A Simulation Study of E-driven ILC Positron Source

Masao KURIKI (Hiroshima University)
Introduction

- The design of the ILC positron source based on off-the-shelf components has been established.

- Further optimization was made to improve the performance and optimize the cost-effective system by,
  - Small beam size on target for better yield. (3.5 mm, 2.0 mm rms)
  - Lower drive beam energy for less cost. (4.8 GeV, 3.0 GeV)
  - Consider only the nominal parameter.

- Booster configuration (lattice) is modified to make the consistency.
20 of 0.48us pulses are handled with NC linacs operated in 300Hz.
100 of 300 pulses are actually fired.
The beam handling and format

Damping Ring

Positron Booster

\( T_b = 6.15 \text{ ns} \)

\( t_p = 480 \text{ ns} \)

33 bunches

81.6 ns 197 ns
Electron Driver

- 3.0 GeV Electron beam with 2.0 mm RMS beam size at the target.
- 2.4 nC bunch charge is giving 0.39 A beam loading.
- S-band Photo-cathode RF gun for the beam generation.
- 80 MW klystron-modulator drives 2 structures.
- The effective input power for each tube is 36 MW. 50 MV/tube.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2856</td>
<td>MHz</td>
</tr>
<tr>
<td>Shunt Impedance</td>
<td>60.0</td>
<td>MΩ/m</td>
</tr>
<tr>
<td>Aperture (2a)</td>
<td>25.3 - 18.4</td>
<td>mm</td>
</tr>
<tr>
<td>Group velocity</td>
<td>2.04 - 0.65</td>
<td>% of c</td>
</tr>
<tr>
<td>Filling time</td>
<td>0.83</td>
<td>μs</td>
</tr>
<tr>
<td>Attenuation</td>
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<td></td>
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<tr>
<td>Q value</td>
<td>13000</td>
<td>m</td>
</tr>
<tr>
<td>Length</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Cost Review of E-driven
- 60 + 4 (spare) of 3m S-band TW structures for the acceleration. The energy is 3.2 GeV.
- The lattice design was based on ATF linac, 4Q + 2RF(S) up to 600 MeV, 4Q+4RF(S) for other.

<table>
<thead>
<tr>
<th>Lattice</th>
<th># of cell</th>
<th>Cell length (m)</th>
<th>Section length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Q+2S</td>
<td>6</td>
<td>8.0</td>
<td>48.0</td>
</tr>
<tr>
<td>4Q+4S</td>
<td>13</td>
<td>14.4</td>
<td>172.8</td>
</tr>
</tbody>
</table>

- The total length is 235.2 + 20 m (RF gun + matching section).
Positron Capture Linac

- 36 L-band SW structures designed by J. Wang (SLAC) for the undulator capture section is employed.
- Two structures are driven by one 50 MW klystron.
- Surrounded by 0.5 T solenoid field.

<table>
<thead>
<tr>
<th>Structure Type</th>
<th>Simple π Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Number</td>
<td>11</td>
</tr>
<tr>
<td>Aperture 2a</td>
<td>60 mm</td>
</tr>
<tr>
<td>Q</td>
<td>29700</td>
</tr>
<tr>
<td>Shunt impedance r</td>
<td>34.3 MΩ/m</td>
</tr>
<tr>
<td>$E_0$ (8.6 MW input)</td>
<td>15.2 MV/m</td>
</tr>
</tbody>
</table>
Beam Loading in SW Linac

Single Cell Model: Simple, but not realistic

- The field in SW accelerator

\[
V(t) = \frac{2\sqrt{\beta} P_0 r L}{1+\beta} \left( 1 - e^{-\frac{t}{T_0}} \right) - \frac{rIL}{1+\beta} \left( 1 - e^{-\frac{t-t_b}{T_0}} \right)
\]

\[
T_0 = \frac{2Q}{\omega(1+\beta)}
\]

- The voltage becomes constant if

\[
t_b = -T_0 \ln \left( \frac{I}{2} \sqrt{\frac{rL}{\beta P_0}} \right)
\]

\[
V_0 = \frac{2\sqrt{\beta} P_0 r L}{1+\beta} \left( 1 - \frac{I}{2} \sqrt{\frac{rL}{\beta P_0}} \right)
\]
**Multi-Cell Model: More realistic**

