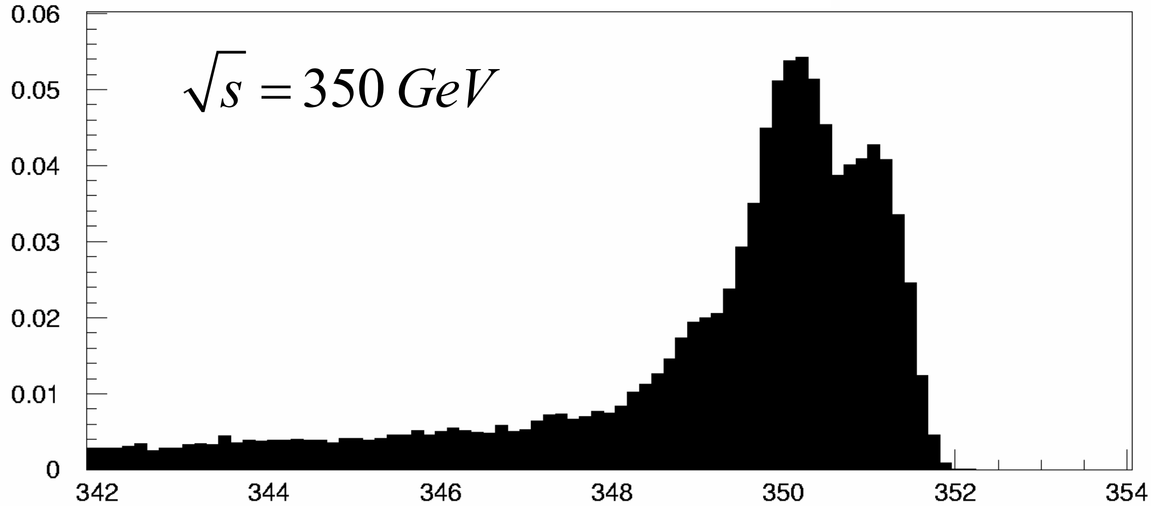
Effect of Energy Spread on LC Mass Measurements

Tim Barklow
SLAC
April 29, 2004

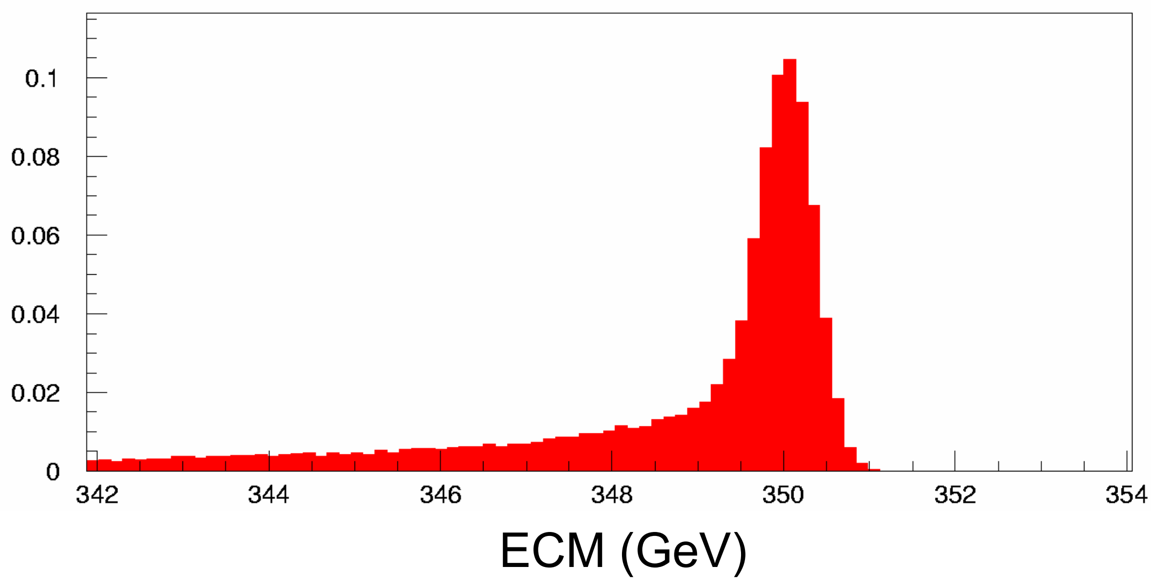
Study Effect of Energy Spread on Top, Higgs, and SUSY Mass Meas

Normalized Lumi Weight Ecm Distributions
including Beamstralung & Linac Energy Spread



