Beam-Beam simulation and experiment

M. Tawada, K. Ohmi

Feb. 11 2003

KEKB Review

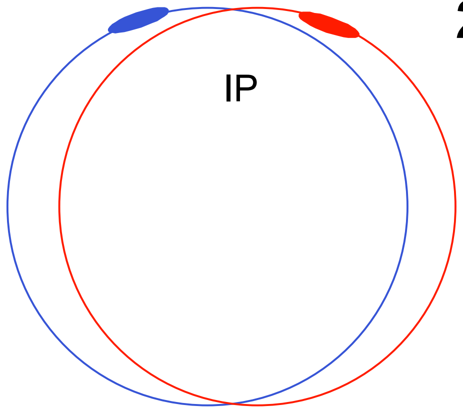
Contents

Simulation code

- **3D particle-in-cell code**
- **Beam-beam force is obtained by solving Poisson equation, using FFT.**
- **Includes longitudinal beam dynamics.**
- **Finite crossing angle can be treated.**
- **Can implement machine errors.**

Simulation code (cont'd)

Step



1. Generate macro-particles

2. Beam-Beam kick

$$\phi = \frac{1}{(2\pi)} \int G(x - x')\rho(x')dx', \quad G(x) = \ln|x|$$

$$\phi = \frac{1}{(2\pi)^2} \int \hat{G}(k)\hat{\rho}(k)\exp(-ik \cdot x)dk, \quad \hat{\rho}(k) = \int dx\rho(x)\exp(ik \cdot x)$$

$$\hat{G}(k) = \int dxG(x)\exp(ik \cdot x)$$

$$\Delta p = -\frac{e}{p_0}\frac{\partial \phi}{\partial x}$$

3. Revolution

$$x(s^* + C) = Mx(s^*)$$

4. Radiation damping and quantum excitation

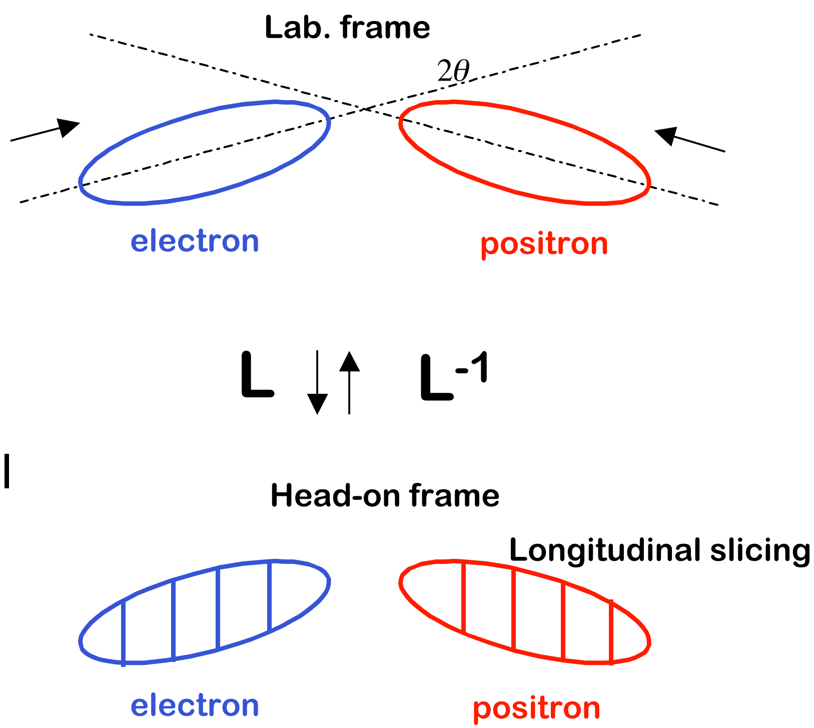
- **Repeat 2-4**.

Simulation code (cont'd)

