Physics Beyond the Standard Model

Exercise Sheet 9 - Solutions

Aufgabe 1: Gluinos and squarks at the LHC

- The exclusion regions depend strongly $m_{1/2}$ but only weakly on m_0. In general,small values of $m_{1/2}$ are best suited for finding SUSY. In combined searches ($0l$+$1l$+ 2OS) squarks up to 2.5TeV can be found for all values of m_0 and $m_{1/2}$. The gluino masses are almost independent of m_0. For large m_0 it is not possible to find gluinos with masses above 2.5 TeV. In general the cross-sections are larger for smaller SUSY masses.

- We use the approximate expression for the SUSY masses.

  Sfermions: $m_{\tilde{f}}^2 = \alpha M_0^2 + \gamma M_{1/2}^2 + \ldots$
  $\rightarrow$ Ellispse with centre at$(m_{1/2}, m_0) = (0, 0)$

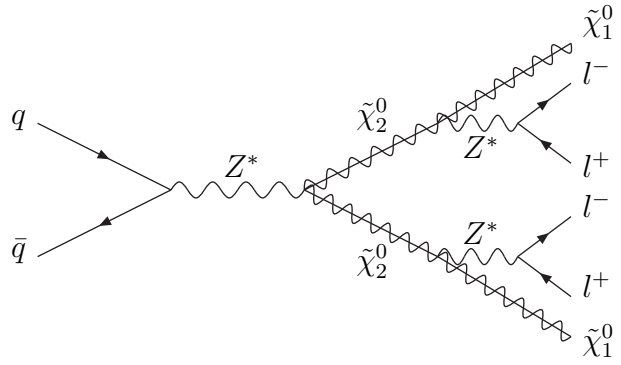
  Gauginos: $M_1 = M(\tilde{\chi}_1^0) \sim \frac{1}{2} m_{1/2}$
  $M_2 = M(\tilde{\chi}_2^0) \sim (\tilde{\chi}_1^{\pm}) \sim m_{1/2}$
  $M_3 = M(\tilde{g}) \sim 3m_{1/2}$

  How would the plot look for $\tan\beta = 5$?

- Sfermions: The masses are only weakly dependent on β as these terms are proportional to M_Z
$$m_{\tilde{f}} = \alpha M_0^2 + \gamma M_{1/2}^2 + \lambda M_Z^2 \cos 2\beta.$$
  $\tan\beta = 30(5) \Rightarrow \beta = 88.3°(78.7°) \Rightarrow \cos 2\beta = -1.00(-0.92)$
  $\Rightarrow m_{\tilde{f}}$ decreases (increases) for larger $\tan\beta$, if λ is positive (negative).

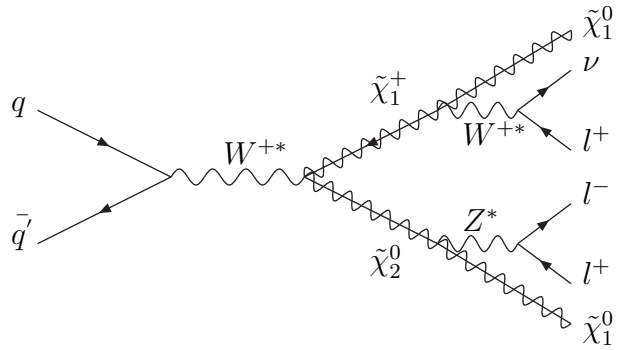
- Gluino: The gluino mass depends on the unification mass $M_3 \sim 3m_{1/2}$. However, this is a running parameter, therefore there are corrections, which dependon the sfermion masses. The gluino mass therefore has a non-trivial dependence β.

