Effects of electroweak contributions to squark pair production at the LHC

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in collaboration with
Bornhauser, Drees, Dreiner, Kim [Phys. Rev. D76, 2007, Phys. Rev. D80:09500, 2009]
Bornhauser, Drees, Grab, Kim [work in progress]

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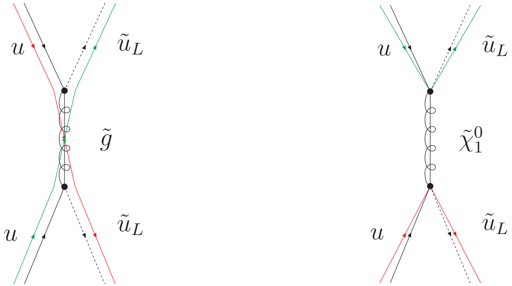
Outline

1. EW contributions to squark pair production
   - Role of EW contributions
   - Results
2. Rapidity gap events
   - Basic idea of a rapidity gap
   - Caveats of rapidity gap events
   - Results
3. Stop searches with two b jets and missing energy
   - $pp \to b\bar{b}\tilde{t}_1\tilde{t}_1^*$
   - Preliminary results
4. Summary

EW contributions @ LO

- Detection of squarks might be around the corner!
- EW contributions to $\sigma(\tilde{q}\tilde{q})$ @ LO



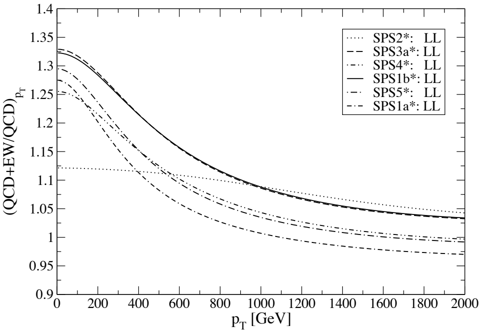
(a) (b)

Numerical results

- EW contributions enhance $\sigma(\tilde{q}_L\tilde{q}_L)$ up to 20% in mSUGRA
- SU(2)–contributions are significant
- Interference between EW t– and QCD u–channel is dominant
- $|\mathcal{M}_{\rm interference}(\tilde{q}_L\tilde{q}_L)|^2 \propto m_{\rm gaugino}$
- EW contributions can exceed 50% in SUGRA

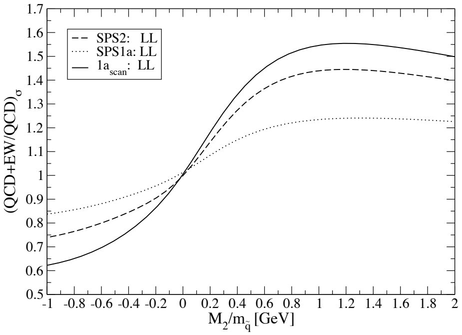
Scenario	m_0 GeV	$m_{1/2}$ GeV	$m_{\tilde{q}}$ GeV	$\sigma_{\rm QCD}$ in pb Total	LL	$\sigma_{\rm QCD+EW}$ in pb Total	LL	ratio Total	LL
SPS 1a	100	250	560	12.11	3.09	12.55	3.50	1.036	1.133
SPS 1b	200	400	865	1.57	0.42	1.66	0.499	1.055	1.186
SPS 2	1450	300	1590	0.0553	0.0132	0.0567	0.0144	1.025	1.091
SPS 3	90	400	845	1.74	0.464	1.83	0.551	1.055	1.188
SPS 4	400	300	760	3.10	0.813	3.22	0.927	1.040	1.141
SPS 5	150	300	670	5.42	1.41	5.66	1.62	1.042	1.152

p_T dependence



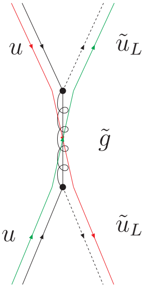
- In mSUGRA, $M_1 : M_2 : M_3 = 1 : 3 : 6$
- EW contributions dominant for $p_T \ll m_{\tilde{q}}$

