Extra jets radiation in inclusive SUSY samples and SM backgrounds

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Outline

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2. SM background simulation

3. SUSY signal simulation

4. Conclusion
Plan

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Inclusive SUSY with 100 pb$^{-1}$ of data, B. Mellado, S. Padhi, S. L. Wu.

$\tilde{g}\tilde{g}$, $\tilde{q}\tilde{q}$, $\tilde{g}\tilde{q}$ simulated as 2→2 processes with Pythia. What would be the impact of extra-radiations simulated with M-E generator on the SUSY signals?

see also MLM work
Introduction

A first investigation of 2→3 and 2→4 has been done using Matrix-Element calculations for $\tilde{g}\tilde{g}$, $\tilde{u}_L\tilde{u}_L$, $\tilde{g}\tilde{u}_L$ at parton level.


New:
Now, the production of SUSY signals with additional radiation(s) calculated at Matrix-Element is possible up to hadronization level with MadGraph/MadEvent thanks to the ME/PS matching technique.
Processes

- Decays of $\tilde{g}$ and $\tilde{q}$ produces large MET (neutralinos) and High $P_T$ jets
  We expect 4 or 5 high-$P_T$ jets from decays + extra jets
- The backgrounds are mainly $W+$jets, $Z+$jets and $t\bar{t}+$jets.
- $\Rightarrow$ A lot of extra-jets should be required for production of $W$ and $Z$ going to leptons
- $\Rightarrow$ Up to 3 extra-jets should be required for production of $t\bar{t}$ inclusive

Production of SUSY and SM background with additional extra-jets will be done using ME/PS matching technique.

*J.Alwall, F.Maltoni, S.de Visscher, Paper in preparation*
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Dealing with ME and PS

**ME**
- parton-level description
- valid when partons are hard and well separated
- needed for multi-jets description

**PS**
- down to hadron-level description
- valid when partons are collinear and/or soft
- needed for realistic studies

Both approaches have to be complementary, without any overlapping in the phase space.
Dealing with ME and PS

- Compute the $|\mathcal{M}|^2$ of $t\bar{t} + 0,1,2,3$ jets with ME generator
- Perform showering with PS software.

Problem: overlapping between samples of different multiplicities:
ex: a $t\bar{t} + 2$ ME partons $\sim t\bar{t} + 1$ ME parton + high $p_T$ jet from showering!

Double counting problem
Matching techniques

To avoid this, use one of the ME/PS matching procedure: set of techniques used for generating correctly the extra-radiation, independently of the processes.

Implementation (J. Alwall and S. Höche) of MLM’s and CKKW methods in MG/ME
MLM in Madgraph/MadEvent

- **MLM philosophy:**
  - generate normally with M-E generator, with a distance (Cone or $K_T$) between extra-partons $>\text{cutoff}$ (gain in efficiency)
  - perform showering
  - group the showered partons (with Cone or $K_T$ algo) into jets
  - match the jets with the extra-partons: this is where rejection of event take place (use the cutoff).

- **Modified MLM method:** use $K_T$

- All procedures available for online/local productions
  - http://madgraph.phys.ucl.ac.be,
  - http://madgraph.hep.uiuc.edu/
Matching parameters

Validation of matching parameters: use the differential jet rate distributions to control the matching.

- Invariance of the global shape with respect to the choice of the cutoff
- Smooth transition from one region of the phase-space to the other.

Systematic control of matching is mandatory (MatchChecker)!
W, Z and $t\bar{t}$

- $\sim 4$ M of $W^{\pm}+1,2,3,4$ jets ($u,d,s,c$), decays into leptons
- 2 M $Z+1,2,3,4$ jets ($u,d,s,c,b$), decays into leptons and $\nu$ (MET is important in the signals due to neutralino presence)
- 800 K $t\bar{t}+0,1,2,3$ jets (inclusive)
- Control of the productions with differential jet rates done
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How to generate SUSY signals with matching technique?

The simulation of SUSY signals is based on the same technique as the SM background. Additional problem: double counting in the final states because of the presence of resonance $\implies$ remove the events!

Note: same problem as for NLO corrections
Removal of events with resonances

- MadEvent uses the $|\mathcal{M}|^2$ as integration channels.
- When the amplitude of the resonant diagram is computed, the information about the resonance is extracted:
  \[ \Rightarrow \text{if the propagator inv. mass} \in [\bar{m}_{\tilde{g},\tilde{q}} - 5\Gamma, \bar{m}_{\tilde{g},\tilde{q}} + 5\Gamma], \]
  it is written in the LHEF event file.
- The rejection take place at Pythia level
Impact of the matching

If the scale ($\sim \sum M$) of the process increases, the parton-shower extra-radiations should tend to increase and approach a M-E description.