- Feynman diagrams:
  - Possible process with $4l$ final state



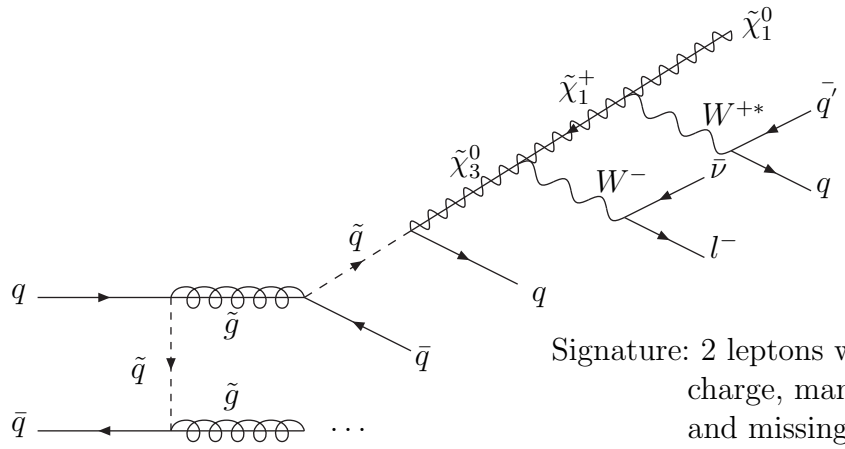
signature: 4 leptons and missing energy

  - Possible process with $3l$ final state



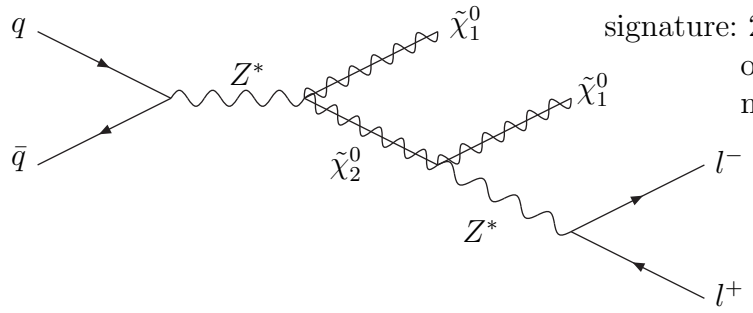
Signature: 3 leptons and missing energy

  - possible process with $2l$ final state with same charge



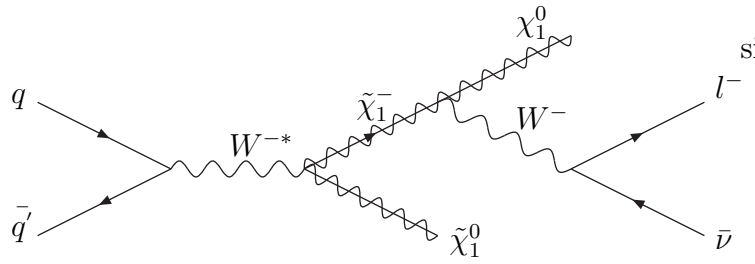
Signature: 2 leptons with same charge, many jets and missing energy

– Possible process with $2l$ final state with opposite charge



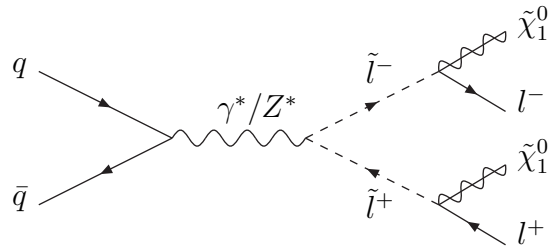
signature: 2 leptons with opposite charge and missing energy

– possible process with $1l$ final state



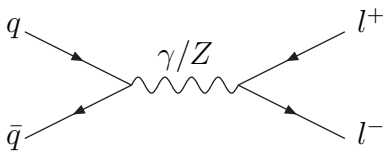
signature: 1 lepton and missing energy

Aufgabe 2: Slepton search

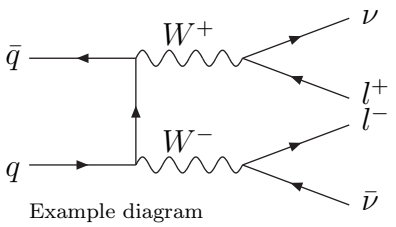
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- signature: 2 leptons and missing energy

- Background:
  - Drell-Yan: $pp \to l^+l^-$

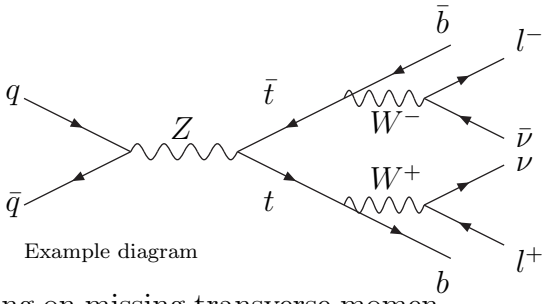


  - W pair production: $pp \to W^-W^+ \to l^+\nu l^-\bar{\nu}$



Example diagram

  - $t\bar{t}$ production: $pp \to t\bar{t} \to bl^+\nu\bar{b}l^-\bar{\nu}$



Example diagram

- The Drell-Yan background can be reduced by cutting on missing transverse momentum. The $t\bar{t}f$ background is reduced by using a jet veto and the W pair production can be reduced by cutting on the lepton angle.

- e^+e^- collider:
  - Different cross-section.
  - The center of mass energy is known, i.e. one can directly use the missing energy rather than the missing transverse energy and one can do energy scans.