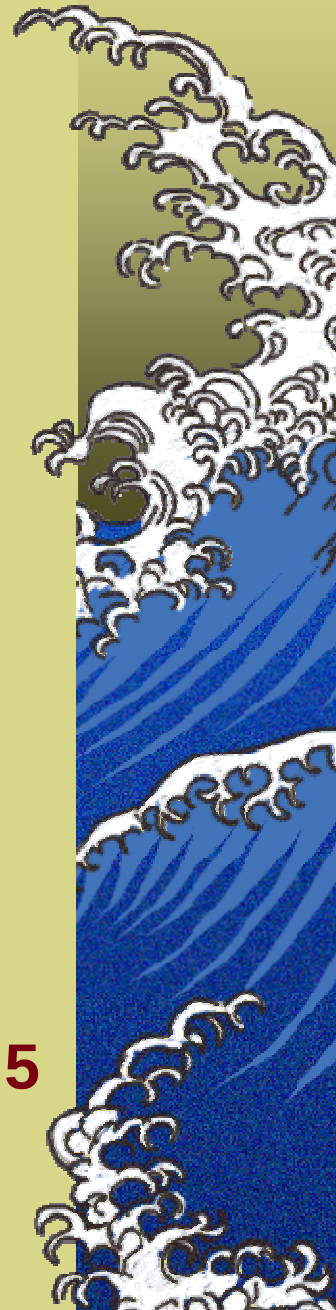


Parameter Choice for ILC (Very Low Charge Case)

J. GAO

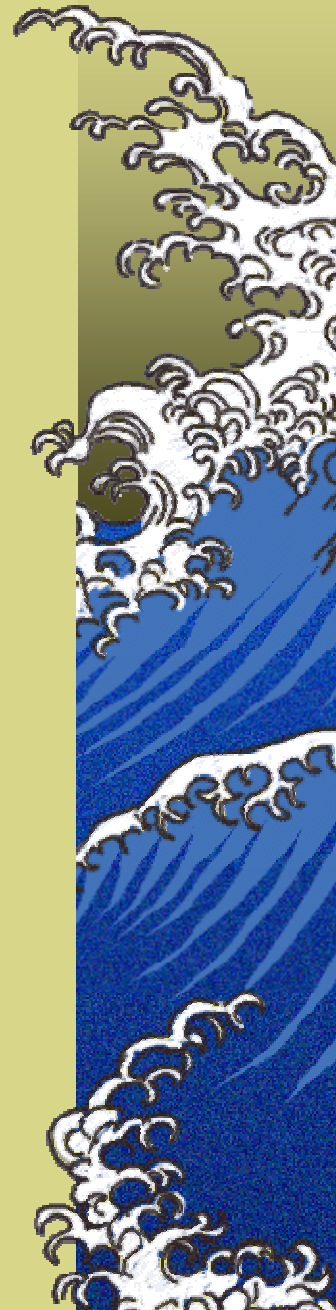
Institute of High Energy Physics
Chinese Academy of Sciences

Snowmass ILC Workshop, August 14-27, 2005



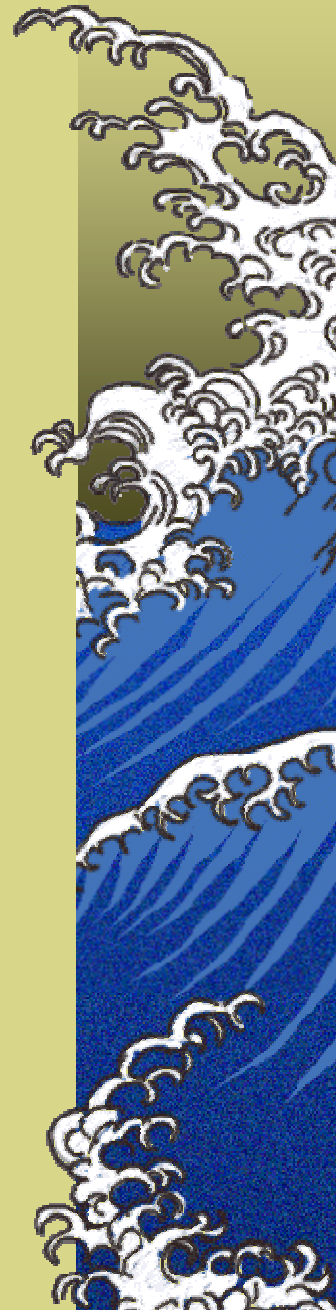
Content

- Design philosophy
- Parameter relations
- Parameter proposal for ILC from IHEP, China
- Conclusion



