Followup to
Modeling of Electron Cloud Buildup in the Final-focus Quadrupole Magnets of the SuperKEKB Positron Ring

(see Electron Cloud/Impedance meeting talk of 4/22/2015)

-- Request from K. Ohmi at IPAC15 for pictures of cloud distributions --

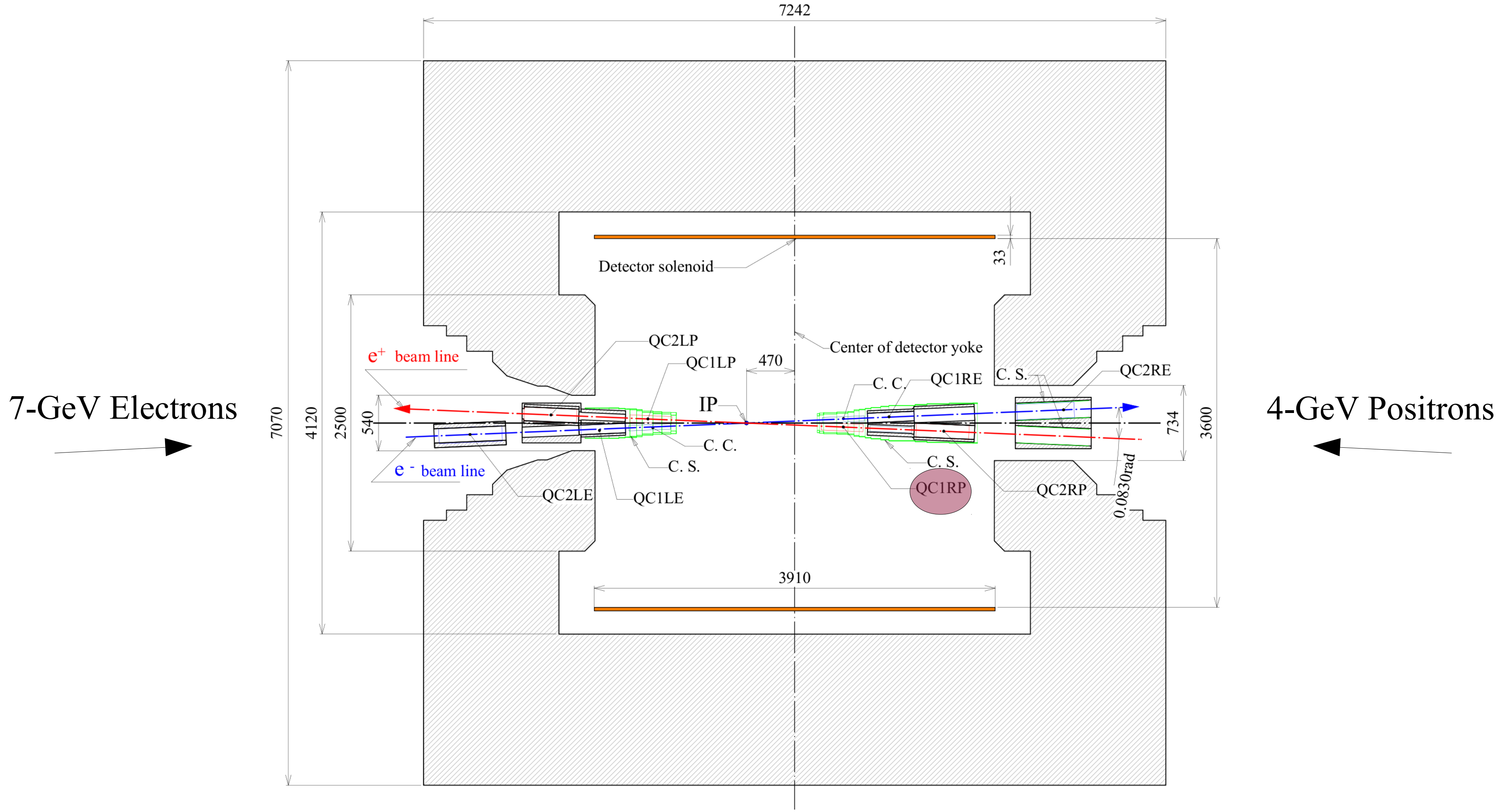
Jim Crittenden

Electron Cloud/Impedance Meeting

27 May 2015

