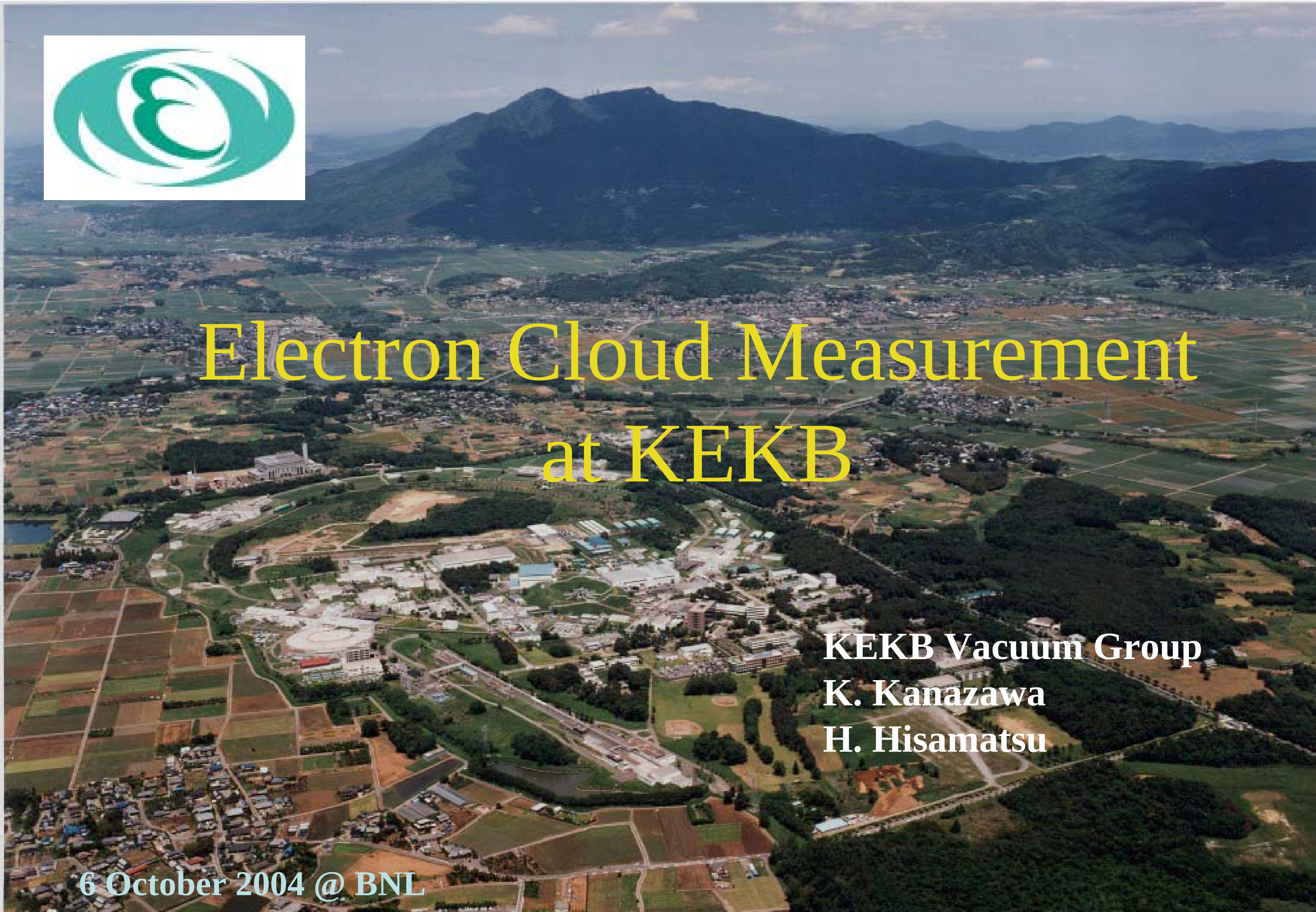


Electron Cloud Measurement at KEKB

KEKB Vacuum Group
K. Kanazawa
H. Hisamatsu

6 October 2004 @ BNL

KEKB

= Asymmetric Double-Ring Collider for B-Physics

8 GeV Electron (HER) + 3.5 GeV Positron (LER)

1989 Designing work starts.

1994 Budget approved. Construction starts.

Dec 1998 HER commissioning starts.

Jan 1999 LER commissioning starts.

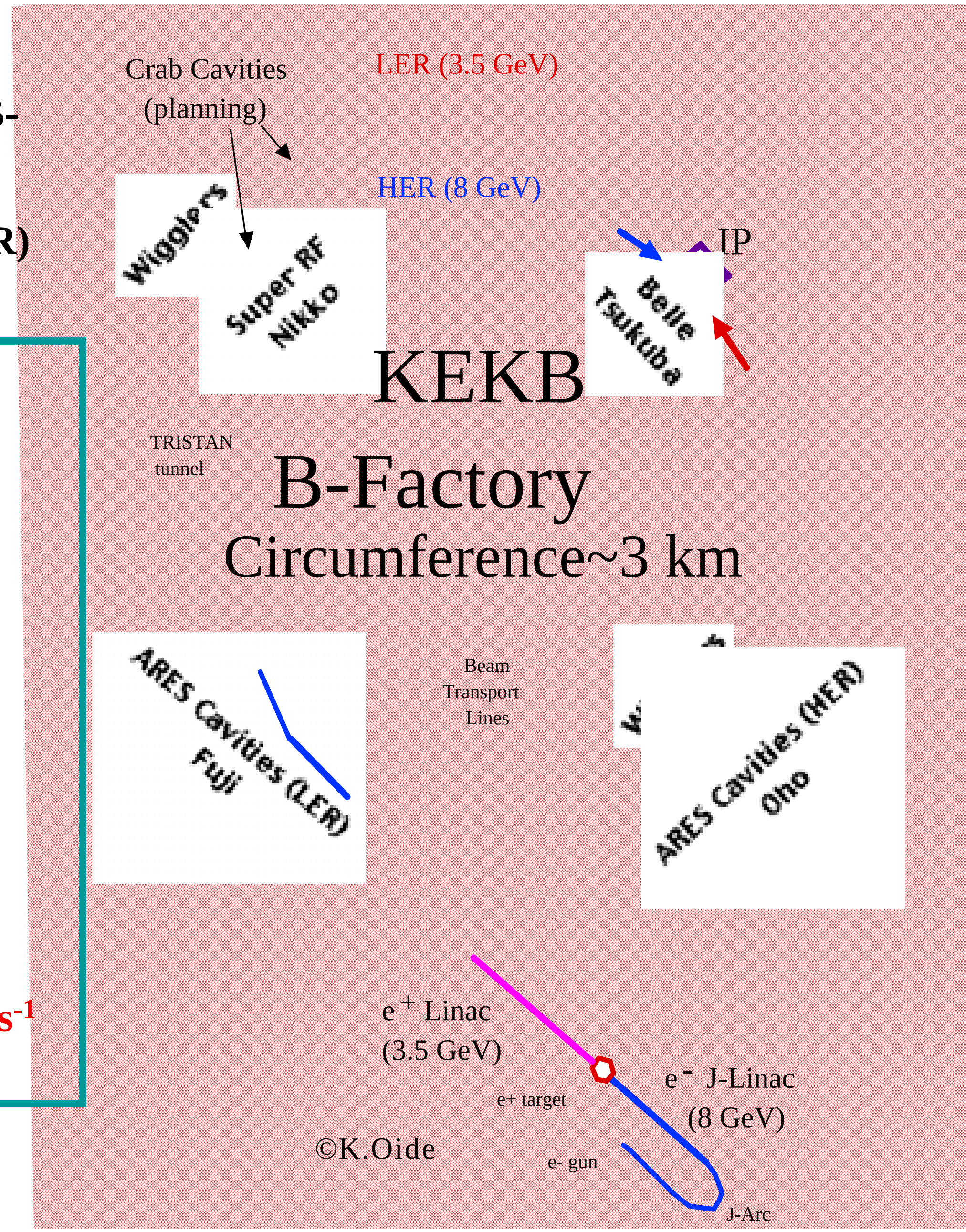
May 1999 Belle Detector rolls in.

Jun 1999 First signal in Belle.

