Linear Collider Collaboration Tech Notes

Effects of Position and Angle Offsets on NLC Luminosity

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Abstract:

We present simulation results for the luminosity reduction due to position and angle offsets in the beams colliding at the NLC interaction point. We look at the nominal NLC-B-500 and NLC-B-1000 designs and also at designs having the vertical beta function doubled at the IP.

Effects of position and angle offsets on NLC luminosity

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The purpose of this note is to study the effect on luminosity of position and angle offsets in the beams colliding at the NLC interaction point.

Baseline NLC interaction point design parameters are as given on the NLC website [1] and a previous note [2]; for convenience we redisplay them in Table 1. In this note we shall focus on the NLC-B-500 and NLC-B-1000 designs and variations away from them. The GUINEAPIG beam-beam program [3] is used to simulate the beam-beam interaction.

An interesting result of a previous study [2] is that the luminosity (not only the total luminosity, but also the fraction of the luminosity near the nominal energy) is quite insensitive to variations in the vertical beta function If the vertical beta function is increased by a factor of two from the nominal value, for zero-offset collisions one obtains a luminosity degradation of only 10% for NLC-B-500 and 15% for NLC-B-1000. The payoff for this luminosity loss is a loosening of tolerances in the final focus. In addition to quantifying the effects of offsets on the nominal NLC, another purpose of this note is to compare the effects of offsets in the relaxed beta function scenario.

If the charge is lowered from its nominal value, the disruption will be reduced further. Obviously the overall luminosity will go down when the charge is lowered. But we also wish to check how the luminosity degradation with offset is affected in the relaxed beta function case. Thus we also examine the case where the charge is reduced from the nominal value of $N = 0.95 \times 10^{10}$ to 0.8×10^{10} (and the vertical beta function is doubled).

We show the results of scans in the full vertical offset (in units of the vertical beam size, except for Figures 4 and 12 in which the offset dy is given in nanometers) and scans in the crossing angle θ_y [NOTE: this is the full angle between the beams, not the half-angle]. In all of Figures 1 through 8, the solid curve is for the nominal parameters (NLC-B-500 in Figures 1 through 8, and NLC-B-1000 in Figures 9 through 16), the dashed curve is for the vertical beta function doubled from its nominal value (i.e. β_y increased to 0.30 mm for NLC-B-1000, and β_y increased to 0.24 mm for NLC-B-500), and the dotted curve is for doubled vertical beta function and reduced charge (from the nominal value of $N = 0.95 \times 10^{10}$ to 0.8×10^{10}).

Figures 1 and 9 show the luminosity $\mathcal{L}_D$ per bunch as the y-offset is varied. Figures 4 and 12 show the same thing, except that the y-offset is plotted in nanometers instead of in units of σ_y. Figures 2 and 10 show the luminosity enhancement factor $H_D \equiv \mathcal{L}_\mathcal{D}/\mathcal{L}_0$ where

TABLE 1. NLC IP parameters for baseline designs

	NLC-A-500	NLC-B-500	NLC-C-500	NLC-A-1000	NLC-B-1000	NLC-C-1000
E_{beam} [GeV]	267.5	257.5	250.	523.	504.	489.
N [10^{10}]	0.75	0.95	1.1	0.75	0.95	1.1
$\gamma\epsilon_x/\gamma\epsilon_y$ [10^{-6} m-rad]	4.0/0.06	4.5/0.1	5.0/0.14	4.0/0.06	4.5/0.1	5.0/0.14
β_x/β_y [mm]	10/0.1	12/0.12	13/0.2	10/0.125	12/0.15	13/0.2
σ_z [μm]	90.	120.	145.	90.	120.	145.
σ_x/σ_y [nm]	276.43/3.39	327.35/4.88	364.50/7.57	197.69/2.71	233.99/3.90	260.62/5.41
$\mathcal{L}_0$ [10^{33} m^{-2}]	4.777	4.496	3.490	8.365	7.870	6.830
A_x/A_y	0.009/0.9	0.010/1.00	0.011/0.725	0.009/0.72	0.01/0.8	0.011/0.725
D_x/D_y	0.094/7.67	0.117/7.87	0.136/6.53	0.094/6.85	0.103/7.03	0.136/6.53
Υ_{avg}	0.14	0.11	0.09	0.39	0.30	0.25
$\mathcal{L}_D$ [10^{33} m^{-2}]	6.51	5.84	5.21	12.57	11.36	10.24
$H_D \equiv \mathcal{L}_D/\mathcal{L}_0$	1.36	1.30	1.49	1.50	1.44	1.50
n_γ	1.08	1.18	1.24	1.39	1.53	1.62
δ_B	4.3%	3.9%	3.7%	9.5%	9.2%	8.7%
Num. bunches per train	95	95	95	95	95	95
Repetition rate	120	120	120	120	120	120
L_D [cm^{-2}sec^{-1}]	7.42	6.66	5.94	14.33	12.95	11.67

