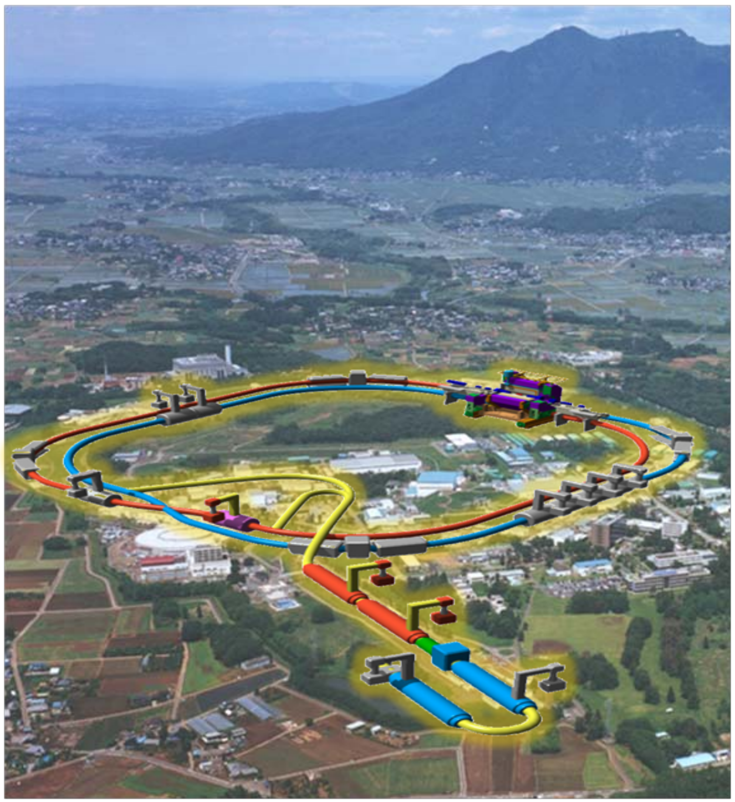
Updates of Electron Cloud Studies at KEKB

Y. Suetsugu, KEKB Vacuum Group

- **Topics in 2008**
  - **Measurement of electron density in solenoid and Q field**
  - **Mitigation using clearing electrode in B field**
  - **Mitigation using groove surface in B field**

EC studies at KEKB

- **Various EC studies have been carried out utilizing the KEKB positron ring.**
  - EC deteriorated the luminosity of KEKB



Energy	3.5 GeV
Circumference	3016.26 m
Nominal bunch current	1~1.3 mA
Nominal bunch charge	10~13 nC
Nominal bunch spacing	6~8 ns
Harmonic number	5120
RMS beam size (x/y)	0.42/0.06 mm
Betatron tune	45.51/43.57
RF voltage	8 MV
Synchrotron tune	0.024
Radiation damping time	40 ms

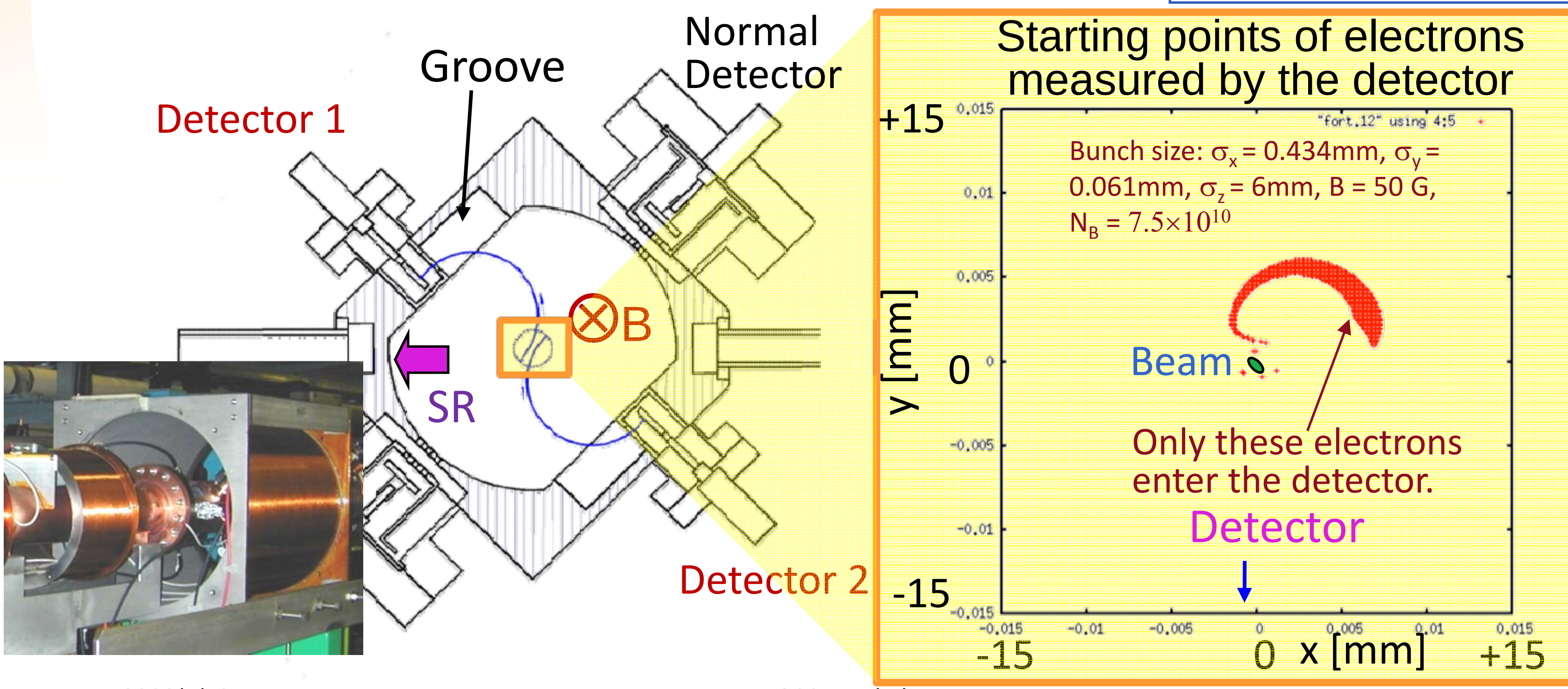
EC studies at KEKB

- **Diagnostics**
  - Beam size blow-up: by SR monitors
  - Beam instabilities (Head-tail instability, coherent instability) : by BOR, Tune measurement
  - Electron density at drift space, in a solenoid and Q field: by electron monitors with RFA
  - Secondary Electron Yield (SEY) at lab. and in situ
- **Mitigation**
  - Solenoid field at drift space →Very effective
  - Beam pipe with antechambers
  - Coating to reduce SEY: TiN, NEG, Graphite, DLC
  - Clearing Electrode in a B field
  - Groove surface in a B field

Electron density in a solenoid

- **Measurements so far have been only at drift space or in B field.**
- **New RFA-type electron detector was installed in a solenoid.**
- **Only high energy electrons produced near the bunch can enter the detector.**

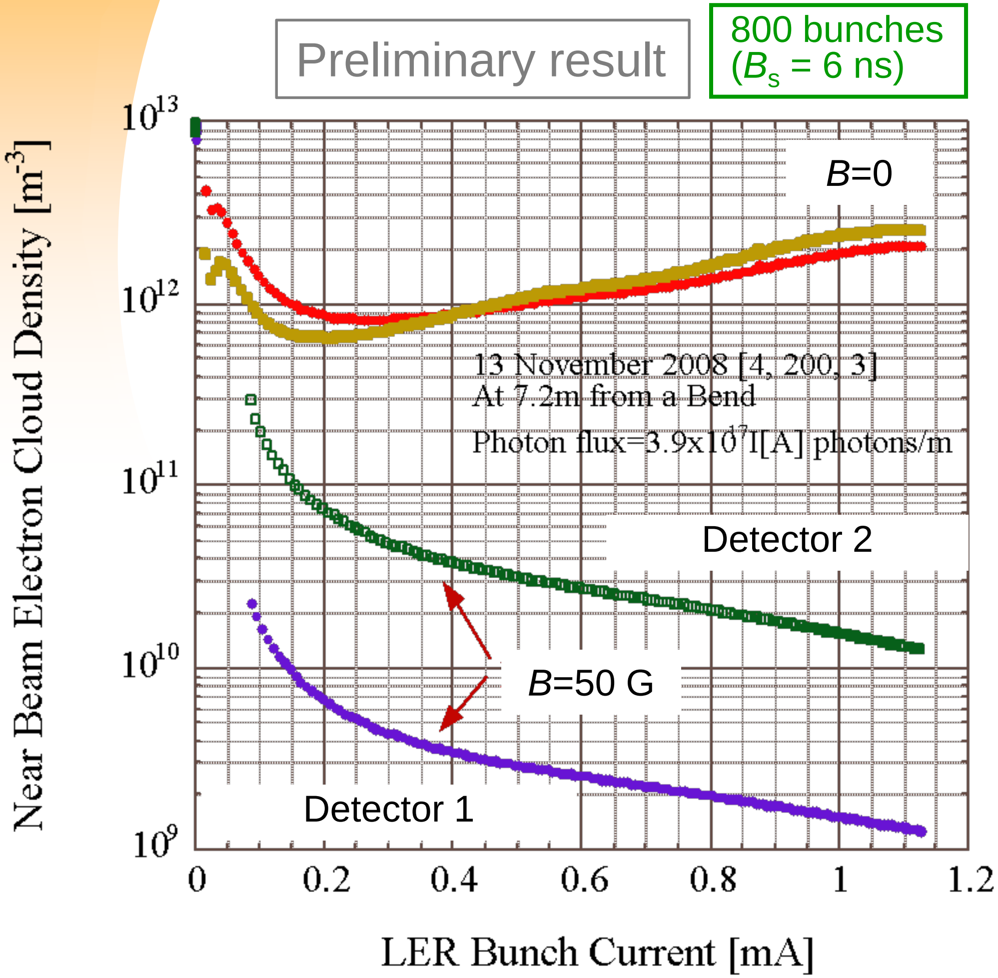
K. Kanazawa and H. Fukuma



Electron density in a solenoid

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

K. Kanazawa and H. Fukuma



- **The electron density decreased less than 1/100 in the solenoid field.**
- **The difference in two detectors may be due to COD and relative position to the primary synchrotron radiation**
- **The measured current in a solenoid field might have included electrons drifting along the wall.**

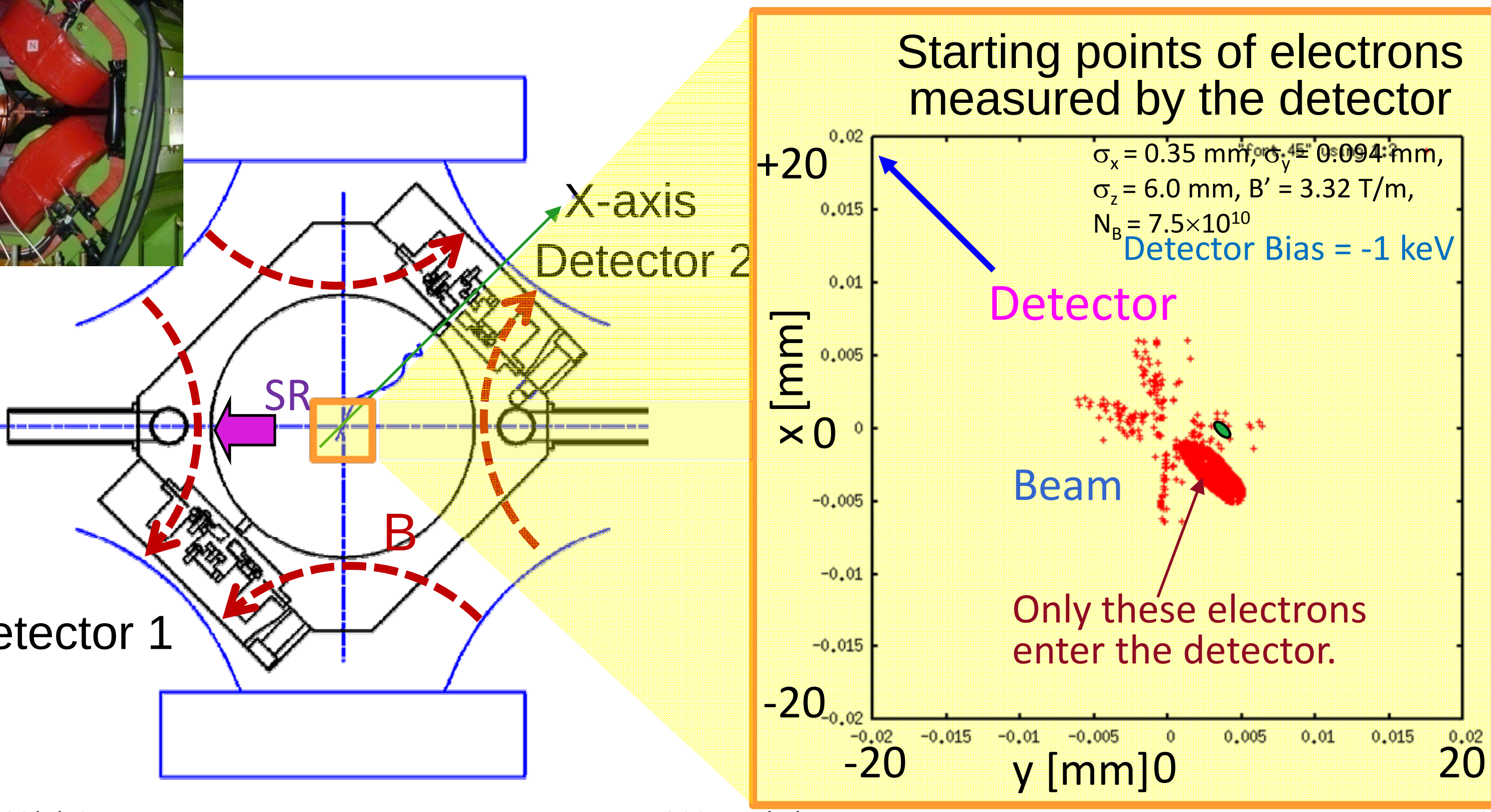
I_e ~ photoelectrons?

