Probing SUSY with degenerate mass spectrum from jet analysis

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Introduction

- SUSY mass spectrum depends on SUSY breaking mechanism.
- Mirage mediation predicts degenerate mass spectrum compared to mSUGRA.
- But missing E_T, M_{eff} distributions may look similar in both models. (Okada-san's talk)
- We will consider whether such a degenerate mass spectrum is distinguishable from mSUGRA at LHC.

Mirage Mediation

SUSY breaking: Modulus(M_0) + Anomaly($m_{3/2}/(4\pi^2)$)

$$\alpha \equiv \frac{m_{3/2}}{M_0 \ln(M_{\rm Pl}/m_{3/2})} \equiv \frac{R}{\ln\left(m_{\rm Pl}/m_{3/2}\right)}$$

Choi,Falkowski,Nilles,Olechowski,'05
Endo,Yamaguchi,Yoshioka,'05
Choi,Jeong,Okumura,'05

$$M_a = M_0\left[1 + \frac{\ln(M_{Pl}/m_{3/2})}{16\pi^2} b_a g_a^2 \alpha\right],$$

$$A_{ijk} = M_0\left[(a_i + a_j + a_k) - \frac{\ln(M_{Pl}/m_{3/2})}{16\pi^2}(\gamma_i + \gamma_j + \gamma_k)\alpha\right]$$

$$m_i^2 = M_0^2\left[c_i - \frac{\ln(M_{Pl}/m_{3/2})}{16\pi^2}\theta_i\alpha - \left(\frac{\ln(M_{Pl}/m_{3/2})}{16\pi^2}\right)^2 \dot{\gamma}_i\alpha^2\right]$$

a_i, c_i Modulus contribution b_a, γ_a, θ_a anomalous dim

$$M_0, \alpha, a_i, c_i, \tan\beta$$

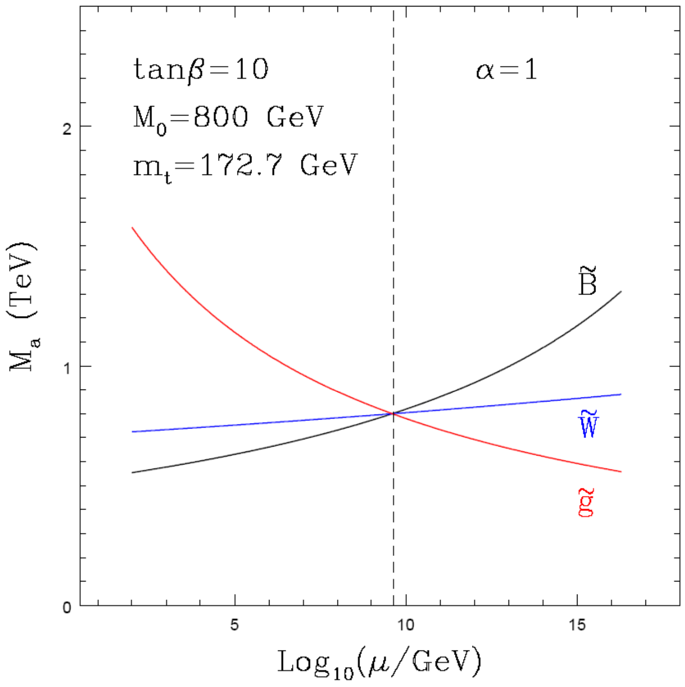
We will take $a_i = c_i = 1$

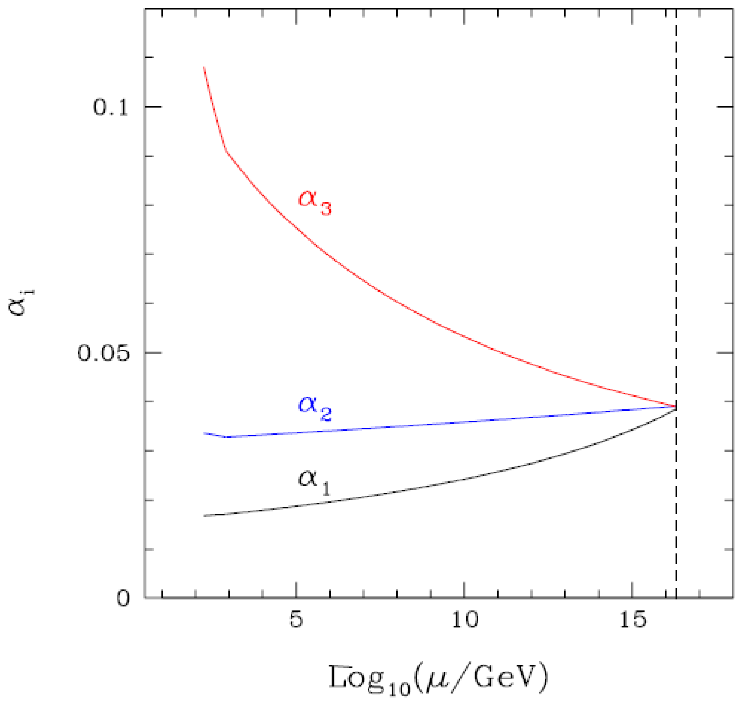
Mirage unification

SUSY breaking masses are unified at the mirage scale

$$M_{\rm Mir} = M_{\rm GUT} \left(\frac{m_{3/2}}{M_P}\right)^{\alpha/2}$$

Choi, Jeong, Okumura, '05





When α is large, the mirage scale becomes low and the SUSY spectrum becomes degenerate.

