Production of $t\bar{t}$ + jets with MadGraph/MadEvent

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Outline

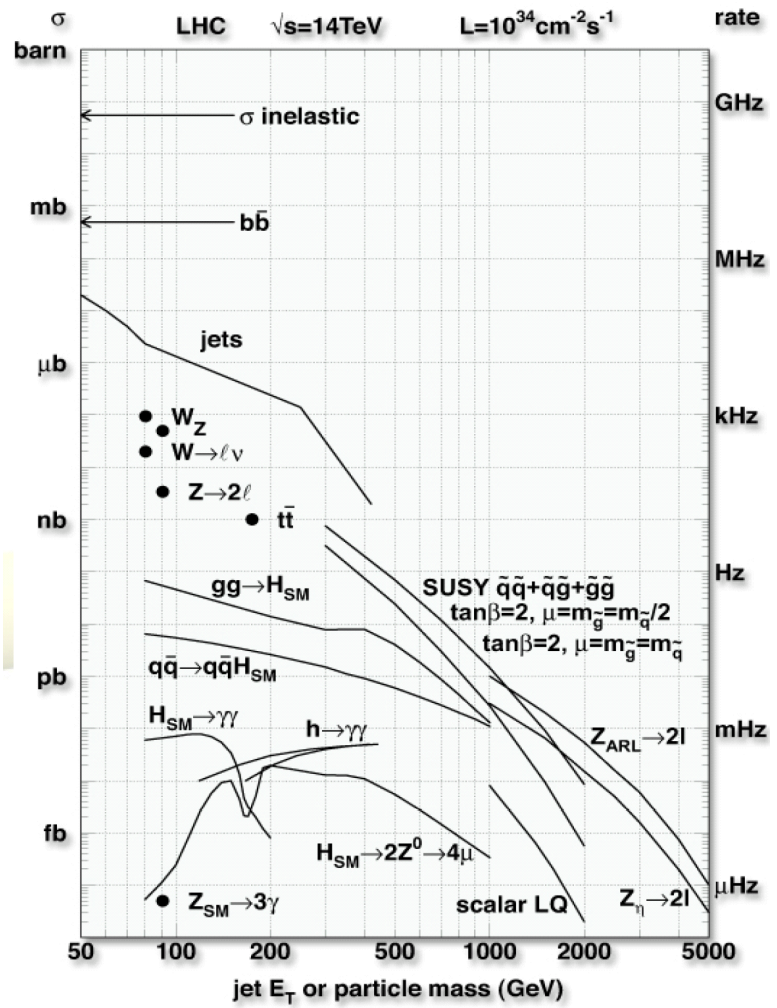
In Standard Model or beyond, many analyses have $t, W, Z, t\bar{t}, \ldots$ + jets as main background(s).

Standard Model:

- ttH production: llbbbb, ljjbbbb or lljjjjbb final states.
- Associated production WH and ZH: ljjjj, lljj final states.
- ...

2HDM :

- $H^{\pm}$ and A^0 production via $t\bar{t}$: llbbbb, ljjbbbb final states
- ...



A correct simulation of their backgrounds is crucial to hope to distinguish rare waited events.

In this talk we will deal with $t\bar{t}$+ N jets processes.

