e-CLOUD'18

Characterisation of beam screens extracted from LHC magnets

V. Petit, H. Neupert, E. Garcia-Tabares, M. Taborelli, *CERN, Geneva, Switzerland*

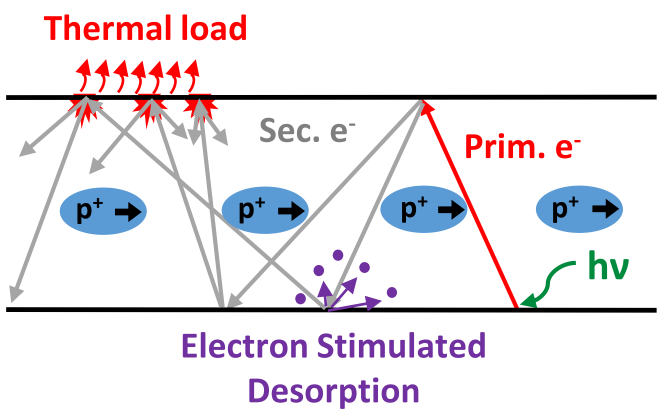
M. Belhaj, T. Paulmier, *ONERA, Toulouse, France*

Thanks to P. Chiggiato, V. Baglin, G. Bregliozzi, CERN, TE-VSC

Context of the study

Primary electrons from
- Residual gas ionization
- Photoelectric effect

Acceleration by proton beam potential



Collisions with vacuum chamber walls

Emission of secondary electrons

Reduction of accelerator performance

e-cloud

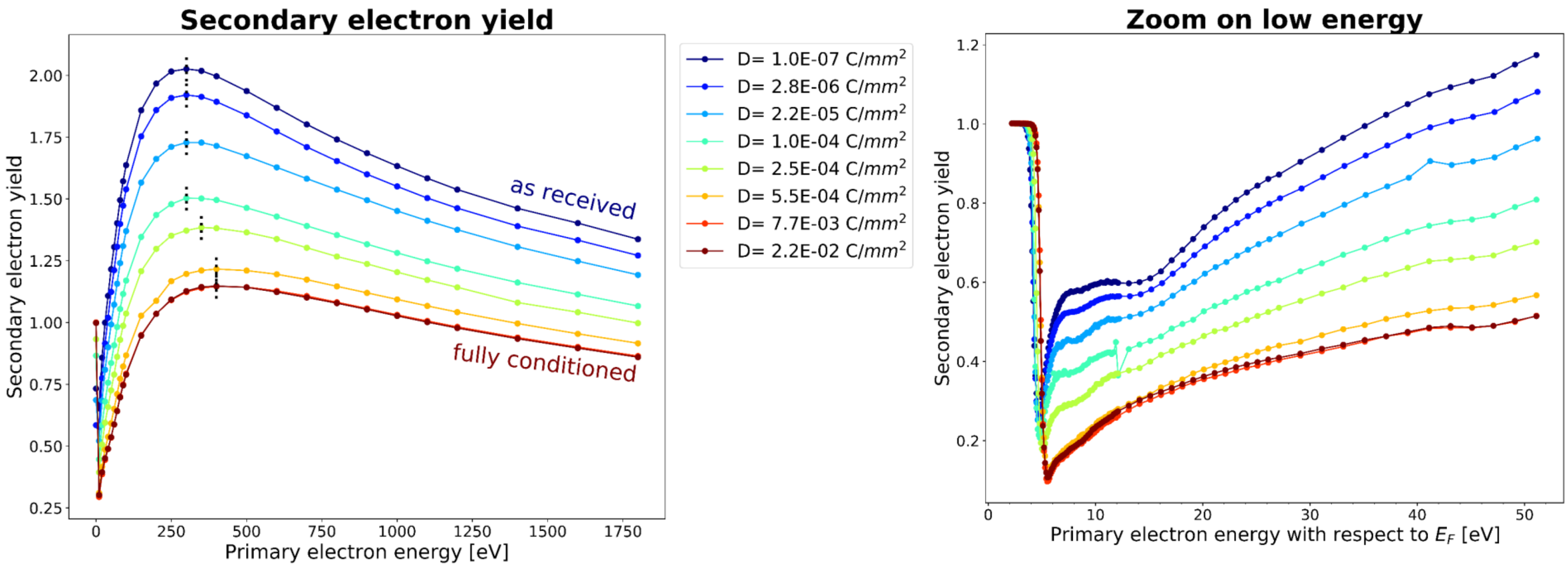
Conditioning
Situation gets better with running time

WHY?

Context of the study

What we know about copper conditioning

Lab conditioning, E = 250 eV, room temperature

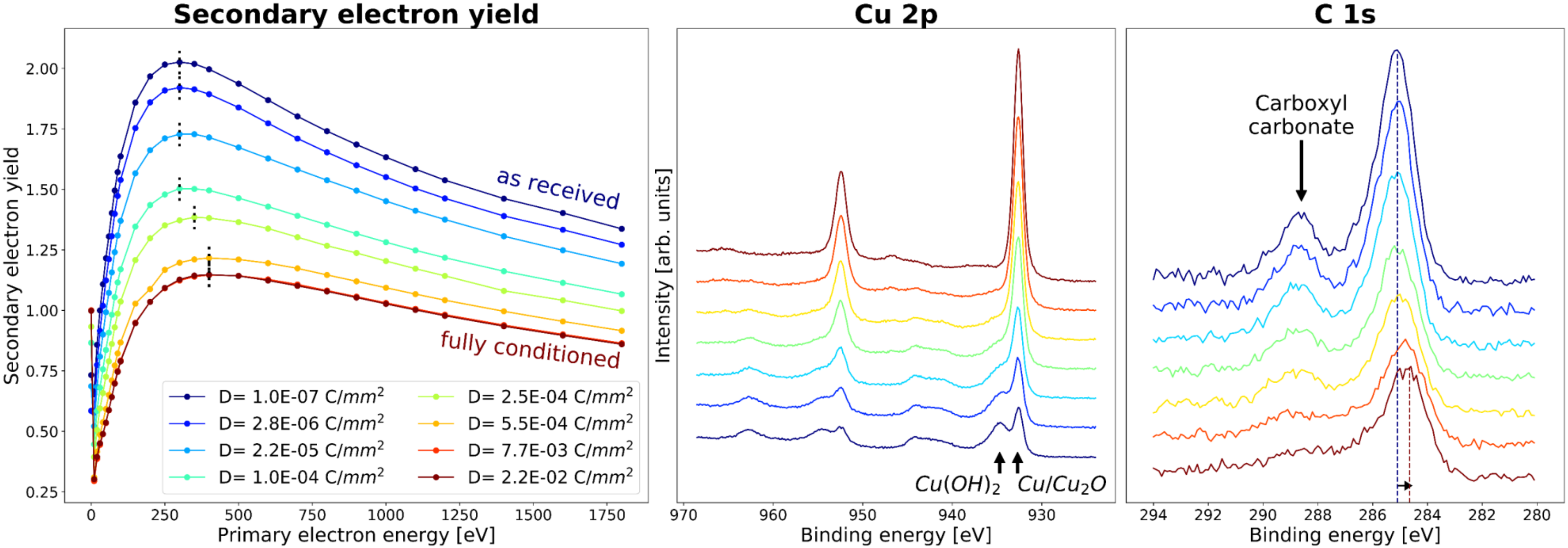


- Global SEY decrease and shift of E_{max} to higher energy

Context of the study

What we know about copper conditioning

Lab conditioning, E = 250 eV, room temperature

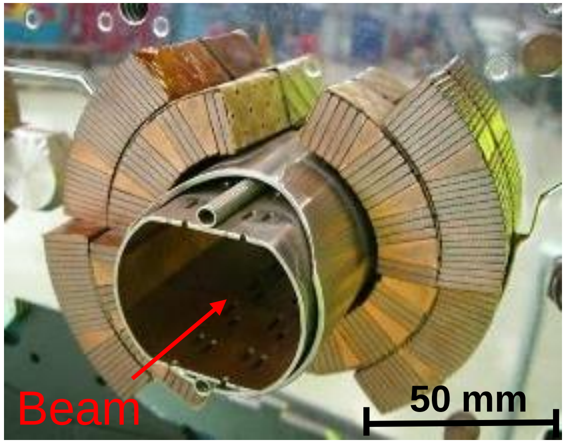


- Vanishing of $Cu(OH)_2$ and carboxyl/carbonate contributions (surface cleaning)
- Shift of C1s peak to lower binding energy (graphitization, see *Cimino et al. PRL, 2012*)

Context of the study

What happens inside the LHC arcs?

