Photo-Reflectivity and Photo Electron Yield of Technical Surfaces

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In collaboration with
F. Schäfers and F. Siewert

Helmholtz-Zentrum, Berlin

September 28, 2022 - La Biodola Bay, Isola d'Elba

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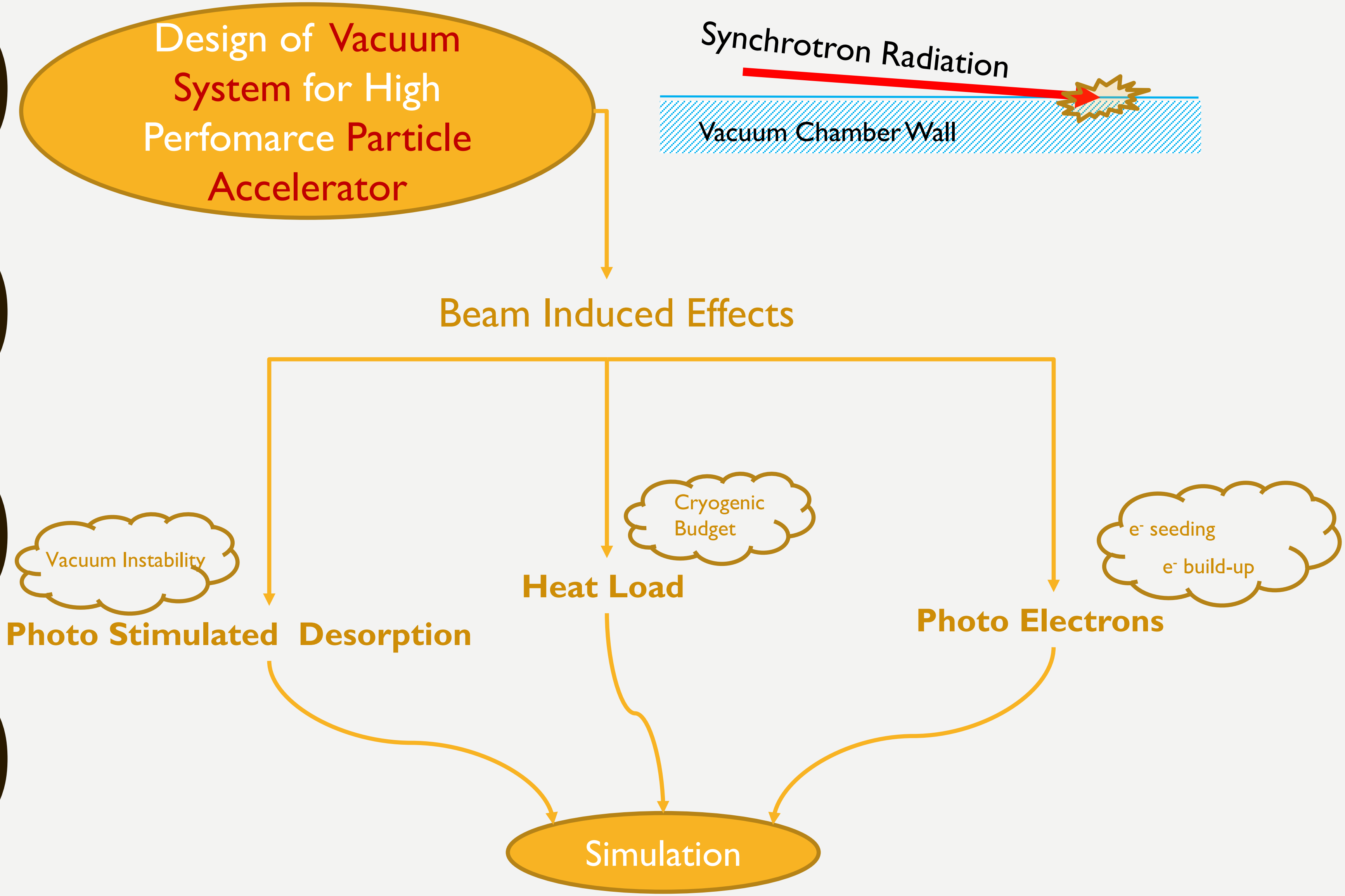
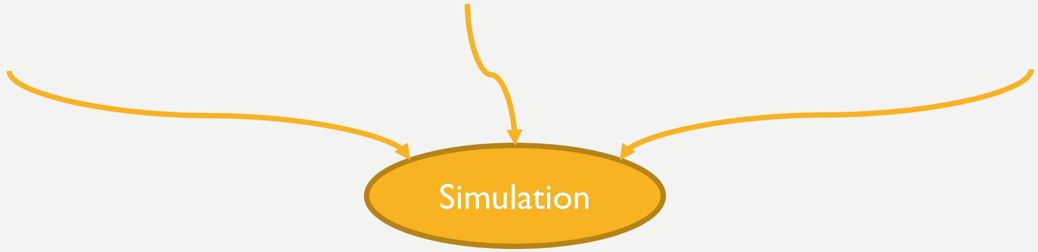
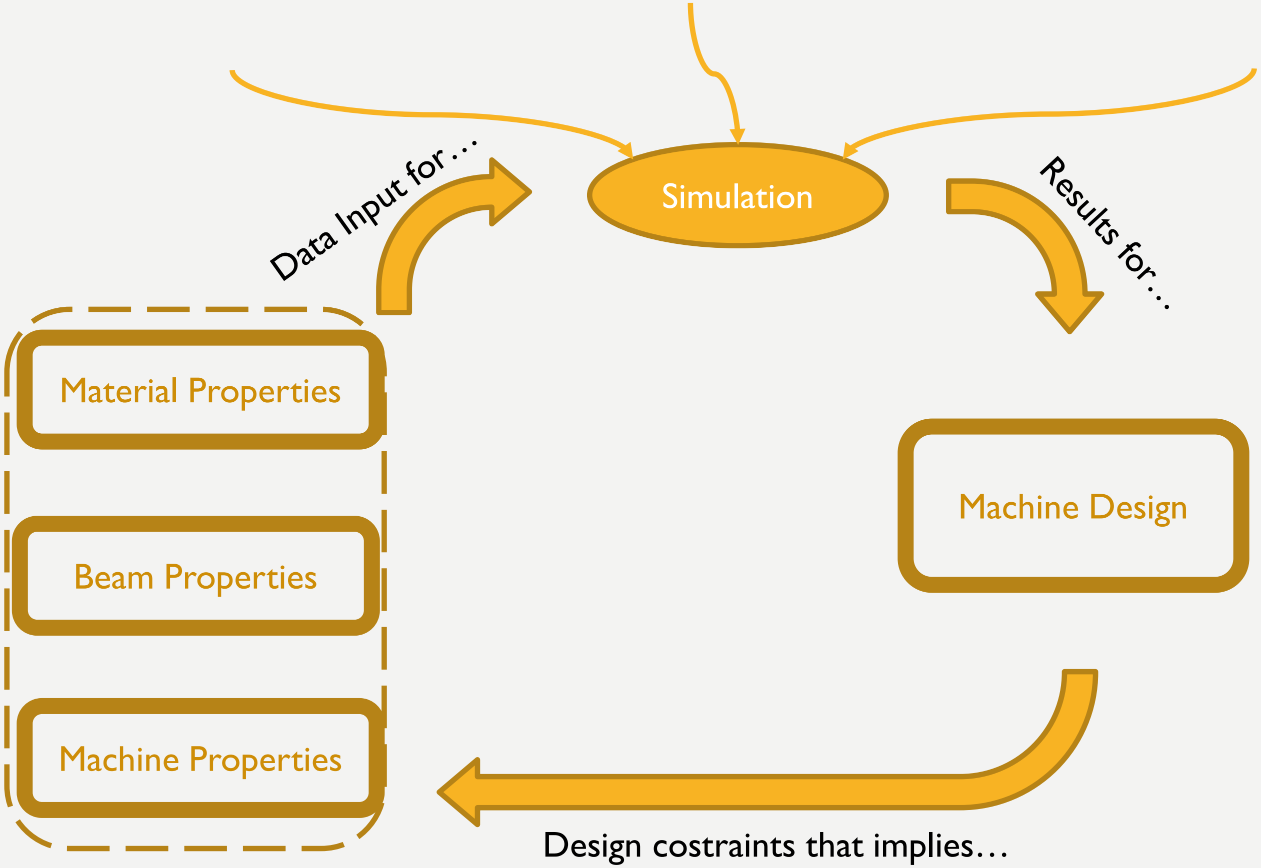
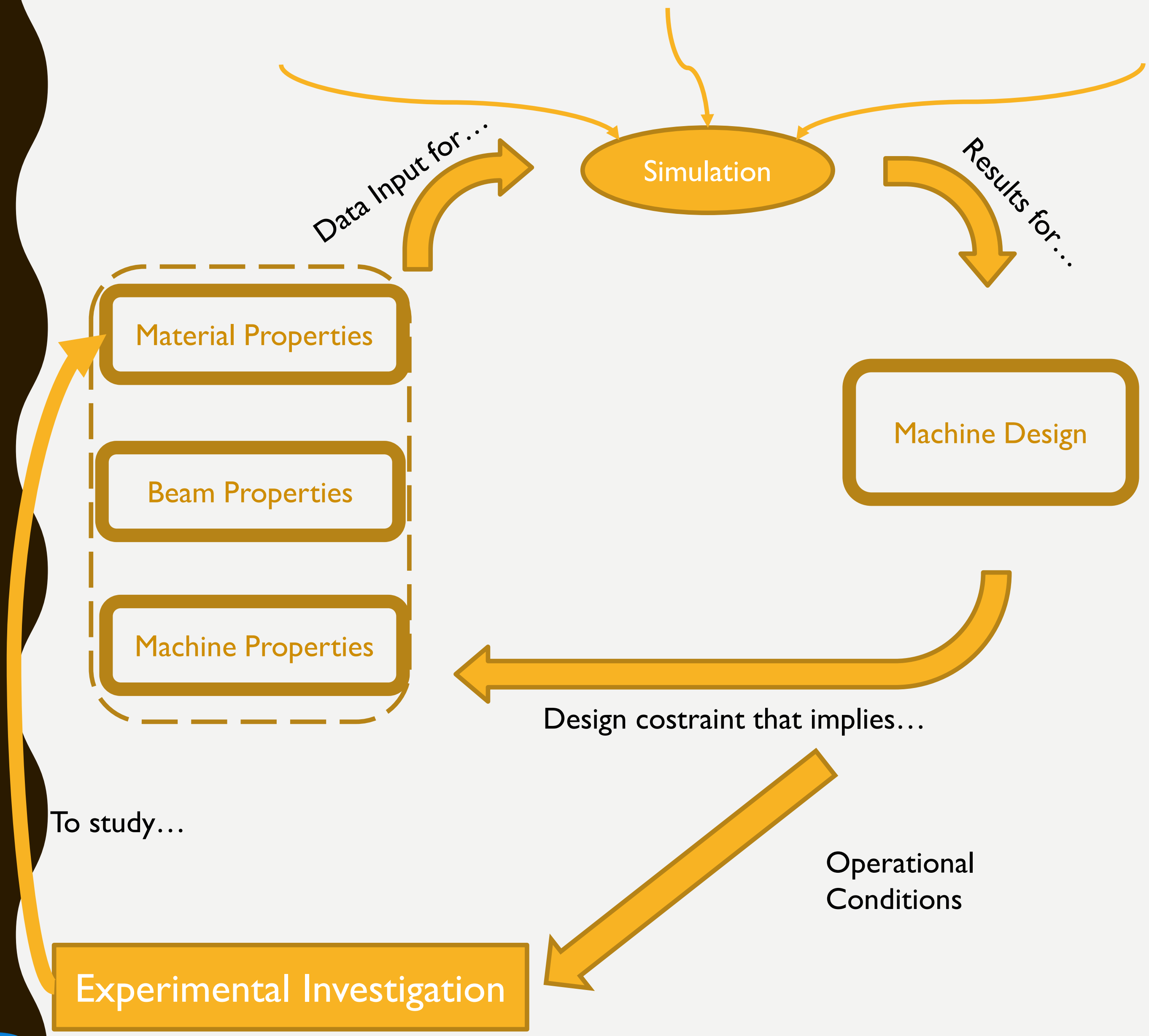

