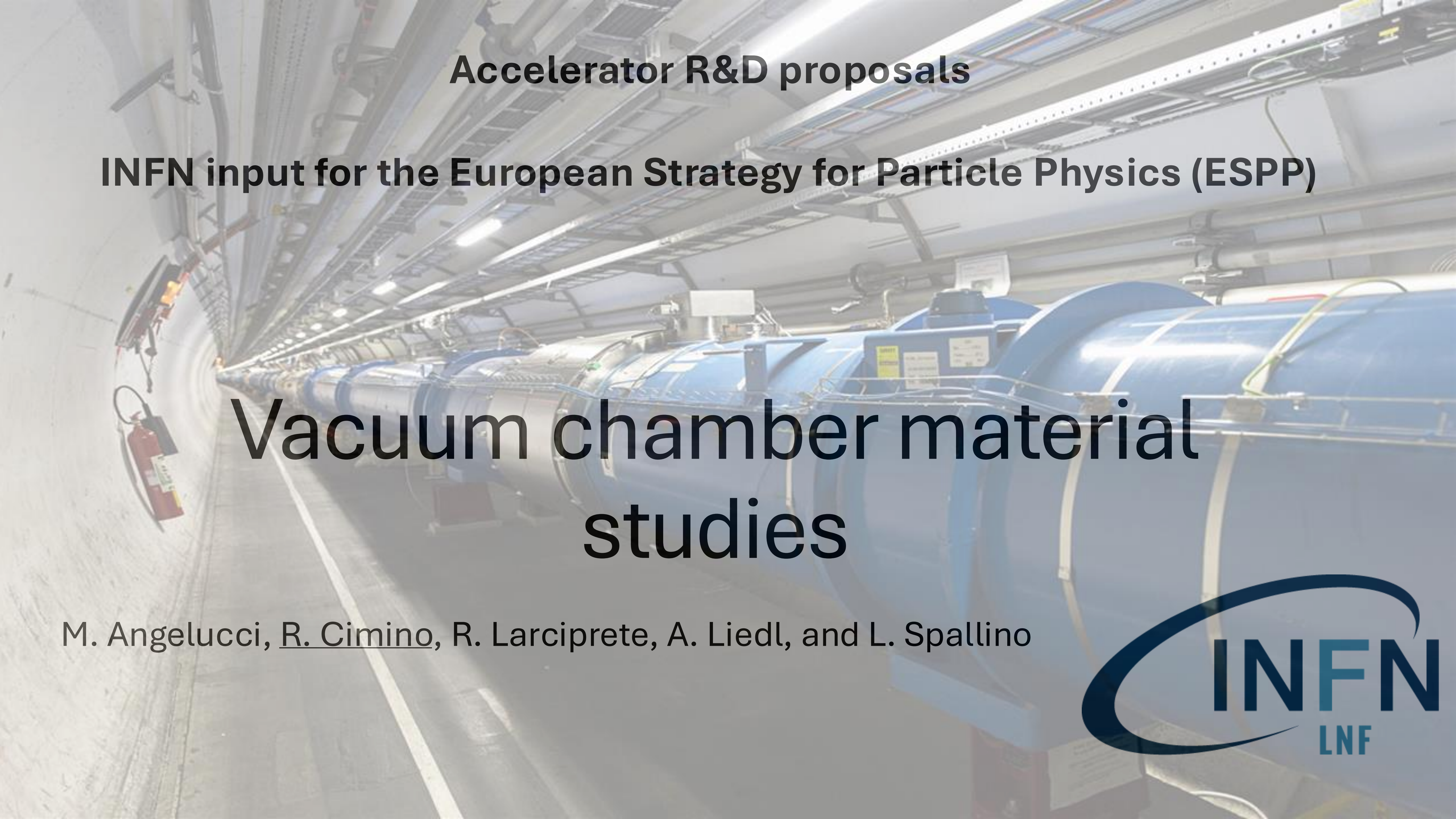


Accelerator R&D proposals

INFN input for the European Strategy for Particle Physics (ESPP)

Vacuum chamber material studies

M. Angelucci, R. Cimino, R. Larciprete, A. Liedl, and L. Spallino

INFN LNF

Vacuum is a ubiquitous item, of importance to all the accelerator projects discussed in the strategy.

Static vacuum:

- ✓ Pressure better than 10^{-9} mbar rapidly reached and stable
- ✓ Few pumps, no bake out (typically no space nor budget),
- ✓ Very low desorption yield
- ✓ High thermal conductivity
- ✓ High electrical conductivity
- ✓ No effect on the magnetic field!!
- ✓ Mechanically robust
- ✓ ….. And, of course, cheap!

- ➢ material choice
- ➢ Fabrication – Realization-Preparation
- ➢ Vacuum compatibility in static conditions

INFN LNF

Latino - Vacuum

1. **Thermal Treatments in UHV and Controlled Atmosphere**
2. **UHV Brazing**
3. **Outgassing Characterization**

At LNF we have a longstanding experience in static vacuum issues and a set of "state of the art" equipment to prepare and analyse materials to be used in UHV

the Latino – Vacuum Facility

UHV and HV Outgassing Test Facility

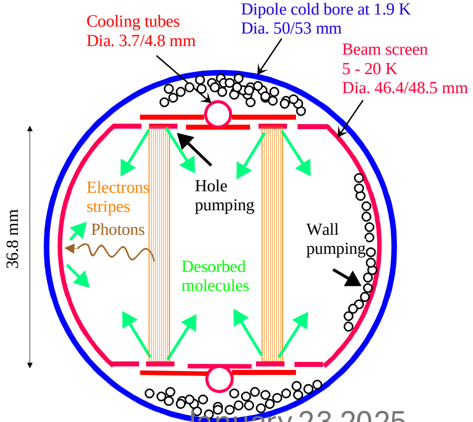
HV Furnace

A. Liedl

But: Vacuum walls interact with the beam!

accelerators walls **interact** with:

- Photons
- Electrons
- Ions



Effects

- Surface Modification (Chemistry)
- Secondary Electron Emission
- Electron Cloud
- Heat Load
- Gas Desorption

