Table 1. Summary of Guinea-PIG runs for ILC-like operation at the Z ($\sqrt{s}$ = 91.2 GeV). The parameters that are varied are the bunch populations, N, the bunch length, σ_z, and correspondingly the beam energy spread. Runs also sometimes use different values for the vertical waist parameter, waist$_y$. The luminosity per bunch crossing, $L_{\rm BX}$, needs to be multiplied by the bunch collision rate ($f_{\rm rep}\ n_{\rm b}$). For the baseline ILC250 this factor is 3.7Hz $\times$ 1312/train = 4854.4 s^{-1}, leading to $L = 2.04 \times 10^{33}$ cm^{-2} s^{-1} for Run Z-120 (reasonably consistent with the initial nominal $L = 2.05 \times 10^{33}$ cm^{-2} s^{-1} and geometric luminosity of $L = 0.95 \times 10^{33}$ cm^{-2} s^{-1} quoted in Yokoya, Kubo, Okugi in arXiv:1908.08212). Also shown are two luminosity spectrum quality metrics, firstly, $f_{0.99}$, the traditional metric with the fraction of the luminosity above 99% of the nominal collision center-of-mass energy, and a new metric, $\sigma_{\rm eff}$, evaluated from one half of the central 68.4% (ie $\pm 1\sigma$ if it were a Gaussian) of the luminosity spectrum to the nominal center-of-mass energy. The three parts of the table show i) effect of lengthening the bunches and decreasing the beam energy spread, ii) the effect of simply increasing bunch populations wrt ILC nominal, and iii) the combined effect of the two types of change. The former change is less invasive, but not as potentially potent as the latter.

Run	N [10^{10} e]	σ_z [μm]	σ_E/E (%)	waist$_y$	$L_{\rm BX}$ [10^{29} cm^{-2}]	$f_{0.99}$ [%]	$\sigma_{\rm eff}$ [%]
Z-120	2.0	410	0.300	+0.9 σ_z	4.20	98.61	0.246
Z-124	2.0	455	0.270	+0.9 σ_z	4.22	98.67	0.224
Z-127	2.0	500	0.246	+0.9 σ_z	4.24	98.66	0.208
Z-141	2.0	615	0.200	+1.0 σ_z	4.40	98.26	0.183
Z-145	2.0	820	0.150	+1.0 σ_z	4.65	97.80	0.160
Z-120	2.0	410	0.300	+0.9 σ_z	4.20	98.61	0.246
Z-146	2.5	410	0.300	+0.9 σ_z	7.51	95.81	0.286
Z-147	3.0	410	0.300	+0.9 σ_z	12.44	90.44	0.384
Z-150	4.0	410	0.300	+0.9 σ_z	28.77	74.52	0.916
Z-145	2.0	820	0.150	+1.0 σ_z	4.65	97.80	0.160
Z-148	2.5	820	0.150	+0.9 σ_z	8.80	93.73	0.253
Z-149	3.0	820	0.150	+0.9 σ_z	14.75	87.93	0.407
Z-151	4.0	820	0.150	+0.9 σ_z	32.13	75.26	0.796

Caveats/Comments

- It is assumed that bunches can easily be lengthened by reducing the compression in the bunch compressor leading to a decrease in the linac beam energy spread.
- If one uses a higher bunch population, N, then given power considerations for a fixed available power, one will need to decrease the number of bunches to satisfy the constraint. Nevertheless, one can clearly get more luminosity this way (but not as much as implied naively by the $L_{\rm BX}$ numbers).
- The ILC sources are specified as $N = 3.0 \times 10^{10}$ in order to guarantee $N = 2.0 \times 10^{10}$ (the nominal design bunch charge) with a substantial safety margin for beam transport losses. Normally higher N is thought to be not so desirable as it impacts substantially the luminosity spectrum quality. Given that $\Gamma_Z/(2m_Z) = 1.35\%$, $\sigma_{\rm eff}$ values as high as 1.0% at the Z may be tolerable. It will certainly necessitate more attention to understanding/measuring the luminosity spectrum. Source designs for higher bunch charge can presumably be envisaged.
- The Guinea-PIG simulations show a feature with a secondary peak in the luminosity vs collision time plot in the higher disruption regime implied by higher bunch charge and longer bunch length. The simulations were run with the force_symmetric flag on. A vertical waist scan was done to optimize the luminosity for runs Z-120 and Z-141.
- One should look into whether the spent beam exits the interaction region OK and check how much detector backgrounds are increased.