*Time differential of the energy of the center cell,*

\[
\frac{dW_0}{dt} = -GV_0^2 - 2kQGV_0^2 + 2kQGV_1^2 + G_{wg}V_{in}^2 - G_{wg}(V_{in} - NV_0)^2 - IV_0,
\]

- **Power flow to next cells**
- **Input Power**
- **Beam loading**
- **Power loss**
- **Power flow from next cells**
- **WG loss**
Time differential of the voltage

\[ \frac{dV_0}{dt} = - \left[ \frac{(1 + N \beta) \omega}{2Q} + k\omega \right] V_0 + k\omega V_1 + \frac{\omega \beta}{Q} V_{in} - \frac{\omega RI}{2Q}. \]

For the intermediate cells,

\[ \frac{dV_1}{dt} = k\omega V_0 - \left( \frac{\omega}{Q} + 2k\omega \right) V_1 + k\omega V_2 - \frac{\omega RI}{Q}. \]

For the end cells,

\[ \frac{dV_5}{dt} = k\omega V_4 - \left( \frac{\omega}{Q} + k\omega \right) V_5 - \frac{\omega RI}{Q}. \]
11 linear simultaneous differential equations

\[
\frac{dV}{dt} = AV + C,
\]

\[
\begin{pmatrix}
\vdots \\
V_{-1} \\
V_0 \\
V_1 \\
V_2 \\
V_3 \\
V_4 \\
V_5 \\
\end{pmatrix}
= 
\begin{pmatrix}
a & \alpha & 0 & 0 & 0 & 0 & 0 \\
\alpha & a_0 & \alpha & 0 & 0 & 0 & 0 \\
0 & \alpha & a & \alpha & 0 & 0 & 0 \\
\vdots & 0 & 0 & \alpha & a & \alpha & 0 \\
0 & 0 & 0 & 0 & \alpha & a & \alpha \\
0 & 0 & 0 & 0 & 0 & 0 & \alpha \\
\end{pmatrix}
\begin{pmatrix}
V_{-1} \\
V_0 \\
V_1 \\
V_2 \\
V_3 \\
V_4 \\
V_5 \\
\end{pmatrix}
+ 
\begin{pmatrix}
\frac{-\omega R I}{Q} \\
\frac{\omega \beta}{Q} V_{in} - \frac{\omega R I}{2Q} \\
\frac{-\omega R I}{Q} \\
\frac{-\omega R I}{Q} \\
\frac{-\omega R I}{Q} \\
\frac{-\omega R I}{Q} \\
\frac{-\omega R I}{Q} \\
\end{pmatrix}
\]

\[
\begin{align*}
a_0 &= -\frac{(1 + N/\beta)\omega}{2Q} - k\omega \\
a &= -\frac{\omega}{2Q} - k\omega \\
a_5 &= -\frac{\omega}{2Q} - \frac{1}{2}k\omega \\
\alpha &= \frac{1}{2}k\omega
\end{align*}
\]
A can be diagonalized with a orthogonal matrix $R$ as

$$R^TAR = B = \begin{pmatrix}
\lambda_5 \\
\vdots \\
0 \\
0 \\
\lambda_0 \\
\vdots \\
\lambda_5
\end{pmatrix}$$

$$\frac{dR^TV}{dt} = R^TARR^TV + R^TC.$$

Because $B$ is diagonal, the equations for $V'$ are 11 independent linear differential equations,

$$\frac{dV'}{dt} = BV' + C'.$$

$$\frac{dV_i'}{dt} = \lambda_i V_i' + C_i'.$$
The solution for $V'$ is

$$V'_i(t) = \tau_i C'_i \left(1 - e^{-\frac{t}{\tau_i}}\right),$$

The solution for $V$ is expressed as a linear sum of the solution for $V'$

$$V = RV'.$$

$$V_i(t) = \sum_{j=0}^{5} R_{ij} \tau_j C'_j \left(1 - e^{-\frac{t}{\tau_j}}\right).$$
Acceleration Field

- $L=1.27 \text{ m (11 cells, L-band SW)}$
- $R=34e+6 \text{ Ohm/m}$
- $P_0=22.5 \text{ MW (50MW at klystron, 5MW wave guide loss)}$.
- $10.36 \text{ MV/tube with beta}=6.0$. 
RF Mode and Beam Loading Mode

- The total acceleration voltage is given as sum of the RF mode and the Beam-loading mode.
- They are not identical, but the dominant mode is common (τ = 1.22 us).
- The RF mode has the second dominant mode, but nothing for BL. This gives the imperfection on the BL compensation, but the effect is not large.