Design of Vacuum System for High Perfomarce Particle Accelerator
Synchrotron Radiation
Vacuum Chamber Wall
Beam Induced Effects
Vacuum Instability
Photo Stimulated Desorption
Cryogenic Budget
Heat Load
e⁻ seeding
e⁻ build-up
Photo Electrons
Simulation


Simulation



Choices for

- Optics
- Vacuum System
- RF System
- Machine Layout
- …
- …

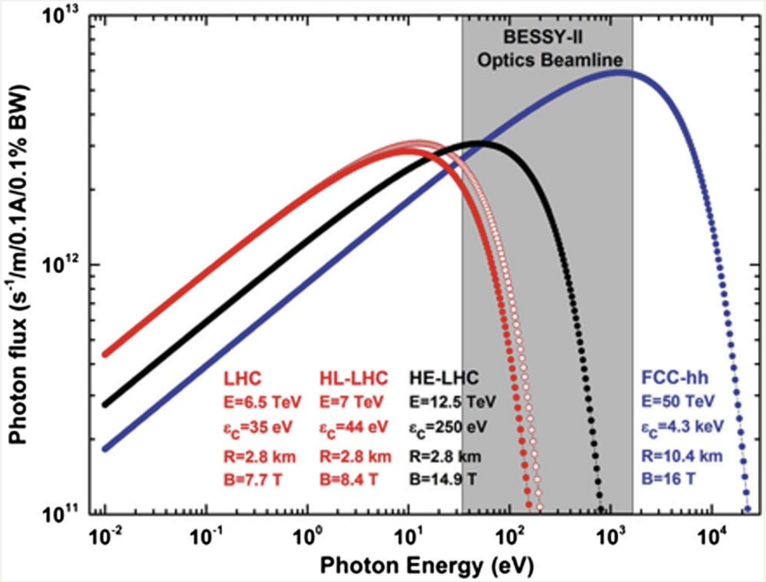


Choices for
- Optics
- Vacuum System
- RF System
- Machine Layout
- …
- …

SR on High Energy Accelerator Wall

Operational Conditions

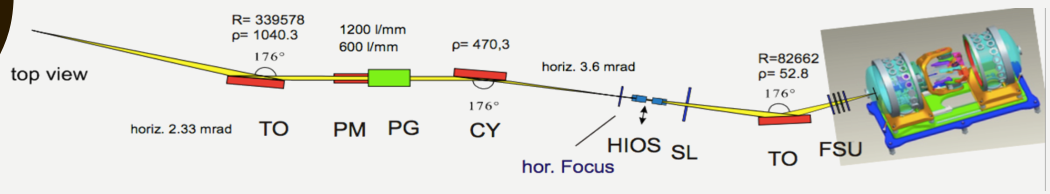
- **Energy Range**: from eV to keV
  e.g. HL-LHC εc =44eV
- **Incidence Angles**: grazing
  from 0.08° (FCC) to 0.27° (HL-LHC)
- **Proposed Materials** and Treatments
  Candidates for beam pipe/beam screen etc..



