Measurement of Photoelectron Yield at KEK PF

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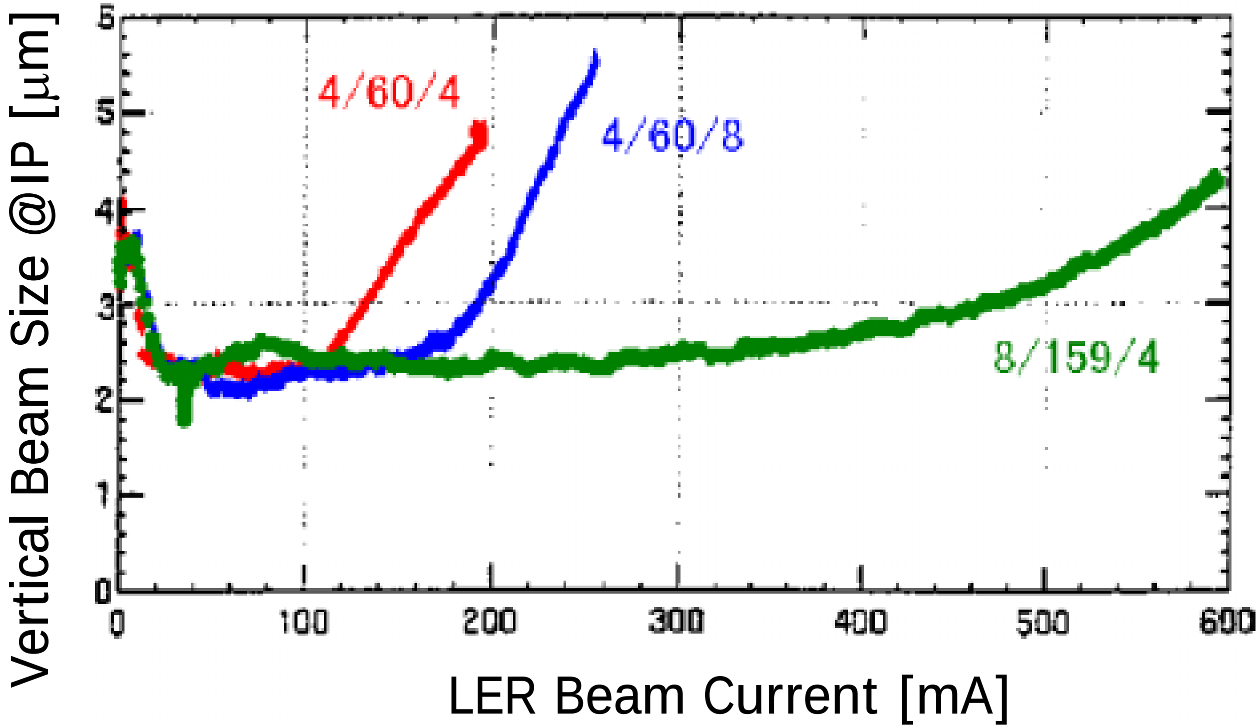
Introduction

- One of the latest serious problems for KEKB is a beam size blow up of the positron beam.

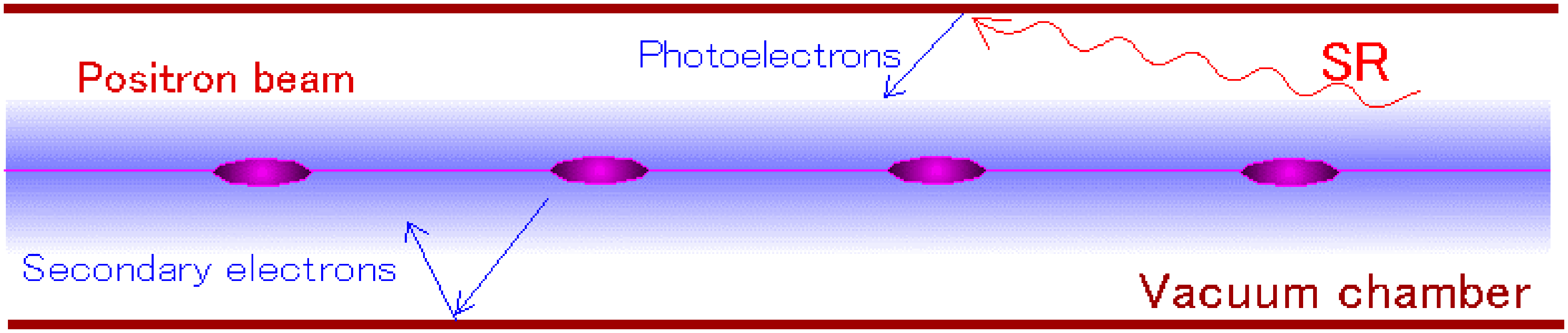


Without Solenoid

The symbol of 4/60/8, for an example, means that the beam consists of 4 trains of 60 bunches filled with every 8 RF buckets spacing (16 ns).

Introduction - 2

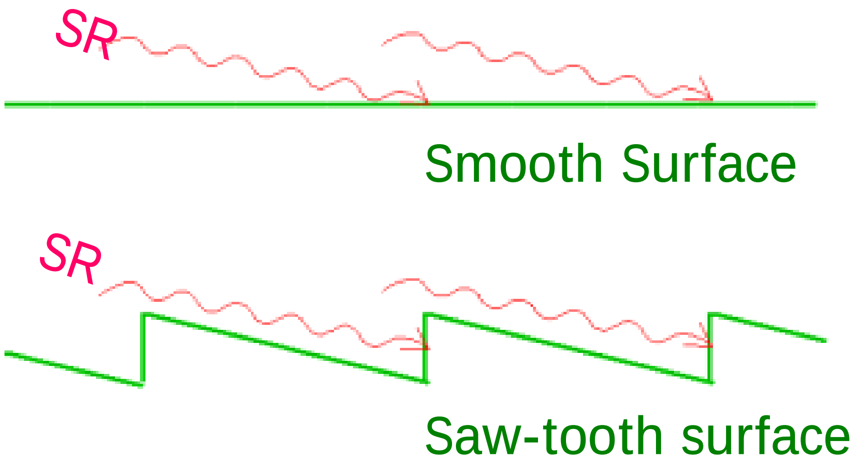
- The blow up is considered to be caused by a single-beam instability due to an electron cloud around the positron beam.



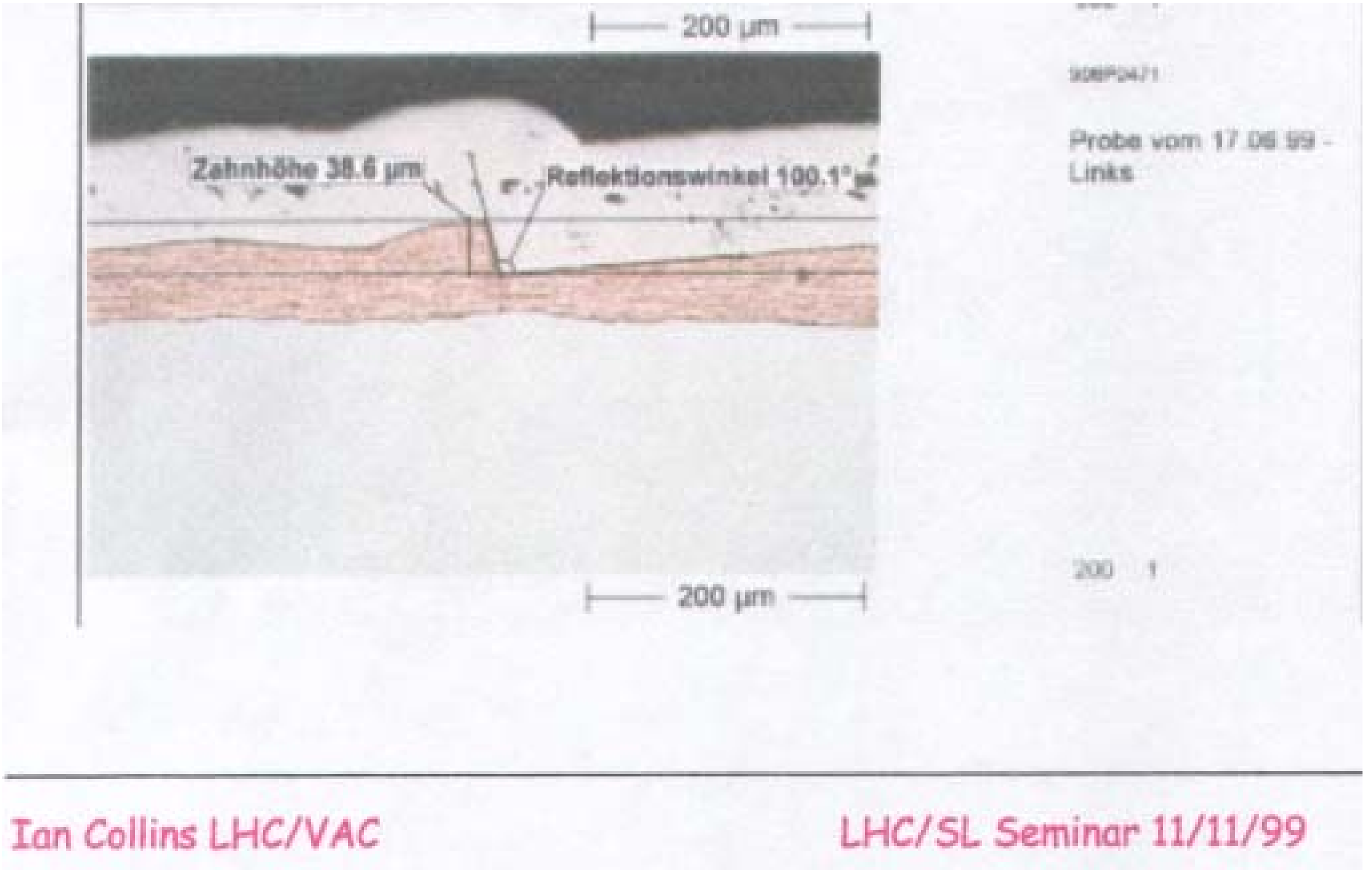
- The seed of the electron cloud is mainly the photoelectrons emitted from the chamber surface irradiated by synchrotron radiation (SR). Some electrons may be multiplied by multipactoring.

Purpose of Experiment

- Consider a saw-tooth surface as a promising method to reduce the photoelectron yield. The reduction was verified by SR with small critical energy at CERN (45-195 eV).
- Measure the photoelectron yield using the SR with a critical energy of 4.1 keV from the KEK Photon Factory (PF) using a test chamber and find the effect of the saw-tooth surface and its availability to the LER.
- Also investigate the spatial distribution of photoelectrons, the effect of positive potential and external magnetic fields.

