Cesr-TA Simulations: Overview and Status

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Overall program goals

- *Understand cloud buildup* in drift, quadrupole, dipole and wiggler sections of CesrTA, with different cloud suppression techniques.
- *Understand interaction of the cloud and the beam* in CesrTA, including instabilities and emittance growth.
- *Validate cloud buildup and cloud dynamics simulations using CesrTA data*, in order to develop confidence in the application of these simulations to predict cloud behavior in the ILC damping ring.
- *Demonstrate cloud suppression techniques* suitable for use in the ILC damping ring.

Simulations

- Tools:
  - Simulation codes: POSINST, ECLOUD, CLOUDLAND
  - Analytic and numerical estimates of response of beam to cloud
  - RFA response models
- Initial steps *(carried out more or less simultaneously):*
  1. Benchmark simulation codes using simple cases relevant to CesrTA and ILCDR conditions. *(Joe Calvey's talk)*
  2. Simulate cloud buildup in RFA-instrumented chambers, and RFA instrumental response, to guide RFA experiments as probes of average cloud density. *(Joe Calvey's talk)*
  3. Simulate coherent tune shifts, to guide tune shift measurements as probes of cloud density and dynamics
     - Compute EC-related parameters for all beamline elements in CesrTA
     - Simulate ring-averaged cloud buildup and compute coherent tune shifts

Coherent tune shift measurements

- "Witness bunch" technique:
  - a train of "loading bunches" generates a cloud density around the ring
  - "witness bunches" are placed at variable times after the loading train, and the coherent tune of the witness bunch is measured. The coherent tune shift is a measure of the beam-averaged field gradient due to the cloud charge density at the time of the witness bunch
- Coherent tune shift measurements (both vertical and horizontal tune) using the witness bunch technique have been done in a variety of conditions
  - Electrons and positrons
  - 1.9 GeV and 5.3 GeV
  - Various loading trains
- We have also made measurements of the systematic variation of tune shift along a train vs. bunch current

Coherent tune shift calculations

- In general, coherent tune shifts are related to the field gradients generated by the electron cloud, averaged over the beam and integrated around the ring:

$$\Delta Q_{x(y)} = \frac{e}{4\pi E} \oint ds\ \beta_{x(y)} \langle \frac{\partial E_{x(y)}}{\partial x(y)} \rangle$$

  - The field gradients depend on the magnitude and detailed shape of the cloud density distribution.
  - The cloud density distribution in a given ring element is obtained from the cloud simulation codes.
  - We need the ring-averaged cloud density, which is an average over all the elements in the ring.

Ring-averaged cloud density

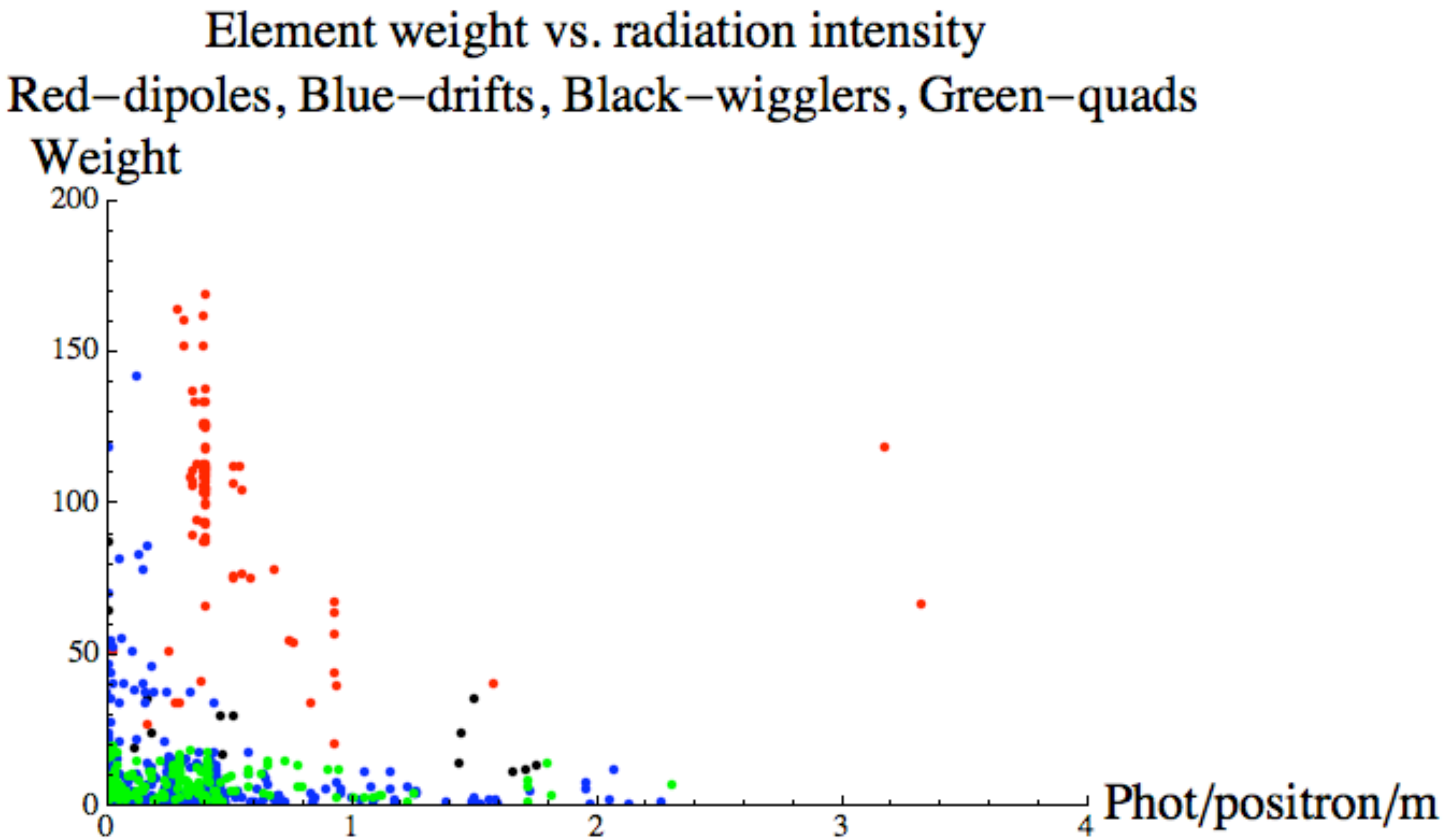
- Let there be *m* types of beamline elements (e.g. drifts, dipoles, etc) There are n_k element of type *k*. The *i*th element has a length L_i, beta function β_i, and radiation intensity I_i
- If the field gradient in element type *k*, with radiation intensity *I*, is $G_{x(y),k}(I)$, then

