ECLOUD Calculations of Coherent Tune Shifts for the April 2007 Measurements

- Study of SEY Model Effects -

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Conversion of Space-charge Field Values to Tune Shifts

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

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. Ten bunches filled, followed by ten empty bunches.
   - 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_{beam} = 1.885e9 eV
2. f_{rev} = 390 kHz
3. Ring circumference C=768 m ($C f_{rev}$ = c = 2.998e8 m/s)
4. Ring-averaged β 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

The sole difference relative to slide 2 of the March 4 talk is that ten rather than eleven bunches are filled.

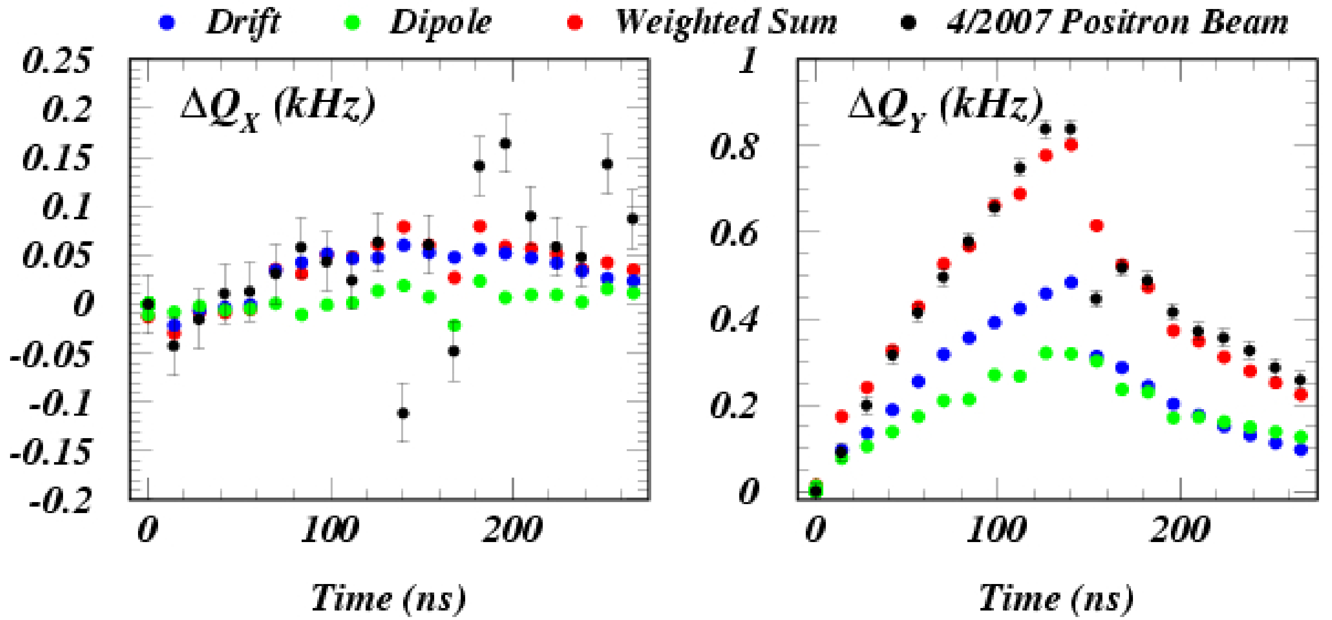
ECLOUD Tune Shift Calculations
-- Positron Beam --

Two systematic improvements since the March 4 results:

1) Reduced space charge grid size by factor 2 from 4.5 mm x 2.5 mm to 2.25 mm x 1.25 mm

This brought the calculated horizontal tune into agreement with the measurements.

2) Removed a limit on the number of macroparticles which was causing fluctuations in the dipole results.



