Cornell University
Laboratory for Elementary-Particle Physics

# *Update to ECLOUD Calculations for the 3.2 and 6.4 km ILC Damping Ring Lattice Designs*

- *Update to quadrupole calculations presented 10 March 2010 after bug fix in secondary yield routine (see also CesrTA electron cloud meeting on 17 March 2010)*

- *Calculations for 20 G solenoids replacing the drift regions, and the consequences for coherent tune shifts*

- *Movies for electron cloud formation in quadrupoles and solenoids*

***All material available at http://www.lepp.cornell.edu/~critten/ilcdr/23mar10***

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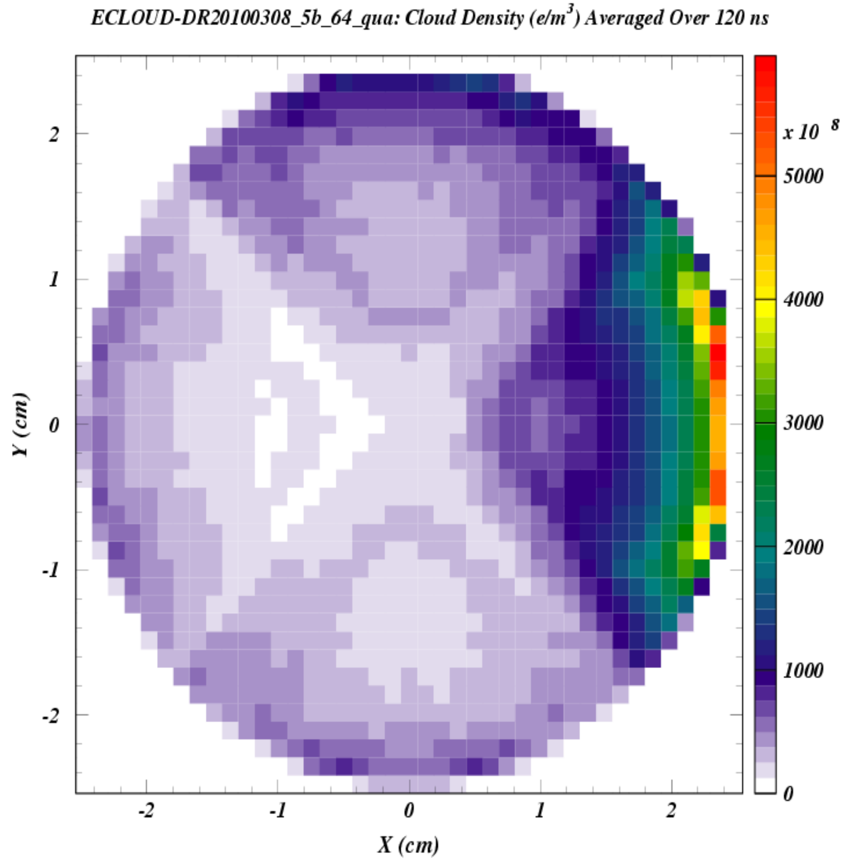
*ILC Damping Ring Electron Cloud Working Group Meeting*

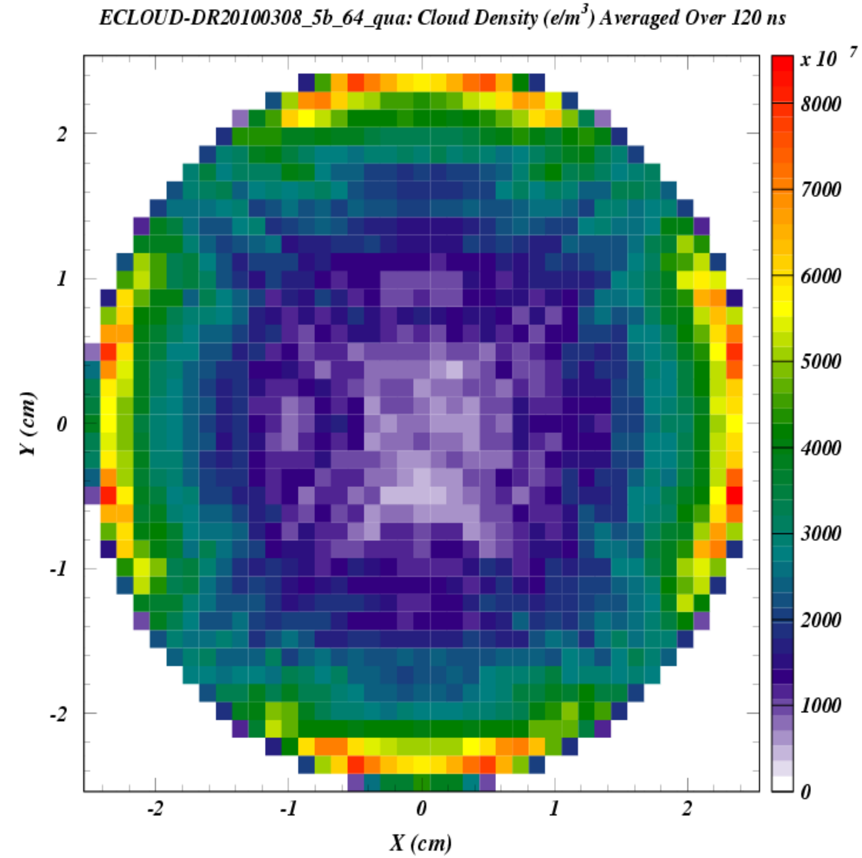
*23 March 2010*

# *ILC Damping Ring Working Group Meeting of 10 Mar 10*
# *ECLOUD movie of quadrupole simulation showed unexpected asymmetry*

