

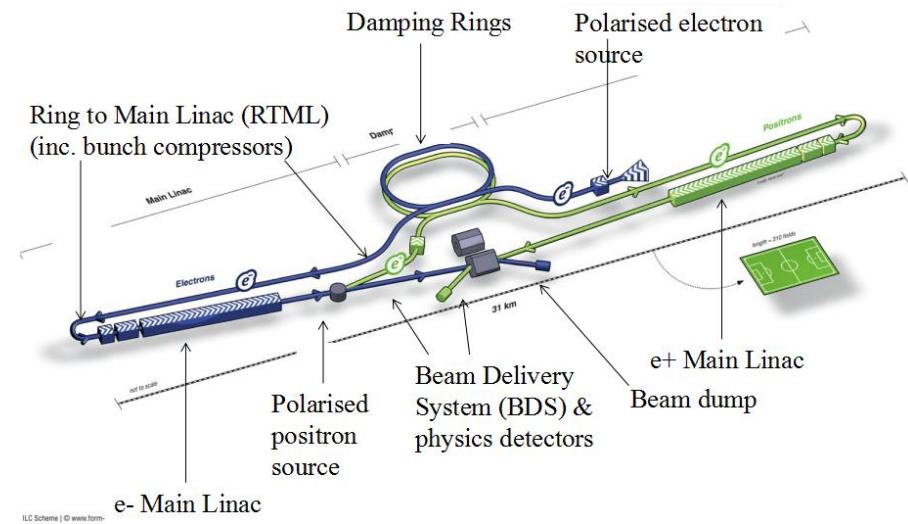
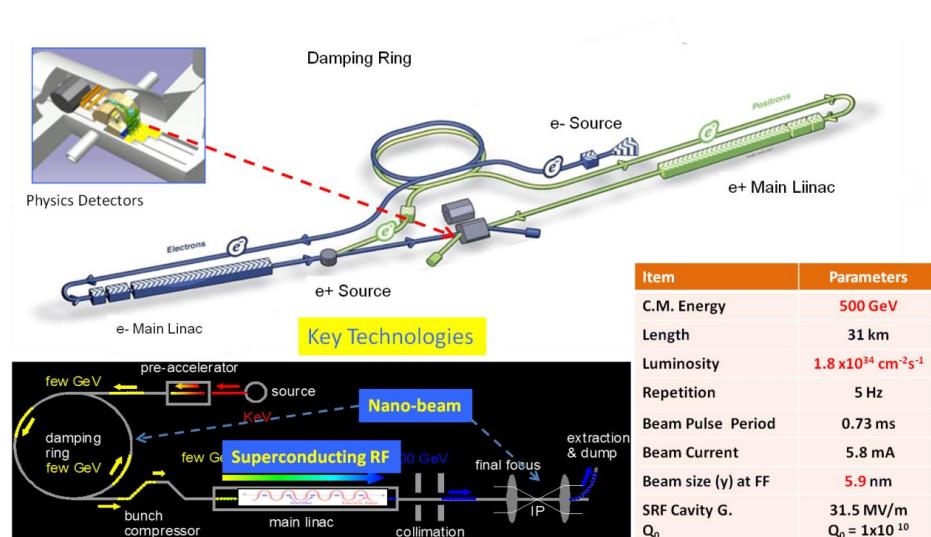
ILC High Luminosity Study at 250GeV

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Introduction-1



Introduction-2

- Compare with Yokoya's parameter set @ 125GeV
- Try to increase higher luminosities with higher back ground level
- Determine beam parameters start from the luminosity goal and the IP physical constraints

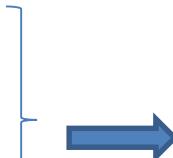
Given parameters: L_0 , δ_B , N_{had} , D_y , H_D , n_γ ...

Parameter calculation-1*

➤ Step 1:

$$\delta_B = \frac{2.6r_e^3 N_e^2 \gamma}{3\sigma_x^{*2} \sigma_z}$$

$$n_\gamma \approx \frac{2\alpha r_e N_e}{\sigma_x^* + \sigma_y^*} \approx \frac{2\alpha r_e N_e}{\sigma_x^*} \Rightarrow \frac{N_e}{\sigma_x^*} = \frac{n_\gamma}{2\alpha r_e}$$



$$\sigma_z = \frac{2.6r_e \gamma n_\gamma^2}{12\alpha^2 \delta_B}$$

➤ Step 2:

