E-cloud effects in the CLIC damping rings

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for the CLIC Workshop, 15 October 2008
* thanks to the SPSU Working Team

- Introduction and damping Rings parameters
- Electron cloud in the CLIC Positron ring
  - Simulations
  - Technical solutions under investigation
- Conclusions

Updated list of parameters → last column

Damping rings' parameter evolution

- At injection:
  - $(\varepsilon_x,\varepsilon_y)=(60,1.5)\mu m$
  - $\sigma_s=10mm$
  - $\sigma_\delta=0.5\%$
- No impact to output parameters

PARAMETER	2005	2006a	2006b	2007a	2007b
energy [GeV]	2.424				
circumference [m]	360	365.2			
bunch population [E+09]	2.56+5%			5.20+5%	4.00+5%
bunch spacing [ns]	0.533			0.667	
number of bunches/train	110			311	
number of trains	4			1	
store time/train [ms]	13.3			20	
rms bunch length [mm]	1.55	1.51	1.59	1.49	1.53
rms momentum spread [%]	0.126	0.136	0.130	0.138	0.135
hor. normalized emittance [nm]	540	380	308	443	386
ver. normalized emittance [nm]	3.4	2.4	3.9	4.3	4.1
lon. normalized emittance [eV.m]	4725	5000	4982	4998	4993
(horizontal, vertical) tunes	(69.82, 34.86)	(69.82, 33.80)			
coupling [%]	0.6		0.13		
ver. dispersion invariant [µm]	0		0.248		
wiggler field [T]	1.7	2.5			
wiggler period [cm]	10	5			
energy loss/turn [MeV]	2.074	3.903			
hor./ver./lon./ damping times [ms]	2.8/2.8/1.4	1.5/1.5/0.75			
RF Voltage [MV]	2.39	4.25	4.185	4.345	4.280
number of RF cycles	2			1	
repetition rate [Hz]	150			50	
RF frequency [GHz]	1.875			1.499	

From Y. Papaphilippou, in CLIC-Parameter-WG

More parameters needed for the collective effects (I)

Description	Unit	Value
Average β_x dipoles	m	0.5
Average β_y dipoles	m	0.5
Average β_x wigglers	m	4.0
Average β_y wigglers	m	4.0
Number of bends		96
Dipole length	m	0.545
Number of wigglers		76
Wiggler length	m	2
Momentum compaction α		8.02×10^{-5}
Hor. chromaticity Q'_x		2.03
Vert. chromaticity Q'_y		-0.24

From the 2008 DR design

$\Rightarrow$ Average beta functions together with the emittances define the **average bunch transverse sizes** over tha arcs and the wigglers

$\Rightarrow$ Number and length of dipoles and wigglers define the fraction of the ring covered by those elements and therefore a **scaling factor for the e-cloud density** to be used in instability simulations

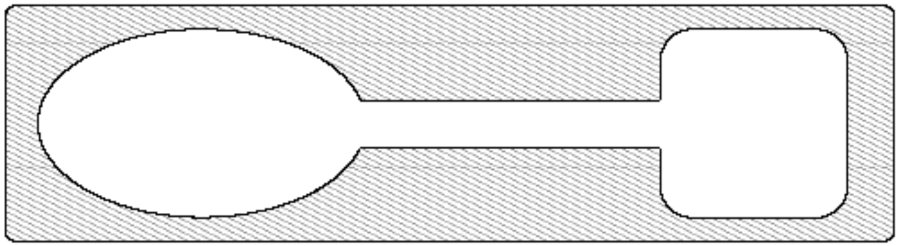
More parameters needed for the collective effects (II)

Vacuum chamber dimensions

	CLIC DR	
	Arc	Wiggler
horizontal semi axis /mm	22	16
vertical semi axis /mm	18	9
antechamber-slot half height		3
chamber area /cm^2	12.4	5.8

D. Schulte, R. Wanzenberg, F. Zimmermann, in Proceed. ECLOUD'04

Design of the vacuum chamber with antechamber in the arcs (it has double sided ante-chamber in the wigglers)