<table>
<thead>
<tr>
<th>RF mode</th>
<th>τ</th>
<th>0.020</th>
<th>0.006</th>
<th>0.011</th>
<th>0.068</th>
<th>1.22</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell -5</td>
<td>0.063</td>
<td>-0.003</td>
<td>-0.026</td>
<td>-0.232</td>
<td>2.078</td>
<td></td>
</tr>
<tr>
<td>cell -4</td>
<td>-0.013</td>
<td>0.010</td>
<td>0.034</td>
<td>-0.149</td>
<td>2.043</td>
<td></td>
</tr>
<tr>
<td>cell -3</td>
<td>-0.074</td>
<td>-0.016</td>
<td>0.015</td>
<td>-0.013</td>
<td>1.975</td>
<td></td>
</tr>
<tr>
<td>cell -2</td>
<td>-0.045</td>
<td>0.021</td>
<td>-0.039</td>
<td>0.127</td>
<td>1.873</td>
<td></td>
</tr>
<tr>
<td>cell -1</td>
<td>0.038</td>
<td>-0.026</td>
<td>-0.002</td>
<td>0.222</td>
<td>1.740</td>
<td></td>
</tr>
<tr>
<td>cell 0</td>
<td>0.075</td>
<td>0.030</td>
<td>0.040</td>
<td>0.238</td>
<td>1.578</td>
<td></td>
</tr>
<tr>
<td>cell 1</td>
<td>0.038</td>
<td>-0.026</td>
<td>-0.002</td>
<td>0.222</td>
<td>1.740</td>
<td></td>
</tr>
<tr>
<td>cell 2</td>
<td>-0.045</td>
<td>0.021</td>
<td>-0.039</td>
<td>0.127</td>
<td>1.873</td>
<td></td>
</tr>
<tr>
<td>cell 3</td>
<td>-0.074</td>
<td>-0.016</td>
<td>0.015</td>
<td>-0.013</td>
<td>1.975</td>
<td></td>
</tr>
<tr>
<td>cell 4</td>
<td>-0.013</td>
<td>0.010</td>
<td>0.034</td>
<td>-0.149</td>
<td>2.043</td>
<td></td>
</tr>
<tr>
<td>cell 5</td>
<td>0.063</td>
<td>-0.003</td>
<td>-0.026</td>
<td>-0.232</td>
<td>2.078</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BL mode</th>
<th>τ</th>
<th>0.020</th>
<th>0.006</th>
<th>0.011</th>
<th>0.068</th>
<th>1.22</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell 0</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.004</td>
<td>-0.710</td>
</tr>
<tr>
<td>cell 1</td>
<td>0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.698</td>
</tr>
<tr>
<td>cell 2</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.674</td>
</tr>
<tr>
<td>cell 3</td>
<td>0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.639</td>
</tr>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.594</td>
</tr>
<tr>
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<td>-0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.539</td>
</tr>
<tr>
<td>cell 6</td>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.594</td>
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<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.639</td>
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<tr>
<td>cell 8</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.674</td>
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<tr>
<td>cell 9</td>
<td>0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.698</td>
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<tr>
<td>cell 10</td>
<td>-0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.004</td>
<td>-0.710</td>
</tr>
</tbody>
</table>
No big difference on the no-load voltage, but 30 % less on the heavily loaded voltage,

<table>
<thead>
<tr>
<th>Voltage (MV)</th>
<th>One cell model</th>
<th>Multi-cell model</th>
<th>difference</th>
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<tbody>
<tr>
<td>No load</td>
<td>18.7</td>
<td>18.0</td>
<td>-0.7</td>
</tr>
<tr>
<td>Beam Loading (2.0A)</td>
<td>-8.6</td>
<td>-10.8</td>
<td>-2.2</td>
</tr>
<tr>
<td>Total</td>
<td>10.1</td>
<td>7.2</td>
<td>-2.9</td>
</tr>
</tbody>
</table>

The beam loading compensation works well. Flatness is less than 0.1%.
Capture Simulation

- 1000 electrons on target by GEANT 4.
- The positron is decelerated and bunched at the acceleration phase by phase-slipping.
- Positrons with a large z (longitudinal position) are not captured by the final acceptance. This is not the case for δ.

