Recent Electron-Cloud Mitigation Studies at KEK

E-cloud mitigation mini-workshop on 20-21 November at CERN

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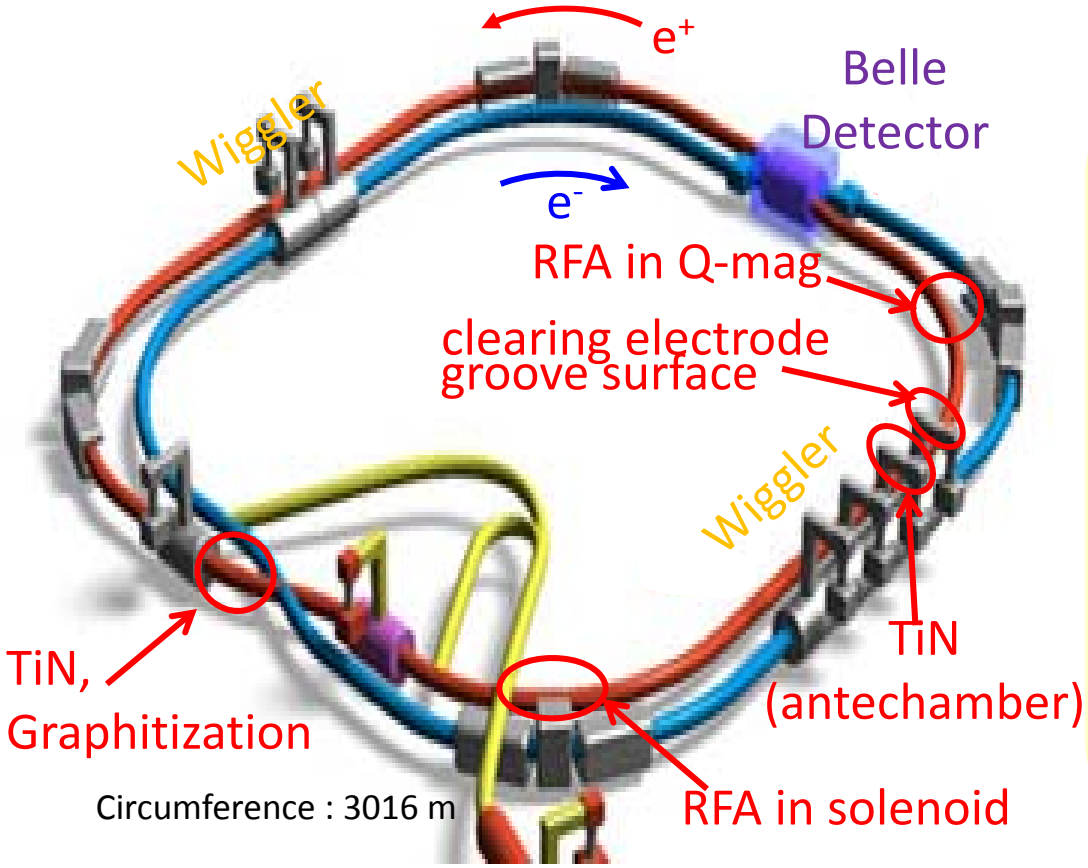
Introduction

- KEKB : double ring collider with one collision point
  - High Energy Ring (HER) : Electron ring

    Energy : 8 GeV, Current : ~970 mA, bunch space : 3~6 ns, bunch charge : ~0.9×10^{-8} C
  - Low Energy Ring (LER) : Positron ring

    Energy : 3.5 GeV, Current : ~1600 mA, bunch space : 3~6 ns, bunch charge : ~1.2×10^{-8} C



E-cloud study items at LER

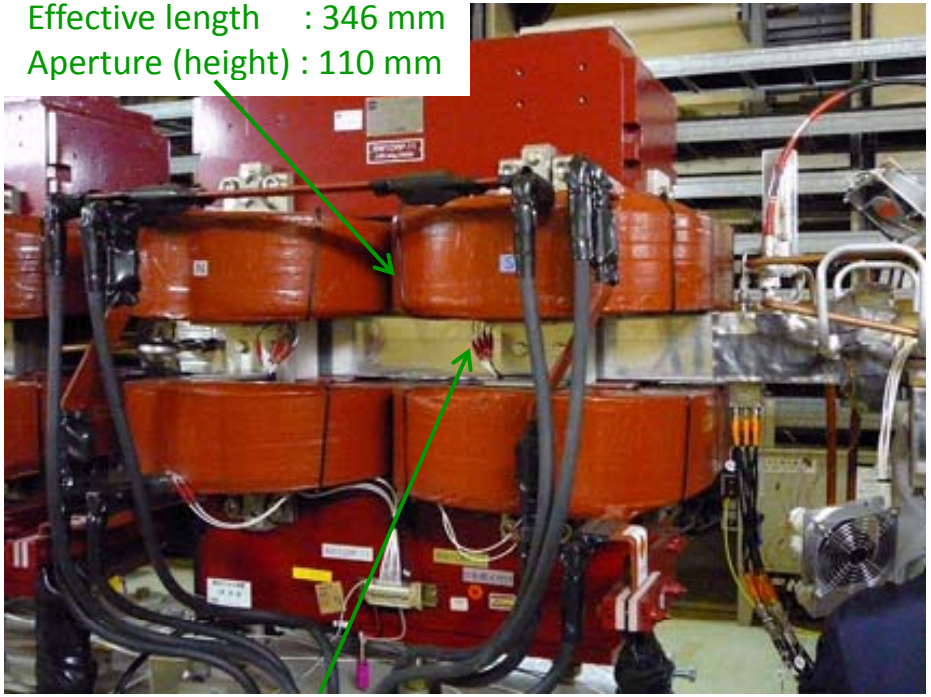
- Clearing electrode
- Groove surface
- TiN coating
- Graphitization
- RFA type electron detectors
- Beam duct with antechambers
- and so on…

Clearing Electrode 1

- Mitigation of E-cloud in Magnets
  - Clearing electrode and electron detector was installed in Wiggler magnet. (placed at the center of pole)
  - To ascertain the effect of electrode, the electron density was measured from just under electrode.
  - Tolerance for high beam current was also tested.

Wiggler magnet

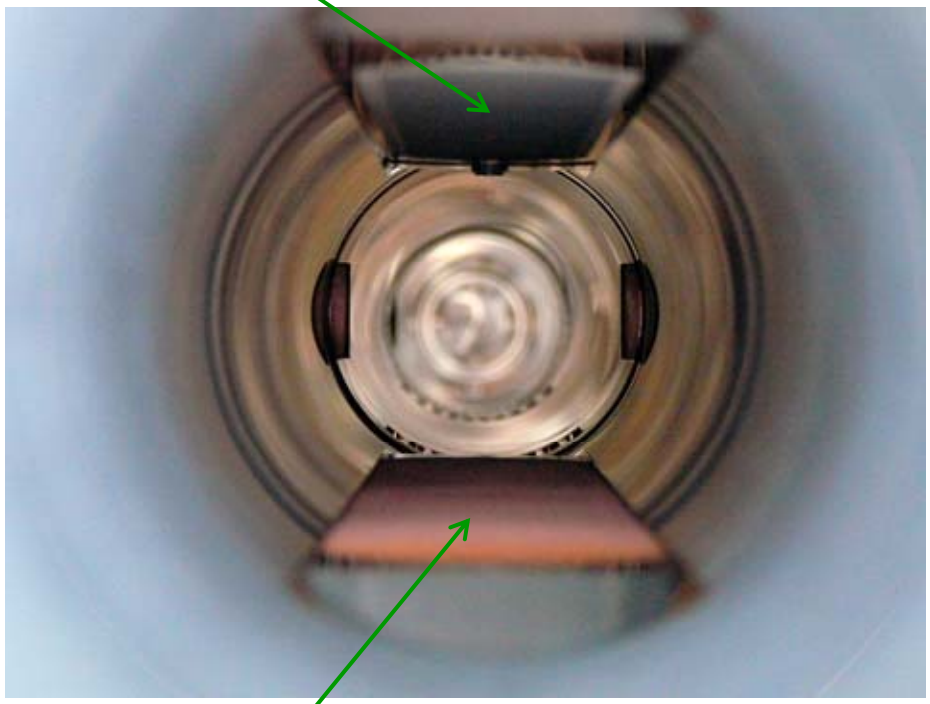
Magnetic filed : 0.77 T
Effective length : 346 mm
Aperture (height) : 110 mm



