# Reflectivity and Photo Yield measurements of technical surfaces

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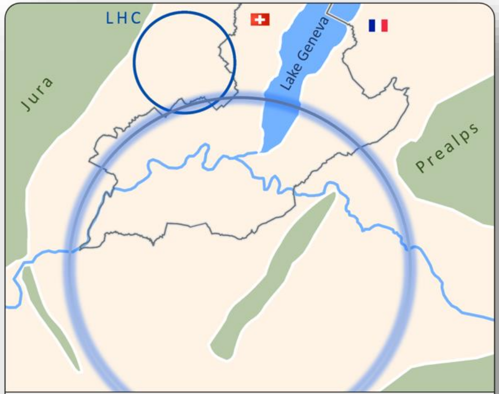
# Outline

- Synchrotron radiation in FCC-hh
- Reflectivity
- Carbon Reflectivity
- Bessy II measurements
- Conclusions

# Synchrotron Radiation detrimental effects

- Heat load on the accelerator walls
- Photon stimulated desorption
- Production of secondary electrons
- Beam instability

LHC has a non negligible SR production.



Schematic of an 80 – 100 km long tunnel

In the Highest Energy Proton Circular Collider ever designed, FCC-hh, large production of Synchrotron Radiation is expected

# FCC Parameters

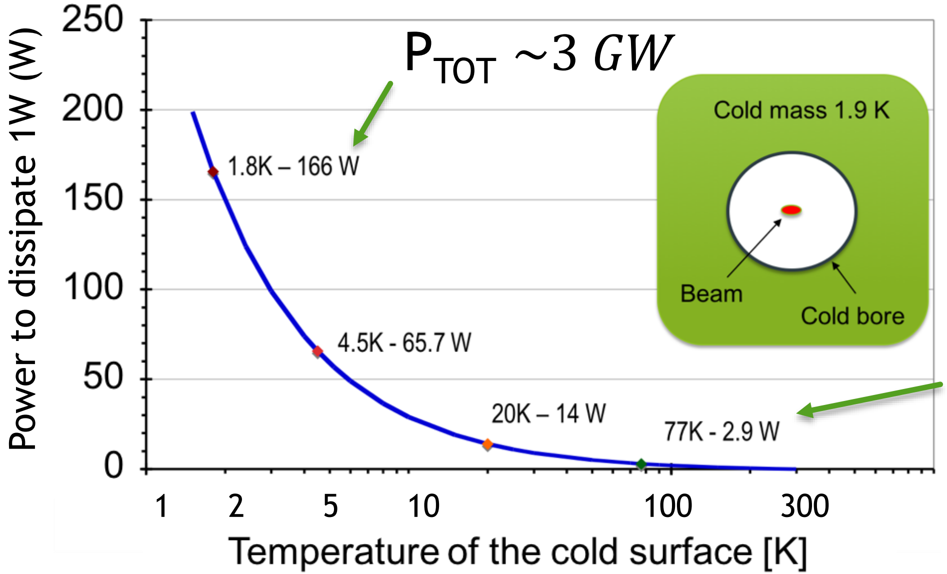
http://tlep.web.cern.ch/content/fcc-hh

| Parameters | LHC | H-L LHC | FCC-hh |
|---|---|---|---|
| c.m. Energy [TeV] | 14 | | 100 |
| Circumference *C* [km] | 26.7 | | 100 (83) |
| Dipole field [T] | 8.33 | | 16 (20) |
| Injection energy [TeV] | 0.45 | | 3.3 |
| Peak luminosity [$10^{34}$ $cm^{-2}s^{-1}$] | 1.0 | 5.0 | 5.0 |
| Stored beam energy [GJ] | 0.392 | 0.694 | 8.4 (7.0) |
| SR power per ring [MW] | 0.0036 | 0.0073 | 2.4 (2.9) |
| Arc SR heat load [W/m/aperture] | 0.17 | 0.33 | 28.4 (44.3) |
| Critical photon energy [keV] | 0.044 | | 4.3 (5.5) |