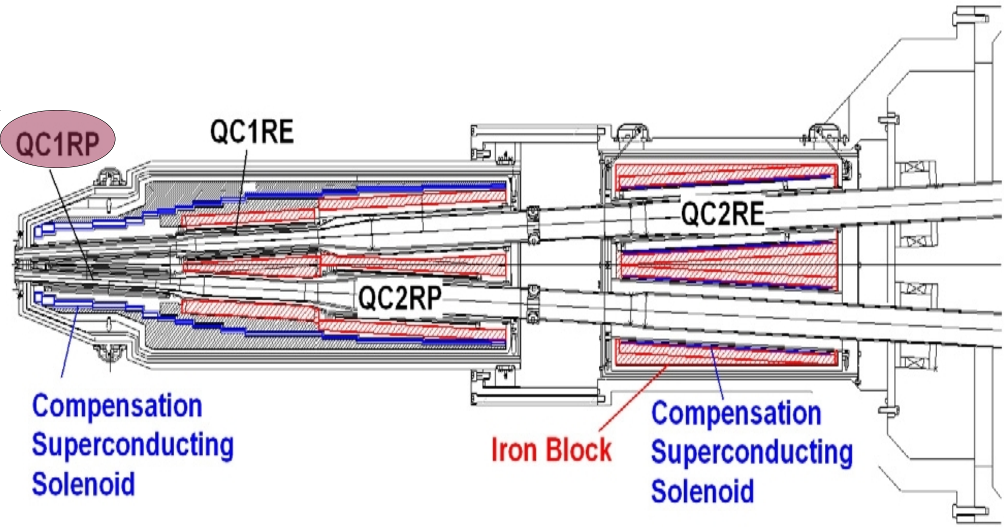
SuperKEKB Interaction Region

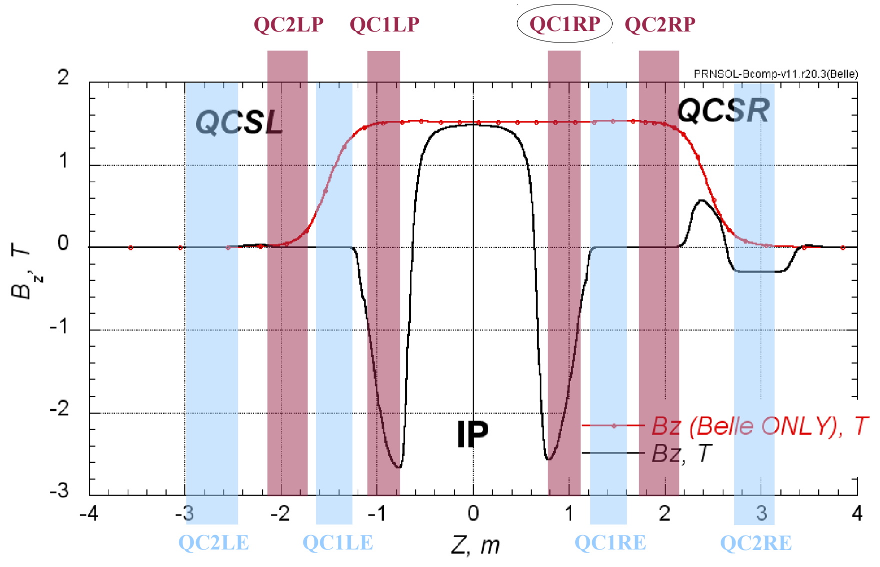
(Y. Arimoto et al, IPAC14, WEPRI086)



The BELLE-II solenoid is offset by 470 mm relative to the IP in the flight direction of the 7-GeV electron beam. The final-focus quadrupole QC1RP for the 4-GeV positron beam is in the region of uniform solenoid field.

