Electron Cloud Build-up in ilcDR

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Electron cloud buildup simulation

- Cloud buildup was calculated by code “ECLOUD” developed at CERN.

- Assumptions:

  - Dipole and wiggler regions (modeled as a uniform dipole)
  - A reduced number of primary electrons is artificially used in order to take into account the reduction of electron yield by the ante-chamber:

$$e^- / e^+ / m = dn_\gamma / ds \cdot Y \cdot (1 - \eta)$$

  where: dn_γ/ds is the average number of emitted photons per meter per e^+, Y is the quantum efficiency, and η is the percentage of photons absorbed by the antechambers.
  - A fraction R of the primary electrons are uniformly produced on chamber wall.

Build Up Parameters for DC04 & DSB3

Beam energy	E_b[GeV]	5
Bunch population	N_b	2.1×10^{10}
Number of bunches	N_b	45 x 8 trains
Bunch gap	*Ngap*	15
Bunch spacing	L_{sep}*[m]*	1.8
Photoelectron Yield	*Y*	0.1
RMS bunch length	σ_z	5
Antechamber full height	*h[mm]*	10
Antechamber protection	η	0%:90%;97%;99%
Fraction of uniformely dist photelectrons	*R*	10%; 20%; 40%
Max. Secondary Emission Yeld	δ_{max}	0.9;1.0;1.1;1.2;1.3;1.4
Energy at Max. SEY	E_m*[eV]*	300
SEY model	Cimino-Collins *($\delta(0)=0.5$)*	

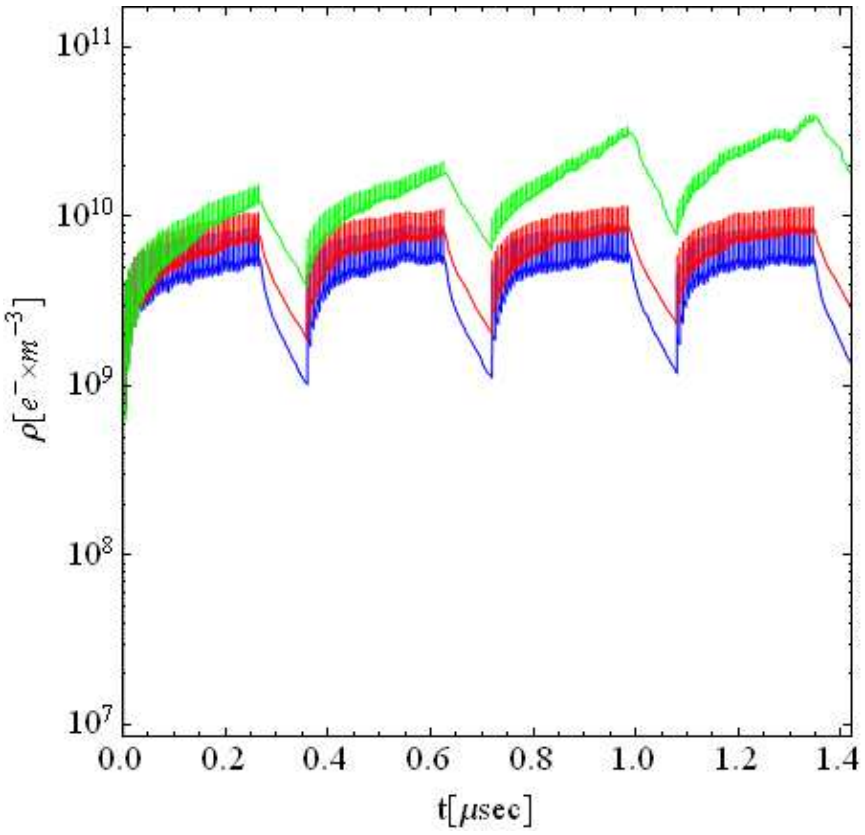
*https://wiki.lepp.cornell.edu/ilc/pub/Public/DampingRings/WebHome/DampingRingsFillPatterns.xls

