

**EFFECT OF THE ELECTRON CLOUD ON
THE COUPLED-BUNCH INSTABILITY AT KEKB LER**

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Workshop on
Electron-Cloud Simulations for Proton and Positron Beams
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Contents

- **Introduction**
- **Experimental studies of coupled bunch instability**
- **Electron cloud simulation studies**
- **Summary**

Introduction

- ✧ LER is a positron ring

 - Beam energy = 3.5 GeV

 - Beam chamber radius = 47 mm

- ✧ Solenoids were installed to suppress the blow-up of the beam due to electron cloud instability since September 2000.

 - After 5th installation, about 95% of the drift region is covered.

 - The typical solenoid field at LER is ~ 45 G

- ✧ Objectives:

 - to study the effect of electron cloud on coupled bunch instability,

 - to compare the simulation results with experimental observation.

Experimental studies

- ◆ **Filling pattern**
 - 1/1153/4 (10% abort gap)
 - 4 rf bucket spacing = 7.86 ns = 2.356 m
- ◆ **Bunch oscillation data:**
 - Bunch oscillation data are recorded for 4 k-turn by Bunch Oscillation Recorder (BOR) after turning off feedback system.
- ◆ **Data analysis**
 - Bunch oscillation data are taken at fixed location.
 - Bunch by bunch Fast Fourier transform (fft) is applied to the data.
 - The data are then multiplied by a factor of $e^{-i\omega\beta\Delta t}$.
 - Snap shot data are obtained after applying inverse fft to the data.
 - Mode spectrum is determined by applying fft to the snapshot data turn by turn.
 - Growth rate is determined by fitting of bunch oscillation.

Solenoid-Off

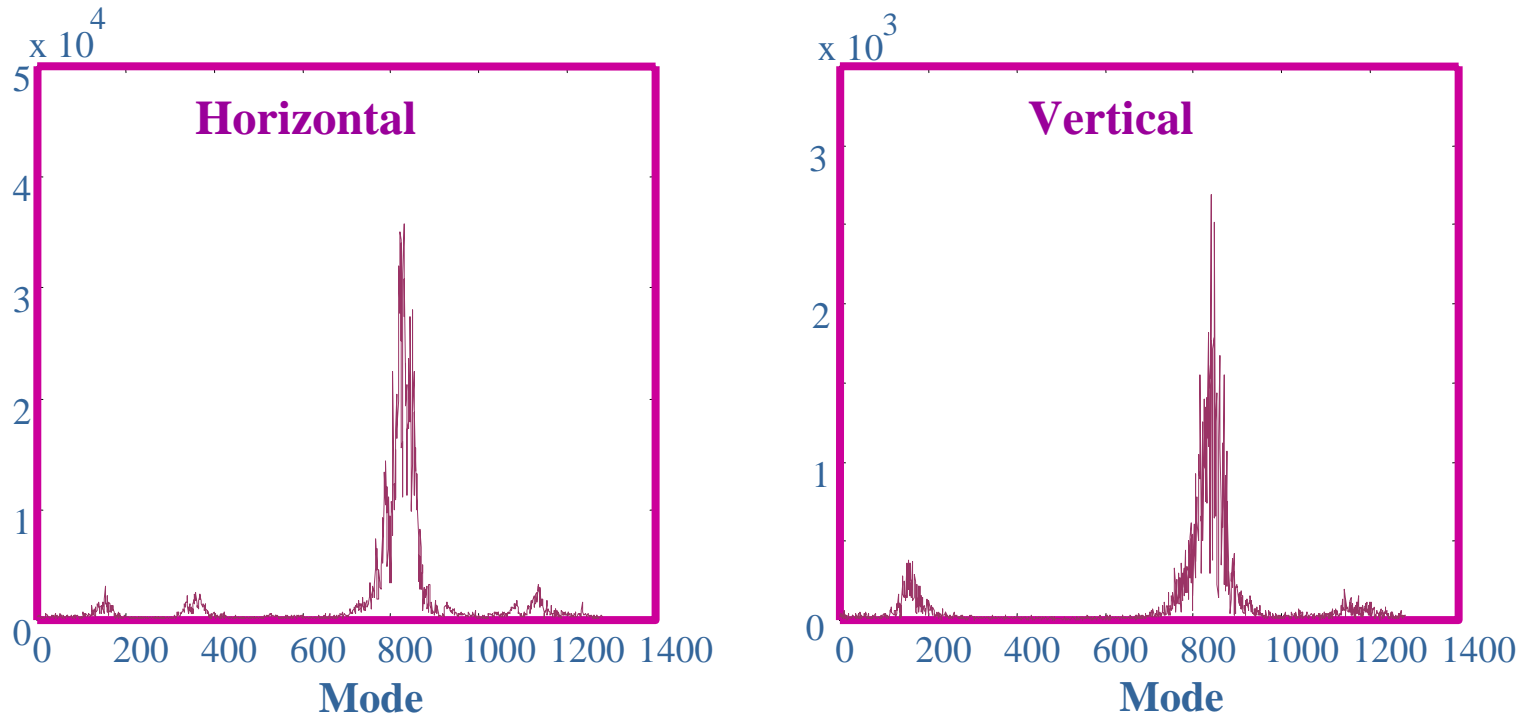


Fig. The mode spectra observed when solenoid-off (Beam current 600 mA).

The similar mode spectra with broad peak at 800 are observed for horizontal and vertical direction.

Solenoid-On

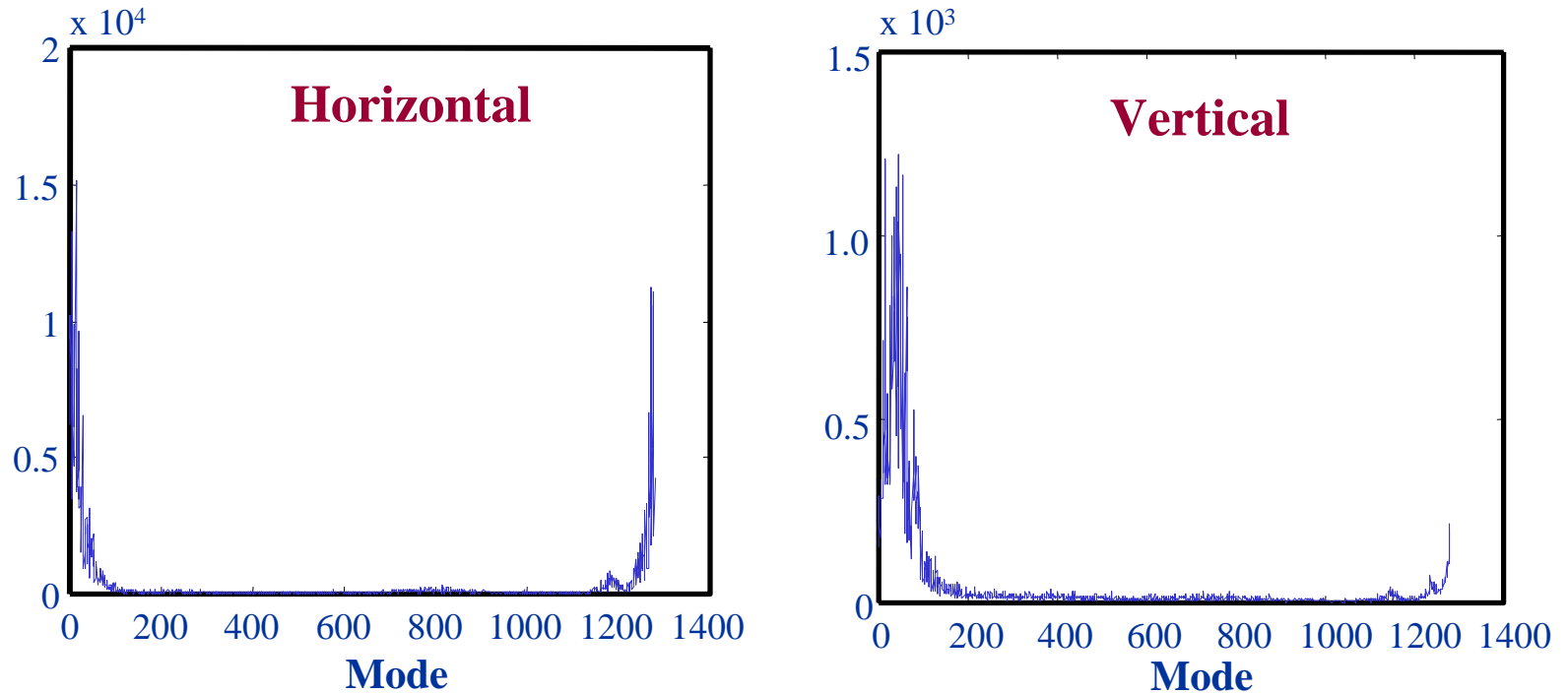


Fig. The mode spectrum observed when solenoid-on (Beam current 600 mA).

