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# Search for supersymmetry in top final states at CMS

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**Abstract**
A search for SUSY using the top quark plus missing transverse energy (MET), in a low mass mSUGRA test point is performed. A two–constraints kinematic fit is utilized to extract the top quark, either b-jet the ones that is recognizable or it is not recognizable. It is shown that for point LM1, for the former situation, a $5\sigma$ excess can be achieved with 30 $pb^{-1}$; and for the latter situation, it can be observed with $9.6\,pb^{-1}$. The ratio of the final signal over background for both situations is 12.0.

**Keywords:** supersymmetry, top quark, CMS

## 1. Introduction

Supersymmetric scenarios [1] provide a very promising extension for the standard model (SM), solving the quadratic divergences and hierarchy problem. Supersymmetry imposes a new symmetry between the fermionic and bosonic degrees of freedom. In this analysis we focus on mSUGRA, where gravity is responsible for soft supersymmetry breaking. A top quark can be generated inclusively from the decay of heavy squarks or gluinos accompanied by a neutralino. This neutralino can be either the lightest supersymmetric particle (LSP) or a heavier neutralino that decays inclusively in a LSP (assuming R-parity conservation) that is a stable particle and appears as a missing transverse energy (MET). Hence in final state there is at least a top quark plus a large MET. The approach to use this feature is to look for an excess in the number of the extracted top quarks in the tail of the MET distribution from the $t\bar{t}$ events. The analysis is optimized to have a pure sample as the signal.

To illustrate the SUSY discovery with this signature, the conditions of the Compact Muon Solenoid (CMS) [2][3] detector at LHC [2] is used. The CMS experiment which is going to take data before the end of 2009 is a multipurpose detector. Electrons, photons, muons and jets can be reconstructed with a very good precision. Its high magnetic field enables CMS to reconstruct the charged tracks very precisely. The tracks can be used to tag the jets from the b-quarks (b-tagging) by looking for the highly displaced vertices inside the jets. The designed center of mass energy of LHC is 14 TeV.

In a previous study [4] which uses the top quark as the SUSY signature, a perfect detector was assumed. In the present study, we try to optimize the analysis for the early data where still a complete knowledge about the detector and its systematic uncertainties is not available. The official CMS software (CMSSW) [5] is used for this analysis which is different with the framework of the previous analysis.

The structure of this note is as follows: section 2 is devoted to a kinematic fit and top extraction. The samples that are used in this analysis are described in section 3. Section 4 is devoted to results of the fit. In section 5, the production and decay of the related sparticles is reviewed. Section 6 describes the analysis selection path and cut optimization. The final results of the full simulation are reported in section 7. Section 8 concludes the note.

## 2. 2C Kinematic fit for top quark extraction

Extracting the top quark in a multi-jet environment requires eliminating the huge combinatorial background which can easily hide the signal. In order to select the real combination of the jets originated from a top quark decay, we utilize a kinematic fit with constraints.

As the purpose of the study is not to measure the mass of the top quark, this mass is used as a constraint; so in a hadronic decay of a top quark, the two main constraints are:

**W mass:** The invariant mass of two non b-tagged jets must be equal to the known mass of the W boson.

**Top mass:** The invariant mass of these two jets and a b-tagged jet must be equal to the mass of the top quark.

**2. 1. The mathematical description of the kinematic fit**

The jets are assumed to be massless and the uncertainty on their directions to have a negligible effect on the fit. Assigning mass to b-jet (~5 GeV/$c^2$) has a minor effect corresponding to our investigation. The negligible effect of the direction error was shown in reference [6]. Therefore, smearing and detector effects can affect only the energy of the jets and in the fit only the energy of the jets is varied.

If $E_i$ is the true energy of the i-th jet and $E_i^m$ is its measured energy with uncertainty $\sigma_i$, the $\chi^2$ for every combination of three jets can be written as:

$$\chi^2 = \sum_{i=1}^{3} \frac{\left(E_i - E_i^m\right)^2}{\sigma_i^2}, \quad (1)$$

where the sum is over the jets and the third jet is a b-jet. This $\chi^2$ must be minimized when the following two constraints are also satisfied.

$$\begin{aligned} &m_W^2 - (p_1 + p_2)^2 = 0, \\ &m_{Top}^2 - (p_1 + p_2 + p_3)^2 = 0, \end{aligned} \quad (2)$$

$p_i$ stands for the true 4-vector of the i-th jet. To take into account the width of the W and top quark, the masses in eq. (2) are free to change, but the $\chi^2$ eq. (1) is modified to control this change. The new form of eq. (1) is chosen to be:

$$\chi^2 = \sum_{i=1}^{3} \frac{\left(E_i - E_i^m\right)^2}{\sigma_i^2} + \frac{\left(m_W - M_W\right)^2}{\left(\Gamma_W/2\right)^2} + \frac{\left(m_{Top} - M_{Top}\right)^2}{\left(\Gamma_{Top}/2\right)^2}, \quad (3)$$

