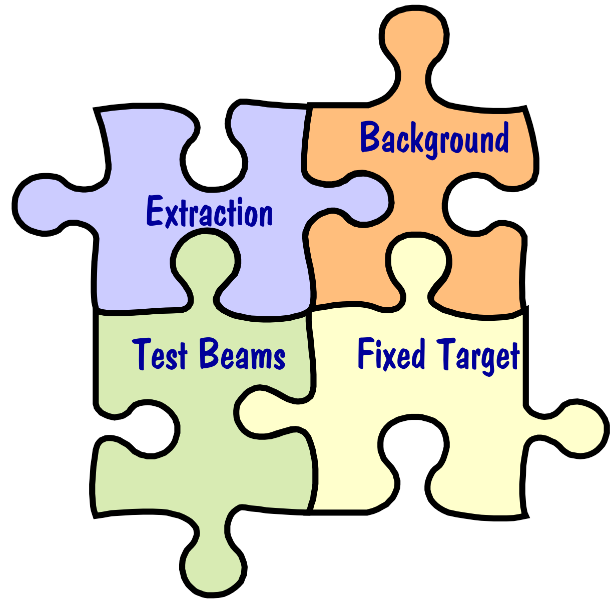
Fixed Target Physics at the NLC



What is the physics?

What is needed?

What beams are required?

What is the impact?

How does this all fit together?

Rainer Pitthan

LCWS, FermiLab, October 2000

NLC Centers Around Colliding Beams.....

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

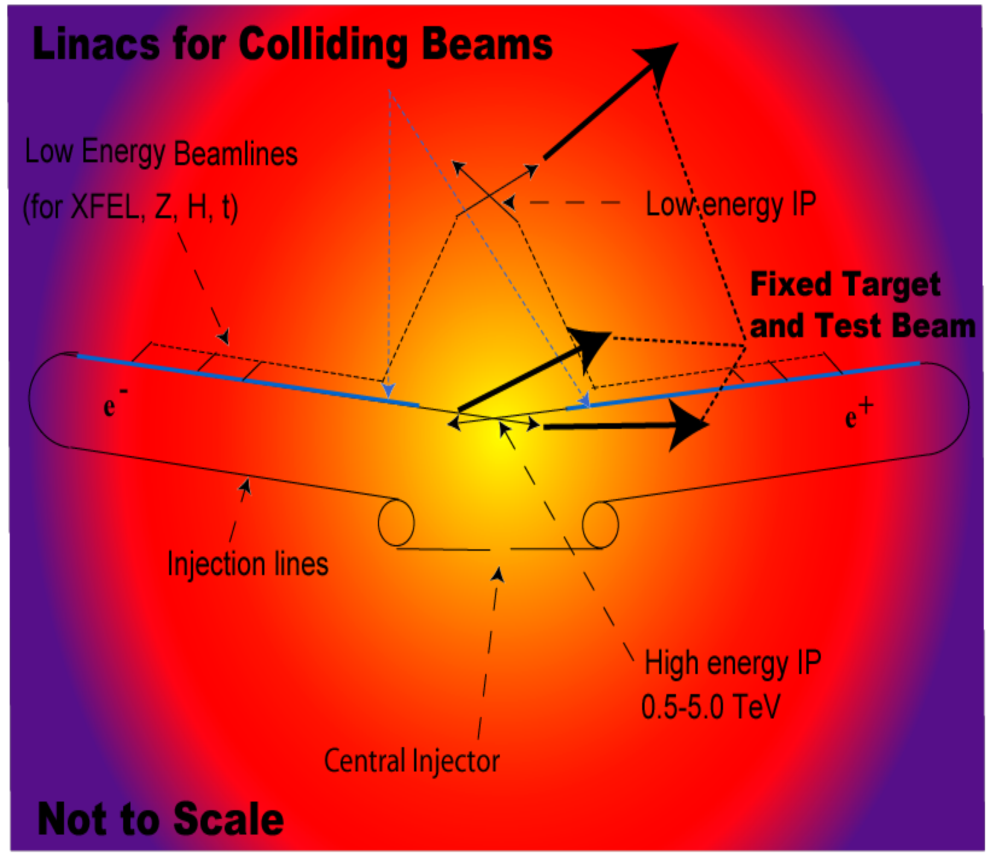
Those spent beams also may be used for:

- Test Beam Facility

  (Detector development)

- A Fixed Target Facility

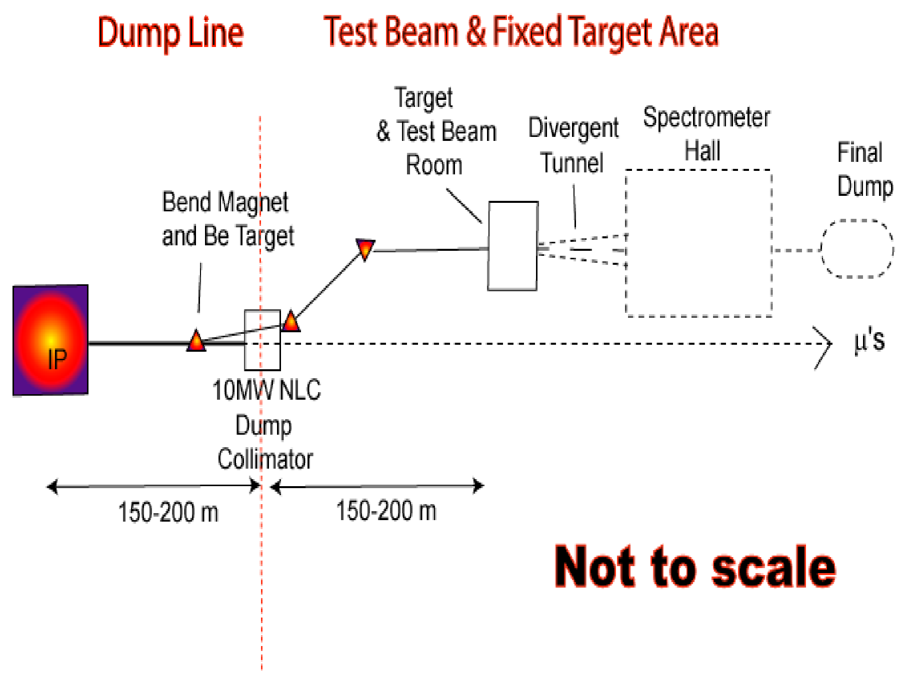
if so desired by the user community



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.



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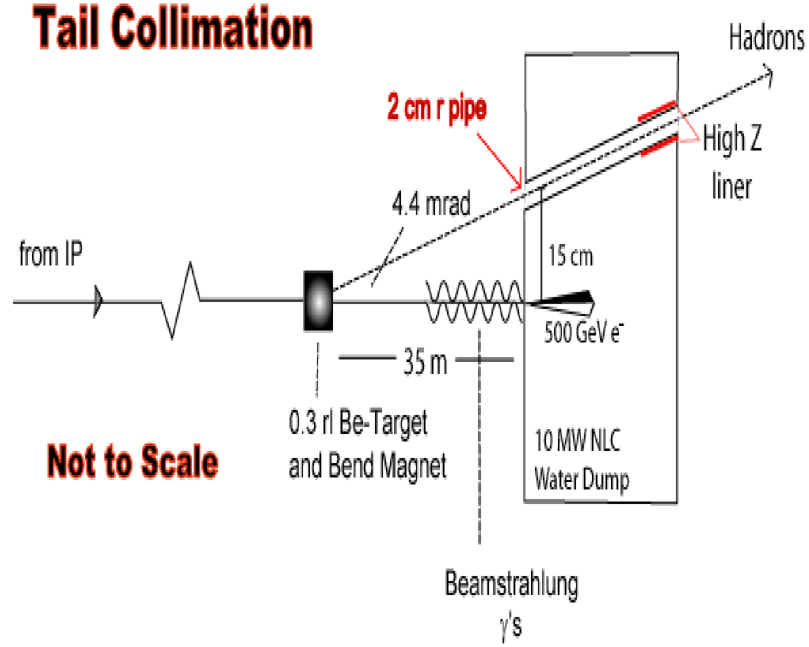
Requirements of Test Beams

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

e^+, π^+, K^+ and protons (or e^-, π^-, 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).

