Electron cloud in Final Doublet

ILC Interaction Region Engineering Design Workshop (IRENG07)

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Motivation

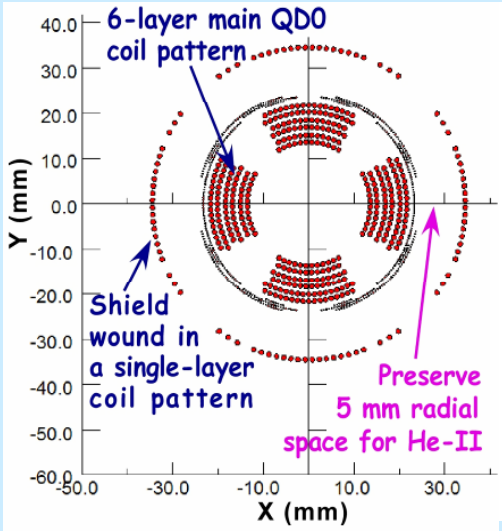
- In 14mrad crossing angle (baseline), the two beams are separated at Final Doublet (SC) where electron cloud is one concern.

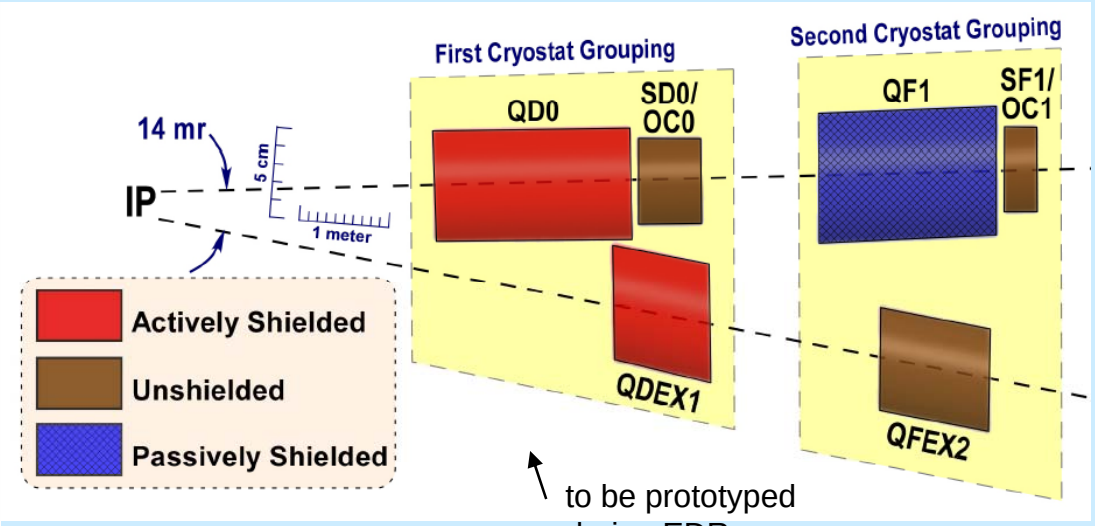
- Quadrupole field can trap electrons by mirror field trapping; There are also strong solenoid field in QD0 which also may confine electrons.