Test chamber

Clearing electrode

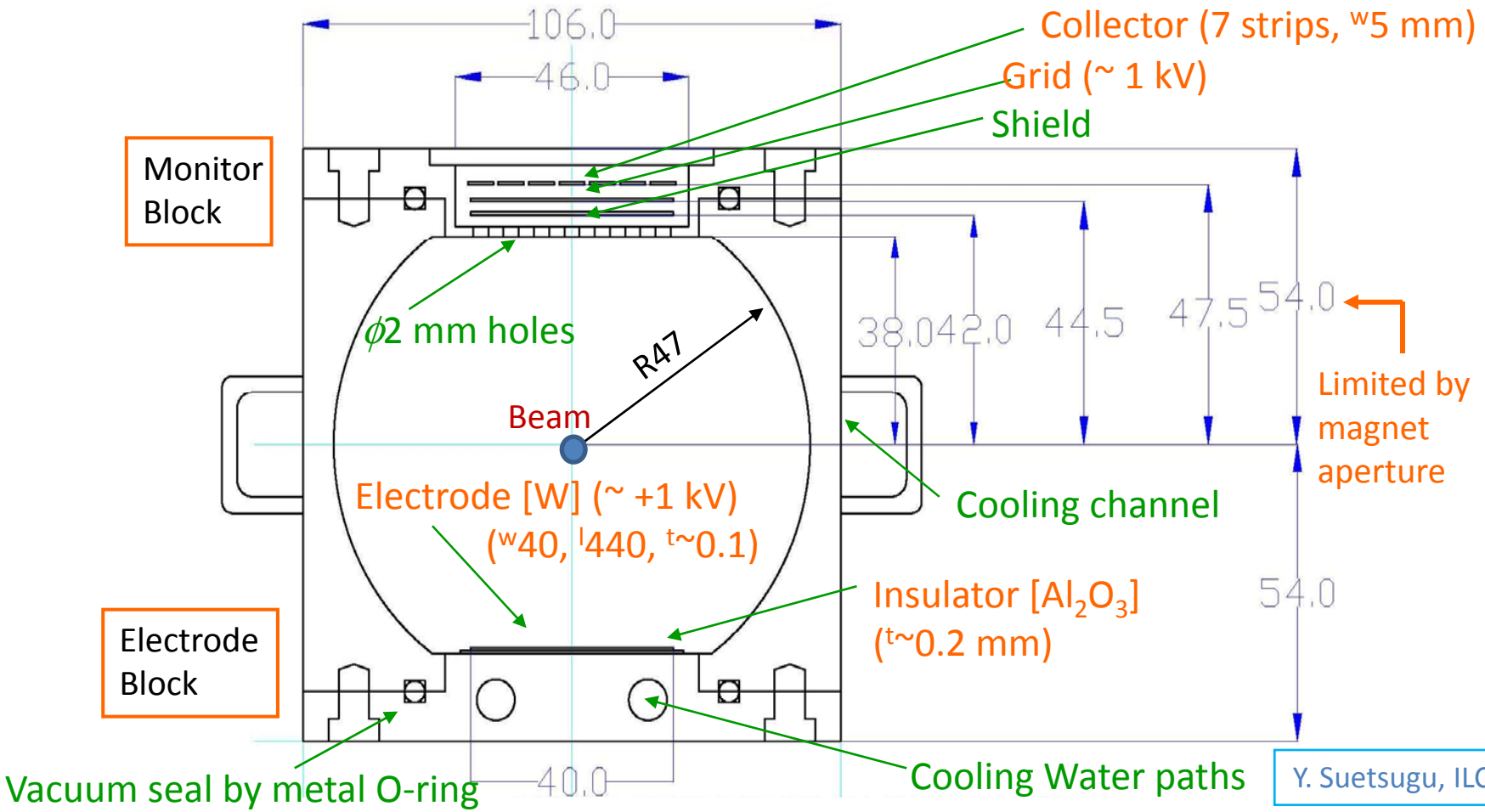
Y. Suetsugu, ILCDR2008



Electron detector

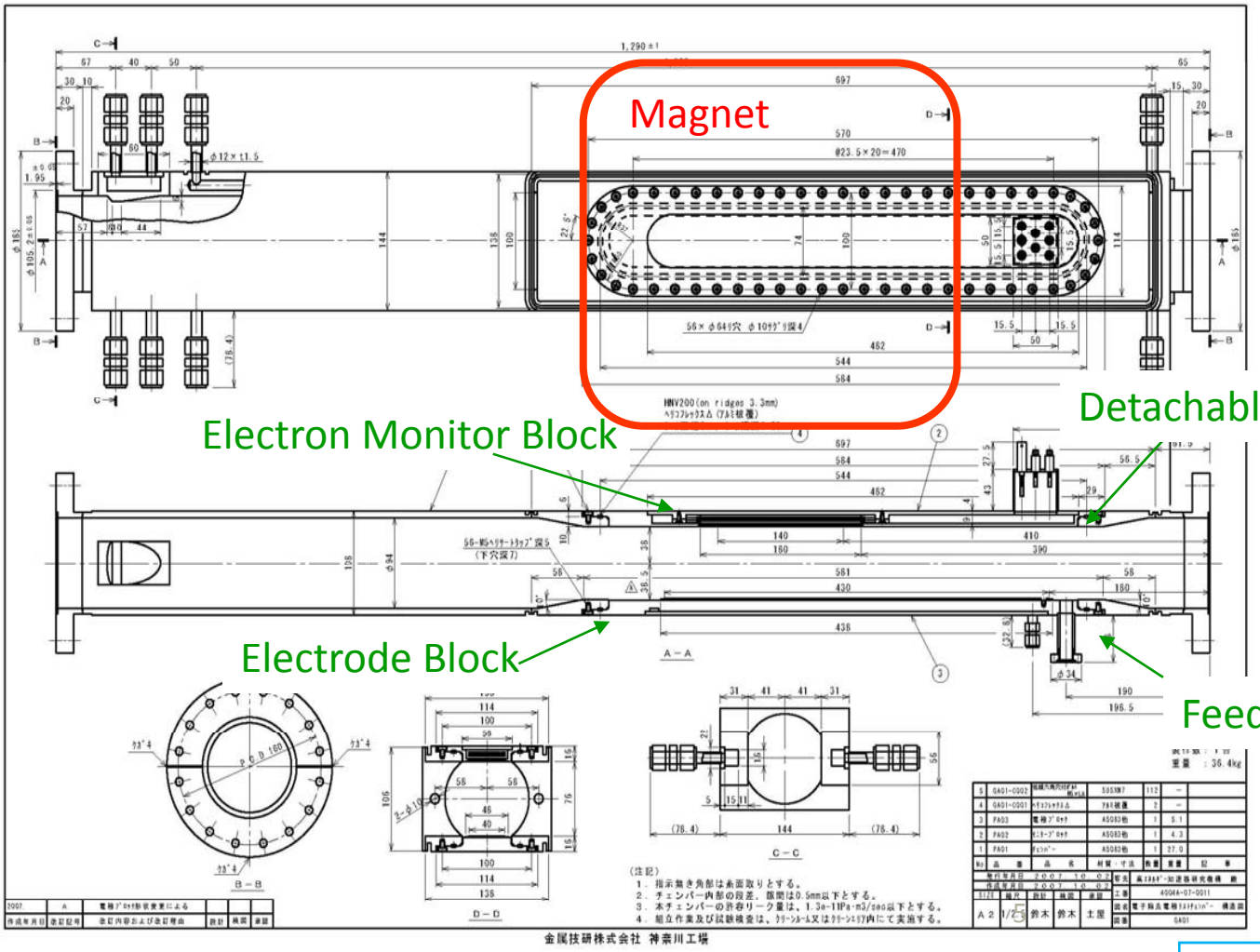
Clearing Electrode 2

- Cross-section Drawing
  - Very thin electrode (0.1 mm, Tungsten) and insulator (0.2 mm, Al_2O_3) were developed.
  - 7 strips measure the horizontal spatial distribution of the e-cloud.



