Center for the Advancement of Natural Discoveries using Light Emission

SYNCHROTRON RESEARCH INSTITUTE

The methods of bunch length measurement

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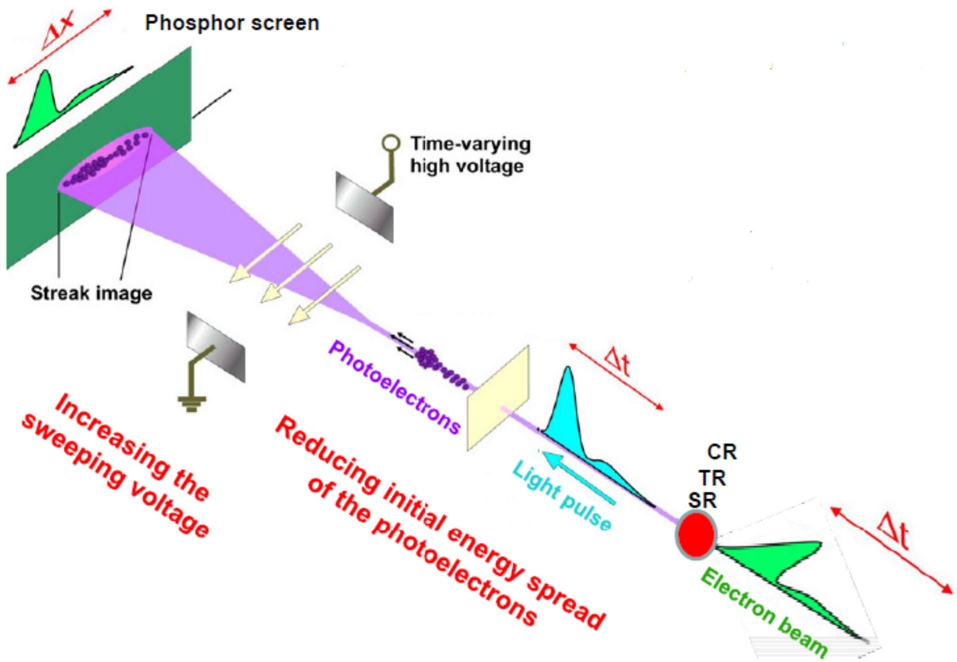
The task

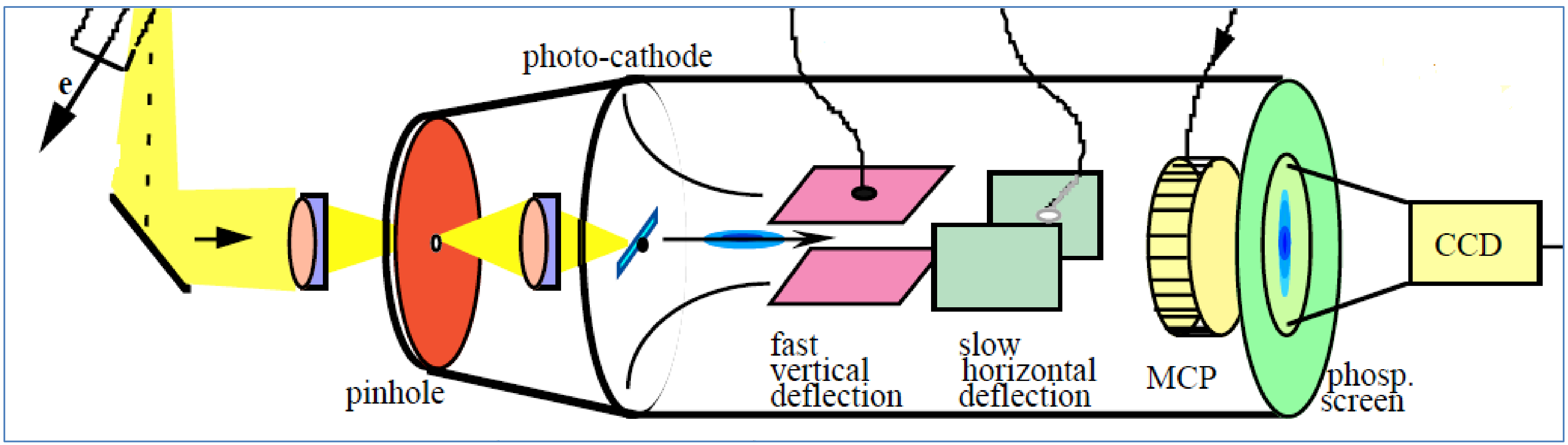
- Study all measurement methods of bunch length
- Choose the suitable method for AREAL

