Polarized e^+e^- Linear Colliders
Searches for New Physics – Supersymmetry

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1. Introduction and general remarks
   $\rightarrow$ Longitudinal beam polarization
2. Deviations from the Standard Model (SM):
   Electro–weak precision tests at
   $\rightarrow$High $\sqrt{s}$ (also transverse beam polarization)
   $\rightarrow$Giga Z
3. Supersymmetry: MSSM
4. Other kinds of New Physics
5. Conclusions and outlook

1. Introduction and general remarks

Goal of the Linear Collider

'Precision physics in the energy range between LEP and O(1 TeV)'

* High precision measurements: tests of the SM
* Discovery of New Physics (NP) (together with Hadron Colliders)
* 'Unveiling' of the NP: precise determination!

$\Rightarrow$ Beam polarization = decisive tool!

Interplay of Hadron Colliders and the LC:

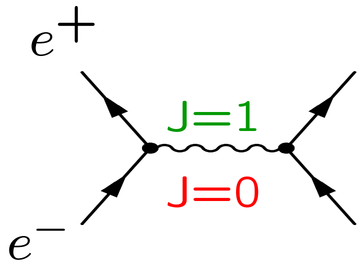
$\Rightarrow$ LHC/LC Study Group

(contact: G. Weiglein, http://www.ippp.dur.ac.uk/~georg/lhclc/)

Introduction: general remarks

Which configurations are possible in principle?

s–channel:



$\leftarrow$ only from RL,LR: SM (γ, Z)

$\leftarrow$ only from LL,RR: NP!

$\Rightarrow$ In principle: $P(e^-)$ fixes also helicity of e^+!

However, $P(e^+)$ can increase the effects:

- Effective polarization
- Effective luminosity = fraction of colliding particles

General remarks

- Effective polarization

$$P_{eff} := (P(e^-) - P(e^+))/(1 - P(e^-)P(e^+))$$
$$= (\#LR - \#RL)/(\#LR + \#RL)$$

- Fraction of colliding particles

$$\mathcal{L}_{eff}/\mathcal{L} := \frac{1}{2}(1 - P(e^-)P(e^+))$$
$$= (\#LR + \#RL)/(\#all)$$

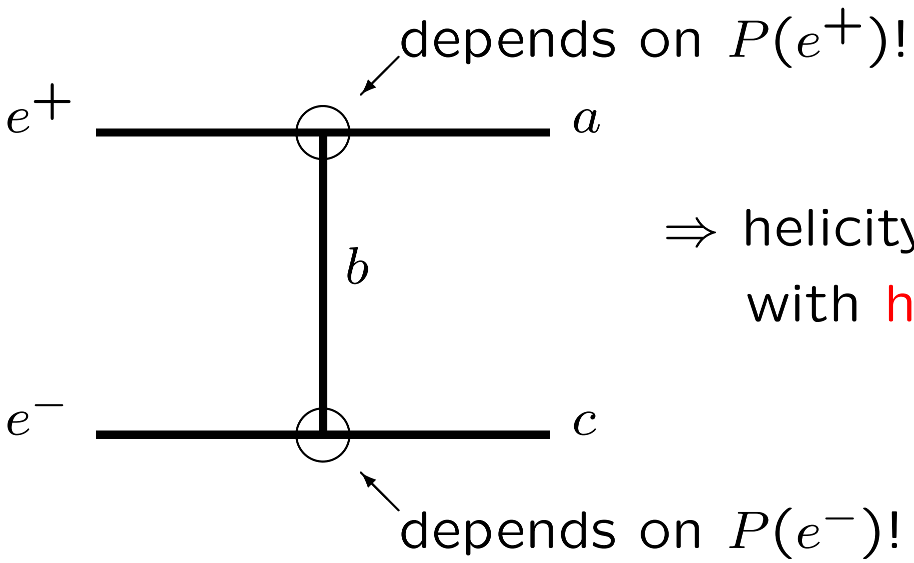
Colliding particles:

	RL	LR	RR	LL	P_{eff}	$\mathcal{L}_{eff}/\mathcal{L}$
$P(e^-) = 0$, $P(e^+) = 0$	0.25	0.25	0.25	0.25	0.	0.5
$P(e^-) = -1$, $P(e^+) = 0$	0	0.5	0	0.5	-1	0.5
$P(e^-) = -0.8$, $P(e^+) = 0$	0.05	0.45	0.05	0.45	-0.8	0.5
$P(e^-) = -0.8$, $P(e^+) = +0.6$	0.02	0.72	0.08	0.18	-0.95	0.74

$\Rightarrow$ Enhancing of $\mathcal{L}_{eff}$ with $P(e^-)$ and $P(e^+)$!

Which configurations are possible in principle?

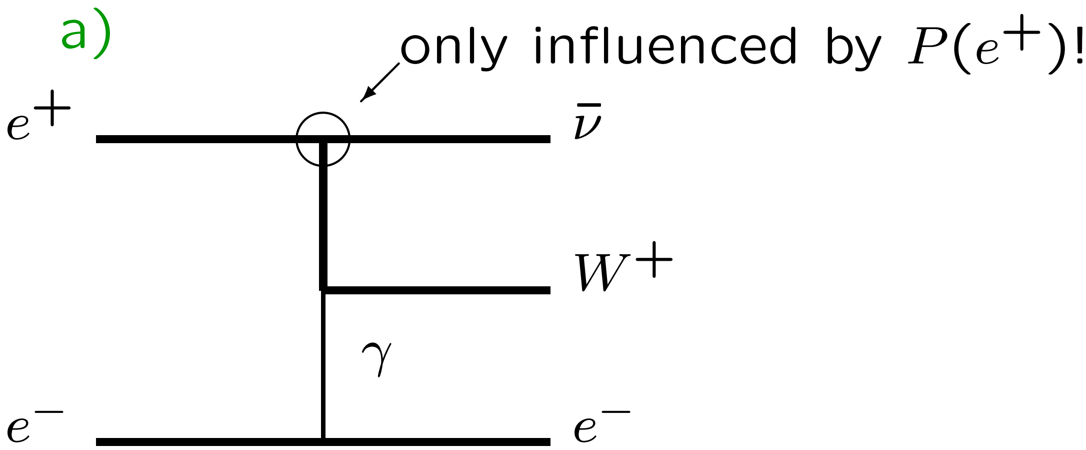
t–channel:



$\Rightarrow$ helicity of e^- not coupled with helicity of e^+!

Two examples:

a)



b) Bhabha–background:

$\rightarrow$ γ, Z exchange in s–channel: selects LR, RL

$\rightarrow$ γ, Z exchange in t–channel: LL,RR possible!

more important for high $\sqrt{s}$!

Background suppression

E.g. suppression of W^+W^- background!

W^- couples only left–handed:

$\rightarrow$ WW background strongly suppressed with right polarized beams!

Scaling factor$=\sigma^{pol}/\sigma^{unpol}$ for WW and ZZ:

$P_{e^-}=\mp 80\%$, $P_{e^+}=\pm 60\%$	$e^+e^- \to W^+W^-$	$e^+e^- \to ZZ$
$(+0)$	0.2	0.76
(-0)	1.8	1.25
$(+-)$	0.1	1.05
$(-+)$	2.85	1.91

Some technical remarks

- polarized electron source:
  similar design as for SLC!
  $\rightarrow$ strained photocathode technology
  $\rightarrow$ in 1994/95: $P(e^-) = (77.34 \pm 0.61)\%$
  $\Rightarrow$ $P(e^-) \approx 80\%$ expected

- polarized positrons at a LC: complete novelty!
  design for TESLA, NLC:
  $\rightarrow$ helical undulator: source for polarized γ
  $\rightarrow$ photoproduction of polarized e^+:
  $\Rightarrow$ $P(e^+) \approx 40 - 60\%$ expected

- Measurement of polarization:
  Compton polarimetry: $\Delta P(e^\pm) \leq 0.5\%$
  (M ǿller polarimetry: under discussion)
  'Blondel scheme': high precision polarimetry

- Designed luminosity
  * $\mathcal{L} = 300$ fb^{-1}/year at $\sqrt{s} = 500$ GeV
    ($\mathcal{L} = 5.8 \cdot 10^{34}$ cm^{-2}s^{-1})
  * $\mathcal{L} = 500$ fb^{-1}/year at $\sqrt{s} = 800$ GeV
    ($\mathcal{L} = 3.4 \cdot 10^{34}$ cm^{-2}s^{-1})
  * 10^9 Z's at GigaZ (in 100 days!)