High-Q^2 and low-Q^2 simulations

ME

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

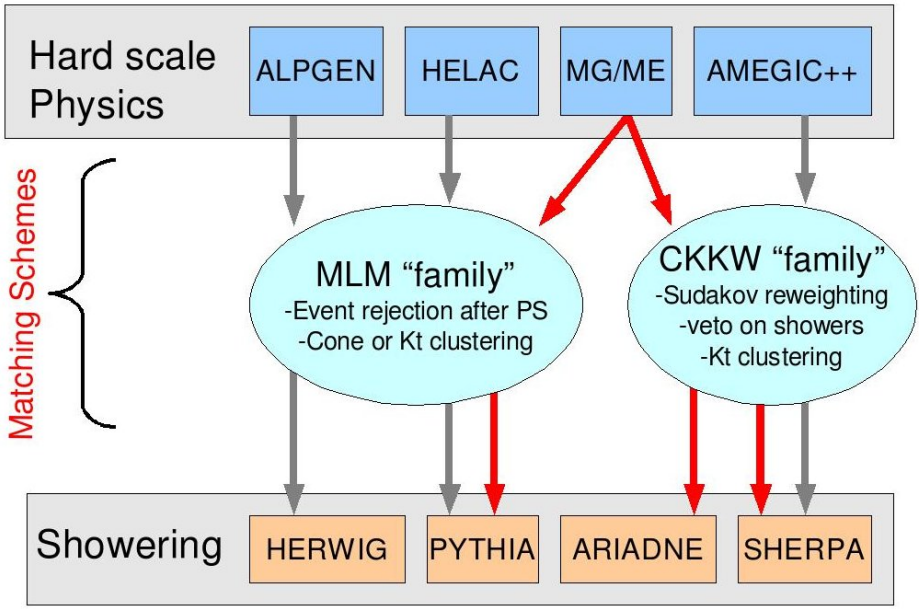
PS

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

- Both approaches are complementary!
- Without matching: overlapping between subsamples:
  ex: a $t\bar{t} + 2$ ME partons can be similar to a $t\bar{t} + 1$ ME parton + high p_T jet from showering!

Matching schemes: present status

- Avoid double counting: match each jet with ME partons!
- Describe correctly all regions of the phase-space.
- Make possible the production of inclusive samples with correct relative cross-sections of different multiplicity samples.



Different combinations of Generator-matching-PS software are possible and some have already been tested.
We will concentrate on MadGraph/MadEvent + Modified MLM Method + Pythia chain.

What is MadGraph/MadEvent?

MG/ME is a user-driven matrix element events based generator.

Madgraph (T.Stelzer and W.F.Long - 1994)

- Identify and plot Feynman diagrams and create a F77 code for the matrix element squared. (HELAS library used)
  - Can handle tree-level processes with many particles in final states particles
  - Keeps full spin correlations / interference

MadEvent (F.Maltoni and T.Stelzer - 2003)

Uses the madgraph output and diagram information to automatically build an efficient phase space integration and packages it in a process-dependent self-contained MC package for cross section evaluation and event generation

