Energy Spectrum of Electron Cloud with Short Bunch

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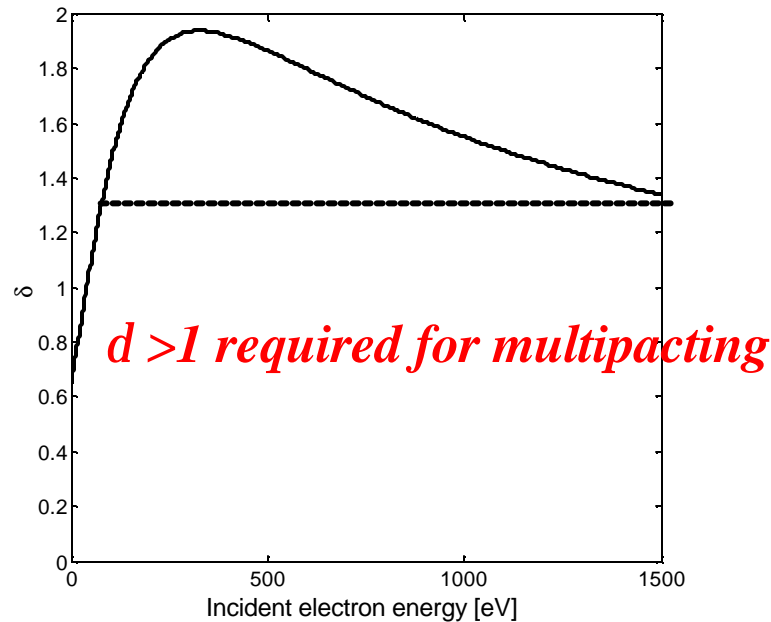*H. Fukuma (KEK, Tsukuba, Japan)*

> ➢ *Motivation*
>
> ➢ *Introduction*
>
> ➢ *Stopband phenomenon of energy spectrum*
>
> ➢ *Parameters related to energy spectrum*
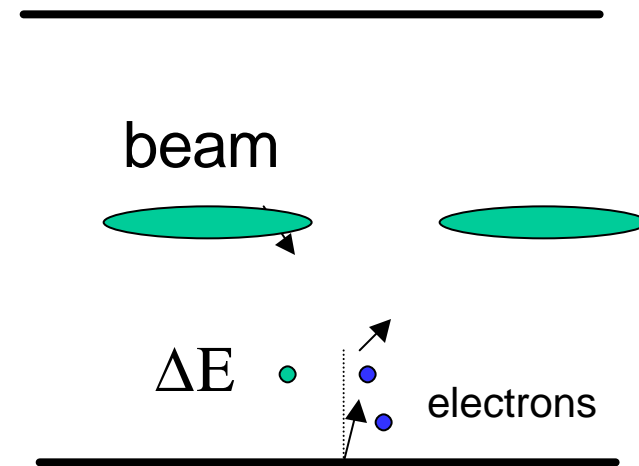>
> ➢ *Conclusion*

Motivation

➢ **To understand electron multipacting**

➢ **To understand the measurement of electron energy**

Introduction--I

Secondary emission yield

Beam driven multipacting

d >1 required for multipacting

beam

ΔE

electrons

Key parameters for Multipacting (Strong energy and SEY dependence)

➢Beam-electron interaction dependence (beam pattern, bunch current, bunch shape, bunch length, chamber size…)

Introduction--II

ANALYSIS of electron energy spectra:

➢ **J. Scott Berg, Energy gain in an electron cloud during the passage of a bunch, LHC Project Note 97**

➢ **S. Heifets, Qualitative Analysis of the Electron cloud Formation, SLAC-PUB-9105, 2002**

➢ **….**

SIMULATION of electron energy spectra:

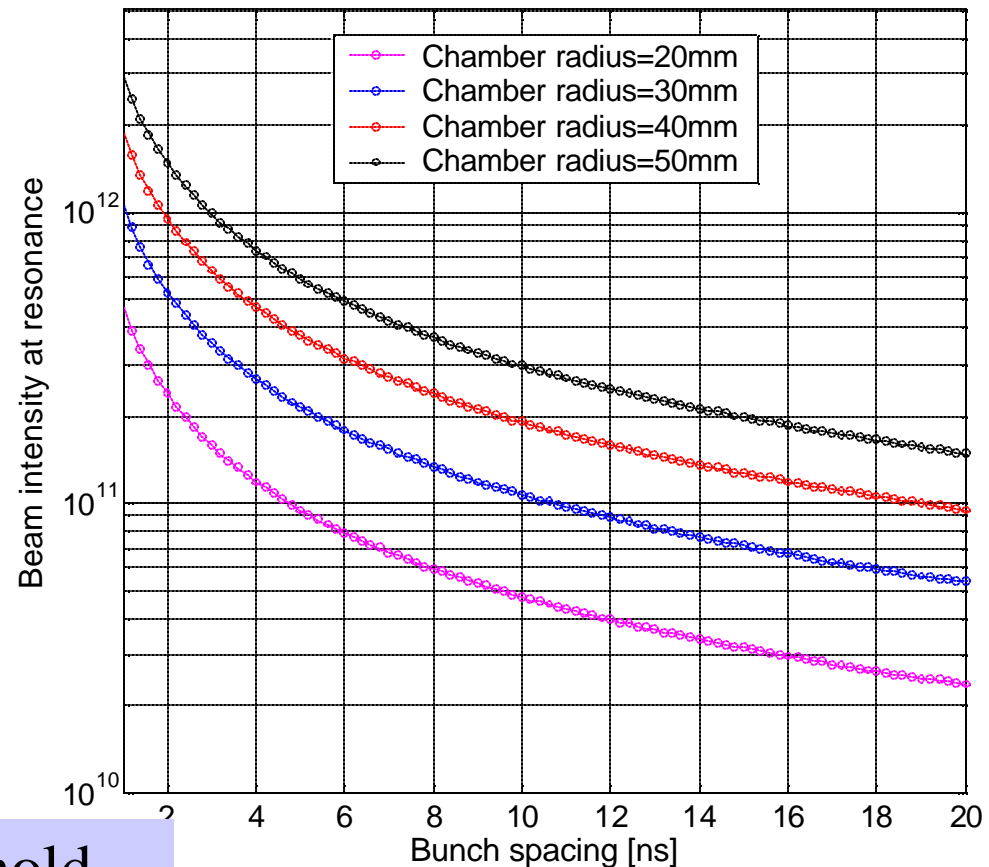➢ **A. Arauzo and F. Zimmermann, Electron cloud energy and angular distribution, CERN-SL-Note-2000-057 AP**

➢ **….**

**Resonance/Multipacting condition:**

$$N_{th} = \frac{R^2}{r_e c t_{sp}}$$

Most machines (B-factories, LHC, SPS) run with beam intensity below multipacting!

