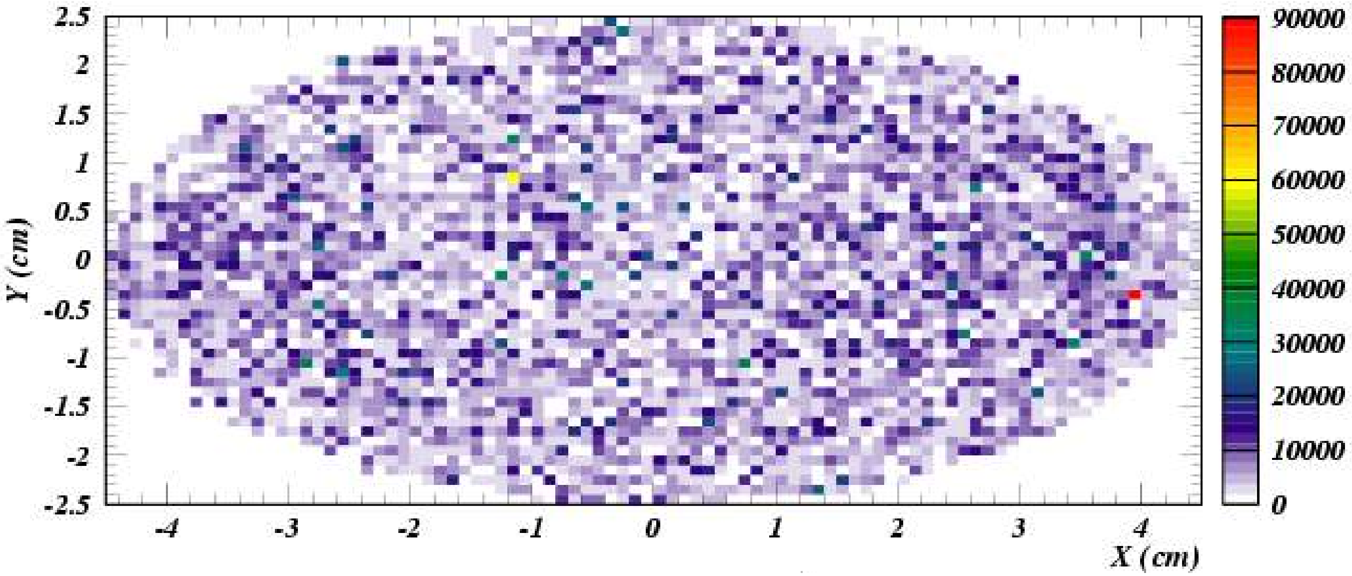
Cornell University
Laboratory for Elementary-Particle Physics

ECLOUD Simulations for CESR Witness Bunch Tune Shift Measurements

Jim Crittenden

Cornell Laboratory for Accelerator-Based Sciences and Education



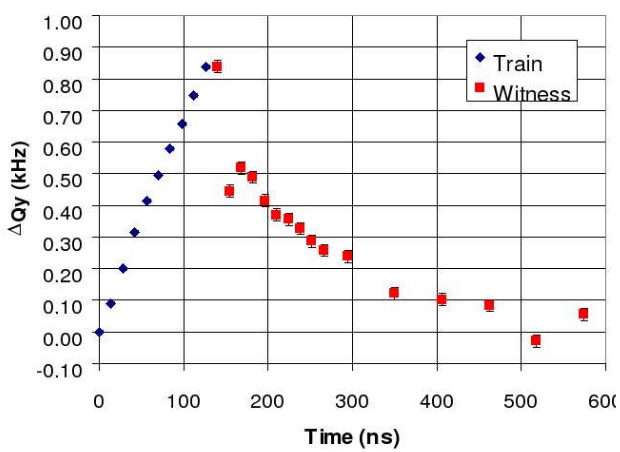
CESR Tune Measurements 2007

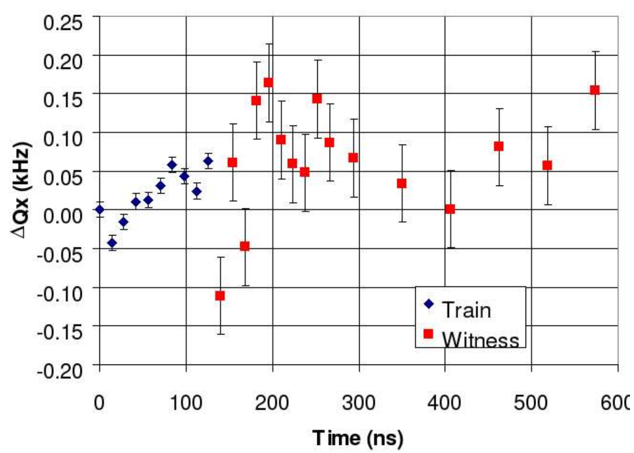
- Train of ten 1.9 GeV, 0.75 mA positron bunches generates the electron cloud
- Measure tune shift and beamsize for witness bunches at various spacings using bunch-by-bunch, turn-by-turn beam position monitor
- Error bars represent measurement spread