I. Remarkable overall scale agreement for ΔQ_Y. Cloud decay time constant also very good.

- ***Used POSINST input parameters without tuning, e.g. reflectivity. This ECLOUD result is an even better match. (See GD/February 5)***

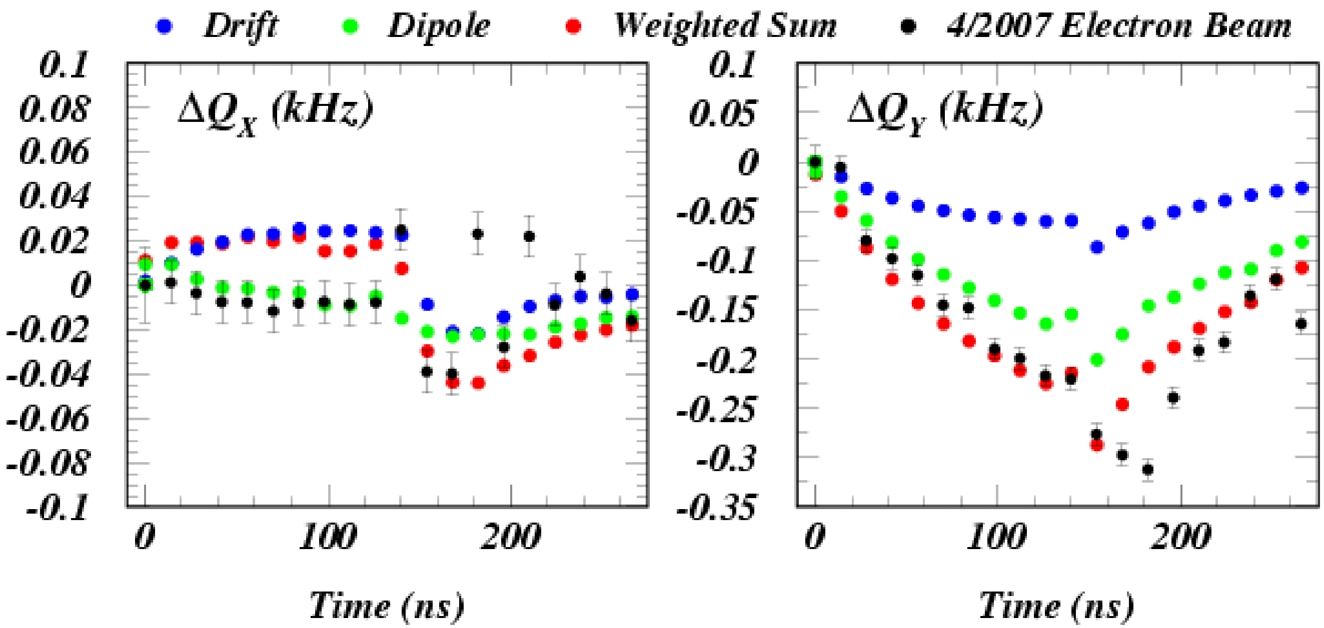
II. Large $\Delta Q_Y / \Delta Q_X$ ratio now accurately reproduced (Holy Grail since ILCDR08 last July)

- ***This required the accounting for dynamic effects related to the pinger kick used for measuring tunes***

III. ECLOUD does not reproduce the bunch 13 'bounceback' in ΔQ_Y

- ***POSINST gets it right! This motivates a study of the effects on the tune shift calculations of the SEY model***

ECLOUD Tune Shift Calculations
-- Electron Beam --



I. Again overall scale agreement for ΔQ_Y quite good

1. Used tuned POSINST parameters, e.g. reflectivity. This ECLOUD result is even better. (See GD presentation of February 5)