Bunch Length Measurements

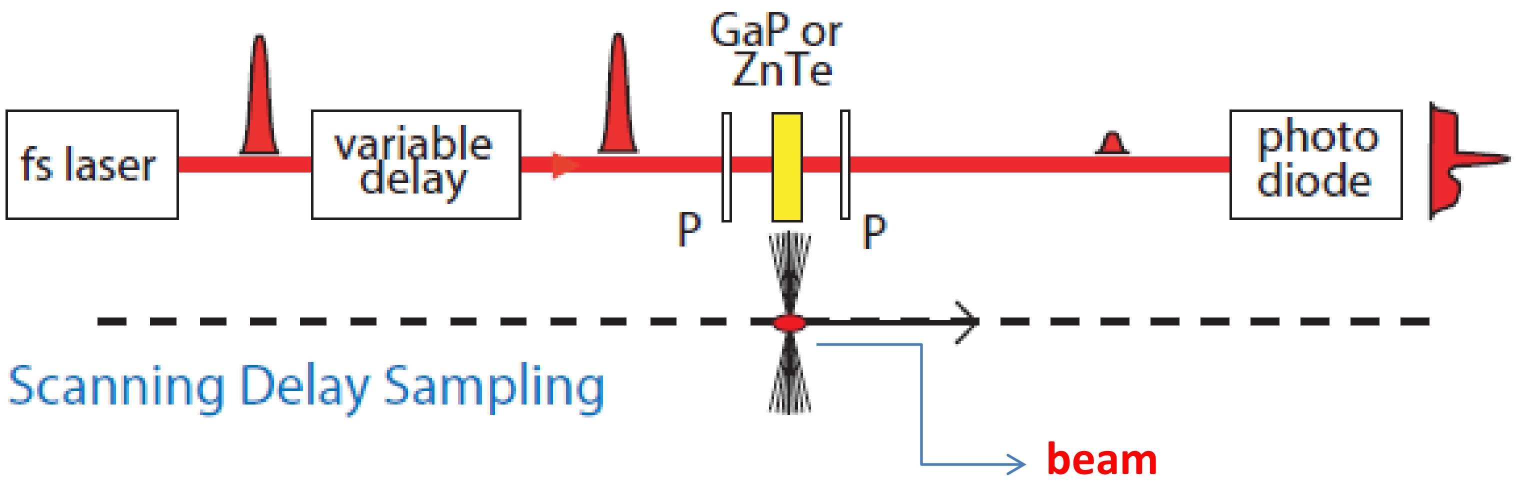
- By Streak camera
- By Electro - Optical Method
- By RF Deflecting Cavity
- By RF - Phasing Method

