Photoemission from LHC vacuum chamber materials: electron energy distribution curves

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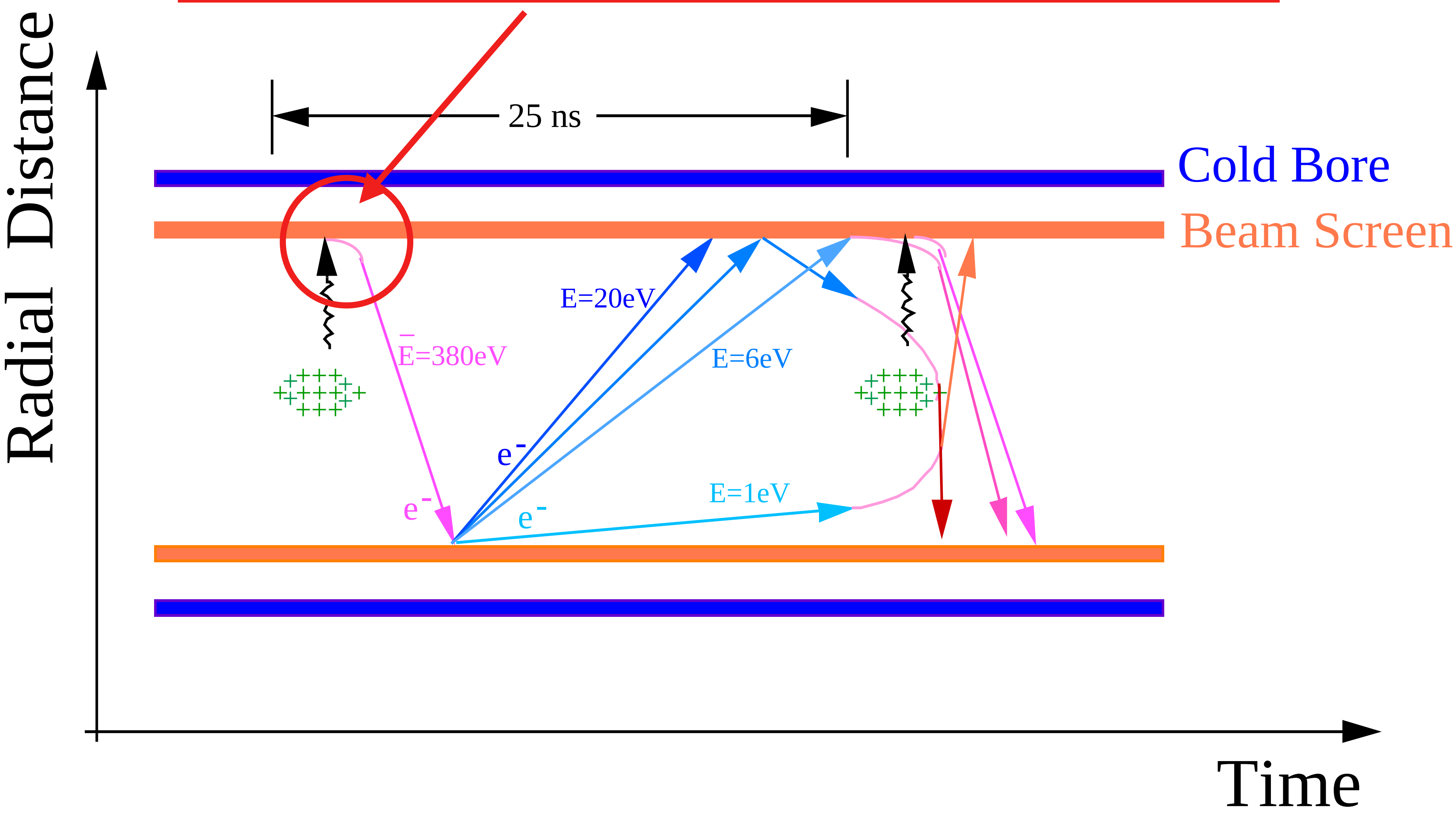
- Introduction.
- Photoemission and LHC.
- Importance of measuring EDC
- Results and discussion
- Conclusion.