→New detector with RFA (2009)

Electron density in a Q magnet

- **New RFA-type electron detector was also installed in a Q magnet**
- **Only high energy electrons produced near the bunch can enter the detector.**

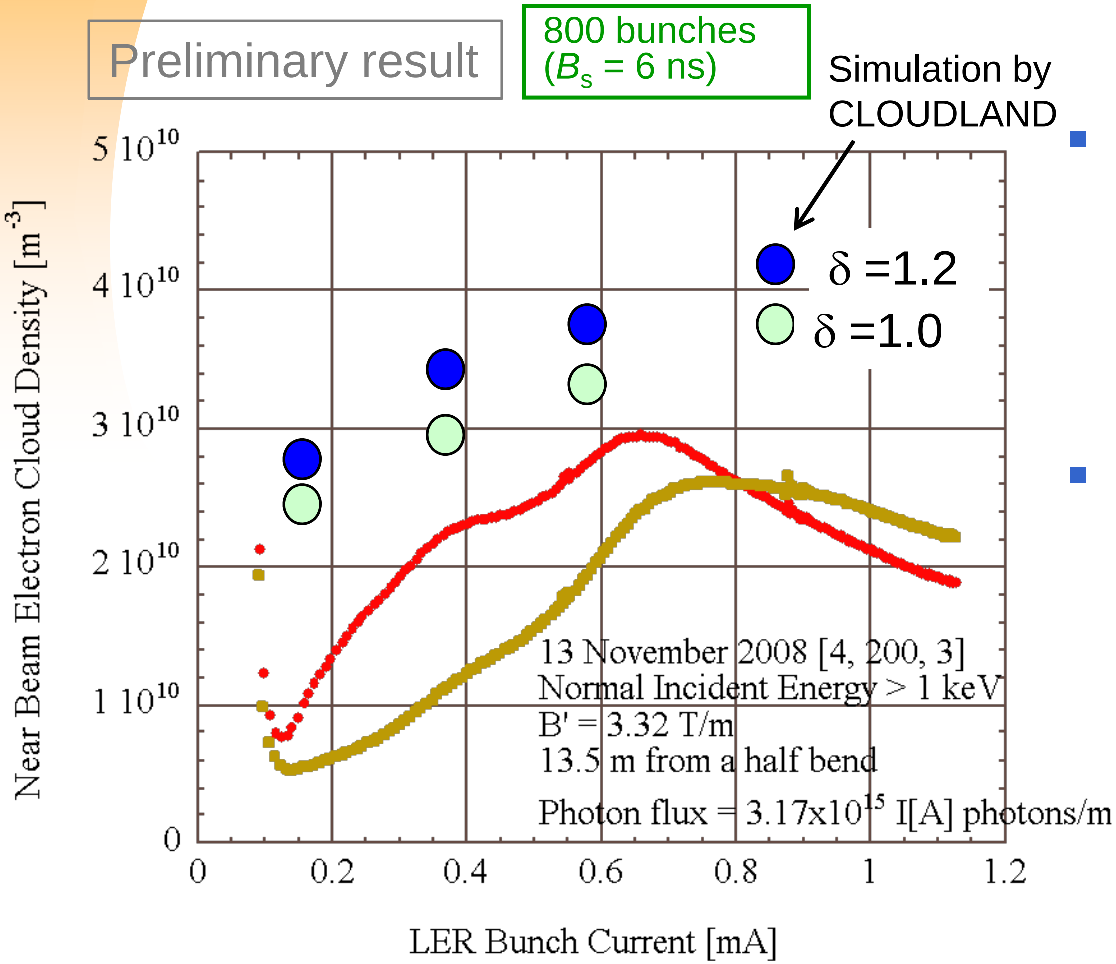
K. Kanazawa and H. Fukuma



Electron density in a Q magnet

- **Electron cloud density in Q magnet (B' = 3.32 T/m)**

K. Kanazawa and H. Fukuma



- **The observed value in the Q-Magnet was close to the estimation by simulation [CLOUDLND]. (δ_{max} at 250 eV)**
- **The difference in two detectors may be due to COD and relative position to the primary synchrotron radiation**

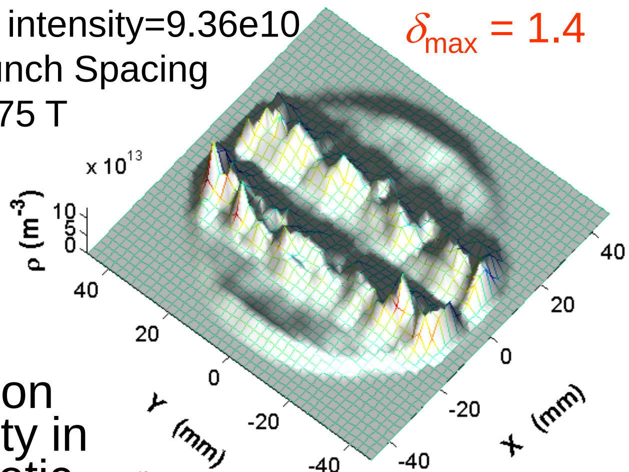
Mitigation in magnets

- **Mitigation techniques of EC in magnets have recently attracted attention.**
  - Solenoid field is very effective at a drift space.
- **A clearing electrode and a groove had been said to be effective even in magnets from simulations.**
- **However, no experimental demonstration in high intensity positron rings was reported so far.**
  - Clearing electrode:
    - Experiments were carried out at CERN (proton ring).
    - Impedance and heating is key problems for positron ring.
  - Groove:
    - Experiments at a drift space were carried out at SLAC.
- **Experimental demonstrations of the clearing electrode and the groove were tried using a wiggler magnet in the KEKB positron ring.**

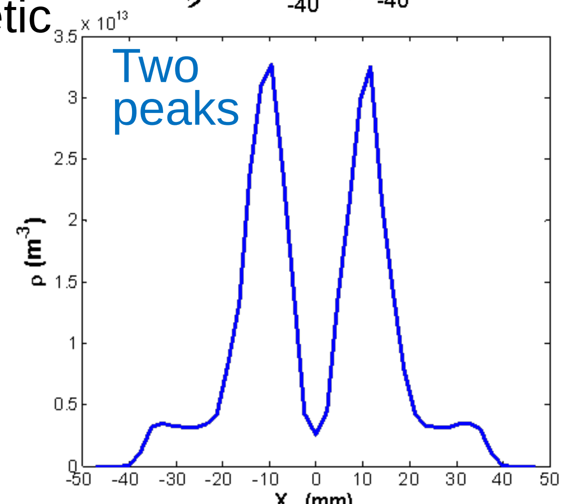
Clearing electrode

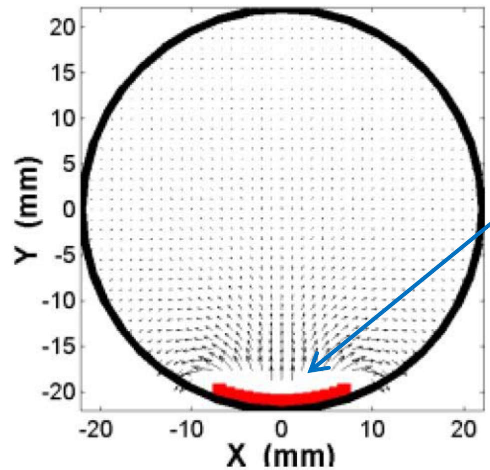
- **Electrode in a beam pipe attracts or repels the electrons around the beam orbit.**

R-pipe=38mm
bunch intensity=9.36e10
3.5 Bunch Spacing
B = 0.75 T

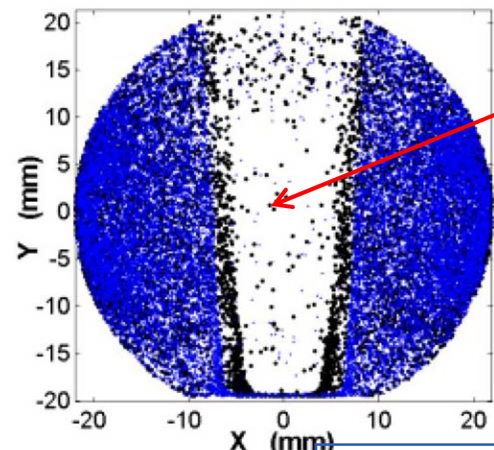


Electron Density in magnetic field





Electrode (+)



Little electrons

L. Wang et al, EPAC2006, p.1489

Clearing electrode

- **New strip-line type electrode was developed.**
- **Very thin electrode and insulator;**
  - Insulator: ~0.2 mm, Al_2O_3, by thermal spray.
  - Electrode: ~0.1 mm, Tungsten, by thermal spray.
- **Low beam impedance, high thermal conductivity**
  - Input power ~ 100 W

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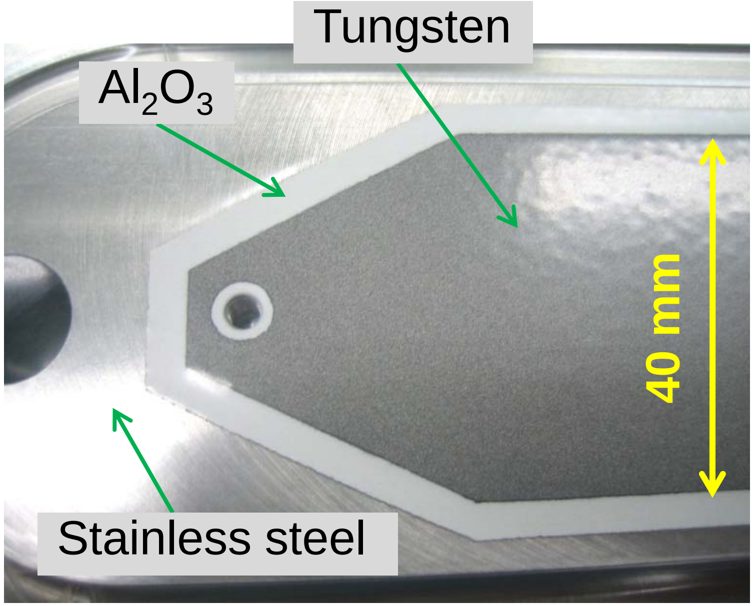
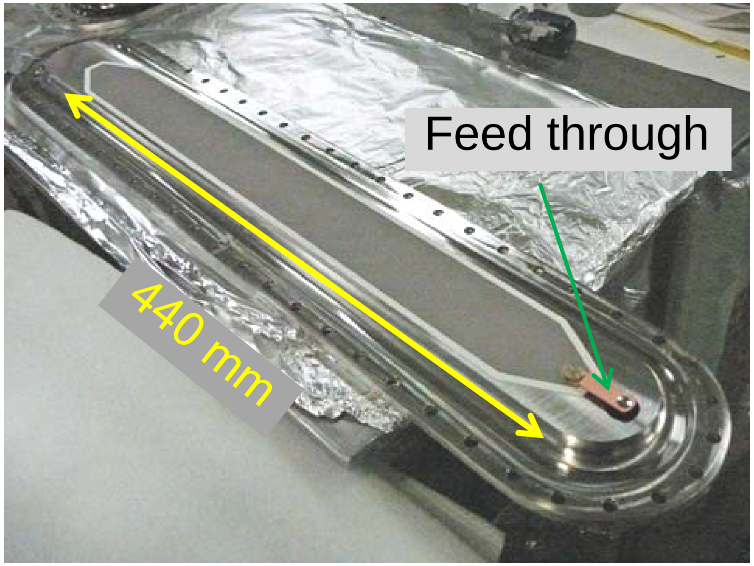
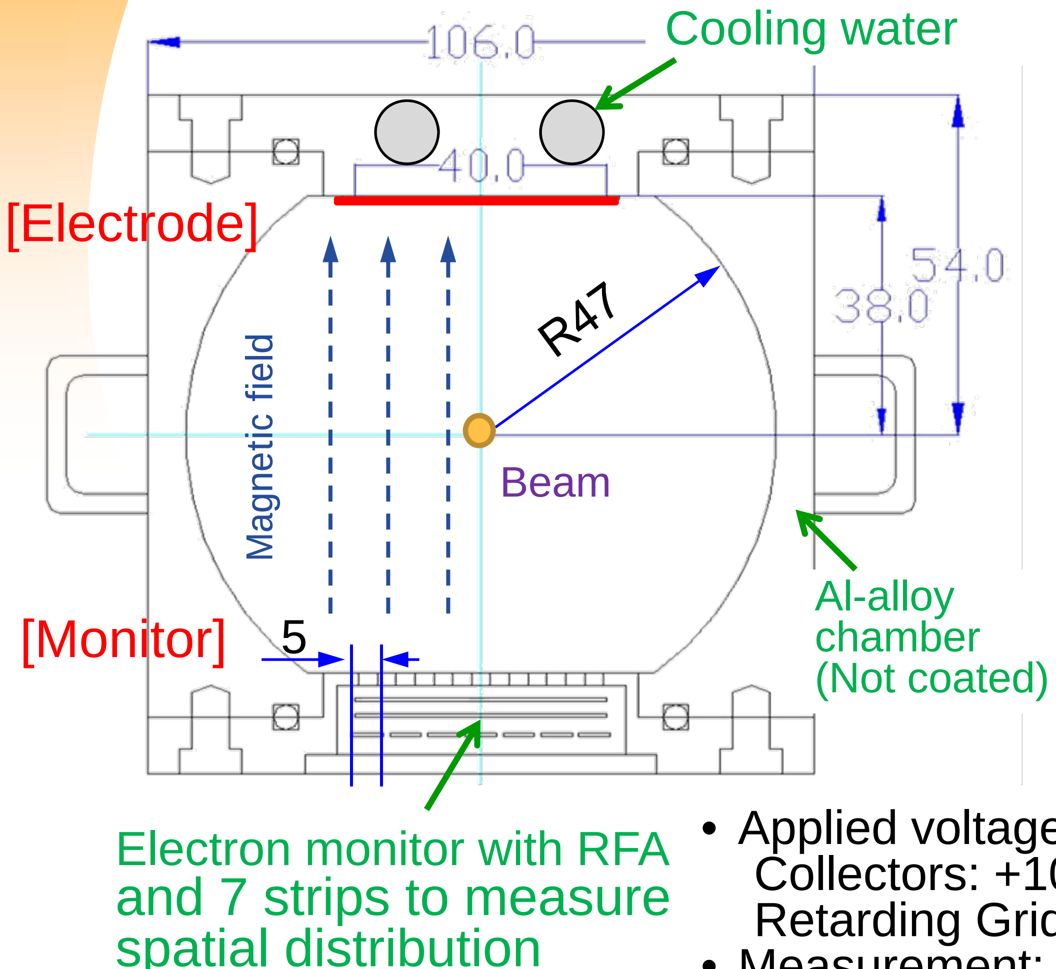
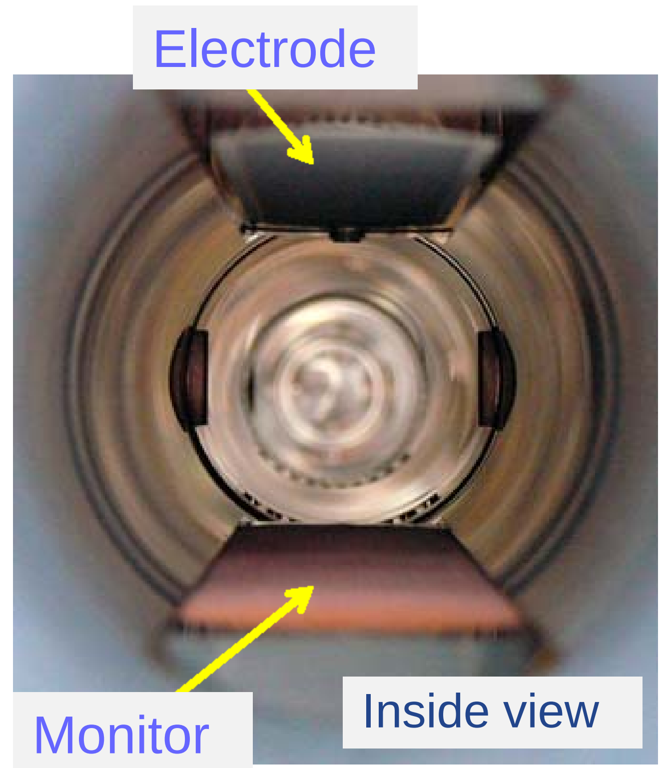