Mirage vs mSUGRA

KKLT

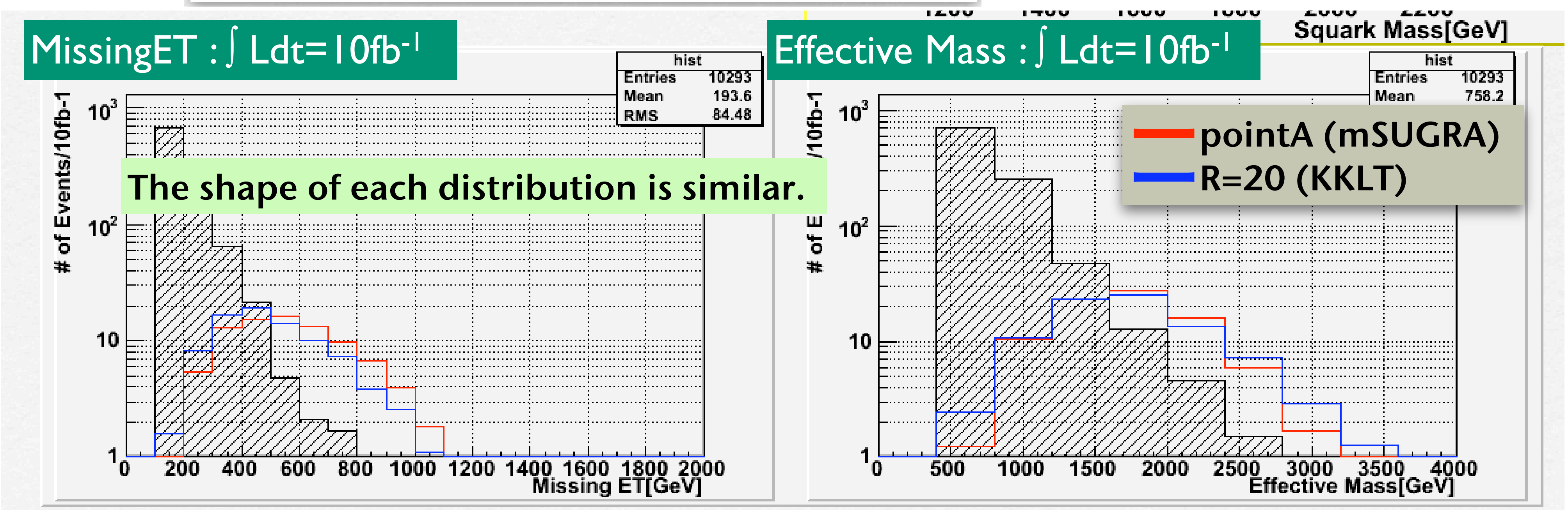
$R = 20, m_3(M_{\rm GUT}) = 650, \tan\beta = 10$
$(\alpha = 0.61, M_0 = 802)$

mSUGRA

$m_0 = 1475, m_{1/2} = 561, A_0 = 0, \tan\beta = 10$

	R=20	point A
# of evt/10fb-1	87.66 events	88.28 events

Okada-san's talk



Looks very similar.

$$M_{\rm eff} \equiv \sum_{i=1,..,4}^{leading-4jets} P_T + \sum^{leptons} P_T + \not{E}_T$$

Masses and branching ratios

	Mirage mass	Mirage Br	mSUGRA mass	mSUGRA Br
$\tilde{g}$	1491	$t\,\tilde{t}_1(67),\ b\,\tilde{b}_1(16)$	1358	$t\,b\,\chi_2^{\pm}(30),\ t\,t\,\chi_1^0(12)$
$\tilde{q}_L$	1473	$\tilde{q}'_L\,\chi_1^{\pm}(66),\ \tilde{q}_L\chi_2^0(33)$	1852	$q'\,\tilde{g}(53),\ q_L\chi_1^{\pm}(30)$
$\tilde{q}_R$	1415	$\tilde{q}_R\,\chi_1^0(100)$	1830	$q\,\tilde{g}(96),\ q\,\chi_1^0(4)$
$\tilde{e}_L$	916	$\nu\,\chi_1^{\pm}(51),\ e\,\chi_2^0(27)$	1518	$\nu\,\chi_1^{\pm}(56),\ e\,\chi_2^0(30)$
$\tilde{e}_R$	845	$e\,\chi_0^{\pm}(100)$	1488	$e\,\chi_0^{\pm}(100)$
$\tilde{t}_1$	1014	$t\,\chi_0^{\pm}(63),\ b\,\chi_1^{\pm}(27)$	1237	$b\,\chi_2^{\pm}(39),\ t\,\chi_3^0(22)$
χ_2^0	695	$h\,\chi_0^{\pm}(97),\ Z\chi_1^{\pm}(2)$	450	$h\,\chi_0^{\pm}(93),\ Z\chi_1^{\pm}(7)$
$\chi_1^{\pm}$	696	$W\,\chi_0^{\pm}(100)$	450	$W\,\chi_0^{\pm}(100)$
χ_1^0	487		237	

Mirage: $\tilde{g} > \tilde{q}_L > \tilde{q}_R > \tilde{t}_1$

mSUGRA: $\tilde{q}_L > \tilde{q}_R > \tilde{g} > \tilde{t}_1$

MC simulation

ISAJET.V7.75+Herwig + Acerdet

I will consider signals only. (No BG analysis)

Standard CUT (to reduce SM background)

P_T >100 GeV 1st jets, others 50 GeV, $|\eta|<3$.

P_T>20 GeV, $|\eta|<3$, isolated leptons.

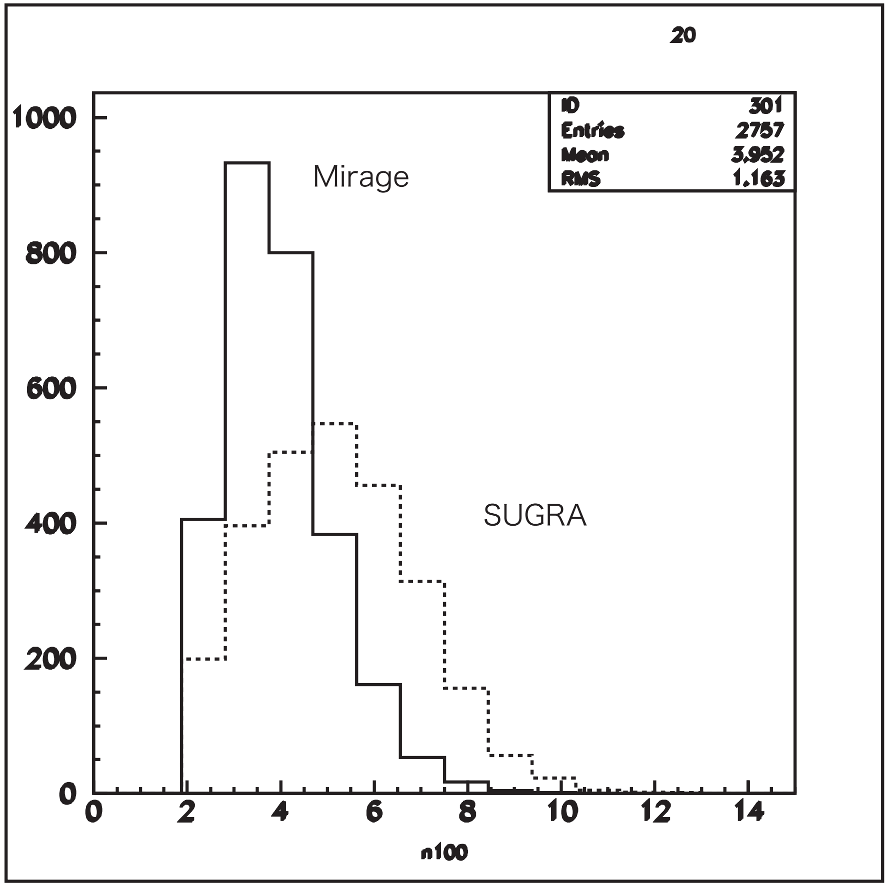
Missing E_T> max(0.2*M_{eff}, 100 GeV)

