LHC(CMS) SUSY discovery potential for nonuniversal gaugino and squark masses and the determination of the effective SUSY scale

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Abstract

We review the results on the investigation of the LHC(CMS) SUSY discovery potential for the case of nonuniversal gaugino and squark masses.

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One of the LHC supergoals is the discovery of the supersymmetry. In particular, it is very important to investigate a possibility to discover strongly interacting superparticles (squarks and gluino). In Ref.[1] (see also Refs.[2]) the LHC squark and gluino discovery potential has been investigated within the minimal SUGRA-MSSM framework [3] where all sparticle masses are determined mainly by two parameters: m_0 (common squark and slepton mass at GUT scale) and $m_{\frac{1}{2}}$ (common gaugino mass at GUT scale). The signature used for the search for squarks and gluino at LHC is $(n \geq 0)$ $isolated\ leptons + (m \geq 2) jets + E_T^{miss}$ events. The conclusion of Ref. [1] is that LHC is able to detect squarks and gluino with masses up to $(2 - 2.5)\ TeV$.

Despite the simplicity of the SUGRA-MSSM framework it is a very particular model. The mass formulae for sparticles in SUGRA-MSSM model are derived under the assumption that at GUT scale ($M_{GUT} \approx 2 \cdot 10^{16}$ GeV) soft supersymmetry breaking terms are universal. However, in general, we can expect that real sparticle masses can differ in a drastic way from sparticle masses pattern of SUGRA-MSSM model due to many reasons, see for instance refs. [4, 5, 6, 7]. Therefore, it is more appropriate to investigate the LHC SUSY discovery potential in a model-independent way for general case of nonuniversal gaugino and squark masses.

In this report we review our previous results [8]-[11] on the investigation of the LHC(CMS) SUSY discovery potential for the case of nonuniversal squark and

gaugino masses. We also give some new results on the determination of the effective SUSY scale for models with nonuniversal gaugino masses.

The decays of squarks and gluinos depend on the relation among squark and gluino masses. For $m_{\tilde{q}} > m_{\tilde{g}}$ squarks decay mainly into gluino and quarks and gluino decays mainly into a quark-antiquark pair and a gaugino. For $m_{\tilde{q}} < m_{\tilde{g}}$ gluino decays mainly into squarks and quarks, whereas squarks decay mainly into quarks and a gaugino. The next-to-lightest gauginos have several leptonic decay modes giving a lepton and missing energy, for instance:

$$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 + l^{\pm} + \nu, \tag{1}$$

$$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 + l^{\pm} l^{\mp} \tag{2}$$

As a result of chargino and second neutralino leptonic decays, besides the classical signature $(n \geq 2, 3, 4)$ *jets plus* E_T^{miss} signatures such as $(n \geq 2, 3, 4)$ *jets plus* $(m \geq 1$ *leptons*$)$ *plus* E_T^{miss} with leptons and jets in final state arise.

In our concrete calculations all SUSY processes, with full particle spectrum, couplings, production cross section and decays have been generated with ISASUSY code [12]. The Standard Model backgrounds have been generated by PYTHIA code [13]. Our simulations have been made with parametrized detector responses based on detailed detector simulations. Namely, the CMS(Compact Muon Solenoid) detector fast simulation code CMSJET [14] has been used. It appears that the following SM processes give the main contribution to the background:

W + *jets*, Z + *jets*, $t\bar{t}$, WZ, ZZ, $b\bar{b}$ *and* $QCD(2 \to 2)$ *reactions* .

As it has been mentioned previously in our study we have considered as signatures $(n \geq l)$ jets plus $(m \geq k)$ isolated leptons plus E_T^{miss}, where $l = 2, 3, 4$ and $k = 0, 1, 2, 3, 4$. More detailed information on the used cuts can be found in Refs.[8]-[11].

For squark and gluino pair production we have considered 4 different kinematic regions:

- A. $m_{\tilde{g}} \gg m_{\tilde{q}}$
- B. $m_{\tilde{q}} \gg m_{\tilde{g}}$
- C. $m_{\tilde{q}} \sim m_{\tilde{g}}$, $m_{\tilde{q}} > m_{\tilde{g}}$
- D. First 2 squark generations are heavy $m_{\tilde{q}_{1,2}} \gg 1\ TeV$. Only 3 rd squark generation is relatively light.

We have found that the LHC(CMS) SUSY discovery potential depends rather strongly on the relation among $m_{\tilde{\chi}_1^0}$ and $min(m_{\tilde{g}}, m_{\tilde{q}})$ and it decreases with the increase of the LSP mass $m_{\tilde{\chi}_1^0}$. For LSP mass $m_{\tilde{\chi}_1^0}$ close to $min(m_{\tilde{g}}, m_{\tilde{q}})$ it is possible to detect SUSY for $min(m_{\tilde{g}}, m_{\tilde{q}}) \leq (1.2 - 1.5)\ TeV$ (cases A,B,C). For the case D it is possible to detect SUSY with $m_{\tilde{q}_{1,2}} \leq 800\ GeV$. Our results are presented in Figs.(1-5).