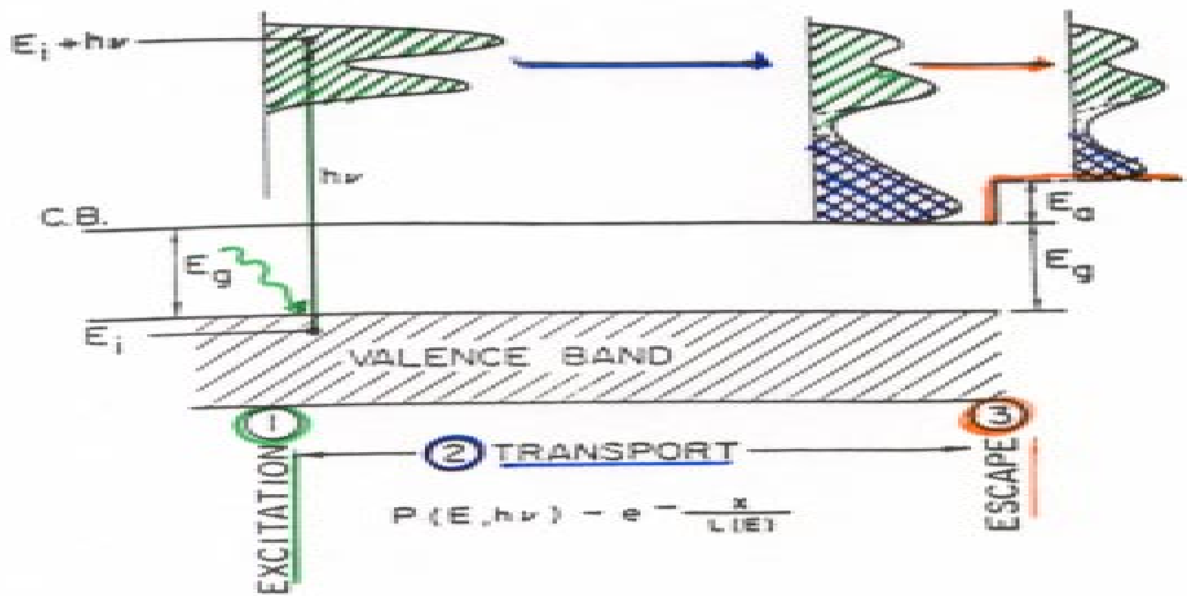
• This is Photoemission!



The Three- Step Model of Photoemission

Photoemission can be treated as a three steps sequence:

1. Optical excitation of an electron
2. Its transport through the solid (including the possibility of inelastic scattering by other electrons etc..)
3. Escape through the sample surface to the vacuum



The primary distribution of electrons can be factorized (according to the three step model) as :

$$I_p(E, h\nu) = N_I(E, h\nu) \times T(E) \times S(E) .$$

where :

$N_I(E, h\nu)$ is the internal distribution of photoexcited electrons

$T(E)$ is the transmission function

$S(E)$ is the escape function

The internal distribution of photoexcited electrons: $\mathbf{N_I (E, h\nu)}$

Assuming:

- Fermi golden rule.
- Interaction matrix element is a slowly varying function of **k** and can be written as $|\overline{M_{if}}|$.
- The final state is not strongly affected by the crystalline potential and can be considered as the one of a free electron

Than:

$$N_I (E, h\nu) \propto |\overline{M_{if}}|^2 \rho(E)$$

where $\rho(E)$ is the initial states density !

