Coatings for e-cloud mitigation

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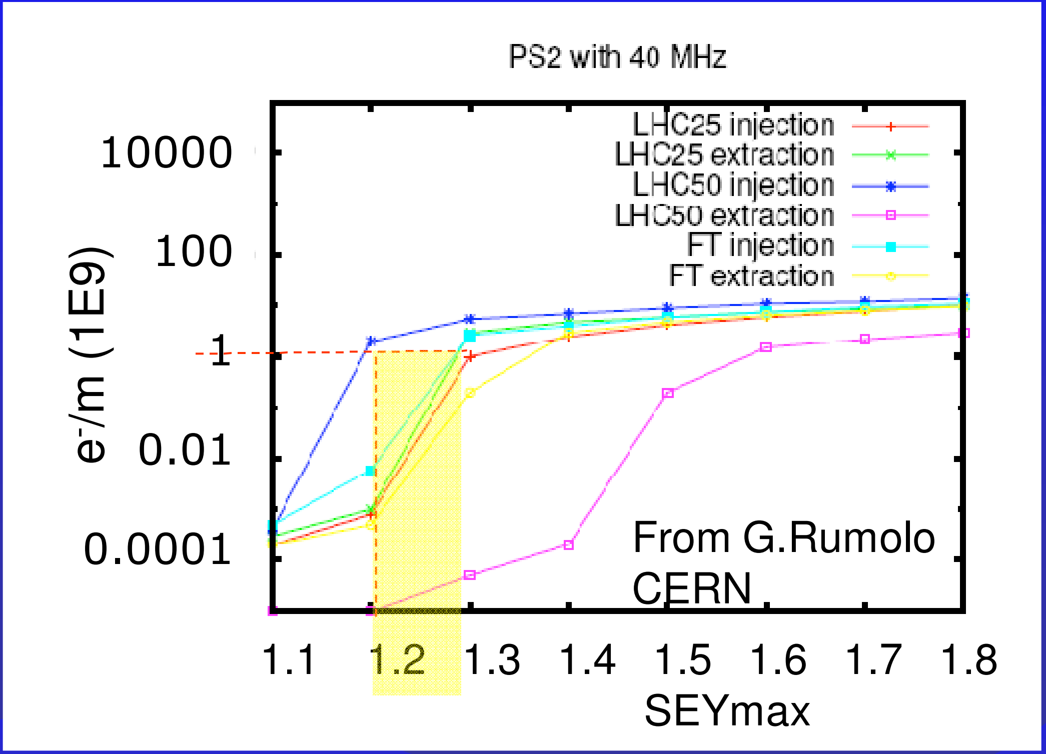
Properties of the coating

-low the SEY (Secondary Electron Yield) to reduce electron multiplication at the walls and suppress e-cloud
-sufficiently low SEY also after air venting (maintenance, installation..) or recovered by treatment in situ
What does it mean sufficiently low? ➔ simulations



For PS2

δmax <1.2

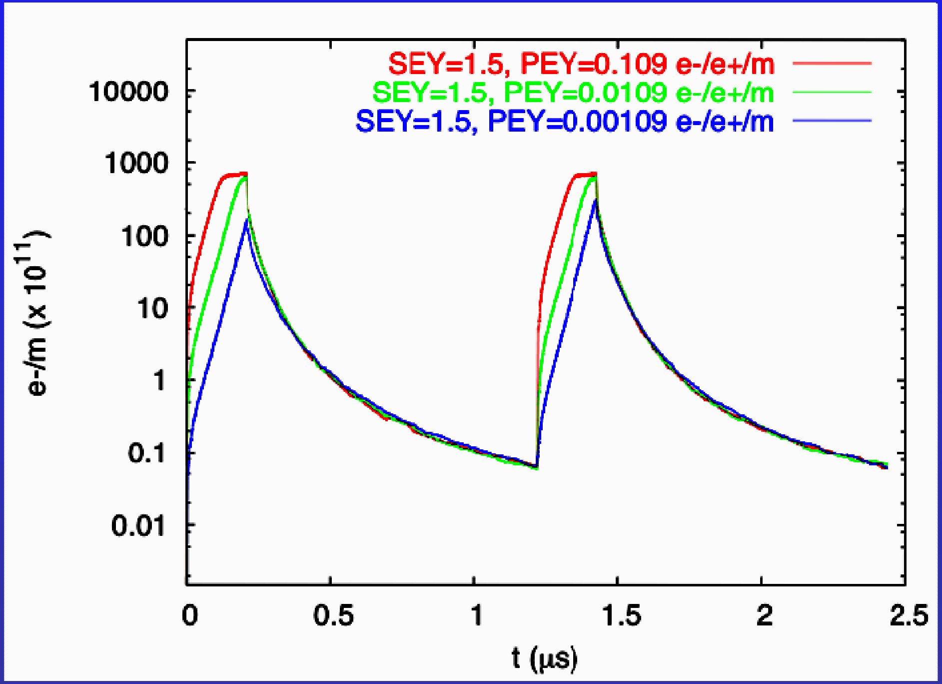
For the SPS we need **δmax** <1.3 to suppress e-cloud with nominal LHC beam

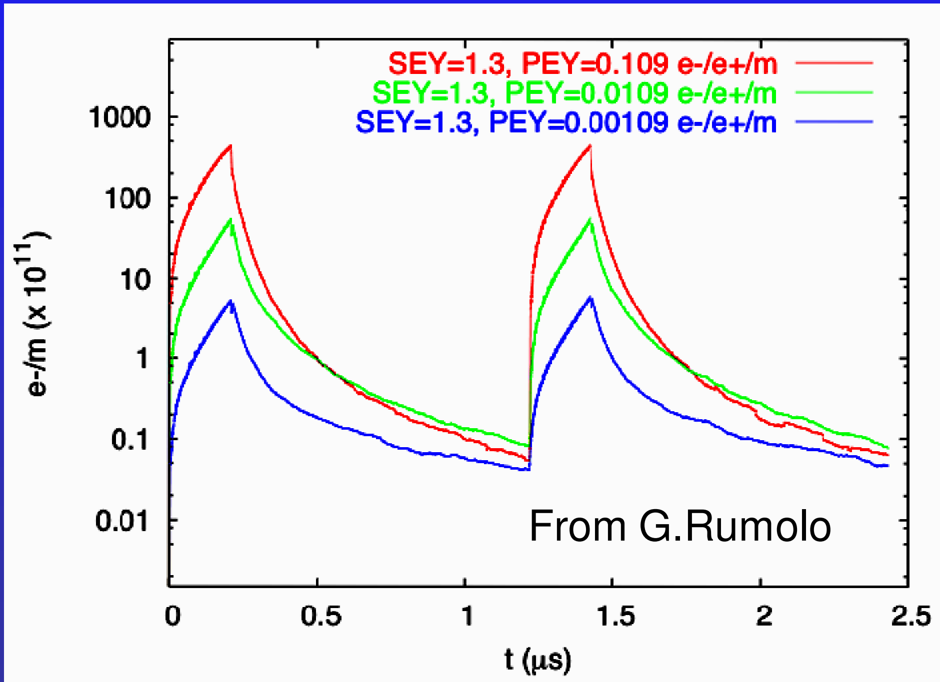
δmax >1.3

No chance to reduce e-cloud even by absorbing all the photons

δmax <1.3

In this case the e-cloud depends on the effective photoyield





Low **SEY coatings**

Typically we need a surface with SEY below 1.2

-coating with material having intrinsically low SEY

-coating with micro-roughness……but this is worse for degassing

-a low SEY can in principle be obtained with long conditioning (for photons at least)

Two cases to be discussed:

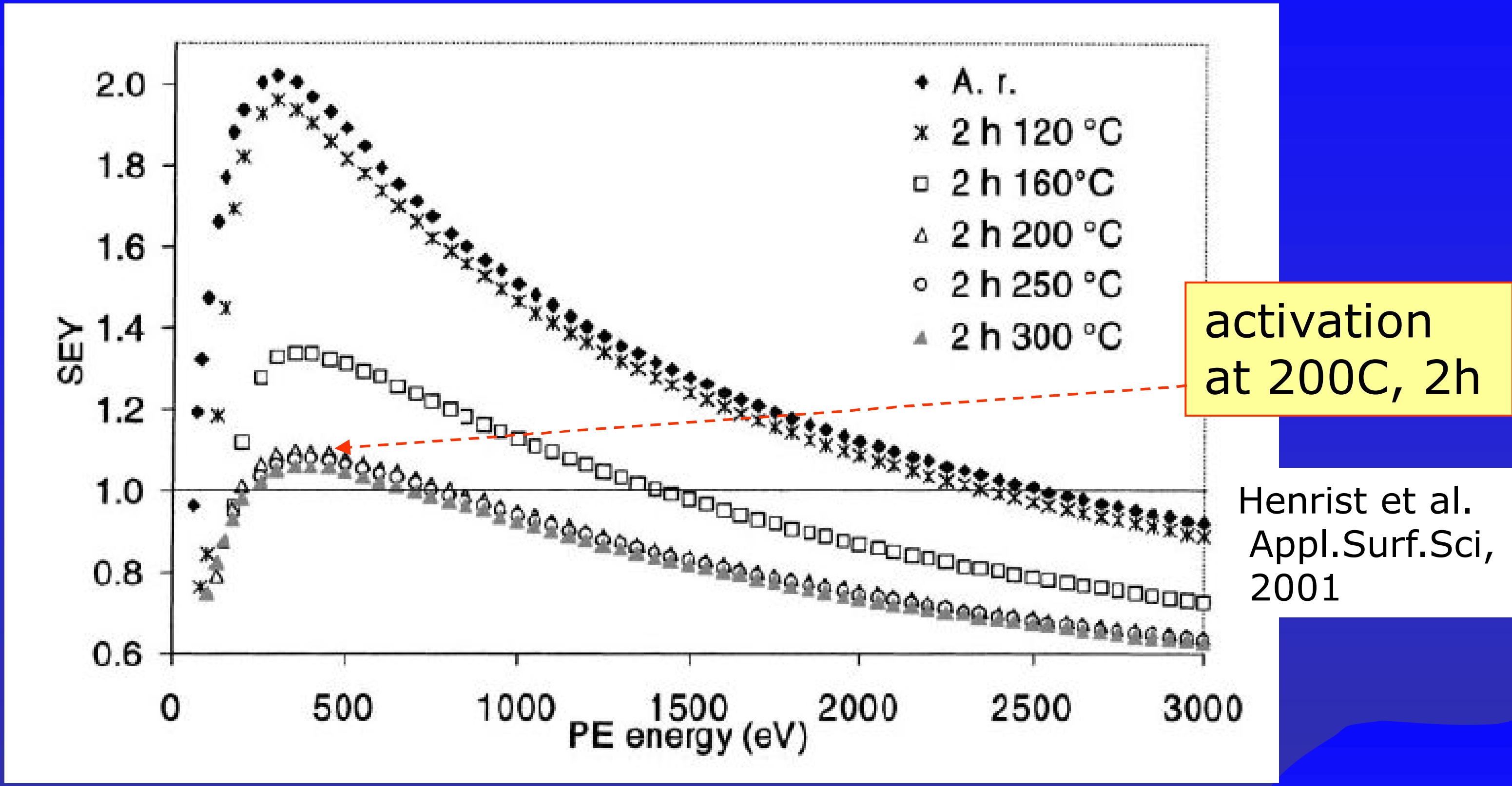
bakeable vacuum system

non-bakeable vacuum system

Bakeable system

NEG coatings

TiZrV NEG thin films can provide a surface with low δmax after heating at the lowest temperature compared with other materials:



