Latest development for ME-PS matching with MadGraph/MadEvent

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Outline

In Standard Model or beyond, many analyses have $t, W, Z, t\bar{t}, ... +$ jets as main background(s).
A correct simulation of those backgrounds is crucial to hope to distinguish rare waited events.

ME

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

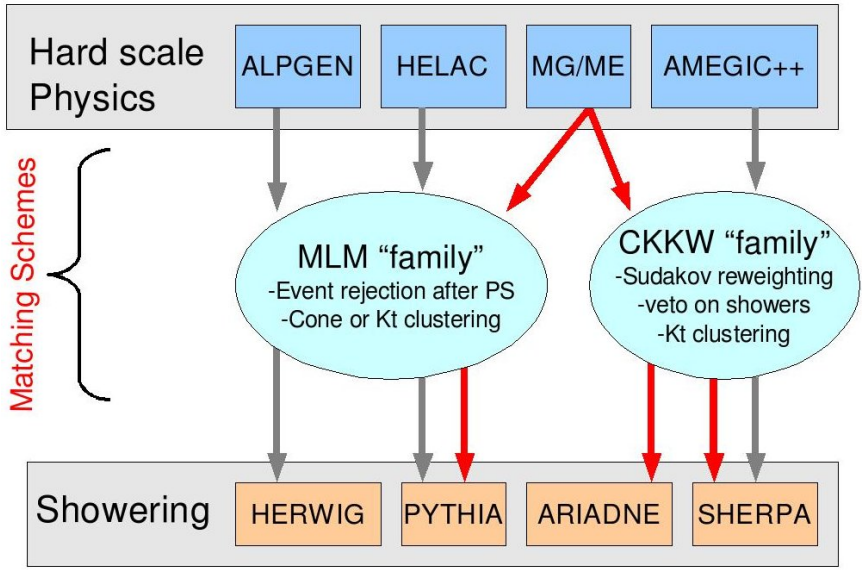
PS

- 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

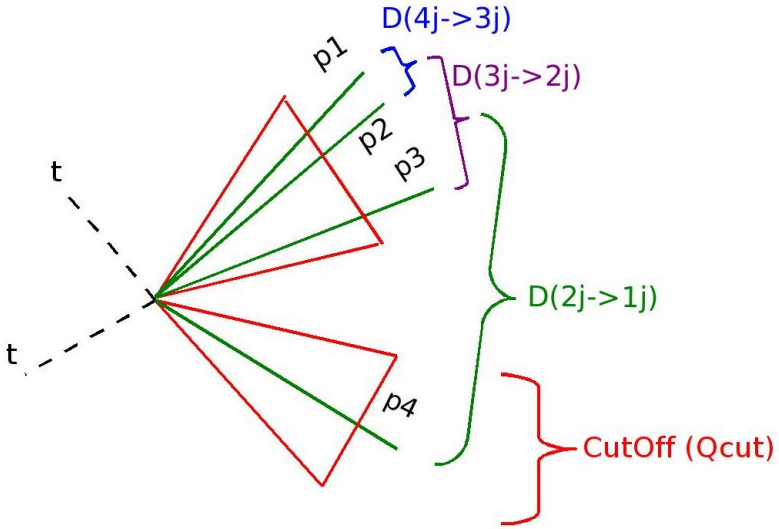
- Avoid double counting: match each jet with ME partons!
- Describe correctly all regions of the phase-space.
- Make possible the production of inclusive samples with correct relative cross-sections of different multiplicity samples.



Different combinations of Generator-matching-PS software are possible and some have already been tested (hep-ph/07062569).
We use MadGraph/MadEvent + Modified MLM Method (J. Alwall) + Pythia chain.

