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Measurement of Electron Cloud in KEKB LER with RFA

K. Kanazawa (KEK)

Collaborators

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BNL : C. Foerster, R. J. Todd, H. C. Hseuh

Contents

1. Electron monitors
2. Effect of synchrotron radiation
3. Energy spectrum of electrons
4. Signal observed with MCP
5. Scrubbing
6. Effect of antechamber
7. Effect of Coating
8. Comparison of antechamber and coating
9. Measurement in a dipole field
10. Estimation of the cloud density in a drift space
11. Effect of the bunch pattern on the density
12. Summary

KEKB LER Parameter related to this report

Circumference = 3016m

Inner diameter of LER vacuum chamber = 94 mm

Chamber material = Cu

Typical bunch size

σ_x ~ 0.4 mm

σ_y ~ 0.06 mm

σ_z ~ 6mm

RF Frequency = 508.88MHz

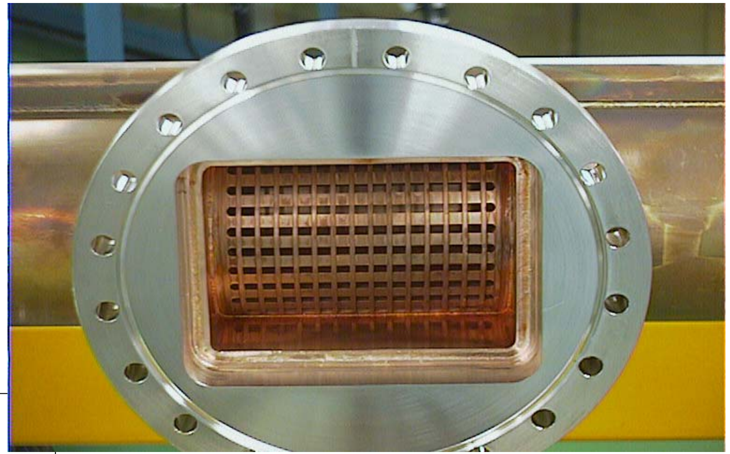
Harmonic number = 5120

1 Bunch Space = 0.6m = 2ns

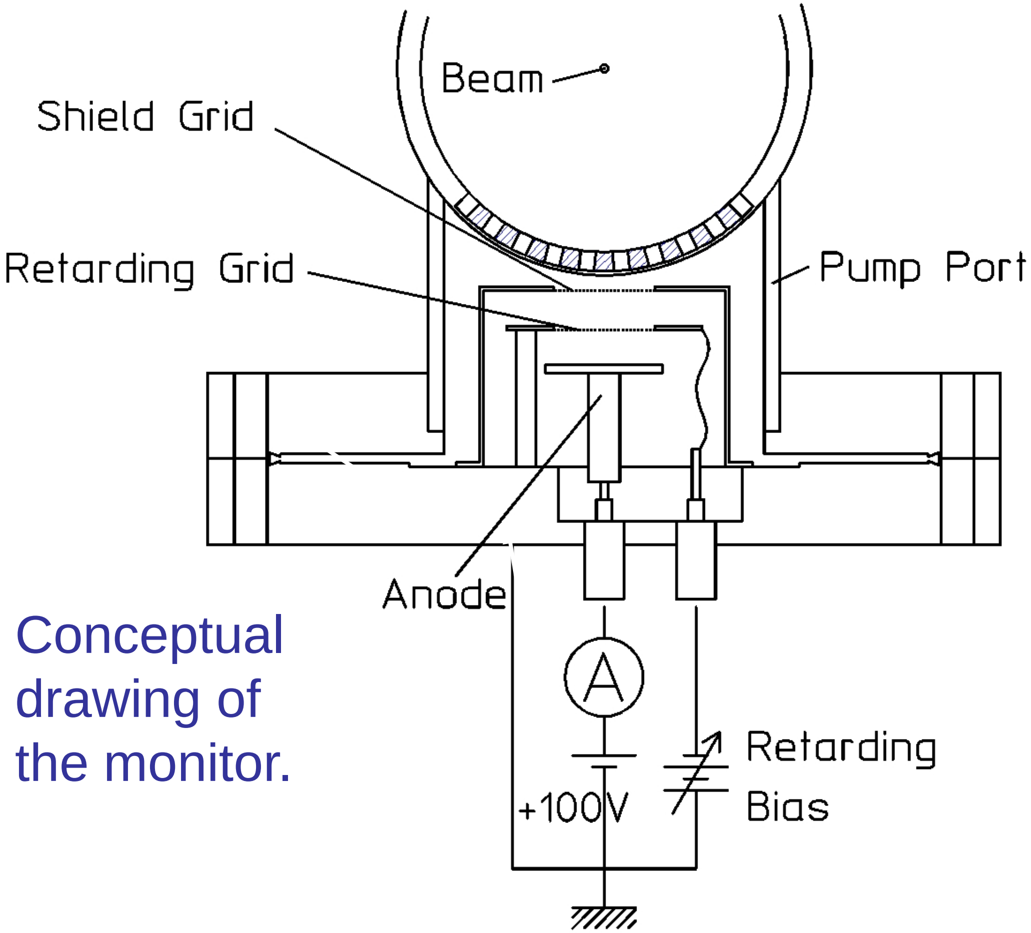
Bunch pattern :[No. of train, No. of bunch in a train, Bunch space]

Electron Monitors (1)

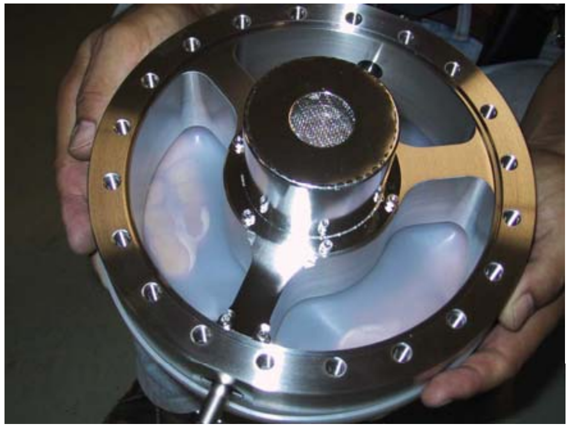
Retarding field analyzer (RFA) type electron monitors are usually set at pump ports of KEKB LER.



Pump port of KEKB LER

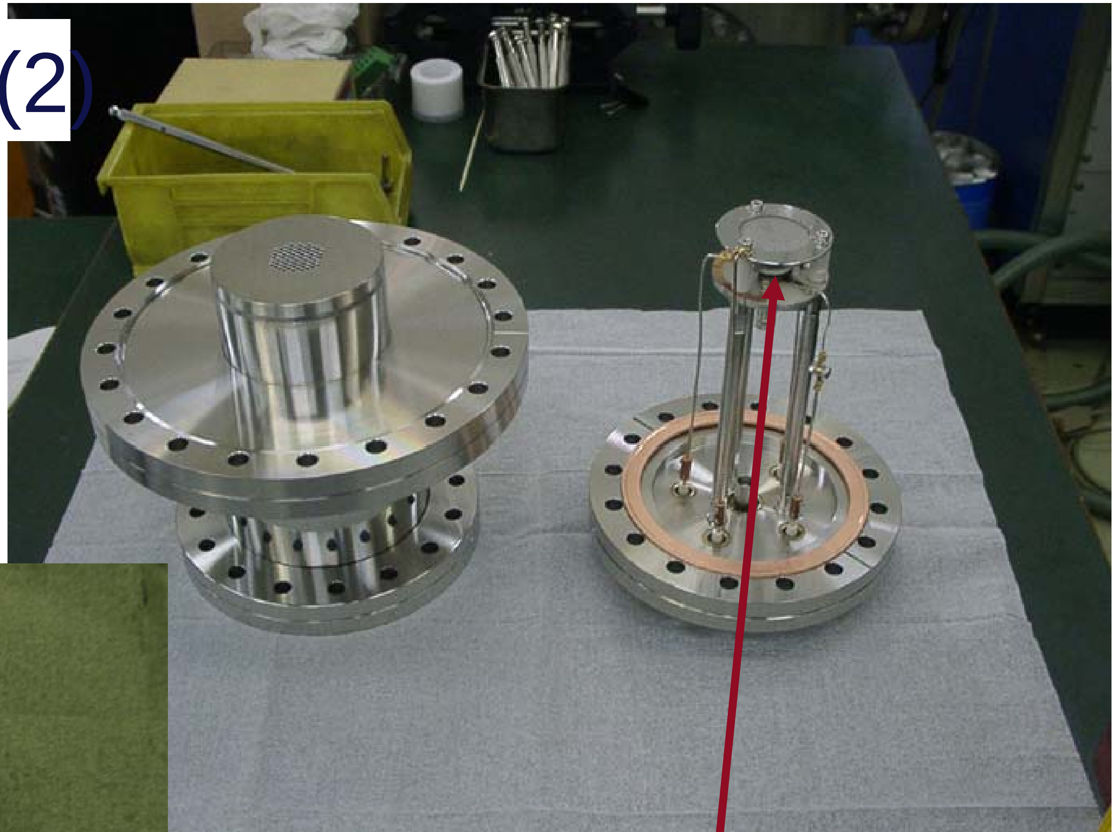


Conceptual drawing of the monitor.

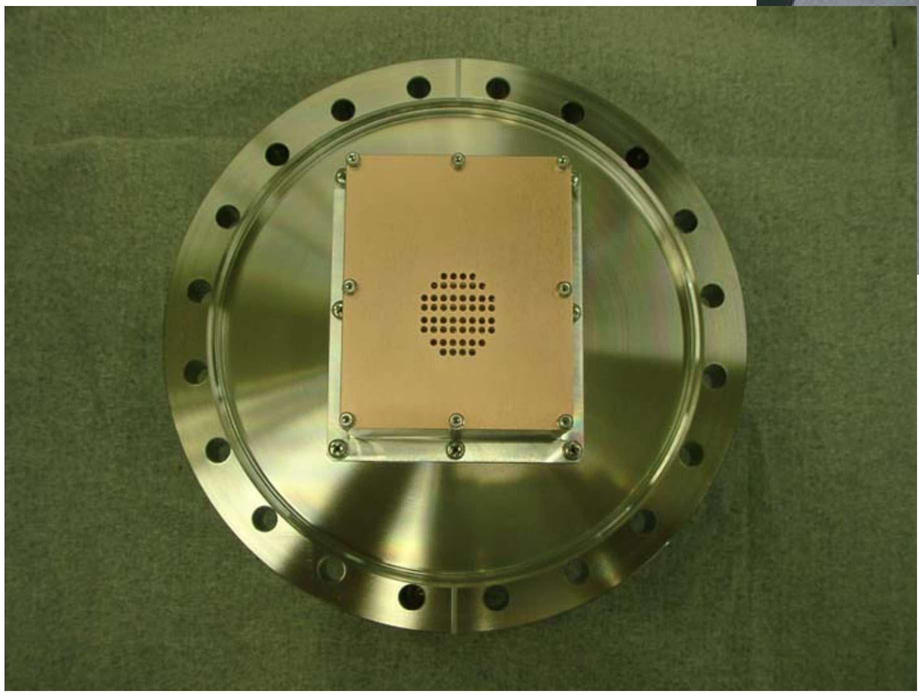


Electron Monitor (with modified flange)

