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Beam-beam simulation studies for PEP-II and KEKB

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1 Study Issues

- Comparison of 3D PIC beam-beam simulation code.
- Comparison of 2D PIC beam-beam simulation code.
- Comparison between 2D PIC solver and exact Gauss solution in Weak-Strong simulation
- Comparison between head-on collision and xangle+crab cavity by KEK code.
- Crossing angle dependence of luminosity for PEP-II and KEKB parameter.
- Tune scan for PEP-II by using weak-strong code at the crossing angle of 0, 3, 5 mrad.

1.1 Comparison of 3D PIC code

We have performed 3D PIC simulations for PEP-II, SuperKEKB and KEKB parameters by using SLAC[1], LBL[3] and KEK[2] code. Input parameters for PEP-II, SuperKEKB and KEKB are listed in table 1, 2, 3, respectively. The simulation results are shown in Fig. 1, 2, 3 and 4. These results are in reasonable agreement.

For PEP-II parameter at the LER horizontal tune of 0.5125, Luminosity by KEK code is slightly larger than that by SLAC code, which is 8.5 and 7.4 $\times 10^{30}$ $/cm^2$/sec, respectively (Fig. 1). Luminosity by LBL and KEK code is almost same and which is 6.1 and 5.7×10^{30} $/cm^2$/sec at the $\nu_x^+ = 0.5253$ (Fig. 2), respectively.

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Table 1: Present PEP-II parameter

	LER	HER
E (GeV)	3.1	9.0
N	7.34×10^{10}	5.58×10^{10}
β_x^*/β_y^* (cm)	51/1.21	25/2.33
τ_t/τ_s (turn)	9800/4800	5030/2573
ϵ_x/ϵ_y (nm-rad)	22/1.49	49/2.33
ν_x/ν_y	0.5125(0.5235)/0.5639	0.5203/0.6223
ν_s	-0.027	-0.040
σ_z (cm)	1.05	1.25
σ_p	6.5×10^{-4}	6.10×10^{-4}
xangle (mrad)	0	
f_0 (Hz)	136312	
Luminosity/bunch ($cm^{-2}sec^{-1}$)	6.8×10^{30}	

Table 2: SuperKEKB design parameter

	LER	HER
E (GeV)	3.5	8.0
N	1.2×10^{11}	5.2×10^{10}
β_x^*/β_y^* (cm)	15/0.3	15/0.3
τ_t/τ_s (turn)	4000/2000	4000/2000
ϵ_x/ϵ_y (nm-rad)	24/0.18	24/0.18
ν_x/ν_y	0.508/0.550	0.508/0.550
ν_s	-0.02	-0.02
σ_z (cm)	0.3	0.3
σ_p	7.0×10^{-4}	7.0×10^{-4}
xangle (mrad)	0	
f_0 (Hz)	99462	
Luminosity/bunch ($cm^{-2}sec^{-1}$)	1.2×10^{31}	

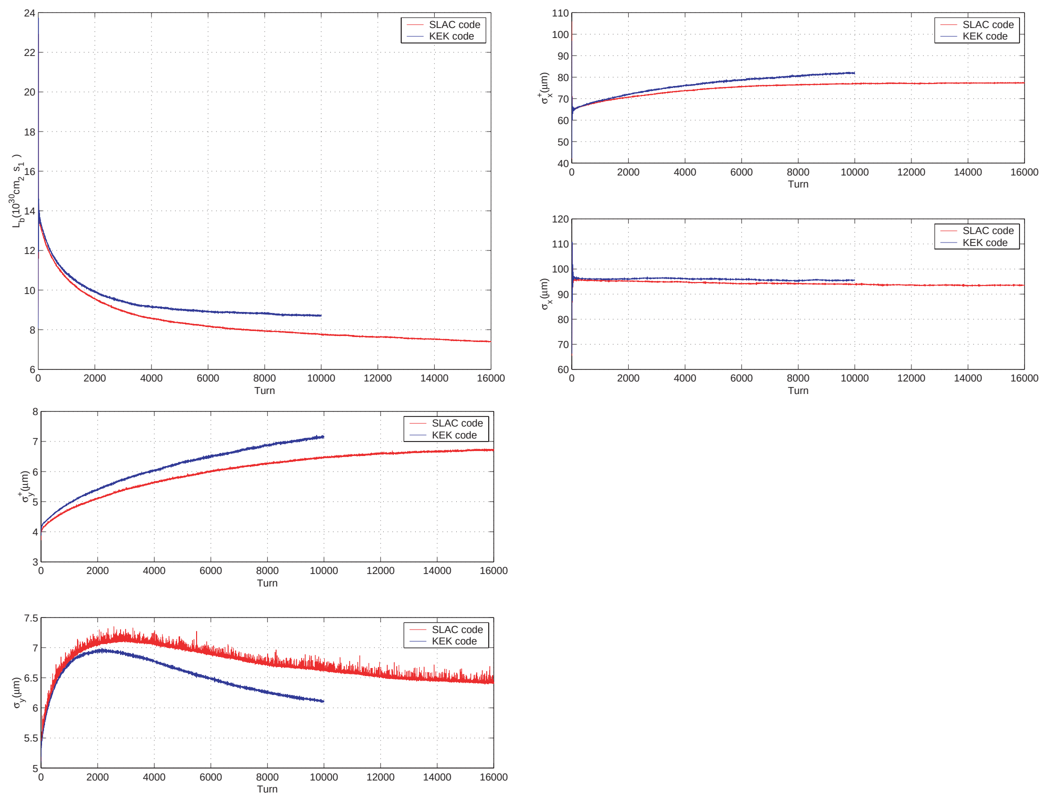

Figure 1: Simulation for the present PEP-II parameter at the $\nu_x^+ = 0.5125$. Red and blue line shows the results by using SLAC and KEK code, respectively. Luminosity by SLAC and KEK code is about 7.3 $\times 10^{30}$, 8.5×10^{30} $/cm^2/sec$, respectively.