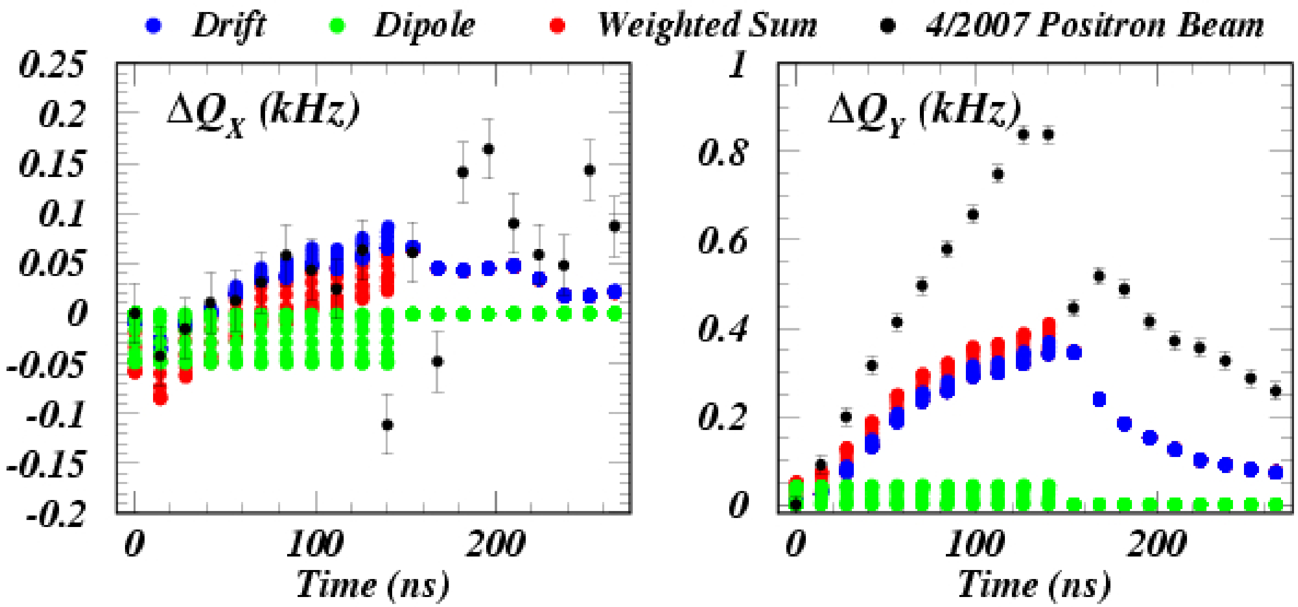
II. ΔQ_X agreement not good and raises the issue of relative drift/dipole contribution

1. POSINST found equal contributions to ΔQ_Y during buildup for both positrons and electrons. It matches ΔQ_X much better.
2. ECLOUD finds ΔQ_Y dominated by dipole regions for electrons and by driftregions for positrons.

III. ECLOUD finds too little post-beam increase in ΔQ_Y.

1. POSINST finds a greater effect. This again motivates a study of the effects on the tune shift calculations of the SEY model

REFL = 15% --> 0 %



I. Turning off reflectivity does two things:

- *It removes the azimuthally uniform contribution to primary generation on the beampipe wall*
- *It increases the primary rate at the source point by 15%*

II.This calculation used the field gradients averaged over the transverse cross section of the bunch

- *So it does not account for the dynamic effects associated with kicking the beam*
- *The longitudinal dependence during bunch passage are shown.*

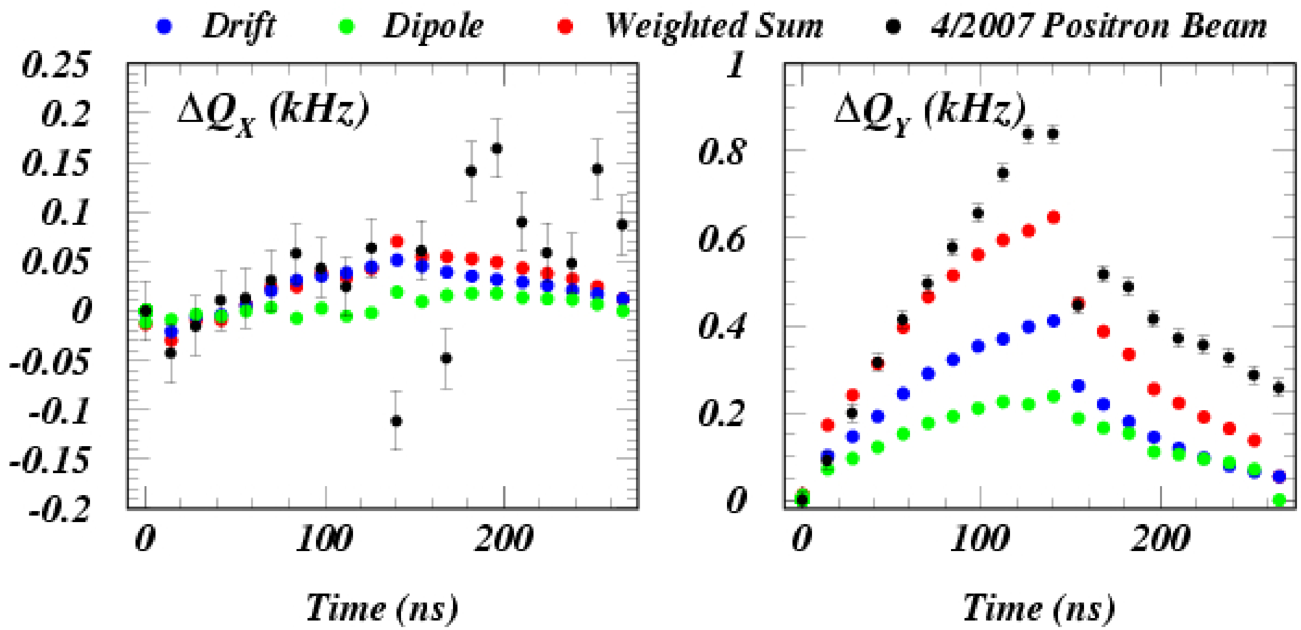
III. The dipole contribution depends critically on the poorly known reflectivity parameter