Clearing electrode

- **The electrode and an electron monitor were set face to face in a test chamber.**

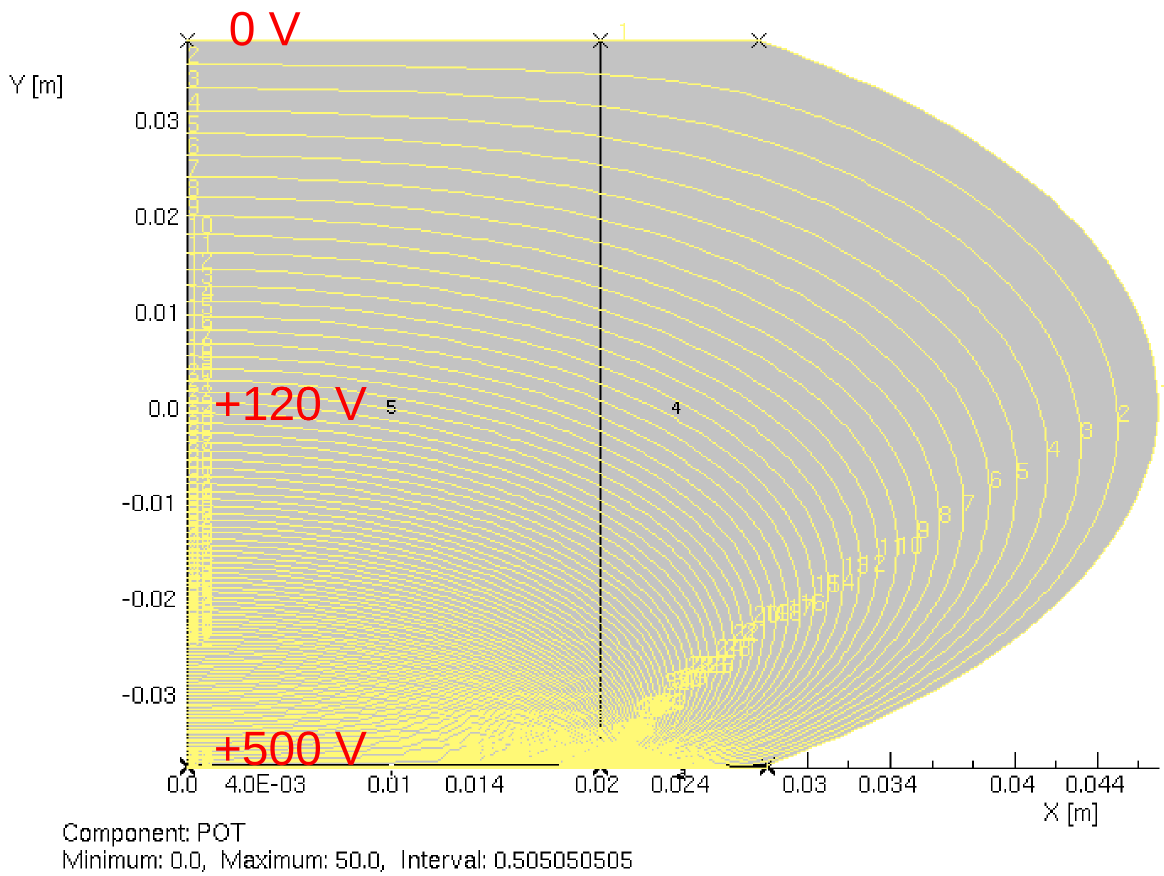




- Applied voltage
  Collectors: +100V
  Retarding Grid: 0 ~ -1 kV
- Measurement: DC mode

Clearing electrode

- **Electric potential in the chamber by this electrode**

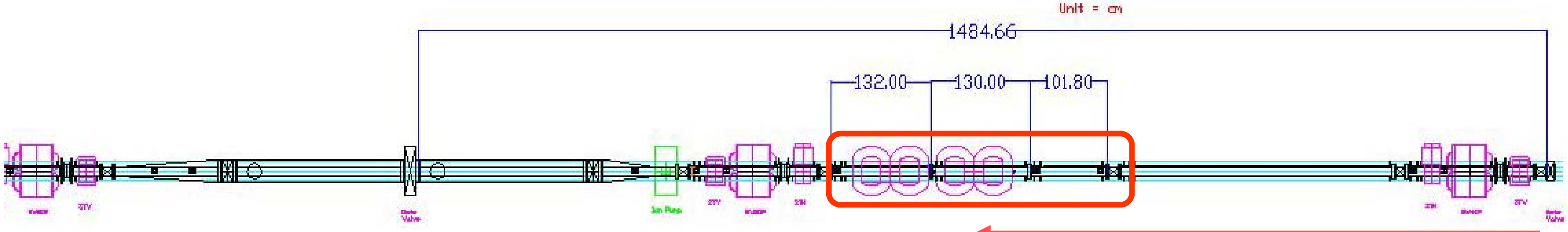


Clearing electrode

- **Test chamber was installed into a wiggler magnet**
  - Wiggler magnet.
    - Magnetic field: 0.77 T
    - Effective length: 346 mm
    - Aperture (height): 110 mm
- **Placed at the center of pole**
- **SR: 2×10^{17} photons/s/m at 1600 mA**
- **Electrode voltage (V_{elec}): V_{elec} = -500 ~ +500 V**
- **Repeller voltage (V_r): V_r = 0 ~ -1 kV**

Feed through

Test chamber



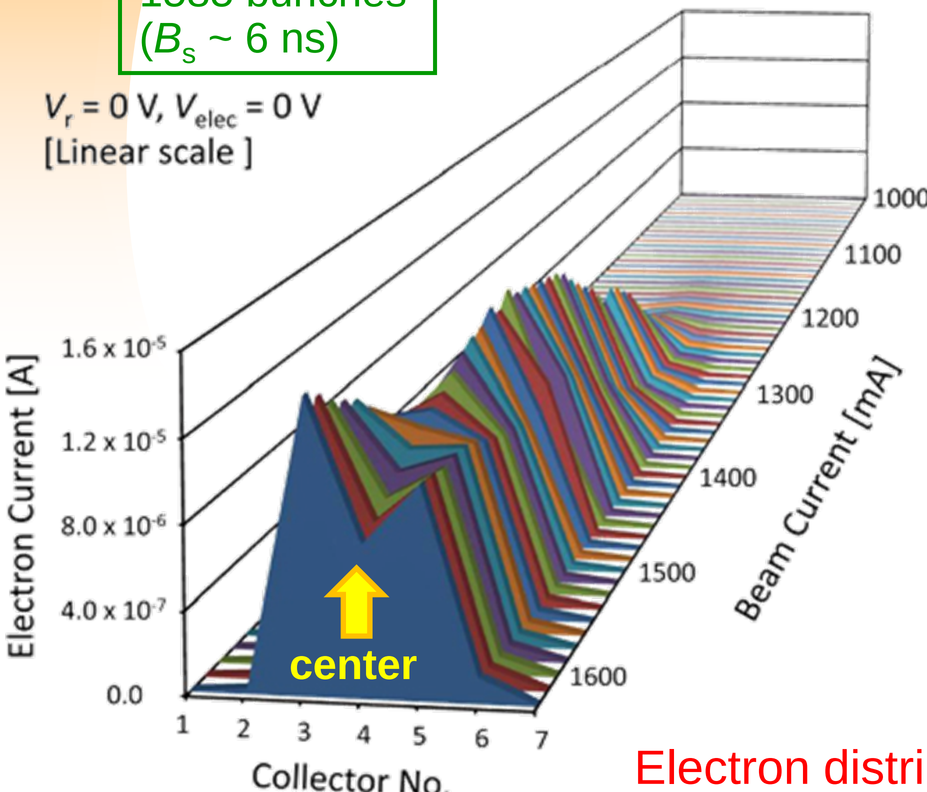
Gate Valve

Gate Valve

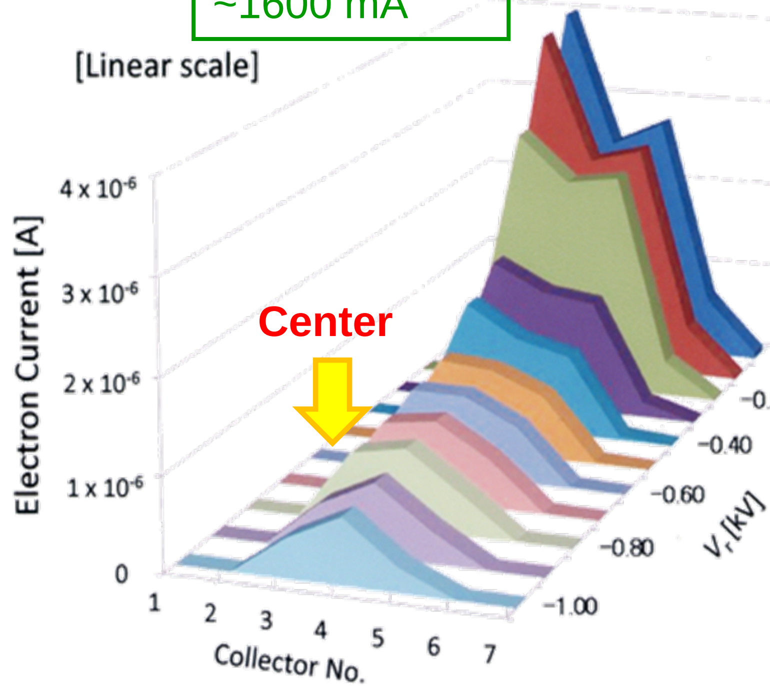
Clearing electrode

- **Spatial and energy distribution of EC (V_{elec} = 0 V)**
  - Also for checking of electron monitor

1585 bunches (B_s ~ 6 ns)



1585 bunches (B_s ~ 6 ns) ~1600 mA



Electron distribution splits to two peaks at high current.

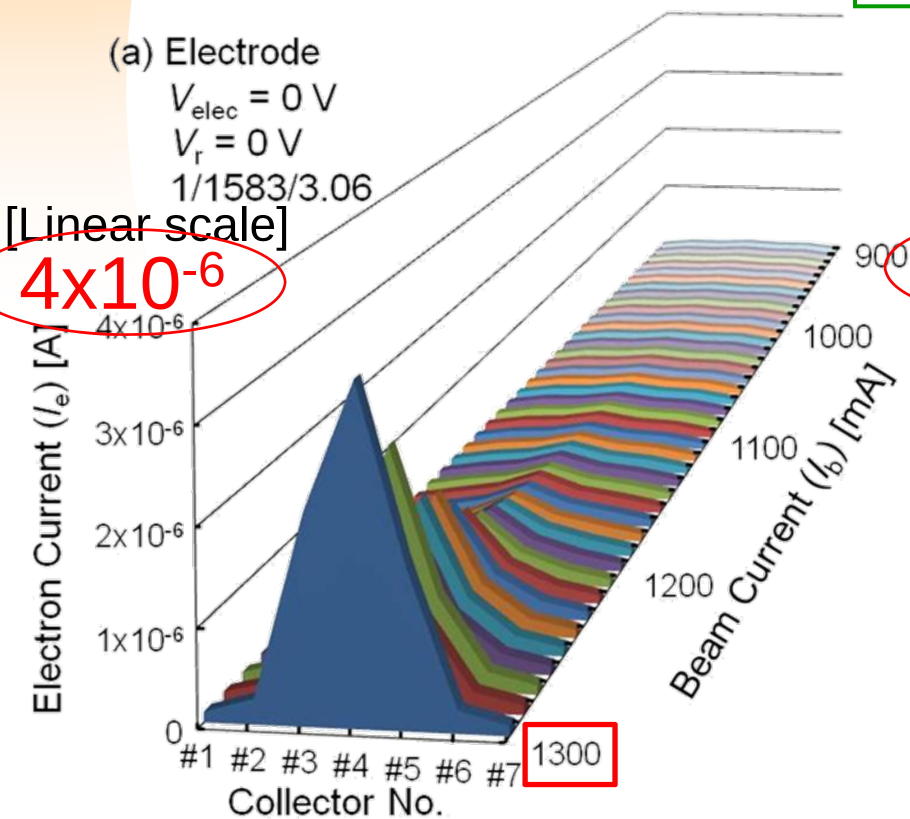
High energy electrons are at the beam position.

