ALPGEN, status and validation

http://cern.ch/alpgen

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Available processes in current release v2.13

- **WQQ**+N jets, **Z/γ+QQ**+N jets (Q=c,b,t), N≤4
- **W**+ N jets, **Z/γ**+ N jets, N≤6
- **W**+**c**+ N jets, N≤5
- **QQ** + N jets (Q=c,b,t), N≤6
- **QQQ'Q'** + N jets (Q,Q'=b,t), N≤4
- N jets, N≤6
- QQ+**Higgs**+ N jets (Q=b,t), N≤4
- n**W** + m**Z** + p**Higgs** + N jets, N < n+m+p+N ≤8, N≤3
- n **γ** + N jets, N< n+N≤6
- single top production
- **Higgs**+ N jets (via the ggH vertex)
- **W**+ m**γ**+ N jets, m≤2, N≤3
- **W**+ **QQ** +m**γ**+ N jets, m≤2, N≤3
- **QQ** + n **γ** + N jets, N< n+N≤6

New features in the next release

- New procs/features:
  - Z' production
  - Full spin correlations in top decays in tttt and ttbb + N jets, spin correlations in WW/WZ/ZZ
  - Interface to external processes (user provides matrix element/ phase-space, Alpgen provides overall infrastructure)...
- Automatic removal of hvy Q's produced by the shower, if required (e.g. to combine wjet and wqq data files)
- Factorize generation of different regions of phase-space, to samples high-pt tails with better statistics
- Include recent sets of PDFs (D.Lopez Mateos)
- New input structure for Herwig/Pythia runs (driven by input parameters, as for the Alpgen PL runs)
- Les Houches II .lhe output format as option (backward compatible to read old event files)
- Review choices of hard scales etc for processes with initial-state heavy quarks

Validation issues

- Validation of internal consistency of matching algorithm
- Validation against data
- Validation against NLO
- Systematic uncertainty estimates

Consistency of matching algo

Key criteria:

the shower evolution should generate final states that reproduce, for inclusive observables, the LO parton-level distributions (with the resummation of appropriate Sudakov logs)

In general, the inclusion of higher parton multiplicities through the ME/shower matching should at best achieve a LO description of observables which are non-trivial, at the lowest order, for multijet final states.

Example: DY pt spectrum

At large pt, this observable is of $O(\alpha_S)$. Its description obtained including up to 1,2, 3 or more hard partons in the ME should be all be equivalent. The use of MEs for partons in addition to the first will only affect higher-order observables.

E.g. m[jj] in W+jets requires at least 2 hard partons in the ME, E_T(jet 3) requires at least 3 hard partons, etc.

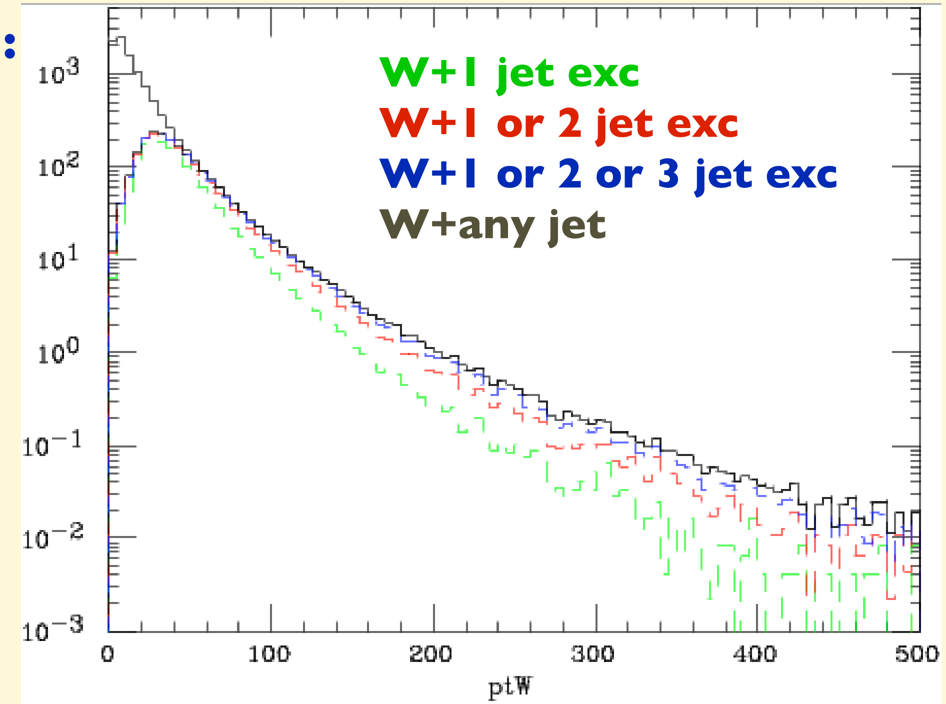
The fact that inclusion of several partons in addition to the 1st, each with its own cross-section, matching efficiency and extra-jet-veto efficiency, leads to a DY pt distribution equal to the $O(\alpha_S)$ result, provides a non-trivial consistency check of the algorithm.

