Large Piwinsky Angle and Crab Waist for LHC

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High luminosity requires:

- **short bunches**
- **small vertical emittance (for flat beams)**
- **large horizontal size and emittance to mimimize beam-beam**

For a ring:

- **easy to achieve small horizontal emittance and horizontal size**
- **Vertical emittance goes down with the horizontal**
- **Hard to make short bunches**

Crossing angle swaps X with Z, so the high luminosity requirements are naturally met:

Luminosity goes with $1/\varepsilon_x$ and is weakly dependent by σ_z

Advantages

1. Large Piwinski's angle

$$\Phi = tg(\theta)\sigma_z/\sigma_x$$

a) Geometric luminosity gain

b) Very low horizontal tune shift

2. Vertical beta comparable with overlap area

$$\beta_y \approx \sigma_x/\theta$$

a) Geometric luminosity gain

b) Lower vertical tune shift

c) Vertical tune shift decreases with oscillation amplitude

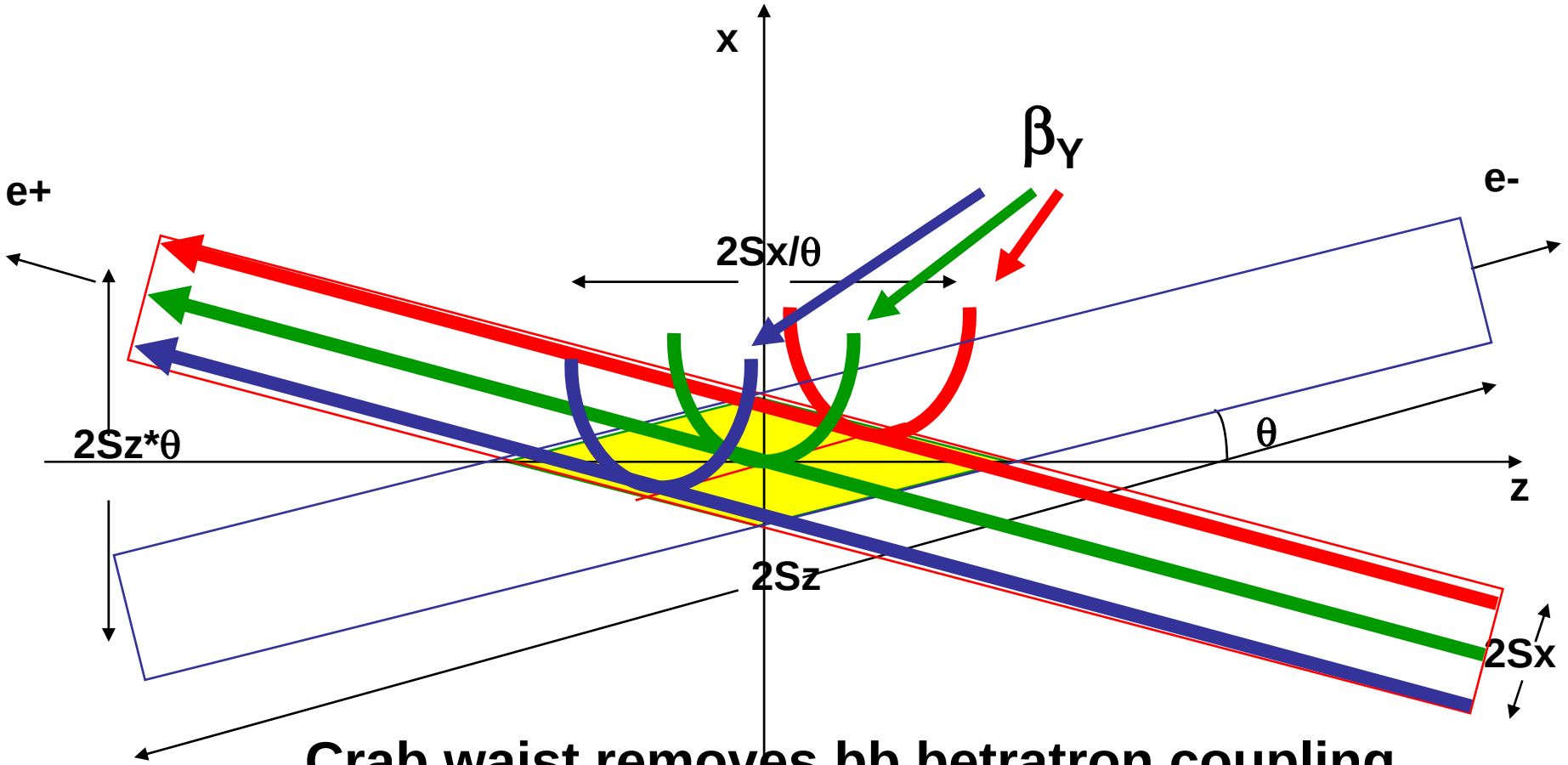
d) Suppression of vertical synchro-betatron resonances

