Diamond-based Beam Halo Monitor

Equipped with RF Fingers for SACLA

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SPring-8 Angstrom Compact Free Electron Laser
(newly named!)

"Sakura" in Japanese is a cherry blossom.

Outlines

1. Introduction
   - Purpose of the halo monitor
   - Detection limit of diamond detector

   required : 2 ×10^4 e$^-$ / pulse
   achieved : 2 ×10^3 e$^-$ / pulse

2. Adoption of diamond detector into the halo monitor
   - Point for installation is

     Handling of intense wake field. → RF fingers are indispensable.
   - Problem to overcome is

     Radiation (cascade shower) generated in the RF fingers.

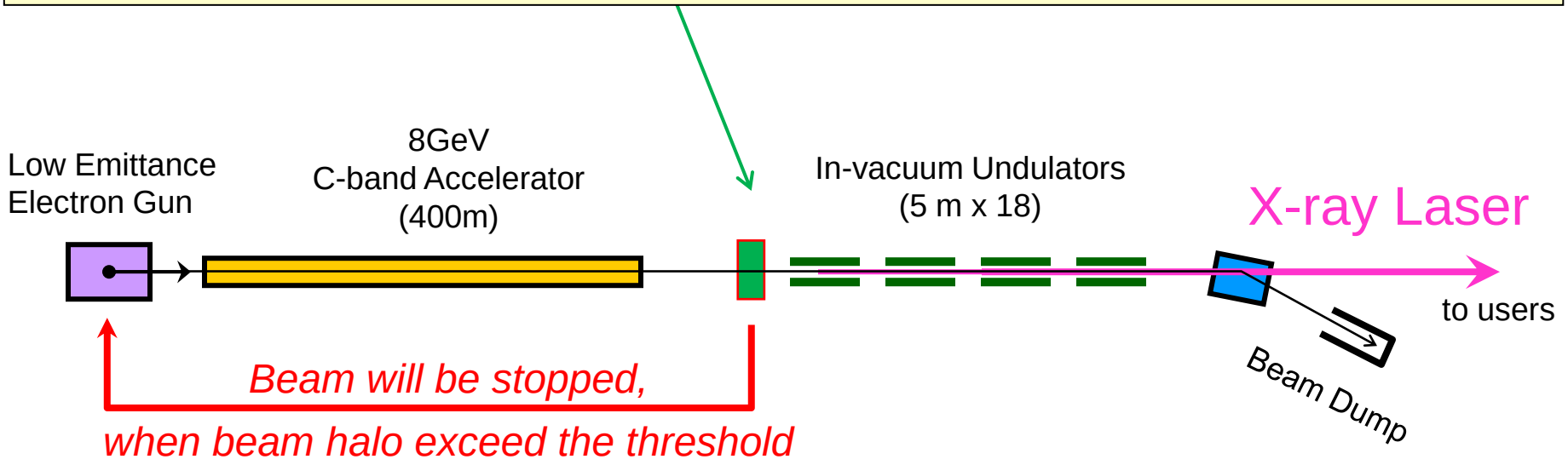
     → Evaluation of effect of the cascade shower must be done.

3. Operational Experience at SACLA
   - Filtering of high frequency component with low pass filters
   - Verification of required detection limit with the halo monitor

4. Summary

Purpose of the Halo Monitor

In order to protect the undulator permanent magnets against radiation damage, Beam Halo Monitor has been installed in front of the in-vacuum undulators.



If the undulator magnets are irradiated with beam halo, the magnets are fatally demagnetized.

Required Detection Limit

We set the required detection limit as follows.

1. We assume the demagnetization of the undulator magnets by *1% in 10 years* is tolerable.

2. Experimental results* says that irradiation with *4×10^{14} e^-* in 8GeV results in demagnetization by 1 %. *(*Bizen et al.)*

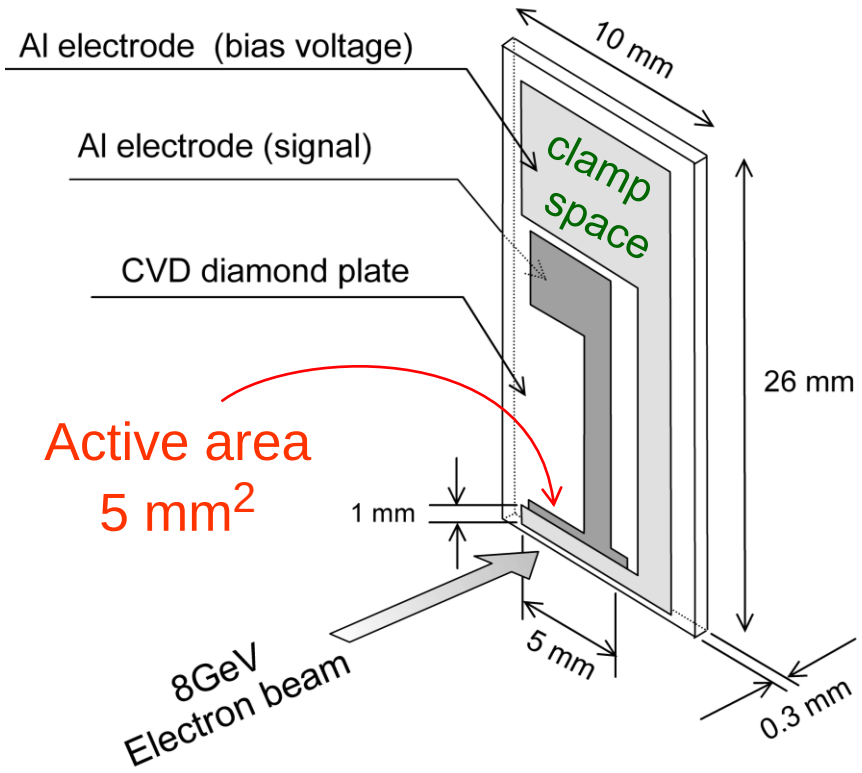
So that, the required detection limit goes to **2×10^4 e^- / pulse.**