**Similar mode spectrum is observed for horizontal and vertical direction.
The mode spectra are changed when solenoid-on.**

Experimentally observed Growth rates

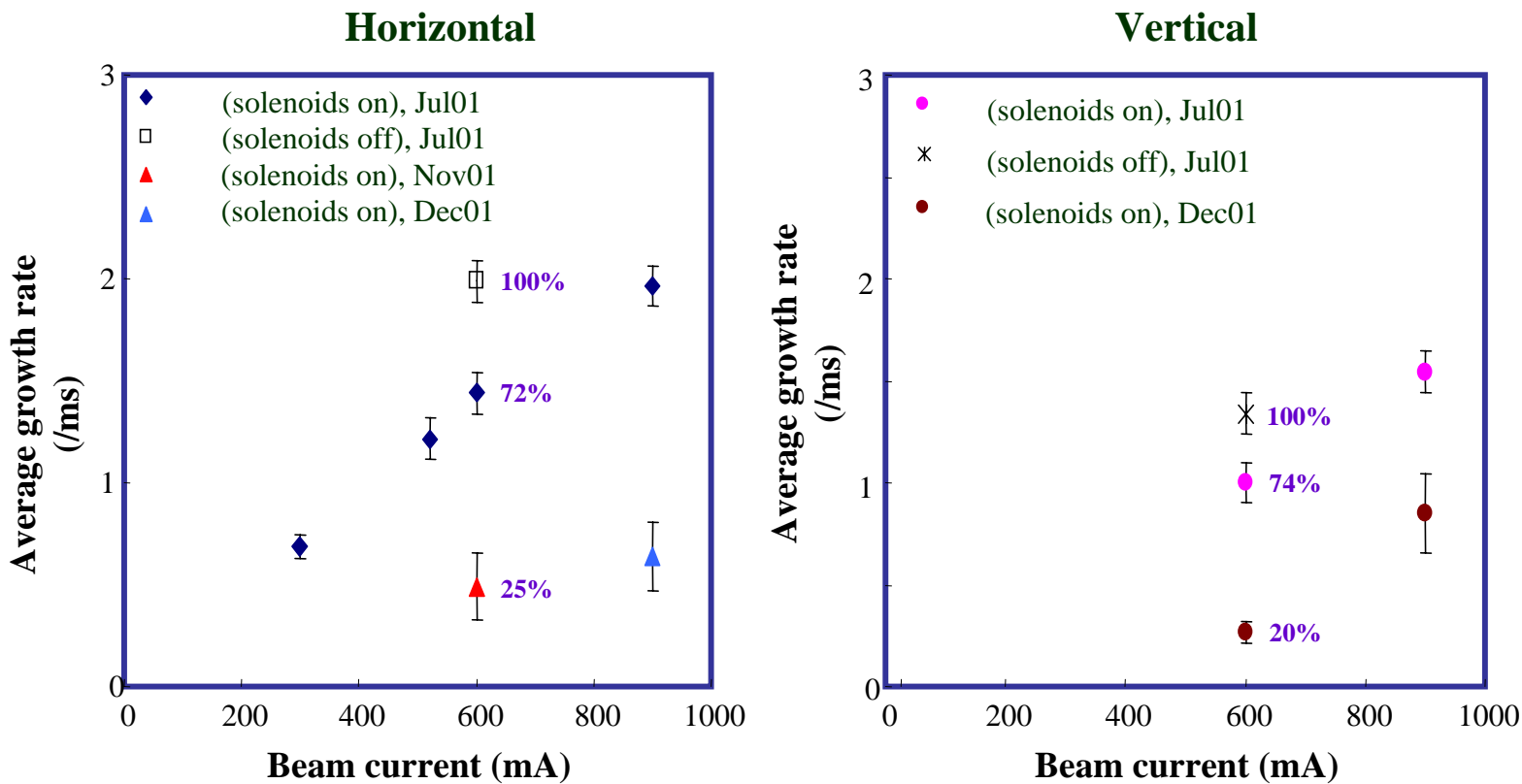


Fig. Growth rates of bunch oscillation at different conditions of solenoid-on & solenoid-off.

Simulation study

- The coupled bunch instability due to electron cloud was studied by the simulation program “**PEI**”.
- The program “**PEI**” was originally developed by **K. Ohmi** (KEK).
- Beam oscillations are calculated by particle tracking.
- The mode spectra are determined from the bunch oscillation or the wake field.
- **The following parameters are assumed for the particle tracking.**
 - Average $\beta_x/\beta_y = 10$ m/10 m
 - Betatron tune $\nu_x/\nu_y = 45.515/43.569$
 - The initial photoelectrons energy is considered as truncated Gaussian distribution with 10 ± 5 eV.
 - Photoelectron yield, $\eta = 0.1$
 - No elastic electron is considered.
 - Secondary production is assumed to have a peak at $E_{\text{sec}} = 200$ eV.
 - Maximum secondary electron yield, $\delta_{\text{max}} = 1.0$
 - Bunch current, $I_b = 0.52$ mA
 - Fill pattern = 1/1153/4

Production at the illumination point & Solenoid-OFF (1)

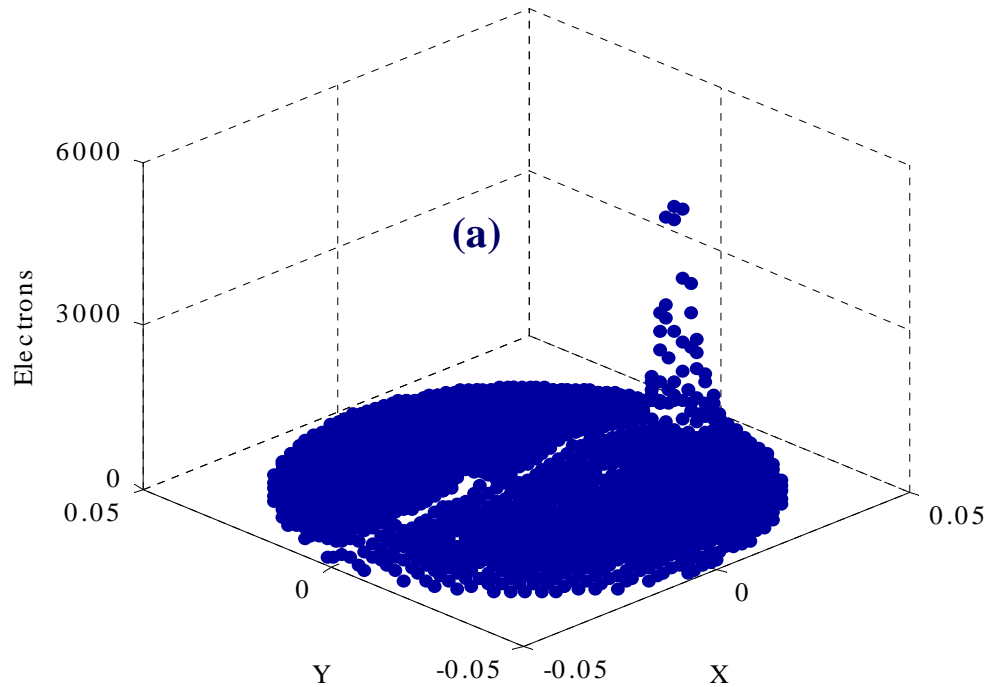
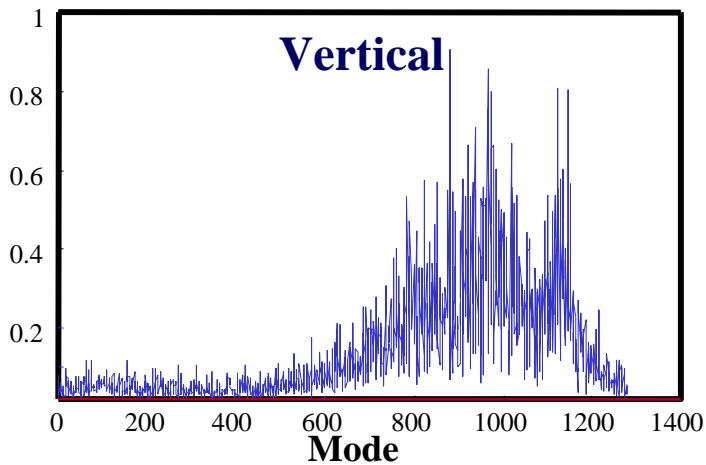
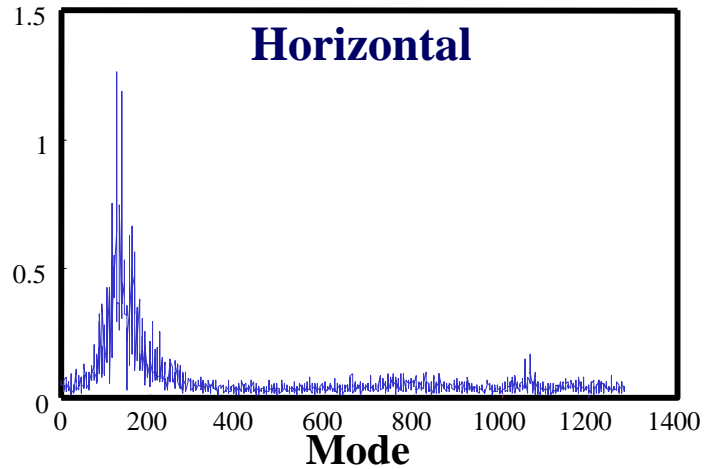