Hadron Production and Tail Collimation



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Yields and Production Angle

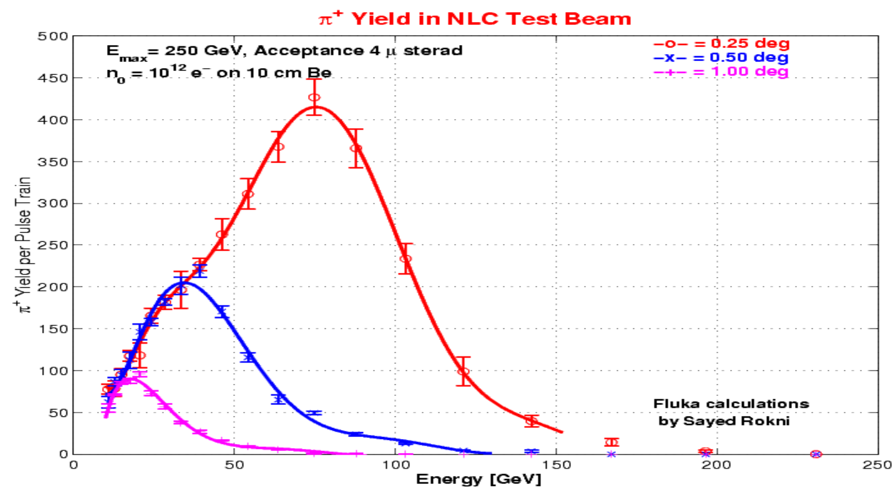
Production angle:

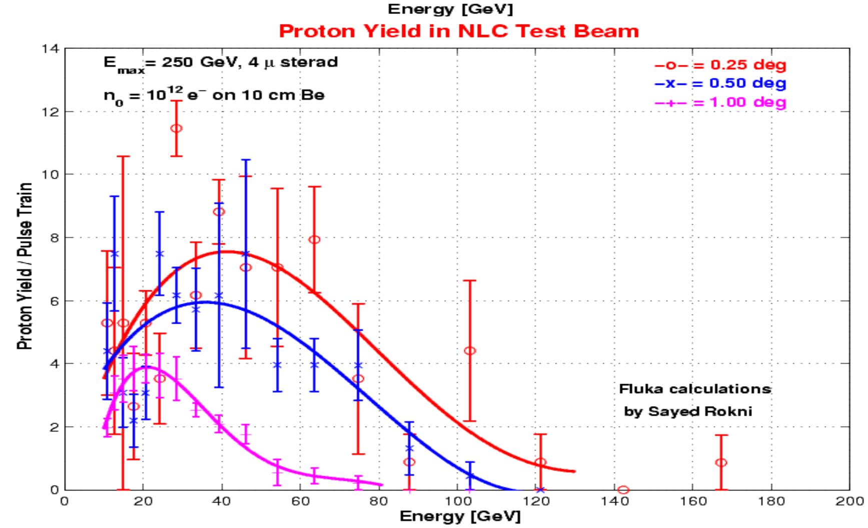
0.25^0 optimized for Test Beams - may need larger angle for collimation requirements of Fixed Target Beams.

0.5^0 (x's)shown in blue.

1.0^0 (+'s) shown in magenta.

Yield is adequate.





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Requirements of Fixed Target Beams

Easy if dedicated beams:

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

More demanding:

Charge Jitter	< 2%
Position Jitter on Target	<100 μm

Beam Asymmetries require feedback:

$\Delta Q/Q$ <~ 10^{-9} integrated over run

Δx < 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:

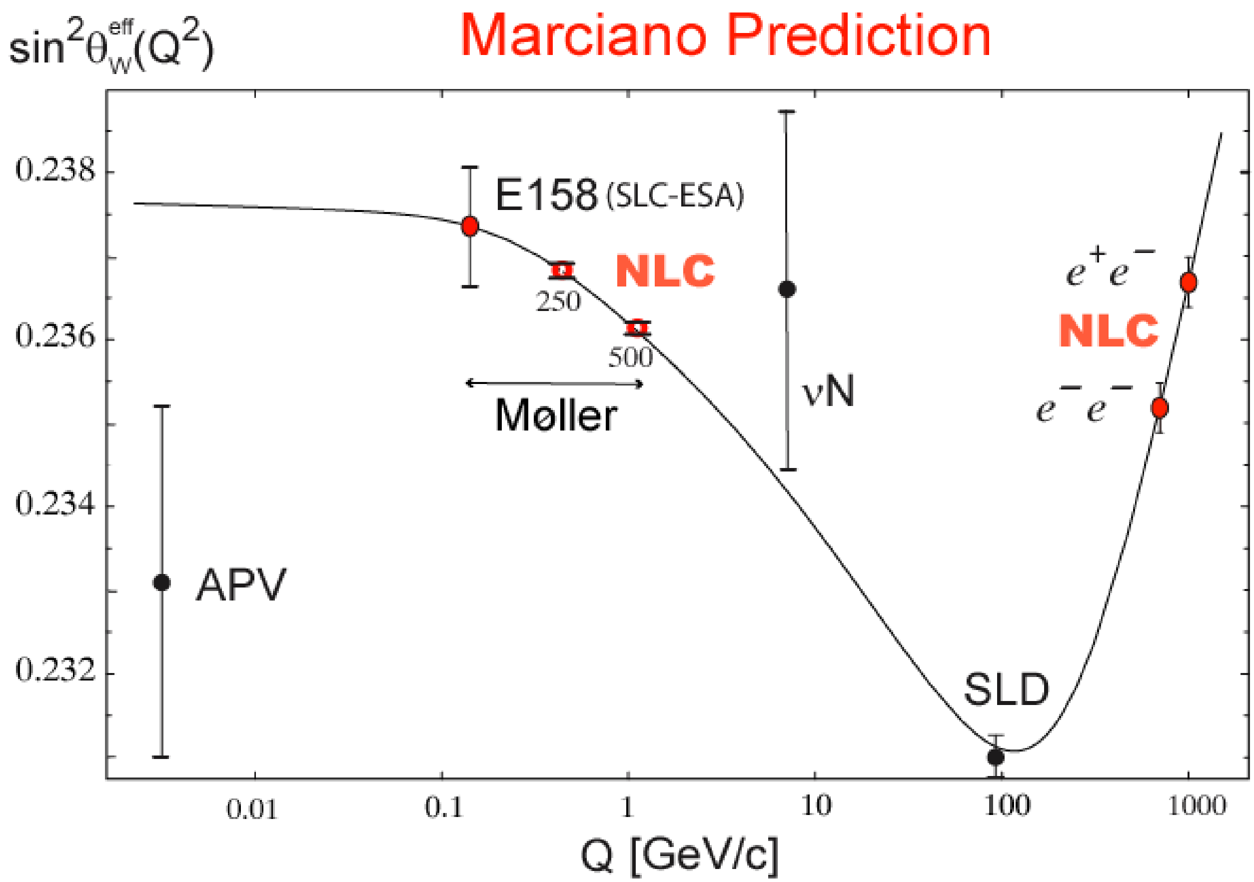
- A_{LR} by Møller Scattering ($\sin^2\Theta_W$)
- Polarized Gluon Density – measurement with γ's!!
- Gerasimov-Drell-Hearn Sum Rule (GDH)
- Spin Structure Functions at very low x
- Charm Physics
- New ideas

will discuss in detail.

Holy Grail of nuclear physics, thought to not be solved in next 10 years. Large community, great interest.

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

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



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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, $4.5\cdot 10^{11} e^-$/pulse train @ 120 Hz, 4 month, 43 % efficiency, $\delta P=2.7\%$ (R. Carr et al., '97):

$$\delta(\sin^2\Theta_W) \text{ @ } 46.4 \text{ GeV} = 0.00073$$

NLC-Møller Projection with 90% polarization, $6\cdot 10^{11} e^-$/pulse train @ 180 Hz, 1 Snowmass Year =32% efficiency, $\delta P=0.3\%$ (K. Kumar in Snowmass '96):

$$\delta(\sin^2\Theta_W) \text{ @ } 250 \text{ GeV} = 0.000092$$

$$\delta(\sin^2\Theta_W) \text{ @ } 500 \text{ GeV} = 0.000082$$

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Statistical Error Advantage of Møller Ccattering

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:

Experiment	E-158	NLC	NLC
E/GeV	46.4	250	500
$A_{LR}/10^{-7}$	3.2	16.1	32.2
δ from A_{LR} alone:	1/5.4	1/10.8	

Powerful handle on new physics, including the Higgs sector, not available with classical e^+e^-.

