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Publication Date
2000-05-19

hep-ph/0005199
ANL-HEP-CP-00-057
DESY 00-076

PREDICTIONS FOR ASSOCIATED PRODUCTION OF GAUGINOS AND GLUINOS AT NLO IN SUSY-QCD

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NLO SUSY-QCD contributions to associated production of gluinos and gauginos are shown to enhance the cross sections by about 10% at the Tevatron and by as much as a factor of two at the LHC. They shift the mass determinations or discovery limits, soften the p_T spectra, and stabilize the predictions against variations of the renormalization and factorization scales.

1 Introduction

The search for supersymmetry (SUSY) is a major goal of the Tevatron Run II and LHC physics programs. If SUSY exists at the electroweak scale, SUSY partners of the Standard Model (SM) particles will either be discovered at these hadron colliders, or a very large region of SUSY parameter space will be excluded, provided reliable theoretical predictions in next-to-leading order (NLO) SUSY-QCD are available[1,2,3,4]. We calculate the NLO contributions for associated production of gauginos and gluinos at hadron colliders[5,6]. This production channel is enhanced by the strong coupling of the gluino and by the mass of the gaugino which is small in many popular models of SUSY breaking. The leptonic decay of the gaugino makes this process a good candidate for a mass determination of the gluino or the discovery or exclusion of a light gluino.

2 NLO SUSY-QCD Formalism

The 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, virtual loop corrections must be considered which involve the exchange of intermediate SM or SUSY particles in self-energy, vertex correction, or box diagrams. Ultraviolet

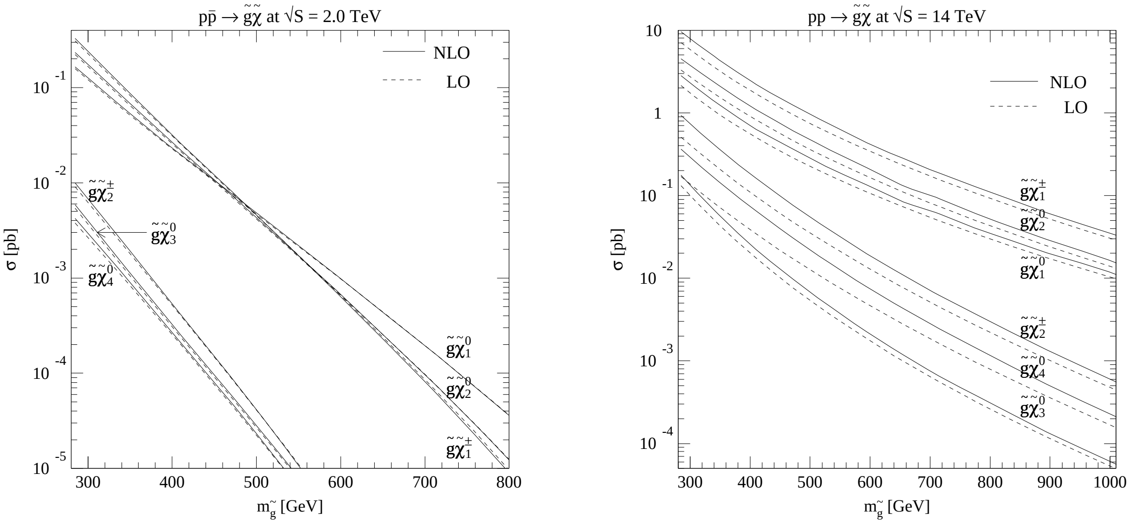

Figure 1: Total hadronic cross sections at Run II of the Tevatron and at the LHC in a typical SUGRA model as functions of the gluino mass.

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 2 to 3 parton (real emission) diagrams that have an additional gluon radiated into the final state. At NLO there is a second 2 to 3 parton process, one with a qg initial state and a light quark emitted into the final state. In addition to soft divergences, real emission contributions have collinear divergences that are factored into the NLO parton densities.

3 Tevatron and LHC Cross Sections

To obtain quantitative predictions for the associated production of gauginos and gluinos at Run II of the Tevatron and at the LHC, we convolve LO and NLO partonic cross sections with CTEQ5 parton densities in LO and NLO ($\overline{\mathrm{MS}}$) along with 1- and 2-loop expressions for α_s, the corresponding values of Λ, and five active quark flavors. To constrain the SUSY parameter space, we choose an illustrative SUGRA model with $m_0 = 100$ GeV, A_0=300 GeV, tan $\beta = 4$, sgn $\mu = +$, and 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, and $\tilde{\chi}^\pm_{1,2}$ are almost mass degenerate with $\tilde{\chi}^0_{2,4}$. The mass $m_{\tilde{\chi}^0_3} < 0$ inside a polarization sum. Our method is not restricted to the SUGRA case and can be applied to any SUSY breaking model.

