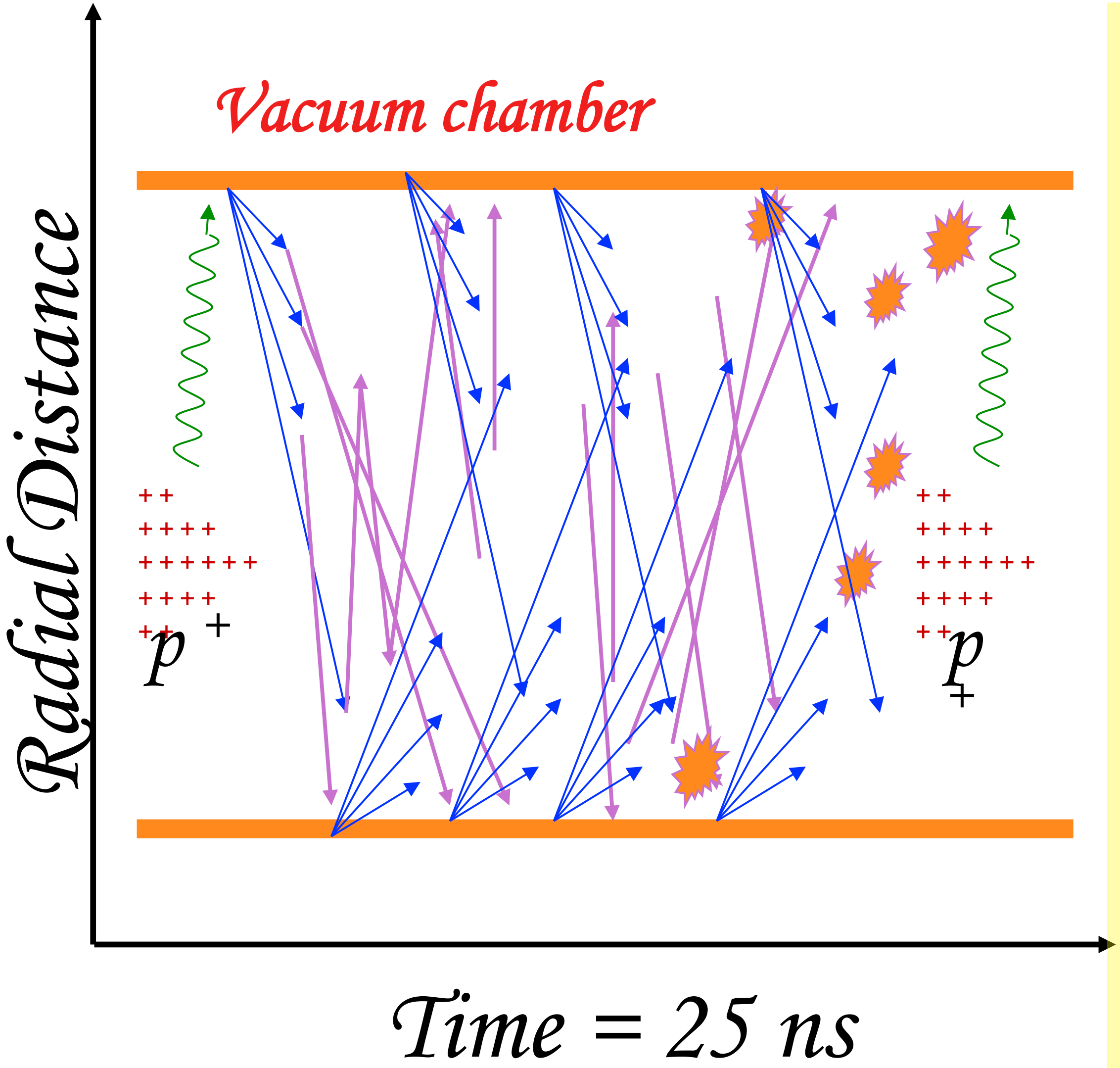
A surface Study on the origin of SEY reduction on accelerator walls.

Roberto Cimino LNF-INFN

For the NTA-IMCA and Nuvola-GrV collaboration

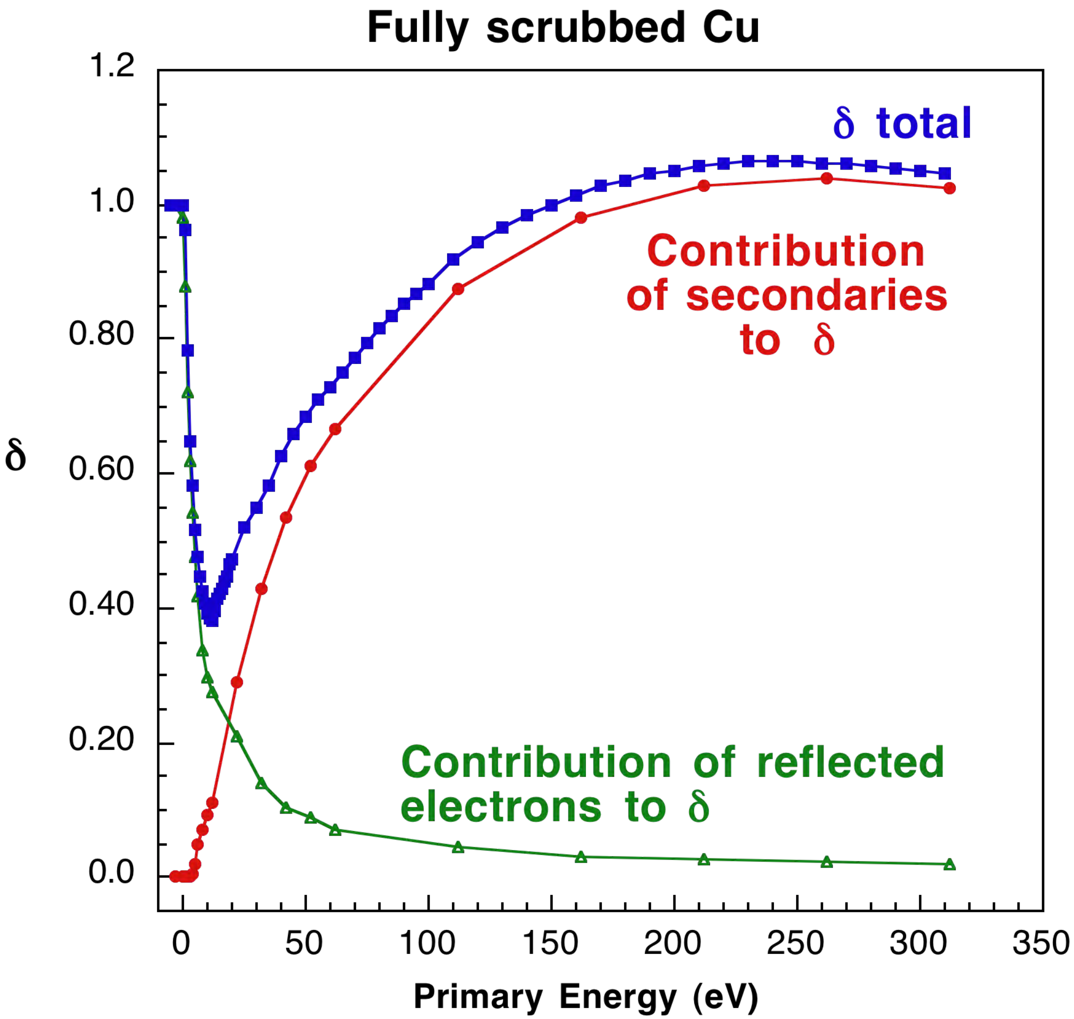
- *Introduction to the e-cloud problem*
- *Ongoing work in other Laboratories (state of the art)*
- *Material Science Laboratory@LNF first results.*
- *Conclusion.*

The "e-cloud" phenomenon (in pils)



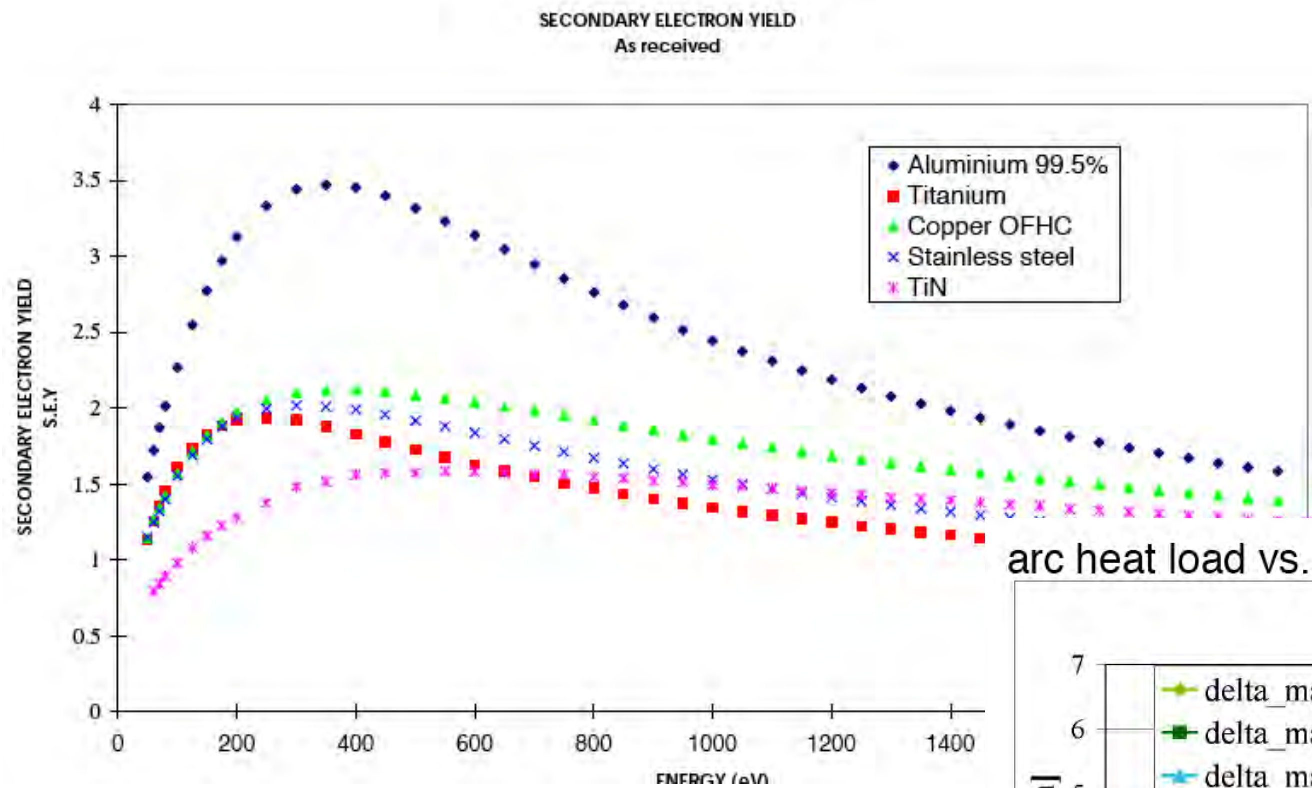
The accelerated particle beam produces SR and/or e⁻ that, by hitting the accelerator's walls generate photo-e⁻ or secondary-e⁻.
Such e⁻ can interact with the beam (most efficiently for positive beams) and multiply, inducing additional heat load on the walls, gas desorption and may cause severe detrimental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

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



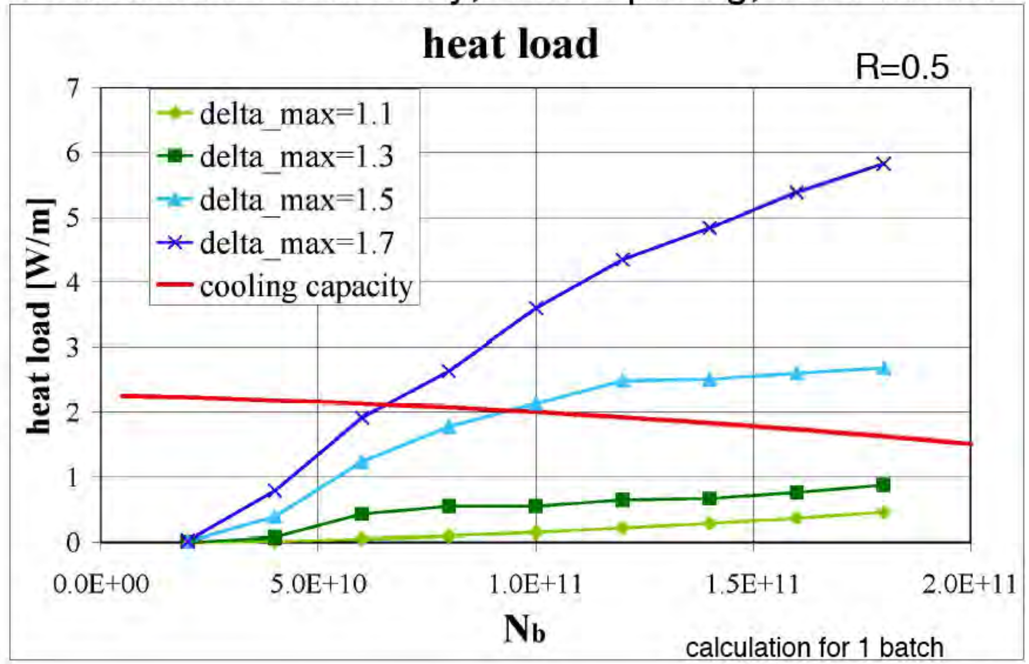
I.e.: the number of electrons created after bombardment of a single electron.