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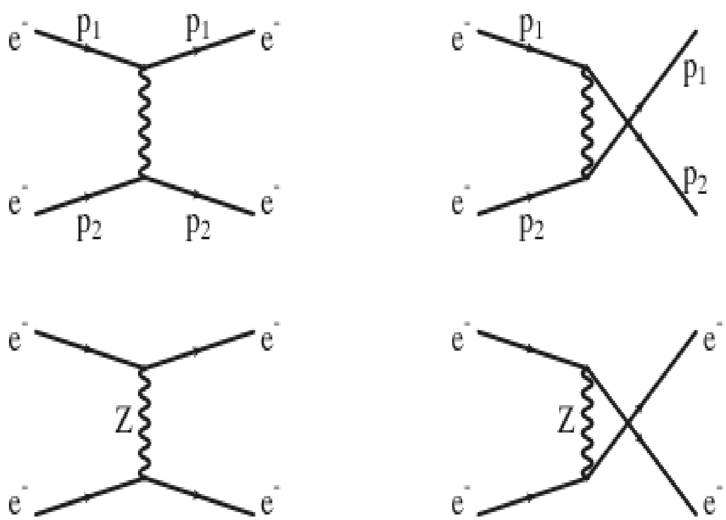
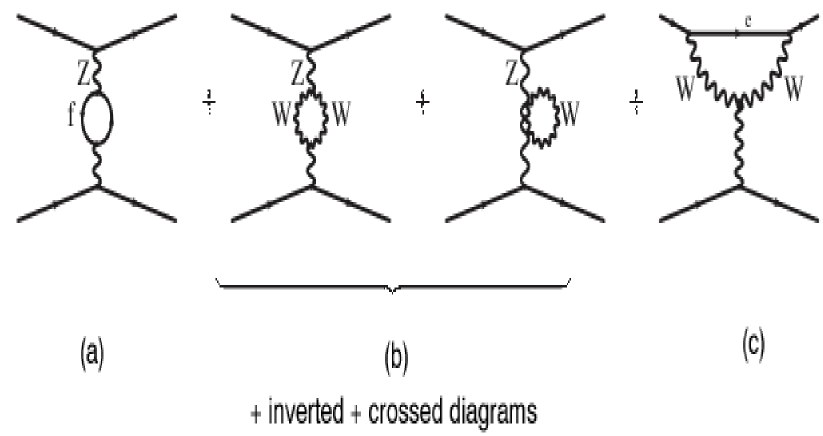
Relevant Feynman Diagrams



Neutral Current Amplitudes Leading to A_{LR}



Dominant electroweak corrections to A_{LR}: γ–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}: x 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%

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Can this be done with a Disrupted Beam?

Since it only needs one beam, Møller 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 de-polarization is small....

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*SLC experience!

Disrupted Beam: Energy Spread?

