Simulating e-cloud induced coherent tuneshifts using POSINST: first results

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Coherent tuneshifts are calculated from 3D averages of e-field over bunch density

Kick received by bunch particle at eCloud station s=s_i

$$\Delta y' = \Delta s \left(\frac{d^2 y}{ds^2}\right)_{EC} = \frac{q\Delta s}{v_0 p_0} E_y(x, y, s = s_i; t),$$

Equation of motion for centroid of k-bunch in train

$$\frac{d^2\langle y_k\rangle}{ds^2} + \kappa_y(s)\langle y_k\rangle = \frac{q}{v_0 p_0}\sum_{i=1}\delta(s - s_i)\Delta s_i \int dx dy dz E_y(x, y, s_i; k, z)\rho_k(x, y, z).$$

Assume interaction with eCloud is dominated by first moments (centroids) of bunches

$$\frac{q}{v_0 p_0}\int dx dy dz E_y(x, y, s_i; k, z)\rho_k(x, y, z) \simeq \sum_{j=1}^{k} C_{kj}^{(i)}\langle y_j\rangle.$$

Assume coupling coefficient are diagonal

$$\frac{d^2\langle y_k\rangle}{ds^2} + \kappa_y(s)\langle y_k\rangle = \langle y_k\rangle C_{kk}^{(i)}$$

Coefficient is supposed to be independent of centroid offset

$$C_{kk}^{(i)} = \frac{q}{v_0 p_0 \langle y_k\rangle}\int dx dy dz E_y(x, y, s_i; k, z)\rho_k(x, y, z)$$

Tuneshift contribution from eCloud station s=s_i

$$\Delta\nu_y(k) = \frac{1}{4\pi}\beta_y(s_i)\Delta\kappa_y(s_i)\Delta s$$

$$\Delta\kappa_y(s_i) = -C_{kk}^{(i)}.$$

Recent POSINST developments

- POSINST has already the capability of determining eCloud induced wake fields by displacing bunches in train one at the time.
  - e-fields generated by e^- calculated using Bassetti-Erskine like formulas (and summing over all electrons) – some approximation to handle image charges.
  - no average on z

- Extend existing capability
  - by allowing for offset of all bunches in train at once
  - for efficiency, option to use for e-fields the solution to the Poisson equation that POSINST already employs to calculate electrons-to-electron space-charge kick
  - do averaging over x,y; option to average over z of bunch densities
  - introduce option to have a witness bunch following bunch train (with same charge as the other bunches). It is possible to have the witness bunch span trailing region in a single run w/o need to start anew.
  - output is
    - Ex and Ey averaged in x and y as a function of z (for each slice)
    - Ex and Ey averaged over x,y, and z for each train bunch and witness bunch
    - Tuneshifts determined by post-processing POSINST output

Simulations Parameters, etc.

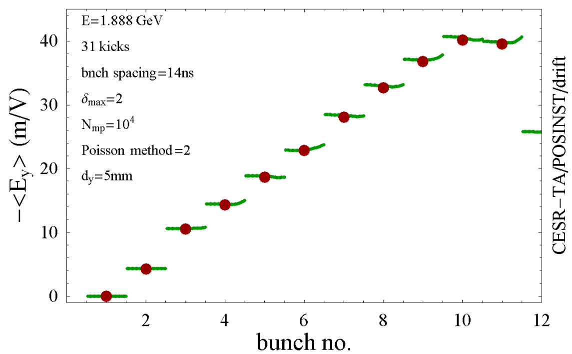
- Use CesrTA tuneshift measurement setting of April/2007 (POSINST input deck set up and kindly provided by G. Dugan)
- 1.885 GeV; 11 bunch trains with uniform 14 ns bunch spacing; 0.75 mA/bunch

- In simulations I mostly used SEY=2 and reflectivity 15% (I did some exploration of sensitivity of results to values of these parameters)
- For speed I mostly used 31 kicks (or bunch slices); not big differences found when using 51 kicks.
- 10,000 photo(macro)electrons

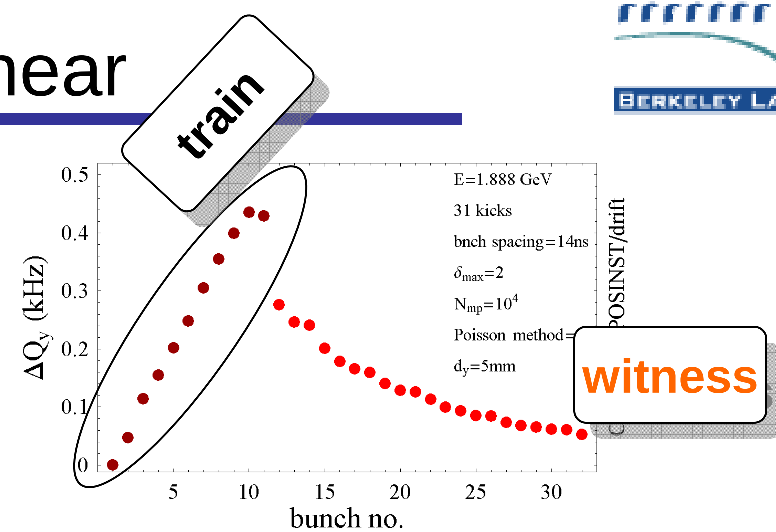
- Following simulation results are for positron bunches in DRIFTS and Soft-DIPOLES (for relevant parameters like beta functions, radiation deposition, etc. see spreadsheet LatticeRadiationWeights.xls by G. Dugan)