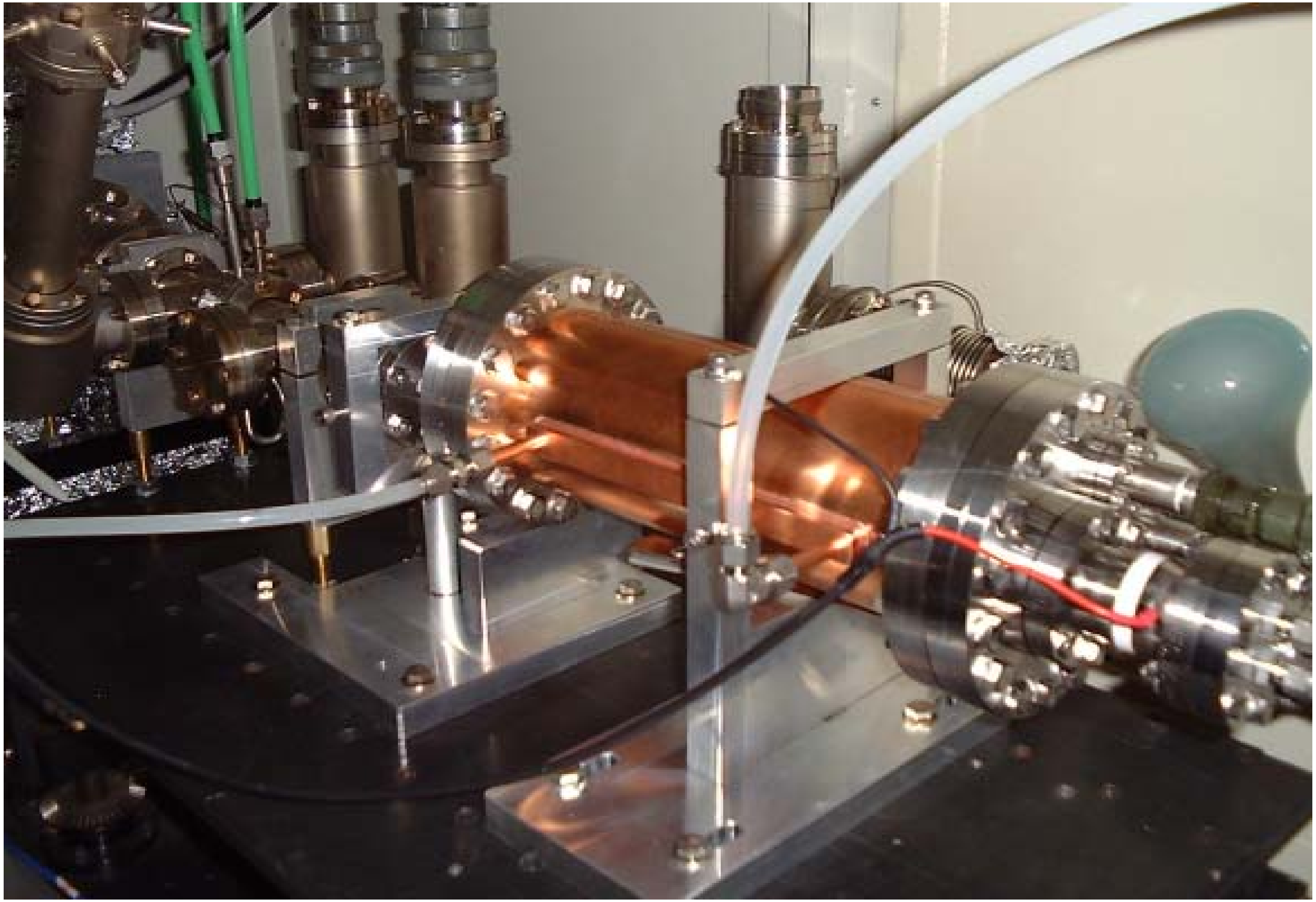


Saw-Tooth tested at CERN

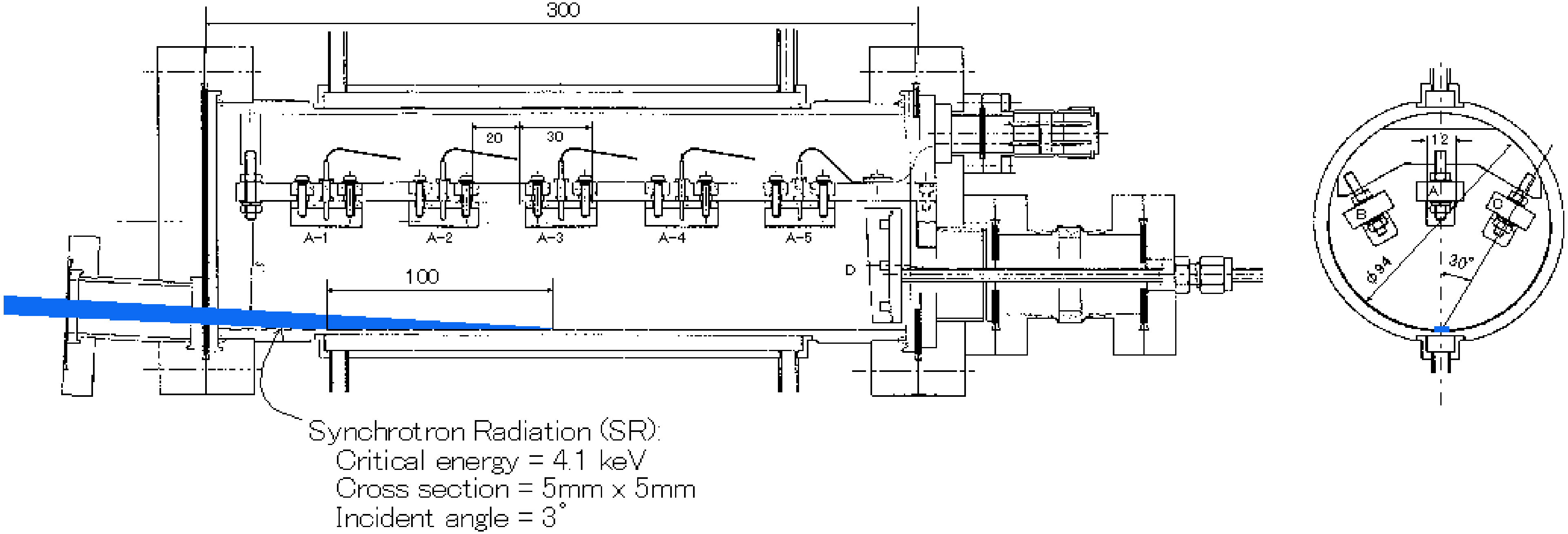


† I.R.Collins and F.Zimmermann,
"Electron Cloud Investigation, Electron Cloud Simulation", in LHC/SL Seminar, 11/11/99, http://wwwslap.cern.ch/collective.

Test Chamber at Beam Line

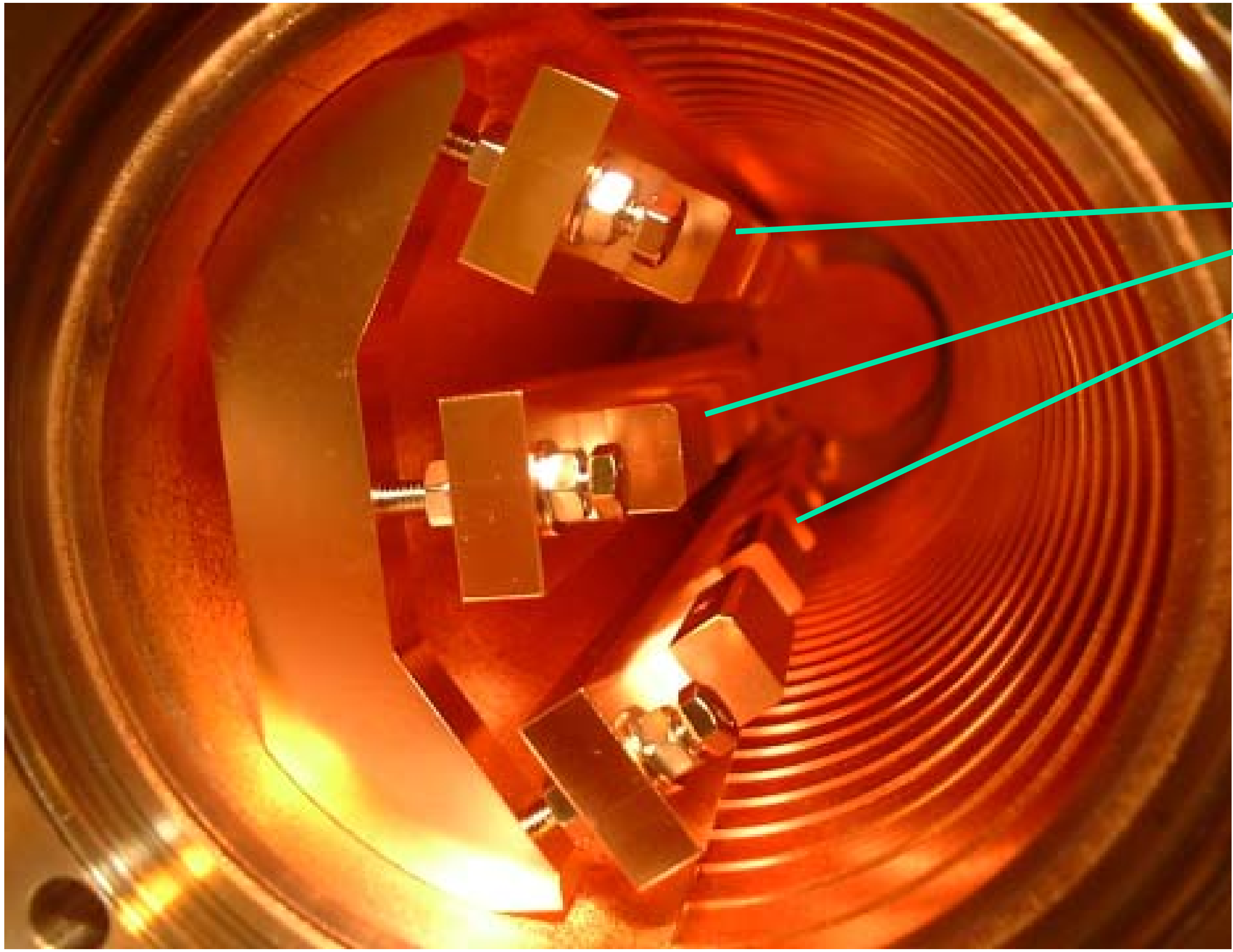


Inside of Test Chamber



- The total photon number is about 4.9×10^{13} photons s^{-1} for a unit beam current in mA.
- 15 copper electrodes (12 mm x 30 mm), five rows axially (No.1-No.5) and three lines azimuthally (A,B,C), are arranged above the irradiated surface.

