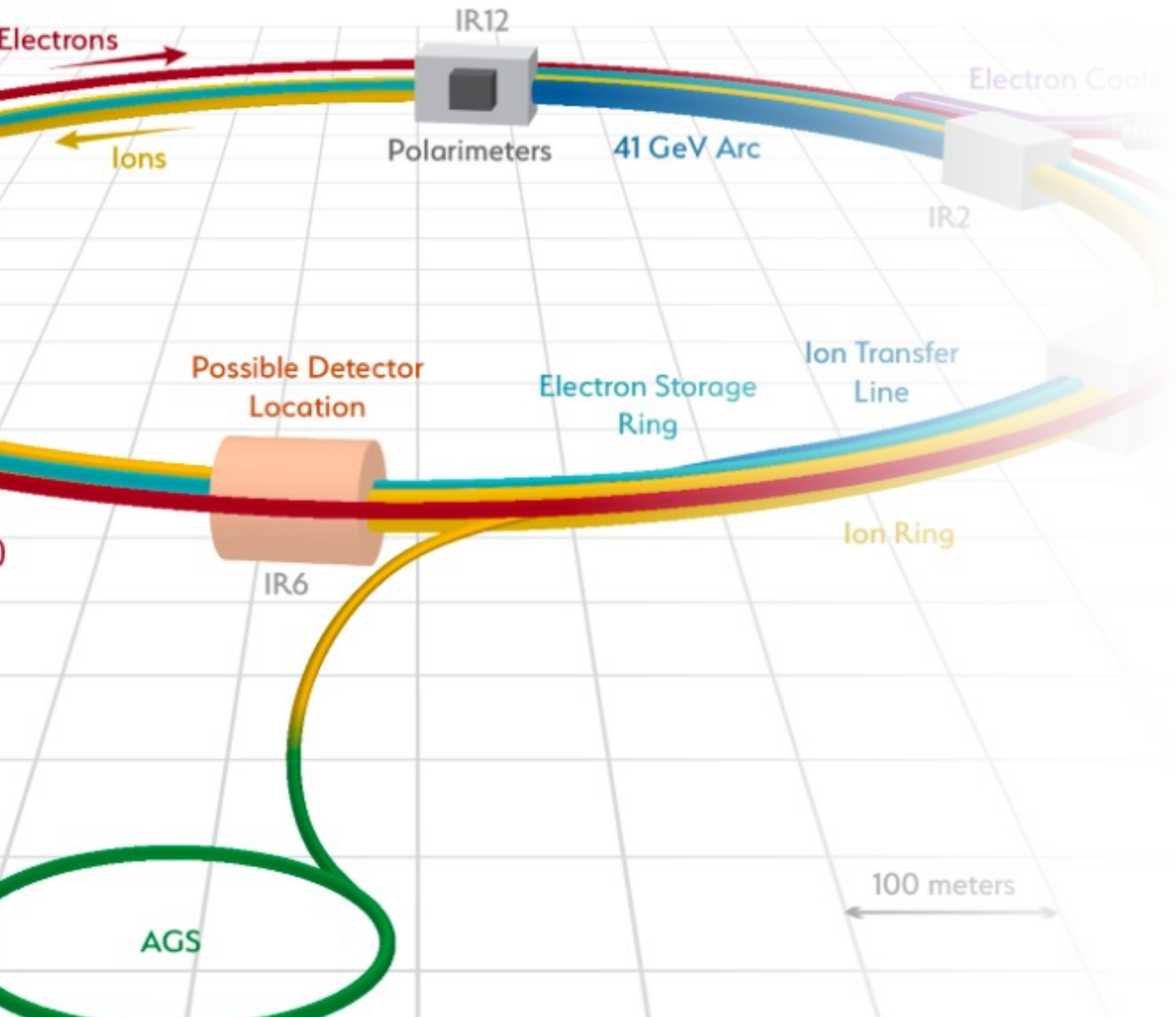

Electron and (photo stimulated) desorption at cryogenic temperatures

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EIC Accelerator Partnership Workshop 2021

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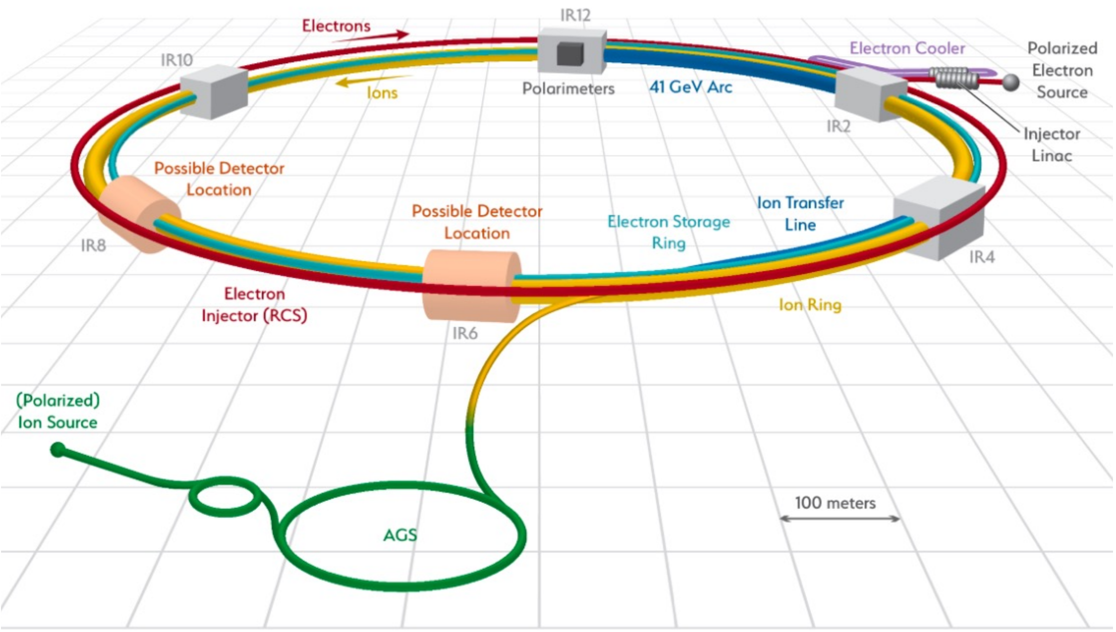


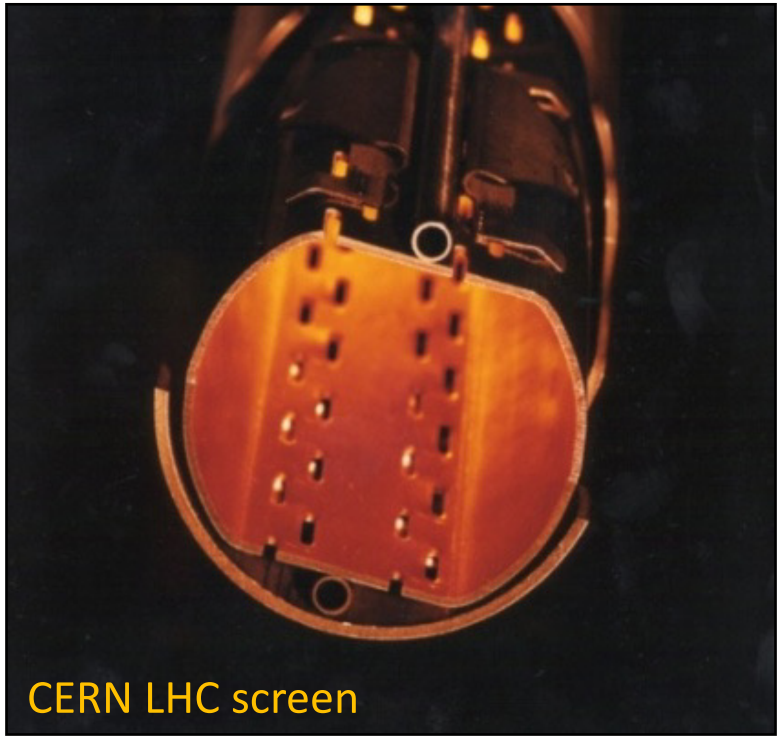
Photodesorption acts only in the electron ring at RT

