Electron cloud mitigation via new materials and material coating.

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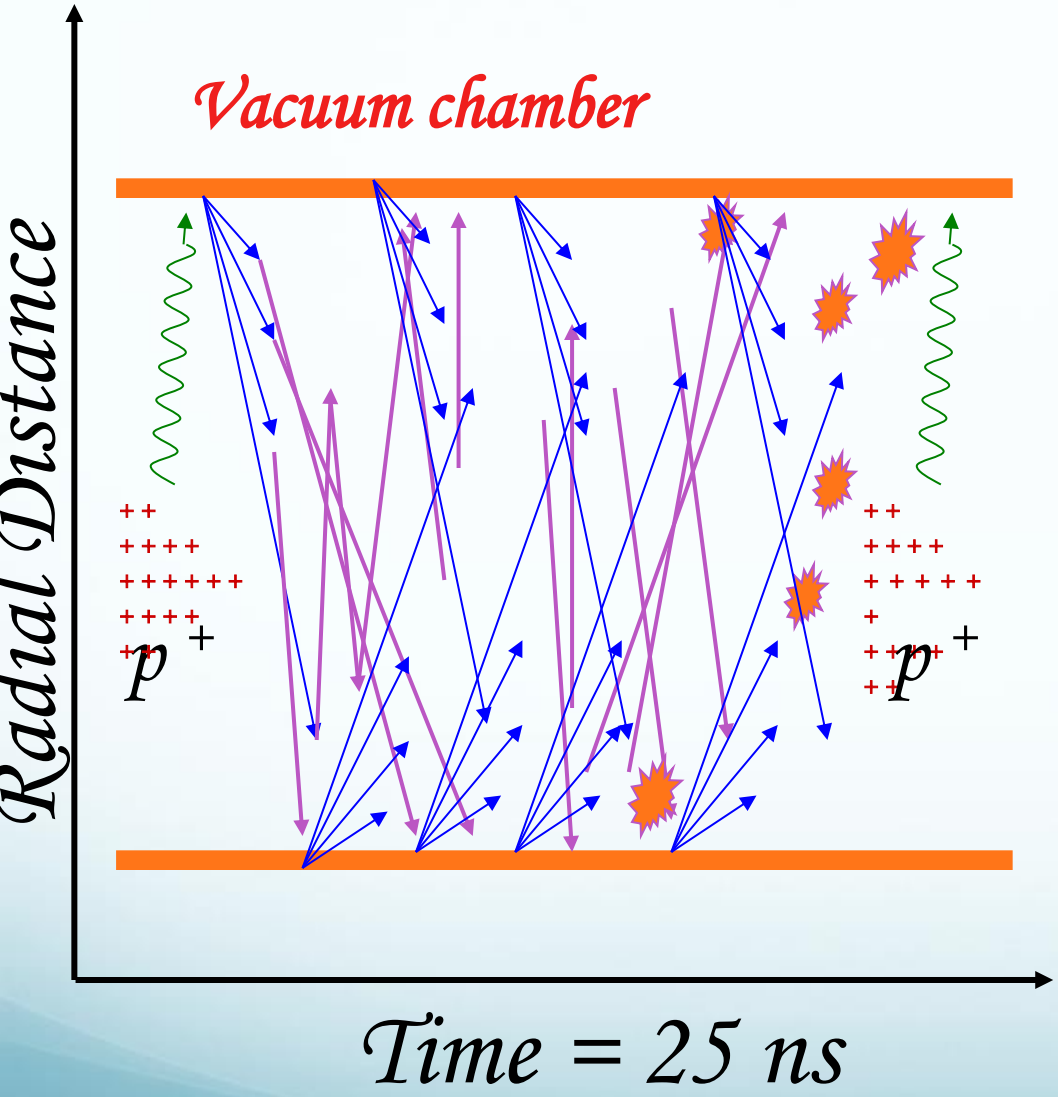
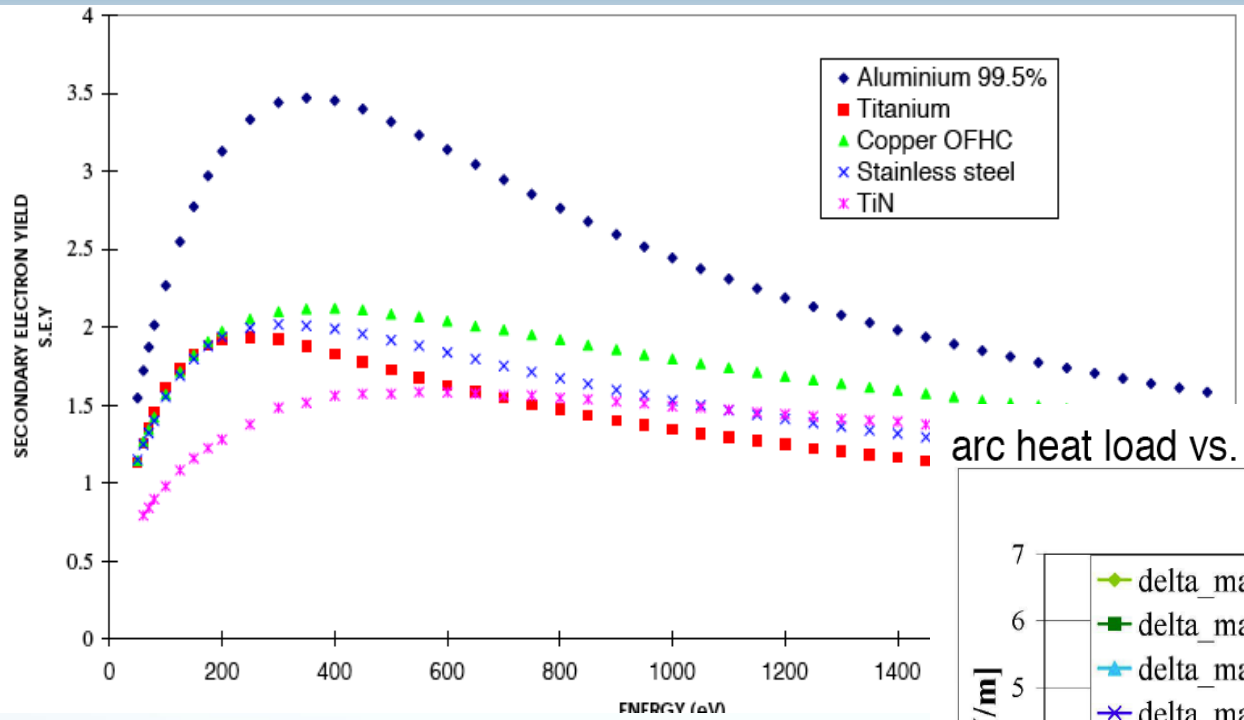
The "e-cloud" phenomenon (in pils)



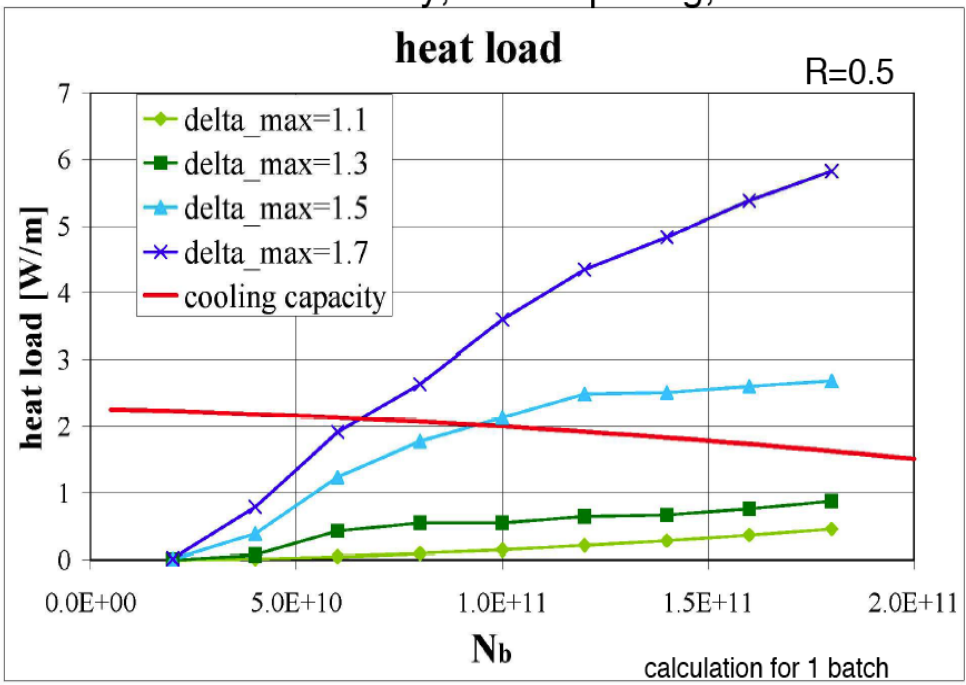
The accelerated particle beam produces SR and/or e^- that, by hitting the accelerator's walls generate photo-e^- or secondary-e^-.

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.

The Secondary e⁻ Yield depends on the surface type and condition:



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



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

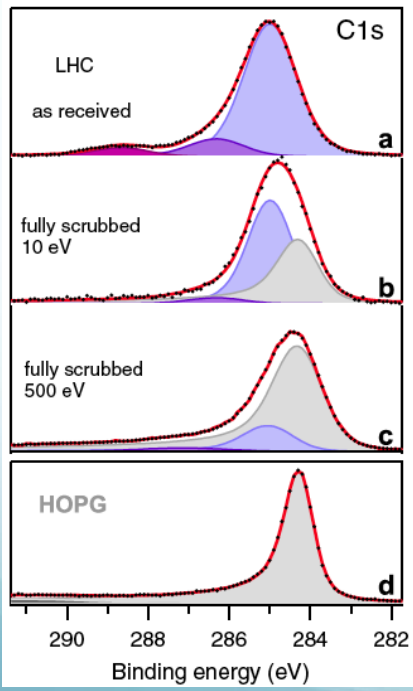
Frank Zimmermann, LTC 06.04.05

…. And has a tremendous impact to simulations (see calculation for LHC).

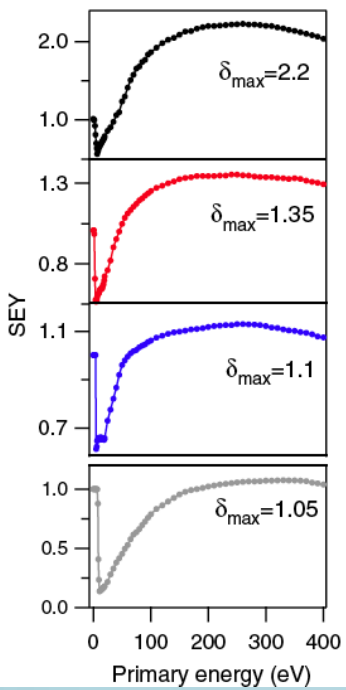
Towards mitigation Strategies….