3. Crabbed waist transformation

$$y = xy'/(2\theta)$$

a) Geometric luminosity gain

b) Suppression of X-Y betatron and synchro-betatron resonances



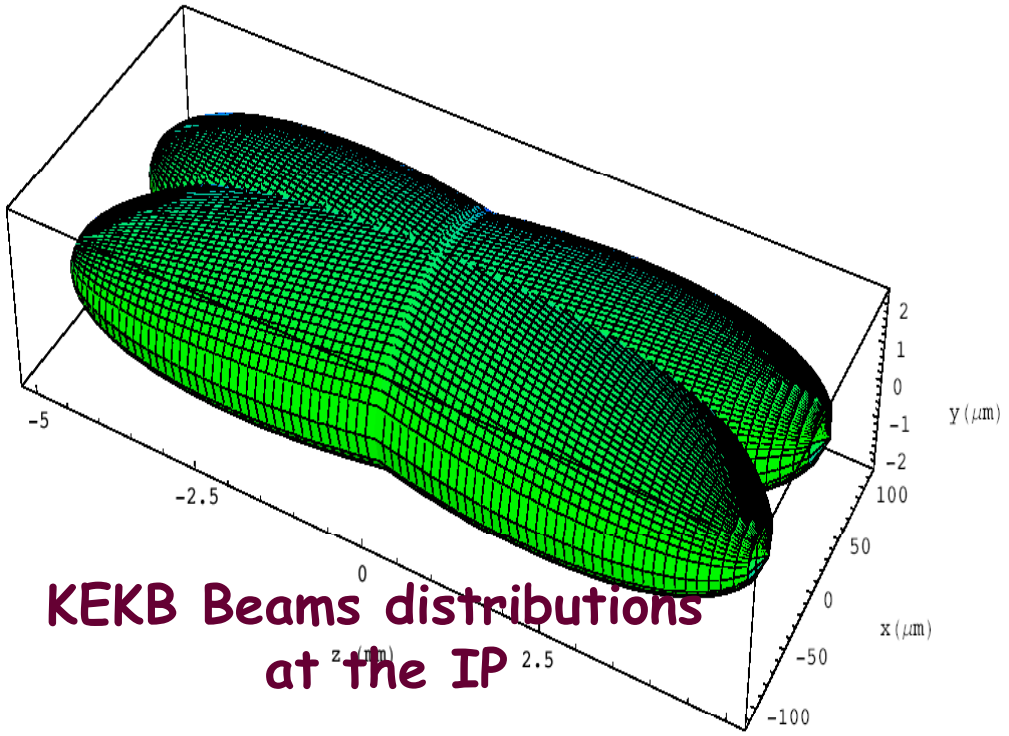
Crab waist removes bb betratron coupling
Introduced by the crossing angle

Vertical waist has to be a function of x:

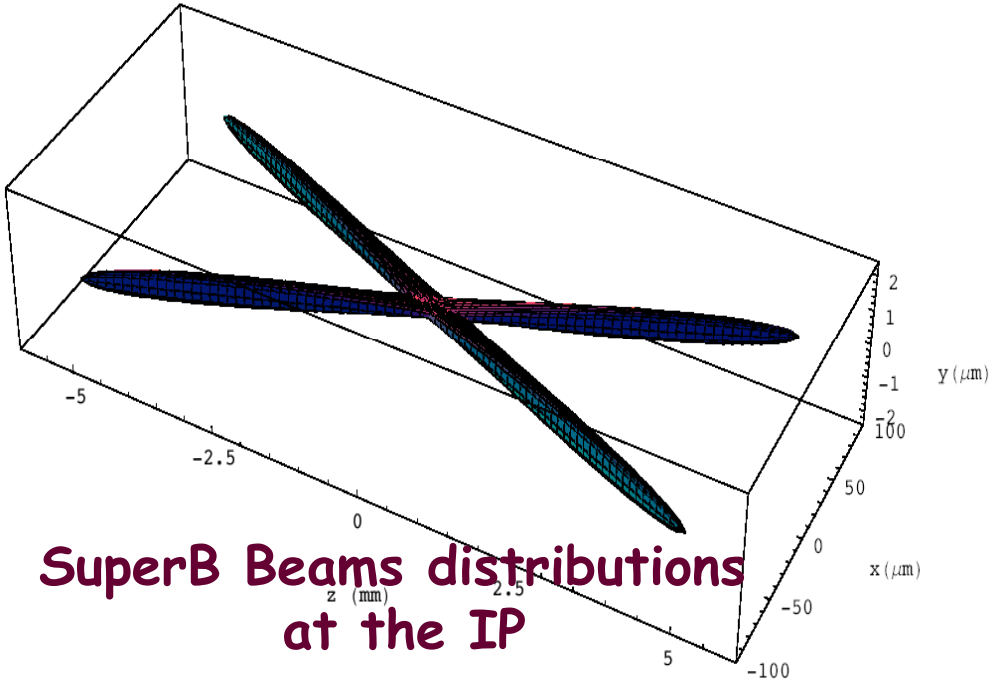
Z=0 for particles at $-\sigma_x$ ($-\sigma_x/2\theta$ at low current)