NLC

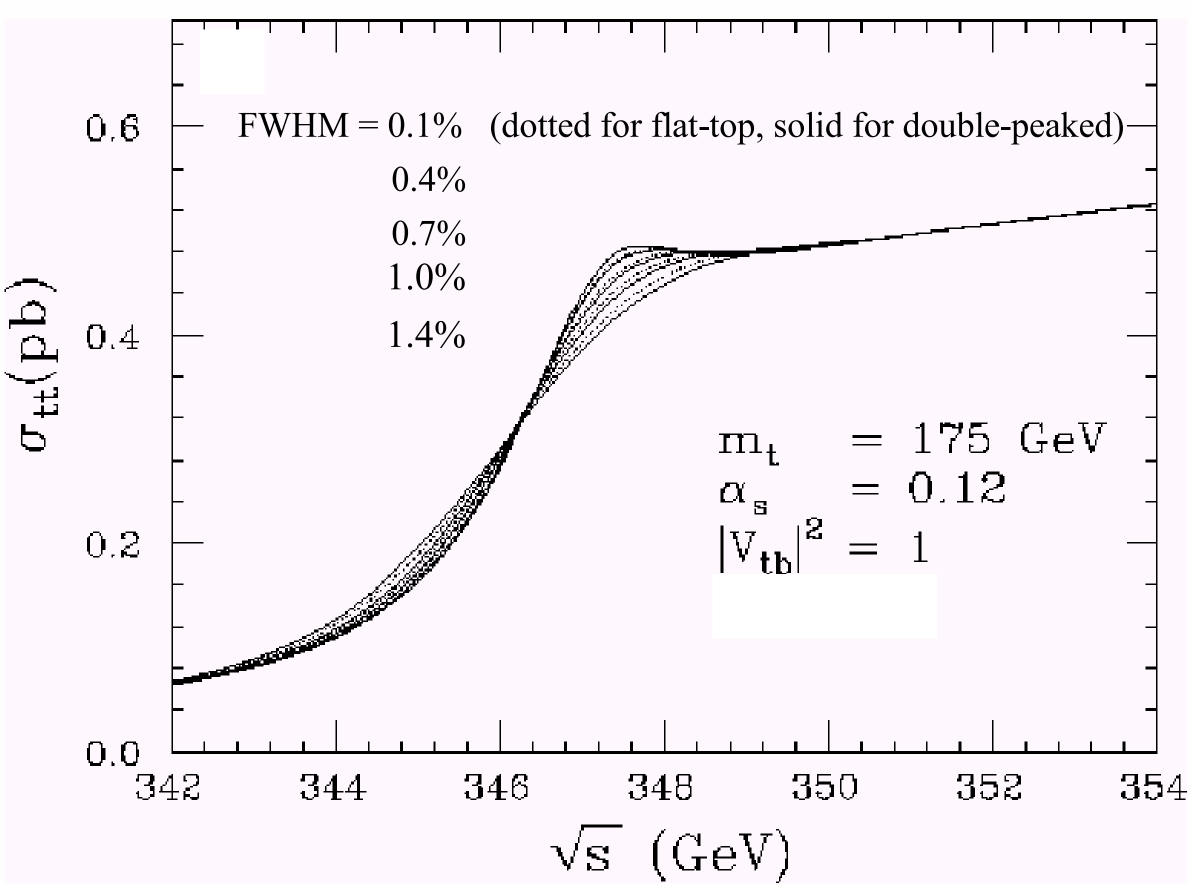
FWHM ≈ 0.6% (peak region)



TESLA

FWHM ≈ 0.2% (peak region)

Top Pair-Prod. Cross Section @ Threshold



from ACFA report
hep-ph/0109166

- **need knowledge of E-spread FWHM to level of ~0.1%**
- **top mass error still under study, but statistical improvement should be small when E-spread is reduced from 0.6% FWHM to 0.2% FWHM**