$$\Delta Q_{x(y)} = \frac{e}{4\pi E} \sum_{k=1}^{m} G_{x(y),k}(\langle I_{x(y),k} \rangle) w_{x(y),k}$$

$$\langle I_{x(y),k} \rangle = \frac{\sum_{i=1}^{n_k} \beta_{x(y),i} L_i I_i}{w_{x(y),k}} \qquad w_{x(y),k} = \sum_{i=1}^{n_k} \beta_{x(y),i} L_i$$

- This assumes (incorrectly) that the cloud density is a linear function of the radiation intensity. This assumption can be fixed in a more elaborate formulation.

Weights and radiation intensity at 2 GeV



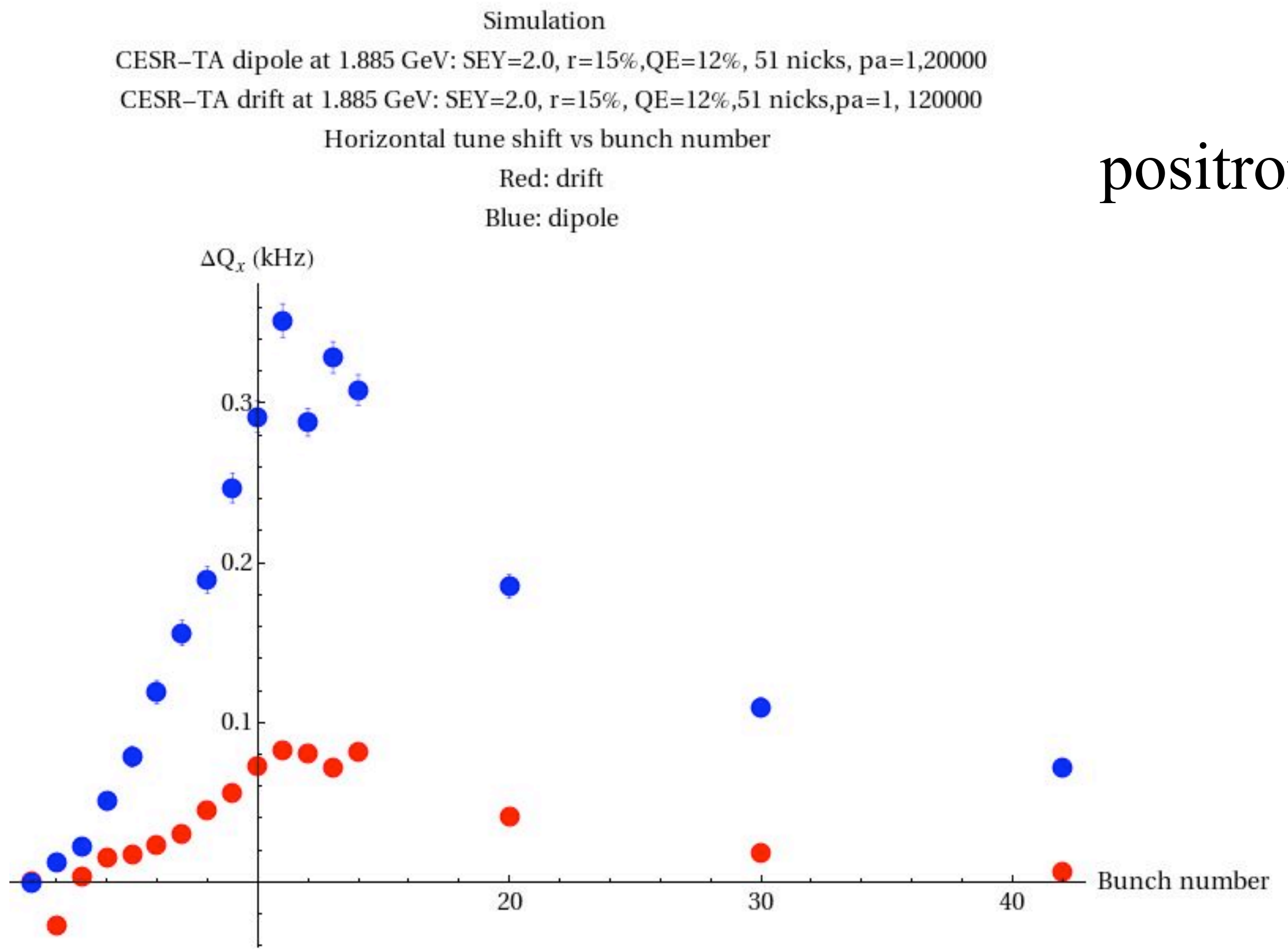
Simulations to date have only included drifts and dipoles