**Before fix**




**After fix**




***A branch on quadrupole case in the routine for generating secondary electrons erroneously backwards-extrapolated macroparticles outside the v.c. back to the wrong place on the wall.***

# *Element-averages of Twiss functions, beam sizes and photon rates on the outer vacuum chamber wall*

$\varepsilon_x$ = 441 pm $\varepsilon_Y$ = 2 pm
$\sigma_Z = 5.6$ mm $\delta_E = 0.127\%$

## *6.4 km (DCO4)*

| Element | Nr Seg | <Length> | Tot Length | Fraction | <Beta X> | <Beta Y> | <Sig X> | <Sig Y> | <Phot/m/e> |
|---|---|---|---|---|---|---|---|---|---|
| Dipole | 45231 | 0.010 | 451.2 | 7.0% | 10.5 | 24.6 | 0.216 | 0.007 | 0.285 |
| Drift | 545317 | 0.010 | 5410.0 | 84.0% | 21.2 | 19.5 | 0.270 | 0.006 | 0.146 |
| Wiggler | 21673 | 0.010 | 215.8 | 3.4% | 10.7 | 12.1 | 0.069 | 0.005 | 1.451 |
| Quadrupole | 28827 | 0.010 | 284.3 | 4.4% | 21.3 | 21.1 | 0.285 | 0.006 | 0.184 |
| Sextupole | 9950 | 0.010 | 97.8 | 1.5% | 20.4 | 20.3 | 0.366 | 0.006 | 0.037 |
| Solenoid | 0 | 0.000 | 0.0 | 0.0% | 0.0 | 0.0 | 0.000 | 0.000 | 0.000 |
| Octupole | 0 | 0.000 | 0.0 | 0.0% | 0.0 | 0.0 | 0.000 | 0.000 | 0.000 |
| Non-dipole | 605767 | 0.010 | 5996.4 | 93.1% | 20.8 | 19.4 | 0.266 | 0.006 | 0.194 |
| Non-drift | 105681 | 0.010 | 1049.6 | 16.3% | 14.4 | 20.7 | 0.218 | 0.006 | 0.474 |
| Total | 650998 | 0.010 | 6437.7 | 100.0% | 20.1 | 19.8 | 0.263 | 0.006 | 0.200 |

$\varepsilon_x$ = 525 pm $\varepsilon_Y$ = 2 pm
$\sigma_Z = 5.3$ mm $\delta_E = 0.118\%$

## *3.2 km (DSB3)*

| Element | Nr Seg | <Length> | Tot Length | Fraction | <Beta X> | <Beta Y> | <Sig X> | <Sig Y> | <Phot/m/e> |
|---|---|---|---|---|---|---|---|---|---|
| Dipole | 39491 | 0.010 | 391.2 | 12.1% | 3.8 | 18.6 | 0.095 | 0.006 | 0.919 |
| Drift | 250278 | 0.010 | 2487.0 | 76.7% | 22.8 | 23.2 | 0.149 | 0.007 | 0.154 |
| Wiggler | 7870 | 0.010 | 78.5 | 2.4% | 10.7 | 12.1 | 0.075 | 0.005 | 1.234 |
| Quadrupole | 23950 | 0.010 | 237.2 | 7.3% | 20.7 | 20.5 | 0.215 | 0.006 | 0.249 |
| Sextupole | 4848 | 0.010 | 48.0 | 1.5% | 21.9 | 24.1 | 0.312 | 0.007 | 0.145 |
| Solenoid | 0 | 0.000 | 0.0 | 0.0% | 0.0 | 0.0 | 0.000 | 0.000 | 0.000 |
| Octupole | 0 | 0.000 | 0.0 | 0.0% | 0.0 | 0.0 | 0.000 | 0.000 | 0.000 |
| Non-dipole | 286946 | 0.010 | 2851.5 | 87.9% | 22.3 | 22.7 | 0.155 | 0.006 | 0.191 |
| Non-drift | 76159 | 0.010 | 755.1 | 23.3% | 10.9 | 18.8 | 0.144 | 0.006 | 0.692 |
| Total | 326437 | 0.010 | 3243.2 | 100.0% | 20.0 | 22.2 | 0.148 | 0.006 | 0.279 |

*New tables with step size reduced from 10 cm to 1 cm.*
*Note the higher ring fraction (factor 1.7) and radiation (factor 3.2) in dipoles for the 3.2 km ring.*