Electron Monitors (2)



Recent design



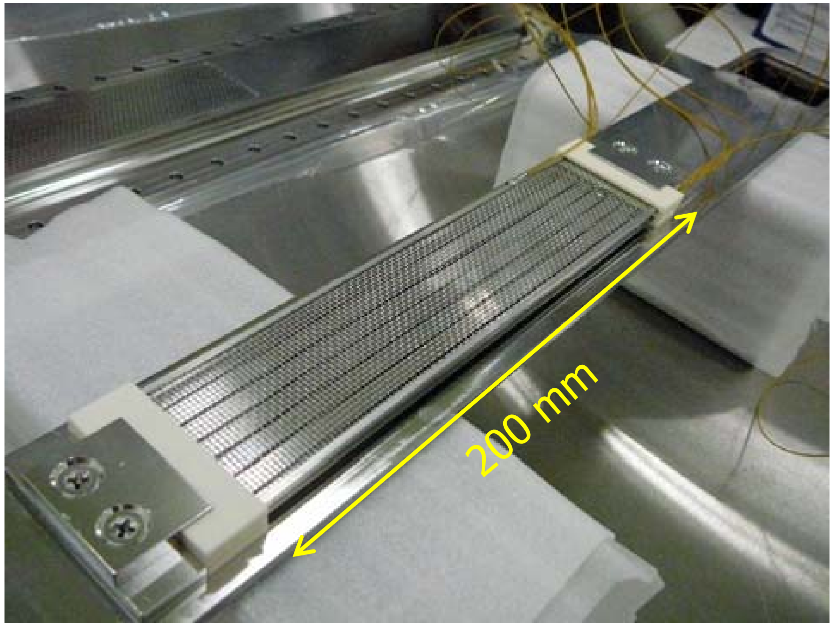
Monitor with a micro channel plate (MCP) (HAMAMATSU F4655-12) for high time resolution

Electron Monitors (3)

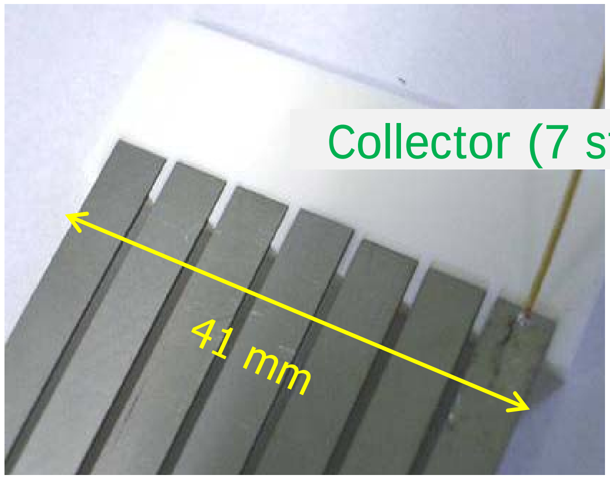
Y. Suetsugu

- RFA with 7-strip anode to measure the horizontal spatial distribution of electrons in a dipole field.

Monitor part



Output feed-through

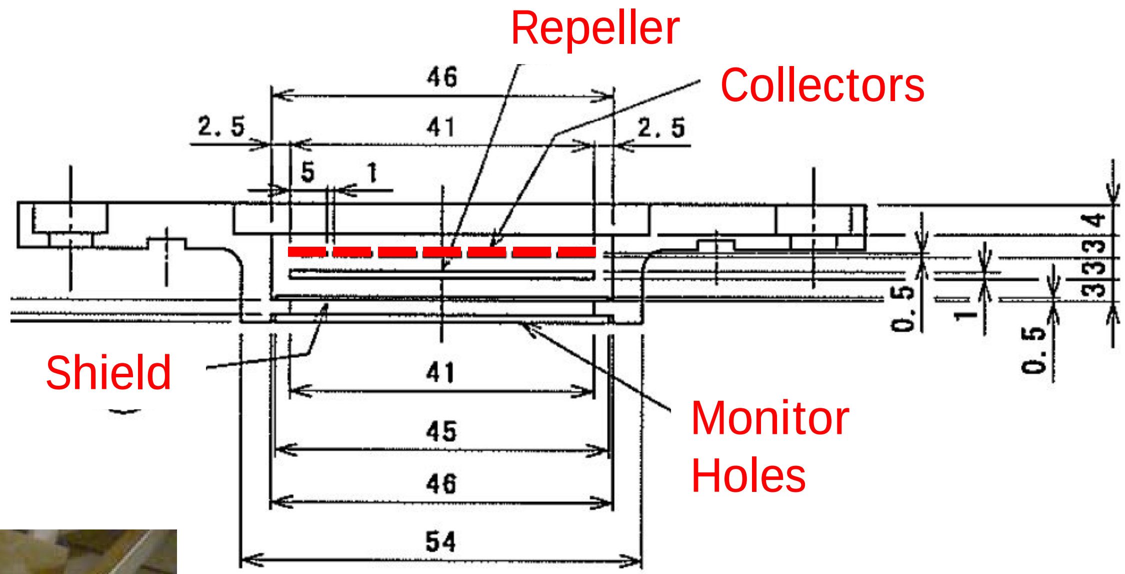


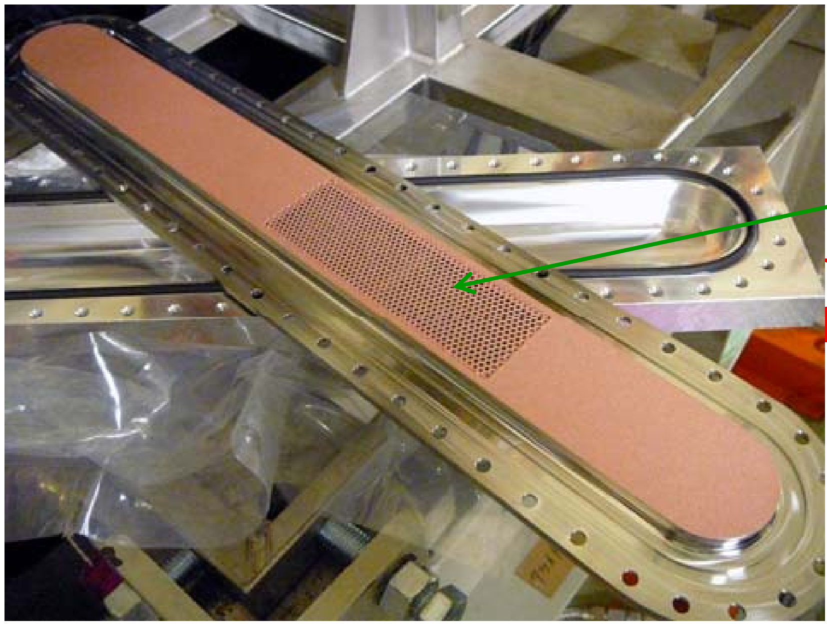
Collector (7 strips)

Electron Monitors (4)

Y. Suetsugu

- Assembly of RFA with 7-strip anode
  - Four layers
  - With Repeller grid





- Applied voltage
  Collectors: +100V
  Retarding Grid: 0 ~ -1 kV
- Measurement: DC mode

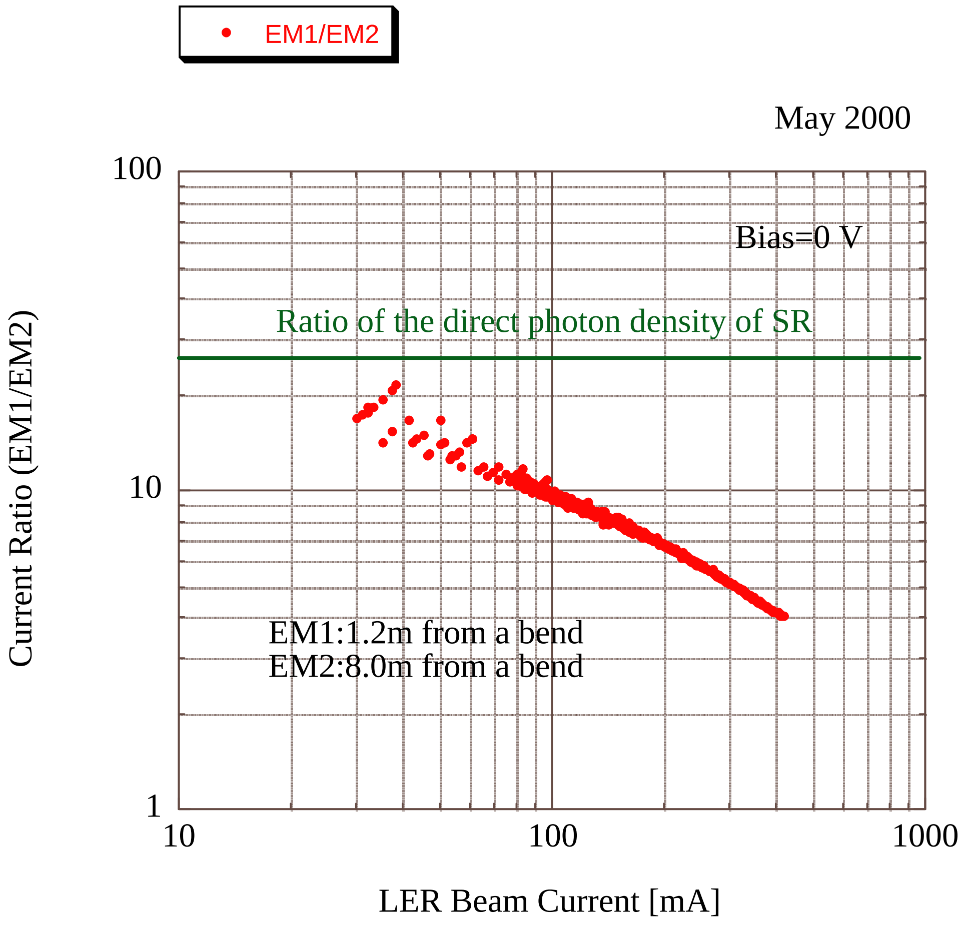
Effect of synchrotron radiation

In 2000, two RFA's were installed to LER. One (EM1) is close to a bending magnet (1.2m). The other (EM2) is far from the bending magnet (8m).

EM1 detects electron current higher than EM2.

Correlation with the intensity of synchrotron radiation is obvious. However the ratio is not equal to the ratio of the linear photon density.

At low current, the ratio of the electron current approaches to that of the linear photon density.

