Luminosity and Site AC Power of the ILC

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Table 1 summarizes the ILC luminosities and relevant accelerator parameters. It is assumed that the baseline (namely, undulator-based) positron source is used. The numbers are taken from documents submitted to the European Particle Physics Strategy Update 2018-2020[1], its supplementary document[2] as well as the ILC technical design report[3].

Collision energy(GeV)	Lum.($/\mathrm{cm}^2\mathrm{s}$)	Pol.(P^-/P^+)	Nbunch×freq.	power(MW)
250 (baseline)	1.35	$\pm 0.8/\pm 0.3$	1312×5	129
250 (Nbunchx2)	2.7	$\pm 0.8/\pm 0.3$	2625×5	∼150
250 (above + 10 Hz)	5.4	$\pm 0.8/\pm 0.3$	2625×10	∼200
500 (baseline)	1.8	$\pm 0.8/\pm 0.3$	1312×5	163
500 (Nbunchx2)	3.6	$\pm 0.8/\pm 0.3$	2625×5	204
1000 (baseline)	3.6	$\pm 0.8/\pm 0.2$	2450×4	300
1000 (high L)	4.9	$\pm 0.8/\pm 0.2$	2450×4	300

Table 1: Summary of ILC accelerator parameters. For each operation mode, luminosity, polarizations of electron and positron, number of bunch per pulse and pulse frequency (Hz), and site AC power are shown. For the power requirements of the upgraded 250 GeV operations, see the descriptions in text.

1 Luminosity vs Energy

Figure 1. shows the luminosities of the ILC as functions of energy. Those of FCCee, CEPC[1], and CLIC are also shown[1]. The luminosities shown are per IP. For FCCee and CEPC, the CDRs assume 2 IPs each.

The baseline ILC luminosity at 250 GeV reflects what is described in Ref [4]. The difference from the TDR value[3] is the smaller horizontal beam size (by $1/\sqrt{2}$) due to smaller horizontal emittance (by 1/2). This increases the geometrical luminosity by $\sqrt{2}$ which is further enhanced by the larger pinching effect. The overall effect by squeezing the horizontal beam size increases the luminosity from the TDR value $0.8 \cdot 10^{34}/\mathrm{cm}^2\mathrm{s}$ to $1.35 \cdot 10^{34}/\mathrm{cm}^2\mathrm{s}$. The TDR value was a result of simple scaling from the 500 GeV parameters assuming the same horizontal emittance and β_x^*. The horizontal beam size at 500 GeV was limited by the beam background (the so-called pair background). Its effect is less at lower collision energies thereby allowing a smaller horizontal beam size at 250 GeV as verified by detector simulation studies[5]. For 1000 GeV, the high luminosity option corresponds to a smaller beam size achieved mostly by using a smaller β_x^* [3].

At 250 GeV and 500 GeV, the ILC luminosity can be doubled by doubling the number of bunches per pulse, from 1312 to 2625. This requires 50% more klystrons and modulators. The increase in construction cost was estimated to be 6% for the 500 GeV machine[3]. Even though further survey is necessary for the 250 GeV machine, it is expected that the cost

[1]For the CEPC luminosity at Z, the midpoint of the range given in the reference is used.