Gluinos and squarks are strongly produced at the LHC, so it is important to find a variable that measures the produced mass for events with missing transverse energy. In Ref.[15] [1] a variable that works rather well within SUGRA-MSSM model has been defined as the sum of the missing energy and the p_T's of the first four jets,

$$M_{eff} = E_T^{miss} + p_{T,1} + p_{T,2} + p_{T,3} + p_{T,4} \tag{3}$$

As it has been mentioned in Ref.[15] in SUGRA-MSSM model the distribution of SUSY cross section $\frac{d\sigma_{SUSY}}{dM_{eff}}$ has maximum at some point $M_{SUSY} \equiv M_{peak}$ and the value of M_{SUSY} coincides within 10 percent accuracy with $min(m_{\tilde{g}}, m_{\tilde{q}})$, namely

$$M_{SUSY} \equiv M_{peak} \approx min(m_{\tilde{g}}, m_{\tilde{q}}) \tag{4}$$

We have investigated the dependence of M_{SUSY} on squark, gluino and LSP masses in general case of arbitrary relations among LSP, squark and gluino masses. Our results are presented in Figs.(6-8). As it follows from our results in general case for LSP mass $m_{\tilde{\chi}_1^0} \leq m_{\tilde{g}}$ there is no linear dependence of M_{SUSY} on gluino or squark masses. The value of M_{SUSY} is nonlinear and nontrivial function on gluino, squark and LSP masses. So, in general case it would be rather nontrivial to determine more or less accurately the squark and gluino masses with the help of M_{SUSY}.

In conclusion we would like to stress that even for the most difficult case when LSP mass is rather heavy and close to squark or gluino masses the LHC is able to discover SUSY for the most interesting from the theoretical point of view case when sparticle masses are lighter than 1 TeV.

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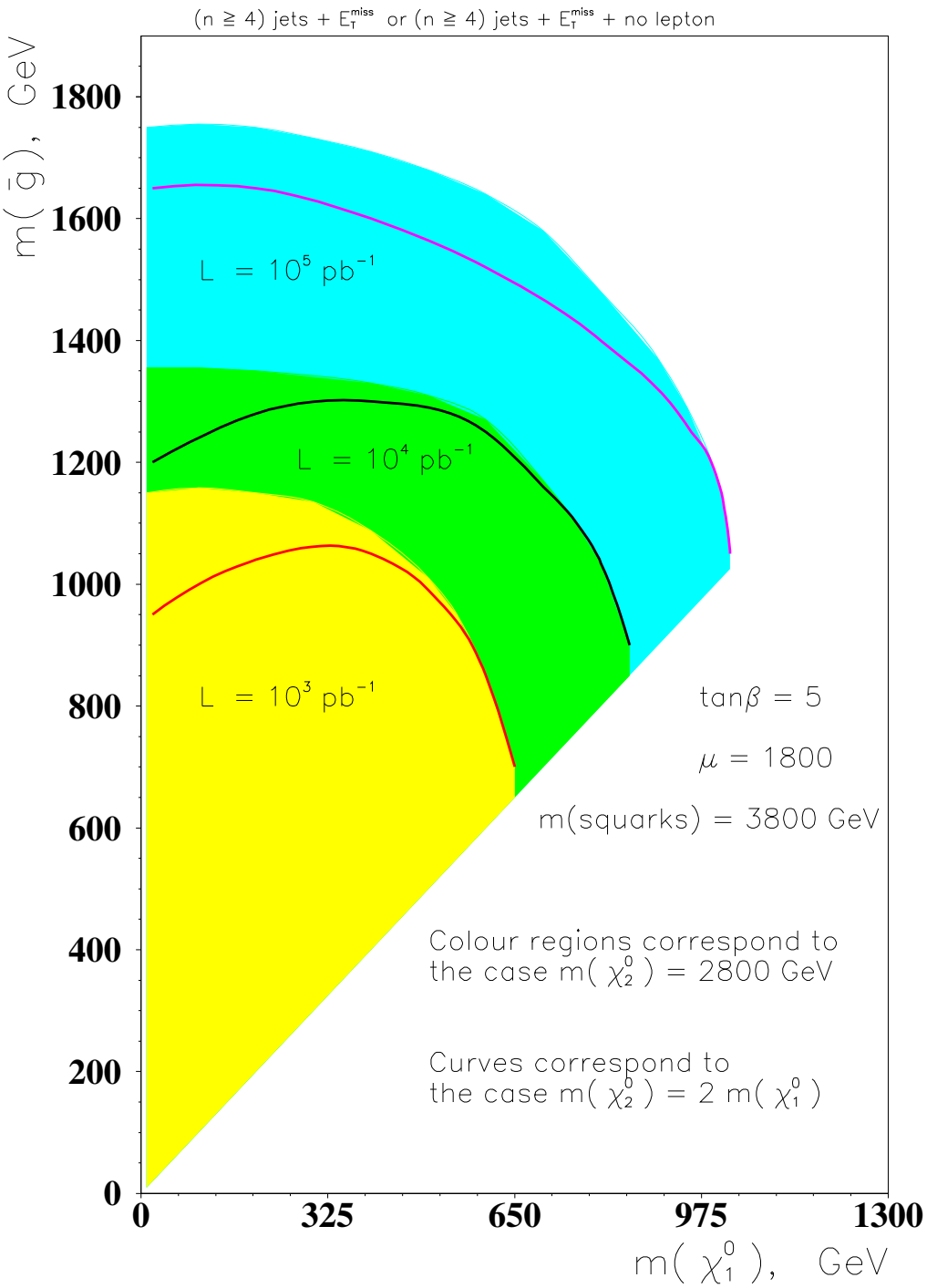

