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NEXT-TO-LEADING ORDER SUSY-QCD CALCULATION OF ASSOCIATED PRODUCTION OF GAUGINOS AND GLUINOS

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Results are presented of a next-to-leading order calculation in perturbative QCD of the production of charginos and neutralinos in association with gluinos at hadron colliders. Predictions for cross sections are shown at the energies of the Fermilab Tevatron and CERN Large Hadron Collider for a typical supergravity (SUGRA) model of the sparticle mass spectrum and for a light gluino model.

1 Motivation

The mass spectrum in typical supergravity and gauge-mediated models of supersymmetry (SUSY) breaking favors much lighter masses for gauginos than for squarks. Because the masses are smaller, there is greater phase space at the Tevatron and greater partonic luminosities for gaugino pair production, and for associated production of gauginos and gluinos, than for squark pair production. In this contribution, we summarize our recent calculations at next-to-leading order (NLO) in perturbative quantum chromodynamics (QCD) of the total and differential cross sections for associated production of gauginos and gluinos at hadron colliders[1,2]. Associated production offers a chance to study the parameters of the soft SUSY-breaking Lagrangian. Rates are controlled by the phases of the $\tilde{\chi}$ and $\tilde{g}$ masses and by mixing in the squark and gaugino sectors. In addition to the potentially large cross section for associated production, the leptonic decay of the gaugino makes this process a good candidate for mass determination of the gluino and for discovery or exclusion of an intermediate-mass gluino.

2 NLO SUSY-QCD Formalism

Associated production of a gluino and a gaugino proceeds in leading order (LO) through a quark-antiquark initial state and the exchange of an intermediate squark in the t-channel or u-channel. At NLO, loop corrections must be included. In addition, there are 2 to 3 parton processes initiated either by quark-antiquark scattering, with a gluon radiated into the final state, or by quark-gluon scattering with a light quark radiated into the final state. For the quark-antiquark initial state, the loop diagrams involve the exchange of intermediate Standard Model or SUSY particles in self-energy, vertex, or box diagrams. Ultraviolet and infrared divergences appear at the upper and lower boundaries of integration over unobserved loop momenta. They are regulated dimensionally and removed through renormalization or cancellation with corresponding divergences in the 2 to 3 parton (real emission) diagrams that have an additional gluon radiated into the final state. In addition to soft divergences, real emission contributions have collinear divergences that are factored into the NLO parton densities. The full treatment is presented in our long paper[2].

3 Tevatron and LHC Cross Sections

To obtain numerical predictions for hadronic cross sections, we choose an illustrative SUGRA model with parameters $m_0 = 100$ GeV, A_0=300 GeV, tan $\beta = 4$, and sign $\mu = +$. Because the gluino, gaugino, and squark masses all increase with parameter $m_{1/2}$ (but are insensitive to m_0), we vary $m_{1/2}$ between 100 and 400 GeV. The resulting masses for $\tilde{\chi}^0_{1...4}$ vary between 31...162, 63...317, 211...665, and 241...679 GeV; $\tilde{\chi}^{\pm}_{1,2}$ are almost degenerate in mass with $\tilde{\chi}^0_{2,4}$. The mass $m_{\tilde{\chi}^0_3} < 0$ inside a polarization sum. Our approach is general, and results can be obtained for any set of gaugino and gluino masses. For our second model, we select one[3] with an intermediate-mass gluino as the lightest SUSY particle (LSP), fixing $m_{\tilde{g}} =$ 30 GeV, and $m_{\tilde{q}} = 450$ GeV. We choose a weak sector identical to the SUGRA case. In our paper[2], we also quote results for anomaly mediated, gauge mediated, and gaugino mediated models.

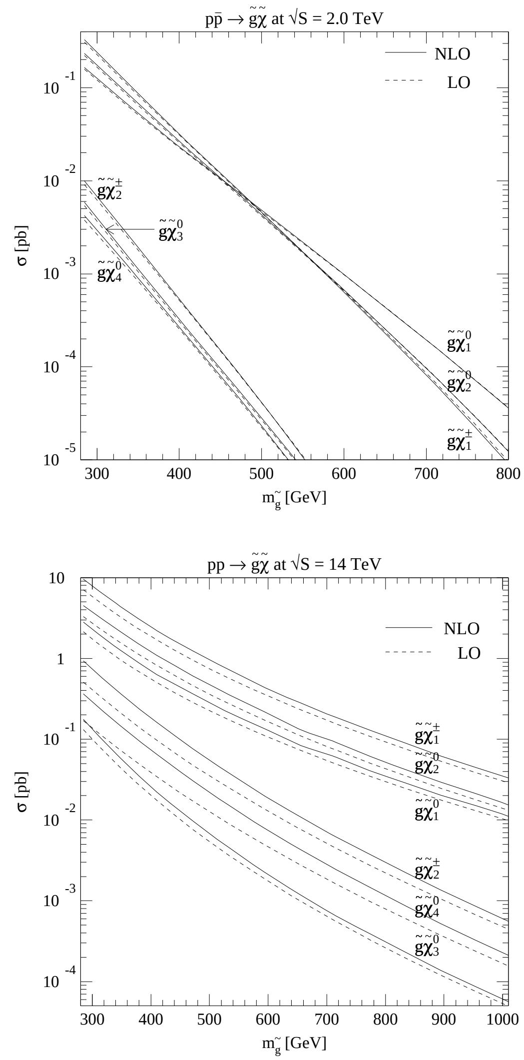

Figure 1. Predicted total hadronic cross sections at Run II of the Tevatron and at the LHC for all six $\tilde{g}\tilde{\chi}$ channels in a typical SUGRA model as functions of the gluino mass.