Differential Jet Rate: test of matching parameters

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



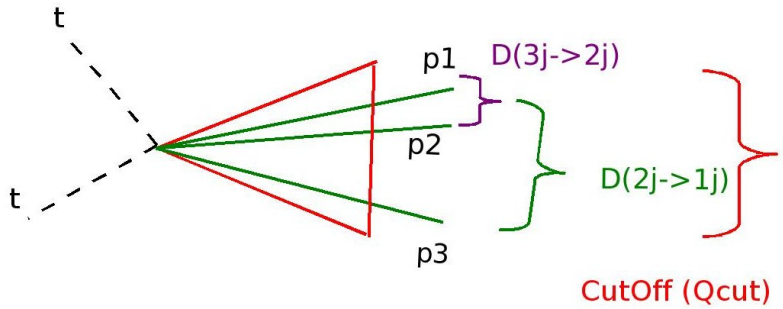


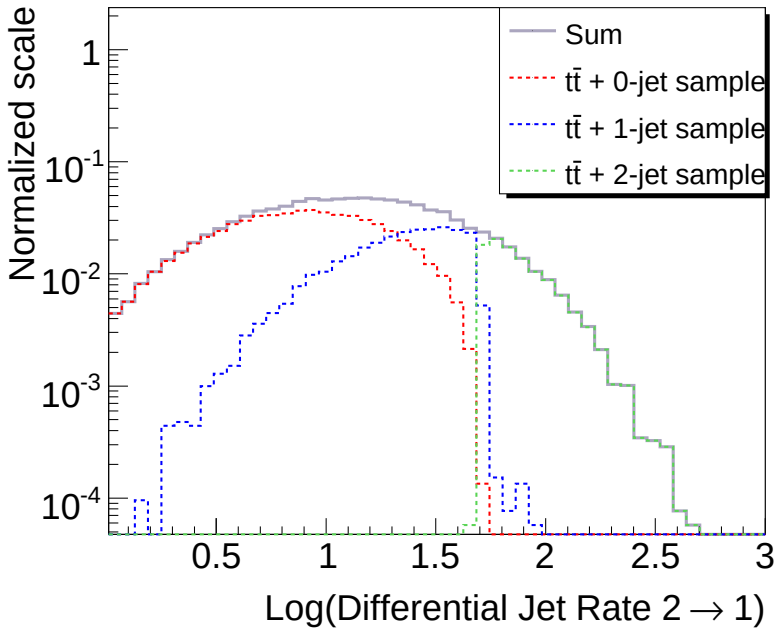
Illustration of a $t\bar{t}+2$ ME partons after (very simplified) showering.
D(2 jets $\rightarrow$ 1 jets)$> Qcut$: **link partons with distance typical of ME-level generation**

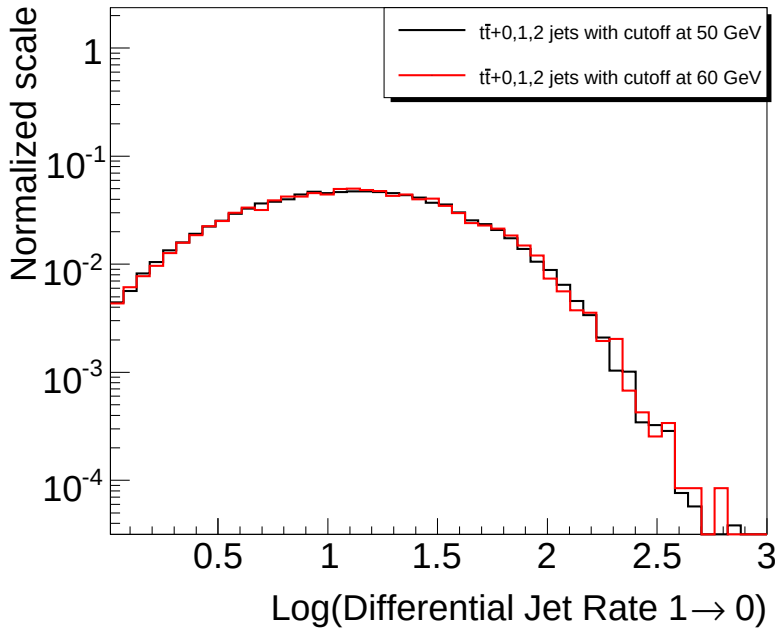
Illustration of a $t\bar{t}+1$ ME partons after (very simplified) showering.
D(2 jets $\rightarrow$ 1 jets)$< Qcut$: **link partons with distance typical of PS-level generation**