- ✓ *We measure and feed material parameters (R, PY, and SEY) into simulations.*
- ✓ *Understand their profound nature to:*
- ✓ *Optimize chemical (mechanical) process to reduce their detrimental influence on beam.*
- ✓ *Search for new material / coatings with intrinsically "good" parameters.*

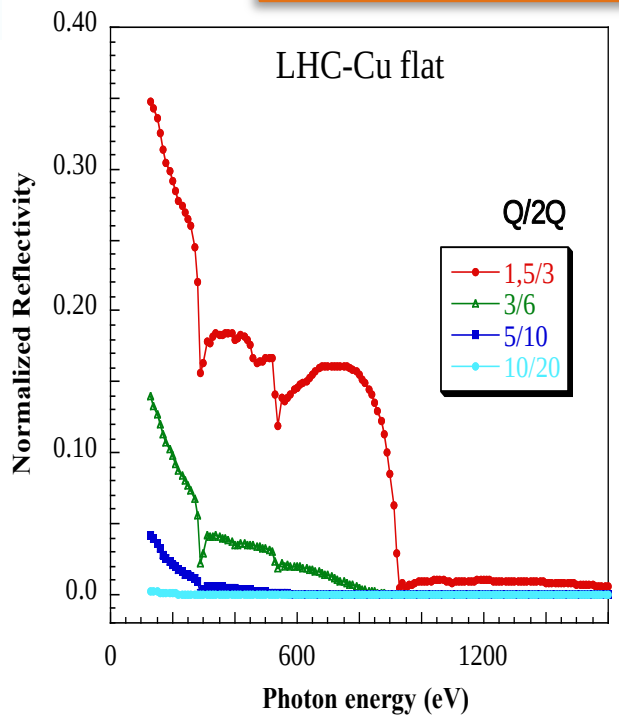
XPS

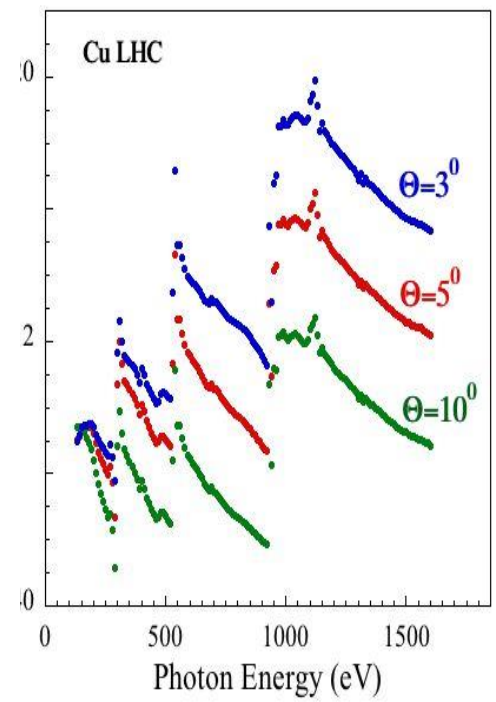


SEY



SR Reflectivity and PY (@BESSY-II)





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!

Mitigation Strategies

Surface Scrubbing (or conditioning)

Intrinsically low SEY material

Geometrical modifications

Electrodes in the lattice.

External solenoid field

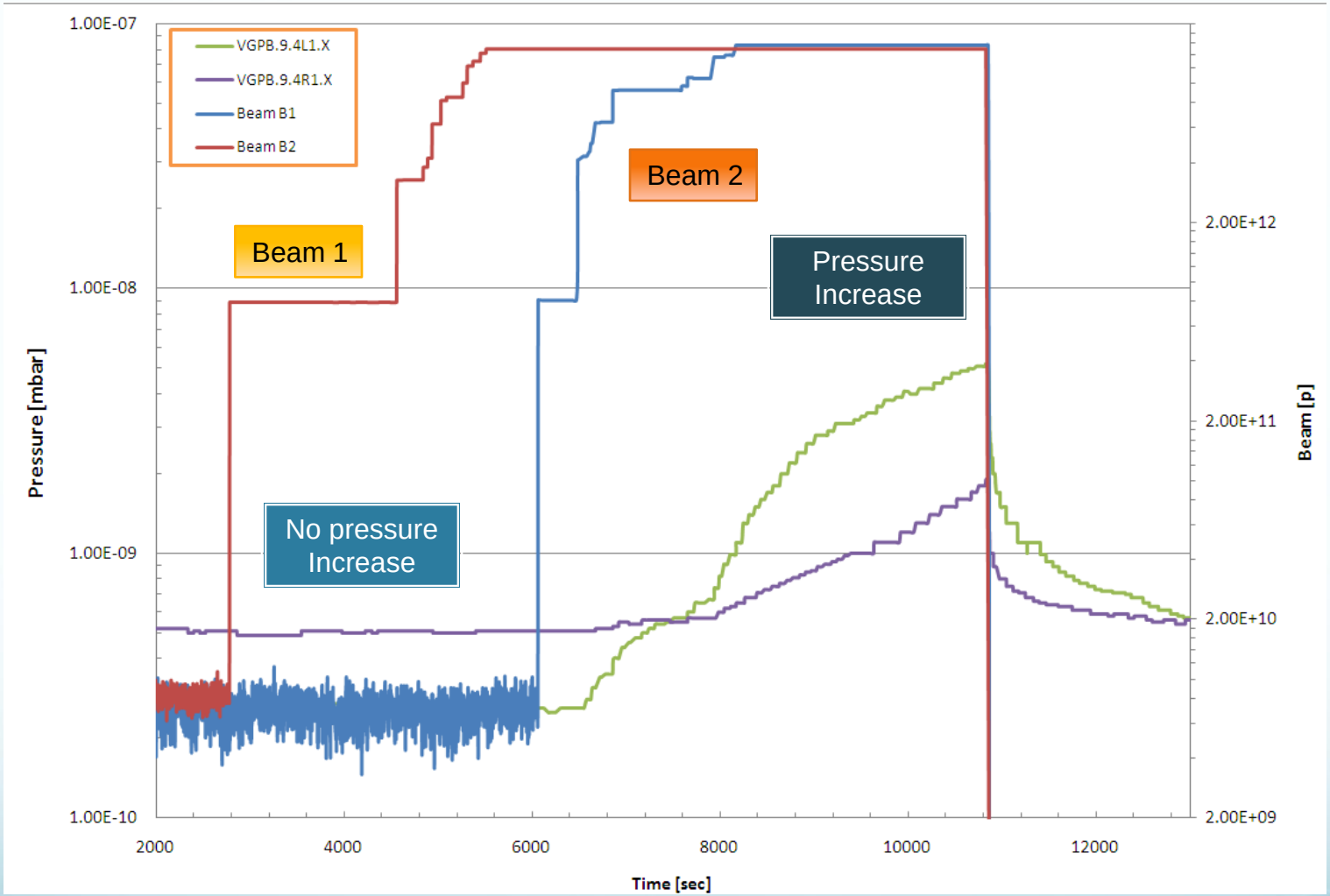
Surface Scrubbing (or conditioning)	➡	*-Efficiency (time & final SEY)…*
Geometrical modifications	➡	*Impedance. Space, Machining costs.*
Intrinsically low SEY material	➡	*Stability and material choice…*
Electrodes in the lattice.	➡	*If possible… (Impedance, costs.)*
External solenoid field.	➡	*Not always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

External solenoids: one example.

8-10-2010

450 GeV – 150 ns bunch spacing: Merged vacuum @ LHC

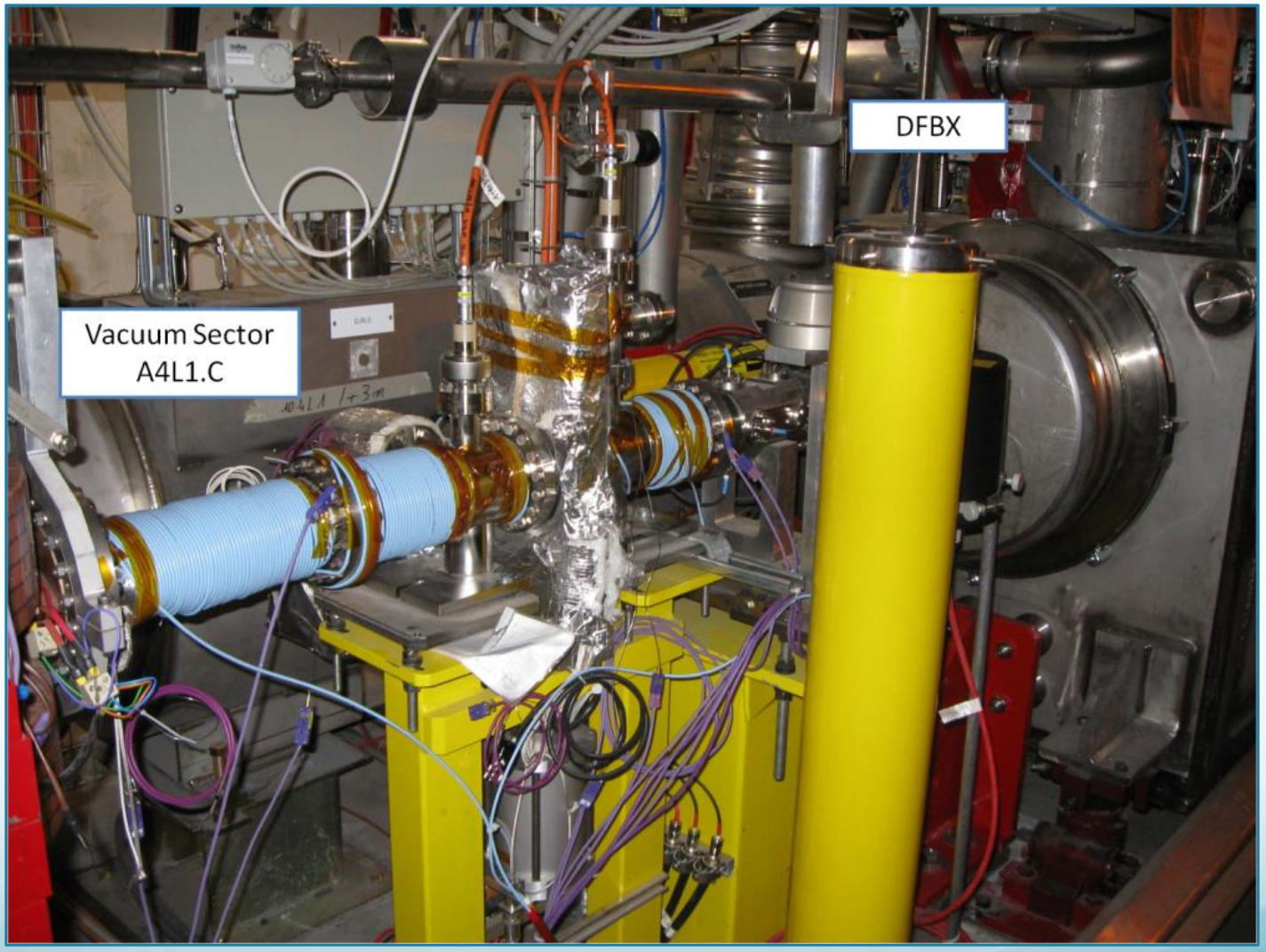
Exotic Vacuum behavior @ LHC:



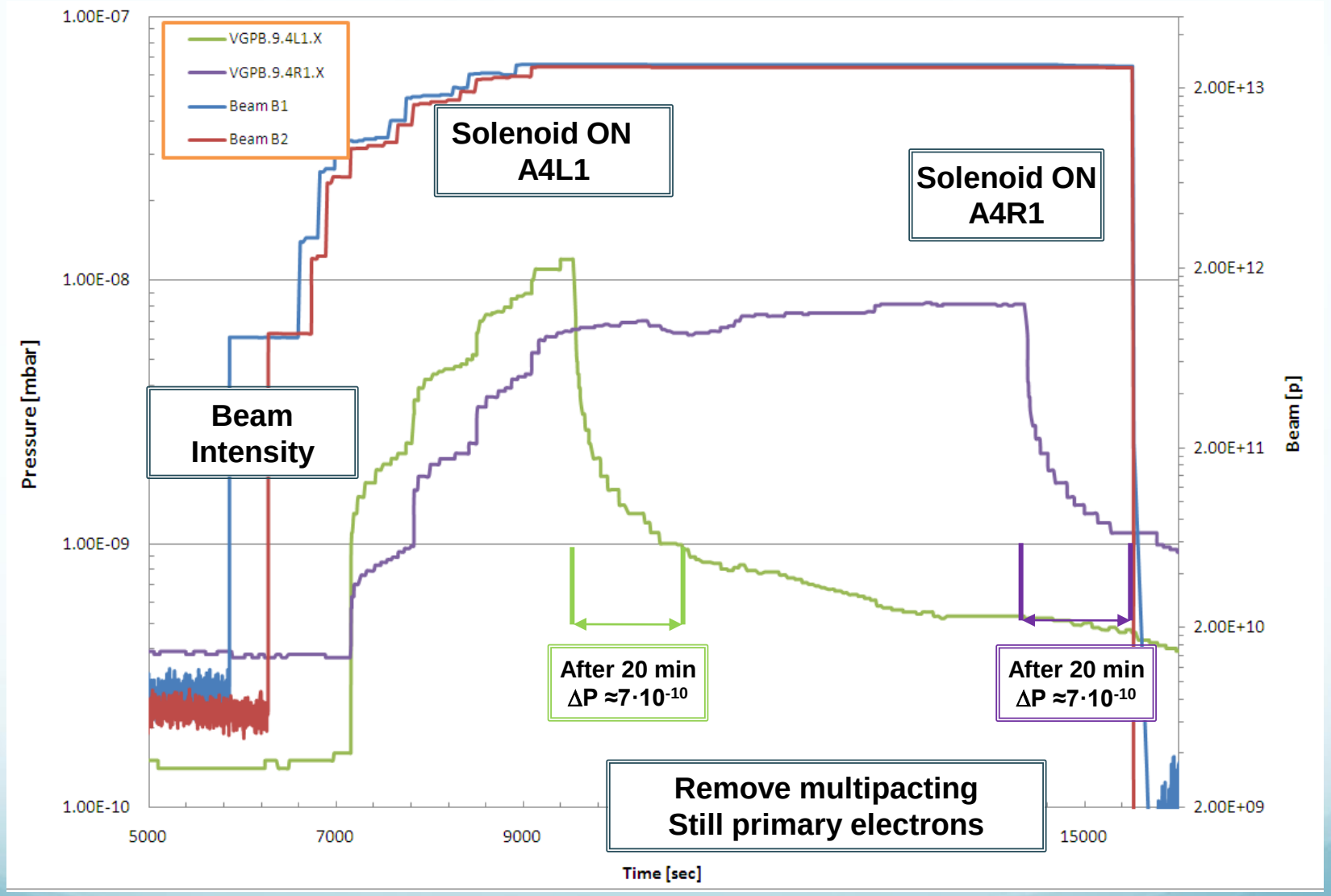
450 GeV – 150 ns bunch spacing: Merged vacuum

8-10-2010

Easily solved: Installation of Solenoids

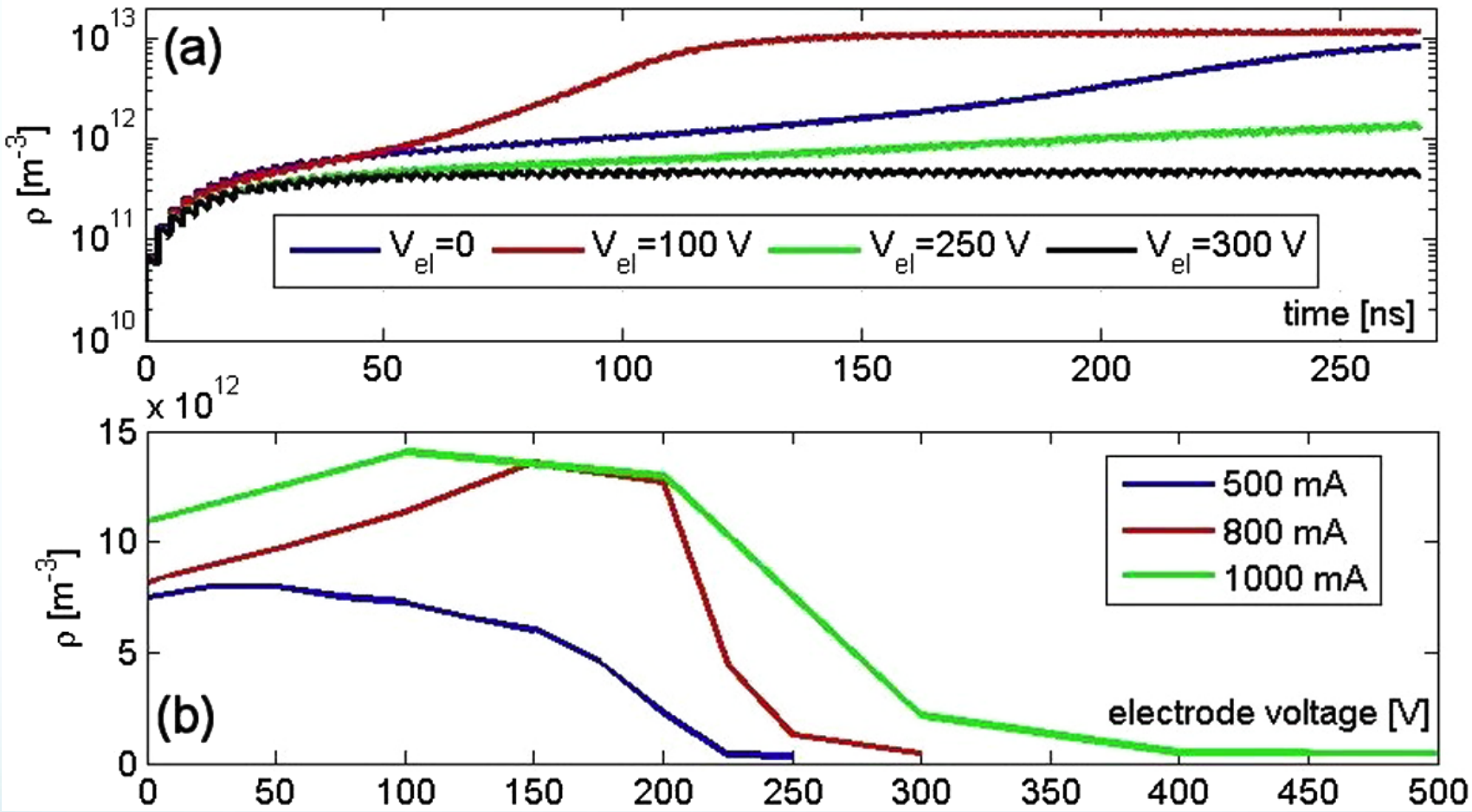


Solenoids effect on pressure



Electrodes at DAΦNE

Electrodes at DAΦNE

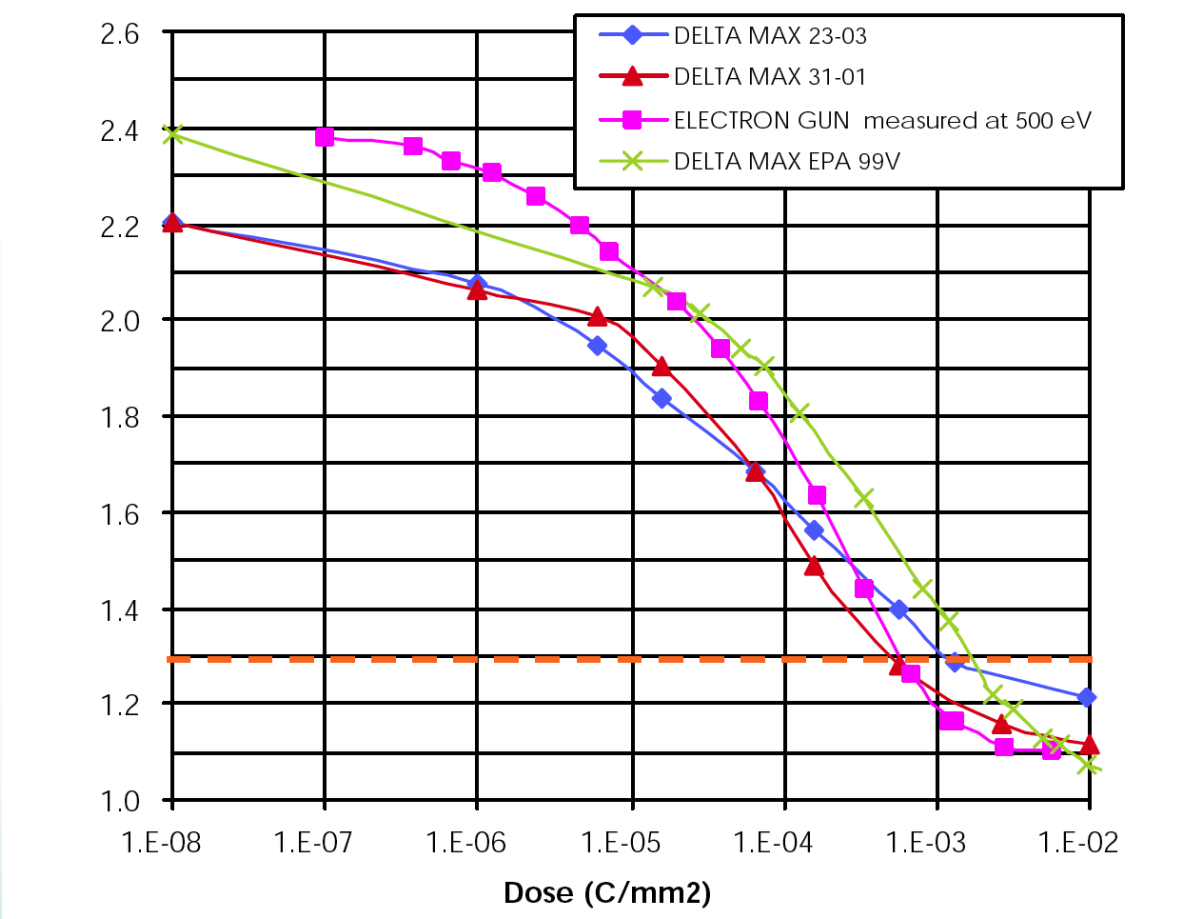


(a) Evolution of the averaged cloud density for different values of the electrode voltage. (b) e− cloud density at the end of the bunch train.