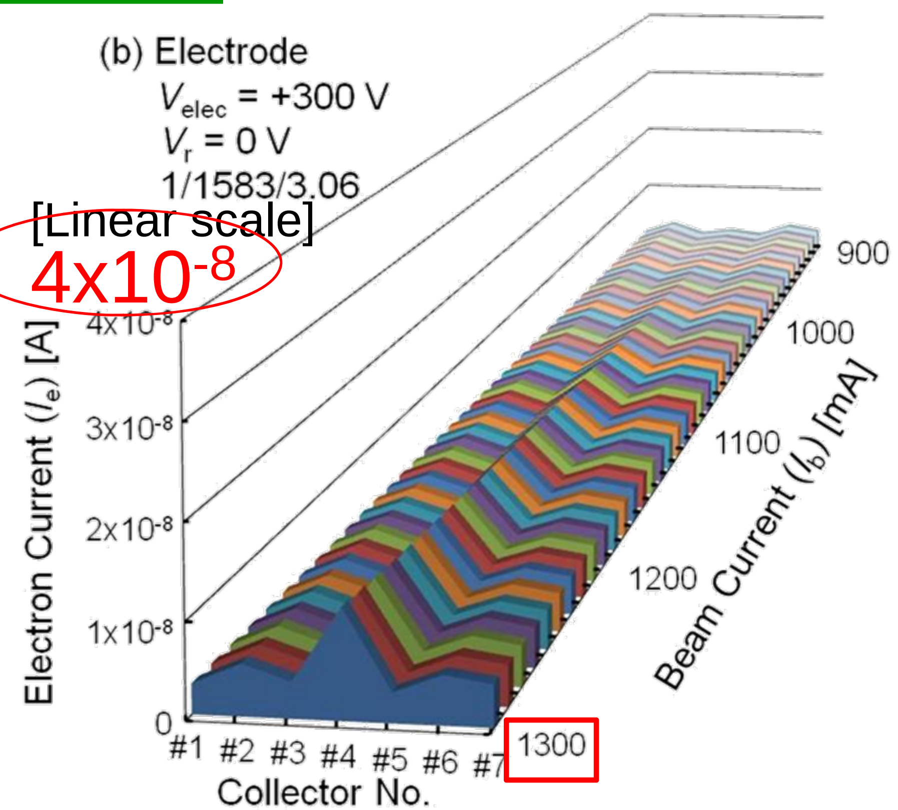
Clearing electrode

- **Spatial growths of EC for clearing electrode**
  - EC for V_{elec} = + 300 V was much smaller than the case for V_{elec} = 0V.

Preliminary result (2009)

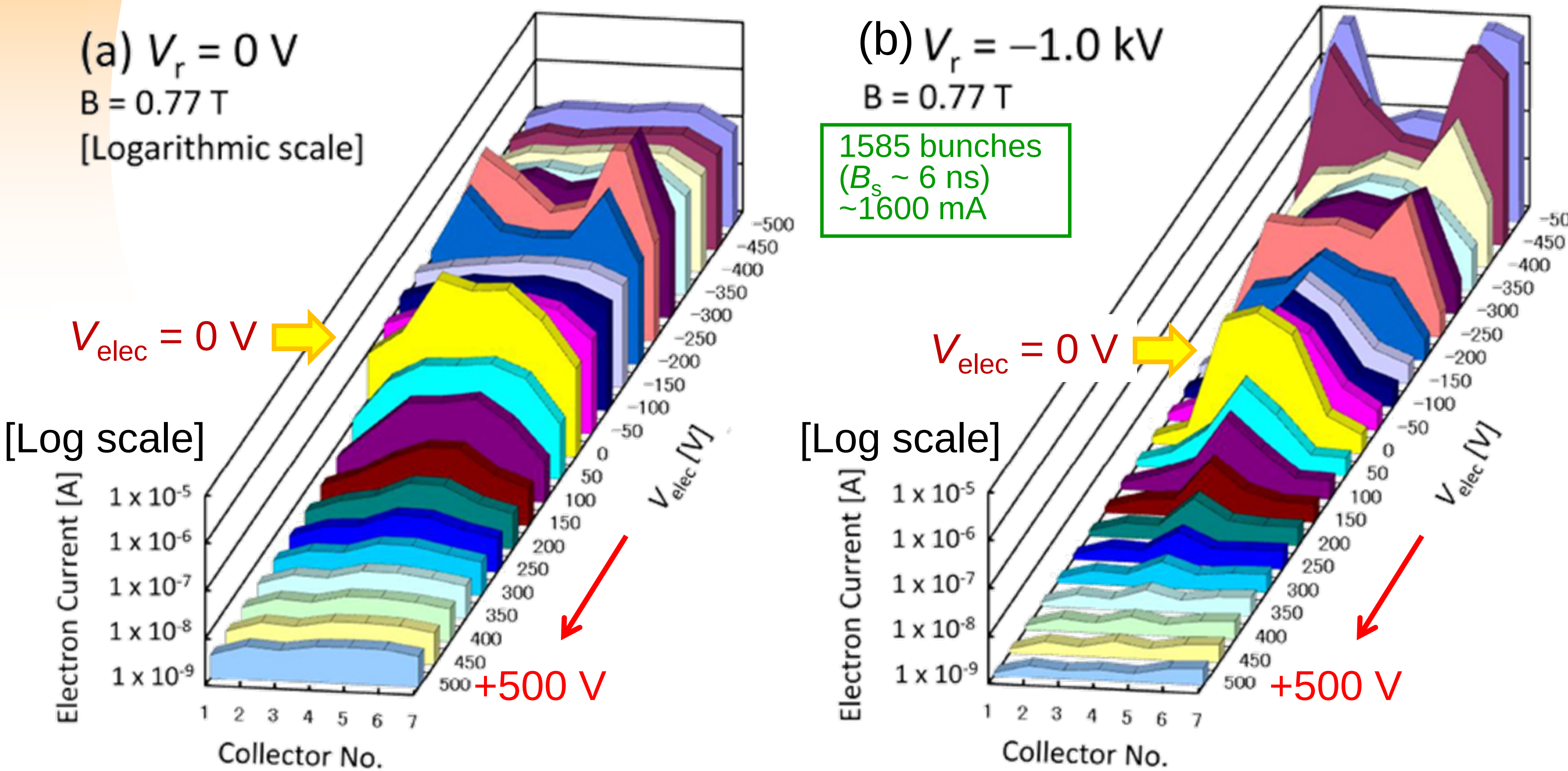
1585 bunches (B_s ~ 6 ns)





Clearing electrode

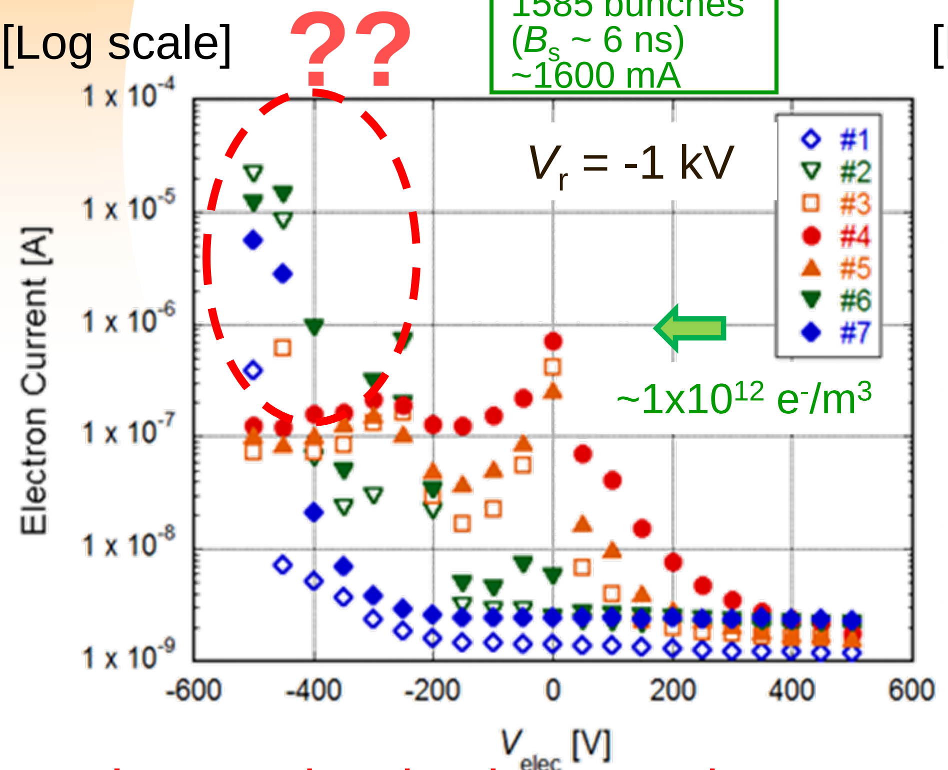
- **Effect of electrode voltage (V_{elec})**
  - Drastic decrease in electron density was demonstrated by applying positive voltage.



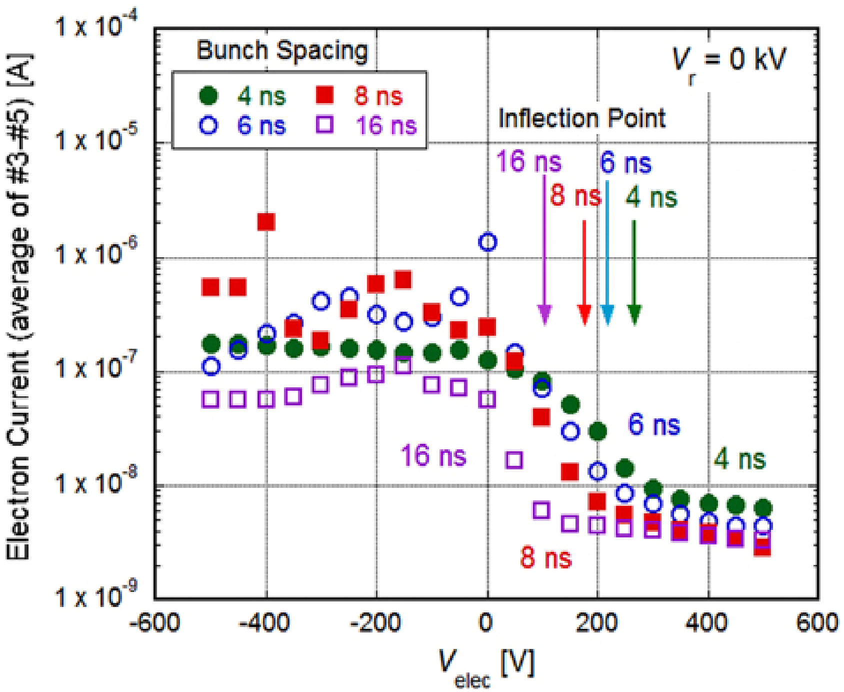
Clearing electrode

- **Effect of electrode voltage (V_{elec})**
  - Smooth decrease in density for positive V_{elec}
  - Effective for various bunch filling patterns

[Log scale]



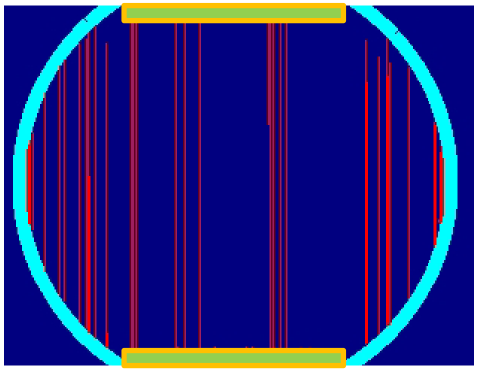
[Log scale] Different bunch filling patterns



Electron density decreased to
1/10 at V_{elec} = + 100 ~ 200 V, 1/100 at V_{elec} = + ~ 500 V

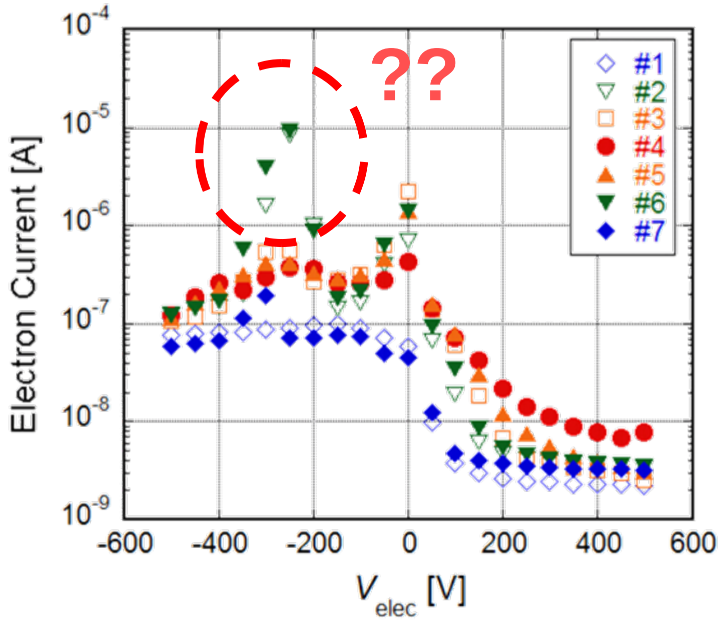
Clearing electrode

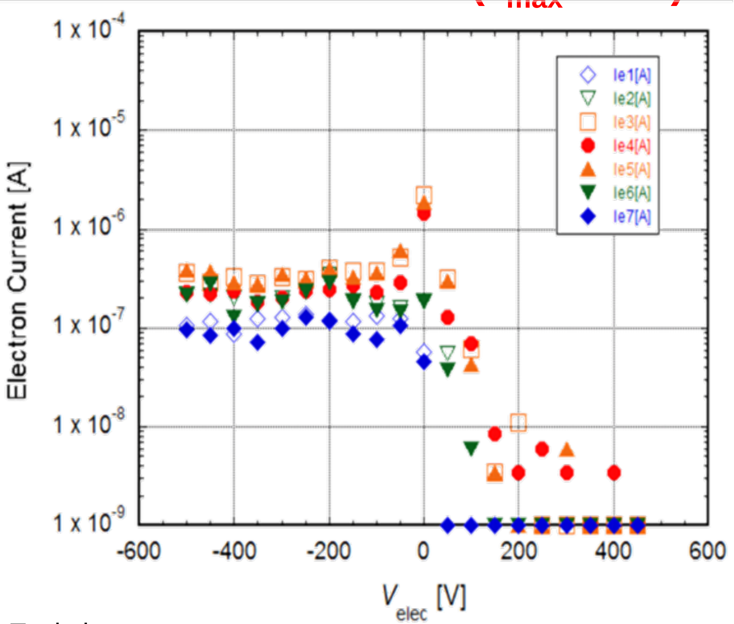
- **Simulation for measured electron current is undergoing.**
  - Electrons moves only along B field.
- **Behaviors were roughly reproduced, but those at the negative V_{elec} were not still understood.**
  - Effect of the repeller grid?



