Compton Scattering of Picosecond Electron and CO2 beams

T. Hirose (TMU) @BNL user meeting, Jan. 31, 2002

Japan/US cooperation in high energy physics (Supported by JSPS from 1998)

"Development of a pico-second CO2 laser for production of polarized positron beams at linear colliders"

Japan: Tokyo Metropolitan University (TMU)

KEK (High Energy Accel. Research Organization)

Waseda University

US: BNL-ATF

1. Polarized positron beam for an e+e- linear collider JLC

2. Review of activities both at BNL and KEK
Electron-Positron Linear Collider  

500 GeV JLC-I → 1.5 TeV JLC

1.5 TeV Configuration

- 85 bunches x 150 Hz
- 85 bunches x 150 Hz
- Positron
- Electron

Updated for MCFARCH by N. Toge 1/2/97
Schematic design for a polarized positron

1.28 GeV \( e^- \) beam

Circularly Polarized Laser Light

Compton scattering

Polarized \( \gamma \)-ray

Pair Creation

\( e^- \) beam

Tungsten

\( e^- \)

\( e^+ \)

\( \gamma \)-ray

Spin


LSS (Laser Synchrotron Source)
Budget:

<table>
<thead>
<tr>
<th>Year</th>
<th>Facilities(yen)</th>
<th>Traffic expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>5,000,000</td>
<td>1,500,000</td>
</tr>
<tr>
<td>1999</td>
<td>7,000,000</td>
<td>2,800,000</td>
</tr>
<tr>
<td>2000</td>
<td>10,000,000</td>
<td>4,200,000</td>
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<tr>
<td>2001</td>
<td>12,000,000</td>
<td>5,500,000</td>
</tr>
<tr>
<td>Total</td>
<td>34,000,000</td>
<td>14,000,000</td>
</tr>
</tbody>
</table>

BNL-ATF  
- e-: 60 MeV, CO2 laser, E_{max} = 6 keV
  - Nonlinear Compton process
  - Compton-in-capillary (Plasma channel)

KEK-ATF  
- e-: 1.28 GeV, Nd:YAG laser, E_{max} = 54 MeV
  - Polarization measurement
  - Conceptual design for JLC
Compton Chamber

- CO2 laser beam
- 60 MeV
- 0.5 nC
- 1 mm mrad
- 3.5 ps

X-ray detector with shielding
- Faraday cup
- Be window
- ZnSe windows

Parabolic Cu mirror
- F = 15 cm
- with 5 mm hole

Retractable alignment target
- 2-axis tilt with stepper motors

IR camera
Experimental Result

A: 3J, 200ps, 15GW \Rightarrow a = 0.05

B: 3J, 3ps, 1TW \Rightarrow a = 1.09
Simulation by CAIN
Multilayer Crystal

45 layers of W/C (d=30Å)

\[
\sin \theta_B = n \cdot \frac{0.207}{E_{X-ray} [keV]}
\]
Reflectivity of Multilayer Crystal

X-ray Energy [keV]

Reflectivity

45 layers

1 layer
JLC e⁺ beams: exceptionally high intensity

\[ 10^{10} \text{ e⁺ / bunch} \]

High energy laser beam: 10J

Nonlinear Compton process

Diminish the e⁺ polarization
\[ \Downarrow \]

High intensity and high polarization
\[ \Downarrow \]

Relatively low energy laser beam

Extend interaction distance
\[ \Downarrow \]

Plasma Channel
\[ n_{cr} = \frac{\pi m c^2}{e^2 \lambda^2} \]

\[ n_{cr}(CO_2) \approx 10^{19} / cm^3 \approx \frac{1}{100} n_{cr}(YAG) \]
Transportation of CO₂ Laser through the Plasma Capillary

18mm = 6 × Rayleigh Length

0.15mm (FWHM)
High Energy Accel. Research Organization (KEK)

Accelerator Test Facility for LC
New Compton Chamber

Wire: electron beam size
Screen: position
Knife-edge: laser size

Beam Size [µm]  0.6  20

$\sigma_{\text{laser}}$  265  130  265

Nd:YAG
$\lambda = 532$ nm
$I = 400$ mJ/pulse
\(\gamma\)-ray Polarization Measurement

Cross section of Compton scattering

\[ (\sigma_{comp}(\uparrow\uparrow) < \sigma_{comp}(\uparrow\downarrow)) \]

\[ \downarrow \]

Transmission depends on the direction of the magnetic field

[Diagram showing the interaction of polarized \(\gamma\)-rays with a magnetic field, Fe target, Pb converter, and Cherenkov counter. The diagram illustrates the spin of the \(\gamma\)-rays and the direction of the magnetic field.]
Measured Asymmetry

\[ A = 1.0 \pm 0.2 \% \]

\[ A = -0.9 \pm 0.2 \% \]

(Error: statistical)