Here: $t\bar{t}$+jets and $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{q}$+jets with and without matching (using Pythia shower scale=factorization scale=$M^2 + P_T^2$)

$$H_T = \sum_{\text{visible}} P_T + \text{MET}.$$ 

Matching impact is clearly important for the backgrounds (low masses) and not negligible for the SUSY signals.
New for SUSY: the decay chains (J. Alwall - T. Stelzer)

- Permit to decrease the number of diagrams by selecting the dominant ones.
- Allows for higher-multiplicity final states
- Spin correlation is consistently treated
- The information about the presence of the resonance is properly propagated up to the event level

An example of use: $pp \rightarrow u\chi_1^0\bar{b}b\mu^+\mu^-\chi_1^0$

A possibility written with MadGraph syntax:

$pp > (ur>un1)(go>b \ (b1>(b(n2>mu+(mul->mu-n1))))))$
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Conclusion

- Inclusive SUSY searches have been done in the past in 2→2 mode ⇒ what about 2 → 2+jets?
- The ME/PS matching will be used for background simulation as well as SUSY signals: problem of double counting in final states solved!
- Impact of the matching is quite important on backgrounds and need to be more investigated for the high mass signals
- Decay chains are implemented
Back-up slides
The matching in MG/ME: the proc_card

```
# Begin PROCESS # This is TAG. Do not modify this line

pp>gogo @0            # First Process
QCD=99
QED=0
end_coup

pp>gogoj @1           # First Process
QCD=99
QED=0
end_coup

pp>gogojj @2          # First Process
QCD=99
QED=0
end_coup

done                  # Write 'done' to tell MG to stop
```
The matching in MG/ME: the run_card

Choose the matching scheme: MLM or CKKW:

```plaintext
F = fixed_ren_scale ! if .true. use fixed ren scale
F = fixed_fac_scale ! if .true. use fixed fac scale
174.0 = scale ! fixed ren scale
174.0 = dsqrt_q2fact1 ! fixed fact scale for pdf1
174.0 = dsqrt_q2fact2 ! fixed fact scale for pdf2
1 = scalefact ! scale factor for event-by-event scales

# Matching - Warning! ickkw > 0 is still beta
#******************************************************************************
1 = ickkw ! 0 no matching, 1 MLM, 2 CKKW matching
#
```

and choose the cutoff (<cutoff at pythia level)

```plaintext
0 = xptl ! minimum pt for at least one charged lepton

#******************************************************************************
# WBF cuts
#******************************************************************************
0 = xetamin ! minimum rapidity for two jets in the WBF case

#******************************************************************************
# Jet measure cuts
#******************************************************************************
33 = xqcut ! minimum kt jet measure between partons
```

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Introduction

SM background

SUSY signal

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The matching in MG/ME: the pythia_card

Contains the value of the cutoff and the switch to remove events with on-shell $\tilde{q}$ and $\tilde{g}$

```
!...Cutoff in jet measure for matching
QCUT = 60
!...Excluded resonances
EXCRES=1000021
EXCRES=1000001
EXCRES=2000001
EXCRES=1000002
EXCRES=2000002
EXCRES=1000003
EXCRES=2000003
EXCRES=1000004
EXCRES=2000004
```
MatchChecker (S de Visscher, P.Demin)

Package useful to validate a choice of matching parameter for a given "X + n jets" process, evaluate the impact of the matching,...

- Input: STDHEP files
- can compare any number of productions on different variables
  - Differential jet rates: $4 \rightarrow 3$, $3 \rightarrow 2$, $2 \rightarrow 1$, $1 \rightarrow 0$
  - $P_T(X)$, $\Delta(X_1, X_2)$, $M_{inv}(X)$, $\eta(X)$,...
  - $P_T(j_1, ..., j_4)$, $\eta(j_1, ..., j_4)$ with jet definition up to the user, and with minimal user’s $P_T$ cut
  - $H_T(2, ...)$
  - MET

- Very simple to use: one card to fill, one command to execute...
- A Postscript report is done with everything organized (ToC, possibility of adding banners, sections...)
Decay chains

- Gauge invariant when narrow width approx. is valid
- BW cutoff at $\pm 5\Gamma$ from resonance mass in MadEvent.

Particularly useful:

- For spin correlation between particles in decays
  (Alves, Eboli, Plehn hep-ph/0605067)
- To include effects of pdf’s for non-zero widths
  (Berdine, Rainwater hep-ph/0703058)
- For spin studies in more complicated processes (WBF for SUSY particles pairs)