Fig. (a) Electron distribution over the cross section of vacuum chamber (X and Y in m)

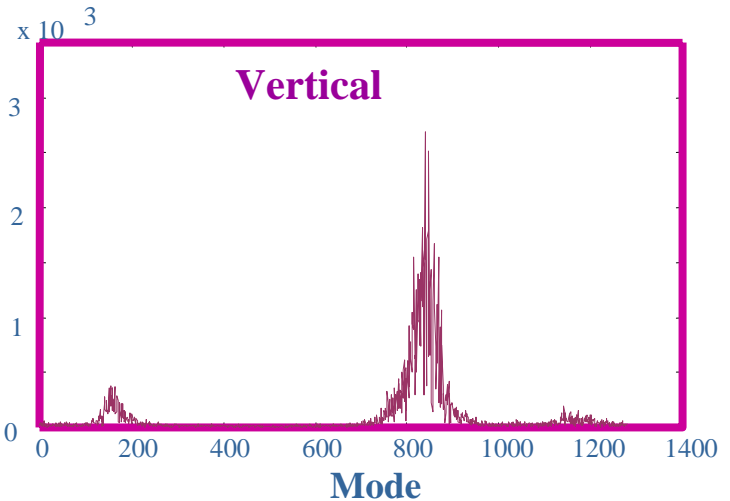
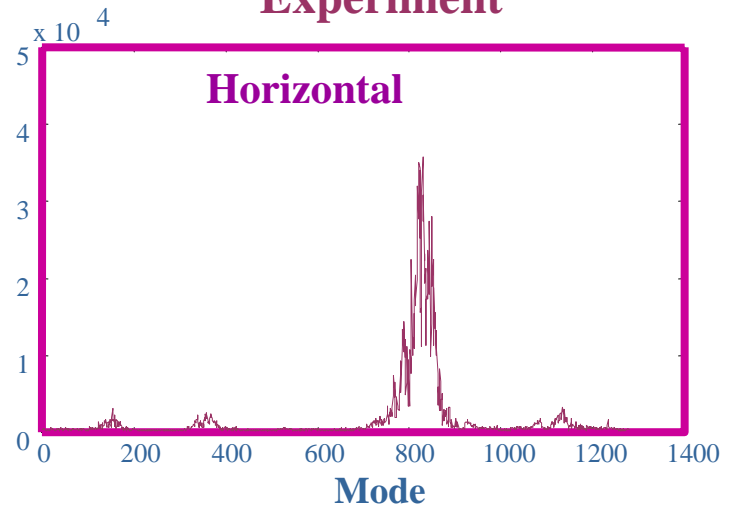
**Photoelectrons are assumed to be produced mainly at the illumination point.
The electron density is 9.38×10^{11} electrons/m³.**

Production at the illumination point & Solenoid-OFF (2)

Simulation



Experiment



- Horizontal mode spectrum shows a broad peak at 200 which is different from the experiment.
- Vertical mode spectrum is similar to the experimental one in shape, but different in the peak locations.

Uniform production of electron & Solenoid-OFF (1)

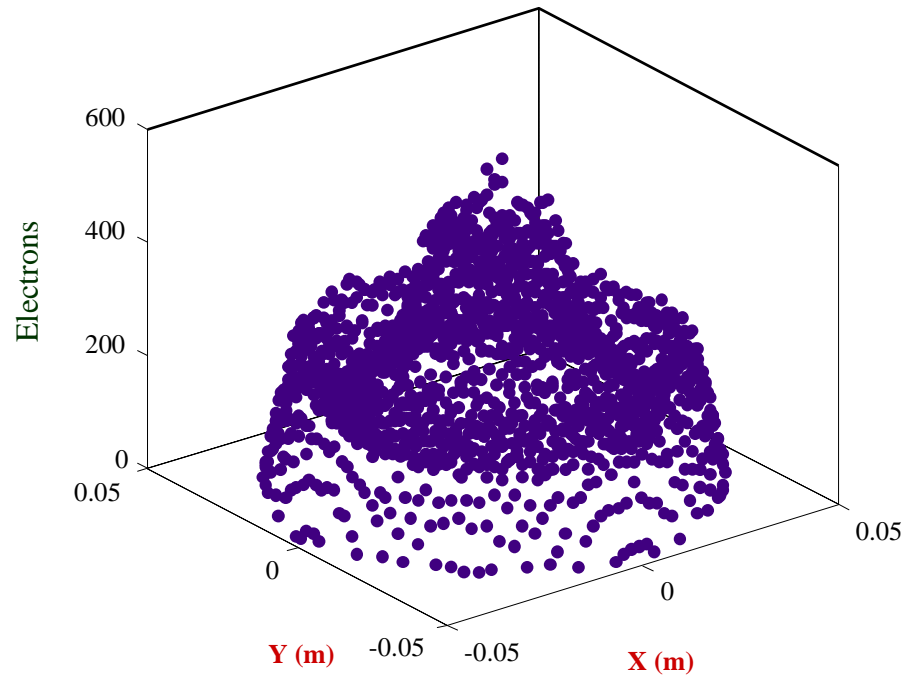
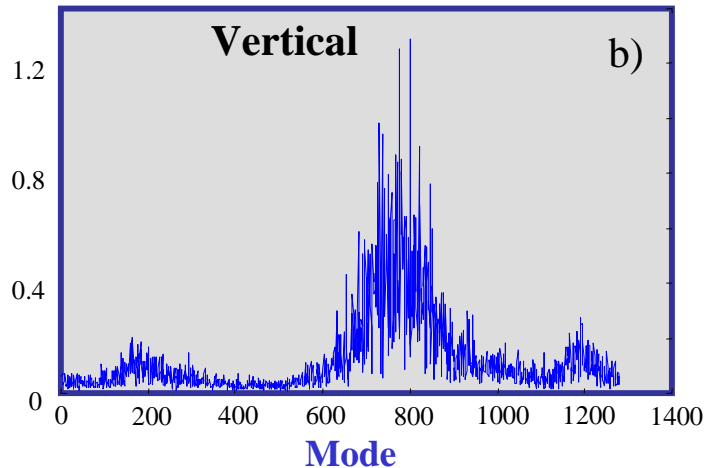
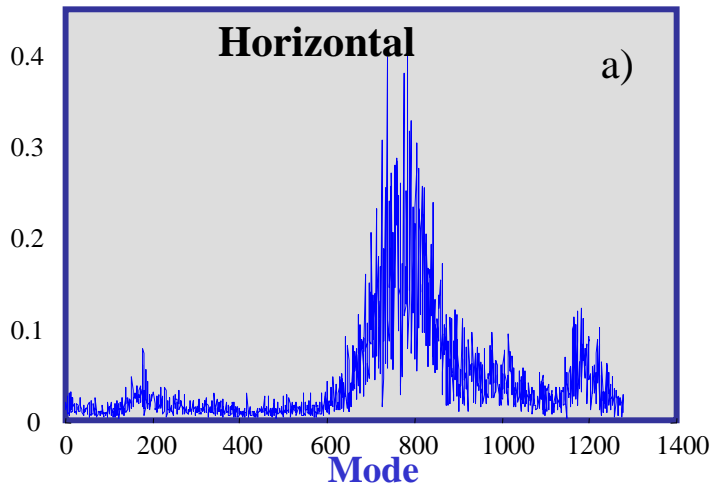