Capture Linac exit

Chicane exit
Booster

- A first half is implemented by L-band acc. and the last half is by S-band.
- 50MW L-band Klystron drives two L-band acc. (2a = 34 mm).
- 80MW S-band Klystron drives two S-band acc. (2a = 20 mm).
- The gradient at 0.78 A (4.8nC/bunch) beam loading is assumed.
- The beam loading compensation and its accuracy determine the accelerator gradient.
Beam-loading in TW Linac

- Transient beam-loading is compensated by Amplitude Modulation.
- Acceleration voltage by a flat RF,

\[ V(t) = E_0 L + \frac{r_0 LI_0}{2(1 - e^{-2\tau})} \left[ \frac{\omega}{Q} e^{-2\tau (t - t_f)} - 1 + e^{2\tau - \frac{\omega}{Q} t} \right]. \]
Beam Loading Compensation with AM

Laplace transformation of TW accelerator voltage $V(s)$ is

$$V(s) = \frac{\omega L}{Q(1 - e^{-2\tau})s + \omega/Q} \frac{1}{E(s)} \left(1 - e^{-(s+\omega/Q)t_f}\right)$$

$$-\frac{\omega r_0 L}{2Q(1 - e^{-2\tau})} \frac{I_0}{s^2} e^{-st_f} \left[1 - e^{-\omega t_f/Q} - \frac{\omega(1 - e^{-st_f-2\tau})}{Q(s + \omega/Q)}\right],$$

where $E(s)$ is the Laplace transformation of applied voltage (power). $E(s)$ is determined to cancel $s$ ($t$) dependence of $V(s$ or $t)$. 
Step Modulation

\[ E(t) = E_0 U(t) + E_1 U(t - t_f), \]
\[ E(s) = \frac{E_0}{s} + \frac{E_1}{s} e^{-s t_f}, \]
\[ V(t) = E_0 L + \frac{L E_1}{1 - e^{-2\tau}} \left( 1 - e^{-\frac{\omega}{Q}(t-t_f)} \right) - \frac{r_0 LI_0}{2(1 - e^{-2\tau})} \left[ -\frac{\omega}{Q} e^{-2\tau} (t - t_f) + 1 - e^{-\frac{\omega}{Q}(t-t_f)} \right] \]

\[ E_1 = \frac{r_0 I_0}{2} \left( \frac{2\tau e^{-2\tau}}{1 - e^{-2\tau}} - 1 \right) \]
Saw Modulation

\[ E(t) = E_0 U(t) + E_1 U(t - t_f) + \frac{E_2}{t_f} (t - t_f) U(t - t_f) \]

\[ E(s) = \frac{E_0}{s} + \frac{E_1}{s} e^{-s t_f} + \frac{E_2}{t_f s^2} e^{-s t_f} \]

\[ V(t) = E_0 L + \frac{L}{1 - e^{-2\tau}} \left( E_1 - \frac{Q}{\omega} E_2 \right) \left( 1 - e^{-\frac{\omega}{Q} (t - t_f)} \right) + \frac{L e^{-2\tau}}{1 - e^{-2\tau}} E_2 (t - t_f) \]

\[ - \frac{r_0 L I_0}{2(1 - e^{-2\tau})} \left[ -\frac{\omega}{Q} e^{-2\tau} (t - t_f) + 1 - e^{-\frac{\omega}{Q} (t - t_f)} \right], \]

\[ E_1 = \frac{r_0 I_0}{2} (1 - e^{-2\tau}), \]

\[ E_2 = -\frac{r_0 I_0 \omega}{2} Q e^{-2\tau}, \]
Actual Compensation (Trade off)

- Saw modulation is ideal, but it requires a high peak power.
- Step modulation is a replacement, but it has an imperfection (energy spread).
- If $t_p << t_f$, an optimization for $P_0$ gives smaller energy spread.
2m L-band TW structure (Positron Booster)