Figure 1: CMS discovery potential for different values of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{g}}$ in the case of $m_{\tilde{g}} > m_{\tilde{\chi}_1^0}$.

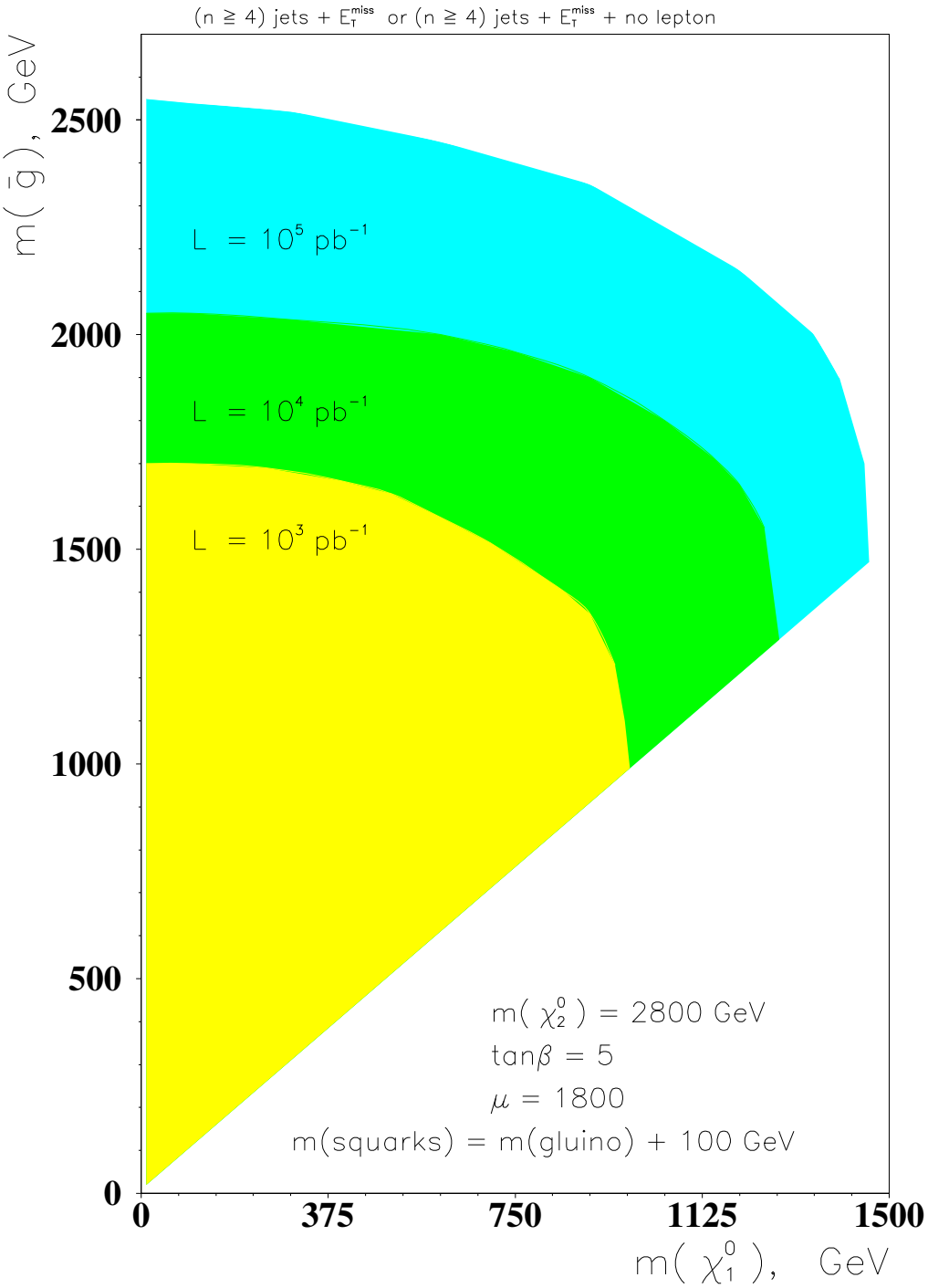

Figure 2: CMS discovery potential for different values of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{g}}$ in the case of $m_{\tilde{g}} > m_{\tilde{\chi}_1^0}$

