Bunch length measurement using the tran sverse electric field in injector cavity

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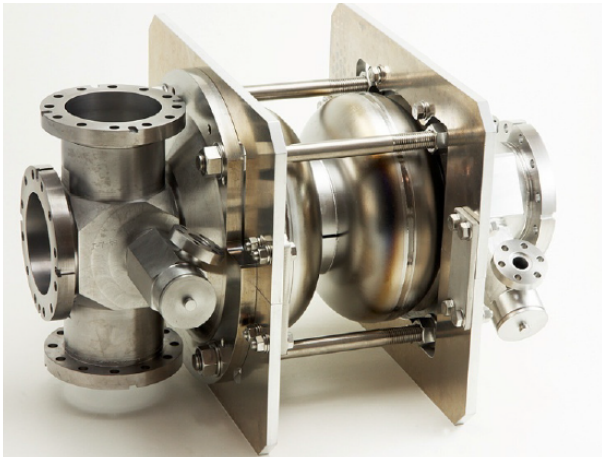
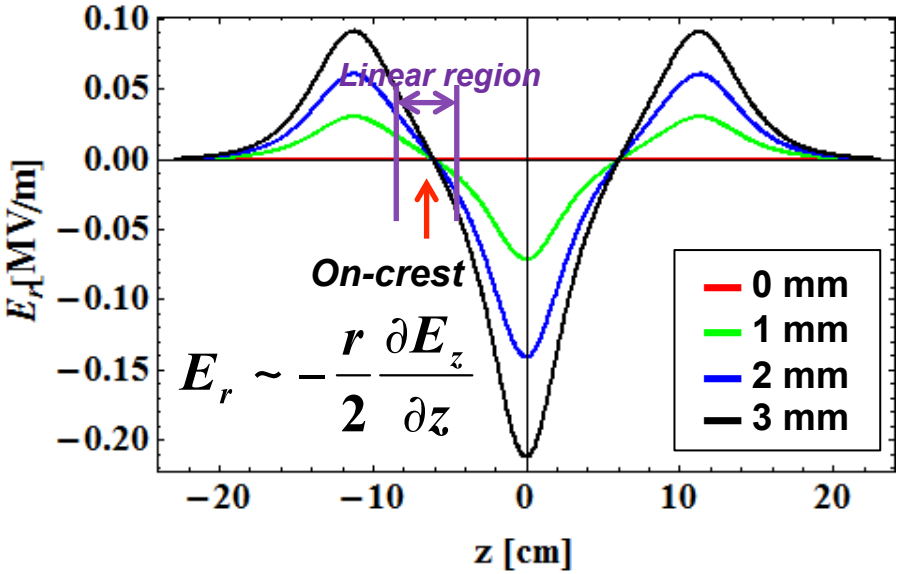
Motivation

- The SC injector cavity also has the transverse electric field which can cause the correlation between the bunch length and beam size as like TR(deflecting) cavity.

