FUTURE CIRCULAR COLLIDER

FCC WEEK 2021
28TH JUNE – 2ND JULY

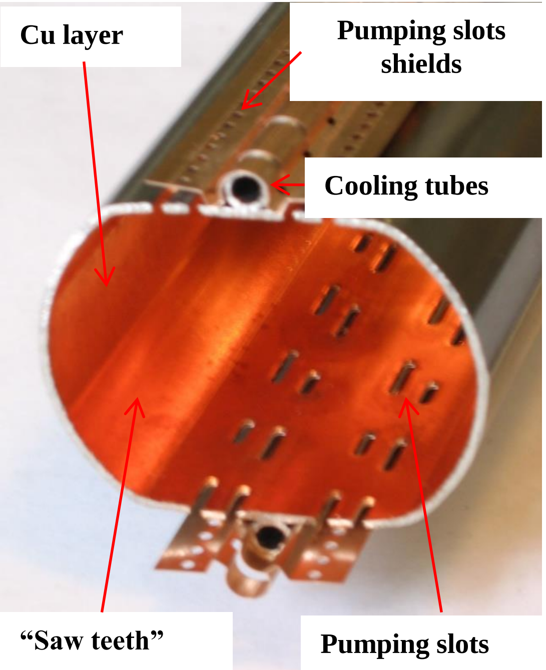
KEY VACUUM SURFACE PARAMETERS FOR FCC-ee OPERATION

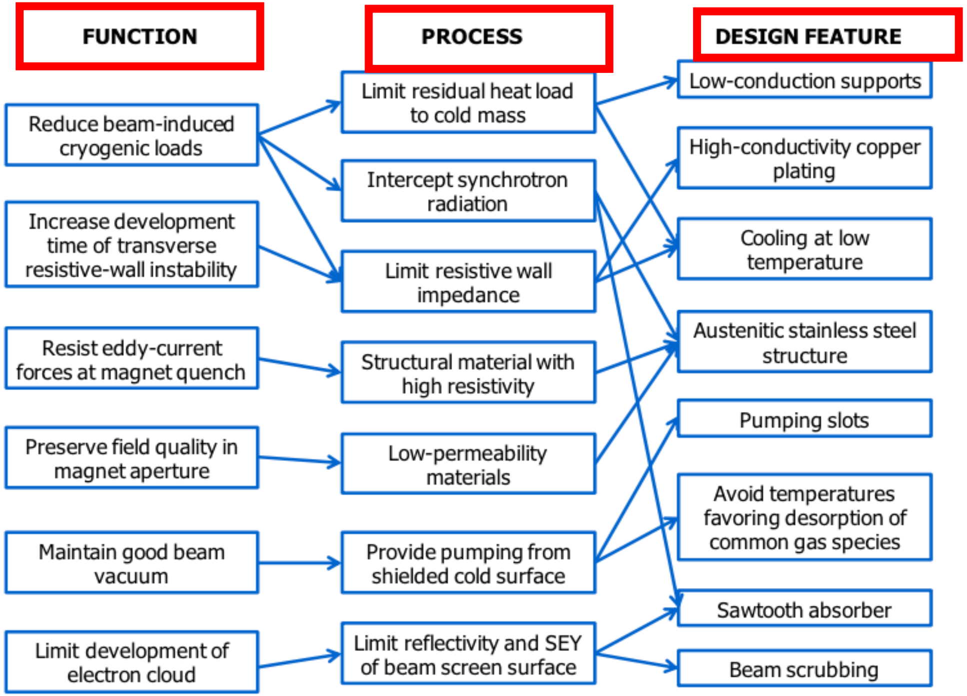
R. Cimino LNF-INFN

- ~~Introduction:~~
- What lessons from the study on surfaces for FCC-hh (and LHC) are relevant for FCC-ee?
- Prospective and conclusion

The Vacuum system should be compliant with a complex **functional diagram** **(from LHC and FCC-hh)**

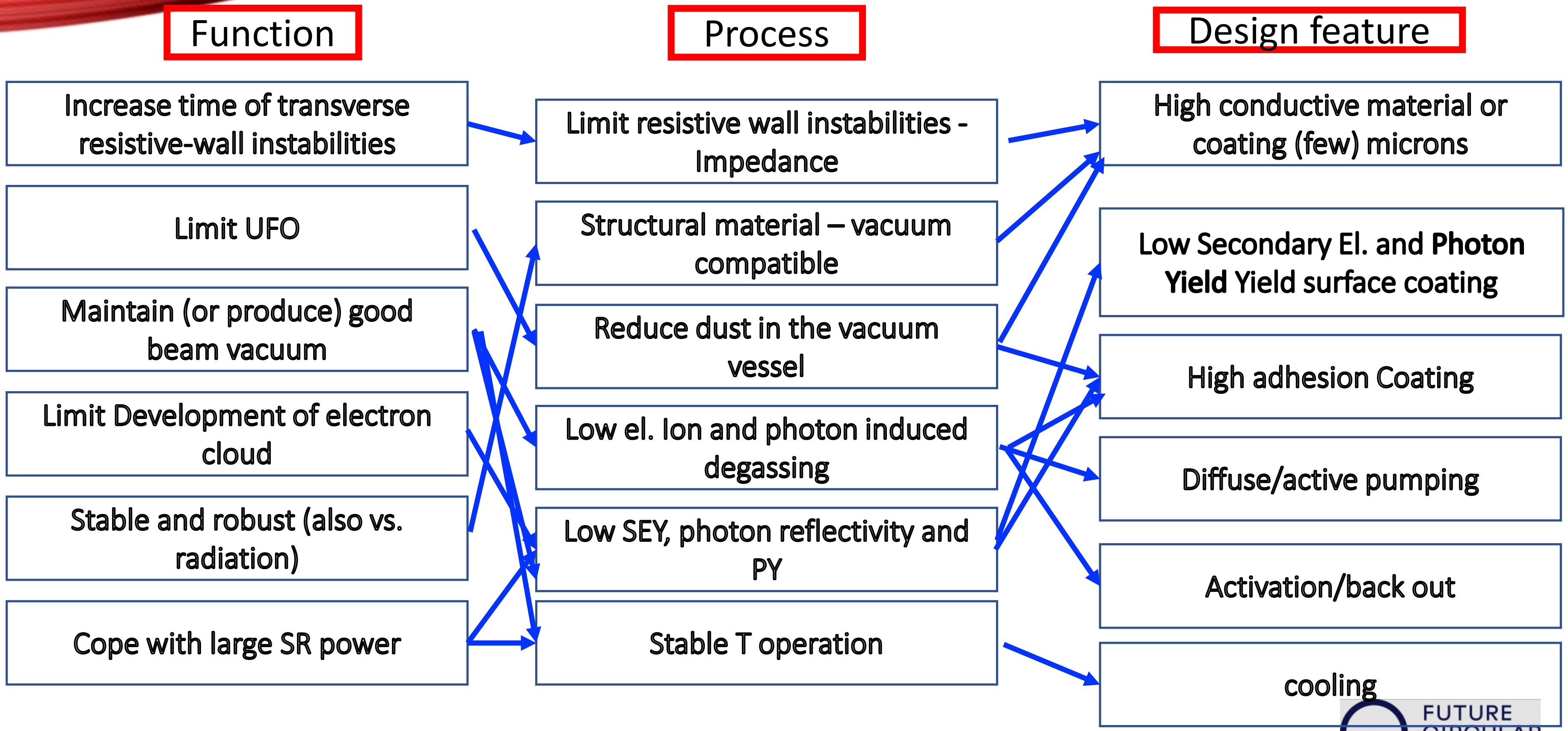
LHC Beam Screen (BS)





V. Baglin et al. CERN-ATS-2013-006

The Vacuum beampipe at RT simplify the diagram.