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



Measure of Secondary e⁻ YIELD

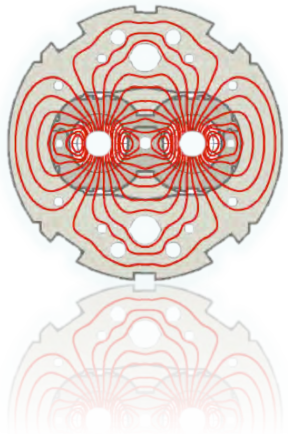
arc heat load vs. intensity, 25 ns spacing, 'best' model



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

Frank Zimmermann, LTC 06.04.05

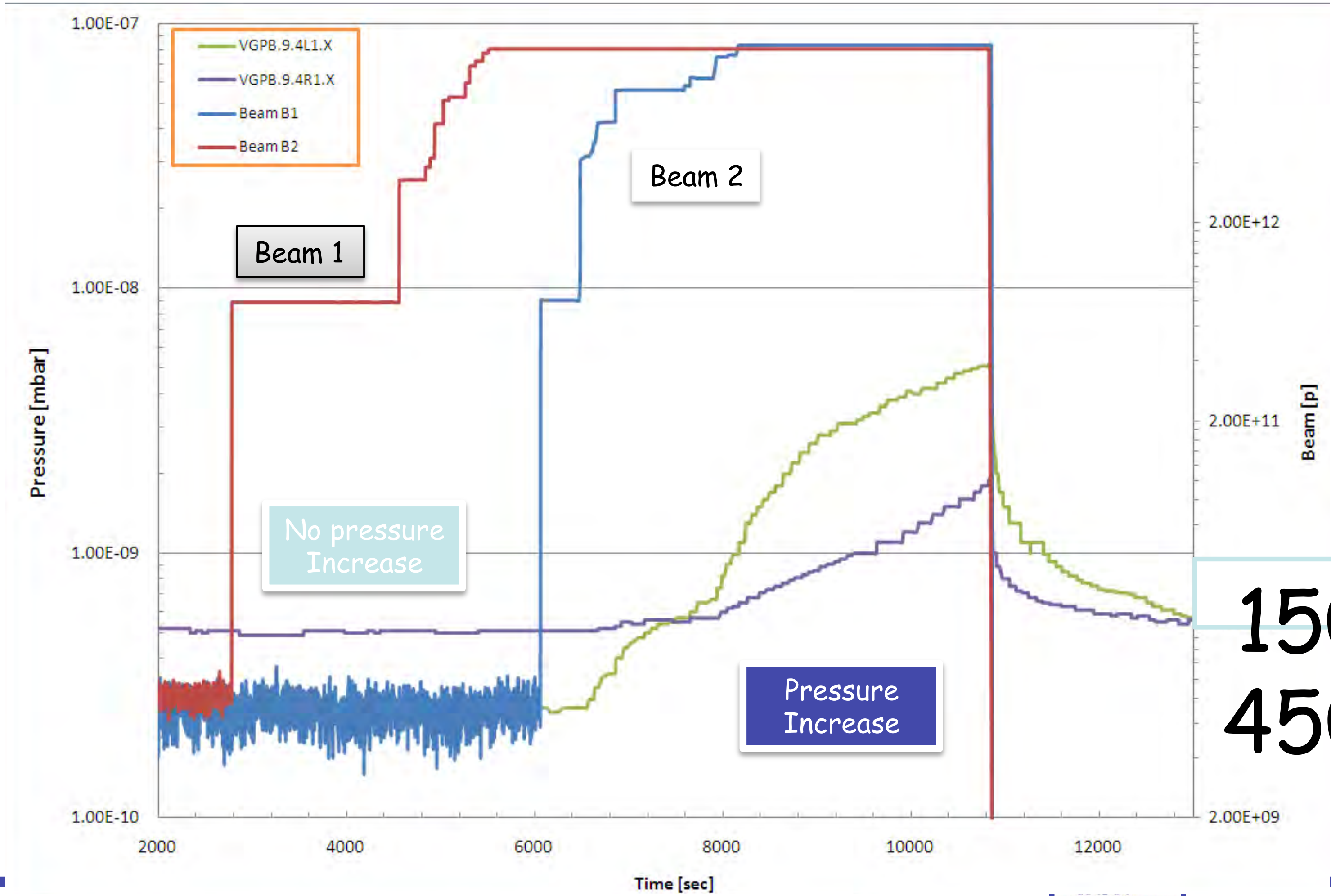
…. And its impact to simulations (see calculation for LHC).



See: CERN-GSI Electron Cloud Workshop. CERN 7-3-2011

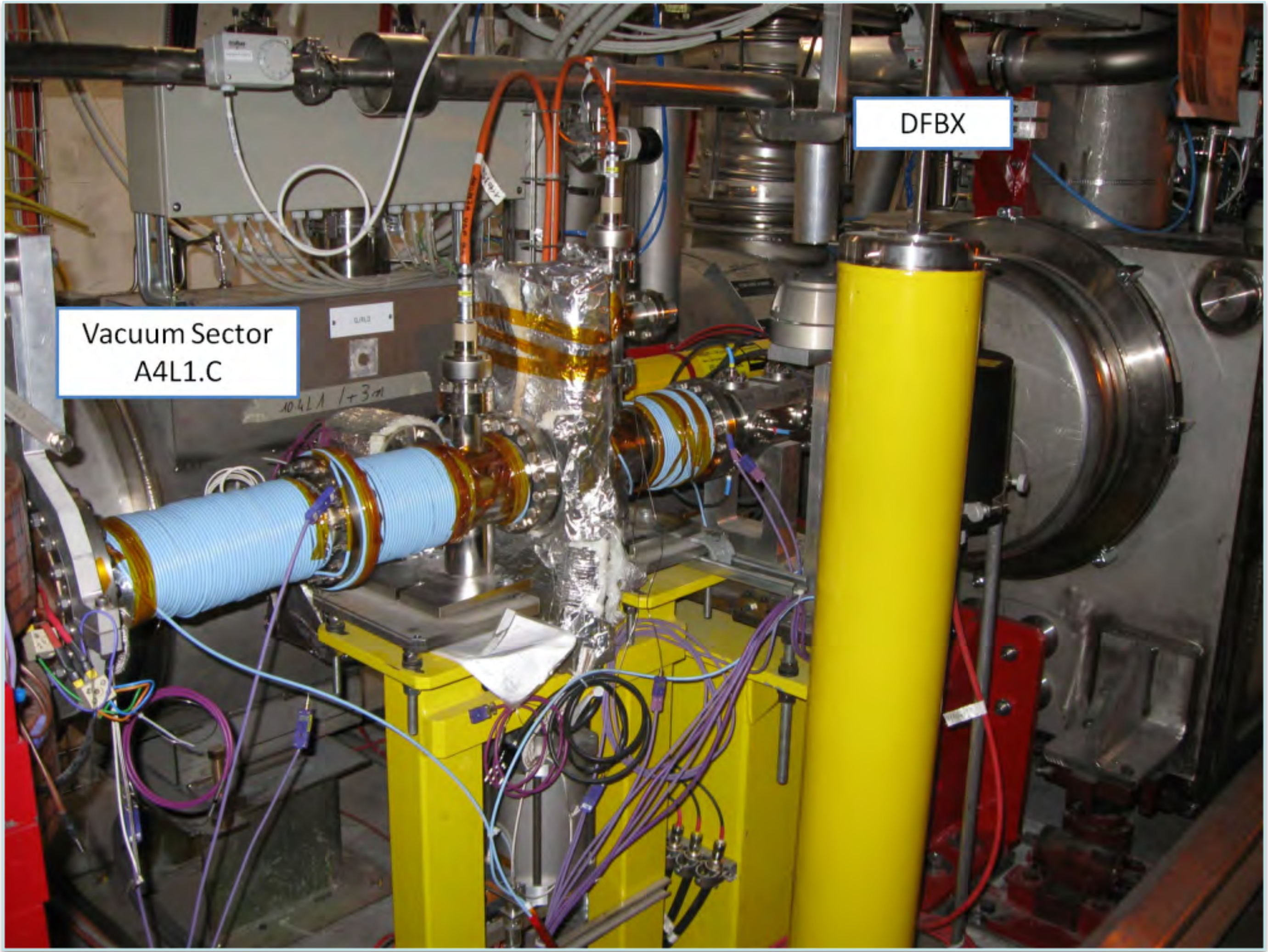
e-cloud @ LHC: a Real Issue

First observation of e-cloud activity @ LHC: 8-10-2010. 150 ns bunch spacing: Merged vacuum

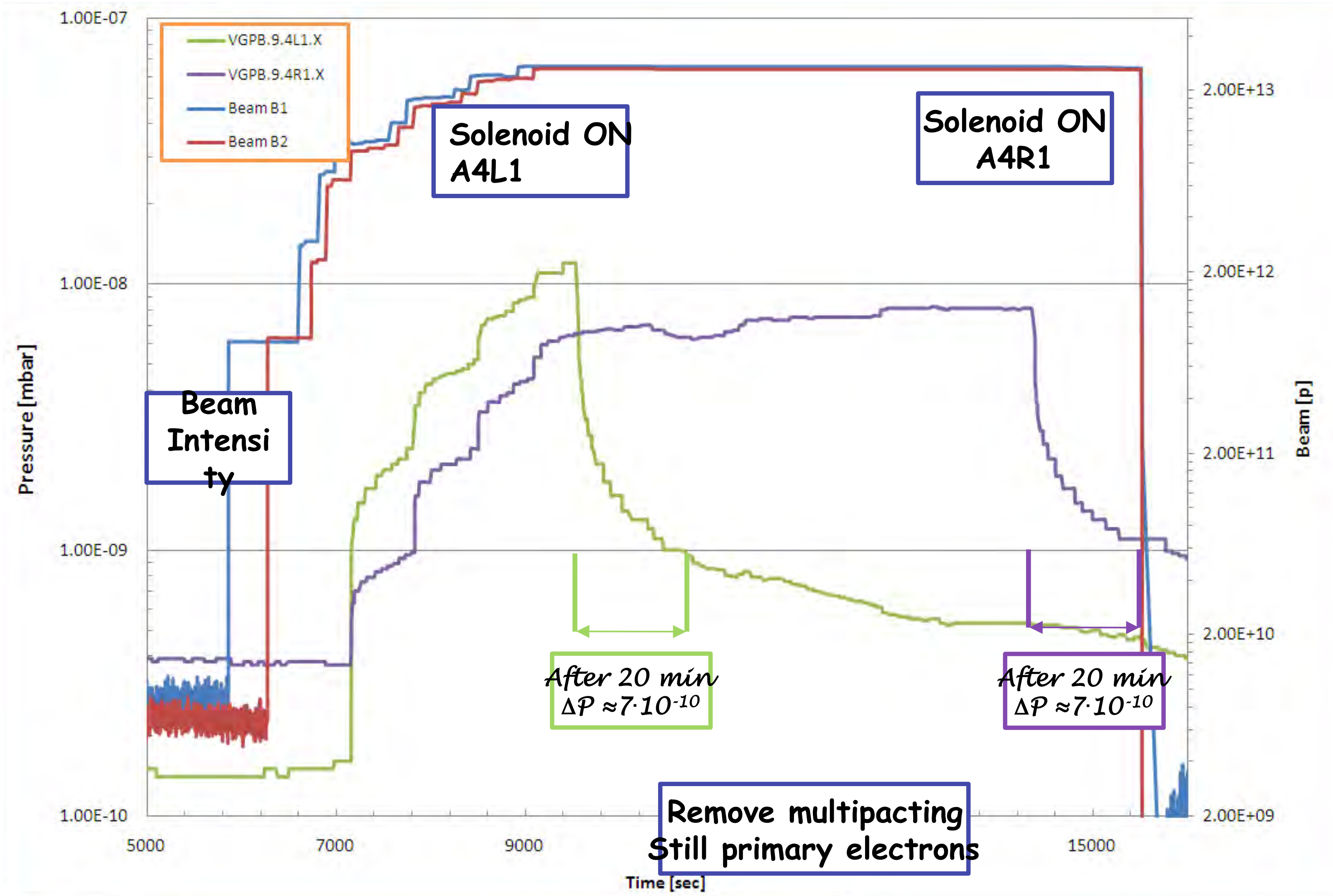


150 ns - 450 GeV

Easily solved: Installation of Solenoids



Solenoids effect on pressure



3. Plans for Super KEKB

Y. Suetsugu, KEK
on behalf of KEKB Vacuum Group

- Required electron density to avoid single bunch instability

K. Ohmi , KEK Preprint 2005-100 (2006)

$$\rho_{e,th} = \frac{2\gamma\nu_s\omega_{e,y}\sigma_z/c}{\sqrt{3}KQr_e\beta L}.$$

Here,

$$\omega_{e,y} = \sqrt{\frac{\lambda_+ r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}}$$

E [GeV] = 4.0				
γ = 7828	N_b	= 6.25E+10		
ν_s = 0.0185	Q_b[C]	= 1.4E-08	(1.4 mA/bunch)	
	S_b [m]	= 1.2	(4ns)	
σ_z [m] = 6.E-03	λ [C/m]	= 5.2E+12	($Q_b/2/\sigma_z$)	
c [m/s] = 3.E+08	σ_y [m]	= 2.E-05		
K = 11	σ_x [m]	= 2.E-04		
Q = 7				
r_e [m] = 2.80E-15	ω_e	= 5.46E+11	$K = \omega_e\ \sigma_z/c$	
β_y [m] = 25	$\omega_e\ \sigma_z/c$	= 10.9	$Q = \mathrm{Min}(Q_{nl},\ \omega_e\ \sigma_z/c)$	
L [m] = 3016			Q_{nl} ~7	

ρ [m^{-3}] =1.13E11 ➜ Our target =1E11 m^{-3}

Single Bunch Instability Threshold for Super-B (courtesy of T. Demma)

		June 2008		January 2009		March 2009		Sep.2009
		ρ_{int} [$10^{15}m^{-2}$] solenoids	ρ_{int} [$10^{15}m^{-2}$] no solenoids	ρ_{int} [$10^{15}m^{-2}$] solenoids	ρ_{int} [$10^{15}m^{-2}$] no solenoids	ρ_{int} [$10^{15}m^{-2}$] solenoids	ρ_{int} [$10^{15}m^{-2}$] no solenoids	ρ_{center}
SEY=1.1	95%	0.06	2.1	0.09	2.5	0.22	2.7	0.1
	99%	0.02	0.25	0.04	0.3	0.04	0.7	0.07
SEY=1.2	95%	0.22	2.8	0.27	3.2	0.45	6.5	0.3
	99%	0.045	0.71	0.06	0.82	0.07	2.4	0.1
SEY=1.3	95%	2.7	20.2	2.9	25.7	5.4	25	2.0
	99%	0.94	3.2	1.3	4.1	4.5	13	0.7

Most of the existing and planned accelerator machines base the reaching of their design parameters to the capability of obtaining walls with a SEY ~1.2 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…*

Activity of the LNF Material Science Laboratory:

Our Laboratory is becoming a reference Lab for material science analysis and tests of relevance for e-cloud studies.