Apr 2001 Luminosity world record (3.4 /nb/s)

Oct 2002 Integrated Luminosity world record (100/fb)

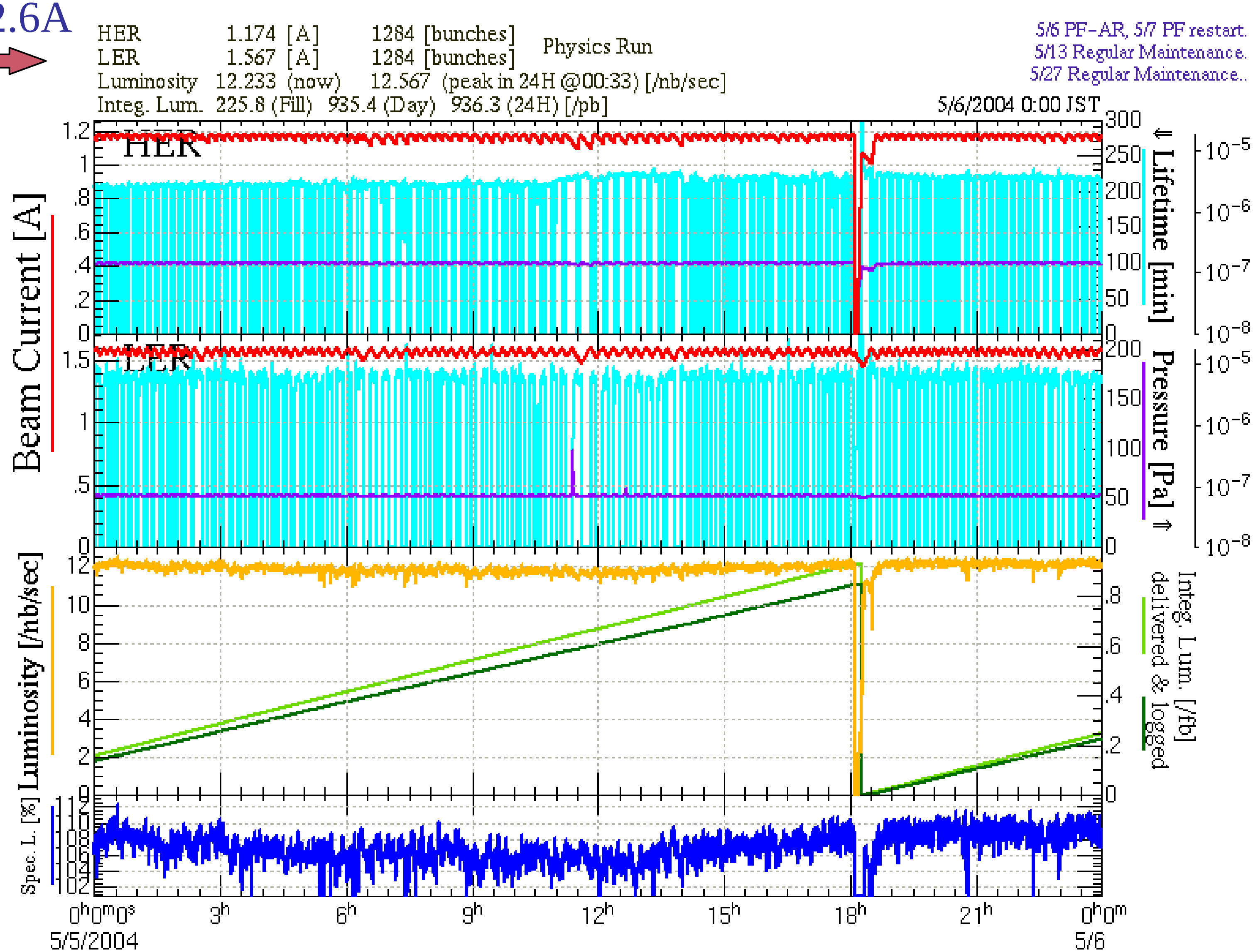
9 May 2003, 07:26 Design Luminosity $10^{34}cm^{-2}s^{-1}$ (10 /nb/s) was achieved。



Typical Operation of KEKB (One day)

Design current
HER=1.1A
LER=2.6A

3.77 bucket spacing, Bucket space = 0.59m (2ns)
Harmonic number = 5120



Pictures of Arc section

Two rings lie side by side horizontally.

Most vacuum chambers are made of OFC. The total number exceeds 2000.

LER lies inside.

HER lies inside.

Electron Cloud Problem in KEKB LER (Positron Ring)

1) Coupled bunch instability

Cured by the transverse feedback system.

2) Beam size blow up

Cannot achieve a higher luminosity by increasing the LER beam current.

• The effect of the cloud is stronger for a higher bunch current and a shorter bunch space.

Remedies:

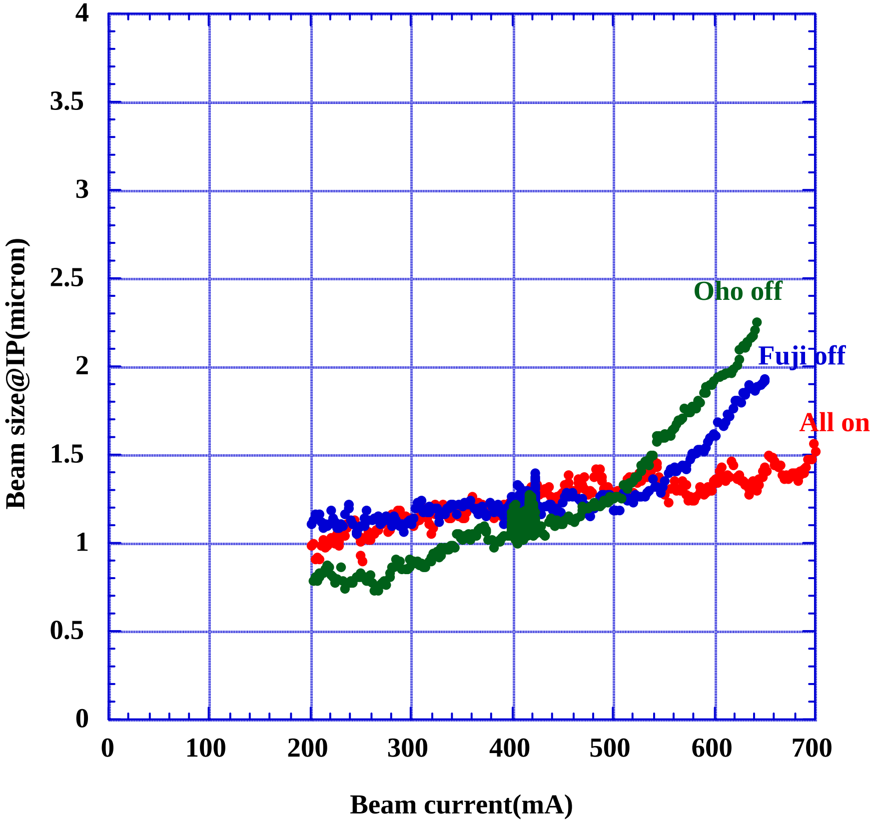
Solenoid (to confine electrons near the chamber wall): Nearly all drift spaces are covered

Antechamber (to remove photoelectron): under test

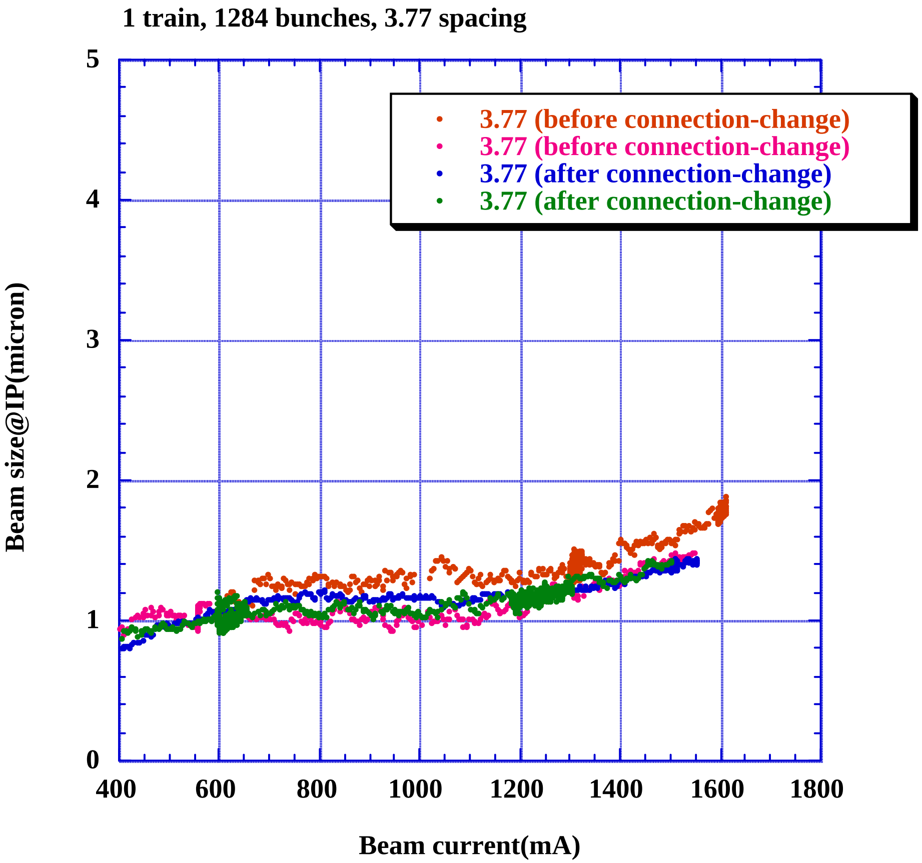
NEG, TiN coating (to stop multipacting): under test

Effect of Solenoid on Electron Cloud

[H. Fukuma]