Example with a $t\bar{t}$ + N jets production

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 $Qcut$=50 GeV and $Qcut$=60 GeV





A new tool: MadMatchChecker (S. de Visscher, P. Demin)

Aims

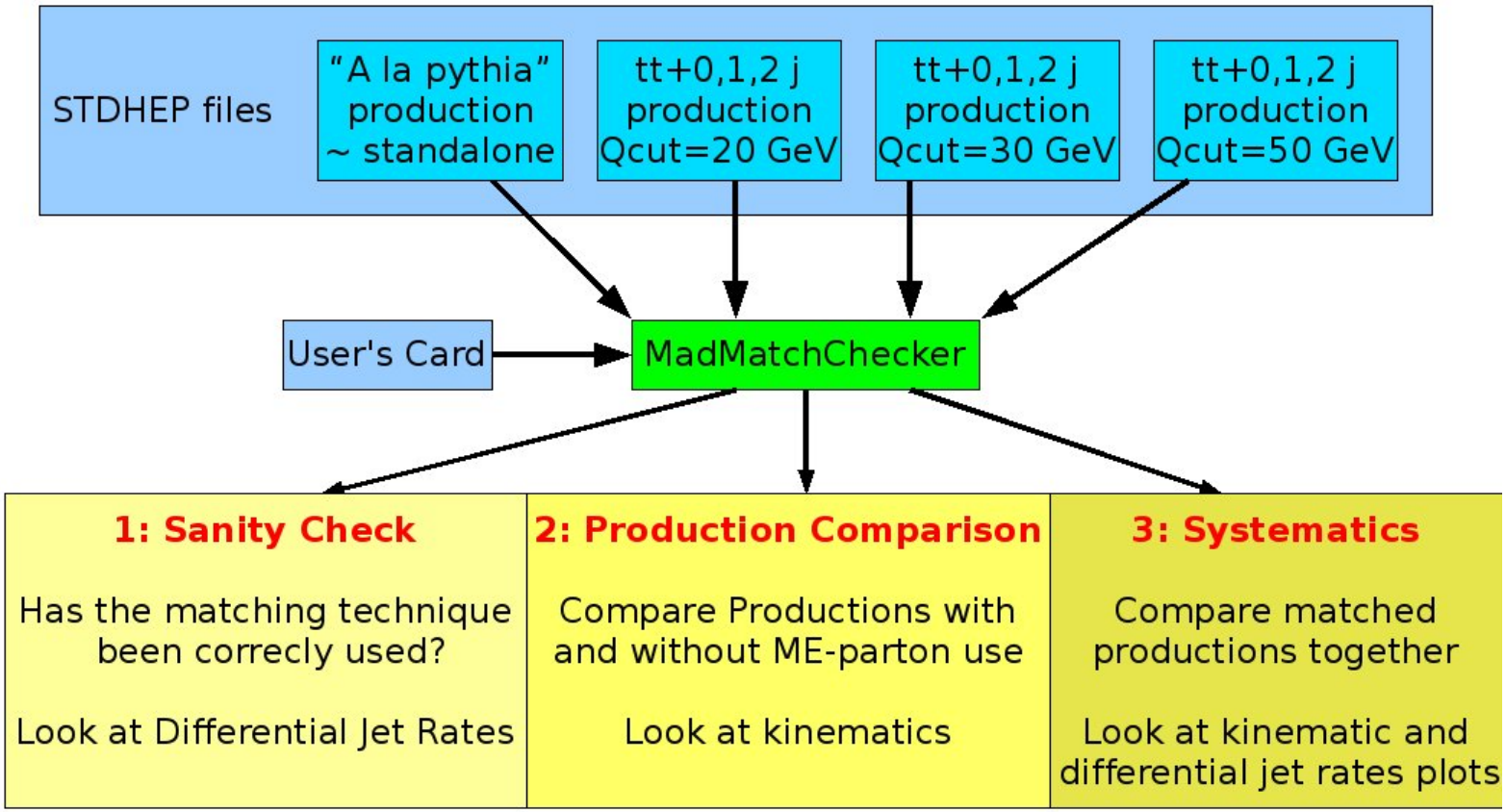
The main goal of this tool is to provide to the user an easy access to matching-related datas in order to

- Check if a sample is internally consistent by automatically plotting the key distributions
- Compare samples coming from different MC's (different ME's, matching schemes, approaches) or perform studies on the systematics.

