Electron cloud in the NLC Main Damping Ring an Update

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NLC Main Damping Ring parameters

parameter	symbol	NLC
energy	E, GeV	1.98
number of particles per bunch	N_p	1.5×10^{10}
circumference	C, m	296
dipole field at 1.98 GeV	B, T	1.2
bunch length rms	σ_z, mm	3.6
bunch size	σ_x, σ_y μm	41, 4.97
bunch spacing	L_{bb}, m	0.84
bunch period	T, ns	2.8
vacuum chamber, round	r_w, mm	16
beam tube temperature	T_w, ^oK	~294
length of D3 drift section	l_s, m	0.975
length of BB dipole section	l_d, m	0.96
length of D2F inj. section	l_i, m	4.4

simulation code as for PEP II simulations

We assume that the ring consist of 36 identical, evenly-spaced BB dipole bending magnets of length 0.96m, 68 field free D3 drift sections of length 0.975m and 45 D2F inj. sections in between every pair of dipole.

circumference= 296.6m

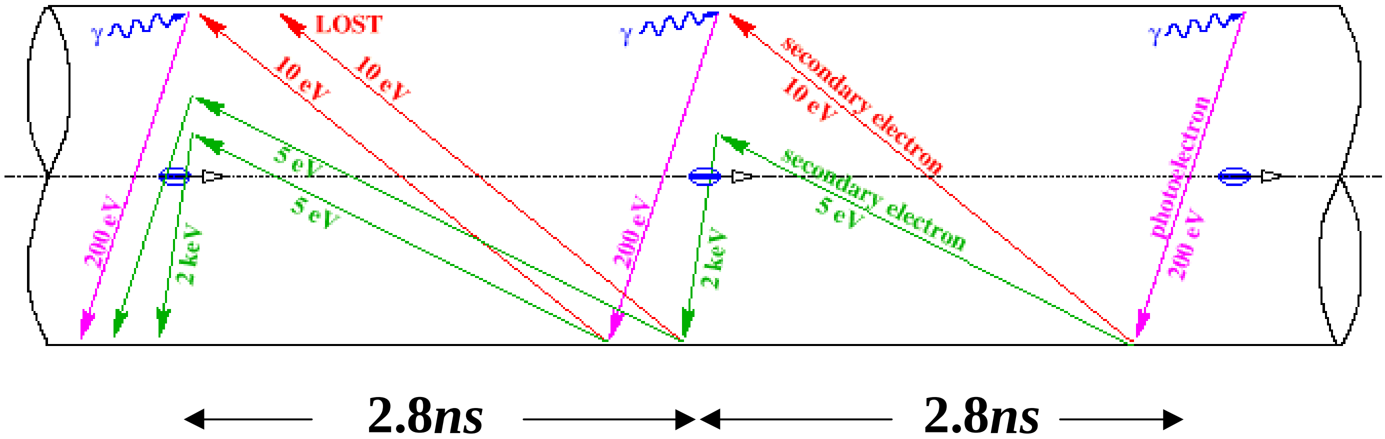
Electron-cloud instability

(ISR['70], LANL-PSR, PEPII, KEKb, SPS+LHC ...)

NLC: photoemission from Synchrotron Radiation

$$N_\gamma = \frac{5}{2\sqrt{3}}\alpha\gamma \quad \frac{photons}{radian} \longrightarrow 9.2\times10^{10} \quad \frac{photons}{magnet\ \ bunch}$$