QD0: G=140T/m

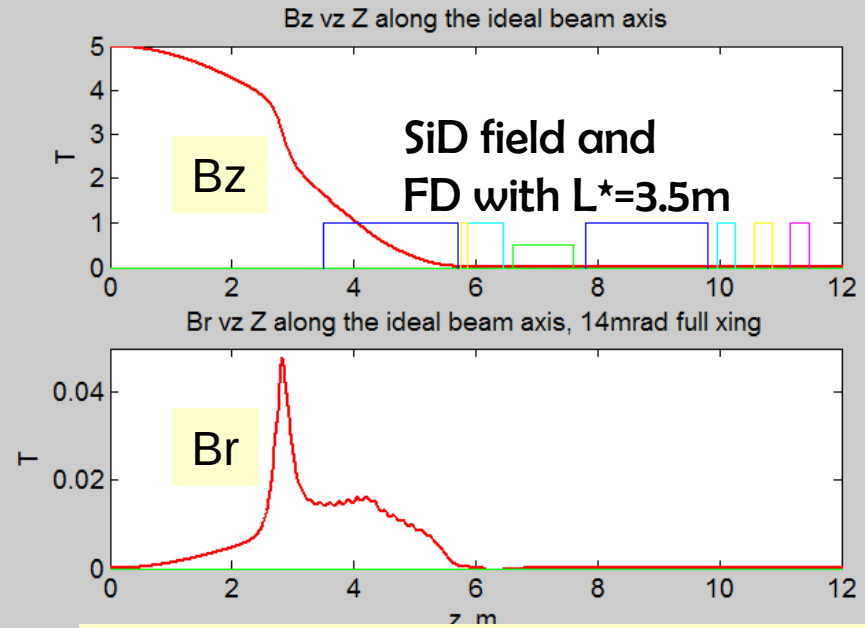
QF1: G=80T/m

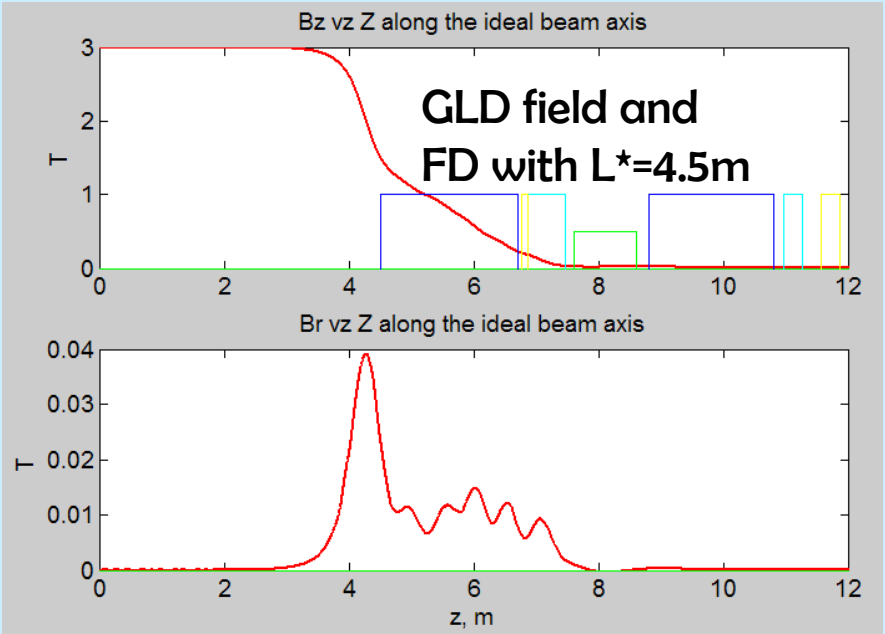
Radius=10 mm



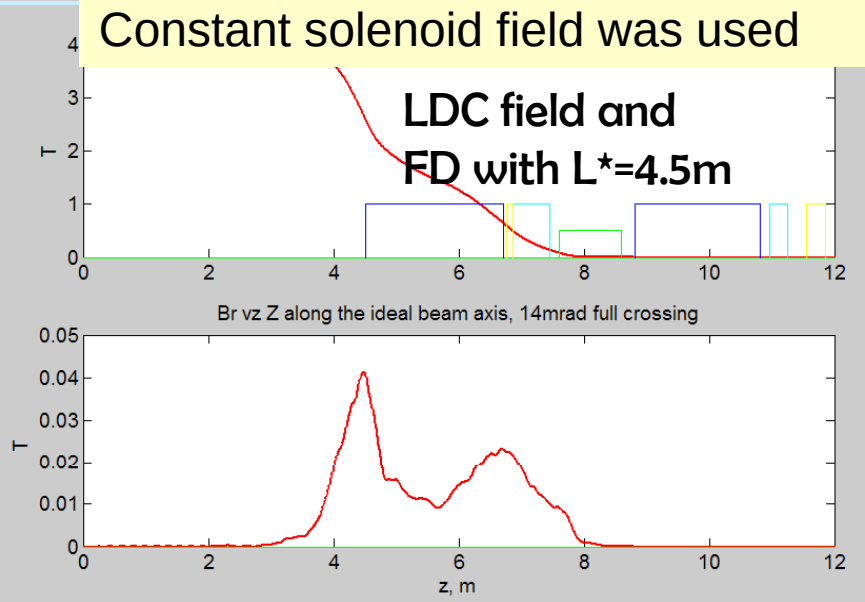


Solenoid field in QD0





Constant solenoid field was used



- Use 2005 field maps for SiD and GLD and older TESLA field for LDC
- Use 14mrad total crossing angle, L*=3.51m for SiD detector and L*=4.51m for GLD and LDC
- Use same FD structure, with FD quads and sextupoles rematched

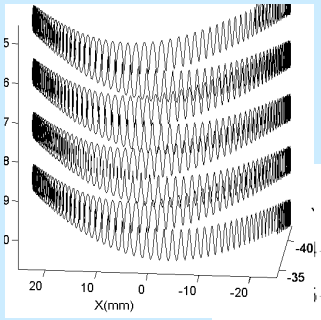
Program & Model

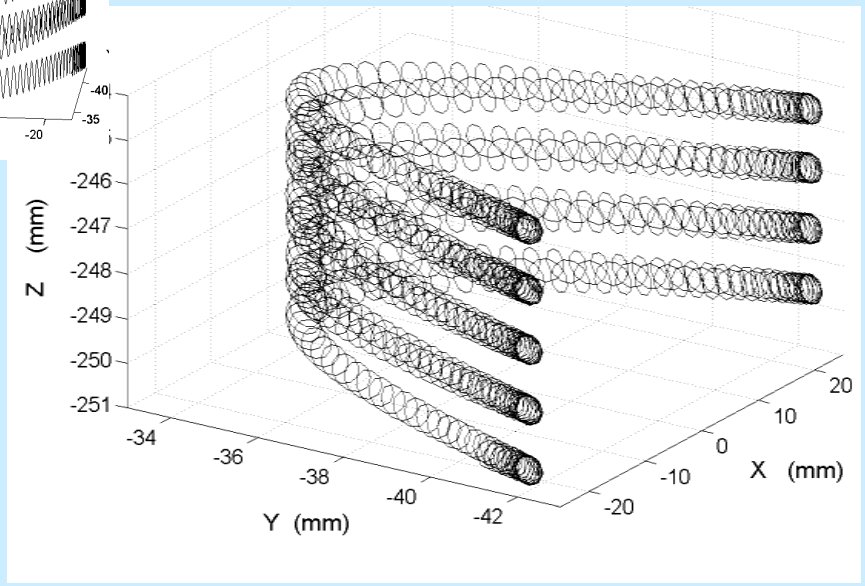
CLOUDLAND: 3D PIC code for e-cloud

- **3D space charge solver (FEM)**
- **Various Magnetic and electric field**
  - General 3-dimensional fields given by expression.
  - Fields can also be import from other program using table
  - Field solver for electrode, solenoid, etc
- **Beam field**
  - Gaussian bunch in round chamber (image charge is included)
  - PIC method for general geometry
- **Clearing electrode, Solenoid, Grooved chamber,**
- **Applied to various accelerators: SNS, PSR, KEKB,RHIC, ILC DR…**

