Event Shape Variables in SUSY searches.

Dipan Sengupta
Work done in association with Monoranjan Guchait and R.M. Chatterjee
arXiv:1206.5770 and Phys.Rev. D84 (2011) 055010 ,(arXiv:1102.4785).

Tata Institute Of Fundamental Research

August 23, 2012

I Know What You Wanted Last Winter

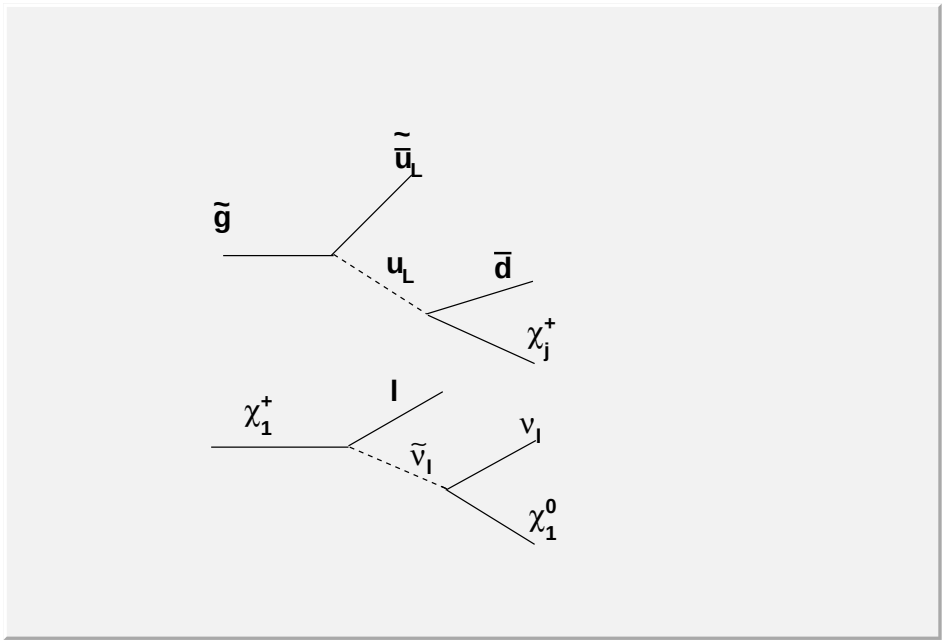
God's Dilemma

CMSSM/mSUGRA and its Parameters

- 4 Parameter + a sign constrained version mediated by gravity.
- Unification of soft gaugino masses to $m_{1/2}$ and SSB masses of all fermions and Higgs doublets to m_0, Common trilinear A_0, defined at GUT scale
- tanβ and $sgn\mu$ determined at electroweak scale.
- Assumed to conserve discrete R-parity $R_p = (-1)^{2S+L+3B}$ multiplicatively.Ensures a stable LSP as a Cold Dark Matter candidate.
- CMSSM is a Minimal flavor violating scenario.
- RGE running$\rightarrow$ $M_3 : M_2 : M_1 = g_3^2 : g_2^2 : \frac{5}{3} g_Y$ holds at all energies between weak scale and GUT upto two loops.
- $M_1(100GeV) \sim 0.41 M_{1/2}$, $M_2(100GeV) = 0.82 M_{1/2}$, $M_3(500GeV) \sim 2.6 M_{1/2}$;
- $M_{\tilde{g}}^{pole} \sim M_3(M_3)[1 + \frac{\alpha_3(M_3)}{4\pi}(15 + \Sigma ln \frac{m_{\tilde{q}}}{M_3})]$
- $M_{u_L}^2(500GeV) = m_0^2 + 5.6 M_{1/2}^2 + (\frac{1}{2} - \frac{2}{3} sin^2\theta_W) M_Z^2 cos2\beta$

Collider Searches: sParticle production and decay

- $$pp \quad \rightarrow \tilde{g}\tilde{g}, \tilde{q}\tilde{q} + \tilde{q}\tilde{q}^*, \tilde{g}\tilde{q},$$
  $$\rightarrow \tilde{t}_i\bar{\tilde{t}}_j, \tilde{b}_i\bar{\tilde{b}}_j : i,j = 1,2$$



- Vertices dependent on couplings $\rightarrow$ drives the phenomenology and generic signatures.