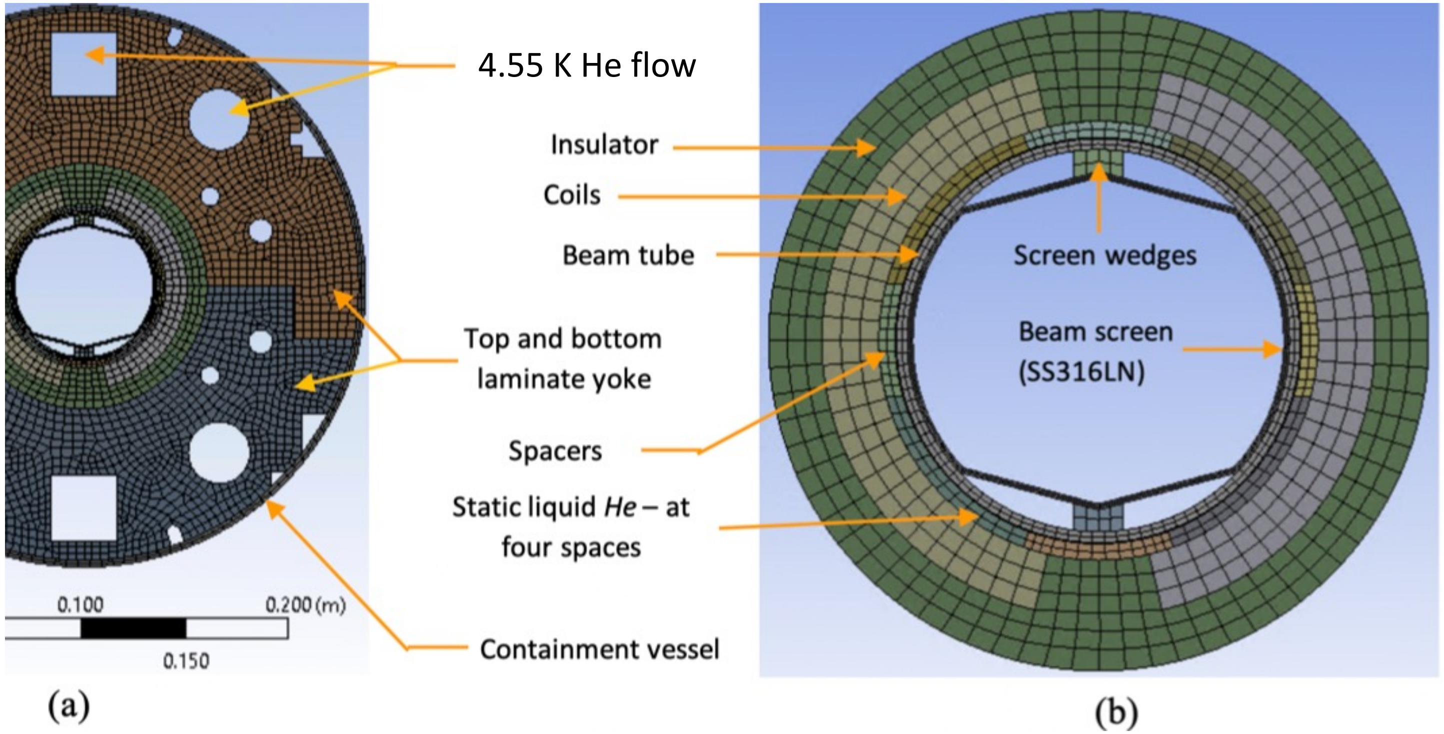
Table 1.1: Maximum luminosity parameters.

Parameter	hadron	electron
Center-of-mass energy [GeV]	104.9	
Energy [GeV]	275	10
Number of bunches	1160	
Particles per bunch [10^{10}]	6.9	17.2
Beam current [A]	1.0	2.5
Horizontal emittance [nm]	11.3	20.0
Vertical emittance [nm]	1.0	1.3
Horizontal β-function at IP β_x^* [cm]	80	45
Vertical β-function at IP β_y^* [cm]	7.2	5.6
Horizontal/Vertical fractional betatron tunes	0.228/0.210	0.08/0.06
Horizontal divergence at IP $\sigma_{x'}^*$ [mrad]	0.119	0.211
Vertical divergence at IP $\sigma_{y'}^*$ [mrad]	0.119	0.152
Horizontal beam-beam parameter ξ_x	0.012	0.072
Vertical beam-beam parameter ξ_y	0.012	0.1
IBS growth time longitudinal/horizontal [hr]	2.9/2.0	-
Synchrotron radiation power [MW]	-	9.0
Bunch length [cm]	6	0.7
Hourglass and crab reduction factor [17]	0.94	
Luminosity [10^{34} cm^{-2} s^{-1}]	1.0	

EIC HSR Beam Screen should grant:

- Low impedance to limit dynamic heat load to the cryogenic system and to avoid impedance-driven instabilities.
- Adequate vacuum level and stability
- Control of e-cloud build-up





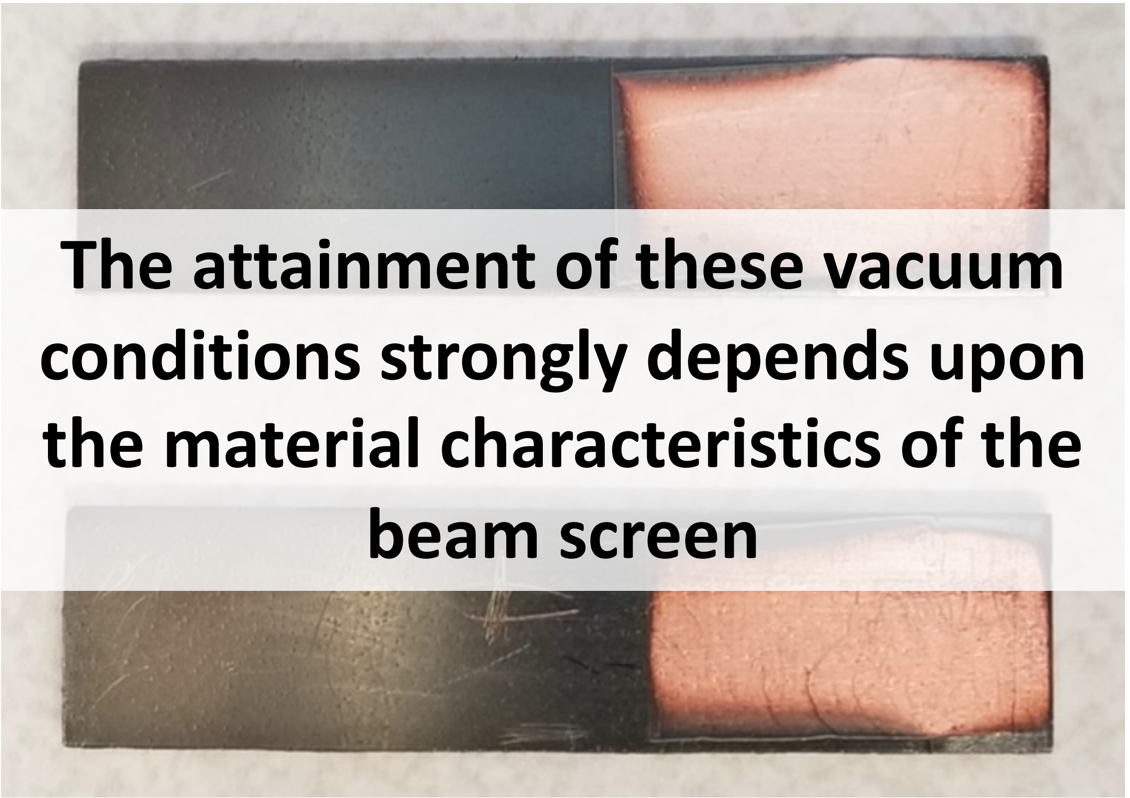
Vacuum level and stability in the Hadron Storage Ring

To preserve the beam lifetime and contain emittance growth, a low static and dynamic vacuum level in the EIC hadron beampipe is very important.