ILC Design Philosophy

- Required Colliding energy, luminosity
- Background noise (low) and beam quality (good)
- Operational condition (stable)
- Technical constrains (realisable)
- Damping ring (small space charge effect, reasonable circumference...)
- Total AC power (reasonable)



Parameter Relations (1)

Luminosity

$$L = \frac{f_{rep} N_b N_e^2}{4\pi\sigma_x\sigma_y} H_D$$

Disruption parameter

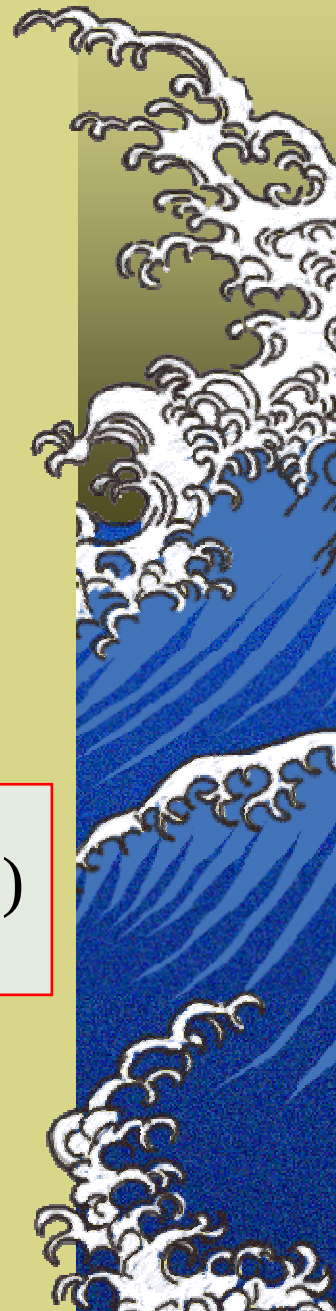
$$D_{x,y} = \frac{2r_e N_e \sigma_z}{\gamma\sigma_{x,y}(\sigma_x + \sigma_y)}$$

Beamstrahlung induced energy spread

$$\delta_B = \frac{2r_e^3 N_e^2 \gamma}{3\sigma_x \sigma_y \sigma_z} F(R)$$

$$F(R \gg 1) = 1.3 / R$$

$$R = \frac{\sigma_x}{\sigma_y}$$



Parameter Relations (2)

$$n_{\gamma} \approx \frac{2 \alpha r_e N_e}{\sigma_x}$$

$$R \gg 1$$

(per incident particle)

$$N_{Had} = \frac{1}{4\pi} \left(\frac{N_e}{\sigma_x} \right)^2 \frac{\sigma_x}{\sigma_y} H_D n_{\gamma}^2 \sigma_{\gamma\gamma \rightarrow Had} \quad (\text{per crossing})$$

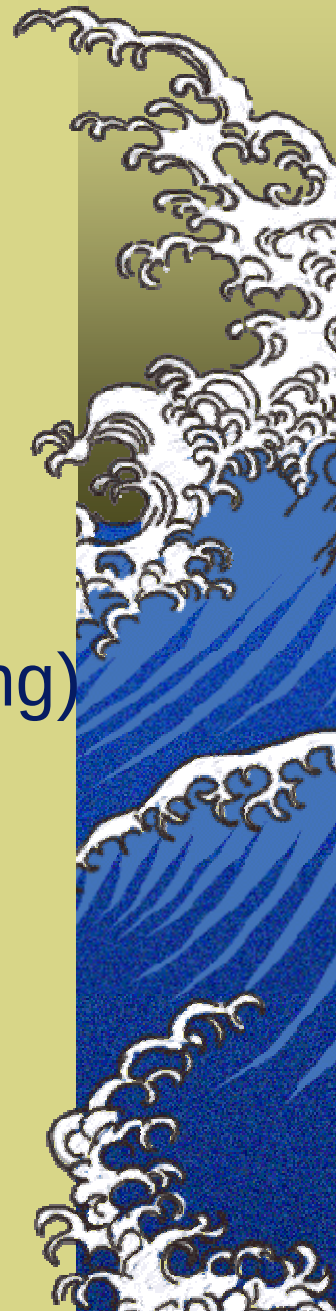
$$\sigma_{\gamma\gamma \rightarrow Had} = 4.2 \times 10^{-35} m^2$$

r_e

Classical radius of electron

N_e

Particle population inside a bunch



Parameter proposal for ILC from IHEP, China (1)

$$L = f_{rep} N_b \left(\frac{N_{had}}{n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had}} \right)$$

