ECLOUD Calculations of Coherent Tune Shifts for the April 2007 Measurements

- Thanks to Marco for clarifying the drift/dipole weighting -
- Thanks to Gerry for updating comparisons of 11 Feb 2009 -

Jim Crittenden
Cornell Laboratory for Accelerator-Based Sciences and Education

Electron Cloud Simulations Meeting
Wilson Lab
4 March 2009
Conversion of Space-charge Field Values to Tune Shifts

\[ \Delta f_x = f_{\text{rev}} \frac{e}{4\pi E_{\text{beam}}} \oint dE_x ds \approx f_{\text{rev}} \frac{e}{4\pi E_{\text{beam}}} C \langle \beta_x \rangle_{\text{ring}} \oint dE_x \left\langle \left\langle \frac{dE_x}{dx} \right\rangle_{\text{beam}} \right\rangle_{\text{ring}} \]

I. ECLoud Input Parameters
1. Sync rad photon rate per meter per beam particle at primary source point (Drift R=0.23, Dipole R=0.53)
2. Quantum efficiency (12%)
3. Beam particles per bunch (0.75 mA/bunch -> 1.2e10 e/bunch).
4. Eleven bunches filled, followed by nine empty.
   • In the POSINST calculations, only the first ten bunches and the witness bunch for which the tune is calculated are filled.
5. Contribution of reflected sync rad photons uniform in azimuth (15%).
   • This contribution is also subtracted from the primary source point.
6. The primary p.e. generation model is identical to POSINST's (panghel=1).
7. Secondary emission peak yield (SEY=2.0) at peak energy (E_{peak} = 310 eV)
   • These values are also used by POSINST, but the POSINST SEY model is very different from ECLoud's.

II. Field Difference or Gradient --> Tune Shift Conversion Parameters
1. \( E_{\text{beam}} = 1.885e9 \) eV
2. \( f_{\text{rev}} = 390 \) kHz
3. Ring circumference \( C=768 \) m \( (C f_{\text{rev}} = c = 2.998e8 \) m/s)
4. Ring-averaged \( \beta \) values (from sync rad summary tables, see my presentation 18 Feb 09)
   - \( e+ \) beam: Drift \( \beta_x (\beta_y) = 19.6(18.8) \), Dipole \( \beta_x (\beta_y) = 15.4(18.8) \)
   - \( e- \) beam: Drift \( \beta_x (\beta_y) = 19.4(19.3) \), Dipole \( \beta_x (\beta_y) = 15.3(19.4) \)

III. Relative Drift/Dipole Weighting (from sync rad summary tables)
1. Ring length fraction
   • Drift: \((174.9/768) = 0.228\)
   • Dipole: \((473.9/768) = 0.617 \) (MV used 377.99 m. I weight his tune shift by 473.9/377.99 in this talk.)
2. \( \beta \)-averaged photon rate values
   • \( e+ \) beam: Drift \( R_x (R_y) = 0.987(1.061) \), Dipole \( R_x (R_y) = 1.100(0.911) \)
   • \( e- \) beam: Drift \( R_x (R_y) = 0.957(1.030) \), Dipole \( R_x (R_y) = 1.098(0.911) \)
Example Tune Shift Calculation

$$\Delta f_x = f_{rev} \frac{e}{4\pi E_{beam}} \oint \beta_x \left( \frac{dE_x}{dx} \right)_{beam} ds \approx f_{rev} \frac{e}{4\pi E_{beam}} C \left( \beta_x \right)_{ring} \left( \frac{dE_x}{dx} \right)_{beam} \left( \frac{dE_x}{dx} \right)_{ring}$$

Example: $\Delta E/\Delta Y = 1000 \text{ V/m}^2$, $\beta_Y = 20 \text{ m} \Rightarrow \Delta f = 253 \text{ Hz}$

April 2007 Conditions

Positron beam beam-averaged field values for vertical offsets $\pm 5 \text{ mm}$

$\Delta E/\Delta Y$ averaged over bunch 11

Drift: $9.038e3 \text{ V/m}^2$  Dipole: $2.610e3 \text{ V/m}^2$

(Omit $\beta$-weighted photon rate correction for purposes of this comparison)

$$\Delta f_Y = \frac{2.998e8}{4\pi 1.885e9} \left( 0.228 \times 18.8 \times 9.038e3 + 0.617 \times 18.8 \times 2.610e3 \right)$$

$$\Delta f_Y = 0.873 \text{ kHz}$$
Note that the tune shifts are derived from the differences of fields calculated for two different beam offsets. The above fields are for the positive beam offset only.
ECLOUD Tune Shift Calculations
-- Positron Beam --

\[ \Delta Q_x (kHz) \]

\[ \Delta Q_y (kHz) \]

Time (ns)

Drift, Dipole, Weighted Sum, 4/2007 Positron Beam
ECLOUD Tune Shift Calculations
-- Electron Beam --

![Graph showing tune shift calculations for electron beam](image-url)

- Drift
- Dipole
- Weighted Sum
- 4/2007 Electron Beam

ΔQₓ (kHz) vs. Time (ns)

ΔQᵧ (kHz) vs. Time (ns)