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

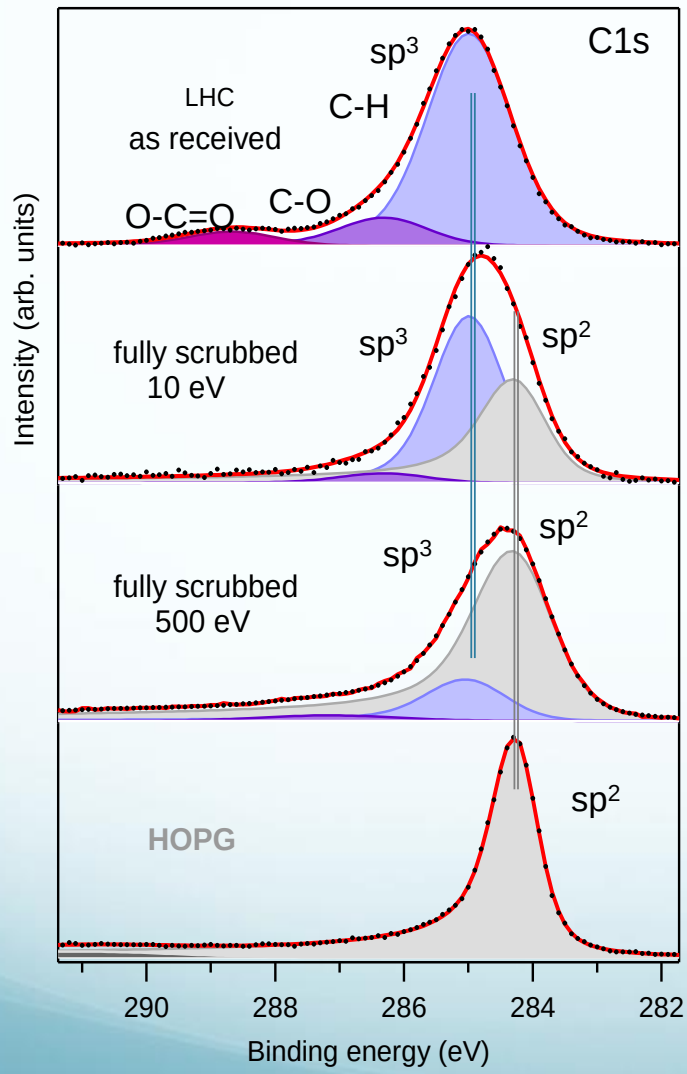
from LHC PR 472 (Aug. 2001):

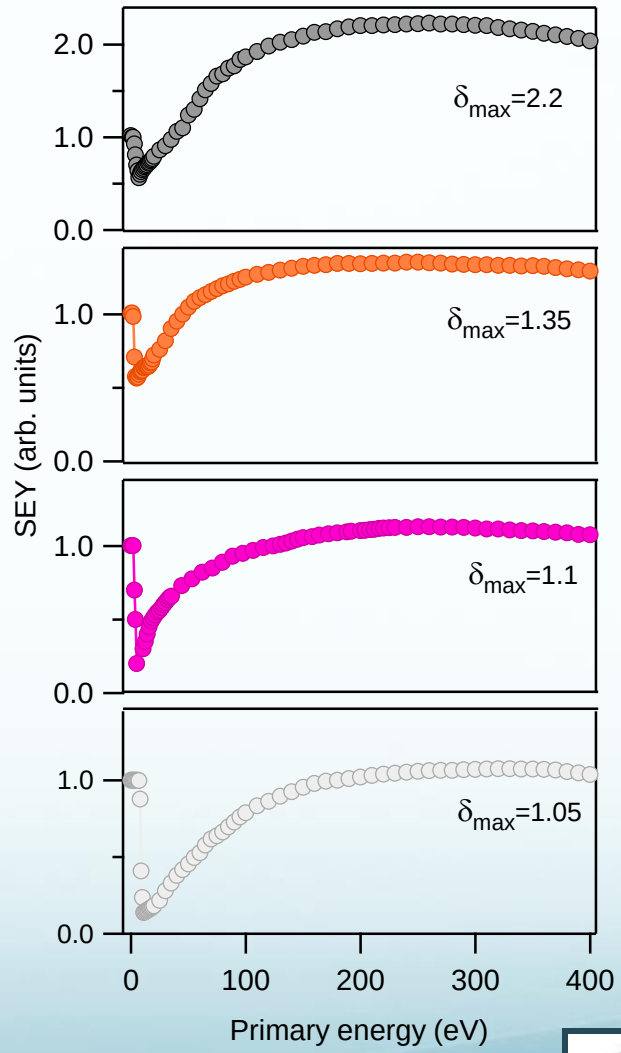
"…Although the phenomenon of conditioning has been obtained reproducibly on many samples, the exact mechanism leading to this effect is not properly understood. This is of course not a comfortable situation as the LHC operation at nominal intensities relies on this effect…"



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

co-laminated Cu for LHC beam screen

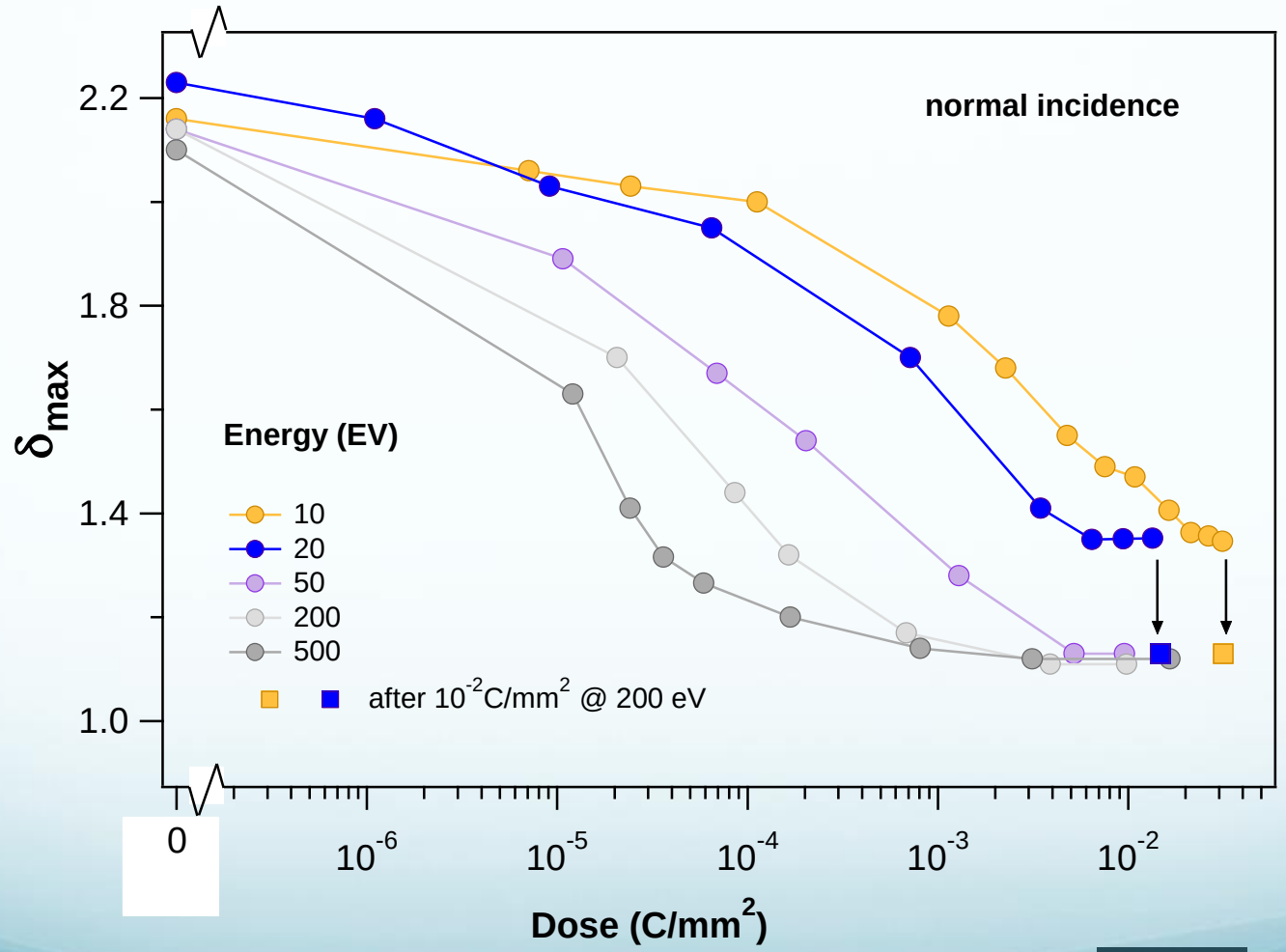




R. Cimino et al. PRL
109 064801 (2012)

co-laminated Cu for LHC beam screen

R. Cimino et al. PRL ***109 064801 (2012)***



Theo Demma (LAL) simulation :

R. Cimino et al. PRL ***109 064801 (2012)***

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	-	$7.98 \cdot 10^{-4}$
maximum SEY δ_{max}	-	1.2(0.2)2.0
energy for max. SEY E_{max}	eV	237