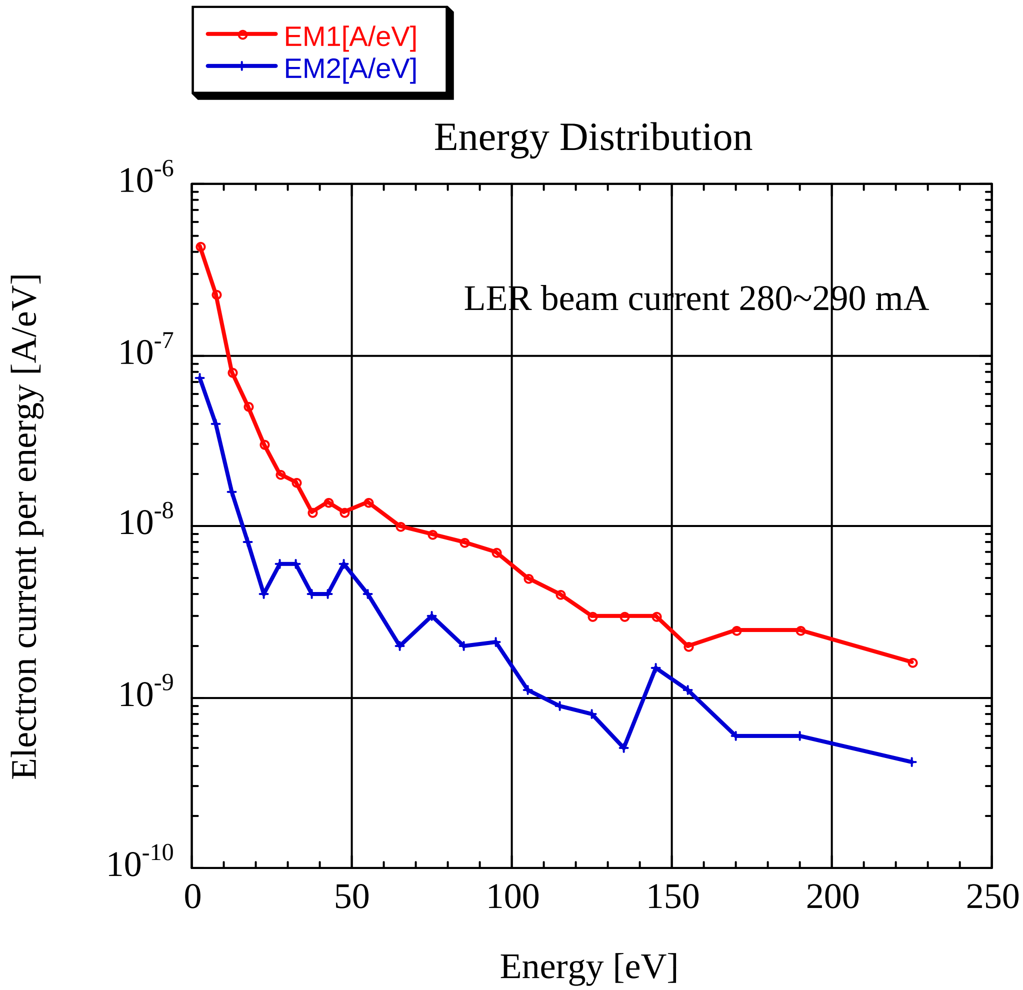


Energy spectrum of electrons

Energy spectrum was measured for the stored current of 280~290 mA.

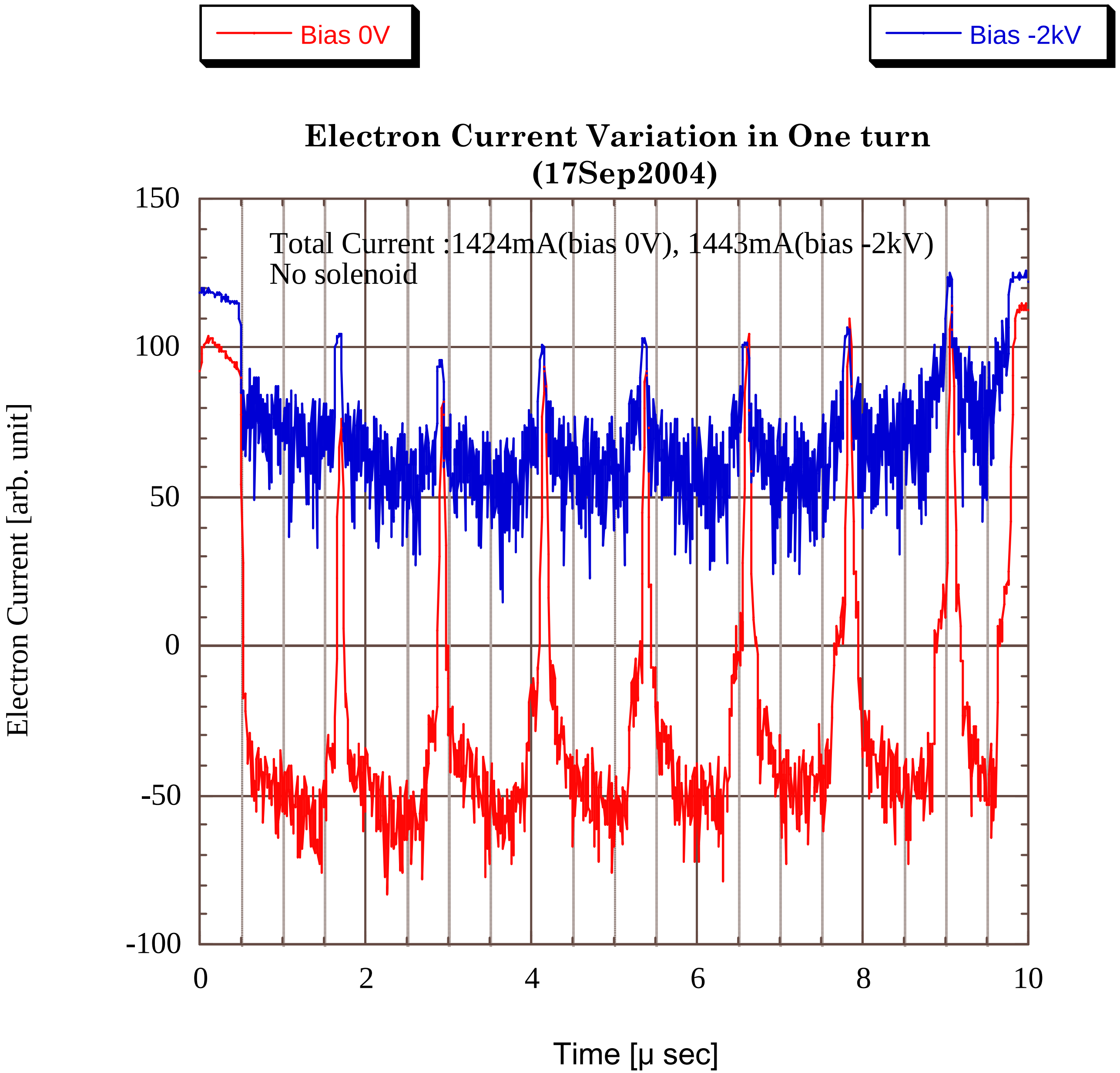
Most of electrons that enter the RFA have an energy lower than 20 eV.

By attaching a fast analog amplifier to RFA, we succeeded to observe the electron current variation corresponding to the bunch train of the stored beam. However, the bunch structure was not resolved and studies along this line was not continued.



Y. Ohishi, M. Tanaka, and T. Murakami (KEK)

Electron Measurement by MCP (1)



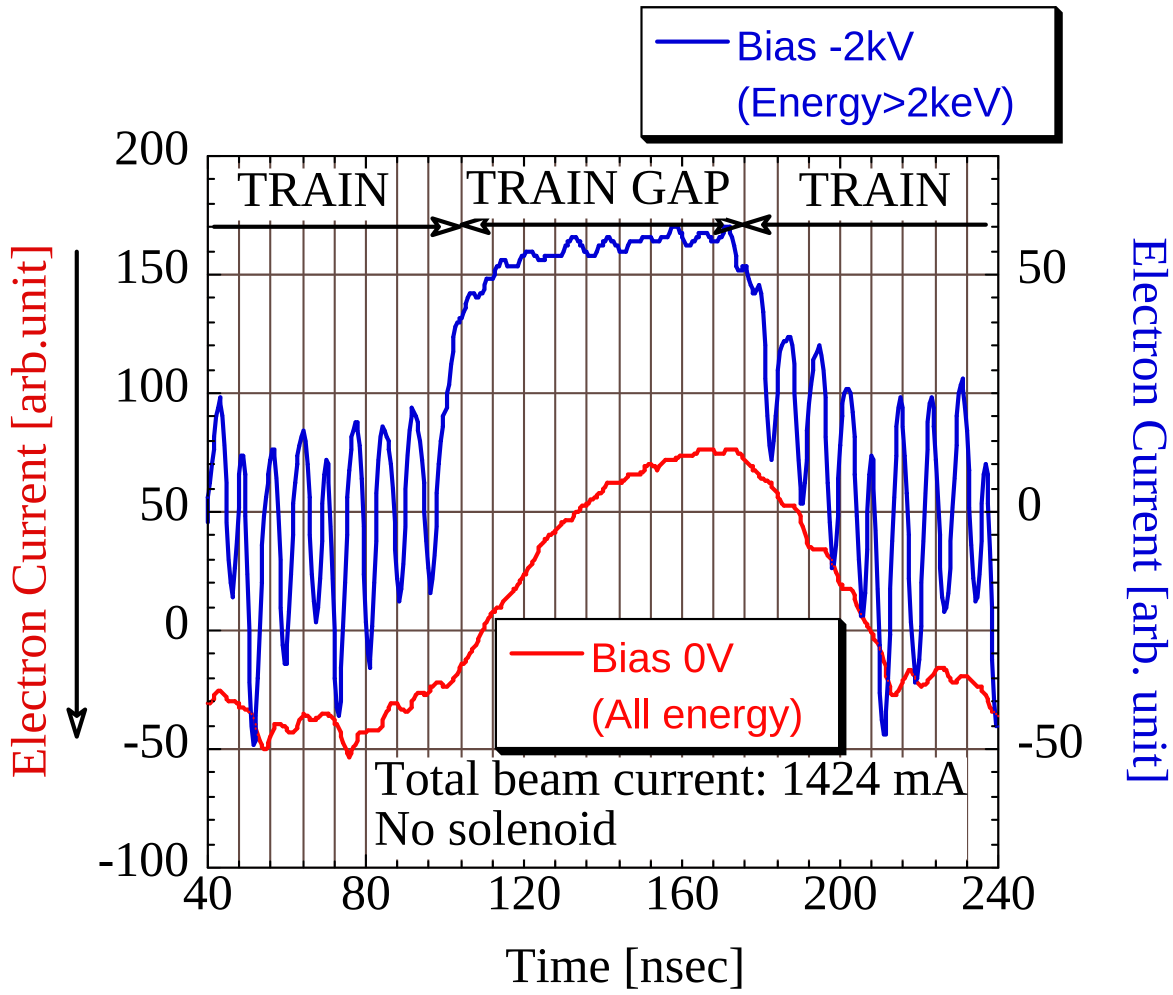
This RFA was located 1.2 m from a bend

The number of incoming electrons is far beyond the normal operating range of MCP.

The horizontal range corresponds to the one turn for LER

Electron Measurement by MCP (2)

•Detailed structure of the previous picture



High energy electrons show sharp peaks that coincide with the bunch pattern.