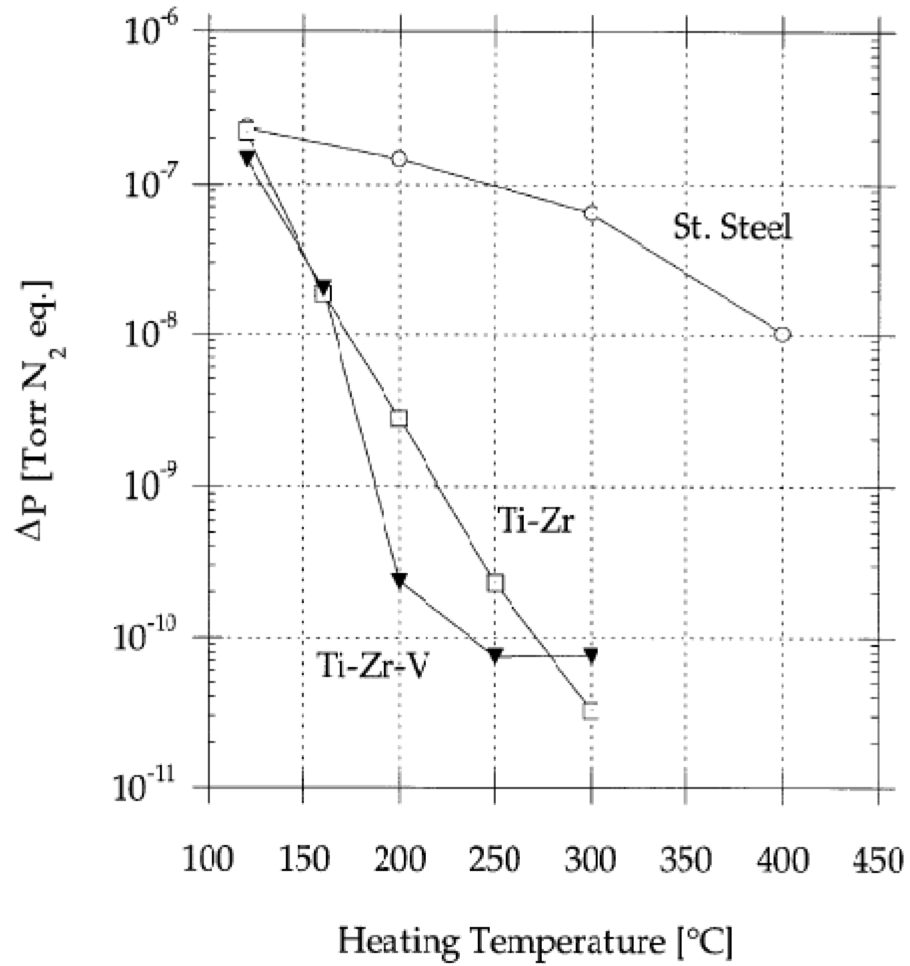
Henrist et al. Appl.Surf.Sci, 2001

-2h at 200C or 24h at 180C

-data for 8 re-activations of 2h at 250C after air-venting show an SEY below 1.3

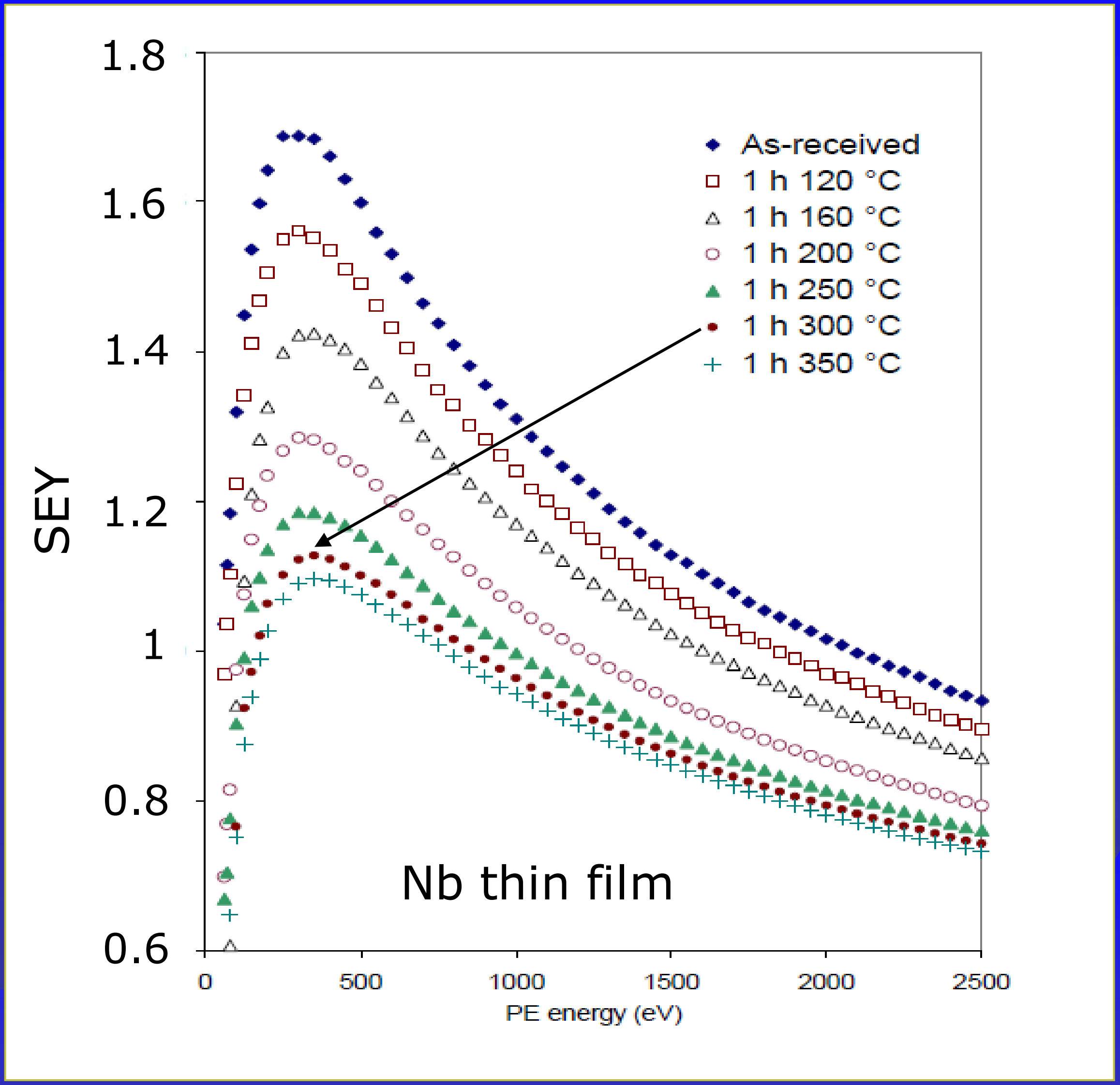
-LHC long straight sections (6 km, more than 1000 chambers) to provide pumping and low SEY

Electron Stimulated Desorption (ESD) of activated NEG compared to StSt



C. Benvenuti et al. / Vacuum 53 (1999) 219–225

Nb: needs heating at higher temperatures



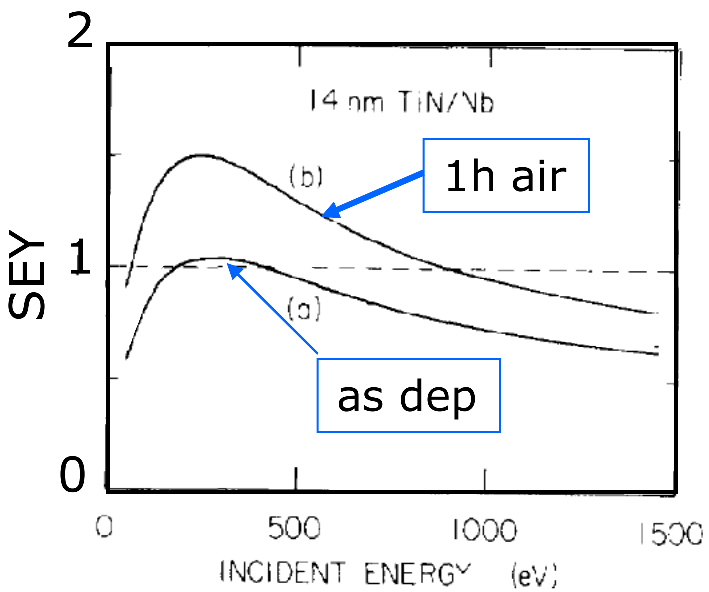
No bake

Surfaces with initially low SEY: TiN and effect of air exposure

As deposited TiN has a δmax = 0.9-1.1 ; **clean copper** has 1.3

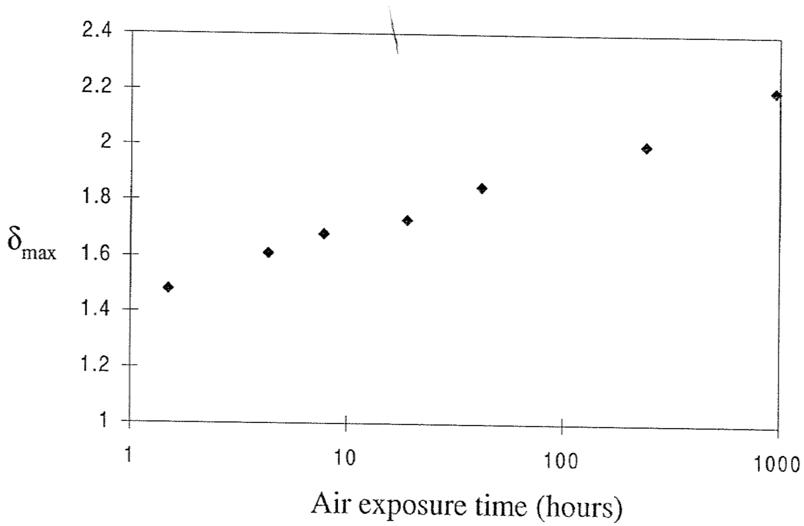
Upon air exposure the TiN yield increases to δ**max** = 1.5-2.5 and the one of copper to δmax =1.6-2.2

TiN



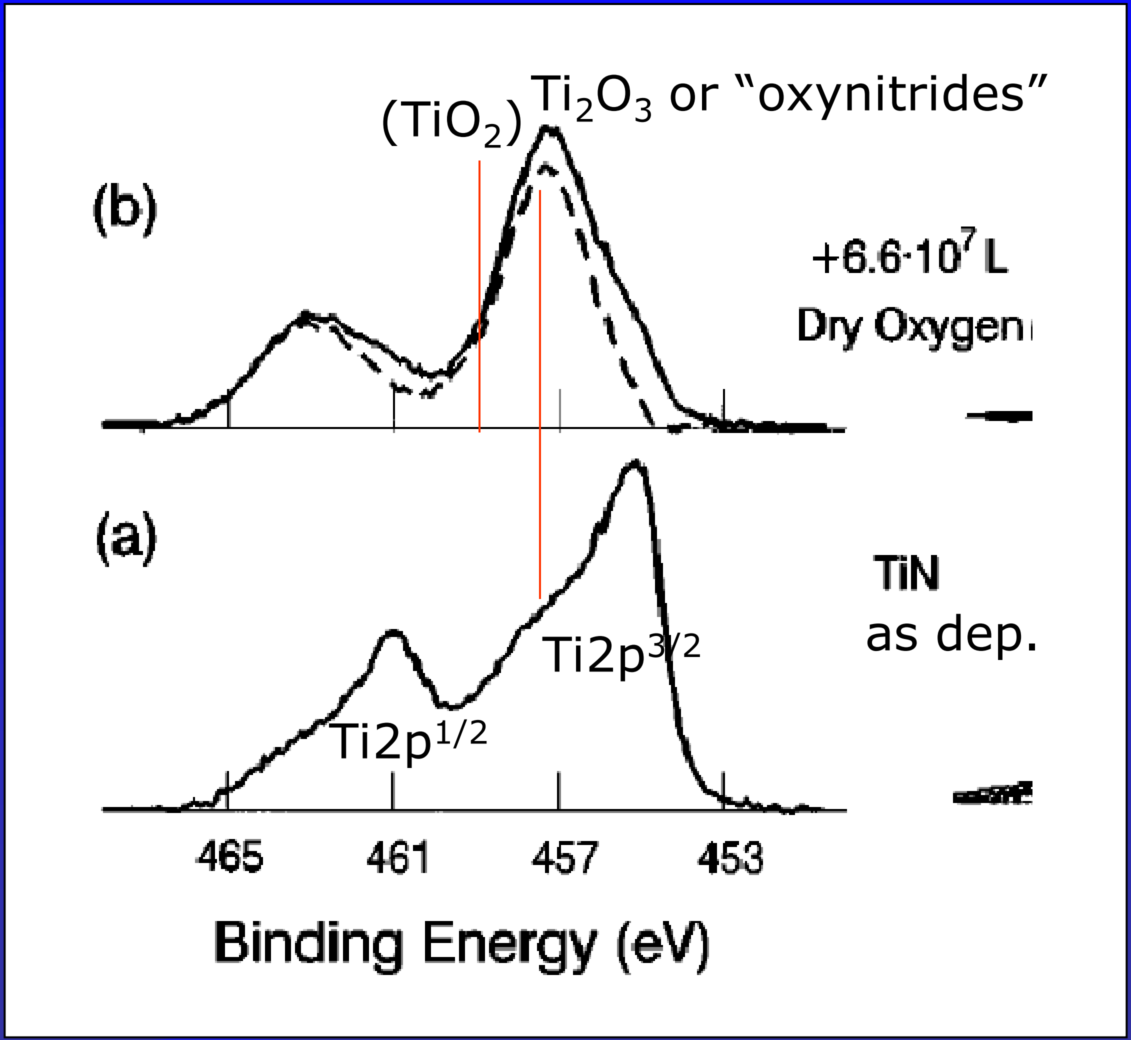
(E.L.Garwin et al. 1987)

Copper: air exposure



(Scheuerlein, 1999)

“Excursus”: oxidation of TiN in XPS:



Change of surface composition

(Prieto et al 1995, Similar results by Kato et al.2005)

Low SEY coating for unbaked systems: which material?

