# Looking for Split Supersymmetry in Higgs Signals

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# Outline

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SUSY broken within TeV helps to avoid fine-tuning of the Higgs mass.

A broken SUSY leads to a large cosmological constant, $\Lambda$, the escape from which is fine-tuning of a more severe kind (around 60 places or so).

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Gauginos and Higgsinos can be within the TeV scale.

## Features ...

Due to large scalar masses FCNC will be highly suppressed.

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Lightest neutralino (LSP) is in the right mass range to become a dark matter candidate.

The unification of the coupling constants can still remain unaffected.

## Effective Lagrangian

$$
\begin{aligned}
\mathcal{L} \quad = \quad & m^2 H^\dagger H - \frac{\lambda}{2}\left(H^\dagger H\right)^2 \\
& - \Big[ h^u_{ij}\bar{q}_j u_i \epsilon H^* + h^d_{ij}\bar{q}_j d_i H + h^e_{ij}\bar{\ell}_j e_i H \\
& + \frac{M_3}{2}\tilde{g}^A\tilde{g}^A + \frac{M_2}{2}\tilde{W}^a\tilde{W}^a + \frac{M_1}{2}\tilde{B}\tilde{B} + \mu \tilde{H}_u^T \epsilon \tilde{H}_d \\
& + \frac{H^\dagger}{\sqrt{2}}\left(\tilde{g}_u \sigma^a \tilde{W}^a + \tilde{g}'_u \tilde{B}\right)\tilde{H}_u + \frac{H^T \epsilon}{\sqrt{2}}\left(-\tilde{g}_d \sigma^a \tilde{W}^a + \tilde{g}'_d \tilde{B}\right)\tilde{H}_d + h.c. \ ]
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\lambda(m_s) \quad = \quad \frac{\left[g^2(m_s) + g'^2(m_s)\right]}{4}\cos^2 2\beta
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h^u_{ij}(m_s) &= Y^{u*}_{ij}(m_s)\sin\beta, & h^{d,e}_{ij}(m_s) &= Y^{d,e*}_{ij}(m_s)\cos\beta, \\
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$m_S$ is SUSY breaking scale.

Matching Conditions:
$Energy < m_S \rightarrow SM$ with one Higgs + Gauginos + Higgsinos.
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Matching conditions at $m_S$ gives the low energy Lagrangian.

# Higgs Boson in Split SUSY

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Que: Can we distinguish it with the SM signals at the future colliders?

At tree-level, it is very difficult because such processes are unlikely to produce SUSY particles from decay of the Higgs.

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We need to look at the loop-induced decays of Higgs boson in which SUSY particles may appear in the loops.

# Di Photon Production

The most prominent decay mode in the above mass range Di photon production.

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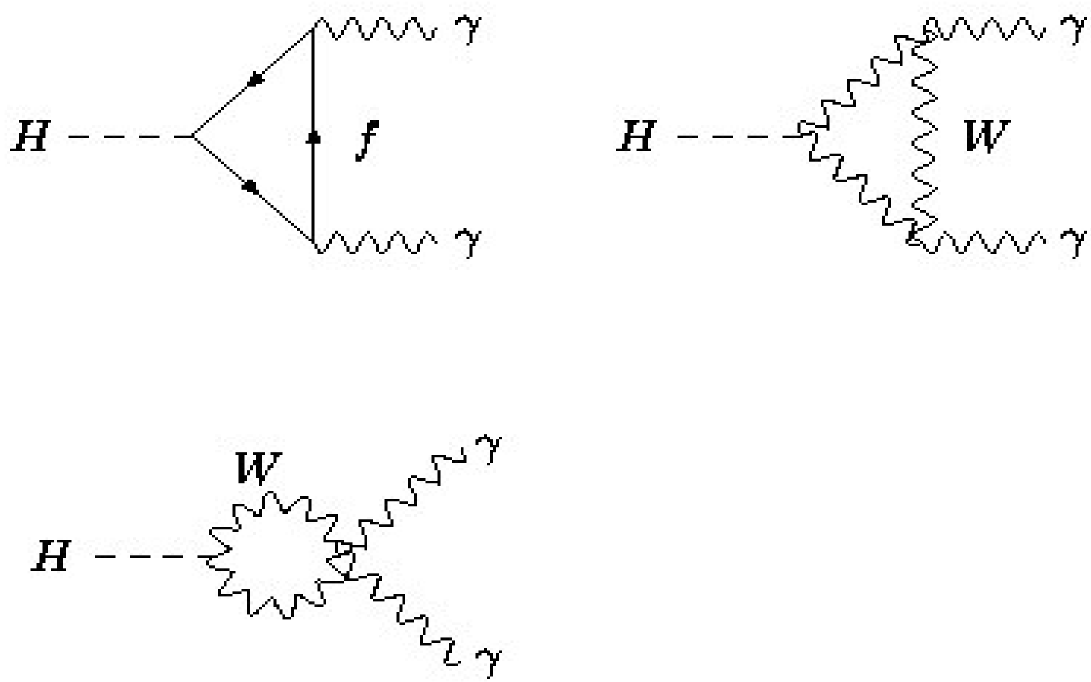
Additional contribution comes due to Chargino loops.

