CERN

Development and Production of Non Evaporable Getter Coatings For the Vacuum Chambers of the 3GeV storage ring of Max IV

P. Costa Pinto, S dos Santos, A. Sapountzis, M. Mensi, I. Wevers, M. Grabski, E. El Dmour, J. Albach

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- Conclusion

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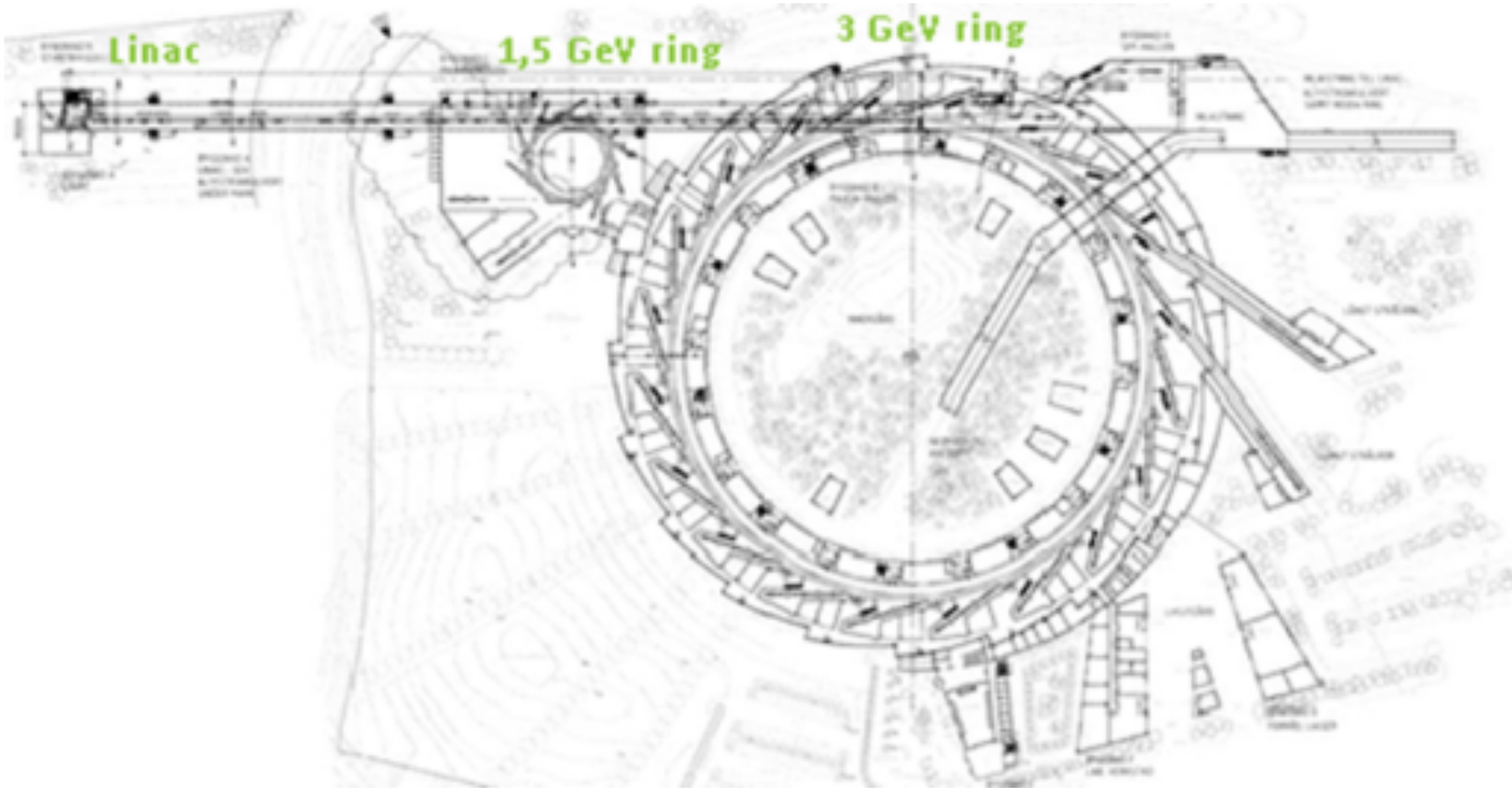

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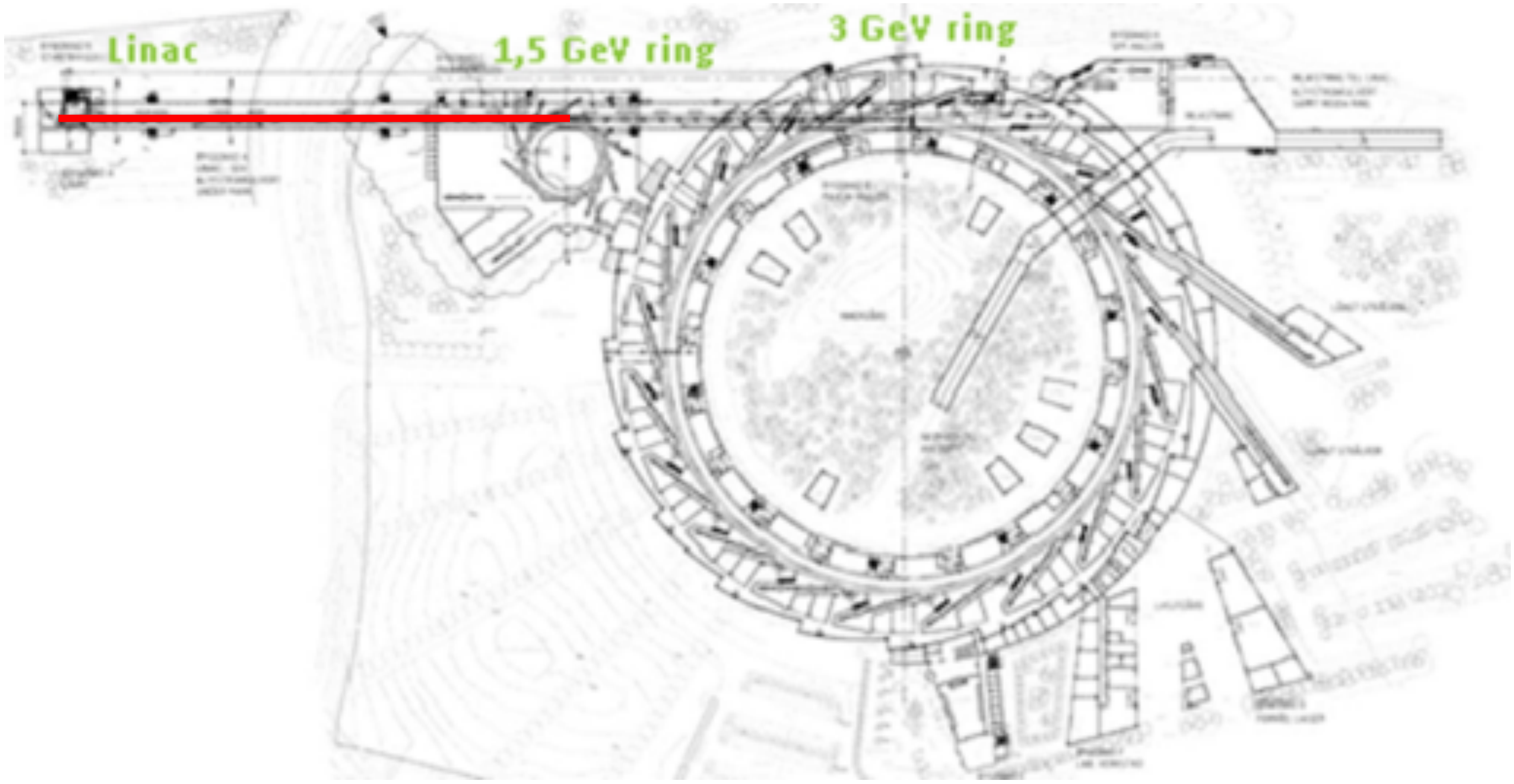

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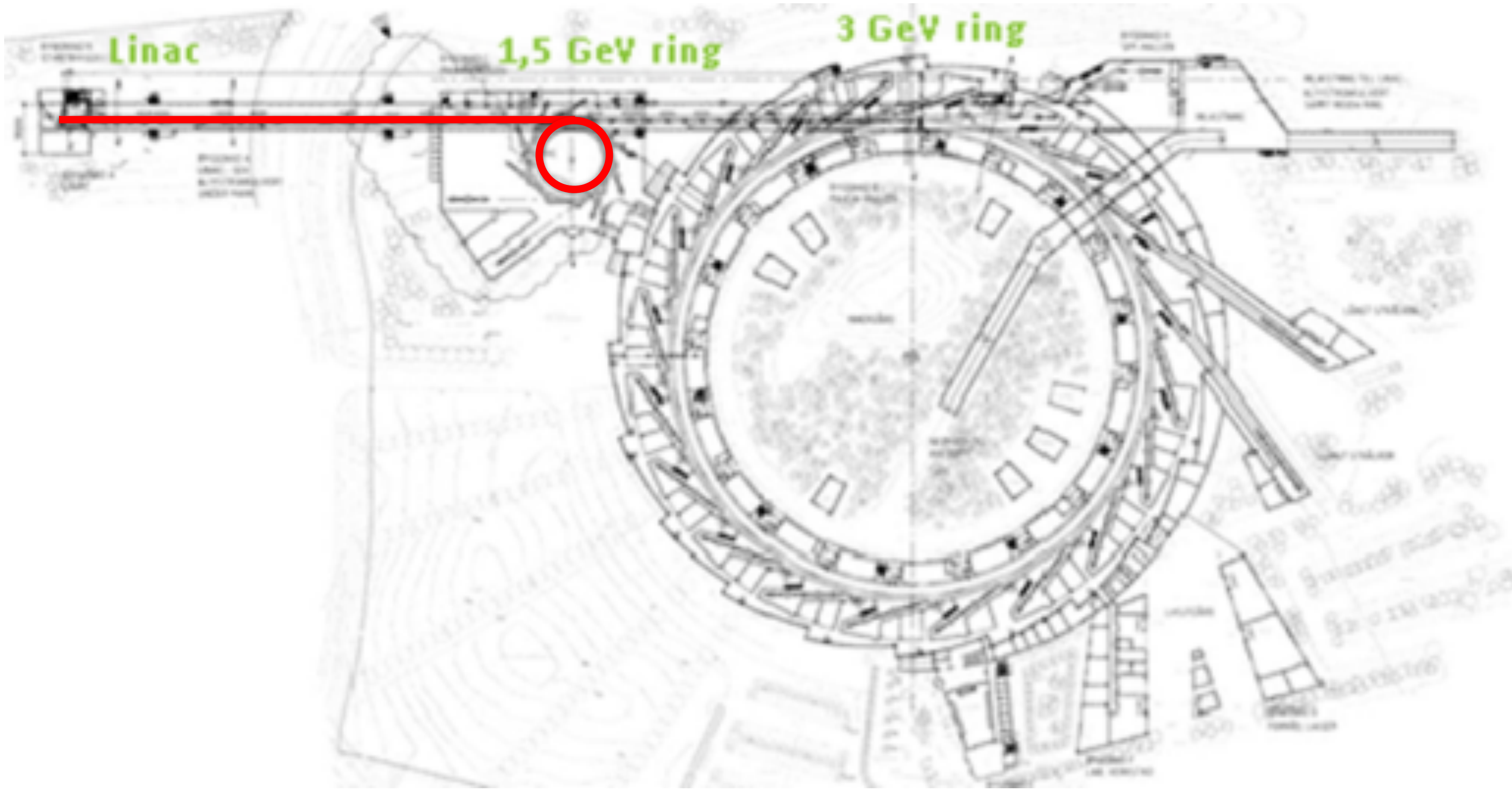

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Circumference (m)	*528*
Straight sections	*20*
Injection	*full energy, top-up*
Stored current (mA)	*500*
Horizontal emittance (nm rad)	*0.2 - 0.3*
Vertical emittance (nm rad)	*< 0.008*
Horizontal beam size (σ μm)	*42 - 52*
Vertical beam size (σ μm)	*< 6*

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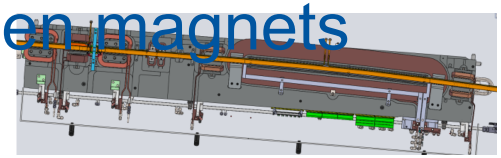

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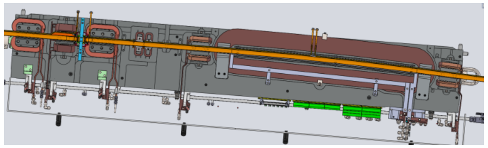

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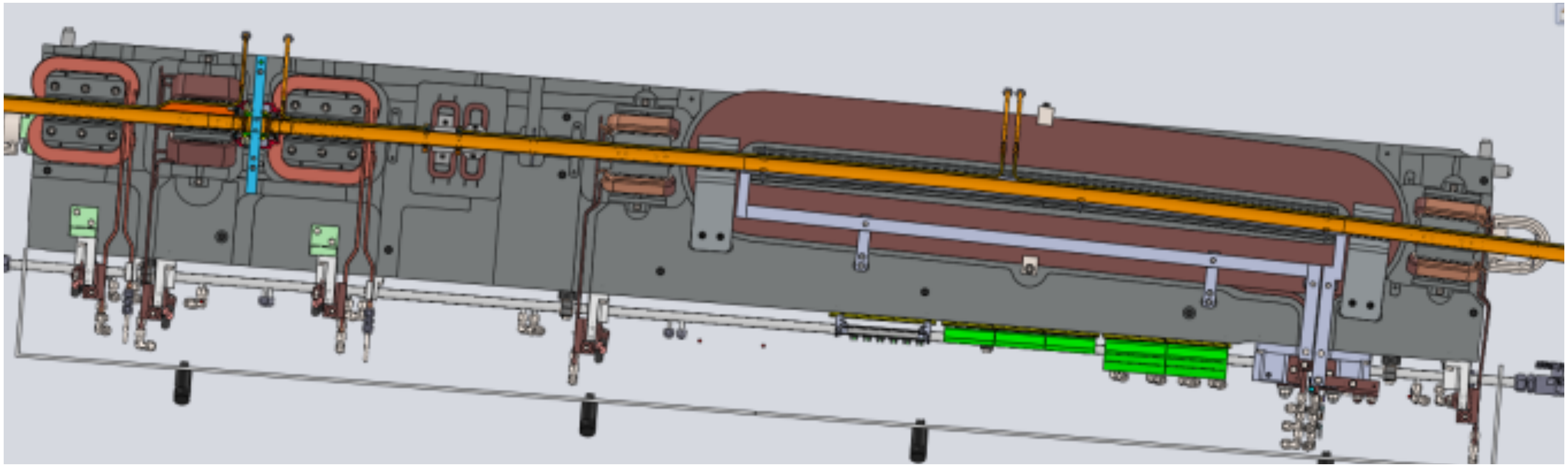

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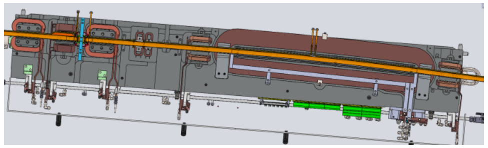

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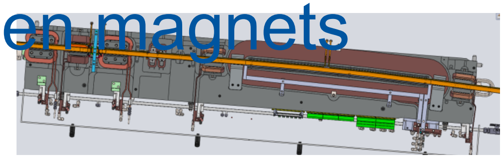

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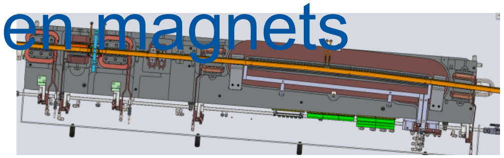

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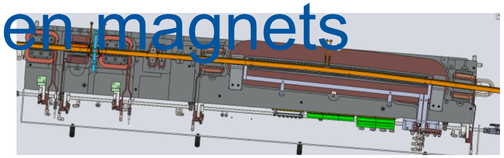

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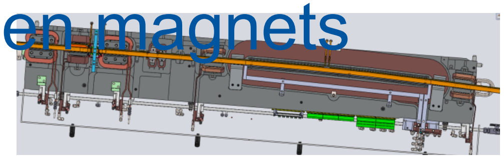

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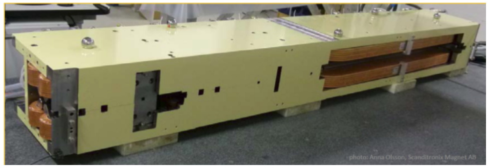

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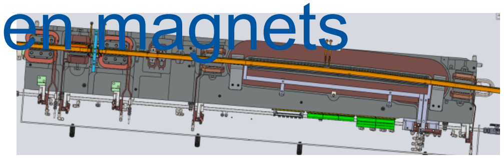

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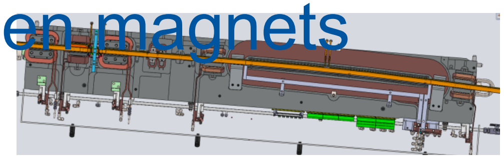

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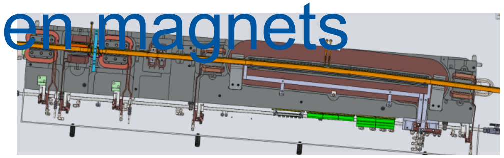

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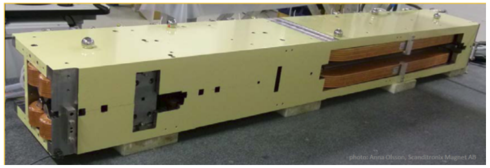

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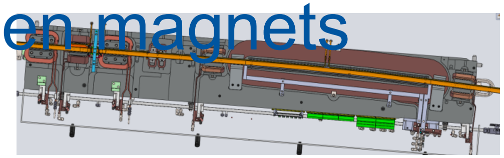

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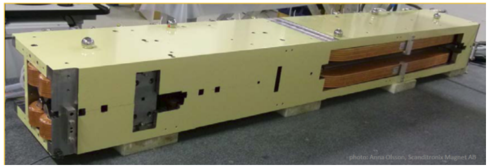

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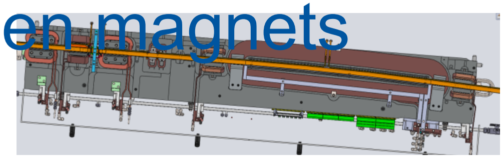

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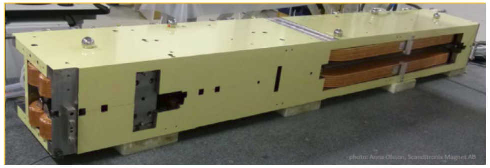

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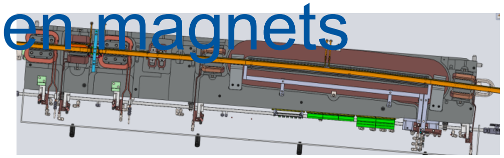

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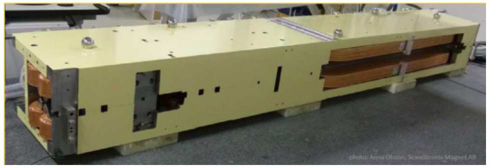

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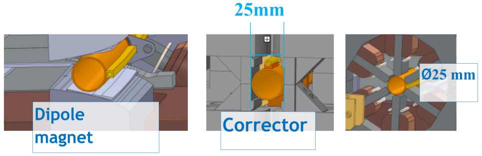

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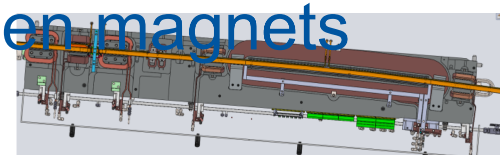

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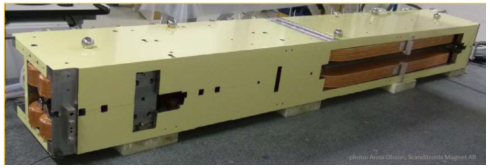

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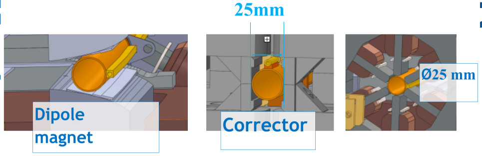

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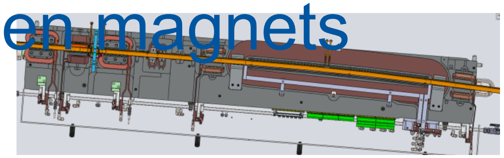

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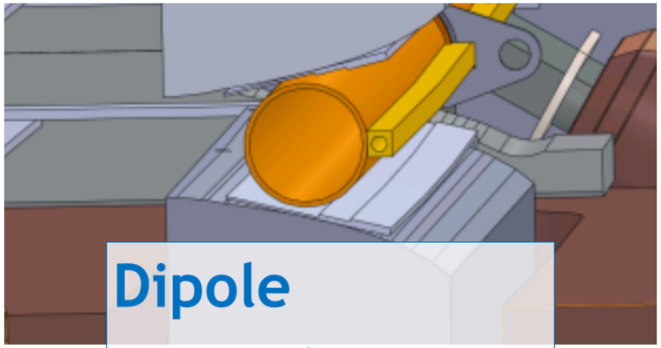

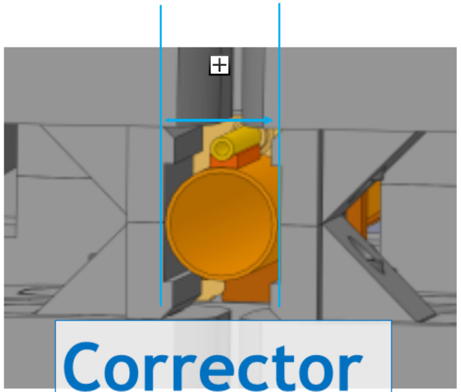

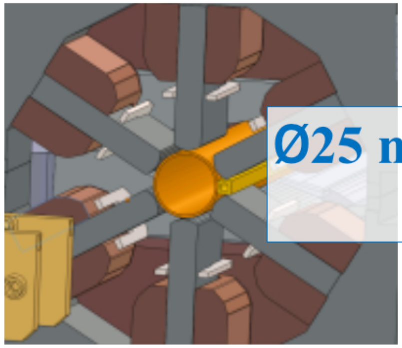

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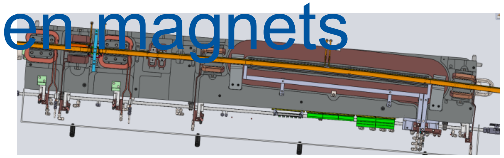

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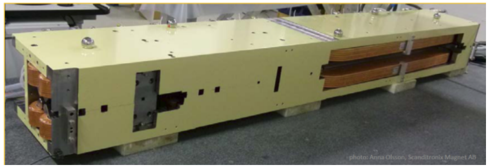

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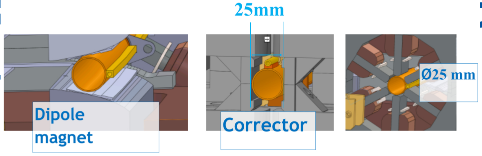

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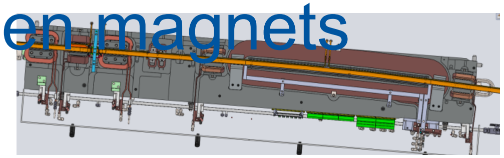