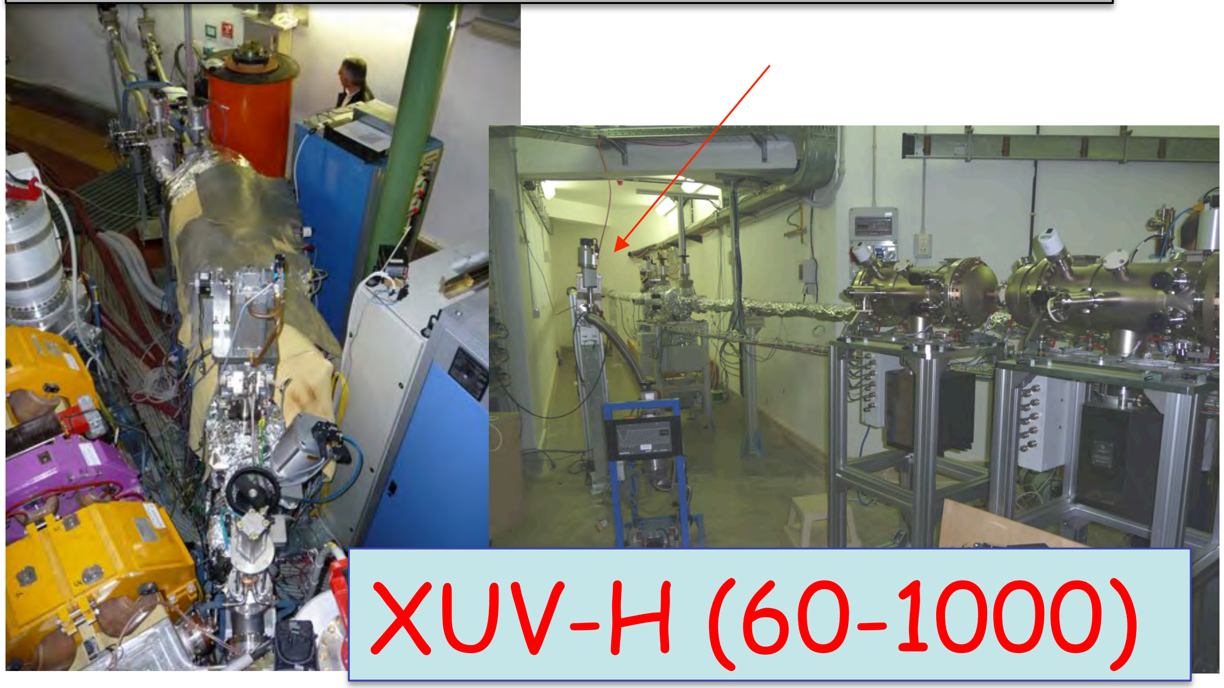
We are studying (in collaboration with the respective institutes):

- CERN- LHC (Dipole chamber) Cu Samples
- CERN – SPS a-C Coatings
- Al from DAFNE and PETRA 3 (DESY)
- Stainless Steal (from RICH, Brookhaven)
- TiN "test" samples produced at LNF and from PEP
- NEGs ……

… and we are learning a lot!!!

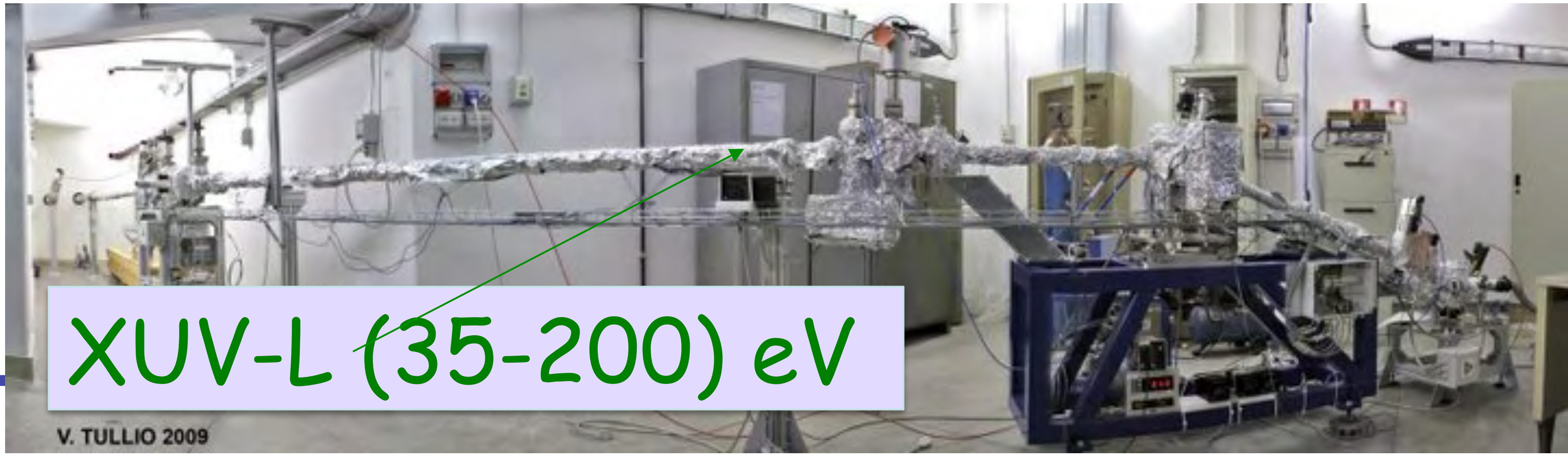
- *Together with the SEY experiments, @ LNF, we are able to "see" the chemical modification at the surface. This will be more effective by using two SR beamlines from a DAΦNE BM which we are now carefully aligning and commissioning!*

LNF XUV Beam Lines



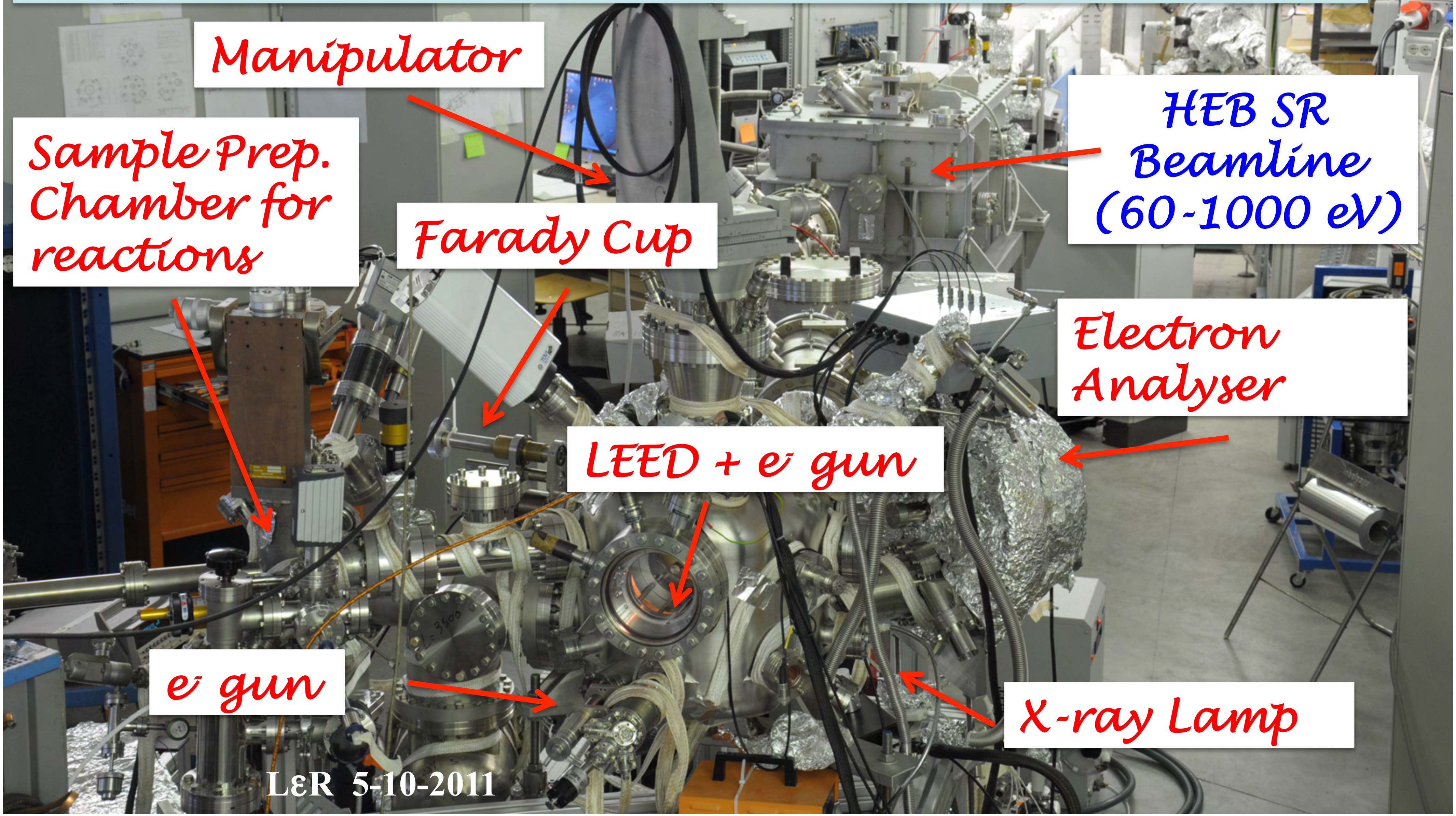
XUV-H (60-1000)

When ready we will be one of the few laboratory in the wolrd 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 it has never been studied in a laboratory experiment.

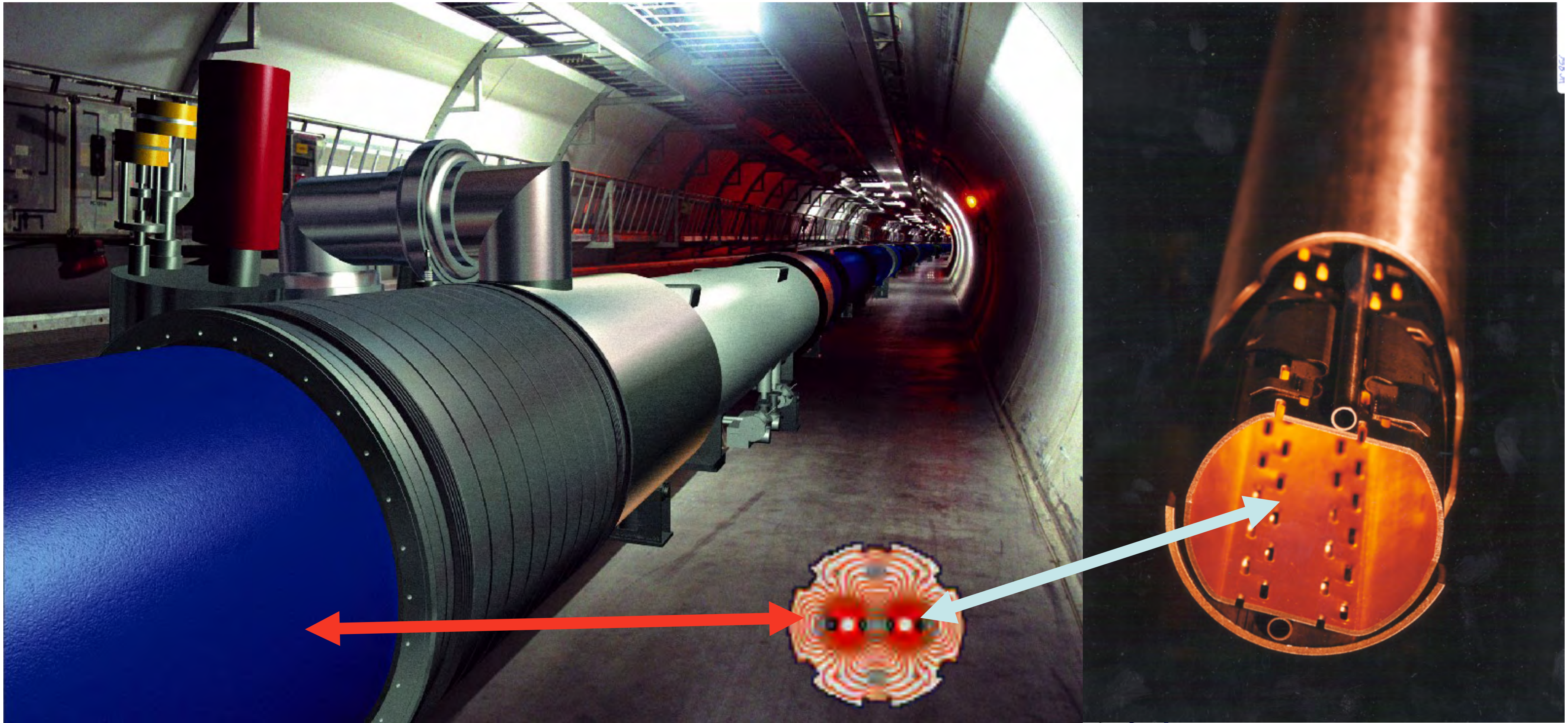


XUV-L (35-200) eV

We are working on up a State of the art Surface Science system to study, produce and test low SEY films.

