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

Roberto Cimino LNF-INFN

For the NTA-IMCA and Nuvola-GrV collaboration

- *No introduction to the e-cloud problem*
- *No ongoing work in other Laboratories (only some requirements)*
- *Material Science Laboratory@LNF first results.*
- *Conclusion.*

R. Cimino

1

Open problems

@ KEK for Super KEKB

@ LNF for Super-B

@ LHC for (maybe) running at 25 ns and (for sure) for the upgrade

@ ILC DR etc….

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

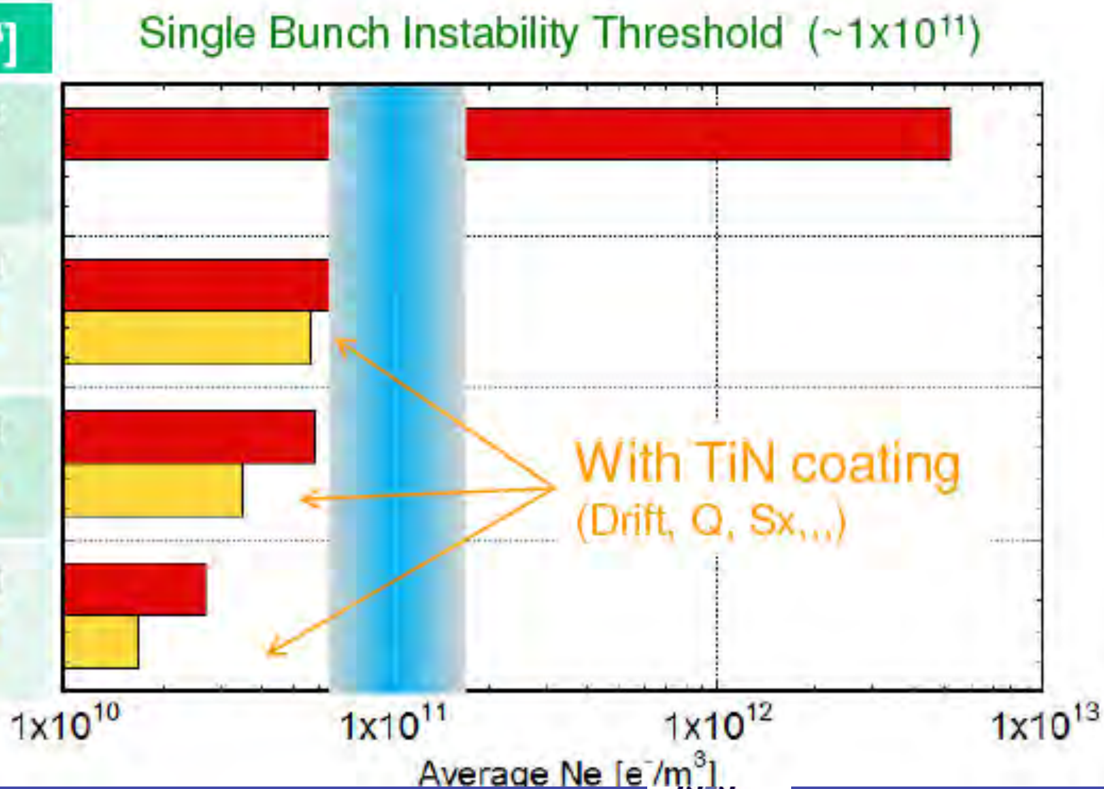
ρ [m^{-3}] =1.13E11 ➡ **Our target =1E11 m^{-3}**

3. Plans for Super KEKB

Y. Suetsugu, KEK
on behalf of KEKB Vacuum Group

- Summary
  - Major electron cloud will be reduced by antechamber scheme and solenoid field at arc section. But it seems still insufficient.
  - Electrodes in wiggler and grooves in bending magnets will decrease EC further and increase the safety margin.
  - The groove in B is still under consideration → further R&D.

Condition	ne [m^{-3}]
Circular Cu chamber [KEKB beam pipe]	5.2E12
Solenoid at Drift (1/50) +Cu Antechamber (1/4)	9.4E10 5.7e10
+Electrode in Wiggler (1/200)	5.8E10 3.5E10
+Groove in B (1/10)	2.7E10 1.7e10



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

		June 2008		January 2009		March 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
SEY=1.1	95%	0.06	2.1	0.09	2.5	0.22	2.7
	99%	0.02	0.25	0.04	0.3	0.04	0.7
SEY=1.2	95%	0.22	2.8	0.27	3.2	0.45	6.5
	99%	0.045	0.71	0.06	0.82	0.07	2.4
SEY=1.3	95%	2.7	20.2	2.9	25.7	5.4	25
	99%	0.94	3.2	1.3	4.1	4.5	13

Sep.2009
ρ_{center}
0.1
0.07
0.3
0.1
2.0
0.7

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):

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

… 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

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.

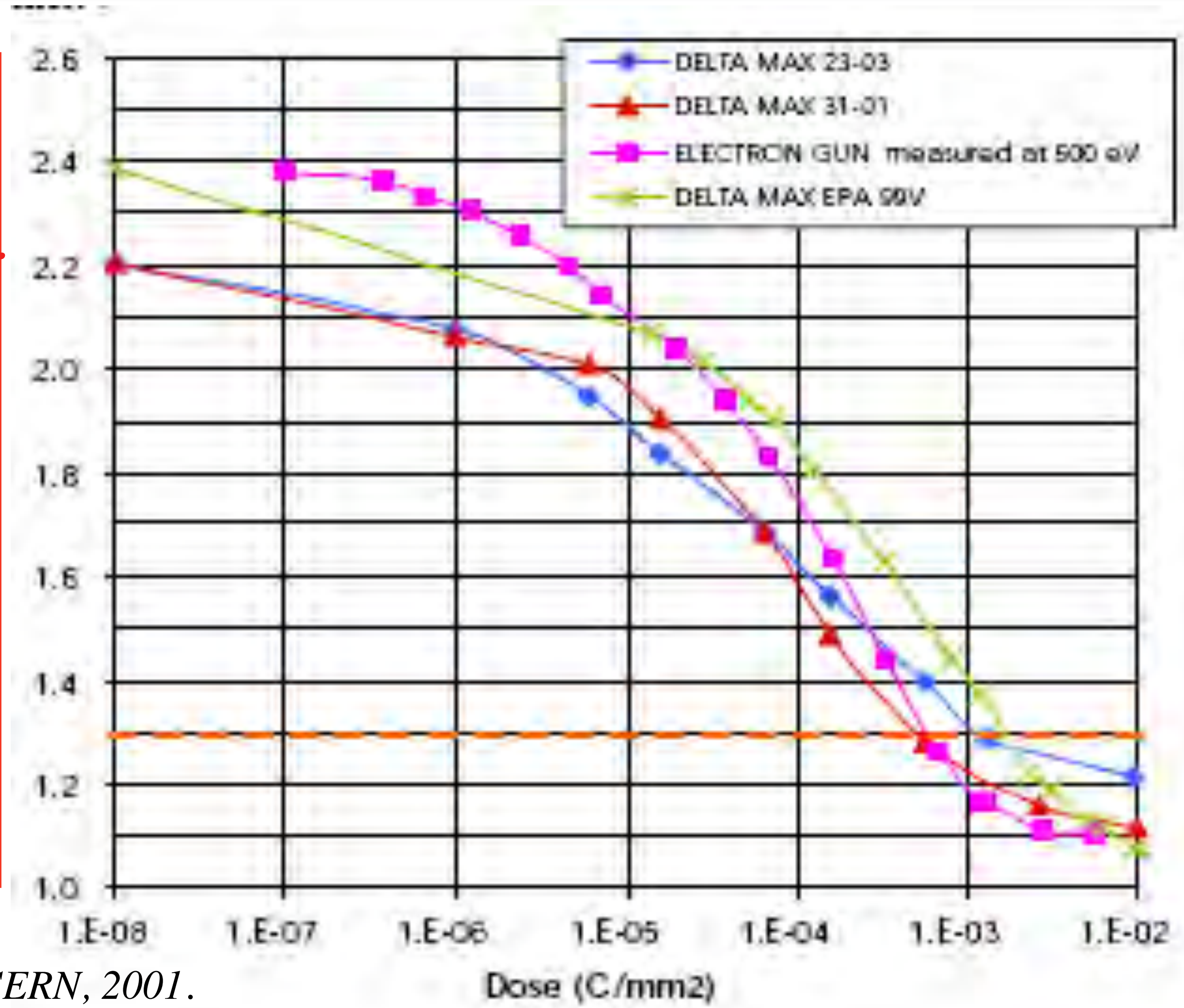
XUV-H (60-1000)

XUV-L (35-200) eV

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

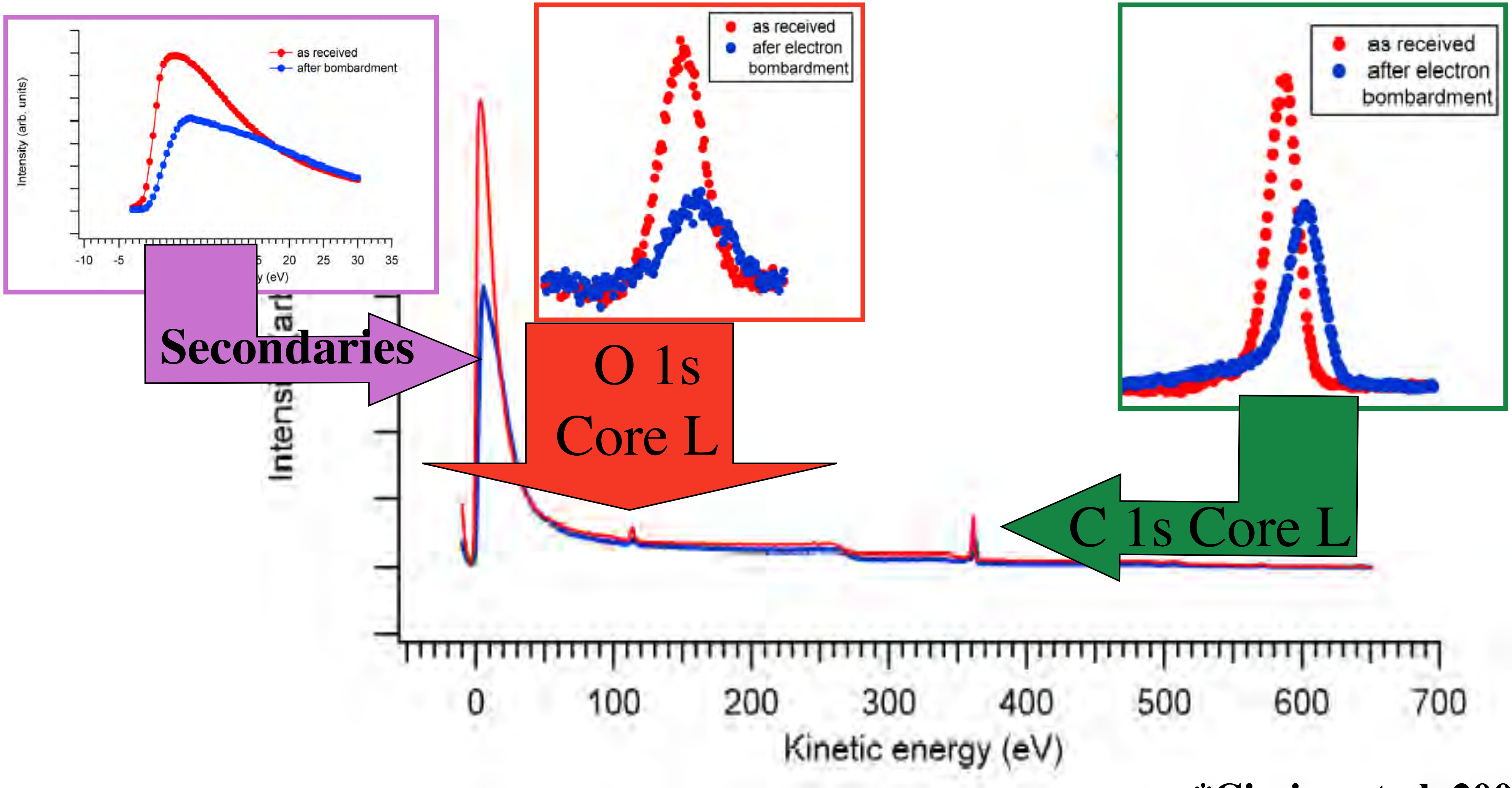
The Beam "scrubbing" effect is the ability of a surface to reduce its SEY after e^- bombardment.

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.