Polarized positrons

Polarization of e^+ is very tricky!
$\rightarrow$ world–wide collaboration needed!

Future plans in order to get a prototype:

a) experience from DESY, SLAC, Cornell, . . .
b) prototype for hel. undulator at Daresbury, U.K.
c) undulator based positron beams at SLAC

Links for further information:

- POWER Group:
  (POlarization at Work in Energetic Reactions)
  interaction forum: machine$\leftrightarrow$exp$\leftrightarrow$theory
  http://www.desy.de/~gudrid/power/

- IP Beam Instrumentation Working Group:
  conceptual ideas for beam instrumentation
  http://www.slac.stanford.edu/~torrence/ipbi/

- Polarized Positron Source Studies at SLAC:
  50 GeV damp. beam of FFTB $\rightarrow \gamma \rightarrow$ pol. e^+
  http://www.slac.stanford.edu/~achim/positrons/

2. Deviations from the SM

High $\sqrt{s}$

Process: $e^+e^- \to W^+W^-$

Rates: $\sigma_{pol} \sim (1 - P_{e^+}P_{e^-})\sigma_u + (P_{e^-} - P_{e^+})\sigma_{pol,L}$

Test of anomalous gauge couplings

e.g. $\mathcal{L} \sim g_V^1 W^*_{\mu\nu} W_\mu A_\nu, \kappa_V W^*_\mu W_\nu F_{\mu\nu}, \lambda_V W^*_{\rho\mu} W_{\mu\nu} F_{\nu\rho}$

error $[10^{-4}]$:	Δg_Z^1	$\Delta\kappa_\gamma$	λ_γ	$\Delta\kappa_Z$	λ_Z
unpolarized beams					
$\sqrt{s} = 500$ GeV	38.1	4.8	12.1	8.7	11.5
$\sqrt{s} = 800$ GeV	39.0	2.6	5.2	4.9	5.1
only electron beam polarized, $\lvert P_{e^-}\rvert = 80\%$					
$\sqrt{s} = 500$ GeV	24.8	4.1	8.2	5.0	8.9
$\sqrt{s} = 800$ GeV	21.9	2.2	5.0	2.9	4.7
both beams polarized, $\lvert P_{e^-}\rvert = 80\%$, $\lvert P_{e^+}\rvert = 60\%$					
$\sqrt{s} = 500$ GeV	15.5	3.3	5.9	3.2	6.7
$\sqrt{s} = 800$ GeV	12.6	1.9	3.3	1.9	3.0

Menges

(TESLA TDR)

$\Rightarrow$ P_{e^-}, $[+P_{e^+}]$ improves sensitivity up to a factor 1.8 [2.5] and can save running time!

Deviations from the SM
Impact of transverse beam polarization

Process: $e^+e^- \to W_L^+ W_L^-$

$\sigma \sim (1 - P_{e^+} P_{e^-})\sigma_u + (P_{e^-} - P_{e^+})\sigma_{pol,L} + P^T_{e^-} P^T_{e^+} \sigma_{pol,T}$

Use of transverse beams separates $W_L^+ W_L^-$!

- LL probes electroweak symmetry breaking
  $\to$ Unitarity!

- Study of A_T:

$$\frac{d\sigma A_T}{d\cos\theta} = \int \frac{d^2\sigma}{d\cos\theta d\Phi} \cos 2\Phi d\Phi$$

$\Rightarrow$ LL mode dominates at high $\sqrt{s}$
($A_T \sim 10\%$ at $\sqrt{s} = 500$ GeV)

$\Rightarrow$ suitable in particular for high $\sqrt{s}$!

Fleischer,Kolodziej,Jegerlehner

Deviations from the SM
GigaZ

Process: $e^+e^- \to Z \to f\bar{f}$

Measurement of effective mixing angle $\sin\Theta^\ell_{eff}$:

$$A_{LR} = \frac{2(1 - 4\sin^2\Theta^\ell_{eff})}{1 + (1 - 4\sin^2\Theta^\ell_{eff})^2}$$

Gain in statistical power of 'Z-factory' only if $\Delta A_{LR}(pol) < \Delta A_{LR}(stat)$

$\Rightarrow \Delta P_{eff} \sim 10^{-4}$ needed!
not possible with only polarimetry.....

Use of Blondel Scheme:

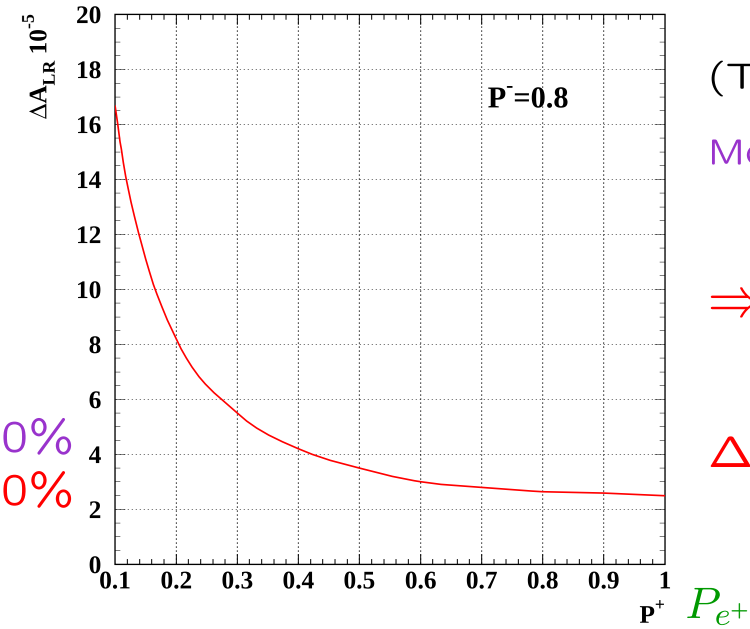
$$A_{LR} = \sqrt{\frac{(\sigma^{++} + \sigma^{+-} - \sigma^{-+} - \sigma^{--})(-\sigma^{++} + \sigma^{+-} - \sigma^{-+} + \sigma^{--})}{(\sigma^{++} + \sigma^{+-} + \sigma^{-+} + \sigma^{--})(-\sigma^{++} + \sigma^{+-} + \sigma^{-+} - \sigma^{--})}}$$

$\Rightarrow P(e^+)$ needed!

Deviations from the SM
GigaZ

LR–Asymmetry expressed via polarized rates
$\longrightarrow$ leads to highest accuracy:

$\Delta A_{LR}^{stat} 10^{-5}$



$P_{e^+} = 40\%$
$P_{e^+} = 60\%$

P_{e^+}

(TESLA TDR)

Moenig

$\Rightarrow \Delta A_{LR} \sim 10^{-4}$

$\Delta \sin^2 \theta^{\ell}_{eff} = 0.000013$!!!

Expected precision:

	LEP2/Tev.	Tev./LHC	LC	GigaZ/WW
M_W	34 MeV	15 MeV	15 MeV	6 MeV
$\sin^2 \theta_{eff}$	0.00017	0.00017	0.00017	0.00001
m_t	5 GeV	2 GeV	0.2 GeV	0.2 GeV
m_h	–	0.2 GeV	0.05 GeV	0.05 GeV

$\Rightarrow$ Unprecedented sensitivity to deviations from the SM!

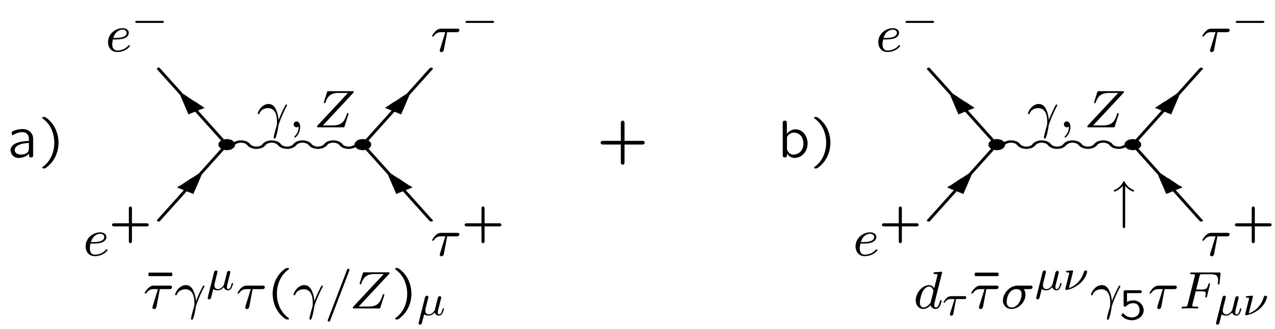
CP–violation beyond the SM

Process: $e^+e^- \to \tau^+\tau^- \to \pi\nu_\tau$ or $\rho\nu_\tau$

Ananthanarayan, Rindani, Stahl

SM: practically no CP violation in lepton sector!