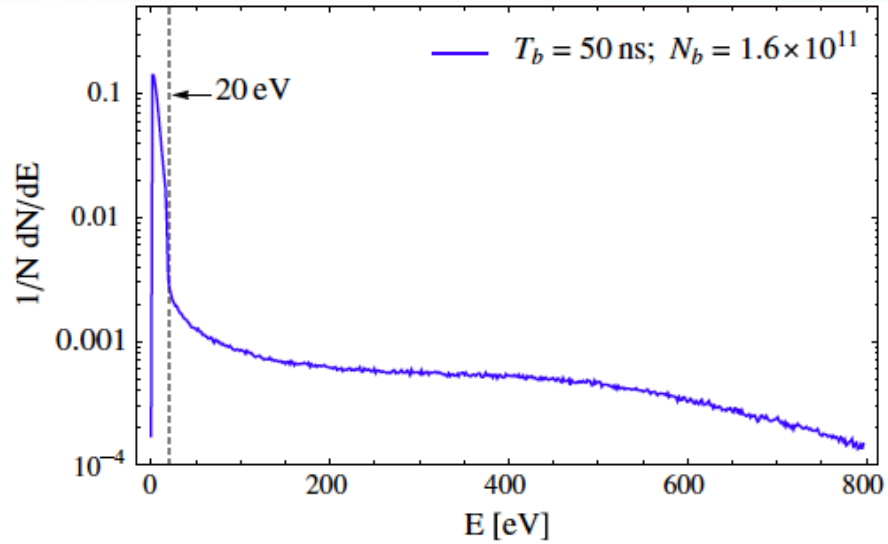
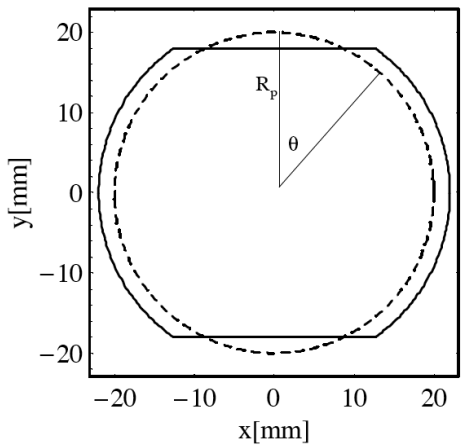
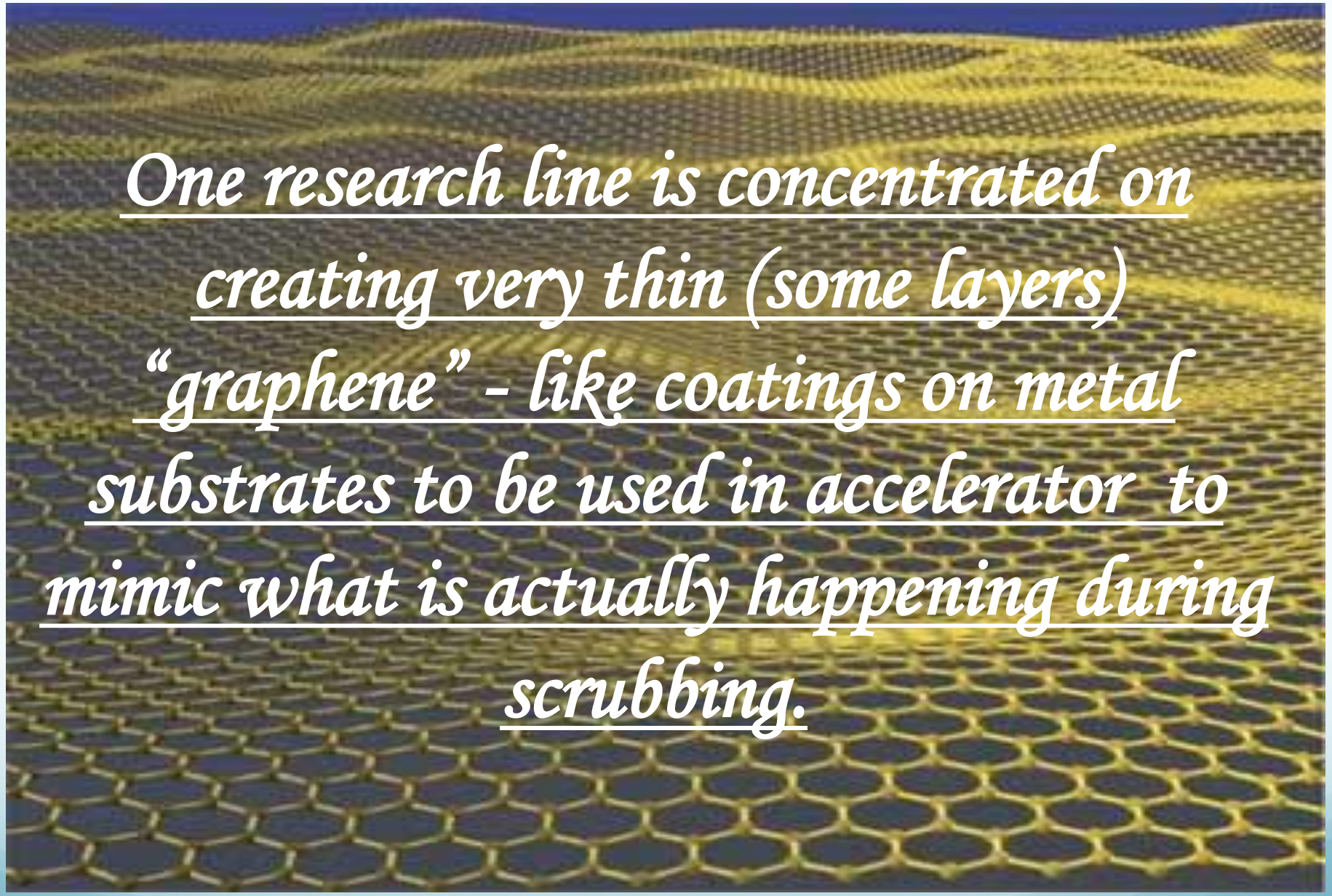


FIG. 3 (color online). Calculated electron energy distribution at the LHC accelerator wall. The number of electrons below and above 20 eV (dotted line) is nearly equal.



- ***optimize the "scrubbing" process @ LHC with beam parameters enhancing the presence, in the cloud, of higher energy el.***
- ***Give a more reliable estimate of the needed scrubbing time.***



One research line 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.