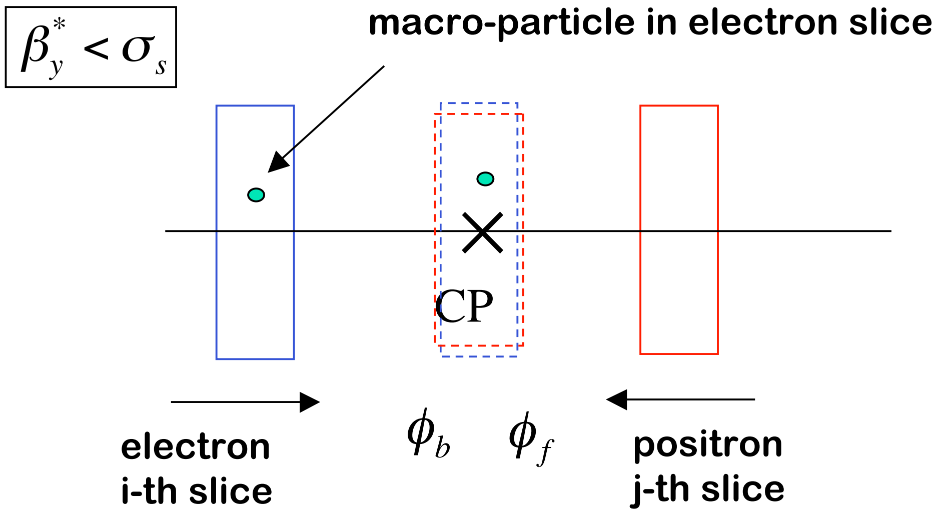
A collision

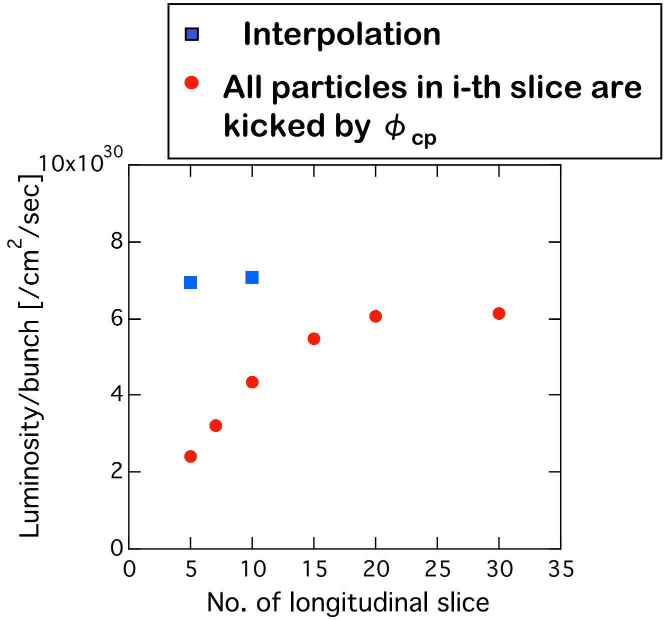
$$x(0^*) \xrightarrow{L} x^*(0^*) \xrightarrow{kick} x^{*}{}'(0^*) \xrightarrow{L^{-1}} x'(0^*)$$

1. Transform to head-on frame.
2. Both bunches are divided to longitudinal slices, respectively.
3. Collide each pair of slices sequentially, updating (x, $p_{x\_}$,y, p_y) after each pair-wise collision of slices.
4. Transform to Lab. frame.



Simulation code (cont'd)





Each particle is kicked by interpolated force between ϕ_f and ϕ_b, depending on its longitudinal position.

ϕ_f **:** potential when positron's slice is at the forward position of electron's slice

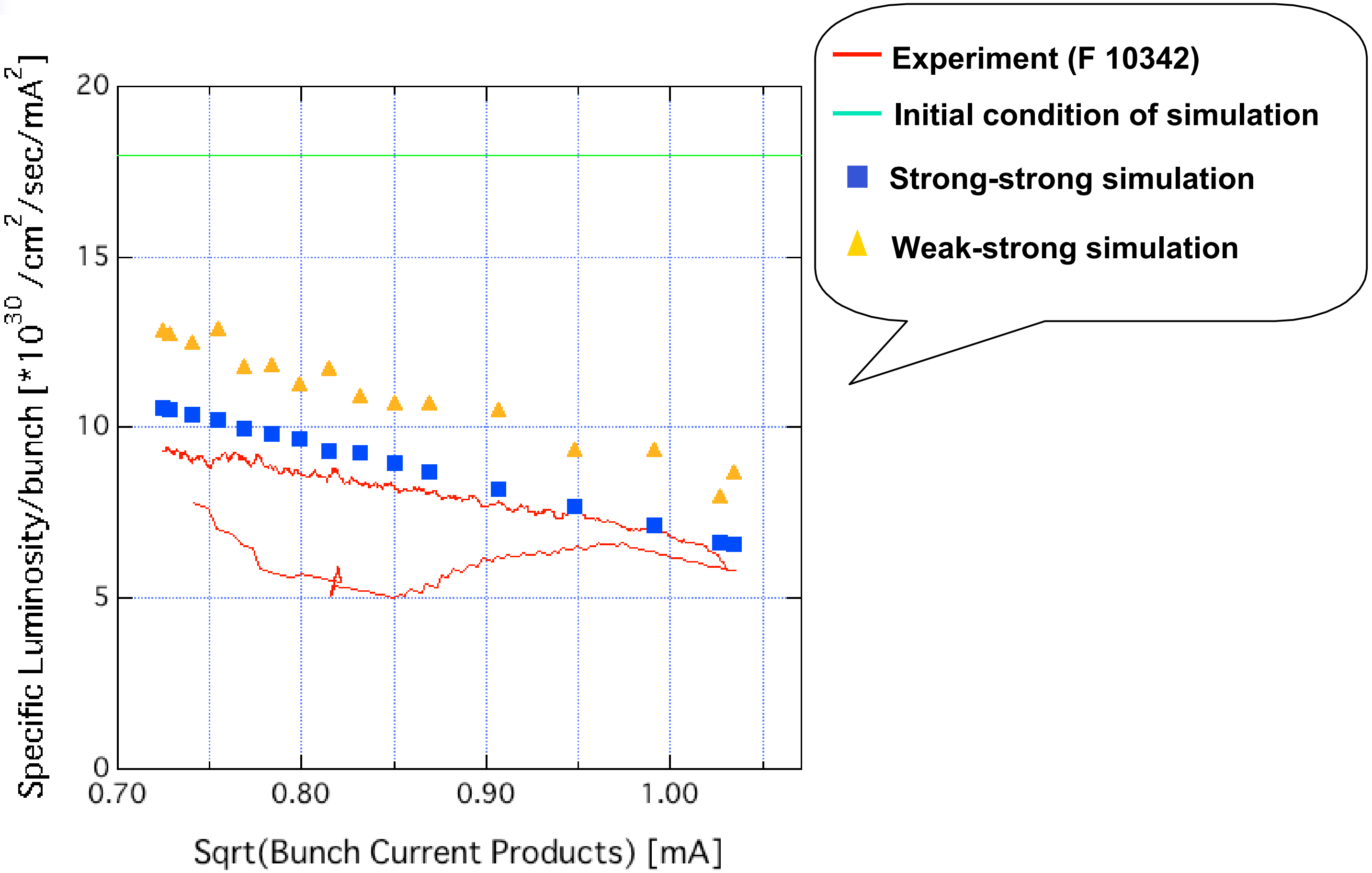
ϕ_b **:** potential when positron's slice is at the backward position of electron's slice