Coherent tune shift simulations

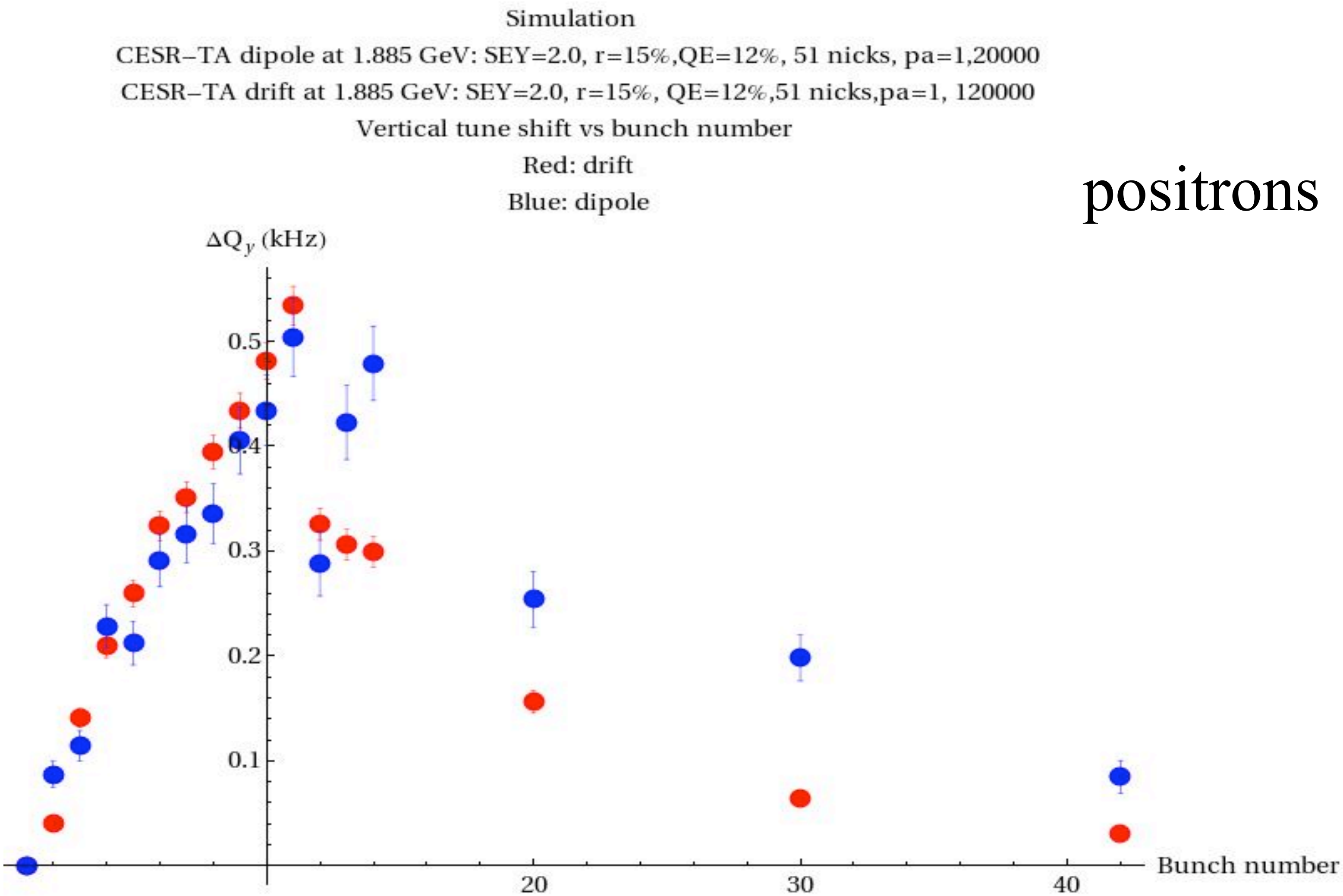
- For each type of beamline element, the electron cloud is simulated in POSINST and ECLOUD
- For tune shift calculations, the field gradients are averaged in space and time over the beam.
- Most recent work: for POSINST simulations,
  - Cloud image charge effects have been included when computing the field gradients
  - Dynamic effects related to motion of the cloud electrons close to the beam during the beam passage have been included approximately.