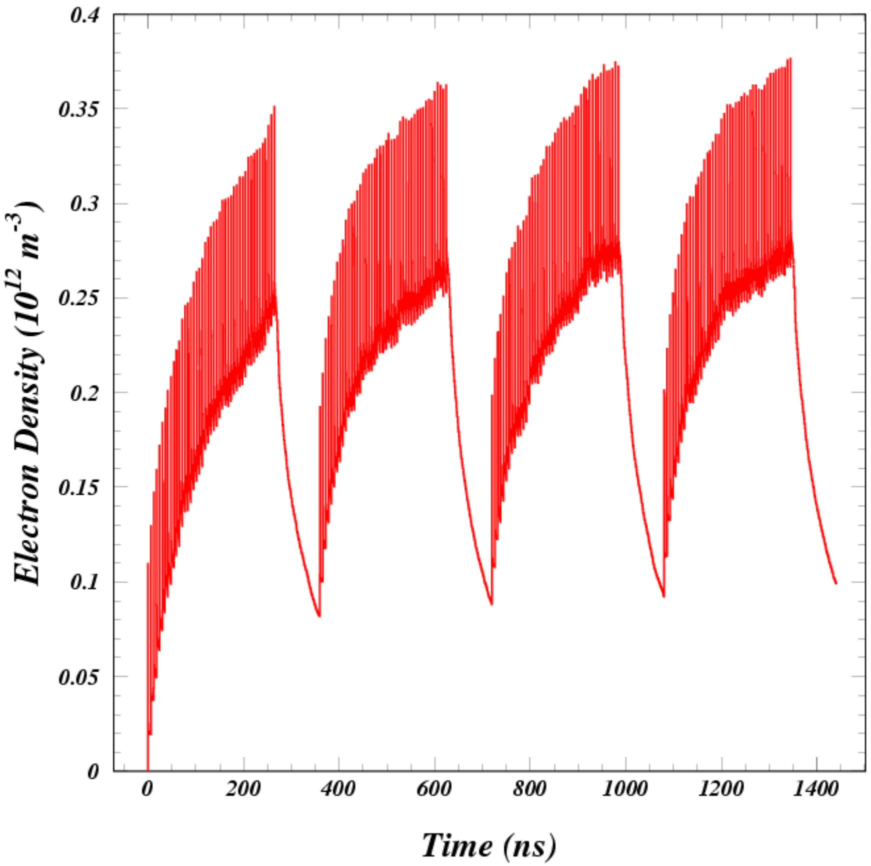
# *ECLOUD input parameters*

| | | |
|---|---|---|
| Bunch population | $N_b$ | 2.1x$10^{10}$ |
| Number of bunches | $N_b$ | 45 x 4 trains |
| Bunch gap | $Ngap$ | 15 |
| Bunch spacing | $L_{sep}[m]$ | 1.8 |
| Bunch length | $\sigma_z\,[mm]$ | See previous slide |
| Bunch horizontal size | $\sigma_x\,[mm]$ | See previous slide |
| Bunch vertical size | $\sigma_y\,[mm]$ | See previous slide |
| Photoelectron Yield | $Y$ | 0.1 |
| Photon rate ($e^-/e^+$/m) | $dn_\gamma/ds$ | See previous slide |
| Antechamber protection | $\eta$ | 90% |
| Photon Reflectivity | $R$ | 20% |
| Max. Secondary Emission Yeld | $\delta_{max}$ | 1.2 (1.01 t.s. & 0.19 rediff) |
| Energy at Max. SEY | $E_m\,[eV]$ | 300 |
| SEY model | Cimino-Collins $(\delta(0)=0.5)$ | |

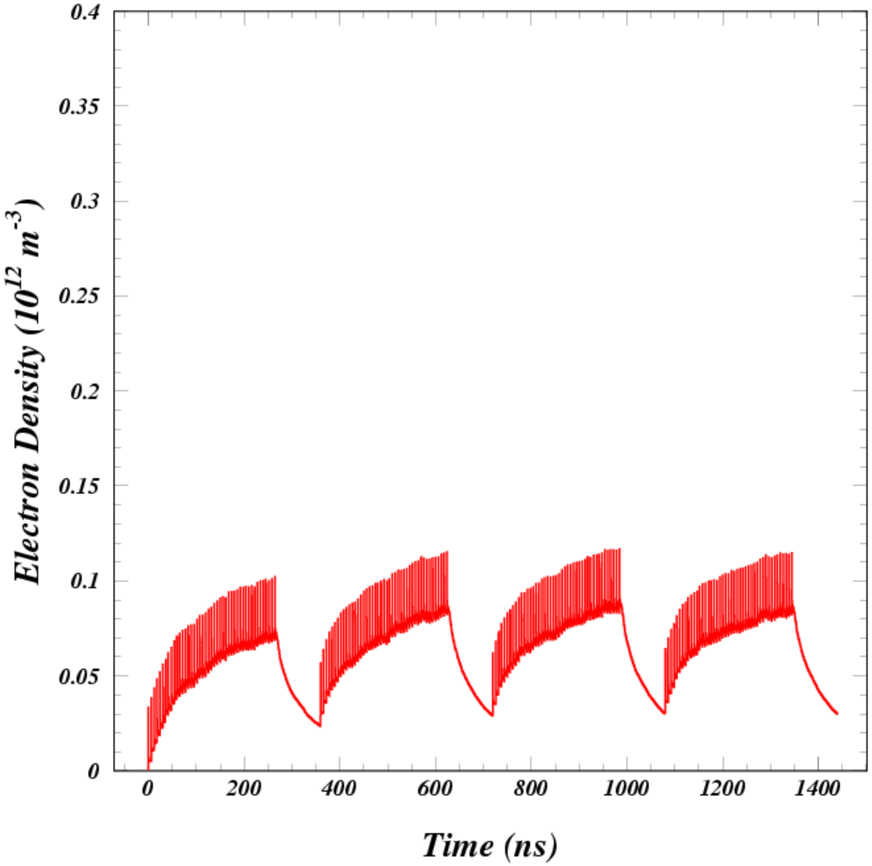
***Dipole field: 0.27 T***
***Quadrupole field: 7.0 T/m***

