KEY VACUUM SURFACE PARAMETERS
FOR FCC-ee OPERATION

- 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).

V. Baglin et al. CERN-ATS-2013-006
The Vacuum beampipe at RT simplify the diagram.

<table>
<thead>
<tr>
<th>Function</th>
<th>Process</th>
<th>Design feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase time of transverse resistive-wall instabilities</td>
<td>Limit resistive wall instabilities - Impedance</td>
<td>High conductive material or coating (few) microns</td>
</tr>
<tr>
<td>Limit UFO</td>
<td>Structural material – vacuum compatible</td>
<td>Low Secondary El. and Photon Yield surface coating</td>
</tr>
<tr>
<td>Maintain (or produce) good beam vacuum</td>
<td>Reduce dust in the vacuum vessel</td>
<td>High adhesion Coating</td>
</tr>
<tr>
<td>Limit Development of electron cloud</td>
<td>Low el. Ion and photon induced degassing</td>
<td>Diffuse/active pumping</td>
</tr>
<tr>
<td>Stable and robust (also vs. radiation)</td>
<td>Low SEY, photon reflectivity and PY</td>
<td>Activation/back out</td>
</tr>
<tr>
<td>Cope with large SR power</td>
<td>Stable T operation</td>
<td>cooling</td>
</tr>
</tbody>
</table>
• 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)

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**

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.
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.

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.

In XPS:

\[
\begin{align*}
I_{\text{Cu}}^C &= (I_{\text{Cu,bulk}}^C) \times \exp(-d/\lambda_{\text{Cu,C}}) \\
I_C &= I_{C,\text{bulk}} \times (1 - \exp(-d/\lambda_{\text{C,C}}))
\end{align*}
\]

where \(d\) is the unknown thickness and \(\lambda\) is the inelastic mean free path.

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

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.

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

\( \delta_{\text{max}}, E_{\text{max}} \) 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.

\( \delta_{\text{max}} (<1) \) and \( E_{\text{max}} \) are set after 6-8 nm of a-C

A thin (~ 10 nm) a-C surface coating could be applied to reduce SEY without having any (significant) impact on the impedance budget.
Clearly, for **NEGs** this reasoning does not apply since a too thin NEG layer will not grant a sufficient pumping reservoir. Optimization must follow.

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

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

FCC- SR incidence angle: 0.035 deg (0.62 mrad) ~ 21 m from source
Photon fan strip ~ 2mm
BESSY-II Optic Beamline and Reflectometer

Investigate from 35 to 1800 eV

At a minimum angle of incidence of $0.25^\circ$

(factor ~ 2 higher than for LHC)

(factor ~ 7 higher than for FCC!)
Two adopted experimental configurations:

Some representative results for Cu with different Roughness

Reflectivity:

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

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.

Some representative results for Cu with different Roughness

- Photon Yield

- 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 $\delta_{\text{max}}$ - $E_{\text{max}}$ variation during operation (scrubbing etc.)

• Ideally, rather than using parametrised SEY curve (which may depend 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: M. Angelucci, A. Liedl, R. Larciprete e L. Spallino.

Tanks to the technical support of DAΦNE-L Team: A. Grilli, M. Pietropaoli, A. Raco, V. Tullio, V. Sciarra and G. Viviani

Thanks to EuroCirCol project and to its scientific community

Thanks to MICA supporting project funded by INFN-SNC5

Thanks to CERN-INFN bilateral agreement KE3724/TE/HL-LHC-Addendum No. 4 to Agreement TKN3083
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.

Ecloud 18→ [https://agenda.infn.it/event/13351/](https://agenda.infn.it/event/13351/)