Bunch Length Measurements

Working principle and additional effects

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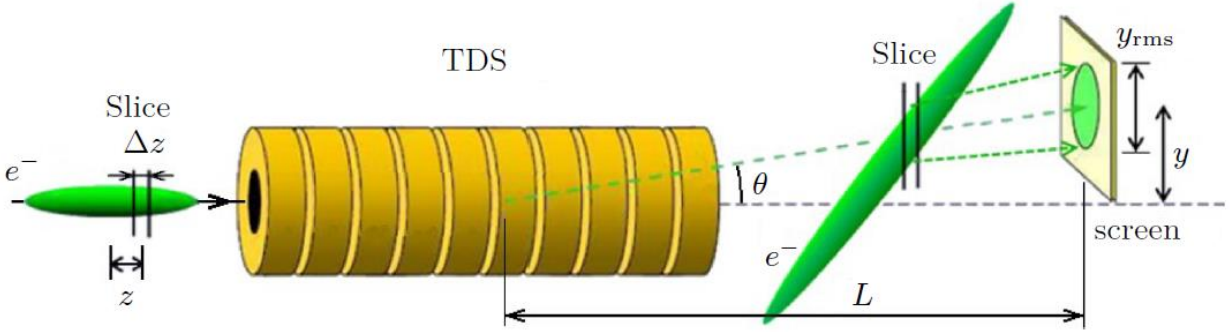
RF deflector

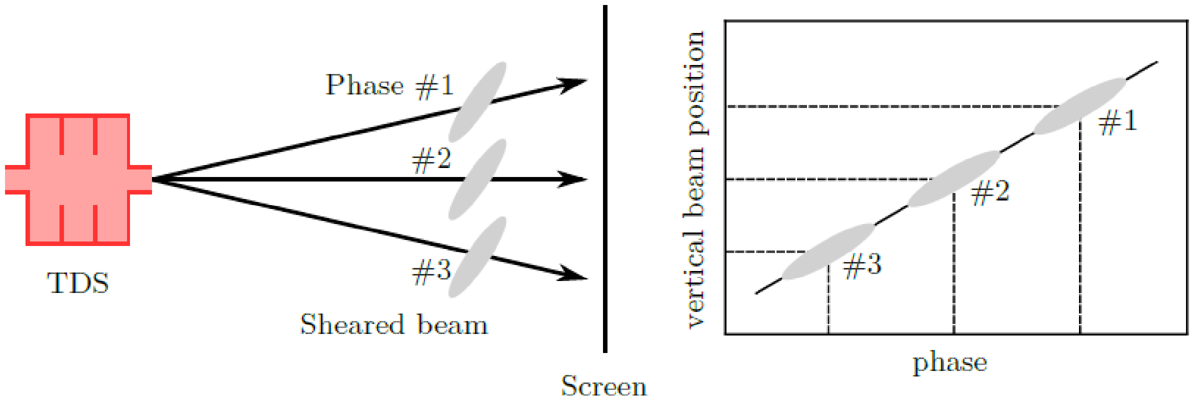
Developed for particle separation, used for bunch profile measurements

- Bunch is deflected transversely
- Mapping longitudinal to transverse coordinate
  - Bunch profile
  - Slice emittance
  - Longitudinal phase space
  - Mapping via $y = S \cdot z$ $\qquad S = \frac{eV_0k}{pc}R_{34}$



- Shear parameter calibration
  - TDS phase scan
  - Shear parameter S from slope
  - Zero-crossing phase from zero crossing

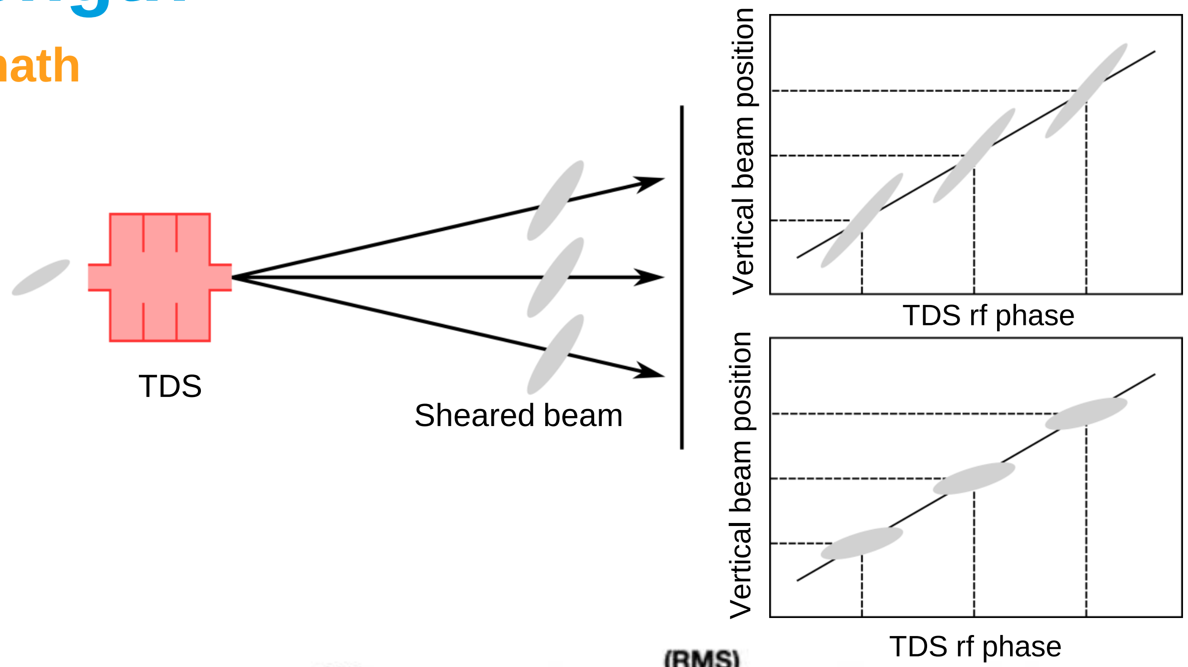
$$y = S \cdot z = S\frac{\Delta\varphi}{k}$$



TDS calibration and bunch length

Considering further effects – creating general math

- Finite transverse beam size
  - Mapping changes: $y = S \cdot z$ → $y_{\rm rms}^2 = \beta_y(s)\epsilon_y + S^2 z_{\rm rms}^2$
  - Gives resolution limit: Unsheared beam size



- But missing: Initial *y – z* correlation
  - Gives additional component to TDS deflection: $S \to S + S_0$
    - Increases net shear on one rf phase
    - Reduces net shear on other rf phase

- Net formula becomes

$$y_{\rm rms}^2 = \beta_y\epsilon_y + (S+S_0)^2 z_{\rm rms}^2 = \beta_y\epsilon_y + S_0^2 z_{\rm rms}^2 + 2SS_0 z_{\rm rms}^2 + S^2 z_{\rm rms}^2$$

  - 2nd-order polynomial
  - Take vert. beam size @ both zero-crossing, and TDS off
  - Fitting determines bunch length, initial correlation, resolution
    - Done at Eu-XFEL, see right image