- $W_{cm}=500\text{GeV}$
- Luminosity $L = 2 \times 10^{34} \text{ cm}^{-2} \cdot \text{s}^{-1}$
- Beamstrahlung energy spread $\delta_B = 0.03$
- Mean number of beamstrahlung photons
- per Electron $n_\gamma = 0.8$
- Number of hardronic events per crossing $N_{Had} = 0.125$

(Low background noise)



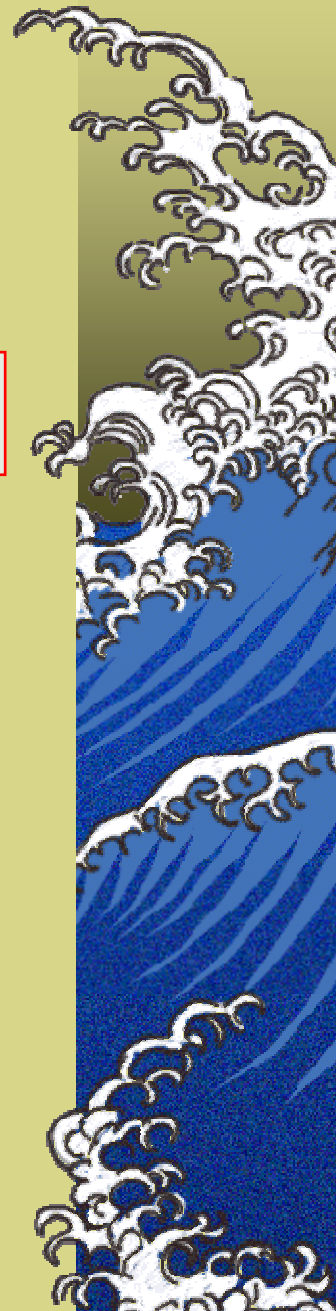
Parameter proposal for ILC from IHEP, China (2)

- *Disruption parameter* $D_y = 9$ $H_D = 1.5$

(Operationally stable, small kink instability)

- $R=103$ (flat beam)

- $N_e = 6 \times 10^9$ *Very Low Charge* (VLC) is good for many things



$$\frac{\sigma_x}{\sigma_y} = \frac{16\pi\alpha^2 r_e^2 N_{Had}}{H_D n_\gamma^4 \sigma_{\gamma\gamma \rightarrow Had}}$$

Parameter proposal for ILC from IHEP, China (3)

$$\sigma_x = \frac{\pi r_e^3 H_{had}}{2.6 \delta_B \alpha H_D n_\gamma \sigma_{\gamma\gamma \rightarrow Had}}$$