Fig. (a) Electron distribution over the cross section of vacuum chamber

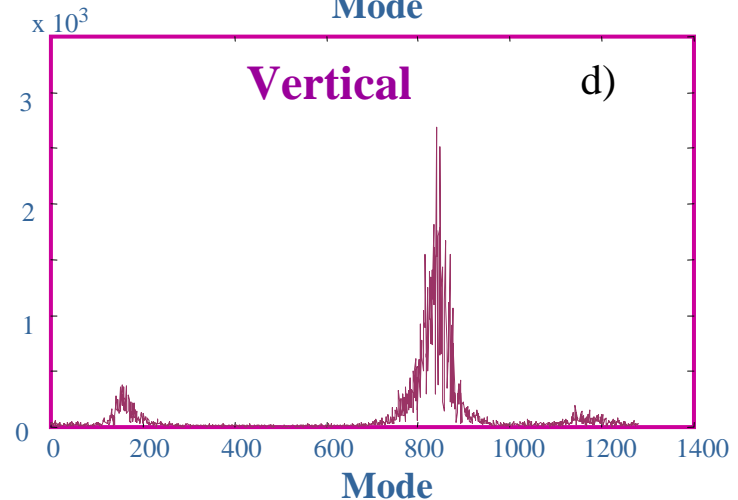
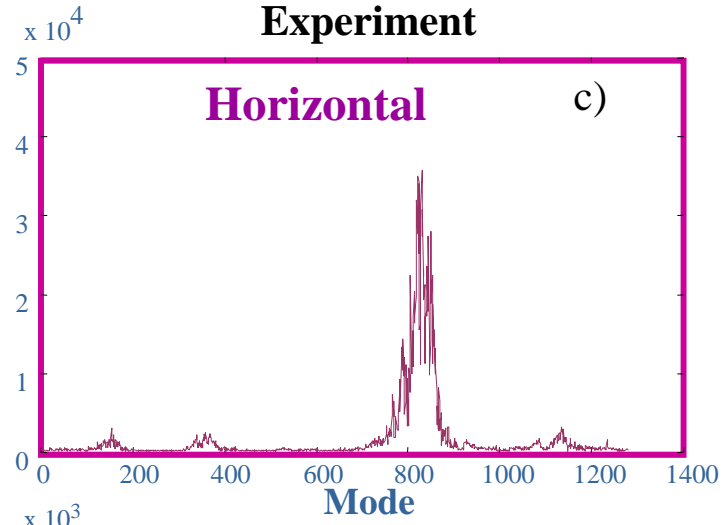
- Electrons are assumed to be produced uniformly over the surface of the vacuum chamber.
- The electron density is 9.38×10^{11} electrons/m³.

Uniform production of electron & Solenoid-OFF (2)

Simulation



Experiment



- Both horizontal and vertical mode spectra are consistent with experiment in terms of the peak locations.
- The shapes are similar to experimental observations, but the width of simulated mode spectra are broader.

Projection of electron density

Production at the illumination point & Solenoid-ON (1)

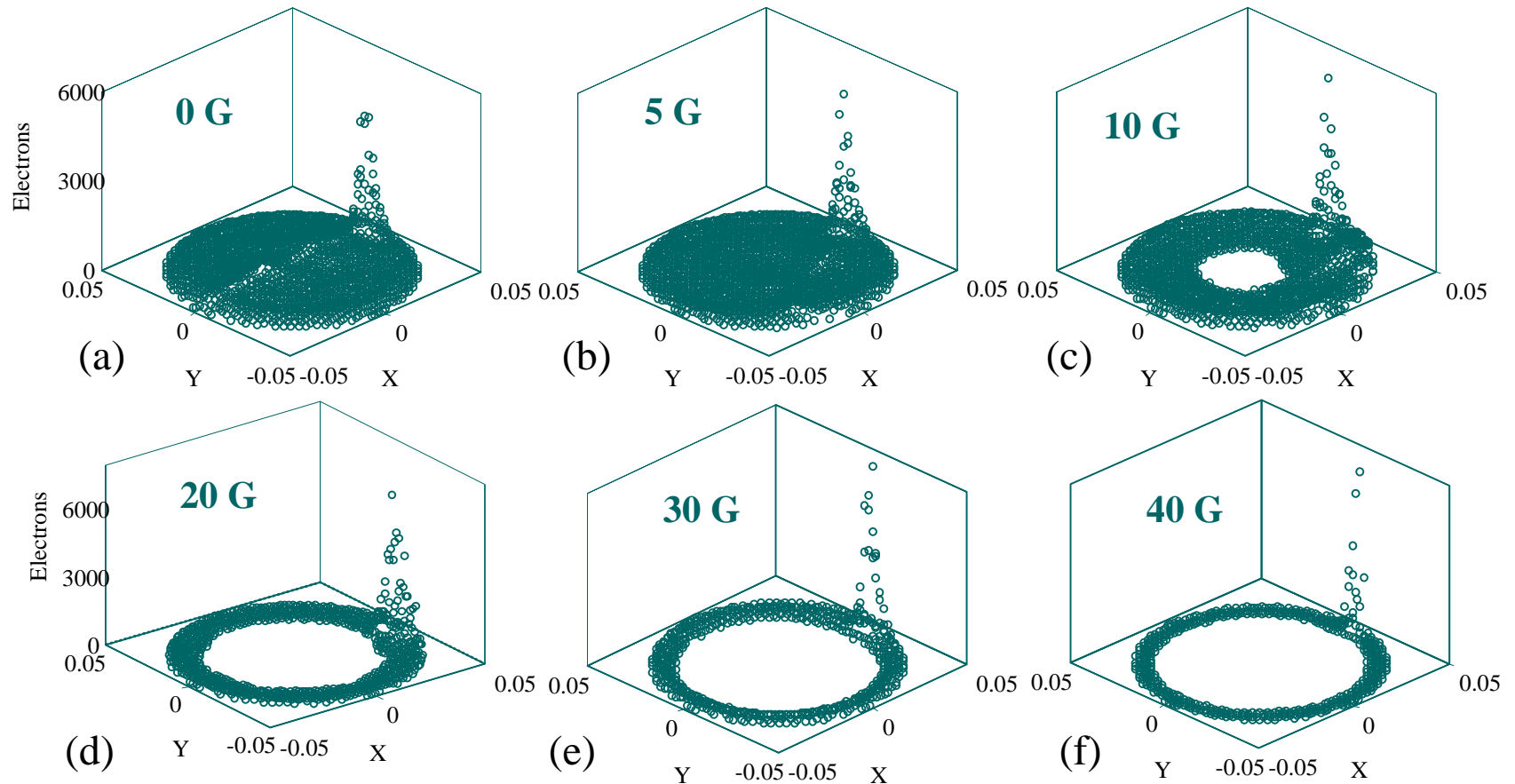
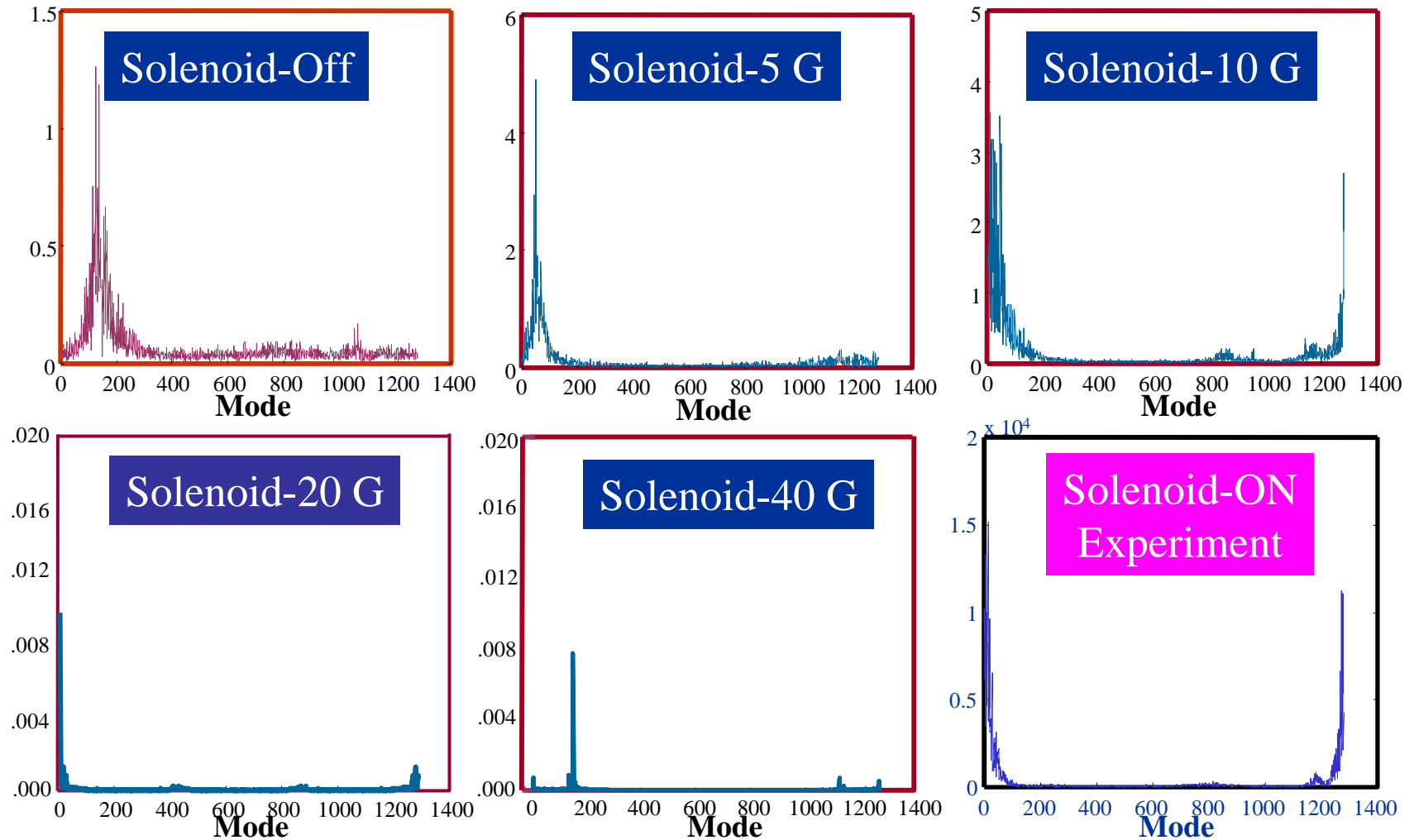