No theory able to predict the absolute SEY value for a given material

Known facts:

- in the periodic system, elements with **less electrons** (on the left side) have in general lower SEY (…and lower work function)
- air exposed metallic surfaces have SEY around 2 or more
- insulators have high SEY (electrons escape from deep layers)
-"beam scrubbed" surfaces are covered by more **carbon** (at least Cu and StSt)

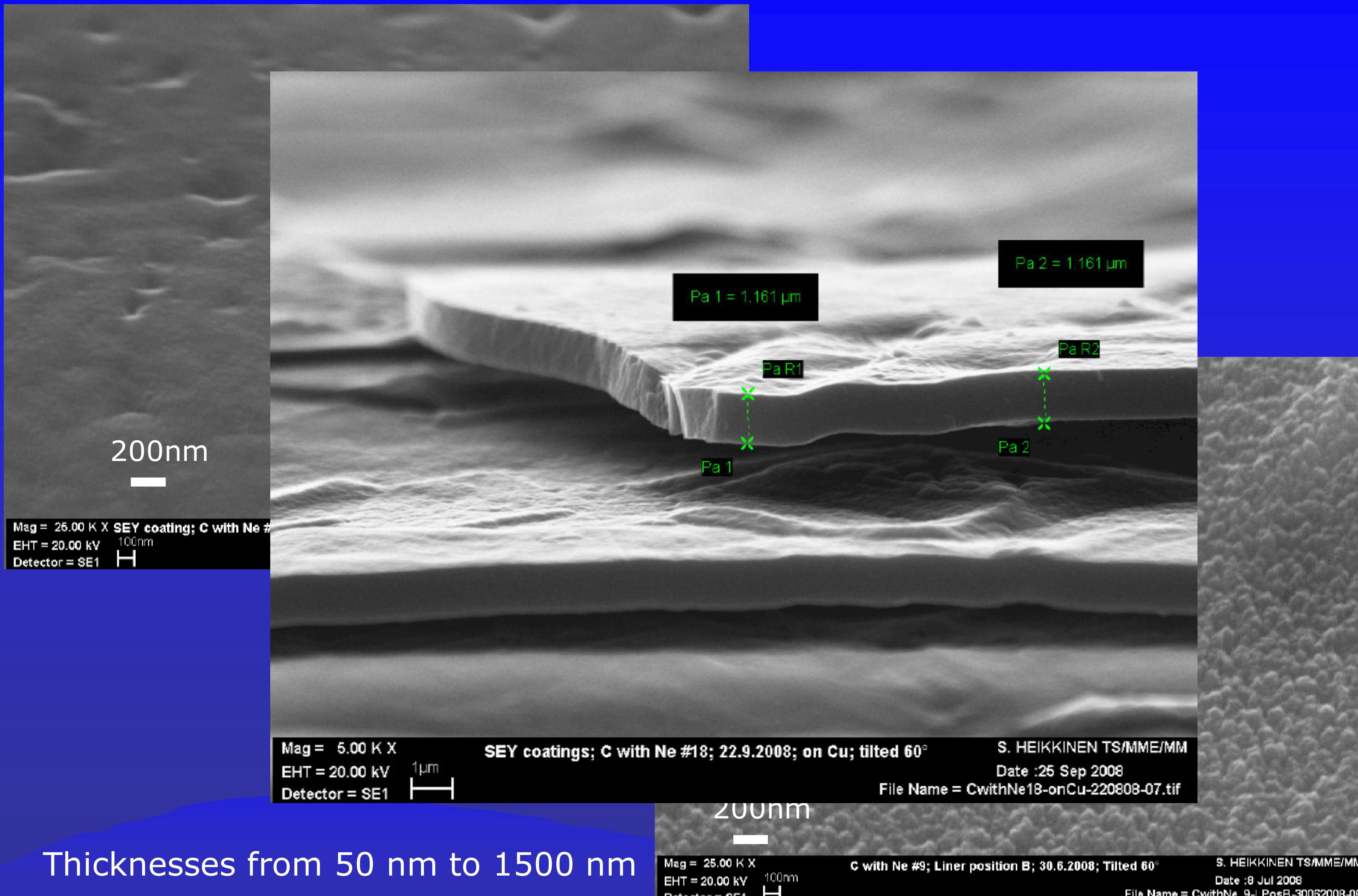
➔ **take C**, which has few electrons

➔ SEY of **graphite** (100% sp^2) is much lower than diamond (100% sp^3), so try to make sp^2 and avoid sp^3

➔ graphite is not very reactive, should be less affected by air exposure

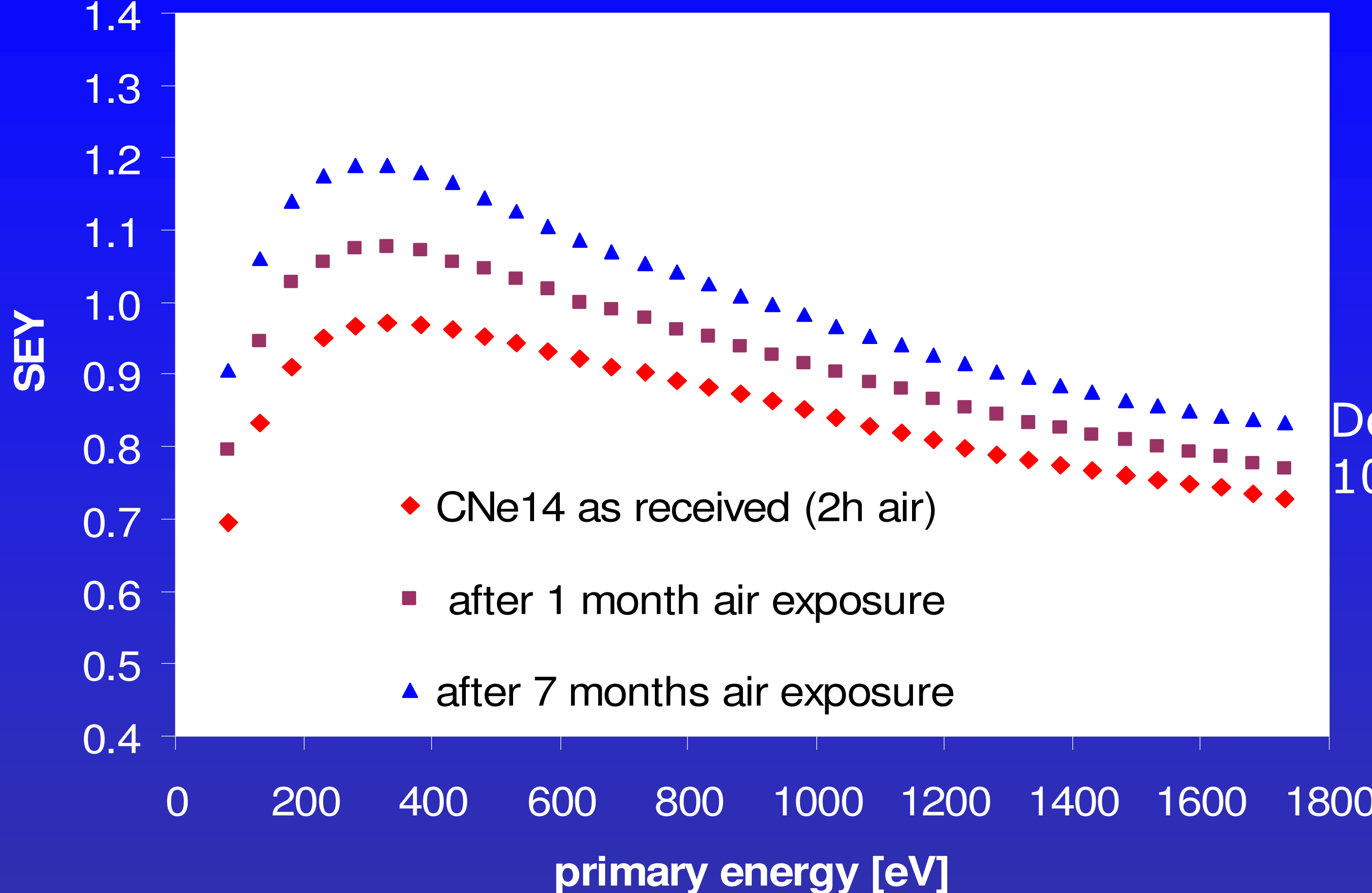
No bake

SEM images of a-C coatings (magnetron sputtering)



Thicknesses from 50 nm to 1500 nm

SEY of a-C carbon coatings (no bake):