Z= σ_x/θ for particles at + σ_x ($\sigma_x/2\theta$ at low current)

Crab waist realized with 2 sextupoles in phase with the IP in X and at $\pi/2$ in Y



KEKB Beams distributions at the IP



SuperB Beams distributions at the IP

Beams are focused in the vertical plane 100 times more than in the present factories, thanks to:

- small emittances
- small beta functions
- large crossing angle
- Crab waist

Tune shifts and longitudinal overlap greatly reduced

	KEKB	SuperB
current	1.7 A	2.3 A
betay	6 mm	0.3 mm
betax	300 mm	20 mm
sigmax	~80μm	~6μm
sigma y	~3μm	0,035μm
Sigma z	6 mm	6 mm
L	$1.7\ 10^{34}$	$1\ 10^{36}$

Parameters for LHC

- **The smaller the emittances the better, full advantages come with the smallest possible emittance from the injection system**
- **Assuming βy=4cm and βx=20cm and σz=10cm we do need a Crossing angle of 2*0.25mrad (θ=σx/βy)**
- **In this case, assuming emi_y=1.75um, we get an effective beam cross Section at the IP: σy*θ*σz=3.2um*25um=80um2 (given the large vertical emittances actually we get a smaller effective cross section is we increase betay...)**
- **This should be compared with about σy*σx=7um*7um=50um2 that we get assuming 3.5um emittances and 10cm betas in both planes. It seems that we lose a factor about 1.6... unless the bunch length goes down to 6cm.**
- **We should study:**

  1) If a layout with such parameters is simpler and easier to make wrt the "standard" one (or viceversa, from the simplest layout come up with the best possible parameters)

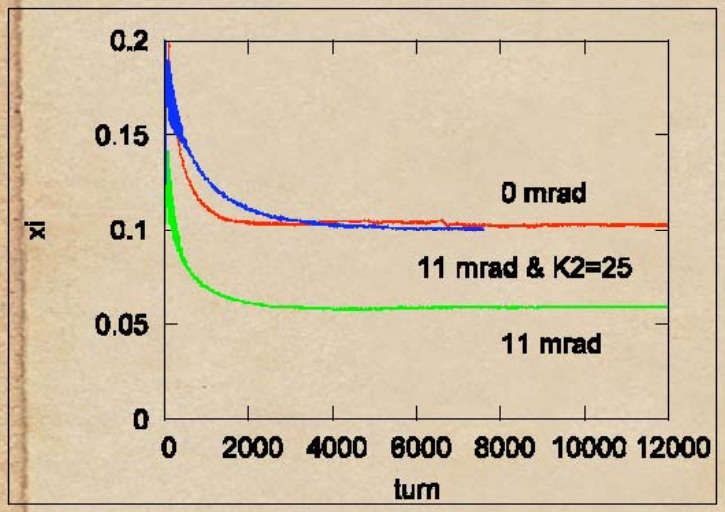
  2) If the parameters could be pushed in order to get a smaller effective cross section at the IP

  3) The beambeam behaviour with the large piwinskly angle and crab waist parameters

  4) where and if it is possible to insert the crabwaist sextupoles

- **In general the luminosity for the crabwaist scheme increases linearly with 1/emittance (assuming both planes emittances going down togheter), while the tune shifts and the beambeam stay constant. It could be worth to study the luminosity behaviour wrt emi at least for fun...**

Crab Waist for present KEKB



$H = K_2 \, x \, p_y^2$

- Crab waist may improve the luminosity of present KEKB as powerful as the crab crossing.
- Actual lattice design is going on.
- Another term proportional to x^3 arises if only one pair of sexts is used. Its effect will be studied.
- Can be tested after the crab cavity test.

K. Ohmi

Crab waist removes the harmful effects of the crossing angle as well as the crab cavity