

Special Option #1 and #3 Summary

Precision EW & e^+ Polarization

E3 - Linear Collider Plenary

Snowmass 2001

July 17th, 2001

Snowmass, Colorado

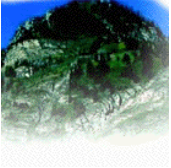
Eric Torrence

University of Oregon

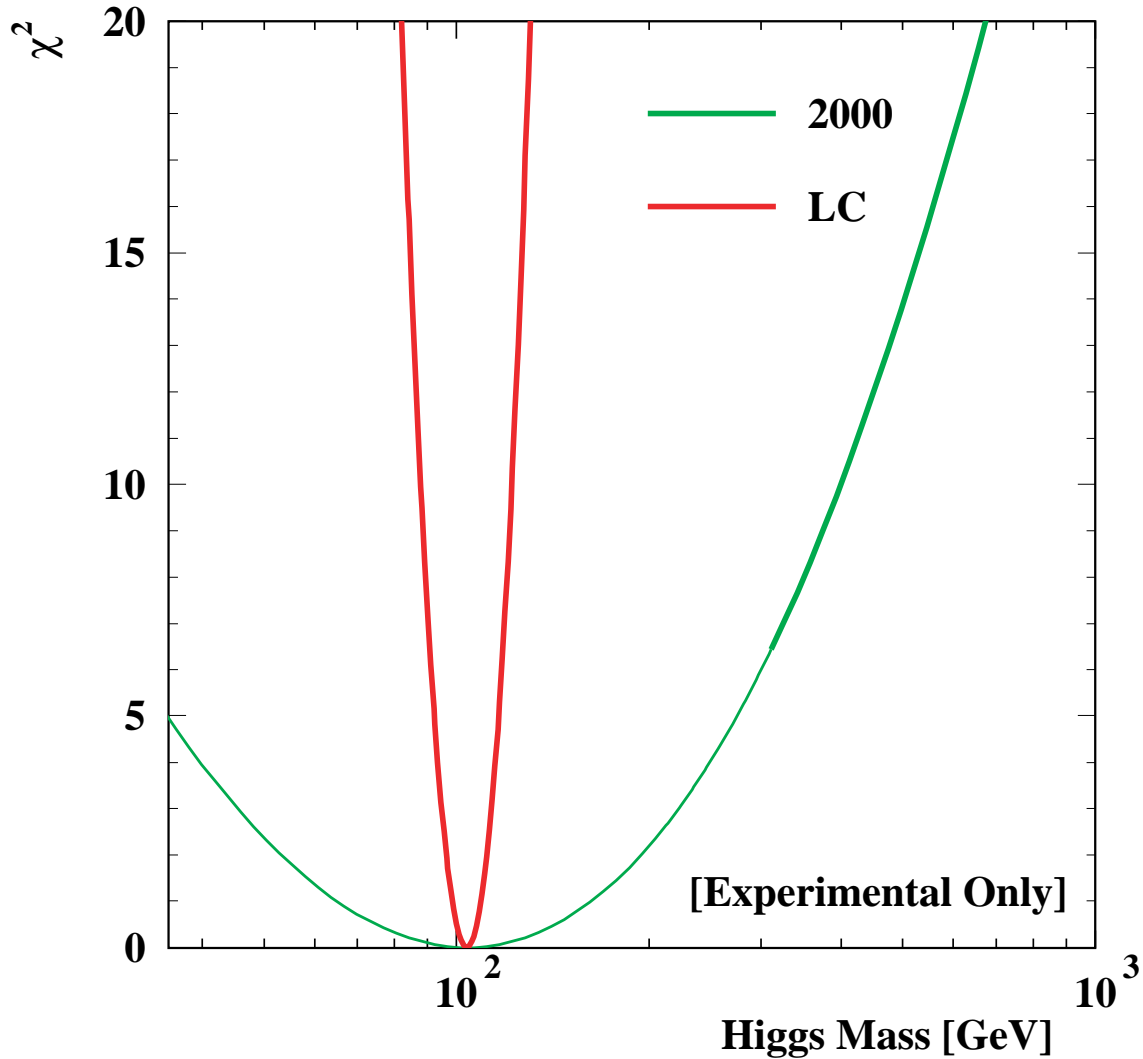
- Giga-Z
- Beam Energy
- Polarimetry

Please note: I am a virtual expert...