Materials Properties of Interest

- **Reflectivity (R)**
- **Photo Electron Yield (PY)**

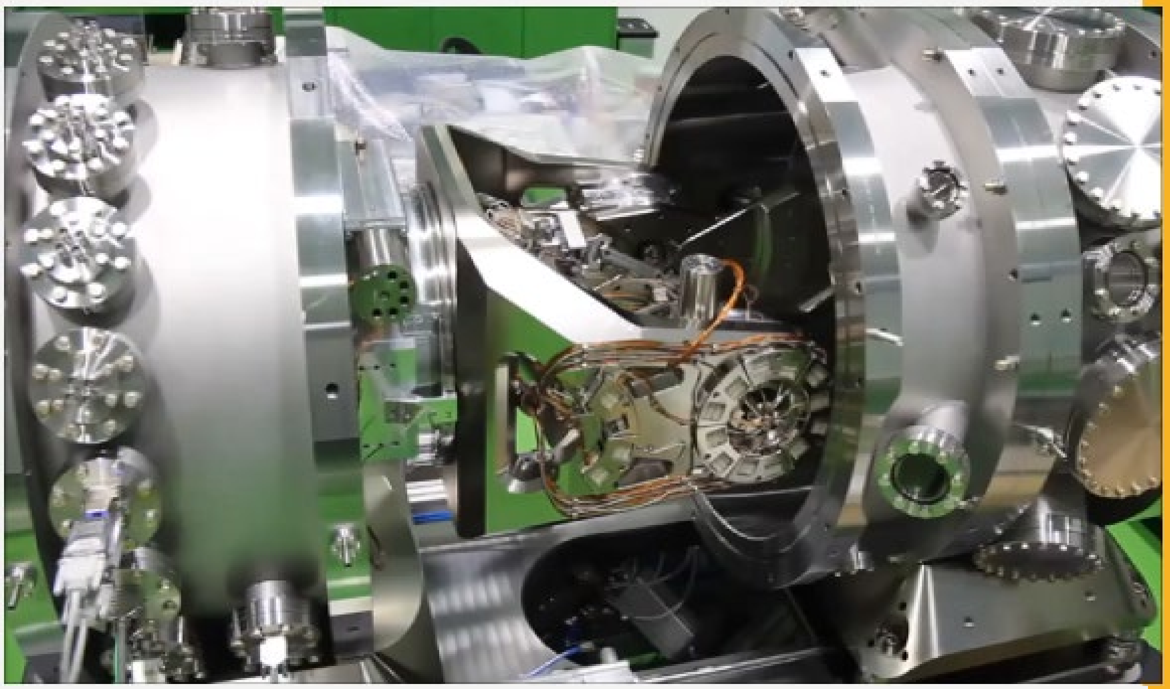
BESSYII "Optics" beamline



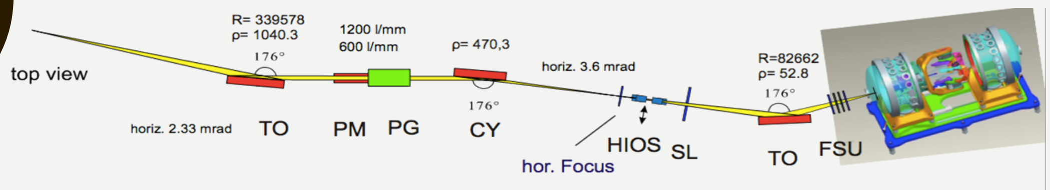
Axis	Hardware	Range	Pos. accuracy
Azimuth angle β	HUBER 430	-180° - 180°	3.6"
Sample angle θ	HUBER 411	-90° - 270°	3.6"
Detector angle 2θ	HUBER 411	-180° - 180°	3.6"
Detector off-plane (2 axes)	Ceramic motors	-25 mm – 25 mm (-4° - 4°)	50 nm
Sample Adjustment Tx, Ty, Tz	Ceramic motors	-20 mm – 20 mm (not simul.)	500 nm
Sample Adjustment Rx, Ry, Rz	Ceramic motors	-10° - 10° (not simul.)	1"

Experimental Parameters

- Phot. Energy range 35÷1800 eV
- Beam height h=0.3 mm
- Incident Beam measurement
- GaAsP Photodiodes (4x4mm) (0.1*4mm)
- Incidence angle 0.1, 0.25, 0.5, 1 deg



BESSYII "Optics" beamline



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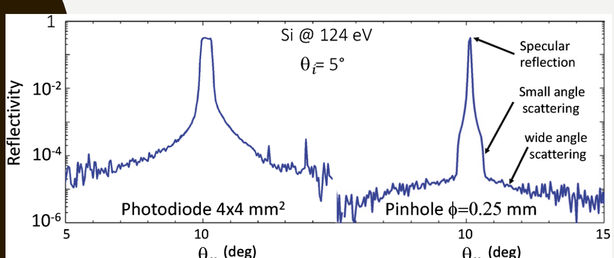

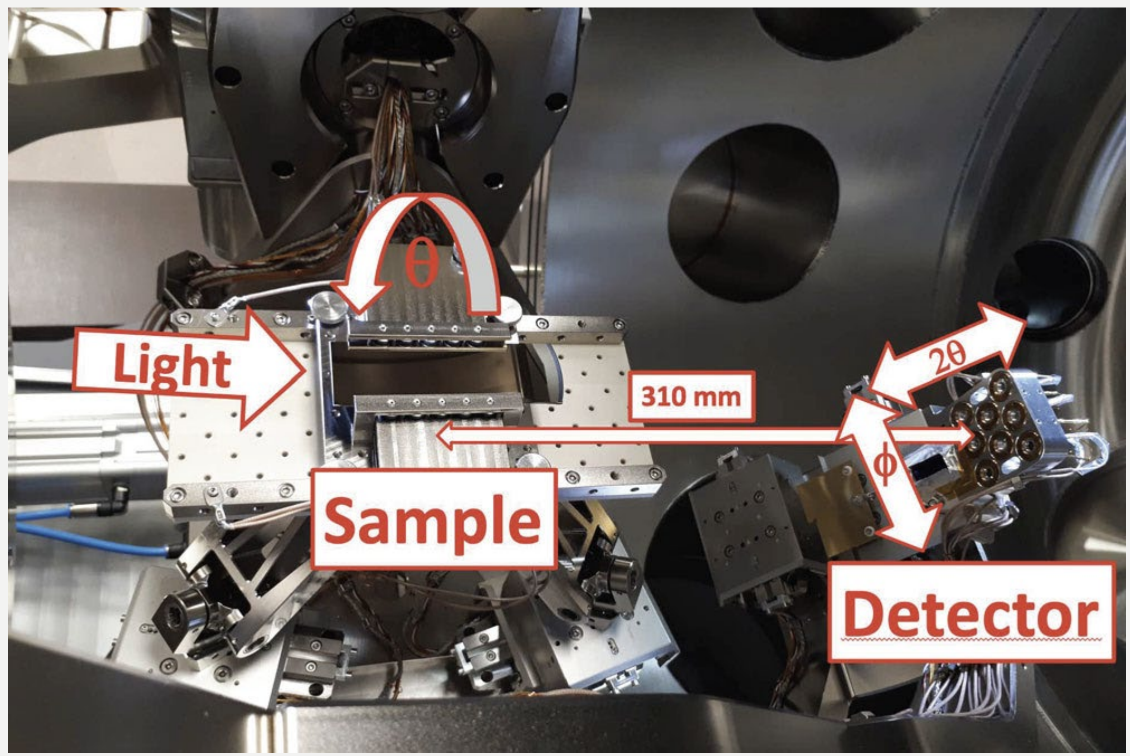

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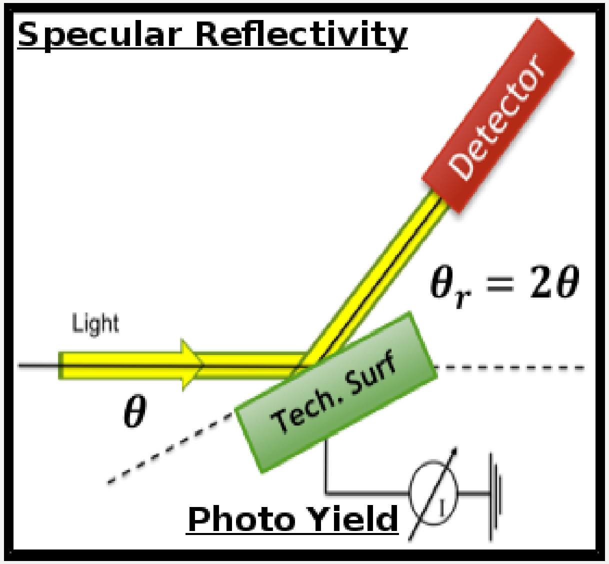
EXPERIMENTAL CONFIGURATION



Reflectivity $$R = \frac{I}{I_0}$$

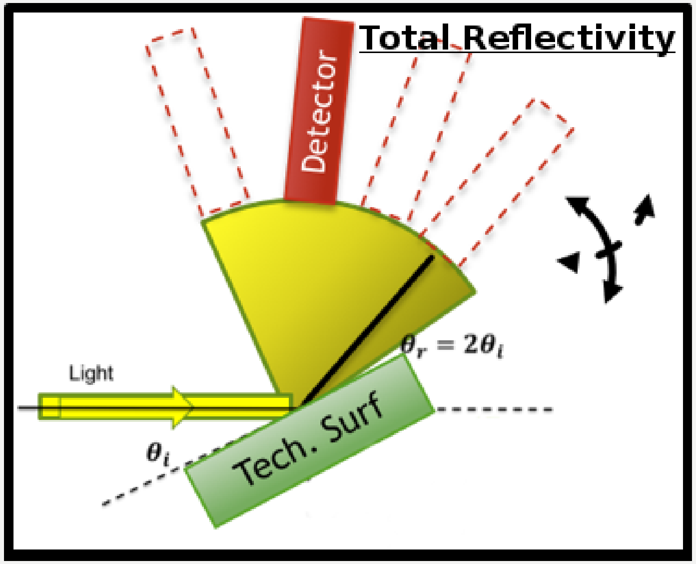
Photo Electron Yield $$PY = \frac{N_e}{N_\gamma}$$

