Using Tau Polarization to Discriminate different SUSY models and Determine SUSY parameters

D.P.Roy, R.M.Godbole, MG, Phys Lett.2005.

LCWS06, 9-13th March,2006,Bangalore

Monoranjan Guchait
TIFR, Mumbai

• Polarization of tau plays a very crucial role in collider searches.

D.P.Roy et.al,1995

• Use of it in the case of Higgs searches is helpful; In case of SUSY searches it also acts as a very good tool.

• In the context of ILC, its importance is also under investigation

M.M.Nojiri et.al, 1996, E. Boos et. al. 2003

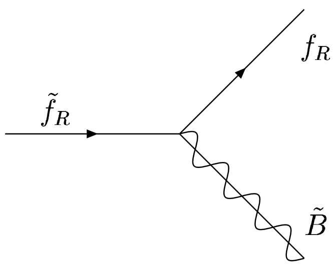
• Our plan

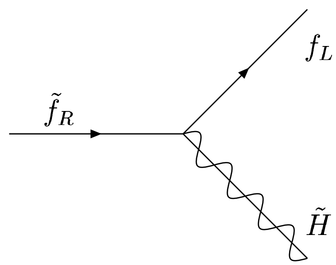
⇒ Discriminate SUSY models.

⇒ Determination of SUSY parameters.

Tau particles are polarized: $\tilde{\tau}_1 \to \tau + \chi_1^0$

$f = t/\tau$





$$P_\tau = \frac{\Gamma(\tau_R) - \Gamma(\tau_L)}{\Gamma(\tau_R) + \Gamma(\tau_L)} = \frac{(a_{11}^R)^2 - (a_{11}^L)^2}{(a_{11}^R)^2 + (a_{11}^L)^2}$$

$$a_{11}^R = -\frac{2g}{\sqrt{2}} N_{11} \tan\theta_w \sin\theta_{\tilde{\tau}} - \frac{g m_\tau}{\sqrt{2} m_W \cos\beta} N_{13} \cos\theta_{\tilde{\tau}}$$

$$a_{11}^L = \frac{g}{\sqrt{2}} [N_{12} + N_{11} \tan\theta_W \cos\theta_{\tilde{\tau}}] - \frac{g m_\tau}{\sqrt{2} m_W \cos\beta} \sin\theta_{\tilde{\tau}} N_{13}$$

$$\tilde{\chi}_1^0 = N_{11}\tilde{B} + N_{12}\tilde{W}_3 + N_{13}\tilde{H}_1^0 + N_{14}\tilde{H}_2^0$$

$$\Rightarrow P_\tau = P_\tau(M_1, \mu, \tan\beta, \theta_{\tilde{\tau}}) \text{(CP conserving SUSY)}$$

τ-Decays

$$\tau^+ \rightarrow \pi^+\nu_\tau(12.5\%)$$
$$\rightarrow \rho^+\nu_\tau \rightarrow \pi^+\pi^0(24\%)$$
$$\rightarrow a_1\nu_\tau \rightarrow \pi^+\pi^0\pi^0\nu_\tau(7.5\%)$$

"1- prong" channel

Angular distributions:

$$\frac{1}{\Gamma_\pi}\frac{d\Gamma_\pi}{d(\cos\theta)} = \frac{1}{2}(1+P_\tau\cos\theta)$$

$$\frac{1}{\Gamma_\pi}\frac{d\Gamma_{v,L}}{d(\cos\theta)} = \frac{m_\tau^2/2}{m_\tau^2+2m_v^2}(1+P_\tau\cos\theta)$$

$$\frac{1}{\Gamma_\pi}\frac{d\Gamma_{v,T}}{d(\cos\theta)} = \frac{m_v^2}{m_\tau^2+2m_v^2}(1-P_\tau\cos\theta)$$

$$p_{\tau-jet}=xp_\tau$$

$$\cos\theta = \frac{2x-1-m_{\pi,v}^2/m_\tau^2}{1-m_{\pi,v}^2} \;(\mathrm{E} >> m_\tau)$$

$$P_\tau = +1; \Rightarrow \tau_{jet} \sim \pi, \rho_L, a_{1L}$$

$$P_\tau = -1; \Rightarrow \tau_{jet} \sim \rho_T, a_{1T}$$

Energy sharing among decay products, π^+ and π^0:

$$\rho^0 \to \pi^+\pi^-$$

$$\frac{1}{\Gamma_{\pi\pi}}\frac{d\Gamma(\rho_L \to \pi^+\pi^0)}{d(\cos\theta')} \simeq \frac{3}{2}(2x'-1)^2$$

$$\frac{1}{\Gamma_{\pi}}\frac{d\Gamma(\rho_T \to \pi^+\pi^0)}{d(\cos\theta')} \simeq 3x'(1-x')^2$$