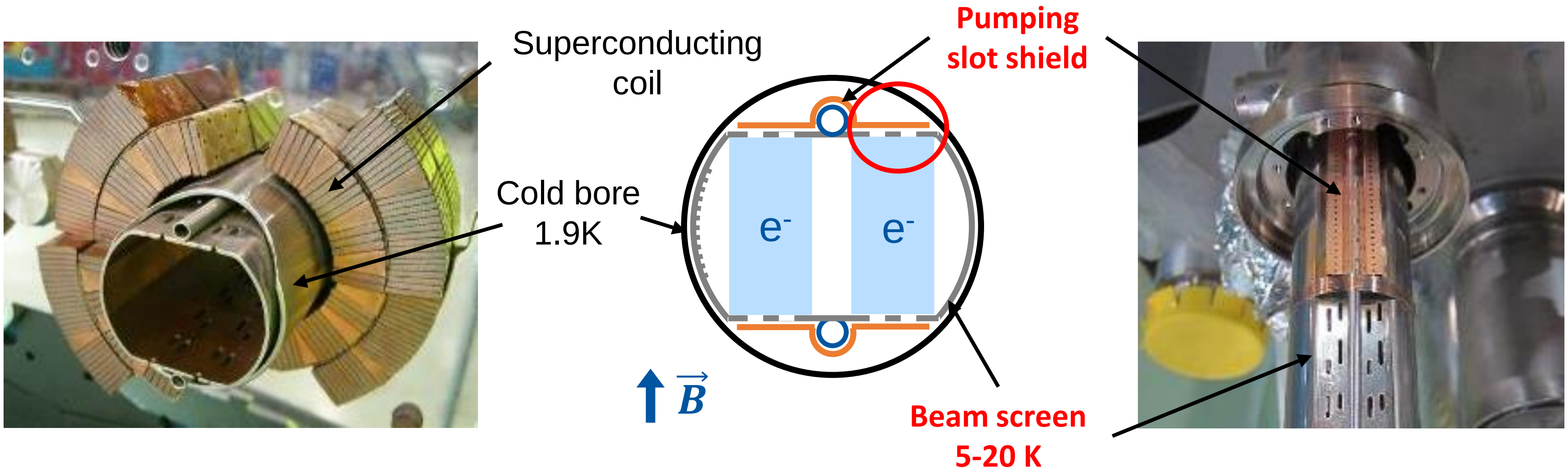
EYETS 2016-2017 : LHC dipole magnet extraction from the tunnel



Investigate surface modifications due to exposure to the e-cloud inside the machine

- Secondary Electron Yield reduction
- Surface chemistry modification

Analysed components



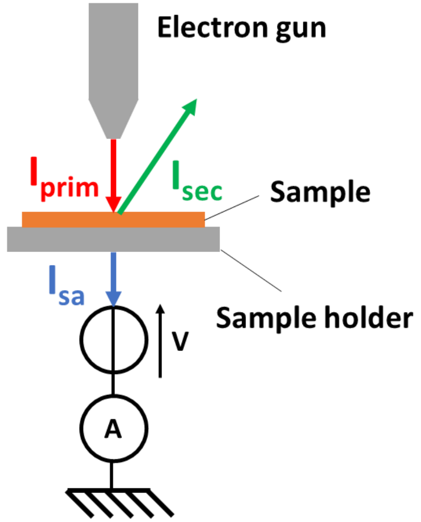
- Beam screen (colaminated Cu on Stainless Steel)
  Samples cut at different positions along the magnet
  Looking for SEY differences due to e^- confinement

- Pumping slot shield (chromic acid passivated Cu-Be alloy)
  Looking for SEY differences due to beam screen pumping slots

Air exposure (1–2 months) : deconditioning

Characterisation techniques

- SEY measurements

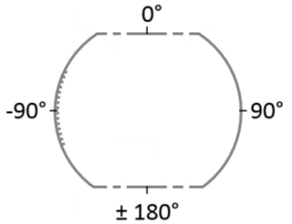


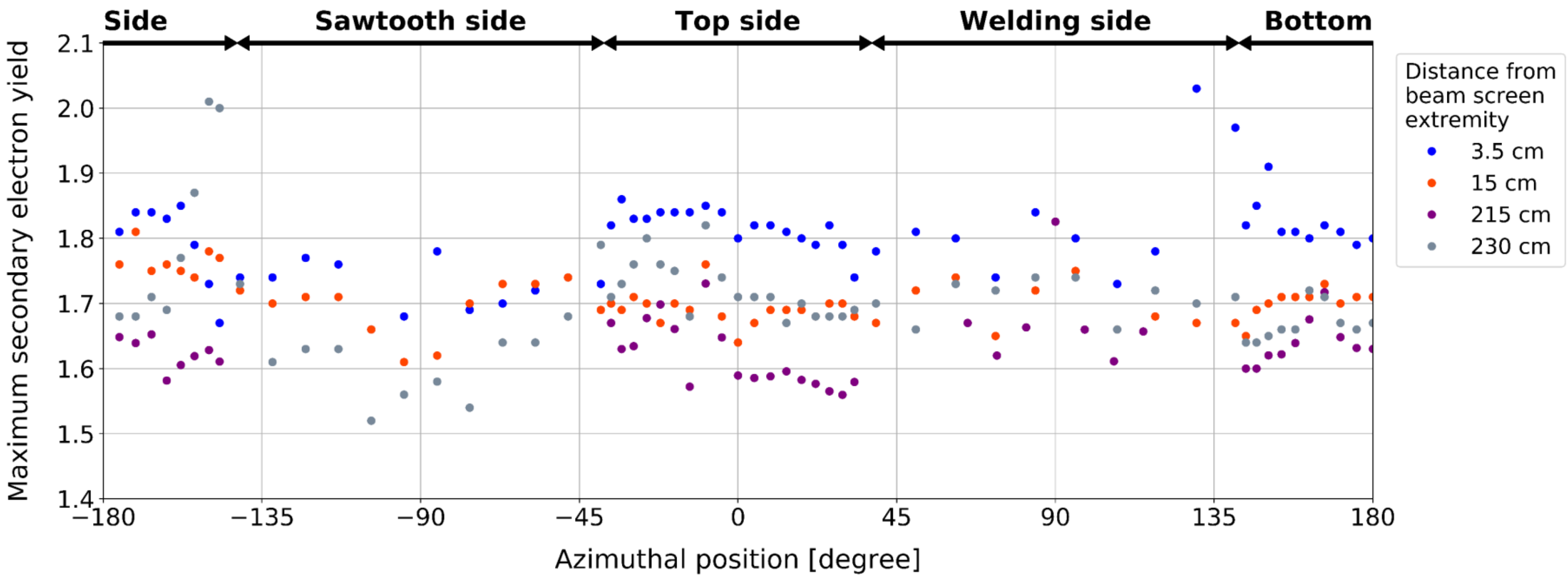
- V = + 40 V → $I_{sample} = I_{prim}$
- V = - 40 V → $I_{sec} = I_{prim} - I_{sample}$
- $\delta(E) = \frac{I_{sec}(E)}{I_{prim}(E)}$
- E_p = 10 -1800 eV

- X-ray Photoelectron Spectroscopy analysis

Monochromatic Al Kα X-ray source (hv = 1486.6 eV)

Beam Screen

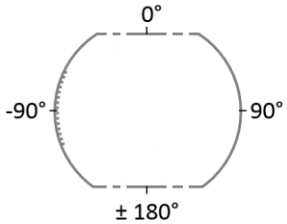


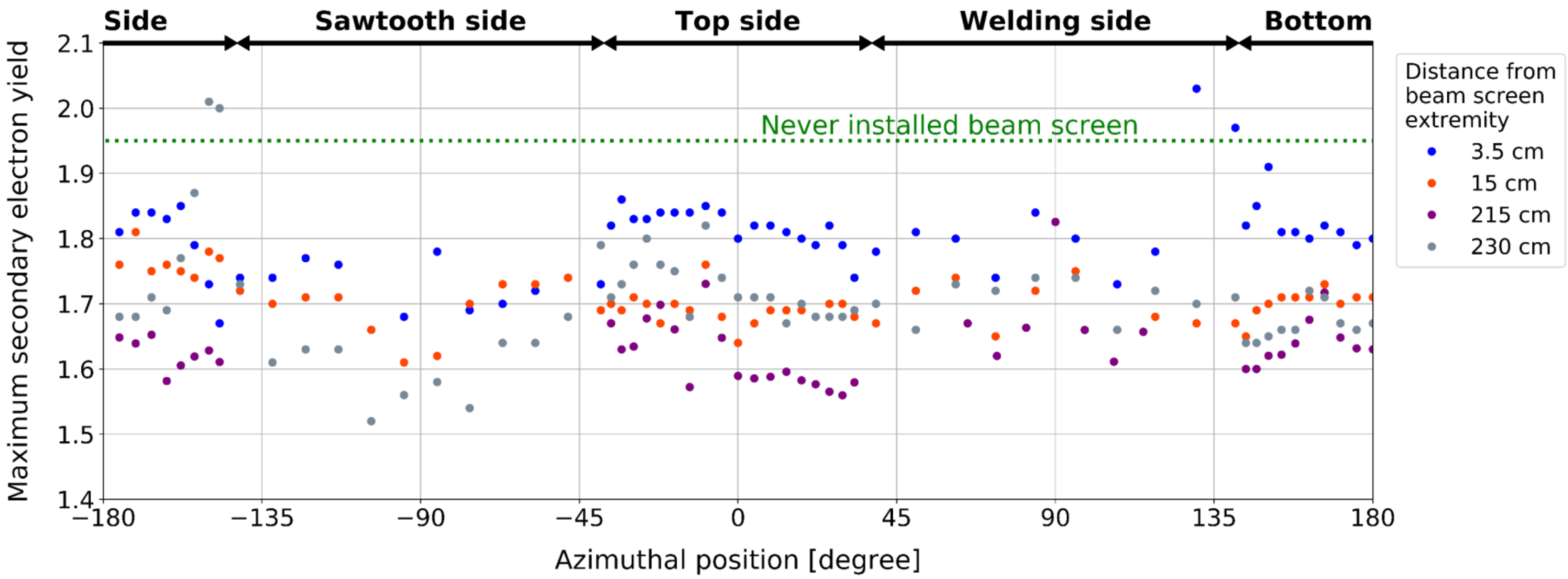


- No significant difference between flat sides / welding side in spite of dipole field

