Surface Studies for SEY reduction by Scrubbing

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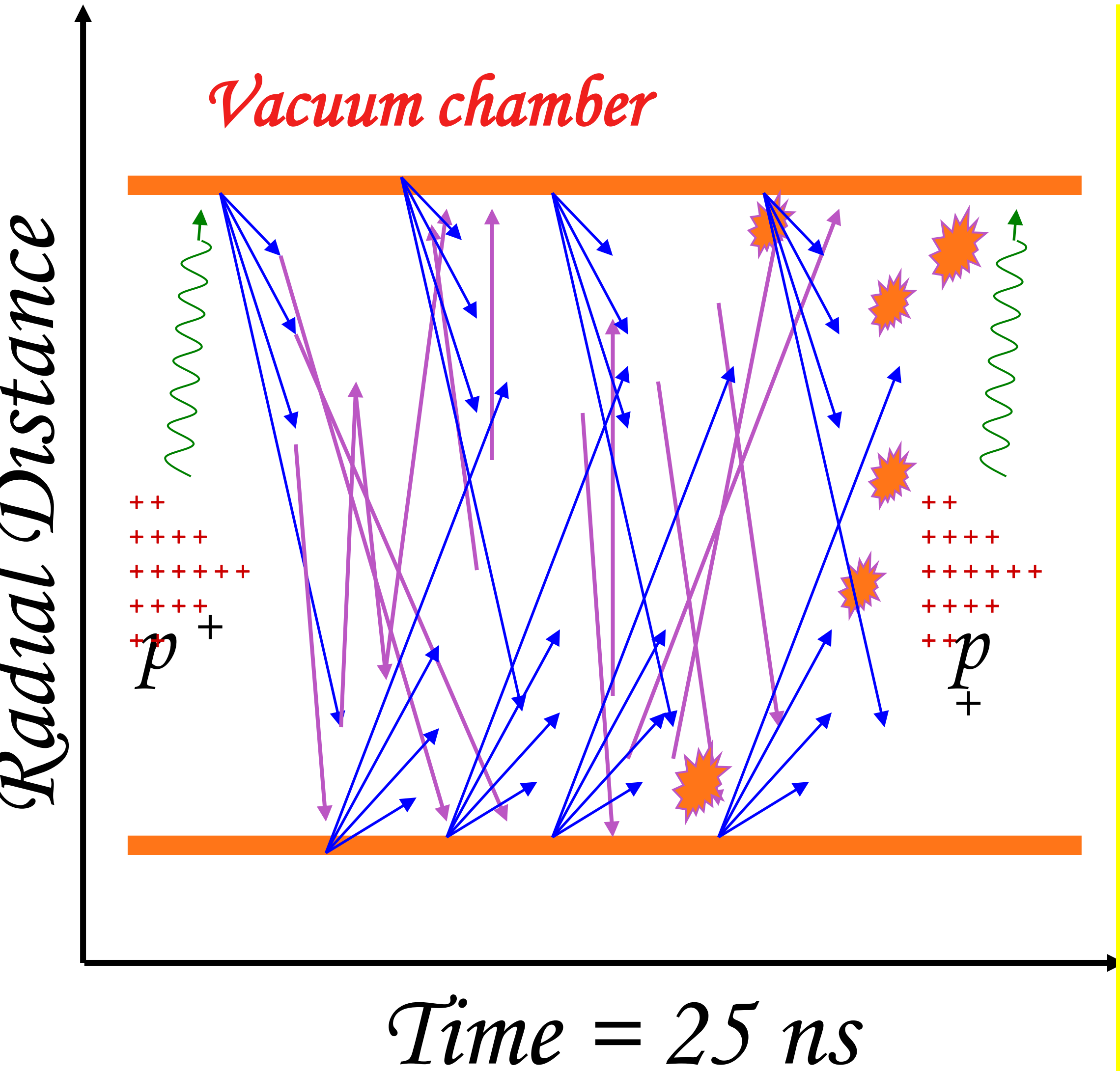
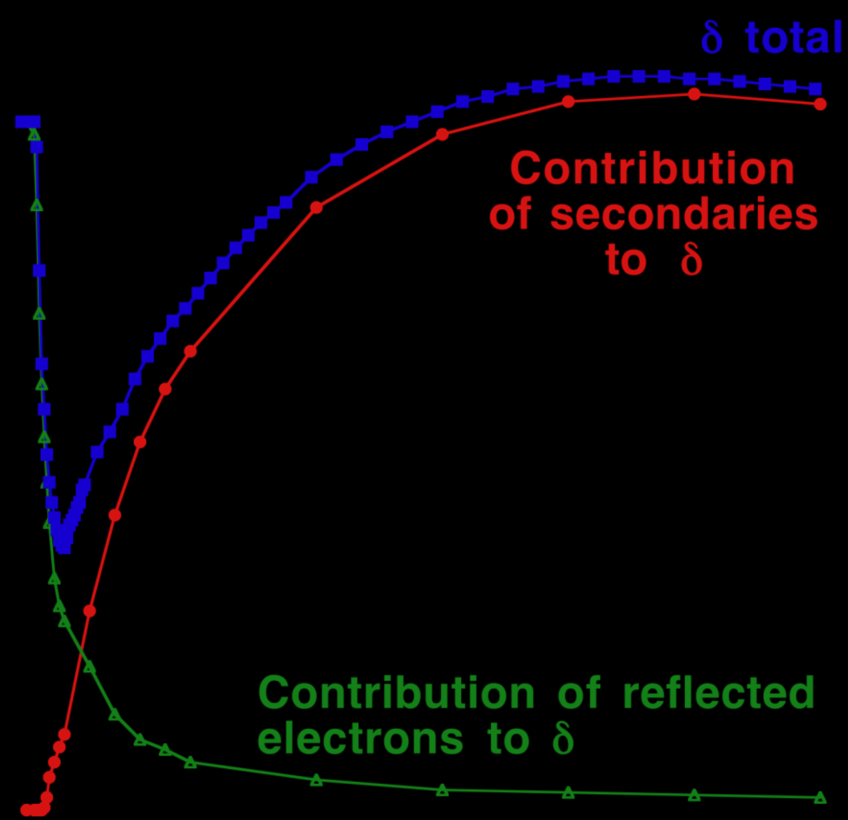
The "e-cloud" phenomenon (in pills)



The accelerated particle beam produces SR and/or e^- that, by hitting the accelerator's walls generate photo-e^- or secondary-e^-.
Such e^- can interact with the beam (most efficiently for positive beams) and multiply, inducing additional heat load on the walls, gas desorption and may cause severe detrimental effects on machine performance.

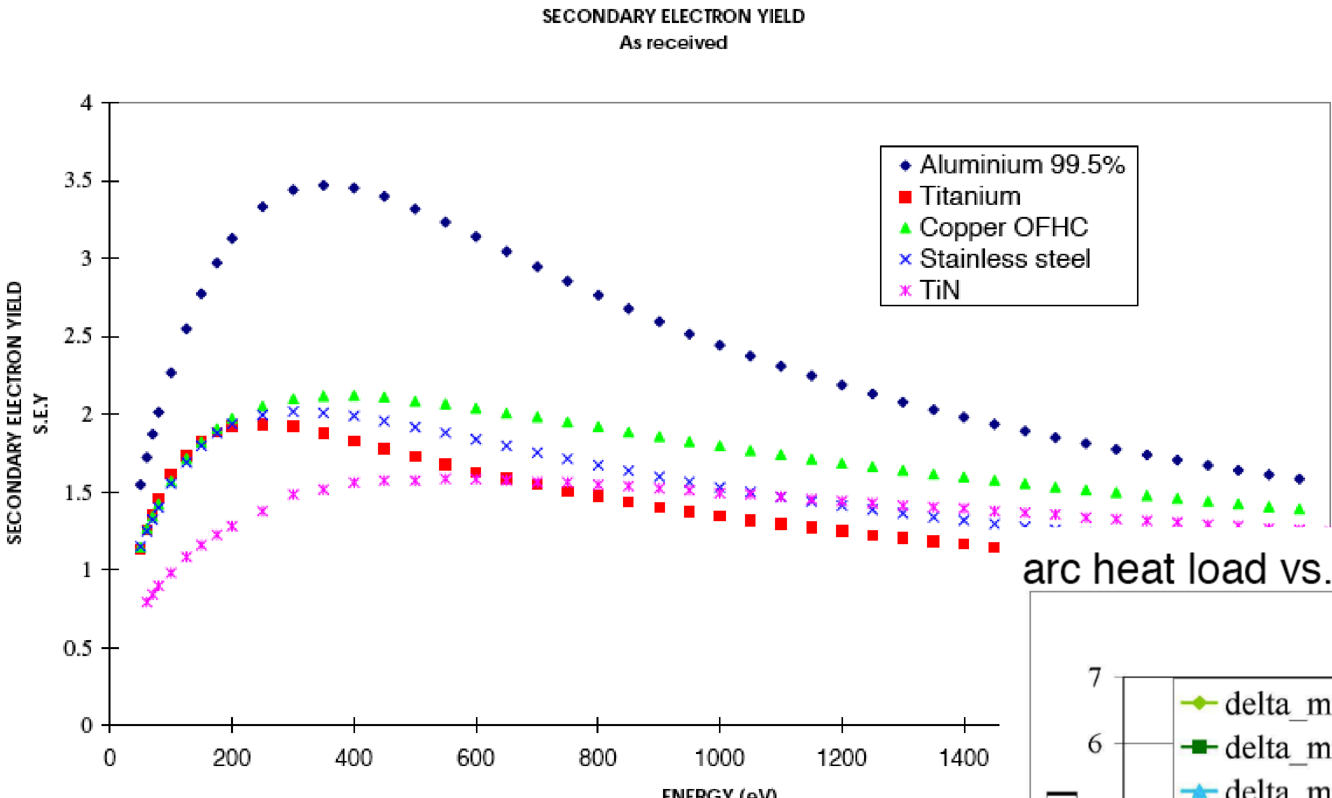
One of the most relevant parameter for e-cloud studies is: S.E.Y. (or δ)



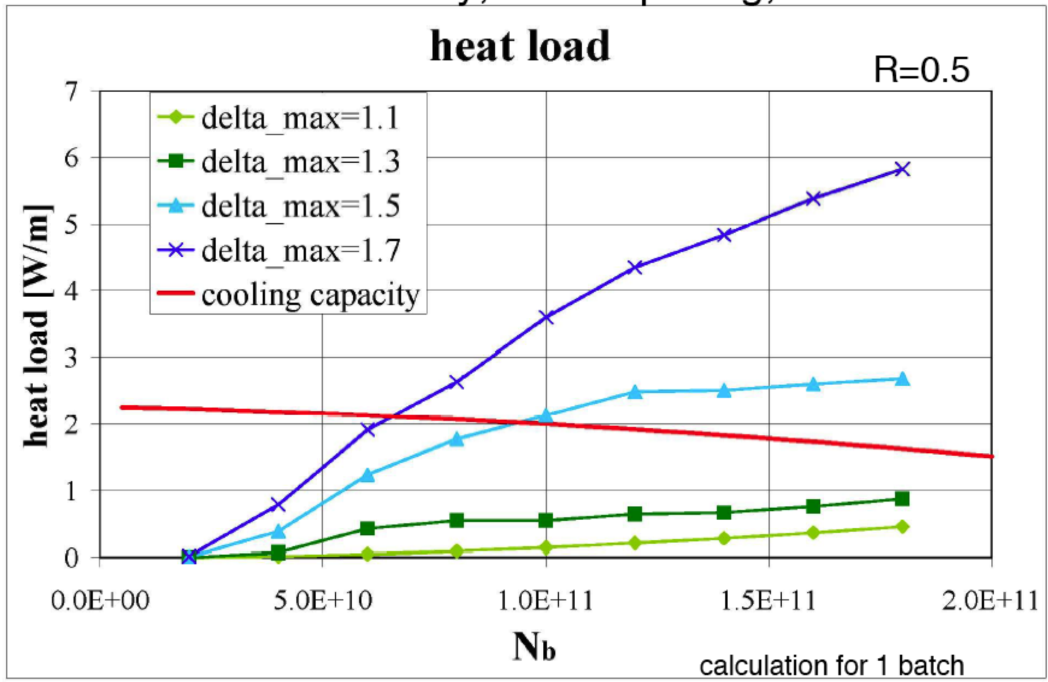
I.e.: the number of electrons created after bombardment of a single electron.