In other words...

- Input STDHEP for the moment, HEPMC in the future
- Do easily comparison of particles and jets kinematics between sample with different multiplicities and different parametrization
- Package works with any MC output.

A simple example with $t\bar{t}$ + jets production

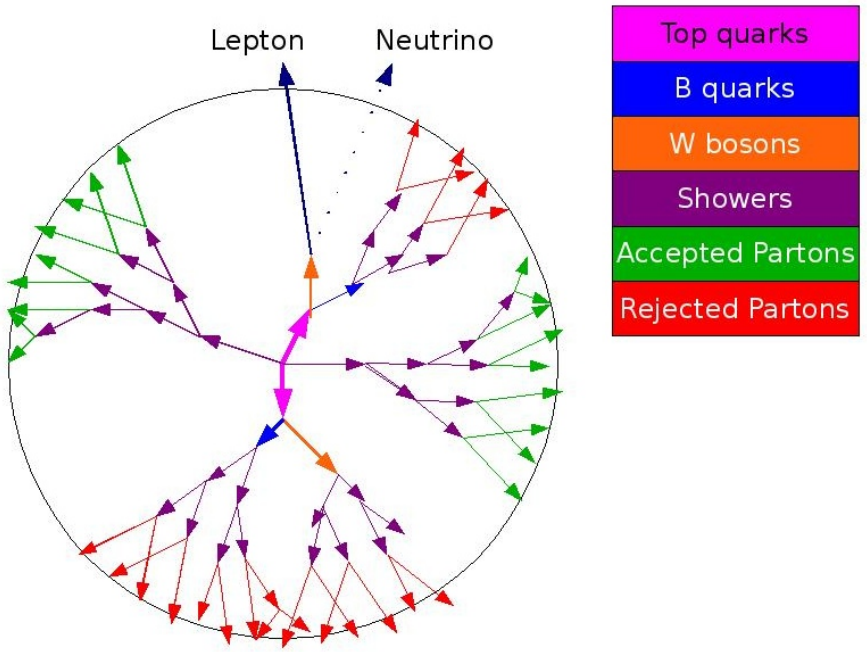


Works with any "X" + n jets process
Already used on ttbar and WW + N jets

Parton information

To calculate Differential Jet Rate and extra jet kinematics, only showered partons with an extra radiation as origin can be taken into account. MadMatchChecker uses ExRootAnalysis (P.Demin) to run over STDHEP file to build the array of accepted showered partons. For about 99.9 % of $t\bar{t}$ + N jet processes, all partons are correctly assigned to the original ME-parton.

Example: $t\bar{t}$+ N jets with or without top decay)



The KTJET code is then called to calculate DJR and jet clustering.