Assume

$$\left\{ \begin{array}{l} \beta_y^* = A\sigma_z \\ \frac{\beta_x^*}{\beta_y^*} = B \frac{\varepsilon_x^*}{\varepsilon_y^*} \end{array} \right.$$



$$R = \frac{\sigma_x^*}{\sigma_y^*} = \frac{\beta_x^*}{A\sqrt{B}\sigma_z}$$

$$\beta_x^* = \frac{3.47\pi\gamma r_e^3 N_{Had}}{\delta_B H_D \sigma_{\gamma\gamma \rightarrow Had} n_\gamma^2} A\sqrt{B}$$

$$N_{Had} = \frac{1}{4\pi} \left(\frac{N_e}{\sigma_x^*} \right)^2 R H_D n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had}$$

*Reference:

1. J. Gao, Habilitation à diriger des recherches, **LAL, LAL96-45**, Mai 1996, pp. 151-167
2. J. Gao, Parameter Choice for International Linear Collider (ILC), **HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS**, Vol. 30, Supp. Feb., 2006
3. J. Gao, Review of some important beam physics issues in electron positron collider designs, **Modern Physics Letters A**, Vol. 30, No. 11 (2015) 1530006 (20 pages)
4. D. Wang, J. Gao, K. Kubo, New Low Charge Parameters for ILC, ICFA BD newsletter, No. 54 Apr. 2011.

Parameter calculation-2*

➤ Step 3:

$$\left. \begin{aligned}
 \delta_B &= \frac{2.6r_e^3 N_e^2 \gamma}{3\sigma_x^{*2} \sigma_z} \\
 n_\gamma &\approx \frac{2\alpha r_e N_e}{\sigma_x^* + \sigma_y^*} \approx \frac{2\alpha r_e N_e}{\sigma_x^*} \\
 D_y &= \frac{2N_e r_e}{\gamma} \frac{\sigma_z}{\sigma_y (\sigma_x + \sigma_y)} \approx \frac{2N_e r_e}{\gamma} \frac{\sigma_z}{\sigma_x \sigma_y}
 \end{aligned} \right\} \quad \rightarrow \quad \sigma_y^* = \frac{2r_e N_e \sigma_z}{\gamma \sigma_x^* D_y} = \frac{r_e n_\gamma^3}{4.6 \delta_B \alpha^3 D_y}$$

➤ Step 4:

$$\sigma_x^* = R \sigma_y^*$$

$$\beta_y^* = A \sigma_z$$

$$\gamma \epsilon_x^* = \frac{\gamma \sigma_x^{*2}}{\beta_x^*} \quad \gamma \epsilon_y^* = \frac{\gamma \sigma_y^{*2}}{\beta_y^*}$$

$$N_e = \frac{n_\gamma}{2\alpha r_e} \sigma_x^*$$

Parameter calculation-3*

➤ Step 5:

$$\begin{aligned}
 L_0 &= \frac{f_{rep} N_b N_e^2}{4\pi \sigma_x^* \sigma_y^*} H_D \\
 N_{Had} &= \frac{1}{4\pi} \left(\frac{N_e}{\sigma_x^*} \right)^2 R H_D n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had} \\
 \Rightarrow f_{rep} N_b &= L_0 / \left(\frac{N_{Had}}{n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had}} \right)
 \end{aligned}
 \quad \longrightarrow \quad
 L_0 = f_{rep} N_b \left(\frac{N_{Had}}{n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had}} \right)$$

➤ Step 6:

$$P_b = f_{rep} N_b N_e E_{cm} \quad I_b = \frac{N_e}{\Delta T_b}$$

Disruption angle: $\theta = \frac{\sigma_{x,y}^*}{f_{x,y}} = \frac{2r_e N_e}{\gamma(\sigma_x^* + \sigma_y^*)}$

IP beam angle spread: $\theta_{x,y} = \sqrt{\frac{\epsilon_{x,y}}{\beta_{x,y}}}$

Some constraints

- Beam power/beam $\leq 2.65 \text{ MW}$
- Beam current $< 6\text{mA}$
- RF pulse length $\leq 1.6\text{ms}$ (MBK klystron)
- the out coming pair angle $< 1.1\text{mrad}$
- beam angle spread $\theta_y < 18.7\text{urad}$
- Horizontal emittance $5\text{nm} < \varepsilon_x < 10\text{nm}$