R. Cimino, et al.,
Phys. Rev. Lett.
93 (2004) 014801

Measure of Secondary e⁻ YIELD



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

…. And its impact to simulations (see calculaion for LHC).

Most of the existing and planned accelerator machines base the reaching of their design parameters to the capability of obtaining walls with a SEY ~1.3 or below!

Surface Scrubbing (or conditioning)

Intrinsically low SEY material

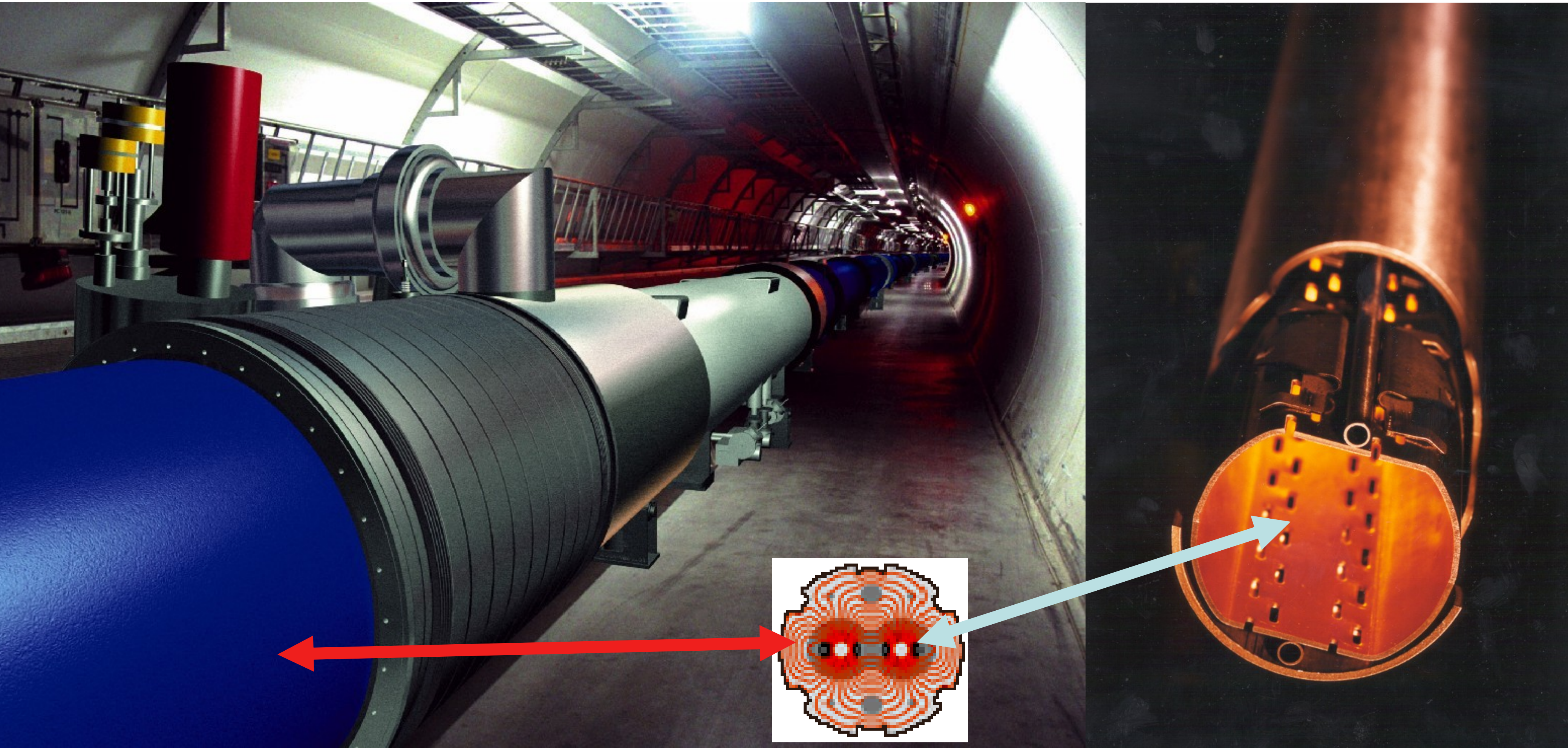
Geometrical modifications

Electrodes in the lattice.

External solenoid field

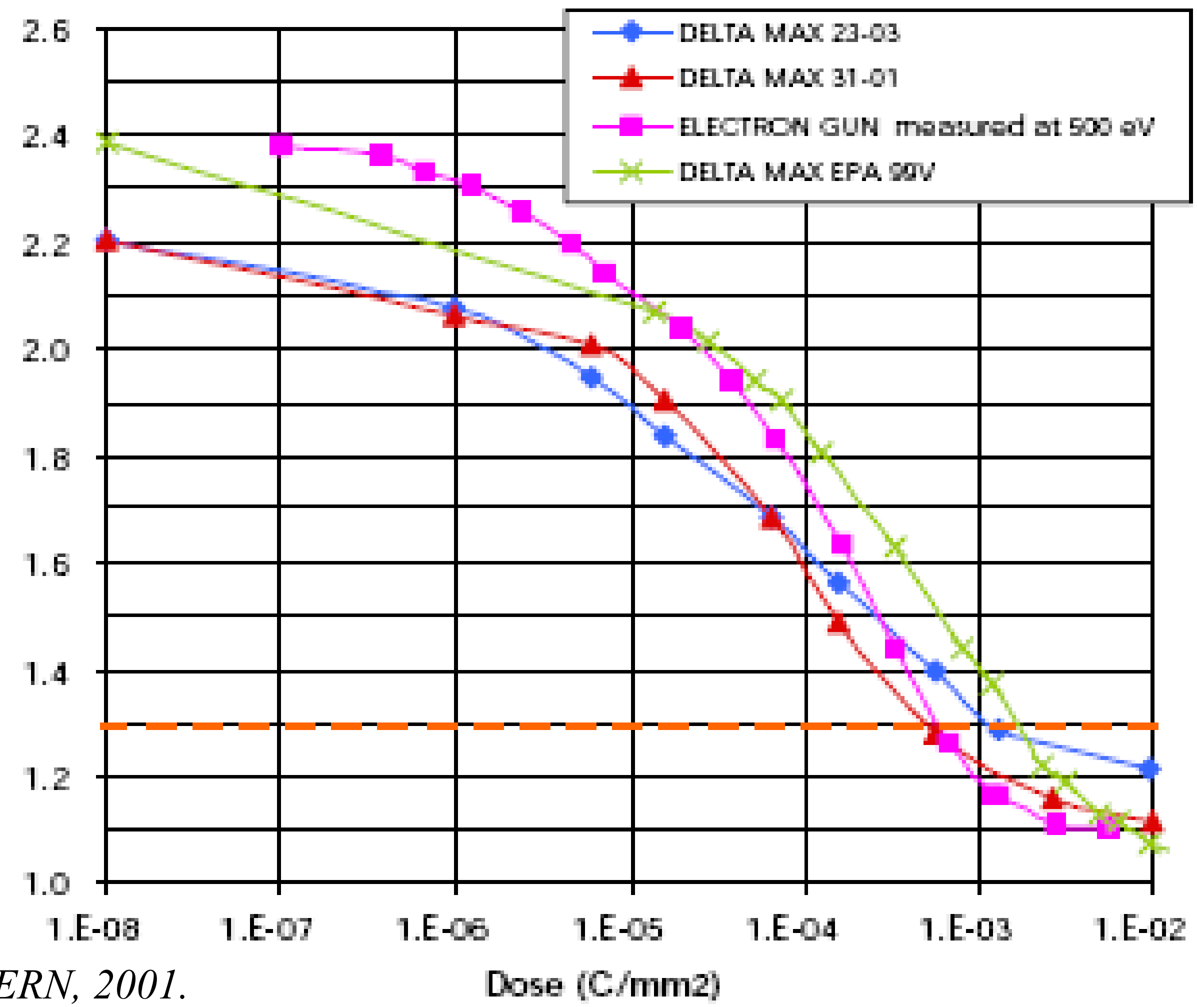
Surface Scrubbing (or conditioning)	-Efficiency (time & final SEY)…
Geometrical modifications	Impedance. Machining costs.
Intrinsically low SEY material	Stability and material choice…
Electrodes in the lattice.	If possible… (Impedance, costs.)
External solenoid field.	Not always possible…

For LHC: Cupper surfaces and "scrubbing" in the LT dipole regions.



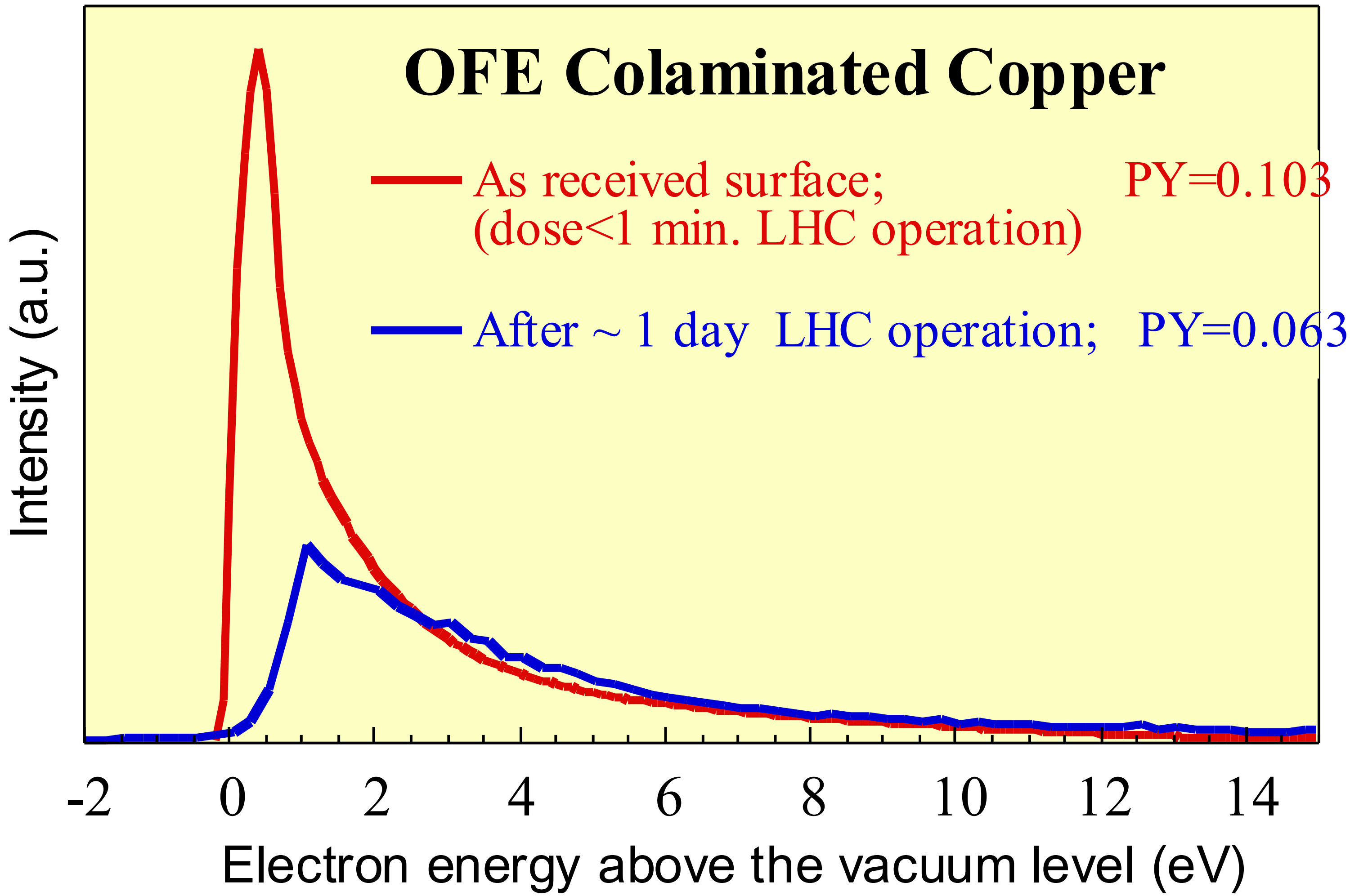
The Beam "scrubbing" effect is the ability of a surface to reduce its SEY after e^- bombardment.