Table 3: present KEKB parameter

	LER	HER
E (GeV)	3.5	8.0
N	7.364×10^{10}	5.2858×10^{10}
β_x^*/β_y^* (cm)	59/0.58	58/0.7
τ_t/τ_s (turn)	4000/2000	4000/2000
ϵ_x/ϵ_y (nm-rad)	18/0.18	24/0.24
ν_x/ν_y	0.506/0.545	0.508/0.586
ν_s	-0.0249	-0.0207
σ_z (cm)	0.87	0.71
σ_p	7.3×10^{-4}	6.7×10^{-4}
xangle (mrad)	±11	
f_0 (Hz)	99462	
Luminosity/bunch ($cm^{-2}sec^{-1}$)	8.2×10^{30}	

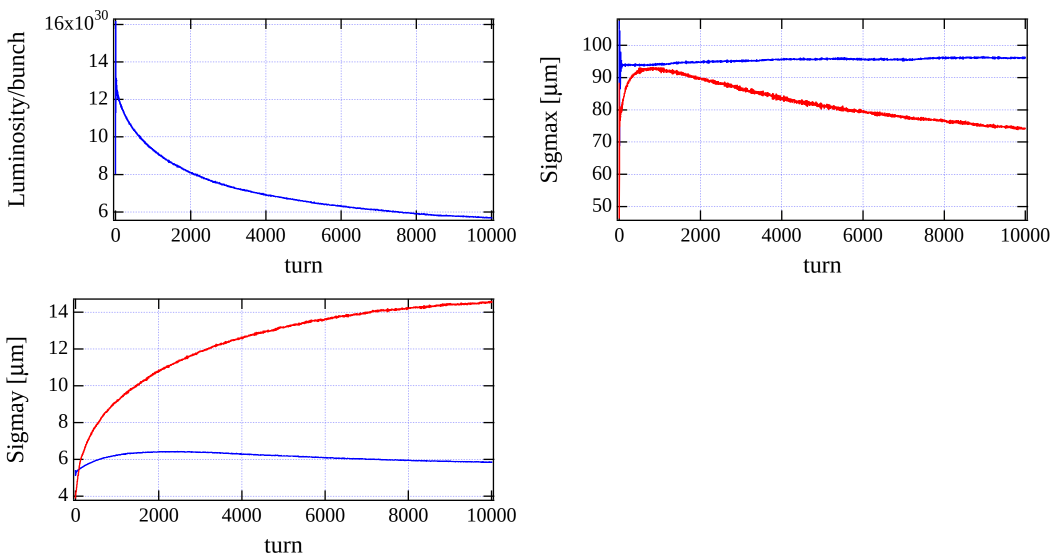

Figure 2: Simulation for the present PEP-II parameter by KEK code at the $\nu_x^+ = 0.5253$. Red and blue line show the beam size for LER and HER, respectively.

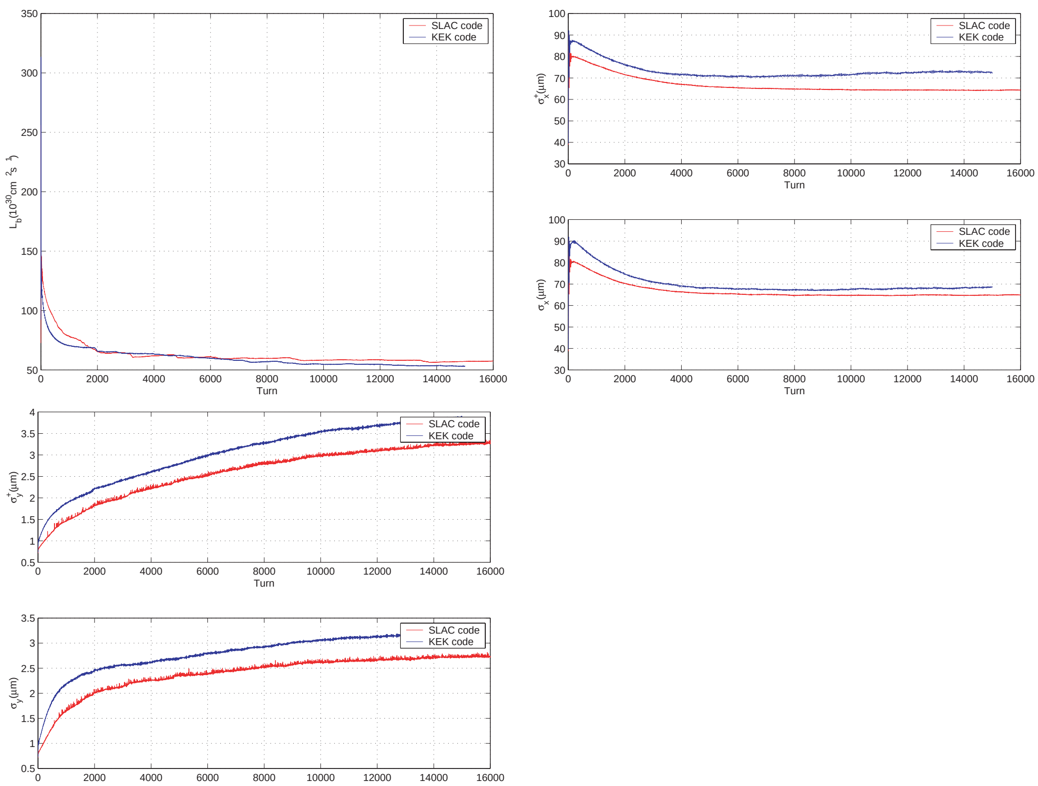

Figure 3: Simulation for the SuperKEKB parameter. Red and blue line shows the results by using SLAC and KEK code, respectively.