Advanced technological solutions tailoring the geometry and the material properties to the required performance

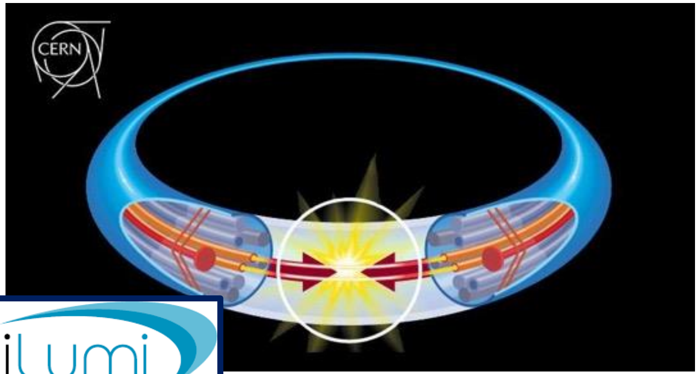
Fields of investigations:

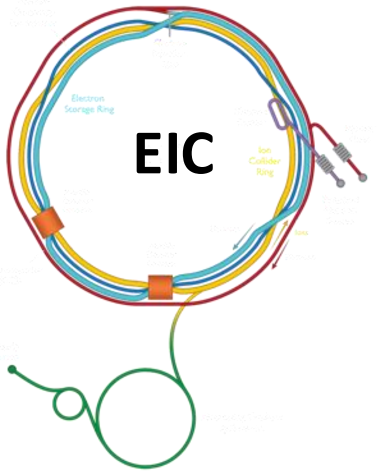
- Surface electronic properties
- Low Secondary electron materials
- Surface coatings
- Cryogenic Behavior
- Photon reflectivity

XUV - MaSSLab

1. **Surface Studies and characterization**
2. **Electronic properties**
3. **...**

The background



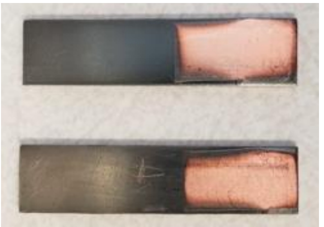


R&D Activities for particles accelerators

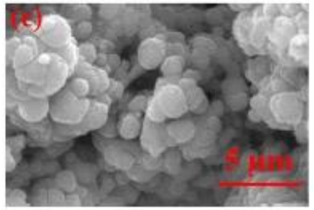
Studies on surface properties and on vacuum stability to validate materials' compliance with accelerators operating conditions.
Studies on effects induced on surfaces due to thermal and nonthermal interactions.

Specifically

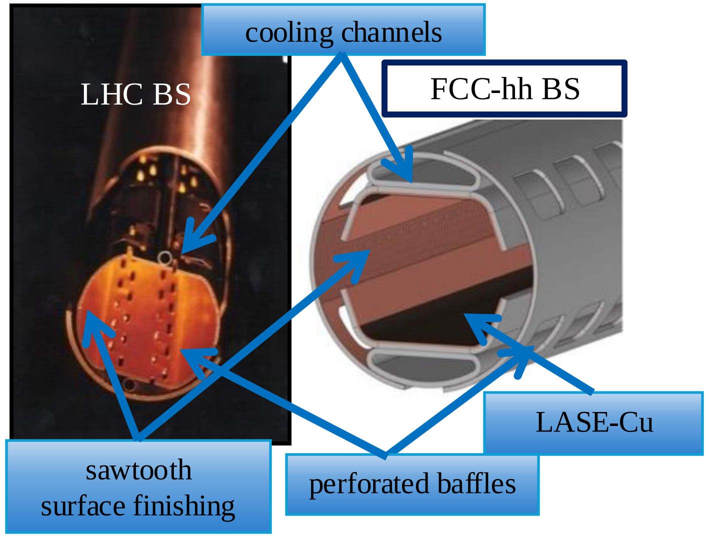
Beam Screen (BS) surface treatments to mitigate instability phenomena (thermal load, e-cloud,…) and **ensure adequate cryogenic vacuum level and stability**

