

NLO accuracy for production and decay of squarks matched with parton shower

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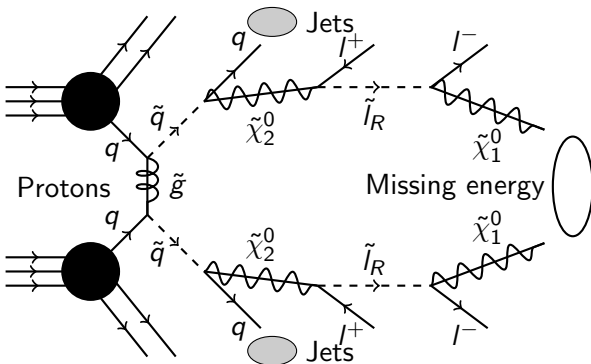
Desy Theory Workshop - Hamburg

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Outline

- Introduction
- Squark-antisquark production with decay
- Parton shower effect
- Impact of search cuts

- Supersymmetric particles decay via cascades



- Production of $\tilde{q}\tilde{q}, \tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{g}\tilde{q} \dots$
... and decays $\tilde{q} \rightarrow q + \tilde{\chi}_1^0, \tilde{g} \rightarrow q + \tilde{q} \dots$
... **at NLO with parton shower**
- **Aim:** Fully differential implementation in a Monte Carlo program (to analyse cuts, parton shower effects etc.)

- **Matching Squark Pair Production at NLO with Parton Showers**
[1305.4061] see also [Hollik, Lindert, Pagani, 1207.1071] [Goncalves-Netto et al., 1211.0286]
 - K factor treatment
 - Parton shower effect
- **Squark-antisquark production and decay at NLO matched with parton shower**
- Gluino production and decay, spin effect, etc.

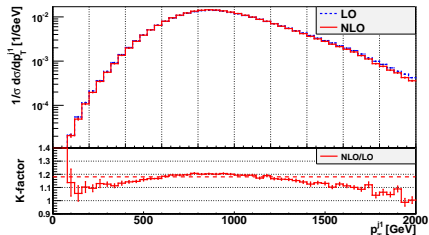
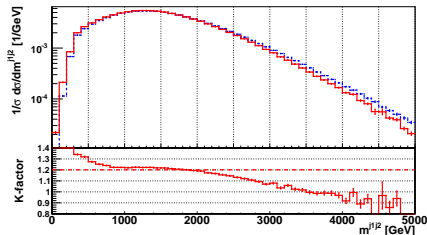
Standard procedure:

- LO distribution
- Global K-factor from PROSPINO2
[Beenakker, Hopker, Krämer, Plehn, Spira, Zerwas]
- Rescale the LO distribution by the global K-factor

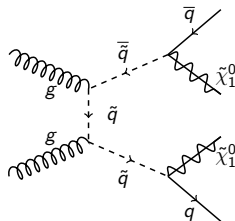
Problems:

- Assume degenerate squark masses
- Assume no shape distortion in LO / NLO distributions

- Non flat K-factor for squark pair production



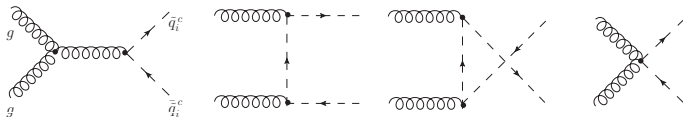
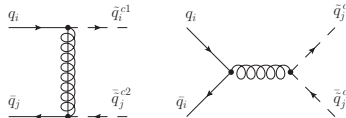
$m_{\tilde{q}} \simeq 1800\text{GeV}$, $m_{\tilde{g}} \simeq 1600\text{GeV}$ and $\sqrt{s} = 8\text{TeV}$

