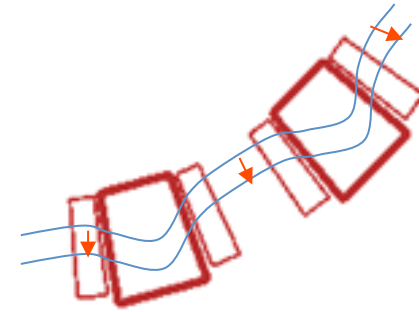


Development of Large Aperture Non-Destructive Beam Position Monitor for 150 MeV FFAG (1)

Tatsuya Fujinaka (Kyushu Univ.)

Introduction

In case of the 150 MeV FFAG,
Orbital radius changes 4.47 to 5.20 m



FFAG magnet and beam orbit



Requirement

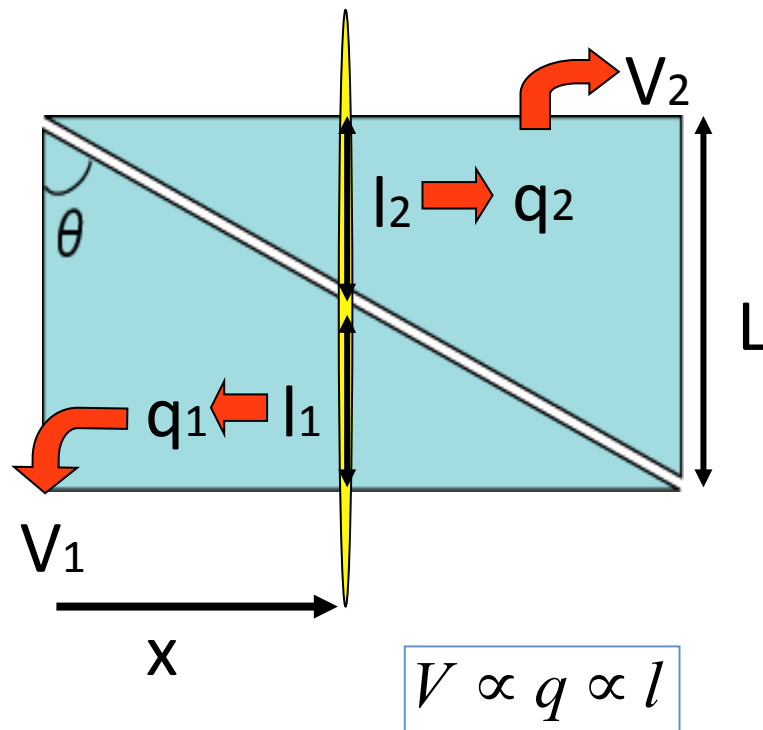
- **Large aperture for radial direction** ... More than 730 mm aperture
- **Non-destructive** ... To prevent activation
- **High resolution** ... the goal is 1 mm (1/10 of beam size)

Beam position monitor with triangle electrodes

- • • It consists of two pairs of triangular electrodes

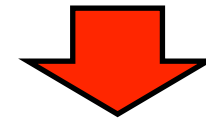
Advantages

- excellent position linearity
- large signal strength
- easy to manufacture



Induced charges (q_1, q_2) are proportional to the beam pass length (l_1, l_2).