M_{eff}>400 GeV

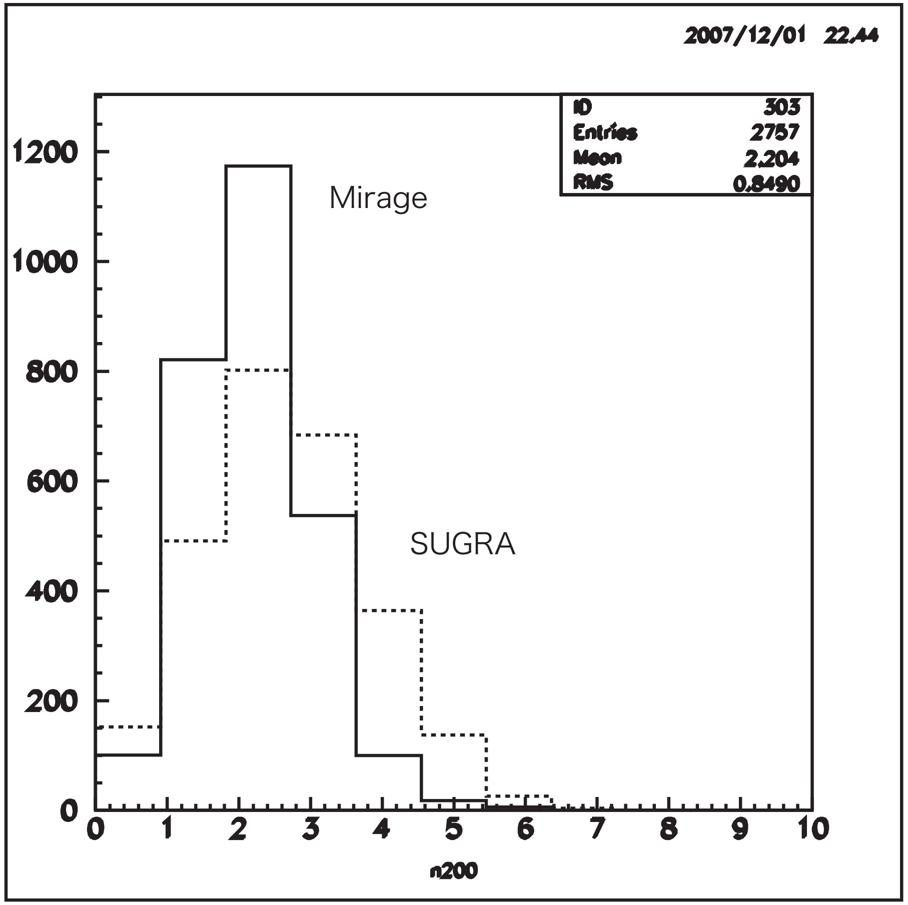
S_T>0.2

Jets distributions

There are more high P_T jets in mSUGRA because squark → gluino is allowed.



