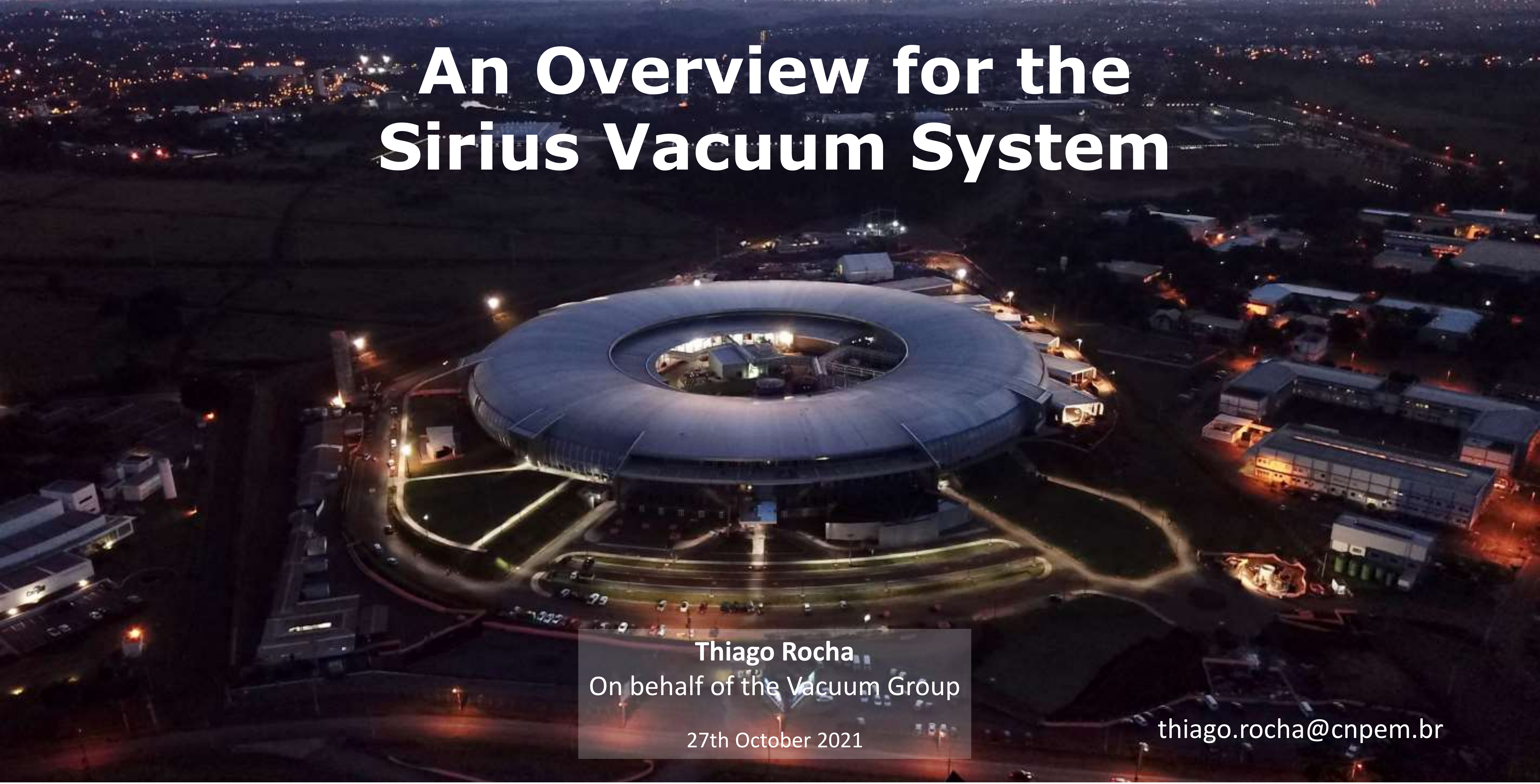
An Overview for the Sirius Vacuum System



Thiago Rocha
On behalf of the Vacuum Group

27th October 2021

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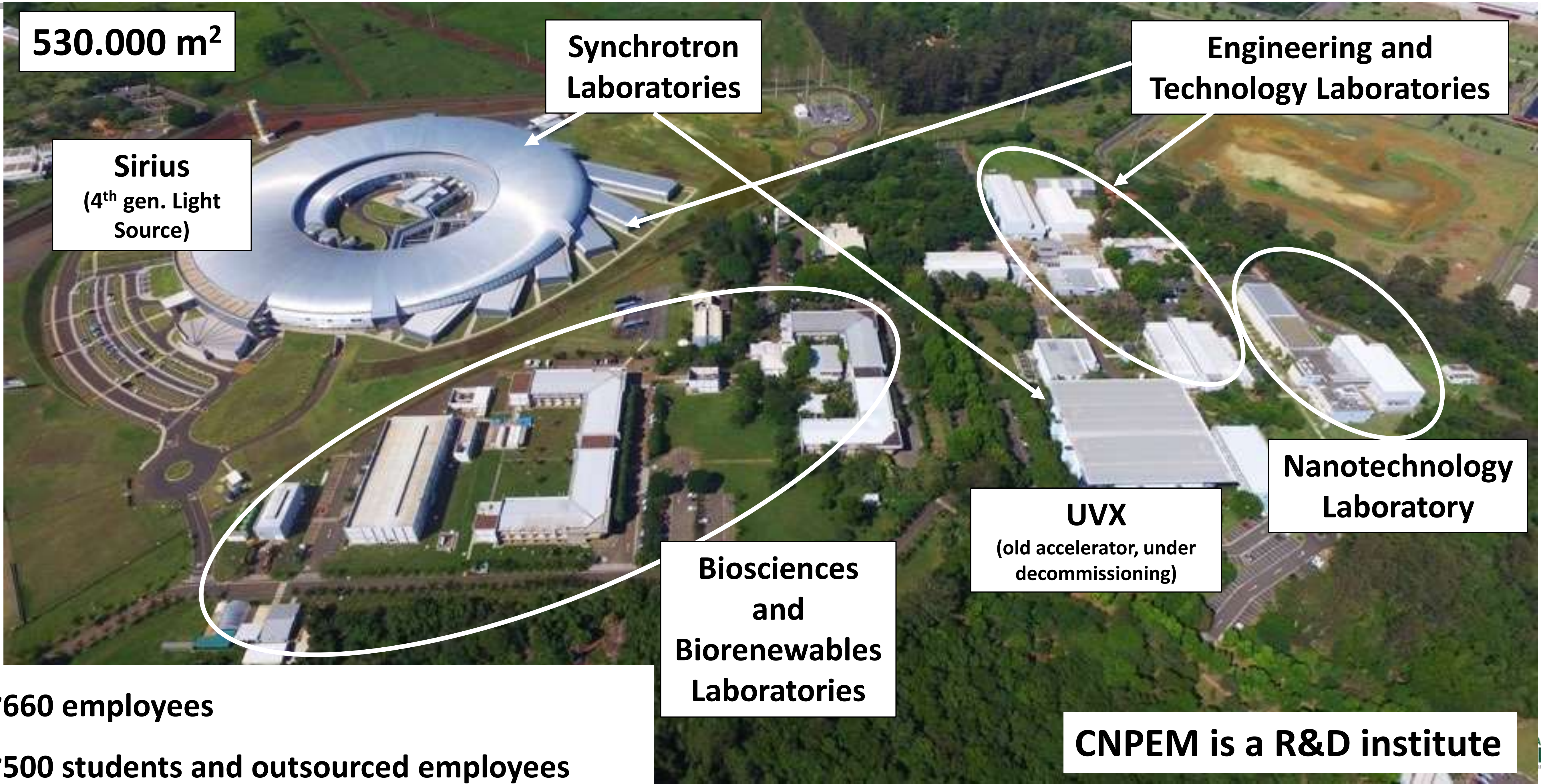
Outline

- Accelerators Layout
- Vacuum system overview
  - Fabrication
  - Installation
  - Vacuum performance
  - Vacuum related problems
  - IDs
- Final Remarks

CNPEM is a private institute, non-profit, supervised by the Brazilian Government



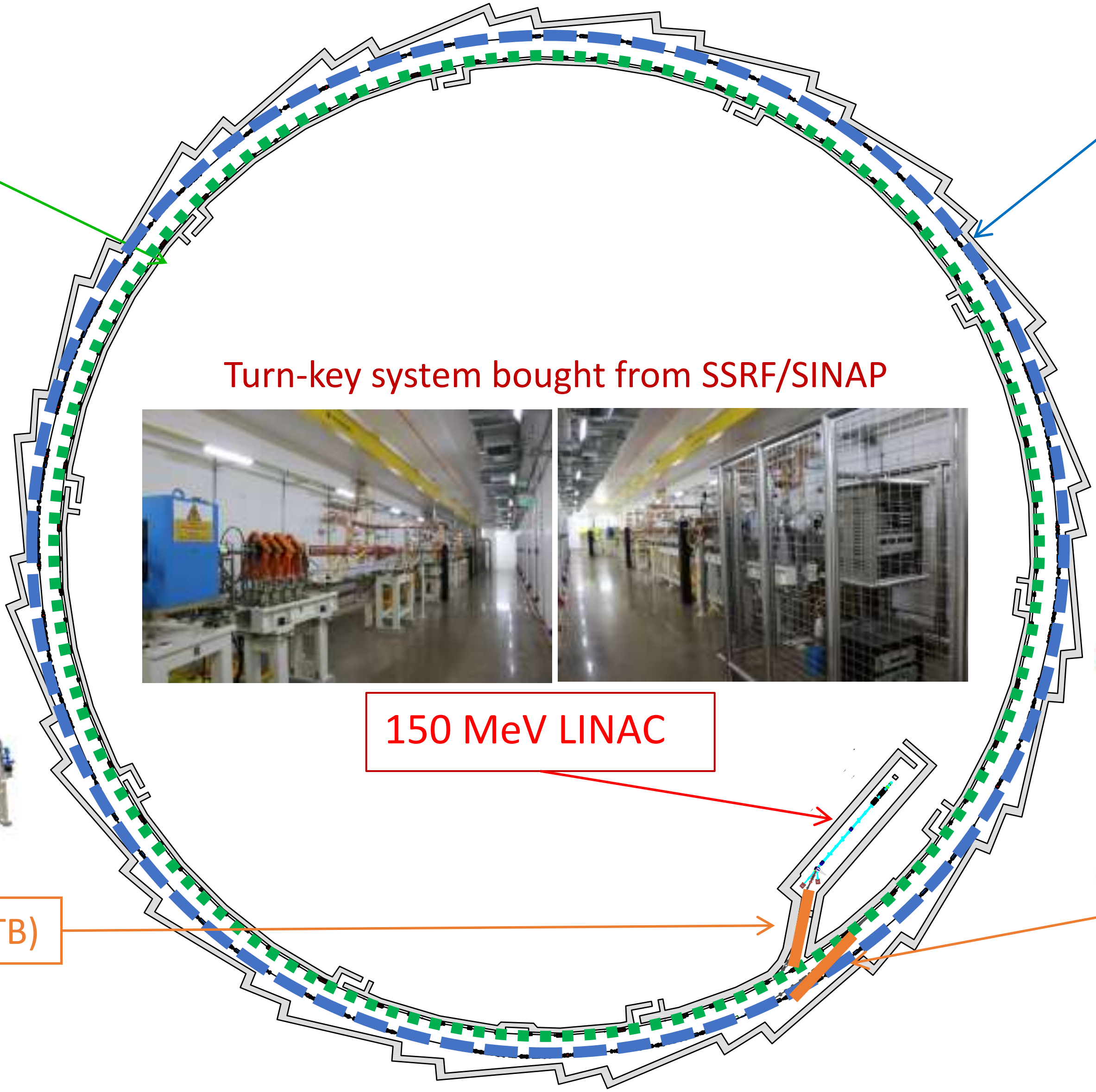
- ~660 employees
- ~500 students and outsourced employees

CNPEM is a R&D institute

Accelerators layout

3 GeV BOOSTER

C = 497 m
Lattice = 50 FODO
Emittance = 3.5 nm·rad



Turn-key system bought from SSRF/SINAP

150 MeV LINAC

3 GeV STORAGE RING

C = 518 m
Lattice = 5BA
Emittance = 0.25 nm·rad

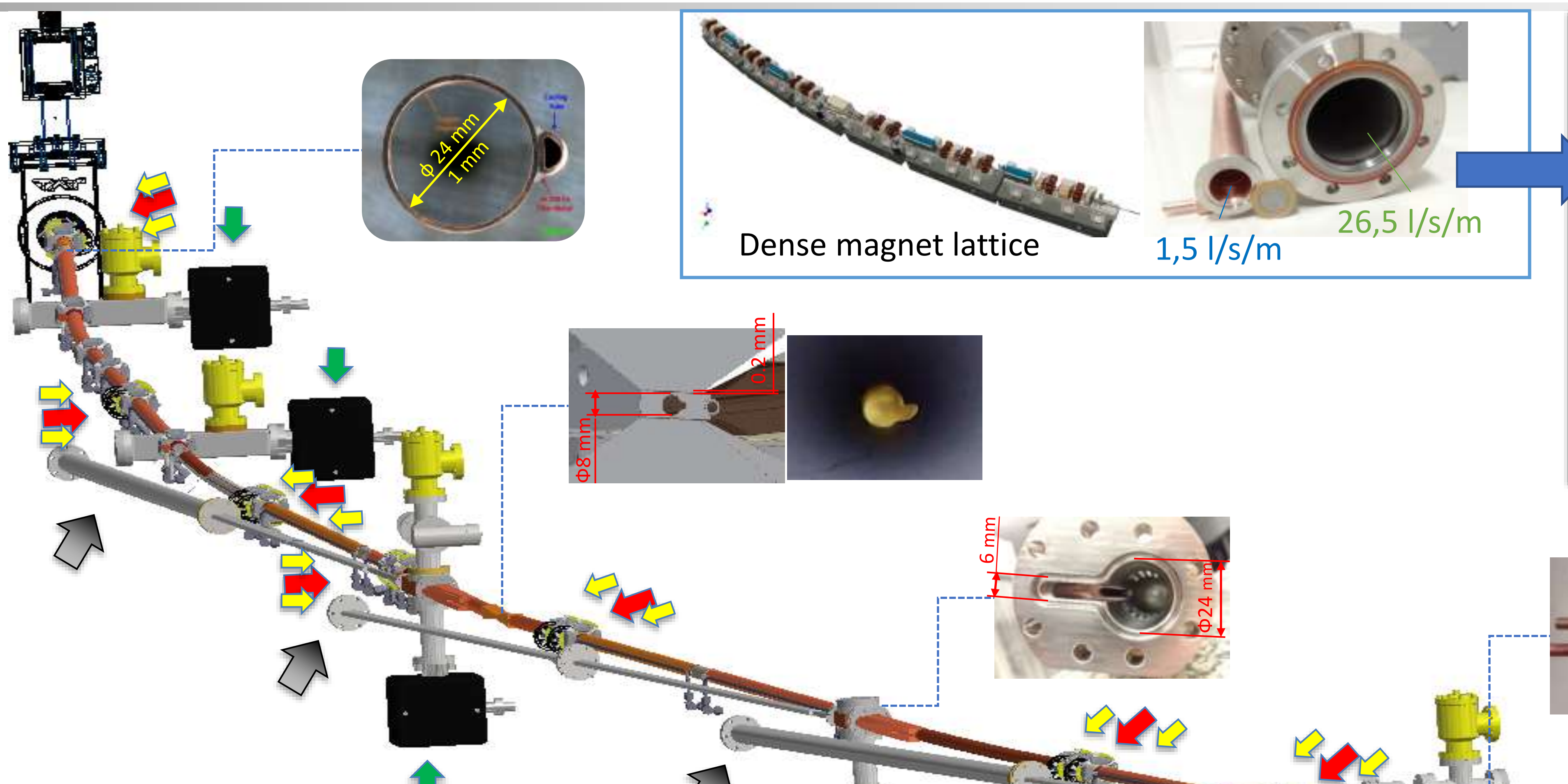
Linac to Booster (LTB)

