ESTABLISHING THE MIRAGE MEDIATION MODEL

AT THE LARGE HADRON COLLIDER

A Thesis

by

KECHEN WANG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2011

Major Subject: Physics

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Approved by:

Chair of Committee,	Bhaskar Dutta
Committee Members,	Teruki Kamon
	Stephen A. Fulling
Head of Department,	Edward Fry

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ABSTRACT

Establishing the Mirage Mediation Model at the Large Hadron Collider.

(August 2011)

Kechen Wang, B.S., Nankai University, China

Chair of Advisory Committee: Dr. Bhaskar Dutta

This thesis describes the research I did during my Master's study. I investigated the stau-neutralino coannihilation region of the Mirage Mediation Model at the Large Hadron Collider (LHC). By constructing five kinematic observables at the LHC, the masses of supersymmetric particles (sparticles) were determined. The Mirage Mediation Model parameters were determined from the sparticles' masses. This is the first time to establish the Mirage Mediation Model at the LHC. All these techniques can be applied to other coannihilation regions of the Mirage Mediation Model and other supersymmetry (SUSY) models.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Dutta, and my committee member, Dr. Kamon, for their guidance throughout the course of this research. I also want to thank my other committee member, Dr. Fulling, for his attentions.

Thanks also go to Abram Krislock and Kuver Sinha for providing useful discussions. I also learned a lot of computing skills from Abram and a lot of physics theory knowledge from Kuver. I want to extend my gratitude to the colleagues and the department faculty and staff for making my time at Texas A&M University a great experience

Finally, thanks to my mother and father for their encouragement.

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1. INTRODUCTION

High energy physics is currently at the dawn of a new era, in which the Large Hadron Collider (LHC) will test many ideas for physics beyond the Standard Model (SM). Of these ideas, low energy supersymmetry (SUSY) [1] is the best motivated candidate for new TeV scale physics. It provides a solution to the hierarchy problem, and leads to the unification of the gauge coupling constants. Low energy SUSY with R parity invariance also provides a natural candidate, the lightest SUSY particle (LSP), for the cold dark matter of the universe [2]. But SUSY must be broken spontaneously in some sector hidden from the observable sector, and the effect of SUSY breaking must be communicated to the observable sector by some mediation mechanism. There are many proposed SUSY breaking and mediation mechanisms, such as gravity-mediation, gauge-mediation [3, 4] and anomaly-mediation [5]. The phenomenology of such theories, including the minimal supersymmetric standard model (MSSM), depends crucially on the super partner mass spectrum, which is governed by the soft supersymmetry breaking sector.

Recent development in Kachru-Kallosh-Linde-Trivedi (KKLT)-type [6] string moduli stabilization has led to a new pattern of soft SUSY breaking terms. Because the gravitino mass $m_{3/2}$ is bigger than the moduli-mediated soft masses m_{moduli} in this type of models, the loop-induced anomaly-mediated contributions [5] become comparable to the moduli-mediated contributions [7]. This leads to the mixture of modulus- and

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anomaly- mediation contributions to the SUSY breaking parameters. Such models are called mirage-mediation or mixed-modulus-anomaly-mediation models.

Phenomenologically, the Mirage Mediation Model gives the sfermion masses at the low energy scale μ,

$$m_i^2(\mu)=\left(\frac{m_{3/2}}{16\pi^2}\alpha\right)^2\left[\,c_i-\frac{1}{8\pi^2}Y_i\left(\sum_j c_j Y_j\right)g_Y^2(\mu)\ln\left(\frac{M_{GUT}}{\mu}\right)\right.$$
$$\left.+\frac{1}{4\pi^2}\left\{\gamma_i(\mu)-\frac{1}{2}\frac{d\,\gamma_i(\mu)}{d\ln\mu}\ln\left(\frac{\mu_{mir}}{\mu}\right)\right\}\ln\left(\frac{\mu_{mir}}{\mu}\right)\right] \qquad (1.1)$$

where $m_{3/2}$ is the gravitino mass and α is the ratio of the modulus-mediation to anomaly-mediation contribution to the SUSY breaking soft terms. $c_i = 1 - n_i$, Y_i is the $U(1)_Y$ hypercharge, γ_i is the anomalous dimension.

Gaugino masses are given as,

$$M_a(\mu)=\frac{m_{3/2}}{16\pi^2}\alpha\left[1-\frac{1}{8\pi^2}b_a g_a^2(\mu)\ln\left(\frac{\mu_{mir}}{\mu}\right)\right] \qquad (1.2)$$

where b_a are the gauge β function coefficients for gauge group a and g_a are the corresponding gauge couplings.