IV. The reflectivity contribution need not be proportional to the direct contribution (MAP)

- *Need to modify the ECLOUD primary generation model to account for this added flexibility*

Study of SEY Model Effects (I)

SEY = 2.0 --> 1.6 E_{peak} = 310 eV



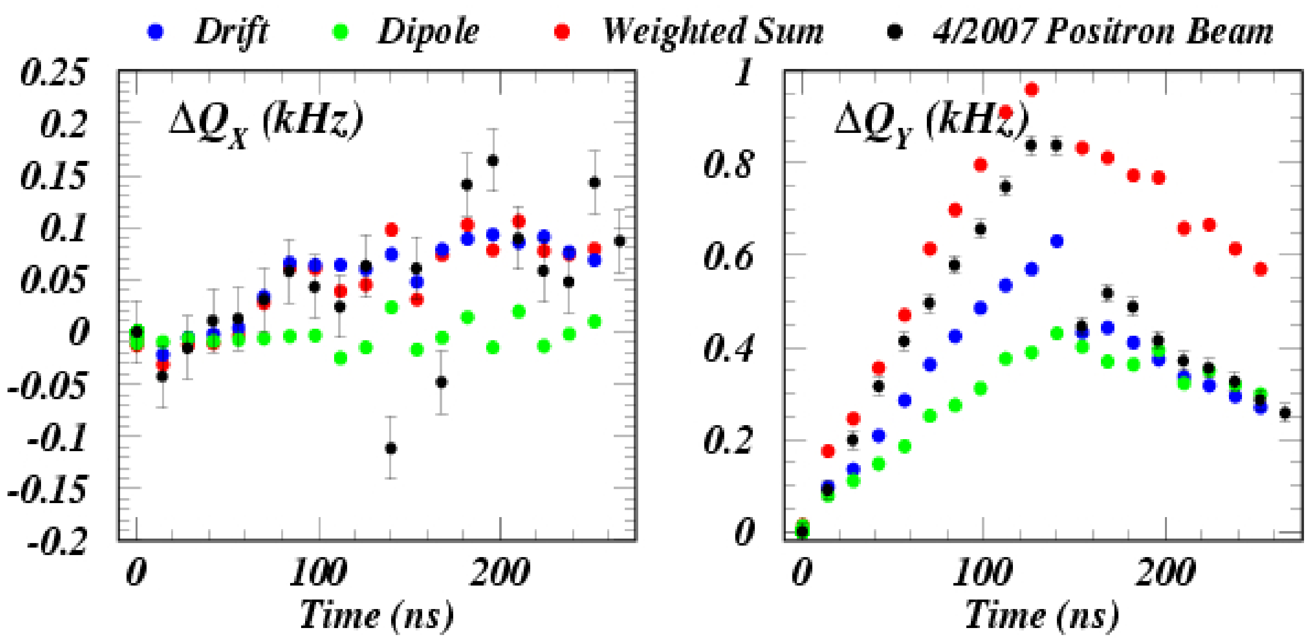
I. Insufficient SEY contribution during buildup of ΔQ_Y

II. Cloud decay time remains accurate

III. ΔQ_X modelling also accurate

Study of SEY Model Effects (II)

