Beam-beam update

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Simulation code

- One turn linear map and beam-beam map

$$M(s+C,s) = M_0(s+C-\varepsilon, s+\varepsilon)M_{BB}$$

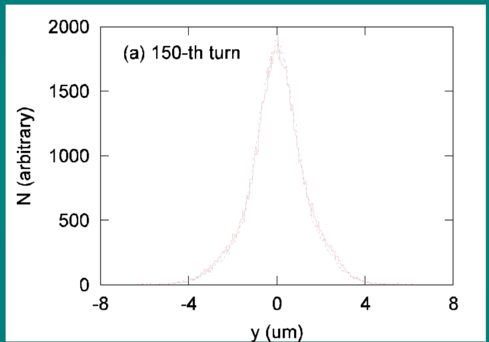
- 3D particle-in-cell code
- Beam are sliced longitudinally and particles are mapped on the transverse grid space
- Arbitrary beam distribution can be treated
- Poisson solver using FFT
- Linear interpolation between longitudinal slices
- Longitudinal beam dynamics
- Finite crossing angle and parasitic crossing
- Machine errors can be treated.
- Using MPI only for parameter scan.

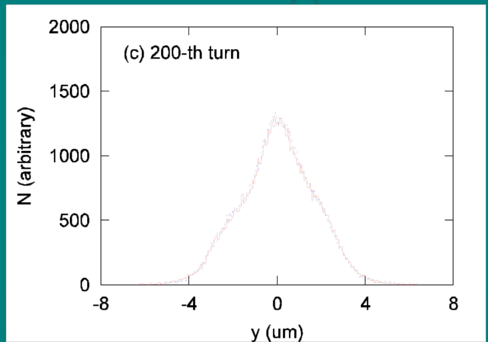
Simulation computer

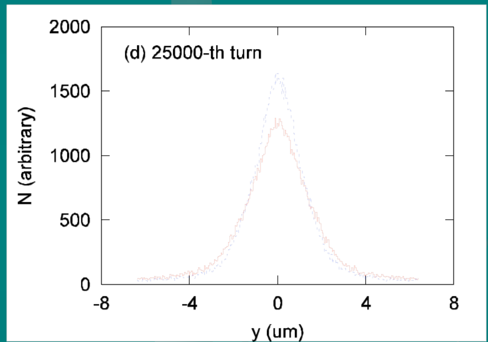
- Using supercomputer of KEK (Hitachi SR8000F1) 12GFlops(peak)x100 node
- For typical job with 128x256x5 grids, it takes about 8 hours for 12000 turns.
- >50% of calculation time is for FFT.
- 2x32 nodes are available for parameter scan.

Beam-beam limit

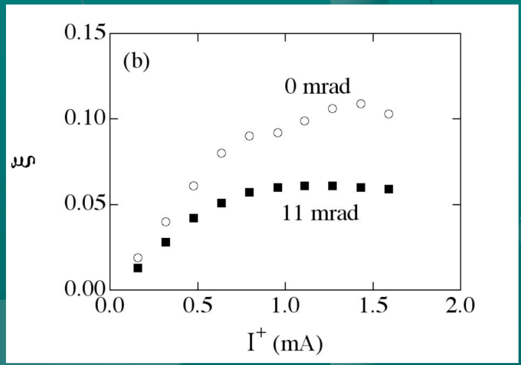
- Simulation results show particle distribution are changed due to the collision
- The incoherent effect is essential to determine beam-beam limit.