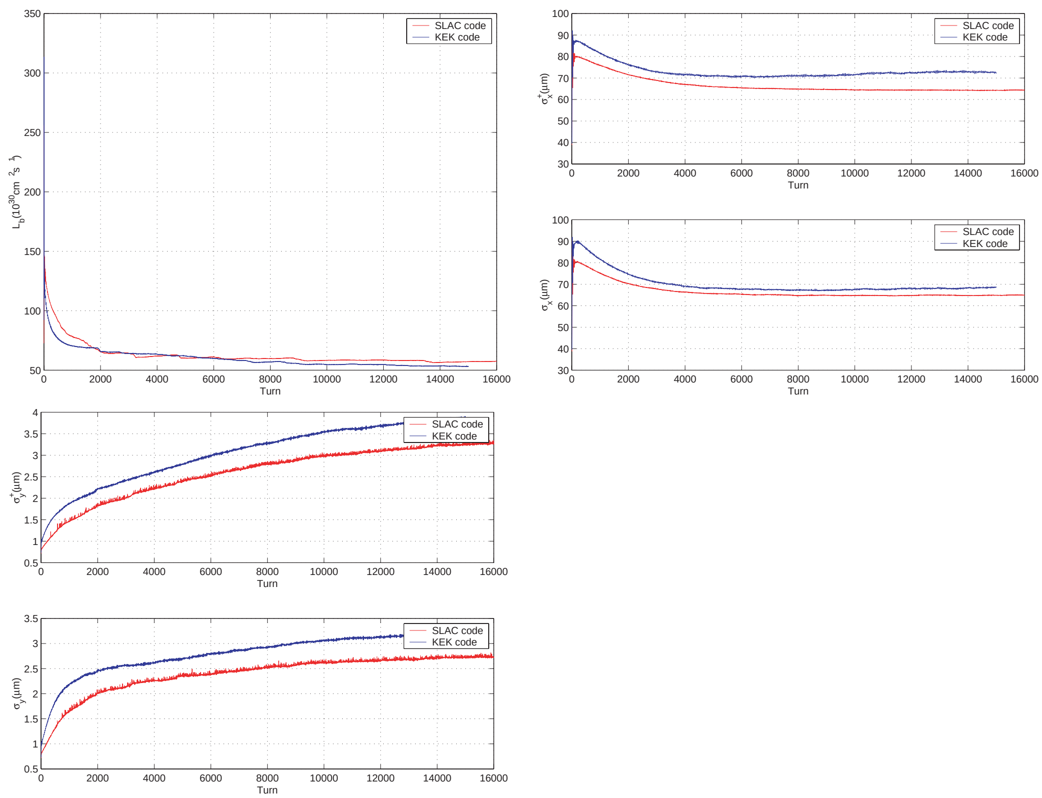

Figure 4: Simulation for the present KEKB parameter. Red and blue line shows the results by using SLAC and KEK code, respectively.

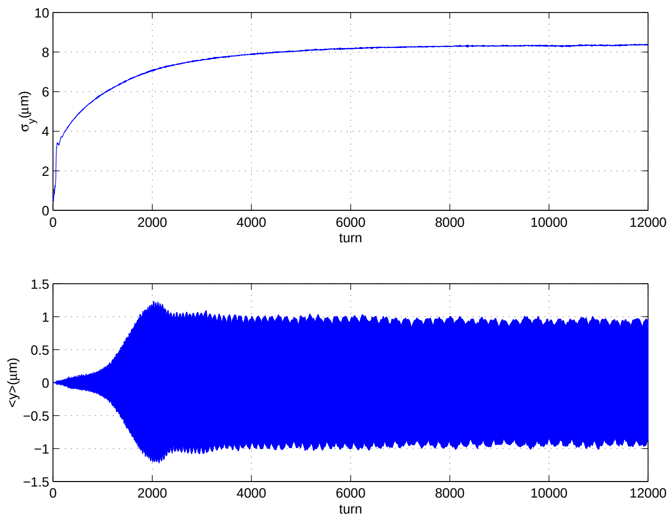

Figure 5: Simulation for SuperKEKB parameter at one longitudinal slice by SLAC code.

1.2 Comparison of 2D code

We have performed PIC calculation for SuperKEKB and PEP-II parameter by using SLAC, LBL and KEK, respectively. Fig. 5 and 6 shows the simulation results at one logitudinal slice for SuperKEKB parameter by SLAC and KEK code, respectively. The results at one and 20 longitudinal slices for SuperKEKB parameter are shown in Fig. 7, 8 and 9. At one longitudinal slice, The results of SLAC, KEK, LBL are in good agreement. The result for PEP-II parameter by LBL code is shown in Fig. 10.

1.3 Comparison between 2D PIC solver and exact Gauss solution in Weak-Strong simulation

We have compared simulation of 2D PIC with Gauss for SuperKEKB parameter by using LBL and KEK code, respectively. The results are shown in Fig. 11 and 12, respectively. These results are in good agreement.

1.4 Comparison between head-on and xangle+crab

We have compared simulations between with head-on and with crossing angle of 15 mrad + crab cavity kick of -15 mrad. The result is shown in Fig. 13. There is no difference for Luminosity and vertical beam sizes. The difference of horizontal beam size is due to cut angle of horizontal beam size.

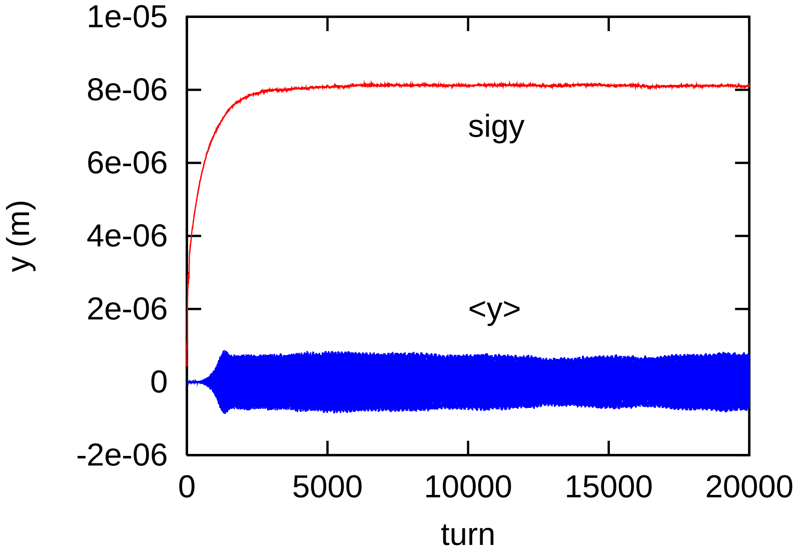

Figure 6: Simulation for SuperKEKB parameter at one longitudinal slice by KEK code.

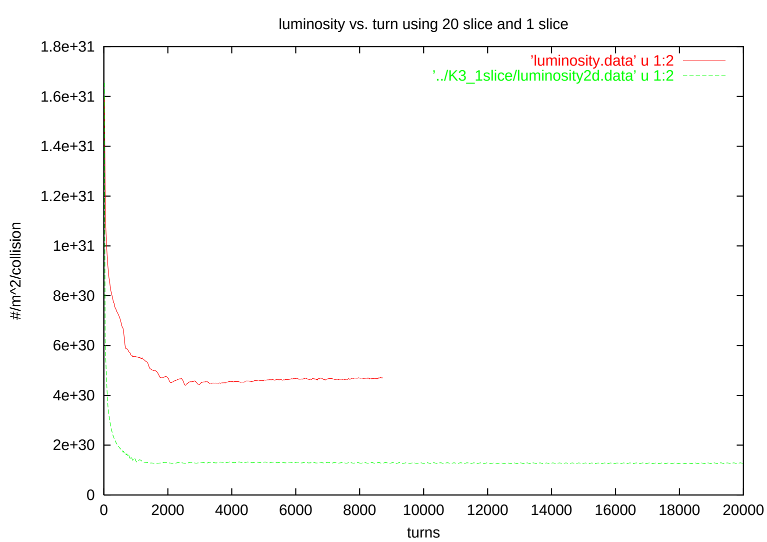

Figure 7: Luminosity for SuperKEKB parameter by LBL code at one (green line) and 20 longitudinal slices (red line).

