Determination of the Gaugino Mass Parameter M_1 in Different Linear Collider Modes

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I. Introduction and Motivation

First detection of SUSY:

L(arge) H(adron) C(ollider): $\tilde{q}$, $\tilde{g} < 2.5$ TeV

What is left for a Linear Collider:

precise determination of underlying SUSY parameters

Unconstrained SUSY: **105** free parameters !

$\rightarrow$ to reduce parameters: assumptions on their behavior at the GUT-scale, CP, FCNC,...

$\rightarrow$ few free parameters, e.g. gaugino masses M_1, M_2 and M_3

One usual Assumption:

Unification of M_1, M_2 and M_3 at the GUT-Scale

$$\Downarrow$$

RG equations

$$\Downarrow$$

$$\boxed{M_1 = \frac{5}{3}\tan^2\theta_W M_2}$$

But:

- Unification - assumption must not be right!

- Different SUSY breaking scenarios:

F_Φ	M_1	M_2	M_3
1	$1(\sim 6)$	$1(\sim 2)$	$1(\sim 1)$
24	$2(\sim 12)$	$-3(\sim -6)$	$-1(\sim -1)$
75	$1(\sim 6)$	$3(\sim 6)$	$-5(\sim -5)$
200	$1(\sim 6)$	$2(\sim 4)$	$10(\sim 10)$
OII	$1(\sim 6)$	$5(\sim 10)$	$53/5(\sim 53/5)$

Chen, Drees, Gunion, 1997/1999

$\rightarrow$ M_1 determination necessary

Particle Content of the MSSM

Particles of the SM	SUSY Particles		
	Int-ES	Mass-ES	
$l = e, \mu, \tau$	$\tilde{l}_L, \tilde{l}_R$	$\tilde{l}_1, \tilde{l}_2$	Slepton
$\nu = \nu_e, \nu_\mu, \nu_\tau$	$\tilde{\nu}$	$\tilde{\nu}$	Sneutrino
$q = u, d, s, c, b, t$	$\tilde{q}_L, \tilde{q}_R$	$\tilde{q}_1, \tilde{q}_2$	Squark
$W^\pm$	$\tilde{W}^\pm$	$\tilde{\chi}_j^\pm$	Chargino
$H^\pm$	$\tilde{H}^\pm$		
γ	$\tilde{\gamma}$		
Z	$\tilde{Z}$	$\tilde{\chi}_j^0$	Neutralino
H_1^0	$\tilde{H}_1^0$		
H_2^0	$\tilde{H}_2^0$		
g	$\tilde{g}$	$\tilde{g}$	Gluino

$$\tilde{\chi}_i^0 = N_{i1}\tilde{\gamma} + N_{i2}\tilde{Z} + N_{i3}\tilde{H}_1^0 + N_{i4}\tilde{H}_2^0$$

Parameters of the MSSM

- M_2: SU(2) gaugino mass parameter
- M_1: U(1) gaugino mass parameter
- μ: Higgsino mass parameter
- $\tan\beta = \frac{v_2}{v_1}$: ratio of the Higgs vacuum expectation values
- $m_{\tilde{f}_{L/R}}$: sfermion masses (corr. to m_0, the common sfermion mass at the GUT scale)

"Usual" GUT-Relation: $M_1 = \frac{5}{3}\tan^2\theta_W M_2$

Neutralino - Mixing

Mass matrix of the neutralinos:

$$\mathcal{Y} = \begin{pmatrix} M_2 \sin^2\theta_W + M_1 \cos^2\theta_W & (M_2 - M_1)\sin\theta_W \cos\theta_W & 0 & 0 \\ (M_2 - M_1)\sin\theta_W \cos\theta_W & M_2 \cos^2\theta_W + M_1 \sin^2\theta_W & m_Z & 0 \\ 0 & m_Z & \mu \sin 2\beta & -\mu \cos 2\beta \\ 0 & 0 & -\mu \cos 2\beta & -\mu \sin 2\beta \end{pmatrix}$$

Masses of the neutralinos:

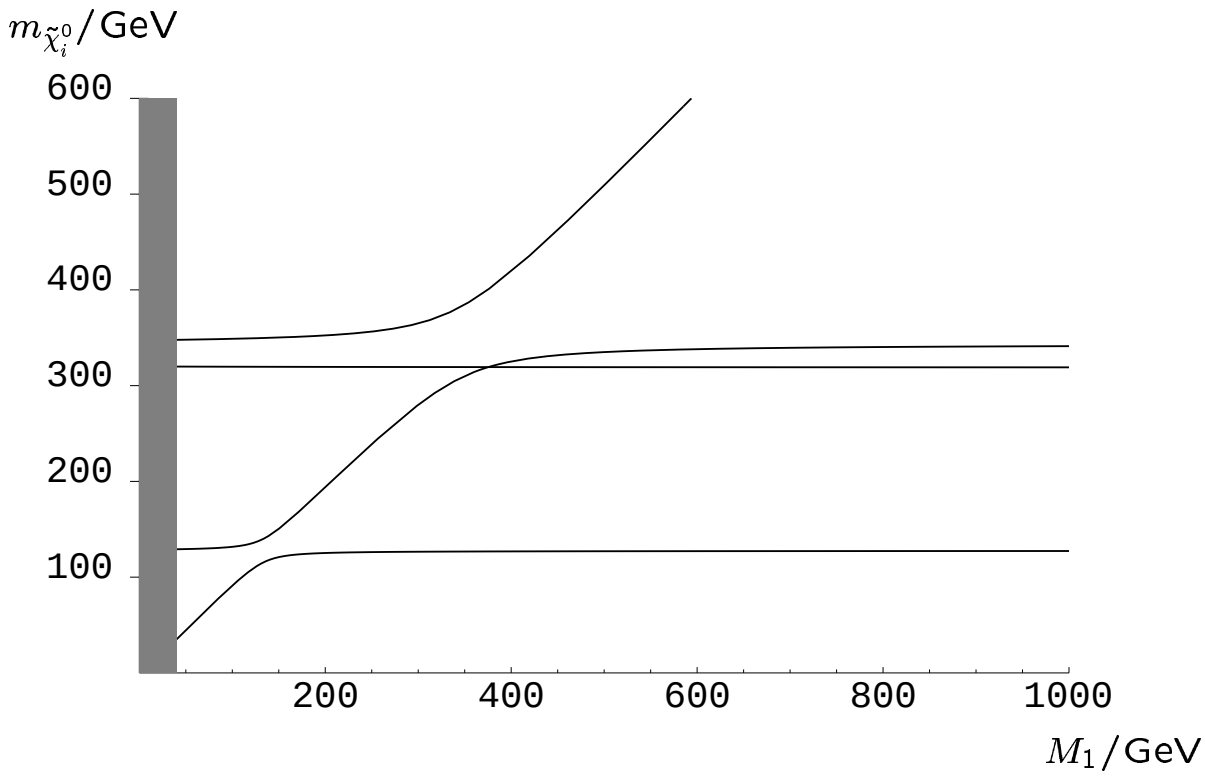
$$\left(m^2_{\tilde{\chi}^0_i} - \mu^2\right)\left(m_{\tilde{\chi}^0_i} - M_2\right)\left(m_{\tilde{\chi}^0_i} - M_1\right) - m_Z^2\left(m_{\tilde{\chi}^0_i} + \mu \sin 2\beta\right) \cdot$$
$$\cdot \left(m_{\tilde{\chi}^0_i} - M_2 \sin^2\theta_W - M_1 \cos^2\theta_W\right) = 0$$

Neutralino Eigenstates:

$$\tilde{\chi}_i^0 = \frac{1}{N_i} \begin{pmatrix} (M_2 - M_1) \sin\theta_W \cos\theta_W \left(m^2_{\tilde{\chi}_i^0} - \mu^2\right) \\ \left(m_{\tilde{\chi}_i^0} - M_2 \sin^2\theta_W - M_1 \cos^2\theta_W\right)\left(m^2_{\tilde{\chi}_i^0} - \mu^2\right) \\ \left(m_{\tilde{\chi}_i^0} - M_2 \sin^2\theta_W - M_1 \cos^2\theta_W\right)\left(m_{\tilde{\chi}_i^0} + \mu \sin 2\beta\right) \\ -\left(m_{\tilde{\chi}_i^0} - M_2 \sin^2\theta_W - M_1 \cos^2\theta_W\right)\mu \cos 2\beta \end{pmatrix}$$

$$\begin{aligned} N_i \;=\; & \{ \left(m^2_{\tilde{\chi}_i^0} - \mu^2\right)^2 \left(\sin^2\theta_W \left(m_{\tilde{\chi}_i^0} - M_2\right)^2 + \cos^2\theta_W \left(m_{\tilde{\chi}_i^0} - M_1\right)^2 + \right. \\ & + \left(m_{\tilde{\chi}_i^0} - M_2\right)^2 \left(m_{\tilde{\chi}_i^0} - M_1\right)^2 m_Z^{-2} \Big) + \\ & + \left(m_{\tilde{\chi}_i^0} - M_2 \sin^2\theta_W - M_1 \cos^2\theta_W\right)^2 (m_Z \mu \cos 2\beta)^2 \}^{\frac{1}{2}} \end{aligned}$$

Neutralino Masses $m_{\tilde{\chi}_i^0}$



$M_2 = 152$ GeV

$\mu = 316$ GeV

$\tan\beta = 3$

II. Some References

- MSSM without M_1/M_2 GUT-Relation

  C.H. Chen, M. Drees, J.F. Gunion, Phys.Rev.Lett. 76 (1996) 2002

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- Monte Carlo Simulations

  J.L. Feng, M.J. Strassler, Phys.Rev. D51 (1995) 4661

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  T. Tsukamoto, et al., Phys.Rev. D51 (1995) 3153

  M.M. Nojiri, K.Fujii, T. Tsukamoto, Phys.Rev. D54 (1996) 6756

- e^-e^- Collisions

  M.E. Peskin, Int.J.Mod.Phys. A13 (1998) 2299-2306

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- "Analytical" from Chargino/Neutralino Masses

  J.-L. Kneur, G. Moultaka, Phys.Rev. D59 (1999) 015005

- "Analytical" from Chargino Production and $m_{\tilde{\chi}_1^0}$

  S.Y. Choi, et al, Eur.Phys.J. C7 (1999) 123-134

  S.Y. Choi, et al, Eur.Phys.J. C8 (1999) 669-677

- Processes in this talk .....