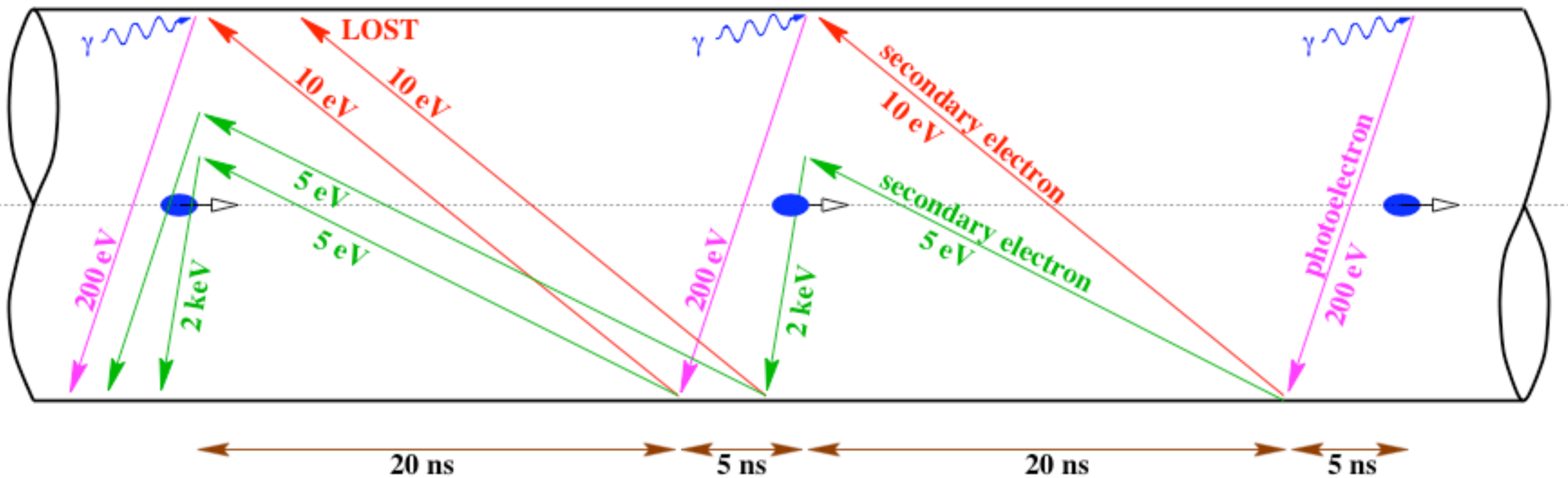
The antechamber absorbs 90 to 99.9% of the synchrotron radiation and gives a photoemission yield in the main chamber 10 to 1000 times lower than in a design w/o antechamber

Photoemission yields

	CLIC DR	
	Arc	Wiggler
N_0 /10^{10}	0.5	0.5
ρ/m	8.67	4.58
dN_γ/dz [/e^+/m]	5.764	10.903
$Y_{\rm eff}$	0.01	0.01
dN_{e^-}/dz [/e^+/m]	0.0576	0.109
$dN_{e^-}/dz^{\rm ion}$ [/e^+/m]	4×10^{-8}	4×10^{-8}

Electron cloud build up: a multi-bunch process...

$$\frac{h_y^2}{N_b r_e L_{sep}} = 1$$



Principle of the multi-bunch multipacting.

⇒ Electrons can be generated via photoemission, rest gas ionization or beam loss at the chamber walls. They then multiply due to the seconday emission process

Effects of the electron cloud on the beam:

Tune shift

The tune increases along a train of positively charged particle bunches because the bunches at the tail of the train feel the strong focusing effect of the electron cloud formed by the previous bunches.