Inside of Test Chamber

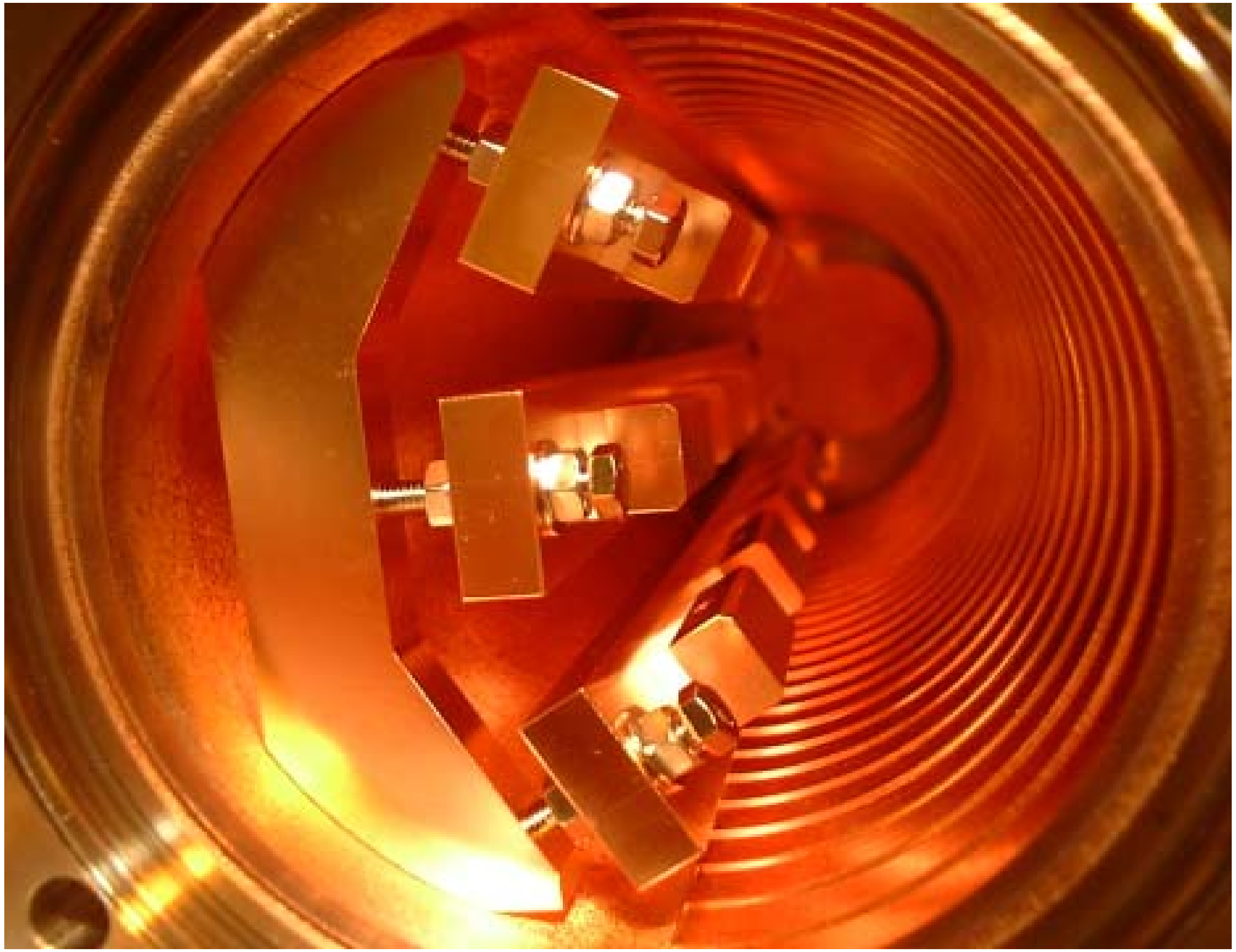


Electrodes

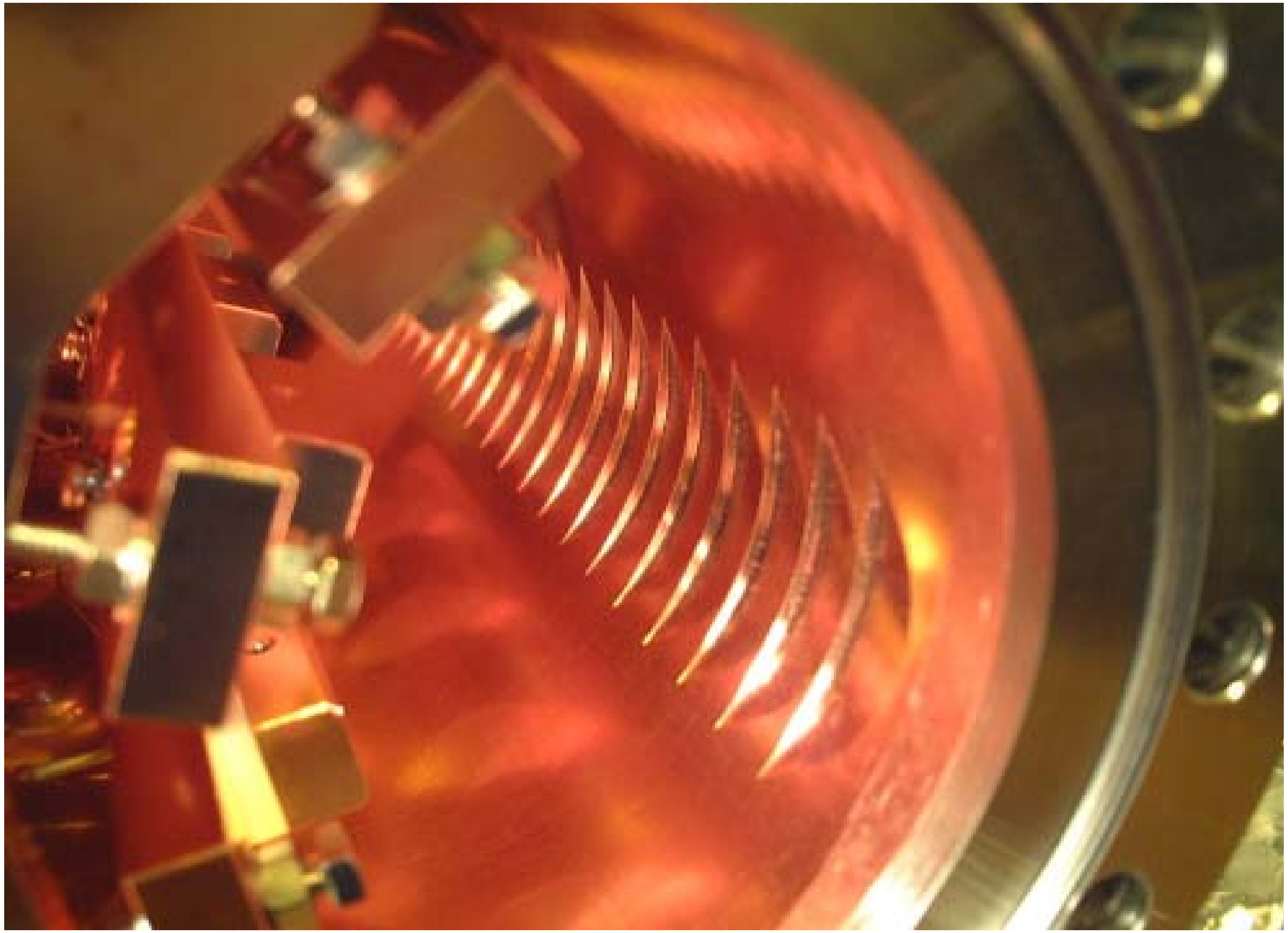
Surfaces Prepared

- (1)[Saw-tooth_1] The saw-tooth surface with a pitch and a depth of 10 mm and 1 mm, respectively. The machining was performed for a half of the chamber surface.
- (2)[Saw-tooth_2] The saw-tooth surface is the same as (1), but machining was done only for about 20 mm width around the irradiated area.
- (3)[Machining (R_a = 7)] The surface was lathed azimuthally with a mean roughness (R_a) of about 7.
- (4)[Smooth (R_a = 0.02)] A cold-drawn chamber same as that used for the LER.