III. M_1-dependence of SUSY Processes

MSSM-Parameters:

$$\begin{array}{ccccc} M_1, & M_2, & \mu,\ \tan\beta,\ m_{\tilde{e}_L},\ m_{\tilde{e}_R} \\ \uparrow & \uparrow & \nwarrow\ \nearrow \\ U(1) & SU(2) & m_0 \end{array}$$

GUT-Relation: $\boxed{M_1 = M_2 \cdot \frac{5}{3} \tan^2 \theta_W}$

CP-Conservation: M_1, M_2, μ real

Parameters for all processes:

$$M_2 = 152 \text{ GeV}$$

$$\mu = 316 \text{ GeV}$$

$$\tan\beta = 3$$

Different choices for:

$\sqrt{s_{ee}}$, $m_{\tilde{e}_L}$, $m_{\tilde{e}_R}$, polarized e^+e^-/γ beam

III.1. Neutralino Production in e^+e^- Annihilation

Process:

$$e^- + e^+ \xrightarrow[\tilde{e}_{L/R}]{Z^0} \tilde{\chi}_1^0 + \tilde{\chi}_2^0$$

$$\tilde{\chi}_2^0 \xrightarrow[\tilde{e}_{L/R}]{Z^0} \tilde{\chi}_1^0 + e^+ + e^-$$

- Associated production of $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ with leptonic decay of $\tilde{\chi}_2^0$

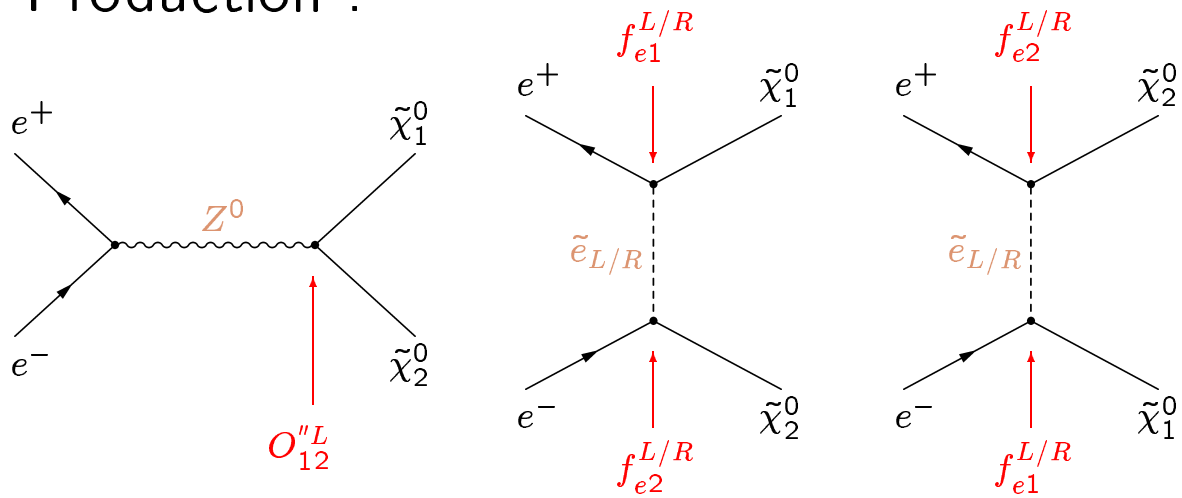
- Complete spin correlations between production and decay:

  $+$ contributions independent of $\tilde{\chi}_2^0$-polarisation

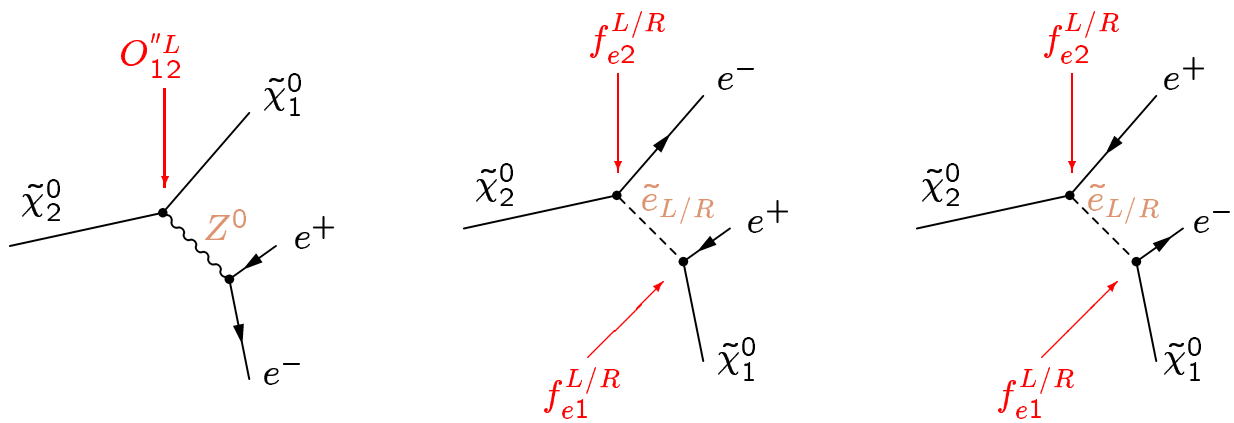
  $+$ contributions depending on $\tilde{\chi}_2^0$-polarisation

Feynman Graphs for Neutralino Production and Leptonic Decay

Production :



Decay :



M_1 in Production and Decay:

- masses $m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_2^0}$

- couplings O''^L_{12}, $f^L_{e1} f^L_{e2}$, $f^R_{e1} f^R_{e2}$

Couplings for the Different Processes

$$O^L_{11} = -\frac{1}{\sqrt{2}}\left(\cos\beta N_{14} - \sin\beta N_{13}\right) V^*_{12} + \left(\sin\theta_W N_{11} + N_{12}\right) V^*_{11}$$

$$O^R_{11} = \frac{1}{\sqrt{2}}\left(\sin\beta N^*_{14} - \cos\beta N^*_{13}\right) U_{12} + \left(\sin\theta_W N^*_{11} + N^*_{12}\right) U_{11}$$

$$O''^L_{12} = -\frac{1}{2}\left(N_{13}N^*_{23} - N_{14}N^*_{24}\right)\cos 2\beta - \frac{1}{2}\left(N_{13}N^*_{24} + N_{14}N^*_{23}\right)\sin 2\beta$$

$$O''^R_{12} = -O''^{L*}_{12}$$

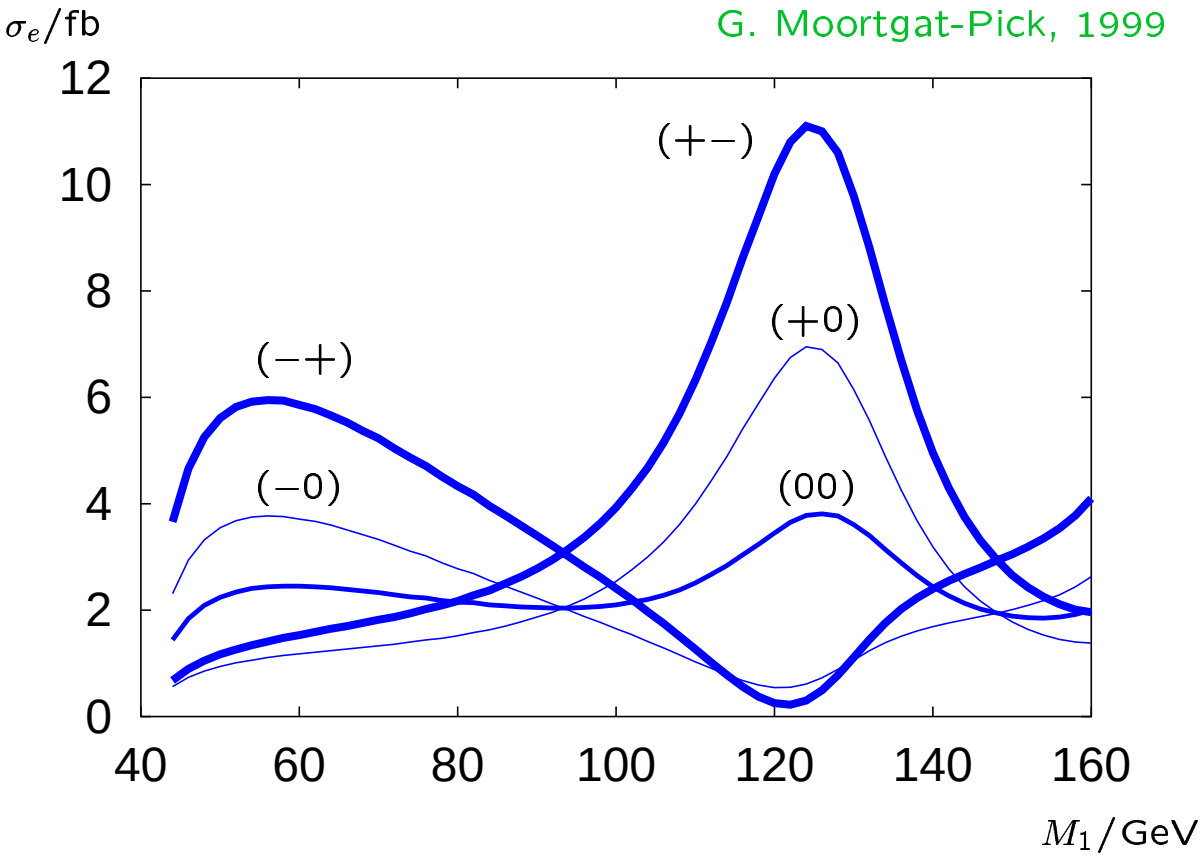
$$f^L_{ei} = -\sqrt{2}\left(\frac{1}{\cos\theta_W}\left(T_{3e} + \sin^2\theta_W\right) N_{i2} - \sin\theta_W N_{i1}\right)$$

$$f^R_{ei} = \sqrt{2}\sin\theta_W\left(\tan\theta_W N^*_{i2} - N^*_{i1}\right)$$

$$f^L_{\nu 1} = -\frac{\sqrt{2}}{\cos\theta_W} T_{3\nu} N_{12}$$

Total Cross Section σ_e

$$\sigma_e = \sigma\left(e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0\right) \times BR\left(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 e^+e^-\right)$$



$$\sqrt{s_{ee}} = m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_2^0} + 30 \text{ GeV}$$