- Not all the requirements are easily accounted for
- Need to find a compromise
- Need to know the detailed performance of the selected material / composite
- Is the blanket too short?

Thickness vs. impedance and SEY reduction: the case of amorphous –carbon (a-C)

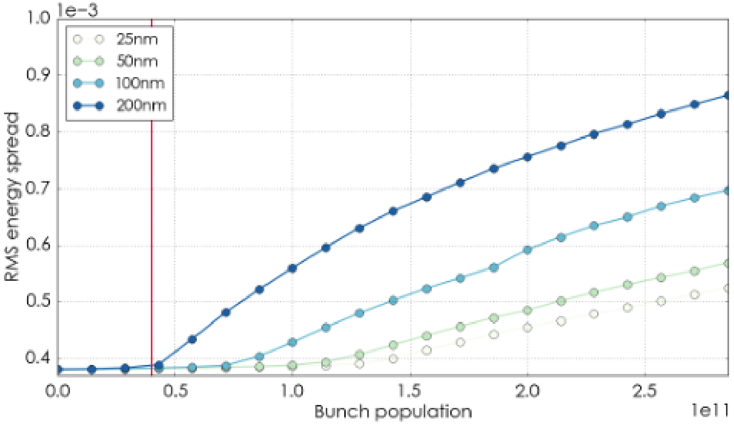
E. Belli - Impedance model and collective effects for FCC-ee

Microwave Instability (MI)

1 Does the material thickness affect the MI?

- Example: Amorphous Carbon, no Beamstrahlung ($\sigma_z = 2.1mm, \sigma_{dp} = 0.038\%$)
  - ✓ The MI threshold is **3x higher in case of 25nm thickness**

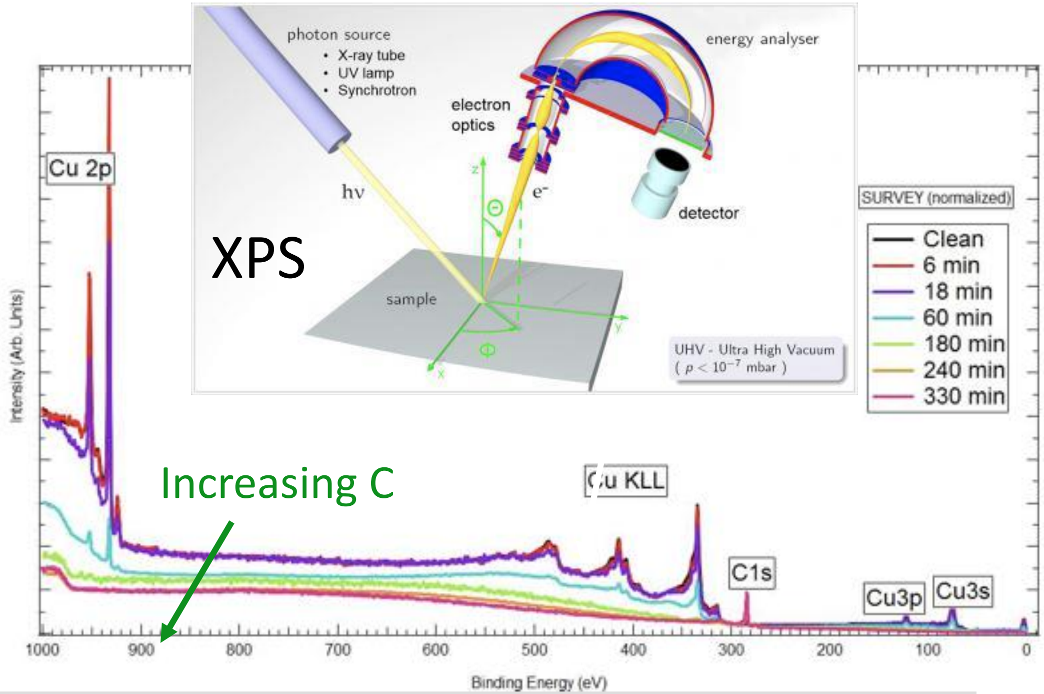
Possible optimizations

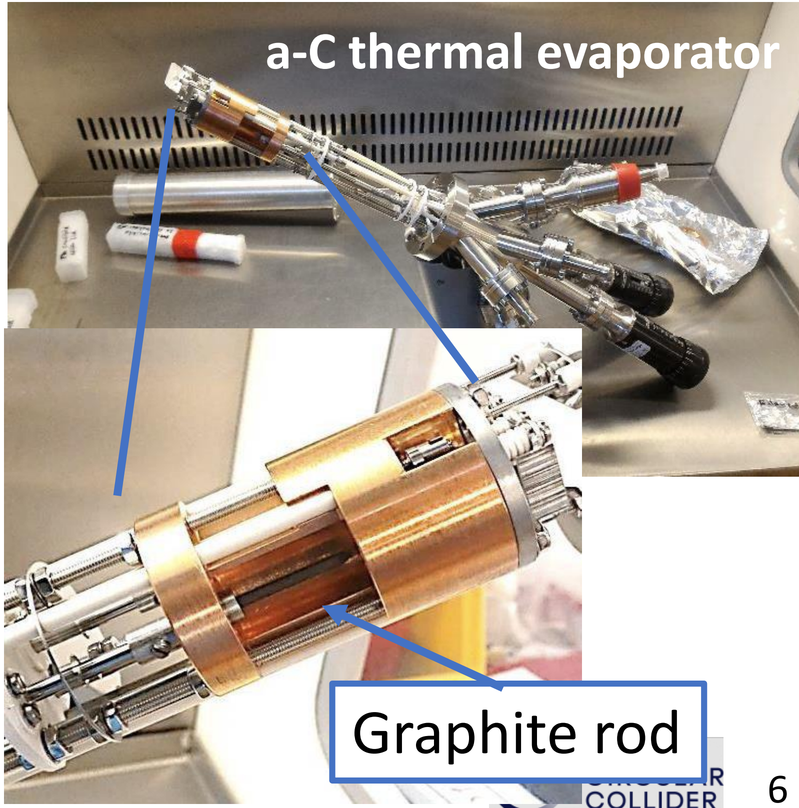


How much should be the a-C layer to reduce SEY to < 1.1?