Drift and dipole comparison
Horizontal tune shifts, 1.9 GeV

positrons



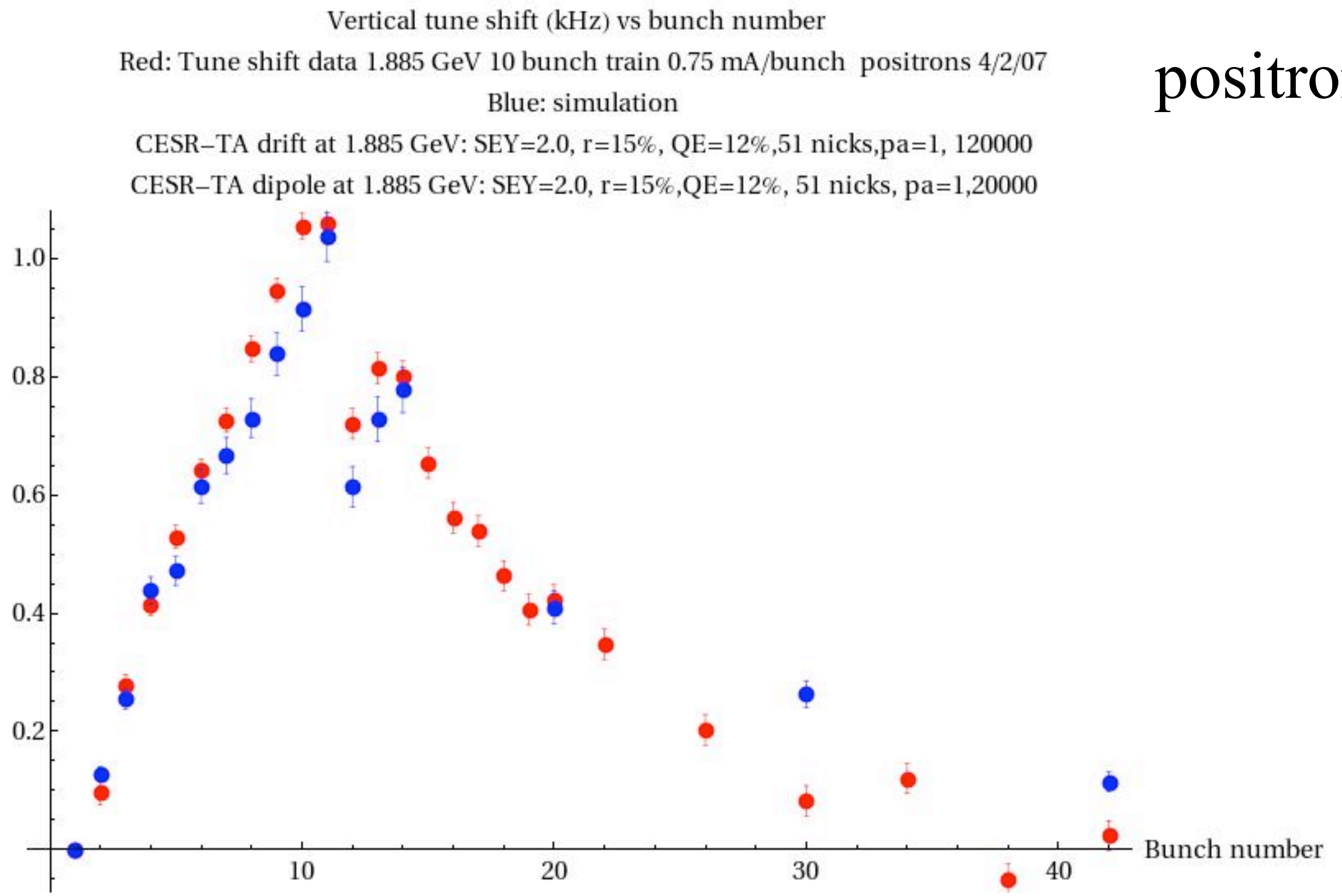
Drift and dipole comparison Vertical tune shifts, 1.9 GeV