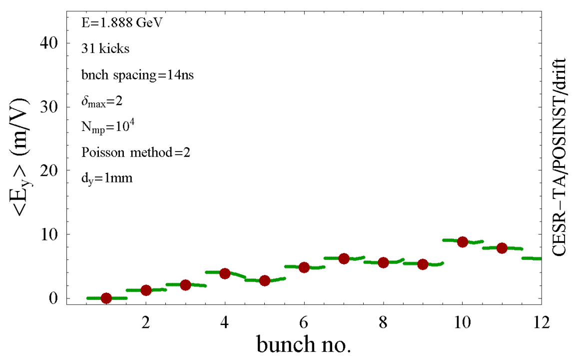
DRIFTS

DRIFT:: Vertical motion: <Ey> vs. dy=<y> is about linear

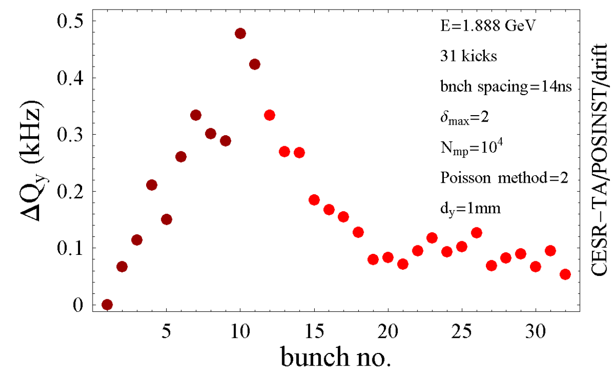


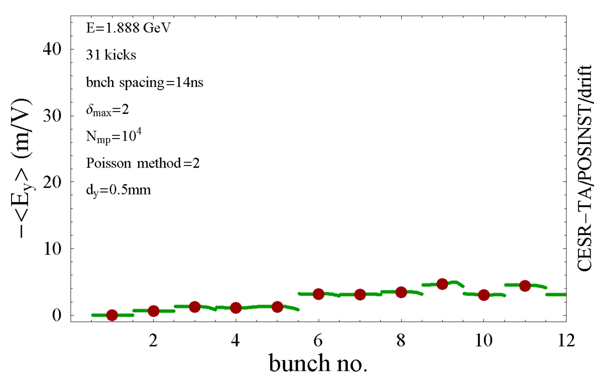
dy=5mm



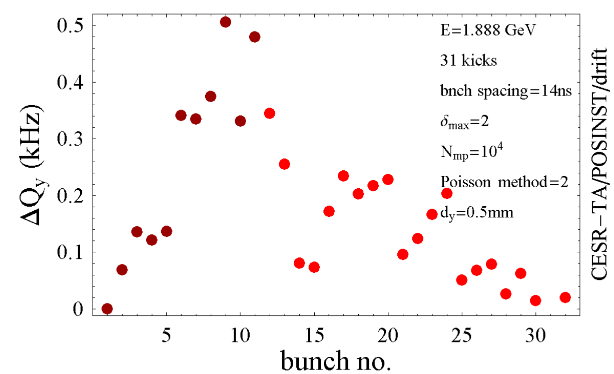


dy=1mm

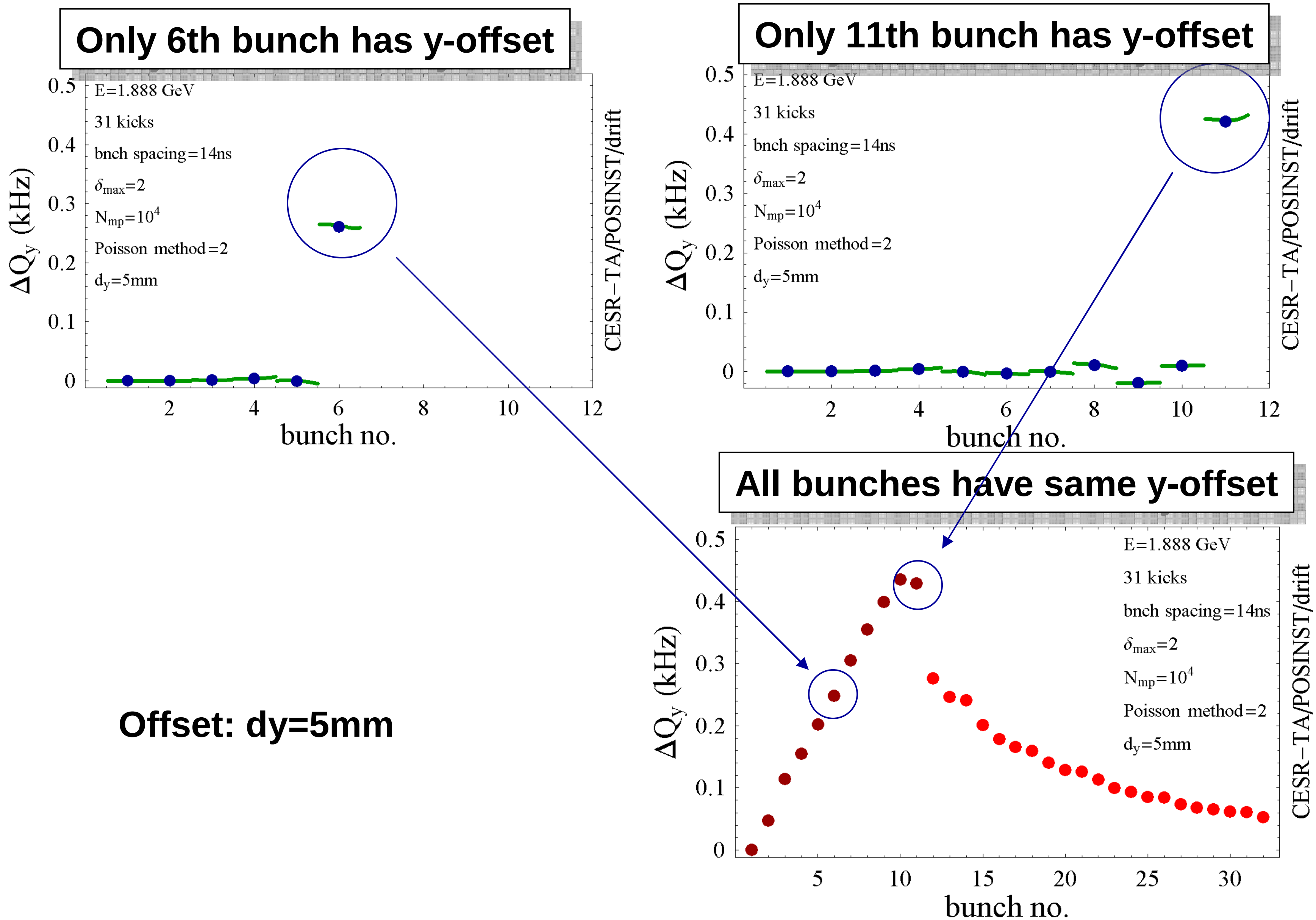




dy=0.5mm



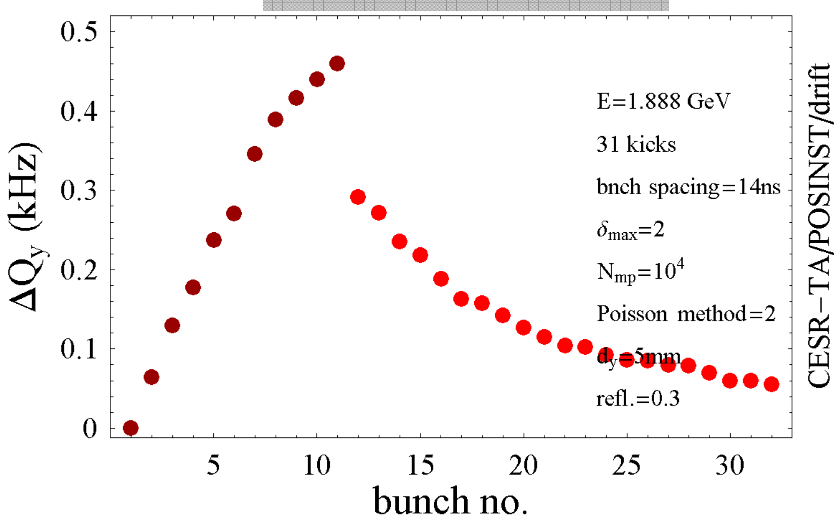
DRIFT:: **Vertical** motion: tuneshift largely independent of leading bunches offset



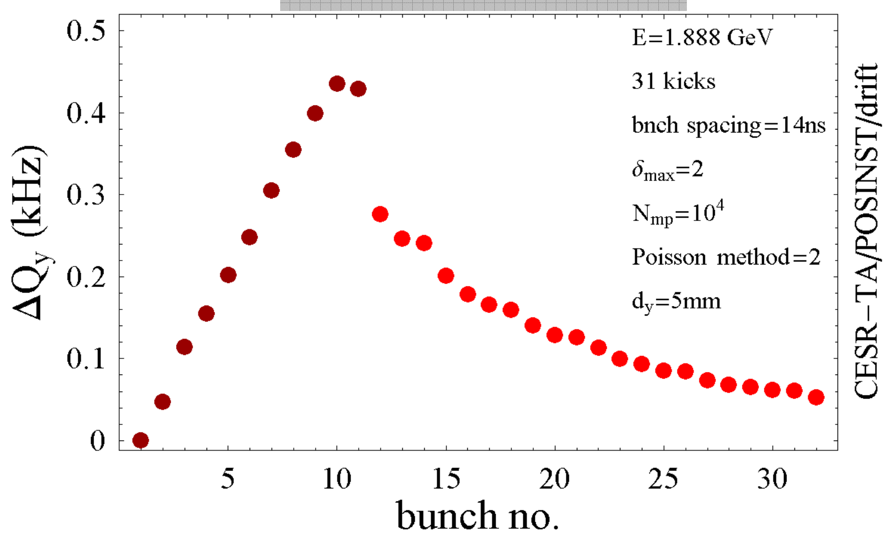
Offset: dy=5mm

DRIFT:: **Vertical** motion: tuneshift not very sensitive to value of reflectivity