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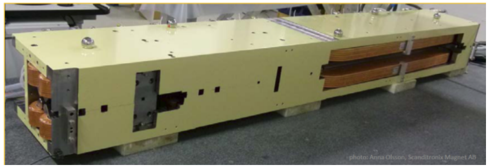

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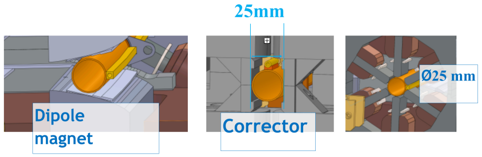

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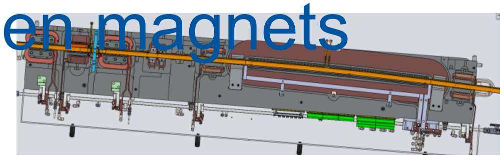

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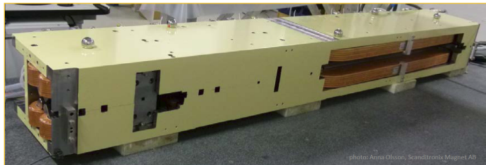

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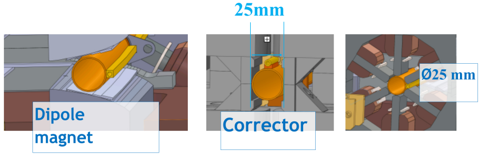

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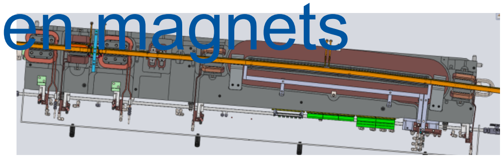

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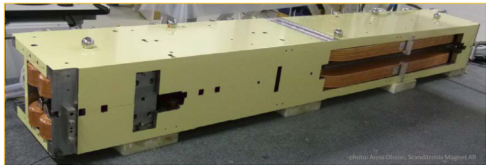

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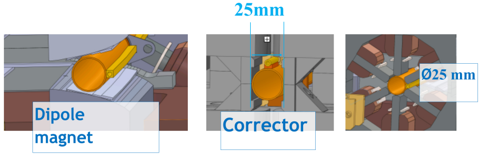

- Low target pressure with beam

  Average dynamic pressure 1 10-9 mbar

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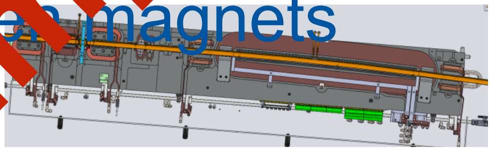

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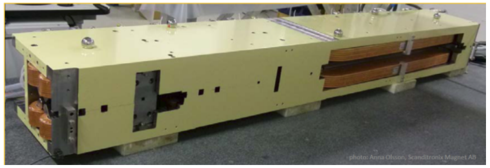

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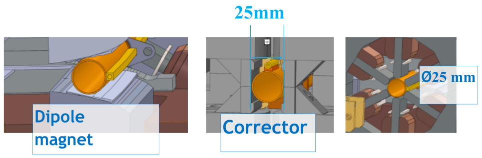

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Need of NEG thin-film coating for the pumping

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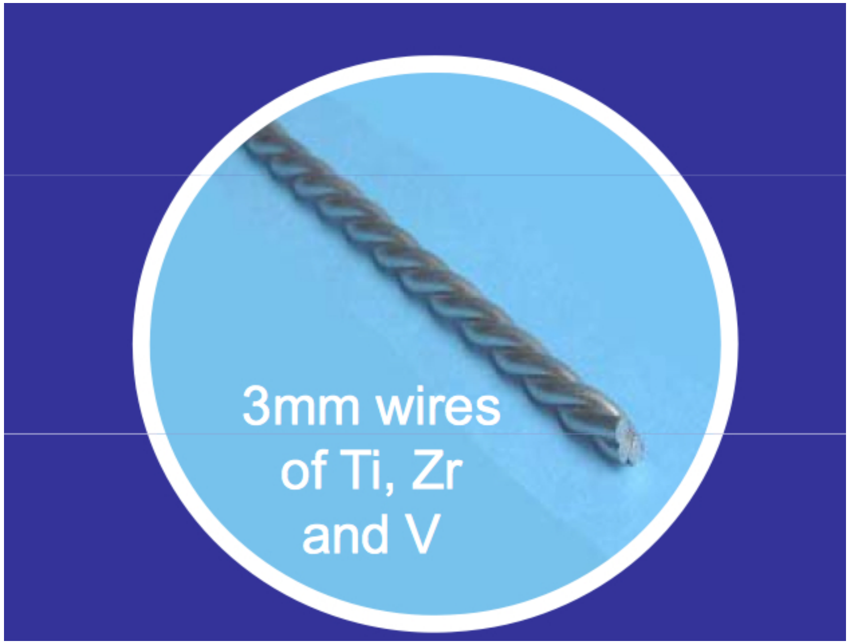
  - It can be activated at 180°C in 24 hours

Vacuum system constraints and requirements



- The coating is done by DC magnetron sputtering from a cathode composed of 3 different wires

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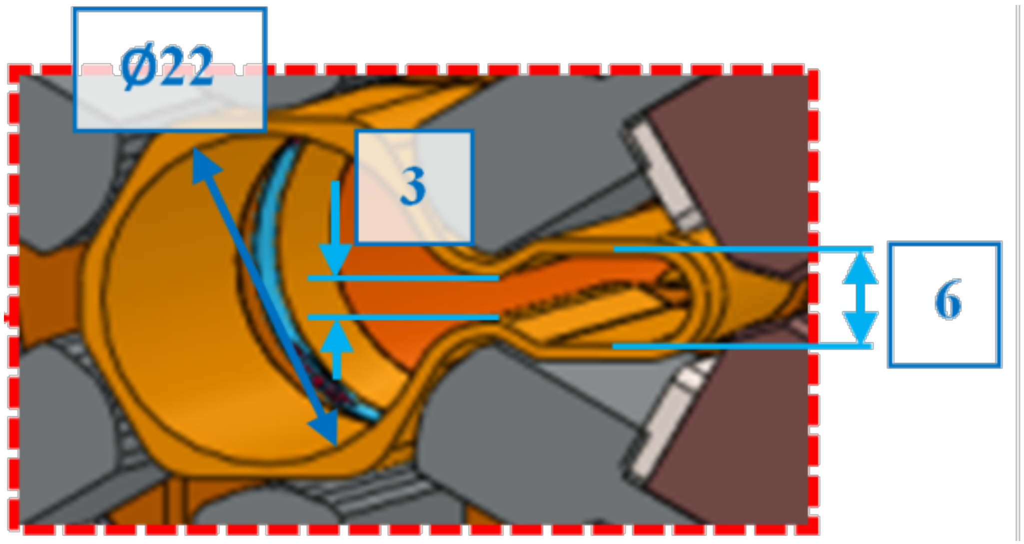
- Coating of the chambers for photon beam extraction is made at CERN
  - A total of 80 chambers of different types

Vacuum system constraints and requirements



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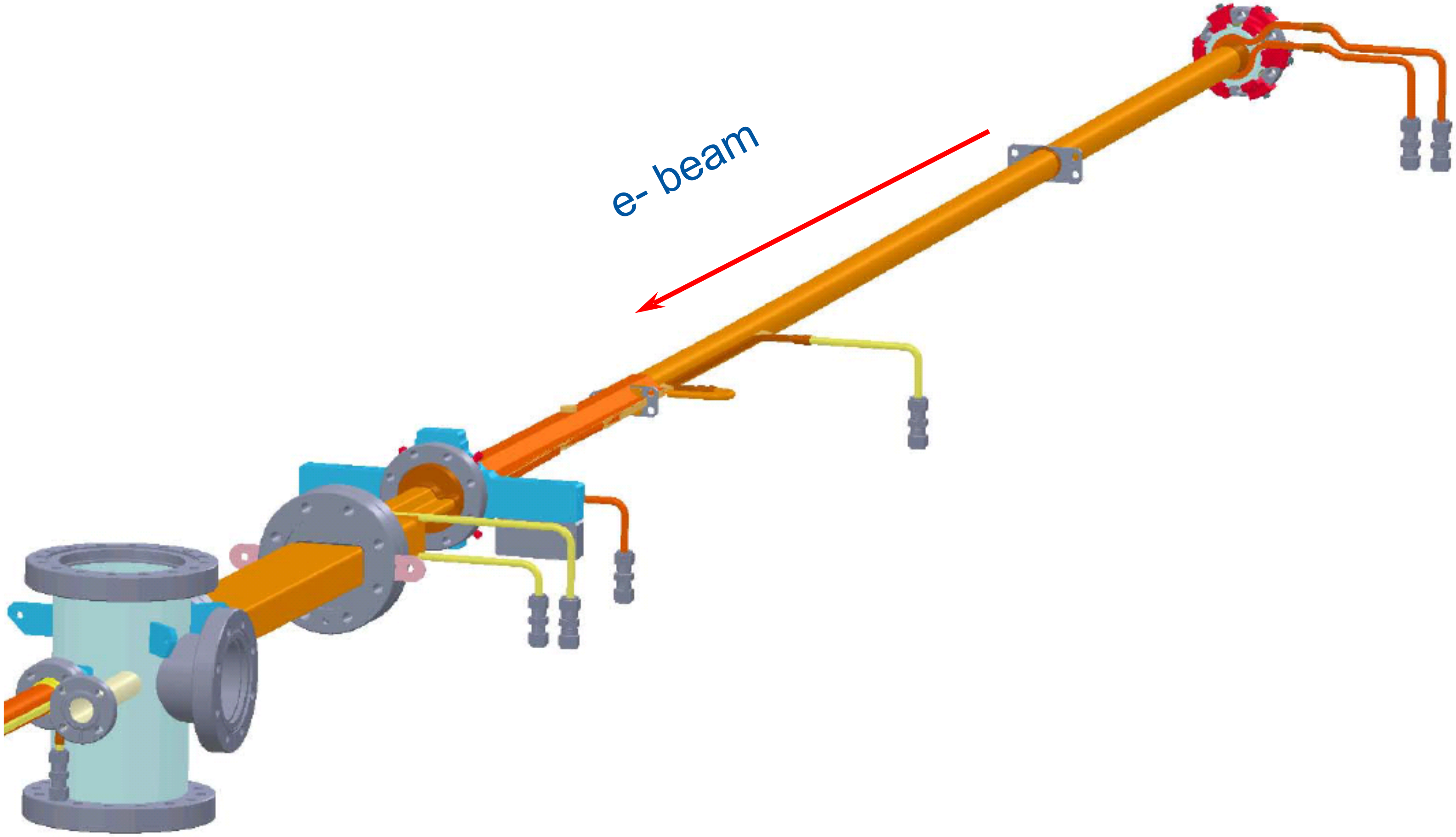

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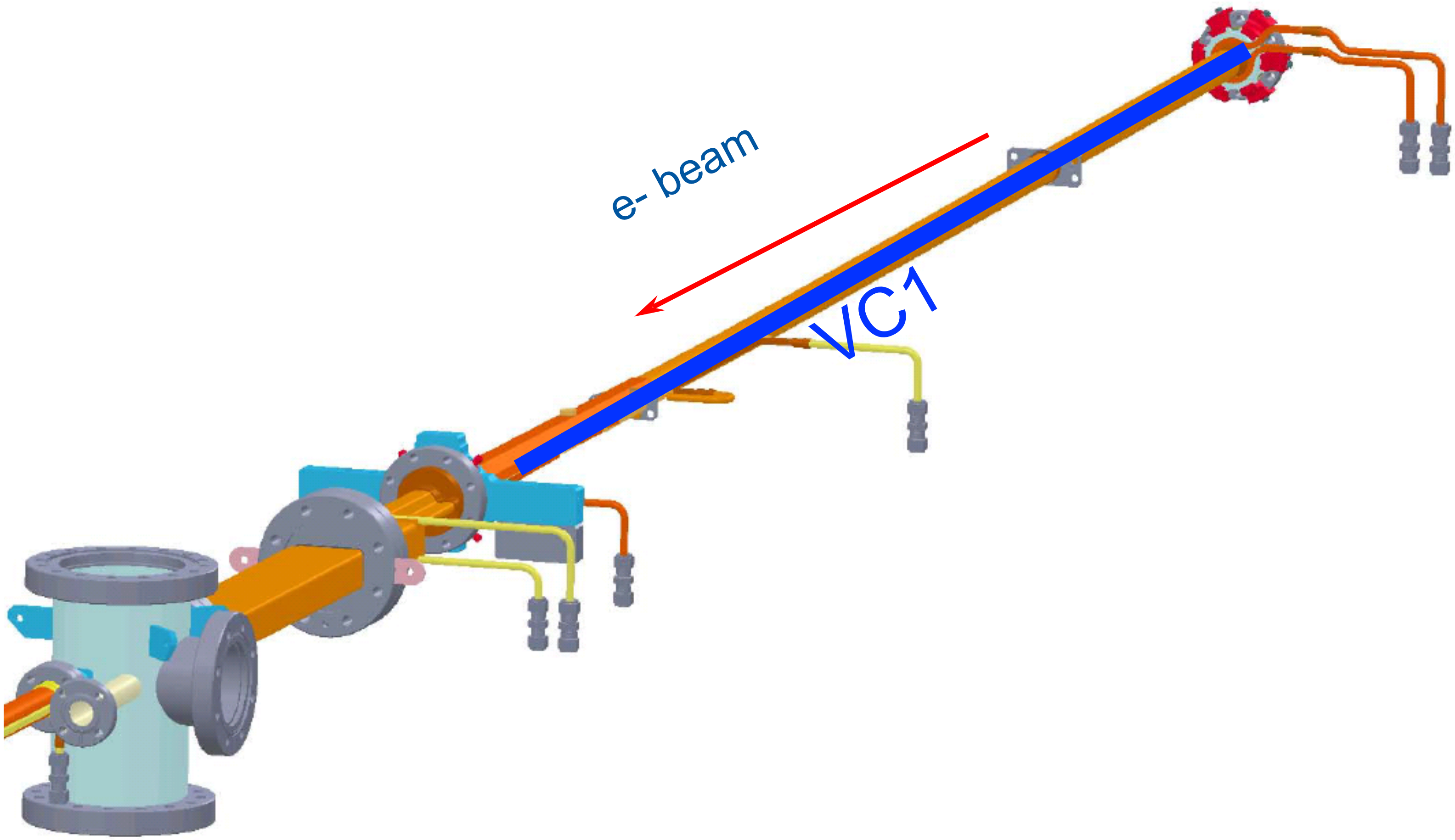

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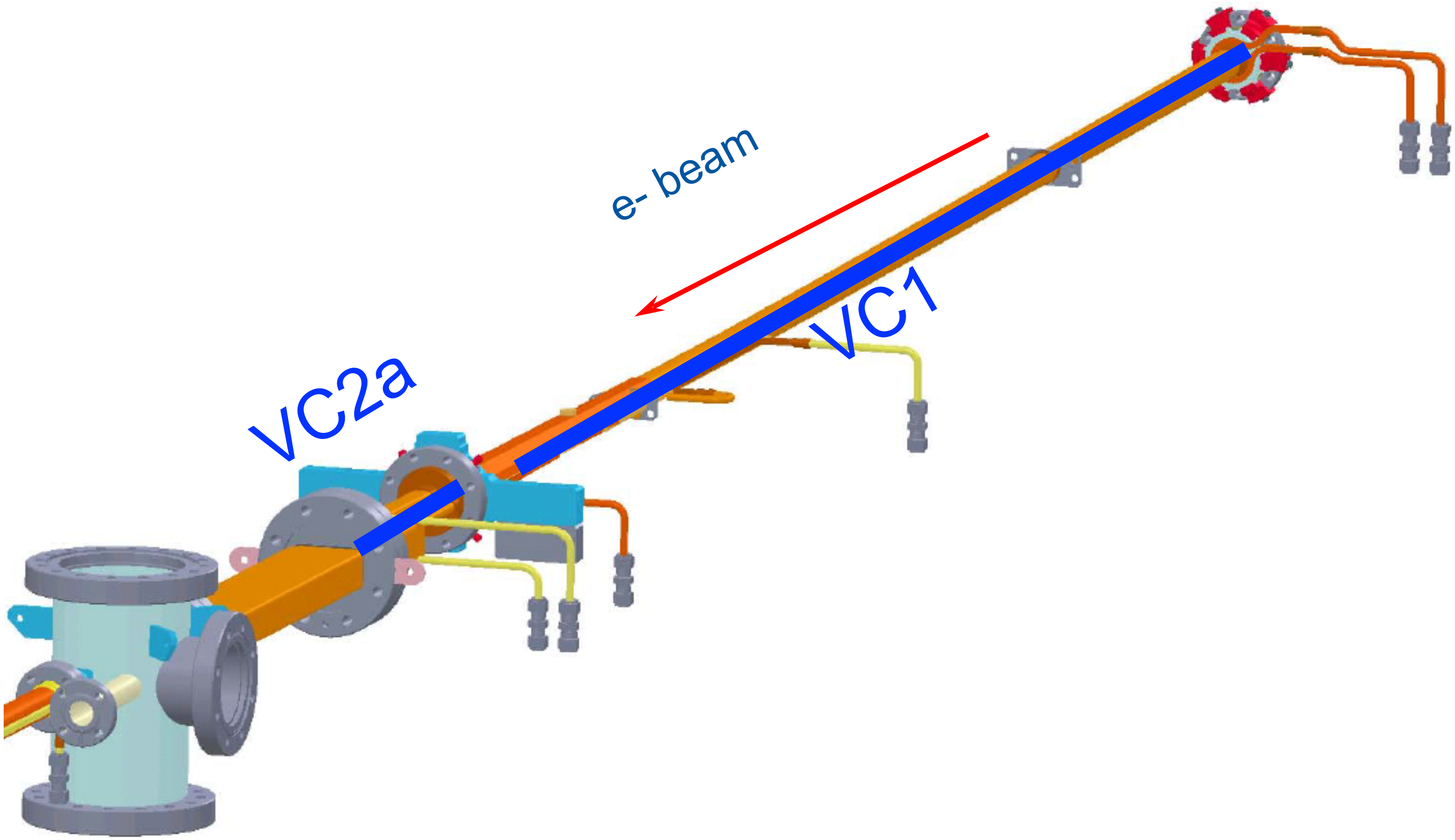

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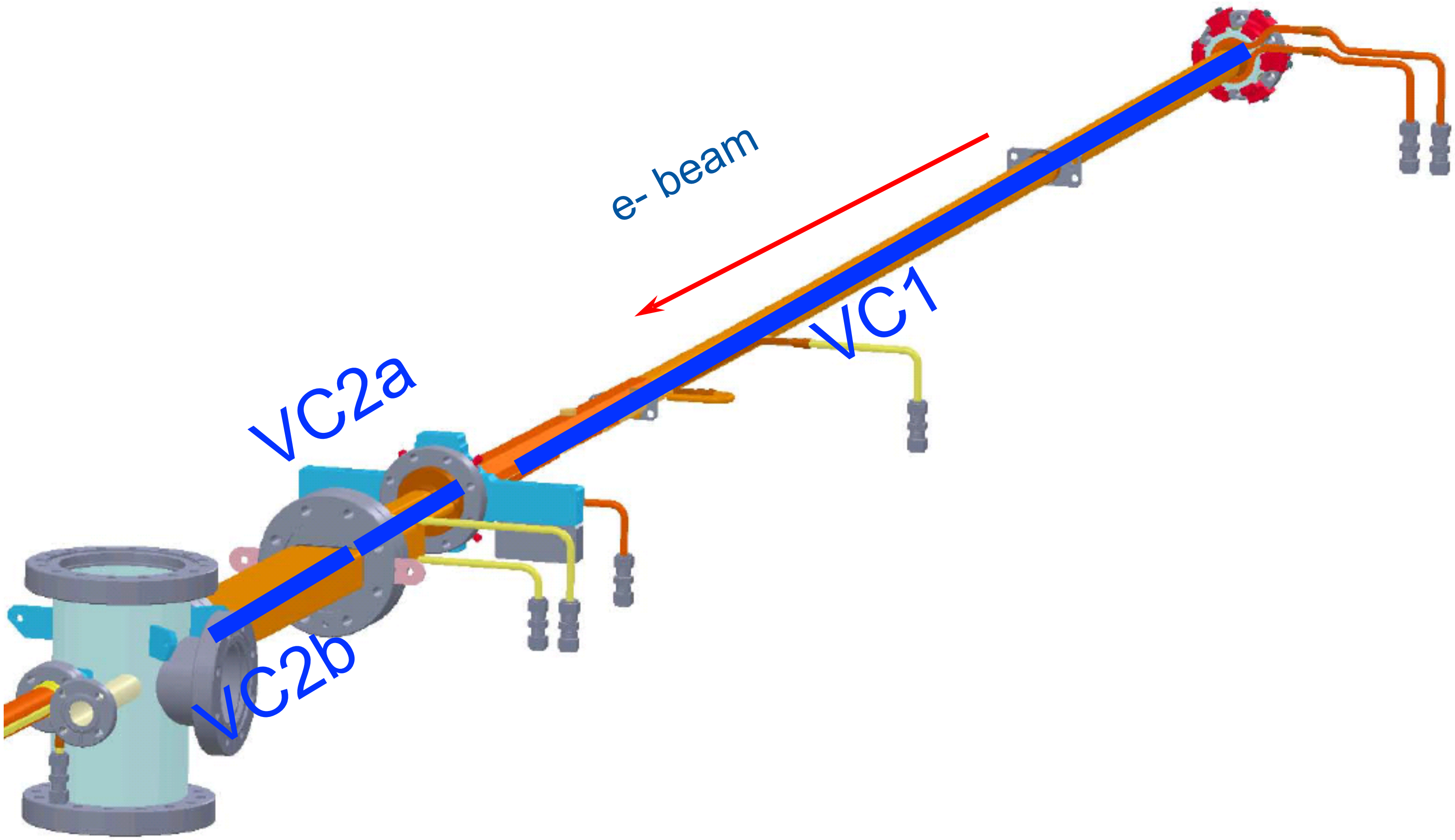