(10 year × 365 day × 24 hour × 60Hz ⇒ 1.9×10^{10} pulse)

*Note: It corresponds to loss rate of **10^{-5}** .*

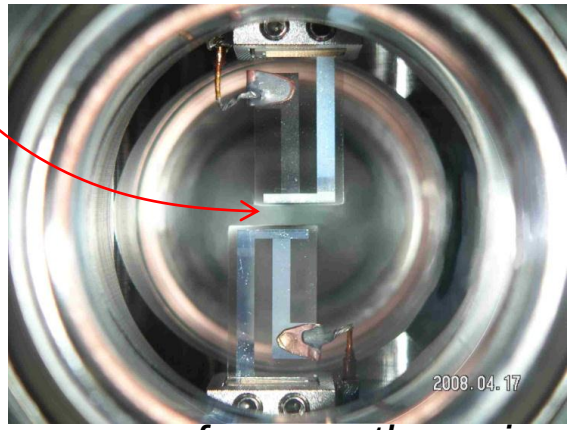
Number of electron is 2×10^9 e^- / pulse (0.3 nC/pulse).

Diamond detector in photo-conduction mode



The e-h pairs generate in bulk of diamond crystal.

Beam core passes through between diamond detectors.



seen from on the axis

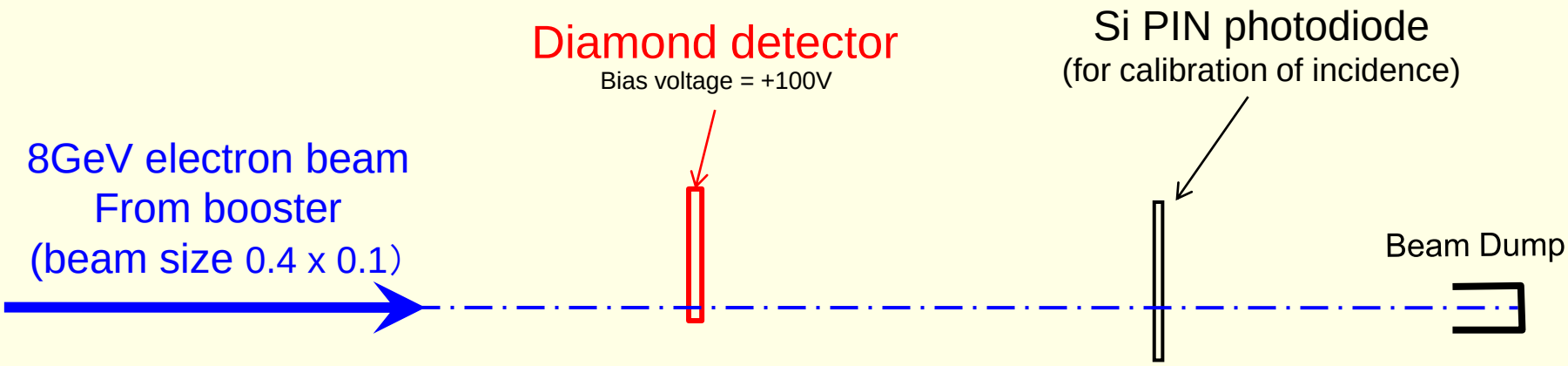
Advantages of diamond:

- High radiation hardness (durable)
- Sufficient heat resistance (bakable)
- High insulation resistance (low dark current)

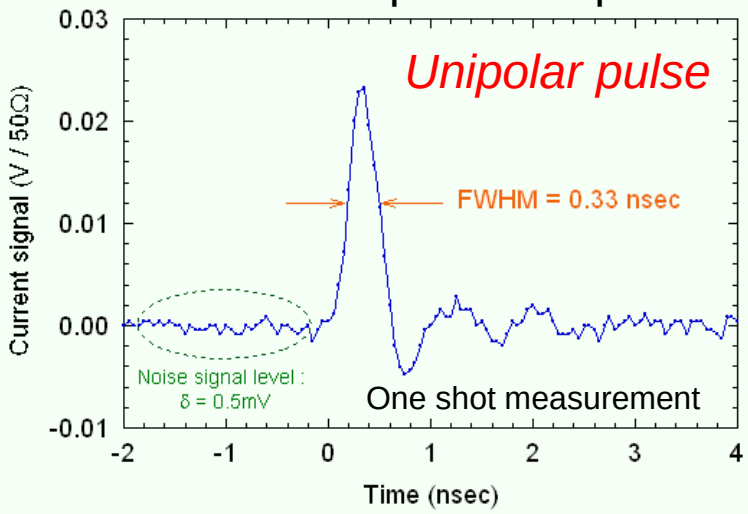
Manufactured by Kobelco

Achievement of Required Detection Limit of 2×10^4 e$^-$/pulse

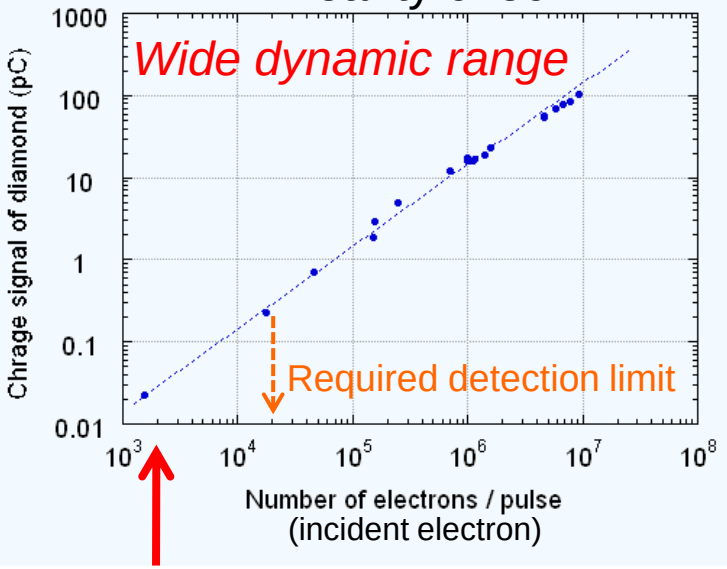
Carried out at the dump area of 8GeV booster synchrotron



Check of pulse shape



Linearity check



Practical detection limit* is 2×10^3 e$^-$ /pulse.