RHIC runs above the threshold

# Strong dependence of e's motion on initial condition

Multipacting with short bunch is different from the regular multipacting. The orbit and energy of electron vary randomly according to its initial condition (has a spread) and beam, chamber geometry. In general, it is a random multipacting.
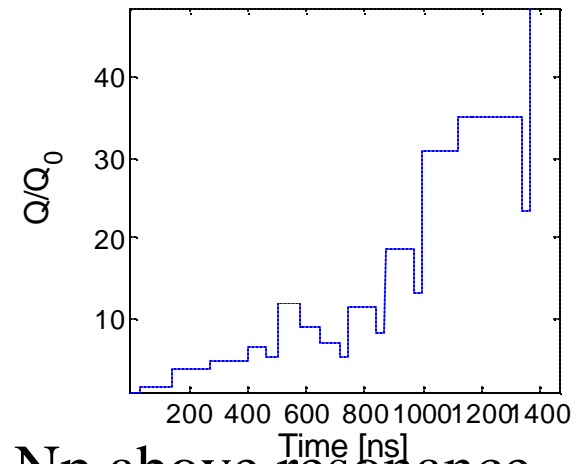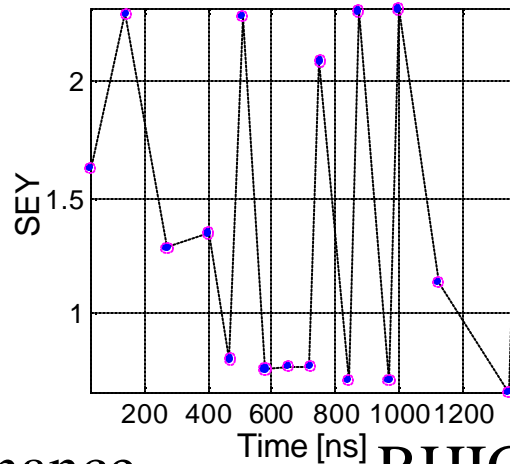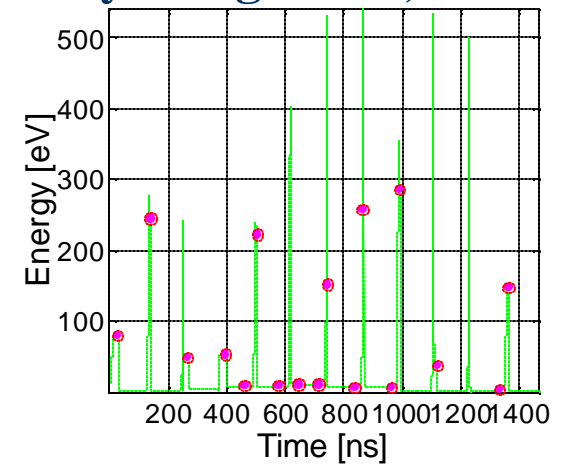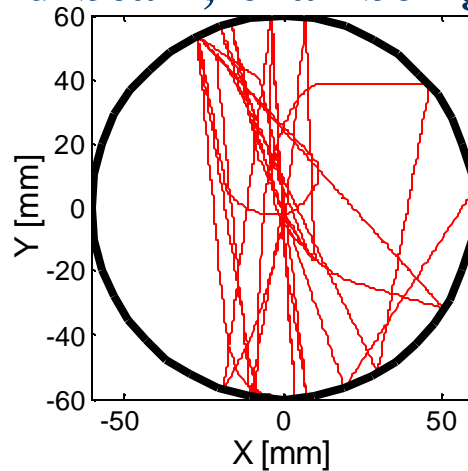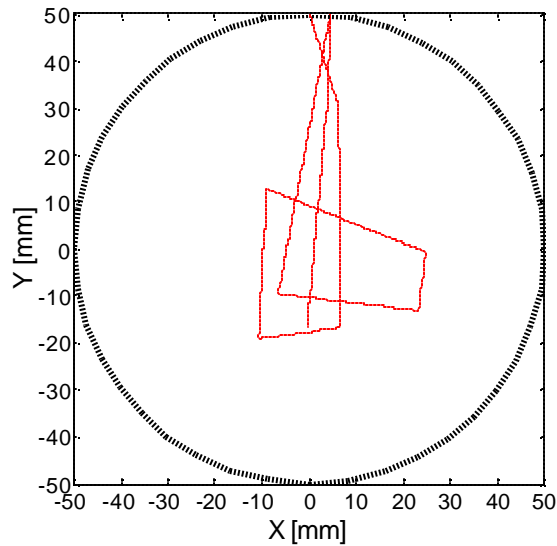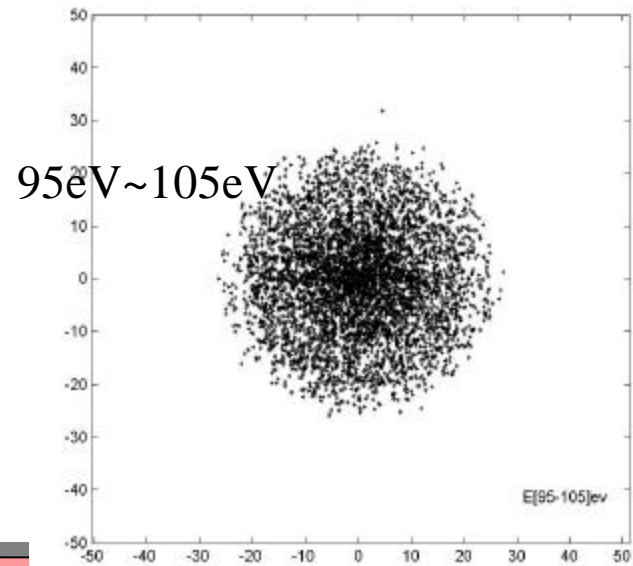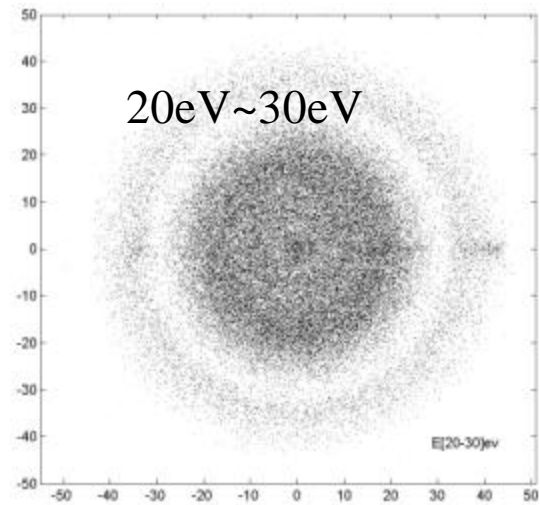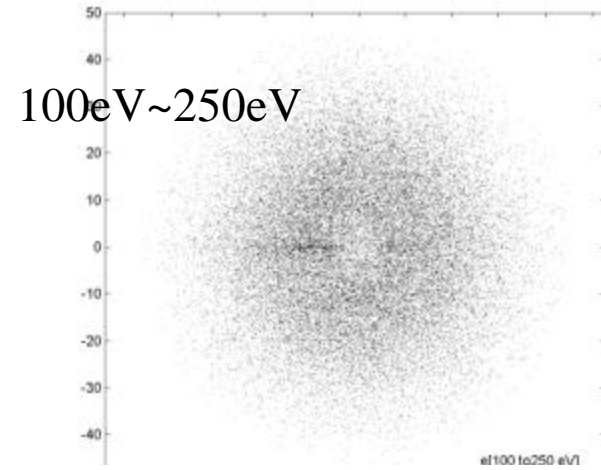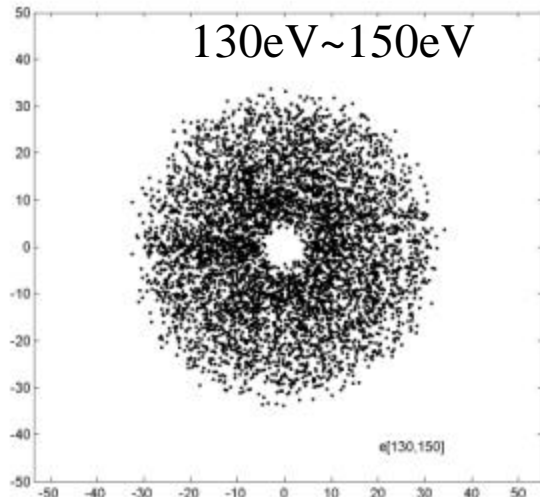