# of jets with P_T>100



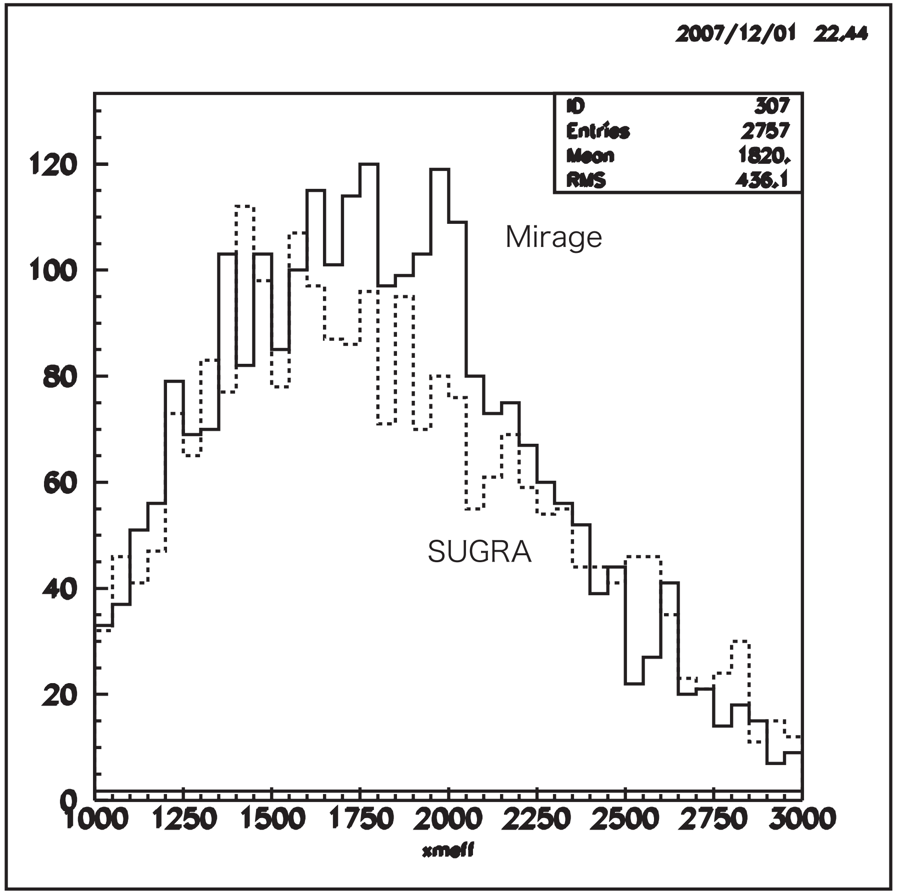
# of jets with P_T>200

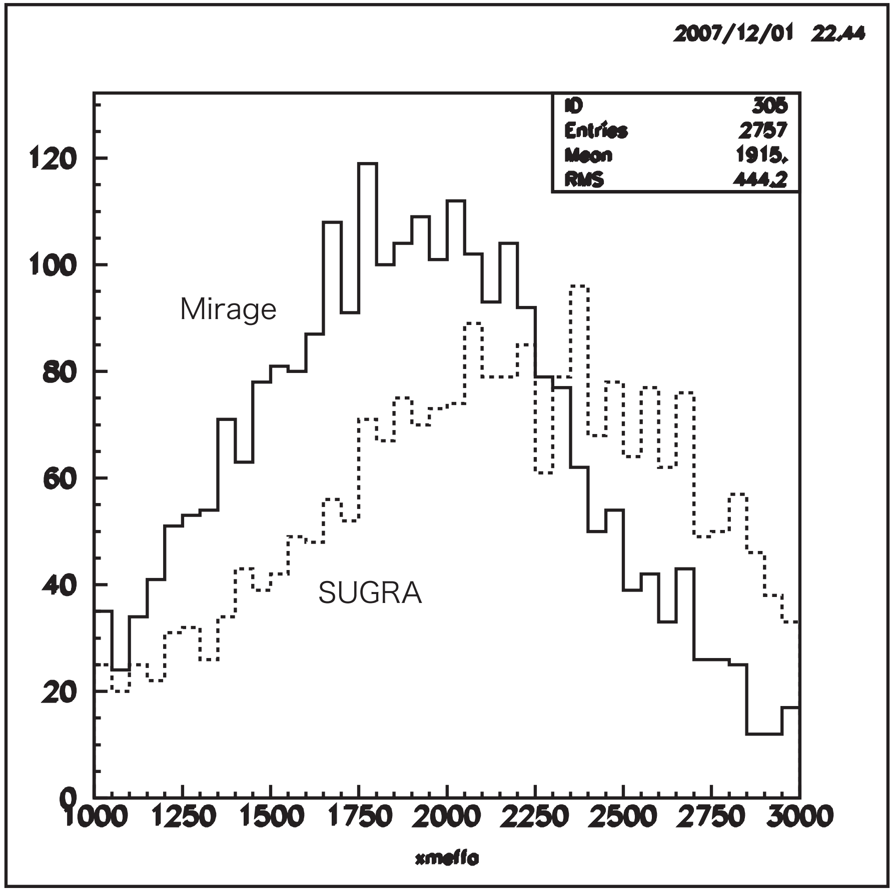
Meff distributions

We modify the definition of M_{eff} due to many high PT jets.

$$M_{\rm eff} \equiv \sum_{i=1,..,4}^{leading-4jets} P_T + \sum^{leptons} P_T + \not{E}_T$$

$$M'_{\rm eff} \equiv \sum_{i=1,..,}^{P_T>50} P_T + \sum^{leptons} P_T + \not{E}_T$$





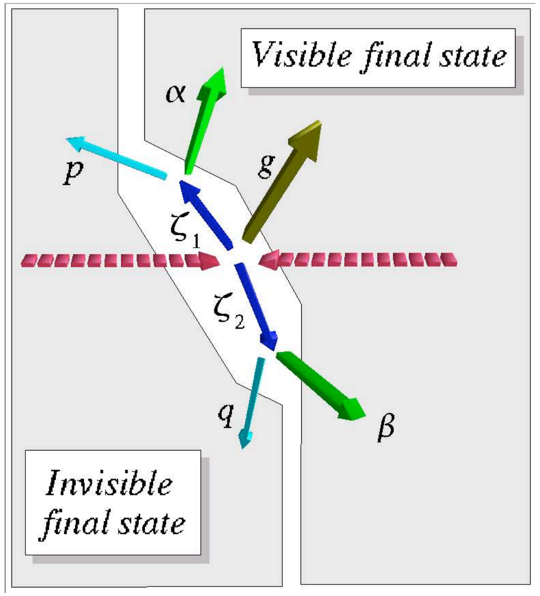
Squark MT2

MT2 is useful to determine the masses.

→Yeong Gyun's talk

$$\tilde{q}_R\,\tilde{q}_R \to q\,\chi_1^0\;q\,\chi_1^0$$

$$m_T^{(i)} = \sqrt{(m_{vis}^{(i)})^2 + m_\chi^2 + 2(\,E_T^{vis(i)}E_T^{\chi(i)} - \mathbf{p}_T^{vis(i)}\cdot\mathbf{p}_T^{\chi(i)})},$$



Barr, Lester, Stephens, '03

$$m_{T2}(\mathbf{p}_T^{vis(1)},\,m_{vis}^{(1)},\,\mathbf{p}_T^{vis(2)},\,m_{vis}^{(2)},\,m_\chi) \equiv \min_{\{\mathbf{p}_T^{\chi(1)}+\mathbf{p}_T^{\chi(2)}=-\mathbf{p}_T^{vis(1)}-\mathbf{p}_T^{vis(2)}\}}\left[\max\{m_T^{(1)},m_T^{(2)}\}\right],$$

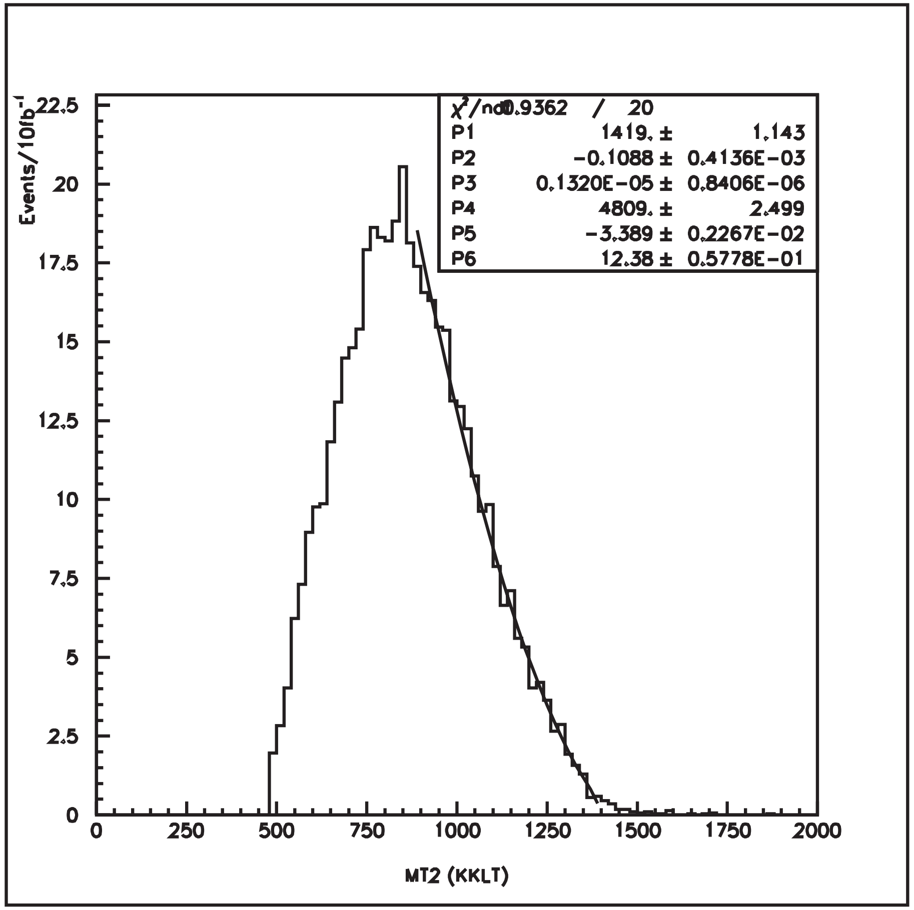
Trial LSP momenta $\mathbf{p}_T^{\chi(1)} + \mathbf{p}_T^{\chi(2)} = \mathbf{p}_T^{miss}$