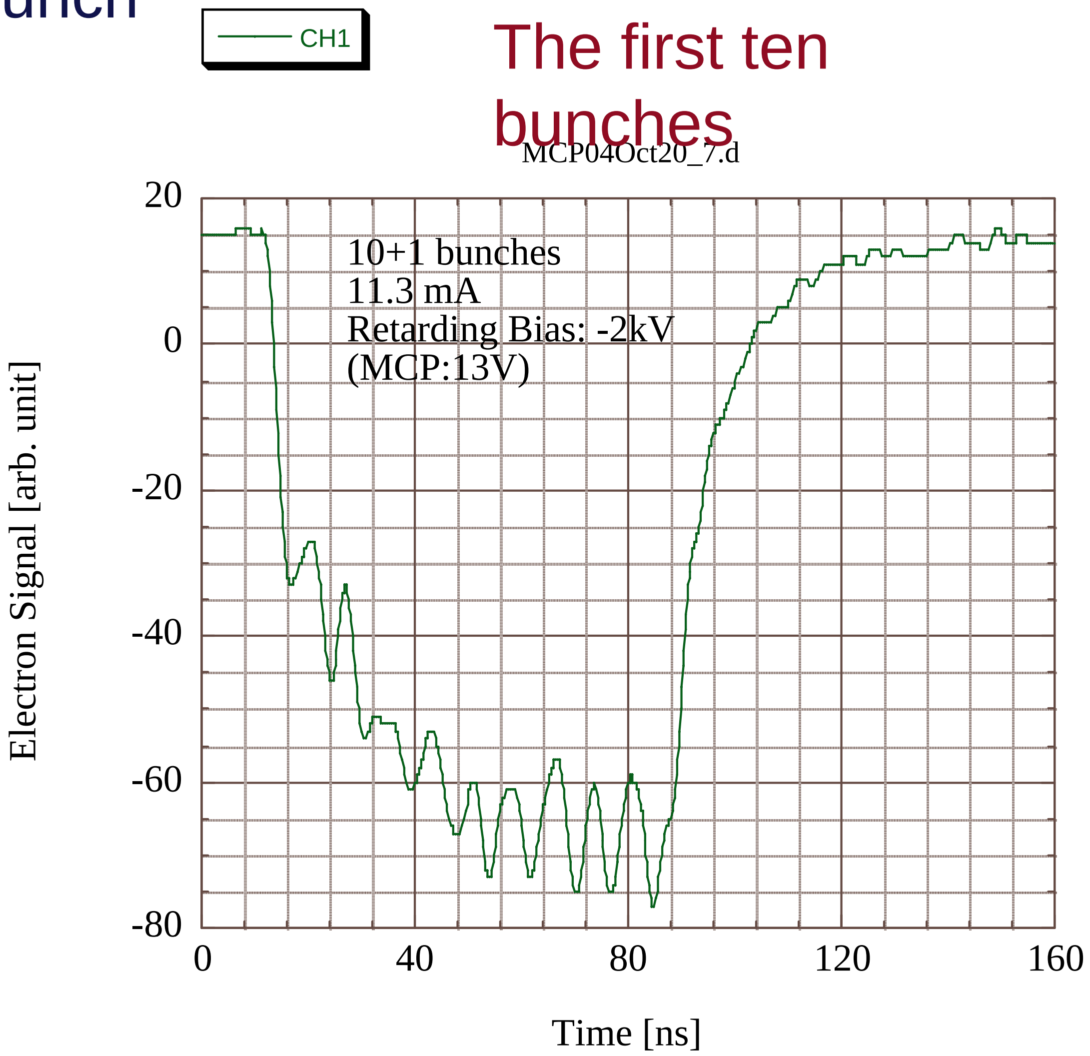
Low energy electron current decays more slowly than high energy component.

The peak of high energy component consists of electrons located near the beam and accelerated by the passing bunch (energetic electrons are produced near the bunch).
>>Density estimation

Electron Measurement by MCP (3)

Signal from the beam with ten 8 ns spaced bunch plus one pilot bunch

The first ten bunches



Though the bunch current is not so different from the previous slide, the total current is much lower.

In this case, electron signal is much smaller than the previous case and peaks of high energy component are not so clear.

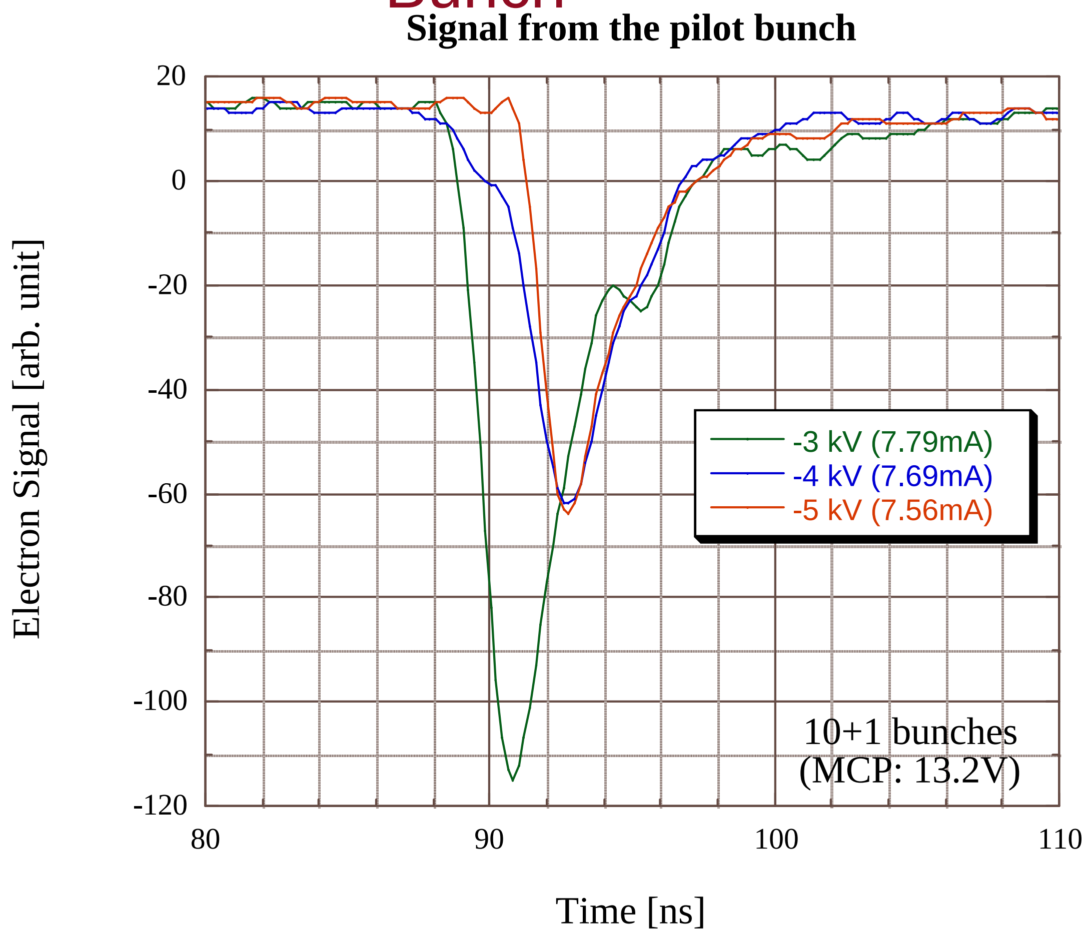
Electron Measurement by MCP (4)

Signal from the beam with ten 8 ns spaced bunch plus one pilot bunch

The pilot bunch locates more than 9 μs behind the train and about 0.5 μs before the train.

This observation may suggest long surviving electrons in a vacuum chamber.

