Advanced Low Emittance Rings Technology workshop (ALERT2014)

NEG-coating for MAX IV

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Valencia, Spain

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- NEG-coating R&D at CERN,
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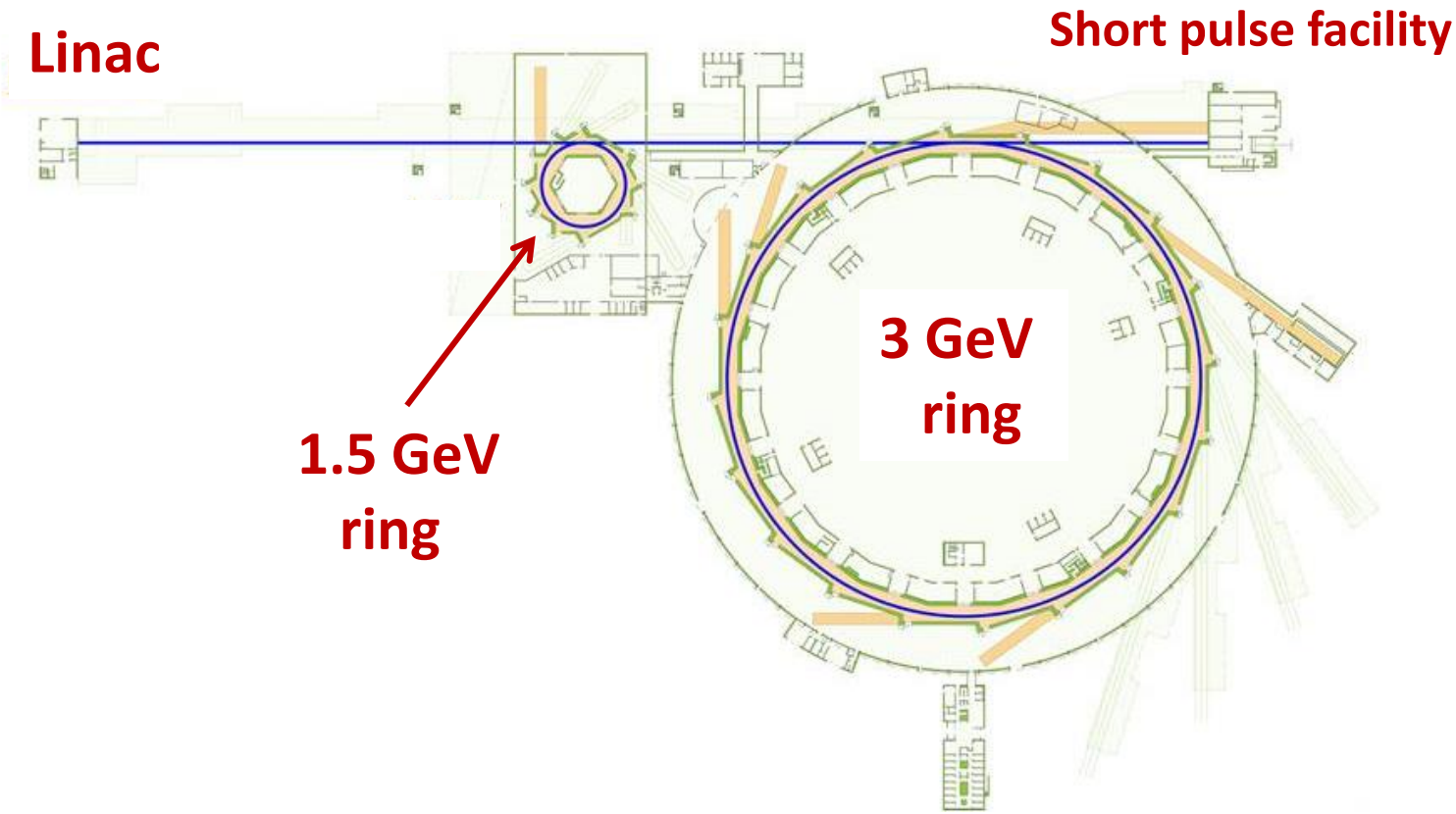
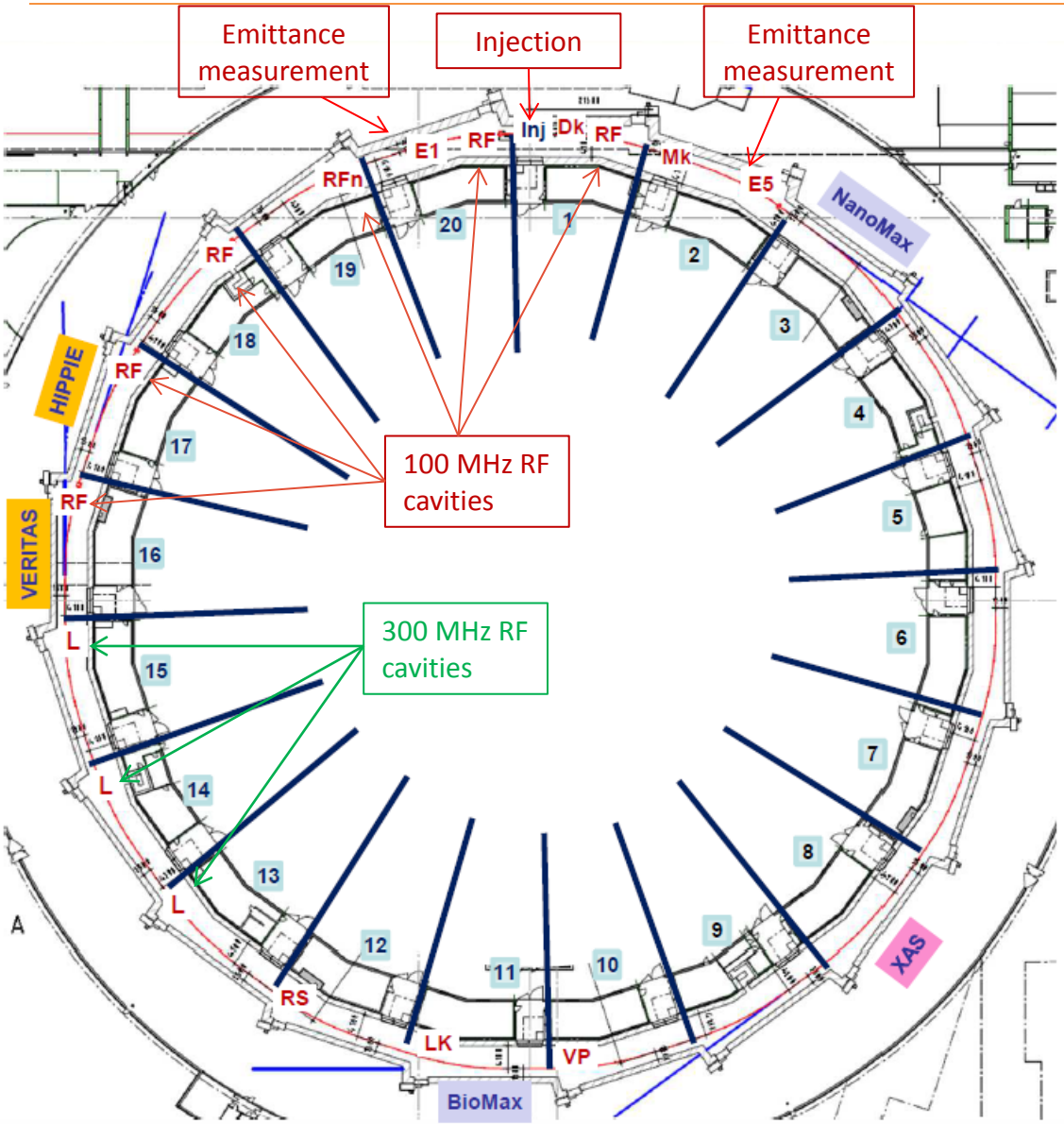
MAX IV layout



