Searching for octet scalars in the ttbar channel at the LHC

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based on work by S.Y. Choi, M. Drees, J. Kalinowski, J.M. Kim, E. Popenda, P.M. Zerwas, Phys.Lett.B672:246-252,2009 [arXiv:0812.3586]

Motivation

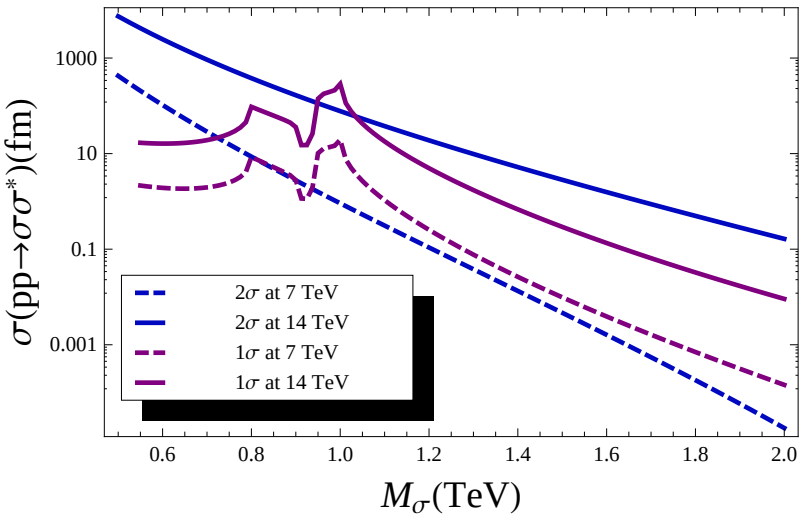
Large interest in the colored sector at the LHC

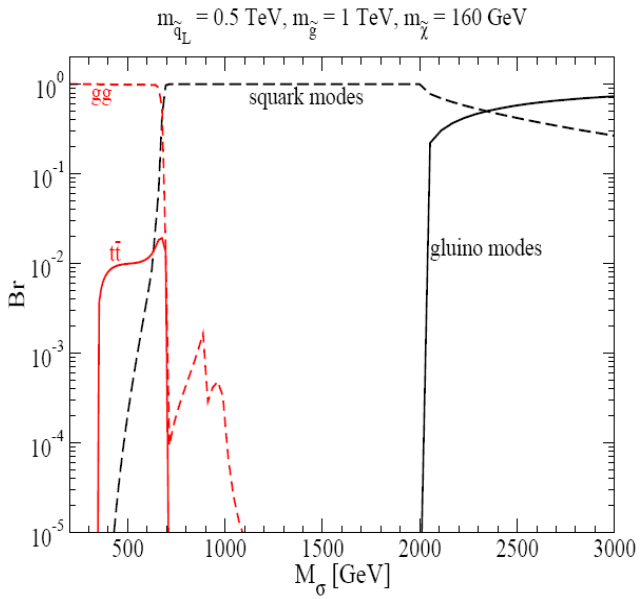
- Gerbush, M. and others - *Color-octet scalars at the LHC* [arXiv:0710.3133] - analysis of experimental signature for production of scalar pair
- Fileviez - Perez, P. and Wise, Mark - *On the Origin of Neutrino Masses* [arXiv:0906.2950] - color octet scalars, charged under $SU(2)_L$, as a source of neutrino masses
- Gresham, M. and Wise, M. - *Color Octet Scalars Production at the LHC* [arXiv:0706.0909] - single scalar one-loop production
- Fileviez - Perez, P. and others - *Grand Unification and Light Color-Octet Scalars at LHC* [arXiv:0809.2106] - color octet scalars in the context of SU(5) GUT
- Choi, S. Y. and others - *Color-octet Scalars of $N = 2$ Supersymmetry at the LHC* [arXiv:0812.3586] - scalars and their partners, gauginos
- Han, T. and others - *Colored Resonant Signals at the LHC: Largest Rate and Simplest Topology* [arXiv:1010.4309]
- Idibi, A. and others - *Pair Production of Color-Octet Scalars at the LHC* [arXiv:1007.0865]
- Bai, Y. and Dobrescu, B. - *Heavy octets and Tevatron signals with three or four b jets* [arXiv:1012.5814]
- Dicus, D. and others - *Discovering Colorons at the Early Stage LHC* [arXiv:1012.5694]

Features of color octet scalars (σ)

- large production cross section at the LHC
  direct coupling to gluons, strong coupling constant, color factor
- pair production is (almost) model independent

plots for model defined in [arXiv:0812.3586]