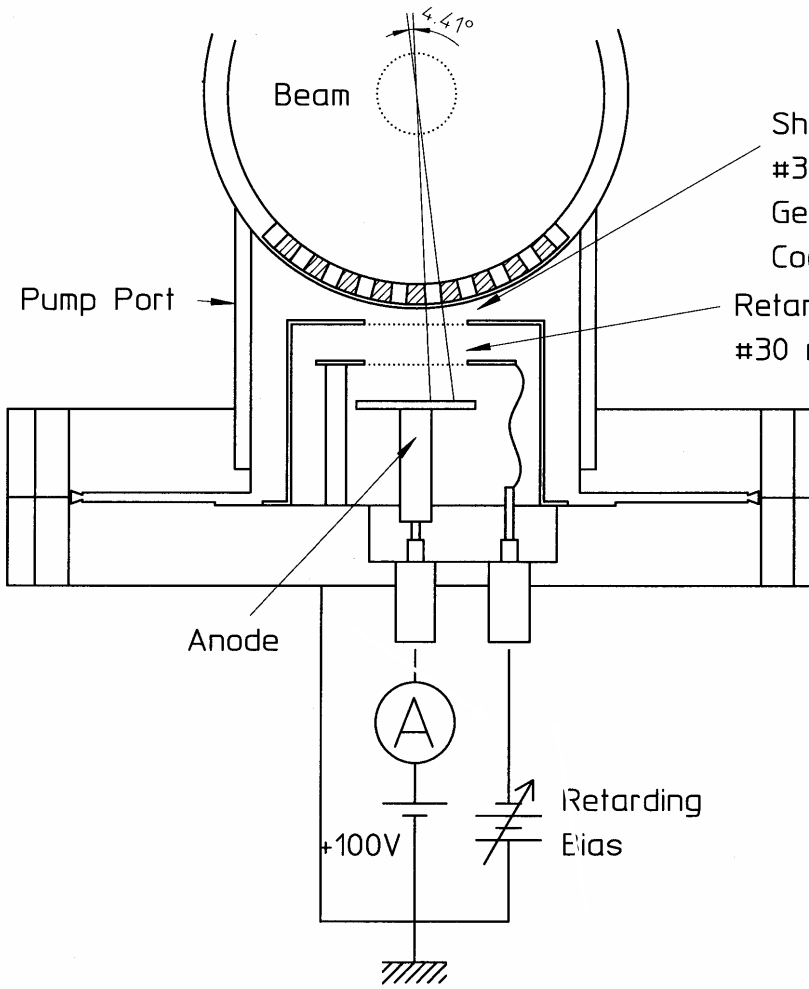
The effect of the total length of a solenoid field on the vertical beam size.

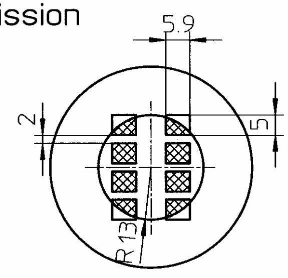


Even with a solenoid field (~30 Gauss), the vertical beam size starts to grow at the LER beam current of 1.2 A.

Electron Monitor

Measures electrons that hit the chamber wall.



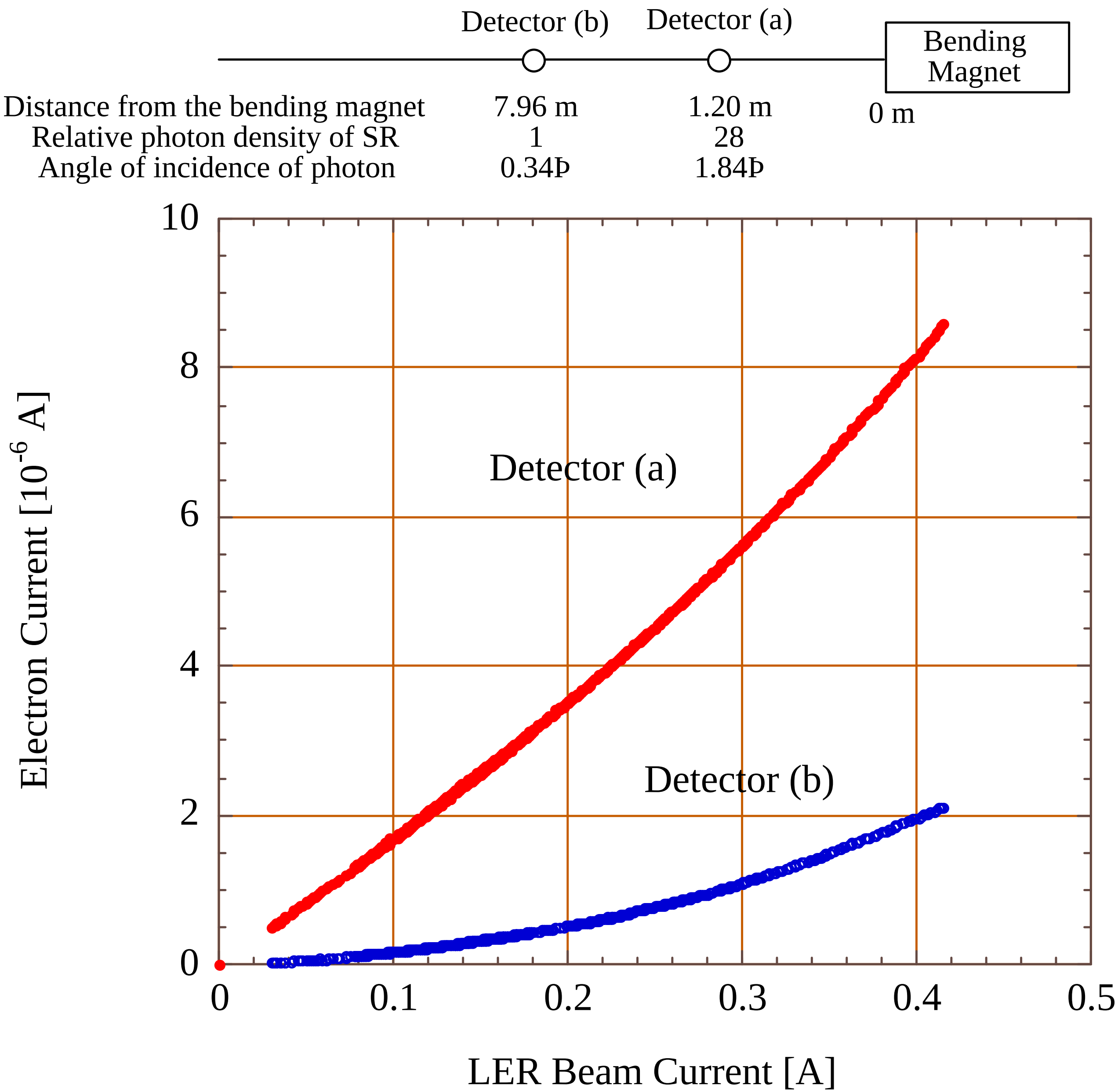


Acceptance
for fast electron

Pump port

Electron Monitor (Modified Type)

DC Measurement (1)

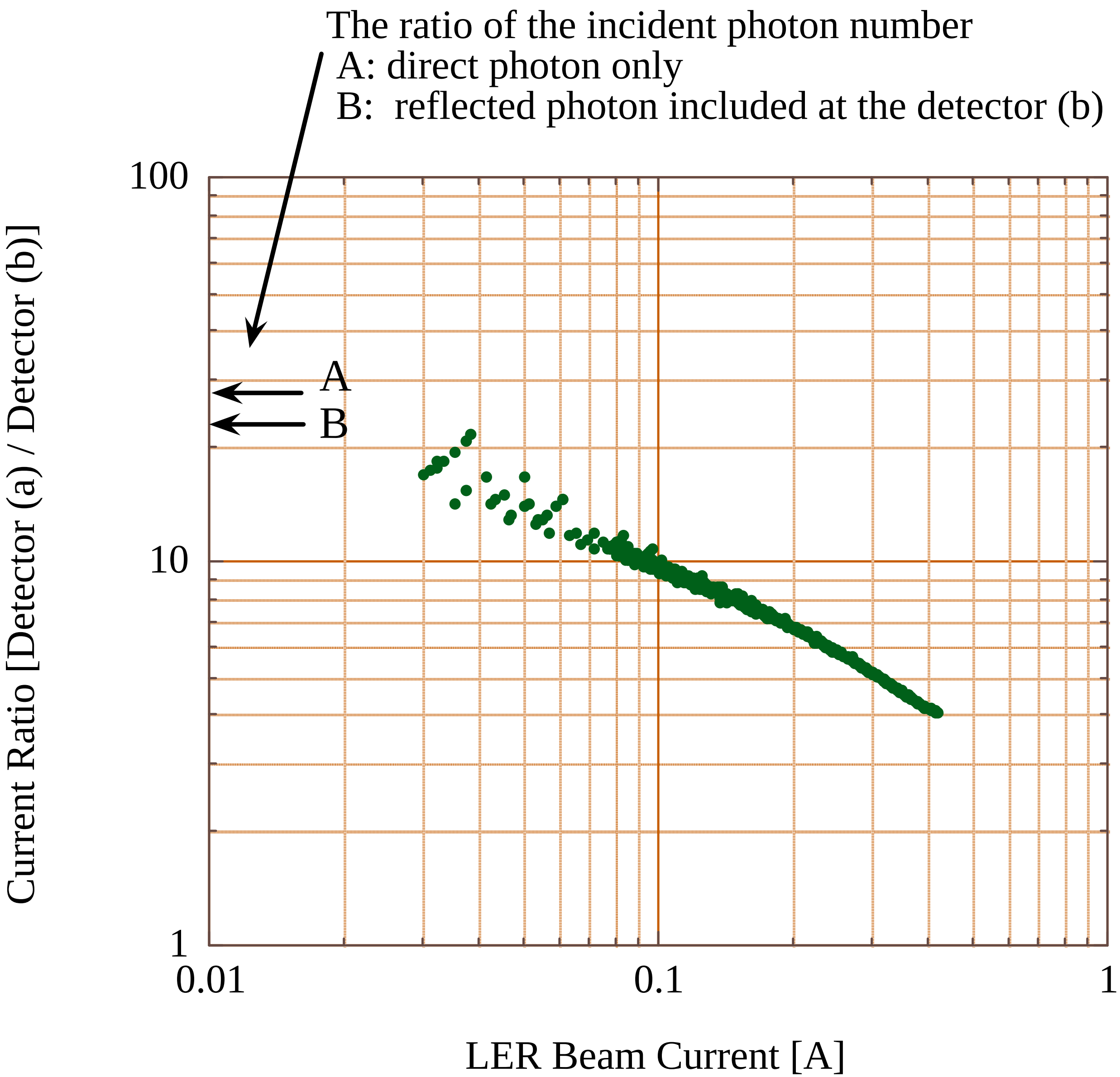


Electron monitors are set downstream of a bending magnet.