# Cloud density averaged over the vacuum chamber for the dipole regions

**3.2 km lattice (DSB3)**



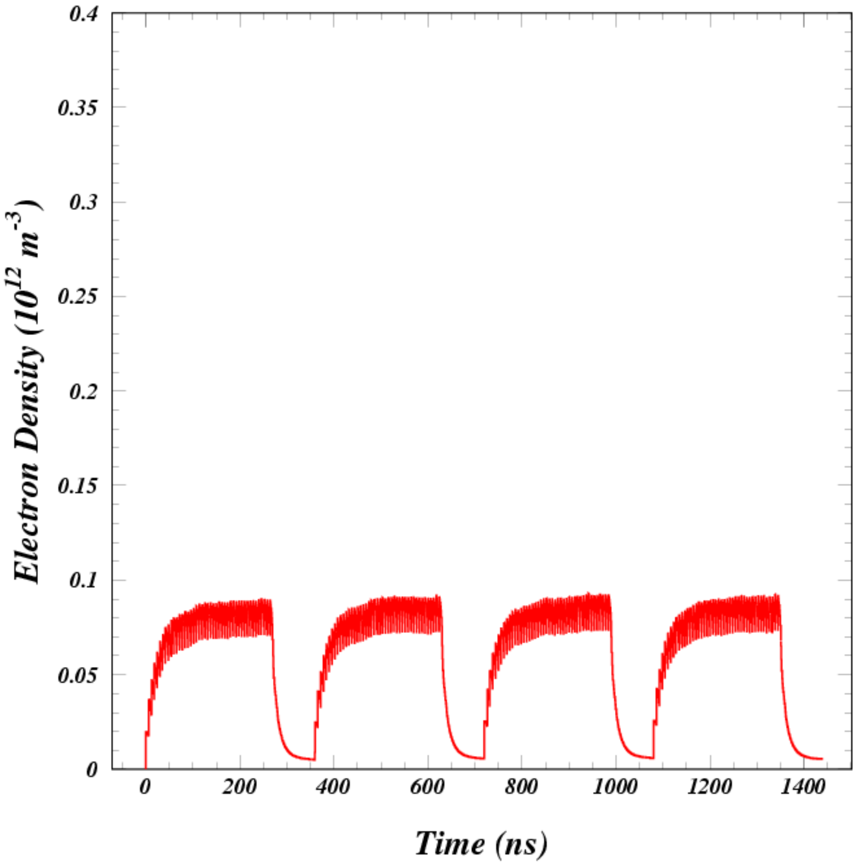

**6.4 km lattice (DCO4)**



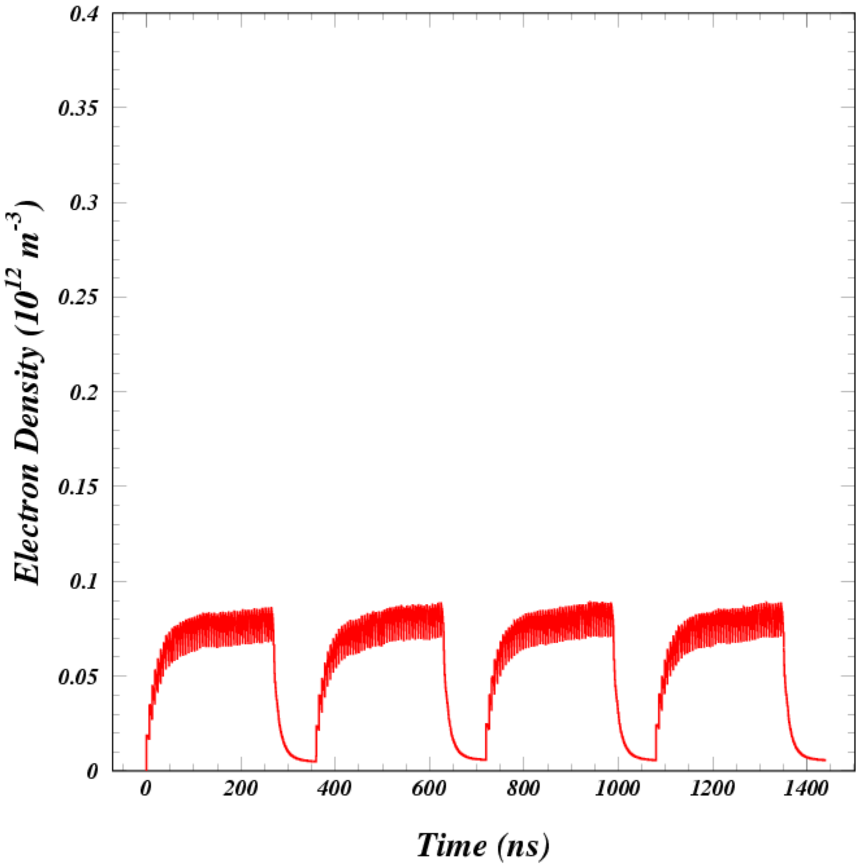

***The 3.2 km lattice has similar magnet strengths, but the density of dipoles in the arcs is higher. The analysis of 23Feb10 found 0.05e12. Introducing a rediffused component of 20% of the total SEY of 1.2 was later found to increase this maximum density value to about 0.1e12 without crossing the runaway threshold.***

