the ALPGEN generator (v2.13)

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Top Workshop, October 24th, 2008

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JHEP 0307 (2003) 001

Outline

- Introduction to the code
  - available pocesses
  - single top
  - review of the MLM matching procedure
- Example of study of internal systematics for $t\bar{t}$ production
- Comparison with MC@NLO
- Summary

Introduction to the code

- ALPGEN is a matrix element event generator designed for simulation of final states with high jet multiplicity
- matrix elements calculated numerically by means of the ALPHA algorithm
- matching between matrix elements and parton showering implemented with the MLM procedure (see later)
- heavy particles (W, Z, top-quark and Higgs) are decayed according to the exact tree-level matrix elements so that spin correlations are always accounted for. In particular the decay $t \to bf\bar{f}'$ is implemented
- concerning top-quark couplings, a parameter allows to change the left and right couplings with respect to the SM values

available processes in v2.13

- $(W \to f\bar{f}') + N$ jets, $N \leq 6$, $f = l, q$
- $(Z/\gamma^* \to f\bar{f}) + N$ jets, $N \leq 6$, $f = l, \nu$
- $(W \to f\bar{f}')Q\bar{Q} + N$ jets, $(Q = b, t)$, $N \leq 4$, $f = l, q$
- $(Z/\gamma^* \to f\bar{f})Q\bar{Q} + N$ jets, $(Q = c, b, t)$, $N \leq 4$, $f = l, \nu$
- $(W \to f\bar{f}') + c + N$ jets, $N \leq 5$, $f = l, q$
- $n\ W + m\ Z + k\ H + l\ \gamma + N$ jets, $n + m + l \leq 8$, $N \leq 3$
- $Q\bar{Q} + N$ jets, $(Q = c, b, t)$, $N \leq 6$
- $Q\bar{Q}Q'\bar{Q}' + N$ jets, $(Q, Q' = c, b, t)$, $N \leq 4$
- $Q\bar{Q}H + N$ jets, $(Q = b, t)$, $N \leq 4$
- N light jets, $N \leq 6$
- $M\ \gamma + N$ jets, $N \geq 1$, $N + M \leq 8$, $M \leq 6$
- $gg \to H + N$ jets $(m_t \to \infty)$
- single top
- $(W \to f\bar{f}') + M\gamma + N$ jets, $M \leq 2$, $N \leq 6$, $f = l, q$
- $(W \to f\bar{f}') + Q\bar{Q} + M\gamma + N$ jets, $M \leq 2$, $N \leq 6$, $f = l, q$
- $Q\bar{Q} + M\gamma + N$ jets, $(Q = c, b, t)$, $M + N \leq 6$

single top

four different final states are implemented:

- $t(\bar{t})q$ (t-channel)
- $t(\bar{t})\bar{b}(b)$ (s-channel)
- $t(\bar{t})W$
- $t(\bar{t})\bar{b}(b)W$

For each channel the subprocesses considered include all configurations with up to two quark currents (including the top contribution)

MLM matching

- Generate parton-level configurations for all final-state parton multiplicities up to N, with partons constrained by

$$p_T^{part} > p_T^{min} \ , \quad |\eta_{part}| < \eta_{max} \ , \quad \Delta R > R_{min} \ ,$$

- Perform the shower evolution on each n-parton sample, using HERWIG or PYTHIA shower MC codes.
- For each event, apply a cone jet algorithm to all partons resulting from the shower evolution, before hadronization. The resulting jets *clusters* are defined by a minimum E_T, E_T^{clus}, and by a jet cone size R_{clus}, parameters which are related but not necessarily identical to the partonic generation parameters p_T^{min} and R_{min}

MLM matching

- Associate each parton from the PL event to one and only one of the reconstructed clusters:
  - Starting from the highest-p_T parton, select the cluster with minimum distance ΔR from it; if $\Delta R < R_{match}$, where R_{match} is a fixed parameter called the matching radius, then we say that the parton is *matched*.
  - Remove the cluster from the list of clusters, go to the next parton and iterate until all hard partons have been processed. Thus a given cluster can only be matched to a single parton.

