TLEP luminosity in the presence of Beamstrahlung

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TLEP workshop

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Previous episodes

- We have seen in the last meeting that the maximum luminosity for beams colliding straight-on is linearly proportional to the beam-beam limit ,the SR power and the radius of the collider.
- The above is true, but in the *presence of beamstrahlung limitations* the integrated luminosity is much lower
- *[also, optimization of* β^*_y *w.r.t. the hourglass factor has not been done]*

The effect of Beamstrahlung

- Beamstrahlung severely limits the lifetimes of the beams if the problem is not addressed
- Up to now we have assumed that we can increase the momentum acceptance of the machine to the very high value of 4%
- Is this the only way out?

Do we need huge momentum acceptance at TLEP?

- The original TLEP/LEP3 parameters had a non-aggressive horizontal and vertical emittances:

	LEP2	LEP3	TLEP-Z	TLEP-H	TLEP-t
horizontal emittance [nm]	48	25	30.8	9.4	20
vertical emittance [nm]	0.25	0.10	0.15	0.05	0.1
ratio	192	250	205	188	200

- If we were able to push the vertical emittance down, it would buy us momentum acceptance…

Do we need huge momentum acceptance at TLEP?

- Lets go back to the root of the problem, Beamstrahlung...

Beamstrahlung

- I am using the approach of Telnov throughout
- The energy spectrum of emitted photons during a collision of two intense bunches (usual bremstrahlung formula) is characterized by a critical energy

$$E_c = \frac{\hbar 3 {\gamma_0}^3 c}{2\rho}$$

- Where ρ is the radius of curvature of the affected electron which depends on the field he sees

$$\rho = \frac{\gamma_0 m c^2}{eB}$$

- And the maximum field can be approximated by

$$B_{max} = \frac{2 e N_b}{\sigma_x \sigma_z}$$

Beamstrahlung

TLEP H $Z^0 W^- W^+$

constants

- And the critical energy turns out to be

$$E_c = E_0 \frac{3 r_e{}^2 \gamma_0 N_b}{\alpha \sigma_x \sigma_z}$$

for the maximum field (it would be smaller for a smaller field)

Telnov's approximation:

- 10% of electrons see maximum field
- 90% of electrons see zero field

Beamstrahlung

- Electrons are lost if they emit a gamma with an energy larger than the momentum acceptance, η: $E_\gamma \geq \eta E_0$
- We define $u = \eta \frac{E_0}{E_c}$ or otherwise $u = \frac{\alpha}{3\gamma {r_e}^2} \eta \frac{\sigma_x \sigma_z}{N_b}$
- The number of photons with $E_\gamma \geq \eta E_0$:

$$n_\gamma = \frac{\alpha^2 \eta \frac{\sigma_z}{2}}{\sqrt{6\pi} r_e \gamma u^{3/2}} e^{-u}$$