THE GENERIC SUSY SIGNAL

- $$pp \quad \rightarrow \tilde{g}\tilde{g}, \tilde{q}\tilde{q} + \tilde{q}\tilde{q}^*, \tilde{g}\tilde{q} \rightarrow m - leptons + n - jets + \not{p}_T$$
- High p_T and high multiplicity jets, leptons.
- LESSON $\rightarrow$ EXPLOIT TO DESIGN SUITABLE VARIABLES TO SUPRESS BACKGROUND.
- Existing search strategies by CMS and ATLAS, special techniques like α_T,razor,m_T^2 ... .
- Can we do better?
- Investigate 3 possible final states

$$\text{Single lepton}(e, \mu) + \text{jets} + \not{p}_T.$$
$$\text{dilepton} + \text{jets} + \not{E}_T.$$
$$\text{Jets} + \not{E}_T$$

- Look for regions of high multiplicity, jets , leptons, ..
- Typical Scenarios, gluino lighter than squarks. Low $m_{1/2}$, high m_0.
- Predomiant decay mode: $\tilde{g} \rightarrow tb\chi^{\pm}$

THE EVENT SHAPE ANALYSIS

- Transverse Thrust

$$T_T = max_{\vec{n}_T} \frac{\Sigma_i |\vec{p}_{T,i}.\vec{n}_T|}{\Sigma_i |\vec{p}_{T,i}|}$$

- Describes the geometry or shape of the event
  Infra red safe Variable.
  Ratio of quantities $\rightarrow$ less systematic errors.
  $T \backsimeq 1 \rightarrow$ pencil like dijet events. $\rightarrow$ PREDOMINANT IN BACKROUNDS
  $T < 1 \rightarrow$ isotropic multijet events. $\rightarrow$ PREDOMINAT IN SIGNAL

THE EVENT SHAPE ANALYSIS

- Transverse Thrust

$$T_T = max_{\vec{n}_T} \frac{\Sigma_i |\vec{p}_{T,i}.\vec{n}_T|}{\Sigma_i |\vec{p}_{T,i}|}$$

- Describes the geometry or shape of the event
  Infra red safe Variable.
  Ratio of quantities $\rightarrow$ less systematic errors.
  $T \backsimeq 1 \rightarrow$ pencil like dijet events. $\rightarrow$ PREDOMINANT IN BACKROUNDS
  $T < 1 \rightarrow$ isotropic multijet events. $\rightarrow$ PREDOMINAT IN SIGNAL
-

$$R_T = \frac{\Sigma_{i=1}^{n_{jsel}} p_T^i}{H_T}$$

  Variable dependent on Jet Multiplicity and Jet Hardness.
  SUSY $\rightarrow$ Hard multijet events as compared to Background.
  Specially effective in suppressing multijet background processes like $t\bar{t} + jets$, $Z + jets$, $W + jets$
  Ratio of quantities $\rightarrow$ less systematic errors.
- $m_T^{j_1 j_2} = \sqrt{p_T^{j_1} p_T^{j_2} \times (1 - cos\phi)}$.