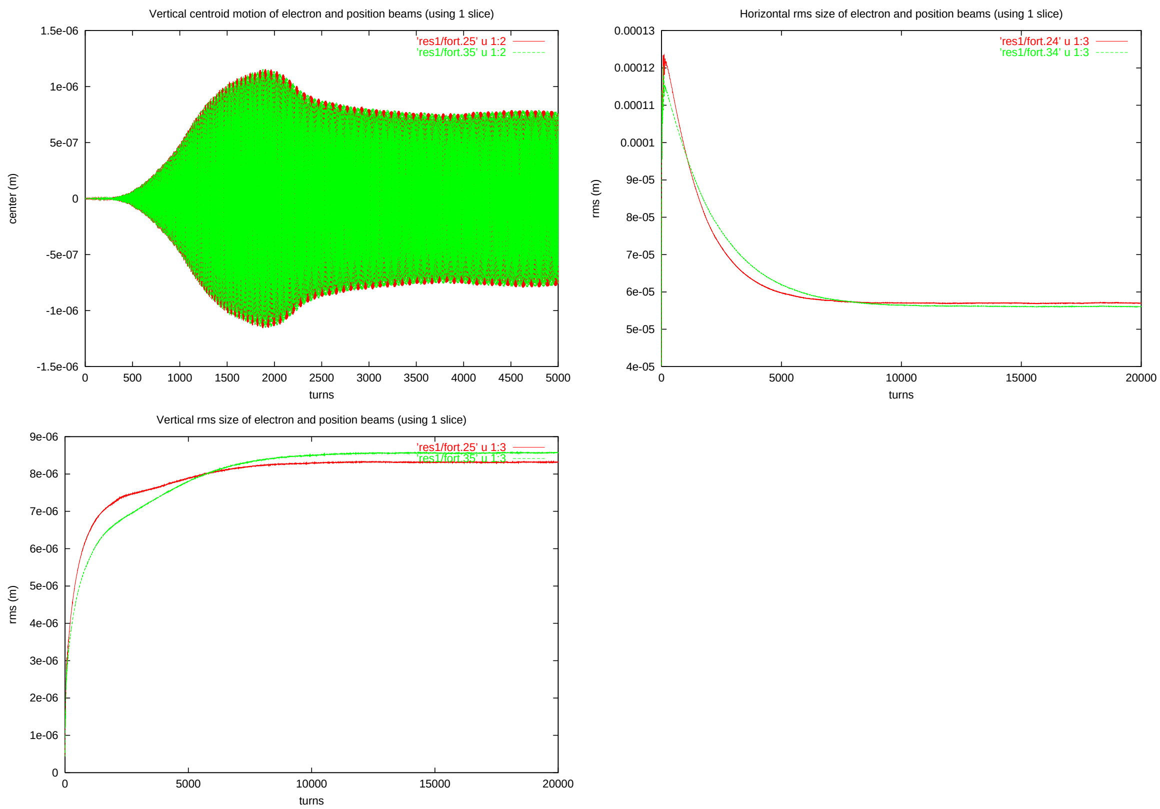

Figure 8: Simulation for SuperKEKB parameter by LBL code at one longitudinal slice. Each figure shows (a) vertical centroid motion, (b) horizontal rms beam size and (c) vertical rms beam size, respectively.

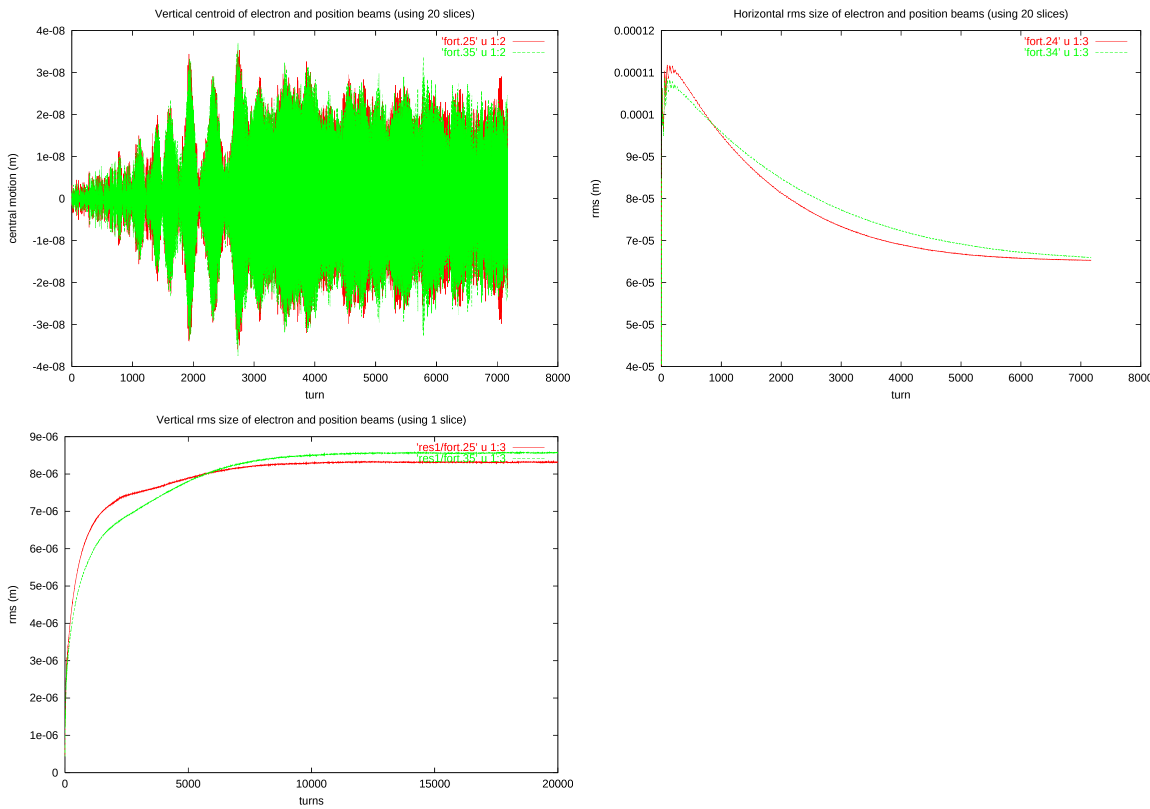

Figure 9: Simulation for SuperKEKB parameter by LBL code at 20 longitudinal slices. Each figure shows (a) vertical centroid motion, (b) horizontal rms beam size and (c) vertical rms beam size, respectively.