https://www.maxlab.lu.se/maxiv

3 GeV ring layout

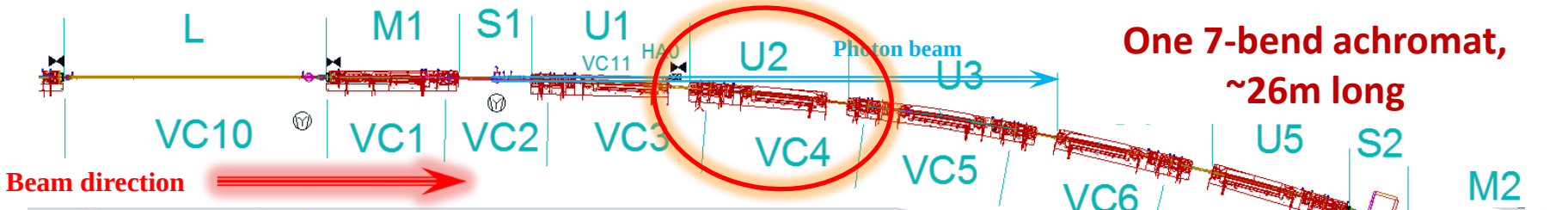


Circumference 528 m,

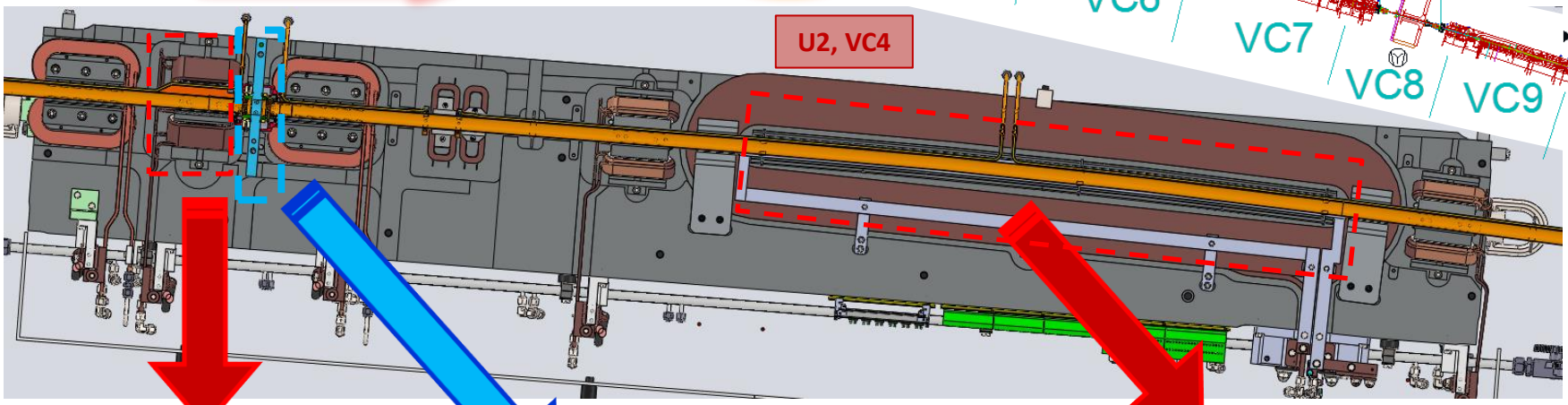
20 achromats,

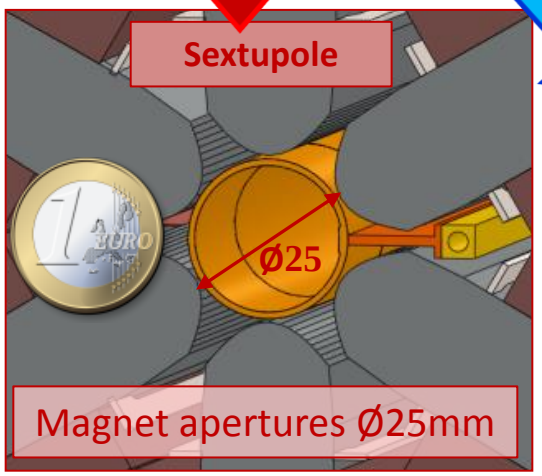
19 straight sections available for IDs.

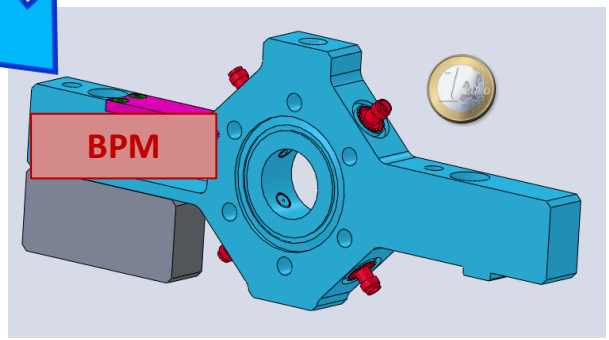
3 GeV magnet layout

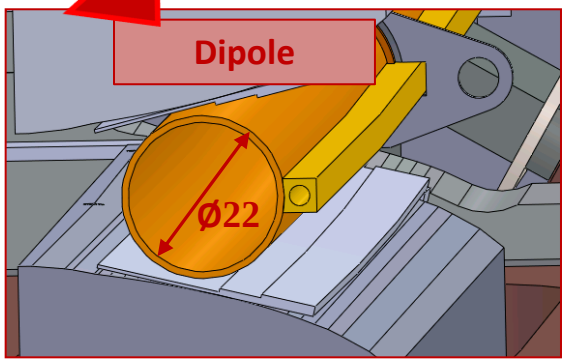


One 7-bend achromat, ~26m long



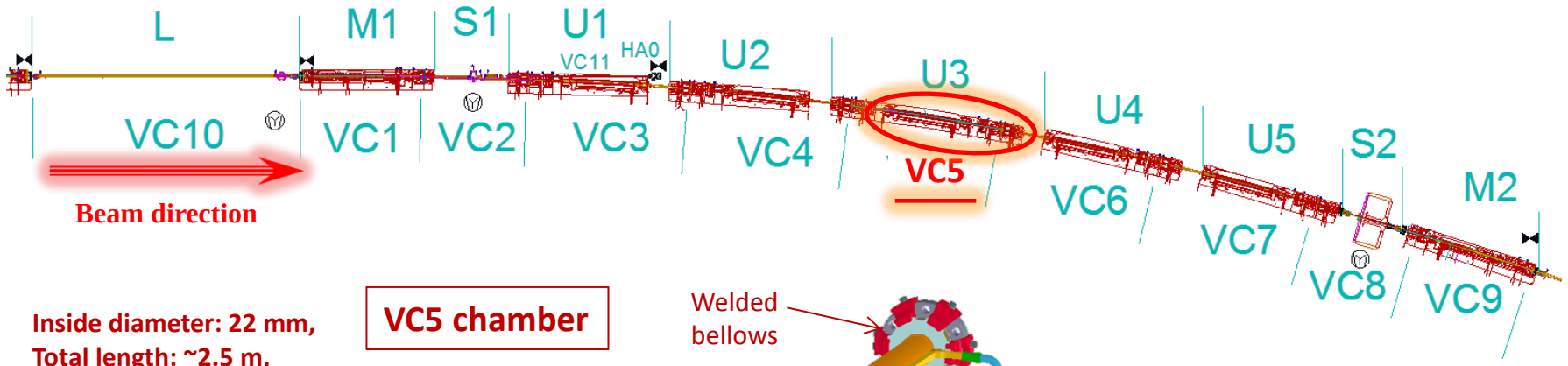






Min. clearance with the iron 0.5 mm, min. clearance with the coils 2 mm.

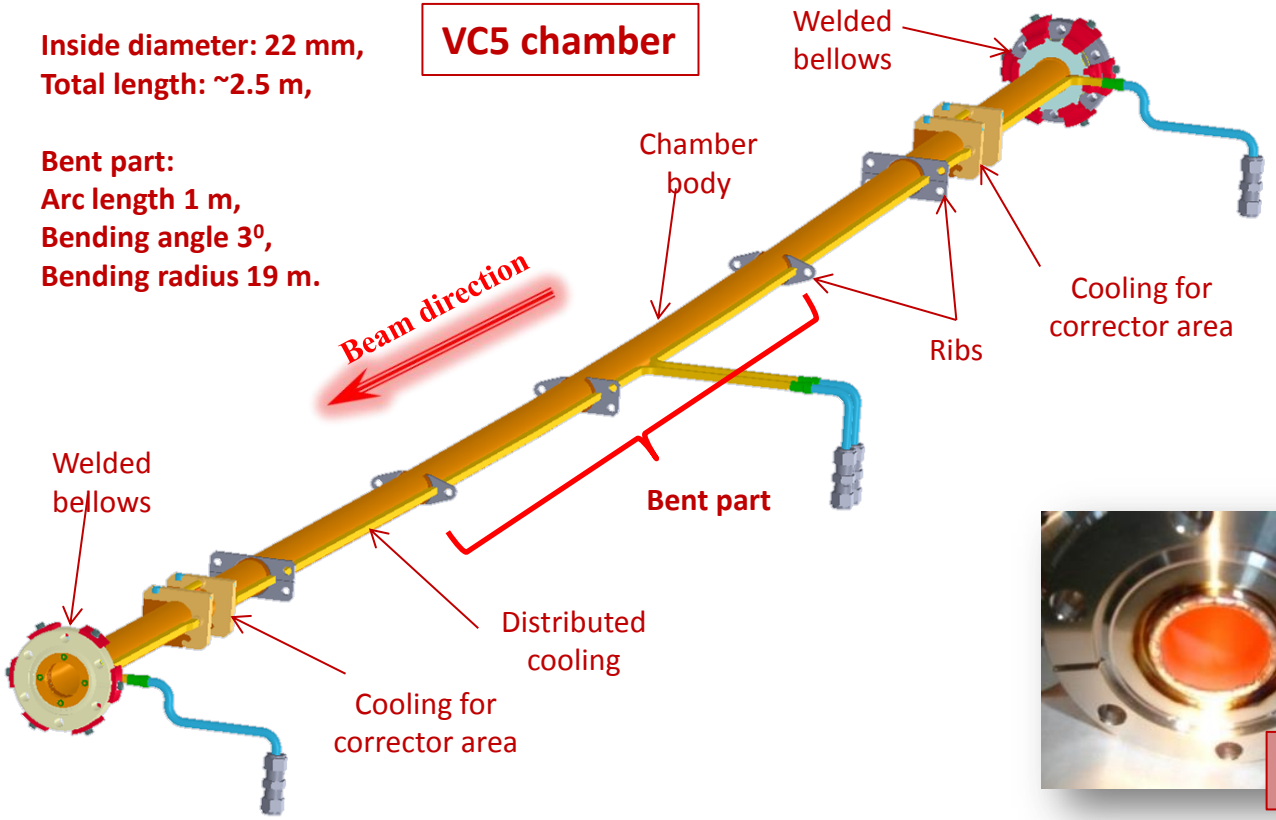
Standard vacuum chamber geometry



Inside diameter: 22 mm,
Total length: ~2.5 m,

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

VC5 chamber



Distributed pumping and low PSD, utilizing thin film **NEG-coating**.