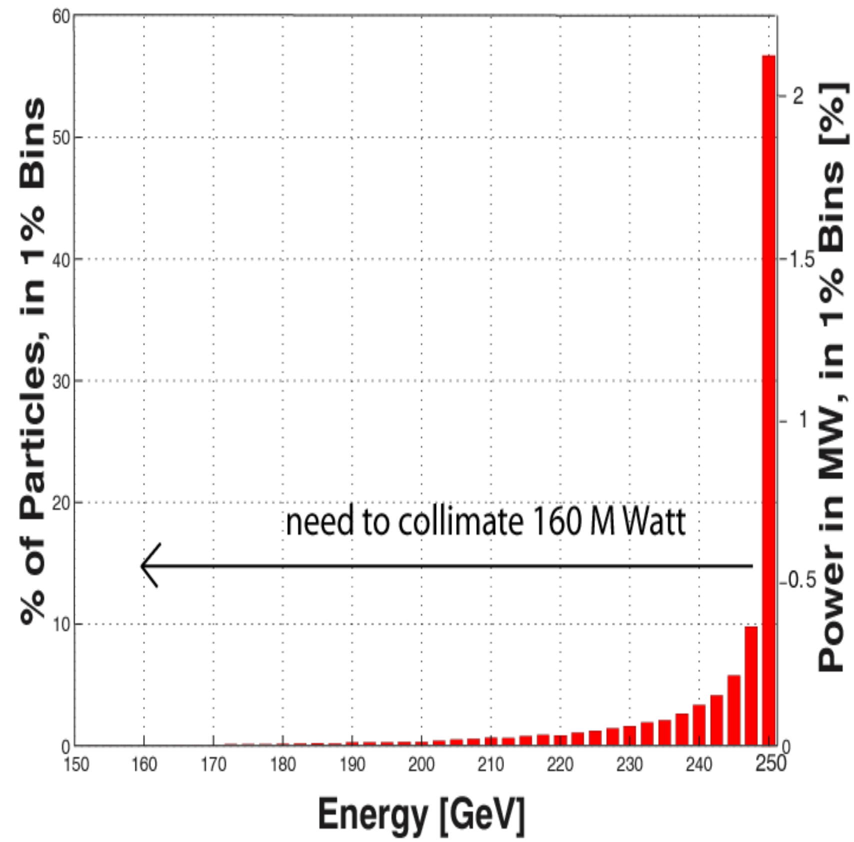
Energy Collimation:

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 Case B, 500 GeV cms



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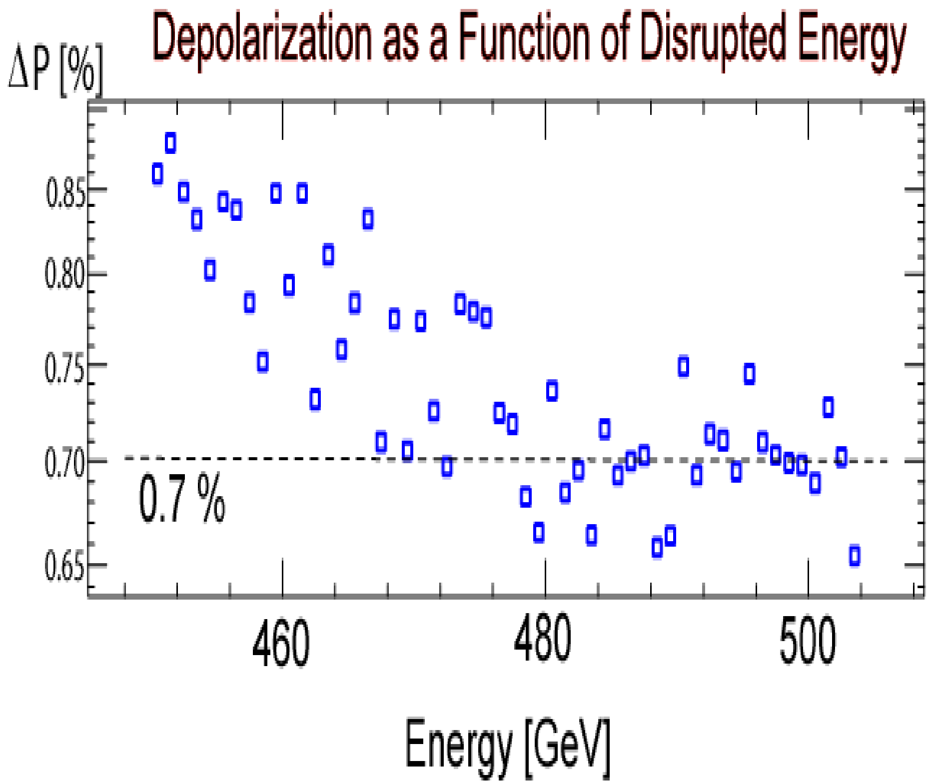
Disrupted Beam: De-Polarization?