$$\sigma_x = 3.1 \times 10^{-7} m$$

$$\sigma_y = \frac{r_e n_\gamma^3}{41.5 \delta_B \alpha^3}$$

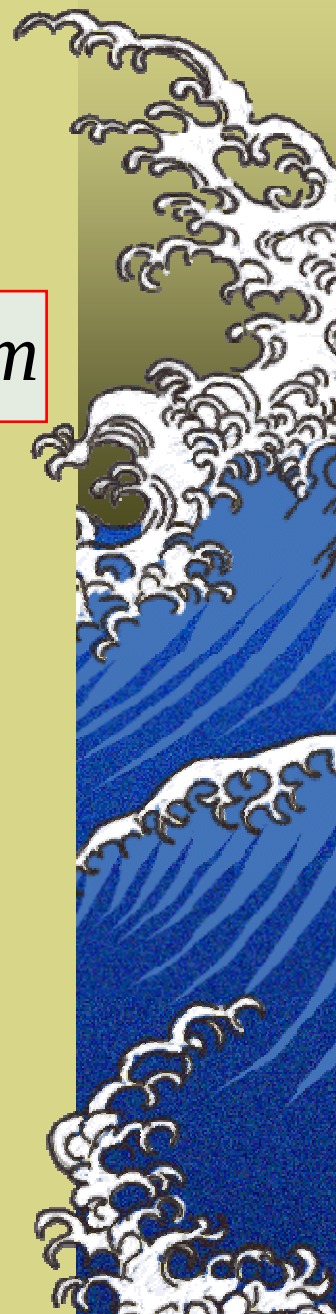
$$\sigma_y = 3 \times 10^{-9} m$$

$$\sigma_z = \frac{r_e n_\gamma^2 \gamma}{4.6 \delta_B \alpha^2}$$

$$\sigma_z = 1.2 \times 10^{-4} m$$

$$R = \frac{\sigma_x}{\sigma_y} = \frac{16\pi\alpha^2 r_e^2 N_{Had}}{H_D n_\gamma^4 \sigma_{\gamma\gamma \rightarrow Had}}$$

$$R = 103$$



Parameter proposal for ILC from IHEP, China (4)

- $$\beta_x = \frac{3.5\pi\gamma r_e^3 N_{Had}}{\delta_B H_D \sigma_{\gamma\gamma \rightarrow Had} n_\gamma^2} \quad \beta_x = 0.012 m$$

- $$\beta_y = \sigma_z / 0.75 \quad \beta_y = 1.6 \times 10^{-4} m$$

- $$\gamma\epsilon_x = \frac{\pi r_e^3 N_{Had}}{23.4\delta_B H_D \alpha^2 \sigma_{\gamma\gamma \rightarrow Had}} \quad \epsilon_{n,x} = 3.74 \times 10^{-6} m * rad$$

- $$\gamma\epsilon_y = \frac{0.75 n_\gamma r_e^3}{374 \delta_B \alpha^4} \quad \epsilon_{n,y} = 2.72 \times 10^{-8} m * rad$$

Parameter proposal for ILC from IHEP, China (5)

$$N_e = \frac{\pi r_e^2 N_{Had}}{5.2 \delta_B H_D \alpha^2 \sigma_{\gamma\gamma \rightarrow Had}}$$

$$N_e = 0.6 \times 10^{10}$$

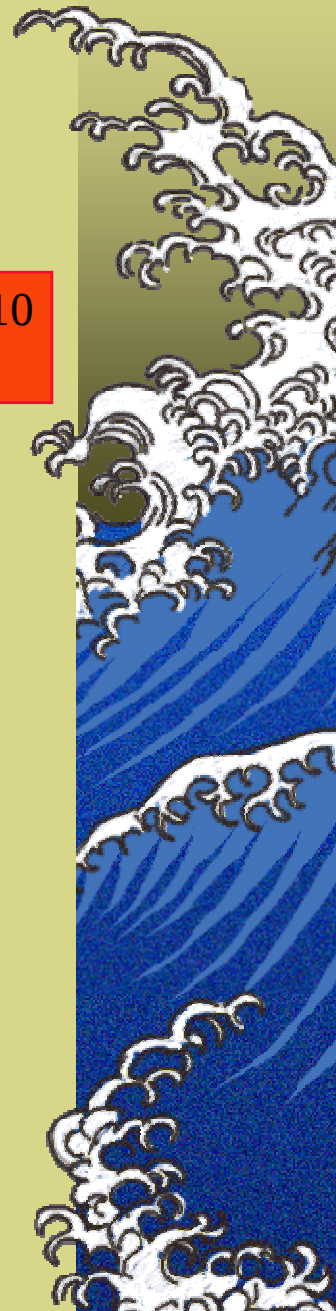
$$\frac{N_e}{\sigma_x} = \frac{n_\gamma}{2 \alpha r_e}$$

$$f_{rep} N_b = \frac{L n_\gamma^2 \sigma_{\gamma\gamma \rightarrow Had}}{N_{Had}}$$

$$f_{rep} N_b = 43010$$

$$P_b = \frac{\pi e W_{cm} r_e^2 n_\gamma^2 L}{10.4 H_D \delta_B \alpha^2}$$

$$P_b = 10.3 MW$$



Parameter proposal for ILC from IHEP, China (6)