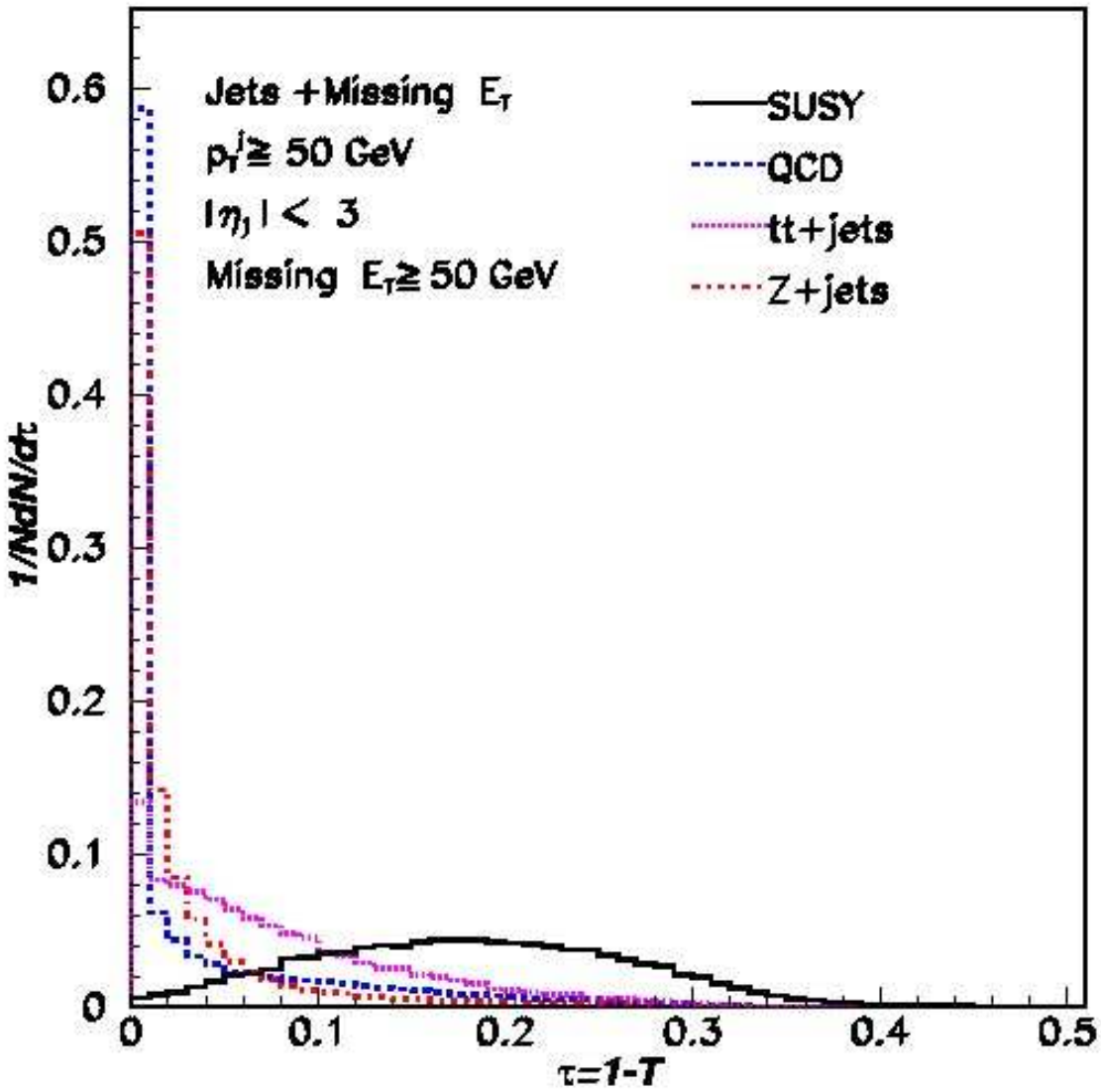


Figure: Distribution of$\tau = 1 - T$

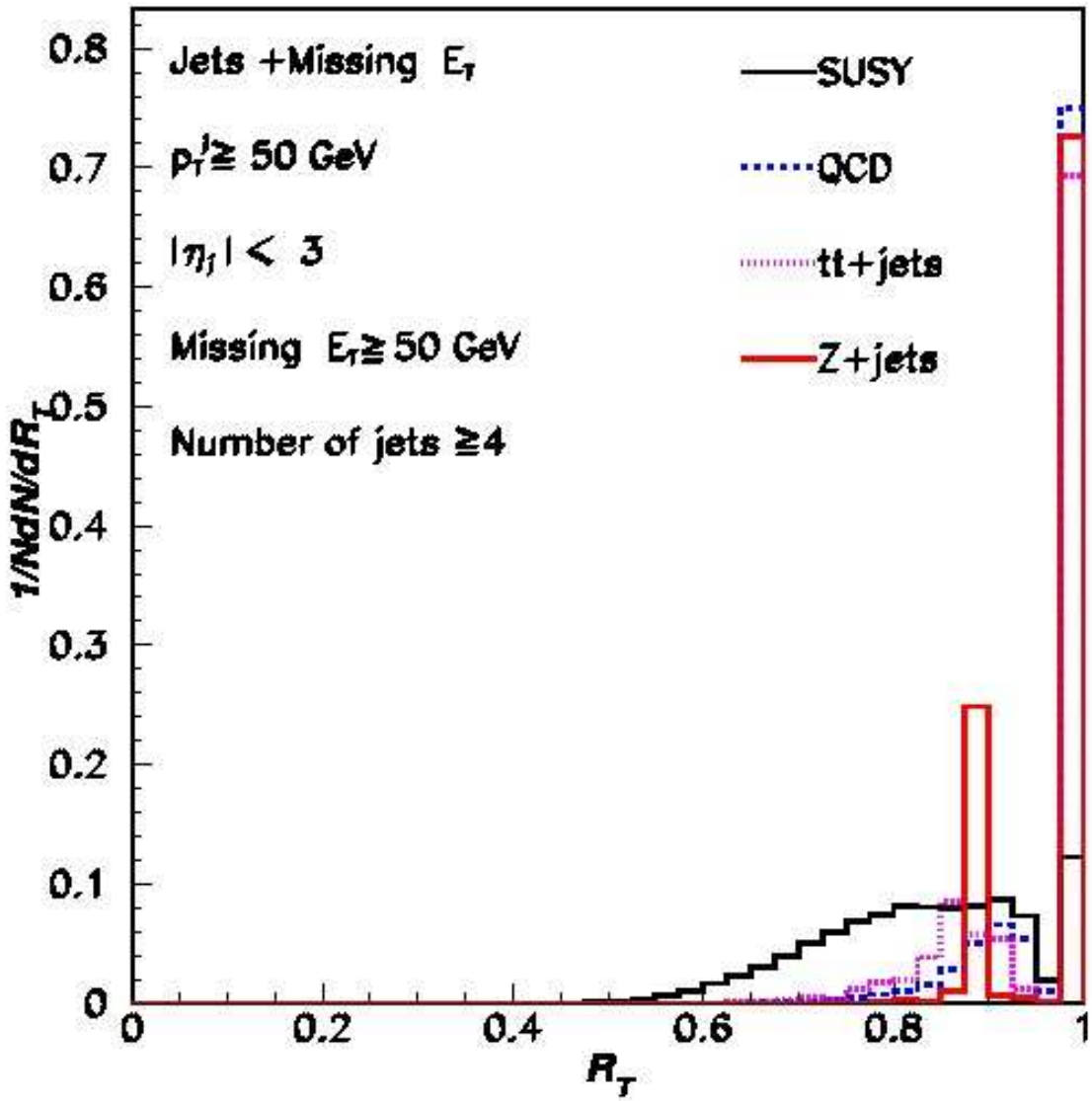


Figure: R_T distribution

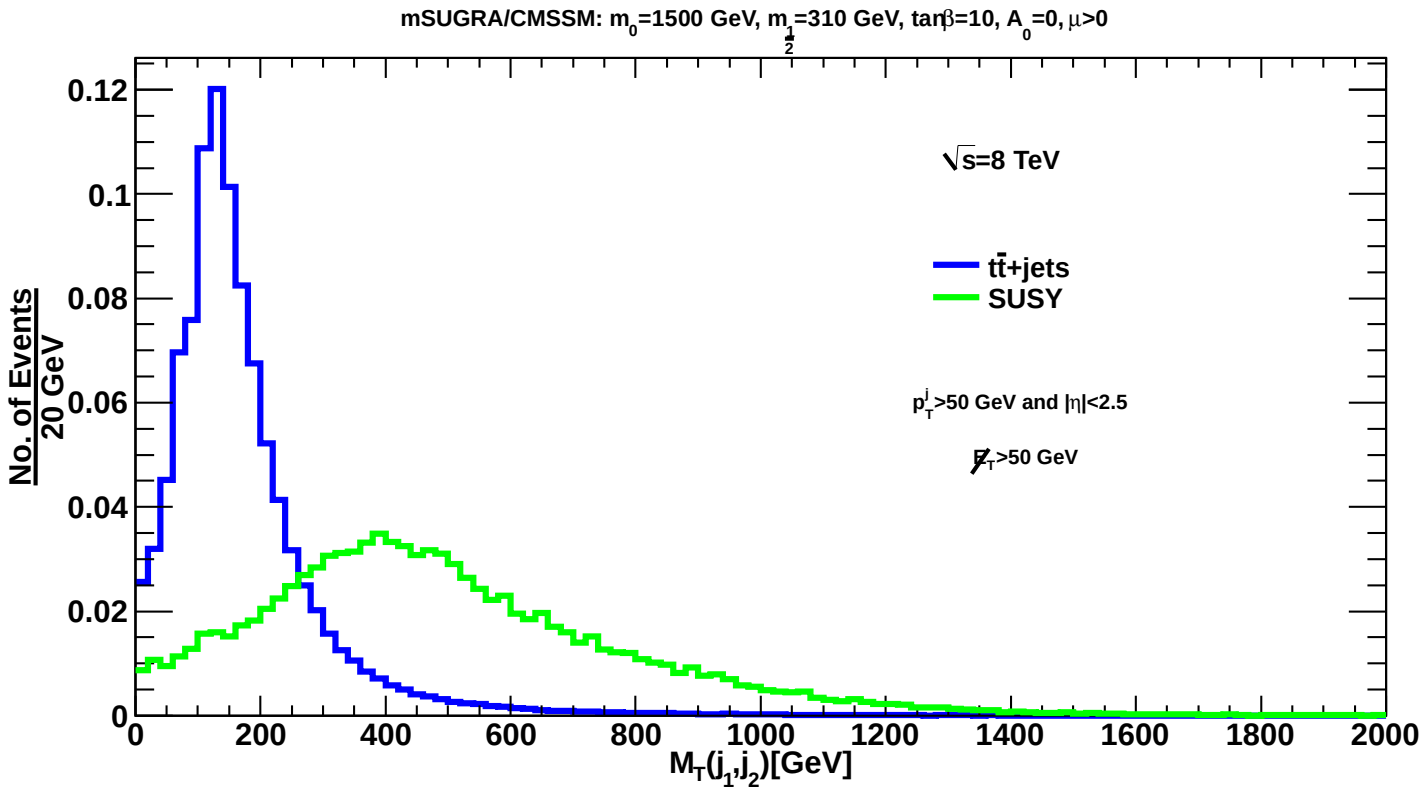


Figure: m_T distribution

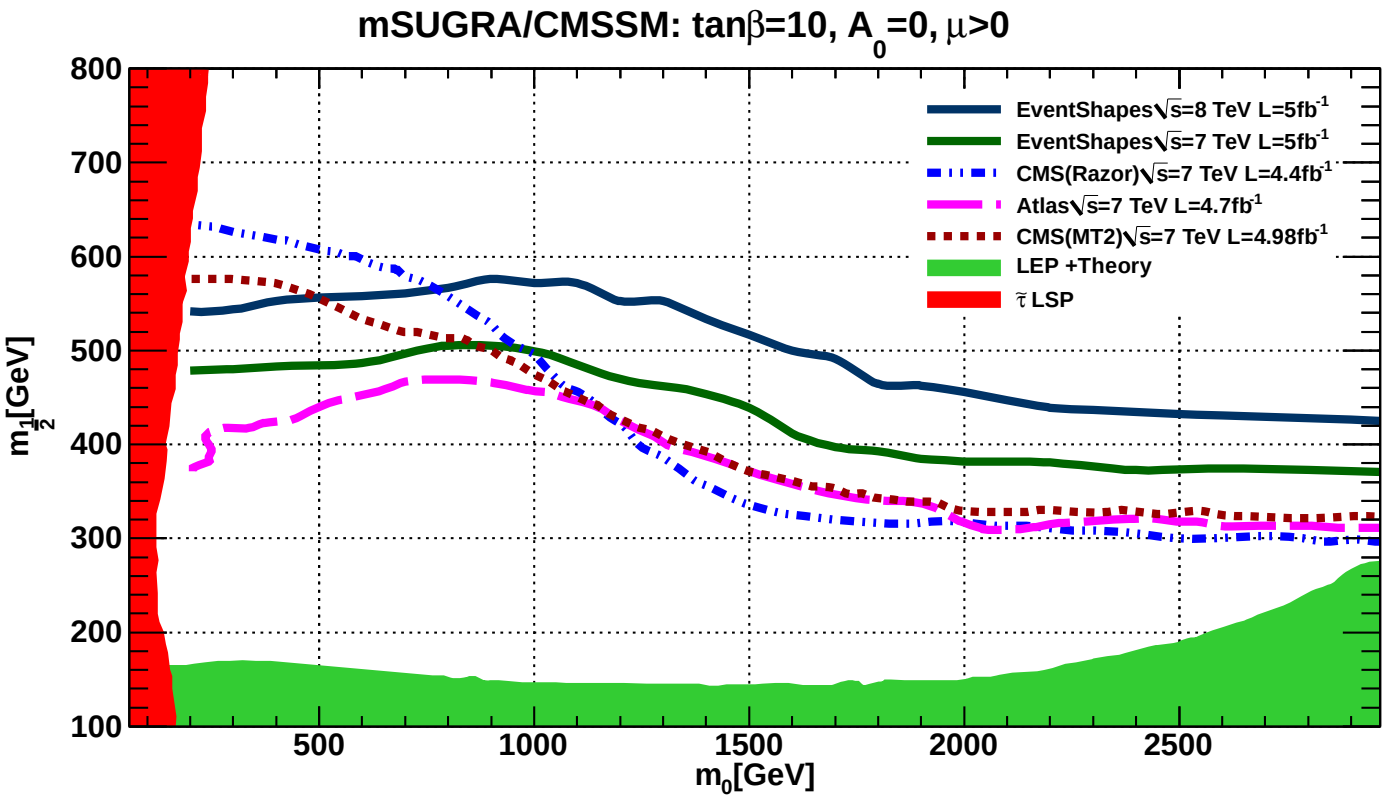


Figure: Discovery Reach in the $m0 - m1/2$ plane

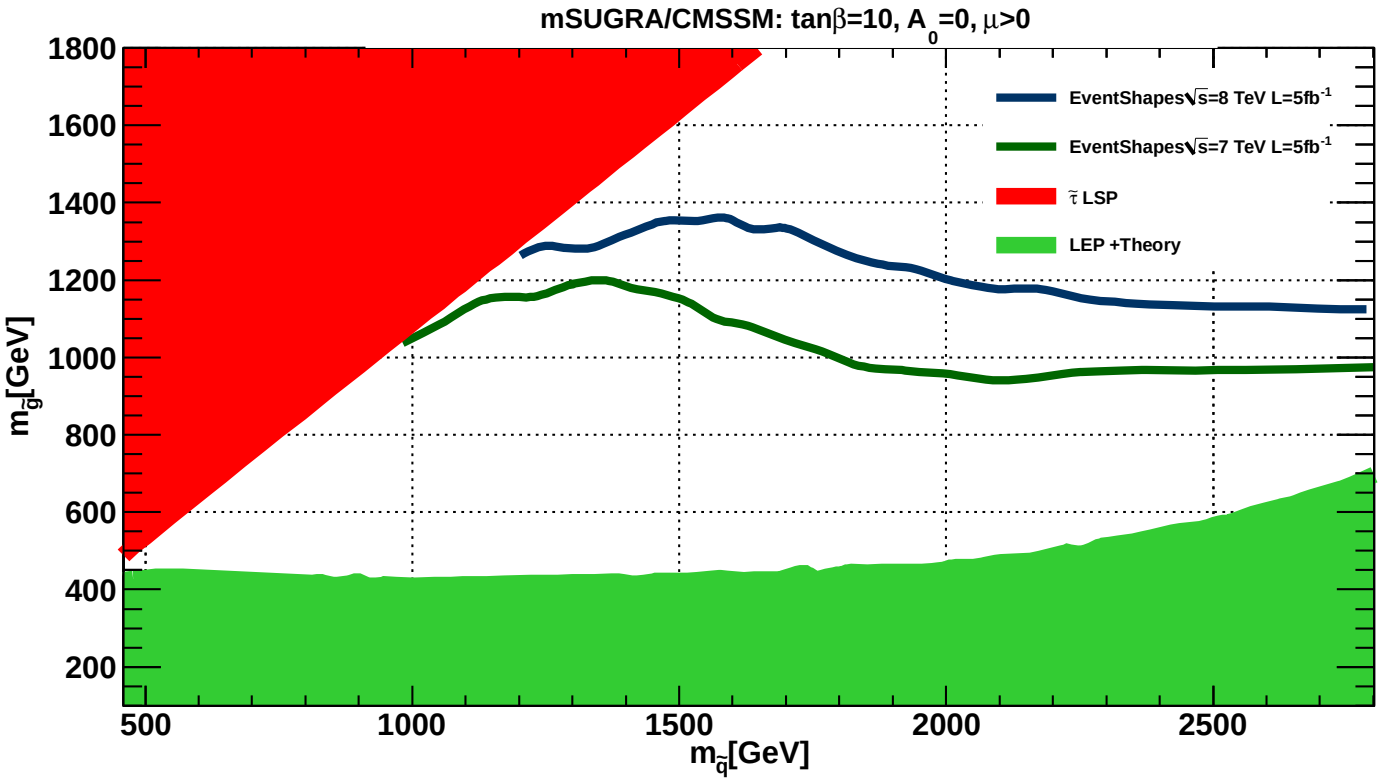