$$E_{crit} = \frac{3\hbar c}{2\rho}\gamma^3 \approx 3874eV$$

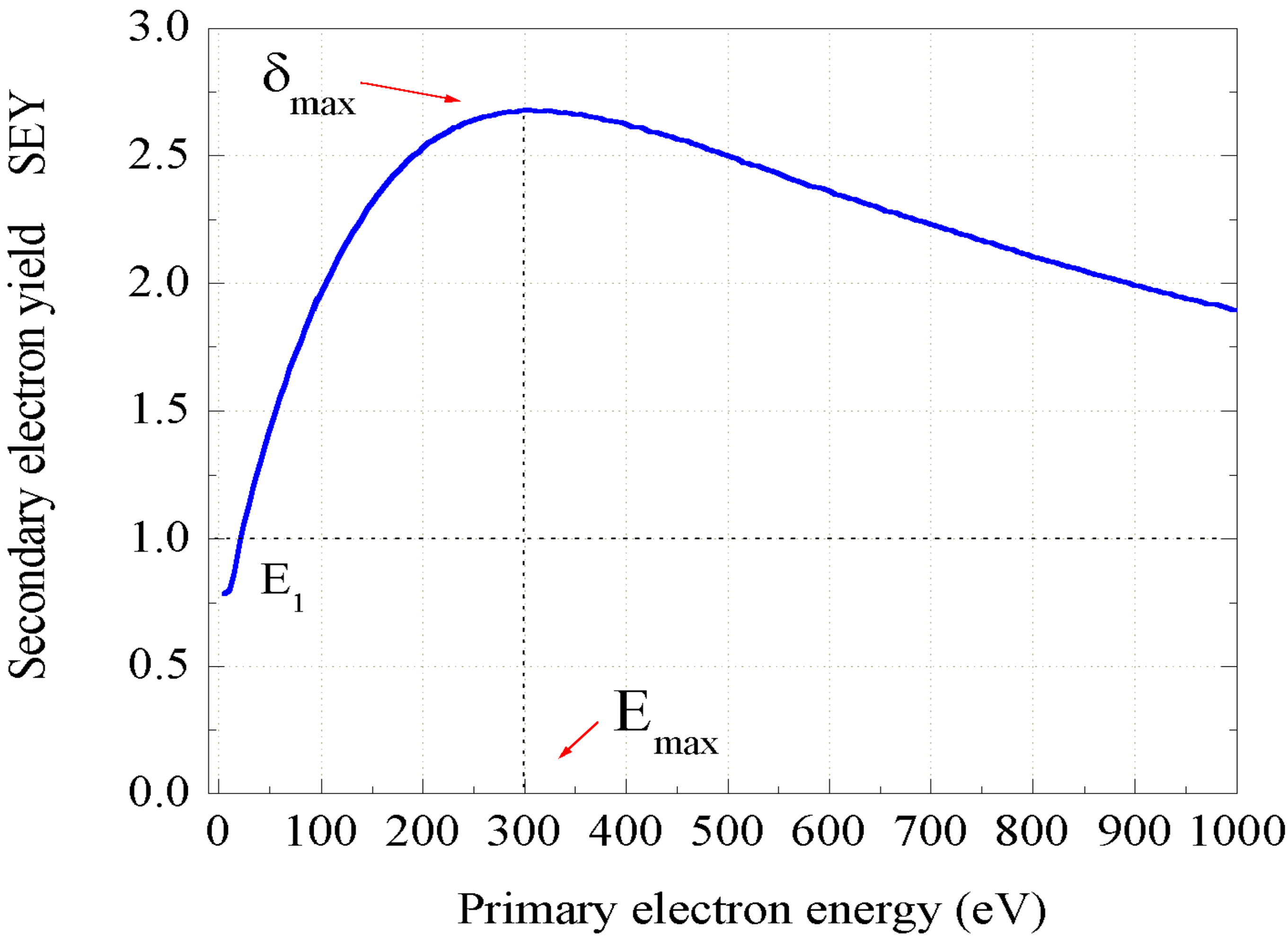


Schematic of electron-cloud build up in the NLC beam pipe (F. Ruggiero drawing)

assuming a photoelectric yield $Y'=0.2$

$$\longrightarrow 1.85\times10^{10} \quad \frac{photoelectrons}{m\times bunch\ passage}$$