$x' = \frac{1+\sqrt{1-4m_\pi^2/m_\rho^2}\cos\theta'}{2} = \frac{p_\pi}{p_\rho}$

$\rho_L \to \pi^+\pi^0$; asym sharing; x' $\to 0/1$

$\rho_T \to \pi^+\pi^0$; equal sharing; x' $\to 0.5$

$$\Rightarrow \boxed{R = \frac{E_\pi}{E_{\tau-jet}}}$$

Similarly features also hold for $a_1 \to \pi^+\pi^0\pi^0$

Stau pair production and decays

For a wide class of SUSY models "$\tilde{\tau}_1$ NLSP". (low m_0, high $\tan\beta$ scenario)

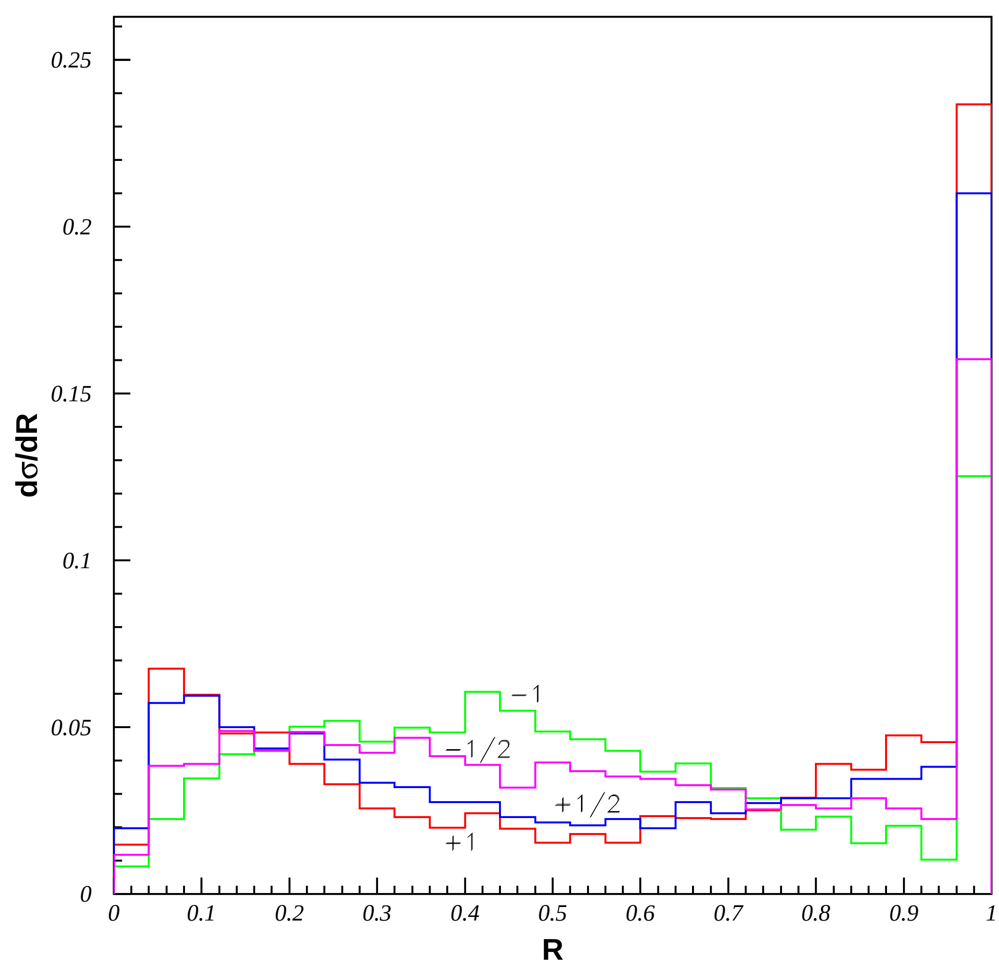
Unambigous SUSY signal from the pair production:

$$e^+e^- \quad \rightarrow \quad \tilde{\tau}_1\tilde{\tau}_1 \rightarrow \tau^+\tau^-\widetilde{\chi}_1^0\widetilde{\chi}_1^0$$