SuperKEKB Interaction Region
Solenoid and quadrupole magnetic fields





Final-focus Quadrupole Magnets for the 4 GeV Positron Beam

QC2RP: 0.410 m 28 T/m

QC1RP: 0.334 m 69 T/m

QC2LP: 0.410 m 28 T/m

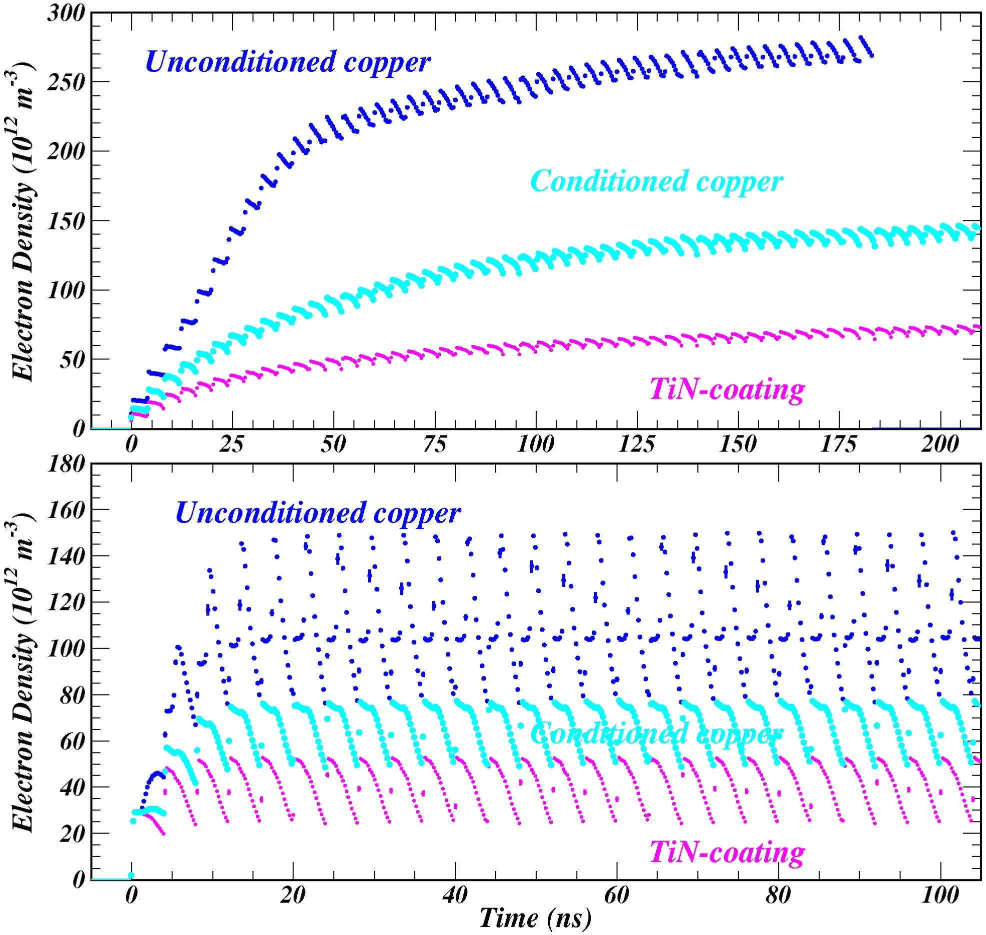
QC1LP: 0.334 m 69 T/m

The combined BELLE-II detector solenoid and compensation solenoid fields produce a field which varies along the length of QC1RP, ranging from about 0.6 T to about 2.6 T. The direction of the field is rotated 83/2 mrad relative to the positron beam axis.

Electron cloud buildup results with and without quadrupole and solenoidal magnetic fields

SuperKEKB Positron Ring Operating Parameters

4 GeV　　2500 bunches @ 9.4e10 e+　　σ_z = 6 mm　　4 ns spacing



B' = 69 T/m
B_z = 2 T

B' = 0 T/m
B_z = 0 T

B_z is oriented along the BELLE-II axis, i.e. it is rotated around the vertical axis by 83/2 mrad relative to the positron beam axis.

The model does not account for the longitudinal variation of B_z, nor for any radial component associated with that variation.

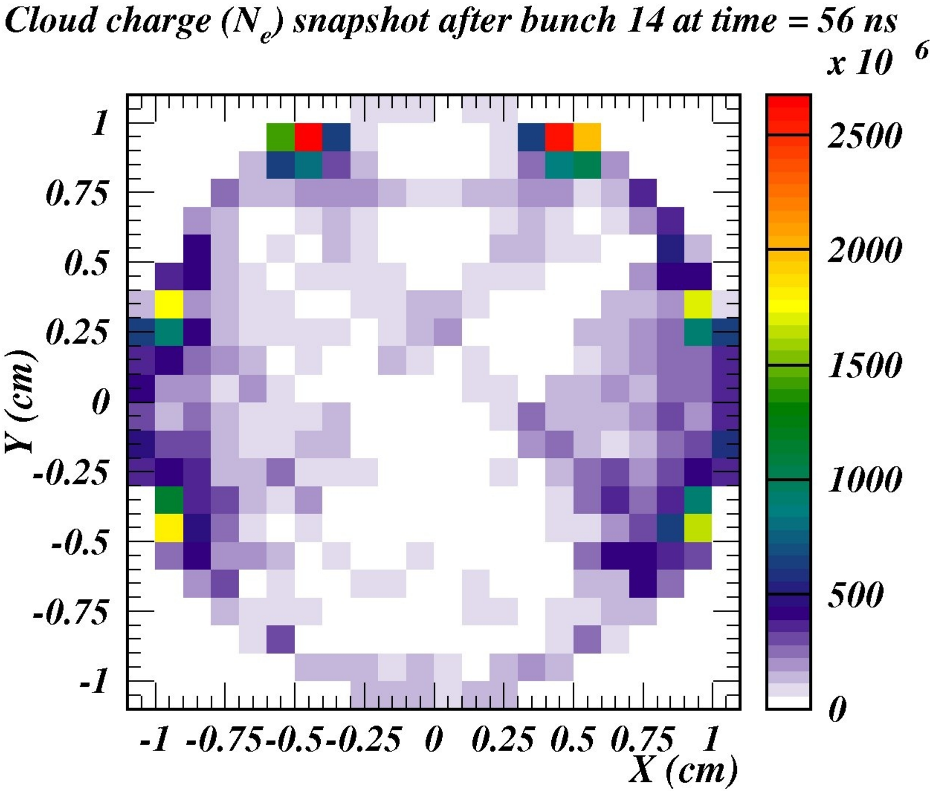
Conclusion: the magnetic fields prevent the cloud from dissipating between bunch passages.