HOW A COATING MODIFY SEY? (the case of a-C on Cu)

We followed the growth of thin a-C layers on Cu with XPS to measure its thickness





M. Angelucci et. al; Phys. Rev. Research Rapid comm. 2, 032030(R) (2020)

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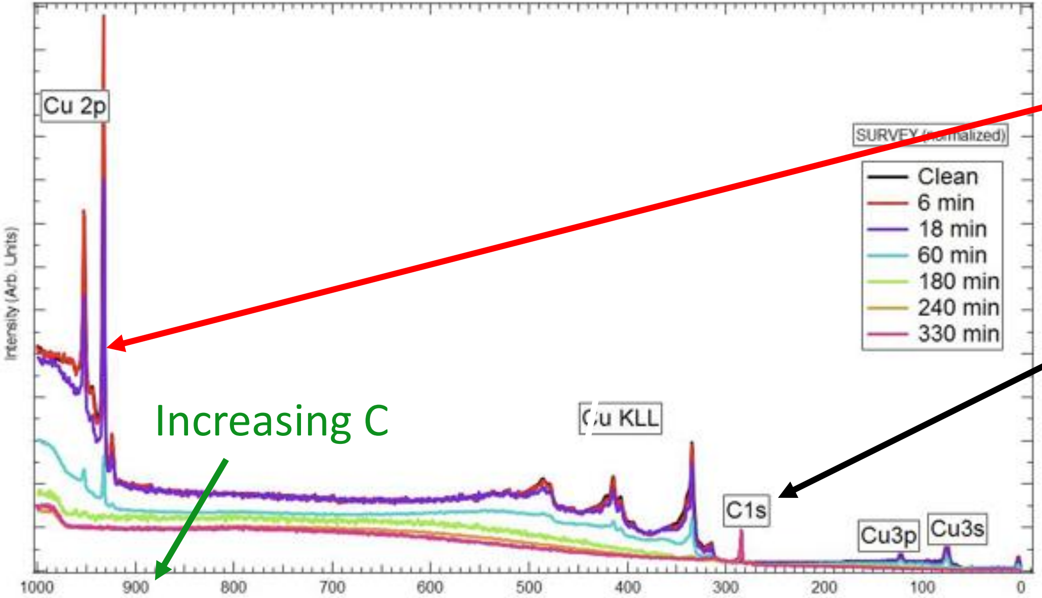

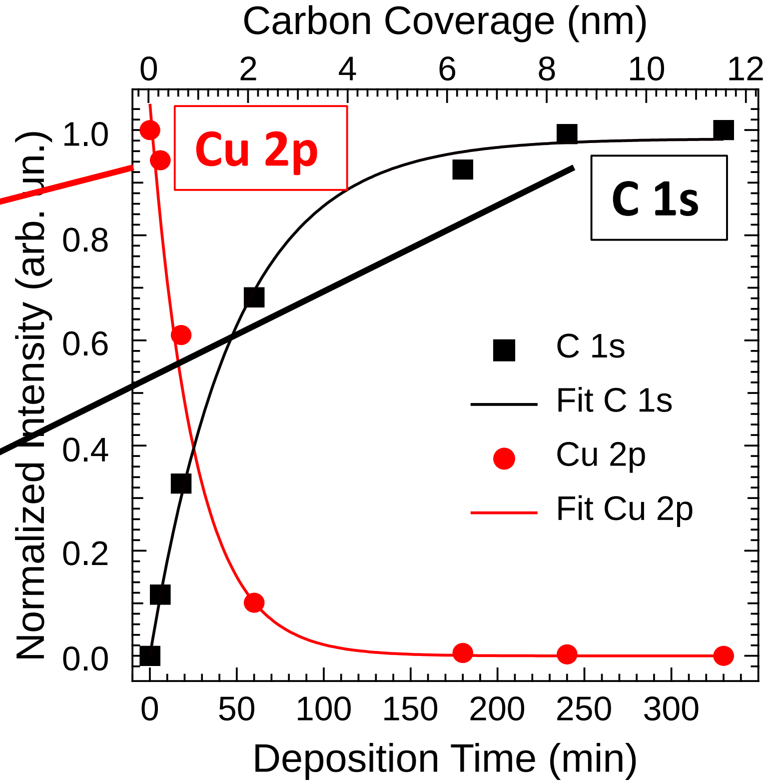

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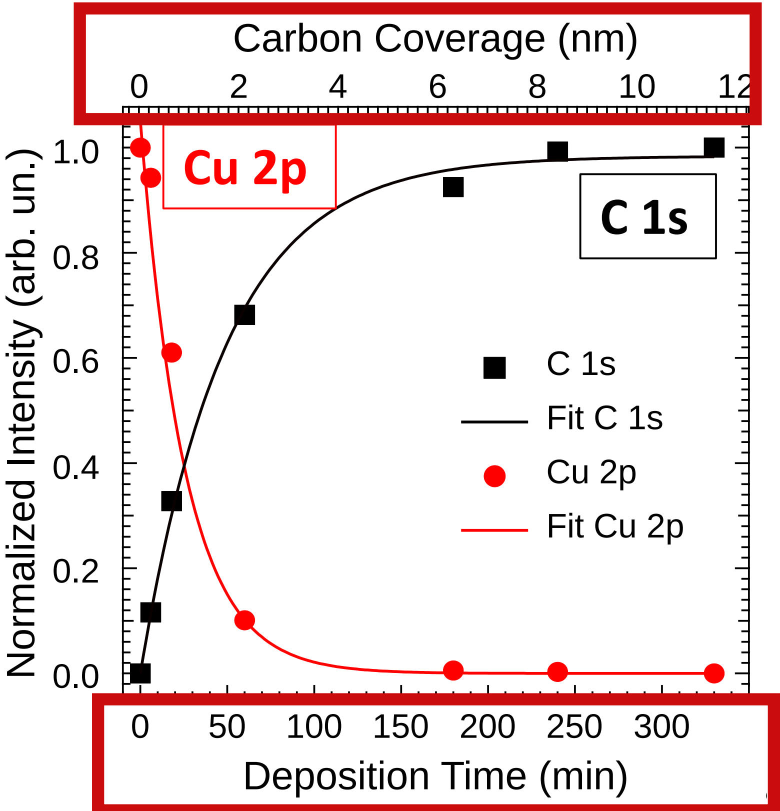
In XPS:

$$I_{Cu}^{C} = (I_{Cu,bulk}^{C}) * \exp(-d/\lambda_{Cu,C})$$

$$I_{C} = I_{C,bulk} * (1 - \exp(-d/\lambda_{C,C}))$$

where **d** is the unknown thickness and λ is the inelastic mean free path.