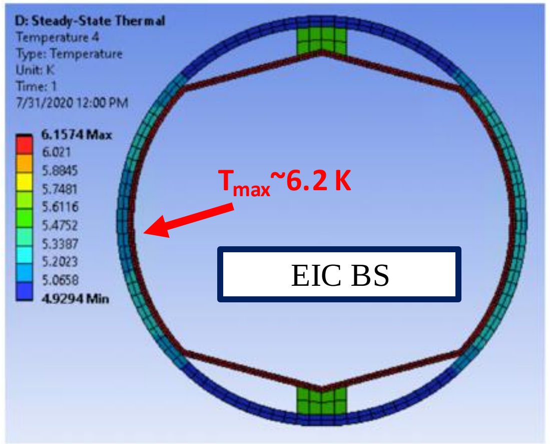


coating



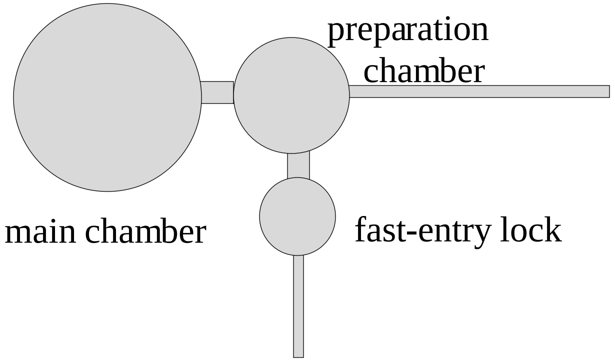
surface morfology modification





Experimental set-ups at LNF

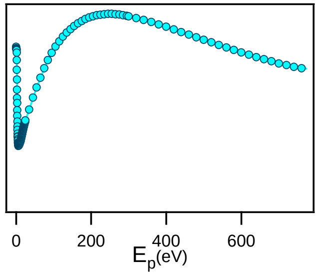
Ultra high vacuum systems

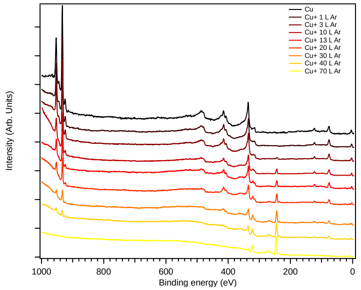


- LNF-cryogenic manipulator
- Sample at **15-300 K**

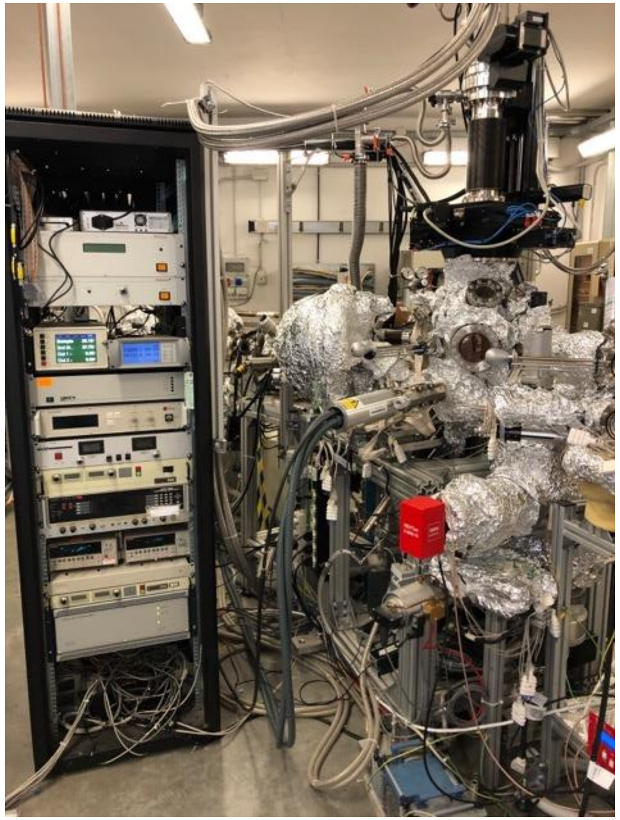
Secondary Electron Yield (SEY) measurements

Equipment : Electron gun, Faraday cup





X-Ray Photoelectric Spectroscopy (XPS) Equipment : Prevac & Omicron EAC125 electron analyzer, Mg/Al/Ag Kα sources



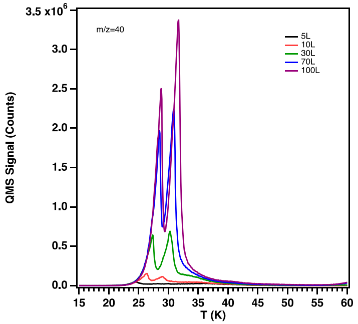
Raman Spectroscopy

Equipment: Horiba micro raman

CDV Deposition

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

Equipment : QMS (Hiden HAL 101 Pic)

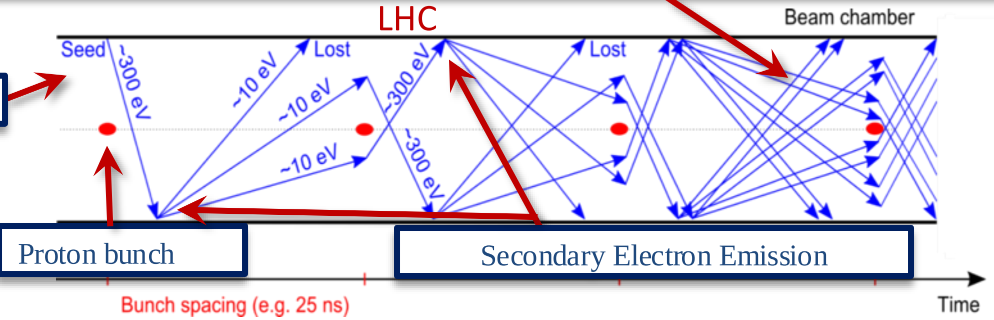


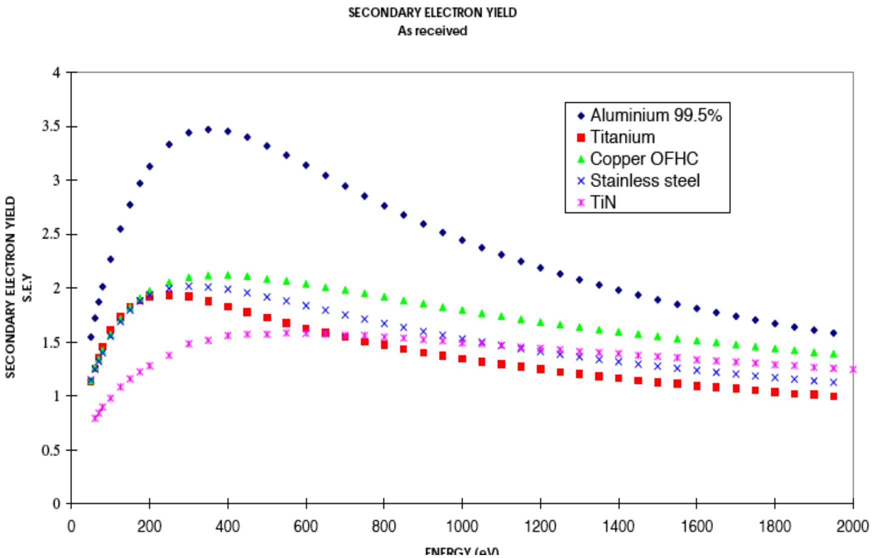
e-Cloud

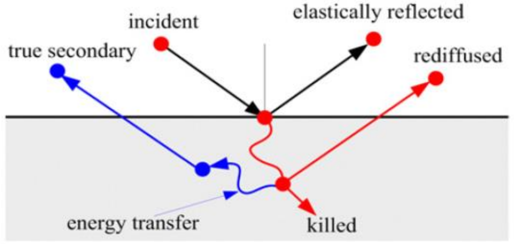
R. Cimino and T. Demma
"Electron cloud in Accelerators" Int. J. Mod. Phys. A 29 (2014) 1430023 (pag. 65).