# Di Photon ...



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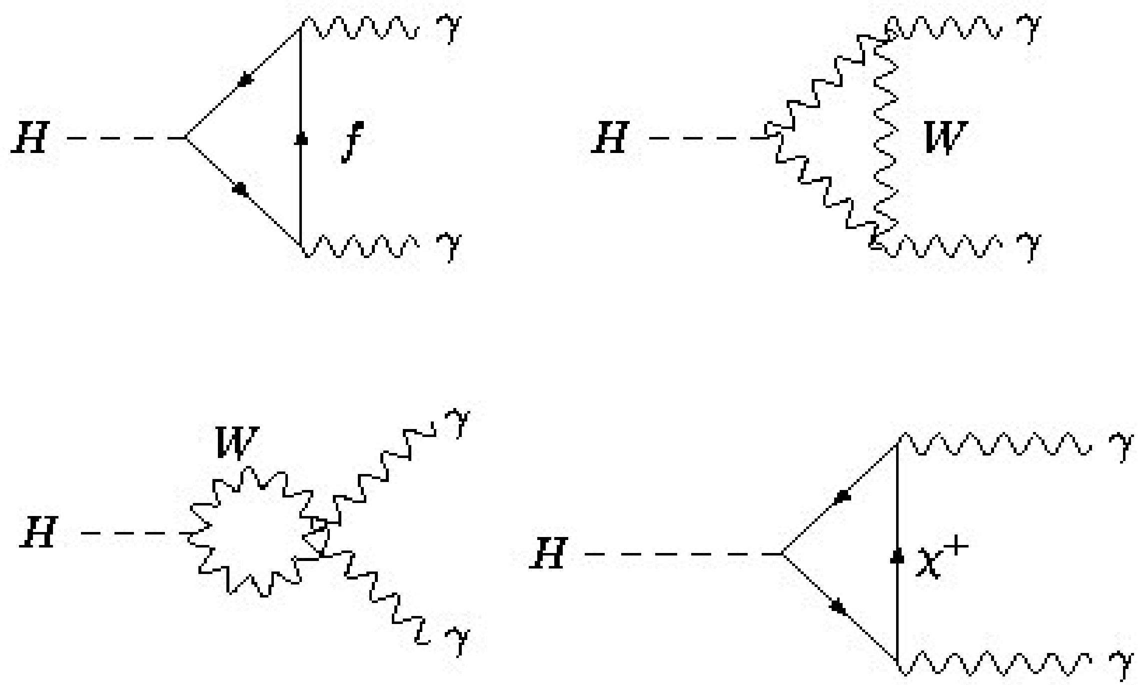