# Cloud density averaged over the vacuum chamber for the solenoid regions

**3.2 km lattice (DSB3)**



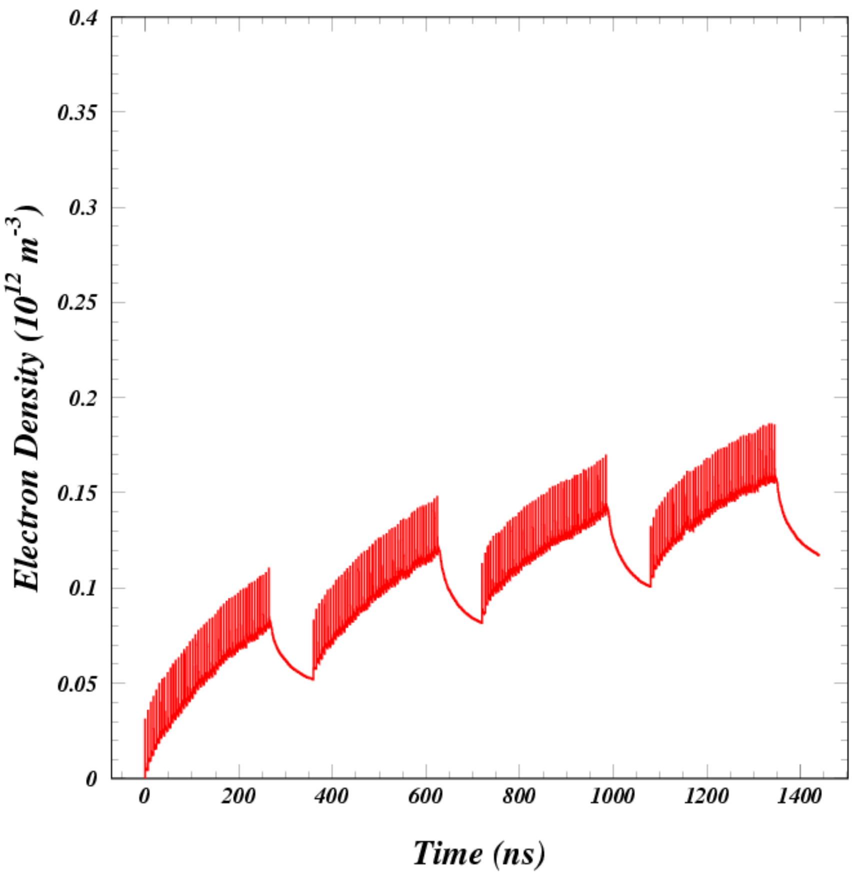

**6.4 km lattice (DCO4)**



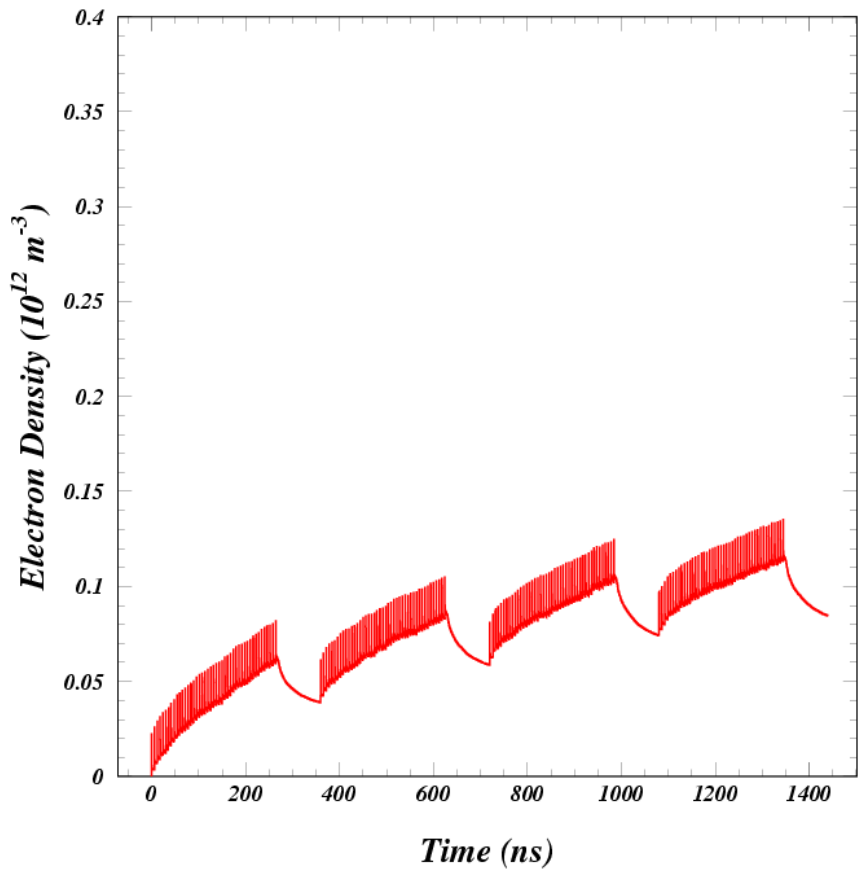

***The vacuum-chamber average of the cloud density is similar in the two rings, comparable to the dipole regions of the 6.4 km ring.***