We present the total hadronic cross sections in Figure 1 as functions of the gluino mass. The light gaugino channels should be observable at both colliders, while the heavier Higgsino channels are suppressed by about one order of magnitude and might be observable only 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. Figure 2 shows that 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. Enhancements of this size can shift mass determinations or discovery limits for SUSY particles by tens of GeV and must therefore always be taken into account.

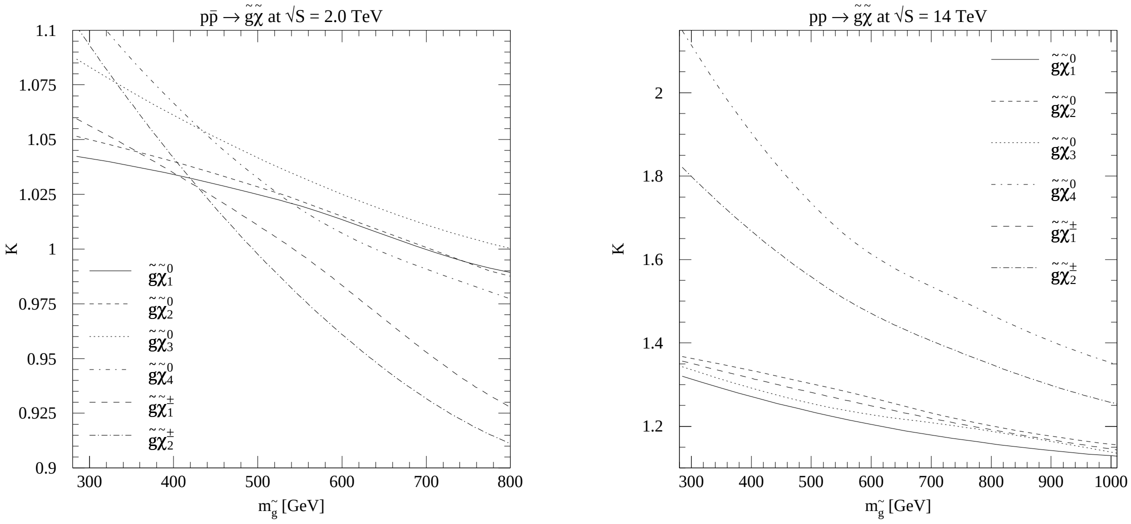

Figure 2: K factors at Run II of the Tevatron and at the LHC in the SUGRA model as functions of the gluino mass.

An important measure of the theoretical uncertainty is the variation of the hadronic cross section with the renormalization and factorization scales. At LO, these scales enter only in the strong coupling constant and the parton densities, while at NLO they appear also explicitly in the hard cross section. As a result, the scale dependence is reduced considerably, as can be seen in Figure 3. The Tevatron (LHC) cross sections vary by ±23(12)% at LO, but only by ±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 Figure 4 we demonstrate that NLO contributions can have a large impact on p_T spectra, especially at the LHC, where contributions from the gq initial state become important. At the Tevatron the NLO p_T-distribution is shifted to lower p_T with respect to the LO expectation.

4 Conclusions

The direct search for SUSY particles is a major goal at hadron colliders. For associated production of gauginos and gluinos, we demonstrate that NLO SUSY-QCD corrections stabilize the LO estimates against variations of the renormalization and factorization scale. The cross sections are increased by as much as a factor of two at the LHC, and the p_T spectra are softened.

Acknowledgments

M.K. thanks the organizers of the XXXVth Rencontres de Moriond for the kind invitation and financial support. Work at ANL is supported by the U.S. Department of Energy, Division of High Energy Physics, under Contract W-31-109-ENG-38. M.K. is supported by the Bundesministerium für Bildung und Forschung under Contract 05 HT9GUA 3, by Deutsche Forschungsgemeinschaft under Contract KL 1266/1-1, and by the European Commission under Contract ERBFMRXCT980194.

