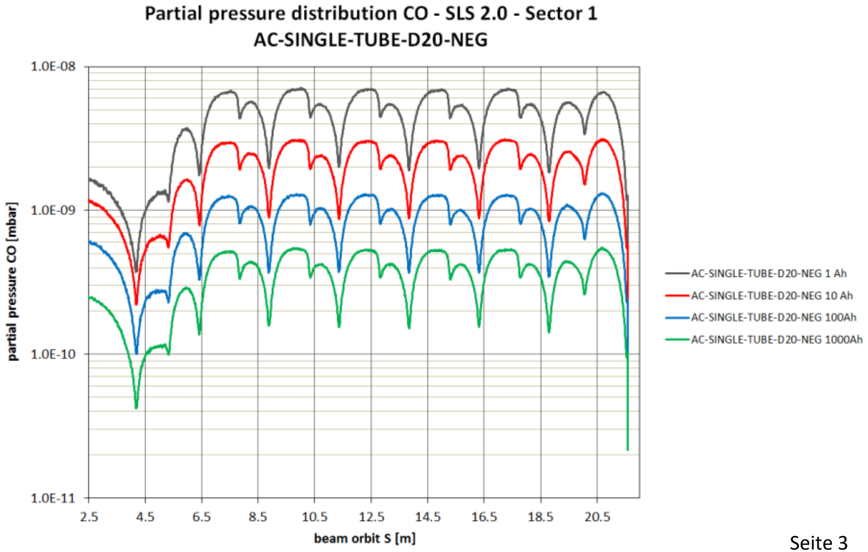
Vacuum system concept

Constrains of the basic concept:

- Aperture of the electron beam channel is **∅18mm** (**∅20mm** under discussion)
- The average vacuum pressure goal is **1.0E-9mbar** (CO equivalent) @ an accumulated beam dose of **100 Ah** (400mA)
- Around the electron beam a continuous **copper layer of minimum 5µm** is required (reduction of resistive wall impedance)
- In the region of the strong bending magnets the synchrotron radiation can pass through a slot with a vertical height of 3mm into the ante-chamber and is absorbed by a crotch-absorber. While the synchrotron radiation from the reverse bends can be absorbed by the inside wall of the vacuum chamber

Vacuum performance study (SLS-2 CDR 2017)
from Lothar Schulz
Simulations done with
Synrad & MolFlow





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Vacuum system concept

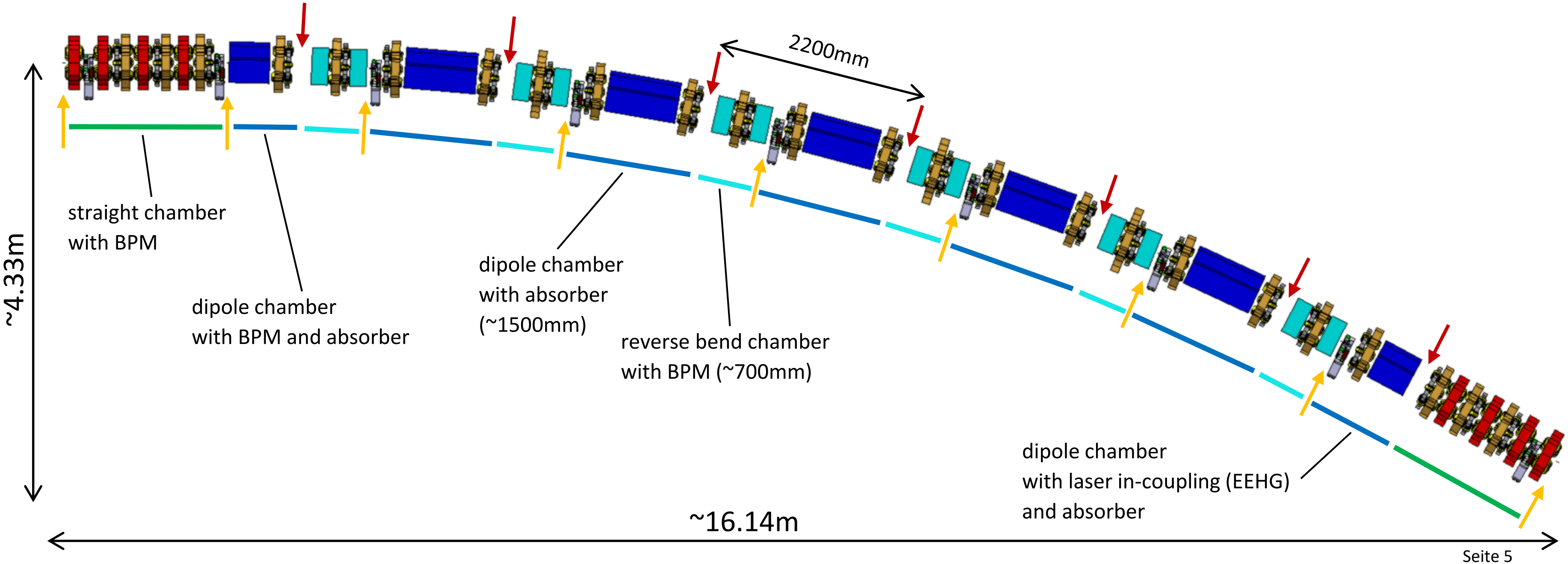
- Copper or Copper-alloys are used as vacuum chamber material
  - Best performance in heat dissipation (all vacuum chambers are impinged with SR and need to be cooled)
- All the vacuum chambers are NEG-coated:
  - **Lower static outgassing:** For compensation of the conductance limitation
  - **Lower PSD-yield:** To reduce the initial gas load and achieve the required average pressure quick
  - The thickness of the NEG film in the electron beam channel must be within **150nm to maximum 300nm** (increase of resistive wall impedance)
  - The pump capacity of the thin **NEG-film is not taken into account for pumping**
- Pumping is done with ion getter pumps and discrete NEG-pumps.
- There is no space for bellows available within the ARC due to the narrow lattice:
  - No insitu bake-out or insitu NEG-activation is possible
  - The complete assembled and by sector valves sealed off vacuum sector will be baked-out (NEG activation) in a dedicated oven before being installed on the lower magnet halves

Vacuum system concept

overview arc (lattice B, length of the electron beam path 16.98m)

→ 7 slots for crotch absorbers, IG-pumps, flange connection (length 170mm)

→ 9 slots for beam position monitors and flange connection (length 57mm)



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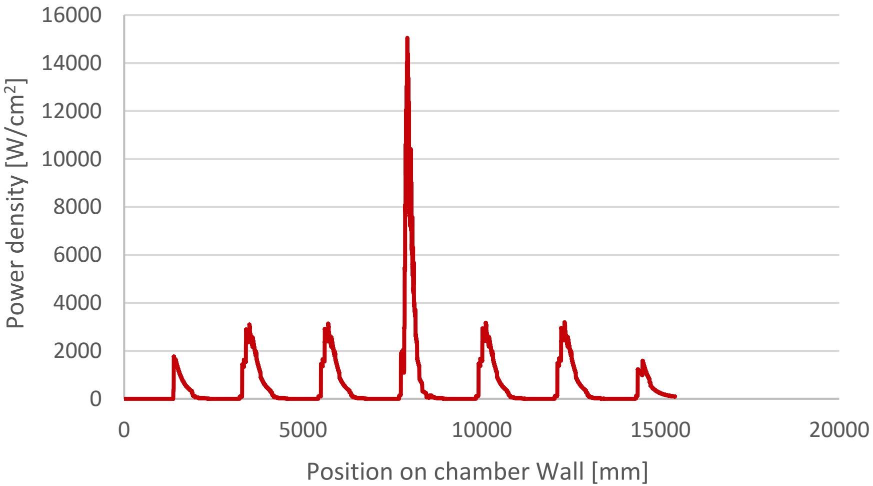
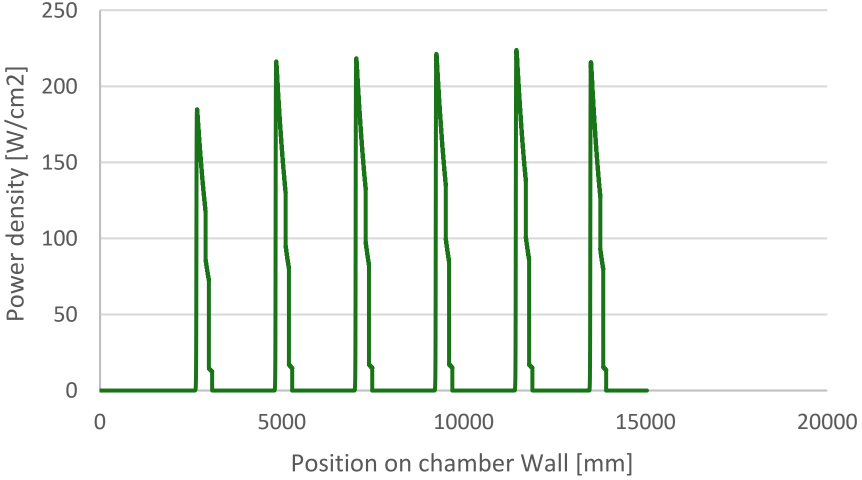
Vacuum system concept