Plots details

Differential Jet Rate

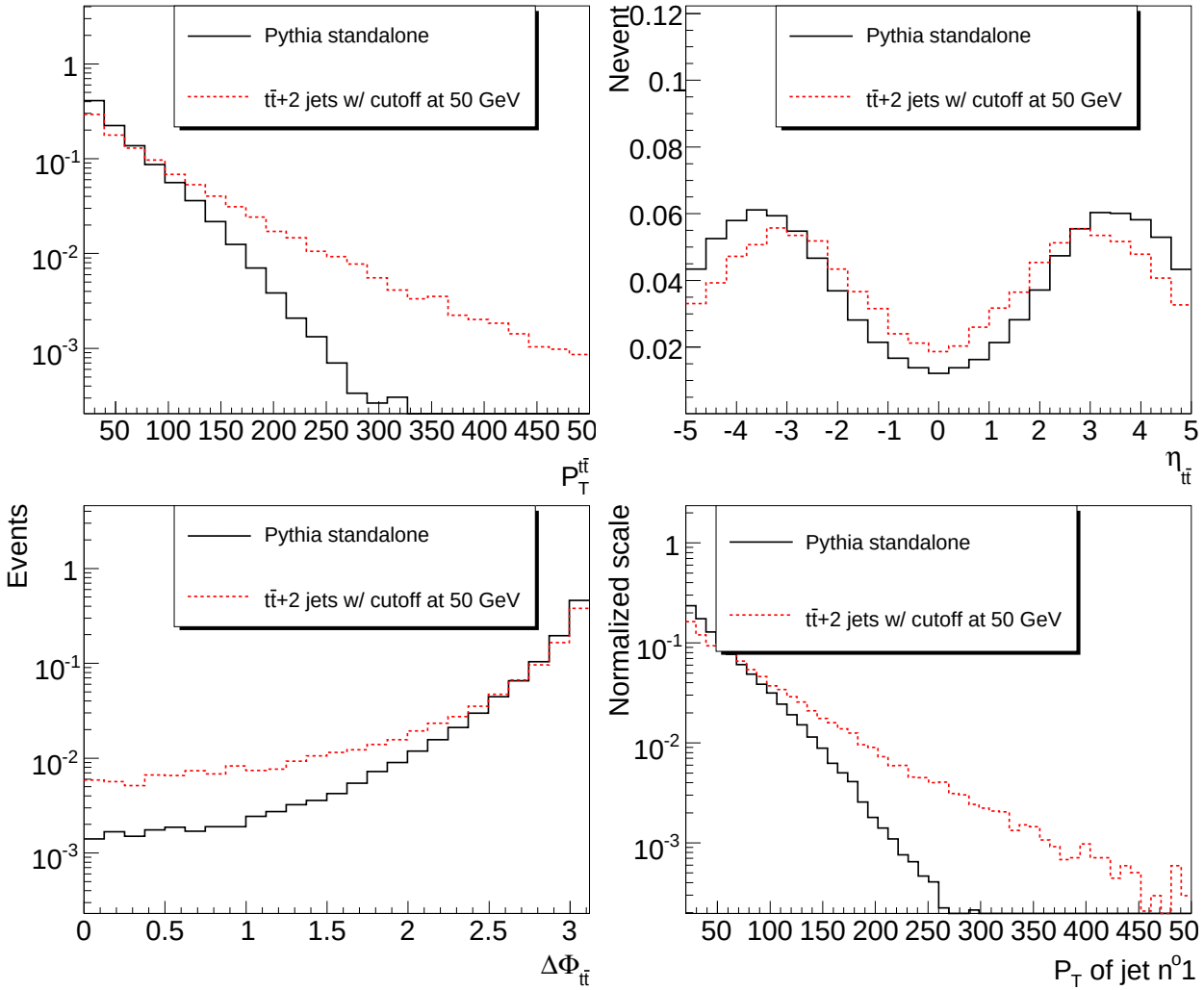
- For each production, a $4 \to 3$, $3 \to 2$, $2 \to 1$, $1 \to 0$ DJR are done, with different multiplicities detail.
- Global shapes of each DJR are compared if production with different matching parametrization are present. $\to$ systematics

Kinematic variables

- For each production, the following variables are plotted with different multiplicities detail:
  - $P_T(X)$, $\Delta\Phi$ between components of X, $\eta(X)$, $P_T(X^i)$, $y(X^i)$, $m(X)$, MET,...ask for others!
  - P_T and rapidity of jets with and without P_T cut.
- Global shapes of kinematic variable are compared if different productions. $\to$ systematics