Input parameters that vary from DC04 to DSB3

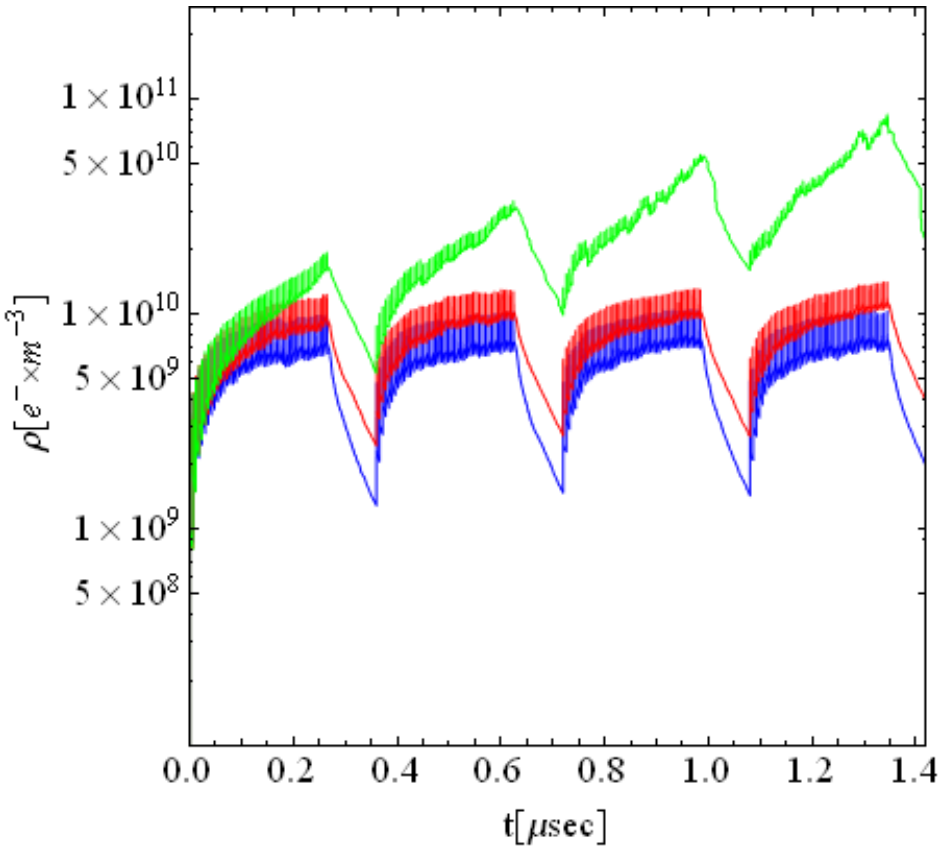
	DC04		DSB3	
Circumference [Km]	6.4		3.2	
	wiggler	**bend**	**wiggler**	**bend**
Chamber radius r [mm]	23	25	23	25
n'_e [photo.-el./e^+/m] (w/ antech.)	0.0045	0.001	0.0037	0.0014
n'_e [photo.-el./e^+/m] (w/O antech.)	0.151	0.033	0.125	0.047
(σ_x,σ_y) [μm]	(70,5)	(260,6)	(70,5)	(110,5)
B [T]	1.6	0.27	1.6	0.36

Average e-cloud density in ILC-DR dipole (SEY=0.9;1.2;1.4)