The measured electron current reflects the intensity of synchrotron radiation (SR) at each location.

Photoelectron is a source of the electron cloud.

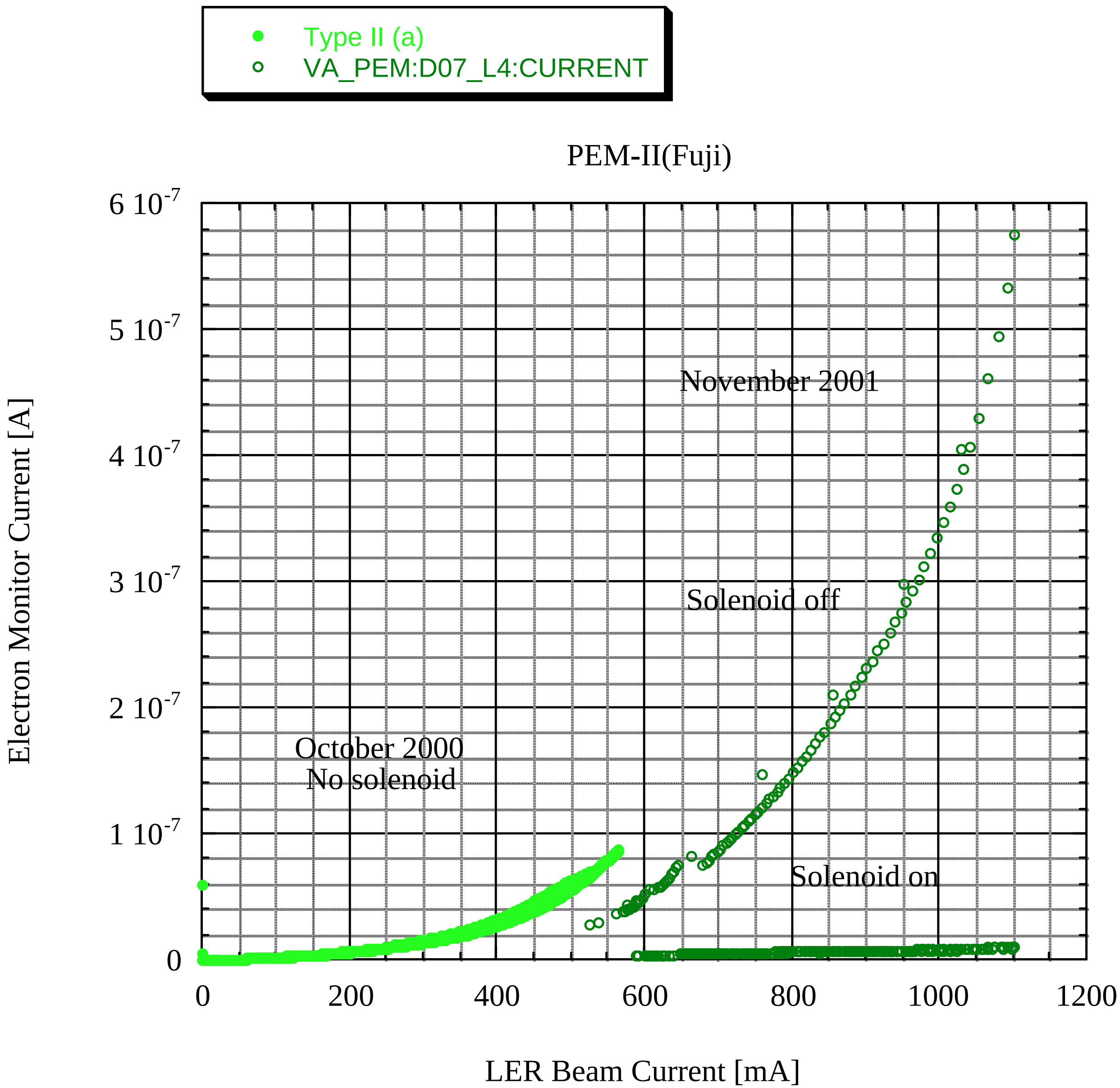
DC Measurement (2)



The ratio of the electron current of the previous measurement is different from that of the intensity of SR.

This suggests that SR is not an only source to determine the density of the electron cloud.

DC Measurement (3)

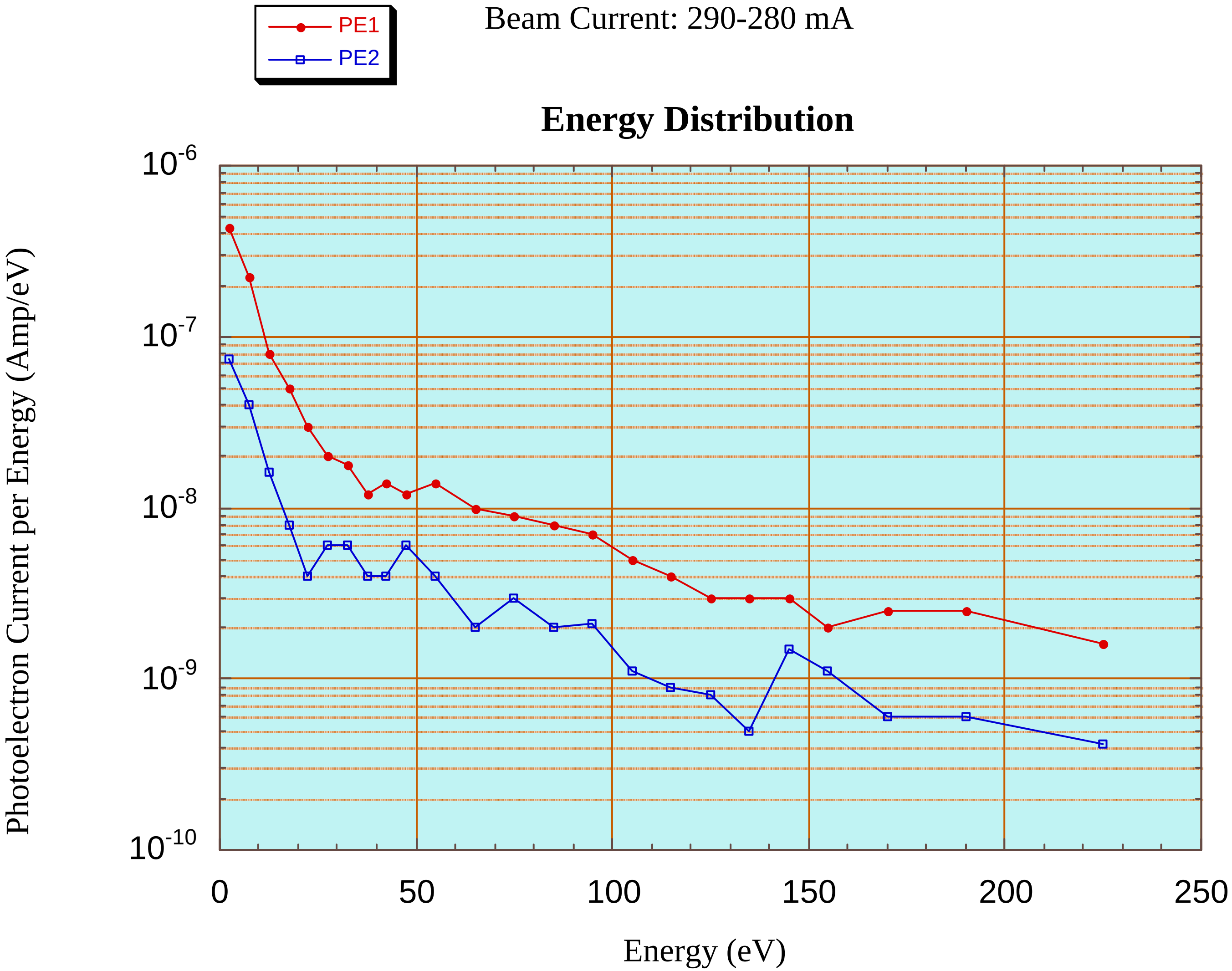


Measurement at a location where SR is negligible.