CesrTA Electron Cloud R&A Overview

Mark Palmer,

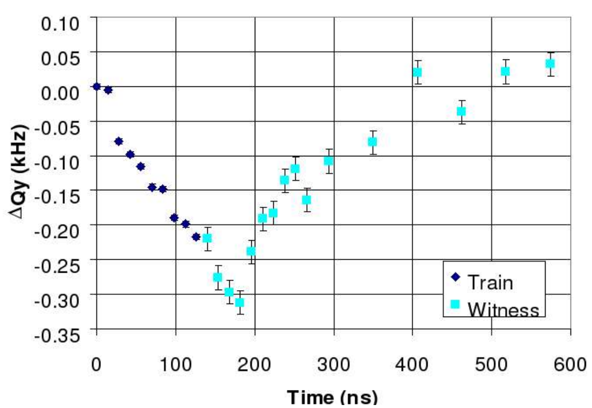
5 March 2008, TILC08, Sendai, Japan

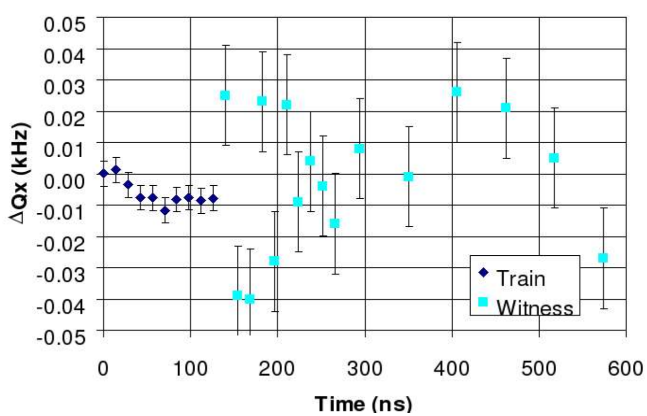




Positron Beam

- Strong vertical focusing effect
- Horizontal tune shift much smaller, either sign





Electron Beam

- Vertical defocusing effect
- Horizontal tune shift much smaller
- Large spread in horizontal tune measurements for witness bunches

Electron Cloud Calculations Underway at Cornell

- **ECLOUD program V3.2** (G. Rumolo & F. Zimmerman)
  - 2D, intensive development 1997-2003, flexible, 20k lines readable F77
  - Adapted to CESR tune shift measurements 2007 and CesrTA North Area Triple-RFA measurements
  - Continued development (output info, graphics, field calculations)
  - Talks/results archive http://www.lepp.cornell.edu/~critten/cesrta/ecloud
- **POSINST** (Gerry Dugan with Miguel Furman)
- **CLOUDLAND** (Joe Calvey with Lanfa Wang)

An ambitious effort comparing simulations to each other and to measurement is now underway at Cornell

See ILCDR08 talks by G. Dugan and J.Calvey
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/EcloudParams

Interpretation by K.Ohmi, et al.

Electron Cloud Effects at CESR and KEKB

K. Ohmi, KEK

29 February 2008, Cornell seminar

- Bunch population $N_p = 2\times10^{10}$
- electrons created by a bunch passage in a meter
- $N_p x Y_{pe} = 1.7\times10^9$ (5GeV) 6.8×10^8 (2GeV)
- If electrons are accumulated 5 times,
- electron line density (m^{-1}) 8.5×10^9 (5GeV), 3.4×10^9 (2GeV)
- volume density(m^{-3}) 1.7×10^{12} , 6.8×10^{11}
- Corresponding Tune shift 0.0037, 0.0037 (7.4e-4/bunch)
- Beam line density $N_p/4.2 = 4.8\times10^9$