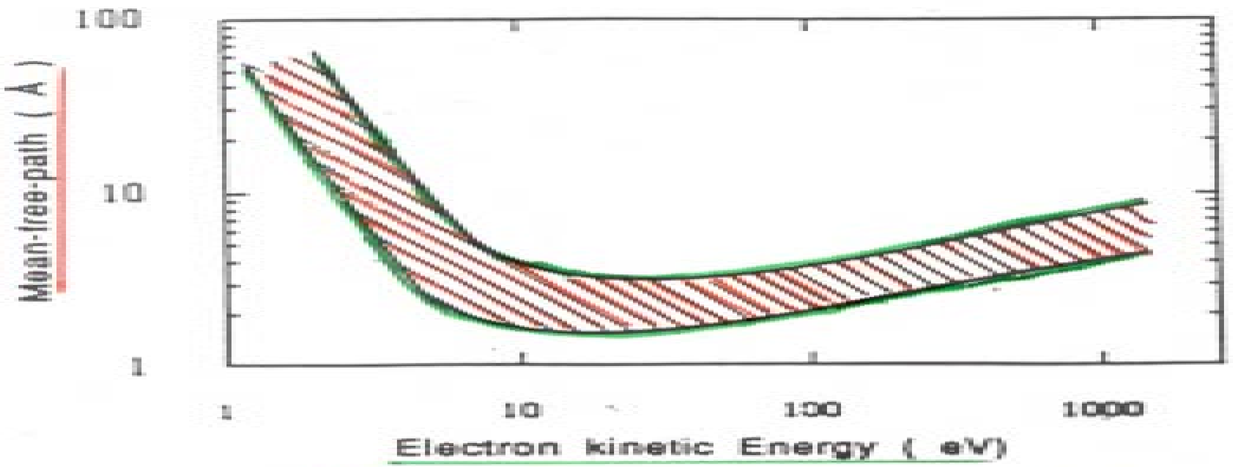
Photoemission gives a "distorted" replica of the density of states of the material under study!

The transmission function T(E)

$P(E,z) \sim \exp[-z\ \lambda(E)]$ is the probability that an electron with kinetic energy E travels in the solid a distance z without suffering inelastic scattering; $\lambda(E)$ is the electron mean free path

Only electrons emitted in a region distant $\lambda(E)$ from the surface have a non-negligible probability to escape into vacuum: in photoemission $\lambda(E)$ ia also called escape depth.

$\lambda(E)$ can be assumed to be largely independent from the material.



$$==> \quad T(E) = \frac{\alpha\lambda(E)}{1+\alpha\lambda(E)} \propto \alpha\,\lambda(E)$$

where: α is the light absorption coefficient.

Photoemission is surface sensitive !

The escape function $S(E)$

Escape from the solid is only possible for those electrons with a kinetic energy component normal to the surface sufficient to surmount the potential barrier $E_F + \phi_s$

Assuming the excited photoelectrons to be plane-wave-like with $E = k^2/2$, this condition defines an escape cone with an opening angle relative to the surface normal:

$$\cos\Theta = \left(\frac{\phi + E_F}{E} \right)^{1/2}$$

For an isotropic distribution of electrons inside the solid, the fraction $D(E)$ which escapes is than given by

$$D(E) = 1/2\left[1 - \left(\frac{\phi + E_F}{E} \right)^{1/2} \right] \quad ; E > \phi + E_F$$

$$= 0 \quad ; \text{elsewere}$$

D(E) is generally a smooth function of E beyond the low energy cut-off.

The secondary electrons $I_S(E, h\nu)$

The most important process to produce secondary electrons is electron-electron scattering.

The electron-electron scattering cross section, proportional to the inverse of the mean free path, leads to a strong multiplication of electrons and thus to the actual accumulation of electrons at low kinetic energies, where the scattering cross section is small ($\lambda(E)$ is big).

Multiple scattering process will make this distribution rather structureless with the possible exception of peaks due to strong plasmon losses or Auger processes.