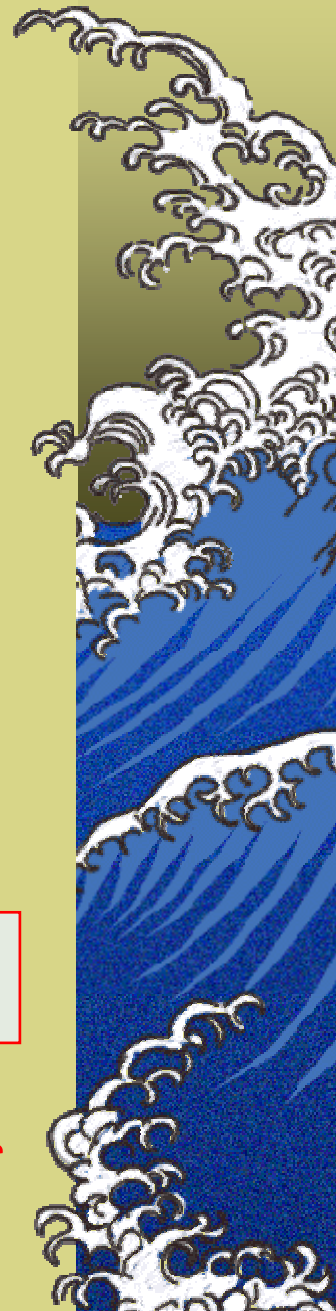
★ *If* $f_{rep} = 8 H_z$ *then* $N_b = 5376$

★ $T_{bunch-seperation-ring} = 10.5 ns$

★ $T_{bunch-seperation-linac} = 150 ns$

★ $I_{beam} = 6.45 mA$ $T_{beam} = 0.8 ms$

* *Assuming damping ring's circumference is 17km.*



Parameter proposal for ILC from IHEP, China (7)

Beam current $I_b = 6.45 \text{ mA}$

Beam pulse length **0.8ms**

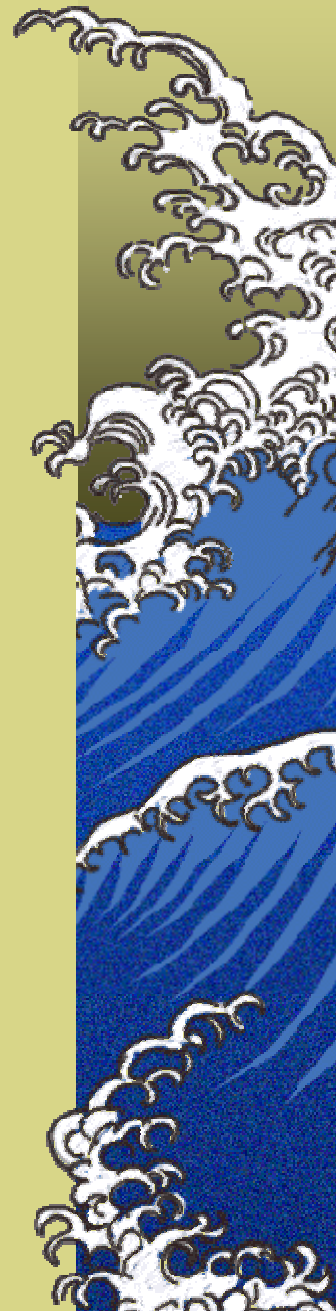
Peak power per cavity ($E_{ac}=35 \text{ MV/m}$)
is **234kW**

$Q_{ext} = 3.16 \times 10^6$ ($Q_0 = 6 \times 10^9$, or over
coupling factor **1.72**
with $Q_0 = 1 \times 10^{10}$)

Fill time **0.536ms**

Rf pulse length **1.34ms**

Total AC power is around 100MW

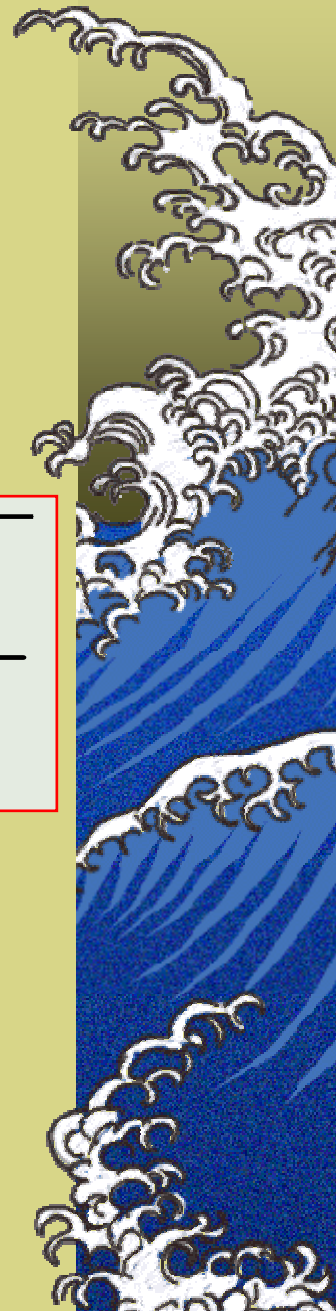


Parameter proposal for ILC from IHEP, China (8)