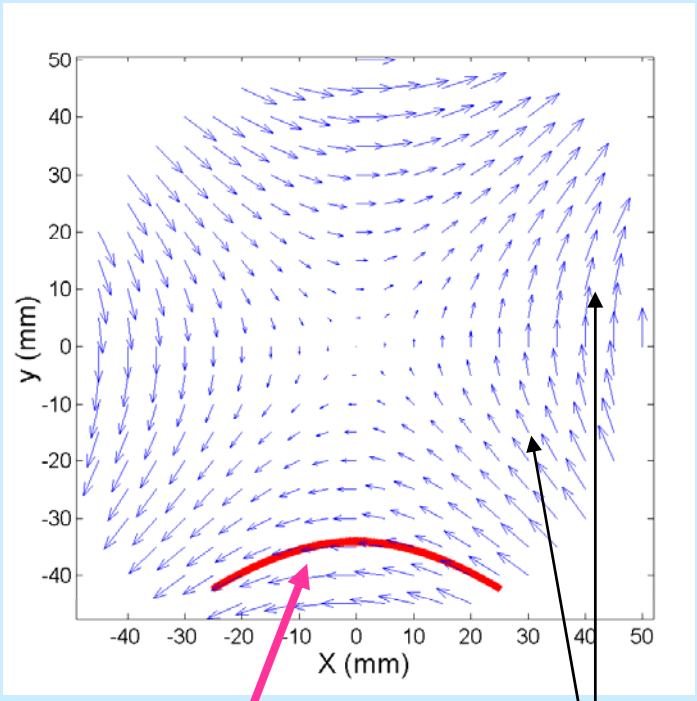
Mirror Field Trapping+beam effects

Trapping phenomenon---in quadrupole magnet





3D orbit



2D orbit

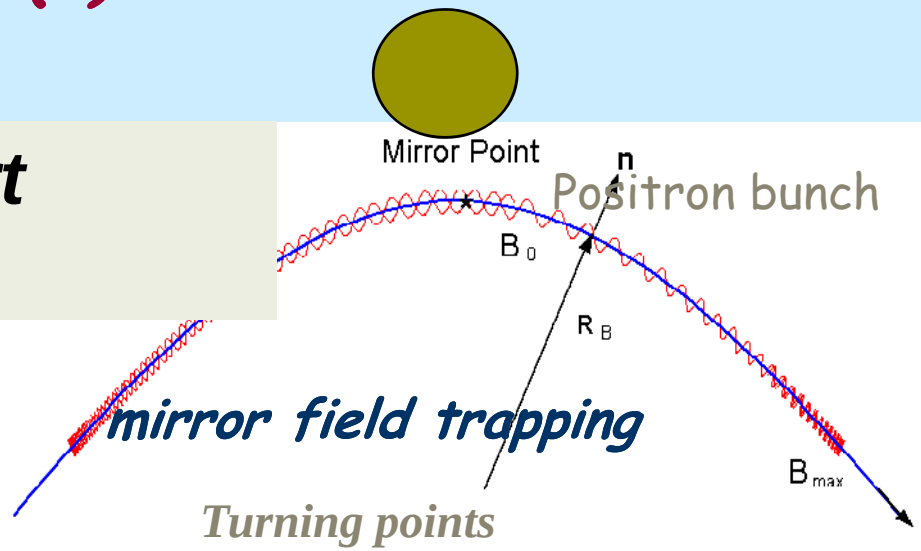
Field lines

Orbit of a trapped photoelectron in normal quadrupole magnet during the train gap (field gradient=0.5T/m)

Trapping mechanism (2)– Short bunch

ILC bunch (300μm) is short enough for trapping!

$$\frac{1}{2} m \upsilon_{\parallel}^2 + \mu_m B = const$$



→ Reflective Points: $\upsilon_{\parallel}=0$

Trapping condition

$$\Gamma_{trap} > 1$$

$$\Gamma_{trap} = \frac{F_\upsilon}{F_B} = \frac{\upsilon_{\perp 0}^2}{\upsilon_{\perp 0}^2 + \upsilon_{\parallel 0}^2} \frac{B_{\max}}{B_0}$$

Trap factor is constant if no other force (except B force) disturbs the electron and smaller than 1.0, no trapping

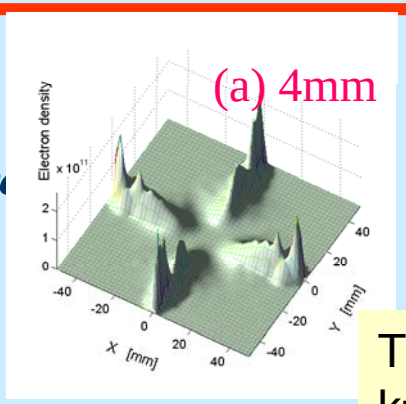
$$\Gamma_{trap} = \left. \frac{\upsilon_{\perp 0}^2}{\upsilon_{\perp 0}^2 + \upsilon_{\parallel 0}^2} \right|_{\text{at the emission point}} = cons\tan t \le 1$$