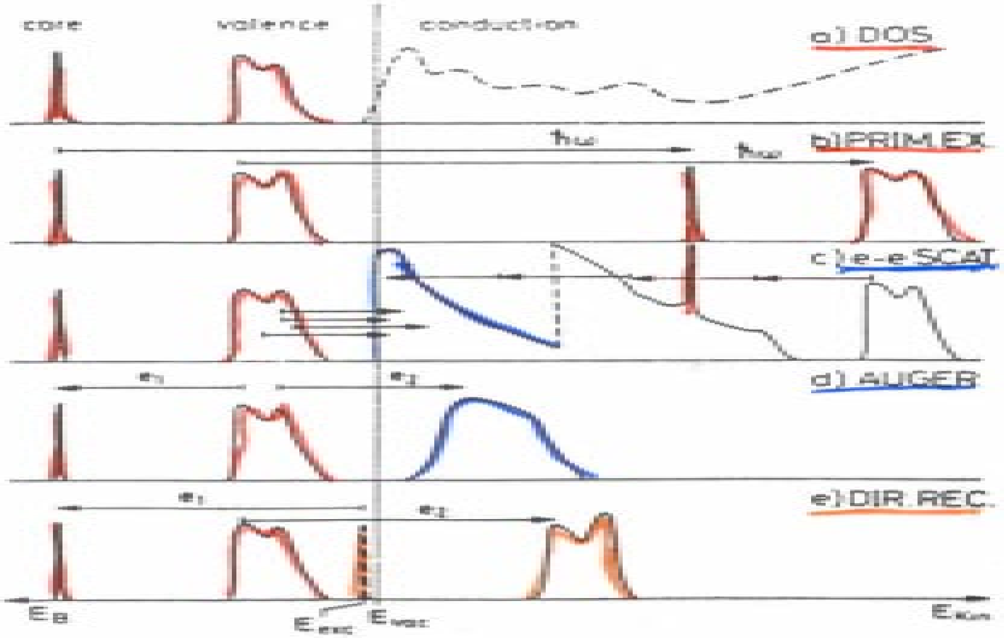
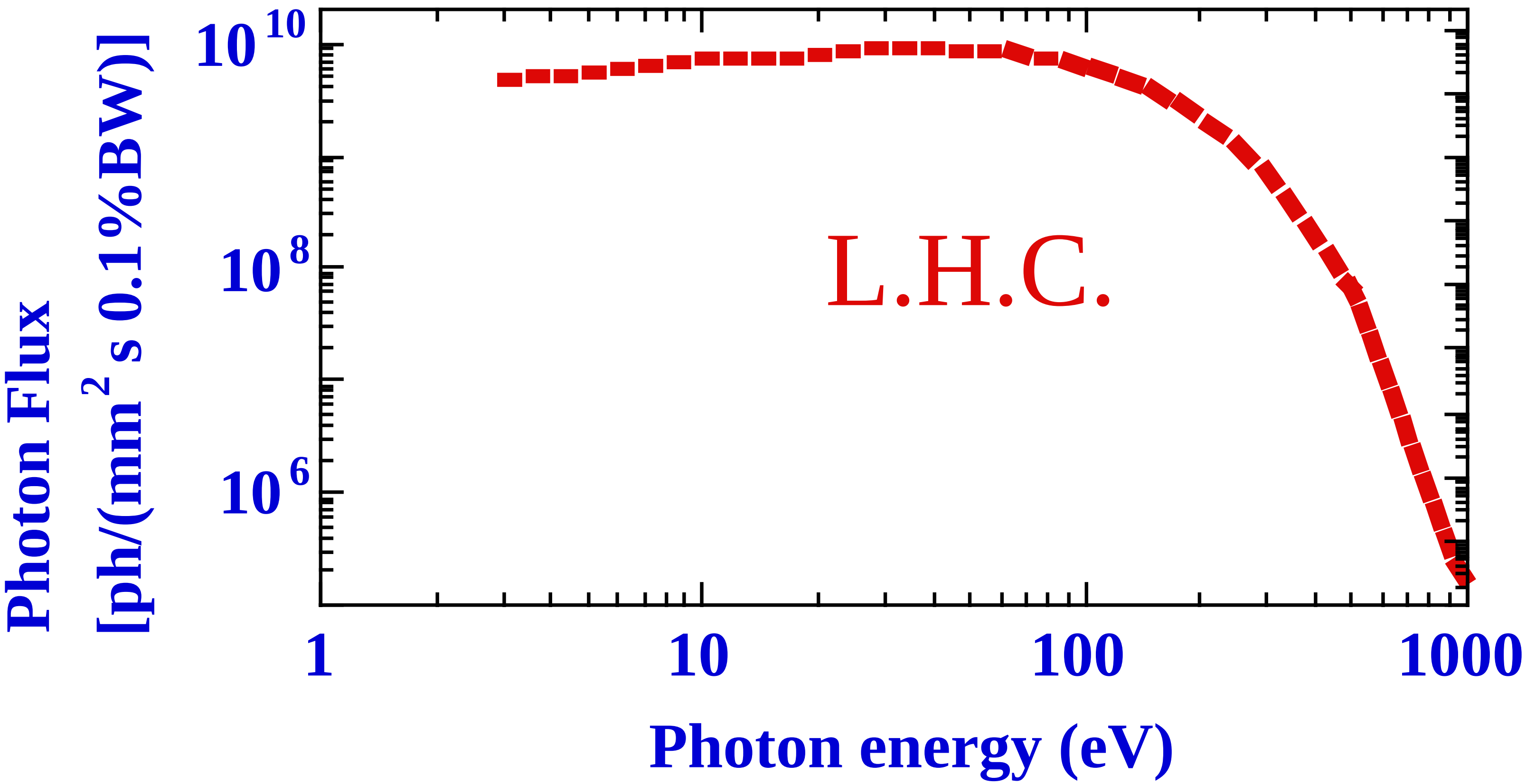