Such electron cloud densities are 3-4 orders of magnitude higher than the ring average estimated by the KEK vacuum group.

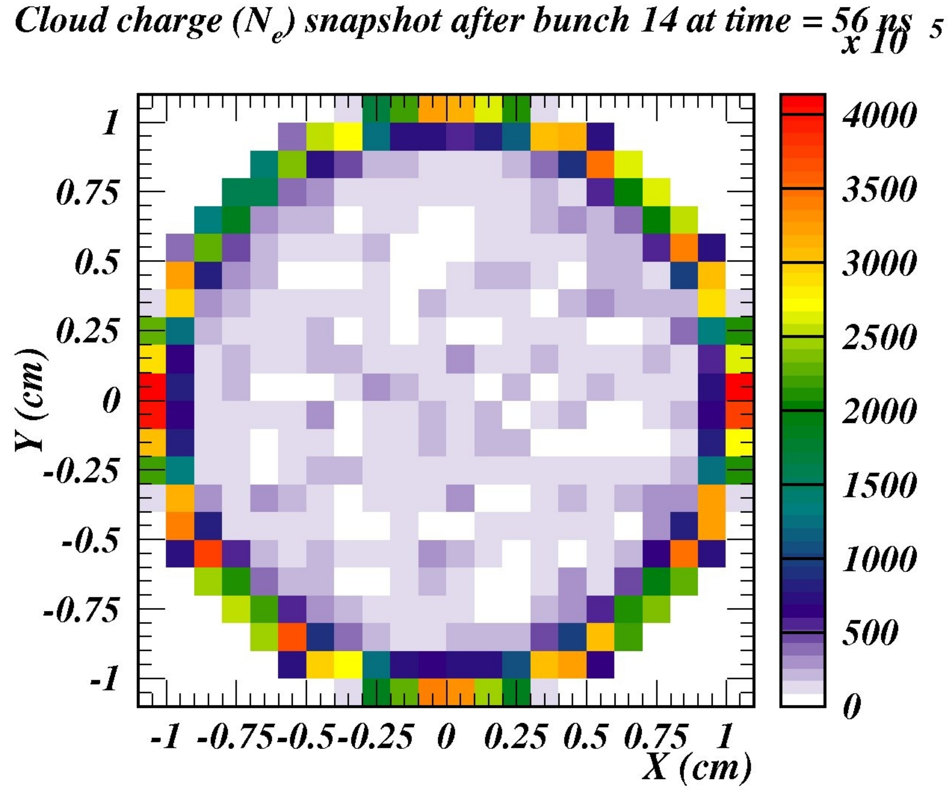
Snapshots of transverse cloud distribution

(Vacuum chamber diameter 21 mm. Unconditioned copper surface.)