ϕ_{cp} **:** potential when positron's slice is at CP

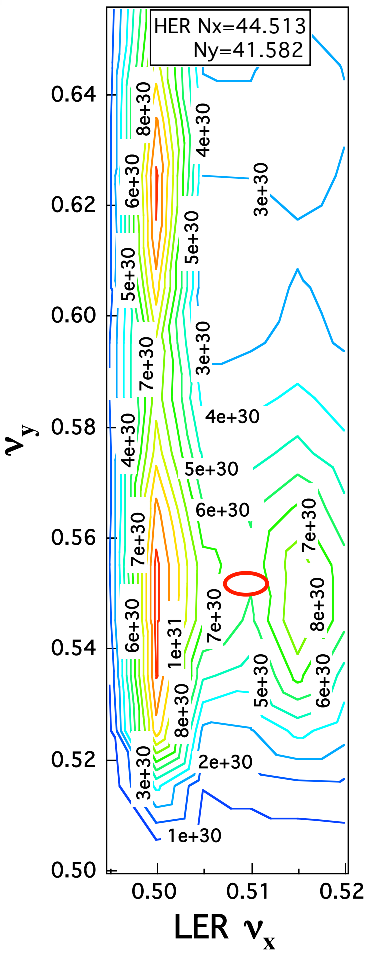
Calculation speed

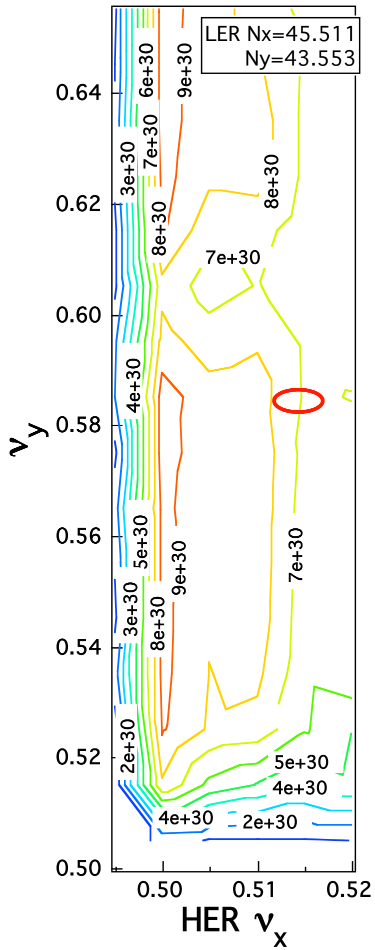
- Runs on the supercomputer at KEK.
- Typically 100,000 particles in each beam.
- A typical run with 128x256x5 grid takes about 7 hours for 12,000 turns.
- FFT takes about 70% of the computation time.
- Using MPI (Message Passage Interface) Library to run the code with a large set of varying parameters (e. g. for tune scan).

