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MonteCarlo simulations of the $t\bar{t}$ + N jets process at hadron colliders

in collaboration with:
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Hera and the LHC
CERN, June 7 2006

Summary

- Matrix Element calculations VS Parton Shower
- matching prescription implemented in ALPGEN: mlm prescription
- Stability analysis of the mlm prescription: $t\bar{t} + \leq 3$ jets case study
- Comparisons between ALPGEN & MC@NLO: $t\bar{t} + \leq 1$ jet
  - Inclusive Observables
  - Jet Observables
  - Spin Correlations
- Conclusions

Multi jets final states processes can be simulated by means of 2 different techniques:

- I strategy: generate partonic process as simple as possible, allowing Parton Shower to generate further partons.
  - soft e collinear terms are resummed
  - problems in large angle emission
- II strategy: generate by means of Exact Matrix Element events with largest multiplicity, then apply PS.
  - large angle emission is more accurate
  - double counting problems → IR & Collinear sensitivity

Idea: make the two different approaches (ME & PS) complementary by means of an effective separation of the phase space

Merging: state of the art

e^+e^- physics: a solution has been proposed which avoids double counting and shifts the dependence on the resolution parameter beyond NLL accuracy

[S. Catani et al., JHEP 0111 (2001) 063, L. Lönnblad, JHEP 0205 (2002) 046]

The method consists in separating arbitrarily the phase- space regions covered by ME and PS, and use vetoed parton showers together with reweighted tree- level matrix elements for all parton multiplicities

Proposal to extend the procedure to hadronic collisions: no proof of NLL accuracy

F. Krauss, JHEP 0208 (2002) 015

Recent work for CKKW implementation in hadronic environment

- `Herwig` (P. Richardson)
- `Pythia` S. Mrenna and P. Richardson, JHEP **0405** (2004) 040
- `SHERPA with APACIC++/AMEGIC++`

  F. Krauss, A. Schälicke, S. Schumann and G. Soff, Phys. Rev. D **70** (2004) 114009

  F. Krauss, A. Schälicke, S. Schumann and G. Soff, Phys. Rev. D **72** (2005) 054017

the mlm procedure

- prescription for merging Matrix Element + Parton Shower, which applies a veto procedure in order to remove double counting

- no modification of PS procedure and indipendent from the particular PS implementation

- ME: α_s reweighting

- for critical comparison with other matching procedures, see:

  S. Hoche, F. Krauss, N. Lavesson, L. Lonnblad, M. Mangano, A. Schälicke and S. Schumann, "Matching parton showers and matrix elements [hep- ph/0602031]

- now implemented in ALPGEN(2.05)

  M. L. Mangano, M. Moretti, F. Piccinini, R. Pittau and A. D. Polosa, JHEP **0307** (2003) 001 [hep- ph/0206293]

mlm prescription

M.L. Mangano, FNAL MC Workshop, October 2002

The veto procedure removes double counting at double- log (soft and collinear) and single- log (collinear) level by removing ME events described better by the PS.

Essentially we have two distinct set of parameters:

- P^t and ΔR which define partons at generation level
- $E^t_{jet}(\geq P^t)$ and $\Delta R_{jet}(\geq \Delta R)$ at reconstructed- jet level, which define the veto procedure and separate ME and PS region

Ideally the whole prescription leads to samples independent from both generation and matching cuts.
In practice the dependence from the parameters is a measure of the success of the matching prescription.

We look for a parameter region where:

- prediction is stable against slight parameter variations
- matching efficiency is high.

Simulation Setup

- $t\bar{t}$ + 0,1,2,3 jets production
- interface with HERWIG
- simulations both LHC and TeVatron
- jet reconstruction: GETJET cone- clustering algorithm

  F. E. Paige and S. D. Protopopescu, in "Physics of the SSC", Snowmass, 1986, Colorado, edited by R. Donaldson and J. Marx
- Undecayed Top
- NO hadronization nor underlying event

Reduce as much as possible common systematics (hadronization, jets from top, . . .) in order to emphasize possible discrepancies

Stability of the mlm prescription

strategy: let vary the matching and/or generation parameters

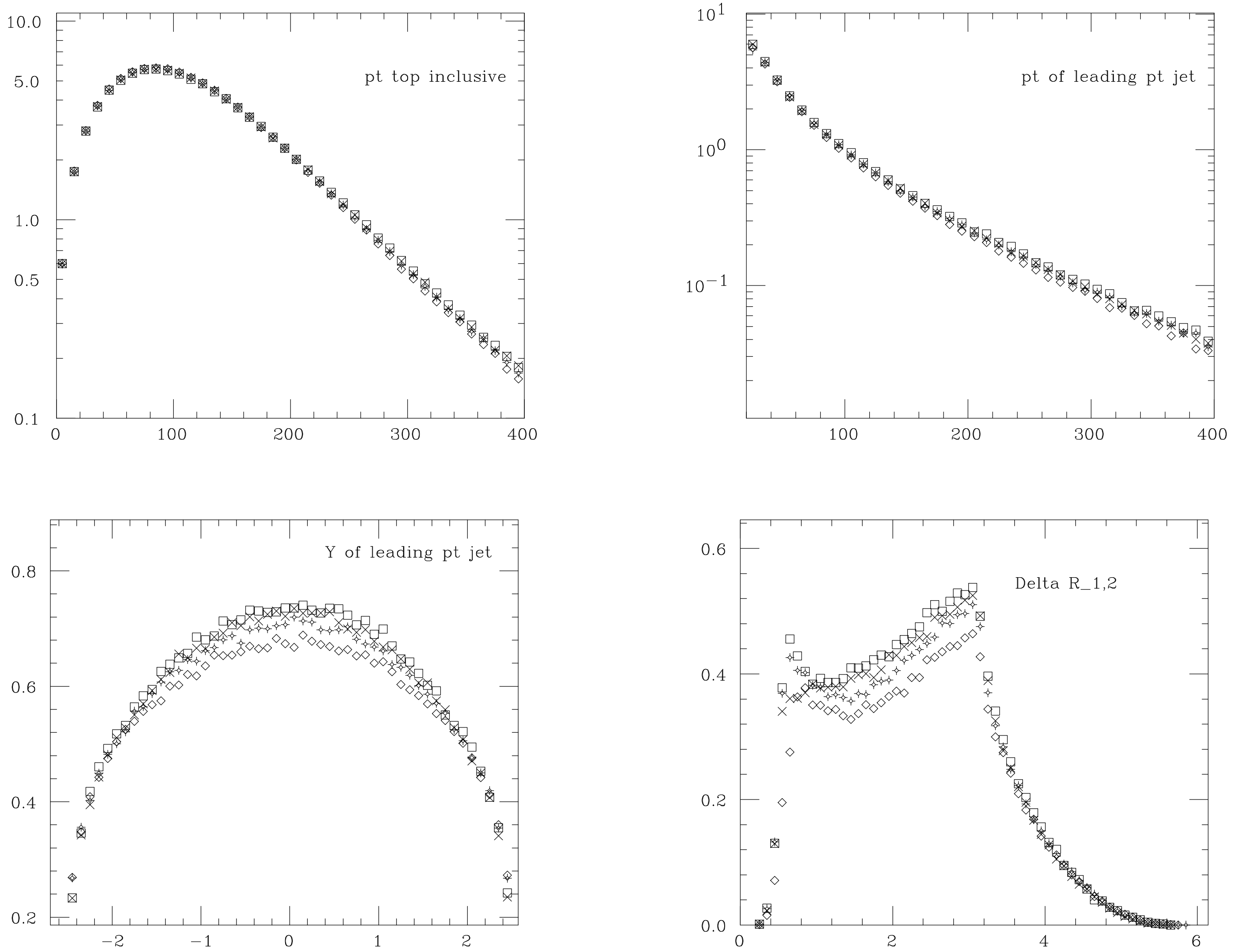
Matching	$\sigma_{tot}(pb)$
$E^t_{min} = 20\,GeV,\ \Delta R = 0.7$	434.3(7)
$E^t_{min} = 30\,GeV,\ \Delta R = 0.5$	432.3(7)
$E^t_{min} = 20\,GeV,\ \Delta R = 0.9$	442.3(7)
$E^t_{min} = 30\,GeV,\ \Delta R = 0.7$	450.6(7)