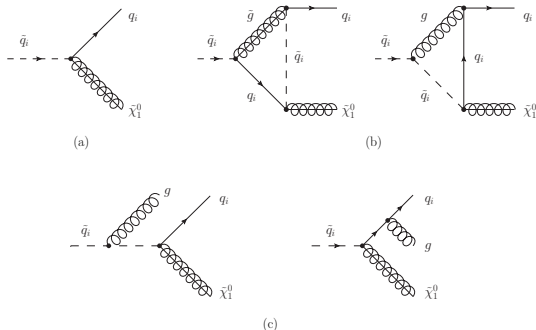


- No spin correlation has to be taken into account.
- Narrow-width approximation i.e. intermediate particle is on-shell.
- Only first two generations of squarks.
- Implementation in the POWHEG-BOX

[Nason, hep-ph/0409146], [Frixione, Nason, Oleari, 0709.2092], [Alioli, Nason, Oleari, Re, 1002.2581]

Process	$\sigma_{\text{LO}}[\text{fb}]$	$\sigma_{\text{NLO}}[\text{fb}]$	K-factor
$\tilde{u}_L \tilde{\bar{u}}_L$	$9.51 \cdot 10^{-2}$	$1.43 \cdot 10^{-1}$	1.50
$\tilde{u}_R \tilde{\bar{u}}_R$	$1.14 \cdot 10^{-1}$	$1.72 \cdot 10^{-1}$	1.51
$\tilde{d}_L \tilde{\bar{d}}_R$	$1.41 \cdot 10^{-1}$	$1.70 \cdot 10^{-1}$	1.21
$\tilde{u}_R \tilde{\bar{d}}_L$	$2.94 \cdot 10^{-1}$	$3.49 \cdot 10^{-1}$	1.19
$\tilde{u}_R \tilde{\bar{d}}_R$	$8.36 \cdot 10^{-2}$	$9.54 \cdot 10^{-2}$	1.14



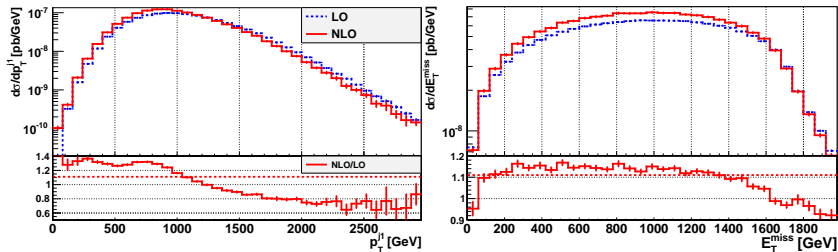


Two different methods:

- Analytical integration [Campbell, Ellis, Tramontano, hep-ph/0408158]
- V2 of POWHEG BOX for resonant decay (FKS scheme)

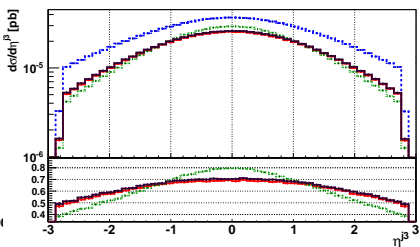
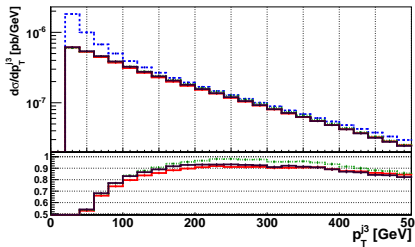
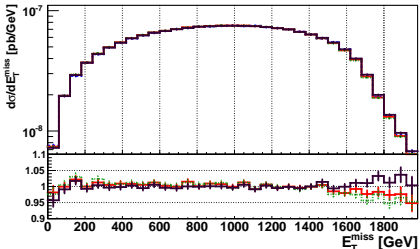
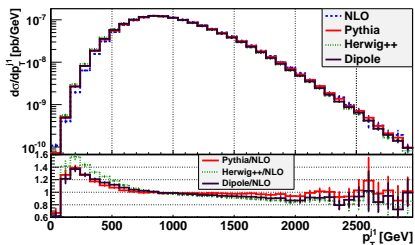
[Frixione, Kunszt, Signer, hep-ph/9512328]

