Beam lifetime

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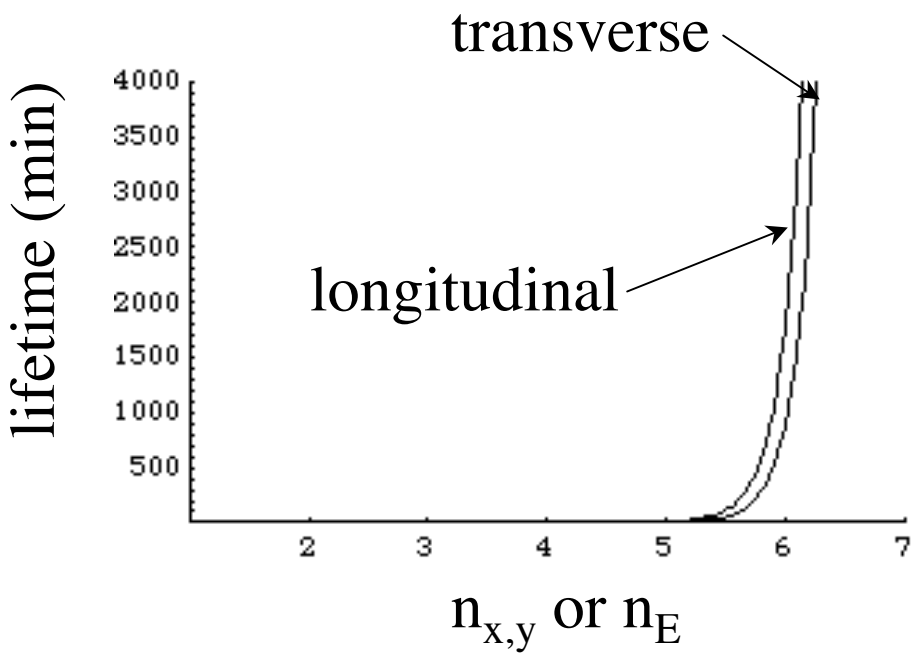
Quantum lifetimes

- Particle losses occurs for Gaussian beam due to finite transverse or energy aperture.
- Quantum lifetime is not serious problem in principle.
- Transverse : mask aperture / longitudinal : momentum aperture.

$$\tau_q = \frac{\tau_u}{2}\frac{e^{\xi_u}}{\xi_u} \qquad u = x, y, s$$



$$\xi_{x,y} = \frac{1}{2}\left(\frac{A_{x,y}}{\sigma_{x,y}}\right)^2 = \frac{1}{2}n_{x,y}^2$$

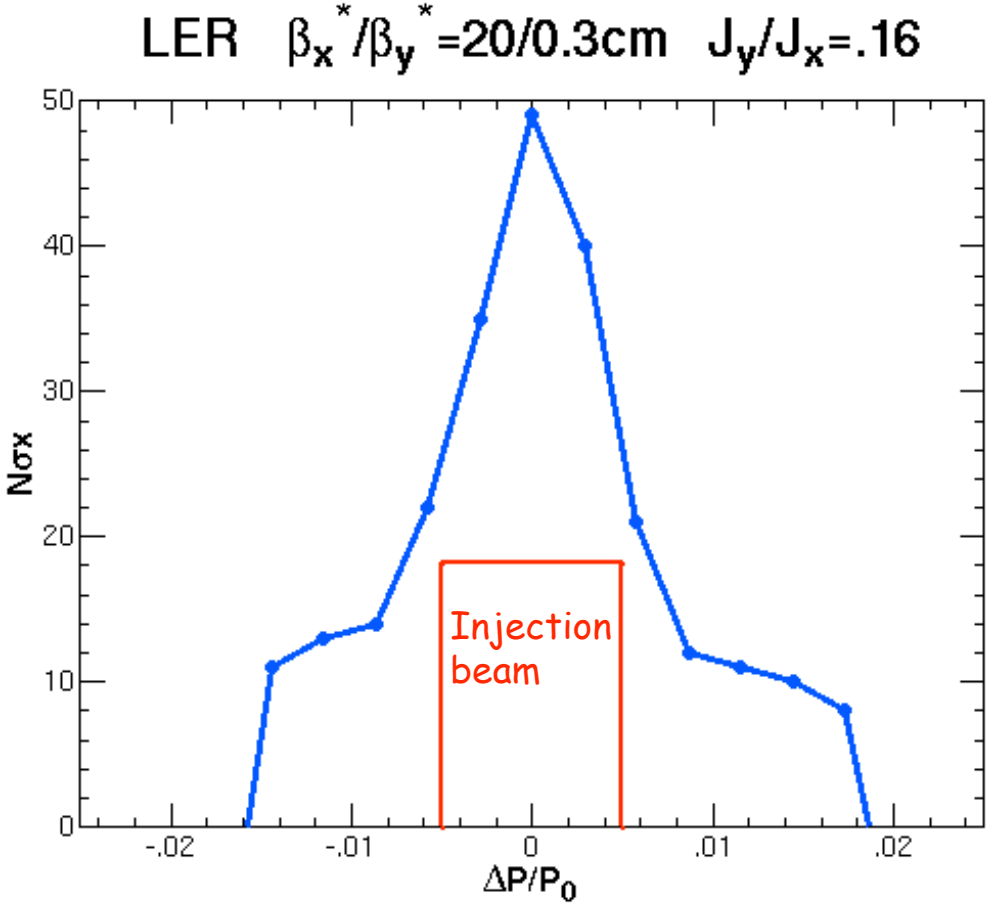
$$\xi_s = \frac{1}{2}\left(\frac{\Delta E/E_0}{\sigma_E/E_0}\right)^2 = \frac{1}{2}n_E^2$$

Vacuum lifetime

- Bremsstrahlung
- Pressure ~ 5×10^{-7} Pa.
- Vacuum lifetime is expected to be ~10 hours for LER and HER.