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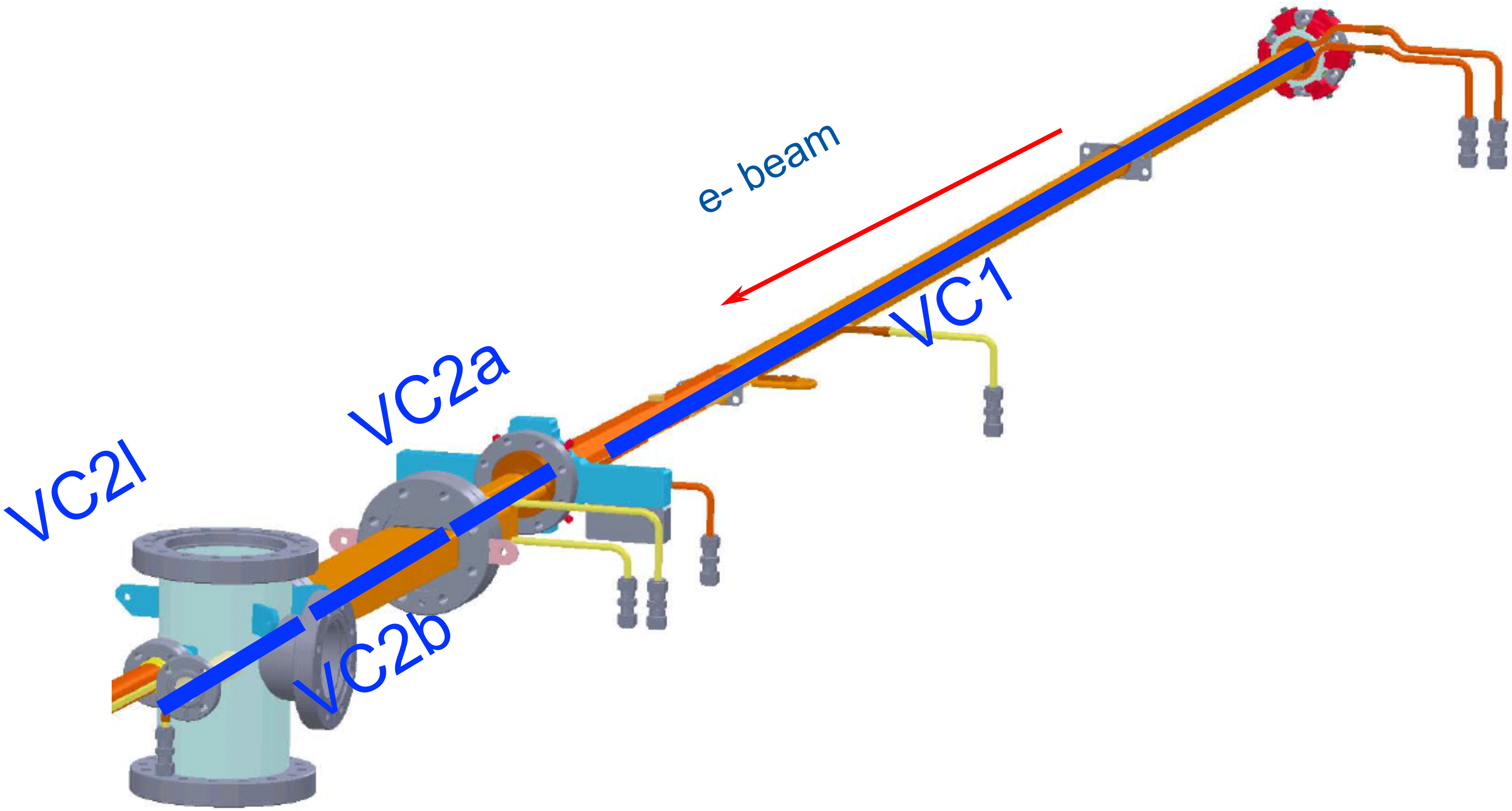
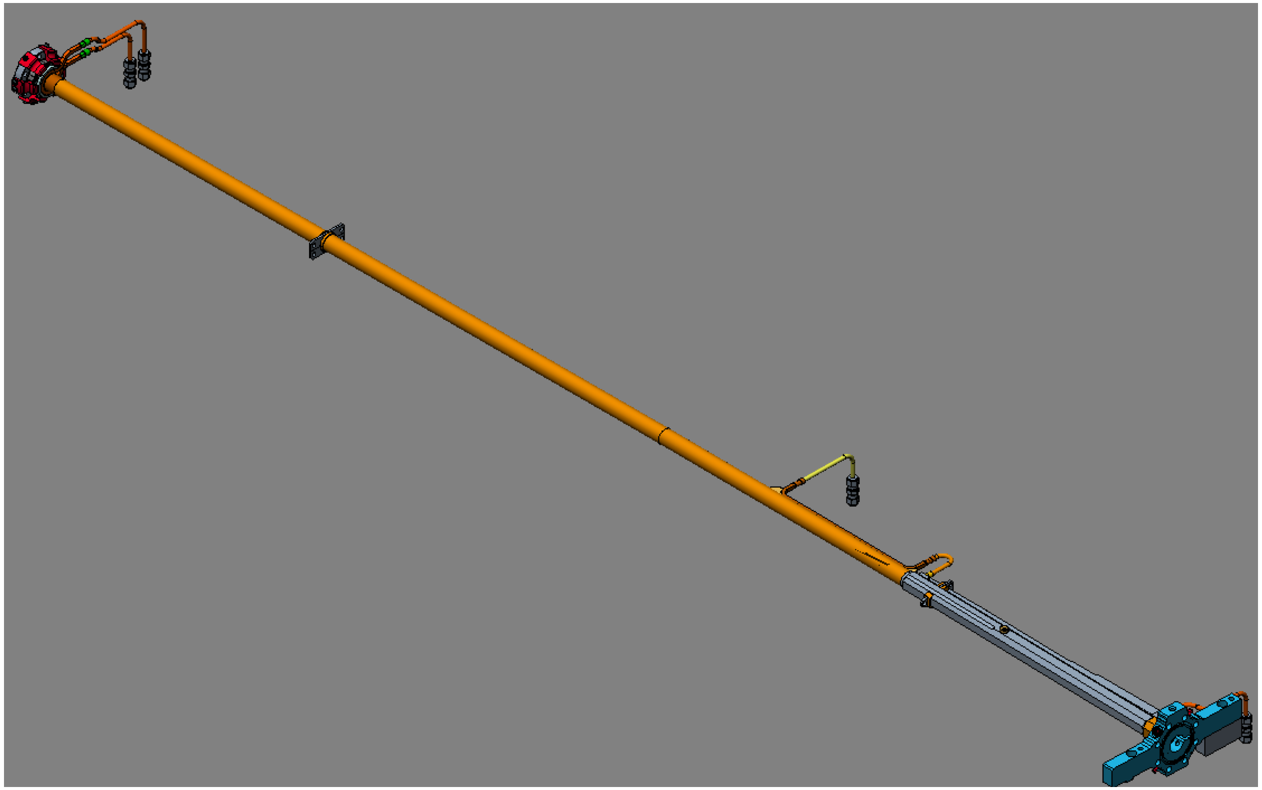


Vacuum chambers for beam extraction

VC1



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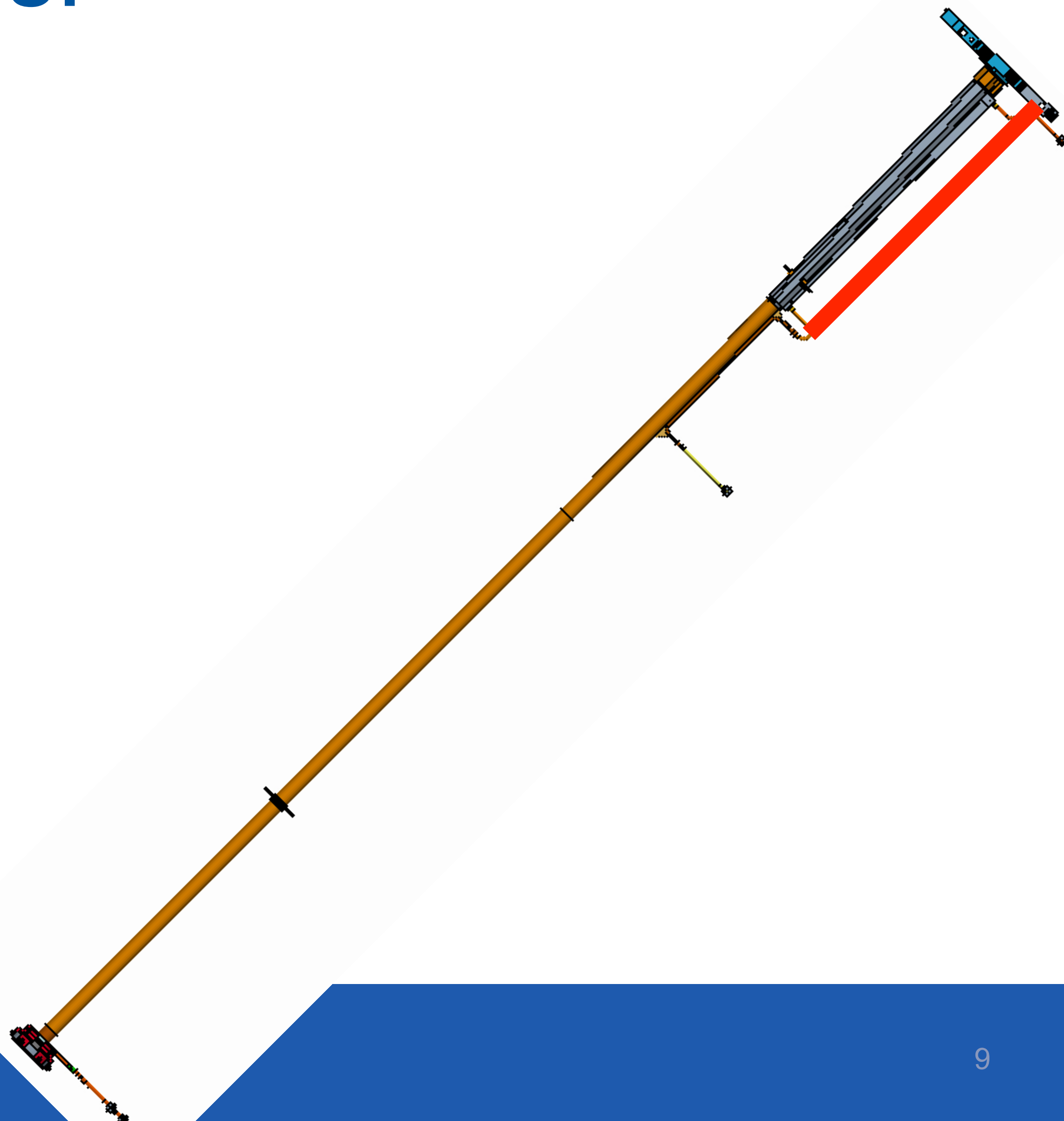

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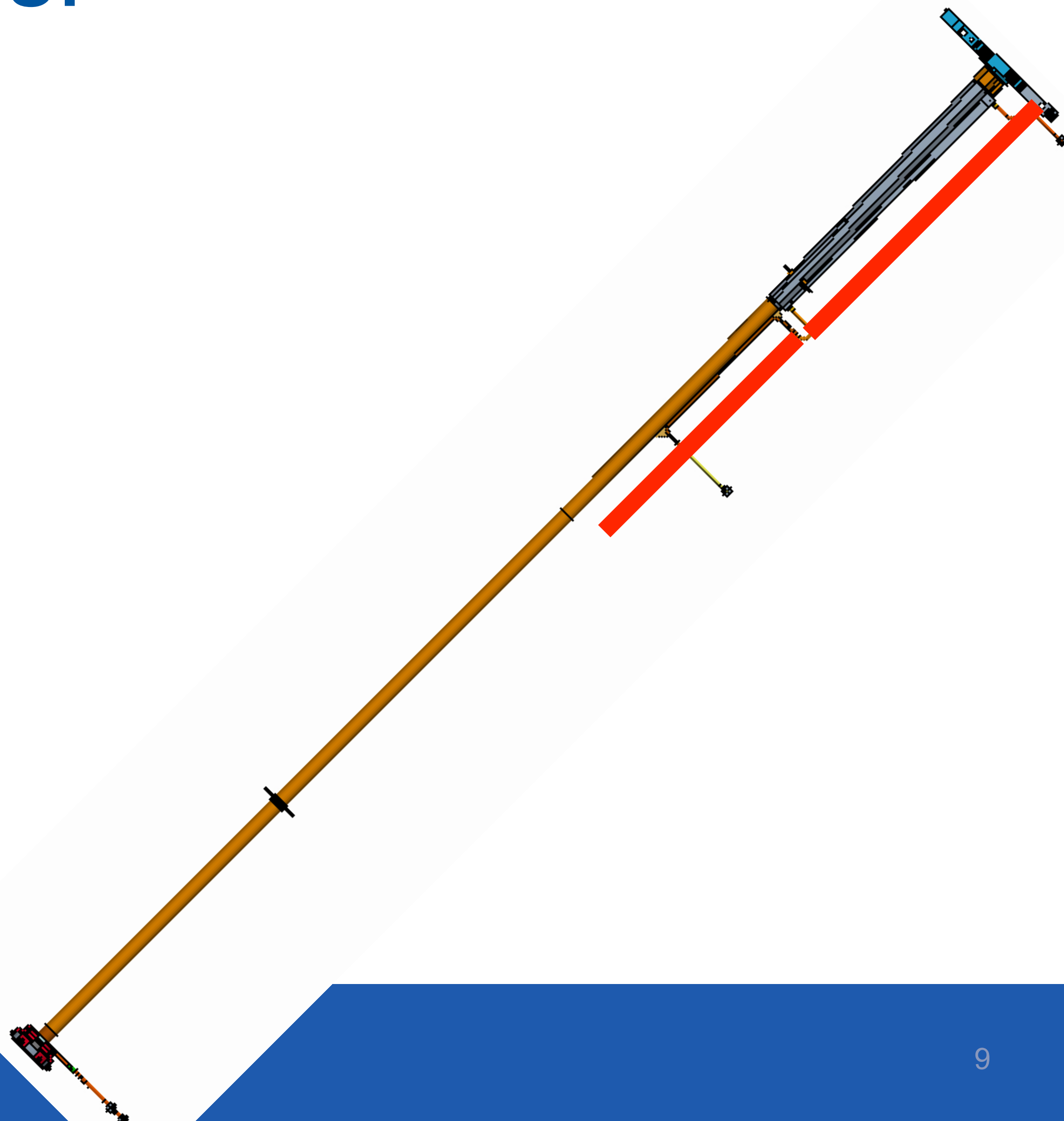

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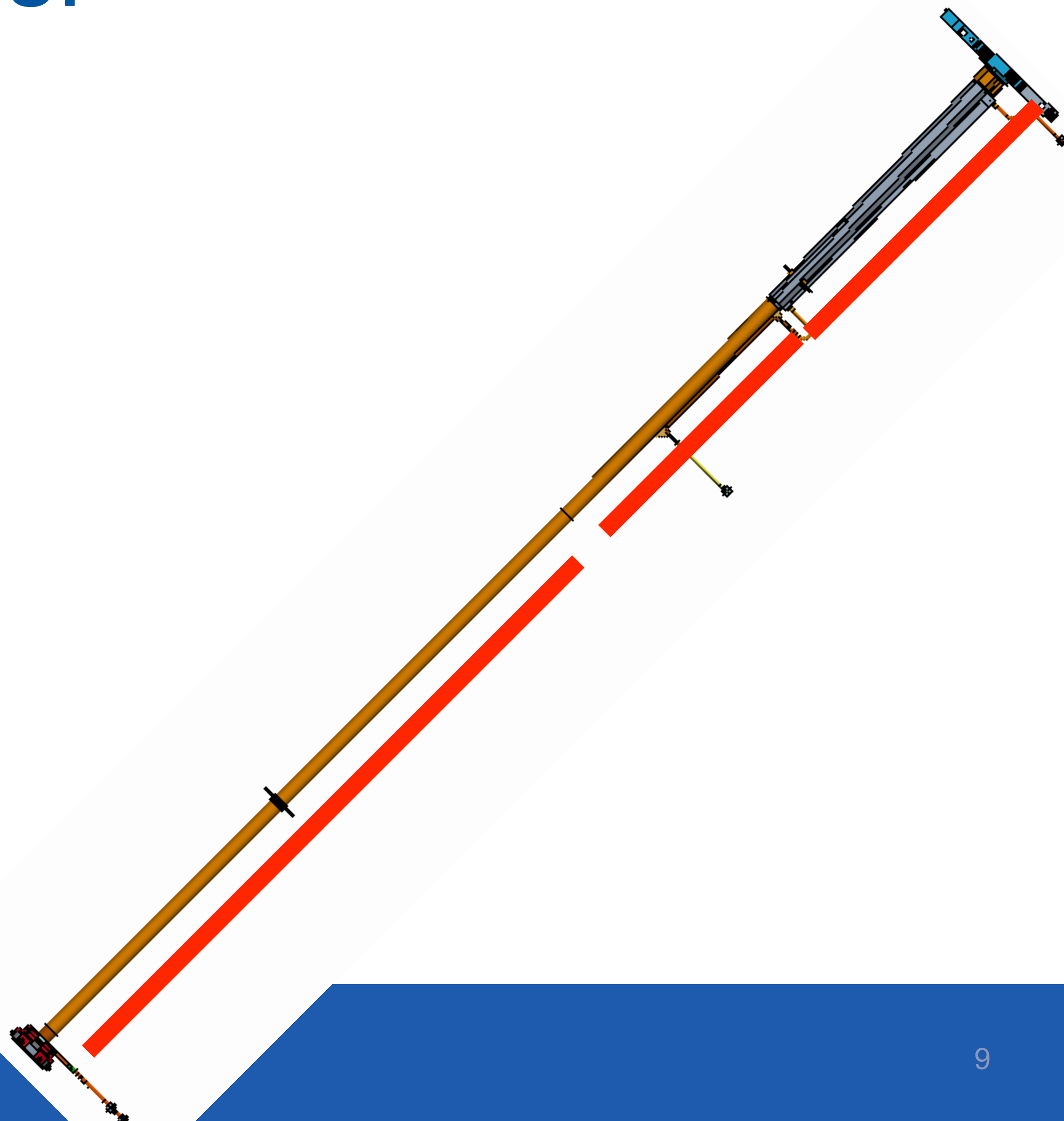

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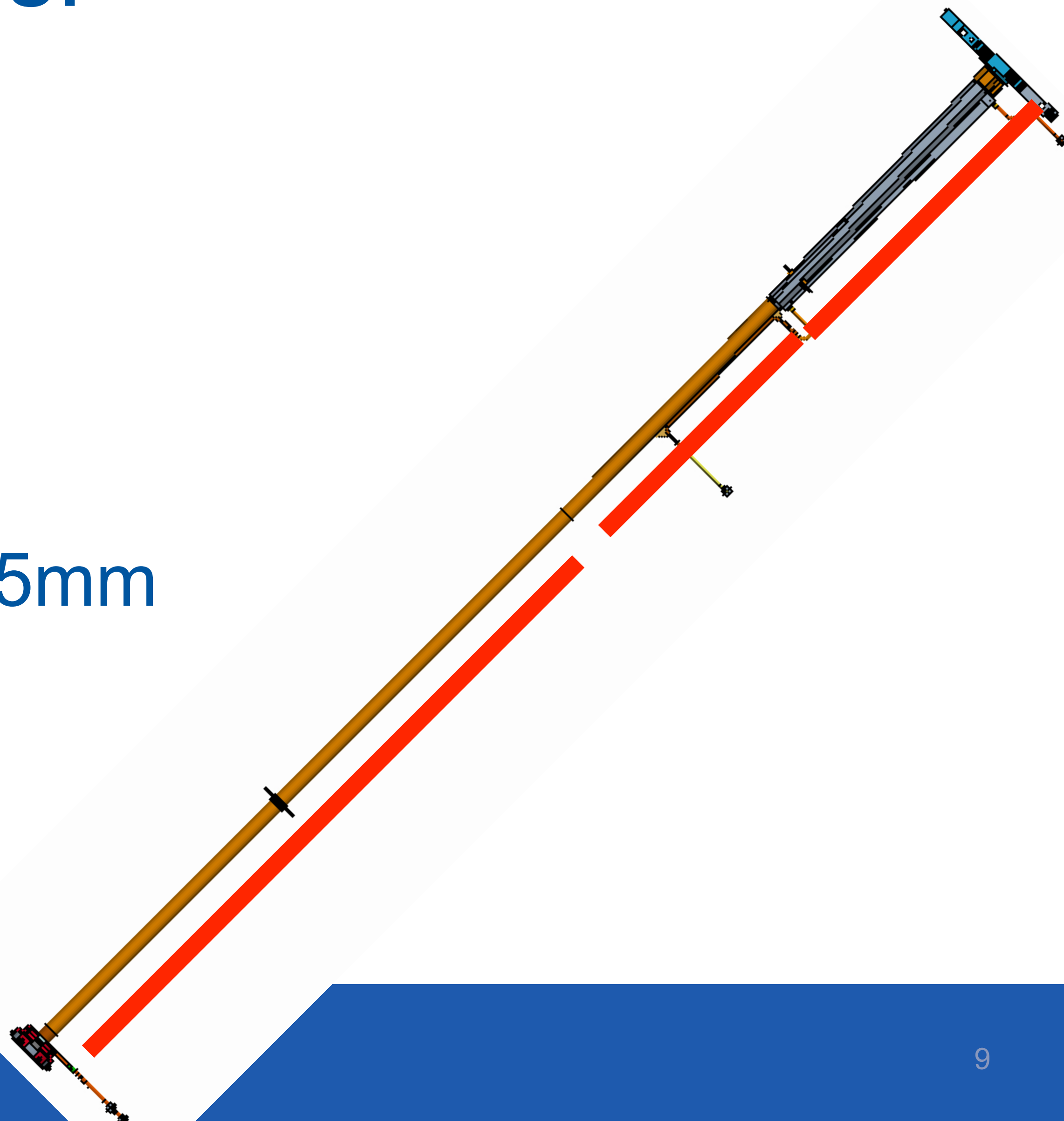

Vacuum Chamber 1 (VC1) Characteristics:

- 2.38m length
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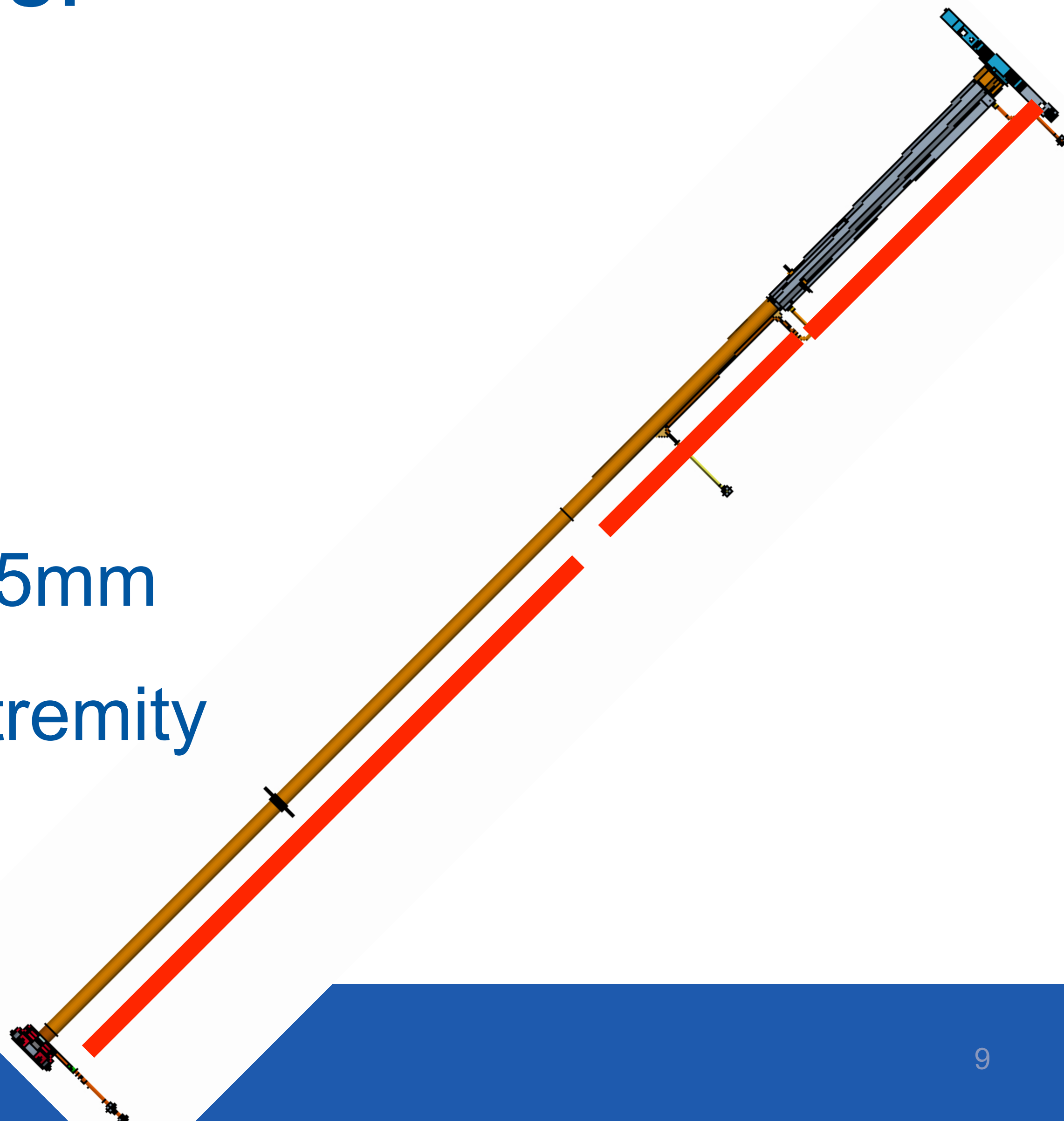
- BPM at one extremity