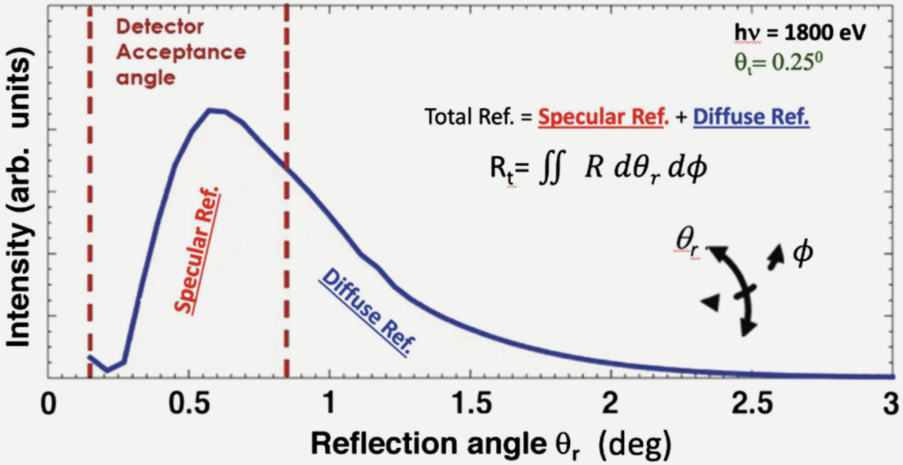
Acquiring modalities:

Energy Scan
Depending on Energy (fixed angle)

Angular Scan
Depending on Angle (fixed Energy)

EXPERIMENTAL CONFIGURATION





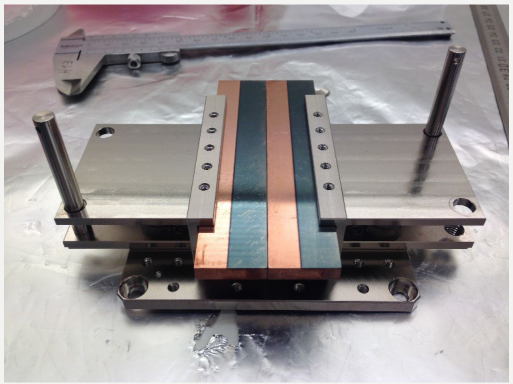
Acquiring modalities:

Energy Scan
Depending on Energy (fixed angle)

Angular Scan
Depending on Angle (fixed Energy)

SAMPLE

Cu

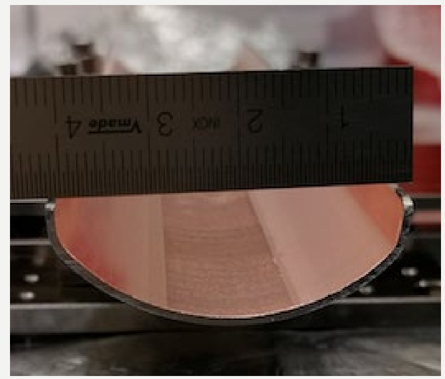


(No. 1-3)

Cu-LHC

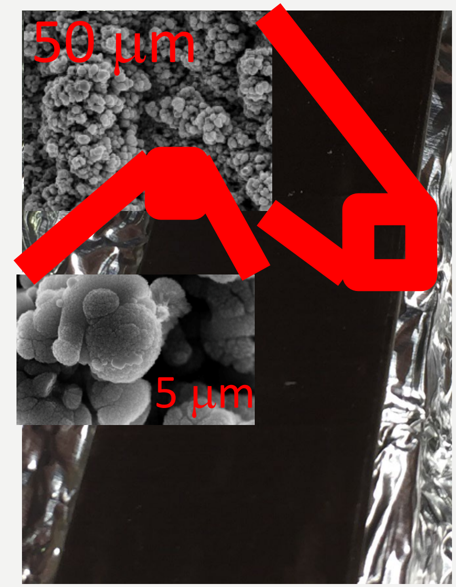
(No. 4)

ST-LHC



(No. 5)

Cu-LASE

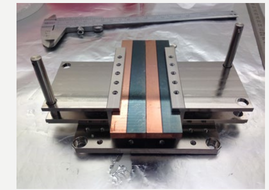


(No. 6)

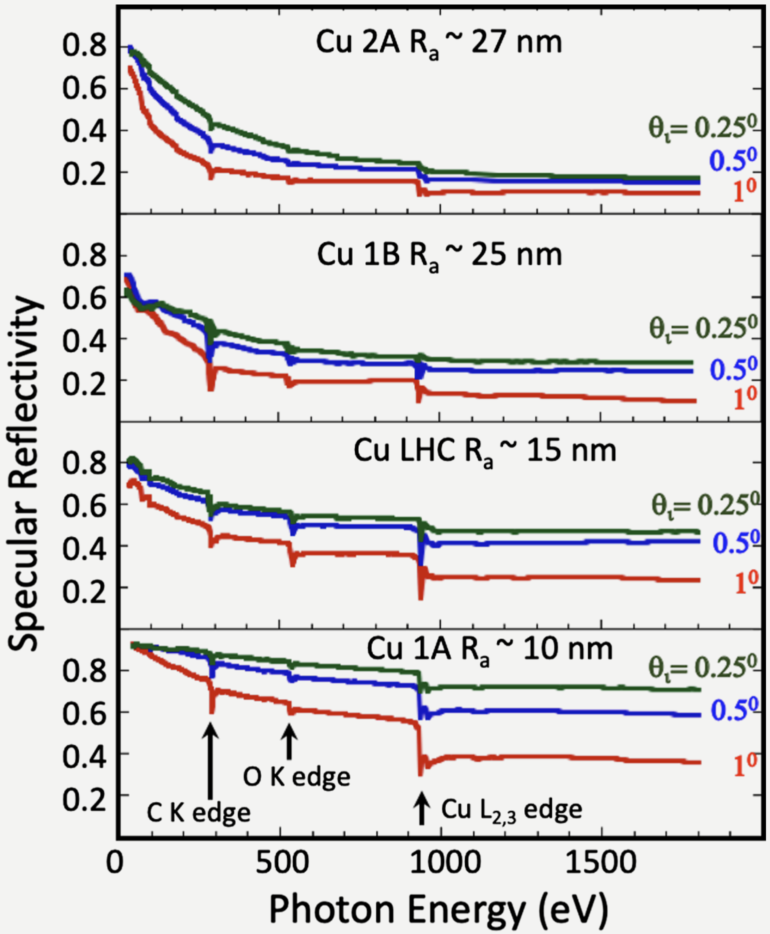
Flat- Cu (No. 1–4)

No.	Sample	Material	Length (mm)	Treatment	Ra ± 10%	δmax ± 10%
1	Cu 1A	Cu	100	El. Polished	10 nm	2,2
2	Cu 2A	Cu	100	El. Polished	27 nm	2,2
3	Cu 2B	Cu	100	Lapped	25 nm	2,2
4	Cu LHC	Cu	300	Co-Laminated	15 nm	2,2
5	ST-LHC	Cu	300	Co-Laminated	≈40 um	2,25
6	Cu-LASE	Cu	300	Laser Treated	≈10 um	<≤0,75

FLAT-Cu



Specular Reflectivity VS Energy for Θ=0,25° Θ=0,5° Θ=1°



- Specular R is Higher at lower Energy
- Specular R is higher at lower Θ
- Cu $L_{2,3}$ absorption edge is evident and causes a drop in R
- C and O edges are evident and represent effects of surface contaminants
- Roughness is more important than surface treatment for Reflectivity behaviour

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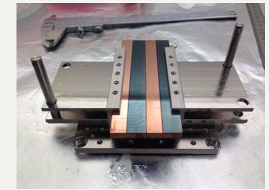
FLAT-Cu