- Our simulation result shows the beam-beam parameter of 0.1 can be achieved with crab crossing.
- L=2.5E35 for 10A betay=0.3cm



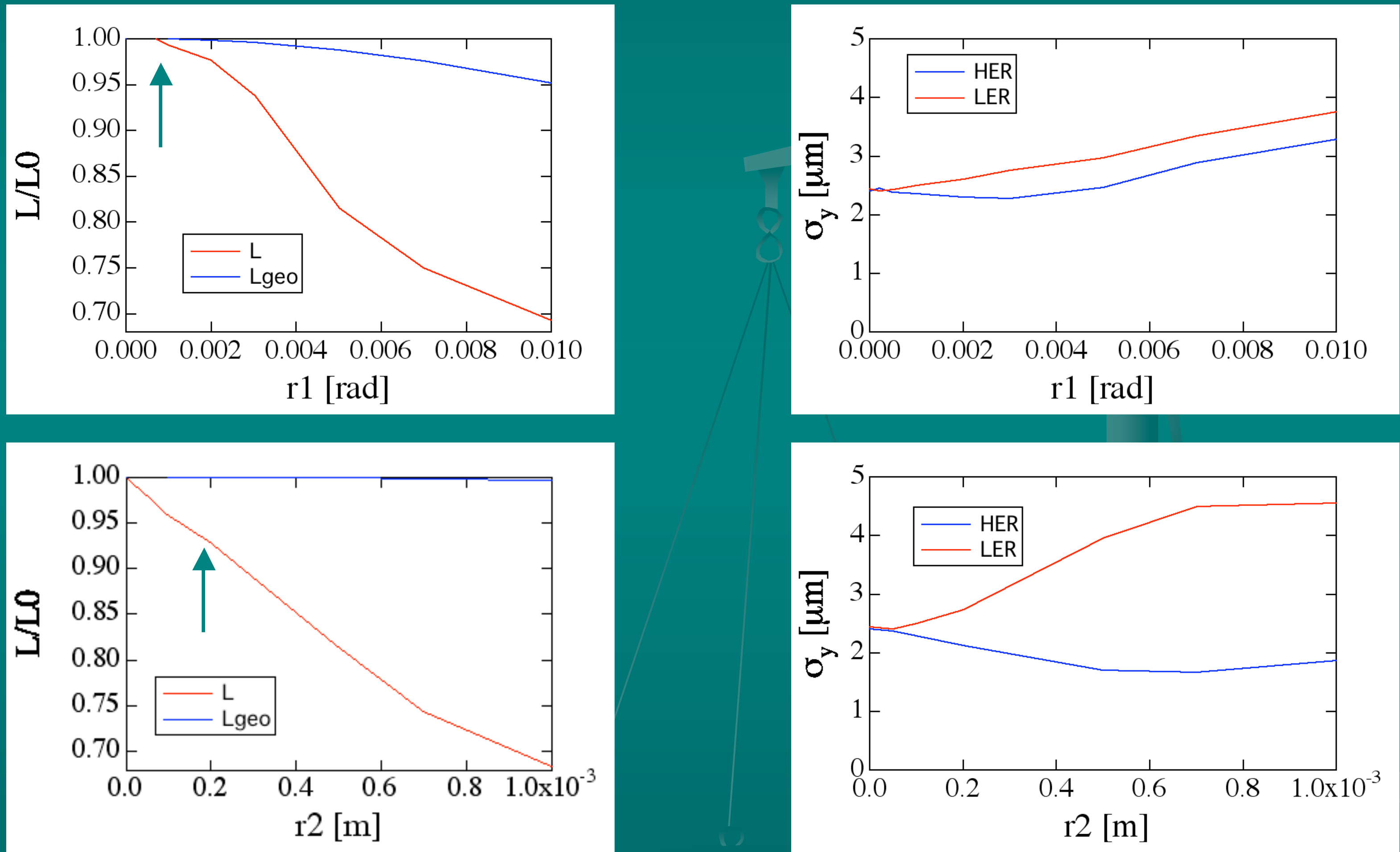
$$L = 7.6 \times 10^{34} \frac{I(A)\xi_y}{\beta_y^*(cm)}$$