Validation of internal consistency: DY spectrum

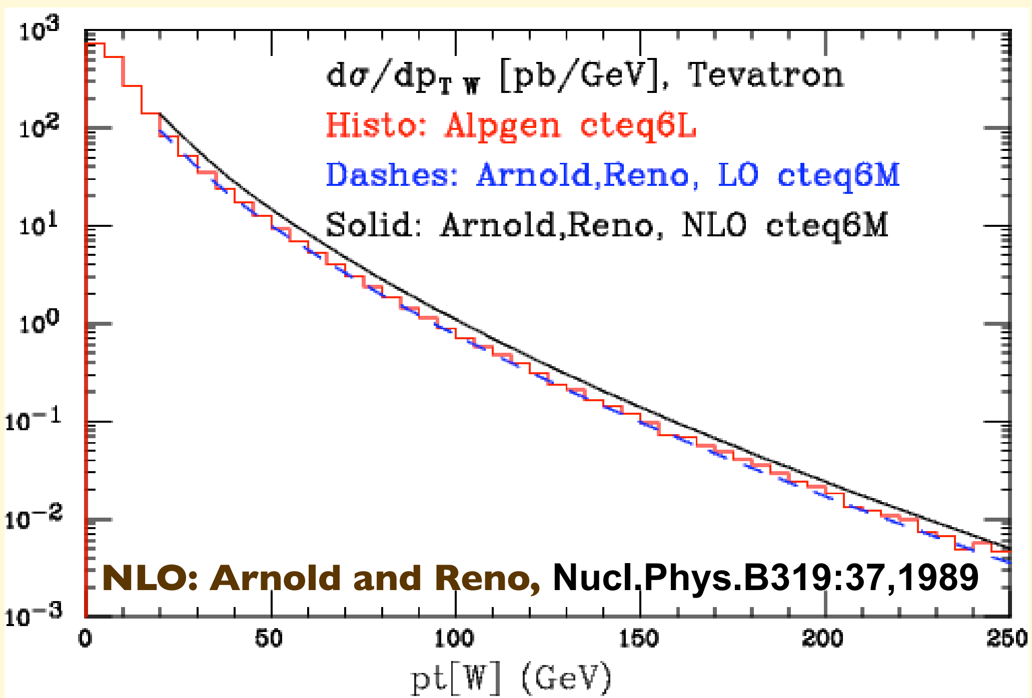
ME+shower with merging of multiparton MEs :

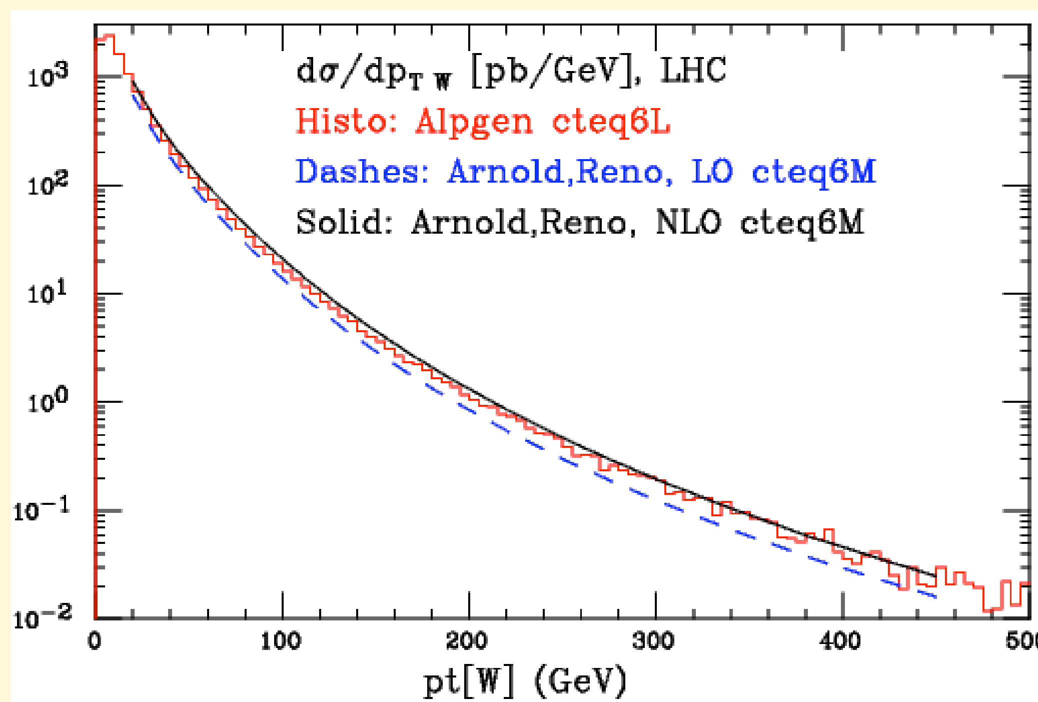
- The inclusive rate can be represented by the sum of multijet final state contributions: at high pt multijet final states dominate over the W + 1 jet rate!