From (1.2), we can see an interesting consequence of this mixed mediation is that the gaugino masses, can be unified at a mirage messenger scale [8, 9],

$$\mu_{mir}=M_{GUT}\,e^{-8\pi^2/\alpha} \qquad (1.3)$$

The mirage mediation model also provides natural solutions to the SUSY *CP* problem since there are no physical *CP* violating phases in μ, gaugino masses and A terms. Because of the heavy gravitino mass ($m_{3/2}$ ~ 10-100 TeV) in this model, the cosmological gravitino problem [10, 11, 12] may be significantly relaxed as well.

In this thesis, I present how to construct the kinematic observables (signals) of Mirage Mediation Model at the LHC and how to analyze the signals of this model. The thesis is organized as follows. In section 2, I will introduce the parameter space of this model. Focused on the stau-neutralino coannihilation region, I will show how to choose the benchmark point and the character of my benchmark point. In section 3, five kinematic observables are constructed. In section 4, I will show how to analyze these kinematic observables, including how to measure the SUSY particle (sparticle) masses from the constructed kinematic observables and how to determine the model parameters from the the sparticle masses. Section 5 is the summary and discussion. All the figures are listed in the Appendix A, while all the tables are listed in the Appendix B.

2. PARAMETER SPACE

The parameter region of Mirage Mediation Model has been studied in [9, 13]. Take the same convention as in Ref. [9], the mirage mediation model is completely specified by six parameters:

(i) $m_{3/2}$ (the gravitino mass),

(ii) α (the ratio of the modulus-mediation to anomaly-mediation contribution to the SUSY breaking soft terms. This is also the conversion used in event generator ISAJET [14]),

(iii) tanβ (the ratio of the vacuum expectation values of the up-type and down-type Higgs, $<H_u>/<H_d>$),

(iv) sign(μ) (μ is the biliear Higgs coupling constant),

(v) n_i (modular weights of matter fields and Higgs fields),

(vi) l_a (specifying how the visible sector is constructed).

I assumed $\mu > 0$, since positive μ is favored from the muon g – 2 experiment [15]. Grand Unification implies matter particles within the same GUT multiplet have common modular weights, and that the l_a are universal. I will assume that all $l_a = 1$ and, for simplicity, a common modular weight n_m for all matter particles, but allow a different (common) modular weight n_H for the two Higgs doublets of the Minimal Supersymmetric Standard Model (MSSM).

Then five free model parameters will be left: $m_{3/2}$, α , tanβ, n_m and n_H .

I mostly used the coannihilation mechanism scenarios (where another particle was thermally available with the dark matter candidate of the model, the lightest neutralino, in the early universe) under the mirage mediation model. I found two coannihilation mechanism scenarios exist: the stau-neutralino coannihilation and the stop-neutralino coannihilation. In this thesis, I focused on the stau-neutralino coannihilation parameter space region. Using DarkSusy [16], I selected the benchmark model points that can satisfy various experimental constraints:

(a) neutralino is the LSP,

(b) the dark matter relic density Ωh^2 by WMAP [17], $0.085 < \Omega h^2 < 0.119$,

(c) the muon (g – 2), $20 \sim 40 \times 10^{-10}$

(d) the branching ratio of b to sγ, $2.3 \sim 3.5 \times 10^{-4}$

(e) other constraints, like stau1 mass $m_{\tilde{\tau}_1} > 95$ GeV, gravitino mass $m_{3/2} = 10 \sim 20$ TeV etc.

The benchmark model point I found in the stau-neutralino coannihilation parameter space region is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1.

Table 1 shows the sparticle mass spectrum of my benchmark point calculated by ISAJET 7.80. The mass difference between $\tilde{\tau}_1$ and $\tilde{\chi}_1^0$ is about 26 GeV. This conforms that we are in the stau-neutralino coannihilation region.

For this benchmark point, $\tilde{\chi}_1^0$ is the LSP and almost bino. The 1st and 2nd generation squarks ($\tilde{u}_L$, $\tilde{d}_L$, $\tilde{s}_L$, $\tilde{c}_L$) can decay to $\tilde{\chi}_2^0$ with a large decay ratio. The $\tilde{\chi}_2^0 \dashrightarrow \tilde{\tau}_1^{\pm} + \tau^{\mp}$ is dominant, and the branching ratio for $\tilde{\chi}_2^0 \dashrightarrow \tilde{l} + l$ is very small. The decay ratio for $\tilde{\tau}_1^{\pm} \; --> \; \tilde{\chi}_1^0 + \tau^{\pm}$ is 100%. These characters lead one interesting decay chain:

$$\tilde{q}_L \; --> \; \tilde{\chi}_2^0 + q \; --> \; \tilde{\tau}_1^{\pm} + \tau^{\mp} + q \; --> \; \tilde{\chi}_1^0 + \tau^{\pm} + \tau^{\mp} + q \qquad (2.1)\ .$$

3. KINEMATIC OBSERVABLES AT THE LHC

I combined the jets (j's), taus (τ's) with large transverse missing energy E_T to construct the kinematic observables. Events were generated using PYTHIA [18], which is linked with ISAJET to generated the sparticle mass spectrum. These events were passed to a detector simulator called PGS4 [19].