10^{-11} Torr (2×10^{7} molecules/cm^{3})
mainly H_2 and He

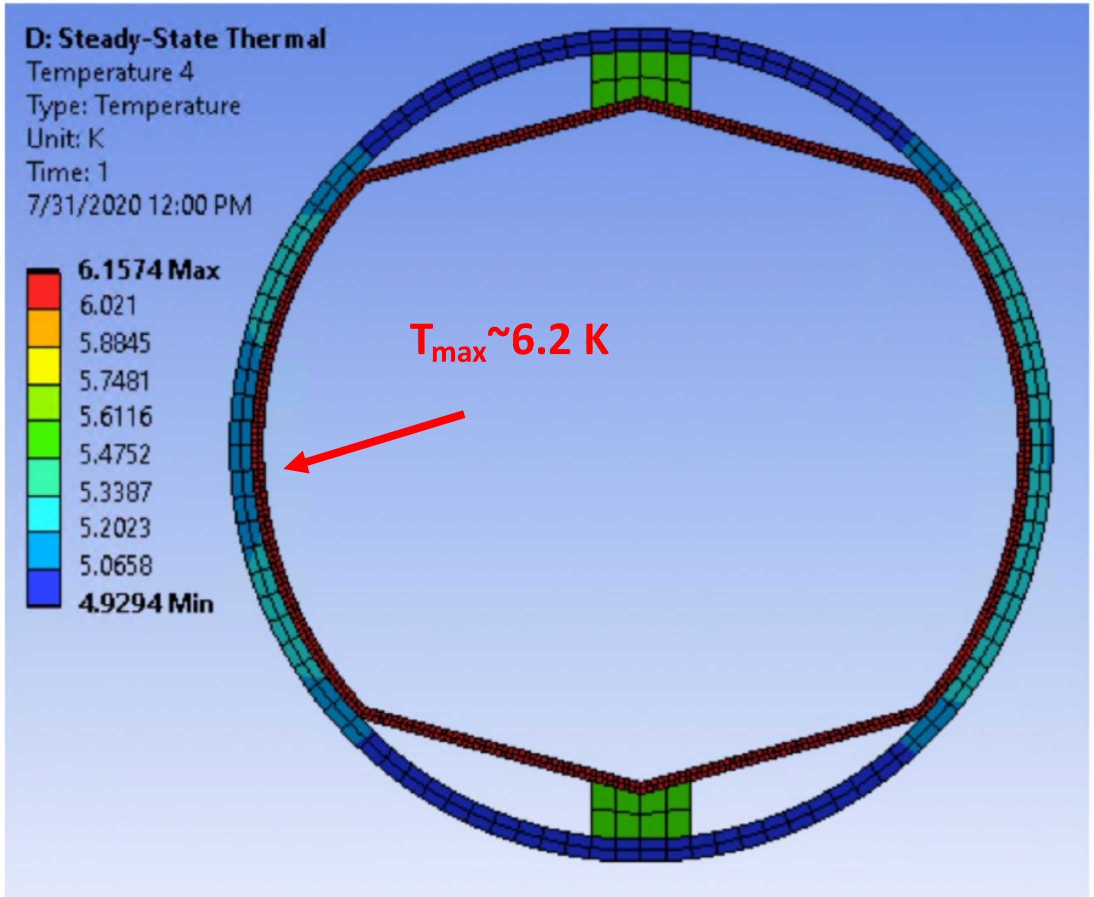
↓

Beam lifetime ~240 hours



The attainment of these vacuum conditions strongly depends upon the material characteristics of the beam screen

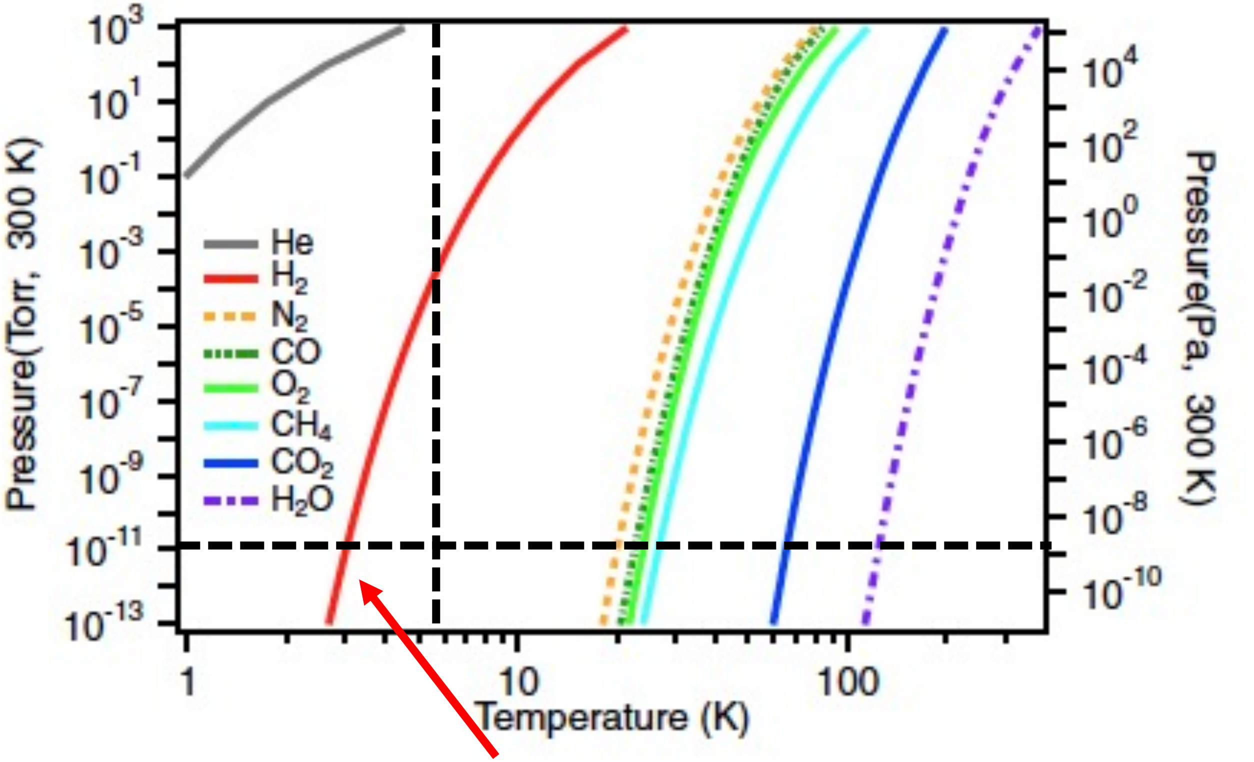
BS at cryogenic temperature



Thermal simulation for the beam screen in the Hadron Storage Ring of EIC considering a RW heat load of 0.5 W/m after including magneto-resistance, beam offset, a-C film, and screen geometry effects. (From EIC CDR 2021)

Residual gas adsorption on the beam screen walls

Saturated vapour pressure curves from R. E. Honig and H. O. Hook, RCA Rev. 21, 360 (1960)