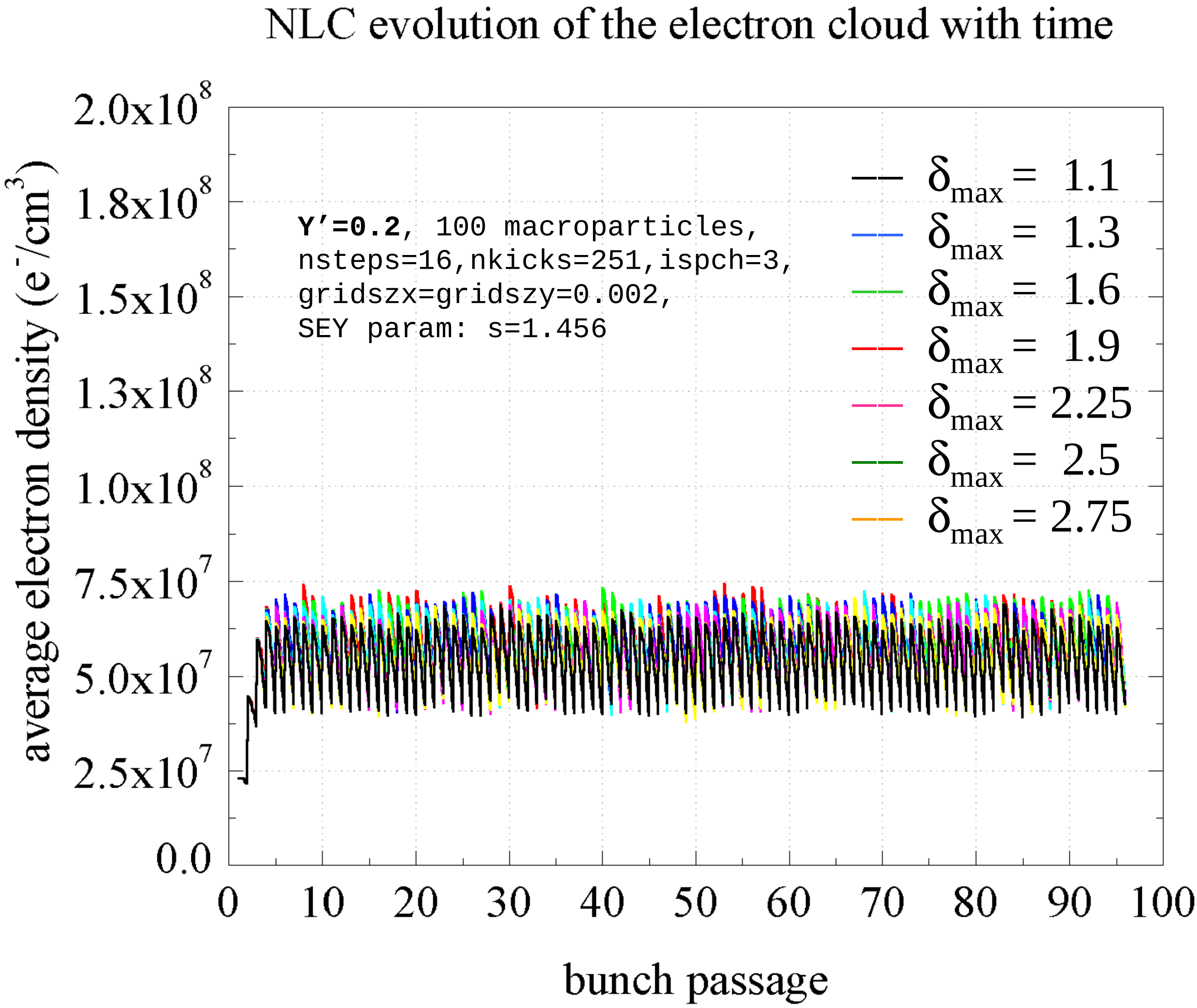
Secondary electron yield SEY for aluminum (courtesy of R. Kirby, SLAC)



Secondary electron yield SEY for etched aluminum, SLAC data. In the simulations we assumed δ_{max}=2.75, $E_{\max}$=300*eV*.

NLC electron cloud build up in the Main Damping Ring, field free region

Previous simulations (April 2001)



Assuming photoelectric yield Y'=0.2.

Simple SEY including true secondary only, with no redifused and no elastically reflected electrons. Note that E0tspk decreases linearly, from E0tspk=315eV (when δ_{max}=2.75) to E0tspk=170eV (when δ_{max} =1.1).

NLC electron cloud build up in the Main Damping Ring, field free region

Gröbner formulae to estimate the beam current threshold for multipacting, (resonance time of flight condition during two bunch passage, electrons considered initially at rest and near the wall):

$$\begin{cases} I_{thres} = \dfrac{(4\pi\epsilon\, m_e c)}{e}\left(\dfrac{r_{pipe}}{\tau_{bb}}\right)^2 = 6.2\ \text{A} \quad (I_{nominal} = 0.85\,\text{A}) \\ N_p = \dfrac{r_{pipe}^2}{r_e L_{bb}} = 1.08 \times 10^{11} \end{cases}$$

no electron multipacting ?!