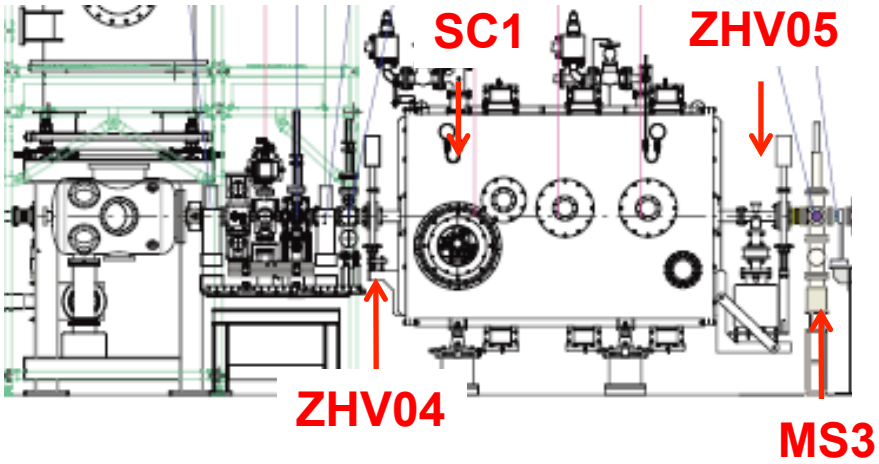


2 cell injector cavity

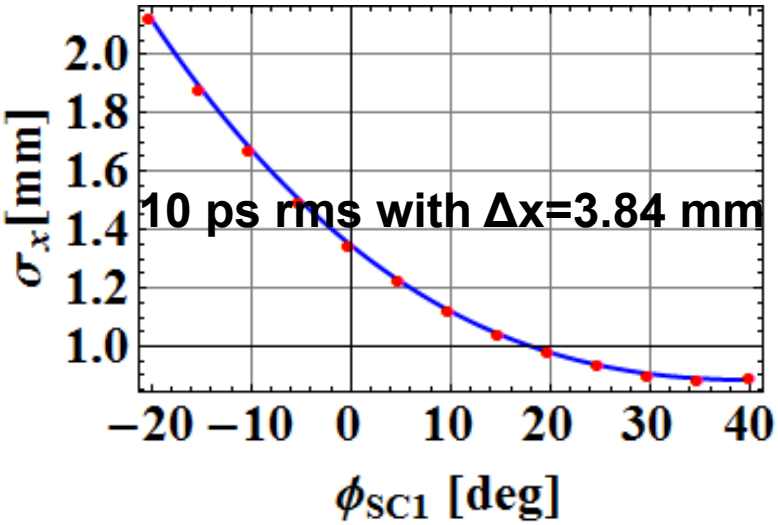


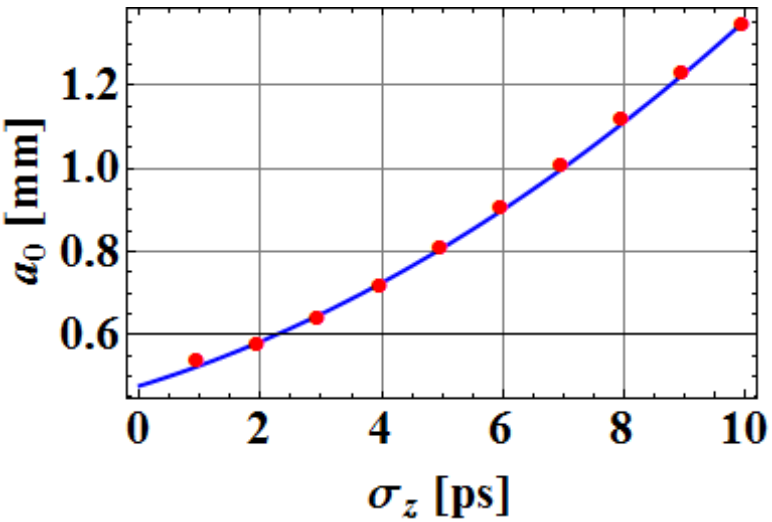
- The strength of transverse electric field is depend on the phase of RF field in cavity and the displacement of orbit at the entrance of cavity.

The variation of the beam size as a function of the phase



$$\Delta x = x_{c,SC1} - x_{c,ZHV04}$$





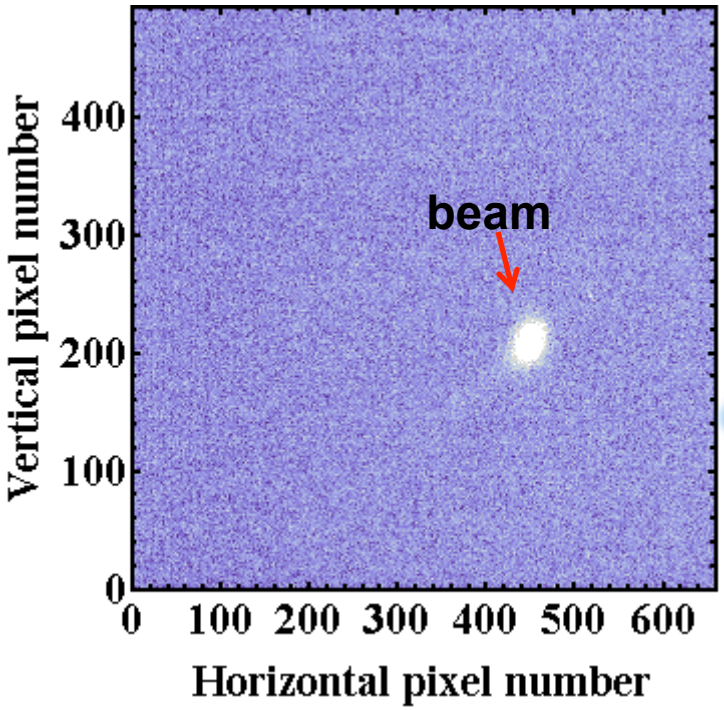
The beam size as a function of the phase can be explained by the linear function such as