*Version 1.0 (2014-02-11)*

Dipoles at cryogenic temperature of 1.9 K

# Heat Load Dissipation VS Temperature



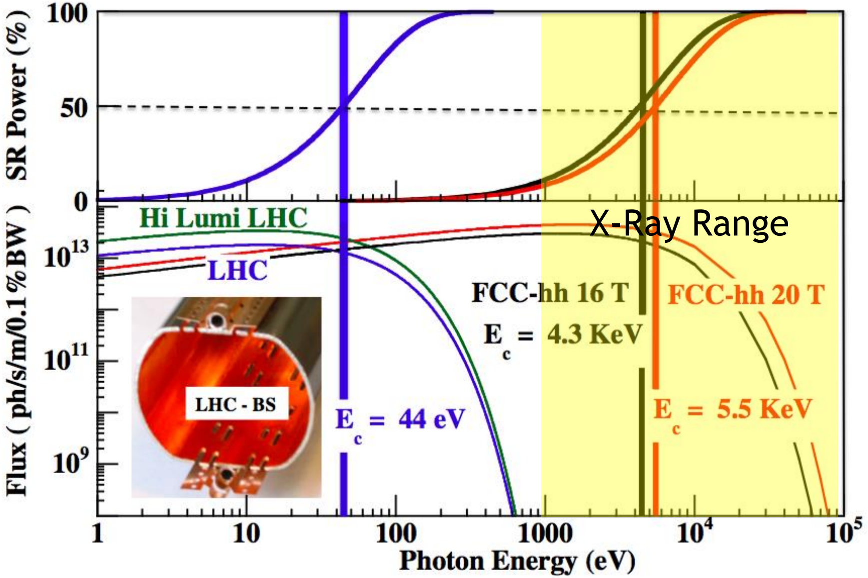

$P_{TOT} \sim 3\ GW$

$P_{TOT} \sim 80\ MW$

Credits: R. Kersevan -- Beam Dynamics meets Vacuum, Collimations, and Surfaces

FCC needs a Beam Screen at the highest possible temperature compatible with vacuum stability, impedance…

# Synchrotron Radiation interaction with Matter




FCC-hh SR incidence angle:
0.035 deg (0.62 mrad)
~ 21 m from source
Photon fan strip ~ 2mm

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# Synchrotron Radiation interaction with Matter

Arc SR Heat Load = 28.4 (44.3) W/m/aperture

=

Reflected + Absorbed + ~~Transmitted~~

Specular reflected

Scattered

To be increased in cold parts (Superconductor Magnets)

To be increased in high temperature parts (BS)



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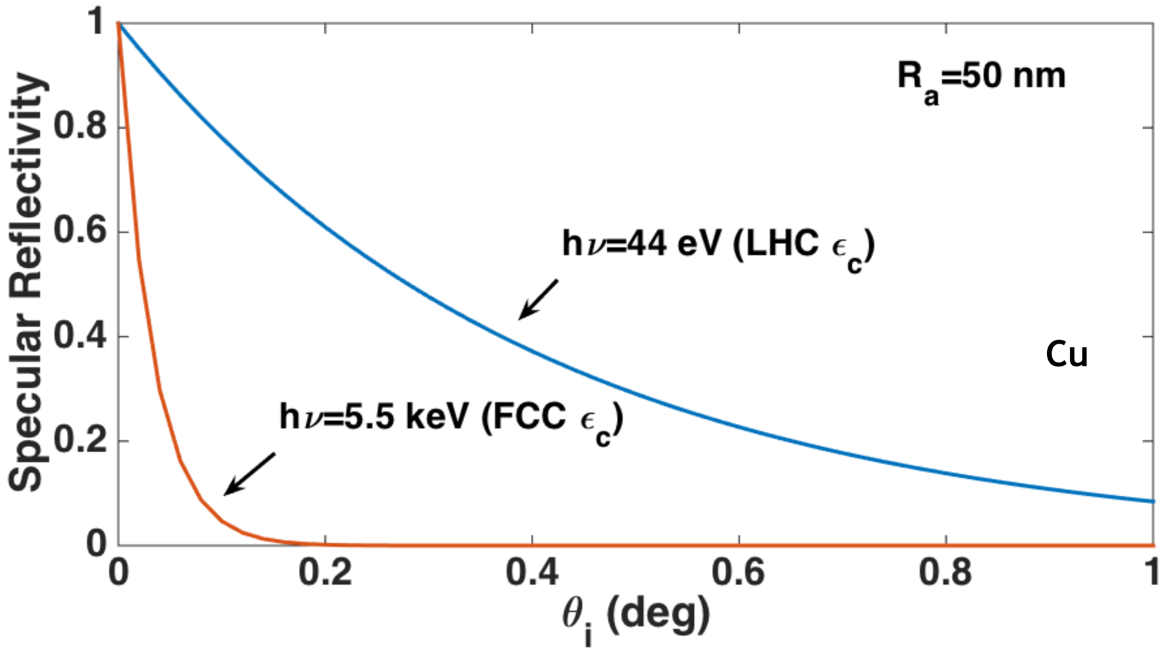
# Reflectivity

X-Ray Reflectivity depends on a limited number of parameters:

- Photon energy and light polarization
- Angle of incidence
- Surface roughness
- Material