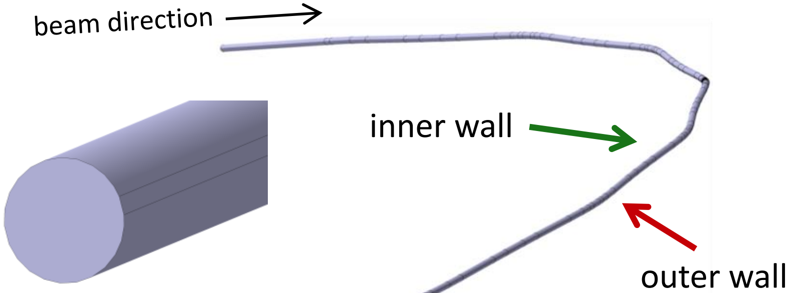
Power densities (lattice B)

Power density on outer chamber Wall (Sector 2)



Power density on inner chamber Wall (Sector 2)





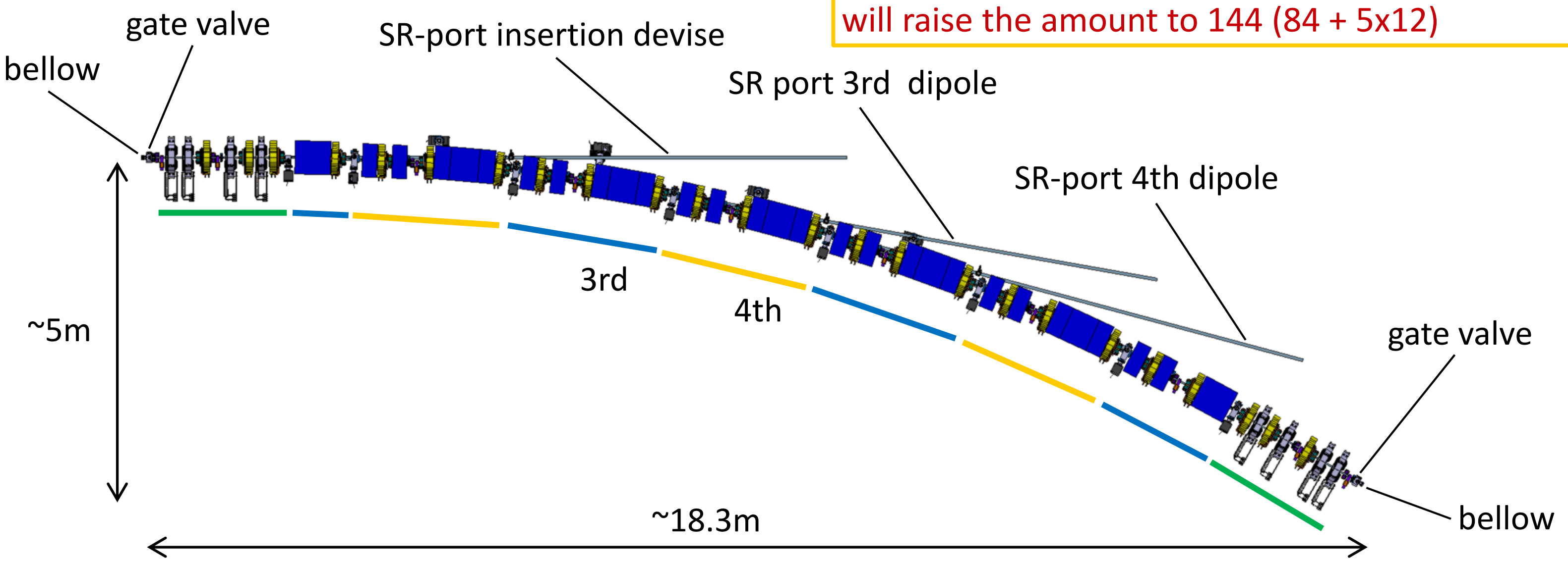
Courtesy of Colette Rosenberg
Simulations done with Synrad

Vacuum chamber design

overview arc (lattice June 2018)

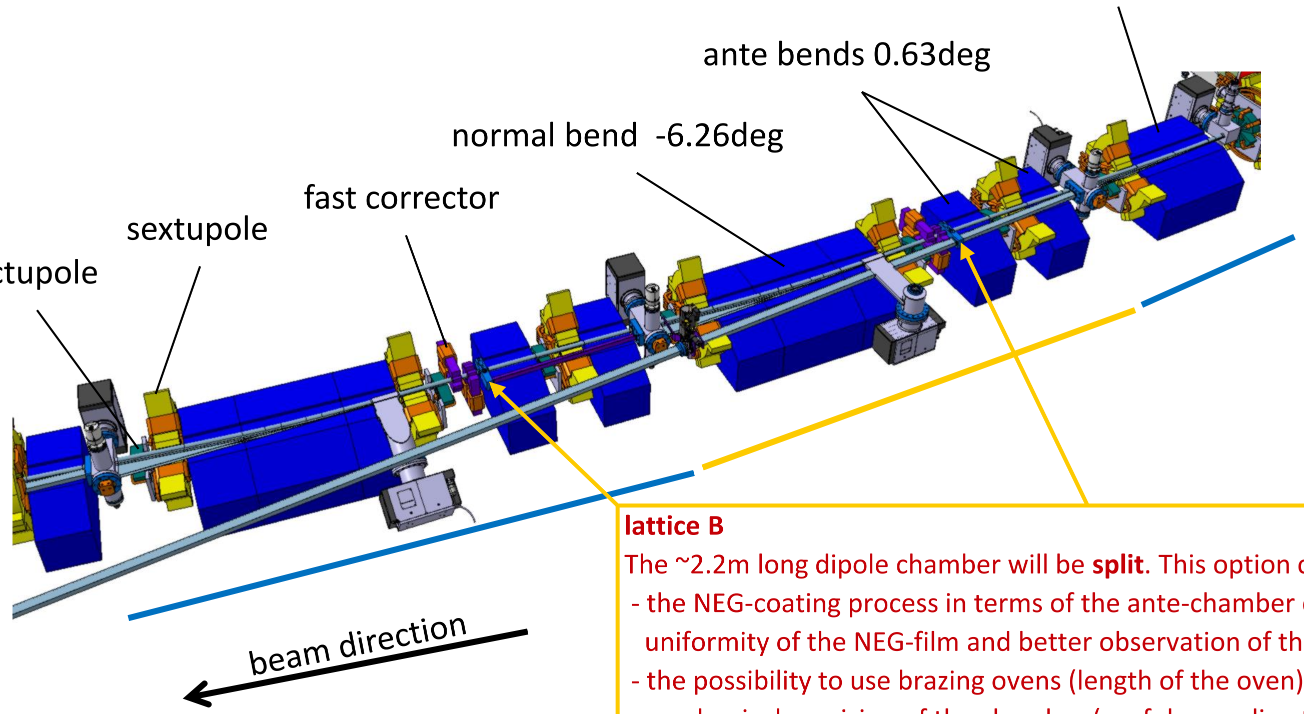
- 2 chambers for straight sections (total 24 straight chambers)
- 7 chambers for bending sections (total 84 dipole chambers)

lattice B
Splitting the combined "reverse bend and dipole chamber" will raise the amount to 144 (84 + 5x12)