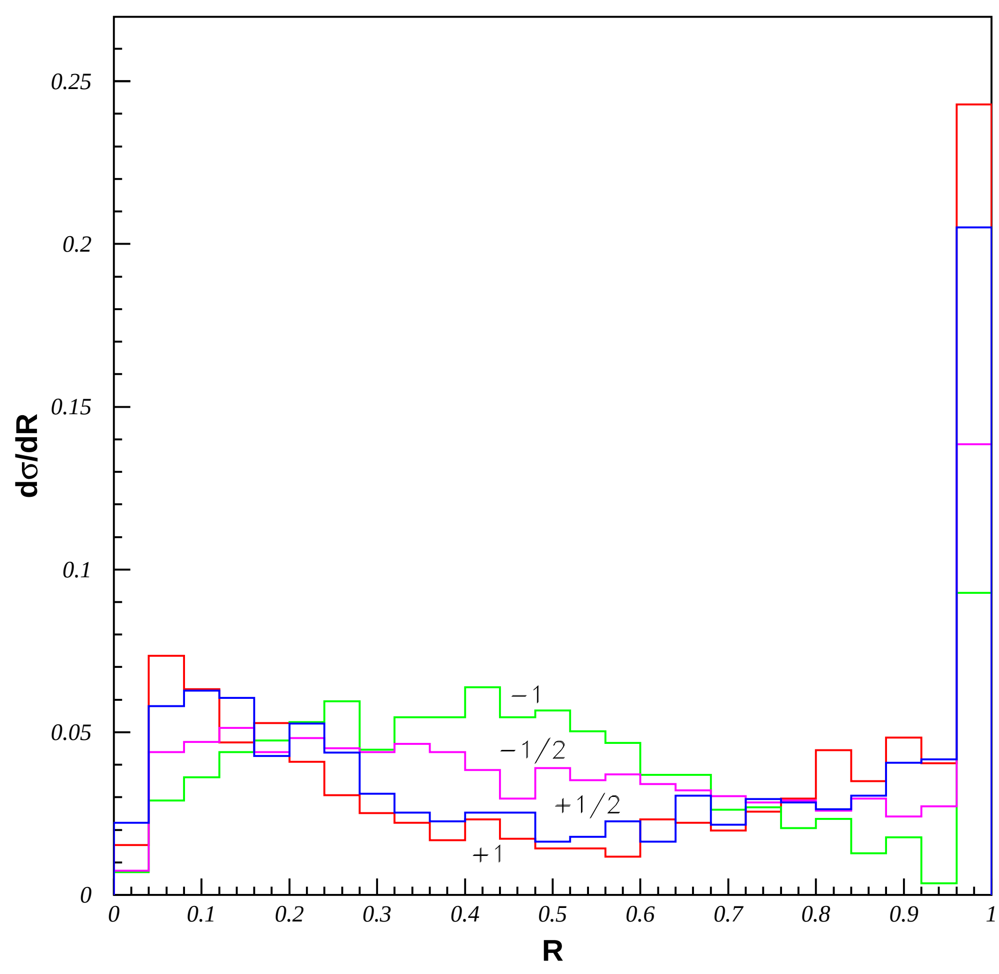
Cross section depends on $m_{\tilde{\tau}_1}, m_{\tilde{\chi}_1^0}$ and $\cos\theta_{\tilde{\tau}_1}$. $\mathrm{Br}(\tilde{\tau}_1 \rightarrow \tau\tilde{\chi}_1^0) = 1$
Our Analysis $\sqrt{s}$=350 GeV, $m_{\tilde{\tau}_1}$ =150 GeV, $m_{\tilde{\chi}_1^0}$=100 GeV.
$\sigma \sim 200$ fb $\Rightarrow 2 \times 10^4$ signal events for $\mathcal{L}$=100 fb^{-1}.