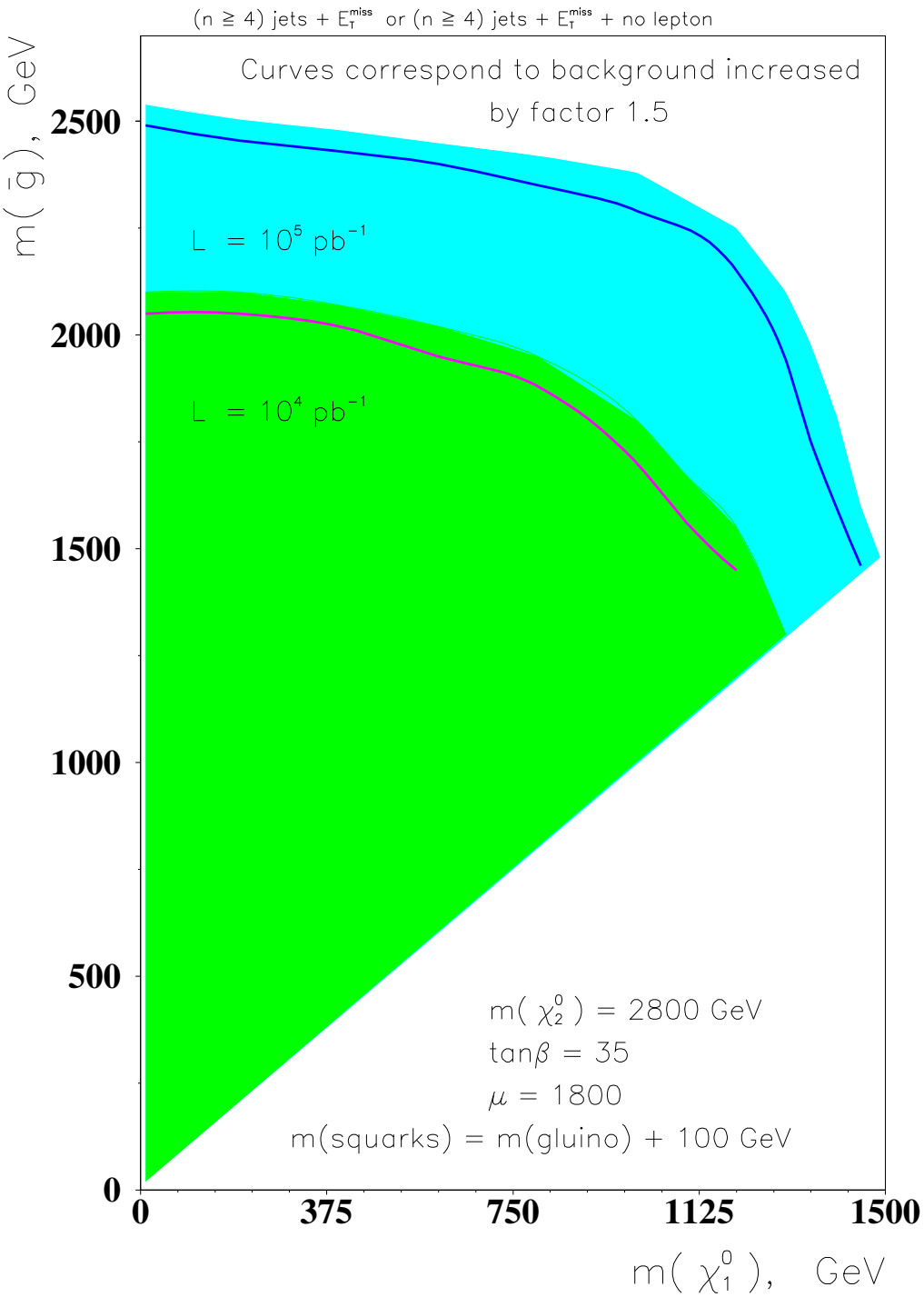

Figure 3: CMS discovery potential for different values of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{g}}$ in the case of $m_{\tilde{g}} > m_{\tilde{\chi}_1^0}$.

