International Linear Collider at Stanford Linear Accelerator Center

Code comparison and simulation benchmarking: ILC DR wiggler

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Specify SEY limits from the electron cloud

- working plan for task 6 -

Expressions of interest and available tools
Build-up simulation codes are PEI (KEK), POSINST (LBNL/SLAC), ECLOUD (CERN), and CLOUDLAND (BNL/SLAC). Instability simulation codes are PEHTS (KEK) and HEADTAIL (CERN) for single-bunch instabilities, and PEI-M for multi-bunch instabilities (KEK). Multi-bunch wake fields can be extracted from POSINST and ECLOUD. There also exists a single-bunch instability code written by Y. Cai at SLAC. DESY, INFN, and CERN are collaborating in the EUROTeV WP3 ECLOUD subtask, the goals of which overlap with the ILC WG3 ‘electron-cloud’ task. Rainer Wanzenberg (DESY) has started a compilation of ring and beam parameters. Further contributions are highly welcome!

Comparisons with existing machines
A benchmarking program is ongoing at the CERN SPS and at DAFNE, in addition to PSR, PEP-II and KEKB, and can support the predictions.

ILC 17 km TESLA DR wiggler sections

(TESLA) Wiggler:

Peak field 1.68 T
Period 0.40 m

Chamber semi-axis 16x9mm

~rectangular with
antechambers on both sides

Different models for the wiggler field:

a) dipole

b) Cartesian model, Halbach

$$B_x = 0$$

$$B_y = B_0 \cosh\left(\frac{2\pi}{\lambda} y\right)\cos\left(\frac{2\pi}{\lambda} z\right),$$

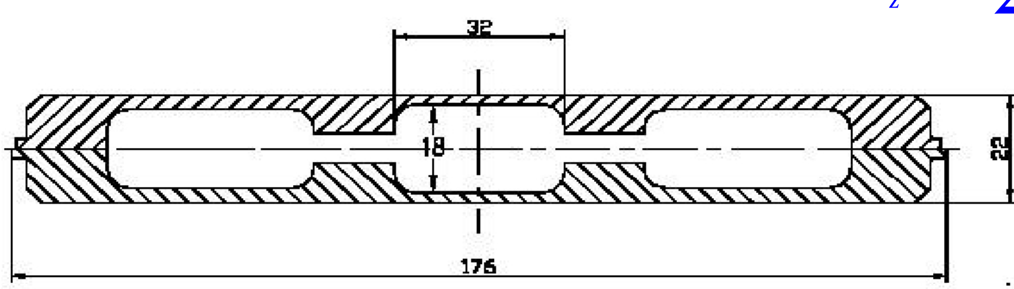
$$B_z = B_0 \sinh\left(\frac{2\pi}{\lambda} y\right)\sin\left(\frac{2\pi}{\lambda} z\right)$$

c) Cylindrical expansion model, Wolski-Venturini, first 60 modes included

$$B_\rho = \sum c_{mn} I'_m(nk_z\rho)\sin(m\phi)\cos(nk_z z)$$

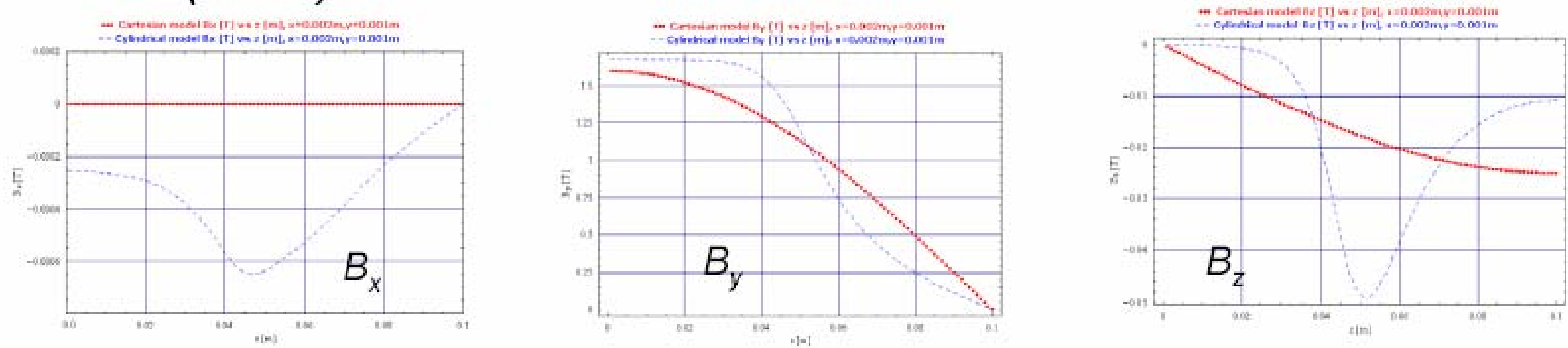
$$B_\phi = \sum c_{mn} \frac{m}{nk_z\rho} I_m(nk_z\rho)\cos(m\phi)\cos(nk_z z)$$