Limits for $\sqrt{s} = 500$ GeV (from LEP) estimated:
Formfactors: EDM $d_\tau^\gamma \leq 10^{-19}$ ecm,
WDM $d_\tau^Z \leq 10^{-20}$ ecm



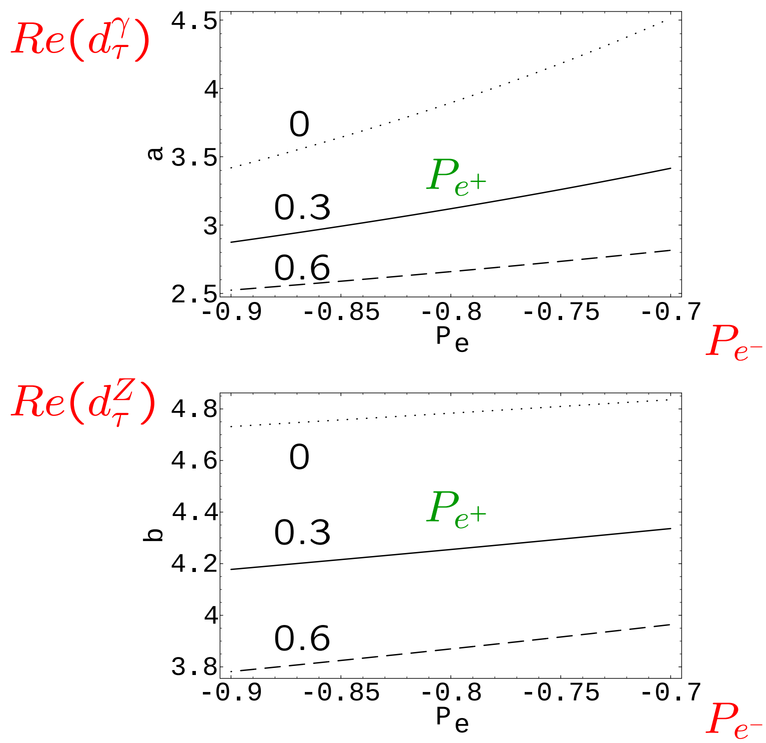
Contributions: $|a)|^2 \to$ SM
2 Re$[a) \cdot b)] \to$ $\not{C}$P
$|b)|^2 \to \Delta\sigma(\tau\tau) \sim d_\tau^2$

CP–violation beyond the SM

Strategy:

CP–odd triple product correlations between p's

$\Rightarrow$ sensitive to $Re(d_\tau^V)$ or $Im(d_\tau^V)$



$\sqrt{s}$ GeV	$Re(d_\tau^\gamma)$	$Re(d_\tau^Z)$
500	$3.8 \cdot 10^{-19}$	$5.4 \cdot 10^{-19}$
800	$2.7 \cdot 10^{-19}$	$3.9 \cdot 10^{-19}$

$\rightarrow$ similar sensitivity as LEP limits but higher q^2!

$\Rightarrow$ P_{e^-} is mandatory, P_{e^+} improves $\sim$ factor 2

$\Rightarrow$ detection of $\not{C}\not{P}$ of O(10^{-19}) seems to be possible!

3. Supersymmetry – MSSM

SM particle + its superpartner: super multiplets

'Vector': $\binom{\text{Spin}1}{\text{Spin}\frac{1}{2}} = \binom{g_\mu^{a=1,\ldots,8}}{\tilde{g}_\mu^{a=1,\ldots,8}}, \binom{W_\mu^{i=1,2,3}}{\tilde{W}^{i=1,2,3}}, \binom{B_\mu}{\tilde{B}}$

'Chiral': $\binom{\text{Spin}\frac{1}{2}}{\text{Spin}0} = \binom{q_{L,R}}{\tilde{q}_{L,R}}, \binom{\ell_{L,R}}{\tilde{\ell}_{L,R}}, \binom{\nu_\ell}{\tilde{\nu}_\ell}$

Enlarged Higgs sector – Two doublets H_1, H_2:

'Higgs': $\binom{\text{Spin}0}{\text{Spin}\frac{1}{2}} = \binom{H_1}{\tilde{H}_1}, \binom{H_2}{\tilde{H}_2}$

$\Rightarrow$ Physical states: h^0, H^0, A^0, $H^\pm$

Extended SUSY models are also possible:

- e.g. enlarged Higgs sector
- enlarged gauge boson sector

$\Rightarrow$ additional SUSY particles

The MSSM

Problem: $m_p \neq m_{\tilde{p}}$

$\Rightarrow$ SUSY has to be broken:

soft breaking terms lead to 105 parameters!

$\Rightarrow$ Mixing of eigenstates:

charginos: $\tilde{W}^{\pm}$, $\tilde{H}^{\pm}_{1,2} \stackrel{mixing}{\longrightarrow} \tilde{\chi}^{\pm}_{1,2}$

neutralinos: $\tilde{W}^{3}$, $\tilde{B}^{0}$, $\tilde{H}^{0}_{1,2} \stackrel{mixing}{\longrightarrow} \tilde{\chi}^{0}_{1,2,3,4}$

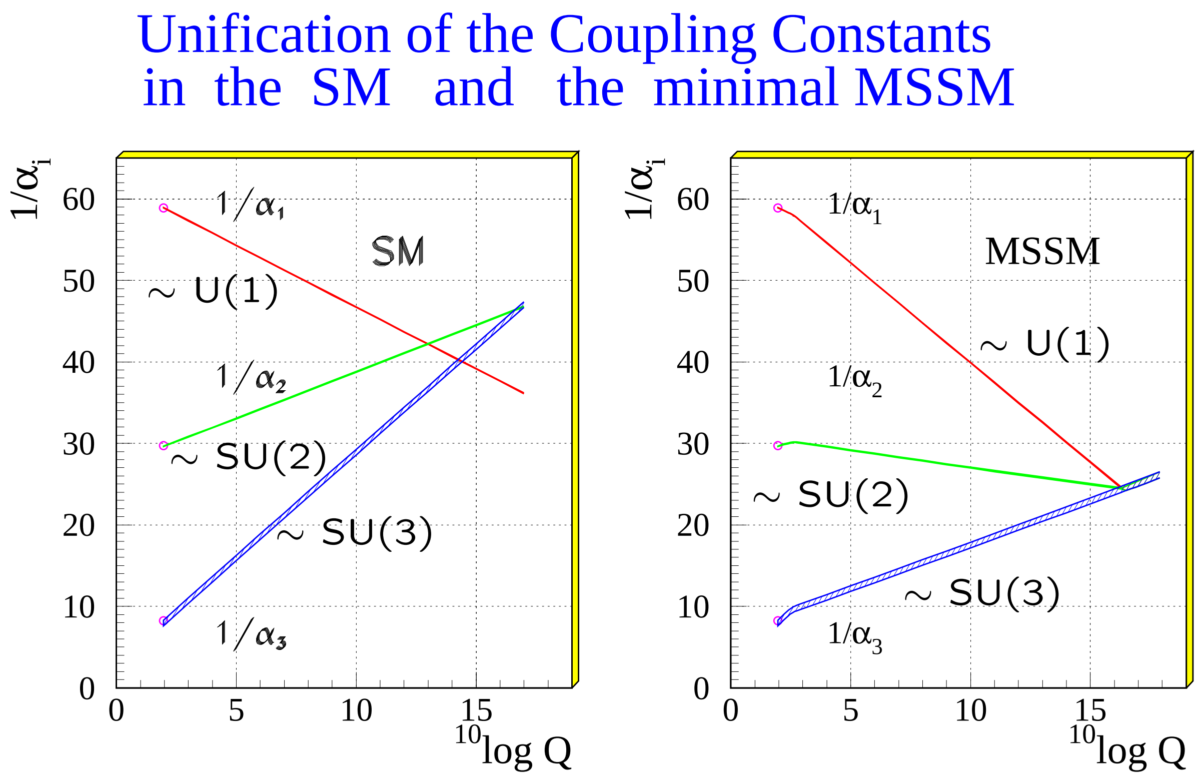
$\Rightarrow$ Schemes: mSUGRA, AMSB, GMSB, ...