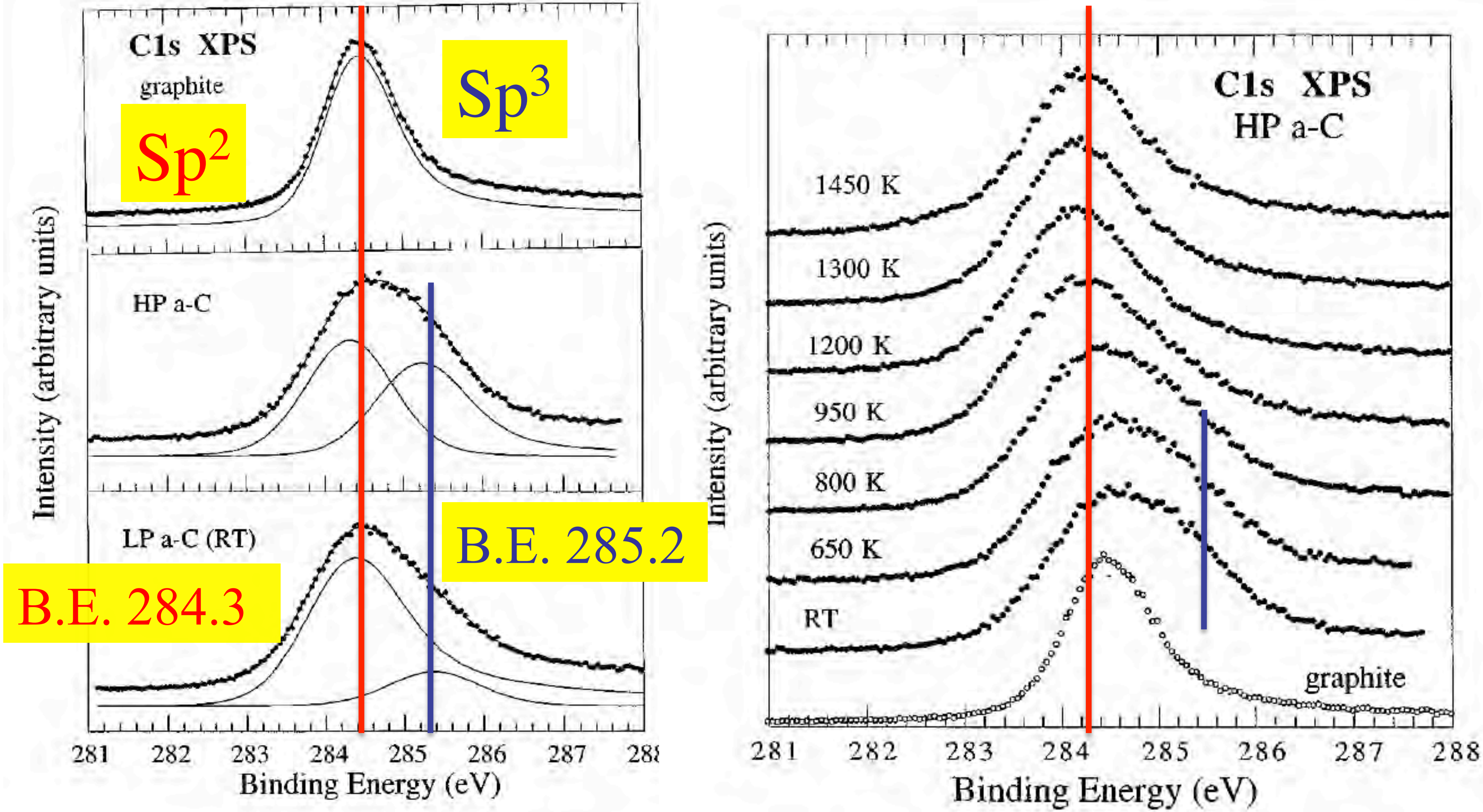


***Cimino et al. 2004**

PHYSICAL REVIEW B VOLUME 54, NUMBER 11 15 SEPTEMBER 1996-I

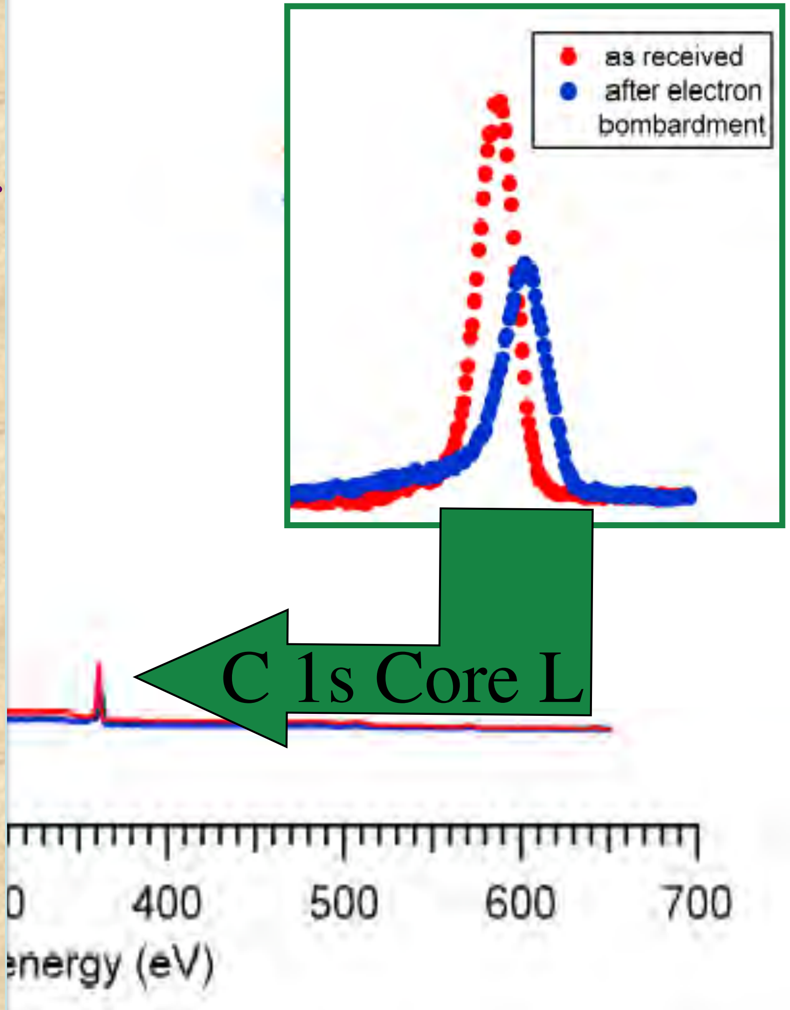
Separation of the sp^3 and sp^2 components in the C 1*s* photoemission spectra of amorphous carbon films

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)



Photoemission spectroscopy during electron scrubbing.

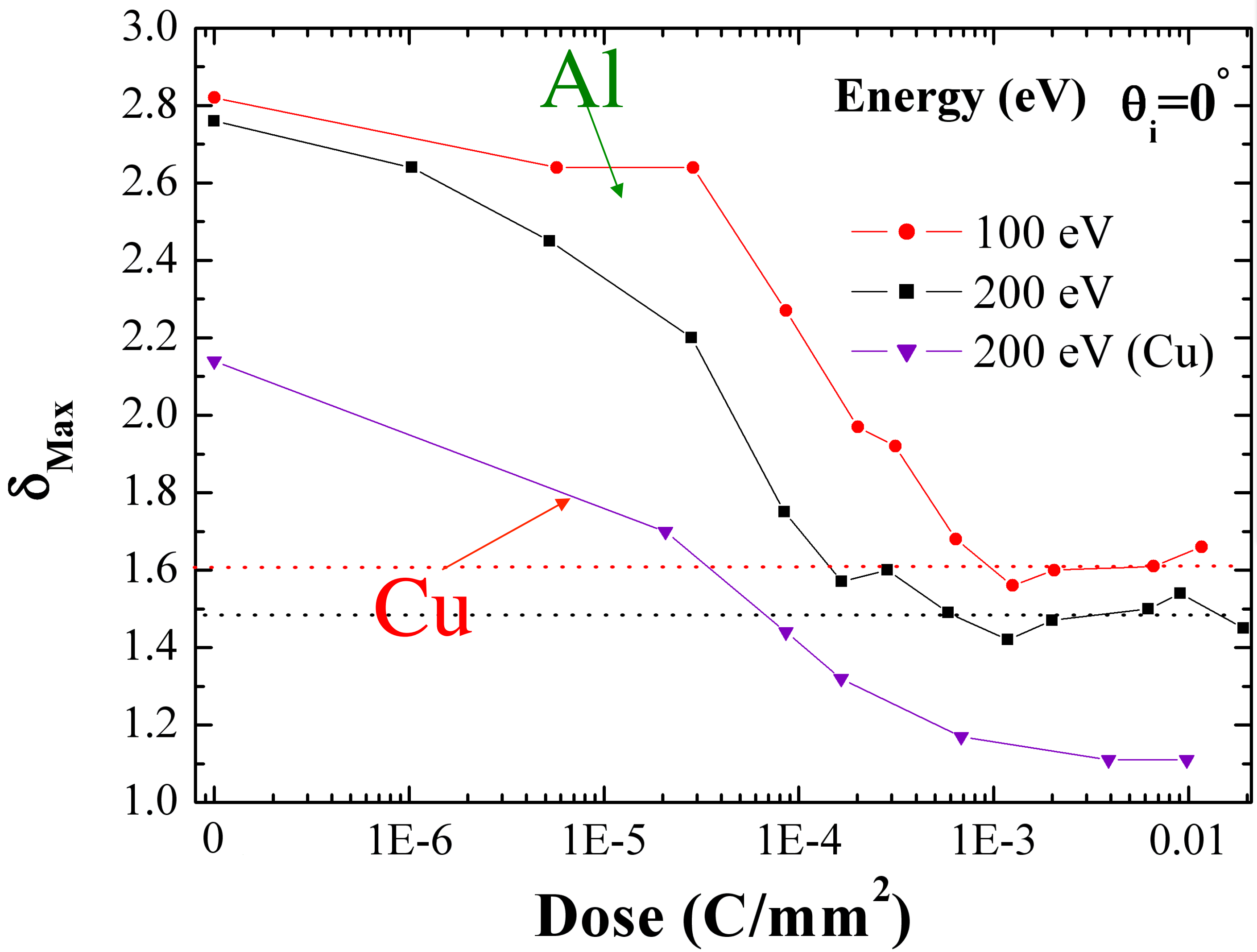
From photoemission spectra we notice that on LHC copper samples, oxigen does not vary significantly with electron bombardment, and carbon levels shows a clear formation of a sp^2 layer indicating a graphitization of the sample.



*Cimino et al. not published

SEY and XPS studies: Al from DAΦNE and Petra III

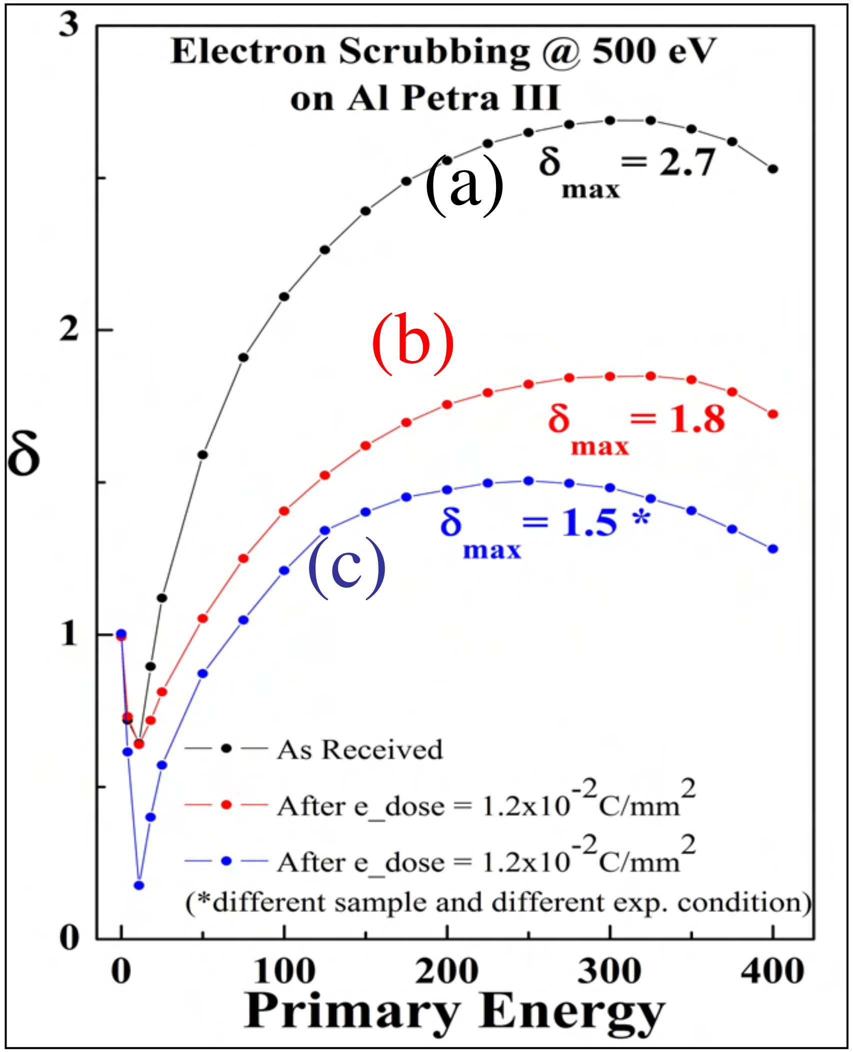
SEY and XPS studies: Al from DAΦNE and Petra III



When you deal with industrially prepared materials: ***Not all the materials are what they are called!***