$$B_z = -\sum c_{mn} I_m(nk_z\rho)\sin(m\phi)\sin(nk_z z)$$

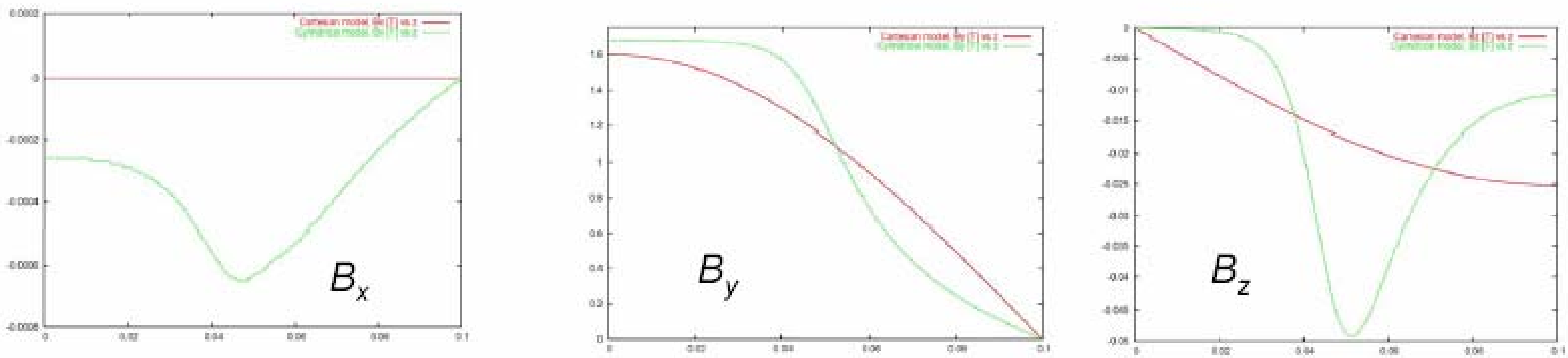


Vacuum chamber design with ante-chambers,
Reduced number of photons

POSINST (Mauro)



ECLOUD (Frank)



Horizontal, vertical, and longitudinal magnetic field as a function of longitudinal position for Cartesian and cylindrical models at x=2 mm and y = 1 mm from the wiggler axis

Primary Photon Flux & Photoelectron Rate

The ECLOUD simulations assume a photon flux of 4×10^{18} photons per meter per second, based on simulations with the PHOTON code (ECLOUD04 paper by D. Schulte, R. Wanzenberg, and F. Zimmermann). Not counting photons absorbed in the antechamber (with a full slot height of 6 mm), and assuming a photo-emission yield of 0.1, I assume an emission of 0.1 photoelectron per passing positron per meter wiggler for the emittances at injection, which decreases by a factor of about 10 for the final emittances. The 0.1 number was initially taken in the ECLOUD simulations.
Since Maur used much smaller number (0.0007 photonelectrons per meter per e+) we compromised at an intermediate value of **0.007 per m per e+ for the primary e- rate**

Chamber Geometry

Chamber geometry: a=16mm b=9mm with 2 antechambers on both sides
full height h=10mm (ECLOUD assumes 6 mm full height). **The antechamber is not modeled in ECLOUD** (only taken into account by not emitting photoelectrons from the region of the antechamber slots).

