Fixed Target Physics at the NLC

What is the physics?
What is needed?
What is the impact?
What beams are required?
How does this all fit together?

Rainer Pitthan
LCWS, FermiLab, October 2000
but after collision, the 5 MWatt of spent beams must be transported to a beam dump, reasonably far away, without too much loss (~200 m).

Those spent beams also may be used for:

- **Test Beam Facility**
  (Detector development)
- **A Fixed Target Facility**

if so desired by the user community
Extraction Line, Test Beams, Fixed Target Beams....

....all 3 must be designed together

Test Beams and Fixed Target beams must eliminate the tail to be useful.

The extraction (dump) line must neutralize the tail, i.e., not allow background to be created close to the IP.

Conceptually this task is easier for test beams and fixed target beams because they are further away from the IP.
**Requirements of Test Beams**

**Test Beam:** generally require < 1 particle per pulse of electrons and hadrons.

$e^+, \pi^+, K^+$ and protons (or $e^-, \pi^-, K^-$ and anti-protons) can be produced by the disrupted beam on a 10 cm Be target.

(The **Fixed Target** beam will be deflected by a bend magnet. The 10 MW NLC Dump does double duty as an energy collimator).
Production angle:

0.25° optimized for Test Beams
- may need larger angle for collimation requirements of Fixed Target Beams.

0.5° (x’s) shown in blue.

1.0° (+’s) shown in magenta.

Yield is adequate.
Requirements of Fixed Target Beams

**Easy if dedicated beams:**

- Modest energy spread: \( \leq 1\% \Delta E/E \)
- Polarization: > 80%
- Beam size can be large: \( \sim 1\) mm or more on target (emittance!)

**More demanding:**

- Charge Jitter < 2%
- Position Jitter on Target < 100 \( \mu m \)

**Beam Asymmetries require feedback:**

- \( \Delta Q/Q \leq 10^{-9} \) integrated over run
- \( \Delta x < 10\) nm integrated over run

These requirements are not a large leap from present day spin physics experimental requirements. And for Fixed Target physics NLC could run with a higher than nominal current, shortening the required calendar time.
A Quick look at Possible Experiments

Thought of Experiments:

- $A_{LR}$ by Møller Scattering ($\sin^2 \Theta_W$) will discuss in detail.
- Polarized Gluon Density - measurement with $\gamma$’s!!
- Gerasimov-Drell-Hearn Sum Rule (GDH)
- Spin Structure Functions at very low $x$
- Charm Physics
- New ideas

Some are bread and butter experiments, some are very exciting. Availability of high energy, high flux, high polarization $\gamma$-beams will spawn new and exciting proposals because the figure of merit of $\gamma$-absorption experiments goes up with energy.

Rainer Pitthan
The Running of $\sin^2 \Theta_W$ and Polarized Møller Scattering

Marciano Prediction

$\sin^2 \theta_w(Q^2)$ vs. $Q$ [GeV/c]

- E158 (SLC-ESA)
- NLC
- Møller
- vN
- SLD
- APV

Rainer Pitthan
More on Errors

SLD Data, \( \delta P = 0.5\% \) (T. Abe, Osaka 2000):
\[
\sin^2 \Theta_W = 0.23098 \pm 0.00026
\]

E-158 Proposal with 80\% polarization, \( 4.5 \cdot 10^{11} e^-/\text{pulse train} @ 120 \text{ Hz}, 4 \text{ month}, \)
43 \% efficiency, \( \delta P = 2.7\% \) (R. Carr et al., ‘97):
\[
\delta (\sin^2 \Theta_W) @ 46.4 \text{ GeV} = 0.00073
\]

NLC-Møller Projection with 90\% polarization, \( 6 \cdot 10^{11} e^-/\text{pulse train} @ 180 \text{ Hz}, 1 \text{ Snowmass Year} = 32\% \text{ efficiency}, \delta P = 0.3\% \) (K. Kumar in Snowmass ‘96):
\[
\delta (\sin^2 \Theta_W) @ 250 \text{ GeV} = 0.000092
\]
\[
\delta (\sin^2 \Theta_W) @ 500 \text{ GeV} = 0.000082
\]
Unique characteristic of Møller scattering: $\sigma \sim 1/E$ (vs. $1/E^2$ for inelastic electron scattering in general), $A_{LR} \sim E$, but figure of merit is: $A^2 \sigma \sim E$.

