Luminosity and Beam Beam for very large crossing angles

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Basic concept:

Luminosity is generally higher for high energy rings for several reasons, some of the more beneficial are:

1) Tune shifts scales with 1/Energy (E) leading to a fundamental linear increase of the luminosity vs Energy
2) Radiation damping-time decrease with $1/E^3$ leading to higher limits for tune-shifts
3) Touschek effect decrease with $1/E^3$
4) Natural bunch lenght shorter
5) Beam stiffer, single and multi bunch instabilities decrease with 1/E

2) and 3) lead to smaller "Design" horizontal emittance for higher Energy colliders

If we want to collide at the Φ-pole, we could increase the ring Energy by greatly increasing the crossing angle 2α, such as:

$$E_{cm} = 2E_{beam}\cos(\alpha)$$

In principle the rings energies could be anything, and could be choosen to optimize luminosity and detector layout.

For example $\alpha=60°$ corresponds to $E_{beam}=1GeV$

Luminosity and tune-shifts could be greatly affected, we consider two cases:

1) with Crab-crossing

2) without Crab-crossing

Crab Crossing case:

$L = L_0 \cos(\alpha)$

However when the beam is crabbed, the horizontal size and the interaction lenght do change:

$\sigma_x = \sigma_{x0} \cos(\alpha)$; $\sigma_z = \sigma_{z0} / \cos^2(\alpha)$

such as L does not change, but the IP-bunch length is longer, leading to an increase of the minimum βy at the IP, with a corresponding loss in the luminosity reach.

No Crab Crossing case:

$L=L_0\sigma_x/(\sigma_z\tan(\alpha))$ $\alpha>>0$

$\xi_x=\xi_{x0}(\sigma_x/(\sigma_{z0}\tan(\alpha)))^2\cos(\alpha)$ -> $\cos(\alpha)/(\sigma_z\tan(\alpha)))^2$

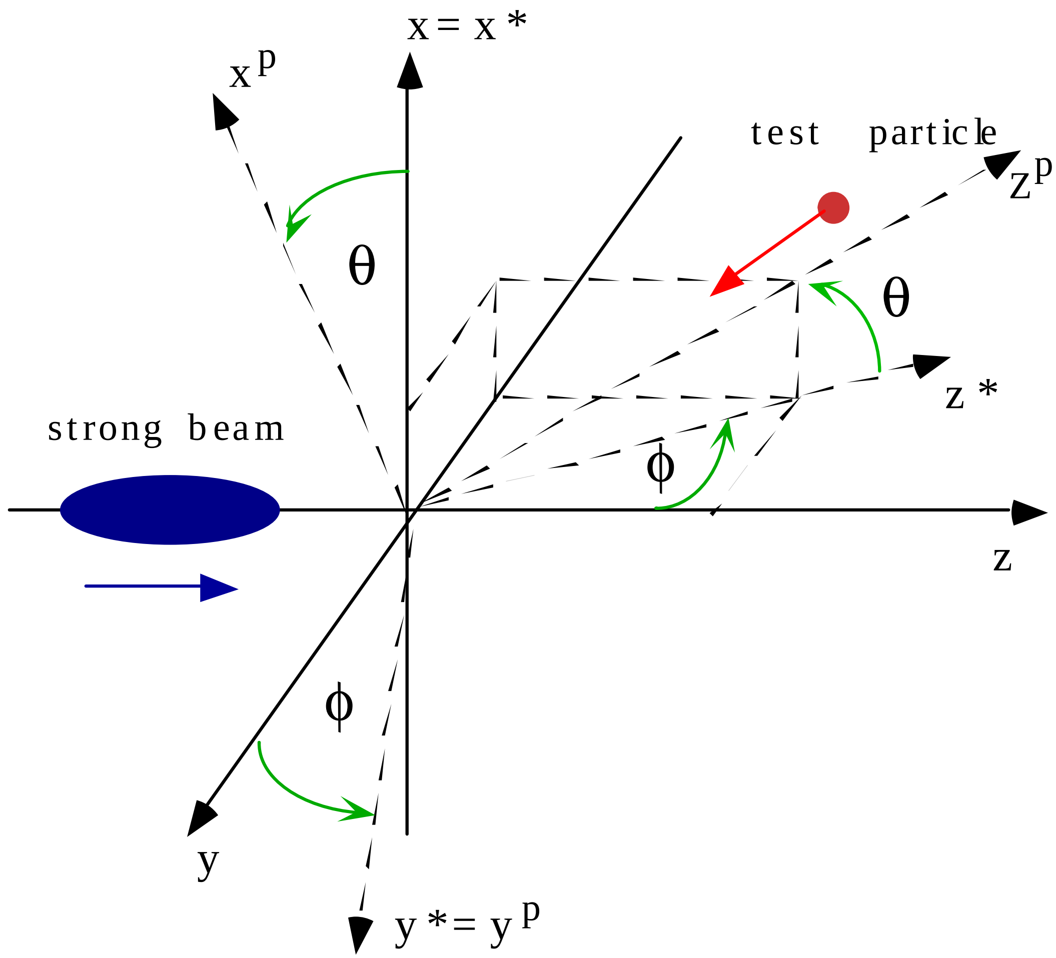
$\xi_y=\xi_{y0}(\sigma_x/(\sigma_{z0}\tan(\alpha)))\cos(\alpha)$ -> $\cos(\alpha)/(\sigma_z\tan(\alpha))\sigma_y)$