** Definition: The pulse height is 10 times of noise signal level (σ).*

2. Adoption of Diamond Detector into Halo Monitor

We had confirmed the reliability of diamond detector itself.
Then we started to work on adopting diamond detector into the Halo Monitor.

Most important point for the adoption is handling of intense wake field. → *RF finger is indispensable.*

Main purpose of the RF fingers is

to reduce the wake field for preserving electron beam quality. *(not to disturb XFEL oscillation)*

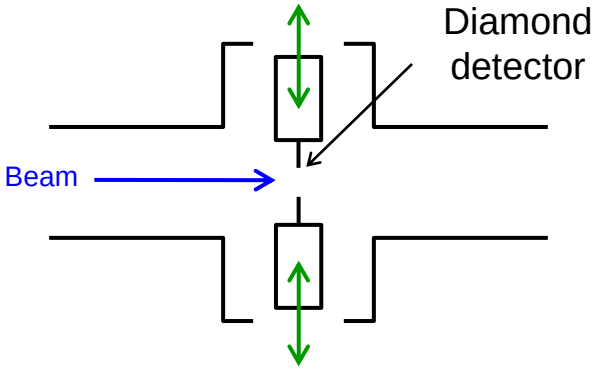
As a by-product,

Induced current* that emerges in the signal of the diamond detector can be muted.

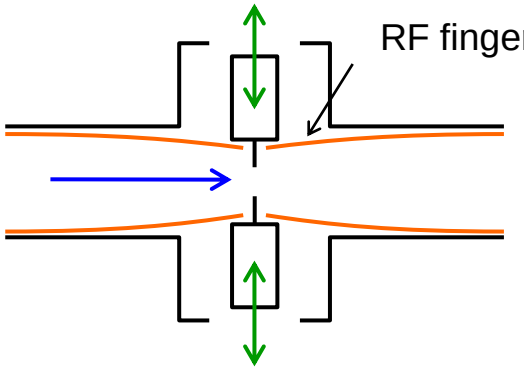
**Wake field causes the induced current.*

Configuration of RF Fingers

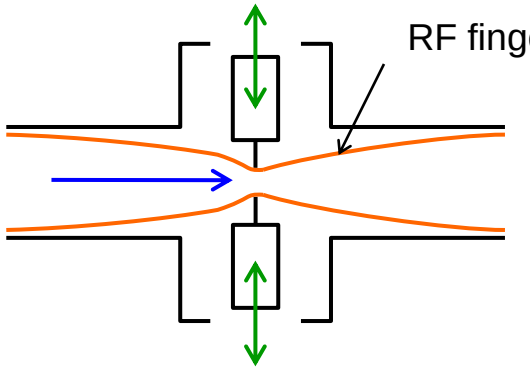
Finger type 0
(no fingers)



Finger type 1
(not covered)

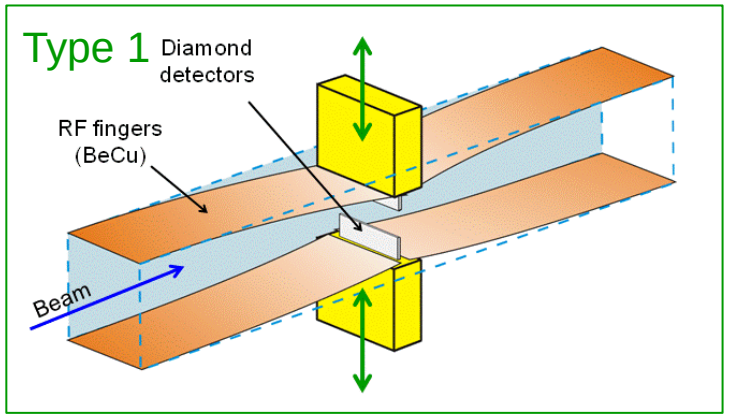


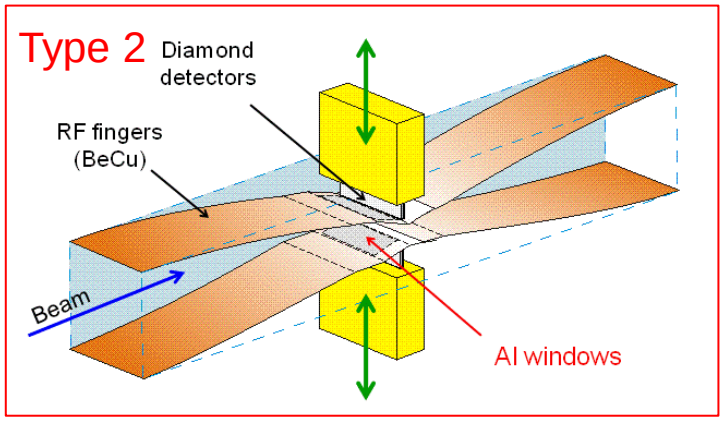
Finger type 2
(fully covered)



In the configuration of type 1, the active areas of the diamond detectors project from between RF fingers.

In the configuration of type 2, the RF fingers are connected without bumps.



