Interaction Region & BDS

T. Tauchi, Linear Collider 测定器検討会, 19 August, 2003

- Estimation of Background in Detectors -
- Nanometer Stabilization -
Beam Parameters
Beam Delivery System
Collimation
Interaction Region
Dump Line
Instrumentations
## Beam Parameters

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center-of-mass energy</td>
<td>$E_{CM}$</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Linac repetition rate</td>
<td>$f_{rep}$</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>Number of particles / bunch</td>
<td>$N$</td>
<td>0.75</td>
<td>$\times 10^{10}$</td>
</tr>
<tr>
<td>Number of bunches / pulse</td>
<td>$n_b$</td>
<td>192</td>
<td></td>
</tr>
<tr>
<td>Bunch separation</td>
<td>$t_b$</td>
<td>1.4</td>
<td>ns</td>
</tr>
<tr>
<td>Bunch train length</td>
<td>$n_b t_b$</td>
<td>268.9</td>
<td></td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>110</td>
<td>$\mu$m</td>
</tr>
<tr>
<td>Beam power / beam</td>
<td>$P_B$</td>
<td>8.65</td>
<td>11.53</td>
</tr>
<tr>
<td>Unloaded gradient</td>
<td>$E_{NL}$</td>
<td>64.8</td>
<td></td>
</tr>
<tr>
<td>Loaded gradient$^1$</td>
<td>$E_L$</td>
<td>49.8</td>
<td></td>
</tr>
<tr>
<td>Effective gradient$^2$</td>
<td>$E_{eff}$</td>
<td>44.1</td>
<td></td>
</tr>
<tr>
<td>Average RF phase</td>
<td>$\langle \phi \rangle$</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Linac length / beam$^3$</td>
<td></td>
<td>7.25</td>
<td>14.11</td>
</tr>
<tr>
<td>Beam delivery length / beam</td>
<td></td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Total site AC power</td>
<td></td>
<td>233</td>
<td>300</td>
</tr>
<tr>
<td>Normalized emittance at DR exit</td>
<td>$\gamma \epsilon_x/\gamma \epsilon_y$</td>
<td>3.0 / 0.02</td>
<td>$\times 10^{-6}$ m-rad</td>
</tr>
<tr>
<td>Normalized emittance at IP</td>
<td>$\gamma \epsilon_x^* / \gamma \epsilon_y^*$</td>
<td>3.6 / 0.04</td>
<td>3.6 / 0.04</td>
</tr>
<tr>
<td>Beta function at IP</td>
<td>$\beta^<em>_y / \beta^</em>_y$</td>
<td>8 / 0.11</td>
<td>13 / 0.11</td>
</tr>
<tr>
<td>Beam size at IP</td>
<td>$\sigma_z^* / \sigma_y^*$</td>
<td>243 / 3.0</td>
<td>219 / 2.1</td>
</tr>
<tr>
<td>Full crossing angle</td>
<td>$\theta_c$</td>
<td>7</td>
<td>mrad</td>
</tr>
<tr>
<td>Disruption parameters</td>
<td>$D_x / D_y$</td>
<td>0.16 / 13.1</td>
<td>0.10 / 10.3</td>
</tr>
<tr>
<td>Pinch enhancement factor</td>
<td>$H_D$</td>
<td>1.49</td>
<td>1.42</td>
</tr>
<tr>
<td>Average beamstrahlung parameter</td>
<td>$\Upsilon$</td>
<td>0.13</td>
<td>0.28</td>
</tr>
<tr>
<td>Average energy loss by beamstrahlung</td>
<td>$\delta_B$</td>
<td>4.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Number of photons / electron</td>
<td>$n_v$</td>
<td>1.26</td>
<td>1.30</td>
</tr>
<tr>
<td>Nominal luminosity$^4$</td>
<td>$\mathcal{L}_0$</td>
<td>17.7</td>
<td>18.5</td>
</tr>
<tr>
<td>Peak luminosity$^4$</td>
<td>$\mathcal{L}$</td>
<td>25.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

1) Includes single- and multi-bunch loading.
2) Includes cos $\phi$ and 8% overhead for BNS, failure and feedback.
3) Includes diagnostics sections.
4) $\mathcal{L}_0 = f_{rep} n_b N^2 / 4\pi \sigma_x^* \sigma_y^*$.
BDS Layout

4.9 Beam Delivery Section
4.9.1 Introduction

The electron and positron beams, after passing through the main linac, are divided into different sections:
- **Bypass**: Allows for a path for the beams to bypass the diagnostics.
- **Switchyard & diagnostics**: Point where beams can be monitored and tested.
- **Collimator**: Filters the beams, ensuring they are properly shaped.
- **Final Focus System**: Precisely focuses the beams for collision.
- **IP1, IP2**: Interaction Points for collision of beams.
- **Beam Dump**: Safely disposes of the beams after collision.