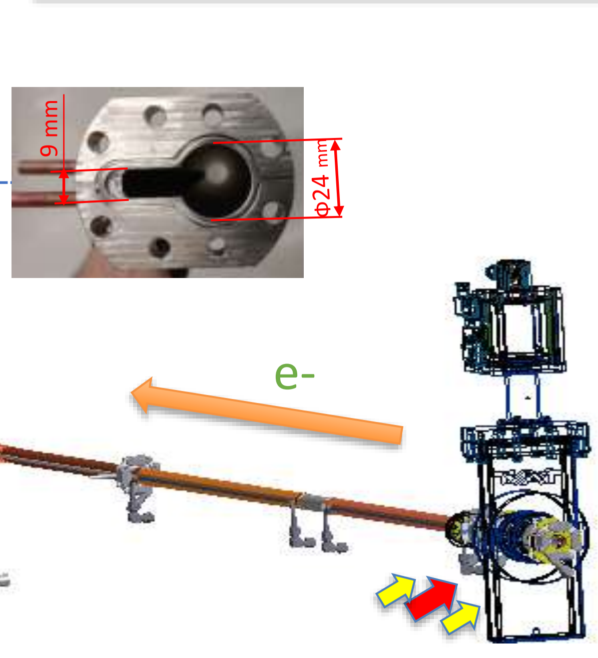
L = 21.3 m
150 MeV

Booster to Storage Ring (BTS)

L = 26.9 m
3 GeV

Storage Ring: layout for a typical sector





One superperiod (1/20 of the machine)

Target Pressure <= 1.10^{-9} mbar

Pumping strategy

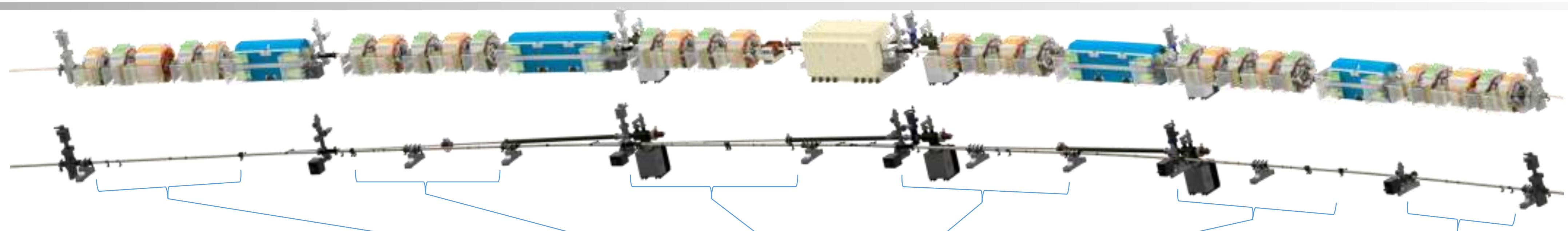
- **Fully NEG-coated chambers** (except RF-cavities, bellows, valves and BPMs).
- 20 l/s SIPs + 200 l/s NEG cartridges (post dipoles)

Chamber materials

- **OFS copper**
- 316L SS (flanges, pumping ports and FOCs)
- Ti-6Al-4V (BPMs)

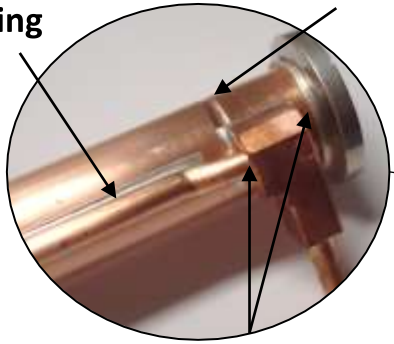
- 16 chamber segments
- 8 BPMs
- 5 Pumping stations
- 16 Bellows
- Photon beam extraction

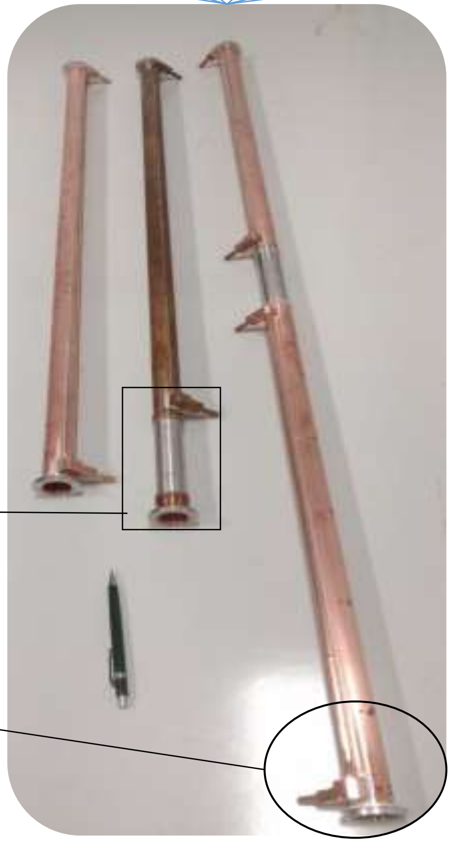
Storage ring: multipole chambers



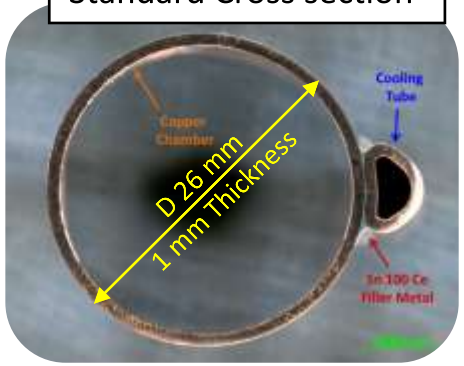
27 different models, with lengths from 500 to 2500 mm

Fast-orbit corrector sector



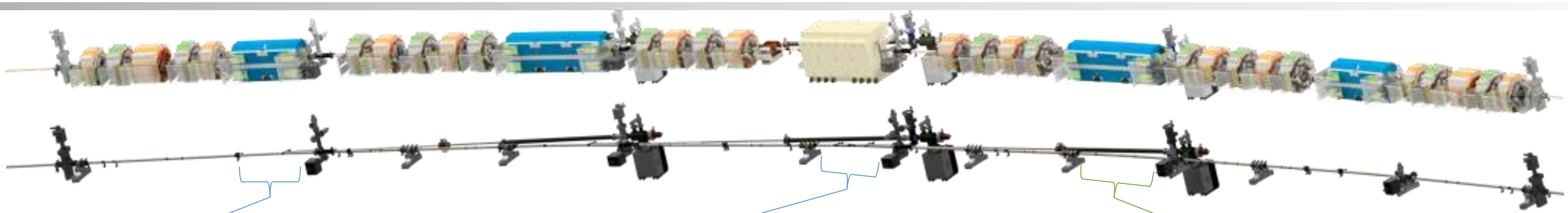


Standard Cross section

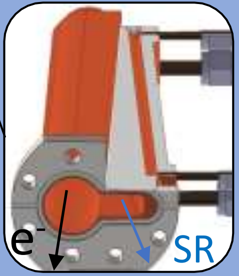


Inconel chain clamp developed w/ a Brazillian company

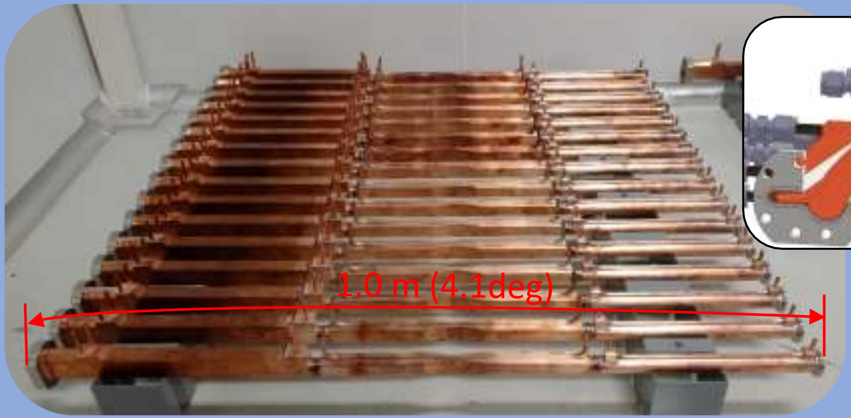
Storage ring: dipole chambers

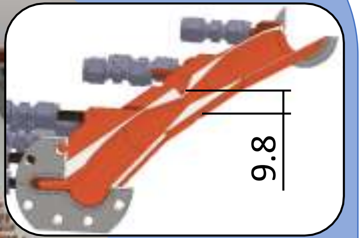


IDs photon extraction



High field dipoles, w/ narrow sector





Fabrication technologies:

1. Precision machining
2. EDM and deep holing
3. 7 brazings at the same time
4. TIG welding Cu-Cu
5. Bending radius forming
6. 2 runs of NEG coating

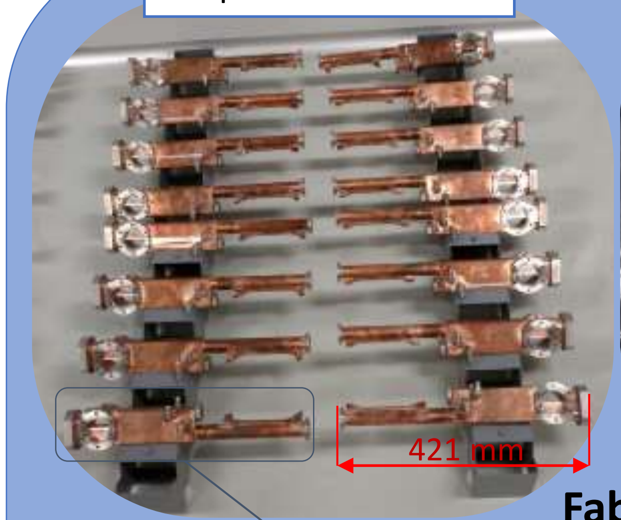
Simple design

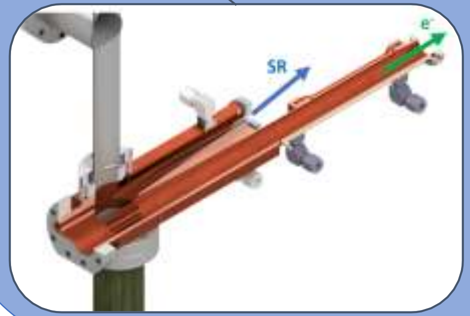
Fabrication technologies:

1. Machining
2. 2 brazings
3. TIG welding
4. 1 run of NEG coating
5. TIG welding post-NEG coating

Storage ring: pumping stations

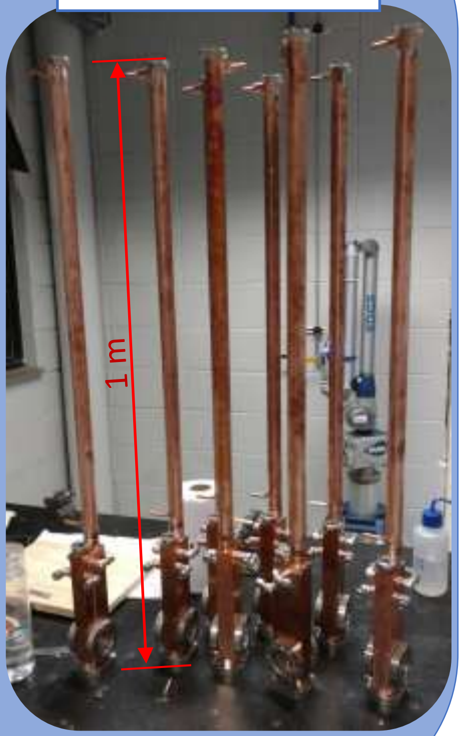
IDs photon extraction





Low field dipoles,
Diagnostic beamlines

High field dipoles,
w/ narrow sector



Fabrication technologies:

1. Precision machining
2. EDM
3. Deep holing
4. 15 brazings at the same time
5. TIG welding Cu-Cu
6. 2 runs of NEG coating