Generation: $P^t_{min} = 20\,GeV/c,\ \Delta R = 0.7$

Matching = Generation	$\sigma_{tot}(pb)$
$E^t_{min} = 30\,GeV,\ \Delta R = 0.7$	430.4(7)
$E^t_{min} = 20\,GeV,\ \Delta R = 0.5$	444.2(7)
$E^t_{min} = 20\,GeV,\ \Delta R = 0.7$	434.3(7)
$E^t_{min} = 20\,GeV,\ \Delta R = 0.9$	415.3(7)

- variations are confined well below 10%: good stability
- matching parameters dependence not so obvious (work in progress)

Stability against matching parameters (LHC)

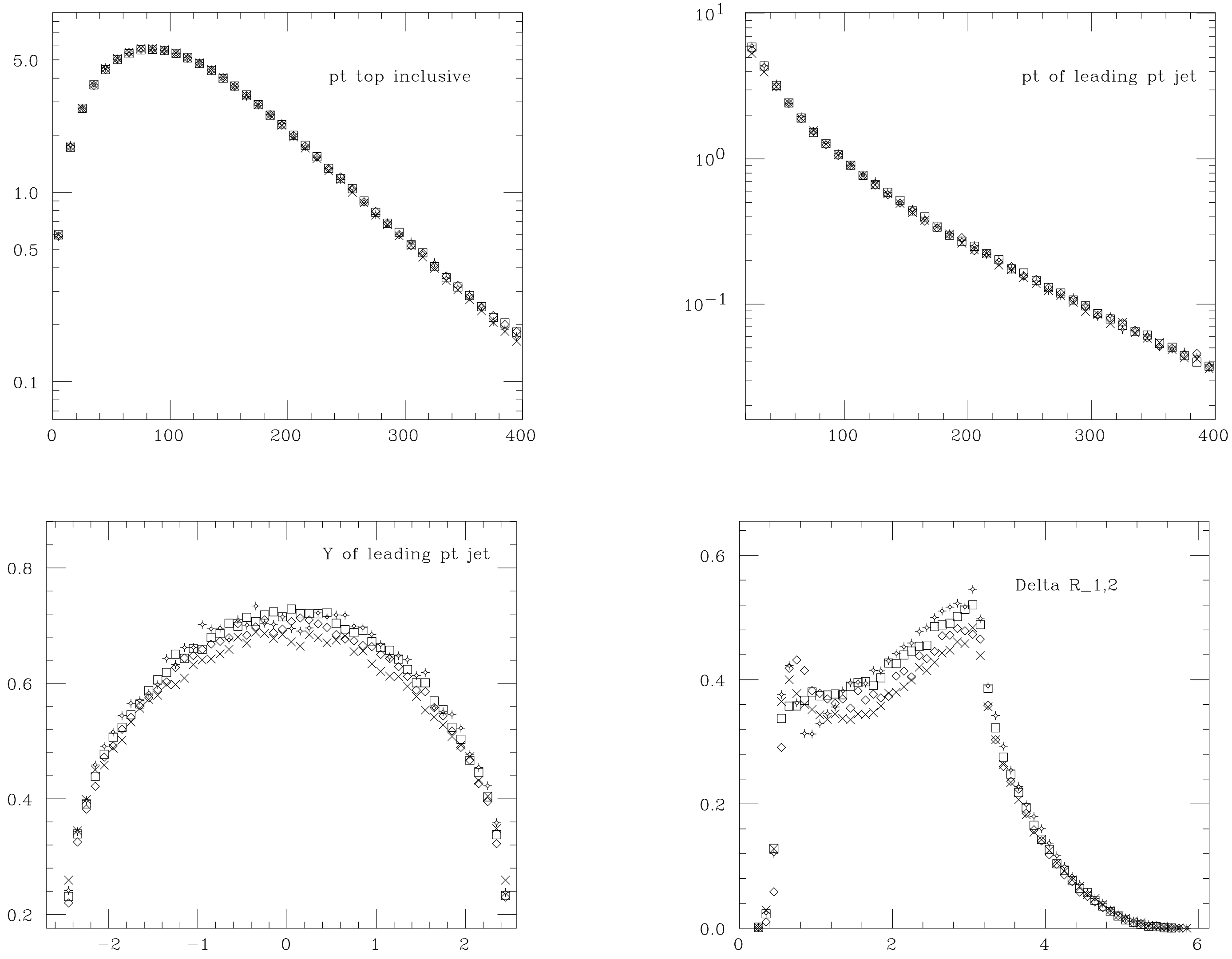


Matching: × $E^t_{min} = 20\,GeV$, $\Delta R = 0.7$ ◇ $E^t_{min} = 30\,GeV$, $\Delta R = 0.5$ □ $E^t_{min} = 20\,GeV$, $\Delta R = 0.9$

✧ $E^t_{min} = 30\,GeV$, $\Delta R = 0.9$ N.B. generation cuts: $P^t_{min} = 20\,GeV/c$, $\Delta R = 0.7$

$\Delta R_{1,2}$ = distance in the (η, ϕ) plane between leading and sub-leading jet

Stability against generation cuts (LHC)



Generation cuts: × $P^t_{min} = 30\,GeV/c$, $\Delta R = 0.7$ ◇ $P^t_{min} = 20\,GeV/c$, $\Delta R = 0.5$

□ $P^t_{min} = 20\,GeV/c$, $\Delta R = 0.7$ ✧ $P^t_{min} = 20\,GeV/c$, $\Delta R = 0.9$ N.B. matching same as generation cuts

ALPGEN & MC@NLO

Process: $t\bar{t} + 1$ jet

- S. Frixione and B. R. Webber, “The MC@NLO 3.2 event generator”hep- ph/0601192

  General approach: S. Frixione and B. R. Webber, JHEP **0206** (2002) 029 [hep- ph/0204244];

  $t\bar{t}$ production: S. Frixione, P. Nason and B. R. Webber, JHEP **0308** (2003) 007[hep- ph/0305252].