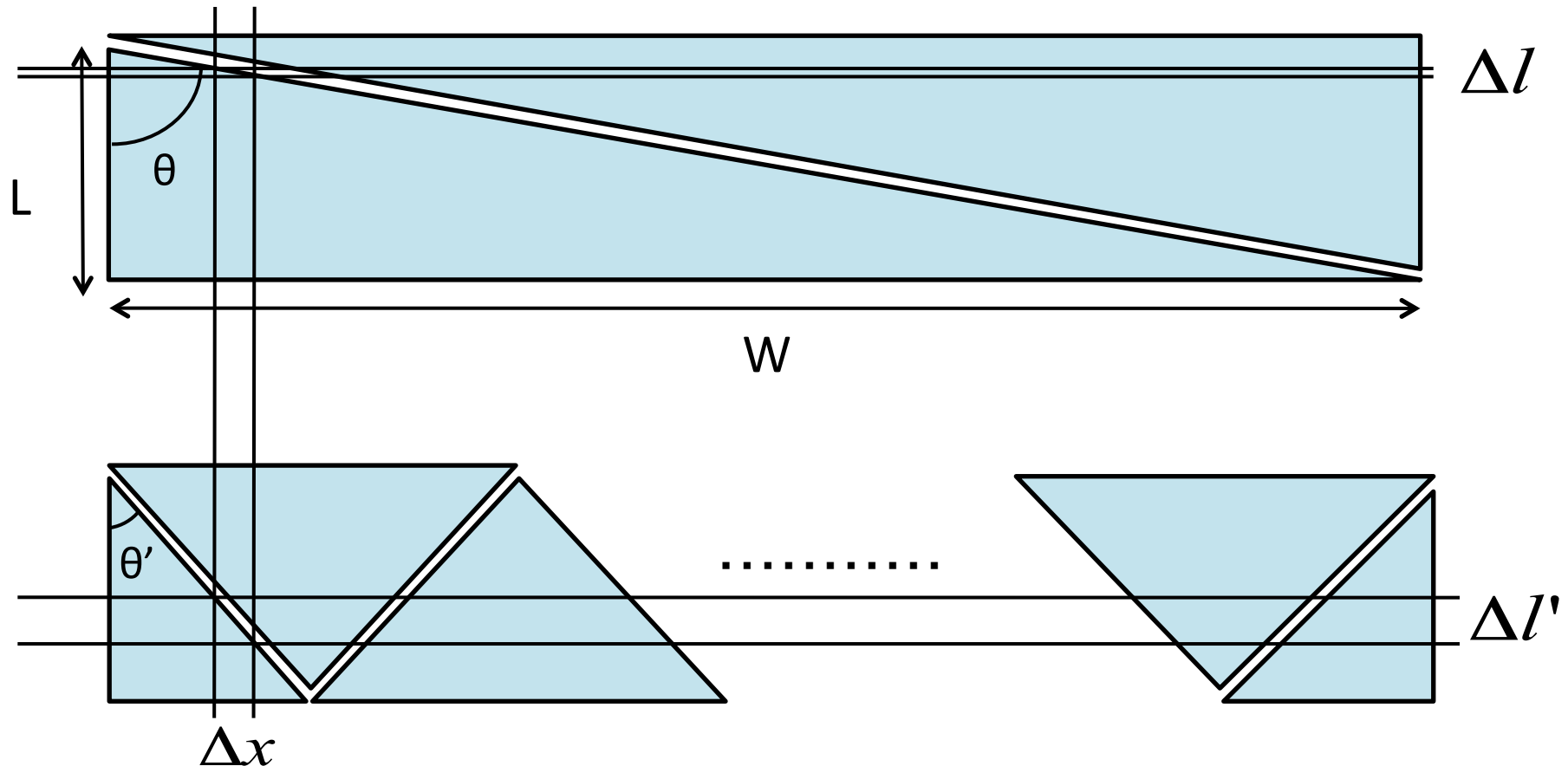
Between the electrode and the chamber, voltages (V_1, V_2) are induced. Voltages are proportional to the induced charge.



x can be expressed as this equation.

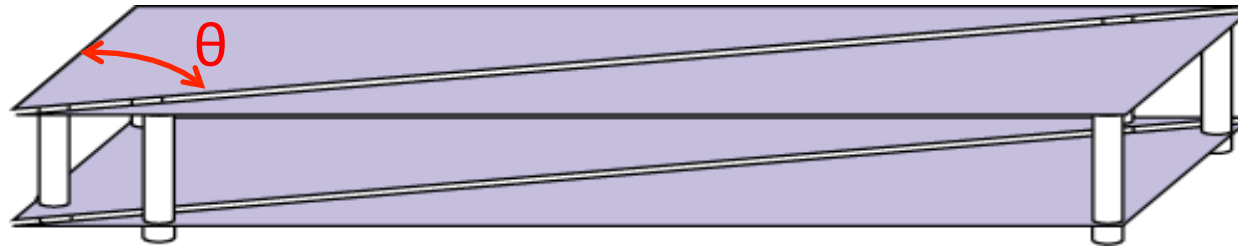
$$x = \frac{L \tan \theta}{2} \frac{V_2 - V_1}{V_2 + V_1} + \frac{L \tan \theta}{2}$$