Consider the decay chain (2.1), the first signal I analyzed is the 2jets + 2taus + E_T sample.

The following cuts were set to subtract the SM backgrounds and pick up our SUSY events: (a) Apply the tau efficiency of the detector. Each tau with visible $P_T \geq 20$ GeV and $|\eta| \leq 2.5$ has 50% probability to be recognized as a tau, where η is the pseudorapidity. Each tau with visible $P_T \geq 30$ GeV and $|\eta| \leq 2.5$ has 50% probability to be mistakenly recognized as a jet.

(b) Apply the jet efficiency of the detector. Each b jet will be definitely recognized as a jet. Each regular jet with visible $P_T \geq 30$ GeV and $|\eta| \leq 2.5$ has 99% probability to be recognized as a jet. Each regular jet with visible $P_T \geq 20$ GeV and $|\eta| \leq 2.5$ has 1% probability to be mistakenly recognized as a tau.

(c) Total Missing energy $E_T \geq 180$ GeV.

(d) At least two leading jets, jet1 and jet2, each with transverse momentum $P_T \geq 200$ GeV as well as $|\eta| \leq 2.5$.

(e) We require both jet1 and jet2 are regular jets (not b jets), discard the event when either of them is tagged as a b jet. (This will remove the background from SUSY events containing the 3rd generation squarks, sbotom and stop.)

(f) $P_T^{jet1} + P_T^{jet2} + E_T \geqslant 600\, GeV$, here jet1 and jet2 are the first two leading regular jets.

(g) discard the event when number of electrons and muons is not zero. (We prefer the hadronically decaying jets and taus.)

(h) After the previous cuts, at least two taus exist.

Four kinematic observables ($M_{\tau\tau}^{end}$, $M_{j\tau}^{end}$, $M_{j\tau\tau}^{end}$, PT_{τ}^{slope}) at the LHC were constructed from the 2jets + 2taus + ET sample:

3.1 $M_{\tau\tau}^{end}$

The visible Tau+Tau invariant mass $M_{\tau\tau}$ is formed by combine the two tau particles.

$$M_{\tau\tau} = \sqrt{(E_{\tau_1} + E_{\tau_2})^2 - (\vec{p}_{\tau_1} + \vec{p}_{\tau_1})^2} \qquad (3.1)$$

Consider the decay chain (2.1), the end point (maximal value) of the visible Tau+Tau invariant mass distribution $M_{\tau\tau}^{END}$ can be calculated as a function

$$M_{\tau\tau}^{END} = M_{\tau\tau}^{max} = m_{\tilde{\chi}_2^0} \sqrt{(1 - \frac{m_{\tilde{\tau}_1}^2}{m_{\tilde{\chi}_2^0}^2})(1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{\tau}_1}^2})} \qquad (3.2)$$

Using the program ROOT, I created the kinematic observable histogram figures from the analyzed data. Figure 1 shows the histogram graph I gained for $M_{\tau\tau}$

distribution. The luminosity is at 600 fb^{-1}. In order to identify the ditau pairs from the decay chain,

$$\tilde{\chi}_2^0 \; --> \; \tilde{\tau}_1^{\pm} + \tau^{\mp} \; --> \; \tilde{\chi}_1^0 + \tau^{\pm} + \tau^{\mp} \qquad (3.3)$$

I categorize all pairs of taus into opposite-sigh (OS) and like-sigh (LS) combinations, and then use the OS minus LS (OS-LS) distribution to effectively reduce the Standard Model (SM) events background as well as the combinatorial SUSY backgrounds.

In the LHC experiment, the endpoint of each observable can be gained by directly analyzing the corresponding signal.

3.2 $M_{j\tau}^{end}$

The Jet+Tau invariant mass $M_{j\tau}$ is formed by combine the first two leading jets and the visible tau with higher P_T.

$$M_{j\tau} = \sqrt{(E_j + E_\tau)^2 - (\vec{p}_j + \vec{p}_\tau)^2} \qquad (3.4)$$

Consider the decay chain (2.1), the end point (maximal value) of the visible Jet+Tau invariant mass distribution $M_{j\tau}^{END}$ can be calculated as a function

$$M_{j\tau}^{END} = M_{j\tau}^{max} = m_{\tilde{q}_L} \sqrt{\left(1 - \frac{m_{\tilde{\chi}_2^0}^2}{m_{\tilde{q}_L}^2}\right)\left(1 - \frac{m_{\tilde{\tau}_1}^2}{m_{\tilde{\chi}_2^0}^2}\right)} \qquad (3.5)$$

Figure 2 shows the histogram graph I gained for $M_{j\tau}$ distribution. The luminosity is at 600 fb^{-1}. I still use the (OS-LS) technique distribution to identify the tau from the decay chain (2.1). When I combine the jets with the tau, I use a very new technique called, bi-event subtraction technique (BEST) developed at TAMU to remove the SUSY backgrounds.