NB : ranking of SEY of samples does not correspond to chronology of measurements

Beam Screen

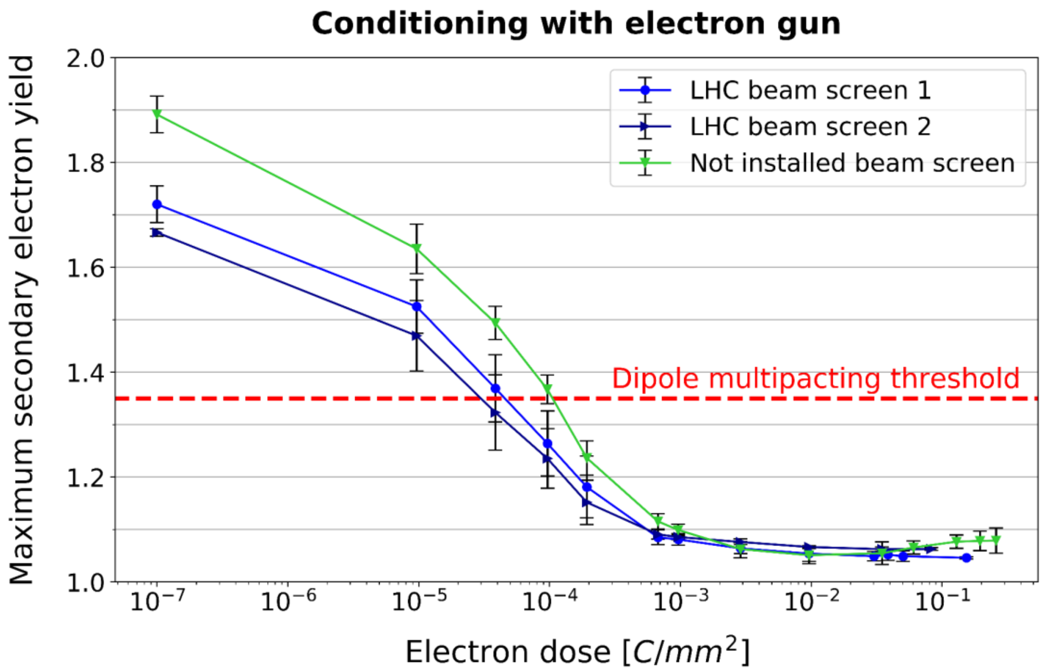




- Maximum SEY below « not installed » beam screen

NB : ranking of SEY of samples does not correspond to chronology of measurements

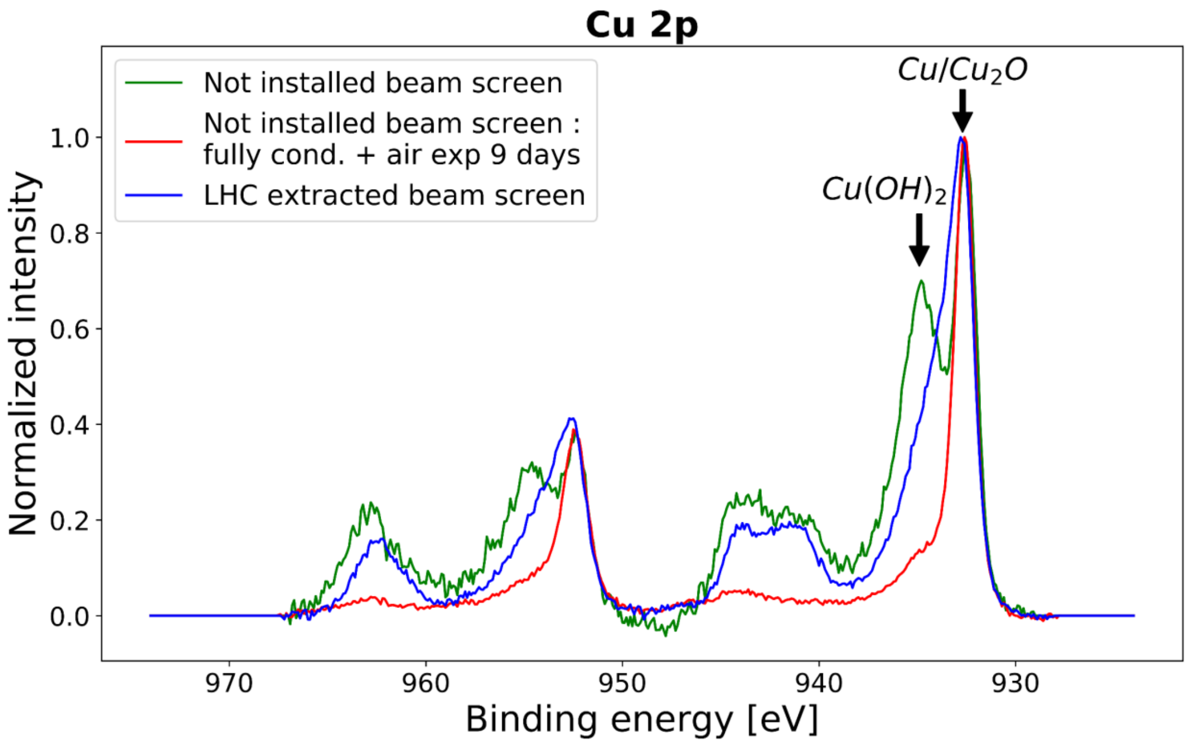
Beam Screen : comparison "extracted" and "not installed"



- Conditioning at E_p = 250 eV
- Room temperature
- Base pressure P = 2.10^{-9} mbar
- Error bars : dispersion over 4 measurement points

- LHC beam screen samples
  - Identical conditioning path for both samples
  - Ultimate limit δ_{max} = 1.05
- LHC versus «not installed » beam screen
  - LHC extracted beam screen needs a lower dose to reach δ_{max}=1.35 (threshold for e-cloud in LHC dipole) than « not installed » one

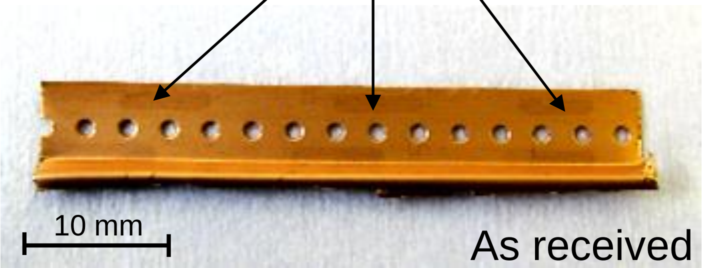
Beam Screen : comparison "extracted" and "not installed"

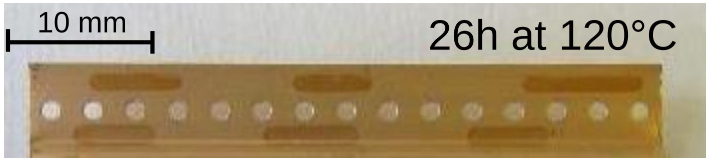


- LHC beam screen : intermediate Cu 2p peak shape between « not installed » and deconditioned beam screen
- No clear difference in C1s line between « extracted » and « not installed » beam screen