The Pilot Bunch

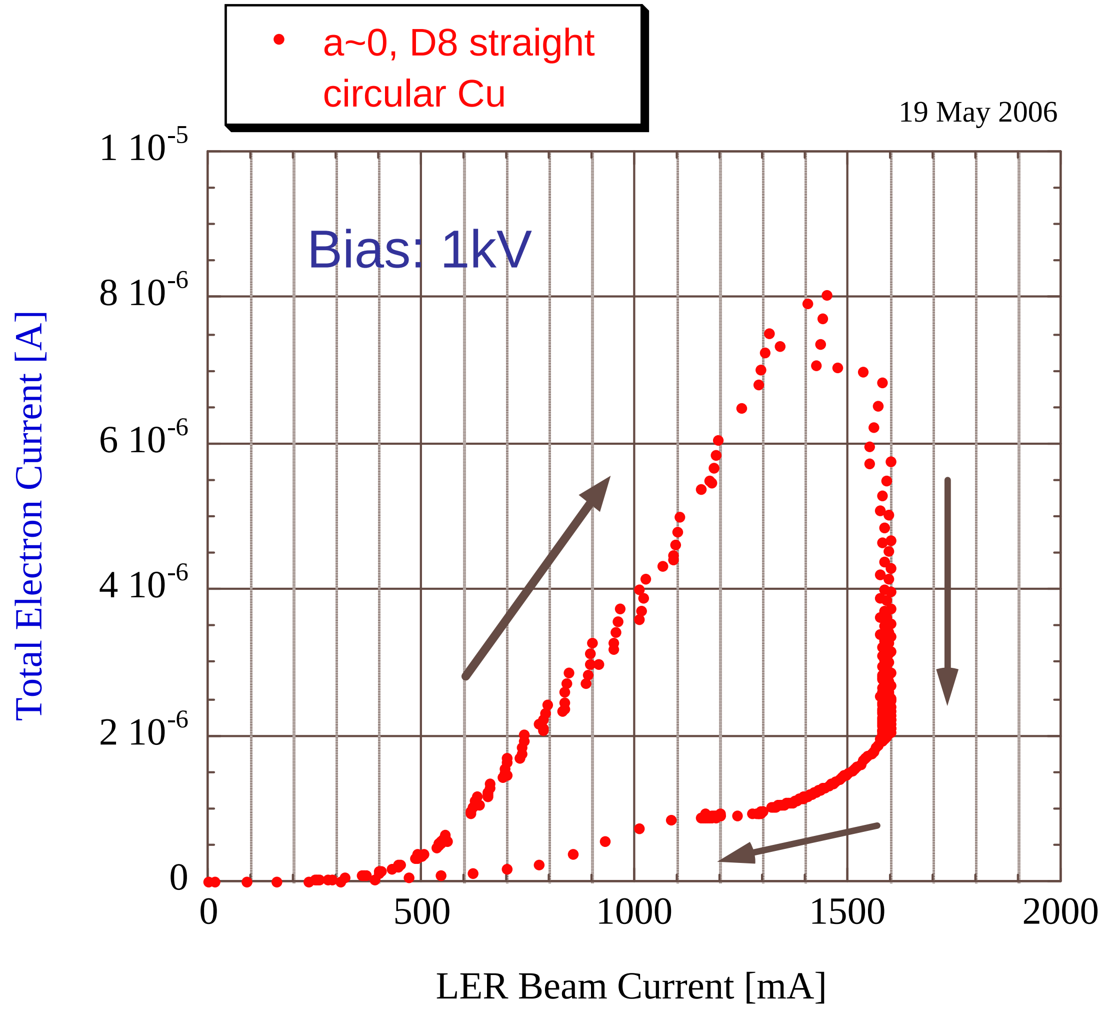


Scrubbing

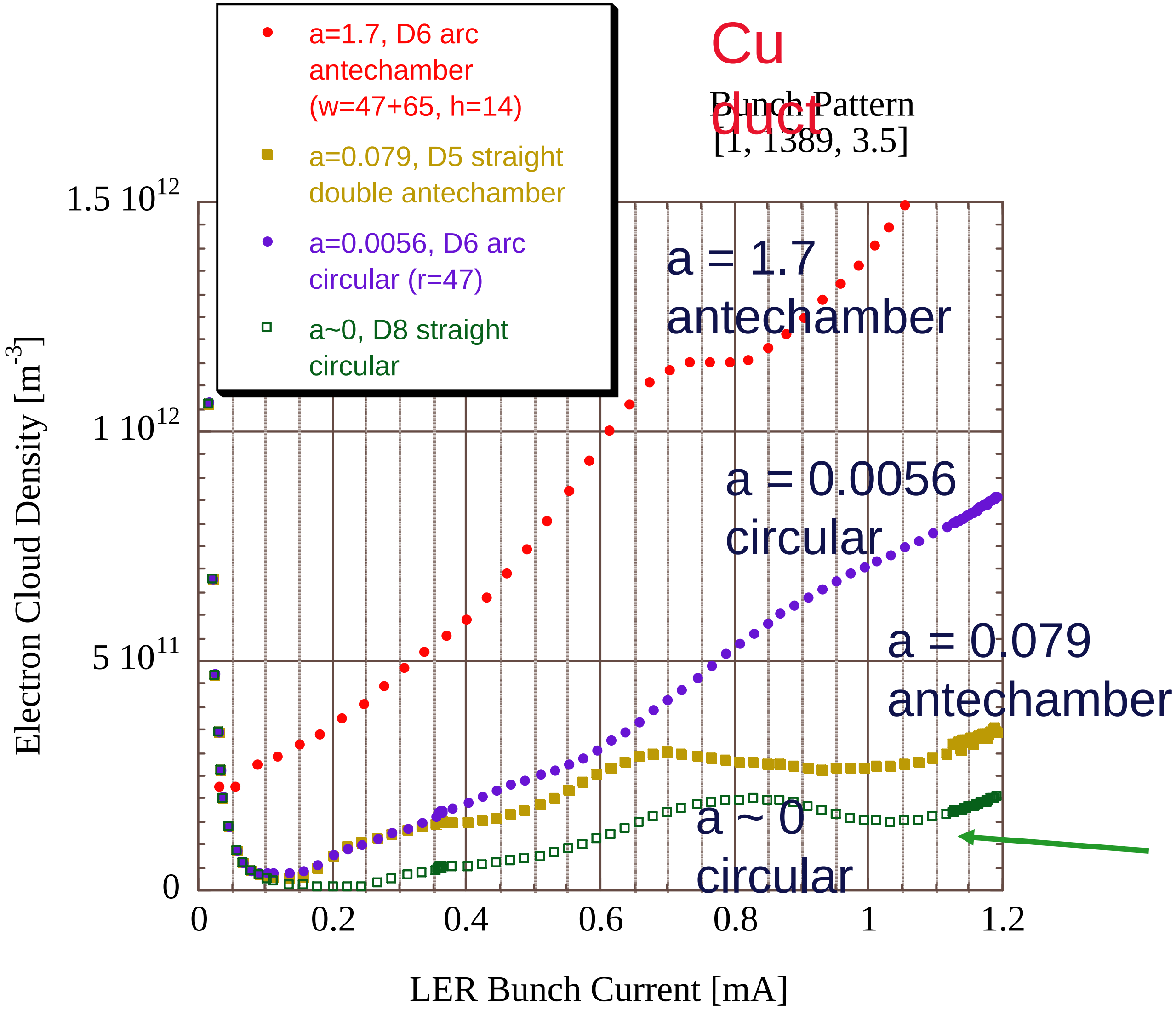
A newly installed chamber shows a high electron current.

The current decreases during beam scrubbing.

At the location of this chamber, direct synchrotron radiation is negligible. The decrease is understood mainly due to the decrease of SEY.



Effect of antechamber



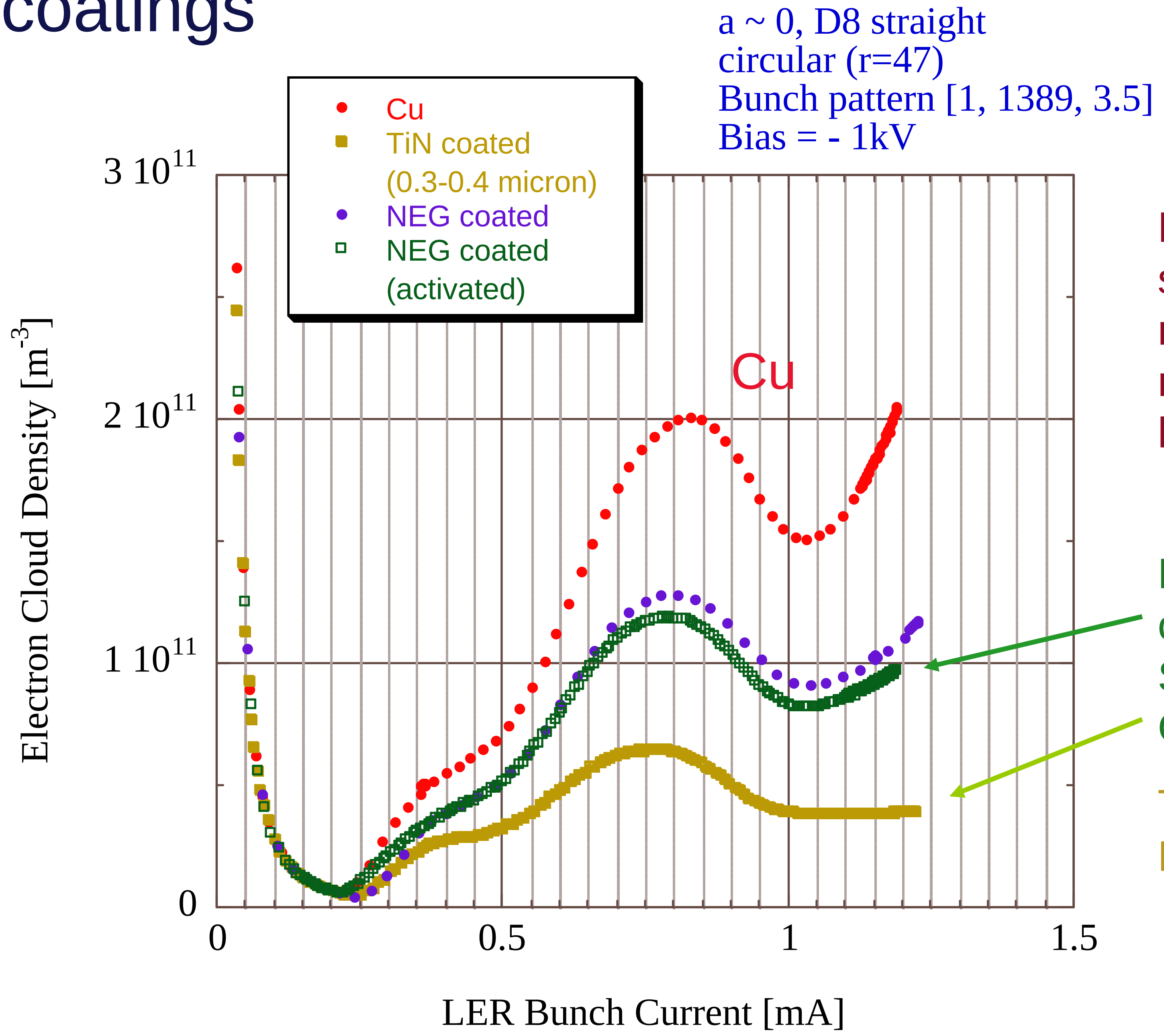
The antechamber is effective to reduce the contribution of photoelectrons to the electron cloud.

Antechamber reduces the electron cloud density drastically.

However the removal of photoelectrons is not complete compared to the place where synchrotron light is negligible.

‘a’ represents the photon intensity of direct synchrotron radiation. (Linear photon density per meter) = (a/360)•(Total

Effect of coatings

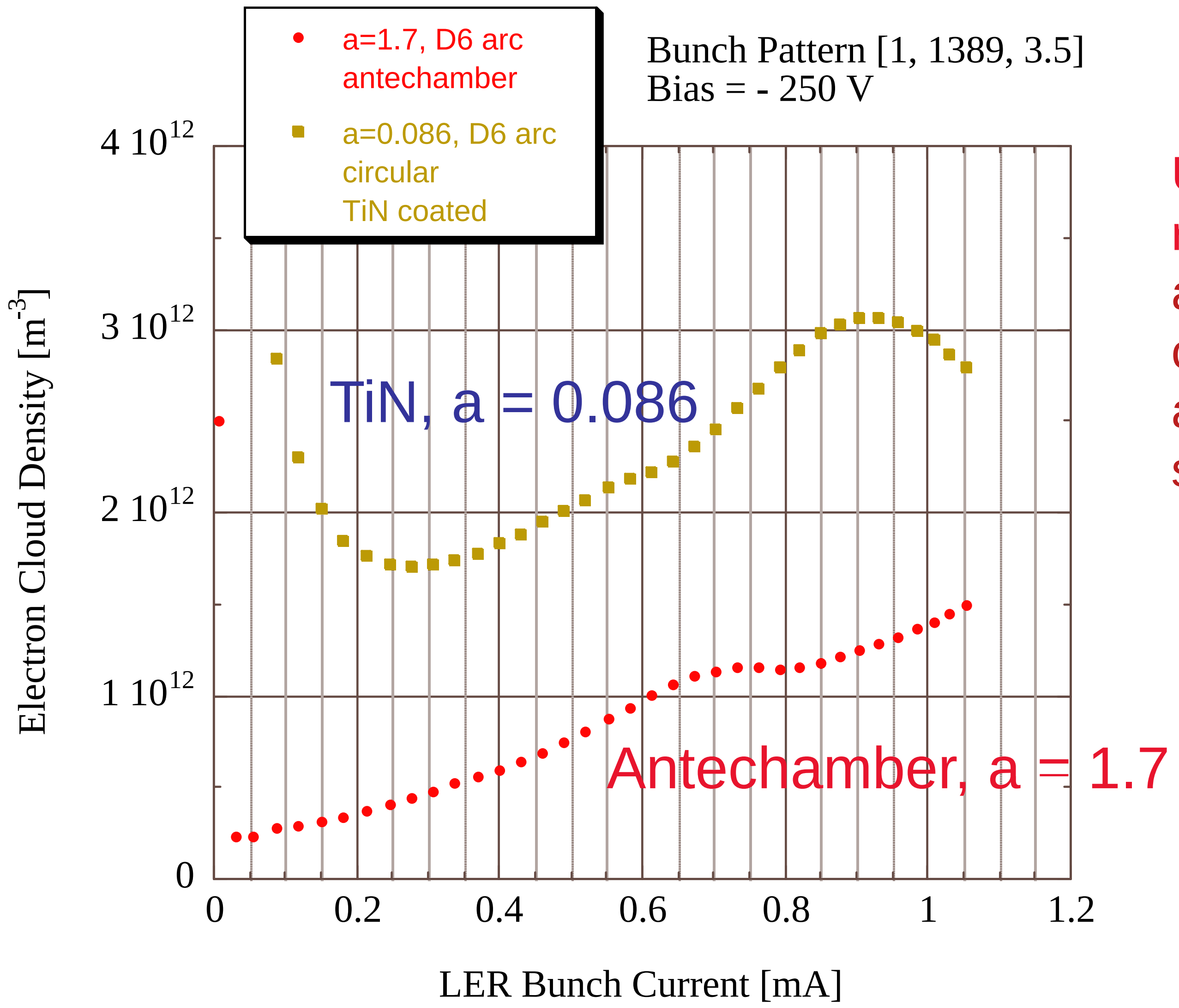


Direct synchrotron radiation is negligible here (a ~ 0)