DC04 R=20% η=97%

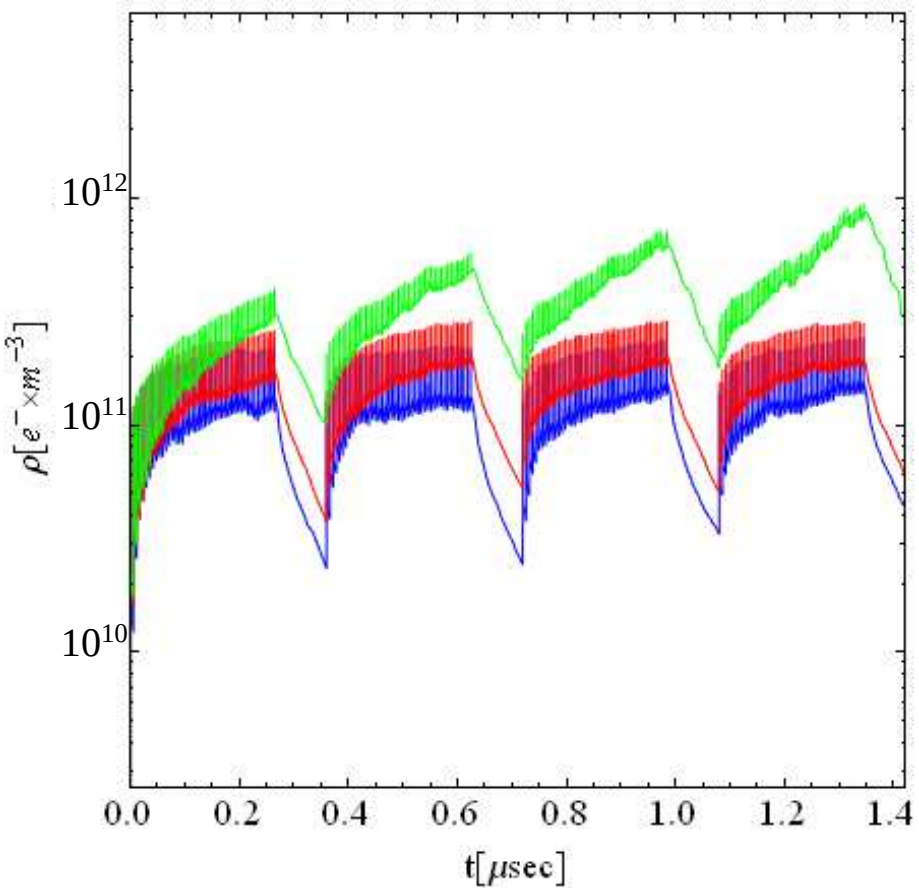


DSB3 R=20% η=97%

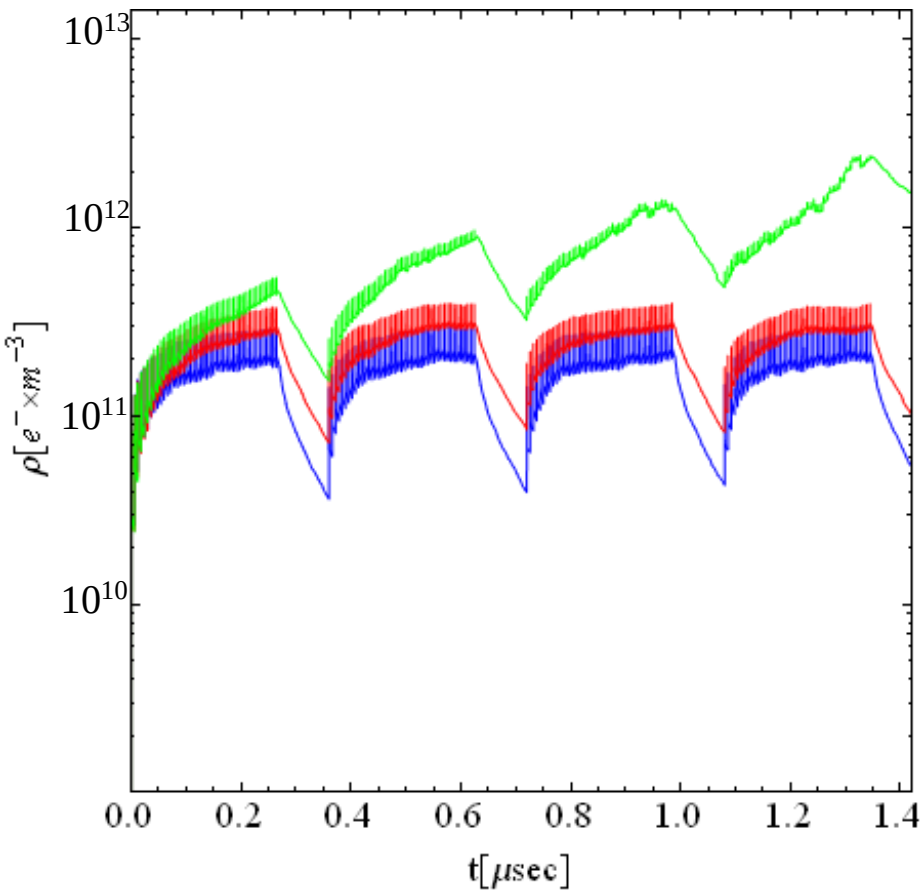


Average e-cloud density in ILC-DR wiggler (SEY=0.9;1.2;1.4)