# Specular Reflectivity VS Incidence angle



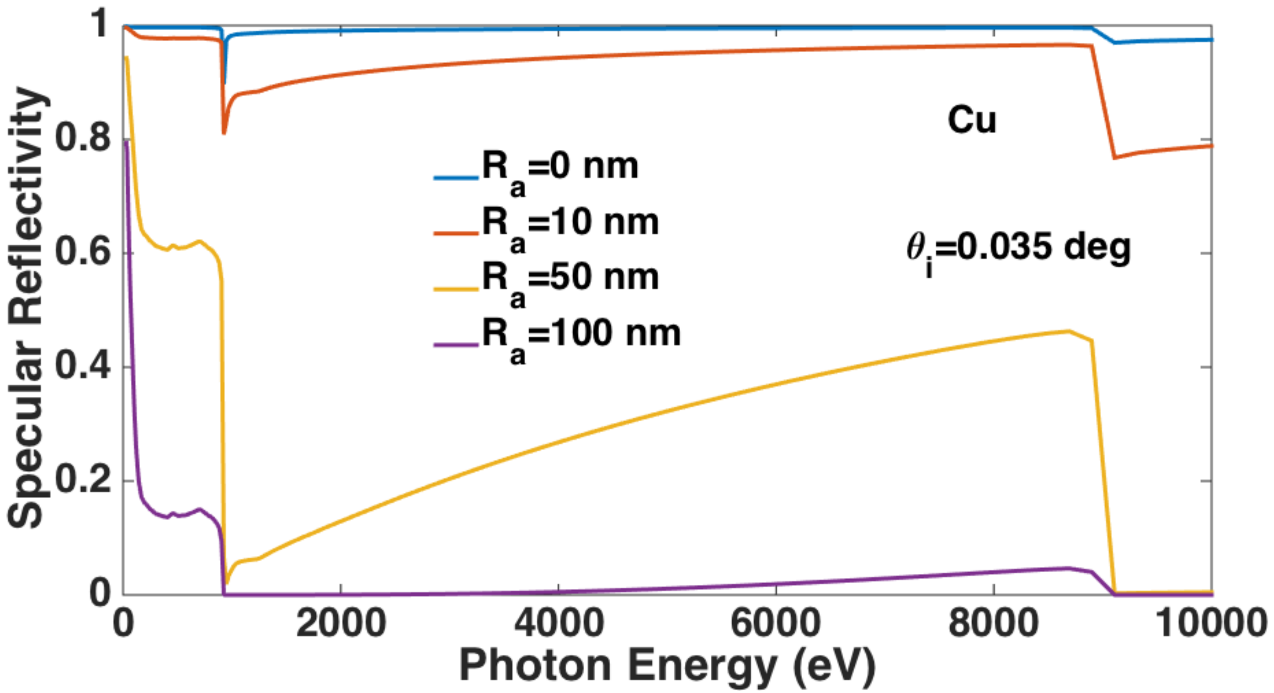

http://henke.lbl.gov/optical_constants/

# Reflectivity

X-Ray Reflectivity depends on a limited number of parameters:

- Photon energy and light polarization
- Angle of incidence
- Surface roughness
- Material