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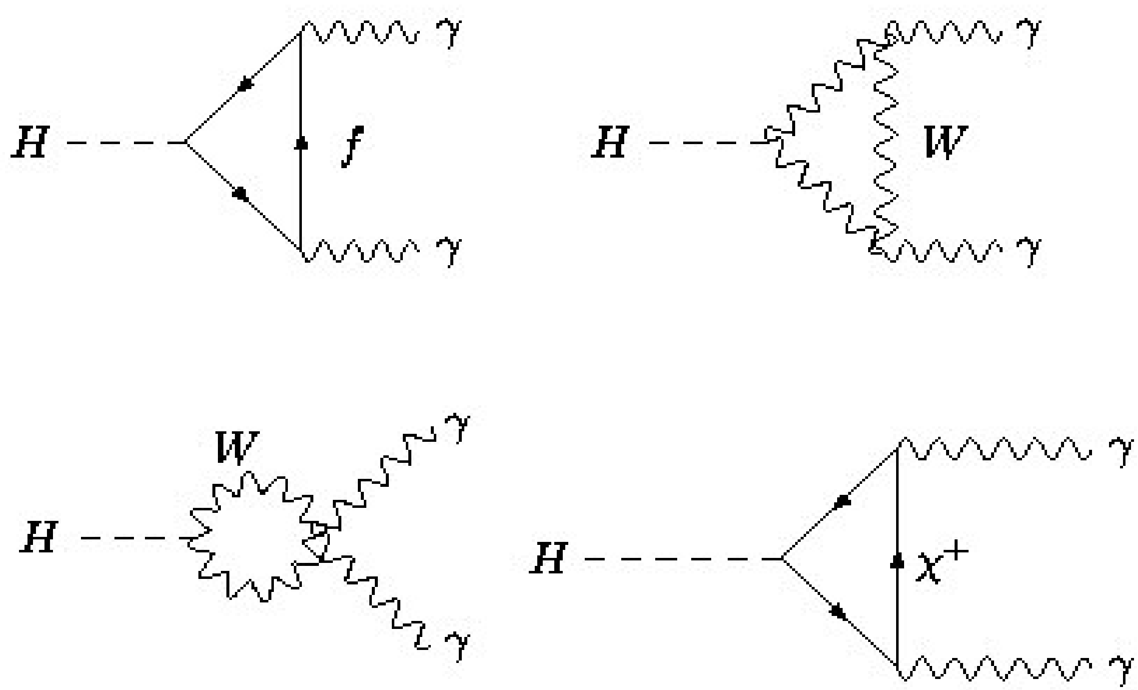


$$\Gamma(h \to \gamma\gamma) = \frac{G_F}{128\sqrt{2}} \frac{\alpha^2 m_h^3}{\pi^3} \left| \sum_i A_i \right|^2$$

$i$ stands for different particles in the loop.

# Di Photon ...

The rate (LO) for the process (via gluon fusion) $pp \to h + X \longrightarrow \gamma\gamma$

$$R = \frac{\pi^2}{8 m_h S} \frac{\Gamma_{h\to 2g}\Gamma_{h\to 2\gamma}}{\Gamma_{tot}} \int_\tau^1 d\zeta \frac{1}{\zeta} g\left(\zeta, m_h^2\right)\ g\left(\frac{\tau}{\zeta}, m_h^2\right)$$

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The total uncertainty in $R^{SM}$ can be expressed as

$$\left(\frac{\delta R^{SM}}{R^{SM}}\right)^2 = \left(\frac{\delta R^{SM}}{R^{SM}}\right)^2_{th} + \left(\frac{\delta R^{SM}}{R^{SM}}\right)^2_{exp}$$

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$\sigma_{R_i}$ stands for the spread in the prediction of $R^{SM}$ due to uncertainty in the $i^{th}$ parameter relevant for the calculation.

A NNLO level Monte Carlo simulation has been performed using MRST PDF and HDECAY3.0.

Proper experimental cuts and efficiency factor has been used to get the effective rates.