Dose below 10^{-6} Clb/mm^2

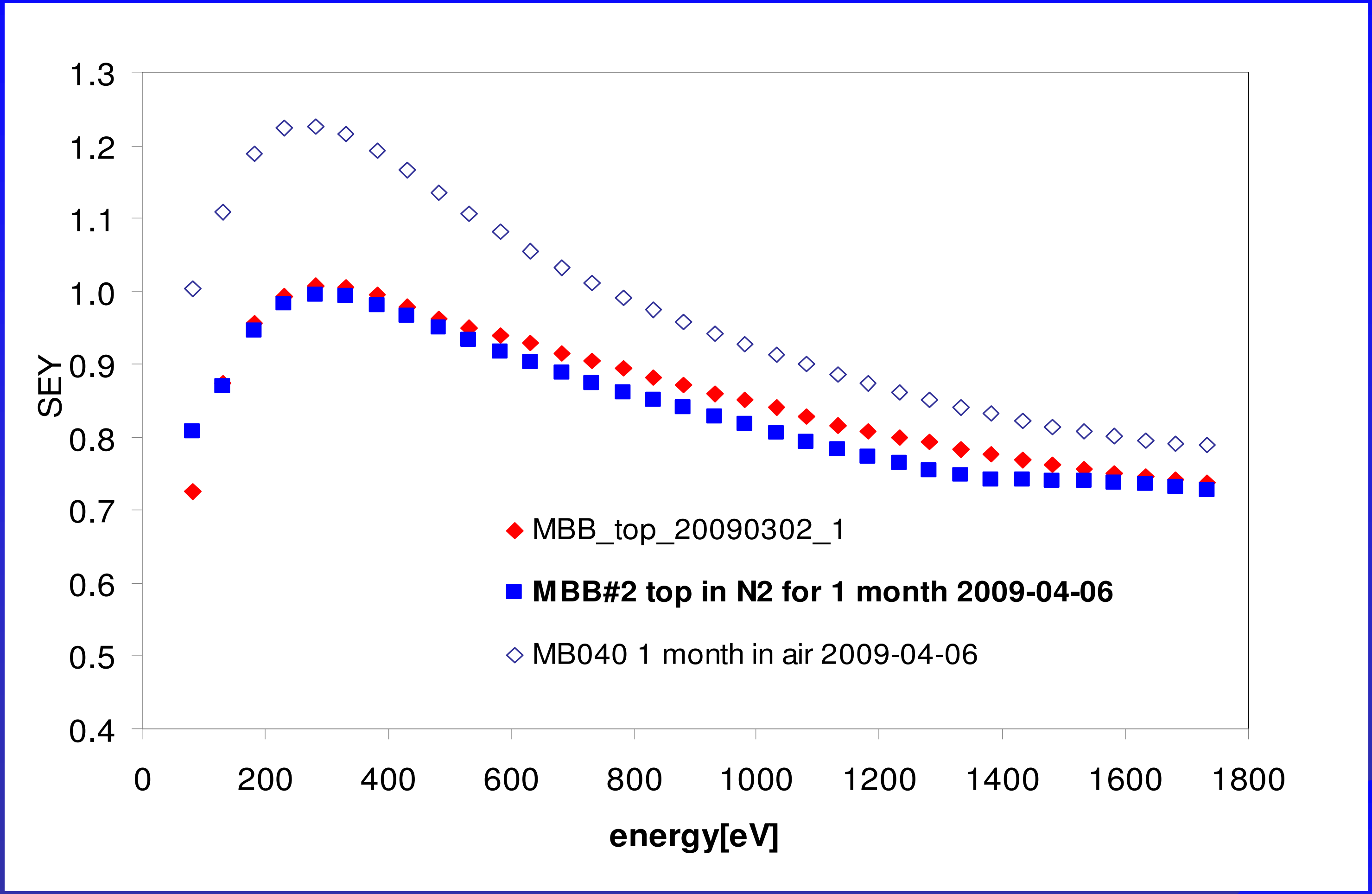
-initial δmax between 0.9 and 1.1, some scattering in the aging values for air exposure

-No change with thickness above 50 nm

-Aging is difficult to study by surface analysis since it is difficult to distinguish adsorbed hydrocarbons….. on carbon

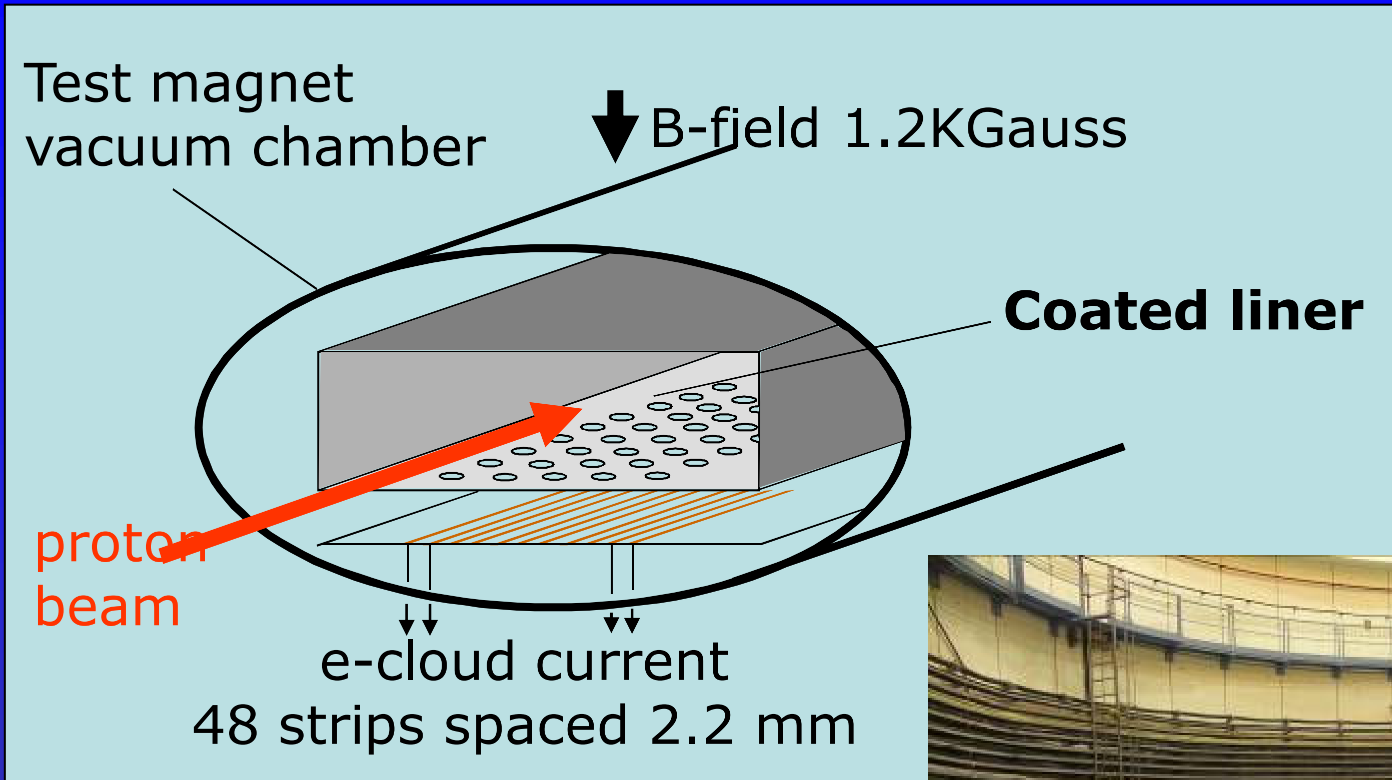
No bake

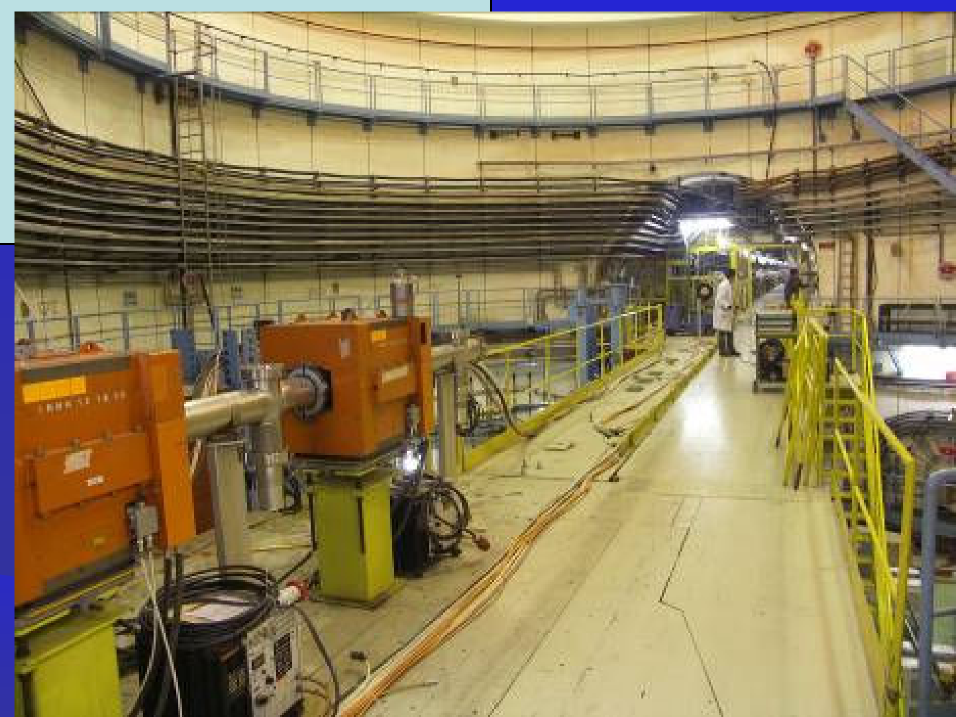
Compare storage of a-C in air vs N_2



- Clear difference between laboratory air (in a polymer box) and N_2 in a stainless steel vessel (samples from the same coating run)
- The N_2 stored has a lower surface O concentration than air stored

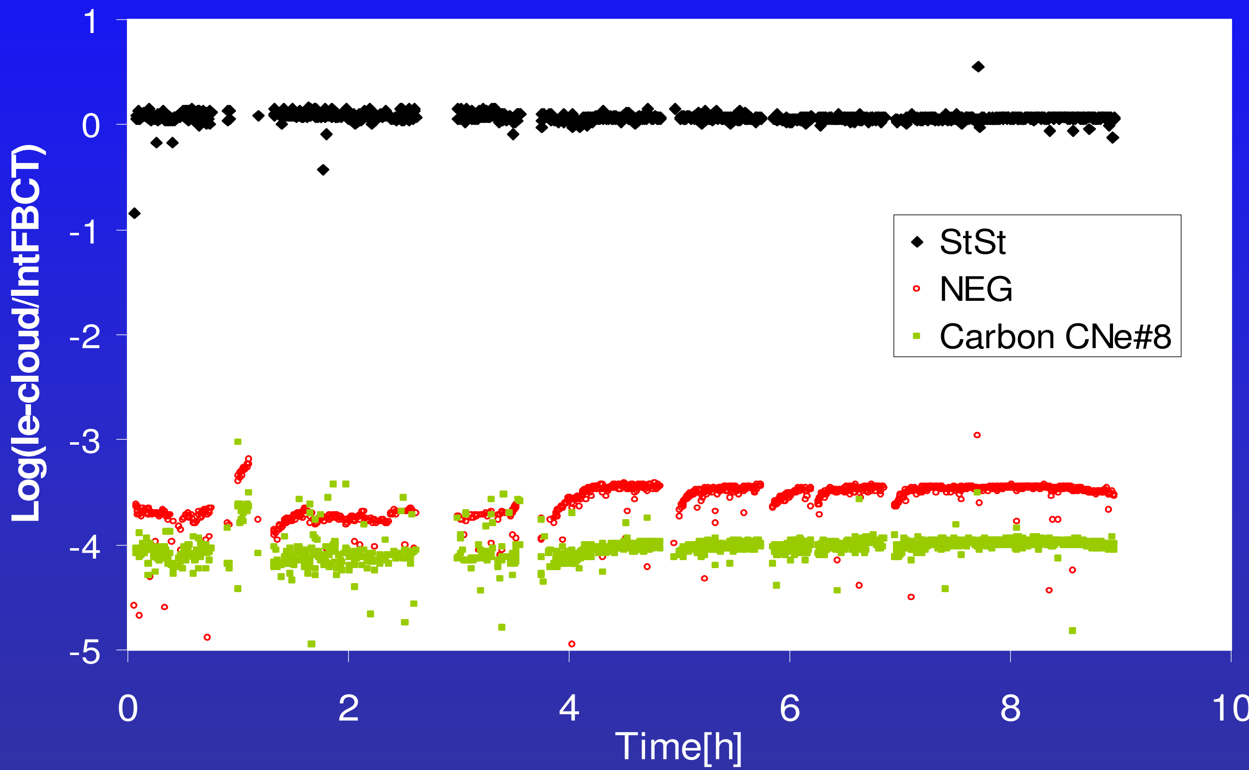
Tests in SPS with electron cloud monitors





a-C coating in e-cloud monitors in SPS, MD run w28

Set-up: a-C coated liner with strip detector in 1.2KGauss field
Beam: 2-3 batches, 72 proton bunches, 25 ns spacing, 450 GeV/c