Vacuum chamber design

overview dipole chambers (lattice June 2018)



lattice B

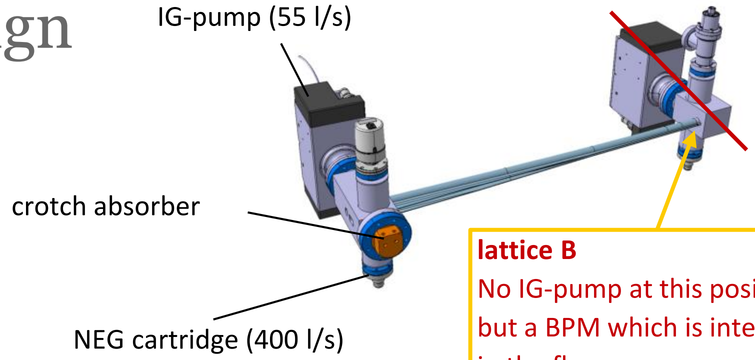
The ~2.2m long dipole chamber will be **split**. This option can improve:

- the NEG-coating process in terms of the ante-chamber coating, uniformity of the NEG-film and better observation of the BPM region
- the possibility to use brazing ovens (length of the oven)
- mechanical precision of the chamber (useful regarding the lack of bellows)

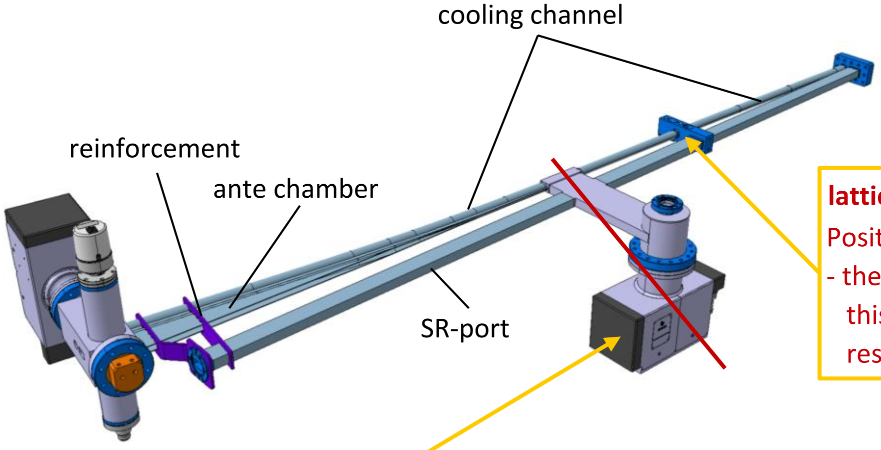
→ **if the specifications can be achieved without splitting the chamber this option can be withdrawn**

Vacuum chamber design

dipole chambers (lattice June 2018)

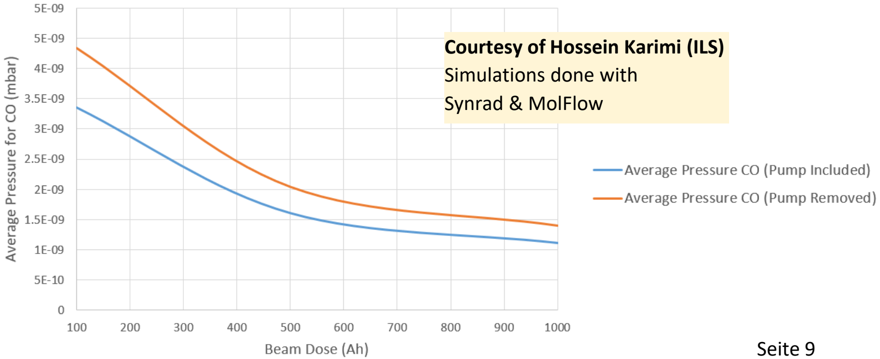


lattice B
No IG-pump at this position, but a BPM which is integrated in the flange



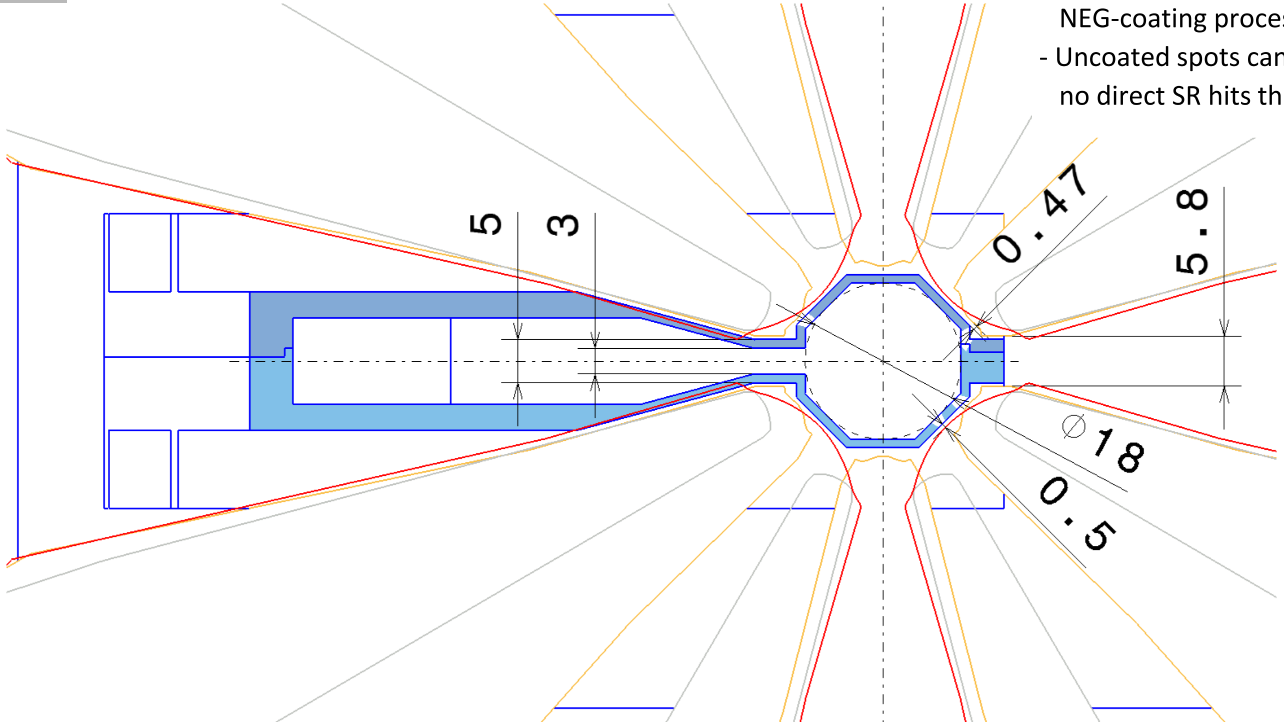
lattice B
Position of the break up:
- the SR-port will not be part of the dipole chamber anymore
  this reduces the amount of different dipole chamber types, respectively avoids manufacturing of useless SR-ports

lattice B
No IG-pump at this position:
- a comparison shows that the reduction of the dynamic average pressure using this additional IG-pump is negligible
- like this the number of IG-pumps per sector is reduced from 13 to 7



Vacuum chamber design

chamber cross section (lattice B)



lattice B

Advantages to previous round beam channel profile:

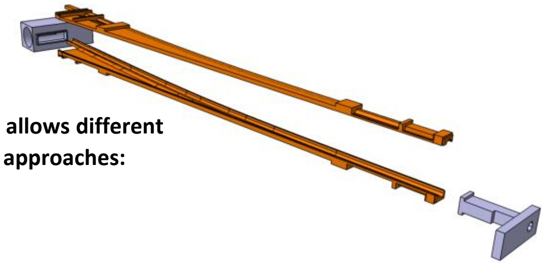
- the joining of the chamber can easily be made out of axis
- BPM buttons can be flat (no orientation needed when mounting)
- Spacers holding the cathode in position during the NEG-coating process are guided while inserting the cathode
- Uncoated spots can be properly defined where no direct SR hits the chamber wall

Quadrupole (bore hole ∅21)*
Sextupole (borehole ∅22)
Octupole (bore hole ∅29)
Vacuum (octagon inside ∅ 18/wall 1)