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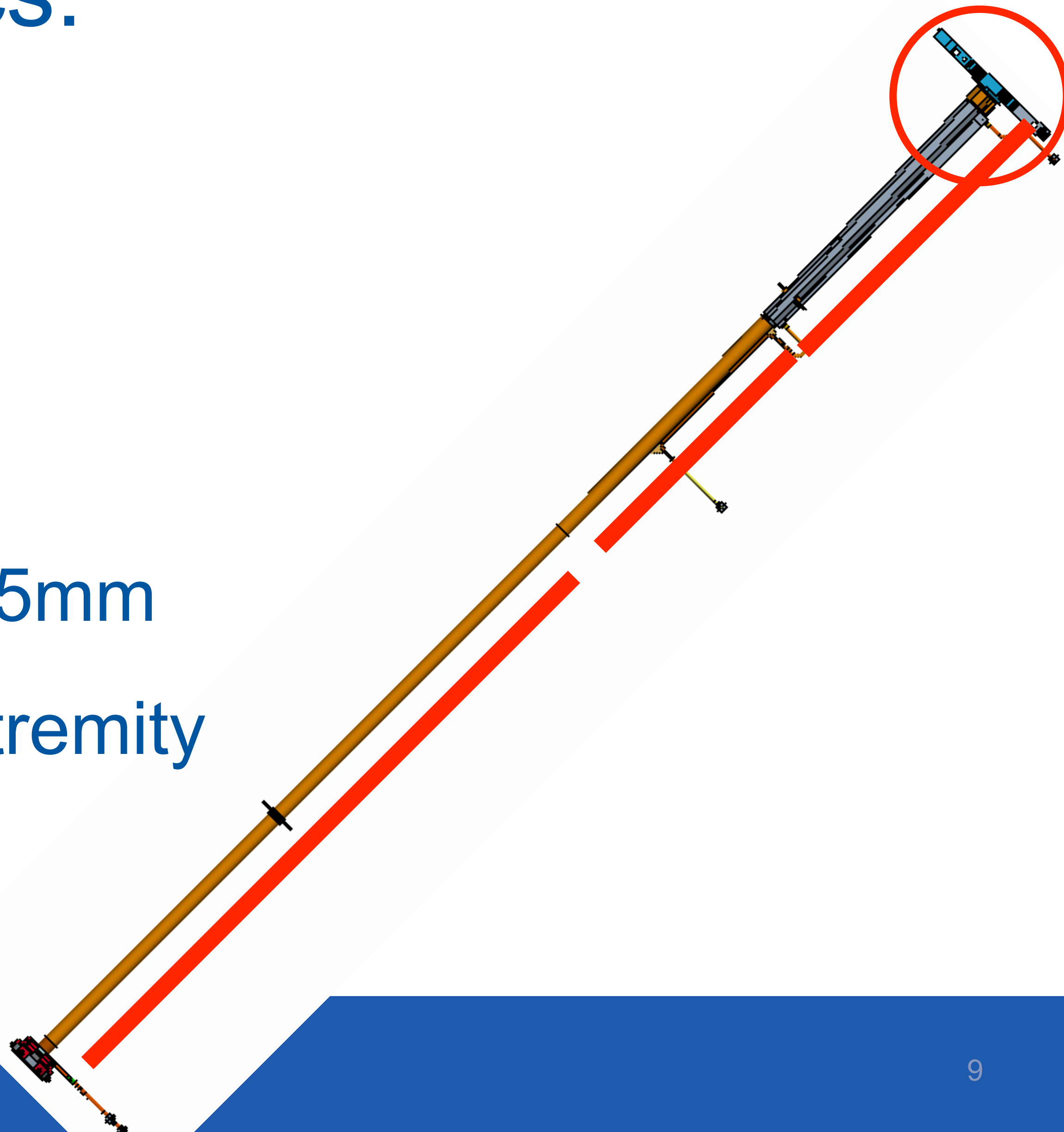
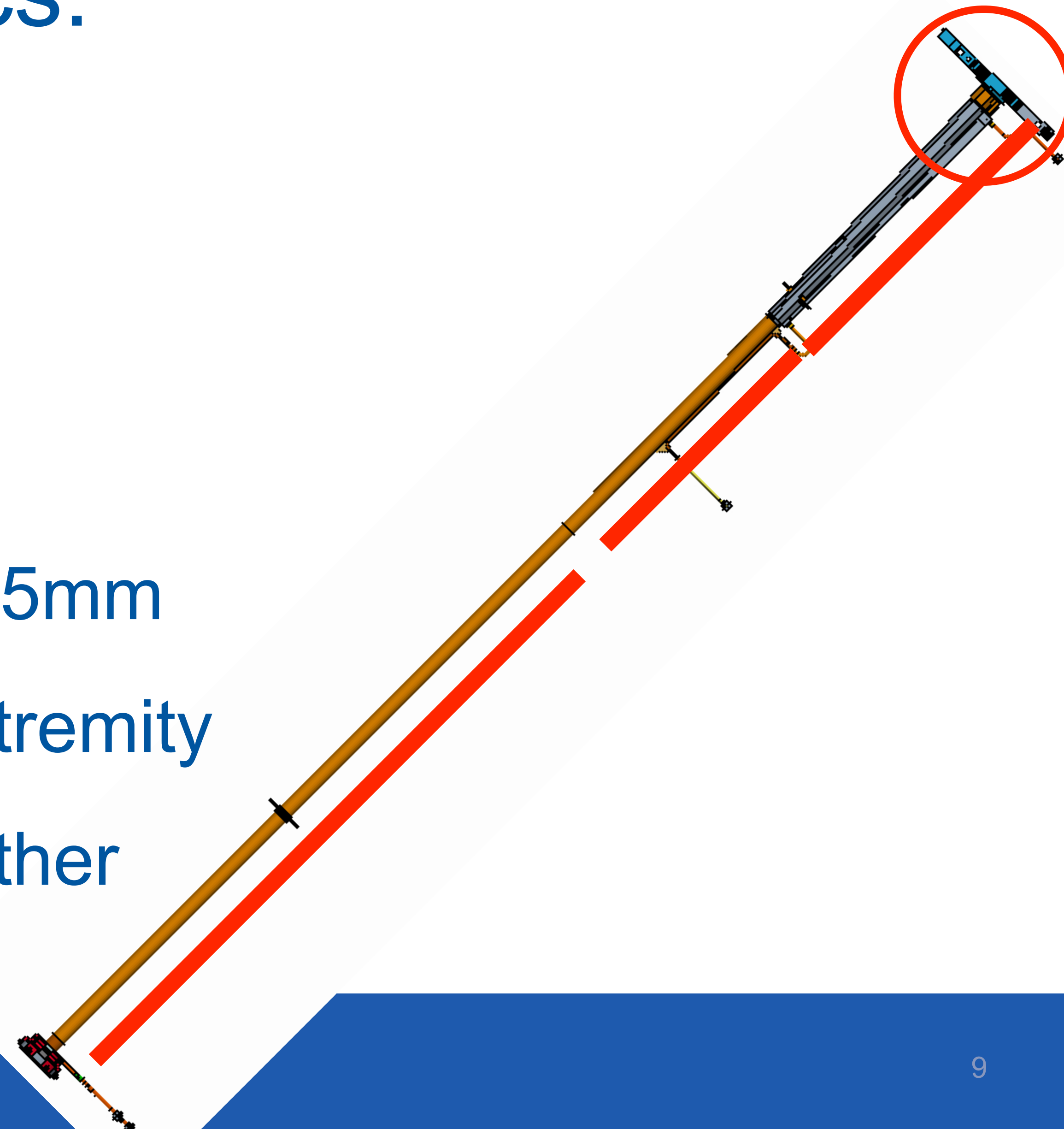


Vacuum Chamber 1 (VC1) Characteristics:

- 2.38m length
- 3 bent section
- diameter of 21.5mm
- BPM at one extremity
- Bellow at the other



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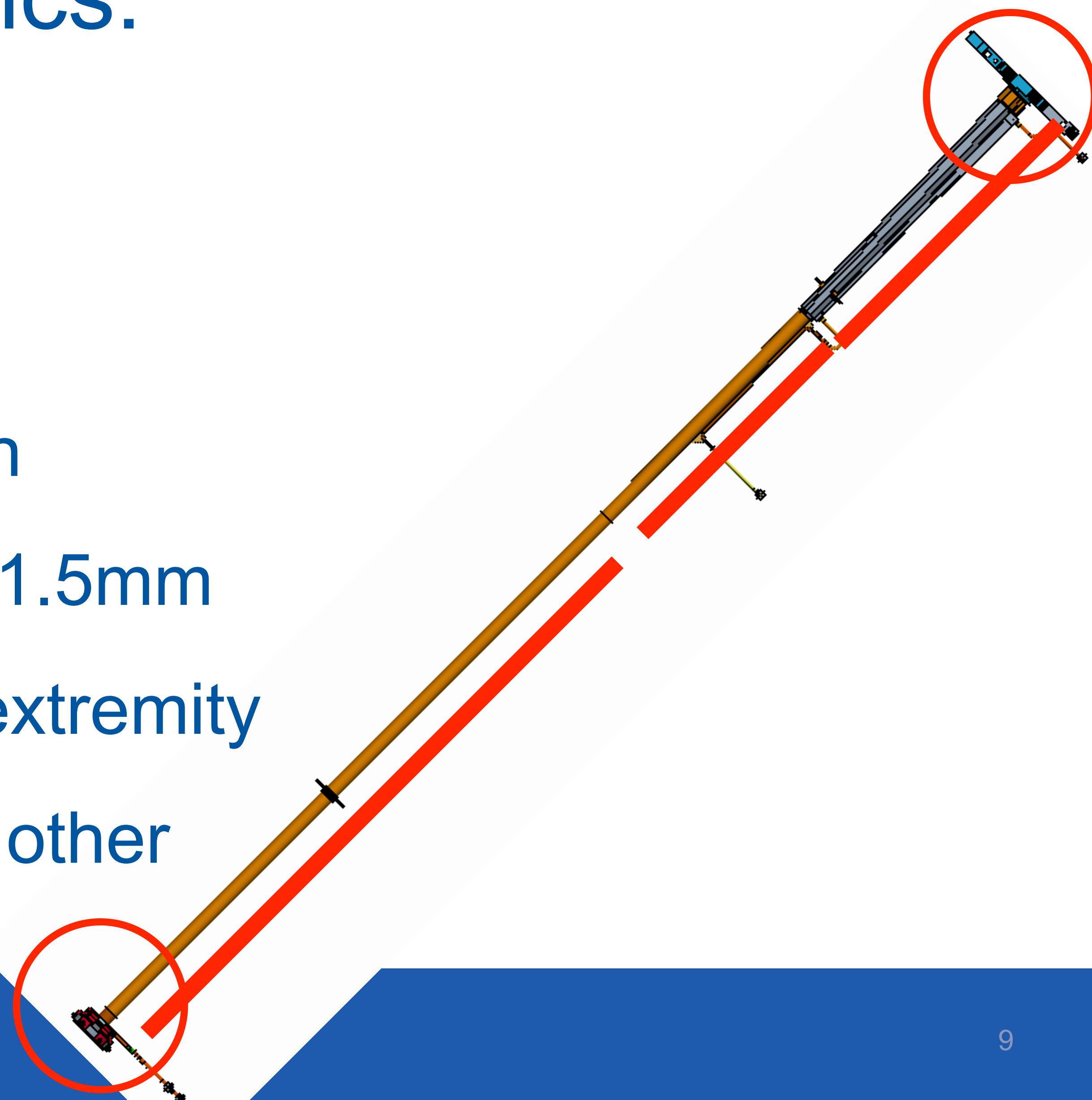

Vacuum chamber 1

Vacuum chamber 1

- A special support was design by Max IV to protect the shape of the chamber

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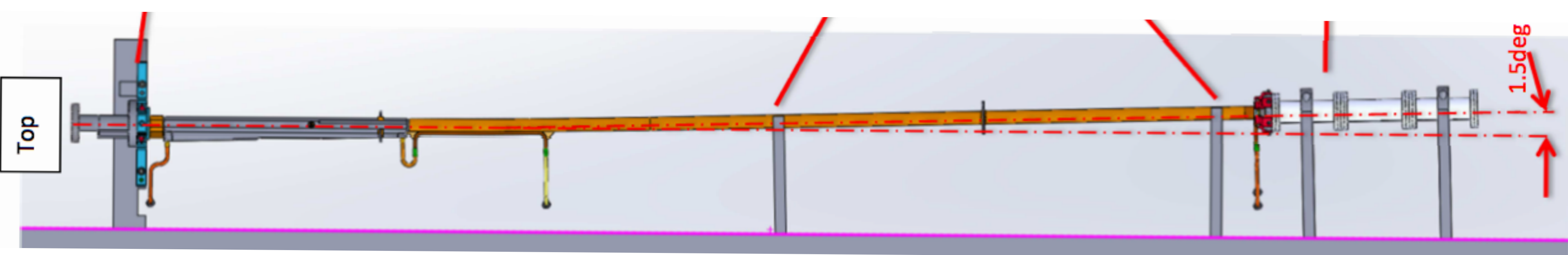

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- 2 chambers can be produced simultaneously

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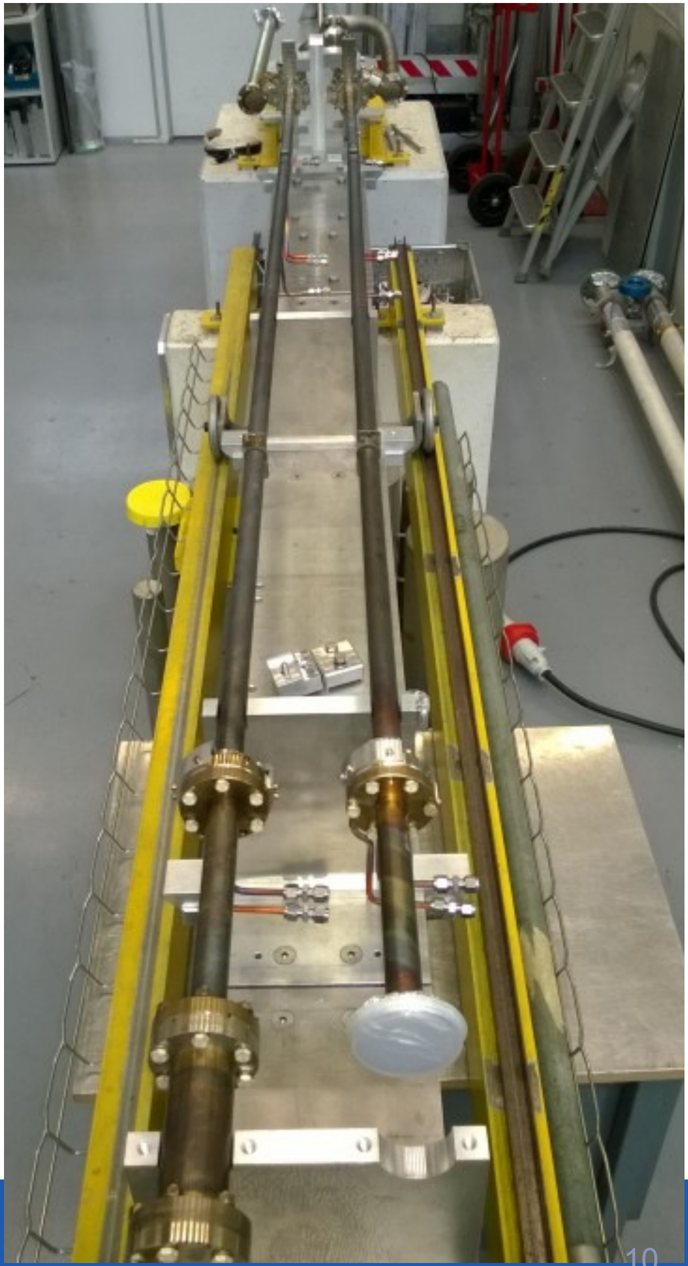
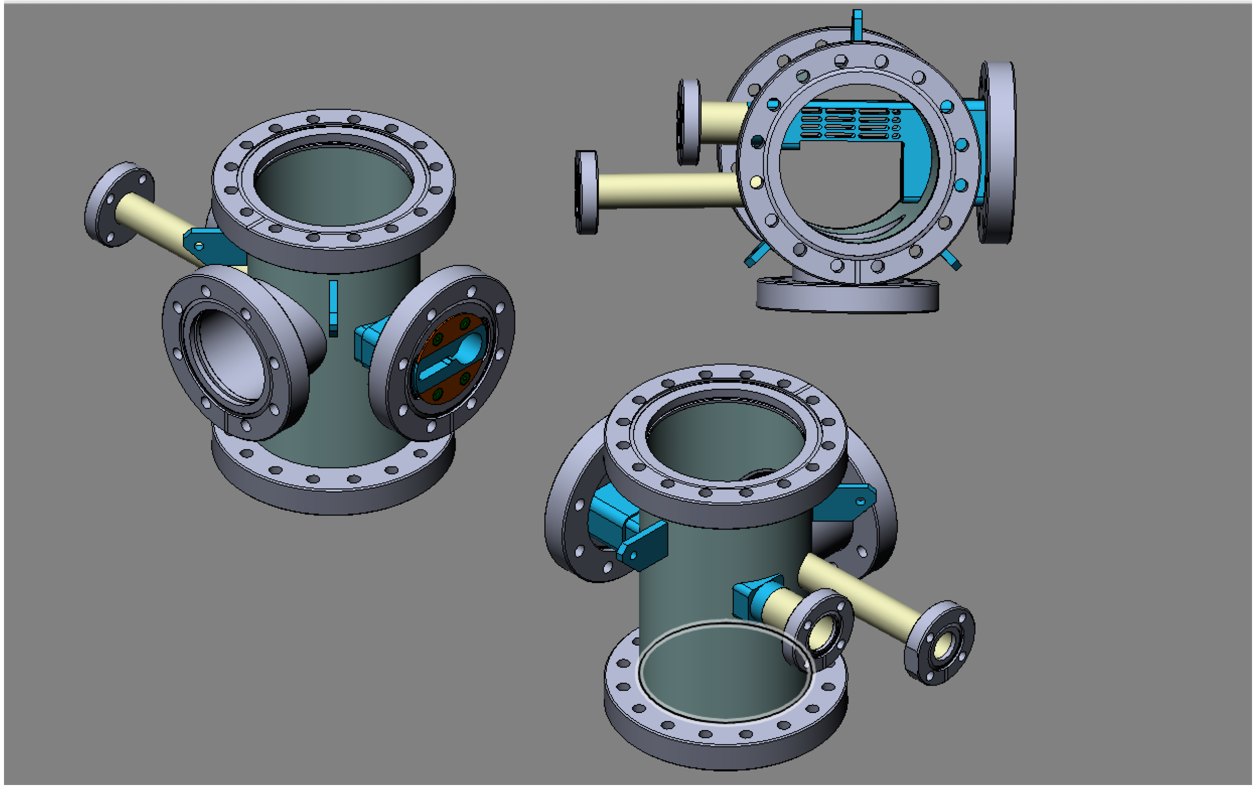


Vacuum chamber 1

Power density W/m	Voltage V	Current A	Pressure mbar	Magnetic field G	Coating duration hours
25	450	0.12	1.1 10-1	185	10

Vacuum chambers for beam extraction

VC2I

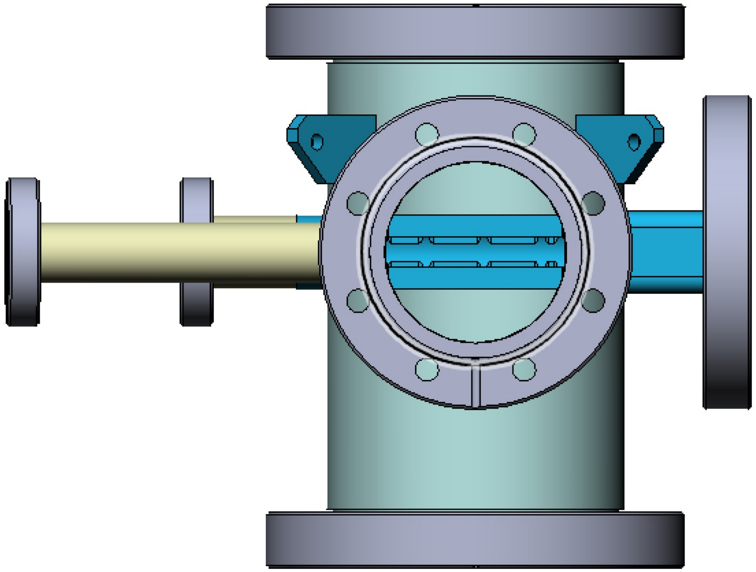


Vacuum chamber 2l

- VC2l

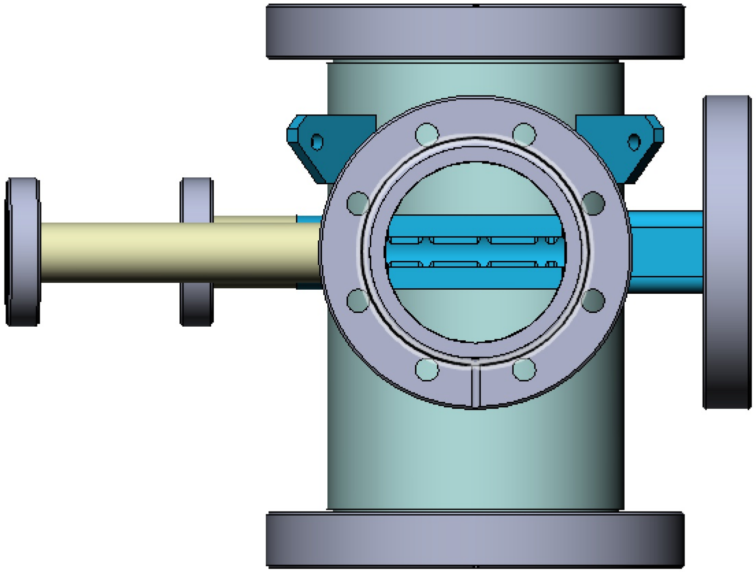
Vacuum chamber 2I

- VC2I



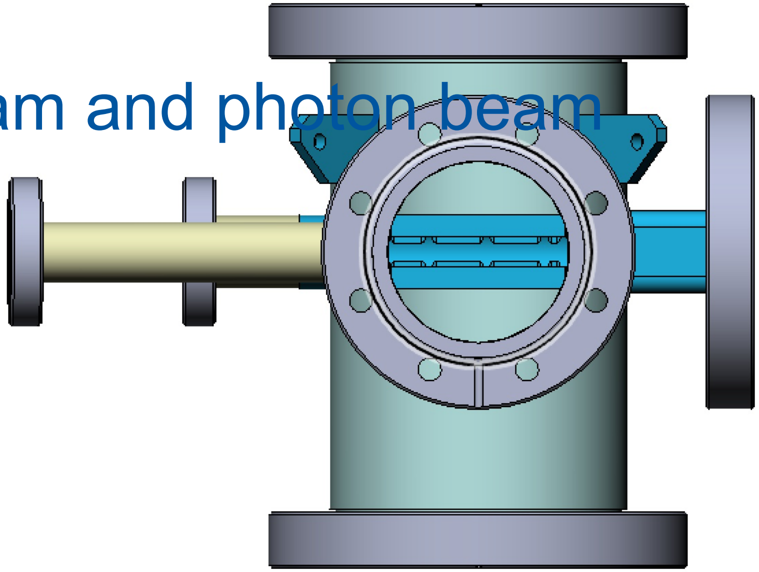
Vacuum chamber 2l

- VC2l
  - 300mm length



Vacuum chamber 2I

- VC2I
  - 300mm length
  - 2 pipes for electron beam and photon beam



Vacuum chamber 2I

- VC2I
  - 300mm length
  - 2 pipes for electron beam and photon beam

Vacuum chamber 2l

- VC2l
  - 300mm length
  - 2 pipes for electron beam and photon beam
  - Crotch absorber