$M$ and $\Gamma$ stand for the known masses and full widths of W and top quark. One can write the last two equations in a matrix form:

$$\chi^2 = c^T G c,$$

$$F = \begin{pmatrix} \frac{1}{2}\left(M_W^2 - (p_1 + p_2)^2\right) \\ \frac{1}{2}\left(M_{Top}^2 - (p_1 + p_2 + p_3)^2\right) \end{pmatrix} = 0, \quad (4)$$

where $c$ and $G$ are defined as:

$$c = \begin{pmatrix} E_1 - E_1^m \\ E_2 - E_2^m \\ E_3 - E_3^m \\ m_W - M_W \\ m_{Top} - M_{Top} \end{pmatrix},$$

$$C = G^{-1} = \begin{pmatrix} \sigma_1^2 & 0 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 & 0 \\ 0 & 0 & 0 & \left(\Gamma_W/2\right)^2 & 0 \\ 0 & 0 & 0 & 0 & \left(\Gamma_{Top}/2\right)^2 \end{pmatrix} \quad (5)$$

$C$ is the covariant matrix. Since the $E_i^m$ are independent measurement s, $G$ is diagonal. The constraints in eq. (4) are halved to make the implementation easier.

Now the problem is to minimize the $\chi^2$ in eq. (4) and simultaneously keep F very small. A general method to solve such problems is to introduce the Lagrange multipliers and mini-mize a new function:

$$L = \chi^2 + 2\lambda_k F_k = c^T G c + 2\lambda_k F_k, \quad (6)$$

with respect to the variables $c$ and $\lambda$. The minimization is equivalent to the roots of the system of the equation:

$$\begin{aligned} &\frac{\partial L}{\partial E_i} = 2Gc + 2\lambda_k \left(\frac{\partial F_k}{\partial E_i}\right) = 0, \\ &\frac{\partial L}{\partial \lambda_k} = 2F_k = 0. \end{aligned} \quad (7)$$

If the constraints are linear, the solution is obtained in a single step. But in our case the constraints are not linear and one should iterate over the solutions until a convergence is obtained [7]. After linearization of the problem, the solution is computed iteratively by the inversion of a matrix. This inversion is simplified by using the matrix that contains blocks of zero which can be reduced to operations on smaller matrices, this method called "Partitioned Matrix Method". Details of the mathematical framework of a more generic procedure can be found in reference [7].

The only remaining parameter for this fit is the number of degrees of freedom, *ndf*. This can be written as the difference between the number of constraints and number of unmeasured parameters. In this problem, there is no unmeasured parameter, so the number of degrees of freedom is simply equal to the number of constraints which is 2.

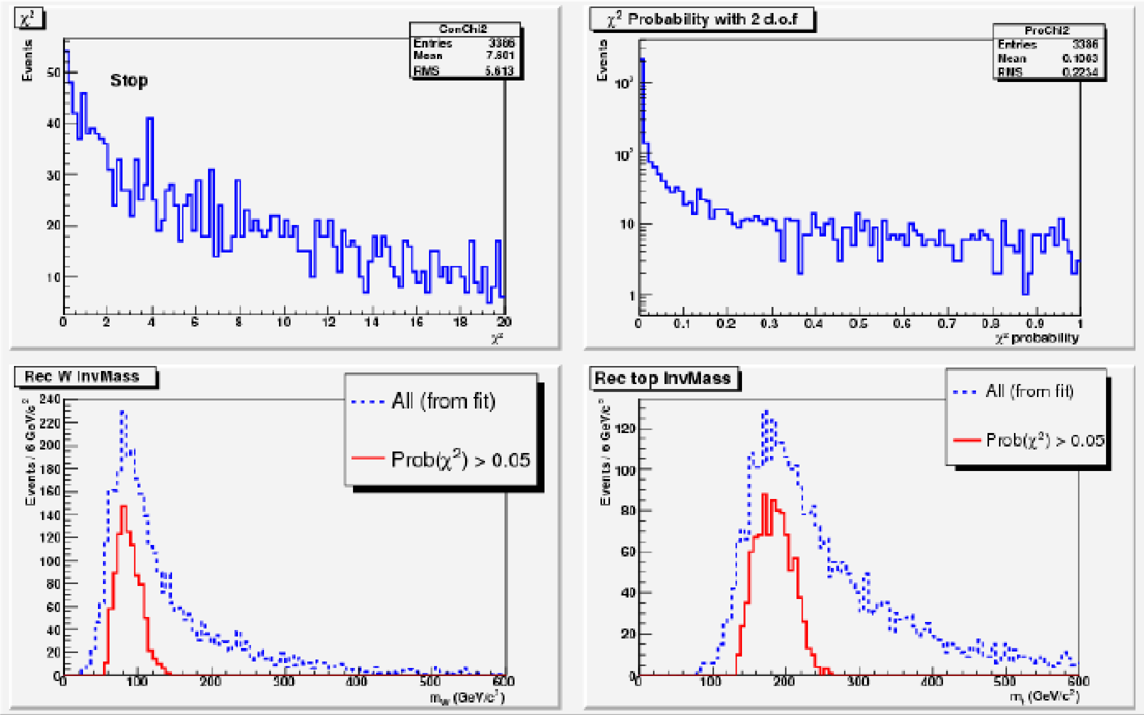


**Figure 1.** The distribution of the least $\chi^2$ solution in every event (top-left) and distribution of its probability (top-right). The dijet and bjj invariant masses for the least $\chi^2$ are shown in the second row.

