Next-to-leading order accuracy for production and decay of squarks

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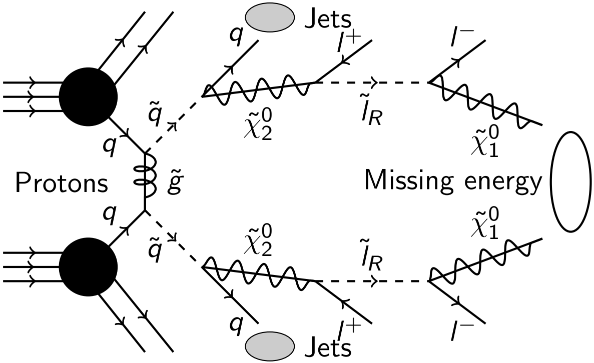
SFB TR9

Outline

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

- Supersymmetric particles decay via cascades



- Production of $\tilde{q}\tilde{q}$, $\tilde{q}\overline{\tilde{q}}$, $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$ ...
  ... and decays $\tilde{q} \to q + \tilde{\chi}_1^0$, $\tilde{g} \to q + \tilde{q}$ ...
  ... **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:

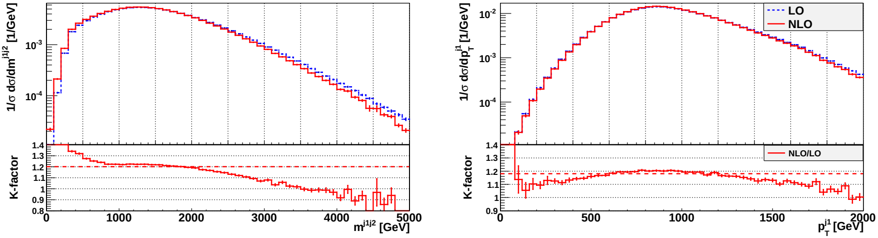
- LO distribution
- Global K-factor from PROSPINO2

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

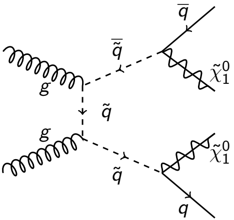
Problems:

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

- Non flat K-factor for squark pair production



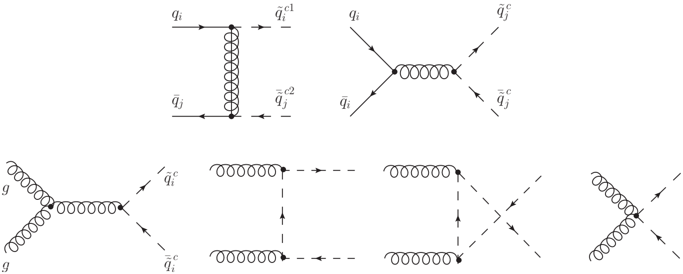
$m_{\tilde{q}} \simeq 1800\text{GeV}, \; m_{\tilde{g}} \simeq 1600\text{GeV}$ and $\sqrt{s} = 8\text{TeV}$

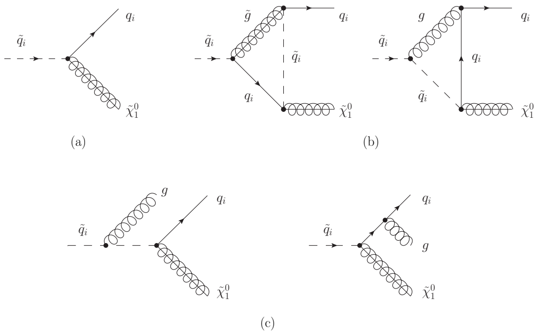


- No spin correlation has to be taken into account.
- Narrow-width approximation i.e. intermediate particle is on-shell.
- Only first two generations of squarks.
- Implementation in the POWHEG-BOX