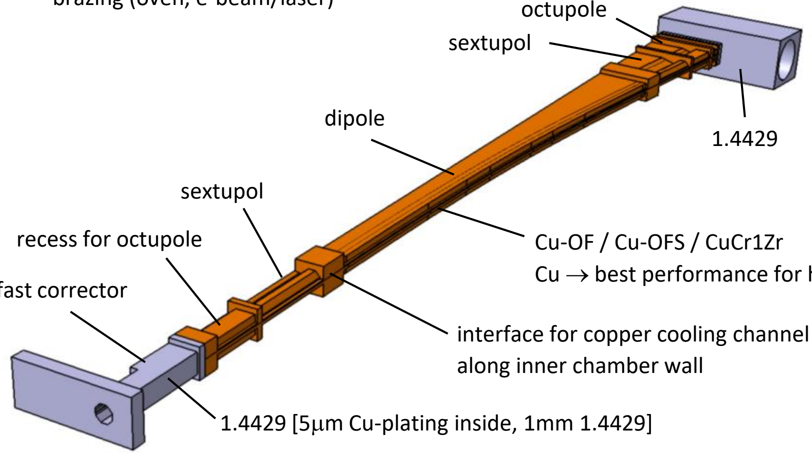
* Quadrupoles are not located in the region of the ante-chamber

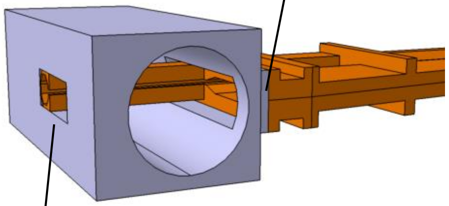
Vacuum chamber design

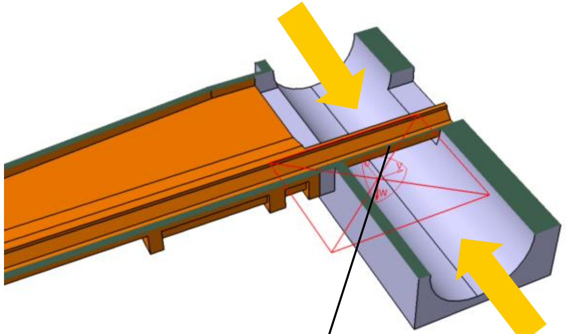
1st draft for dipole chamber (lattice B)

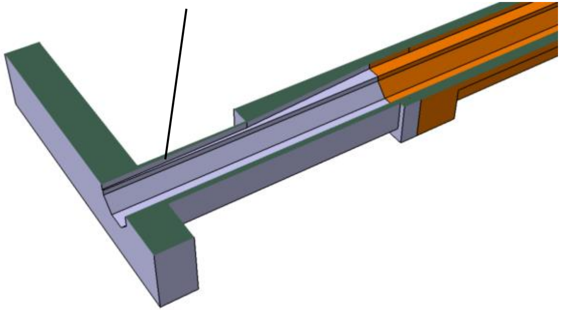


4 pieces design allows different manufacturing approaches:
- milling
- stamping
- wire eroding
- welding (TIG, e-beam/laser)
- brazing (oven, e-beam/laser)





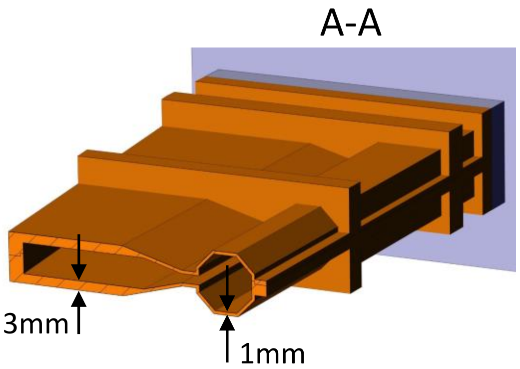


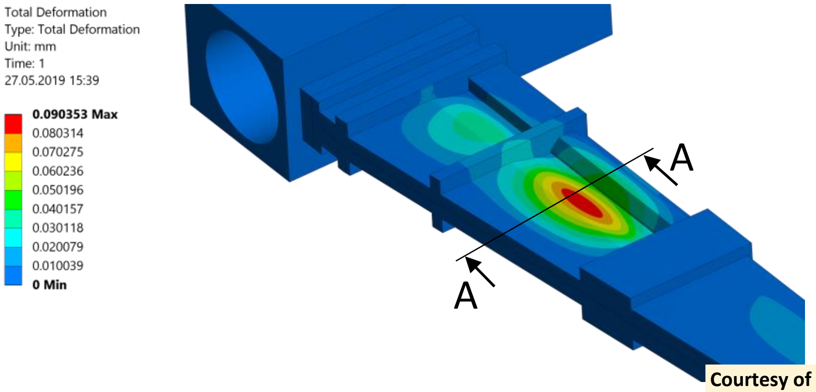


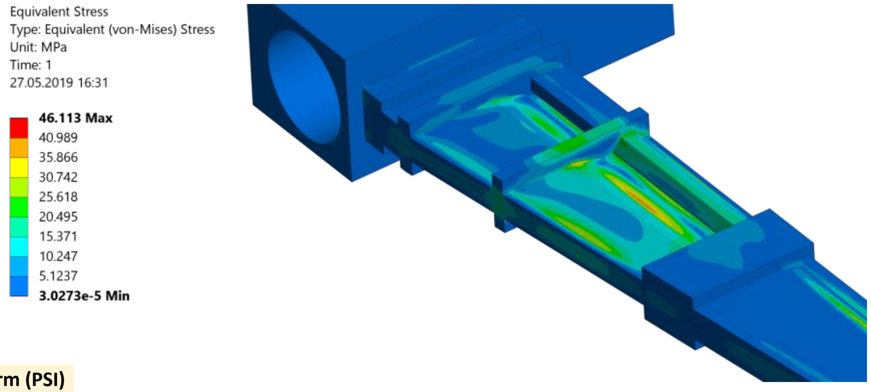
Vacuum chamber design

FE-analysis for 1st lattice B dipole chamber draft

The FE-analysis shows, that even with **annealed copper** ($R_{P0.2}$ 90MPa, R_m220MPa, elastic modulus 118 GPa) the deformation of the chamber wall, due to the pressure differential forces, is less than 0.1mm and the equivalent stress maximum 47MPa







Courtesy of Maximilian Wurm (PSI)
Simulations done with
ANSIS

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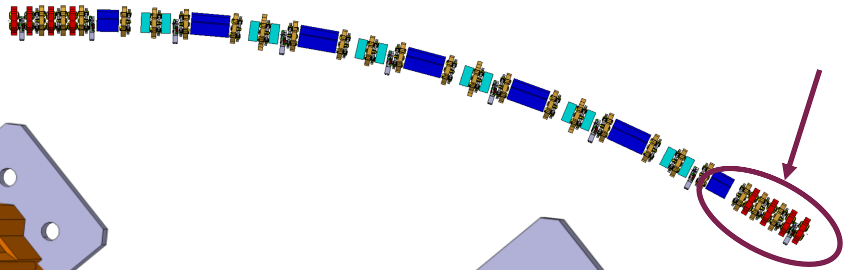
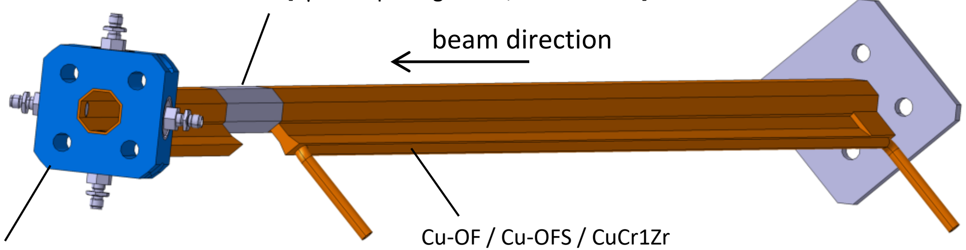
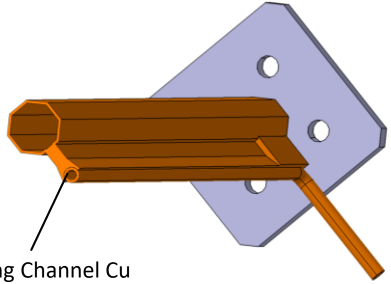
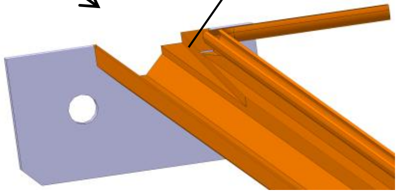
Vacuum chamber design