Vacuum chamber 2l

- VC2l
  - 300mm length
  - 2 pipes for electron beam and photon beam
  - Crotch absorber
    - Need of NEG coating on the grid

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  - Crotch absorber
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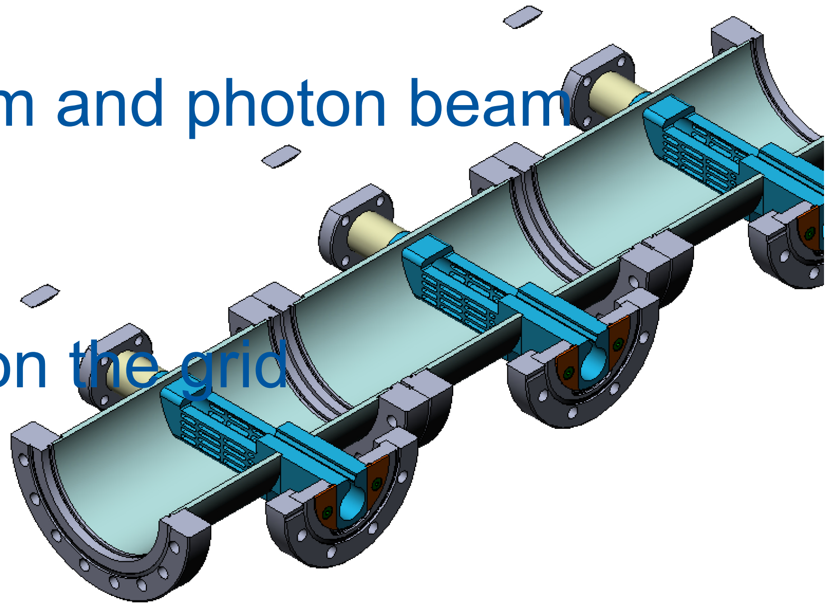

Vacuum chamber 2I

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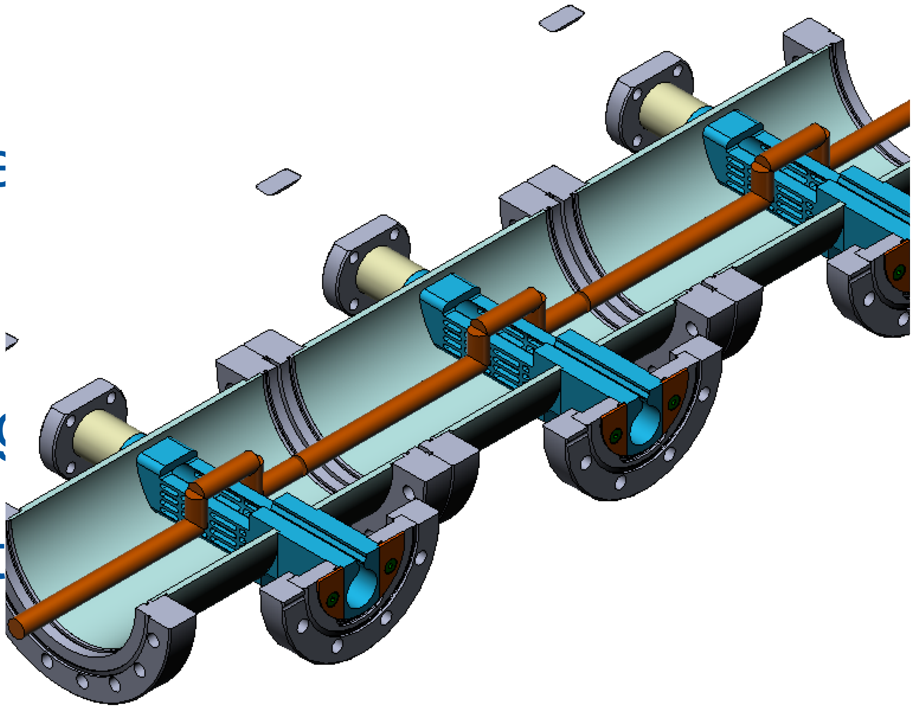

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Vacuum chamber 2l

- VC2l
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  - 2 pipes for electron beam and photon beam
  - Crotch absorber
    - Need of NEG coating on the grid
    - Use of a cathode with bent sections to avoid too thick film
  - 3 chambers can be produced simultaneously

Vacuum chamber 2l

Power density W/m	Voltage V	Current A	Pressure mbar	Magnetic field G	Coating duration hours
80	420	0.3	1.4 10-2	185	13

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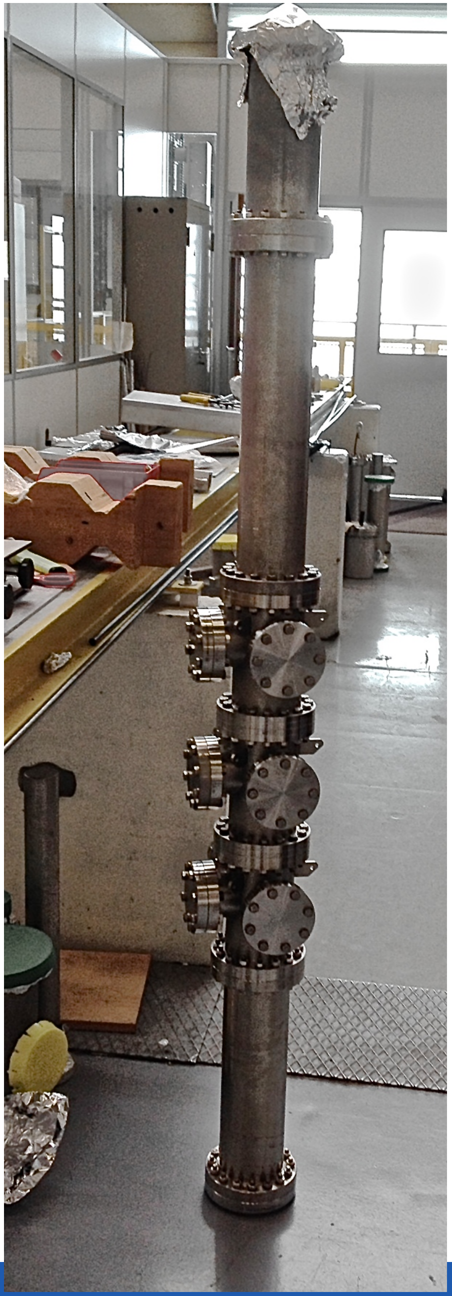
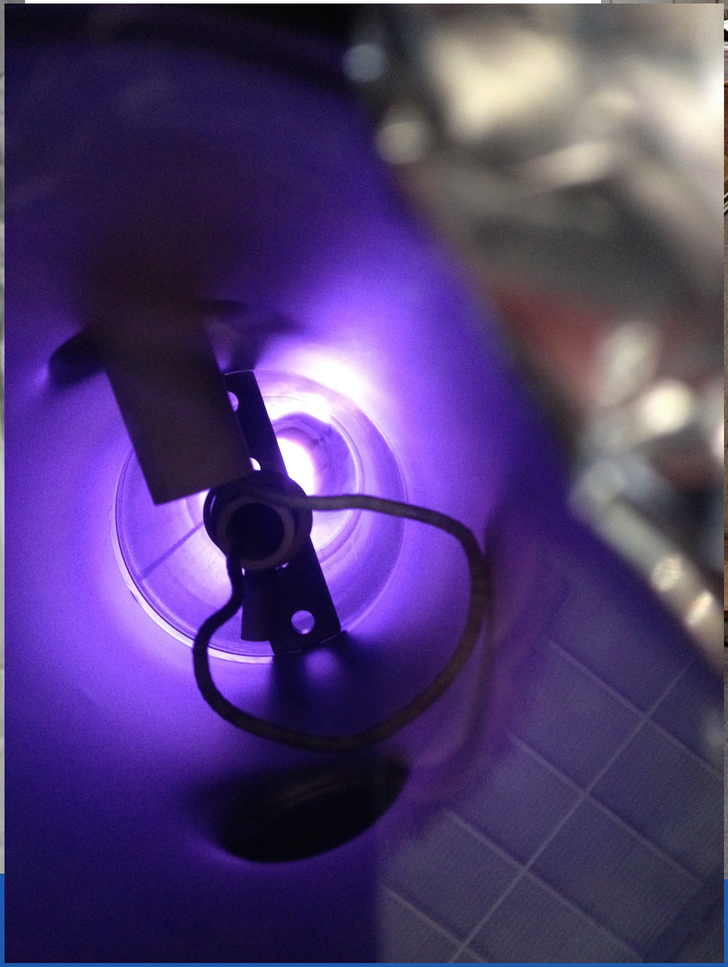
Vacuum Chamber 02 I

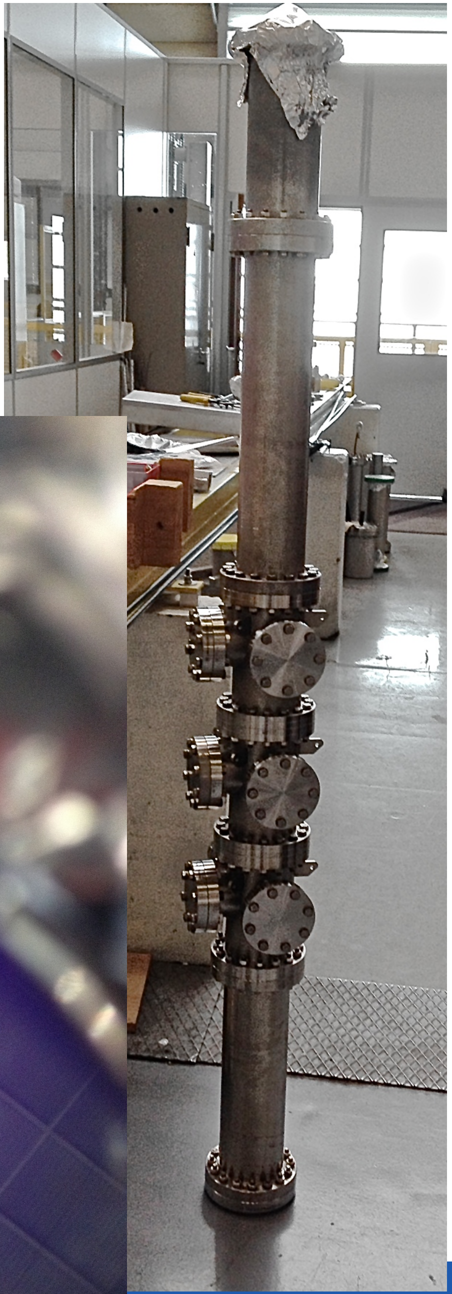
Vacuum Chamber 02 I

Vacuum Chamber 02



Vacuum Chamber 02





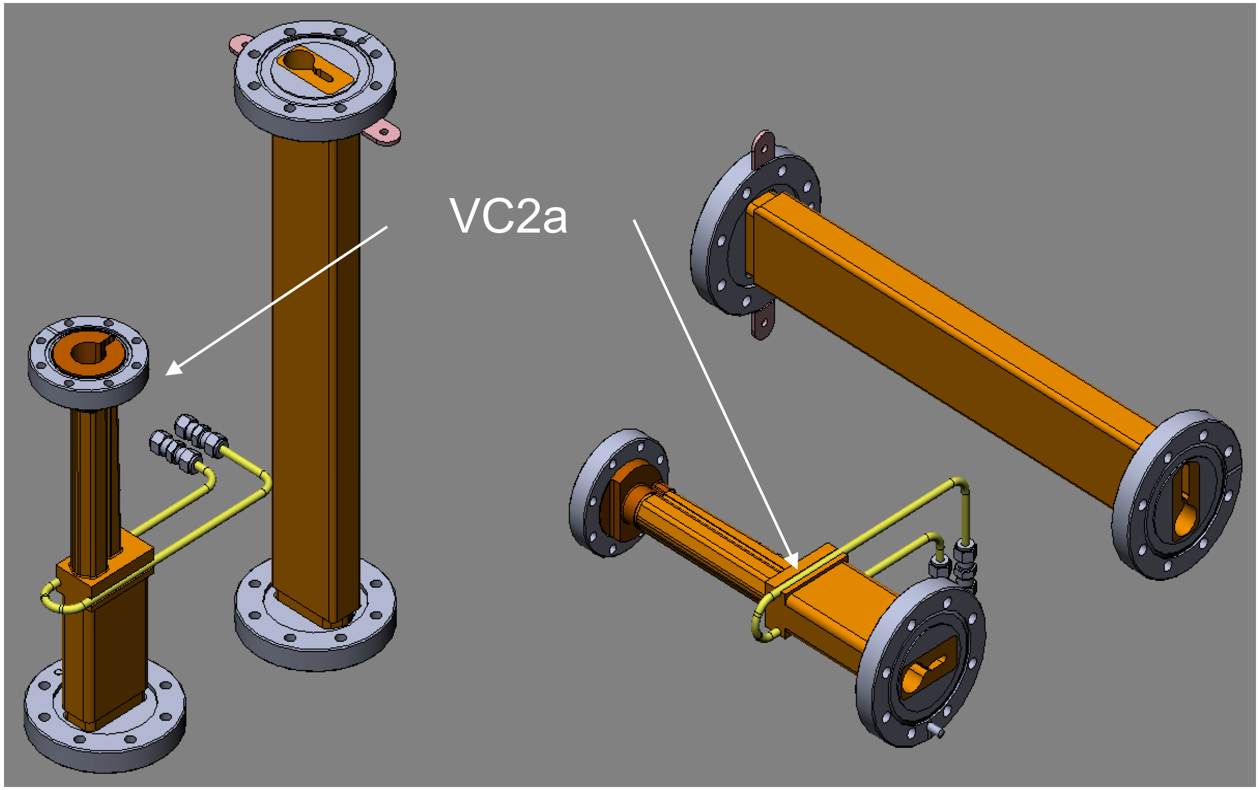
Vacuum chambers for beam extraction

Vacuum chambers for beam extraction

VC2a and VC2b

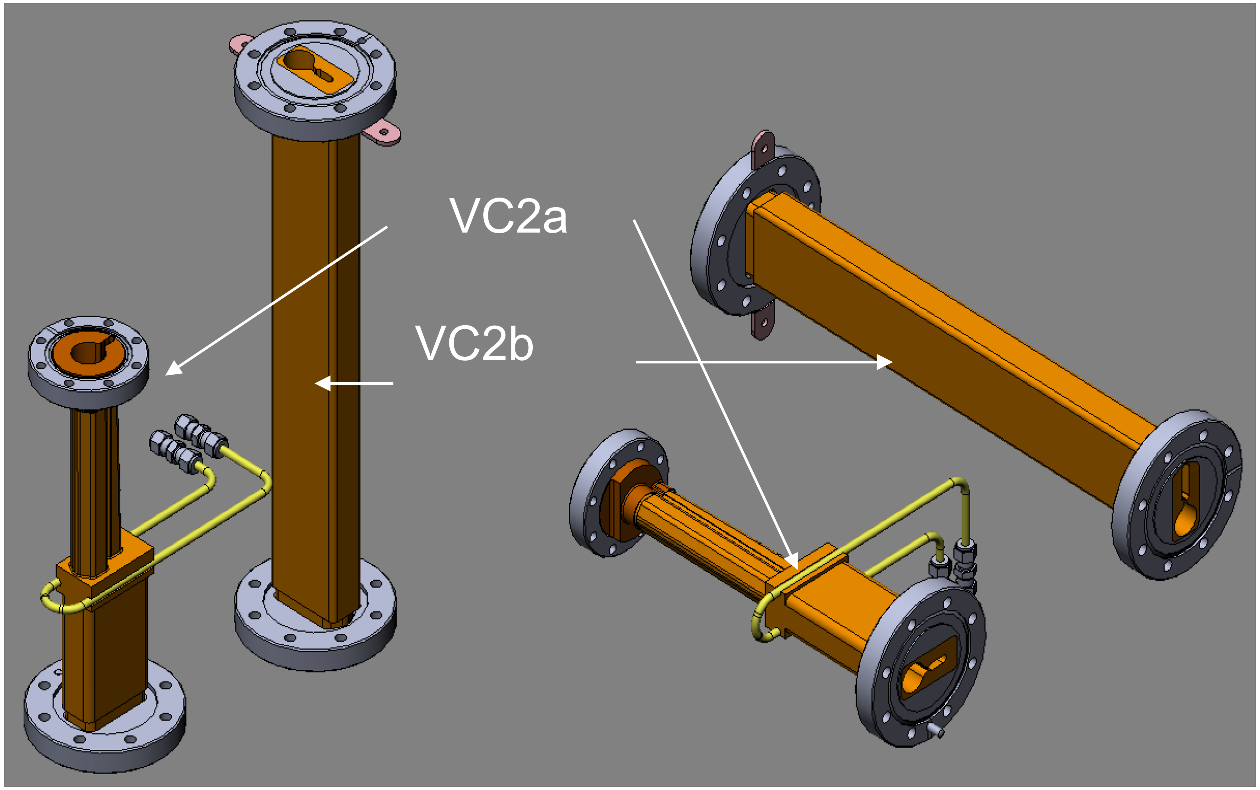
Vacuum chambers for beam extraction

VC2a and VC2b



Vacuum chambers for beam extraction

VC2a and VC2b



Vacuum chamber 2a/b

- VC2a

Vacuum chamber 2a/b

- VC2a
  - Test on a mockup made of two shells

Vacuum chamber 2a/b

- VC2a
  - Test on a mockup made of two shells
  - 300 mm length

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  - Test on a mockup made of two shells
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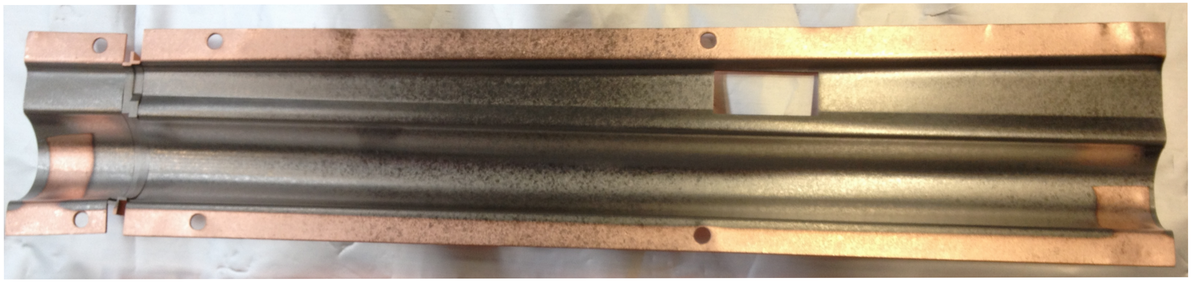
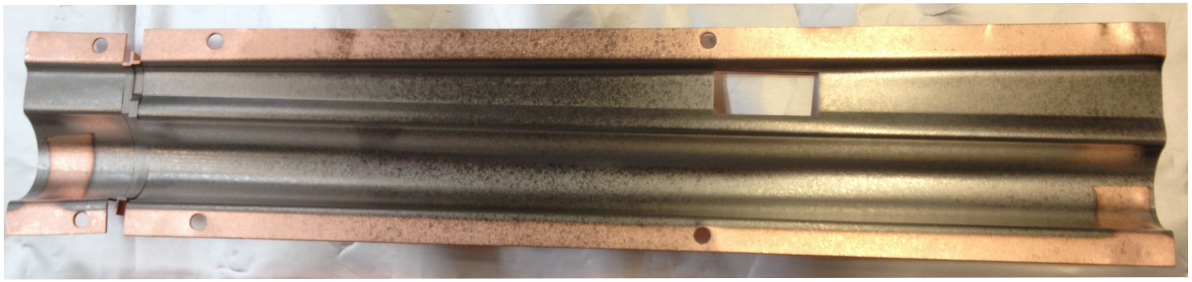


Vacuum chamber 2a/b

- VC2a
  - Test on a mockup made of two shells
  - 300 mm length
  - Electron chamber : One cathode of ø 1mm wires



Vacuum chamber 2a/b

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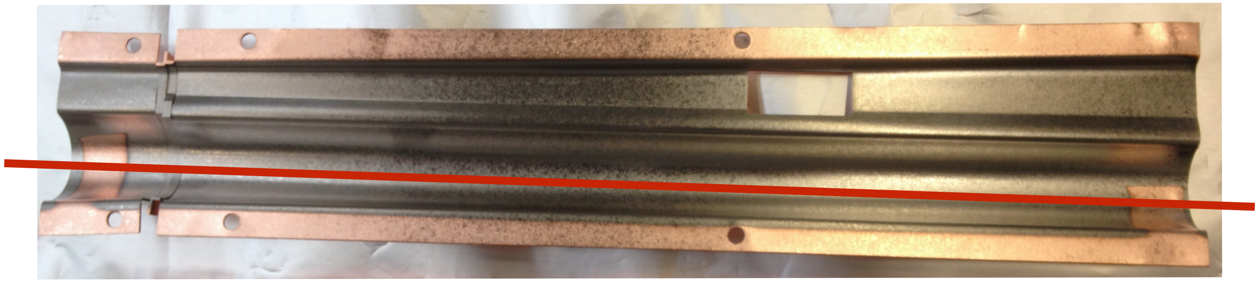
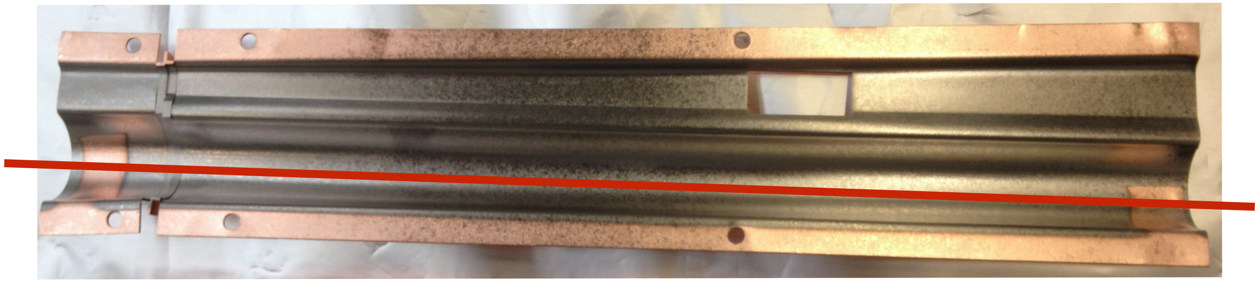