● Relation between the damping ring characteristic parameters and the beam parameters at IP:

$$\frac{\gamma_d^2 \sigma_{zd}}{L_d} \geq \frac{33 N_e \delta_B \alpha^3}{\pi^2 \xi_{sc,y} n_\gamma^2 r_e} \sqrt{\frac{H_D \sigma_{\gamma\gamma \rightarrow Had}}{N_{Had}}}$$

Where L_d is the damping ring circumference,
 σ_{zd} is the bunch length after bunch
 Lengthening, γ_d is the normalized damping
 ring's energy, and $\xi_{sc,y}$ is the tolerable **space**
charge tune shift.



Parameter proposal for ILC from IHEP, China (9)

If TESLA type damping ring is adopted

- Damping ring Length $L_d=17\text{km}$

- $E_d=5\text{GeV}$, $N_e=6\times 10^9$ damping time $\tau_y=28\text{ms}$

- Bunch length inside the damping ring:

$\sigma_{z,d} = 8\text{ m m}$ after bunch lengthening

- Space charge tune shift (y):

$$\xi_{sc,y} = - \frac{r_e N_e L_d}{(2\pi)^{3/2} (\epsilon_{n,x} \epsilon_{n,y})^{1/2} \beta^2 \gamma_d^2 \sigma_{z,d}}$$

$$|\xi_{sc,y}| = 0.075$$



Parameter choice for damping ring (10)

- Damping ring Length $L_d=17\text{km}$
- $E_d=5\text{GeV}$, $N_e=6\times 10^9$ damping time $\tau_y=28\text{ms}$
- Space charge tune shift (y):

$$\xi_{sc,y} = - \frac{r_e N_e L_d}{(2\pi)^{3/2} (\varepsilon_{n,x} \varepsilon_{n,y})^{1/2} \beta^2 \gamma_d^2 \sigma_{z,d}}$$

- Stored time: $\tau_{st}=200\text{ms}$
- Particle's lifetime due to nonlinear space charge forces

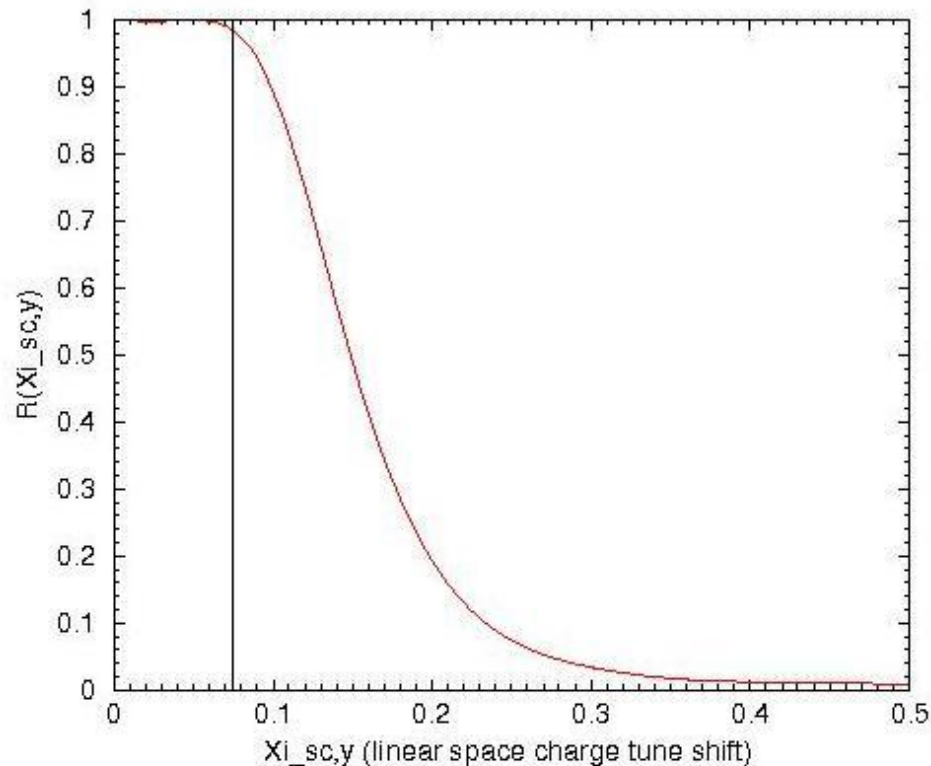
$$\tau_{sc,y}(\xi_{sc,y}) = \frac{\tau_y}{2} \left(\frac{3}{\sqrt{2\pi}\xi_{sc,y}} \right)^{-1} \exp \left(\frac{3}{\sqrt{2\pi}\xi_{sc,y}} \right)$$