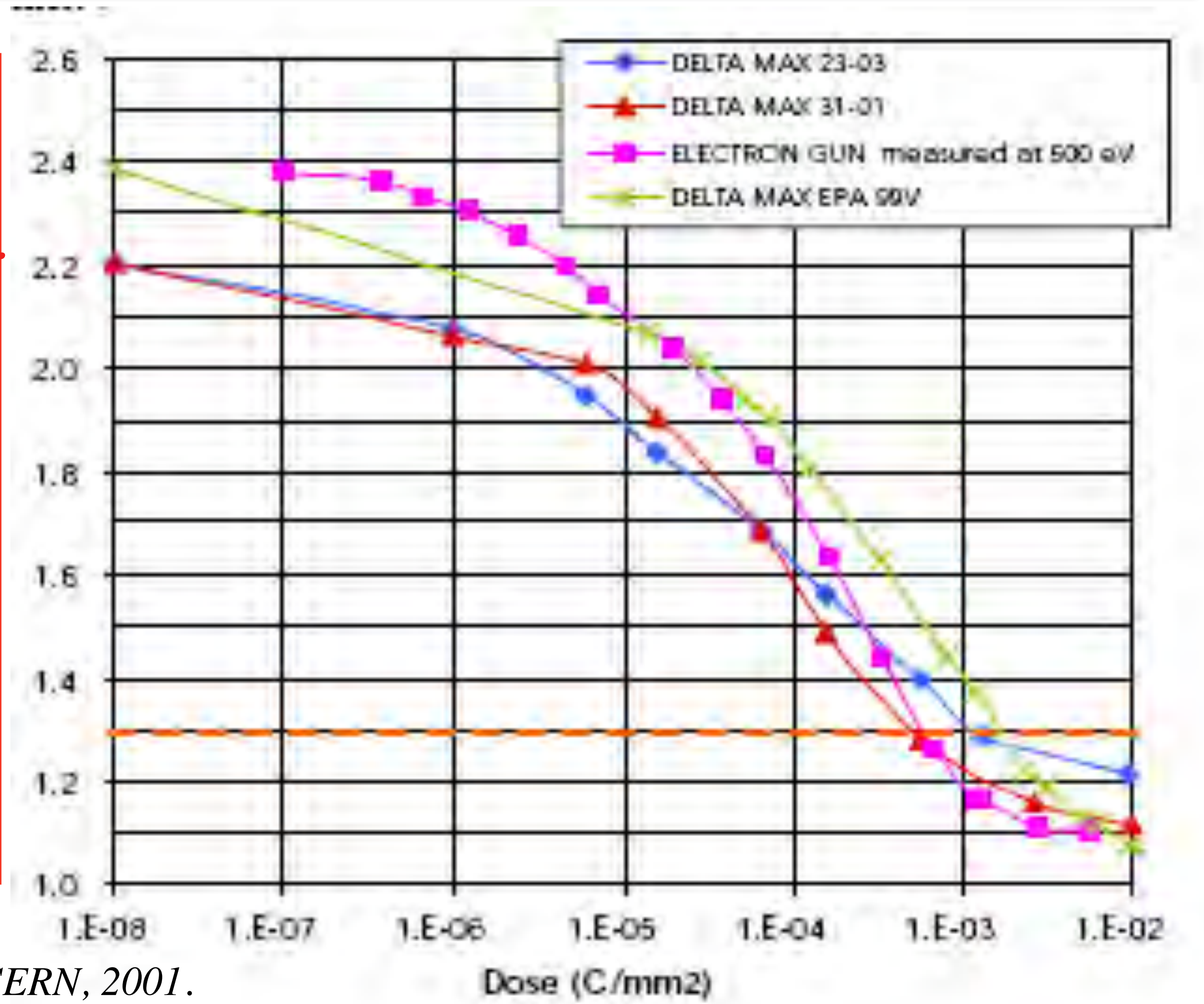


Our study on the Cu surfaces of the LT dipole regions of LHC: "scrubbing" and chemical modifications



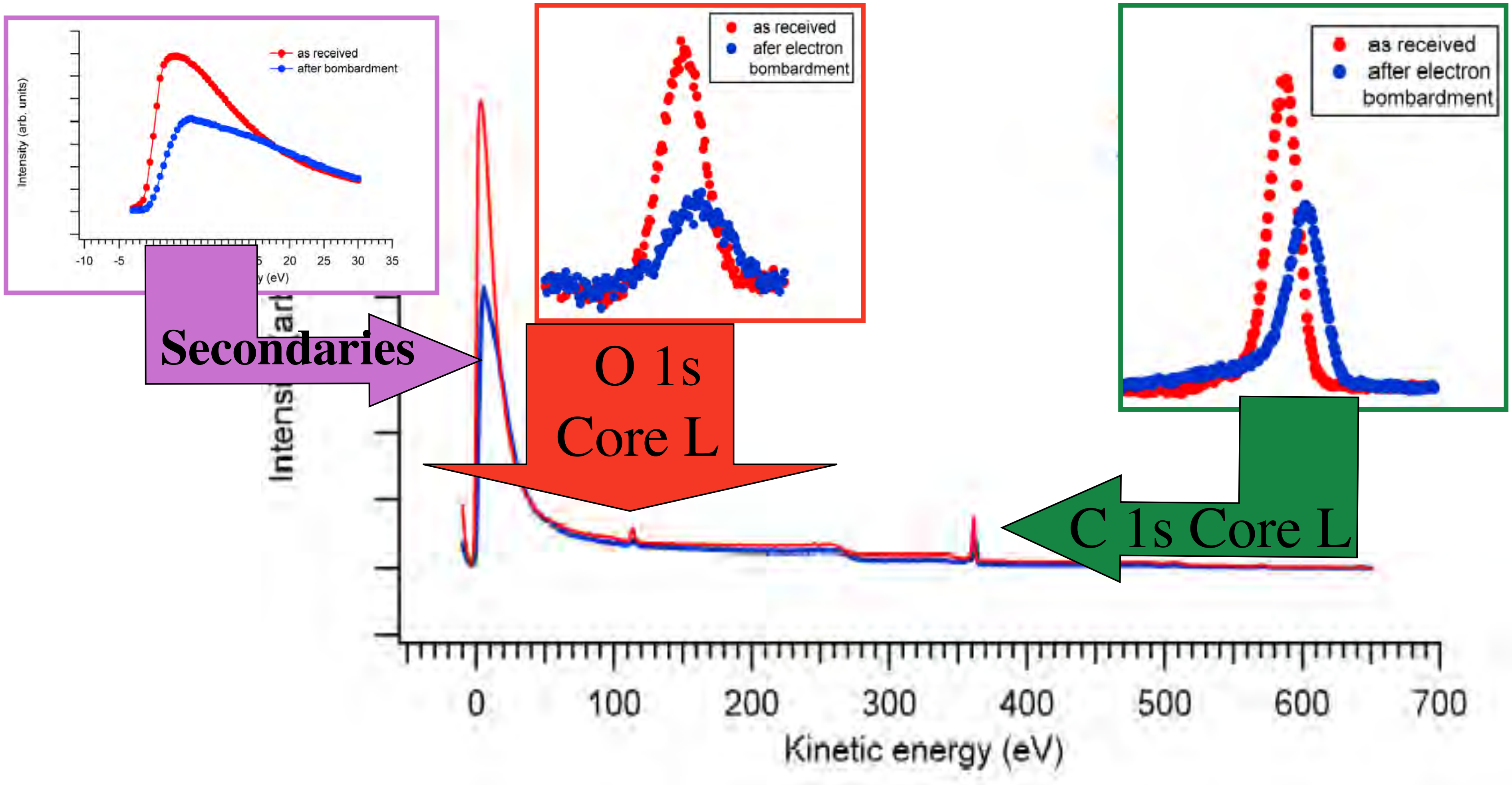
The Beam "scrubbing" effect is the ability of a surface to reduce its SEY after e⁻ bombardment.

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.

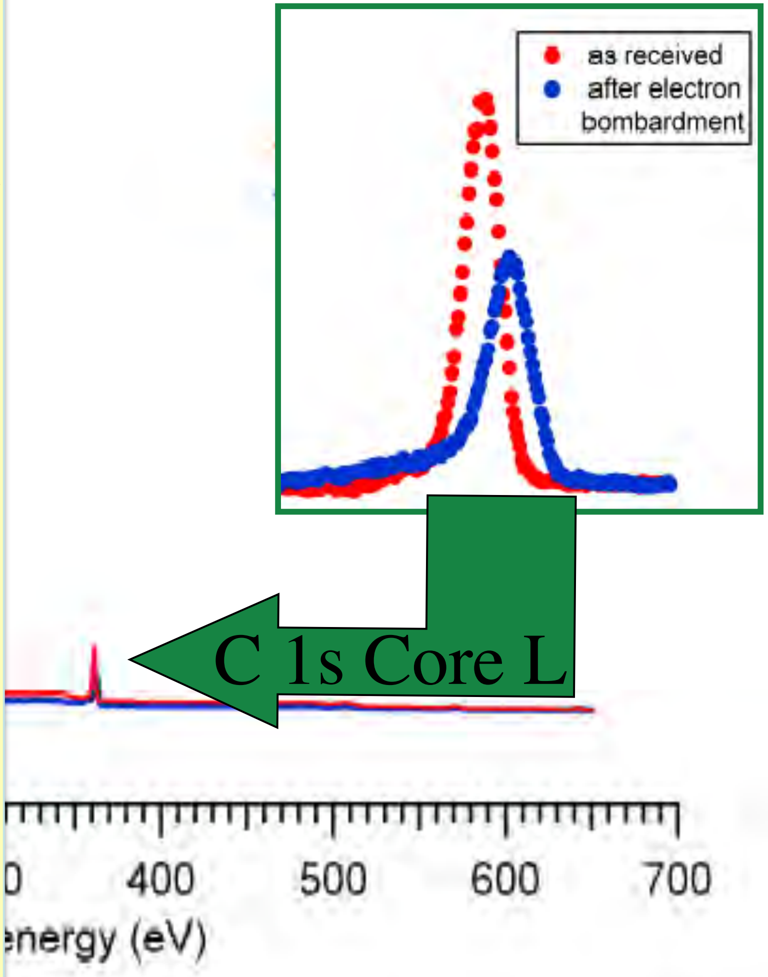
Photoemission spectroscopy during electron scrubbing.



*Cimino et al. not published

Photoemission spectroscopy during electron scrubbing.

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



*Cimino et al. not published

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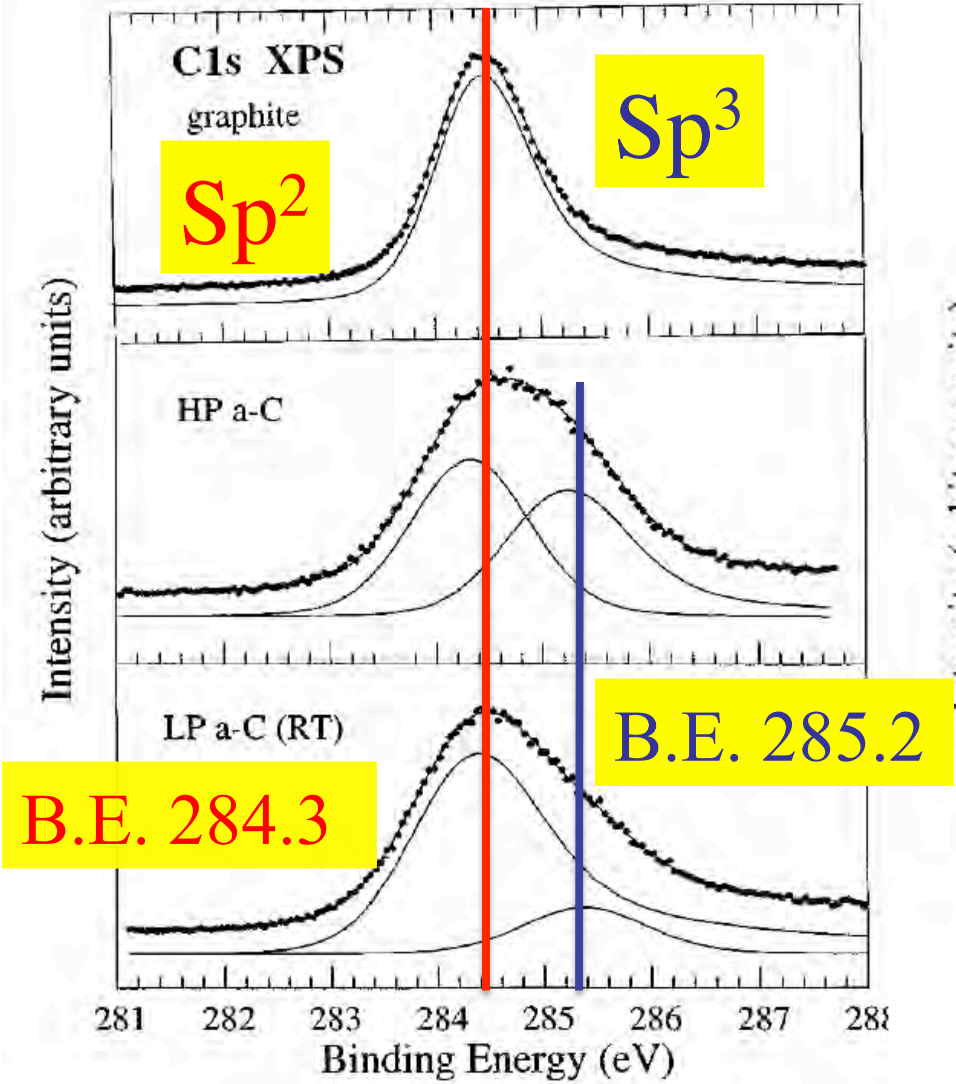
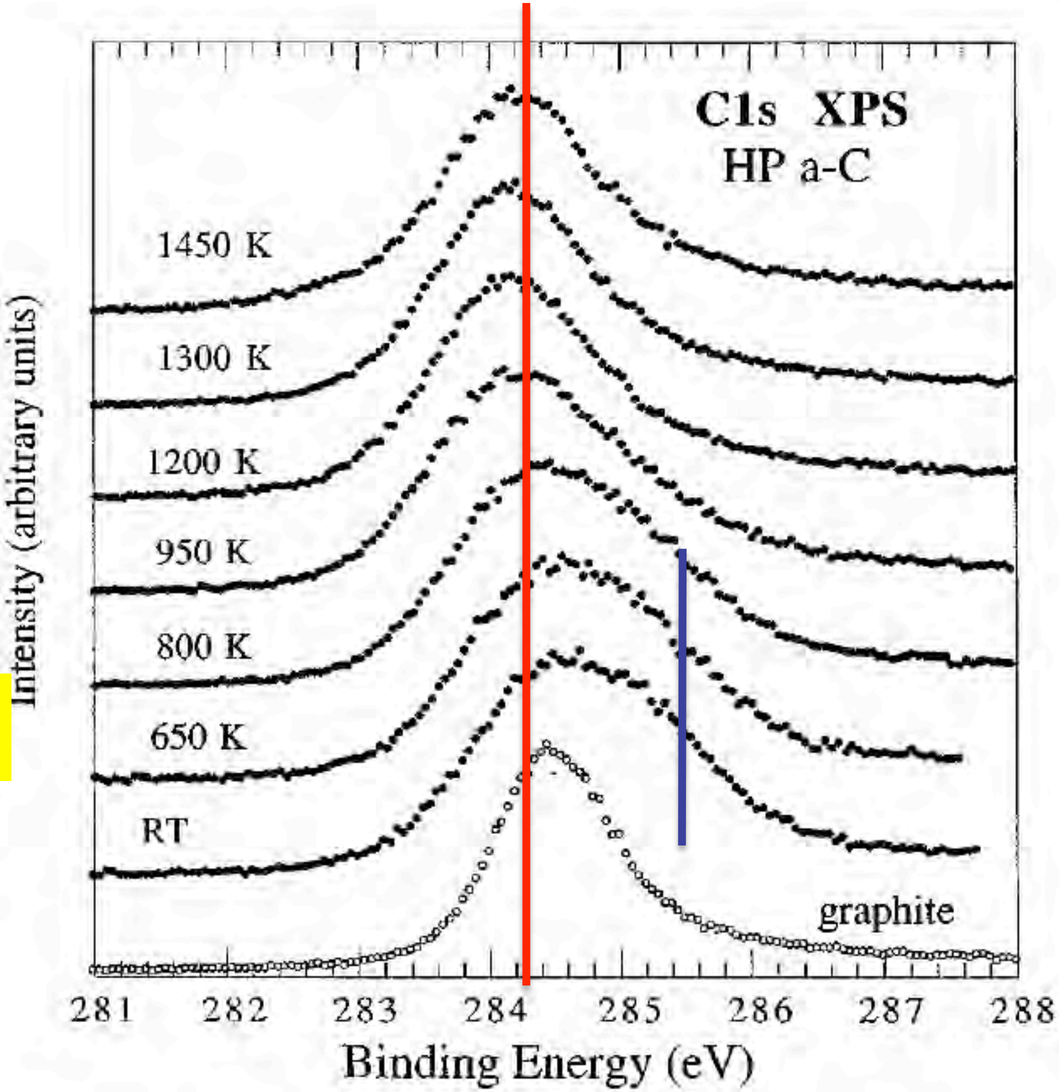
Separation of the sp^3 and sp^2 components in the C 1s photoemission spectra of amorphous carbon films