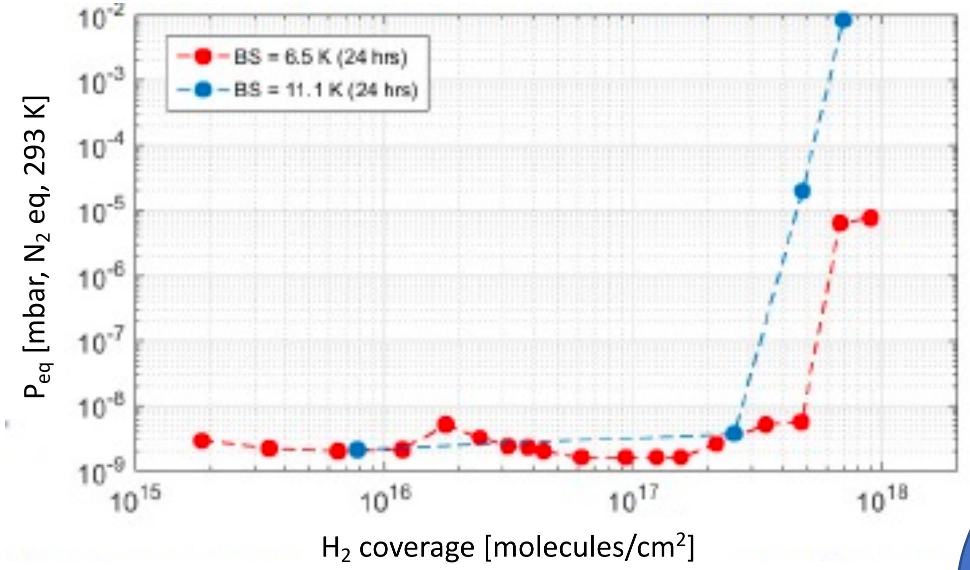


How can Hydrogen be pumped?

CERN (2016) a-C coating at cryogenic temperature

Improvement of the cryogenic vacuum performance

a-C H_2 adsorption isotherms at 6.5 K and 11.1 K

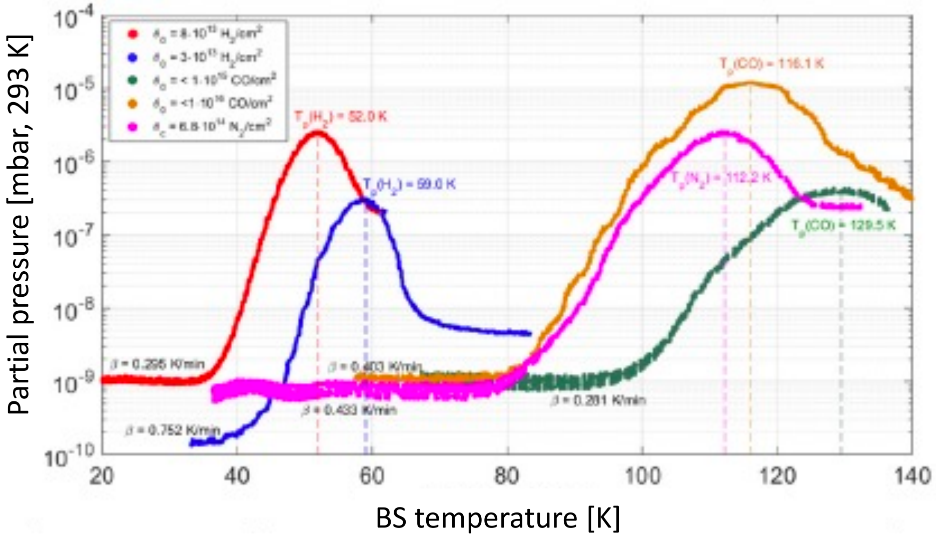


R. Salemme et al., Proceedings of IPAC2016, Busan, Korea

The CERN a-C film increases the adsorption capacity by a factor 100 (~10^{17} H_2/cm^2) compared to flat SS and Cu

Those results depend on surface morphology

TDS for H_2, N_2 and CO measured for a-C coating as function of θ_0 and β

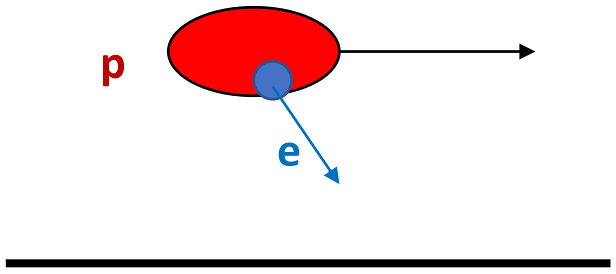


R. Salemme et al., Proceedings of IPAC2016, Busan, Korea

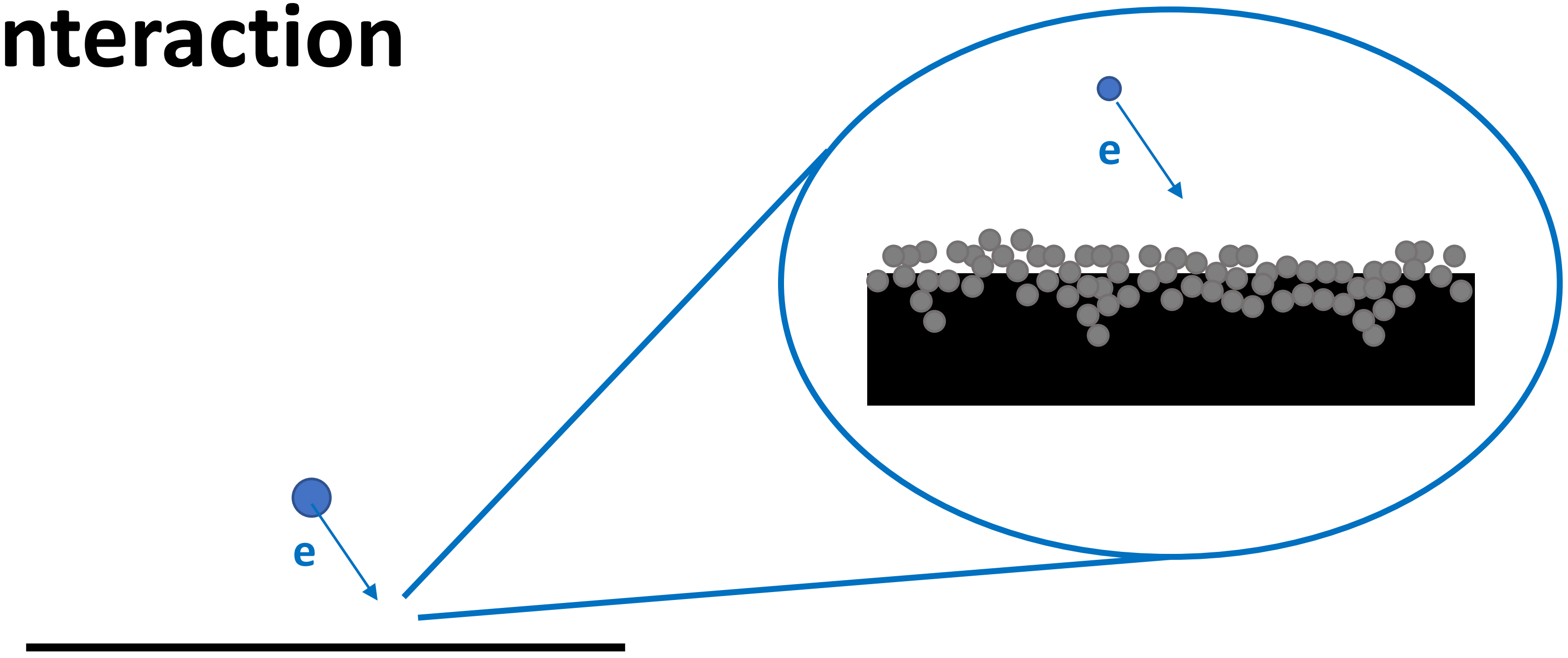
The CERN a-C film presents higher desorption temperatures for H_2 and CO, respectively, 30 and 60 K.