Tolerances of the optics error

- Map of lattice with optics errors (crossing angle, tilt, offset…) induces coupling of freedom.
- Weak-strong simulation indicates that in a high beam-beam parameter region of 0.1, optics errors easily induce Arnold diffusion and degrade the luminosity.
- Tolerances for coupling parameter (r1-r4), dispersion, waist and vertical offset are presented here.
- The definition of coupling parameter is

$$\begin{pmatrix} \mu & 0 & r_4 & -r_2 & 0 & 0 \\ 0 & \mu & -r_3 & r_1 & 0 & 0 \\ -r_1 & -r_2 & \mu & 0 & 0 & 0 \\ -r_3 & -r_4 & 0 & \mu & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

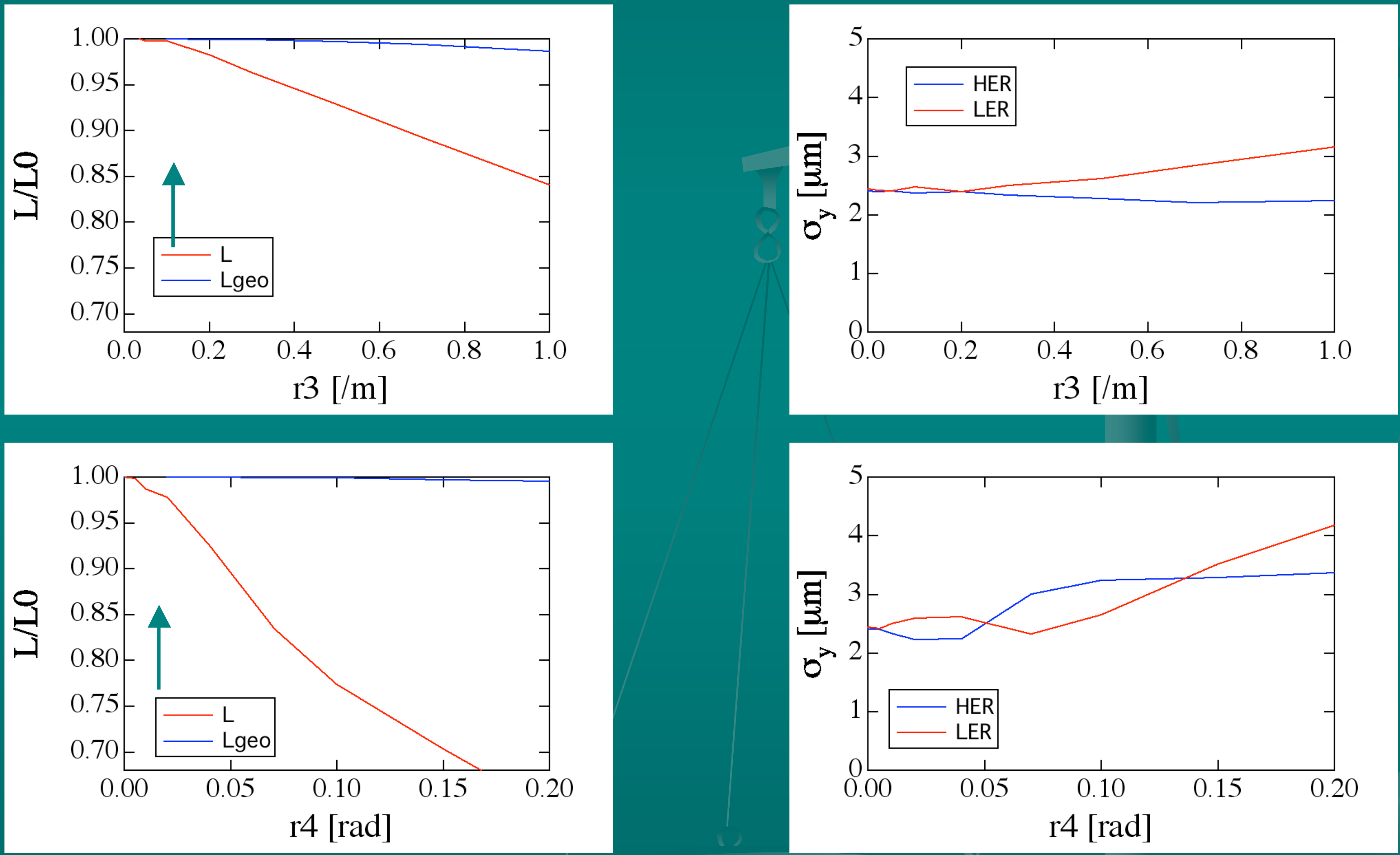
Optics parameter r1, r2



1 unit for KEKB tuning: r1=0.0008 (rad), r2=0.00022 (m)

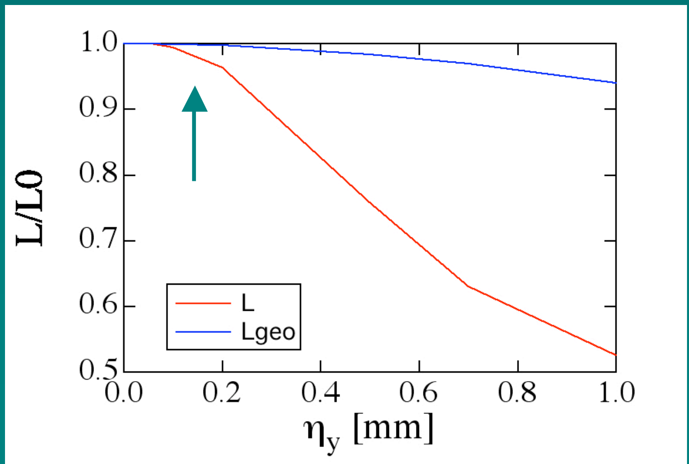
r3, r4

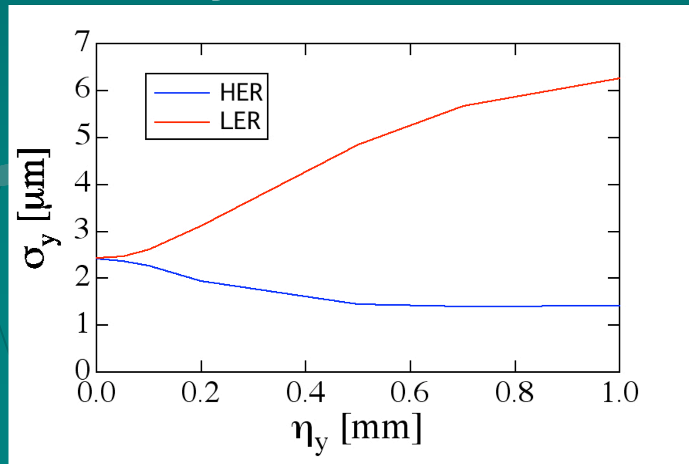
1 unit for KEKB tuning: r3=0.07 (/m), r4=0.021 (rad)