Fig. 6.13a–e. Contribution of primary and secondary processes to an EDC spectrum (schematic): **a** as an example a DOS of an insulator is assumed with one core and one valence band; **b** primary excitations with photons of energy $\hbar\omega$; **c** electron-electron scattering of energetic electrons; **d** Auger decay of a hole in the core state; **e** direct recombination of a bound core exciton state (autoionization) [6.39]

The cutoff of the secondary electrons measure the sample work function.

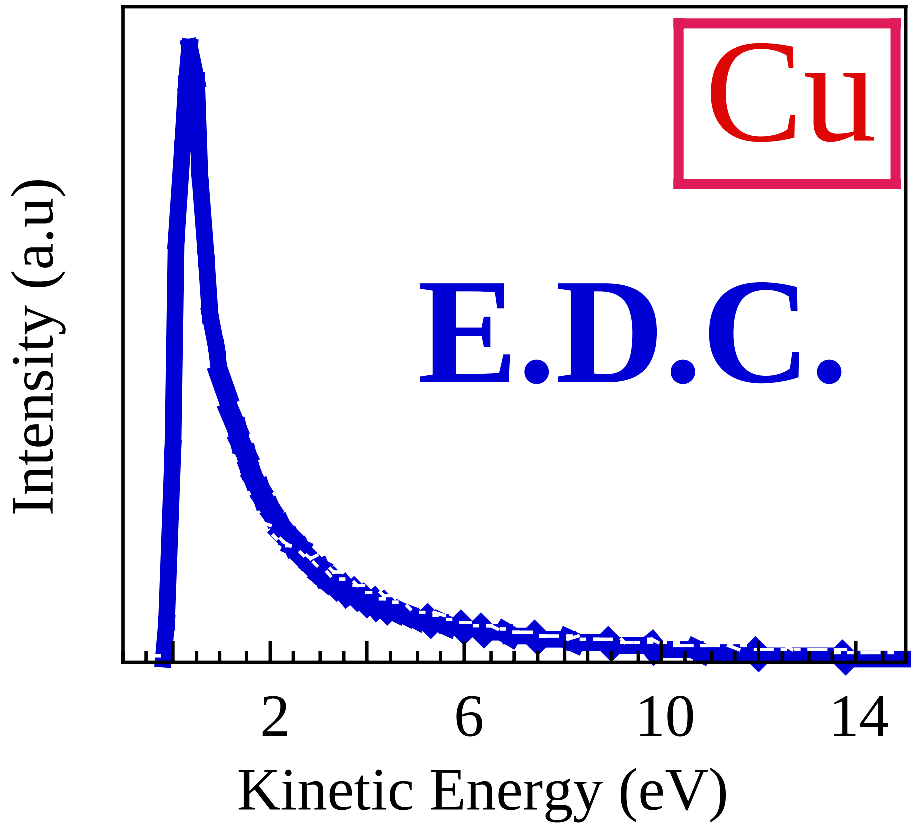
LHC as a photon source:



LHC vacuum chamber as a photo-electron source:

DEPENDS ON:

- Material temperature, type and condition.
- Photon energy distribution (may change after reflection)
- Angle of incidence and emission
- Presence of a magnetic field....