## 3. The data samples and object selection

The main sample (referred as LM1-stop sample) used to study the kinematic fit in section 4 was produced for the scalar top quark search in point CMS-LM1 (mSUGRA scenario, $m_0 = 60\text{GeV}/c^2$, $m_{1/2} = 250\text{GeV}/c^2$, $A_0 = 0.0$, $\tan(\beta) = 10$ and $\mu > 0$). Every event is required to have at least one scalar top quark that decays as follows:

$$\tilde{t}_1 \to t + \chi_2^0 \to t + \tilde{l}_R + l \to t + l + l + \chi_1^0 , \qquad (8)$$

the $\tilde{t}_1$ is produced inclusively. The sample that contains 6629 events was generated and reconstructed using CMSSW-1-6-12 [5], that is called CSA07 [8] at CMS. The detailed simulation of the detector effects were considered in the data production [8]. All of the background samples are from the same official production (CSA07 [8]). Jets within $|\eta| \le 2.5$ are used throughout this analysis. They are corrected using photon-jet balancing [2]. Corrected jets are required to have $E_T \ge 30\text{GeV}$ . Jets are b-tagged by looking for a displaced vertex inside the jet [2].

## 4. Results for top extraction

The analysis is performed for two different situations: when b-tagged jets are recognizable and when they are not recognizable. In each different combinations are fitted and the minimum $\chi^2$ for every combination is found. Each combination contains two non b-tagged jets and one b-tagged jet. When the fit converges, the combination with the least $\chi^2$ is selected as the right combination.

### 4. 1. b-tagged jets are recognizable

Figure 1 shows different distributions for these selected combinations. The $\chi^2$ probability distribution in figure 1 (top-right), has a peak in the low probability region. These events have a large $\chi^2$ either because the tested hypothesis is wrong or because the uncertainty on the jet resolution used in the fit is not correctly estimated. To remove the effect of these 'low probability' events, a cut on the $\chi^2$ probability is introduced and combinations with a $\chi^2$ probability less than 0.05 ( $\chi^2$ > 6) are rejected. The W and the top quark invariant mass distribution after applying the cut are shown in figure 1 (bottom) with thick (red) lines. This cut mostly removes combinations in the tails of the mass distribution of the W and the top.

In about 10% of events more than one top can be extracted. The fit results with applying cut (thick-red) and without applying cut (narrow blue) are compared. The fit gives a narrower distribution with controllable tails. We have considered first top quark as the best top quark because it has dedicated the least $\chi^2$ to itself.

Table 1 shows results of the top extraction. 'RecTop' stands for the number of events for which the fit converges for at least one jet combination. 'Matched'

**Table 1.** The results for top extraction.

| Algorithm | Rec Top | Matched | Purity | Eff | Res $E_W$ Imp | Res $E_{Top}$ Imp |
|---|---|---|---|---|---|---|
| Partition Matrix | 3386 | 1166 | 34% | 25% | - | - |
| Part Mat ( $\chi^2 < 6$ ) | 935 | 362 | 38% | 8% | 3% | 24% |

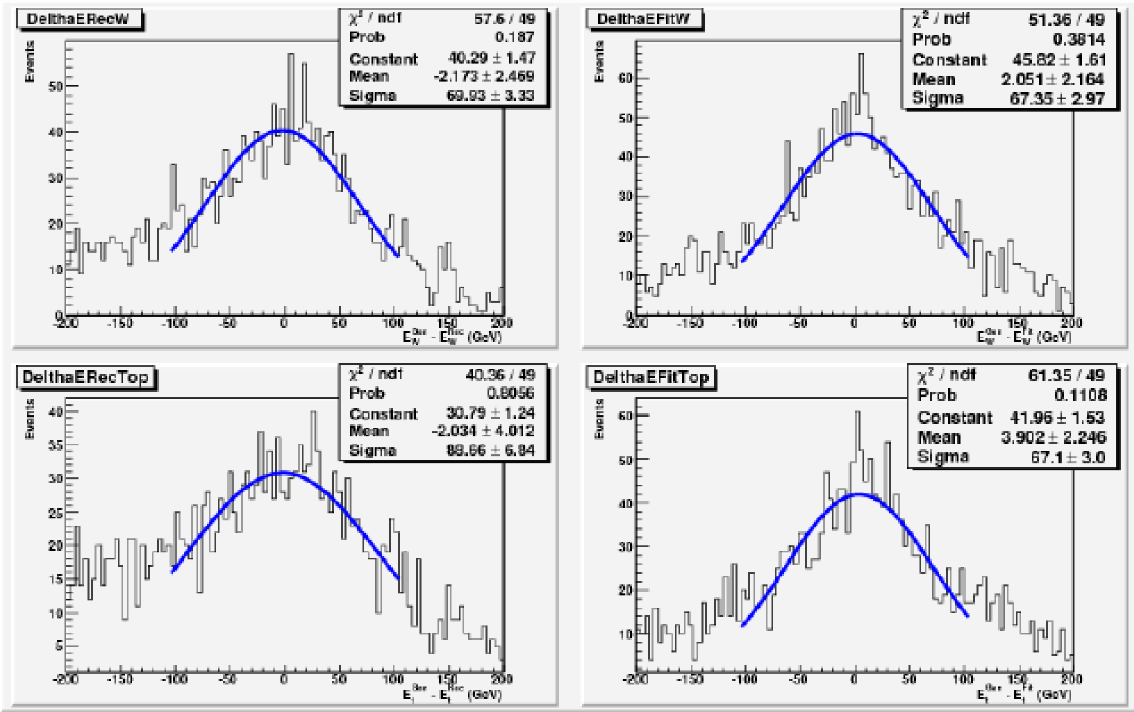


**Figure 2.** The difference between the energy of the reconstructed/fitted W (top) and the generated W (top). Fitted jet combinations pass the probability cut. The central parts of the distributions (-105,105) are fitted with a Gaussian function (thick-blue lines) to emphasize and quantify the improvement in the resolution. The fit improves the resolution of the energy of the W and top quark by 3% and 24%, respectively.

refers to the number of the extracted top quarks that are closer than $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} \le 1$ to a generated top quark decaying hadronically and all of its partons pass the kinematic cuts of the jets ( $E_T \ge 30\text{GeV}$ and $|\eta| \le 2.5$ ). The number of generated top quarks in our sample is 4508.