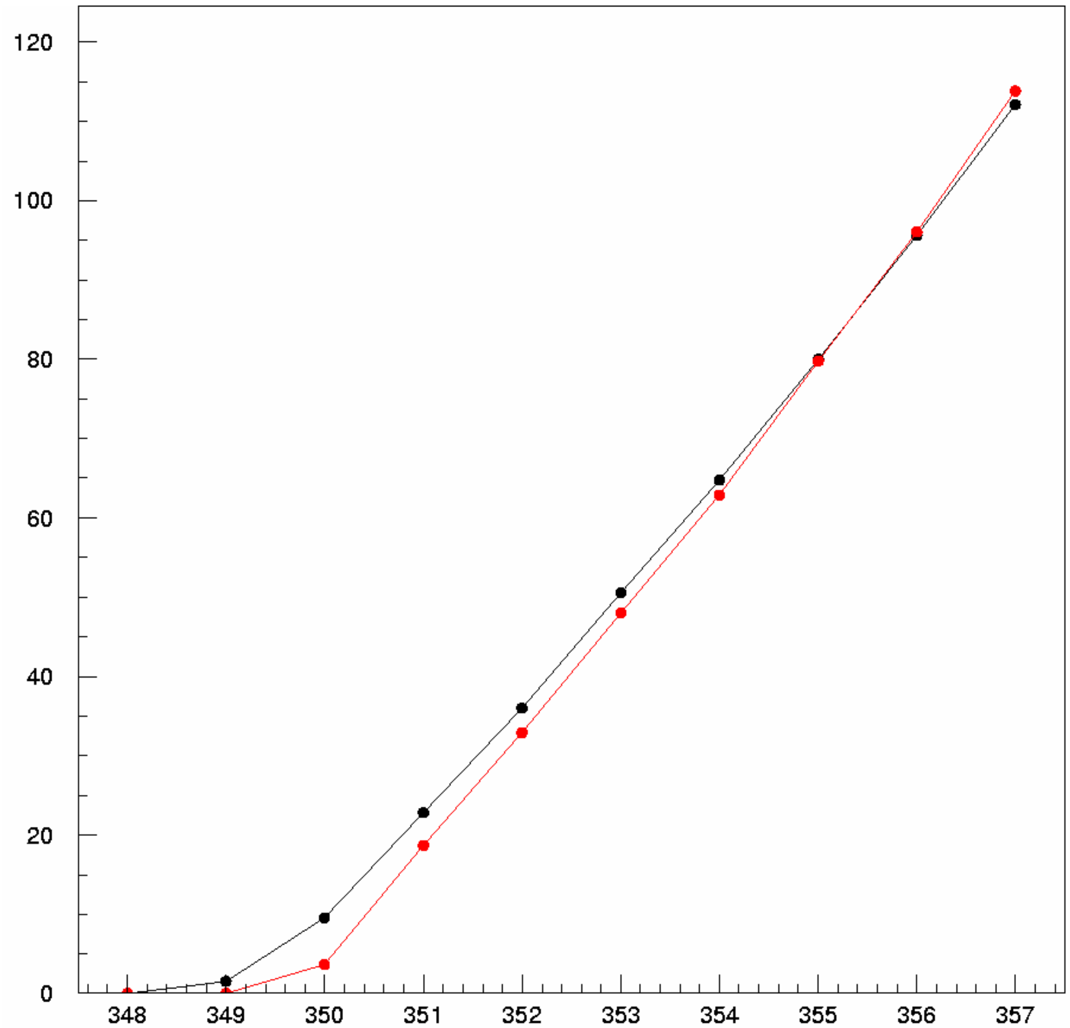
$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-$ Threshold Scan   20 fb^{-1} per point

SPS1a $\tilde{\chi}_1^+$: BR($\tilde{\chi}_1^+ \to \tilde{\tau}^+\nu_\tau$) ≈ 100% $\Gamma_{\tilde{\chi}_1^+} = 8$ MeV

Events

● NLC

● TESLA



$\sqrt{s}$ (GeV)

