IPBSM response to non-Gaussian beam

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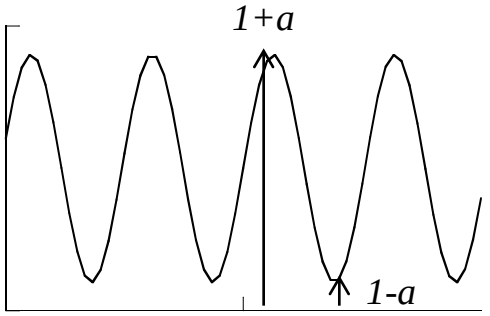
Motivation of this study

- We sometimes observe apparent discrepancies between beam sizes measured with different IPBSM crossing angles (different modulation pitches)
- May come from systematic errors of IPBSM
- But, may come from non-Gaussian beam shape, because beam size is evaluated assuming Gaussian beam.
  - How IPBSM measurement depends on beam shape?

What IPBMS measures

Interference of two laser beams: photon density is

$$p(y,\varphi) = \frac{A}{2}\left(1 + a\cos(2\pi y/h + \varphi)\right)$$



For electron density ρ(y), signal height is

$$G(\varphi) \propto \int_{-\infty}^{\infty} \rho(y)dy$$

$$+ a\cos\varphi \int_{-\infty}^{\infty} \rho(y)\cos(2\pi y/h)dy - a\sin\varphi \int_{-\infty}^{\infty} \rho(y)\sin(2\pi y/h)dy$$

Scanning the phase φ , “modulation” is

$$M = \frac{G_{\max} - G_{\max}}{G_{\max} + G_{\max}} = a\frac{\left|\int_{-\infty}^{\infty} \rho(y)\exp[i(2\pi y/h)]dy\right|}{\int_{-\infty}^{\infty} \rho(y)dy}$$

Modulation is, basically,
amplitude of Fourier transformation of electron density.

For Gaussian beam

$$\rho(y) \propto \exp\left(-\frac{y^2}{2\sigma^2}\right) \qquad M = a\exp\left(-\frac{2\pi^2\sigma^2}{h^2}\right) \qquad \sigma = \pi h\sqrt{\frac{1}{2}\ln\left(\frac{a}{M}\right)}$$

For two Gaussians beam

$$\rho(y) \propto C\exp\left(-\frac{y^2}{2\sigma_C^2}\right) + T\exp\left(-\frac{y^2}{2\sigma_T^2}\right)$$

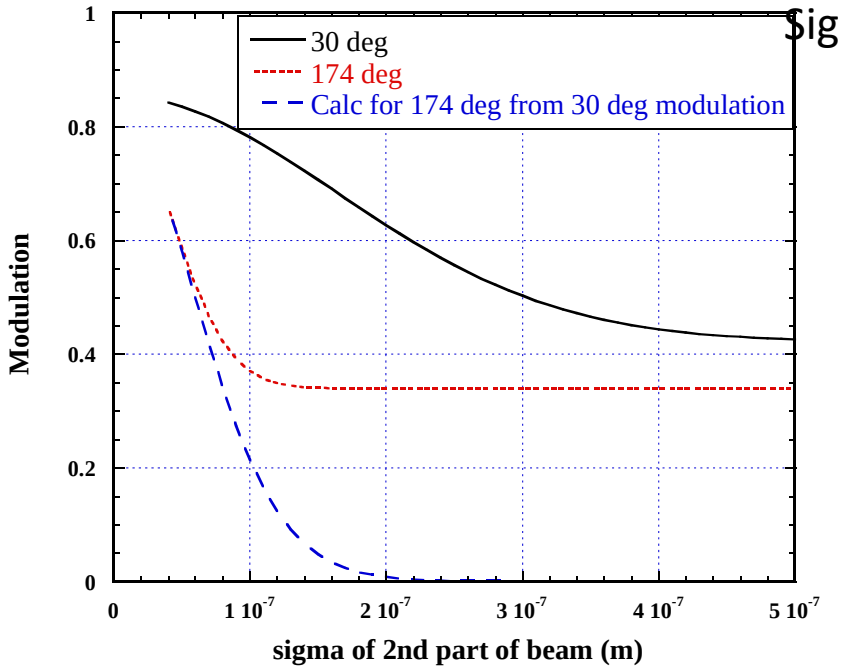
$$M = a\frac{C\exp\left(-\frac{2\pi^2\sigma_C^2}{h^2}\right) + T\exp\left(-\frac{2\pi^2\sigma_T^2}{h^2}\right)}{C+T}$$

Cannot tell beam size and beam shape.