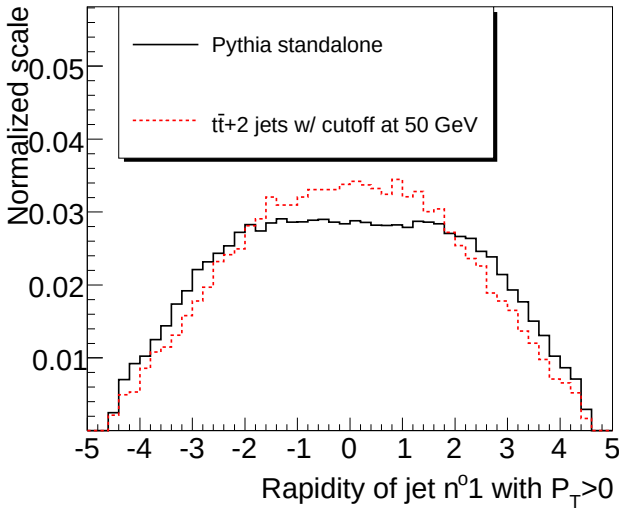
$t\bar{t}$ kinematic variables: top and jets

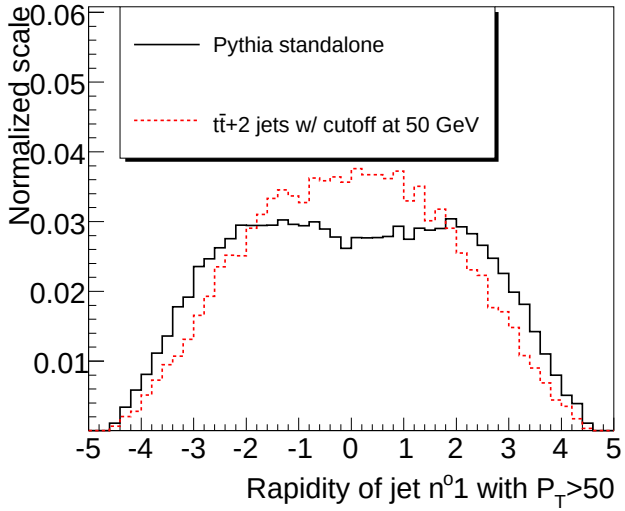
Comparison of global distribution related to $t\bar{t}$+0,1,2 partons and $t\bar{t}$+ 0 partons productions. For jets, Qcut=50 GeV

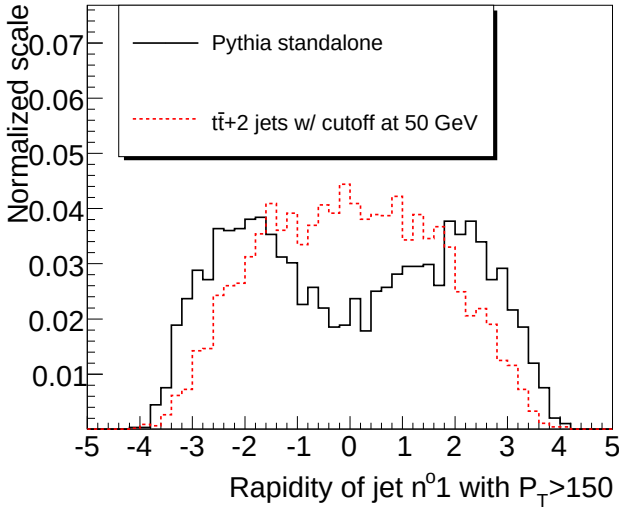


Jets rapidity

Comparison of global distribution related to $t\bar{t}$+0,1,2 partons and $t\bar{t}$+ 0 partons productions. (Qcut=50 GeV) Rapidity is plotted for different cuts on transverse momentum (user's choice).