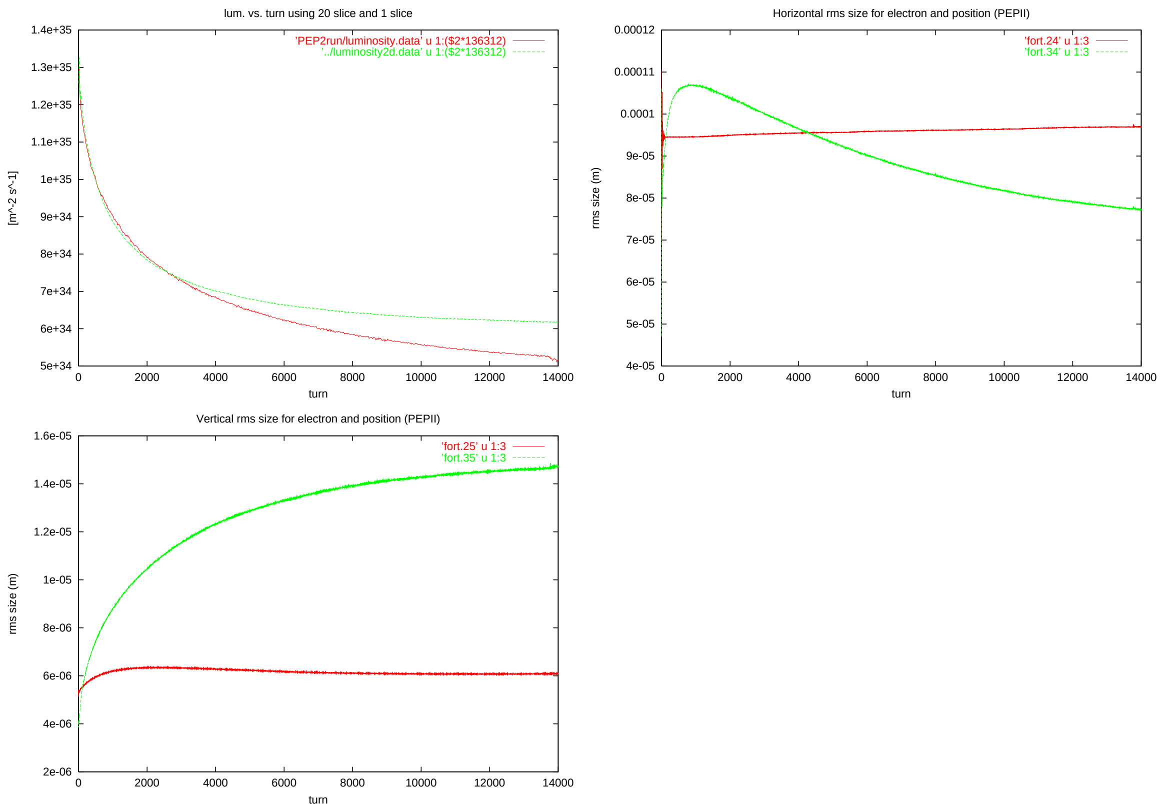

Figure 10: Simulation for for PEP-II parameter by LBL code. Each figure shows (a) Luminosity at one (green) and 20 slice (red) (b) horizontal rms beam size at 20 slice (c) vertical rms beam size at 20 slices. We have used LER horizontal tune of 0.5253 in this calculation.

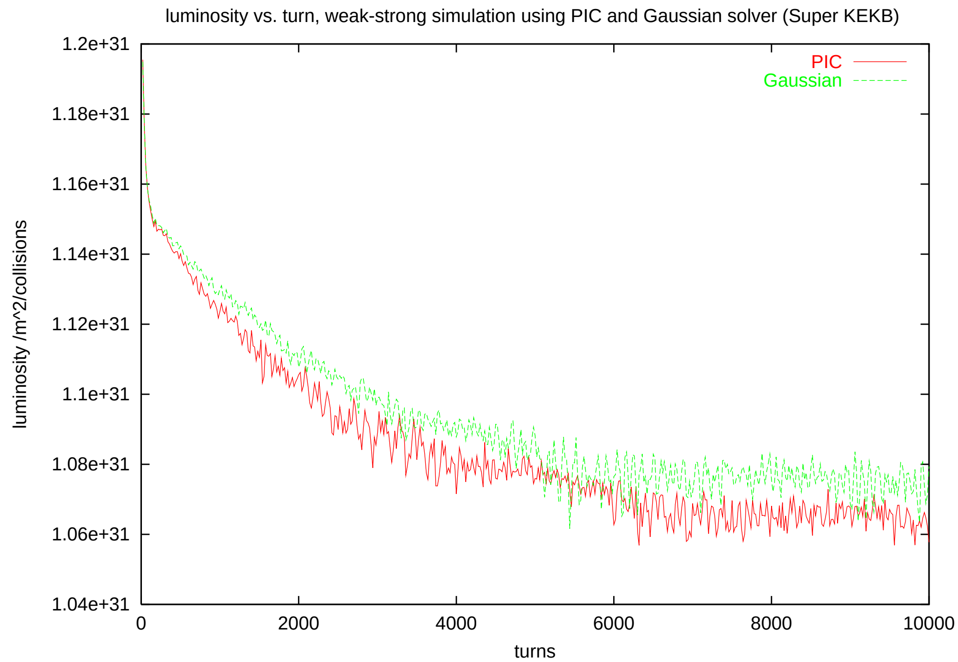

Figure 11: Comparison of 2D PIC solver and exact Gauss solution in Weak-Strong simulation for SuperKEKB parameter by LBL code.