- So we see that η can directly be traded off by $\frac{N_b}{\sigma_x \sigma_z}$

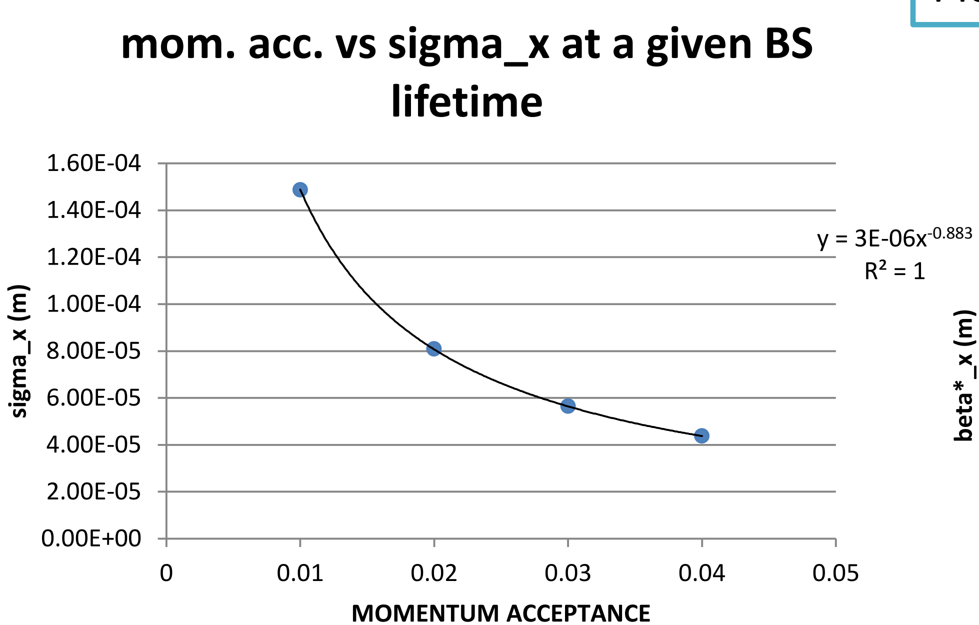
A word of caution

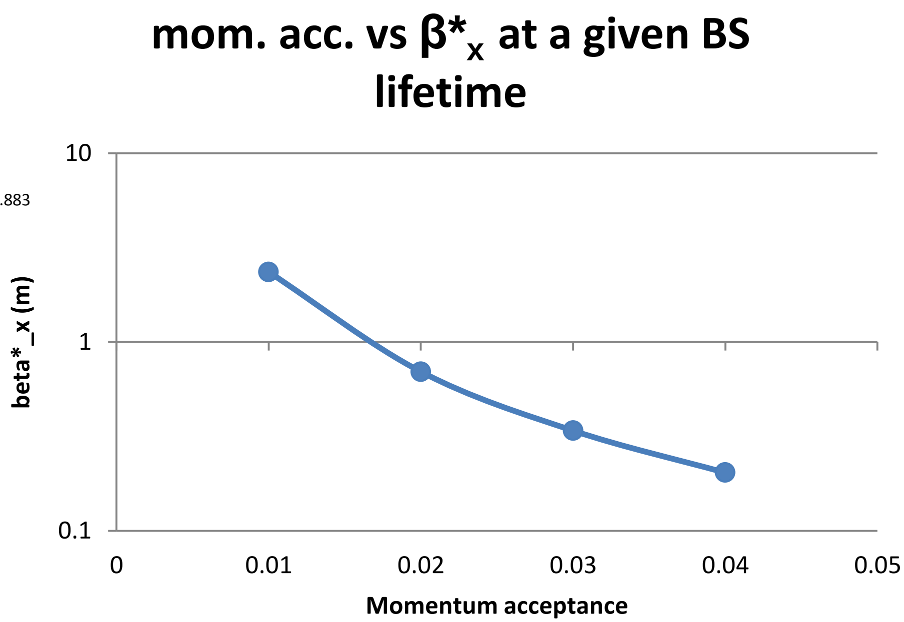
- The Telnov formula contains approximations and must be verified with simulation
- This will be done by the next workshop

Trading mom. acceptance for σ_x

- A factor of 2 in momentum acceptance is nearly equivalent to beams which are a factor of 2 wider
- To be able not to lose in luminosity, one needs to reduce the vertical size by the same amount, i.e. Change the vertical emittance by a factor 4. – in other words, one should change the ratio of horizontal to vertical emittance by a factor 4