For true LSP mass, the endpoint of MT2 gives the squark mass.

$$m_{T2}^{\text{math}}(\chi_1^0) = m_{\tilde{q}}$$

Mirage

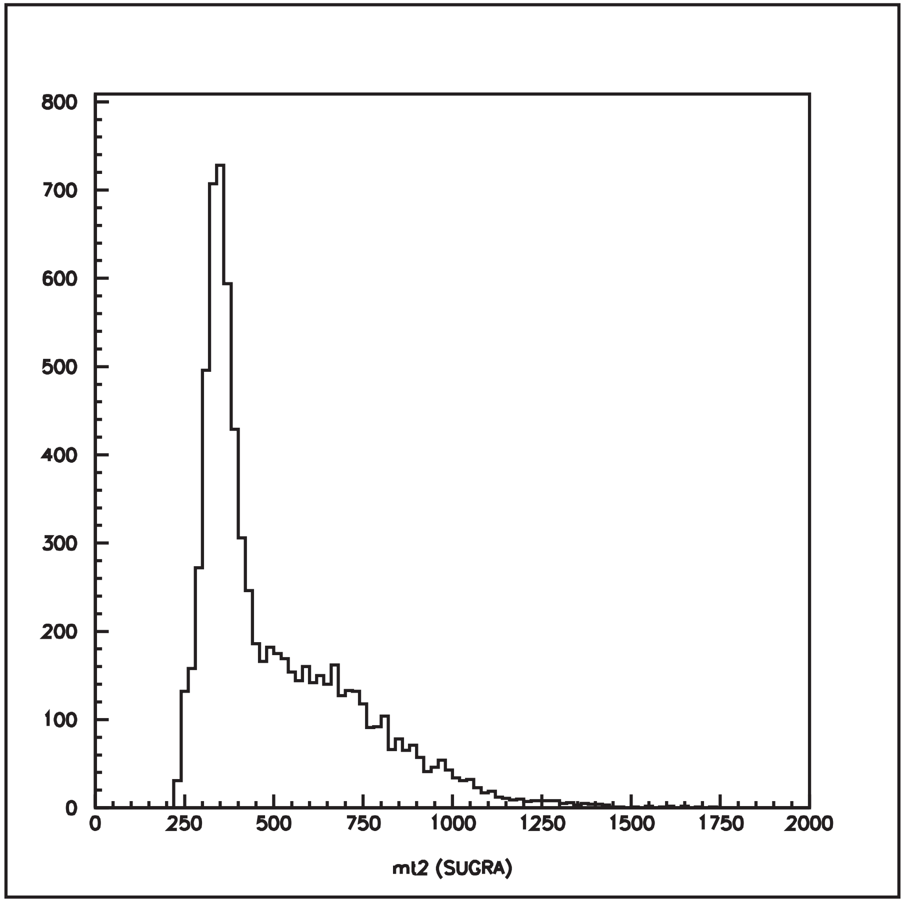
$\tilde{q}_R \, \tilde{q}_R \rightarrow q \, \chi_1^0 \; q \, \chi_1^0$



Clear end point ~m_{qR}=1415

mSUGRA

$\tilde{q}_R \, \tilde{q}_R \rightarrow q \, \tilde{g} \; q \, \tilde{g}$



The LSP mass is fixed as nominal value.

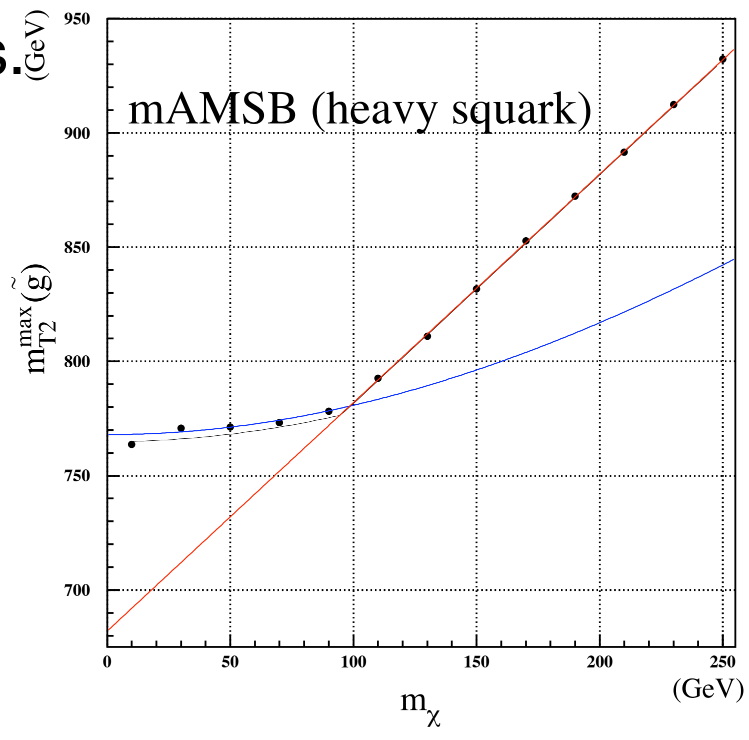
Kink in MT2 distribution

Gluino MT2 (→Yeong Gyun's talk)

Cho, Choi, Kim, Park '07

$$p\,p \to \tilde{g}\,\tilde{g} \to qq\chi_1^0\,qq\chi_1^0$$

MT2 distribution has a kink at true LSP mass.



Recently, it is shown that the kink structure appears more complicated process.