- 2m L-band (1298 MHz) designed for KEKB injector.
- Saw modulation: 22.5 MW input with 0.78 A BL gives 14.41 MV/tube (2m)
- The energy spread is zero (ideal), but the voltage is very limited.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1298</td>
<td>MHz</td>
</tr>
<tr>
<td>Shunt Impedance</td>
<td>47.2</td>
<td>MΩ/m</td>
</tr>
<tr>
<td>Aperture (2a)</td>
<td>39.4 - 35.0</td>
<td>mm</td>
</tr>
<tr>
<td>Group velocity</td>
<td>0.61 - 0.39</td>
<td>% of c</td>
</tr>
<tr>
<td>Filling time</td>
<td>1.32</td>
<td>μs</td>
</tr>
<tr>
<td>Attenuation</td>
<td>0.261</td>
<td></td>
</tr>
<tr>
<td>Q value</td>
<td>20000</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>2.0</td>
<td>m</td>
</tr>
</tbody>
</table>
Step Modulation

- Step modulation: $19.54 \pm 0.51$ MV.
- If $P_0$ is optimized (lowered) for lower energy spread, $17.38 \pm 0.17$ MV.
- The gradient depends on acceptable energy spread and we took $17.38$ MV as our working assumption.
S-band TW accelerator (Positron Booster)

- 2m S-band (2856MHz) accelerator designed for KEKB injector.
- Saw modulation: 22.5 MW input with 0.78 A BL gives 23.03 MV/tube (2m).
- Step modulation gives 29.42 ± 0.69 MV.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2856</td>
<td>MHz</td>
</tr>
<tr>
<td>Shunt Impedance</td>
<td>57.8</td>
<td>MΩ/m</td>
</tr>
<tr>
<td>Aperture (2a)</td>
<td>24.28 - 20.3</td>
<td>mm</td>
</tr>
<tr>
<td>Group velocity</td>
<td>1.24 (av)</td>
<td>% of c</td>
</tr>
<tr>
<td>Filling time</td>
<td>0.507</td>
<td>μs</td>
</tr>
<tr>
<td>Attenuation</td>
<td>0.333</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>1.959</td>
<td>m</td>
</tr>
</tbody>
</table>
Optimization

- Step modulation gives 29.42 ± 0.69 MV.
- P0 optimization does not work, because tf~tp.
- Instead, semi-Step-saw modulation was made with the peak power which is less than that for the perfect compensation.
- The accelerator voltage is determined by the acceptable energy spread.
What is the acceptable energy spread?

- z -d phase space distribution after booster has a larger energy spread by RF curvature.

- Imperfection of the compensation gives additional energy spread.

- The effect is not expected large, because the energy spread is compensated by ECS further.

- As our working assumption, 1% additional energy spread does not affect the yield.

- If larger energy spread is acceptable, the accelerator voltage is gained.
Booster Configuration

- Lattice design was made by Y. Seimiya, but the accelerator voltage was larger than our assumptions.

- We change the cell number for each section giving a close energy at the section end.

<table>
<thead>
<tr>
<th>Lattice configuration</th>
<th>Number of lattice cells</th>
<th>Accelerating energy</th>
<th>energy at the exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Q + 1L</td>
<td>6</td>
<td>240 MeV</td>
<td>490 MeV</td>
</tr>
<tr>
<td>4Q + 2L</td>
<td>12</td>
<td>960 MeV</td>
<td>1450 MeV</td>
</tr>
<tr>
<td>4Q + 4L</td>
<td>8</td>
<td>1280 MeV</td>
<td>2730 MeV</td>
</tr>
<tr>
<td>4Q + 4S</td>
<td>14</td>
<td>2240 MeV</td>
<td>4970 MeV</td>
</tr>
</tbody>
</table>

Seimiya's design

<table>
<thead>
<tr>
<th>Lattice configuration</th>
<th>Number of lattice cells</th>
<th>Accelerating energy</th>
<th>energy at the exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Q + 1L</td>
<td>14</td>
<td>243 MeV</td>
<td>493 MeV</td>
</tr>
<tr>
<td>4Q + 2L</td>
<td>28</td>
<td>974 MeV</td>
<td>1467 MeV</td>
</tr>
<tr>
<td>4Q + 4L</td>
<td>19</td>
<td>1321 MeV</td>
<td>2788 MeV</td>
</tr>
<tr>
<td>4Q + 4S</td>
<td>23</td>
<td>2345 MeV</td>
<td>5133 MeV</td>
</tr>
</tbody>
</table>