KEKB Np Below resonance

RHIC, Np above resonance

Stopband phenomenon of energy spectra
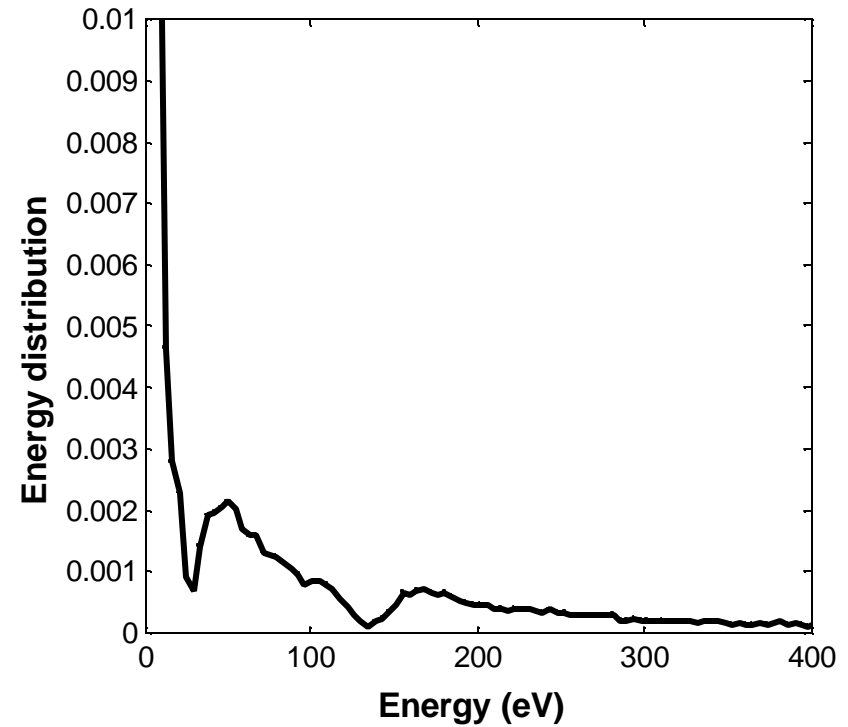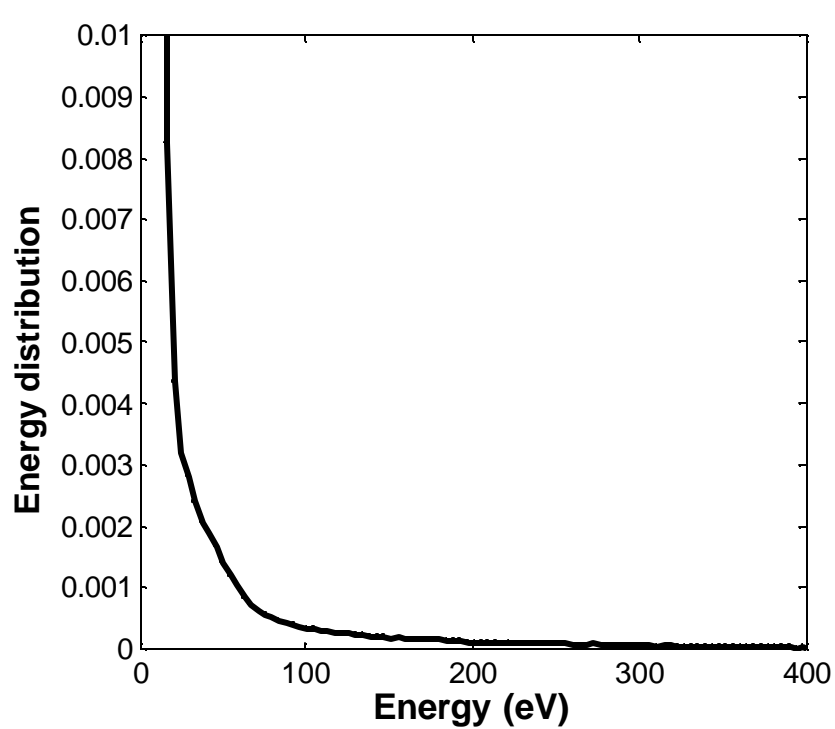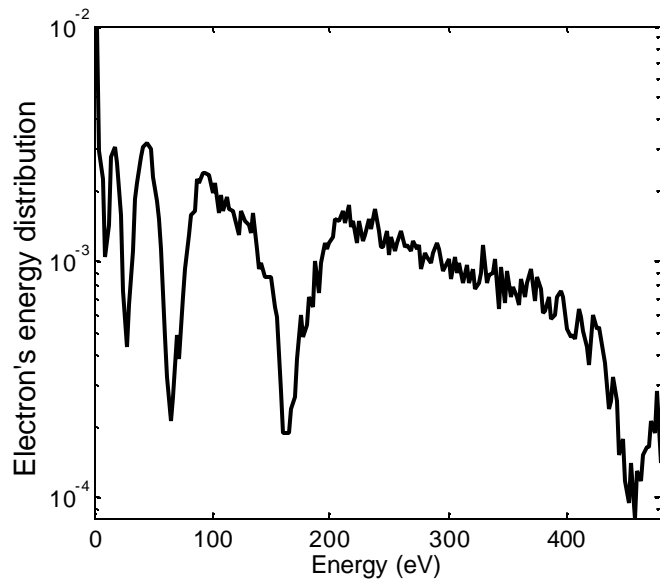

(Left: Live cloud, Right: loss cloud)