DC04 R=20% η=97%



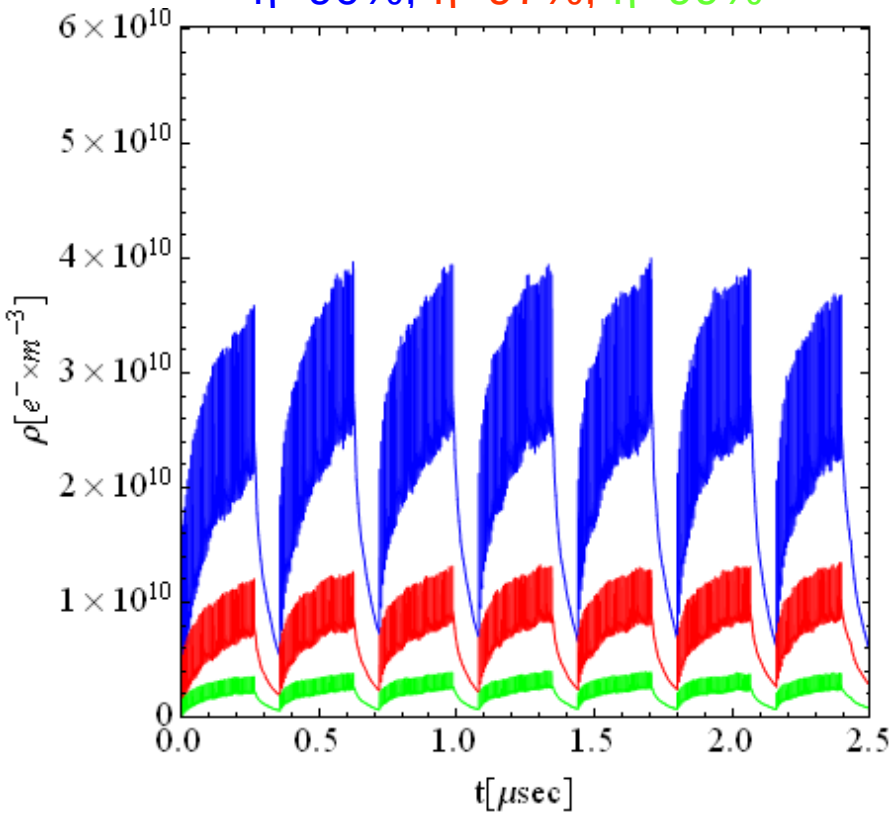
DSB3 R=20% η=97%



Average e-cloud density (DC04 dipole SEY=1.2)

