Extra jets radiation in inclusive SUSY samples and SM backgrounds

Simon de Visscher
Universite catholique de Louvain
Centre for Particle Physics and Phenomenology (CP^3)

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J. Alwall (SLAC), F.Maltoni (UCL)

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Outline

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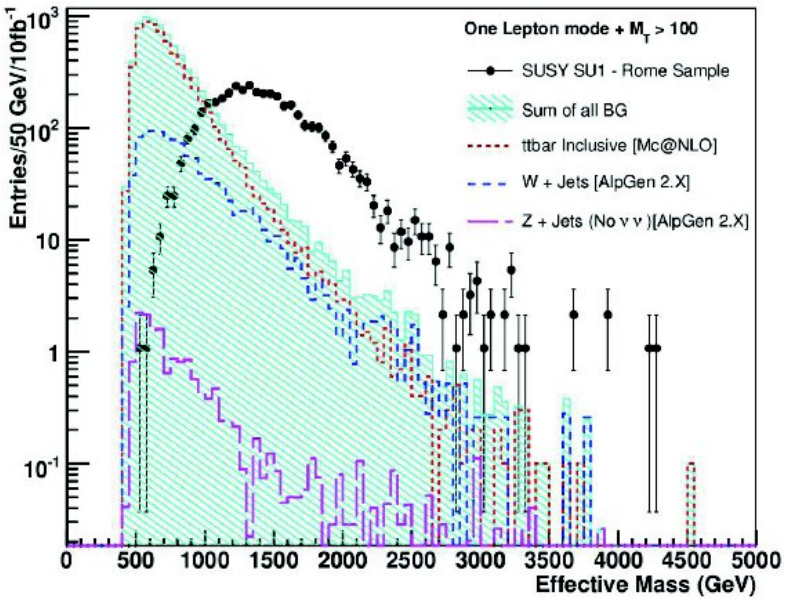
Plan

Introduction



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

see also *MLM work*

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

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.

T. Plehn, D. Rainwater, P. Skands, Phys.Lett.B645:217-221,2007.

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.
- $\Longrightarrow$ A lot of extra-jets should be required for production of W and Z going to leptons
- $\Longrightarrow$ 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

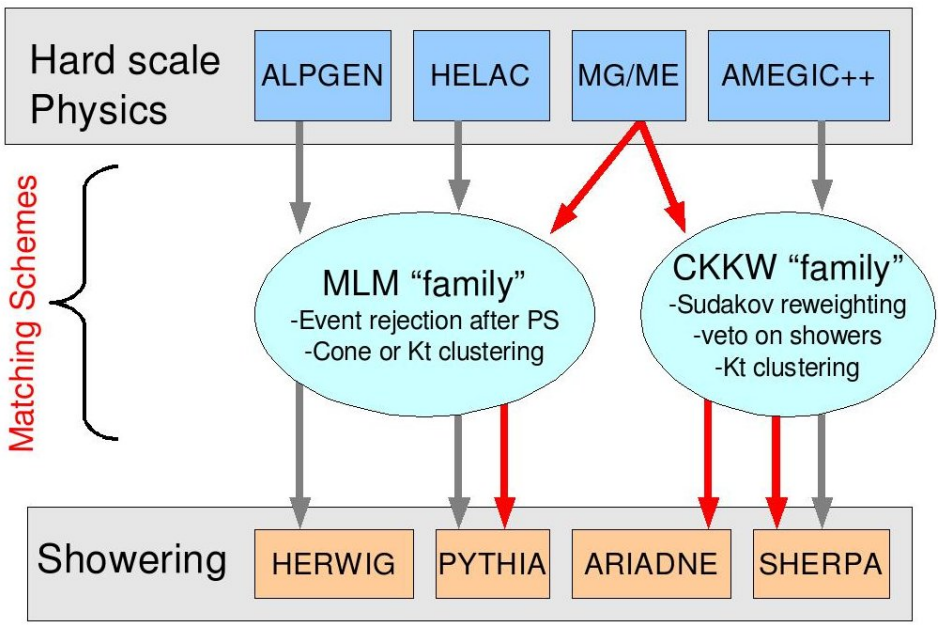
- Compute the $|\mathcal{M}|^2$ of $t\bar{t}$+0,1,2,3 jets with ME generator
- Perform showering with PS software.