D. R. Grosso et al in preparation

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



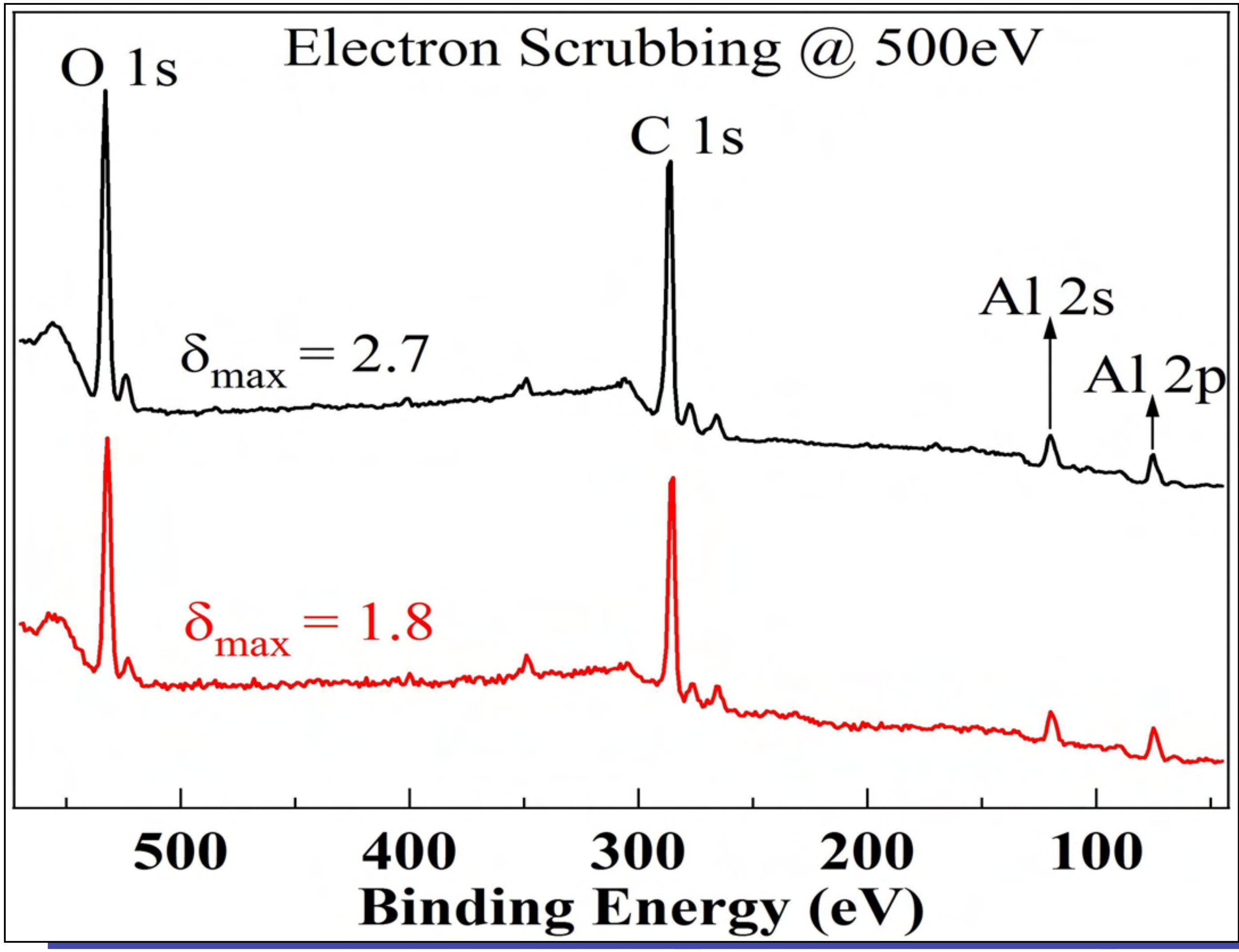
Three SEY spectra recorded in different conditions on Al technical samples cut from the inner walls of the Petra III storage ring,

(a) "as received"

(b) after electron scrubbing at 500 eV KE in UHV at background pressures of low 10^{-9}

(c) after electron scrubbing at 500 eV KE in UHV at background pressures of low 10^{-10} mbar

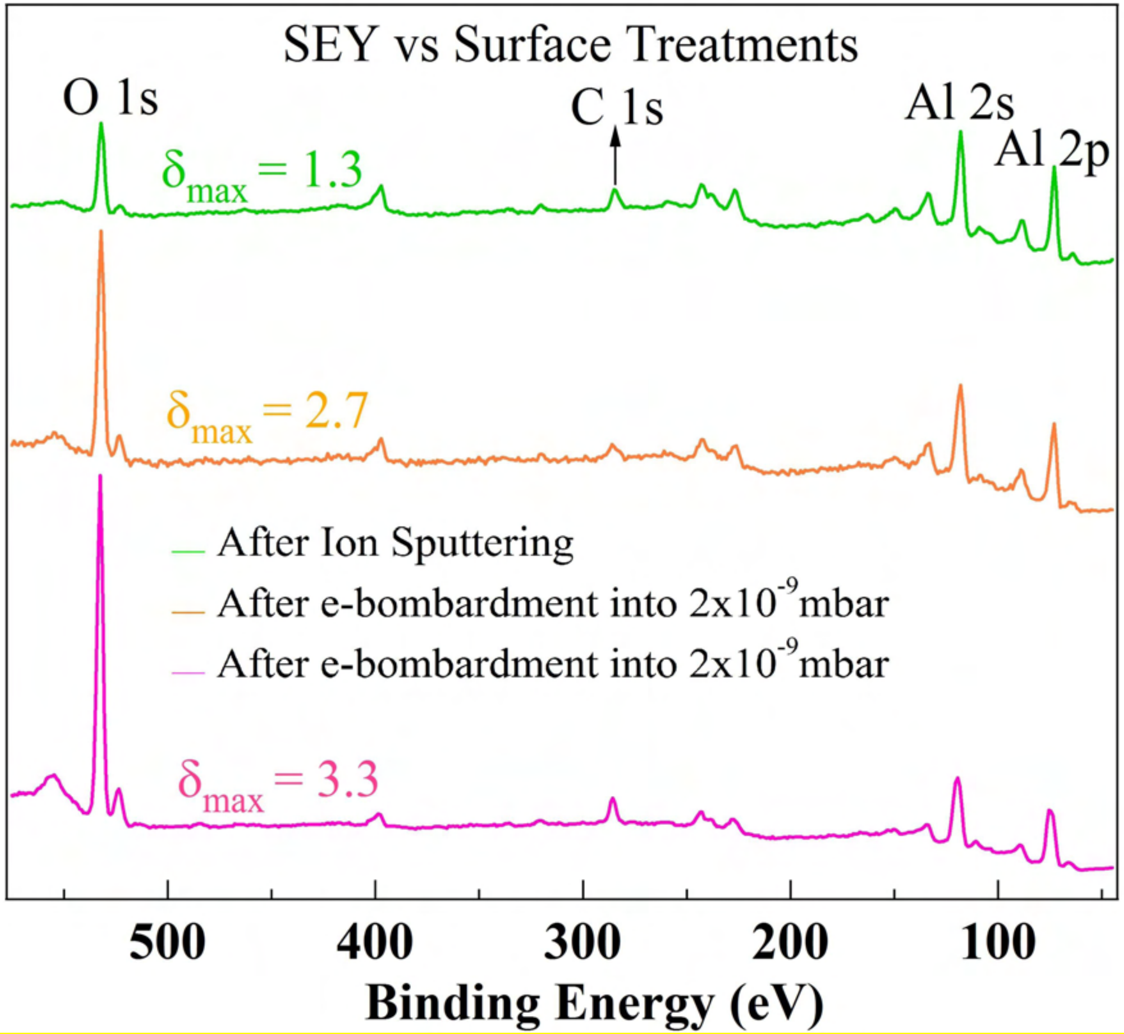
SEY and XPS studies: Al from Petra III (difficulties in reaching low emittance)!



The XPS spectra were acquired on the Al sample characterized by an initial δmax value of 2.7 eV, before and after the exposure to the electron dose.

D. R. Grosso et al in preparation

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



Al samples upon sputtering-scrubbing cycles:

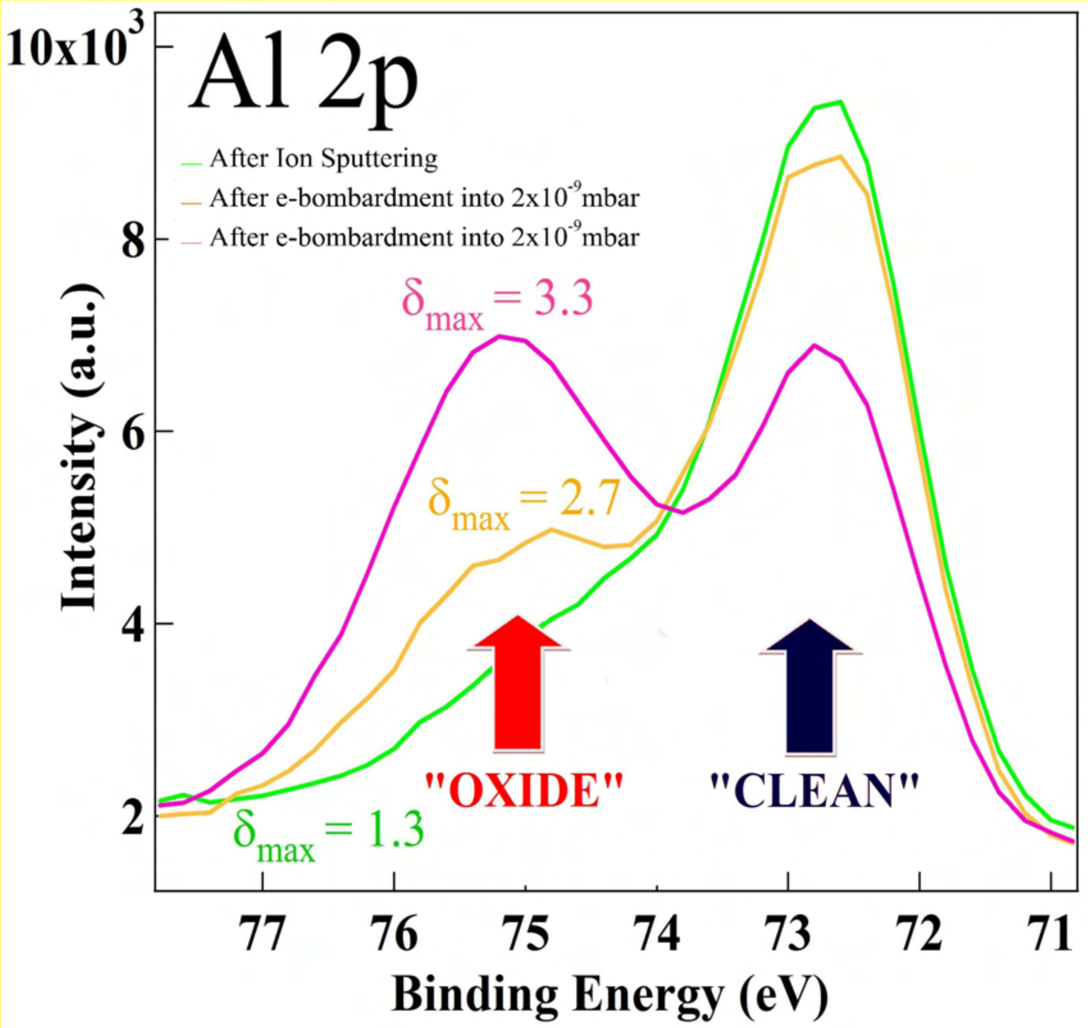
•to simulate the actual presence of ions in the ring

•to reduce the effect of "native" surface contamination and clarify the importance of vacuum dependent e^- induced surface and SEY modifications.

.

D. R. Grosso et al in preparation

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



The XPS characterization of the sample surface, after several cycles of ion sputtering and e^- bombardments, shows clearly that the SEY variation is closely related to the oxidation state of the Al sample, reaching a δ_{max} value as low as 1.3 for our cleanest surface.

D. R. Grosso et al in preparation

XPS and SEY studies on Al : conclusion

- Also in the case of Al the SEY decreases upon electron scrubbing.
- **The SEY measurements may be influenced by the base vacuum at which they are performed**
- **Presumably 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.**

D. R. Grosso et al in preparation

XPS and SEY studies on SS from RICH : Cold bore Beam pipe and Warm bore

XPS and SEY studies on SS from RICH :

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 11, 041002 (2008)

Electron cloud observations and cures in the Relativistic Heavy Ion Collider

W. Fischer,* M. Blaskiewicz, J. M. Brennan, H. Huang, H.-C. Hseuh, V. Ptitsyn, T. Roser, P. Thieberger, D. Trbojevic, J. Wei, and S. Y. Zhang

Brookhaven National Laboratory, Upton, New York 11973, USA

U. Iriso

CELLS, 08193 Bellaterra, Spain

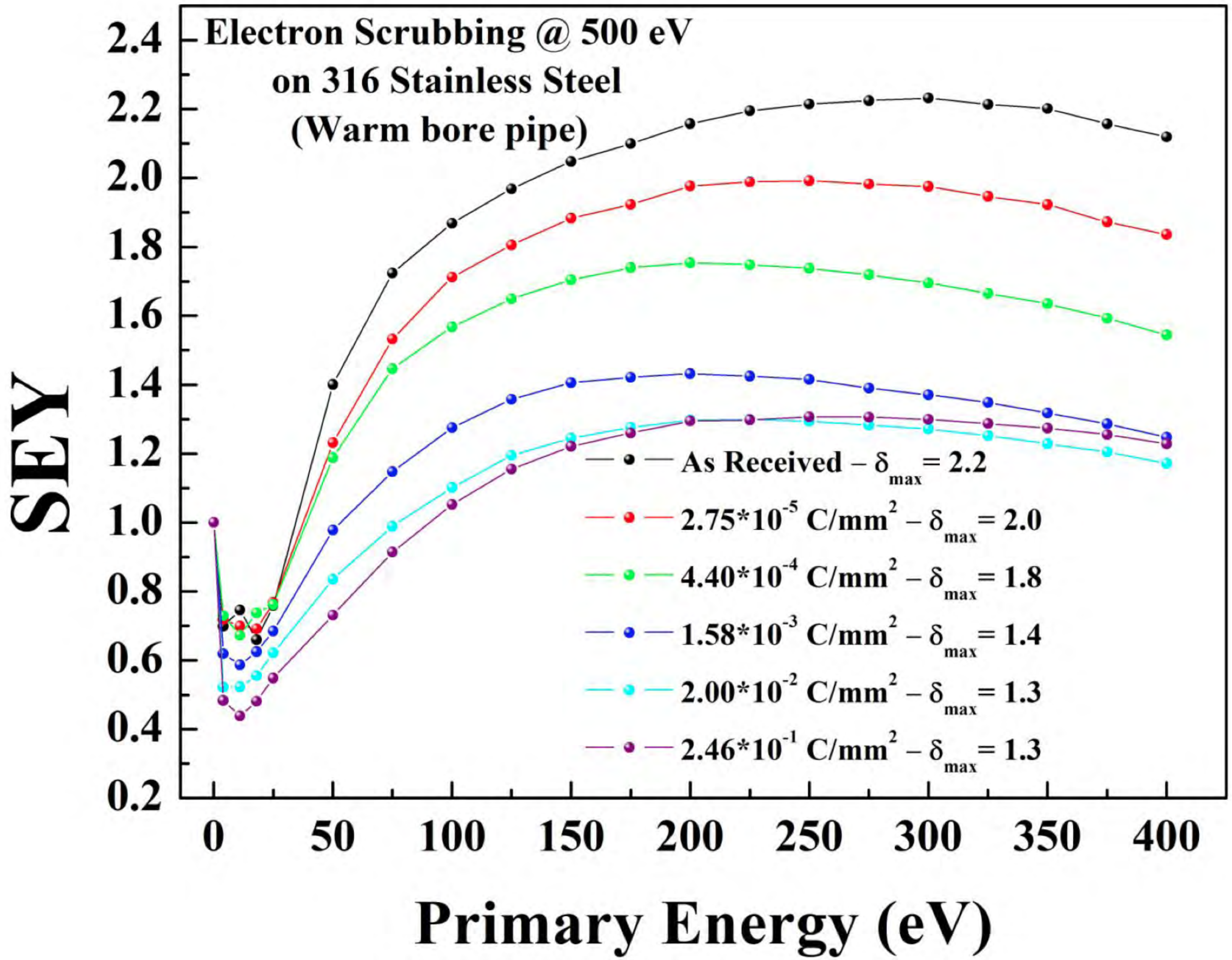
Proceedings of PAC09, Vancouver, BC, Canada TH5PFP002