Saw-tooth 1

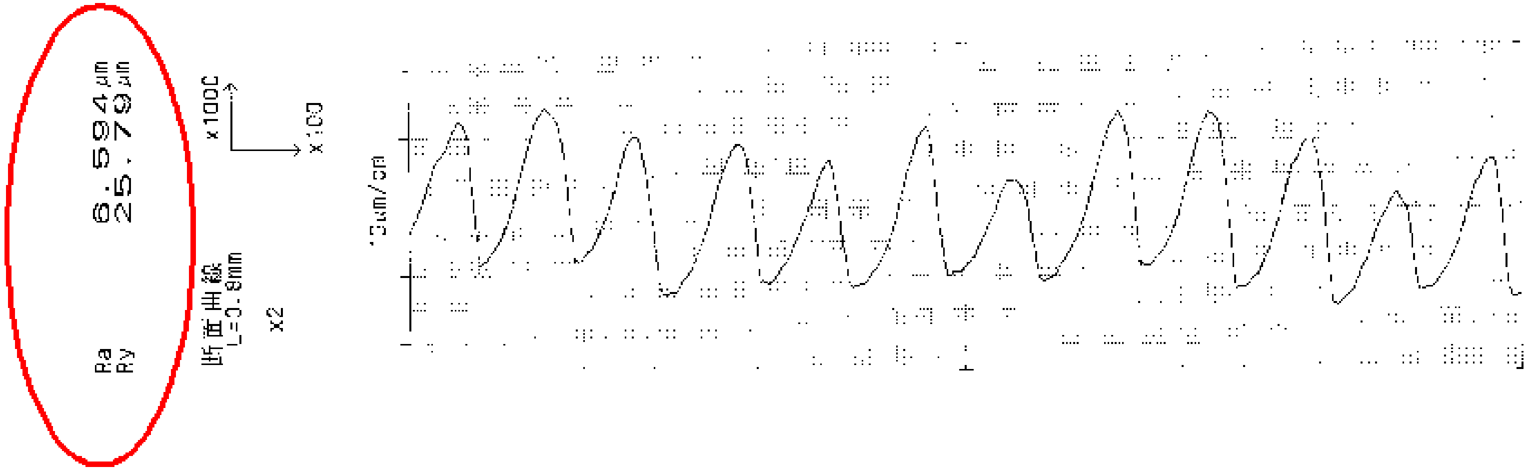


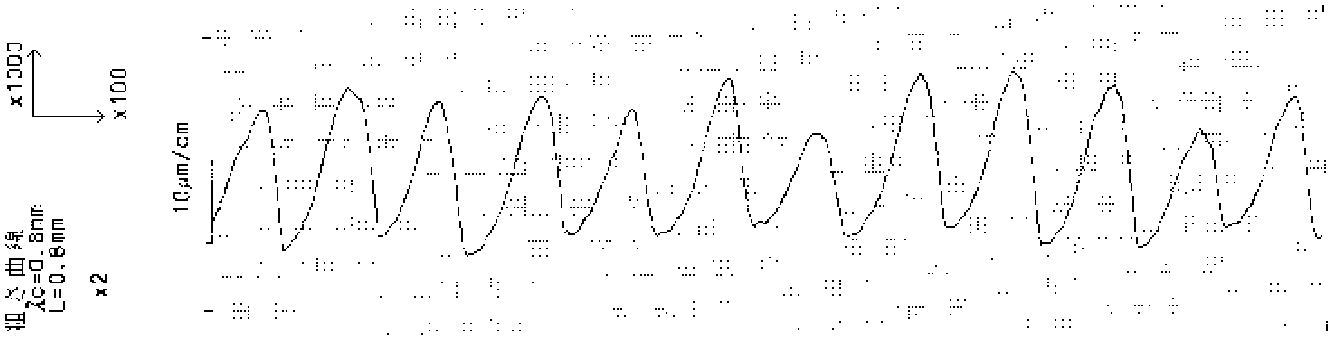
Saw-tooth 2



Machined Surface

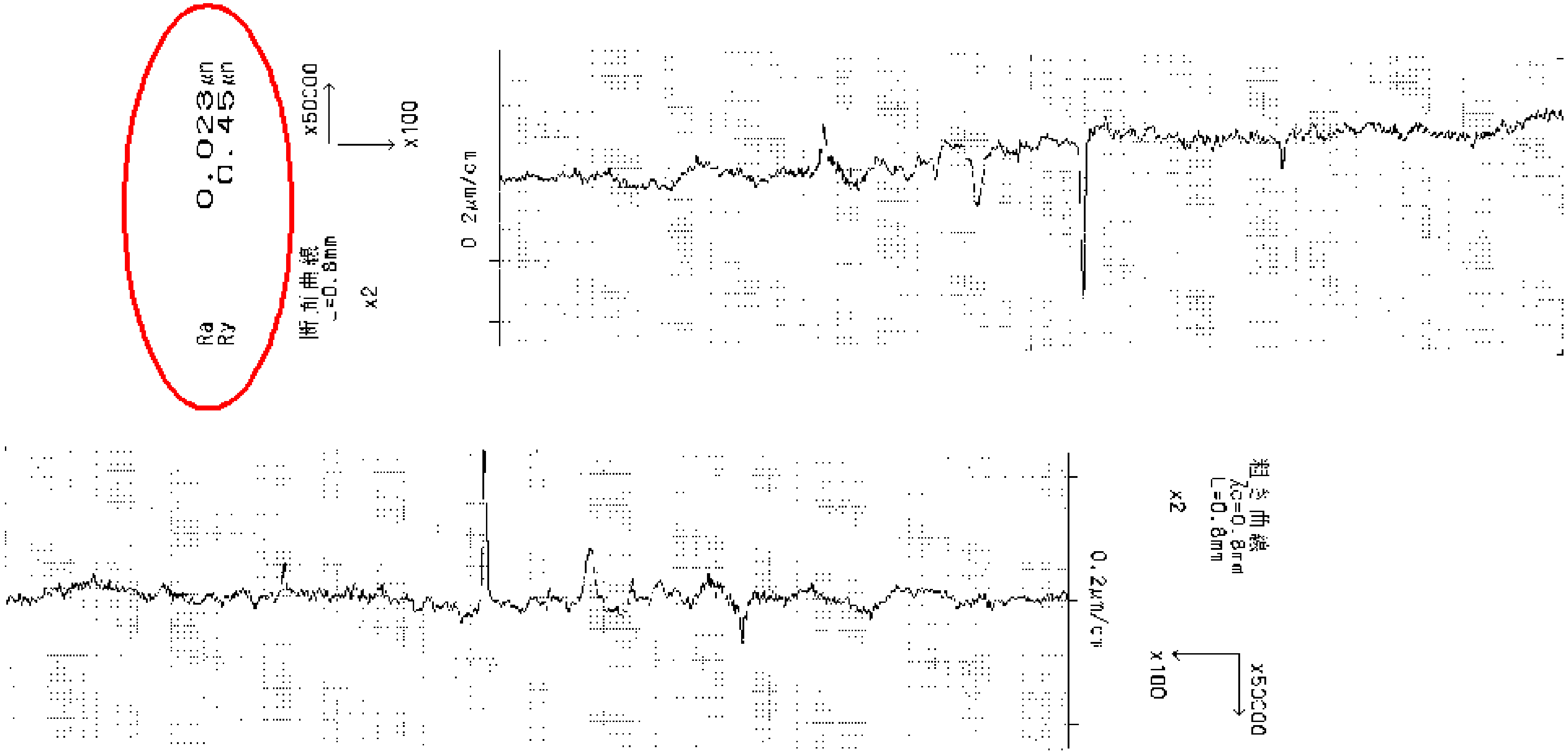
- Axial Roughness





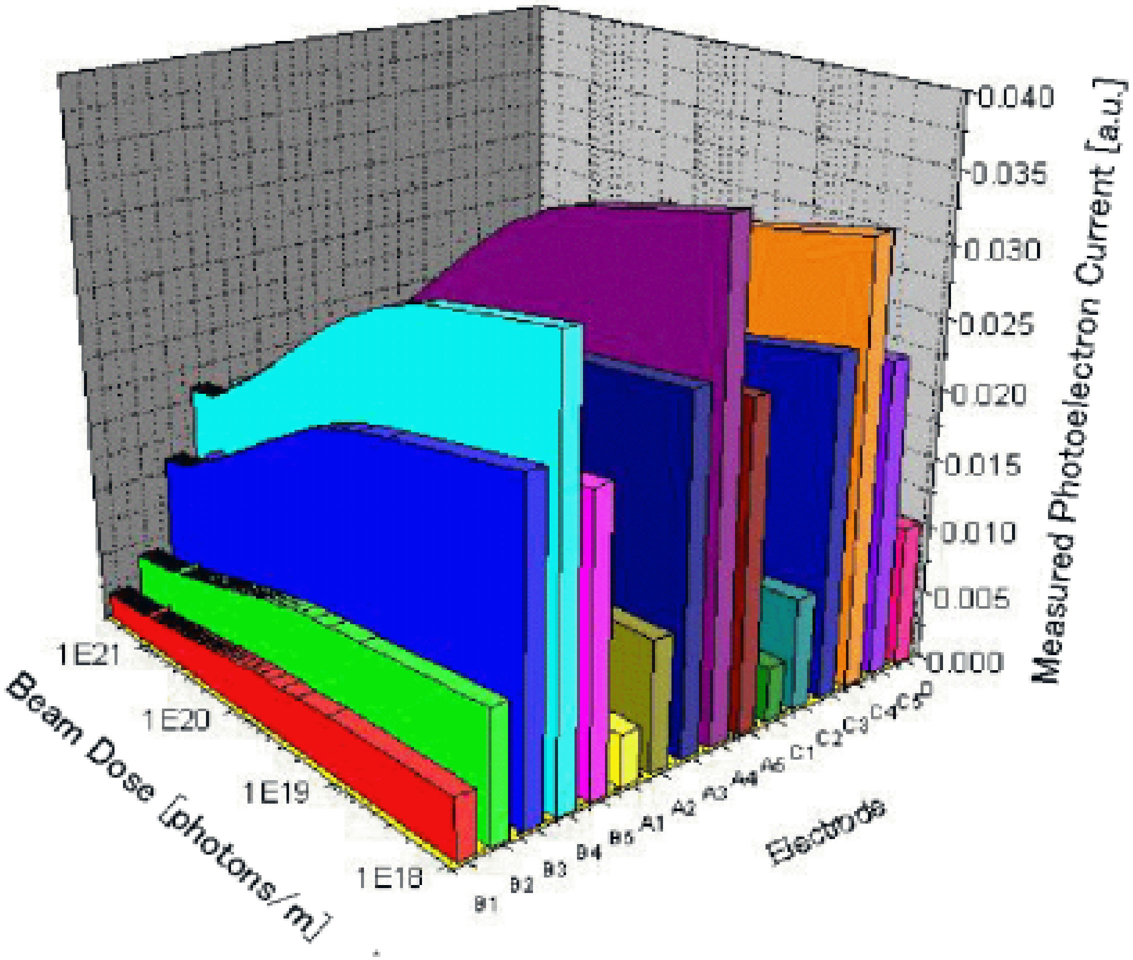
Smooth Surface

- Axial Roughness



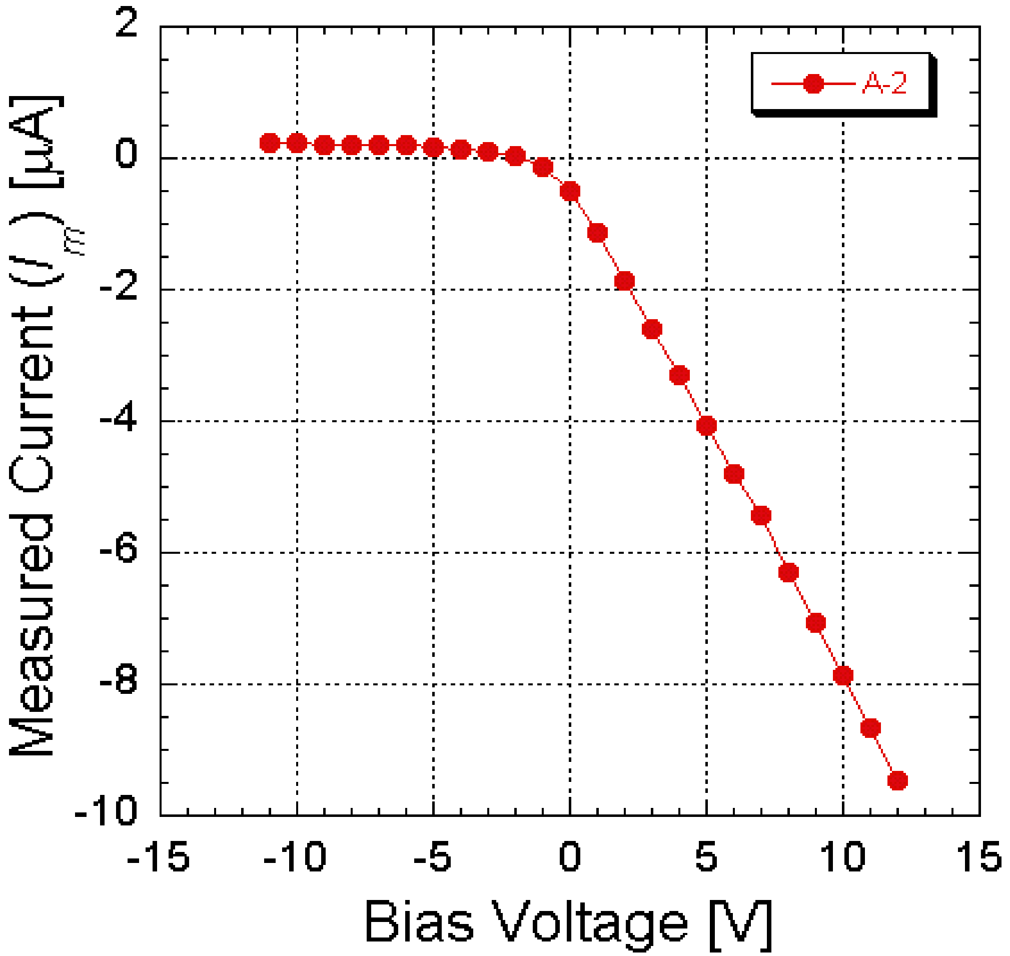
Measured Current

- Change of measured currents against beam dose



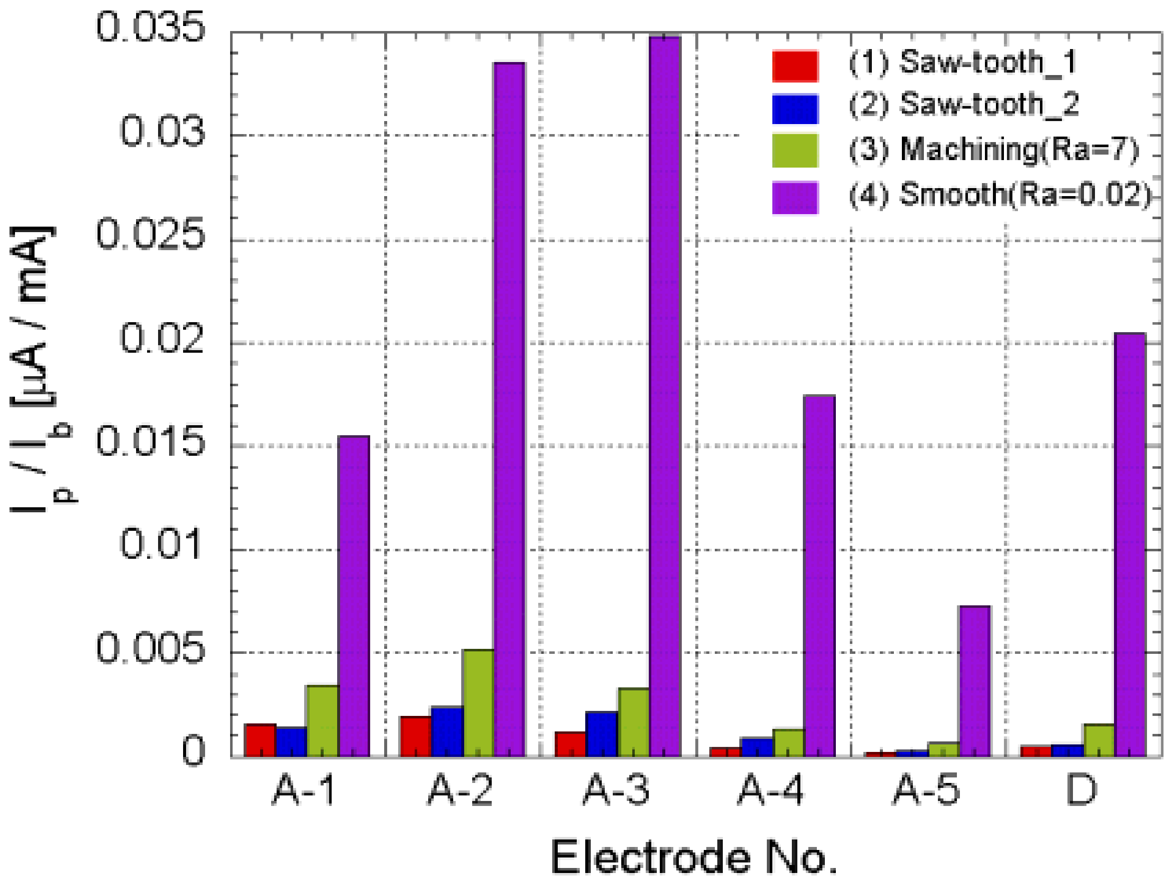
- The following measurements were performed after the integrated photon irradiation of about $3x10^{21}$ photons m^{-1}, where the photoelectron yield settled down to almost a constant value.

Photoelectron Energy



- For a negative voltage, the current saturates at less than 5 eV. This indicates that the energy of photoelectrons is almost less than 5 eV.