$$f(\varphi) = a_0 + a_1\varphi + a_2\varphi^2 + a_3\varphi^3$$

From this estimation, the beam size dependency of a_0 was observed as a 2nd order linear function.

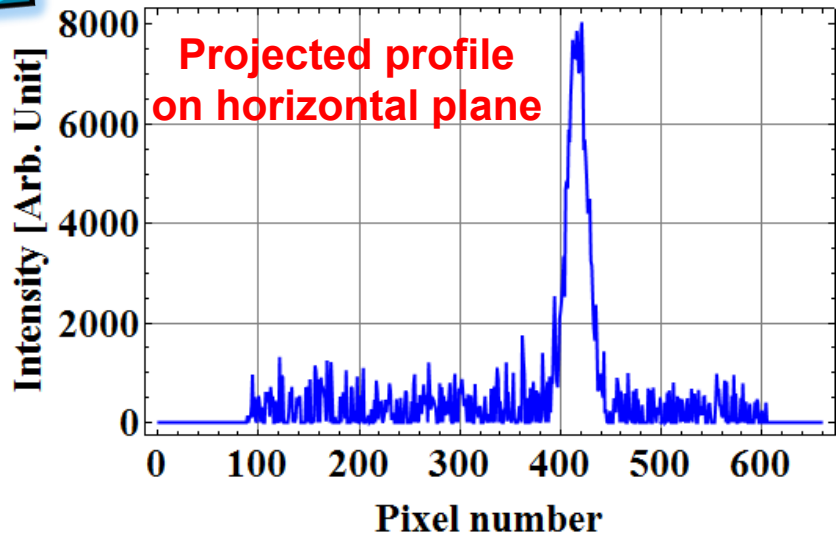
$$a_0(\sigma_z) = b_0 + b_1\sigma_z + b_2{\sigma_z}^2$$

Signal processing

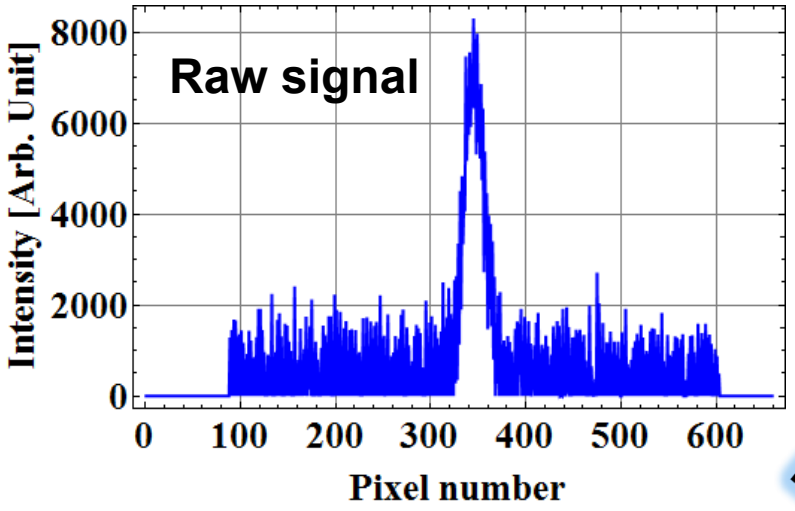


Beam profile at MS3

3 Dimensional profile of the beam on scree n is hard to analyze the signal and also has the large data size. Hence, the data was g ot from the projection on each axis. This me thod is quite comfortable and reasonable to analyze the data except the amplification o f the effect of the noise.