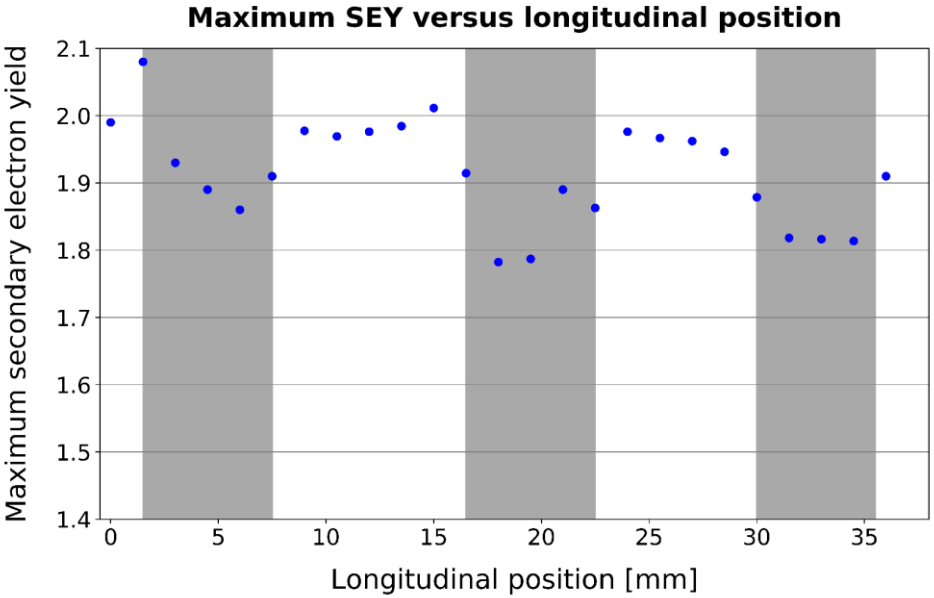
Pumping slot shield

Dark traces corresponding to pumping slot shape and spacing





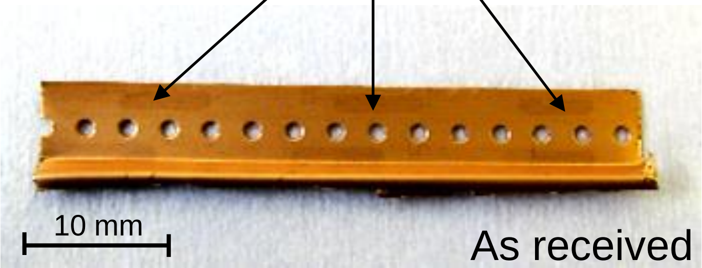
Baking in air enhances colour contrast

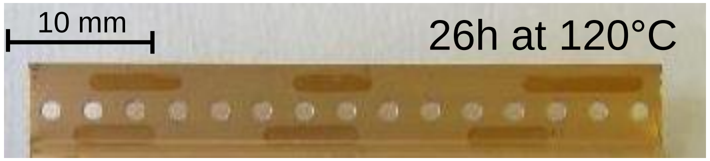


- Dark traces
  - Low SEY regions
- Out of dark traces
  - High SEY regions

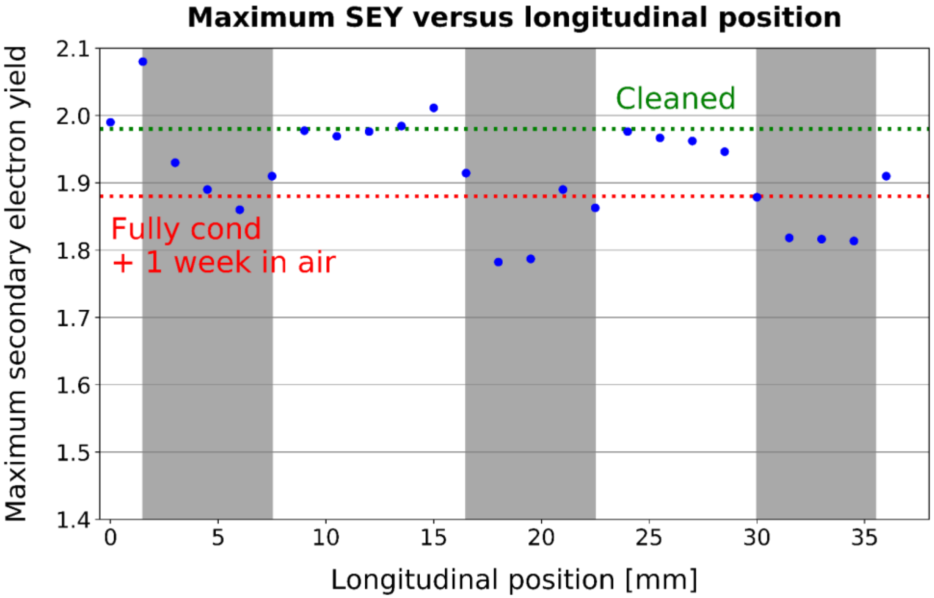
Pumping slot shield

Dark traces corresponding to pumping slot shape and spacing



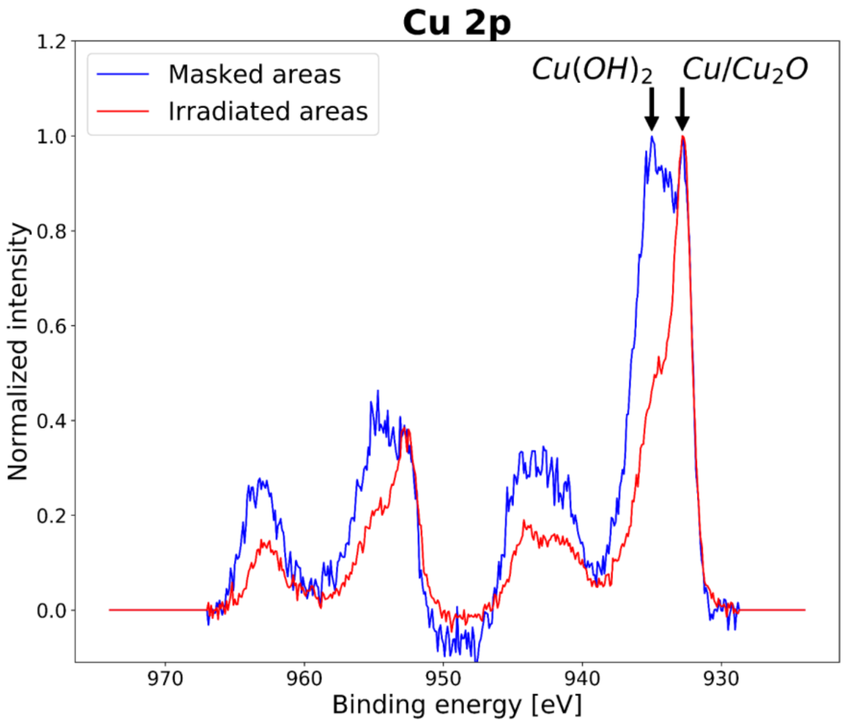


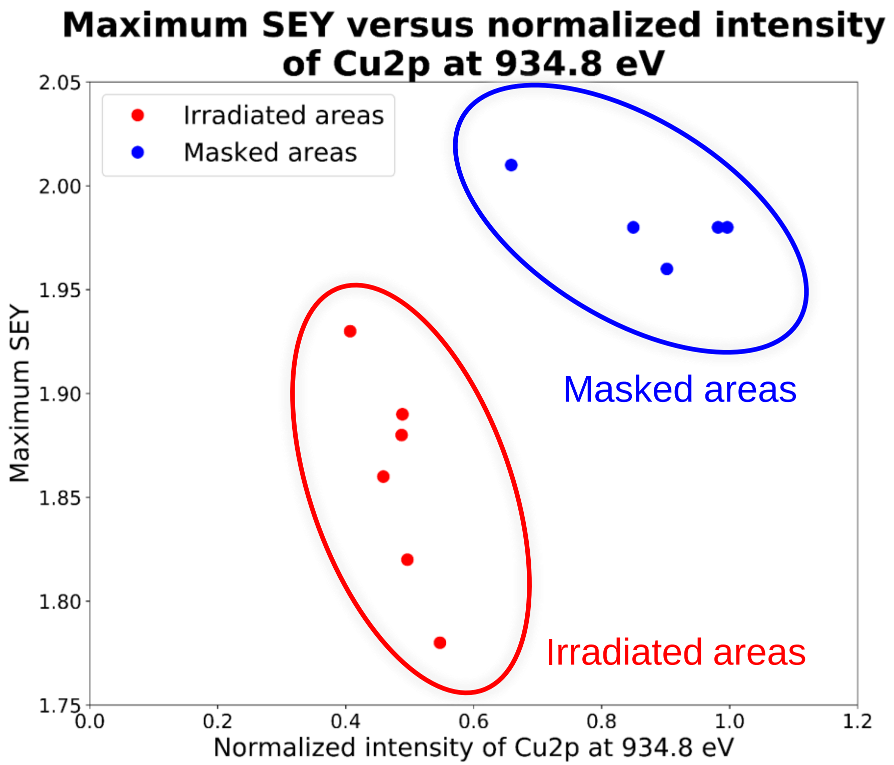
Baking in air enhances colour contrast



- Dark traces
  - Low SEY regions
  - Compatible with “deconditioned” state
- Out of dark traces
  - High SEY regions
  - same δ_{max} as “clean” material