NLC electron cloud build up in the Main Damping Ring, field free region

... high deposited power

δ_{max}	avPD(W/m)
1.1	80
1.3	77.5
1.6	77.7
1.9	83.3
2.25	76
2.5	75.6
2.75	77

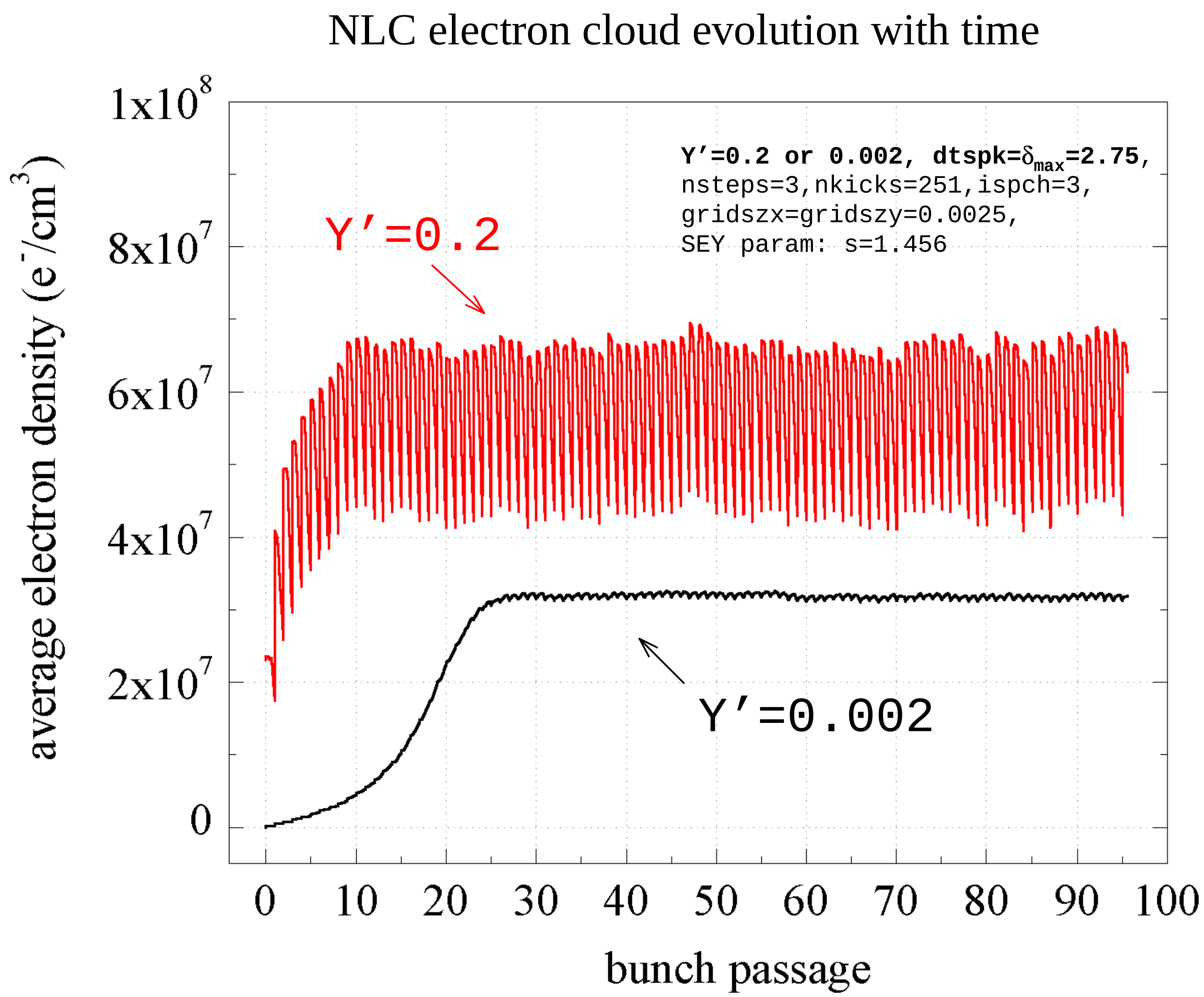
average deposited power per unit length

NLC electron cloud in the Main Damping Ring

- Previous simulation results are puzzling
- discussion with Zimmermann (simulations in very good agreement)
- motivated new simulations