Beam Sizes

3-D beam sizes: sigx= 93e-6m, sigy=7e-6m, sigz=6mm

Bunch Charge

Bunch charge: 2 e10 positrons per bunch

Distribution of Primary Photoelectrons

For the purpose of benchmarking uniform azimuthal photoelectron distribution is used in POSINST, and I adopted the same for ECLOUD (only I do not emit photoelectrons at the location of the antechamber slots).

Wiggler Period and Field Coefficient in Cartesian Expansion

Wiggler period and field coefficient in expansion: period=0.4 m, By=1.6 T

Elastic reflectivity of Low-Energy Electrons

Low-energy elastic reflectivity of electrons: POSINST simulations assume 50% reflectivity at 0eV (!?) for a delta_max~2.0

According to Hilleret's parametrization the reflectivity is a function of delta_max, though there are no measurements confirming this hypothesis. Fitting of ECLOUD simulations to SPS data suggest that the reflectivity at low energy is about 50% for a scrubbed surface with delta_max~1.4.

For the moment, I took the Hilleret formula to benchmark with Mauro's results

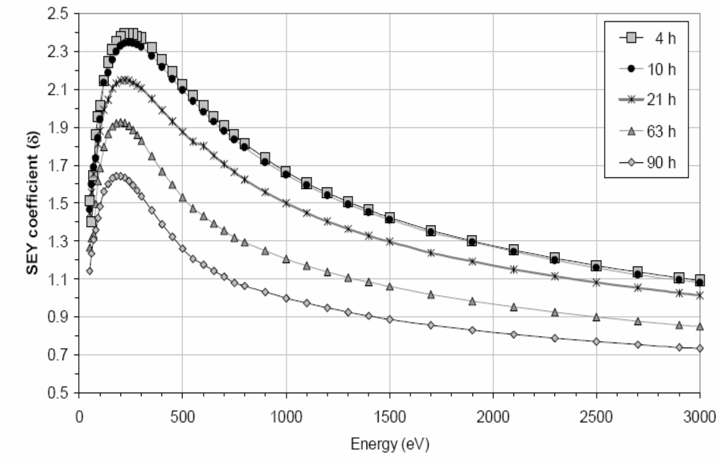
Also: **POSINST includes re-diffused electrons, ECLOUD does not!**

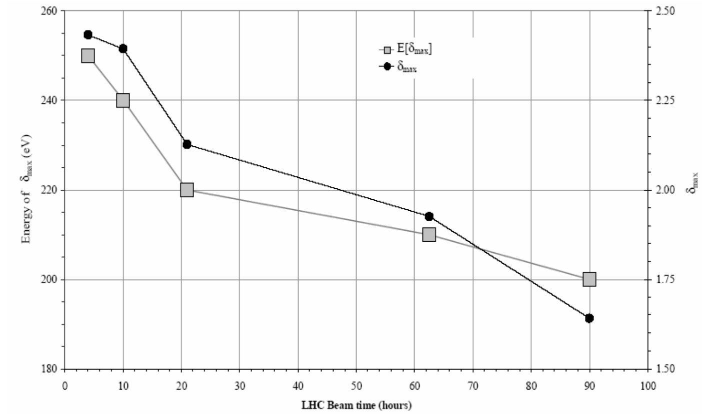
ECLOUD uses other Hilleret parametrization for true-secondary energy spectrum (see ECLOUD'02), reflected e- conserve energy

Bunch Pattern

Two bunch trains with 72 bunches each and a bunch-to-bunch gap of 8 missing bunches

SEY Models





Secondary Emission Yield Model 1)

(**variable Emax and variable e- reflectivity**
extrapolation: based on LHC Proj.Rep-632, SPS measurements SR (?!) + electron conditioning)