- The relative particle's survival population

$$R(\xi_{sc,y}) = \exp \left(- \frac{\tau_{st}}{\tau_{sc,y}(\xi_{sc,y})} \right)$$

Parameter proposal for ILC from IHEP, China (11)

Particle survival
ratio at the
ejection



Space charge tune shift

	<i>Nominal</i>	<i>Low Q</i>	<i>Large Y</i>	<i>Low P</i>	<i>Very low Q (IHEP)</i>
<i>N/bunch</i>	<i>2E10</i>	<i>1E10</i>	<i>2E10</i>	<i>2E10</i>	<i>6E9</i>
<i>Nb/pulse</i>	<i>2820</i>	<i>5640</i>	<i>2820</i>	<i>1330</i>	<i>5376</i>
<i>Tsep(ns)</i>	<i>307.7</i>	<i>153.8</i>	<i>307.7</i>	<i>461.5</i>	<i>150</i>
<i>I_b (mA)</i>	<i>10.4</i>	<i>10.4</i>	<i>10.4</i>	<i>6.9</i>	<i>6.45</i>
<i>γ_εγ (E-8m)</i>	<i>4.0</i>	<i>3.0</i>	<i>8.0</i>	<i>3.5</i>	<i>2.72</i>
<i>β*x (mm)</i>	<i>20</i>	<i>12</i>	<i>10</i>	<i>10</i>	<i>12</i>
<i>β*y (mm)</i>	<i>0.4</i>	<i>0.2</i>	<i>0.4</i>	<i>0.2</i>	<i>0.16</i>
<i>σ_x (nm)</i>	<i>655</i>	<i>495</i>	<i>495</i>	<i>452</i>	<i>310</i>
<i>σ_y (nm)</i>	<i>5.7</i>	<i>3.5</i>	<i>8.1</i>	<i>3.8</i>	<i>3</i>
<i>σ_z (mm)</i>	<i>0.3</i>	<i>0.15</i>	<i>0.5</i>	<i>0.2</i>	<i>0.12</i>
<i>D_y</i>	<i>18.5</i>	<i>10.0</i>	<i>28.6</i>	<i>27.0</i>	<i>9</i>
<i>δB</i>	<i>0.022</i>	<i>0.018</i>	<i>0.024</i>	<i>0.057</i>	<i>0.03</i>
<i> ξ_{sc,y} </i>	<i>0.167</i>	<i>0.096</i>	<i>0.107</i>	<i>0.167</i>	<i>0.075</i>
<i>at 5 GeV</i>					

On damping ring energy and bunch length choice

If we take damping ring energy being 7GeV, $L=17\text{km}$, and bunch length after bunch lengthening effect $\sigma_z = 6\text{mm}$, and

$\xi_{sc,y} \approx 0.05$ the following equation will be satisfied by almost all Tor's parameter lists

$$\frac{\gamma_d^2 \sigma_{zd}}{L_d} \geq \frac{33 N_e \delta_B \alpha^3}{\pi^2 \xi_{sc,y} n_\gamma^2 r_e} \sqrt{\frac{H_D \sigma_{\gamma\gamma \rightarrow H a d}}{N_{H a d}}}$$

Conclusions

- 1) After compared “**Very Low Q**” (VLQ) case with Tor Raubenheimer’s low Q case parameter, we have a clear preference among different parameter lists, “**Very Low Q**” or “**Low Q**”.
- 2) If 17km damping ring is to be adopted, the damping ring’s energy should be **7 GeV** instead of 5 GeV. If short ring is adopted(say 6km), damping ring’s energy can be adjust accordingly (say 5GeV).
- 3) The space charge problem in the damping rings should be **intrinsically eliminated** by parameter choice instead of through coupling technique.