800 bunches
(B_s = 6 ns)
800 mA

[Log scale]

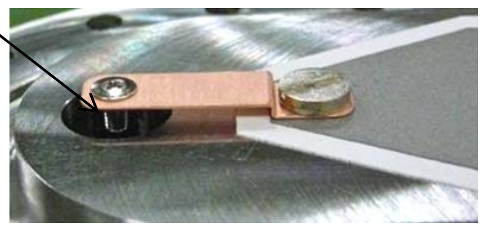


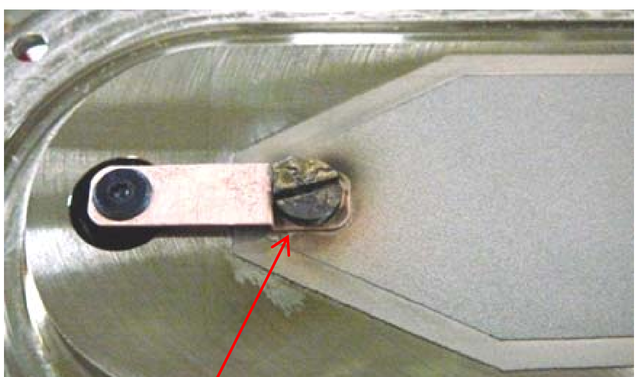


Clearing electrode

- **A key issue: development of a reliable connection to feed through**
  - We had a trouble in the previous version.
  - A revised electrode is under test now (2009).

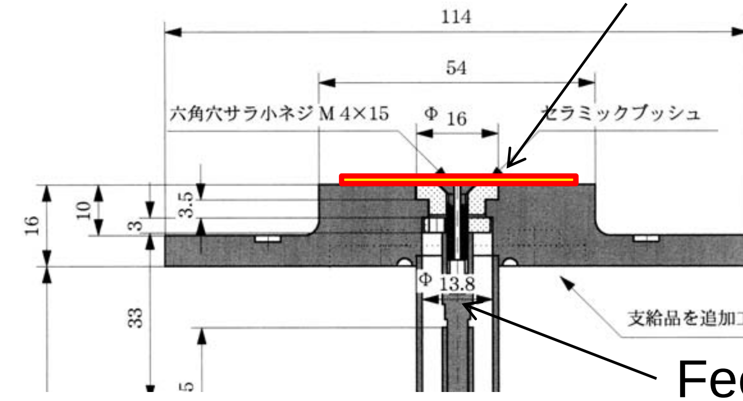
Feed through



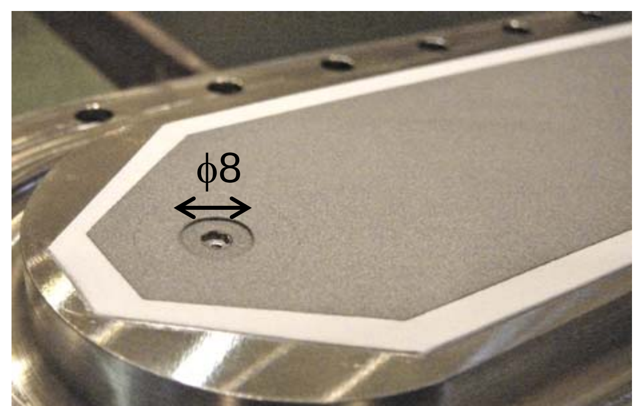


Discharging !

Electrode



Feed through

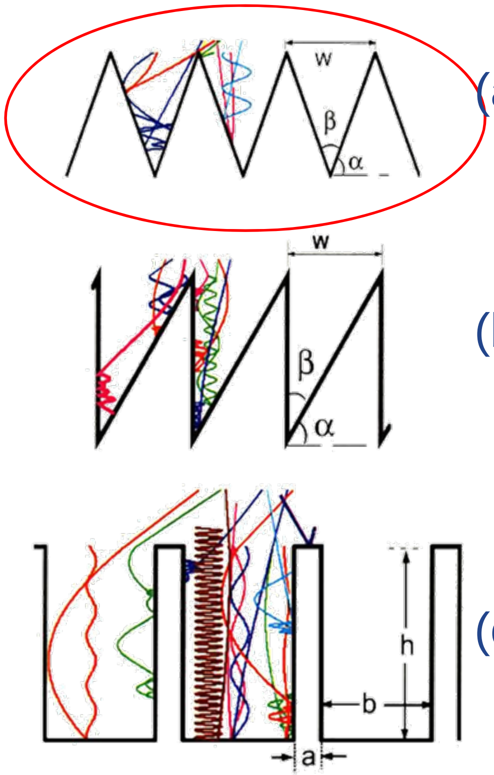


Groove

- **Groove structure can geometrically reduce the effective SEY.**
- **Effective even in magnet.**

L. Wang, T. O. Raubenheimer and G. Stupakov NIM A571 (2007) 588.

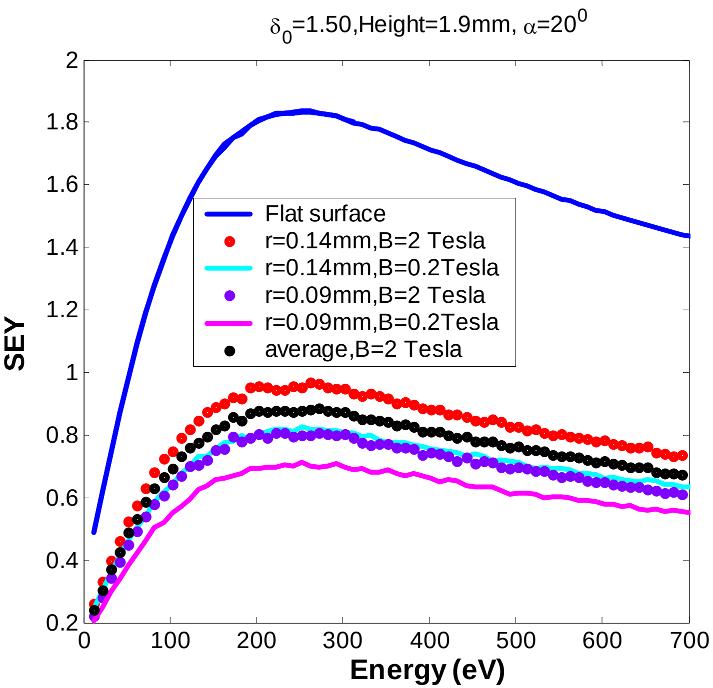
Grooved structure in magnet (simulation)



(a) Isosceles triangular surface

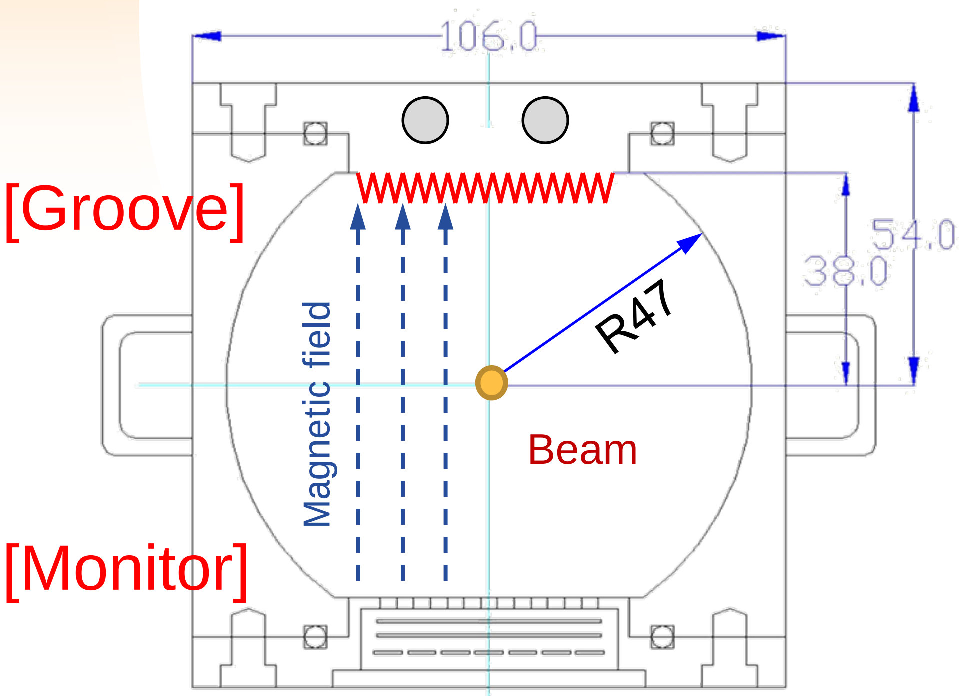
(b) Sawtooth surface

(c) Rectangular surface



Groove

- **The experiment was carried out under collaboration with SLAC (M. Pivi and L. Wang)**
- **EC was measured at the same condition to that for clearing electrode.**
  - The same experimental setup used in the case of electrode



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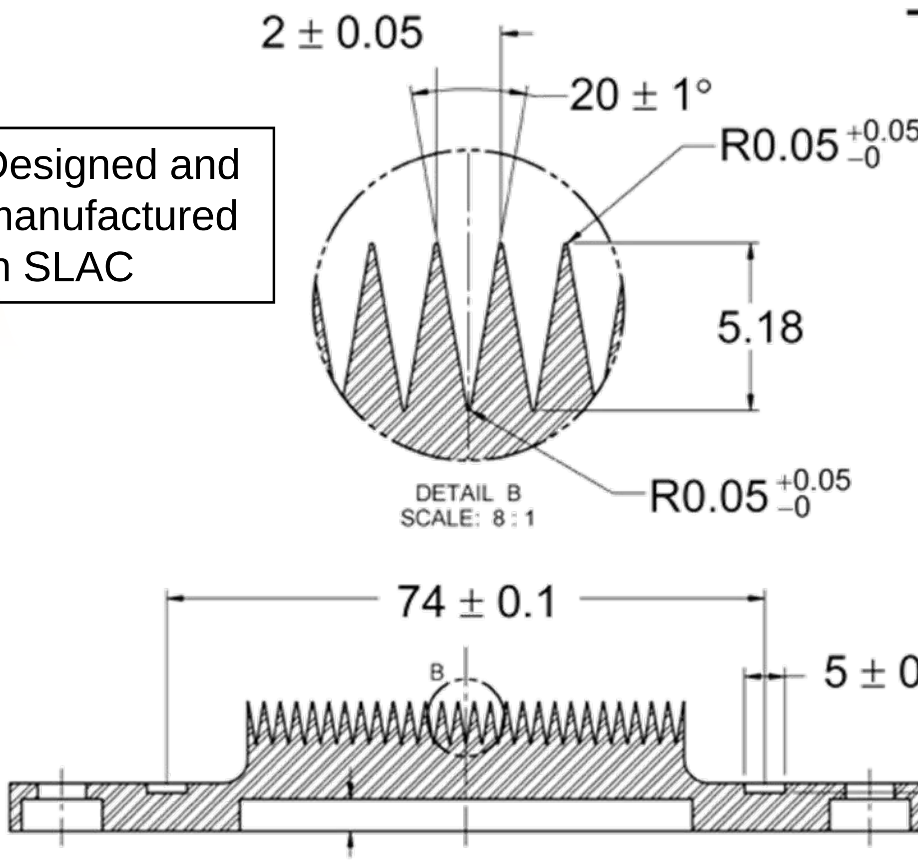
To be published in NIM-PR-A

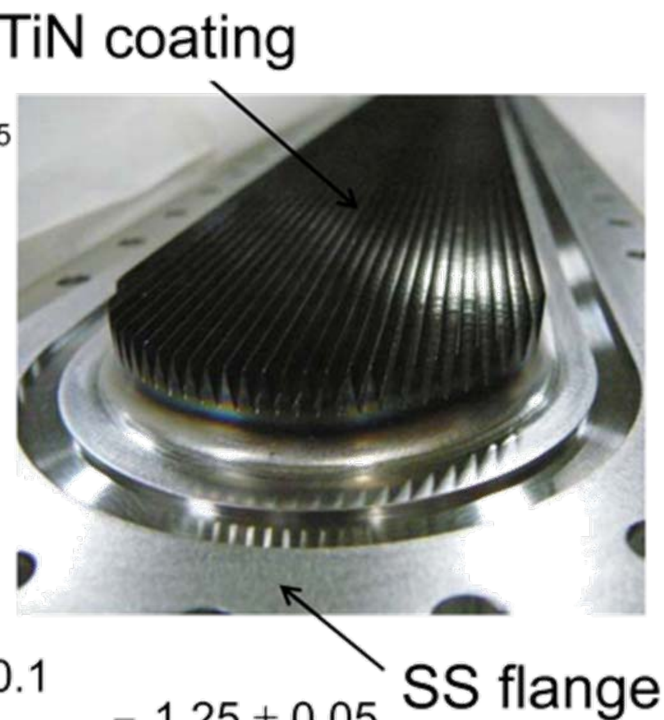
Wiggler magnets
B = 0.77 T

Groove

- **Triangular-type groove structure, with TiN coating**
- **Compared with the data for a flat surface (TiN) and clearing electrode (W)**