Fig. The projection of electrons over the cross-section of the vacuum chamber due to various solenoid field. (X and Y in m)

- Electron density is more at the illumination point.
- At the center of the beam chamber the electrons are cleared due to the solenoid field.

Production at the illumination point & Solenoid-ON (2)

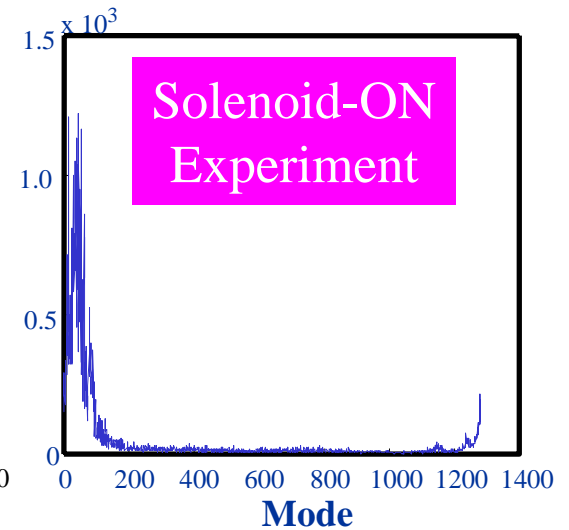
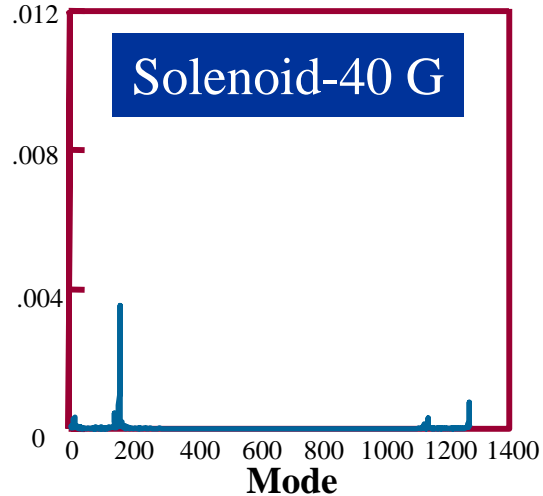
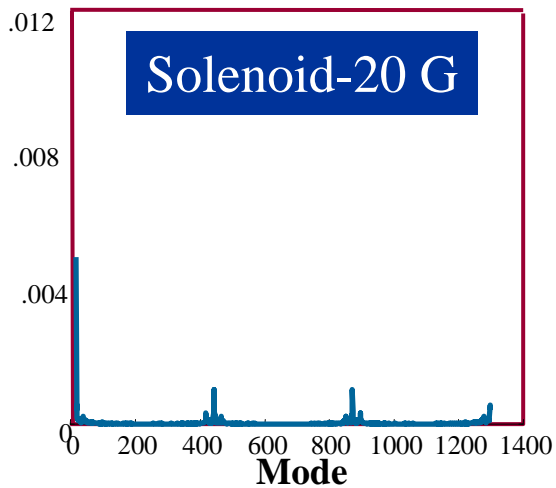
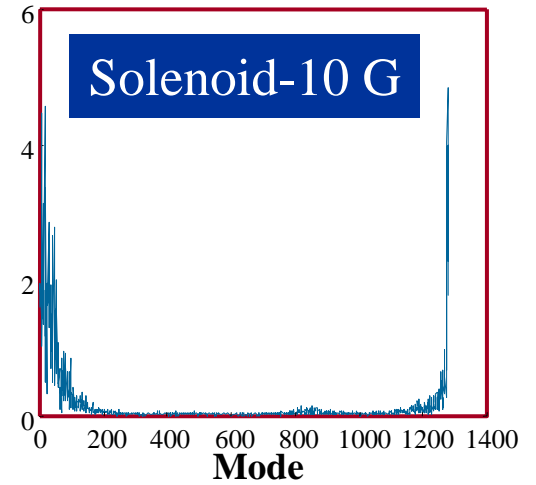
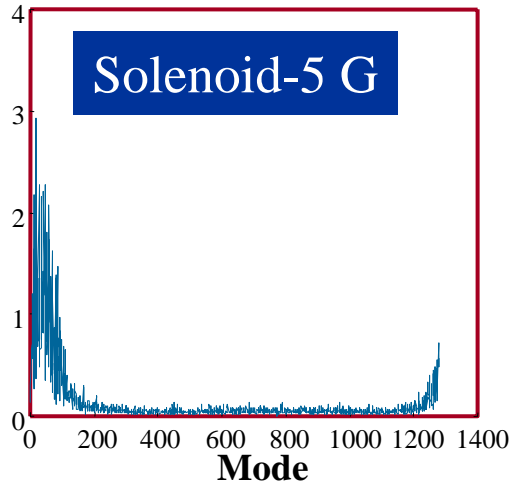
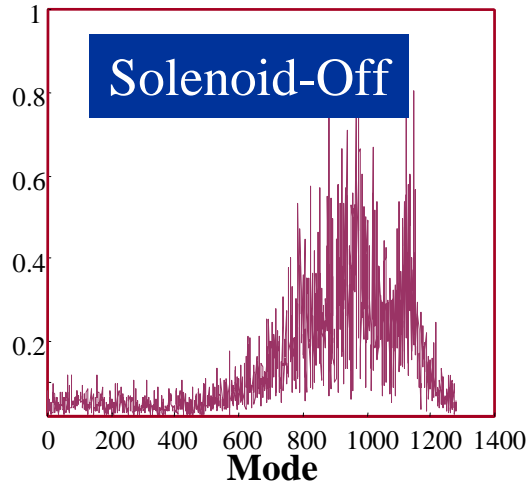
Horizontal



•The mode spectrum due to 10 ~ 20 G solenoid field is consistent with the experimental observation.