Electron cloud instability in rings

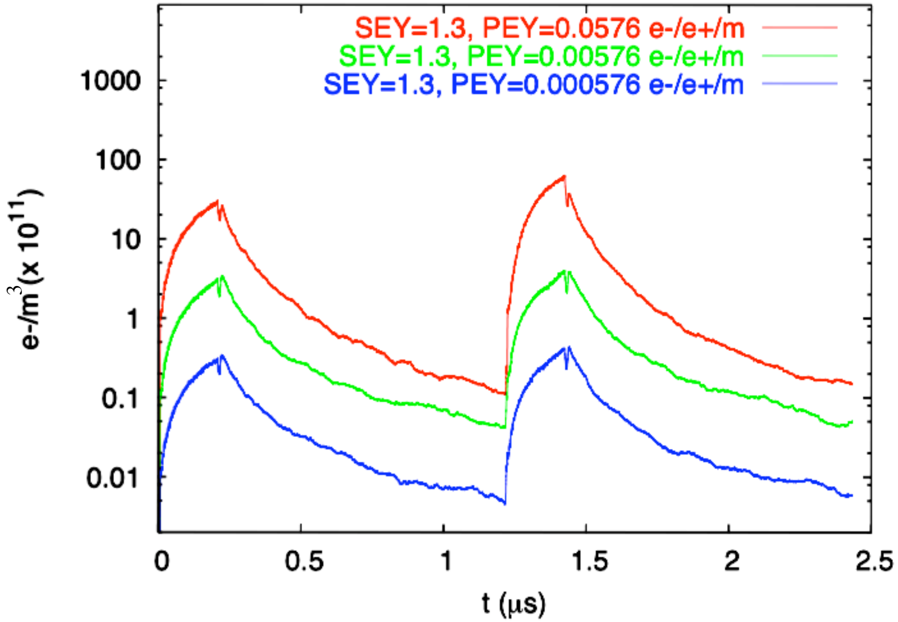
⇒ Coupled bunch phenomenon: the motion of subsequent bunches is coupled through the electron cloud and the amplitude of the centroid motion can grow.

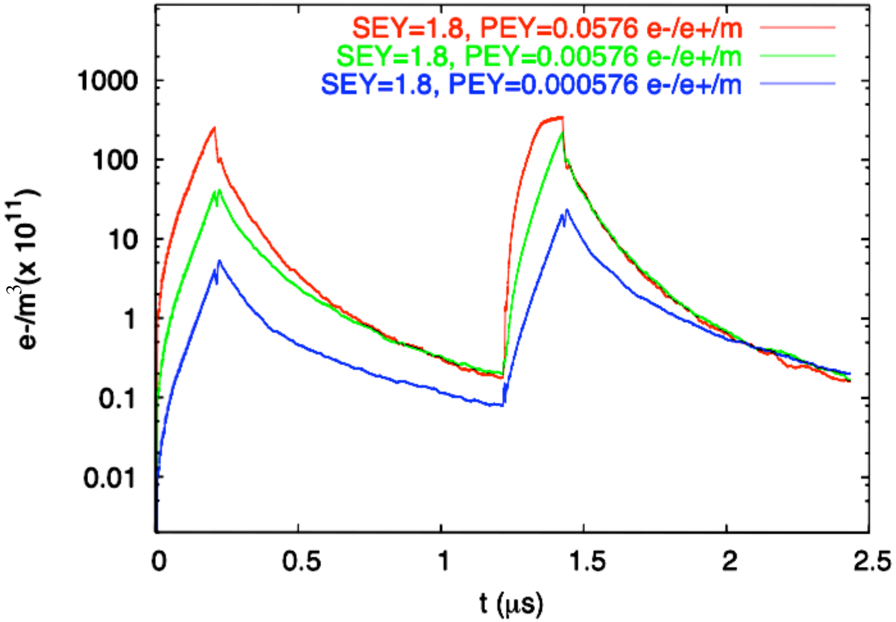
⇒ Single bunch phenomenon: the motion of head and tail of a single bunch can be coupled through an electron cloud and give rise to an instability

