Squark and gluino production at hadron colliders

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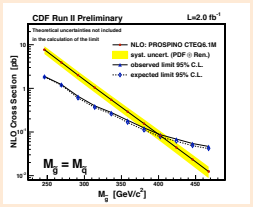
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Motivation: searches for supersymmetry at hadron colliders

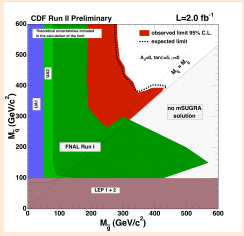
➢ Production of coloured supersymmetric particles (squarks and gluinos) is a very important supersymmetry (SUSY) discovery channel at hadron colliders

$$p\bar{p}^{(-)} \to \tilde{q}\bar{\tilde{q}}, \tilde{q}\tilde{q}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$$

Tevatron



Comparison of 95% C.L. upper experimental limits on the inclusive squark and gluino production cross section with the NLO theoretical predictions in an mSUGRA scenario with equal masses of squarks and gluinos.



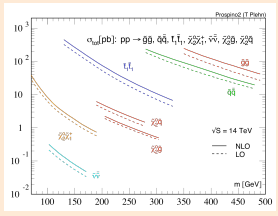
Exclusion plane at 95% C.L. as a function of squark and gluino masses in an mSUGRA scenario with A_0=0, μ>0 and tan β=5,

Knowledge of total cross sections crucial for determining exclusion limits

Large production cross sections at the LHC ➔ "easy" SUSY discovery

Precise prediction for total cross sections highly needed

LHC



Leading-order (LO) and next-to-leading-order (NLO) SUSY-QCD predictions for the production of pairs of supersymmetric particles at the LHC.

Higher-order corrections and the role of soft gluons

➢ Next-to-leading order (NLO) SUSY-QCD corrections to total cross sections for production of squarks and gluinos are known to be significant, of the order of tens of percents. For the gluino-pair production at the LHC, the correction reaches 100% for masses of gluinos ~ 1TeV.

➢Given large masses of squarks and gluinos, the production process is expected to often take place at threshold, defined by the condition $\hat{s} \sim 4m^2$, where *m* is the average mass of a particle in the produced pair.

➢ At threshold, emission of real gluons is suppressed ➔ mostly soft gluons emitted.

➢ Mathematically, the soft gluon emission manifests itself in the theoretical expressions for the total cross sections through appearance of logarithmic terms of the form

$$\alpha_s^n \log^m\left(1 - \frac{4m^2}{\hat{s}}\right) \qquad 0 < m < 2n$$

➢ The logarithmic terms contribute substantially to the full higher-order corrections, as seen at NLO. In the threshold limit $\hat{s} \to 4m^2$ they diverge, leading to breakdown of the conventional fixed-order perturbation theory.

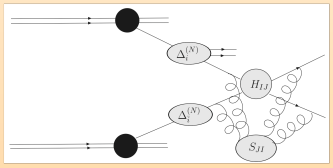
➢ The predictive power of the perturbation theory can be restored in the threshold limit if the most dominant logarithmic contributions are taken into account to all orders.

➔ Threshold resummation of soft gluon corrections

Resummed cross sections

Resummation of soft gluon corrections is performed in the space of Mellin moments *N* taken wrt. variable $4m^2/S$, in which the cross section factorizes.

Schematic representation of factorization for the 2->2 process involving all four particles carrying colour



$$\sigma^{(N)}_{ij\to kl} = \underbrace{H^{(N)}_{ij\to kl,IJ}}_{\text{hard function}} \times \underbrace{\Delta^{(N)}_i \Delta^{(N)}_j}_{\text{soft- collinear radiation}} \times \underbrace{S_{ij\to kl,JI}}_{\text{soft wide-angle emission}}$$

universal factors; KNOWN — process-dependent

matrices in colour space

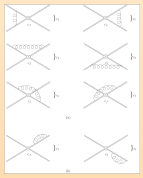
The soft function S_{IJ} is obtained through solving renormalization group equation

$$\left(\mu\frac{\partial}{\partial\mu} + \beta(g)\frac{\partial}{\partial g}\right) S^{(N)}_{JI} = -\Gamma^{\dagger}_{JK} S(N)_{KI} - S(N)_{JL}\Gamma_{LI}$$

At the level of accuracy required here, i.e. so called next-to-leading logarithmic (NLL) accuracy, two new ingredients are required to perform resummation

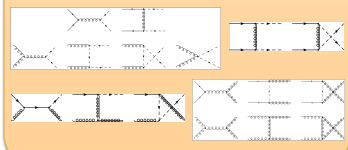
Soft anomalous dimensions

➢ One-loop soft anomalous dimension matrices Γ_{IJ} for 2➔2 processes with non-trivial colour structure and massive final-state particles are calculated by combining appropriate colour structures with one-loop integrals corresponding to the following diagrams calculated in the eikonal approximation.



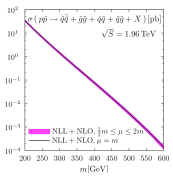
Hard function

➢ At NLL accuracy, the hard function at threshold is given by Mellin moments of the contributions to leading–order cross sections from different colour channels.

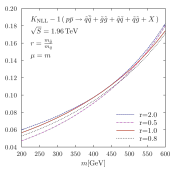


Threshold-resummed predictions for squark and gluino production total cross sections

Tevatron

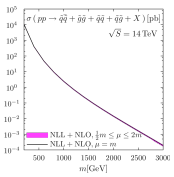


The NLL+NLO cross section for inclusive squark and gluino pair production at the Tevatron as a function of average particle mass *m*.

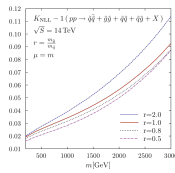


The relative NLL K-factor for inclusive squark and gluino pair production at the Tevatron as a function of average particle mass *m*.

LHC



The NLL+NLO cross section for inclusive squark and gluino pair production at the LHC as a function of average particle mass *m*.



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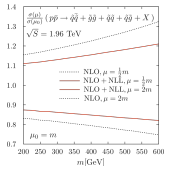


Scale dependence of the NLL+NLO and NLO total cross sections for inclusive production of squarks and gluinos at the Tevatron.

Summary

➢ Total cross sections for all squark and gluino production processes at the LHC and the Tevatron calculated at NLL (+NLO) accuracy.

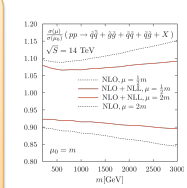
➢ Calculations of one-loop soft anomalous dimension matrices confirm physical picture: at production threshold radiation of soft gluons from the total colour charge of the pair of produced particles.

➢ NLL corrections to the NLO cross sections can be of order of tens of percents, depending on the process and the considered mass range.

➢ Including NLL corrections leads to significant reduction of the theoretical error due to scale variation.

The calculations deliver currently most accurate predictions for inclusive squark and gluino production at hadron colliders and should be taken into account in experimental analysis.

➢ Outlook: NLL corrections to total cross sections for production of SUSY partners of top and bottom quarks and to differential distributions.



Scale dependence of the NLL+NLO and NLO total cross sections for inclusive production of squarks and gluinos at the LHC..

Publications

A. Kulesza and L. Motyka, Phys. Rev. Let. **102**, 111802 (2009); arXiv:0807.2405 [hep-ph].
A. Kulesza and L. Motyka, Phys. Rev. D **80**, 0905004 (2009); arXiv:0905.4749 [hep-ph].
W. Beenakker, S. Brensing, M. Krämer, A. Kulesza, E. Laenen and I. Niessen, arXiv:0909.4418 [hep-ph], submitted to JHEP.