- 2nd order moment ($\langle x_e^2\rangle_c$, $\langle y_e^2\rangle_c$) of electron cloud distribution gives tune shift, where $\langle x^2\rangle_c = \langle x - \langle x\rangle\rangle^2$

$$\Delta\nu_x + \Delta\nu_y = \frac{r_e}{\gamma}\oint \rho_e \beta\, ds \qquad \text{if } \beta_x \sim \beta_y$$

$$(\Delta\nu_x, \Delta\nu_y) = \frac{r_e}{\gamma}\left(\oint \frac{\rho a}{1+a}\beta_x\, ds, \oint \frac{\rho}{1+a}\beta_y\, ds\right)$$

$$\text{where} \quad a = \langle y_e^2\rangle_c / \langle x_e^2\rangle_c$$

Beam and Photoelectron interactions in positron storage rings

Phys. Rev. Lett. 75 (1995) 1526

Study of Coherent Tune Shift Caused by Electron Cloud in Positron Storage Rings, APAC'01, WEP056

- *The observed tune shifts are quantitatively consistent with the expected average cloud density*
- *The calculation depends on ring-averaged quantities*
- *The charge density distribution and the resulting electric field can be quite complicated*
- *Don't forget about the beampipe !*

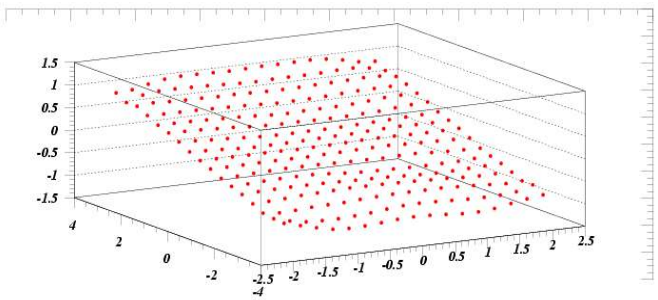
Dave Rubin's Suggestion

In mid-February, Dave Rubin suggested investigating the cloud spacecharge field calculation used by the ECLOUD program.

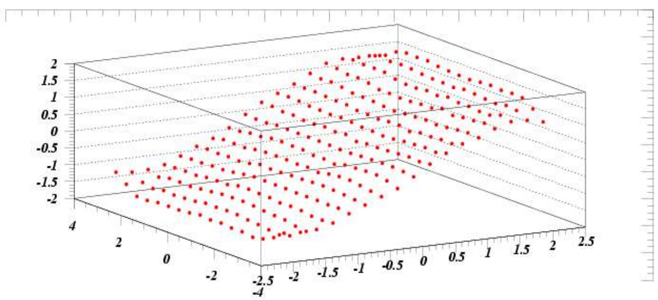
- *Systematics of field calculation*
- *Precision of numerical approximations*
- *Field gradients' dependence on cloud simulation parameters*

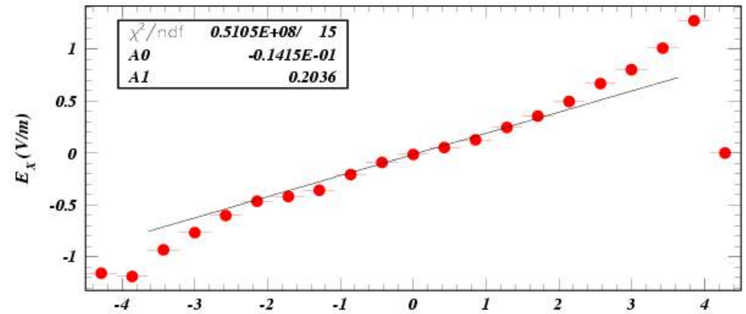
DLR: For a ring-averaged beta value of 30 m, an average field gradient of 3600 V/m^2 will yield a tune shift of 1 kHz.

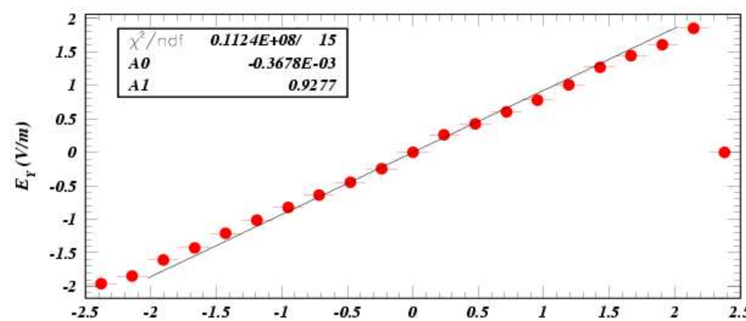
E_X (V/m)