Secondary Electron Emission can drive an **avalanche multiplication** effect filling the beam chamber with an **electron cloud**

e⁻ is emitted (photoelectric effect)







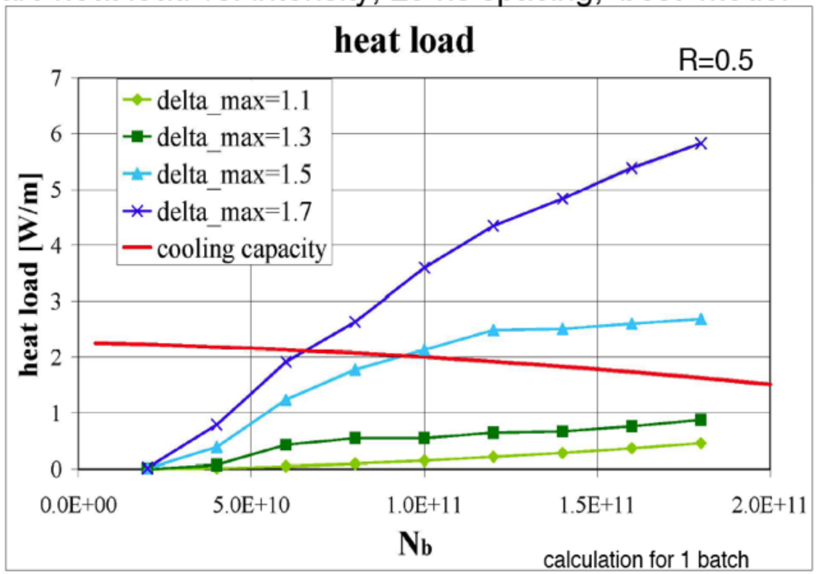
Secondary Electron Emission

$$SEY = \frac{I_{out}}{I_{in}}$$

Intrinsic property of materials, strongly dependent on the surface characteristics:

- chemistry
- adsorbates, even at sub-monolayer coverage
- morphology

arc heat load vs. intensity, 25 ns spacing, 'best' model

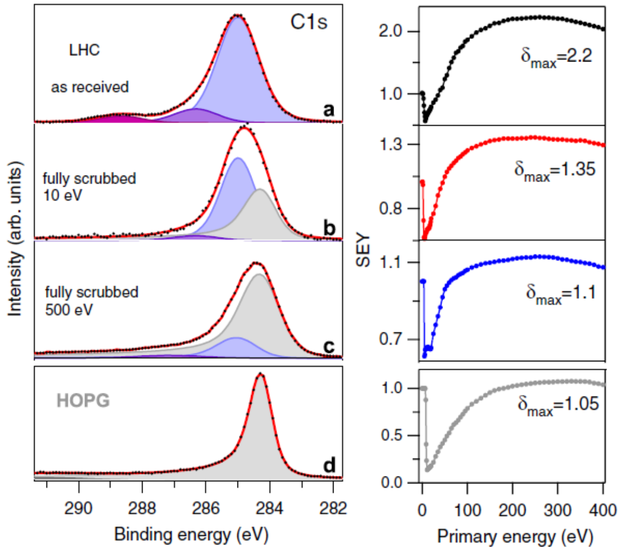


heat load for quadrupoles higher in 2nd batch; still to be clarified

Frank Zimmermann, LTC 06.04.05

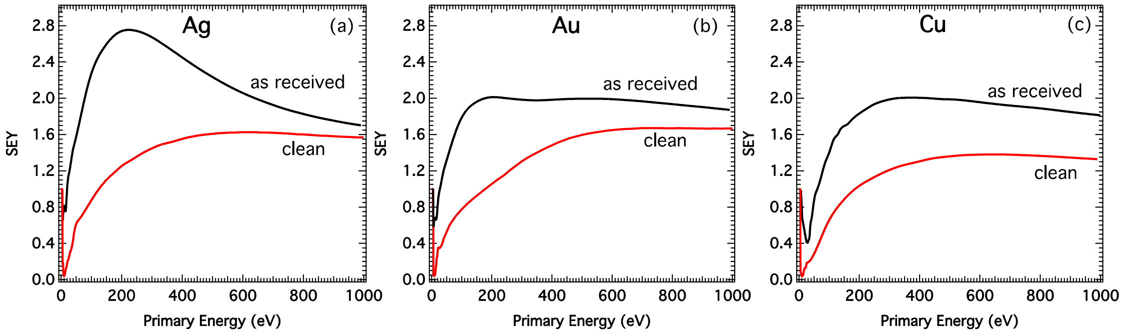
Secondary Electron Yield and Surface Properties