## Uncertainties

| Parameter | Central Value | Present Uncertainty | LHC Uncertainty(projected) |
|---|---|---|---|
| $m_h$ | $120. - 150.$ | $-$ | $0.2$ |
| $m_W$ | $80.425$ | $.034$ | $.015$ |
| $m_t$ | $172.7$ | $2.9$ | $1.5$ |
| $m_b$ | $4.62$ | $.15$ | $-$ |
| $m_c$ | $1.42$ | $.1$ | $-$ |
| $m_\tau$ | $1.777$ | $.0003$ | $-$ |
| $\alpha_s$ | $0.1187$ | $0.002$ | $-$ |

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| Total Uncertainty in Standard Model rate | | |
|---|---|---|
| Higgs mass (GeV) | PDF + Scale Uncertainty$= 15\%$ | PDF + Scale Uncertainty$= 10\%$ |
| $120.0$ | $19.2\%$ | $15.6\%$ |
| $150.0$ | $19.4\%$ | $15.8\%$ |

## Contd...

Theoretical uncertainty has been compounded with the experimental uncertainty to give the total uncertainty in the SM rate, $\delta R_{SM}$.

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$\delta R_{SM}$, at different $\sigma$ levels has been compared with the deviation in central values of rates $(R - R_{SM})$ due to additional split SUSY contribution for different values of SUSY parameters ($M_2, \mu$ and $tan\beta$).

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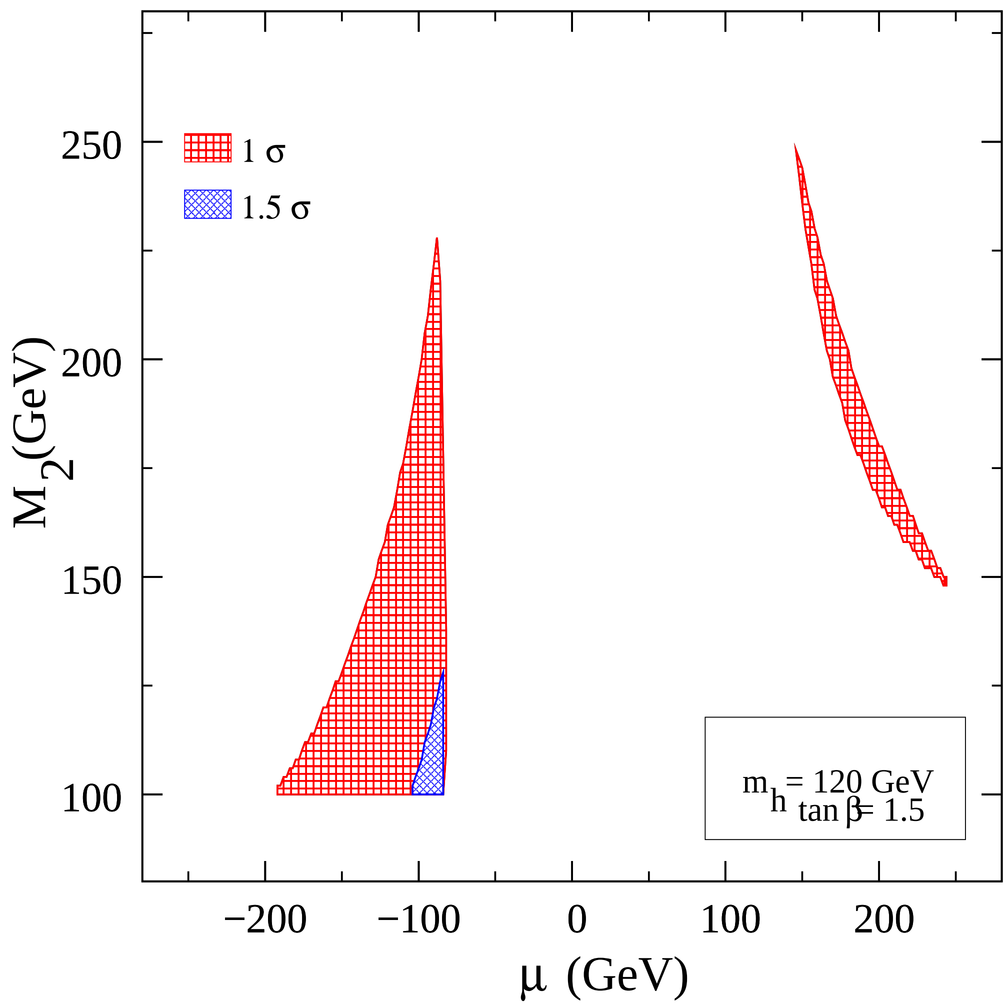
Two sets (for $m_h = 120, 150 GeV$) of plots has been generated for $tan\beta = 1.0, 1.5$ for allowed values of $M_2$ and $\mu$ consistent with the LEP bounds on the lightest Chargino mass.