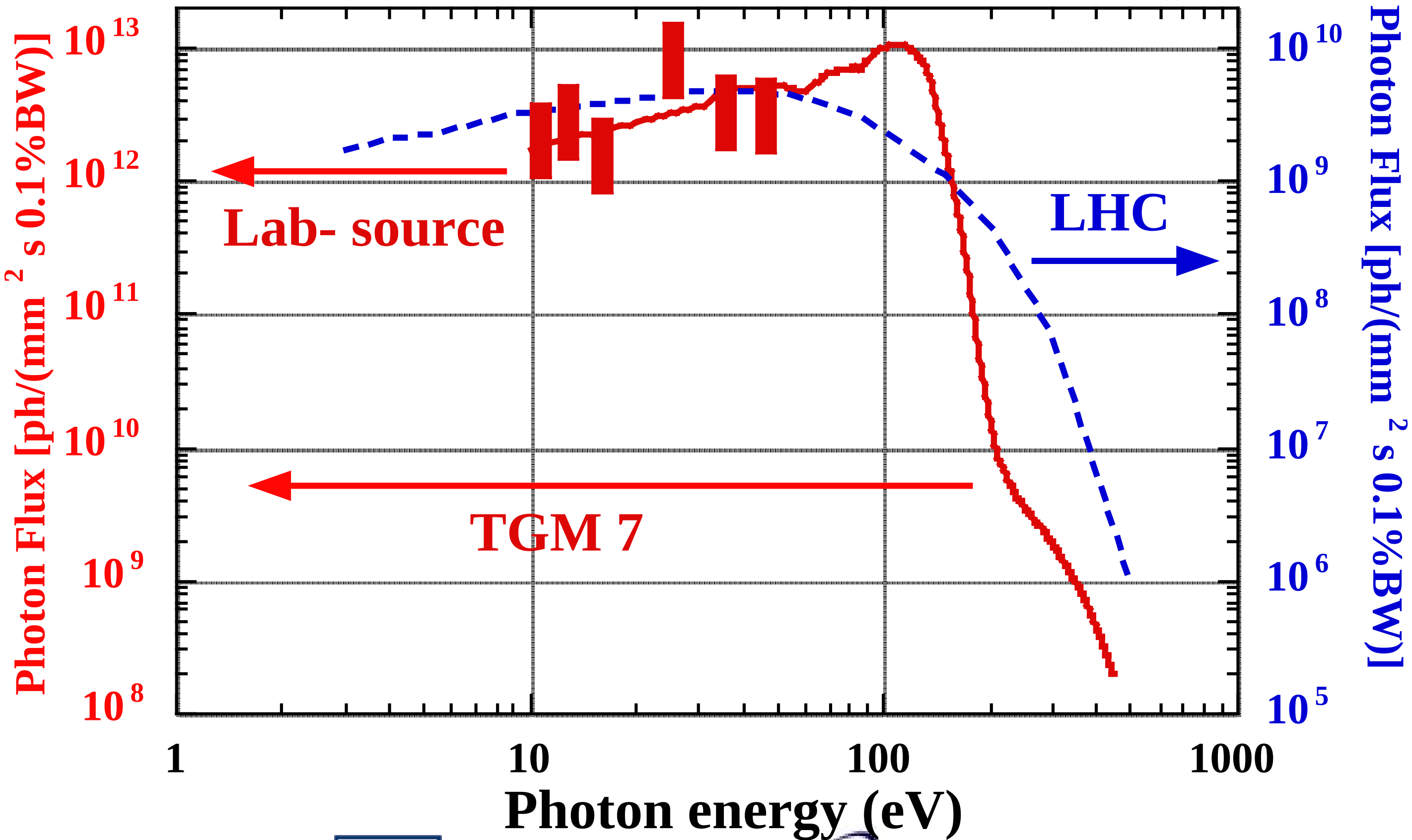
Photoemission is :