Description of MG/ME and tools

Models

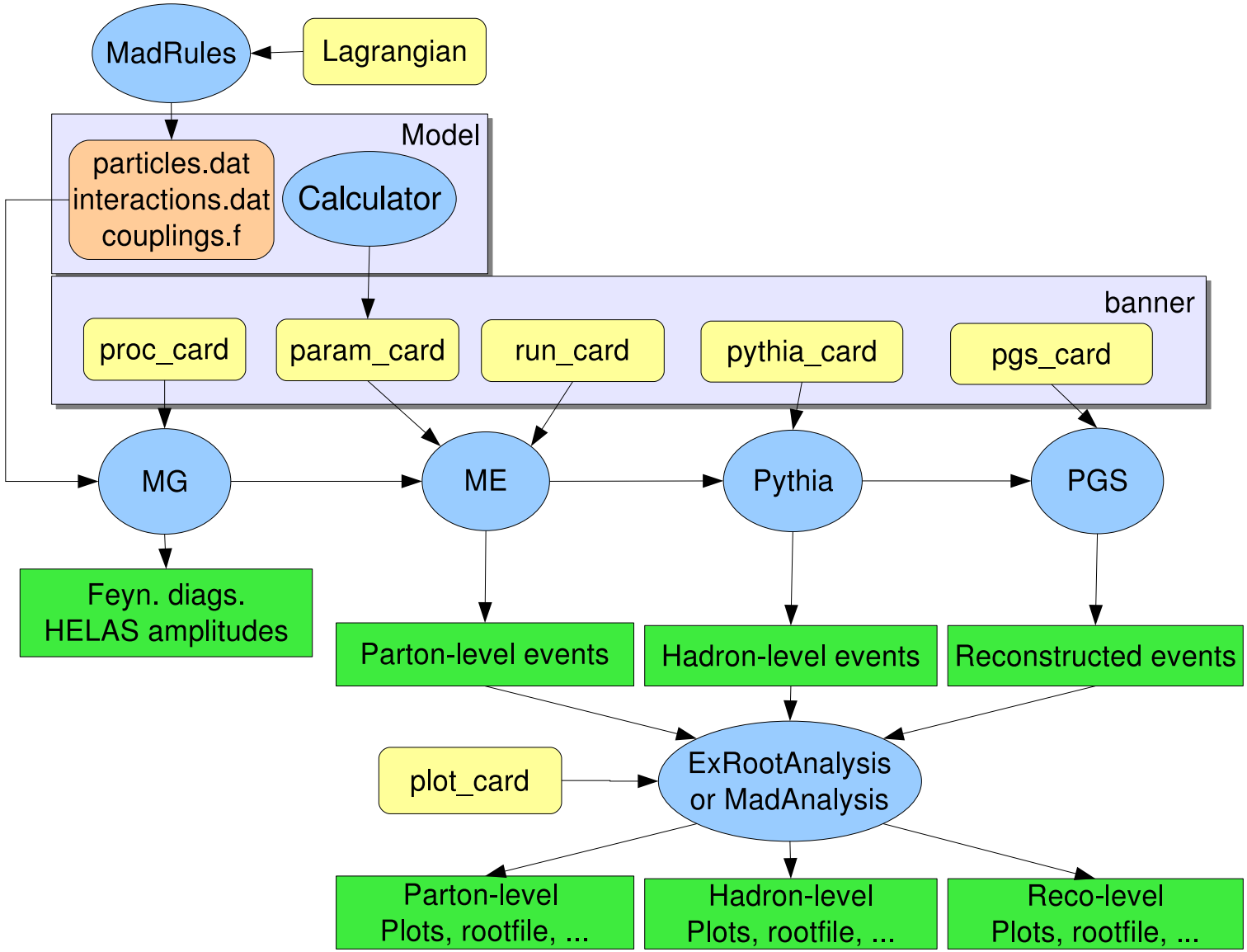
- Implemented by default: SM, SUSY, 2HDM, HEFT and UED: Maltoni, Stelzer, Hagiwara, Plehn, Rainwater, Alwall, Herquet, de Visscher, Frederix, Alves
- Framework for easy implementation of new models: UserMod (de Visscher)
- Possibility of generate a model from Lagragian expression (available soon) (Duhr)

External Tools

- Pythia and PGS interface for shower/hadronization and detector simulation
- MadAnalysis, ExRootAnalysis (Frederix, Demin)
- BRIDGE: Reece, Meade: example of use of MG/ME as an open-source development environnment

CMSSW compatibility

Ouput in "Les Houches" format so easy to use with CMSSW!


MadRules
Lagrangian
Model
particles.dat
interactions.dat
couplings.f
Calculator
banner
proc_card
param_card
run_card
pythia_card
pgs_card
MG
ME
Pythia
PGS
Feyn. diags.
HELAS amplitudes
Parton-level events
Hadron-level events
Reconstructed events
plot_card
ExRootAnalysis
or MadAnalysis
Parton-level
Plots, rootfile, ...
Hadron-level
Plots, rootfile, ...
Reco-level
Plots, rootfile, ...

Modified MLM method

Reminder

Main matching goal is to avoid double counting between ME and PS productions.