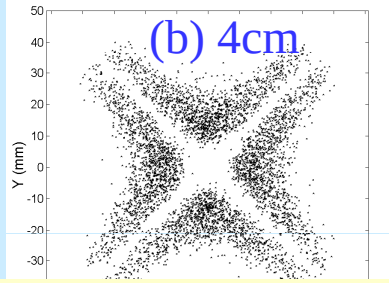
Trap requirement for positron bunch

Bunch length should be shorter than period of gyration motion

$$\sigma_l < \frac{2\pi cm}{e} \frac{1}{B}$$

$$\sigma_l(mm) < 10.7 / B(T)$$



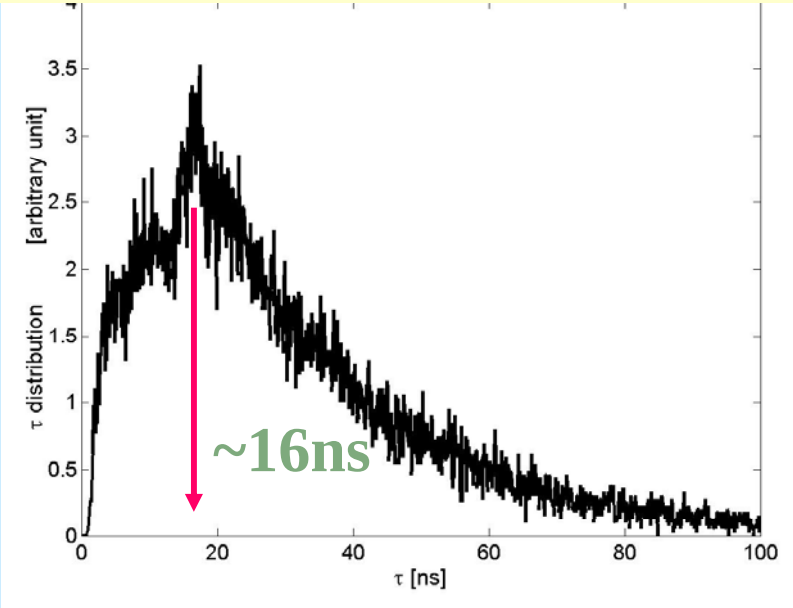


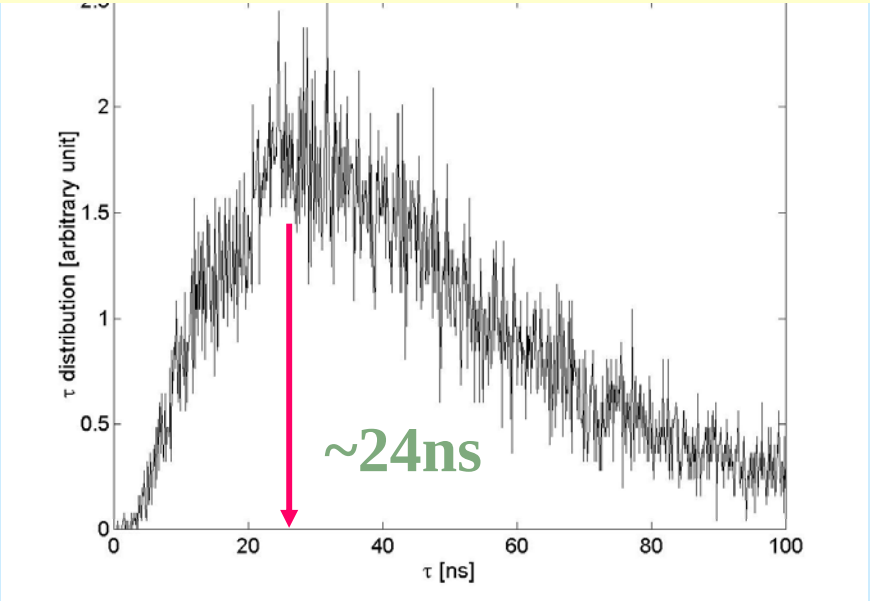
Trapped electrons in Quad k=10.3T/m (KEKB beam)

Trapping mechanism (3) – resonance (bunch spacing)

Resonance of the interaction between e-cloud and positron bunch: Bunch spacing = 1/2 of the period of electron longitudinal motion

ILC has very long bunch spacing 175ns, The probably of resonance is small.