3.3 $M_{j\tau\tau}^{end}$

The Jet+Tau+Tau invariant mass $M_{j\tau\tau}$ is formed by combining the first two leading jets and the ditau pairs.

$$M_{j\tau\tau}=\sqrt{(E_j+E_{\tau 1}+E_{\tau 2})^2-(\vec{p}_j+\vec{p}_{\tau 1}++\vec{p}_{\tau 2})^2} \qquad (3.6)$$

Consider the decay chain (2.1), the end point (maximal value) of the visible Jet + Tau+Tau invariant mass distribution $M_{j\tau\tau}^{END}$ can be calculated as a function

$$M_{j\tau\tau}^{END}=M_{j\tau\tau}^{max}=m_{\tilde{q}_L}\sqrt{(1-\frac{m_{\tilde{\chi}_2^0}^2}{m_{\tilde{q}_L}^2})(1-\frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{\chi}_2^0}^2})} \qquad (3.7)$$

Figure 3 shows the histogram graph I gained for $M_{j\tau\tau}$ distribution. The luminosity is at 600 fb^{-1}. I still use the (OS-LS) technique distribution to identify the ditau pairs from the decay chain (2.1). When I combine the jets with the ditau pairs, I still use the BEST technique to remove the SUSY backgrounds.

3.4 PT_{τ}^{slope}

The visible transverse momentum P_T of the tau from stau1 PT_{τ} is formed by considering the P_T of the lower energy tau in the ditau pair.

$$PT_{\tau}=\sqrt{P_{\tau x}^2+P_{\tau y}^2}\sim e^{\Delta(m_{\tilde{\tau}_1},m_{\tilde{\chi}_1^0})} \qquad (3.8)$$

After take the logarithm of PT_τ, the slope of the distribution could be a function of $m_{\tilde{\tau}_1}$ and $m_{\tilde{\chi}_1^0}$

$$\log(PT_\tau^{slope}) = function(m_{\tilde{\tau}_1}, m_{\tilde{\chi}_1^0}) \qquad (3.9)$$

Figure 4 shows the histogram graph I gained for PT_τ^{slope}. The luminosity is at 600 fb^{-1}. I still use the (OS-LS) technique to identify the lower P_T tau from the ditau pair.

3.5 M_{eff}^{peak}

The effective mass M_{eff} is constructed from the 4jets + E_T sample.

The cuts I used are:

(a) Apply the tau efficiency of the detector. Each tau with visible $P_T \geq 20$ GeV and $|\eta| \leq 2.5$ has 50% probability to be recognized as a tau. Each tau with visible $P_T \geq 30$ GeV and $|\eta| \leq 2.5$ has 50% probability to be mistakenly recognized as a jet.

(b) Apply the jet efficiency of the detector. Each b jet will be definitely recognized as a jet. Each regular jet with visible $P_T \geq 30$ GeV and $|\eta| \leq 2.5$ has 99% probability to be recognized as a jet. Each regular jet with visible $P_T \geq 20$ GeV and $|\eta| \leq 2.5$ has 1% probability to be mistakenly recognized as a tau.

(c) Total Missing energy $E_T \geq 180$ GeV.

(d) At least four jets, jet1, jet2, jet3 and jet4. The first two leading jets, jet1 and jet2, each with transverse momentum $P_T \geq 200$ GeV as well as $|\eta| \leq 2.5$.

(e) I require all the first four leading jets are regular jets (not b jets), discard the event when either of them is tagged as a b jet. (This will remove the background from SUSY events containing the 3rd generation squarks, sbotom and stop.)

(f) $P_T^{jet1} + P_T^{jet2} + E_T \geqslant 600\, GeV$, here jet1 and jet2 are the first two leading regular jets.

(g) discard the event when number of electrons and muons is not zero. (We prefer the hadronically decaying jets and taus.)

(h) We also set the sphericity cut. The sphericity of all the jets is greater than or equal to 0.2 .

The M_{eff} distribution is formed by combining the P_T of the first four leading jets and the missing energy.

$$M_{eff} = P_T^{jet1} + P_T^{jet2} + P_T^{jet3} + P_T^{jet4} + E_T \qquad (3.10)$$

Usually, the peak value of the effective mass M_{eff}^{peak} shows the SUSY mass scale and is a function of $m_{\tilde{g}}$, $m_{\tilde{q}_L}$ and $m_{\tilde{\chi}_1^0}$, but my analysis shows M_{eff}^{peak} is not sensitive to the neutralino1 mass $m_{\tilde{\chi}_1^0}$.