# Specular Reflectivity VS Roughness



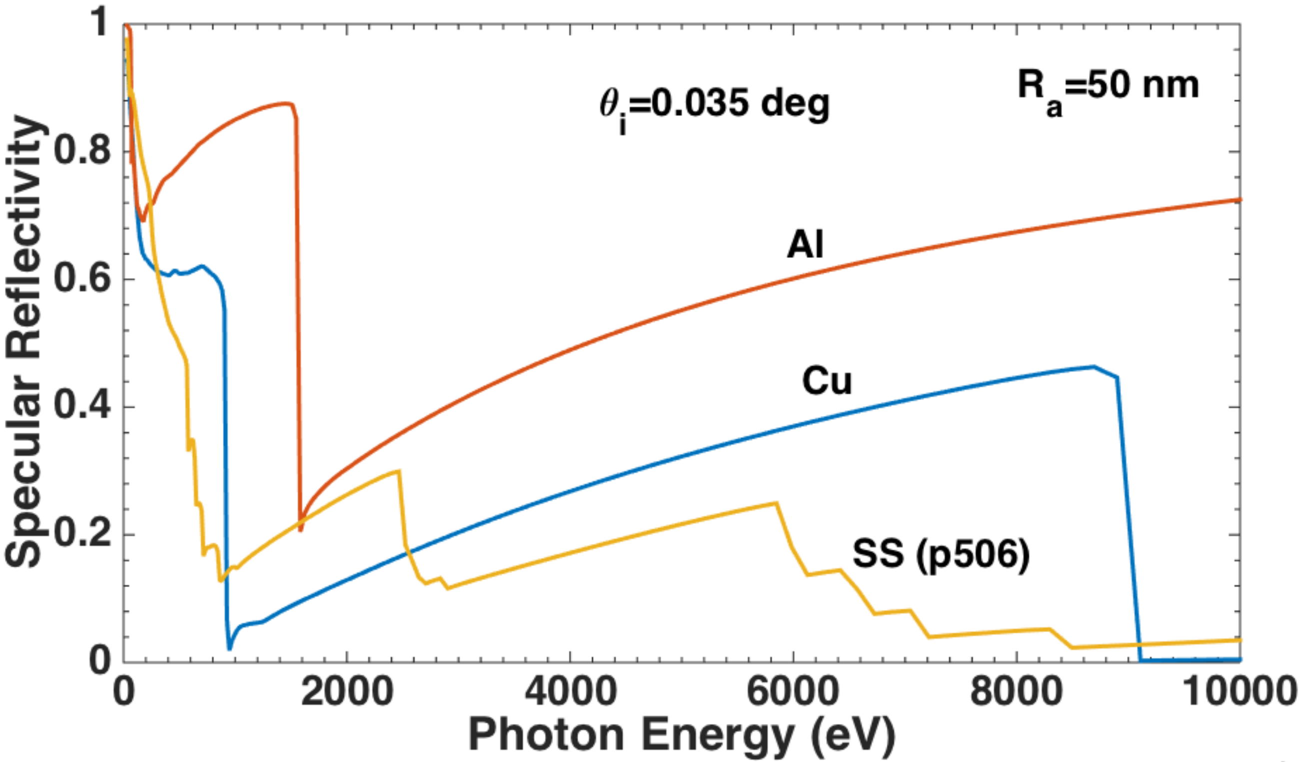

REFLEC simulations

# Reflectivity

X-Ray Reflectivity depends on a limited number of parameters:

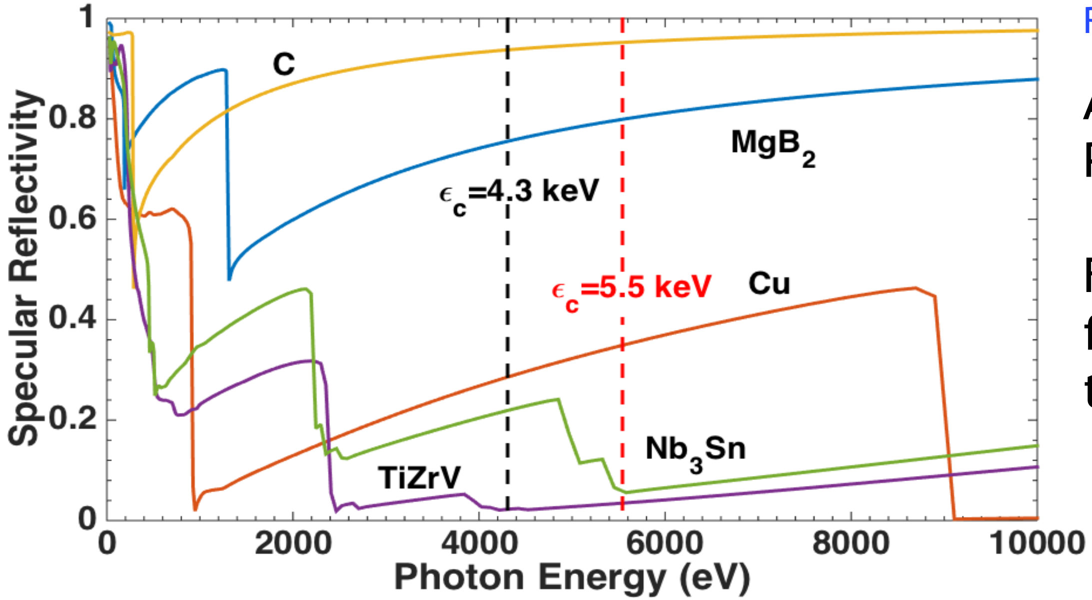
- Photon energy and light polarization
- Angle of incidence
- Surface roughness
- Material

# Specular Reflectivity VS Material




REFLEC simulations

# Specular Reflectivity: the case of Carbon




REFLEC simulations

Attenuation depth ($\lambda$):
$P(x)=\exp(-x/\lambda)$

For x= $\lambda$ the intensity of X-rays falls to 1/e of its value at the surface.

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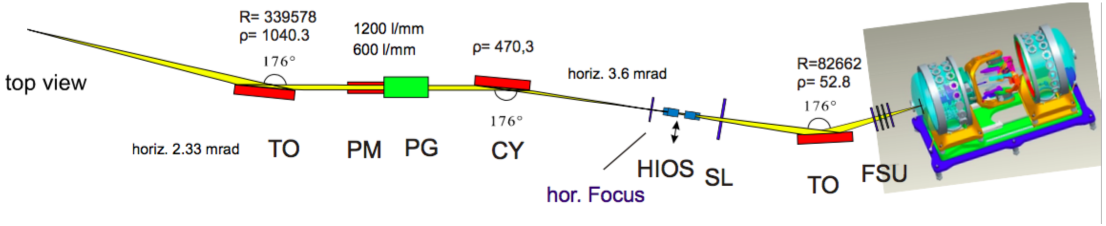
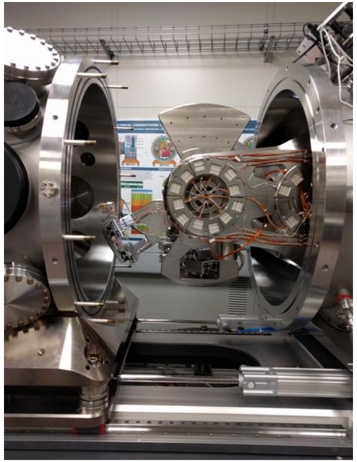
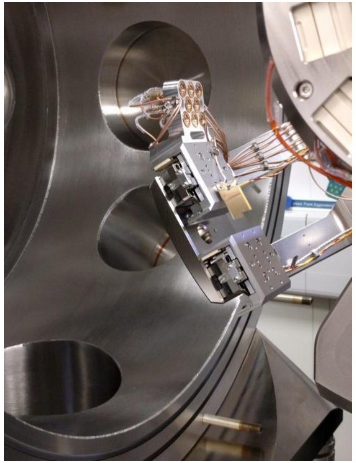
**$\lambda$(C) ~ 3.5 nm (X-ray range)**