Simple design

Fabrication technologies:

1. Machining
2. 1 brazing
3. TIG welding
4. 2 runs of NEG coating
5. TIG welding post-NEG coating

Main chambers and components: Special components

RF shielded bellows

Telescopic

Axial stroke: -9mm/+ 2mm
Radial stroke: 0,02mm

380 units

Gear

Axial stroke: -5mm/+ 2mm
Radial stroke: 0.5mm

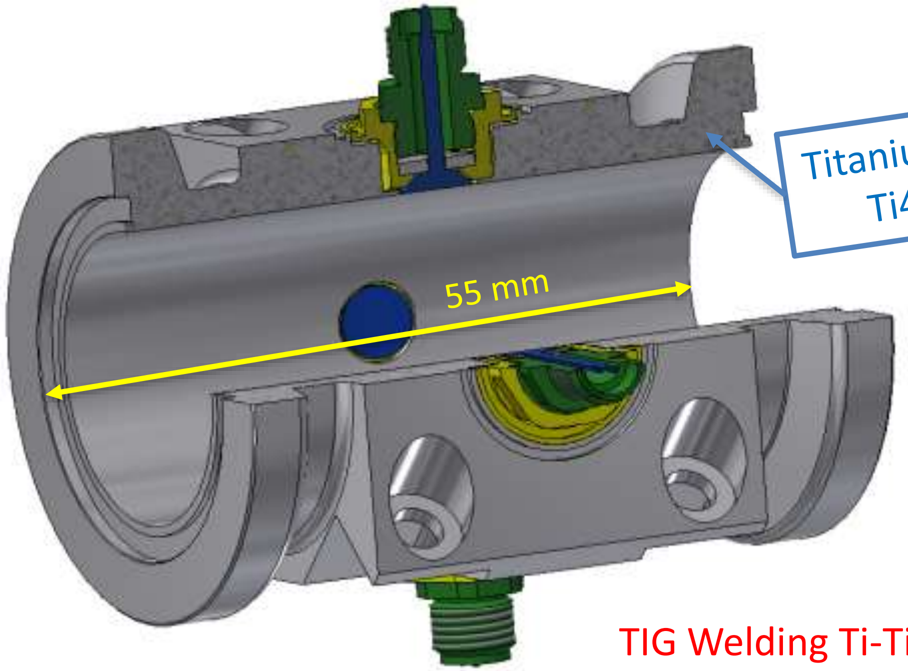
12 units

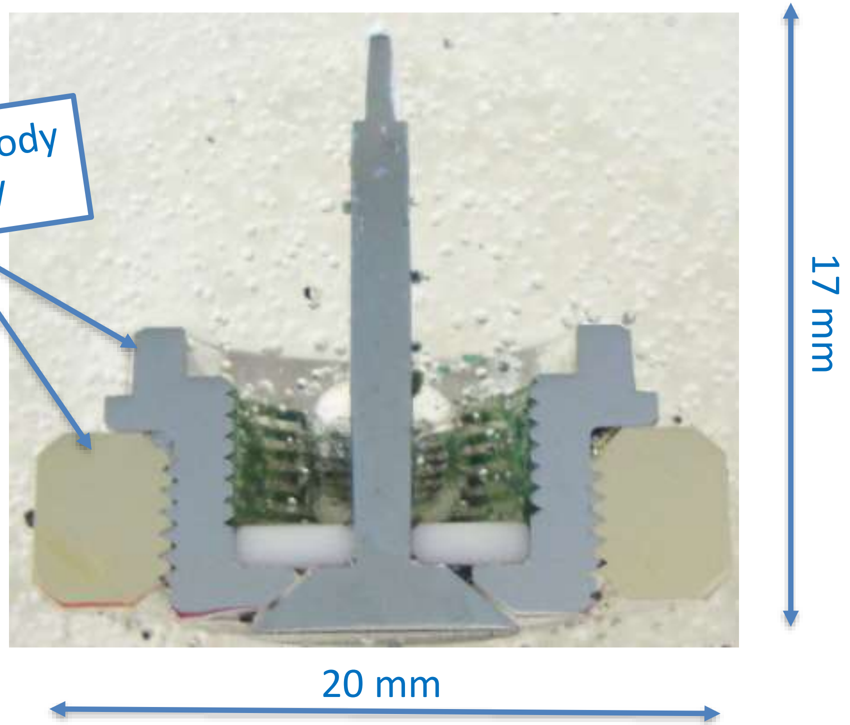
Comb Type

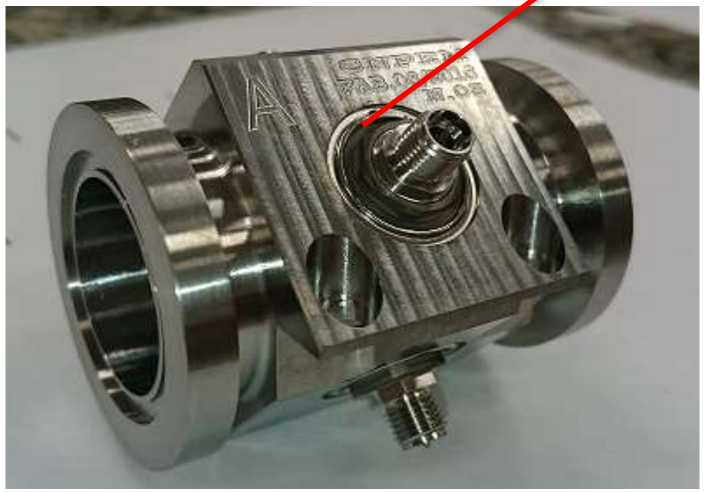
Axial stroke: -9 mm/+ 2mm
Radial stroke: 0.5 mm

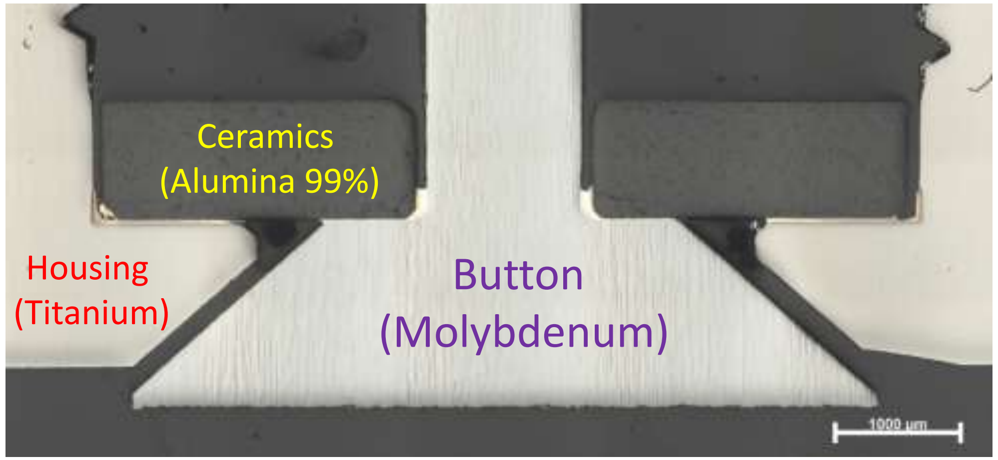
12 units

Main chambers and components: Special components



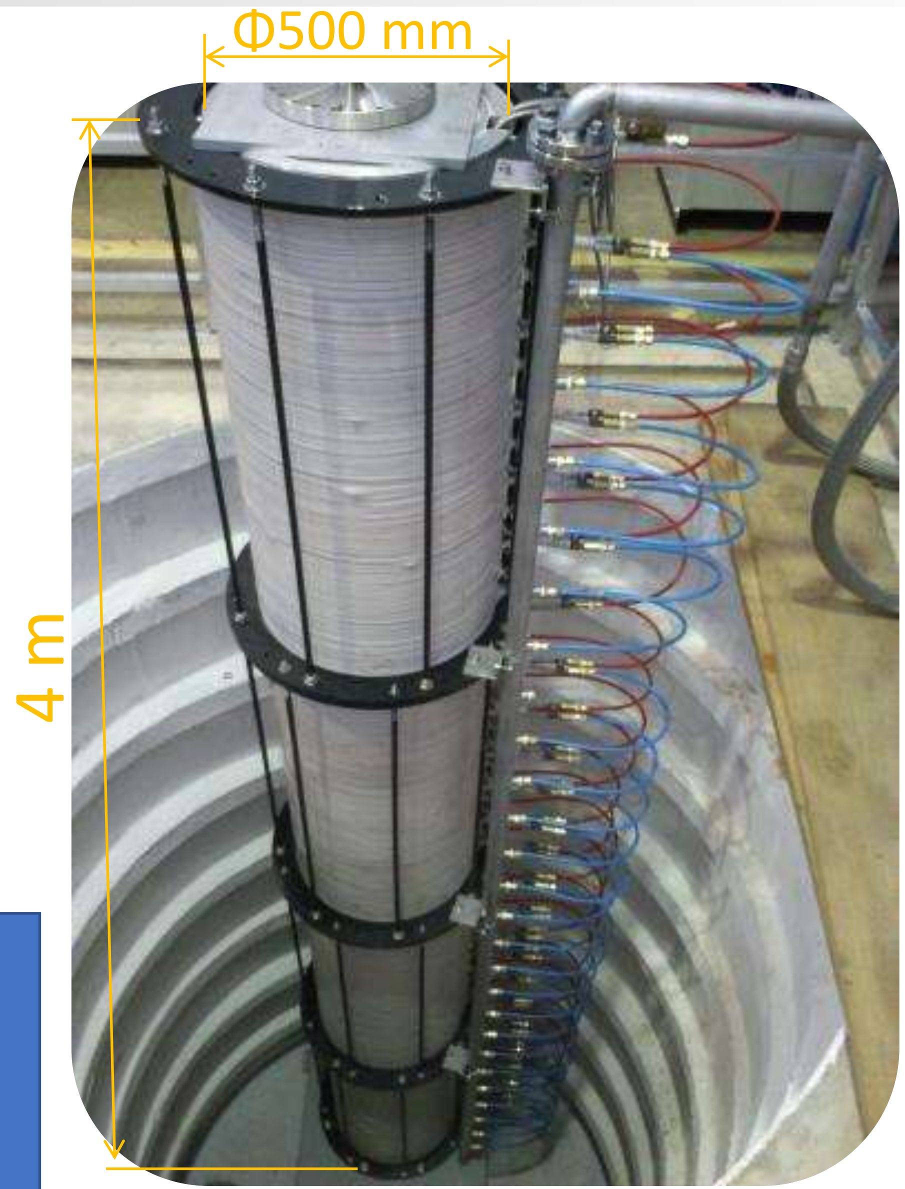






NEG coating facility at CNPEM

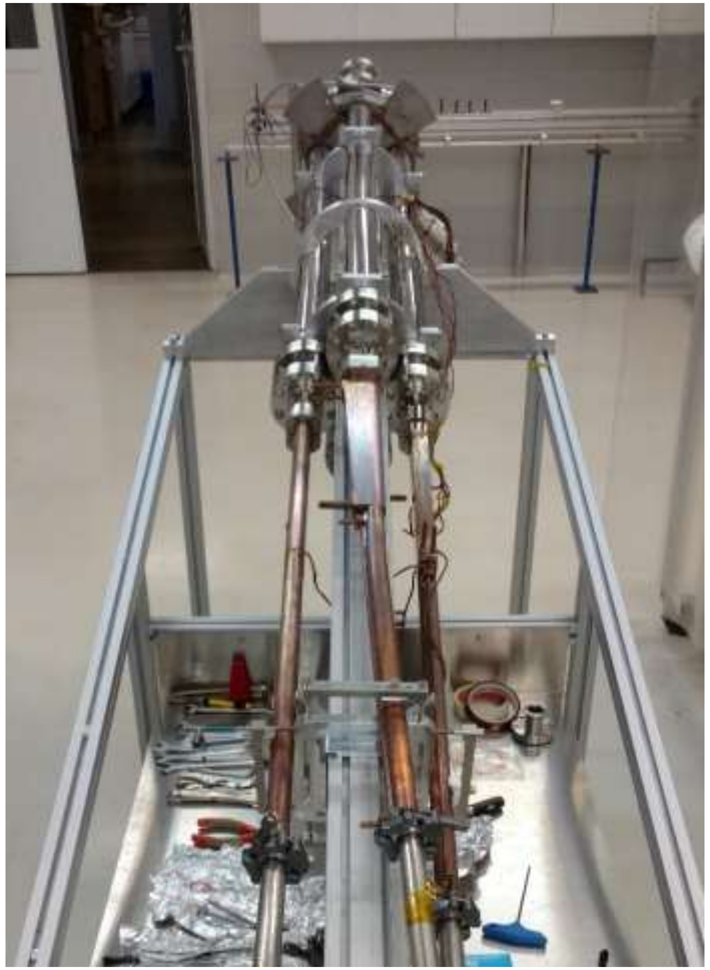
License agreement signed with CERN in 2012



Main characteristics:

- Deposition of up to 3.2 m long chambers
- Magnetic field up to 600 Gauss
- Up to 6 straight chambers simultaneously
- Bake-out system integrated to the solenoids
- Automatic control of the deposition
- Individual control of each chamber