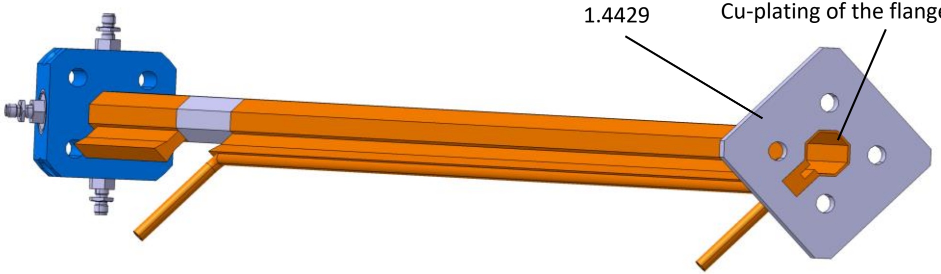
1st draft for straight chamber (lattice B)





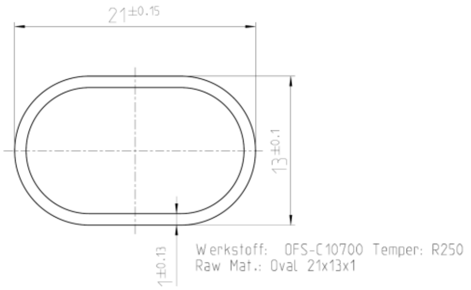




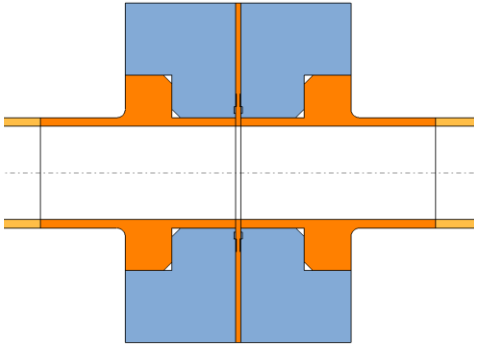


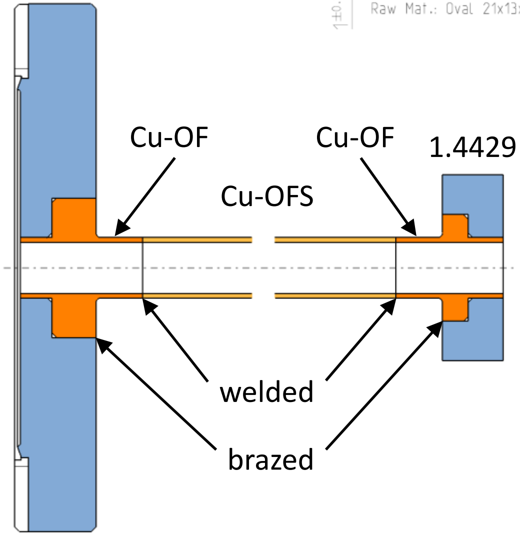
Vacuum chamber design

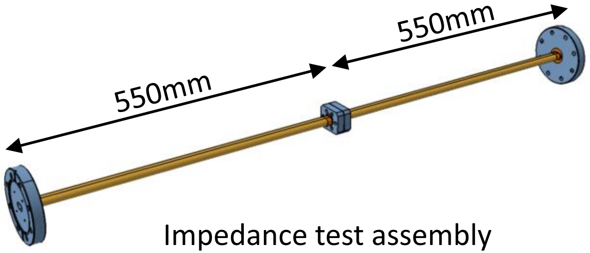
NEG-coated test-tube Profile 1 (race track)



rectangular gasket with race track bore hole (VATSEAL)



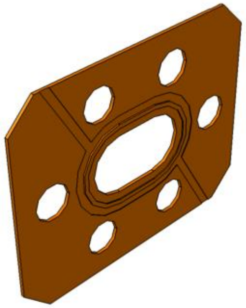




Impedance test assembly

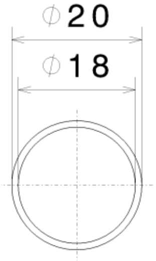
Purpose of the test tube

- Resistive wall impedance measurement of the NEG-coating
- Impact of the flange connection (VAT-seal) on the resistive wall impedance
- Adhesion of the NEG-coating on the Cu-OFE to Cu-OFS welding
- Check what is the provided composition and morphology
- Thickness and uniformity of the NEG-layer along the tube length

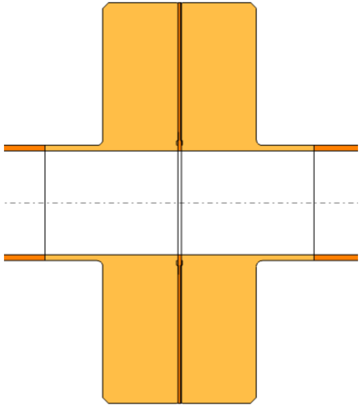


Vacuum chamber design

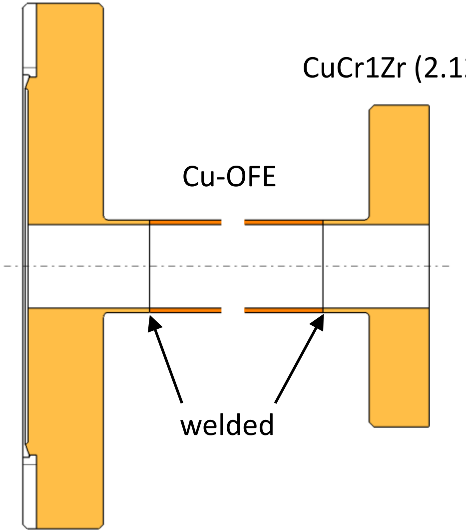
NEG-coated test-tube (round)

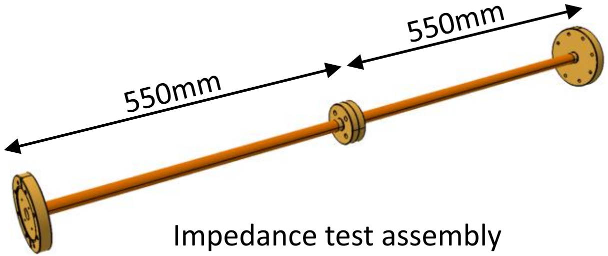


round gasket with Ø18mm bore hole (VAT-seal)



CuCr1Zr (2.1293)

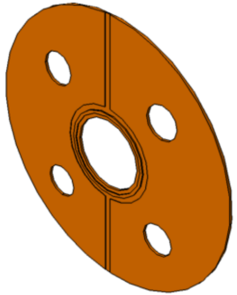




Impedance test assembly

Purpose of the test tubes

- Resistive wall impedance measurement of the NEG-coating
- Impact of the flange connection (VAT-seal) on the resistive wall impedance
- Adhesion of the NEG-coating on the CuCr1Zr
- Adhesion of the NEG-coating on the CuCr1Zr to Cu-OFE welding
- Check what is the provided composition and morphology
- Thickness and uniformity of the NEG-layer along the tube length
- Feasibility of the CuCr1Zr to Cu-OFE welding
- Tightness of the VAT seal flange connection with 4 screws in view of the BPM-valve situation



NEG coating

The NEG-coating of the vacuum chambers will be done by the chamber manufacturer.
A development of the NEG-coating process has to be realized together.