MLM matching

- If each parton is matched to a cluster, the event “matches”, and is kept, else it is rejected.
- In the case of $n < N$, matched events with a number of clusters $N_{clus} > n$ are rejected. This leaves an exclusive sample with $N_{clus} = n$.
- If $n = N$, the largest parton multiplicity for which we generated PL events, accept matched events where $N_{clus} > N$, provided the non-matched clusters (namely those remaining in the cluster list after all clusters matching partons have been removed) are softer than each of the matched clusters.
- After matching, combine the exclusive event samples from each partonic multiplicity $n = 0, \dots, N-1$ and the inclusive event sample with $n = N$ into a single event sample, which will define the fully inclusive sample.

consistency of the matching algorithm for $t\bar{t}$ production

M.L. Mangano, M. Moretti, F.P. and M. Treccani, *JHEP 0701 (2007) 013*

- comparison with parton level results for inclusive quantities
- impact of higher-order parton processes
- generation and matching systematics

PL generation cuts

Collider	p_T^{min} (GeV)	η_{max}	R_{min}
Tevatron	20	4	0.7
LHC	30	5	0.7

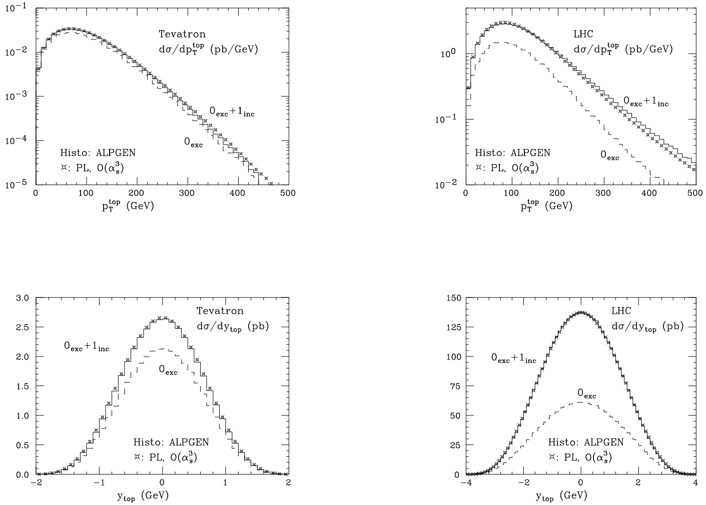
Default matching parameters

E_T^{clus} (GeV)	η_{max}^{clus}	R_{match}
$\max(p_T^{min} + 5\ \mathrm{GeV}, 1.2 \times p_T^{min})$	η_{max}	$1.5 \times R_{min}$

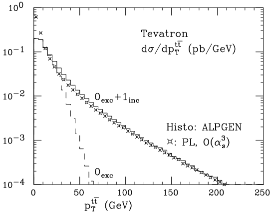
Analysis performed with cone jet algorithm

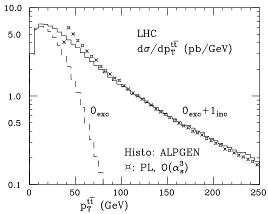
comparison with PL (inclusive) quantities

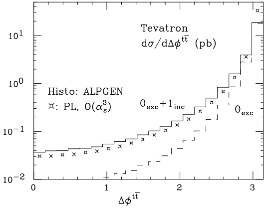
Collider	LO	NLO	0_{exc}	1_{inc}	$0_{exc} + 1_{inc}$
Tevatron	**4.37**	6.36	3.42	0.78	**4.20**
LHC	**471**	769	217	252	**469**