R. Cimino et al., Phys. Rev. Lett. (2012)



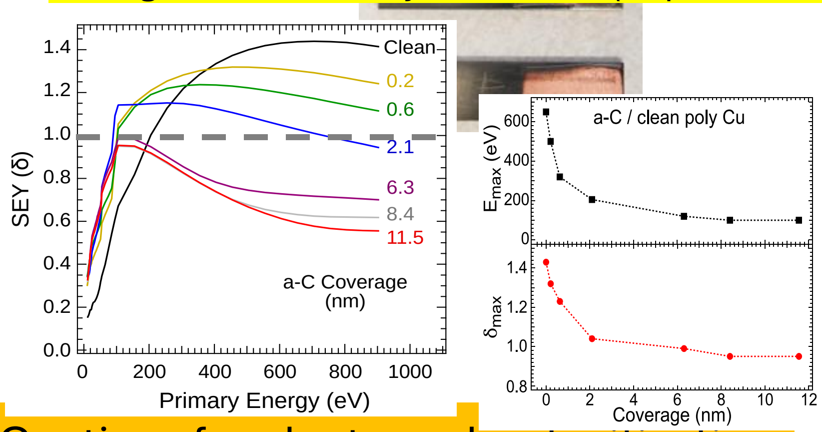
Surface conditioning with electrons

Differences between “As Received” and Atomically Clean Metals

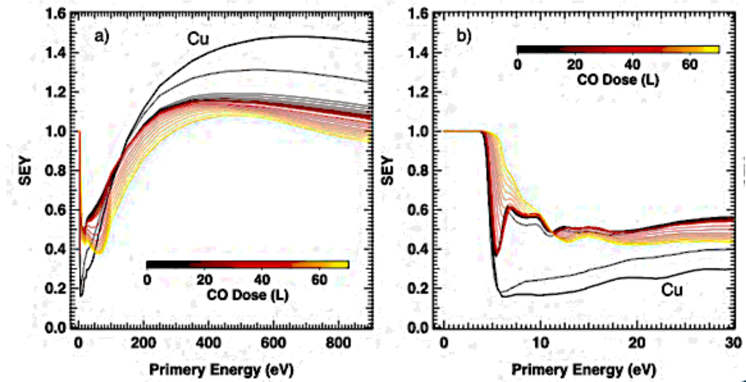


AIP Advances 7, 115203 (2017)

M. Angelucci et al., Phys. Rev. Res. (Rapid Comm.) (2021)



Coatings for electron cloud mitigation



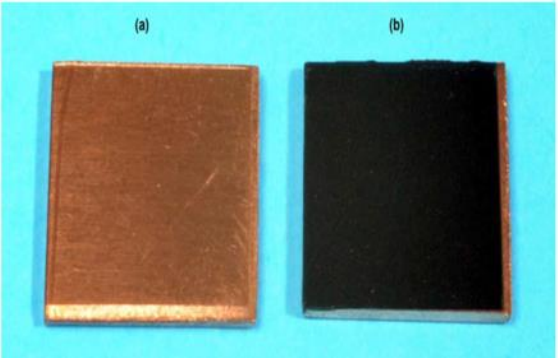
Studies at Cryogenic temperature (10 K)

Thermal Desorption

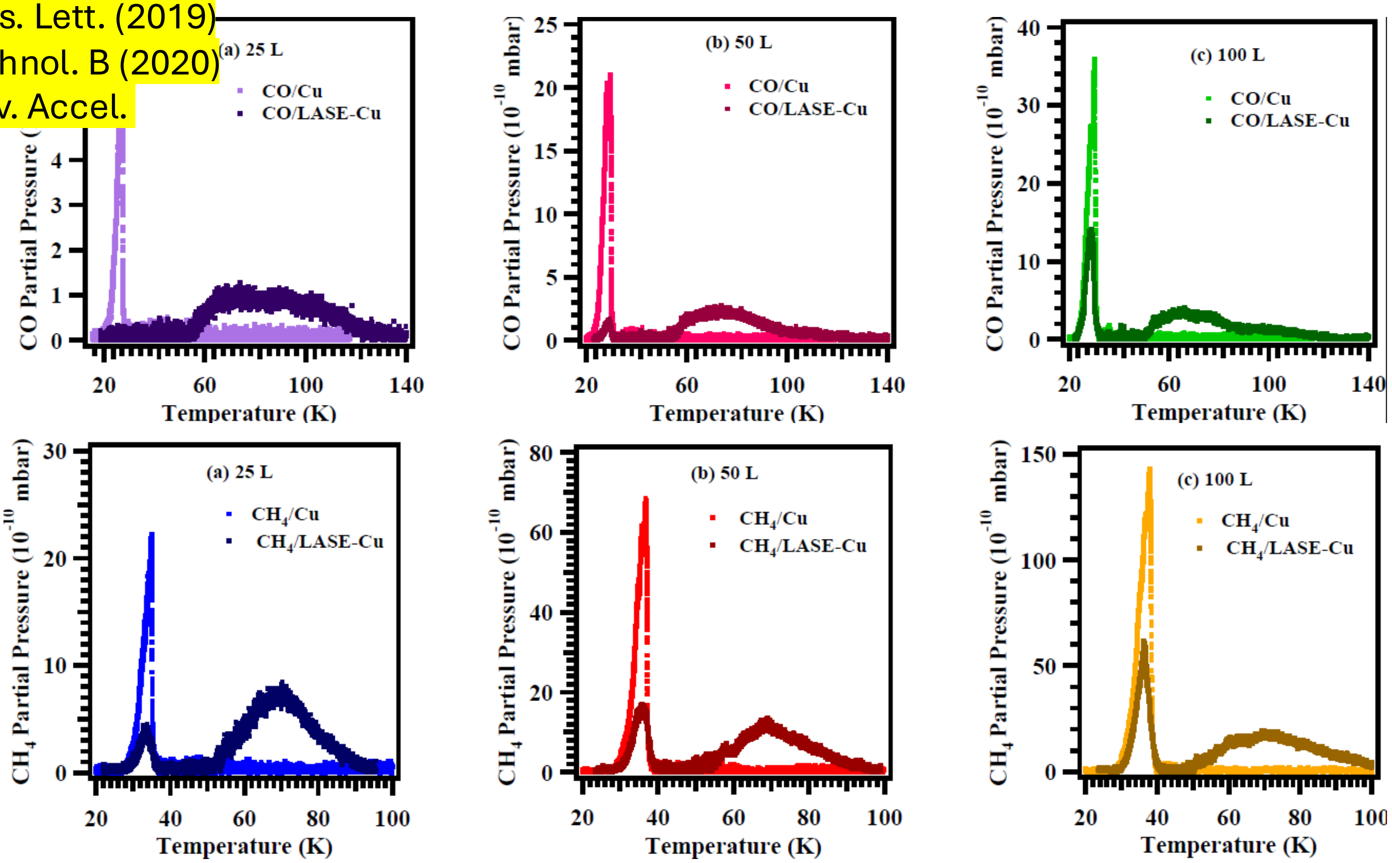
Comparative study of TPD from flat poly-Cu and LASE-Cu samples using different gases (Ar, CH_4 and CO)

