MadGraph/MadEvent at work: from QCD backgrounds to new physics signals.

S.de Visscher
Universite Catholique de Louvain
Center For Particle Physics and Phenomenology (CP3)

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J.Alwall† F.Maltoni∗ M.Herquet∗ P.Demin∗
R.Frederix∗ C.Durh∗ T.Stelzer‡

† SLAC

∗ Universite Catholique de Louvain

‡ University of Illinois

Deep Inelastic Scattering - 18th April 2007

Outline

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

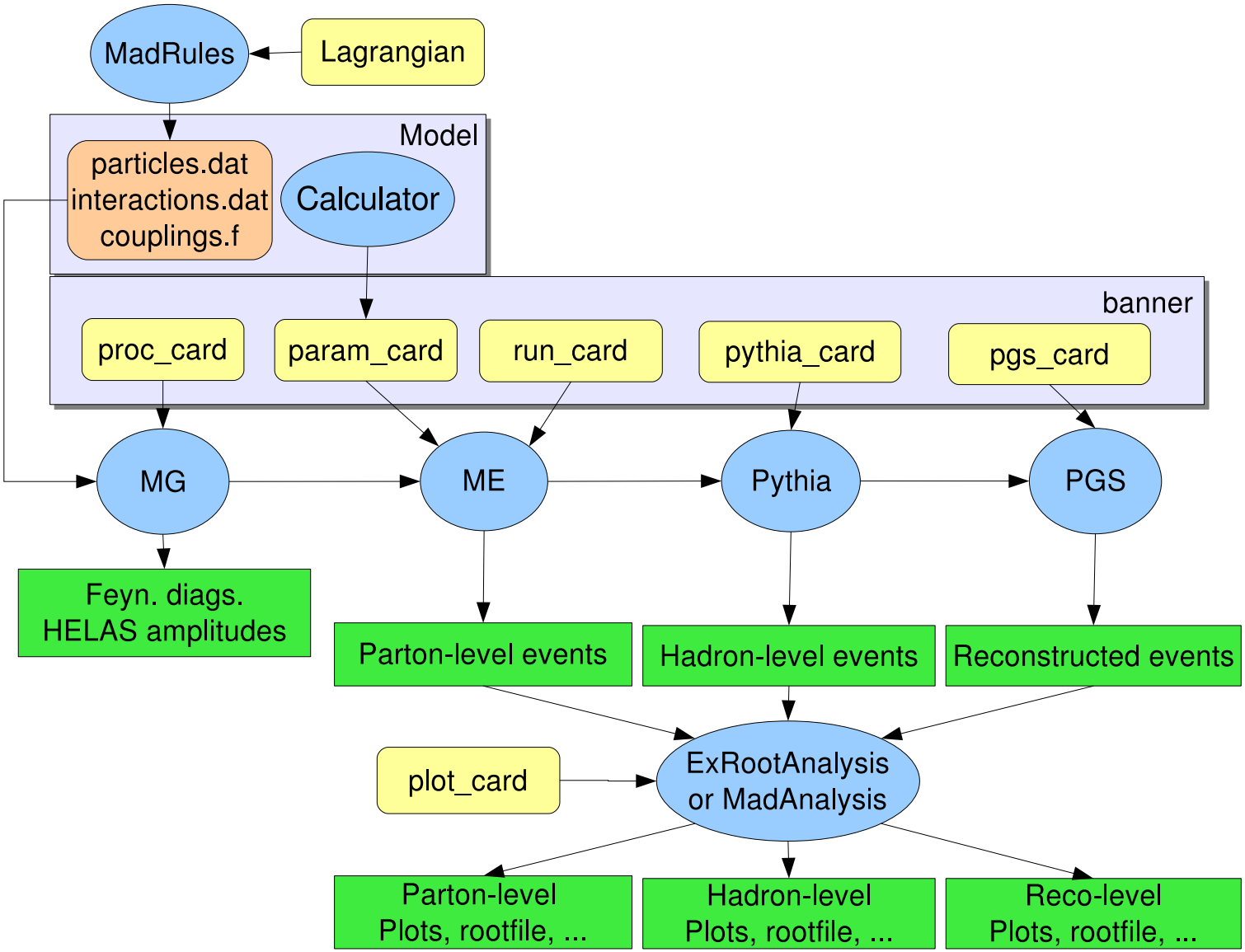
MadEvent (F.Maltoni and T.Stelzer - 2003)

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

With MadGraph/MadEvent and his tools, complete simulation chain available: from hard scale physics to detector simulation!