Designed and manufactured in SLAC



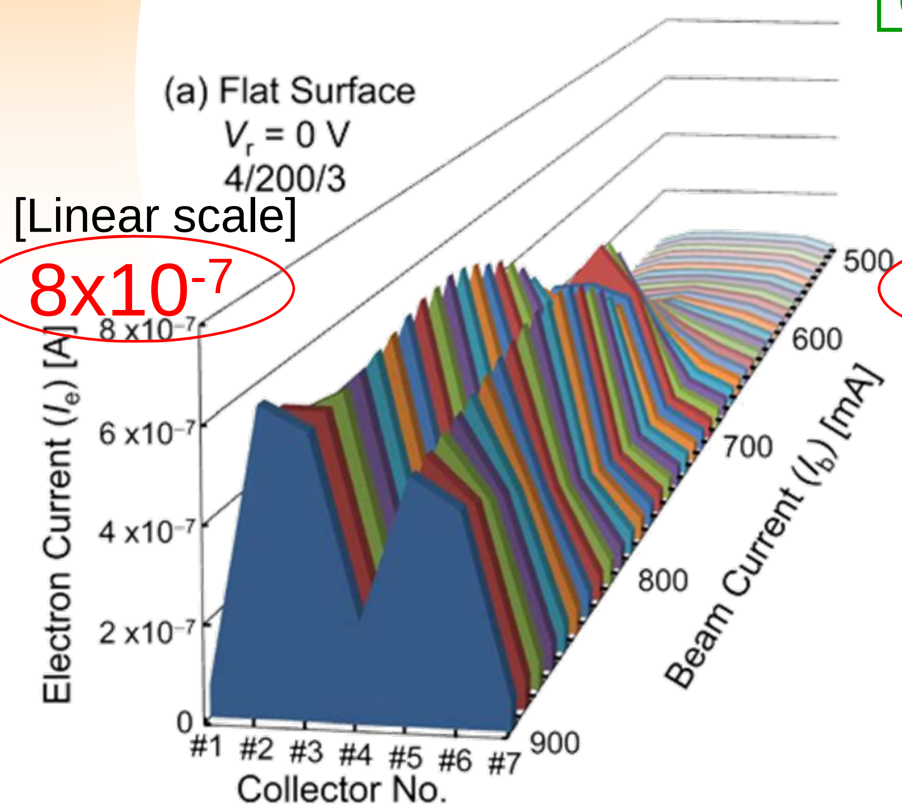


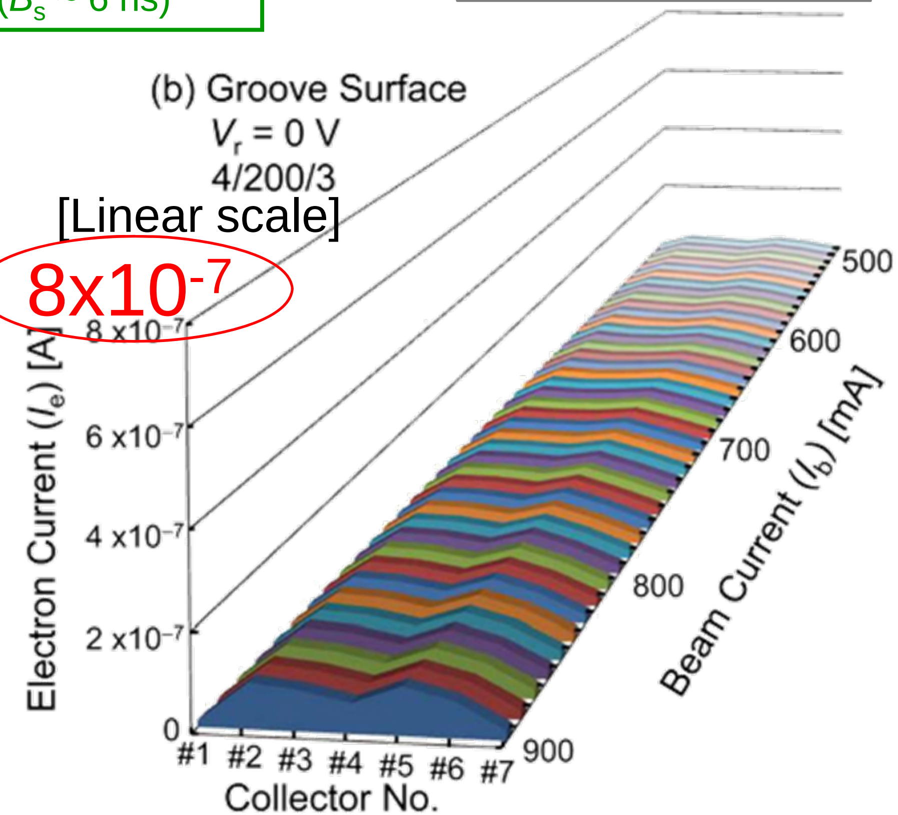
Groove

- **Spatial growths of EC for groove and flat surface**
  - EC for the groove was much smaller than that for flat surface.
  - Small change in the spatial behavior → Small SEY?

1585 bunches
(B_s ~ 6 ns)

Preliminary result





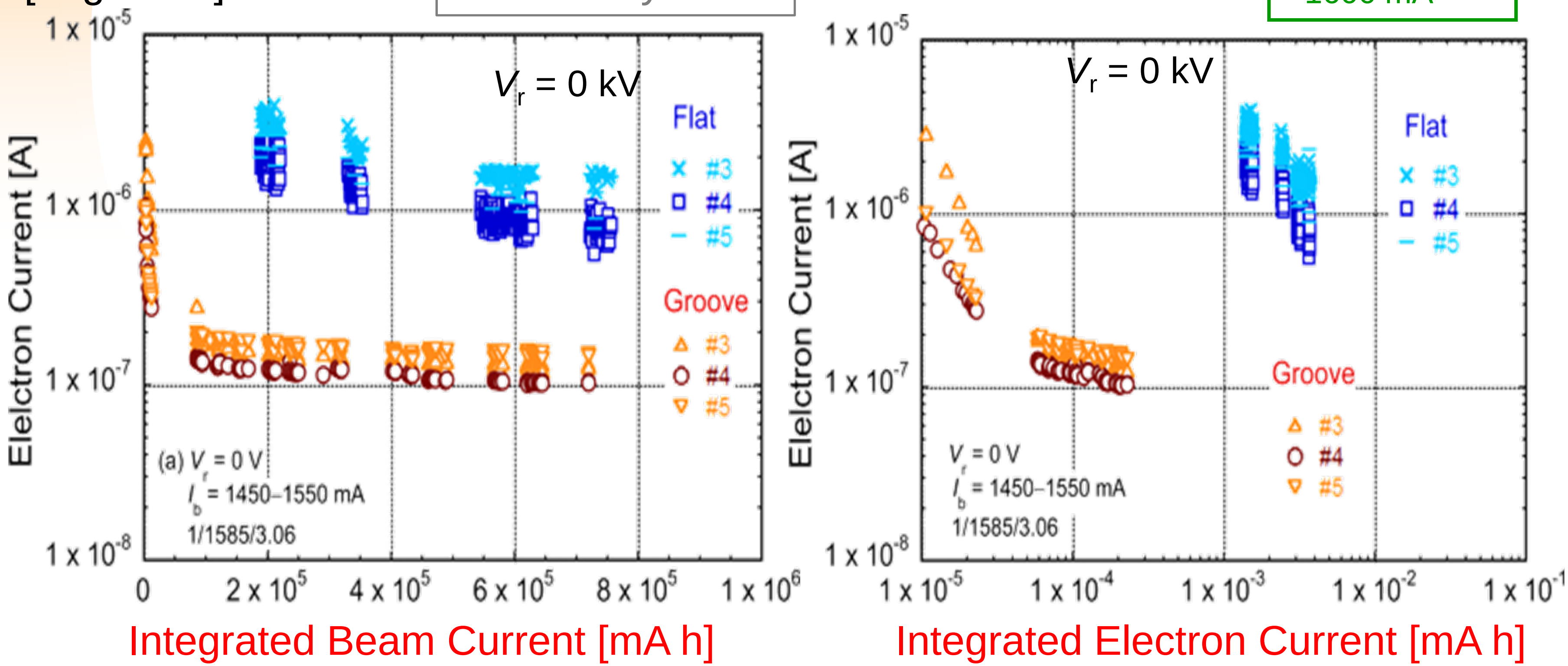
Groove

- **Electron density for the groove was lower than that for the flat surface by ~ one order.**
- **Aging was still proceeding, if plotted by electron dose (integrated electron current).**

1585 bunches
(B_s ~ 6 ns)
~1600 mA

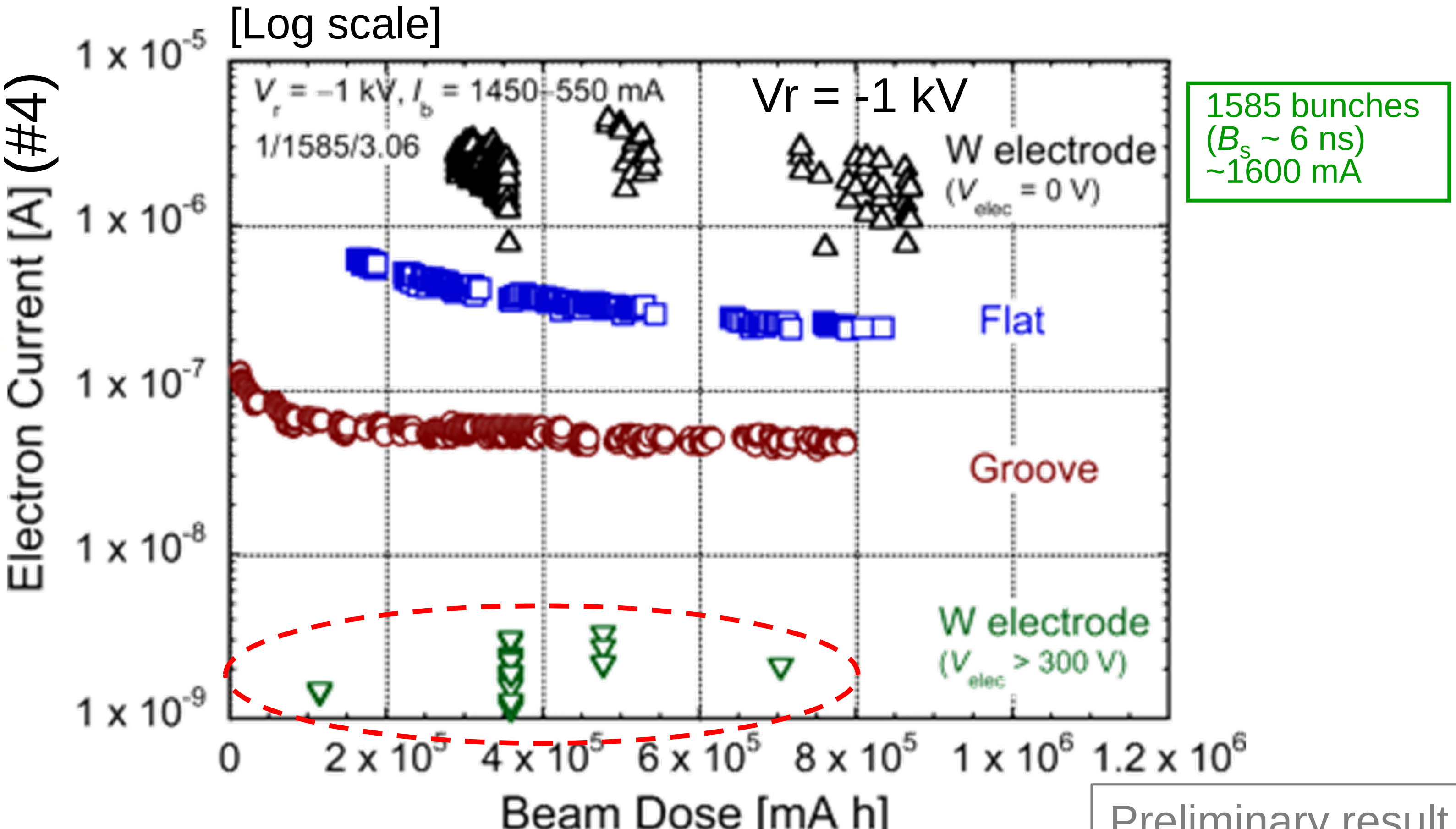
[Log scale]