Production at the illumination point & Solenoid-ON (3)

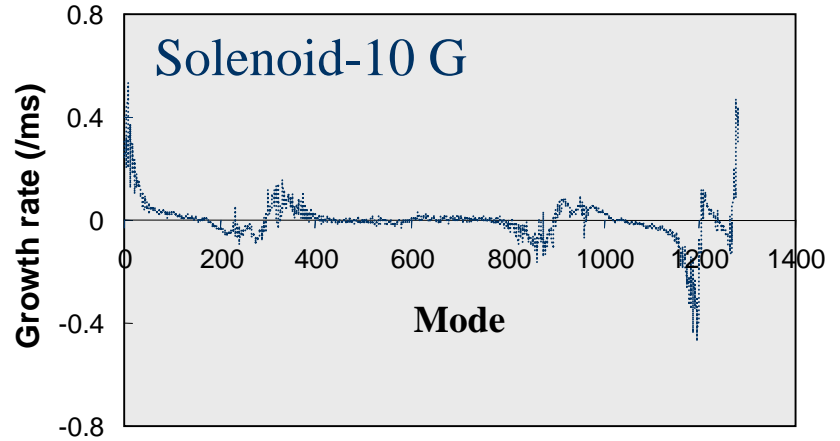
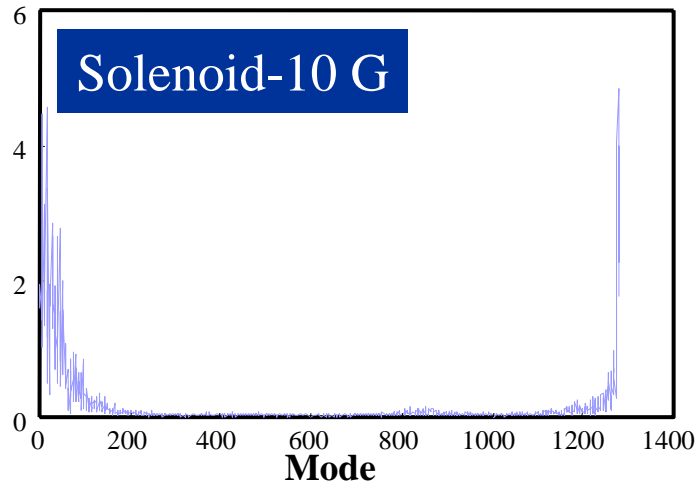
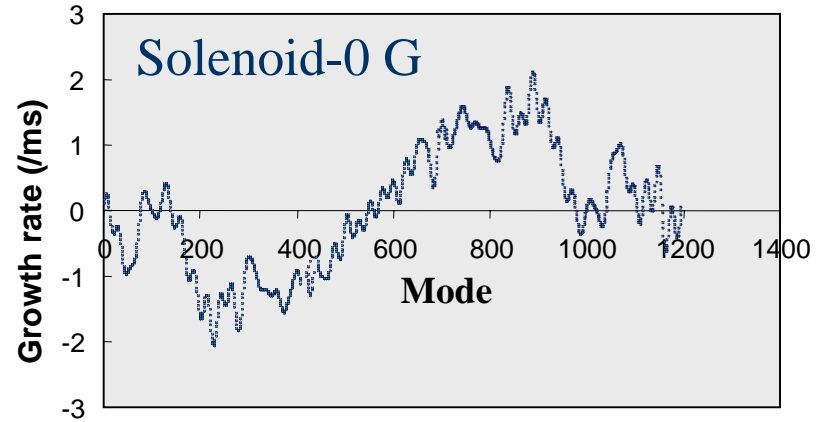
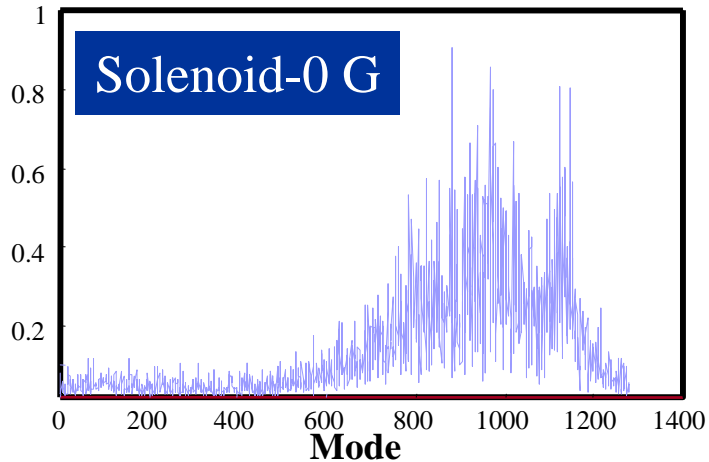
Vertical



•The mode spectrum due to 5 ~10 G solenoid field is consistent with the experimental observation.

Production at the illumination point

- The mode spectra calculated from particle tracking are compared with those by the wake force.
- Both gave similar mode spectra.



By particle tracking

By wake

Uniform production of electron & Solenoid-ON (1)