1. The potential suppliers provide NEG-coated test-tubes (according specifications by PSI).
   Test reports (cleaning, coating parameters and analysis) will be requested.
2. Resistive wall impedance measurements will be done at PSI
3. Check NEG-criteria at PSI (adhesion, composition, morphology and thickness (uniformity))
4. Evaluate capability of the different supplier in view of the WTO
5. Define feasible NEG specifications

The NEG-coating of the series production will be qualified either by

1. witness pieces (end pieces) to be measured at PSI
2. or witness chamber out of the series have to be cut off and analyzed at PSI

→ **To acquire knowledge about NEG-coating, in terms of being able to evaluate the capability of the suppliers and establish NEG-diagnostic at PSI, we started with NEG-activities at PSI…**

* deoxidized with limited residual content of phosphor

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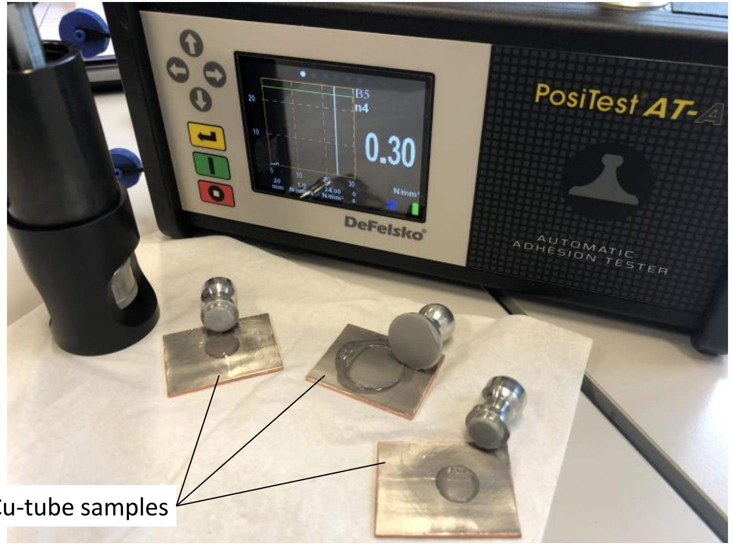
NEG coating

Results from NEG-coating activities at PSI

Adhesion:

- Good adhesion obtained with standard drawn Cu-DHP* tube from PSI store > cleaned (smooth etching) according “PSI copper cleaning receipt”
- > 10 N/mm^2 was measured with the adhesion force measurement tool
- So far in every measurement the glue broke and was the limiting factor

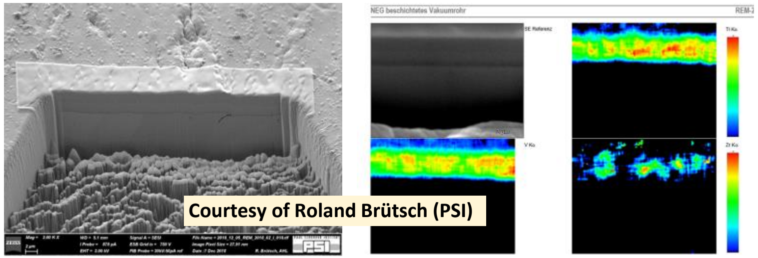


Flattened NEG-coated Cu-tube samples

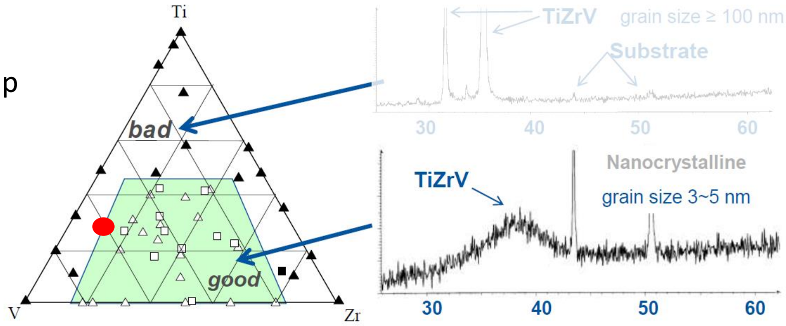
Composition:

The composition achieved so far is: Ti Zr V [30%, 10% , 60%]

- Goal according CERN: Ti Zr V [25%, 40% , 35%]
- Improvement: Cathode power bellow 20W/m to avoid heat up
- Measurement by Focused Ion Beam and EDX @ PSI



Courtesy of Roland Brütsch (PSI)



source: P. Costa Pinto, CERN

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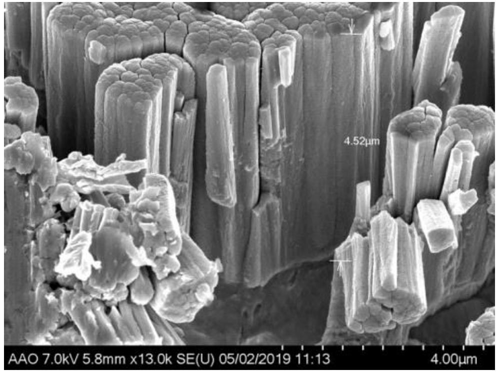
NEG coating

Results from NEG-coating activities at PSI

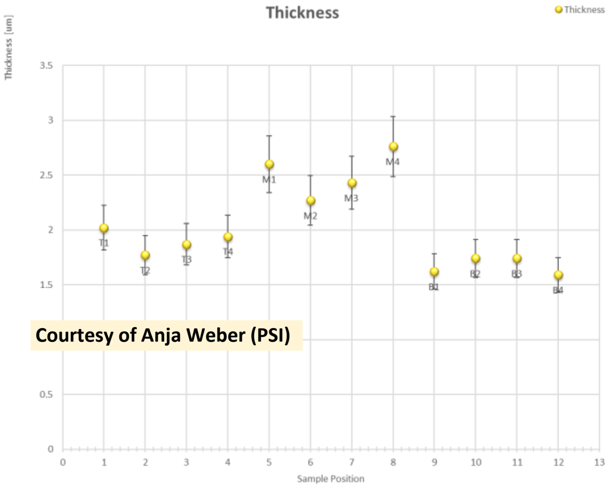
Morphology:

- Coating temperature is 100°C
- Thinner layers turned out dense, thicker layer more columnar
- Typical nanocrystal size 5 to 20nm

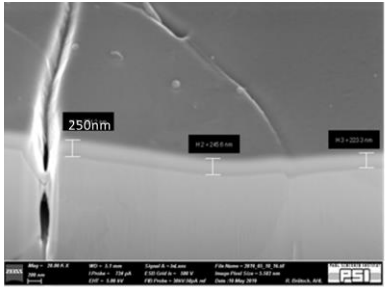


Thickness (uniformity)

- Uniformity for 2µm ±30% (over 0.5m tube length)
- 250nm achieved
- Deposition rate under control (typically 0.1 µm/h) (several thicknesses obtained as expected)



Courtesy of Anja Weber (PSI)

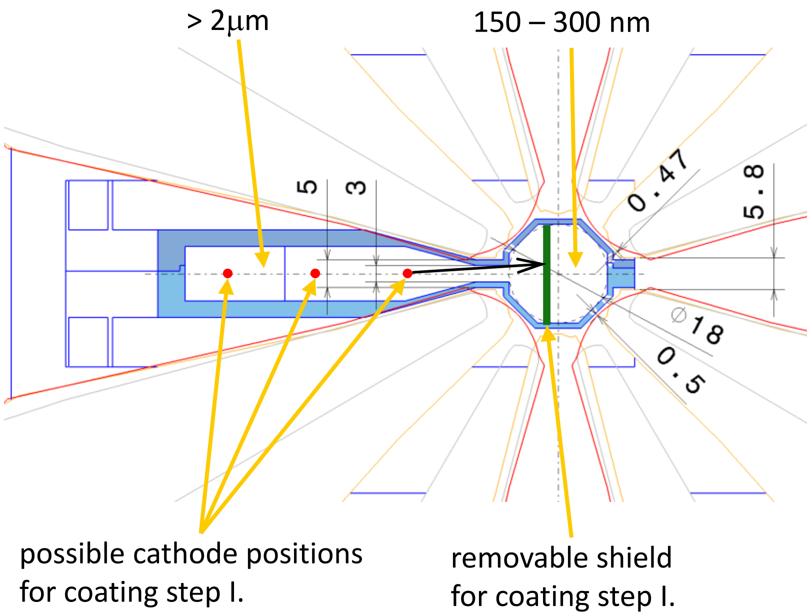


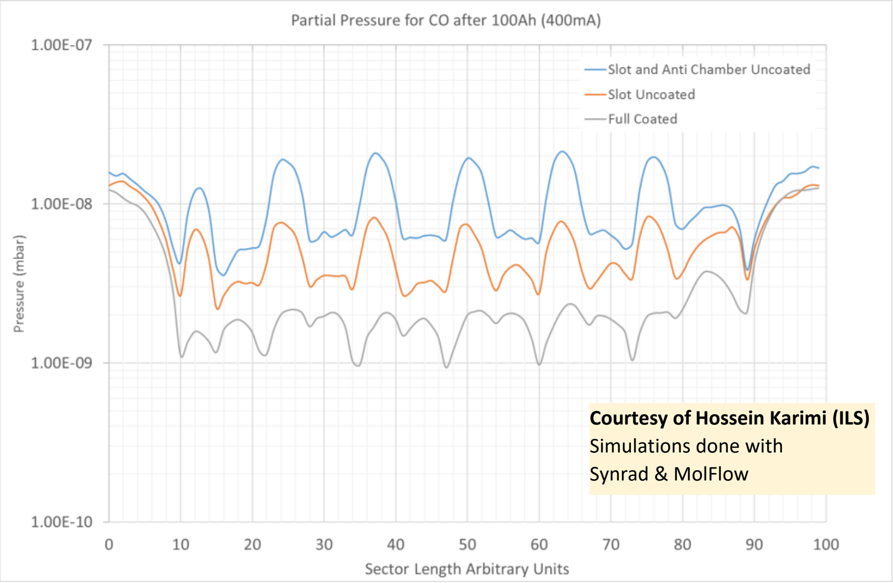
NEG coating

NEG-coating of the ante chamber…in 2 steps

I. Coating of the ante-chamber (>2µm) while protecting the beam channel with a removable shield
II. Coating the 150 – 300nm layer in the beam channel