Clearing Electrode 3

- Top view & side view



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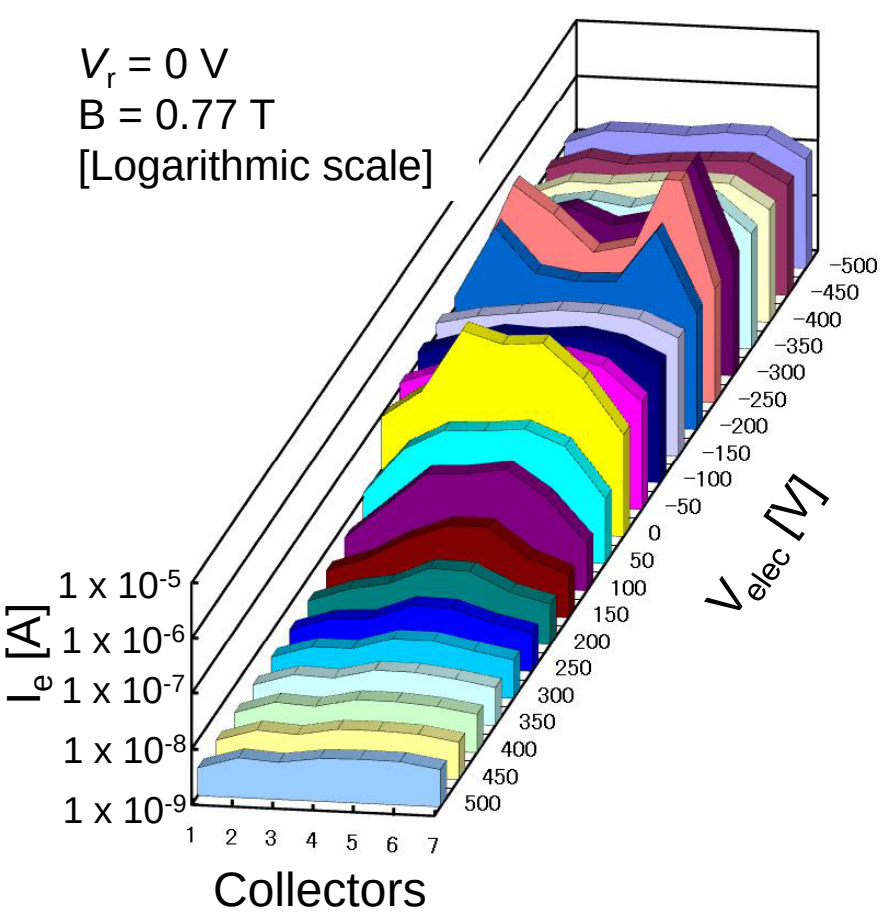
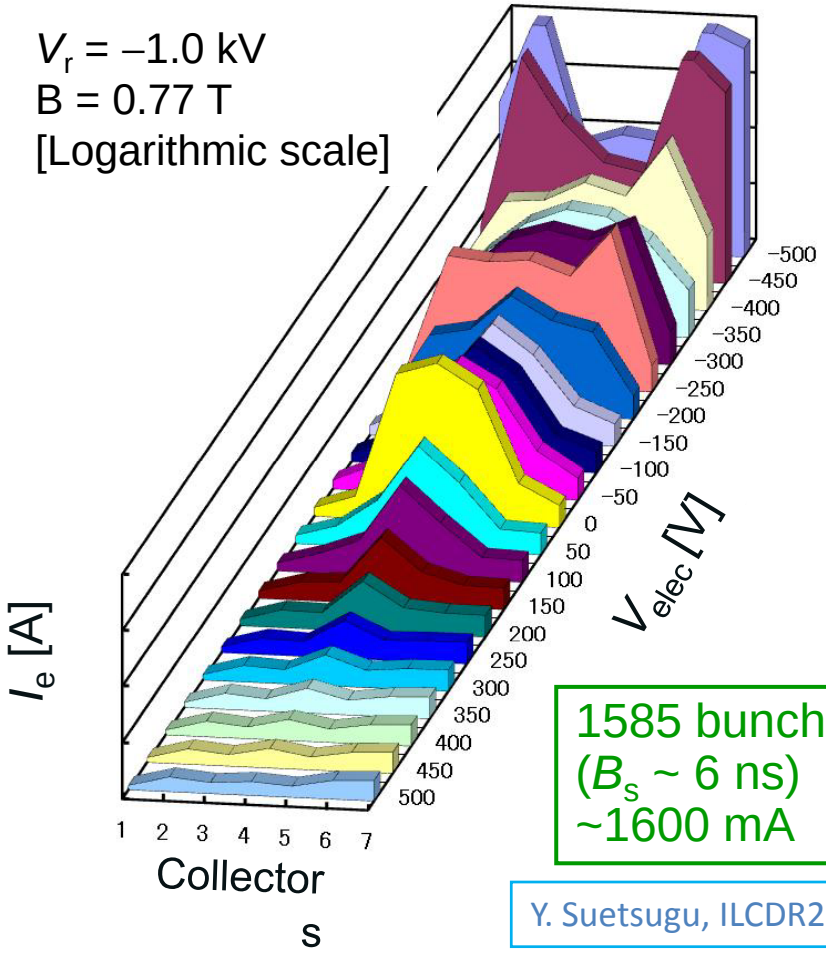
Clearing Electrode 4

- Results
  - Drastic decrease in electron density was demonstrated by applying positive voltage.





1585 bunches
(B_s ~ 6 ns)
~1600 mA

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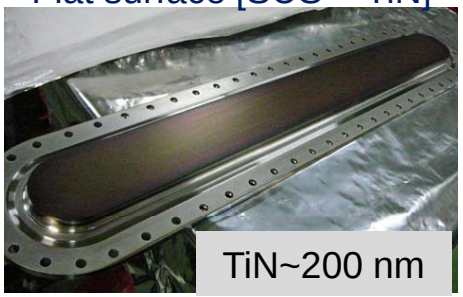
Groove surface (preliminary)

- Effect of groove surface will be ascertained this autumn.
  (collaboration with SLAC)
  - Electrode will be replaced by groove surface.
  - Same setup for clearing electrode is utilized.
  - Groove structure was designed and manufactured in SLAC.
  - Flat surface with TiN coating is now tested for reference.

Flat surface [SUS + TiN]



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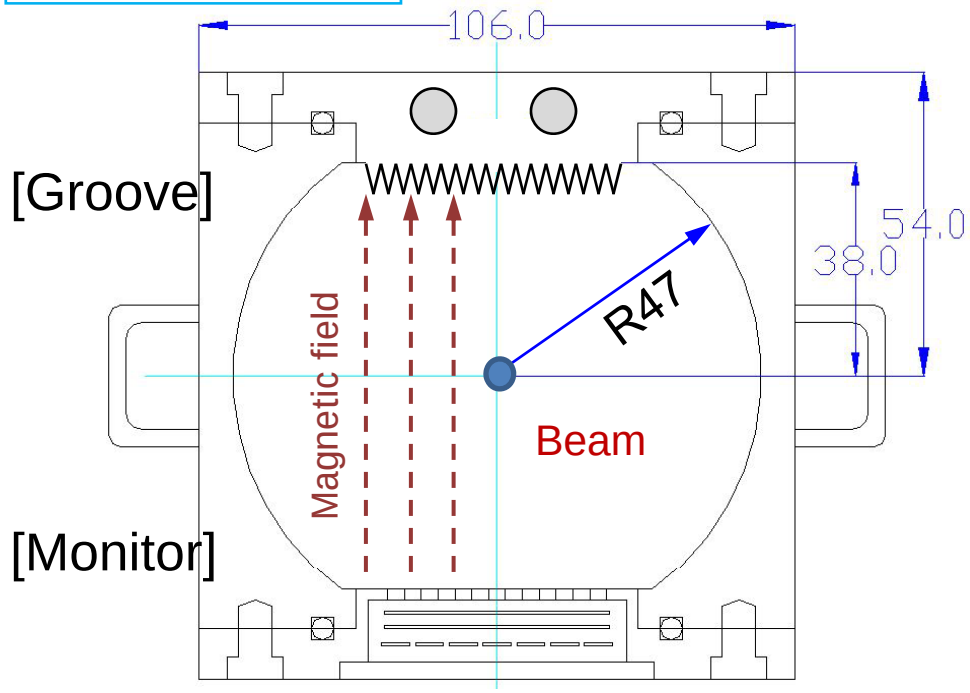
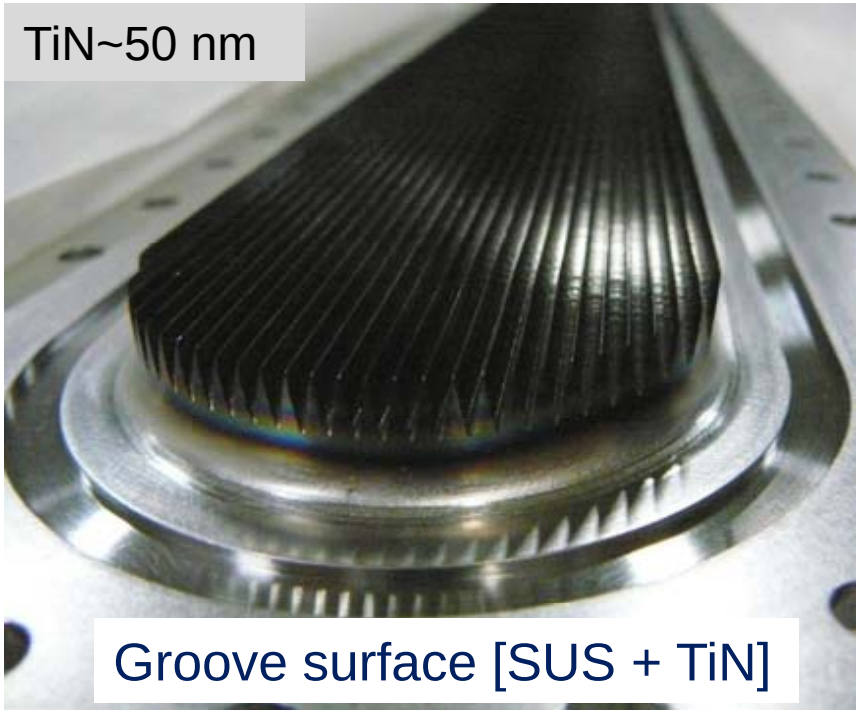
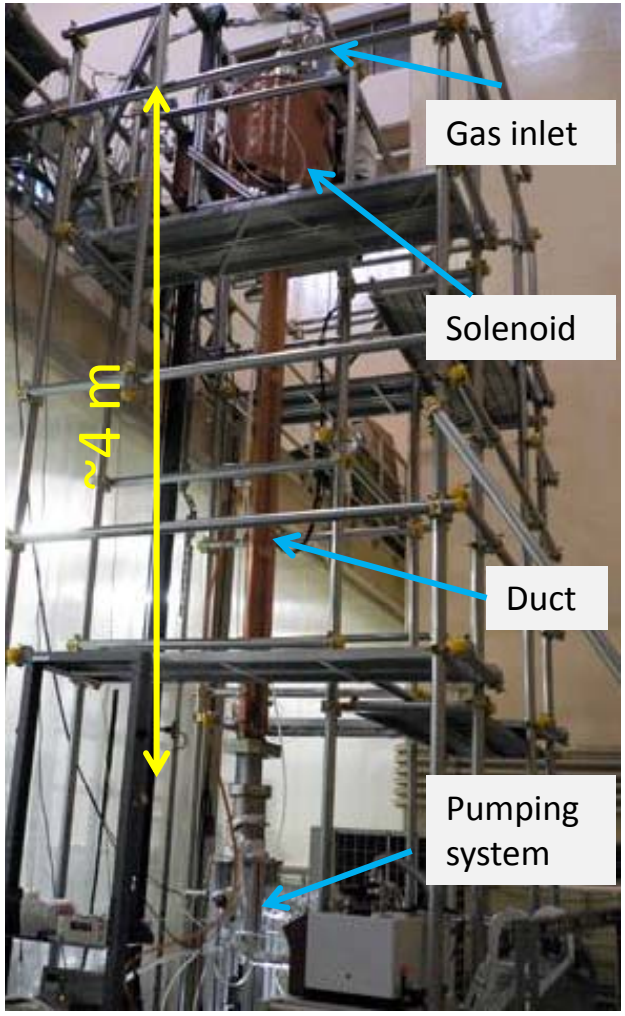