NEG coating: SAES Getters

TiN coating: BNL

Comparison of coating and antechamber

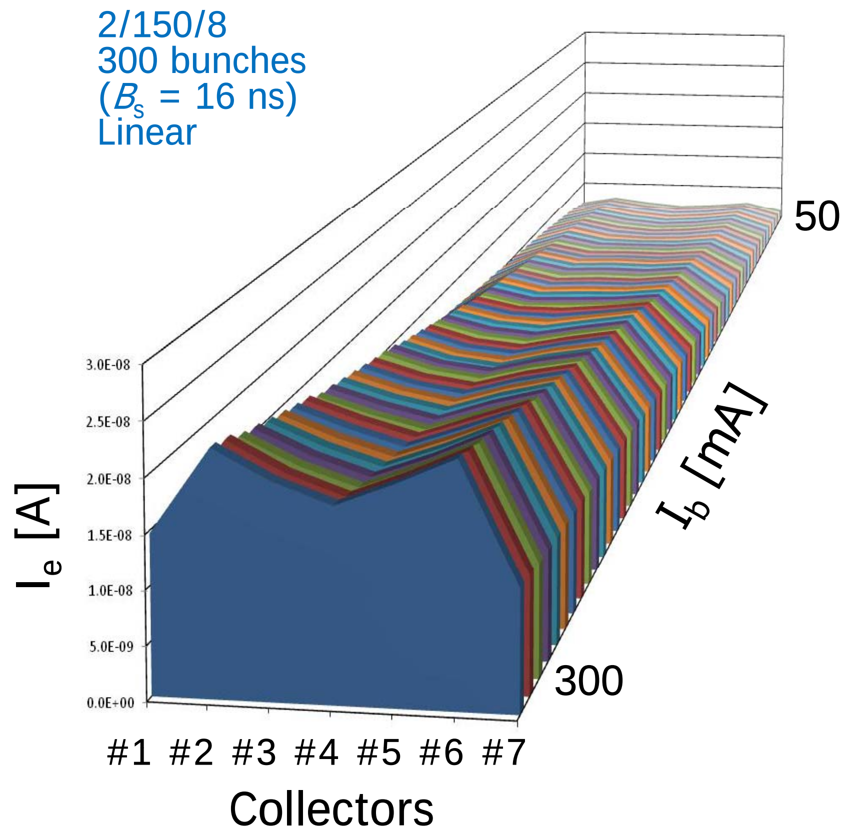


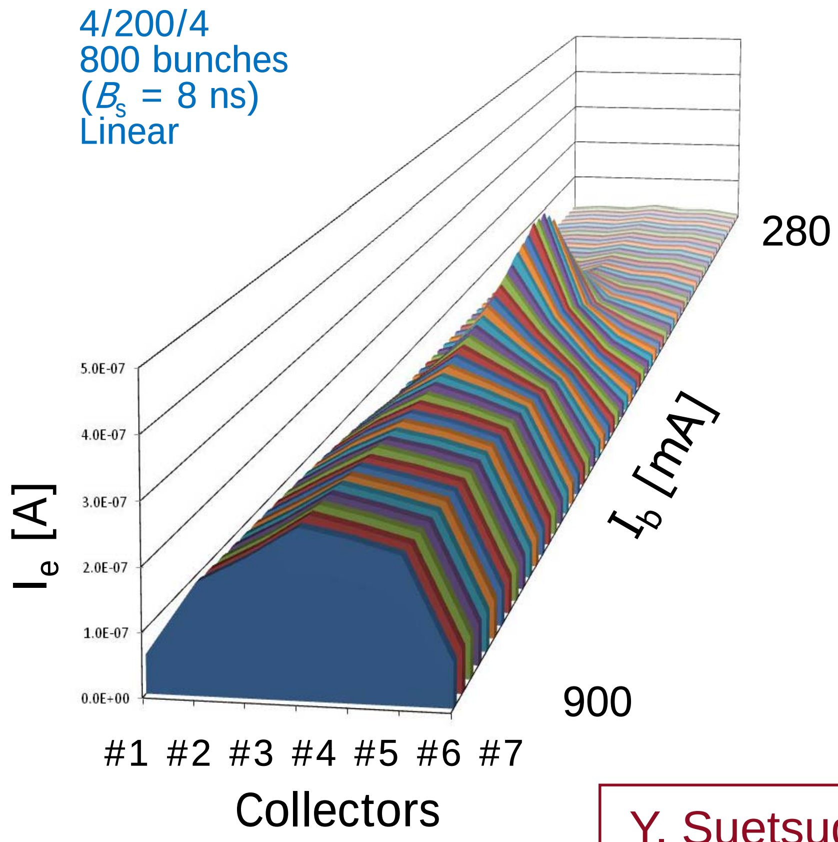
Under synchrotron radiation, TiN coating alone is not effective compared to the antechamber structure.

TiN coating is done by R. J. Todd and H. C. Hseuh (BNL)

Measurement in a dipole field with seven strip anode RFA (1)

- For different fill patterns

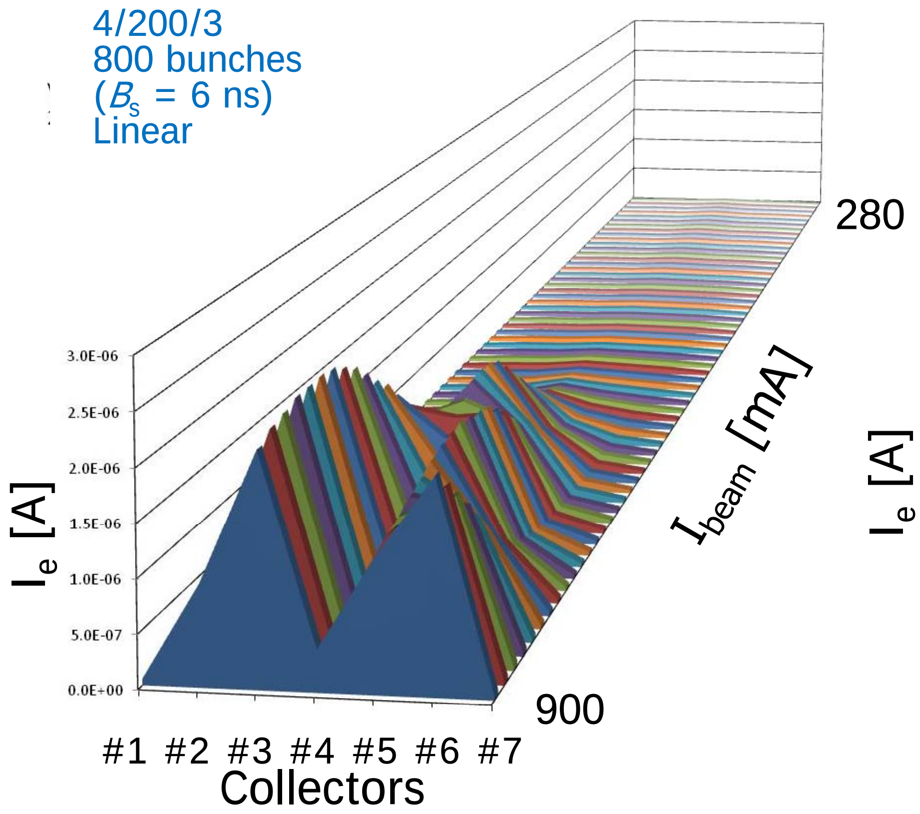


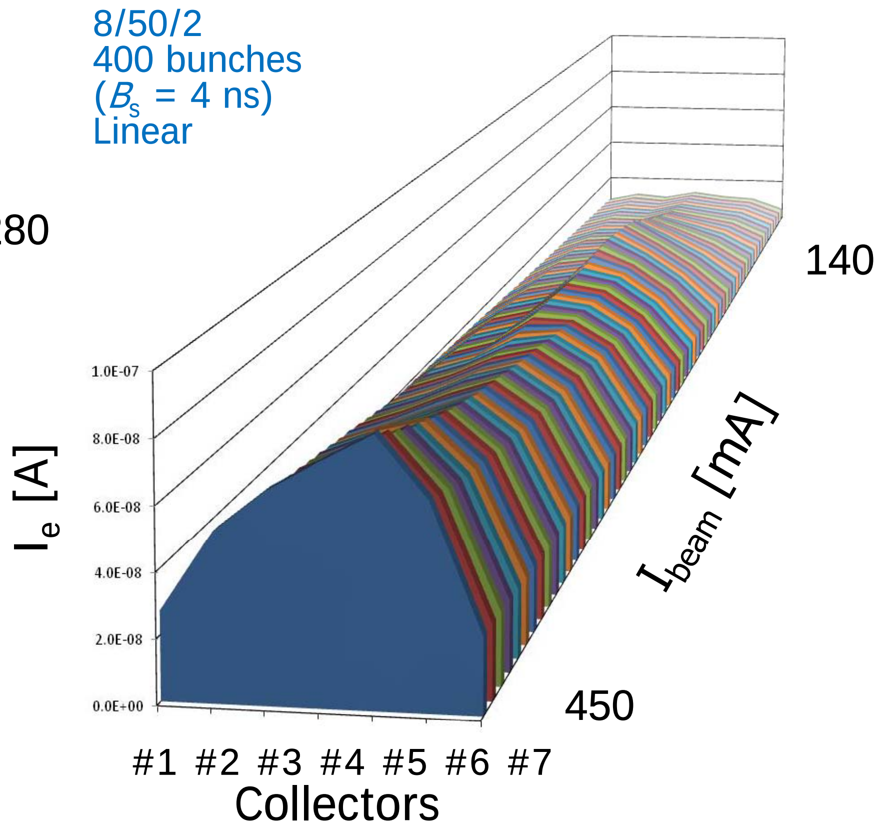


Y. Suetsugu

Measurement in a dipole field with seven strip anode RFA (2)