# *Cloud density averaged over the vacuum chamber for the quadrupole regions*

*3.2 km lattice (DSB3)*




*6.4 km lattice (DCO4)*

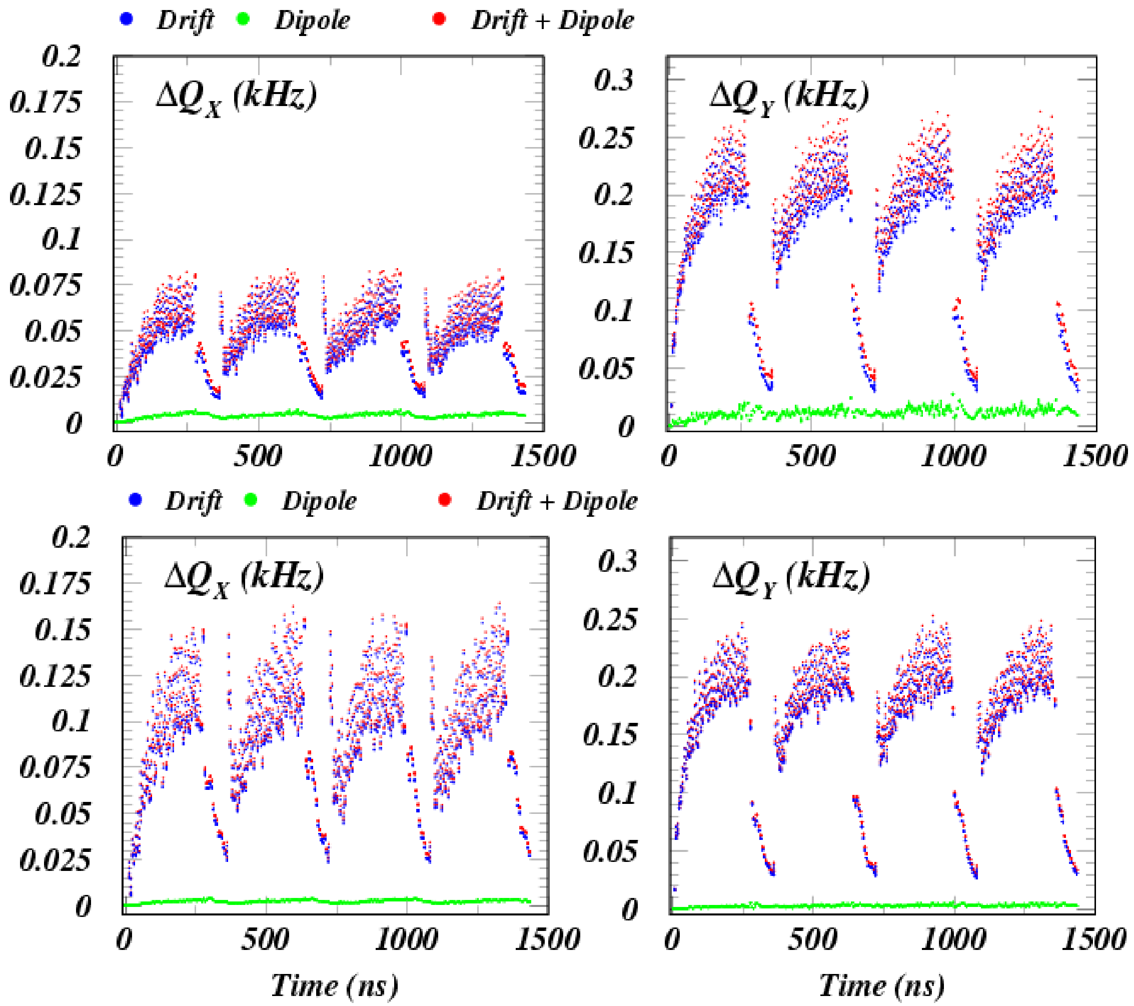



***The vacuum-chamber average of the cloud density in the quadrupoles is slightly higher in the 3.2 km ring..