$$\mathcal{L}_0 \equiv \frac{N^2}{4\pi\sigma_x\sigma_y} \quad . \tag{1}$$

Although the absolute luminosity is of course greatest for the nominal case, note that the luminosity enhancement H_D is less for the nominal case than for the cases with relaxed beta function, even though the disruption is larger. This is because the luminosity is reduced less by the hour-glass effect in the cases with relaxed beta function. The crossing of the H_D curves as one goes to larger y/σ_y is simply due to the fact that σ_y is $\sqrt{2}$ larger for the relaxed beta function cases.

Figures 3 and 11 show the average beamstrahlung energy loss δ_B as a function of y-offset. The initial increase of δ_B with offset is due to the fact that particles in the core of one bunch are passing through the high-field region just outside the core of the other bunch.

Plots of luminosity per bunch ℓ_D, luminosity enhancement H_D, and average beamstrahlung energy loss δ_B, as a function of y-angle offsets, are shown in Figures 5 through 7 for NLC-B-500, and Figures 13 through 15 for NLC-B-1000, and similar remarks apply as in the case of position offsets. We show also n_γ, the number of beamstrahlung photons per incoming particle, in Figures 8 and 16; the behavior of n_γ is similar to that of δ_B, for the same reason i.e., more particles are passing through the high field region as one begins to increase the offset.

The luminosity degradation for an offset of $1\sigma_y$ is essentially the same for all cases, about 8% (see Table 2). The budgeted rms offset jitter for NLC is about

TABLE 2. Luminosity loss at vertical offsets of 1 and $2\sigma_y$

	$1\sigma_y$ offset	$2\sigma_y$ offset
NLC-B-500	-7.6%	-20%
NLC-B-500, relax β	-8.3%	-24%
NLC-B-500, relax β, lower N	-7.7%	-25%
NLC-B-1000	-8.3%	-23%
NLC-B-1000, relax β	-8.5%	-25%
NLC-B-1000, relax β, lower N	-8.0%	-26%

TABLE 3. Luminosity loss at vertical angle offsets of 20 and 40 μrad

	20 μrad	40 μrad
NLC-B-500	-3.1%	-12.0%
NLC-B-500, relax β	-2.3%	-8.7%
NLC-B-500, relax β, lower N	-2.2%	-8.4%
NLC-B-1000	-6.6%	-19.5%
NLC-B-1000, relax β	-3.8%	-13.5%
NLC-B-1000, relax β, lower N	-4.1%	-12.6%

$0.7\sigma_y$. Even at a $2\sigma_y$ offset there is not very much difference among all the cases – the luminosity loss ranges from about 20 to 25%.

The luminosity loss for angle offsets of 20 and 40 μrad is shown in Table 3. The budgeted rms angle jitter for NLC is about $0.7\sigma'_y$, which for NLC-B-500 is 30 μrad and for NLC-B-1000 20 μrad.

Thus the expected luminosity loss due to angle offsets is comparable to that due to position offsets, about 5% for each. Furthermore, the luminosity loss due to vertical angle offsets is even less with a relaxed β_y than with the nominal β_y. Thus relaxing the vertical beta function does not worsen the effect of offsets, even though the disruption is reduced, apparently because the reduced hour glass degradation is more important.

REFERENCES

1. See http://www-project.slac.stanford.edu/lc/nlc-tech.html under Accelerator Physics parameters.
2. K.A.Thompson and T.O.Raubenheimer, "Luminosity for NLC Design Variations", NLC note LCC-0014 (March, 1999).
3. D.Schulte, Ph.D. thesis, 1996.
4. Yokoya,K. and Chen,P., in M.Dienes,et.al. (ed.), Frontiers of Particle Beams: Intensity Limitations, (Springer-Verlag, 1992), p.415.