Vacuum chamber 2a/b

- VC2a
  - Test on a mockup made of two shells
  - 300 mm length
  - Electron chamber : One cathode of ø 1mm wires
  - Photon chamber : One cathode of ø 0.5 mm wires



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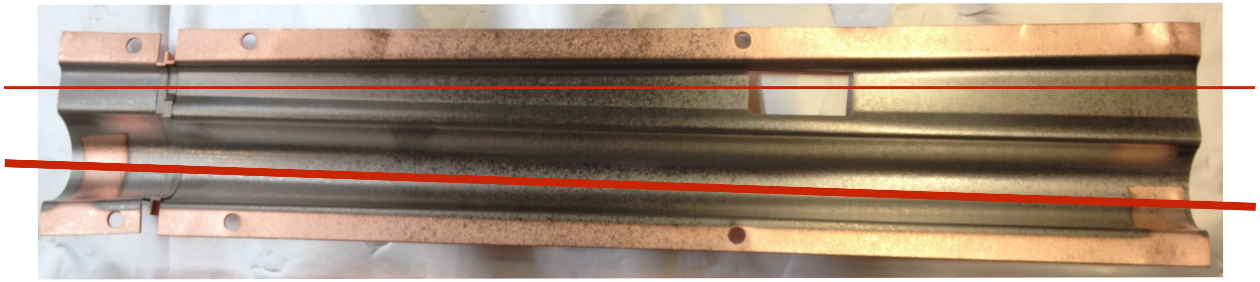
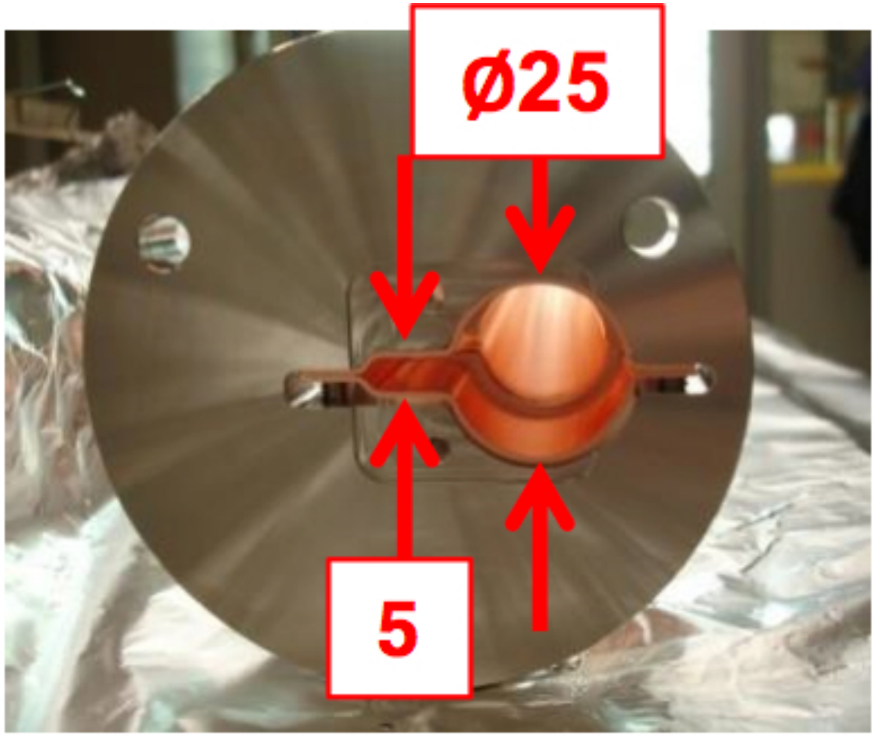
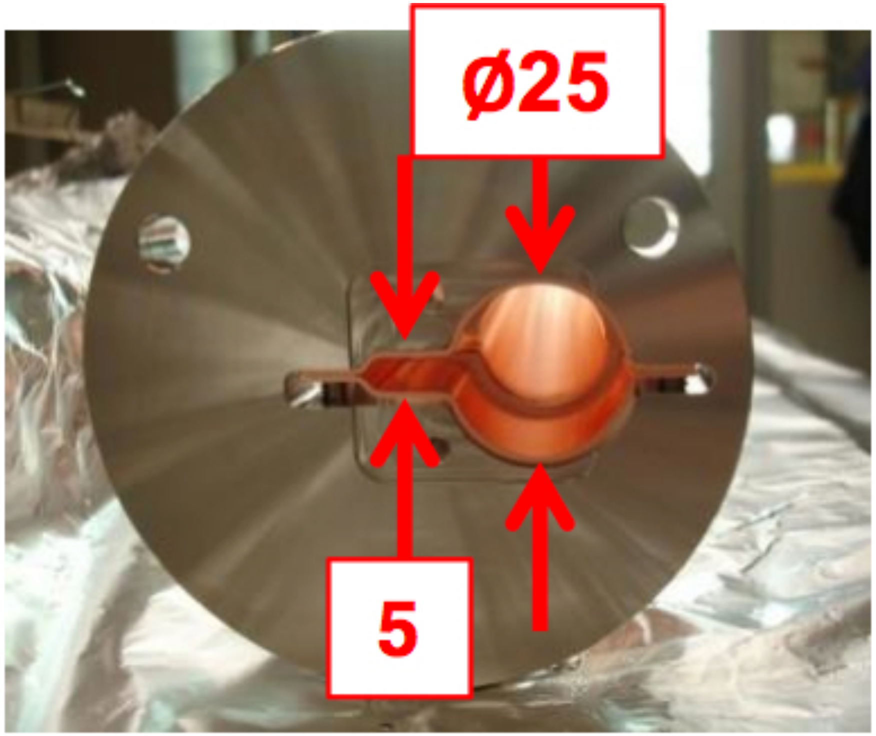


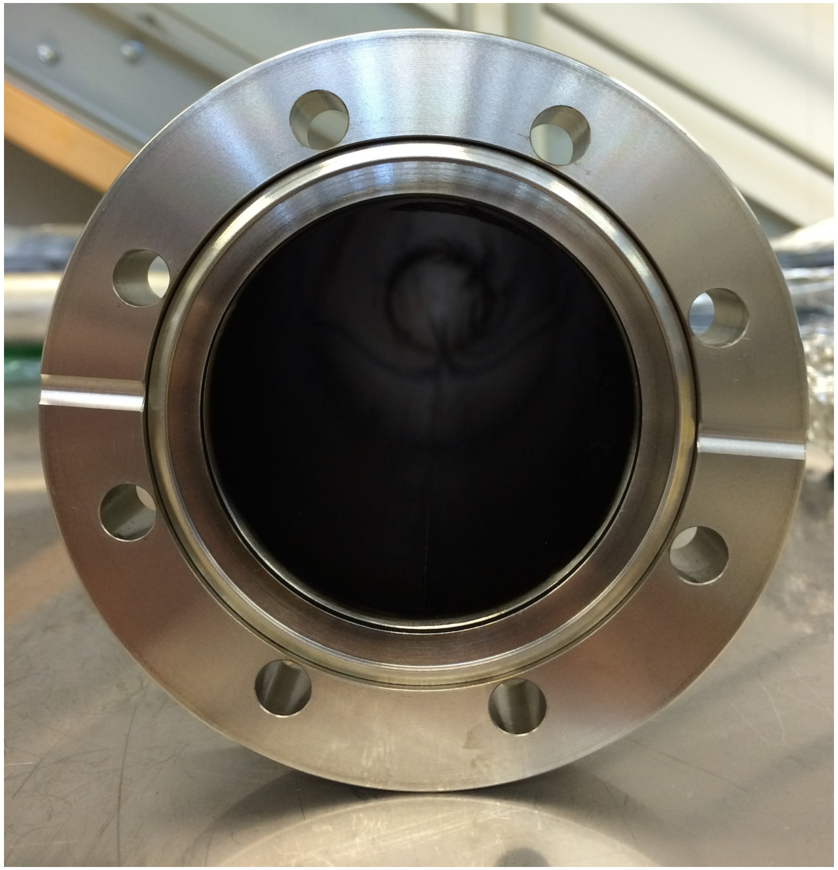
Vacuum chamber 2a/b

Vacuum chamber 2a/b

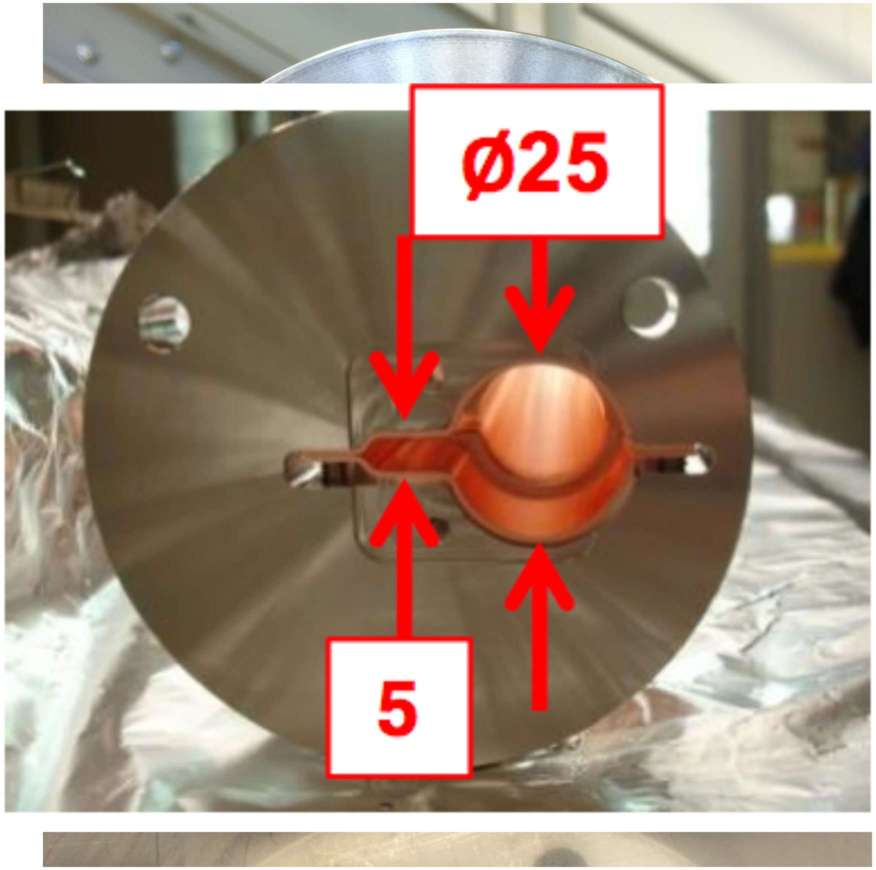


Vacuum chamber 2a/b

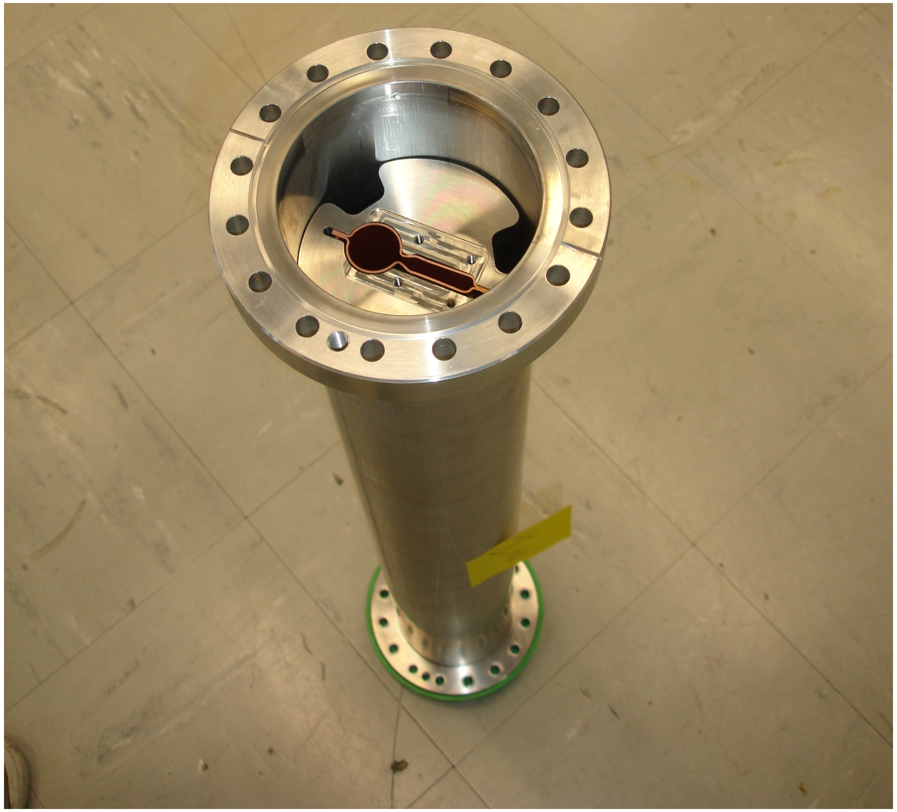




Vacuum chamber 2a/b



Vacuum chamber 2a/b



VC2 a/b mockup for preliminary test

Vacuum chamber 2a/b

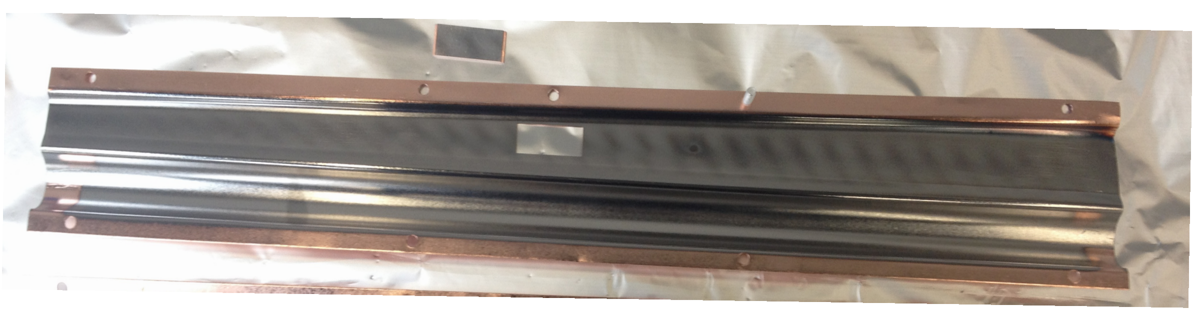
- VC2b

Vacuum chamber 2a/b

- VC2b
  - Test on a mockup made of two shells

Vacuum chamber 2a/b

- VC2b
  - Test on a mockup made of two shells



Vacuum chamber 2a/b

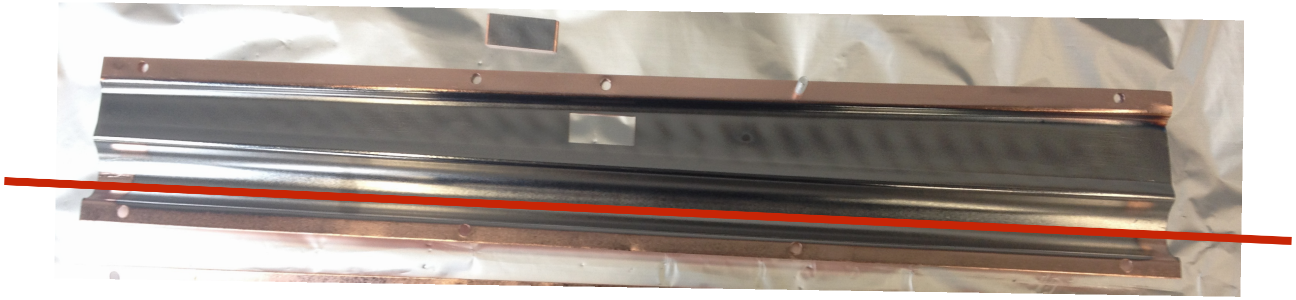
- VC2b
  - Test on a mockup made of two shells
  - 435 mm length

Vacuum chamber 2a/b

- VC2b
  - Test on a mockup made of two shells
  - 435 mm length
  - Electron chamber : One cathode of ø 1mm wires

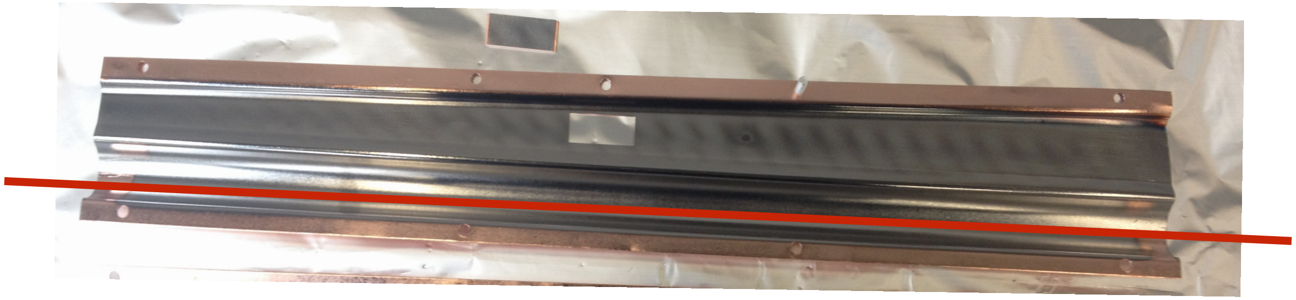
Vacuum chamber 2a/b

- VC2b
  - Test on a mockup made of two shells
  - 435 mm length
  - Electron chamber : One cathode of ø 1mm wires



Vacuum chamber 2a/b

- VC2b
  - Test on a mockup made of two shells
  - 435 mm length
  - Electron chamber : One cathode of ø 1mm wires
  - Photon chamber : Two cathodes of ø 0.5 mm wires



Vacuum chamber 2a/b

- VC2b
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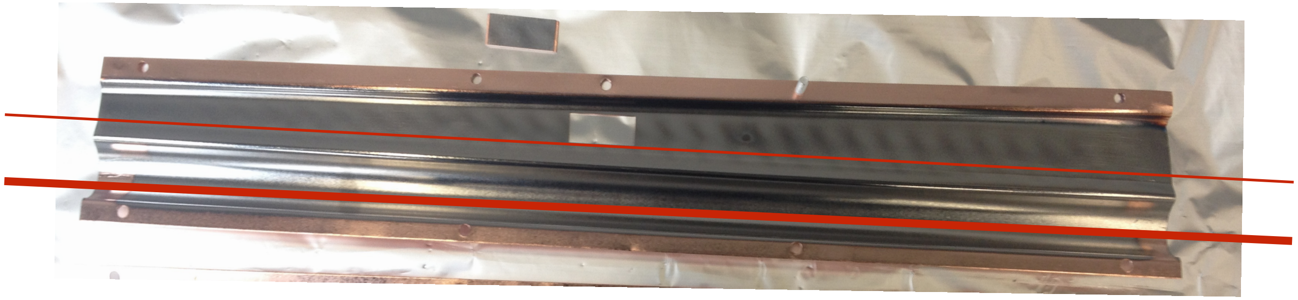
  - 435 mm length
  - Electron chamber : One cathode of ø 1mm wires
  - Photon chamber : Two cathodes of ø 0.5 mm wires



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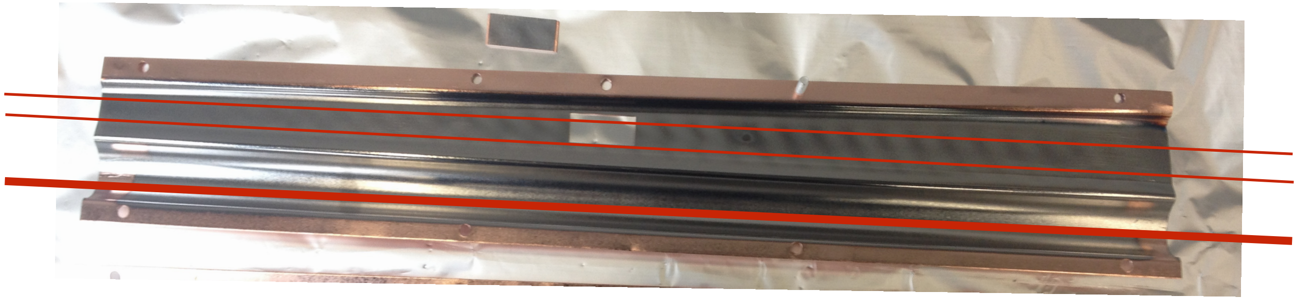


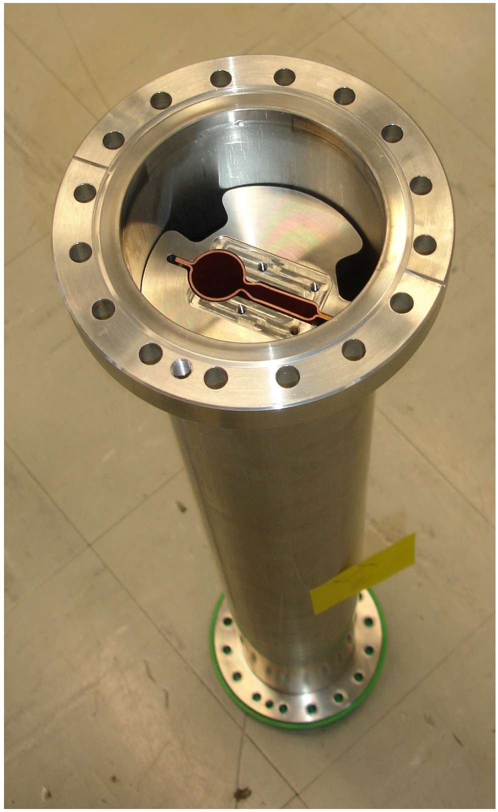
Vacuum chamber 2 a/b

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS



Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition
    - Expected activation temperature

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition
    - Expected activation temperature
  - Photon chamber

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition
    - Expected activation temperature
  - Photon chamber
    - Problems with thickness uniformity