In case, that the narrow 3mm gap remains totally uncoated a distinct degradation of the vacuum performance can be observed



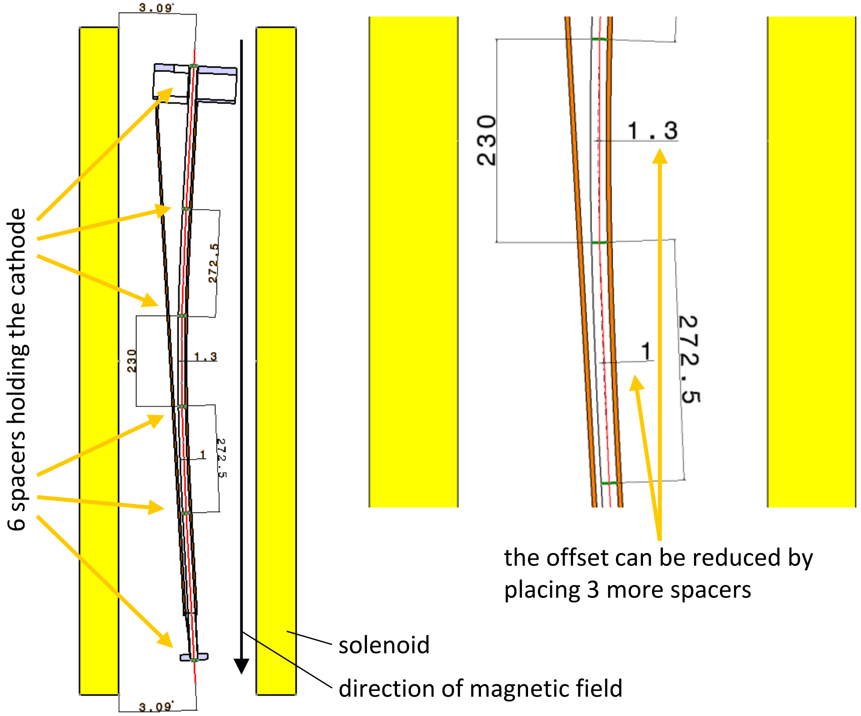


Courtesy of Hossein Karimi (ILS)
Simulations done with
Synrad & MolFlow

NEG coating

Future NEG-coating activities:

- Building NEG-coating **setup with moveable solenoid** for coating length up to 2.5m
- **NEG-coating of bent chambers:** Is there an decisive impact of the cathode offset and the deviation of the magnetic field direction due to the bend chamber, regarding the uniformity of the NEG-layer?
- **NEG-coating of the BPM buttons** without affecting the insulation.



- **Optionally: NEG-coating before welding or brazing** done with PVD (physical vapor deposition) might have the advantage of having a better control of all NEG criteria (adhesion, composition, morphology, thickness (uniformity))

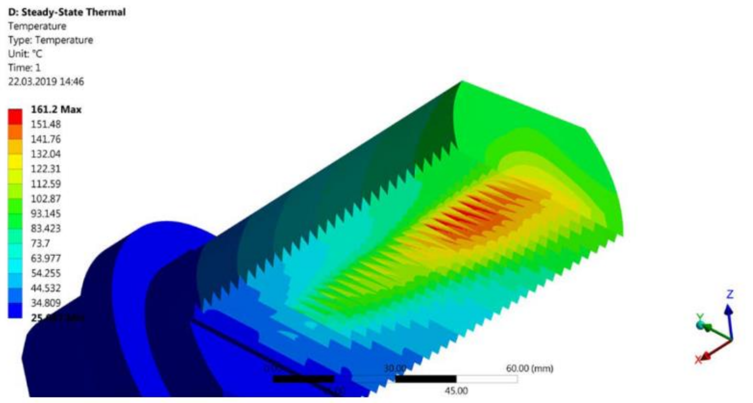
But, when the NEG coating is heated up to much (value?) during the welding or brazing process it may damage!

SR photon absorbers

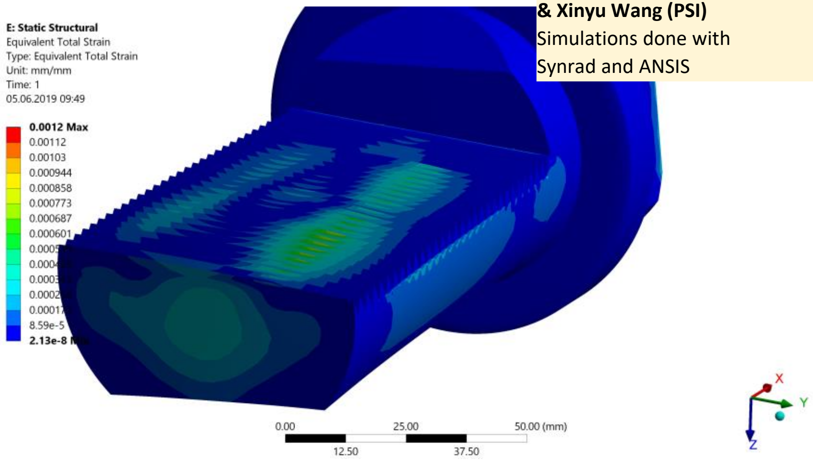
Crotch absorber ESRF EBS design

- Normal Bend (7 per ARC, total amount: 84)
  - **material: CuCr1Zr**
  - max. power density = 18.6 W/mm^2
  - total power = 2.7kW
  - max. temperature = 161.2 °C
  - max. stress = 96.2 Mpa
  - **max. strain = 0.12%**
  - **cycles = 10^5 (strain <0.2%)**

- Super Bend ~6T and 4T (total amount: 3)
  → **under calculation**



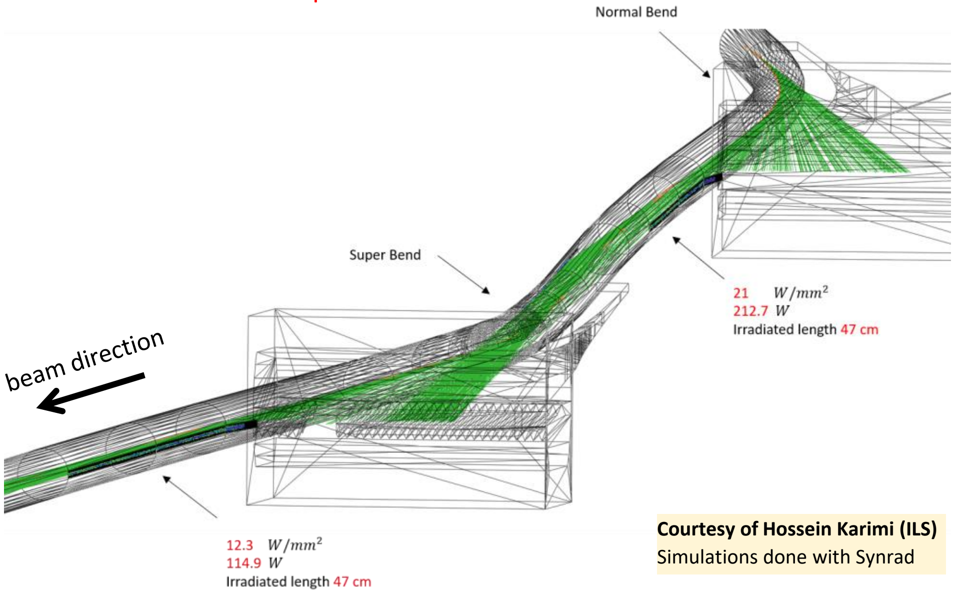
Courtesy of Hossein Karimi (ILS) & Xinyu Wang (PSI)
Simulations done with Synrad and ANSIS