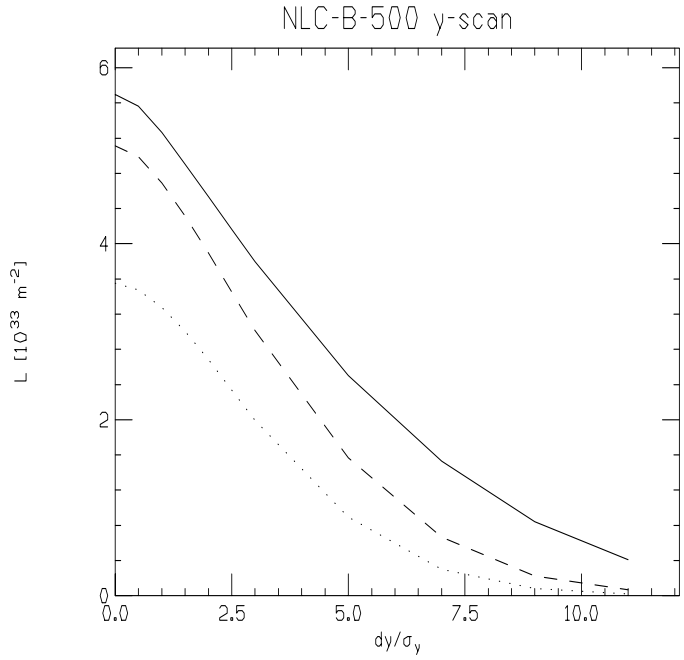

FIGURE 1. Luminosity (per bunch) for y-scan, shown versus dy/σ_y, for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

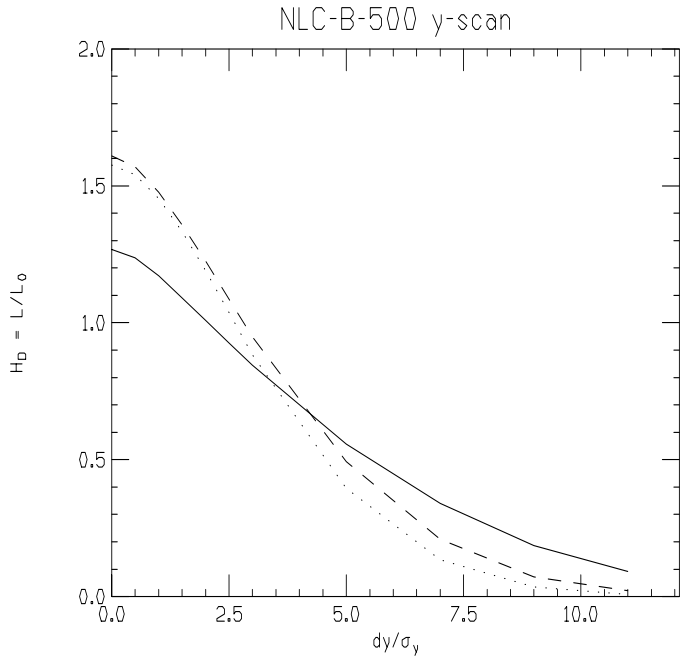

FIGURE 2. Enhancement factor H_D for y-scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

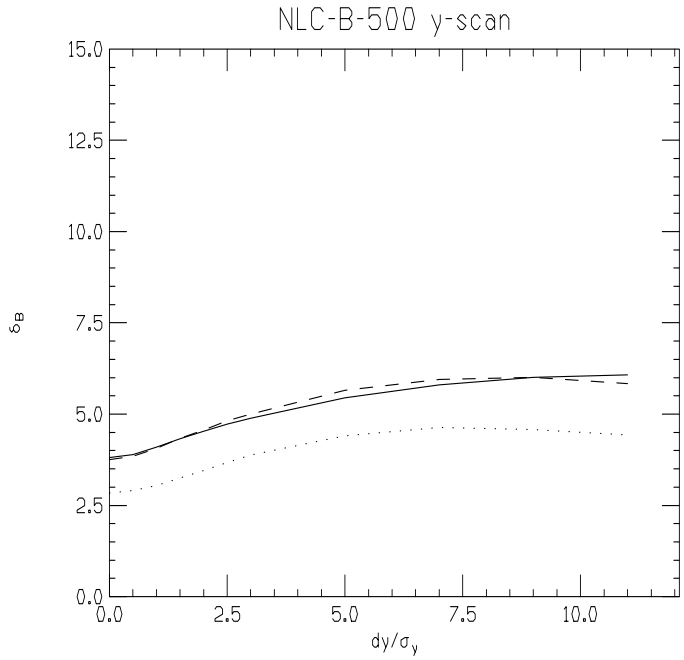

FIGURE 3. Average beamstrahlung energy loss for y-scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