- not only a phenomenon occurring at LHC

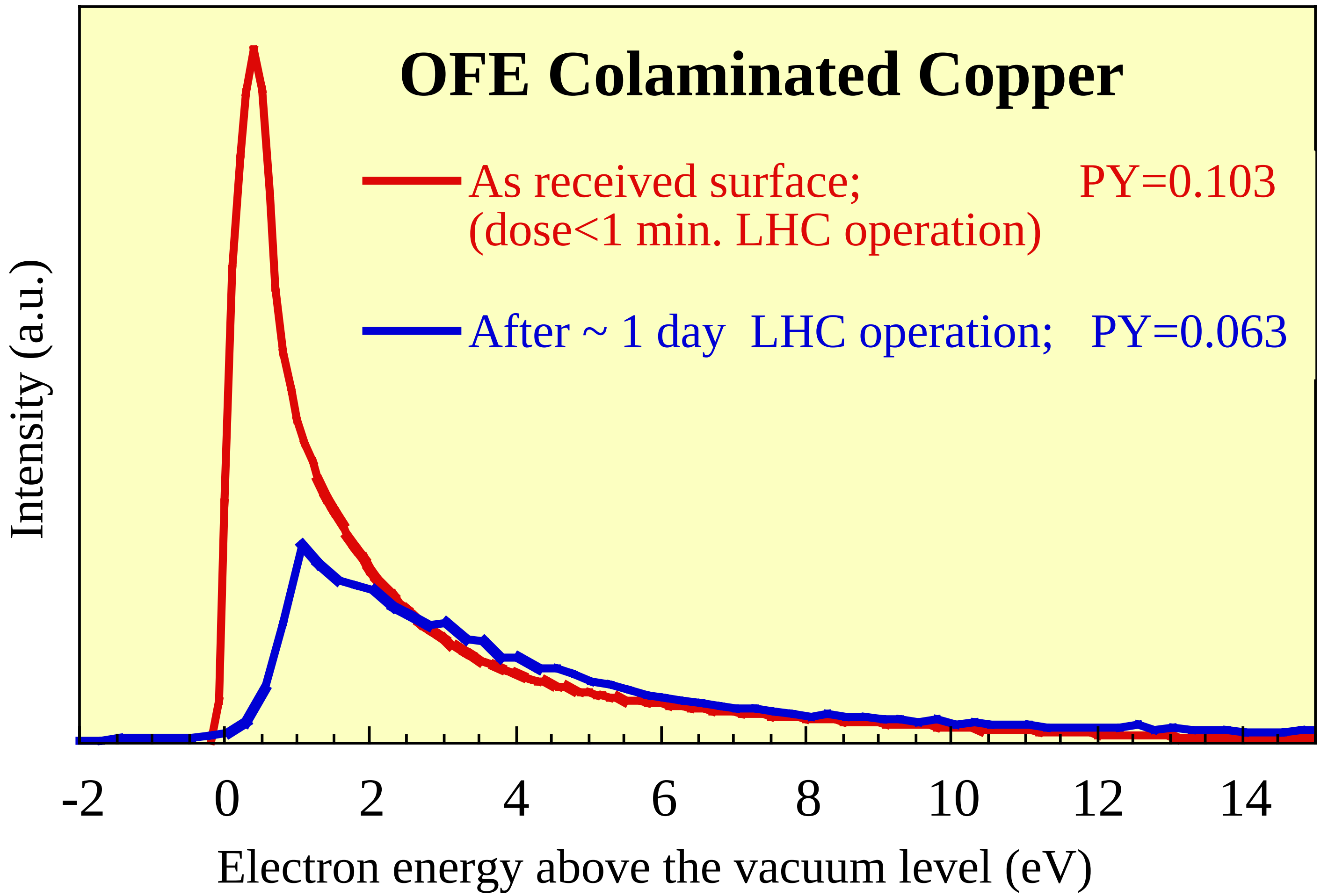
B U T

- A powerful tool to study surface chemistry and surface electronic properties.
- Useful to study secondary electrons with very low doses.