***

# *Drift and Dipole Contributions to the Coherent Tune Shifts*
# *$f_{rev}$ = 47 kHz (6.4 km) and 94 kHz (3.2 km)*

*3.2 km lattice (DSB3)*

*6.4 km lattice (DCO4)*

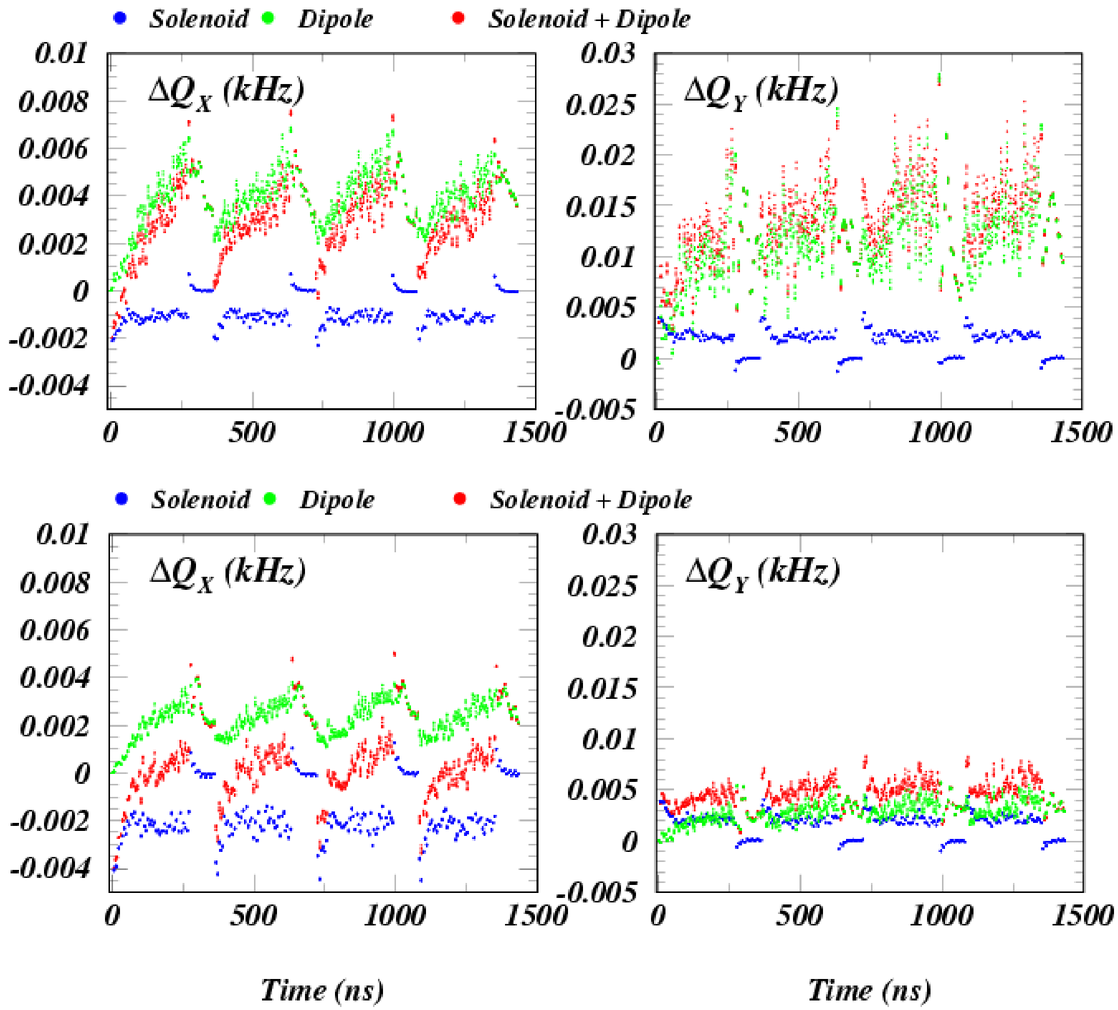



***The tune shifts are dominated by the drift regions in both cases.***
***What happens when we turn on solenoids in the drift regions?***