- ALPGEN:
  - Generation cuts: $P^{t}_{min} = 30\, GeV,\ \Delta R = 0.7$
  - Matching cuts: $E^{t}_{min} = 30\, GeV,\ \Delta R = 0.7$

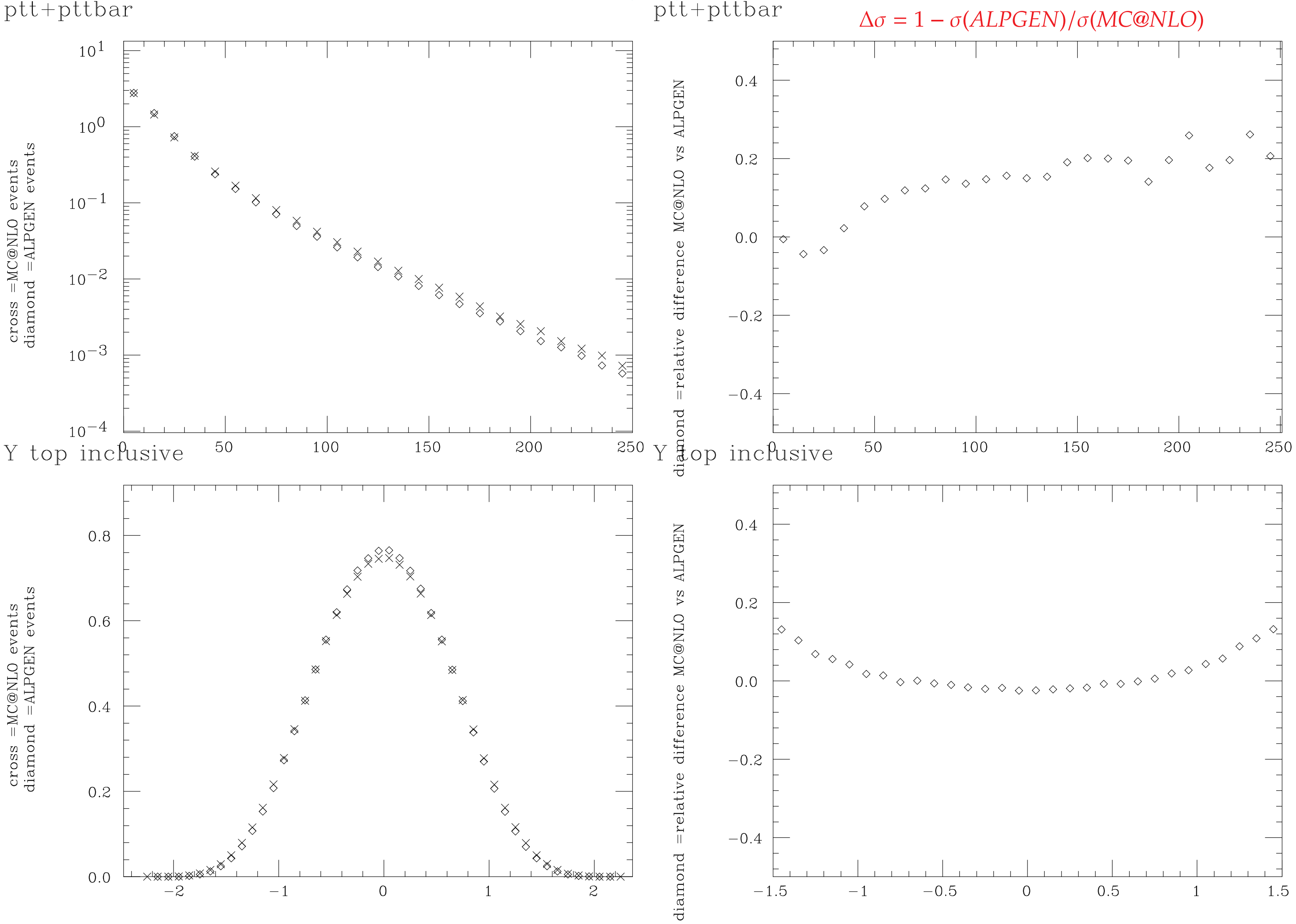
Jet definition adopted in the analysis:

$TeVatron\ E^{t}_{min} = 15\, GeV,\ \Delta R = 0.4$ $LHC\ E^{t}_{min} = 20\, GeV,\ \Delta R = 0.5$

