Surface treatments for e-cloud mitigation

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AT-VAC, TS-MME, AB/OP-RF-BI-ABP

Constraints for CLIC damping rings...and similar

The constraints in order to preserve beam quality are the following:

For e-cloud, low secondary electron yield (SEY):
$\delta_{max} < 1.3$

For the pressure:
dynamic pressure below 10^{-10} mbar

NB: investigations in progress for the SPS to provide injection of nominal LHC luminosity and avoid electron cloud which would:

- increase the pressure by electron stimulated desorption
- provoke emittance growth
- provoke beam instability (head-tail, bunch-to-bunch coupling)
- interfere with the electrodes of beam monitors
- the threshold for electron cloud is also at $\delta max=1.3$ (25 ns spacing)

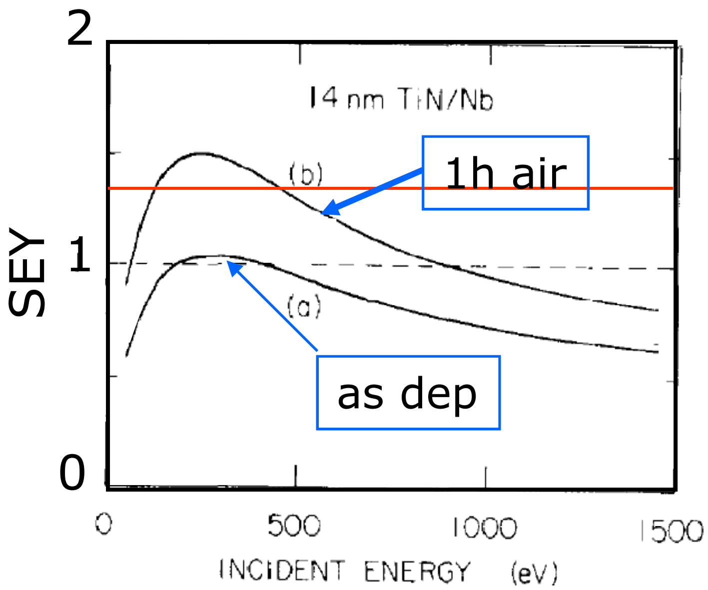
More on this in: http://paf-spsu.web.cern.ch/paf-spsu/default.htm by the SPSU team chaired by E.Shaposhnikova

Surfaces with initially low SEY: effect of air exposure (without bakeout)

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

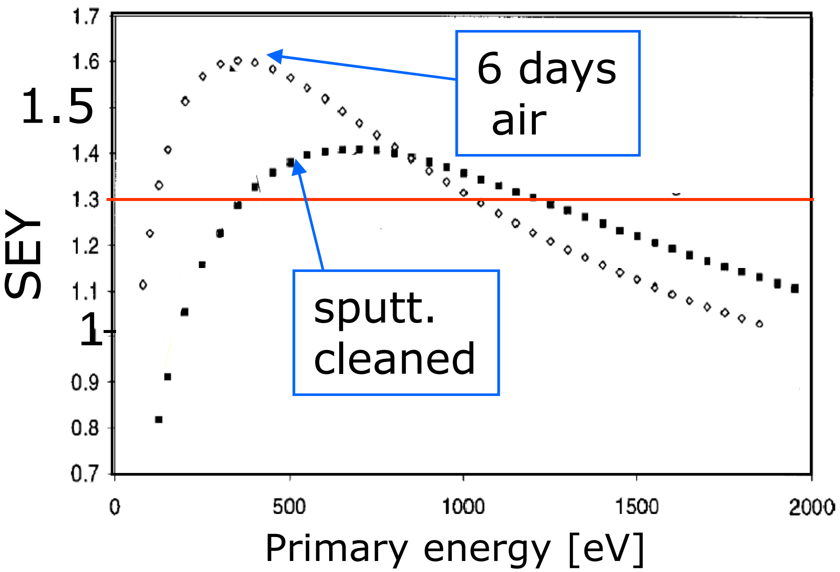
Upon air exposure the TiN yield increases to **δmax** = 1.5-2.5 and the one of copper to δmax =1.6-2.6

TiN



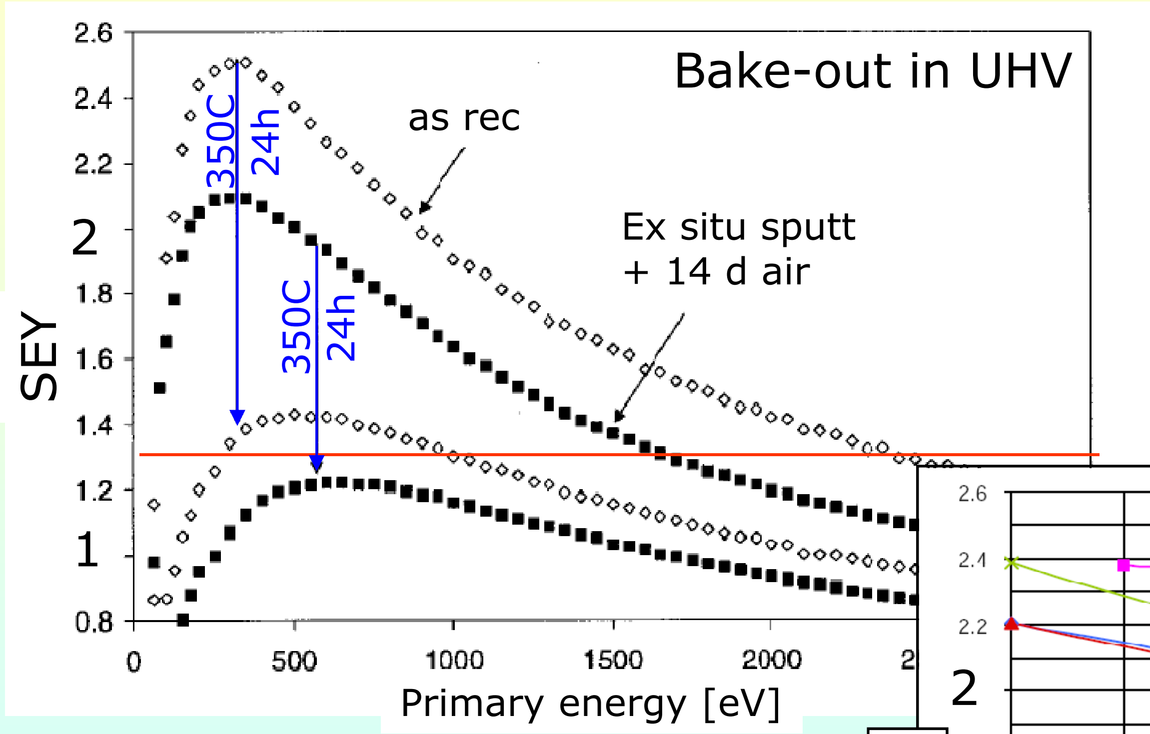
(E.L.Garwin et al. 1987)

Copper



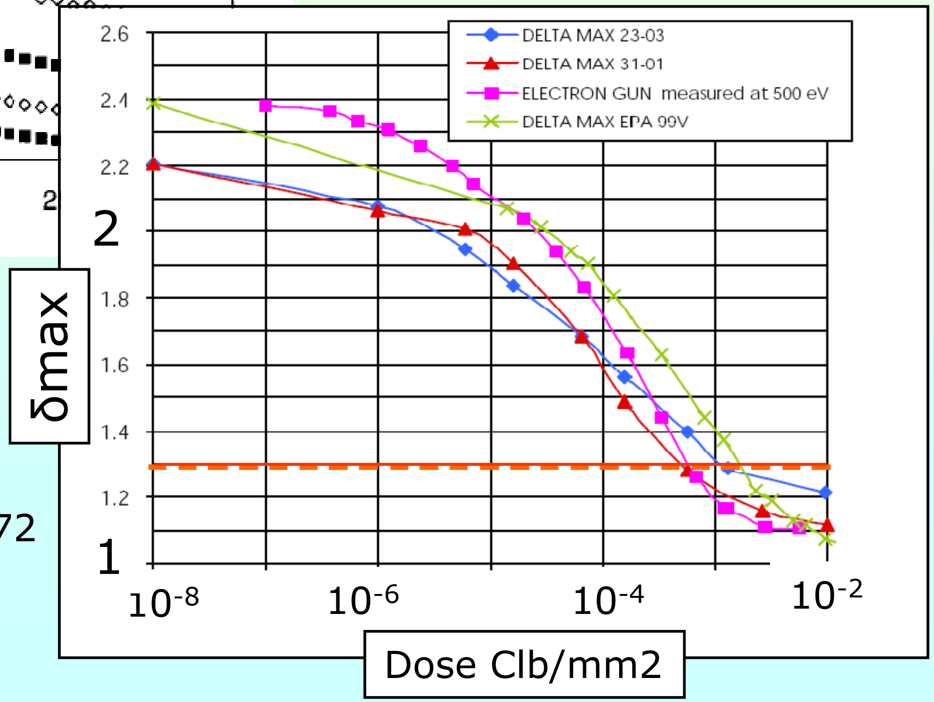
(Bojko, Henrist, Hilleret, Scheuerlein, 2000)

What can we gain with bakeout and conditioning?
Ex: OFE-Copper



Bojko, Henrist, Hilleret,
Scheuerlein JVST A18,972 2000

Conditioning
with electrons



LHC Proj. rept. 472
V.Baglin et al.