A new method of matching: Modified MLM by J.Alwall

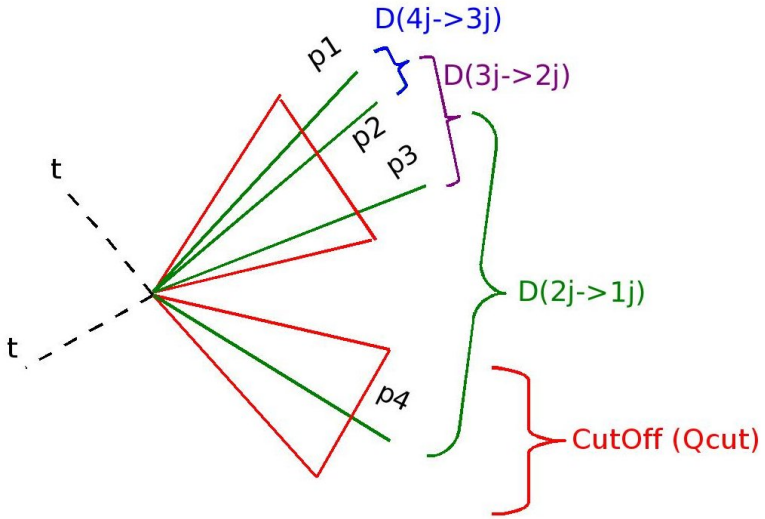
- Generate matrix-element with parton-parton or parton-beam minimal distance (g,u,d,s,c) $d^{(i,j)}, d^{(i,beam)} > xqcut$
  $\rightarrow$ ME-generator only produces events with well separated partons
- Perform Pythia showers(currently v.6.4 is used)
- Cluster partons in jets with $k_\perp$ algorithm.
- Matching between partons and jets ($d^{(jet,parton)} < Qcut$): reject event with Njets $\neq$ Npartons (except for highest multiplicity sample)
  $\rightarrow$ Remaining events have "narrow" showers centered on ME-partons

Note that $xqcut < Qcut$, in general by a factor 1.5 (due to jet measure change during showering).

- For inclusive W production, this method has been fully compared with results from other generators (ALPGEN, ARIADNE, HELAC and SHERPA) and Tevatron data. (J.Alwall et *al, publication to come)*

Test of matching method

Between low-Q^2 and high-Q^2 physics descriptions, transition has to me smooth and independant of $Qcut$ choice! Use differential jet rate to check this!
Def: D(N j$-$ $>$N-1 j):While clustering partons, maximum distance at which an event switch from a N-jet to a N-1 jet configuration.



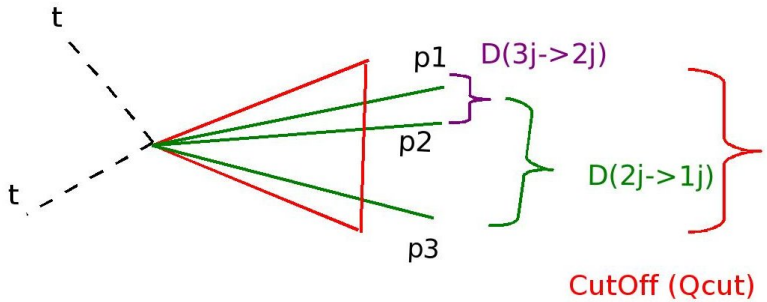


Illustration of a $t\bar{t}+2$ ME partons after (very simplified) showering.
D(2 jets $\rightarrow$ 1 jets)$>$ $Qcut$: **link partons with distance typical of ME-level generation**