**Energy distribution in drift region**(4 bunch spacing=8ns)

Electron distribution with certain energy range

130eV~150eV

100eV~250eV

20eV~30eV

95eV~105eV

Mechanism of the stopband
## in energy spectrum of loss electrons

- *It is the effects of multiple passages of the positron bunches.*
- The number of stopband, *M*, equal the number of passing bunches during one electron reaches the chamber center.
- *The n-th stopband occurs when the electron of that particular energy is swept out by the (2M-n)_th bunch following the birth of that electron.*
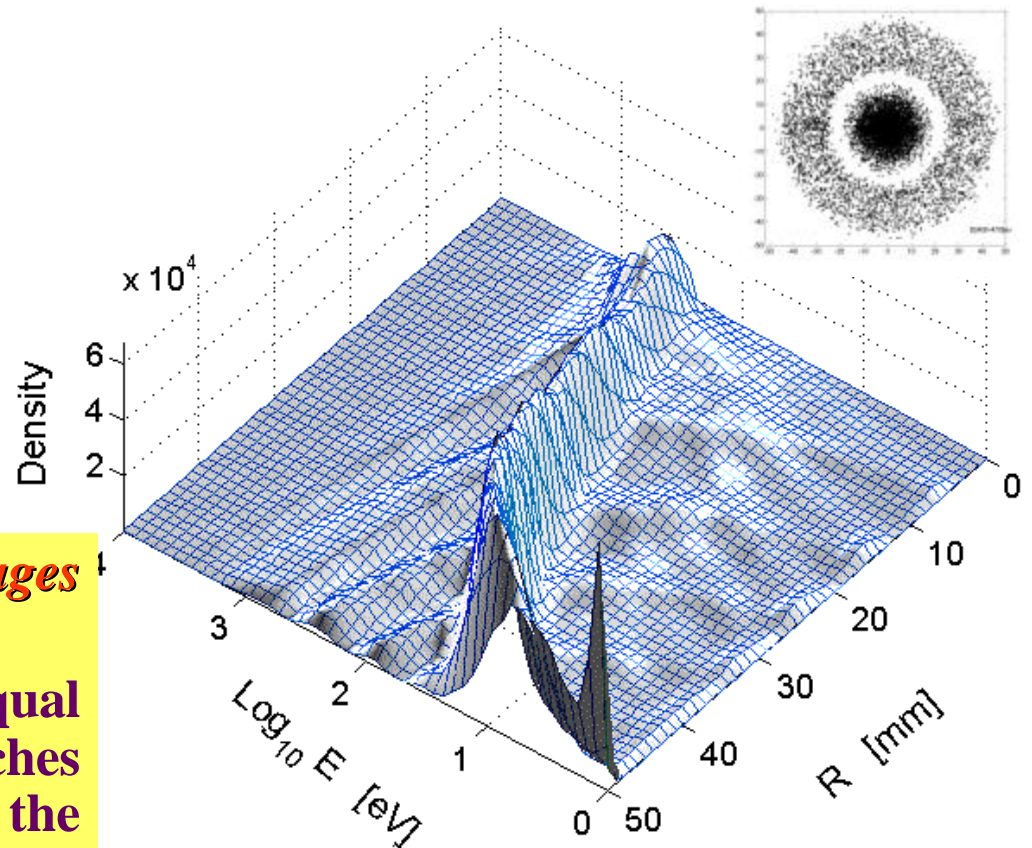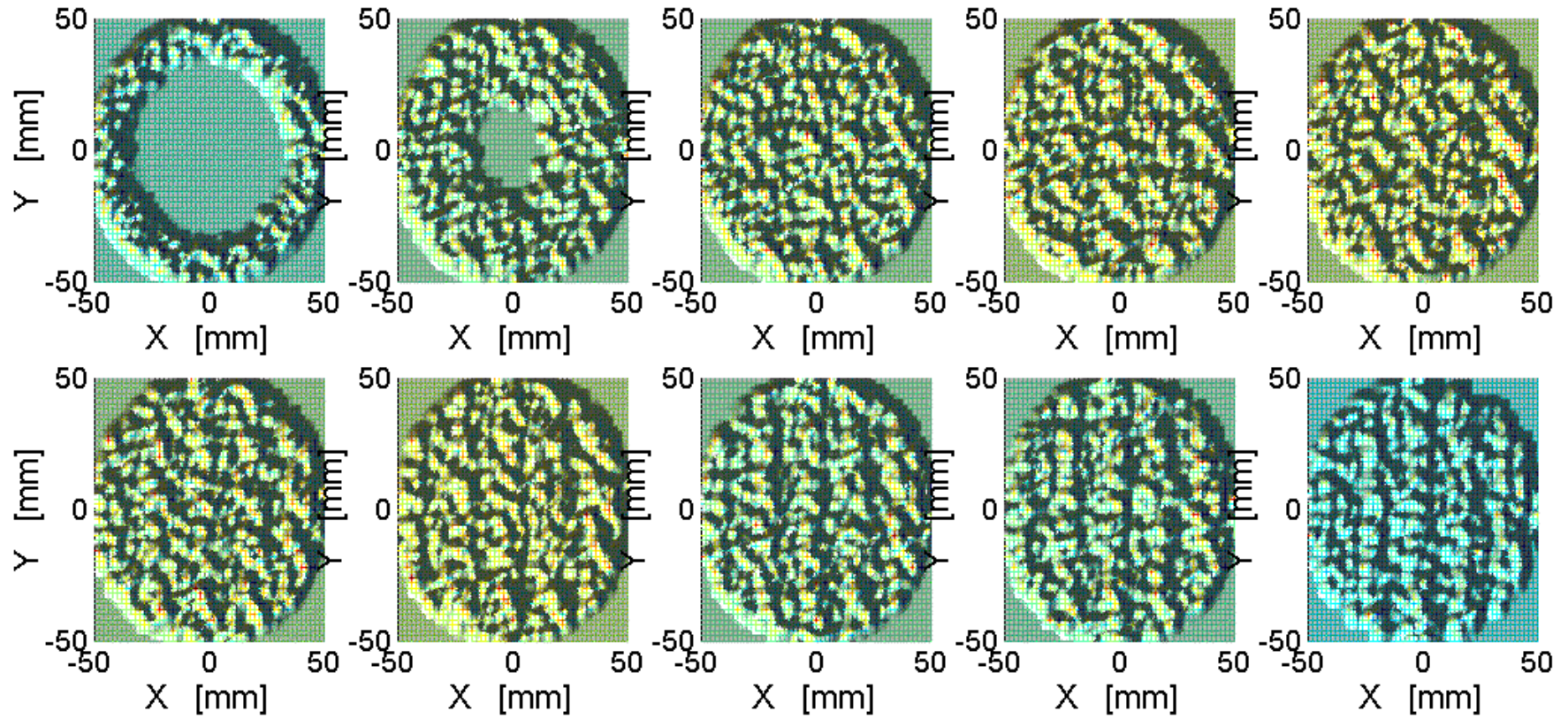
Energy structure of electron inside chamber (2ns spacing)
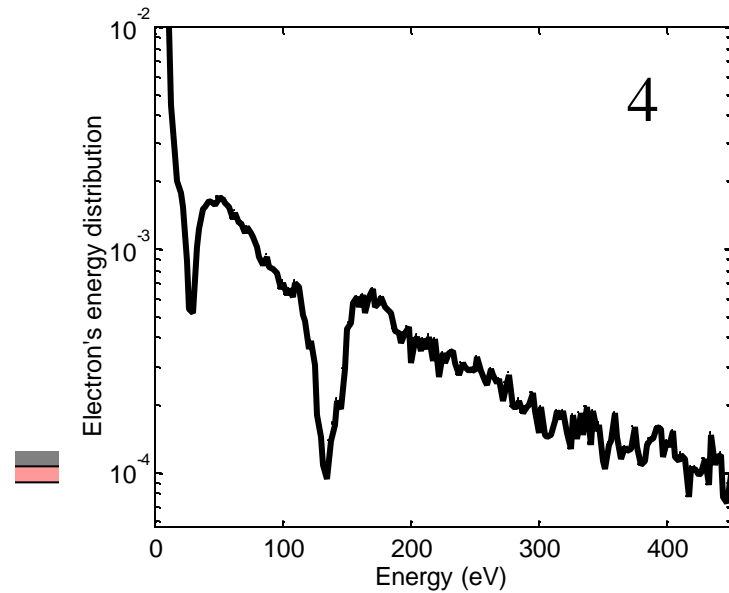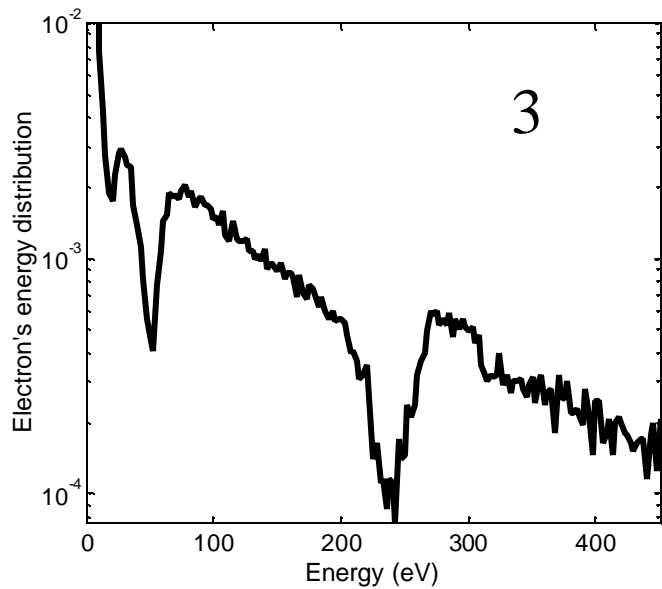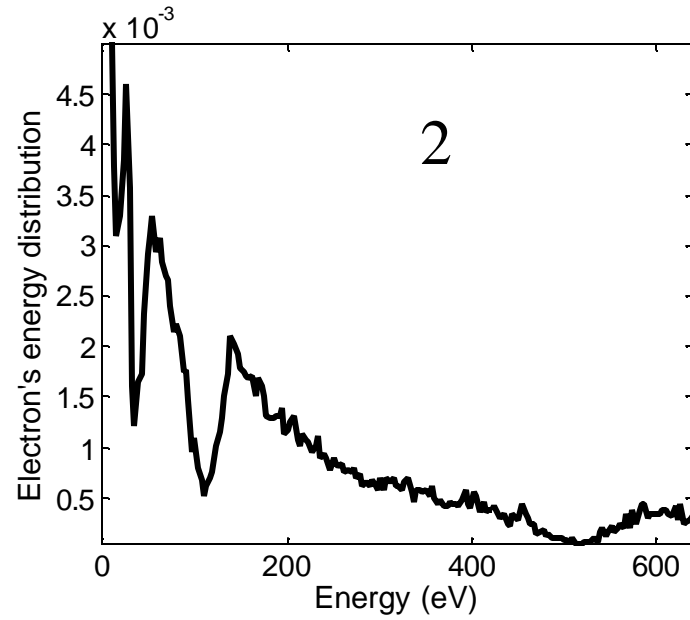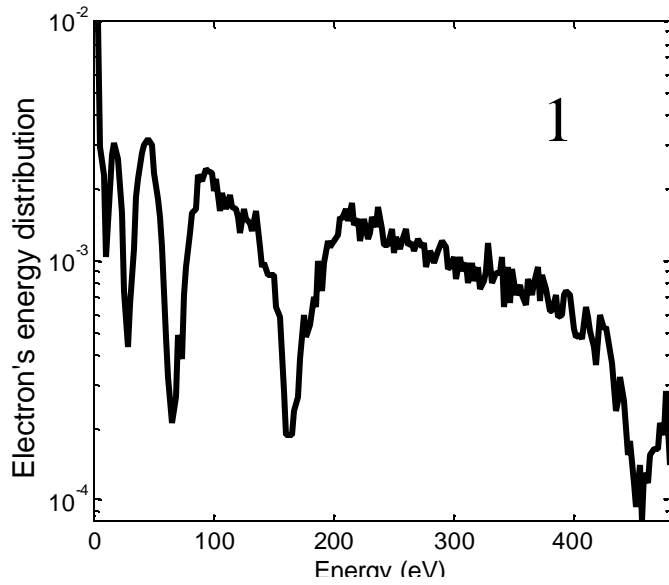
Snapshot of electron cloud-I
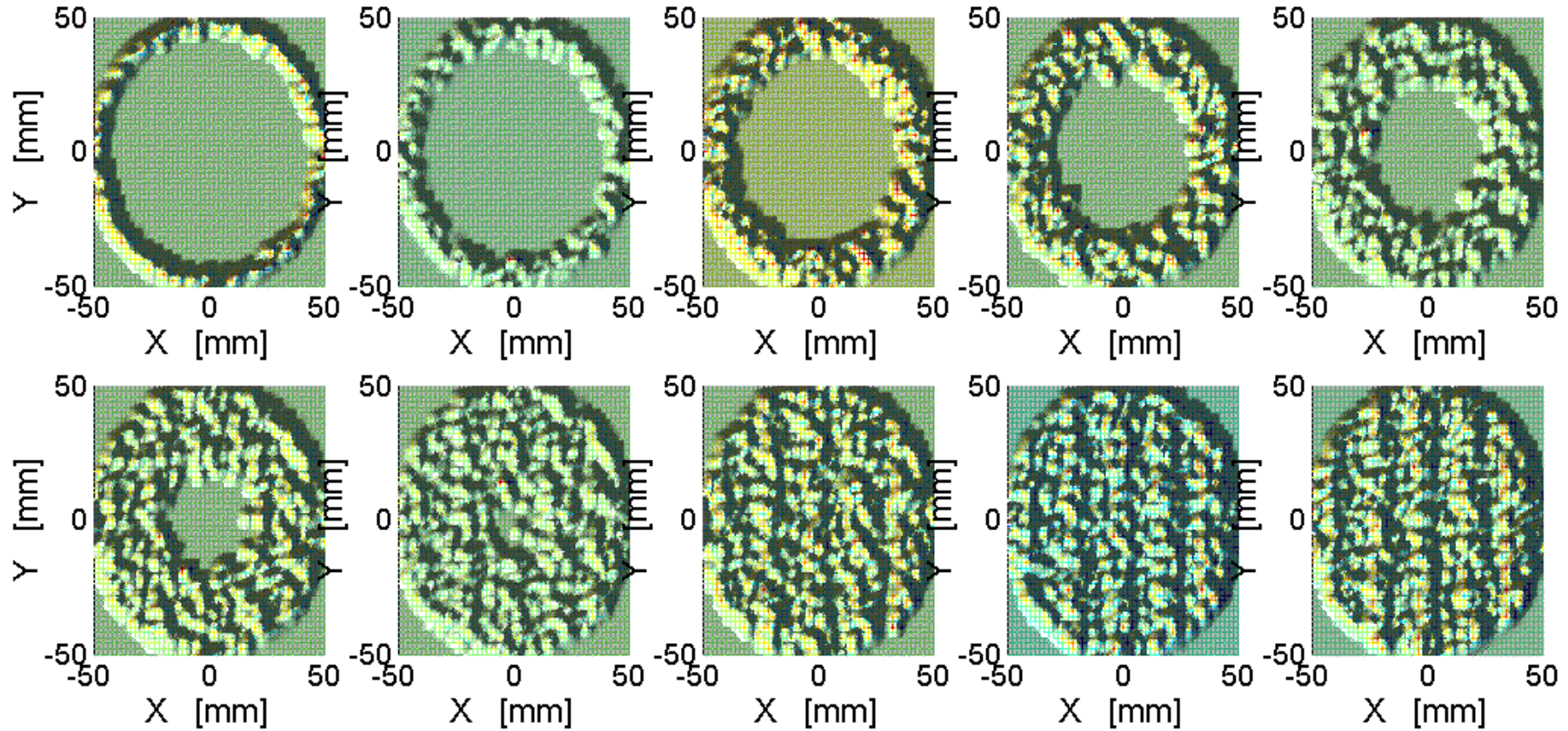
Bunch spacing=2ns=DT