multi-electrode monitor



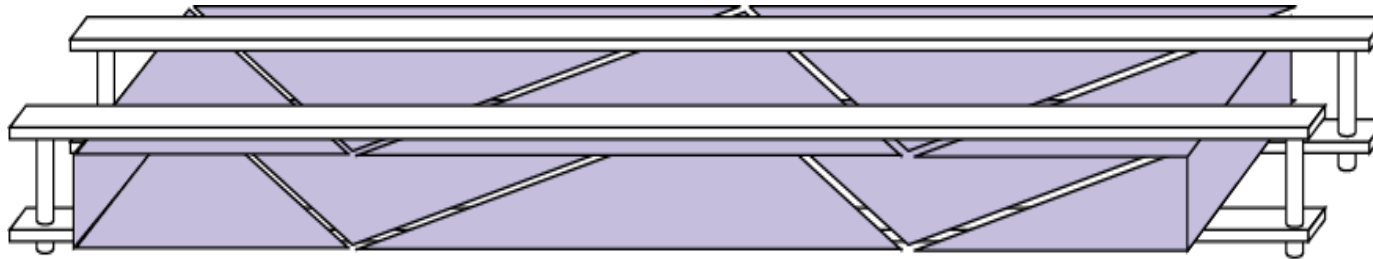
- If L is to be constant, the increase of W results in worse resolution.
- The resolution becomes higher as the angle θ becomes smaller.
- To cover the whole of the beam transit region, we have developed multi-electrode monitor.

Typical beam position monitor with triangle electrodes



Reduce the angle θ to be the resolution higher

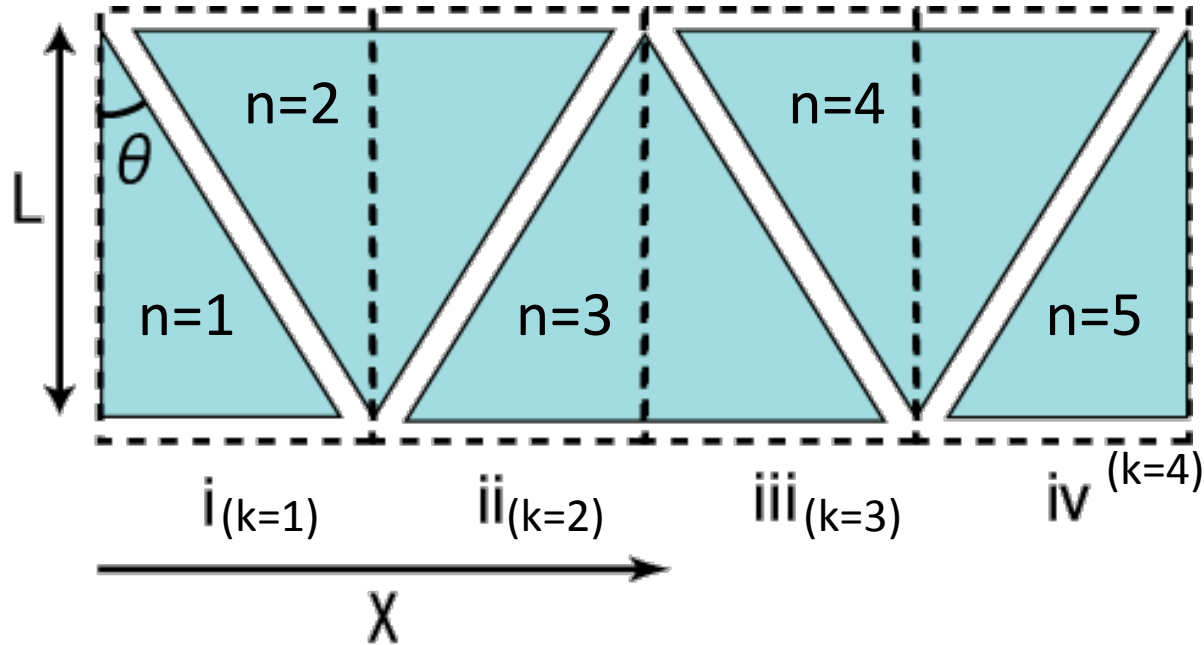
Five electrodes beam monitor



Purpose

- Measuring the position response of new type monitor for calibration
- Evaluating the resolution of position determination