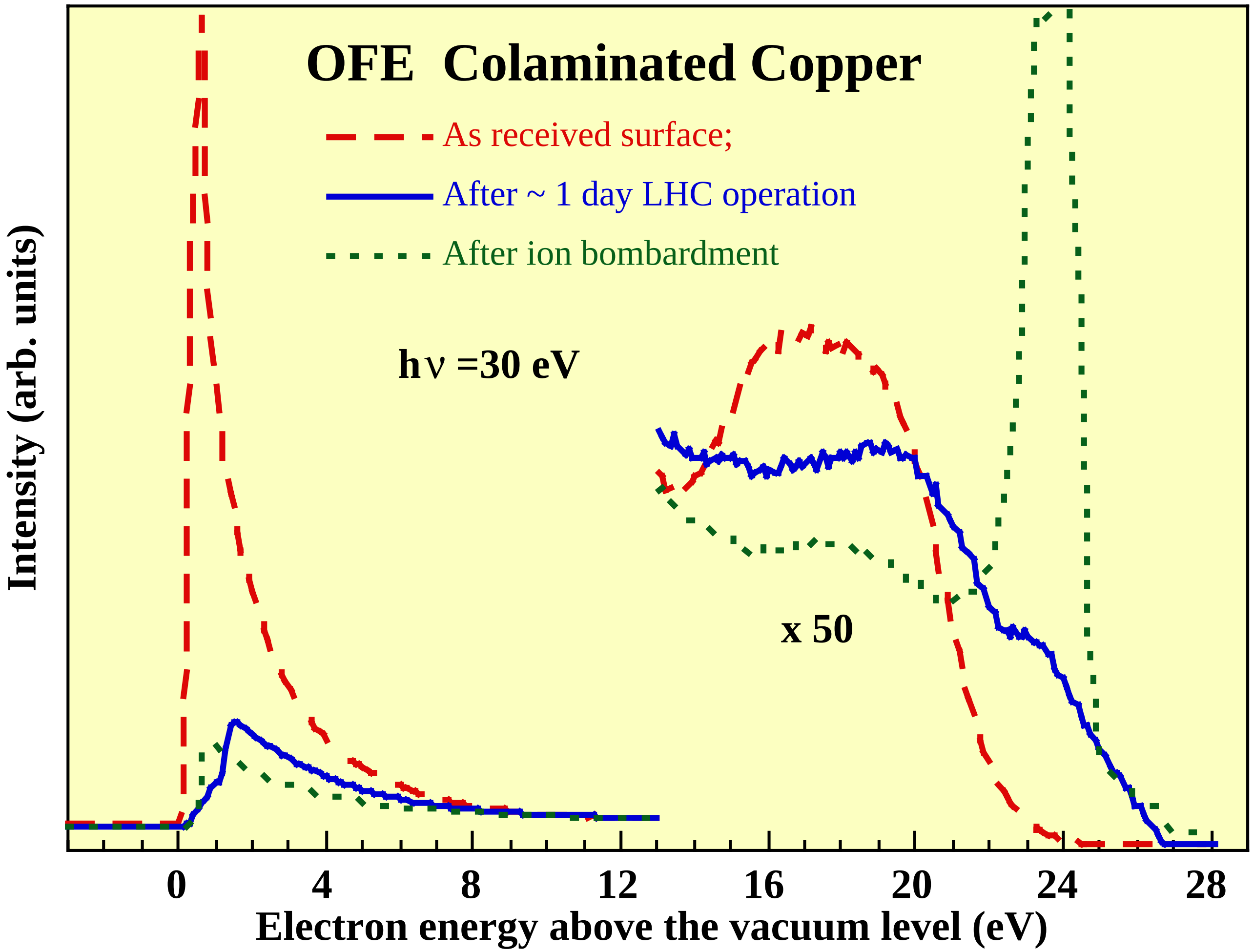
Experiment with Synchrotron radiation and lab-sources.



EDC vs. WL ph. Doses



Photoemission with Monochromatic light



What next:

- Perform experiments in 'as close to reality conditions' as possible. (exp. at low temperature are essential!)
- Produce inputs for BIEM simulations.
- Give a deeper understanding of the chemical processes occurring at surfaces, for example:

from LHC PR 472:

"…Although the phenomenon of conditioning has been obtained reproducibly on many samples, the exact mechanism leading to this effect is not properly understood. This is of course not a comfortable situation as the LHC operation at nominal intensities relies on this effect…"

How:

- Thanks to a CERN - INFN collaboration it is now available at CERN a state of the art surface science apparatus to study energy and angle resolved electron emission from samples at 8<K<400 as exited by photons and electrons.
- An on-going effort is also devoted to guarantee access to Synchrotron radiation facilities, ideal to study in more details LHC related BIEM problems.