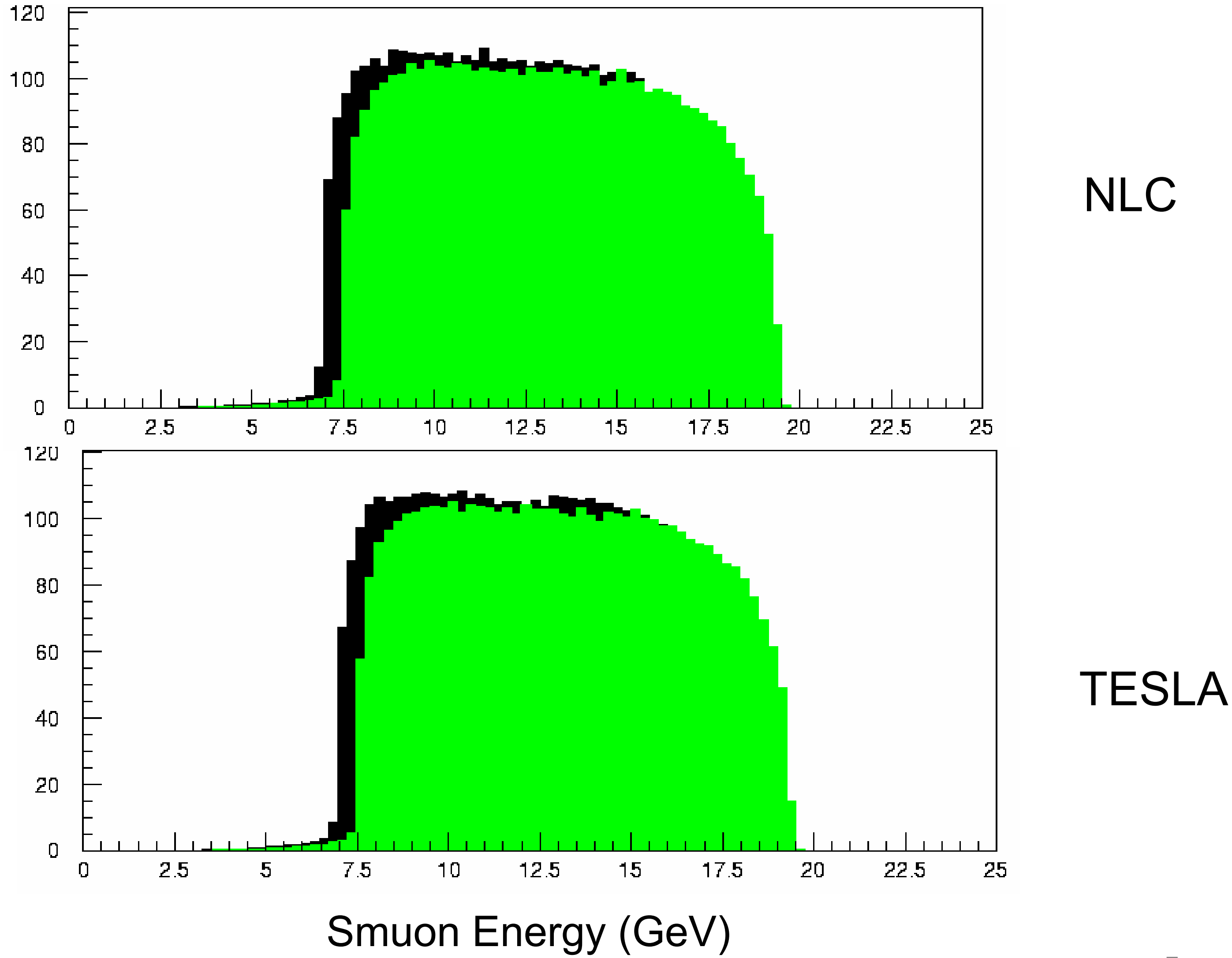
Energy Spread Comparison

NLC $\Delta M_{\tilde{\chi}^+} = 42$ MeV

TESLA $\Delta M_{\tilde{\chi}^+} = 38$ MeV

Simdet Detector Simulation of $e^+e^- \rightarrow \tilde{\mu}_R^+ \tilde{\mu}_R^-$ $\sqrt{s} = 500\ GeV\ L = 500\ fb^{-1}$

$M_{\tilde{\mu}_R} = 223.6\text{GeV}$ vs $M_{\tilde{\mu}_R} = 224.4\text{GeV}$

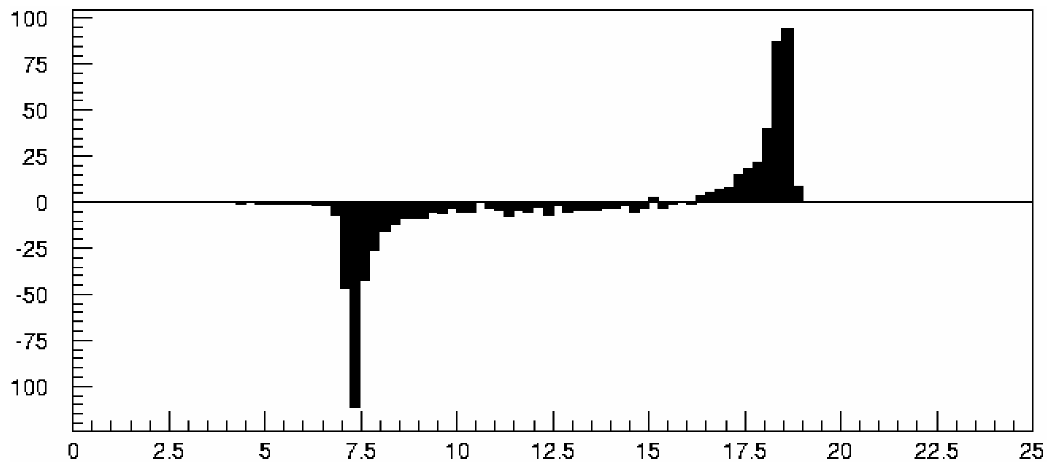


Energy Spread Comparison

Estimate Statistical Error on Smuon Mass Assuming Perfect MC Simulation

$$\sqrt{s} = 500\ GeV \quad L = 500\ fb^{-1}$$

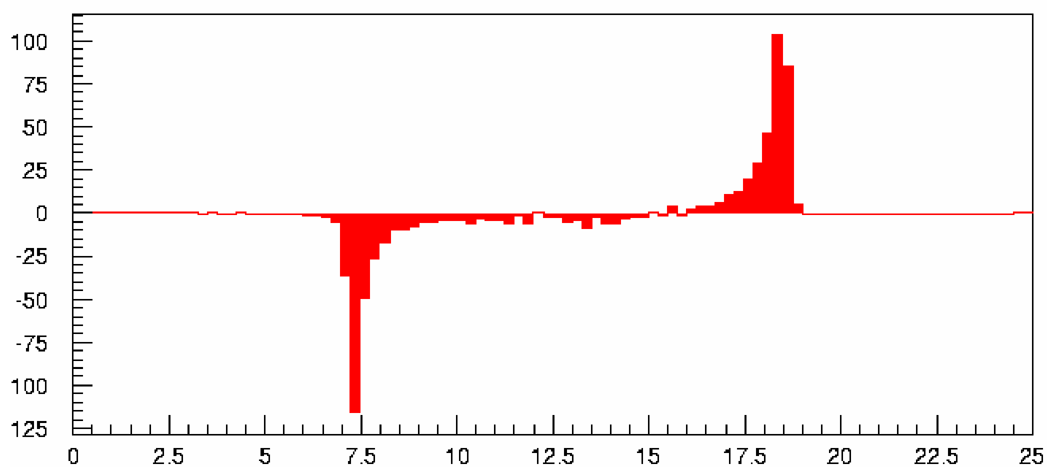
$$\left.\frac{dN_{bin}}{dE_{\tilde{\mu}}}\right|_{M\tilde{\mu}=224\ GeV}$$