- For different fill patterns



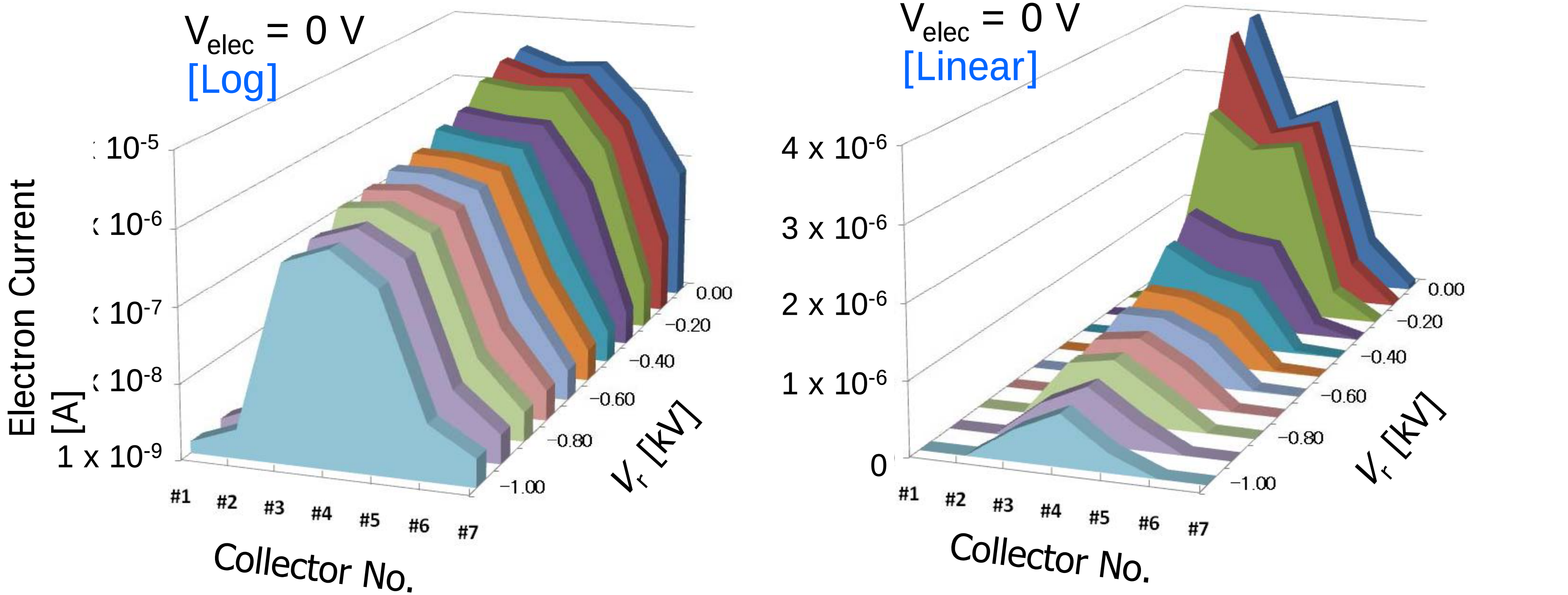


Y. Suetsugu

Measurement in a dipole field with seven strip anode RFA (3)

- Energy Distribution
  - High energy electrons are around the center (beam orbit)

1585 bunches
(B_s ~ 6 ns)
~1600 mA



Y. Suetsugu

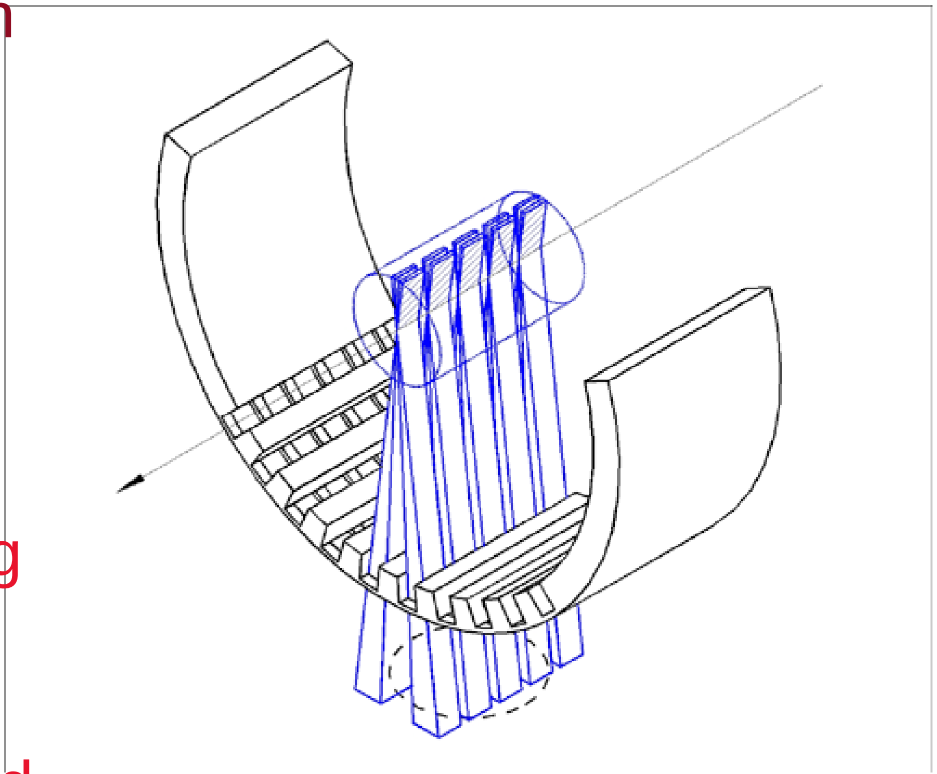
Estimation of the cloud density in a drift space (1)

Within electrons interacted with a bunch, those with a higher energy than a certain value arrive at RFA before the next bunch arrives.
They come from the small volume around the beam.

By applying a suitable retarding bias, such current is selectively measured and the corresponding volume is defined by the bias (~1/volume).

This view is suggested by the MCP observation.

(K. Kanazawa et al. PAC05.

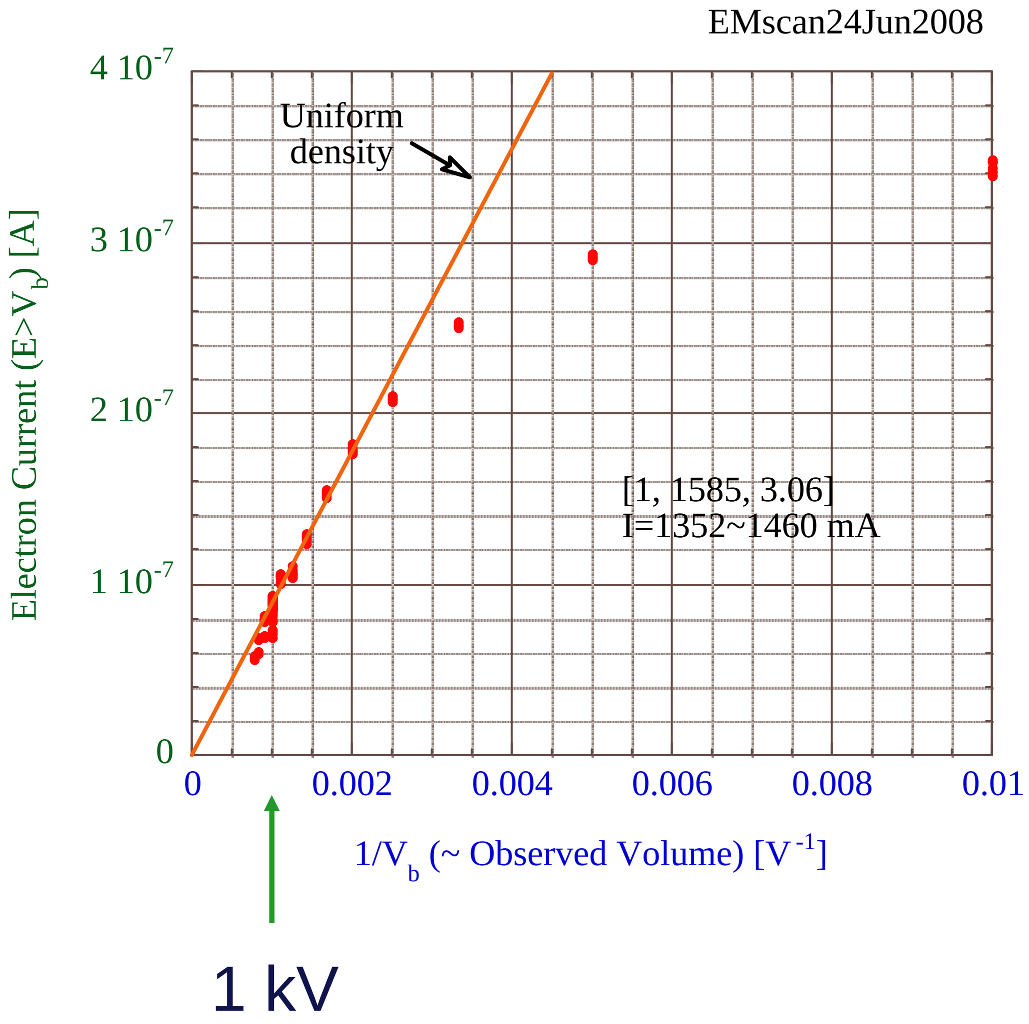


Conceptual drawing of the density measurement.

Estimation of the cloud density in a drift space (2)

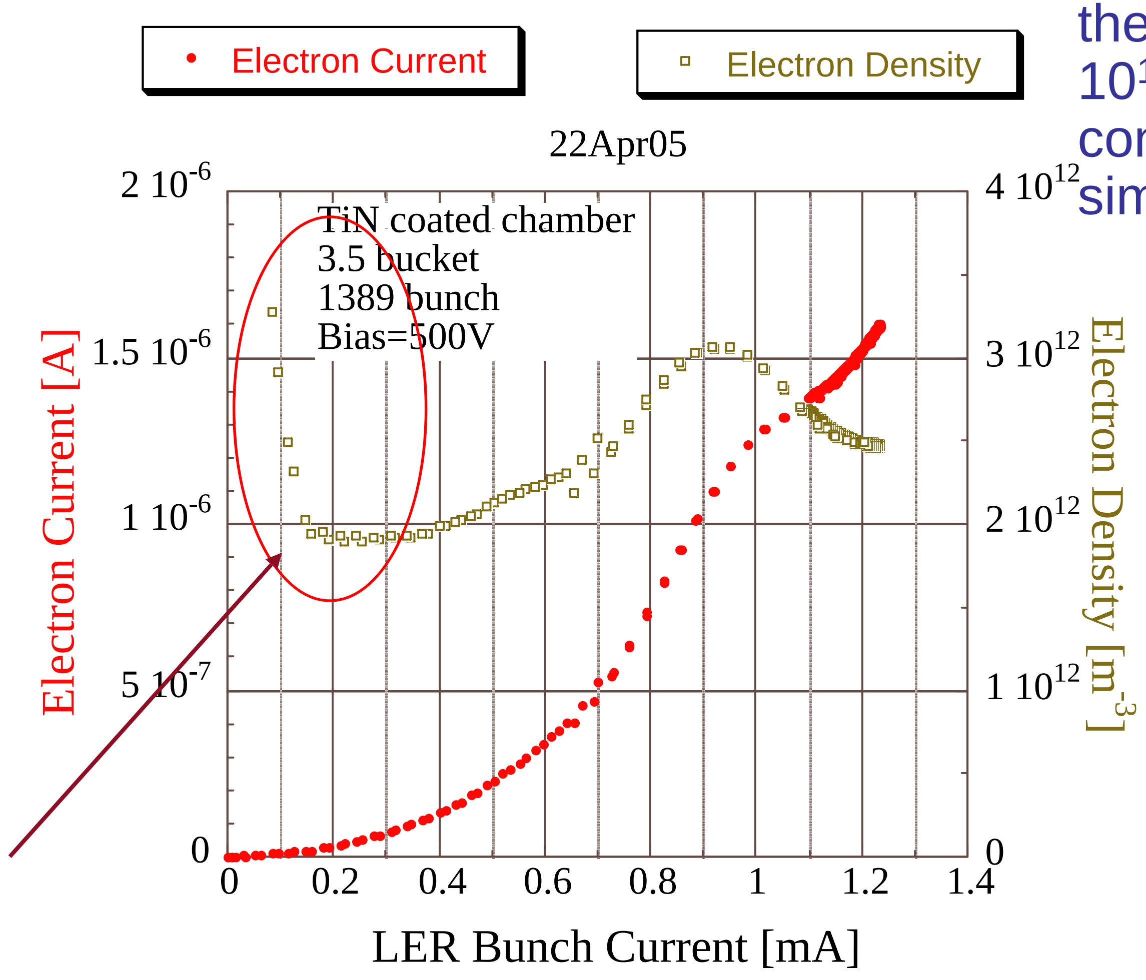
The assumption of this estimation suggests that when the beam current is constant, if the density is uniform, electron current is proportional to the volume given by the retarding bias i.e. inversely proportional to the retarding bias.

