Beam Diagnostics for test facilities of

i) $\gamma-\gamma$

ii) polarized e+ source
Beam Diagnostics at PCTF

Workshop on Low Energy Photon Collider Facilities
SLAC, November 21-22, 2002

Workshop goals:
• examine the possibility and readiness of photon collider testbed facilities
• evaluate their timescale and utility for the International LC project baseline definition.

Workshop info: http://www-conf.slac.stanford.edu/lepcf/
Need diagnostics for:

- $e^+e^-$ collisions
- $e^-$ laser Compton collisions
- $\gamma\gamma$ collisions (for backscattered gammas)

Collision rates for 30Hz running: (suggestion)

- $\sim 2$-4Hz keep-alive pulses for PEP
- $\sim 10$Hz for $e^+e^-$ collisions only
- 10-20Hz with $\gamma\gamma$ collisions

1. $e^+e^-$ collisions
   - need to optimize and stabilize luminosity
     - luminosity dithering to maximize beamsstrahlung or radiative Bhabha signal (dither offsets, waists, …)
     - deflection scans to measure luminosity
     - Compton polarimeter to measure $e^-$ polarization
     - Energy spectrometer to measure beam energies
2. e - laser Compton collisions
   - luminosity measurement from
     a) calorimeter for backscattered gammas. 500W signal; compare to 30W beamstrahlung signal for SLD running.
       - will also see background from off-energy Compton-scattered electrons
     b) toroid comparator (dump vs. IP)
   - Establishing collisions: grid search; scan electron beam transversely and scan laser timing; start with large electron spot
     - diagnostic needed to get electron, laser timing close (100ps?)
   - Maintaining collisions:
     - dither offsets to maximize luminosity; move laser or $e^+, e^-$ beams?
     - stabilize relative timing; timing comparator diagnostic needed
   - need to ensure Compton IP upstream of $e^+e^-$ IP!

3. $\gamma\gamma$ and $\gamma e$ collisions
   - $\gamma\gamma$ luminosity only 1% of $e^+e^-$ luminosity!
   - use $\gamma e$ luminosity for real time diagnostic
     (10% of $e^+e^-$ luminosity)
   - Monitoring only needed; use LAC, LUM measurements
   - Investigate higher rate measurements at smaller angles?
## Comparison of Compton Laser Systems at SLD

<table>
<thead>
<tr>
<th></th>
<th>Wavelength</th>
<th>Pulse Energy</th>
<th>Spotsize at CIP ($\sigma_r$)</th>
<th>Pulse Length</th>
<th>Rayleigh Range</th>
<th>Crossing Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLD Laserwire</td>
<td>349 nm</td>
<td>1 mJ</td>
<td>0.4 $\mu$m</td>
<td>50 ps</td>
<td>5 $\mu$m</td>
<td>90 degrees</td>
</tr>
<tr>
<td>SLD Compton</td>
<td>532 nm</td>
<td>50 mJ</td>
<td>500 $\mu$m</td>
<td>8 ns</td>
<td>1.5 m (but multimode)</td>
<td>10 mrad</td>
</tr>
<tr>
<td>PCTF (proposed)</td>
<td>1047 nm</td>
<td>100 mJ</td>
<td>3 $\mu$m</td>
<td>1.8 ps</td>
<td>100 $\mu$m</td>
<td>0</td>
</tr>
</tbody>
</table>

Finding Compton collisions for SLD Laserwire was difficult

- 3-dimensional search; start search with large electron beam spot
  - beam electrode pickup and fast photodiode to get initial relative timing to 0.5 ns
- saved configs after collisions found, but sometimes difficult to reproduce collisions next day
Vertical motion of $e^+e^-$ IP for SLD running

- Use beam-beam deflection to keep $e^+$ and $e^-$ beams in collision
- Need to implement a dithering-style feedback to keep laser beams in collision with the electron and positron beams
Polarization measurements in extraction line? difficult!