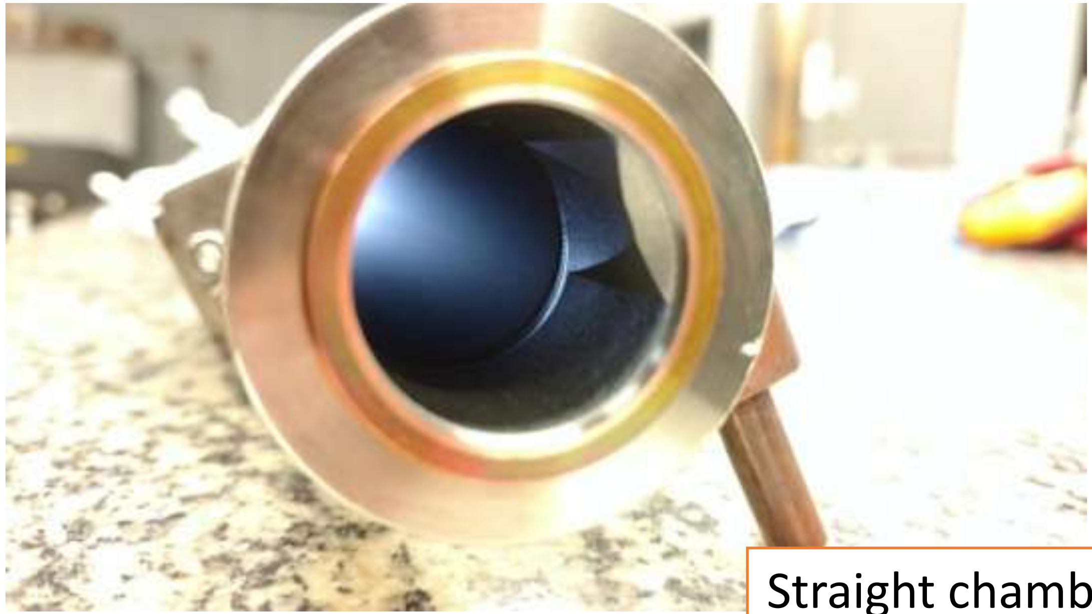
NEG coating production



NEG coating production

About **1100 hours** of NEG coating
- Different cross-sections, lengths, and materials

Pumping station/crotch absorber



Straight chamber

Dipole chamber w/ narrow gap for ph extraction

St. Steel – CF40 – vac. diagnostic cross

Installation – Storage Ring

May - Aug, 2019

1 Preparation

- Components pre-assembling
- Chambers transportation to the tunnel
- Heaters installation on the standard chambers (NEG)

Heaters installation and preparations

2 Installation

- Upper half of the magnets disassembly
- Chambers installation
- Pump-down and leak test
- Upper half of the magnets assembly

Chambers installation

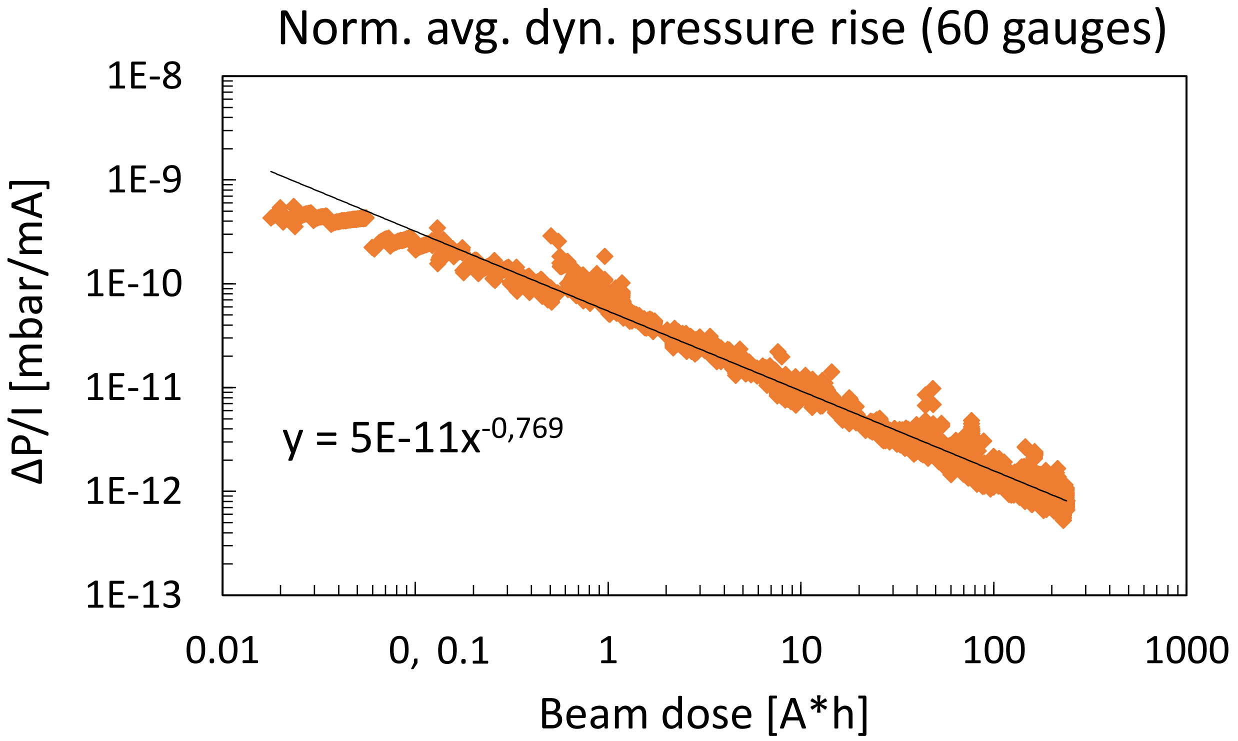
- Prepare for bake-out
- Bake-out and NEG activation
- Remove the bake-out set-up
- System ready

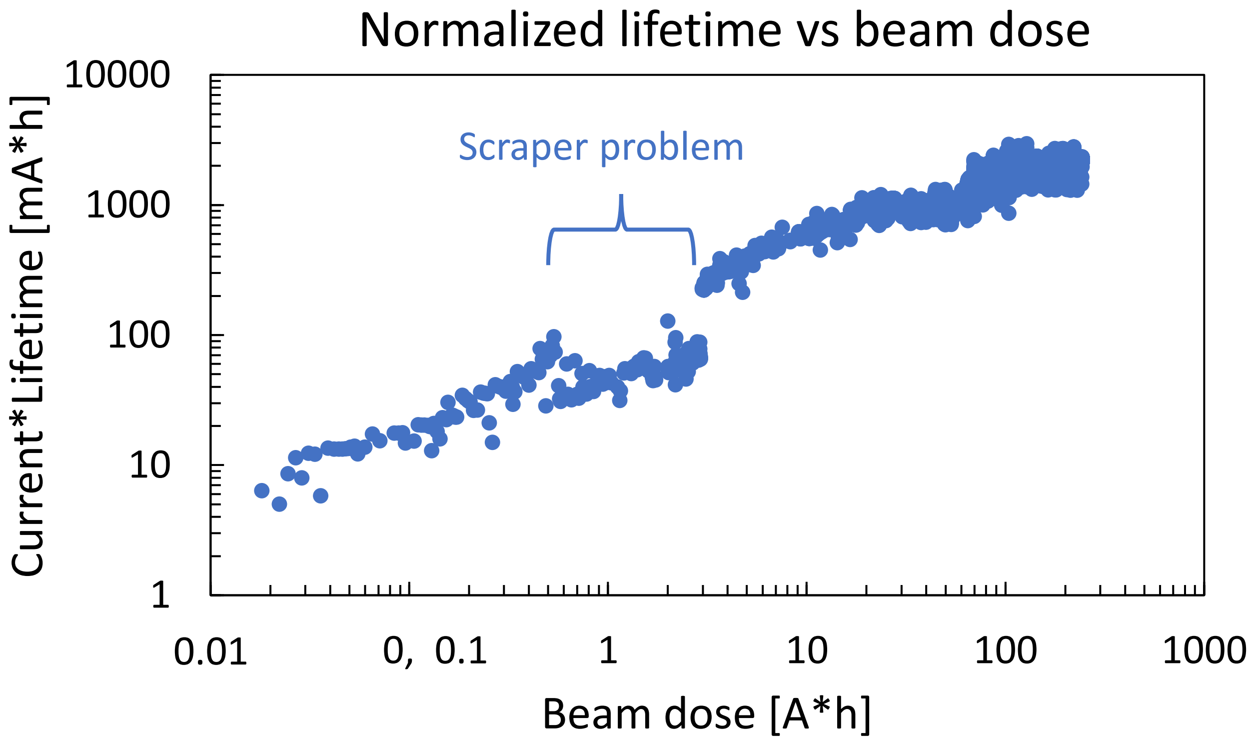
Bake-out and NEG activation

Storage ring: Vacuum Performance

Started in Dec. 2019

Avg Static Pressure = **$8 \cdot 10^{-11}$ mbar**





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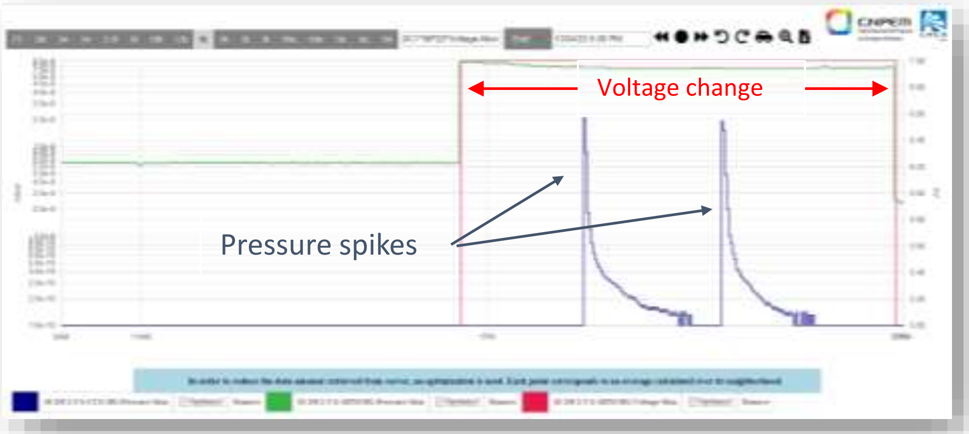
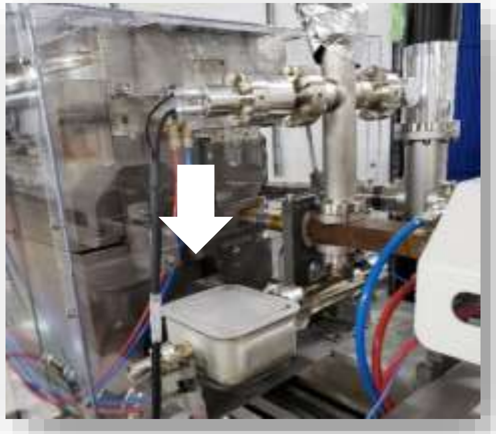
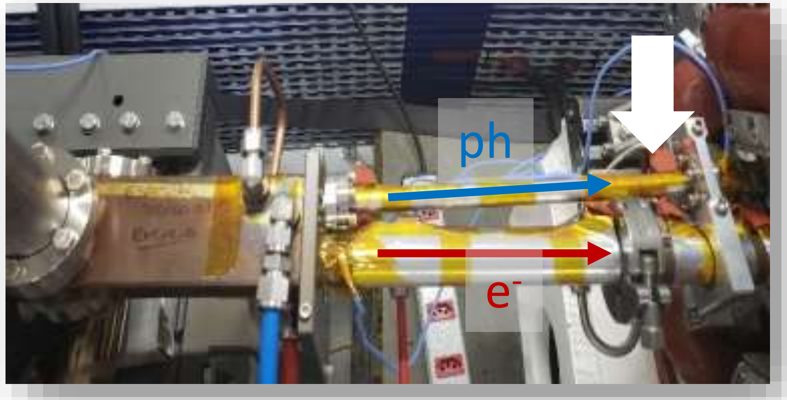
Vacuum related problems



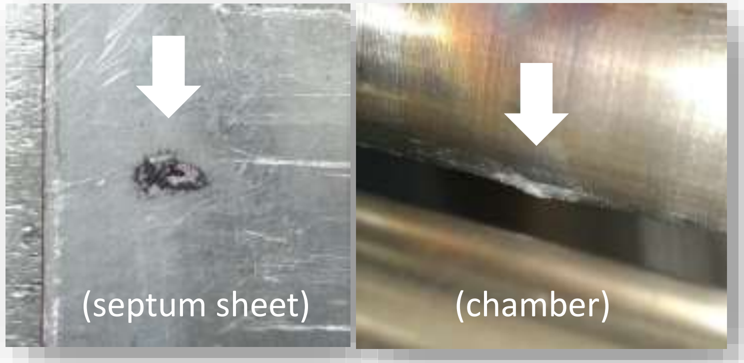
SR ion pump: pressure spikes when operated w/ voltage > 3kV



SR ion pump: short-circuit (1 units)