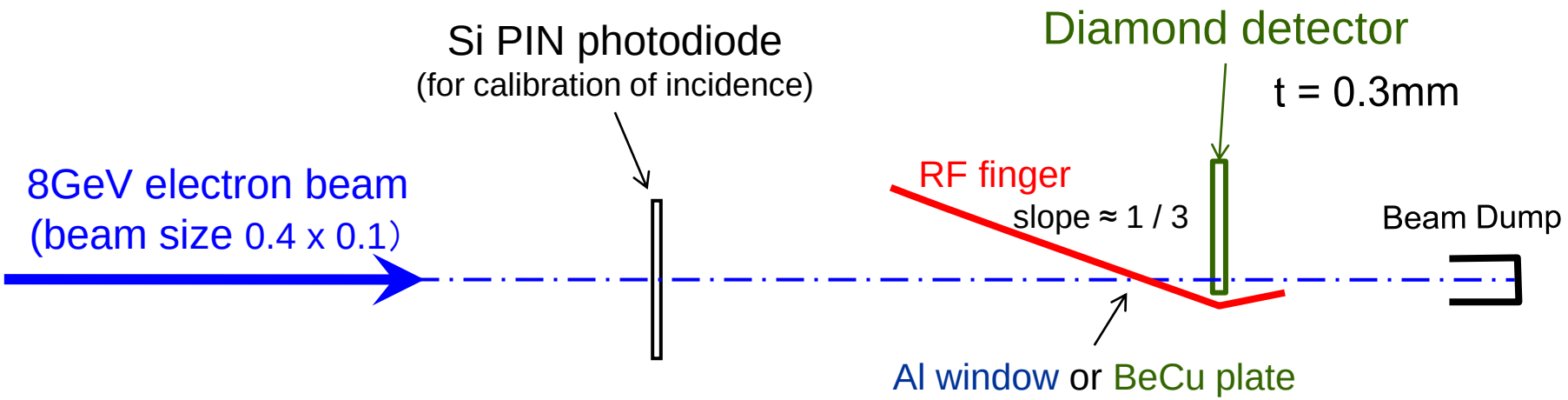


Type 2 seems to be the best, but the detectors are behind the finger.

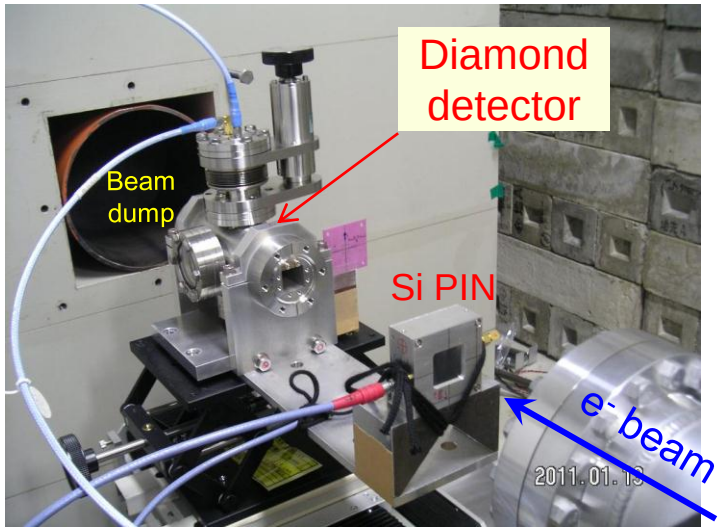
→ *We need to know if the signal blows up by radiation from finger material or not.*

Radiation from RF fingers: experimental setup

Purpose of this measurement is to evaluate increase of the detective efficiency caused by secondary electrons and bremsstrahlung that are generated in the finger material.



Carried out at 8GeV booster synchrotron

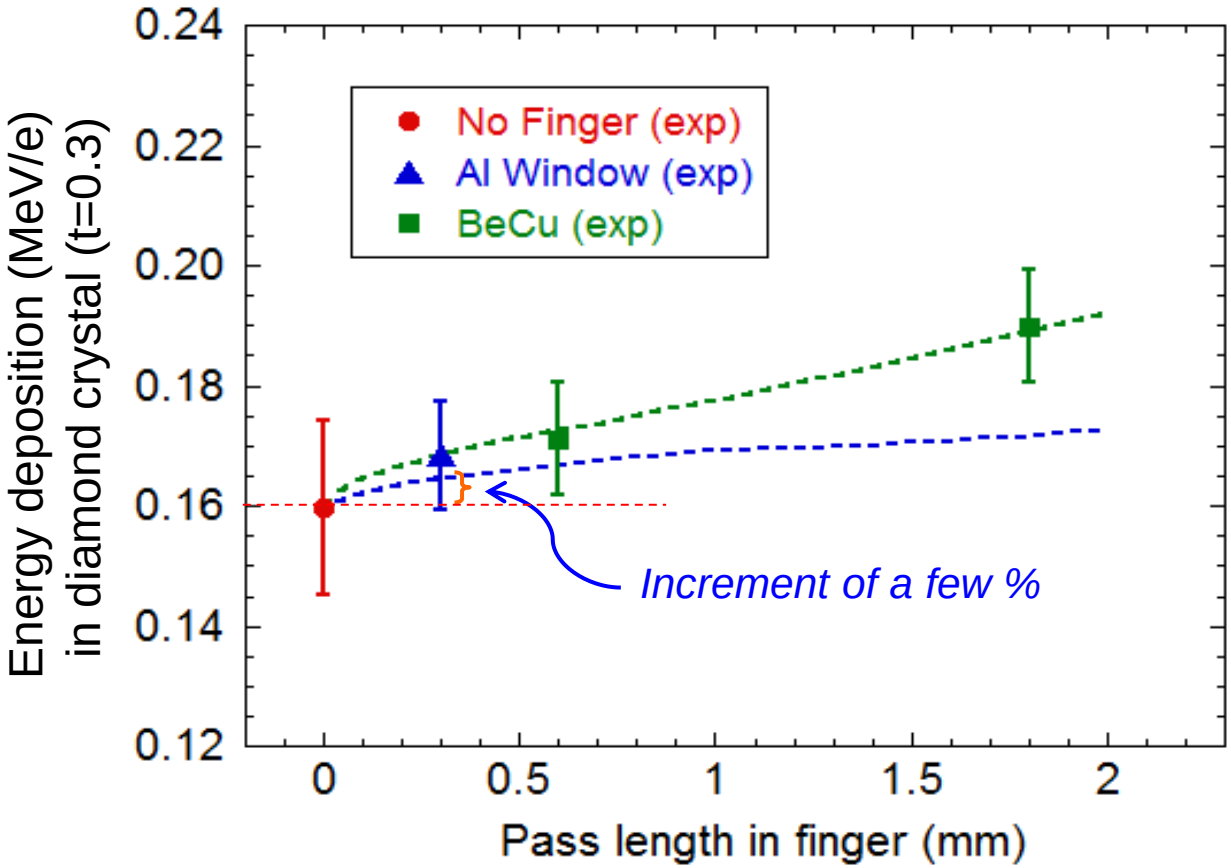


Experimental conditions

Finger material	Thickness	**Pass length**	
none	0 mm	**0 mm**	← ref. data
Al	0.1mm	**0.3mm**	
BeCu	0.2mm	**0.6mm**	
BeCu	0.6mm	**1.8mm**	