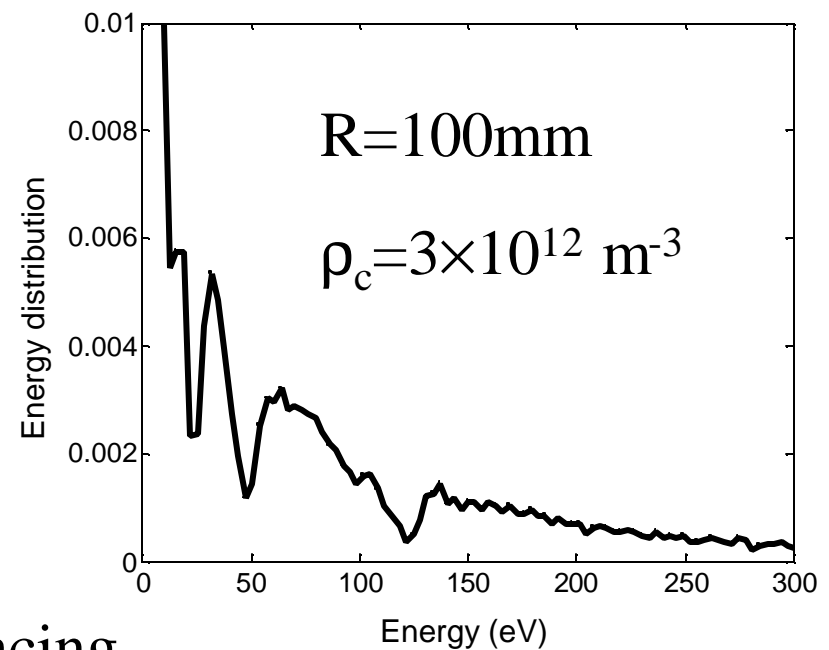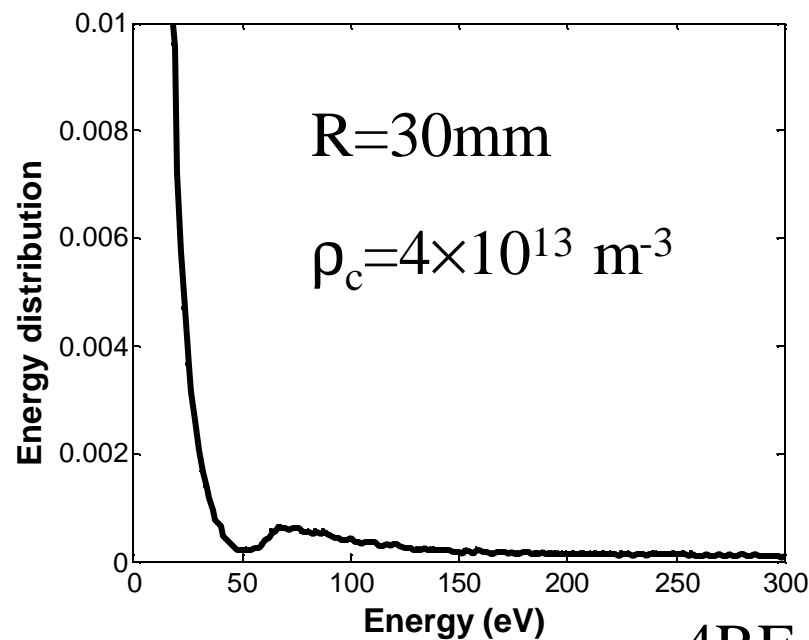# Snapshot of electron cloud-II

Bunch spacing=8ns=DT

Bunch spacing

Chamber radius

➤ **For larger chamber size, there is more stopband due to longer drifting time for electron to cross the chamber**

➤ **Larger chamber size, lower electron density.**

➤ **Larger chamber size, more high energy electrons**
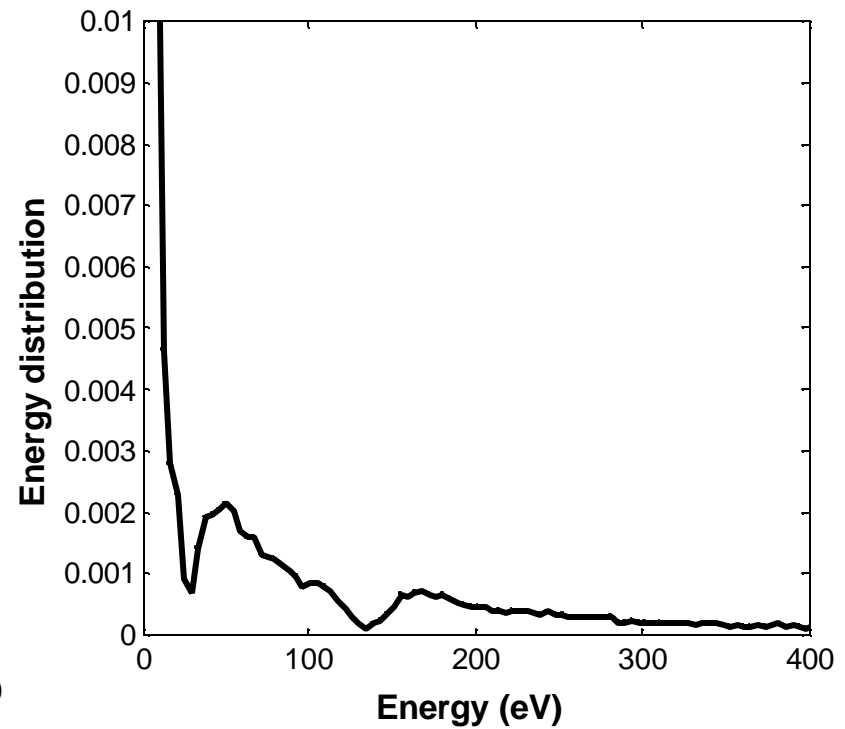