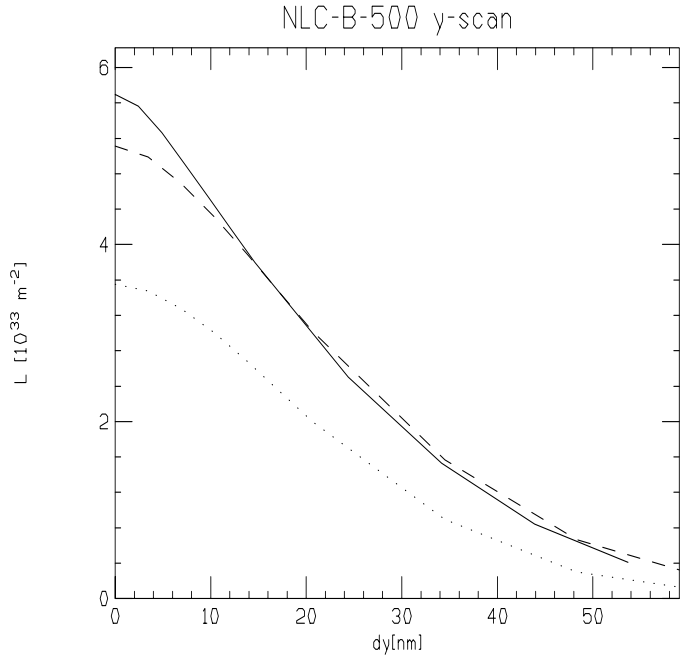

FIGURE 4. Luminosity (per bunch) for y-scan, shown versus dy in nanometers, for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

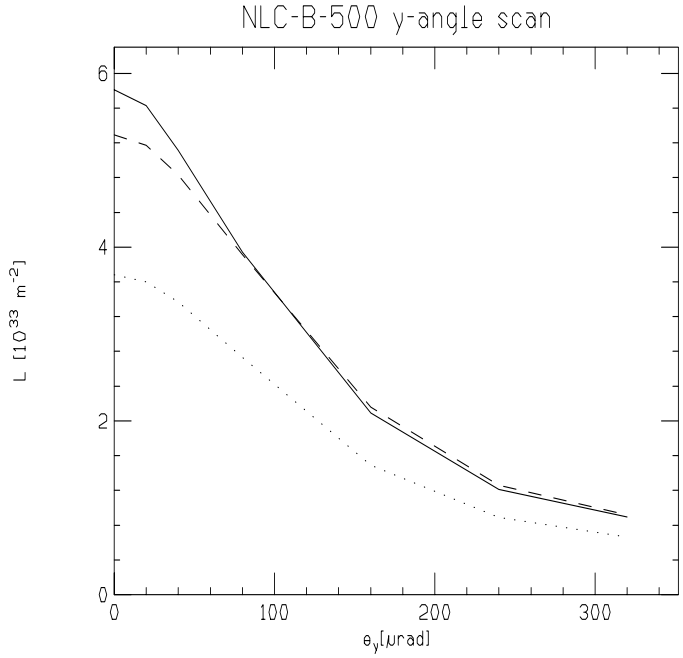

FIGURE 5. Luminosity (per bunch) for y-angle scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