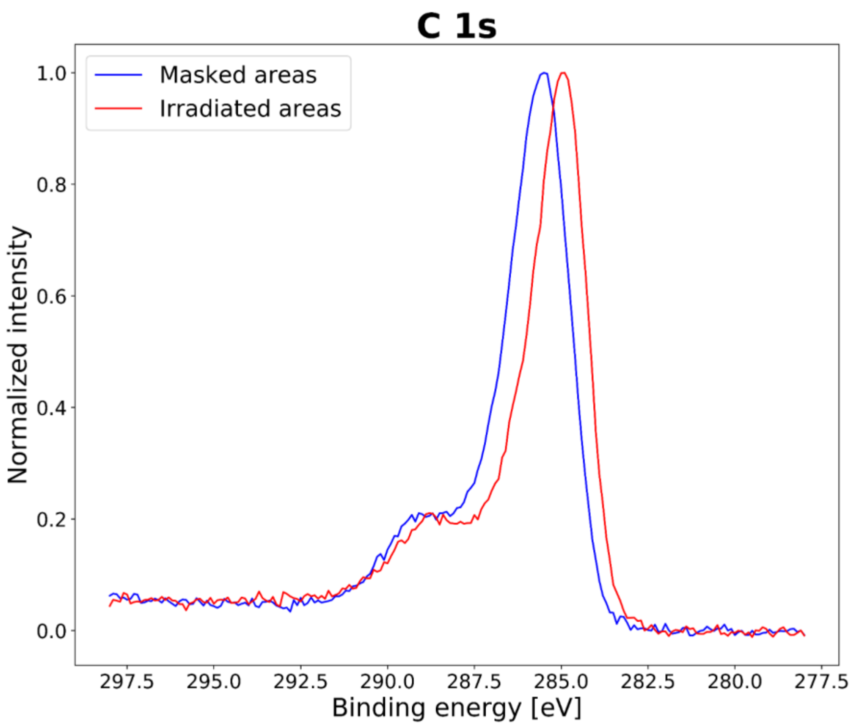
Pumping slot shield

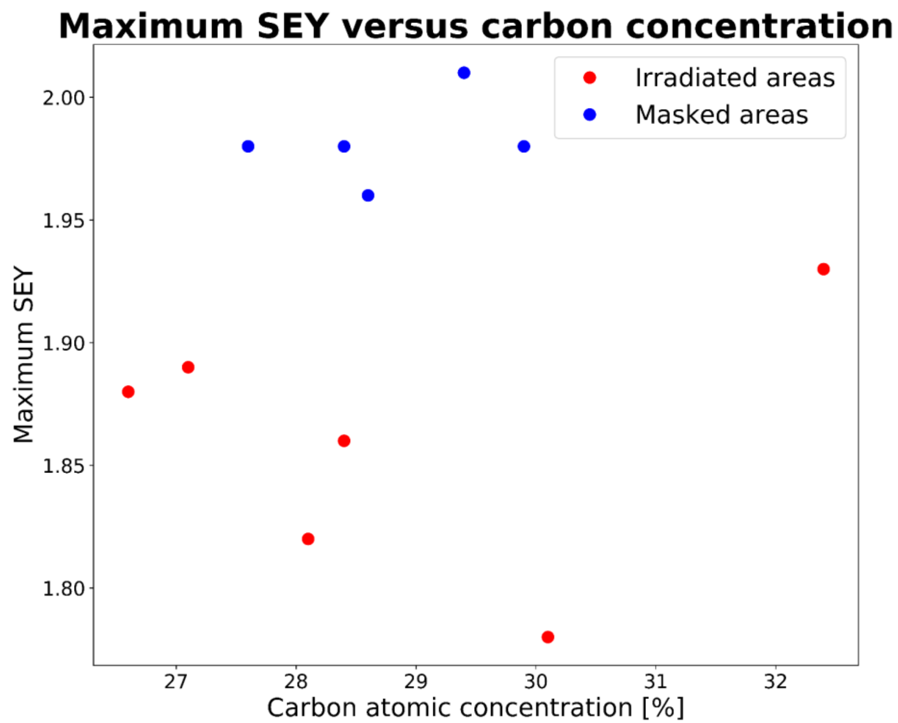




High $Cu(OH)_2$ component in masked areas versus low $Cu(OH)_2$ component in irradiated areas

Pumping slot shield

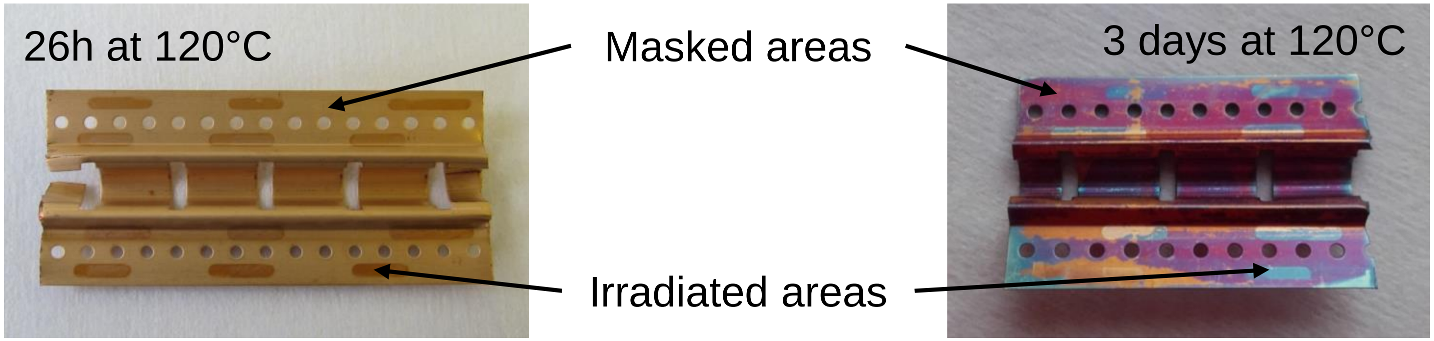




- Slight shift of C1s line towards lower binding energy in the irradiated areas : carbon graphitization
- No carbon increase in the irradiated areas

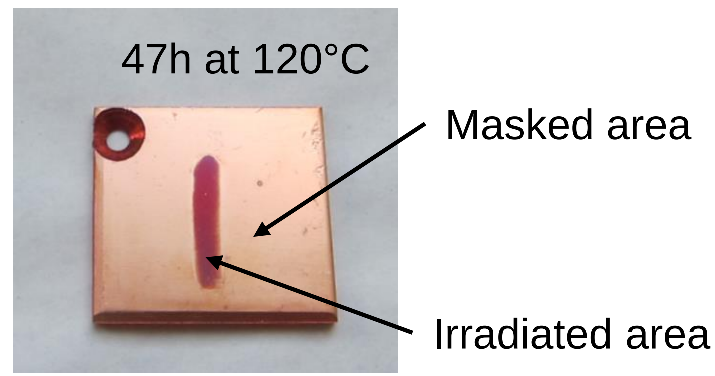
Pumping slot shield

LHC extracted component (chromic acid passivated)



Lab conditioning of passivated Cu OFE

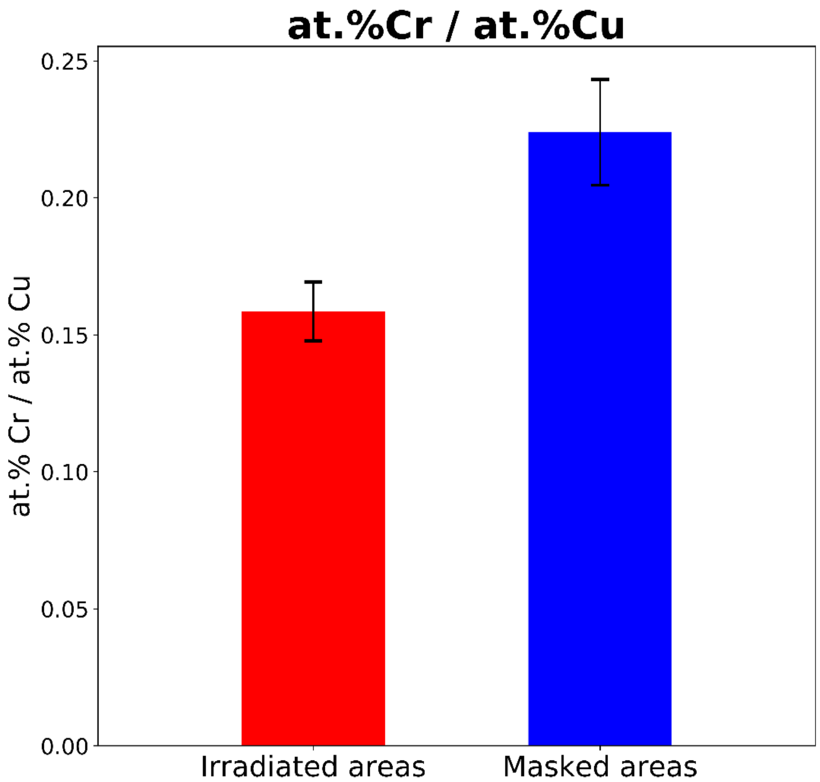
- Using a mask
- E = 250eV
- D = 3.10^{-2} C/mm²
- 47h at 120°C

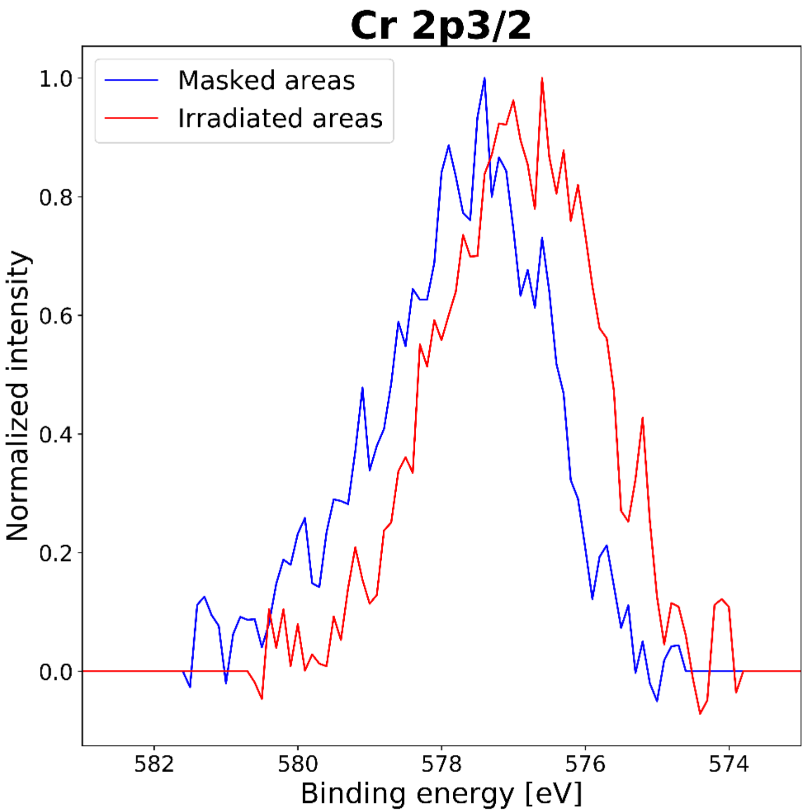


According to coloration : on passivated material, irradiated areas get oxidized faster than not irradiated areas

Pumping slot shield

LHC extracted component





Faster oxidation in irradiated areas could be due to chromium depletion and modification induced by electron bombardment