SR photon absorbers

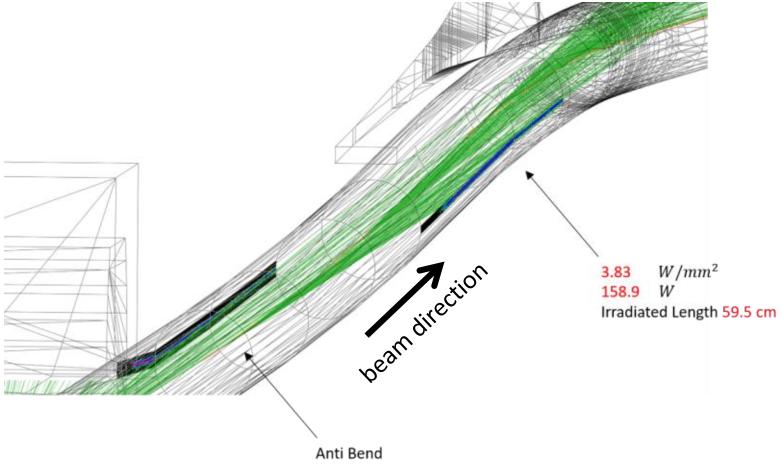
Distributed absorber on revers bend chamber

- Tilted facet behind crotch absorber
  - 21 and 12.3 W/mm² might be to high
    → needs to be optimized



Courtesy of Hossein Karimi (ILS)
Simulations done with Synrad

- inside wall of the vacuum chamber
  - 3.83 W/mm² can be handled



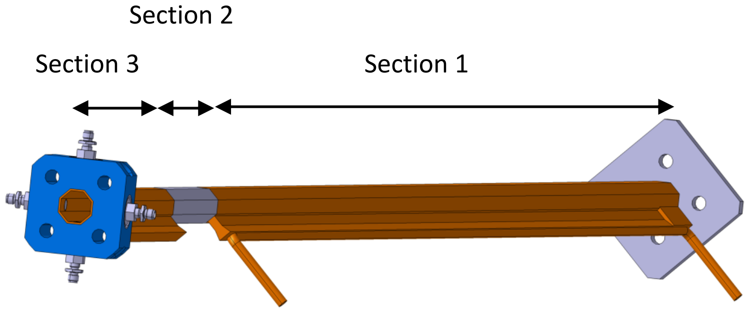
SR photon absorbers

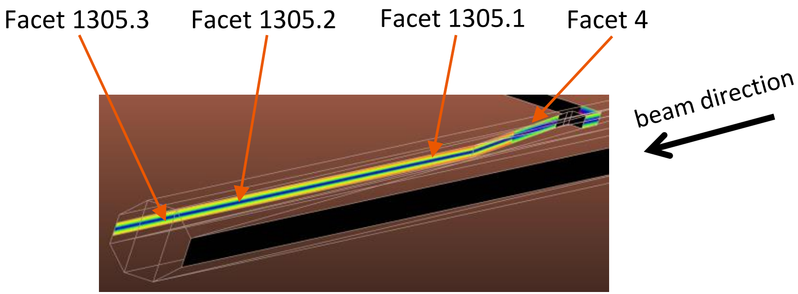
Distributed absorber on straight chamber

- Tilted facet behind crotch absorber
  - 16.3 W/mm^2 might be to high
    → needs to be optimized

Courtesy of Colette Rosenberg
Simulations done Synrad

	Facet 1305.3 Section 3 Cu-OF	Facet 1305.2 Section 2 1.4429	Facet 1305.1 Section 1.2 Cu-OF	Facet 4 Section 1.1 Cu-OF
Max. Power Density [W/mm^2]	0.391276	0.464184	2.42728	16.2364
Total Power [W]	35.49	14.35	242.61	1009.73



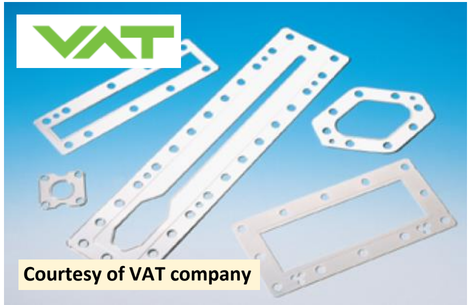


→ Once the lattice is fixed, the final simulations, calculations and resulting optimization can be done

Seals, pumps and valves

Seals: VAT-seal

- Compared to other sealing-systems, minimum longitudinal space is required to dismount a chamber out of the ARC
- Minimum limitations in the shape of the sealing contour
- Gap-free and good-conducting connection in terms of wall resistive impedance
- Amount per ARC: 16 (x12=192)



Courtesy of VAT company

Pumps:

NEG-pump CapaciTorr D 400-2 (SAES)

- Amount per ARC: 7 (x12=84)

IG-pump VacIon Plus 55 l/s (Agilent)

- Amount per ARC: 7 (x12=84)


Courtesy of SAES company


Courtesy of Agilent company

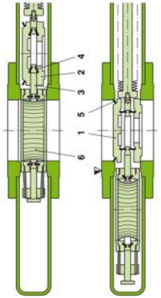
Valves:

VAT-Series 472 RF all-metal gate valve

- A meeting with VAT will take place 12th June 2019 (discussion on our requirements)
- Amount per ARC: 2 (x12=24)

VAT-Series 482 RF all-metal gate valve

- Amount per ARC: 2-3 > not clear yet


Courtesy of VAT company

Vacuum system installation procedures

Activities for each sector (duration 6 weeks)

1. Installation and alignment of the **sector** girders
   Installation of the **sector** chamber on the lower magnet halves and closing magnets
2. Insertion Device installation and alignment in the **straight** section
   Installation of all vacuum components and bake out in the **straight** section
   Final works (e.g. removal of bake out material)
3. Installation of **FrontEnd** supports and alignment
   Installation of all vacuum components and bake out in the **FrontEnd**
   Final works (removal of bake out material)
4. Cabling, commissioning of the vacuum control system

	Wochen	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Sektor 01		1	2	3	4	5	6																		
Sektor 02					1	2	3	4	5	6															
Sektor 03								1	2	3	4	5	6												
Sektor 04											1	2	3	4	5	6									
Sektor 05														1	2	3	4	5	6						
Sektor 06																	1	2	3	4	5	6			
Sektor 07		1	2	3	4	5	6																		
Sektor 08					1	2	3	4	5	6															
Sektor 09								1	2	3	4	5	6												
Sektor 10											1	2	3	4	5	6									
Sektor 11														1	2	3	4	5	6						
Sektor 12																	1	2	3	4	5	6			
Injektion																					1	2	3	4	
Cavity																						1	2	3	4
3HC ?																									

Sektor	Aktivität pro Sektor	eitbedarf [Tage]	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr
					1							2							3							4							5							6		
1	1 Girder in Tunnel, vorinstalliert, Magnete offen	2	K1	K1																																						
	Girder Vermessung	2																																								
	Vakuumkammer einsetzen	1					+																																			
	Magnete Schliessen	6				K	K					K	K							K	K																					
2	ID Support Installation	1			K1																																					
	Vermessung	1																																								
	ID Installation (Doppelundulator mit Zwischentrecke)	2								K1	K1																															
	Vermessung	2																																								
	Vakuumverbindungen, Pumpen, Lecktest	1																																								
	Ausheizen einrichten	2																																								
	Ausheizen	3																	Wasser																							
	Endarbeiten	2																																								
3	FE Support Installation	2.5															K1	K1	K1																							
	Vermessung	2.5																																								
	Vakuumverbindungen, Pumpen, Lecktest	2																																								
	Ausheizen einrichten	2																																								
	Ausheizen	3																																								
	Endarbeiten Ausheizen	2																																								
4	Verkabelung, Inbetriebnahme Kontroller	3																																								

To fulfill the installation within 24 weeks, two sectors has to be mounted in parallel. Therefore the usage of two overhead cranes (K and K1) is necessary. During this installation period the cranes are fully booked.

PAUL SCHERRER INSTITUT

Wir schaffen Wissen – heute für morgen

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