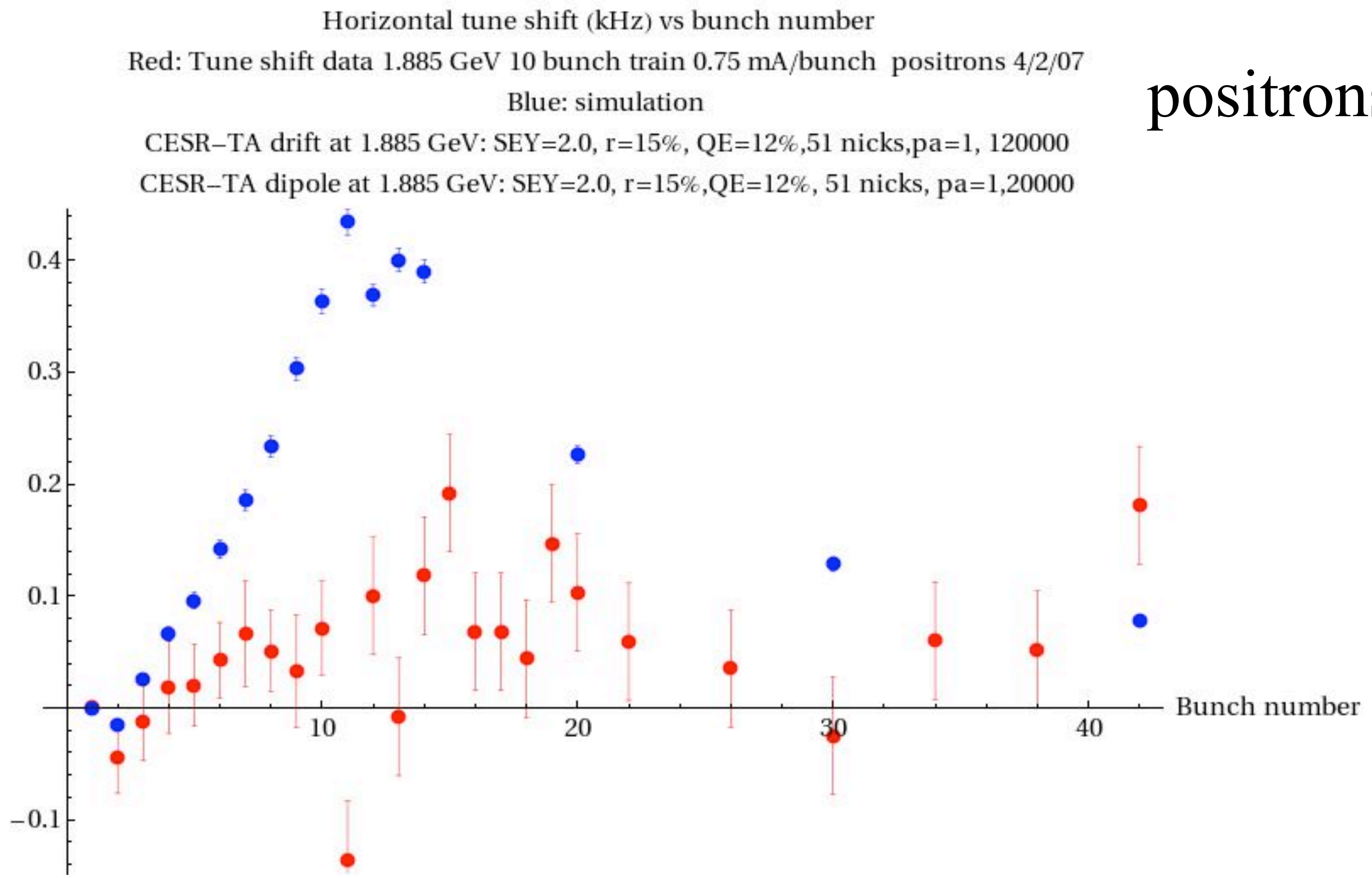
positrons

Comparison with data of 4/2/07
Coherent vertical tune shifts at 1.9 GeV

positrons

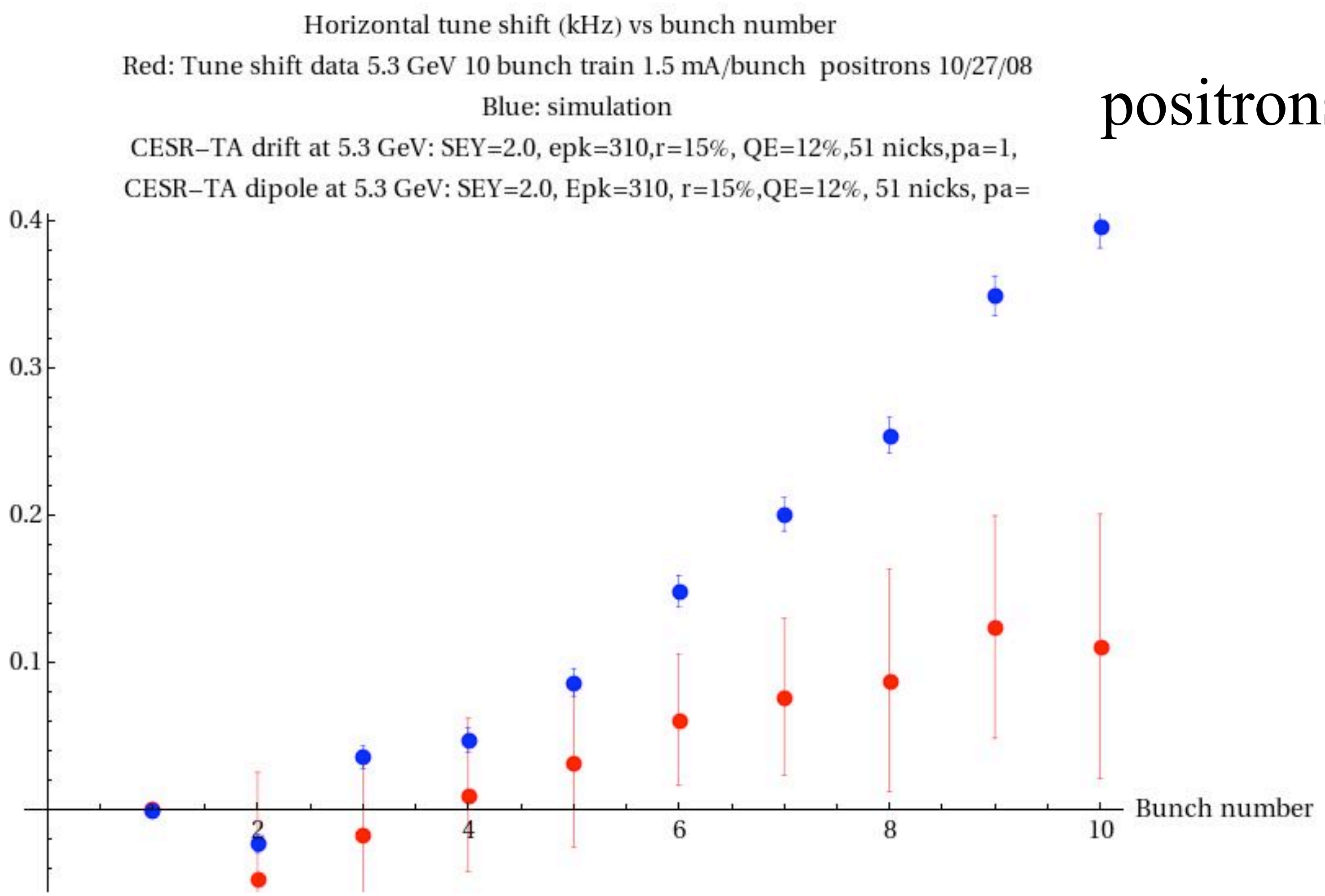