Comparison between ALPGEN & MC@NLO→ introduce the K- factor

$TeVatron$ $K = 1.46$ LHC $K = 1.80$

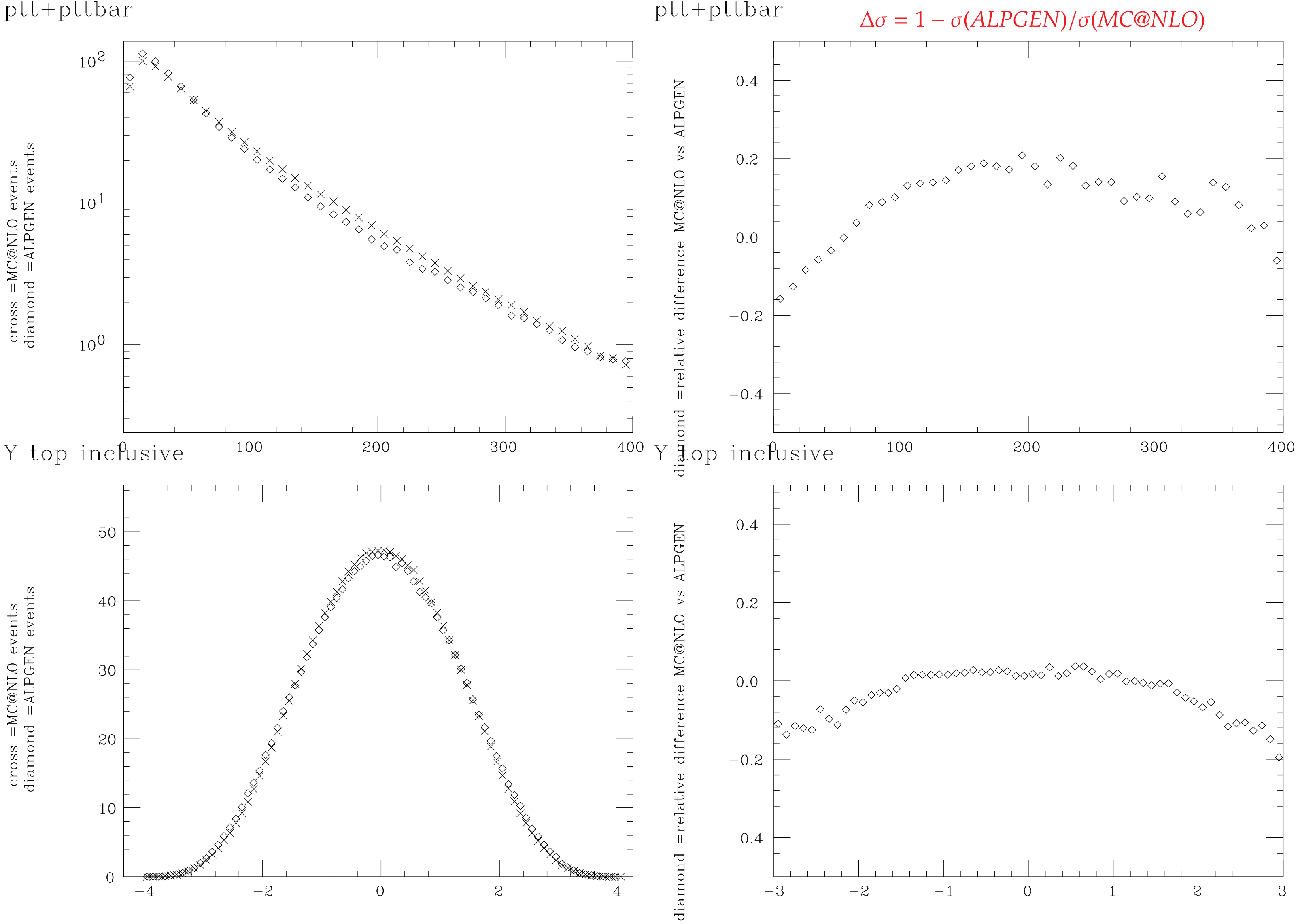
TeVatron, $P^T_{t+\bar{t}}$, $Y_{t(\bar{t})}$



$\Delta\sigma = 1 - \sigma(ALPGEN)/\sigma(MC@NLO)$

relatively good agreement in the shape (×MC@NLO ◇ALPGEN)

LHC, $P^T_{t+\bar{t}}$, $Y_{t(\bar{t})}$



ptt+pttbar

ptt+pttbar

$\Delta\sigma = 1 - \sigma(ALPGEN)/\sigma(MC@NLO)$

Y top inclusive

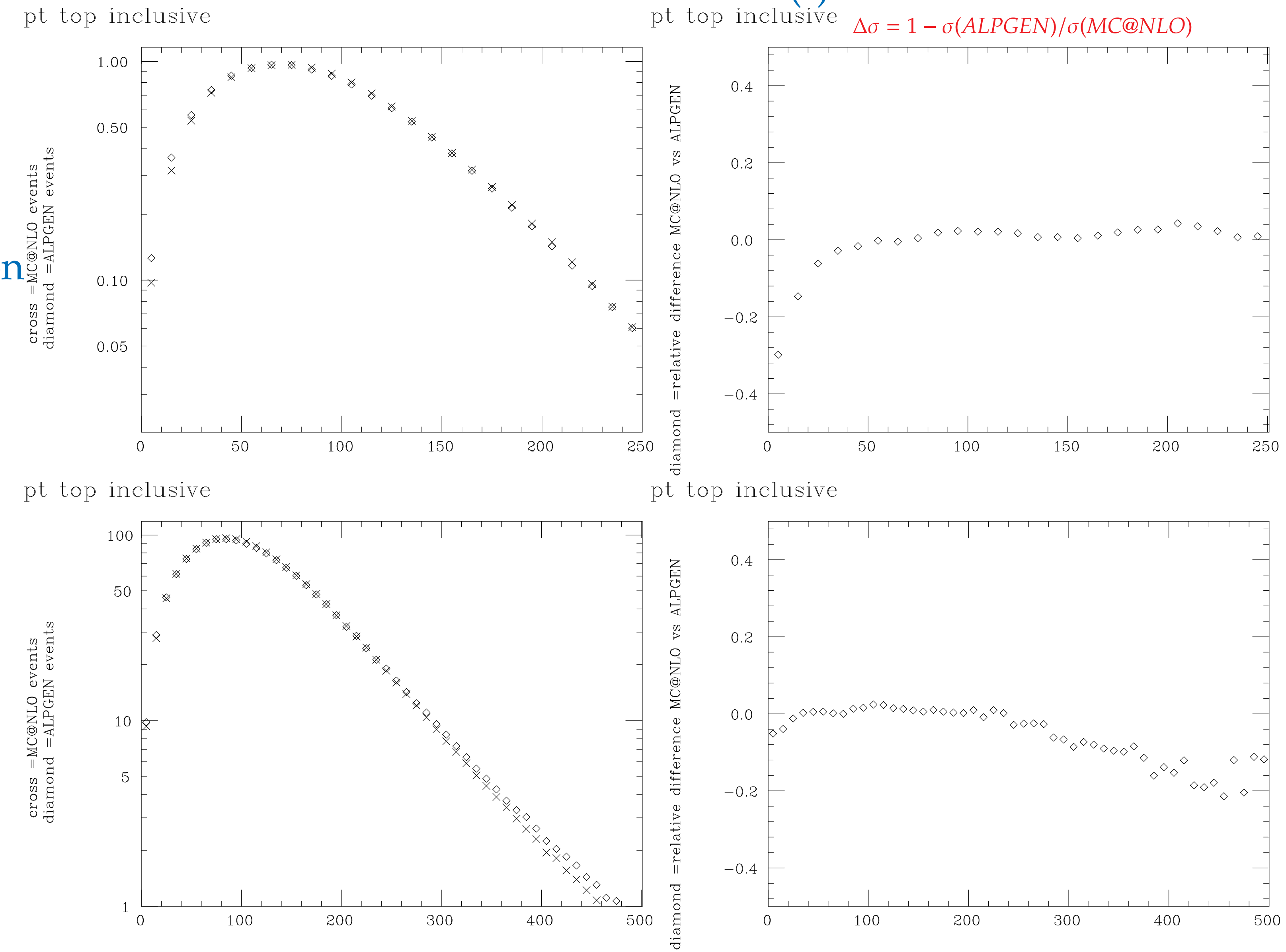
Y top inclusive

relatively good agreement in the shape (×MC@NLO ◇ALPGEN)