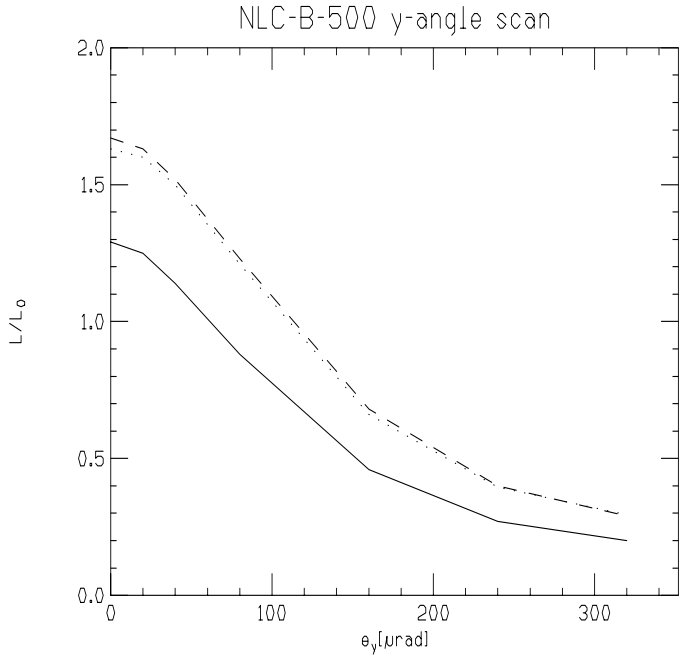

FIGURE 6. Enhancement factor H_D for y-angle scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

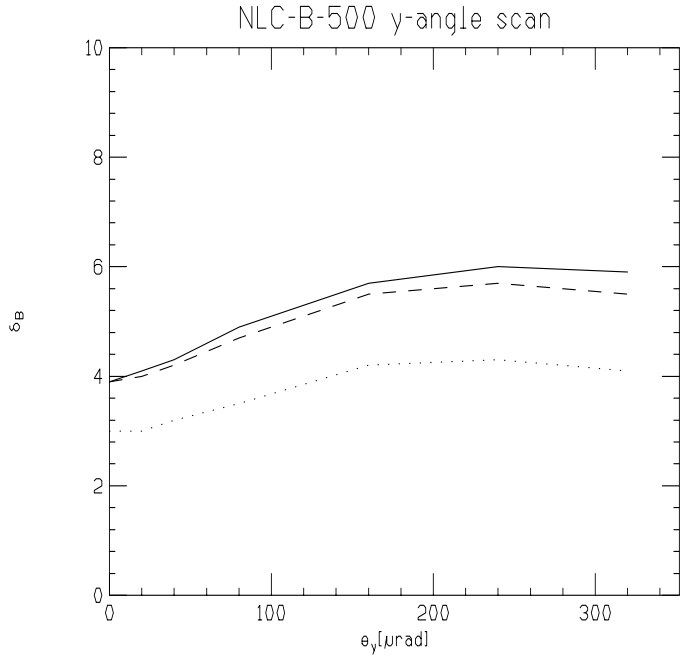

FIGURE 7. Average beamstrahlung energy loss for for y-angle scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

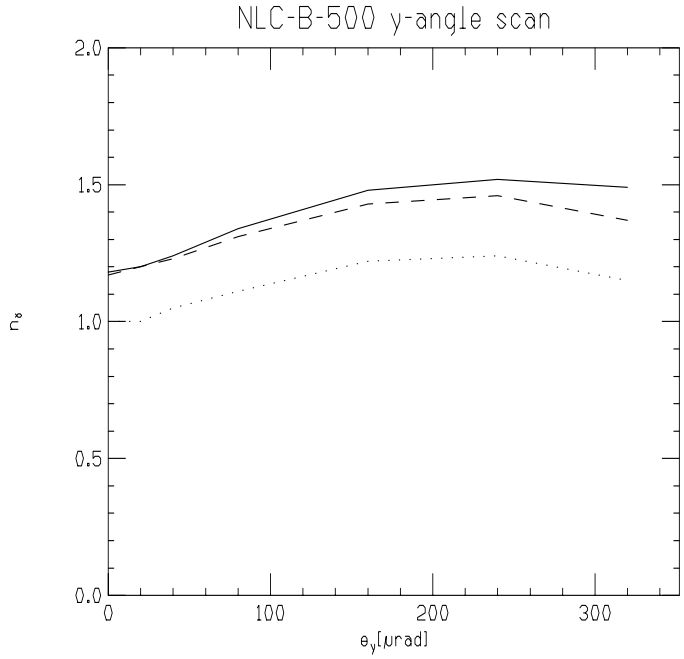

FIGURE 8. Average number of photons produced per incoming particle for y-angle scan for nominal NLC-B-500 (solid), NLC-B-500 with $\beta_y = 0.24$ mm (dashed), NLC-B-500 with $\beta_y = 0.24$ mm and $N = 0.8 \times 10^{10}$ (dotted).