Since we select one top quark per event, to find the efficiency (shown in table as 'Eff') the 'Matched' number is divided by 4508. The 'purity' is defined as the percentage of the 'RecTop' which are 'Matched'.

### 4. 2. Impact of the fit on the kinematics of the reconstructed top

The combination of jets with least $\chi^2$ is selected as the correct hypothesis provided its $\chi^2$ probability is greater than 0.05. To compare its features with a generated top quark, it is "matched" as defined in previous section. Figure 2 shows the result of the comparison between the energy resolution before and after the fit for both the top quark and W boson. It is clear that, the fit has improved the energy resolution of both reconstructed objects. Table 1 summarizes this comparison. 'Imp $E_x$ Res' is the difference between the sigma of the Gaussian fit to the central part of the distribution (-105,105 GeV) before and after using the fit divided by the former value.

### 4. 3. The b-tagged jet is not recognizable

We have repeated the last analysis when we cannot recognize b-tagged jets. To tag a jet as a b-jet, it is necessary to reconstruct the charged tracks precisely. With early data when there is not sufficient data to check the alignment of the tracker system, it is not possible to trust the tracks. Also b-tagging has some inefficiency and fake rate. We try to see if the constrained kinematic fit can recover these errors. Again in about 10% of events more than one top can be extracted. Figure 3 shows the results of this analysis.

Figure 4 shows the result of the comparison between the energy resolution before and after the fit for both the top quark and W boson when the b-tagged jet is not recognizable.

Comparing table 2 and table 1 shows that without b-tagging, both purity and efficiency can get improved, although the improvement in top energy measurement is not a lot.

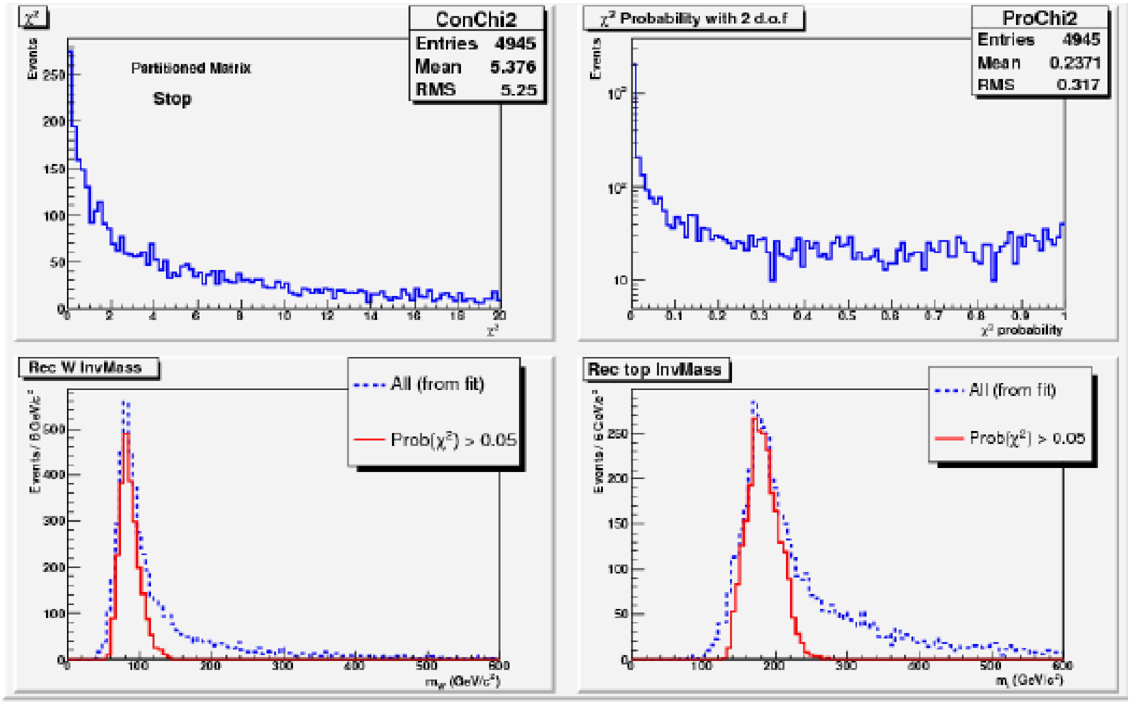


**Figure 3.** The distribution of the least $\chi^2$ solution in every event (top-left) and distribution of its probability (top-right), when we cannot recognize b-tagged jets. The dijet and bjj invariant masses for the least $\chi^2$ are shown in the second row. The fit results with (thick-red) and without (narrow blue) are compared. The fit gives a narrower distribution with controllable tails.