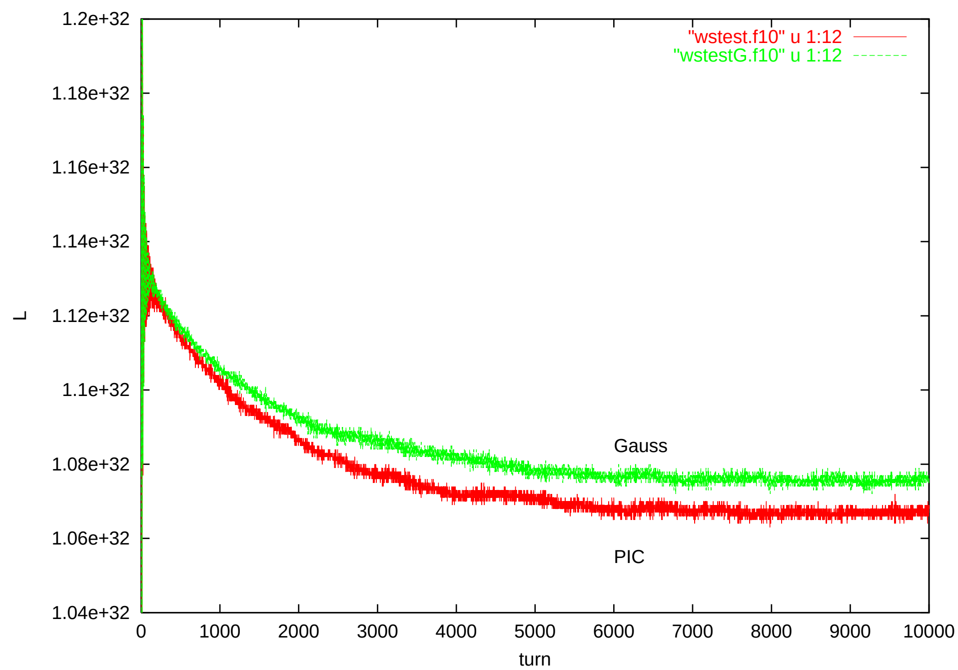

Figure 12: Comparison of 2D PIC solver and exact Gauss solution for SuperKEKB parameter by KEK code.

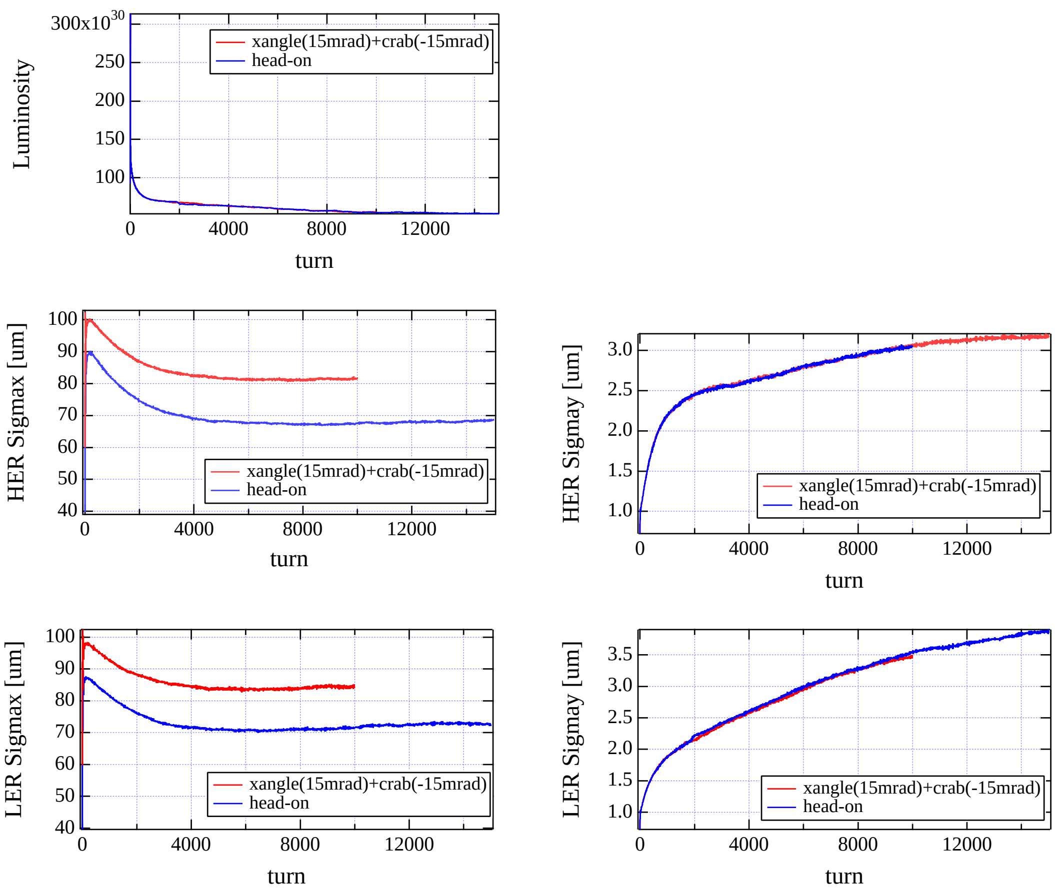

Figure 13: Comparison between head-on and xangle+crab for SuperKEKB parameter by using KEK code.

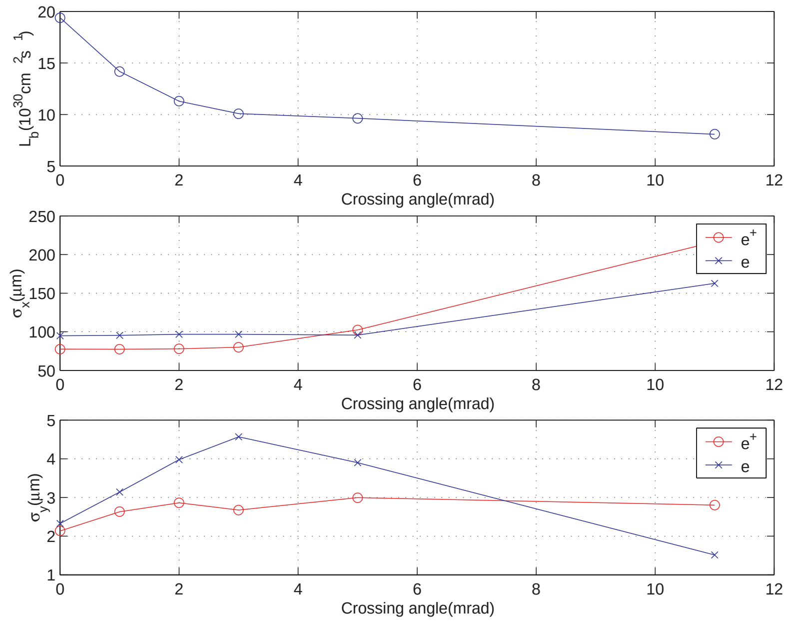

Figure 14: Crossing angle dependence for present KEKB parameter by using SLAC code.