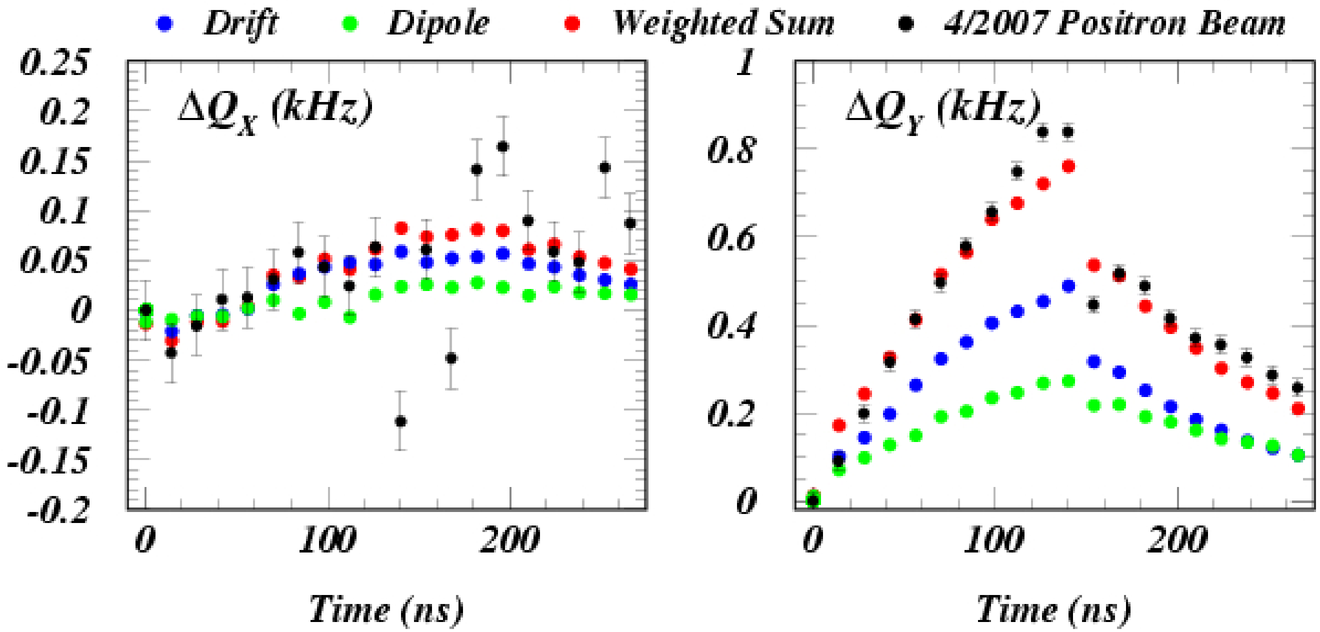
SEY = 2.0 --> 1.6 E_{peak} = 310 eV --> 170 eV



Yield for low-energy cloud electrons too high

Study of SEY Model Effects (III)

SEY = 1.6 --> 1.2 $\quad E_{peak}$ = 310 eV --> 170 eV



I. Lower values of SEY and Epeak cannot be excluded

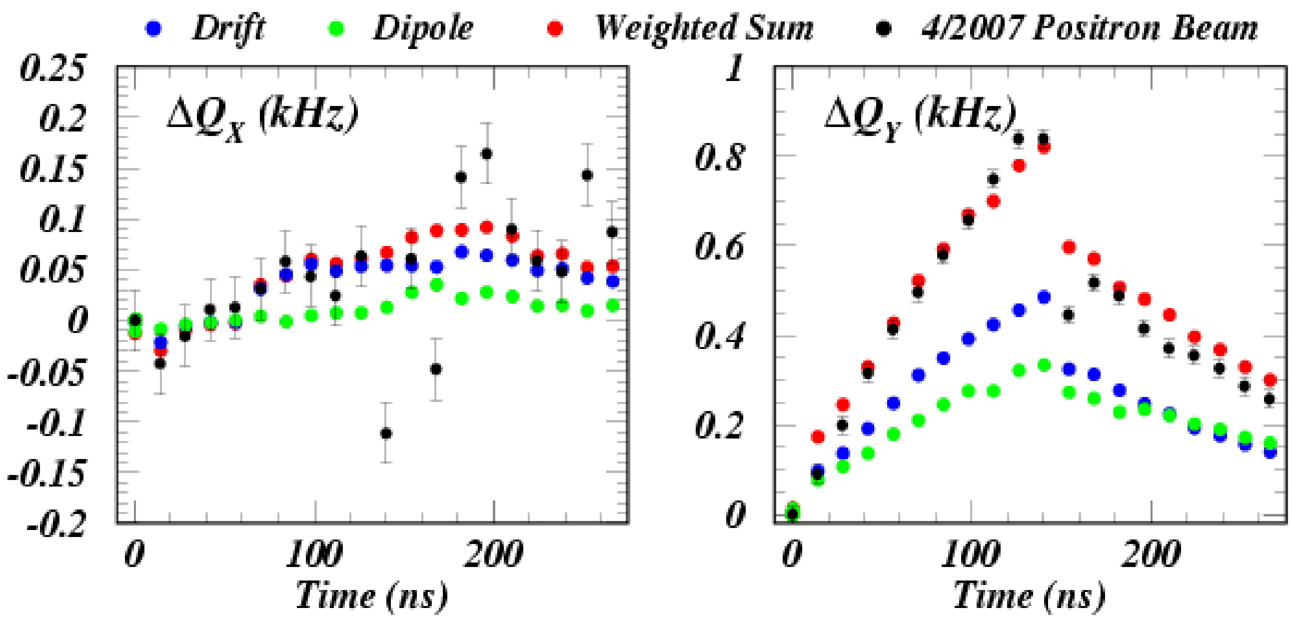
- *Epeak can likely be determined independently using dipole RFA data*