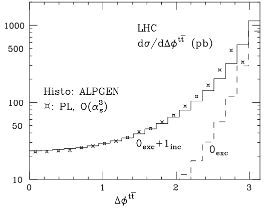


comparison with (more exclusive) PL quantities



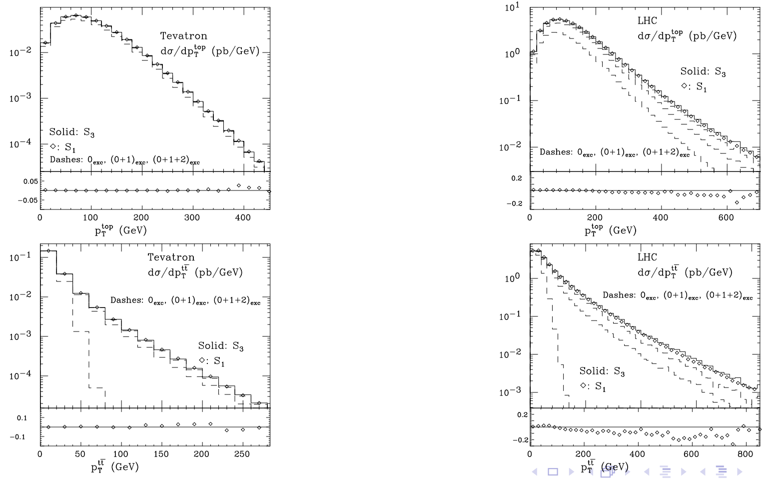




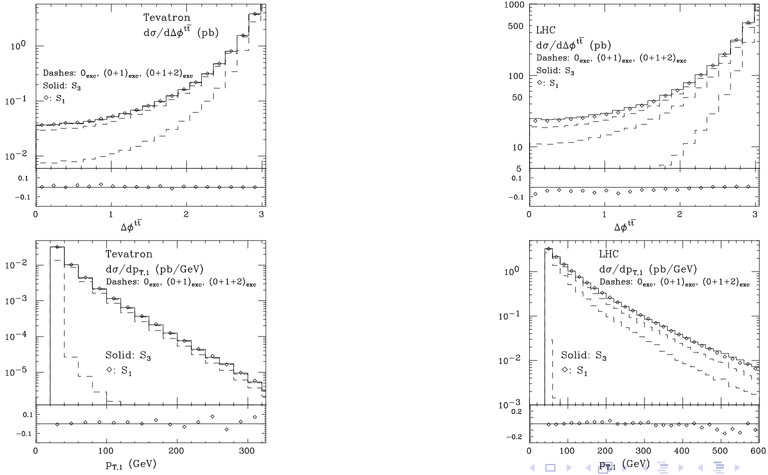


impact of h.o. parton processes

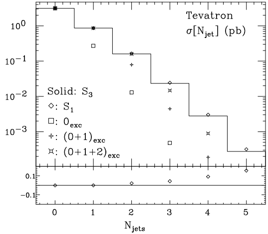
	Tevatron	LHC
0_{exc}	3.42	216.6
1_{exc}	0.66	149.9
2_{exc}	0.09	65.8
3_{inc}	0.010	29.9
Total	4.18	462.2