SIMULATION OF ELECTRON CLOUD DENSITY DISTRIBUTIONS IN RHIC DIPOLES AT INJECTION AND TRANSITION AND ESTIMATES FOR SCRUBBING TIMES*

P. He, M. Blaskiewicz and W. Fischer, Brookhaven National Laboratory, Upton, NY 11973, U.S.A.

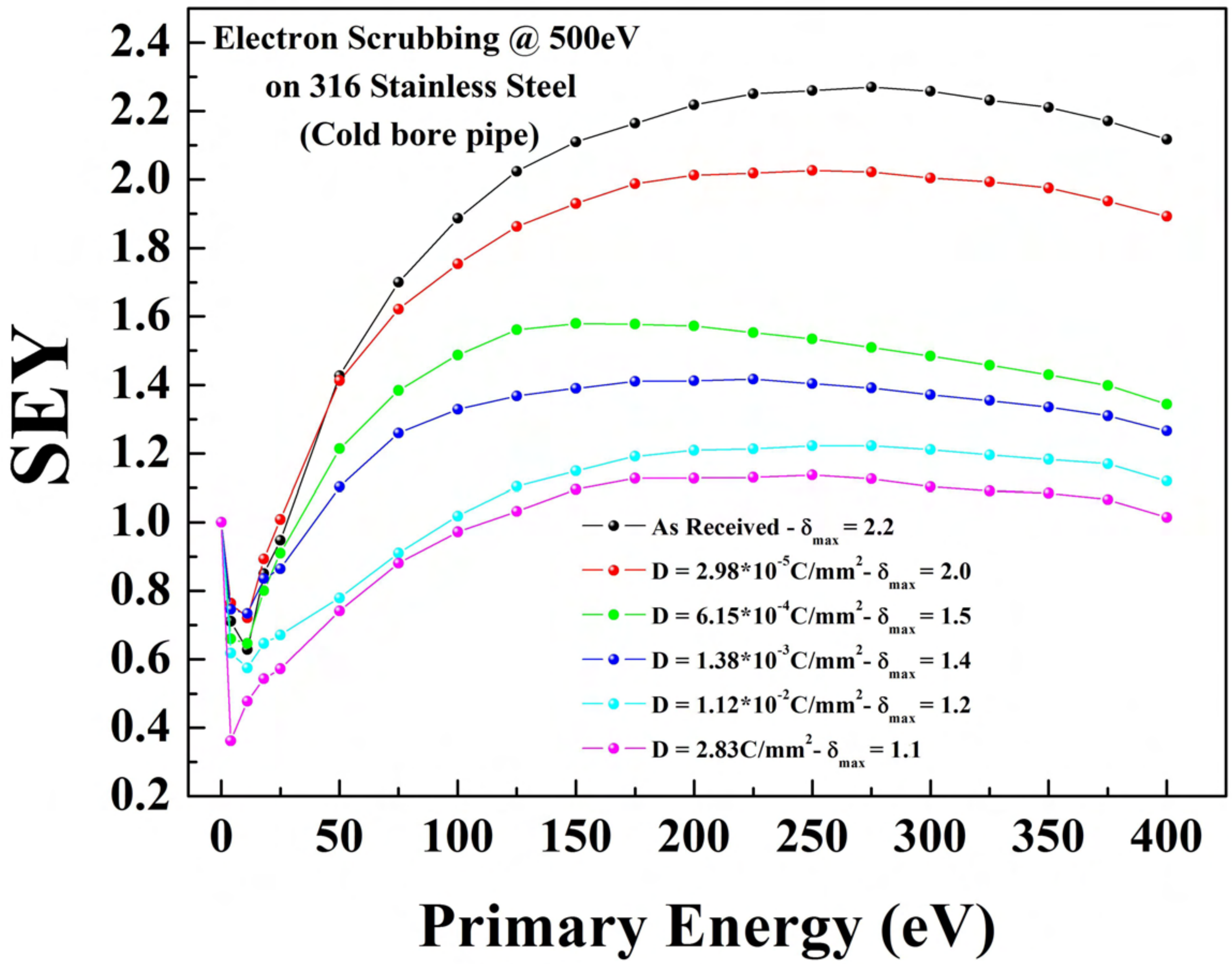
NEED realistic estimate of SEY and SEY vs Scrubbing

XPS and SEY studies on SS from (WB) RICH :



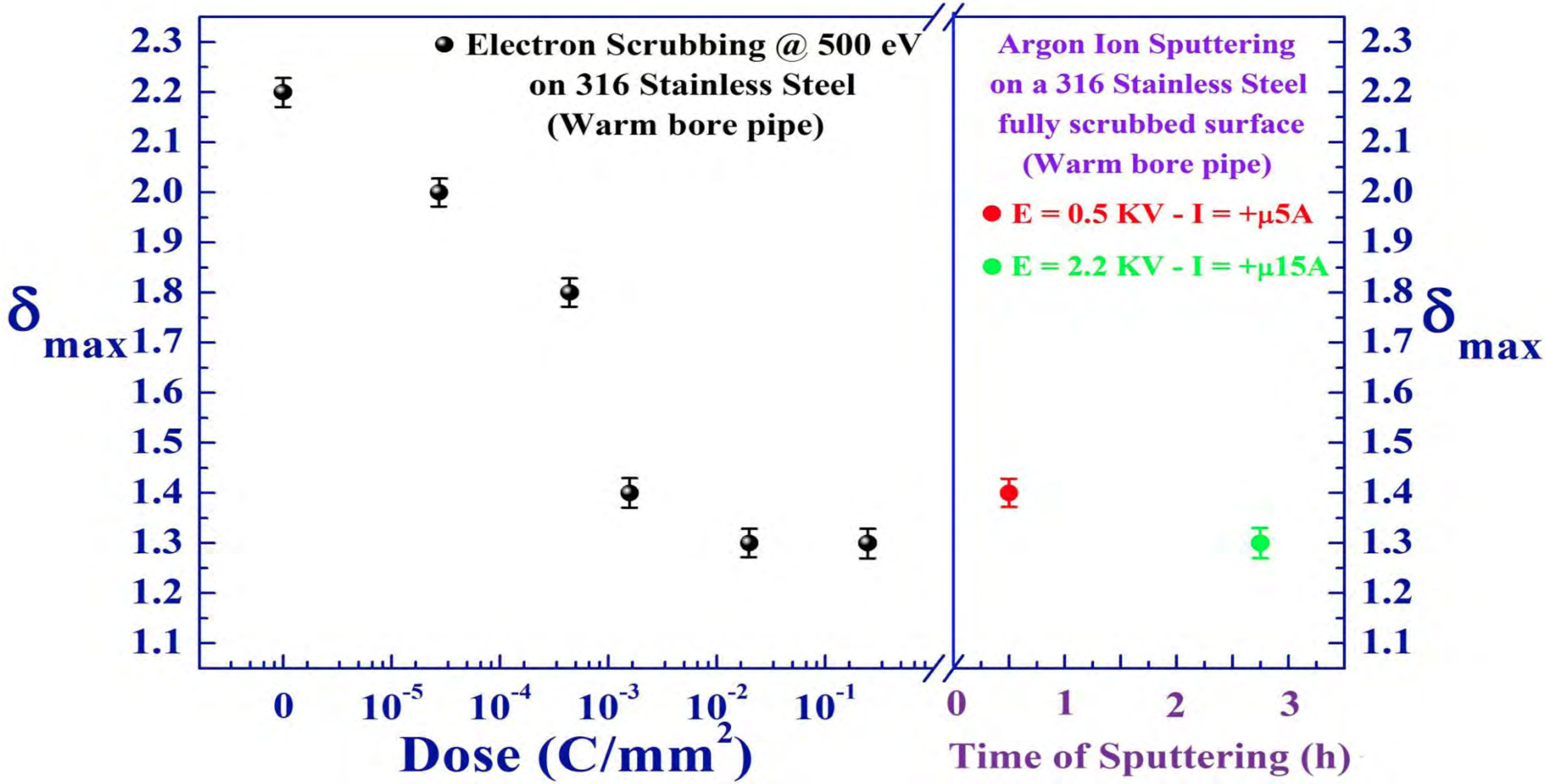
W. Fischer et al in preparation

XPS and SEY studies on SS from (CB) RICH :



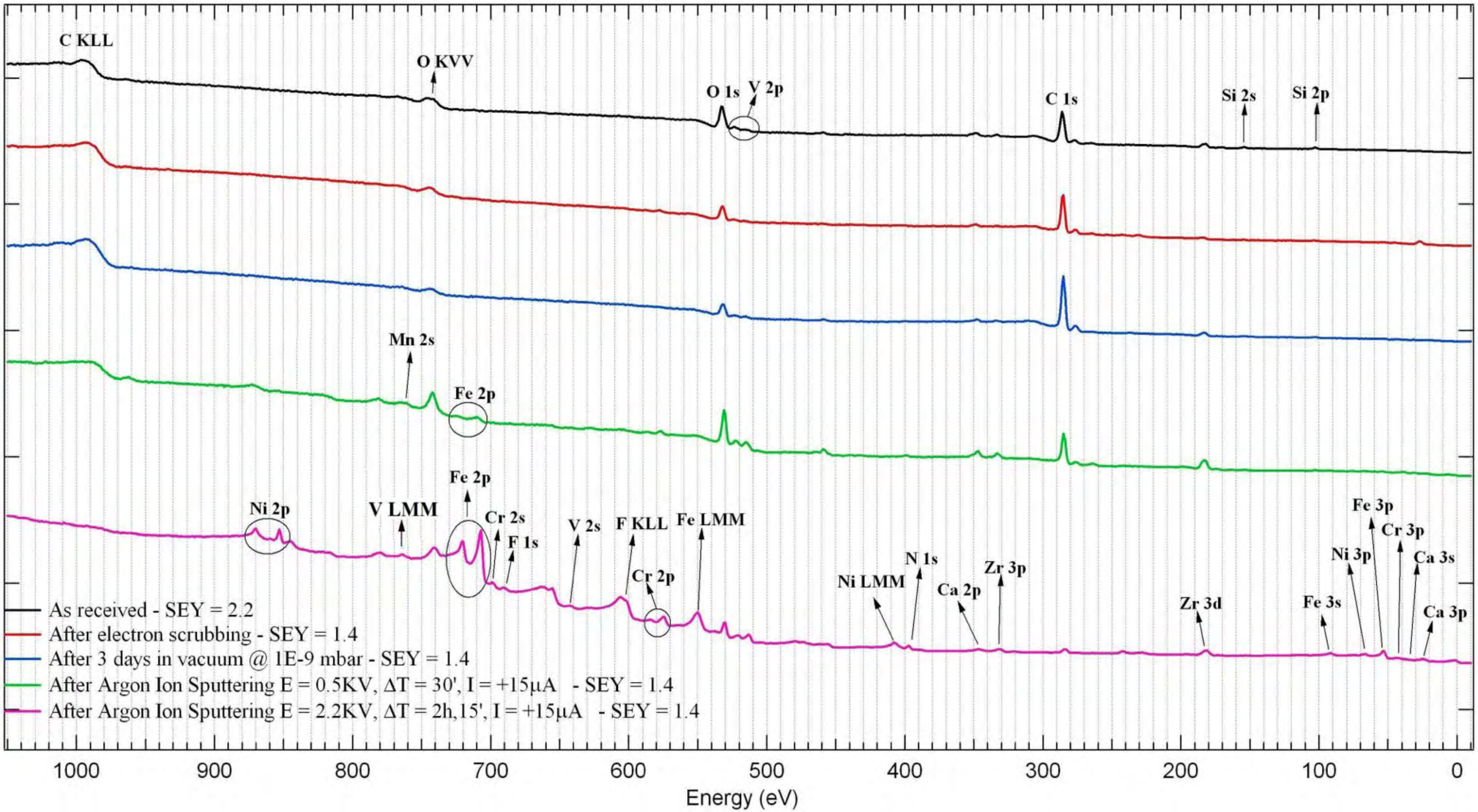
W. Fischer et al in preparation

XPS and SEY studies on SS from (WB) RICH :