NEG-coating R&D at CERN

Three stages of NEG-coating (Ti, Zr, V) by magnetron sputtering validation in collaboration with CERN were undertaken:

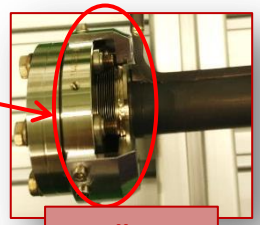
1. Define and perform initial **surface treatment** of copper substrate.
2. Validate compatibility with NEG-coating:
    a). On **Copper** substrate.
    b). On **Wire-eroded** surfaces and used **brazing** alloys.
3. Neg-coating validation of the vacuum chamber g**eometry.**

1. Surface treatment (R&D at CERN)

1. Define and perform surface treatment of the OFS copper tubes (~300 tubes) basing on experience with LHC.

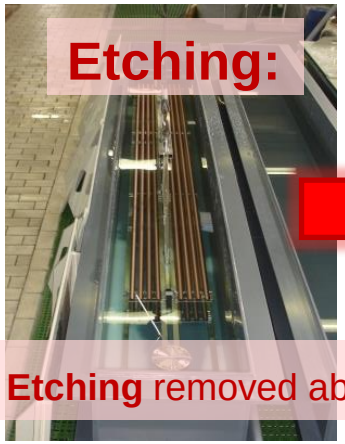
Chosen treatment: 1st step - degreasing, 2nd step - etching and passivation.

*** Due to presence in the final chambers welded bellows the surface treatment was done prior to the final manufacturing.**



UHV compatible

Not yet NEG-coating compatible



~300 tubes treated at CERN, 10% discarded

Etching removed about 50 µm of the material

NEG coating compatible

Ready for manufacturing

2. Material compatibility (R&D at CERN)

2 a). Confirm compatibility of NEG-coating on etched OFS copper substrate.

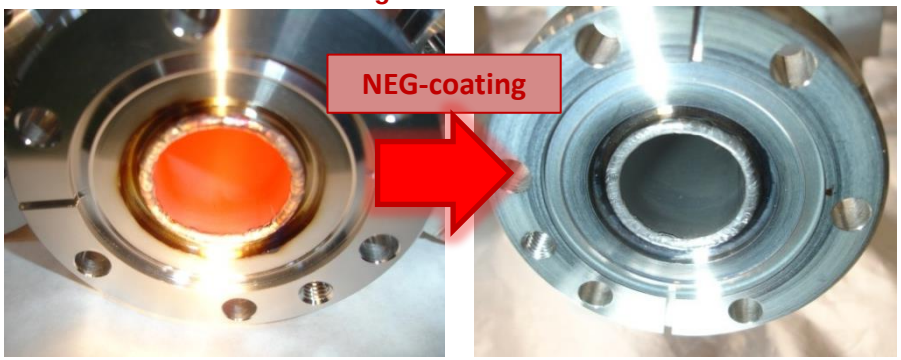
Two 3m long OFS copper chambers (degreased and etched) were coated with NEG.

OFS Copper chambers during thermal cycling

10 times thermally cycled up to 200^{0}C for at least 12 h and vented with air between the cycles.

Chamber before coating

Chamber after coating and thermal cycling



No peel-offs observed

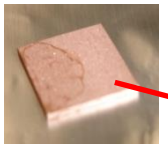
2. Material compatibility (R&D at CERN)

2 b). Evaluate compatibility of coating on wire-eroded surfaces and used brazing types.

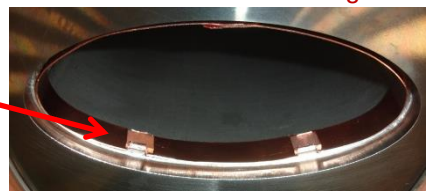
Wire-eroded copper samples (coating and measurements):

Small samples (for XPS):

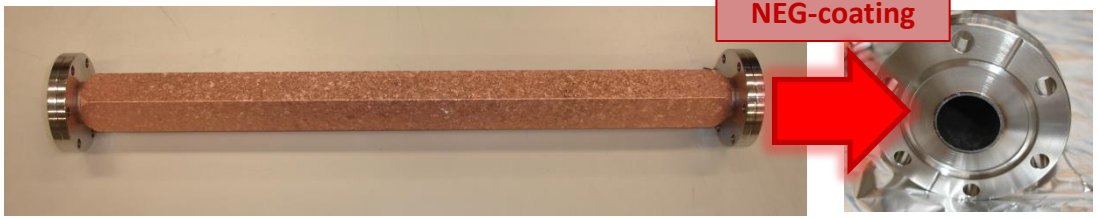
As received:



Installed for NEG-coating:

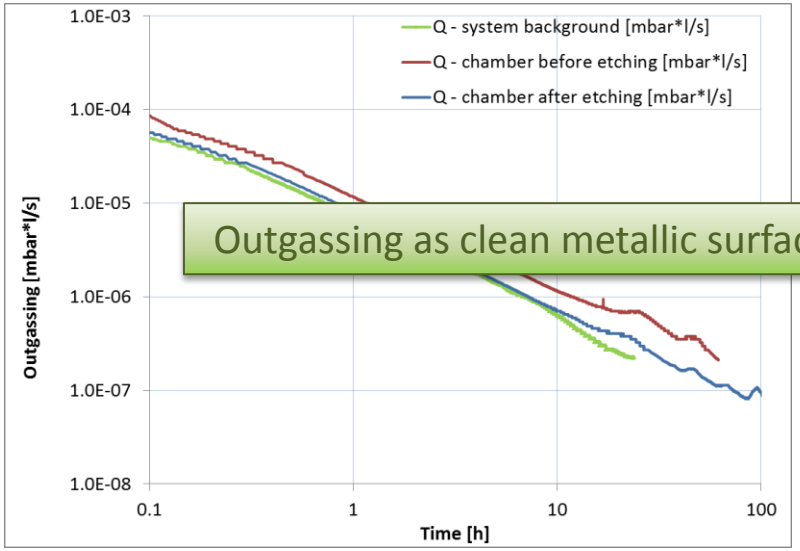


Vacuum chamber:



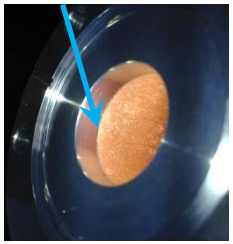
Adhesion and activation - OK

Pumpdown and outgassing by accumulation measurements performed.



Outgassing as clean metallic surface

c). Brazing types:



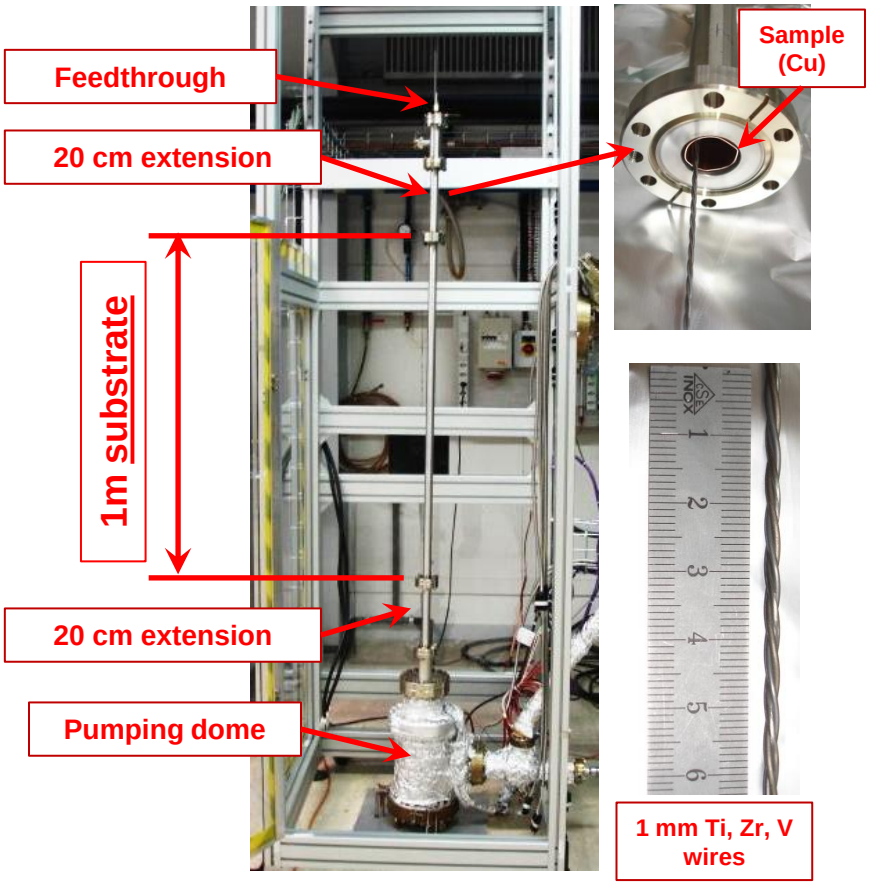
2 brazing alloys tested: Ag and Ni based.