Bunch Length Measurement by Streak camera



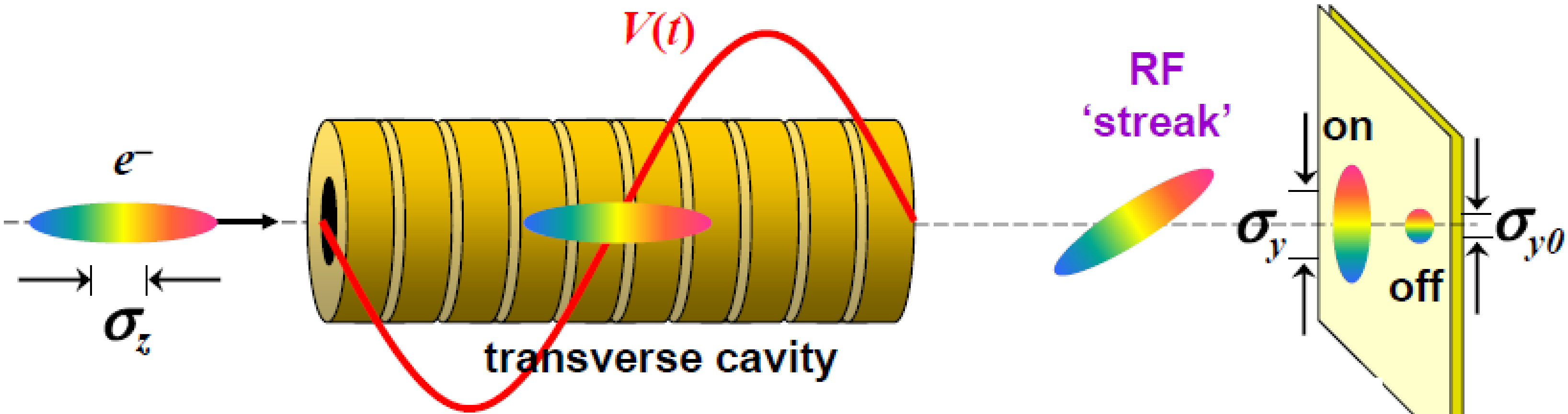


Bunch Length Measurement by Electro - Optical Method



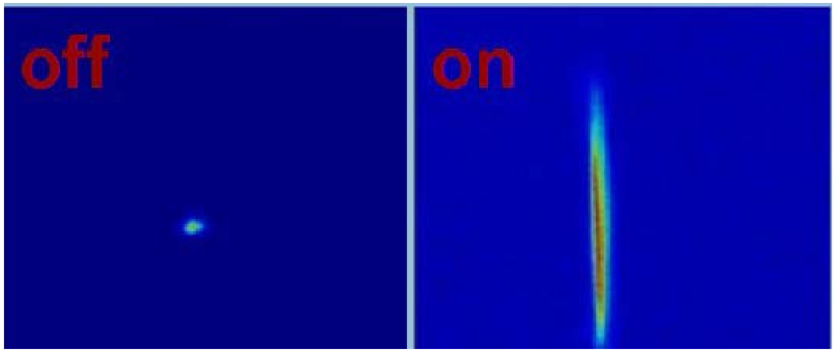
This method is based on the polarization change of a laser beam which passes through a crystal itself polarized by the electrons electric field .
Bunch length is reconstructed by measuring the intensity of the polarization change as a function of laser timing

Bunch Length Measurement by RF Deflecting Cavity

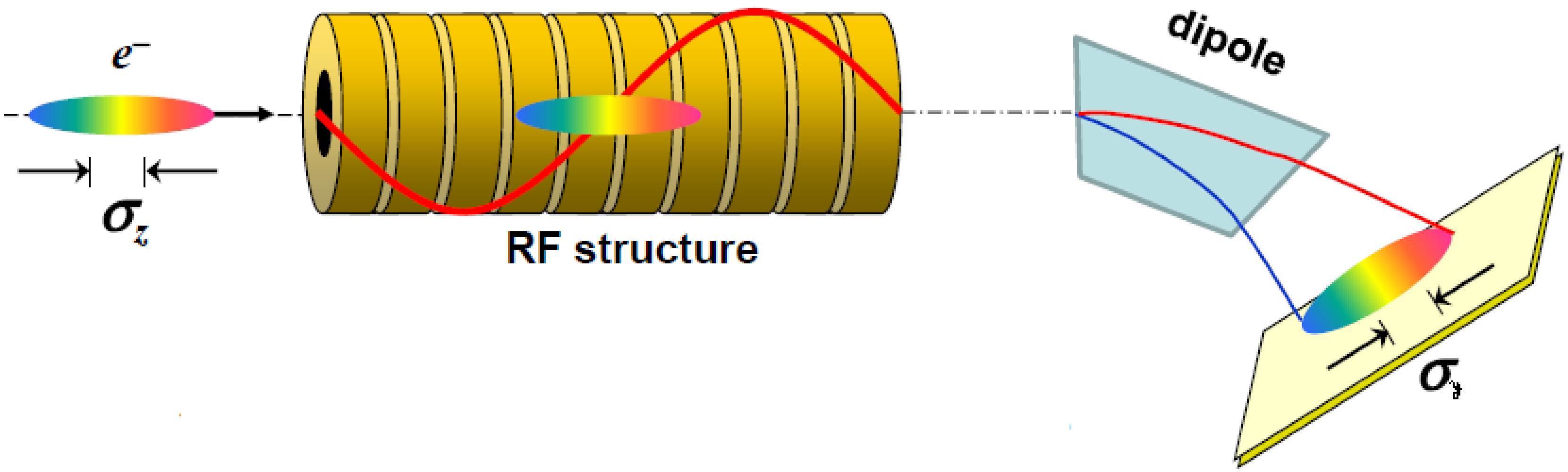


$$\sigma_y^2 = \sigma_{y_0}^2 + \sigma_z^2$$

Transversal deflection of the bunch. The bunch length is then deduced measuring the beam size at a downstream position using a screen.