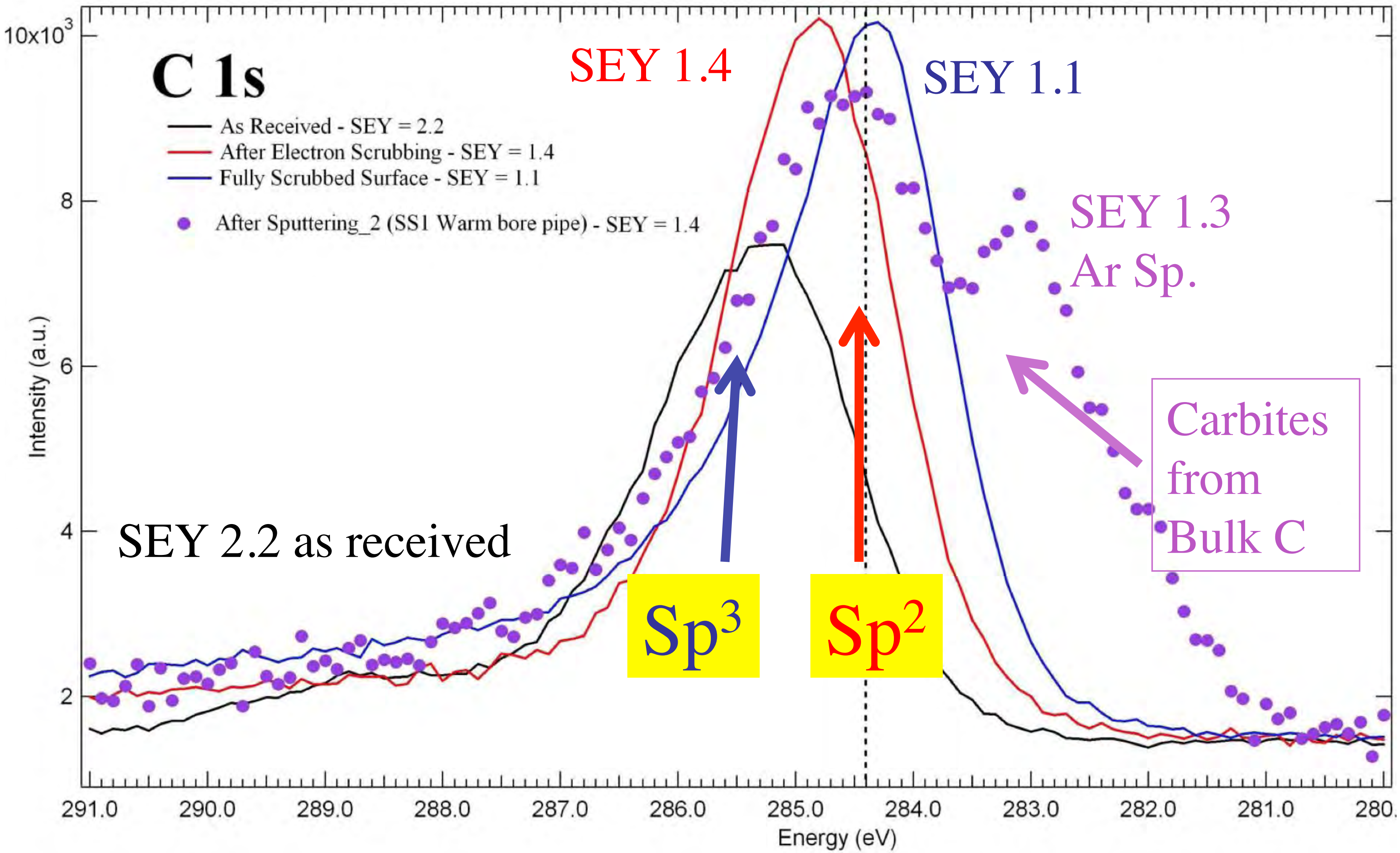


D. R. Grosso et al in preparation

XPS and SEY studies on SS from (WB) RICH :



XPS and SEY studies on SS from (CB) RICH :



TiN

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

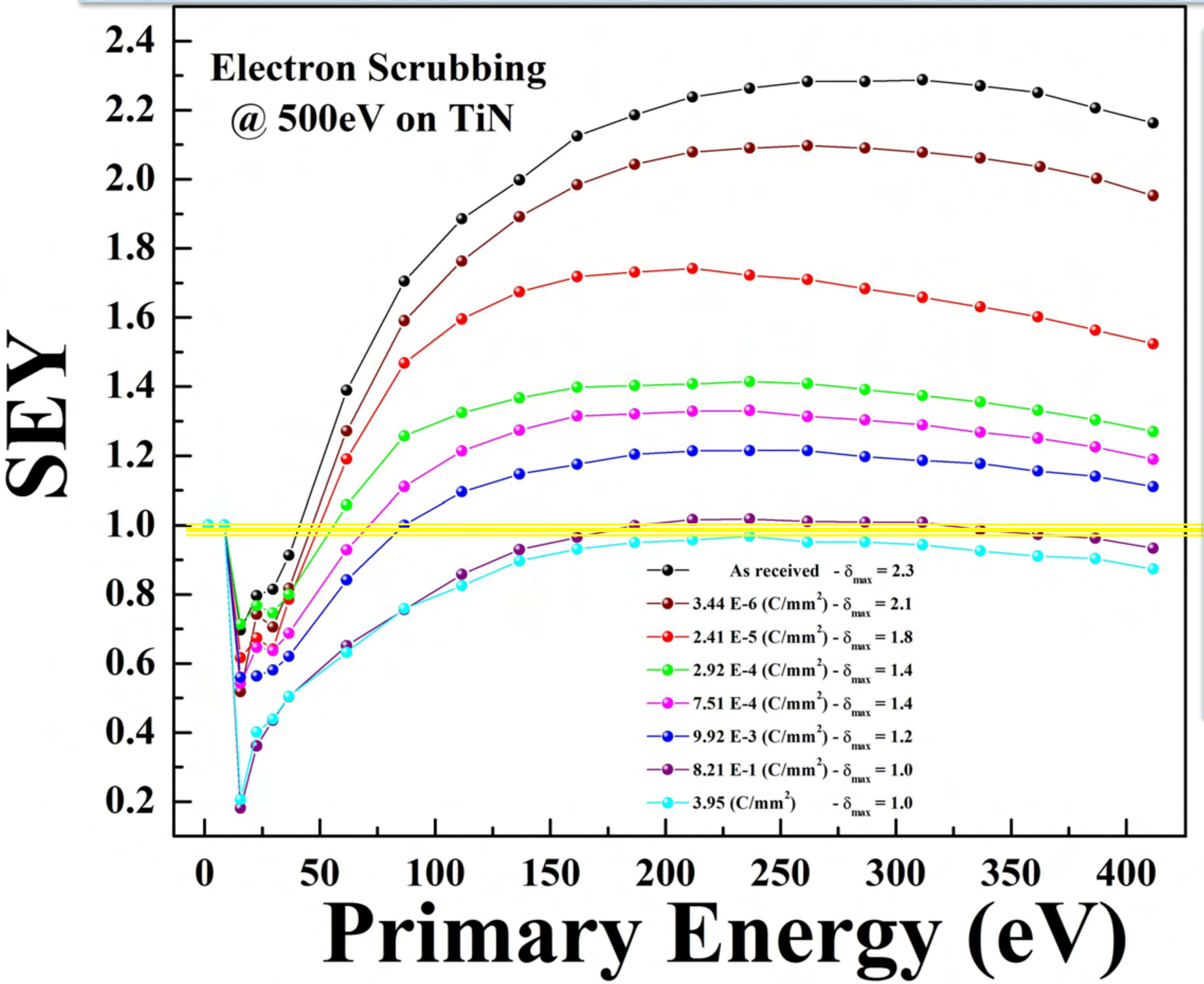
Of interest for SuperB

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

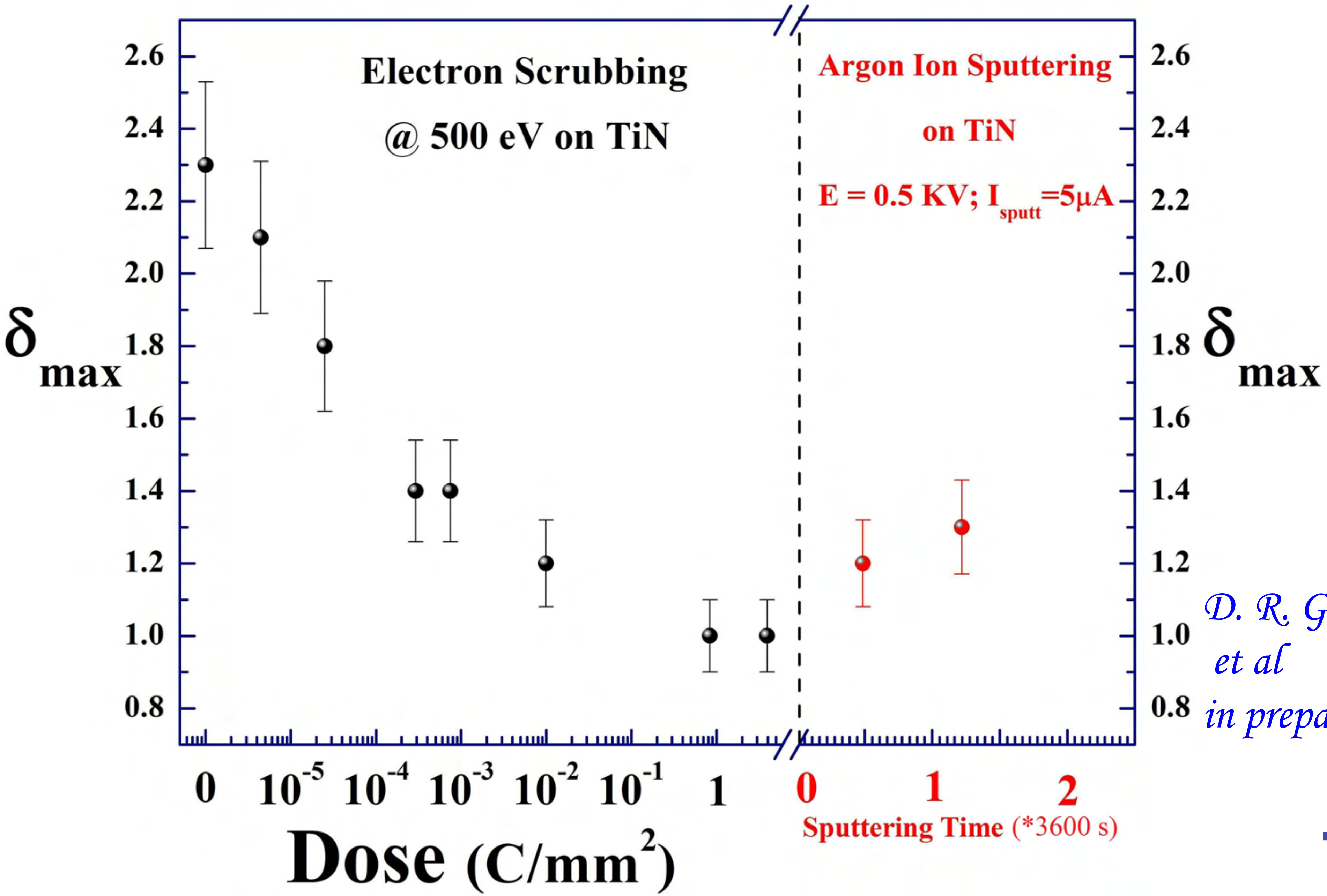
On such TiN we measured SEY vs. electron Dose and….



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

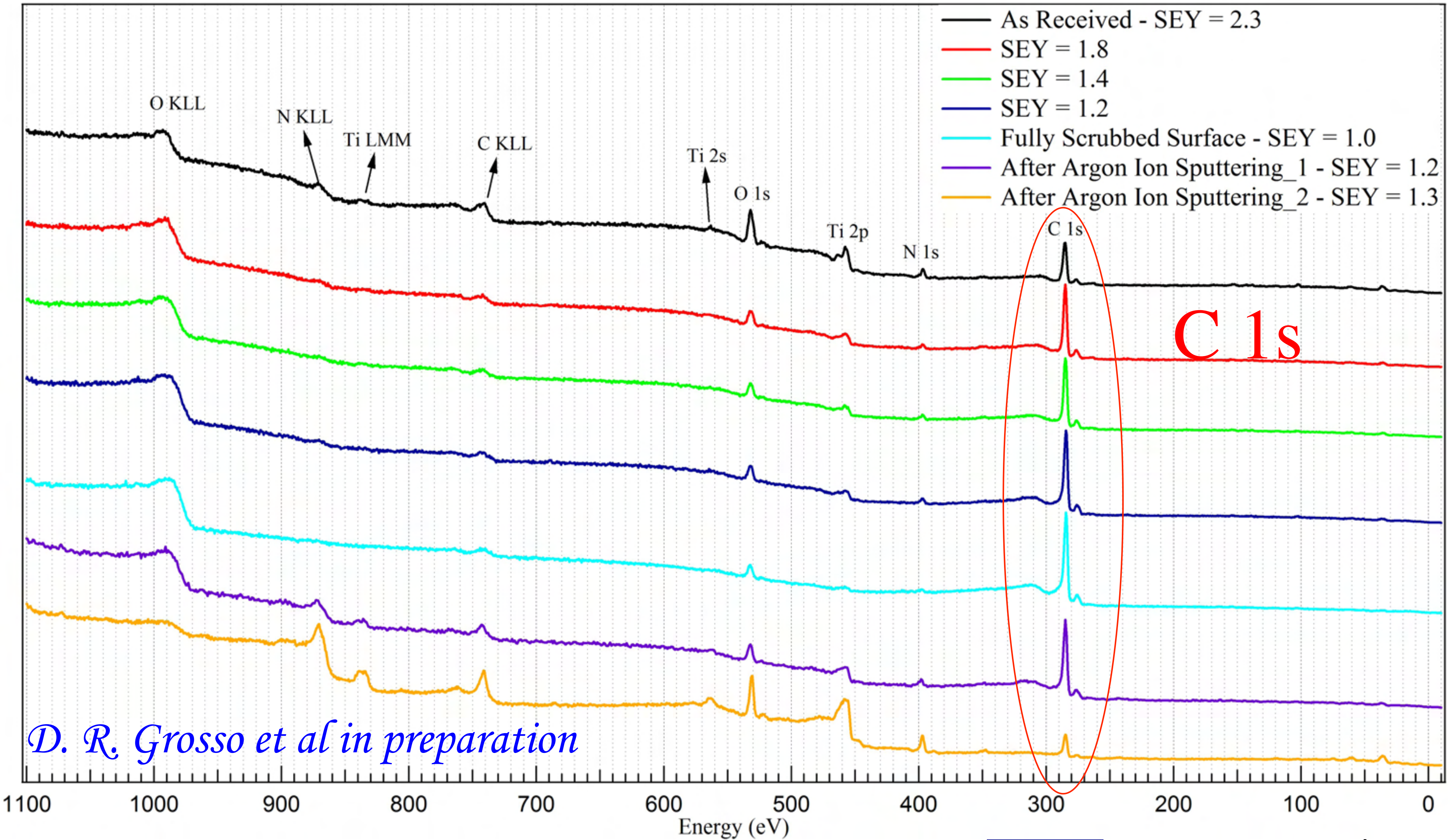
D. R. Grosso et al in preparation

We measured δ_{max} vs. e^- Dose and Ion sputtering and..