Plots for TLEP with BS lifetime of 100 s

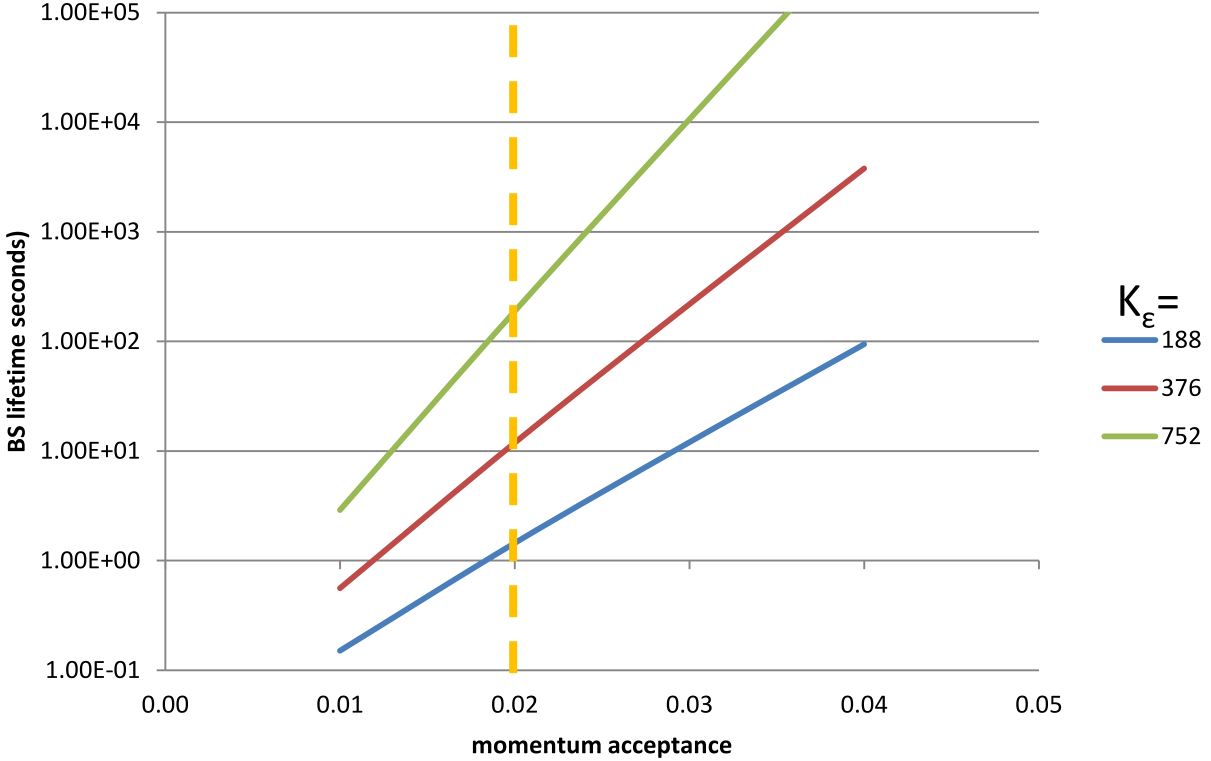




BS lifetime vs κ_ε

- $K_\varepsilon = \varepsilon_x/\varepsilon_y$

Lifetime versus mom. acceptance for various κ_ε values



Lifetime increases dramatically with K_e

All curves at equal luminosity