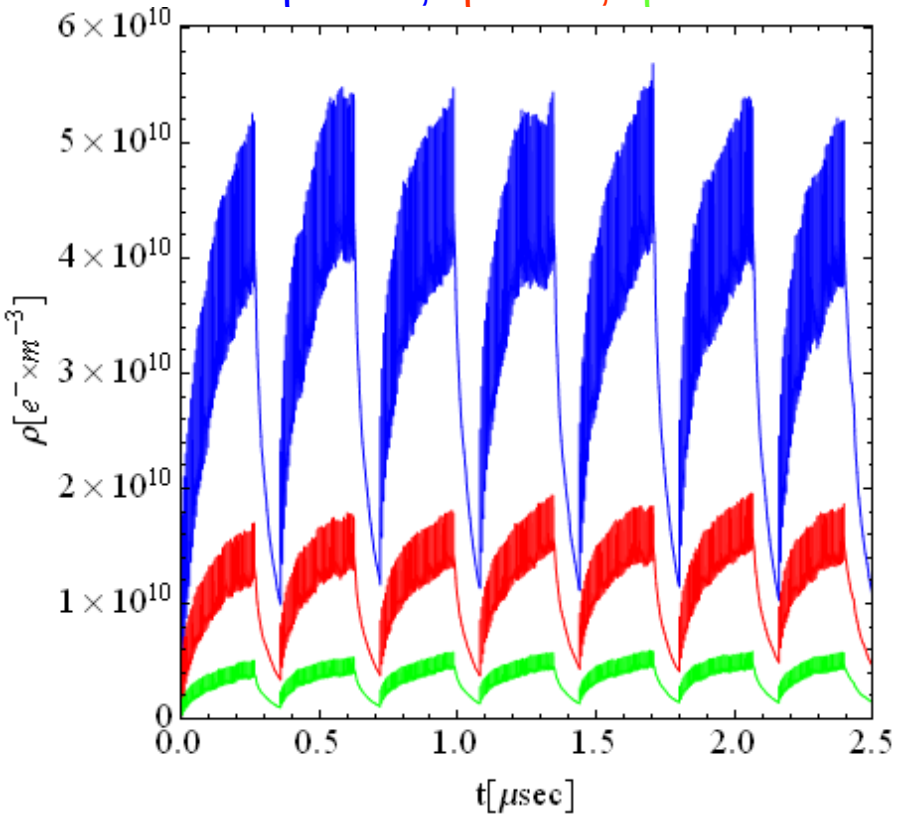
R=10%

η=90%; η=97%; η=99%



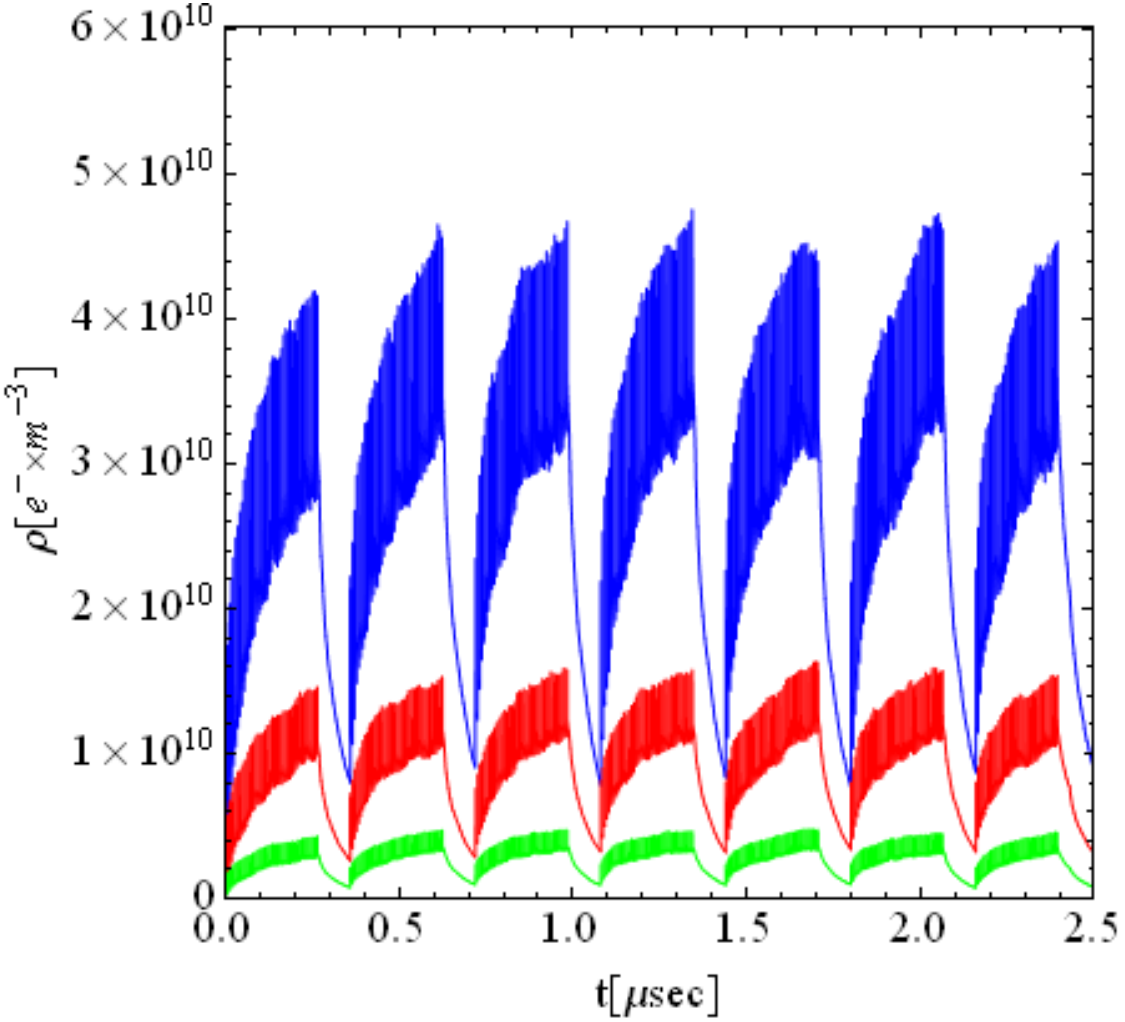
R=40%

η=90%; η=97%; η=99%