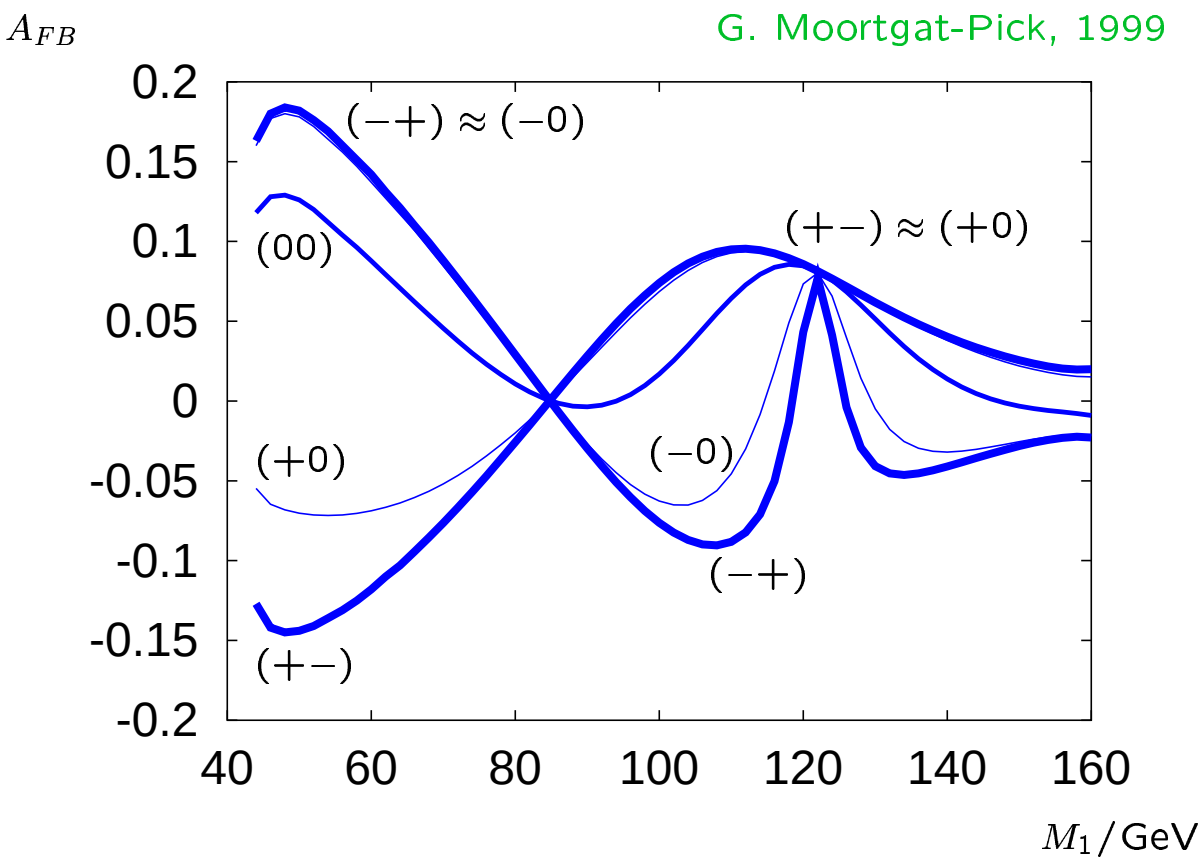
$$m_{\tilde{e}_R} = 161 \text{ GeV}$$

$$m_{\tilde{e}_L} = 176 \text{ GeV}$$

$$P_- = 0, \pm 0.85,\ P_+ = 0, \pm 0.6 \to \left(\text{sgn}(P_-), \text{sgn}(P_+)\right)$$

Asymmetry A_{FB} of the decay electron

$$A_{FB} = \frac{\sigma_e\,(\cos\Theta_e > 0) - \sigma_e\,(\cos\Theta_e < 0)}{\sigma_e\,(\cos\Theta_e > 0) + \sigma_e\,(\cos\Theta_e < 0)}$$



$\sqrt{s_{ee}} = m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_2^0} + 30$ GeV

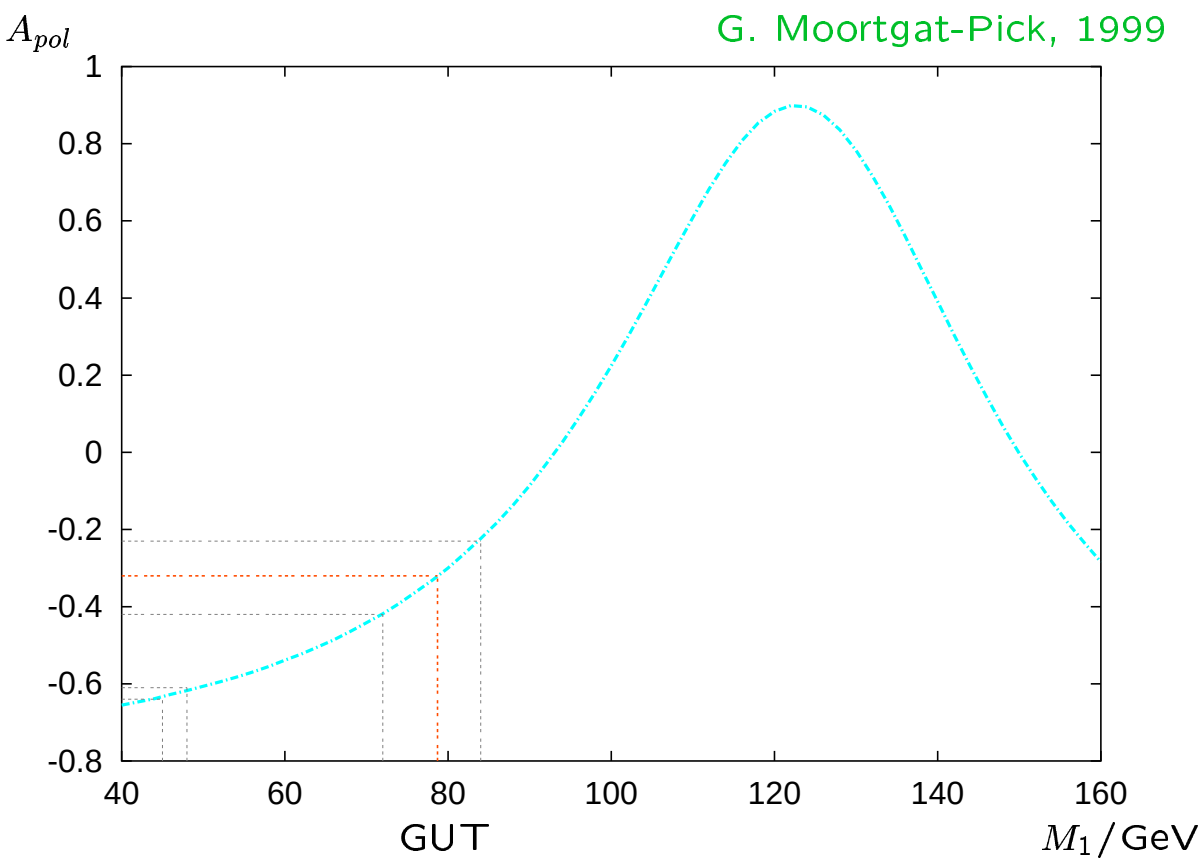
$m_{\tilde{e}_R} = 161$ GeV

$m_{\tilde{e}_L} = 176$ GeV

$P_- = 0, \pm 0.85,\ P_+ = 0, \pm 0.6 \rightarrow \big(\mathrm{sgn}(P_-), \mathrm{sgn}(P_+)\big)$

Polarization Asymmetry A_{pol}

$$A_{pol} = \frac{\sigma_{ee}(+0) - \sigma_{ee}(-0)}{\sigma_{ee}(+0) + \sigma_{ee}(-0)}$$



$\sqrt{s_{ee}} = m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_2^0} + 50$ GeV

$m_{\tilde{e}_R} = 161$ GeV

$m_{\tilde{e}_L} = 176$ GeV

$P_- = \pm 0.9,\ P_+ = 0$

III.2. LSP/Selectron Production in $e\gamma$ Scattering

Process:

$$e^- + \gamma \xrightarrow[\tilde{e}^-_{L/R}]{e^-} \tilde{\chi}^0_1 + \tilde{e}^-_{L/R}$$

$$\tilde{e}^-_{L/R} \longrightarrow \tilde{\chi}^0_1 + e^-$$

- LSP/Selectron production with leptonic decay
- Photon beam: Compton-backscattering of laser photons
- Higher mass reach in $m_{\tilde{e}_{L/R}}$ for $e\gamma$-mode
- For the plots in this section:

  P_e = long. polarization of the electron beam

  λ_L = circular polarization of the laser beam

  λ_k = long. polarization of the converted electron beam

Observable σ_{ee}:

Total cross section in the $e\gamma$-cms:

$$\sigma_{e\gamma}^{L/R} = \sigma_P\left(s_{e\gamma}\right) \cdot BR\left(\tilde{e}_{L/R} \longrightarrow e^- \tilde{\chi}_1^0\right)$$

Important relation:

$$\boxed{\sigma_{e\gamma}^{L/R} \quad \propto \quad \left(f_1^{L/R}\right)^2}$$

Convolution

Total cross section in the ee-cms:

$$\sigma_{ee}^{L/R} \quad = \quad \int dy P_C(y) \hat{\sigma}_{e\gamma}^{L/R}(s_{e\gamma} = y s_{ee})$$

$P_C(y = \frac{E_\gamma}{E_k}) = \gamma$ - spectrum of the Compton backscattered laser photons

$\longrightarrow \lambda_k =$ helicity of the converted e^-

$\longrightarrow \lambda_L =$ helicity of the laser photons

$$\hat{\sigma}_{e\gamma}^{L/R} = \frac{1}{2}(1+\lambda(y))\left(\sigma_{e\gamma}^{L/R}\right)^{+} + \frac{1}{2}(1-\lambda(y))\left(\sigma_{e\gamma}^{L/R}\right)^{-}$$

$\left(\sigma_{e\gamma}^{L/R}\right)^{+/-}$ = total cross sections for a completely right (left) circular polarized photon beam

$\lambda(y)$ = mean helicity of the photon beam

Same final states for $\tilde{e}_R$ and $\tilde{e}_L$

$$\longrightarrow \sigma_{ee} = \sigma_{ee}^{L} + \sigma_{ee}^{R}$$

Polarisation Asymmetries:

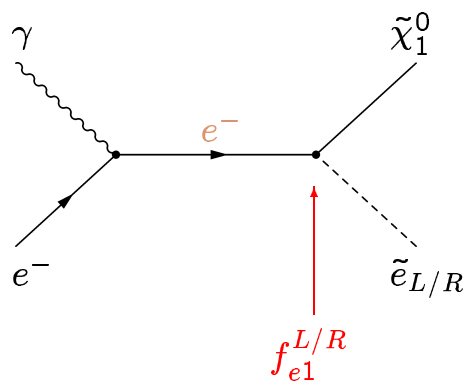
$$A_e = \frac{\sigma_{ee}(+P_e) - \sigma_{ee}(-P_e)}{\sigma_{ee}(+P_e) + \sigma_{ee}(-P_e)}$$