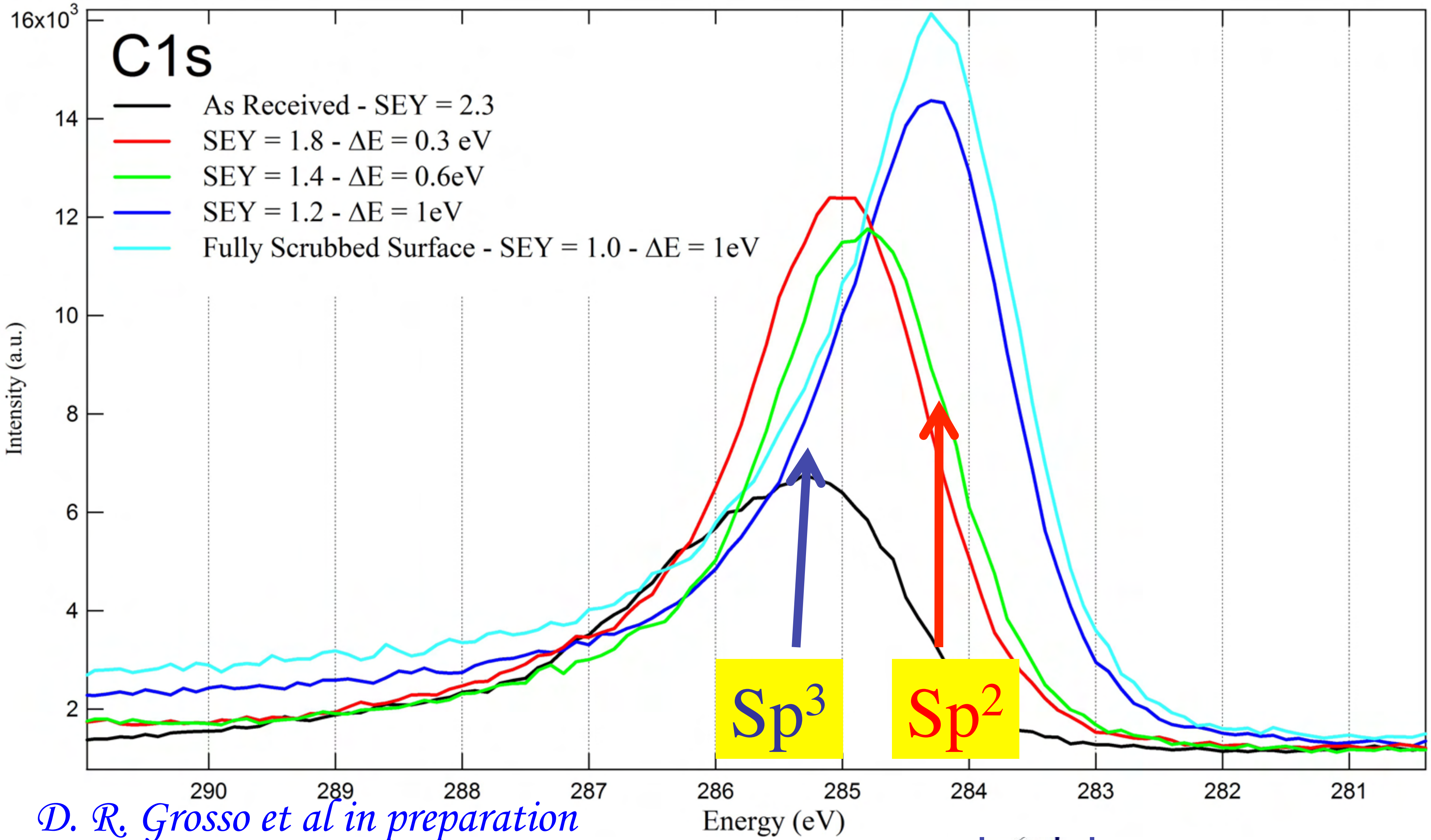
D. R. Grosso et al in preparation

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



D. R. Grosso et al in preparation

Also in TiN the SEY reduction is accompanied by C-sp² formation



D. R. Grosso et al in preparation

a little (but useful) detour on the scrubbing process

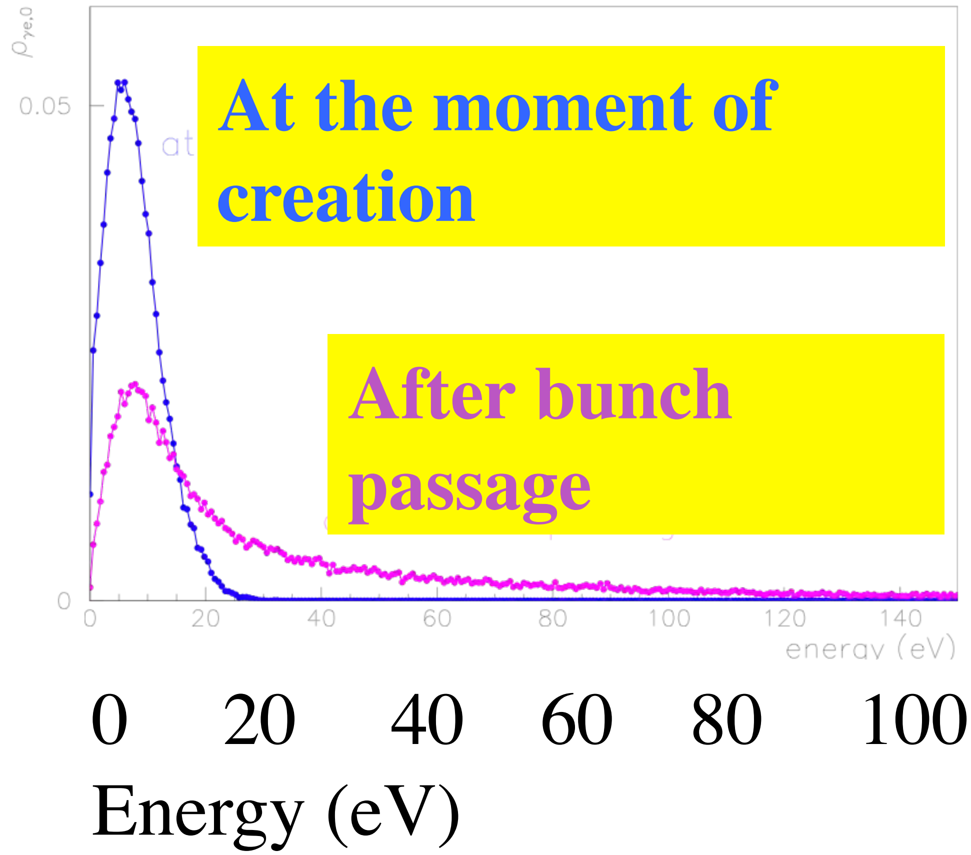
Most of the data on "scrubbing" have been obtained in laboratory experiments by bombarding surfaces with 500 eV electrons for increasing Time (i.e: dose)

Dose= N°e⁻ x t(s) xA (mm²)

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

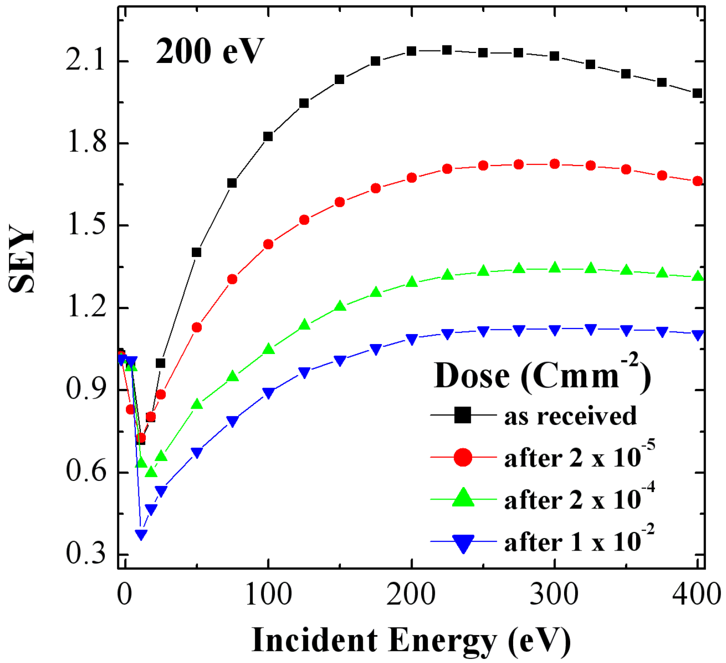
Simulation by F. Zimmermann (2001) shows that the main contribution lies at low energy!

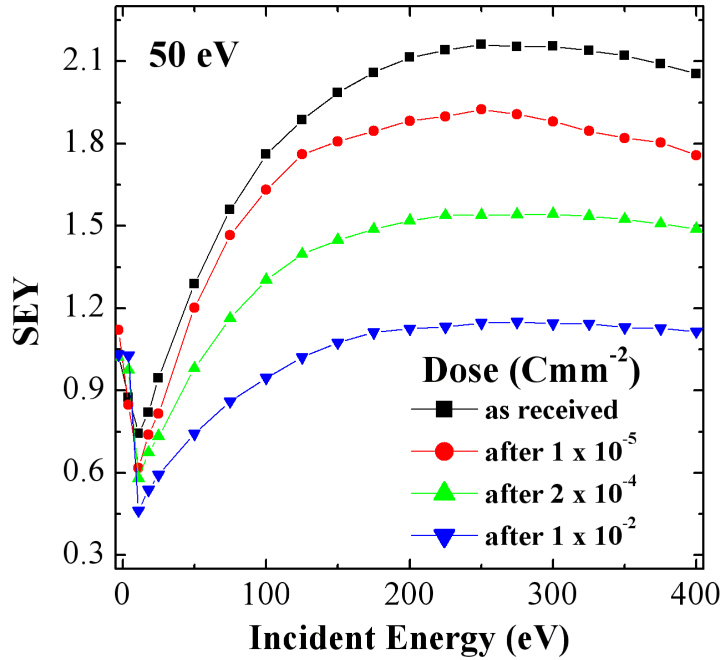
- *do 10 e⁻ @ 500 eV scrub as*
- *10 e⁻ @ 10 eV?*