Touschek lifetime

Momentum aperture determines lifetime.
LER lifetime is shorter than HER.



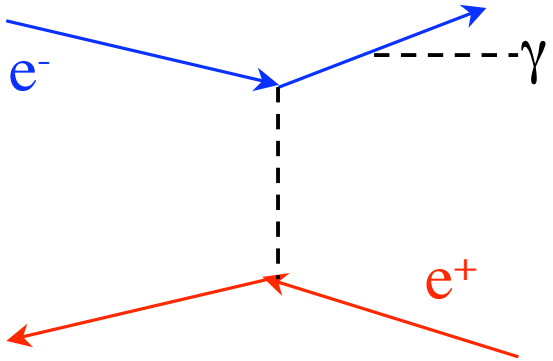
- Dynamic aperture in LER
- Machine errors are not included.
- Transverse aperture is acceptable.

SuperKEKB-LER

Coupling	Lifetime
1%	51 min
2%	72 min
4%	102 min
6%	145 min

Luminosity lifetime

Luminosity lifetime is determined by cross section of radiative Bhabha and luminosity.



Particle loss rate :

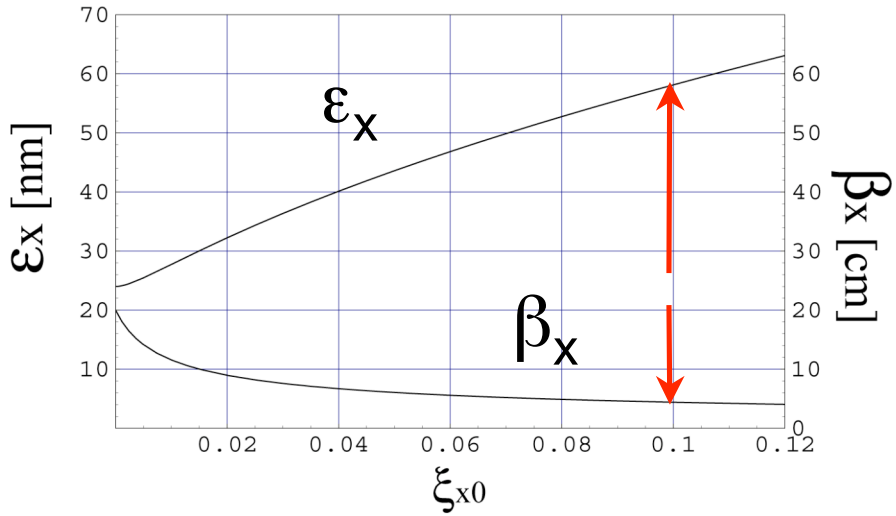
$$\frac{dN}{dt} = -\sigma L$$

$$\sigma = \frac{16\alpha r_e^2}{3}\left[\left(\log\frac{1}{\varepsilon} - \frac{5}{8}\right)\left\{\log\left(\frac{2\sqrt{2}\pi\sigma_y^*}{\lambda_e}\right) + \frac{\gamma_E}{2}\right\} + \frac{1}{4}\left(\frac{13}{3}\log\frac{1}{\varepsilon} - \frac{17}{6}\right)\right]$$

$$\varepsilon = \Delta E / E_0$$

σ=2x10^{-25} cm^2 (ε=1%) and L=2.5x10^{35} cm^{-2}s^{-1}
$\Rightarrow$ lifetime = 195 min (LER) / 85 min (HER)

Lifetime due to beam-beam effects



- Lifetime will depend on betatron tunes.
- Dynamic emittance may relax lifetime.
- Momentum aperture may decrease due to beam-beam effect (dynamic beta).
- Still open question.

Summary of lifetime

	10^{35} PEP-II		10^{36} PEP-II		$2.5x10^{35}$ KEKB	
	LER	HER	LER	HER	LER	HER
Quantum	6000	3000	6000	3000	long	long
Vacuum	180	360	120	240	600	600
Touschek	110	923	45	360	51	200 ?
Luminosity	150	75	50	25	195	85
Beam-beam	30	30	20	20	30 ?	30 ?
Total w/o b-b	47	57	20	21	38	54
Total	18	20	10	10	17 ?	19 ?

J.Seemen, Hawaii Super B-Factory WS, Jan, 2004.

Beam-beam parameters

- Luminosity is given by overlap integral:

$$L = \frac{f_c}{c}\int \mathrm{d}^3 x\,\mathrm{d}t\,\rho_+(\vec{x},t)\rho_-(\vec{x},t)\times\sqrt{c^2(\vec{v}_+-\vec{v}_-)^2-(\vec{v}_+\times\vec{v}_-)^2}$$

(cm^{-2}s^{-1})

$$\int d^3x\rho_\pm(\vec{x},t) = N_\pm \qquad f_c = c\beta/s_b$$

$$L = \frac{\gamma}{2er_e}\left(\frac{I\hat{\xi}_y}{\beta_y^*}\right) = 7.6\times10^{34}\cdot\frac{9.4(A)\cdot\hat{\xi}_y}{\beta_y^*(cm)}$$

Beam-beam parameter is extracted from luminosity obtained from beam-beam simulations (Ohmi's definition).

$$\hat{\xi}_y = \left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)\cdot\xi_y$$

~1 ~0.8

Luminosity strongly depends on betatron tunes.

$\hat{\xi}_y$ includes beam size ratio and ratio of reduction factors.