Therefore,

$$M_{eff}^{peak} = function(m_{\tilde{g}}, m_{\tilde{q}_L}) \qquad (3.11)$$

Figure 5 shows the histogram graph I gained for M_{eff} distribution for my benchmark point. The luminosity is at 600 fb^{-1}.

4. ANALYSIS OF KINEMATIC OBSERVABLES

4.1 Determining the Sparticle's Masses

As we can see from (3.2), (3.5), (3.7), (3.9) and (3.11), the kinematic observables I constructed are dependent on the masses of sparticles ($m_{\tilde{g}}$, $m_{\tilde{q}_L}$, $m_{\tilde{\chi}_2^0}$, $m_{\tilde{\tau}_1}$ and $m_{\tilde{\chi}_1^0}$). By fixing other four masses and varying just one individual sparticle mass I constructed the corresponding kinematic observable. In this way, I found the functional relationships between the observables and sparticle masses.

By coupling the five equations and inverting the functional relationships, I determined these sparticle masses. Since equations are polynomial equation of high order, more than one set of real mass solution may exist. Table 2 shows two sets of solutions I gained from my data.

4.2 Determining the Model Parameters

I followed the same idea as section 4.1 to determine the Mirage Mediation Model parameters from the sparticles' masses I have found. The sparticle masses are sensitive to the model parameters. By fixing other four parameters and just vary one individual parameter, I can generate the corresponding sparticles' masses. In this way, I can found the functional relationships between sparticles' masses and model parameters. I can still inverting the functional relations to solve for the model parameters.

Gluino and neutralino1 (almost bino), as the gaugino, their masses are most sensitive to model parameters parameters α and $m_{3/2}$. Thus, I solved α and $m_{3/2}$ from

$m_{\tilde{g}}$ and $m_{\tilde{\chi}_1^0}$. Squark mass is sensitive to α , $m_{3/2}$ and n_m. Neutralino2 mass is sensitive to α , $m_{3/2}$, n_m and n_H. Stau1 mass is sensitive to all the model parameters, α , $m_{3/2}$, n_m, n_H and $\tan\beta$. Therefore, n_m , n_H and $\tan\beta$ is determined from $m_{\tilde{q}_L}$, $m_{\tilde{\chi}_2^0}$ and $m_{\tilde{\tau}_1}$, respectively.

Table 3 shows the corresponding model parameters I gained for the mass solution (b).

For mass solution (a), I cannot find the corresponding model parameters. This is because the Mirage Mediation Model cannot allow this mass spectrum. Solution (a) is a invalid solution.

5. SUMMARY AND DISCUSSION

I investigated the stau-neutralino coannihilation region of the Mirage Mediation Model at LHC. Starting from the benchmark point, five kinematic observables are constructed. I analyzed these kinematic observables and extracted the mirage mediation model information. The sparticles masses were determined from these observables. Then the model parameters were determined from the sparticle masses. In the LHC experiment, the end point or peak of each observable can be gained by directly analyzing the corresponding signal.

The gaugino (bino, wino and gluino) mass ratios are different in the Mirage Mediation Model compared to the SUGRA models . That is one remarkable difference of this model. I am finding that this important feature can be understood from the results at the LHC. The work so far is showing that how mirage mediation model parameters can be determined accurately from the measurements at the LHC.

The error of tanβ I found is a little big. This is because the error of squark mass is big, which leads to the change in n_m. The stau1 mass becomes too small due to this change in n_m. Checking the observable Meff(b) can bring in the 3rd generation squarks. This may help to determine a better tanβ. The dark matter relic density in this model can be determined from the model parameters.