1.5 Crossing angle dependence.

The crossing angle dependence for PEP-II and KEKB parameter are calculated by PIC beam-beam simulation. The preliminary results for KEKB parameter by using PEP-II code is shown in Fig. 14. The preliminary results for PEP-II parameter by using KEK code is shown in Fig. 15 with weak-strong simulation results. The sharp peak of luminosity around zero crossing angle is observed in each case.At 5 mrad, horizontal coherent oscillation was observed as shown in Fig. 14. It seems π-mode synchro-betatron resonance between HER's ν_x and LER's ν_s or between LER's ν_x and HER's ν_s.

1.6 Tune Scan for PEP-II

By using weak-strong simulation code, we have performed tune scan for HER and LER at the crossing angle of 0, 3, 5 mrad, respectively. These results are shown in Fig. High luminosity region is reduced as crossing angle is increased.

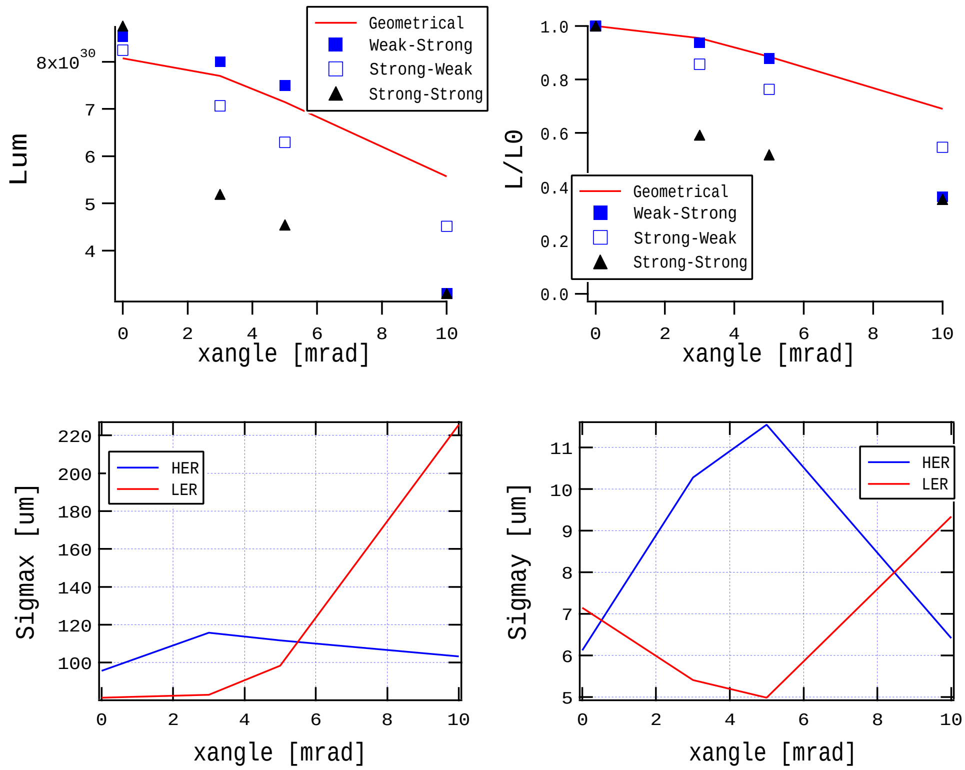

Figure 15: Crossing angle dependence which is calculated for PEP-II parameter by using KEK code.

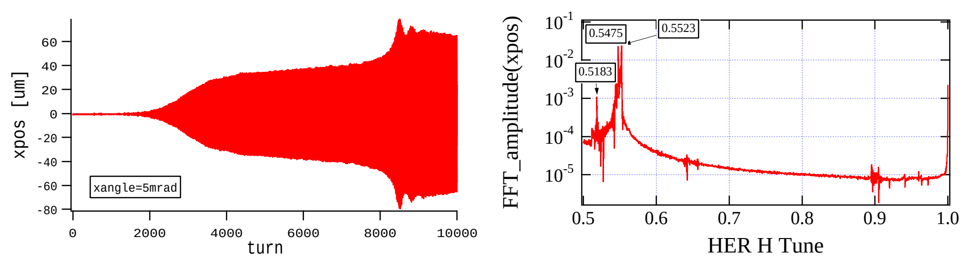

Figure 16: Strong-strong simulation results at the crossing angle of 5 mrad. These graphs show HER horizontal amplitude v.s. turn and FFT amplitude of HER horizontal amplitude, respectively.

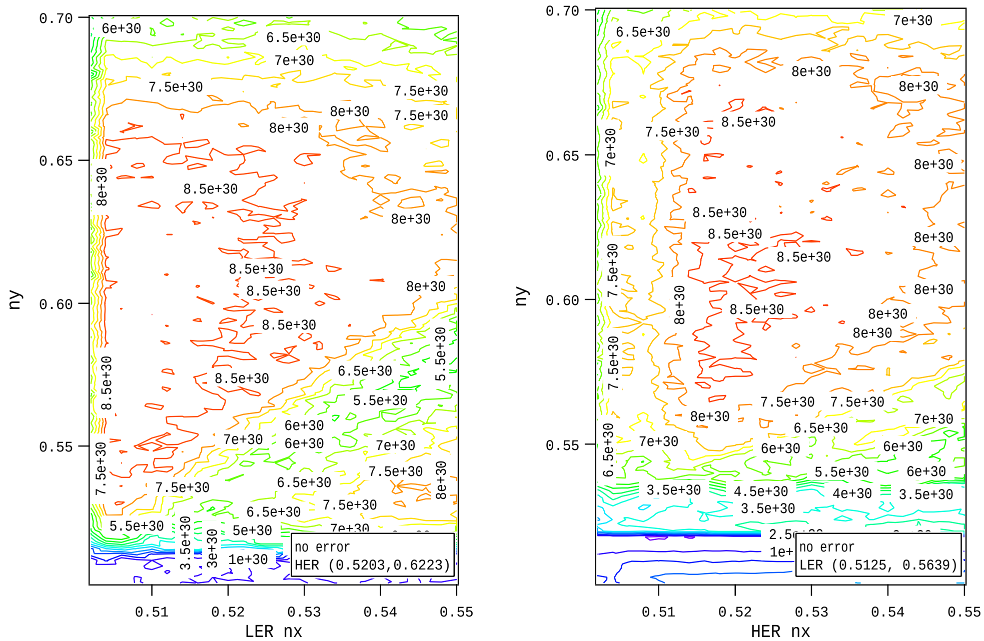

Figure 17: Tune scan for PEP-II parameter at the crossing angle of 0 mrad by using weak-strong simulation code.