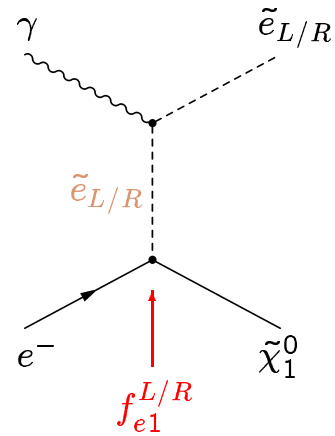
$$A_{\lambda_L} = \frac{\sigma_{ee}(+\lambda_L) - \sigma_{ee}(-\lambda_L)}{\sigma_{ee}(+\lambda_L) + \sigma_{ee}(-\lambda_L)}$$

$$A_\gamma = \frac{\sigma_{ee}(+\lambda_L, -\lambda_k) - \sigma_{ee}(-\lambda_L, +\lambda_k)}{\sigma_{ee}(+\lambda_L, -\lambda_k) + \sigma_{ee}(-\lambda_L, +\lambda_k)}$$

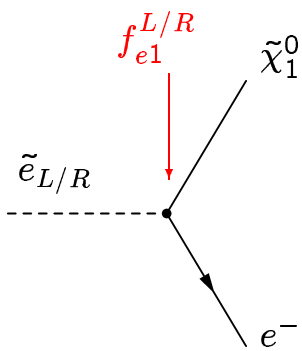
Feynman Graphs for LSP/Selectron Production and Leptonic Decay

Production :





Decay :



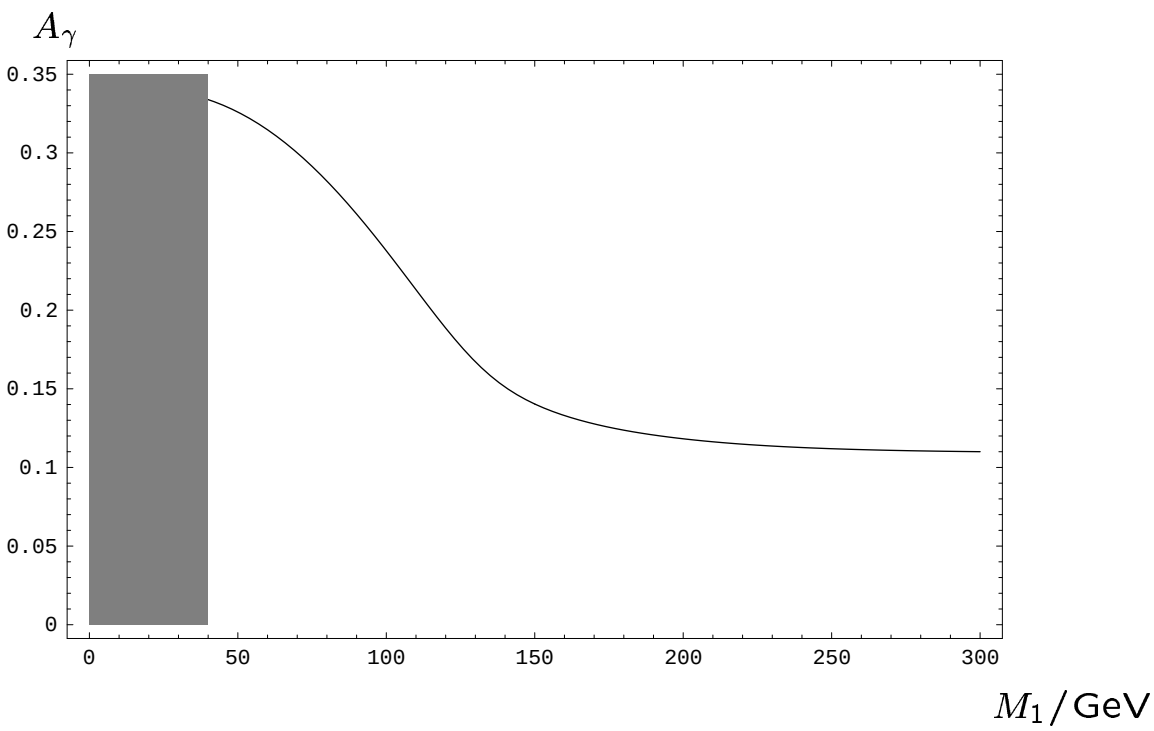
M_1 in Production and Decay:

- mass $m_{\tilde{\chi}_1^0}$

- couplings f_{e1}^L, f_{e1}^R

Polarization Asymmetry A_γ

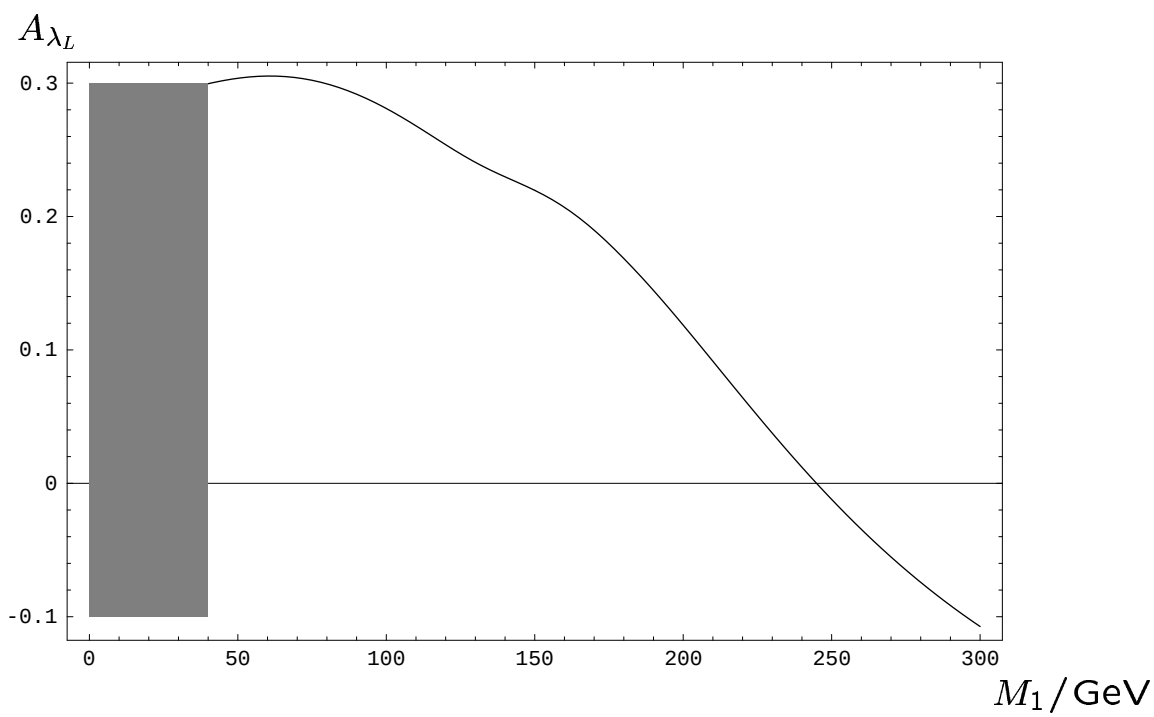
$$A_\gamma = \frac{\sigma_{ee}(s_{ee}, P_e, -\lambda_k, +\lambda_L) - \sigma_{ee}(s_{ee}, P_e, +\lambda_k, -\lambda_L)}{\sigma_{ee}(s_{ee}, P_e, -\lambda_k, +\lambda_L) + \sigma_{ee}(s_{ee}, P_e, +\lambda_k, -\lambda_L)}$$



$\sqrt{s_{ee}} = 500$ GeV
$|\lambda_k| = 0.8$
$|\lambda_L| = 1$
$P_e = 0.8$
$m_{\tilde{e}_L} = 179.3$ GeV
$m_{\tilde{e}_R} = 137.7$ GeV

Polarization Asymmetry A_{λ_L}

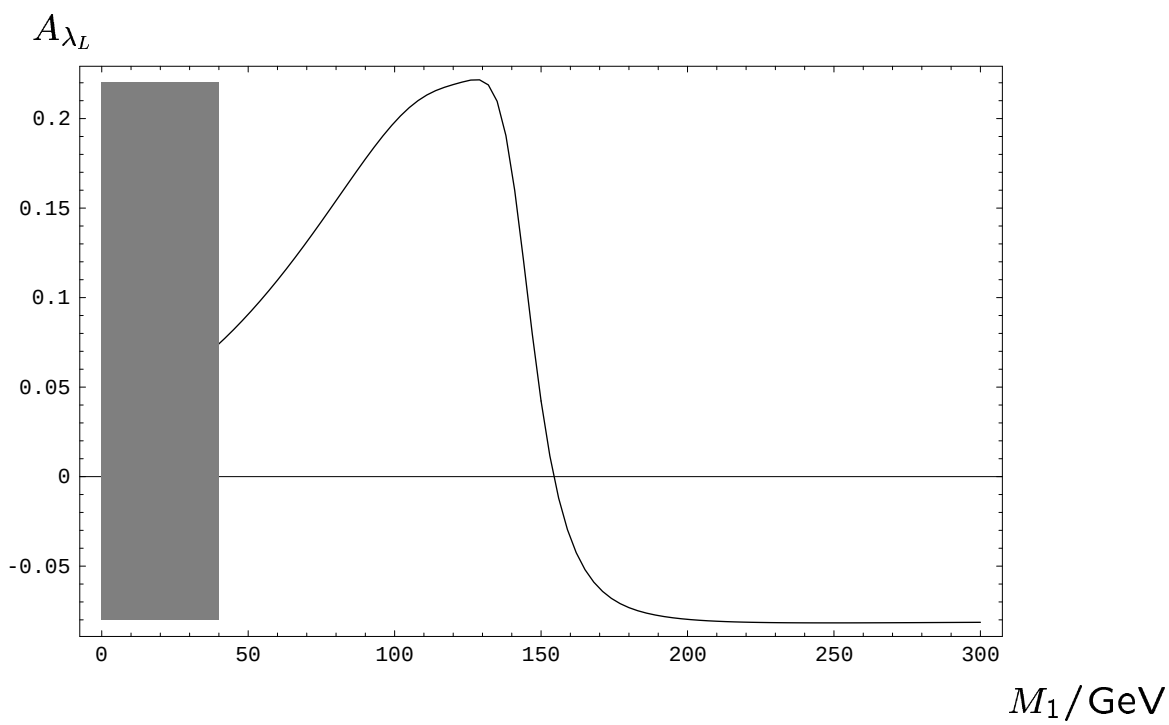
$$A_{\lambda_L} = \frac{\sigma_{ee}\left(s_{ee}, P_e, \lambda_k, \lambda_L\right) - \sigma_{ee}\left(s_{ee}, P_e, \lambda_k, -\lambda_L\right)}{\sigma_{ee}\left(s_{ee}, P_e, \lambda_k, \lambda_L\right) + \sigma_{ee}\left(s_{ee}, P_e, \lambda_k, -\lambda_L\right)}$$