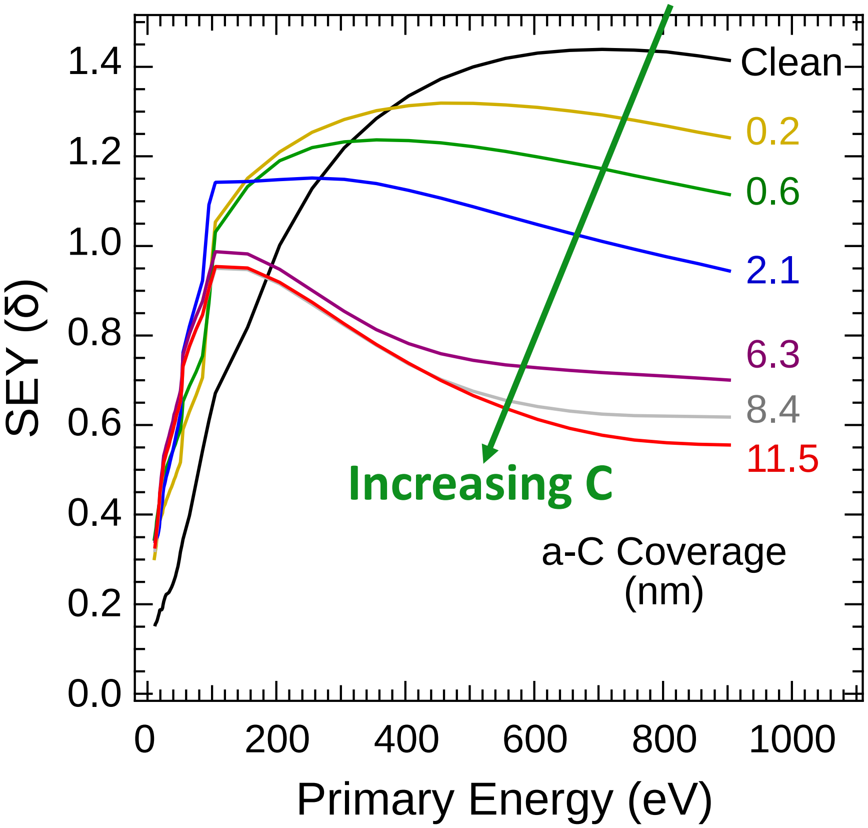


We can convert deposition Time in nm (±30%)

M. Angelucci et. al; Phys. Rev. Research Rapid comm. 2, 032030(R) (2020)

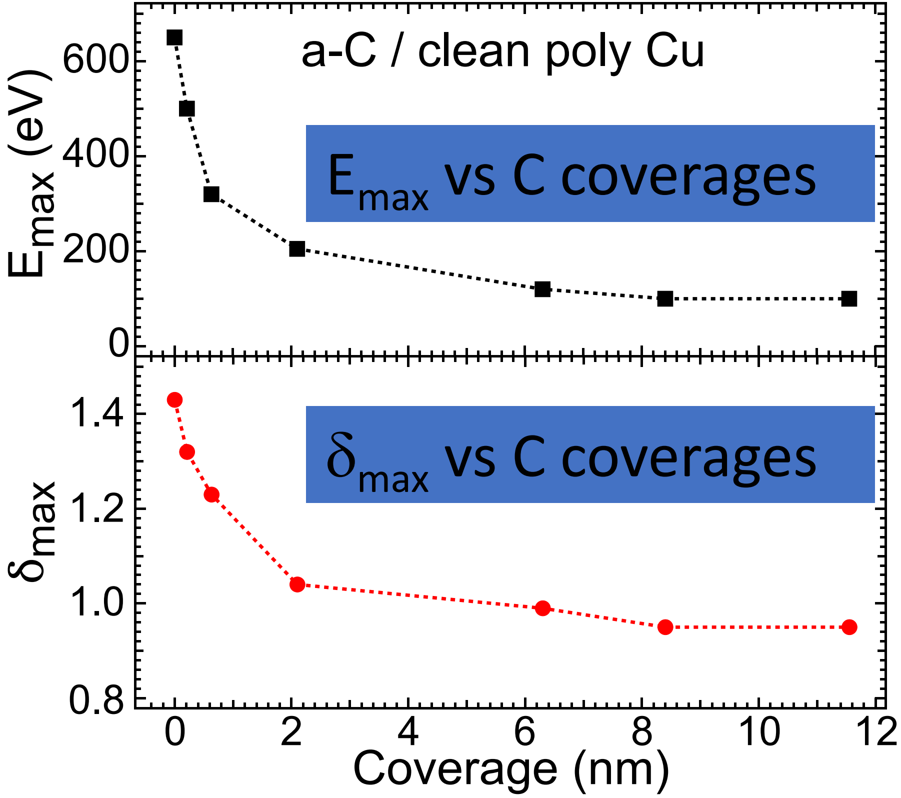
HOW A COATING MODIFY SEY?
(the case of a-C on Cu)

- By simultaneously follow SEY changes with a- C thickness we can measure SEY dependence on the actual a-C coverage.



M. Angelucci et. al; Phys. Rev. Research Rapid comm. 2, 032030(R) (2020)

How a Coating modify SEY? (the case of C on Cu)

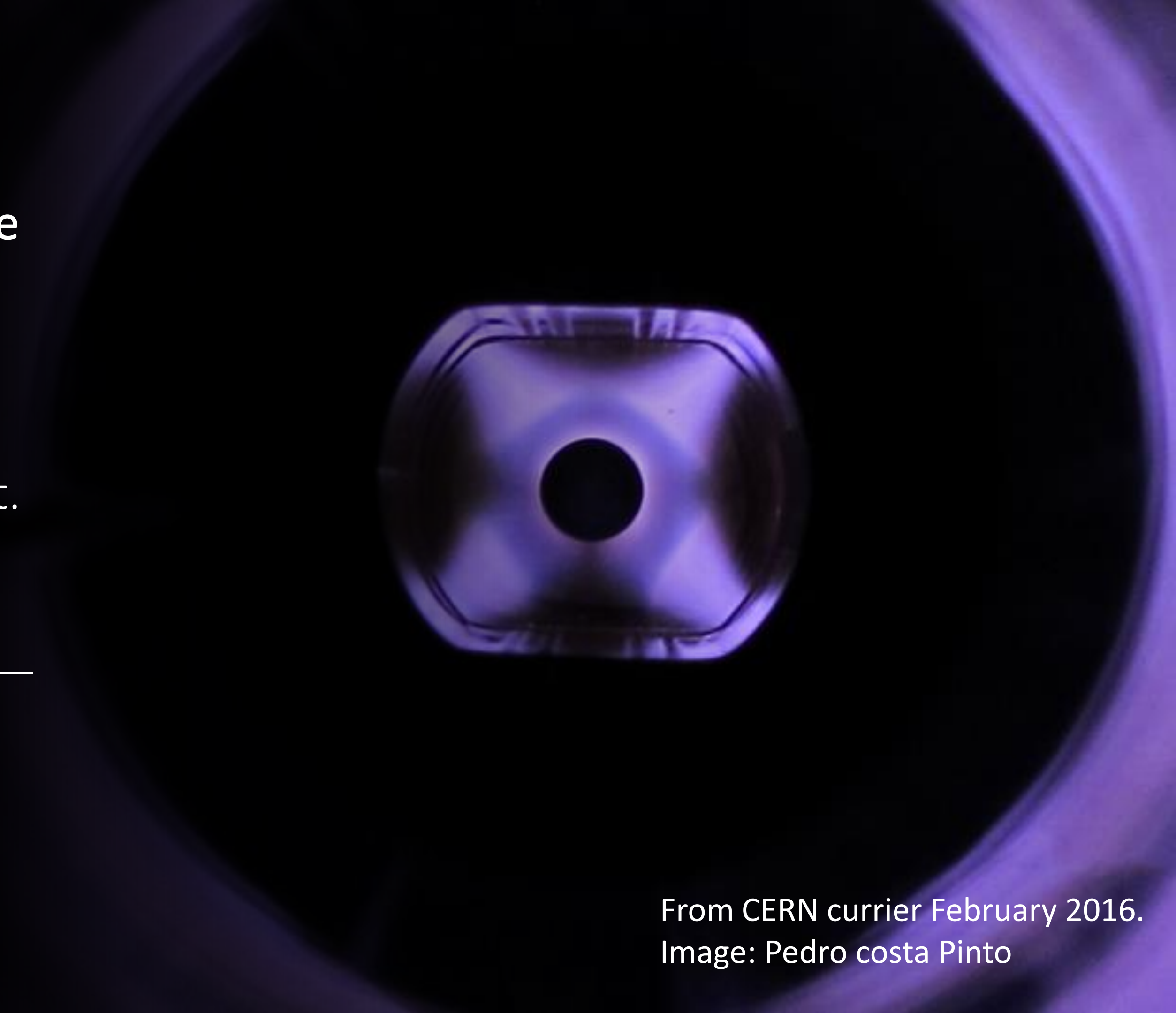


δ_{max}, E_{max} set to their (a-C) final values quite soon, while minor changes still occurs at higher doses in the very low (< ~ 20 eV) and at quite high primary energy (> ~400 eV) part.