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Two cases to be discussed:

bakeable vacuum system

→ NEG coatings

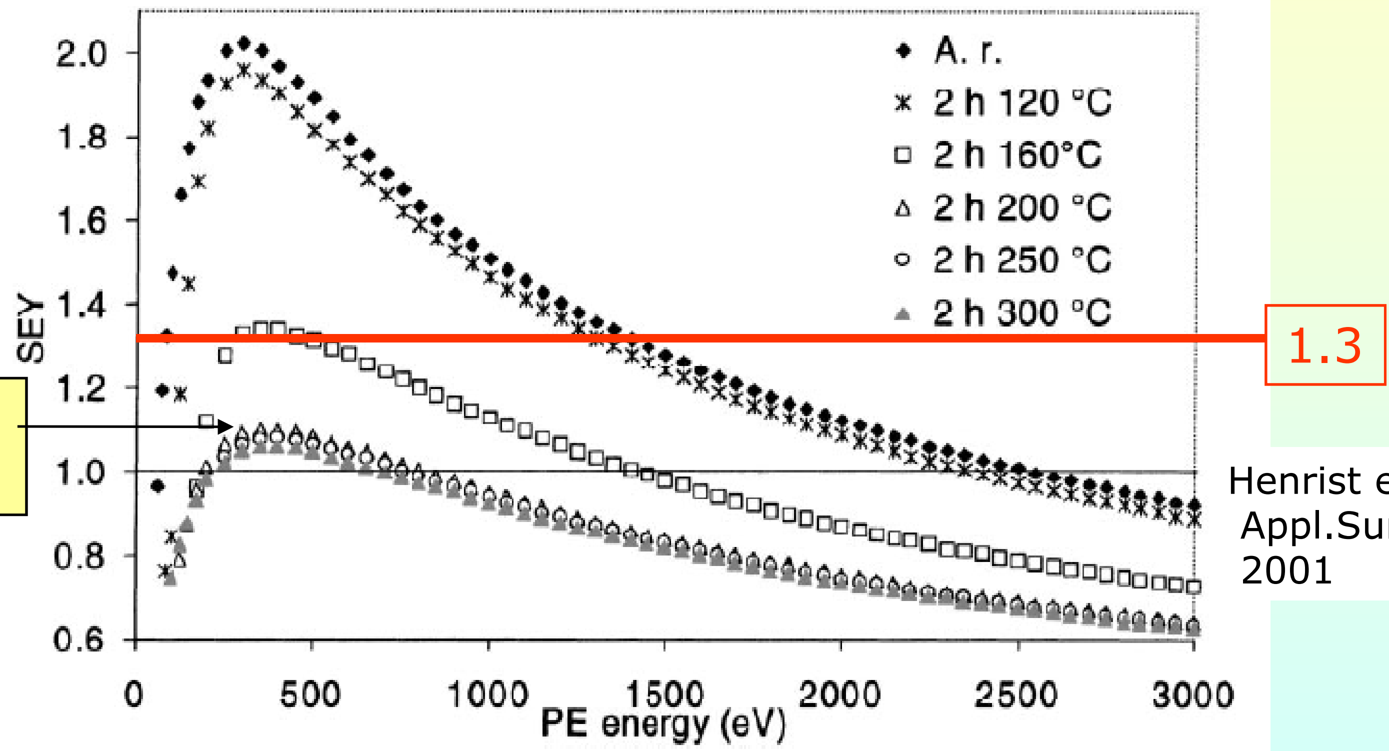
non-bakeable vacuum system

→ -Low SEY smooth coatings
-Macroscopically rough surfaces (not discussed here, can be used as substrate for low SEY coating)

SEY: Non Evaporable Getter (NEG) coatings

TiZrV NEG can provide a surface with sufficiently low δmax :

activation at 200C, 2h

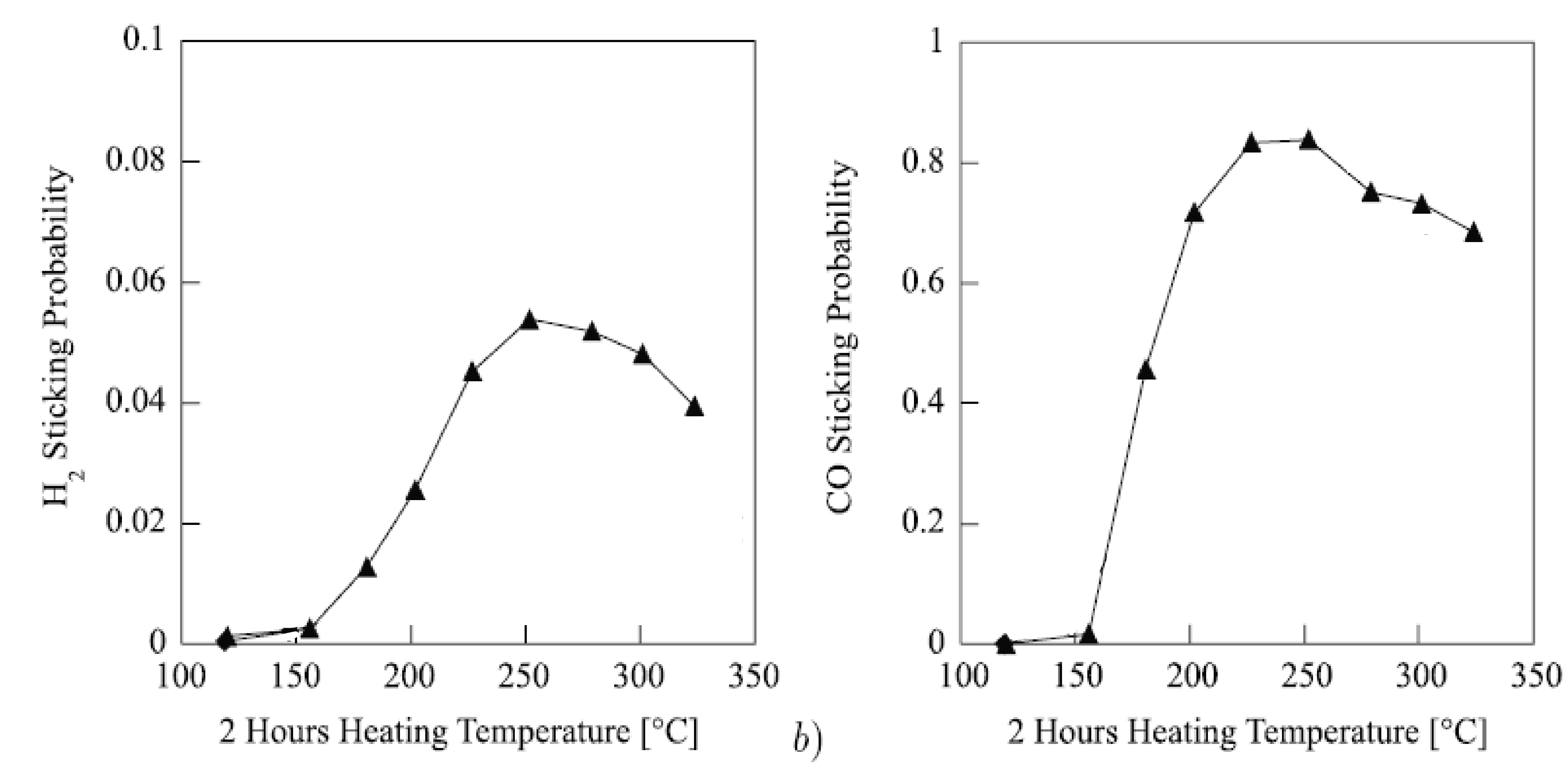


Henrist et al. Appl.Surf.Sci, 2001

-Thermal activation is necessary: 2h at 200C or 24h at 180C
-data for 7 re-activations after air-venting do not indicate e-activity in SPS (A.Rossi, CERN report 2005)
-Already coated by magnetron sputtering LHC long straight sections (6 km, more than 1000 chambers) to provide pumping