Electron-Surface interaction

1160 bunches
6×10^{10} particles/bunch



Beam ionizes
residual gas



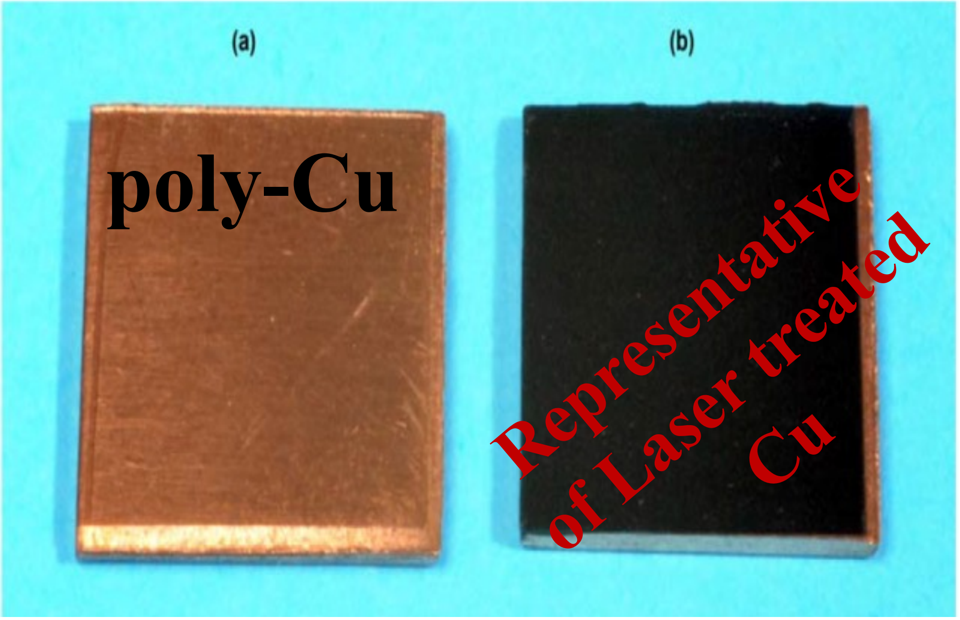
Electrons (also coming from e-cloud)
impact the beampipe

Electron Stimulated Desorption (ESD)

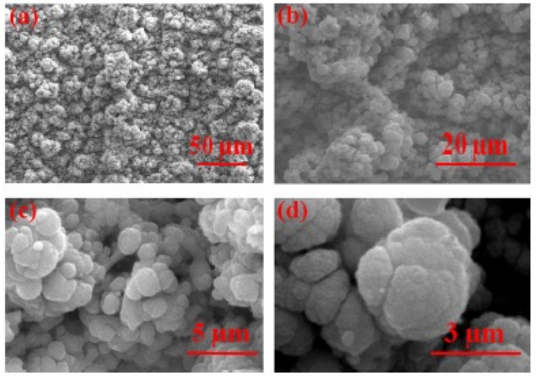
Is there an influence of the morphology?

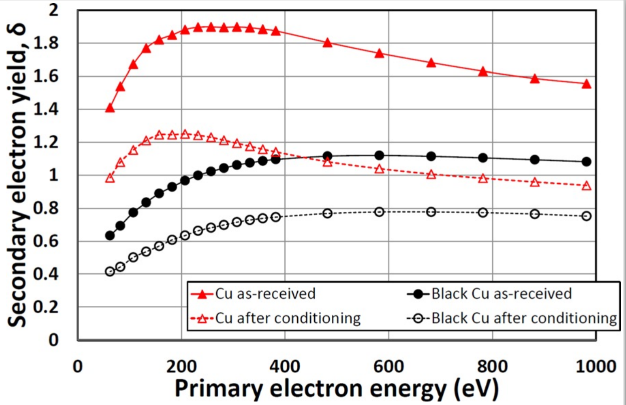
ESD from LASE-Cu for electron induced vacuum transient studies

Comparative study of ESD at 500 eV from different Ar doses delivered on flat poly-Cu and LASE-Cu samples



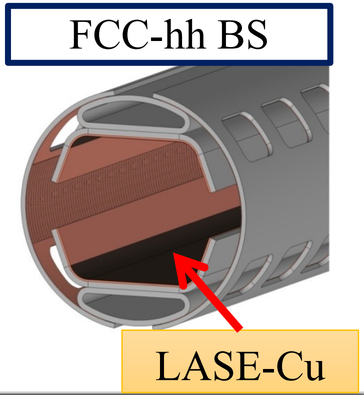
R. Valizadeh et al. , Appl. Surf. Sci. (2017)





L. Spallino et al. , Appl. Phys. Lett. (2019)

LASE-Cu substrate foreseen to be used in FCC-hh as optimum e-cloud mitigator (SEY<1)



ESD yield (η)

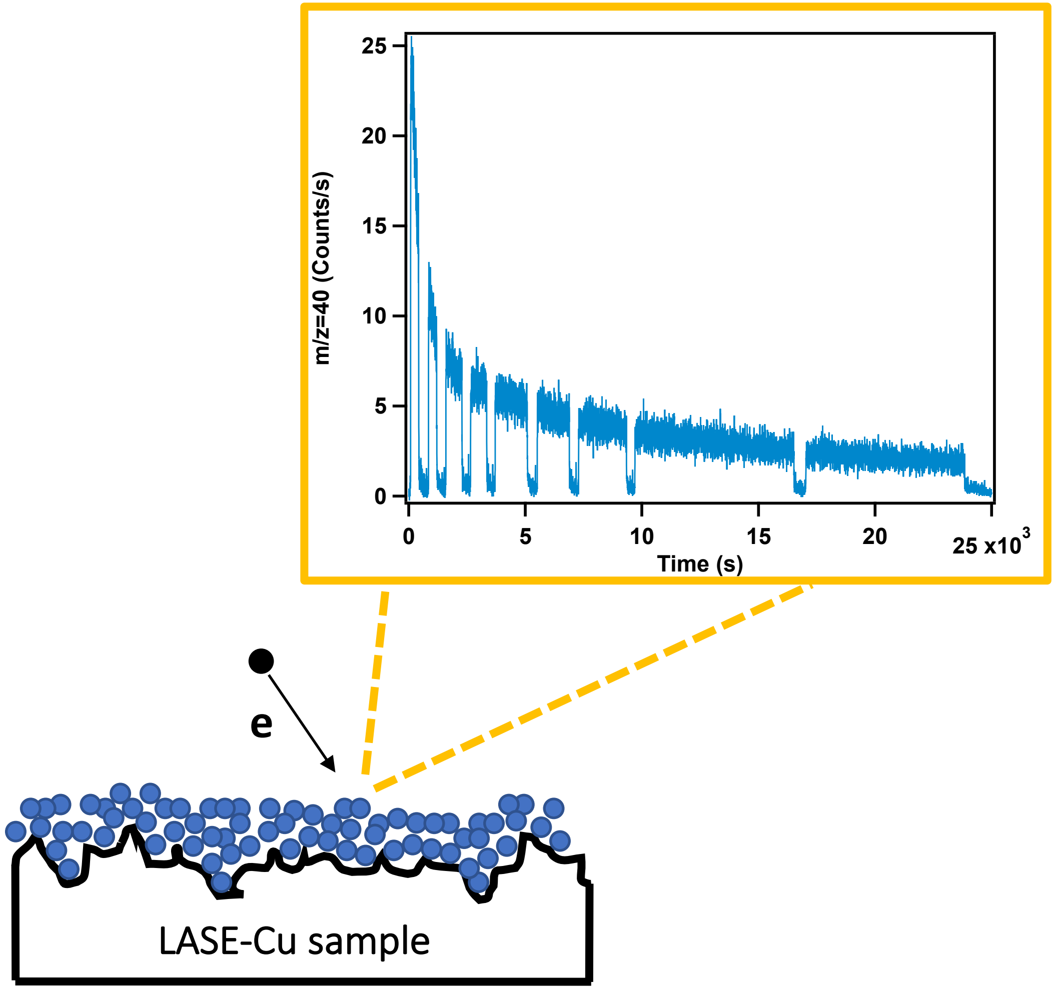
$$\eta = \frac{n_M}{n_e}$$

n_M → Number of desorbed species

n_e → Number of incident electrons

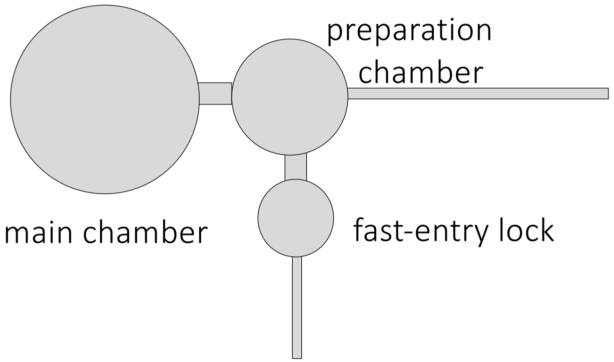
The direct determination of η is a non-trivial task, requiring:

- high sensitivity RGA measurements
- complex calibration procedures



Experimental set-up at LNF

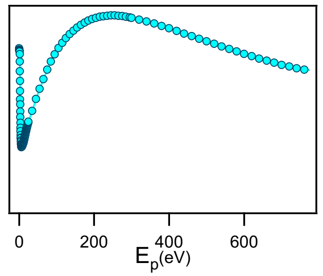
Ultra high vacuum systems

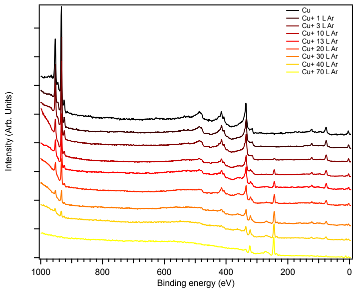


- LNF-cryogenic manipulator
- Sample at **15-300 K**

Secondary Electron Yield (SEY) measurements

Equipment : Electron gun, Faraday cup



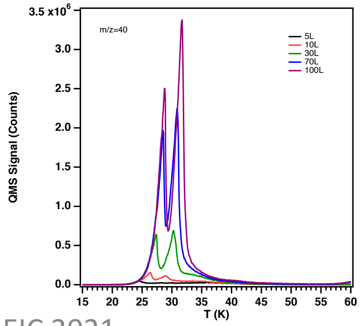


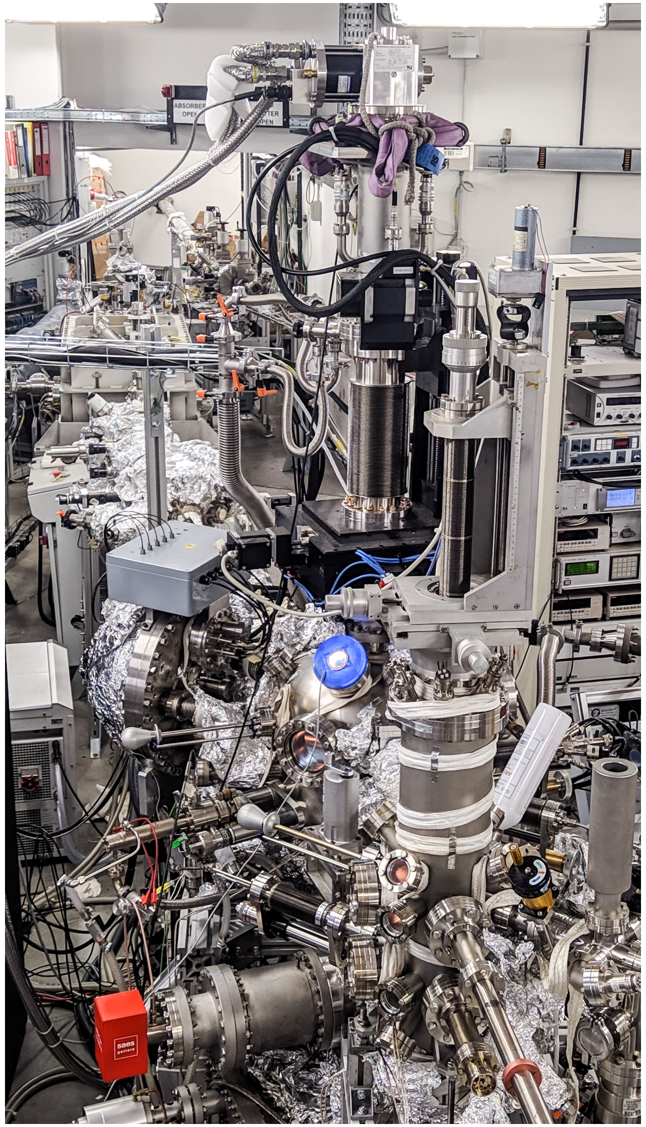
X-Ray Photoelectric Spectroscopy (XPS)

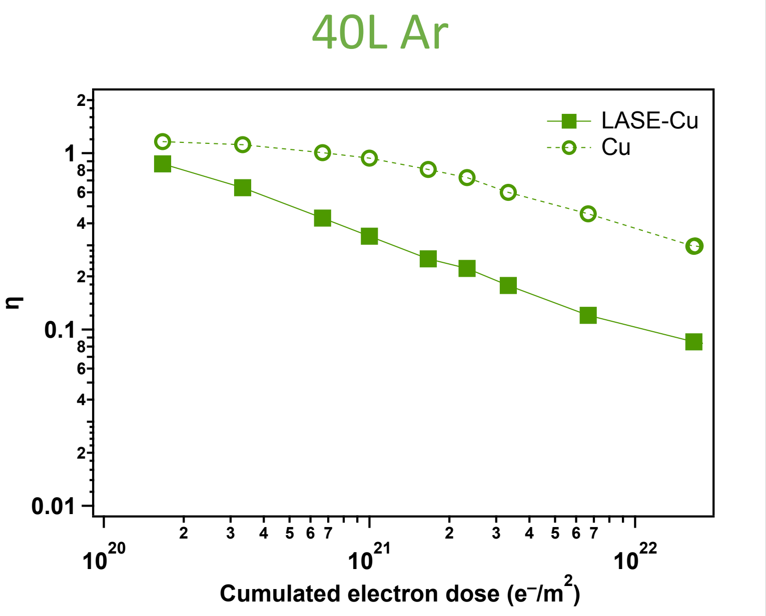
Equipment : Omicron EAC125 electron analyzer, Mg Kα source (hν = 1253.6eV)

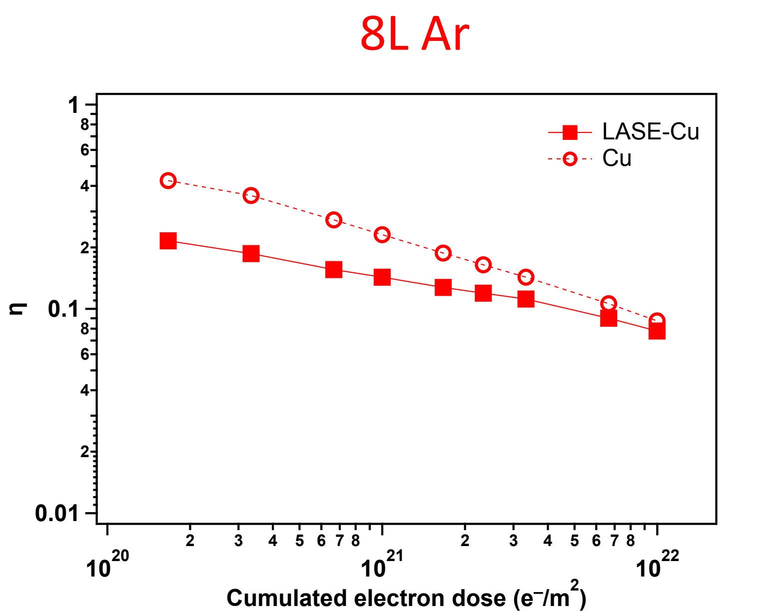
Temperature Programmed Desorption (TPD) and Residual Gas Analysis (RGA) measurements