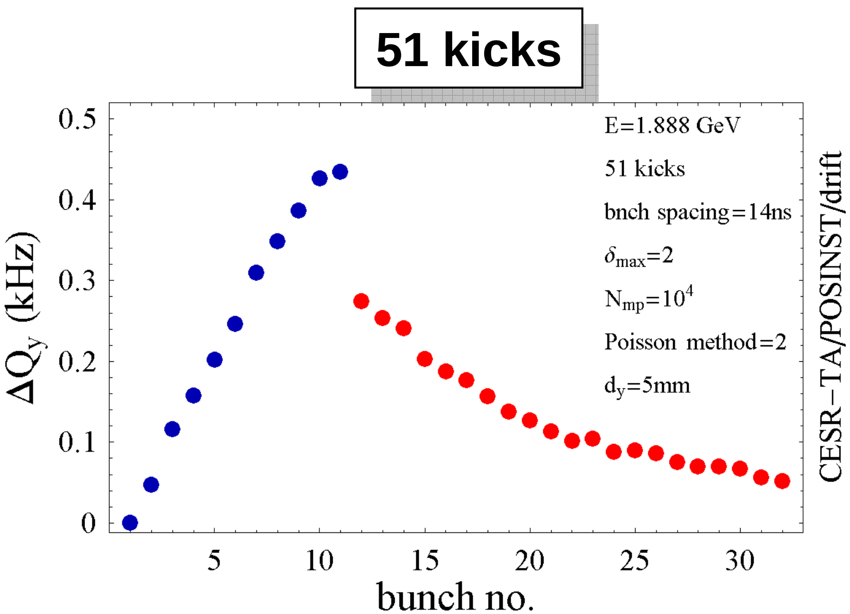
Reflectivity 30%

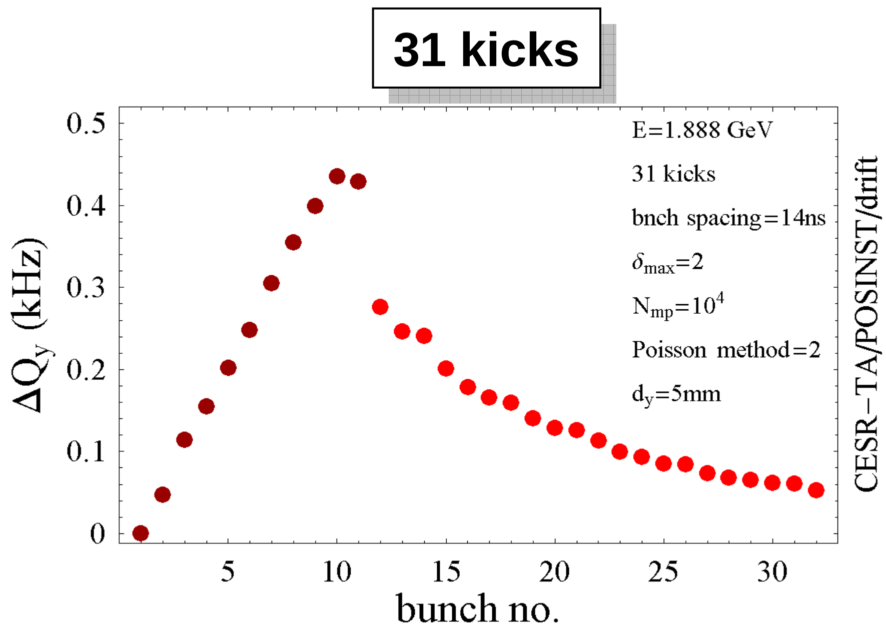


Reflectivity 15%

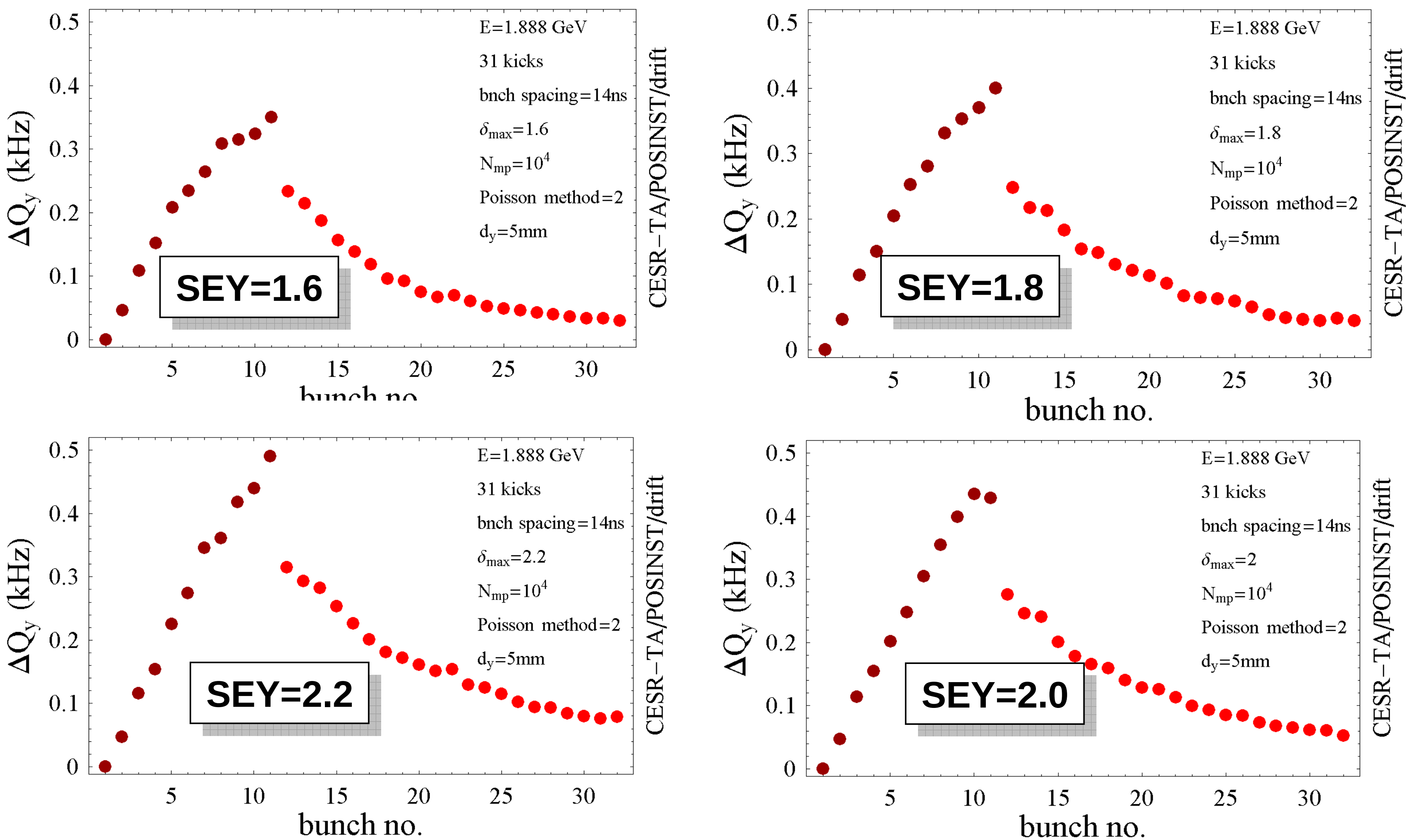


DRIFT:: **Vertical** motion: using 32 or 51 kicks yields about the same results

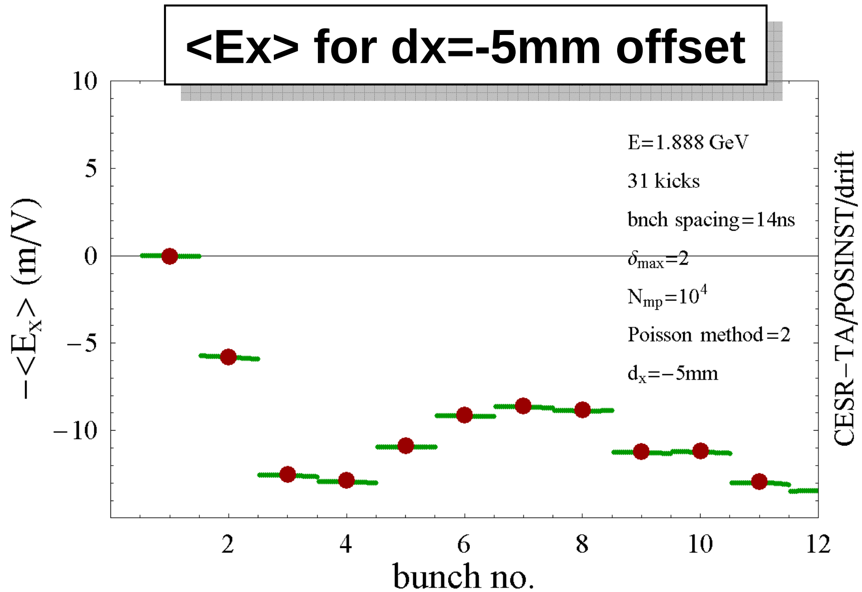


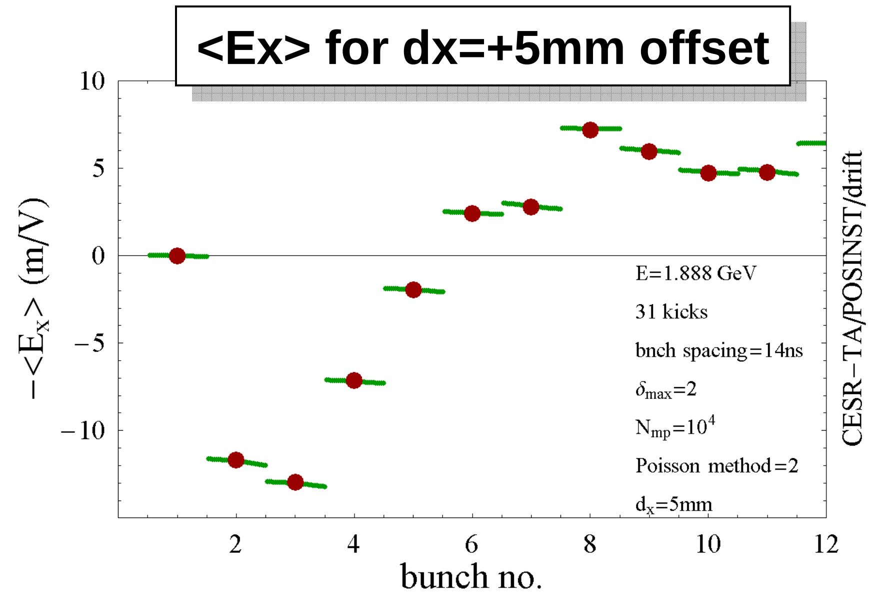