$\sqrt{s_{ee}} = 500$ GeV
$\lambda_L = +1$
$\lambda_k = +0.8$
$P_e = 0.8$
$m_{\tilde{e}_L} = 179.3$ GeV
$m_{\tilde{e}_R} = 137.7$ GeV

Polarization Asymmetry A_{λ_L}

$$A_{\lambda_L} = \frac{\sigma_{ee}\left(s_{ee}, P_e, \lambda_k, \lambda_L\right) - \sigma_{ee}\left(s_{ee}, P_e, \lambda_k, -\lambda_L\right)}{\sigma_{ee}\left(s_{ee}, P_e, \lambda_k, \lambda_L\right) + \sigma_{ee}\left(s_{ee}, P_e, \lambda_k, -\lambda_L\right)}$$

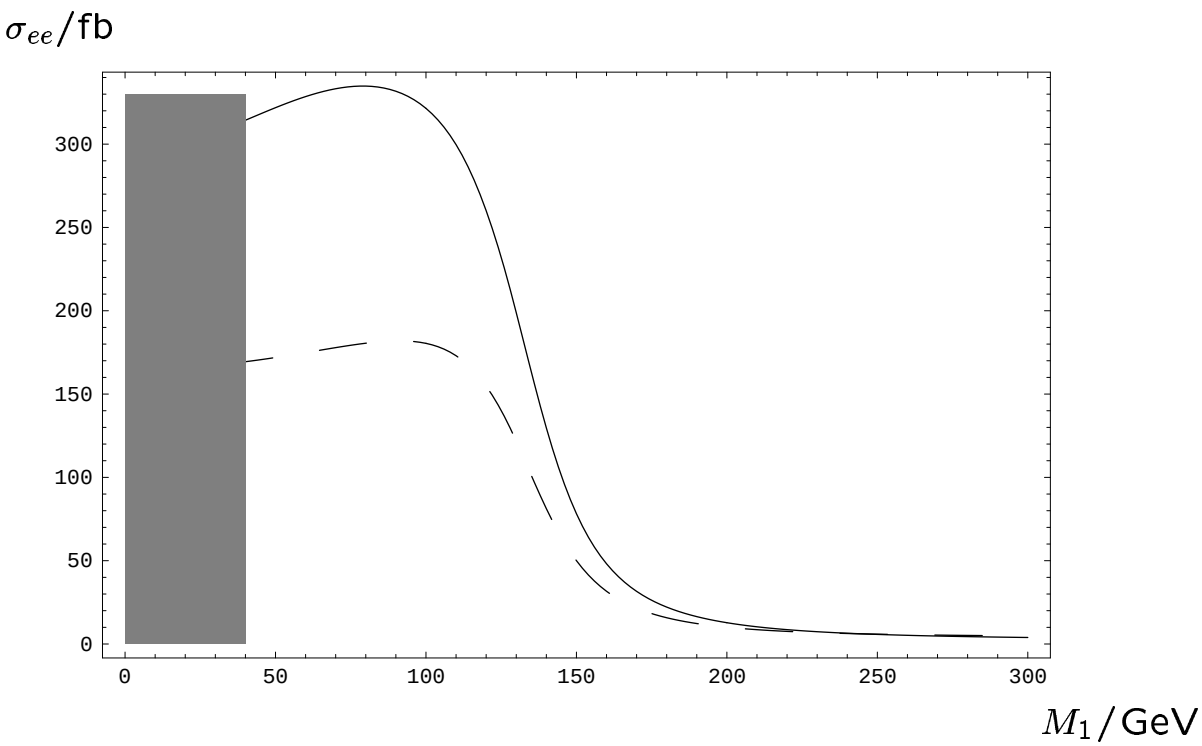


$\sqrt{s_{ee}} = 500$ GeV
$\lambda_L = +1$
$\lambda_k = -0.8$
$P_e = -0.8$
$m_{\tilde{e}_L} = 179.3$ GeV
$m_{\tilde{e}_R} = 137.7$ GeV

Total Cross Section $\sigma_{ee}(\lambda_L = \pm 1)$

Convoluted cross section in the lab. frame:

$$\sigma_{ee}(s_{ee}, P_e, \lambda_k, \lambda_L) = \int dy P(y)\, \sigma_{e\gamma}(s_{e\gamma}) \times BR\left(\tilde{e}_{L/R} \to \tilde{\chi}_1^0 e^-\right)$$



$\sqrt{s_{ee}} = 500$ GeV

$P_e = 0.8$

$\lambda_k = +0.8$

$\lambda_L = +1$ ———

$\lambda_L = -1$ - - - -

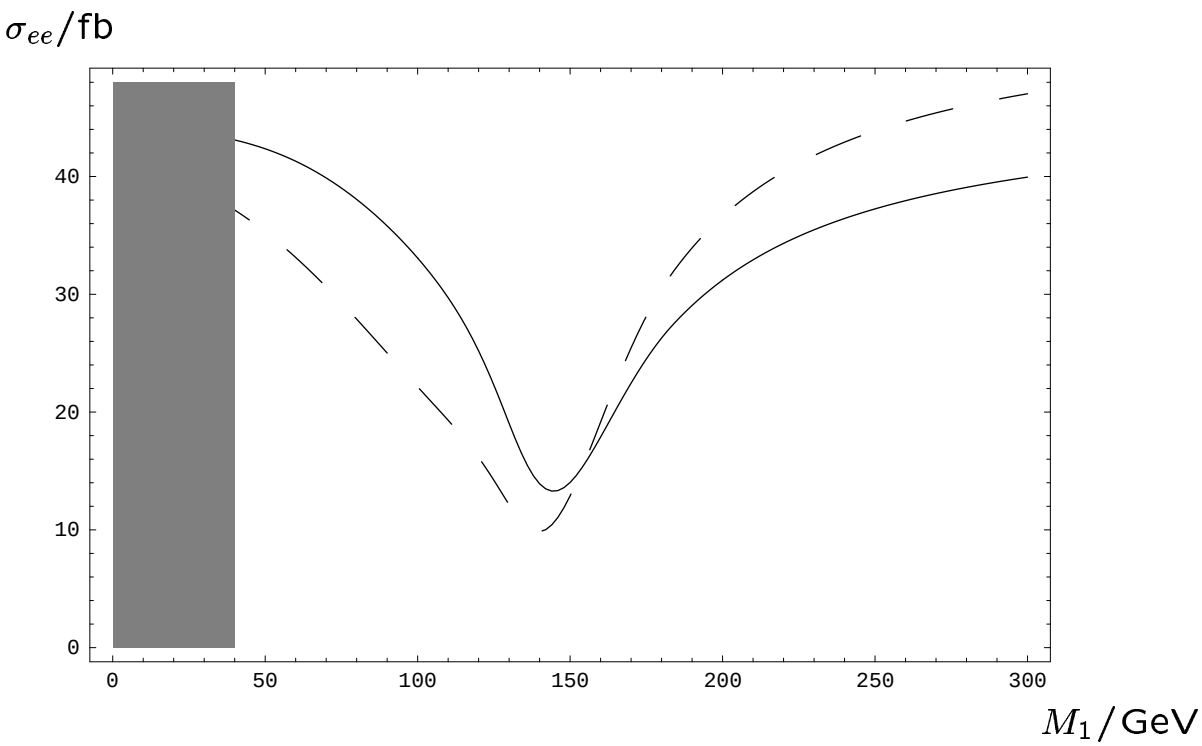
$m_{\tilde{e}_L} = 179.3$ GeV

$m_{\tilde{e}_R} = 137.7$ GeV

Total Cross Section $\sigma_{ee}(\lambda_L = \pm 1)$

Convoluted cross section in the lab. frame:

$$\sigma_{ee}(s_{ee}, P_e, \lambda_k, \lambda_L) = \int dy P(y)\, \sigma_{e\gamma}(s_{e\gamma}) \times BR\left(\tilde{e}_{L/R} \to \tilde{\chi}_1^0 e^-\right)$$



$\sqrt{s_{ee}} = 500$ GeV

$P_e = -0.8$

$\lambda_k = -0.8$

$\lambda_L = +1$ ———

$\lambda_L = -1$ – – – –

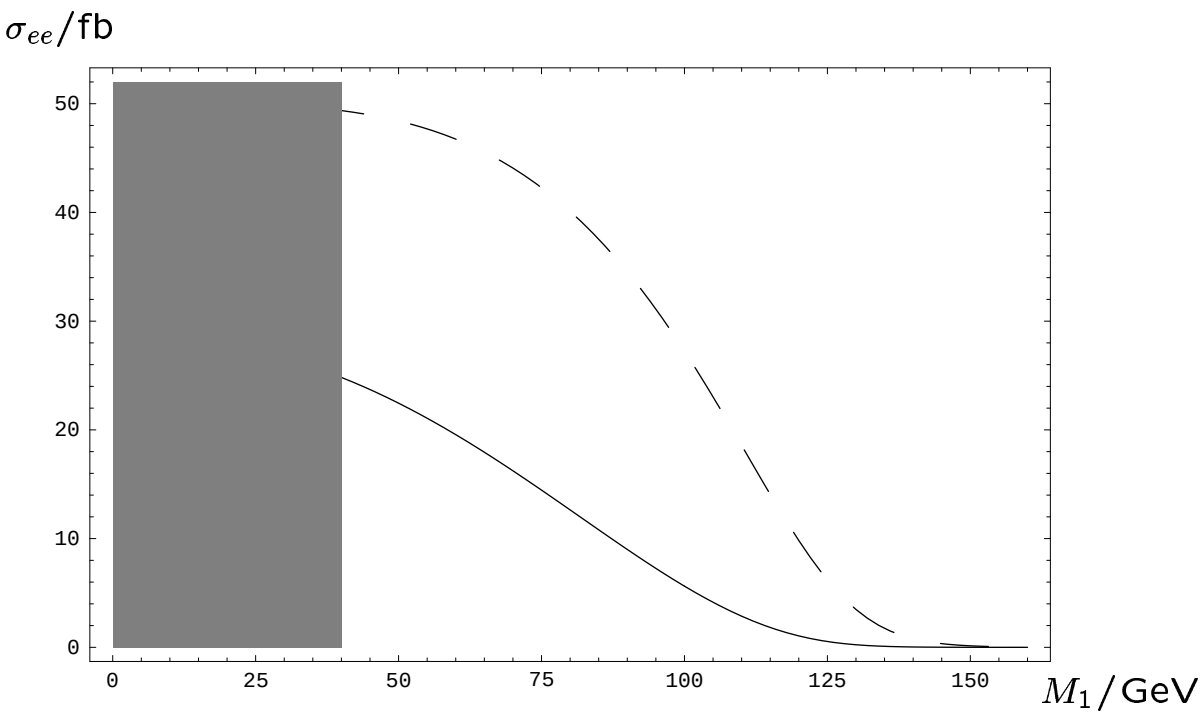
$m_{\tilde{e}_L} = 179.3$ GeV

$m_{\tilde{e}_R} = 137.7$ GeV

Total Cross Section $\sigma_{ee}(\lambda_L = \pm 1)$

Convoluted cross section in the lab. frame:

$$\sigma_{ee}(s_{ee}, P_e, \lambda_k, \lambda_L) = \int dy P(y)\, \sigma_{e\gamma}(s_{e\gamma}) \times BR\left(\tilde{e}_{L/R} \to \tilde{\chi}_1^0 e^-\right)$$