NLC

$$\Delta M_{\tilde{\mu}} = 35\ MeV$$

$$\left.\frac{dN_{bin}}{dE_{\tilde{\mu}}}\right|_{M\tilde{\mu}=224\ GeV}$$



TESLA

$$\Delta M_{\tilde{\mu}} = 34\ MeV$$

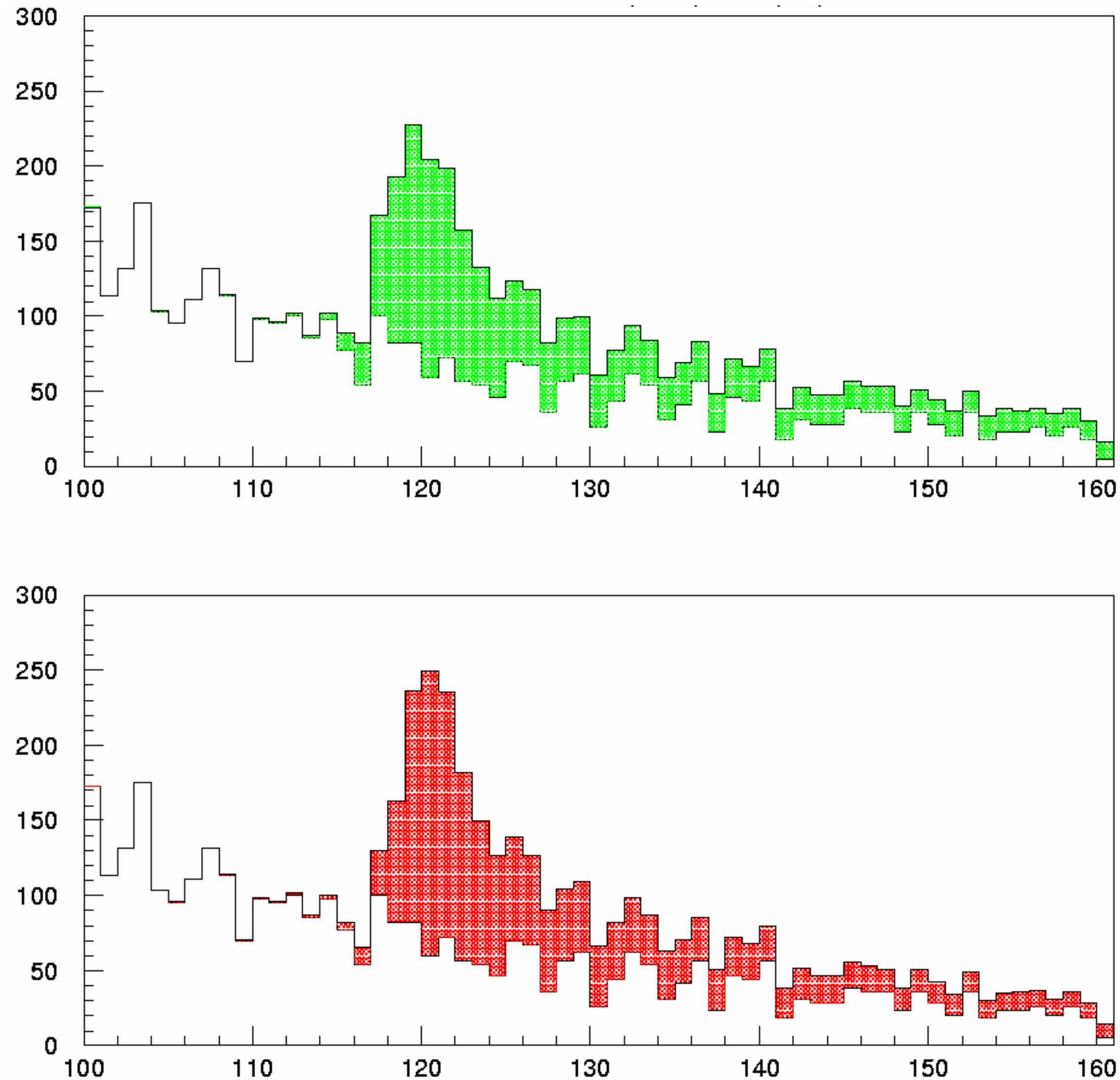
Smuon Energy (GeV)