Signal processing



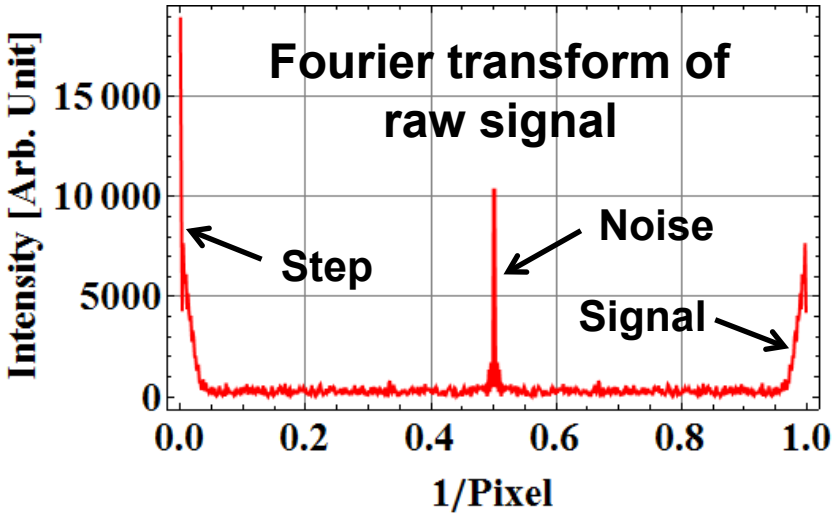
The profile data of horizontal plane was got from the projection. Sometimes, the raw data has large noise. The signal processing based on the fourier transform was applied to reduce the calculation errors due to this noise.

$$\hat{f}(\xi) = \int_{-\infty}^{\infty} f(x) e^{-2\pi i x \xi} dx$$

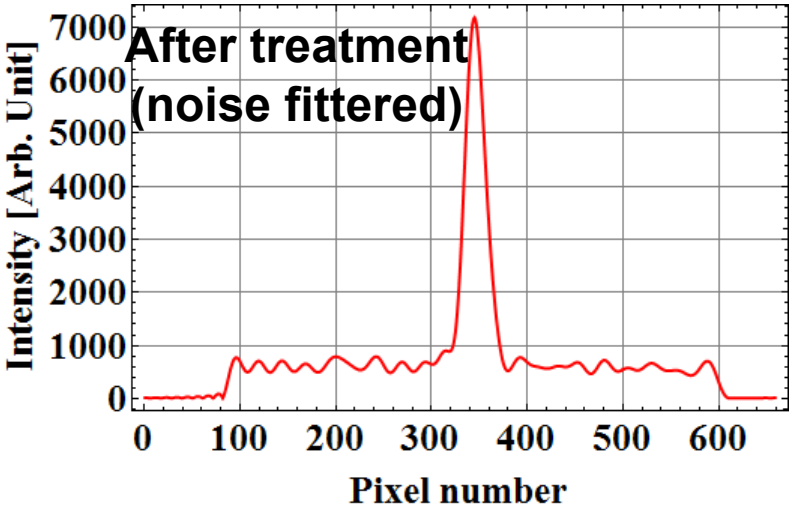
After the fourier transform, the identification of the each peak was investigated. If the beam has an ideal Gaussian distribution, the profile signal give by

$$y(x) = a\, e^{-\frac{(x-b)^2}{2c^2}} + d$$

Here, the ***d*** is step and $a\, e^{-\frac{(x-b)^2}{2c^2}}$ is signal.