DRIFT:: **Vertical** motion: dependence on SEY apparent only in last bunches of train



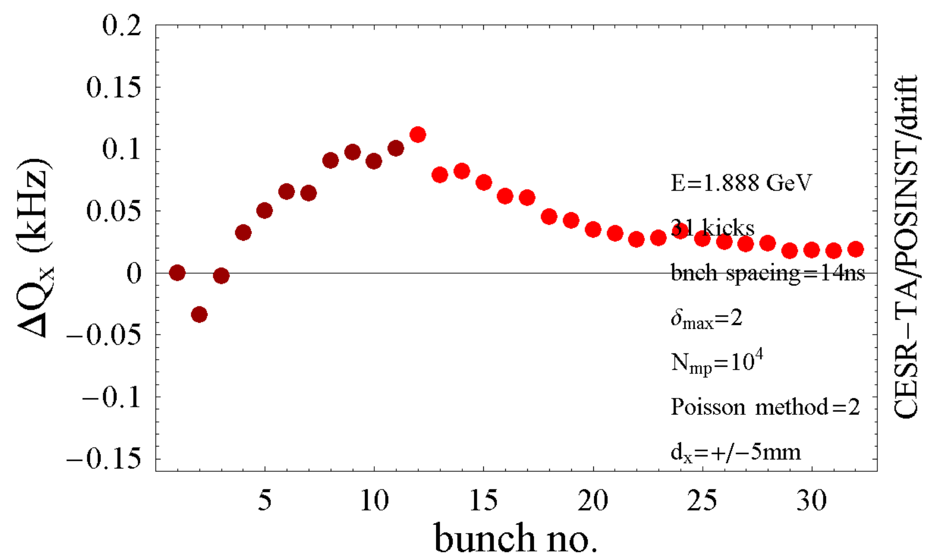
DRIFT:: **Horizontal** motion: <Ex> is not anti-symmetric under inversion of dx sign





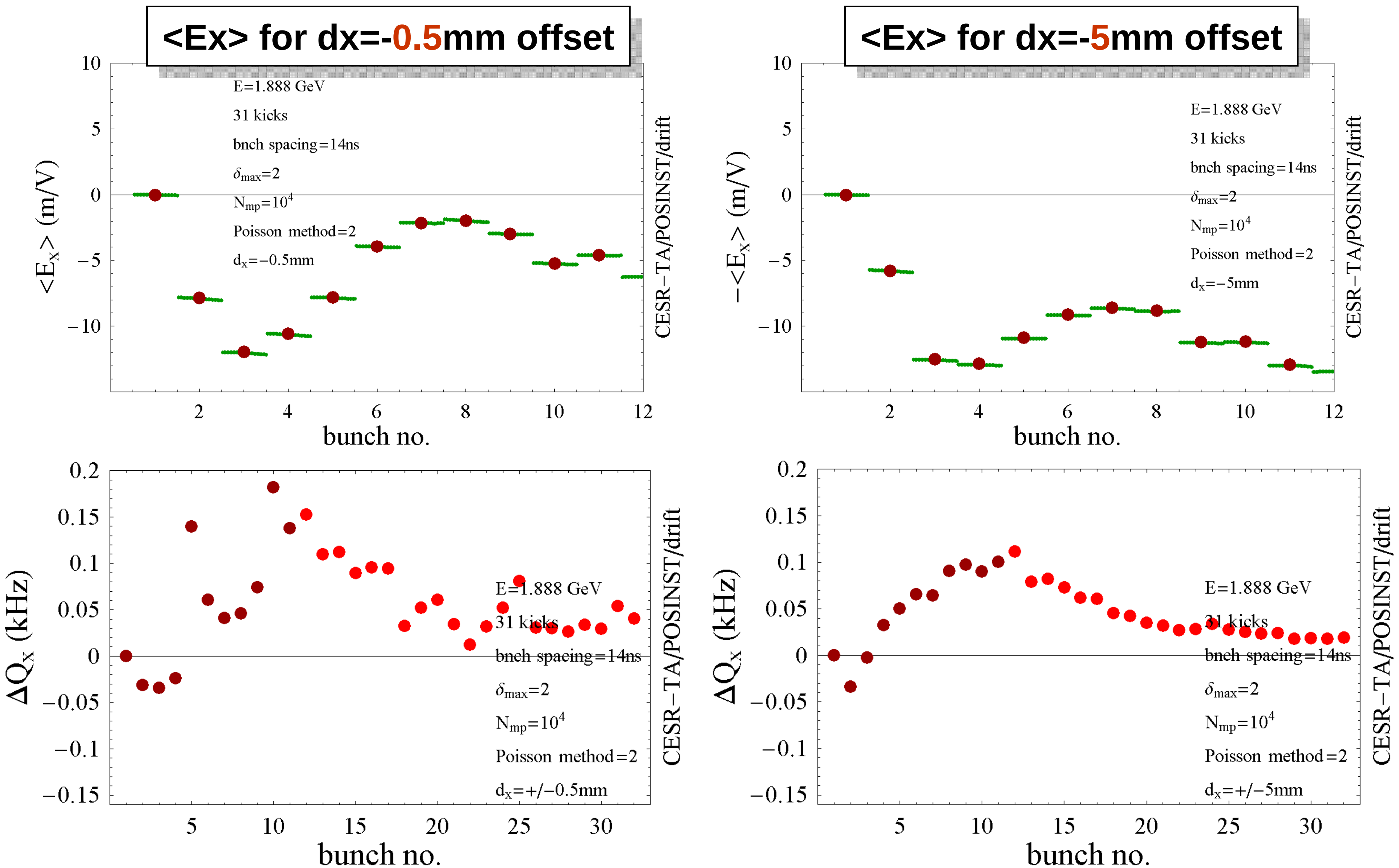
Tuneshift calculated as

ΔQ_x=-(<Ex(dx)> - <Ex(-dx)>)/(2dx)