B' = 69 T/m B_z = 2 T

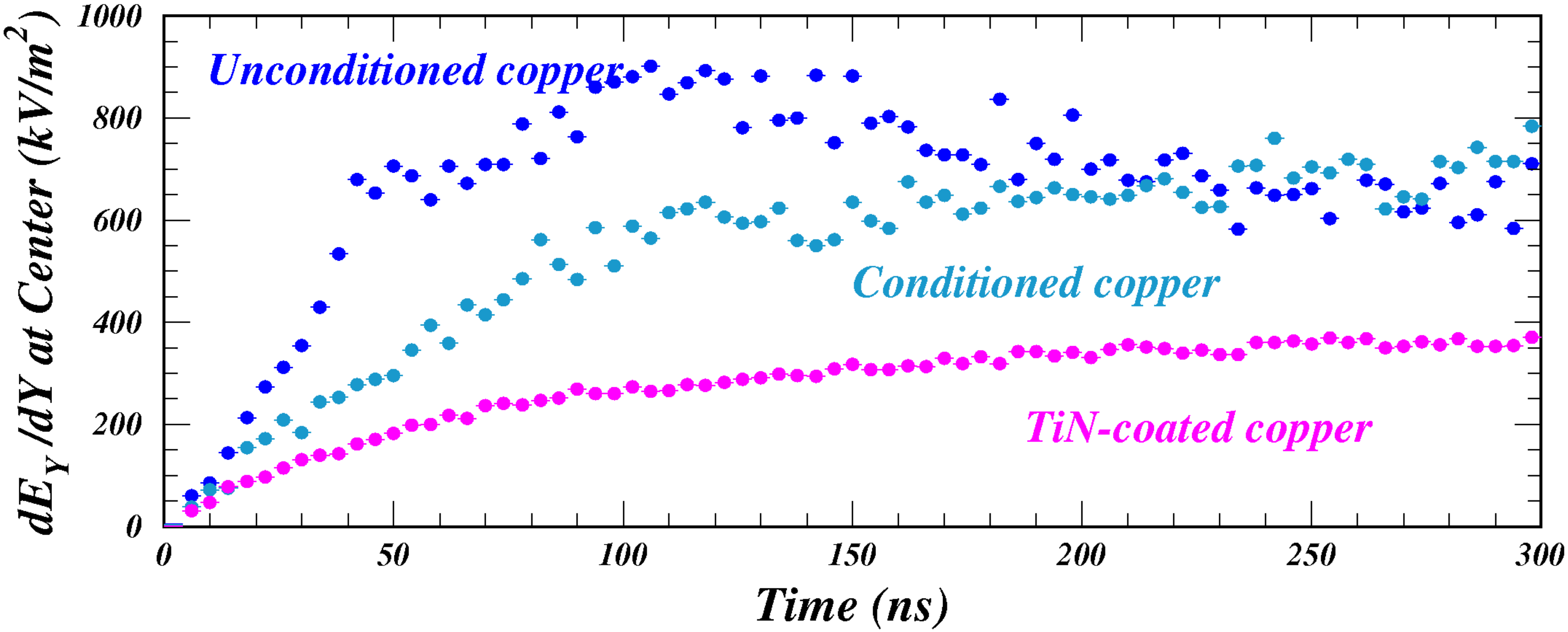


B' = 0 T/m B_z = 0 T



**The quadrupole symmetry is broken by the rotated longitudinal magnetic field.
The magnetic fields causes hot spots near the top of the chamber. With no magnetic field there are hot spots near the sides of the chamber. The hot spots are a factor of six more dense with the magnetic field, reaching more than 2.5×10^9 electrons in one 1-mm by 1-mm bin. The overall cloud density is a factor of three higher.**

Large electric field gradients ==> large tune shifts
Factor >15 larger than Ohmi estimate at IPAC14



Fractional tune shift = $\Delta L*dE_Y/dY * \beta_Y / (4\pi\ E/eV)$ = 2.0e-8 dE_Y/dY (V/m^2) = 0.016
(β_Y = 3000 m !)

Ohmi found a maximum value of 0.001 for excluding ±30 m around the IP (TUPRI020, IPAC14).
During a private discussion at IPAC15, SuperKEKB commissioning group leader Funakoshi estimated the beam-beam tune shift in design conditions to be about 0.5.

No electron cloud production in the final-focus quadrupoles was taken into account, since no photon scattering simulation had been done.

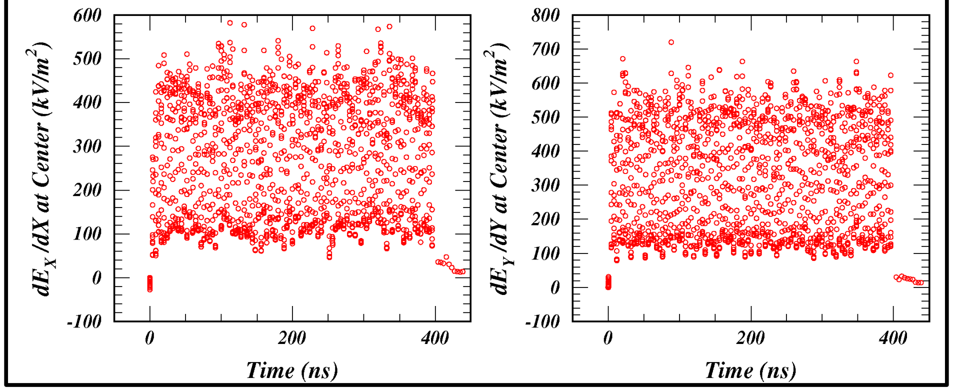
Yoshihiro Funakoshi
Commissioning Group Leader