Javier Díaz,* Guido Paolicelli,† Salvador Ferrer, and Fabio Comin
European Synchrotron Radiation Facility, Boîte Postal 220, 38043 Grenoble Cedex, France

(Received 2 June 1995; revised manuscript received 18 December 1995)





SEY and XPS studies: Al from DAΦNE and Petra III (difficulties in reaching low emittance)

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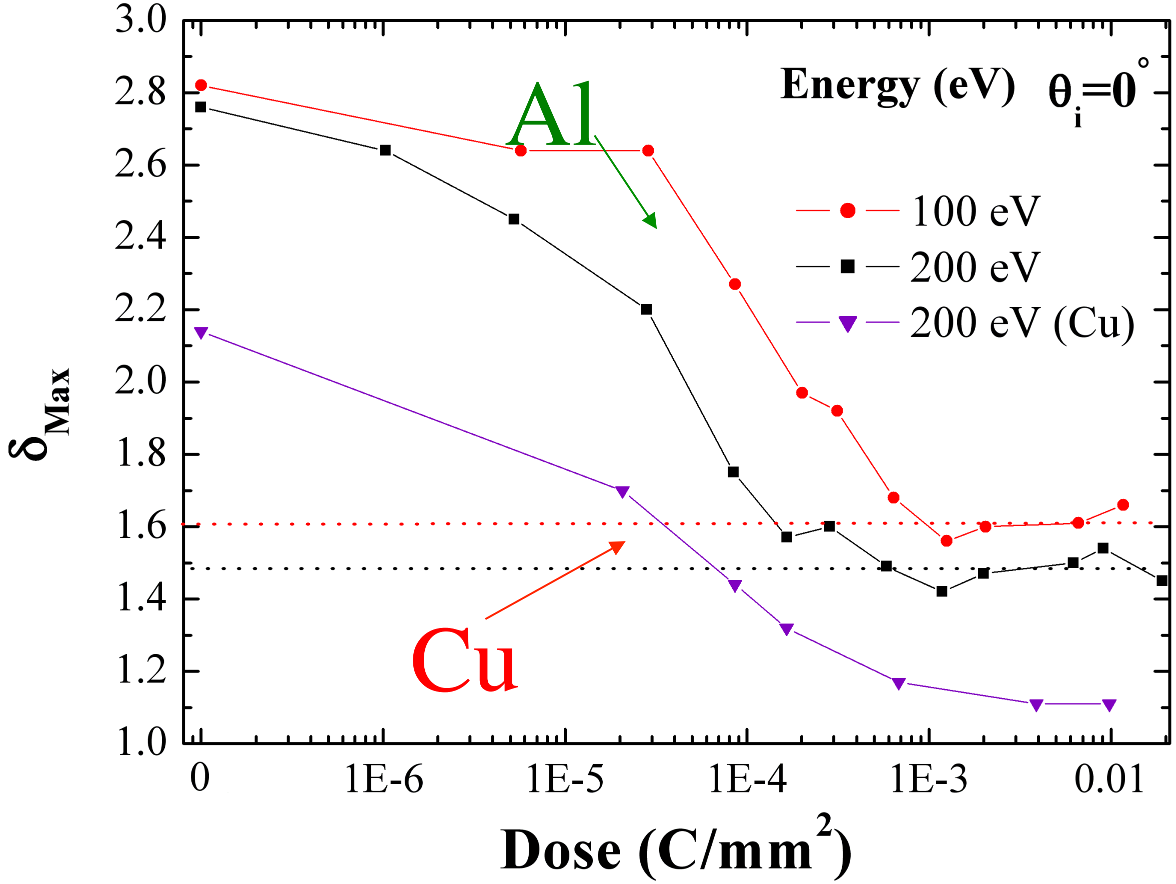
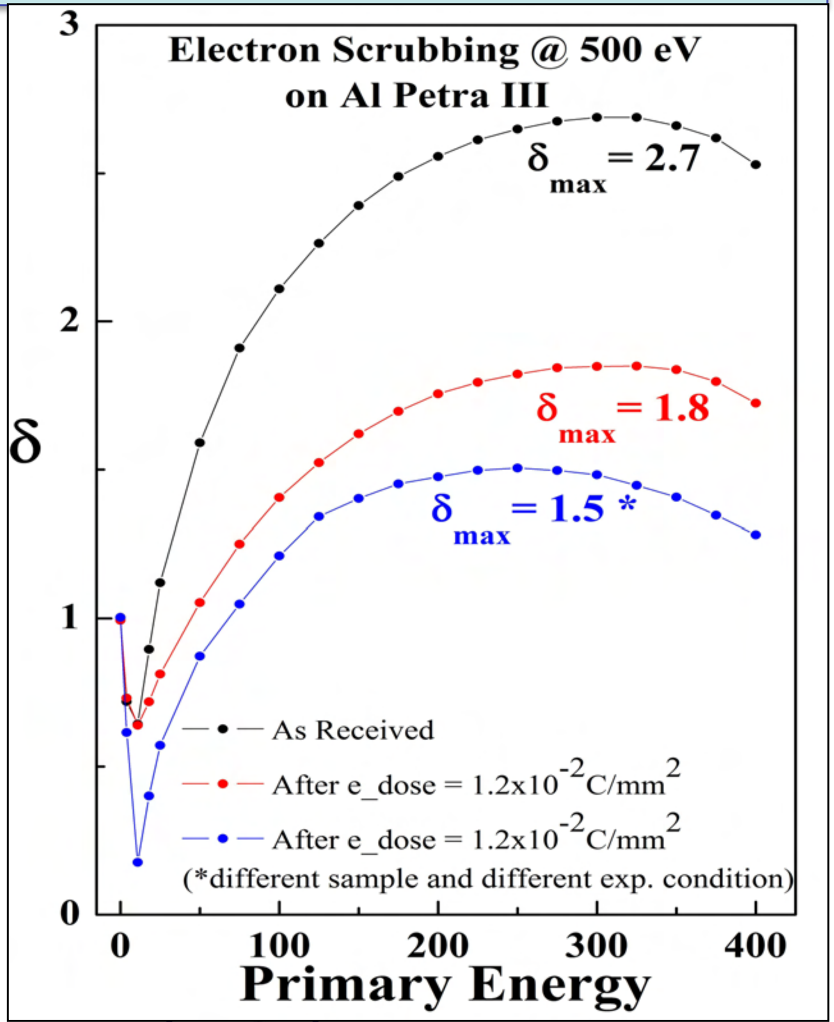
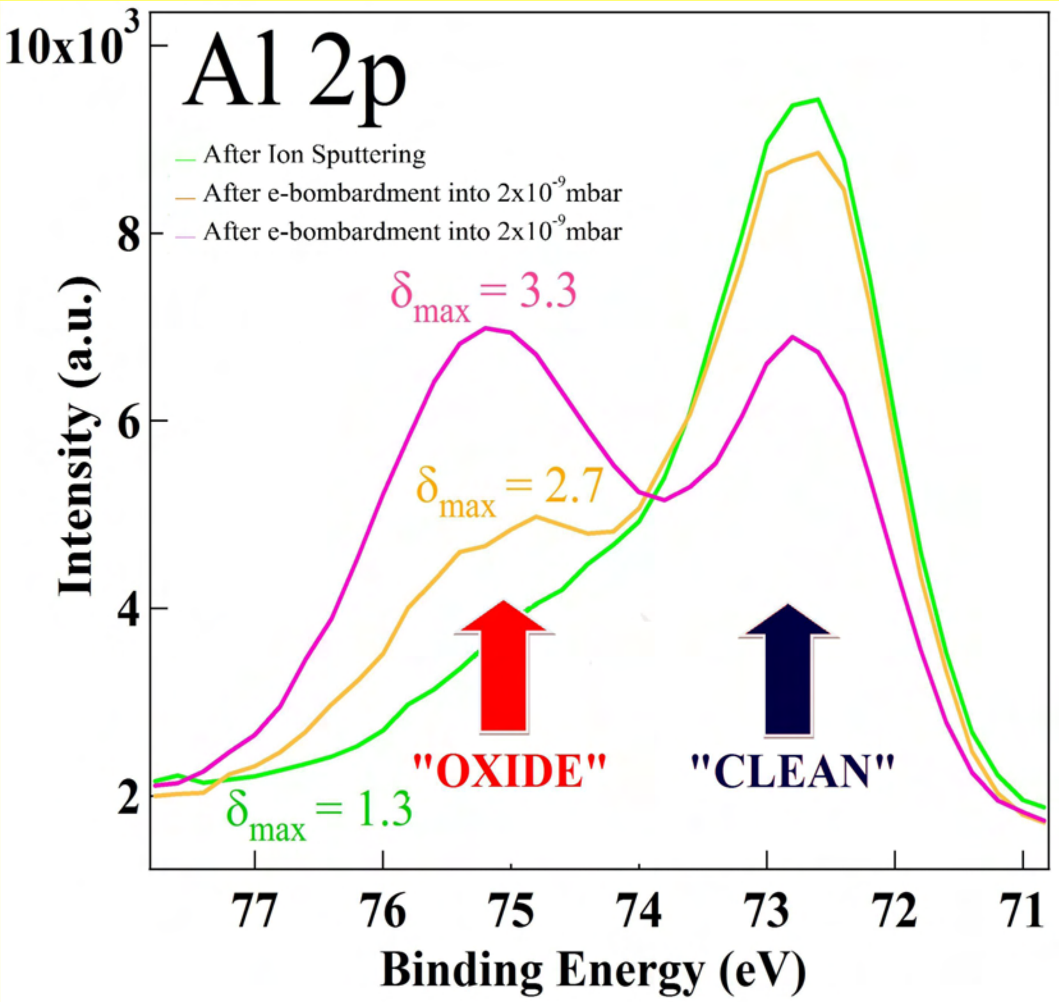




XPS studies on Al as received, sputtered clean and e⁻ scrubbed in 10^{-8} - 10^{-9} mbar:



Conclusion on Al:

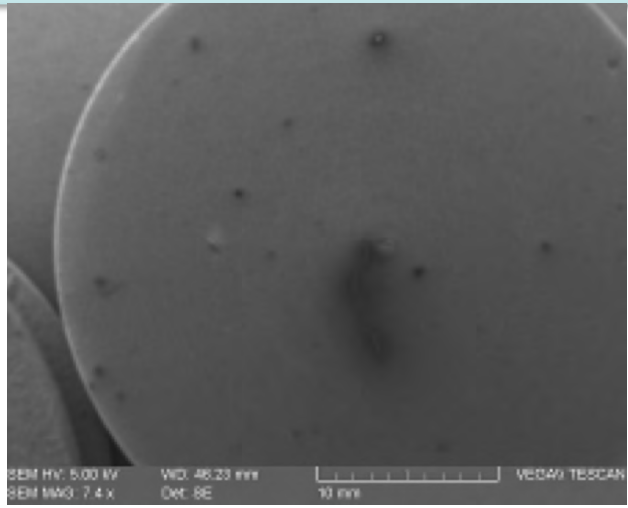
For Al the SEY decreases upon e⁻ scrubbing.

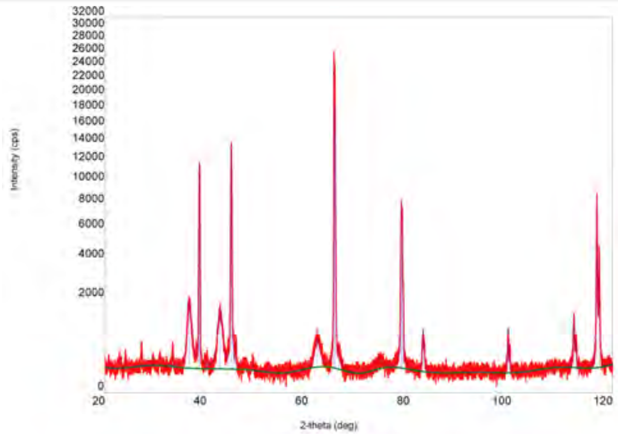
- The SEY may be influenced by the base pressure at which they are performed
- Little role of C and dominant role of Oxidation state to determine SEY
- The extreme reactivity of Al surface, makes Al chambers not suitable for their e-cloud related performances unless coated with a more stable compound.

TiN

Of interest for SuperB, Super KEKB, ILC Damping Rings, etc.

TiN (done by S. Bini & the LNF Vacuum Group).