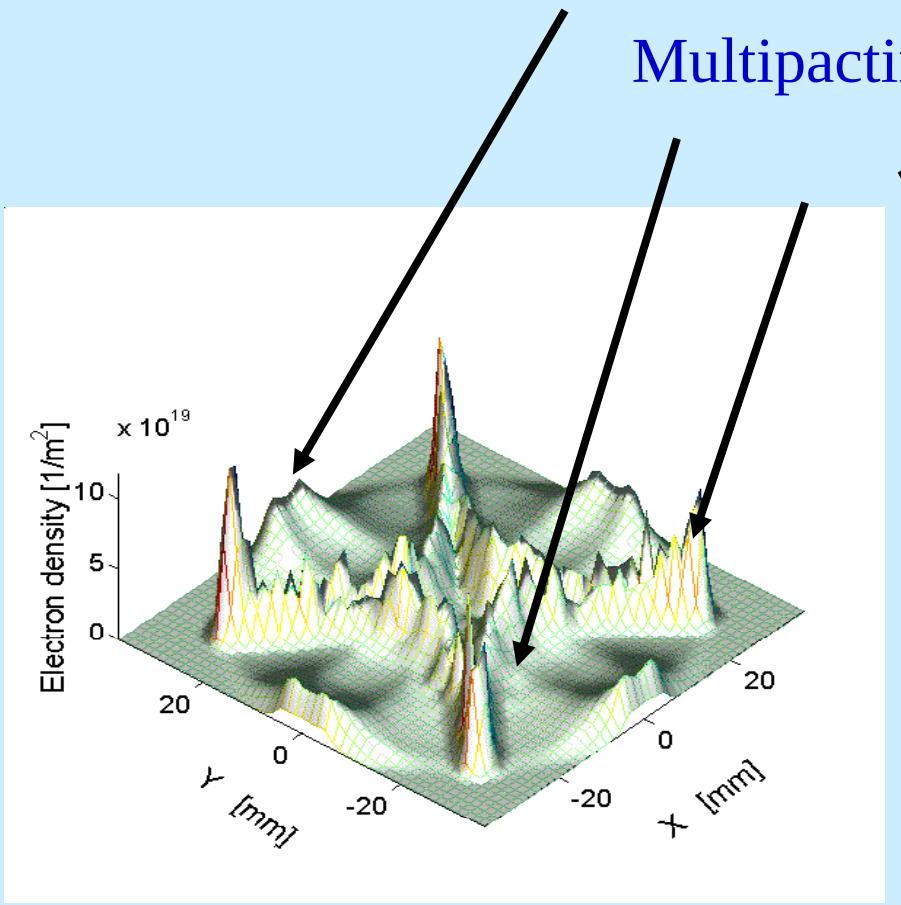




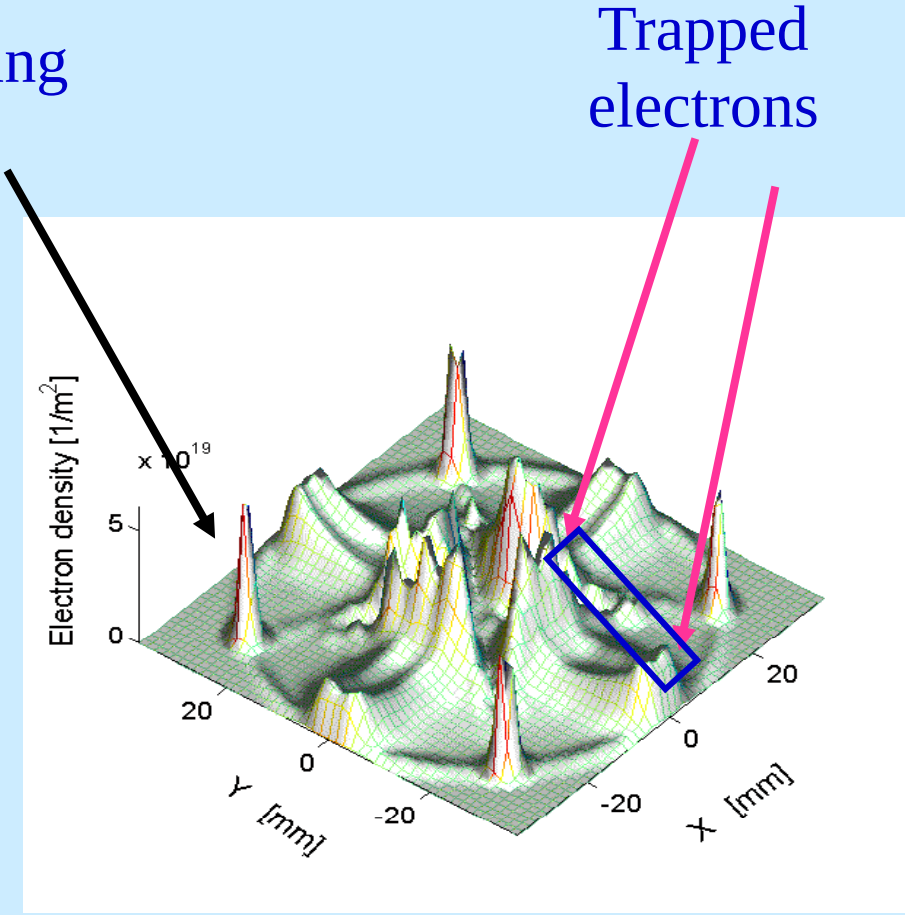
Bunch spacing=8ns ***Bunch spacing=12ns***

Distribution of period τ of the trapped electron cloud in quadrupole of KEKB LER during the train gap for 4mm bunch length

E-cloud in SuperB Quadrupole (H. Fukuma)



At end of bunch train



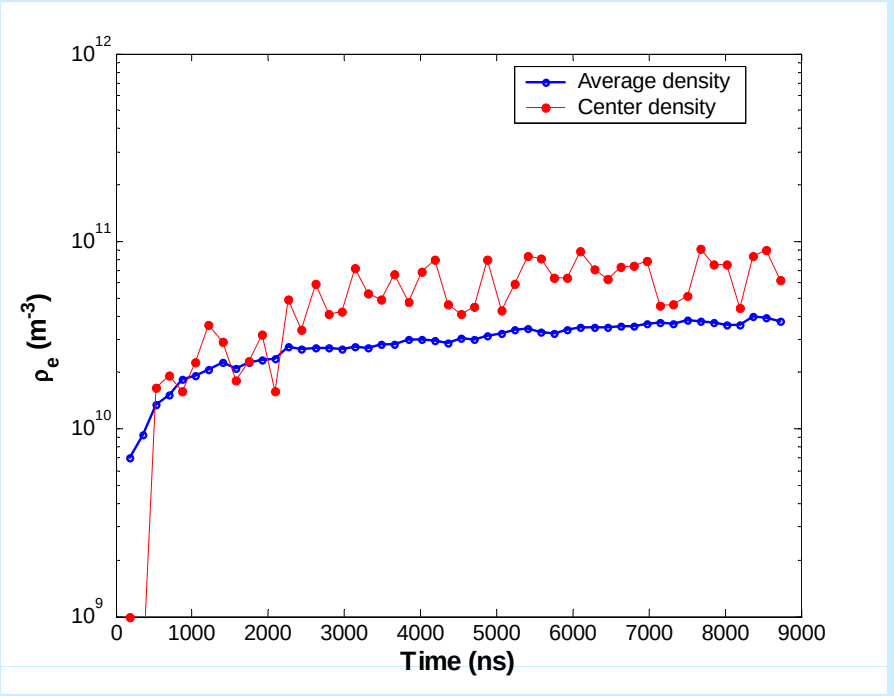
At bunch gap (20 bunch spacing/40ns after the last bunch in the train)

Electron seed (I): from surface of beam pipe (QD0)

Simulation Parameters

- **Photon electron; Beam loss; etc**
- **Large Peak secondary emission yield =2.0**
- **Quad filed +Constant solenoid field (0.2T/1T) is used in QD0**
- **Large initial electron seed:**

  number electron per meter per e+ = 2.40E-3
- **Bunch length 300μm**
- **Beam size 639nm/5.7nm**
- **Bunch intensity 2×10^{10}**