500μrad divergence from FF optics
Geometry constraints; backgrounds from degraded electrons
Can calculate accurately, but need to verify laser polarization at CIP
Verify Polarization with measured distributions of γe, γγ events in LAC, LUM

30 GeV electron, 1.047 μm photon
Pe = +80%
Laser Pγ = -100%, +100%

Unpolarized cross section: 458 mb

Pγ = 0%
Laser Pγ = -100%, +100%
**Design Studies for Flux and Polarization Measurements of Photons and Positrons for SLAC Proposal E166**

-- an experiment to test polarized positron production in the FFTB

M. Woods, Y. Batygin, K. C. Moffeit and J. C. Sheppard
LCC-0107, November 2002

**E166 Goals:** Measure flux, spectrum and polarization of undulator photons and positrons
(10% accuracy ok)
1%-scale mockup of polarized positron source

E166 info: www-project.slac.stanford.edu/lc/local/PolarizedPositrons/index.htm
Undulator Photons

Electron Beam: 50 GeV
5 x 10⁹ electrons / pulse

Undulator: 0.5m length
K=0.17
2.4mm period
Yield is ~ 9 x 10⁸ photons / pulse

Yield/ pulse and spectrum
Helicity spectrum
Production angle of 1st harmonic Undulator Photons
Positrons

Production Target: 0.5 $X_0$ Titanium
Yield is $\sim 0.0045$ e+ per photon

Energy Spectrum

Production Angle Distribution

$P_z$ vs. Energy

$P_z$ vs. Angle

M. Woods (SLAC)
Experimental Setup Considered

Photon measurements:
- Calorimeter and threshold Cherenkov flux counters for flux and spectra measurements
- Transmission Compton polarimeter for polarization measurements

Positron measurements:
- Spectrometer for flux and spectra measurements using a calorimeter and threshold Cherenkov flux counters
- Bremsstrahlung radiator and transmission Compton polarimeter for polarization measurements.
Polarimetry for Undulator Photons with a Transmission Compton Polarimeter

Photon cross sections in Fe:

- $\sigma_{\text{tot}}$
- $\sigma_C$
- $\sigma_{\text{pair}}$

Polarized Compton cross section in Fe:

Intensity Spectrum after 15-cm Fe Target

Intensity Asymmetry Spectrum after 15-cm Fe Target

M. Woods (SLAC)
Polarimetry for Undulator Photons (cont.)

<table>
<thead>
<tr>
<th>Detector*</th>
<th>Threshold Energy</th>
<th>Mean Photon Energy**</th>
<th>Measured Asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorimeter</td>
<td>-</td>
<td>7.7 MeV</td>
<td>3.4%</td>
</tr>
<tr>
<td>Quartz Cherenkov</td>
<td>0.2 MeV</td>
<td>6.8 MeV</td>
<td>2.3%</td>
</tr>
<tr>
<td>Aerogel Cherenkov</td>
<td>3.0 MeV</td>
<td>7.2 MeV</td>
<td>2.8%</td>
</tr>
<tr>
<td>Isobutane Cherenkov</td>
<td>8.1 MeV</td>
<td>8.9 MeV</td>
<td>4.7%</td>
</tr>
<tr>
<td>Propane Cherenkov</td>
<td>11.0 MeV</td>
<td>14.1 MeV</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

*Calorimeter and threshold Cherenkov flux counters are assumed to be ideal for this study; no attempt to include an actual energy response

**For calorimeter, mean energy is determined by energy and flux weighting; for threshold Cherenkov counters only flux weighting used.

5% accuracy (stat. error) on polarization can be achieved in <10 seconds.
Spectrometer has a bend radius of 17cm and an effective aperture radius in the bend of 1.75cm. It provides for adequate flux and spectra measurements.

Positron polarization measurement is still being studied by E-166 collaboration.
- flux and large emittance are considerably less favorable than for photon measurements
- need large aperture detectors, so sensitive to backgrounds and effects from multiple scattering in a transmission Compton polarimeter.

(would prefer to have a flux concentrator and accelerator section to produce a real ‘beam’ for measurements, but this would require a significant investment)