`Tools: PYTHIA interfacing with TAUOLA`(including ISR/FSR effects)

$$p^T_{\tau-\mathrm{jet}} > 25\ \mathrm{GeV}, \cos\theta_{\tau-\mathrm{jet}} < 0.75$$



dσ/dR
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
R
−1
−1/2
+1/2
+1



dσ/dR
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
R
−1
−1/2
+1/2
+1

SUSY Models

- mSUGRA, LSP, $\tilde{\chi}_1^0$ is dominated by $\tilde{B}$ component (N_{11}); $\cos\theta_{\tilde{\tau}_1}$ is small for moderate $\tan\beta$

$$\boxed{P_\tau \simeq +1}$$

- Non universal SUGRA model, LSP is dominated by Higgsino (N_{13});

$$\boxed{\Rightarrow P_\tau \simeq \cos^2\theta_{\tilde{\tau}} - \sin^2\theta_{\tilde{\tau}}}$$

- In AMSB model, LSP is domnated by wino component N_{12}

$$\boxed{P_\tau \simeq -1}$$

- In GMSB model, the LSP is $\tilde{G}$, $\tilde{\tau}_1 \to \tau\tilde{G}$

$$\boxed{P_\tau \simeq \sin^2\theta_{\tilde{\tau}} - \cos^2\theta_{\tilde{\tau}}}$$

$\cos\theta_{\tilde{\tau}}$ =0.5 $\to$ $P_\tau \simeq +1$ -1/2, -1 , +1/2

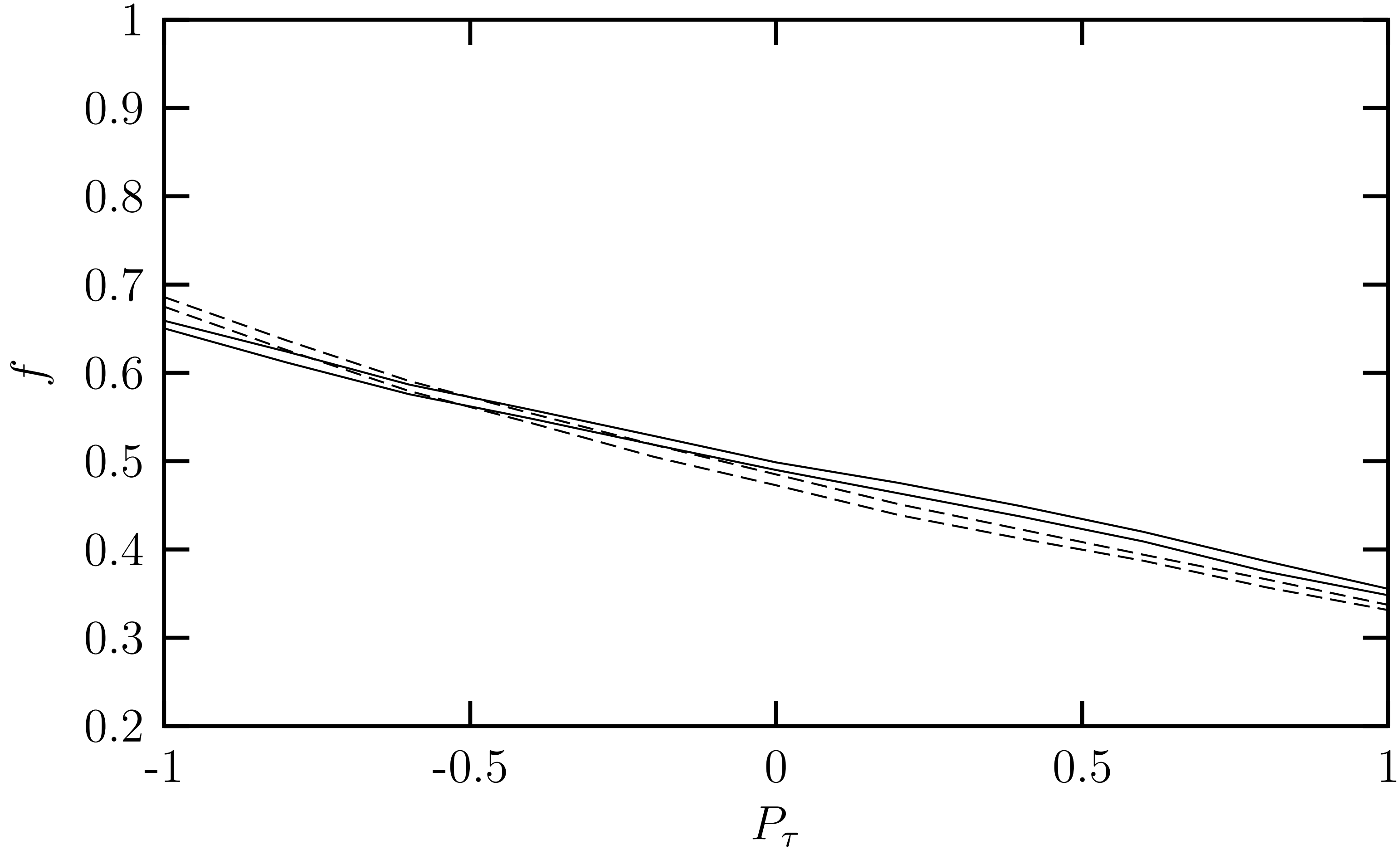
Possible to distinguish different SUSY models by measuring P_τ.