Conclusions

- Beam screen
  - Maximum SEY globally lower than “not installed” beam screen
  - Modification of oxidation state of copper (hydroxide)

  → compatible with a partial conditioning state in the machine

  - Uniform SEY in azimuth

- Pumping slot shield
  - Non uniform SEY
  - Visible pattern due to passivation damage
  - Zones presenting the memory of conditioning (SEY, oxidation state)

Perspectives

- Study the effect of bake out in air on LHC extracted beam screen

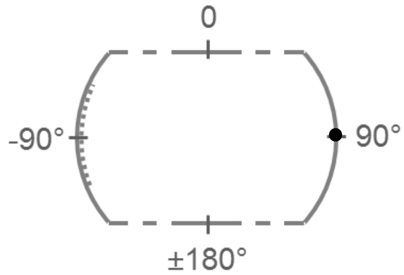
- Study of influence of air exposure on SEY depending on the conditioning level

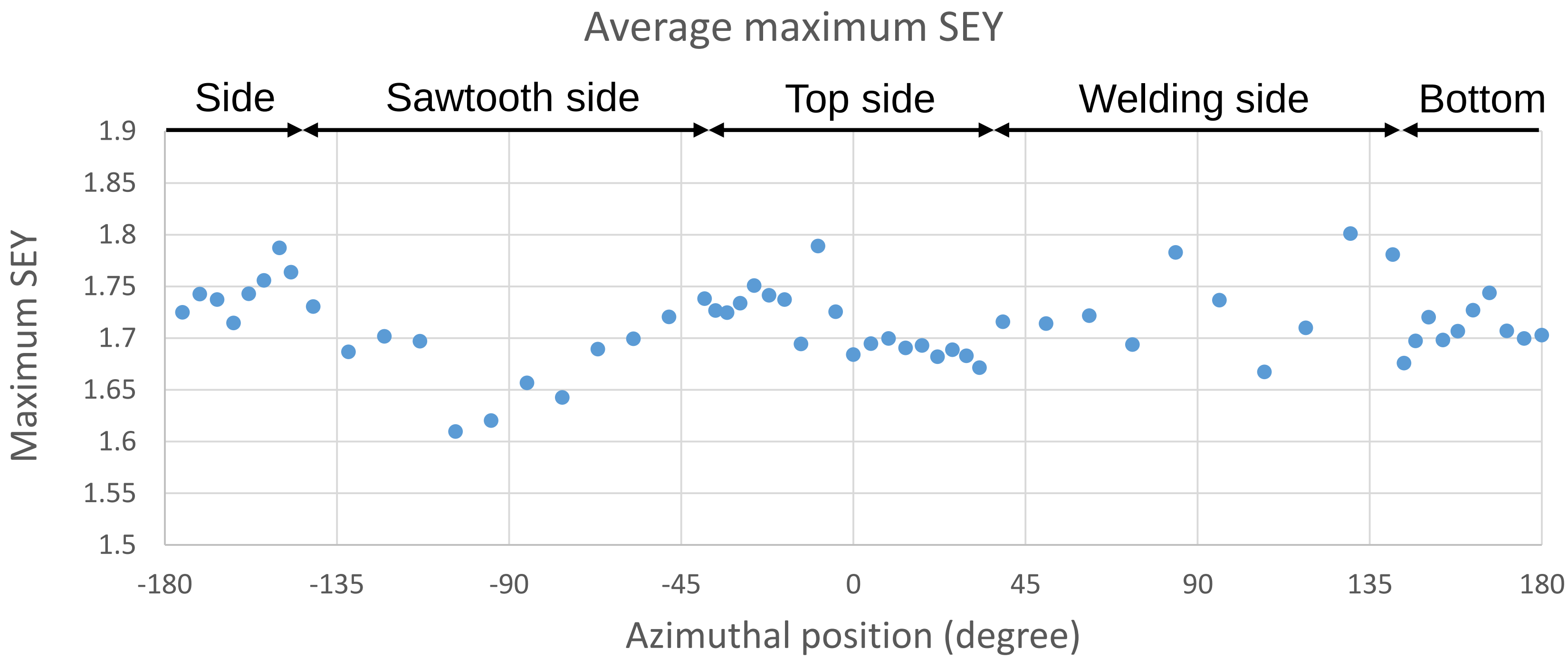
- Analysis and comparison of beam screens extracted from high an low heat load LHC magnets during Long Shutdown 2

Thank you

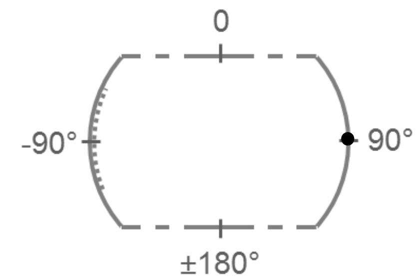
Spares

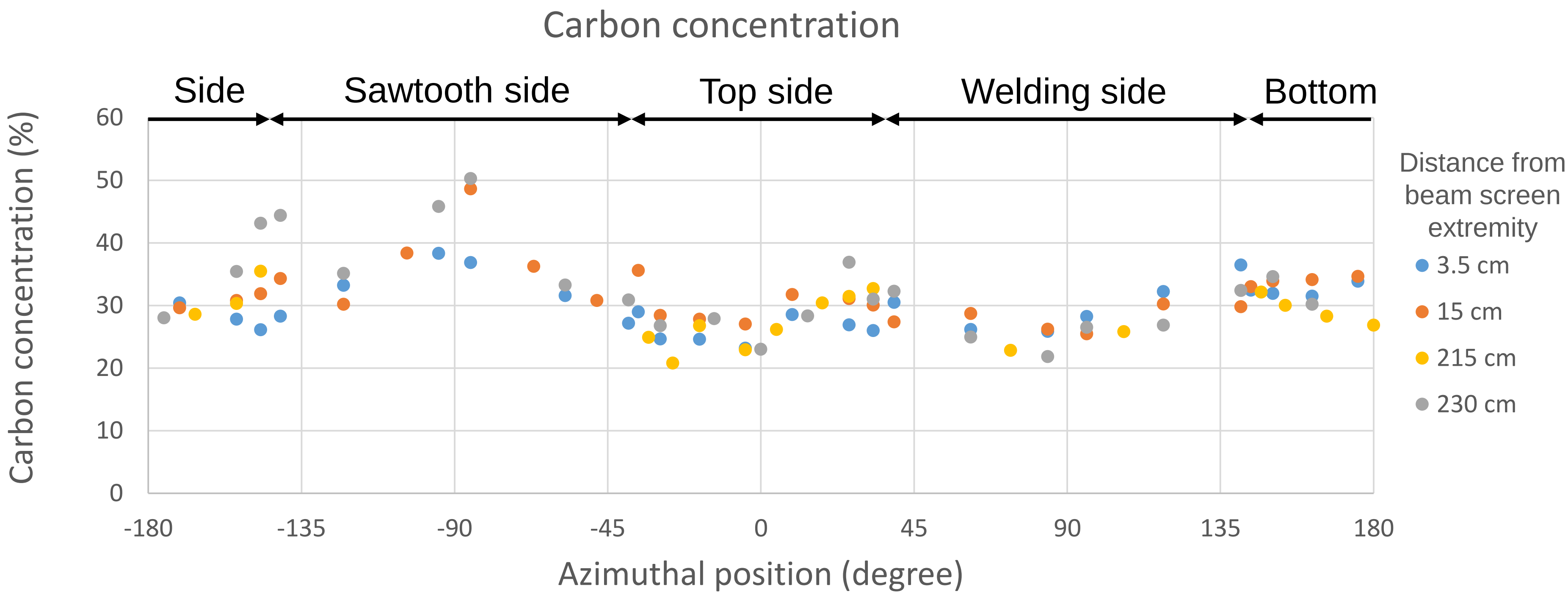
Beam Screen


0
-90°
90°
±180°

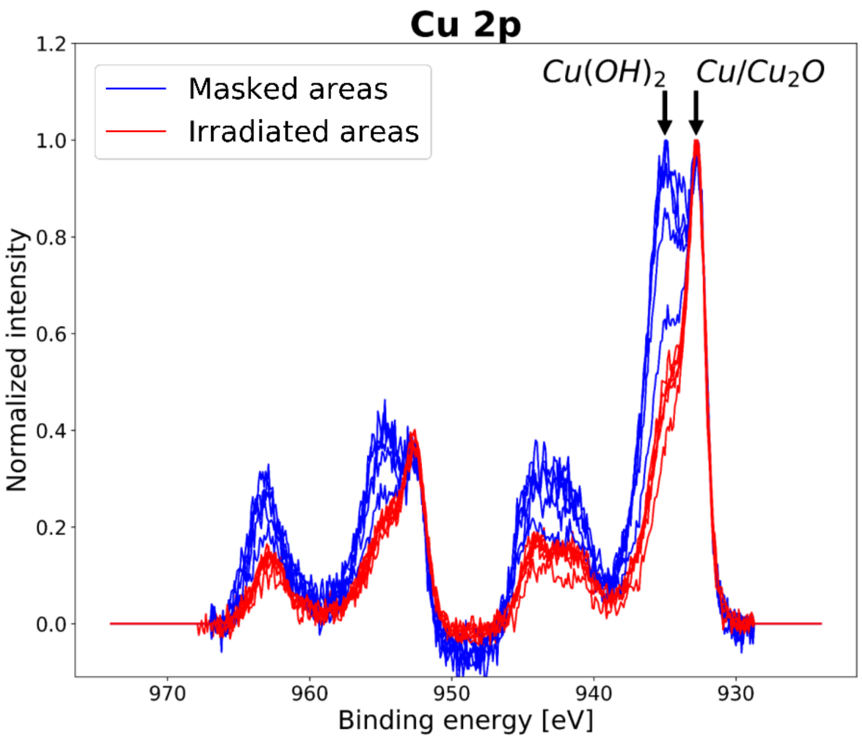

Average maximum SEY
Side
Sawtooth side
Top side
Welding side
Bottom
Maximum SEY
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
-180
-135
-90
-45
0
45
90
135
180
Azimuthal position (degree)