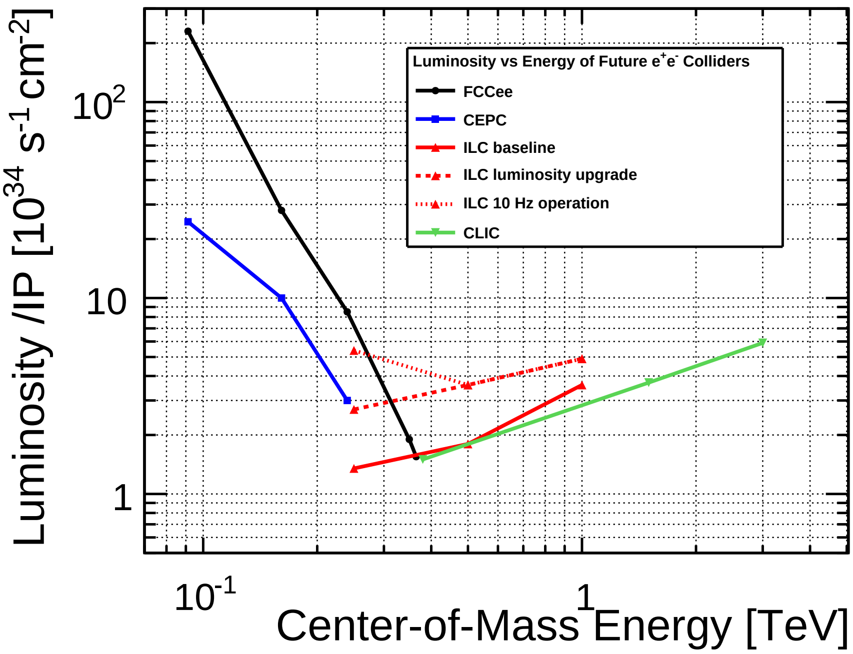

Figure 1: The luminosities of the ILC as functions of energy. Those of other e^+e^- colliders are also shown. The numbers are per IP, while the effect of polarization is not included.

increase be less than 10%. The doubling the number of bunches may or may not require the second positron ring in the damping ring in order to mitigate the electron cloud effect. The cost estimate above includes the second positron ring.

At 250 GeV, the collision rate may be doubled from 5 Hz to 10 Hz increasing the luminosity by another factor of two to $5.4 \cdot 10^{34}/\text{cm}^2\text{s}$. This requires additional cryogenic capacity and effectively the 500 GeV machine operated at 250 GeV.

2 Polarization

For the ILC, the beam polarizations are $P^-/P^+ = \pm 0.8/\pm 0.3$ for 250 GeV and 500 GeV. Polarization is a powerful probe for new physics and is considered to be one of the merits of linear colliders with respect to circular machines. The merit of polarization cannot be measured simply by quoting effective luminosity. Its effect also appears in the standard Effective Field Theory (EFT) fit to the Higgs couplings, however, and it was found that 2 fb^{-1} of polarized data ($P^-/P^+ = \pm 0.8/\pm 0.3$) is roughly equivalent to 5 fb^{-1} of unpolarized data[2]. The electron polarization mostly determines the statistical uncertainties while the positron polarization is important in constraining systematic uncertainties. The effect of polarization is not included in Figure 1.

3 Site AC Power Requirements

Site AC Power requirements as functions of collision energy are shown in Figure 2. The ILC and CLIC numbers are from Ref [2], and the numbers for FCCee and CEPC are taken from corresponding CDRs[6, 7]. The AC power requirement for doubling the number of bunches at 500 GeV is 204 MW with respect to 163 MW for the baseline; namely, $\sim 25\%$ increase.

Similar estimate for 250 GeV has not been performed. The fractional increase in AC power for doubling the number of bunches at 250 GeV, however, is expected to be less than 25%. The power requirement for the 10 Hz collision rate at 250 GeV is approximately the same as that for the 5 Hz operation at 500 GeV with the same number of bunches.

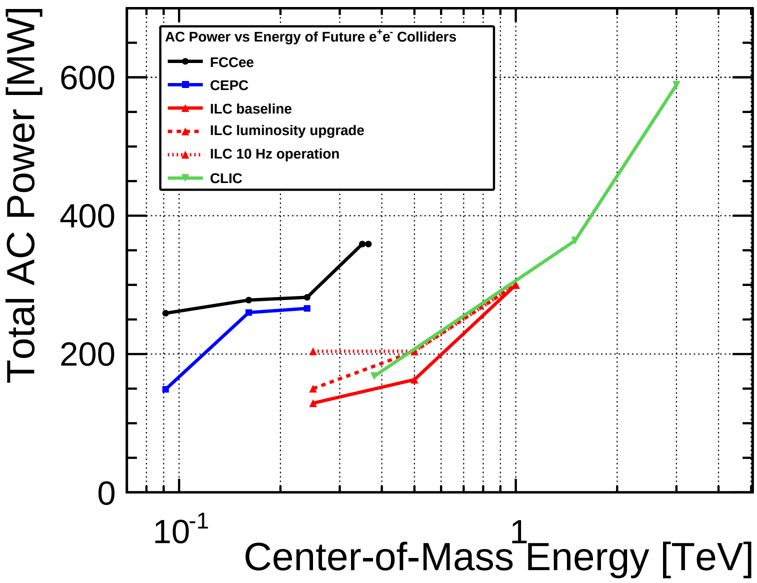

Figure 2: The site AC power requirements for future e^+e^- colliders.

References

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[4] L. Evans and S. Michizono [Linear Collider Collaboration], 'International Linear Collider Machine Staging Report 2017 - Addendum to the International Linear Collider Technical Design Report published in 2013', arXiv:1711.00568 [physics.acc-ph].

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