http://www.cern.ch/torrence/talks/SM01_SO13



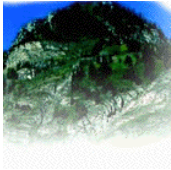
Giga-Z Potential



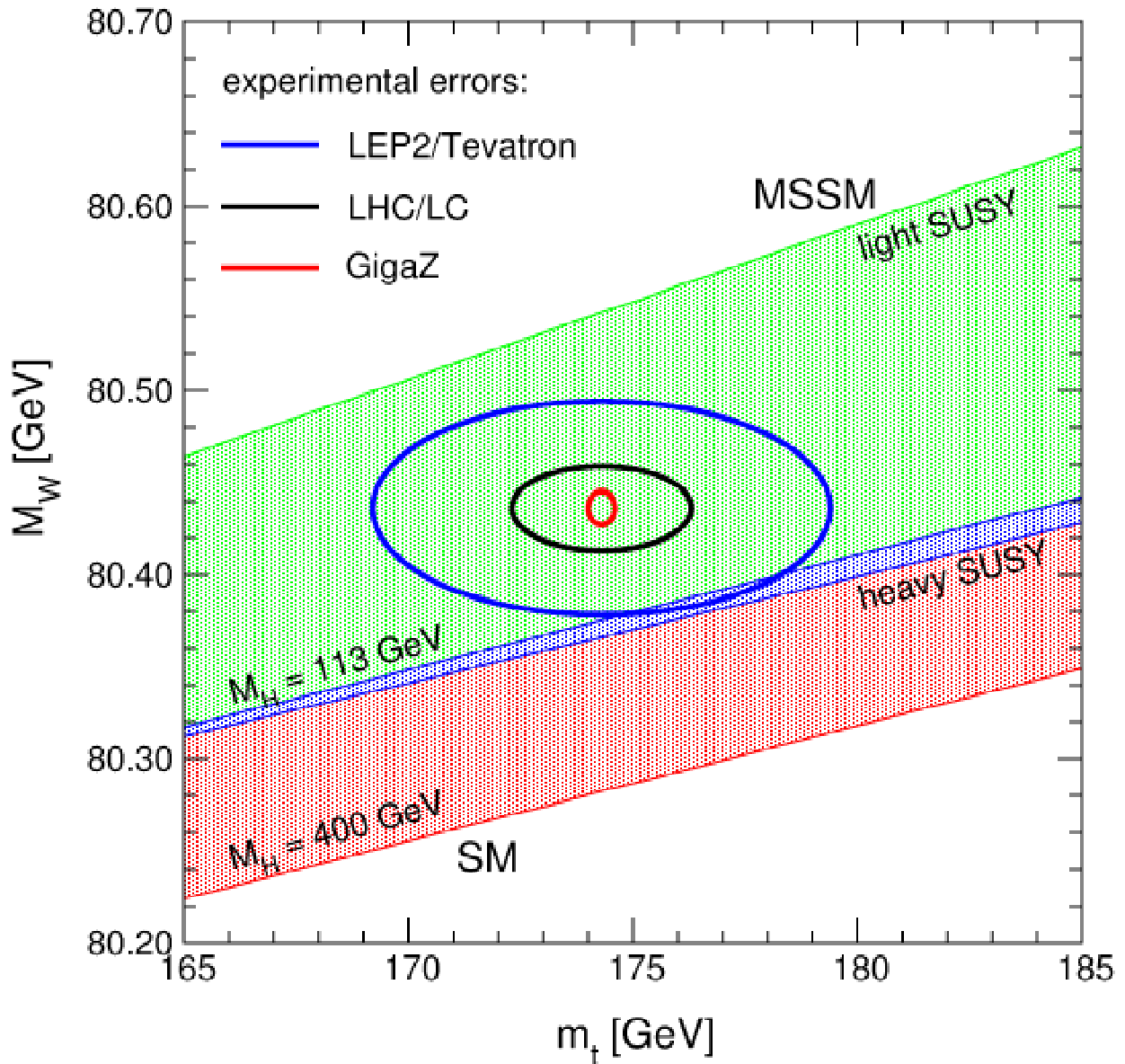
[R. Hawkins, R. Mönig, 2000]

- $\Delta \sin^2 \theta_W$: 0.00017 → 0.00001
- Δm_W : 35 MeV → 6 MeV
- Δm_t : 3 GeV → 0.2 GeV

⇒ $\Delta m_H \sim 5\%$ (also b-physics)