Kazuhito Ohmi
Simulation Group Leader

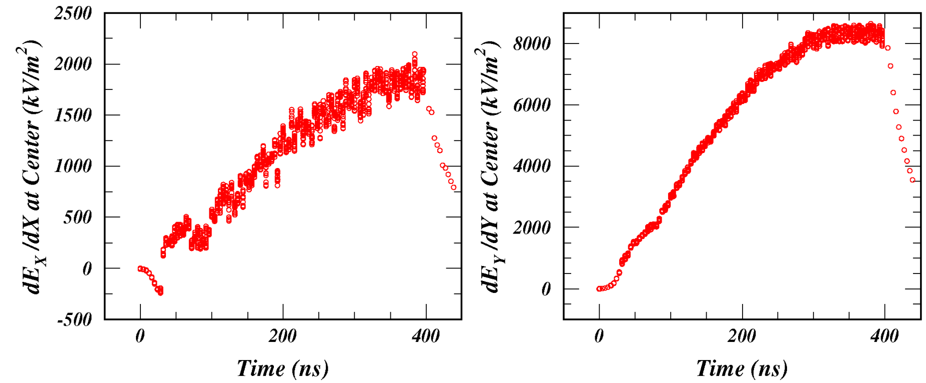
Cornell University
Laboratory for Elementary-Particle Physics

Effect of magnetic fields on the tune shifts
(Unconditioned copper surface)