Gripaios, '07
Bar, Gripaios, Lester, '07
Cho, Choi, Kim, Park '07

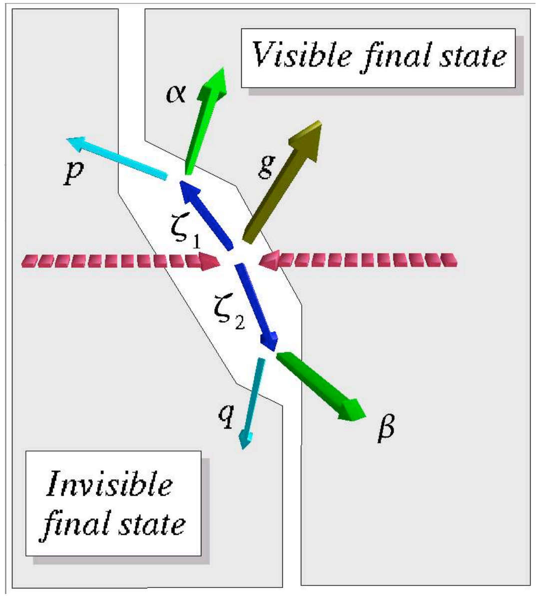
We will try to use this kink method for inclusive processes.

$$p\,p \to \tilde{g}\,\tilde{g},\ \ \tilde{g}\,\tilde{q},\ \ \tilde{q}\,\tilde{q} \to \text{jets}\,\chi_1^0\,\text{jets}\,\chi_1^0$$

Cho, Choi, Kim, Park, '07

Hemisphere analysis

We separate two jet system originating from two parent particles (gluino, squark) by hemisphere analysis.



(1). Each hemisphere is defined by axises P_i (i=1,2 which is the sum of objects P_T> 50(Jets), 10 (Lepton/photon)

(2).High P_T objects k belonging to hemisphere i satisfies

$$d(p_k, P_i) < d(p_k, P_j)$$

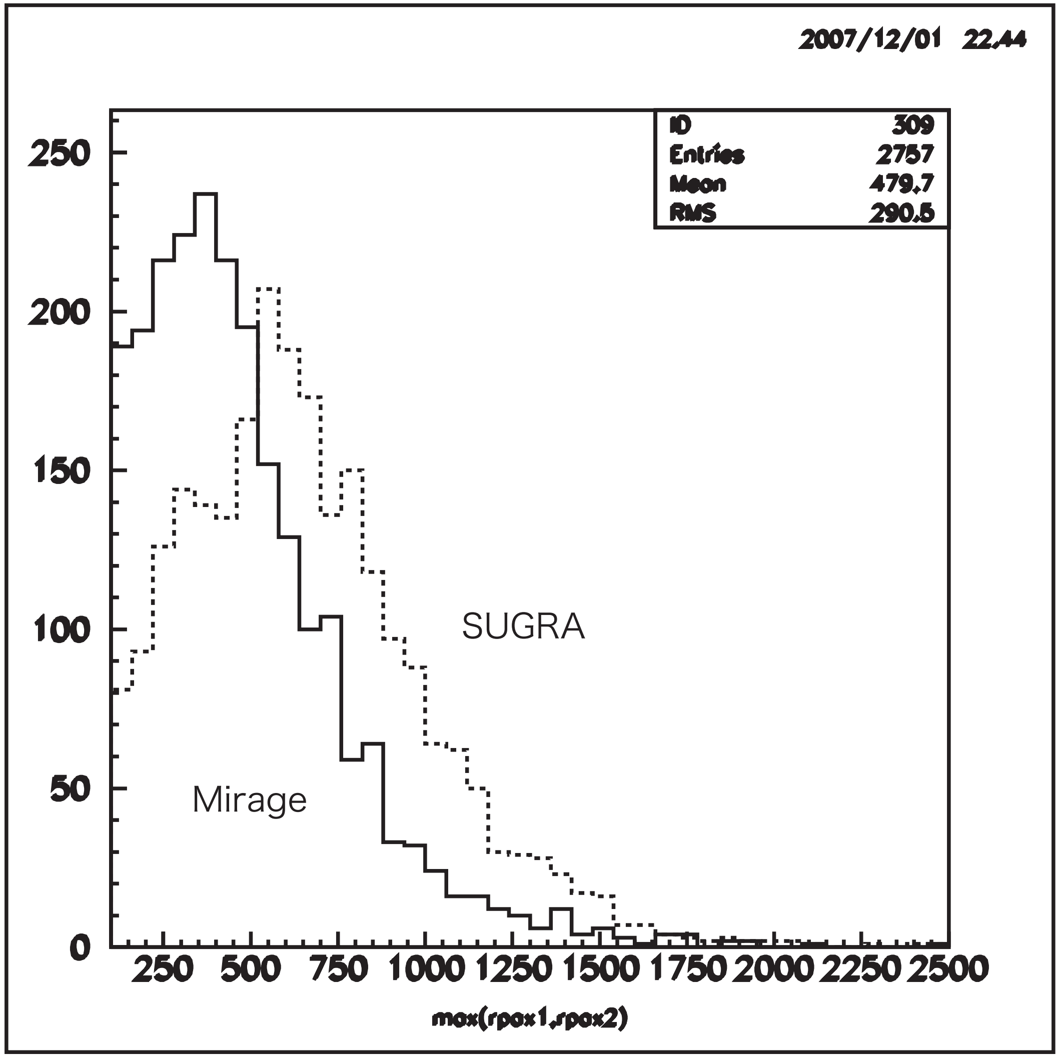
$$d(p_k, P_i) = (E_i - |P_i| \cos\theta_{ik}) \frac{E_i}{(E_i + E_k)^2}$$

Invariant mass of hemisphere jets

Max(invariant masses of two hemispheres)