from LHC PR 472 (Aug. 2001): "…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…"



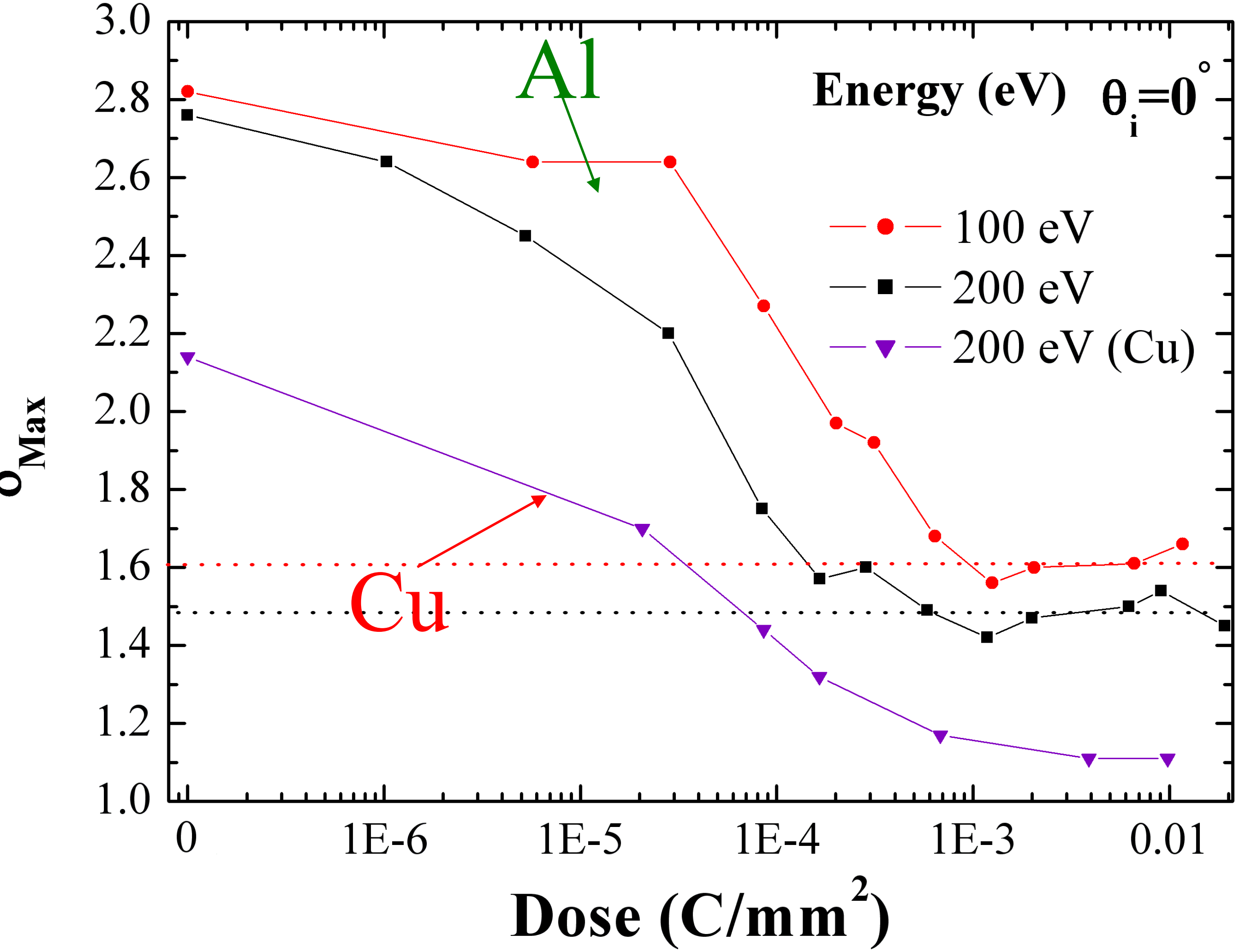
V. Baglin et al, LHC Project Report 472, CERN, 2001.

Addendum (1): also photons can scrub

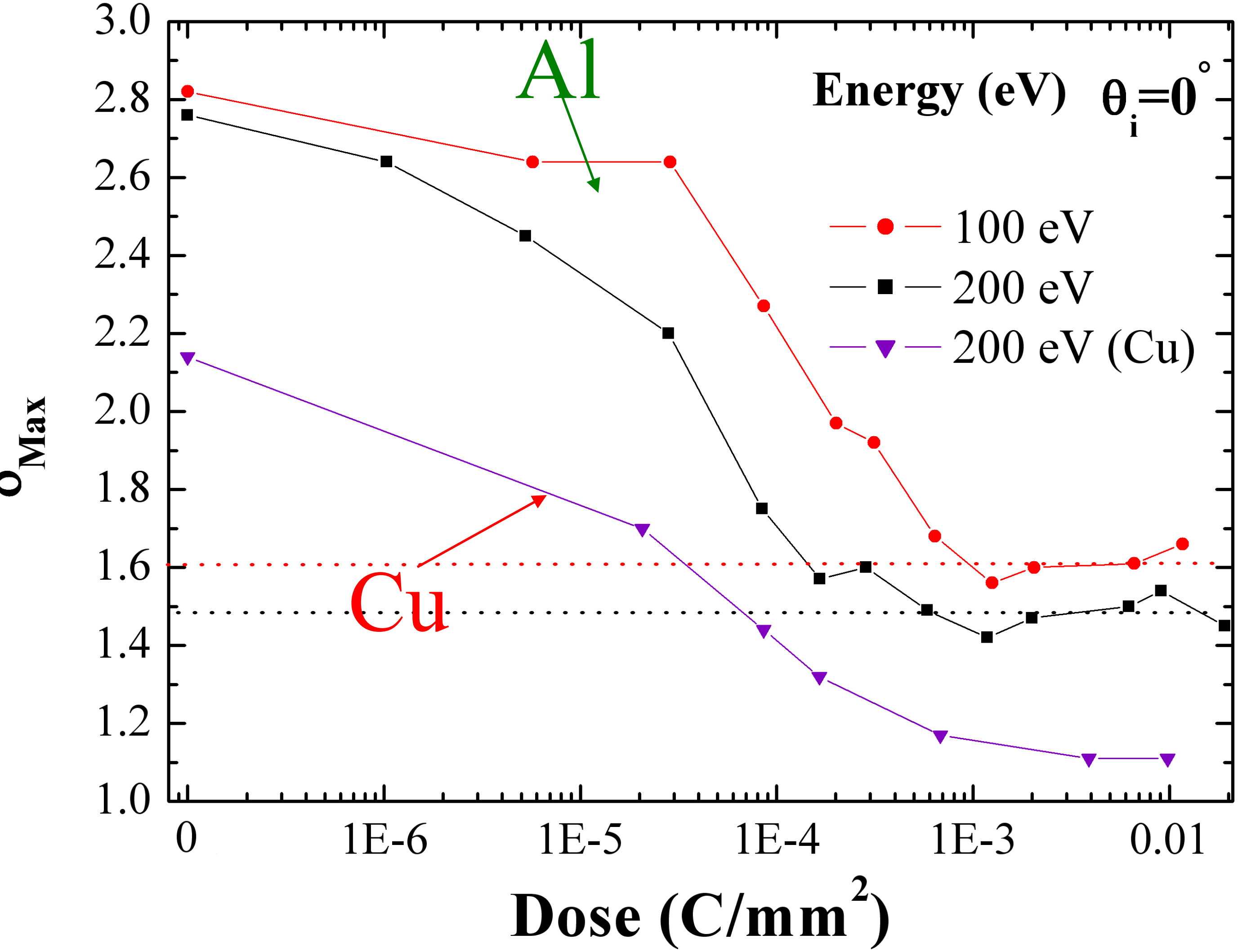


See: R. Cimino et al PRST 2 063201 (1999)

Addendum (2): "our" DAFNE Al -chamber scrubs!



Addendum (2): "our" DAFNE Al -chamber scrubs!



When you deal with industrially prepared materials:

All That Glitters Is Not Gold !!!

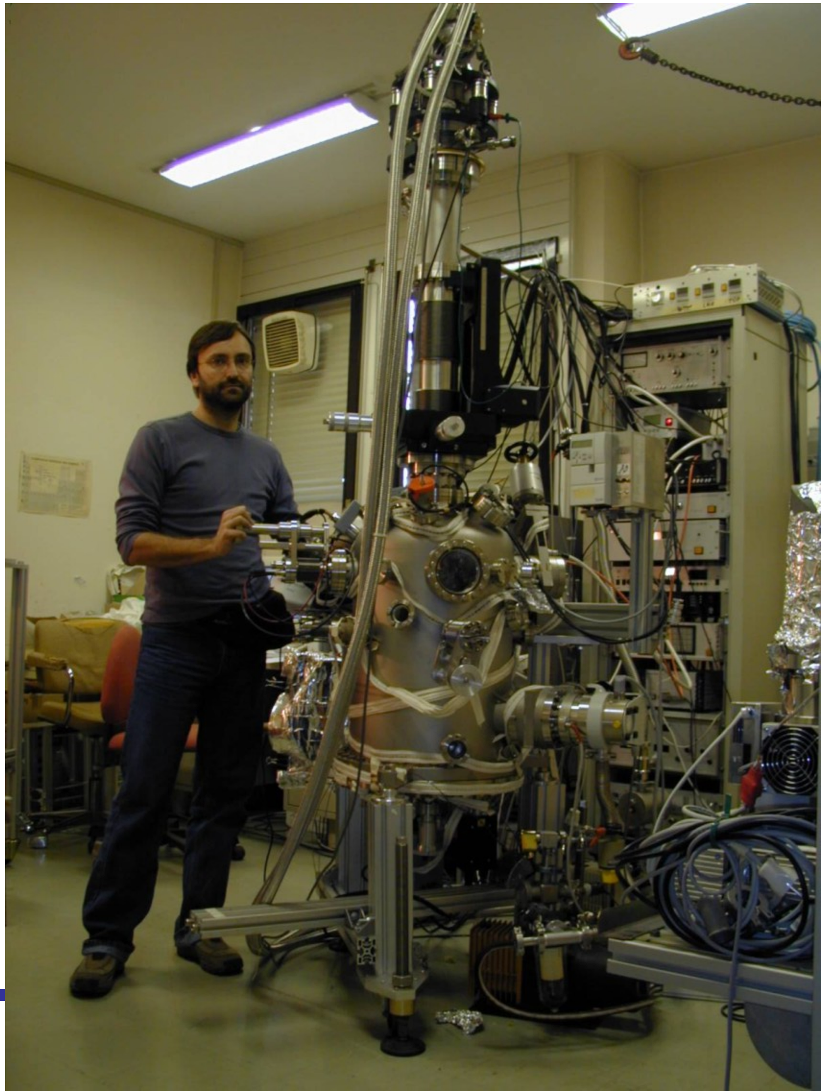
Paper in prepration

Most of the data on "scrubbing" have been obtained in laboratory experiments by bombarding surfaces with 500 eV electrons for increasing Time (i.e: dose)