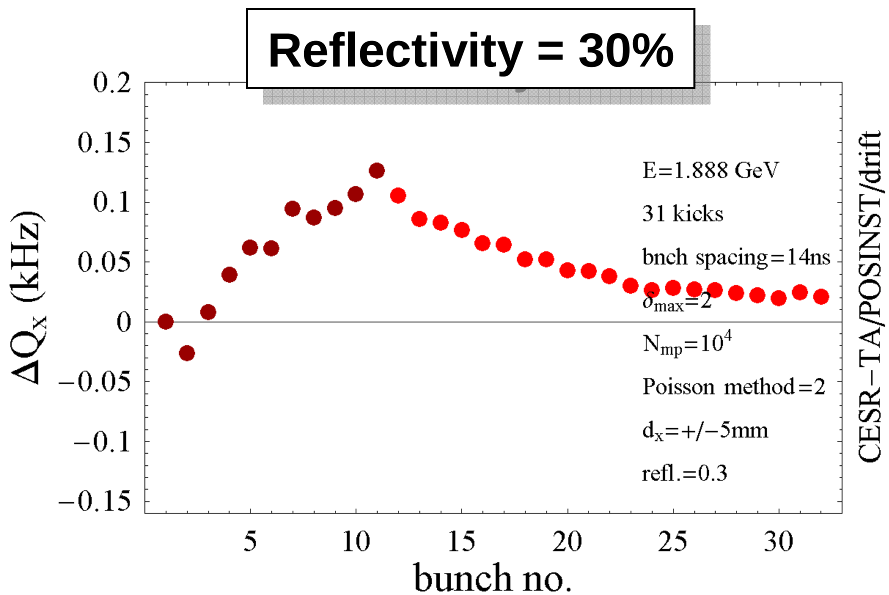


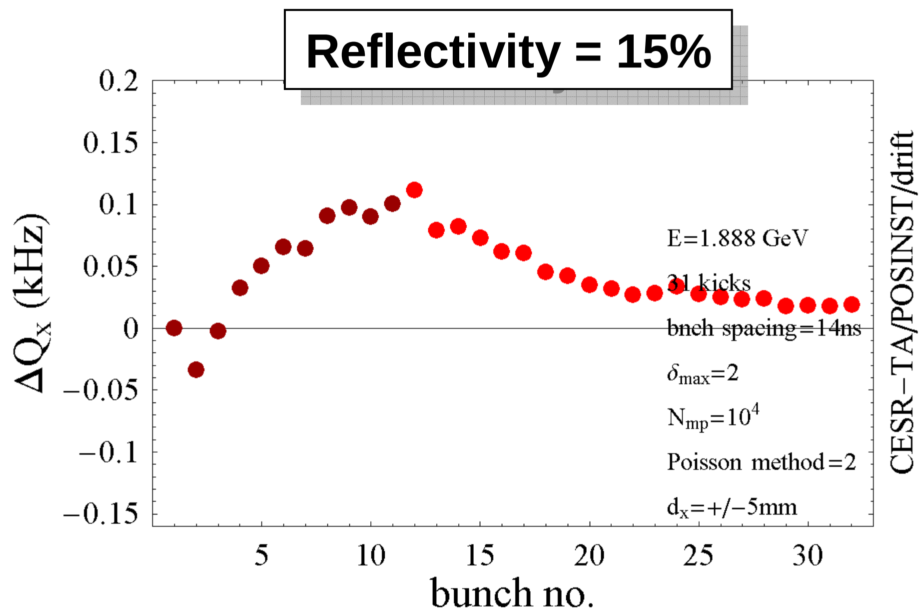
Max ΔQx about 1/5 of max ΔQy

DRIFT:: Horizontal motion: <Ex> is about independent of dx over first 2-3 bunches.



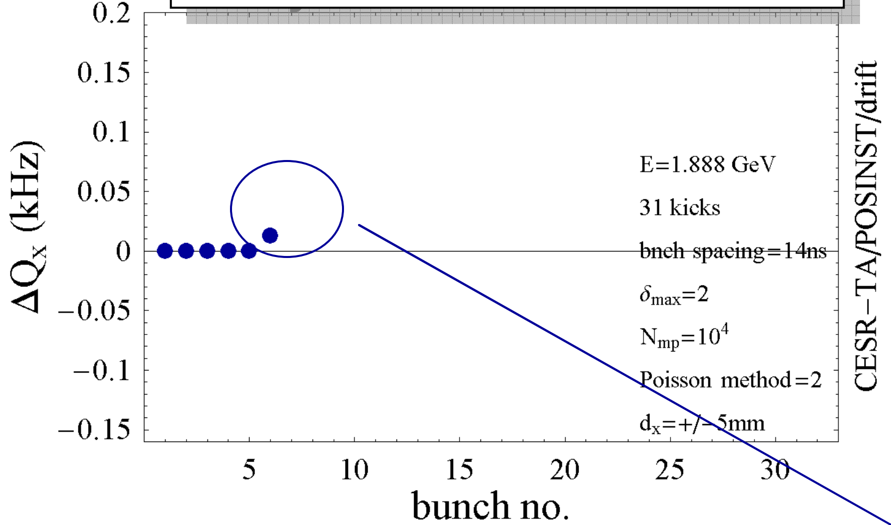
DRIFT:: **Horizontal** motion: confirm insensitivity to reflectivity as in the y-plane.



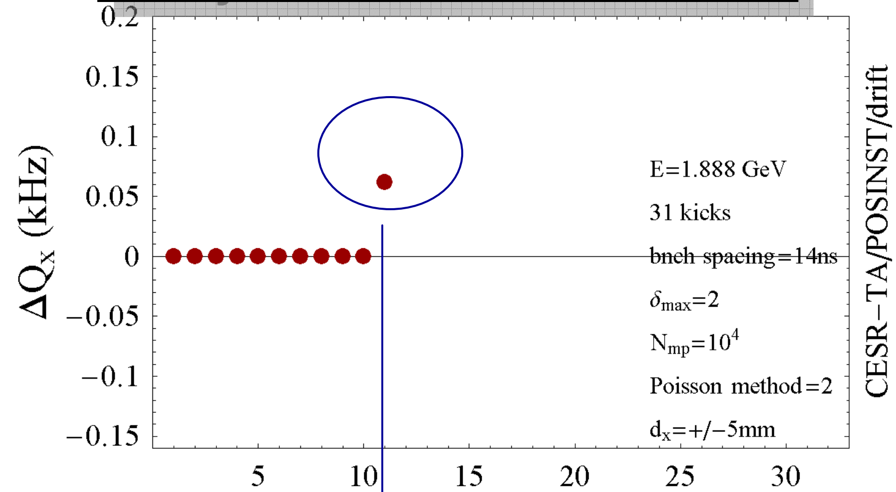


DRIFT:: **Horizontal** motion: some sensitivity to presence/absence of offset in leading bunches.