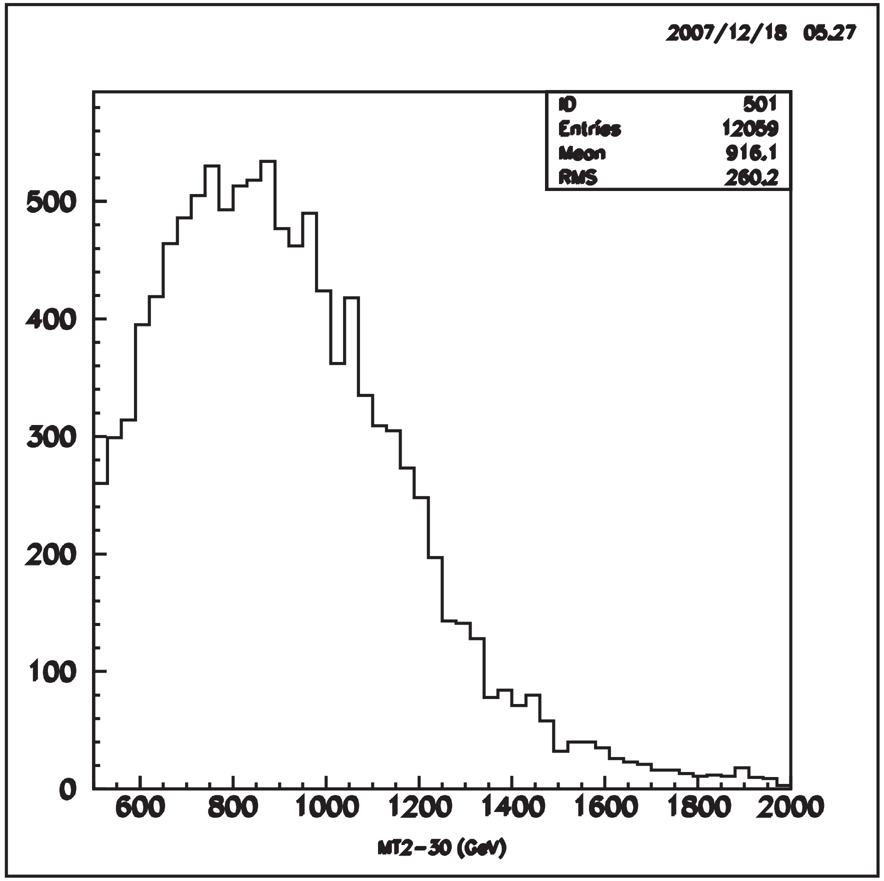
The mSUGRA predicts a lager value.

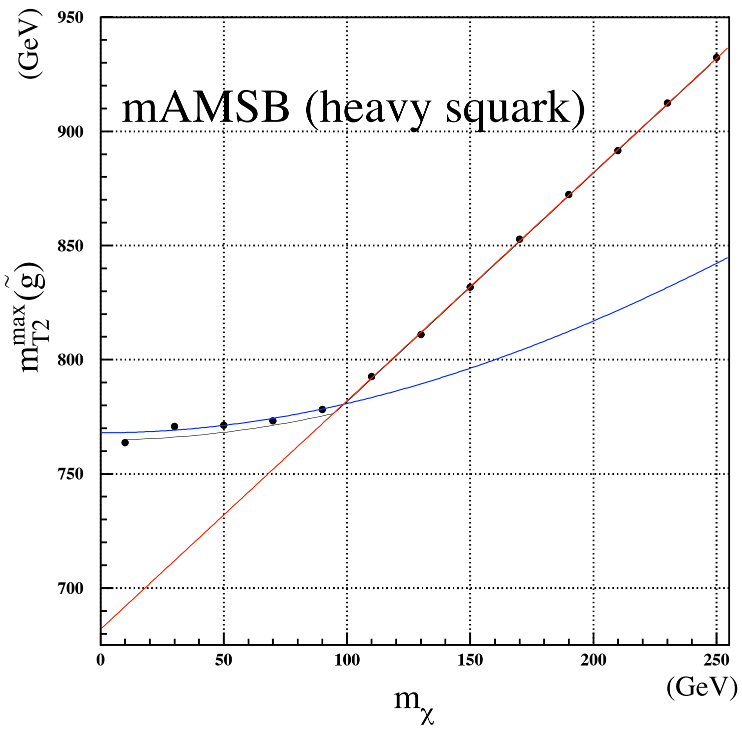
$$\tilde{q}_L \rightarrow \tilde{g} \rightarrow \chi_2^{\pm}$$



MT2 distribution

Mirage trial LSP mass =30 GeV





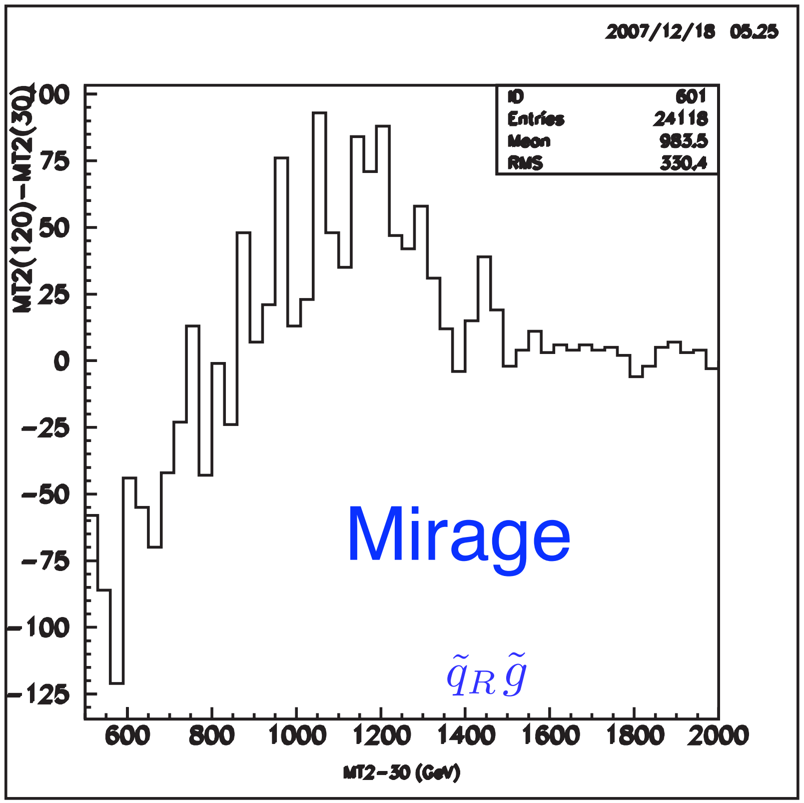
End point is not so clear: inclusive analysis, mis-id of hemisphere, ...