MSSM Potential

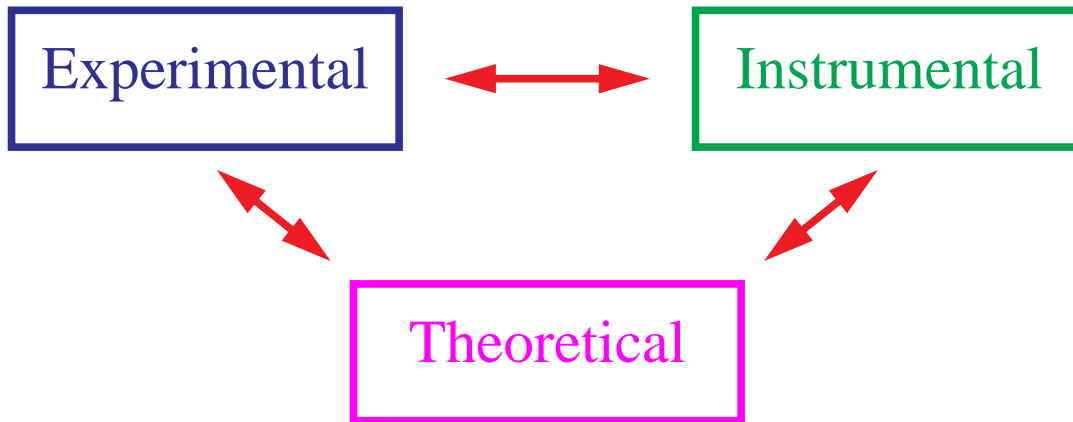


[S. Heinemeyer, G. Weiglein, 2001]

SM Uncertainty: Higgs Mass
MSSM Uncertainty: SUSY particles



Giga-Z Uncertainties



Experimental

- Selection Efficiency
- Background Estimation

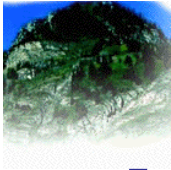
Instrumental

- Beam Energy
- Beam Polarization

Theoretical

- Standard Model Processes
- Electroweak Interpretation

⇒ No Straight Answers!



Theory Constraints



Interpretation

Quantity	Uncertainty	$\Delta \sin^2 \theta_W^{eff}$ [ppm]	Δm_W [MeV]
Δm_t	130 MeV	4	1
Δm_H	50 MeV		
$\Delta \alpha_s$	0.001		
Δm_Z	2.1 MeV	14	2.5
$\Delta \alpha_{had}$	5×10^{-5}	18	1
Estimate		30	3

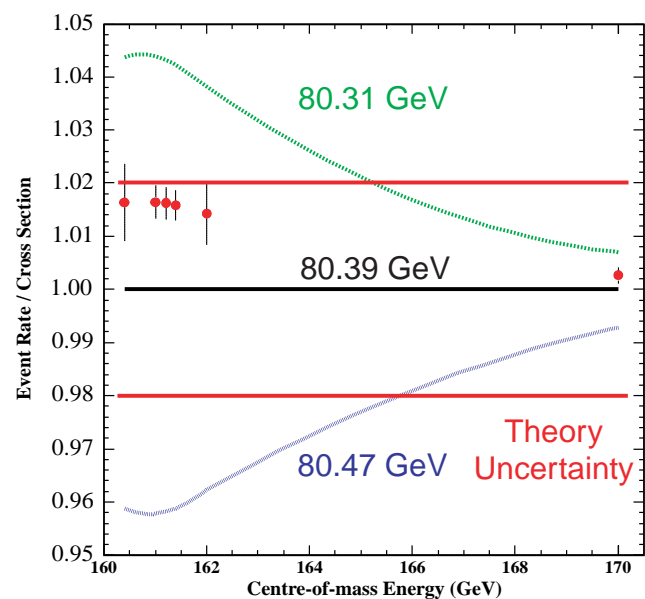
[S. Heinemeyer, G. Weiglein, 2001]

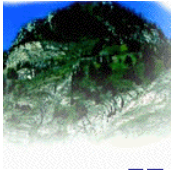
WW Threshold

$$\Delta \sigma_{WW} / \sigma_{WW} \sim 2\%$$

- No DPA
- $O(\alpha)$ 4f+ γ needed

Need $\sim 0.1\%$ on shape





Instrumentation



Weak Mixing Angle

	$\Delta \sin^2 \theta_W^{eff}$	ΔE_{beam} [MeV]	ΔE_{beam} [ppm]
SLD	0.00027	25	500
e^- only	0.00005	~ 5	100
Blondel	0.00002	~ 2	40

e^- only

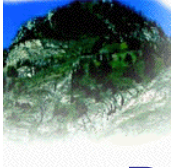
- 50M events
- $P_{e^-} = 80\%$, $P_{e^+} = 0\%$
- $\delta P_e / P_e = 0.25\%$

Blondel scheme

- ~ 100 M events
- $P_{e^-} = 80\%$, $P_{e^+} = 50\%$

W Threshold

$$\Delta E_{beam} < 5 \text{ MeV [50 ppm]}$$



Prior Knowledge



Predicted Improvements

	$\Delta \sin^2 \theta_W^{eff}$	Δm_W [MeV]
Today	0.00017	34
Run IIa (2 fb ⁻¹)	0.00050	30
Run IIb (30 fb ⁻¹)	0.00013	15
LHC	0.00021	15
Cumulative	~ 0.00010	~ 10
Giga-Z	0.00002	6

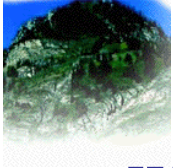
[J. Erler et. al., hep-ph/0005024]

⇒ Further improvements at Run II/LHC possible!