**Table 2.** The results for top extraction.

| Algorithm | Rec Top | Matched | Purity | Eff | Imp $E_W$ Res | Imp $E_{Top}$ Res |
|---|---|---|---|---|---|---|
| Partition Matrix | 4945 | 1846 | 37% | 40% | - | - |
| Part Mat ( $\chi^2 < 6$ ) | 2425 | 1094 | 45% | 24% | 11% | 4% |

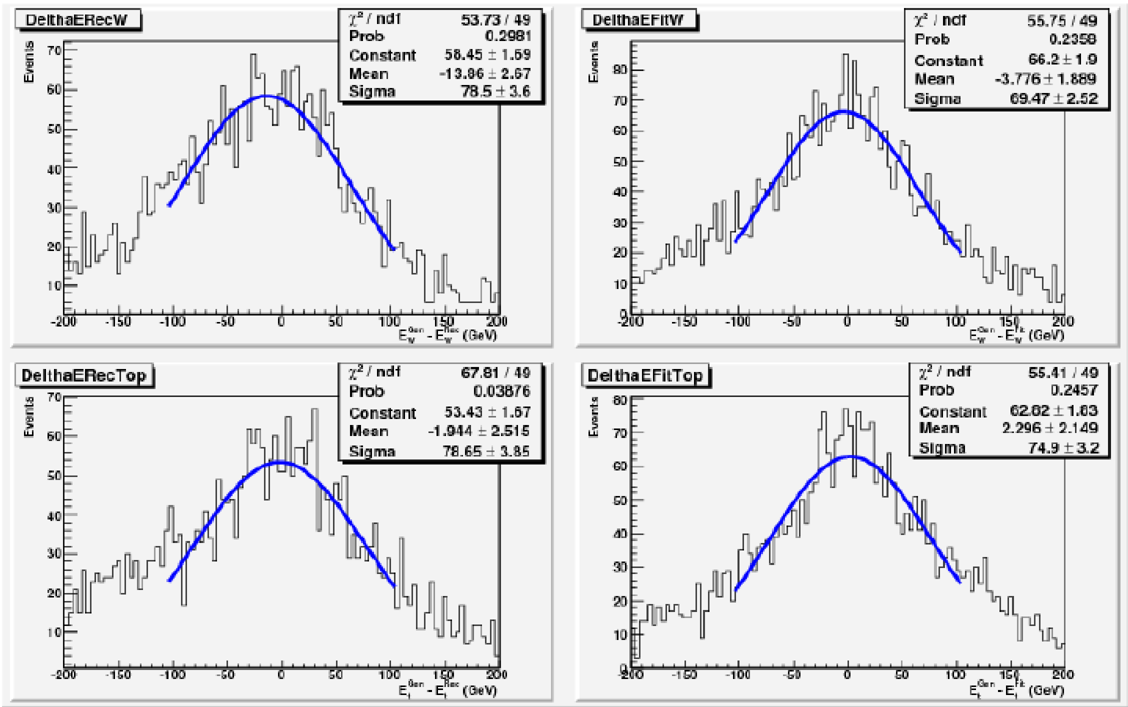


**Figure 4.** The difference between the energy of the reconstructed/fitted W (top) and the generated W (top). Fitted jet combinations pass the probability cut. The central parts of the distributions (-105,105) are fitted with a Gaussian function (thick-blue lines) to emphasize and quantify the improvement in the resolution. The fit improves the resolution of the energy of the W and top quark by 11% and 4%, respectively.

**Table 3.** Part of the spectrum in point LM1 generated by ISAJET 7.69 [10]. $m_t$ is set to 175 GeV/c$^2$.

| Sparticle | Mass(GeV/c$^2$) | Sparticle | Mass(GeV/c$^2$) |
|---|---|---|---|
| t | 175.00 | $\tilde{g}$ | 611.32 |
| $\tilde{c}_R, \tilde{u}_R$ | 541.52 | $\tilde{c}_L, \tilde{u}_L$ | 557.99 |
| $\tilde{d}_R, \tilde{s}_R$ | 541.18 | $\tilde{d}_L, \tilde{s}_L$ | 563.99 |
| $\tilde{b}_2$ | 534.96 | $\tilde{b}_1$ | 514.17 |
| $\tilde{t}_2$ | 575.85 | $\tilde{t}_1$ | 411.91 |
| $\tilde{e}_R, \tilde{\mu}_R$ | 118.81 | $\tilde{e}_L, \tilde{\mu}_L$ | 188.61 |
| $\tilde{\tau}_2$ | 191.69 | $\tilde{\tau}_1$ | 110.53 |
| $\nu_{\tilde{\mu}}, \nu_{\tilde{e}}$ | 168.46 | $\nu_{\tilde{\tau}}$ | 167.88 |
| $\tilde{\chi}_2^{\pm}$ | 360.99 | $\tilde{\chi}_1^{\pm}$ | 179.50 |
| $\tilde{\chi}_4^0$ | 361.81 | $\tilde{\chi}_3^0$ | 341.29 |
| $\tilde{\chi}_2^0$ | 179.56 | $\tilde{\chi}_1^0$ | 94.93 |
| $H^{\pm}$ | 382.17 | $H^0$ | 374.18 |
| $A_0$ | 373.01 | $h^0$ | 112.87 |