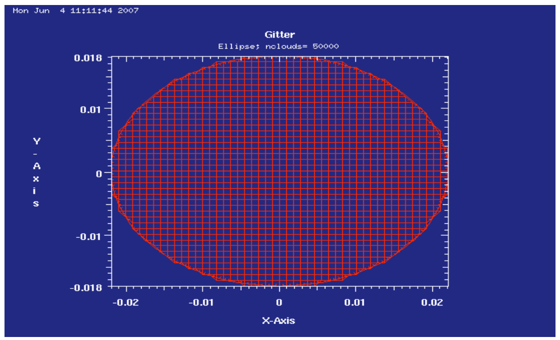
Tune shift along the train as well as instabilities affecting only the last bunches of long trains have been observed in several machines (SPS, KEKB-LER, Cesr-TA), clearly pointing to the electron cloud as source of these phenomena.

Electron cloud build up in the arcs (simulations with Faktor2)

Central electron density in a radius of $5\sigma_x$ x $5\sigma_y$





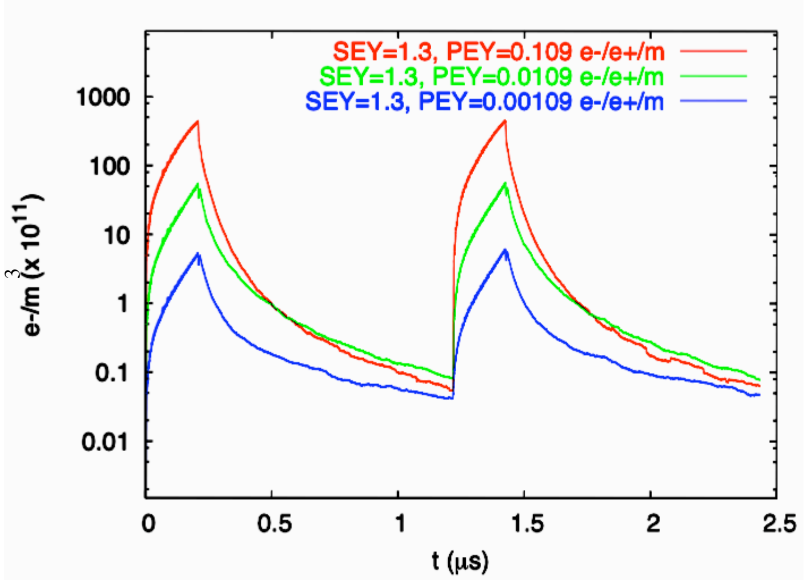


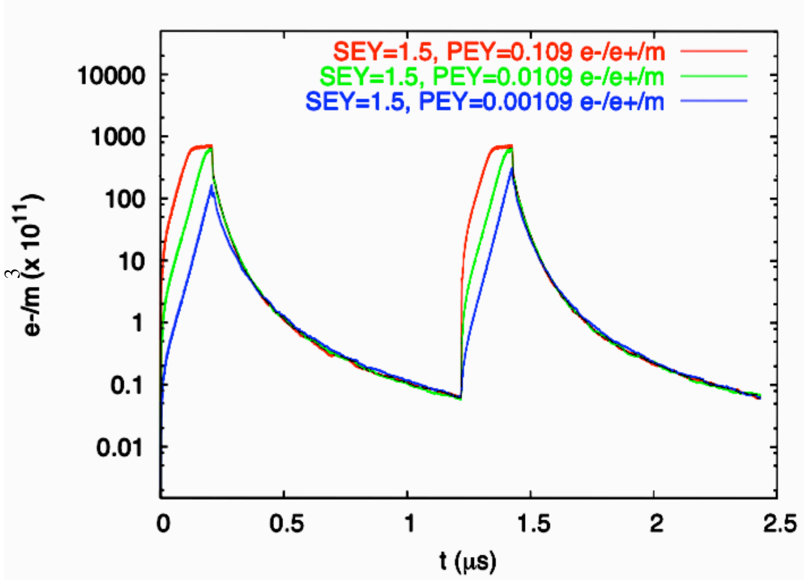
→ Low maximum SEY does not cause high density electron cloud build up