- **7 mrad**: Angle at IP1.
- **30 mrad**: Angle at IP2.

JLC Project Report, Revised, March 12, 2003, 3:21 P.M.
The design of the JLC beam delivery system much resembles that of NLC, because of the similarity in the design of the NLC beam delivery system with only minor changes.

BDS for IP1

A.Seryi, P.Raimondi, P.T. et.al.(NLC)
S.Kuroda (KEK)

1434 m

4.3 m

3mrad

Dump

IP

Bend

Sext,Oct, Dec

E-slit

Absorber

Quad

Spoiler,Absorber

Roadmap Report, 2003

3PBENBQ3FQPSU

222 Chapter 4. Accelerator
Spoilers / Absorbers  Sext, Oct, Decapole magnets

collimator  FFS
Collimation: Muon Attenuators

T. Ohgaki

Collimator (Spoiler/Absorber)

ε^+ beam

60 cm^2 → 156 cm surrounded by sand stone

20 cm^2 → 36 cm

120 m → 20 ~ 77 m
(meam range of a 250GeV muon)
### Collimation: Apertures

#### Material and size of Components

![Diagram of beam collimation components](image)

**Beam**
- Fe: 30 X 30 cm box

**Components**
- **Bend**
- **Quad, Sext, Oct, Dec**
- **Spoiler / Absorber**
- **Cu**

<table>
<thead>
<tr>
<th>Name</th>
<th>Gap X [mm]</th>
<th>Gap Y [mm]</th>
<th>Length [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1,3</td>
<td>0.6(20xₜₜₜ)</td>
<td>0.6(455ₜₜₜₜₜ)</td>
<td>0.858(0.6Xₜₜₜₜ)</td>
</tr>
<tr>
<td>SP2,4</td>
<td>0.6(12xₜₜₜₜₜₜₜ)</td>
<td>0.6(53ₜₜₜₜₜₜₜ)</td>
<td>0.858(0.6Xₜₜₜₜ)</td>
</tr>
<tr>
<td>SP5</td>
<td>0.86(22xₜₜₜₜₜₜₜ)</td>
<td>0.6(530ₜₜₜₜₜₜₜₜ)</td>
<td>0.858(0.6Xₜₜₜₜ)</td>
</tr>
<tr>
<td>SPE</td>
<td>3.2(80xₜₜₜₜₜₜₜ)</td>
<td>8(145ₜₜₜₜₜₜₜₜ)</td>
<td>0.858(0.6Xₜₜₜₜ)</td>
</tr>
<tr>
<td>AB2,4</td>
<td>1(40xₜₜₜₜₜₜₜ,170ₜₜₜₜₜₜₜ)</td>
<td></td>
<td>50(35Xₜₜₜₜ)</td>
</tr>
<tr>
<td>AB3</td>
<td>1(68xₜₜₜₜₜₜₜ,1520ₜₜₜₜₜₜₜₜ)</td>
<td></td>
<td>50(35Xₜₜₜₜ)</td>
</tr>
<tr>
<td>AB5</td>
<td>1.4(73xₜₜₜₜₜₜₜ,2460ₜₜₜₜₜₜₜₜ)</td>
<td></td>
<td>50(35Xₜₜₜₜ)</td>
</tr>
<tr>
<td>ABE</td>
<td>6.8(100xₜₜₜₜₜₜₜ,8(160ₜₜₜₜₜₜₜₜ)</td>
<td></td>
<td>50(35Xₜₜₜₜ)</td>
</tr>
<tr>
<td>AB10</td>
<td>5.6(20xₜₜₜₜₜₜₜ,59ₜₜₜₜₜₜₜₜ)</td>
<td></td>
<td>50(35Xₜₜₜₜ)</td>
</tr>
<tr>
<td>AB9</td>
<td>8.6(18xₜₜₜₜₜₜₜ,148ₜₜₜₜₜₜₜₜ)</td>
<td>14.3(10Xₜₜₜₜ)</td>
<td></td>
</tr>
<tr>
<td>AB7</td>
<td>8.8(1900xₜₜₜₜₜₜₜ,5470ₜₜₜₜₜₜₜₜ)</td>
<td>14.3(10Xₜₜₜₜ)</td>
<td></td>
</tr>
</tbody>
</table>