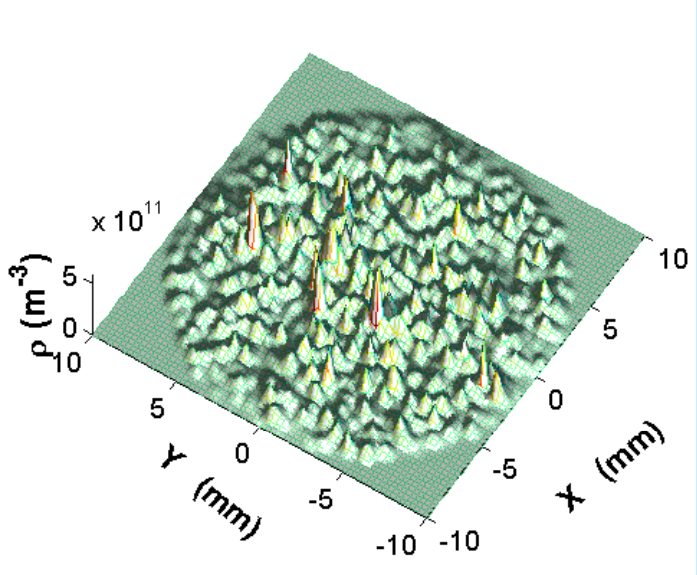
Electron cloud build-up in QD0

Results

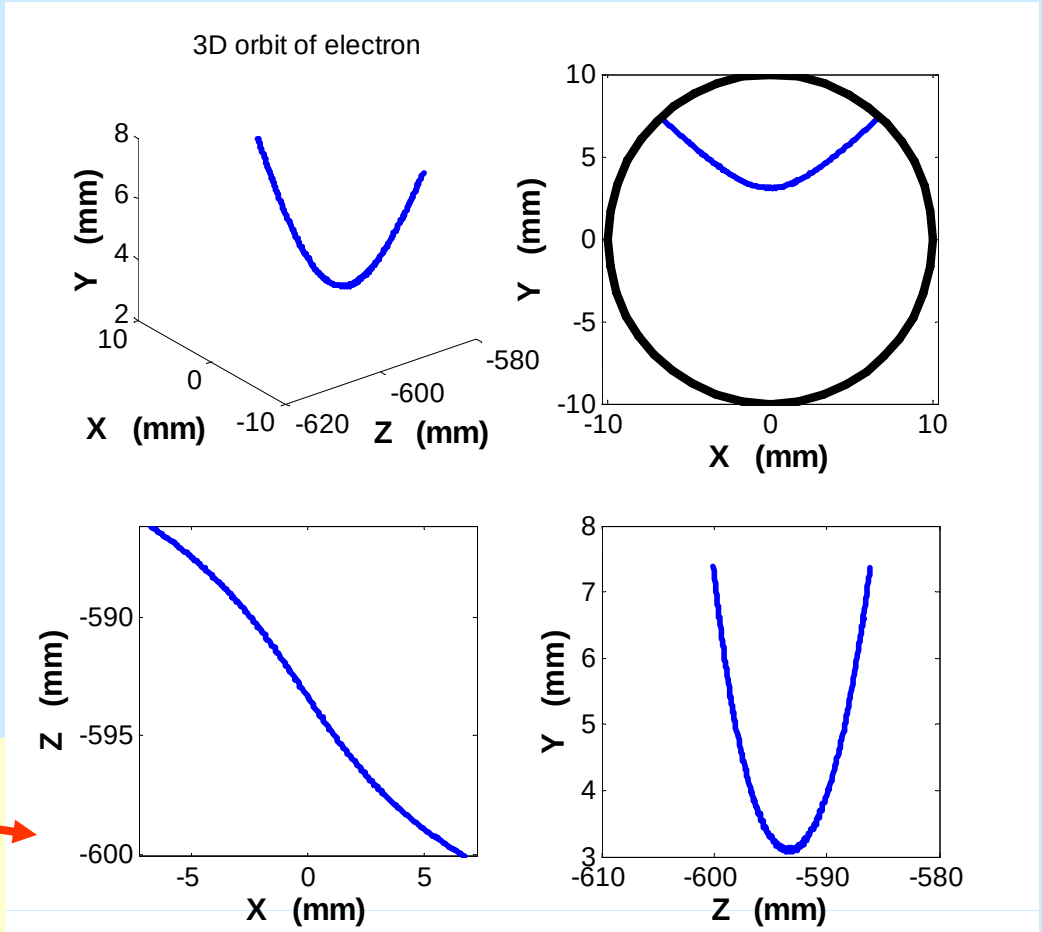
➢**There is no multipacting due to the long bunch spacing**

➢**There is no trapping;**

Electron Distribution & Orbit



Electron distribution in transverse plane



Energy gain 22eV;

Speed of 5eV electron=1e6m/s

Drift distance during one bunch spacing 175ns=230mm

Electron orbit

Electron seed (II): Ionization

Simulation Parameters

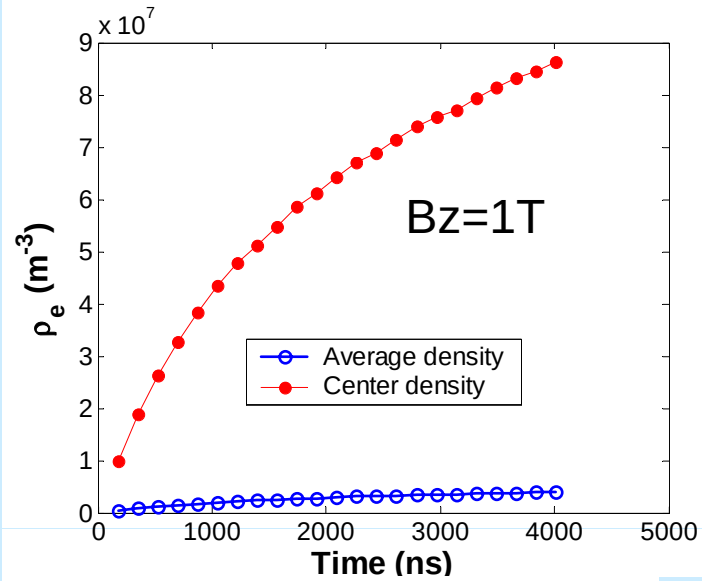
- **Peak SEY 2.0**
- **Constant solenoid field 0.2/1T**
- **1nTorr Pressure**
- **Cross section of ionization 2 Mbarn**

