# Crab Crossing in Compton Sources

## Analytical Study

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Thanks to: A.Variola
& PosiPol Com.

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Proposed by R.B.Palmer (1988), K. Oide and K.Yokoya (1989)

- to avoid synchro–betatron coupling resonances
- to enhance luminosity:
  in crab crossing luminosity equal to head–on collisions
- crossing angle around 22 mrad[1] ($1.26^{o}$)

[1] K.Hosoyama et al. Construction and Commissioning of KEKB Superconducting Crab Cavities

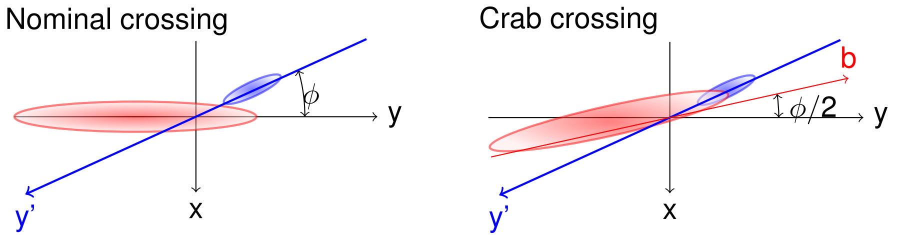
Proposed by A.Variola (2006)[2] to enhance yield.
Main results of extensive simulations

- Optimal crabbing angle is about half of the collision angle
- Under certain conditions attained gain of about 4/5 times higher than nominal
- Shorter bunches are less sensitive to crab
- Collision angle in Compton sources about $8^{o}$ (140 m rad)

[2] A.Variola. Compton Parameters Optimization (PosiPol 06)

- Tri–gaussian distribution both in bunches and laser pulses (no hour–glass effect)
- Crossing in $(x, y)$ plane ($y$ is the longitudinal coordinate)

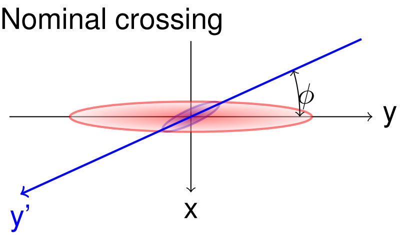
Task: With the laser pulse unchanged find the inclination angle of electron bunch (angle between the orbit and the longitudinal axis of bunch) provided maximal yield of gammas

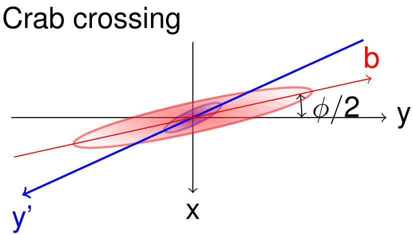



Enhancement in yield (= ratio of geometric denominators)

$$\frac{\text{crab}}{\text{nom}} = \sqrt{\frac{({\sigma'_x}^2 + \sigma_x^2)\cos^2\frac{\phi}{2} + ({\sigma'_y}^2 + \sigma_y^2)\sin^2\frac{\phi}{2}}{\sigma_x^2 + {\sigma'_x}^2\cos^2\frac{\phi}{2} + {\sigma'_y}^2\sin^2\frac{\phi}{2}}}$$

(laser pulse primed)



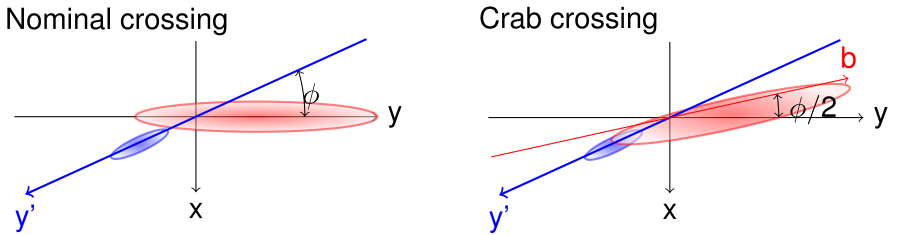




Enhancement in yield (= ratio of geometric denominators)

$$\frac{\text{crab}}{\text{nom}} = \sqrt{\frac{({\sigma'_x}^2 + \sigma_x^2)\cos^2\frac{\phi}{2} + ({\sigma'_y}^2 + \sigma_y^2)\sin^2\frac{\phi}{2}}{\sigma_x^2 + {\sigma'_x}^2\cos^2\frac{\phi}{2} + {\sigma'_y}^2\sin^2\frac{\phi}{2}}}$$