R=30mm

$\rho_c=4\times10^{13}$ m^{-3}

R=100mm

$\rho_c=3\times10^{12}$ m^{-3}

4RF spacing

Bunch length

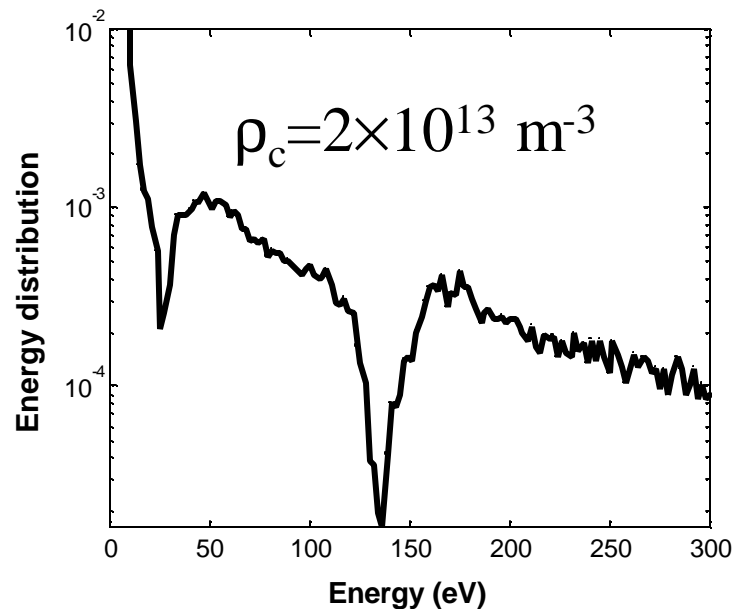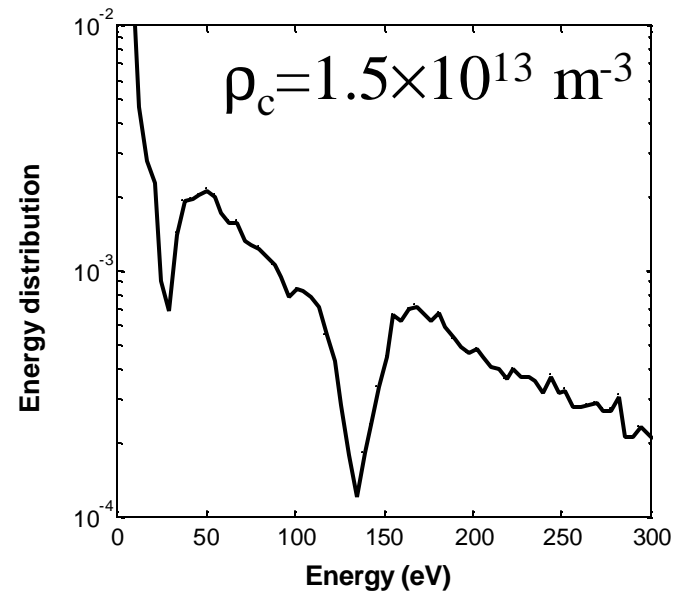➢ **Both energy spectrum and electron density are very similar for 5mm and 15mm bunch length**
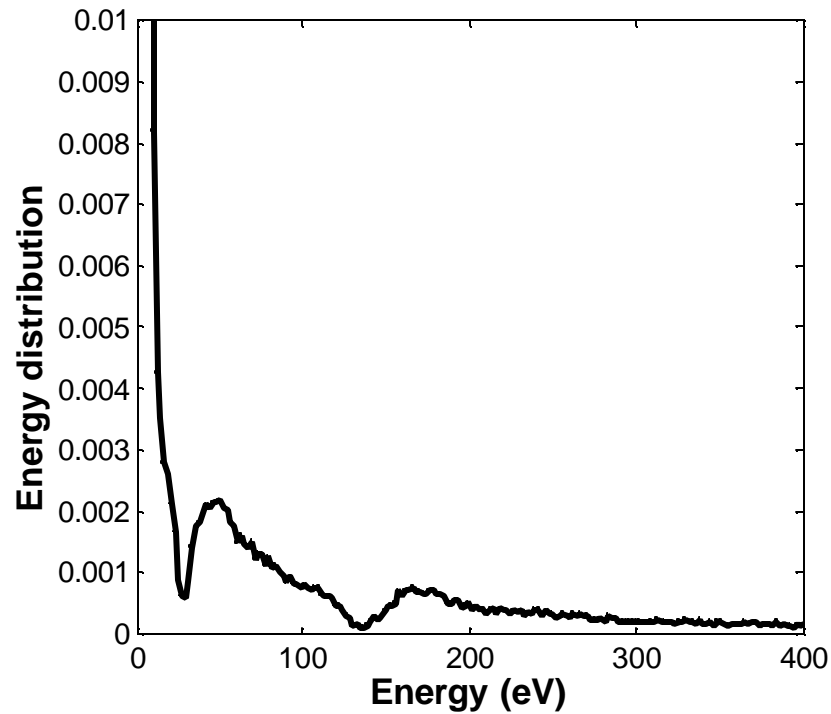
Sigma=15mm

Sigma=5mm

Secondary emission parameters

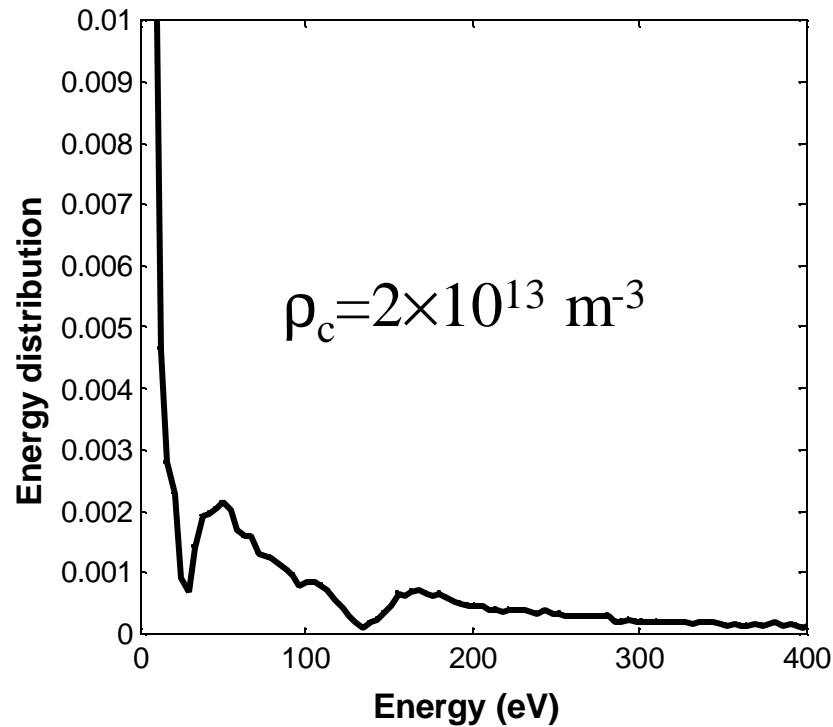- The location of **stopband** is independent of the secondary emission parameter.