Electron cloud build up in the Main Damping Ring field free region

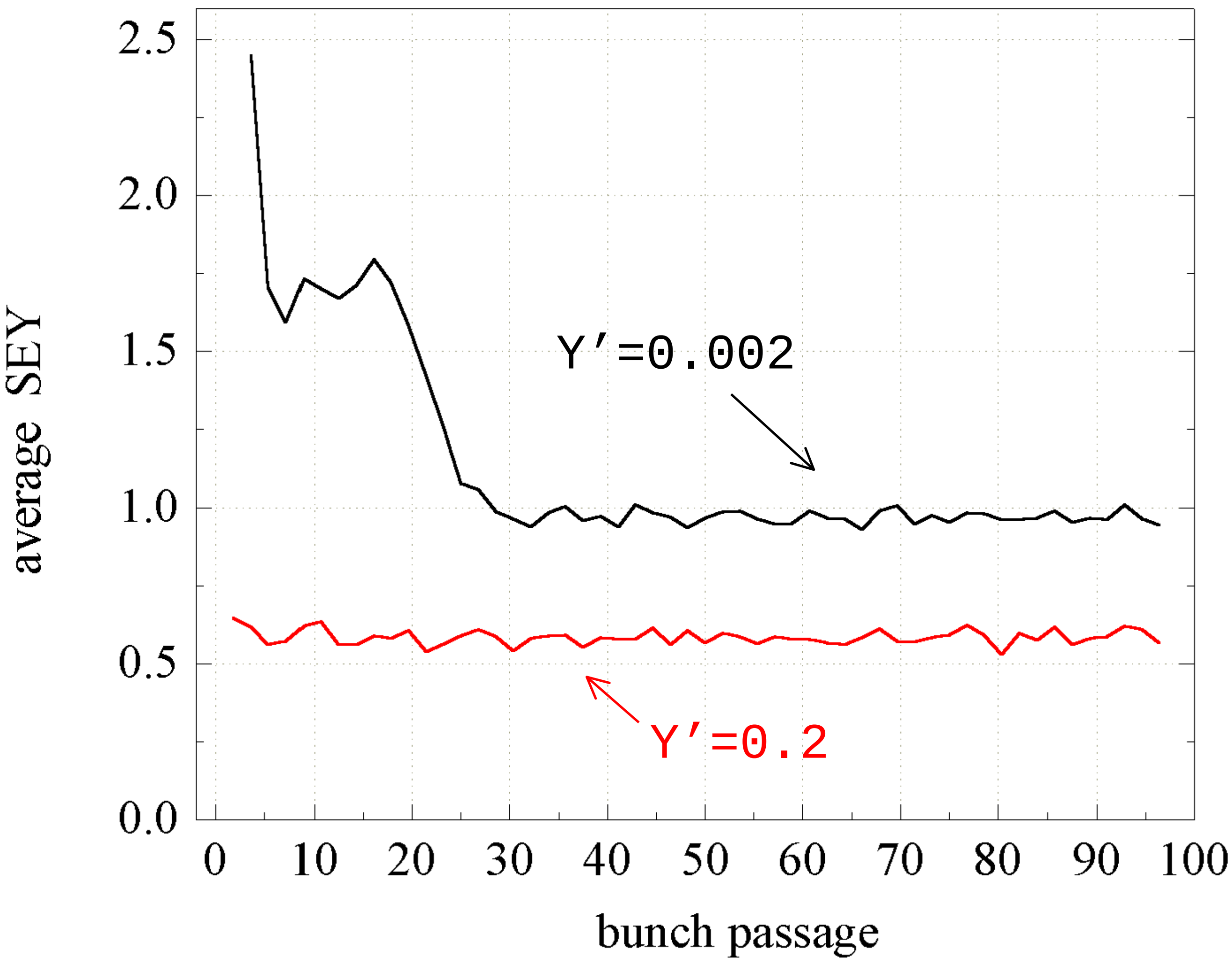
New simulations (October 2001)



assumed SEY=δ_{max} = 2.75

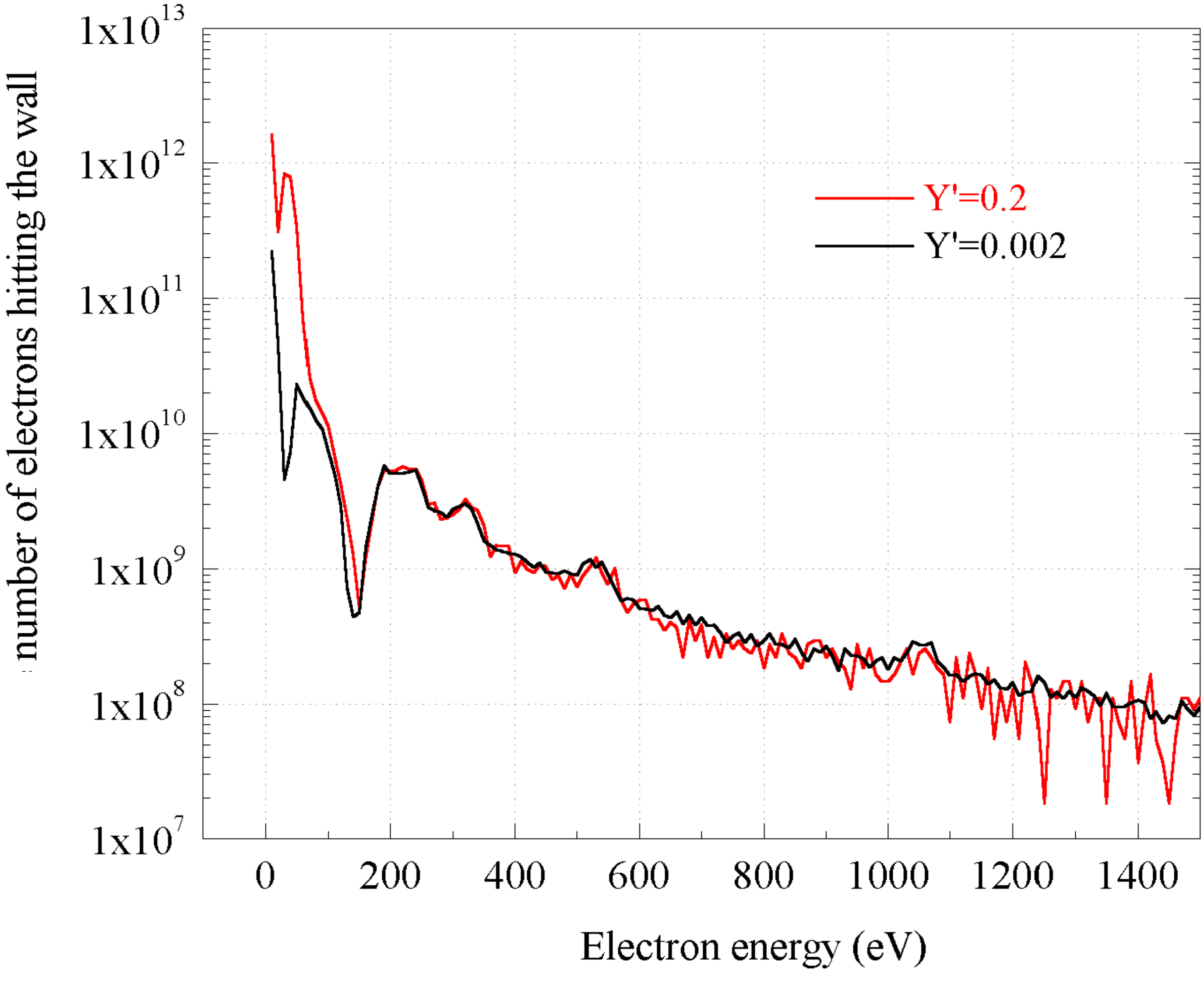
- note that Y'=0.2 is an high value, the general used value is Y'= 0.1.
- Simple SEY including true secondary only, with no redifused and no elastically reflected electrons. Note that E0tspk decreases linearly, from E0tspk=315eV (when δ_{max}=2.75) to E0tspk=170eV (when δ_{max} =1.1).