Preliminary result



Groove

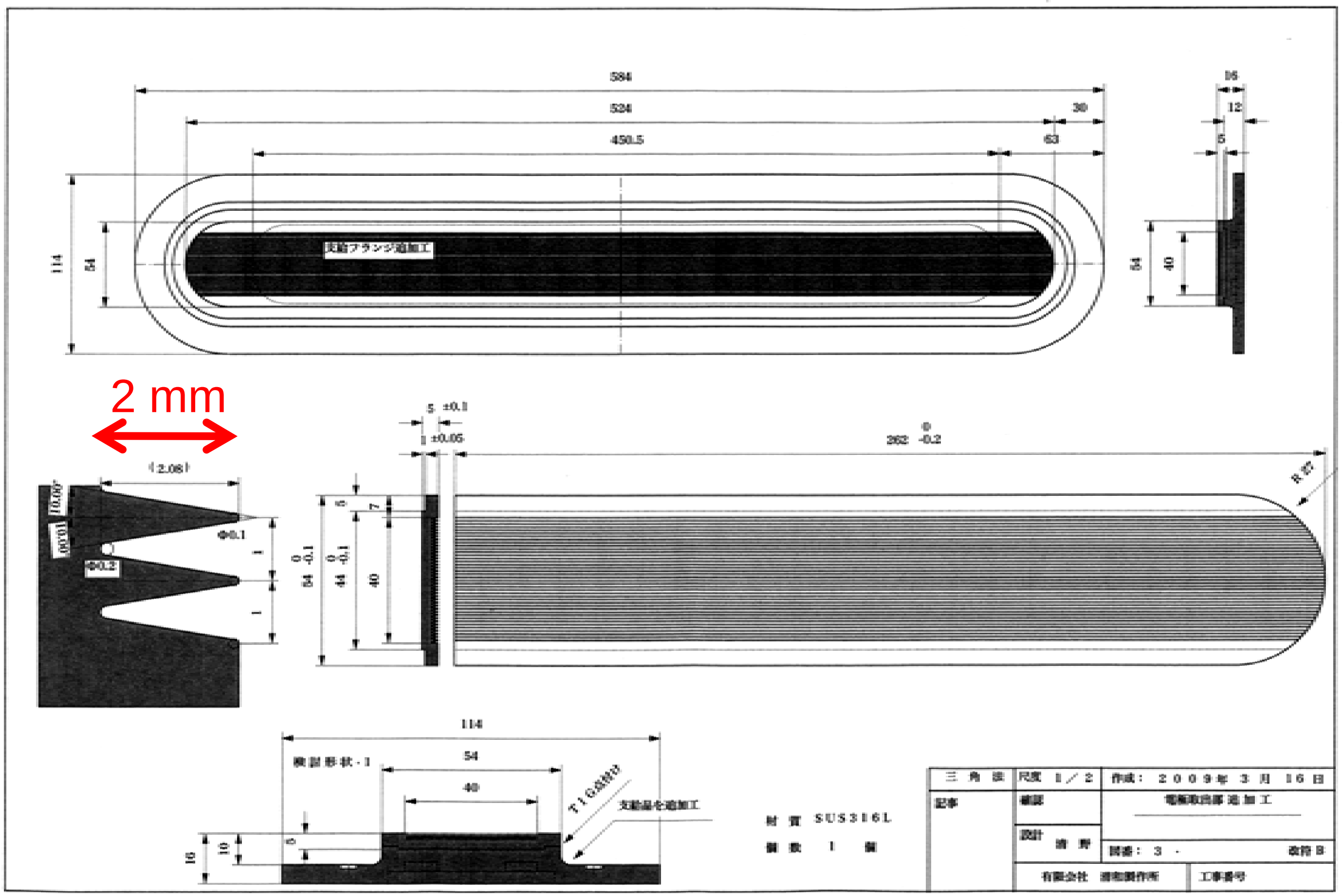
- **However, the electron density is still higher than the case of a clearing electrode with V_{elec} > + 300 V by more than one order of magnitude.**



Preliminary result

Groove

- **A new groove structure with a height of 2 mm is now under consideration (20°).**
- **It will be tested in 2009.**



Comparison

- Both methods can be used in magnetic fields.
- Compared to methods using thin coatings, these methods guarantee long-term stability.
- A common key issue is the beam impedance.
- Clearing electrode is more effective than TiN-coated flat surface, and the TiN-coated groove, in reducing the electron cloud.
- Clearing electrode required a power supply for each electrode. The development of a reliable electrical connection of the feed-through to the electrode is a key issue
- Manufacturing cost may be low for a clearing electrode if the thermal-spray method can be used. Sufficiently accurate manufacturing of grooves might increase the cost.

Summary

- **Various EC studies are undergoing at KEKB**
- **Updates:**
  - Measurement of electron density in a solenoid field and Q-magnet has just started, and the preliminary values were obtained for the first time.
  - Clearing electrode in bending magnetic field was found to be very effective in reducing electron density
  - Groove surface in bending magnetic field was also very effective, next to the electrode.
- **Next step**
  - Development of a reliable feed through for electrode
  - Development of a reliable manufacturing process for groove
  - Estimation of impedance
  - Suitable choice of technique

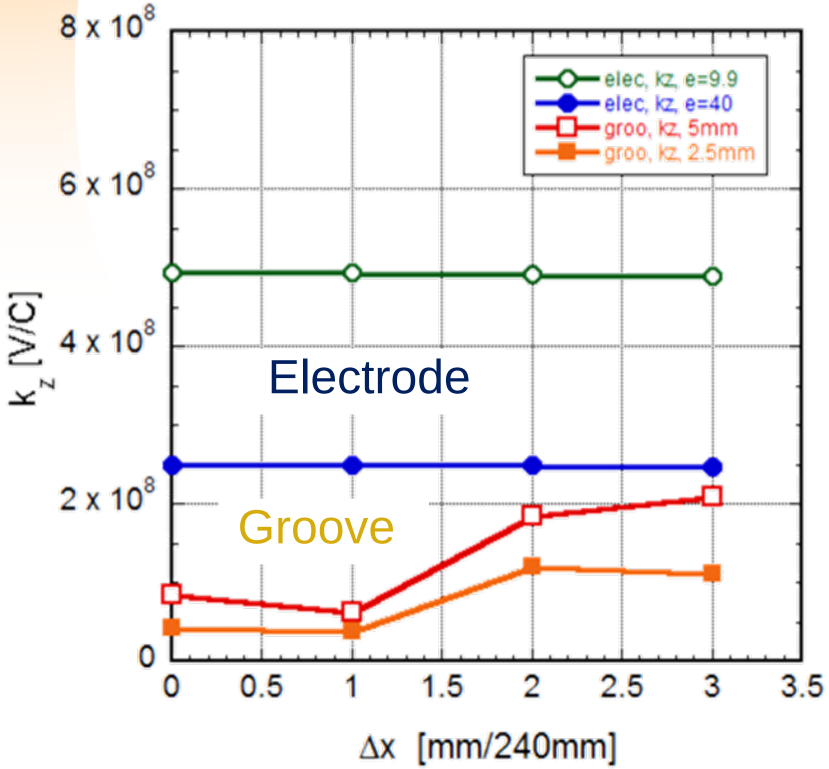
Backup slides

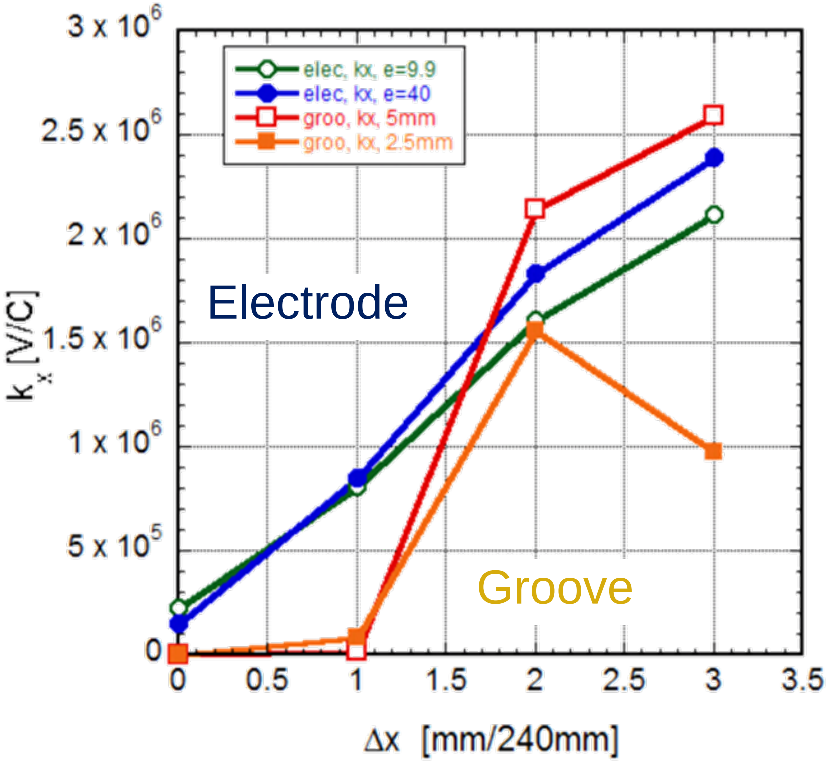
Groove

- **Loss factors and kick factors when the groove or electrode is tilted against a beam.**

σ_z = 8 mm

Preliminary result

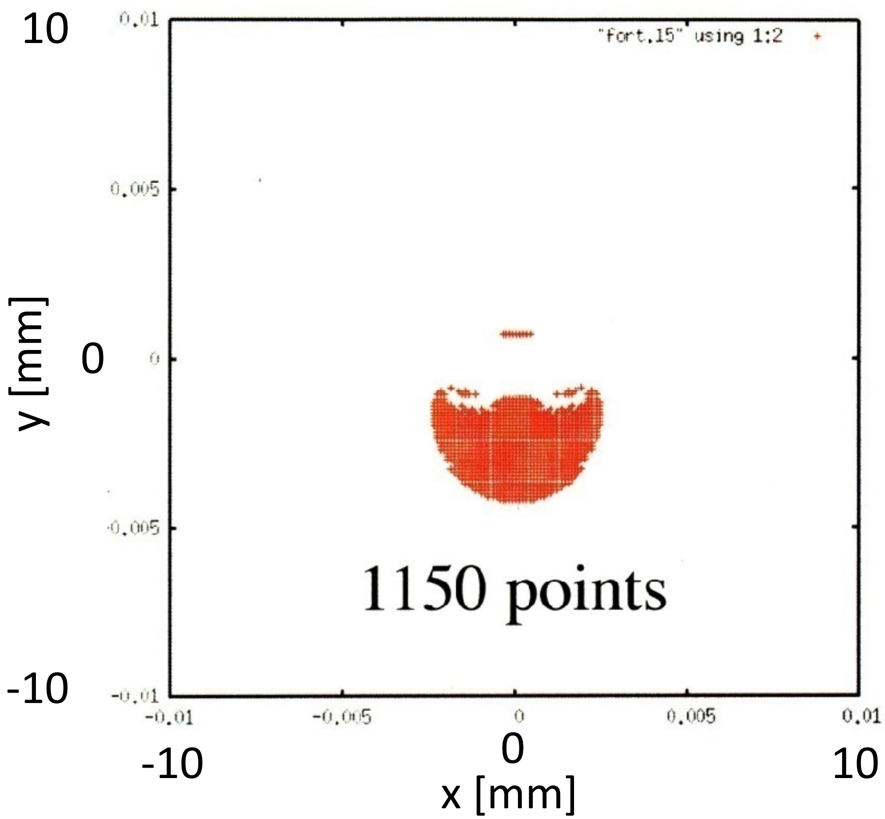




Clearing Electrode

- **Simulation**

Initial (x0,y0) of electrons which entered the monitor and had the kinetic energy normal to the monitor larger than 1keV.



Preliminary result

Clearing electrode

- **New strip-line type electrode was developed.**
- **Very thin electrode and insulator;**
  - Insulator: ~0.2 mm, Al_2O_3, by thermal spray.
  - Electrode: ~0.1 mm, Tungsten, by thermal spray.
- **Low beam impedance, high thermal conductivity**
  - Input power ~ 100 W

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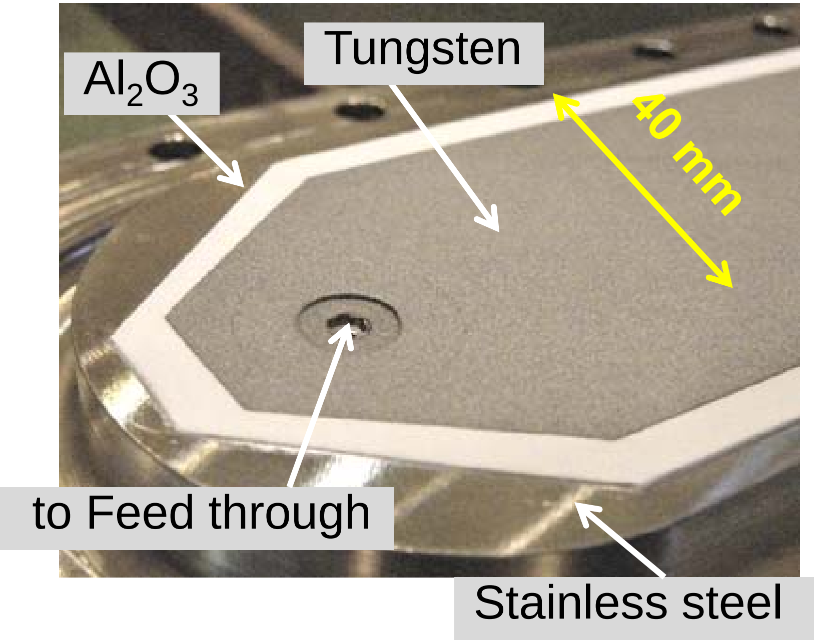
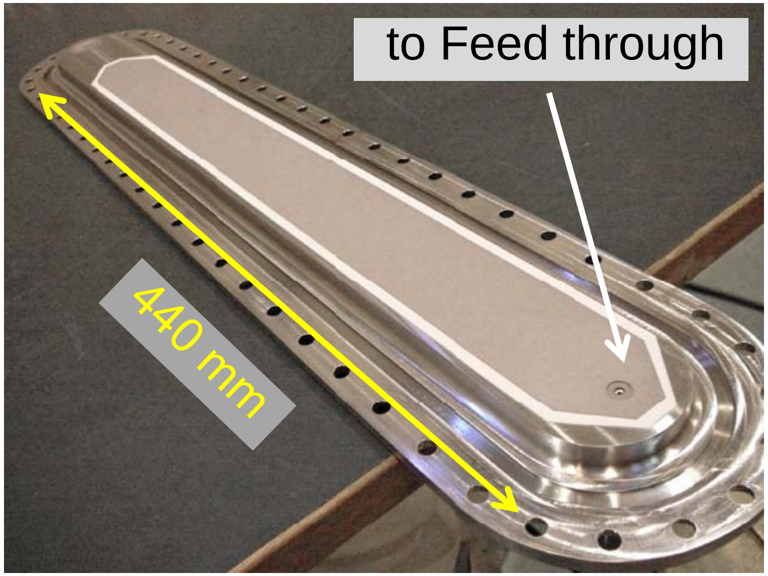
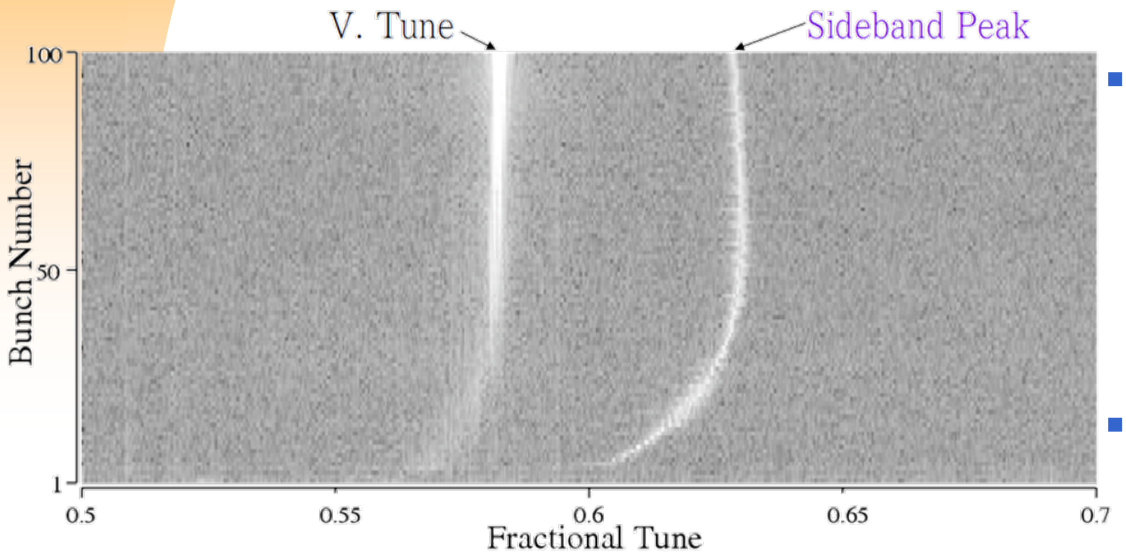