$\rho_c = 2 \times 10^{13}$ m^{-3}

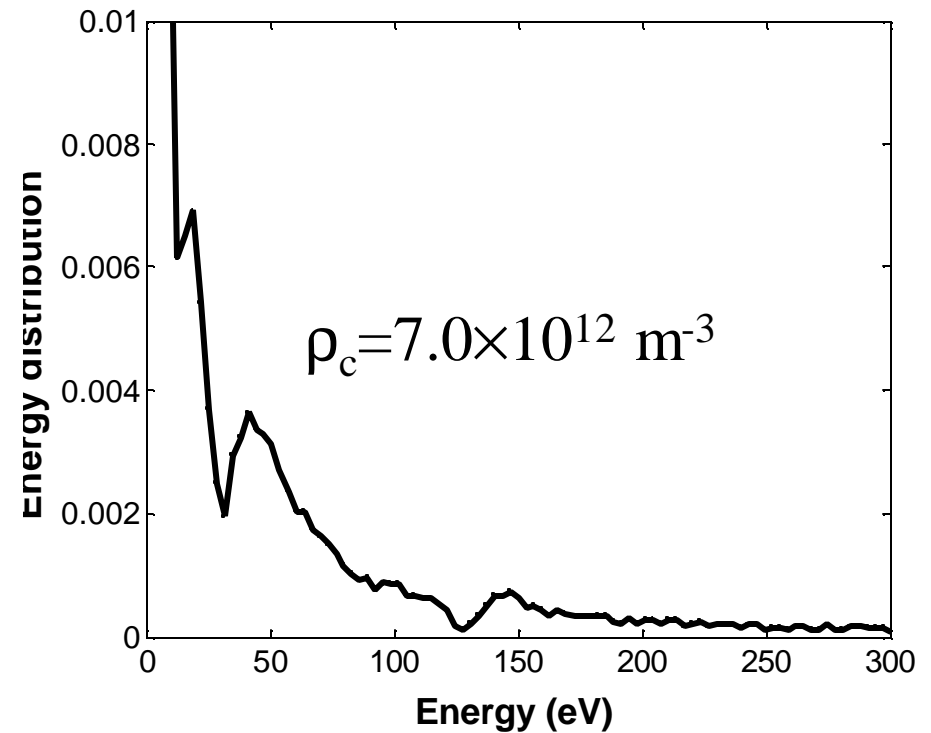$\rho_c = 1.5 \times 10^{13}$ m^{-3}

Emax=150eV, Yield=1.5   Emax=100eV, Yield=1.2

Bunch intensity

➤ **There is more stopband with lower beam density.**

➤ **Electron density is sensitive to bunch intensity!**

$\rho_c = 2 \times 10^{13}$ m^{-3}

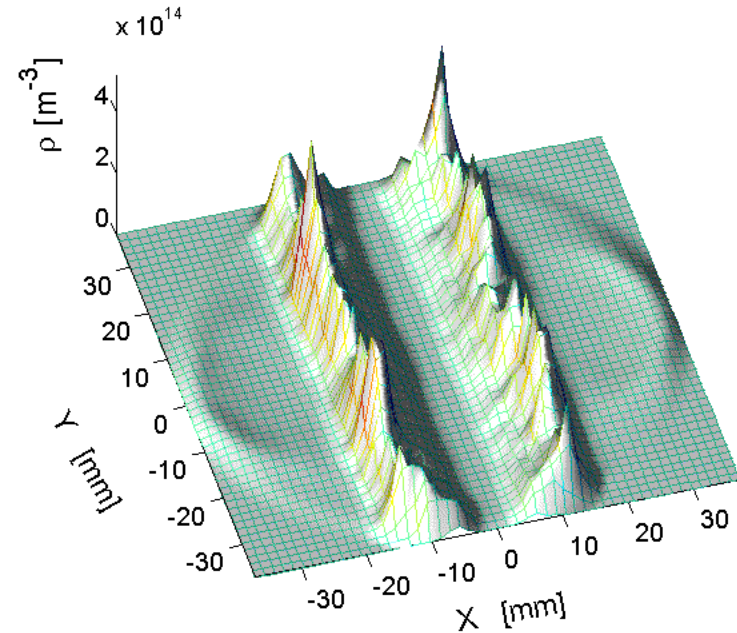$\rho_c = 7.0 \times 10^{12}$ m^{-3}

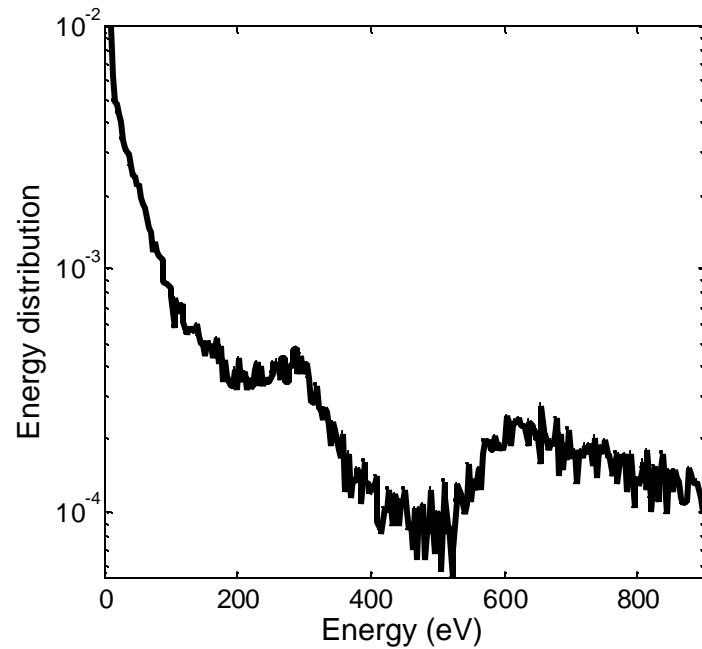N=N0   N=0.5*N0
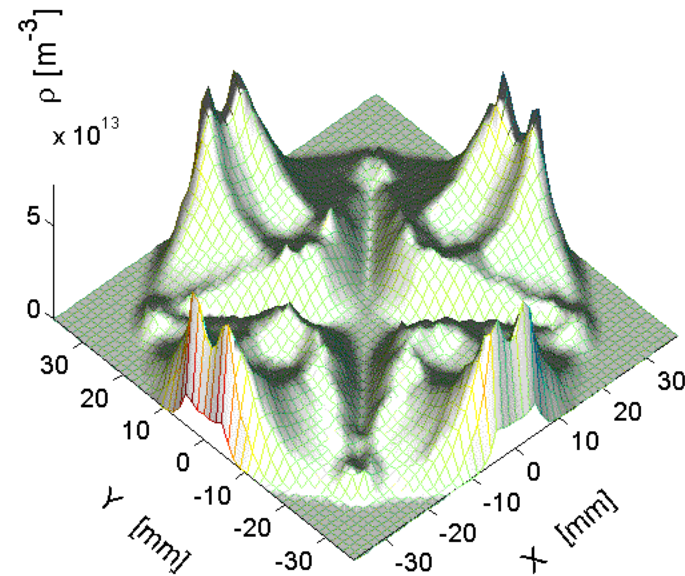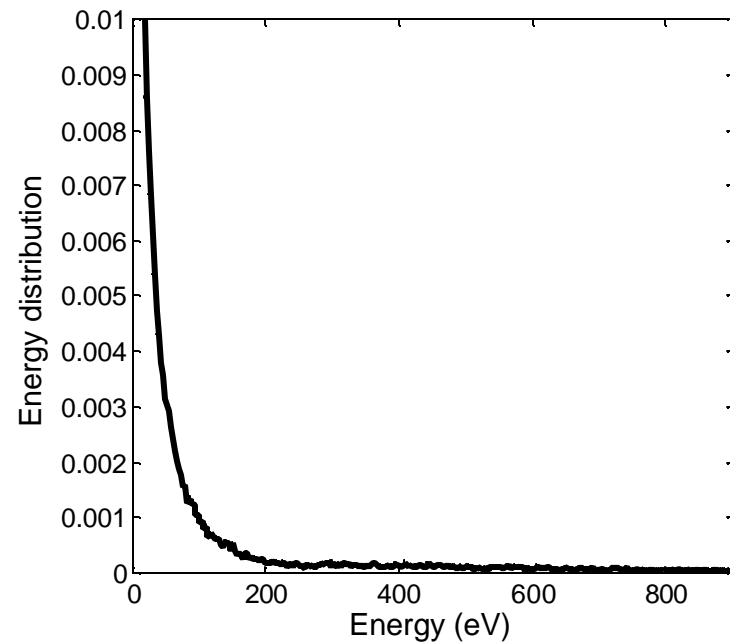
4RF spacing, R=50mm

E-cloud inside dipole magnet

Both multipacting and energy are angular and B-field dependent!