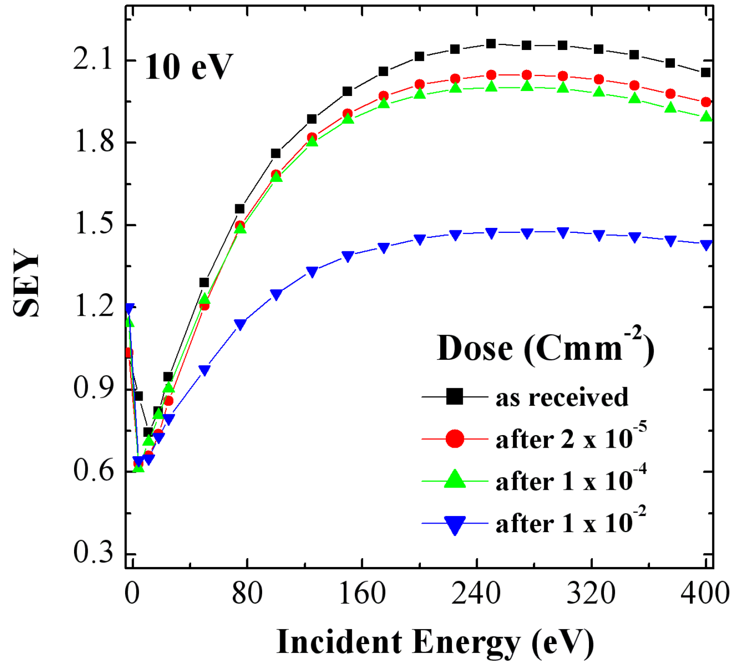


Scrubbing vs impinging electron energy

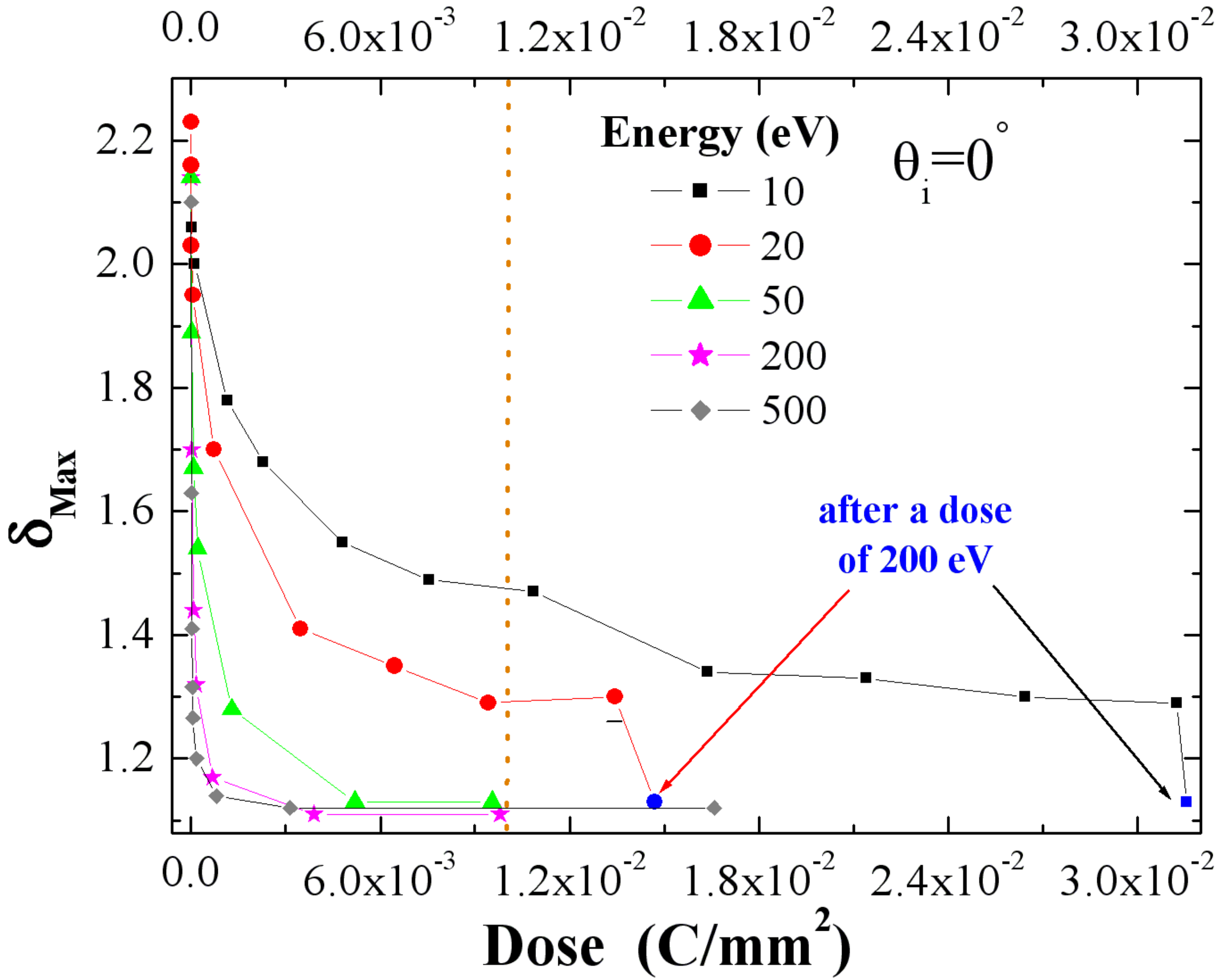
Comisso et al in preparation







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

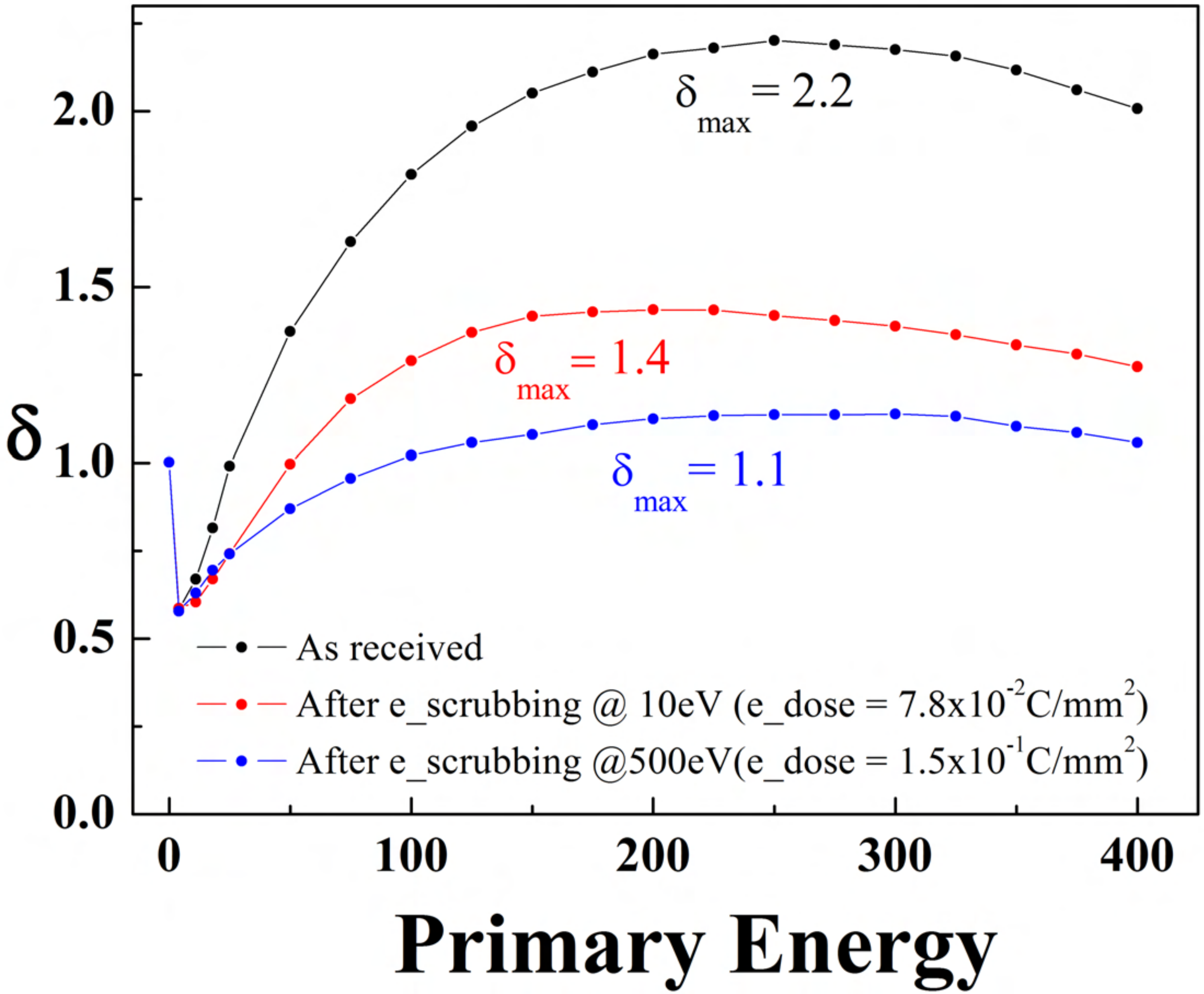


δ_{max} versus dose for different impinging electron energies at normal incidence.

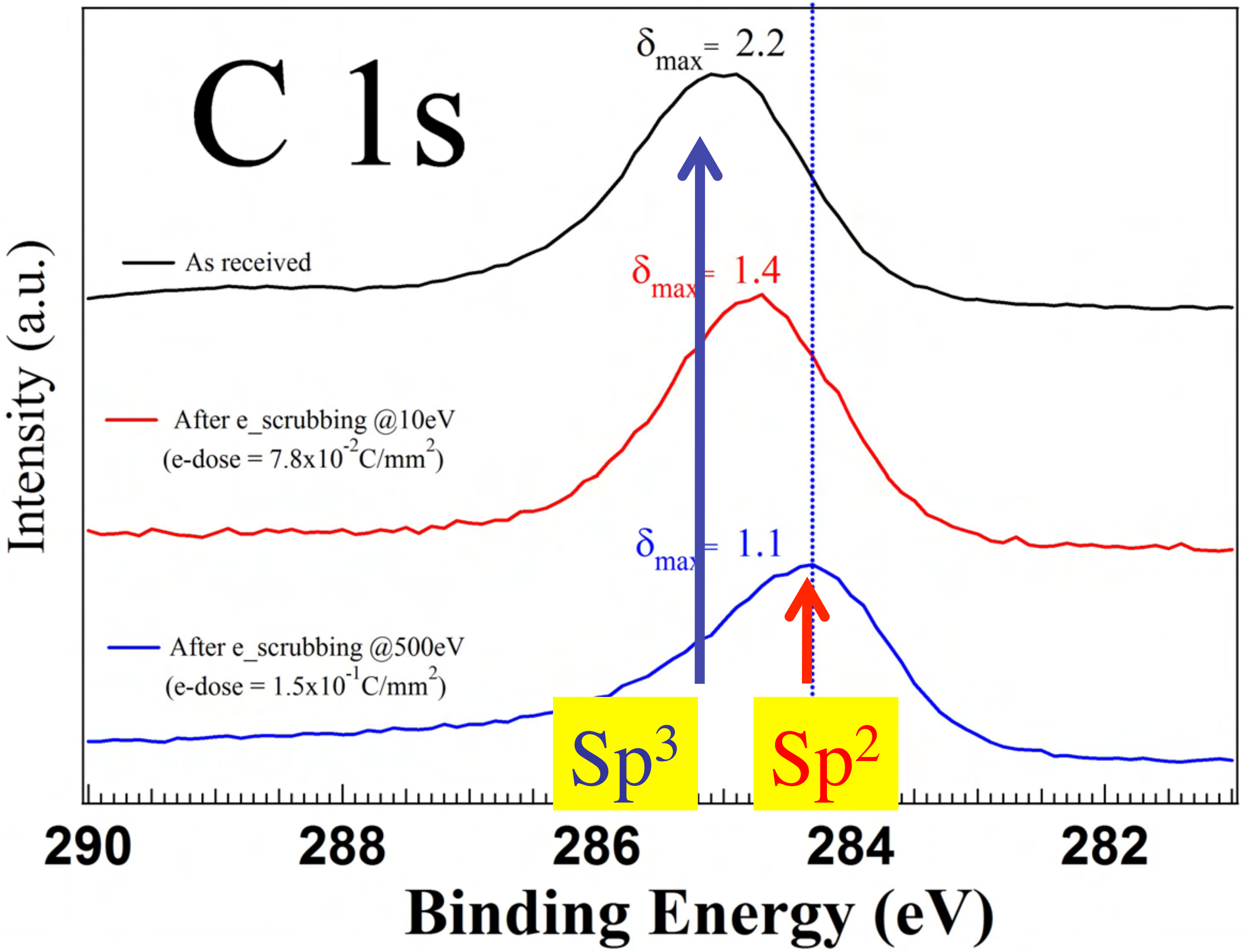
Commisso et al in preparation

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.

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



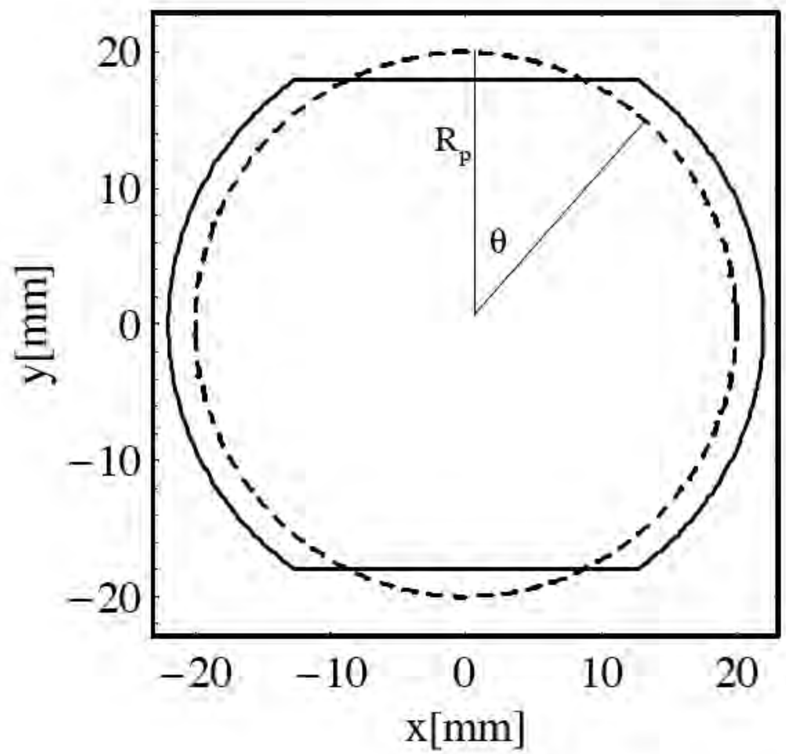
We repeated the experiment to confirm it and to do XPS.



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

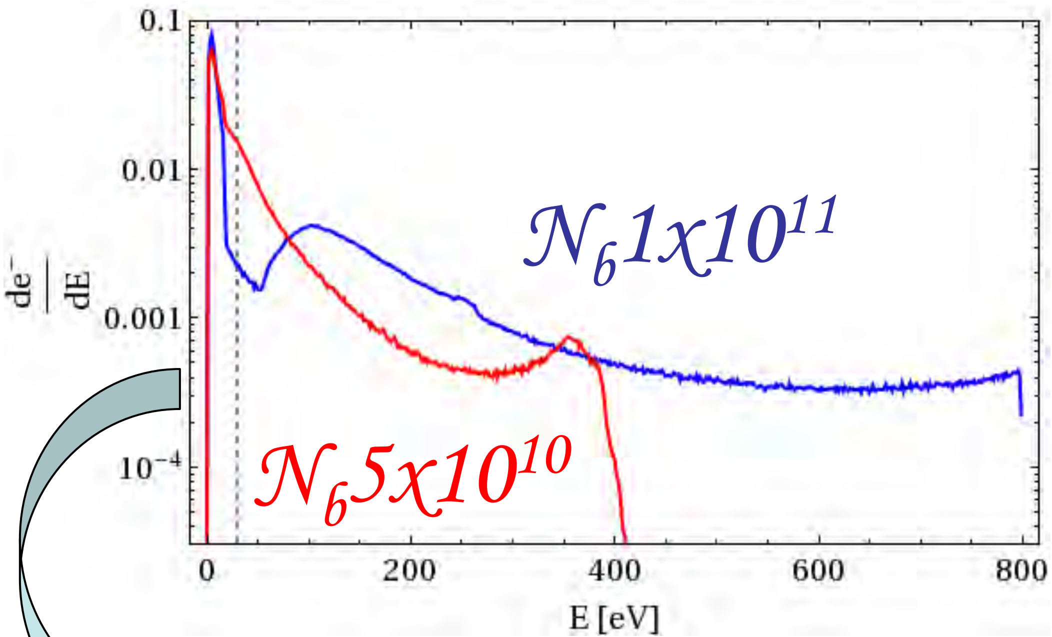
Table 1: Parameters used for ECLOUD simulations.