Head tail instability

- **Measurement of synchro-betatron sidebands**
  - Direct evidence of Head-Tail instability due to EC



- LER single beam, 4 trains, 100 bunches per train, 4 rf bucket spacing
- Solenoids off: beam size increased from 60 μm ->283 μm at 400 mA
- Vertical feedback gain lowered
  - This brings out the vertical tune without external excitation

- **Sideband appears at beam-size blow-up threshold, initially at ~ $\nu_b + \nu_s$, with separation distance from ν_b increasing as cloud density increases.**
- **Sideband peak moves with betatron peak when betatron tune is changed.**
- **Sideband separation from ν_b changes with change in ν_s.**

Bunch Oscillation Recorder (BOR)

– Digitizer synched to RF clock, plus 20-MByte memory.
– Can record 4096 turns x 5120 buckets worth of data.
– Calculate Fourier power spectrum of each bunch separately.

J.W. Flanagan et al,
PRL 94, 054801 (2005)

Head tail instability

- **Simulations of electron cloud induced head-tail instability (PEHTS)**
  - The behavior is consistent with simulation

E. Benedetto and K. Ohmi

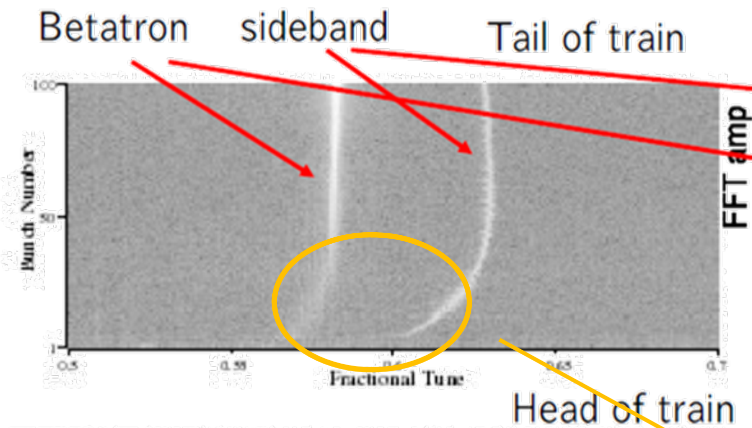
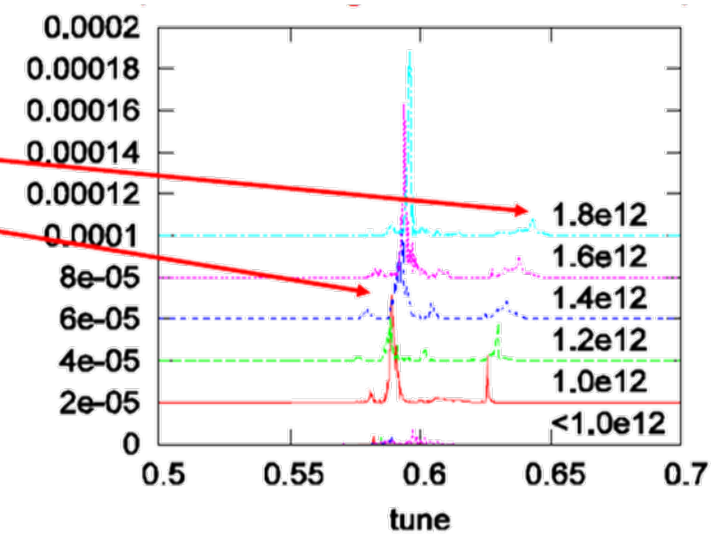
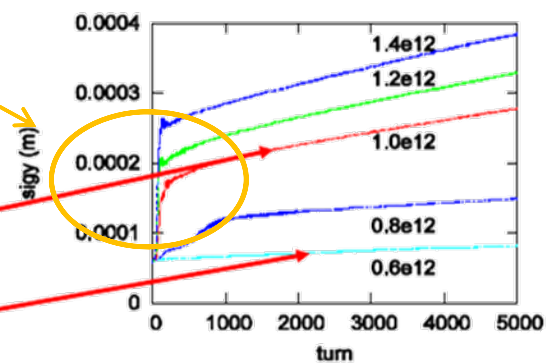


FIG. 1. Two-dimensional plot of vertical bunch spectrum versus bunch number. The horizontal axis is the fractional tune, from 0.5 on the left edge to 0.7 on the right edge. The vertical axis is the bunch number in the train, from 1 on the bottom edge to 100 on the top edge. The bunches in the train are spaced 4-rf buckets (about 8 ns) apart. The bright, curved line on the left is the vertical betatron tune, made visible by reducing the bunch-by-bunch feedback gain by 6 dB from the level usually used for stable operation. The line on the right is the sideband.





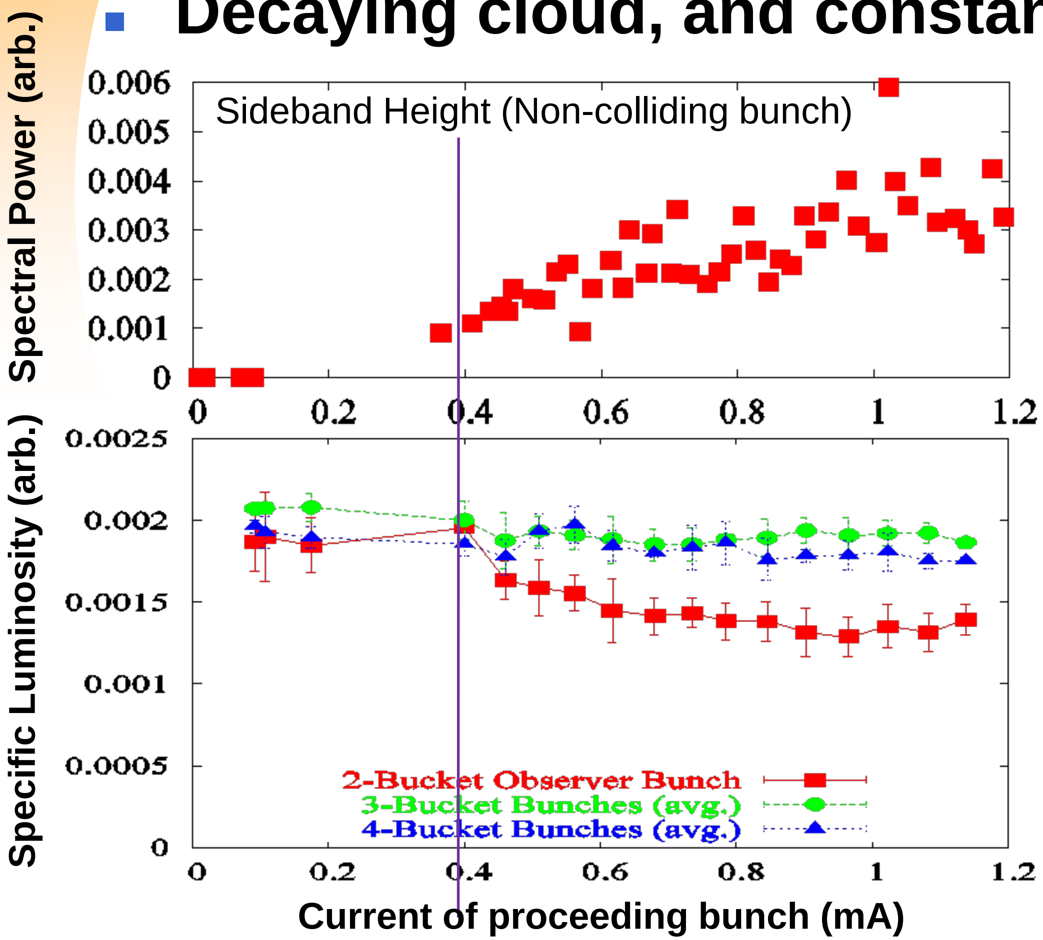
Head-tail regime

Incoherent regime

Head tail instability

- **Presence of sidebands also associated with loss of luminosity during collision.**
- **Decaying cloud, and constant bunch current**

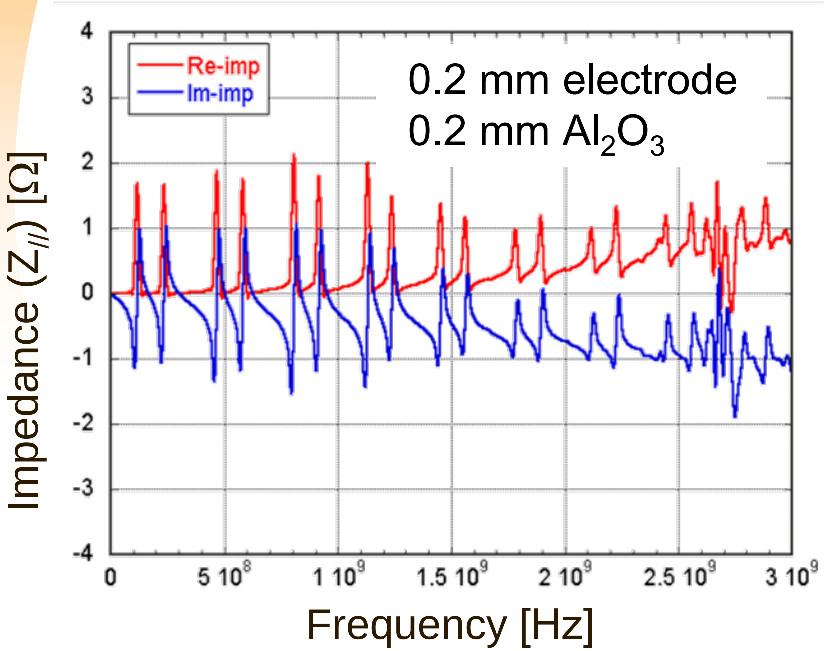
J.W. Flanagan et al, Proc. PAC05

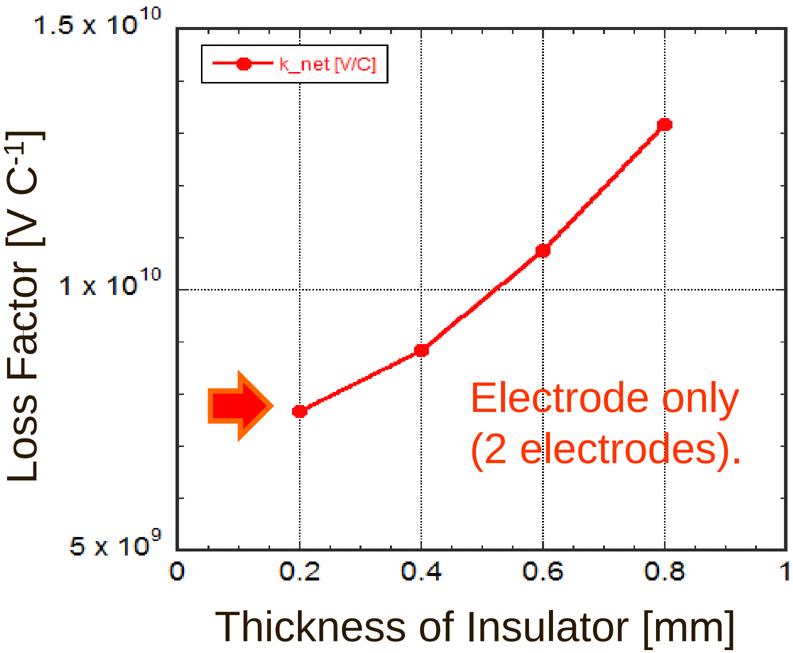


- **Specific luminosity of high-cloud witness bunch is lower than that of regular bunches when leading bunch current is above 0.4 mA, but is the same below 0.4 mA.**
- **Consistent with sideband behavior, and explanation that loss of specific luminosity is due to electron cloud instability.**

Clearing electrode

- **RF properties (calculation by MAFIA)**
  - Thin electrode and insulator→ Low beam impedance





- $Z_{//}$ ~ a few Ohm
- $Z_{//}$ reduced to ~1/5 compared to the case of 1 mm thick.
- R/Q ~ 0.1

- k ~1.5×10^{10} V/C including the connection part (2 electrodes).
- Dissipated power is ~ 120 W for 1 electrode. (@1.6 A,1585 bunches)