Luminosity for e^-e^- linear collider designs at 1.7 TeV

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We consider two designs for a linear collider at 1.7 TeV center of mass energy[1]. The parameters are chosen to be feasible with the two-beam scheme for acceleration [2], a possible upgrade path from ~ 1 TeV to higher energies. These parameter sets are illustrative, not necessarily optimized. The coherent pair background is very high in the high charge per bunch case (see Table II below). This is one reason for considering the other design, which has a large number of low-charge, closely spaced bunches.

The luminosity in e^+e^- mode is about 10^{35} $cm^{-2}sec^{-1}$ for both of these designs. For an e^-e^- machine with the same parameters, the luminosity is of course lower because the mutual interaction between the two like-sign beams blows the transverse beam sizes up rather than pinching them down. The main purpose of this paper is to emphasize and quantify the fact that even though the total luminosity (integrated over all energies) of a linear collider in e^-e^- mode is

Table I Two representative designs at 1700 GeV CM energy

	low charge	high charge
E_{beam} [GeV]	850.	850.
N [10^{10}]	0.0855	1.368
$\gamma\epsilon_x/\gamma\epsilon_y$ [10^{-6} m-rad]	1.1/0.012	3.8/0.05
β_x^*/β_y^* [mm]	1.0/0.1	15/0.12
σ_z [μm]	90.	90.
σ_x/σ_y [nm]	25.7/0.85	185/1.90
$\mathcal{L}_0$ [10^{33} m^{-2}]	2.66	42.4
A_x/A_y	0.09/0.9	0.006/0.09
D_x/D_y	0.191/5.78	0.060/6.46
Num. bunches per train	3600	225
Repetition rate [Hz]	60	60

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[1] R.D. Ruth, private communication

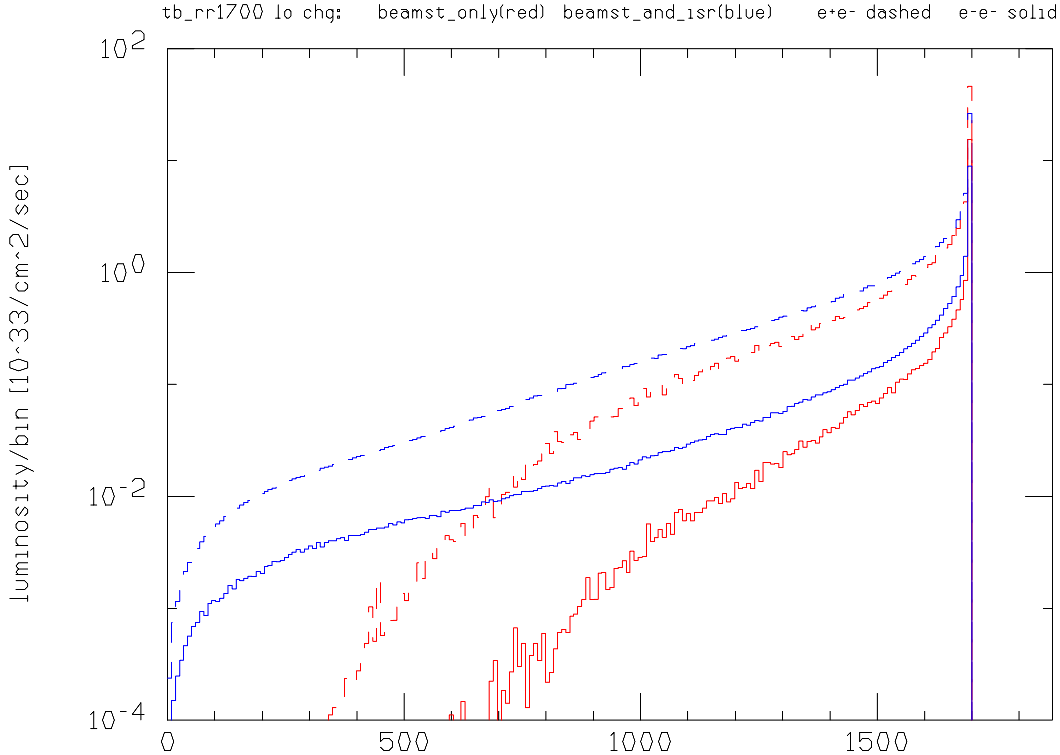

Figure 1: Luminosity spectrum for e^+e^- (dashed curves) and e^-e^- (solid curves), for the low-charge design at 1.7 TeV. For each of these cases, we show the spectrum with beamstrahlung only (red), and with both beamstrahlung and initial state radiation (blue).

much lower than the corresponding design in e^+e^- mode, the comparison between luminosities near the peak energy is not so unfavorable for e^-e^-. This is of course because blowing the beams up results in less beamstrahlung (i.e., radiation of photons and thus energy loss by the electrons and positrons when they are bent by the collective field of the oncoming beam).