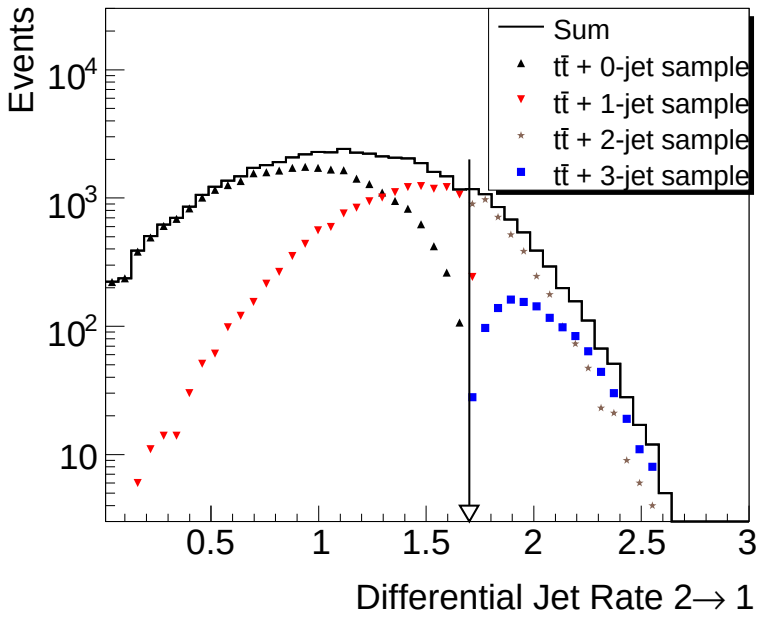
Illustration of a $t\bar{t}+1$ ME partons after (very simplified) showering.
D(2 jets $\rightarrow$ 1 jets)$<$ $Qcut$: **link partons with distance typical of PS-level generation**

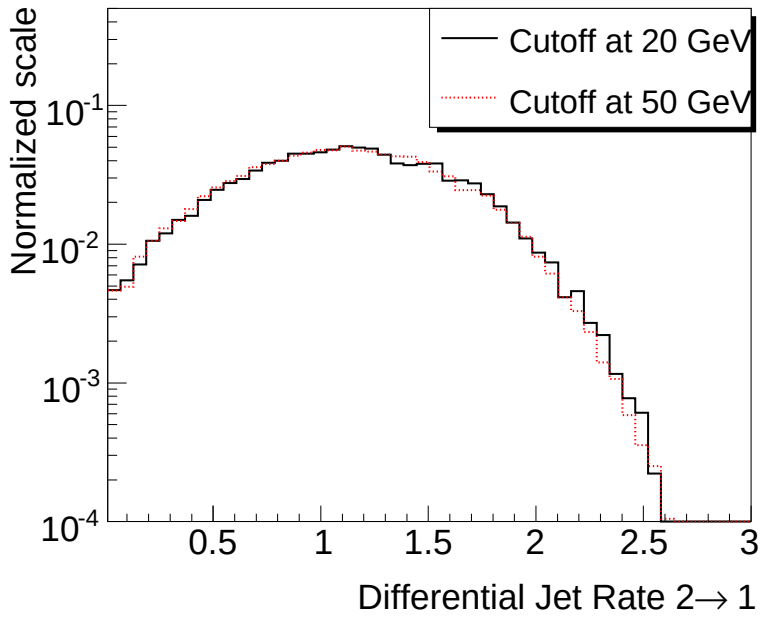
Smoothness and shape invariance

Following results has been presented at DIS2007.

Smooth transition from lefthand side of CutOff to righthand side: differential jet rate (2 jets $\rightarrow$ 1 jet)

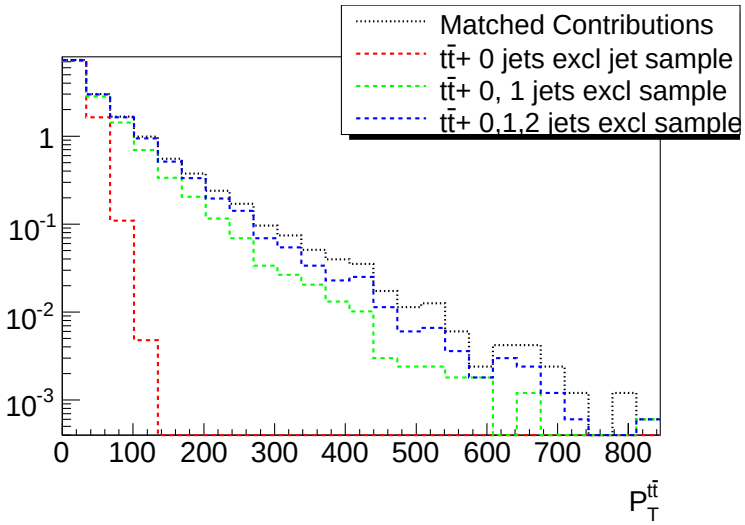
Invariance of global shape (Physical observable) with respect to CutOff choice: comparison of curves for $Qcut$=20 GeV and $Qcut$=50 GeV