Average Secondary Electron Yield SEY



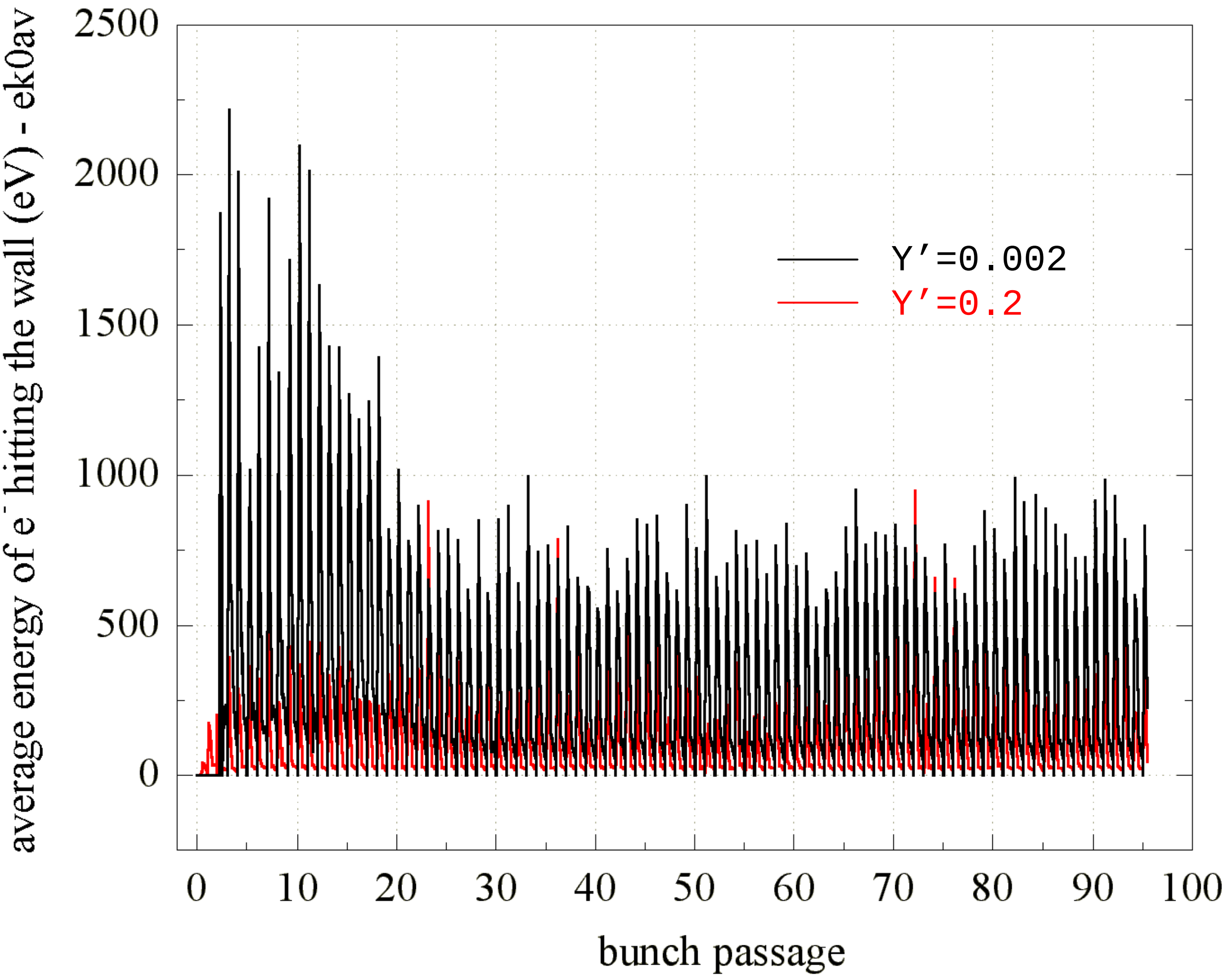
Average SEY as a function of time. Assuming secondary electron yield δ_{max}=2.75, $E_{\max}$=300eV.