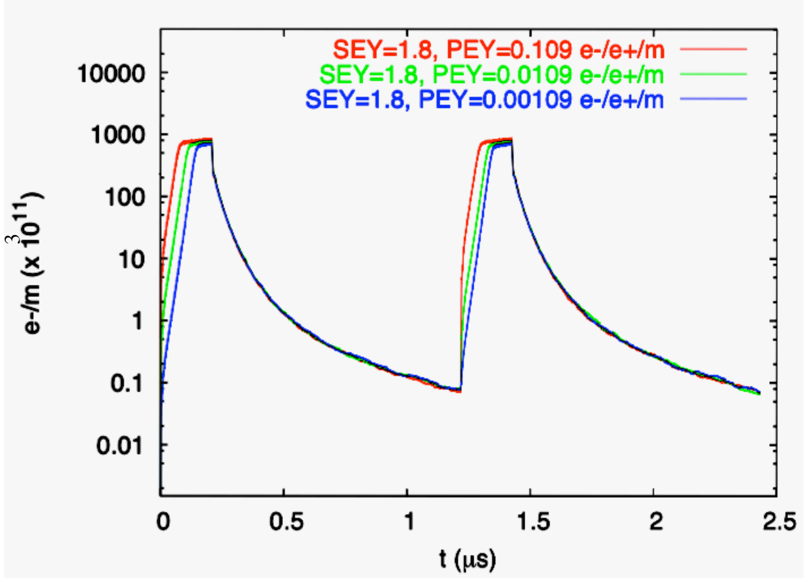
→ High maximum SEY causes exponential rise, which can saturate over few turns if the PEY is also sufficiently high

Electron cloud build up in the wigglers (simulations with Faktor2)

Central densities for different PEYs and SEYs







→ The electron cloud in the wigglers can have high density values if

- ✓ The PEY is high enough (i.e., more than 0.01% of the produced radiation is not absorbed by an antechamber or by special absorbers), even if the SEY is low
- ✓ The SEY is above 1.3, independently of the PEY

Summary of the density values obtained from build up simulations

Chamber	PEY	SEY	10^{12} e^-/m^3
Dipole chamber	0.000576	1.3	0.04
	0.000576	1.8	2
	0.0576	1.3	7
	0.0576	1.8	40
Wiggler chamber	0.00109	1.3	0.6
	0.109	1.3	45
	0.109	1.5	70
	0.109	1.8	80

For these values there is basically a negligible electron cloud

Here the values do not change even with a lower PEY

To model an integrated effect over one turn, these values have to be scaled by:

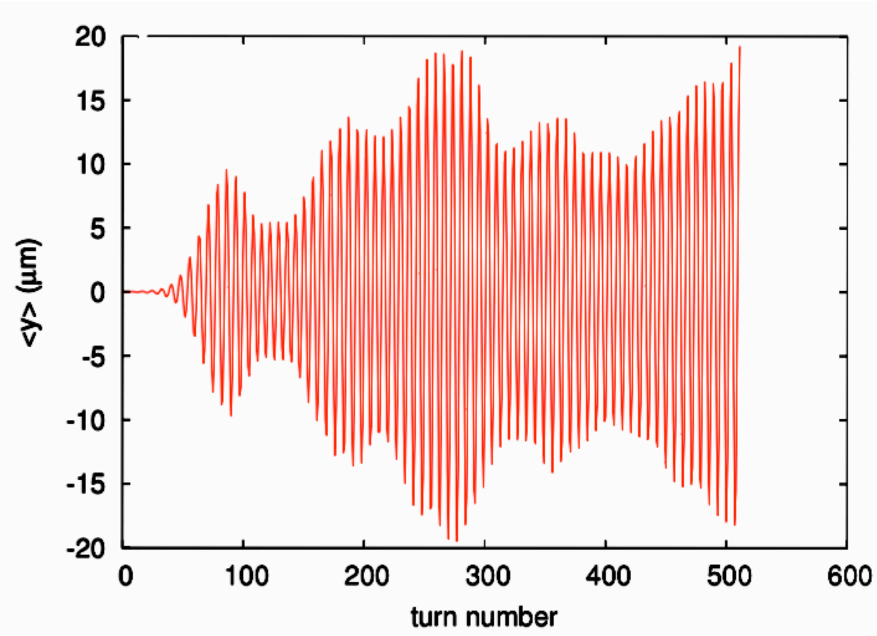
- **Wigglers** $\Rightarrow$ (total wiggler length)/circumference = (76 x 2)/365 = **0.41**
- **Arcs** $\Rightarrow$ (total arc length)/circumference = (96 x 0.545)/365 = **0.143**