Adhesion - OK

3. Geometry validation (R&D at CERN)

3 a). Validation of coating with NEG (Ti, Zr, V) of 22 mm inside diameter vacuum chambers.

Coating of 1 m long, 22 mm diameter tube by magnetron sputtering:



Glow discharge plasma during coating process.

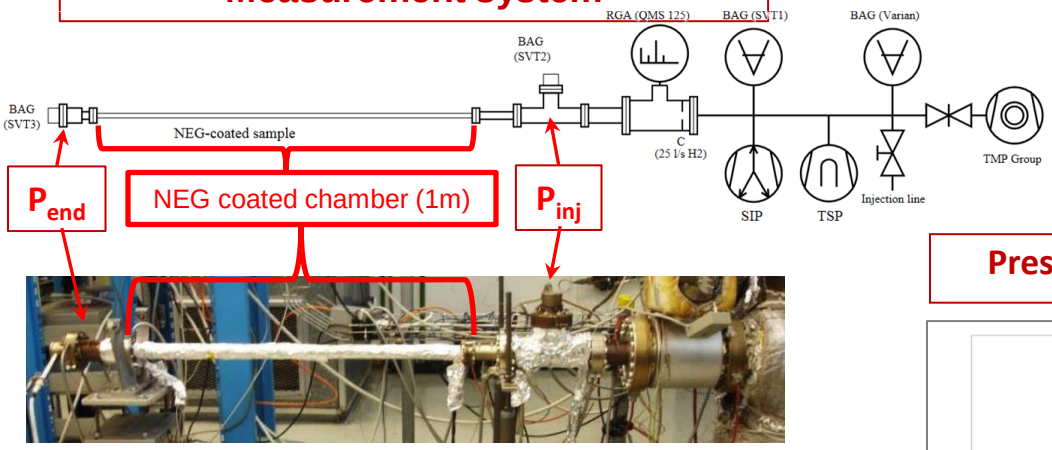
Courtesy of Antonios Sapountzis, CERN

3. Geometry validation (R&D at CERN)

3 a). Validation of coating with NEG (Ti, Zr, V) of 22 mm inside diameter vacuum chambers.

Sticking factor evaluation for hydrogen.

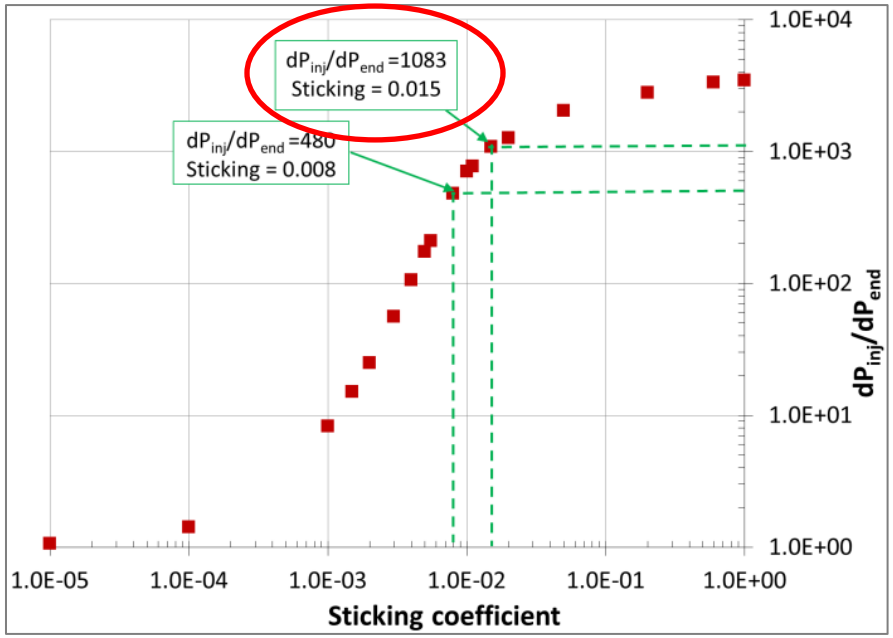
Measurement system



- 22mm chambers are feasible to coat by magnetron sputtering,
- Sticking factor OK.

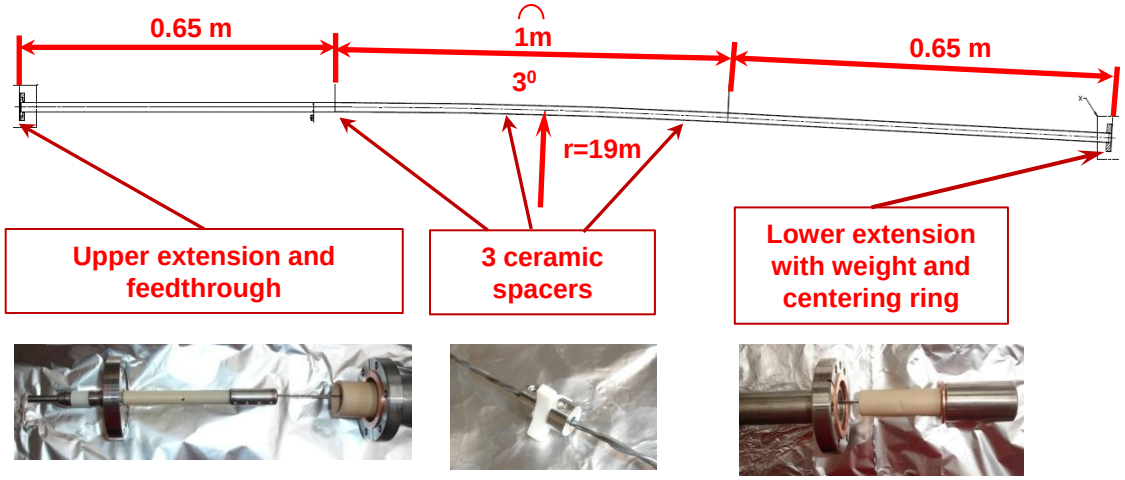
Measurement results:

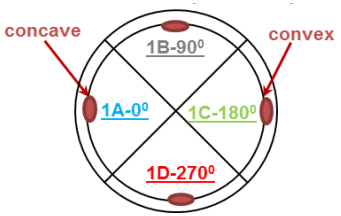
Pressure ratio (dP_{inj})/(dP_{end}) versus sticking factor



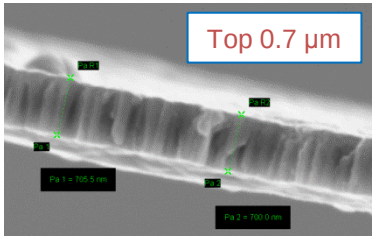
3. Geometry validation (R&D at CERN)

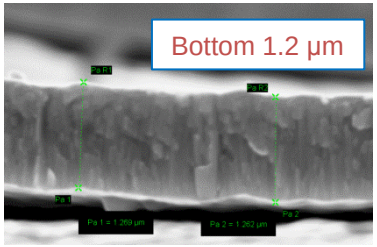
3 a). Coating validation of 22 mm inside diameter bent tubes.



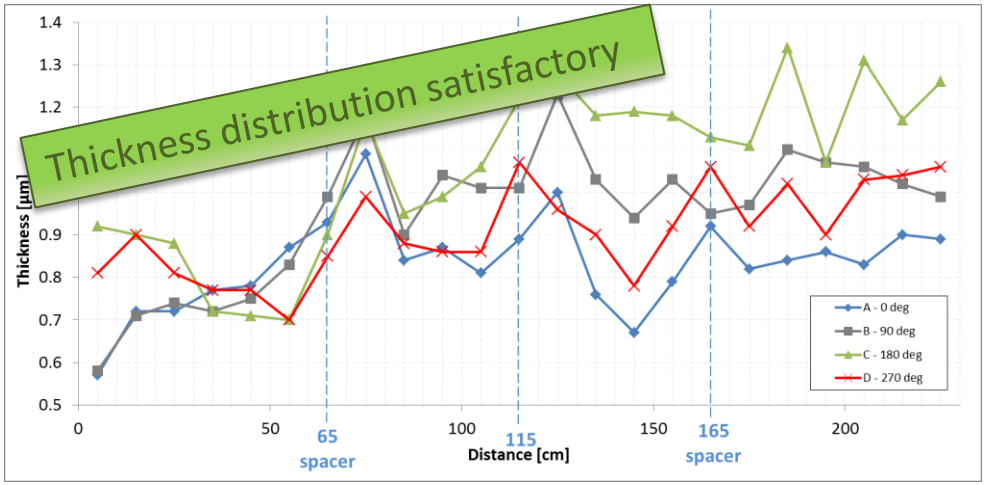


SEM thickness measurements:





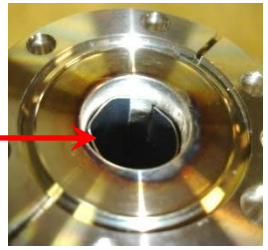
NEG film thickness distribution (measured by XRF):



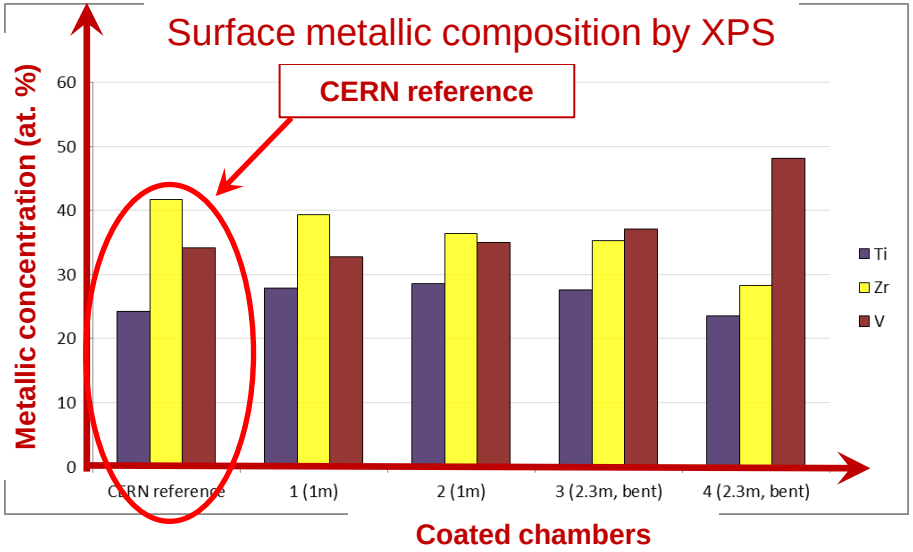
3. Geometry validation (R&D at CERN)

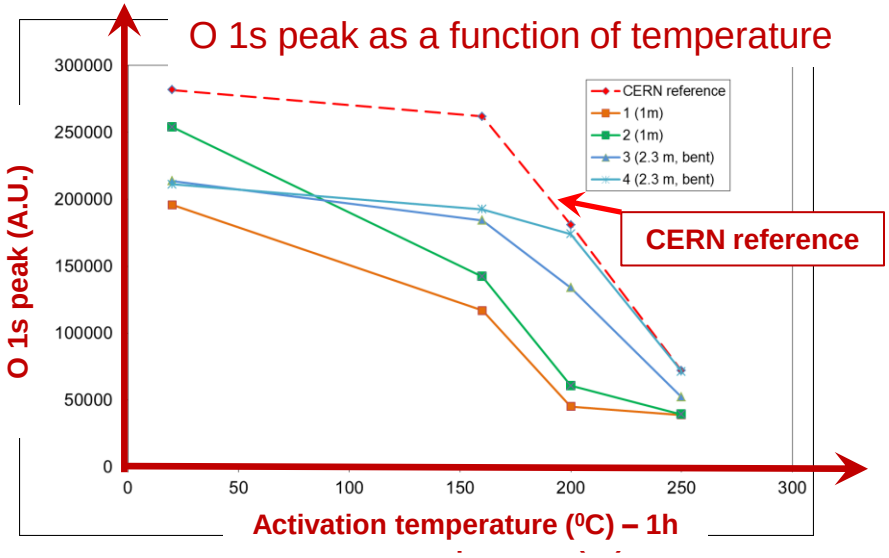
XPS results from the coatings of 22 mm inside diameter and bent chambers showed good composition and activation behavior.

Samples used for characterisations



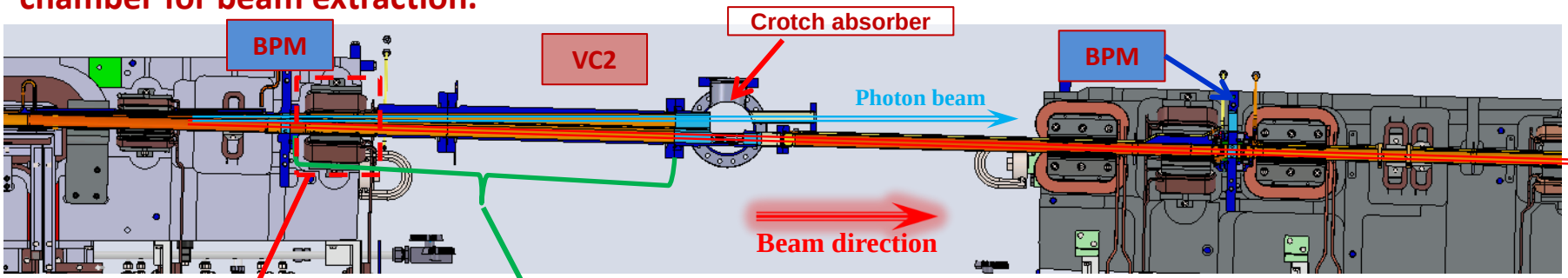
Composition and activation behavior satisfactory

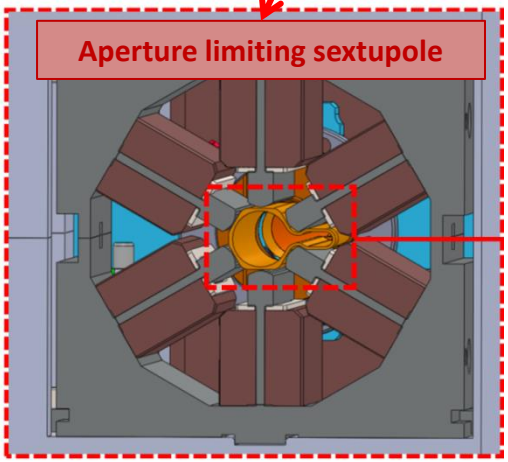


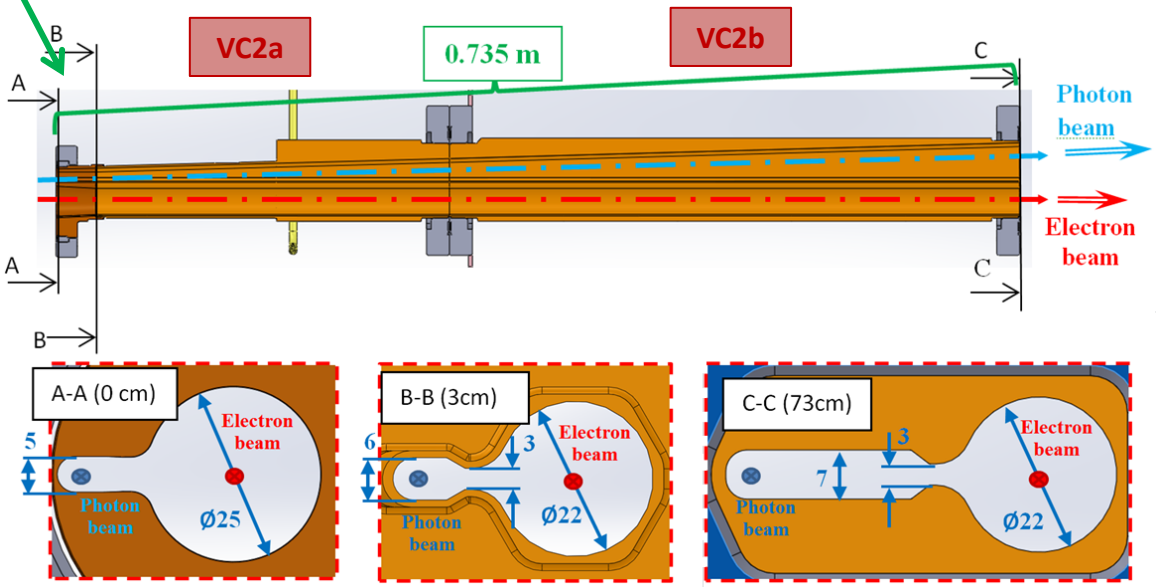


3. b) Complex vacuum chambers (R&D at CERN)

3 b). Establish coating procedure/technology and produce chambers of complex geometry: Vacuum chamber for beam extraction.