$\uparrow$ $\uparrow$ $\uparrow$

4 parameters

5 parameters 5 parameters

Unification of the gauge couplings

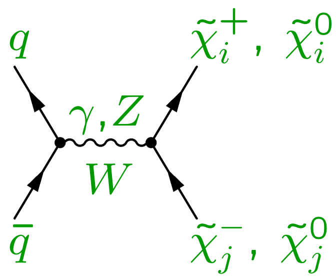


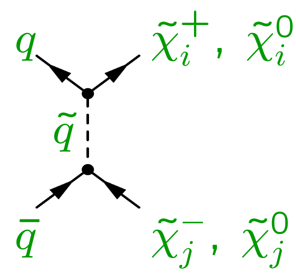
$\Rightarrow$ Unification in the general MSSM!

Parameter determination at the LHC
e.g. in the chargino/neutralino sector

- Direct production of $\tilde{\chi}_i^{\pm}$, $\tilde{\chi}_j^0$, $\tilde{\ell}^{\pm}$ only via Drell-Yan or squark exchange

  $\rightarrow$ EW process, small sensitivity





- Indirect studies via cascade decays

- Mass measurements: endpoint method

  $\rightarrow$ LSP mass 'poorly determined', due to small mass

  e.g. $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^-$ with endpoint: $\sqrt{\frac{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{\ell}})(m^2_{\tilde{\ell}} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{\ell}}}}$

- $\delta(\tilde{m}) \sim O(\%)$ in mSUGRA fits (ATLAS TDR)

- Parameter determination assuming specific SUSY breaking schemes! (CMS+Atlas TDR)

Unveiling the MSSM

Challenging task of a LC:

'Determining the underlying structure of the model!'

$\Rightarrow$ determine parameters without assuming the breaking scheme

$\Rightarrow$ 'proof' of fundamental SUSY assumption

$\Rightarrow$ distinction between different SUSY models by providing precise masses ($\sim$O(100 MeV)),
rates (% level)
branching ratios (% level)

Beam polarization is essential!

Unveiling the MSSM

Beam polarization is essential for

* Measuring as many observables as possible

* with high precision!

Strategy:

- Determining general MSSM parameters
  here: in particular from $\tilde{\chi}^{\pm}$, $\tilde{\chi}^{0}$, $\tilde{\tau}$, $\tilde{t}$
  $\Rightarrow$ disentangle the SUSY breaking mechanism!

- Test of the fundamental SUSY assumptions:
  Coupling relations, e.g.
  $\rightarrow$ Yukawa couplings of $\tilde{\chi}_i^0$
  $\rightarrow$ Chiral quantum numbers of $\tilde{\ell}$

- What else could be done with $P_{e^{\pm}}$?
  $\rightarrow$ helpful for disentangling NMSSM$\leftrightarrow$MSSM

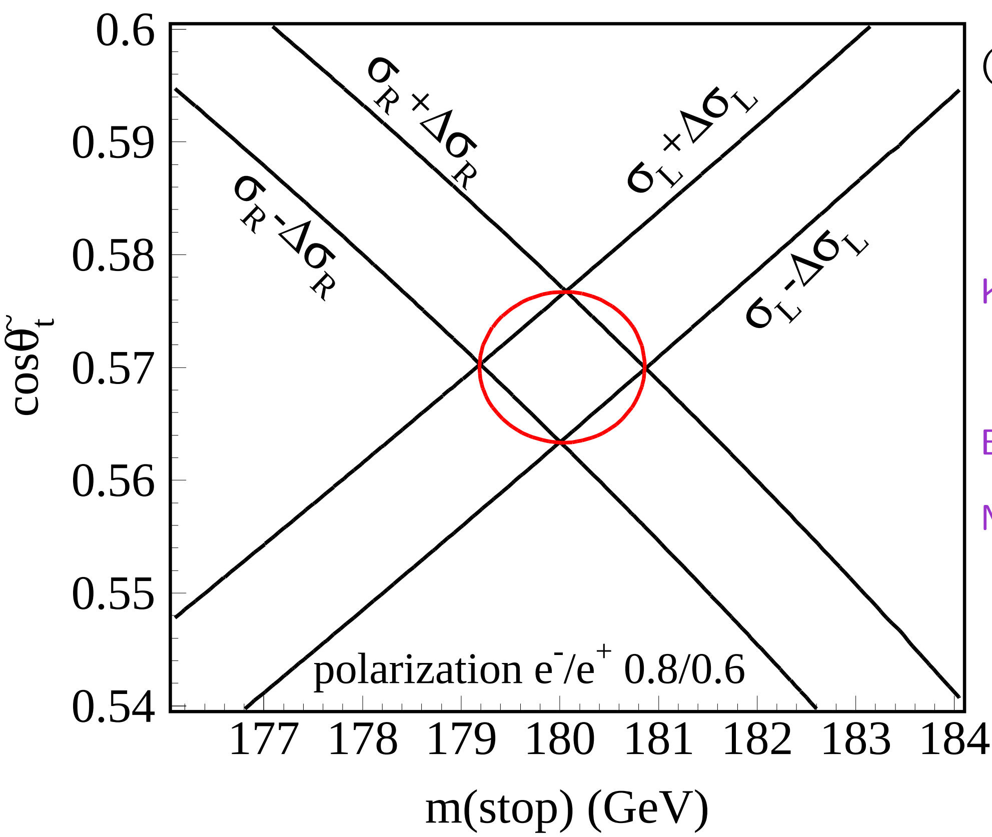
Process: $e^+e^- \to \tilde{t}_1\tilde{t}_1$

Unknown parameter: $m_{\tilde{t}_1}$ and $\Theta_{\tilde{t}}$

$$\tilde{t}_1 = \tilde{t}_L \cos\Theta_{\tilde{t}} + \tilde{t}_R \sin\Theta_{\tilde{t}}$$

How to derive the mixing angle?

$\Rightarrow$ Study polarized cross sections $\sigma = f(m_{\tilde{t}_1}, \Theta_{\tilde{t}})$



(TESLA TDR)

Keränen,Nowak,Sopczak

Bartl,Eberl,Kraml,

Majerotto,Porod

Due to high $\mathcal{L}$ at the LC:

$\Rightarrow$ $\Delta m_{\tilde{t}_1} = 0.8$ GeV and $\Delta\cos\Theta_{\tilde{t}} = 0.008$

precise measurement of mass and mixing angle!!!

Parameters from chargino/neutralino sector

Mass matrix of:

- charginos in $(\tilde{W}^{\pm}, \tilde{H}^{\pm})$ basis:

$$\mathcal{M}_C = \begin{pmatrix} M_2 & \sqrt{2} m_W \cos\beta \\ \sqrt{2} m_W \sin\beta & |\mu|\, \mathrm{e}^{i\Phi_\mu} \end{pmatrix}$$

- neutralinos in $(\tilde{B}, \tilde{W}^3, \tilde{H}_1^0, \tilde{H}_2^0)$ basis:

$$\mathcal{M}_N = \begin{pmatrix} |M_1|\, \exp^{i\Phi_1} & 0 & -m_Z c_\beta s_W & m_Z s_\beta s_W \\ 0 & M_2 & m_Z c_\beta c_W & -m_Z s_\beta c_W \\ -m_Z c_\beta s_W & m_Z c_\beta c_W & 0 & -|\mu|\, \exp^{\Phi_\mu} \\ m_Z s_\beta s_W & -m_Z s_\beta c_W & -|\mu|\, \exp^{\Phi_\mu} & 0 \end{pmatrix}$$

MSSM parameters:

M_1, Φ_1	M_2	μ, Φ_μ	$\tan\beta$
$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
U(1)	SU(2)	higgsino mass par.	VEV of $\frac{v_2}{v_1}$