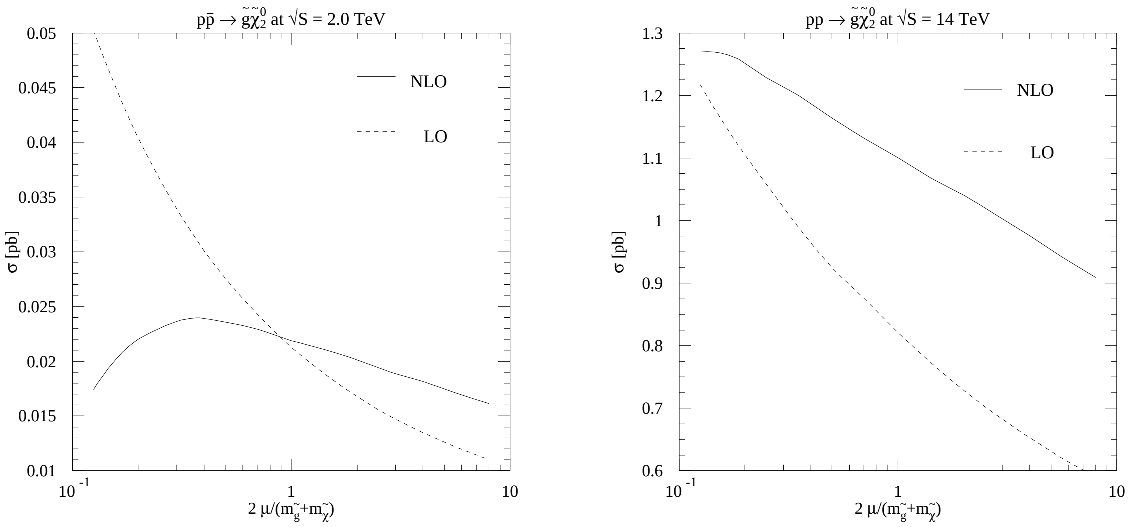

Figure 3: Dependence of the total $\tilde{g}\tilde{\chi}_2^0$ cross section in the SUGRA model on the common renormalization and factorization scale μ. The LO dependence is reduced considerably in NLO.

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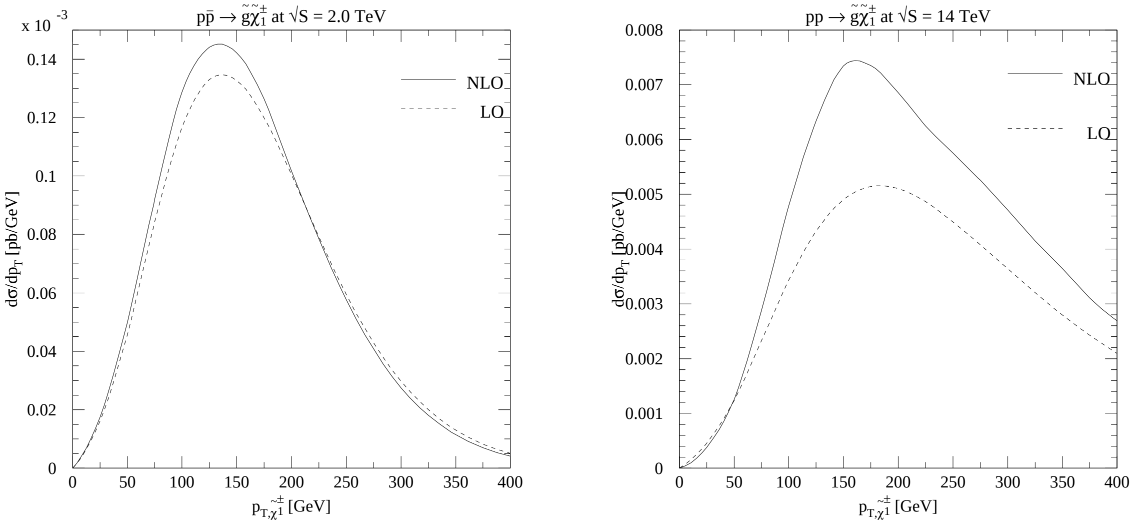

Figure 4: Dependence of the cross section for $\tilde{g}\tilde{\chi}_1^\pm$ in the SUGRA model on the transverse momentum of the light chargino. The NLO distributions are shifted to lower p_T with respect to LO. At the LHC, the NLO enhancement is more prominent.