Signal processing

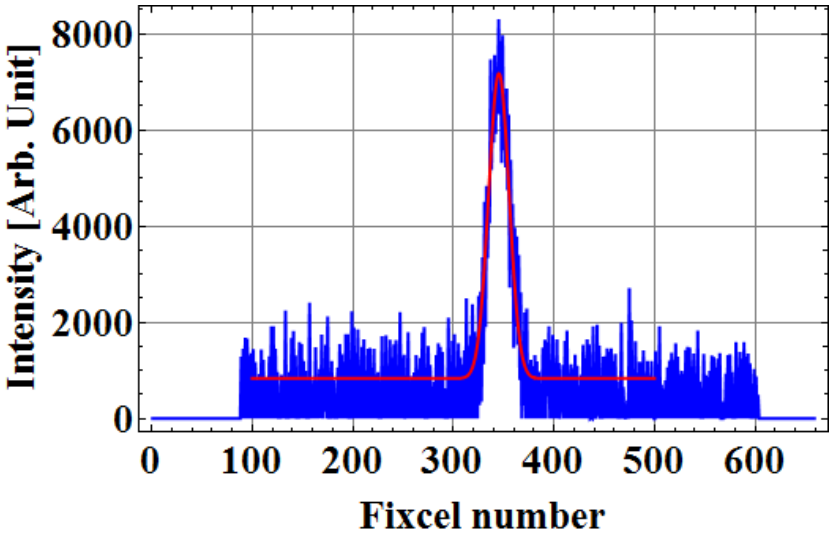


After the filtering of the noise signal fr
om the raw data, the inverse fourier tr
ansform was performed to get the info
rmation about beam size

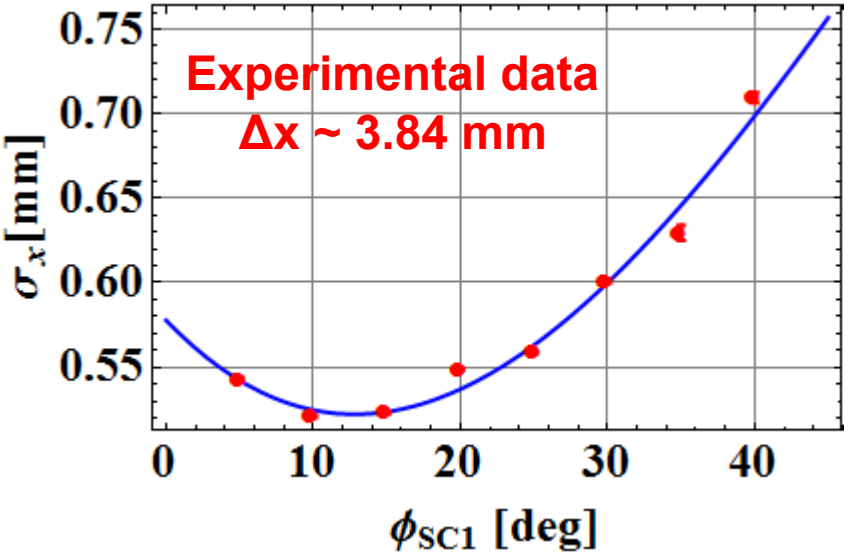
$$f(x) = \int_{-\infty}^{\infty} \hat{f}(\xi) e^{2\pi i x \xi} d\xi$$

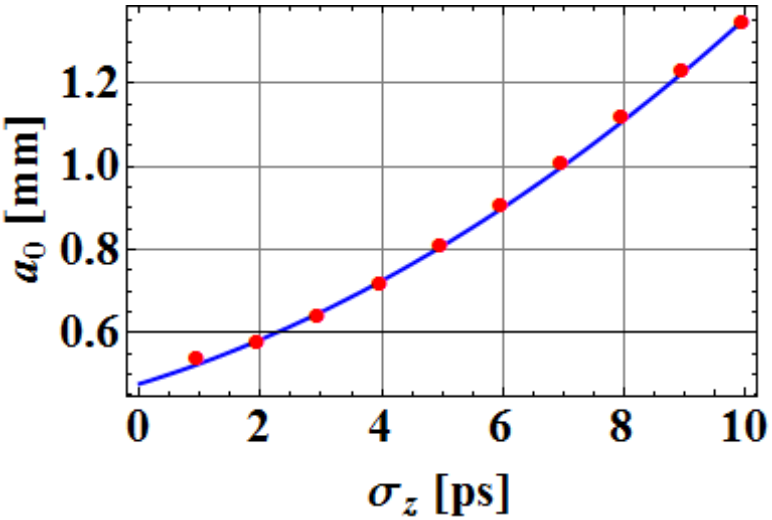
The noise was removed and then we
can get the clear peak of the beam pr
ofile. From this profile, the fitting of th
e data was performed by using followi
ng formula.

$$y(x) = a\, e^{-\frac{(x-b)^2}{2c^2}} + d$$



Experimental result [Horizontal a_0]





From above technique, the beam size was precisely calculated from the measurement data on c-ERL injector system.