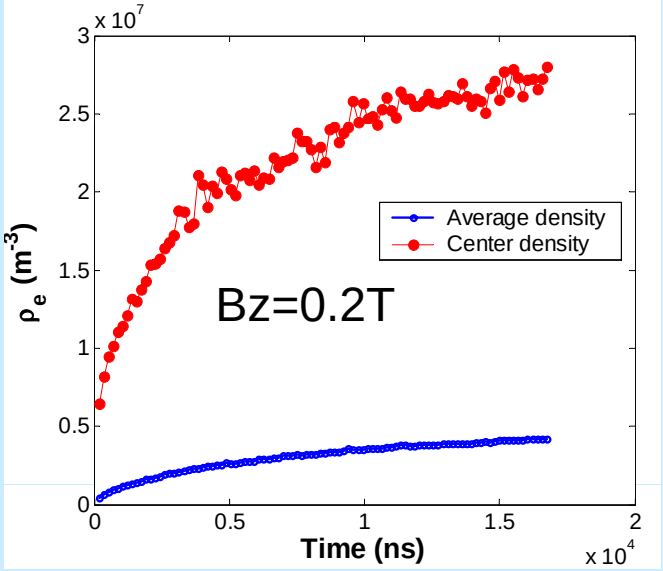
Results

➢ **No multipacting**

➢ **Short time trapping;**

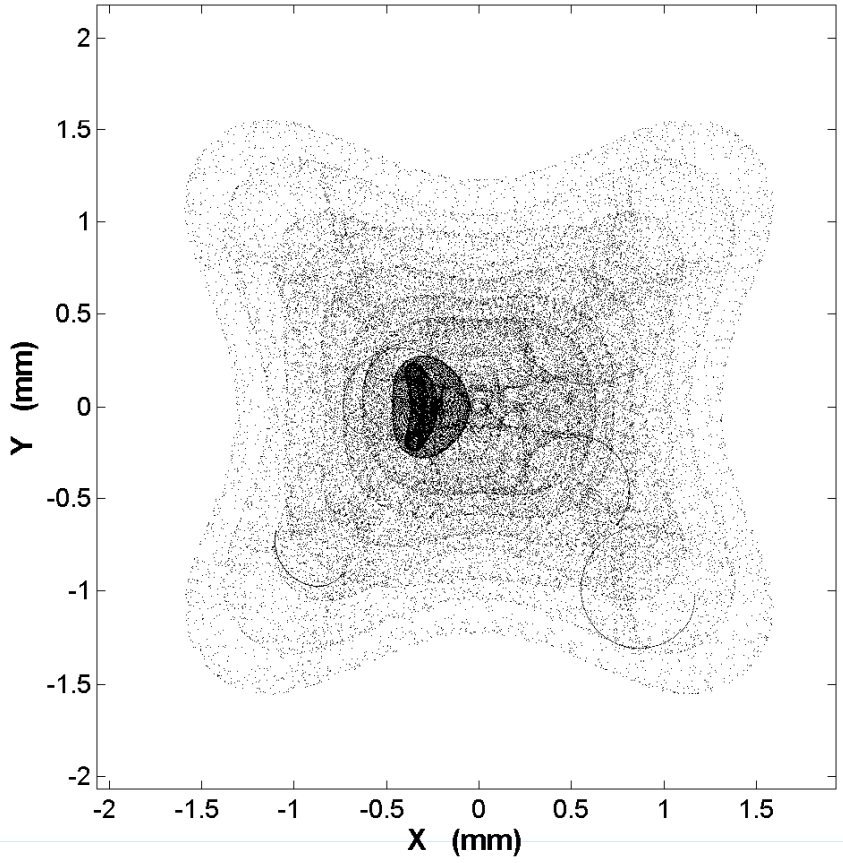
➢ **The accumulated electron density is small**

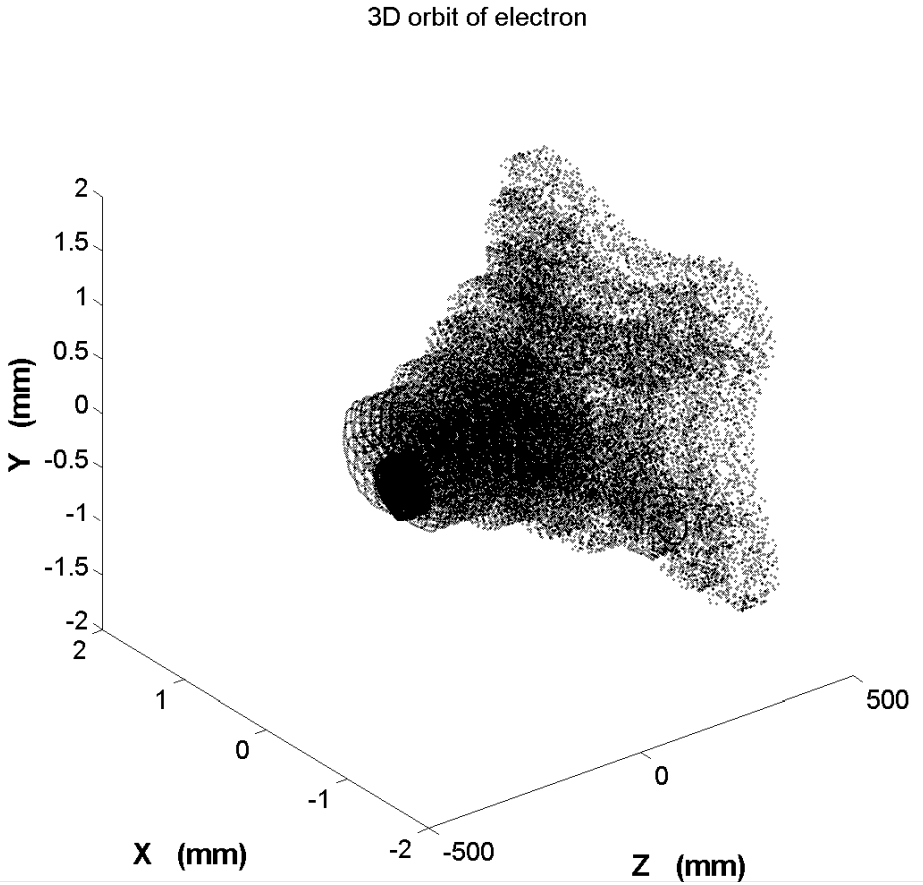




Electron cloud build-up in QD0

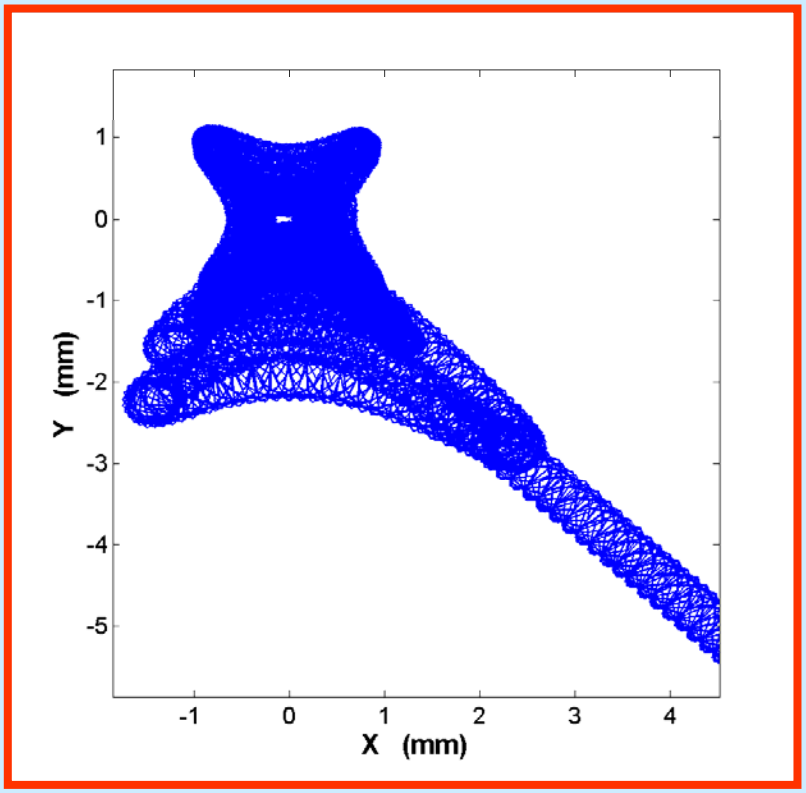
Orbit of Trapped electron (QD0)