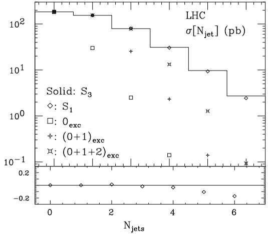


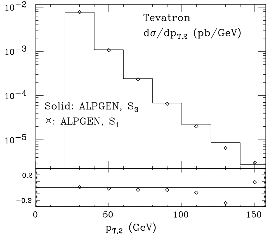
h.o. parton processes

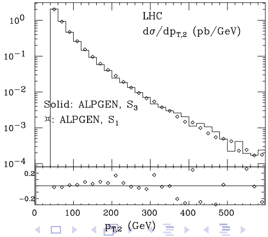


h.o. parton processes for more exclusive distr









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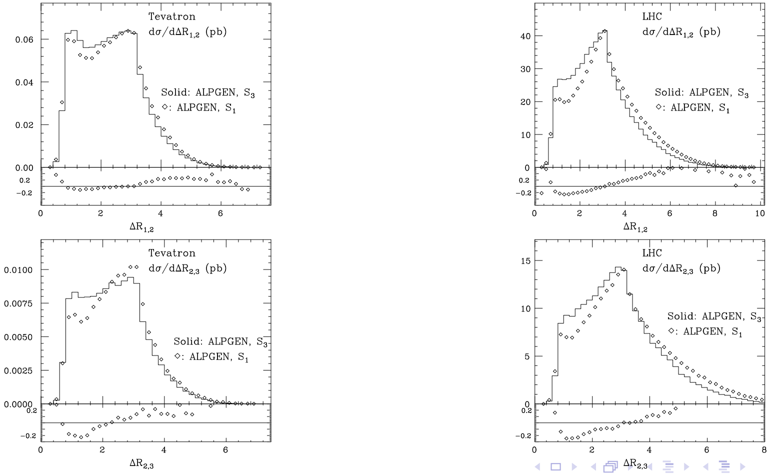


generation and matching systematics

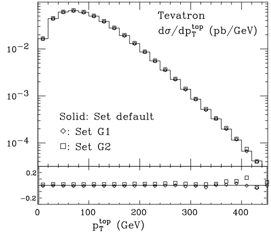
Param set	Generation parameters p_T^{min}	R_{min}	Matching parameters min E_T^{clus}	R_{match}
Tevatron, default	20	0.7	25	1.5×0.7
Tevatron, Set G1	15	0.7	20	1.5×0.7
Tevatron, Set G2	30	0.7	36	1.5×0.7
Tevatron, Set M1	20	0.7	20	1.5×0.7
Tevatron, Set M2	20	0.7	25	1.5×1.0
LHC, default	30	0.7	36	1.5×0.7
LHC, Set G1	25	0.7	30	1.5×0.7
LHC, Set G2	40	0.7	48	1.5×0.7
LHC, Set M1	30	0.7	30	1.5×0.7
LHC, Set M2	30	0.7	36	1.5×1.0

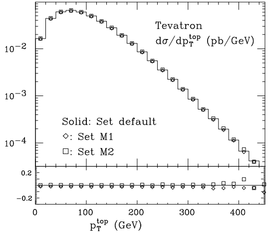
cross sections

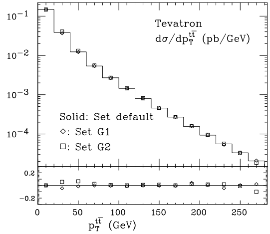
Tevatron	Default	Set G1	Set G2	Set M1	Set M2
0_{exc}	3.42	3.15	3.79	3.14	3.33
1_{exc}	0.66	0.82	0.42	0.78	0.74
2_{exc}	0.09	0.15	0.036	0.13	0.11
3_{inc}	0.010	0.024	0.002	0.021	0.012
Total	4.18	4.14	4.25	4.08	4.19

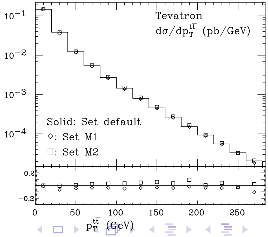
LHC	Default	Set G1	Set G2	Set M1	Set M2
0_{exc}	217	185	267	185	203
1_{exc}	150	156	134	148	160
2_{exc}	66	81	44	74	76
3_{inc}	30	45	15	40	35
Total	462	467	460	447	475

systematics on distributions









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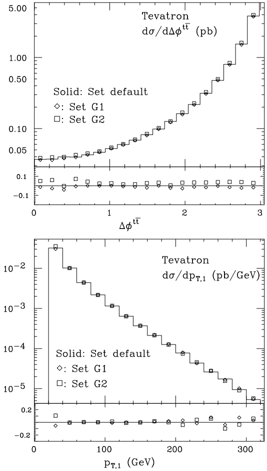