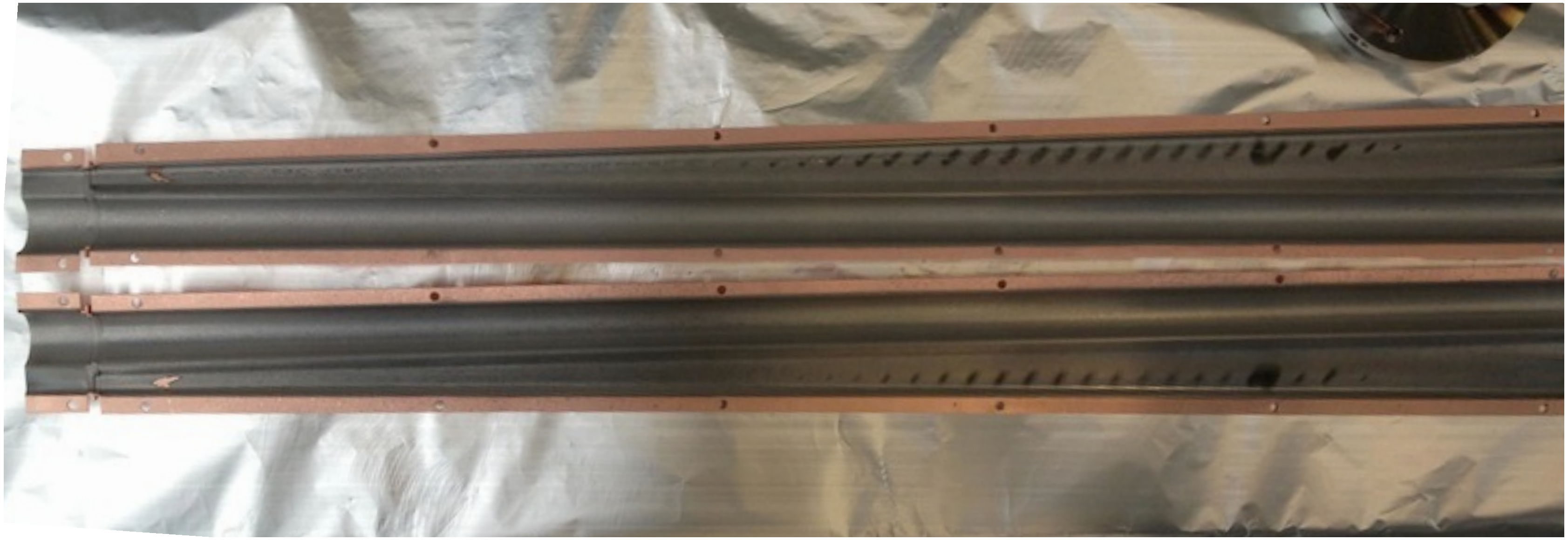
Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition
    - Expected activation temperature
  - Photon chamber
    - Problems with thickness uniformity

Vacuum chamber 2 a/b

- Test on thin film coverage, NEG composition and activation by XPS
  - NEG thin film inside the electron chamber :
    - Correct composition
    - Expected activation temperature
  - Photon chamber
    - Problems with thickness uniformity
    - Increase power density to spread the plasma

Vacuum chamber 2 a/b



Vacuum chamber 2 a/b

After increase of the power density

Vacuum chamber 2 a/b

After increase of the power density

- Photon chamber :

Vacuum chamber 2 a/b

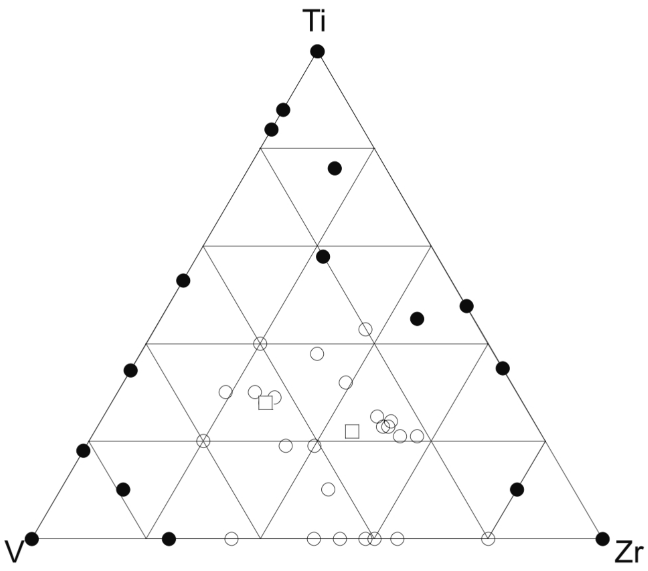
After increase of the power density

- Photon chamber :
  - Wrong composition : high concentration of Vanadium

Vacuum chamber 2 a/b

After increase of the power density

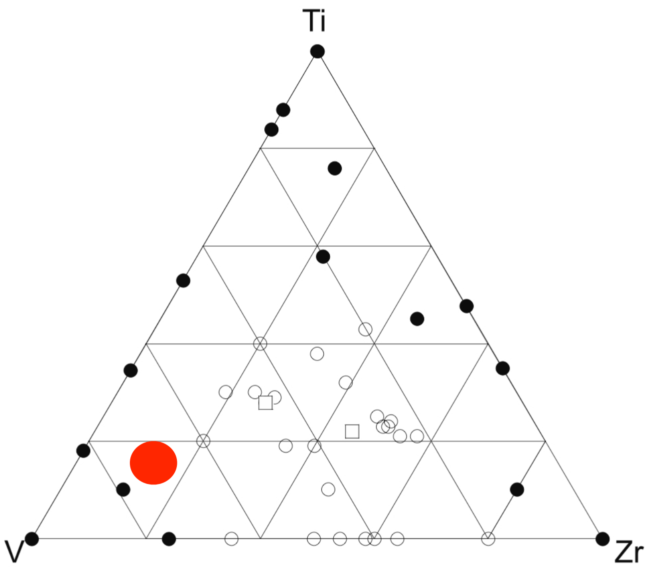
- Photon chamber :
  - Wrong composition : high concentration of Vanadium



Vacuum chamber 2 a/b

After increase of the power density

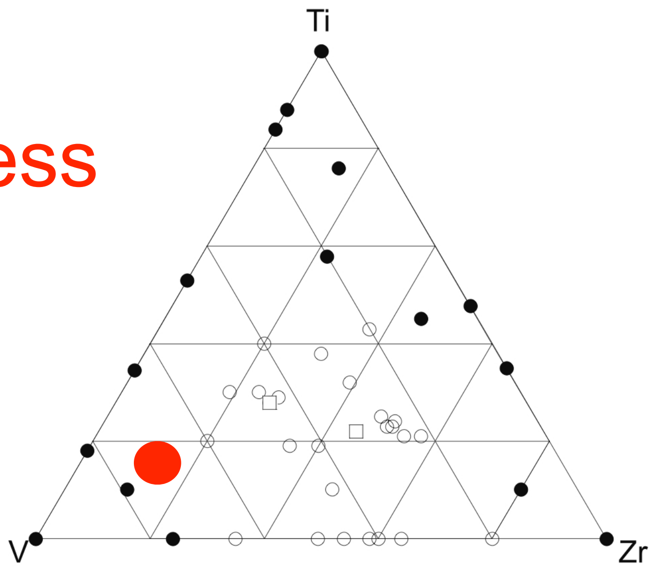
- Photon chamber :
  - Wrong composition : high concentration of Vanadium



Vacuum chamber 2 a/b

After increase of the power density

- Photon chamber :
  - Wrong composition : high concentration of Vanadium
  - Too slow activation process



Vacuum chamber 2 a/b

A known possible cause for high concentration of vanadium is the overheating of the cathode

Vacuum chamber 2 a/b

A known possible cause for high concentration of vanadium is the overheating of the cathode

- Optimisation of the coating parameters to reduce the power density with an acceptable thickness distribution :

Vacuum chamber 2 a/b

A known possible cause for high concentration of vanadium is the overheating of the cathode

- Optimisation of the coating parameters to reduce the power density with an acceptable thickness distribution :
  - Magnetic field, discharge gas pressure

Vacuum chamber 2 a/b

A known possible cause for high concentration of vanadium is the overheating of the cathode

- Optimisation of the coating parameters to reduce the power density with an acceptable thickness distribution :
  - Magnetic field, discharge gas pressure
  - External cooling of the chamber

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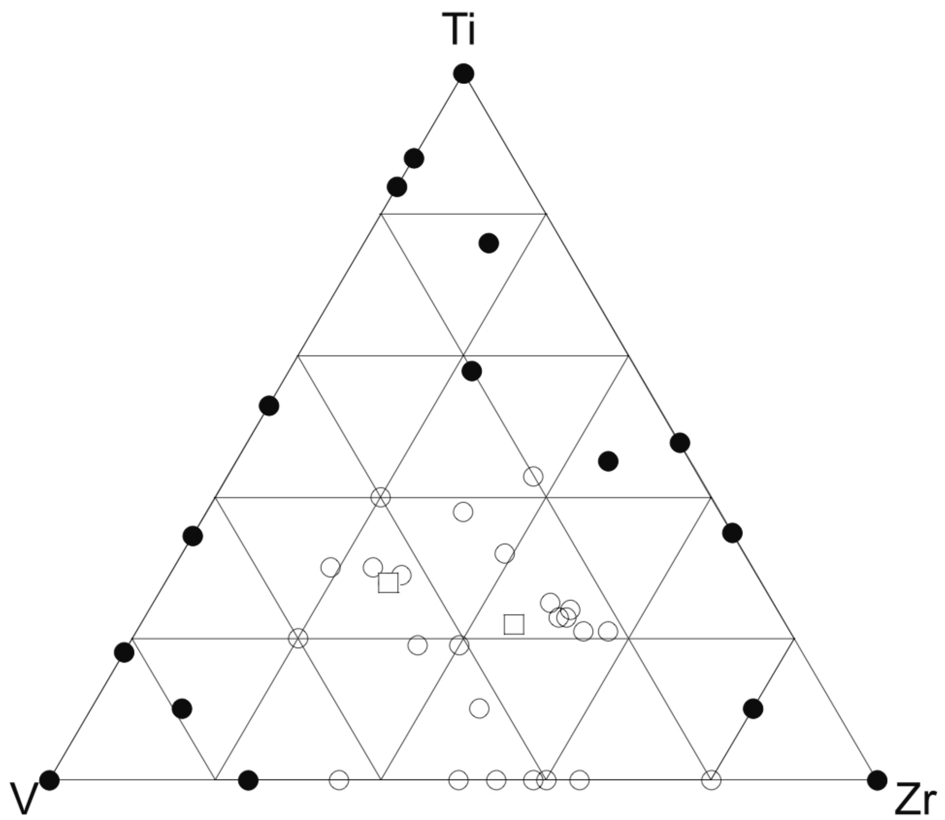
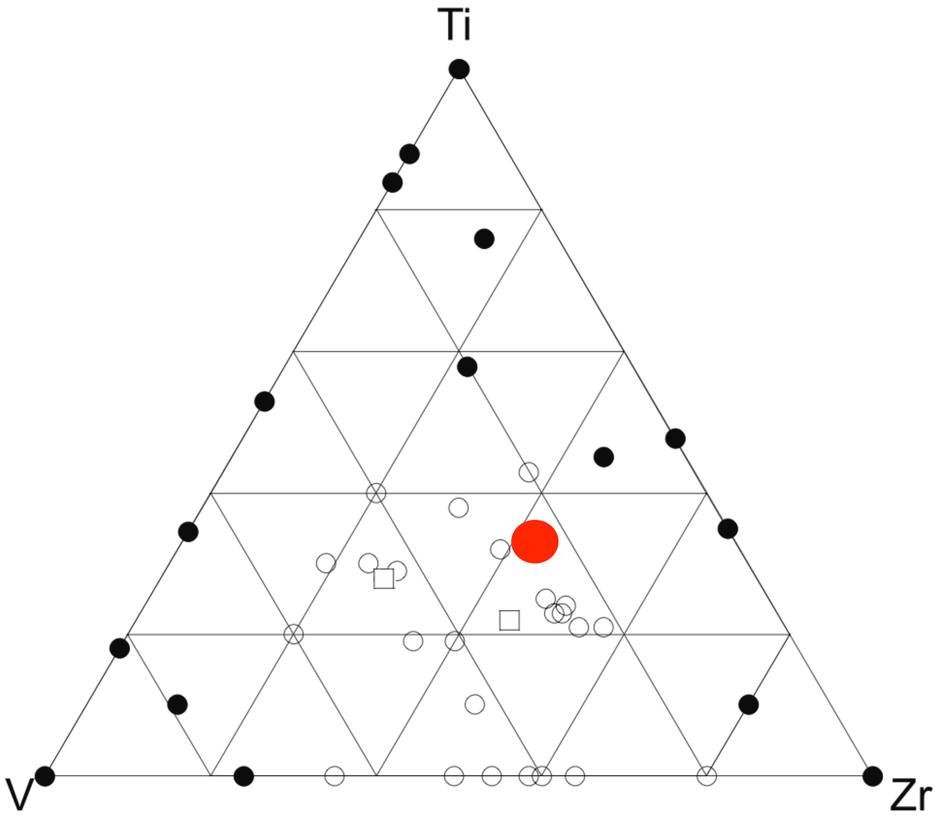
Vacuum chamber 2 a/b

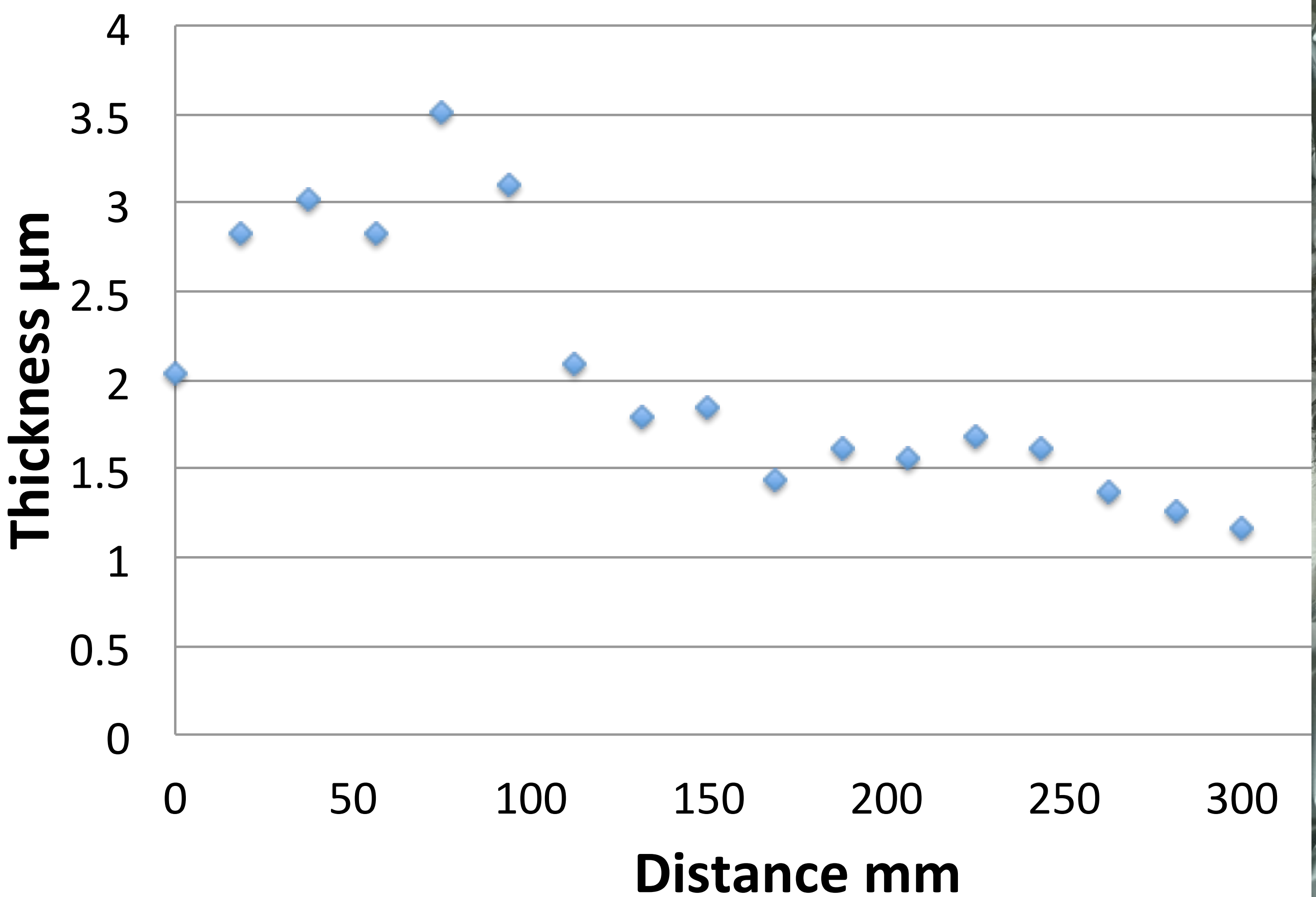
Vacuum chamber 2 a/b



Vacuum chamber 2 a/b



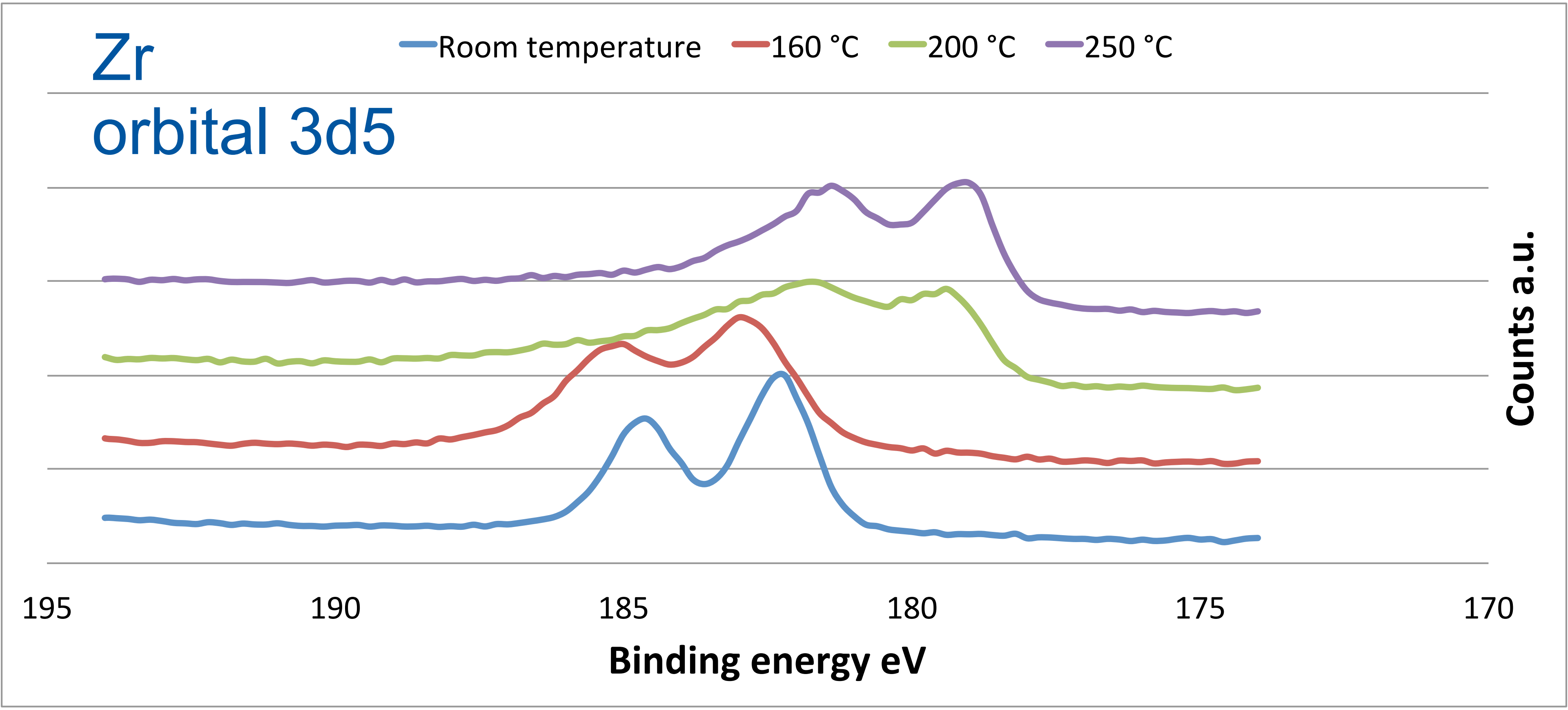
Vacuum chamber 2 a/b



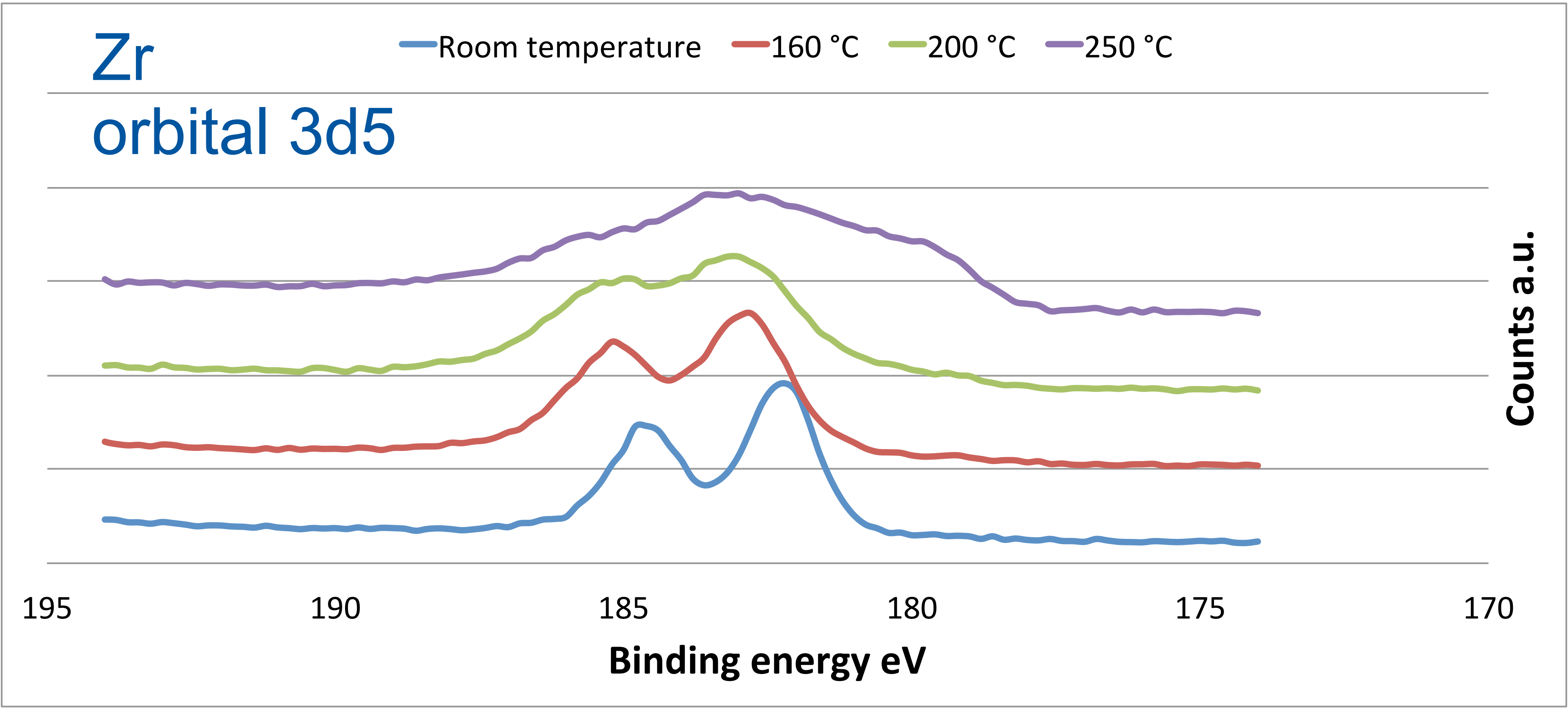
Vacuum chamber 2 a/b

The NEG thin film, inside the photon chamber, has still a delayed activation.