ILC 250GeV parameter comparison-1

ILC@250GeV	Yokoya	IHEP	IHEP-2
E _{cm} (GeV)	250	250	250
N _e	2.0×10^{10}	2.0×10^{10}	2.0×10^{10}
F _{rep} (Hz)	5	5	5
N _b	1312	1312	1312
Bunch separation (ns)	554	554	554
I _b (mA)	5.8	5.8	5.8
P _b (MW)/beam	2.65	2.62	2.62
β _x (mm)	13.0	11.0	9.0
β _y (μm)	410	464	469
γε _x (μm)	5.0	5.05	5.0
γε _y (nm)	35	37.5	37.5
σ _x /σ _y (nm)	515.5/7.66	476.5/8.4	428.9/8.5
σ _z (μm)	300	317.8	328
δ _B	0.024	0.0264	0.0315
n _γ	1.62	1.7	1.88
Dy	34.5	35.8	40.8
H _D	2.43	2.84	3.39
Disruption angle θ (rad)	0.00088	0.00095	0.00105
N _{had}	2.1	2.72	4.4
θx/θy (urad)	39.7/18.7	43.3/18.2	47.6/18.1
L ₀ (cm ⁻² s ⁻¹)	1.285×10^{34}	1.475×10^{34}	1.946×10^{34}

ILC 250GeV parameter comparison-2

Table 5-1: New beam parameters optimized for ILC250GeV.

			TDR	New
Center-of-mass energy	E_{CM}	GeV	250	500
Bunch population	N	e10	2	2
Bunch separation		ns	554	554
Beam current		mA	5.78	5.78
Number of bunches per pulse	Nb		1312	1312
Collision frequency		Hz	5	5
Electron linac rep rate		Hz	10	5
Beam power (2 beams)	P_B	MW	5.26	10.5
r.m.s. bunch length at IP	σ_z	mm	0.3	0.3
relative energy spread at IP (e-)	σ_E/E	%	0.188	0.124
relative energy spread at IP (e+)	σ_E/E	%	0.15	0.07
Normalized horizontal emittance at IP	ϵ_{nx}	μm	10	10
Normalized vertical emittance at IP	ϵ_{ny}	nm	35	35
Beam polarization (e-)		%	80	80
Beam polarization (e+)		%	30	30
Beta function at IP (x)	β_x	mm	13	11
Beta function at IP (y)	β_y	mm	0.41	0.48
r.m.s. beam size at IP (x)	σ_x	nm	729	474
r.m.s. beam size at IP (y)	σ_y	nm	7.66	5.86
r.m.s. beam angle spread at IP (x)	θ_x	μr	56.1	43.1
r.m.s. beam angle spread at IP (y)	θ_y	μr	18.7	12.2
Disruption parameter (x)	Dx		0.26	0.26
Disruption parameter (y)	Dy		24.5	24.6
Upsilon (average)	Υ		0.020	0.062
Number of beamstrahlung photons	n_γ		1.21	1.82
Energy loss by beamstrahlung	δ_{BS}	%	0.97	4.50
Geometric luminosity	L_{geo}	$\text{e}34/\text{cm}^2\text{s}$	0.374	0.751
Luminosity	L	$\text{e}34/\text{cm}^2\text{s}$	0.82	1.79
				1.35

Changes in IHEP new ILC 205GeV parameter

- Higher luminosity ($\sim 2 \times 10^{34}$)
- Smaller β_x^* but larger β_y^*
- Larger ϵ_y^* (37.5nm)
- Smaller σ_x^* but larger σ_y^*
- Longer σ_z^* (328um)
- Larger disruption factor: $D_y = 40.8$, $H_D = 3.4$
- Larger back ground: $n_\gamma = 1.88$, $N_{\text{had}} = 4.4$
- Larger beamstrahlung energy spread (0.0315)
- Larger out coming pair angle and larger horizontal beam angle spread at IP

Risks

- Smaller β_x^* : 13mm → 9 mm, larger beam angle spread θ_x : 39.7 → 47.6
 - Larger nonlinearity → harder FFS tuning
 - Larger beam size at QD0 → background
- Larger disruption factor D_y : 34.5 → 40.8
 - Collision stability
 - Harder feedback
- Stronger noise background level
 - n_γ : 1.62 → 1.88
 - N_{had} : 2.1 → 4.4
- Larger beamstrahlung energy spread δ_B : 0.024 → 0.0315
 - Uncertainty of the physics experiments
- Larger out coming pair angle: 0.88mrad → 1.05mrad
 - Interfere detection of small-angle events

Summary

luminosity	↑	Keeping power & cost	
βx^*	↓	harder FFS tuning SR background at QD0	
βy^*	↑	easier FFS design/tuning	
ϵy^*	↑	easier beam dynamics of ML	
σz^*	↑	easier bunch compressor	
disruption D_y	↑	harder feedback	
n_γ & N_{had}	↑	stronger noise background	
beamstrahlung energy spread	↑	uncertainty of the physics experiments	
out coming pair angle	↑	worse detection of small-angle events	

It is worthwhile to explore more possibilities to increase
the luminosity tolerated by the detector

Thank you for your attendtion