- Here, we define the current due to only the photoelectrons (photoelectron current, I_p) by $I_p = I_m(0\ \text{V}) - I_m(-11\ \text{V})$, where $I_m(0\ \text{V})$ and $I_m(-11\text{V})$ are the measured current at a bias voltage of 0 V and -11 V, respectively.

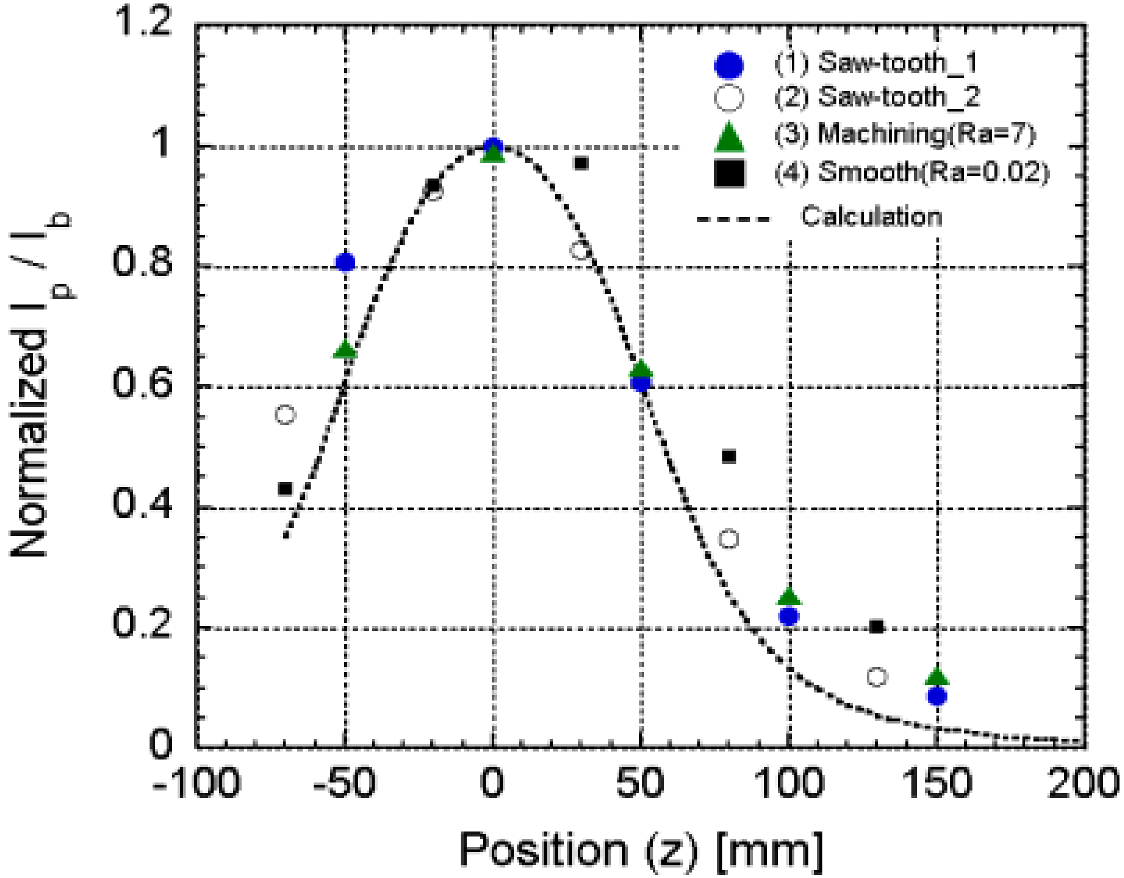
Photoelectron Current



I_b : Beam Current

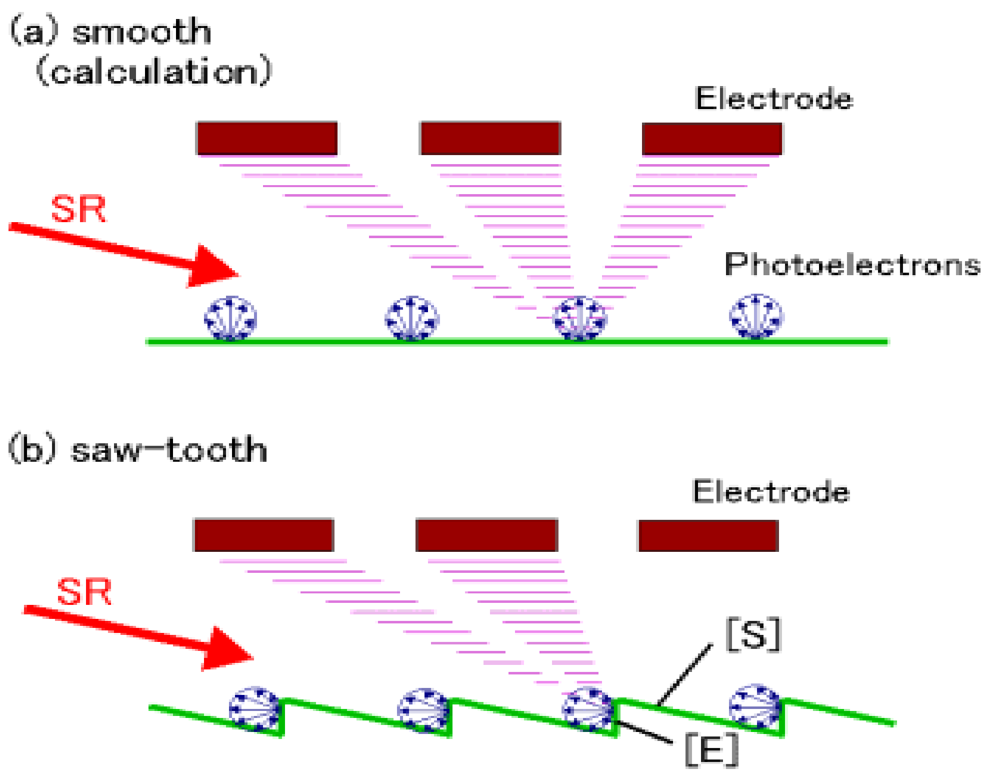
- For the saw-tooth (1) and (2), the peak value is less than 6% of the smooth surface (4).
- Two saw-tooth surfaces, (1) and (2), have almost the same value but slightly smaller for the case (1).
- Even for the machined surface (3), the peak value is about 14% of the smooth surface (4). This means that a rough surface with a roughness of R_a = 7 serves as also a shallow but effective saw-tooth surface.