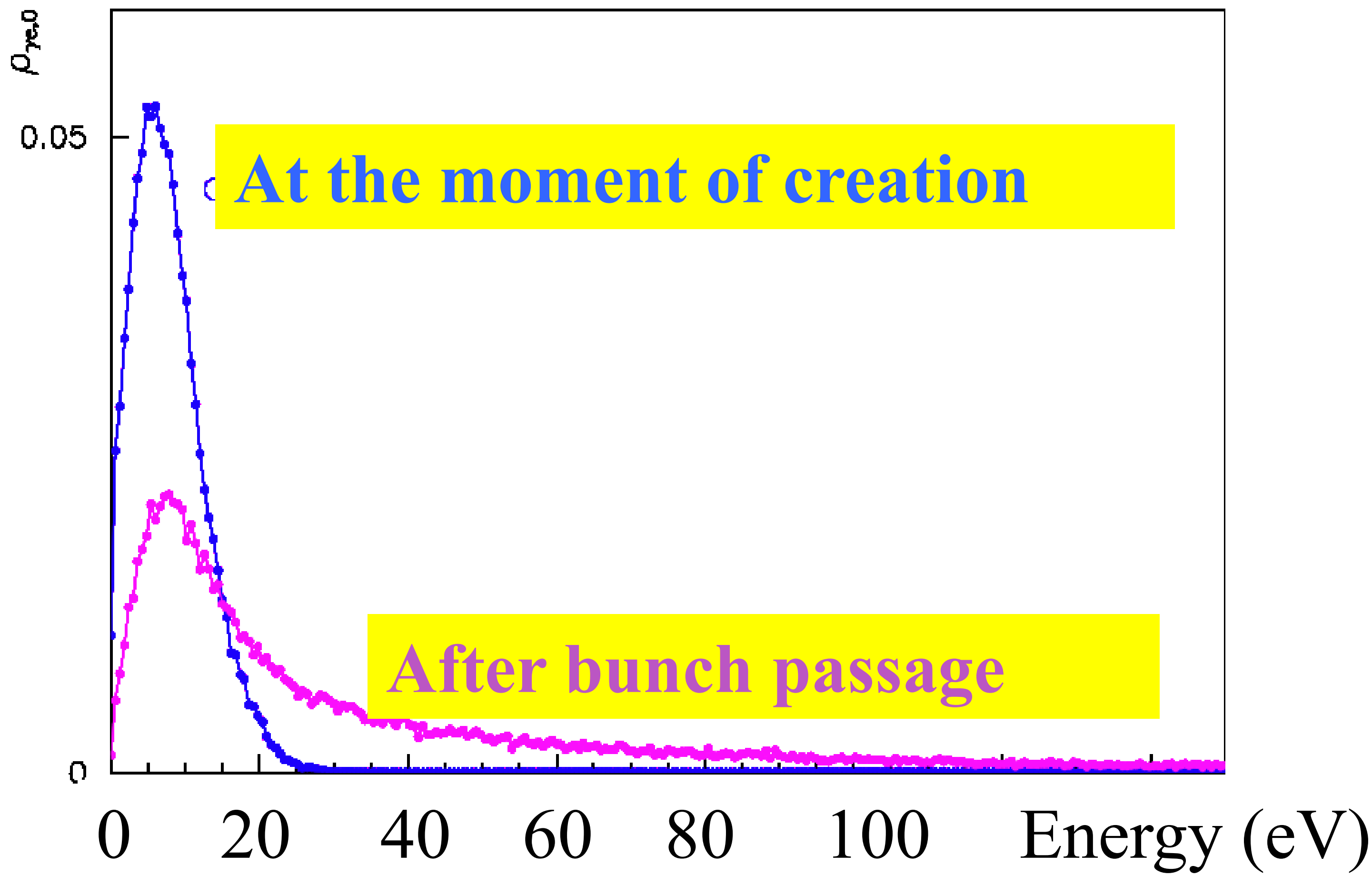
$$\text{Dose} = N^{\circ}\ e^{-} \times t(s) \times A\ (mm^2)$$

- What energy do the e^- participating in the cloud have in the accelerator?

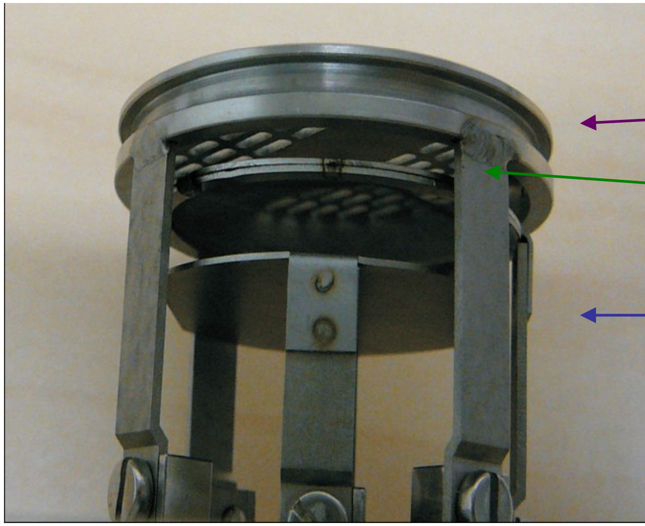
- do 10 e^- @ 500 eV scrub as
  - 10 e^- @ 10 eV?



Simulation by F. Zimmermann (2001) shows that the main contribution lies at low energy!



RFA (from Anka) to measure electron distribution in accelerators!

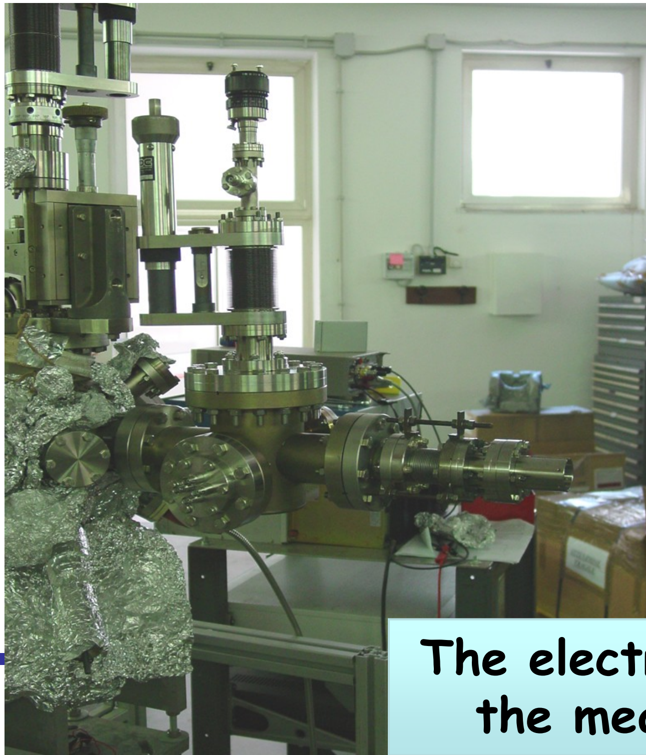


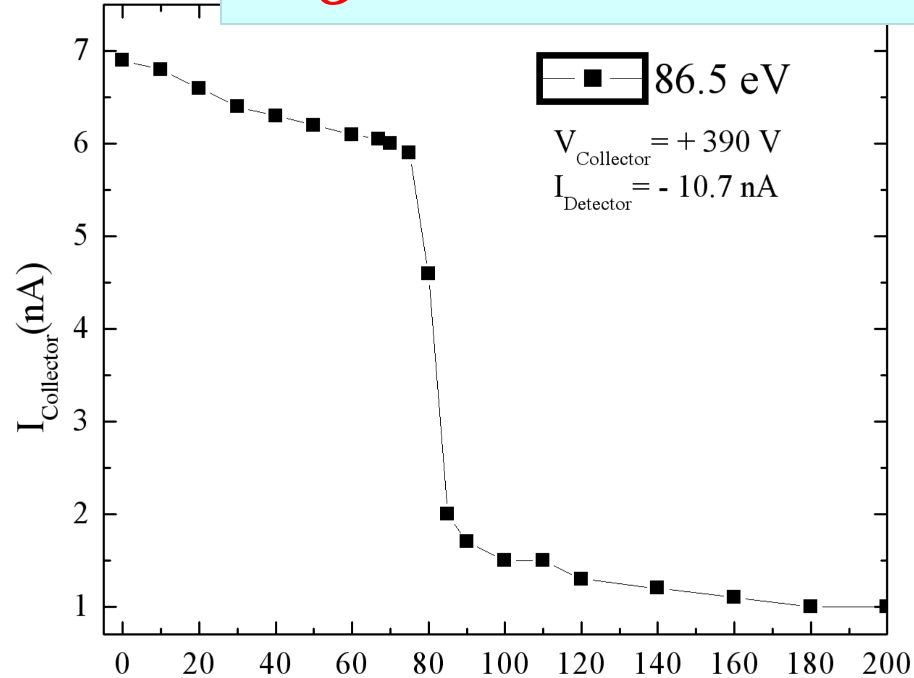
The slotted disc is grounded to present a uniform field to the incoming electrons