- Models
  - Implemented by default: SM, SUSY, 2HDM, HEFT and UED
  - Framework for easy implementation of new models
- Tools
  - Pythia and PGS interface for shower/hadronization and detector simulation
  - MadAnalysis, ExRootAnalysis
  - BRIDGE: Reece, Meade: example of use of MG/ME as an open-source development environnment

- Ouput in "Les Houches" format so easy use with full simulation tool like CMSSW!
- Download the code or web-based generation: three public clusters: at UCL (http://madgraph.phys.ucl.ac.be), in Rome (http://madgraph.roma2.infn.it) and at UIUC (http://madgraph.hep.uiuc.edu).

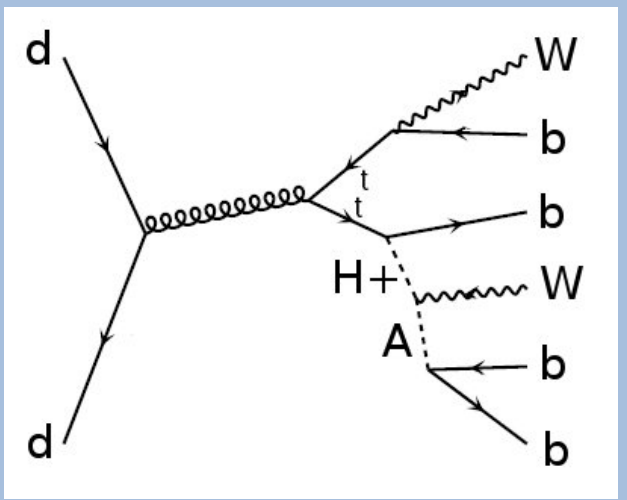

MadRules
Lagrangian
Model
particles.dat
interactions.dat
couplings.f
Calculator
banner
proc_card
param_card
run_card
pythia_card
pgs_card
MG
ME
Pythia
PGS
Feyn. diags.
HELAS amplitudes
Parton-level events
Hadron-level events
Reconstructed events
plot_card
ExRootAnalysis
or MadAnalysis
Parton-level
Plots,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

A quite general aspect of new physics

In BSM Physics, many analyses have $t, W, Z, t\bar{t}, \ldots$ + jets as main background(s), with large cross sections.
A correct simulation of those processes is therefore crucial to distinguish non-SM events.

An example

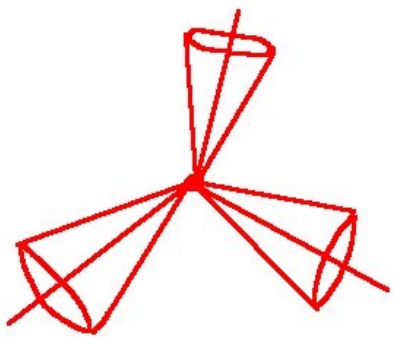
in 2HDM, $pp \to W^+W^-b\bar{b}b\bar{b}$ could be the most interesting channel to discover the charged higgs!



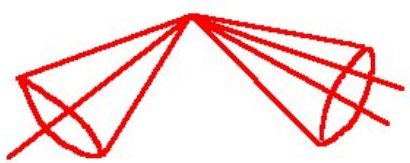
$\to$ Need a reliable $t\bar{t} + 0, 1, 2, 3\ldots$ jets events sample!