This graph shows such case can be seen for a high retarding bias and gives plausibility of the idea.



Estimation of the cloud density in a drift space (3)

Example



Unreliable region.

Volume is too small.

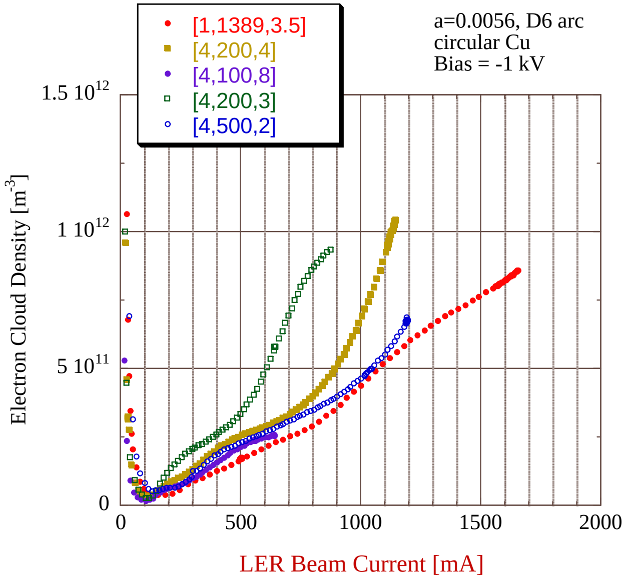
Detection limit of current.

- The density of the order of 10^{12} m^{-3} is consistent with simulations.

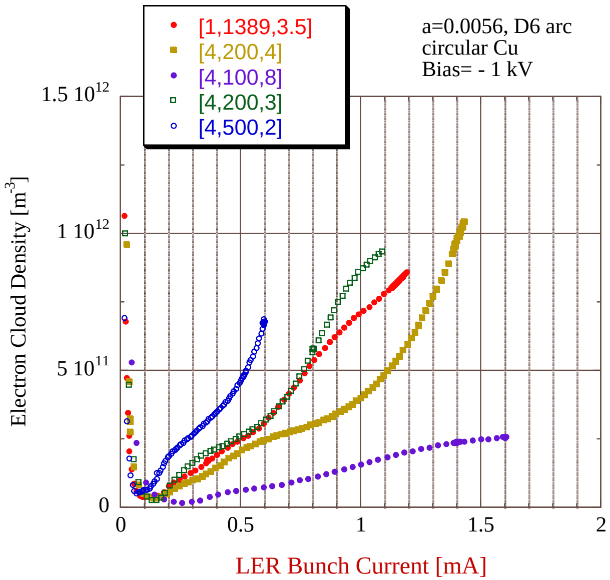
Effect of bunch patterns on the density (1)

Cu

a = 0.0056



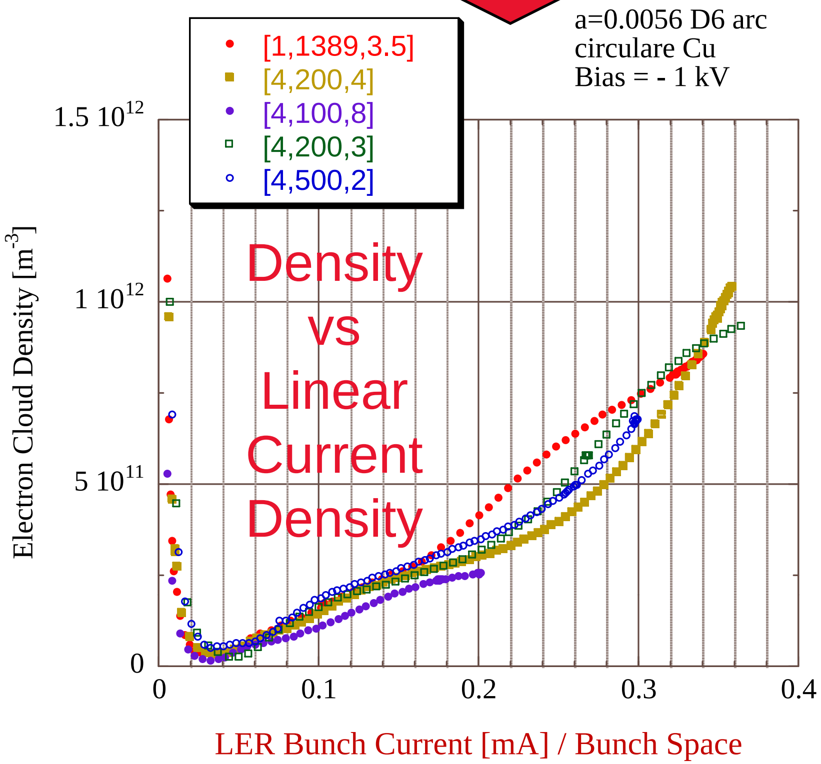
Density vs Total Current



Density vs Bunch Current

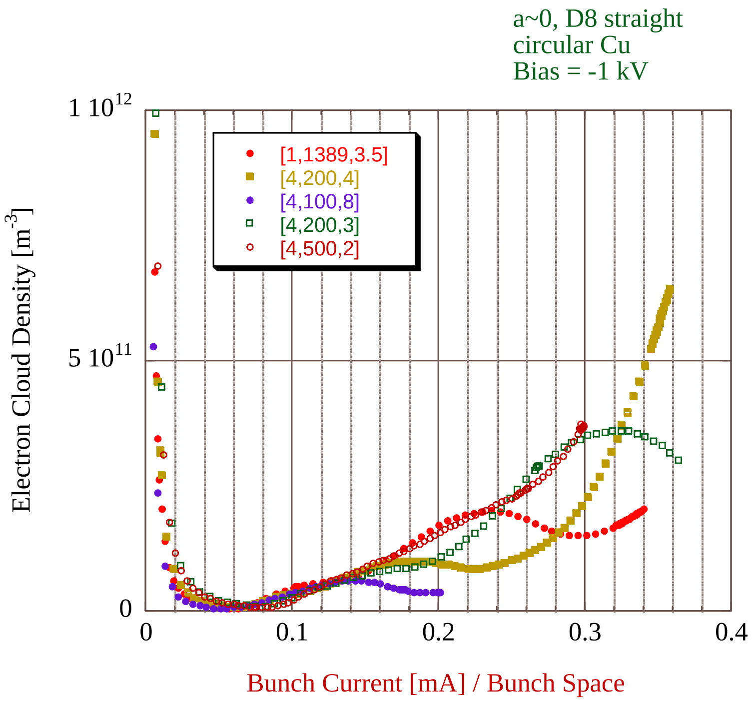
The evolution of the cloud density depends on the bunch pattern,

The variety of curve converges if the density is plotted against the linear density of the stored current. The convergence is especially good if SR exists.

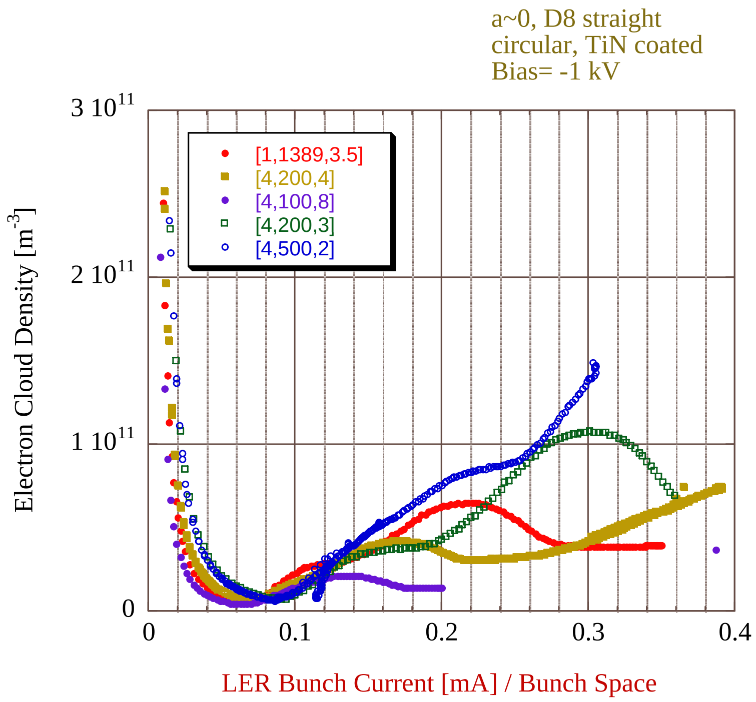


Effect of bunch patterns on the density (2)

For the location where synchrotron radiation is negligible, the variation due to bunch pattern is large even if plotted against current density.



Cu duct



Cu+TiN

Summary

- RFA type electron detectors with Faraday cup or MCP or multi-strip anode are installed to KEKB LER and electron current from the electron cloud is observed under various beam conditions.
- The cloud density depends on the intensity of synchrotron radiation but is not proportional to the intensity.
- Most of electrons that enter RFA have a low energy below 20 eV.
- MCP measurement in a time domain shows high energy electrons have peaks associated with bunches.
- MCP measurement suggests long surviving electrons in a duct.
- The decrease of the cloud density by scrubbing suggests the decrease of SEY of a duct surface.
- Antechamber reduces the electron cloud density but not complete.
- At the location where synchrotron light is negligible, the effect of coating was compared. TiN coating is more effective than NEG coating.
- Under synchrotron radiation the effect of TiN coating alone is not so effective as the antechamber structure.

Summary (continued)

- With multiple strip anode, various patterns of the cloud are observed in a dipole field according to different stored beam current and patterns. These features are mainly produced by low energy electrons.
- By selecting high energy electrons that hit a chamber wall, the density of electron cloud near a circulating beam can be estimated.
- The variety of the evolution pattern of the cloud density due to different bunch patterns converges if the density is plotted against the linear density of the stored current. The convergence is especially good if SR exists.

Thank You !