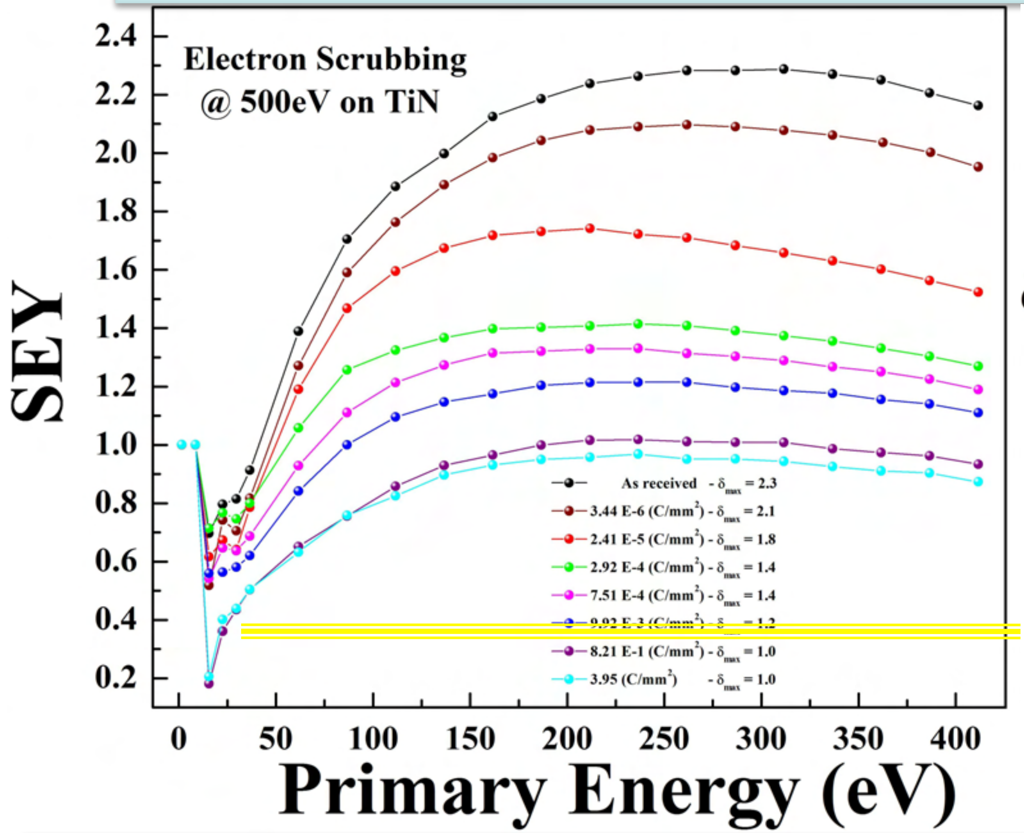


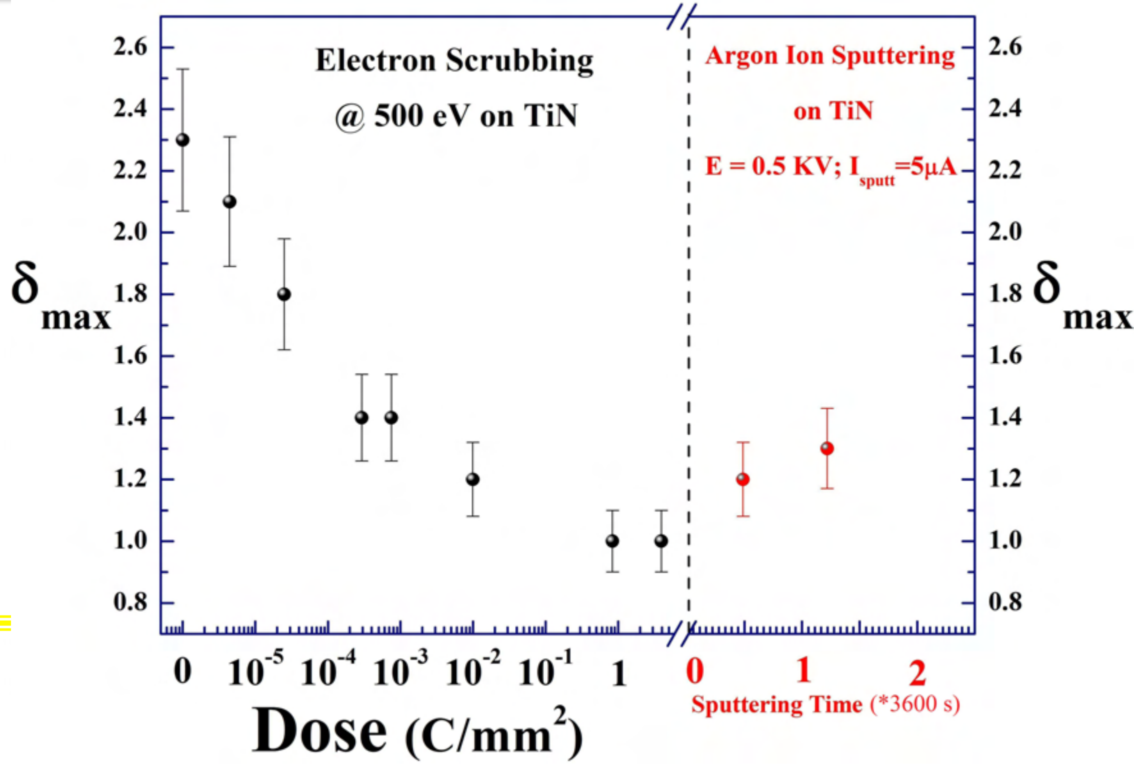


Nanocrystalline TiN thin films has been deposited on aluminum substrates by RF-magnetron sputtering. The "good" quality of the film in terms of microstructural morphology and texture was characterized by SEM and FE SEM and by X – Ray Diffraction.

*D.R. Grosso et al. in preparation

On such TiN we measured SEY vs. electron Dose and….

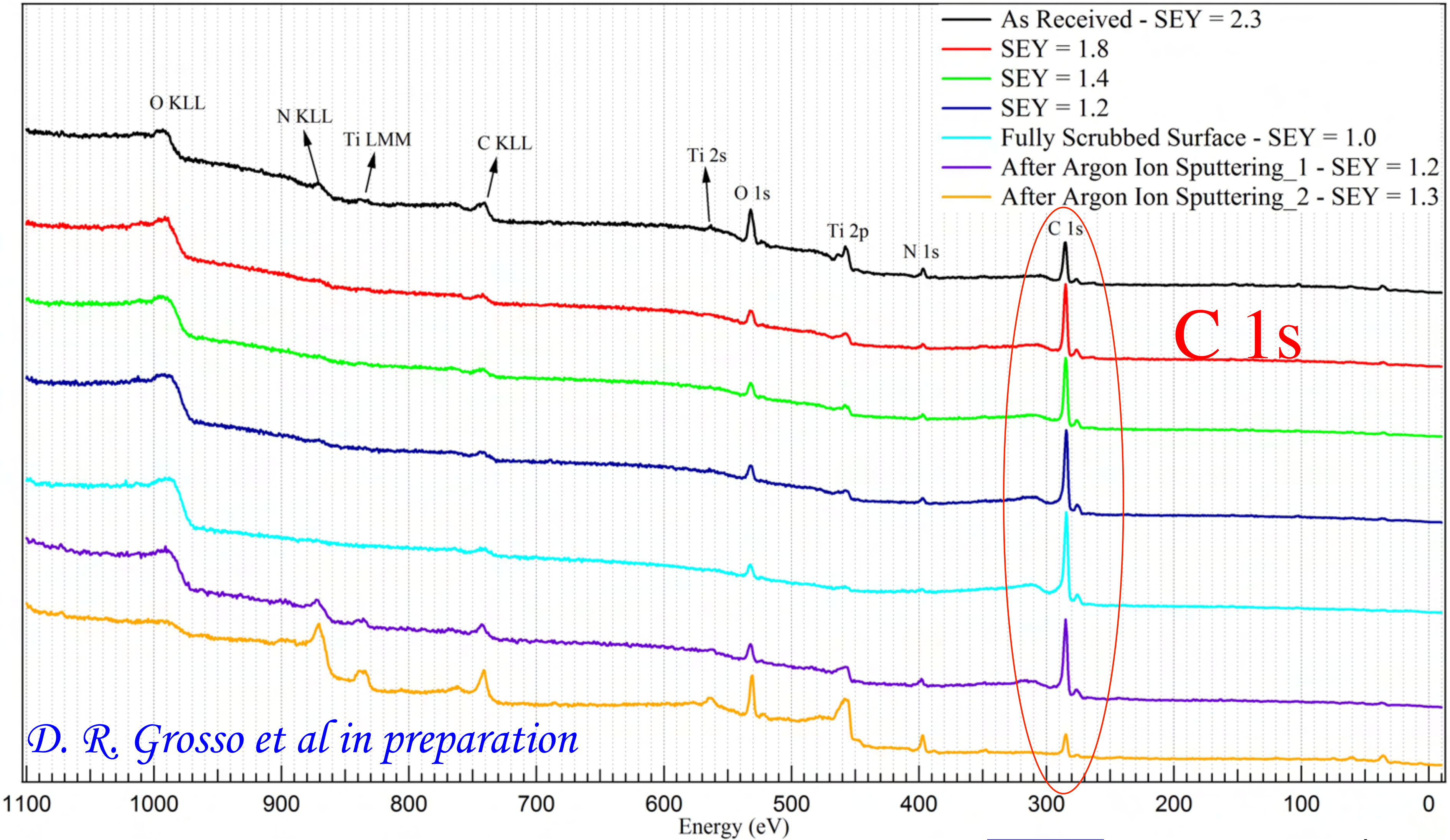




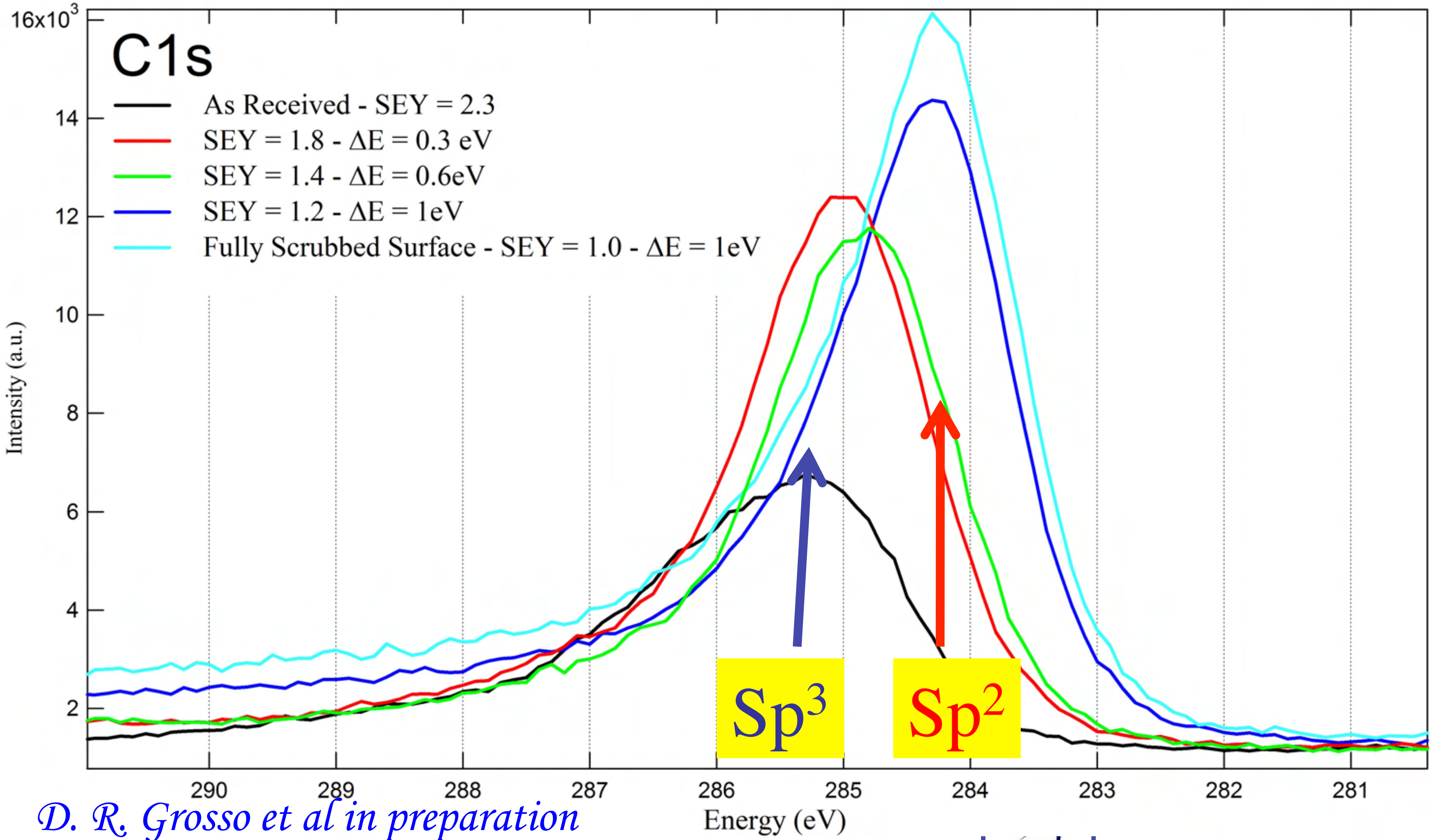
TiN (at least "our") needs scrubbing: then it reaches δ_{max} *~ 1, which is the value quoted at KEK*

D. R. Grosso et al in preparation

We measured XPS vs. e⁻ Dose and Ion sputtering and..