experimental results

Measurement data were normalized as the measurement value with no fingers is corresponding to the energy deposition of 0.16MeV/e, which is the simulation result at thickness = 0.



Dashed lines are simulation results by Monte Carlo simulation code:

EGS5.

Al (EGS)
BeCu (EGS)

The experimental results and the simulation results are in good agreement within the measurement errors.

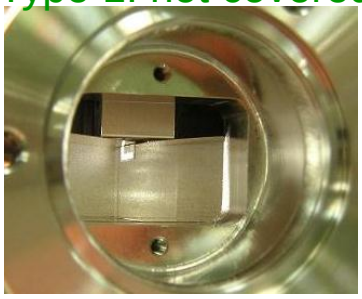
RF finger with Al window can be used for our purpose.

Feasibility Tests of RF Fingers *at 250 MeV SCSS Test Accelerator*

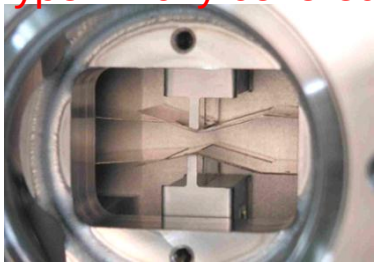
We observed induced current that emerges in the signal of the diamond detector.

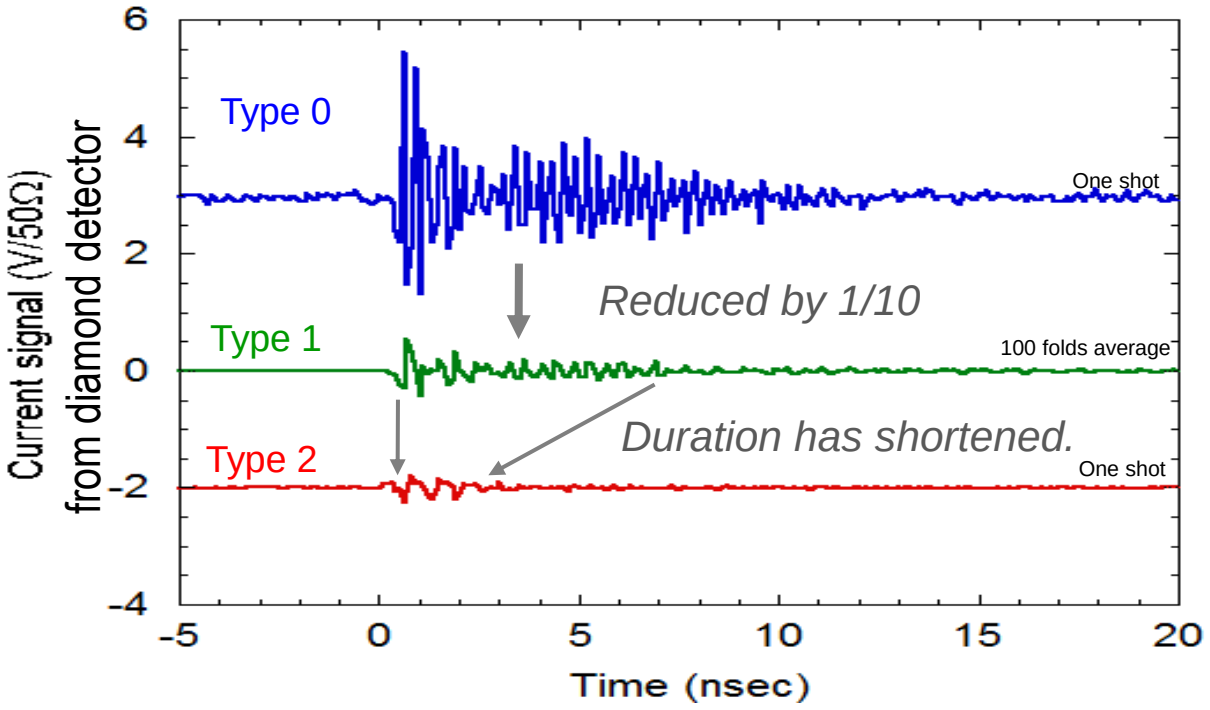
Type 0: no fingers

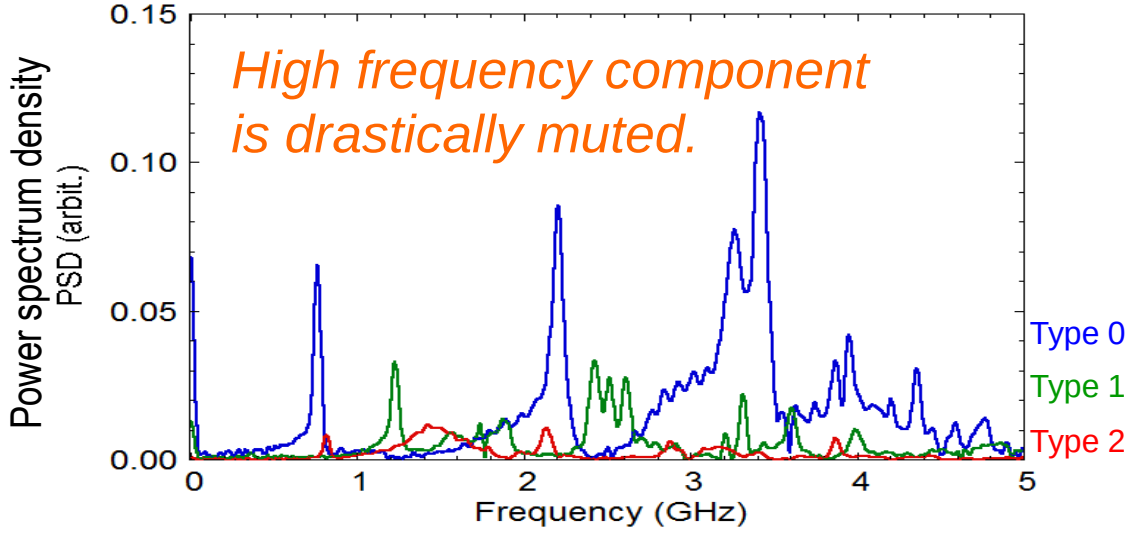
Type 1: not covered



Type 2: fully covered



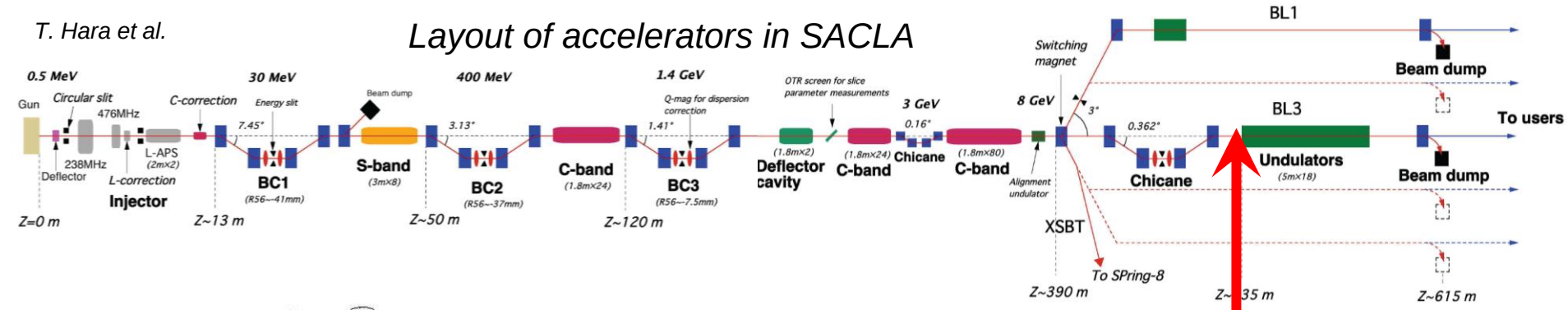