Instability simulations to check beam stability (simulations done with HEADTAIL)

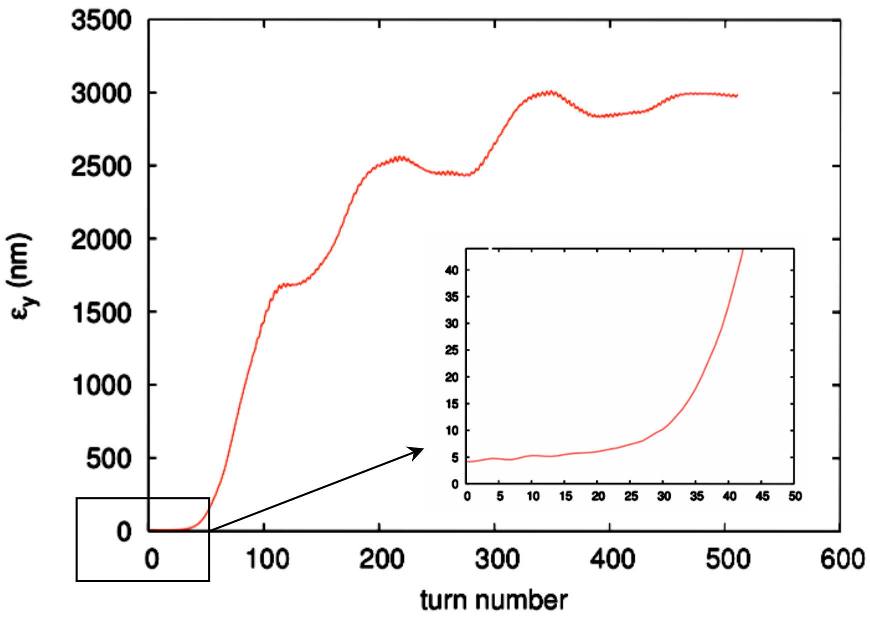
→ In case of electron cloud build up, we assume these density values in arcs and wigglers:

$\rho_{wig} = 1.8 \times 10^{13}\ m^{-3}$ $\rho_{dip} = 3 \times 10^{11}\ m^{-3}$

→ The beam is strongly unstable



*** Vertical centroid motion**



*** Vertical emittance evolution**

Against the electron cloud.....

→ If there is electron cloud in the CLIC-DR, the beam becomes unstable!

- o Conventional feedback systems cannot damp this instability (wider band needed)
- o It is necessary to find techniques against the formation of the electron cloud