TiN coating 1

- Reduction of SEY of beam duct by coating
  - TiN coating system for long beam ducts was built at KEK.
    - Coating was done by DC magnetron sputtering of titanium in Ar and N_2.
    - Thickness : 200 nm
    - Maximum SEY of TiN film on sample piece was 0.84 (electron dose : 0.001 C/mm^2)
  - Several beam ducts have been coated with TiN, and installed in KEKB LER.



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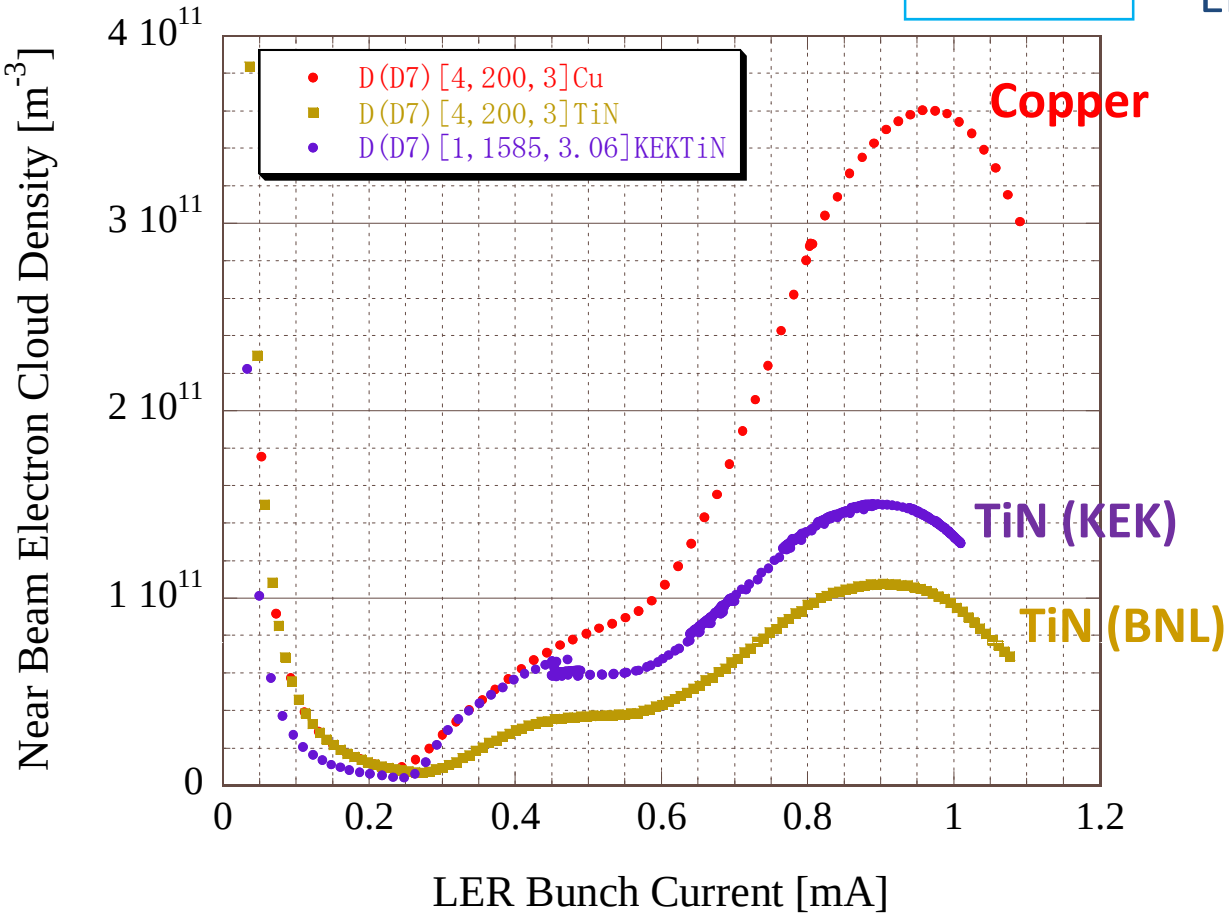
TiN coating 2

- Measurement of electron density in KEKB
  - Electron density in circular beam duct (ϕ94 mm)