From the fitting of beam size data, the coefficient of the 3rd order linear function was determined.

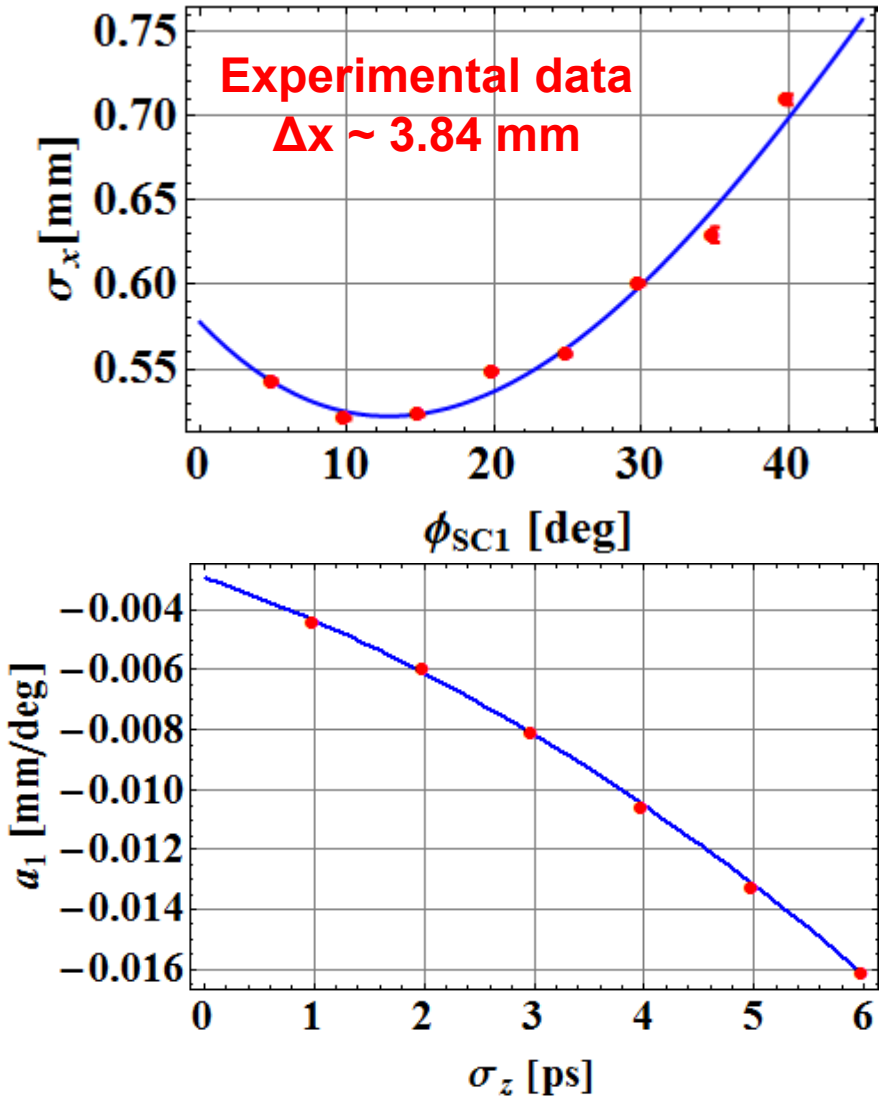
$$f(\varphi) = a_0 + a_1\varphi + a_2\varphi^2 + a_3\varphi^3$$

Here, a_0 = 0.578 ± 0.029 mm.

From the calculation data, it is corresponding to the **1.87 ± 0.58 ps**.

(The pulse duration of laser on the cathode is around 3 ps.)

Experimental result [Horizontal a_1]



The bunch length can be also estimated by the a_1 factor calculated by the fitting from beam size data.

From the fitting of beam size data, the coefficient of the 3rd order linear function was determined.