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

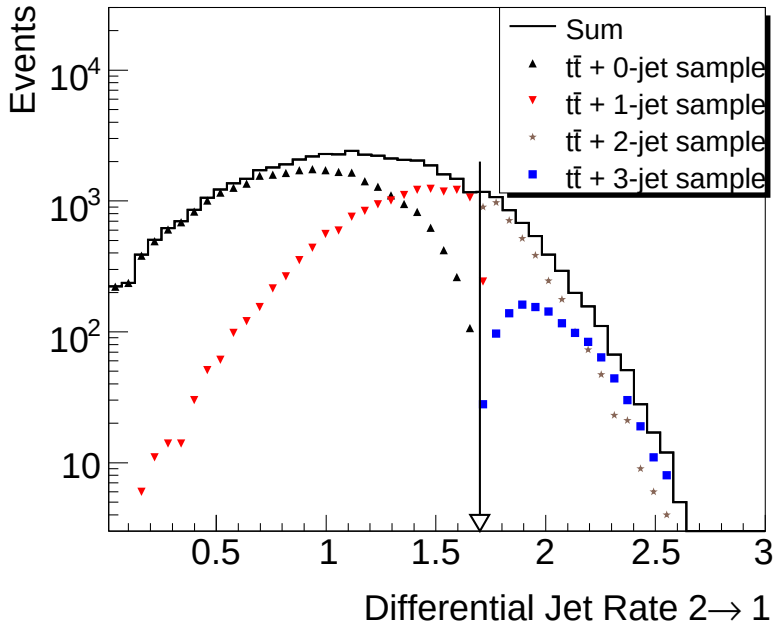
MLM in Madgraph/MadEvent

J. Alwall et al. arXiv:0706.2569

- MLM philosophy:
  - generate normally with M-E generator, with a distance (Cone or K_T) between extra-partons $>$ 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 ν (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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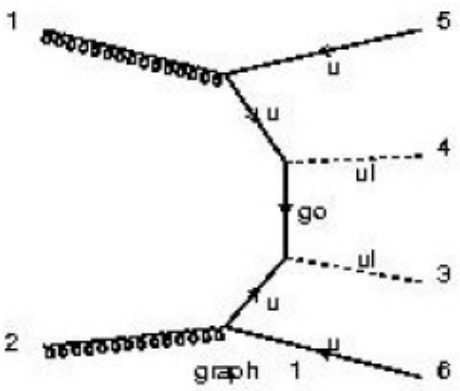
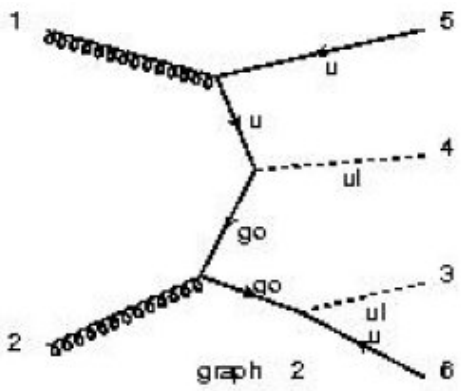
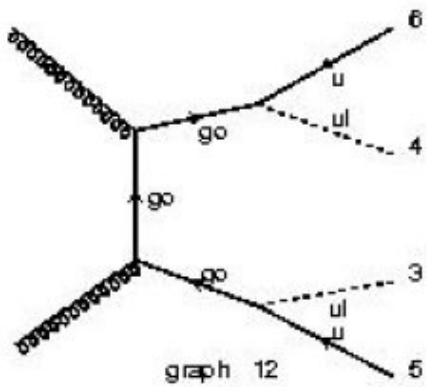
How to generate SUSY signals with matching technique?

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 $\Longrightarrow$ remove the events!