Also in TiN the SEY reduction is accompanied by C-sp^2 formation



D. R. Grosso et al in preparation

a little (but useful) detour on the scrubbing process

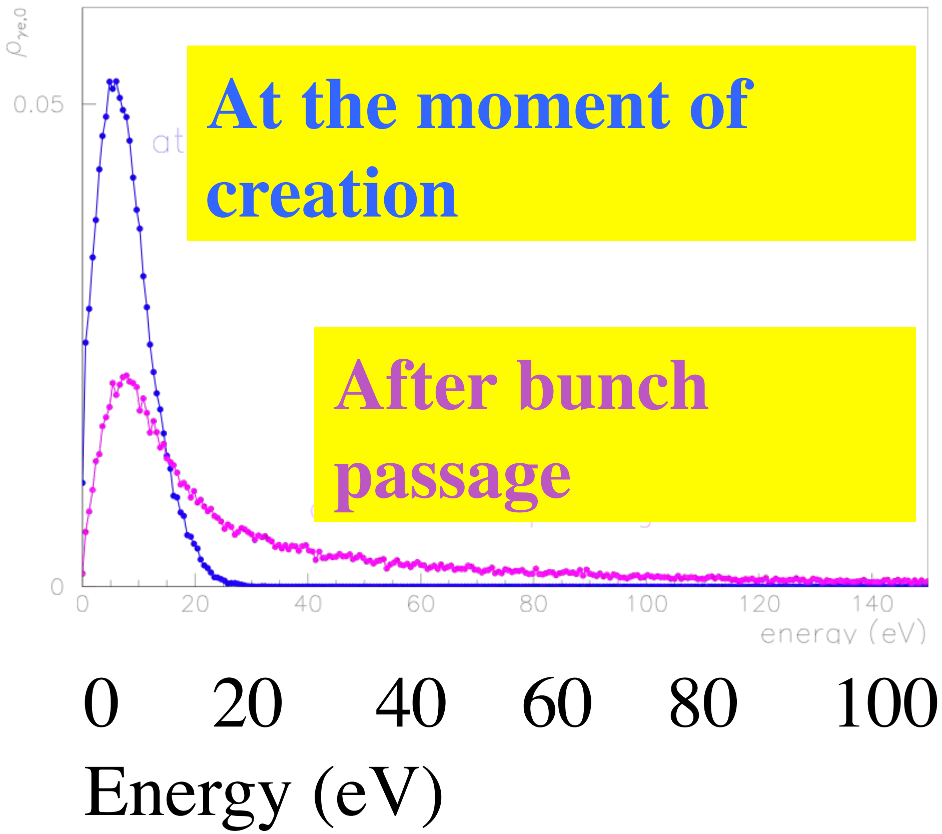
Most of the data on "scrubbing" have been obtained in laboratory experiments by bombarding surfaces with 500 eV electrons for increasing Time (i.e: dose)

Dose= N°e⁻ x t(s) xA (mm²)

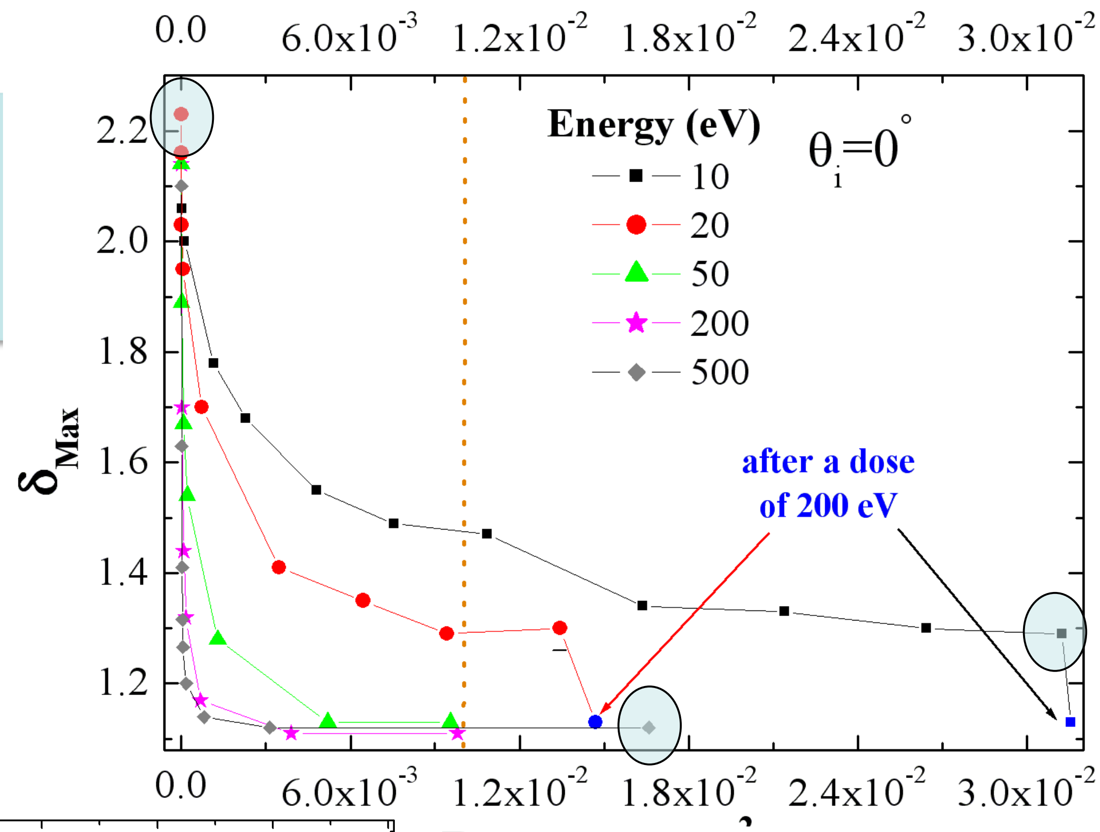
- *What energy do the e⁻ participating in the cloud have in the accelerator?*

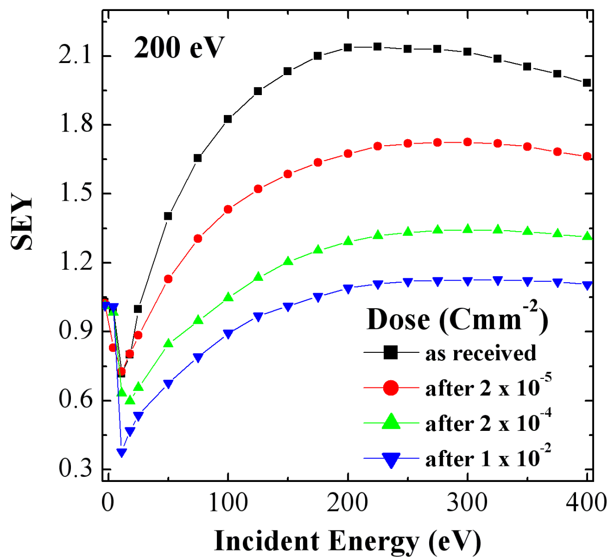
  Simulation by F. Zimmermann (2001) shows that the main contribution lies at low energy!

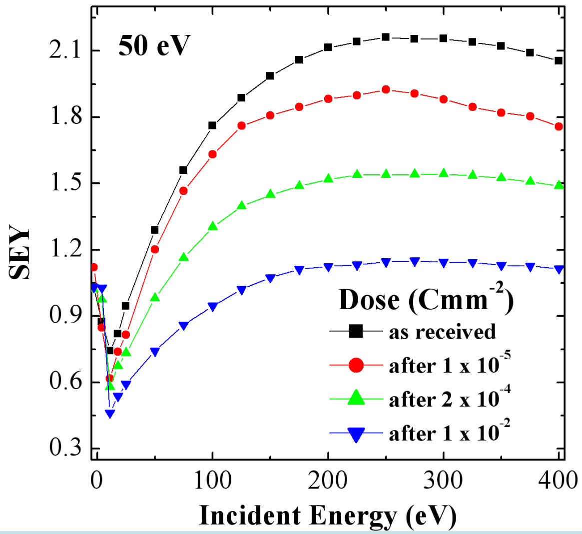
- *do 10 e⁻ @ 500 eV scrub as*
- *10 e⁻ @ 10 eV?*

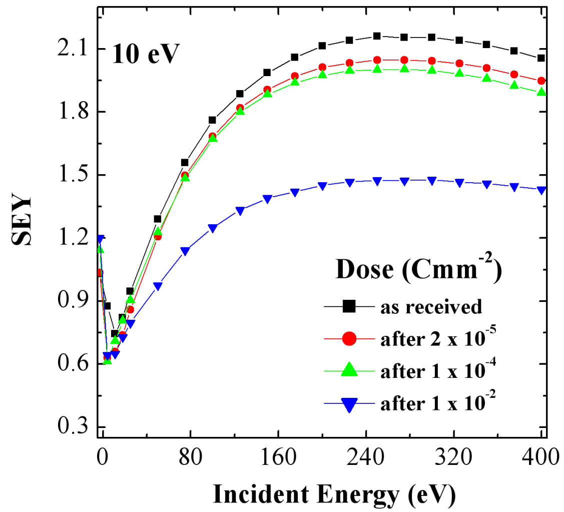


Scrubbing vs impinging electron energy





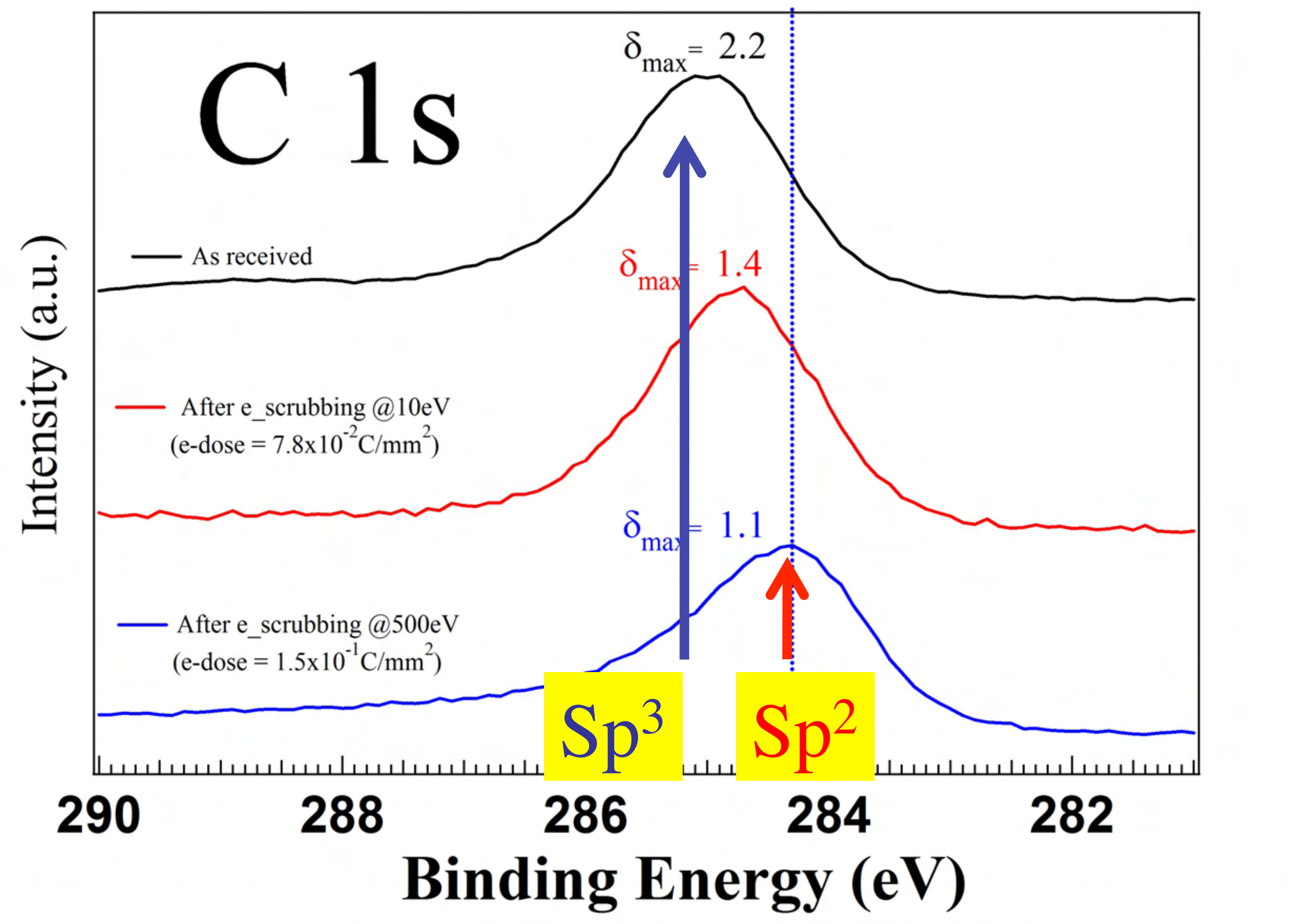




SEY measurements for 200 eV, 50 eV and 10 eV impinging electron energy at normal incidence

the potentiality of an e^- to reduce SEY also depends on its energy.

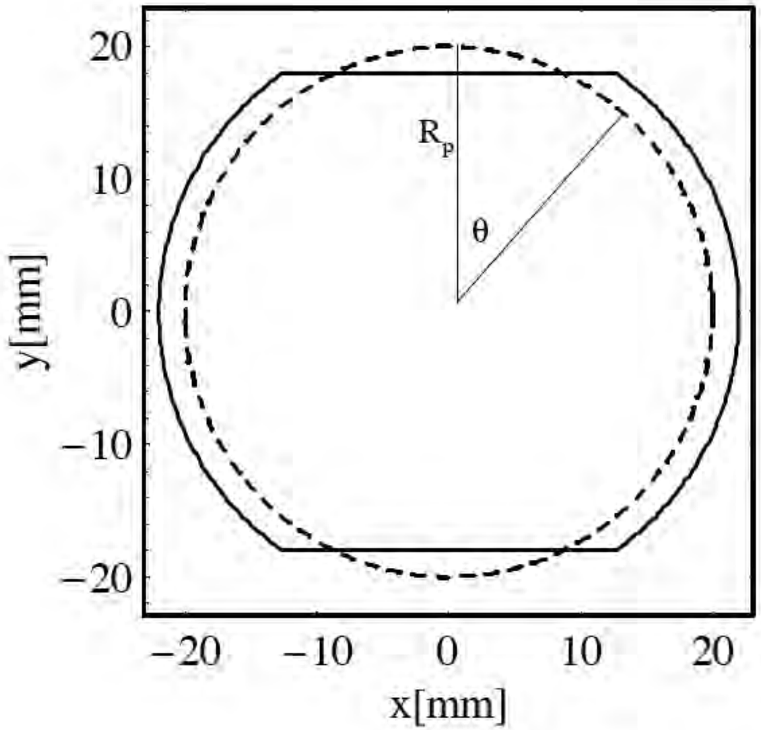
We repeated the experiment to confirm it and to do XPS.