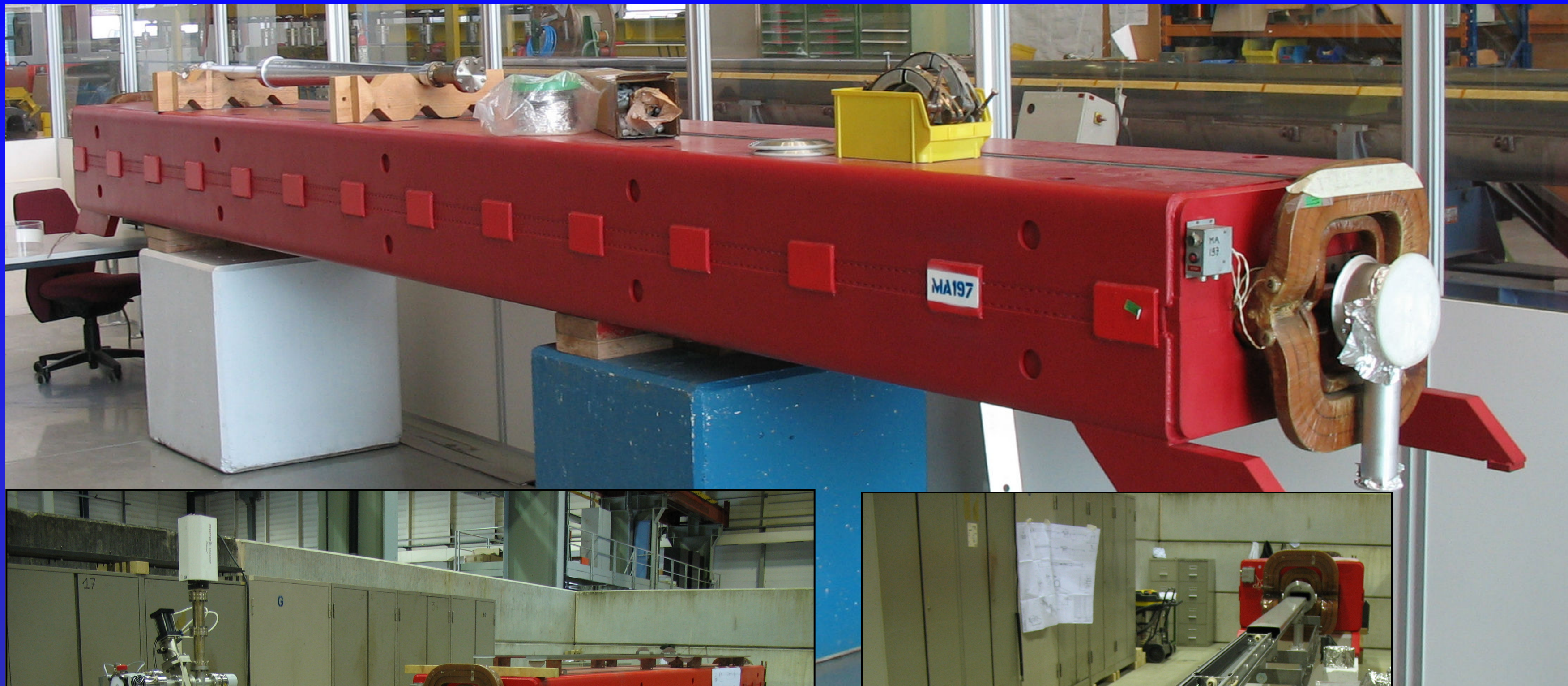
StSt for 2h air exp. δmax=2.5

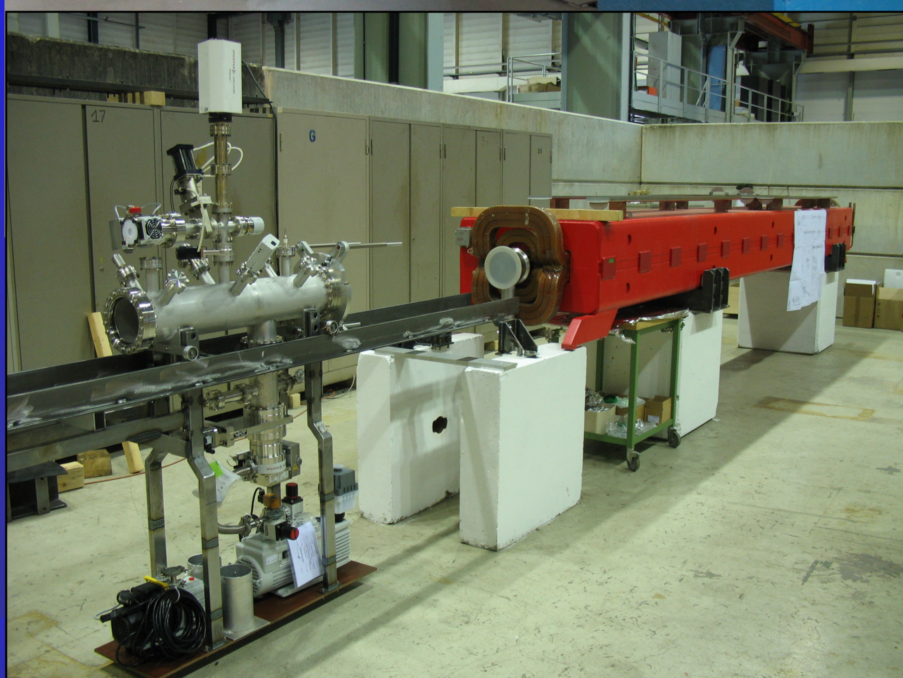
TiZrV-NEG fully activated, δmax=1.1

CNe for 2h air exp.δmax=0.95

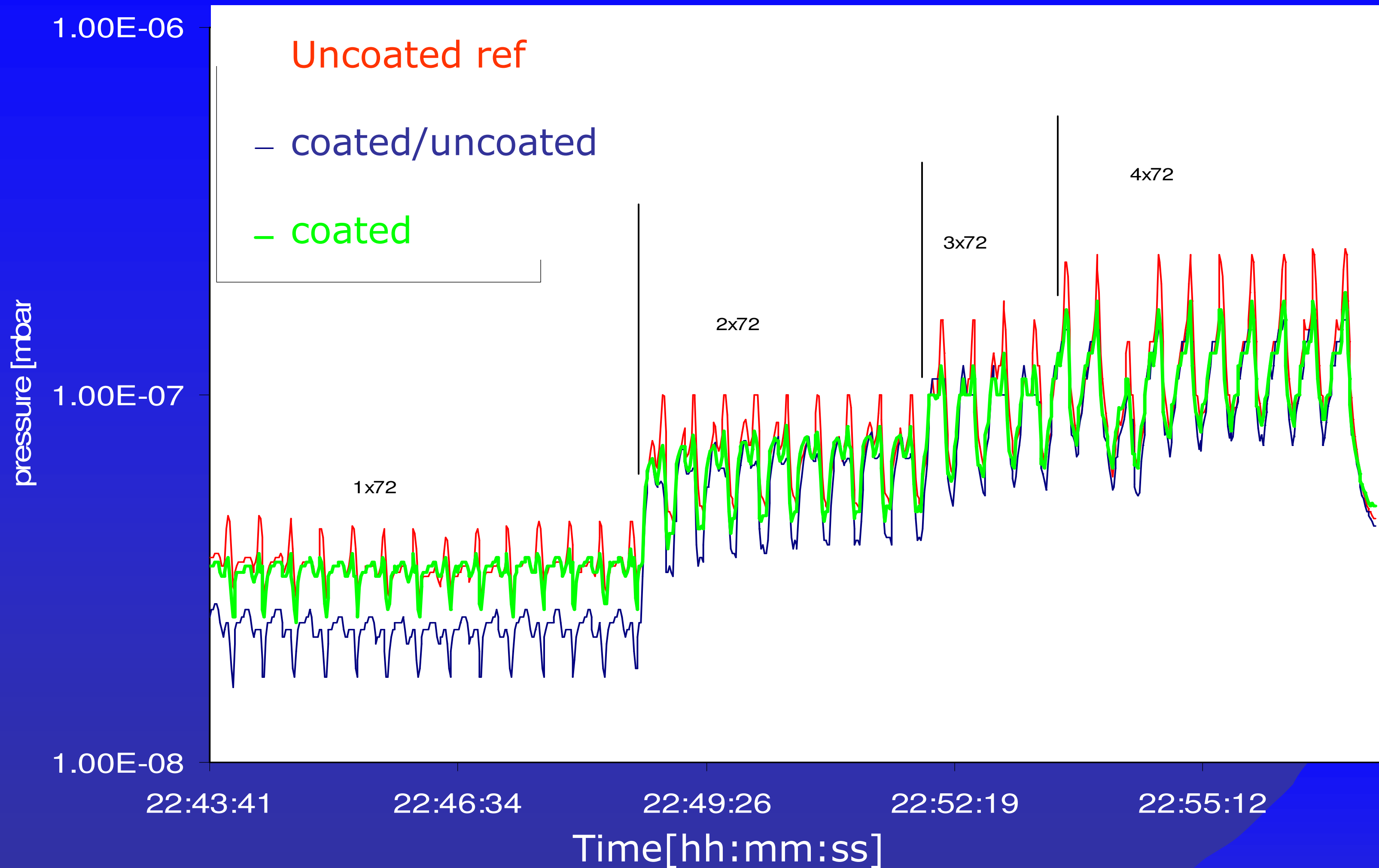
-Coating CNe8 gives **10^{-4} times current compared to StSt**, in agreement with measured δmax
- It is as good as activated NEG

Coating of 3 MBB SPS dipoles inserted in March09



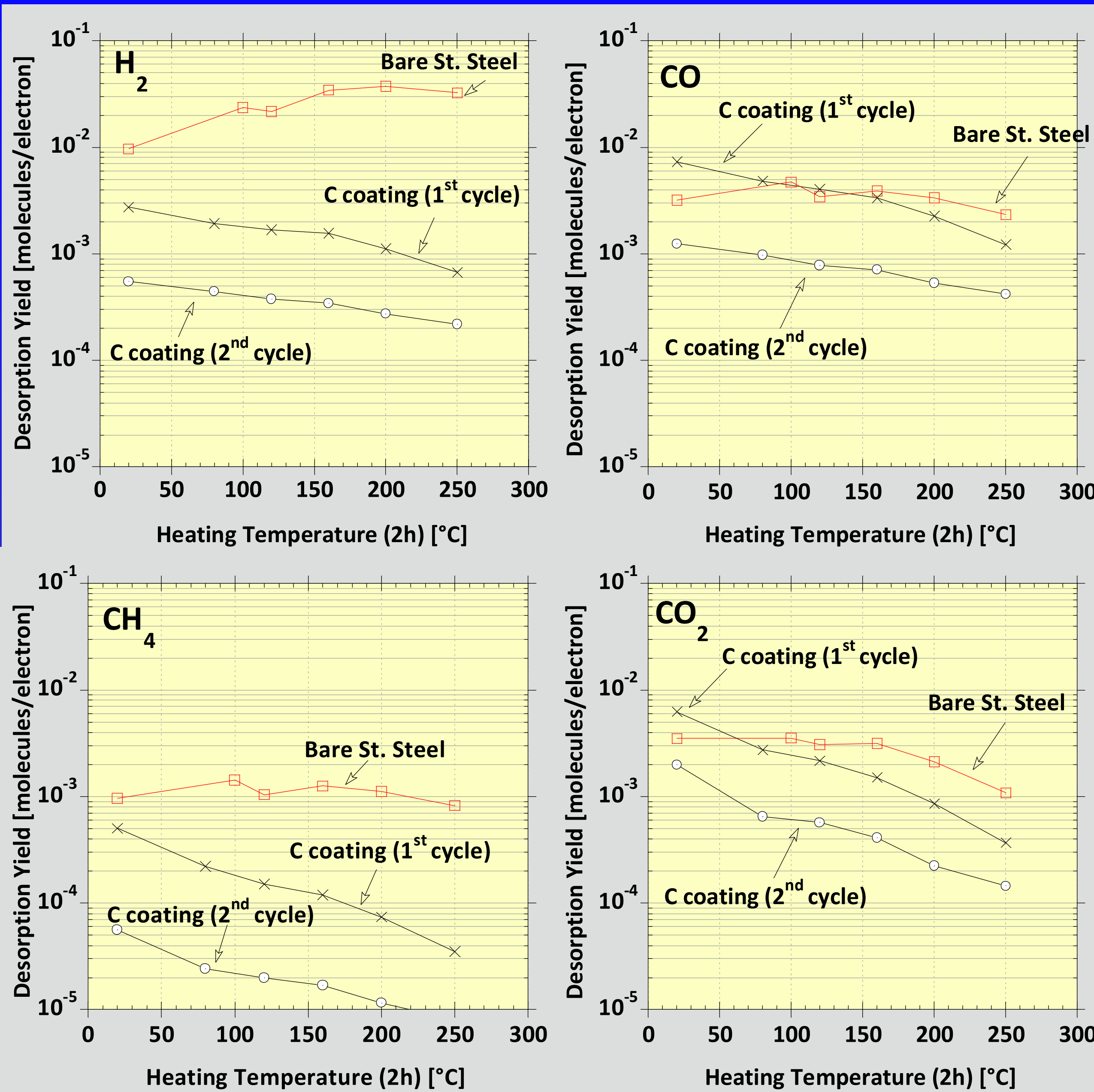


Pressure rise in SPS for coated and uncoated regions: 1➔2 ➔3 ➔4 batches x 72 bunches at 90% intensity, 450GeV



The pressure rise is only slightly lower for coated magnets: still under investigation (influence of other parts of the machine?)