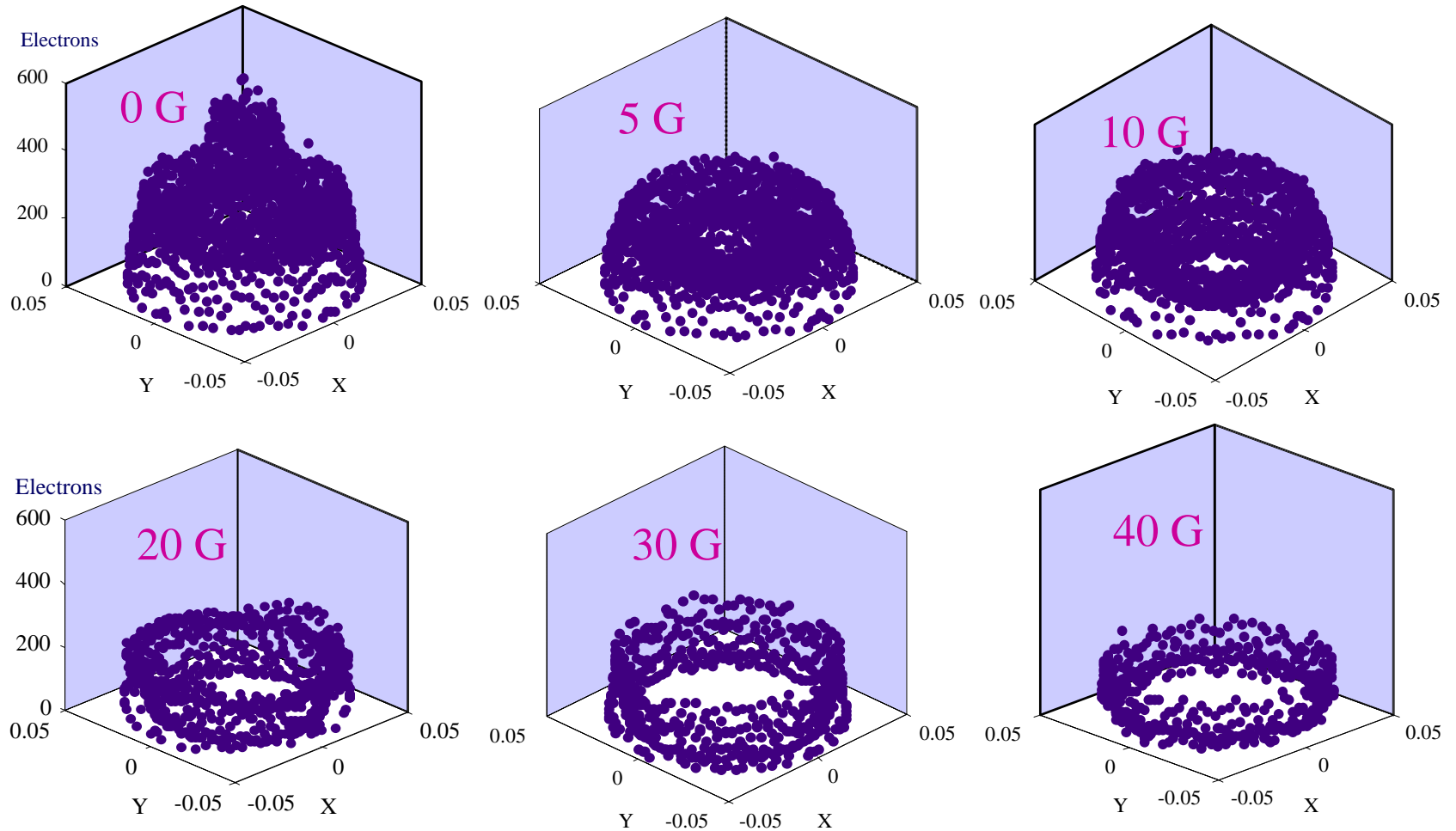
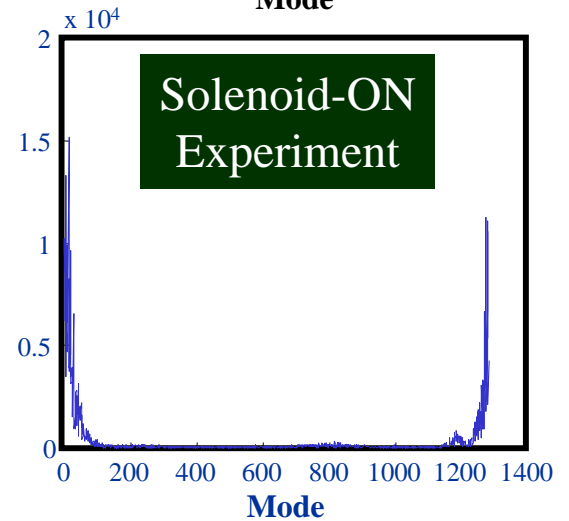
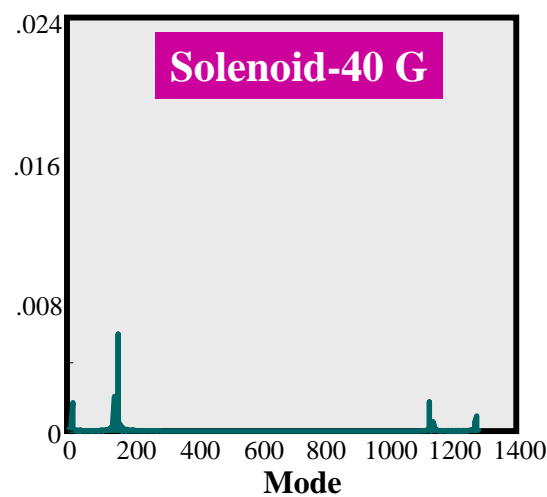
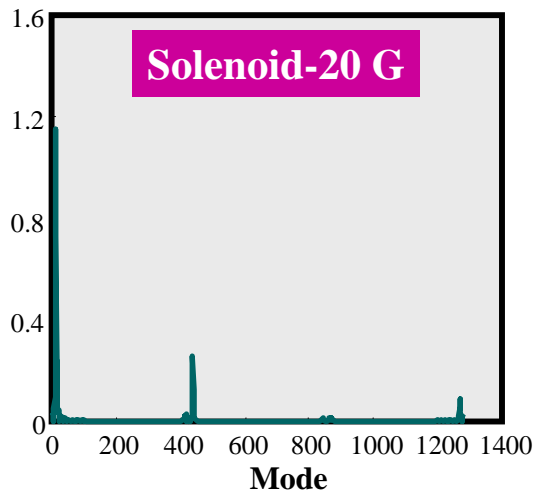
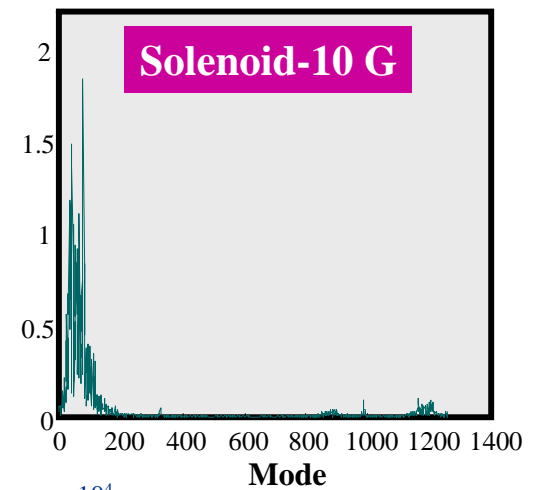
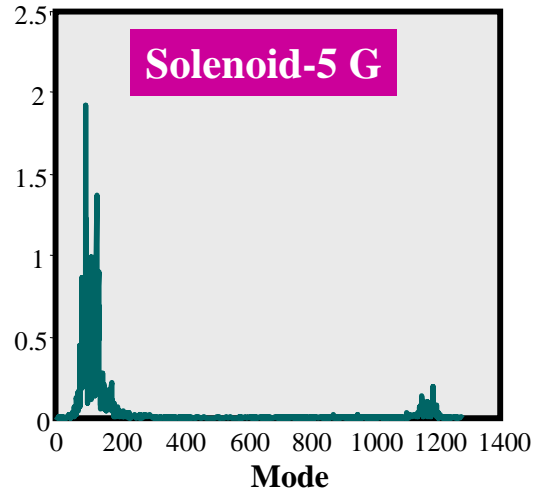
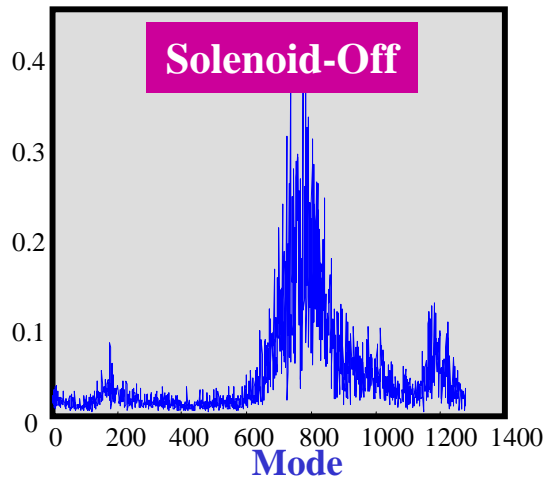


Fig. The projection of electrons over the cross-section of the vacuum chamber due to various solenoid field. (X and Y in m)

Uniform production of electron & Solenoid-ON (2)

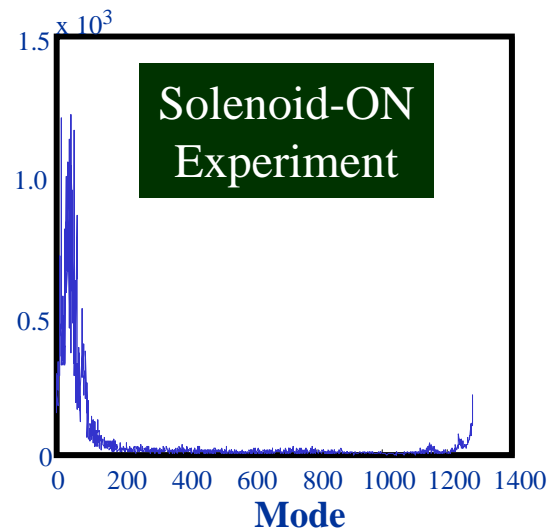
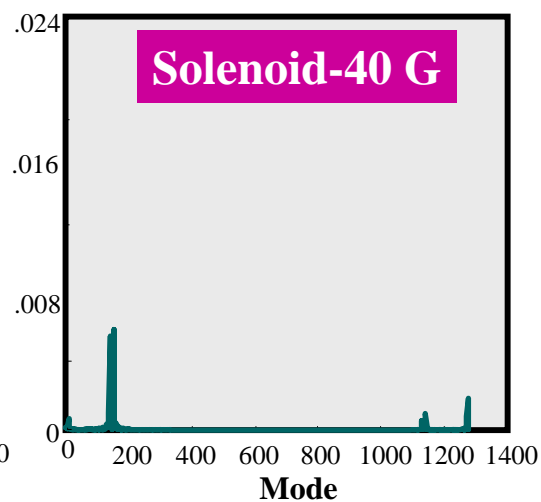
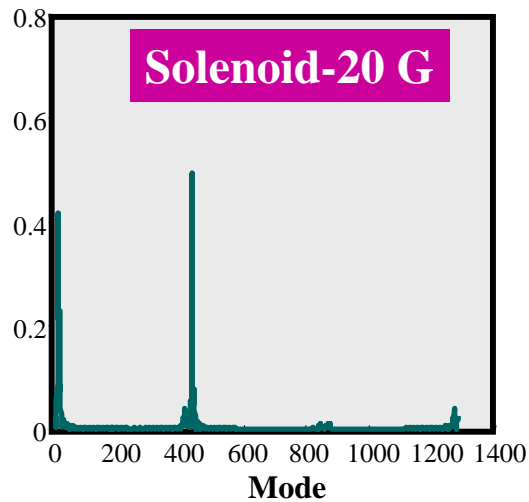
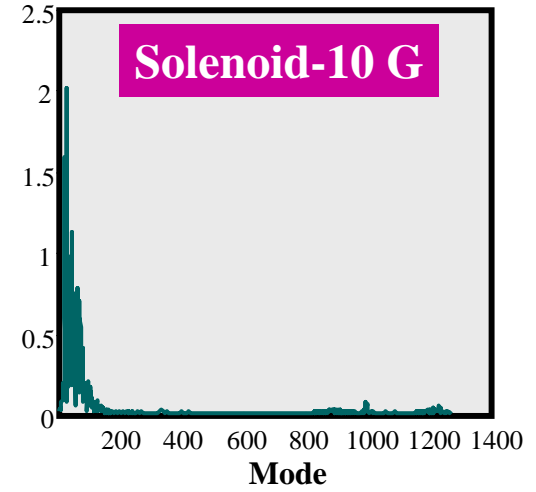
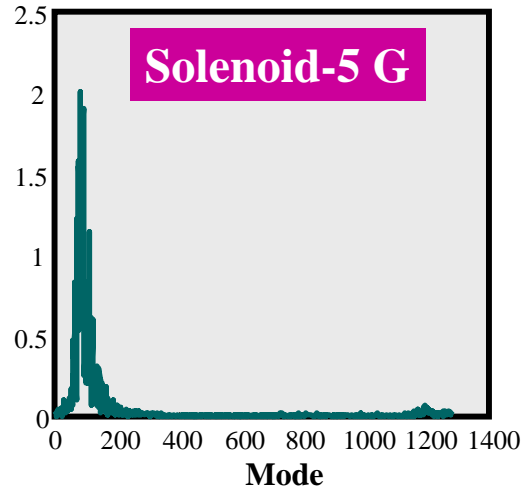
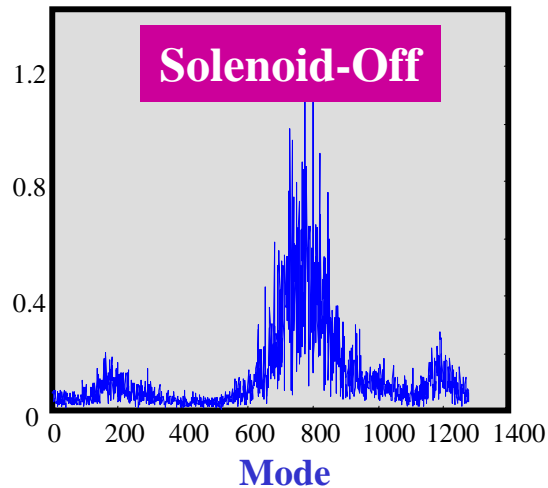
Horizontal