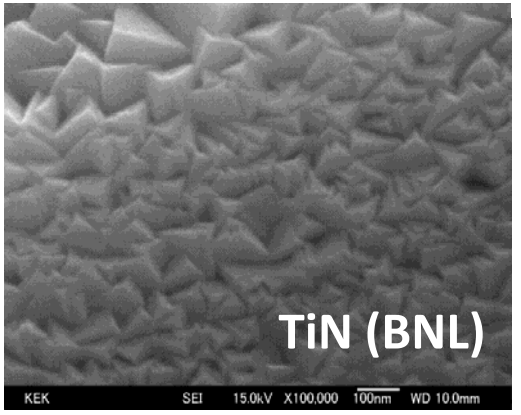
f 94 mm

KEK TiN 04Nov2008

K. Kanazawa



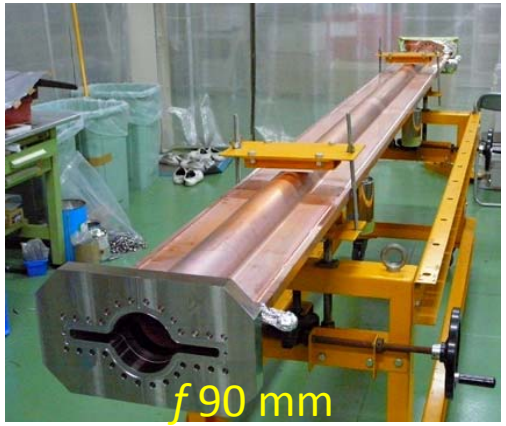
Electron Microscope Image

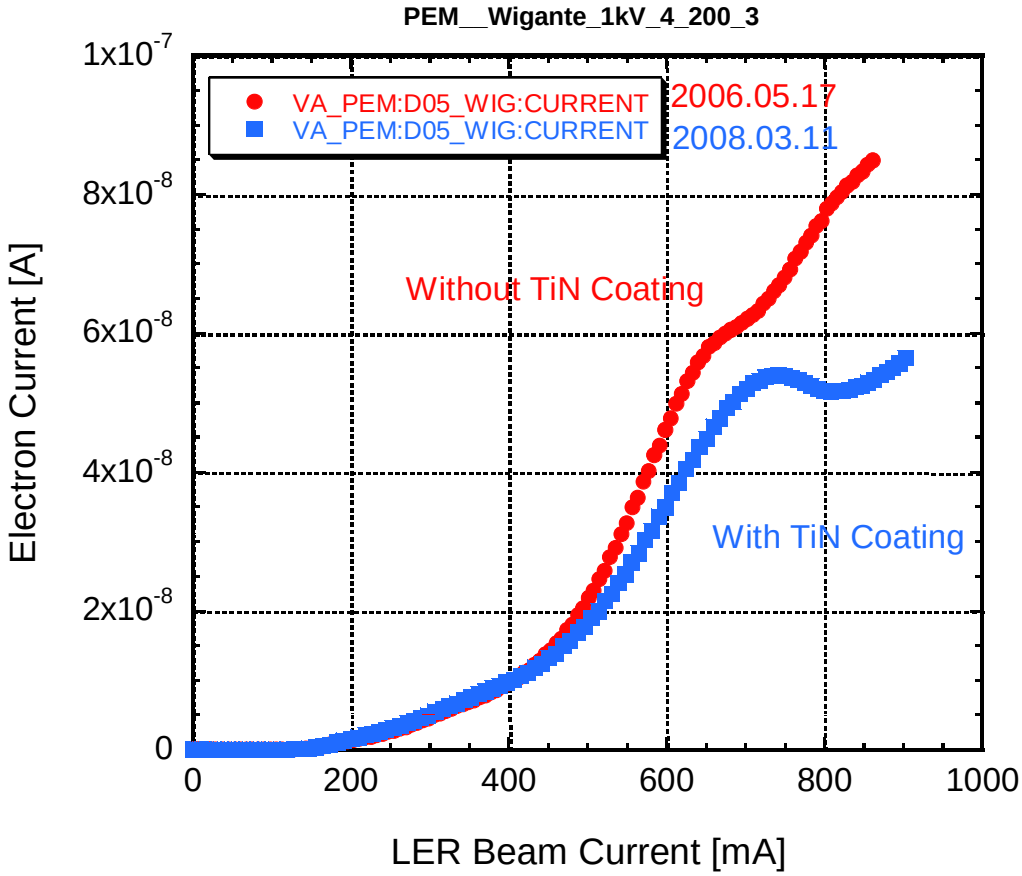


H. Hisamatsu and M. Nishiwaki

TiN coating 3

- Measurement of electron density in KEKB
  - Electron density in beam duct with antechambers





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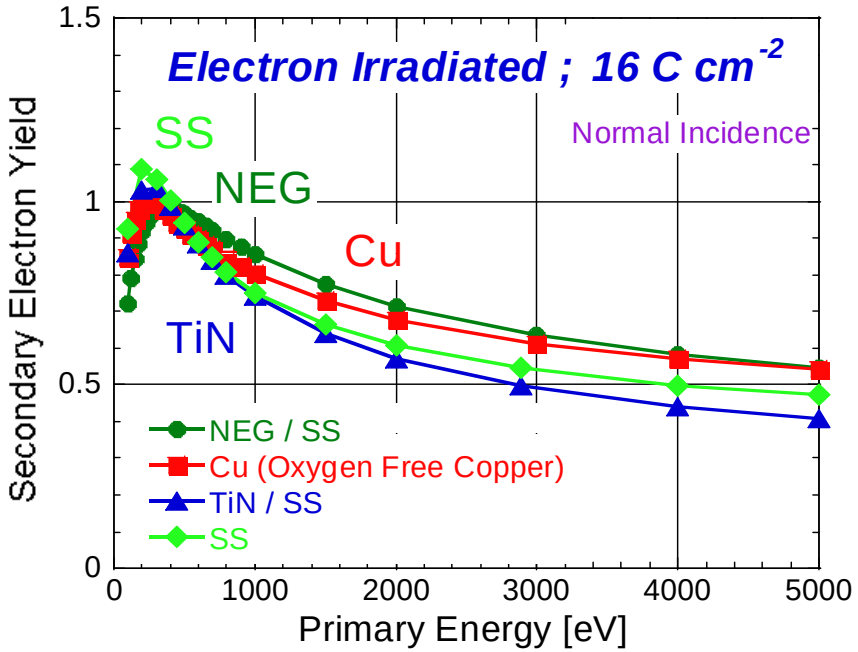
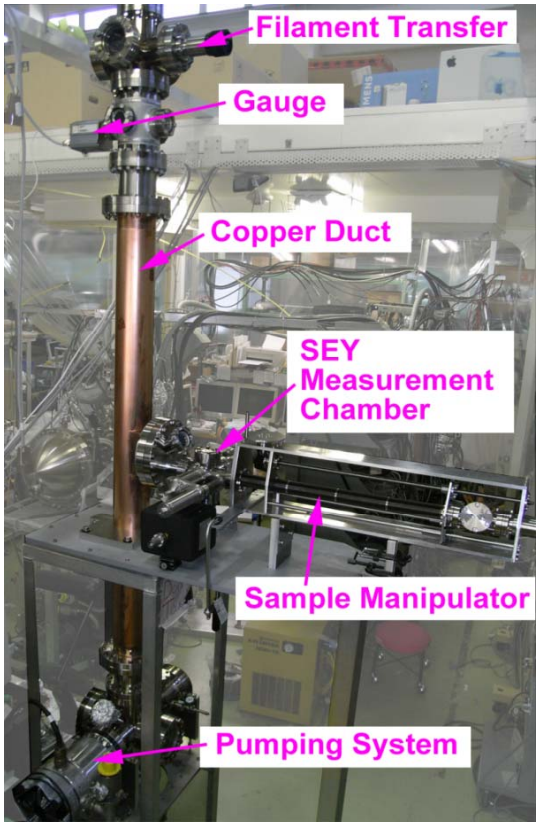
- Combination of beam duct with antechambers and TiN coating is a promising candidate for future high current machines.

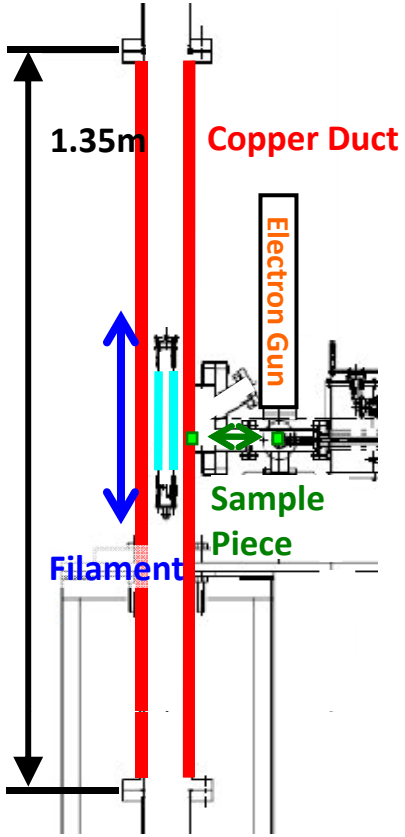
Graphitization 1

- Electron beam induced graphitization is also studied.
  - Graphitized surfaces have shown low SEY in laboratory experiments.
    - Maximum SEY decreased to 1.0-1.1 (electron irradiated : 0.0016 C/mm^2)
  - Setup for graphitization of copper beam duct was newly developed.
    - 500 eV electrons irradiate to duct surface.
    - Emission Current Density : 170μA/cm^2