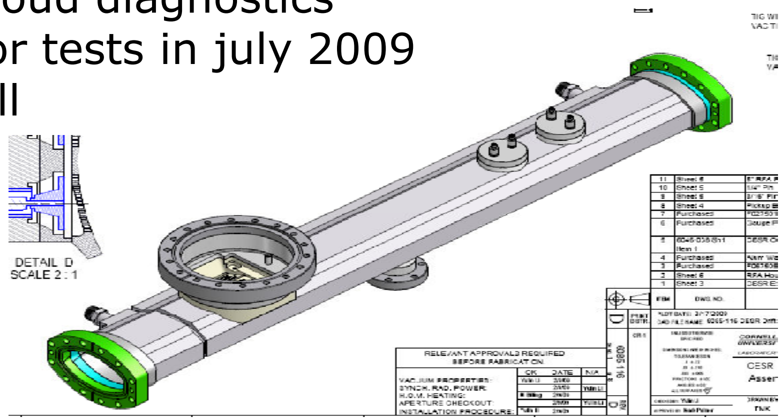
ESD of a-C coating

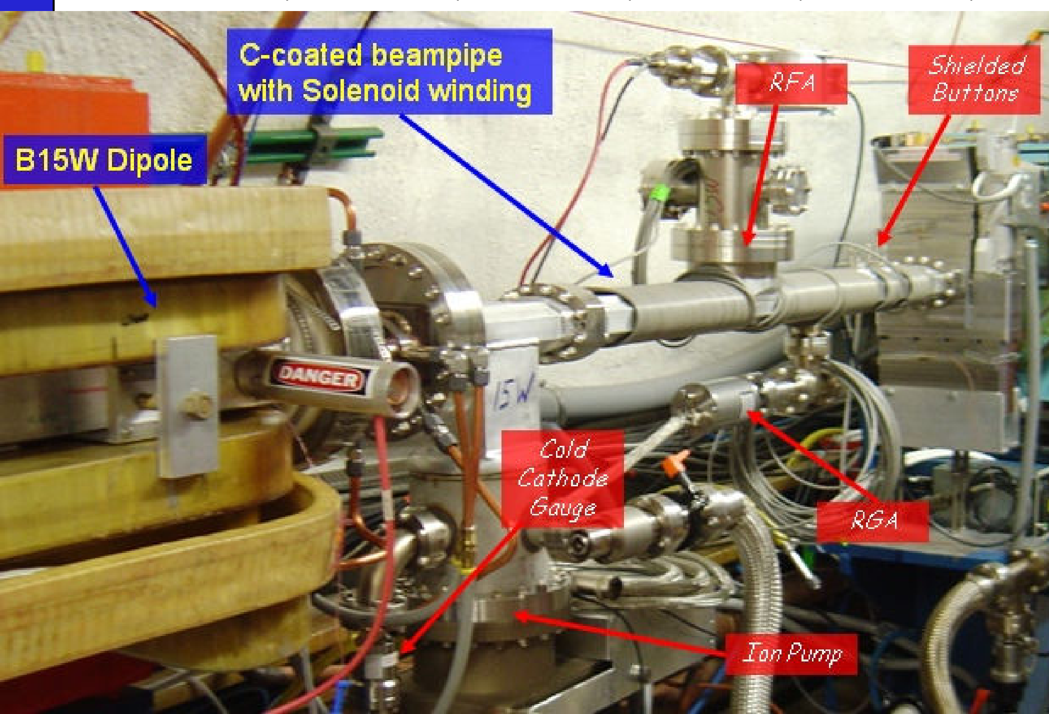


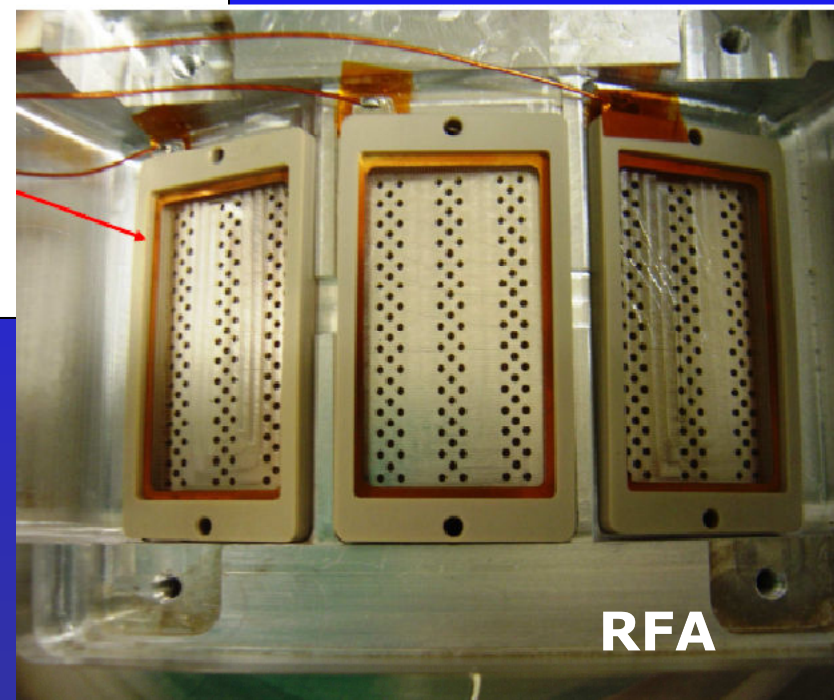
CO and CO2 are slightly higher than for StSt, H2 and CH4 are lower.

Tests at CesrTa (Cornell) for the damping ring case

Al vacuum chamber equipped with e-cloud diagnostics (RFA) for tests in july 2009 in Cornell





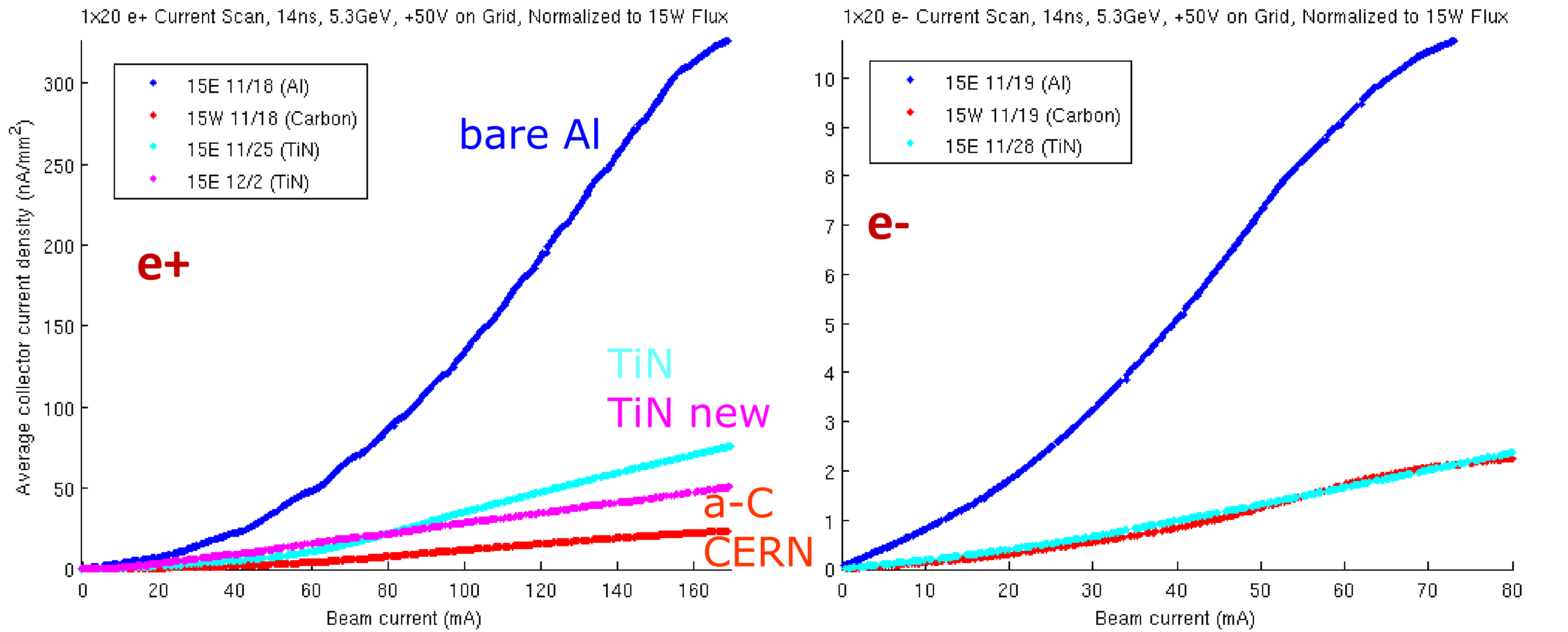


Comparison Al, a-C/Al, TiN/Al at CESRTA

Cornell University
Laboratory for Elementary-Particle Physics

Courtesy of Calvey, Palmer, Li

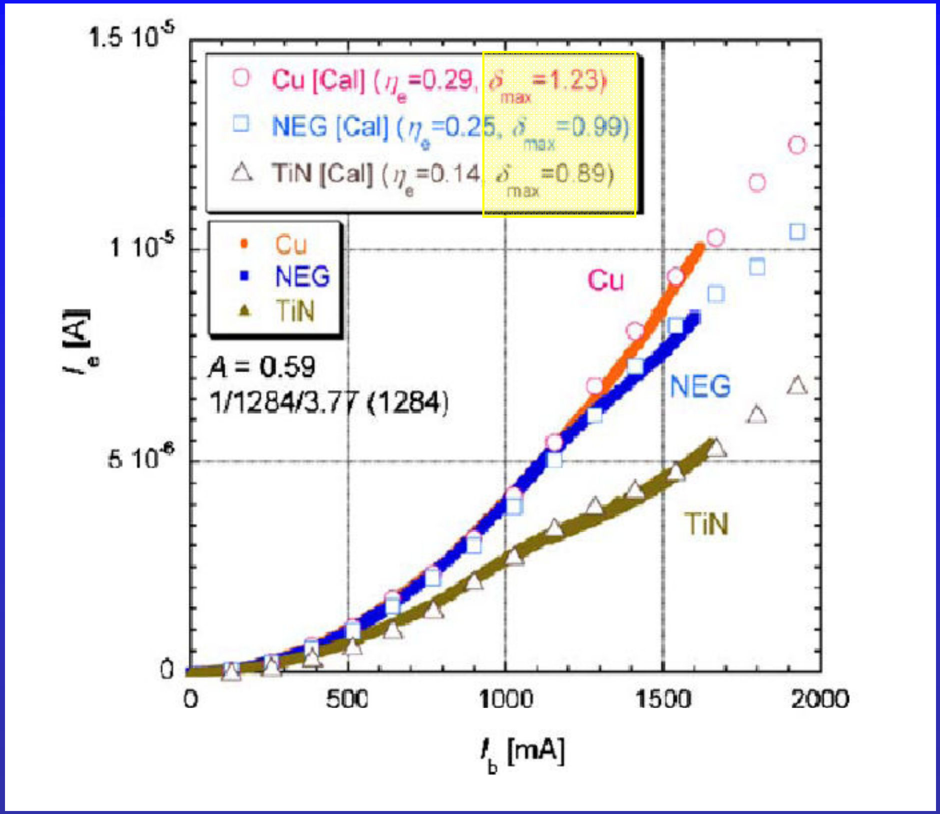
Average collector current densities normalized by photon flux