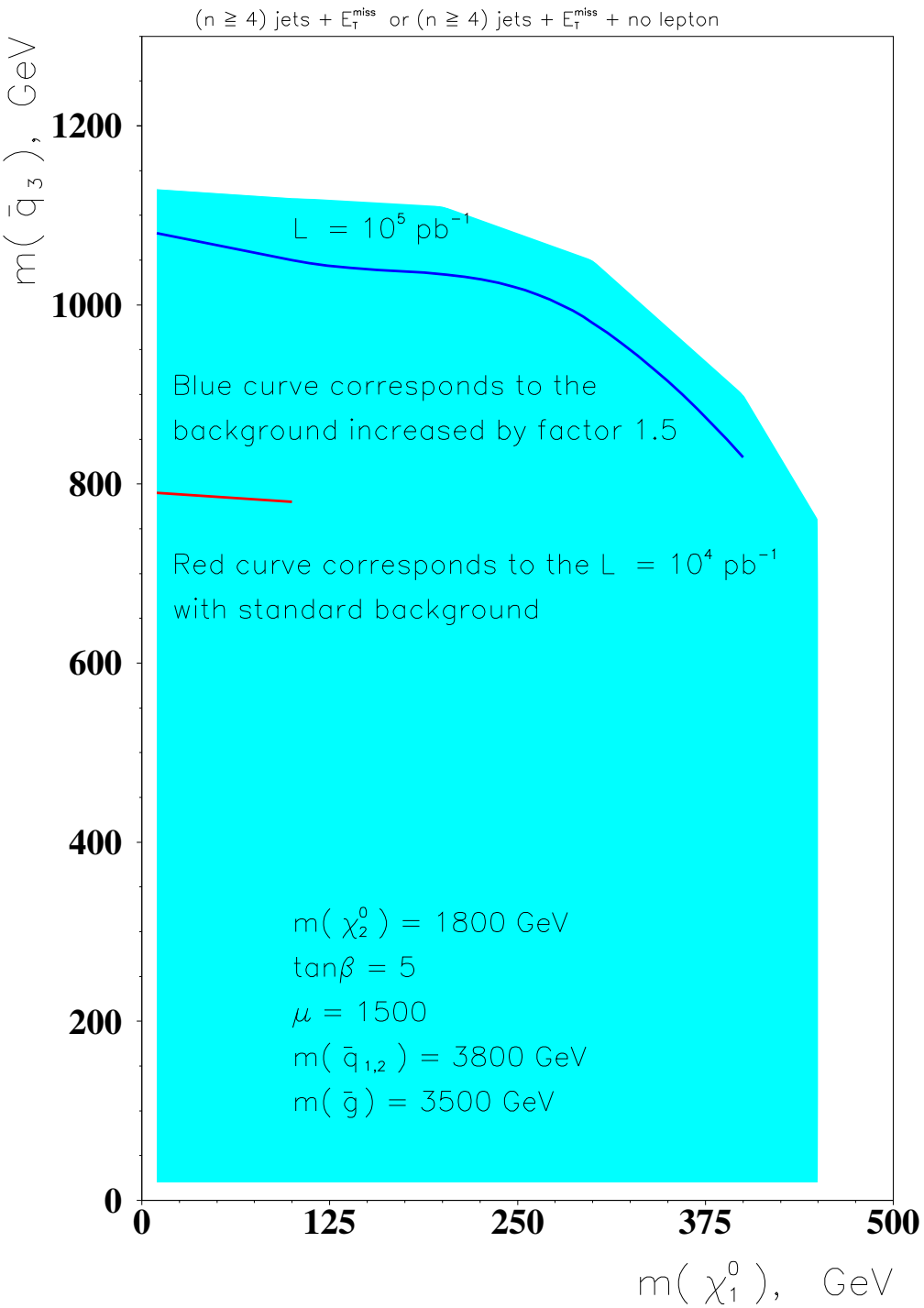

Figure 4: CMS discovery potential for different values of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{q}_3}$ in the case of $m_{\tilde{q}_{1,2}} \gg m_{\tilde{q}_3}$.