Simdet Detector Simulation of e+e- → Zh

$\sqrt{s} = 350\ GeV\ \ L = 500\ fb^{-1}$

$$Z \rightarrow e^{+}e^{-}, \mu^{+}\mu^{-}$$

with background



NLC

TESLA

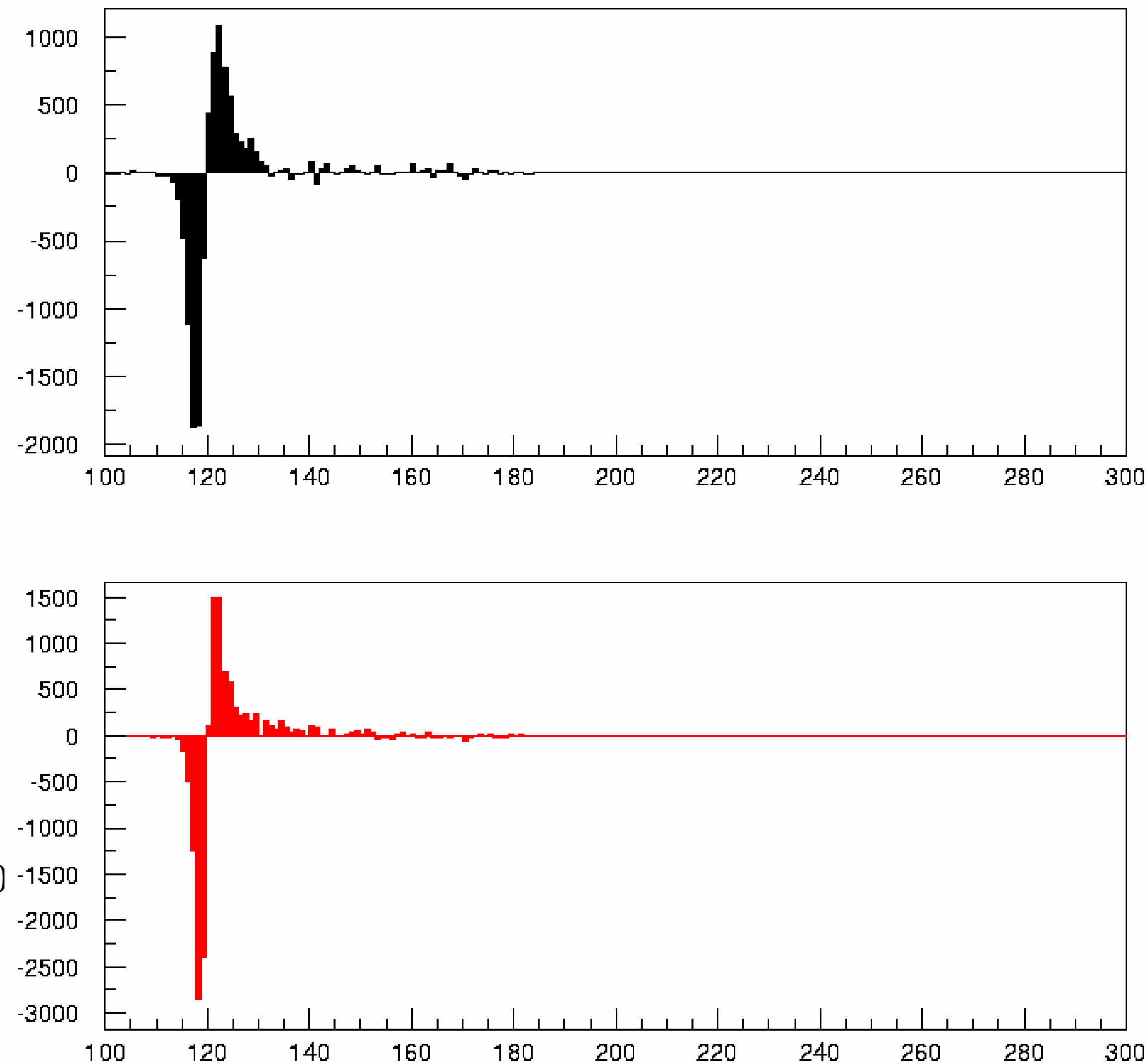
Recoil Mass (GeV)