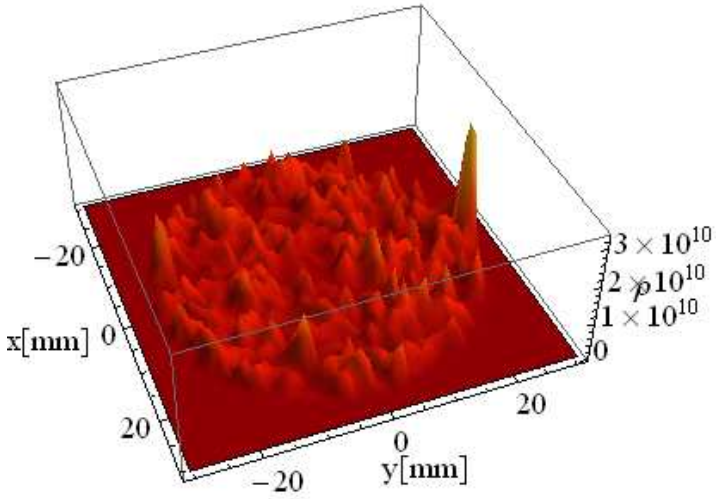
Average e-cloud density (DC04 dipole SEY=1.2, R=20%)

η=90%; η=97%; η=99%

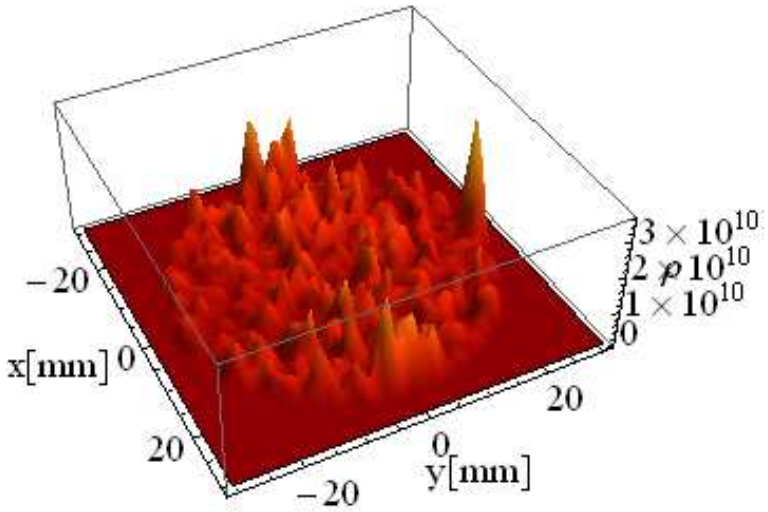


e-cloud “distribution”