Retarding Grid, biased with a retarding potential

Collector positively biased

Calibration by shooting e- gun into the detector

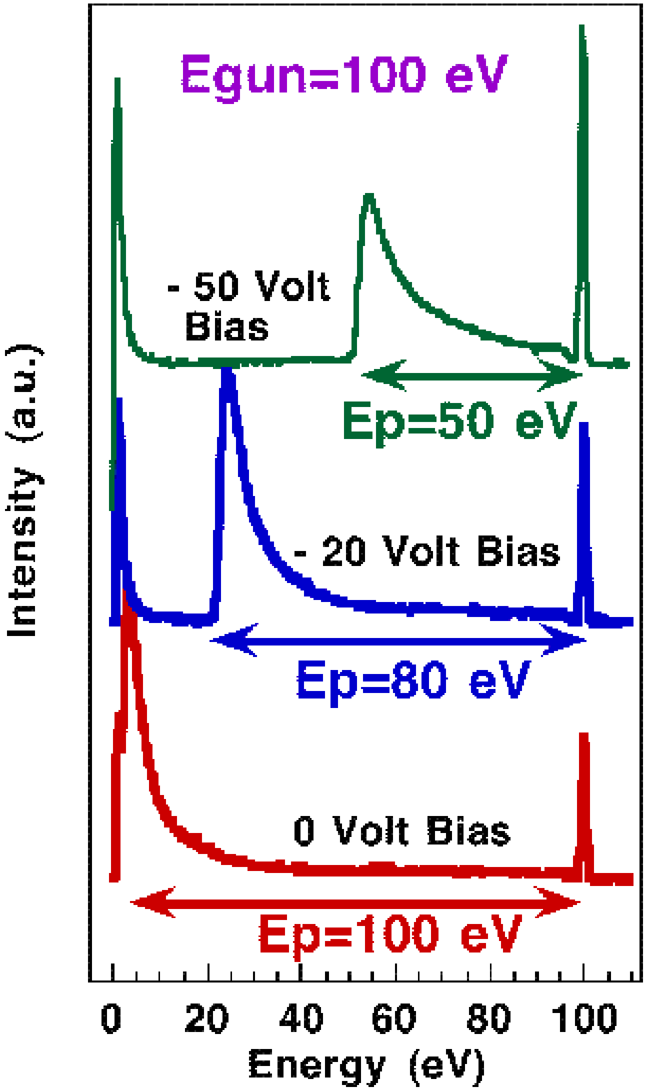




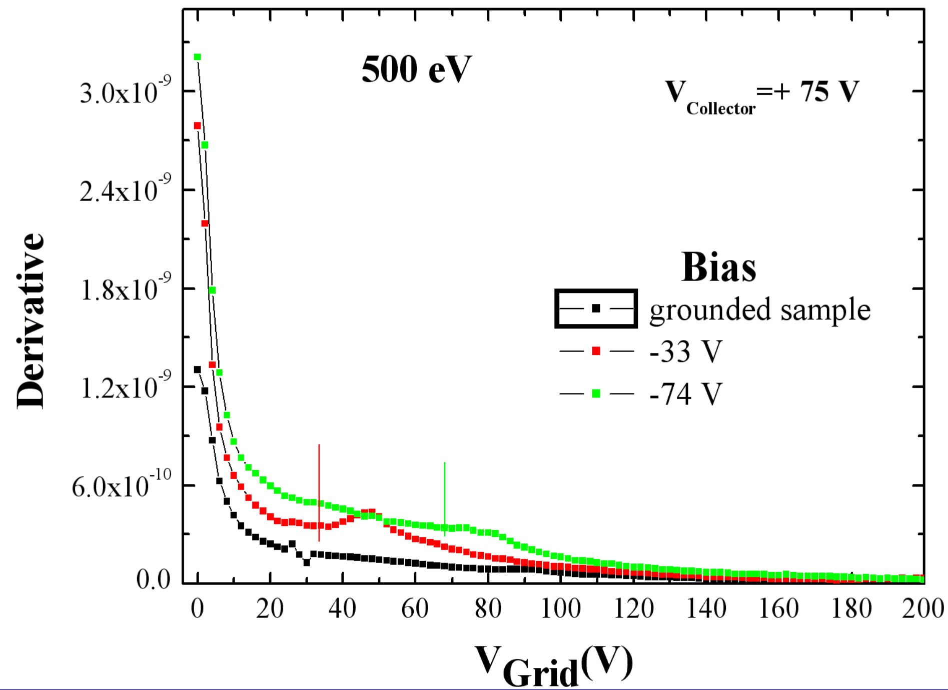
The electron energy spectrum is proportional to the derivative of the measured collector current with respect to the grid bias

Shooting the e⁻ gun on a (biased) sample and measuring its emission!

The spectra show what we should expect to measure



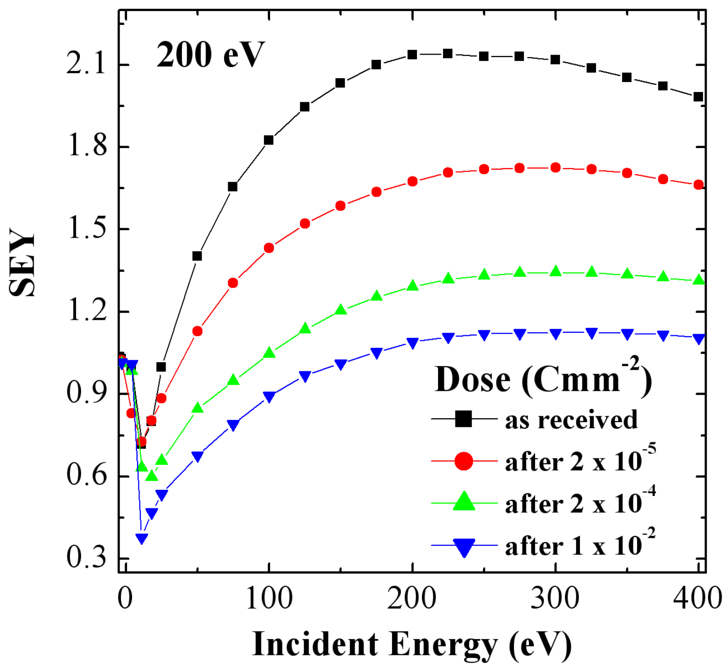
The measured spectra

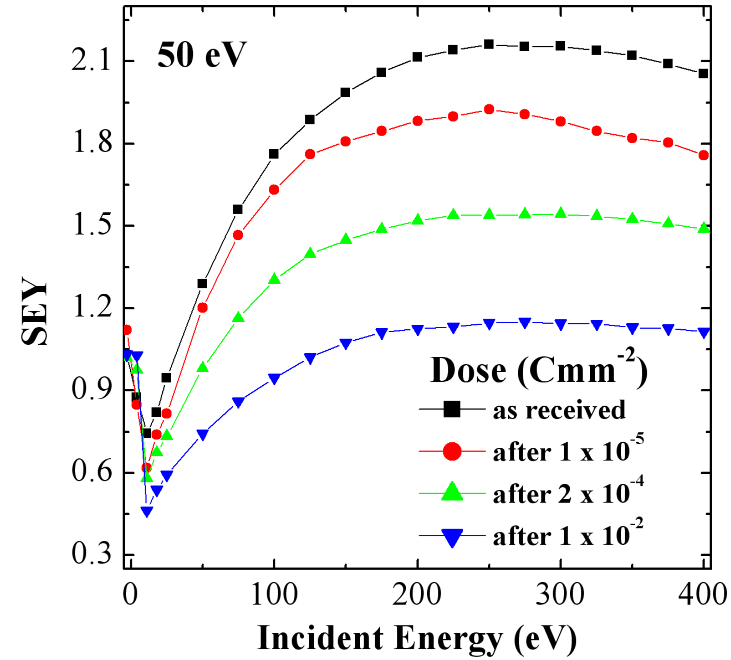


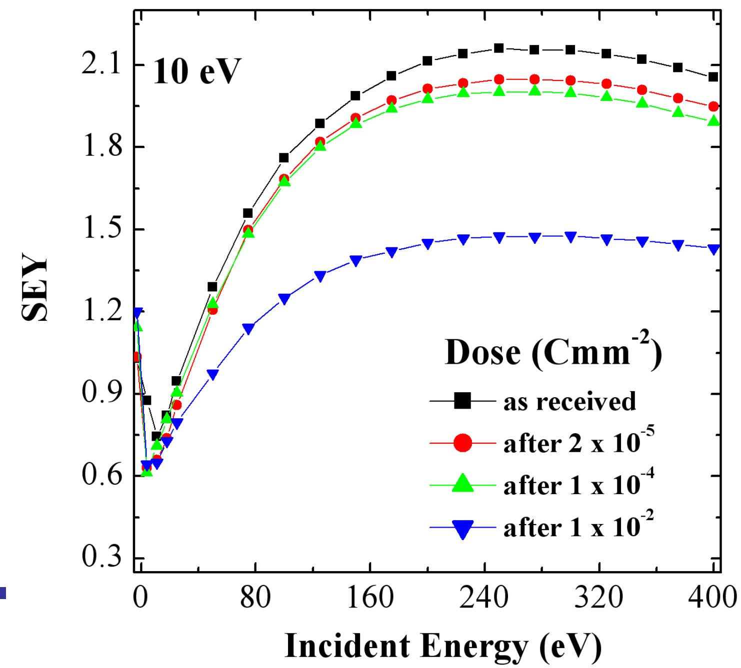
The ratio between the real signal and the signal coming from electrons created within the detector as cascade electrons is low

1) RFA may not be able to give a reliable measure of energy distribution of e-Cloud.
2) Develop detector with etherodine acquisition technique as LEED.

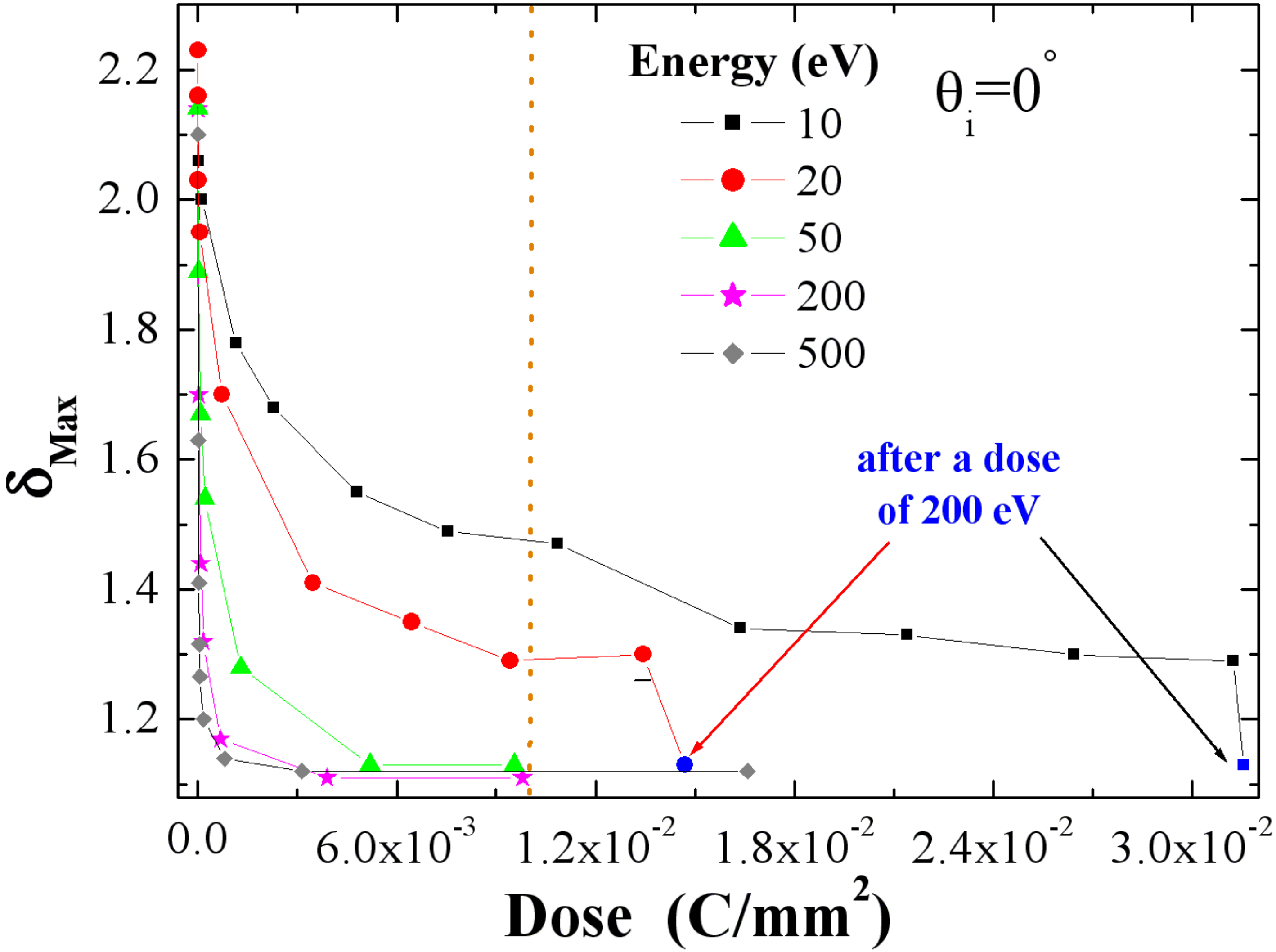
Back to Scrubbing vs impinging electron energy







SEY measurements for 200 eV, 50 eV and 10 eV impinging electron energy at normal incidence