TeVatron & LHC, $p^T_{t(\bar{t})}$

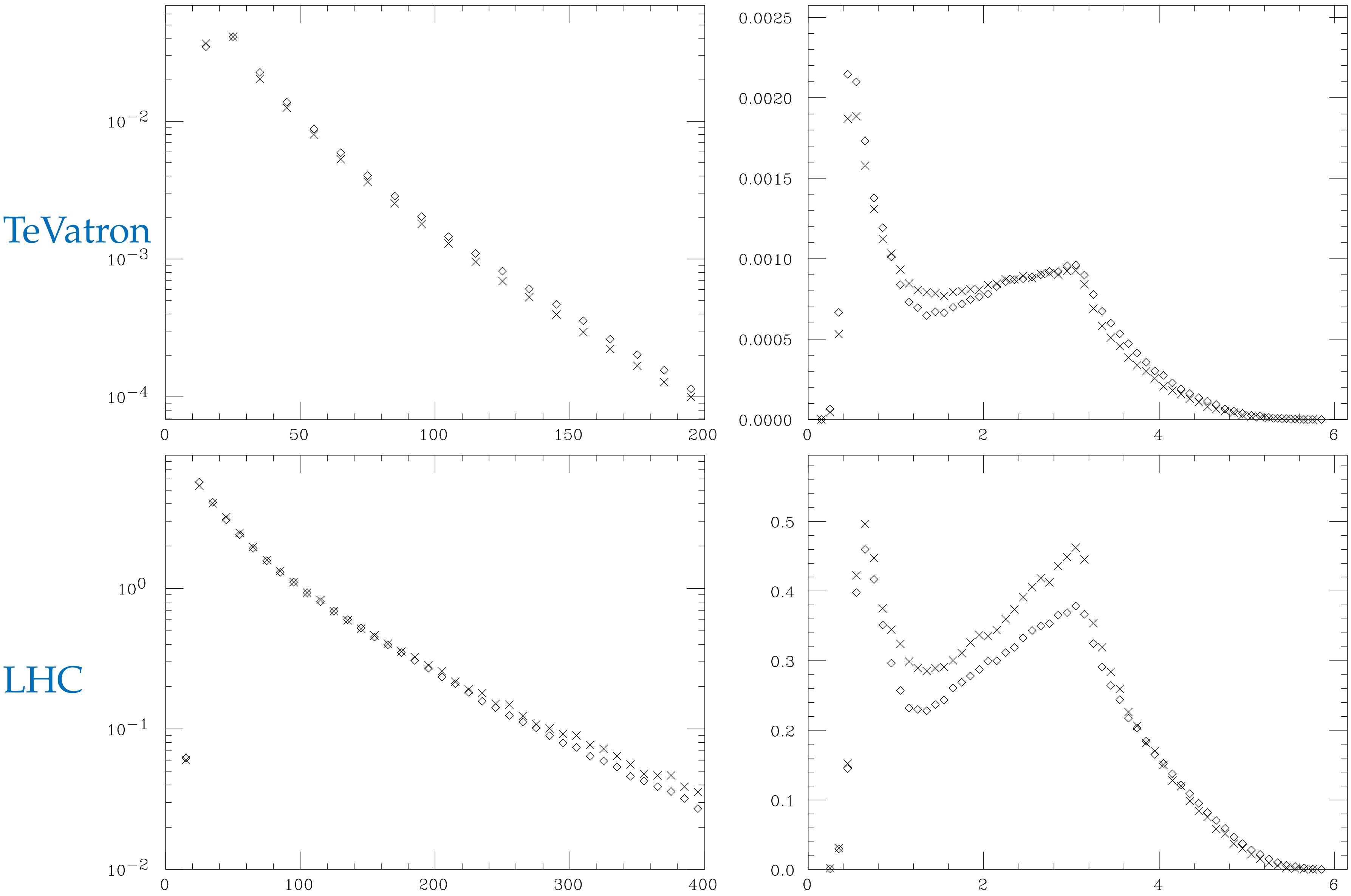
TeVatron

LHC


$\Delta\sigma = 1 - \sigma(ALPGEN)/\sigma(MC@NLO)$

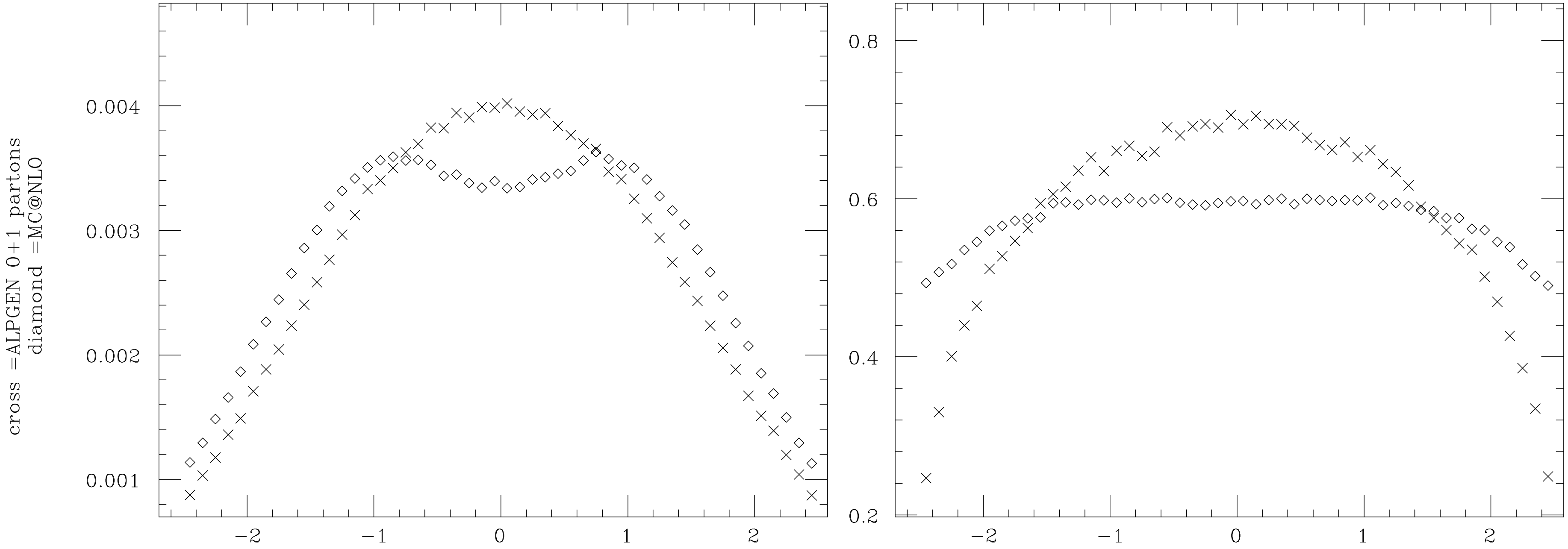
LHC: MC@NLO(×) bit softer w.r.t. ALPGEN(◇) in the tail