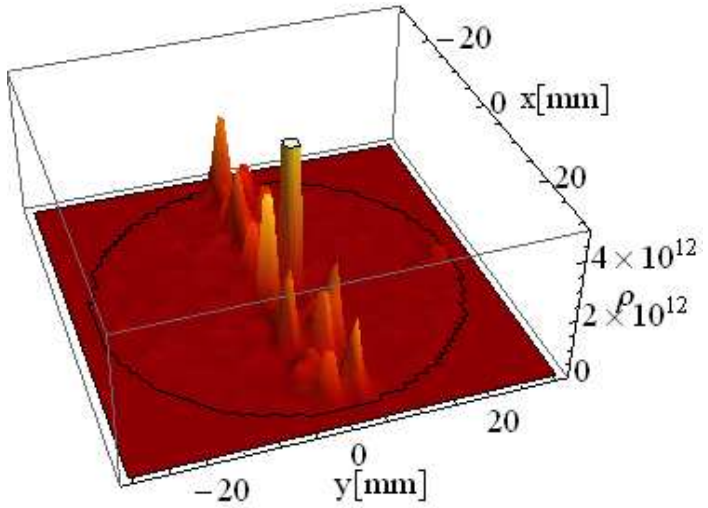
SEY=0.9



SEY=1.2

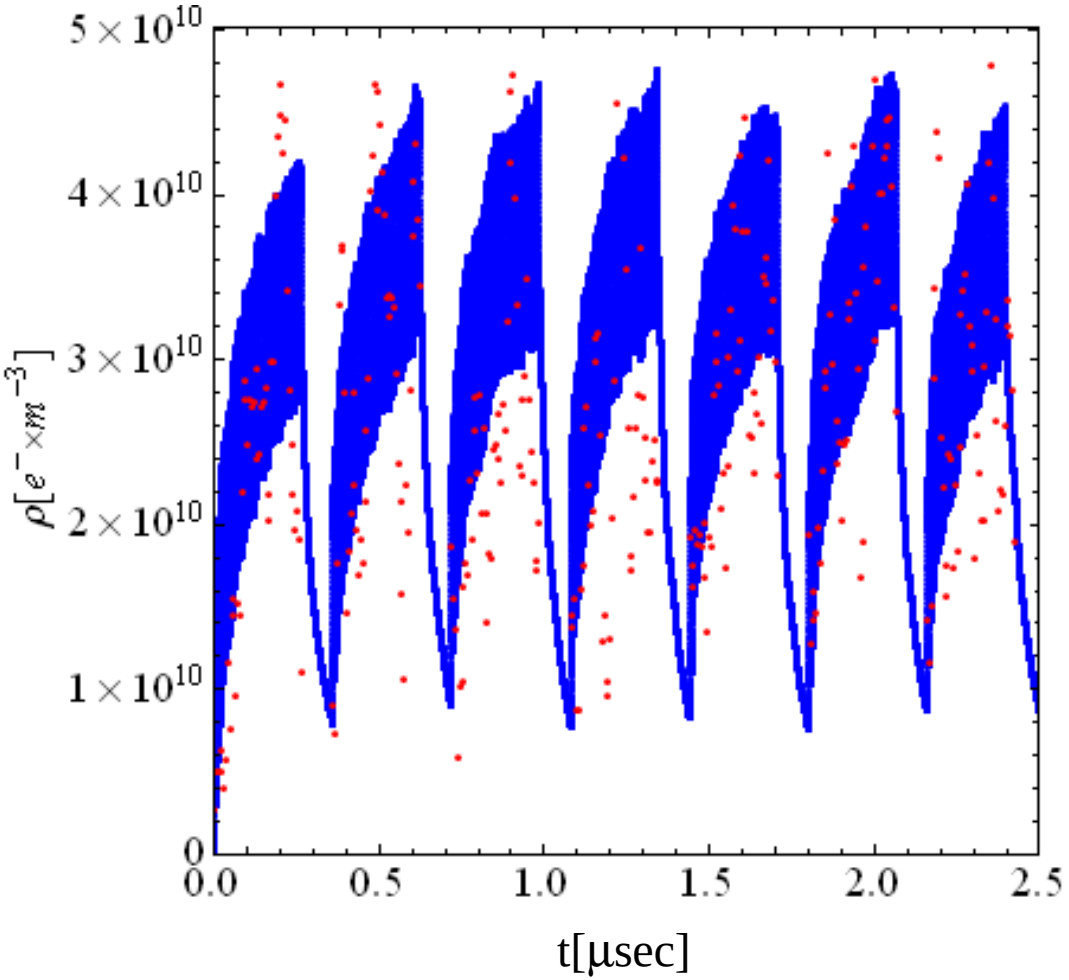


SEY=1.4



Snapshot of the cloud distribution “just before” the passage of the last bunch for: R=25%, η=90%

Average vs central density SEY=1.2, R=20%,η=90%



Red dots mark e-cloud density near the beam (+ -10 sig.) evaluated “just before” the passage of each bunch.

e-cloud density at bunch front within 10 beam σ's **(R=20%)**

	DC04				DSB3			
	Wiggler		Bend		wiggler		bend	
δ_{max}	antch. η=97%	no antch	antch. η=97%	no antch	antch. η=97%	no antch	antch. η=97%	no antch
0.9	0.18	4.1	0.012	0.39	0.30	6.1	0.02	0.66
1.0	0.25	4.9	0.016	0.52	0.42	7.4	0.028	0.88
1.1	0.33	6.3	0.018	0.59	0.55	9.5	0.03	1.00
1.2	0.41	7.2	0.023	0.76	0.65	11.2	0.039	1.29
1.3	>2.1	>12.3	>0.2	>4.2	>3.2	>20.3	>0.34	>6.14
1.4	>3.7	>20.5	>0.4	>7.6	>7.0	>31.7	>0.68	>9.52