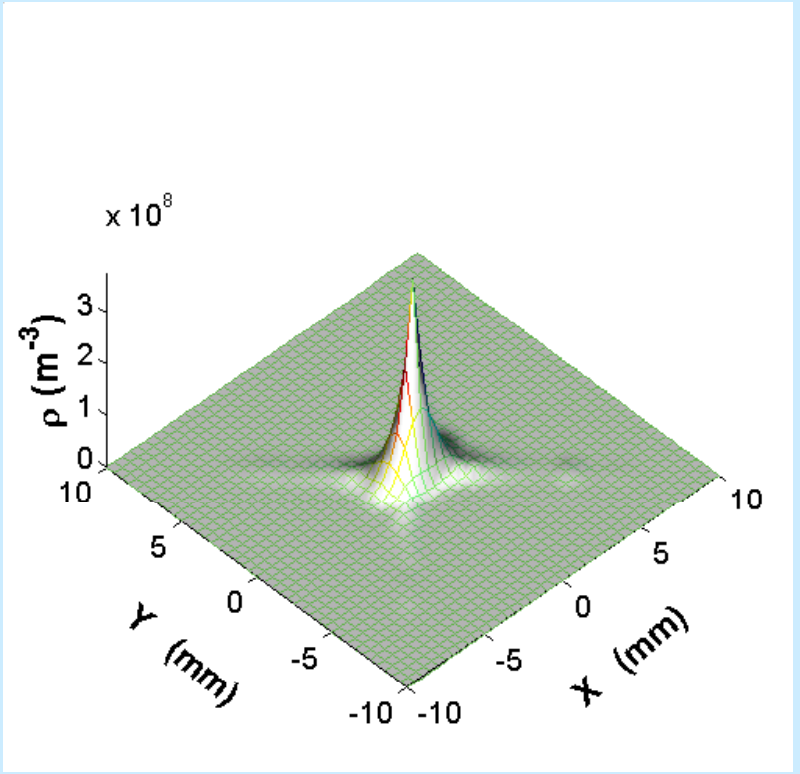


Electron's orbit in QD0 +1T Solenoid

Escape from trapping (QD0)



Electron orbit



Electron distribution

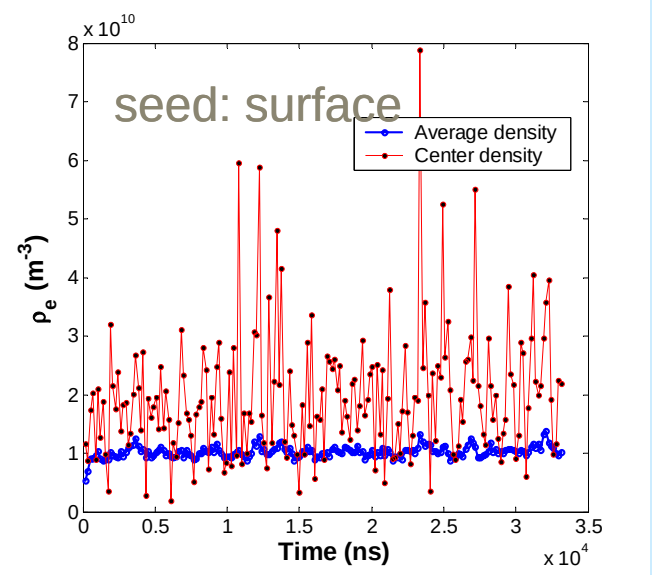
Electron in QF1

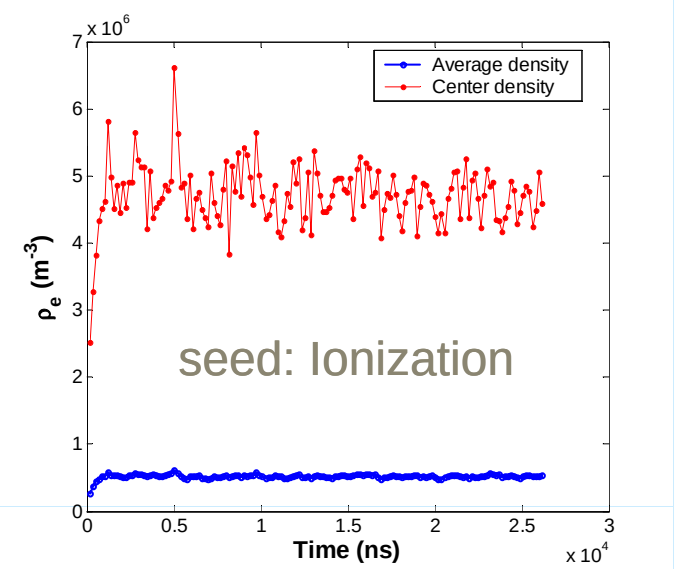
Simulation Parameters

- **Peak SEY 2.0**
- **1nTorr Pressure**
- **Cross section of ionization 2 Mbarn**

Results

- **No multipacting**
- **No trapping;**
- **The accumulated electron density is VERY small**





Electron cloud build-up in QF1

Summary

- The e-cloud in FD is simulated with 3D model
- No multipacting due to long bunch spacing
- No Mirror field trapping due to long bunch spacing
- Some Trapped electrons in QD0 by the solenoid, but the electron density is small
- (To model realistic solenoid field?)

Acknowledgements

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