Very steep increase of the electron current with respect to the stored positron current is observed.

This shows the existence of another process to build up the electron cloud, that is the multipacting process first proposed by O. Gröbner.

DC Measurement (4)

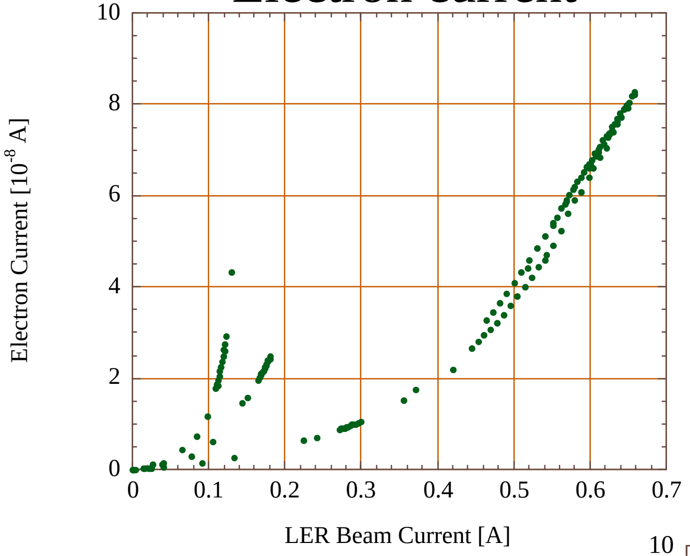


Example of an energy distribution of obtained by the electron monitor.

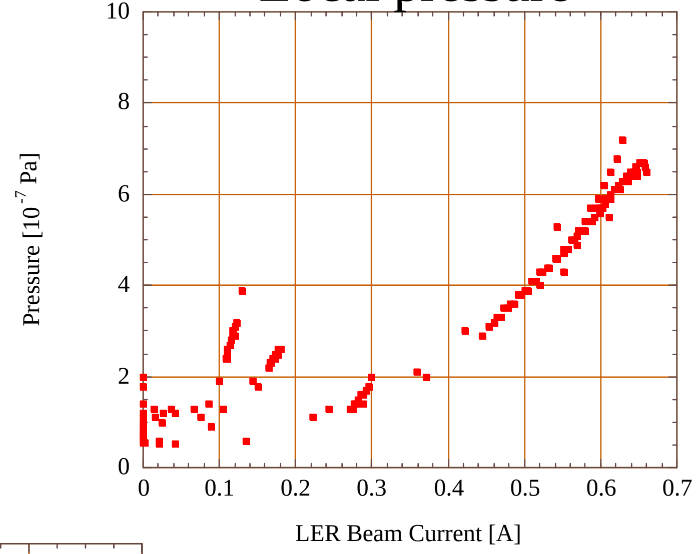
DC Measurement (5)

Correlation between Pressure and Electron Current

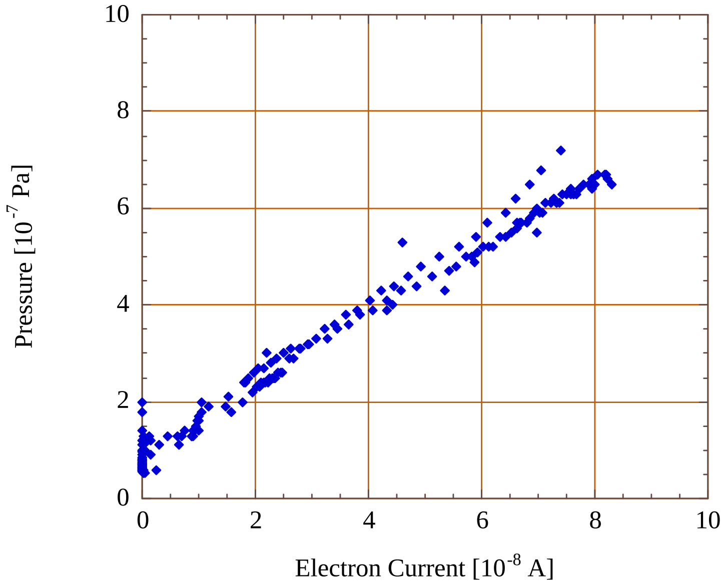
Electron current



Local pressure



Good Correlation

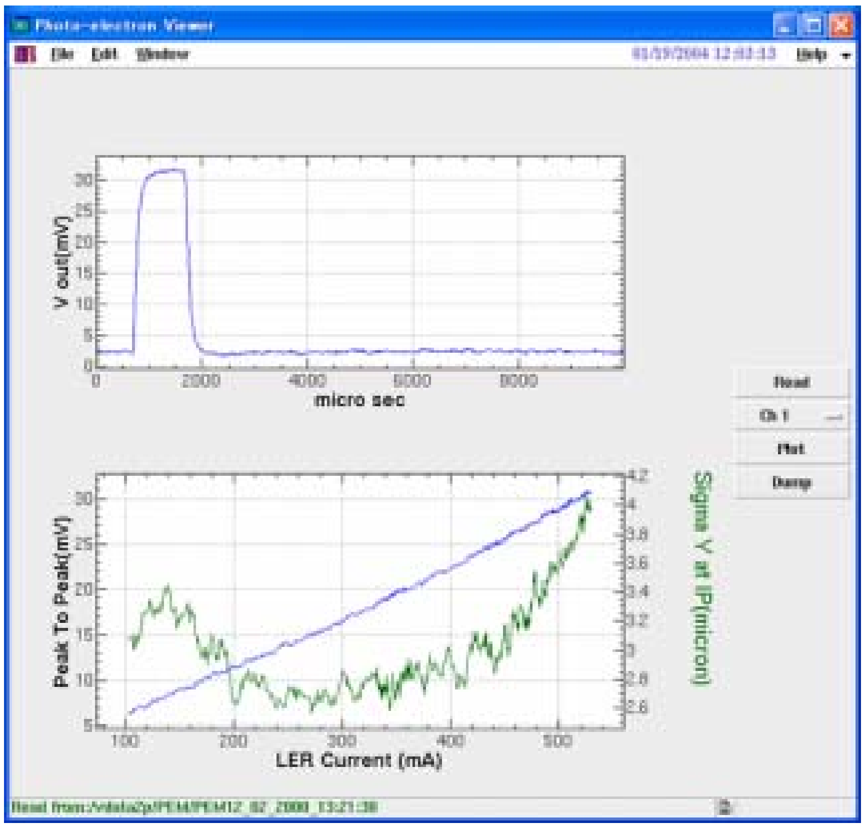


Vacuum pressure is a good indicator on electrons hitting a chamber wall.

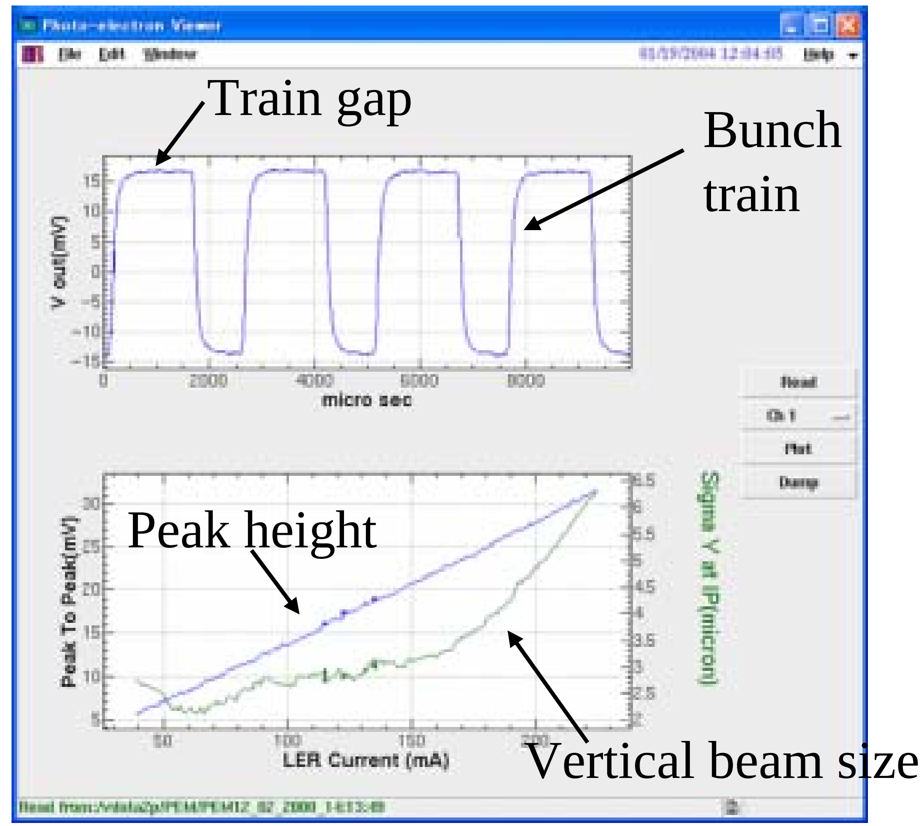
Fast Measurement (1)

[with Y. Onishi, M. Tanaka, and T. Murakami]

The time variation of an electron current corresponding to the bunch pattern is measured. This type of measurement is possible only when the electron current is sufficiently high.