➔ δ_{max} (<1) and E_{max} are set after 6-8 nm of a-C

M. Angelucci et. al; Phys. Rev. Research Rapid comm. 2, 032030(R) (2020)

A thin (~ 10 nm) **a-C surface coating** could be applied to reduce SEY without having any (significant) impact on the impedance budget.



From CERN currier February 2016.
Image: Pedro costa Pinto

- Clearly, for **NEGs** this reasoning does not apply since a too thin NEG layer will not grant a sufficient pumping reservoir. Optimization must follow.

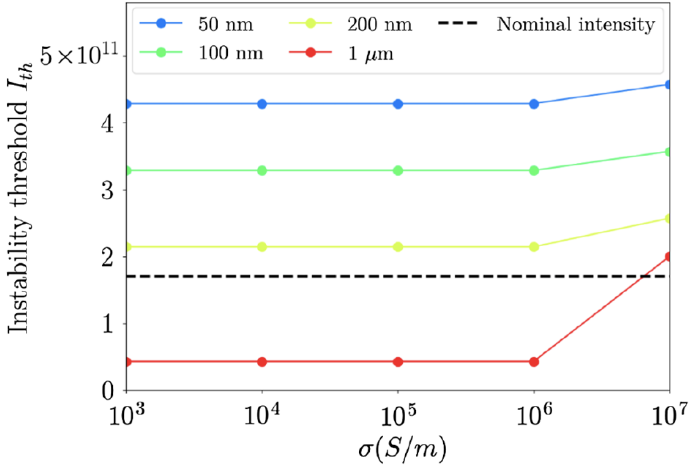
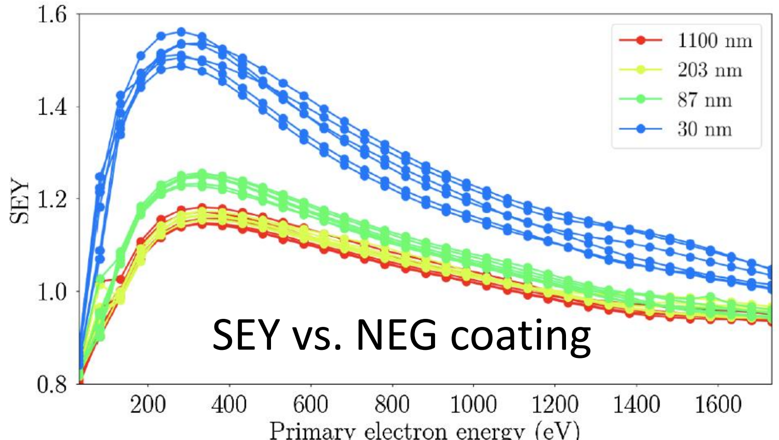


FIG. 5. MI threshold as a function of the coating conductivity for all thicknesses under study. The black dashed line corresponds to the nominal bunch intensity.

See for instance: E. Belli et al. Physical Review Accelerators and Beams 21, 111002 (2018)

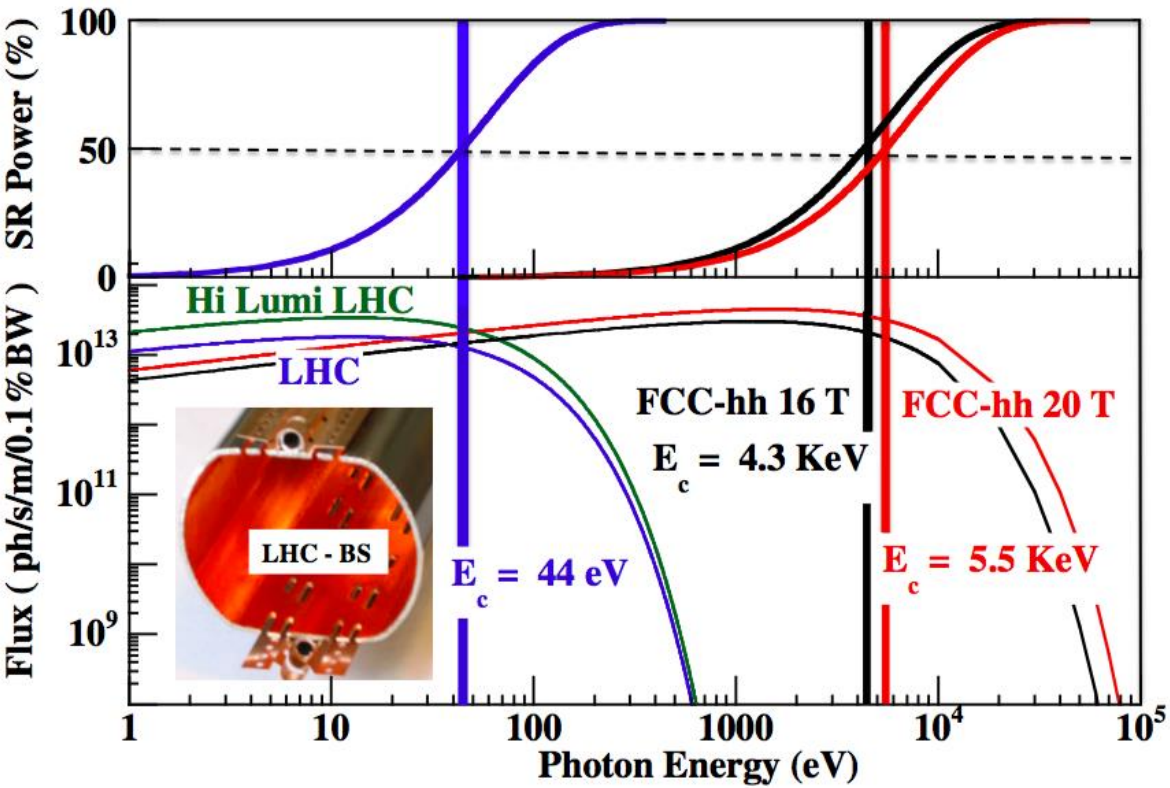


SEY vs. NEG coating

Whatever is the material choice, vacuum simulations need as realistic as possible material parameters.

Experimental characterization of materials and surfaces: Reflectivity and photon Yield.