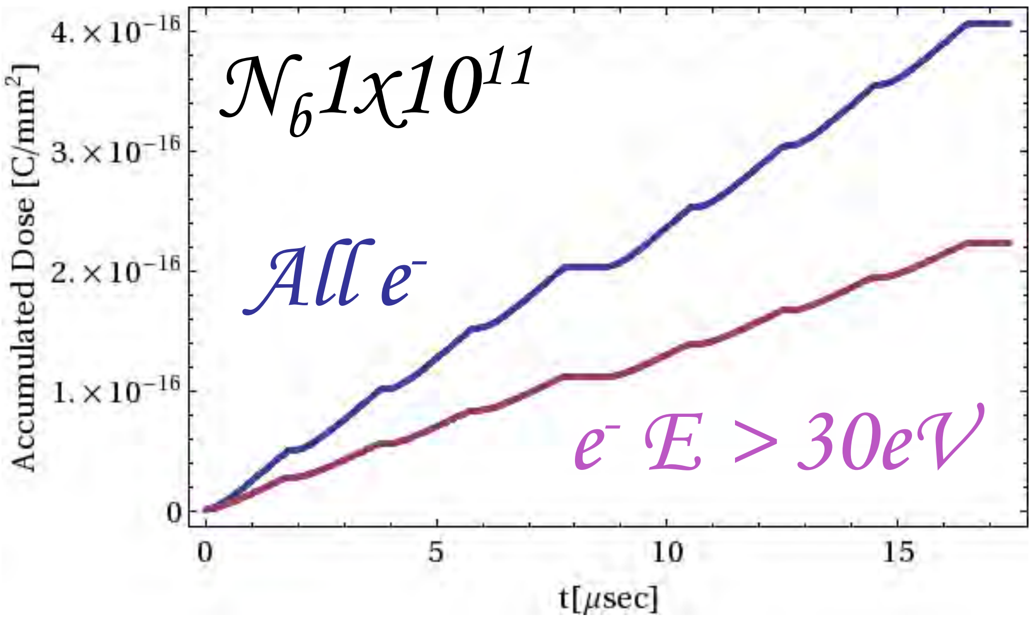
parameter	units	value
beam particle energy	GeV	7000
bunch spacing t_b	ns	25; 50; 75
bunch length	m	0.075
number of trains N_t	-	4
number of bunches per train N_b	-	72; 36; 24
bunch gap N_g	-	8
no. of particles per bunch	10^{10}	10; 3.0
length of chamber section	m	1
chamber radius	m	0.02
circumference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



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

@ 50ns, δ_{max}=1.4 equal e⁻ density

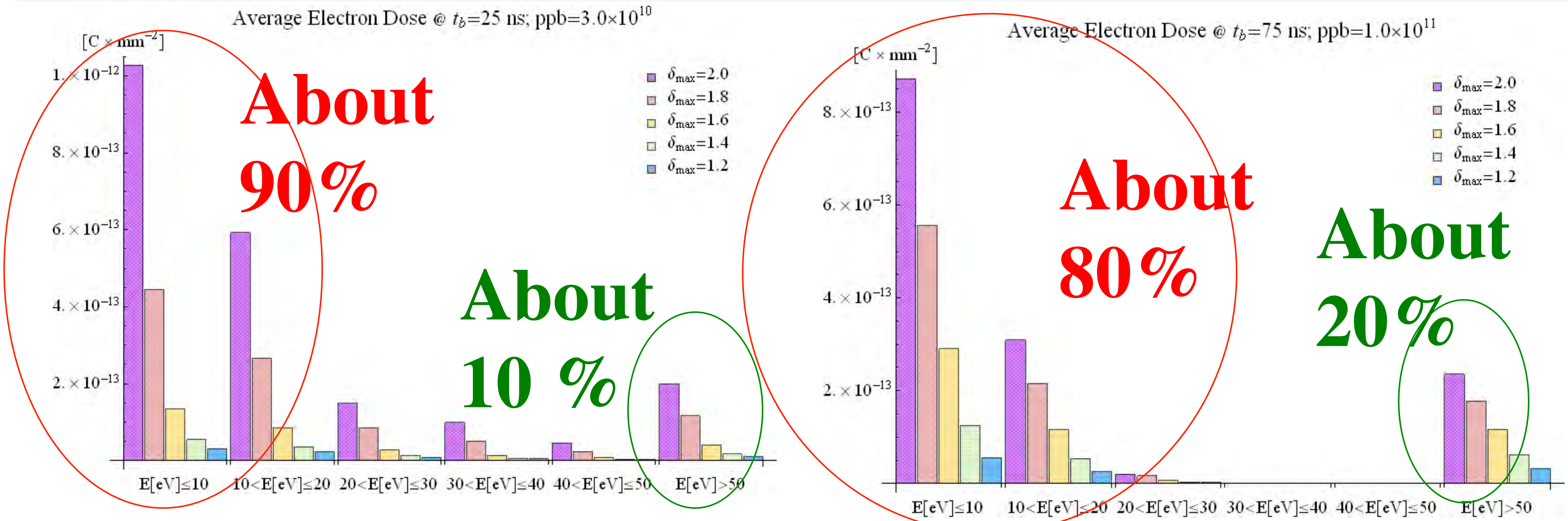




Log Scale!

T. Demma et al. in preparation.

- *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}

M.Commisso, R. Cimino, T. Demma, V. Baglin 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!!

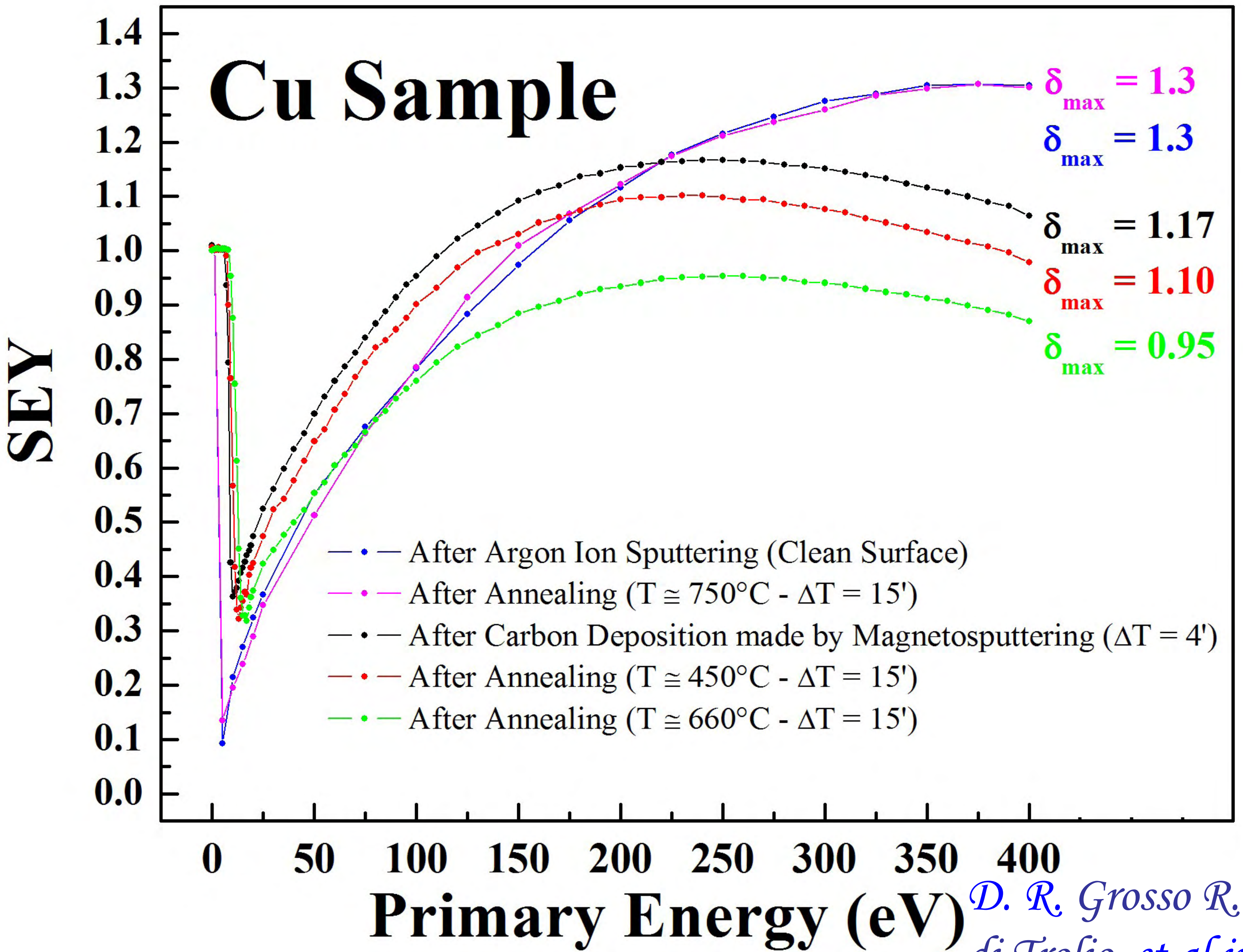
Graphitization is an essential (and quite general, but Al) ingredient in SEY reduction!

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

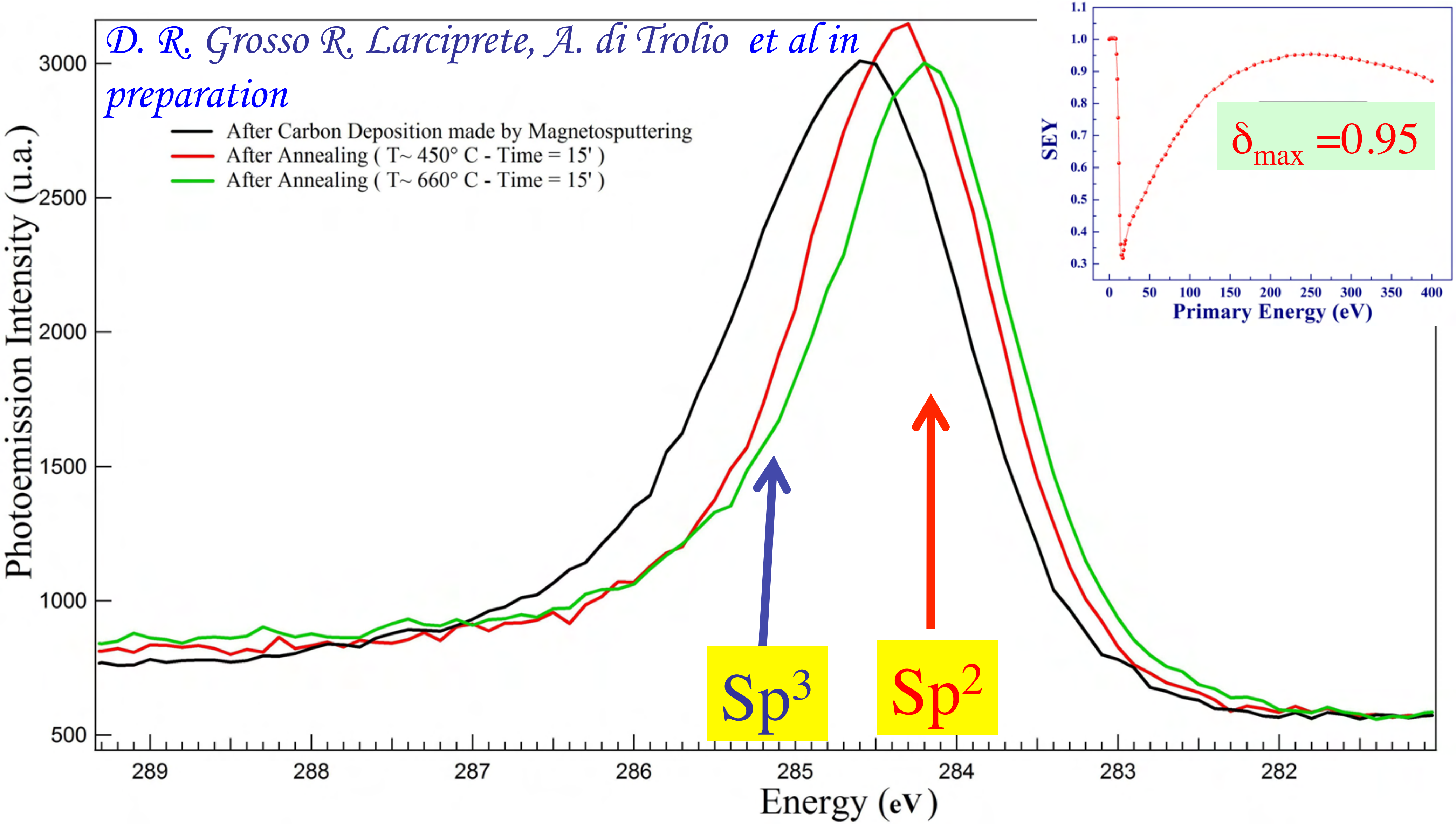
CERN uses magneto-sputtering technique to grow a thick (1-10 μm) of a-C film on accelerator wall surfices.

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 Graphite layer we grow the lowest the SEY…

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..
<u>We need to be able to produce these material in large scale for accelerators……. A lot of work!!!</u>

Acknowledgments:

in the lab:

Commisso and D. R. Grosso

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…..