where the $\cos(\alpha)$ comes from the higher energy

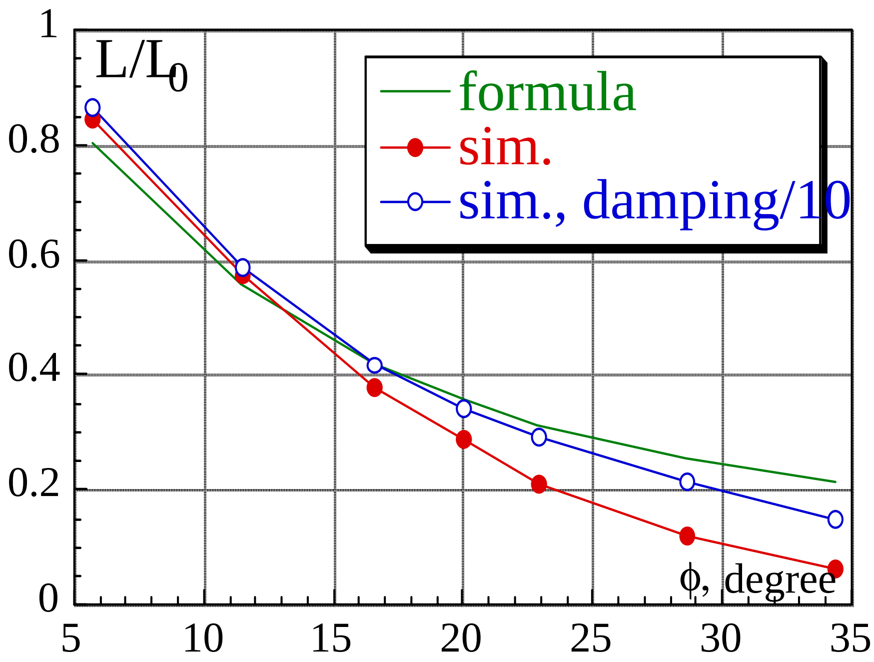
$\sigma_z= \sigma_x/(\cos(\theta)\sin(\alpha))$

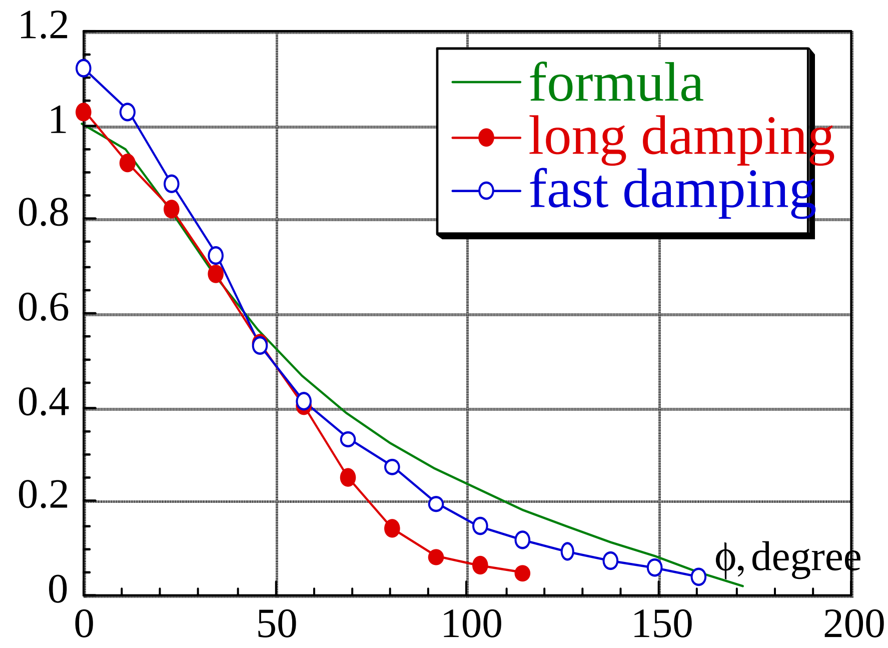
In general L is reduced since $\sigma_z>\sigma_x$, however tune shifts and interaction lenght are way reduced leading to smaller design emittances and βy