# *Solenoid and Dipole Contributions to the Coherent Tune Shifts*
# *$f_{rev}$ = 47 kHz (6.4 km) and 94 kHz (3.2 km)*

*3.2 km lattice (DSB3)*

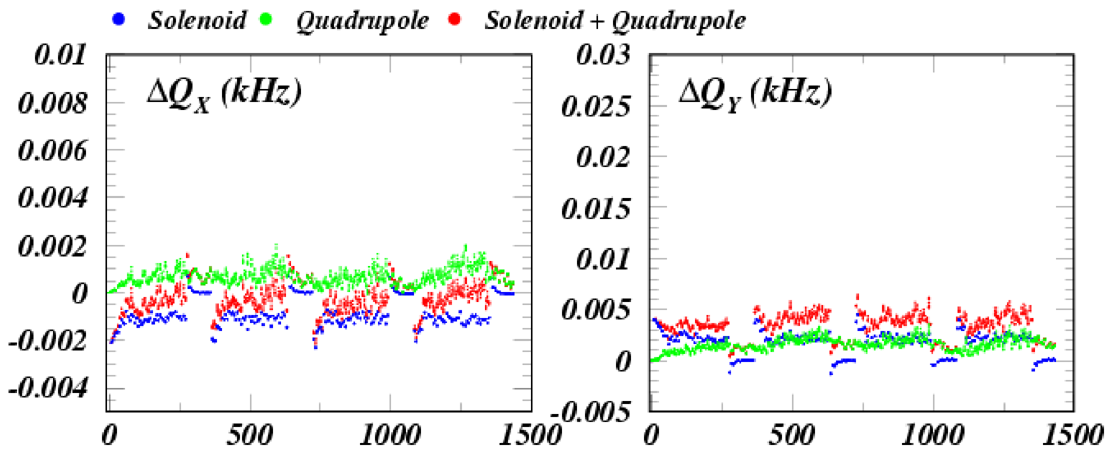
*6.4 km lattice (DCO4)*



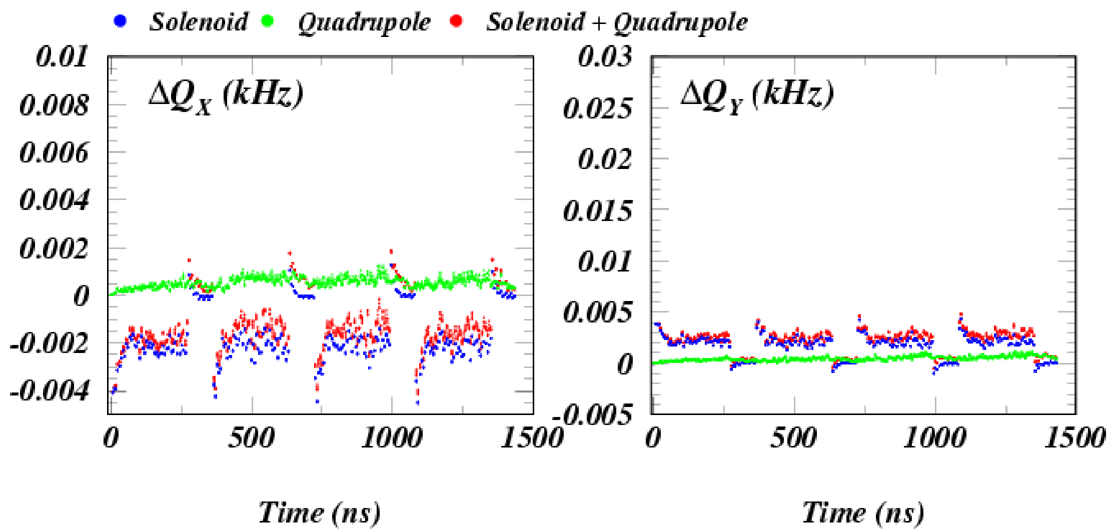

***The solenoids reduce the tune shift by more than an order of magnitude, and can change the sign.***
***Now the dipoles dominate the tune shift in the 3.2 km ring.***

# *Solenoid and Quadrupole Contributions to the Coherent Tune Shifts*
# *$f_{rev}$ = 47 kHz (6.4 km) and 94 kHz (3.2 km)*

*3.2 km lattice (DSB3)*




*6.4 km lattice (DCO4)*




***The quadrupole contribution is much smaller than the dipole contribution, but we may want to study trapping effects.***

# *Mauro's Table*

## *10-sigma density just prior to the passage of the 180th bunch*

## *$10^{12}$ e/m$^3$*

| | DC04 (6.4 km) | | | | | | | | DSB3 (3.2 km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Field-free | | Dipole | | Quadrupole | | Solenoid | | Field-free | | Dipole | | Quadrupole | | Solenoid | |
| $\delta_{max}$ | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr | Antechr | No Antechr |
| 1.0 | 0.6 | 10.2 | 0.4 | 5.3 | 0.1 | <0.1 | <0.1 | <0.1 | 0.6 | 7.6 | 0.5 | 9.8 | 0.1 | 0.4 | <0.1 | <0.1 |
| 1.2 | 0.8 | 14.3 | 0.7 | 4.0 | 0.4 | 1.8 | <0.1 | <0.1 | 1.0 | 12.4 | 1.9 | 2.3 | 0.4 | 1.3 | <0.1 | <0.1 |
| 1.4 | 1.2 | 13.8 | 2.8 | 10.2 | 1.2 | 3.1 | <0.1 | <0.1 | 1.5 | 14.1 | 4.6 | 2.2 | 1.4 | <0.1 | <0.1 | <0.1 |

*Beam parameters and photon rates as on slides 3 and 4.*
*Antechamber suppression 98% applied to both direct and reflected s.r. contribution.*
*Reflected fraction is 90% of total.*
*Direct contribution limited to two 0.5-mm vertical stripes, either together (no antechamber) or separated by 1 cm.*
*NB: In some of the dipole and quadrupole calculations, saturation was not yet reached after the four trains.*
*Also, these 10-sigma density values suffer from substantial statistical fluctuations.*