## 5. Sparticles production and decay in the low mass point (LM1)

For illustration we use point CMS-LM1 as the benchmark point. This point is a little higher than the Tevatron [9] reach and has a sufficiently high cross section making it easier to search for. It must be emphasized that the developed method in this paper is tried to be independent from the features of this special point and it can be applied for different R-parity conserving SUSY benchmarks that can produce top quark in the decay of their particles. mSUGRA is determined by 5 free parameters defined at the Grand Unification Theory (GUT) scale. The corresponding parameters for point LM1 are as follows: common scalar mass $m_0 = 60 \text{ GeV}/c^2$, common gaugino mass $m_{1/2} = 250 \text{ GeV}/c^2$, common trilinear coupling $A_0 = 0.0$, the ratio of the vacuum expectation values of higgs fields $H_u$ and $H_d$, $\tan(\beta) = 10$ and finally the sign of the higgsino mixing parameter, $sign(\mu) = +1$. Table 3 shows the masses of some important particles in point LM1. At this point the top can be generated indirectly in the decay of heavier sparticles (gluino, stops and sbottoms have a chance to decay to top).

## 6. Analysis path

In this note our strategy to search for low mass SUSY is to look at the number of the extracted top quarks for $100\,pb^{-1}$ integrated luminosity. In the following, SUSY events are divided into two parts, SUSY (with Top), SUSY events with at least one generated top quark and SUSY (no Top), SUSY events without a top quark at the generator level. This separation allows to optimize the cuts to suppress the second part as the fake signal. Different cuts and selections used in this analysis are as follows:

**MET > 200 GeV:** The most important background is the inclusive $t\bar{t}$, because it has a very high cross section (830 pb) and it has two real top quarks per event. SUSY events have at least two $\tilde{\chi}_1^0$, that appear as missing transverse energy (MET), but MET in $t\bar{t}$ events comes from neutrinos or miss-measurements and usually does not exceed a few 10 GeV. Figure 5 compares the MET distribution from different samples. To increase the ratio of the SUSY events to $t\bar{t}$ and other SM backgrounds, a cut on MET is introduced (MET > 200 GeV).

**At least 5 jets:** We are looking for a hadronically decaying top candidate, so every event must have at least two light jets apart from the b- jets. Figure 6 shows the jet multiplicity distribution in this step. The events with less than 5 jets are rejected to suppress the SM backgrounds.

**At least 1 b-jet:** The top quark almost always decays to a b-tagged jet plus a W, so in every event at least one jet has to be tagged as a b-jet.

**A convergent fit with a $\chi^2$ probability > 0.05:** To find a top quark, the best jet combination is found by the kinematic fit. A cut on the $\chi^2$ probability is applied to increase the purity of the selected top quarks. Figure 7 shows the distribution of the $\chi^2$ probability for the extracted top quarks in different samples.

**At least one isolated lepton:** To suppress the multi jet backgrounds, events are asked to have at least one isolated electron or muon with $P_T > 5\,\text{GeV}/c$ and $|\eta| < 2.5$. The isolation requirement can suppress the muons coming from the b-quarks.

Table 4 shows the number of the remaining events after each cut. In the table SUSY events are divided in two parts, “SUSY (with Top)” and “SUSY (no Top)”. Although, the sum of both parts is used as the number of signal events (S), we try to increase the ratio of the first part as the real signal against the second part. Asking for a convergent fit and applying the cut on the $\chi^2$