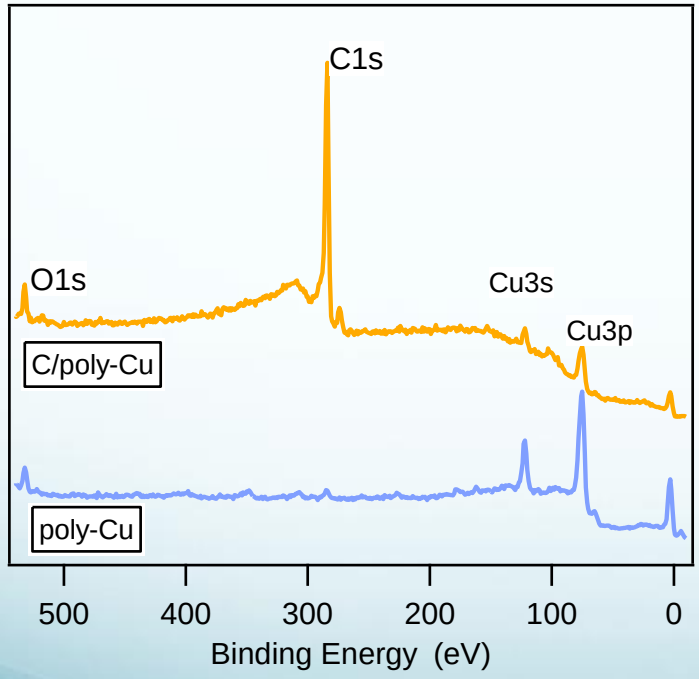
C films on polycristalline Cu

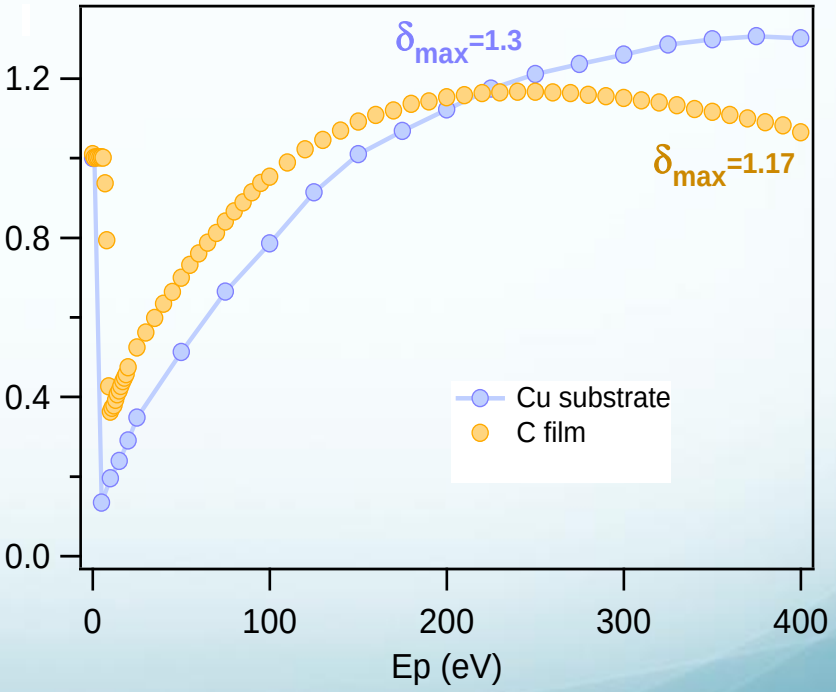
a-C films

magnetron sputtering @ RT

p(Ar)= 10^{-2} mbar Δt = 2min

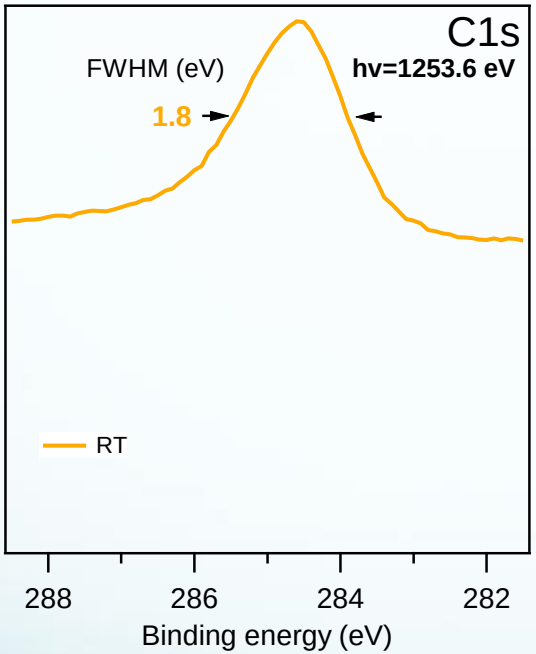
C film thickness 2-3 nm

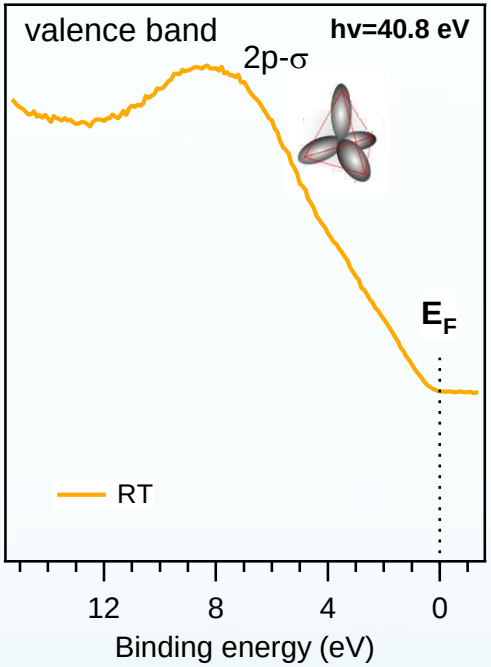


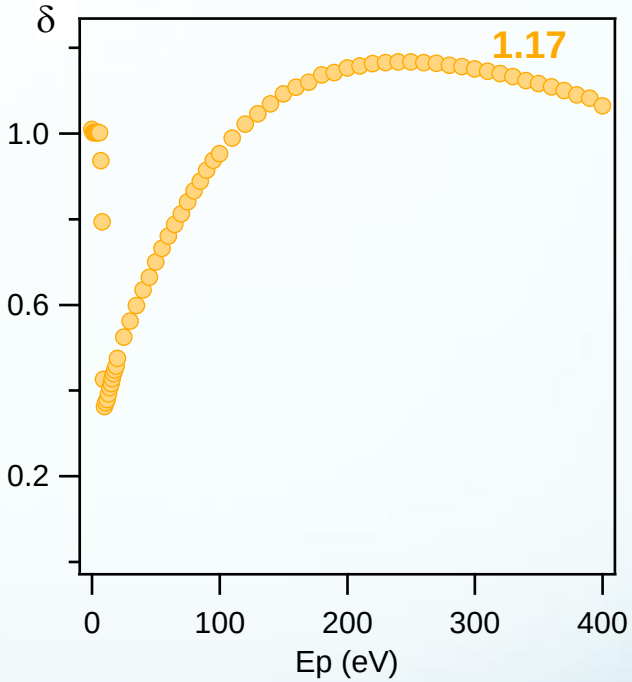


R. Larciprete, A. di Trolio and R. Cimino: in preparation

C films on polycristalline Cu







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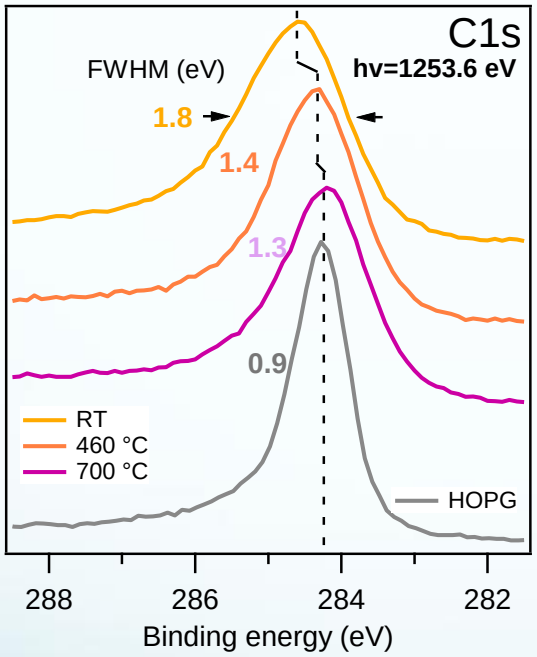
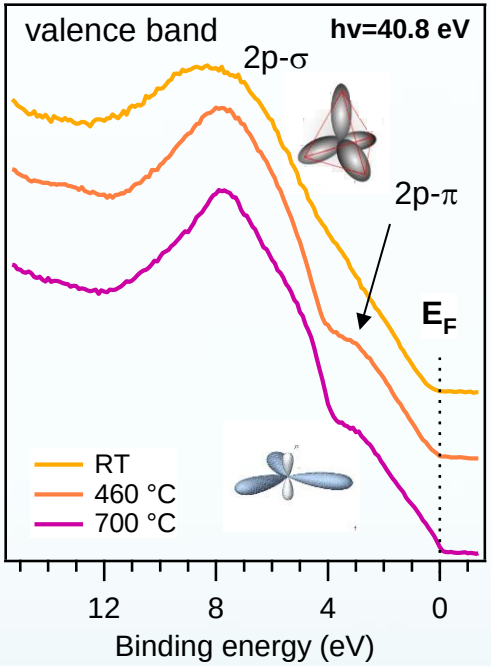
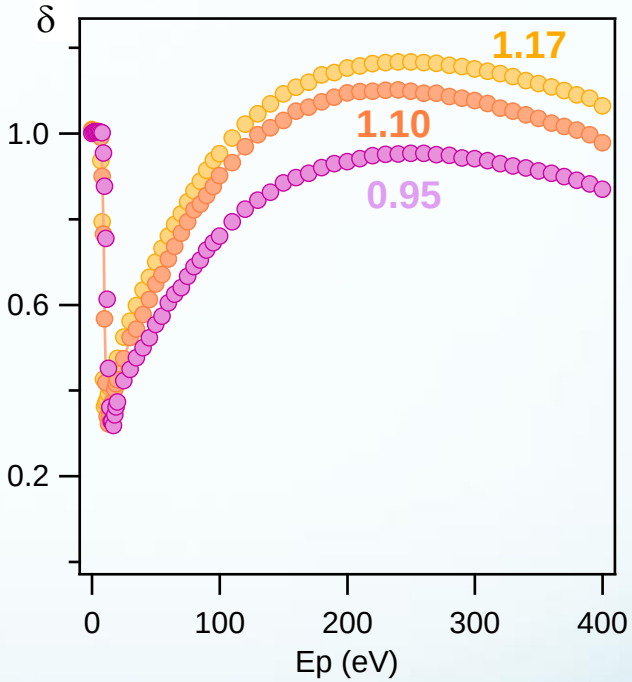
C films on polycristalline Cu







the graphitization of the C films corresponds to a lower SEY

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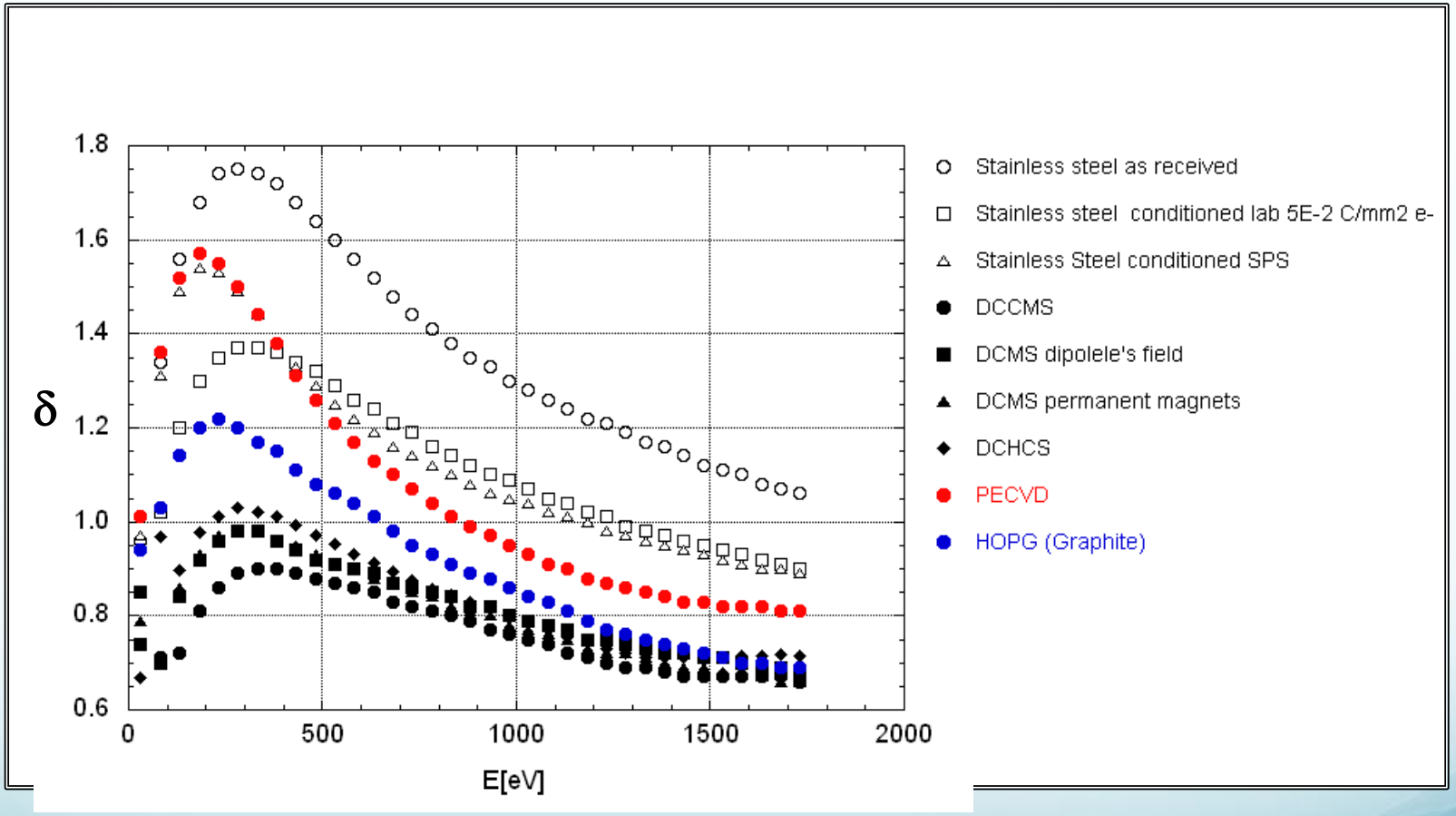
CERN Strategy (thanks to P. Costa Pinto)

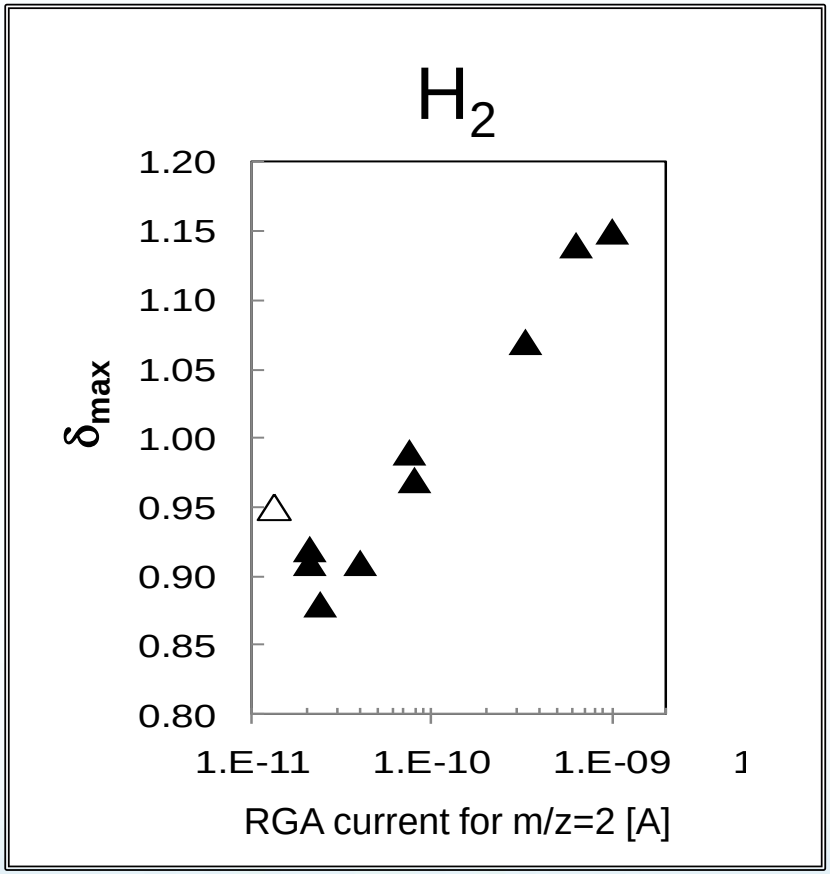
SEY versus the energy of primary electrons