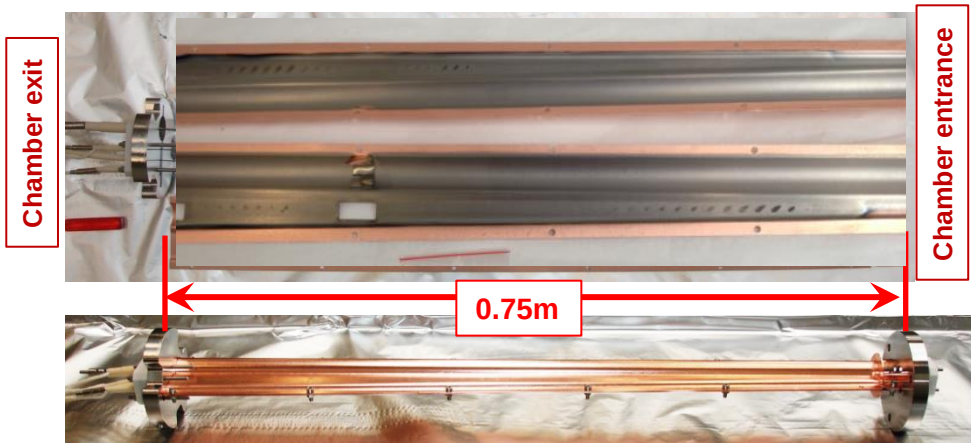


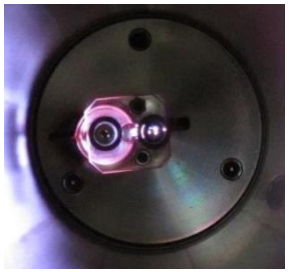




3. b) Complex vacuum chambers (R&D at CERN)

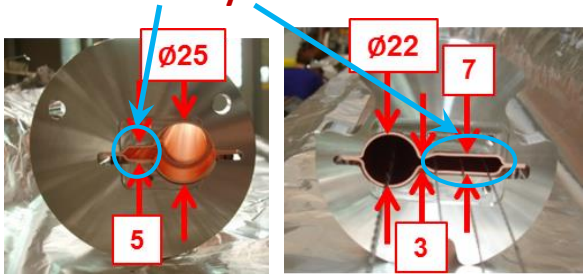
Prototype made was made at CERN in two halves to be able to inspect the coating quality.



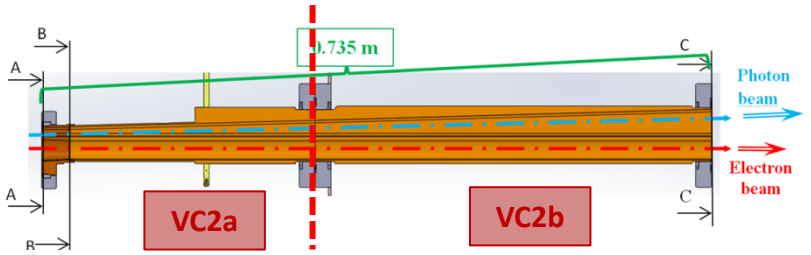


Glow discharge during coating

- ✓ **Thickness – OK,**
- ✓ **Coverage - OK,**
- *X* **- 'delayed' activation**

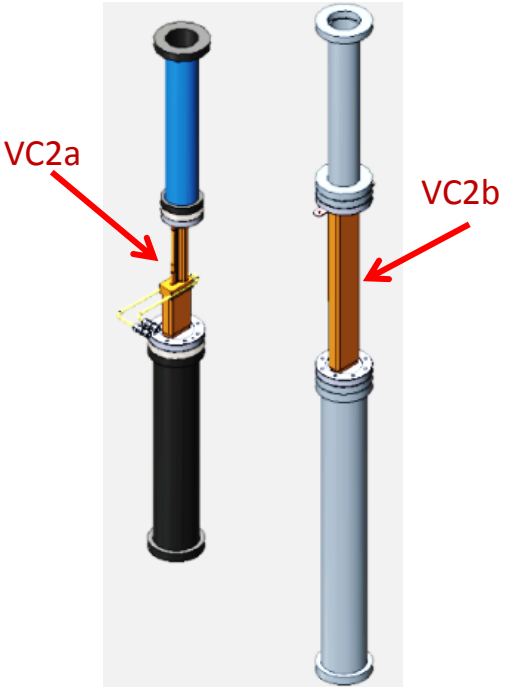


Due to difficulties with coating – chamber for coating was divided and will be coated in 2 runs.



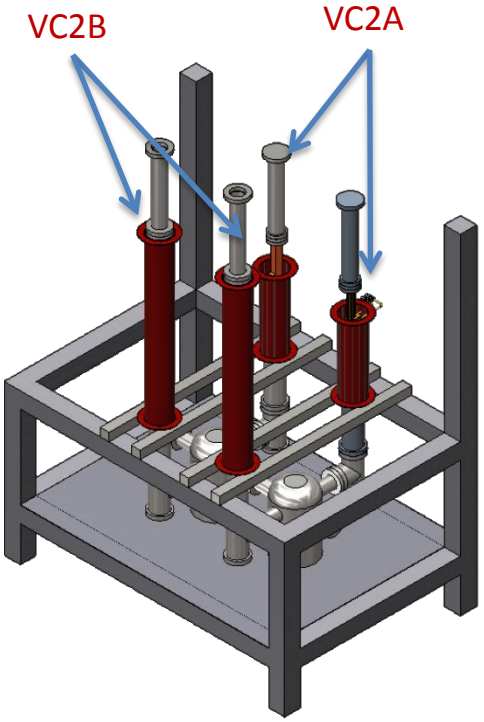
3. b) Complex vacuum chambers (R&D at CERN)

Series coating of complex chambers.



Courtesy of: Pedro Costa Pinto, Sergio Daniel Marques dos Santos - CERN

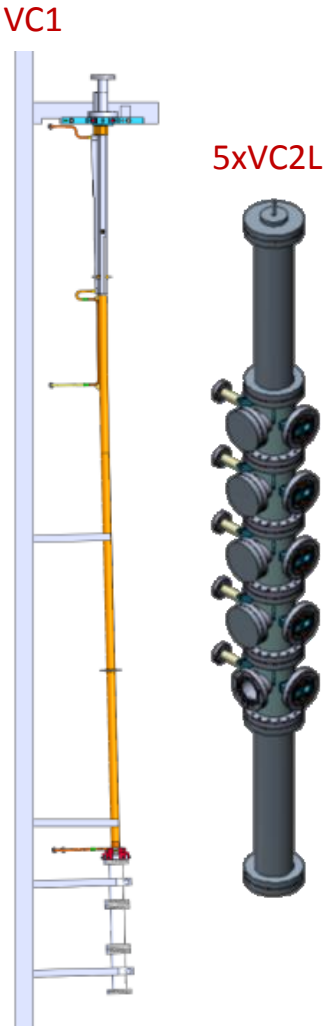
VC2A and VC2B will be coated in a dedicated system



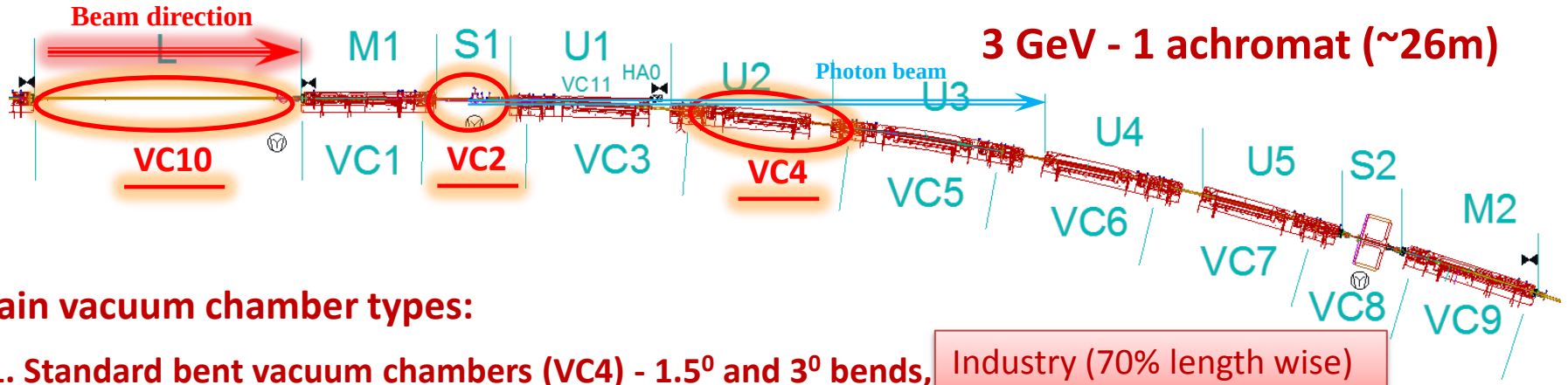
Production started, first chamber (VC1) was coated mid-April.