Giga-Z Outlook

- Substantial improvement in $\sin^2 \theta_W$
- Modest improvement in m_W
- Dramatic improvement in Γ_W ?

Giga-Z provides unique systematics...



Beam Energy Needs



Weak Mixing Angle

$$e^- \text{ only: } \Delta E_{beam} < 5 \text{ MeV [100 ppm]}$$

$$\text{Blondel: } \Delta E_{beam} < 2 \text{ MeV [40 ppm]}$$

WW Threshold

$$\Delta E_{beam} < 5 \text{ MeV [50 ppm]}$$

⇒ Low beamstrahlung needed

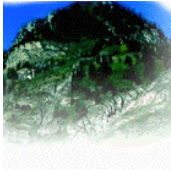
Top Mass

$$40 \text{ MeV in } 10\text{fb}^{-1} \text{ [230 ppm]}$$

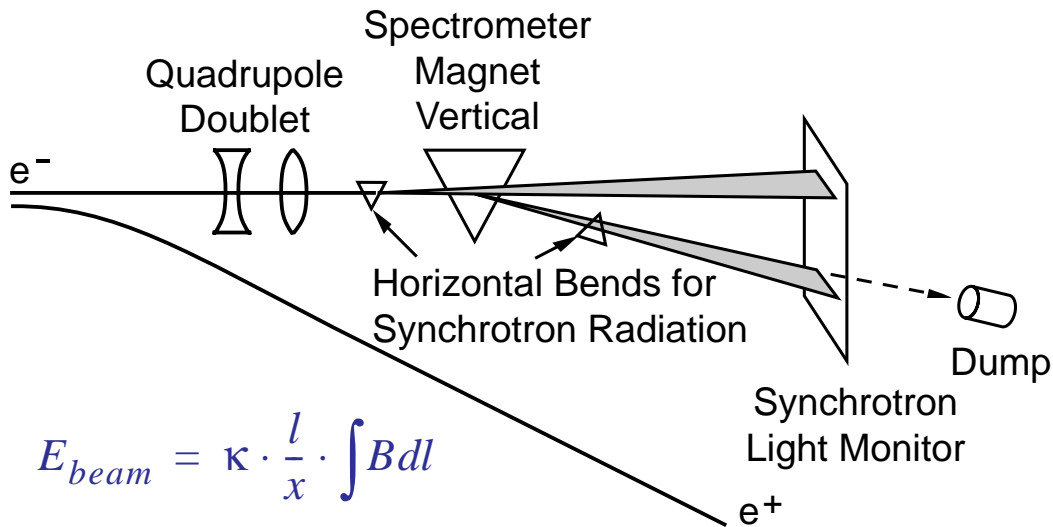
Higgs Mass

$$\sim 50 \text{ MeV (Direct Reconstruction)}$$

⇒ 100-200 ppm ‘adequate’ for HE running



Meet the WISRD



SLC Parameters at 50 GeV

$$\int B dl = 3.05 \text{ Tesla meters}$$

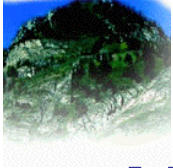
$$l = 15 \text{ meters}$$

$$x = 27 \text{ cm at 50 GeV}$$

Systematic Errors per Beam

$\Delta \int B dl:$	100 ppm
Alignment:	190 ppm
Detector - IP:	135 ppm
Total:	250 ppm \Rightarrow 12.5 MeV at 50 GeV

\Rightarrow 1998 SLC m_Z scan implies a $\sim 40 \pm 20$ MeV offset in E_{CM}



WISRDLimits

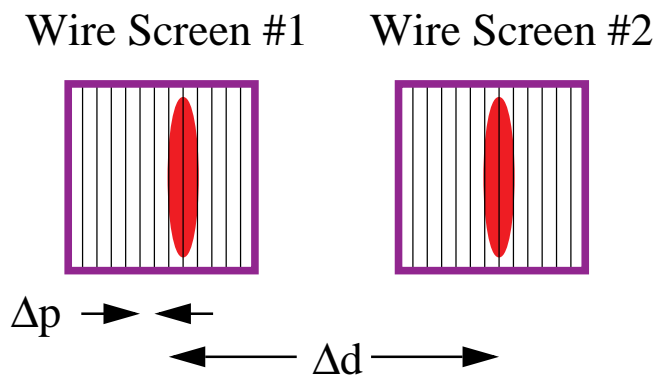


Magnetic Field

- $\Delta \int Bdl$: 100 ppm achieved at SLC
 - Error is relative: Not affected by increasing \sqrt{s}
 - Dominated by absolute scale error
- ⇒ Relative accuracy of ~ 30 ppm achieved at LEP