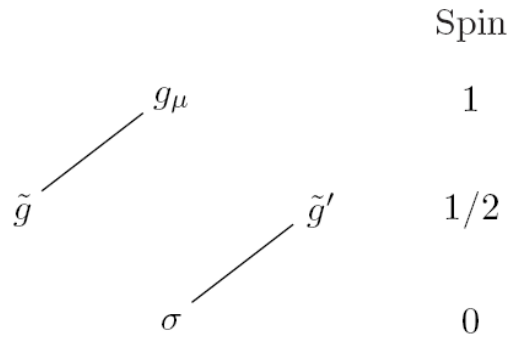




- single σ production, through loop - diagrams, can also be large
- at 7 TeV at the LHC pair production is greatly reduced, resonant not (so much)
- gluon decay modes (dominant in the above scenario) will suffer from large QCD background
- another possibility: decay to ttbar channel - spectacular signature: 4t jets from pair production, 2t from resonant one if $br(\sigma \to ttbar)$ can be enhanced without killing production cross section (subject of this talk)

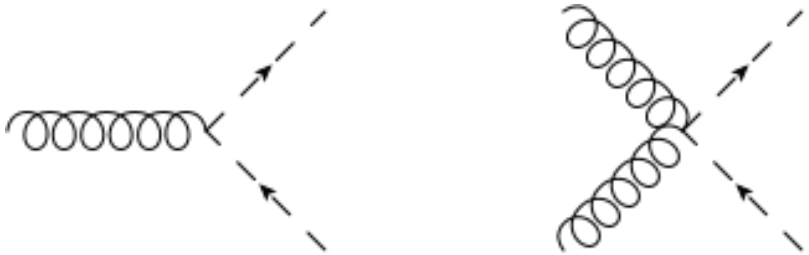
Supersymmetric $N = 1/N = 2$ hybrid model

- extension of MSSM: gluon/gluino $(g^\mu, \tilde{g})$ accompanied by chiral superfield $(\tilde{g}', \sigma)$ in adjoint representatnion of $SU(3)_C$

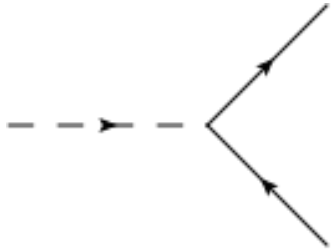


- this forms complete $N = 2$ vector-multiplet
- with proper choice of gluino mass matrix one can get Dirac-type gluino $\tilde{g}_D$ of mass $|M_3^D|$ (motivation of work arXiv:0812.3586)
- $N = 2$ mirror (s)fermions are assumed to be heavy (to avoid chirality problem)
- interesting features of the electroweak sector of this model (not to be discussed here)

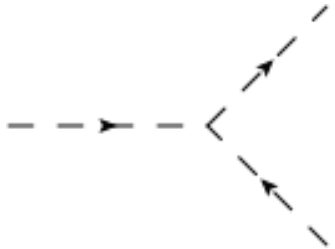
σ couplings



- $g(g)\sigma\sigma$ coupling as required by gauge invariance

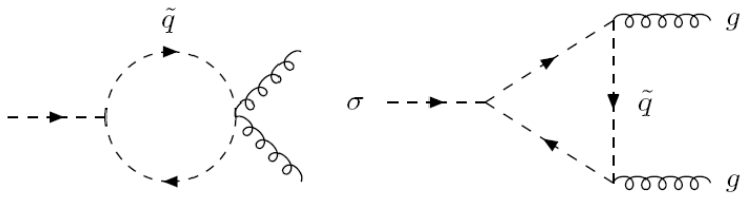


- $\tilde{g}_D\tilde{g}_D\sigma$ coupling also as required by gauge invariance



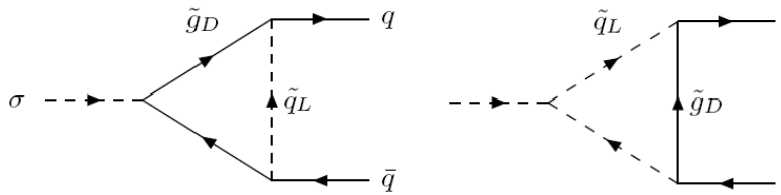
- $\tilde{q}\tilde{q}\sigma$ coupling proportional to $\pm|M_3^D|$ for L/R fermions
- $qq\sigma$ coupling is absent (σ couples to mirror fermions which are assumed to be heavy)
- coupling to gluons and squarks induce σgg and σqq couplings via loops