Photon beam exit port: hot spot



Booster inj. septum chamber: high voltage arc – vacuum leak

SR inj. septum chamber: high voltage arc – vacuum leak

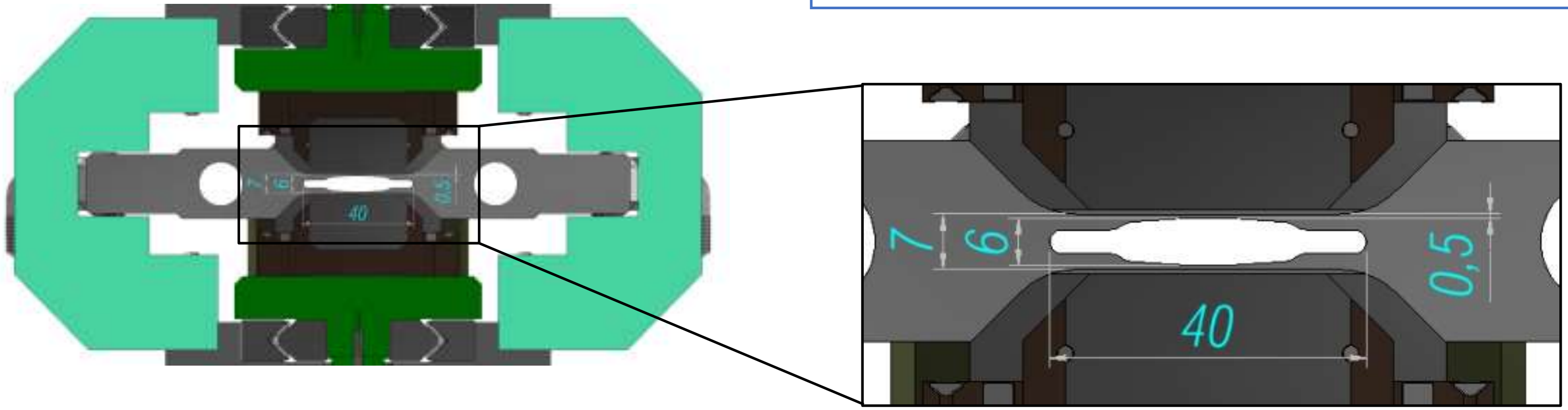
Ver Scraper: coil spring popped up

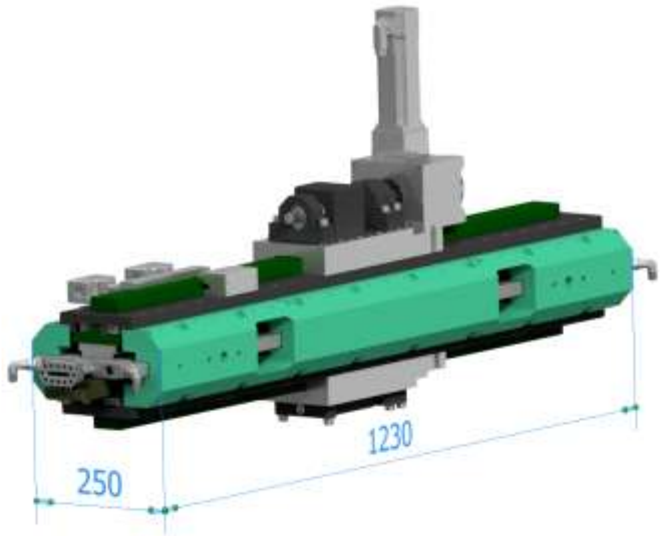
IDs: Comissioning Undulators

Compact Linear Polarizing Undulator (CLPU)

Chambers' fabrication challenges:

- Tight Al extrusion and machining tolerances
- Small wall thickness: 0.5 ±0.1 mm
- Narrow gap = hard to NEG coat





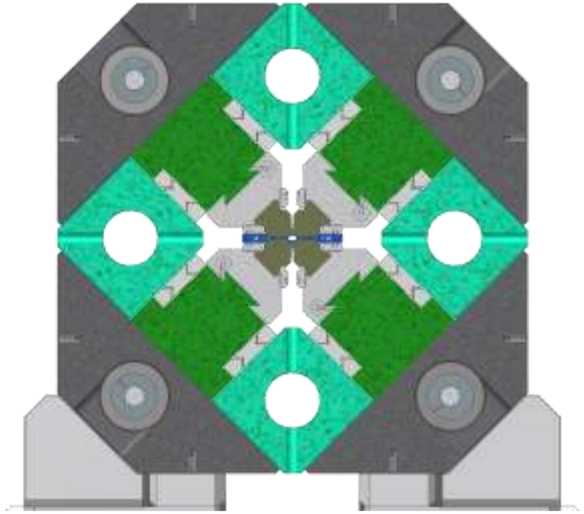
Achieved Static Pressure <= $1 \cdot 10^{-10}$ mbar

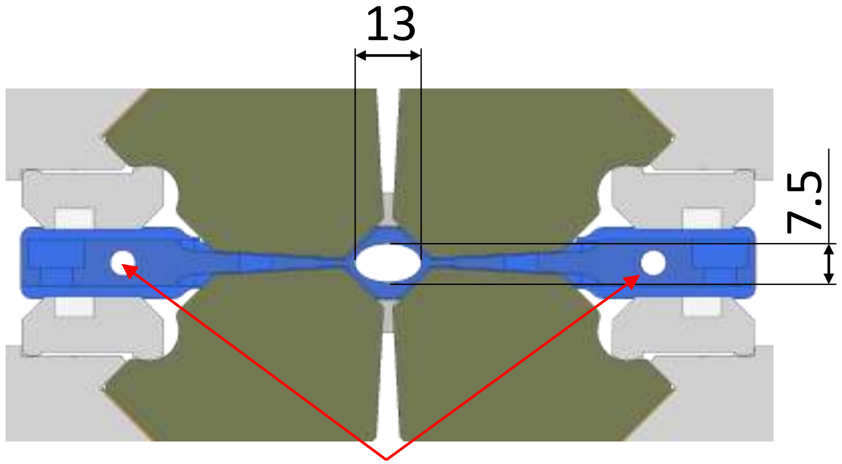
5 installed last year

Fabrication | NEG Coating | Installation

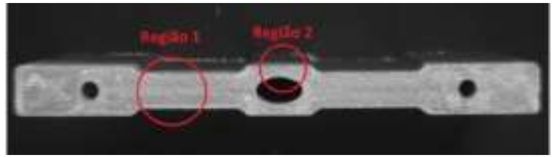
IDs: Ongoing Work

- Delta long period (52.5 mm)
  - Main challenges:
    - Mechanical tolerances
    - Chamber to magnet clearance = 0.25 mm
    - Assembling and NEG activation



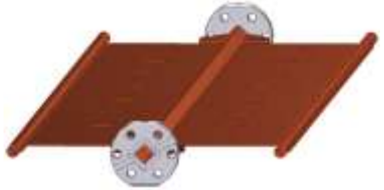


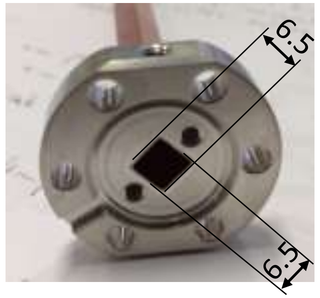
Cooling ch.



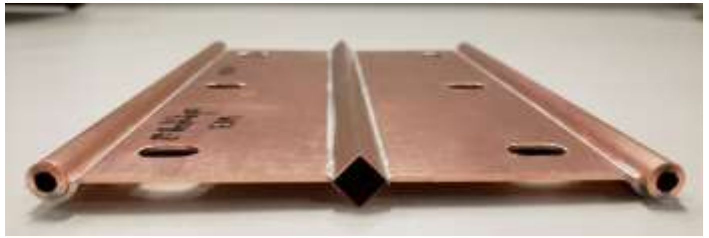
Al extruded profile

- Delta short period (22 mm)
  - Main challenges:
    - Mechanical tolerances
    - NEG coating
    - Chambers' cooling > upstream dipole SR + image curr.
    - Chamber to magnet clearance = 0.025 mm
    - Assembling and NEG activation





L=2.6 m



Patent pending!

NEG coating R&D

Sussccessfully developed

Final Remarks

- The vacuum system installation of the Sirius accelerators went well and was done in a short time
- The expected static pressures were achieved right after the vacuum installation, and the machine was delivered for starting the commissioning without delays
- Despite the few problems that we have faced until now, the vacuum has been performing well, and pressure has decreased as expect with beam conditioning. The design pressure was already achieved at accumulated beam dose of about 70 A·h
- R&Ds to fabricate the challenging chambers for the Delta undulators is ongoing and we hope to install the first prototypes in 2022

Thank you for your attention!

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Aknowledgements:

- OFI Group
- MAT Group
- PRO Group
- LQU Group
- IMA Group
- CON Group
- DIG Group
- Engineering and Technology Division

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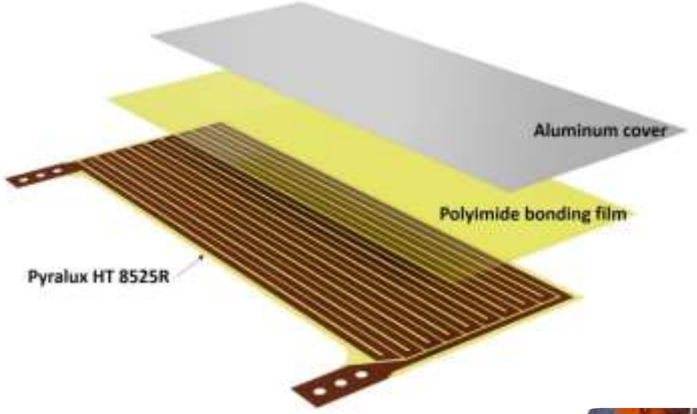
Backup slides

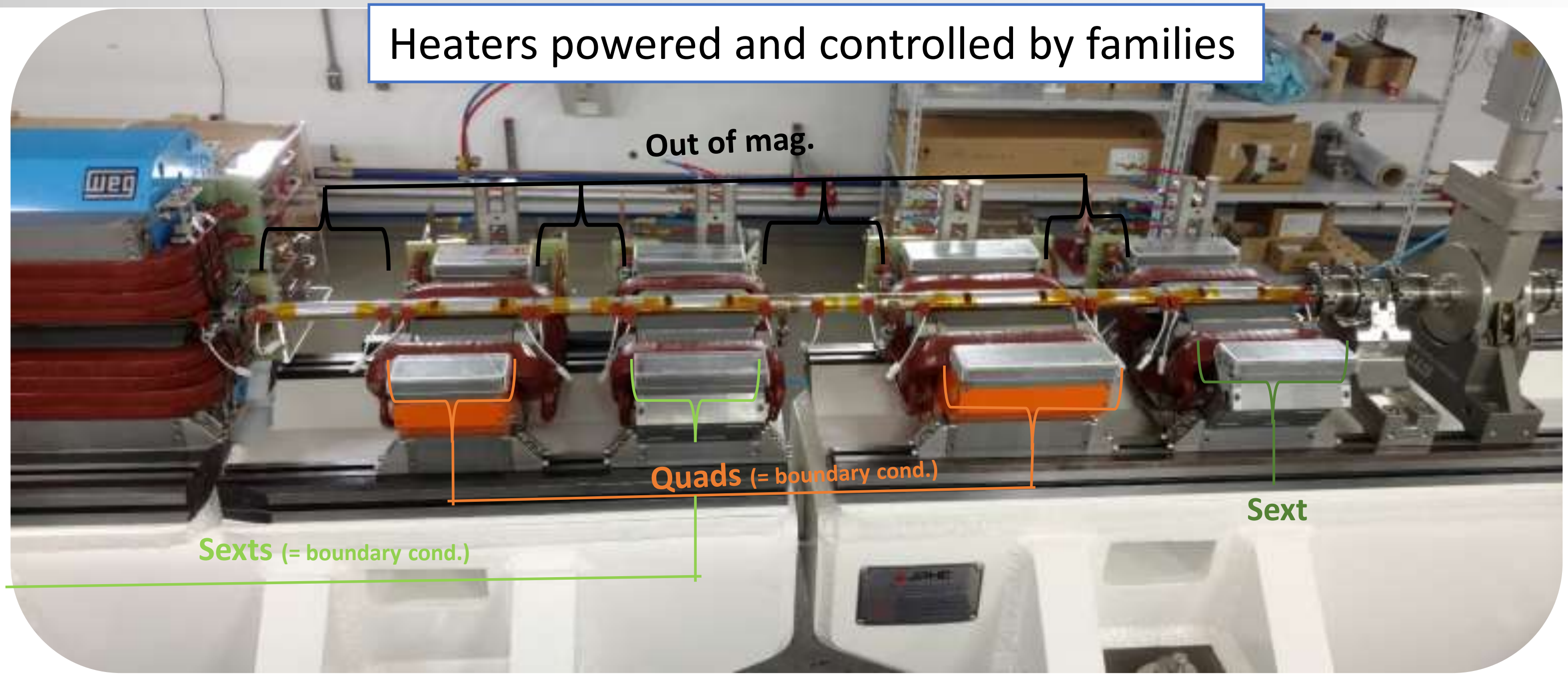
Special Heaters for Bake-out and NEG activation

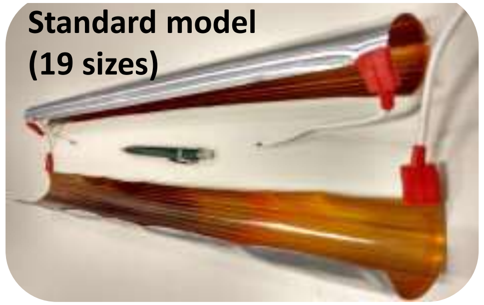
Main characteristics of the special heaters:

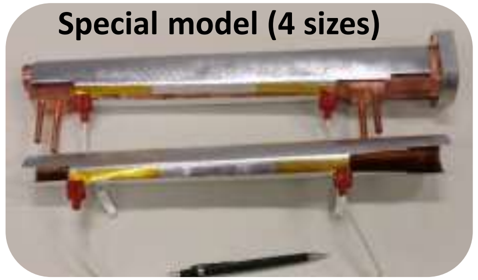
- Developed along with a Brazilian company
- Thickness < 0.4 mm
- Voltage < 50V
- Max. operating temperature = 230 ^{o}C