Detector Alignment

- Magnet to Detector distance irrelevant: $dl/l = 17$ ppm
- Transverse detector precision dominates:



Pitch Error: $\Delta p = 10 \mu\text{m}$

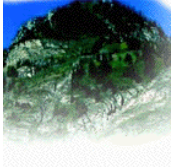
Relative detector distance: $\Delta d = 25 \mu\text{m}$

⇒ 93 ppm at 50 GeV ($d=27$ cm)

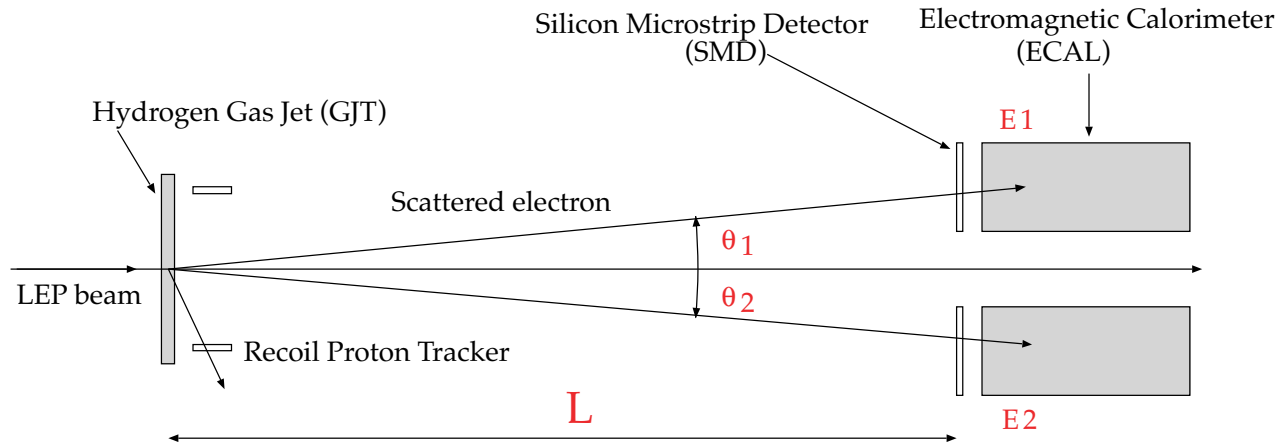
⇒ 370 ppm at 500 GeV! (assuming single screen)

Better detector possible for high energy/small d ?

Intrinsic Synchrotron stripe width ~1mm at SLC...



Møller Scattering



$$E_{beam} = \frac{8m_e}{(\tan\theta_1 + \tan\theta_2)^2} \frac{1}{1 - \kappa^2} - m_e$$

$$\kappa = \frac{\tan\theta_1 - \tan\theta_2}{\tan\theta_1 + \tan\theta_2} \text{ or } \kappa = \frac{E_1 - E_2}{E_1 + E_2}$$

- Use angles only (need IP position)
- Use energy and angles (independent of IP position)

LEP II Study [LEP II Yellow Report]

$l = 30$ meters

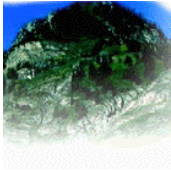
$\theta = 2 - 6$ mRad angular acceptance

$\sigma_E/E = 3.37/E(\text{GeV})^{1/4}\%$ resolution

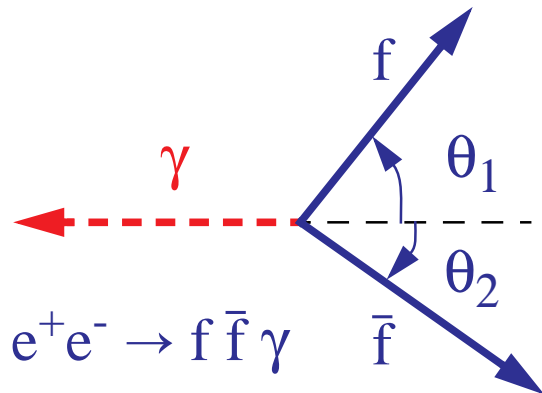
$\Delta E_{stat} = 2\text{MeV}$ in 30 minutes (~ 600 Hz)

$\Delta E_{syst} \sim 2\text{MeV}$ (dominated by Fermi motion)

\Rightarrow Complete study for LC needed... (also Compton)