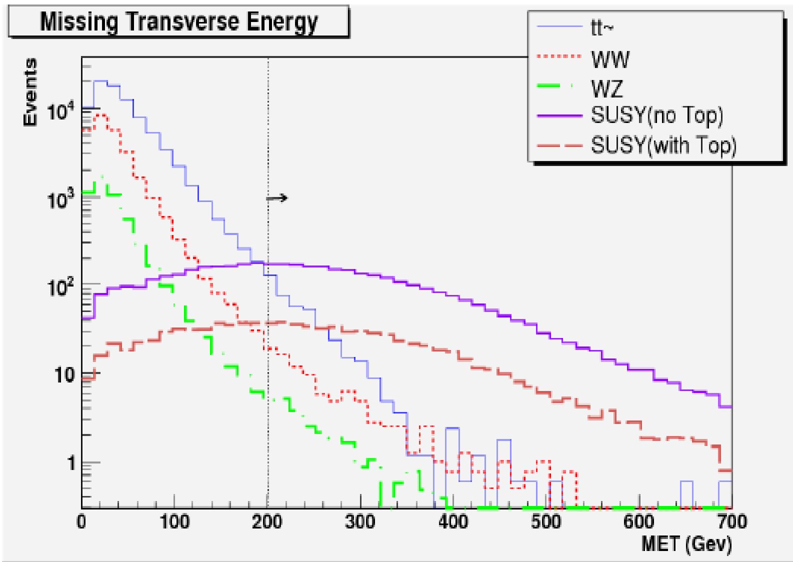


**Figure 5.** MET distributions for different samples.

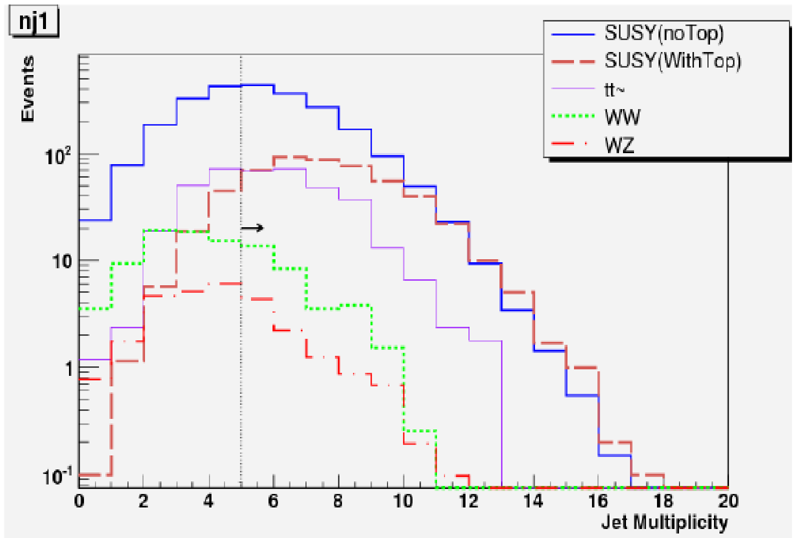


**Figure 6.** The jet-multiplicity in the events that pass the cut on MET.

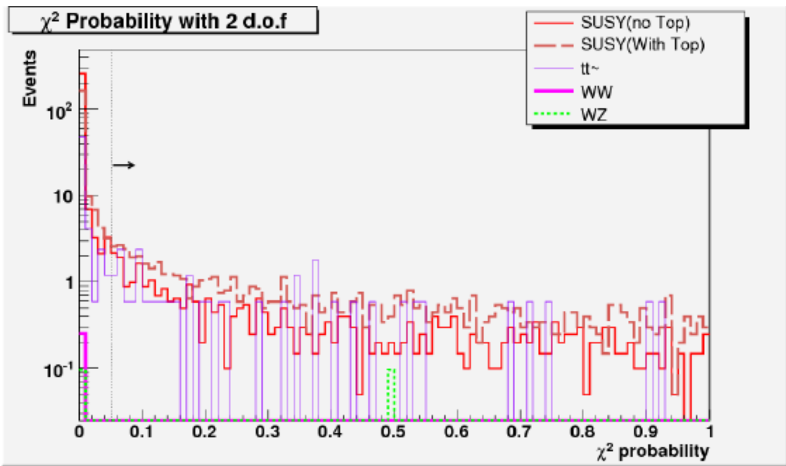


**Figure 7.** $\chi^2$ probability distributions for different samples. Every event passes the cuts on jet multiplicity and has a convergent fit. SUSY( with Top) and SUSY (no Top) are concentrated in different regions.

**Table 4.** Effect of different samples. In every row, the number of the remaining events after that cut is shown. $N_{ev}$ shows the number of events used in this analysis. $N_{ev}^{100pb^{-1}}$ is the same number after normalizing to the cross section times $100pb^{-1}$ and "wT/noT" means $\frac{SUSY(withTop)}{SUSY(noTop)}$.

| requirements | SUSY(wT) | SUSY(noT) | ttInc | WWj | ZWj | wT/noT |
|---|---|---|---|---|---|---|
| x-sec(pb)NLO | 52 | | 830 | 269.91 | 51.5 | - |
| $N_{ev}$ | 1871 | 86523 | 139955 | 106796 | 53469 | 0.21 |
| $N_{ev}^{100pb^{-1}}$ | 925 | 4275 | 83000 | 26991 | 5150 | 0.21 |
| $MET \geq 200$ GeV | 530 | 2467 | 395 | 97 | 28 | 0.21 |
| $n_j \geq 5$ | 460 | 1427 | 250 | 31 | 10 | 0.32 |
| $n_{bj} \geq 1$ | 300 | 385 | 143 | 1 | 1 | 0.77 |
| A Convergent Fit | 251 | 309 | 81 | 0 | 0 | 0.81 |
| $\chi^2$ $probability > 0.05$ | 63 | 34 | 25 | 0 | 0 | 1.81 |
| $n_l \geq 1$ | 28 | 11 | 4 | 0 | 0 | 2.54 |

probability > 0.05, increases the ratio of the real top quarks in SUSY events. This can be understood in the sense that $\chi^2$ probability quantifies the goodness of a reconstructed top quark, so fake top quarks are fitted with a smaller $\chi^2$ probability. To optimize the cuts, each of them was varied separately leading to values presented in table 4. These cuts were optimized to increase $\frac{SUSY(withTop)}{SUSY(noTop)}$ and decrease the SM backgrounds simultaneously, whilst keeping significance sufficiently high. The significance is defined as follows [11]:

$$significance = 2\times\left(\sqrt{S+B}-\sqrt{B}\right) , \qquad (9)$$

where S and B are the number of remaining events after all cuts for signal and background, respectively. We try to find the minimum integrated luminosity to achieve a $5\sigma$ discovery. The significance corresponding to Eq.9 varies with the square root of the integrated luminosity. Using S and B for $100pb^{-1}$, the minimum integrated luminosity can be found by solving the equation:

$$5=\sqrt{\frac{\min IL}{100}}\times 2\times\left(\sqrt{39+4}-\sqrt{4}\right),$$

$$\text{there for , } \frac{\min IL}{100}=0.30pb^{-1}, \qquad (10)$$

$$\text{then we have , } \min IL = 30pb^{-1}.$$

For this integrated luminosity, the corresponding number of events for signal and background are 12 and 1, leading to 100% statistical uncertainty on the background which is larger than systematic uncertainty [6], so the latter one can be neglected. If the fast simulation of the detector response was available, we could scan the $m_0 - m_{1/2}$ plane to find the reach of this analysis in the SUSY parameter space, but it is beyond the scope of this study.