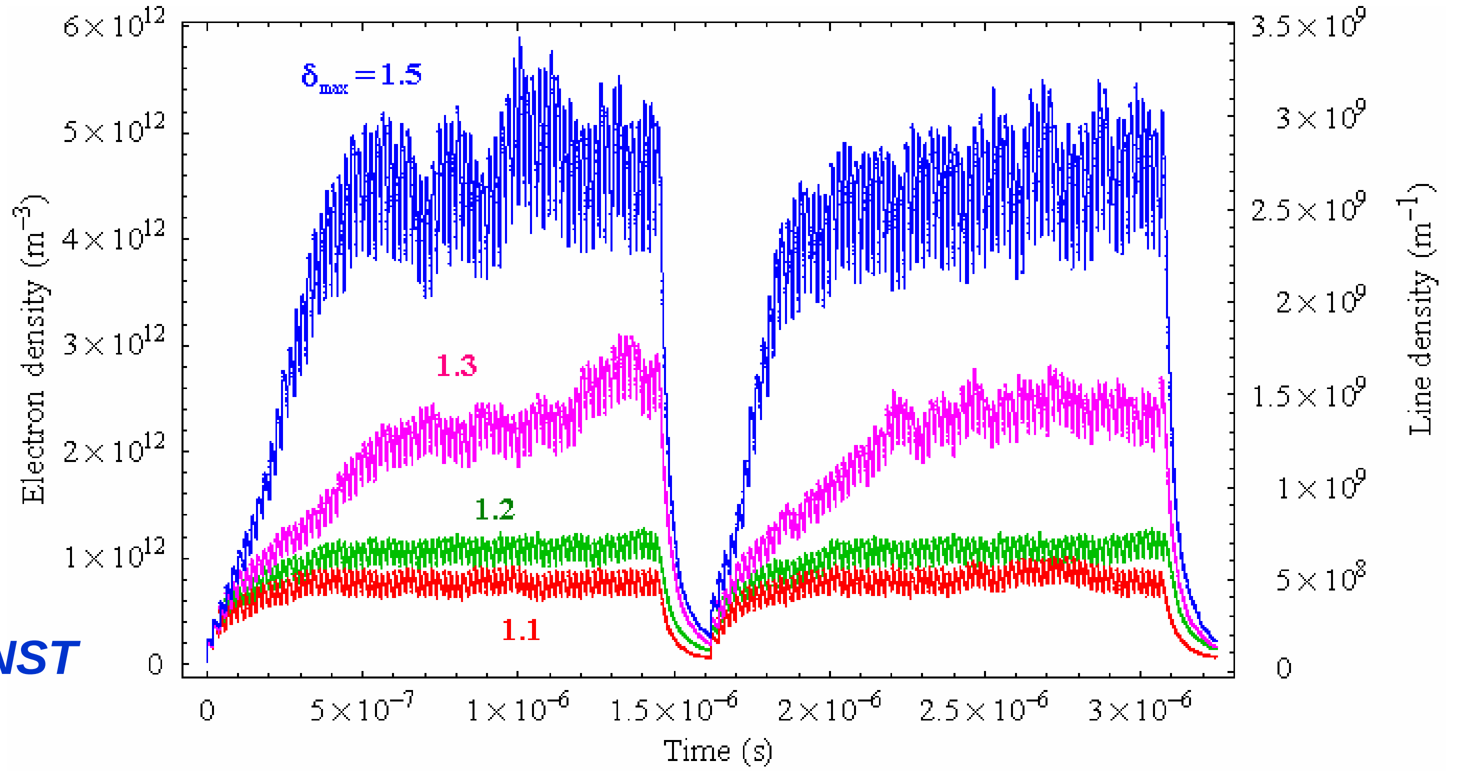
delta_max: 1.3
epsilon_max: Emax= 190 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.3: 35%
delta_max: 1.2
epsilon_max: Emax= 180 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.2: 33%
delta_max: 1.1
epsilon_max: Emax= 170 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.1: 30%

Secondary Emission Yield Model 2)

(~**constant Emax and constant e- reflectivity** based on SPS data and. Hilleret's recommendation)

delta_max: 1.3
epsilon_max: Emax= 234.75 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.3: 50%
delta_max: 1.2
epsilon_max: Emax= 232.38 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.2: 50%
delta_max: 1.1
epsilon_max: Emax= 230 eV (function of delta_max)
low-energy elastic reflectivity of electrons at 1.1: 50%