Coatings obtained by sputtering are similar. PECVD coatings have high SEY

CERN Strategy (thanks to P. Costa Pinto)

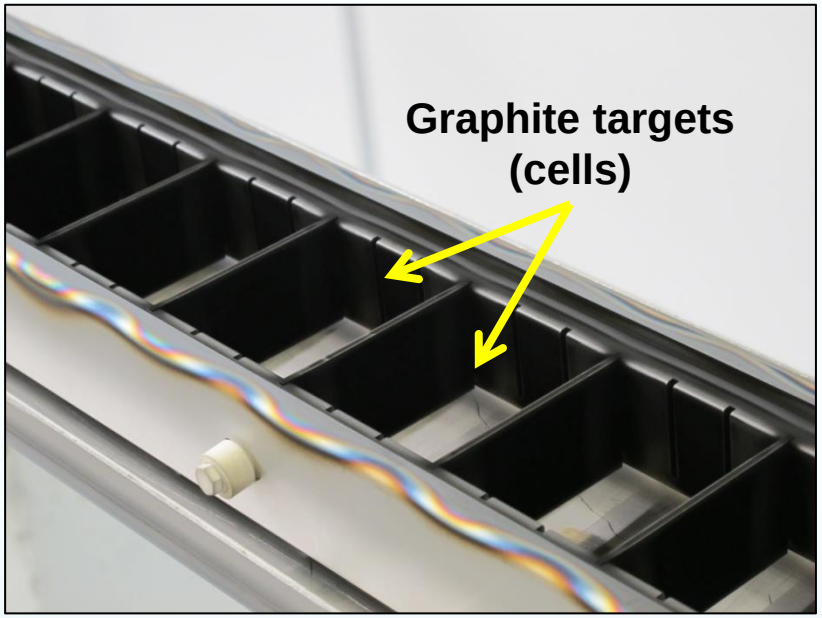
Max SEY (δ_{max}) versus hydrogen in the plasma during the coating by sputtering

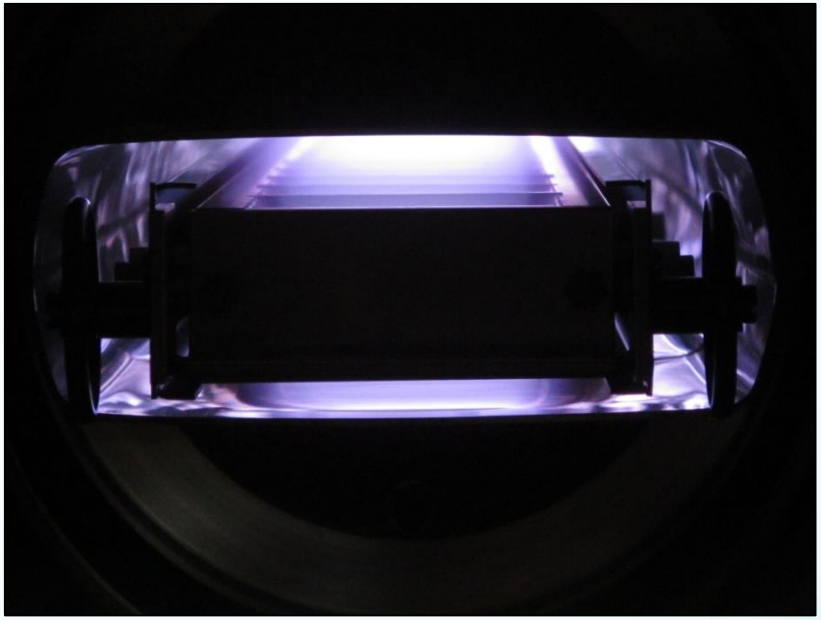


The influence of Hydrogen in sputtered coatings is confirmed by experiments where H_2 is deliberately injected during the coating process

COATING TECHNIQUES @ CERN
(thanks to P. Costa Pinto)

Coat actual beampipes by DC Hollow Cathode Sputtering (DCHCS)

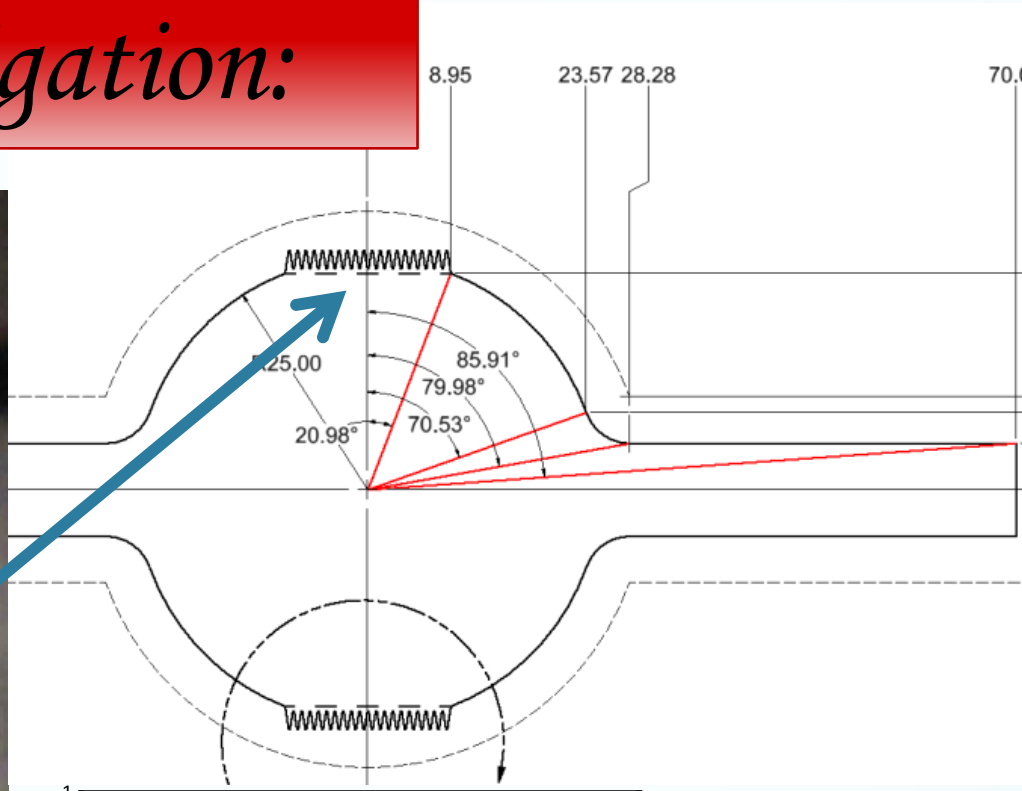


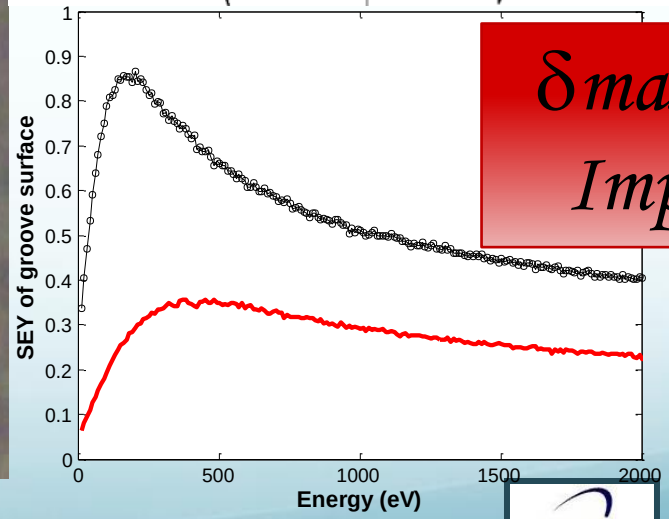


Pressure: 2.4 x10^{-1} mbar (Ar)
Power: 1.8 kW (3A @ 600 V)
0.5 μm in 20 hours

THE TECHNIQUE IS ALMOST MATURE FOR LARGE SCALE PRODUCTION

Geometrical Mitigation:



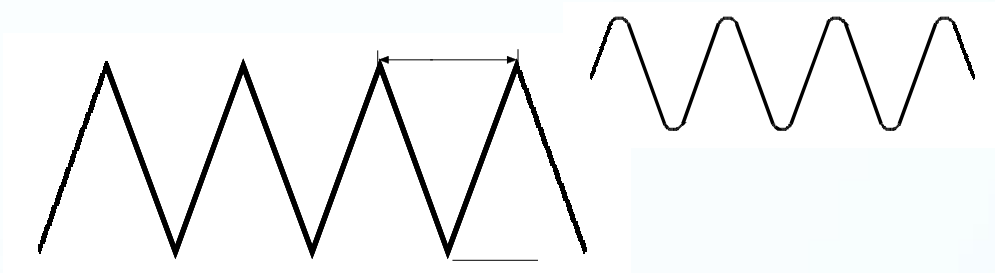


δmax,< .8 …
Impedence?

Impedance enhancement factor

(Code : Finite Element Method, PAC07 THPAS067, L Wang)

$$h = \frac{Z_{groovedsurface}}{Z_{smoothsurface}} = \frac{\oint H^2 ds}{H_0^2 W}$$



The total impedance enhancement = η ⋆ *percentage of grooved surface*

p=1.25mm (period)

d=2.5mm (depth)

t=0.125mm (thickness)

$$h = 1.64$$

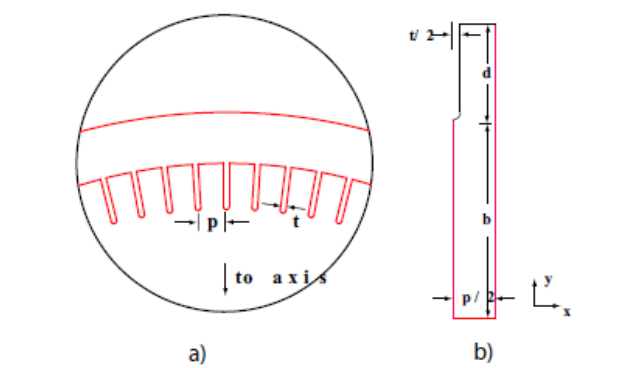


Figure 1: a)—detail of the grooved vacuum chamber wall; dimensions shown are period p and fin thickness t; b)—