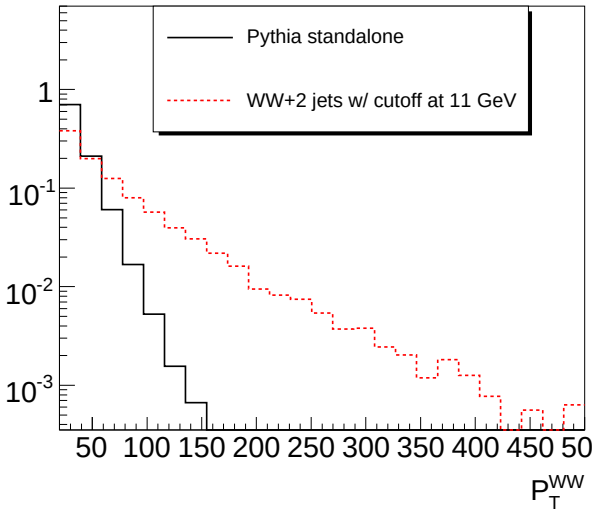


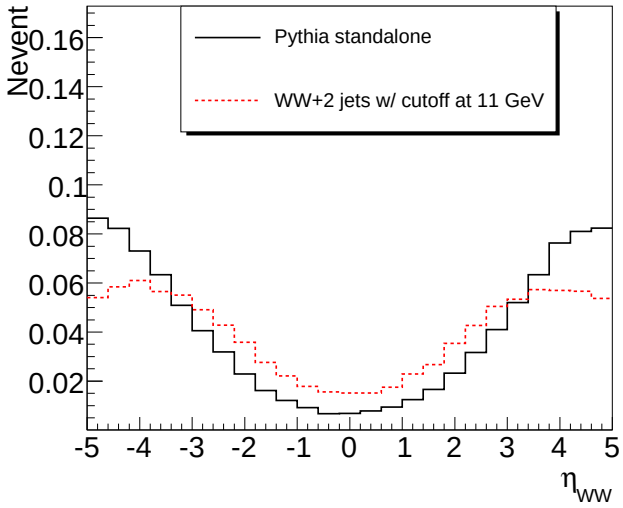


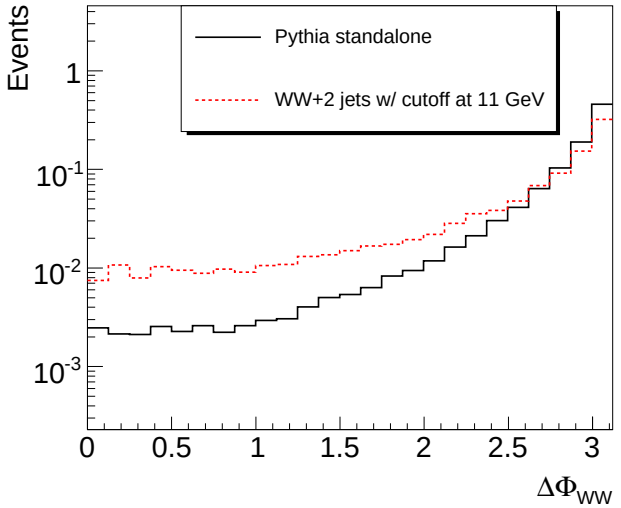


$(W^+ \to \mu^+\nu_\mu)(W^- \to e^-\overline{\nu}_e)$ + 0,1,2 jets

Comparison of global distributions related to WW+0,1,2 partons and WW+ 0 partons productions.







The cross sections (with Qcut=7 GeV) in fully leptonic mode:

$WW \to 0$ jets exclusive 391 fb

$WW \to 1$ jets exclusive 319 fb

$WW \to 2$ jets exclusive 414 fb

$\to$ Inclusive cross section $\sim$ 60 pb.

Summary and to do

- Matching use: only manner to simulate safely multijets processes samples
- MadMatchChecker is a new tool (available soon) to use to validate parametrization in matching procedure for any process but also to compute the production systematics.
- $t\bar{t}$ + N jets and WW + N jets tested with Modified MLM method. Study of systematics is about to start.
- The systematic validation of the MadGraph/MadEvent samples within CMSSW is in progress (W/Z, $t\bar{t}$,$\tilde{t}\tilde{t}$,WW,WZ,ZZ, ...)