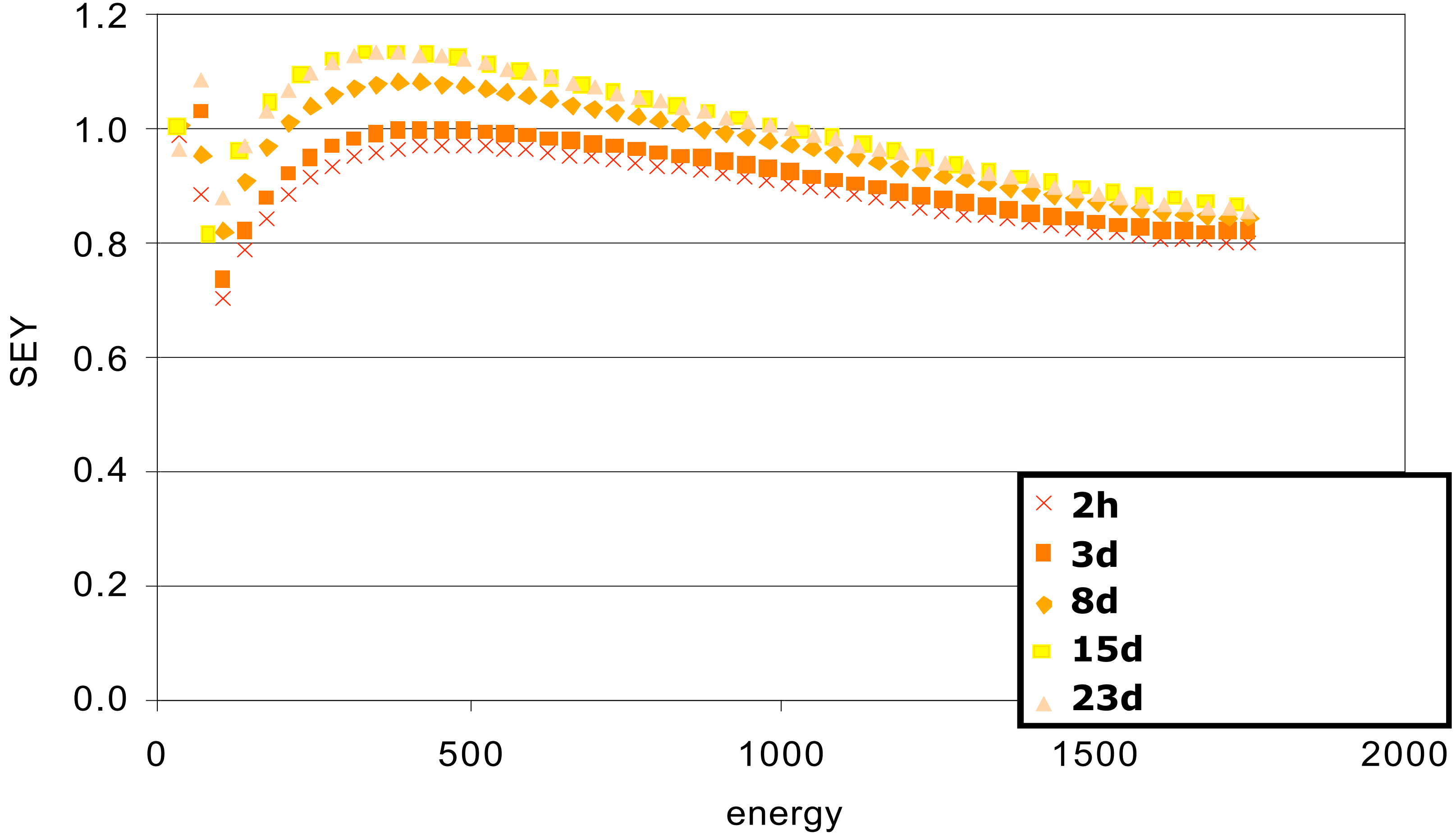
→ Several mitigation techniques are presently under study:

- ✓ Low impedance clearing electrodes
- ✓ Solenoids (KEKB, RHIC) -however only usable in field free regions!
- ✓ Low SEY surfaces
  - Grooved surfaces (SLAC)
  - NEG and TiN coating
  - New coatings presently under investigation (SPS)

Carbon coatings, studied by the SPS Upgrade Working Team, seem very promising and a possible solution....