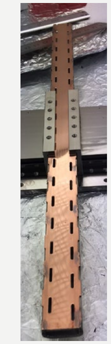
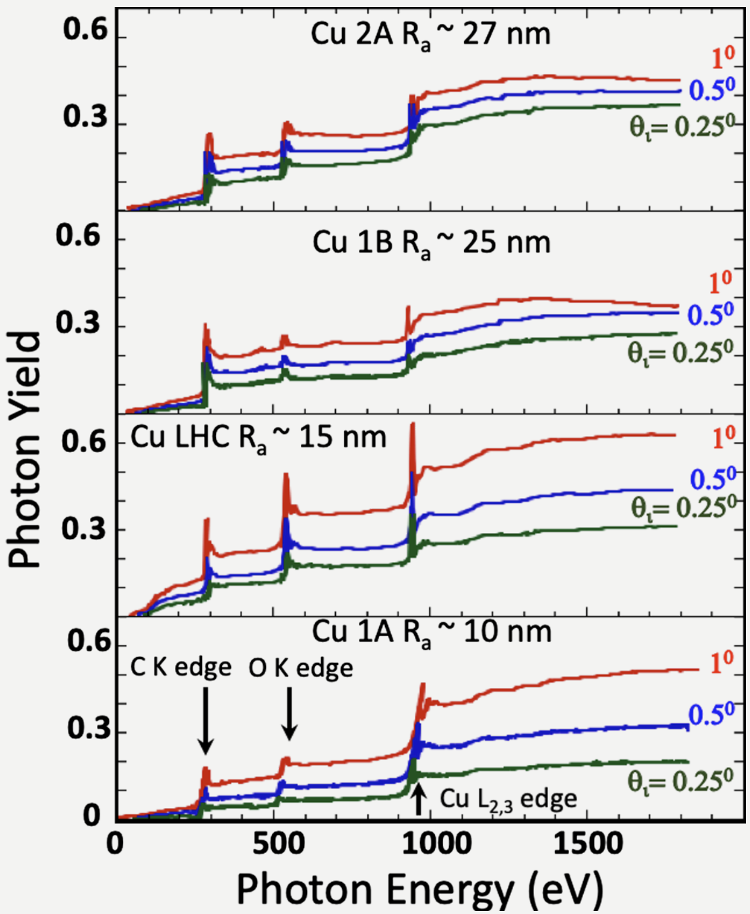


Photo Yield VS Energy

for $\Theta=0,25°$, $\Theta=0,5°$, $\Theta=1°$



- PY is Higher at higher Energy
- PY decreases with lower Θ
- PY is higher for lower Ra
- For higher Ra the dependance on Θ is reduced
- Absorption edges generally enhance PY

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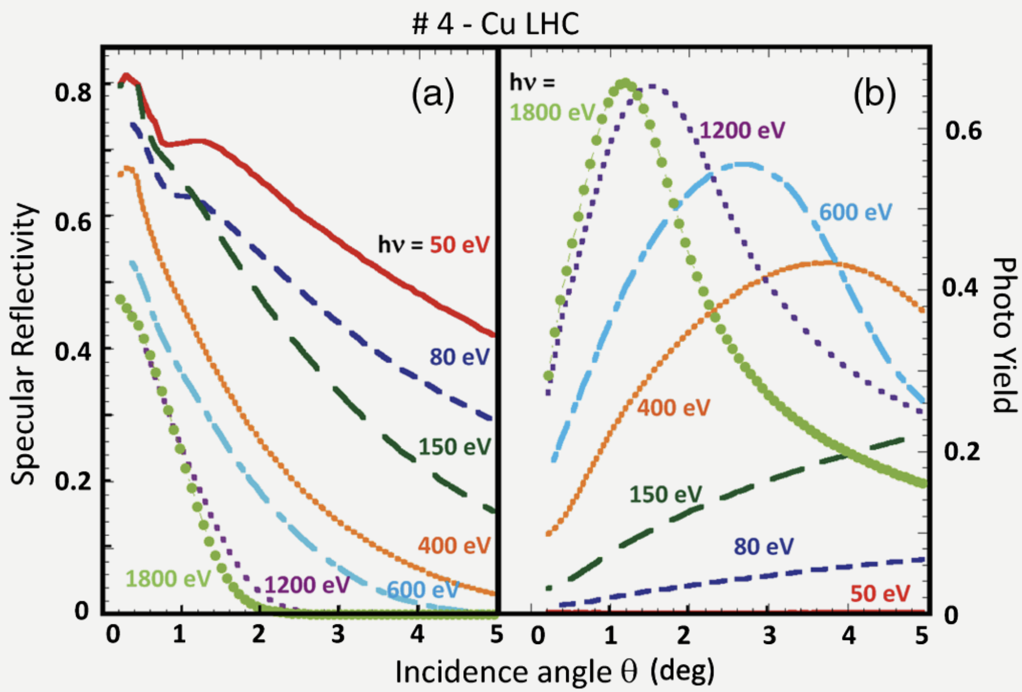
Reflectivity and Photo Yield VS Energy



- High Energy Photons are nearly completely absorbed for Θ>2
- Low Energy Photons are well reflected up to large Θ
- More Photons are reflected less are absorbed (lower PY)

but

- Large Θ means deeper photon penetration: less R and also less PY due to the escape depth

Trade off depends on E

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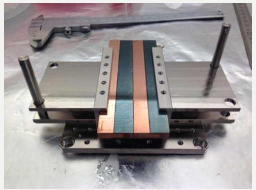
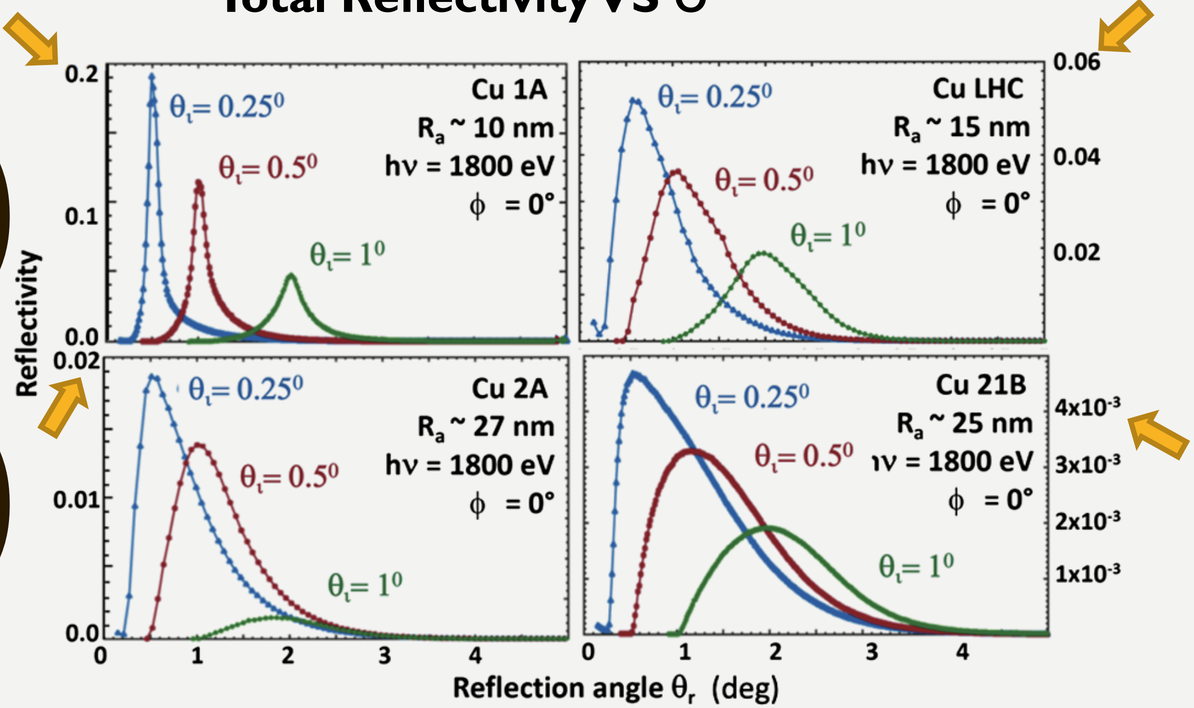
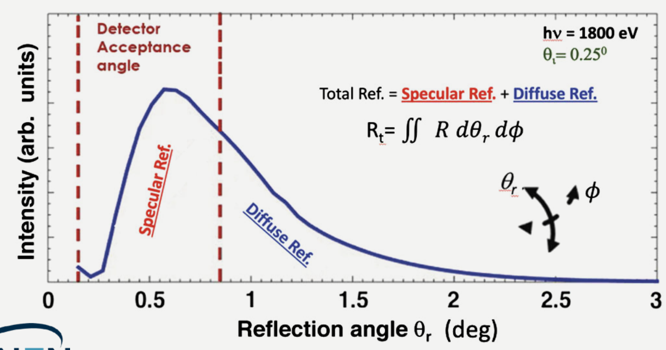
FLAT-Cu