E_Y (V/m)

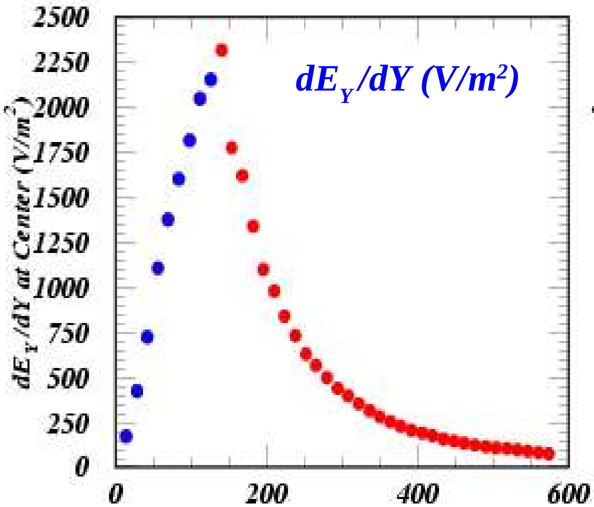


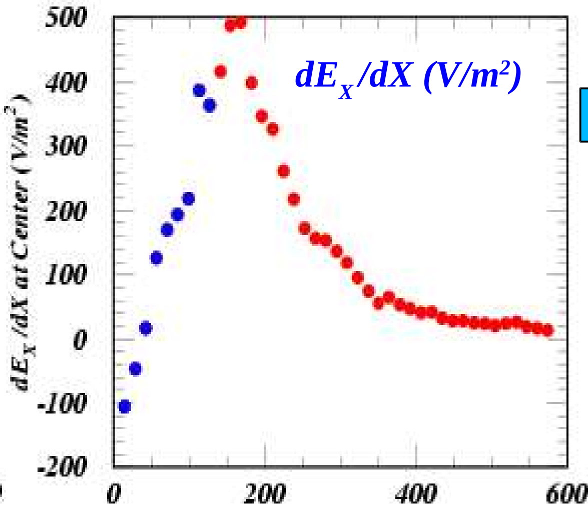


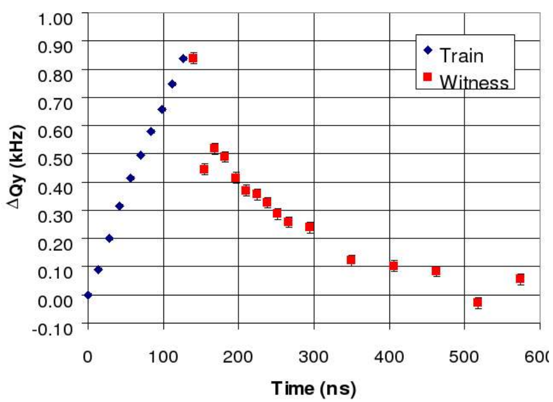


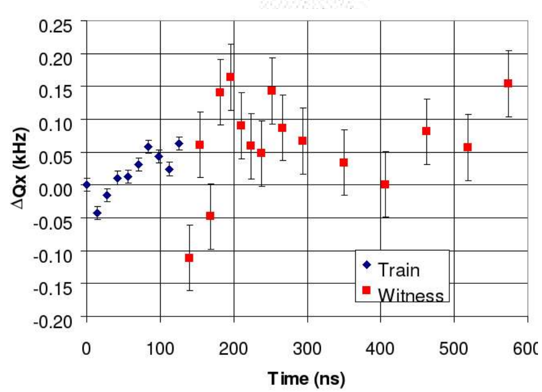
This suggestion resulted in an extraordinarily fruitful line of investigation