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

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



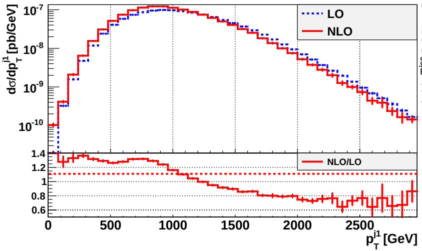


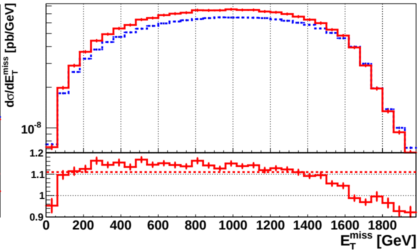
Two different methods:

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

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

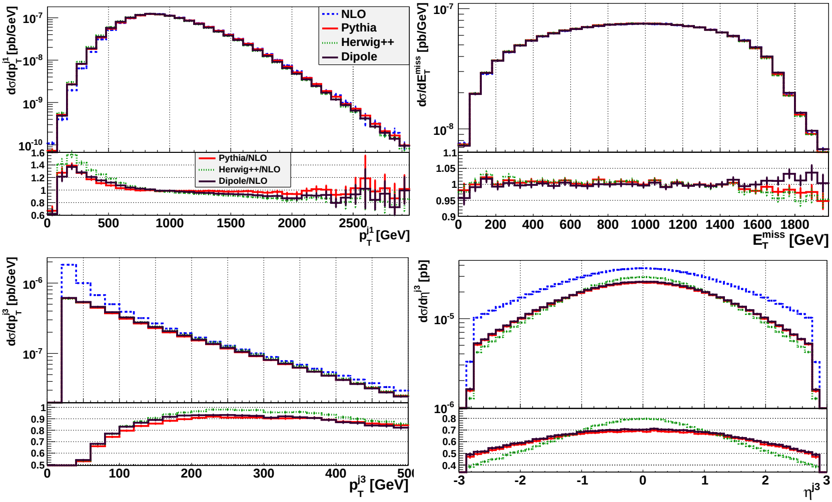
- Distributions including decay





10.3.6* scenario:

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


NLO
Pythia
Herwig++
Dipole
Pythia/NLO
Herwig++/NLO
Dipole/NLO
dσ/dp_T^j1 [pb/GeV]
p_T^j1 [GeV]
dσ/dE_T^miss [pb/GeV]
E_T^miss [GeV]
dσ/dp_T^j3 [pb/GeV]
p_T^j3 [GeV]
dσ/dη^j3 [pb]
η^j3

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

$$p_T^{j_1} > 130\,\text{GeV},\ p_T^{j_2} > 60\,\text{GeV},\ \not{E}_T > 160\,\text{GeV},\ \frac{\not{E}_T}{m_{\text{eff}}} > 0.2,\ m_{\text{eff}}^{\text{incl}} > 1\,\text{TeV},$$

$$\Delta\phi(j_{1/2}, \vec{\not{E}}_T) > 0.4, \quad \Delta\phi(j_3, \vec{\not{E}}_T) > 0.4 \quad \text{if} \quad p_T^{j_3} > 40\,\text{GeV}\,.$$

with $m_{\text{eff}}^{\text{incl}} = \sum_{i=1}^{n_j} p_T^{j_i} + \not{E}_T$

Procedure:

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

	$\tilde{q}\tilde{q}$	$\tilde{q}\bar{\tilde{q}}$
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 $\tilde{q}\bar{\tilde{q}}$ at NLO ...
  ... with decay $\tilde{q} \to q + \tilde{\chi}_1^0$ 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

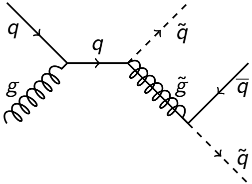
	10.3.6*		10.4.5	
	$\tilde{q}\tilde{q}$	$\tilde{q}\bar{\tilde{q}}$	$\tilde{q}\tilde{q}$	$\tilde{q}\bar{\tilde{q}}$
NLO	0.871 fb	0.0781 fb	6.809 fb	0.696 fb
PYTHIA	0.883 fb	0.0797 fb	6.854 fb	0.704 fb
HERWIG++	0.895 fb	0.0807 fb	6.936 fb	0.711 fb
PYTHIA (approx.)	0.855 fb	0.0664 fb	6.844 fb	0.617 fb
HERWIG++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

Back up

- Subtraction for on-shell intermediate state.