Bakeable system

Pumping action of NEG: sticking probability of H_2 and CO upon thermal activation

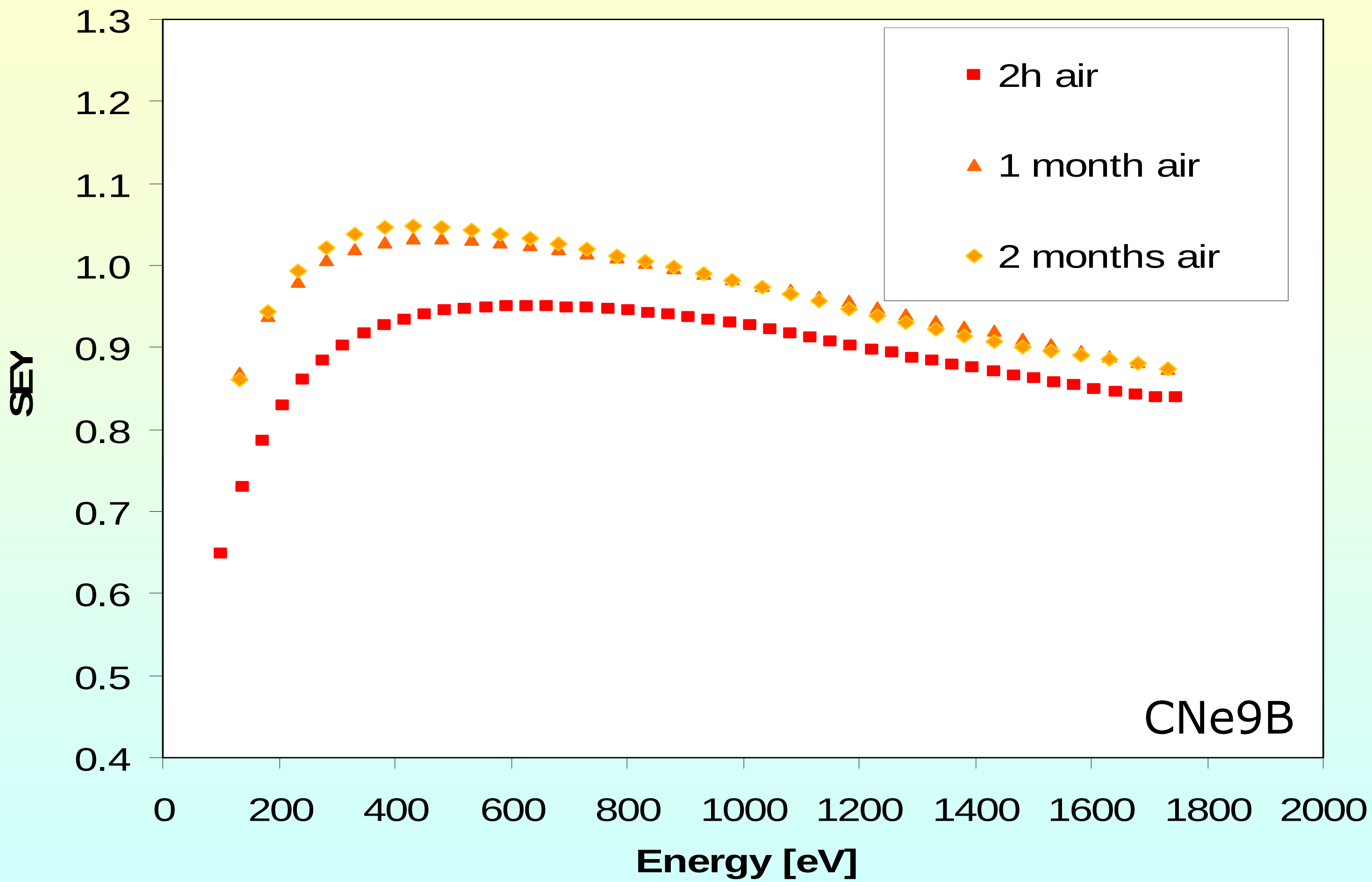


-the pumping speed decreases as 1/n (n=number of venting/activation) and recovers by heating at higher T

Non-Bakeable sys.

Non-Bakeable sys.

Amorphous carbon a-C coating: low SEY without bake



-a-C coating on copper deposited by magnetron sputtering (Ne)
-thickness from 60-1300nm has been successfully tested

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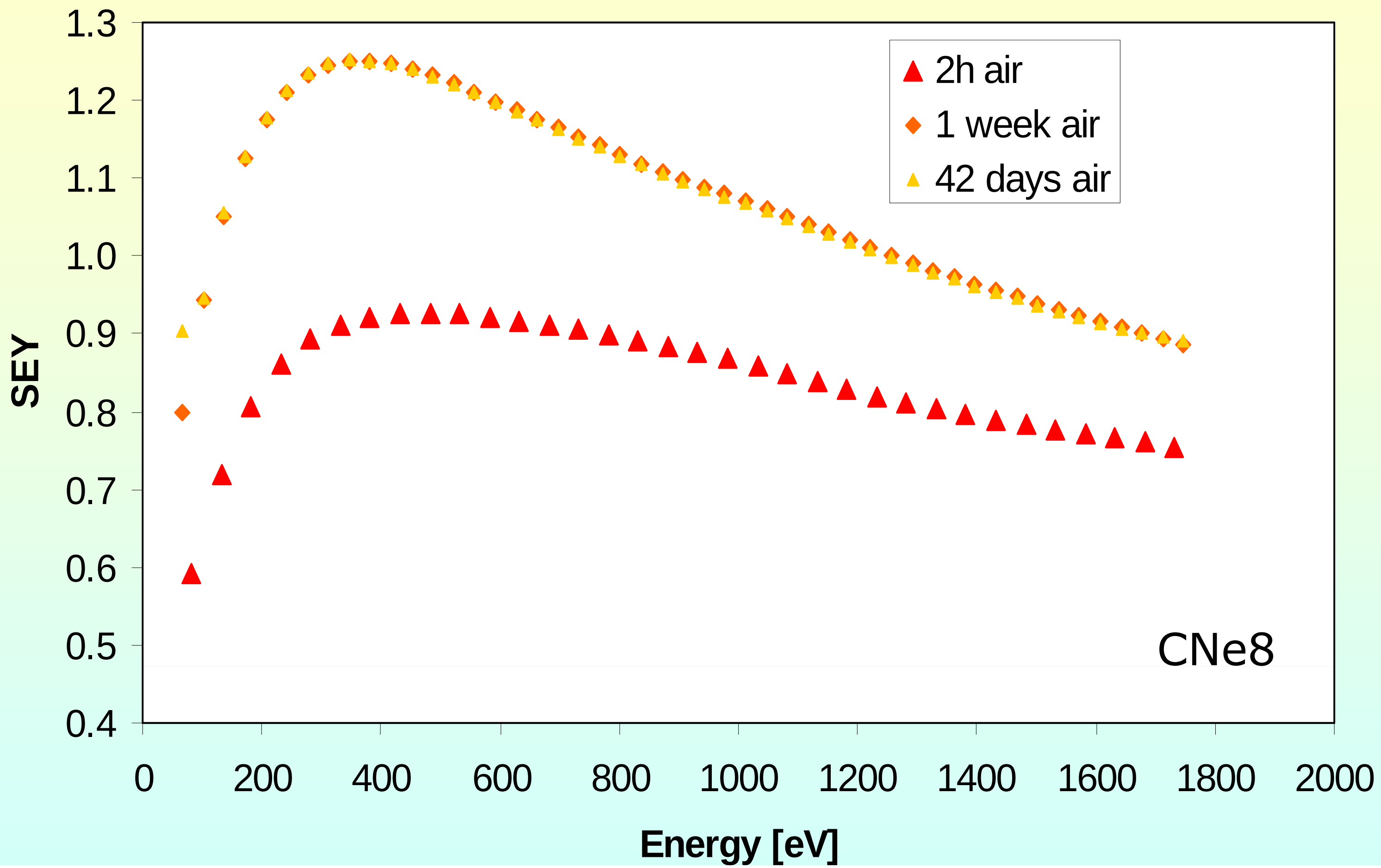
Amorphous carbon coating: “aging” in air