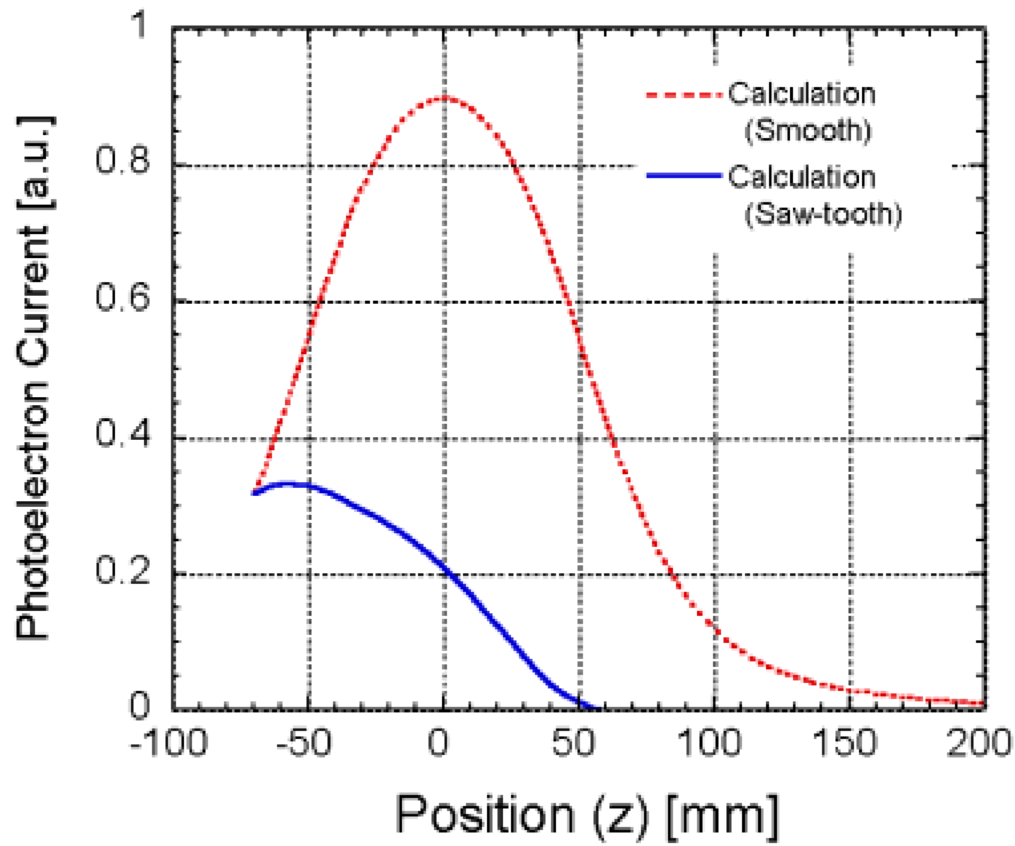
Axial Distribution



- The values are normalized by those near to the center of the irradiated area (z = 0).
- The dotted line is the calculated one assuming that the photoelectrons are emitted following the cosine law from only the directly irradiated area.
- Approximately the measured distribution indicates that the photoelectrons are emitted following the cosine law despite quite different surface structures.

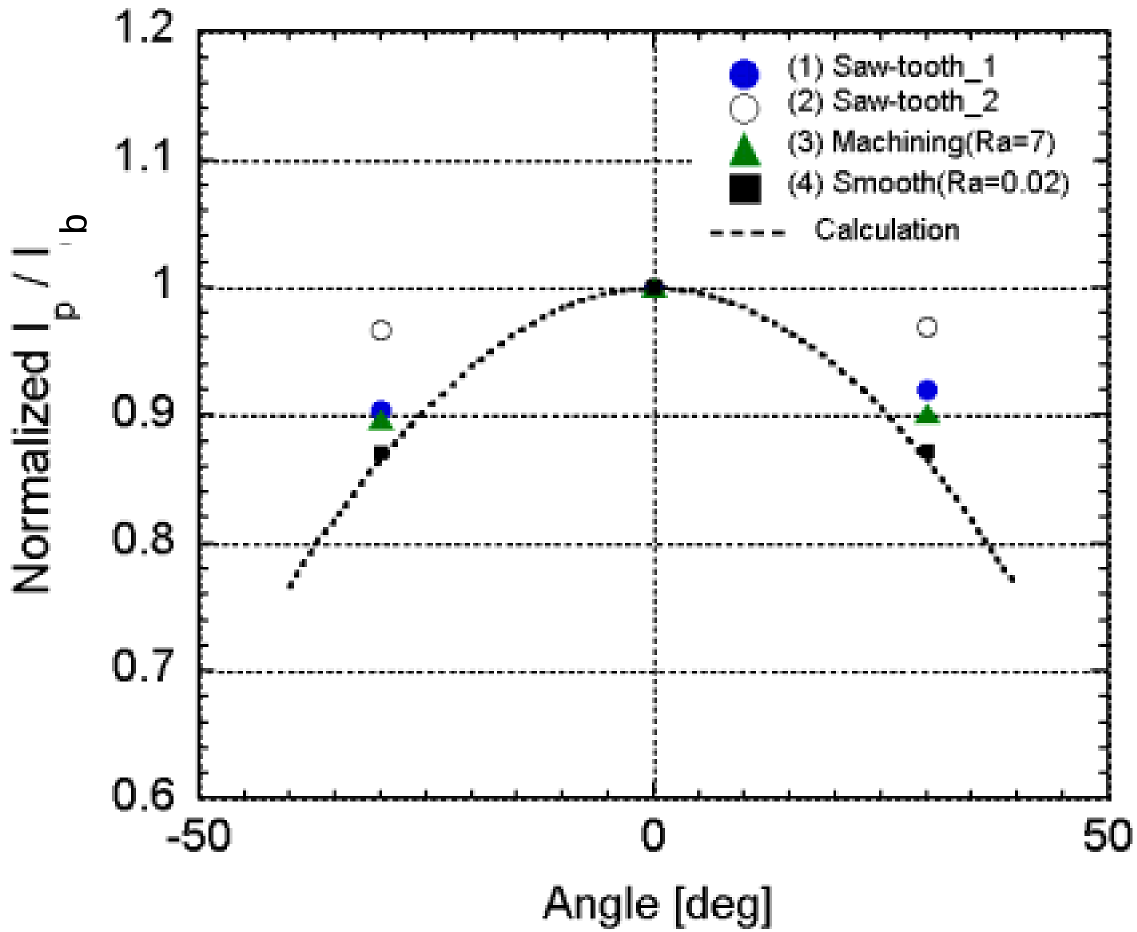
Ideal Model





For the ideal case, the measured photoelectron distribution should be different for the smooth and saw-tooth surface. There may be some effects of scattered photons.

Azimuthal Distribution



- Azimuthal distribution of Ip was also measured and that for the case (4) was almost the same as the calculation using the cosine law.
- For the cases (1) – (3), especially for the case (2), the azimuthal distribution was flatter than the calculation.

Photoelectron Yield (η)

- Here η is calculated assuming that the photoelectron emission follows the cosine law from smooth surface.

Critical Energy	4.1 keV			† 195 eV			† 45 eV		
Incident Angle	52 mrad			11 mrad			11 mrad		
	η	R [%]	η*	η	R [%]	η*	η	R [%]	η*
Saw-Tooth	0.016	0.18	0.016	0.052	1.2	0.052	0.053	1.8	0.053
Machining	0.04	1.1	0.04						
Smooth	0.29	33.2	0.434	0.073	77	0.318	0.022	80.9	0.116

- η* is the effective photoelectron yield considering the reflectivity, R, and given by η/(1-R).