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APPENDIX A

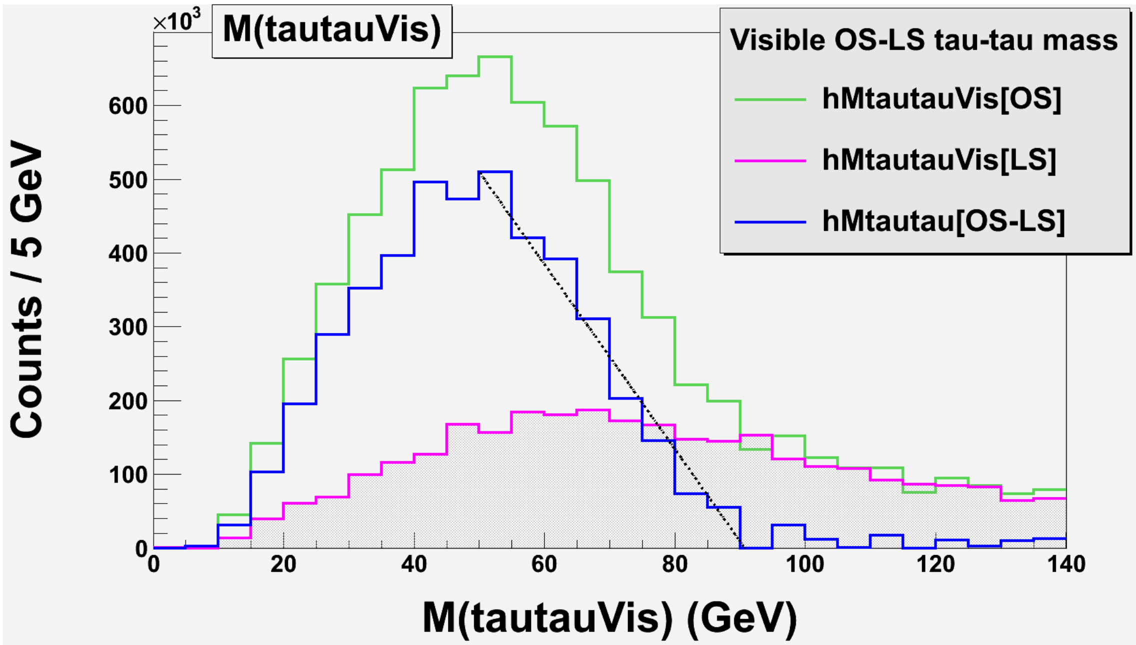

Figure 1: The visible Tau+Tau invariant mass $M_{\tau\tau}$ distribution of benchmark point. This observable is reconstructed using the OS-LS technique under the luminosity 600 fb^{-1}. The red line filled with gray color is subtracted as background. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

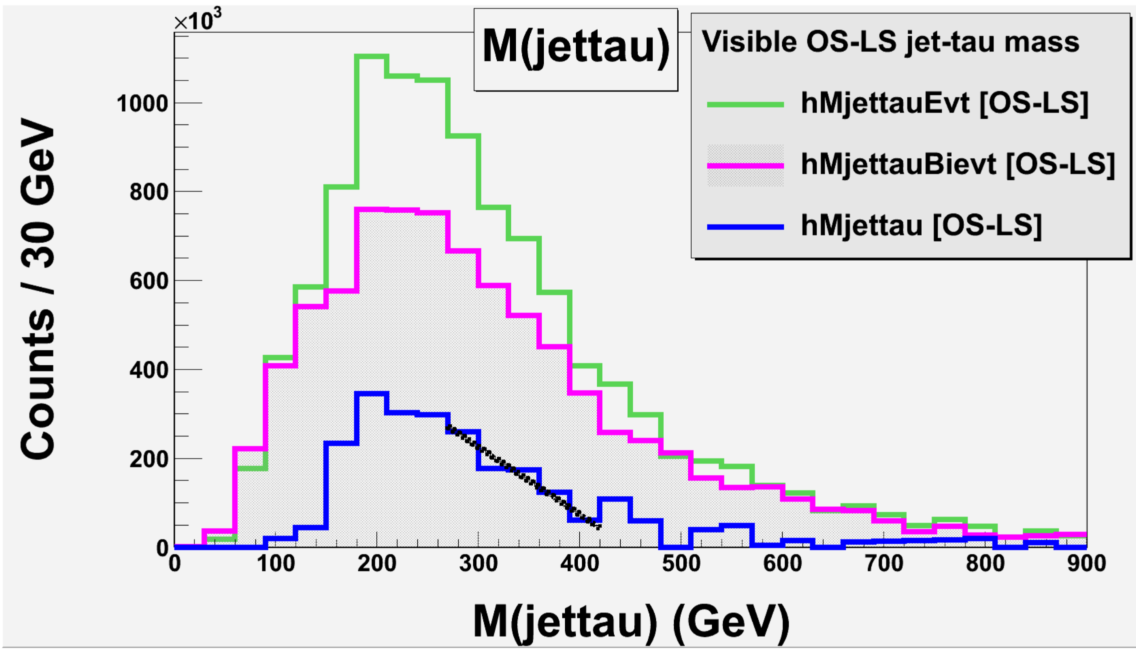

Figure 2: The visible Jet+Tau invariant mass $M_{j\tau}$ distribution of benchmark point. The background from picking up taus is subtracted using the OS-LS technique. The background from combining the correct jets is subtracted using the BEST technique. The red line filled with gray color is the bi-event histogram and acted as final background. The luminosity is 600 fb^{-1}. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