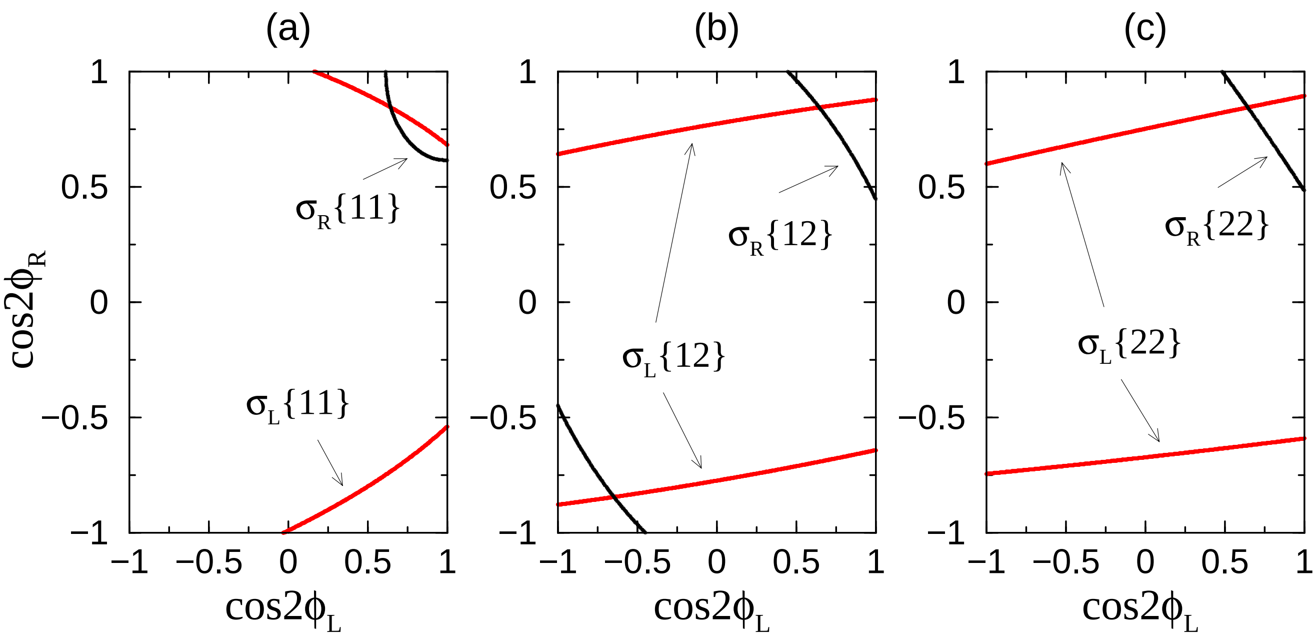
Parameter determination from charginos

Strategy:

Parameters derived from masses + mixing angles

Kneur, Moultaka '00, Choi, Guchait, Kalinowski, Zerwas'00, etc. . .

Observables: $m_{\tilde{\chi}^{\pm}_{1,2}}$, σ_L, σ_R (σ_T)



Determination of M_2, μ and (moderate) $\tan\beta$:

M_2, $|\mu|$, $\tan\beta$, Φ_μ: 2-fold (no, with σ_T) ambiguity

Assumptions:

- highly polarized beams
- $m_{\tilde{\nu}}$ known from . . .
  - measurements at the LHC . . .?
  - or at the LC, even if $m_{\tilde{\nu}} > \sqrt{s}/2$ via decay angular distributions GMP, Fraas, Bartl, Majerotto '00

Missing MSSM parameters: M_1, Φ_1

$\Rightarrow$ either 3 masses or 2 masses + 1 cross section sufficient!

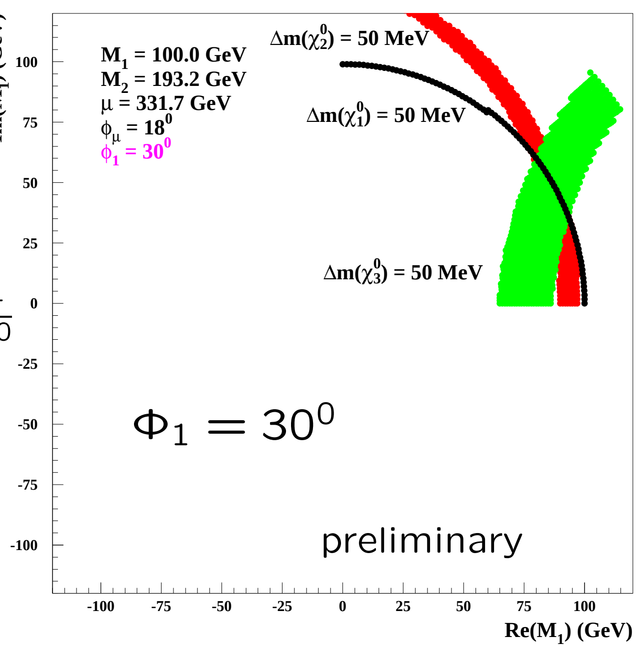
Strategy: $m_{\tilde{\chi}^0_{1,2}}$, polarized $\sigma(\tilde{\chi}^0_1\tilde{\chi}^0_2)_{L,R} \rightarrow M_1$, Φ_1

Choi, Kalinowski, GMP, Zerwas'01

Three masses $m_{\tilde{\chi}^0_1}$, $m_{\tilde{\chi}^0_2}$, $m_{\tilde{\chi}^0_3}$ precisely measured:

$Im(M_1)$ K. Desch, GMP

$\Phi_\mu = \frac{\pi}{10}$



$Re(M_1)$

$\mathcal{L} = 500$ fb^{-1}:

$m_{\tilde{\chi}^0_1} = 96.12 \pm 0.05$ GeV

$m_{\tilde{\chi}^0_2} = 177.13 \pm 0.05$ GeV

$m_{\tilde{\chi}^0_3} = 361.70 \pm 0.05$ GeV

$\Rightarrow \Phi_1 = 30^0 \pm 10^0$

$\Rightarrow$ moderate accuracy in M_1

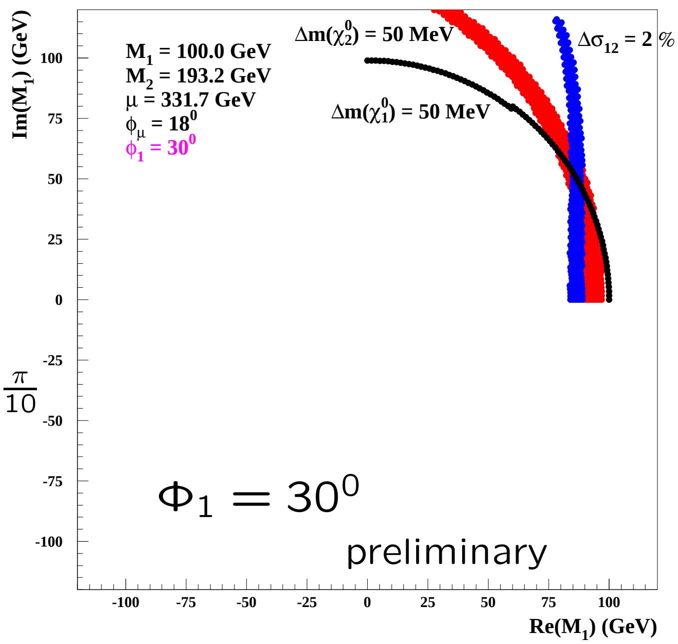
Parameters from the neutralinos

Other possibility:

Two masses $m_{\tilde{\chi}^0_1}$, $m_{\tilde{\chi}^0_2}$ and polarized $\sigma_{L,R}(12)$ precisely measured:

$Im(M_1)$ K. Desch, GMP

$\Phi_\mu = \frac{\pi}{10}$



$Re(M_1)$

$\mathcal{L} = 500\ \text{fb}^{-1}$:

$m_{\tilde{\chi}^0_1} = 96.12 \pm 0.05$ GeV

$m_{\tilde{\chi}^0_2} = 177.13 \pm 0.05$ GeV

$\Delta\sigma(\tilde{\chi}^0_1\tilde{\chi}^0_2) = \pm 2\%$ $(\sim \pm 1\sigma)$

$\Rightarrow \Phi_1 = 30^0 \pm 3^0$

$\Rightarrow$ pretty high accuracy in M_1

$\Rightarrow m_{\tilde{\chi}^0_1}, m_{\tilde{\chi}^0_2}, \sigma(\tilde{\chi}^0_1\tilde{\chi}^0_2) \overset{\text{leads to}}{\longrightarrow}$ higher accuracy!