Introduction to matching problem

Let's take a simple situation: we want to generate an inclusive sample of $t\bar{t}$ + jets. So first we generate at ME level all samples with different multiplicity. Let's focus on $t\bar{t}$+3 jets. At ME level we produce for example $pp \to t\bar{t}ggg$

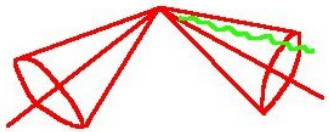


Defining a maximum "size" of a jet, each ME parton produce independant showers$\to$ we have 3 jets with respect to this size!

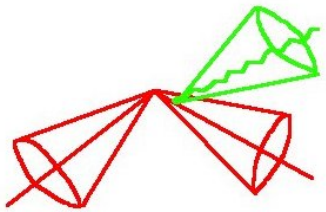


If two partons are too colinear, we get a 2 jets-event! Already taken into acount in $t\bar{t}gg$... Double counting

Other example still in the context of the production of an inclusive sample. We focus here on $t\bar{t}$+2 jets. At ME level we produce for example $pp \to t\bar{t}gg$. The green line indicates a radiation from ME parton.



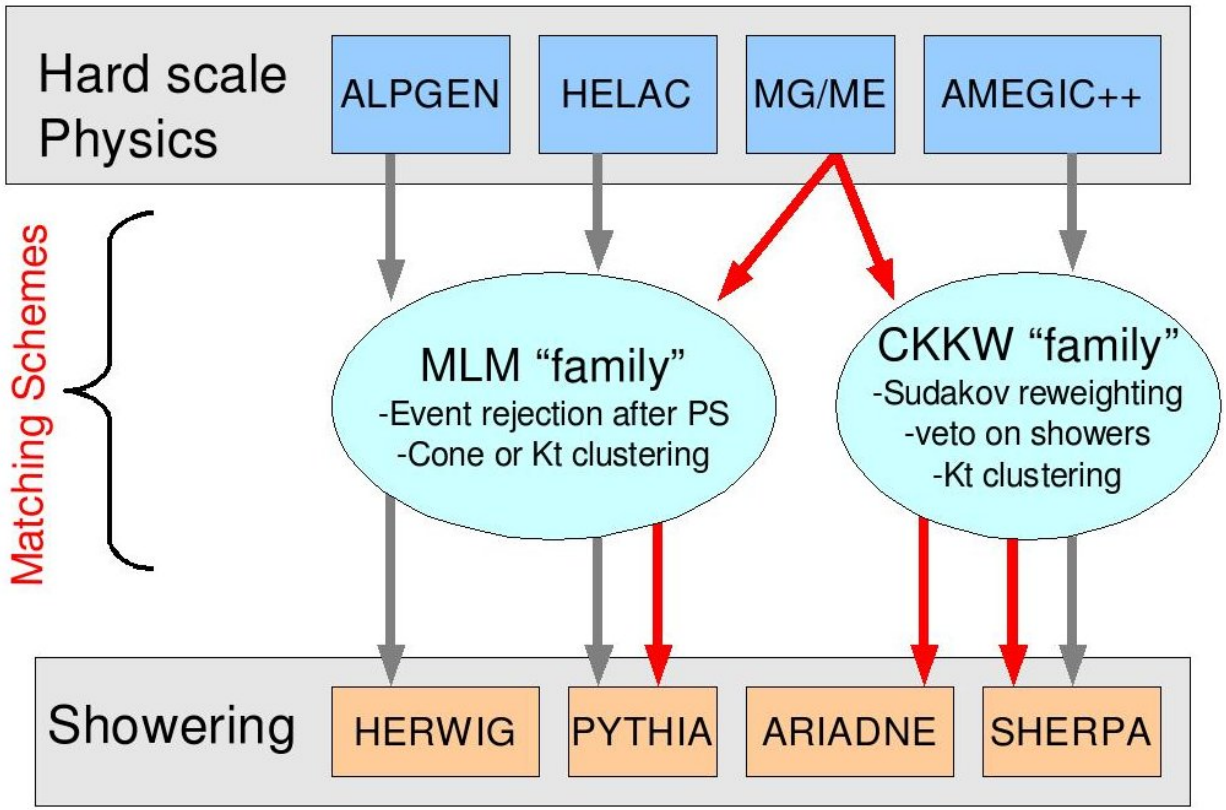
With the radiation soft and collinear, we still get a 2-jets event$\to$ ok!