p=1.25mm

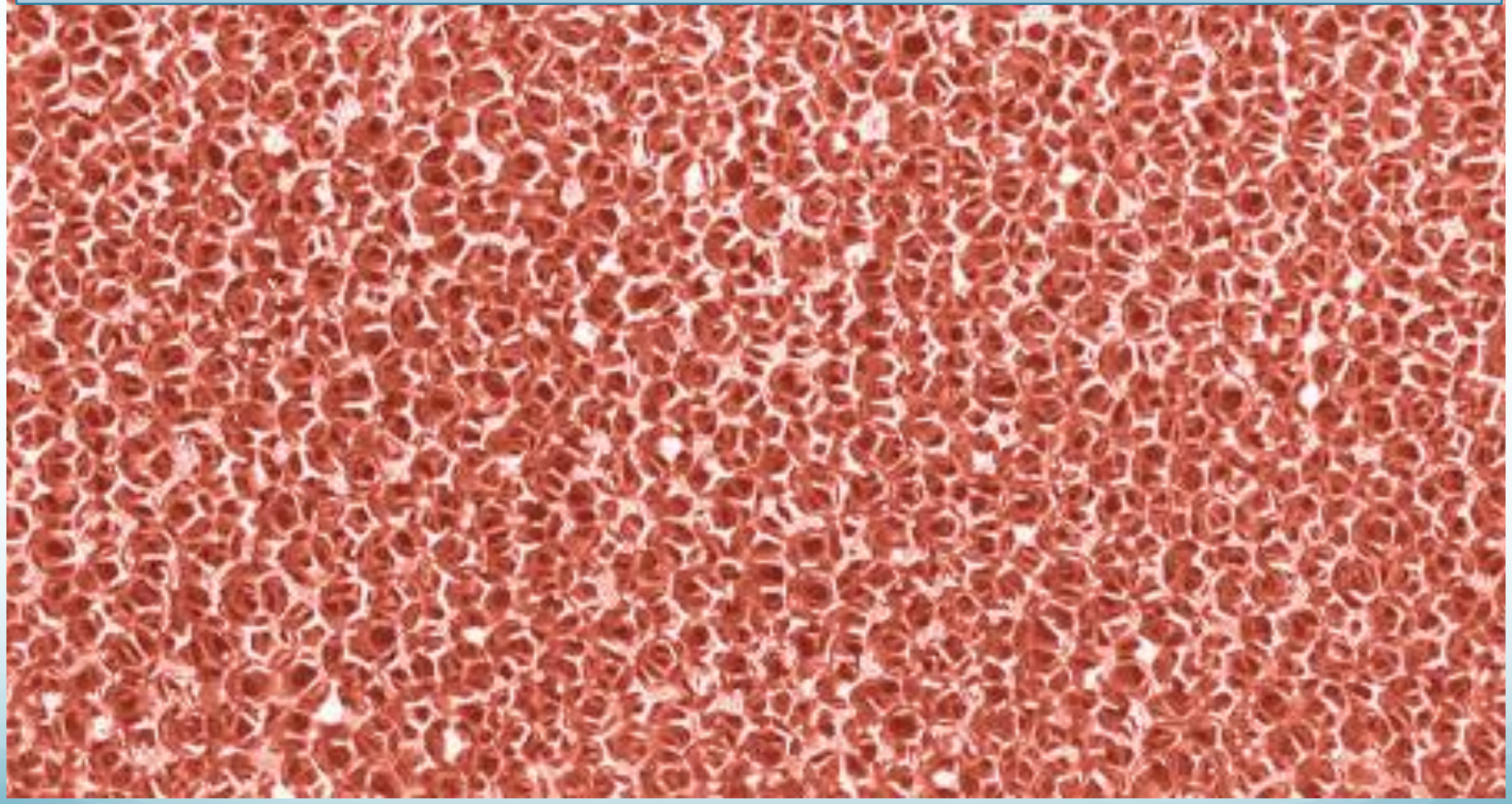
d=2.5mm

t=0.25mm

$$h = 1.42$$

Sponge materials:

R. Cimino, A. Romano S. Petracca, I. Masullo etc: in Preparation



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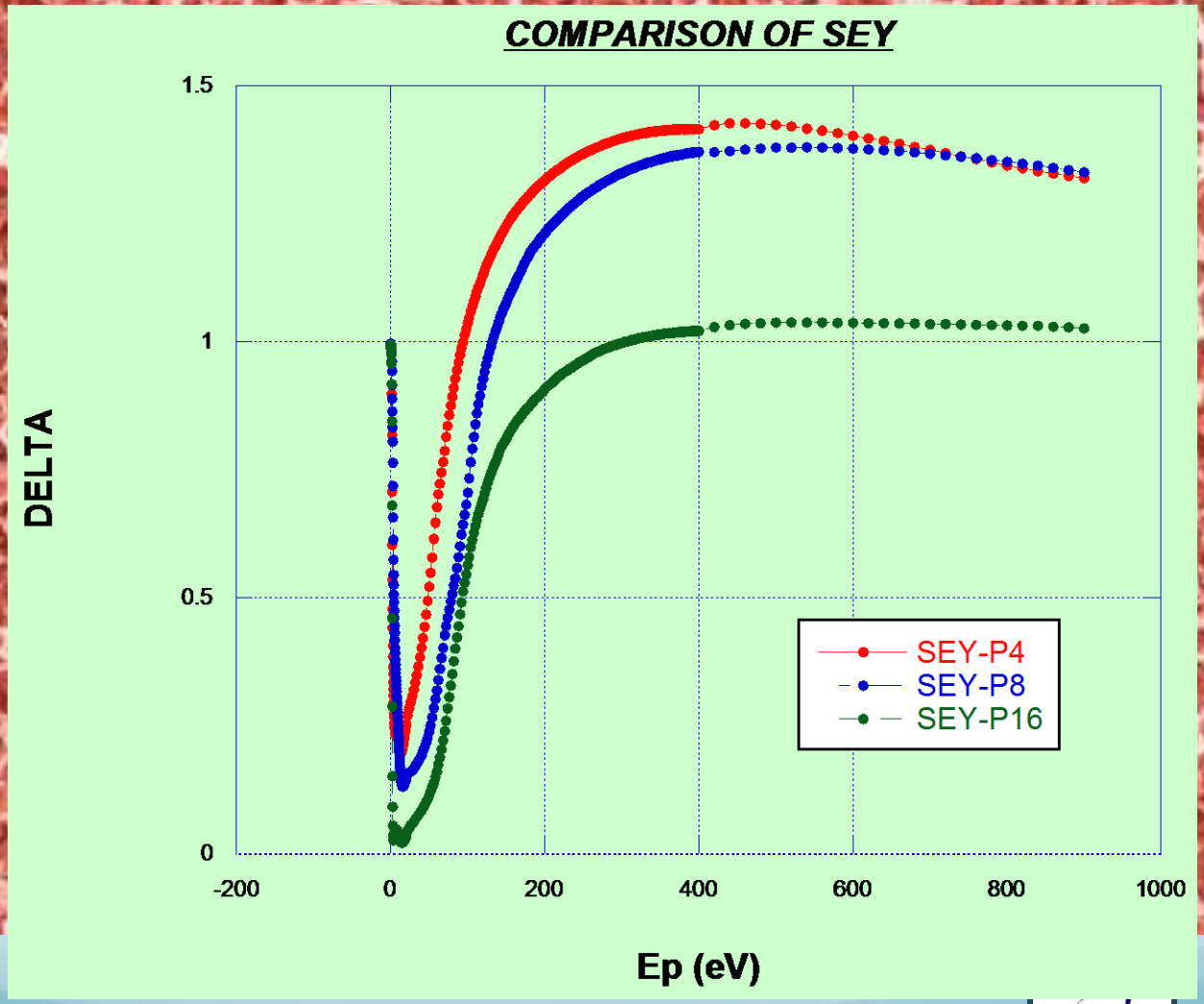

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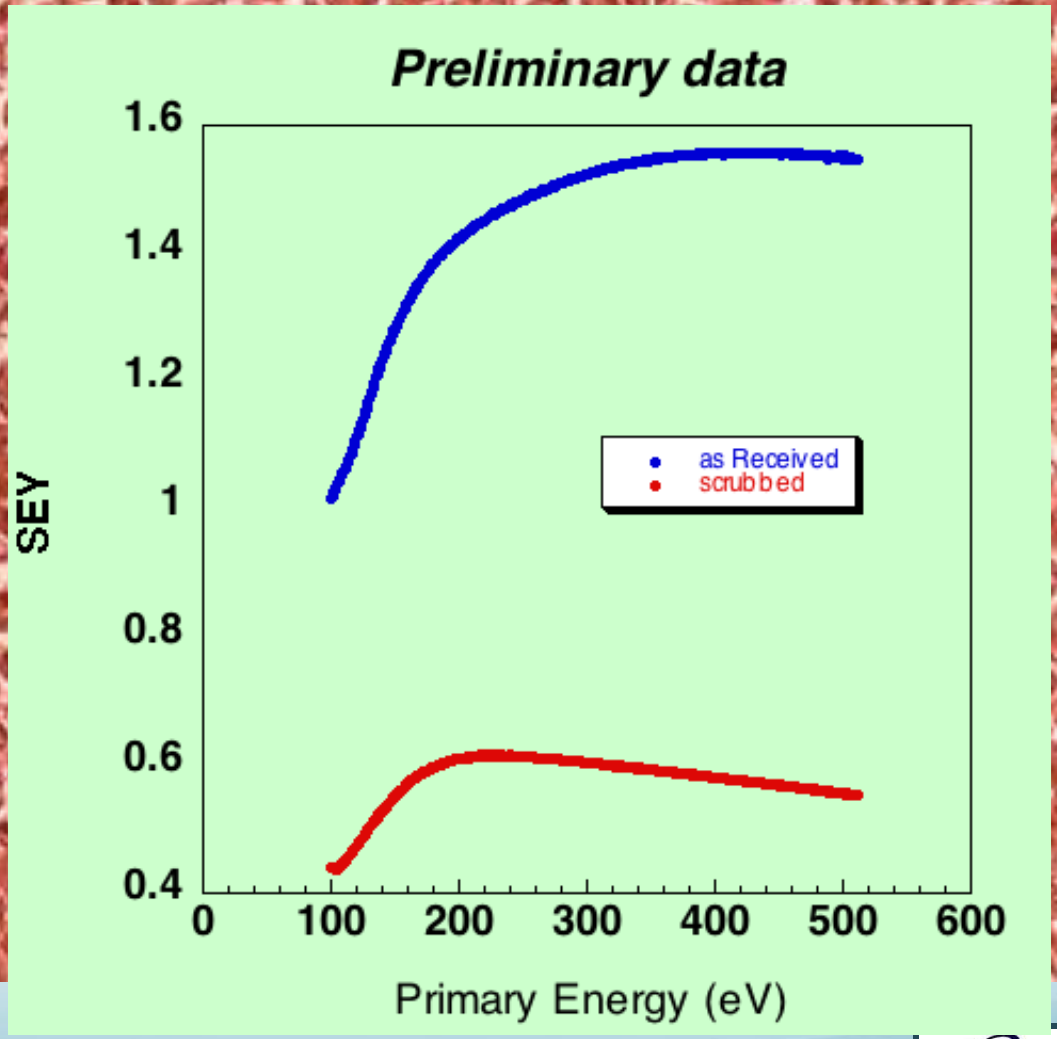

Sponge materials:

R. Cimino, A. Romano, S. Petracca, I. Masullo, M. Taborelli etc: in Preparation

Impedance, vacuum behaviour, desorption properties

are still under study

but seems very promising.

Conclusion

- E-cloud mitigation strategies are coming closer to mature solutions
- There is still a lot to do and to learn
- Synergic efforts, dedicated Surface, Material and Vacuum science laboratories are required to reach desired understanding and performances.

Acknowledgements

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, Switzerland