Extra-radiation, leading jet P^T and ΔR_{jet} (top stable)



LHC: MC@NLO(◇) bit softer w.r.t. ALPGEN(×) in the tail

Extra-radiation, leading jet Y



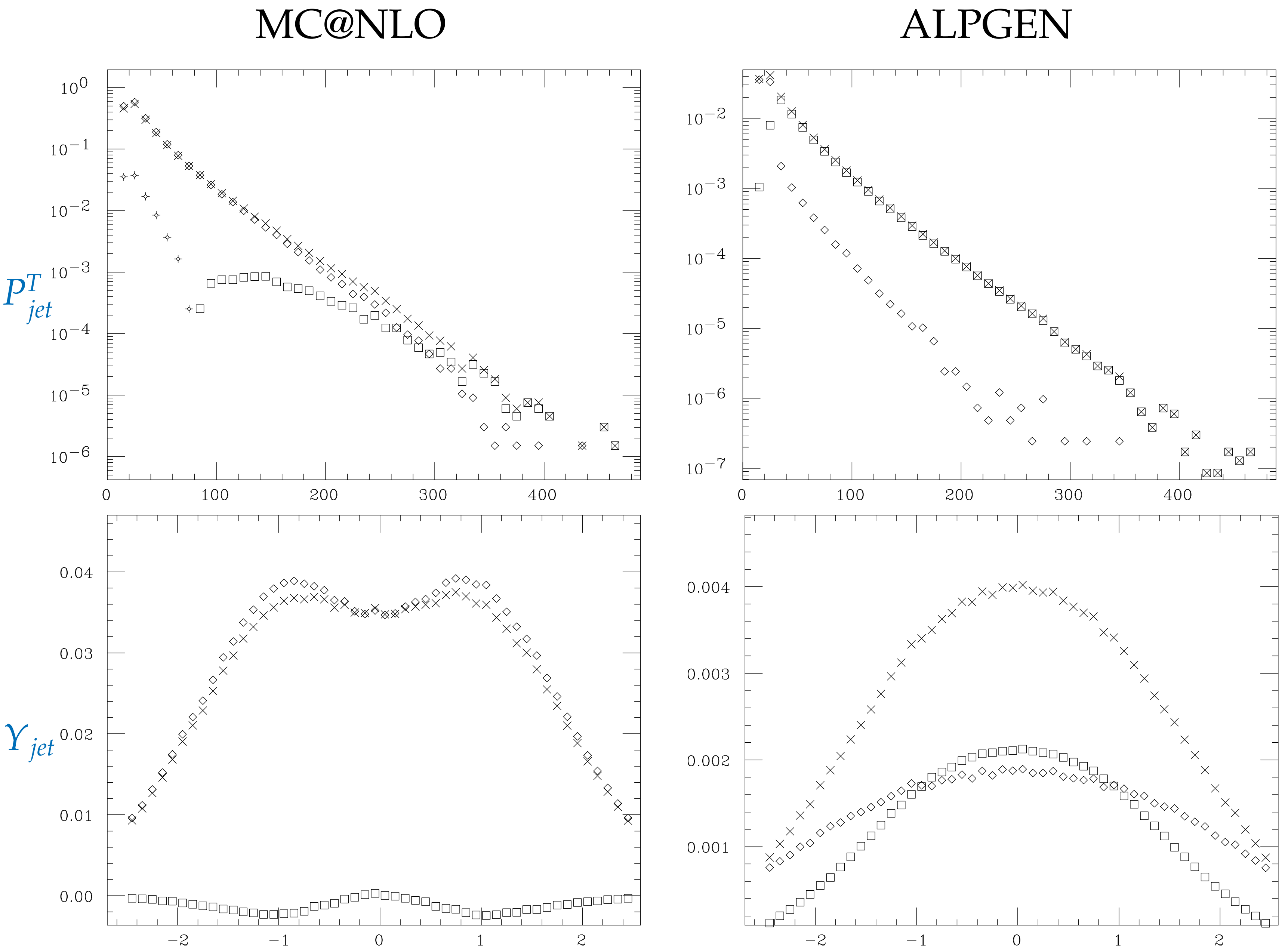
TeVatron

LHC

MC@NLO(◇) ALPGEN(×)

Different structure both at TeVatron and LHC

TeVatron increased effect, let's study partial contributions

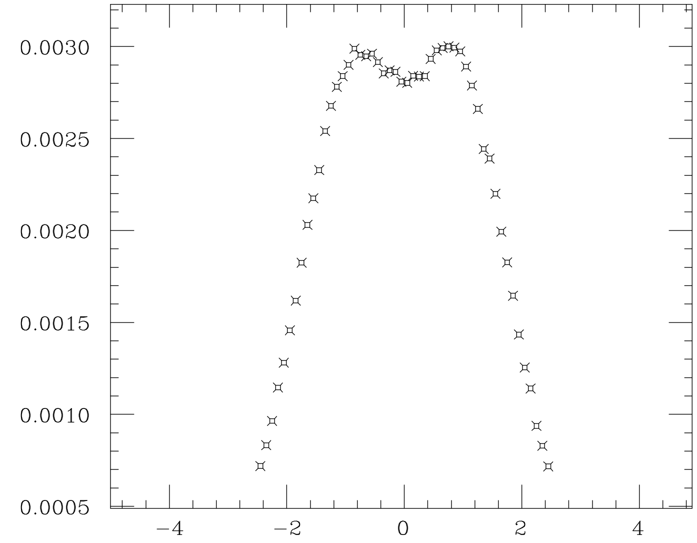


× total distribution (0+1); ◇ 0 parton contribution;