Back-up slides

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

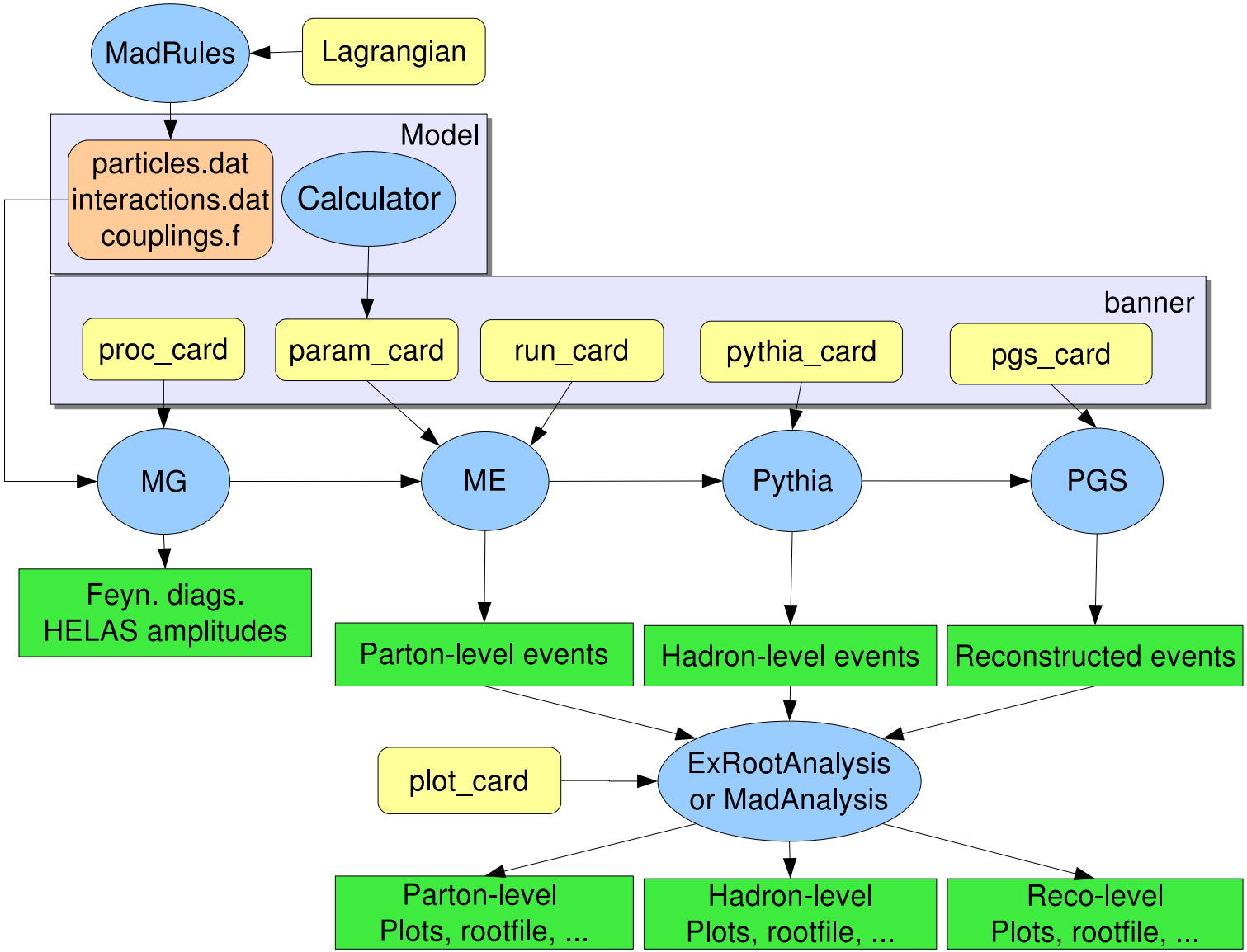
- Implemented by default: SM, SUSY, 2HDM, HEFT and UED: Maltoni, Stelzer, Hagiwara, Plehn, Rainwater, Alwall, Herquet, de Visscher, Frederix, Alves
- Framework for easy implementation of new models: UserMod (de Visscher)
- Possibility of generate a model from Lagragian expression (available soon) (Duhr)

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

Modified MLM (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, hep-ph/07062569)*

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.