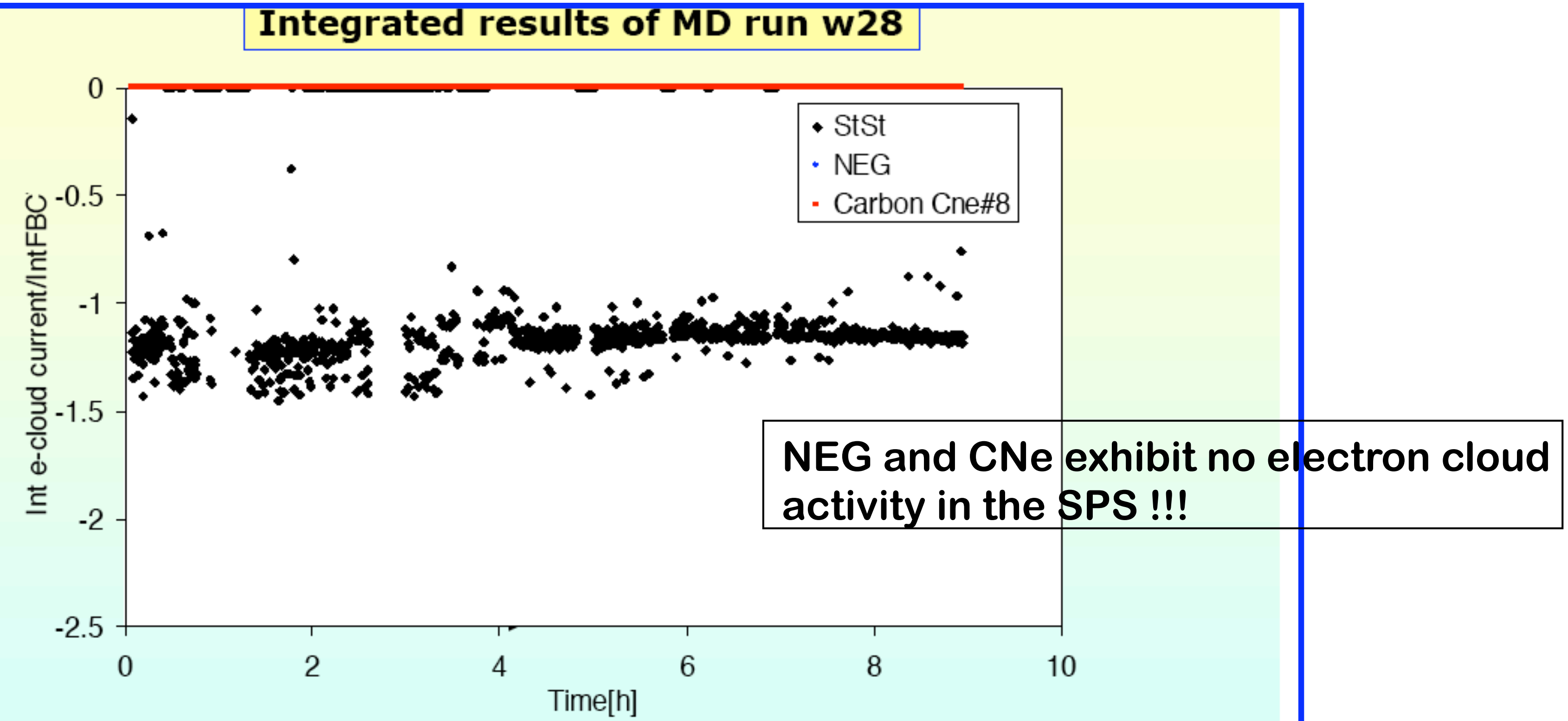
SEY of CNe

Courtesy M. Taborelli from SPSU-WT



The maximum SEY starts from below 1 and gradually grows to slightly more than 1.1 after 23 days of air exposure.
The peak of the SEY moves to lower energy.

Measurements inside the SPS confirm the lab measurements!



Coating C#8 gives almost no current (10^{-4} compared to SS), consistent with measured δmax

Not sufficient effective time to observe clear scrubbing on SS

APC, 18/07/08,
M.Taborelli

Perhaps this is the strategy to get rid of electron cloud issues ??...

→However, need to check the PEY of these coated surfaces in order to fully validate their use for DRs as well!

→ Tests on-going in Cesr-TA

Conclusions

- The electron cloud (build up and instability) in the positron ring poses constraints on PEY and SEY of the beam pipe.
  - Wigglers should be designed such as to be able to absorb 99.9% of the produced synchrotron radiation (new design under study)
  - The maximum SEY should be kept below 1.3
  - Special **chamber coatings** (under study) could be required