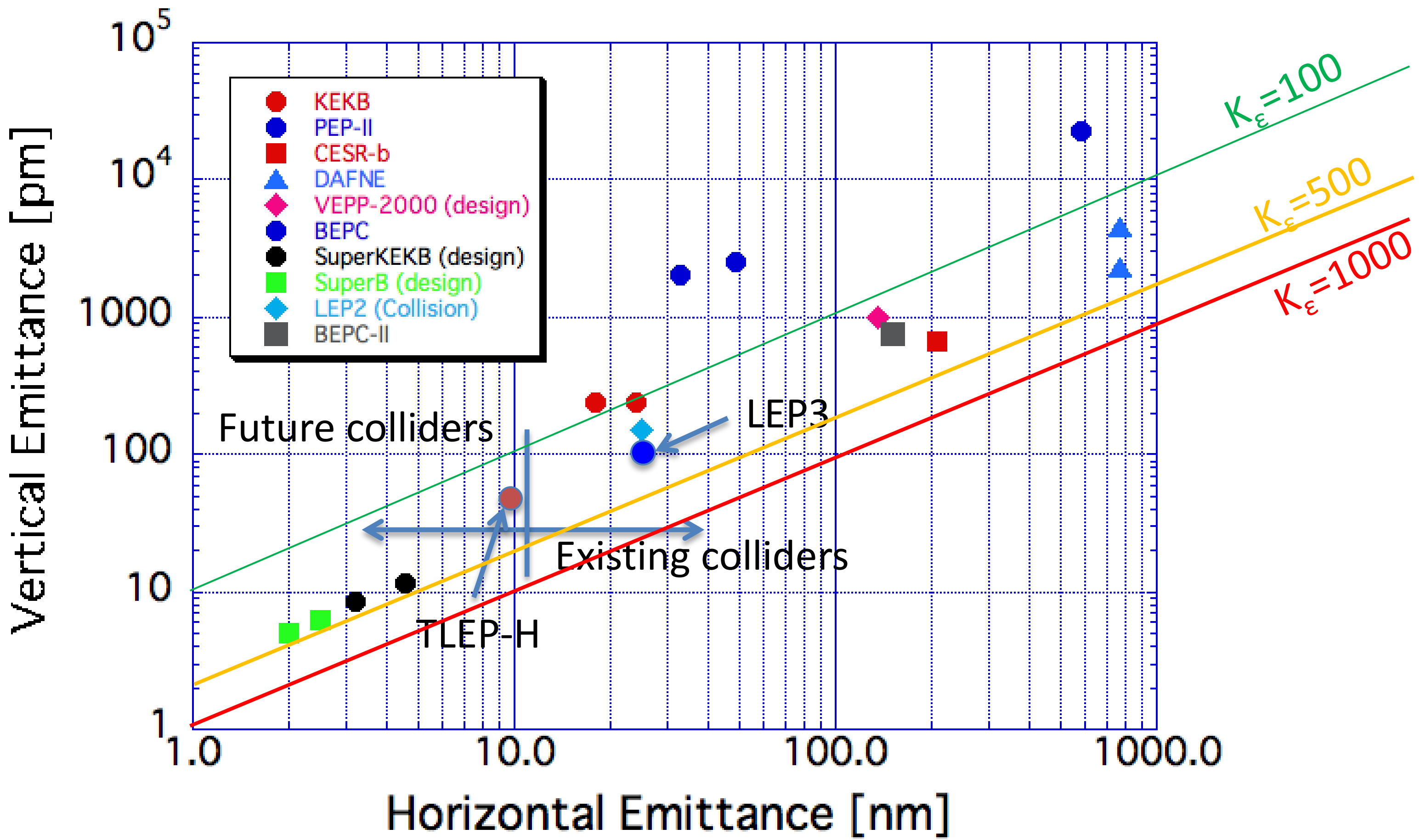
How much can we push K_ε?

- Older colliders: around 200; new designs: around 400; light sources: 2000+

	PEP II	KEKB	LEP2	LER design	HER design	LEP3	TLEP	SLS
ε_x [nm]	32	20	48/27	3.2	4.6	25	9.4	5.5
ε_y [pm]	2000	230	250/180	8.64	11.5	100	50	2
K_ε	16	90	190/150	370	400	250	188	2600