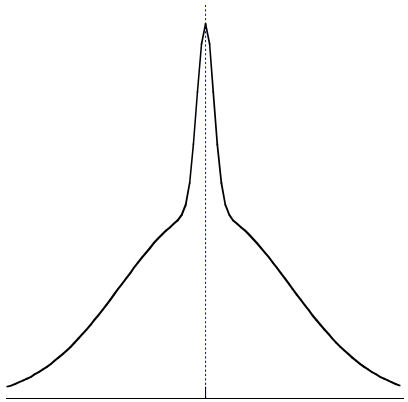
Effect of tail is different for different fringe pitch (crossing angle).

But, only important if T is comparable with C.

Modulation for beam of sum of two Gaussians



Sigma of 1st part =37 nm

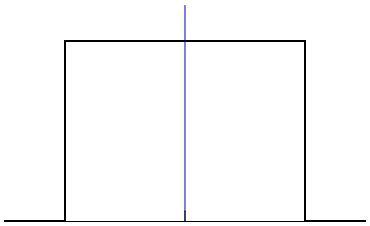


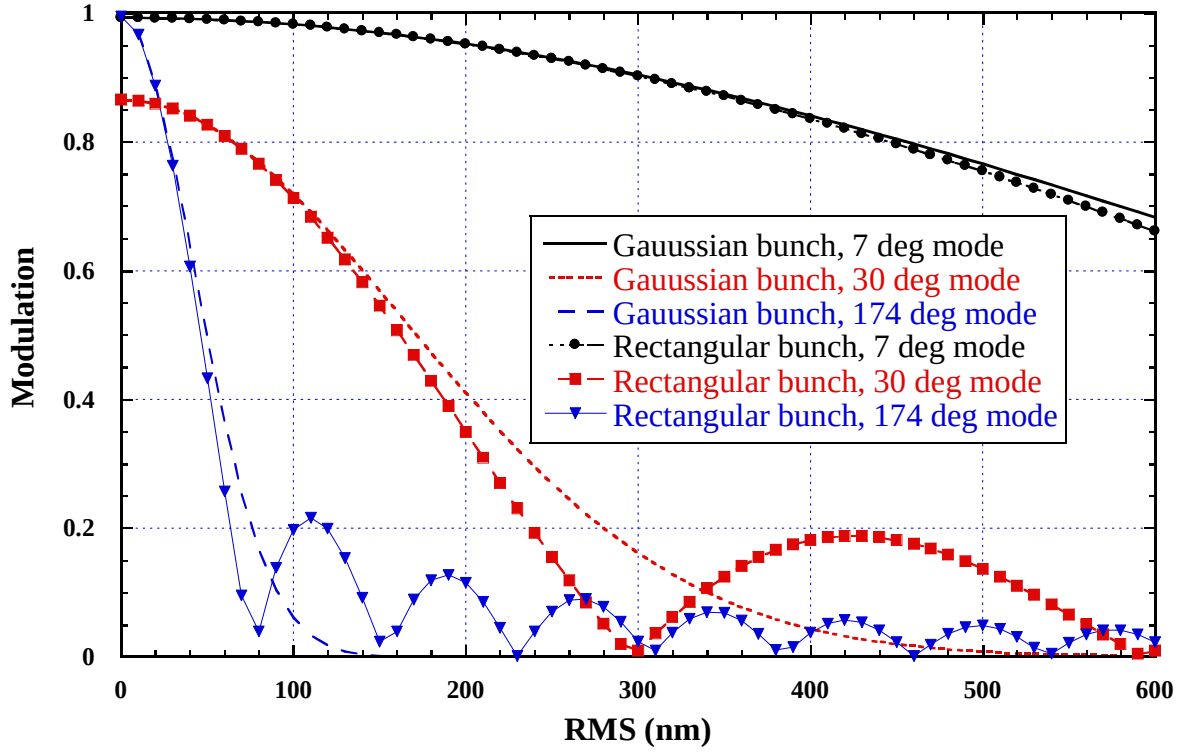
Calculated modulations as functions of sigma of 2nd part (tail) of the beam.
Population of 1st and 2nd part =1:1
Dashed line: Modulation with 174 deg, calculated from the modulation with 30 deg, assuming a single Gaussian beam.