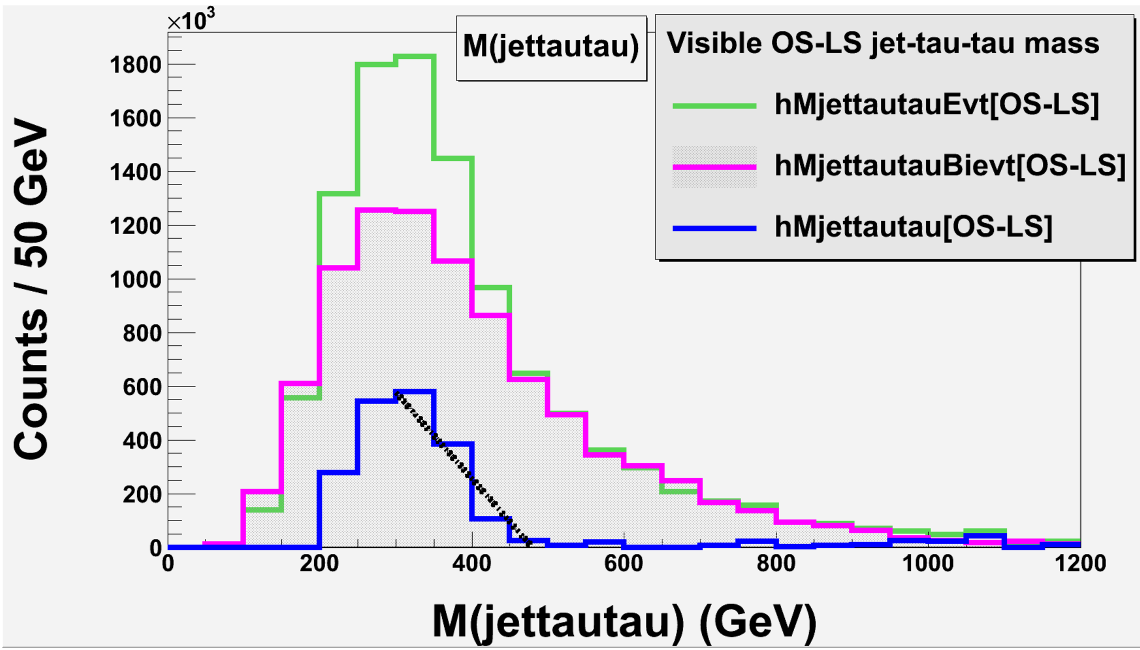

Figure 3: The visible Jet+Tau+Tau invariant mass $M_{j\tau\tau}$ distribution of benchmark point. The background from picking up tau pairs is subtracted using the OS-LS technique. The background from combining the correct jets is subtracted using the BEST technique. The red line filled with gray color is the bi-event histogram and acted as final background. The luminosity is 600 fb^{-1}. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

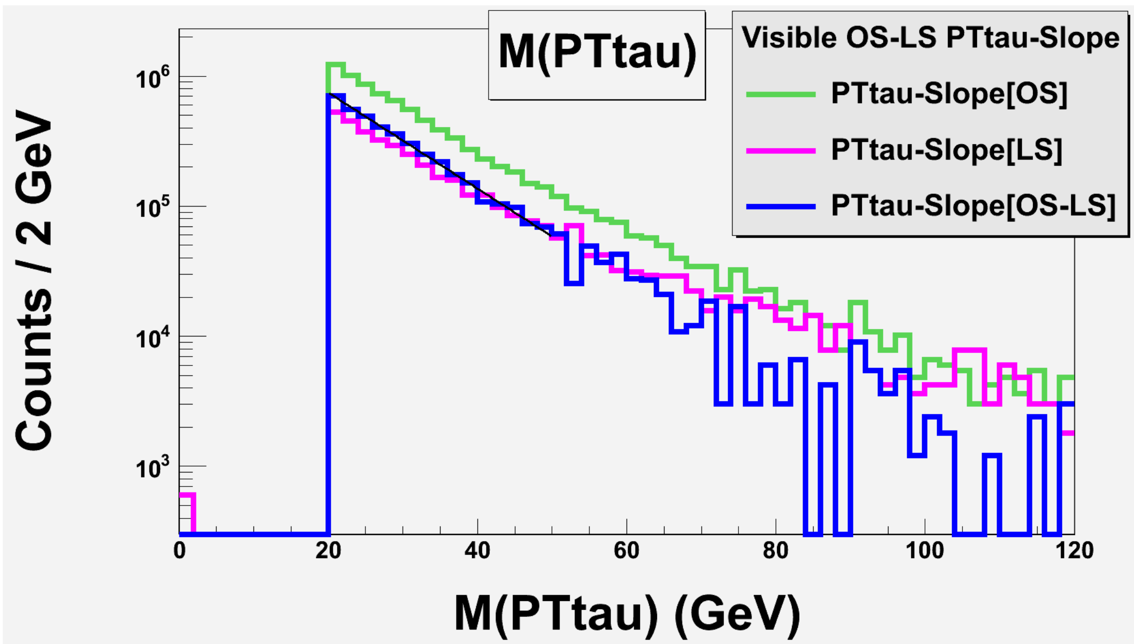

Figure 4: The slope of the visible transverse momentum of the lower energy tau PT_{τ}^{slope} distribution of benchmark point. The vertical axis is the number of counts after taking the logarithm. The background from picking up taus is subtracted using the OS-LS technique. The red line is the background. The luminosity is 600 fb^{-1}. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