Principles of Positioning of five electrodes beam monitor



If the beam is in the region k

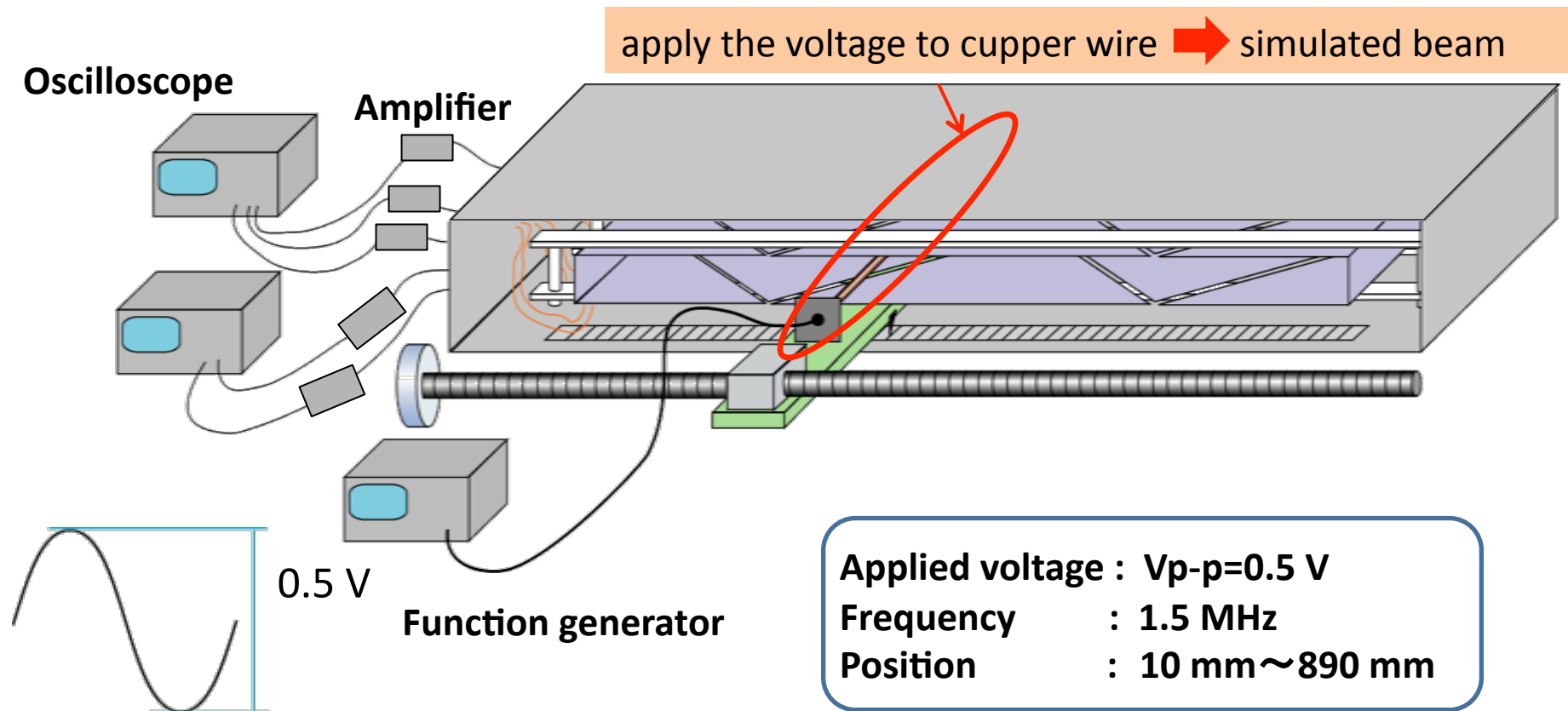
$$X = \frac{L \tan \theta}{2} \frac{q_{k+1} - q_k}{q_{k+1} + q_k} + \frac{L \tan \theta}{2} + (k-1)L \tan \theta$$