Energy Spread Comparison

Estimate Statistical Error on Higgs Mass Assuming Perfect MC Simulation

$$\sqrt{s} = 350\ GeV \quad L = 500\ fb^{-1}$$

$$\left.\frac{dN_{bin}}{dM_h}\right|_{Mh=120}$$



NLC

$$\Delta M_h = 143\ MeV$$

$$\left.\frac{dN_{bin}}{dM_h}\right|_{Mh=120}$$

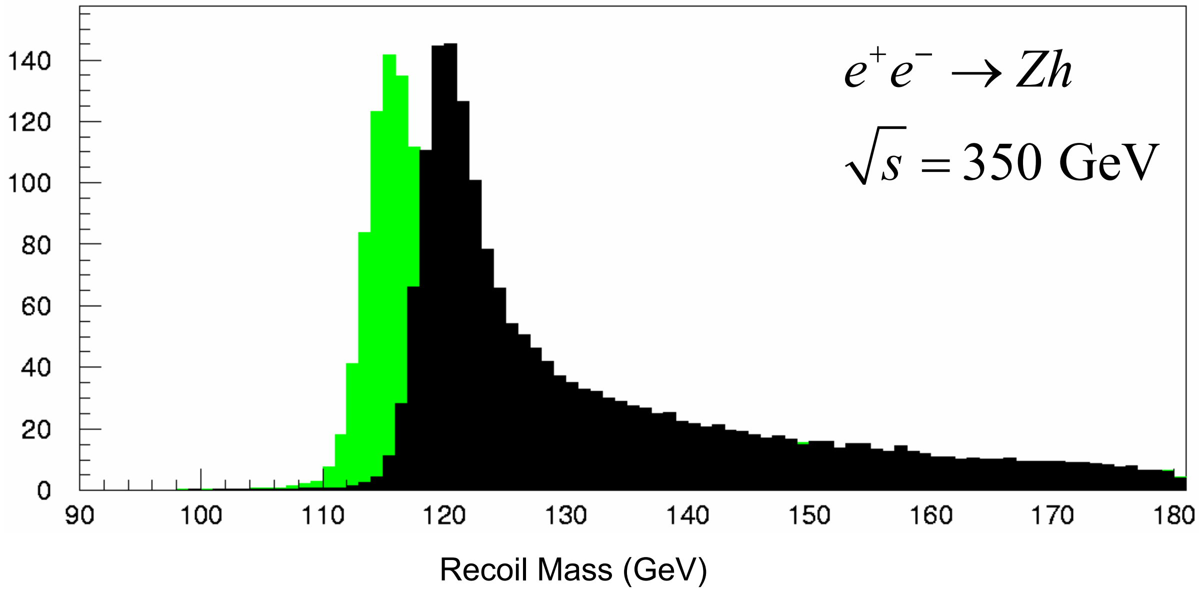
TESLA

$$\Delta M_h = 117\ MeV$$

Recoil Mass (GeV)

Energy Scale Error

— (black) $\frac{\Delta E_b}{E_b} = 0$ — (green) $\frac{\Delta E_b}{E_b} = 0.008$

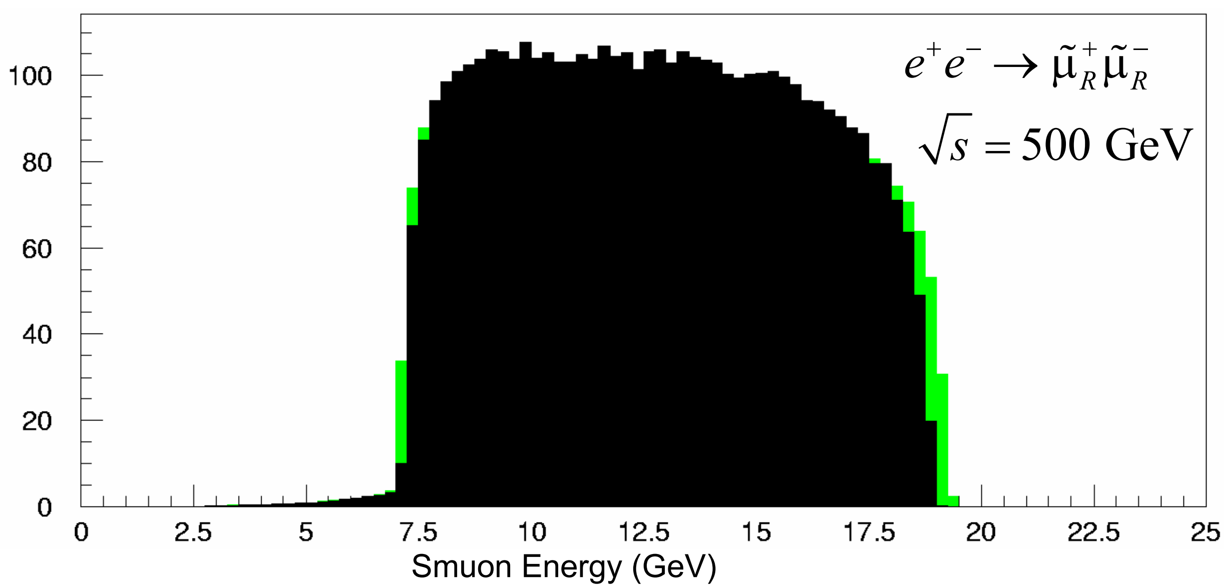


$$\Delta M_h \approx \frac{2E_b}{M_h}\Delta E_b = 2.9\,\Delta E_b \;\Rightarrow$$

$$\frac{\Delta E_b}{E_b} = \frac{M_h^2}{2E_b^2}\frac{\Delta M_h}{M_h} = 0.235\frac{\Delta M_h}{M_h}$$

$$\Rightarrow \frac{\Delta E_b}{E_b} = 100 \text{ ppm}$$

for $\Delta M_h = 50$ MeV



$$\Delta M_{\tilde{\mu}} \approx 0.05\Delta E_b \;\Rightarrow$$

$$\frac{\Delta E_b}{E_b} = 20\frac{M_{\tilde{\mu}}}{E_b}\frac{\Delta M_{\tilde{\mu}}}{M_{\tilde{\mu}}} = 9.0\frac{\Delta M_{\tilde{\mu}}}{M_{\tilde{\mu}}}$$

