Rapidity Gap Events for Squark Pair Production at the LHC

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Outline

Squark Pair Production at the LHC

- Low energy supersymmetry will be tested at LHC
- squark pair production is one of the most important discovery channel
- even heavy squarks have large production cross section due to:
  - cross section is $\mathcal{O}(\alpha_s^2)$
  - there are final states configurations, where initial states are valence quarks

for degenerate 1st and 2nd generation of squarks:

$$\begin{aligned} m_{\tilde{q}} &\approx 1000\,\mathrm{GeV} \\ \sigma &\approx 0.5\,\mathrm{pb} \\ \mathcal{L} &\approx 10\,\mathrm{fb}^{-1}\ \mathrm{per\,year} \\ N_{\mathrm{events}} &= \mathcal{L}\,\sigma \end{aligned}$$

$\Rightarrow$ 5000 events are expected at low luminosity

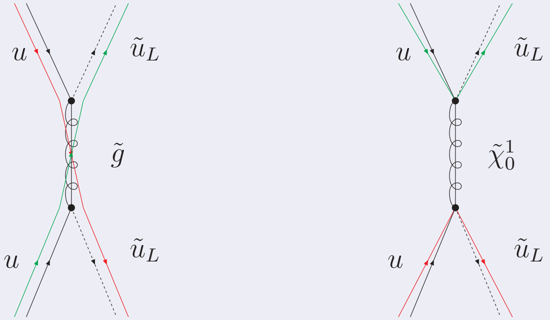
Role of electroweak contributions

- it is important to know the squark pair production cross section with high precision
- NLO QCD correction were calculated in 1995
- correction were up to 20 % and remaining uncertainty is about 10 % level for higher QCD corrections
- we included EW contributions at leading order [Physical Review D76, 2007]

Results of electroweak contributions for squark pair production

- contributions from interference between QCD & EW is dominant
- in mSUGRA, EW contributions enhance cross section for two left-handed squarks up to 20%
- the pure QCD cross section can be enhanced up to 50% in models without assuming gaugino mass unification
- EW contributions can give rise to rapidity gap events

The basic idea of rapidity gap events

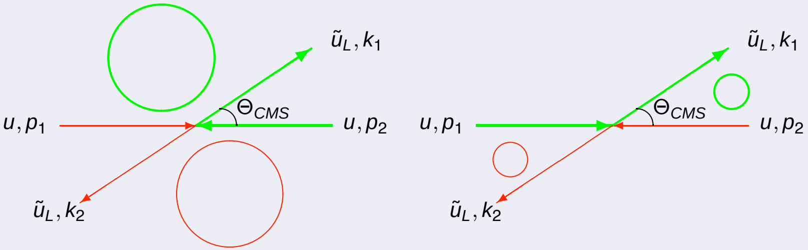


(a) color connected

(b) not color connected

- color connected: QCD radiation between the two outgoing squarks
- not color connected: QCD radiation between the squarks and the beam remnants
- EW channels provide not color connected contributions

Picture of accelerated charge

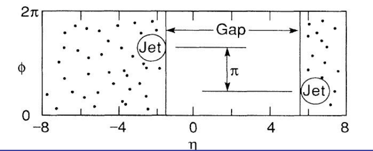


- small Θ_{CMS} dynamically preferred
  $\Longrightarrow$ color connected: bremsstrahlung gluons emitted over most of rapidity region
  $\Longrightarrow$ non color connected: bremsstrahlung only populate a small region in rapidity

Rapidity gap events in a simplified picture

- two high energetic jets from squark decays and subsequent fragmentation
- in not color connected (EW) events $\Longrightarrow$ rapidity region free of energy deposit

$\Longrightarrow$ **Rapidity Gap Event**



Some 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 underlying event (UE) can fill up the gap region

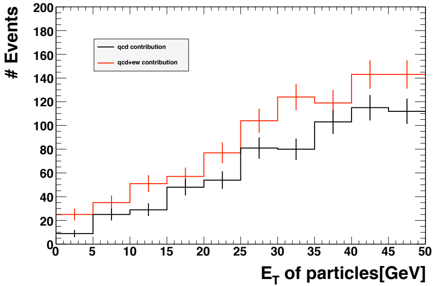
Preliminaries for numerical simulation:

- mSUGRA ($m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $m_{\tilde{q}} \approx 560$ GeV) mass spectrum is assumed
- cross section for production of left-handed squarks is enhanced by a factor of 13% by EW contributions
- right-handed squark decays into lightest neutralino
- left-handed squarks squark decays into heavier neutralino/chargino, latter decaying leptonically

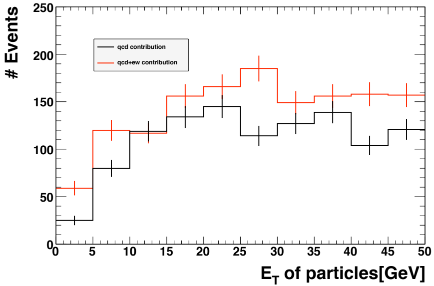
Cuts

- $E_{\mathrm{T}}^{\mathrm{jets}} \geq 100\,\mathrm{GeV}$ and $E_{\mathrm{T}}^{\mathrm{miss}} \geq 200\,\mathrm{GeV}$
- jets must be well separated in rapidity $\Longrightarrow \Delta\eta \geq 3.0$
- EW contributions are much smaller for right-handed squarks in final states
  $\Longrightarrow$ isolate left-handed squarks by requiring at least two charged leptons of SS

E_T of all particles in the gap region



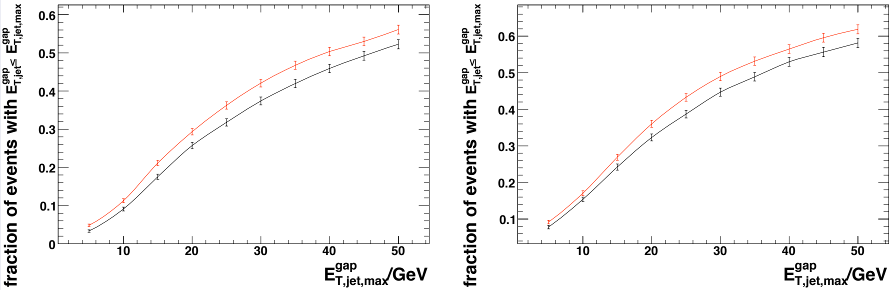
(c) Herwig++



(d) PYTHIA6.4

- fully inclusive quantity
- first bin is statistically significant
- PYTHIA6.4 QCD prediction is larger than Herwig++ EW prediction
  $\Longrightarrow$ current theoretical error cannot be estimated
  $\Longrightarrow$ **significant differences between the MCs**

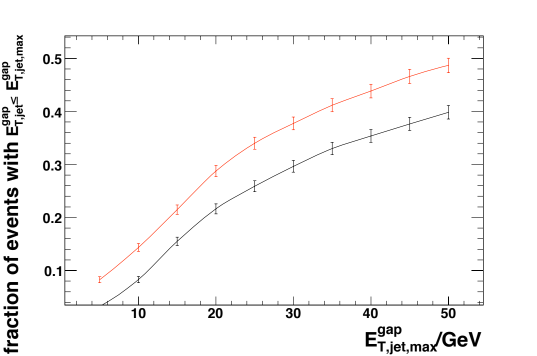
Minijet-veto against underlying event



(e) Herwig++ (f) PYTHIA6.4

- consider exclusive observable
- number of events where most energetic jet in the gap region has $E_T \leq E^{gap}_{T,jet,max}$ (normalized to one)
- consider only jets with $E_T \geq 5$ GeV $\Longrightarrow$ cut against UE
- nearly all bins statistically significant effect of EW contribution

Tuning with SM QCD



(g) red: PYTHIA and black: Herwig++

- Herwig++ vs. PYTHIA6.4: theoretical error larger than the physical ones
- generate SM dijet events
- same systematical differences between the generators
- reduction of systematical differences after tuning with SM data

Conclusion:

- squark pair production will be important; determination of the production cross section with high precision necessary
- even leading order EW contributions are important
- EW contributions give rise to rapidity gap events
- observable I: E_T deposit in rapidity gap region
- observable II: minijet-veto in gap region
- Herwig++ vs. PYTHIA: systematical differences larger than the physical ones
- reduction of the systematical differences might be possible after tuning with SM data
- an independent handle to search for supersymmetric events