$$q_n = C_n V_n$$

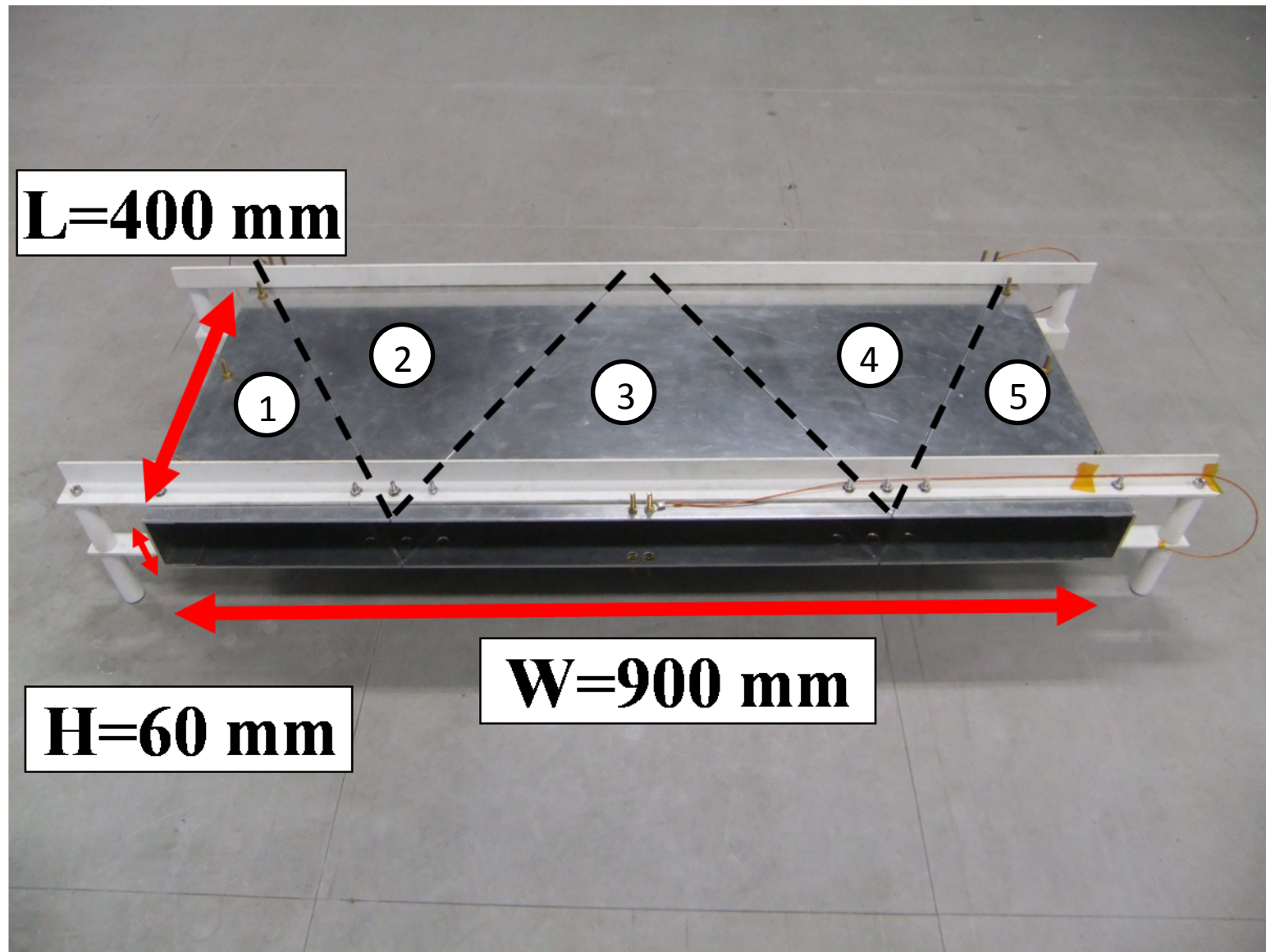
Experiment

- Experimental setup to test the five electrodes beam monitor

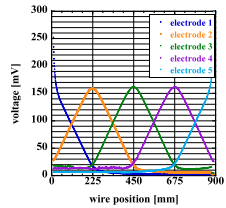
To simulate the electric field distribution of the beam, the voltage was applied to copper wire by a function generator.