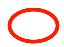
Specific Luminosity



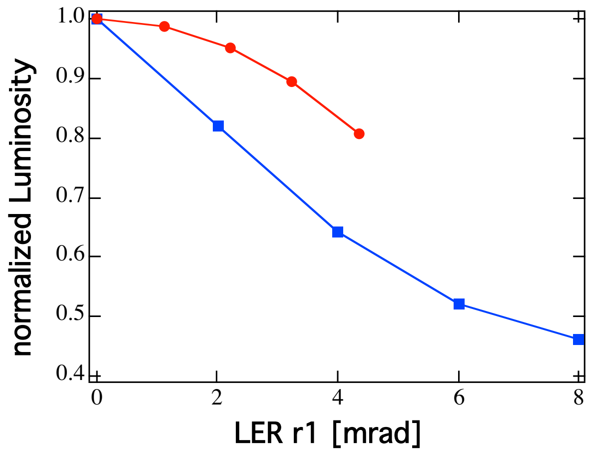
Luminosity Tune Survey

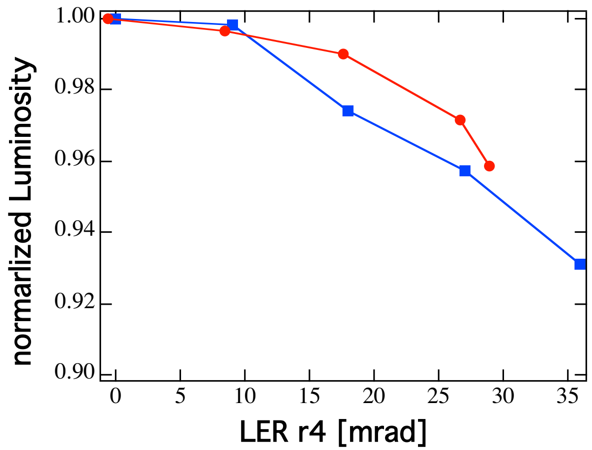






XY Coupling

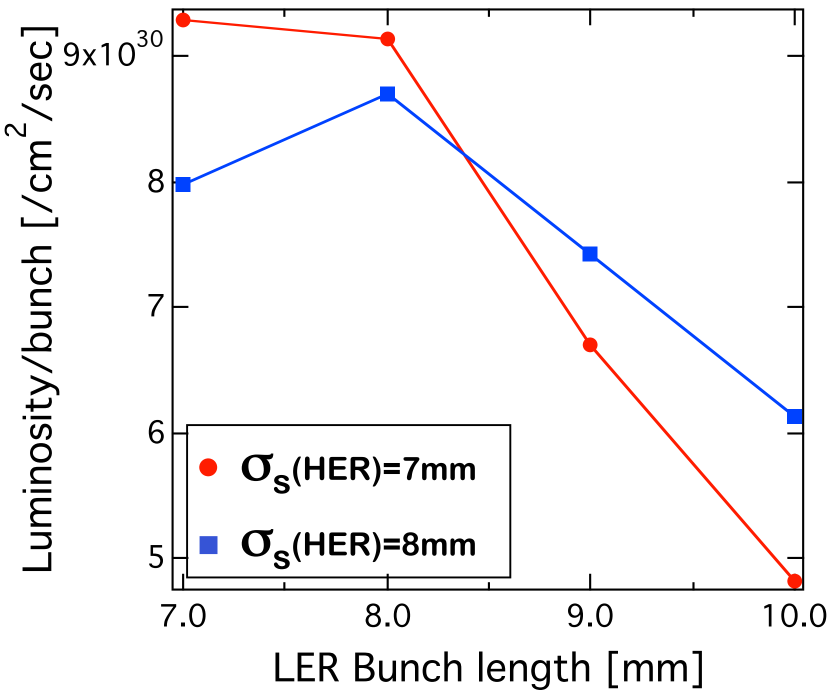




$$R = \begin{pmatrix} \mu & 0 & r_4 & -r_2 & 0 & 0 \\ 0 & \mu & -r_3 & r_1 & 0 & 0 \\ -r_1 & -r_2 & \mu & 0 & 0 & 0 \\ -r_3 & -r_4 & 0 & \mu & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\mu^2 = 1 - r_1 r_4 + r_2 r_3$$

Bunch Length (Simulation only)



- σ_s(LER)> σ_s(HER)
  - σ_s(LER)=8.7mm@1.2mA
  - σ_s(HER)=7.5mm@0.8mA

"σ_s(LER)= σ_s(HER)"
give higher luminosity.

Summary

- **We have performed strong-strong beam-beam simulations with the present KEKB parameters.**
- **The current dependence of specific luminosity and the luminosity tune scans agree very well with observations in KEKB.**
- **Simulation shows making the bunch length of LER shorter is effective to get higher luminosity.**