Bunch Length Measurement by RF - Phasing Method



This method is calibrated using beam screen data and only the RF frequency needs to be known

The Method

$$E(z) = E_i + eV_0\cos(\varphi + kz) + E_0 hz\ , \qquad (1)$$

$$E_0 \equiv E_i + eV_0\cos\varphi_0\ , \qquad (2)$$

$$k|z| << 1$$

$$\delta(z) \approx eV_0[\cos\varphi - \cos\varphi_0 - k\sin\varphi\, z]/E_0 + hz. \quad (3)$$

$$y = \eta\delta.$$

$$\langle y\rangle = \eta\langle\delta\rangle \approx eV_0\eta[\cos\varphi - \cos\varphi_0]/E_0\ . \qquad (4)$$

$$\langle z\rangle = 0,$$

A voltage calibration can then easily be done by measuring the sensitivity of the position centroid, *y,* using small variations of the RF phase

$$\partial\langle y\rangle/\partial\varphi = -eV_0\eta\sin\varphi\,/E_0 \equiv a \qquad (5)$$

$$\varphi = \varphi_0$$

$$y = (\eta h + ak)z \qquad (6)$$

$$\sigma_y = \langle y^2\rangle^{1/2} \qquad \sigma_z = \langle z^2\rangle^{1/2}$$

$$\rightarrow \quad \sigma_y^2 = (\eta h + ak)^2\sigma_z^2 + \sigma_{y0}^2\ , \qquad (7)$$

The sing of a followes the sing of phase, we introduce x as the sing of phase.

$$a \rightarrow |a|x.$$

$$\sigma_y^2 = a^2 k^2 \sigma_z^2 (|\eta| h / |ak| + x)^2 + \sigma_{y0}^2 \qquad (8)$$

$A = a^2 k^2 \sigma_z^2$, $B = |\eta| h / |ak|$, and $C = \sigma_{y0}^2$ $\longrightarrow$ $\boxed{\sigma_z = A^{1/2} / |ak|}$

$$\sigma_y^2 = A(B + x)^2 + C\,, \qquad (9)$$

$$x = -1,\ x = +1,\ \text{or}\ x = 0$$

$$A = \frac{\sigma_{y(\varphi_0)}^2 + \sigma_{y(-\varphi_0)}^2}{2} - \sigma_{y(0)}^2$$

2- point measurement - If crest phase beam size is much smaller than the other two, we can ignorind it.

$$\sigma_z = \left(\frac{\sigma_{y(\varphi_0)}^2 + \sigma_{y(-\varphi_0)}^2}{2} \right)^{1/2} \Big/_{ak}$$

Example

This refined RF phasing method has been tested at LCLS *and* the results are compared to those of the transverse deflector

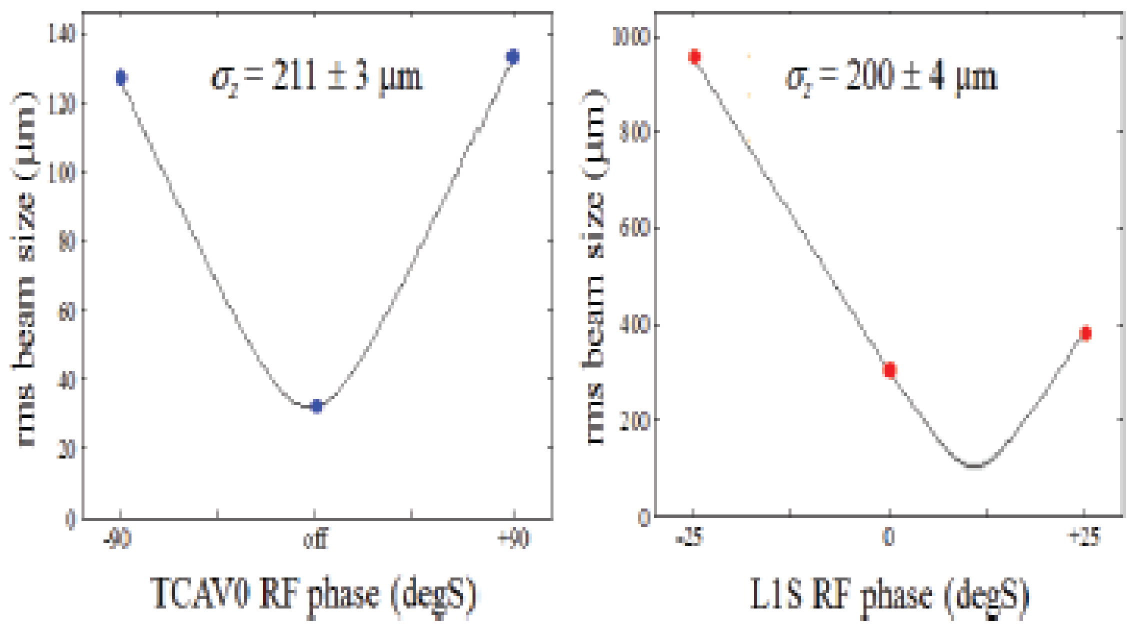


Figure 7: Measured rms beam sizes in *LCLS* injector at 20 pC vs. RF phase (transverse cavity phase at left, and pre-BC1 accelerating phase, L1S, at right). The two independent bunch length measurements agree to within 5% here.

THANK YOU FOR ATTENTION