Comparison between our result and the reported result in reference [4] shows that our result is much better and makes this discovery much faster. The difference can be explained as follows, the analysis frameworks are different and it can affect the jet definition and identification. Pile up is not considered in this analysis, because we assume early data which means lower instant luminosity comparing to the regime that reference [4] assumes. Also apart from these, some background samples were not available at the time of the analysis (QCD multi jet, single top, etc.) and were supposed to be negligible after applying the mentioned cuts. Approving this needs more investigation that is not possible in the time being.

### 6. 1. Search without b-tagging

In this part we repeat the analysis without using the b-tagging information. The cuts and selections of this analysis are same as the last section. Met and jet multiplicity distributions are as past. $\chi^2$ probability distributions for different samples are shown at figure 8.

Table 5 shows the number of the remaining events after each cut. Again we try to find the minimum integrated luminosity to achieve a $5\sigma$ discovery.

$$5=\sqrt{\frac{\min IL}{100}}\times 2\times\left(\sqrt{123+13}-\sqrt{13}\right), \qquad (11)$$

$$\text{it gives} : \min IL = 9.6pb^{-1},$$

For this integrated luminosity, the corresponding number of events for signal and background are 12 and 1, leading to 100% statistical uncertainty on the background which is larger than the systematic uncertainties [6], so the latter one can be neglected.

In this situation QCD multi jet background can

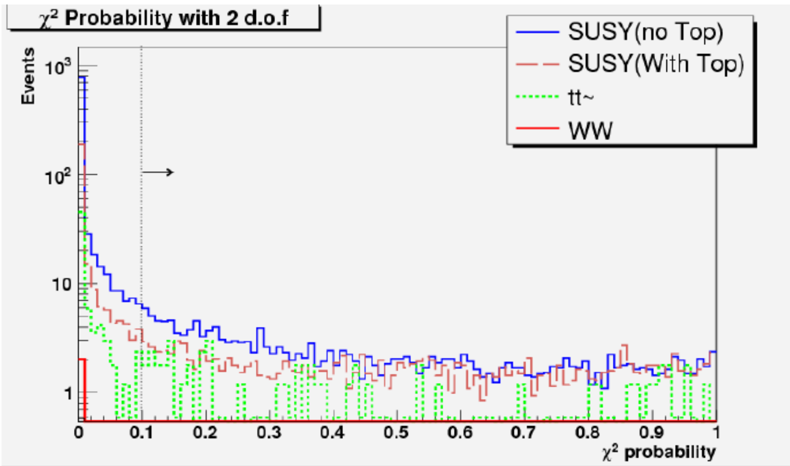


**Figure 8.** $\chi^2$ probability distributions for different samples. Every event passes cuts on Met and jet multiplicity and has a convergent fit.

**Table 5.** same as table 4 for the situation that b-tagged jet is not recognizable.

| requirements | SUSY(wT) | SUSY(noT) | ttInc | WWj | ZWj | wT/noT |
|---|---|---|---|---|---|---|
| x-sec(pb)NLO | 52 | | 830 | 269.91 | 51.5 | - |
| $N_{ev}$ | 18701 | 86523 | 139955 | 106796 | 53469 | 0.21 |
| $N_{ev}^{100\,pb^{-1}}$ | 925 | 4275 | 83000 | 26991 | 5150 | 0.21 |
| MET >= 200 GeV | 530 | 2467 | 395 | 97 | 28 | 0.21 |
| $N_{jet}$ >= 5 | 460 | 1427 | 250 | 31 | 10 | 0.32 |
| A Convergent Fit | 399 | 1095 | 137 | 4 | 1 | 0.36 |
| $\chi^2$ probability > 0.1 | 202 | 154 | 69 | 1 | 0 | 1.31 |
| $N_{lep}$ >= 1 | 68 | 55 | 13 | 0 | 0 | 1.23 |

potentially be dangerous, but due to the lack of the background sample its analysis is not possible right now and needs to be checked later on.

## 7. Results

In the events extracted as signal $\frac{28}{28+11}=71\%$ are from SUSY events which have a top quark at the generator level when the b-tagged jets are recognizable and the same value for the situation that b-tagging information is not used is $\frac{68}{68+55}=55\%$.

## 8. Conclusion

The ability of CMS to find the low mass SUSY in events with a top quark in the final state was studied. A two constraint kinematic fit was utilized to improve the top quark extraction. It is shown that for point LM1 with an integrated luminosity of $30\,pb^{-1}$ for situation that b-tagged jets are recognizable and $9.6\,pb^{-1}$ for the case that b-jets are not recognizable, a $5\sigma$ discovery is achievable provided the uncertainty is statistics dominated. The final signal over background is 12 for both analyses. It must be emphasized that the presented search is for a theoretical model that predicts the production of high momentum invisible particles (leading to large MET) plus top. Discriminating between these models is very challenging and beyond the scope of this analysis. This issue is known as the LHC inverse problem [12] and is an open question in high energy physics community.

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