Positron Beam









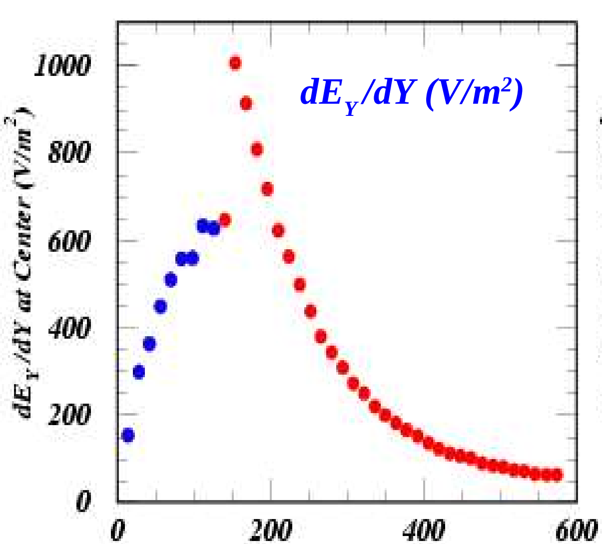
Input Parameter Set

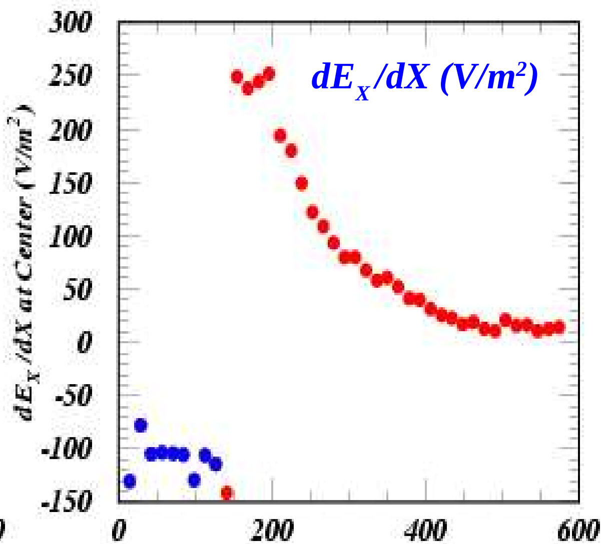
Ten 0.75 mA bunches 1.9 GeV	0.1 s.r. photon per beam particle per m
30 empty witness bunches	20% reflected s.r. photons
No magnetic field	10% photoelectron per s.r. photon
Elliptical chamber 4.5x2.5 cm	Peak secondary yield of 2.0
	Peak SEY energy of 310 eV

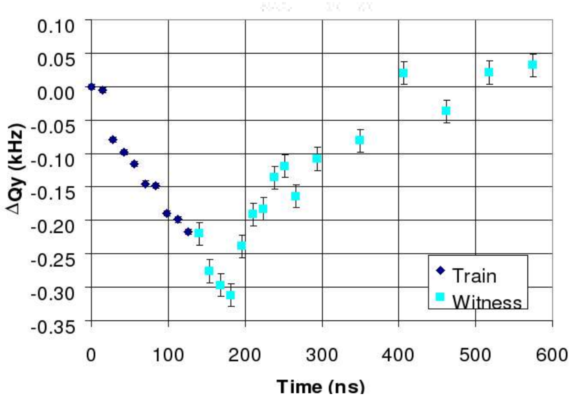
Field gradients averaged over a 9 mm x 5 mm region at the center of the beam pipe

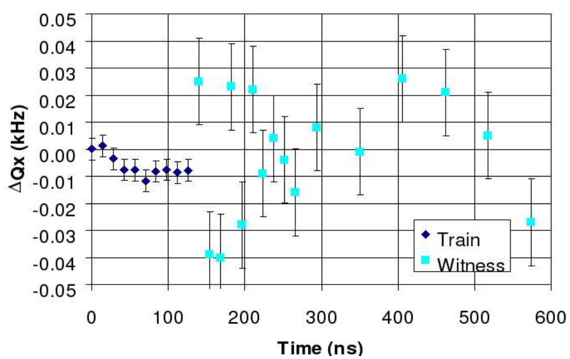
- *Impressively similar time structure*
- *Vertical gradient factor 5 higher*
- *Horizontal gradient bipolar*
- *Predicted vertical tune shift 50% lower than measured even if the entire ring were B-field-free*