-The differences in “aging” in air are still under investigation
-It is important to specify a maximum air exposure time for the application!
-Can partly recover by bake 2h at 160C

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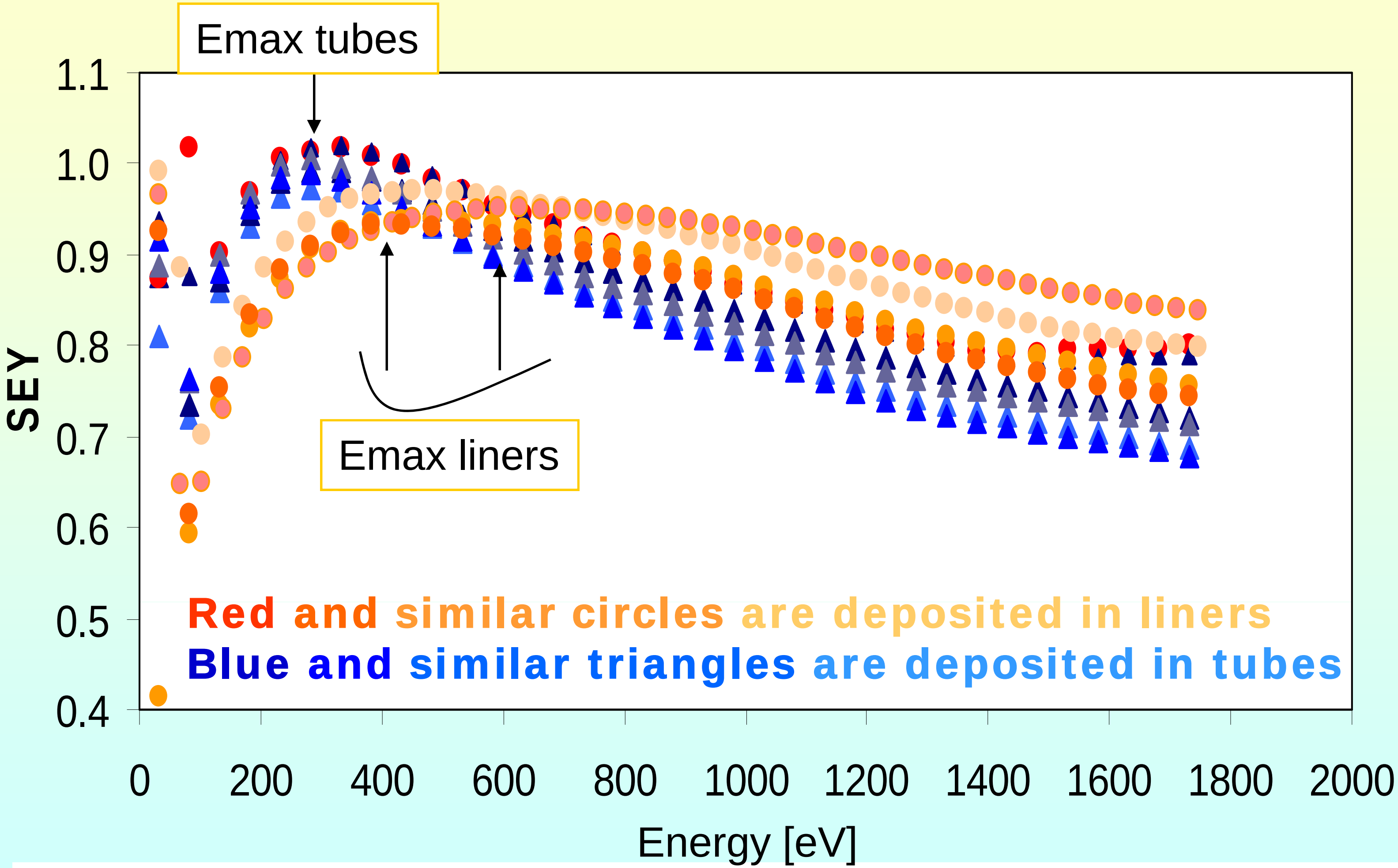
SEY curve dependence on sputtering configuration



-possible differences in substrate T during deposition, atoms energy, angle of arrival on the substrate, (nano-)roughness……..

-related to differences in aging

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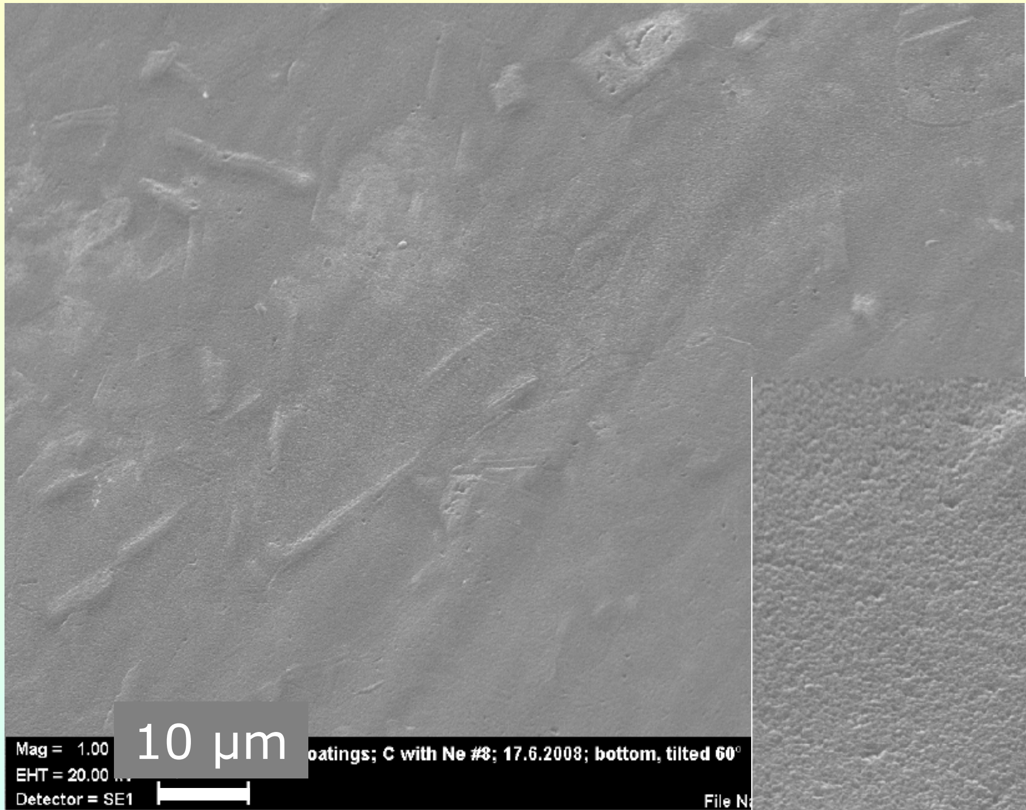
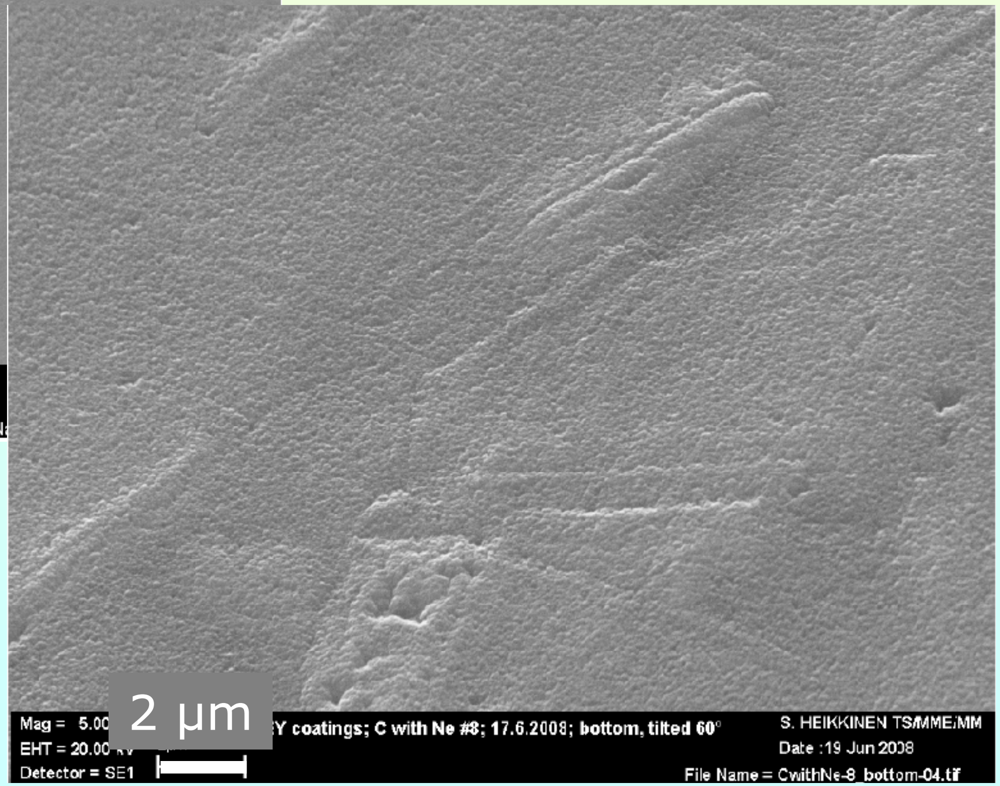
Non-Bakeable sys.