Gaugino mass dependence

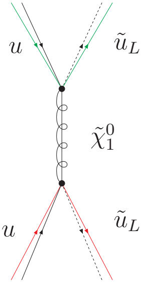


- Final state $\tilde{q}_L \tilde{q}_L$ requires helicity flip
- EW contributions become maximal for $M_2 = m_{\tilde{q}}$

Rapidity gap events in squark pair production



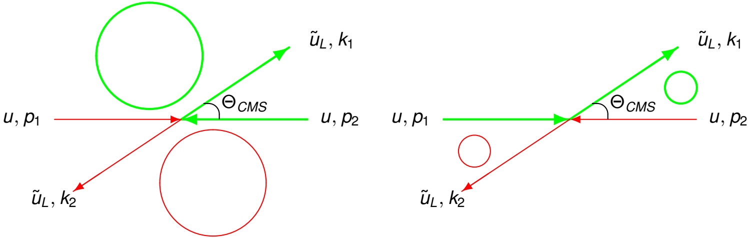
(c) color connected



(d) not color connected

- Color octet exchange: QCD radiation between the two outgoing squarks
- Color singlet exchange: QCD radiation between the squarks and the beam remnants

Classical picture: accelerated color charge



- Small Θ_{CMS} dynamically preferred in t-channel contribution
  $\Longrightarrow$ color connected: Bremsstrahlung gluons emitted over most of rapidity region
  $\Longrightarrow$ non color connected: Bremsstrahlung only populate a small region in rapidity

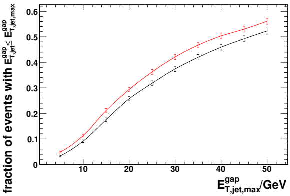
Caveats of rapidity gap events

- Signal: Two energetic jets with little hadron activity in gap region
- Caveats:
  - Color connected events can fake rapidity gap events
  - Interference between color connected and not color connected diagrams
  - Decay products in the gap region
  - ISR, FSR and UE fill up the gap region
  - Uncertainties of the MC generators

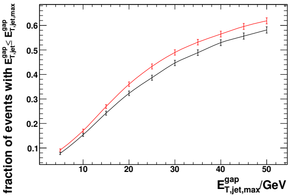
Preliminaries

- mSUGRA ($m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $m_{\tilde{q}} \approx 560$ GeV)
- 14 TeV @ LHC and $\mathcal{L} = 40\,\mathrm{fb}^{-1}$
- SUSY QCD contribution to squark pair production is dominant background
- Cuts
  - $E_{\mathrm{T}}^{\mathrm{jets}} \geq 100\,\mathrm{GeV}$ and $|\eta_j| \leq 5.0$
  - $\Delta\eta_{j_1,j_2} \geq 3.0$
  - At least two leptons of SS
  - $p_{T_{\mathrm{min}}}^{\mathrm{lepton}} = 5$ GeV and $|\eta^{\mathrm{lepton}}| \leq 2.4$
  - $E_{\mathrm{T}}^{\mathrm{miss}} \geq 200\,\mathrm{GeV}$
- Most of the final leptons are τ's at our mSUGRA point
- Assume $\epsilon_{\tau-\mathrm{tagging}} = 1$

Jet–in–the–gap cross section



(e) Herwig++



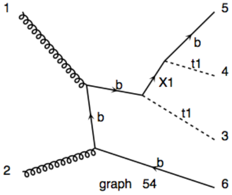
(f) PYTHIA6.4

- Fractions of events where most energetic jet in the gap region has $E_T \leq E_{T,jet,max}^{gap}$
- Jets with $E_T \geq 5$ GeV $\Longrightarrow$ cut against UE
- 5σ effect for $E_{T,jet,max}^{gap} = 30$ GeV

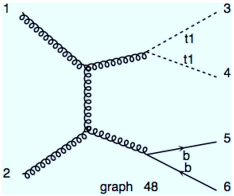
Results

- Pythia QCD prediction is larger than Herwig++ QCD–EW prediction
  $\Longrightarrow$ current theoretical error cannot be estimated
- Both MC's can be tuned by SM-dijet events
- Gives handle to separate EW & QCD SUSY
- Reconstruction of SUSY EW couplings

Signal process and mass spectrum



(g)