Electron Beam





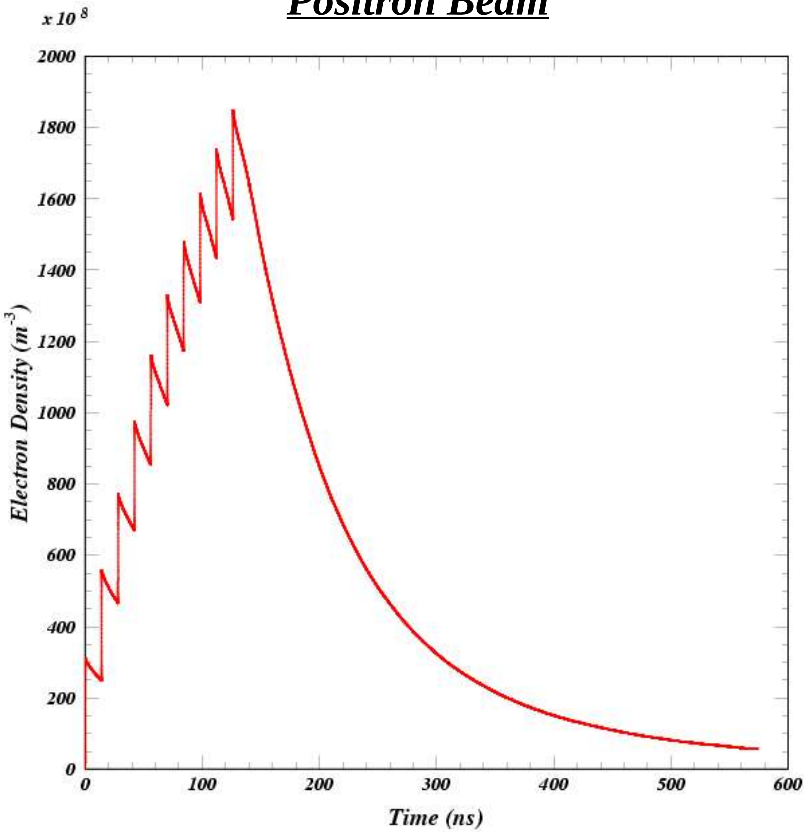




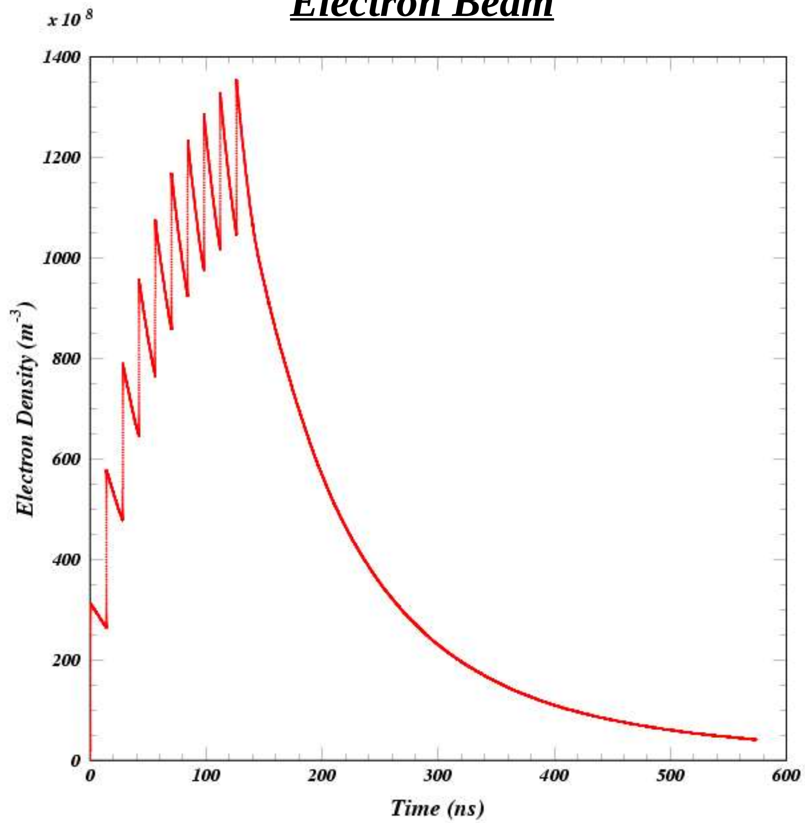
- *Vertical gradient factor 3 lower than for positron beam, as measured*
- *Vertical gradient continues to grow after passage of filled bunches*
- *Polarity of vertical tune shift and gradient as expected for electric field effect*
- *Calculated field gradient shows repulsive effect of beam*
- *Large spread in horizontal tune measurement for the witness bunches not presently understood*

Beam-pipe-averaged cloud density (m^{-3})