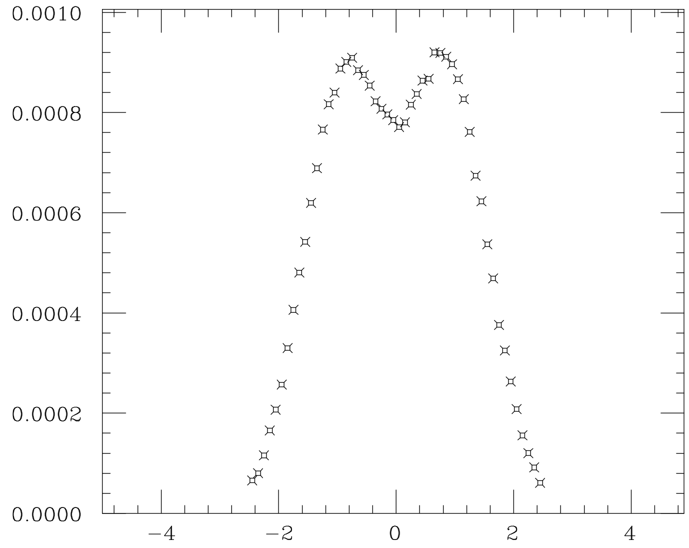
□ 1 parton contribution; + 1 parton contribution, negative weight

jets from extra-radiation, Y_{jet}, HERWIG

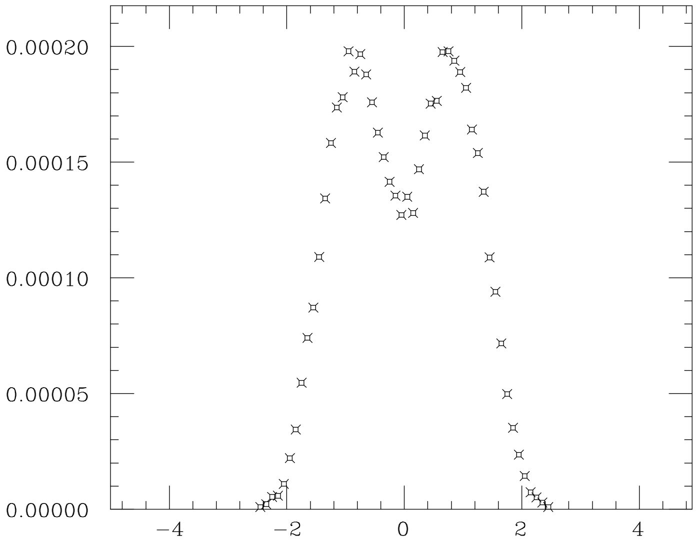
$P^T_{jet} > 20\,GeV/c$



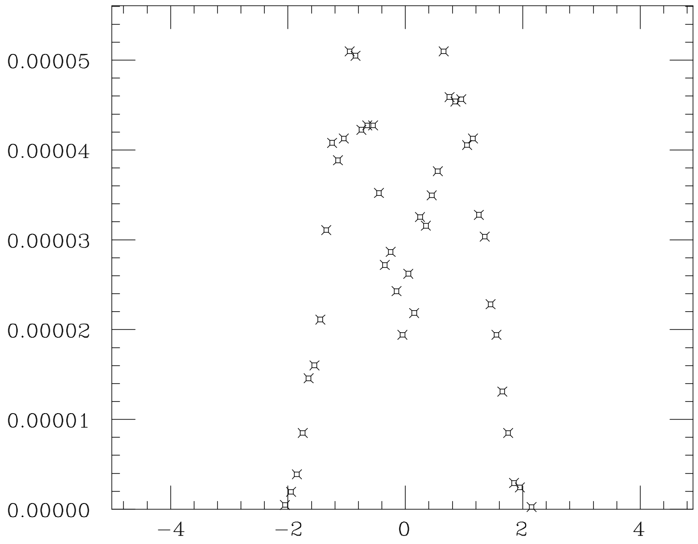
$P^T_{jet} > 50\,GeV/c$



$P^T_{jet} > 100\,GeV/c$

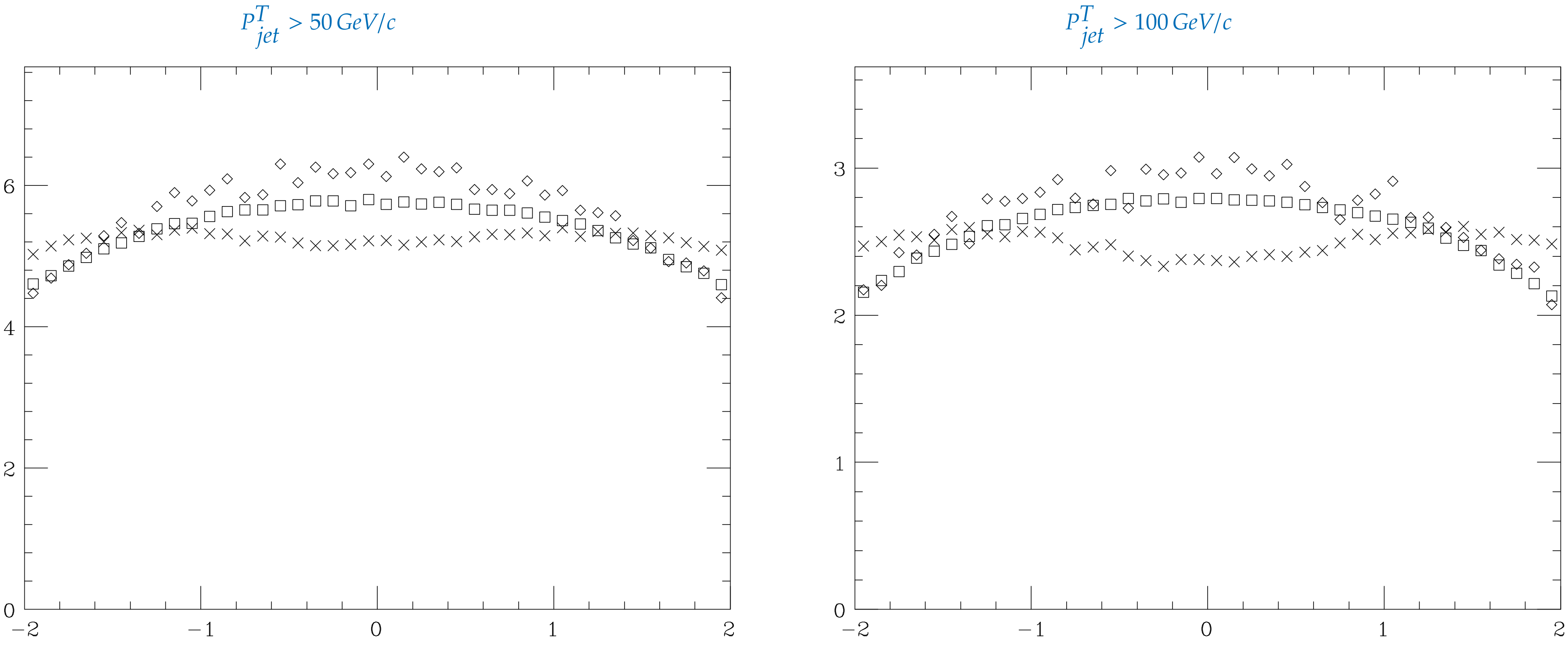


$P^T_{jet} > 150\,GeV/c$



Leading jet Y

Y Jet distribution VS parton level distribution, LHC



MC@NLO(×) ALPGEN(◇) Parton level distribution (□)