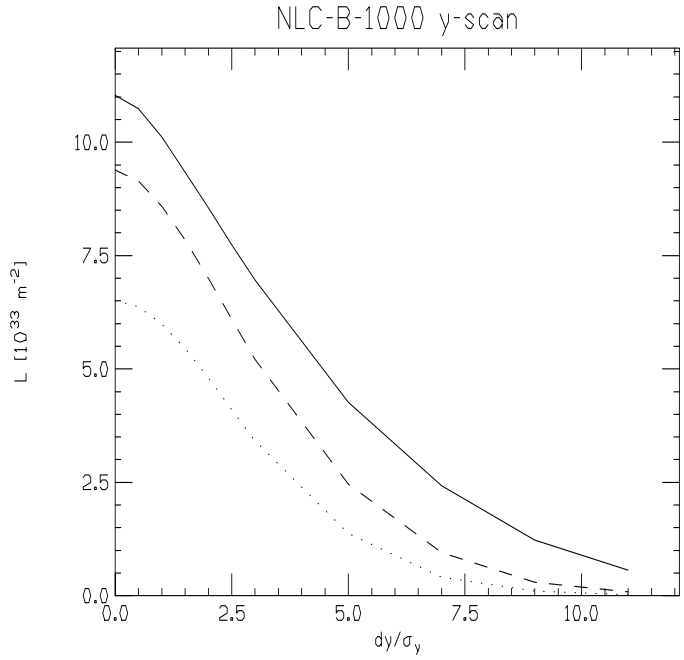

FIGURE 9. Luminosity (per bunch) for y-scan, shown versus dy/σ_y, for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

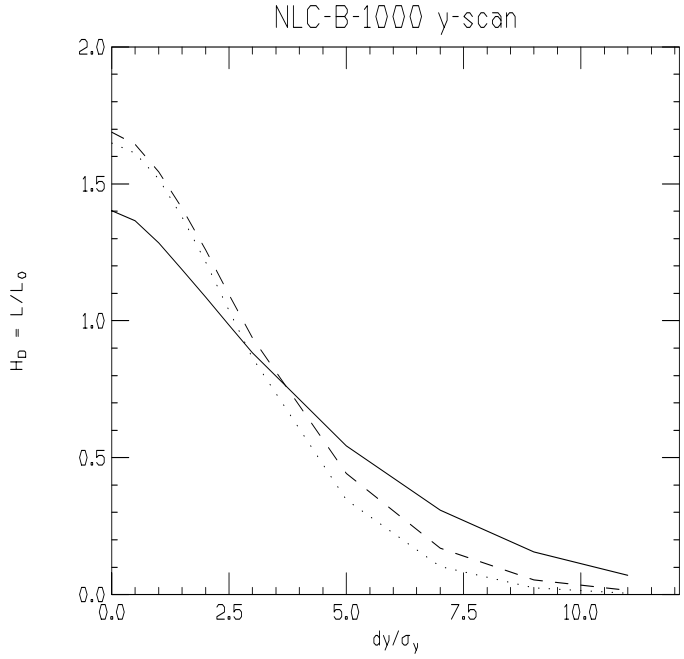

FIGURE 10. Enhancement factor H_D for y-scan, for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

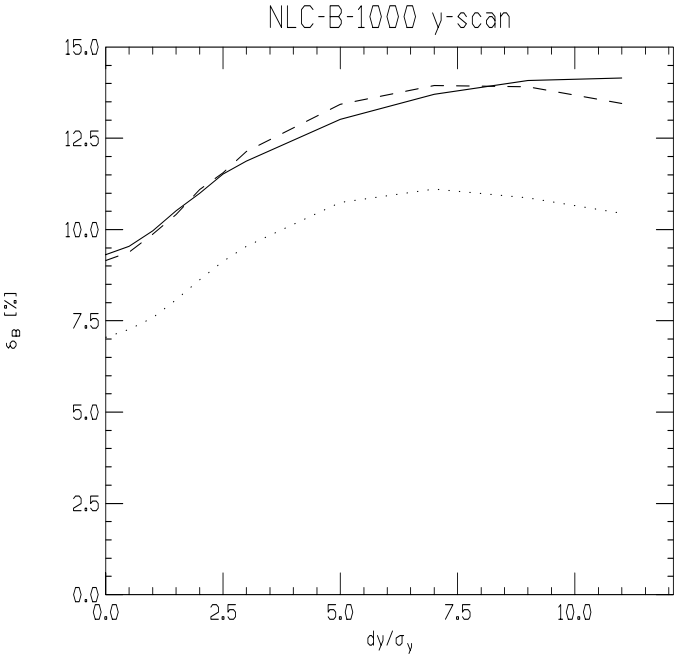

FIGURE 11. Average beamstrahlung energy loss for y-scan for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