Figure: Discovery Reach in the $m_{\tilde{g}} - m_{\tilde{q}}$ plane

CONCLUSION

- We are in an era where BSM physics is put to severe test.
- Supersymmetry in particular CMSSM is being constrained from direct collider searches as well as indirect searches.
- Important to cover more parameter space , look for ways of increasing signal sensitivity.
- Collider ruled out regions have already been ruled out by indirect searches.
- We have proposed a new search strategy which covers more ground in the search of SUSY.
- Negligible Backgrounds, discovery Signal cross section limited.
- Variables dimensionless , Less systematics , easily implementable in experiments.
- Also important to look at models beyond CMSSM, specially relevant to dark matter searches.
- Continue constraining CMSSM, from flavor , dark matter constraints.

CONCLUSION

- We are in an era where BSM physics is put to severe test.
- Supersymmetry in particular CMSSM is being constrained from direct collider searches as well as indirect searches.
- Important to cover more parameter space , look for ways of increasing signal sensitivity.
- Collider ruled out regions have already been ruled out by indirect searches.
- We have proposed a new search strategy which covers more ground in the search of SUSY.
- Negligible Backgrounds, discovery Signal cross section limited.
- Variables dimensionless , Less systematics , easily implementable in experiments.
- Also important to look at models beyond CMSSM, specially relevant to dark matter searches.
- Continue constraining CMSSM, from flavor , dark matter constraints.