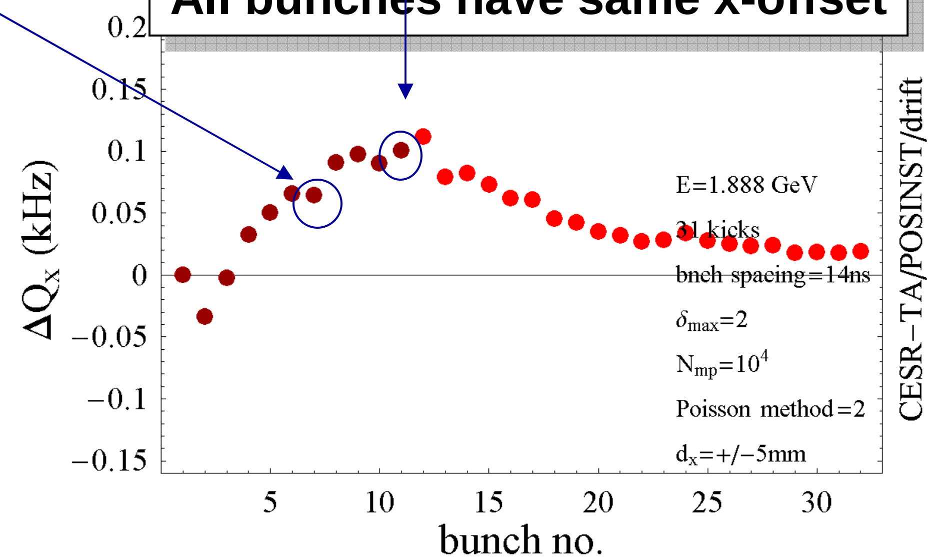
Only 6th bunch has x-offset



Only 11th bunch has x-offset



All bunches have same x-offset

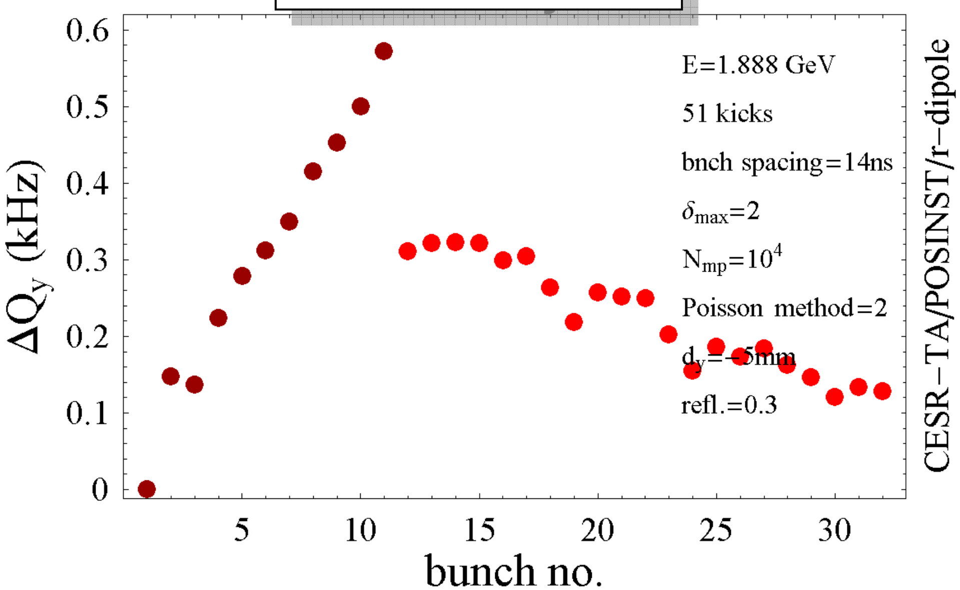


	All bunches offset	Only 6th bunch offset	Only 11th bunch offset
6th	ΔQx=0.065	ΔQx=0.013	
11th	ΔQx=0.100		ΔQx=0.062