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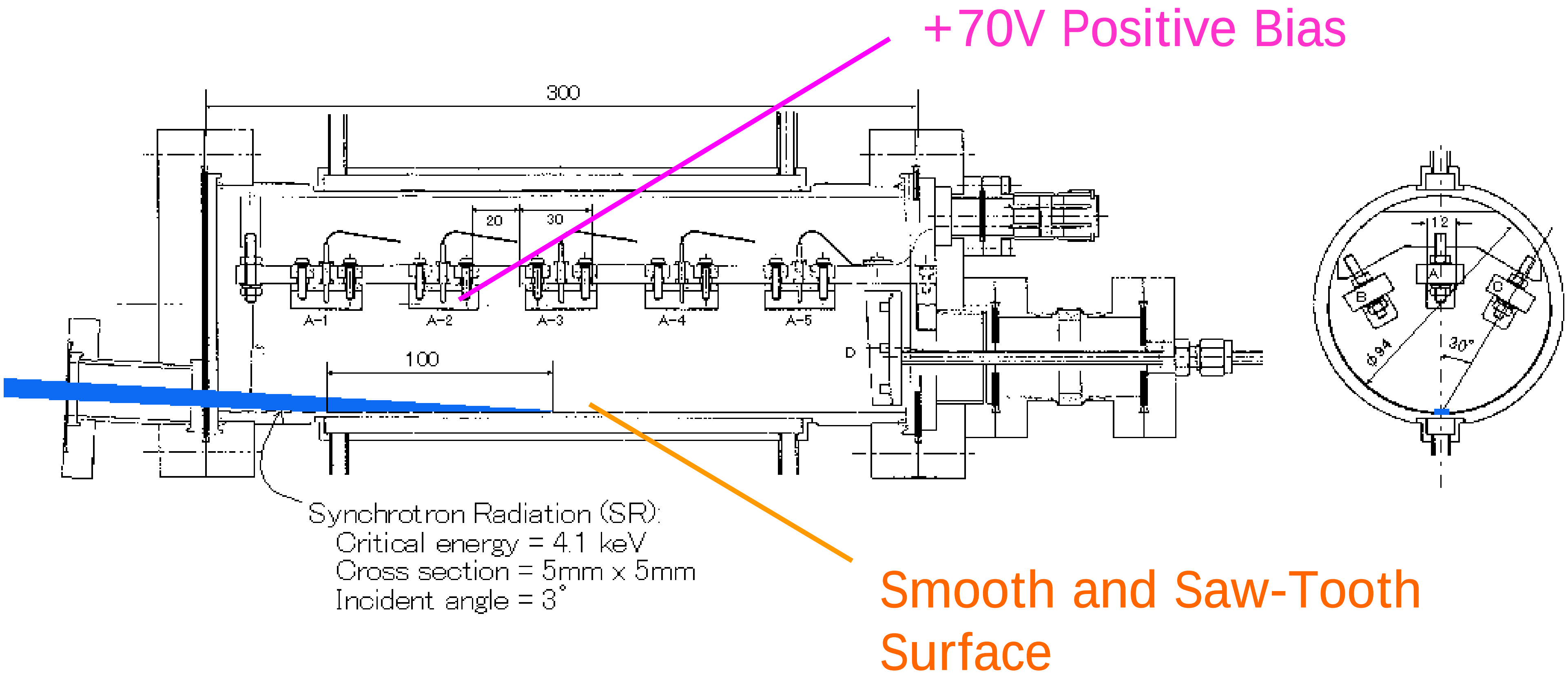
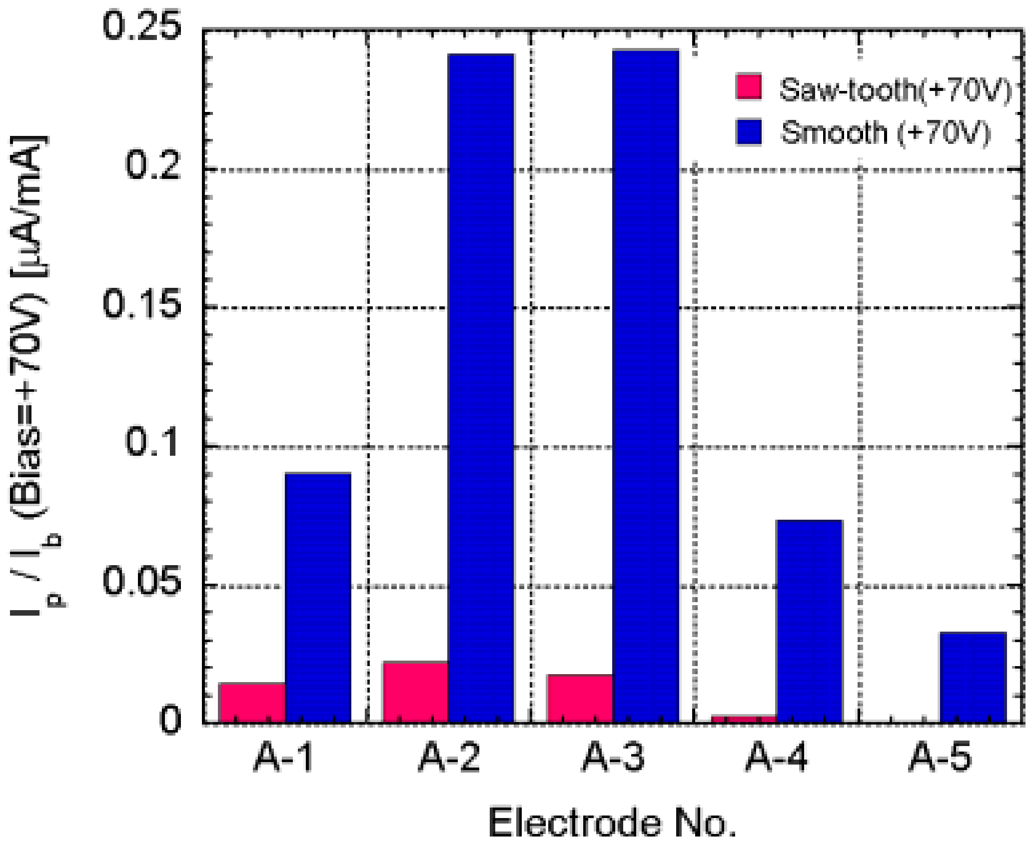
"Electron Cloud Investigation, Electron Cloud Simulation", in LHC/SL Seminar, 11/11/99, http://wwwslap.cern.ch/collective.

Effect of Positive Bias (Setup)



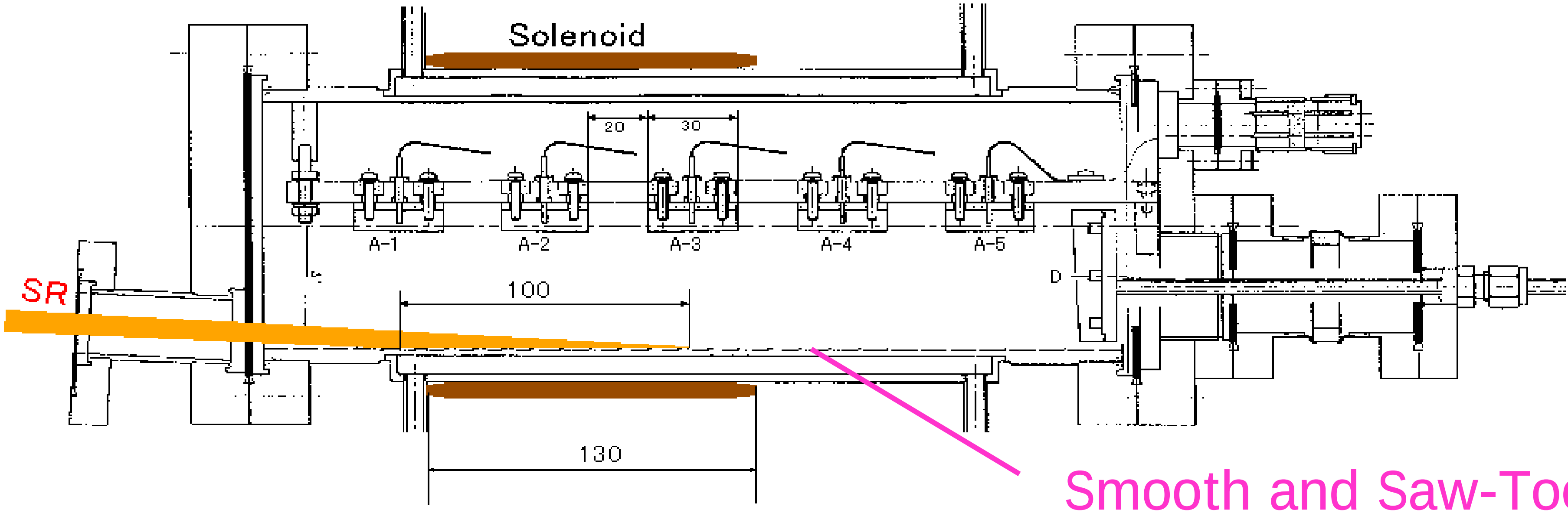
- Positive 70 V bias was applied assuming a positron beam.

Effect of Positive Bias



- Compared to the case without bias voltage, it is found that the I_p / I_b increased by one order of magnitude by applying +70 V for both surfaces.
- However, it should be noted that the reduction of practical photoelectron yield (= the photoelectron current measured at the beam position) by using the saw-tooth surface is still significant, less than 10 %.

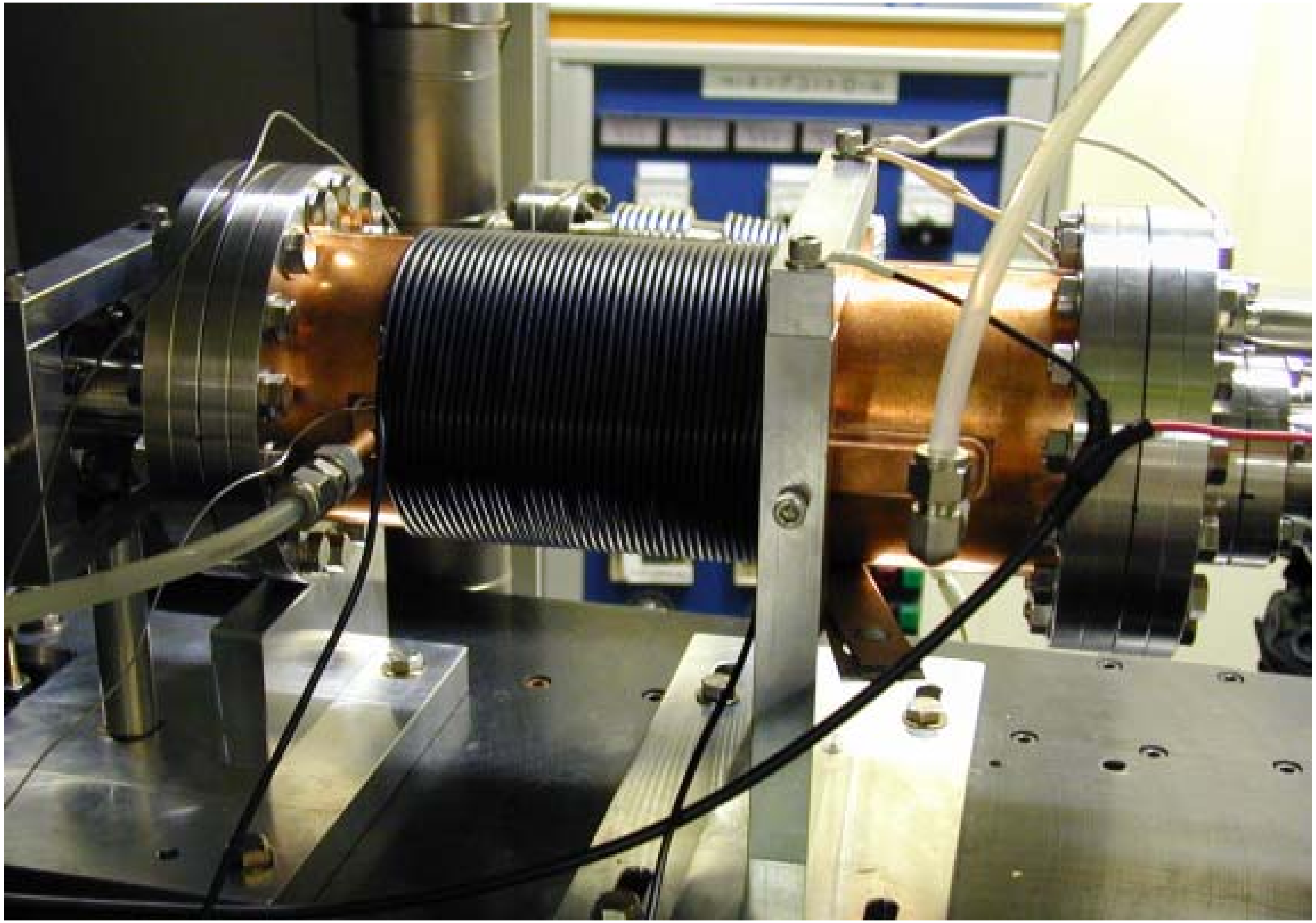
Effect of Solenoid Field (Setup)