Interaction point parameters for the two designs are given in Table I. One design has low charge per bunch ($N = 8.55 \times 10^8$) and 3600 bunches per train, while the other has high charge per bunch ($N = 1.368 \times 10^{10}$) and 225 bunches per train. We use the following definitions: number of particles per bunch N; normalized emittances $\gamma\epsilon_x/\gamma\epsilon_y$; betatron functions at interaction point β_x^*/β_y^*; RMS bunch length σ_z; RMS transverse bunch sizes σ_x/σ_y; geometric luminosity per bunch $\mathcal{L}_0 \equiv N^2/4\pi\sigma_x\sigma_y$; hour-glass parameters $A_{x,y} \equiv \sigma_z/\beta_{x,y}^*$; disruption parameters $D_{x,y} \equiv 2r_e\sigma_z N/\gamma\sigma_{x,y}(\sigma_x + \sigma_y)$;

The GUINEAPIG beam-beam program [1] is used to simulate the beam-beam interaction and resulting luminosity. Luminosity and pair-background results for the two designs at 1700 GeV are given in Table II. Here $\mathcal{L}_D \equiv$ actual luminosity per bunch with disruption and hour-glass effect taken into account; disruption (de)enhancement $H_D \equiv \mathcal{L}_D/\mathcal{L}_0$. For e^-e^-, the effect of disruption is of course a reduction in luminosity compared to the geometric luminosity, i.e. $H_D < 1$. L_D is the luminosity per second taking the number of bunches per train and the repetition rate into account. The average number of beamstrahlung photons produced per incoming beam particle is denoted by n_γ, and the average fractional beamstrahlung energy loss per particle by δ_E.

We show the luminosity spectra for both e^+e^- (dashed curves) and e^-e^- (solid curves) in Figure 1 for the low charge per bunch case. In each case, we show the spectrum with beamstrahlung only (red), and with both beamstrahlung and initial state radiation (blue) included.

The e^-e^- total luminosity is only about 1/4 the total e^+e^- luminosity, for both designs. The ratio of e^-e^- to e^+e^- luminosity within 0.5% of the peak energy is 35% for the low charge per bunch design and 40% for the high charge per bunch design. If one is interested in physics processes near the maximum energy achievable in a very high energy linear collider, the luminosity disadvantage of e^-e^- compared to e^+e^- is not quite as severe as when a broader energy range is usable.

Table II Luminosity and backgrounds results for two 1.7 TeV designs

	low charge	high charge
$\mathcal{L}_0$ [10^{33} m^{-2}]	2.66	42.4
$\mathcal{L}_D$ (e^+e^-) [10^{33} m^{-2}]	4.3	70.
$\mathcal{L}_D$ (e^-e^-) [10^{33} m^{-2}]	1.0	16.
$H_D \equiv \mathcal{L}_D/\mathcal{L}_0$ (e^+e^-)	1.6	1.7
$H_D \equiv \mathcal{L}_D/\mathcal{L}_0$ (e^-e^-)	0.38	0.38
L_D [10^{35}cm^{-2}sec^{-1}] (e^+e^-)	0.94	0.96
L_D [10^{35}cm^{-2}sec^{-1}] (e^-e^-)	0.22	0.22
δ_B(e^+e^-)	10.4%	23%
δ_B(e^-e^-)	7.3%	20%
$n_\gamma^{\rm anlyt}$ (e^+e^-)	1.1	2.2
n_γ (e^+e^-)	1.25	2.4
n_γ (e^-e^-)	0.9	1.9
$\Upsilon_{\rm avg}^{\rm anlyt}$ (e^+e^-)	0.54	1.2
total incoherent pairs (e^+e^-)	2.5×10^4	6.5×10^5
total incoherent pairs (e^-e^-)	7.0×10^3	1.9×10^5
Breit-Wheeler pairs (e^+e^-)	98	4.5×10^3
Breit-Wheeler pairs (e^-e^-)	20	1.2×10^3
Bethe-Heitler pairs (e^+e^-)	1.33×10^4	4.4×10^5
Bethe-Heitler pairs (e^-e^-)	3.6×10^3	1.3×10^5
Landau-Lifshitz pairs (e^+e^-)	1.12×10^4	2.0×10^5
Landau-Lifshitz pairs (e^-e^-)	3.4×10^3	5.9×10^4
total coherent pairs (e^+e^-)	1.02×10^5	9.8×10^7
total coherent pairs (e^-e^-)	2.4×10^4	7.2×10^7

Acknowledgments

I thank Ron Ruth and Clem Heusch for useful discussions and comments.

References

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