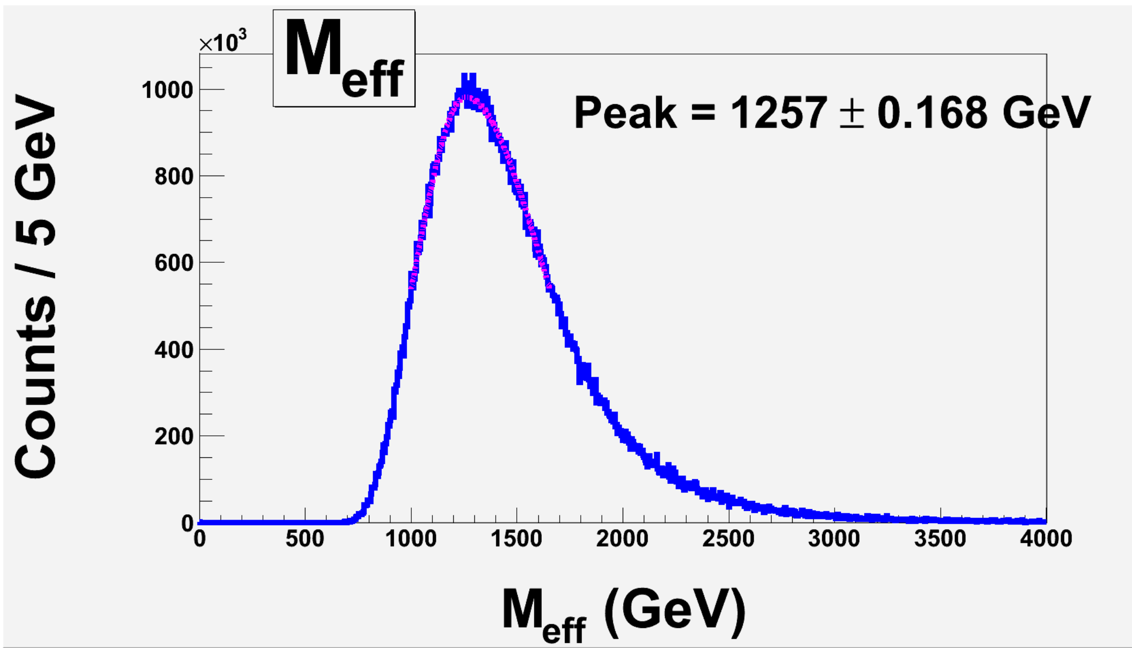

Figure 5: The effective mass M_{eff} distribution of benchmark point.

The luminosity is 600 fb^{-1}. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

APPENDIX B

Table 1: Mass spectrum of the benchmark point. Unit is GeV. The stau-neutralino coannihilation region benchmark point of Mirage Mediation Model used here is $m_{3/2}$=10TeV, α=7.5, tanβ=30, n_m=0.5, n_H=1 and sign(μ)>0, l_a=1.

$\tilde{g}$	$\tilde{u}_L$	$\tilde{b}_2$	$\tilde{t}_2$	$\tilde{e}_L$	$\tilde{\tau}_2$	$\tilde{\chi}_2^0$
	$\tilde{u}_R$	$\tilde{b}_1$	$\tilde{t}_1$	$\tilde{e}_R$	$\tilde{\tau}_1$	$\tilde{\chi}_1^0$
898	841	791	810	427	426	389
	815	736	600	368	310	284

Table 2: Two sets of mass solutions determined from kinematic observables. Unit is GeV.

	$m_{\tilde{g}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_2^0}$	$m_{\tilde{\tau}_1}$	$m_{\tilde{\chi}_1^0}$
Solution (a)	960.222 ± 0.838	754.814 ± 0.638	403.590 ± 0.570	289.585 ± 0.072	245.768 ± 0.291
Solution (b)	900.143 ± 1.747	827.144 ± 2.060	385.746 ± 0.526	301.321 ± 0.561	272.330 ± 0.642

Table 3: The corresponding model parameters for mass solution (b).

$m_{3/2}$	α	n_m	n_H	tanβ
9034 ± 70 GeV	8.178 ± 0.063	0.653 ± 0.025	2.878 ± 0.248	$16.44 -5.13, +2.42$

VITA

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