20 nm of C can reflect all photons

# BESSY-II Optic Beamline and Reflectometer





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# BESSY-II Optic Beamline and Reflectometer

- **Incidence angle θ: -90° – 90°**
- **Detector in-plane 2θ: -180° – 180°**
- **Detector off-plane χ : -4° – 4°**
- **Sample – detector: 310 mm**
- **Six axes sample positioning**
- **Sample current measurement**
- **GaAsP-Photodiodes**
- **Detector slits, pinholes**



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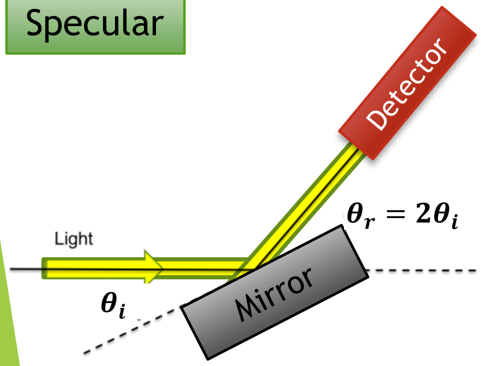
# Bessy II Measurements

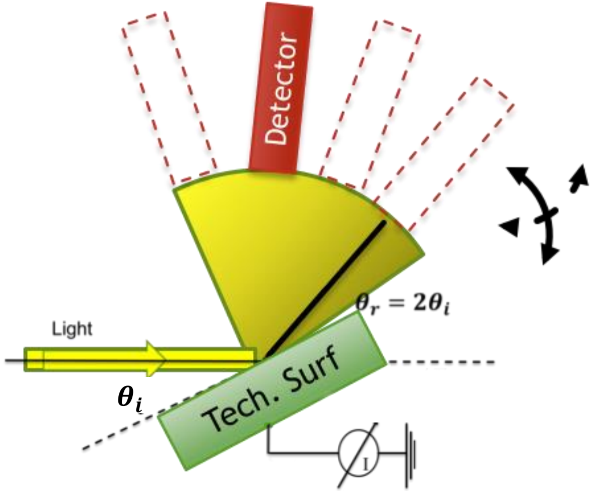
- Photon Energy range 35÷1800 eV
- Beam height h=0.3 mm
- Incident Beam measurement
- GaAsP Photodiodes (4x4mm) (1.2*4mm)
- Incidence angle 0.25, 0.5 deg
- Reflectivity measurement → Specular Reflectivity; Scattered Light