If radiation is too hard, we get a 3 jets-event! Already taken into acount in $t\bar{t}ggg$... also Double counting

Matching aims

- 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.



Comparison between results from differents generators with differents matching schemes make possible the study of systematics!

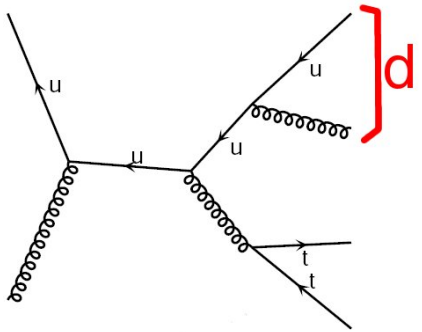
- Already done: Inclusive W production has been fully compared with results from other generators (ALPGEN, ARIADNE, HELAC and SHERPA) and Tevatron data. (J.Alwall et *al, publication to come)*

In the present study

$t\bar{t} + N$ jets at LHC has been investigated with Modified MLM (Pythia showers) in MadGraph/MadEvent 4.1.

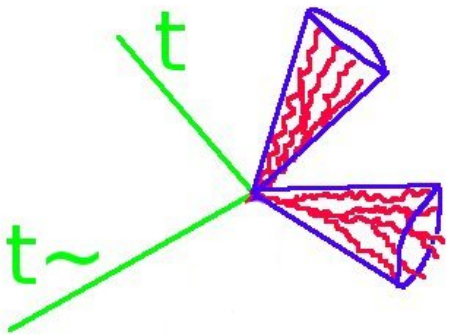
Modified MLM Method

- Generate matrix-element with parton minimal distance (g,u,d,s,c) $d^{(i,j)} > d_{cut}$
- Perform Pythia showers(currently v.6.4 is used)
- Cluster partons in jets with k_T algorithm.
- Matching between partons and jets ($d^{(jet,parton)} < d_{cut}$): reject event with Njets $\neq$ Npartons (except for highest multiplicity sample)

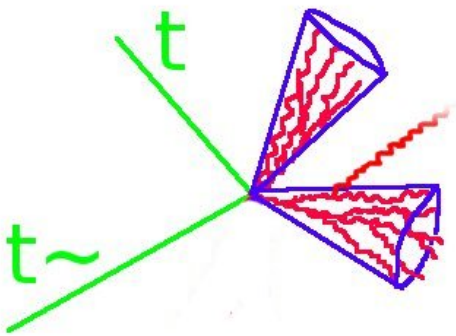


At ME level generation, remove events with $d < d_{cut}$!