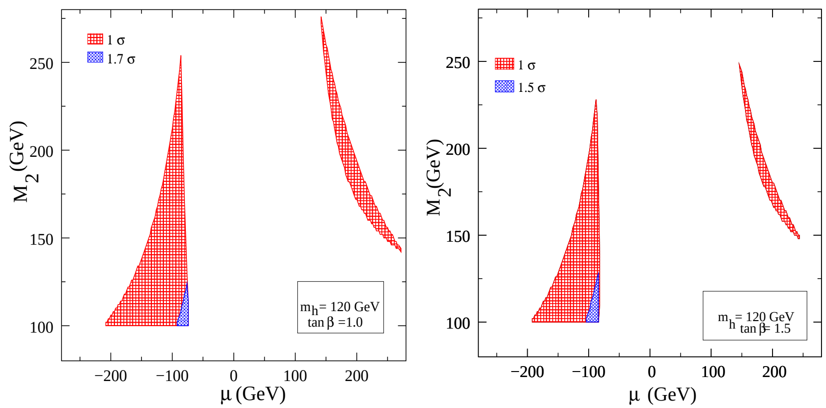
Note: Lower bound on $tan\beta$ in this scenario is $.57$.

# Contd...




Allowed parameter space at various $\sigma$ levels due to present uncertainty.

# Contd ...


1 σ
1.7 σ
$m_h$= 120 GeV
tan β =1.0
250
200
150
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M2 (GeV)
−200
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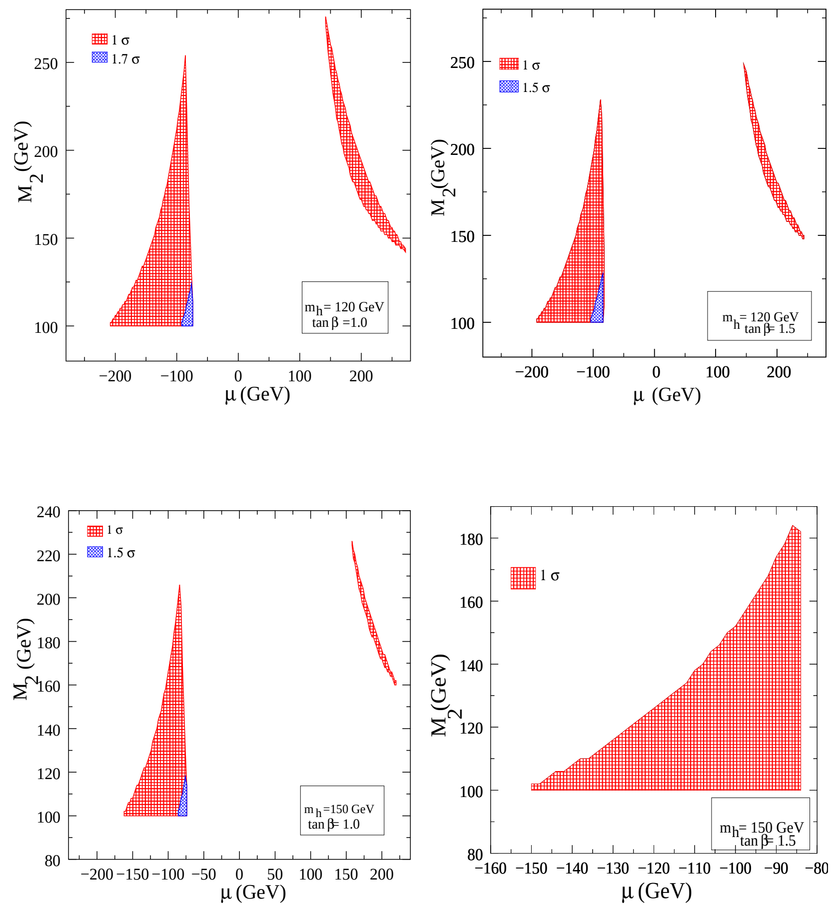