Test of Yukawa couplings

Coupling relations in SUSY:

$$g_{\tilde{W}e\tilde{e}_L} \stackrel{!}{=} g_{Wee}, \; g_{\tilde{B}e\tilde{e}} \stackrel{!}{=} g_{Bee}$$

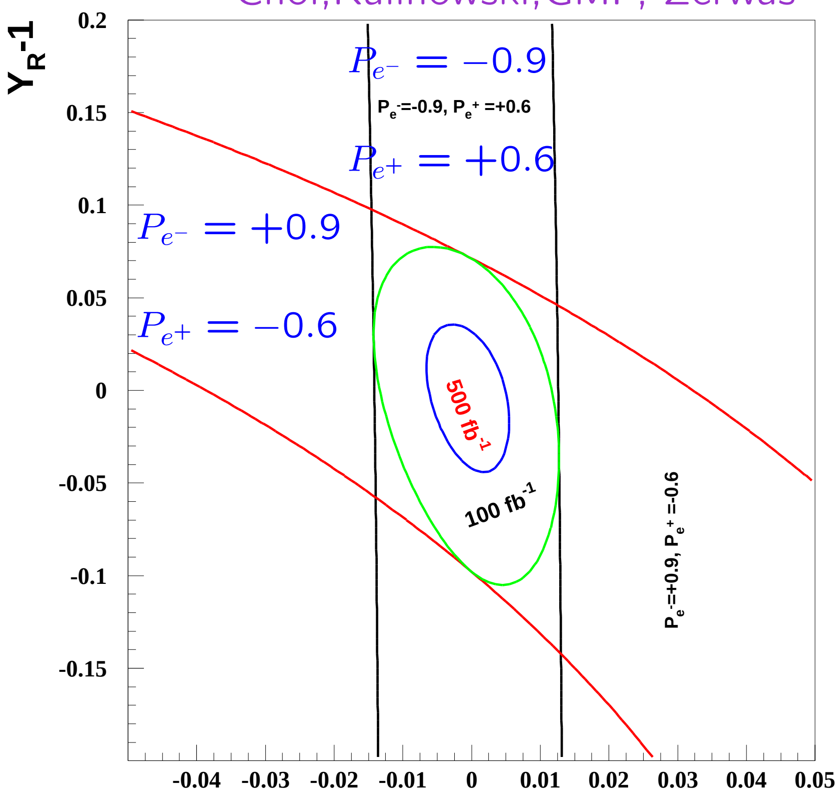
Assumption: M_1, M_2, μ, moderate $\tan\beta$ known
$m_{\tilde{\ell}}$ (even for $m_{\tilde{\ell}} > \sqrt{s}/2$) GMP, Fraas, Bartl, Majerotto

Strategy: $\sigma(\tilde{\chi}^0_1\tilde{\chi}^0_2)$ with polarized beams

$\Rightarrow$ Study of contour lines $\sigma_{L,R} \pm 1\sigma$(stat)

$\frac{g_{\tilde{B}e\tilde{e}}}{g_{Bee}} - 1$

Choi, Kalinowski, GMP, Zerwas



$\frac{g_{\tilde{W}e\tilde{e}}}{g_{Wee}} - 1$ Y_L-1

$\Rightarrow$ High $\mathcal{L} = 500$ fb^{-1}: Y_R, Y_L =O(%)

MSSM parameters with the help of τ's

Determination: M_1, Φ_1, M_2, μ, Φ_μ, mod. $\tan\beta$ $\surd$

$\Rightarrow$ even if only light system $\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$ accessible!

Choi, Kalinowski,GMP,Zerwas '02

Assumed accuracy: O(%) reachable!

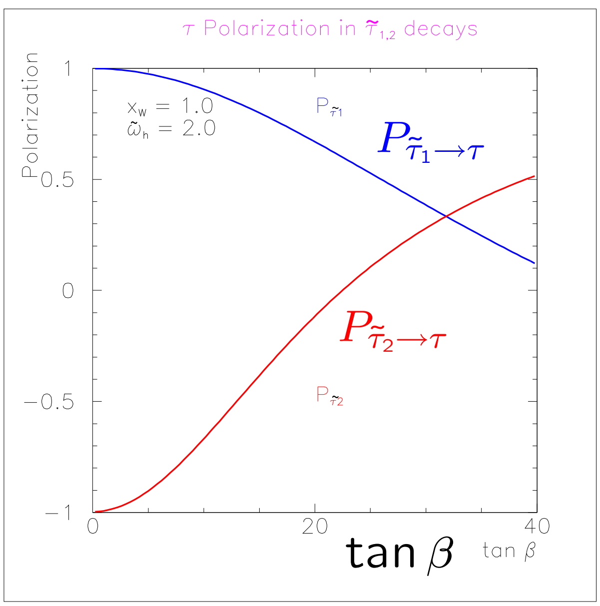
What's about high $\tan\beta$ in the $\tilde{\chi}^\pm$, $\tilde{\chi}^0$ system?

$\Rightarrow$ 'not' sensitive for $\tan\beta > 10$

$\Rightarrow$ Help from $\tilde{\tau}$ sector via $P_{\tilde{\tau}_1 \to \tau}$ Nojiri,Fujii,Tsukamoto

$\Rightarrow$ Suitable mixing of $\tilde{\chi}_1^0$ needed!

Boos,Martyn,GMP,Sachwitz,Vologdin,Zerwas'02



$\Rightarrow$ High sensitivity to $\tan\beta$!

$x_W \equiv$ gaugino–like

$\tilde{w}_h \equiv$ higgsino–like

$\Rightarrow$ Determination of $m_{\tilde{\tau}_1}$, $\theta_{\tilde{\tau}}$ with A_{pol}!

$\Rightarrow$ Preliminary: $\delta(\tan\beta) \sim 9\%$ even for $\tan\beta = 40$!

Test of selectron quantum numbers

SUSY assumption:

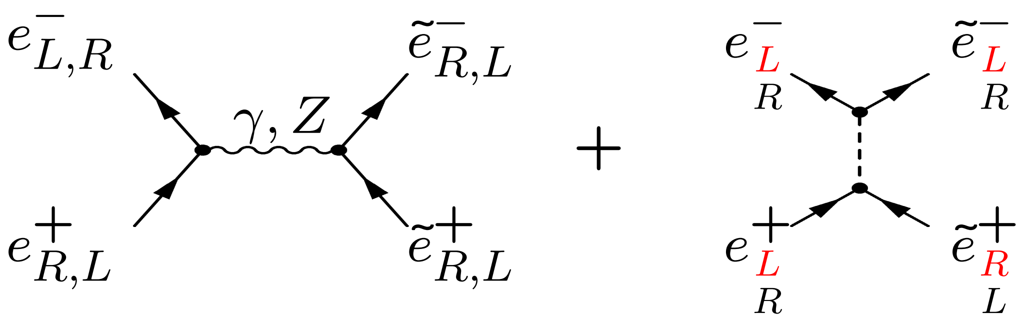
SM $\leftrightarrow$ SUSY have same quantum numbers!

$\Rightarrow$ $e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$

Scalar partners $\leftrightarrow$ chiral quantum numbers!

How to test this association?