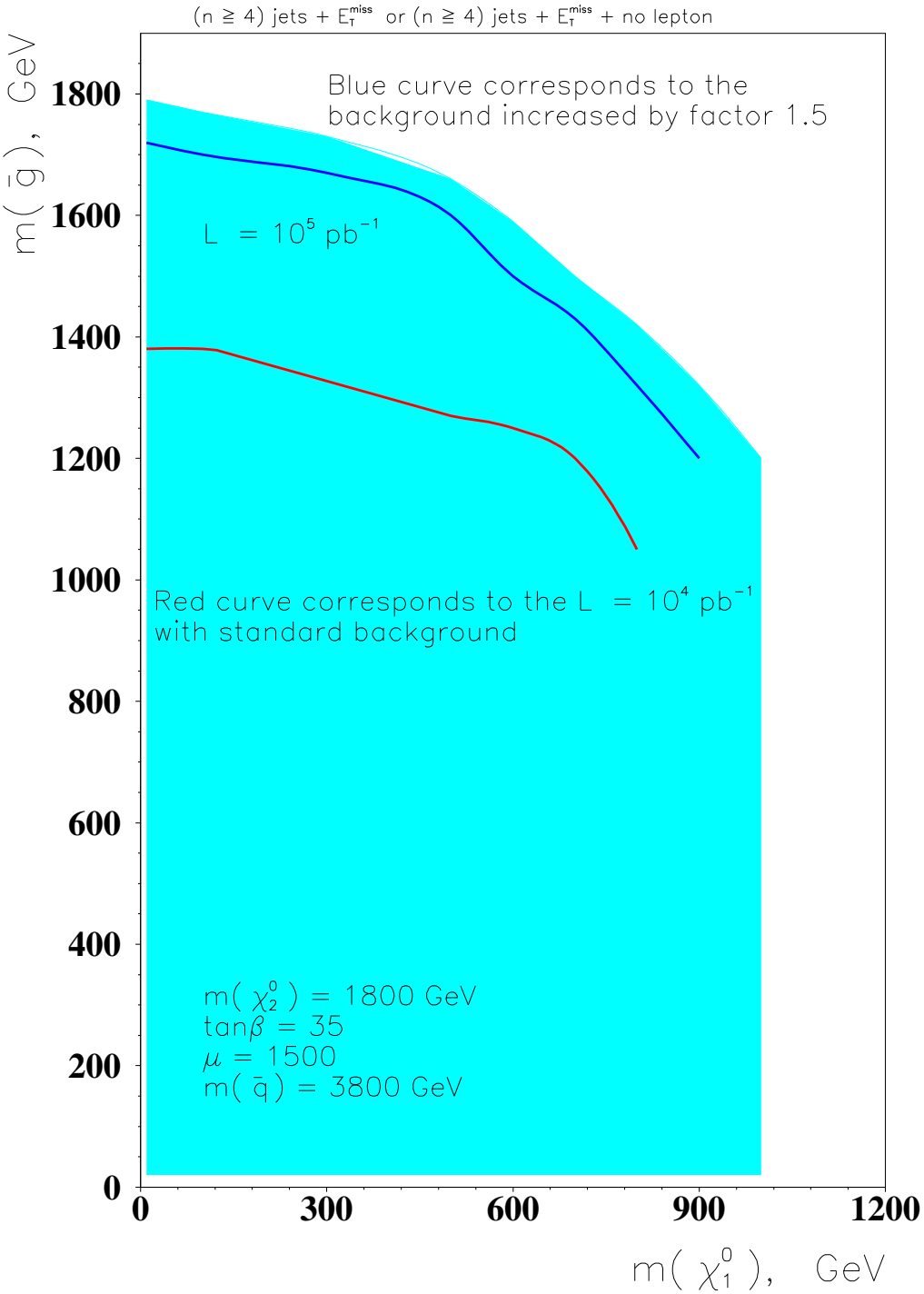

Figure 5: CMS discovery potential for different values of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{g}}$ in the case of $m_{\tilde{q}} \gg m_{\tilde{g}}$.