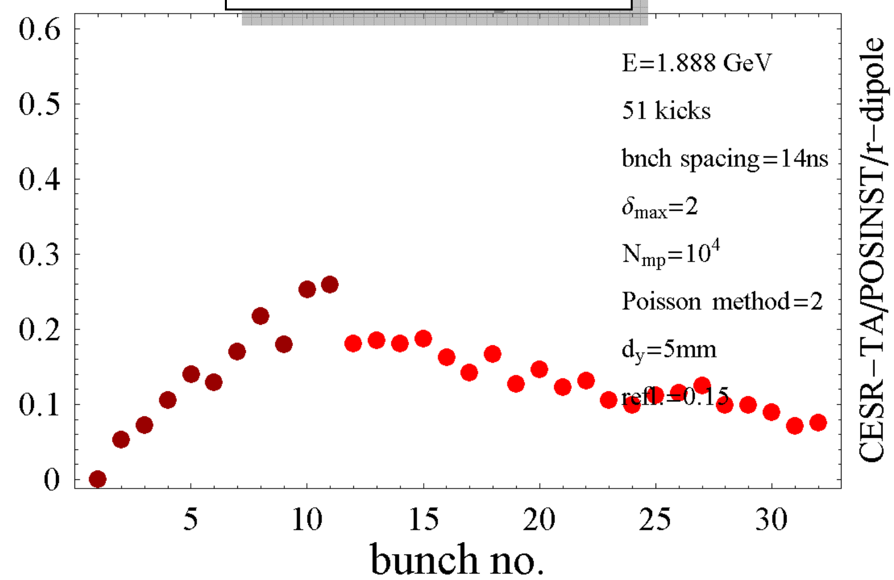
Soft DIPOLES

Soft DIPOLE:: **Vertical** motion: tuneshift sensitive to value of reflectivity

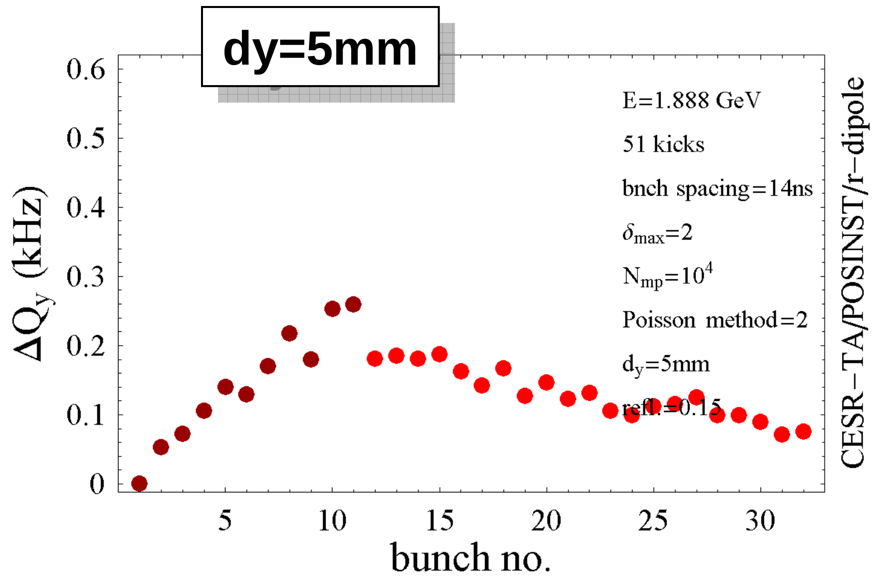
Reflectivity 30%

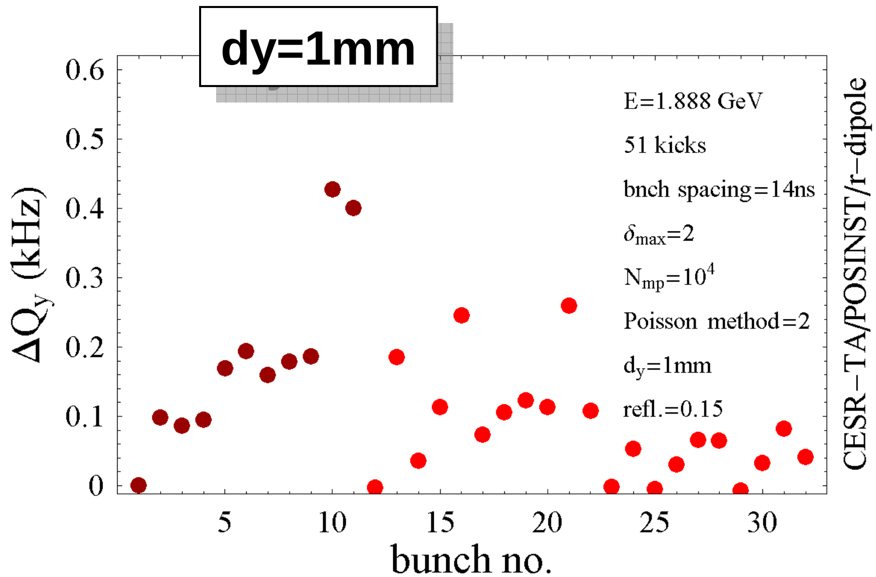


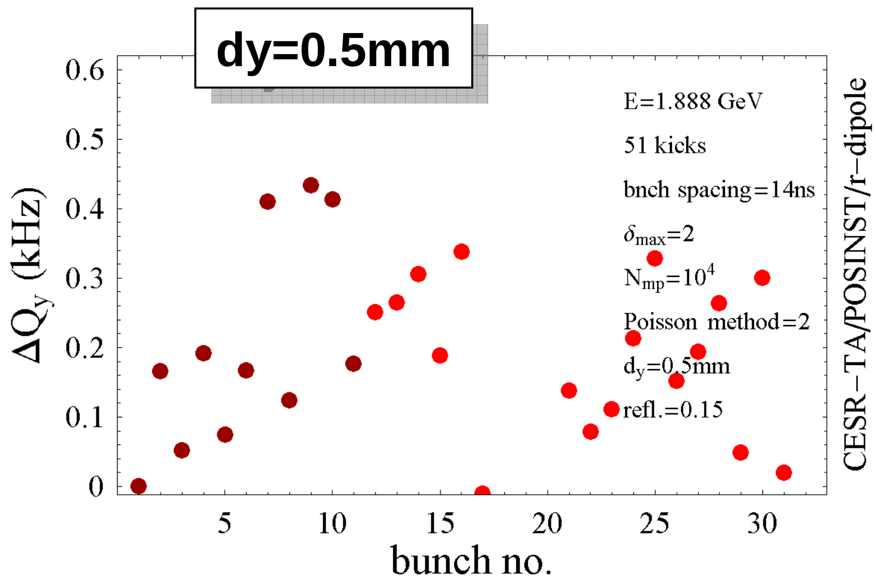
Reflectivity 15%



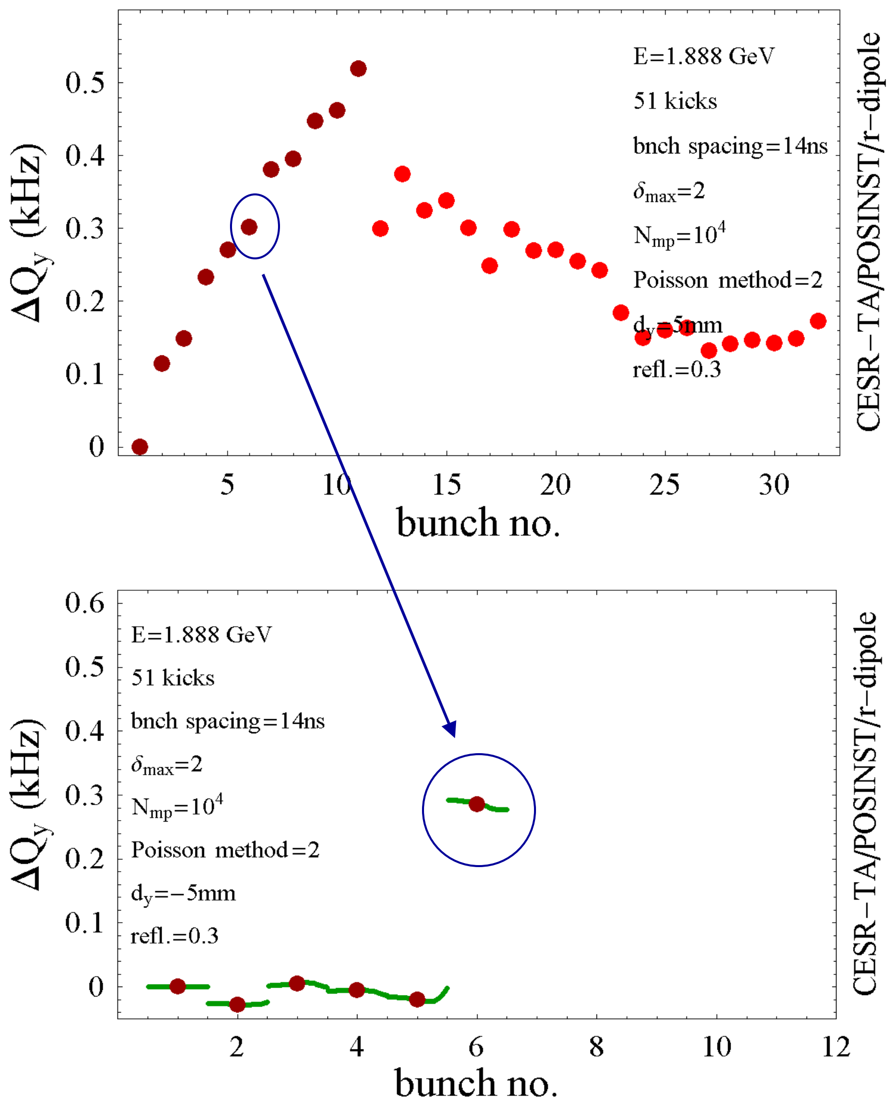
Soft DIPOLE:: Vertical motion: data points become more scattered when offset is smaller







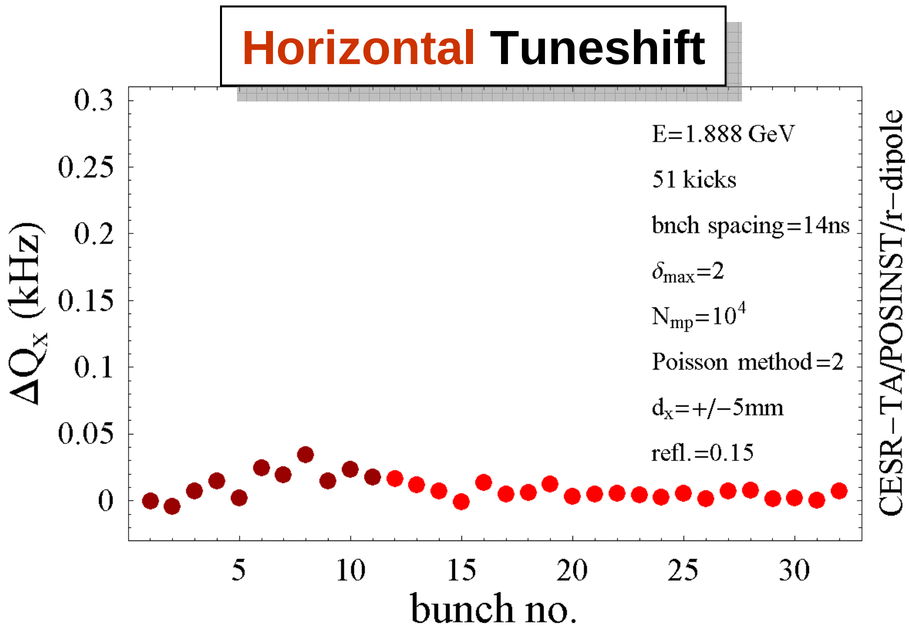
Soft DIPOLE:: **Vertical** motion: insensitivity to offset of leading bunches

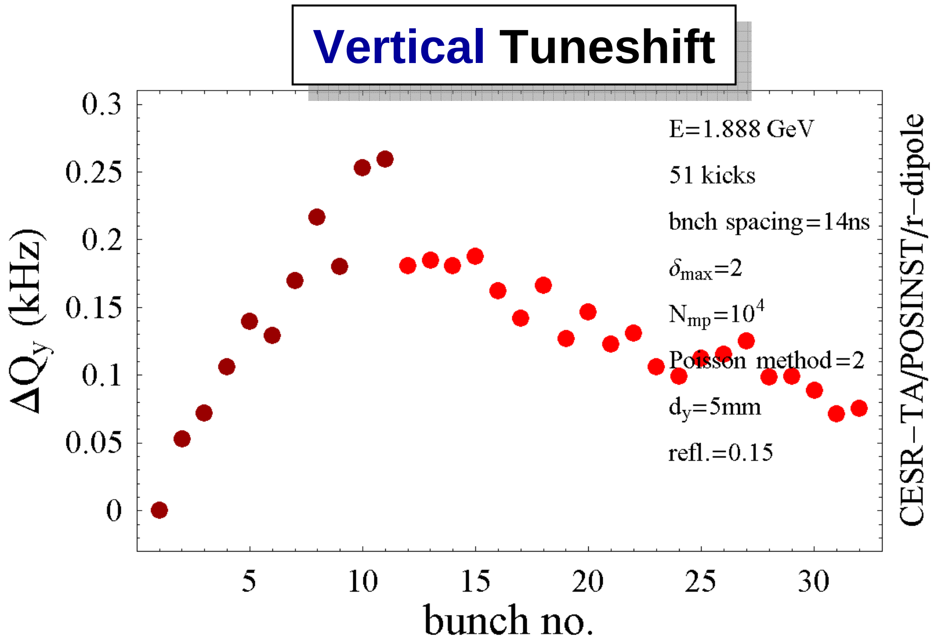


All bunches are offset (dy=-0.5mm)