$\sqrt{s_{ee}} = 500$ GeV

$\longrightarrow \sqrt{s_{e\gamma}}^{max} = 0.91\sqrt{s_{ee}} = 455.1$ GeV

$m_{\tilde{e}_L} = 350.0$ GeV, $m_{\tilde{e}_R} = 330.5$ GeV

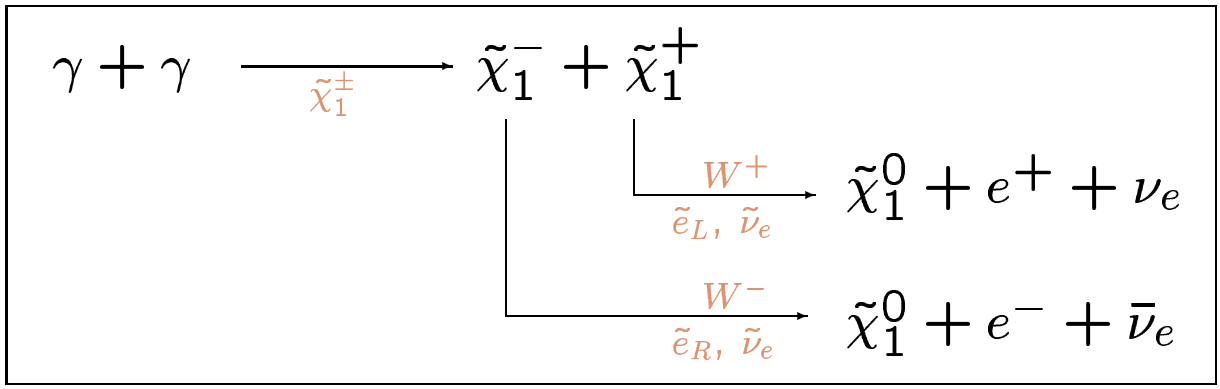
$\to m_{\tilde{\chi}_1^0} = 124.6$ GeV $\to M_1^{max} = 184$ GeV

$P_e = 0.8$ $\qquad$ $\lambda_k = +0.8$

$\lambda_L = +1$ ——— $\qquad$ $\lambda_L = -1$ - - - -

III.3. Chargino Pair Production in $\gamma\gamma$ Scattering

Process:



- Chargino pair production with leptonic decay

- Complete spin correlations between production and decay:

  + contributions independent of $\tilde{\chi}_1^\pm$-polarisation

  + contributions depending on $\tilde{\chi}_1^+/\tilde{\chi}_1^-$-polarisation

  + contributions depending on spin correlations between $\tilde{\chi}_1^+$ and $\tilde{\chi}_1^-$

- In the production only QED!

- For the plots in this section:

  $\lambda_{L_1}, \lambda_{L_2}$ = circular polarization of the laser beams

  $\lambda_{k_1}, \lambda_{k_2}$ = longitudinal polarization of the converted electron beams

Observables

Convoluted cross section in the lab. frame:

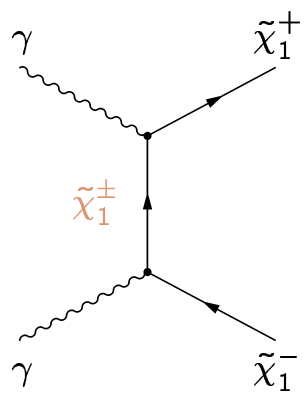
$$\sigma_{ee}\left(s_{ee}, , \lambda_{k_{1,2}}, \lambda_{L_{1,2}}\right) = \int dy_1 dy_2 P\left(y_1\right) P\left(y_2\right) \sigma_{\gamma\gamma} \times BR\left(\tilde{\chi}_1^+ \to \tilde{\chi}_1^0 e^+ \nu\right)$$

Forward-backward asymmetry:

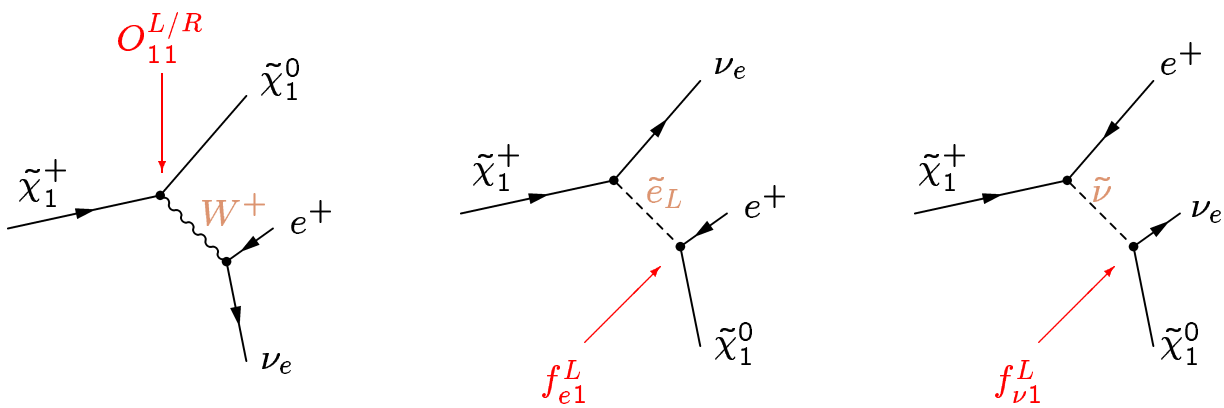
$$A_{FB} = \frac{\sigma_e\left(\cos\Theta_e > 0\right) - \sigma_e\left(\cos\Theta_e < 0\right)}{\sigma_e\left(\cos\Theta_e > 0\right) + \sigma_e\left(\cos\Theta_e < 0\right)}$$

Feynman Graphs for Chargino Pair Production and Leptonic Decay

Production :



Decay :



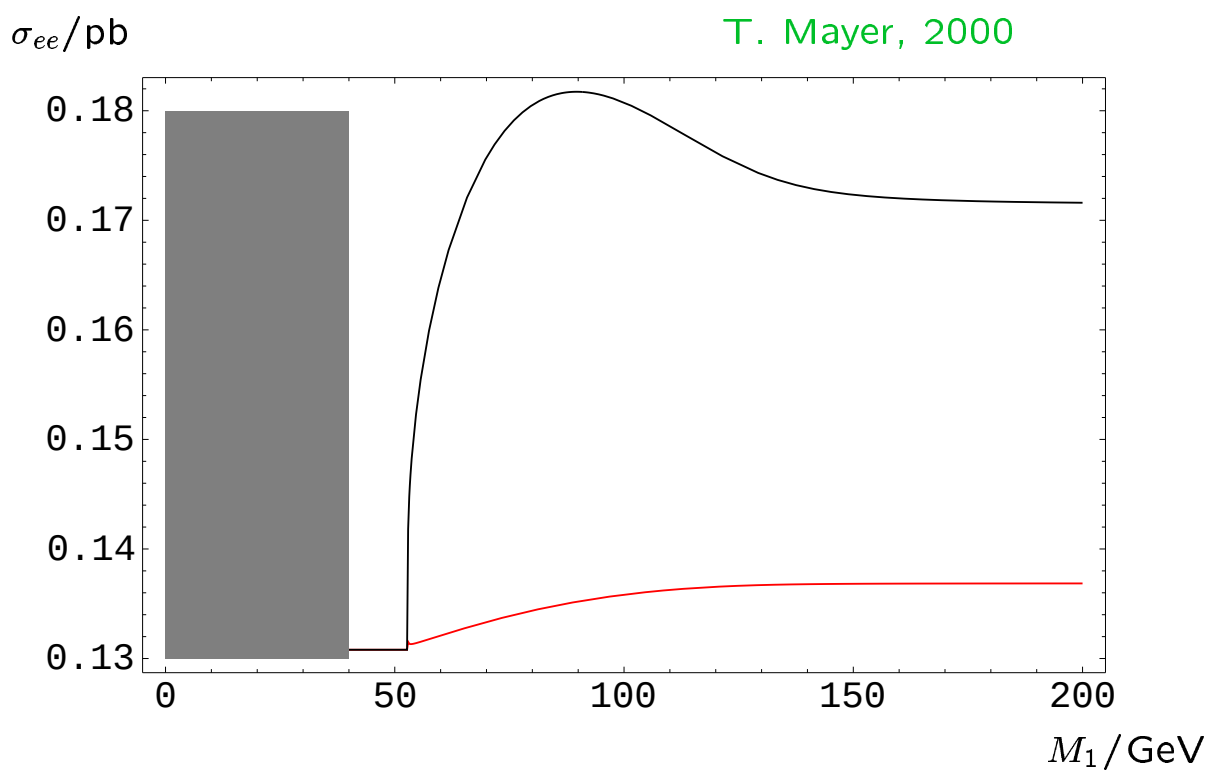
M_1 only in the Decay:

- mass $m_{\tilde{\chi}_1^0}$
- couplings $O_1^{L/R}$, f_{e1}^L, $f_{\nu 1}^L$

Total Cross Section σ_{ee}

Convoluted cross section in the lab. frame:

$$\sigma_{ee}\left(s_{ee},,\lambda_{k_{1,2}},\lambda_{L_{1,2}}\right)=\int dy_1 dy_2 P\left(y_1\right)P\left(y_2\right)\sigma_{\gamma\gamma}\times BR\left(\tilde{\chi}_1^+\to\tilde{\chi}_1^0 e^+\nu\right)$$



$\sqrt{s_{ee}}=1000$ GeV ($\to$ higher cross sections than for $\sqrt{s_{ee}}=500$ GeV)