II. Cloud decay time remains accurate

III. ΔQ_X modelling still good

Study of SEY Model Effects (IV)

SEY = 1.2 --> 1.0 E_{peak} = 170 eV --> 120 eV



I. Even lower values of SEY and Epeak give good results

- *Tune shift data with differing bunch currents will likely distinguish these cases*

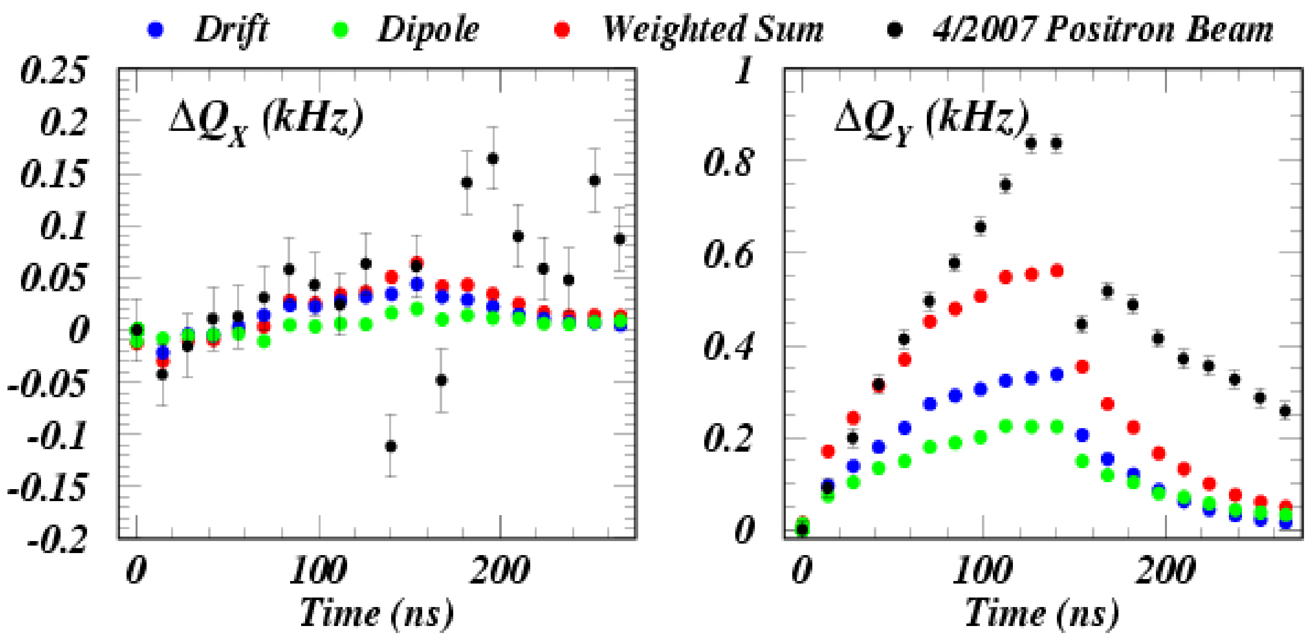
II. Cloud decay time still accurate

III. ΔQ_X modelling unaffected

Study of SEY Model Effects (V)