Total Reflectivity VS Θ





- Increased R_a causes enlarged and lower peaks

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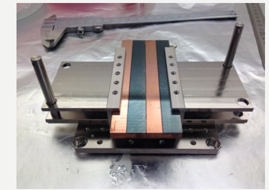
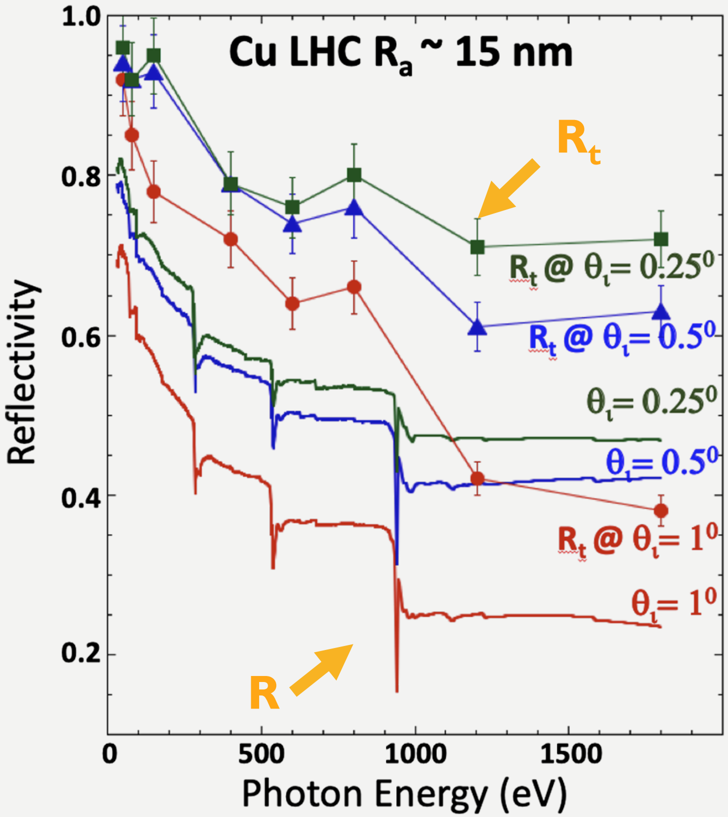
FLAT-Cu



Total Reflectivity VS Specular Reflectivity



E (ev)	R Specular Reflec.	R_t Total Reflec.	Ratio (%) R/R_t
1800	0,47	0,72	65
1200	0,47	0,71	66
800	0,53	0,80	66
600	0,54	0,76	71
400	0,59	0,79	75
150	0,71	0,95	75
80	0,75	0,92	82
50	0,81	0,96	84

Θ=0,25°

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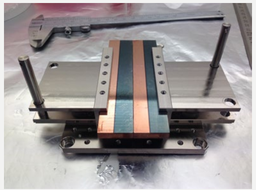
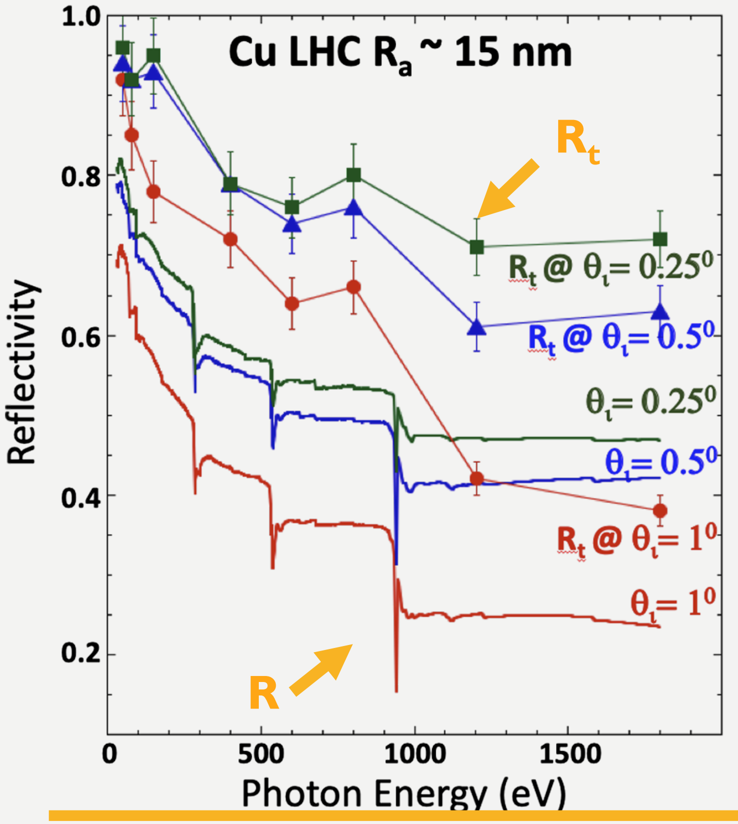
FLAT-Cu



Total Reflectivity VS Specular Reflectivity



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400	0,59	0,79	75
150	0,71	0,95	75
80	0,75	0,92	82
50	0,81	0,96	84

Θ=0,25°

Larger Ra

- While R remarkably decreases, R_t remains above 0.5

No	Ra (nm)	R	R_t	R/R_t (%)
1	10	0,61	0,74	82
2	15	0,47	0,72	65
3	25	0,27	0,55	49
4	27	0,18	0,54	33

Θ=0,25°
E=1800ev

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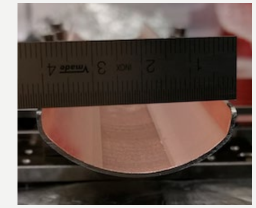
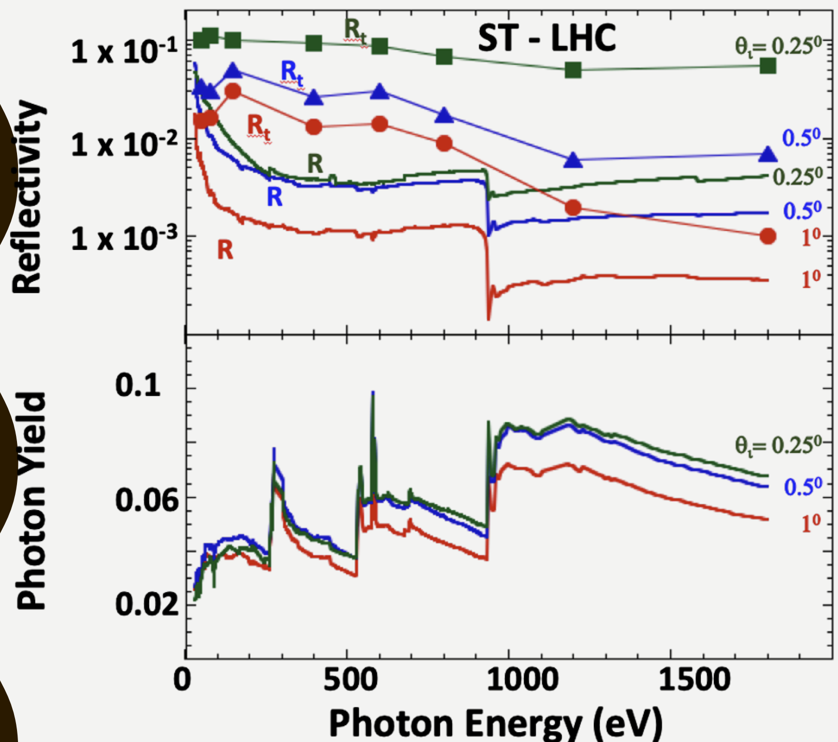
ST-LHC



Reflectivity – Total Reflectivity - PY



- Evident reduction of R
- At lower Θ Reflectivity could be due to ST crests
- PY is reduced, absorption edges are still evident

- Scattered lights is significant amount of total reflection
- Off-plane reflection is negligible (Φ ≥ 2°)

E (ev)	R Specular Reflec.	R_t Total Reflec.	Ratio (%) R/R_t
1800	0,004	0,05	8
1200	0,003	0,05	6
800	0,0045	0,07	3,9
600	0,0035	0,08	4,3
400	0,004	0,1	4
150	0,01	0,10	10
80	0,02	0,11	18
50	0,03	0,10	30

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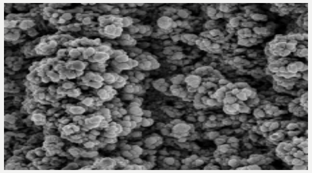
Cu-LASE