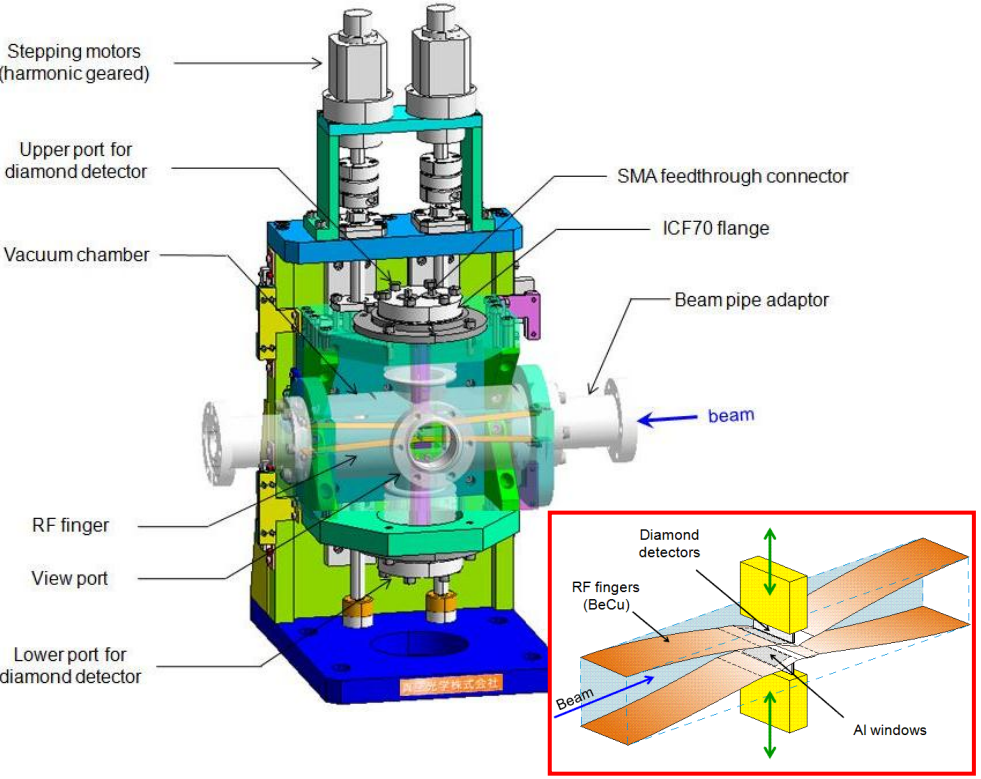


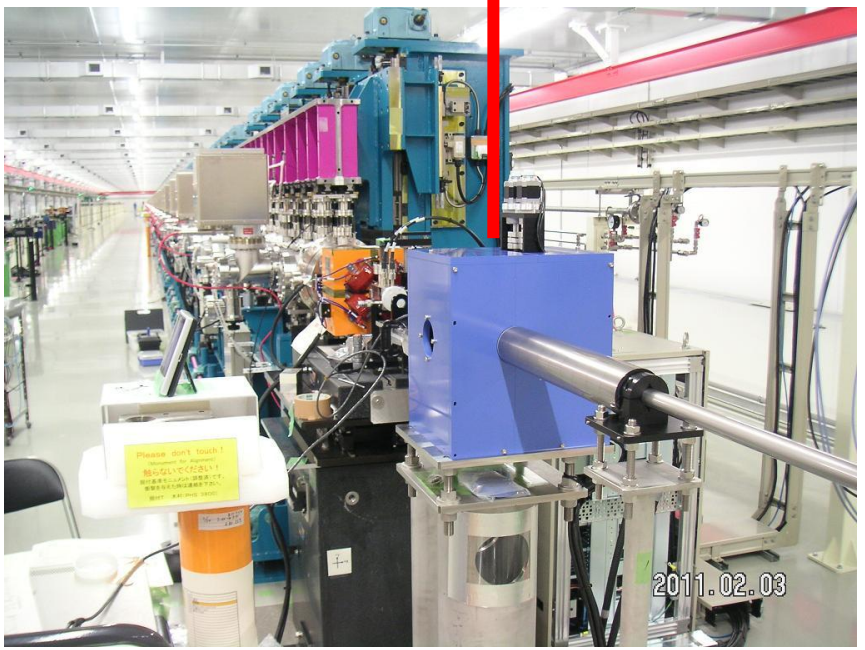
Installation of the Halo Monitor at *SACLA*

T. Hara et al.

Layout of accelerators in SACLA





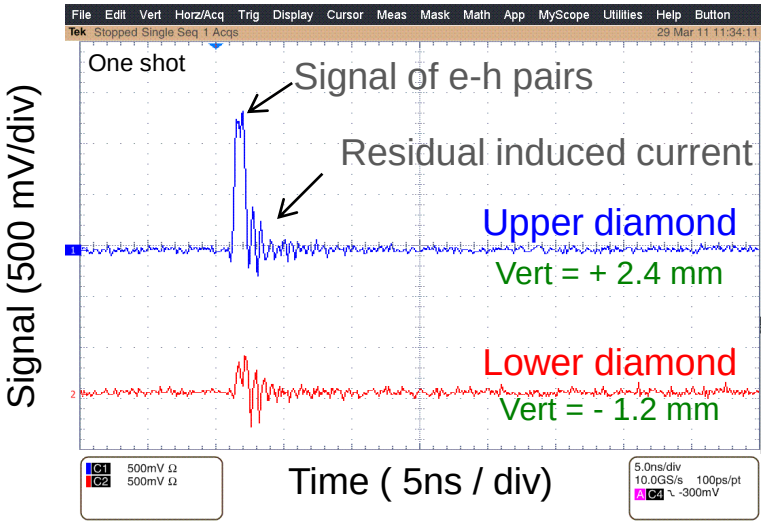


The Halo Monitor equipped with RF fingers (type 2).

*The geomagnetic shield box(**blue box**) is for beam based alignment.*

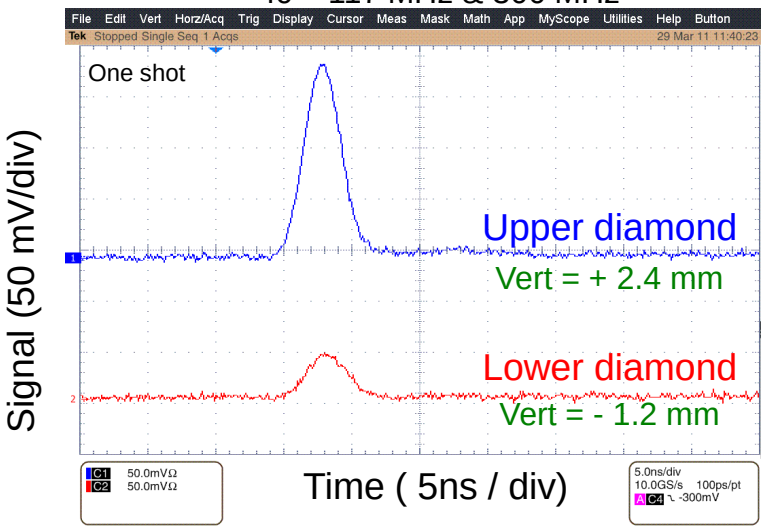
Filtering of residual induced current with LPF