σ loop-induced decays



$$\Gamma(\sigma \to gg) = \frac{5\alpha_s^2}{384\pi^2}\frac{|M_3^D|^2}{M_\sigma}\left|\sum_q (\tau_{\tilde{q}_L} f(\tau_{\tilde{q}_L}) - \tau_{\tilde{q}_R} f(\tau_{\tilde{q}_R}))\right|^2$$

- grows quadratically with $|M_3^D|$ (no hidden dependence on $|M_3^D|$ in loop-functions)

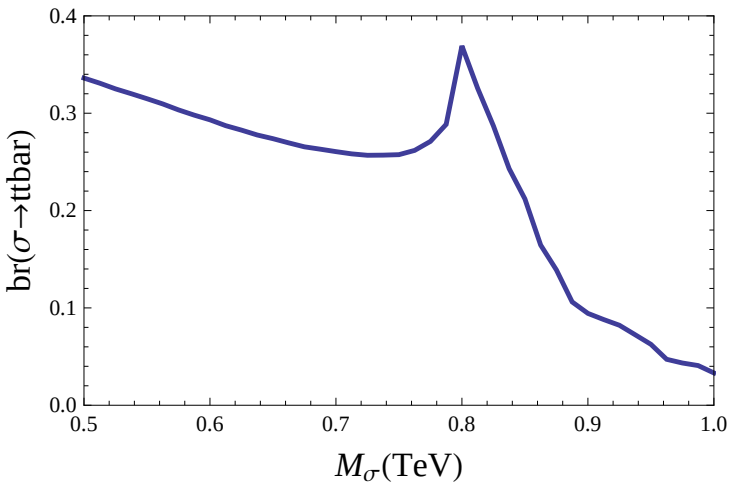


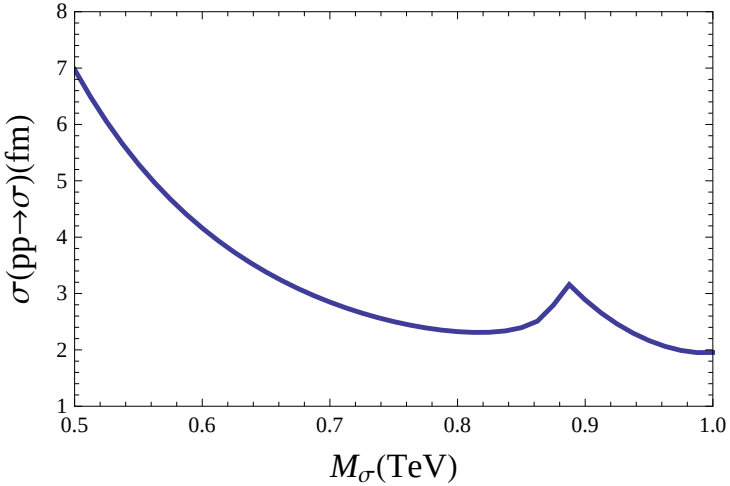
$$\Gamma(\sigma \to q\bar{q}) = \frac{9\alpha_s^3}{128\pi^2}\frac{|M_3^D|^2 m_q^2}{M_\sigma}\sqrt{1-\frac{4m_q^2}{M_\sigma^2}}\left[(M_\sigma^2 - 4m_q^2)|\mathcal{I}_\mathcal{S}|^2 + M_\sigma^2|\mathcal{I}_\mathcal{P}|^2\right]$$

- complicated expression, drops with increasing $|M_3^D|$
- $\Gamma(\sigma \to q\bar{q}) \backsim m_q^2$ - decay channel important only for top quarks
- both channels vanish for degenerate squarks

Single sigma production at the LHC

- competition between cross section and $br(\sigma \rightarrow ttbar) \rightarrow$ optimum parameters: $m_{\tilde{q}_L} = 1\,TeV$, $m_{\tilde{t}_L} = 0.9\,TeV$, $m_{\tilde{t}_R} = 0.44\,TeV$, $m_{\tilde{g}_D} = 0.4\,TeV$





Observations:

- increasing ttbar branching ratio reduces single sigma production cross section (only few signal events expected)
- however we can still exploit relatively large 2σ production cross section
- large p_T of top jets coming from signal
- detailed simulations are required to assess the observability of the signal (including t-decays)

Summary

- large interest in color-octet scalars
- they appear naturally in extended susy models
- Dirac gauginos (we didn't discuss here their impact on dark matter)
- distinctly different signature from the MSSM
- simulations required (work in progress)