M. Nishiwaki and S. Kato, Vasscaa4 2008

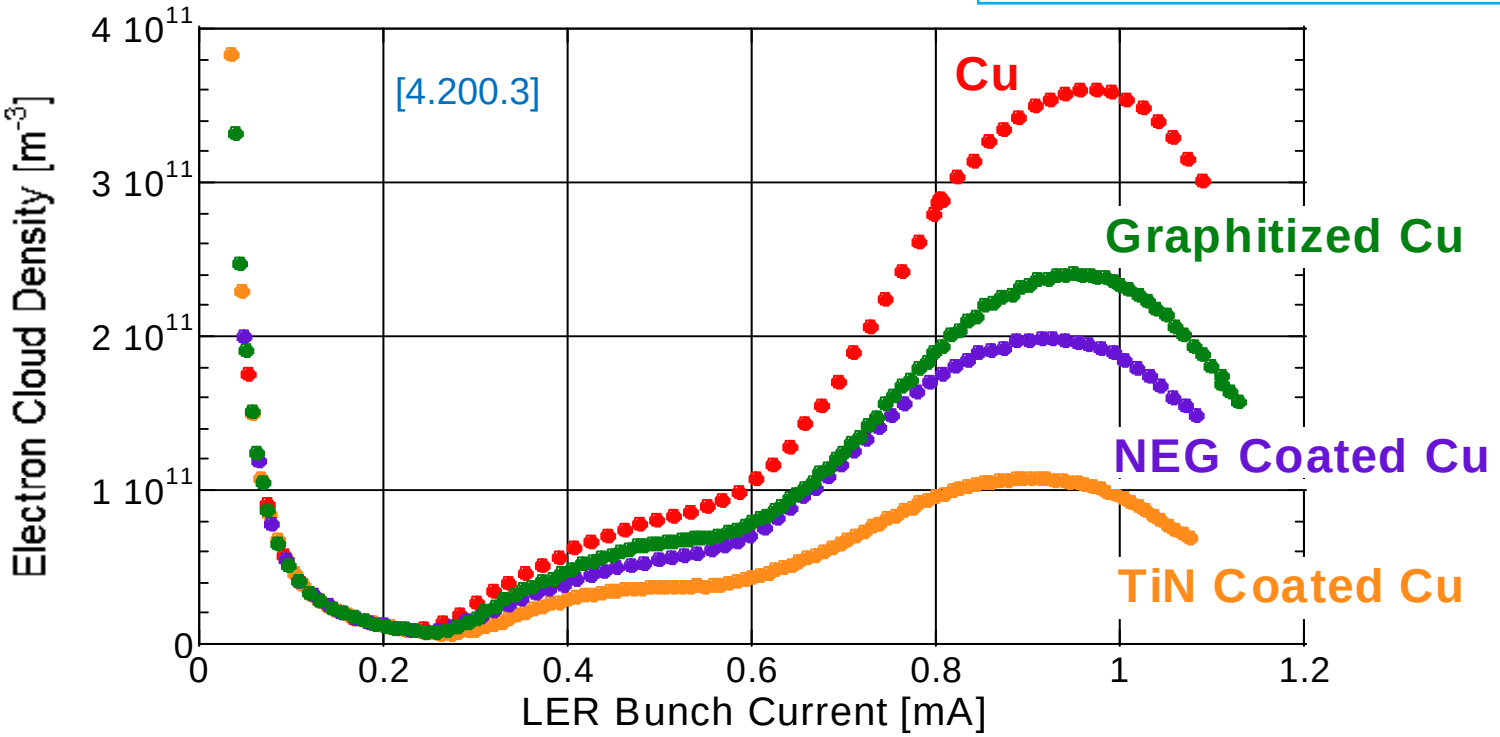




Graphitization 2

- Measurement of electron density in KEKB
  - Graphitization is effective to reduce electron cloud density.
  - Effect is less than TiN and NEG.

M. Nishiwaki and S. Kato, Vasscaa4 2008

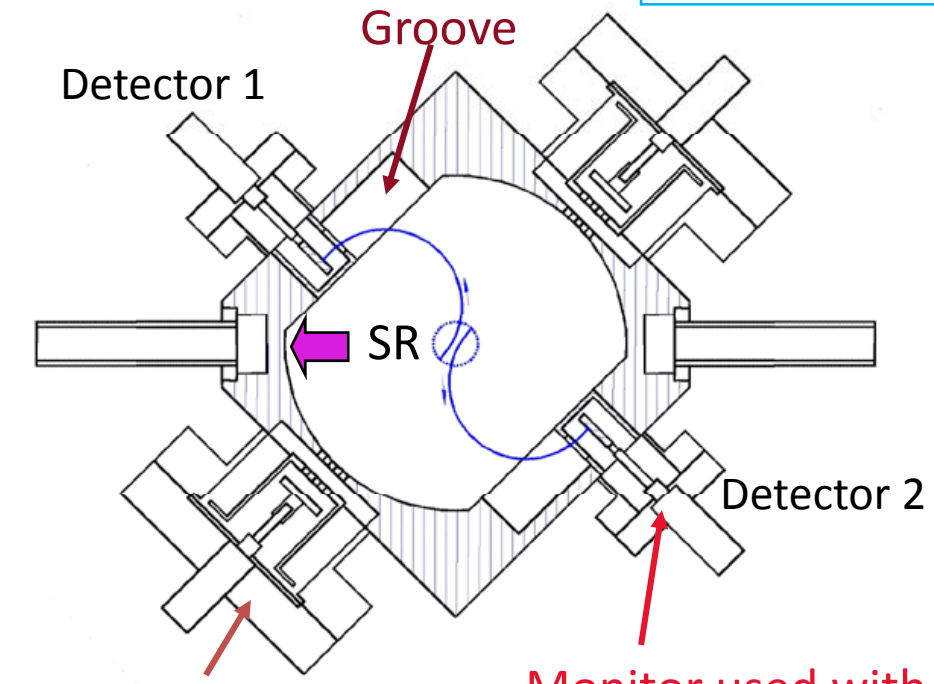


  - Graphite layer was too thin (FWHM ~10 nm).
  - Thicker carbon coating on copper duct is in preparation.

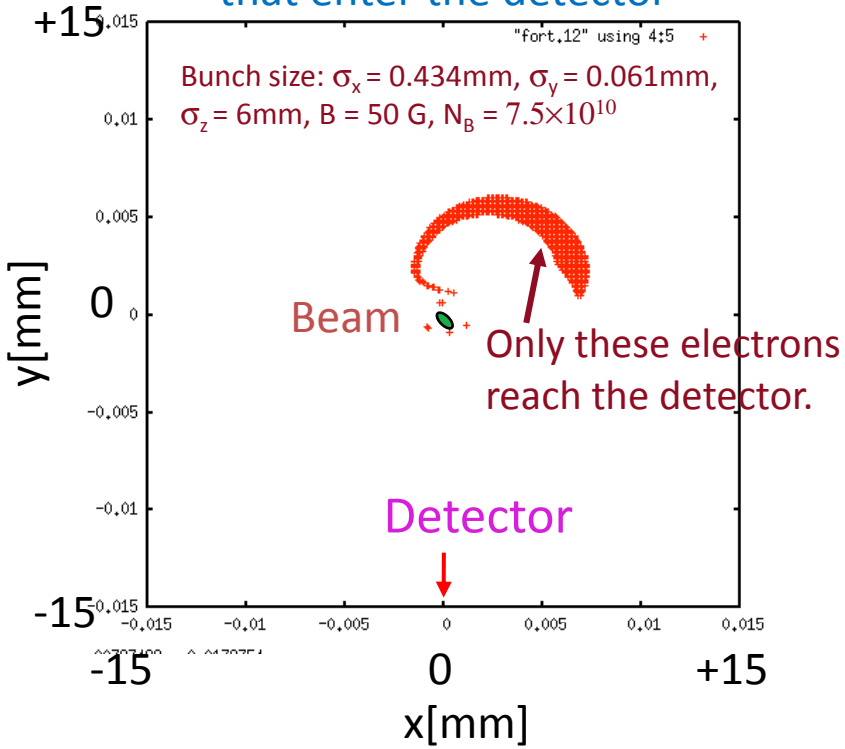
Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 1

- Measurement of electron density in solenoid coil
  - Only high energy electrons produced near the bunch can enter the groove and reach the detector behind it.
  - With the help of simulation detector current is converted into the density near the beam.