Note: same problem as for NLO corrections

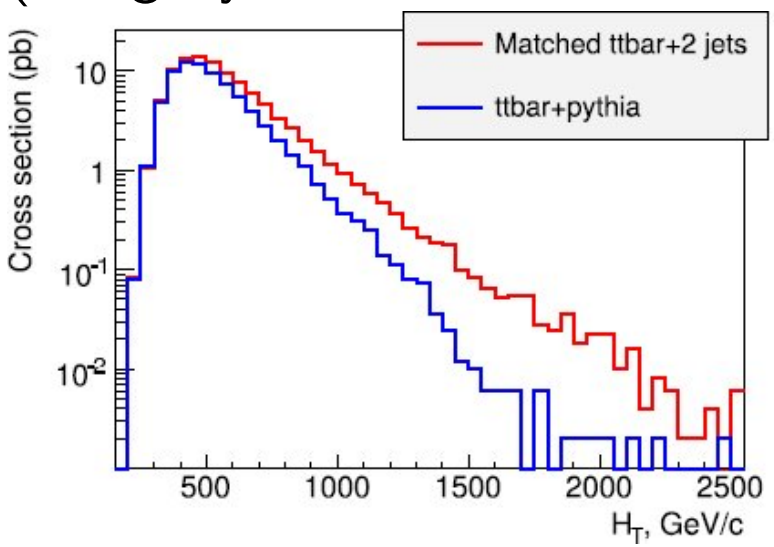
Removal of events with resonances

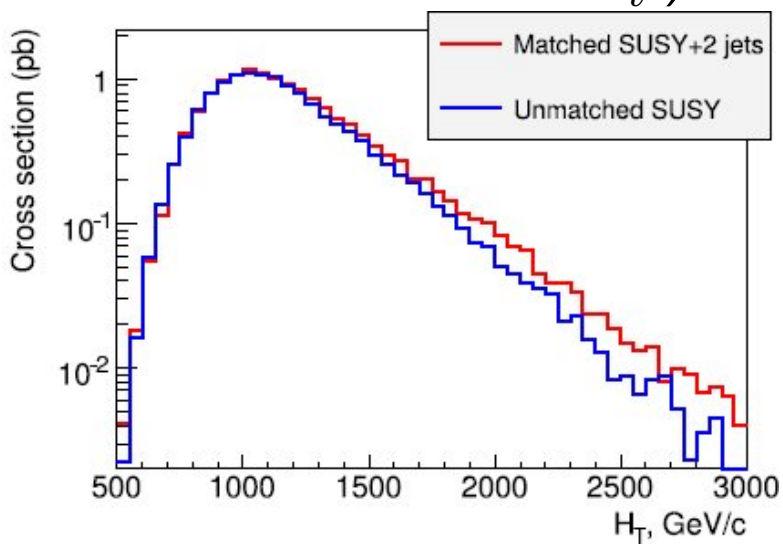
- MadEvent uses the $|\mathcal{M}|^2$ as integration channels.
- When the amplitude of the resonant diagram is computed, the information about the resonance is extracted:
  $\Rightarrow$ if the propagator inv. mass $\in [m_{\tilde{g},\tilde{q}} - 5\Gamma, m_{\tilde{g},\tilde{q}} + 5\Gamma]$, it is written 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=$M^2 + P_t^2$)





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

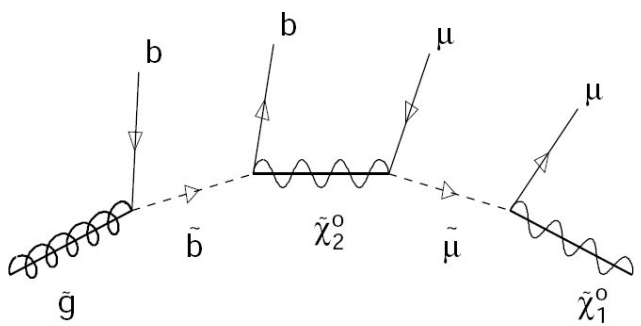
Matching impact is clearly important for the backgrounds (low masses) and not negligible for the SUSY signals

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               # Max QCD couplings
QED=0               # Max QED couplings
end_coup

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

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

done                # Write 'done' to tell MG to stop
```

The matching in MG/ME: the run_card

Choose de matching scheme: MLM or CKKW:

```
 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)

```
 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
#*********************************************************************
```

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 usefull 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: $4 \to 3$, $3 \to 2$, $2 \to 1$, $1 \to 0$
  - $P_T(X)$, $\Delta(X_1, X_2)$, $M_{inv}(X)$, $\eta(X)$,...
  - $P_T(j_1, ..., j_4)$, $\eta(j_1, ..., j_4)$ 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 everyting organized (ToC, possibility of adding banners, sections...)

Decay chains

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

Particularly usefull:

- 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)