- with e+ beam more e-cloud is expected
- a-C chamber was contaminated with silicone (kapton adhesive tape) during acceptance test

NEG, Cu and TiN :

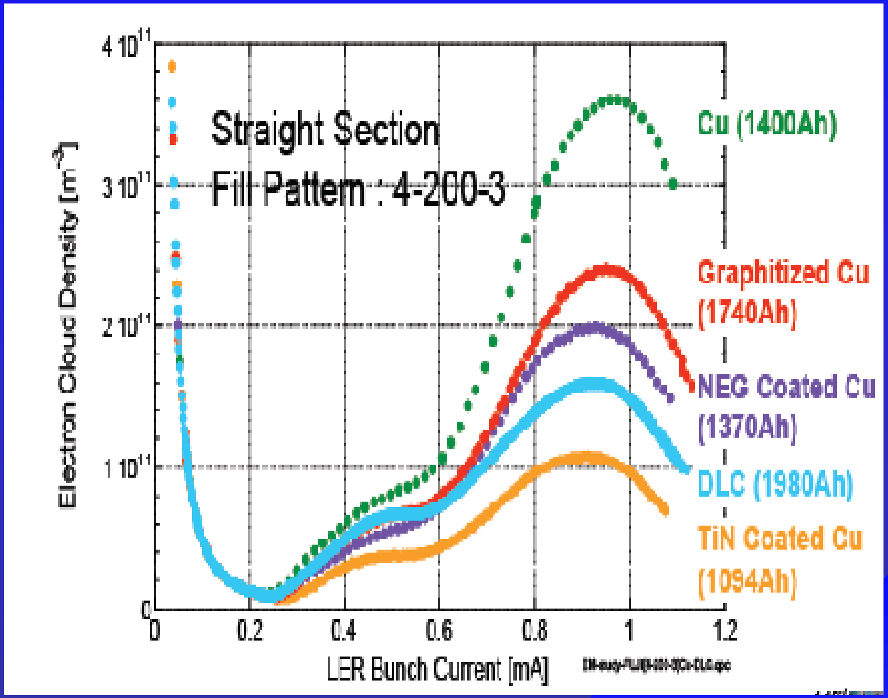
KEKB, arc, downstream of dipole
Suetsugu NIM A556, 399 (2006)



Surfaces conditioned with $10 mC/mm^2$; in this condition all the surfaces have almost the same low SEY and current differences are weak

KEKB, straight section

Nishiwaki,Vacuum 84 743 (2010)



Conditioning not specified, possibly the same

Conclusions

Different coating can mitigate the e-cloud depending if the system can or cannot be baked

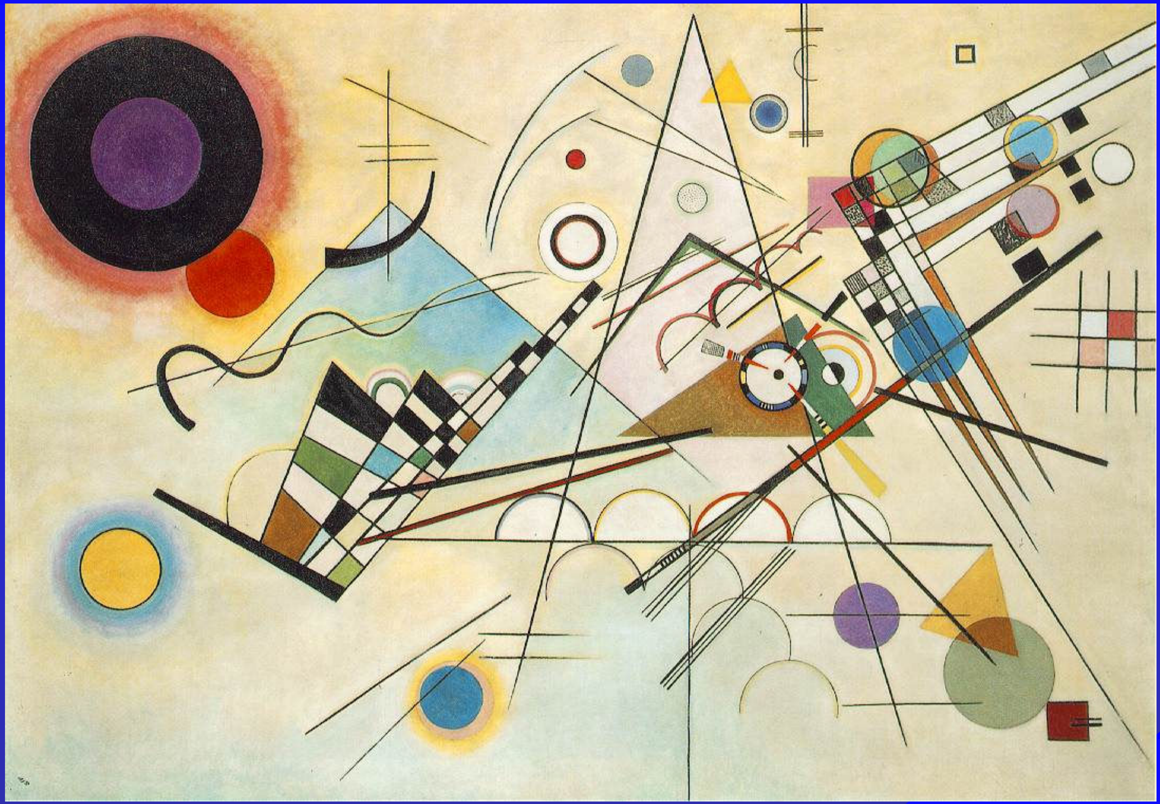
-NEG coatings must be thermally activated, can provide low SEY , low ESD and pumping action. They are already applied in LHC

- a-C coatings do not need thermal activation and are robust against venting. Are under testing in SPS

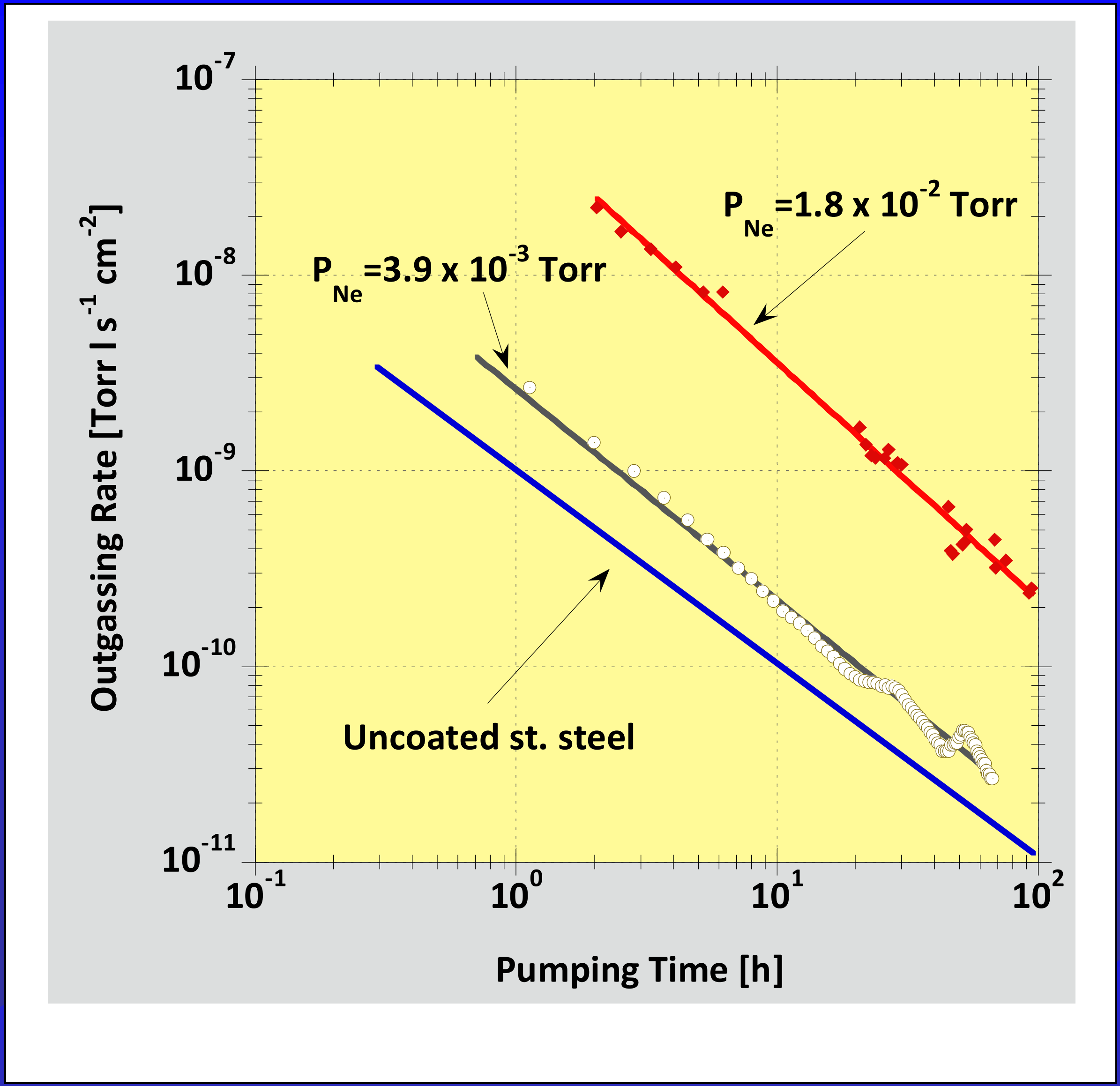
Acknowledgments:

A.Ashraf
E.Benedetto
S.Calatroni
P.Chiggiato
P.Costa Pinto
B.Henrist
H.Neupert
G.Rumolo
E.Shaposhnikova
Ch.Yin-Vallgren
I.Wevers