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

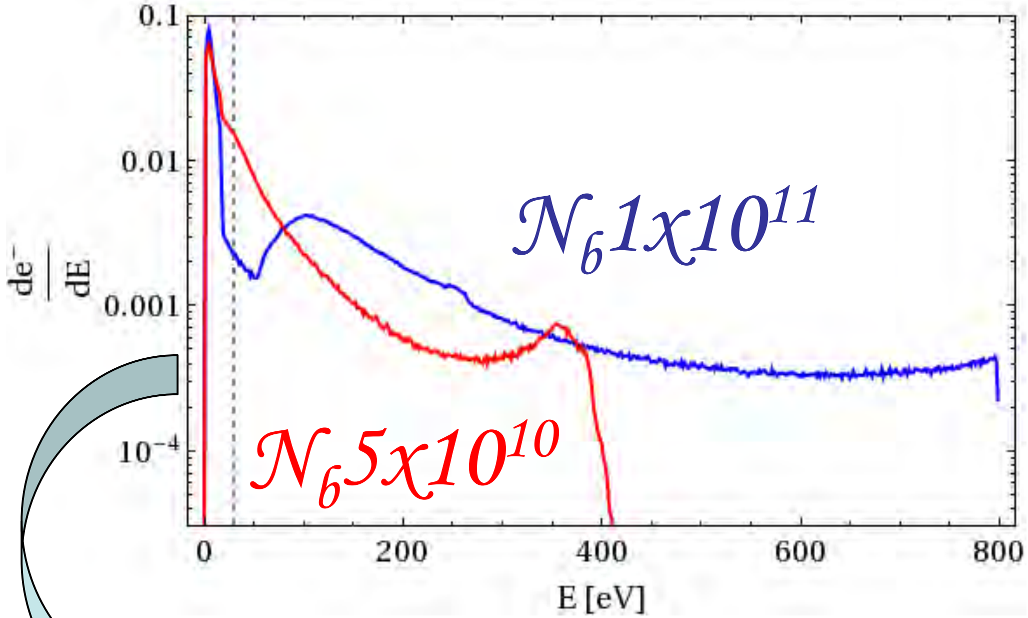
Table 1: Parameters used for ECLOUD simulations.

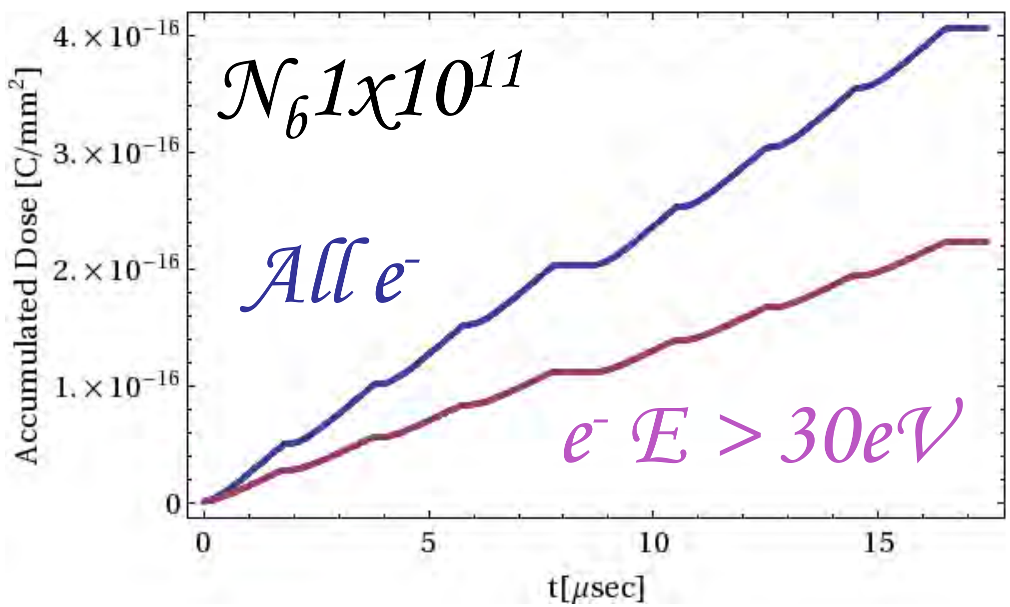
parameter	units	value
beam particle energy	GeV	7000
bunch spacing t_b	ns	$25; 50; 75$
bunch length	m	0.075
number of trains N_t	-	4
number of bunches per train N_b	-	$72; 36; 24$
bunch gap N_g	-	8
no. of particles per bunch	10^{10}	$10; 3.0$
length of chamber section	m	1
chamber radius	m	0.02
circumference	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



- *Some consequences on commissioning: calculation of the e^- dose hitting the walls versus beam parameter and energy. Could define beam parameters to increase e^- >30 eV.*

@ 50ns, δ_{max}=1.4 equal e^- density





Log Scale!

T. Demma et al. in preparation.

What did we learn so far?

Al, is very reactive, ageing etc. produce Oxides with very high SEY! (If used should be coated)

From Surface Analysis we learn that when C on the surface forms an sp^2 layer, then scrubbing is efficient and the δ_{max} goes below 1.2!!

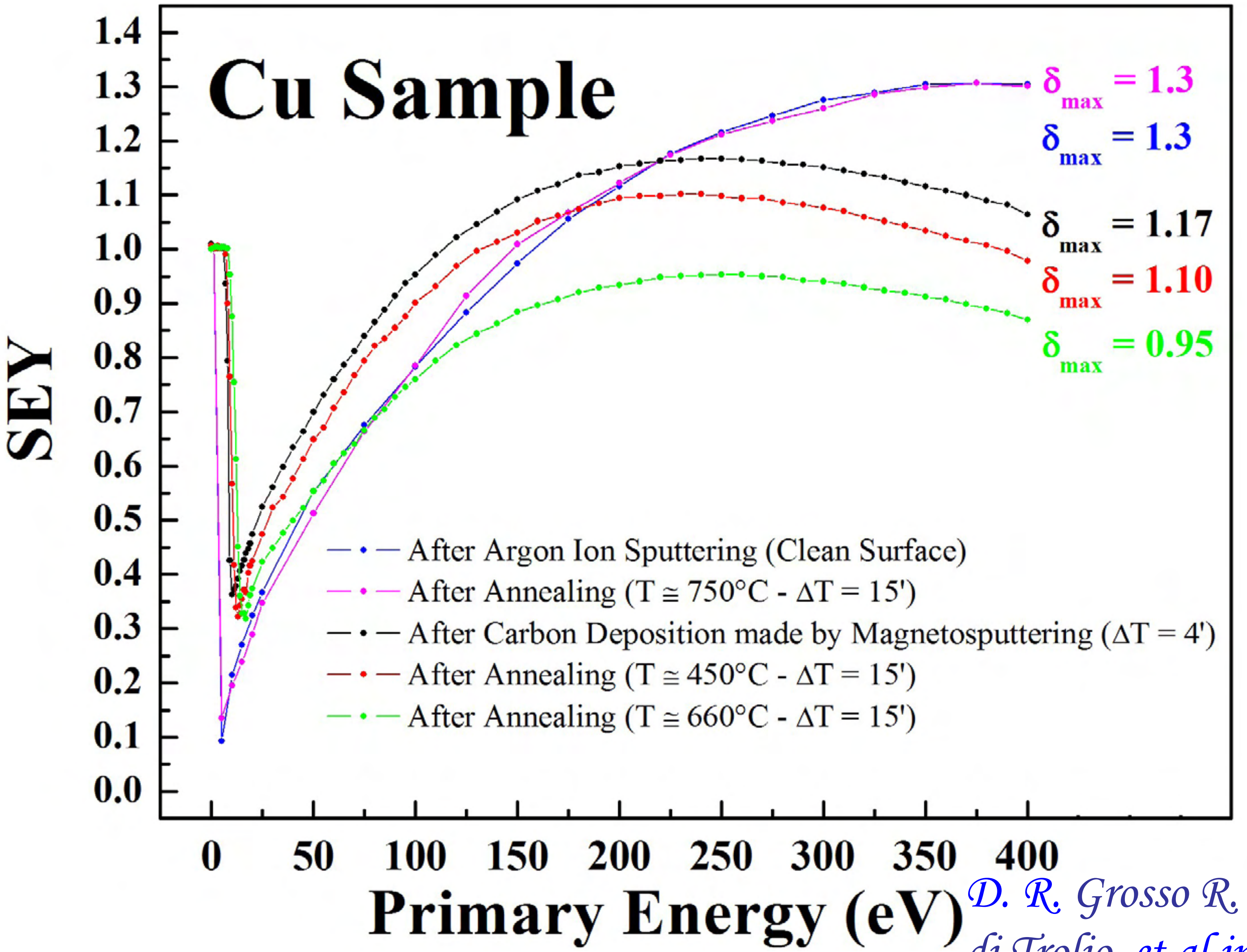
Graphitization is an essential (and quite general, but Al) ingredient in SEY reduction!

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

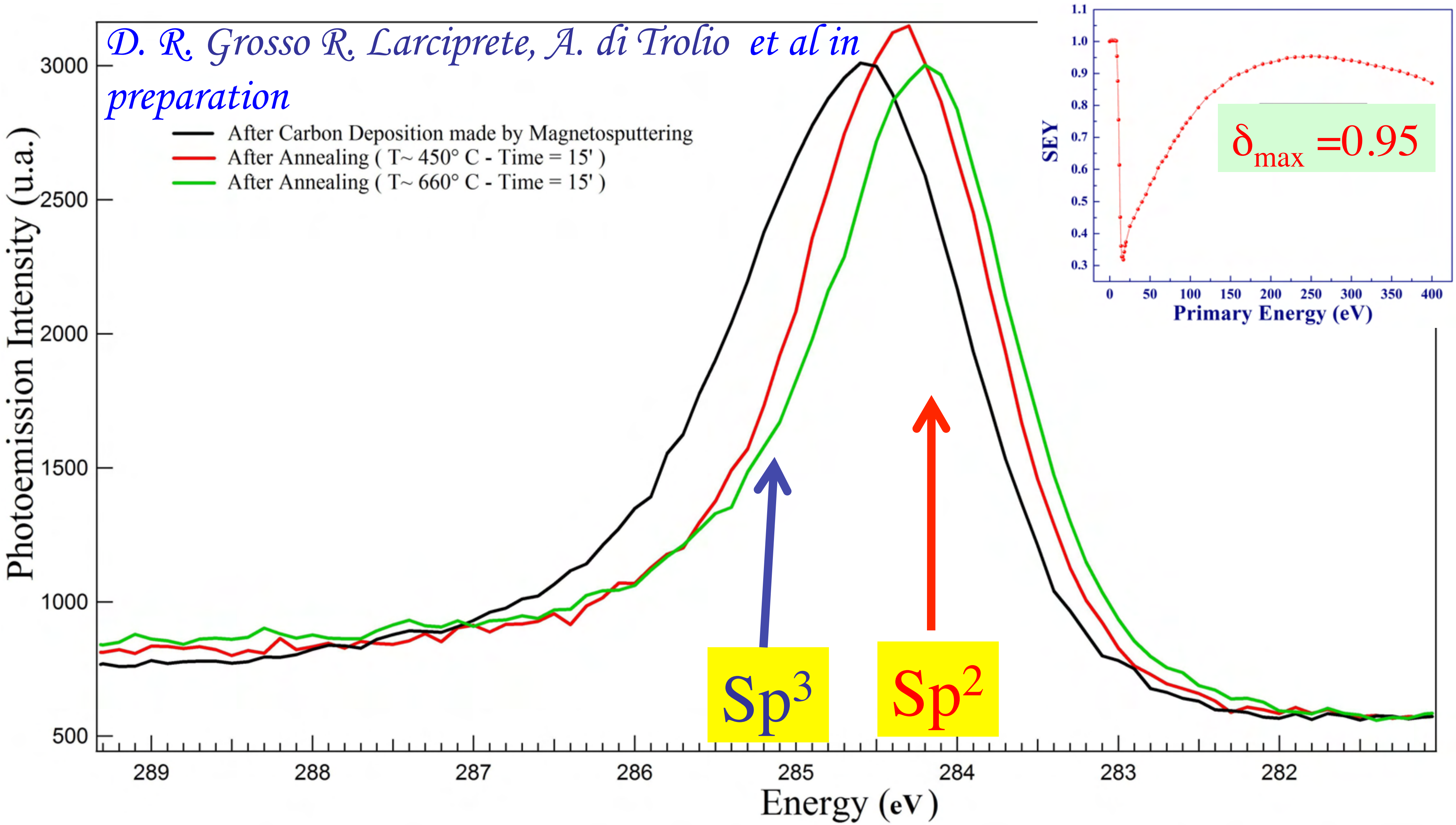
CERN uses magneto-sputtering technique to grow a thick (0.2-10 μm) of a-C film on accelerator wall surfices.

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.



D. R. Grosso R. Larciprete, A. di Trolio et al in preparation



It confirms that the best Graphene/Graphite layer we grow the lowest the SEY is !

Not only we start to understand what is actually happening during SEY reduction, but also using it to develop conceptually new material and coatings.

Results are promising and suggest that this could be the right research direction!

Other accurate studies are necessary to optimize growth parameters, to test the performance of material in terms of stability vs time, adhesion, cost effectiveness etc..
We need to be able to produce these material in large scale for accelerators…… A lot of work!!!

Acknowledgments:

in the lab:

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R. Larciprete, A. di Trolio (CNR-ISC), R. Flammini (CNR-IMIP)

People from the accel. division

- T. Demma, S. Bini, D. Alesini, V. Lollo, C. Vaccarezza, M. Biagini, S. Guiducci, M. Zobov, A. Drago, P. Raimondi……

Last but not least : the e-cloud community

V. Baglin, G. Bellodi, I.R.Collins, M. Furman, O. Gröbner, M. Pivi, A. G. Mattewson✝, F. Ruggero✝, S. Casalboni, G. Rumolo, W. Fischer, F. Zimmermann, M. Palmer, R. Wanzenberg and many others…..

announcement & invitation

ECLOUD’12

La Biodola, Isola d’Elba, Italy
From 5 to 9 June 2012

ECLOUD workshop series started at CERN in 2002.
After 10 years and stops in Napa Valley/CA (2004), Daegu/Korea (2007), and Cornell University/NY (2010), ECLOUD'12 returns to Europe!

Topics: SEY models, e-cloud build & e-cloud effects in accelerators, beam induced multi-pactoring, surface properties, mitigation measures, microwave diagnostics, …

more info will be posted at **https://cern.ch/ecloud12**

we hope to see you there!

Roberto Cimino (Roberto.Cimino@lnf.infn.it)
and Frank Zimmermann (frank.zimmermann@cern.ch)