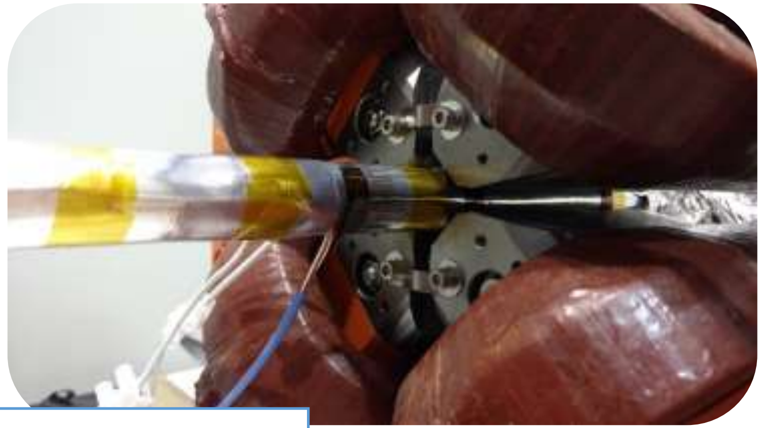


Heaters powered and controlled by families





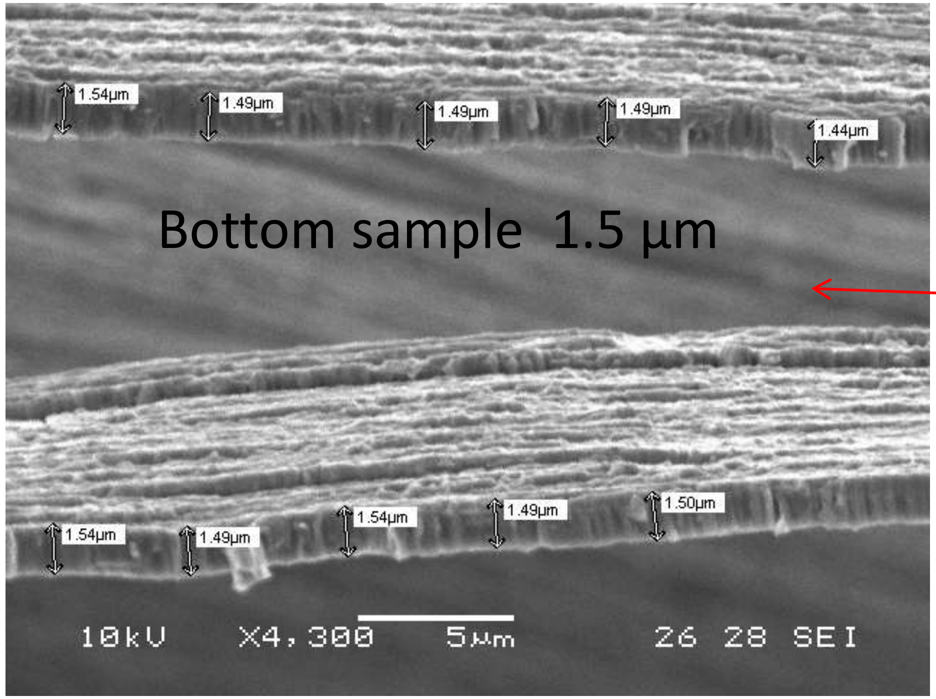


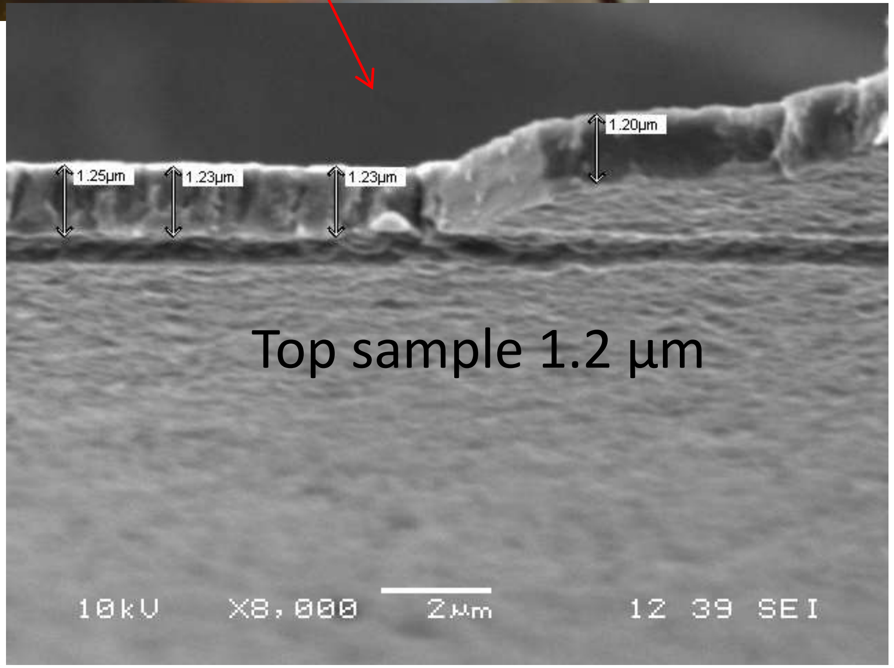


Heaters installed

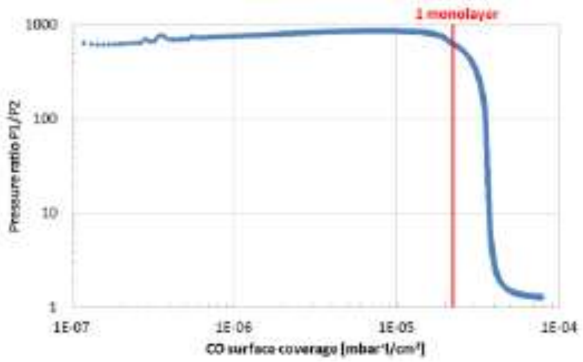
Total of 1635 heaters are installed in the storate ring

NEG films coated at LNLS

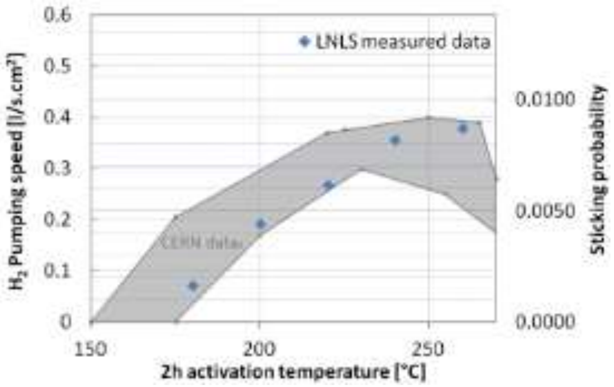




CO pumping capacity (copper chamber)

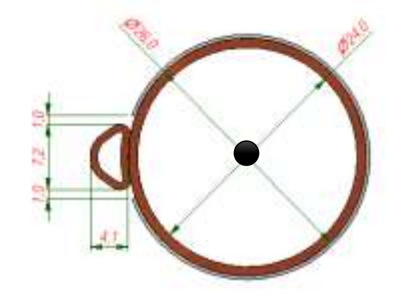


H_2 pumping speed



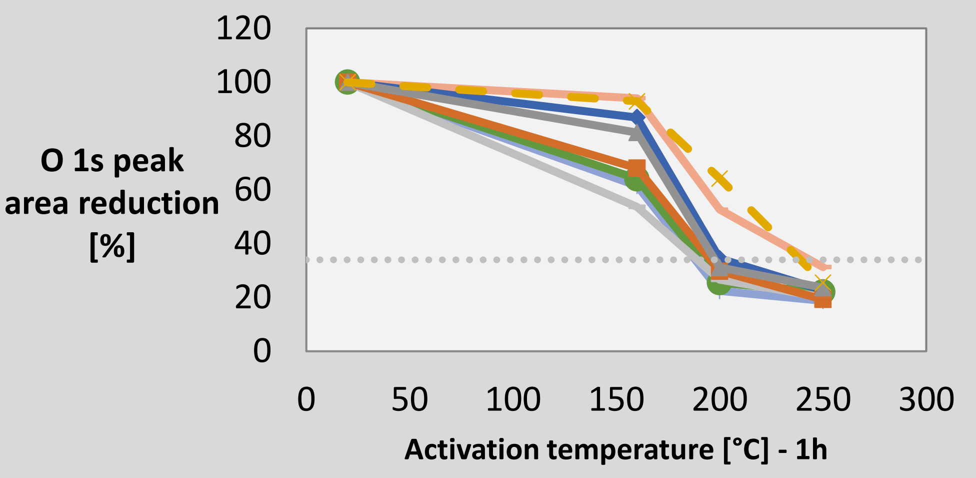
NEG coating R&D – Results

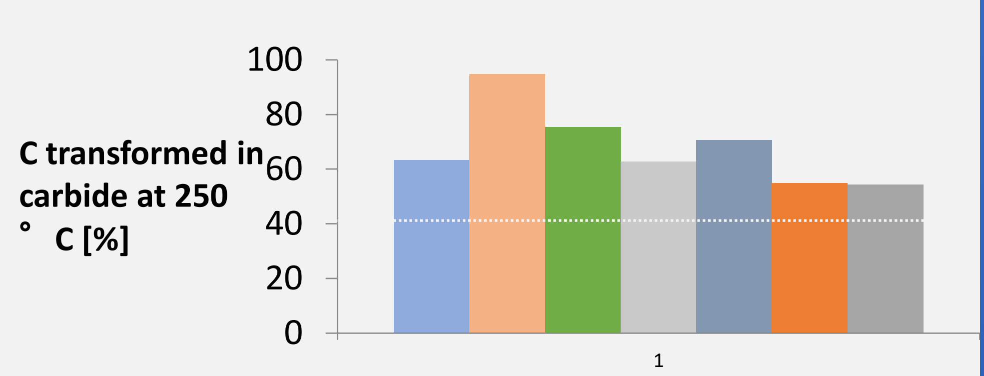
XPS analysis –circular profile



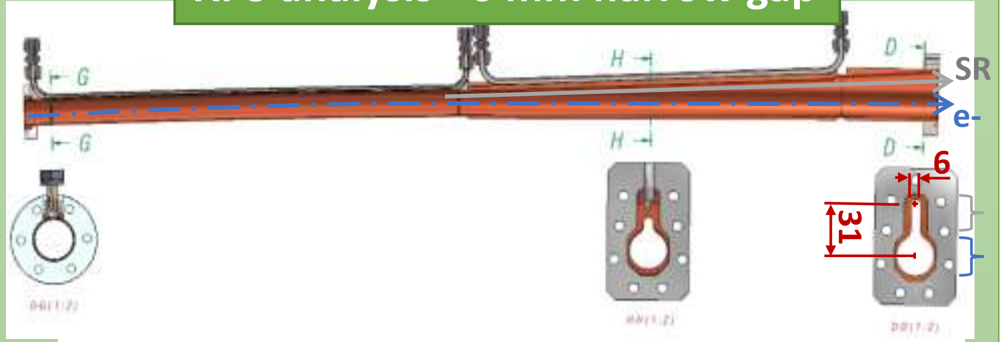
Coating procedure (1 steps):

1. Coating of the circular profile (1 cathode: 1 mm) - > ●



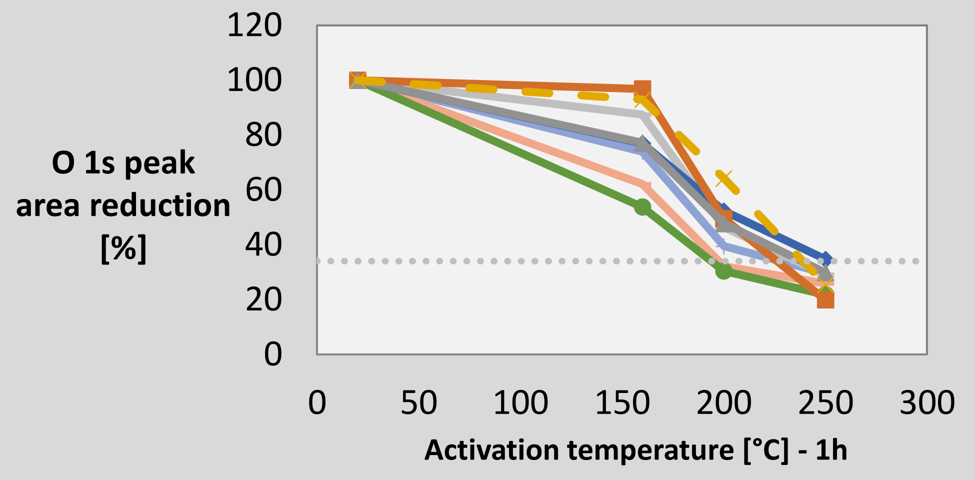


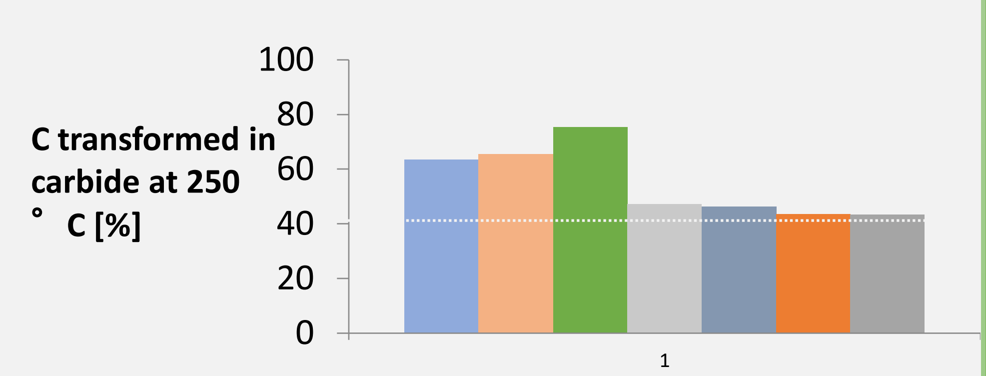
XPS analysis - 6 mm narrow gap



Coating procedure (2 steps):