From a talk by Y. Funakoshi KEK

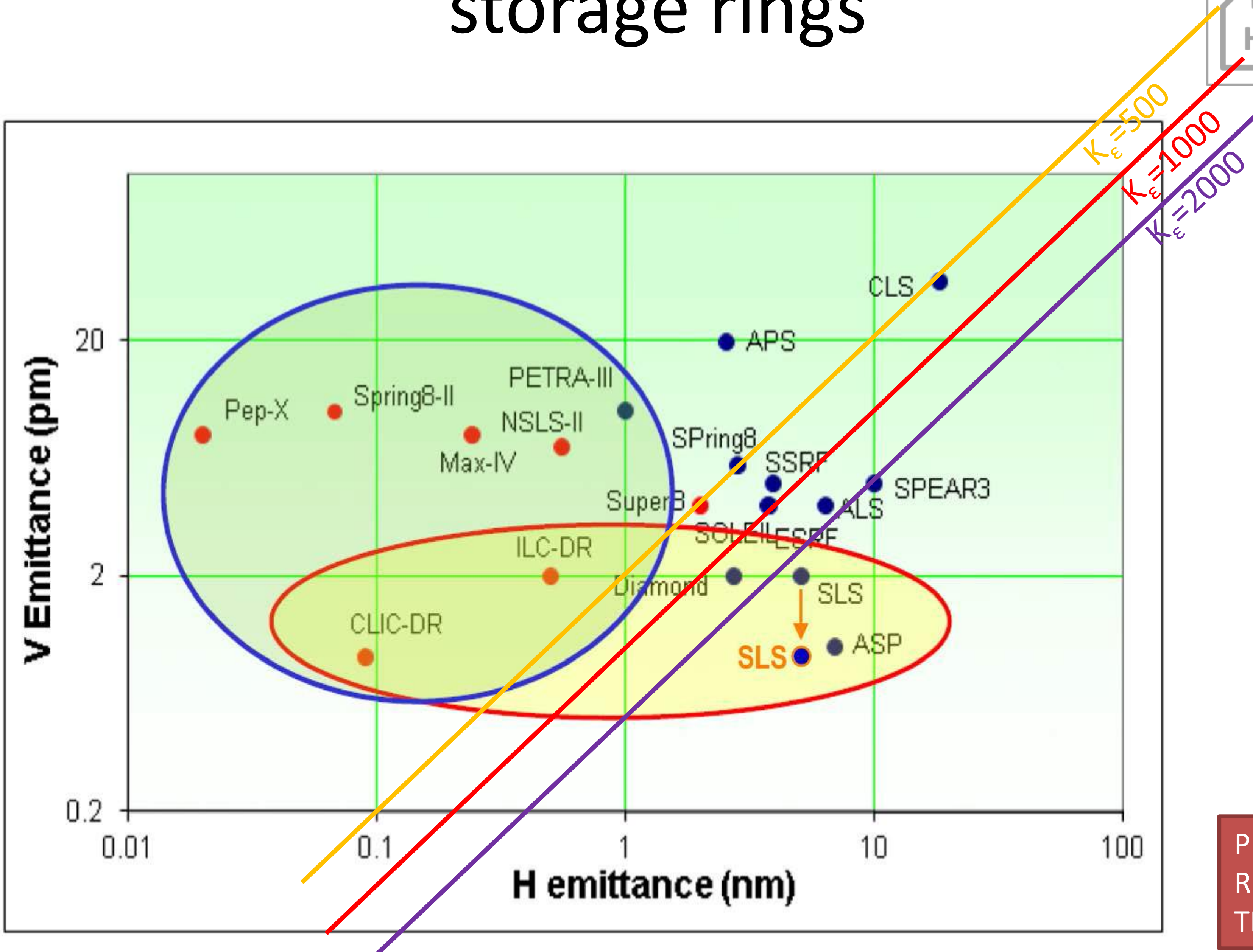
Comparison of emittances of colliders



From Beam Dynamics Newsletter No. 31

Courtesy of F. Zimmermann, H. Burkhardt and Q. Qin

Existing (blue) and future (red) storage rings



Plot from L. Rivkin, 2nd TLEP3 day

Possible baseline scenarios

- We can certainly be more aggressive with the ratio of emittances

	β_x (m)	B_y (mm)	ε_x (nm)	ε_y (pm)	κ_ε	ξ_x	ξ_y	**η max**	$\tau_{bs\ (secs)}$ (Telnov)
TLEP-H parameters 10 Jan 2013	0.2	1	9.4	50	188	0.10	0.10	4%	94
TLEP-H medium	0.4	1	9.4	25	376	0.10	0.10	2.7%	92
TLEP-H aggressive	0.8	1	9.4	12.5	752	0.10	0.10	1.9%	125

Conclusions

- Easier to increase the horizontal to vertical emittance ratio than very big momentum acceptance
- Move towards a baseline design with a more aggressive emittance ratio and less momentum acceptance
- Validation of theory (Telnov's beamstrahlung formula) and simulation to be done