**Photo Yield:**
**PY= $N_e/N\gamma$**

Specular



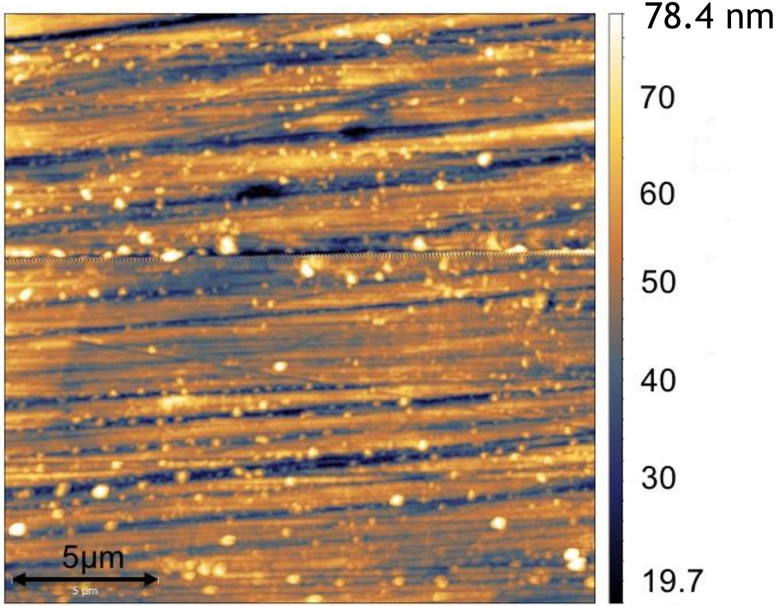

Total

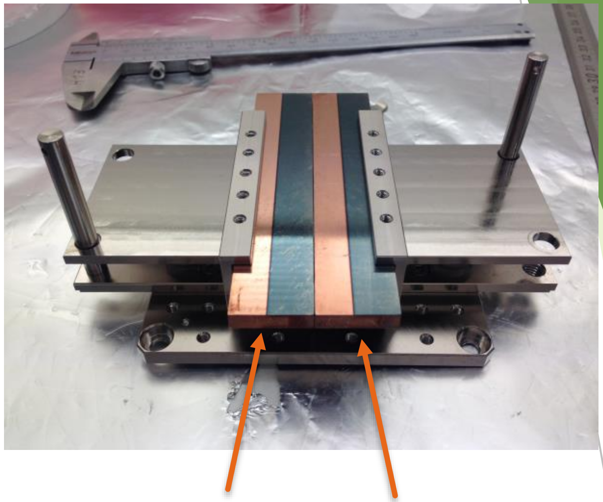


# Copper samples

**AFM (20x20μm²)**

## Cu 1A

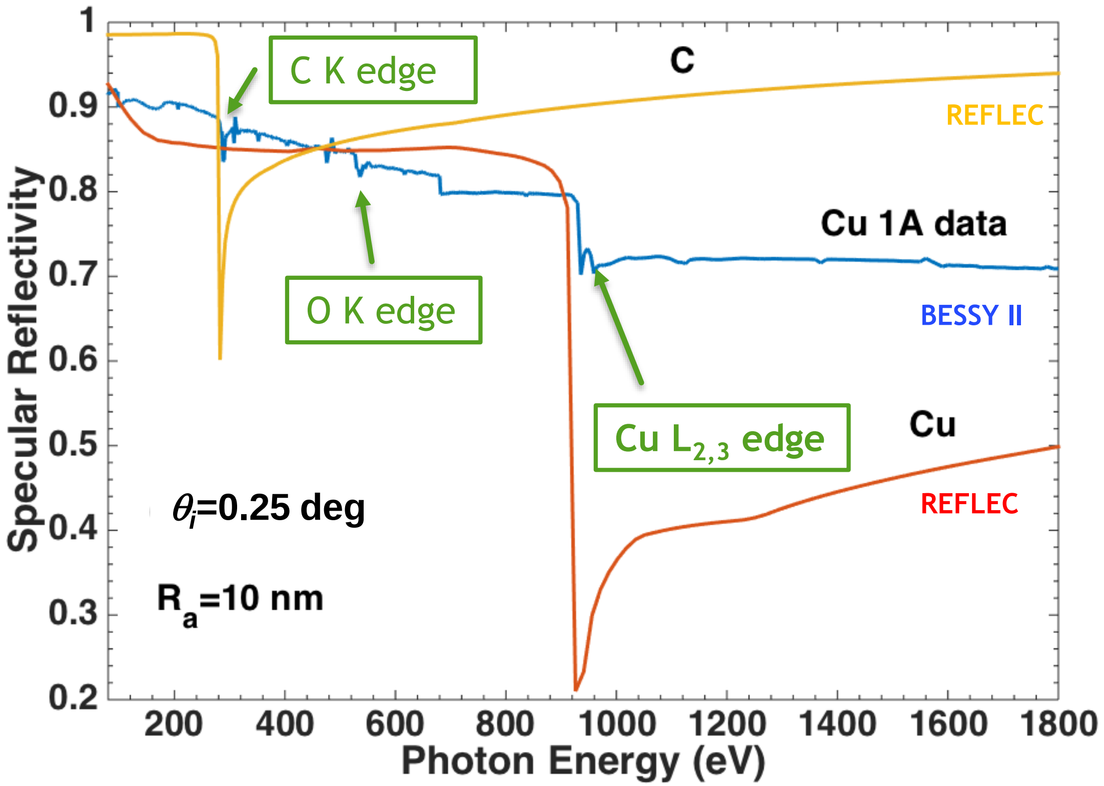


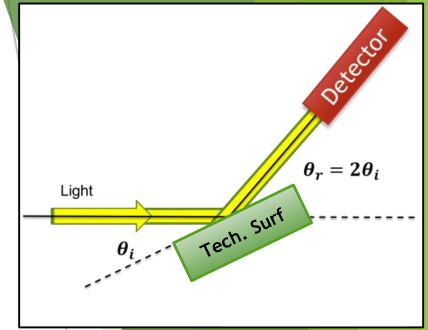




| Sample | RMS Roughness ($R_a$) |
|---|---|
| Cu 1A | 10 nm |
| Cu 2A | 30 nm |

Polished

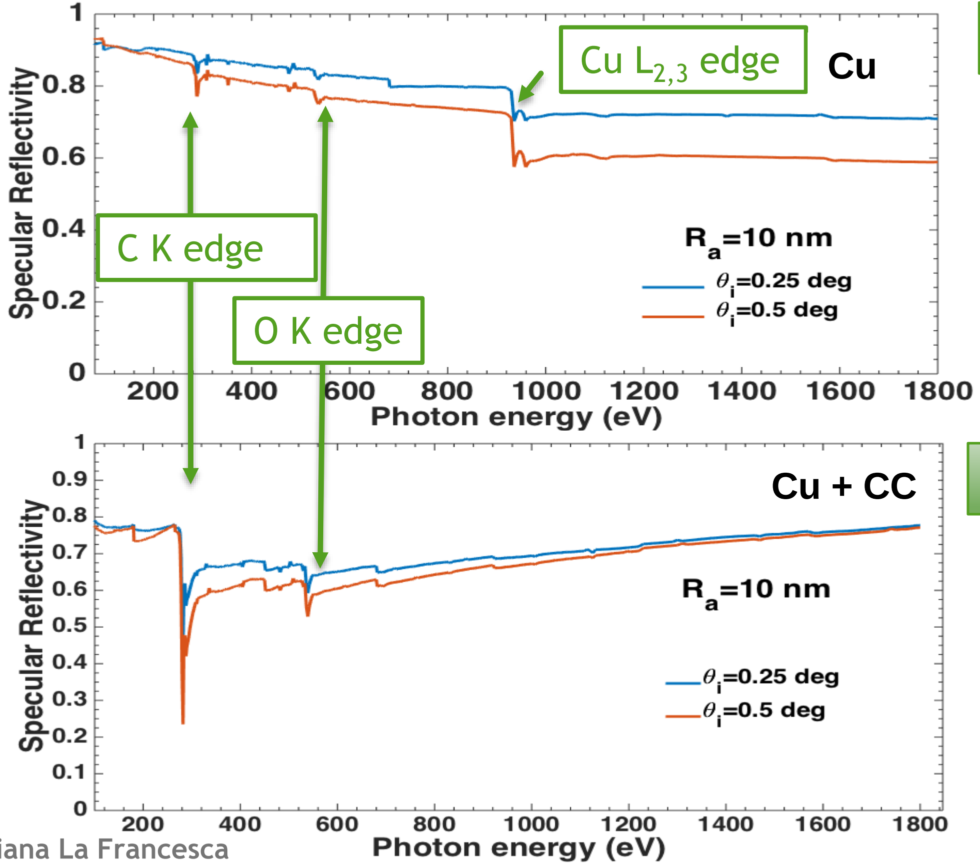