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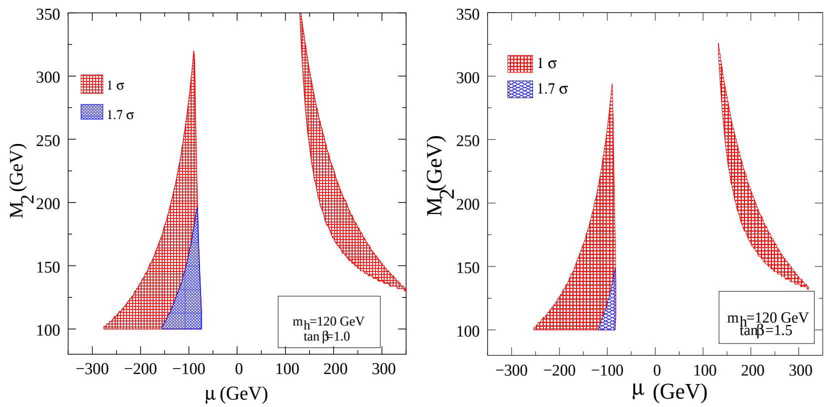

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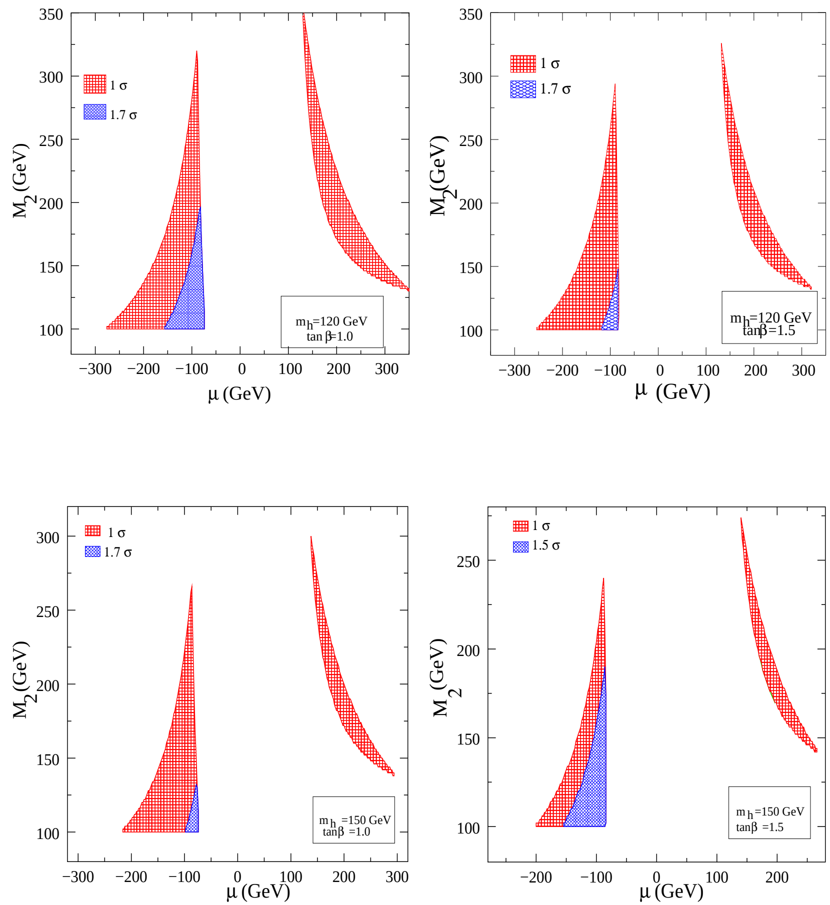


Allowed parameter space at various $\sigma$ levels due to projected uncertainty.

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THANK YOU!