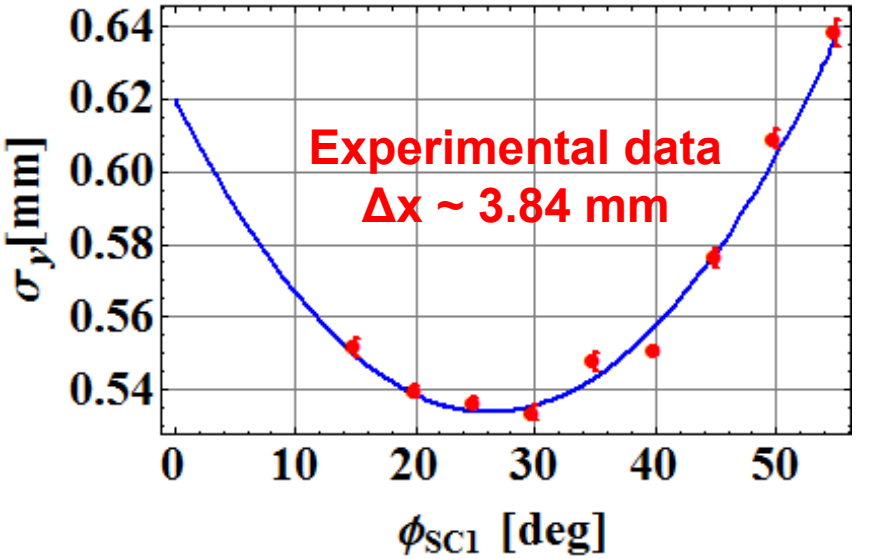
$$f(\varphi) = a_0 + a_1\varphi + a_2\varphi^2 + a_3\varphi^3$$

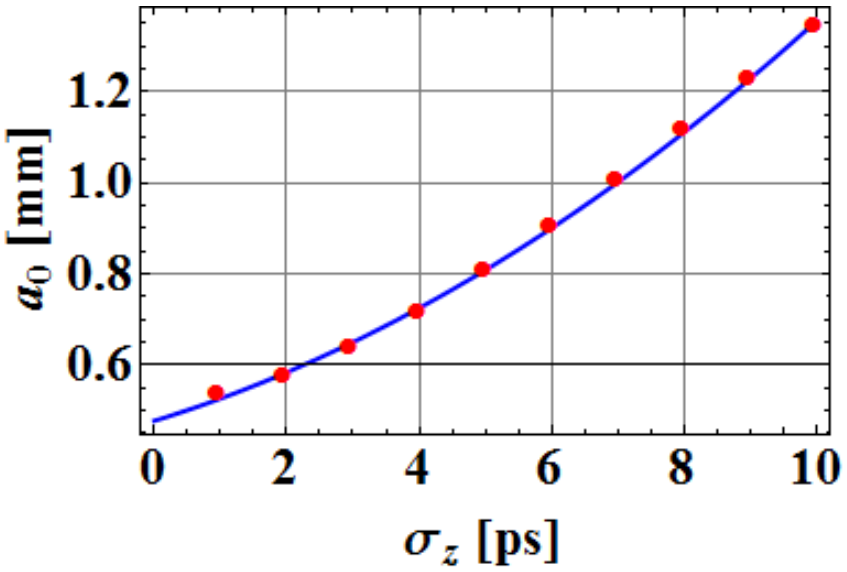
Here a_1 = -0.00907±0.00529 mm/deg.

It is correspond to the **3.41 ± 2.40 ps**.

(The pulse duration of laser on the cathode is around 3 ps.)

Experimental result [Vertical a_0]





From above technique, the beam size was precisely calculated from the measurement data on c-ERL injector system.

From the fitting of beam size data, the coefficient of the 3rd order linear function was determined.