# Copper sample Cu1A and REFLEC simulations

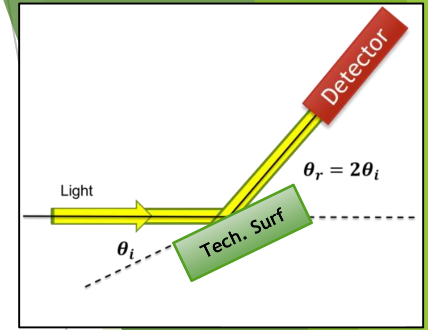



At grazing incidence angle contaminants are influencing Cu Reflectivity

# Specular Reflectivity VS Photon energy (Preliminary Results)



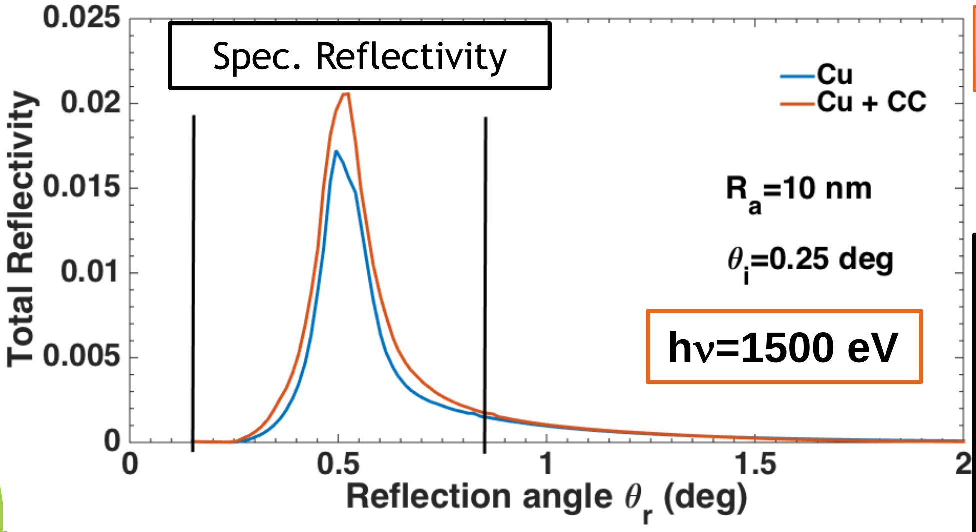

**Cu 1A**

**Cu 1A + CC**

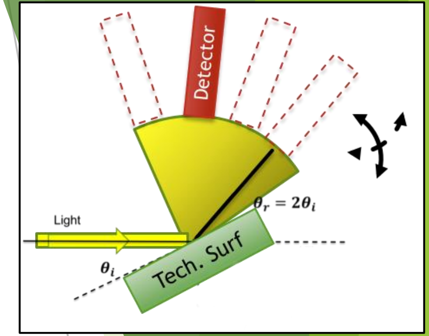
Carbon coating reduces reflectivity at low energy