Scaled design
Booster Configuration (large dE)

If 3% energy spread is acceptable (no significant impact on yield), the configuration is

<table>
<thead>
<tr>
<th>Lattice configuration</th>
<th>Number of lattice cells</th>
<th>Accelerating energy</th>
<th>energy at the exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Q + 1L</td>
<td>12</td>
<td>234 MeV</td>
<td>484 MeV</td>
</tr>
<tr>
<td>4Q + 2L</td>
<td>24</td>
<td>936 MeV</td>
<td>1420 MeV</td>
</tr>
<tr>
<td>4Q + 4L</td>
<td>17</td>
<td>1326 MeV</td>
<td>2746 MeV</td>
</tr>
<tr>
<td>4Q + 4S</td>
<td>20</td>
<td>2352 MeV</td>
<td>5098 MeV</td>
</tr>
</tbody>
</table>

Table 11: Section length of the booster giving 574.4 m total.
ECS Section

- ECS design $R_{56}=1.2m$ and $R_{65}=-0.8$.
- Required voltage is 122 MeV, 3 tubes are enough.
- Beam-loading (phase-shift) can be compensated by an artificial phase-shift of drive RF.
- If it does not work, we need an additional RF for compensate the phase shift., 4 tubes.

ECS optimization

![Graphs showing ECS optimization with different angles](image-url)
Impact of Lattice Modification

- The booster configuration (acceleration field and lattice) are modified.
- The yield is re-evaluated with the modified booster configuration.

<table>
<thead>
<tr>
<th></th>
<th>Seimiya</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td># of RF (L-band)</td>
<td>62</td>
<td>144</td>
</tr>
<tr>
<td># of RF (S-band)</td>
<td>56</td>
<td>92</td>
</tr>
<tr>
<td>Voltage (L-Band)</td>
<td>40 (MV/tube)</td>
<td>17.38 (MV/tube)</td>
</tr>
<tr>
<td>Voltage (S-Band)</td>
<td>40 (MV/tube)</td>
<td>25.49 (MV/tube)</td>
</tr>
<tr>
<td>Booster Length</td>
<td>323.6 (m)</td>
<td>653.6 (m)</td>
</tr>
</tbody>
</table>
Twiss パラメータ $\beta$ の比較

清宮さんの設計

$\sqrt{\beta_x}$：青
$\sqrt{\beta_y}$：赤

今回変更した設計

$\sqrt{\beta_x}$：青
$\sqrt{\beta_y}$：黄
Twiss Parameter

Seimiya's
\[ \sqrt{\beta_x}: \text{青} \]
\[ \sqrt{\beta_y}: \text{赤} \]

New
\[ \sqrt{\beta_x}: \text{青} \]
\[ \sqrt{\beta_y}: \text{黄} \]
### Impact on Yield

<table>
<thead>
<tr>
<th></th>
<th>変更前</th>
<th>変更後</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>2.1</td>
<td>2.0</td>
</tr>
<tr>
<td>Total Energy</td>
<td>5.0070(GeV)</td>
<td>5.0917(GeV)</td>
</tr>
</tbody>
</table>

- Yield is decreased by 5%.
- The reason is now under investigation, but it might be a pseudo effect.
- The aperture is set at the end of tubes. The low gradient and the long booster increased the density of checkpoints.

- The total energy is increased. (We set the margin)
The yield is decreased by 5%, but the number of positrons in booster is decreased by 10% giving a low beam loading.

Further optimization might be possible.
Summary

- E-driven ILC positron source is optimized for nominal parameter (staging).
- RF configuration is modified based on a realistic RF source design.
- The beam loading compensation for SW and TW were studied.
- For SW, it works effectively well.
- For TW, semi-perfect methods for L-band and S-band are considered.
- Lattice is re-designed giving 2.0 yield. The change is not considered real.
Total Length

Electron Driver 255.2 m

Positron Booster 658 (574m)

Target Capture Linac Chicane 59m

ECS 75.2m

Total : 1047(963) m