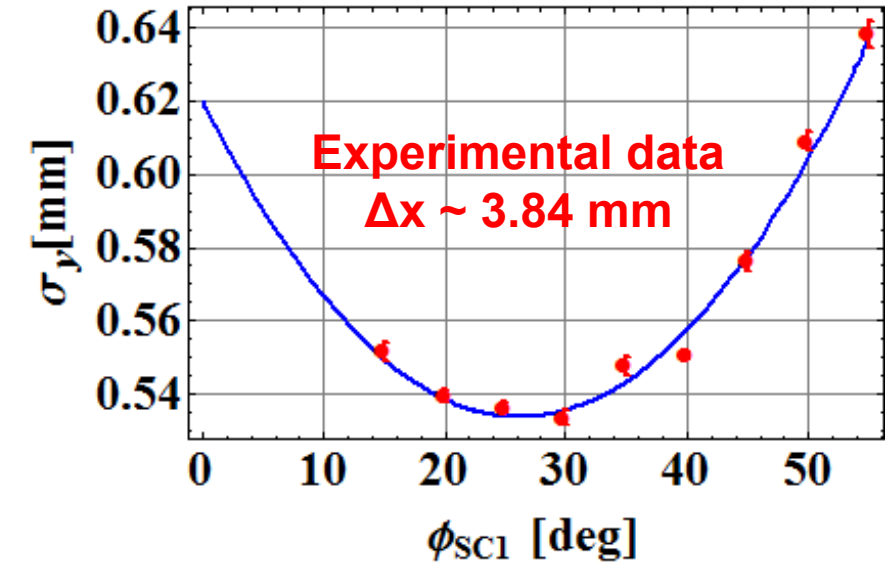
$$f(\varphi) = a_0 + a_1\varphi + a_2\varphi^2 + a_3\varphi^3$$

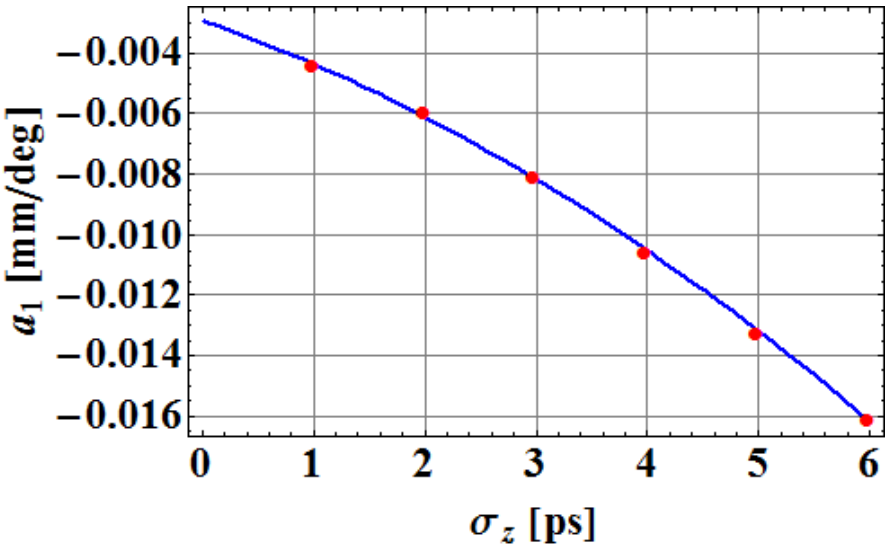
Here, a_0 = 0.620 ± 0.0340 mm.

From the calculation data, it is corresponding to the **2.60 ± 0.534 ps**.

(The pulse duration of laser on the cathode is around 3 ps.)

Experimental result [Vertical a_1]





The bunch length can be also estimated by the a_1 factor calculated by the fitting from beam size data.

From the fitting of beam size data, the coefficient of the 3rd order linear function was determined.

$$f(\varphi) = a_0 + a_1\varphi + a_2\varphi^2 + a_3\varphi^3$$

Here a_1 = -0.00664±0.00338 mm/deg.

It is correspond to the **2.28 ± 1.78 ps**.

(The pulse duration of laser on the cathode is around 3 ps.)

Discussion

- New method for measuring the bunch length using the transverse electric field in a cavity was suggested and studied as preliminary.
- This is novel way to measure the bunch length without the deflecting cavity even the accuracy is largely depend on the field of a cavity.
- I'm not sure this method is good or not because the fitted model was not given by the analytical model.
- The work for analytical model of this method is going on.