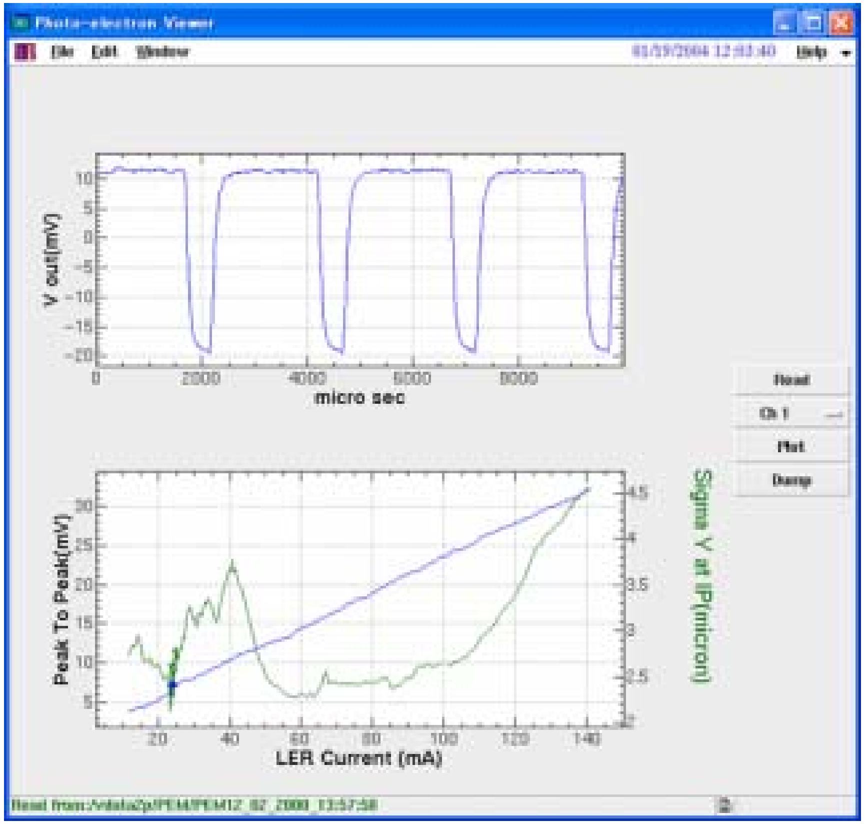
[16 train, 80 bunch/train, every 4 bucket]
Only the abort gap is seen.



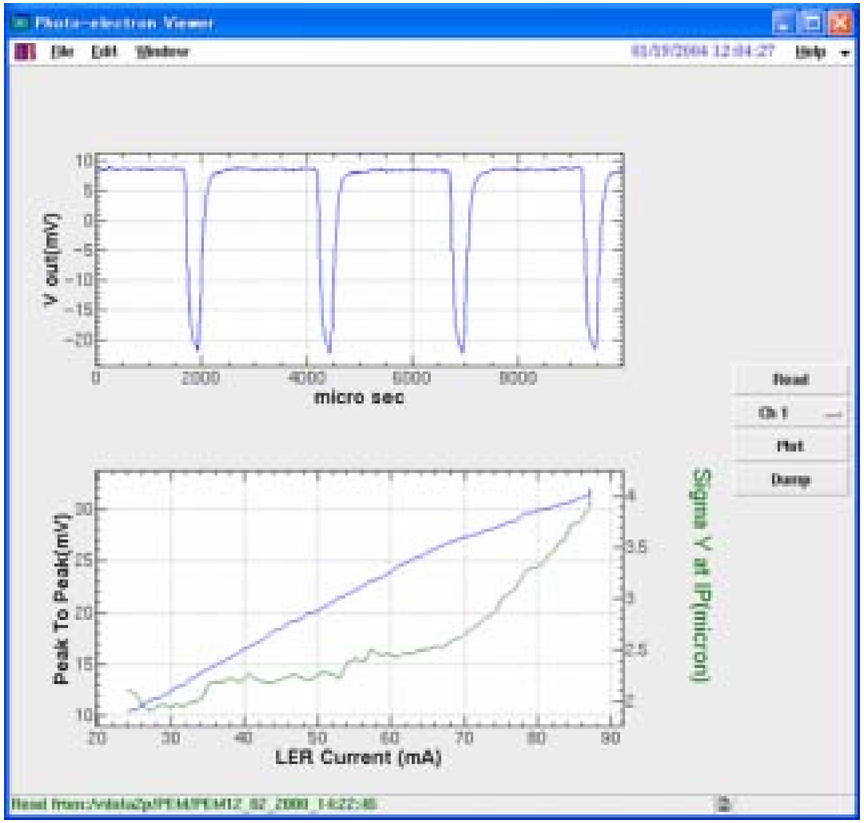
[4, 60, 8]

Fast Measurement (2)

The location of the electron monitor is same as Detector (a) in the sheet ‘DC Measurement (1)’



[4, 60, 4]



[4, 60, 2]

Fast Measurement (3)

· **Summary of the blow up threshould observation by the fast measurement**

1) The electron current is associated with the bunch train.
2) The threshould of the blow up corresponds to the almost same peak height of the electron current .
3) The peak height of the electron current looks proportional to the line density of charge in the train.

(Where photoelectrons are dominant seeds of a cloud)

Blow up Threshold Observation

Bunch Pattern	LER current at the threshould [mA]	Peak height of electron current at thr threshould [mV]	Line density of LER current in the train at the threshould [mA/bucket]
[16, 80, 4]	440	25	0.09
[4, 60, 8]	175	24	0.09
[4, 60, 4]	104	24	0.11
[4, 60, 2]	70	27	0.15

Estimation of Cloud Density near the Beam from DC measurement (1)

Basic Idea:

In LER, electrons in the cloud receive an impact force when a relativistic short(~7mm) bunch passes by. An electron closer to the bunch gains a higher energy.

LER has a bunch space of 6 ~8ns (3~4 bucket). After 6~8ns from the impact by the preceeding bunch, most remaining electrons in a duct have a low energy (except few multiply reflected electrons from a duct wall). By the encounter with the next bunch, high energy electrons are produced in the narrow volume around the beam.

- Most high energy electrons are produced by a single encounter with a bunch in the narrow volume around the beam.
- Given a retarding bias and a bunch charge we can estimate the volume from which observed high energy electrons come.

Estimation of Cloud Density near Beam from DC measurement (2)

Formulation

- An electron at a lateral distance r from a bunch gains a kinetic energy,

$$K.E = \frac{1}{2m} p^2 = mc^2 2\left(\frac{r_e N_b}{r}\right)^2$$, where

N_b = Bunch population, r_e = Classical electron radius.

By applying a retarding voltage V_b, only electrons within r enter the monitor,

where r is given by, $r^2 = 2\frac{mc^2}{eV_b} N_b^2 r_e^2$.

Due to the monitoring geometry, the electron monitor sees a part of the cylinder,

$V_{obs.vol}(V_b) = F_m L_a r^2$, where

$L_a = 1.2 \times 10^{-3}$ $[m]$,

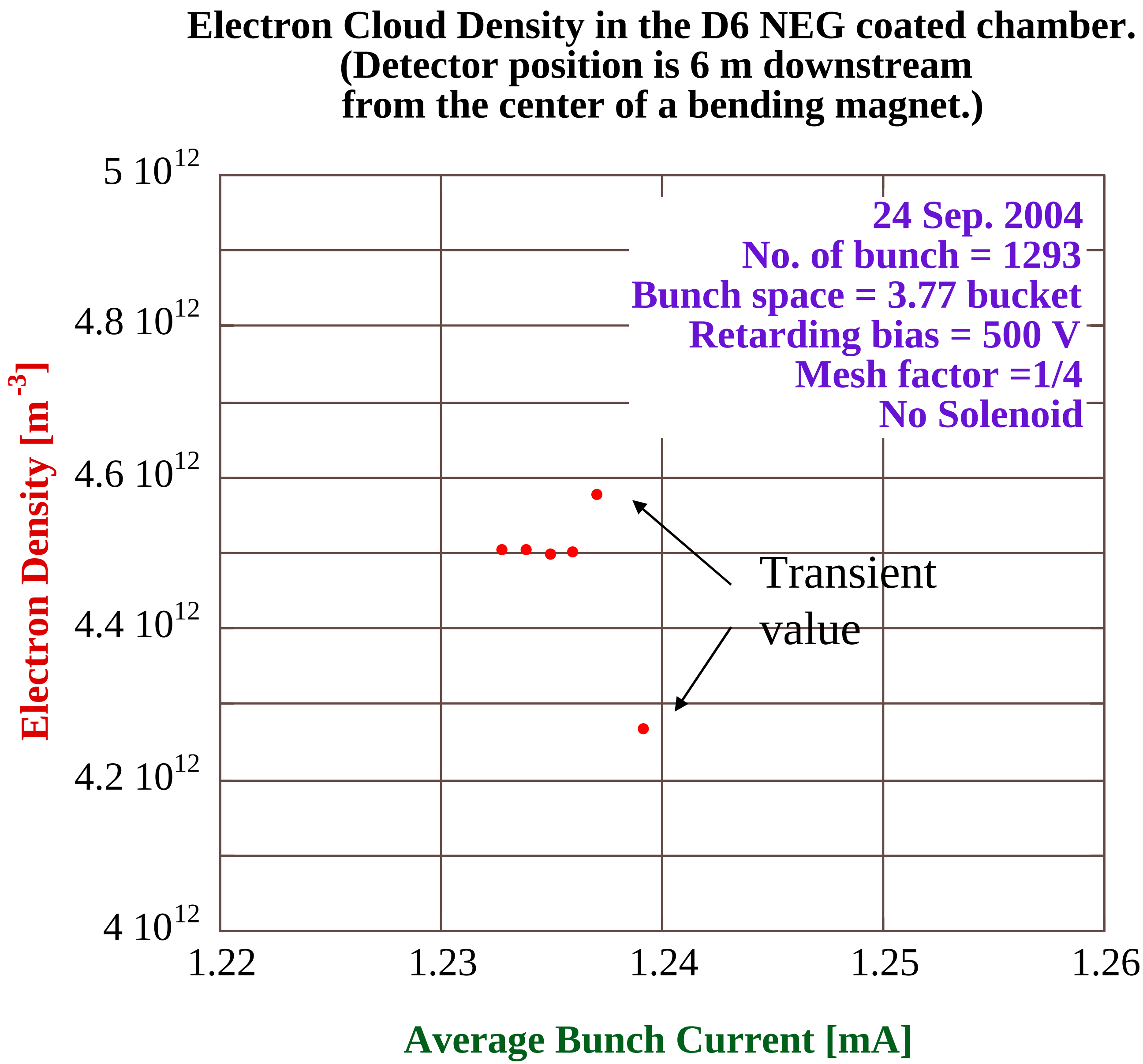
F_m = Mesh factor, depending on an overlapping pattern of two # 30 meshes