**Summary of the dimensions and material content of BDS elements.**

JLC Project Report, Revised, March 12, 2003, 3:21 P.M.
Background: Muons

As described in Section 4.9.2, some part of the beam pipes in the beam delivery section (235) suffers from a high level of background muons, which can be significant with respect to the number of electrons to produce one muon which reaches the IP. The number of background muons can be suppressed by using an iron shield. The figure shows the number of electrons per μm at the IP as a function of distance from the IP (in meters). The red dots represent the number of electrons at the IP for a beam momentum of 250 GeV with an iron shield, while the black triangles represent the number of electrons at the IP for the same beam momentum without an iron shield.
Background: Synchrotron Radiations

BDS-Simulation (GEANT4) by K. Tanabe

from Halo at IP \( \langle E \rangle = 4.8 \text{MeV} \)
Collimation : Beam Halo

With Pre-Linac collimations after the DR and prelinac

The halo would be generated at main LINAC:

- Large angle scattering with residual gas
- Dark current
- Particles at several sigmas behind the bunch
- Particles in incorrect RF buckets

Beam halo has been estimated in the framework of SAD. (T. Yamamura, Univ. of Tokyo)  GLCTA
Model (a) at B=2T
Model (b) at B=3T
L^* = 2m

Model (c)  L^* = 2m
Model (d)  L^* = 4.3m
# Background : e+e- Pairs

## Based on the JLC Design Study, April 1997

<table>
<thead>
<tr>
<th>model</th>
<th>B</th>
<th>T</th>
<th>L* (m)</th>
<th>Mask (mrad)</th>
<th>min.angle (mrad)</th>
<th>VTX (hits/cm²/BX)</th>
<th>CDC(γ) (hits/BX)</th>
<th>CDC(n) (hits/BX)</th>
<th>CAL (MeV/BX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>2</td>
<td>2</td>
<td>150-200</td>
<td>50</td>
<td>0.7</td>
<td>2</td>
<td>30</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>3</td>
<td>2</td>
<td>150-200</td>
<td>50</td>
<td>0.4</td>
<td>1</td>
<td>2</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>3</td>
<td>2</td>
<td>70-100</td>
<td>50</td>
<td>0.4</td>
<td>2</td>
<td>2</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>3</td>
<td>4.3</td>
<td>22</td>
<td>0.4</td>
<td>1</td>
<td>0.1</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Background of VTX at the innermost layer (r=2.4cm) should be multiplied by 3 for the present parameters.

L* = 3.5m in the Roadmap Report
Conventional

L* = 2m
224 T/m
2.2m long
13.7mm-dia.

L* = 4.3m
64.35 T/m
3.36m long
13.7mm-dia.
IR : Super FF Magnet

L*=4.3m
64.35T/m
3.36m long
160mm-dia.
**IR: Permanent FF Magnet**

- **Margin**
- **Y. Iwashita, ISG9**

- **L*=3.5m  
  141.5 T/m  
  2.2m long  
  20mm-dia.**

- At the very beginning part, the saturated iron scheme may not work, because of less magnet space. (depends on params.)

  - 5.5m x 8 m rad = 44mm
  - 3.5m x 8 m rad = 28mm
  - 3.5m x 6 m rad = 21mm
  - 5.5m x 6 m rad = 33mm

- Required: GL = 1.48T/cm x 2m
- Expected: 2.4T/cm @ 8 seg., φ13.8, w/o Fe

- 10~20% less with partial removal at outer area  
  → still 2T/m should be available!

**Final Focus vPMQ**

- Leaving beam
- 8 m rad
- 4m
- 40
- 48
- 56
- 2m Module1 Module2 Module3 Module4

**AccLab NSRF ICR Kyoto University 2002.12.11 ISG9**
IR: Support Tube R&D

Results 1/10 Model
(Taper flange, 12-M6)

A: 77.5Hz

B: 90Hz

C: 258Hz

D: 522Hz

ANSYS- FEM
76, 256, 489 Hz

H.Yamaoka, 7/30 2003
Beam Spot at the 2nd FP

Polarization?
Apertures? Shields?
Background neutrons, photons to be estimated by the BDS-SIM.