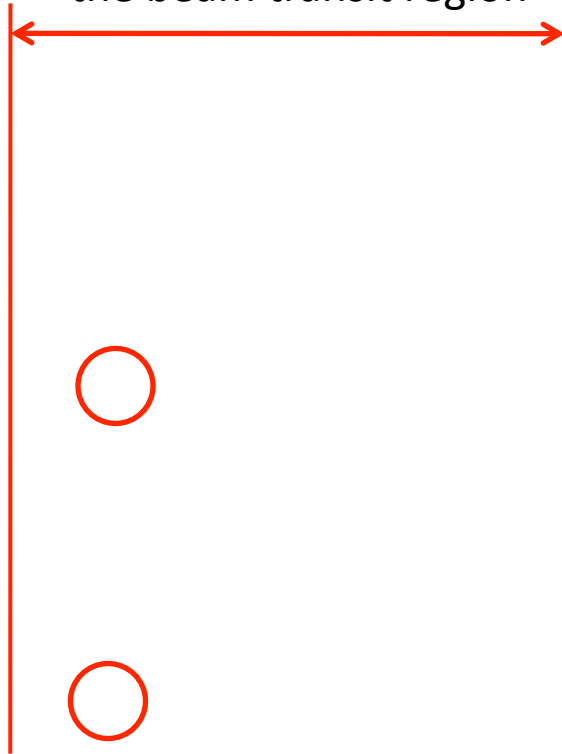
Developed five electrodes beam monitor



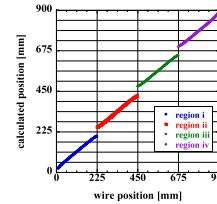
Result



the beam transit region



$$X = \frac{L \tan \theta}{2} \frac{q_{k+1} - q_k}{q_{k+1} + q_k} + \frac{L \tan \theta}{2} + (k-1)L \tan \theta$$

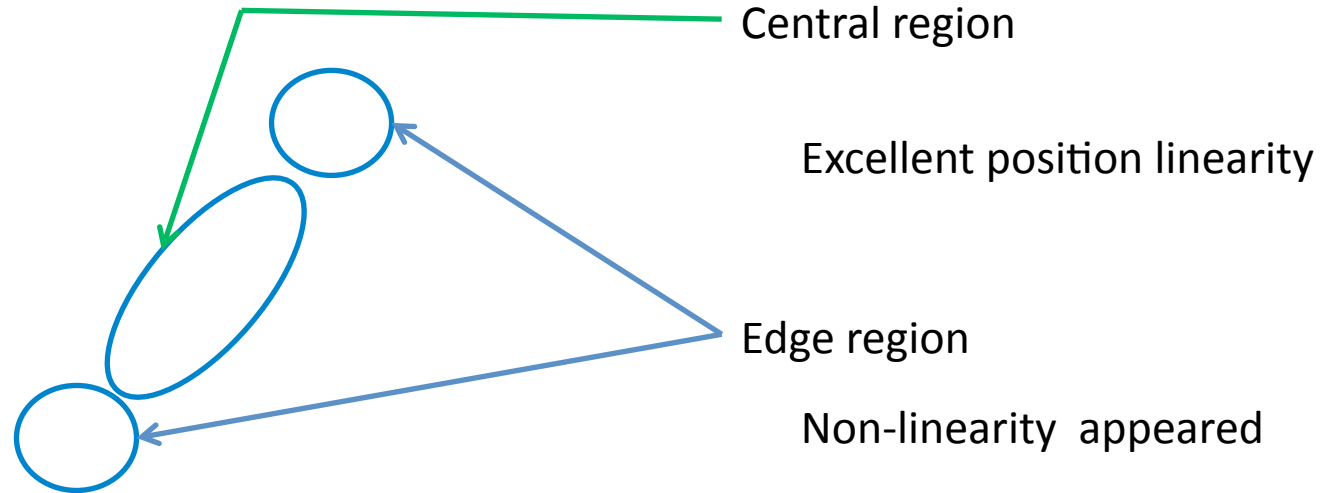


▪ ▪ ▪ Electric charges are induced at besides the nearest electrodes due to electric field leakage