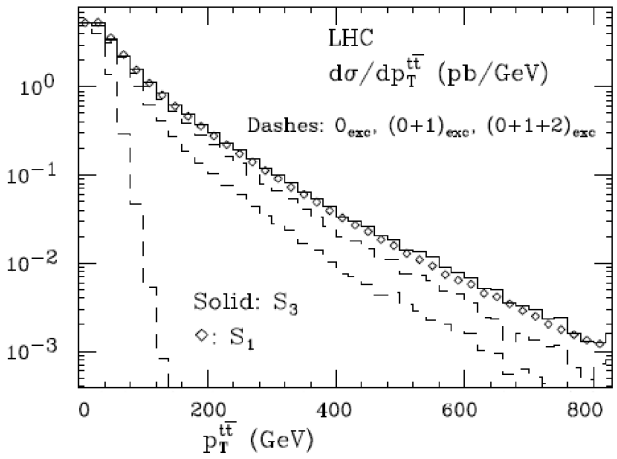


Comparison with other generator: $P_T(t\bar{t})$

Comparison with other generator-matching-showering combination is important to estimate systematics!
In the following, this has been done with ALPGEN-MLM scheme-Herwig

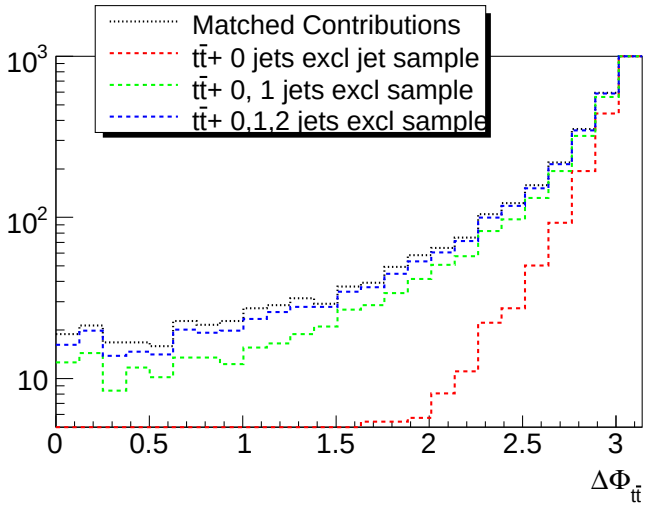


MG/ME with Modified MLM matching, using k_T clustering and Qcut=50 GeV.



ALPGEN with MLM matching, using cone algorithm. (Mangano et *al*: hep-ph/0611129)