Radiative Returns



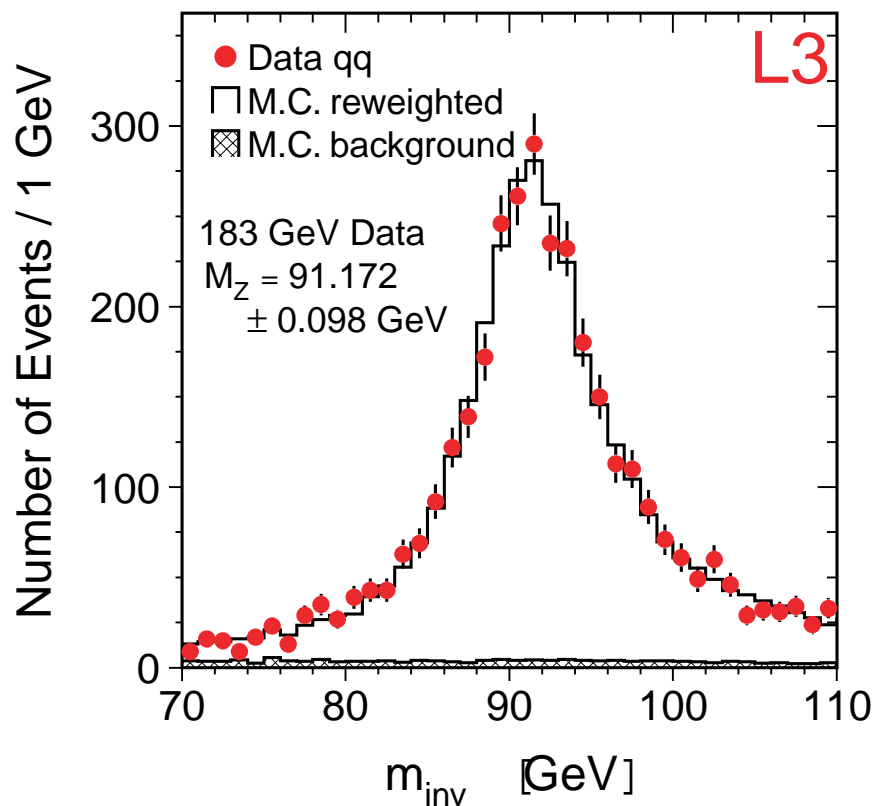
$$\frac{s'}{s} = \frac{\sin \theta_1 + \sin \theta_2 - |\sin(\theta_1 + \theta_2)|}{\sin \theta_1 + \sin \theta_2 + |\sin(\theta_1 + \theta_2)|}$$

Statistics

Channel	ΔE_{beam}
$q\bar{q}\gamma$	$\sim 18 \text{ MeV}$
$\mu\mu\gamma$	$\sim 40 \text{ MeV}$
$ee\gamma$	$\sim 70 \text{ MeV}$

LEP Potential
Statistics Only

2.7 fb^{-1}



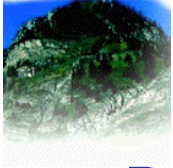
Systematics

- Theoretical Description
- Hadronization Uncertainties
- Detector Understanding

Opal Estimates

$q\bar{q}\gamma$	$\Delta E_{\text{beam}} \sim 70 \text{ MeV}$
$\mu\mu\gamma$	$\Delta E_{\text{beam}} \sim 20 \text{ MeV}$
$ee\gamma$	$\Delta E_{\text{beam}} \sim 80 \text{ MeV}$

Need absolute θ measurement!



Polarimetry Overview



Production

- **Electrons:** ~ 80% (strained GaAs cathode)
- **Positrons:** 0 - 60% (not so simple...)

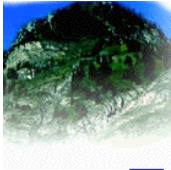
$$P_{eff} = \frac{P_- + P_+}{1 + P_- P_+} \sim 93\% [80\%/50\%]$$

Detection

Uncertainty Source	$\delta P/P$ SLD	$\delta P/P$ LC
Analyzing Power	0.40%	0.20%
Detector Linearity	0.20%	0.10%
Laser Polarization	0.10%	0.10%
Electronic Noise	0.20%	0.05%
Total Uncertainty	0.50%	0.25%
IP Corrections	0.15%	< 0.05

High Energy Needs

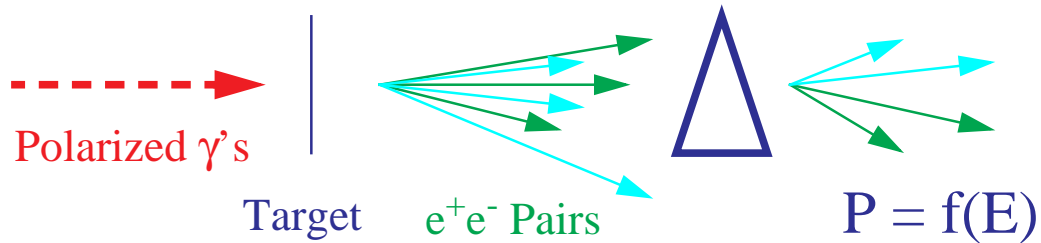
- $\delta P/P \sim 0.25\%$ adequate
- P_{e^+} makes many things easier
- Direct measurement possible in WW