SEM images of CNe8



Good adhesion, no loose particles



Courtesy of S.Heikkinen

Powder dust and particles: not an issue

Two identical SS tubes measured in clean room TUBE + REF

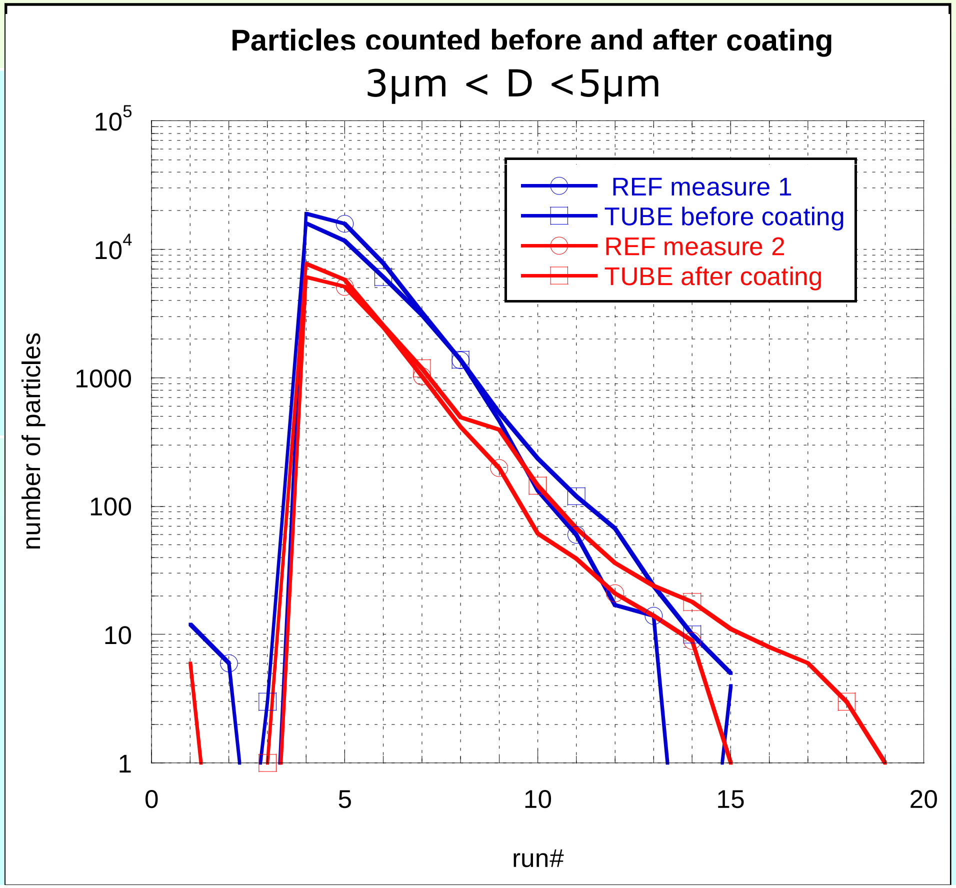
TUBE coated with carbon

REF remains in the coating lab. (closed with plastic covers)

TUBE + REF measured again in the clean room

Measured with an optical particle counter

-Same result for size above 5 µm
-No increase after gentle hammering of the chamber



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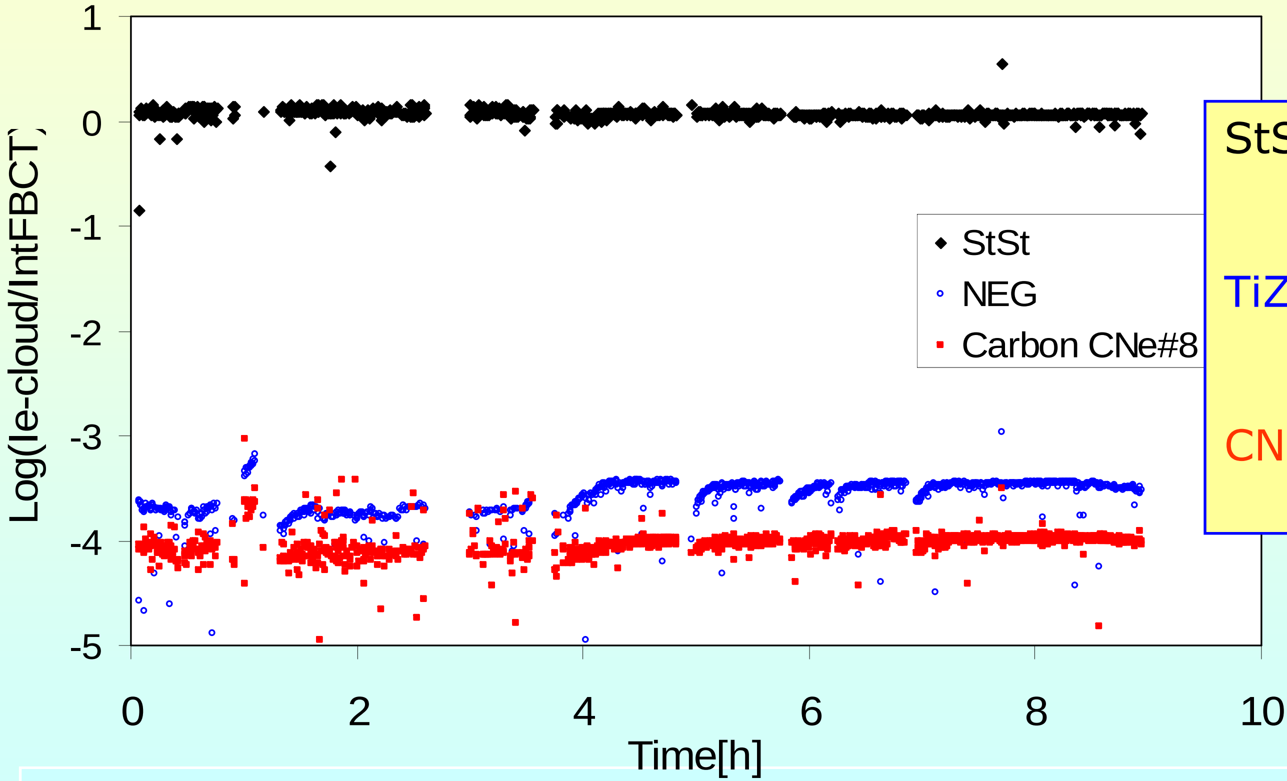
Non-Bakeable sys.