Vacuum chamber 2 a/b (electron chamber)



Vacuum chamber 2 a/b (photon chamber)



Vacuum chamber 2a/b

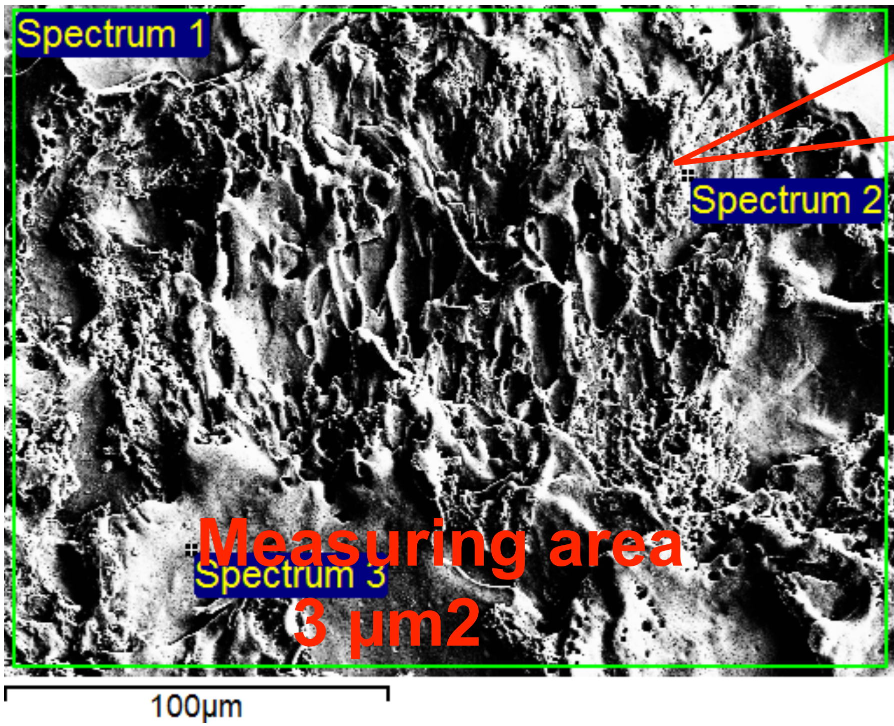
Vacuum chamber 2a/b

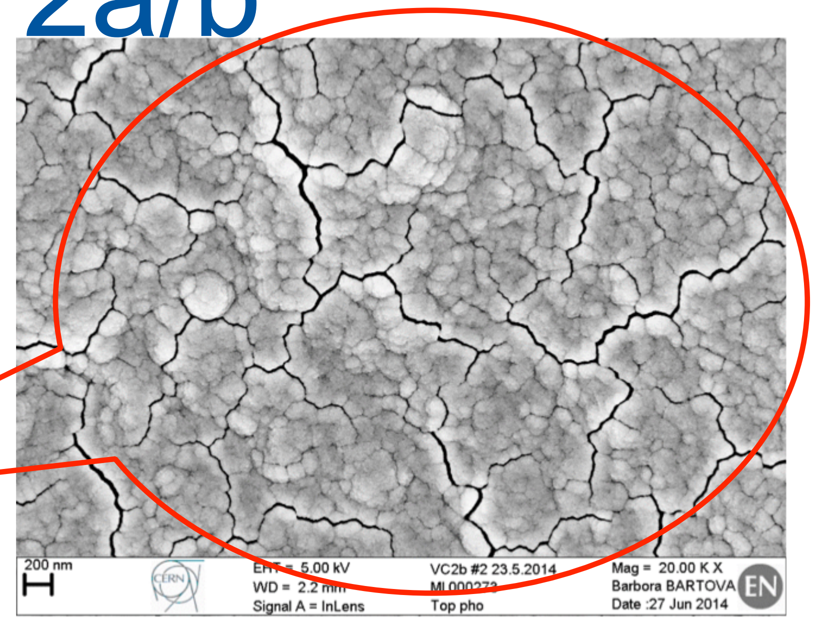
- XRD measurements-> NEG has a small grain size < 10 nm

Vacuum chamber 2a/b

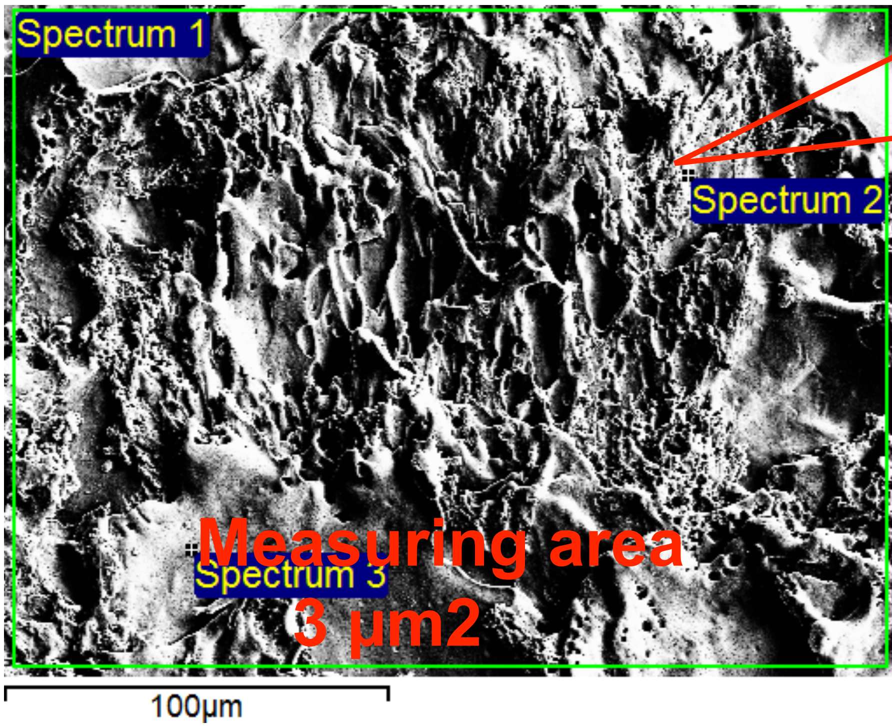
- XRD measurements-> NEG has a small grain size < 10 nm
- EDX measurements -> local non-homogeneous composition

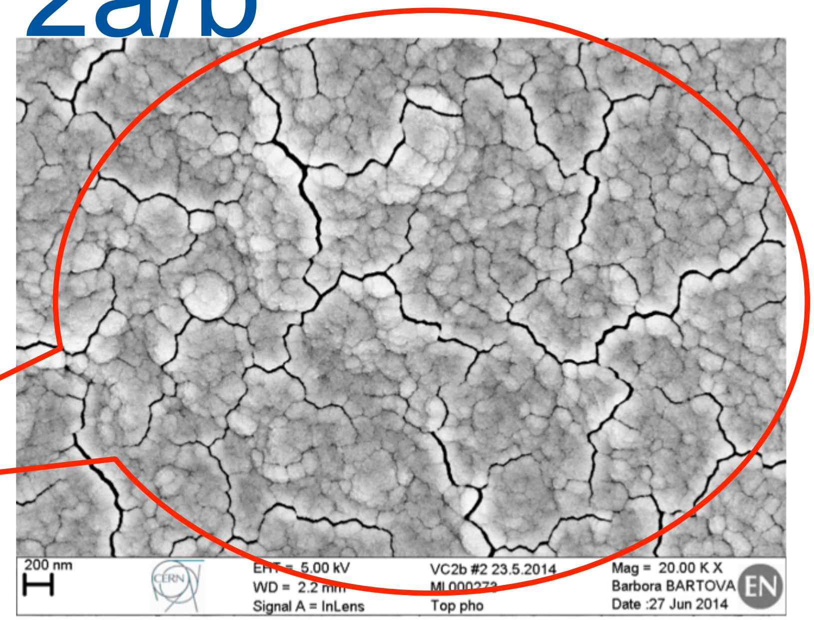
Vacuum chamber 2a/b





Vacuum chamber 2a/b





Spectrum	Ti at.%	V at.%	Zr at.%
Spectrum 1	33.8	39.5	26.7
Spectrum 2	33.0	37.4	29.6
Spectrum 3	33.0	37.4	29.5

Vacuum chamber 2a/b

Vacuum chamber 2a/b

Despite the correct parameter in thickness, composition, grain size

Vacuum chamber 2a/b

Despite the correct parameter in thickness, composition, grain size

- We are unable to have a correct activation of the photon chamber

Vacuum chamber 2a/b

Despite the correct parameter in thickness, composition, grain size

- We are unable to have a correct activation of the photon chamber
- Activation of the photon chamber is not critical for the machine

Vacuum chamber 2a/b

Vacuum chamber 2a/b

- Complete coverage

Vacuum chamber 2a/b

- Complete coverage
- Composition conform with CERN standards

Vacuum chamber 2a/b

- Complete coverage
- Composition conform with CERN standards
  - Electron chamber activates correctly

Vacuum chamber 2a/b

- Complete coverage
- Composition conform with CERN standards
  - Electron chamber activates correctly
  - Photon chamber shows incomplete activation after heating at 250 °C for 2 hours (standard heating cycle for XPS test)

Vacuum chamber 2a/b

Vacuum chamber 2a/b

- However, the lack of full activation is not critical for the beam life time in Max IV and CERN decide to start with the production of the thin film coatings

Vacuum chamber 2a/b

- However, the lack of full activation is not critical for the beam life time in Max IV and CERN decide to start with the production of the thin film coatings
- Need more studies on the coating of small aperture chambers in post production

Vacuum chamber 2a/b

- Production:

Vacuum chamber 2a/b

- Production:
    - Custom installation dedicated to VC2 a/b chambers

Vacuum chamber 2a/b

- Production:
  - Custom installation dedicated to VC2 a/b chambers
  - 4 chambers produced simultaneously

Vacuum chamber 2a/b

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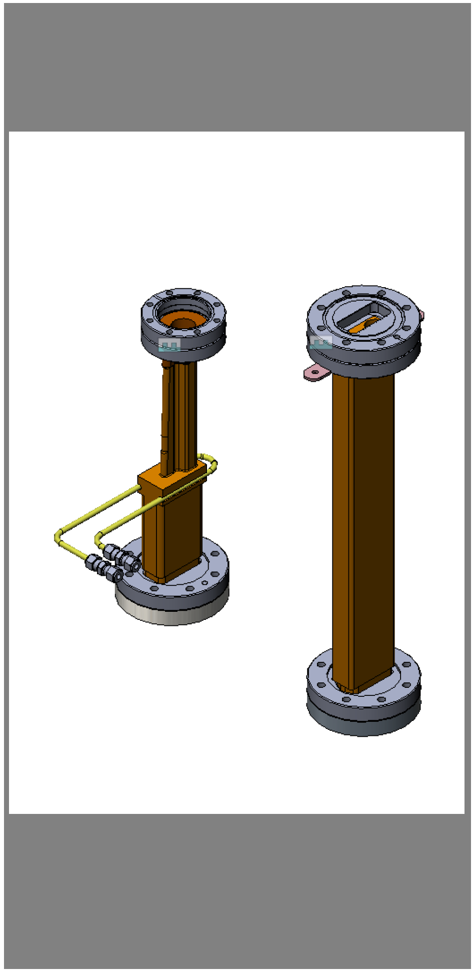
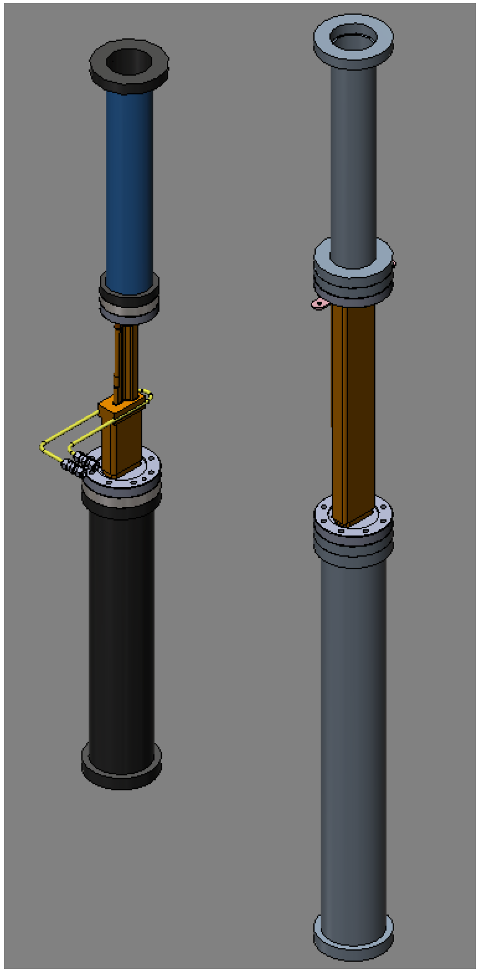
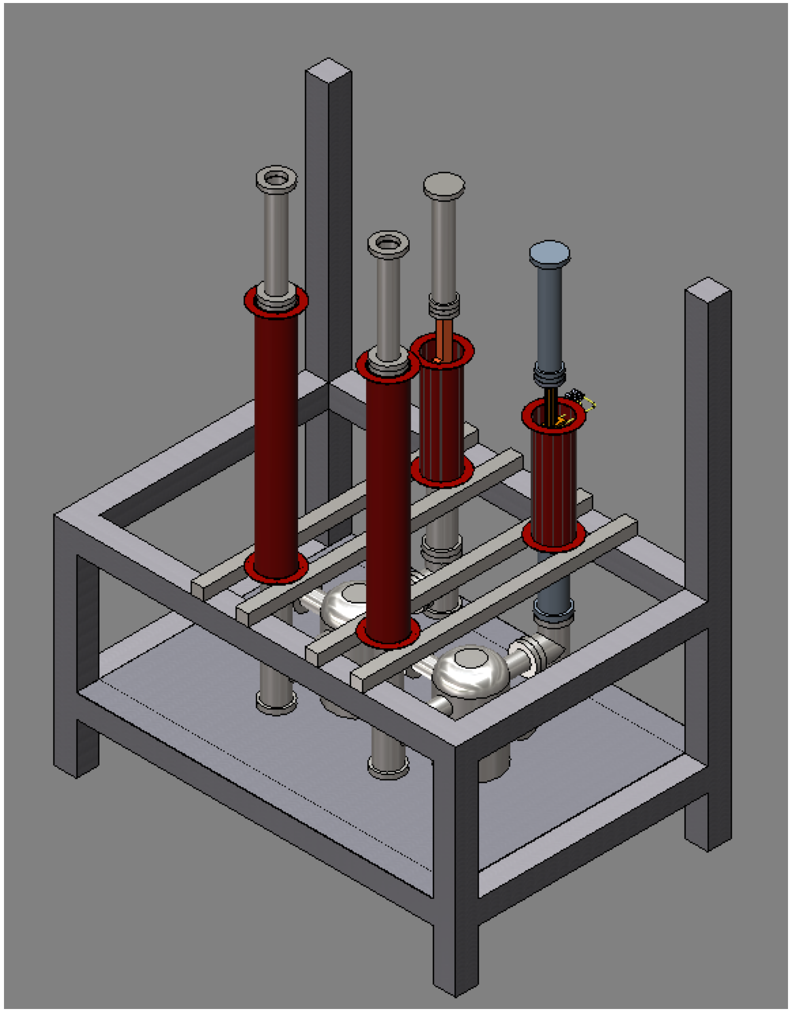


Vacuum chamber 2a/b



Vacuum chamber 2a/b



Vacuum chamber 2a/b (photon)

Power density W/m	Voltage V	Current A	Pressure mbar	Magnetic field G	Coating duration hours
25	370	0.3	6.6 10-1	500	8

CERN

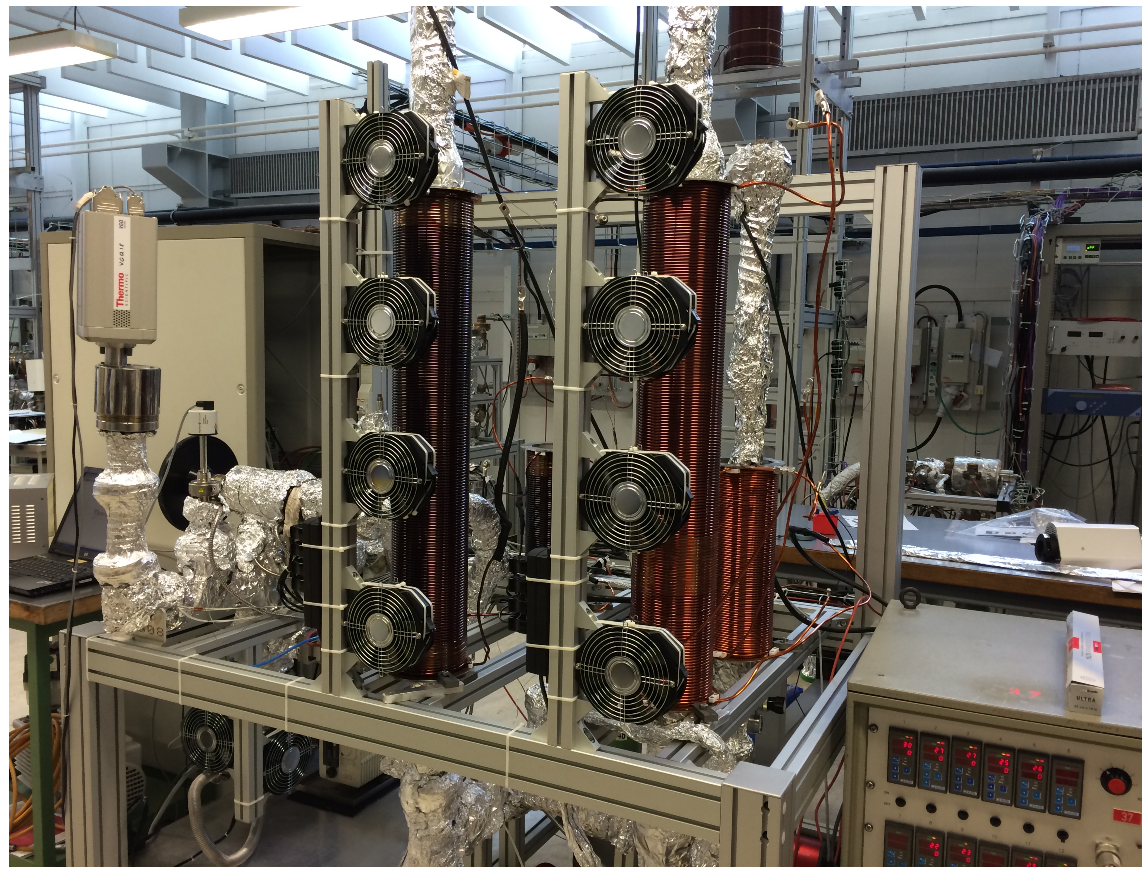
Vacuum chamber 2a/b (electron)

Power density W/m	Voltage V	Current A	Pressure mbar	Magnetic field G	Coating duration hours
25	***350***	***0.4***	***6 10-2***	***185***	***10***

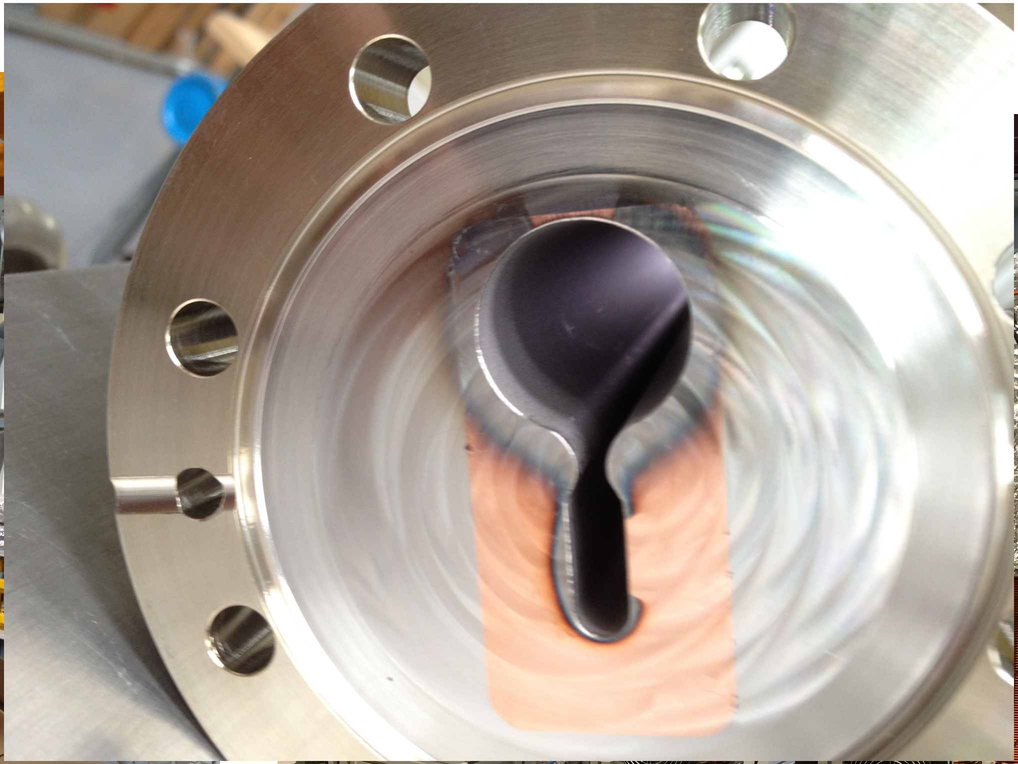
Vacuum chamber 2a/b

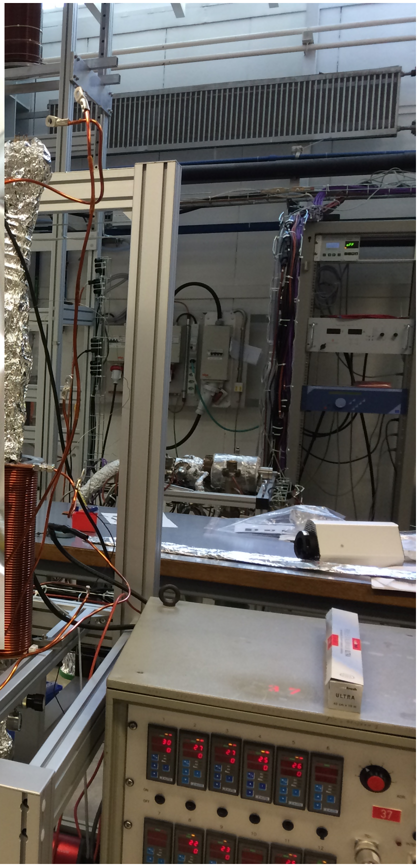
Vacuum chamber 2a/b

Vacuum chamber 2a/b



Vacuum chamber 2a/b





Conclusion

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- 3GeV Ring fully NEG Coated
- Most complicated chambers are being coated at CERN
- Despite the geometrical complexity and small cross section, we succeed to coat the totality of the inner Walls of the chambers
- By the end of 2014, all chambers will be delivered, in due time for the ring installation

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- We measured a delayed activation in the photon beam chamber of the VC2a/b that is not critical for the beam life time

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- We measured a delayed activation in the photon beam chamber of the VC2a/b that is not critical for the beam life time
- This unexpected result will be deeply investigated in the future

Production planning

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