Polarized Positrons



Tesla/JLC production

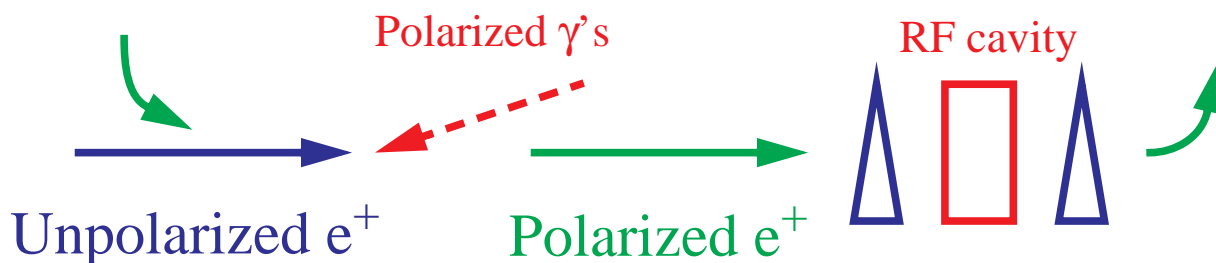


- Circularly polarized photons
- Thin target converts to e^+e^-
- Large energy-polarization correlation

Tesla: helical undulator JLC: Compton scattering

⇒ Lots of R&D needed

New Idea [R. Partridge]



- Compton scattering ($2 \text{ GeV } e^+ + 2 \text{ eV } \gamma$)
- Must restore energy loss ($\sim 4\%$)

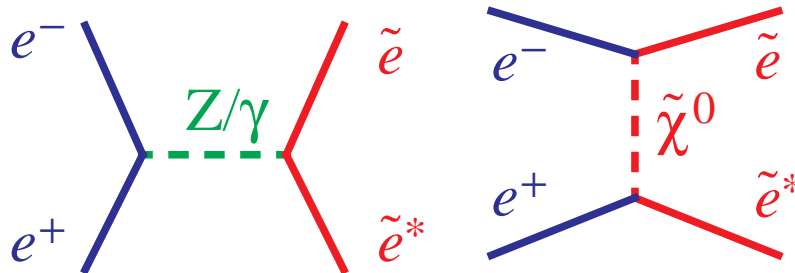
⇒ Ridiculous laser power needed?



Polarized Positron Physics

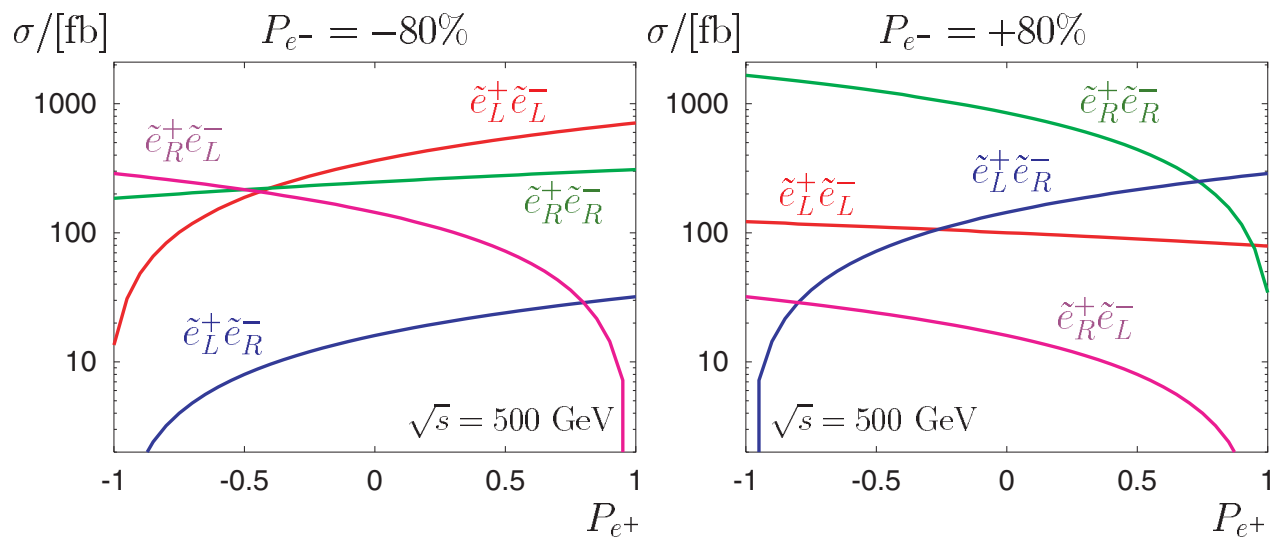


Slepton Production



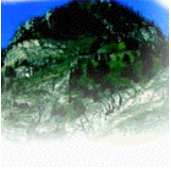
s-channel: $\tilde{e}_L \tilde{e}_L^*$ or $\tilde{e}_R \tilde{e}_R^*$ only