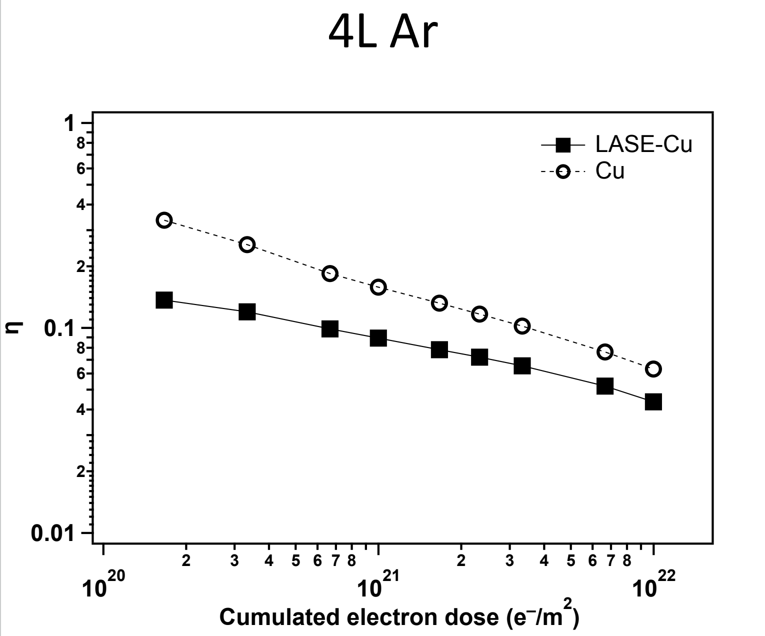
Equipment : QMS (Hiden HAL 101 Pic)







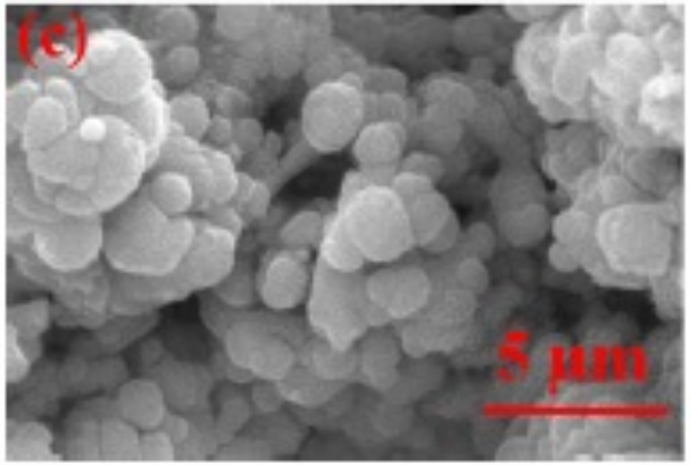




L. Spallino et al. to be published

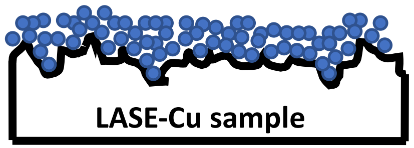
η from Cu is higher than η from LASE-Cu, in agreement with recent literature (A. N. Hannah et al. , Vacuum (2021))

LASE-Cu substrate



Morphological effects of porous surfaces

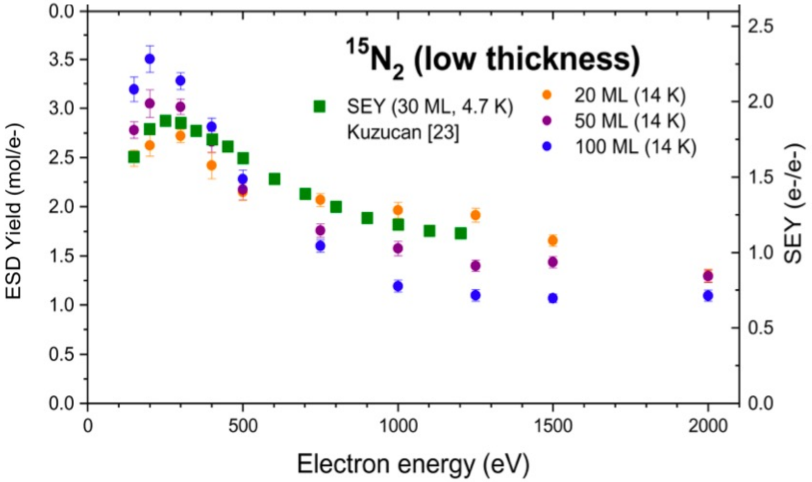
LASE-Cu samples have much greater physical area than that of untreated surfaces where to host gas



One should expect that porous surface adsorbs (desorbs) more than flat substrate

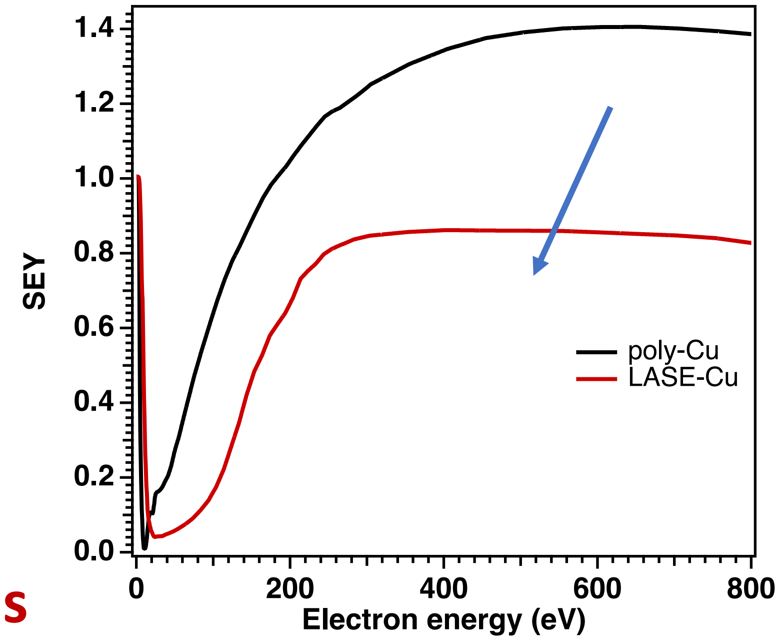
ESD is a surface process mainly governed by the transport of secondary electrons