Spin correlations

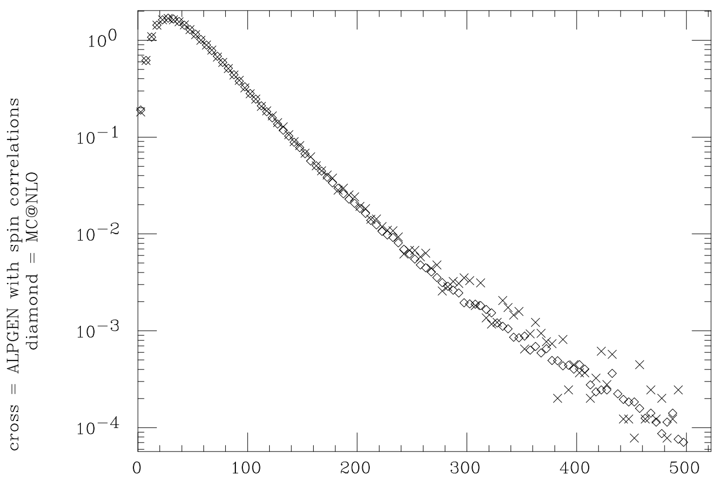
MC@NLO & ALPGEN have different treatment of the top decay:

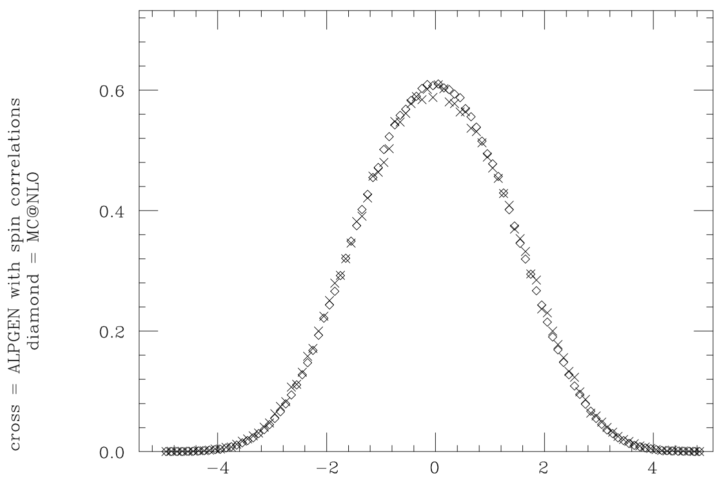
MC@NLO	ALPGEN
t and $\bar{t}$ are generated stable, and then they decay	ME describes both production and decay of t and $\bar{t}$
spin correlation is NOT included	spin correlation is included

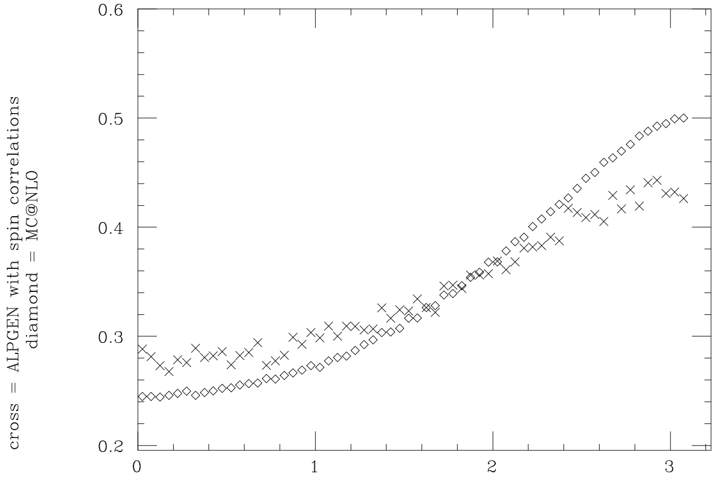
In order to highlight the possible discrepancies, we study the fully leptonic decay channel.

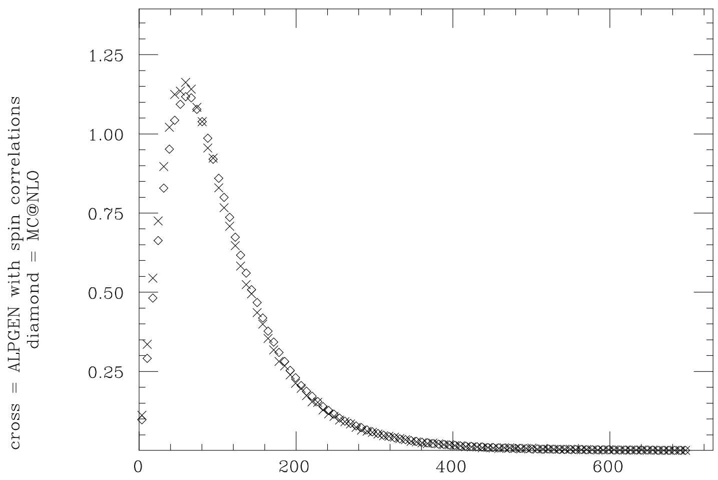
We study the leptonic variables, in particular angular variables between the two leptons, sensible to spin correlation effects

Spin Correlations: Leptonic Observables, LHC


pt1 charged lepton


eta1 charged lepton


Delta Phi(charged lepts)


Inv Mass charged lepts

Differences due to inclusion of spin correlations in ALPGEN

Conclusions

- It has been studied the mlm matching prescription implemented in ALPGEN
- Impact of N extra- parton contributions: mlm matching effectively separates phase space, rejecting double events (double & single collinear logs)
- The matching procedure is stable against (small) parameters variations (work in progress)
- Comparisons between normalized ALPGEN(0+1) and MC@NLO:
  - Inclusive Observables → good agreement
  - Leptonic Observables → differences due to the inclusion of spin correlations in ALPGEN
  - Radiation- related Observables→ evident discrepancies
    - ⁎ PS shows a depletion region in (leading) jet rapidity, near $Y = 0$
    - ⁎ ALPGEN rejects PS events responsible for the depletion adopting instead ME events, filling the depletion