Positron Beam



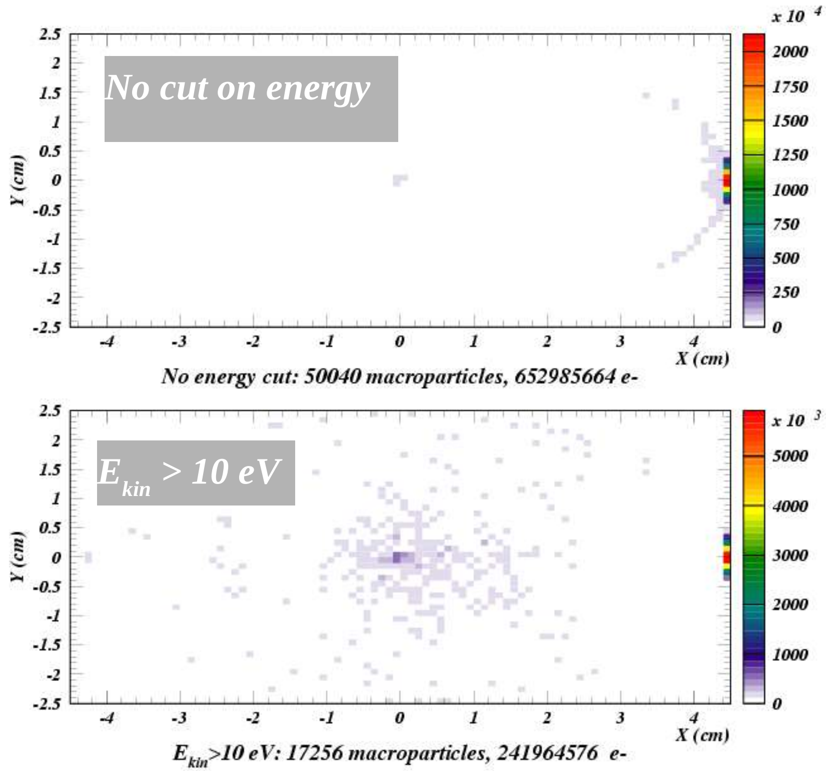
Electron Beam

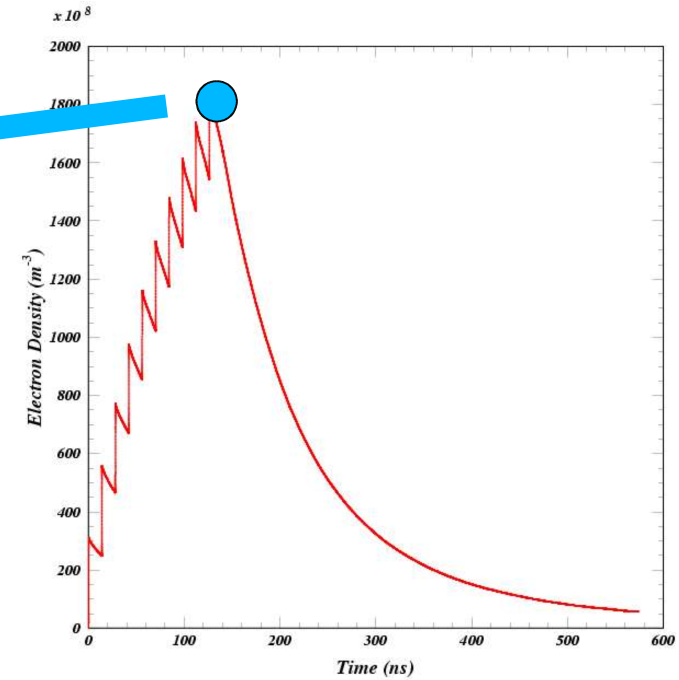


Average cloud density lower by 30% for electrons while field gradients are a factor of 3 smaller !

Cloud profile after last filled bunch

Positron Beam





Large gradients occur also when the central cloud density is small.
These conditions are such an example.
Another example is the electrostatic repulsion of an electron beam.

Critical Parameters

NB: The measured vertical tune shift corresponds to a field gradient of 3000 V/m² continuous around the ring with an average beta value of 30 m.