•The mode spectrum due to 10 G solenoid field is consistent with the experimental observation.

Uniform production of electron & Solenoid-ON (3)

Vertical



•The mode spectrum due to 10 G solenoid field is consistent with the experimental observation.

Growth rate of instability

→ **The growth rates** are calculated using wake force in simulation.

Solenoid-off

	<u>Horizontal (/ms)</u>	<u>Vertical (/ms)</u>
Illumination dominant	1.78	2.08
Uniform production	1.56	1.85
Experimental	2.0	1.33

Solenoid-on^a

0 G	1.78	2.08
5 G	0.96	0.75
10 G	0.53	0.46
20 G	0.33	0.25
Experimental (Dec'01)	0.49	0.26

a. Assuming that the photoelectrons are mainly produced at the illumination point and 30% produced uniformly over the chamber surface.

Growth rates by simulation

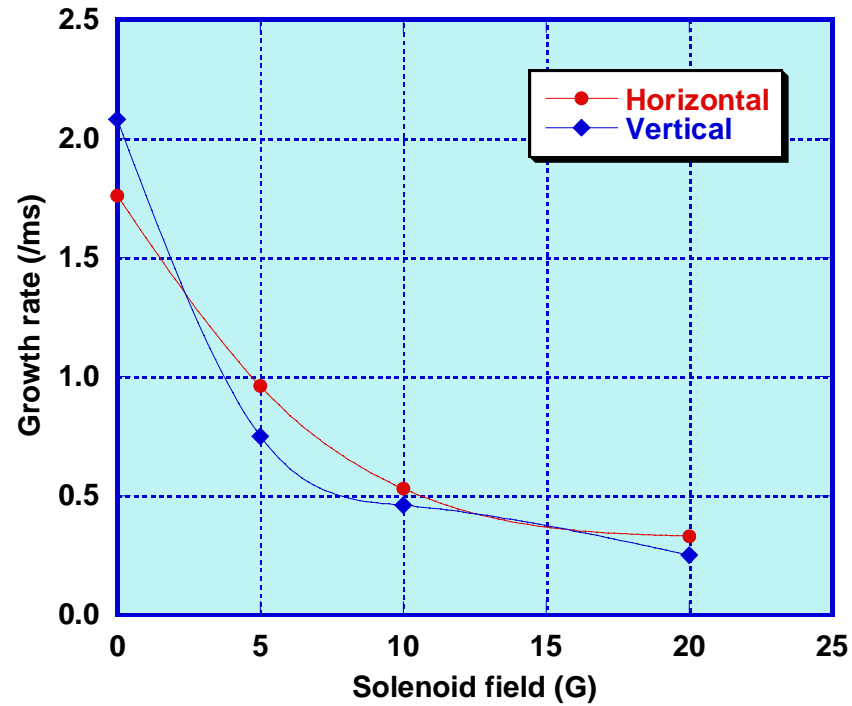


Fig. The simulation results of the growth rates due to solenoid field

Summary

From experimental studies

○ Mode spectra

Solenoid-off:

Horizontal and vertical mode spectra are similar.

Solenoid-on:

Horizontal and vertical mode spectra are similar.

Compared to solenoid-off, the mode spectra change due to the solenoids.

○ Growth rates

Solenoid-off:

The growth rates without solenoid field are 2.0/ms horizontally and 1.34/ms vertically.

Solenoid-on:

Horizontal growth rate decreases to 25% and vertical growth rate to 20% due to solenoid-on.

From the simulation studies

◆ Mode spectra

Solenoid-off:

- ❖ Assuming that *the photoelectrons are mainly produced at the illumination point and 30% produced uniformly over the chamber surface,*
 - ✓ Horizontal mode spectrum is inconsistent with the experimental observation.
 - ✓ Vertical mode spectrum is similar to the experimental observation in shape, but different in the peak positions.
- ❖ Assuming that *the photoelectrons are only produced uniformly over the surface of the vacuum chamber,*
 - ✓ Horizontal and vertical mode spectra are consistent with the experimental observations.

Solenoid-on:

- ✓ Assuming 5~10 G solenoid field, horizontal and vertical mode spectra reproduce the experimental data.

◆ **Growth rates**

solenoid-off

- ❖ **Compared to the experimentally observed growth rates, the horizontal growth rate is 11% lower and vertical growth rate is as twice as higher.**

solenoid-on

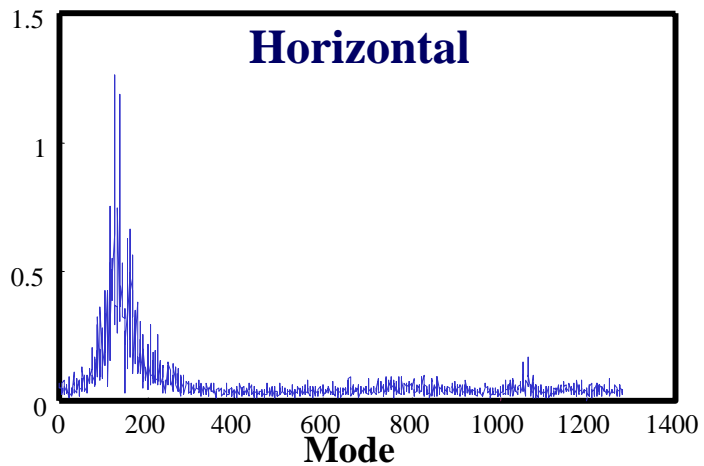
- ❖ **The horizontal and vertical growth rates obtained by simulation applying 10~20 G solenoid field are the same as experimental growth rates.**

◆ **Simulation suggests**

- ✧ **Uniform production of electrons over the surface of vacuum chamber and**
- ✧ **Effective solenoid field of 5~20 G.**

$E_{\text{thsec}}=200 \text{ eV}, \delta_{\text{max}}=1.0$

Simulation



$E_{\text{thsec}}=300 \text{ eV}, \delta_{\text{max}}=1.5$

Simulation