At high energy reflectivity is significantly enhanced

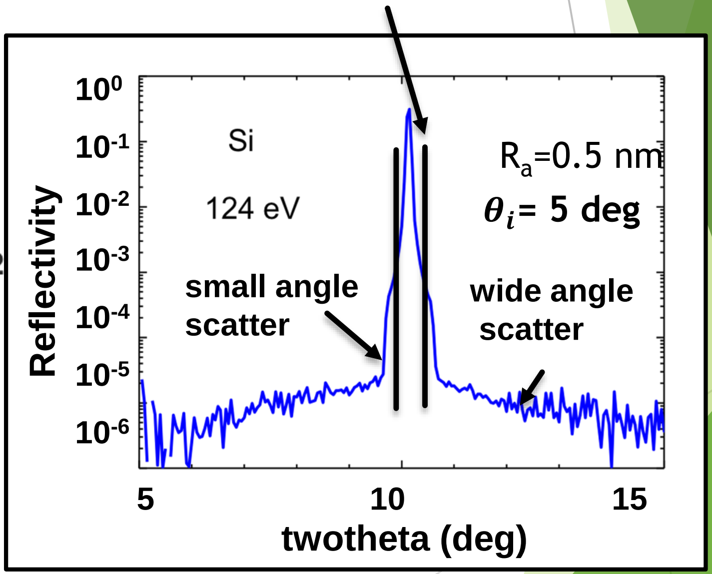
# Total Reflectivity VS Specular Reflectivity




**$R_a$= 10 nm**

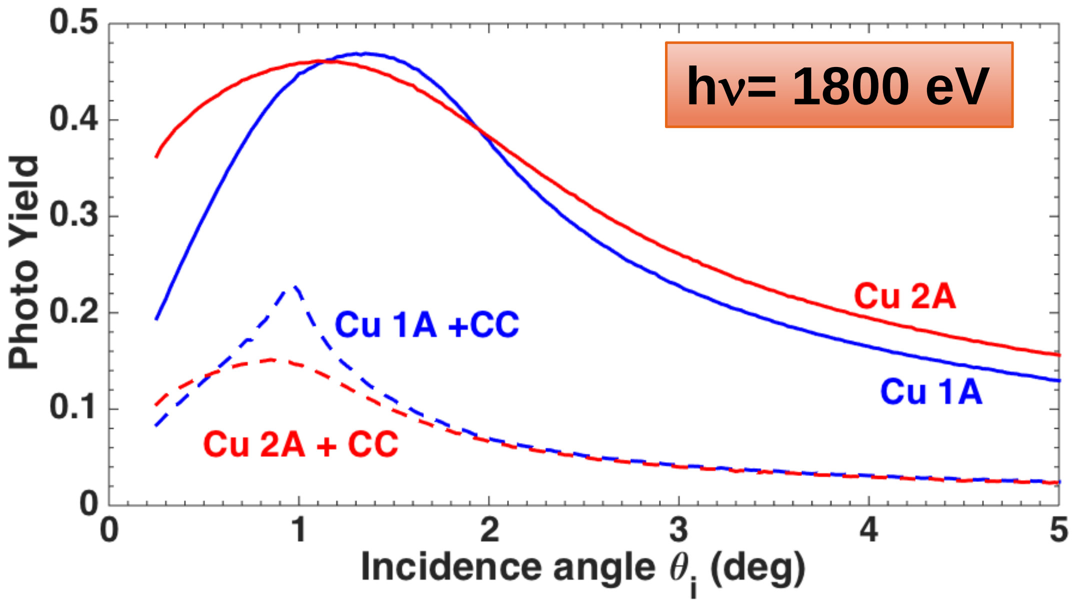


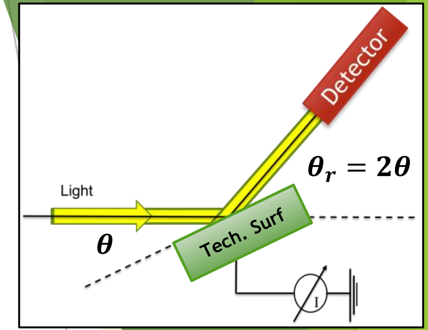

specular reflection




| Sample | Specular Reflectivity | Total Reflectivity |
|---|---|---|
| Cu 1A | 0.61 | 0.73 |
| Cu 1A + CC | 0.78 | 0.90 |

# Photo Yield VS Incidence angle




PY= $N_e/N\gamma$

| Sample | Cu 1A ($R_a$=10 nm) Max value | Cu 2A ($R_a$=30 nm) Max value |
|---|---|---|
| Cu | 0.47 | 0.46 |
| Cu + CC | 0.23 | 0.15 |

Preliminary Results:

- little dependence on roughness
- Carbon coating seems to reduce PY

# Conclusions

- At FCC-hh SR incidence angle contaminants will influence Reflectivity.
- Carbon coating seems to increase Total Reflectivity and reduce absorption and related Heat Load.
- For technical surfaces scattered light cannot be neglected.
- Photo Yield does not seem to significantly depend on roughness and decrease with CC.
- Our preliminary results suggest that further work is needed in order to qualify the use of Carbon Coating to increase Reflectivity.
- Experimental data are important to characterize SR behaviour and HL for all materials to be used in FCC-hh dipoles and Interaction points.

# Thank you for your attention.