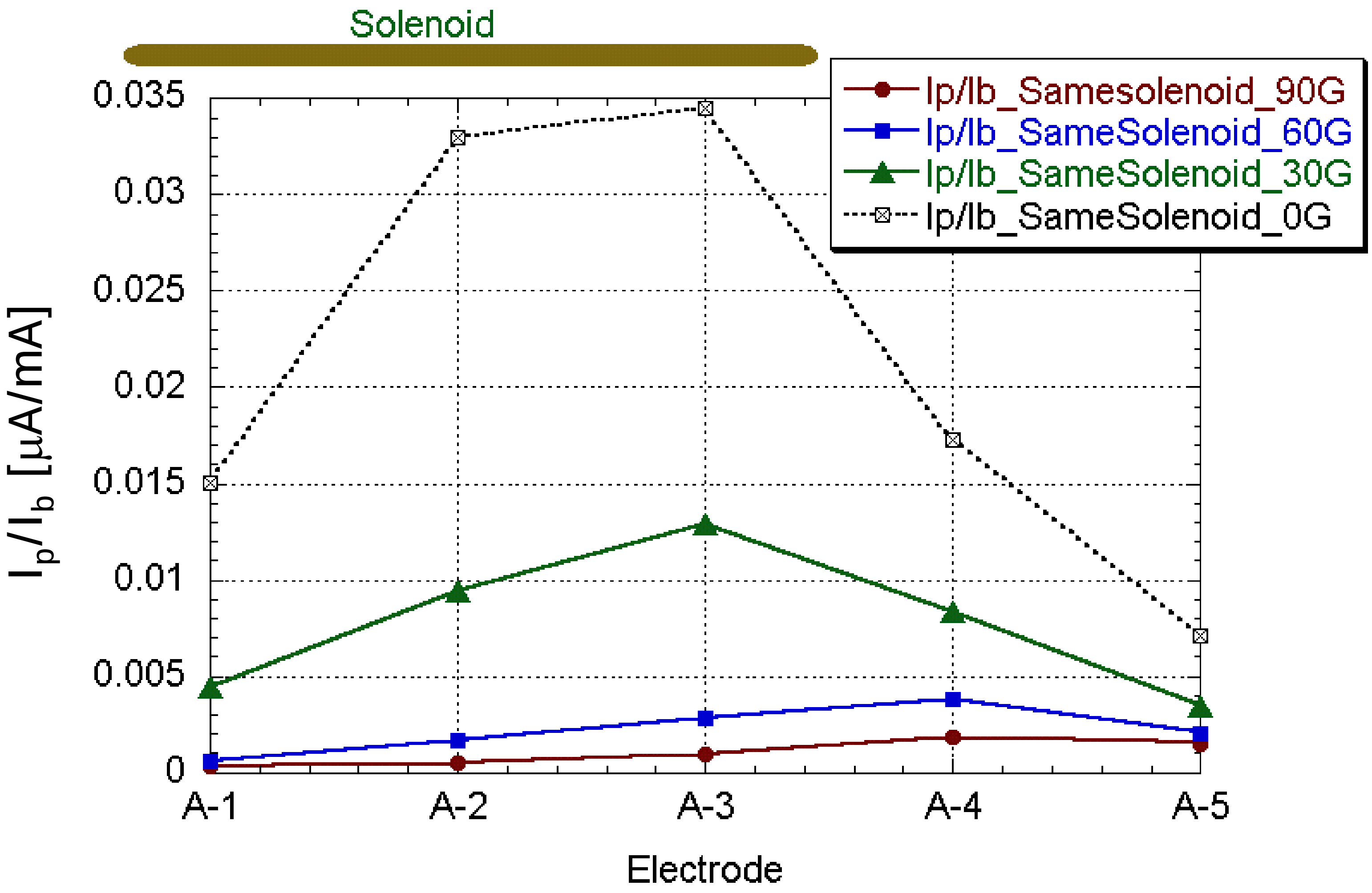
Smooth and Saw-Tooth Surface

- The solenoid field is also a effective method to reduce electrons around the beam (practical yield).
- The total solenoid length was about 130 mm. A typical axial magnetic field just near the surface is about 20 G at the solenoid current of 5 A.

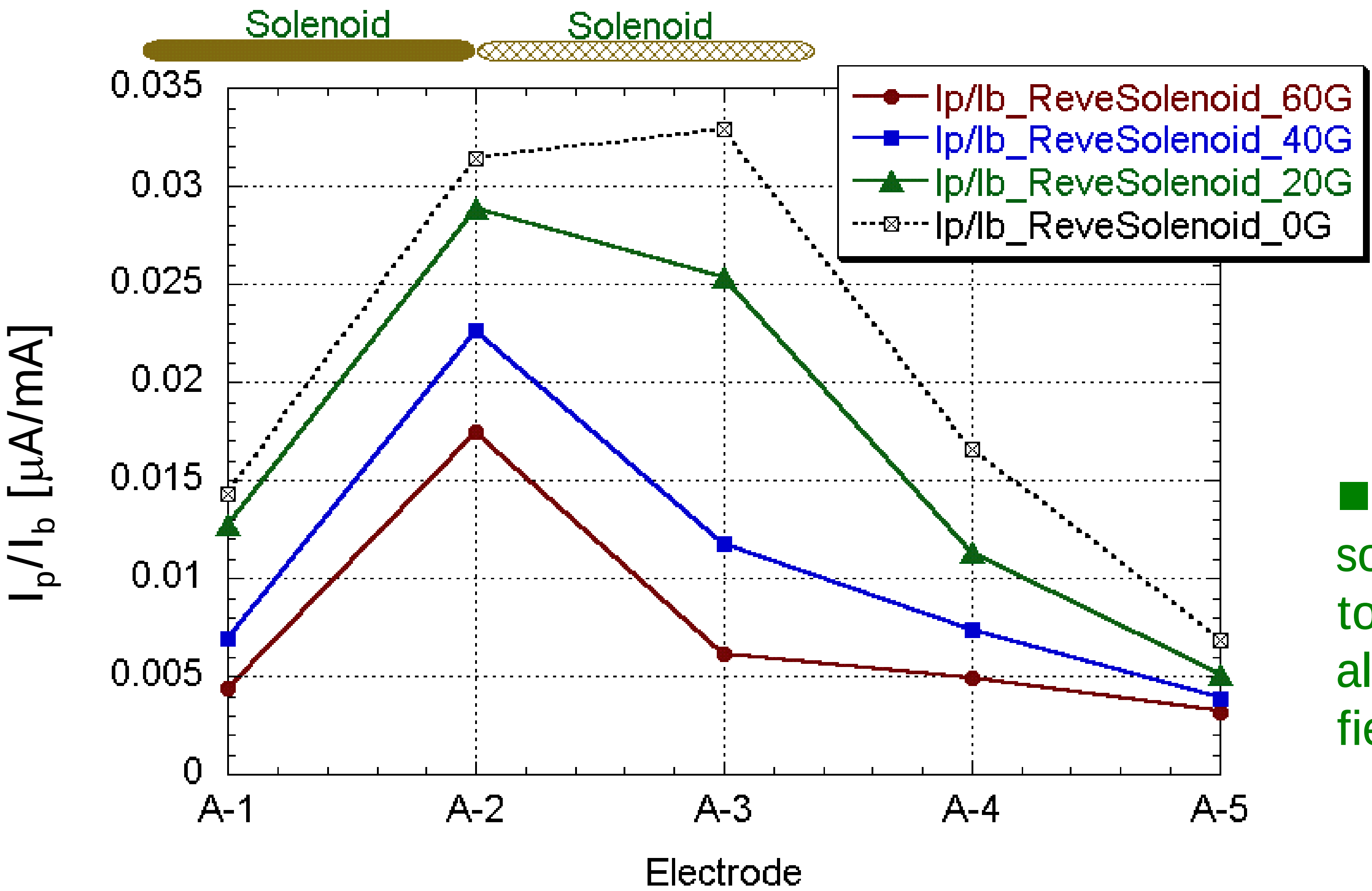
Solenoid around Test Chamber



Effect of Solenoid Field (Uniform)



Effect of Solenoid Field (Non Uniform)



- The previous solenoid was divided to a half and the alternative solenoid field was generated.

Effect of Solenoid Field (Smooth)

	Peak I_p / I_b (A-1 – A-3)	Ratio to No Solenoid
No Solenoid	0.0345	1
Uniform 30G	0.0129	0.373(1/4)
Uniform 60G	0.00284	0.0823(1/12)
Uniform 90G	0.000992	0.0288(1/35)
Non Uniform 20G	0.0289	0.838
Non Uniform 40G	0.0226	0.655
Non Uniform 60G	0.0175	0.507(1/2)

Effect of Solenoid Field (Saw-Tooth)

	Peak I_p / I_b	Ratio to No Solenoid	Ratio to No Solenoid (Smooth)
No Solenoid (Smooth)	0.0345	-	1
No Solenoid (Saw-Tooth)	0.00231	1	0.0670(1/15)
Uniform 30 G	0.000425	0.184(1/6)	0.0123(1/81)
Uniform 60 G	0.000108	0.0468(1/21)	0.00313(1/319)

Effect of Positive Bias + Solenoid

- +70 V bias was applied.

	Peak I_p/I_b	Ratio to No Solenoid	Ratio to No Solenoid (Smooth)
No Solenoid (Smooth)	0.242	-	1
42 G (Smooth)	0.0136	-	0.0562(1/18)
No Solenoid (Saw-tooth)	0.0224	1	0.0926(1/11)
42 G (Saw-tooth)	0.00101	0.0451(1/22)	0.00417(1/240)

Summary

- A saw-tooth surface was found to be effective to reduce the photoelectron yield, even for SR with a critical energy of 4.1 keV.
- The photoelectron yield for the saw-tooth surface was less than 6 % of that for the smooth surface.
- The external magnetic field was found to be useful to reduce the photoelectrons at the beam position. The uniformity of field was important to suppress the electrons effectively.
- The magnetic field larger than 50 G reduce the photoelectrons to less than 10 % at the beam position.

Summary (Contd.)

- Note here that a difference in our experiments and the real ring is the existence of a bunched positron beam, where the multipactoring phenomena may occur.
- Another difference is that there are many scattered photons in the ring. The saw-tooth surface should be prepared at whole inner surface.

Test Chamber for Ring

- A 2.6m test chamber is under construction. It will be installed this winter.