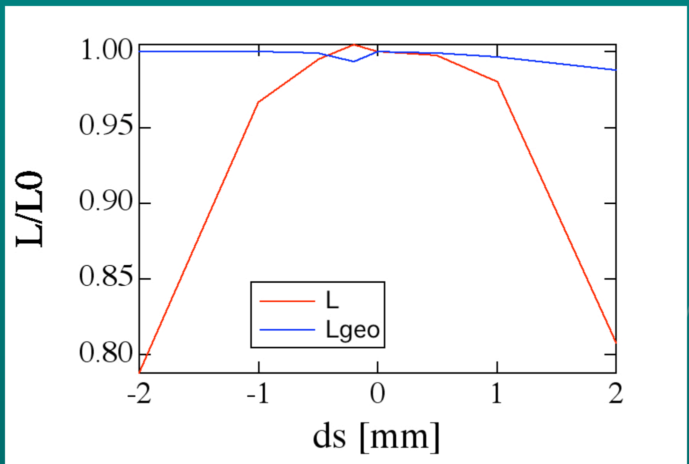


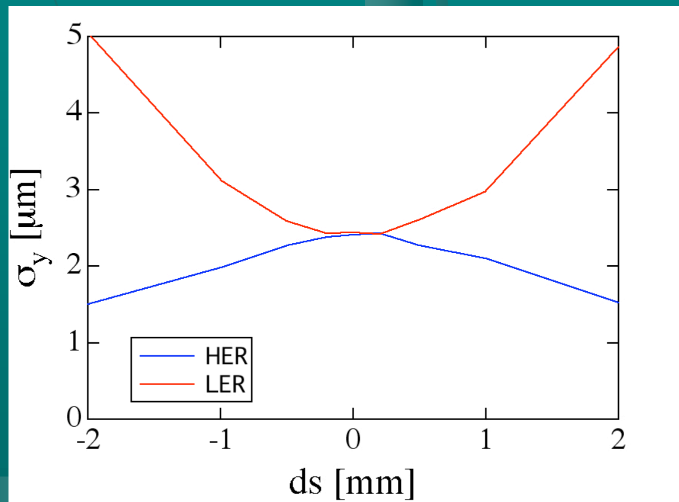
Dispersion, waist

1 unit for KEKB tuning: η_y=0.00016, η_y'=0.016

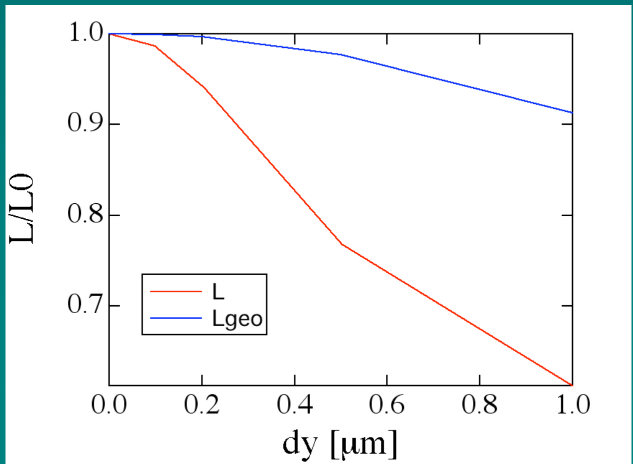


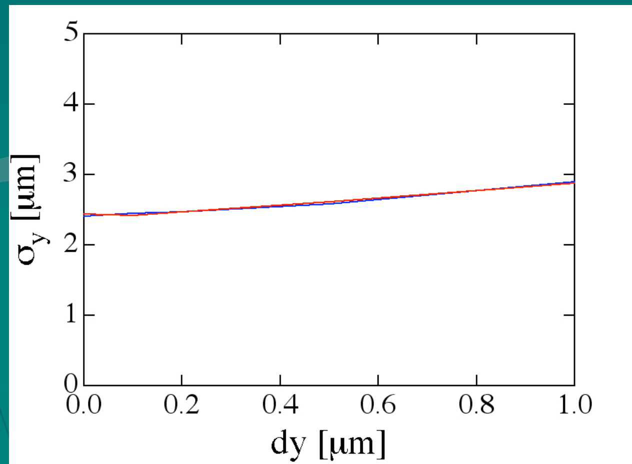


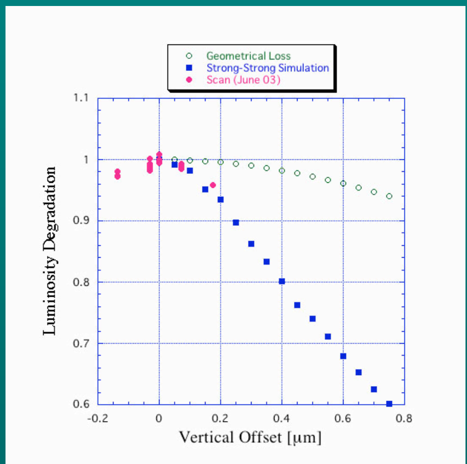


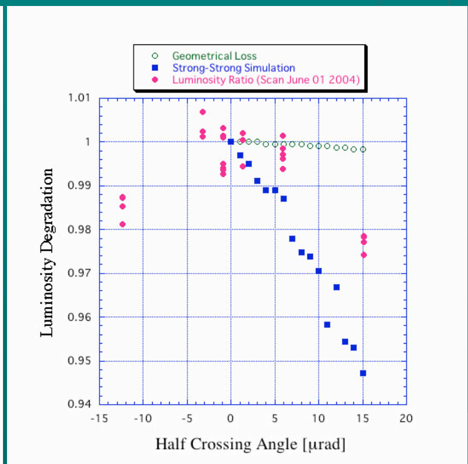