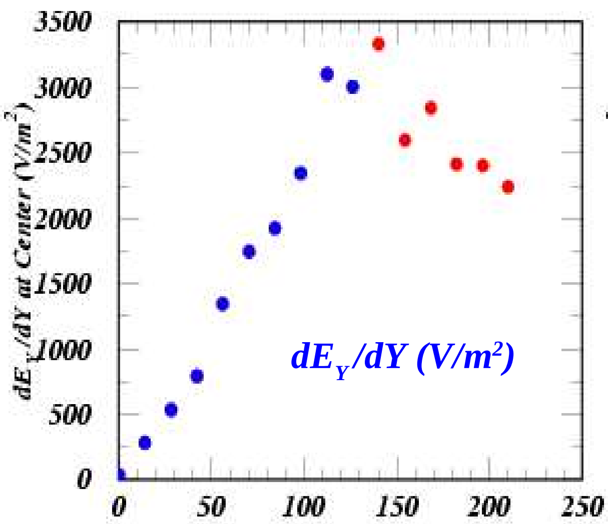
Input Parameter change	Beam-pipe-averaged density (m^{-3})	dE_Y/dY (V/m^2)	dE_X/dX (V/m^2)	
e^+ B=0	1.6E11	2200	400	**e^+ Baseline for comparison**
e^+ $B_\perp$ = 800 G	0.38E11	220	170	Vertical gradient reduced factor 10
e^+ $B_\parallel$ = 20 G	0.40E11	60	-70	Vertical gradient reduced factor 40 !!
e^+ B=0, v.c. image charges off	1.6E11	2000	500	Small effect of BP conductivity
e^+ B=0, round v.c., ρ=4.5 cm	1.2E11	1600	750	BP shape effect on vertical/horizontal
e^+ B=0, REFL=0%	1.4E11	2200	450	Beampipe shape more important than
e^+ B=0, REFL=100%	1.8E11	2250	600	azimuthal source distribution
e^+ B=0, v.c. 5.5 x 2.5 cm	1.1E11	1500	175	Wider horizontal beampipe ellipse
e^- B=0	1.1E11	600	-100	**e^- Baseline for comparison**
e^- B=0, REFL=100%	1.0E11	650	-30	Flat azimuthal source distribution
e^- $B_\perp$ = 800 G	0.23E11	100	<5	Dipole field reduces gradients

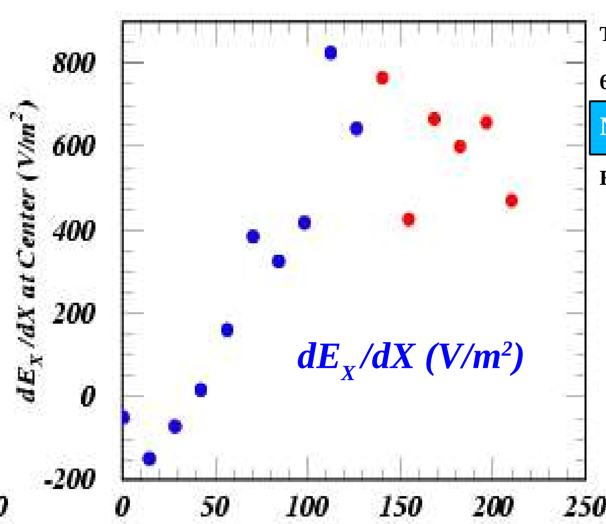
Near -Term Plans

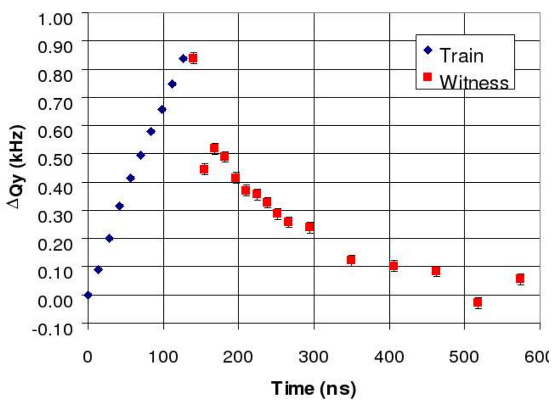
- ***Continue investigation of simulation input parameters***
- ***Compute field gradients averaged over beam profile***
- ***Calculate ring-averaged field gradients & tunes***
- ***Continue beam-pipe shape study***
- ***All suggestions welcome***

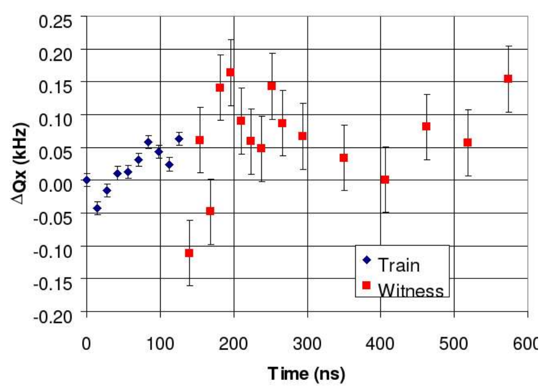
Second Witness Bunch ?

Positron Beam









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	Peak SEY energy of 170 eV

Field gradients averaged over a 9 mm x 5 mm region at the center of the beam pipe

- ***Dip at second witness bunch seen***
- ***Need to investigate dependence on input parameters***