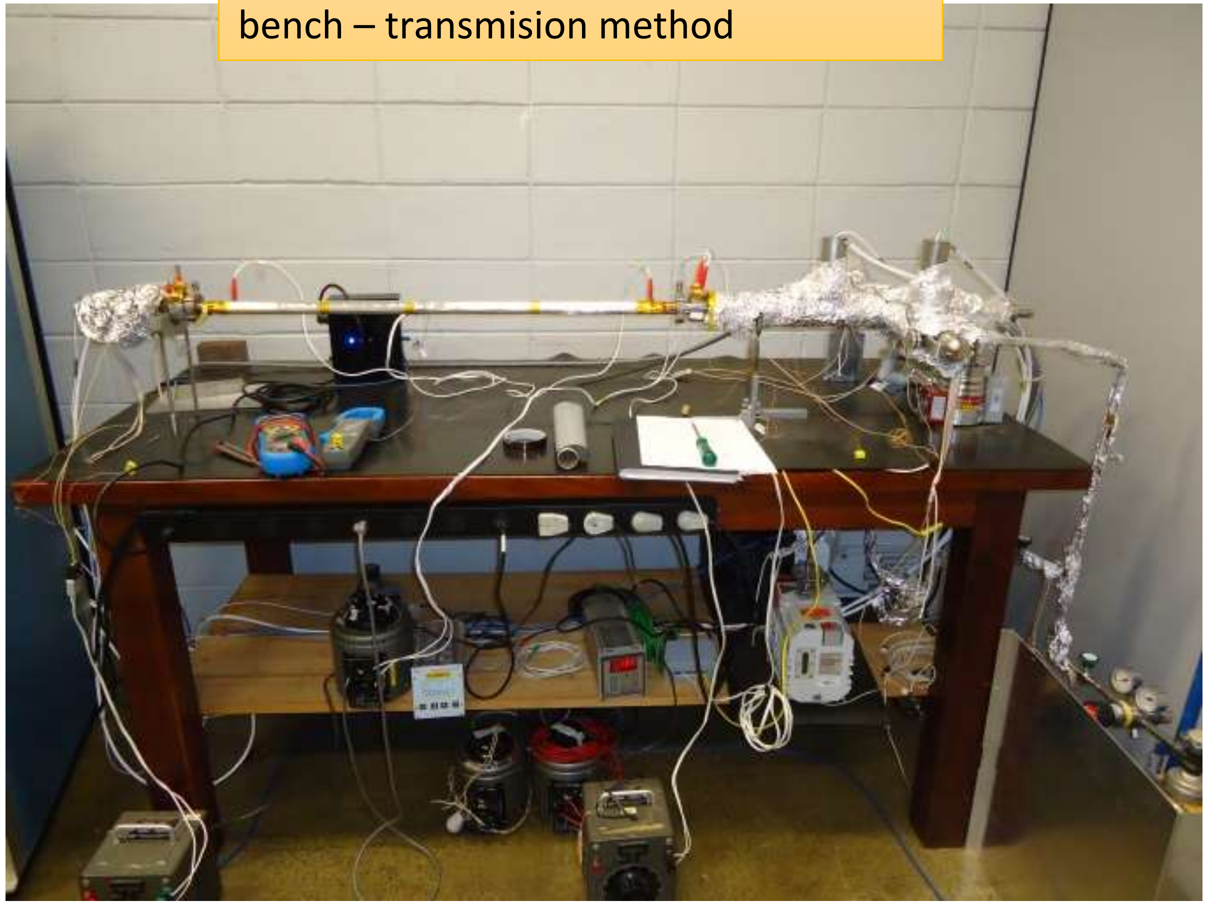
1. Coating of the circular profile (1 cathode: 1 mm) - >
2. Coating of the 6 mm narrow gap (1 cathode: 0.5 mm) ->



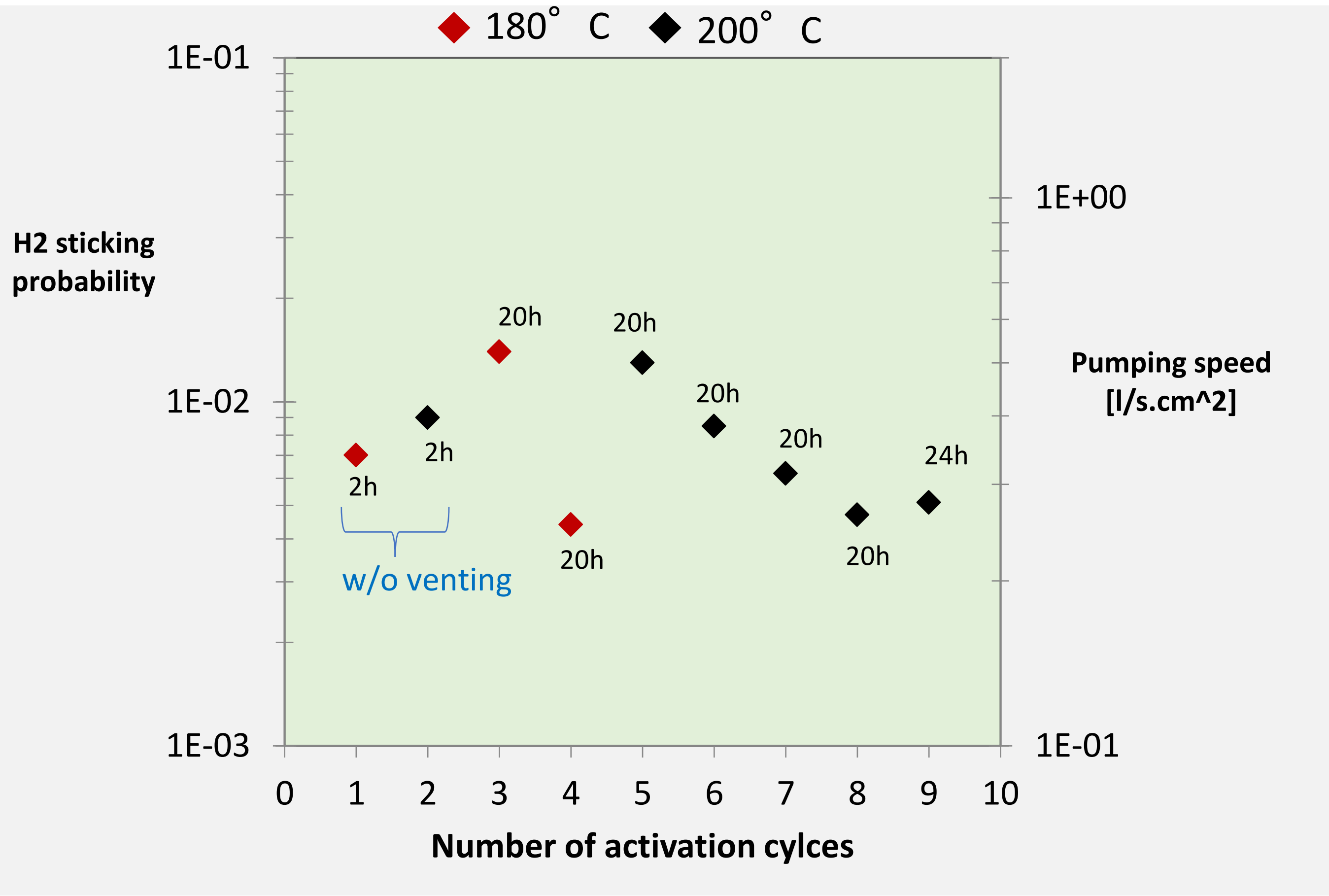


NEG coating R&D – Results

Hydrogen pumping speed measuring bench – transmision method



Aging effect -> copper tube of 24 mm ID and 1 m long



Chamber’s cleaning procedure

Procedure:

1. Tubes and components gross degreasing
2. Tubes etching – LNLS procedure
3. Copper components post-EDM processing???
4. Fabrication process: machining, brazing, welding, etc…
5. Chambers degreasing
6. Light deoxidizing:
   - 5% ammonium citrate

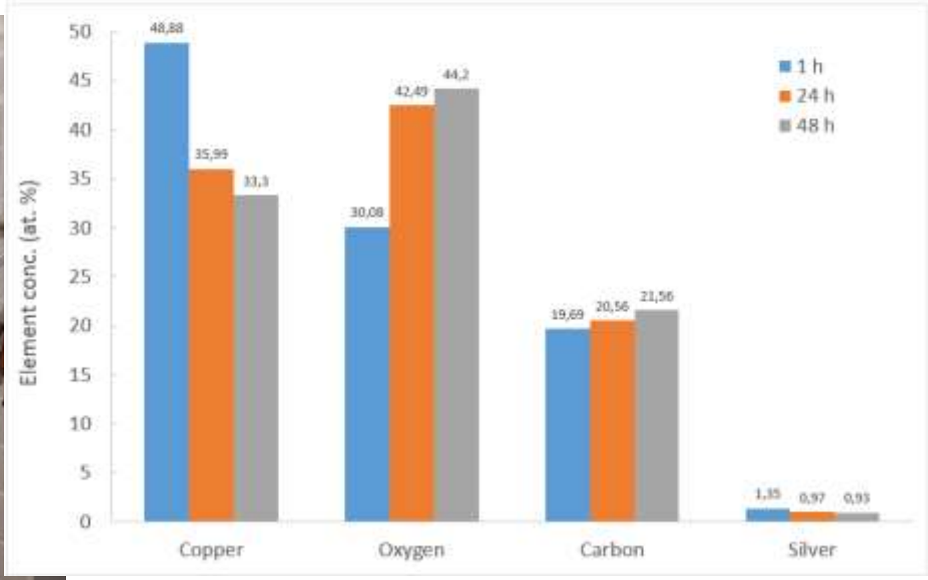
Developed cleaning procedure:

1. 10% ammonium persulfate + 0,1% amonium acetate (etching ~ 15 µm)
2. 5% H_2O_2 (helps to remove silver insoluble residuals)
3. 5% ammonium citrate (deoxide + passivation)

-- Surface roughness < 0.4 µm (Ra) --

Cleaning facility – recirculation system

XPS analysis – LNLS cleaned surface



Cleaning quality criteria (based on CERN):

- Atomic % C < 44%
- Halogens (ex. F, Cl) < 1%
- Other contaminants should be analyzed

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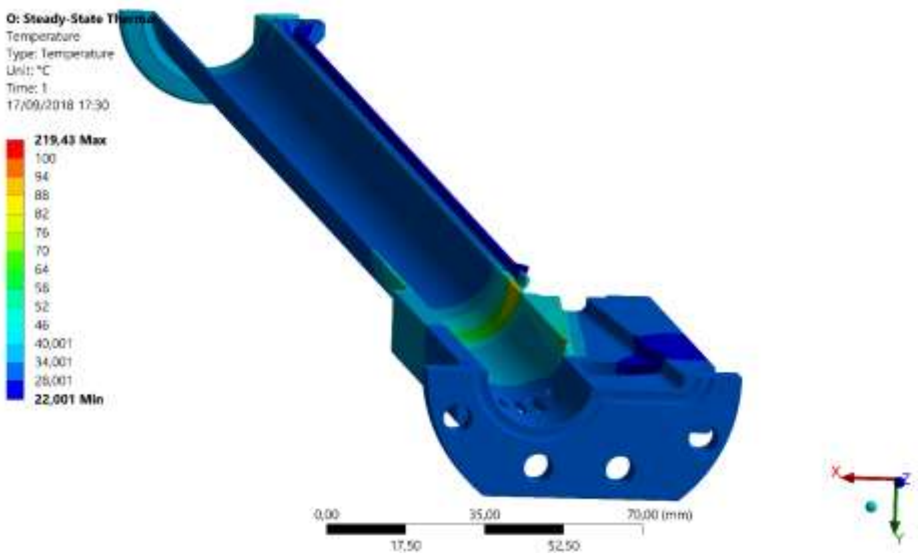
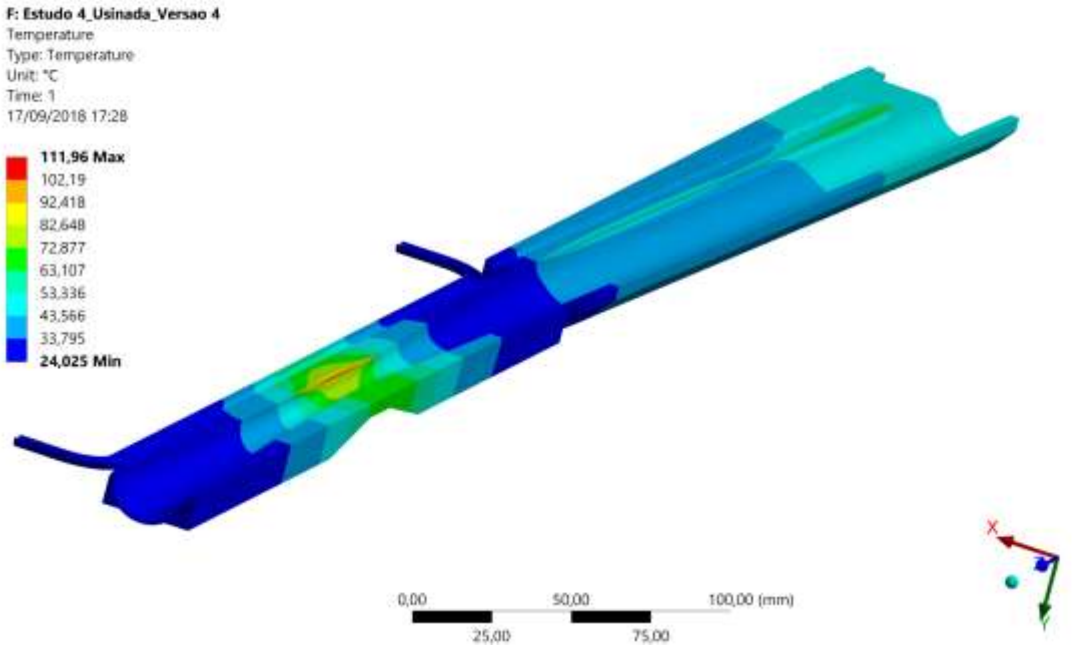
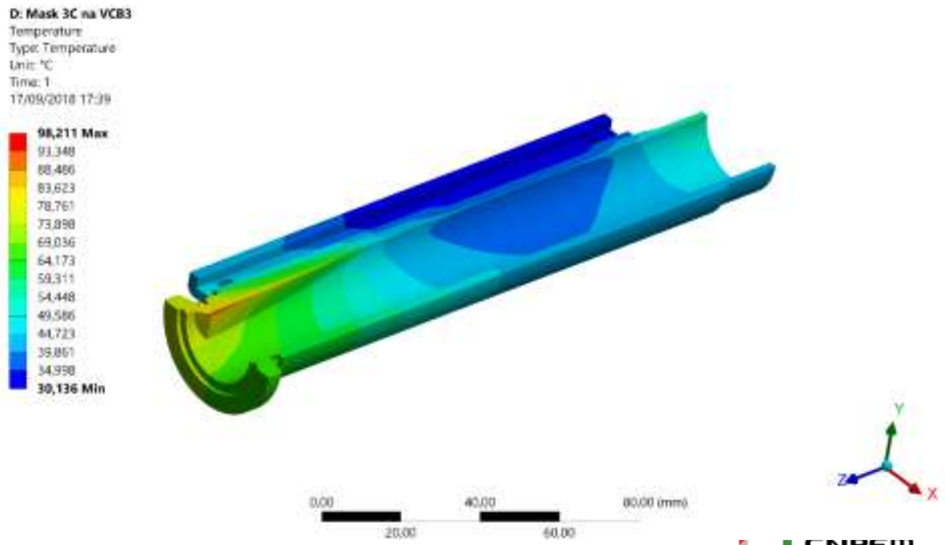
PÁTRIA AMADA BRASIL BRAZILIAN GOVERNMENT