Vertical offset, angle









KEKB experimental data by Y. Funakoshi

Good agreement with simulation

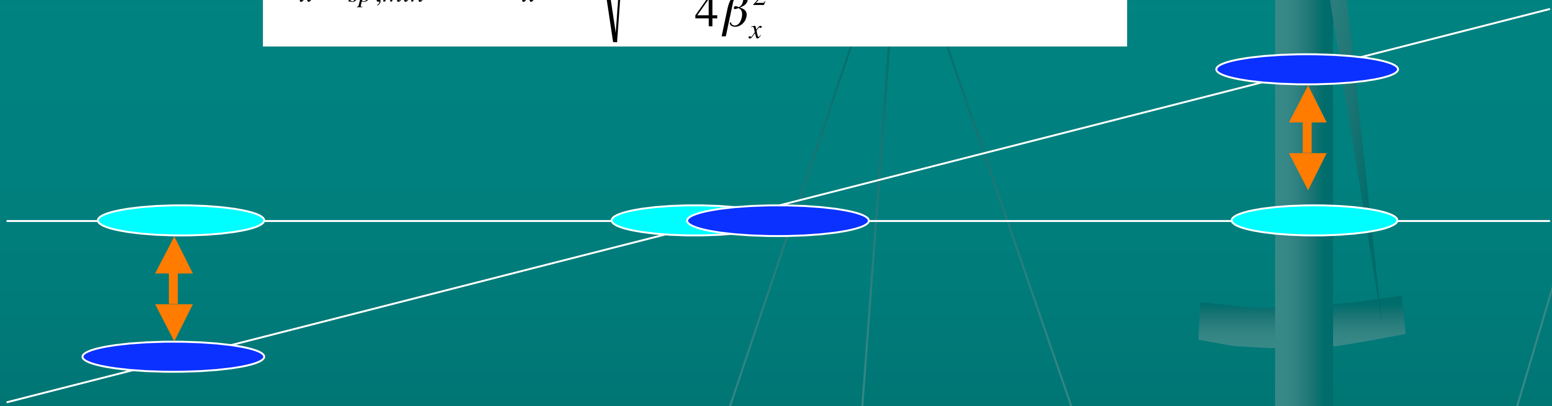
Orbit feedback controls the orbit fluctuation < 0.1 um, <10 urad.

Parasitic collision

- Long range nonlinear beam-beam force
- Beam-beam separation:

$$\Delta x = \theta/2 \times l_{sp,min} = 6.6(KEKB), 9.0(Super)mm$$

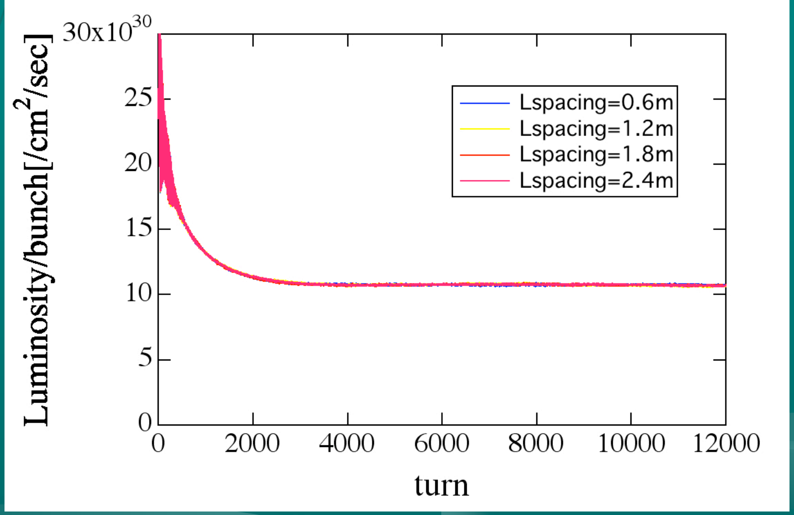
$$\sigma_x(l_{sp,min}) = \sigma_x(0)\sqrt{1+\frac{l_{sp,min}^2}{4\beta_x^2}} = 0.1mm$$



- Simulation includes dynamic beta and dynamic emittance

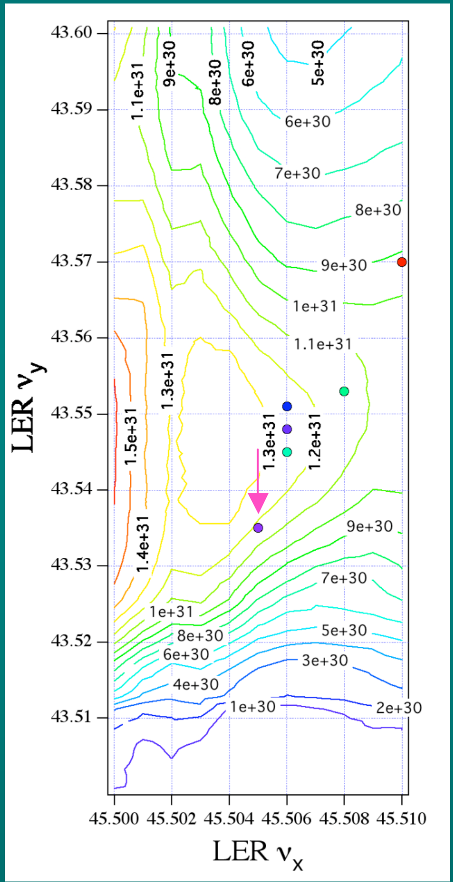
Parasitic collision

- PIC method is used for IP collision.
- Gaussian approximation is used for parasitic crossing
- Two methods, soft target and fixed target with gaussian shape. Both methods give same results.
- Drift is used between parasitic and IP collision.
- 1st, 2nd, 3rd … parasitic collision can be calculated.
- Particle lost are observed at early stage of simulation for horizontal direction.
- It might affect lifetime.

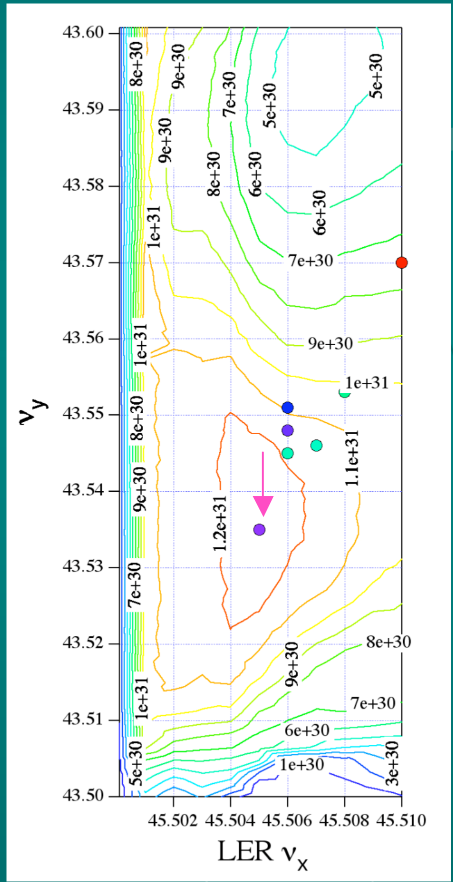


Parasitic collision

w/o parasitic



w/ parasitic (4bkt sp)