$$\Rightarrow \frac{\Delta E_b}{E_b} = 700 \text{ ppm}$$

for $\Delta M_{\tilde{\mu}} = 17$ MeV

TESLA Study of M_H measurement using kinematic fit of qqll and qqbb

Energy scale error

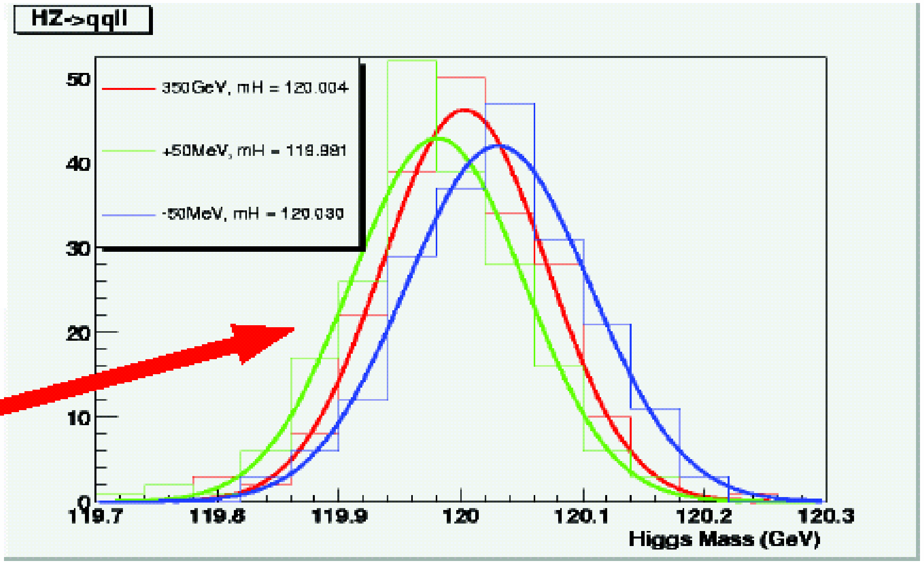
$\delta M_h = 1.0\,\delta E_e \quad (qqll)$

$\delta M_h = 0.8\,\delta E_e \quad (bbqq)$

$\delta E_{e+} = \delta E_{e-} = \pm 25$ MeV results in a mass shift

~ 25 MeV for HZ qq*ll*

~ 20 MeV for HZ bbqq



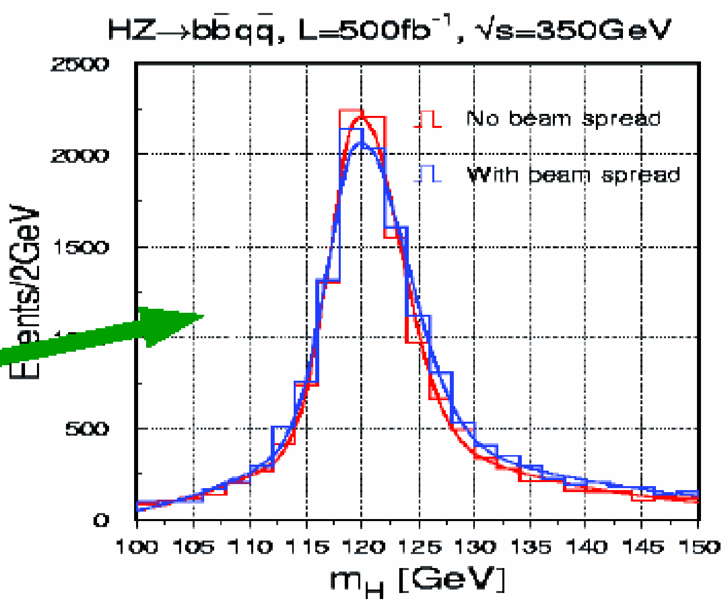
Effect of beam spread

- statistical accuracy degrades
  from 45 to 50 MeV in HZ → bbqq channel
  from 70 to 80 MeV in HZ → bb*ll* channel
  if one assumes 0.5% beam spread for both e^+ and e^-

⇒ statistical accuracy degrades

from 72 to 76 MeV (6%) for TESLA→ NLC (*bbll*)

from 46 to 48 MeV (4%) for TESLA→ NLC (*bbqq*)



	δM_h in MeV		
	TESLA	TESLA	NLC
Decay mode	$\delta E/E=0$	$\delta E/E=0.1\%$	$\delta E/E=0.3\%$
recoil mass	110	117	143
$ZH \to l^+l^- q\bar{q}$	70	72	76
$ZH \to q\bar{q}b\bar{b}$	45	46	48
Combined	38	39	40

MSSM theory error on m_h : (S. Heinemeyer)

Current theory uncertainty: $\delta m_h^{\text{theo,today}} \approx 3$ GeV

Future theory uncertainty: $\delta m_h^{\text{theo,future}} \lesssim 0.5$ GeV necessary/possible

Future parametric uncertainty: $\delta m_h^{\text{para,future}} = \mathcal{O}(0.2 \text{ GeV})$ $(m_t,\ \alpha_s)$

Summary

- The degradation in statistical error for m(SUSY) is negligible for the endpoint technique when the energy spread is increased from 0.1% to 0.3%. The degradation is of *O*(10%) for small width fermion threshold scans (42 MeV vs 38 Mev).

- There is a 20% degradation in the statistical error for m(Higgs) when the energy spread is increased from 0.1% to 0.3%, assuming the recoil mass technique (143 Mev vs 117 Mev). Other Higgs mass measurement techniques, such as a kinematic fit of *llbb* and *qqbb*, have a much smaller degradation.