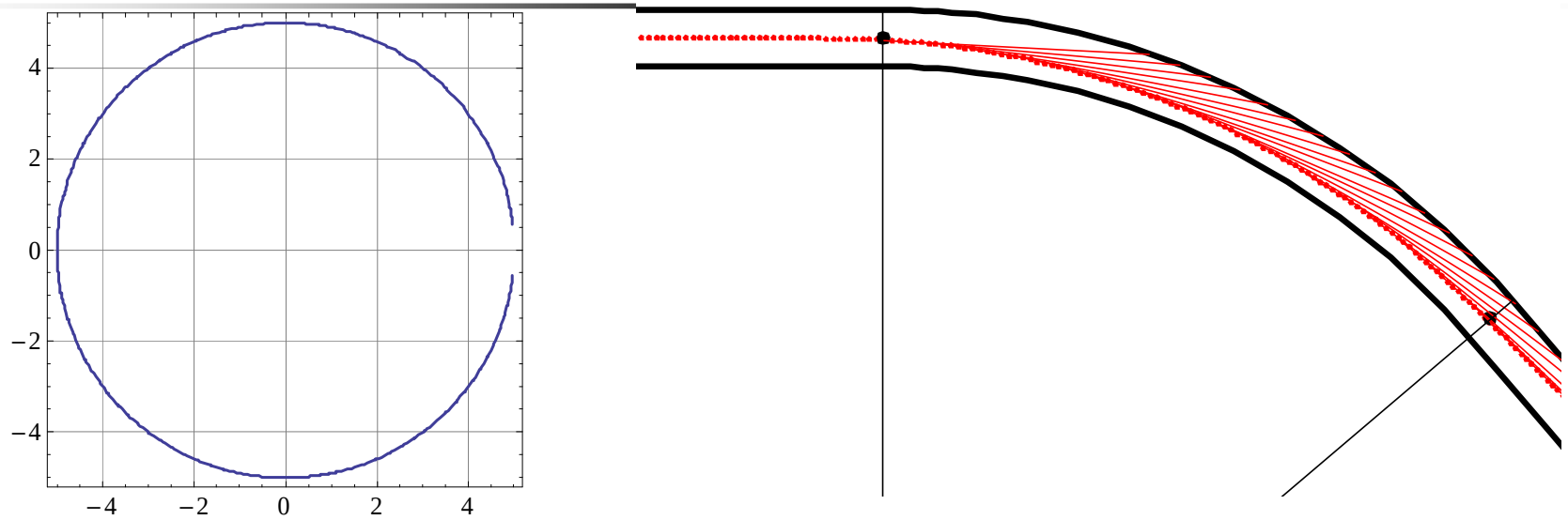
units: 10^{12} m^{-3}

Note: these simulated data have large errors (~30-40%) due to statistical noise. Within these errors, there is no difference between the time-averaged density and the instantaneous density at the last bunch in the train

Summary

- Simulations show a 1st-order phase transition in bends and wigglers with antech. at $\delta_{max} \approx 1.3\text{-}1.4$
- ecloud density in DSB3 is larger than in DC04 by 30-40%
- Antechamber reduce significantly ecloud density (factor ~30-40 for η=97%) relative to no antechamber for all cases explored
- 10-σ front bunch density comparable to average density
- Monotonic dependence of ecloud density on the parmeter R both in wiggler and dipoles (~30% increase when R=10%->R=40%)
- Accurate estimates of parameters η and R are needed

Preliminary estimation of antechamber protection in ILC-DR



• In order to calculate the number of photons that remain inside the chamber, we must integrate the fundamental spectrum of synchrotron radiation

$$\frac{dN_{\gamma/p}}{dnd\phi d\psi} = \frac{\alpha}{3\pi^2} n(\gamma^{-2}+\psi^2)^2 \left[K^2_{2/3}(\xi) + \frac{\psi^2}{\gamma^{-2}+\psi^2} K^2_{1/3}(\xi)\right]$$

$$\xi = \frac{n}{3}(\gamma^{-2}+\psi^2)^{3/2}$$

$$n = \omega/\omega_0 = E/\hbar\omega_0$$

• The calculation is done by numerical integration taking into account the geometry of the chamber and the curvature of the orbit (extrapolated from mad lattice files: https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/WebHome).

• Very preliminary estimate for ILC-DR DCO4 lattice indicate that only ~2% of the radiated photons remain inside the chamber (to be double checked)