• Distributions including decay



10.3.6* scenario:

$$m_{\tilde{\chi}_0^1} \simeq 290\text{GeV}, m_{\tilde{q}} \simeq 1800\text{GeV}, m_{\tilde{g}} \simeq 1600\text{GeV} \text{ and } \sqrt{s} = 8\text{TeV}$$



ATLAS collaboration, signal region 'A-loose' [ATLAS-CONF-2013-047].

$$p_T^{j_1} > 130 \text{ GeV}, \quad p_T^{j_2} > 60 \text{ GeV}, \quad \cancel{E}_T > 160 \text{ GeV}, \quad \frac{\cancel{E}_T}{m_{\text{eff}}} > 0.2, \quad m_{\text{eff}}^{\text{incl}} > 1 \text{ TeV},$$

$$\Delta\phi(j_{1/2}, \vec{\cancel{E}}_T) > 0.4, \quad \Delta\phi(j_3, \vec{\cancel{E}}_T) > 0.4 \quad \text{if} \quad p_T^{j_3} > 40 \text{ GeV}.$$

with $m_{\text{eff}}^{\text{incl}} = \sum_{i=1}^{n_j} p_T^i + \cancel{E}_T$

Procedure:

- Simulation of the production and decay at LO
- Rescaled with global K-factor
- Multiplication with the NLO branching ratio

	$\tilde{q}\tilde{q}$	$\tilde{q}\tilde{\bar{q}}$
NLO	0.871 fb	0.0781 fb
PYTHIA	0.883 fb	0.0797 fb
HERWIG++	0.895 fb	0.0807 fb
PYTHIA (approx.)	0.855 fb	0.0664 fb
HERWIG++ (approx.)	0.858 fb	0.0667 fb

10.3.6* scenario:

$m_{\tilde{\chi}_0^1} \simeq 290\text{GeV}$, $m_{\tilde{q}} \simeq 1800\text{GeV}$, $m_{\tilde{g}} \simeq 1600\text{GeV}$ and $\sqrt{s} = 8\text{TeV}$

Summary

- Production of $\tilde{q}\tilde{q}$ and $\tilde{q}\tilde{\bar{q}}$ at NLO ...
... with decay $\tilde{q} \rightarrow q + \tilde{\chi}_1^0$ at NLO ...
... matched with parton shower
- Importance of a full treatment
- Implementation in the POWHEG BOX
- Public code that can be downloaded at:

<http://powhegbox.mib.infn.it/>

Outlook

- $\tilde{q}\tilde{g}$ and $\tilde{g}\tilde{g}$ production at NLO
- \tilde{g} decay at NLO
- Spin effect

Thank you for your attention

Back up

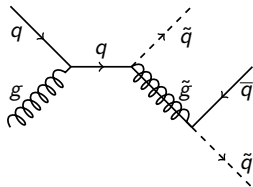
	10.3.6*		10.4.5	
	$\tilde{q}\tilde{q}$	$\tilde{q}\tilde{\bar{q}}$	$\tilde{q}\tilde{q}$	$\tilde{q}\tilde{\bar{q}}$
NLO	0.871 fb	0.0781 fb	6.809 fb	0.696 fb
PYTHIA	0.883 fb	0.0797 fb	6.854 fb	0.704 fb
HERWIG++	0.895 fb	0.0807 fb	6.936 fb	0.711 fb
PYTHIA (approx.)	0.855 fb	0.0664 fb	6.844 fb	0.617 fb
HERWIG++ (approx.)	0.858 fb	0.0667 fb	6.876 fb	0.620 fb

Back up

- Subtraction for on-shell intermediate state.