poly-Cu

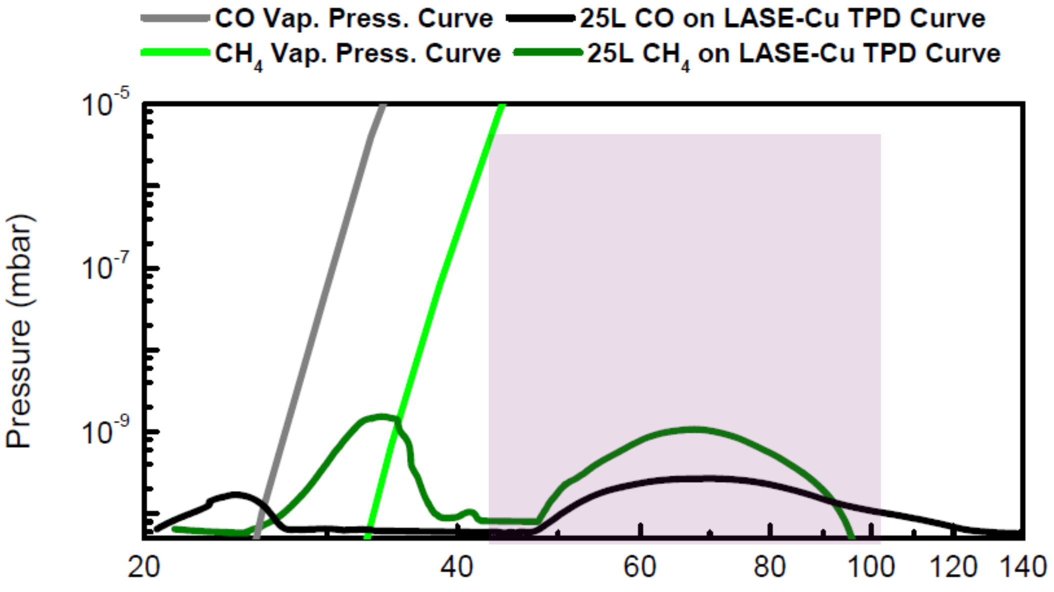
Representative of Laser treated Cu



L. Spallino et al. Appl. Phys. Lett. (2019)
L. Spallino, J. Vac. Sci. Technol. B (2020)
L. Spallino et al., Phys. Rev. Accel. Beams (2020)



Saturated vapour pressure from Honig and Hook (1960)

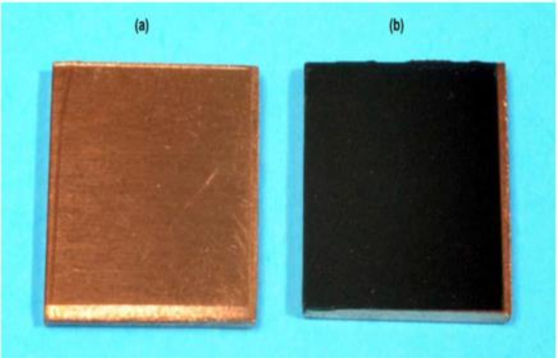


Further studies on this issue and on electron/photon stimulated desorption are necessary to completely <u>validate/optimize</u> LASE-Cu at low T.

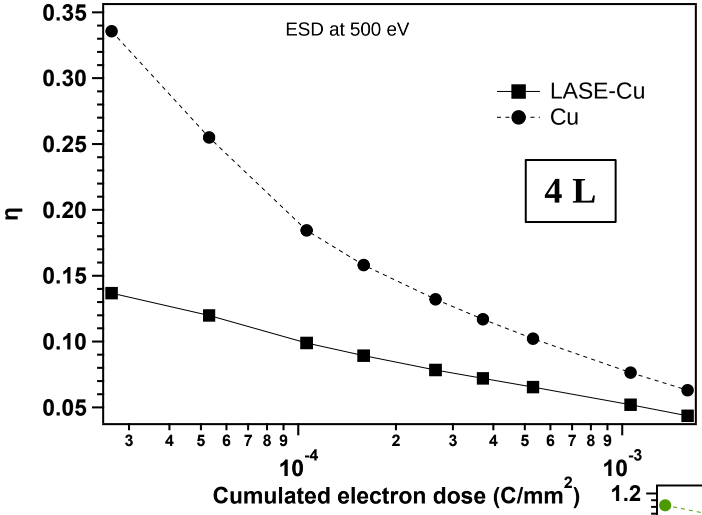
Electron desorption

poly-Cu

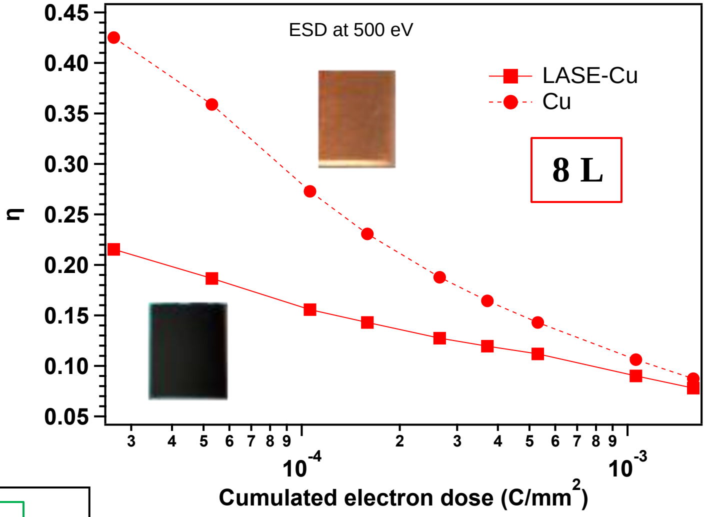
Representative of Laser treated Cu

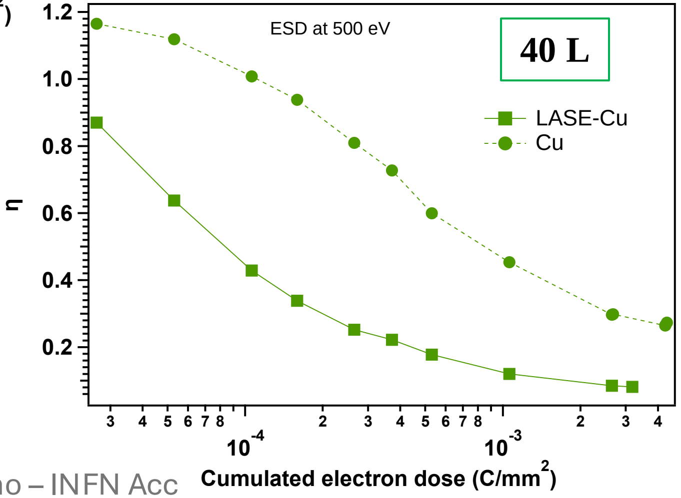


M. Angelucci, Il Nuovo Cimento 45 C, 198 (2022)



On increasing Ar dose





η from Cu is always higher than η from LASE-Cu

Higher Ar coverage

Higher η

i.e.: for FCC hh

Ray tracing calculation:

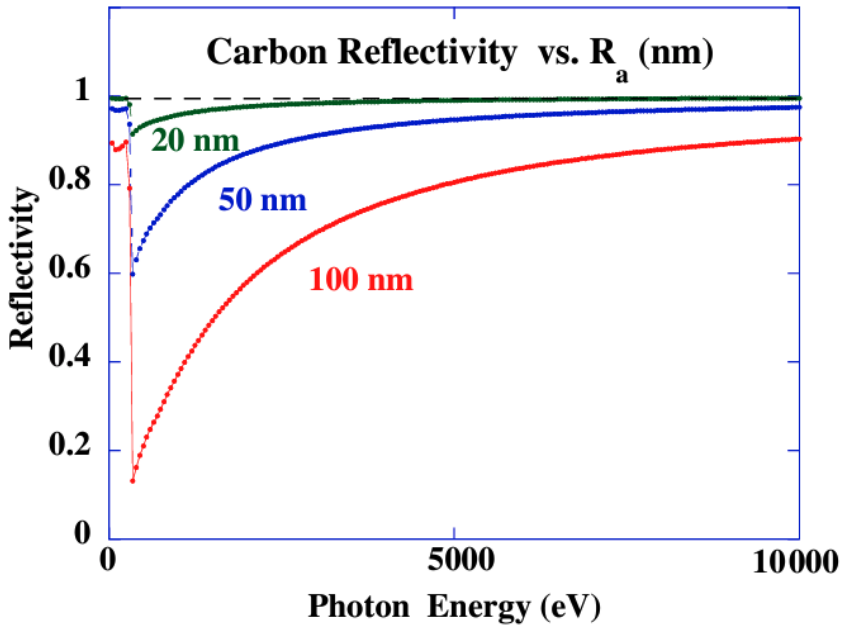


FIG. 3 (color online). Reflectivity calculation at 0.62 mrad angle of incidence for carbon versus achievable R_a in the photon energy range of interest [17].

PRL **115,** 264804 (2015) PHYSICAL REVIEW LETTERS week ending 31 DECEMBER 2015

Potential Remedies for the High Synchrotron-Radiation-Induced Heat Load for Future Highest-Energy-Proton Circular Colliders

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(Received 12 August 2015; published 31 December 2015)

We propose a new method for handling the high synchrotron radiation (SR) induced heat load of future circular hadron colliders (like FCC-hh). FCC-hh are dominated by the production of SR, which causes a significant heat load on the accelerator walls. Removal of such a heat load in the cold part of the machine, as done in the Large Hadron Collider, will require more than 100 MW of electrical power and a major cooling system. We studied a totally different approach, identifying an accelerator beam screen whose illuminated surface is able to forward reflect most of the photons impinging onto it. Such a reflecting beam screen will transport a significant part of this heat load outside the cold dipoles. Then, in room temperature sections, it could be more efficiently dissipated. Here we will analyze the proposed solution and address its full compatibility with all other aspects an accelerator beam screen must fulfill to keep under control beam instabilities as caused by electron cloud formation, impedance, dynamic vacuum issues, etc. If experimentally fully validated, a highly reflecting beam screen surface will provide a viable and solid solution to be eligible as a baseline design in FCC-hh projects to come, rendering them more cost effective and sustainable.

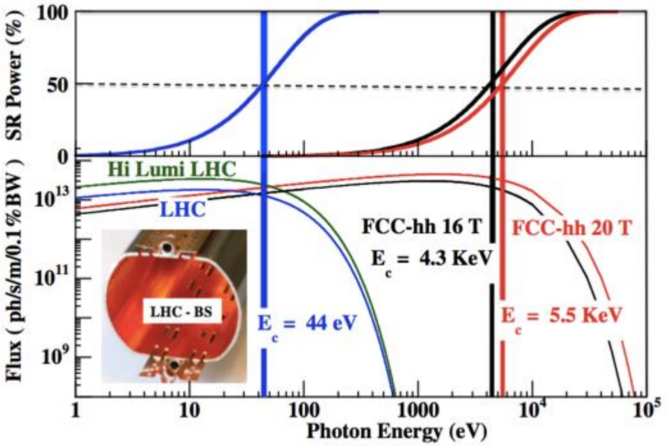
DOI: 10.1103/PhysRevLett.115.264804 PACS numbers: 29.20.-c, 07.30.-t, 29.27.Bd, 78.20.-e

Measure Photon Reflectivity

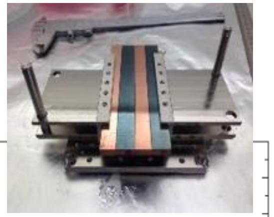
Reflected + Absorbed + Transmitted

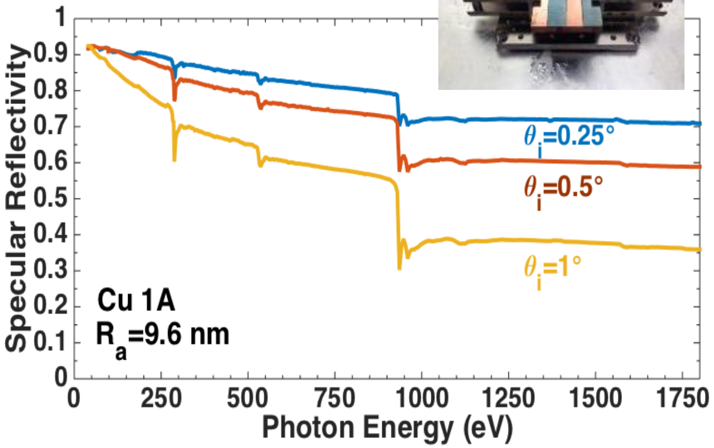
To be increased in cold parts (Superconductor Magnets)