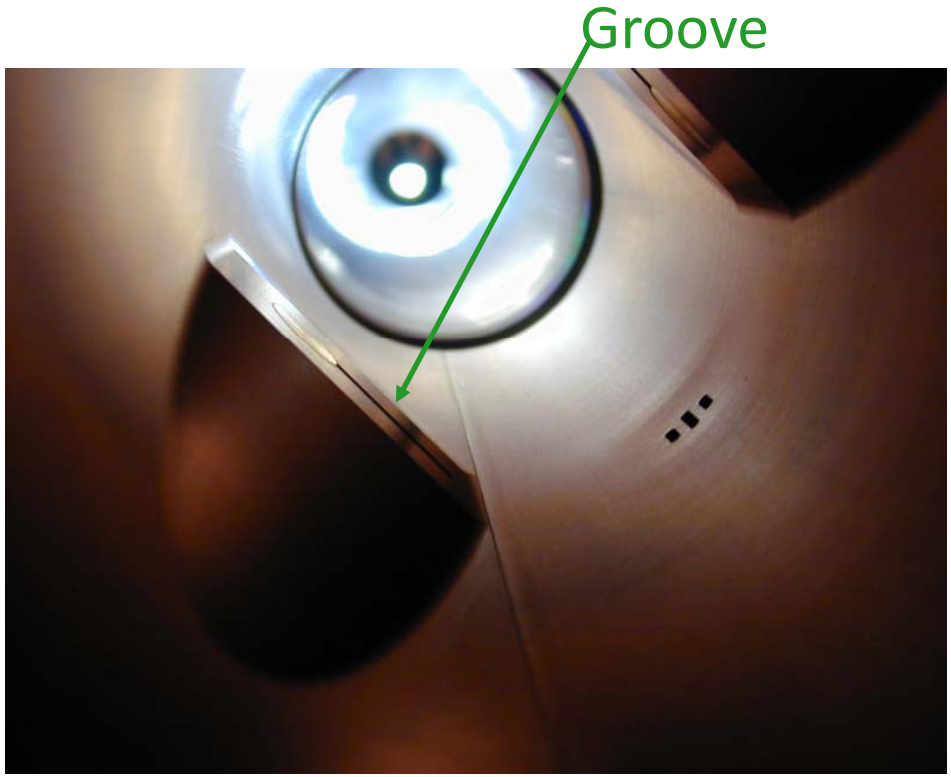
K. Kanazawa and H. Fukuma

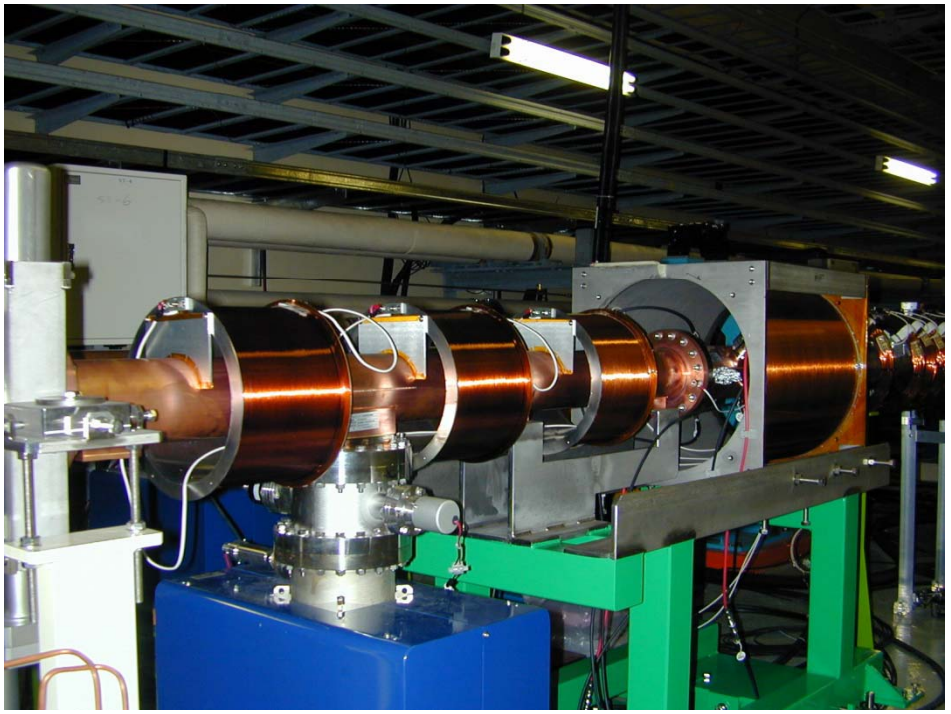


Starting points of electrons that enter the detector



Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 2

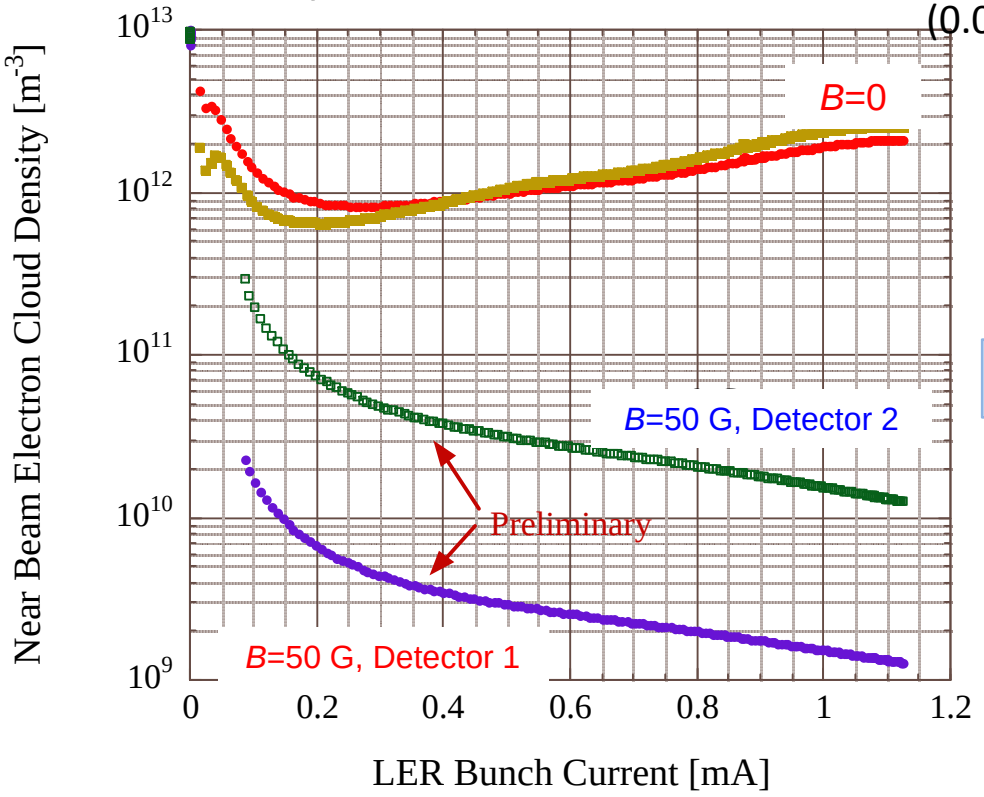




Inside of the chamber

Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 3

- Electron cloud density with solenoid field (B = 50 G)



13 November 2008 [4, 200, 3]
At 7.2m from a Bend
Photon flux=3.9x10^{17}I[A] photons/m

Preliminary result

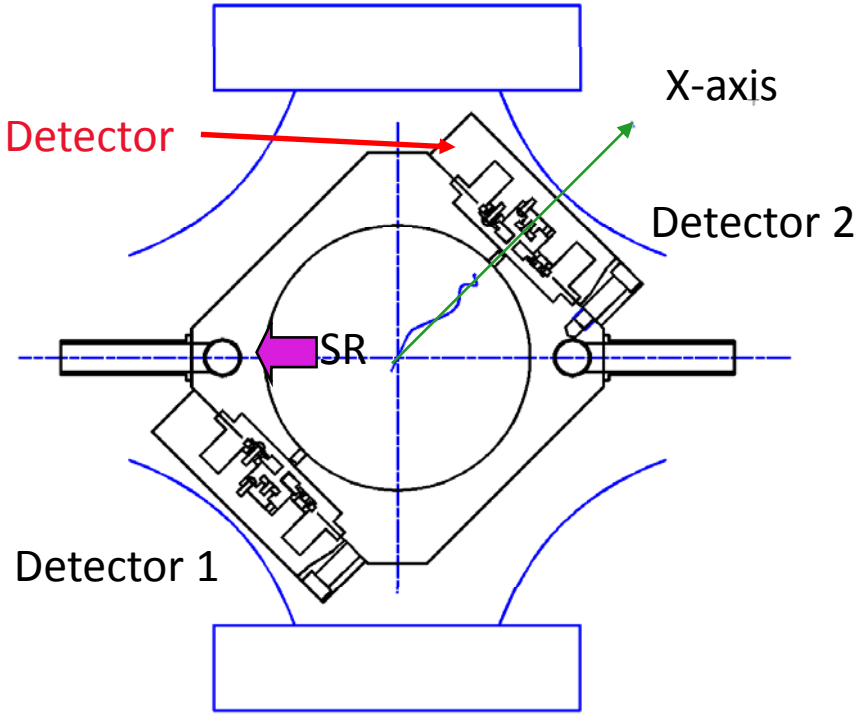
K. Kanazawa and H. Fukuma

- The difference in two detectors may be due to ;
  1) COD
  2) Relative position to the primary synchrotron radiation
  3) Output offset of amplifier in measurement system.
- The measured current in a solenoid field might have included electrons drifting along the wall.

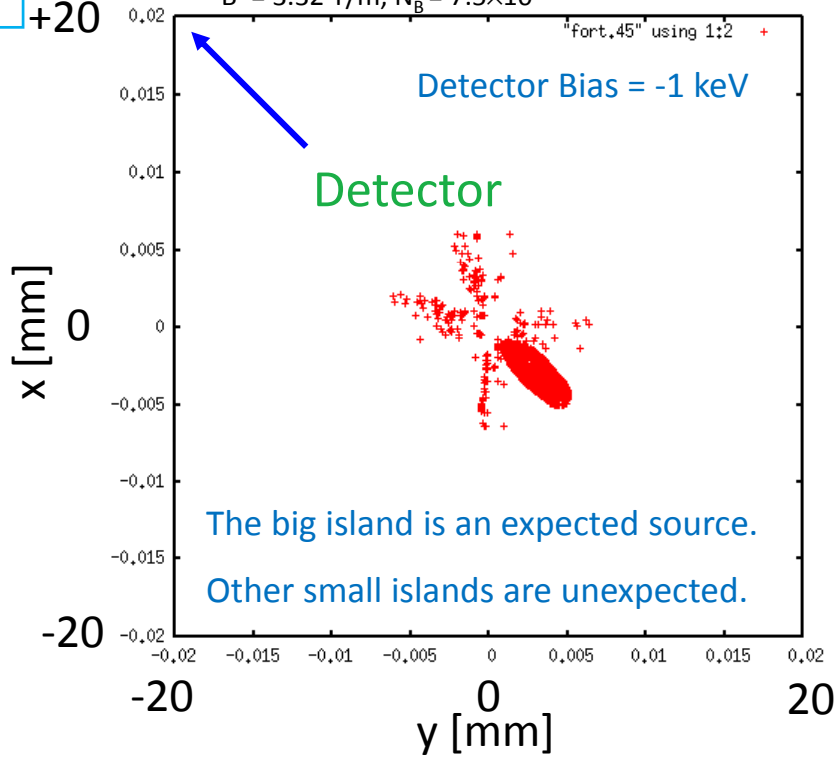
Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 4

- Measurement of electron density in Q-magnet
  - Electrons accelerated by a bunch along X-axis reach the detector.
  - Electrons accelerated with small angle to X-axis moves spirally around X-axis losing their energy along X-axis to the spiral motion.
  - Electrons with sufficient energy and direction close to X-axis reach the detector.
  - With the help of simulation detector current is converted into the density near the beam.