Strip detector in SPS, MD run w28

Set-up: a-C coated liner with strip detector in dipole magnet with 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 SS, consistent with measured δmax

-same result for liner exposed 15 days to air (SPS MD run w33) or 2 months in the SPS vacuum (MD run week 41)

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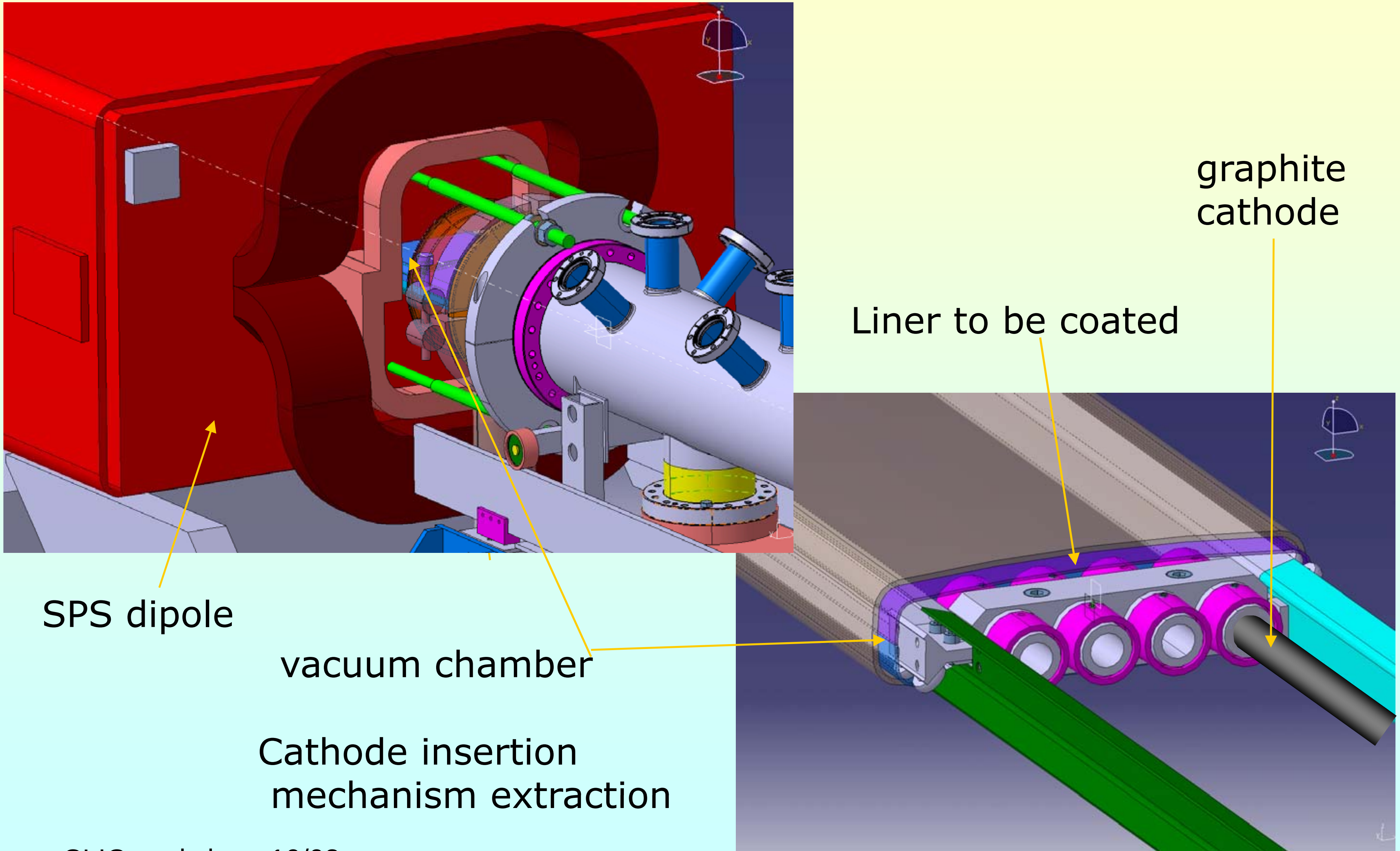
Preparation for SPS magnet prototype coating



Conclusions:

Bakeable system

-**NEG** is a valid solution for $\delta max<1.3$ if the system can be baked at 180C or higher

-the evolution after many venting cycles should be studied

-NEG provides pumping

-it is also conceivable to develop a coating with lower activation T

Non-bakeable system

-**a-C coating** provides $\delta max <= 1$ even after 2h air exposure

-aging of the coating in air is variable in the series of coatings produced so far, but $\delta max<1.3$ for 1 week air exposure

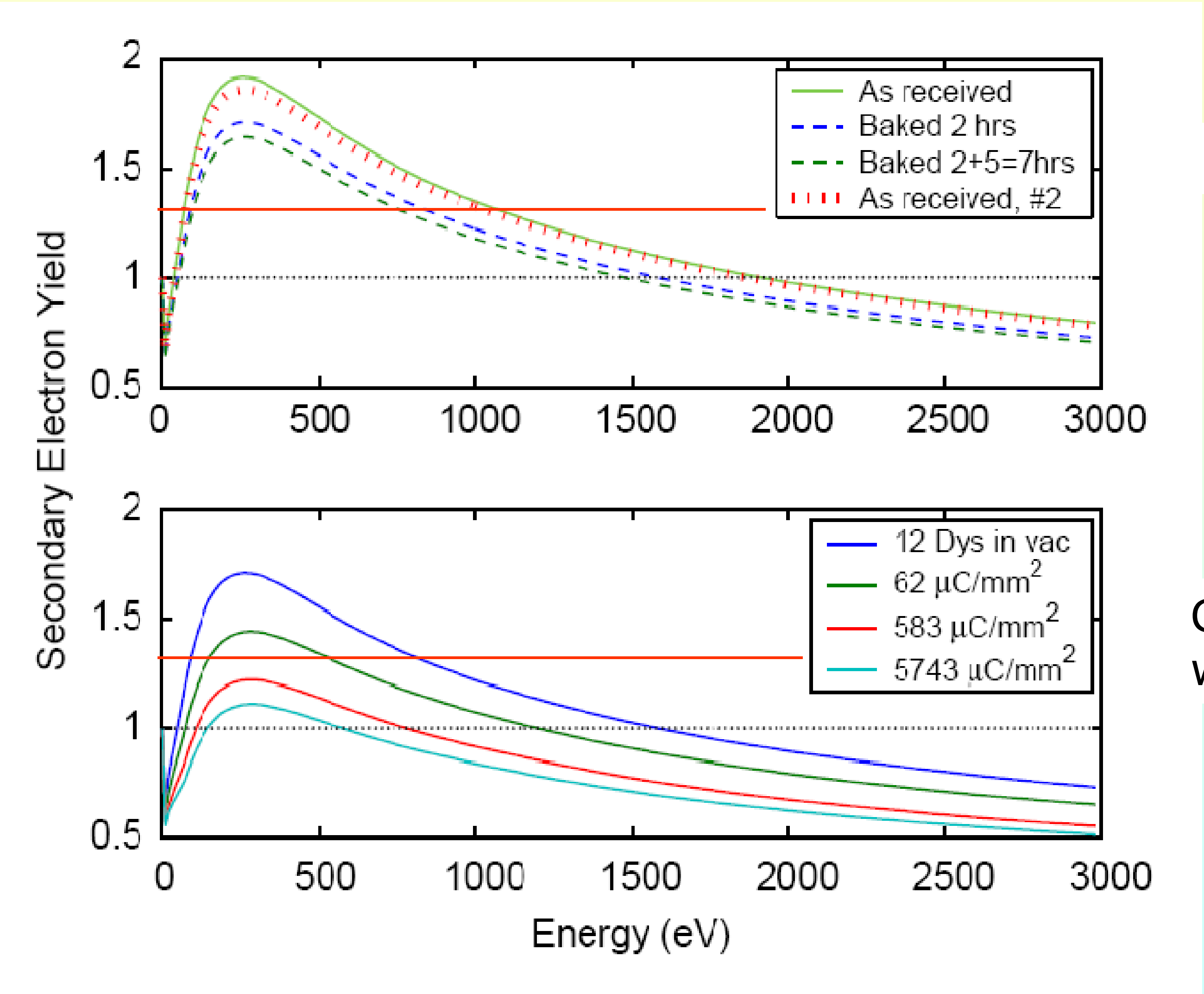
-after 2 months exposure in the SPS vacuum or 15 days air exposure the coatings do not show increase of e-cloud activity

-pumpdown curves can be as good as for stainless steel, depending on the deposition parameters, ESD and PSD measurements in progress (lab and ESRF)