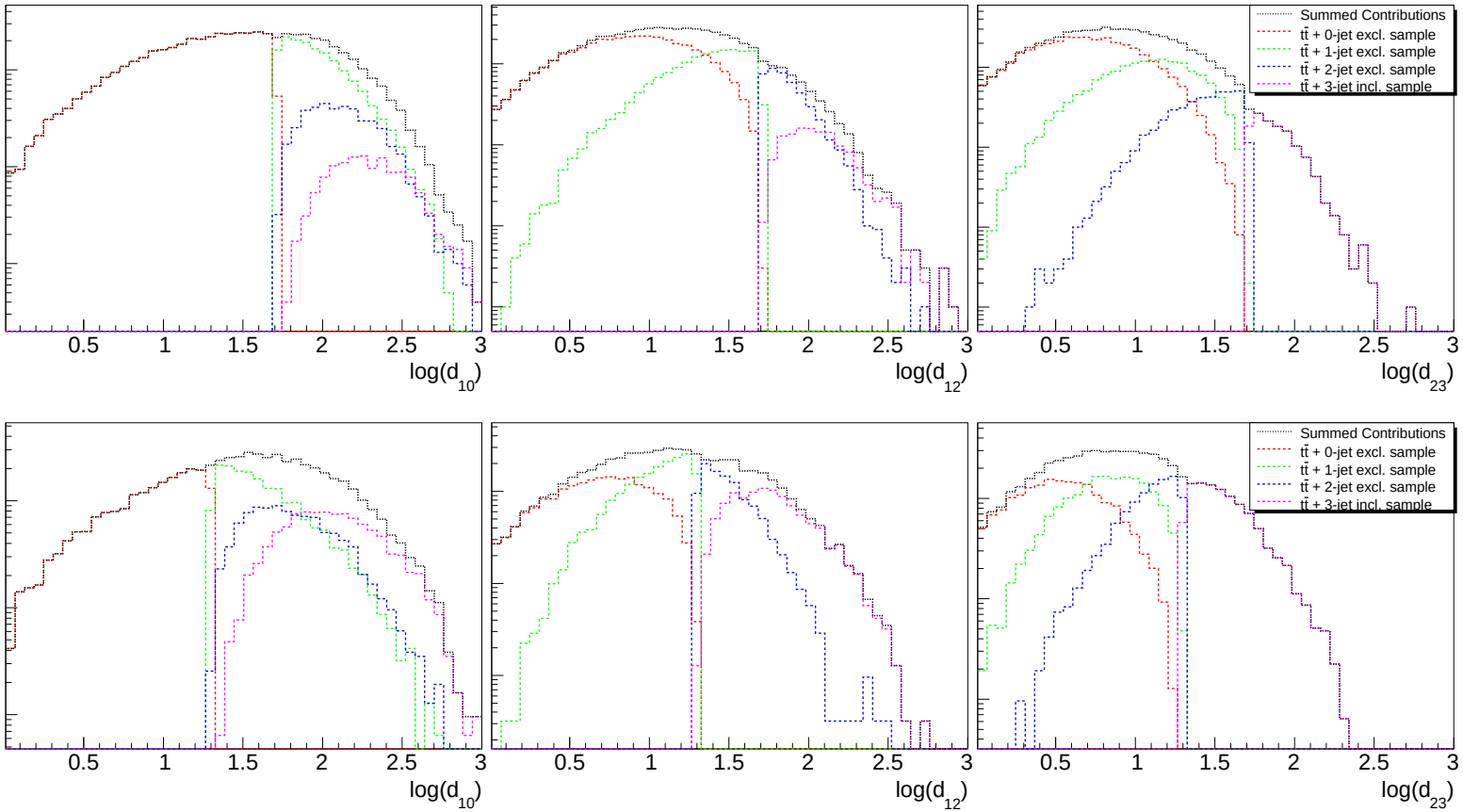
After ME events generation, perform parton shower



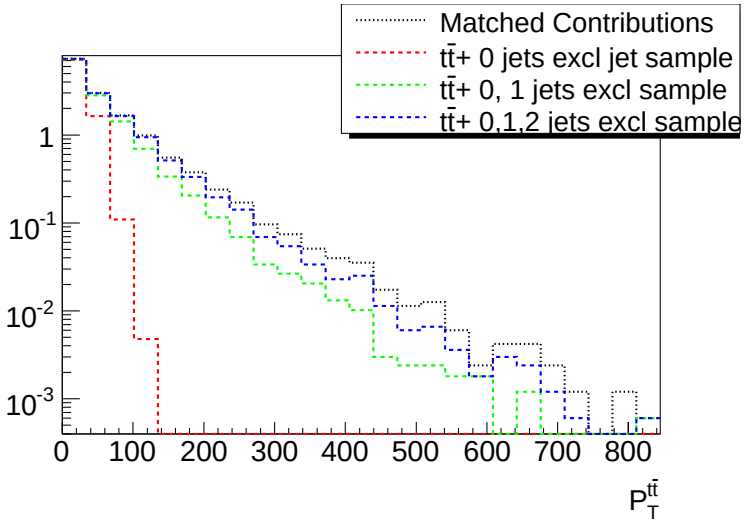
Clustering of shower with d_{cut} as scale: if each ME parton is matched with a jet at shower level: the event is kept!