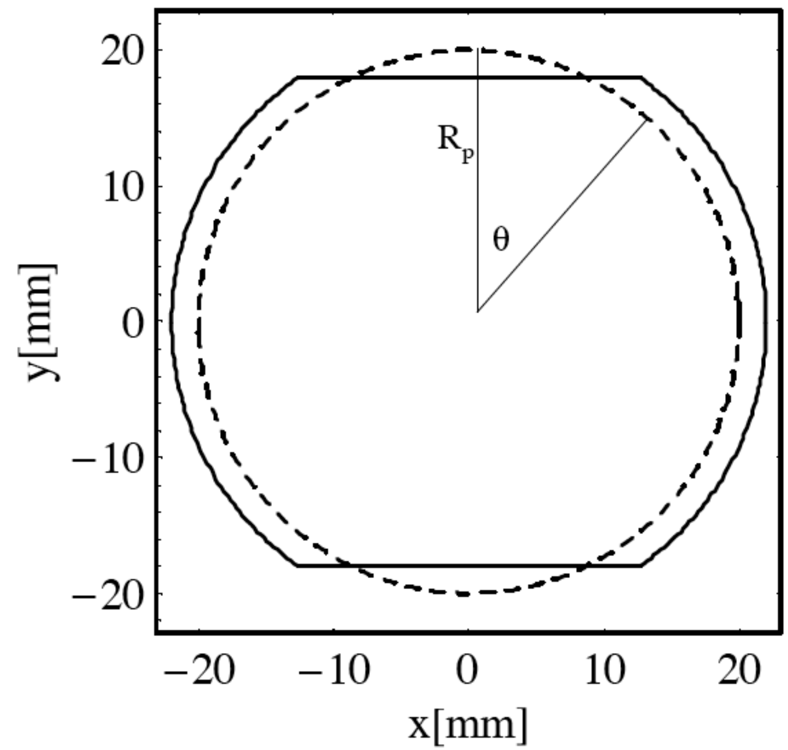
δ_{max} versus dose for different impinging electron energies at normal incidence.

We demonstrate that the potentiality of an electron beam to reduce the SEY does not only depend on its dose, but also on hits energy.

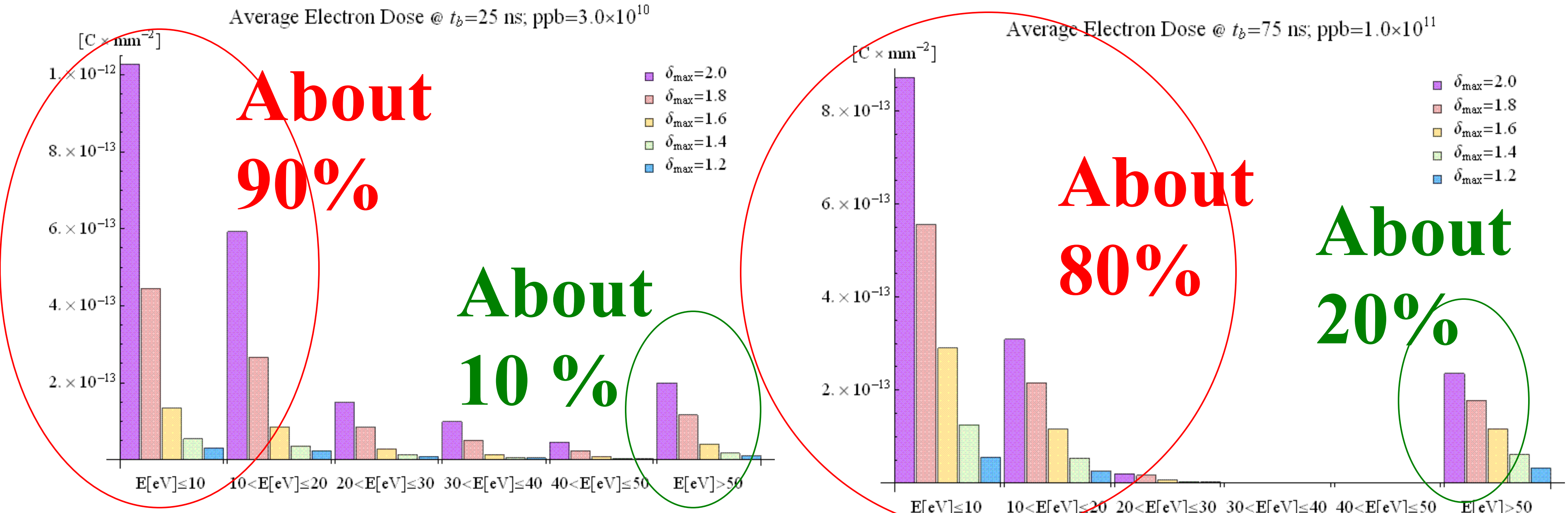
Theo DEMMA performed some preliminary simulation to see if one can optimize the "scrubbing" process @ LHC

Table 1: Parameters used for ECLOUD simulations.

parameter	units	value
beam particle energy	GeV	7000
bunch spacing t_b	ns	25; 50; 75
bunch length	m	0.075
number of trains N_t	-	4
number of bunches per train N_b	-	72; 36; 24
bunch gap N_g	-	8
no. of particles per bunch	10^{10}	10; 3.0
length of chamber section	m	1
chamber radius	m	0.02
circumference	m	27000
primary photo-emission yield	-	$7.98 \cdot 10^{-}$
maximum SEY δ_{max}	-	1.2(0.2)2.0
energy for max. SEY E_{max}	eV	237



• *Potential consequences of these measurements on the commissioning of LHC : calculation of the real e⁻ energy of the cloud (EC) hitting the walls versus beam (preliminary).*



Simulated energy components of electron dose delivered to the chamber walls during the passage of a bunch train for different value of δ_{max}

*Thanks to T. Demma using ECLOUD code, from CERN**

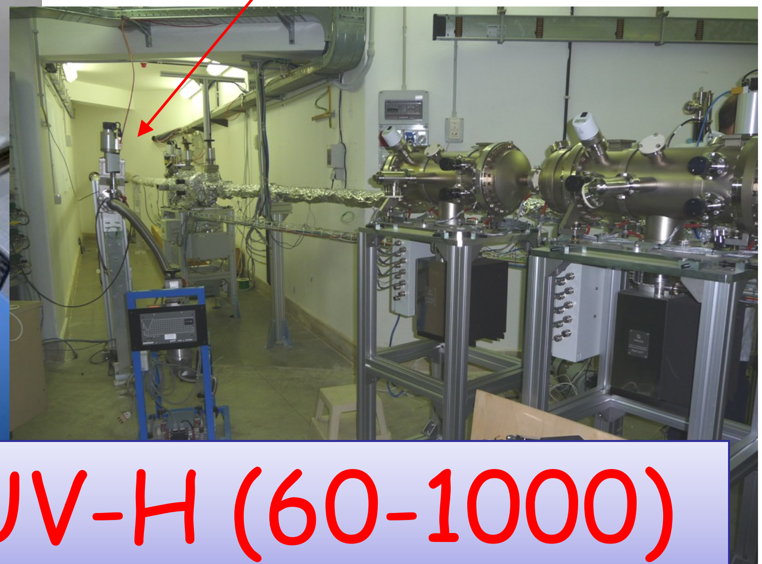
**T. Demma, R. Cimino, M.Commisso, V. Baglin in preparation.*

Scrubbing is than a complex process which depends on many parameters included the energy of the electrons involved in the cloud . It is true it is free during any machine commissioning, but it is effective???

By using state of the art surface science techniques (like Synchrotron Radiation Spectroscopy) we can learn something not only on surface modifications occurring during scrubbing, but we can get useful hints on what would be the "best surface" that should see the beam.

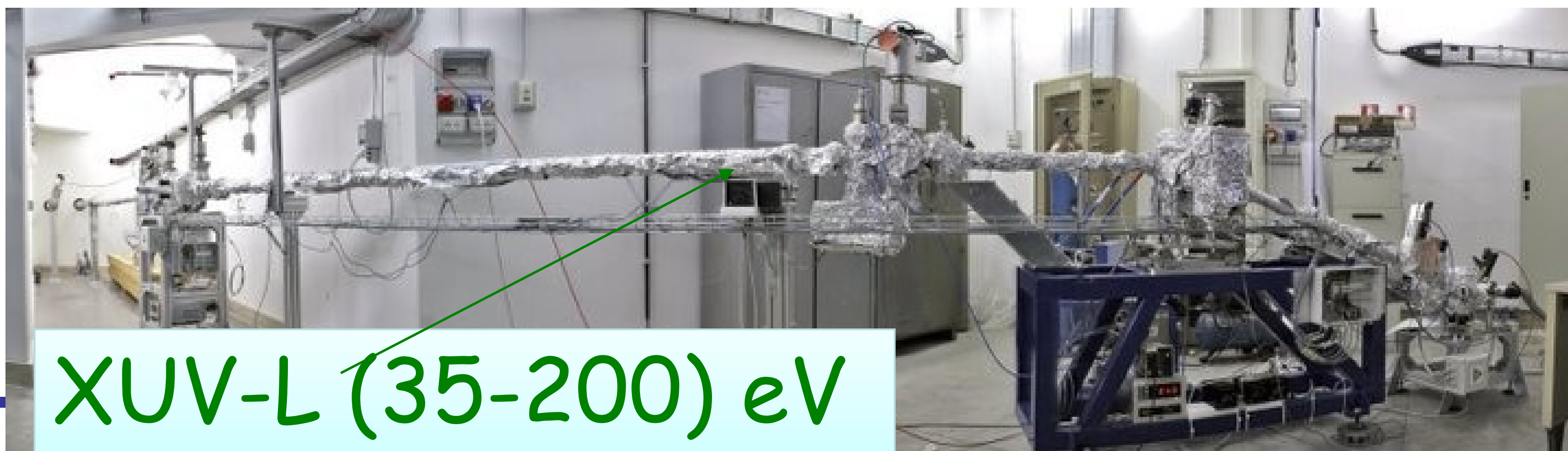
- *In Frascati, using a Bending Magnet of DAΦNE, we are proceeding with the careful alignment of two SR beamlines partially dedicated to those studies, and actually waiting for light to be commissioned!*