Comparison with data of 4/2/07
Coherent horizontal tune shifts at 1.9 GeV



positrons

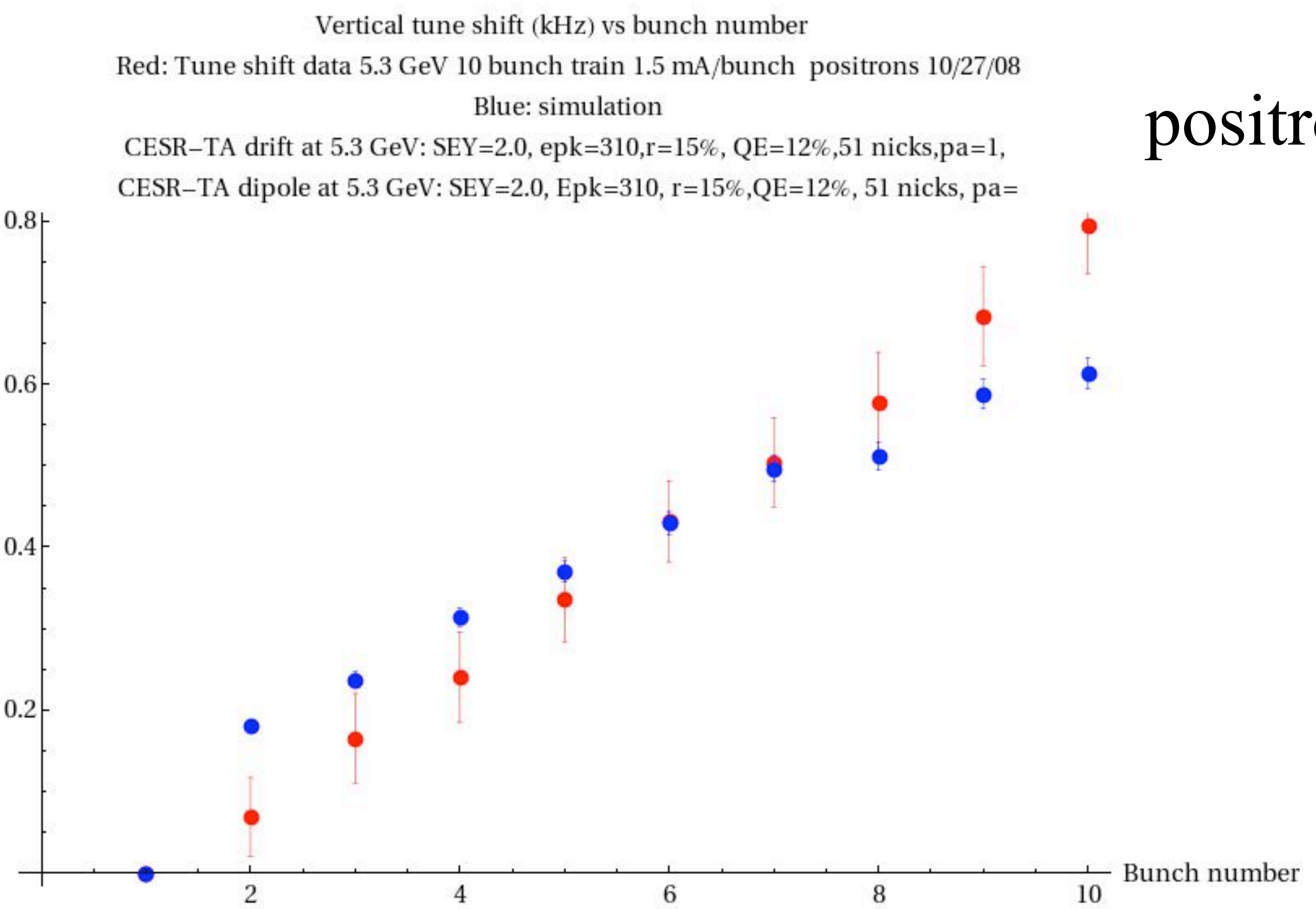
Comparison with data of 10/27/08
Horizontal tune shifts at 5.3 GeV