Collision at arbitrary crossing angle

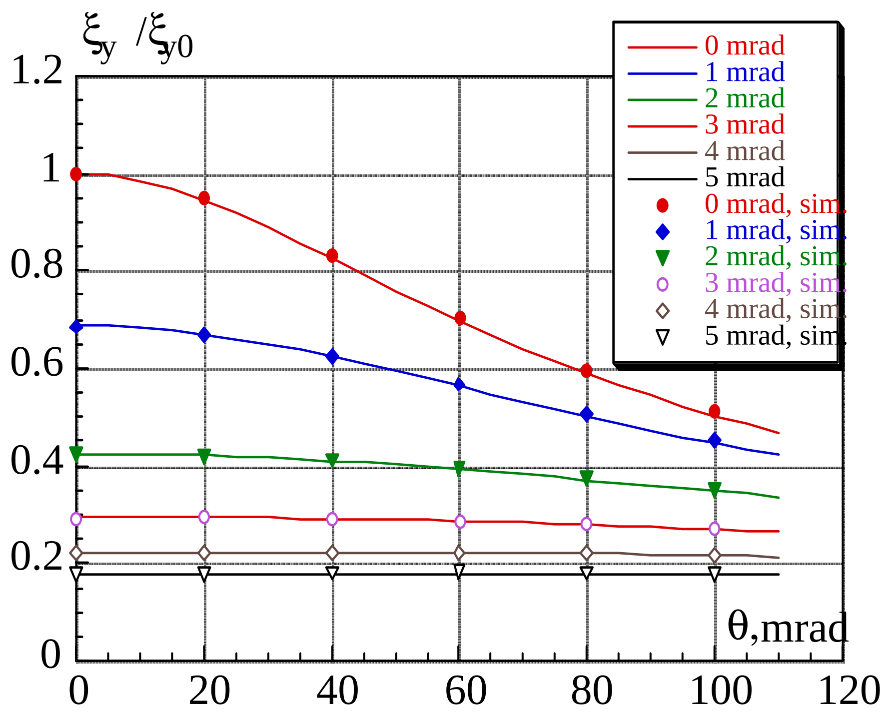


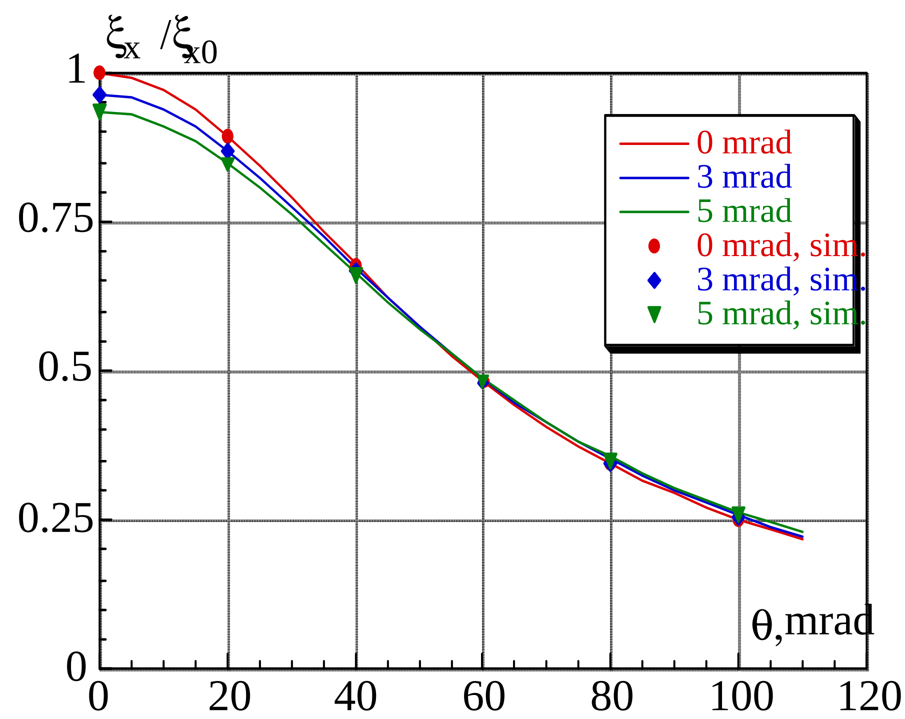
Luminosity versus crossing angle





Tune shifts versus crossing angle





Luminosity expectations

Crab crossing case: probably very similar (within a factor 4 around the 10^{34} region) to the low-crossing angle solution, since most of the gains are suppressed by the lenghtening of the interaction length.

Another disadvantage is the need of several MeV of Crab-cavities.

No-Crab crossing case: also very similar to the low-crossing angle solution, since most of the gains are suppressed by the larger horizontal interaction width. However very small tune shifts and micro-betas lead to a new regime of BB interactions, and probably further investigation is worthed.

Possible big advantages come from:

-a simpler and more flexible IR design, where l*<0.2m could be possible, togheter with very small aperture, low chromaticity final doublet

-kaons will be boosted, so it might be possible to have the detector decoupled by the IR, with big advantages in the design of collider and detector (see F.Bossi talk)

-reversing the direction of one of the beams, we could increase the Ecm very easily allowing the high energy solution as well

On the opposite side a new detectr has to be build, wherease the "standard solution" might require just an upgrade of the existing one.