SR in FCC



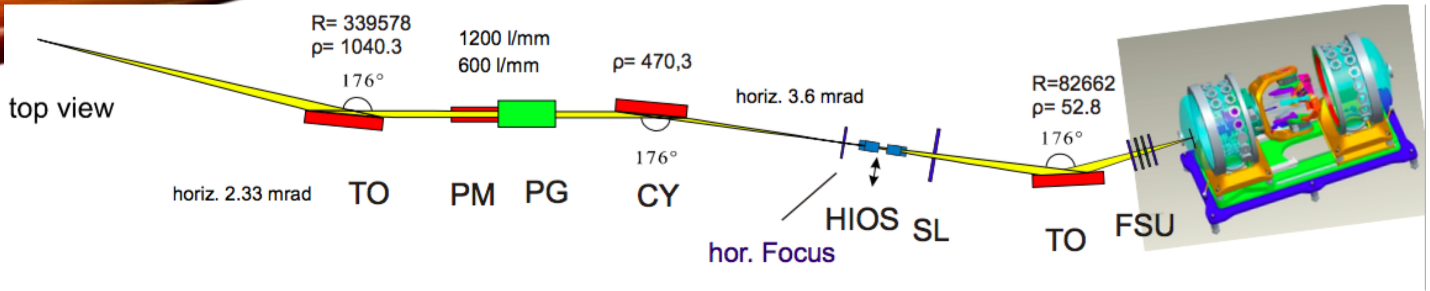
FCC- SR incidence angle: 0.035 deg (0.62 mrad)

~ 21 m from source

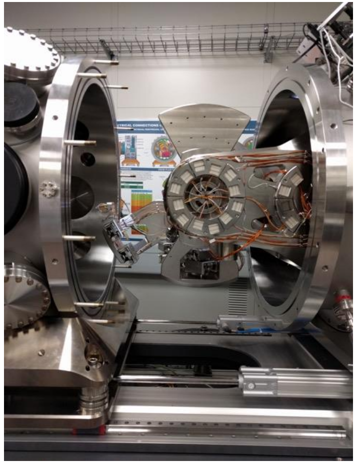
Photon fan strip ~ 2mm

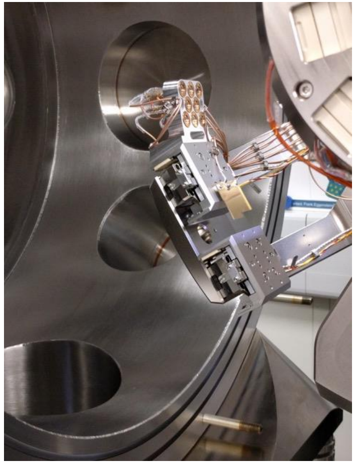
SR is very different for LHC, FCC-hh and FCC-ee Where high energy X-rays are produced.

For LHC and FCC-hh:



BESSY-II Optic Beamline and Reflectometer





HZB Helmholtz Zentrum Berlin

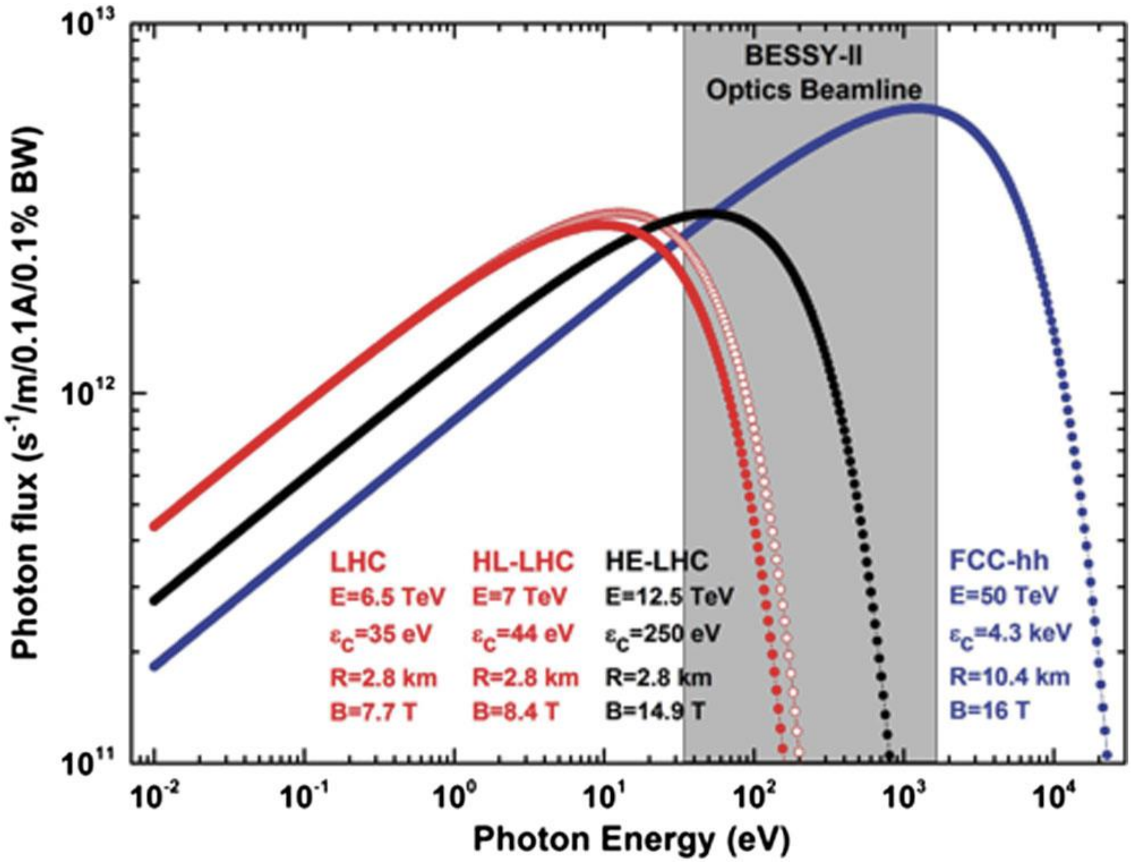
A.A.Sokolov,et al,Proc.of SPIE92060J-1-13(2014)

For FCC-hh:

E. La Francesca Et Al. Phys. Rev. Accel. Beams 23, 083101 (2020)

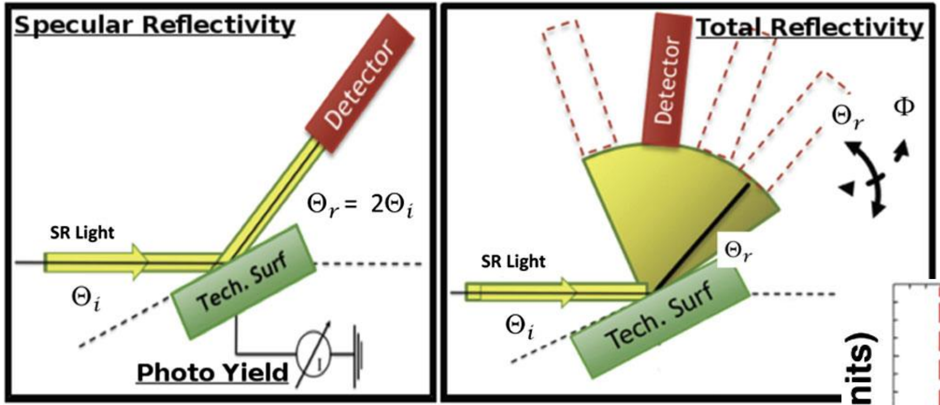
Investigate from 35 to 1800 eV

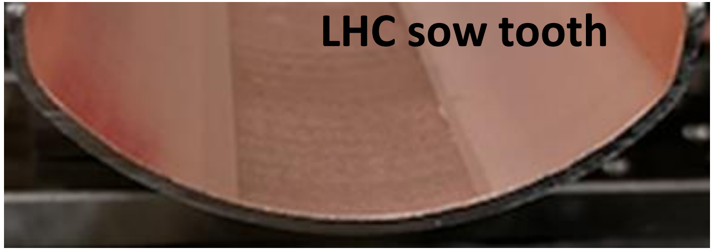
At a minimum angle of incidence of 0.25°
(factor ~ 2 higher than for LHC)
(factor ~ 7 higher than for FCC!)