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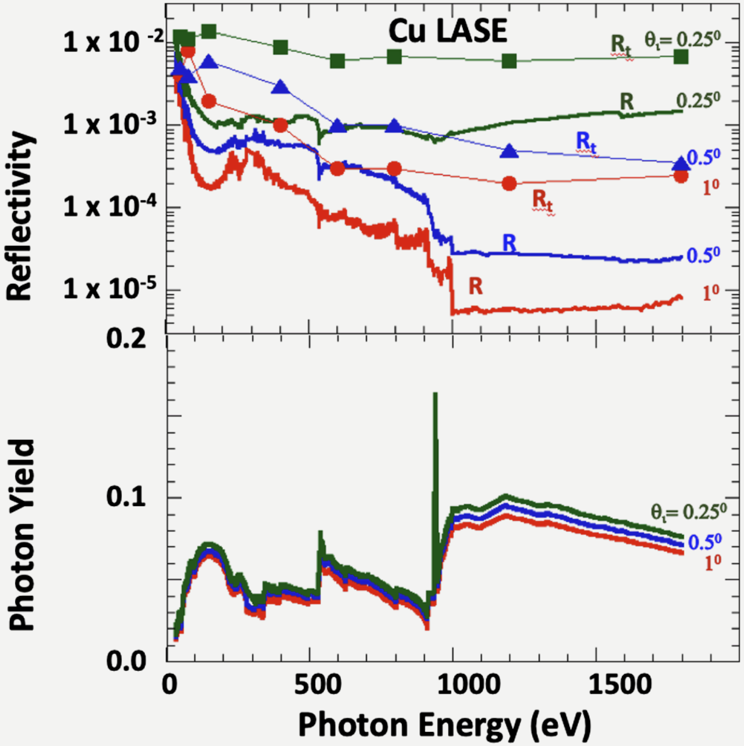
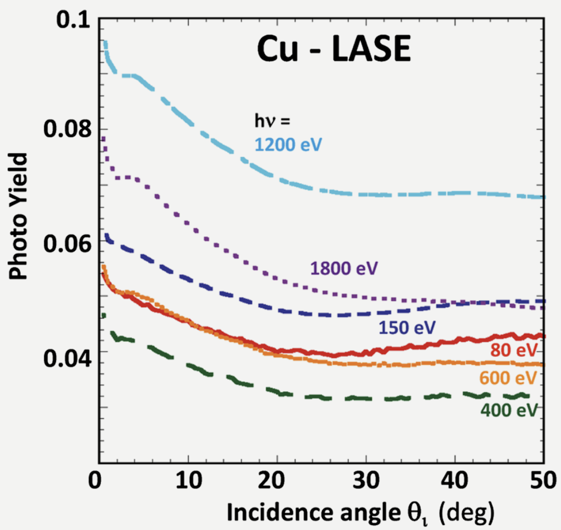


E (ev)	R Specular Reflec.	R_t Total Reflec.	Ratio (%) R/R_t
1800	0,0015	0,007	21
1200	0,0011	0,006	18
800	0,0009	0,007	13
600	0,009	0,006	15
400	0,001	0,009	11
150	0,001	0,014	7
80	0,003	0,011	3
50	0,006	0,012	5

- Rough surface drastically reduces R
- Cu absorption edge is evident in PY, not in R
- PY is not more dependent on Θ



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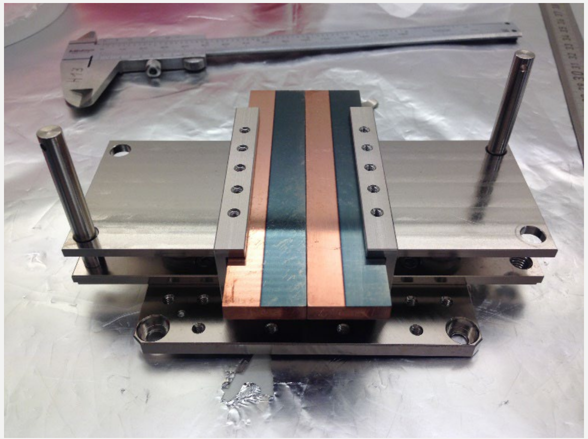
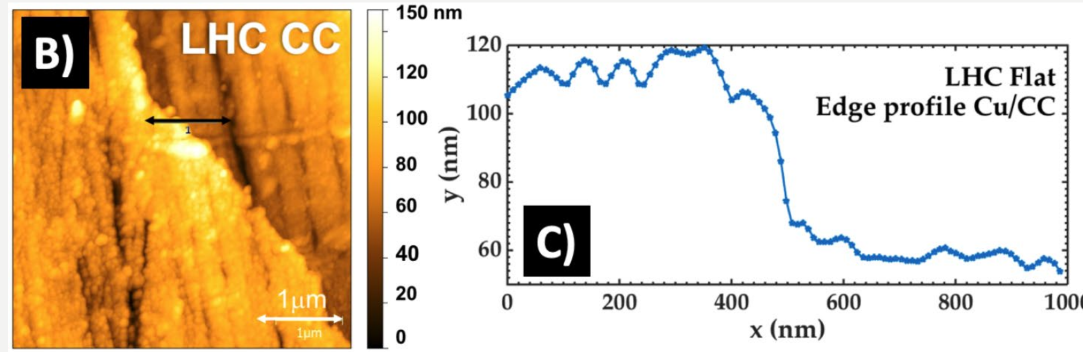
Carbon-Coated Copper

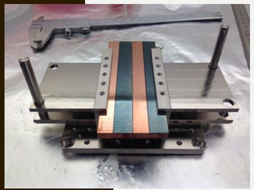


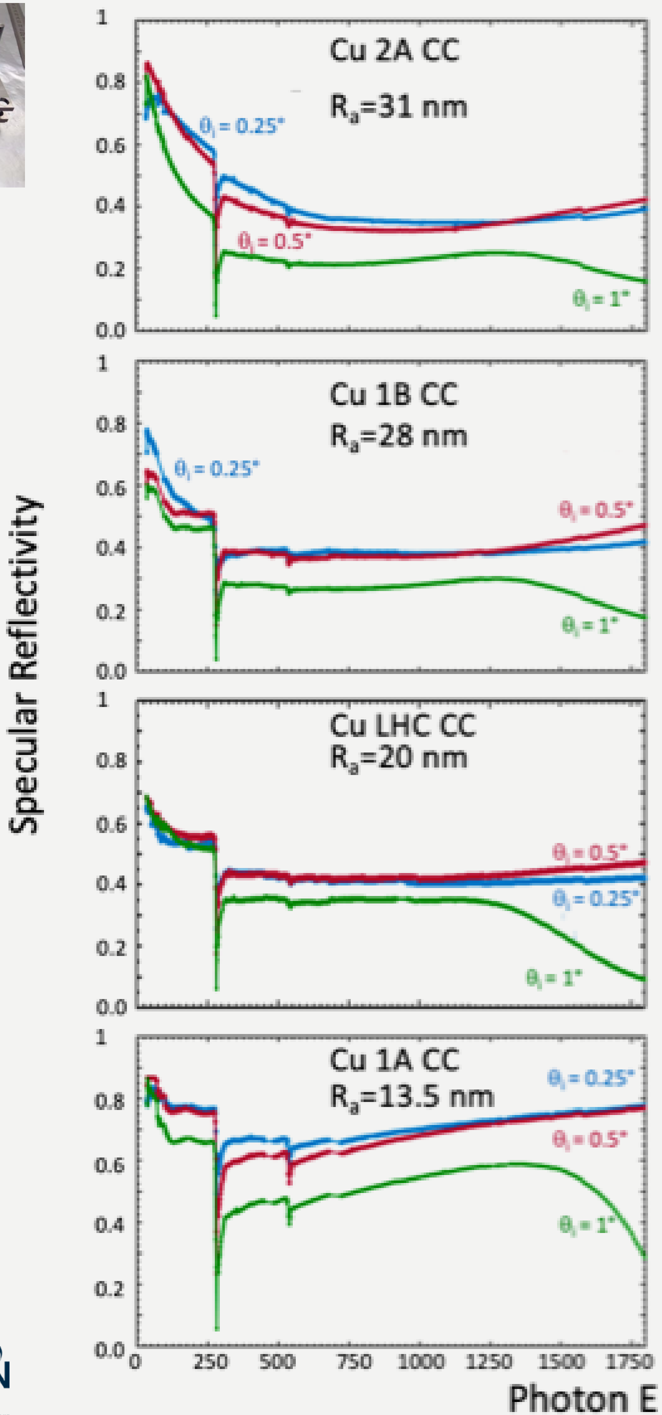


- Magneto-Sputtering Carbon Coating
- Thickness ≈100 nm

Sample	Ra Substrate ± 10%	Ra Coating ± 10%
Cu 1A	10 nm	13.5 nm
Cu 2A	27 nm	31 nm
Cu 2B	25 nm	28 nm
Cu LHC	15 nm	20 nm