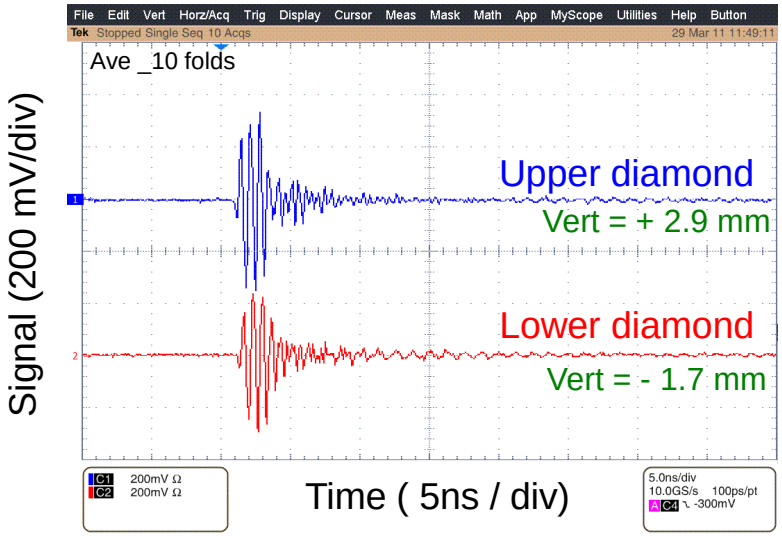
without Low Pass Filter

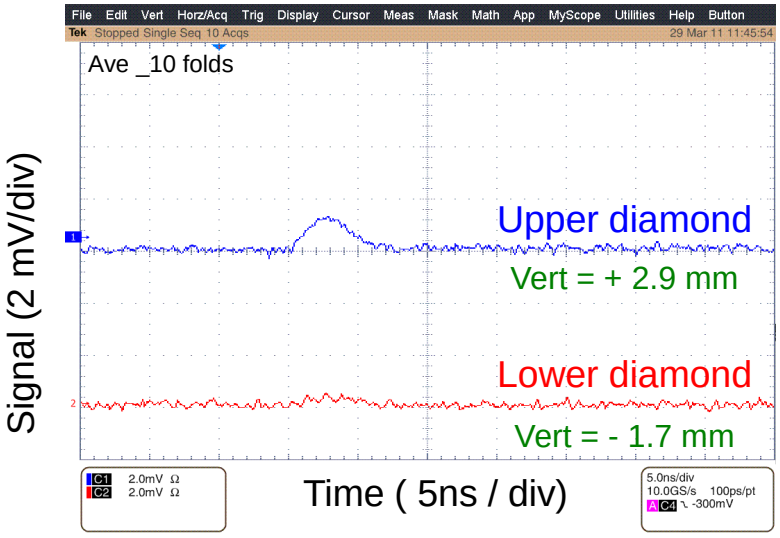


with Low Pass Filter

fc = 117 MHz & 300 MHz



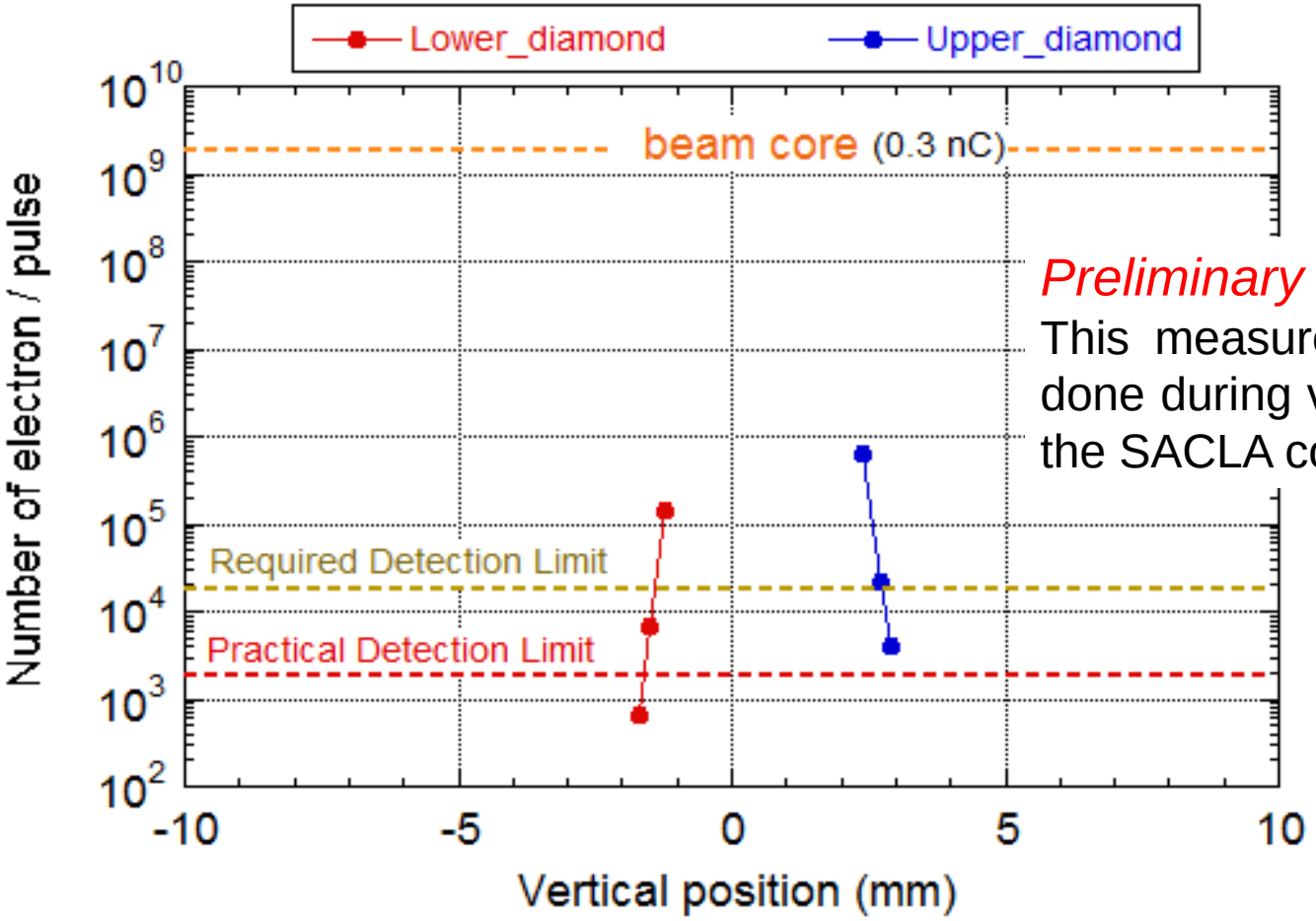




Verification of Required Detection Limit

measurement at SACLA

HM can be used just like a wire profiler.



Preliminary results

This measurement has been done during very first stage of the SACLA commissioning.

BG was not observed. (BG: secondary electron and bremsstrahlung from dark current)

We succeeded in achieving the required detection limit at SACLA.

4. Summary

1. About the Halo Monitor for SACLA
   - Practical detection limit is about 2×10^3 e/pulse. (1ppm of 0.3nC)
   - Dynamic range is 4 orders. (up to 10^7 e/pulse)
2. About equipment with RF fingers
   - Experiment and simulation results suggest that the radiation from Al (0.1t) is not significant. → *Al window has been adopted.*
   - Muting of induction current has been demonstrated.
3. From experiences at SACLA
   - Residual induction current can be removed with LPFs.
   - Required detection limit has been achieved.
   - The commissioning of the halo monitor is in progress.