this value varies from $1/2$ to $1/6$.

- Electron current per bunch : $N_e(V_b) = \frac{I_e(V_b)}{en_b f_{rev}}$, n_b = Number of bunch

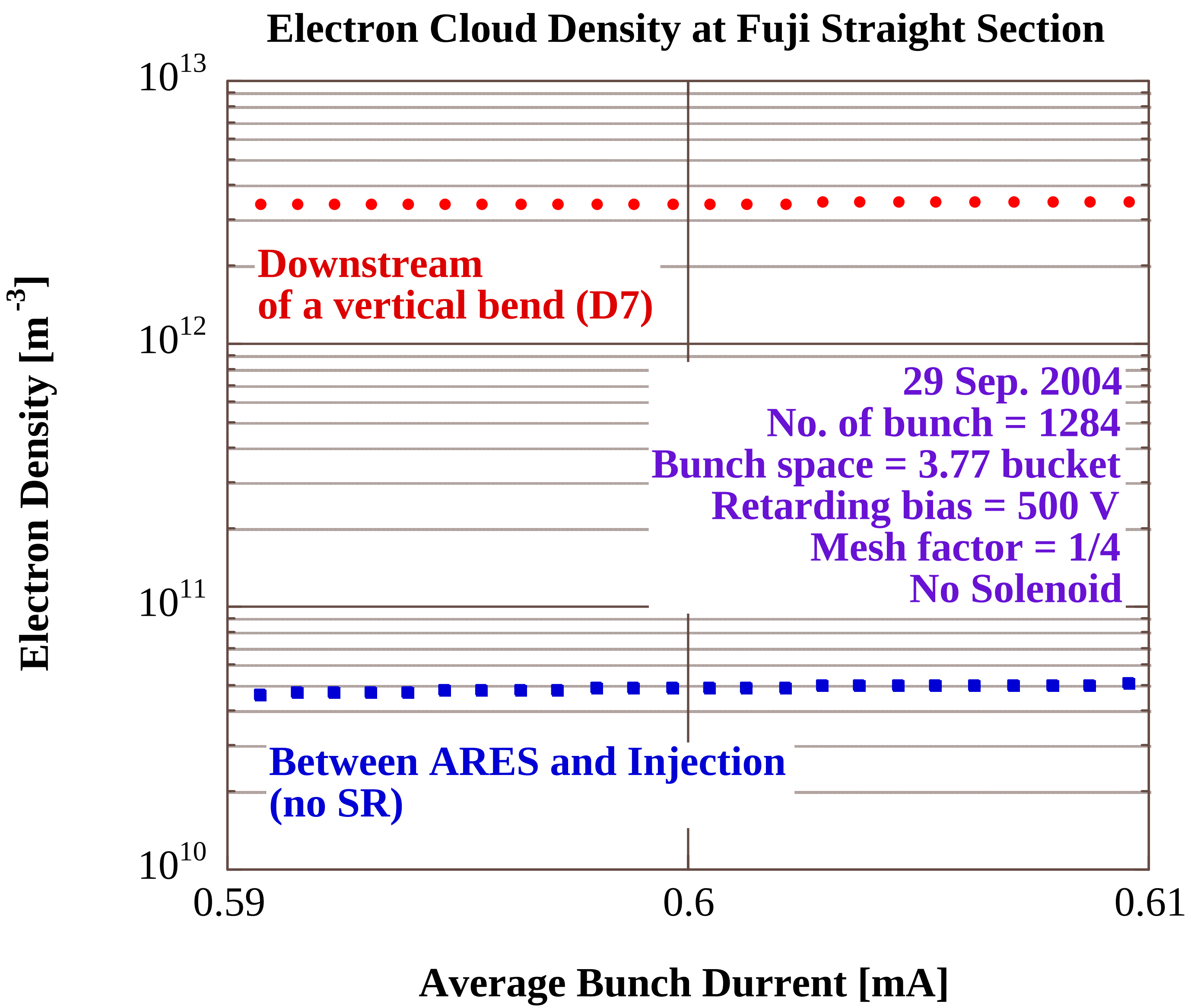
- Density of Cloud : $D = \frac{N_e(V_b)}{V_{obs.vol}(V_b)}$

Estimation of Cloud Density near Beam from DC measurement (3)

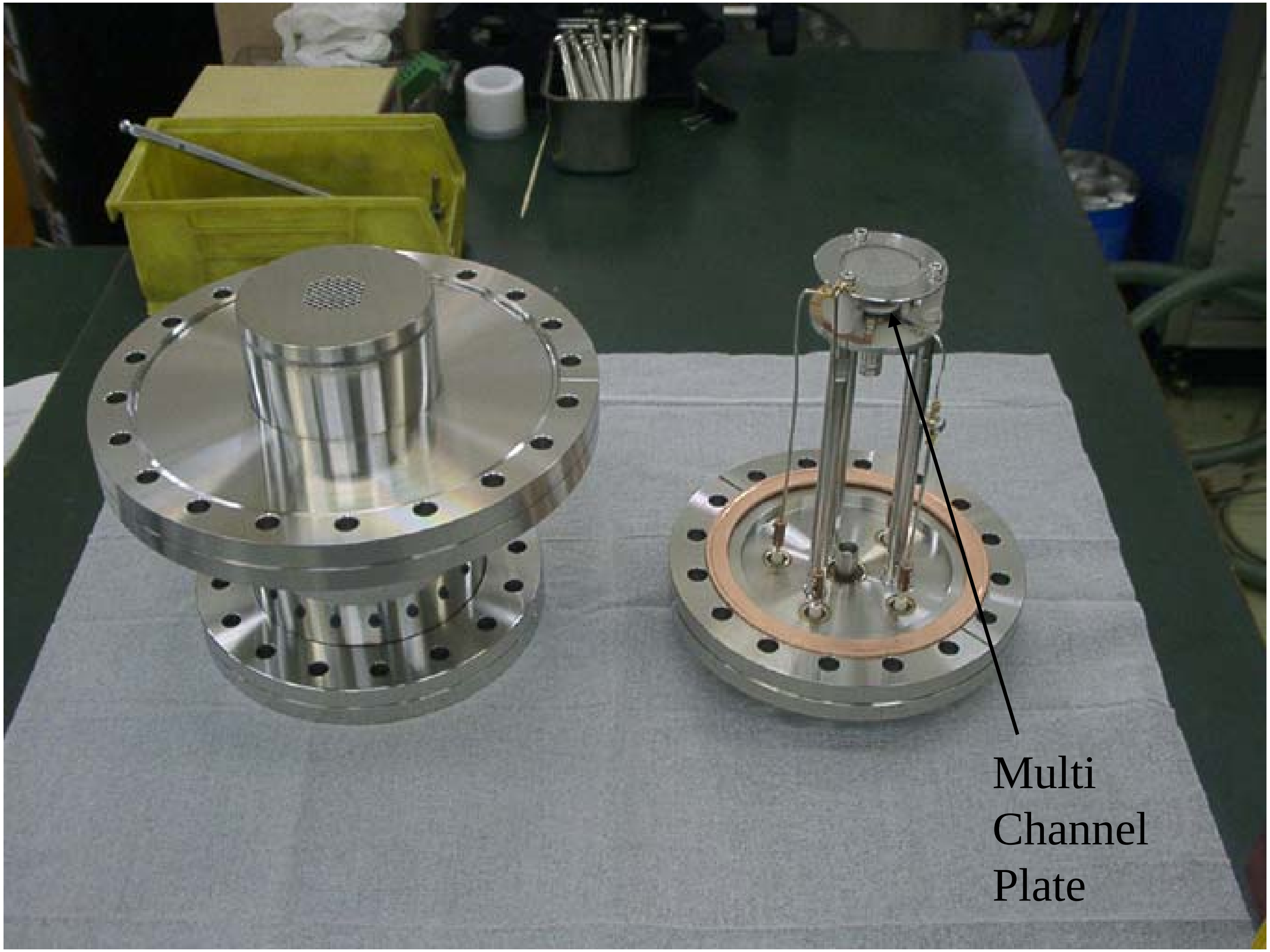


Estimated density is close to the simulation.