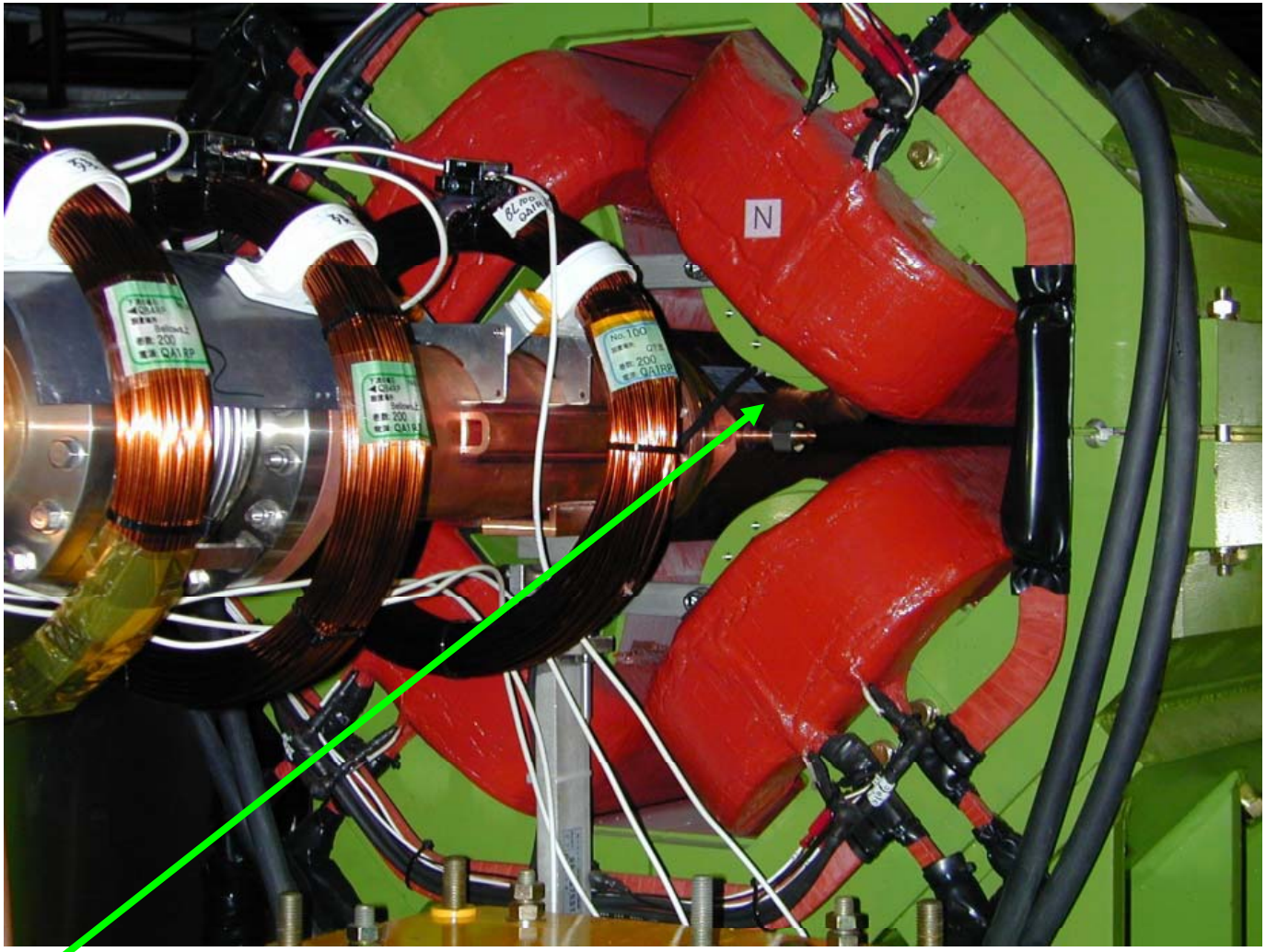
K. Kanazawa and H. Fukuma



σ_x = 0.35 mm, σ_y = 0.094 mm, σ_z = 6.0 mm,
B' = 3.32 T/m, N_B = 7.5×10^{10}



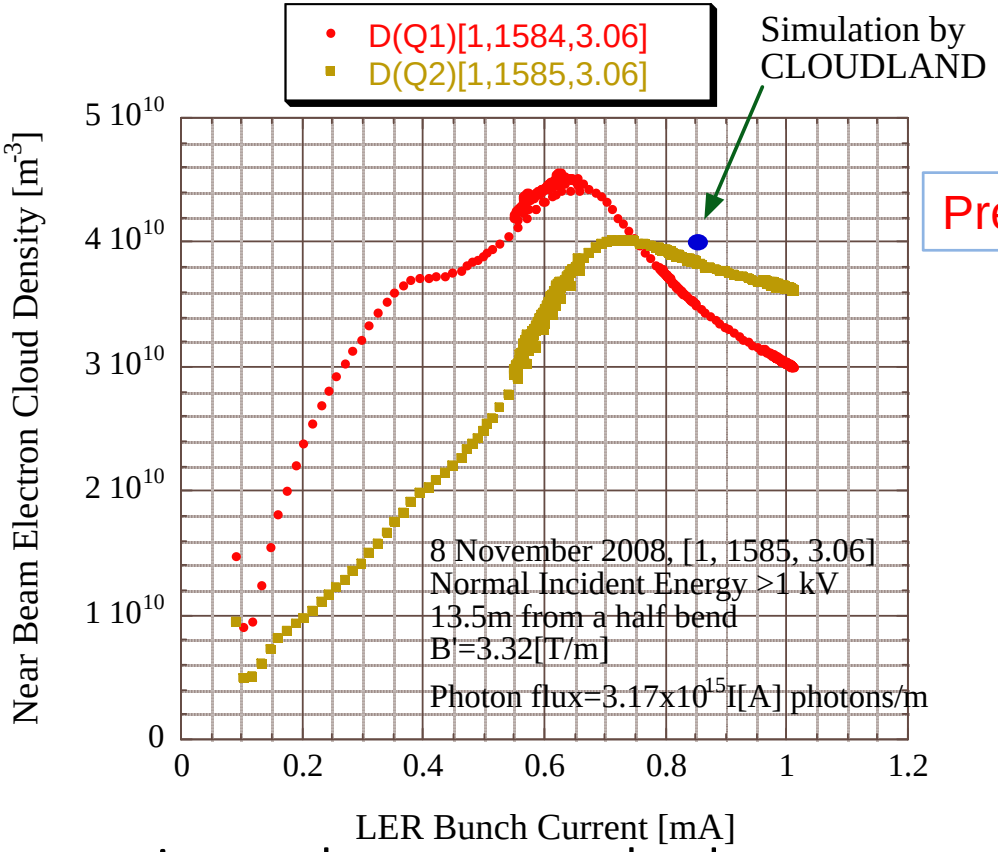
Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 5



Detector

Near Beam Electron Cloud Density Measurement in Magnetic Filed with RFA 6

- Electron cloud density with quadrupole field (B' = 3.32 T/m)



Preliminary result

K. Kanazawa and H. Fukuma

- The difference in two detectors may be due to ;
  1) COD
  2) Relative position to the primary synchrotron radiation
  3) Output offset of amplifier in measurement system.
- The observed value in Q-Magnet is close to the estimation by simulation

Summary

- Various studies on the electron cloud mitigation have been done at KEKB positron ring.
  - Clearing electrode
  - Groove surface
  - TiN coating
  - Graphitization
  - Beam duct with antechambers
- Mitigation methods, such as clearing electrode and coating gave reasonable effect.
- New RFA type electron detectors was developed and installed in KEKB LER to measure the electron cloud density in solenoid coil and quadrupole magnet.
- For SuperKEKB :
  - Drift space : antechamber + solenoid + TiN coating
  - Magnet space : antechamber + TiN coating + clearing electrode? groove surface?