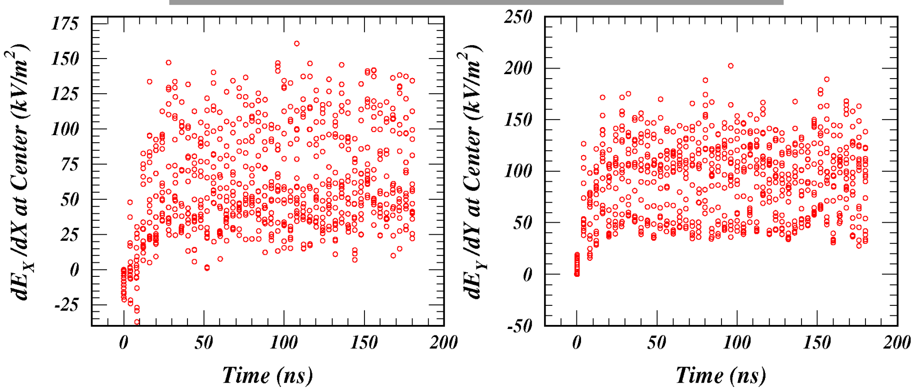
$B' = 0$ T/m $B_Z = 0$ T



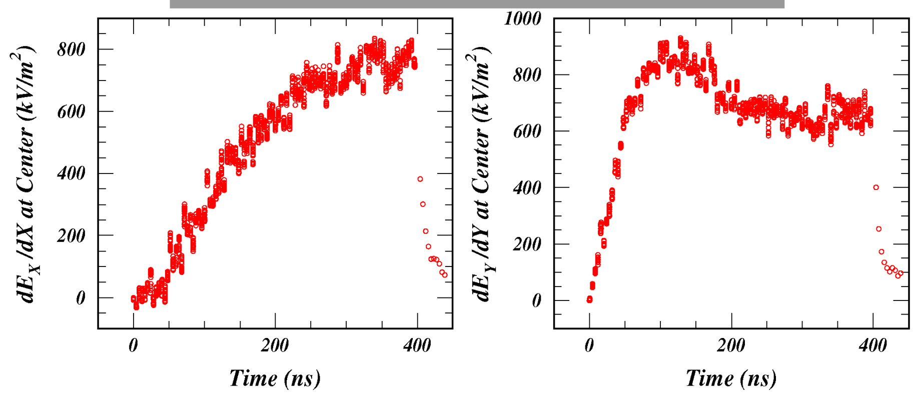
$B' = 0$ T/m $B_Z = 2$ T



$B' = 69$ T/m $B_Z = 0$ T



$B' = 69$ T/m $B_Z = 2$ T

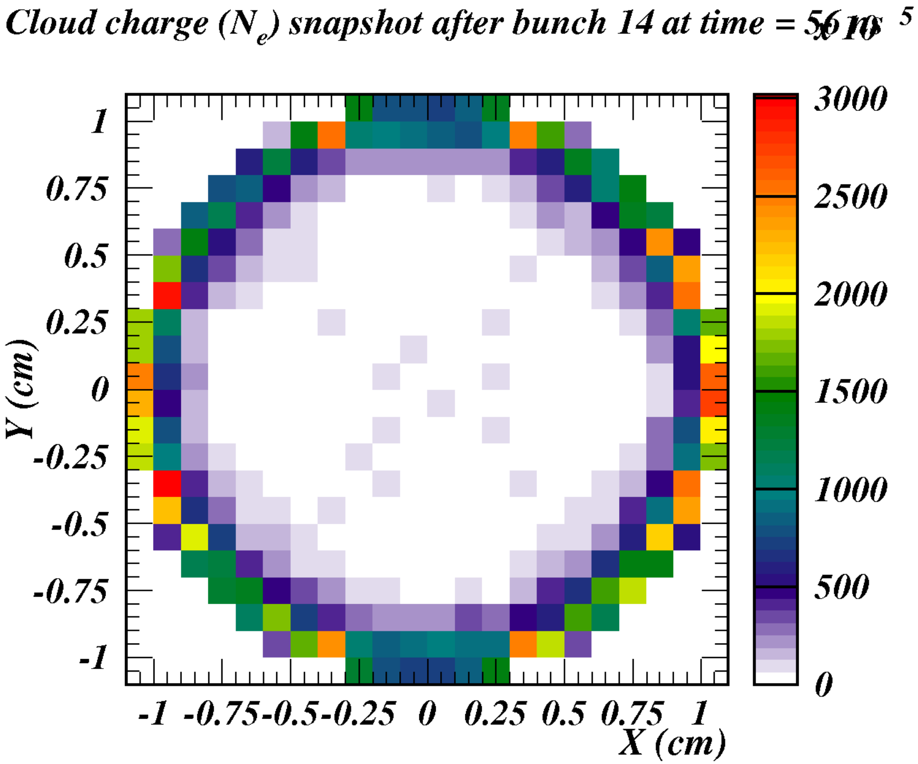


The off-axis solenoidal field causes the high field gradients at the beam.
The additional quadrupole field reduces the gradients.

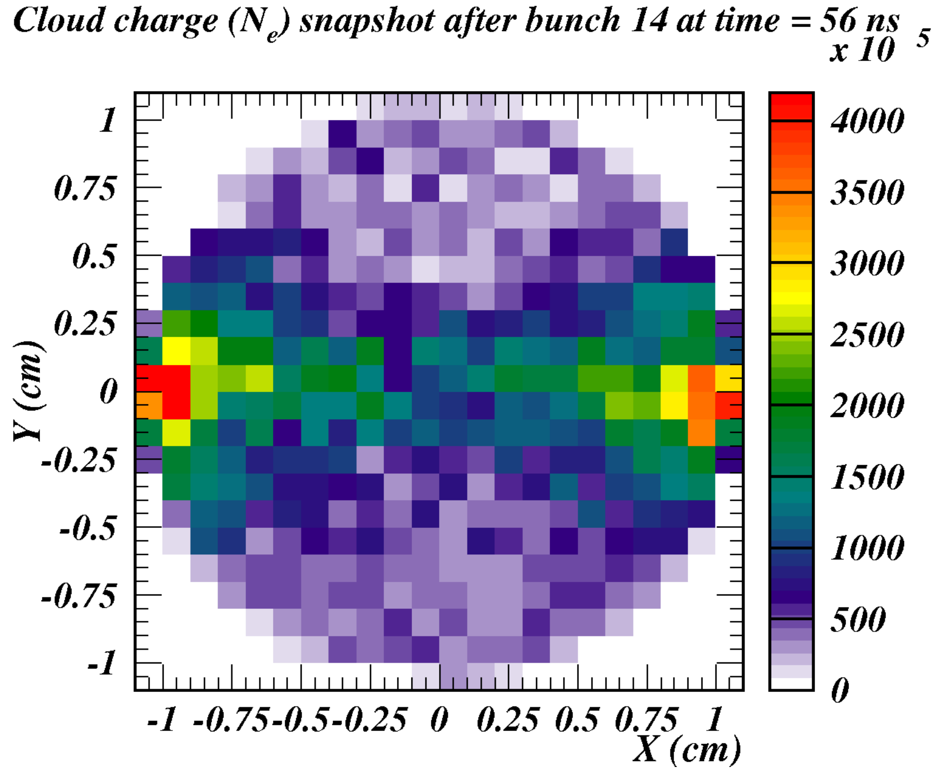
Snapshots of transvers cloud distribution

(Vacuum chamber diameter 21 mm. Unconditioned copper surface.)