We convolve LO and NLO partonic cross sections with CTEQ5 parton densities in LO and NLO ($\overline{\text{MS}}$) along with 1- and 2-loop expressions for α_s, the corresponding values of Λ, and five active quark flavors.

For the SUGRA case, we present total hadronic cross sections in Fig. 1 as functions of the gluino mass. The light gaugino channels should be observable at both colliders. At the Tevatron, for 2 fb^{-1} of integrated luminosity, 10 or more events could be produced in each of the lighter gaugino channels if $m_{\tilde{g}} < 450$ GeV. The heavier Higgsino channels are suppressed by about one order of magnitude and might be observable only at the LHC. As a rough estimate of uncertainty associated with the choice of parton densities, we note that the NLO cross section for $\tilde{\chi}^0_2$ production is lower by 12% at the Tevatron with the CTEQ5 set than for the CTEQ4 set, and 4% lower at the LHC. The impact of the NLO corrections can be seen more readily in the ratio of NLO to LO cross sections computed at a renormalizaton scale set equal to the average mass of the final state particles. The NLO effects are moderate (of $\mathcal{O}$ (10%)) at the Tevatron, while at the LHC the NLO contributions can increase the cross sections by as much as a factor of two. The second initial-state channel, initiated by gluon quark scattering, plays a significant role at the energy of the LHC.

For the case of a gluino with mass 30 GeV, the total hadronic cross sections are shown in Fig. 2 as functions of $m_{1/2}$. At the Tevatron, for 2 fb^{-1} of integrated luminosity, 100 or more events could be produced in each of the lighter gaugino channels if $m_{1/2} < 400$ GeV. In this case, NLO enhancement factors lie in the ranges 1.3 to 1.4 at the Tevatron and 2 to 4 at the LHC.

An important measure of theoretical reliability is the variation of the hadronic cross section with the renormalization and factorization scales. At LO, these scales enter in the strong coupling constant and the parton densities, while at NLO they appear also in the hard cross section. The scale dependence is reduced considerably after NLO effects are included. The Tevatron (LHC) cross sections vary by $\pm 23(12)\%$ at LO, but only by $\pm 8(4.5)\%$ in NLO when the scale is varied by a factor of two around the central scale.

For experimental searches, distributions in transverse momentum are important since cuts on p_T help to enhance the signal. In our long paper[2], we show that NLO contributions can have a large impact on p_T spectra at the LHC, owing to contributions from the gq initial state. At the Tevatron the NLO p_T-distribution is shifted moderately to lower p_T with respect to the LO expectation.

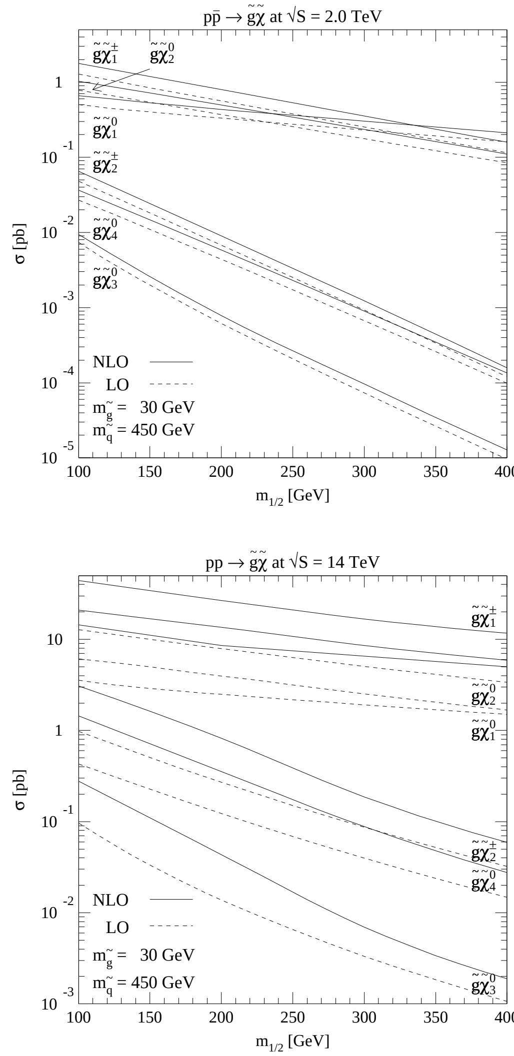

Figure 2. Predicted total hadronic cross sections at Run II of the Tevatron and at the LHC for all six $\tilde{g}\tilde{\chi}$ channels in our model with a gluino of mass 30GeV, as functions of the parameter $m_{1/2}$.

Acknowledgments

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