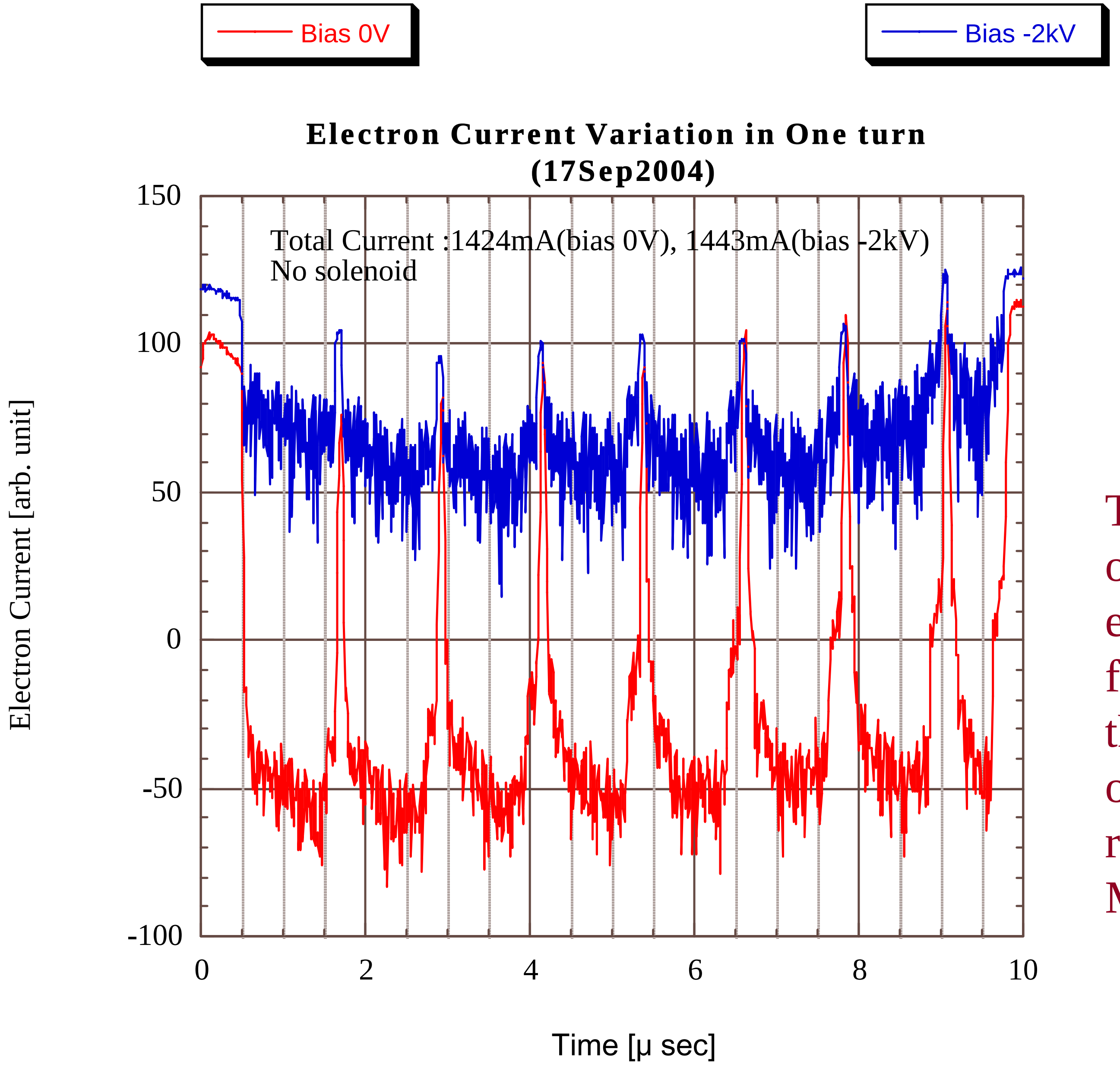
Estimation of Cloud Density near Beam from DC measurement (4)



Electron Measurement by MCP (Preliminary) (1)

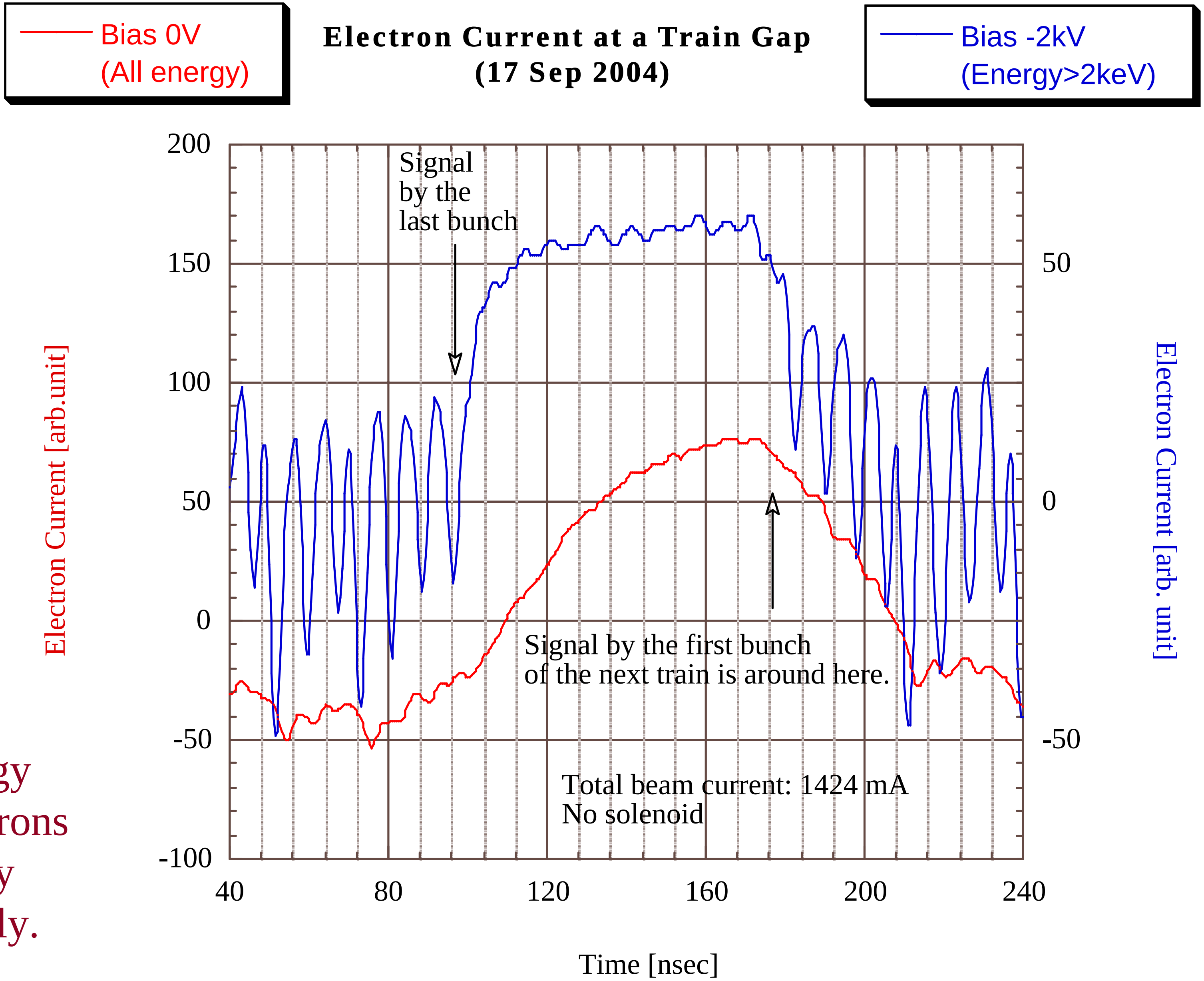


Electron Measurement by MCP (Preliminary) (2)



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

Electron Measurement by MCP (Preliminary) (3)



Low energy electrons decay slowly.

Summary of the Observation

1. Photoelectrons due to synchrotron radiation contribute to the electron cloud density.

2. The electron cloud density is multiplied by the multipacting process.

3. An electron monitor current and a nearby pressure have a good correlation.

4. Monitored current is associated with the bunch train.

5. Beam blowup starts at the nearly same peak current.

6. By measuring high energy electrons that enter the detector by a single kick by a bunch, the density of the cloud can be estimated. The results supports the simulation.

7. Using a MCP, the time variation of electron current can be observed with the nano-second resolution even though the MCP is operated in an unusual range.