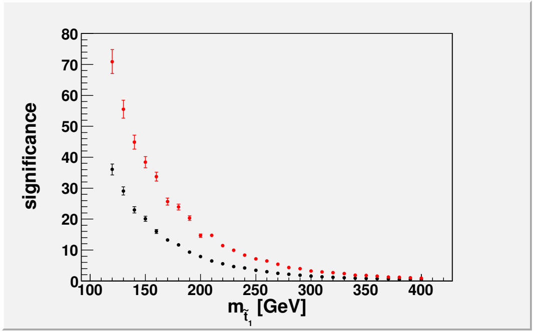
(h)

- Final state $b\bar{b}\tilde{t}_1\tilde{t}_1^*$ with $\tilde{t}_1 \to c\tilde{\chi}_1^0$
- Main contribution from higgsinolike on–shell chargino with $\tilde{\chi}_1^+ \to \tilde{t}_1\bar{b}$
- $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \approx 20$ GeV, $m_{\tilde{\chi}_1^+} - m_{\tilde{t}_1} \approx 20$ GeV
- Remaining sparticles are decoupled

Preliminaries

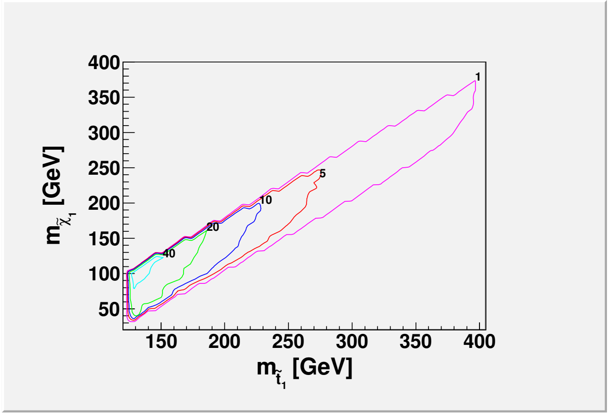
- Backgrounds
  - $t\bar{t}$
  - single t
  - $Wb\bar{b}$
  - $Z\bar{b}b$
- Cuts
  - Isolated lepton veto
  - Require two b-jets
  - $p_T(b1) > 150$ GeV, $p_T(b2) > 50$ GeV and $|\eta_b| < 2.5$
  - $\not{p}_T > 200$ GeV
  - Charge multiplicity > 10
  - $p_T(b1)/\not{p}_T < 1.2$
- $\epsilon_{b-\mathrm{tagging}} \approx 0.6$

Significance



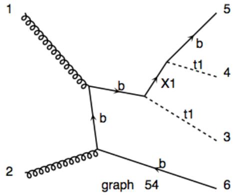
- Significance for $\mathcal{L} = 100\,\mathrm{fb}^{-1}$ @ LHC with $\sqrt{s} = 14$ TeV
- Significance is greatly enhanced

$m_{\tilde{\chi}_1^0}$-$m_{\tilde{t}_1}$-plane

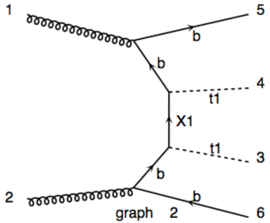


- Significance in the $m_{\tilde{\chi}_1^0}$-$m_{\tilde{t}_1}$ plane
- Provide an alternative discovery channel to detect $\tilde{t}_1$ with $\tilde{t}_1 \to c\tilde{\chi}_1^0$

Determination of the higgsino coupling



(i)



(j)

- Reconstruction of the higgsino-coupling $\tilde{\chi}_1^+ - \tilde{t}_1 - \bar{b}$
- $\tilde{t}_1\tilde{t}_1^* j$ can be used to extract EW coupling from $b\bar{b}\tilde{t}_1\tilde{t}_1^*$
- Theoretical errors, e. g. pdf uncertainties, must be estimated

Summary

- EW contributions @ LO enhances cross section up to 50%
- Rapidity gap events separate the SUSY EW from SUSY QCD contribution
- EW enhancements of $b\bar{b}\tilde{t}_1\tilde{t}_1^*$
- Alternative stop search via b-jets and missing energy
- Determination of SUSY EW coupling might be possible, e.g. the $\tilde{t}_1\tilde{t}_1^* b\bar{b}$ channel $\rightarrow \tilde{\chi}_1^+ - \tilde{t}_1 - b$ coupling