Dealing with unused Synchrotron Radiation





Total power that must absorbed by the chambers: **245.7 kW** (not including IDs)

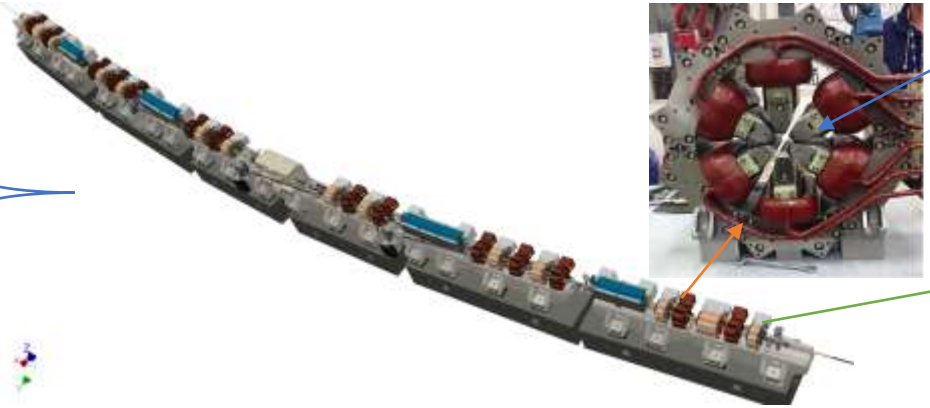


Technical challenges

Dense mag. lattice

High mag. fields

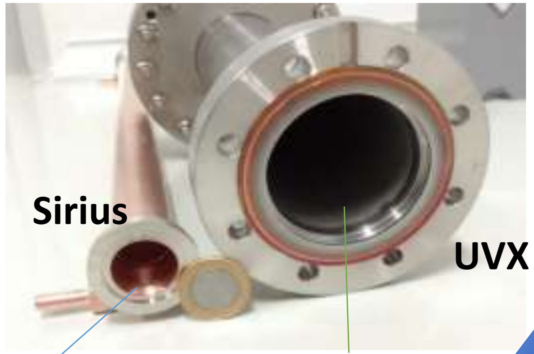
Compact magnets



Avalible aperture for chambers = 28 mm

Small aperture for chambers

High beam-chamber interaction

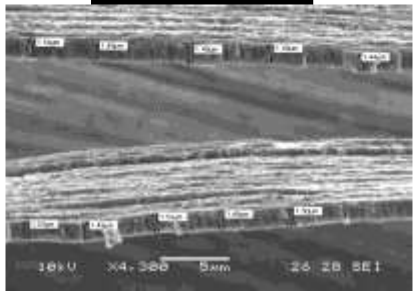


1,5 l/s/m

26,5 l/s/m

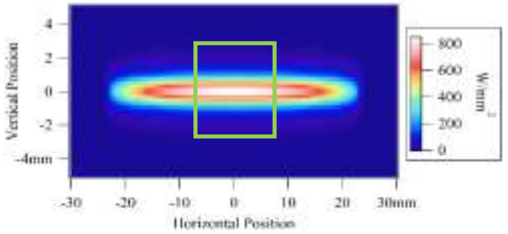
Hard to pump

NEG film



Chambers= pump

Handle high p. dens beams



Vac. chambers impedance

Copper chambers

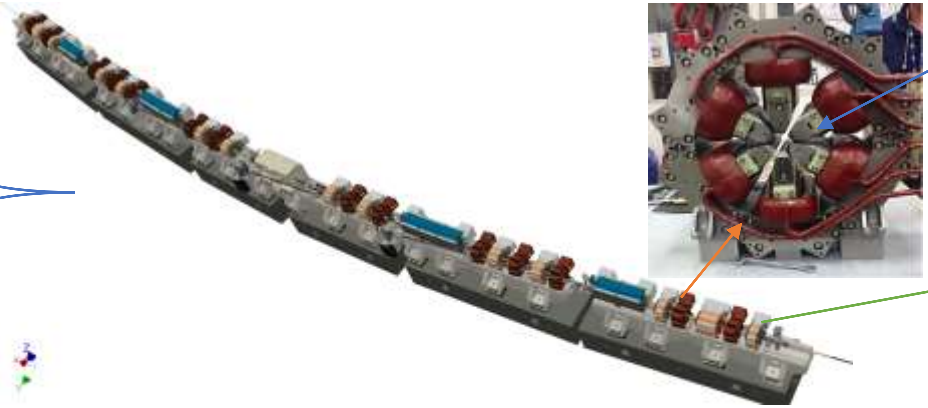
Limited space for pumps

Technical challenges

Dense mag. lattice

High mag. fields

Compact magnets



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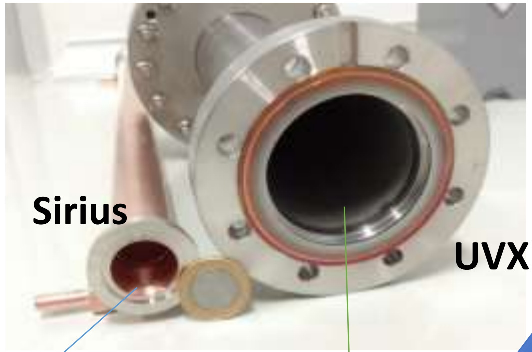
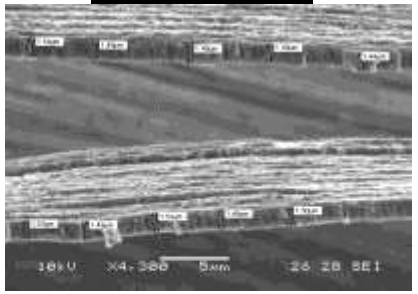


1,5 l/s/m

26,5 l/s/m

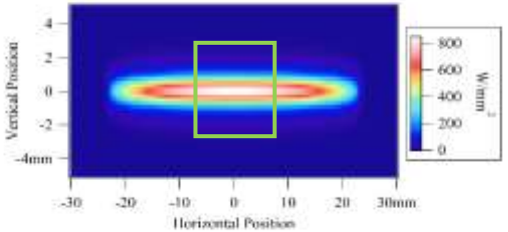
Hard to pump

NEG film



Chambers= pump

Handle high p. dens beams



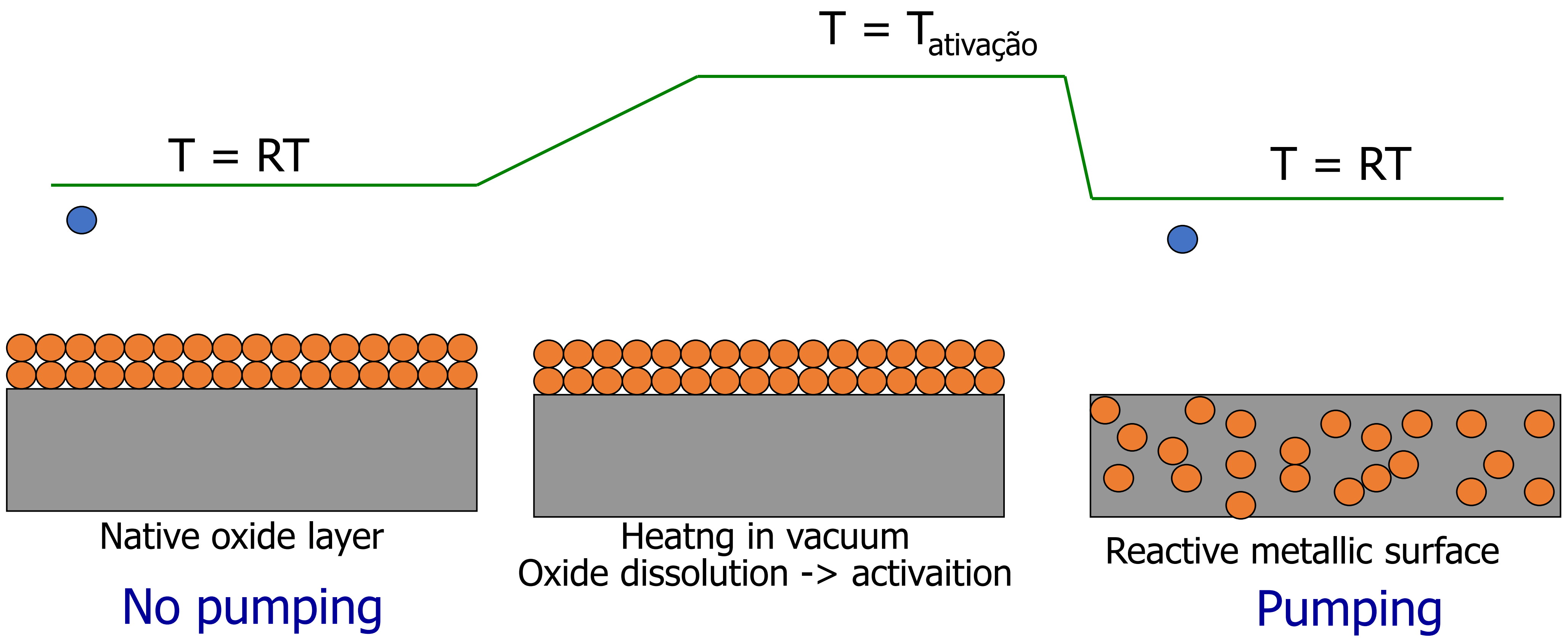
Vac. chambers impedance

Copper chambers

Limited space for pumps

NEG film

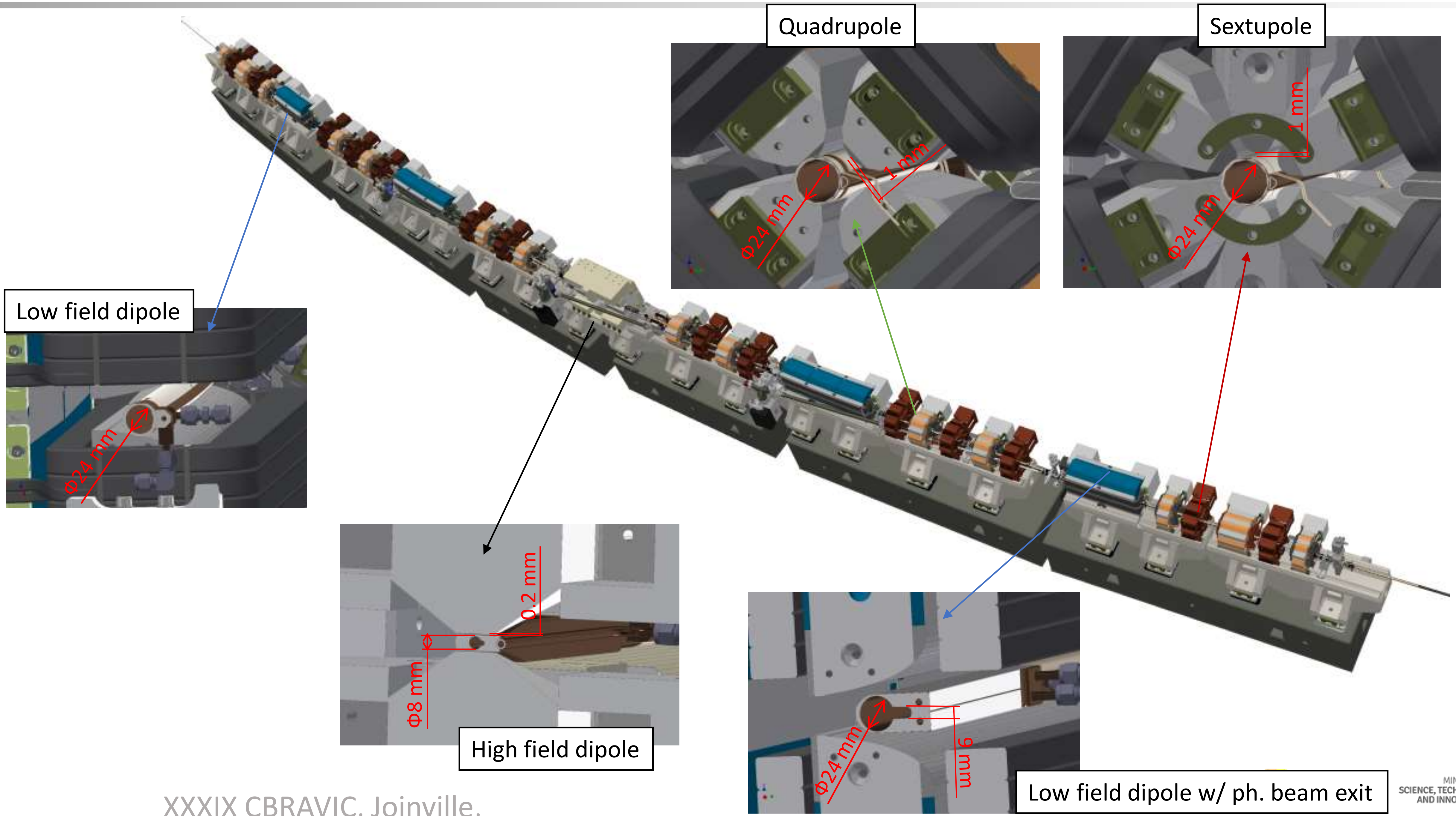
A NEG material is a metallic alloy that can pump most of the gases present in a vacuum system after thermal dissolution of its native oxide layer (activation process).



NEG, when in room temperature, do not pump methane and noble gases.

Adapted from: P. Chiggiato (CERN), ICTF-2005

Storage ring: distinct cross-sections along the sector



Storage Ring: Vacuum Performance