-no particles and peel-off

-to be characterized for impedance and photoyield

What can we gain with bakeout and conditioning? Ex: TiN



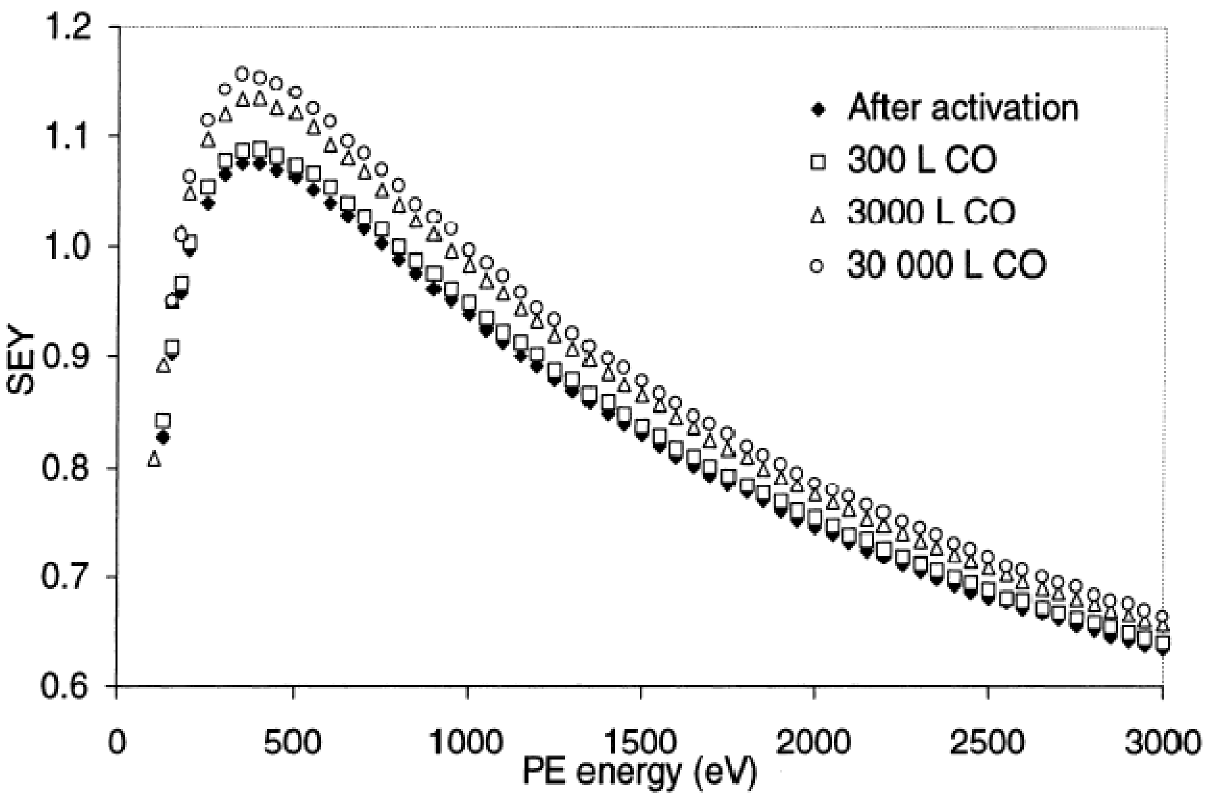
Bake 150C

Conditioning with electrons

Le Pimpec et al. NIM A551, 187, (2005)

Bakeable system

Effect of surface saturation by CO:



Henrist et al. Appl.Surf.Sci, 2001

-The δmax remains below 1.3 even after surface saturation with CO (300 L correspond to 7 days at 5×10^{-10} mbar)

-Aging in air is less a concern, since re-activation for more than 20 times is possible

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E-cloud data displayed as :

Int e-cloud current/Int FBCT =

$$= \frac{\text{current, integrated over all strips, integrated over a supercycle}}{\text{FBCT signal, integrated over a supercycle}}$$

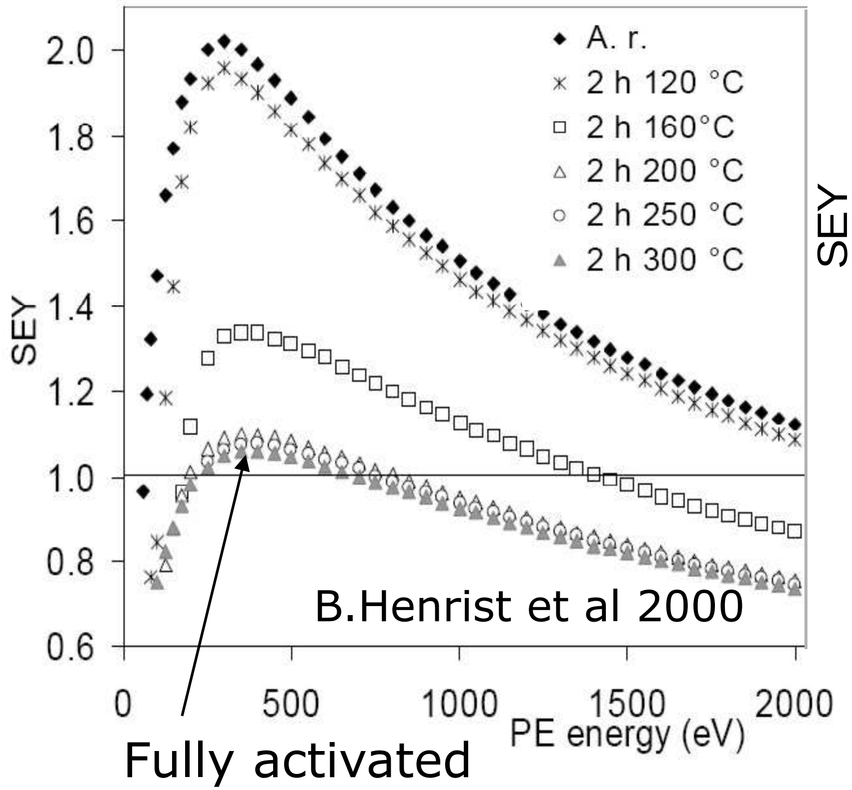
Dose calculated as:

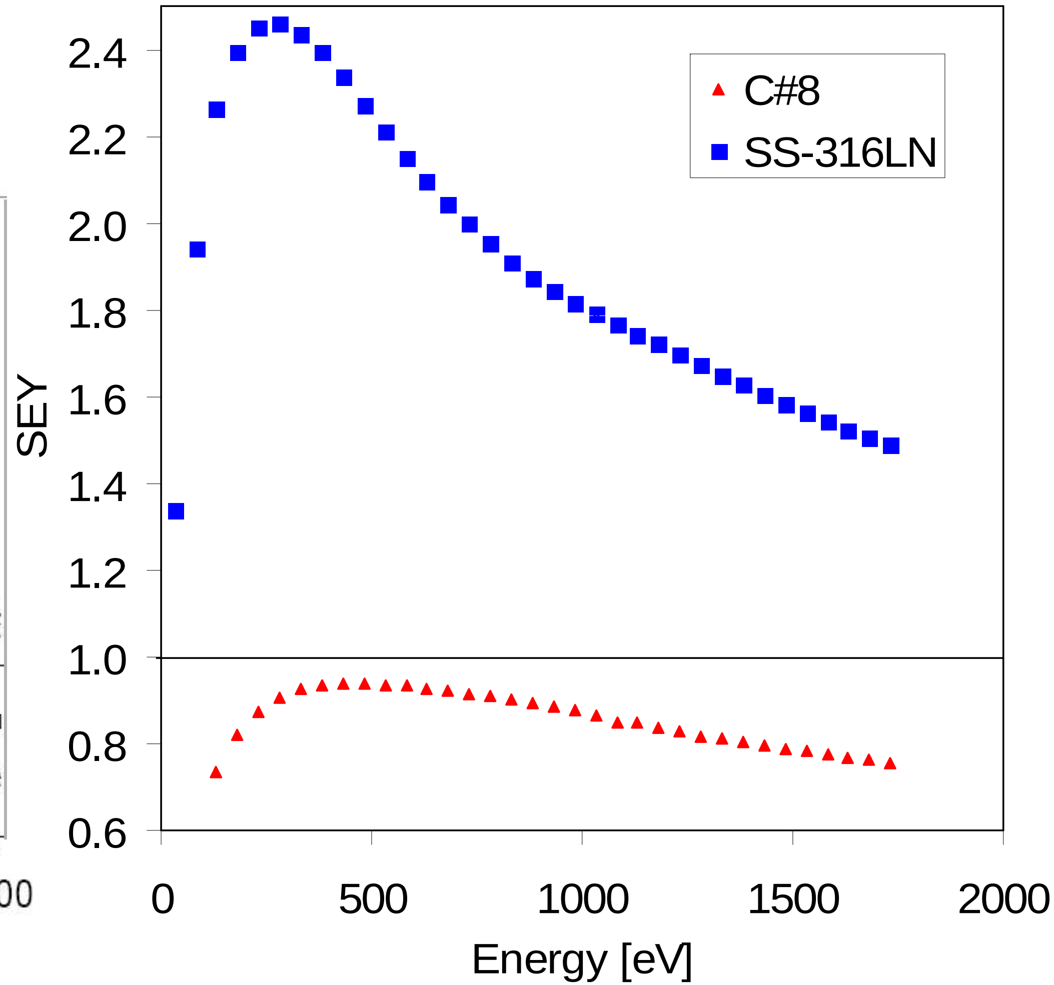
Dose [nC]= Current [nA] integrated over all strips, integrated over time and summed over the supercycles