(laser pulse primed)

## Inclination exactly equal to half of collision angle

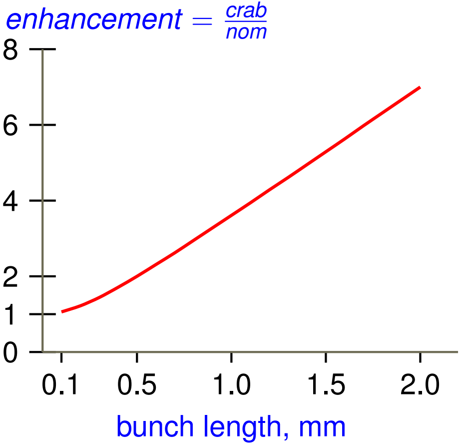



Enhancement in yield (= ratio of geometric denominators)

$$\frac{\text{crab}}{\text{nom}} = \sqrt{\frac{({\sigma'_x}^2 + \sigma_x^2)\cos^2\frac{\phi}{2} + ({\sigma'_y}^2 + \sigma_y^2)\sin^2\frac{\phi}{2}}{\sigma_x^2 + {\sigma'_x}^2\cos^2\frac{\phi}{2} + {\sigma'_y}^2\sin^2\frac{\phi}{2}}}$$

(laser pulse primed)

# Estimations for ERL




Parameters provided by T.Omori

- Emittance $\epsilon_{x,z} = 6.25 \times 10^{-10}$ m
- Beta-functions $\beta_{x,z}^{(\mathrm{cp})} = 0.16$ m
- Laser pulse $\sigma'_{x,z} = 5\,\mu$m
- Laser pulse $\sigma'_{y} = 240\,\mu$m
- Collision angle $\phi = 8^{\mathrm{o}}$ (0.14 rad)

# Simulations and Estimations for CLIC

2008, $\phi = 8^{\circ}$, double–chicane scheme

| pulse $\sigma'_y \rightarrow$ | 900 $\mu$m | 240 $\mu$m |
|---|---|---|
| nominal/cycle | 84 | 88 |
| head-on/cycle | 300 | 390 |
| head-on/nom | 2.57 | 3.3 |
| crab/nom | 1.72 | 2.45 |
| head-on/crab | 1.7 | 1.06 |
| head-on/nom | 2.94 | 2.61 |

But: for CLIC Compton source 2006 ($\phi = 10^{\circ}$, $\sigma_y = 5$ mm) crab crossing will gain 5.4 ($\sigma'_y = 900\,\mu$m) or even 13.2 ($\sigma'_y = 240\,\mu$m)

# Summary and Outlook

Geometric factors of crab crossing to minimize (in red)

$$Y \sim \left[ \left( \sigma_z^2 + {\sigma'_z}^2 \right) \left( \sigma_x^2 + {\sigma'_x}^2 \cos^2 \frac{\phi}{2} + {\sigma'_y}^2 \sin^2 \frac{\phi}{2} \right) \right]^{-\frac{1}{2}}$$

- Crab crossing eliminates the bunch length $\sigma_y$ impact
- Enhancement depends on the pulse length $\sigma'_y$ (a challenge for the laser people)
- Increase in the emitting spot size $\approx \sqrt{\sigma_x^2 \cos^2 \frac{\phi}{2} + \sigma_y^2 \sin^2 \frac{\phi}{2}}$ (negligible for gamma sources)

Further exploration necessary ?