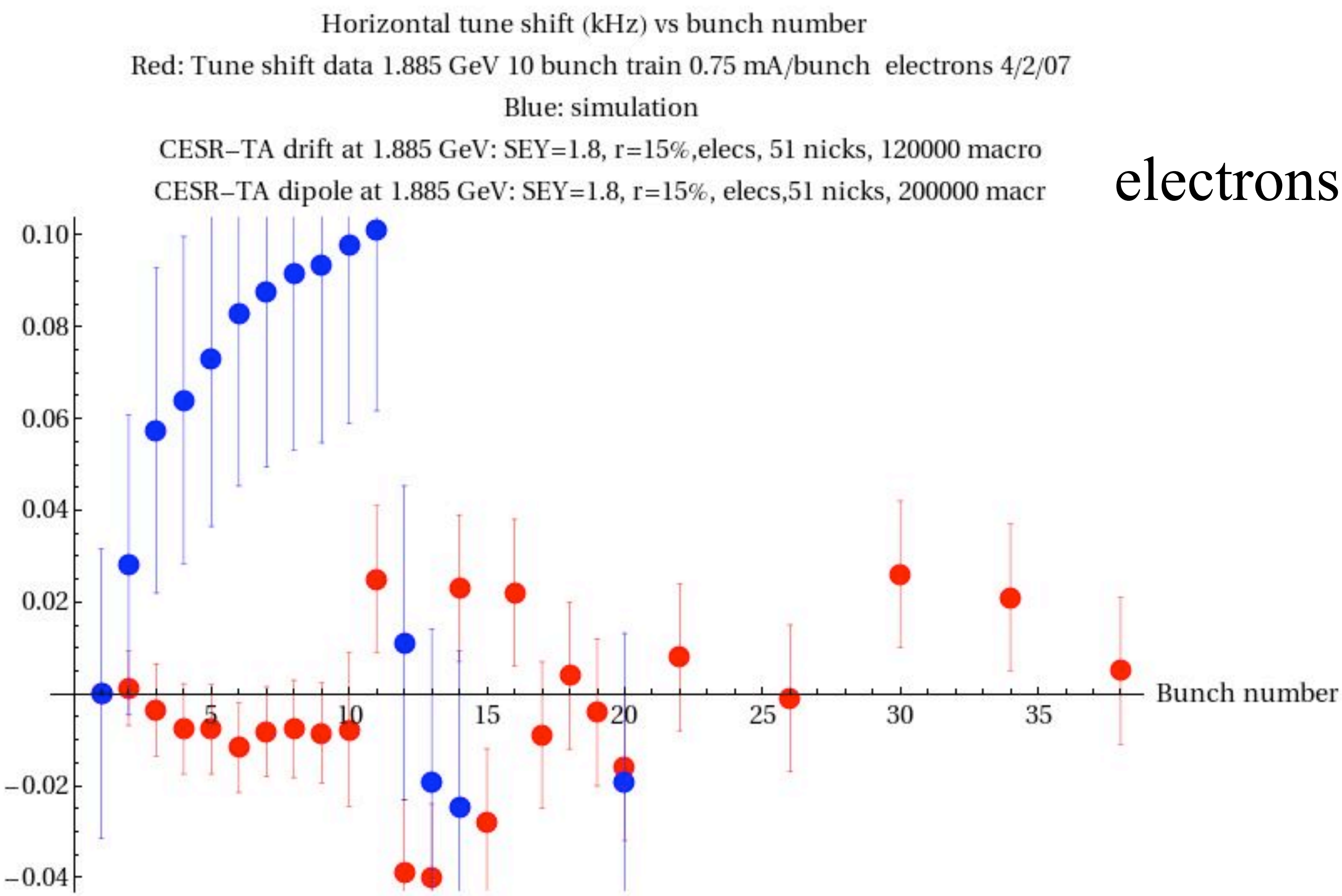
positrons

Comparison with data of 10/27/08
Vertical tune shifts at 5.3 GeV

positrons

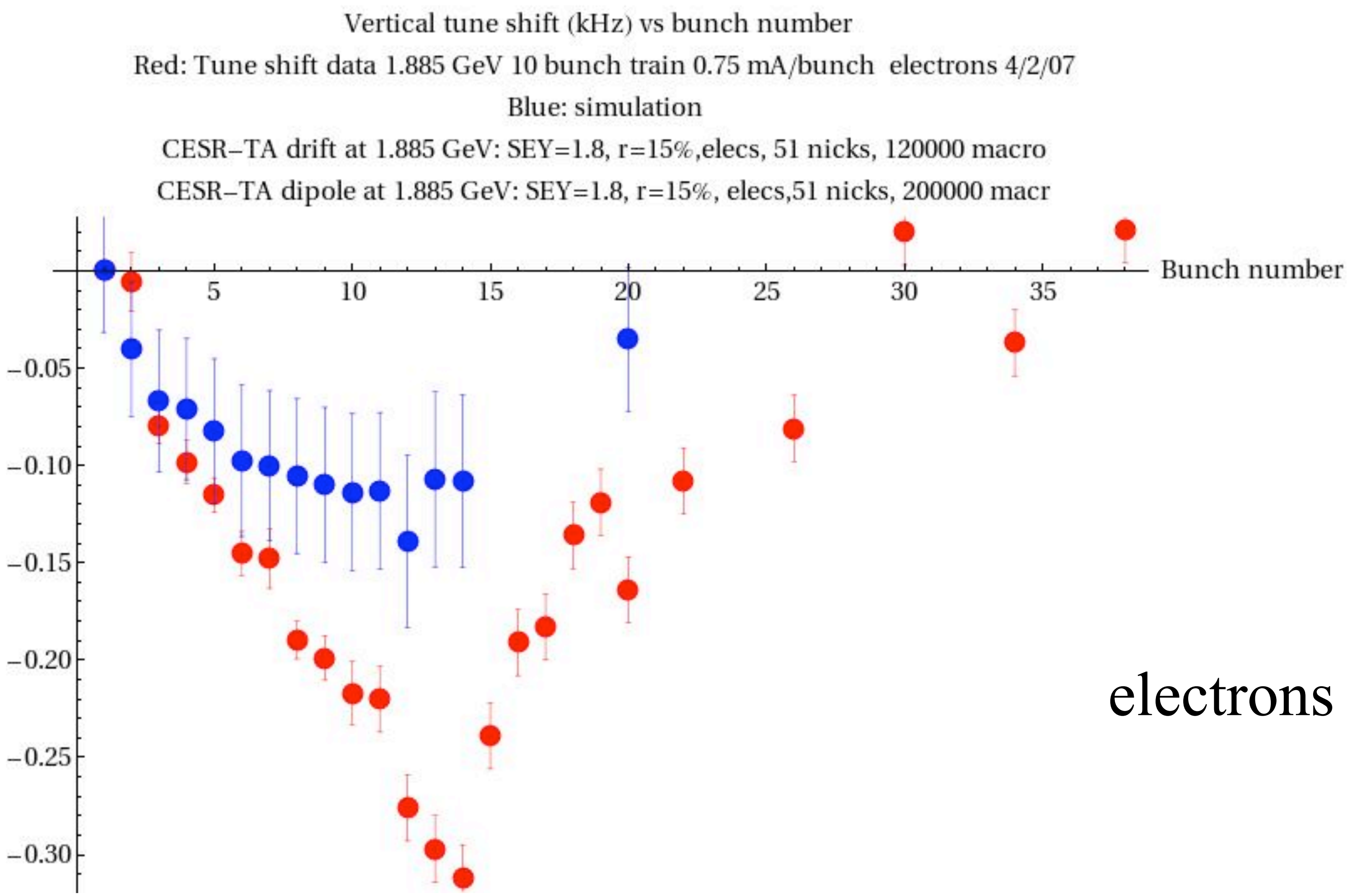


Comparison with data of 4/2/07
Horizontal tune shifts at 1.9 GeV



electrons

Comparison with data of 4/2/07
Vertical tune shifts at 1.9 GeV



electrons

Improvements to tune shift calculations

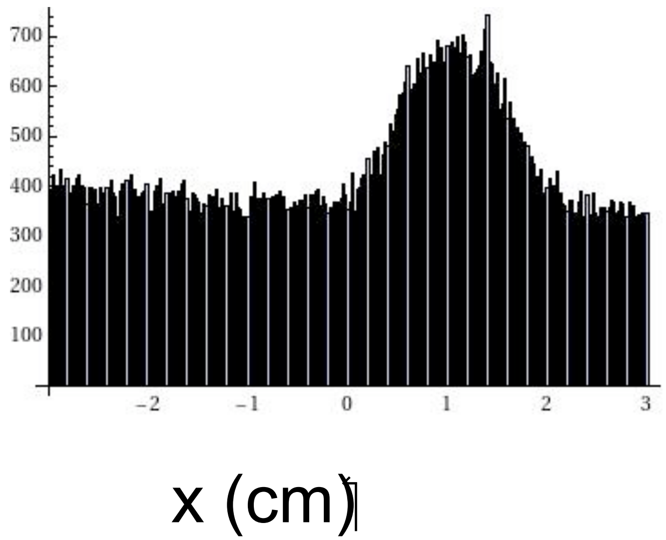
- The tune shift is measured by coherently kicking the bunch train and observing the resulting oscillations at a BPM. Not all bunches receive the same kick.
- To be able to include this effect in the simulation, POSINST has been modified to allow each bunch to be offset individually from center of vacuum chamber.
- This will also allow a direct calculation of the force gradients (and resulting tune shifts) by taking the difference between the forces on offset bunches relative to on-axis bunches. All dynamic effects are automatically included with no approximations.

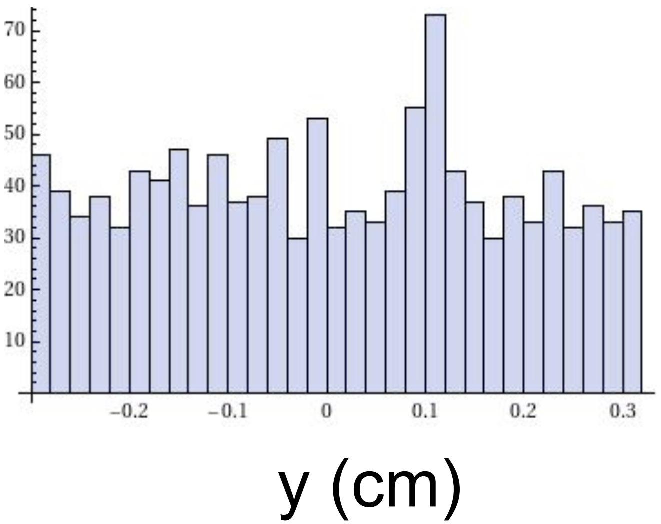
POSINST cloud distribution with offset to beam

Cesr-TA dipole, 1.9 GeV

Bunch 11 in 11 bunch train: offset x =1 cm, y = 1 mm

Projected cloud density distributions





Future plans

• We need to complete the code comparison (benchmarking) and fully understand the differences between the SEY models in ECLOUD, CLOUDLAND and POSINST.

• For RFA data, we need an improved model of the RFA response (in progress).

• For the tune shift data, we need to fully include dynamic effects in the calculations (requires integration of beam motion into the simulation codes).

• RFA's installed in new wiggler chamber allow measurement of cloud-induced current in a wiggler field. We need a 3D simulation code to analyze this. The present plan is to use WARP-POSINST, relying on our LBNL collaborators.

• Measurements of cloud-induced incoherent emittance growth can be made using XBSM. We need to estimate this in a simulation.

• Measurements of instability thresholds, growth rates, mode spectrum, TE wave dispersion can be made. We need supporting calculations.

• Dependence of cloud effects on beam as a function of energy, species, bunch population, bunch spacing, and emittance, in alliance with the simulation program, can provide a comprehensive validation of the codes.