Production planned to finish in November 2014

VC1 and VC2L will be coated in the coating systems for LHC



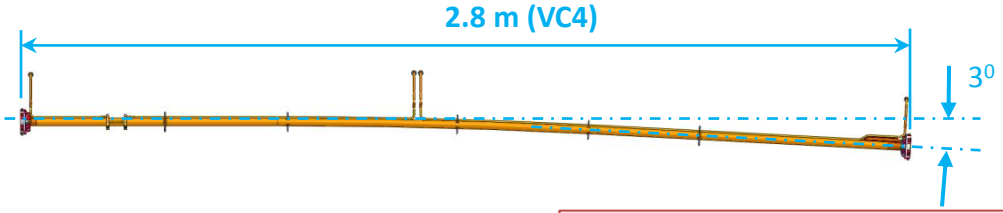
NEG-coating series production

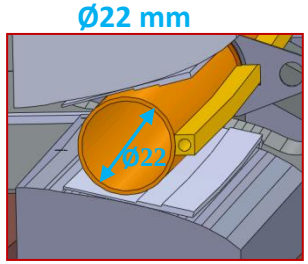


3 GeV - 1 achromat (~26m)

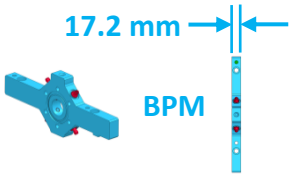
Main vacuum chamber types:

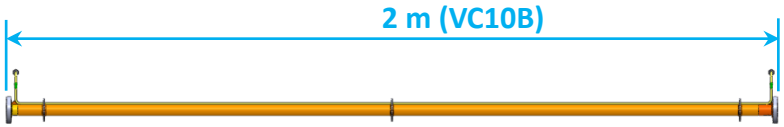
1. Standard bent vacuum chambers (VC4) - 1.5⁰ and 3⁰ bends, Industry (70% length wise)





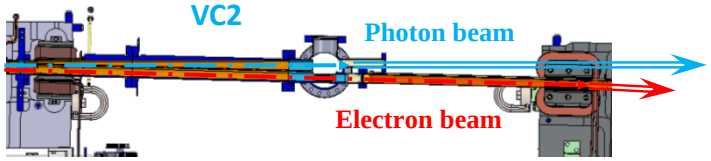
2. Straight vacuum (VC10)chambers, Collaboration with ESRF (15%)

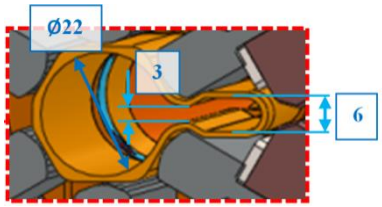




3. Special vacuum chambers.

Collaboration with CERN (15%)





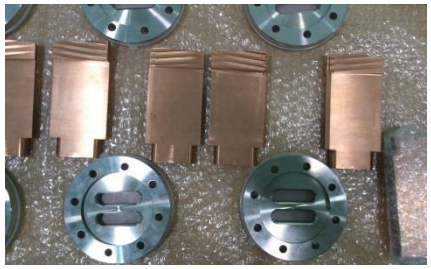
Production status at FMB

FMB is the manufacturer of vacuum chambers for MAX IV and also does the NEG coating.

- **Manufacturing of components,**
- **Final cleaning of the vacuum chambers and welding bellows,**
- **Dimensional and vacuum testing,**
- **NEG-coating.**

In 2012 FMB purchased the license for NEG coating from CERN and proved its ability to deliver coated chambers within specifications.

Crotch absorbers:



VC1 dimensional check:

Launch of the NEG-coating campaign depended on the approval of the vacuum chamber final cleaning.

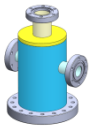
After many trials and discussions the cleaning was approved by CERN on the 2nd December 2013.

Currently about 70% of 750 chamber units are produced

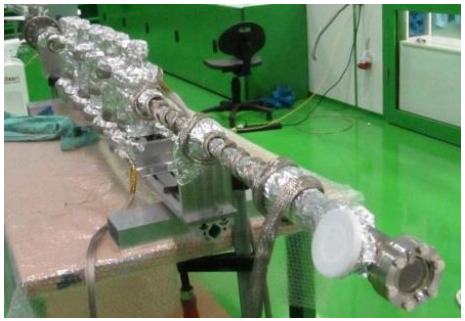
Production status at FMB

After approval of the cleaning procedure the series cleaning of the chambers started and final manufacturing steps were completed and the NEG-coating was started.

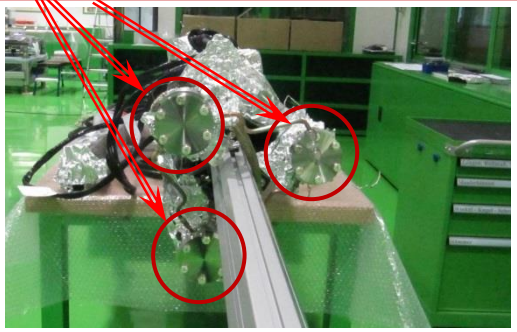
Two coating towers available at FMB:



VC8G, VC10C



3xVC5 – preparation for coating (21 units to coat)



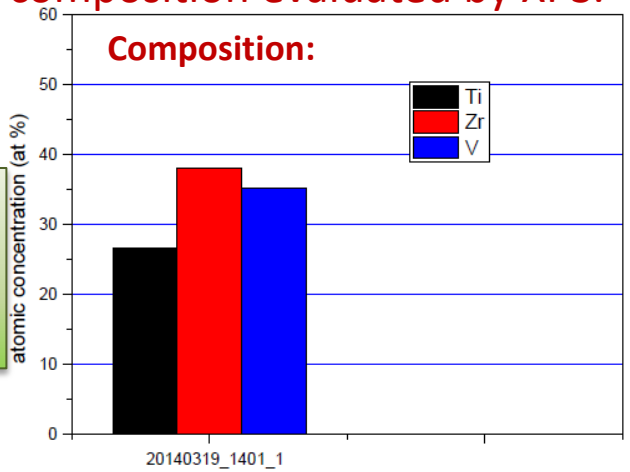
Production status at FMB

Quality control at FMB:

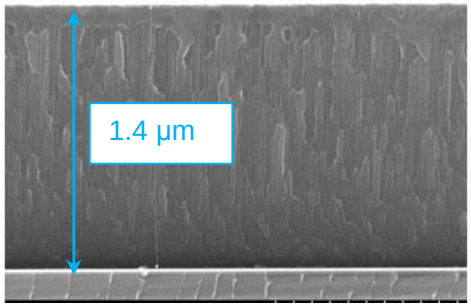
The cleaning water quality is checked regularly.

Chambers are being coated according to the schedule. One coating failed – new chamber was manufactured

Film activation properties and surface composition evaluated by XPS.

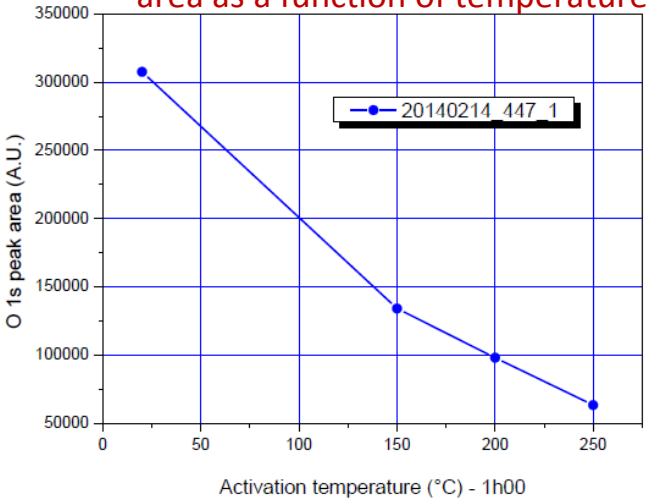


Sample from each coated chamber is characterized for: film thickness by SEM.



Visual inspection by endoscope performed for all the chambers

Activation curve - O 1s peak area as a function of temperature

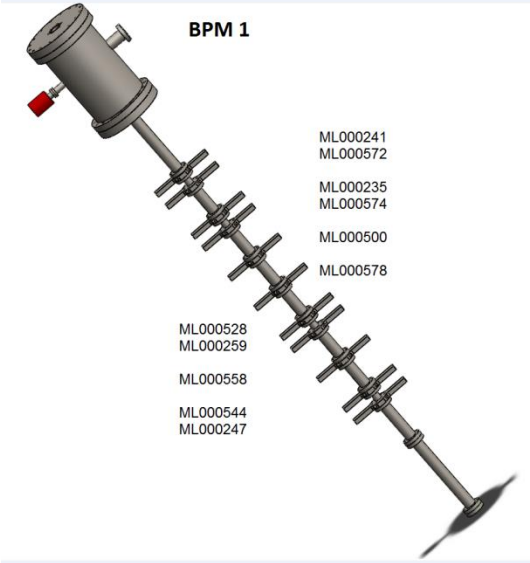


Activity status at ESRF

To increase the coating throughput and perform vital measurements of NEG-coated chambers collaboration with ESRF was established.

One new coating tower was built and commissioned at ESRF that will be used for ESRF future upgrade.