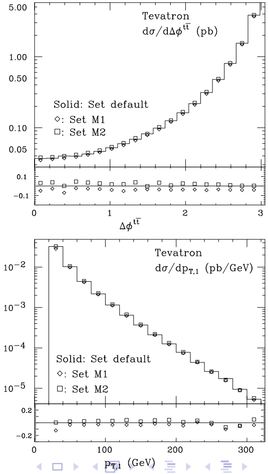

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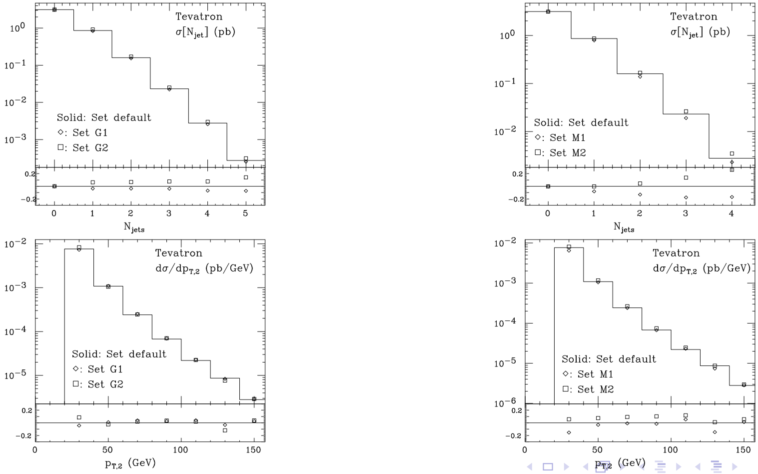

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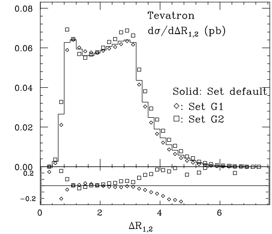
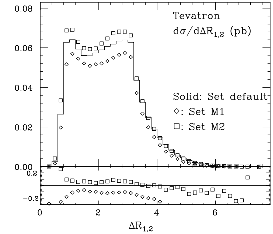
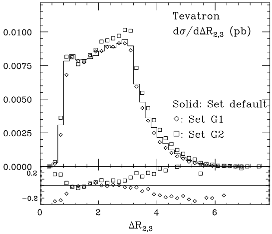
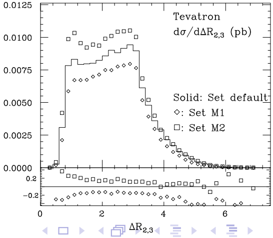


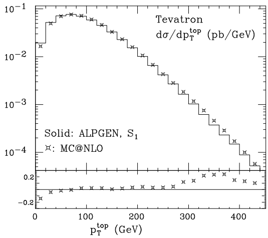


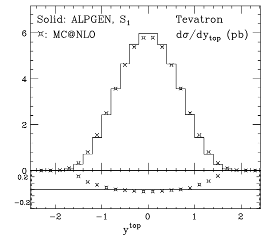


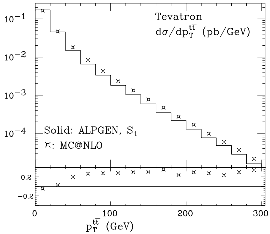


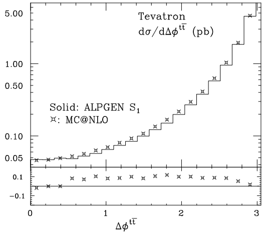
comparison with MC@NLO

Up to a K-factor the comparison between ALPGEN and MC@NLO is very satisfactory (@LHC the agreement is on the same level)









comparison with MC@NLO

This comparison allowed to point out a problem in MC@NLO in the treatment of leading jet rapidity. POWHEG confirmed the ALPGEN prediction

Message: it is of utmost iportance to use all independent available tools (having in mind pros and cons) in order to have a sound estimate of theoretical uncertainties

summary

- ALPGEN is one of the available matrix element event generators
- it is working for several processes up to large jet multiplicities
- an example of the intrinsic theoretical uncertainties due to matching has been given for $t\bar{t}$ production
- an exhaustive estimate of theoretical uncertainties and comparisons among different generators has been performed for $W+$ jets in

J. Alwall et al., EPJC 53 (2008) 473

Looking forward to having LHC data available...