Electron Energy spectrum



Electron energy spectrum of the electrons hitting the wall of a NLC field free region, averaged over the all run.

Energy of the electrons hitting the vacuum chamber wall during bunches passage

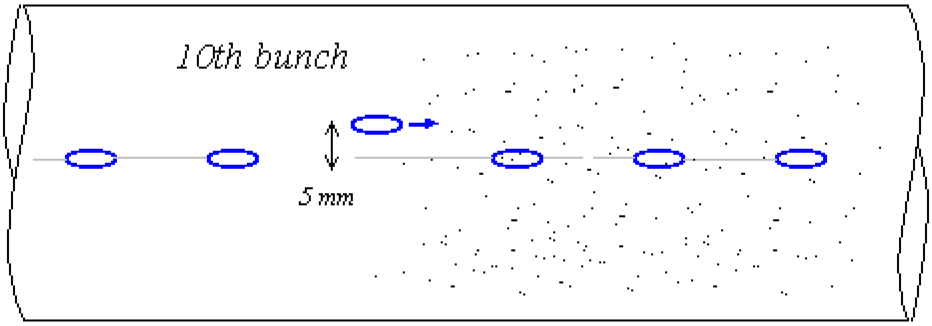


Energy of the electrons hitting the wall during bunch passage. Assuming secondary electron yield δ_{max}=2.75.

(Files: C:\Physics NLC\NLC runs and results - NEW input files)

Instability studies: e-cloud "wake" field

After the electron-cloud reaches stabilization, we displace 1 bunch in the vertical (horizontal) direction by Δy=5mm



Following the notation of A. Chao "*Physics of collective beam instabilities in high energy accelerator*" p. 203, the dipole "wake" function given by the kick Δp_y esperienced by the trailing bunch traversing a section of length L, assuming N_{sect} such sections is given by:

$$W_y(z) = -\frac{cN_{sect}}{(eN_p)} \cdot \frac{\Delta p_y}{\Delta y}$$

the coherent dipole frequency Ω_μ of oscillation mode μ, in first order perturbation theory, is given by

$$\Omega_\mu - \omega_\beta = \frac{ce^2 N_p}{4\pi E \nu_\beta} \sum_{k=0}^{M-1} W(ks_B)\, e^{2\pi i k(\mu+\nu_\beta)/M}$$

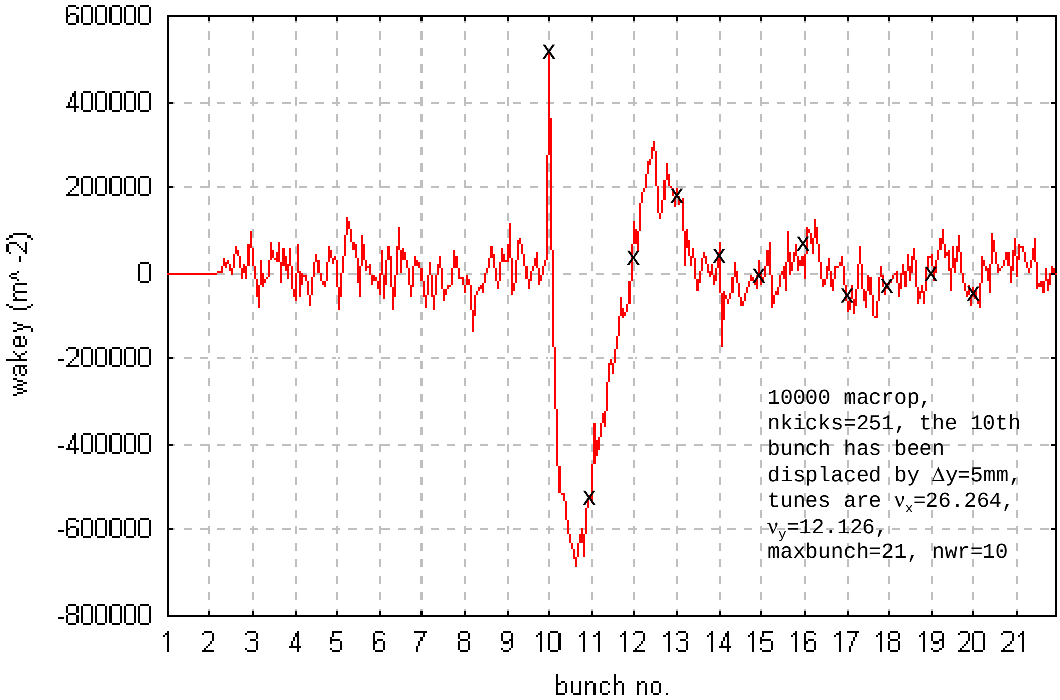
with $\omega_\beta = \omega_0 \nu_\beta$ the vertical (horizontal) betatron angular frequency and ν_β the vertical (horizontal) tune of the ring. The bunch centroid is oscillating according to $y_\mu(t) \propto \exp(-i\Omega_\mu t)$, then, the mode is unstable when $\mathrm{Im}\Omega_\mu > 0$ and damped when $\mathrm{Im}\Omega_\mu > 0$. With the wake function beeing short-ranged, W(sB)>>|W(ksB)| for k≥2, an estimate of the growth rate from k=1 is given by:

$$\tau^{-1} \cong \frac{ce^2 N_p}{4\pi E \nu_\beta} \cdot |W(s_B)|$$

Instability studies: e-cloud wake field

bunch displacement in y direction

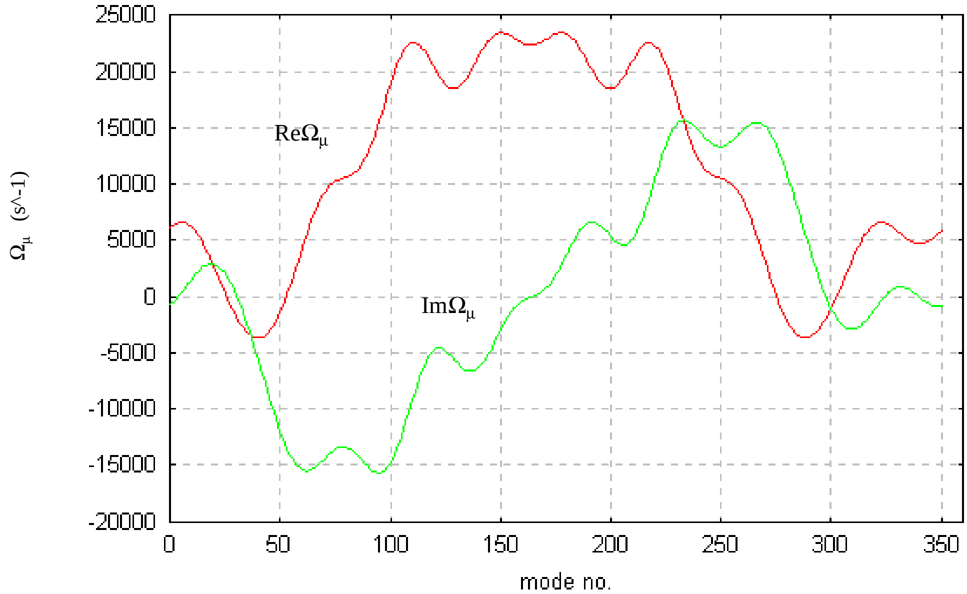
Wake-y field (field free region)



estimated vertical growth rate (runpar.dat): $\tau^{-1} = 1.15\,10^{4}\ s^{-1}$

vertical coherent tune shift: $\Delta\nu_{\beta} = 0.0017$

Choerent dipole frequency - y (field free region)



Conclusions so far:

Simulations for the NLC Main Damping Ring field free region (worse case).

After previous simulation results (April 2001) and farther triangular discussions (Zimmermann, Furman, Pivi) we run new simulations with lower photoelectric yield:

- evidence of electron multiplication (antechamber may not have significant effect ?!)
- the electron cloud results in high deposited power ~80 *W/m*

  and

- in a high neutralization density, leading to multi-bunch instability, with estimated vertical growth time $\tau_y = 0.1$ msec

  then, more simulations are needed:

- investigate emittance blow-up and single bunch instability
- with antechamber check sensitivity to SEY and sensitivity to residual gas ionization effect
- electron cloud at different stages of damping
- damping and pre-damping ring with antechamber
- need to verify the effect of a TiN coating
- check electron cloud effect in the LINAC

note that we used a model for the SEY with only true secondary electron, rediffused and reflected electrons were not included yet

Appendix: Final electron energy versus intial radial position just after one single bunch passage, assuming a uniform initial electron distribution

To have a good convergence for these results, need to use 251 kicks per bunch passage with a 5 σz bunch length.