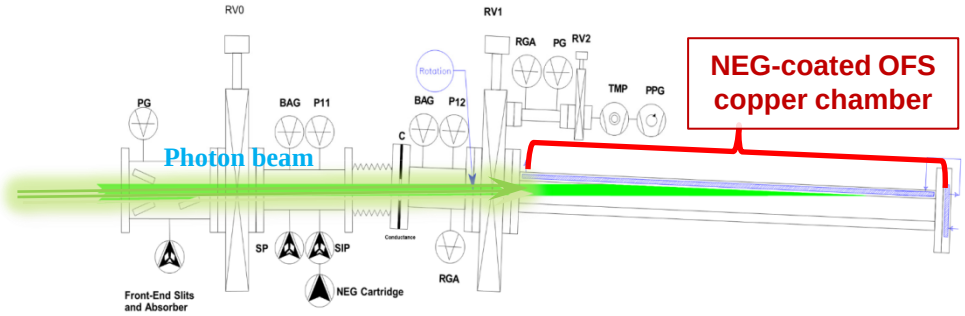
Coating of 11 BPMs in series

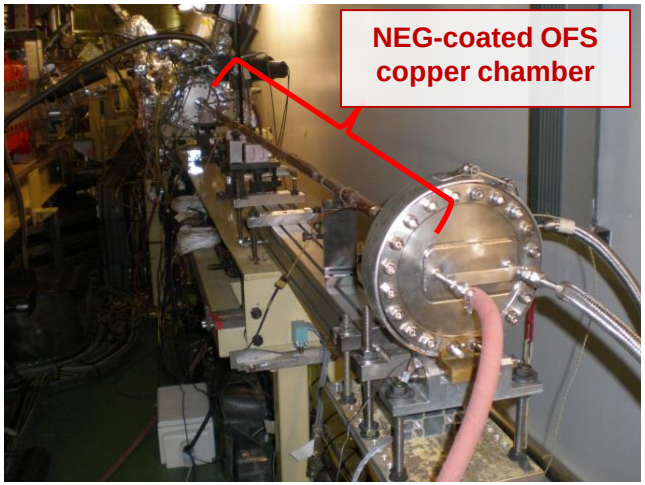


Courtesy of: H.P. Marques, M. Hahn - ESRF

Activity status at ESRF

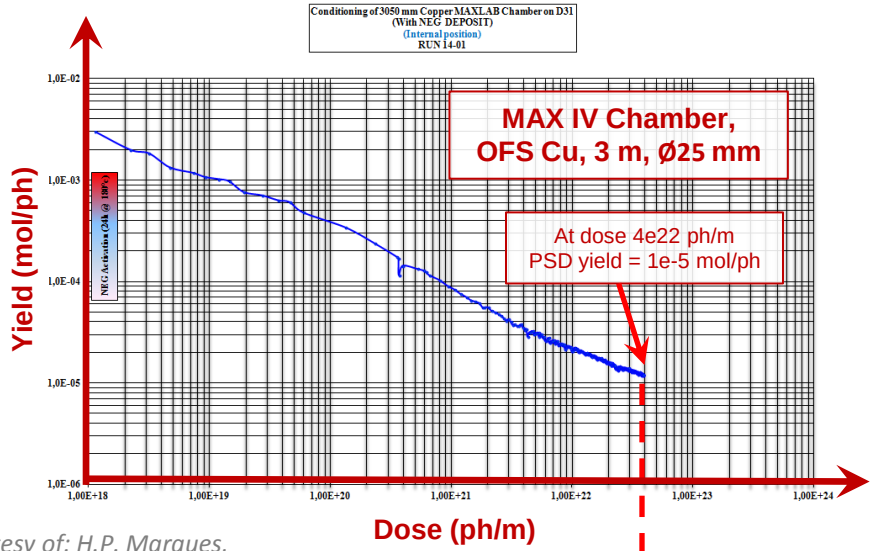
Photon stimulated desorption (PSD) measurements at ESRF at beamline D31.



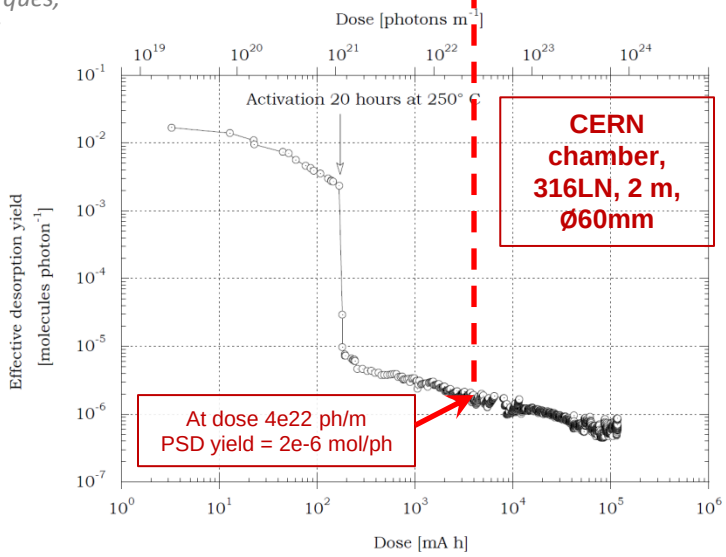


Measurement results:

- **PSD yield of the tested chamber is higher as expected,**
- **The conditioning of MAX IV chambers seems to be slightly faster.**



Courtesy of: H.P. Marques, M. Hahn - ESRF

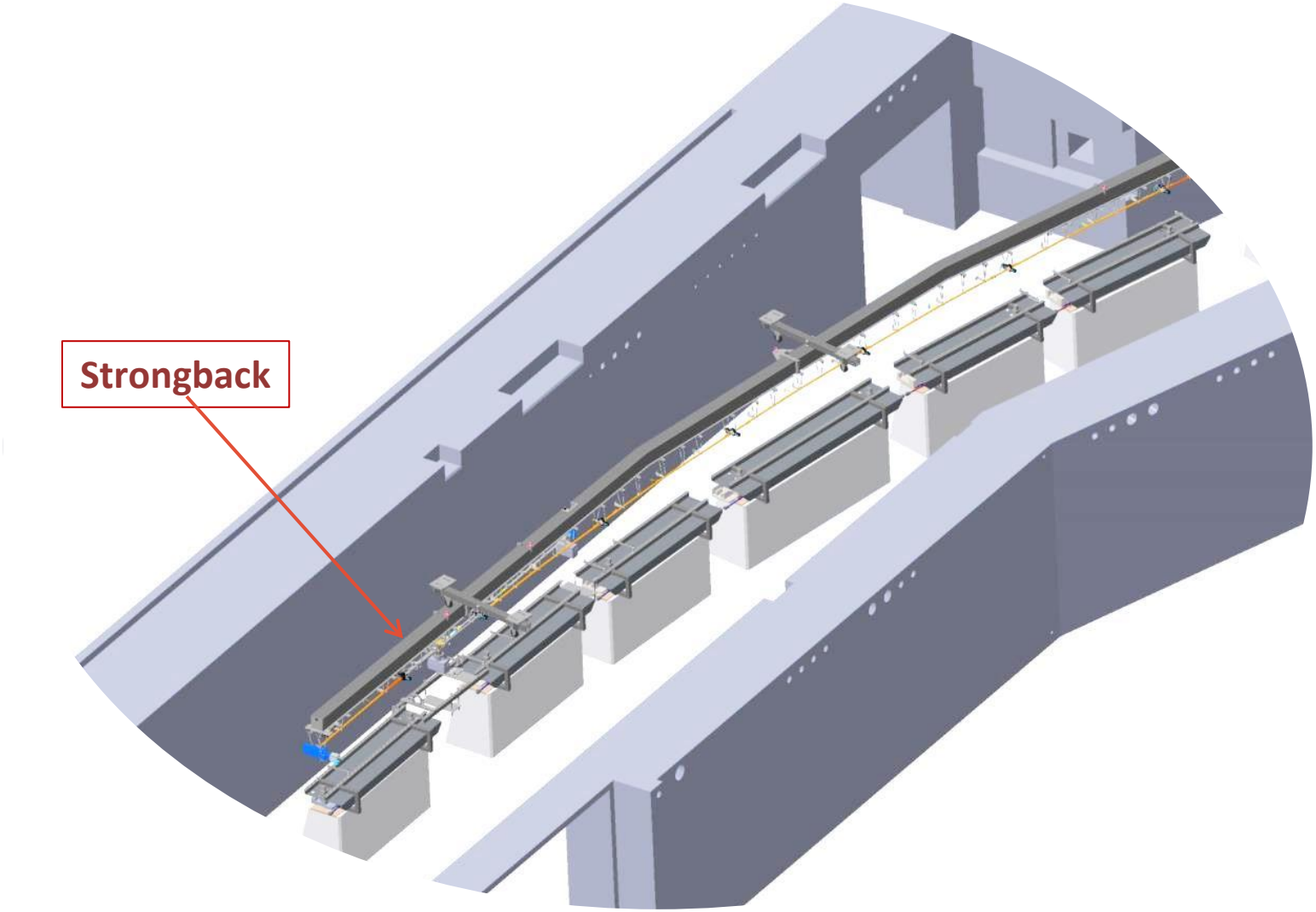


'Synchrotron Radiation-Induced Desorption from a NEG-Coated Vacuum Chamber', P. Chiggiato, R. Kersevan

Installation - 3 GeV ring

Installation will be rehearsed in a mock-up of one achromat.

Installation view



Summary

- R&D was needed - possible thanks to collaboration with CERN.
- Coating being done in 3 different places – beneficial for the production throughput.
- Single manufacturer of all the chambers and provider of the NEG-coating for ~70% of chambers.
- NEG-coating production started. First series coating in January 2014.
- NEG-coating quality control showed three issues so far.
- PSD measurement results at ESRF show higher yield as was expected, however the conditioning seems faster.
- **NEG-coating should to be considered at the beginning of the design as it implies limitations to the design.**
  The earlier the NEG-coating is considered in the design - the easier and less risky will be the manufacturing, integration and installation.


Thank you for your attention
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