NB: measured currents taken without consideration of transmission factor of the “grid” (7%)

SEY of the inserted materials

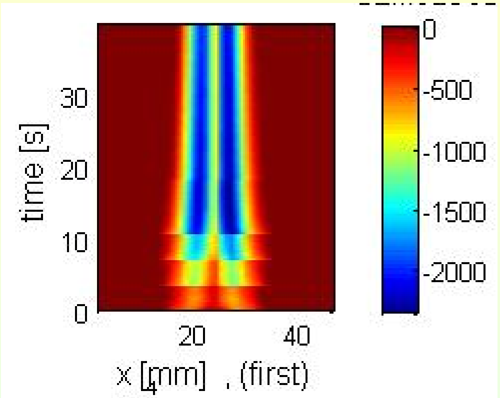
TiZrV-NEG, δmax=1.1 fully activated
C#4, (scrub. run), δmax~1.4 for 2h air exp. (measurements at 500eV only)
C#8,(MD) δmax=0.95 for 2h air exp.
SS, δmax=2.5 for 2h air exp.

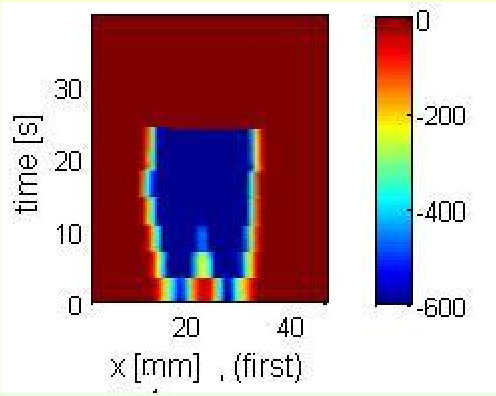




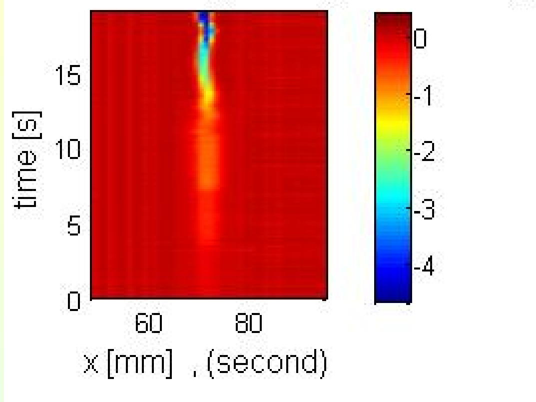
Stripes and lines of both runs

scrub **SS** MD

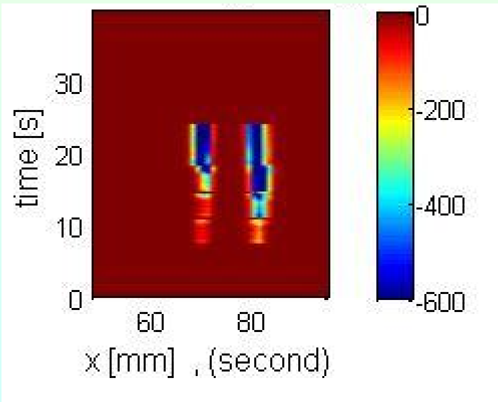




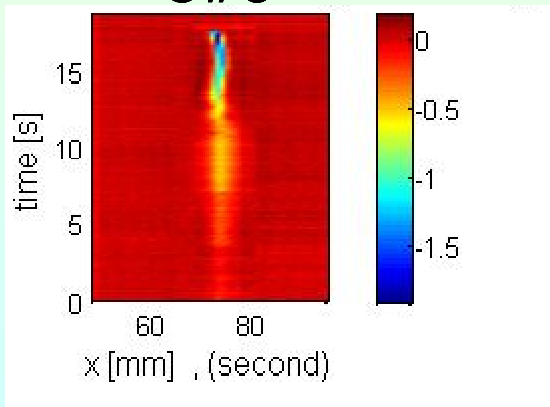
NEG



C#4



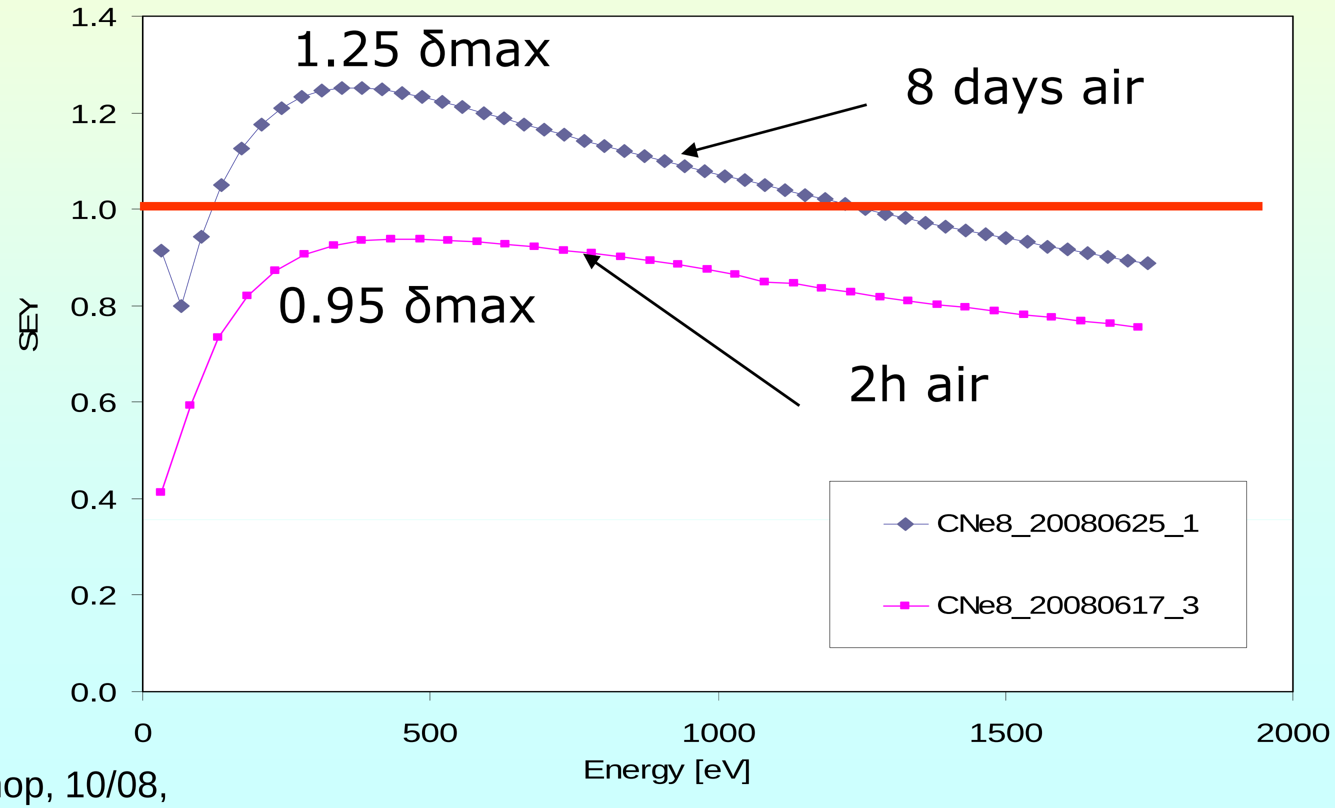
C#8



The single stripe could be just due to ionization of residual gas; the order of magnitude is close

Perspective and problems:

-- Characterize and reproduce the C#8 type coating
-- SEY increases upon air exposure; the kinetic of the effect is presently investigated with measurements in the lab to define a typical “allowed” exposure
-- Other remedies: possible combination of carbon with rough substrate



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