LNF XUV Beam Lines



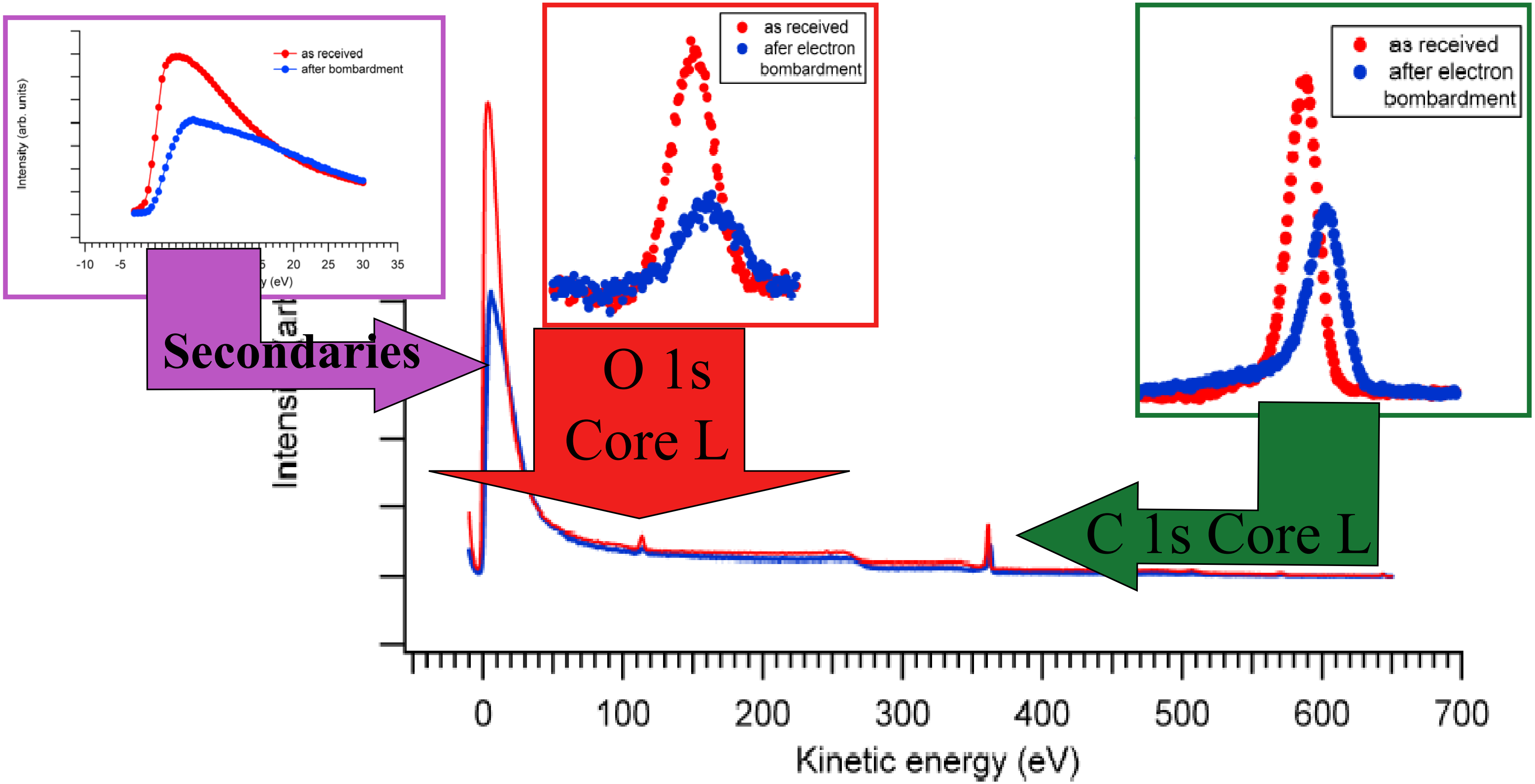
XUV-H (60-1000)

When ready we will be one of the few laboratory in the word to be able to analyse SEY (PEY) variation after electron and photon scrubbing on the same samples. This is a situation which does occur in real accelerators, but has never been studied in a laboratory experiment.



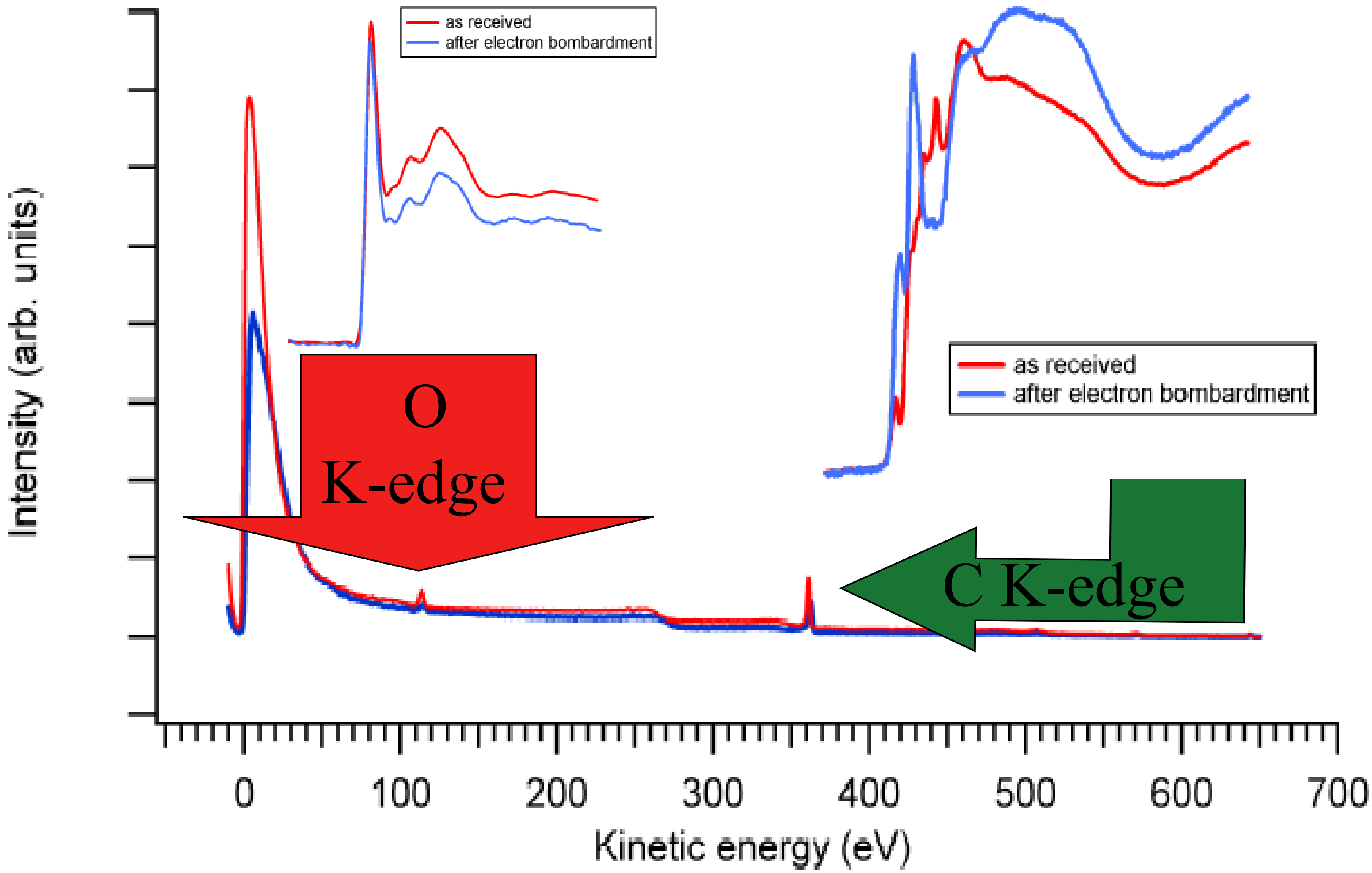
XUV-L (35-200) eV

Photoemission spectroscopy during electron scrubbing.

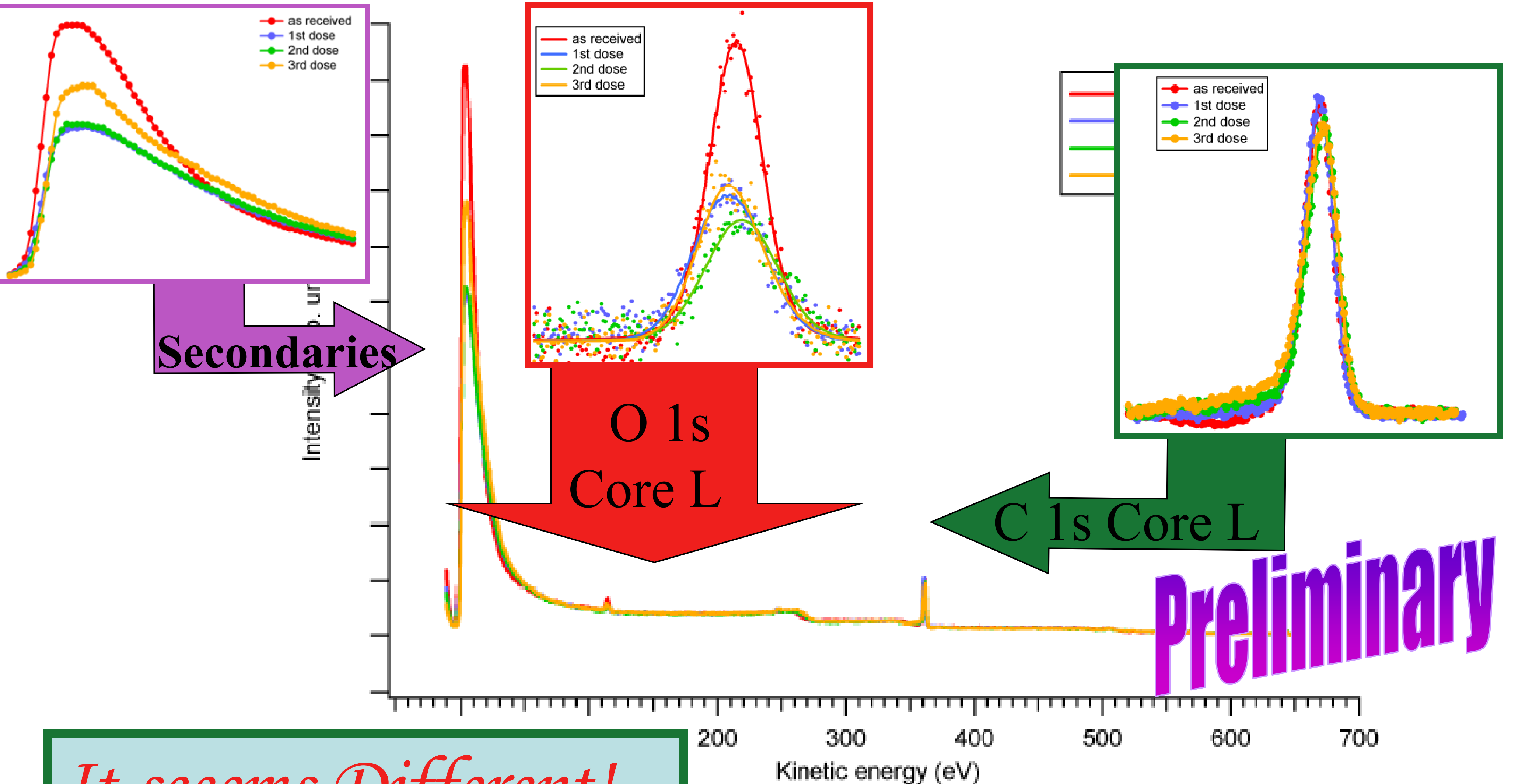


*Cimino et al. not published

XAS spectroscopy during electron scrubbing.



Same experiments but after photon scrubbing…



It seeems Different!

Back to electron scrubbing.

From Absorption and photoemission spectra we notice that oxigen does not vary significantly with electron bombardment, carbon levels shows a clear formation of a sp^2 layer indicating a graphitization of the sample.