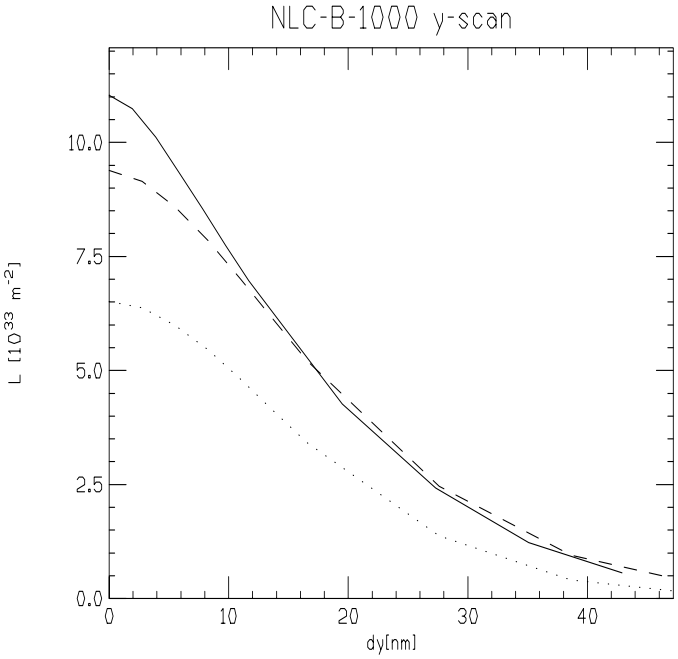

FIGURE 12. Luminosity (per bunch) for y-scan, shown versus dy in nanometers, for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

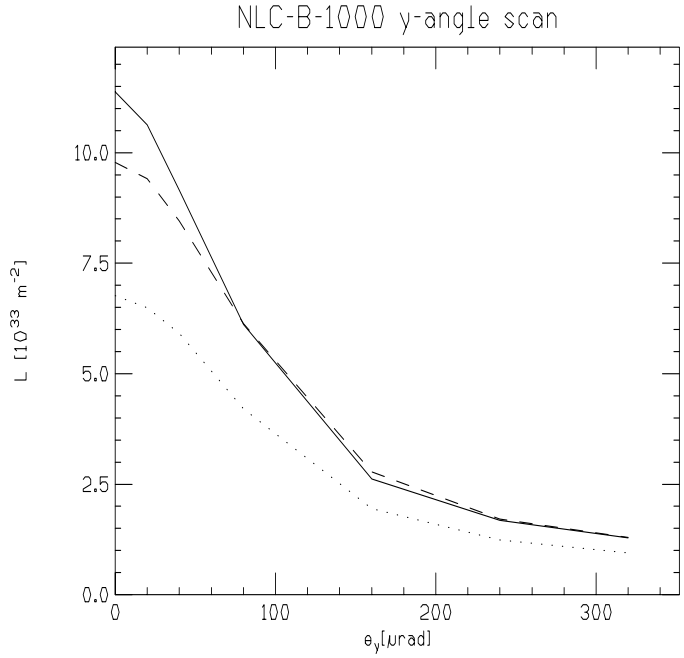

FIGURE 13. Luminosity (per bunch) for y-angle scan for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