Rectangular beam

$$\rho(y) \propto \begin{cases} 1 & (|y| \le b) \\ 0 & (|y| > b) \end{cases}$$

$$M = a\frac{\sin(2\pi b/h)}{(2\pi b/h)}$$

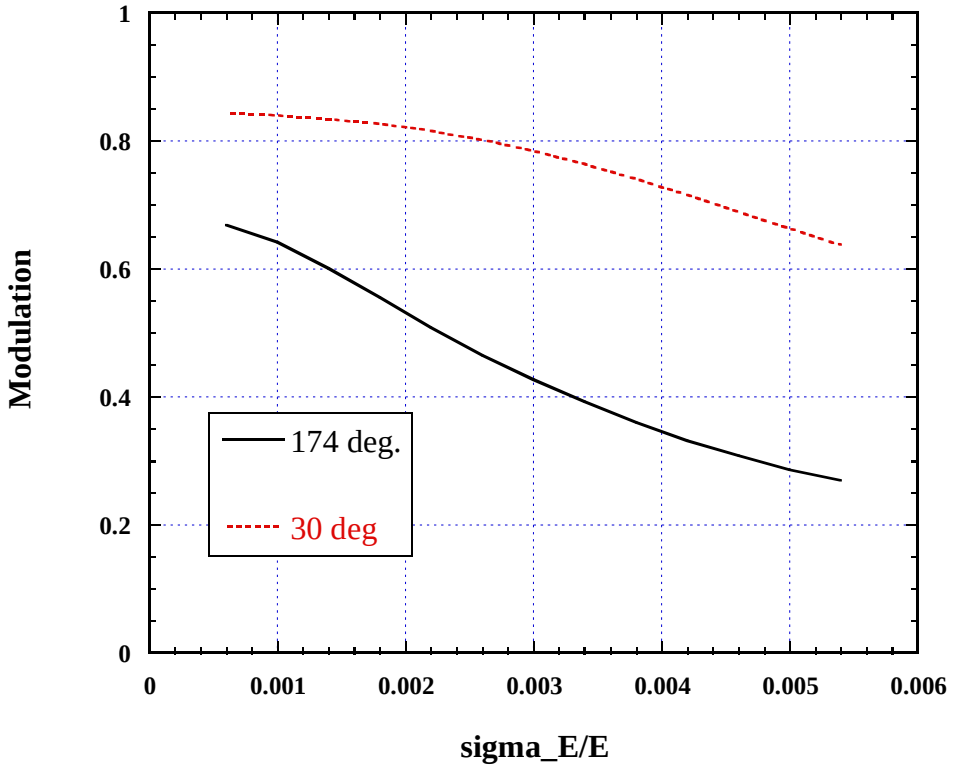


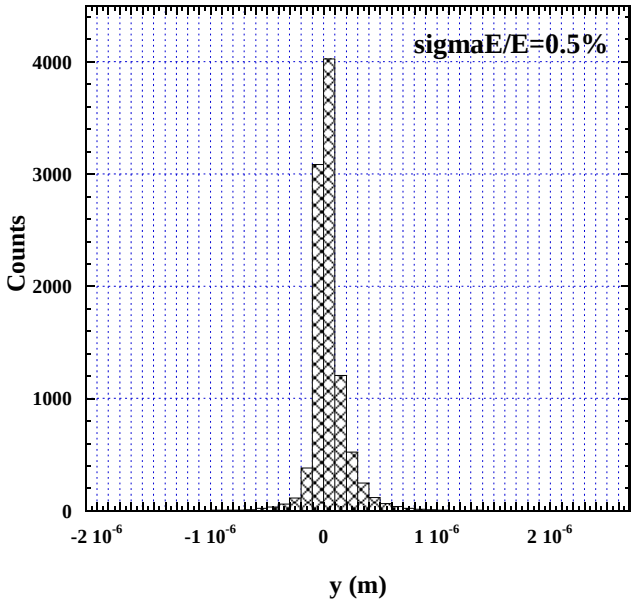


Tracking simulation of ATF2 beam line → IPBSM modulation

Set very large energy spread

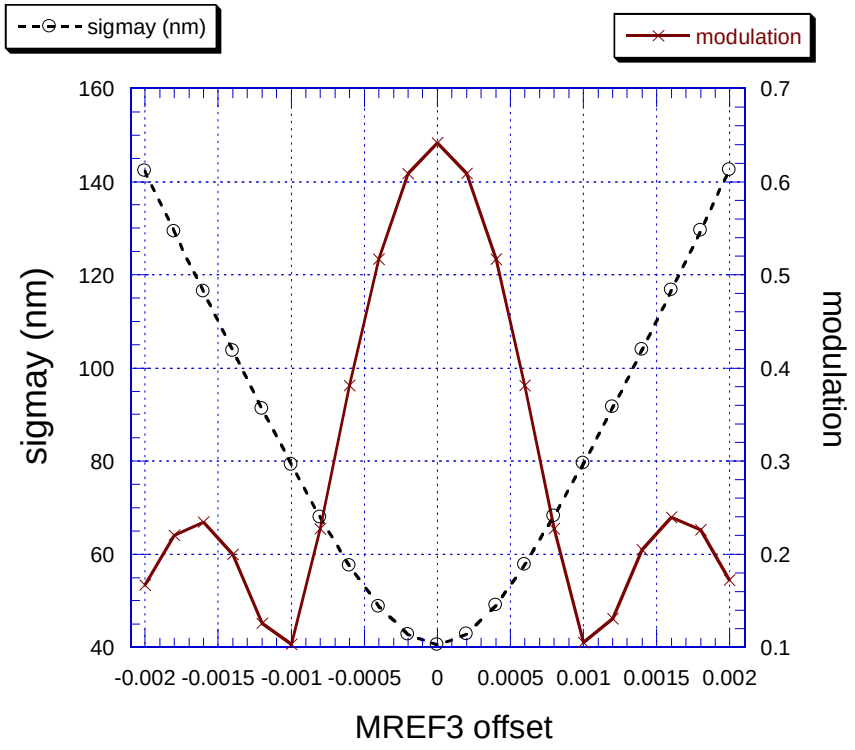
→ might simulate large non-linear effects (?) → large tail

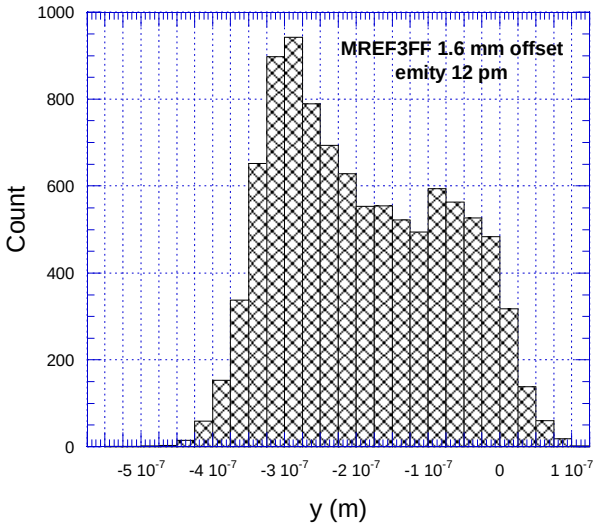




Tracking simulation of ATF2 beam line → IPBSM modulation

Set strong transverse wakefield





Conclusion

We should keep in mind that

- IPBSM is not necessarily measuring sigma or RMS beam size.
- Modulation is not necessarily monotonic function of RMS, or sigma of core part of the beam.
- Evaluated beam size from modulation assuming Gaussian beam can be different for different crossing angle on leaser beams.

If electron beam shape is far from Gaussian.

No conclusion about the actual beam size and beam shape.

Here, only possibilities are shown.