Simulation by K. Thompson:

Depolarization

E_0/GeV	ΔP/%
500	0.3
1000	0.7
1500	0.9

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 μ's produced in the collimator-dump.

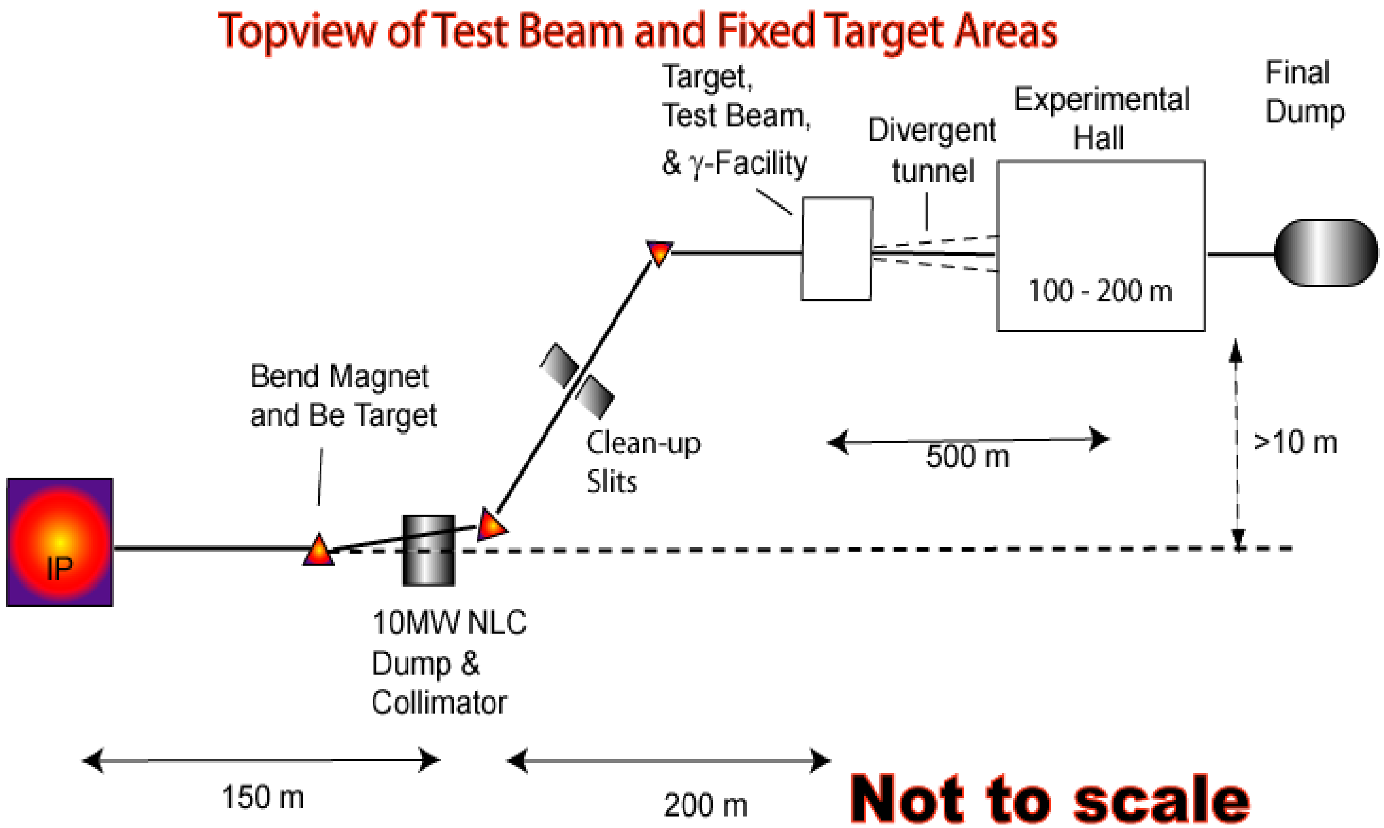
No net bend angle relative to IP at target (spin precession).

Small scattering angles because of small electromagnetic cross section at high energies (~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.

Schematic



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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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