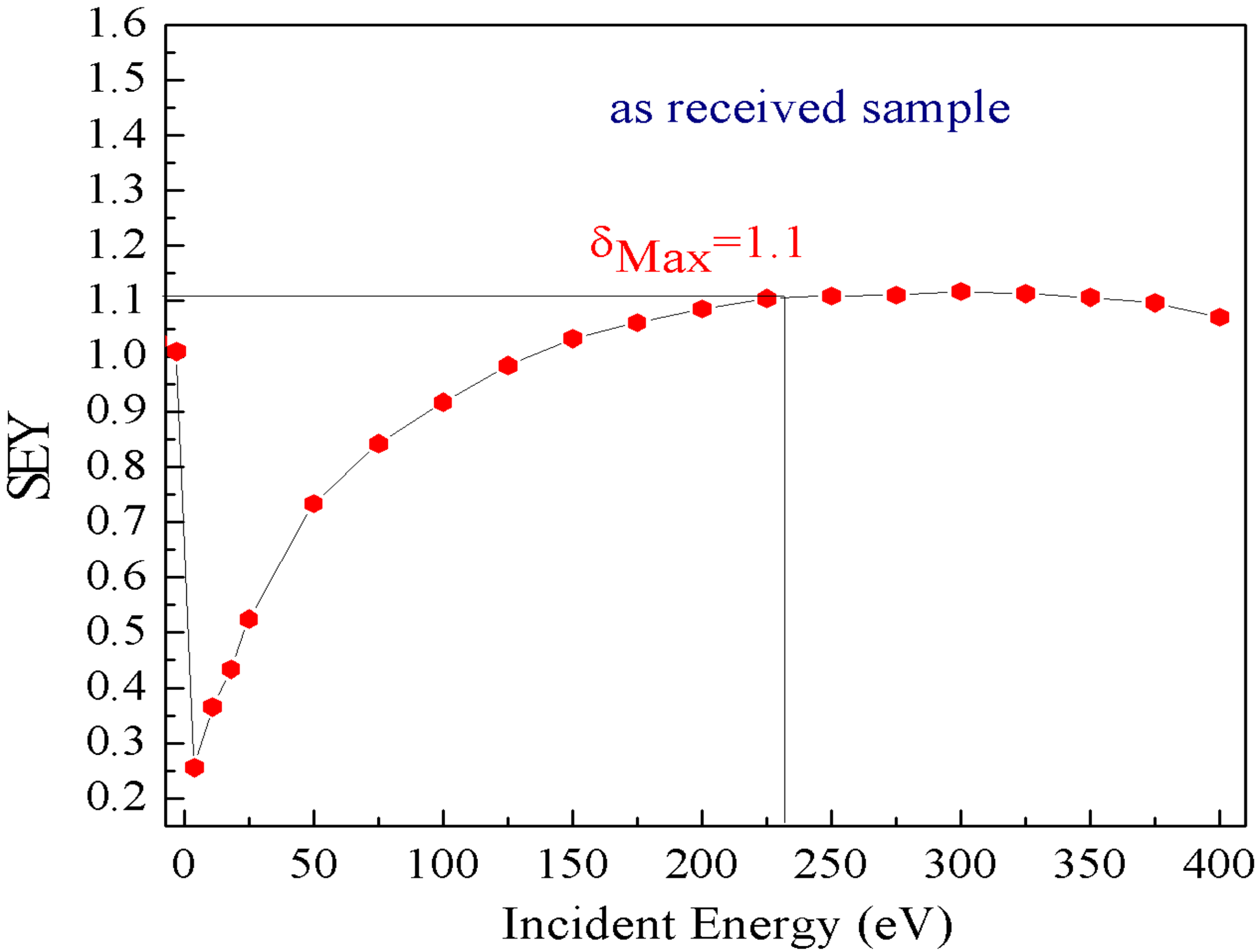
Is there an alternative way to graphitize samples in order to have low SEY surfaces? Can we deposit stable carbon or graphite coatings ?

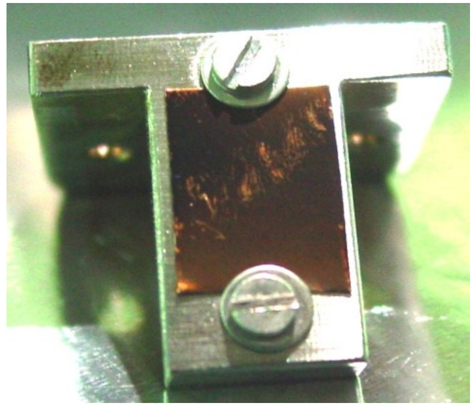
CERN uses magneto sputtering technique to growt a thick (10-100 μm) of graphite film on accelerator wall surfices.

Results are promising and under study in terms of stability versus time, adhesion etc.

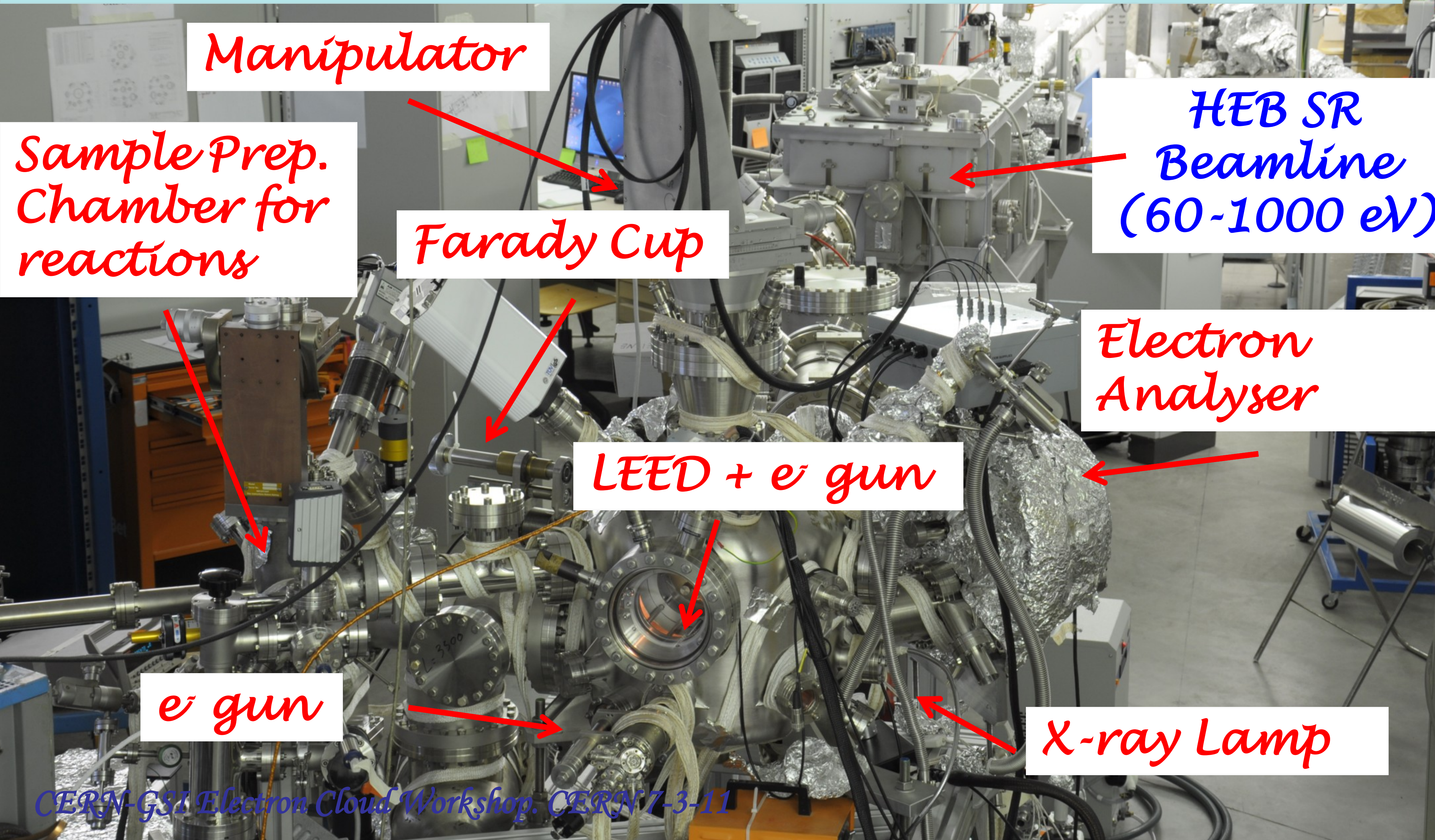
Our line of work is concentrated on creating very thin (some layers) "graphene" - like coatings on metal substrates to be used in accelerator to mimic what is actually happening during scrubbing.

PRELIMINARY

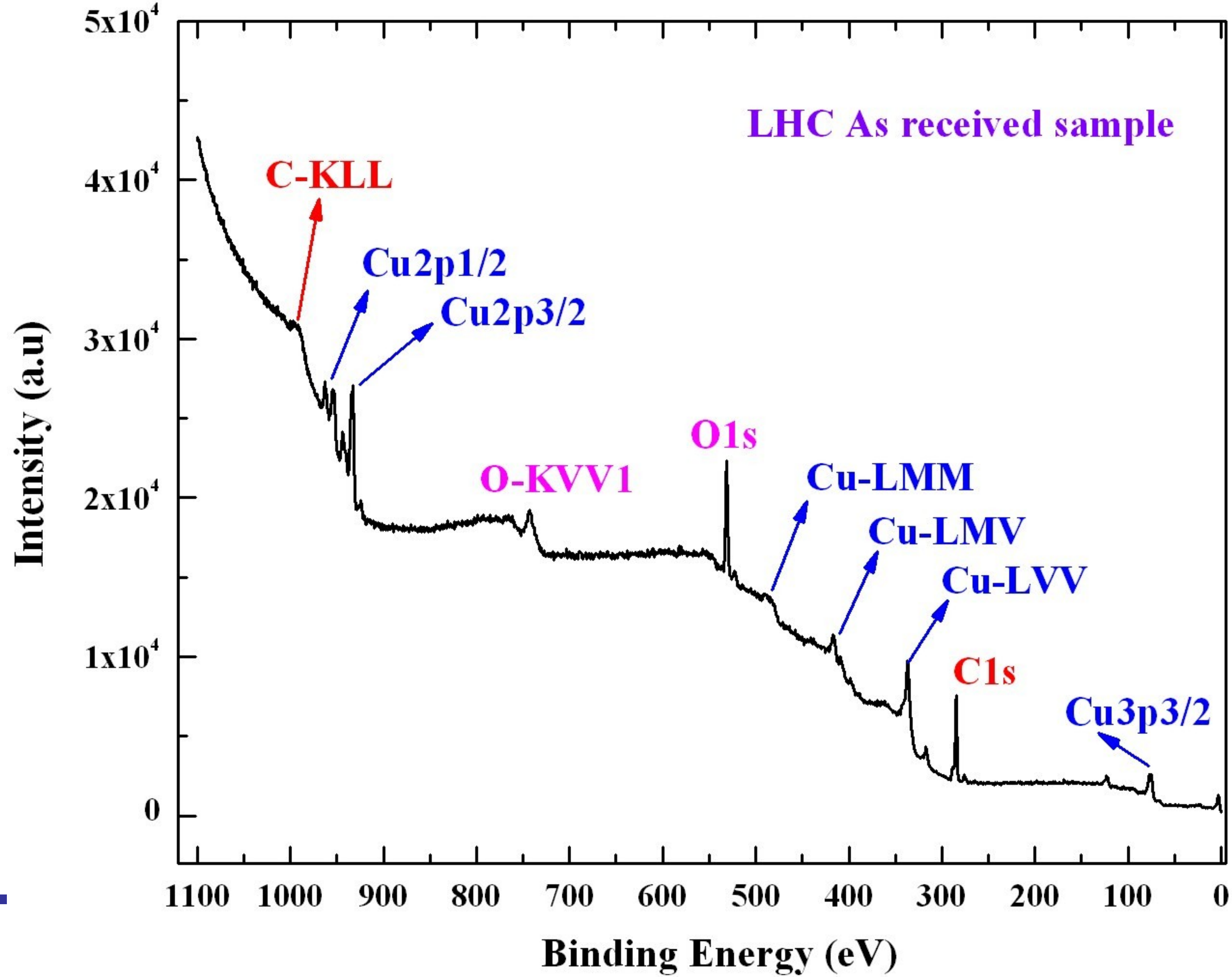




We are setting out a Stat of the art Surface Science system to produce and tests such films.



We can study "in situ" chemical modification during scrubbing, growth, etc. A lot to learn!



Results are promising and suggest that this is an interesting research direction but other accurate studies are necessary to optimize growth parameters, to test the performance of material in terms of stability versus time, adhesion, cost effectiveness etc..

We need to be able to produce these material in large scale for accelerators!!!

Acknowledgments:

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