$m_{\tilde{e}_R}=137.7$ GeV $\qquad$ $m_{\tilde{e}_R}=330.5$ GeV

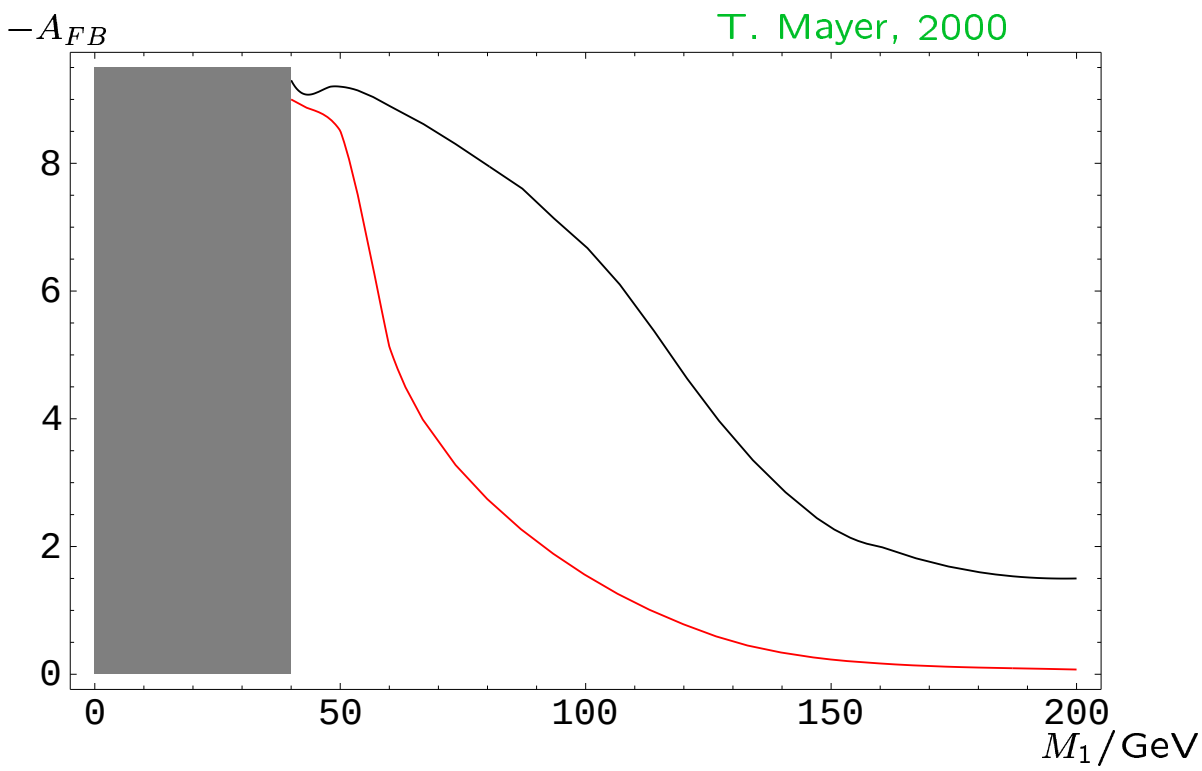
$m_{\tilde{e}_L}=179.3$ GeV $\qquad$ $m_{\tilde{e}_L}=350.0$ GeV

$\lambda_{L_1}=\lambda_{L_2}=0$

$\lambda_{k_1}=0.8$ $\qquad$ $\lambda_{k_2}=-0.8$

Asymmetry A_{FB} of the decay electron

$$A_{FB} = \frac{\sigma_e\,(\cos\Theta_e > 0) - \sigma_e\,(\cos\Theta_e < 0)}{\sigma_e\,(\cos\Theta_e > 0) + \sigma_e\,(\cos\Theta_e < 0)}$$



$\sqrt{s_{ee}} = 1000$ GeV ($\rightarrow$ smaller A_{FB} than for $\sqrt{s_{ee}} =$ 500 GeV)

$m_{\tilde{e}_R} = 137.7$ GeV $\qquad$ $m_{\tilde{e}_R} = 330.5$ GeV

$m_{\tilde{e}_L} = 179.3$ GeV $\qquad$ $m_{\tilde{e}_L} = 350.0$ GeV

$\lambda_{L_1} = \lambda_{L_2} = 0$

$\lambda_{k_1} = 0.8$ $\qquad$ $\lambda_{k_2} = -0.8$

III.4. Selectron Pair Production in e^-e^- Scattering

Process:

$$e^- + e^- \xrightarrow[\tilde{\chi}_i^0]{} \tilde{e}^-_{L/R} + \tilde{e}^-_{L/R}$$

$$\tilde{e}^-_{L/R} \longrightarrow \tilde{\chi}_1^0 + e^-$$

$$\tilde{e}^-_{L/R} \longrightarrow \tilde{\chi}_1^0 + e^-$$

- All 4 neutralinos as exchange particles

- Polarized electron beams
  $\rightarrow$ better polarisation than in e^+e^-

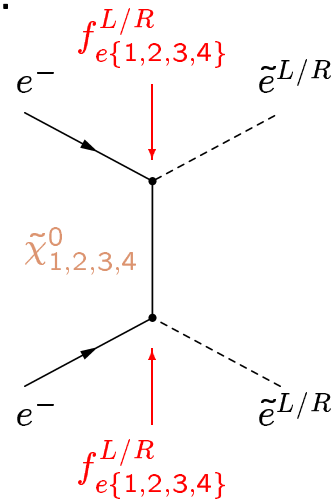
- For the plots in this section:

  $P_{e_{1,2}}$ = long. polarization of the electron beams

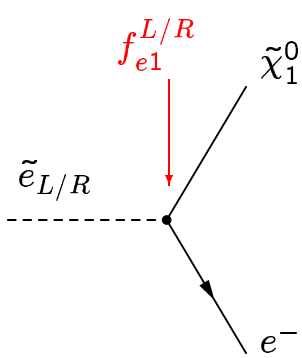
Feynman Graphs for Selectron Pair Production and Decay

Production :

$$\sum_{i=1}^{4}$$



Decay :



$\rightarrow$ signature: $e^- + e^- + \not{E}$

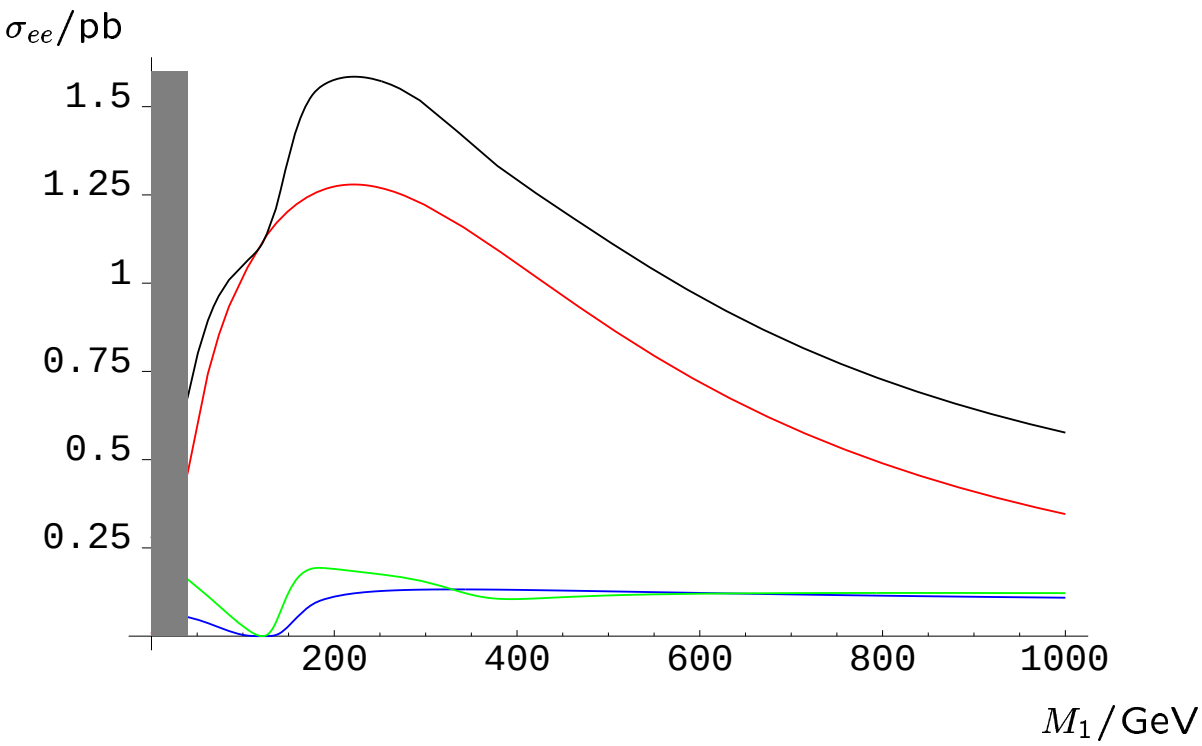
M_1 in Production and Decay:

- mass $m_{\tilde{\chi}^0_i}$

- couplings f^L_{ei}, f^R_{ei}

Total Cross Section σ_{ee}

$$\sigma_{ee} = \sigma\left(e^-e^- \to \tilde{e}_{L/R}\tilde{e}_{L/R} \to e^-e^-\tilde{\chi}_1^0\tilde{\chi}_1^0\right)$$