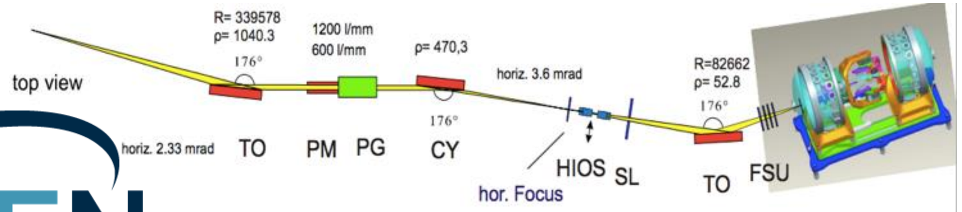
To be increased in high temperature parts (BS)



Reflectivity







HZB Helmholtz Zentrum Berlin

Synchrotron Radiation on High Energy Accelerator Walls

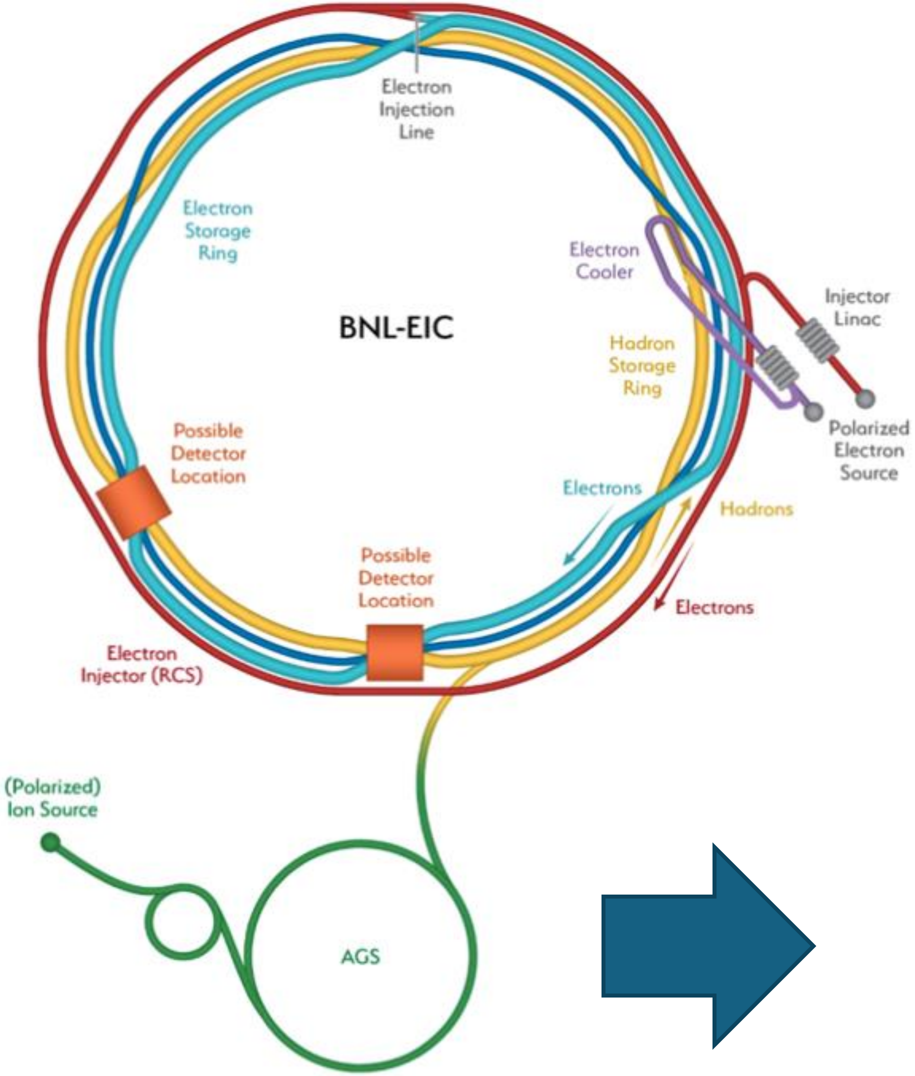
FCC-hh SR incidence angle: 0.035 deg (0.62 mrad)
Arc SR Heat Load = 28.4 (44.3) W/m/aperture

Sample	hν (eV)	q_i (deg)	Specular Reflect. (E) (± 10%)	Total Reflect. (E) (±10%)	PY (E) (±2%)
Cu + Carbon	1500	0.25°	0.77	0.92	0.09
		0.5°	0.70	0.90	0.14
Cu Ra=9.6 nm	1500	0.25°	0.61	0.74	0.18
		0.5°	0.57	0.67	0.30
LHC-ST	1800	0.25°	0.0040	0.054	0.07
		0.5°	0.0017	0.006	0.06

E. La Francesca et al., Phys. Rev. Acc. And Beams 23 (2020)

Photon reflectivity from accelerator walls is of great importance also for the FCC-ee

Presently the group is:



a-C Sample Production

Procedure Upgrade

SEY/XPS Studies
- Conditioning
- Low Temperature

EIC Brookhaven National Laboratory

INFN Istituto Nazionale di Fisica Nucleare

collaboration

Conclusions:

- At LNF we have experience and state of the art set-ups to perform qualification / preparation of materials to be used in UHV.
- At LNF there is a long-standing tradition, specific competences and refined surface science experimental set-ups to address unconventional material properties of great relevance in determining the dynamic behavior of a vacuum system.
- We hope we can actively contribute to the future challenges ahead of us.

Istituto Nazionale di Fisica Nucleare