Consequence: The statistical error decreases with increasing beam energy!

With 100% Polarization assumed:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>E-158</th>
<th>NLC</th>
<th>NLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>E/GeV</td>
<td>46.4</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>$A_{LR}/10^{-7}$</td>
<td>3.2</td>
<td>16.1</td>
<td>32.2</td>
</tr>
<tr>
<td>$\delta$ from $A_{LR}$ alone:</td>
<td>1/5.4</td>
<td>1/10.8</td>
<td></td>
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</tbody>
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Powerful handle on new physics, including the Higgs sector, not available with classical $e^+e^-$. 
Relevant Feynman Diagrams

Neutral Current Amplitudes Leading to $A_{LR}$

Dominant electroweak corrections to $A_{LR}$: $\gamma-Z$ mixing and $W$-loop contributions.
Relative Error Accounting

Why is the NLC-Møller error so small compared to E-158?

Main and essential difference comes from $A_{LR}$: $\times 5.4$

But everything helps:

- **40 Coulomb** on target @ 46.4 GeV Luminosity Weighted Energy for E-158
  - 2 month at 120 Hz, at 2 Energies @ 43% efficiency

- **170 Coulomb** on target @ 250 GeV for NLC-Møller
  - 8 month at 120 Hz @ 45% efficiency

Efficiencies for Fixed Target experiments is higher than Snowmass Year (= 32[]):

- Only one system($e^{-}$), $e^{+}$ is not needed
- Emittance requirements much lower
- Assume $x\sqrt{2}$ higher $\Rightarrow$ 45%
Can this be done with a Disrupted Beam?

Since it only needs one beam, Möller Scattering would be a good start-up/tune-up experiment. But does Fixed Target Physics at the NLC in general work with a disrupted beam?

For 250 GeV 57% of disrupted beam is within $\Delta E/E = 1\%$.

Assume 45% efficiency* $\Rightarrow$ 120 Coulomb in 9 month

Summary:

Use of disrupted beams is possible – if energy collimation can be solved and depolarization is small....

*SLC experience!
Energy Collimation:

Possible, needs design effort.

Long tails of particles.

For $\Delta E/E = 1\%$, 1.6 MW have to be collimated.

At higher energy, the beams at collision get smaller, and the beamstrahlung and coherent pair production effects more severe.
Disrupted Beam: De-Polarization?

Simulation by K. Thompson:

Depolarization

<table>
<thead>
<tr>
<th>$E_0$/GeV</th>
<th>$\Delta P$/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>0.3</td>
</tr>
<tr>
<td>1000</td>
<td>0.7</td>
</tr>
<tr>
<td>1500</td>
<td>0.9</td>
</tr>
</tbody>
</table>

No problem for the physics, but $P$ needs to be measured.
Fixed Target Area Design Parameters

Must be accessible during colliding beam operation. Colliding beam dump at 150 m assumed to be hermetic. Transverse separation from primary line-of-sight must be >10 m, to avoid the $\mu$’s produced in the collimator-dump.

No net bend angle relative to IP at target (spin precession).

Small scattering angles because of small electromagnetic cross section at high energies ($\sim 1/137$):

- 1-4 mrad for Moller
- $\approx 20$ mrad for spin structure

Long detector hall, or a target room connected with a diverging tunnel to a spectrometer hall 500 m down stream.
Summary

Single Beam use at the NLC offers possibilities for Fixed Target physics at (relatively) modest cost. We have investigated for now the possibilities of attaching a single beam facility to the low energy IR. Other locations are possible.

Important for NLC Detector development and testing is the early availability of a 250 GeV Test Beam.

For Fixed Target operation a wide variety of experiments is possible.

Parameters have not been optimized – the development of NLC beam delivery and final focus itself is still in flux.
Thanks

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