An observable:

$$f = \frac{\sigma(0.2 < R < 0.8)}{\sigma_{total}}$$

The fractional cross sections in the interval $0.2 < R < 0.8$ plotted against τ polarization for $p^T_{\tau-jet}$ >25 GeV (solid lines) and $p^T_{\tau-jet}$ >50 GeV (dashed lines).

$$\Delta P_\tau = \pm 0.03 \ (\pm 0.05) \text{ near } P_\tau{=}{-1}(+1)$$

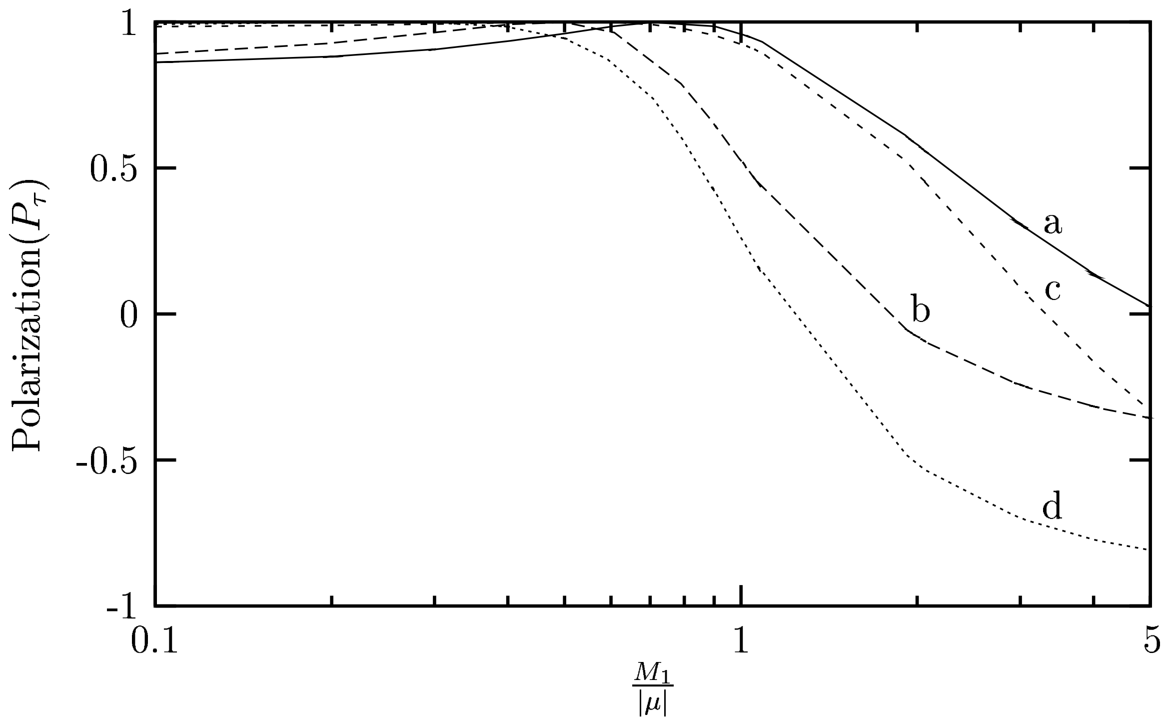


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
f
-1
-0.5
0
0.5
1
P_τ

Partial determination of SUSY parameters

- $\tan\beta$ and $\cos\theta_{\tilde{\tau}}$ is known from some other measurements

- Assume also $M_1 \simeq 0.5 M_2$ which is true for most of the model.
- Assume that the absolute scale of one of the SUSY masses, in terms some combinantion of M_1, M_2 and μ, can be measured.
- Polarization of τ is shown against $M_1/|\mu|$ for a fixed value of $m_{\tilde{Z}_1} = 100$ GeV and M_1/M_2=0.5 and different sets of parameters:(a)$\tan\beta = 10, cos\theta_{\tau}$ =0.5; (b)$\tan\beta = 40, cos\theta_{\tilde{\tau}}$ =0.5; (c)$\tan\beta = 10, cos\theta_{\tilde{\tau}}$ =0.2; (d)$\tan\beta = 40, cos\theta_{\tilde{\tau}}$ =0.2.