Benchmarking of ECLOUD and POSINST in ILC TESLA DR wiggler



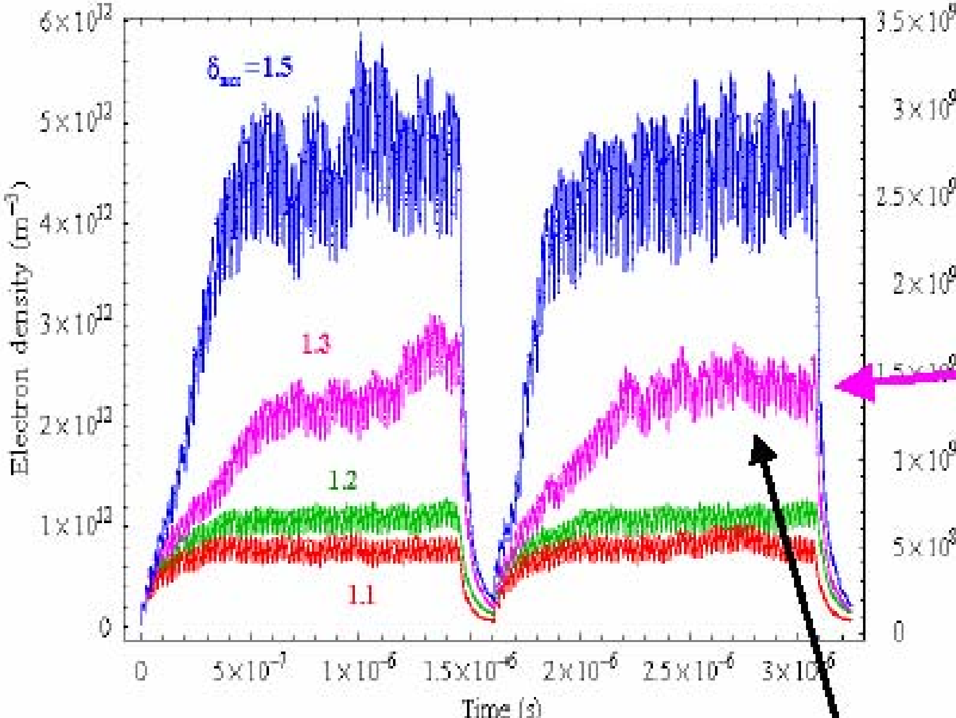
POSINST

Simulated electron cloud density with POSINST vary SEY params (Ex. deltamax=1.3, Emax=190eV). Photoelectrons rate is 0.007 electrons per meter per positron. Wiggler field "Cartesian" model. Rectangular chamber with semi-axis axb=16x9mm and two antechambers 10mm full size on both sides.

$$B_x = 0$$
$$B_y = B_0 \cos(k_z z)\, Cosh(k_z y)$$
$$B_z = -B_0 \sin(k_z z)\, Sinh(k_z y)$$

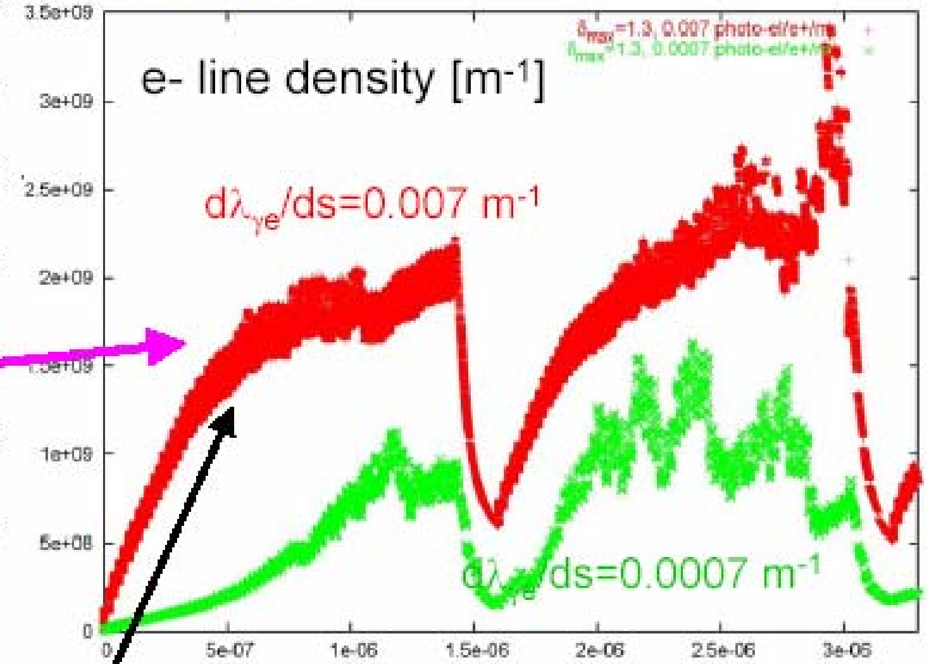
Electron line density (m^{-1})