Better with large crossing angle of 20 mrad?

Beam Dump
1.6m-dia. x 10m
Dumpline: Optics

Beam diagnostics (focus)

IP

\sqrt{\beta_x} \sqrt{\beta_y} (\text{m})

\eta_x, \eta_y (\text{m})

0 100 200 300

Sc1 Qc1 Slc2 Qe1 Qd1 Bh1 Bh2 Qd2 Qf2 Bv1 Bv2 Qm1 Bq11 Bq12 Bq13 Bq14 Bq15 Bq21 Bq22 Bq23 Bq24 Bq25 Bq35
Crossing Angle

Small angle: \( \phi \lesssim \frac{2\sigma_x}{\sigma_z} \),

Large angle: \( \phi \gtrsim \frac{2\sigma_x}{\sigma_z} \)

Why Small Crossing Angle?

- Detector \( \cos \theta \) coverage
- Timing of crab cavity (50 vs 16fs)
- Radiation in the solenoid magnet

\[ \sigma(\delta y) \propto \phi^{5/2} \]

\[ = 0.074 \text{nm with } \phi = 20 \text{mrad} \]

Why Large Crossing Angle?

- Background to the detector
- Multi-bunch crossing instability
- Design of the final quadrupole magnet
- Layout of the beam dump

\[ \frac{\Delta y}{\sigma_y} = \frac{1.6}{0.6} \text{ at } L^* = 3.5 \text{m} \]
7 mrad Crossing Angle

- We decided $\phi \approx 7\text{mrad}$ many years ago
- Background tolerable
- Luminosity loss not too significant ($\sigma_x$ was larger than today's value, $\sigma_z$ was smaller)

Luminosity vs. $\phi \Rightarrow$ by today's params.

Luminosity without Crab Crossing

$\sigma_x=0.243\mu\text{m}, \sigma_z=110\mu\text{m}$

500 GeV (CM)
FEATHER
FEedback AT High Energy Requirements
Fast Feedback System on Intra-Beam

Simulation Result of the improved model

Initial offset=10 $\sigma_y$

To be tested at the extraction line of the ATF in FY2003.
FEATHER: $L^* = 4.3m, 8mrad$
Pair Monitor for Beam Size Measurement
Brunnel, Hawaii, KEK, Stanford, Tohoku Collaboration

The sensor arrangement; the top side faces the IP.

One 'segment'; the bottom side faces the IP.

3D Pixel

1. Fast charge collection
   < 1 nsec : bunch separation

2. Radiation hard
   >> 50kRad/year, $10^7 n/cm^2/year$

3. Flexible geometry

4. Active edge
Pair Monitor

1. Fabricated by S. Parker et. al., at CIS, Stanford.
2. Trapezoidal shape possible for disk or cone. (180µm thick, 200µm readout pitch, 3mm long)
3. Fabrication completed and being tested at LBL and Tohoku.

Dead region near electrodes

Current on any strip vs X-ray position (unit: 2µm)

Laser Interferometer/Wire?
Experimental Set-up (top view)

Photon detector system

Laser wire system

12.8m

Bending Magnet

Scattered γ

electron

0.5mm Pb collimator

Csl(pure) Scintillator

Laser wire system Expanded view

Reflection

Optical diode

D

Optical diode

D

Green laser

Optical Cavity

CCD

Trans

D

Lens system

Piezo

Feedback to lock the cavity

Written by H. Sakai

Experimental Set-up (side view)

Position monitor

Read

QM15R.1 move

Read

QM14R.1 move

Electron

Optical cavity

Movable table

Laser

Written by H. Sakai

1 hour

Long term stability

( Side view of the laser wire )

0.2 nm control was succeeded

Keep the resonance condition for a day

Instrumentation:

Laser Wire (Kyoto univ., KEK)
Instrumentation: NanoBPM (KEK, SLAC, LLNL, ...)

Three cavity-BPMs at the ATF extraction line (Old setup)

New setup will be tested with LLNL support system in FY2003, and KEK system is under study.