R. Dupuy et al. , J. Appl. Phys. (2020)

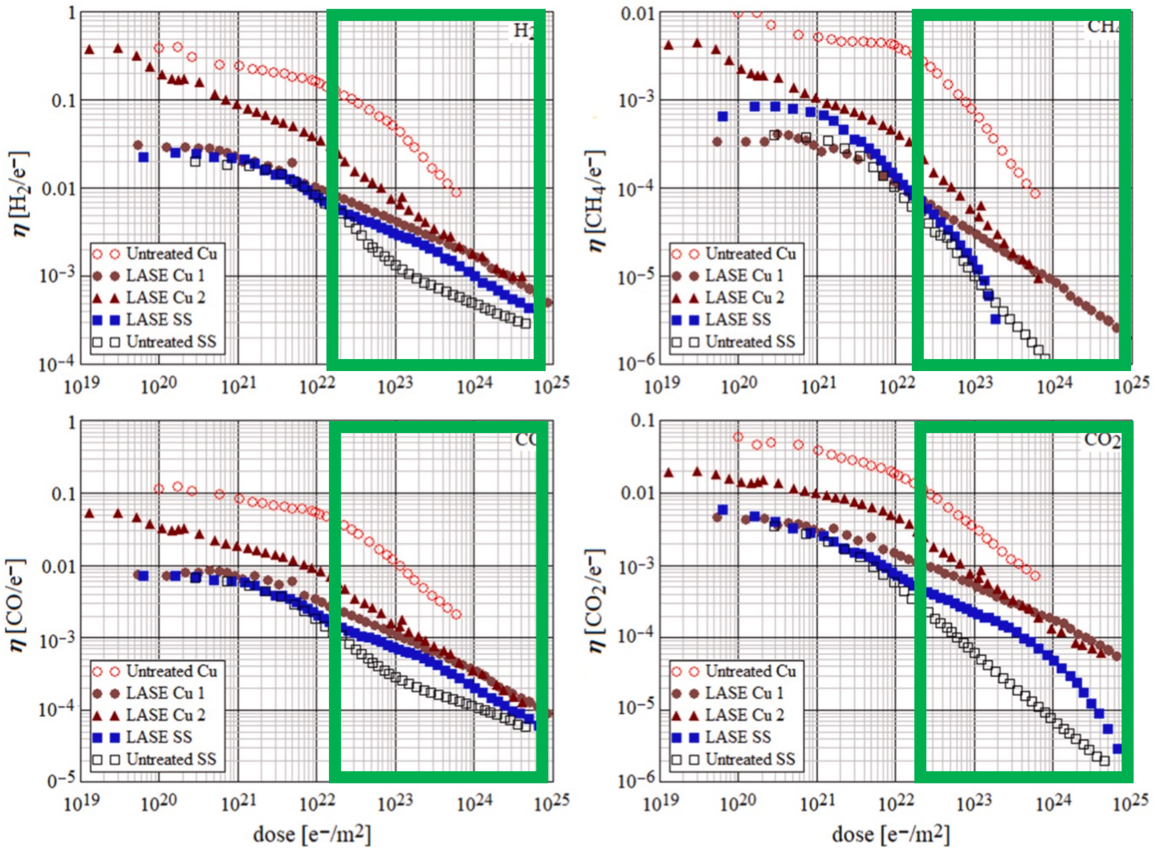


Electrons, both primary and secondary, are “trapped” by the highly porous structure thus leading to a very low LASE-Cu SEY

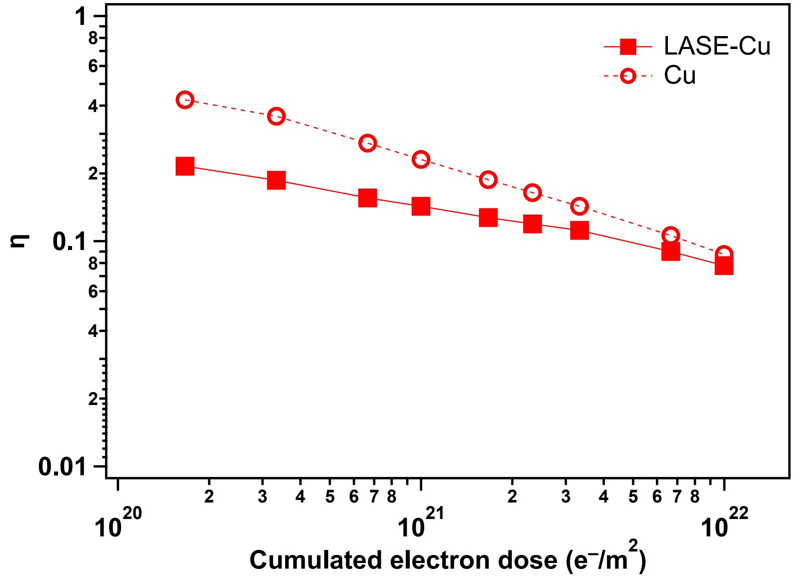
The lower the SEY, the lower ESD is



A. N. Hannah et al. , Vacuum (2021)



The difference in η decreases on increasing the electron dose (scrubbing)



From LASE-Cu the desorption is less efficient, but does it last longer?

Useful information for vacuum analysis during operation

Summary

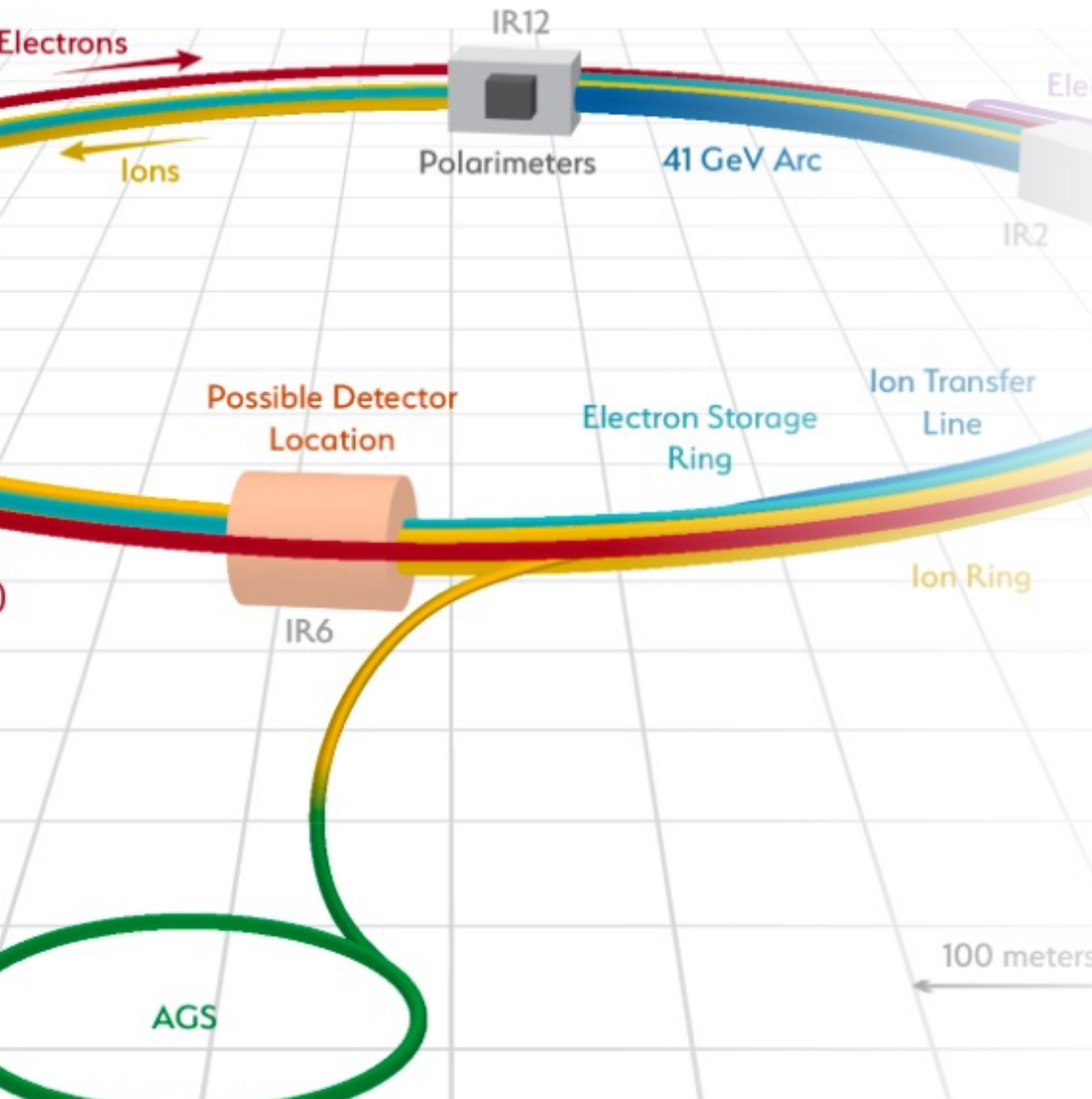
- Electron Desorption Yield of Ar condensed on the porous substrate is lower than the one observed from the same quantity of gas condensed on the flat counterpart.

- The Electron Desorption Yield from porous materials depends on the morphological features and on the high specific surface of the material.

- From the vacuum stability point of view, these aspects indicate an advantage for the use of porous materials in cryogenic beam screens where high-intensity bunches of protons favors the generation of a high number of electrons in the tube.

Open questions

- Long time exposure to electrons need to be studied to finally compare η form flat and porous materials.
- The study on Ar has singled out processes not involving gas-substrate chemistry. Further studies are mandatory with gas species (especially H_2) usually composing residual vacuum and with a realistic substrate mimicking a-C as grown for EIC. Dissociation or reaction may occur.
- Given the known reactivity among a-C and atomic H, one should study the atomic H presence and the induced reactivity.



Thank you for your kind attention

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M. Angelucci

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