Strategy: $\sigma(e^+e^- \to \tilde{e}^+_{L,R}\tilde{e}^-_{L,R})$ with polarized beams



$\Rightarrow$ t–channel: unique relation between

chiral fermion $\longleftrightarrow$ scalar partner

Use e.g. $e^+_L e^-_L$ $\quad \tilde{e}^+_R \tilde{e}^-_L \longrightarrow \tilde{e}^+_R \leftrightarrow \tilde{e}^-_L$

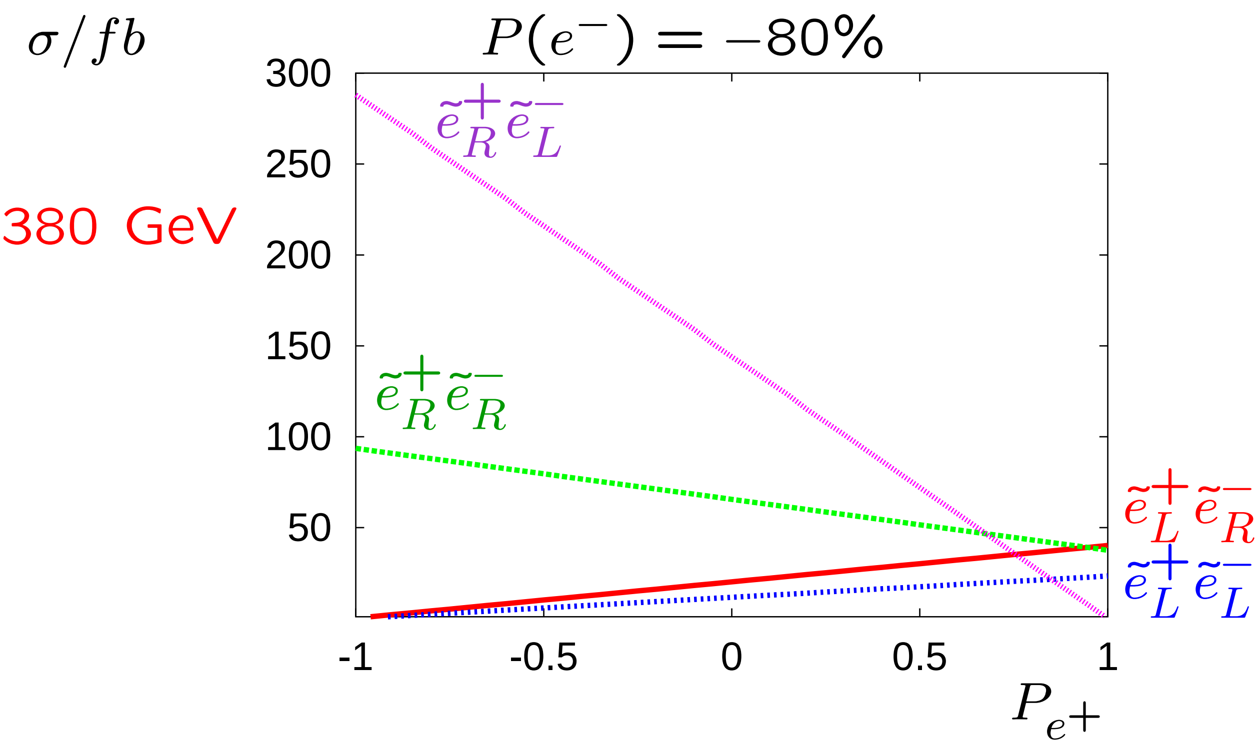
no s–channel

Test of selectron quantum numbers

Process: $e^+e^- \to \tilde{e}^+\tilde{e}^-$

Strategy: suppress s–channel with polarized beams

$\sqrt{s} = 380$ GeV



$\Rightarrow$ separation of $\tilde{e}_R^+ \leftrightarrow \tilde{e}_L^-$ via charge identification and decay processes

Blöchinger, Fraas, GMP, Porod '02

Positron polarization is essential

Further effect of beam polarization:

SUSY and SM background suppression

$\rightarrow$ precise $m_{\tilde{e}}$ determination Dima et al. 02

‘Extended’ neutralino sector: NMSSM

Beam polarization can help disentangling
NMSSM$\leftrightarrow$MSSM

NMSSM: additional Higgs singlet $\rightarrow$ 5 $\tilde{\chi}^0_i$’s
($\mu_{\text{eff}} = \lambda x = 352$ GeV, $x = 1$ TeV, $\kappa = 0.0493$)

Similar light mass spectra possible:

$m_{\tilde{\chi}^0_1} = 96$ GeV, $m_{\tilde{\chi}^0_2} = 177$ GeV

$\hat{=}$ scenario ‘Snowmass Points and Slopes’ SPS 1

Ghodbane, Martyn ’02, Allanach et al. ’02

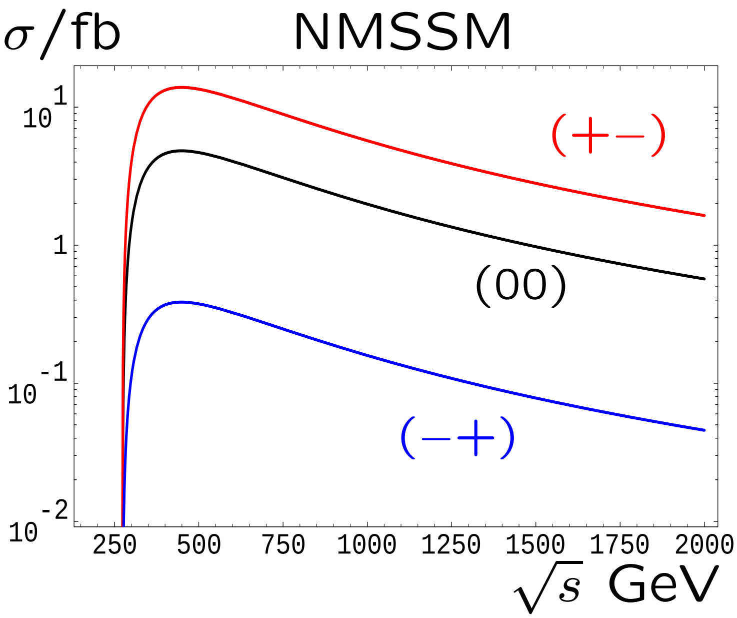
$\Rightarrow$ $\tilde{\chi}^0_1$ is singlino-like with $|\langle\tilde{\chi}^0_1|\tilde{S}\rangle|^2 = 0.95$

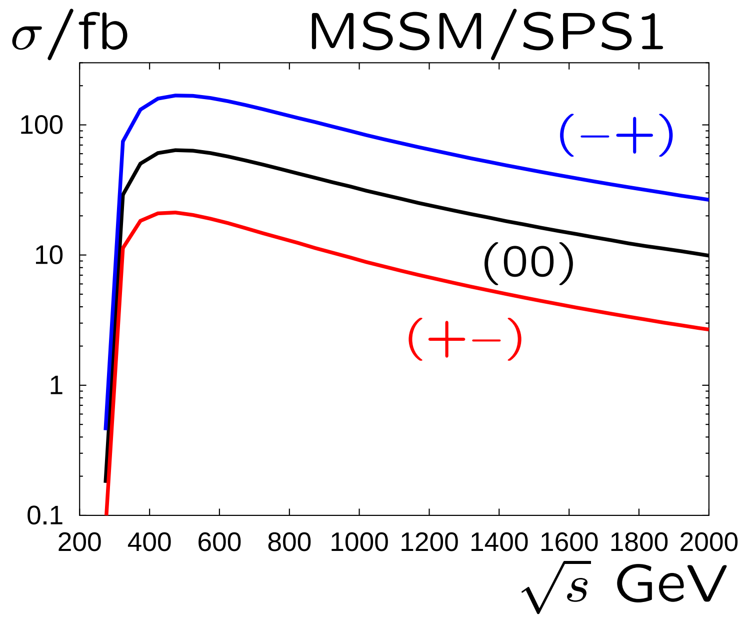
$\Rightarrow$ distinction from spectra might be difficult!

'Extended' neutralino sector: NMSSM

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

Strategy: study of polarized cross sections





- NMSSM: 'singlino'–like $\Rightarrow$ small rates
- different polarization dependence as in MSSM
  GMP, Hesselbach, Franke, Fraas'99, Hesselbach, Franke, Fraas'01
- direct production of singlinos ('99%') at a LC:
  $\sigma \sim$ fb up to x=0(10 TeV) Franke, Hesselbach'02

If polarized beams available:

$\Rightarrow$ distinction between MSSM$\leftrightarrow$NMSSM
might be possible!