1
0.5
0
-0.5
-1
Polarization(P_τ)
0.1
1
5
$\frac{M_1}{|\mu|}$
a
b
c
d

Parameter determination

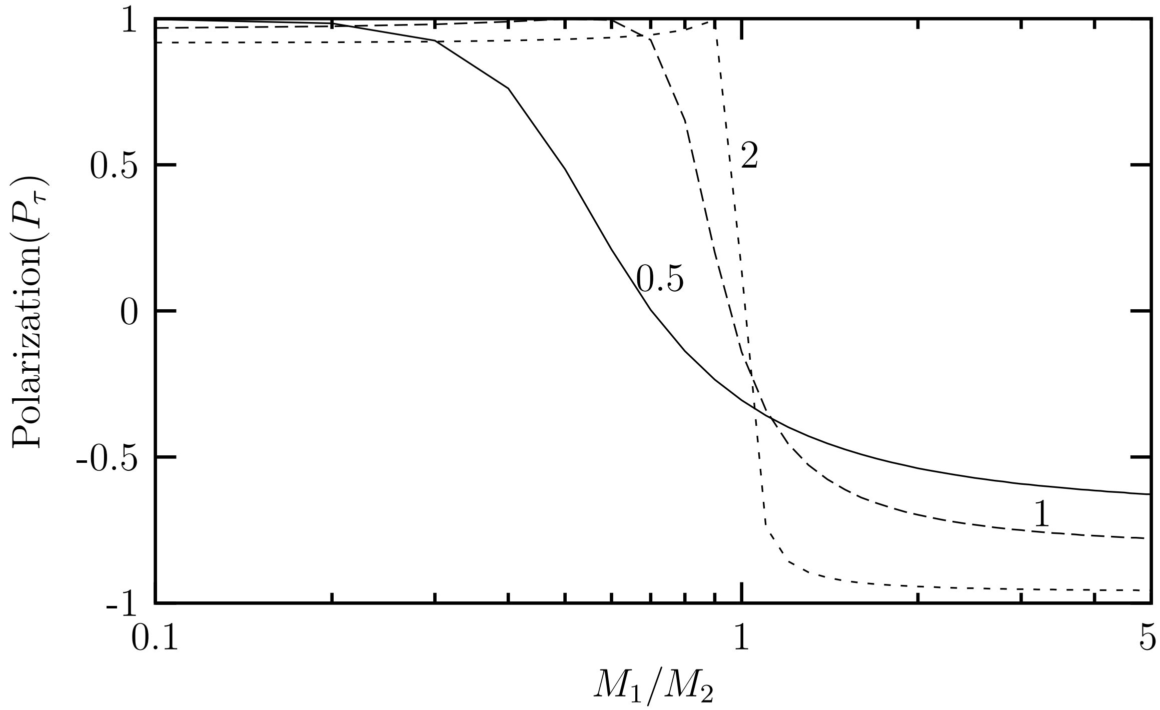
Parameters: $M_2, M_1, \mu, \tan\beta$

• Chargino sector: $M_2, \mu, \tan\beta$

• Measurements: $m_{\tilde{\chi}_1^\pm}, \sigma_L, \sigma_R, \sigma_T \Rightarrow M_2, \mu, \tan\beta$ and $m_{\tilde{\nu}}$

• Combining these measurements and measuring P_τ and $\theta_{\tilde{\tau}} \Rightarrow M_1$.

• In a global fit P_τ will be one of the important variable in a model independent determination of $\theta_{\tilde{\tau}}, M_2, \mu$ and $\tan\beta$



1
0.5
0
-0.5
-1
0.1
1
5
Polarization(P_τ)
M_1/M_2
2
0.5
1

Conclusion

- Polarization of τ depends on the composition of $\tilde{\chi}_1^0$.

- Polarisation of τ is different for different SUSY models.

- It is possible to discriminate different SUSY models by measuring P_τ. Resolution error, basically statistical error in measurements of P_τ.

- Partial determination of SUSY parameter(M_1) is possible.

- Full determination of SUSY EW paramters are possible in association with the measurements of Chargino sector,may also offer for consistency checks