SEY = 1.2 --> 1.0 E_{peak} = 170 eV --> 120 eV

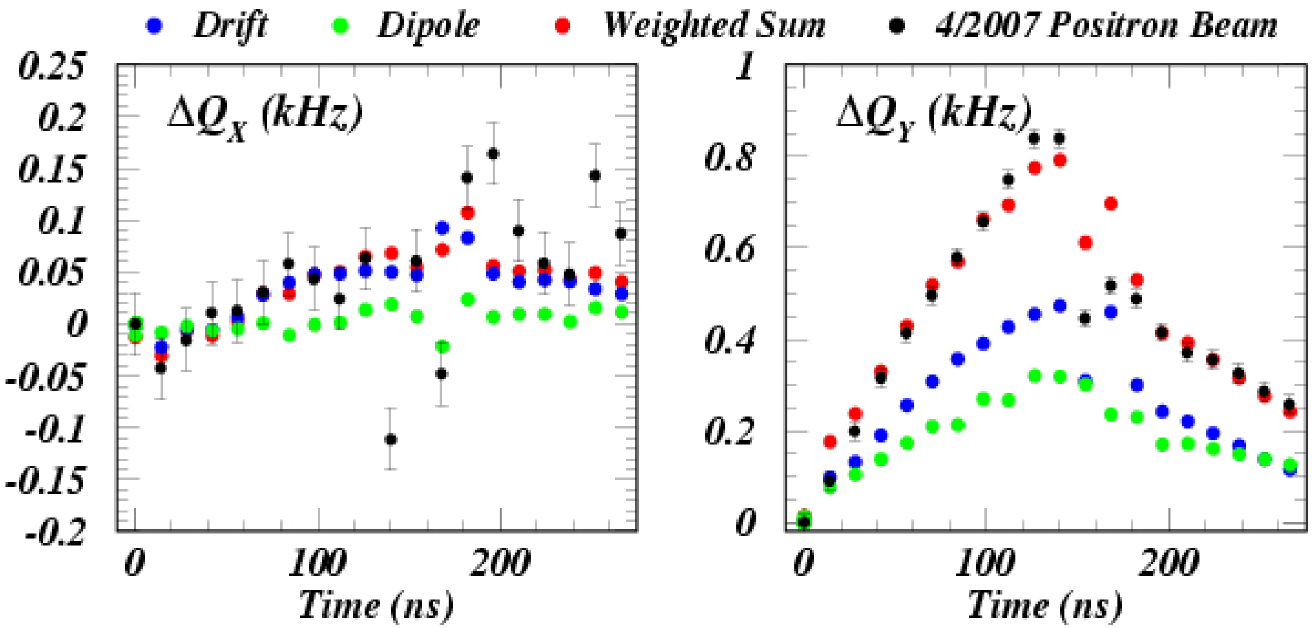
Elastic secondaries turned off



The contribution of elastic secondary yield component is important !

Monkey Wrench / Revelation

This study of the effects of the secondary yield model on calculations of tune shifts was motivated by an attempt to model the bunch 13 bounceback in ΔQ_Y. I also tried a few other systematic changes, fooling with the dipole field tracking model options, other models of the elastic contribution, angle-of-incidence cutoff, and more. Last night it occured to me to check the pinch effect, filling bunch 12.



I. Oops. SEY study barked at the wrong herring. The bounceback can be modelled as a pinch effect
II. Beware: These plots are an intermediate hybrid. I filled bunch 12 for the drift model only
III. Modelling the pinch for witness bunches is non-trivial
- ***MV and GD made use of the cloud-memorisation feature of POSINST, non-existent in ECLOUD***
- ***Without adding this feature to ECLOUD, eight 9-hour runs are necessary for each witness bunch***

Conclusions

I. The measurements of coherent tune shifts provide a wealth of information

1. *The azimuthal distribution of primary generation determines the contribution of the dipole regions*
2. *The SEY model parameters can be narrowly constrained, but are highly correlated*
3. *The two SEY parameters can likely be distinguished by the measurements at differing bunch currents*
4. *Additional info from electron beam will likely address the drift/dipole contribution issue*
5. *Will the new feedback-notch means of measuring tune shifts obviate the need for modelling beam offsets?*

II. ECLOUD / POSINST comparison

1. *So far unclear if the more sophisticated POSINST SEY model is necessary to model the tune shift data*
2. *The two models disagree on the relative drift/dipole contributions, even for the same reflectivity*
3. *POSINST can model witness bunch pinch effects. ECLOUD needs a lot of work to do so*