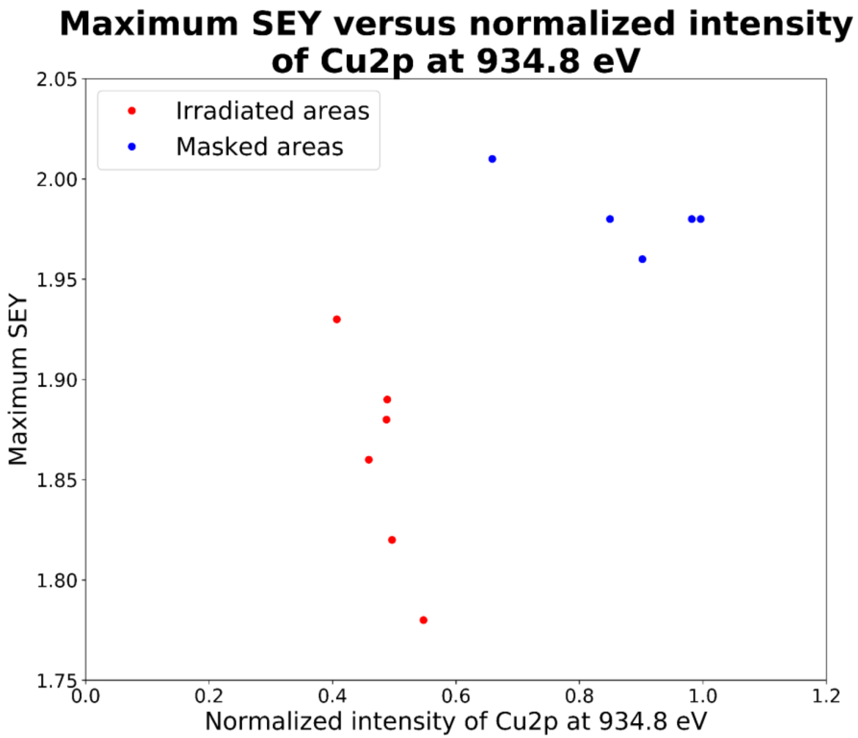
Beam Screen


0
-90°
90°
±180°

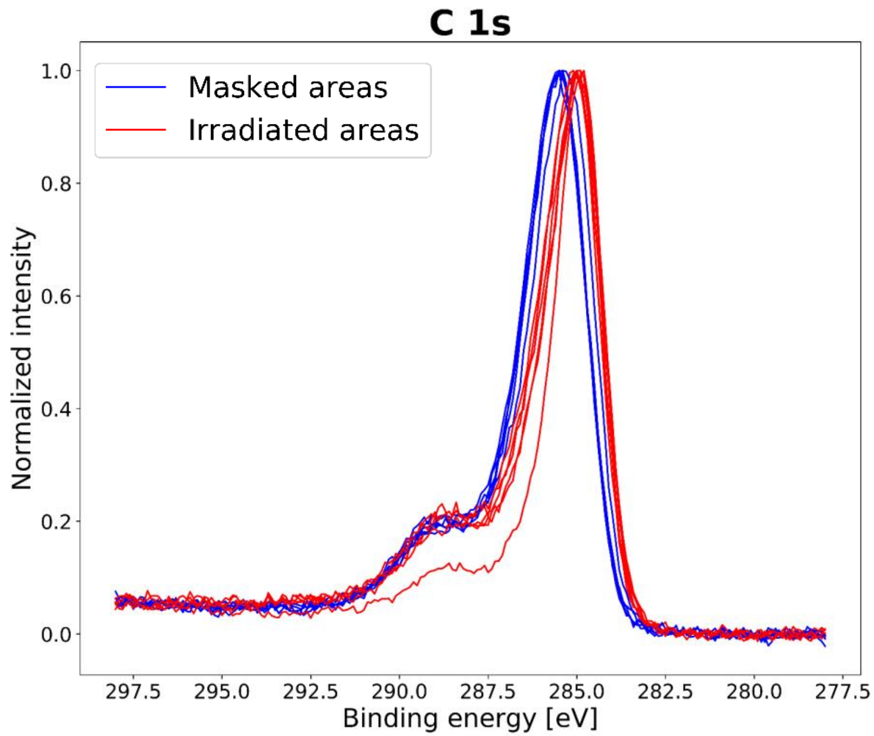

Carbon concentration
Side
Sawtooth side
Top side
Welding side
Bottom
Carbon concentration (%)
0
10
20
30
40
50
60
-180
-135
-90
-45
0
45
90
135
180
Azimuthal position (degree)
Distance from beam screen extremity
3.5 cm
15 cm
215 cm
230 cm