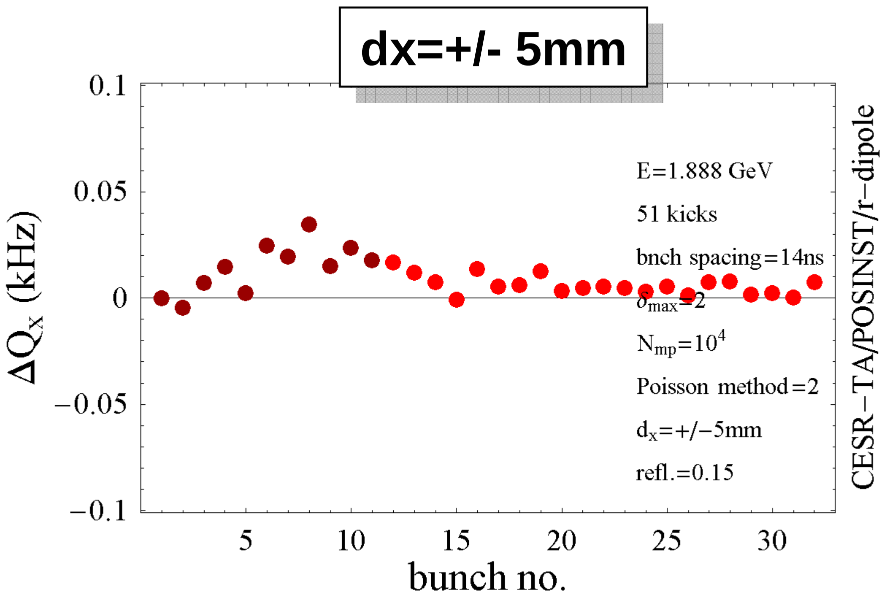
Only 6th bunch is offset (dy=-0.5mm)

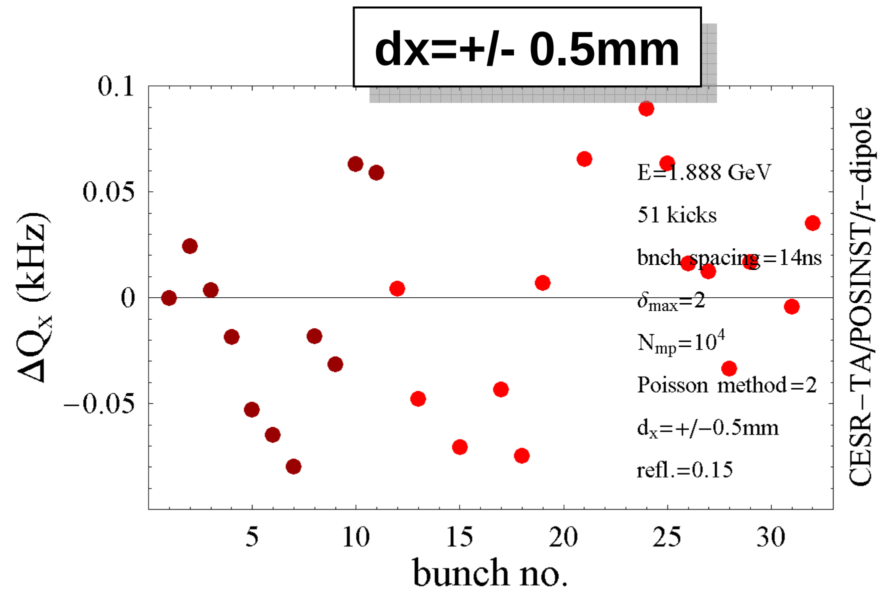
Soft DIPOLE:: **Horizontal** motion: max x-tuneshift about 1/7 of max y-tuneshift



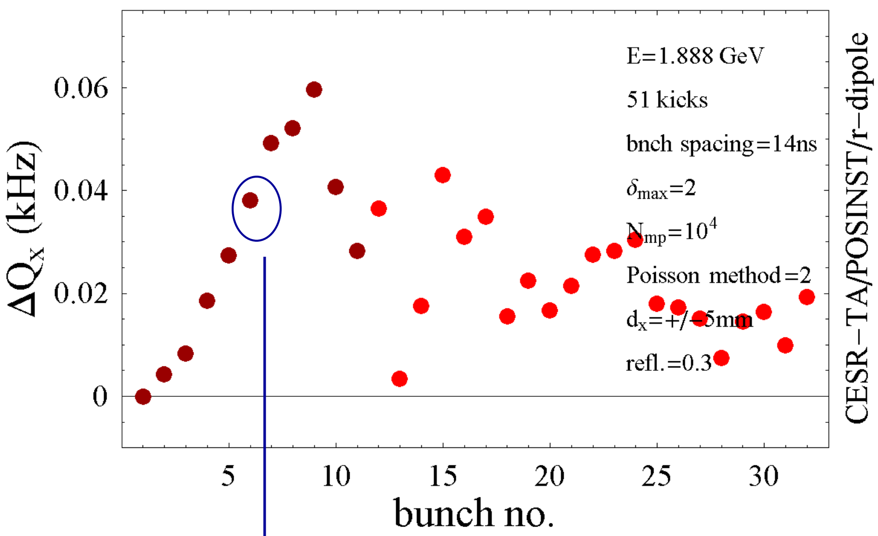


Soft DIPOLE:: **Horizontal** motion: data points look more scattered at smaller offset

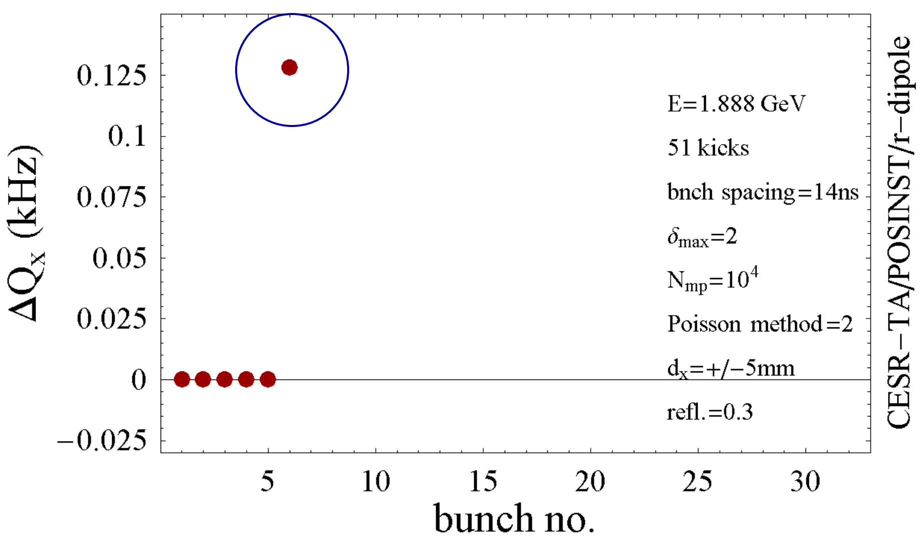




Soft DIPOLE:: **Horizontal** motion: tuneshift is sensitive to offset in leading bunches



All bunches are offset (dy=+/- 0.5mm)



Only 6th bunch is offset (dy=+/- 0.5mm)

Reflectivity=30%