$$\sigma_{ee} = \sigma_{RR} + \sigma_{LL} + \sigma_{LR} + \sigma_{RL}$$

$\sqrt{s_{ee}} = 500$ GeV

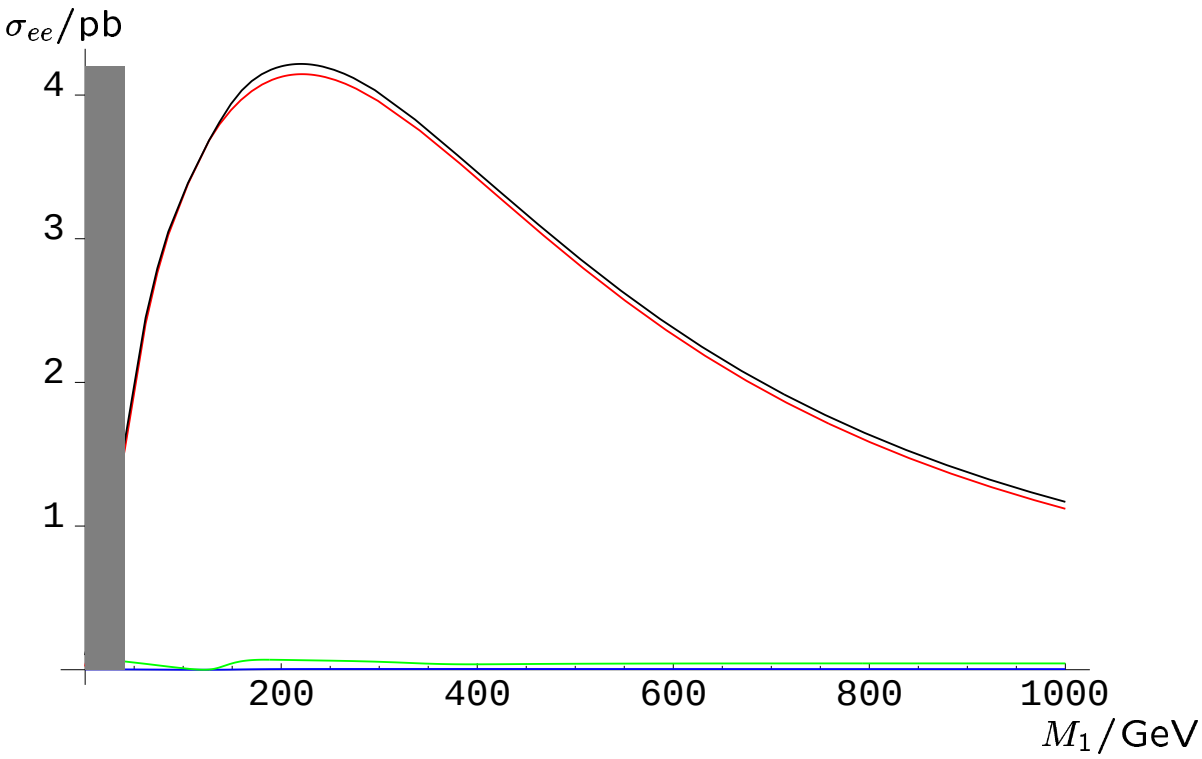
$m_{\tilde{e}_R} = 137.7$ GeV

$m_{\tilde{e}_L} = 179.3$ GeV

$P_{e_1} = P_{e_2} = 0\%$

Total Cross Section σ_{ee}

$$\sigma_{ee} = \sigma\left(e^-e^- \to \tilde{e}_{L/R}\tilde{e}_{L/R} \to e^-e^-\tilde{\chi}_1^0\tilde{\chi}_1^0\right)$$



$$\sigma_{ee} = \sigma_{RR} + \sigma_{LL} + \sigma_{LR} + \sigma_{RL}$$

$\sqrt{s_{ee}} = 500$ GeV

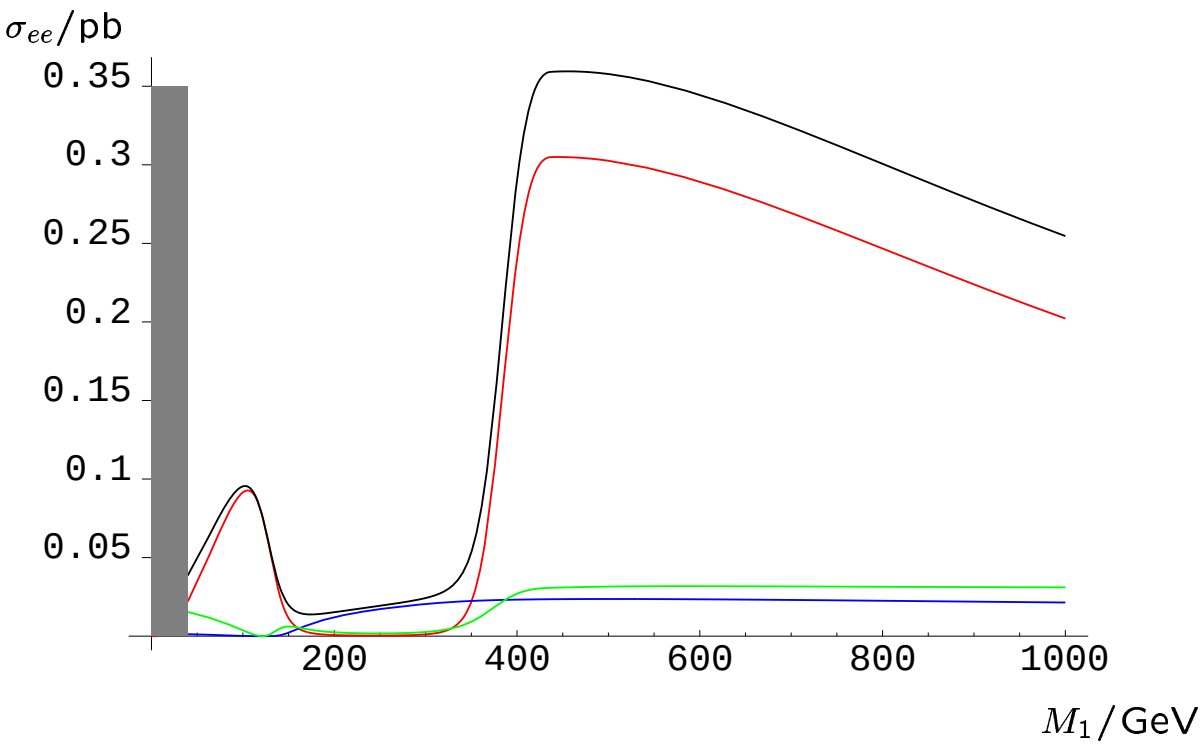
$m_{\tilde{e}_R} = 137.7$ GeV

$m_{\tilde{e}_L} = 179.3$ GeV

$P_{e_1} = P_{e_2} = 80\%$

Total Cross Section σ_{ee}

$$\sigma_{ee} = \sigma\left(e^-e^- \to \tilde{e}_{L/R}\tilde{e}_{L/R} \to e^-e^-\tilde{\chi}_1^0\tilde{\chi}_1^0\right)$$



$$\sigma_{ee} = \sigma_{RR} + \sigma_{LL} + \sigma_{LR} + \sigma_{RL}$$

$\sqrt{s_{ee}} = 1000$ GeV

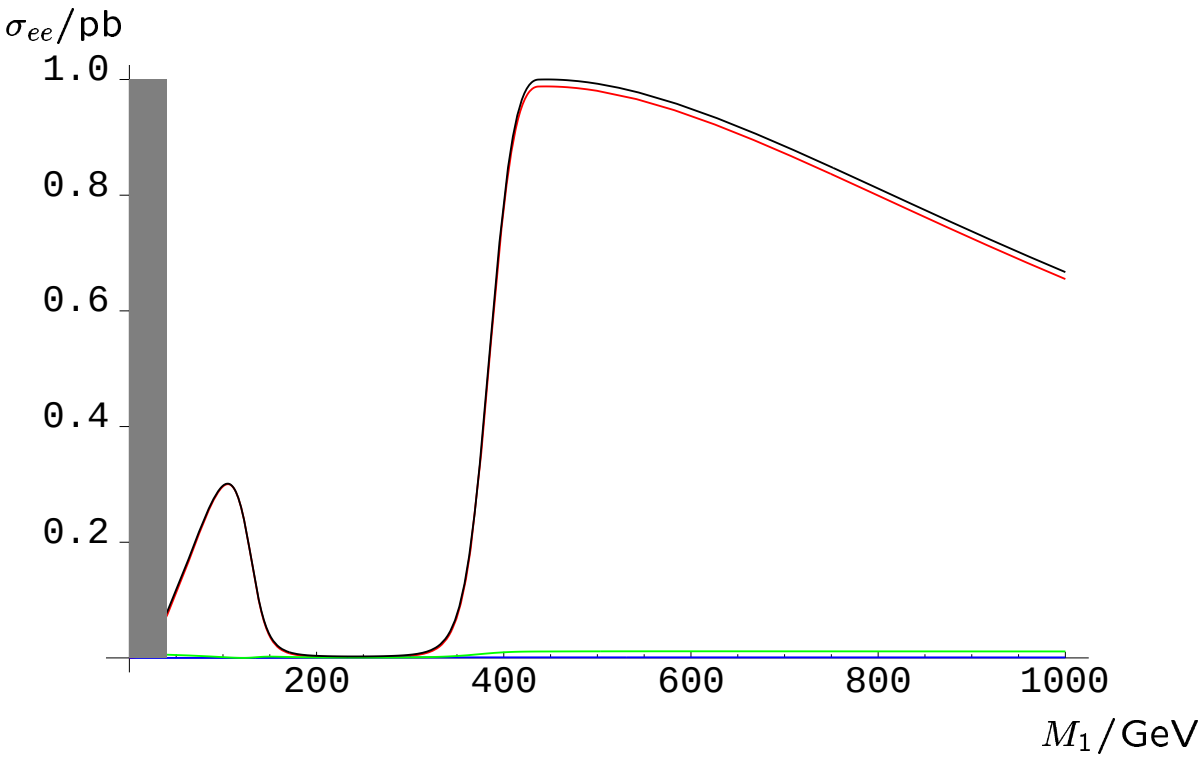
$m_{\tilde{e}_R} = 330$ GeV

$m_{\tilde{e}_L} = 350$ GeV

$P_{e_1} = P_{e_2} = 0\%$

Total Cross Section σ_{ee}

$$\sigma_{ee} = \sigma\left(e^- e^- \to \tilde{e}_{L/R}\tilde{e}_{L/R} \to e^- e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0\right)$$



$$\sigma_{ee} = \sigma_{RR} + \sigma_{LL} + \sigma_{LR} + \sigma_{RL}$$

$\sqrt{s_{ee}} = 1000$ GeV

$m_{\tilde{e}_R} = 330$ GeV

$m_{\tilde{e}_L} = 350$ GeV

$P_{e_1} = P_{e_2} = 80\%$

IV. Conclusions and Outlook

- Determination of the gaugino mass parameter M_1 in principle possible in every mode of a linear collider

- $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^-$:

  σ_e, A_{FB} sensitively dependent on M_1.
  Complicated M_1-dependence
  $\to$ ambiguities for 40 GeV$< M_1 <$ 160 GeV.
  Possibility to seperate ambiguities via A_{pol} (depends on selectron masses and splittings).

- $e\gamma \to \tilde{\chi}_1^0\tilde{e} \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^-$:

  σ_{ee}, A_{λ_L} sensitively dependent on M_1 for 40 GeV$< M_1 <$ 300 GeV.
  With both observables: no ambiguities.

- $\gamma\gamma \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to \tilde{\chi}_1^- \tilde{\chi}_1^0 e^+ \nu_e$:
  strong dependence of σ_e, A_{FB} on M_1 only for 40 GeV$< M_1 <$ 160 GeV.
  With both observables: no ambiguities.

- $e^- e^- \to \tilde{e}\tilde{e} \to e^- e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$:
  Widest range for M_1 (40 GeV$< M_1 <$ 1000 GeV)
  Ambiguities, seperation via asymmetries?

- Accuracy between $O(0.1\%)$ and $O(10\%)$ depending on the mode and the parameter point

- Polarization is necessary in every mode for M_1-determination !

- Outlook: selectron pair production in $e^- e^-$
  selectron pair production in $\gamma\gamma$
  ISR