t-channel: $\tilde{e}_L \tilde{e}_R^*$ and $\tilde{e}_R \tilde{e}_L^*$ also

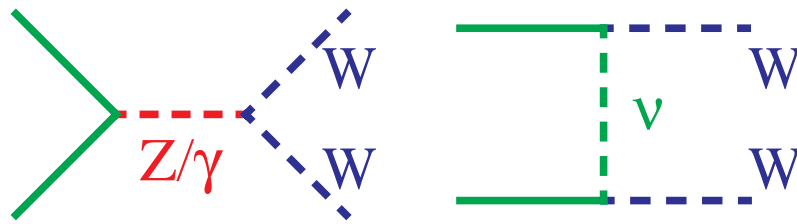


[G. Moortgat-Pick, H. Steiner, 2000]

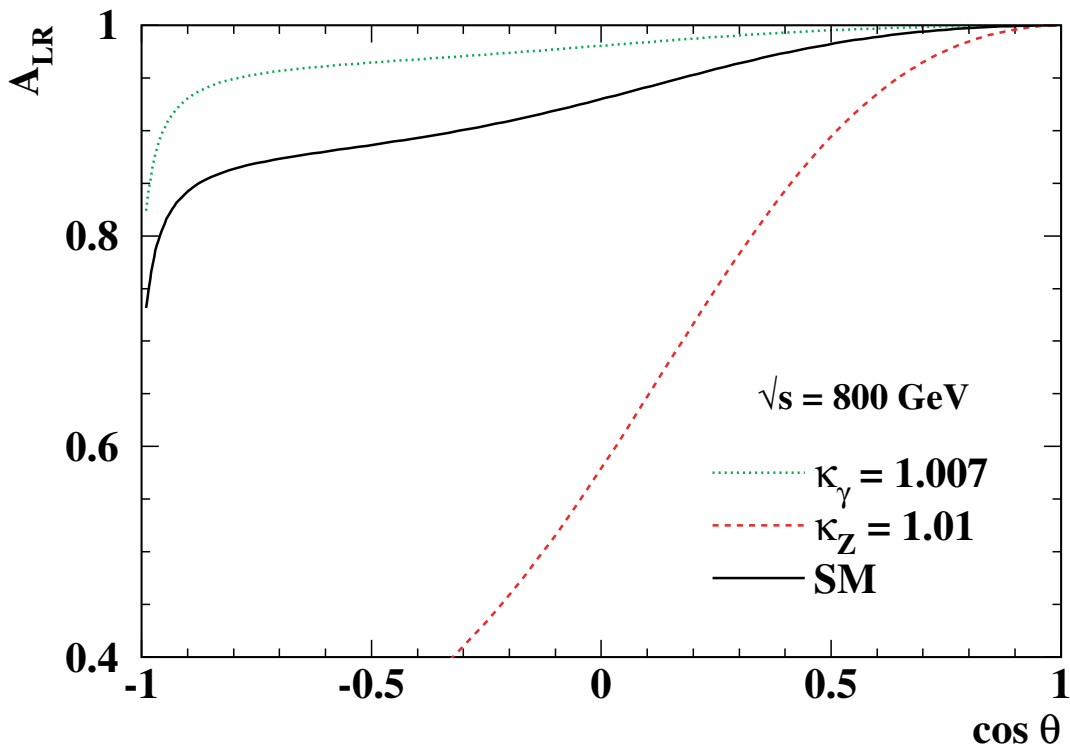
⇒ Unique manipulation of helicity states



Direct Polarization



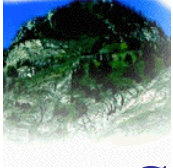
$$\sigma = 12 - 7 \text{ pb at } \sqrt{s} = 350 - 500 \text{ GeV}$$



[K. Mönig, Snowmass 2001]

$\delta P/P < 0.1\%$ for 500 fb^{-1} at 350 GeV (9/1 L ratio)

\Rightarrow Similar with e^- only



Summary



Giga-Z

- e^- only: $\Delta \sin^2 \theta_W \sim 0.00005$
- e^+ also: $\Delta \sin^2 \theta_W \sim 0.00002$
- Threshold: $\Delta m_W \sim 6 \text{ MeV}$

Need $\Delta E_{beam} < 50 \text{ ppm!}$

Beam Energy Needs

- **WISR**D spectrometer for general operation
- Need detector ideas/R&D for **Giga-Z**
- **Radiative returns** interesting for WW

Polarization

- e^+ production needs lots of work
- WW provides $\delta P/P < 0.1\%$
- e^+ improves most analyses

Some are probably crucial ($\tilde{e}\tilde{e}^*$)

\Rightarrow Expect the Unexpected!