Potential Remedies for the High SR Induced Heat Load for Future Highest-Energy-Proton Circular Colliders .
R. Cimino, V. Baglin, F. F. Schäfers , PRL 115, 264804 (2015)





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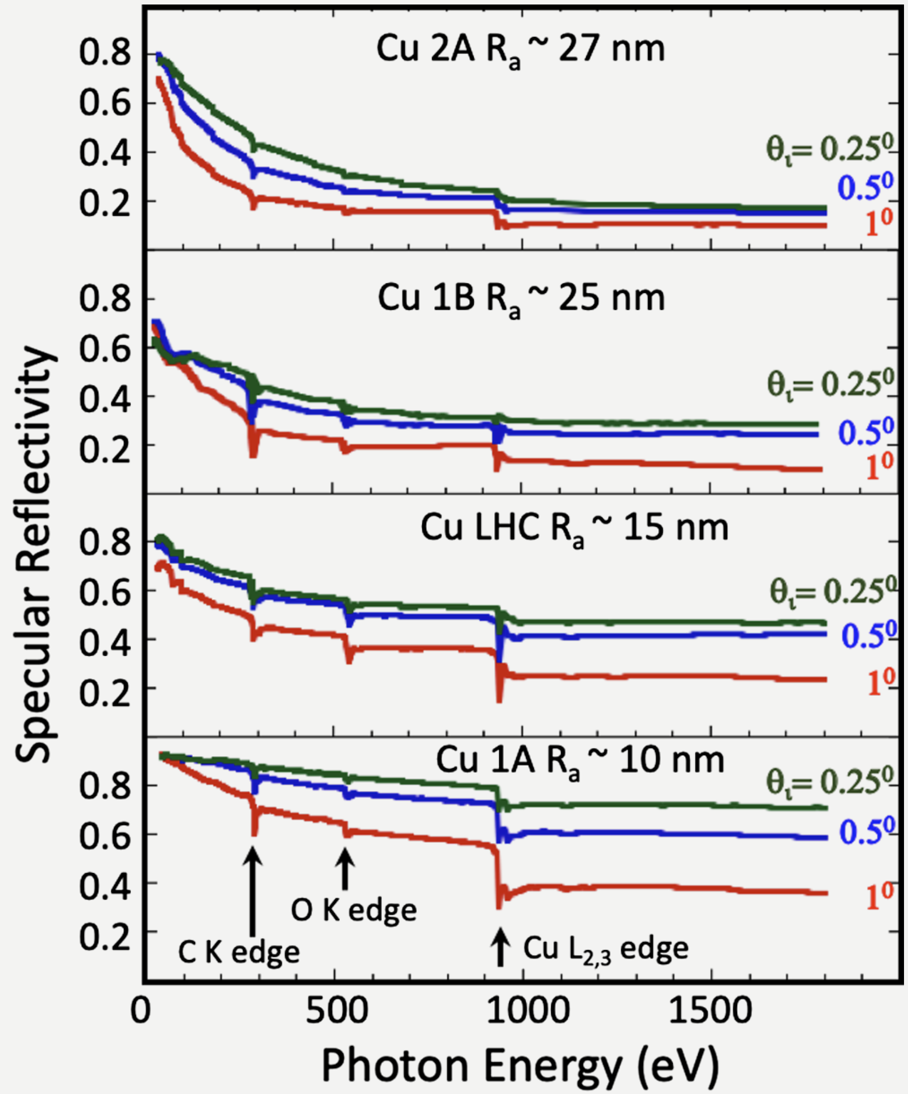
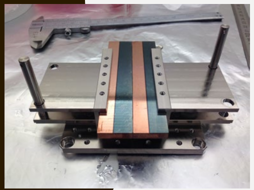


A.Liedl - Photo-Reflectivity and Photo Electron Yield of Technical Surfaces



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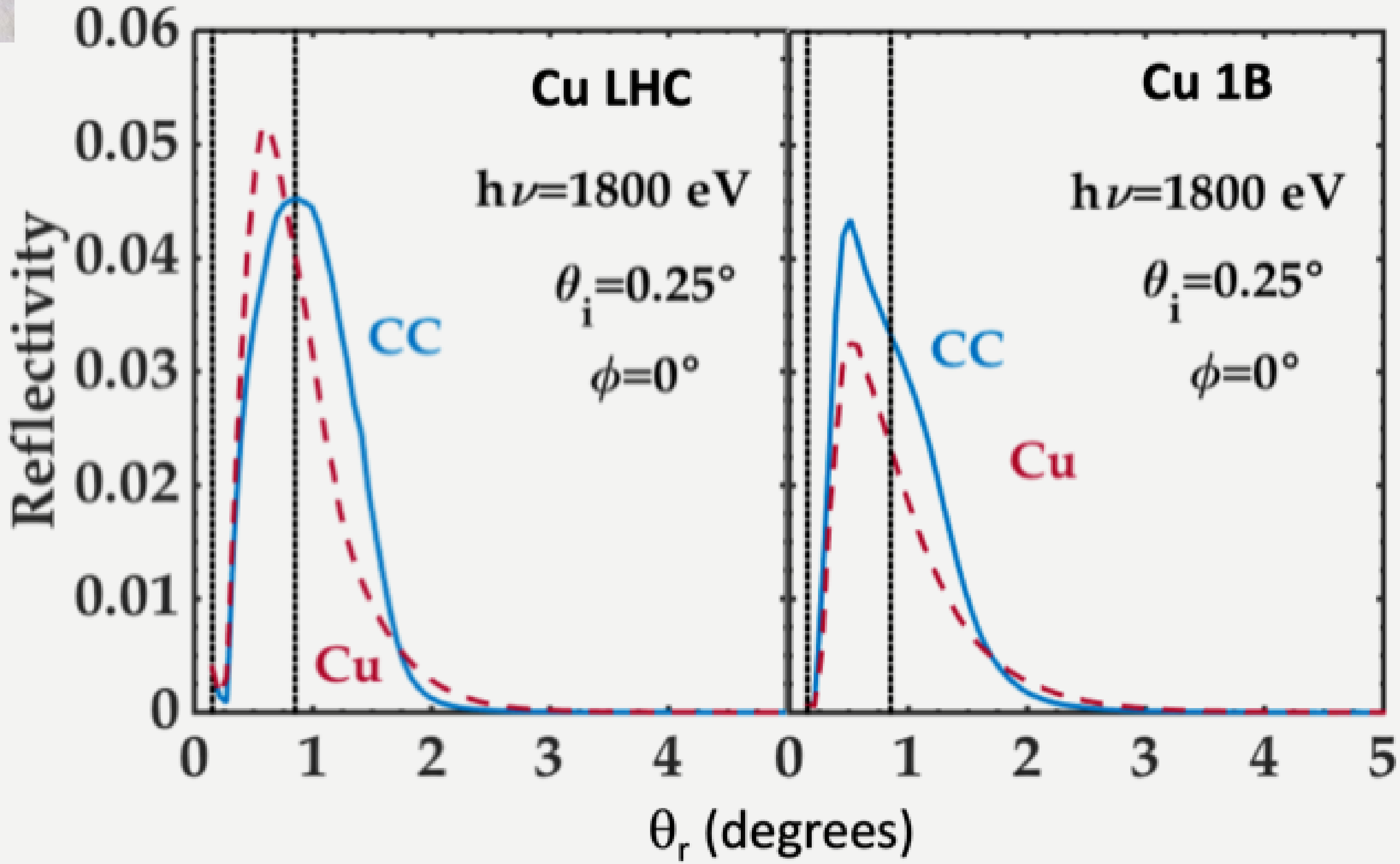

- General Increase of Total Reflectivity

Potential Remedies for the High SR Induced Heat Load for Future Highest-Energy-Proton Circular Colliders .
R. Cimino, V. Baglin, F. F. Schäfers , PRL 115, 264804 (2015)

Conclusion

- Experiments at BESSY-II Optics beamline allow characrerizarion of different Cu-sample
- Reflectivity and Photon Yield have been measured in the energy region 35-1800 ev starting from incidence angle of 0.25°
- The obtained results are now available for codes and simulation
- The experimental approach has been validated and the study could be simply extended to other Material, Beam and Experimental conditions such as
    - Surface coatings and treatments
    - Energy ranges
    - Exposure time to SR

Thank you for attention!