POSINST



4 different values of δ_{max}

ECLOUD **Frank Zimmermann**



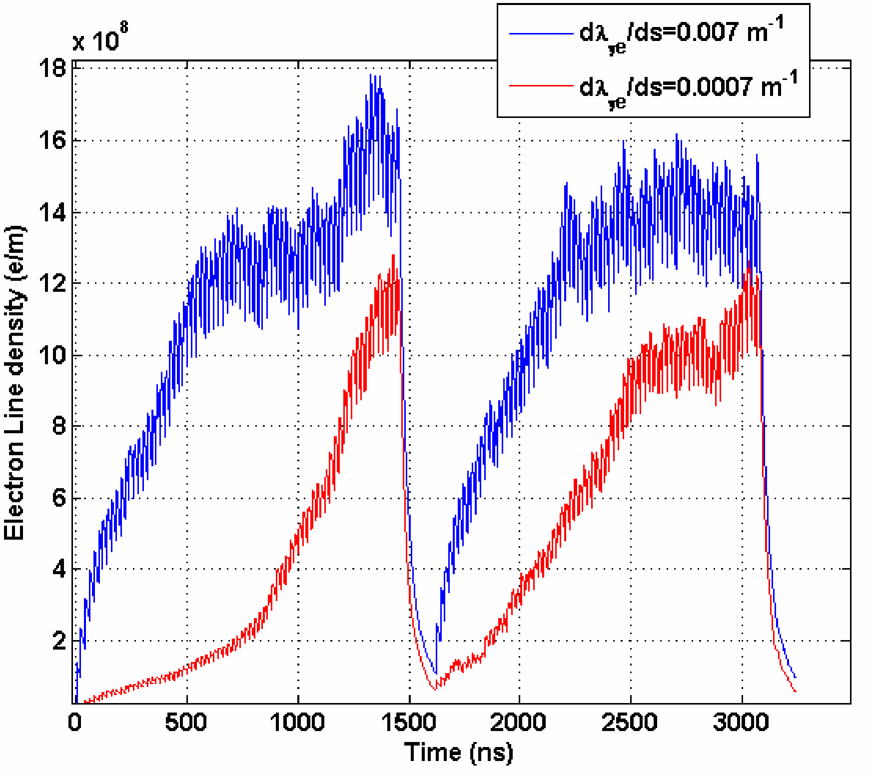
time [s]

2 different primary rates

these two curves should be the same;
they agree within ~25%

Benchmarking of ECLOUD and POSINST in ILC TESLA DR wiggler

POSINST



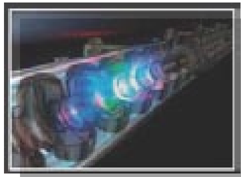
δ_{max}=1.3

2 different primary e- rates

Simulated electron cloud density with POSINST (SEY params deltamax=1.3, Emax=190eV). Photoelectrons rate are 0.007 and 0.0007 photo-electrons per meter per positron. Wiggler field "Cartesian" model. Rectangular chamber with semi-axis axb=16x9mm and two antechambers 10mm full size on both sides.

$$B_x = 0$$
$$B_y = B_0 \cos(k_z z)\, Cosh(k_z y)$$
$$B_z = -B_0 \sin(k_z z)\, Sinh(k_z y)$$

Future Directions



- Simulate build-up for all the regions of all the DR rings: compare, benchmark POSINST and ECLOUD.
- Compare ECLOUD and POSINST wiggler simulation results with CLOUD_LAND L. Wang (SLAC) 3D space charge forces
- Explore dependence on SEY models 1 and 2 and assumptions (reflectivity, rediffused electrons, etc.)
- Determine instability thresholds for all rings PEHTS (benchmark with HEAD-TAIL)

- <u>By October 2005</u> task force 6 Co-ordinators deliver the information that will be necessary for making a DR configuration selection.