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

For $(p_{\overline{q}} + p_{\tilde{q}})^2 \to m_{\tilde{g}}^2$.



Back up

Production $\times$ Decay @ NLO

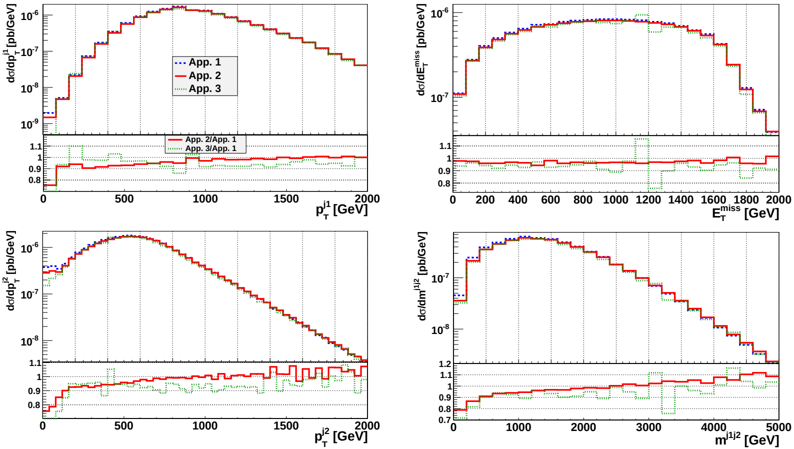
$$dP_{i,j} = \frac{1}{\Gamma^0_{tot}\Gamma'^0_{tot}}\left(d\sigma_0 d\Gamma^i_0 d\Gamma'^j_0\left(1-\alpha_s\left(\frac{\Gamma^1_{tot}}{\Gamma^0_{tot}}+\frac{\Gamma'^1_{tot}}{\Gamma'^0_{tot}}\right)\right)+\alpha_s d\sigma_0\left(d\Gamma^i_0 d\Gamma'^j_1 + d\Gamma'^j_0 d\Gamma^i_1\right)+\alpha_s d\sigma_1\left(d\Gamma^i_0 d\Gamma'^j_0\right)\right)$$

$$dP_{i,j} = \frac{1}{(\Gamma^0_{tot}+\alpha_s\Gamma^1_{tot})(\Gamma'^0_{tot}+\alpha_s\Gamma'^1_{tot})}\left[d\sigma_0 d\Gamma^i_0 d\Gamma'^j_0 + \alpha_s\left(d\sigma_0\left(d\Gamma^i_0 d\Gamma'^j_1 + d\Gamma'^j_0 d\Gamma^i_1\right)+d\sigma_1 d\Gamma^i_0 d\Gamma'^j_0\right)\right]$$

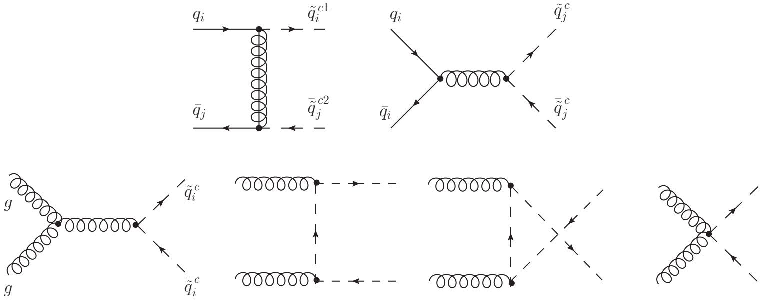
$$dP_{i,j} = (d\sigma_0 + \alpha_s d\sigma_1)\frac{(d\Gamma^i_0+\alpha_s d\Gamma^i_1)}{(\Gamma^0_{tot}+\alpha_s\Gamma^1_{tot})}\frac{(d\Gamma'^j_0+\alpha_s d\Gamma'^j_1)}{(\Gamma'^0_{tot}+\alpha_s\Gamma'^1_{tot})}$$

Back up

Production × Decay @ NLO



Back up
Production @ LO



Squark-antisquark production at LO.