Position conversion formula should be improved

Calibration

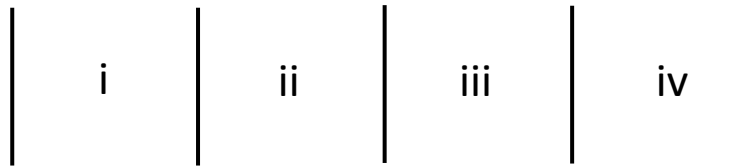
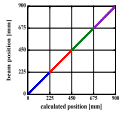
● region ii



This graph is assumed to be represented by the sum of linear and two exponential functions

$$X = a_1 x + a_2 + b_1 \exp(b_2 x) + c_1 \exp(c_2 x)$$

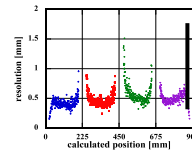
Result 2



Resolution

$$\Delta X = \sqrt{\left(\frac{\partial X}{\partial V_1}\right)^2 \sigma_{V_1}^2 + \left(\frac{\partial X}{\partial V_2}\right)^2 \sigma_{V_2}^2}$$


Fluctuations of measurements

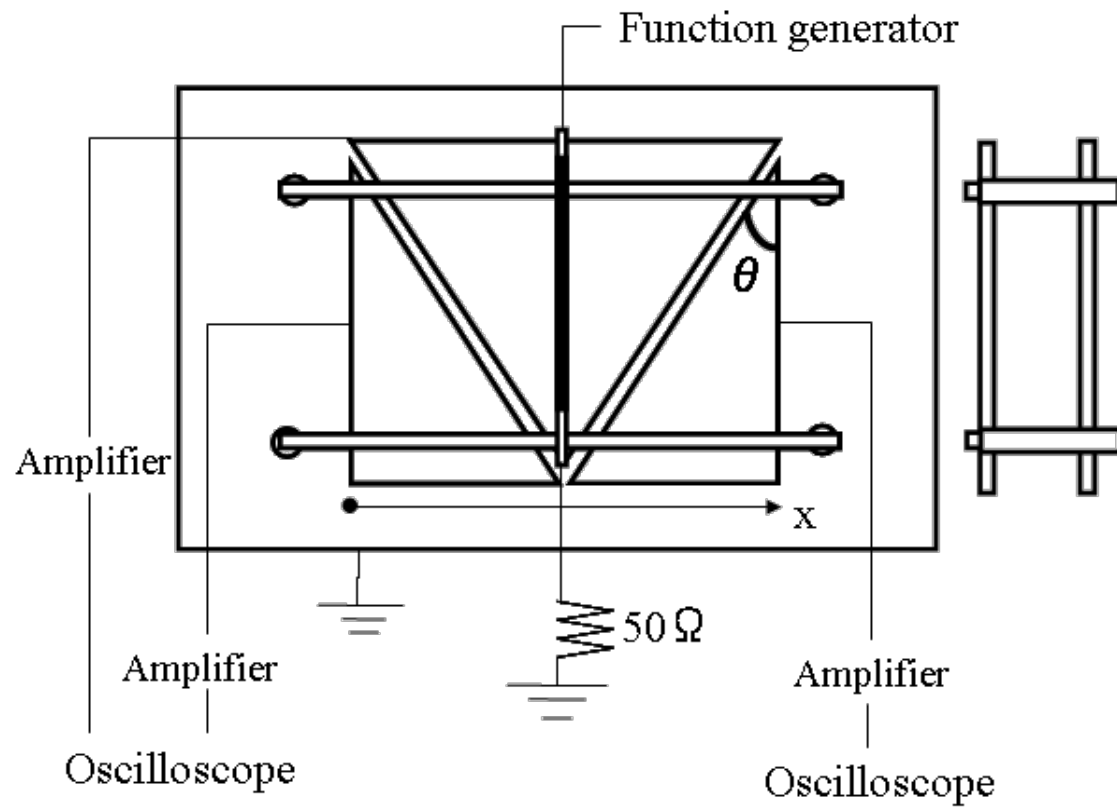


resolution is about 0.5 mm
 ••• it becomes worse at the edge
 of each region

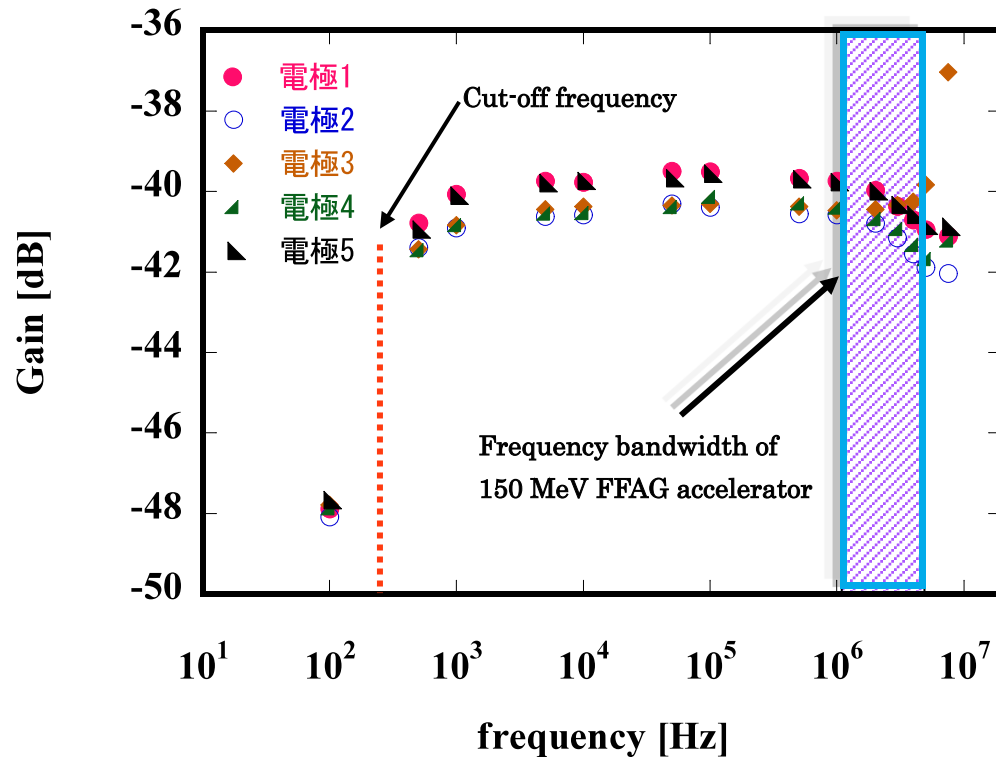
Beam position can be calculated from the improved formula.

Summary