B' = 69 T/m B_z = 0 T



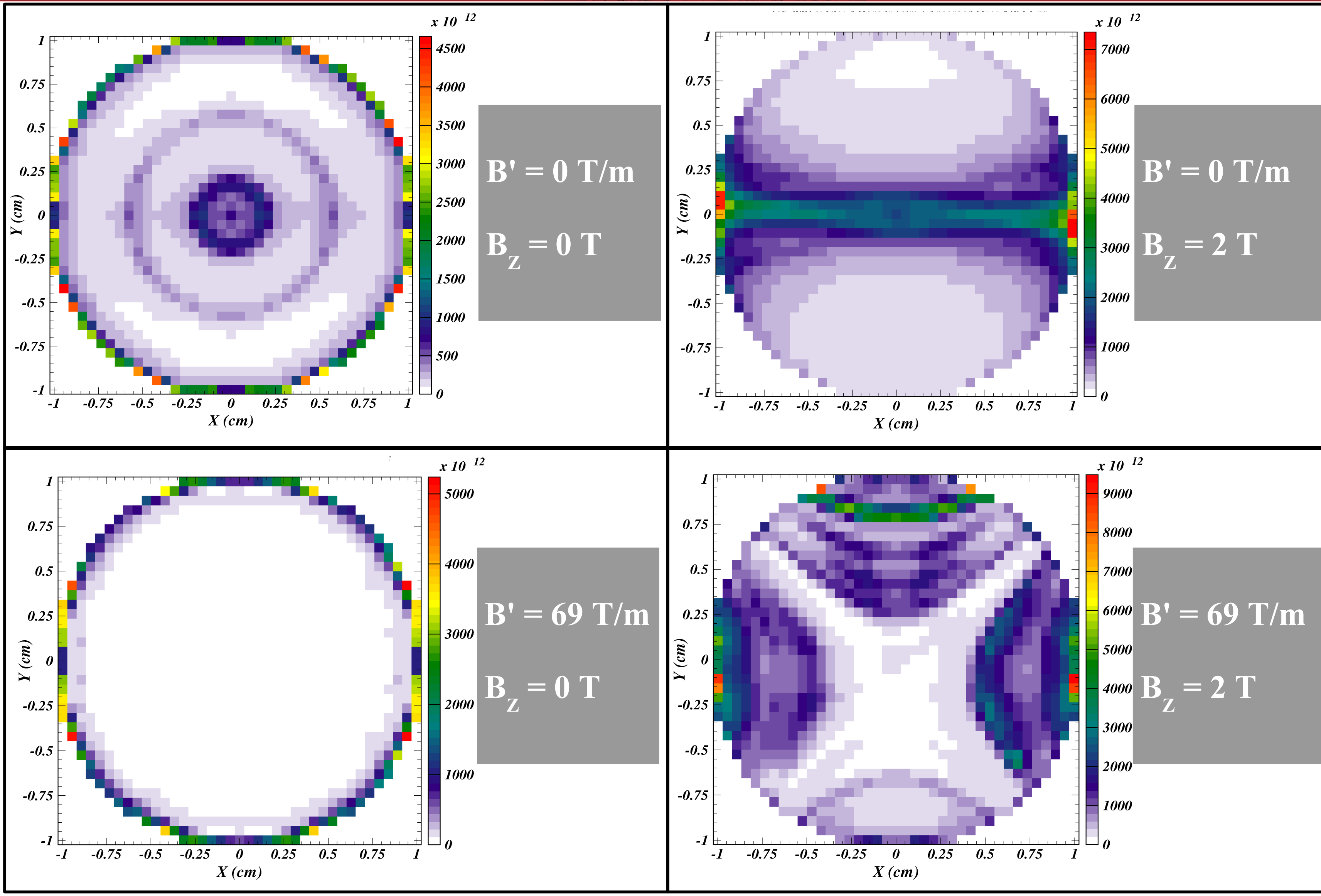
B' = 0 T/m B_z = 2 T



The quadrupole symmetry is restored when the rotated solenoid compensation field is removed.

The solenoid compensation field causes high cloud densities and electric field gradients at the beam in both planes.

Transverse cloud distributions averaged over the full simulation time of 438 ns
(Density (e/m^3) in 0.5×0.5 mm bins)



All questions, comments and suggestions are welcome.