Beam Instrumentation
Requirements at High Energy

Arlington Linear Collider Roundup
January 10th, 2003
UT Arlington

Eric Torrence
University of Oregon

• Beam Energy
• Polarization
• Luminosity

(Will focus on NLC500...)

http://www.slac.stanford.edu/~torrence/ipbi/
$e^+ e^-$ electroweak physics

- $m_Z, \Gamma_Z$ (LEP I)  Energy  Lumi
- $m_W$ (LEP II)  Energy
- $\sin^2\theta_w$ (SLC)  Polarization

Dependent upon Beam Instrumentation

LCBI Mandate

⇒ Ensure instrumentation for physics needs!

Principle LCBI Topics (L,E,P)

- Luminosity spectrum $\frac{dL}{dE}$ and scale $\int L dt$
- Beam energy scale and width
- Beam polarization

Significant overlap with other efforts

Accelerator, Beam Delivery,
Detector Groups, Physics Groups
Production Threshold

Kinematic Fits

Common Scale Uncertainty \( \frac{\delta M_W}{M_W} \approx \frac{\delta E_{Beam}}{E_{Beam}} \)
Energy Needs

• Target 200 ppm from $2m_t < \sqrt{s} < 1 TeV$
  \[ \Delta m_t, \Delta m_H \sim 50 \text{ MeV} \]

• Recognize desire for 50 ppm at $2m_W$ ...
  Could we use higher precision?

Energy Proposal

• BPM-style at upstream 1mRad bend
  RT monitor, possible absolute scale

• WISRD-style at post-IP chicane
  RT monitor, possible absolute scale

  Energy width?

• Forward tracking 200-500 mRad
  Lumi-weighted absolute scale ($\mu^+\mu^-\gamma$)
Polarization Physics

<table>
<thead>
<tr>
<th>Process</th>
<th>Events per 80 fb(^{-1})</th>
<th>A(_{LR}) (stat) in %</th>
<th>(dA/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>560 k</td>
<td>99%</td>
<td>0.07</td>
</tr>
<tr>
<td>qq</td>
<td>250 k</td>
<td>45%</td>
<td>0.5</td>
</tr>
<tr>
<td>ll</td>
<td>120 k</td>
<td>10%</td>
<td>3.2</td>
</tr>
</tbody>
</table>

⇒ Also WW background suppression, SUSY, new physics, etc.
Compton Polarimeter Prospects

0.5% per beam achieved at SLC
0.25% per beam possible (not proven)

P\(^-\) only

- absolute scale limiting factor
- IP depolarization significant

Expect \(\Delta P/P \sim (0.3 - 0.5)\)%

P\(^+\) also

\[ P_{\text{eff}} = \frac{(P^+ + P^-)}{(1 + P^+P^-)} \Rightarrow (0.1 - 0.2)\% \text{ precision} \]

Blondel scheme gives lumi-weighted P\(^+\),P\(^-\)

- Lose some luminosity (or don’t gain as much)
- Still need \(\Delta = |P_L| - |P_R|\), relative Lumi
- Precision depends upon P\(^+\) reversal freq.

1/Days \(\Delta P/P \sim 0.1\%\)

120 Hz \(\Delta P/P \sim 0.01\%\)
Compton Polarimeter

- $\delta P / P \sim 0.25 - 0.5\%$ per beam
- Downstream polarimeter foreseen
- Out of collision measurements if necessary

$\Rightarrow$ $e^+$ polarization a big help!

Simplified upstream relative polarimeter also possible (desirable?)

WW (t-channel) asymmetry (Moenig, Snowmass 01)

- lumi-weighted polarization
- does not interfere with s-channel TGCs

$\delta P / P < 0.3\%$ for 80 fb$^{-1}$ at 350 GeV
(with or without $e^+$ pol)

$\Rightarrow$ Need good forward tracking...

How about $Z\gamma$?

$\Rightarrow$ Good for either polarimetry or physics...
LEP History

• \( \Delta L/L \) of 0.07% achieved

⇒ No mean feat, must be justified for LC...

Higgs Branching Fractions

• Much more modest needs \(~1\%\)

SM Cross Sections

• Hadronic cross-section/contact interactions
• Total WW cross-section

⇒ Can other errors be controlled?

Current Thinking (flawed?)

• Modest precision adequate \(~(0.3 - 0.5)\%\)
• Relative precision better
• Optimal detector not clear
Beyond ISR

Highly dynamic distribution...

Linac energy spread

\[ \frac{dn}{dE} \]

E
Key Reactions

- Threshold scans (top mass)
- Mass reconstruction (Higgs mass)

⇒ Plus many, many more...

Highly dynamic distribution

- Variance: increased statistical errors
- Uncertanty: increased systematic errors

Both need consideration

Rough physics needs

- Scans mostly need shape (tails to 1%)
- Mass analyses need mean $\sqrt{s'}$ (200 ppm)

⇒ More input needed here
need dedicated WG efforts
Several European studies

Moenig (TESLA)
Battaglia, Jadach, Bardin (CLIC)

Personal Observations

• Most attention paid to tail not core
• Statistical precision is available, detector systematics, other inputs?
• Must verify for NLC500
• Really measuring boost of system

Must separate tail, core width, energy imbalance, etc...

Need external inputs (with what precision)?
Beamstrahlung Correlations

- Dispersion effects
- Early-late correlations
- Banana tail effects

Probably can’t trust simulation alone...

Need data-tuned models integrated into generators

Final State Beamstrahlung Interactions

Particularly important for LA Bhabhas?
Conclusions

Beam Energy

- Target 200 ppm from $2m_t < \sqrt{s} < 1 TeV$

  $\Delta m_t, \Delta m_H \sim 50$ MeV

- Recognize desire for 50 ppm at $2m_W$ ...

Polarization

- Target $\delta P / P = 0.25\%$ per beam

  SM, SUSY, other asymmetries

- Recognize desire for $\delta P_{\text{eff}} / P_{\text{eff}} = 0.1\%$

  $\Rightarrow$ Positron Polarization

Luminosity

- Target $dL / dE$ tail precision at 1%

  mean $\sqrt{s'}$ at 200 ppm

- Target absolute $\int L dt \sim (0.3 - 0.5)\%$