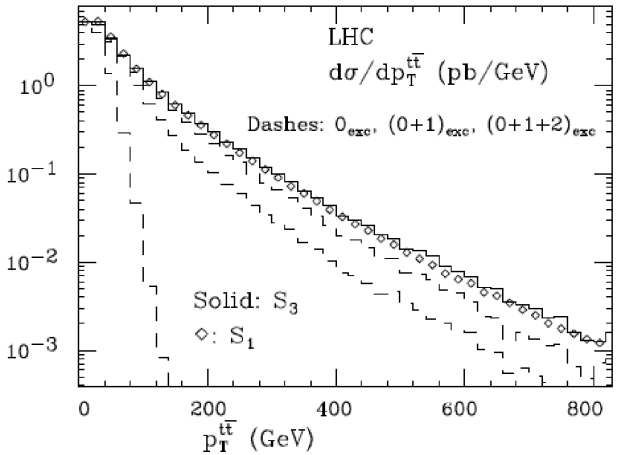
If there is one more jet, the events is kept only for highest multiplicity samples.



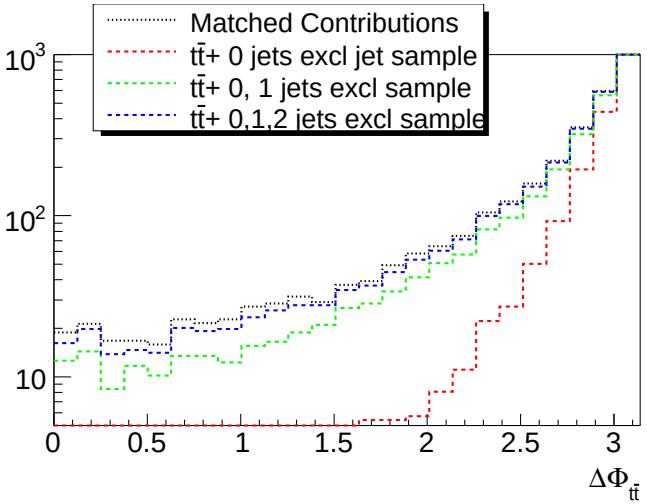
Check smoothness and shape invariance of differential jet rates for 1→0, 2→1, 3→2 for d_{cut}=50 (first line) and 20 (second line) GeV.



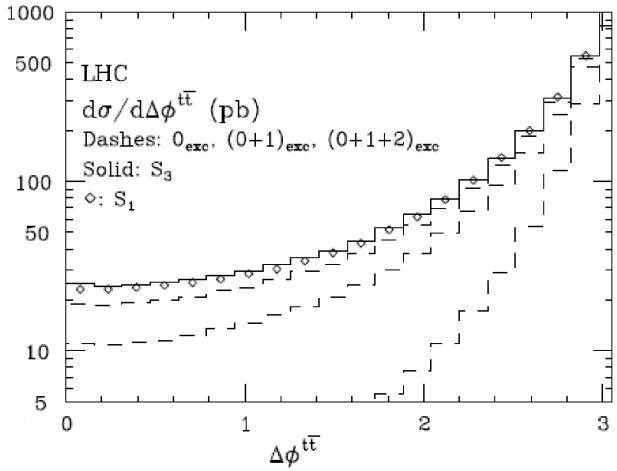
MG/ME with Modified MLM matching, using k_T clustering.