Non–standard couplings in R violating SUSY

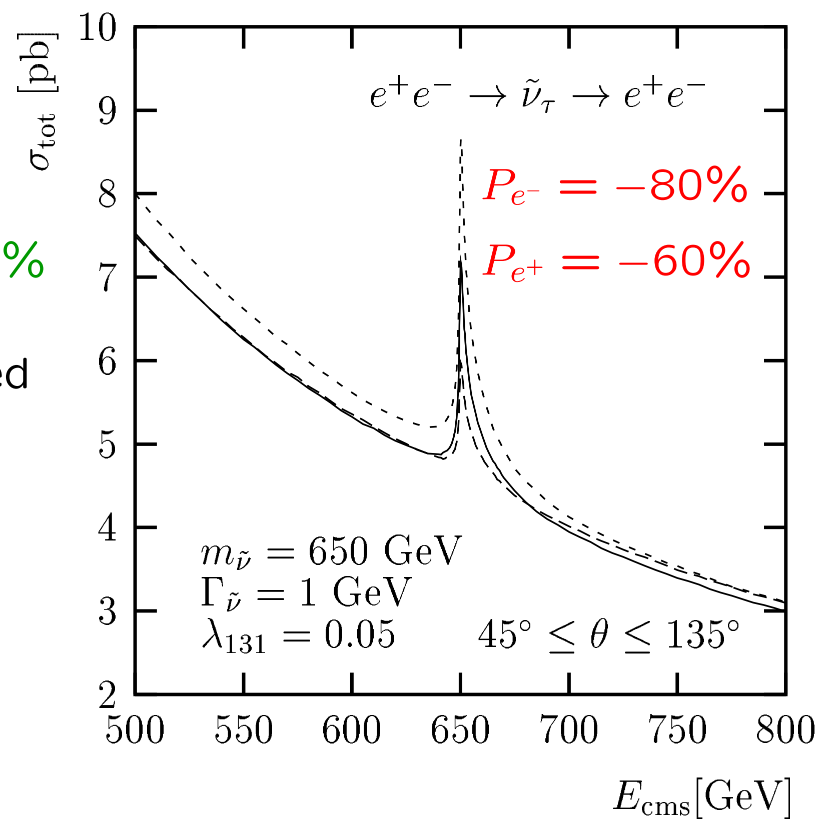
R-parity: 'new' SUSY quantum number
SM$\rightarrow +1$, SUSY$\rightarrow -1$

(If conserved: lightest SUSY particle is stable
$\rightarrow$ good candidate for CDM!)

R violating process: $e^+e^- \rightarrow \tilde{\nu} \rightarrow e^+e^-$
$\tilde{\nu}$ exchange in s–channel: $\Rightarrow e^+_L e^-_L$ needed!

$P_{e^-} = -80\%$

unpolarized



Spiesberger

(TESLA, TDR)

$\Rightarrow$ Strong signal!

Non–standard couplings in R violating SUSY

polarization	$\sigma(e^+e^- \to e^+e^-)$ with $\sigma(e^+e^- \to \tilde{\nu} \to e^+e^-)$	Bhabha
unpolarized	7.17 pb	4.49 pb
$P_{e^-} = -80\%$	7.32 pb	4.63 pb
LL: $P_{e^-} = -80\%$, $P_{e^+} = -60\%$	8.66 pb	4.92 pb

$\Rightarrow$ very high sensitivity to non–standard coupling!

$\Rightarrow$ P_{e^+} is essential (factor 10!)

Same final state also with $e^+e^- \to Z' \to e^+e^-$:

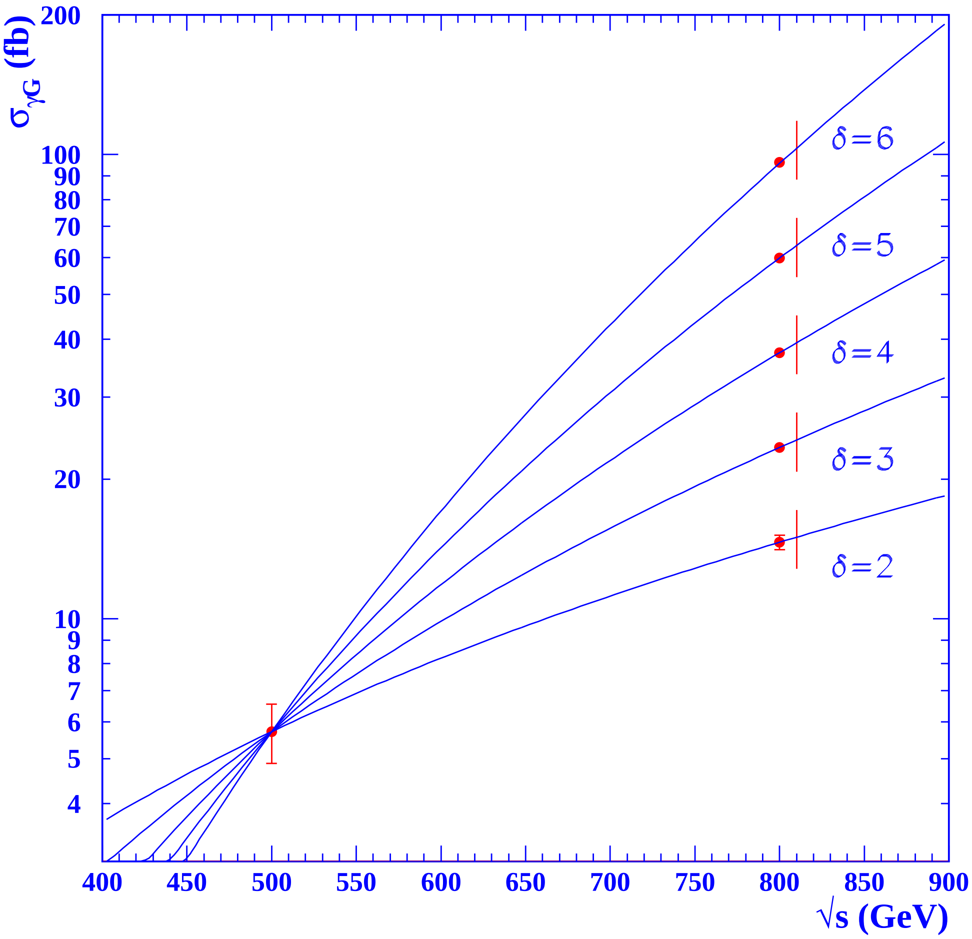
however with $e^+_R e^-_L$ or $e^+_L e^-_R$!

$\Rightarrow$ with P_{e^-} and P_{e^+}: fast analysis possible!

Signal for Large Extra Dimensions

Process: $e^+e^- \to \gamma G$

Strategy: $n(ED)$ with running at two $\sqrt{s}$!



Wilson

(TESLA, TDR)

Sensitivity to M_* in TeV at $\sqrt{s} = 800$ GeV, 1 ab^{-1}:

Polarization	$\delta = 2$	$\delta = 4$	$\delta = 6$
0	5.9	3.5	2.5
80%(e^-)	8.3	4.4	2.9
80%(e^-), 60%(e^+)	10.4	5.1	3.3

$\Rightarrow$ P_{e^-}, P_{e^+} enlarge the discovery range!

Signal for Large Extra Dimensions

Background: $e^+e^- \to \nu\bar{\nu}\gamma$

$\Rightarrow$ High sensitivity to beam polarization!

$\Rightarrow$ $S/\sqrt{B}$ increases:

by a factor 2.1 for +80%(e^-)

by a factor 4.4 for +80%(e^-), −60%(e^+)

Highlights :

$P(e^-)$ and $P(e^+)$ at a LC very useful for

(Summary in GMP, Steiner '01)

- Electroweak precision tests with unprecedented accuracy!
  $\rightarrow$ anomalous gauge couplings
  $\rightarrow$ CP–violation
  $\rightarrow$ operating as a Higgs–factory
- Discovery and 'unveiling' of SUSY
  $\rightarrow$ fundamental MSSM parameters
  $\rightarrow$ test of SUSY assumptions
  quantum numbers, Yukawa couplings etc.
  $\rightarrow$ disentangling of 'extended' SUSY models
- Discovery of other kinds of New Physics
  $\rightarrow$ large extra dimensions
  $\rightarrow$ extended gauge theories
- Further advantages:
  $\rightarrow$ backround suppression ...
  $\rightarrow$ improves statistics significantly
  $\rightarrow$ extends discovery range for all kinds of NP

But still open questions...

$\Rightarrow$ POWER working group:
close contact between Th/Exp/Machine
($\rightarrow$ http://www.desy.de/~gudrid/power)