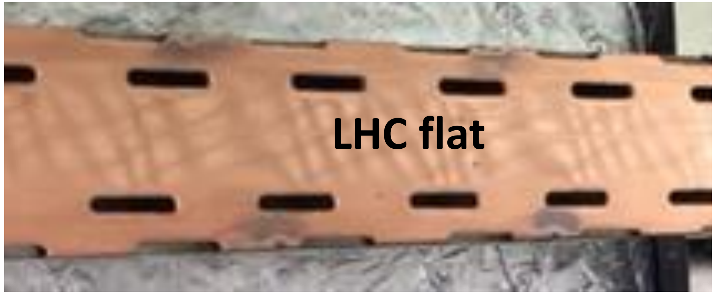


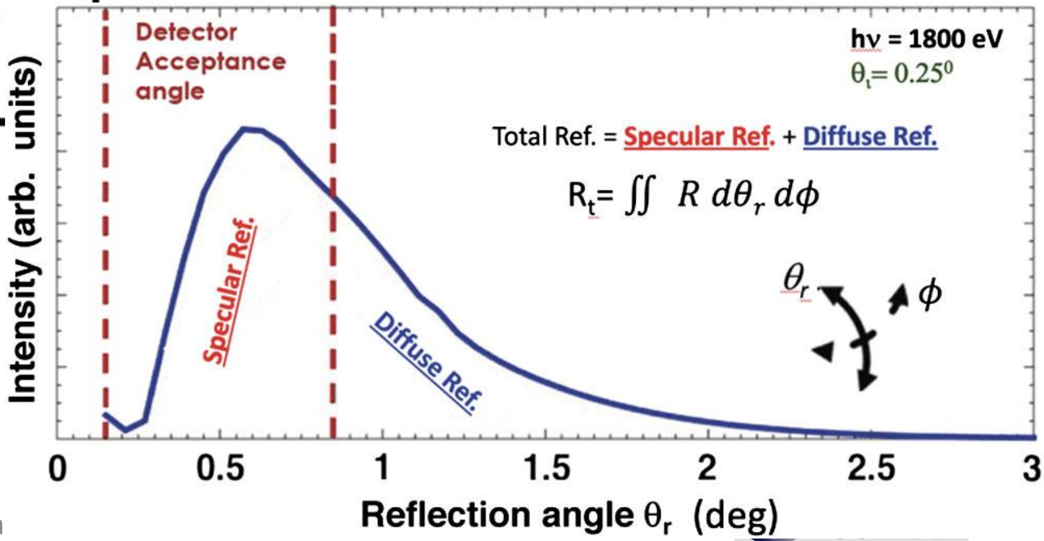
Two adopted experimental configurations:

E. La Francesca Et Al. Phys. Rev. Accel. Beams 23, 083101 (2020)



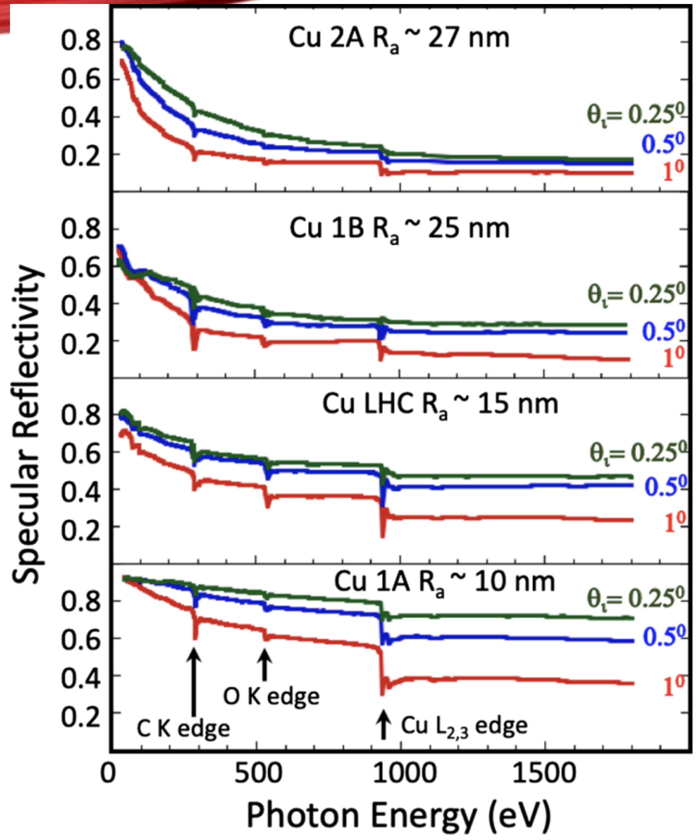


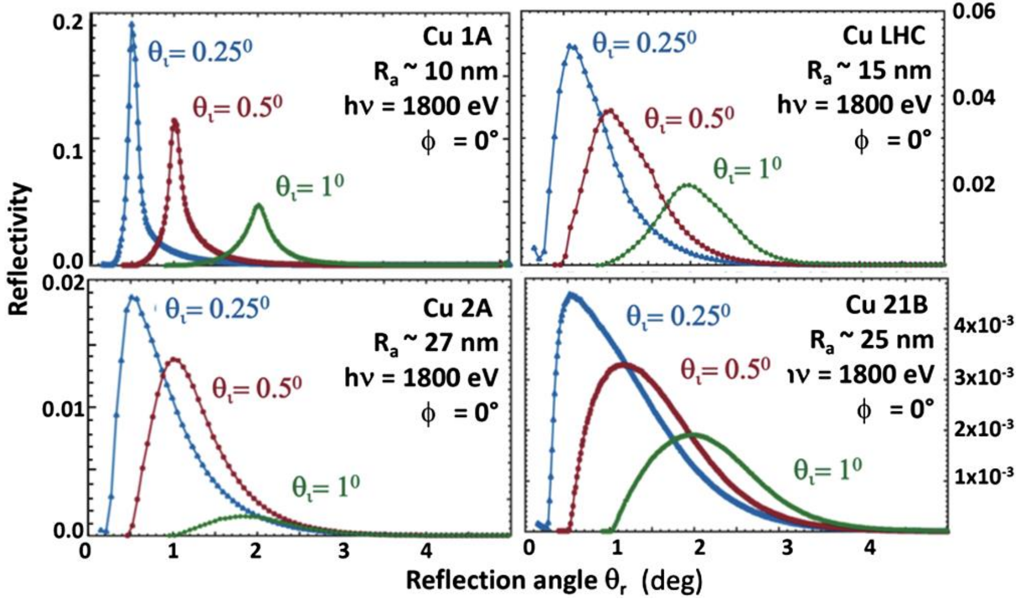




Reflectivity:

Some representative results for Cu with different Roughness



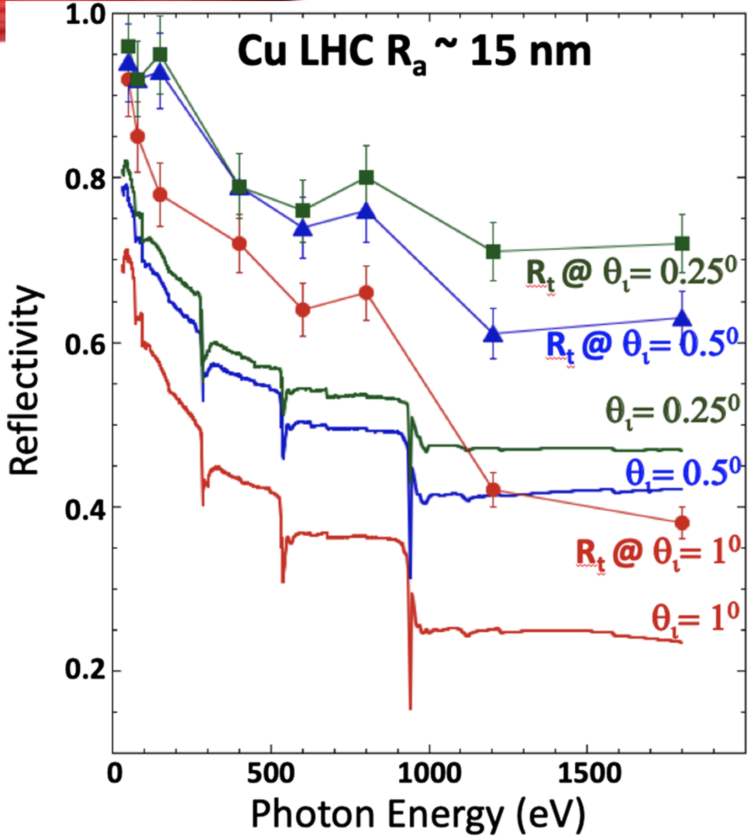


The highest the roughness the more photons gets scattered outside geometrical reflection

E. La Francesca Et Al. Phys. Rev. Accel. Beams 23, 083101 (2020)

Reflectivity:

Total reflectivity ≠ Specular reflectivity



The very low angle of incidence significantly increase the number of photons reflected (either specularly or diffused) that will be staying into the vacuum system producing:

- Photon induced desorption
- Photon electrons
- Etc.

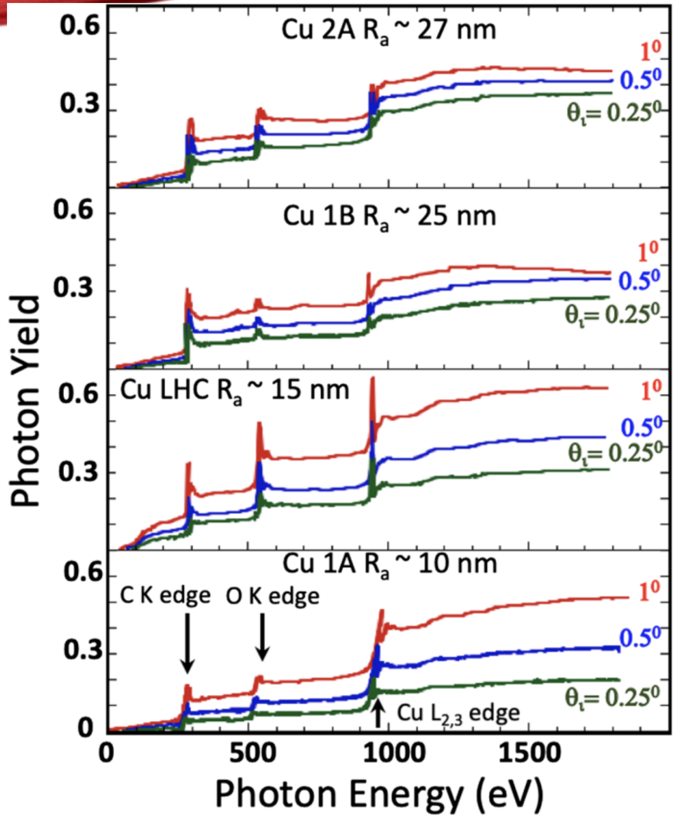
Ray tracing them may be essential to know where such photons will actually hit the vacuum vessel and generate el. and gas desorption.

Need to study this effect at higher Photon energies and on realistic geometry and materials

E. La Francesca Et Al. Phys. Rev. Accel. Beams 23, 083101 (2020)

Some representative results for Cu with different Roughness

Photon Yield



E. La Francesca Et Al. Phys. Rev. Accel. Beams 23, 083101 (2020)

- PY (mildly) depends on the **material composition** (absorption edges) **surface roughness**, (more) on the **incident angle** and (significantly) on the **incident photon energy**.
- The more energetic the photons the more electrons are produced
- BUT also, the more they penetrate into the solid.
- →The electrons they produced do not travel enough to reach the surface and do not contribute to PY
- Given the very grazing angle, (~7 times higher than in FCC-ee) we did not see the expected decrease in PY with increasing photon energies.
- Need a wider photon energy range and lower incidence angle.

Unfortunately, it is difficult to extrapolate the results obtained in the energy range available (35 - ~ 1800 eV) and at the minimal grazing incidence angle achievable at BESSY2 to an energy range and angle of incidence of relevance for FCC-ee.

- Similar experiments at dedicated Synchrotron radiation centres can be done to obtain results in a much wider (higher) energy and (lower) incidence angle range.
    - Relevant to FCC-ee.

SEY for e-cloud studies

- Much work has been done for LHC and code results are directly compared with machine performances with great efficiency and success.
- Parametrised SEY curves are used in simulations. They do take into account only δ_{max} - E_{max} variation during operation (scrubbing etc.)
- Ideally, rather than using parametrised SEY curve (which may depends on the parametrization used) using realistic and measured SEY curves (and their actual dependence on operation) will improve the simulation validity.
- If this is worth the effort and the much more time consuming computational time is still under debate.
- For sure, SEY curves can be measured very accurately in many laboratories and at CERN and than used for more accurate simulations.

Conclusion

- FCC – ee, being at RT seems less challenging for material choice and performance than LHC and FCC-hh.
- Still, some peculiarities as due to **impedance issues, dust, High power and energy of SR** produced, **Vacuum** requests, etc. still require some significant R&D.
- The path indicated during "EuroCircol" collaboration (FCC-hh) is still valid and the experimental procedures used to fully characterize LHC and FCC-hh BS material can be successfully adapted for FCC-ee R&D.
- Material choice can indeed be performed and optimized by simulations based on measured experimental parameters from realistic material and material surfaces.
- A material/surface characterization campaign should be agreed and launched.

Thank you for your attention

Thanks to the low temperature team at LNF:
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Tanks to the technical support of DAΦNE-L Team:
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Ecloud 18→ https://agenda.infn.it/event/13351/

We planned to reconvene in 2021 but we decided to plan **ECLOUD22** from **25 to 29 September 2022** in La Biodola (Elba Island).

We hope to see a numerous participation from the FCC community.