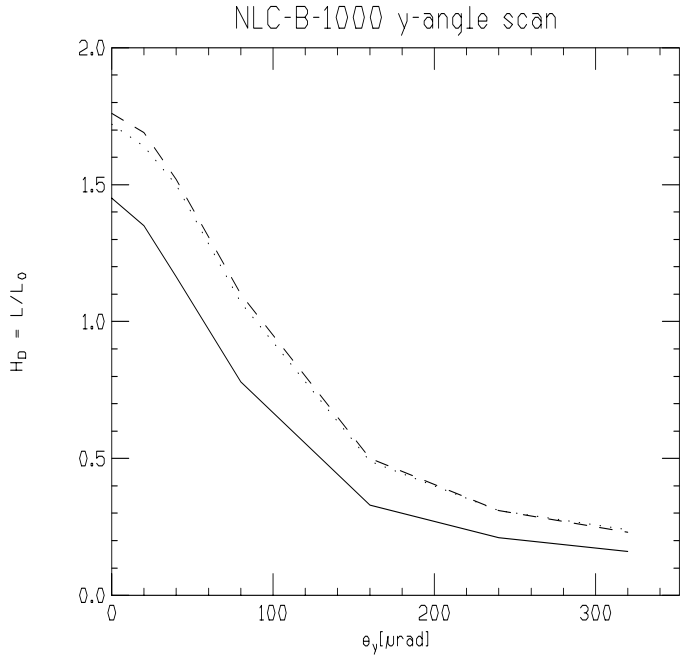

FIGURE 14. Enhancement factor H_D for y-angle scan for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

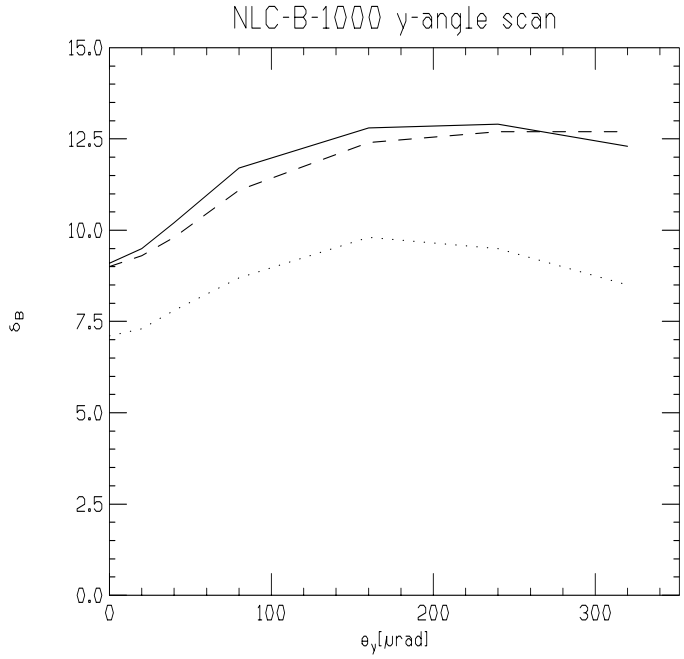

FIGURE 15. Average beamstrahlung energy loss for y-angle scan for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).

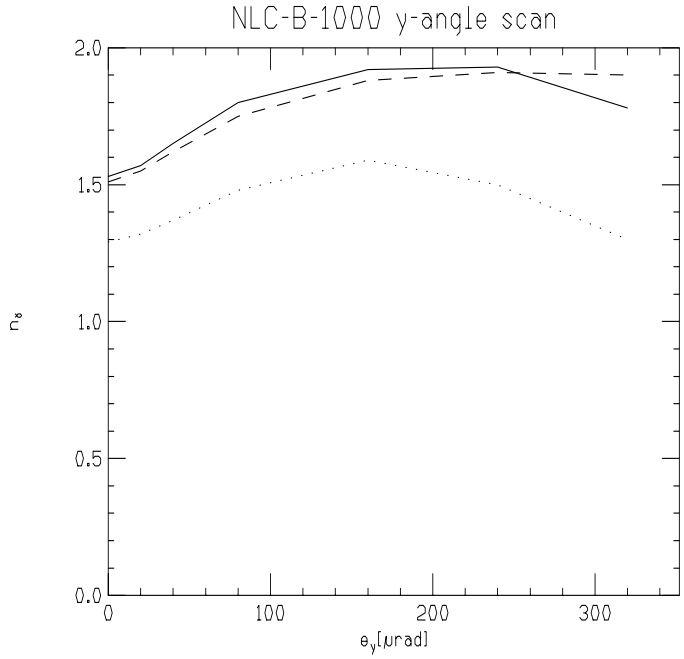

FIGURE 16. Average number of photons produced per incoming particle for y-angle scan for nominal NLC-B-1000 (solid), NLC-B-1000 with $\beta_y = 0.30$ mm (dashed), NLC-B-1000 with $\beta_y = 0.30$ mm and $N = 0.8 \times 10^{10}$ (dotted).