Comparison with other generator: $\Delta\phi(t\bar{t})$



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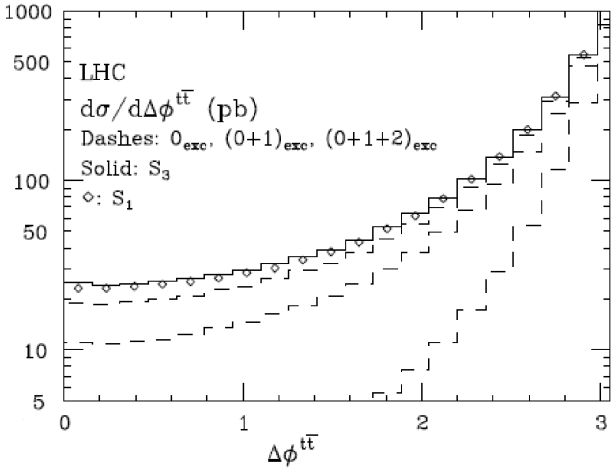
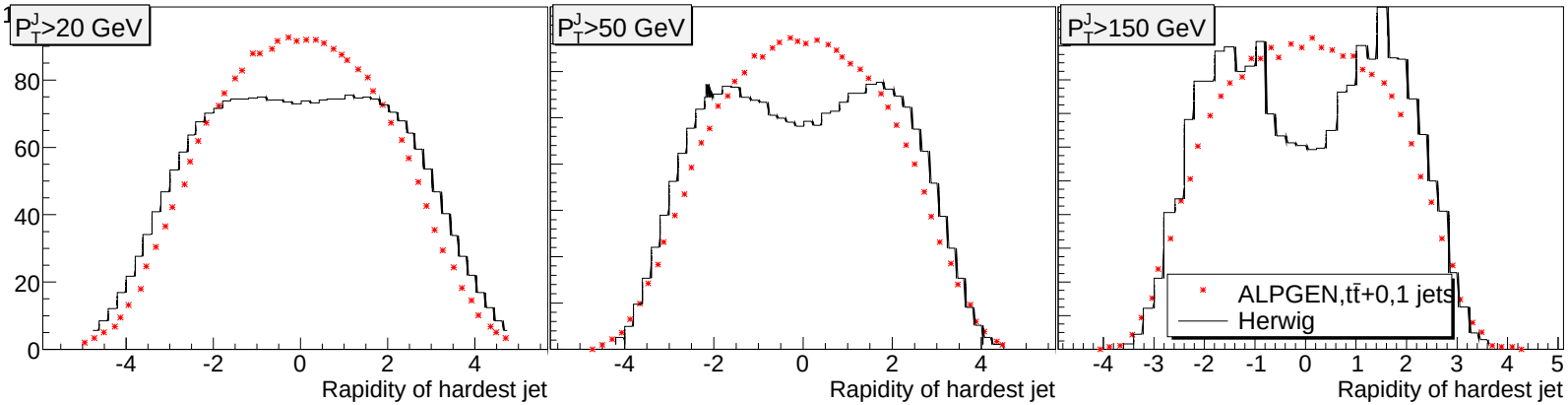


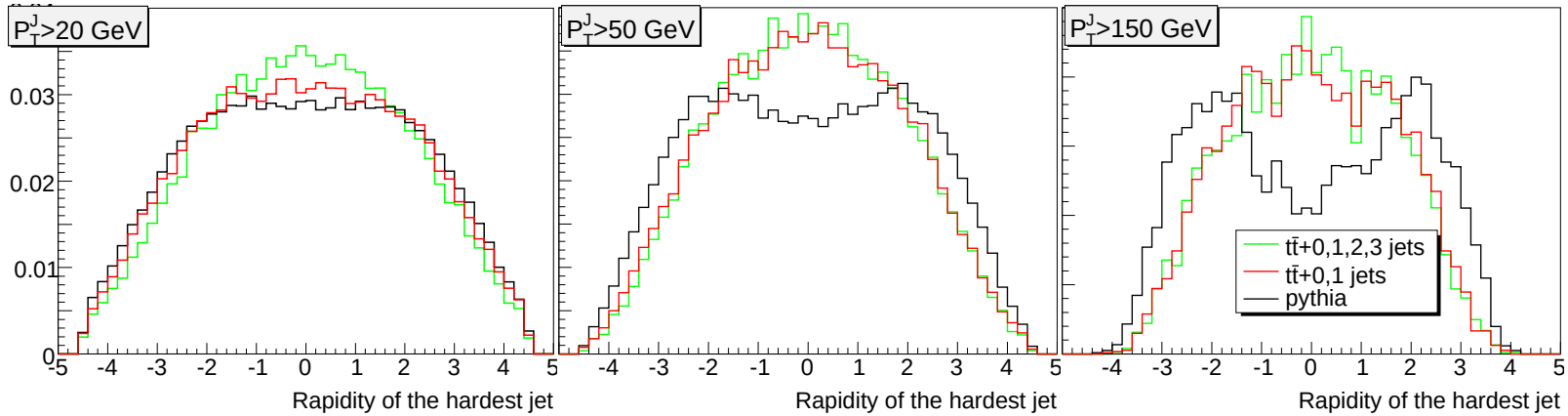
ALPGEN with MLM matching, using cone algorithm. (Mangano et *al*: hep-ph/0611129)