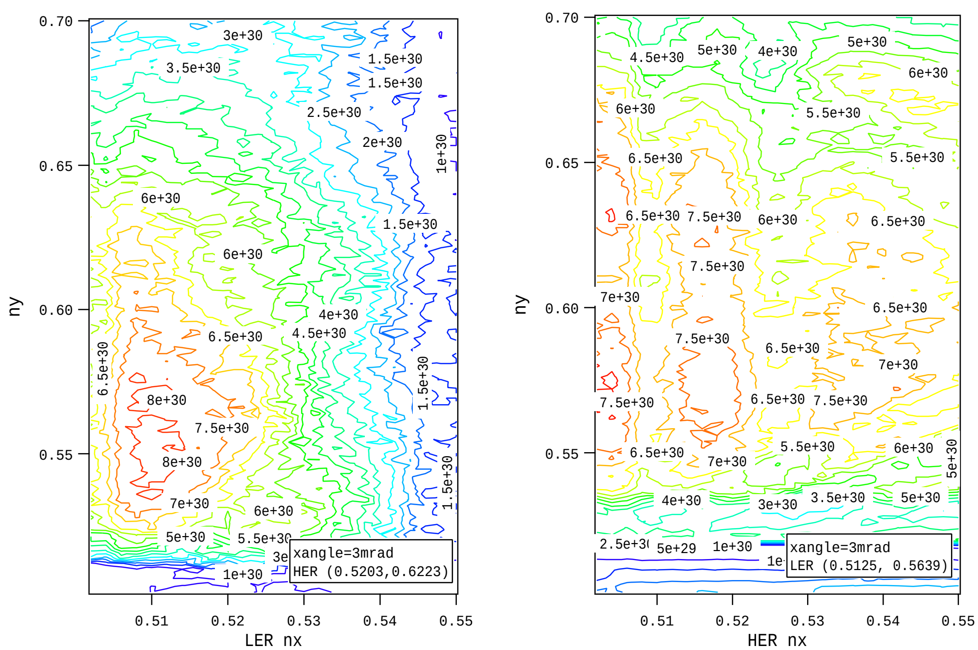

Figure 18: Tune scan for PEP-II parameter at the crossing angle of 3 mrad by using weak-strong simulation code.

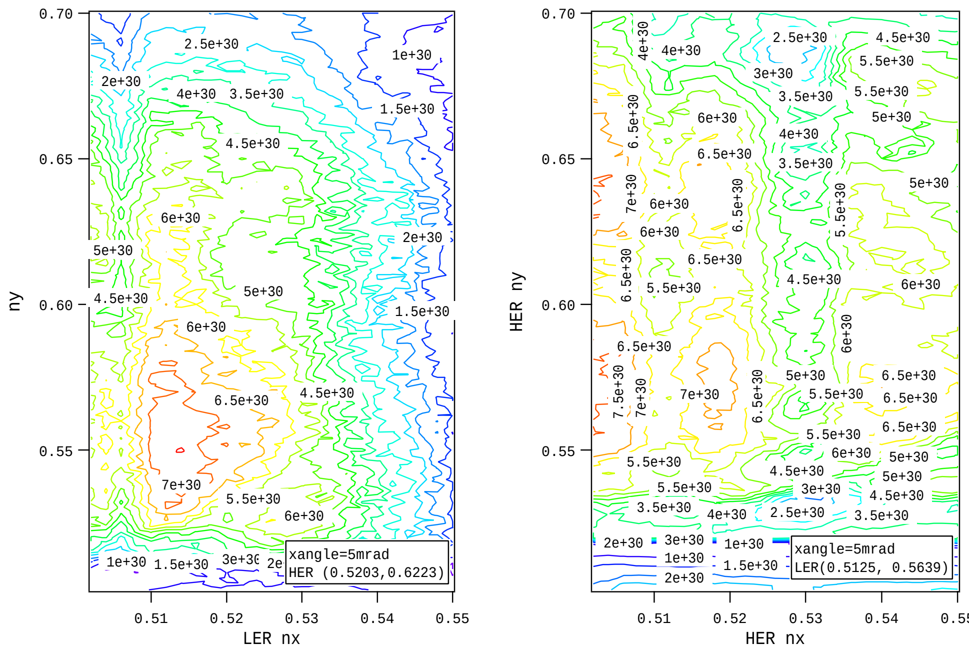

Figure 19: Tune scan for PEP-II parameter at the crossing angle of 5 mrad by using weak-strong simulation code.

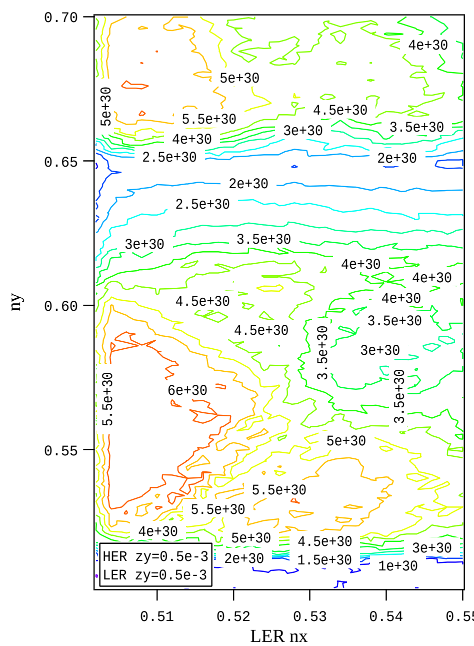

Figure 20: Tune scan for PEP-II parameter at the crossing angle of 0 mrad with vertical crossing angle of 1 mrad by using weak-strong simulation code.

References

[1] Y. Cai, A. W. Chao, S. I. Tzenov and T. Tajima, Phys. Rev. ST Accel. Beams **4**, 011001 (2001).

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