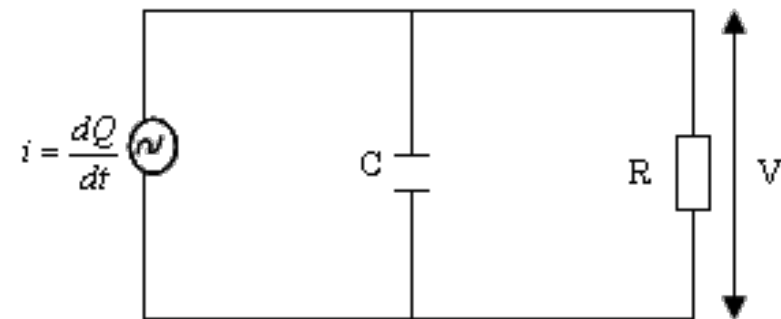
- We have developed five split electrodes beam monitor, and measured position response of the monitor.
- From the experiments, we have improved the position conversion formula taking into account the effect of electric field leakage.
Resolution: about **0.5 mm**
- We have been analyzing the electric field leakage.  Next presentation
- We will install the developed monitor to the 150 MeV FFAG and utilize it for beam commissioning.



frequency and induced voltages



Equivalent circuit schematic of the beam position monitor



$$\frac{dV}{dt} + \frac{V}{CR} = \frac{1}{C} \frac{dQ}{dt}$$



the equivalent circuit serves as a Low-Cut Filter

- cutoff frequency : **300 Hz**
- 1.55 ~ 4.56 MHz (150 MeV FFAG) ▪ ▪ ▪ Gain changes less than 1.0 dB