Comparison with other generator: Rapidity of the hardest jet

Comparison of shape of the rapidity of the leading jet for differents P_T^{jet} cut: ALPGEN $t\bar{t} + 0, 1$ jets and Herwig [hep-ph/0611129]):



MadGraph/MadEvent with $t\bar{t} + 0, 1, 2, 3$ jets, $t\bar{t} + 0, 1$ jets and pythia:



Plots are normalized and scale is arbitrary.

Matching with CMSSW (in coll with D.Kcira)

Practically

Possible to generate an inclusive production in one sample or separate samples ex for separate sample:

- $t\bar{t} + 0, 1, 2$ jets exclusive :IEXC tag=0
- $t\bar{t} + 3$ jets exclusive :IEXC tag=1

where IEXC is a tag to use in pythia card. (a bit different in CMSSW cfr Dorian's talk).

at Louvain (CP3)

A test sample of $\sim$ 1M events is currently being generated with Modified MLM matching and CMSSW.
MadEvent produces LHE files usable directly by pythia within CMSSW.
Separate samples (semi and fully leptonic (e,μ, τ) decays of top quarks) of $t\bar{t} + 0, 1, 2, 3$ jets

- xqcut=20 GeV and Qcut=30 GeV
- CTEQ5L
- Fact. and ren. scales fixed at 174 GeV.
- $P_T(j)$ >15 GeV

Summary

- Matching use: only manner to simulate safely multijets processes samples
- Matching has been implemented on MadGraph and is available!
- Inclusive W + N jets matched samples compared with Tevatron data and other generators simulations.
- $t\bar{t}$ + N jets tested with Modified MLM method.
- "Pythia Step" of the matching has been implemented in CMSSW: Mass production of inclusive sample has started!

Back-up slides

New physics

New model implementation

- MSSM (Hagiwara, Plehn, Rainwater, Stelzer and Alwall)
  - CP and R-parity conserving MSSM, sfermions mixing and Yukawa couplings for 3rd generation.
  - Comparison and validation of cross sections between Smadgraph, Omega and Amegic++ (hep/ph/0512260)
  - Input files available for the 10 SnowMass points (inputs in Les Houches format).
- 2HDM (Herquet and de Visscher)
  - Generic, with FCNC and CP violation
  - Tested with MSSM and SM in Madgraph and Comphep
- HEFT (Frederix): ggS and $\gamma\gamma S$ effective couplings with S a (pseudo-)scalar in SM or 2HDM
- UED (Alexandre Alves): work in progress

User Model (de Visscher)

Framework to install easily and safely new physics models. For example: add a $Z^{'}$, $t^{'}$, graviton, ... or all in the same time.
To do:

- Edit particle and interaction content
- Run a script that creates all other files needed by MadGraph/MadEvent to run properly
- Define values of new parameters and new couplings.

Following provided explanations on website, this could take only 10 or 15 min for cases described here above!

Used at Stanford, Berkeley, KEK, UCL,...

Note that

- Current work (Duhr) for make first step completely automatic from the expression of any Lagrangian (renomalizable or not)
- Also we try to have more flexibility than HELAS structure.