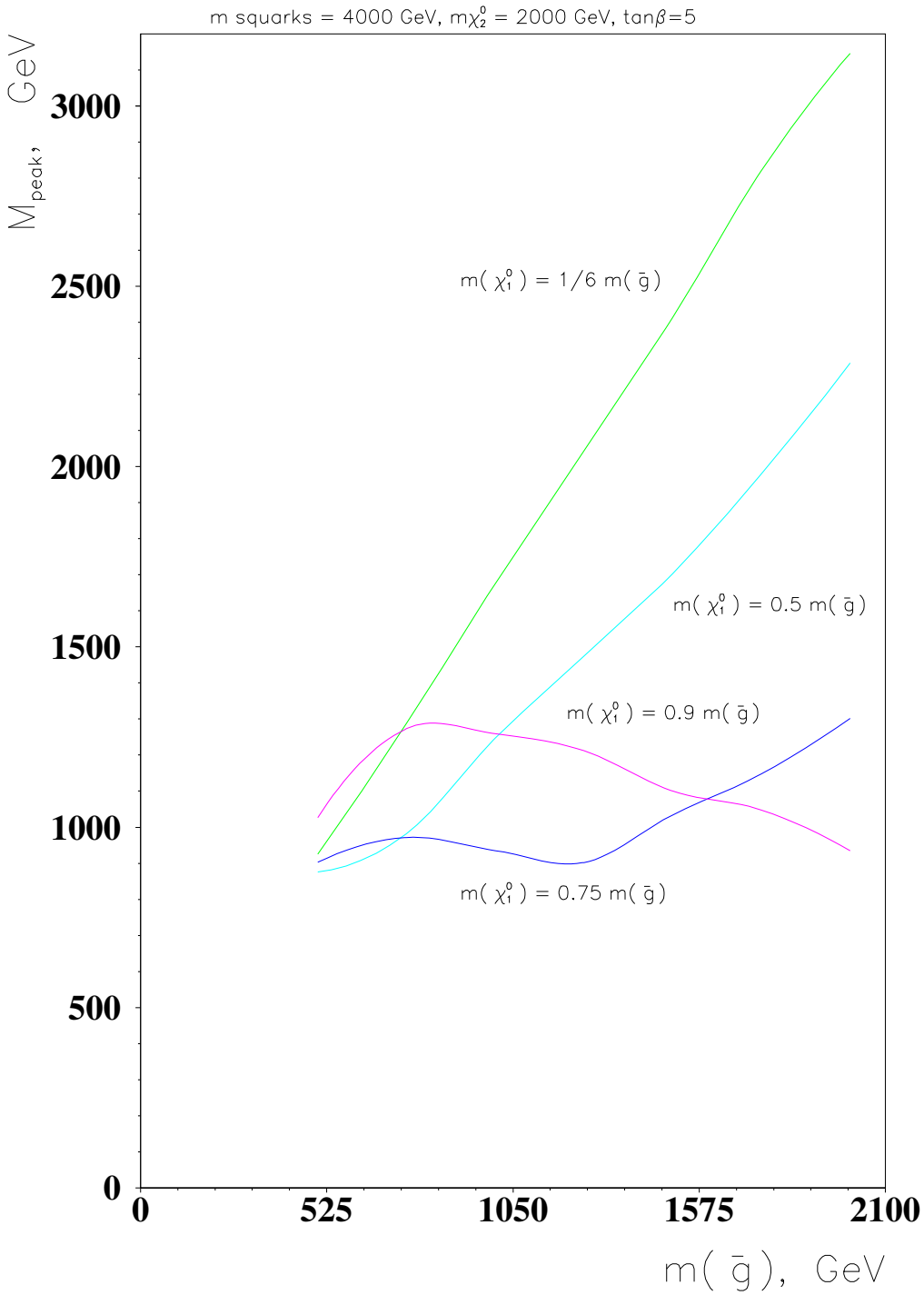

Figure 6: The dependence of $M_{susy} \equiv M_{peak}$ on the gluino mass for different values of $m(\chi_1^0)$.