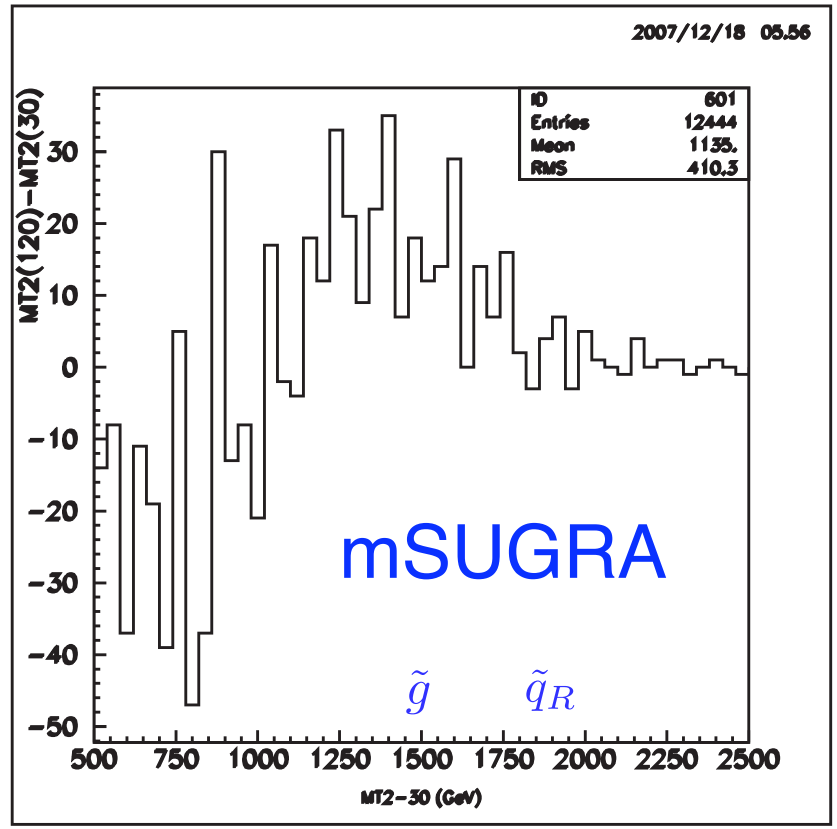
Kink in MT2 distribution

Consider difference of MT2 distributions of different trial LSP mass.

Right edge corresponds to Kink in MT2 distribution.

→ True squark/gluino mass





MT2~min[Max(MT(i))]→sensitive to heavier parents mass.

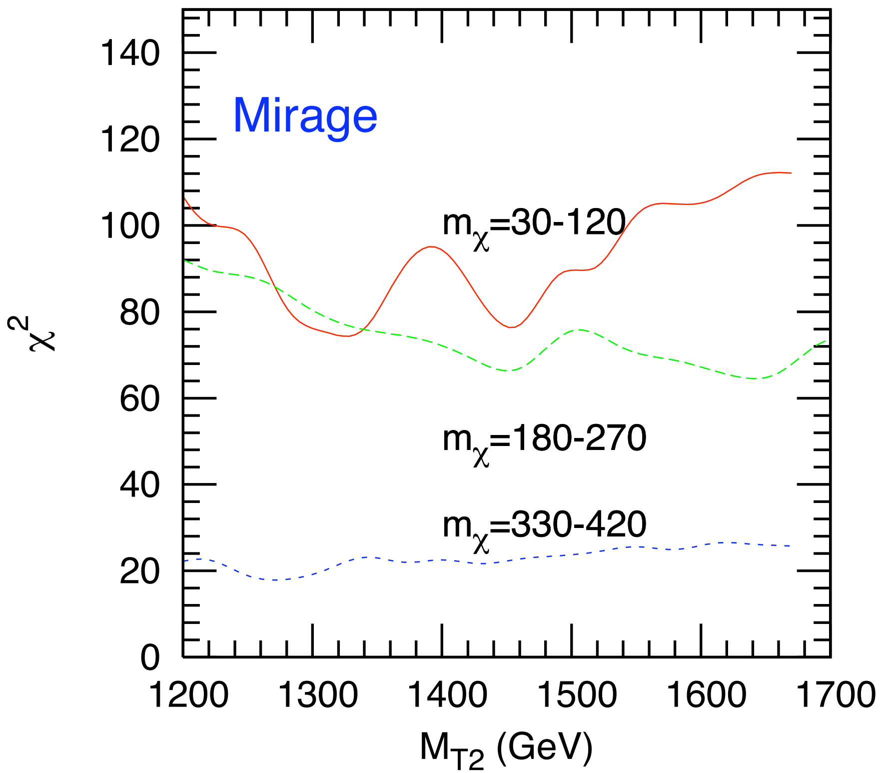
We can see a heavier edge in mSUGRA.

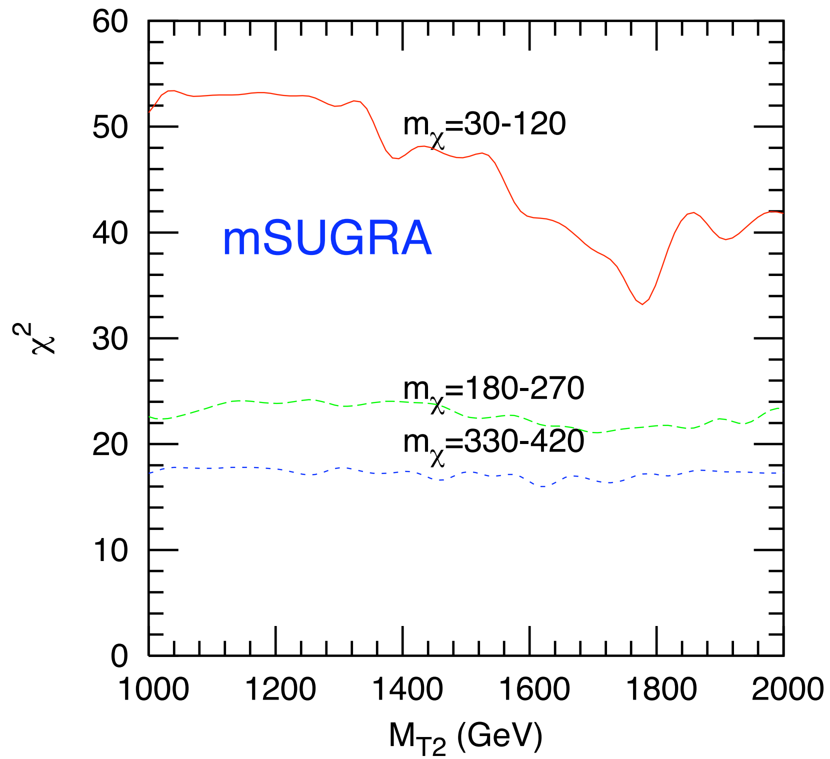
χ2 fitting

Fit the difference with step function.

$$\chi^2(n) = \sum_{i=1}^{n} \frac{(\Delta_i - a)^2}{x_i} + \sum_{i=n+1}^{N} \frac{\Delta_i^2}{x_i}$$

N: Total bin, x_i: Number of MT_2 for trial LSP,
y_i: Number of MT_2 for different LSP, $\Delta_i = y_i - x_i$





Summary

- We investigate whether we can discriminate SUSY with degenerate mass (mirage mediation) and mSUGRA.
- It may be possible to discriminate two models by inclusive analysis. (Jet, modified Meff, MT2 distributions)
- We also see the kink structure in the MT2 distribution, but it is not so clear.
- From the kink, we can guess the squark mass.