$$|M_{qg}|^2 = |M_{nr}|^2 + |M_r|^2 + 2\text{Re}[M_r M_{nr}^*].$$

$$\text{For } (p_{\bar{q}} + p_{\tilde{q}})^2 \rightarrow m_{\tilde{g}}^2.$$



Back up

Production \times Decay @ NLO

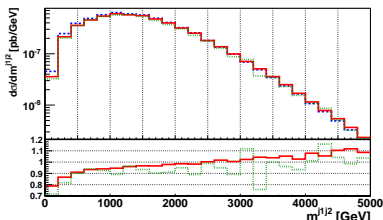
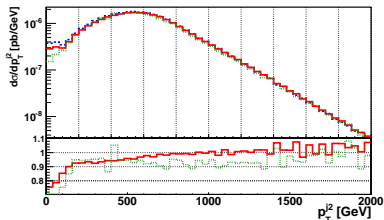
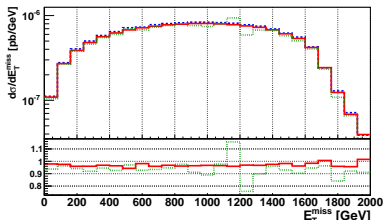
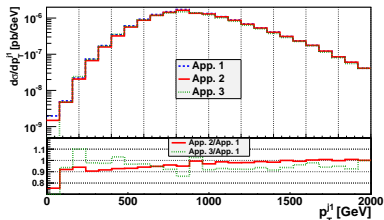
$$dP_{i,j} = \frac{1}{\Gamma_{tot}^0 \Gamma_{tot}^{\prime 0}} \left(d\sigma_0 d\Gamma_0^i d\Gamma_0^{\prime j} \left(1 - \alpha_s \left(\frac{\Gamma_{tot}^1}{\Gamma_{tot}^0} + \frac{\Gamma_{tot}^{\prime 1}}{\Gamma_{tot}^{\prime 0}} \right) \right) + \alpha_s d\sigma_0 \left(d\Gamma_0^i d\Gamma_1^{\prime j} + d\Gamma_0^{\prime j} d\Gamma_1^i \right) + \alpha_s d\sigma_1 \left(d\Gamma_0^i d\Gamma_0^{\prime j} \right) \right)$$

$$dP_{i,j} = \frac{1}{(\Gamma_{tot}^0 + \alpha_s \Gamma_{tot}^1)(\Gamma_{tot}^{\prime 0} + \alpha_s \Gamma_{tot}^{\prime 1})} \left[d\sigma_0 d\Gamma_0^i d\Gamma_0^{\prime j} + \alpha_s \left(d\sigma_0 \left(d\Gamma_0^i d\Gamma_1^{\prime j} + d\Gamma_0^{\prime j} d\Gamma_1^i \right) + d\sigma_1 d\Gamma_0^i d\Gamma_0^{\prime j} \right) \right]$$

$$dP_{i,j} = (d\sigma_0 + \alpha_s d\sigma_1) \frac{(d\Gamma_0^i + \alpha_s d\Gamma_1^i)}{(\Gamma_{tot}^0 + \alpha_s \Gamma_{tot}^1)} \frac{(d\Gamma_0^{\prime j} + \alpha_s d\Gamma_1^{\prime j})}{(\Gamma_{tot}^{\prime 0} + \alpha_s \Gamma_{tot}^{\prime 1})}$$

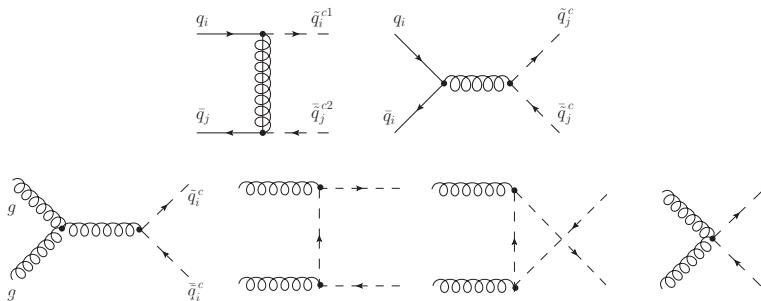
Back up

Production \times Decay @ NLO



Back up

Production @ LO



Squark-antisquark production at LO.