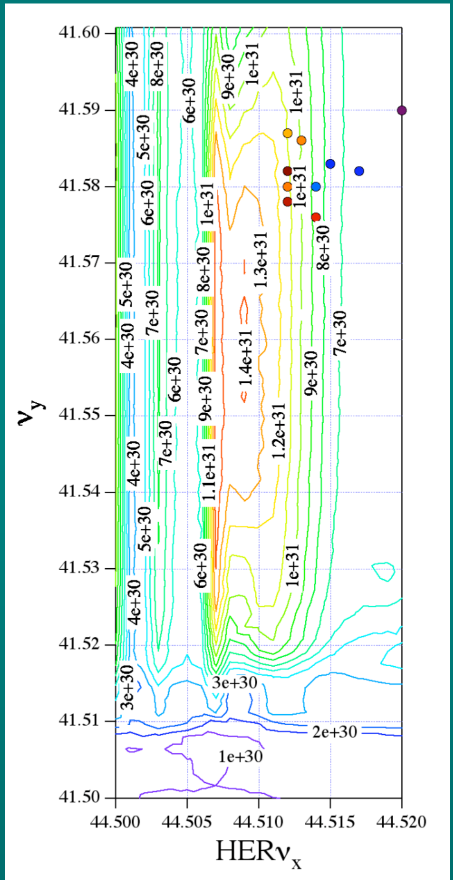
Parasitic collision simulation for KEKB LER. Each graph shows the luminosity contour plot w/o and w/ parasitic collision.

Marker shows the history of working point.

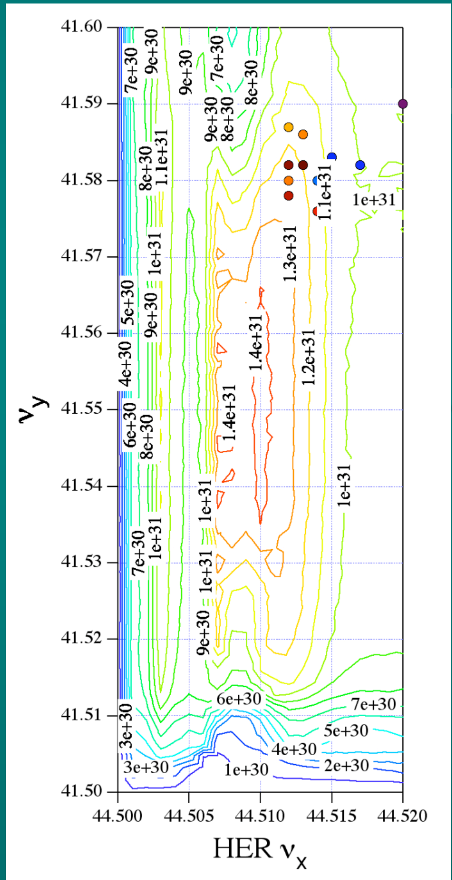
Specific luminosity was improved by lowering LER-V tune. But there is no direct evidence of parasitic effect in KEKB.

Parasitic collision

w/o parasitic



w/ parasitic (4bkt sp)



Parasitic collision simulation for KEKB HER.

Synchro-beta resonance line are observed in HER.

Conclusion

- Severe tolerances of optics error may be required for high beam-beam parameter region.
- The simulation shows the luminosity degradation due to the parasitic collision is negligible if good working point are chosen.
- There is no remarkable effect with many parasitic collisions.
- Particle lost are observed at the early stage of simulation with parasitic collision. Lifetime issue should be studied.