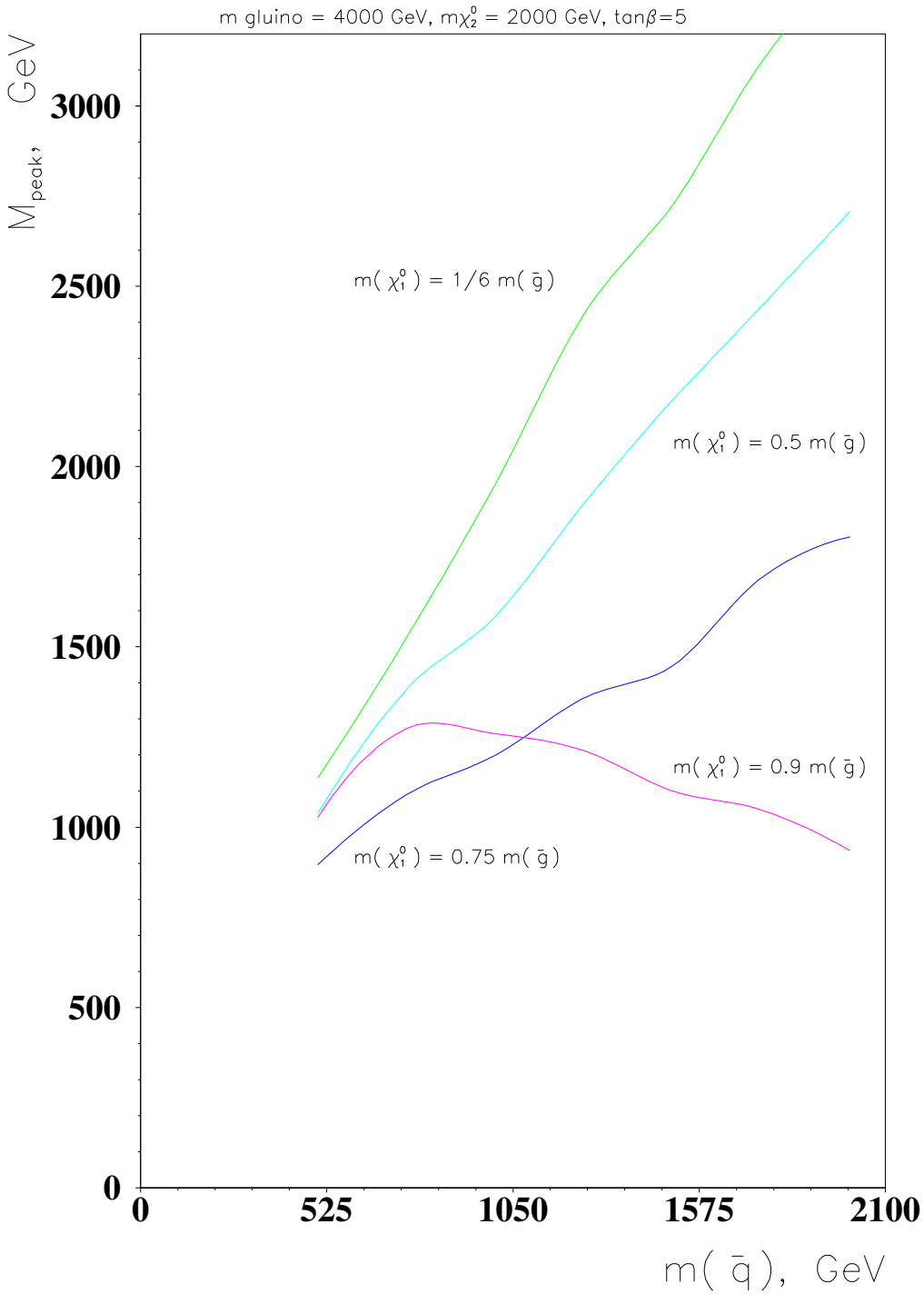

Figure 7: The dependence of $M_{susy} \equiv M_{peak}$ on the squark mass for different values of $m(\chi_1^0)$.

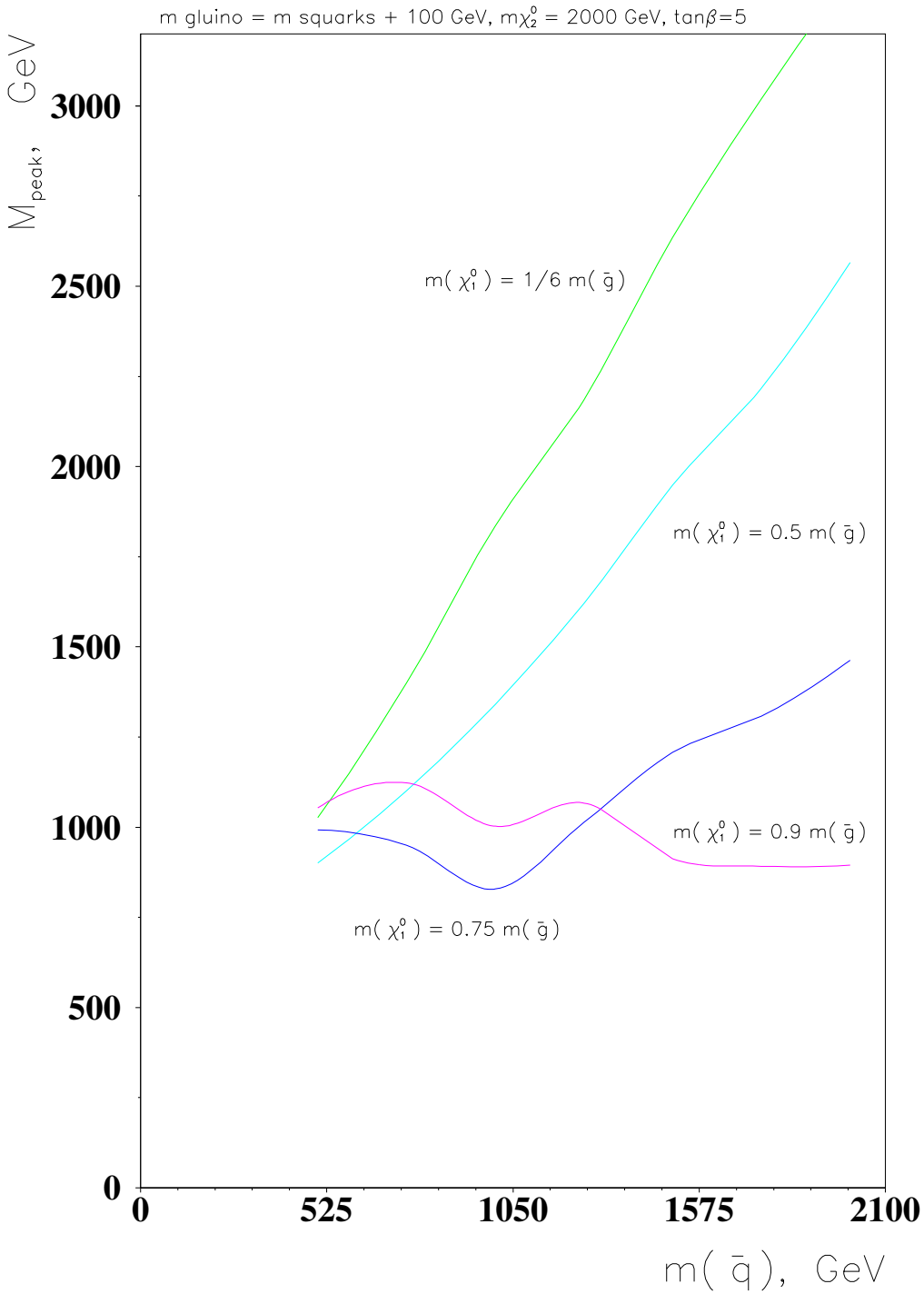

Figure 8: The dependence of the $M_{susy} \equiv M_{peak}$ on the squark mass for different values of $m(\chi_1^0)$.