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

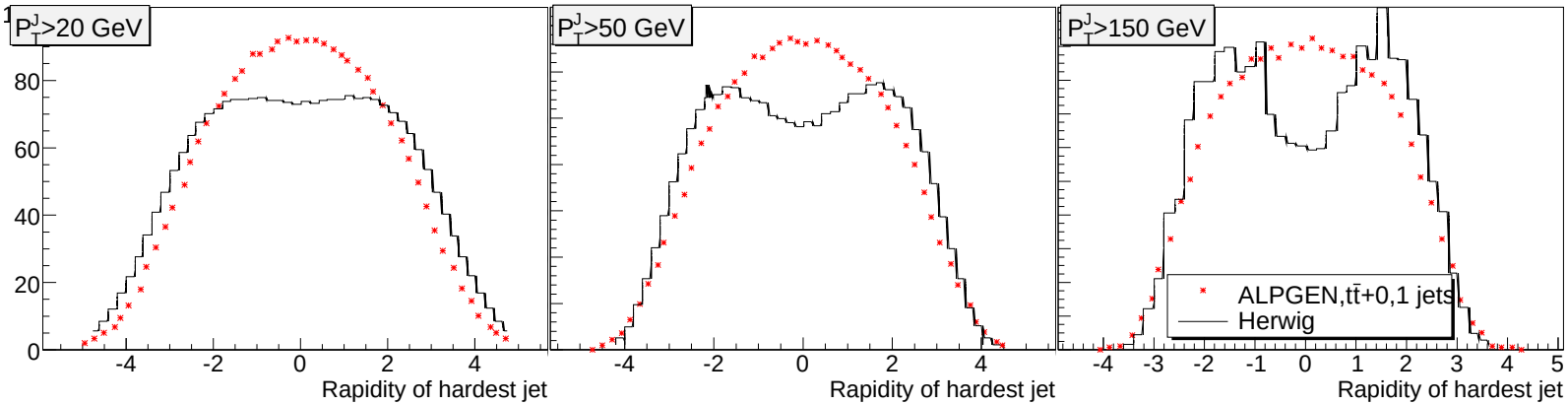


MG/ME with Modified MLM matching, using k_T clustering.

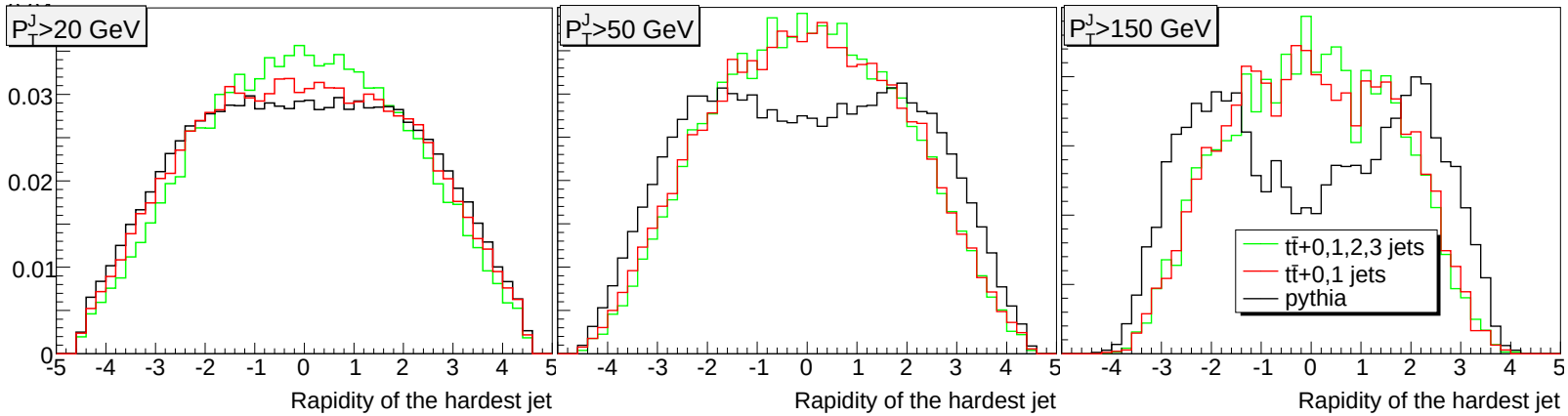


ALPGEN with MLM matching, using cone algorithm. (Mangano et *al*: hep-ph/0611129)

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.

Summary

- MadGraph/MadEvent: a tool to generate any process in already implemented model or your own model!
- 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 k_T clustering and modified MLM matching scheme. Mass production of inclusive sample should start soon!

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.

Comparison of rapidity of leading jet with MC@NLO, ALPGEN and MG/ME.