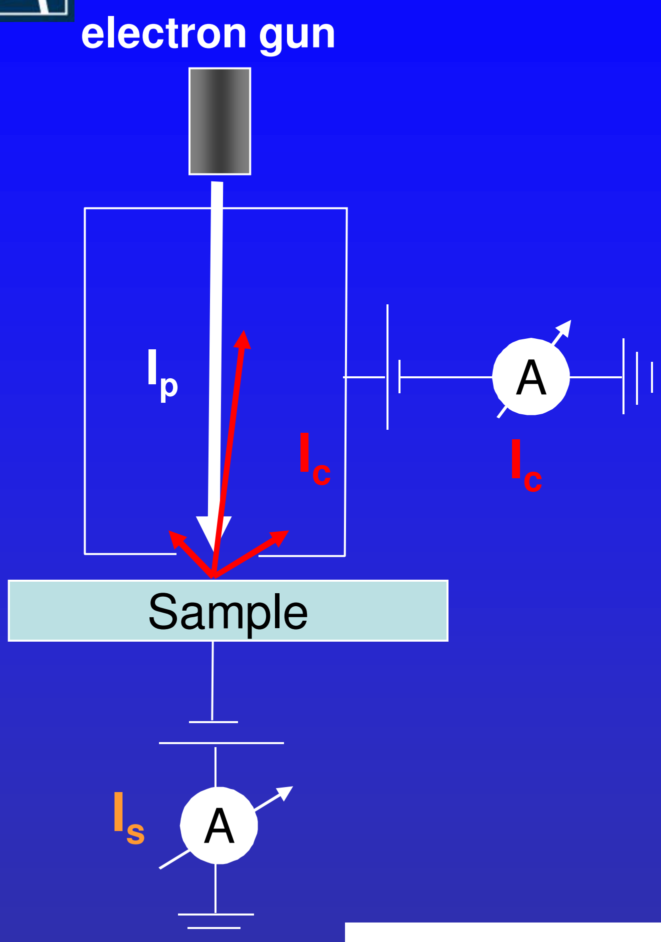
CesrTa team

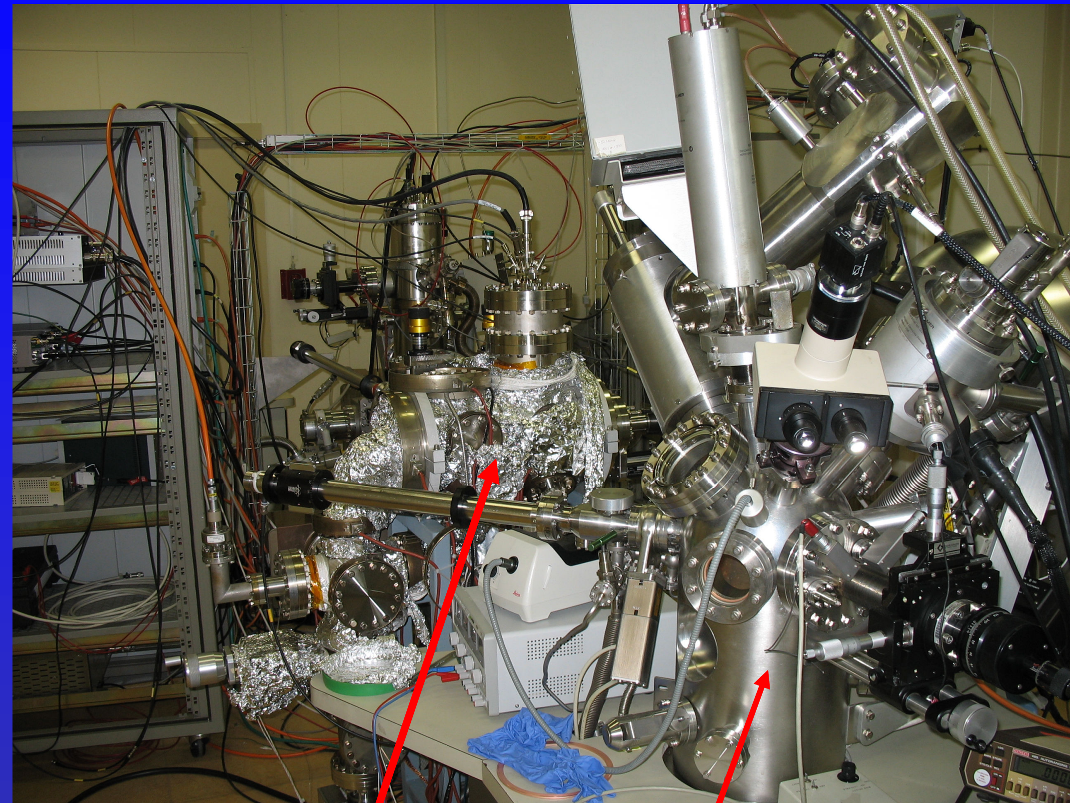


UHV compatibility: pumpdown curve



Measurement of SEY

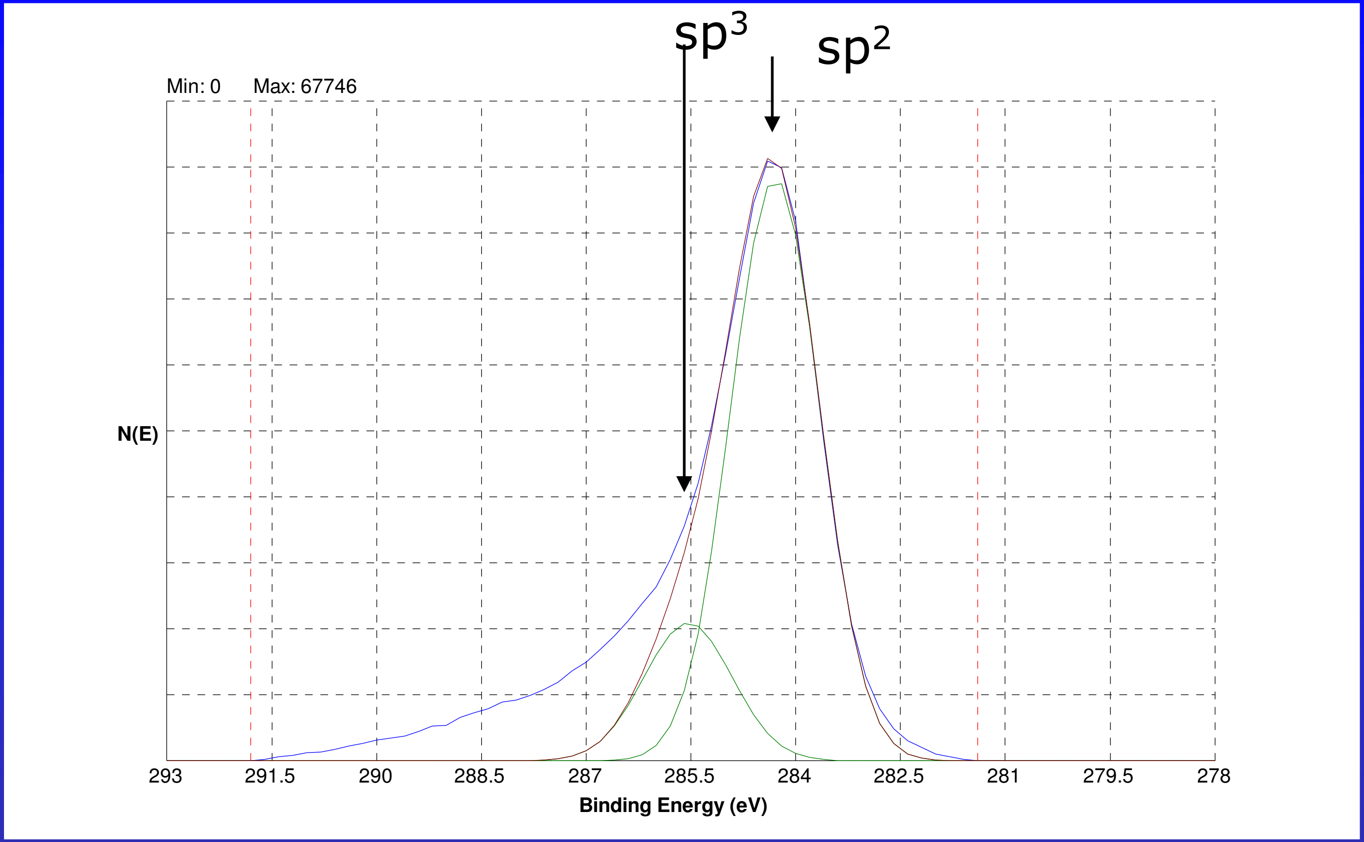




$$I_p = I_s + I_c$$

$$\delta = I_c / (I_s + I_c)$$

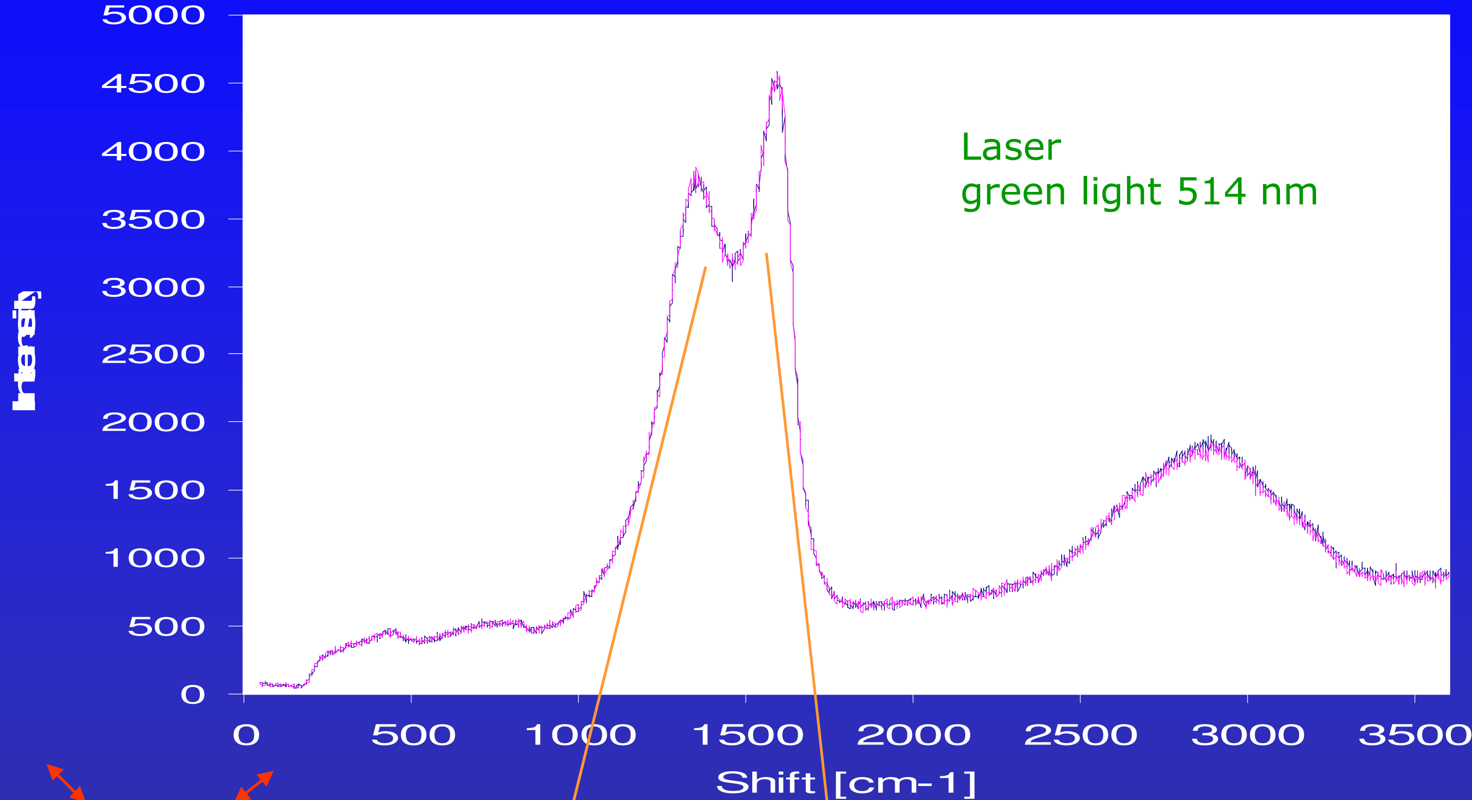
C1s lineshape

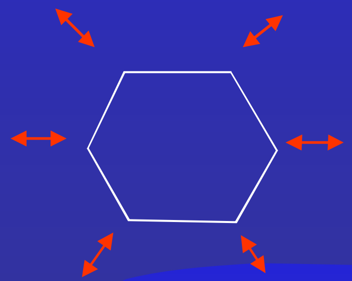


-Peaks as from Jackson and Nuzzo: 284.3eV +/-0.1 eV and 285.5 eV+/-0.1 , FWHM 1.5eV for both peaks, interpreted as sp^2 and sp^3

$\Rightarrow$ 11-27% of the intensity in the sp^3 peak in a-C (no correlation observed with SEY values) $\Rightarrow$ mainly sp^2

Structural order: Raman spectroscopy
(data from University of Cambridge UK, A.Ferrari et al)





D peak,
breathing mode
(disorder)

G peak, chain stretching (Graphite)

→ Extract ratio D/G and G position

Powder, dust and particles: optical particle counter

2 StSt tubes measured in clean-room

1 coated with carbon

1 reference (in the lab. with plastic covers)

both measured again in clean-room

-No difference in particles between coated and uncoated tube

-No increase after shaking and gentle hammering of the chamber

-No increase for a chamber left in air for months

-Same result for size above 5 µm