R=45mm, 2ns spacing, N=1.2e11

E-cloud inside Quadrupole magnet(SuperKEKB)

- ➤ **Most of electrons have low energy (<200eV)**
- ➤ **Very weak multipacting**

KEKB

Measured energy distribution of electrons

Fill pattern (40/24/4)

Beam current 513 - 390 mA
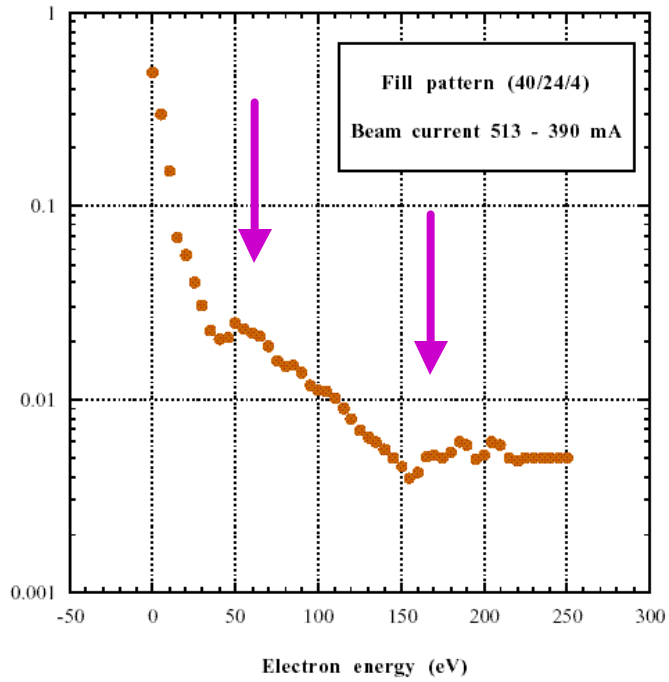
Electron energy (eV)

Exp. Fukuma

Simulation, L.Wang

4 bucket spacing, 0.3 T/m +
4 bucket spacing, no field ×
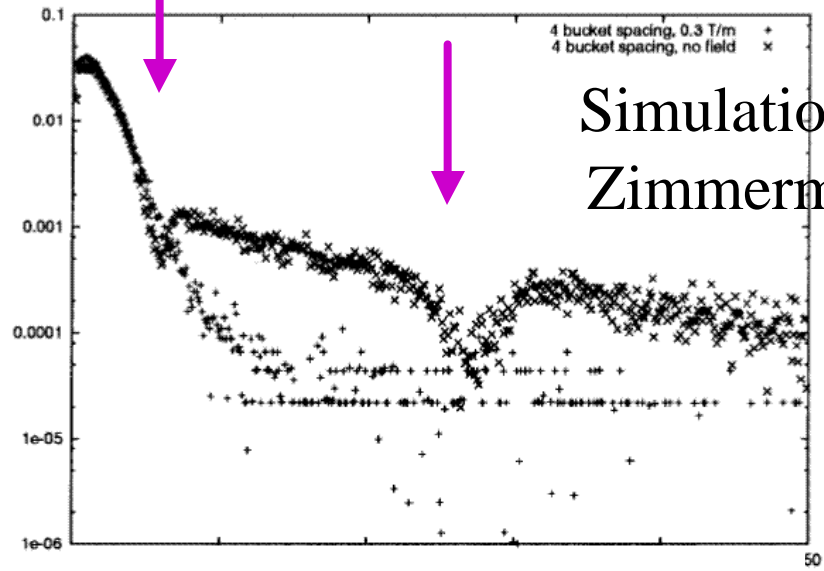
Simulation, F. Zimmermann

Electron's energy distribution
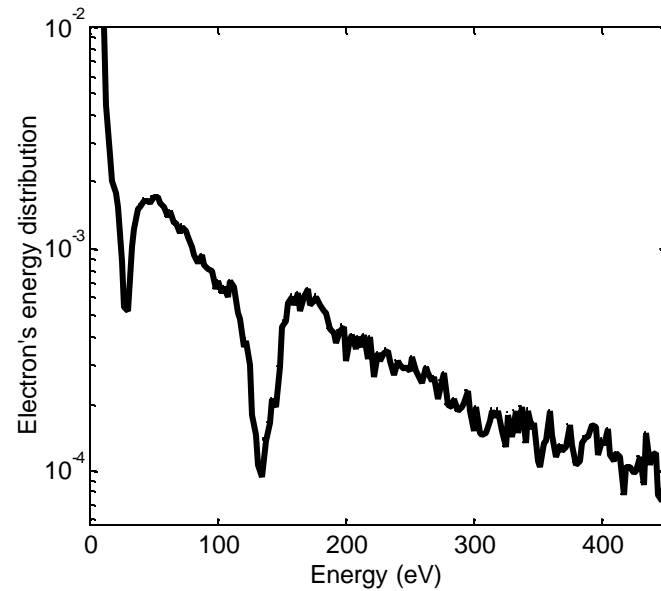
Energy (eV)

RHIC experiment
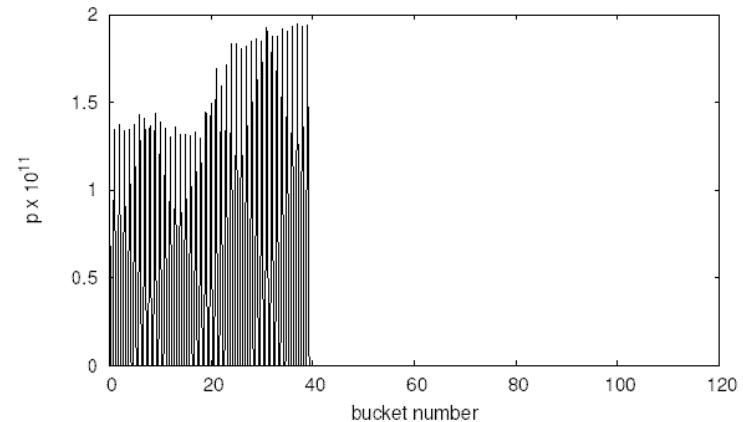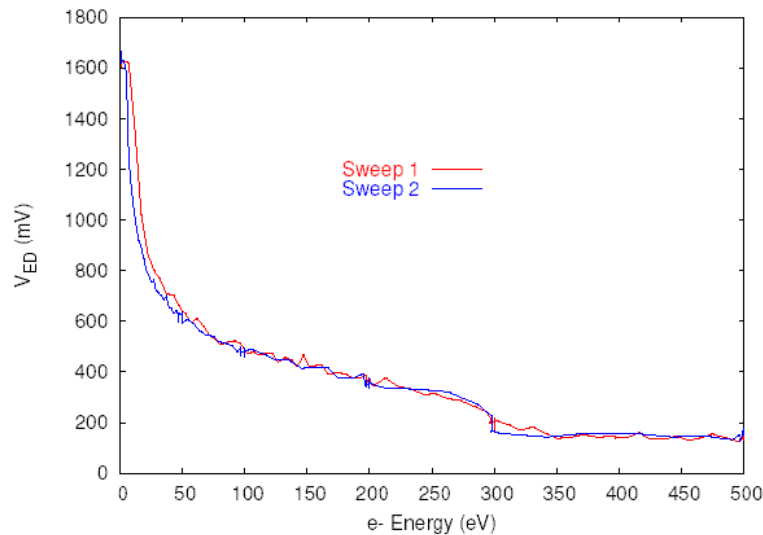
R=60mm, Spacing=106ns

U. Iriso, et. al., BNL
C-A/AP #129

Electron signal in the ED when filtering the electron energy from 0 to 500 V. This corresponds to an integrated energy spectrum.

Conclusion

- **A stopband phenomenon in electron energy spectrum was found. It is caused by the multi-passage of positron/proton bunch.**

- **Energy spectrum depends on the beam (bunch spacing, bunch current, bunch length) and chamber geometry. In others words, multipacting depends on these parameters. (The real chamber geometry must be modeled in the simulation to get realistic result)**

- **Multipacting with short bunch is different from the regular multipacting (long bunch case). The orbit and energy of electron vary randomly according to its initial condition (has a spread) and beam, chamber's geometry. In general, it is a random multipacting (not a resonance one).**