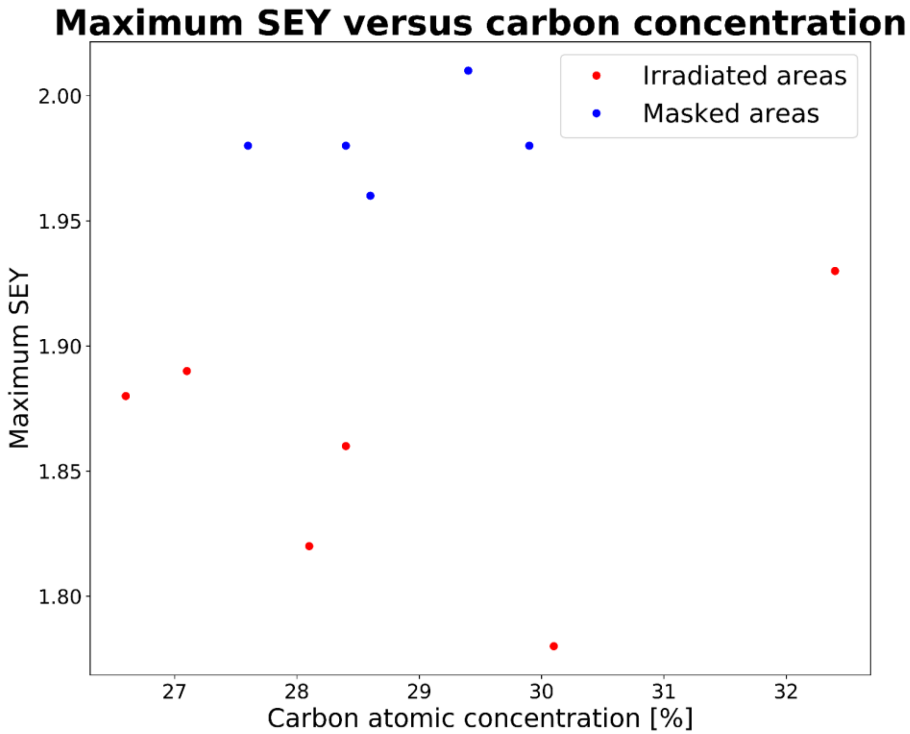
Pumping slot shield



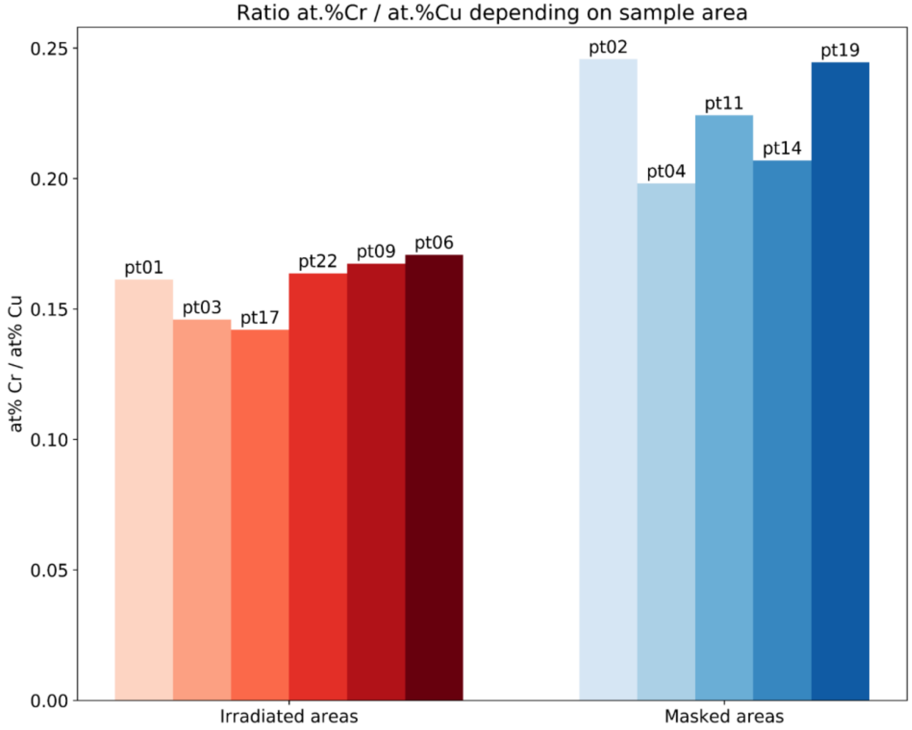


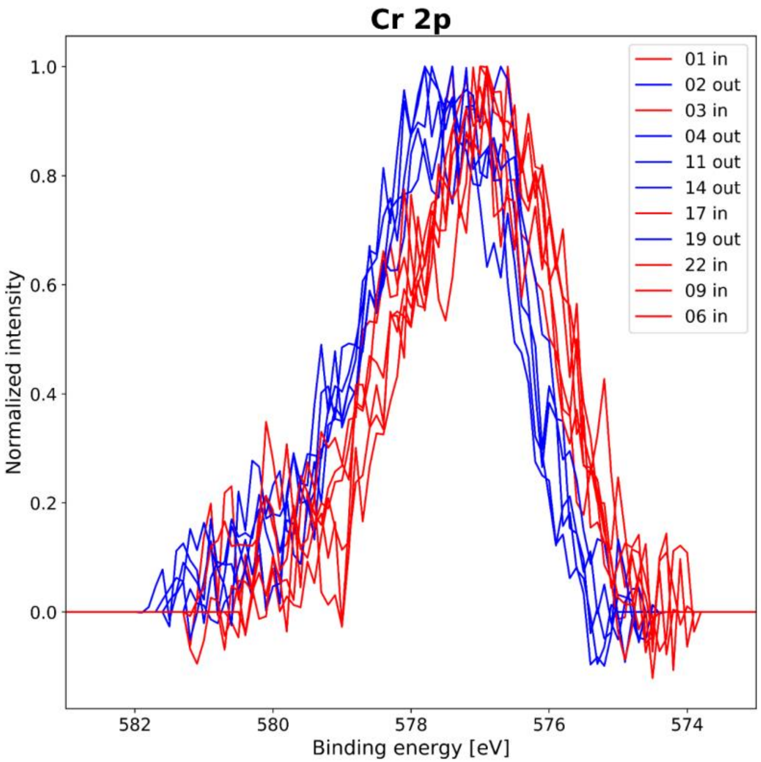
Pumping slot shield



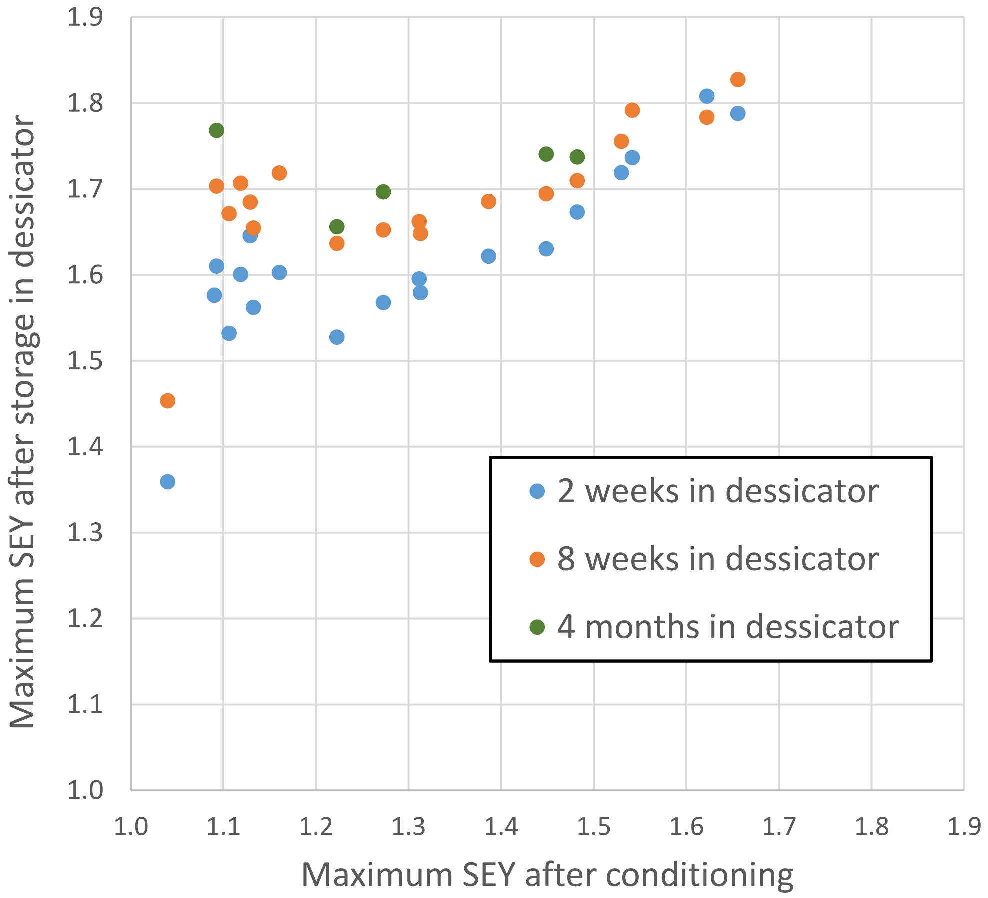


Pumping slot shield



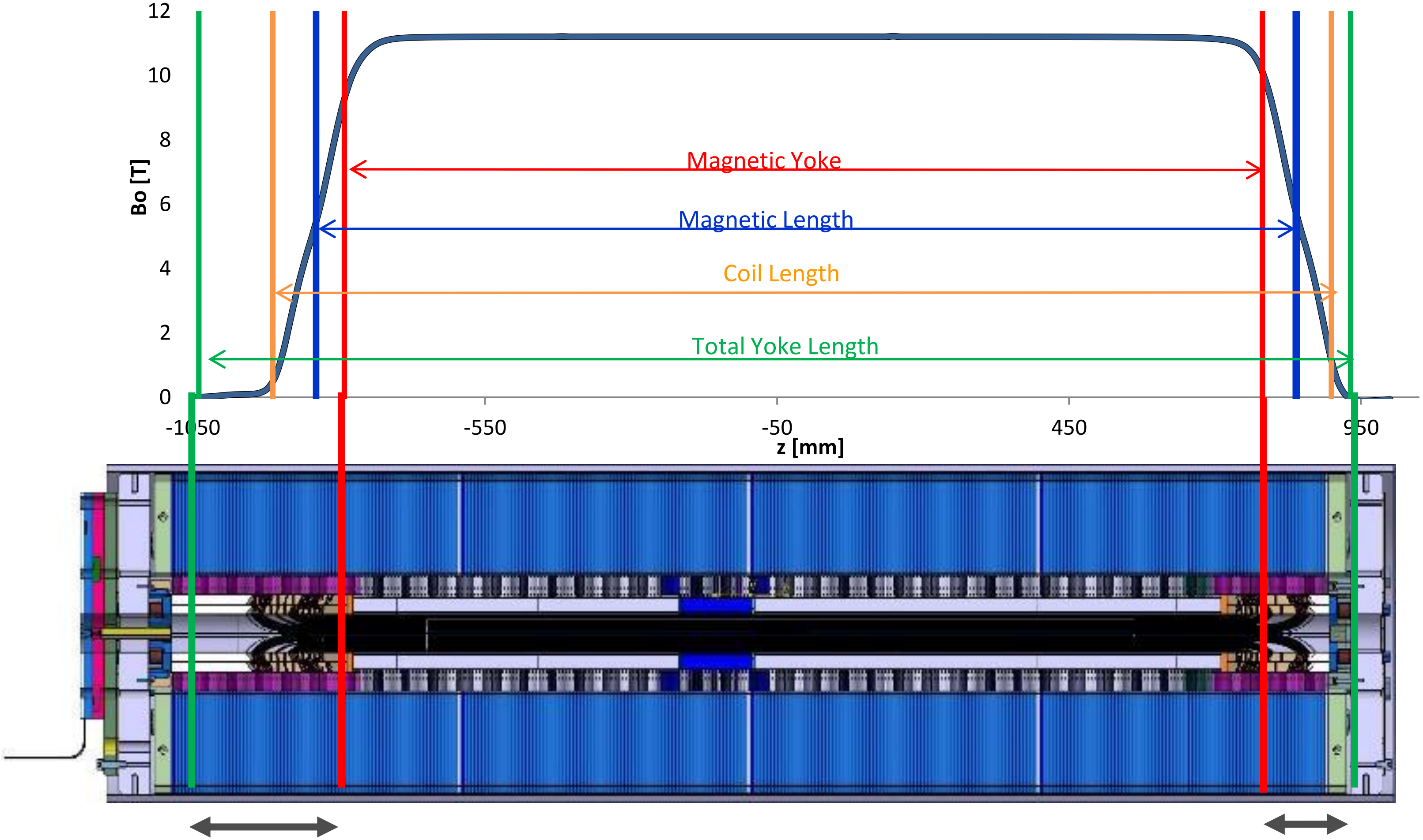


Deconditioning



- Cu OFE copper cleaned with the same procedure as for the LHC beam screen
- Conditioning at E_p = 250 eV
- Room temperature
- Base pressure P = 2.10^{-9} mbar
- Storage in Al foil into dessicator

Magnetic field



250 mm non magnetic (43 laminations)

S. Izquierdo Bermudez

150 mm non magnetic (26 laminations)