- The matching algorithm accurately combines the independent multijet final states into a fully inclusive sample



Inclusive W pt spectrum, NLO vs LO MLM matching



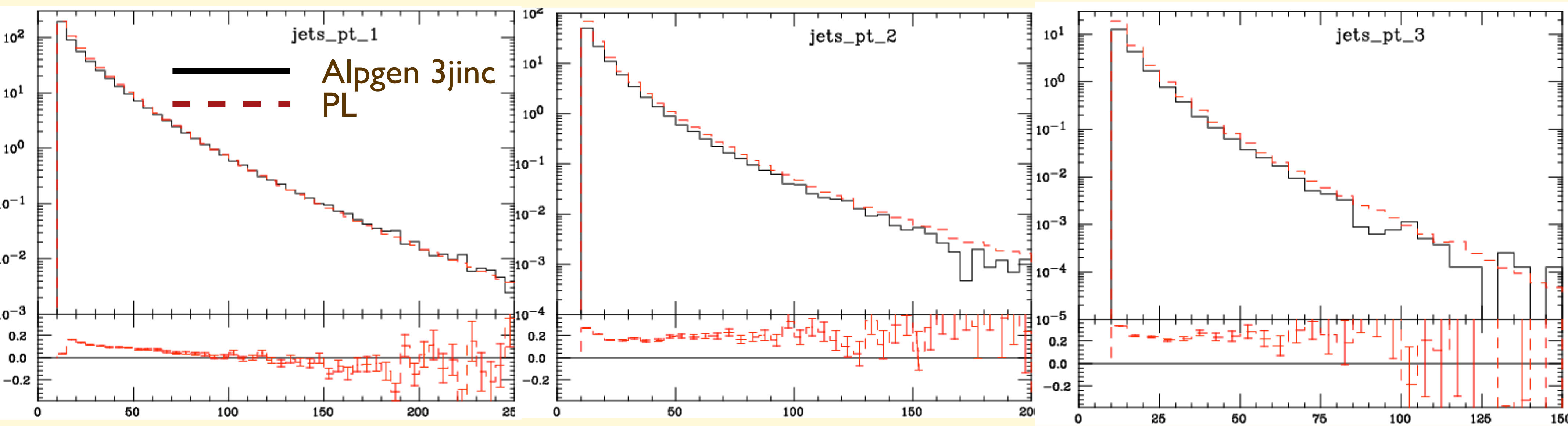


Validation of internal consistency: jet spectra in W+jets

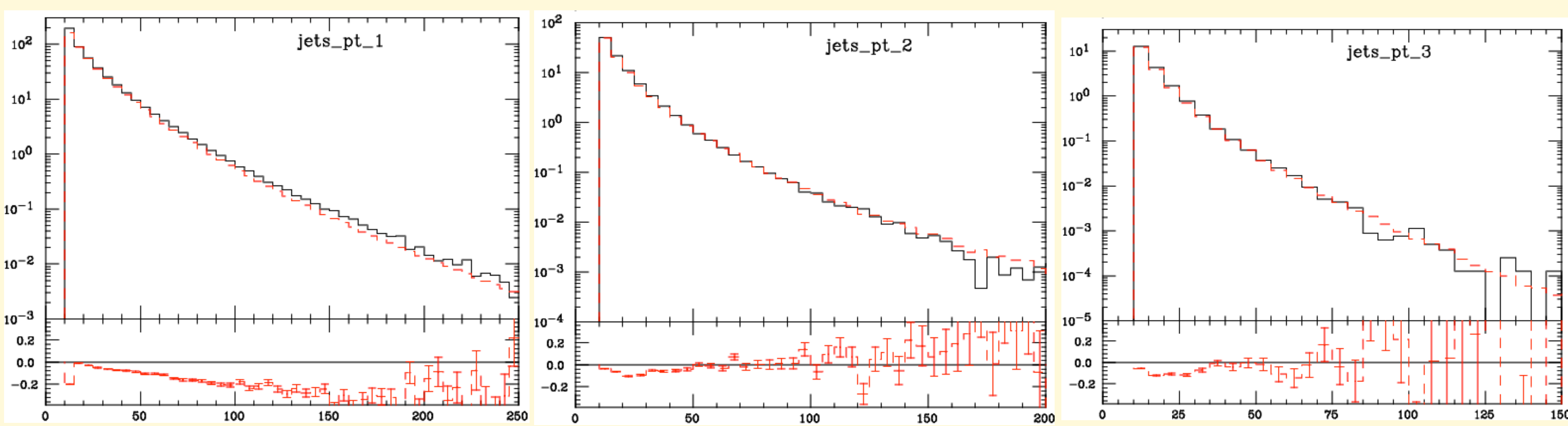
E_T spectra of 1st, 2nd and 3rd jets, comparing:

PL: pt_1 in W+1 parton, pt_2 in W+2 partons, pt_3 in W+3 partons

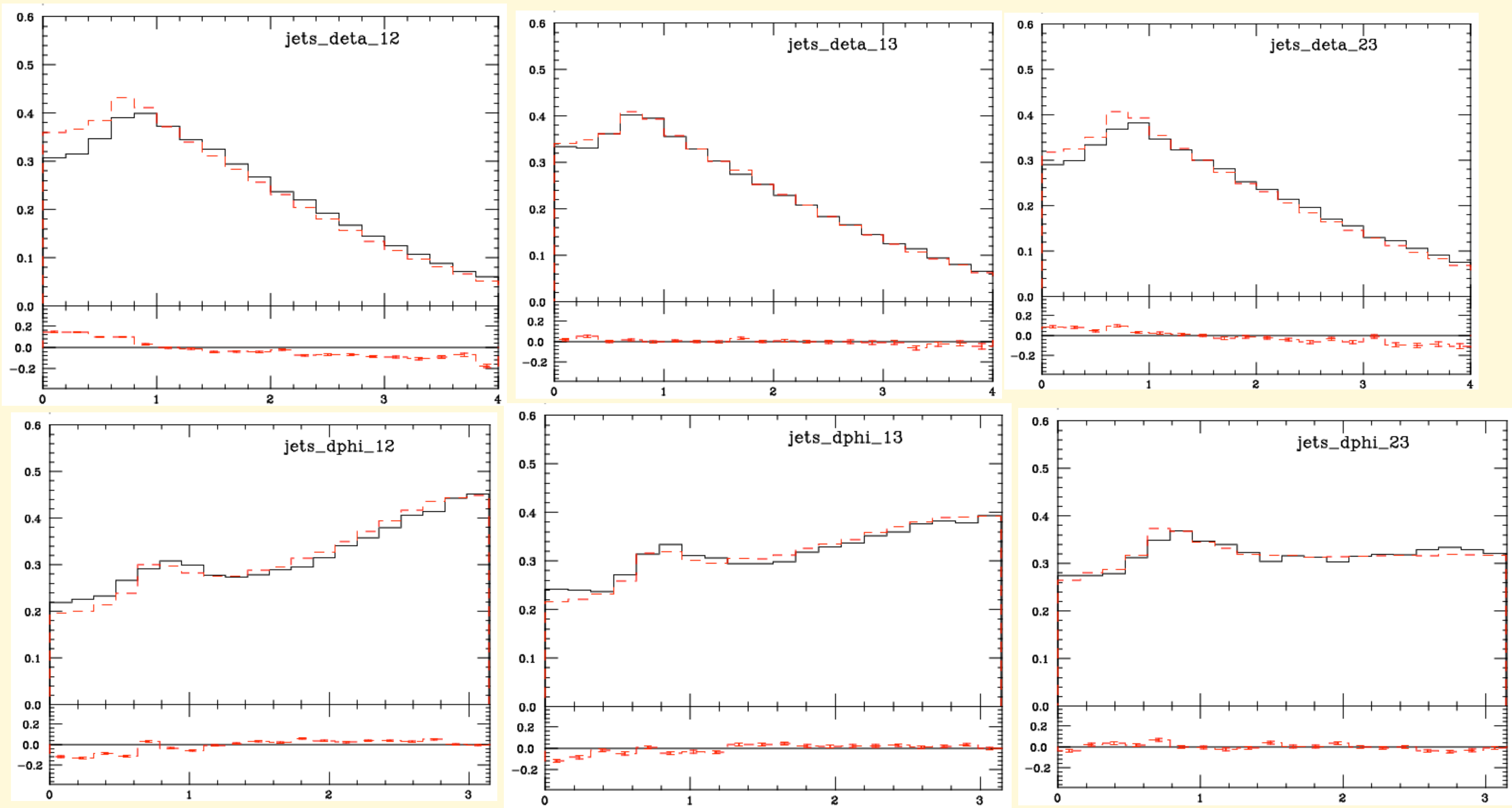
Alpgen: inclusive sample obtained after shower and matching of W+0, W+1, W+2 and W+3 parton samples



With out-of-cone corrections, to connect jet energy with parton energy:

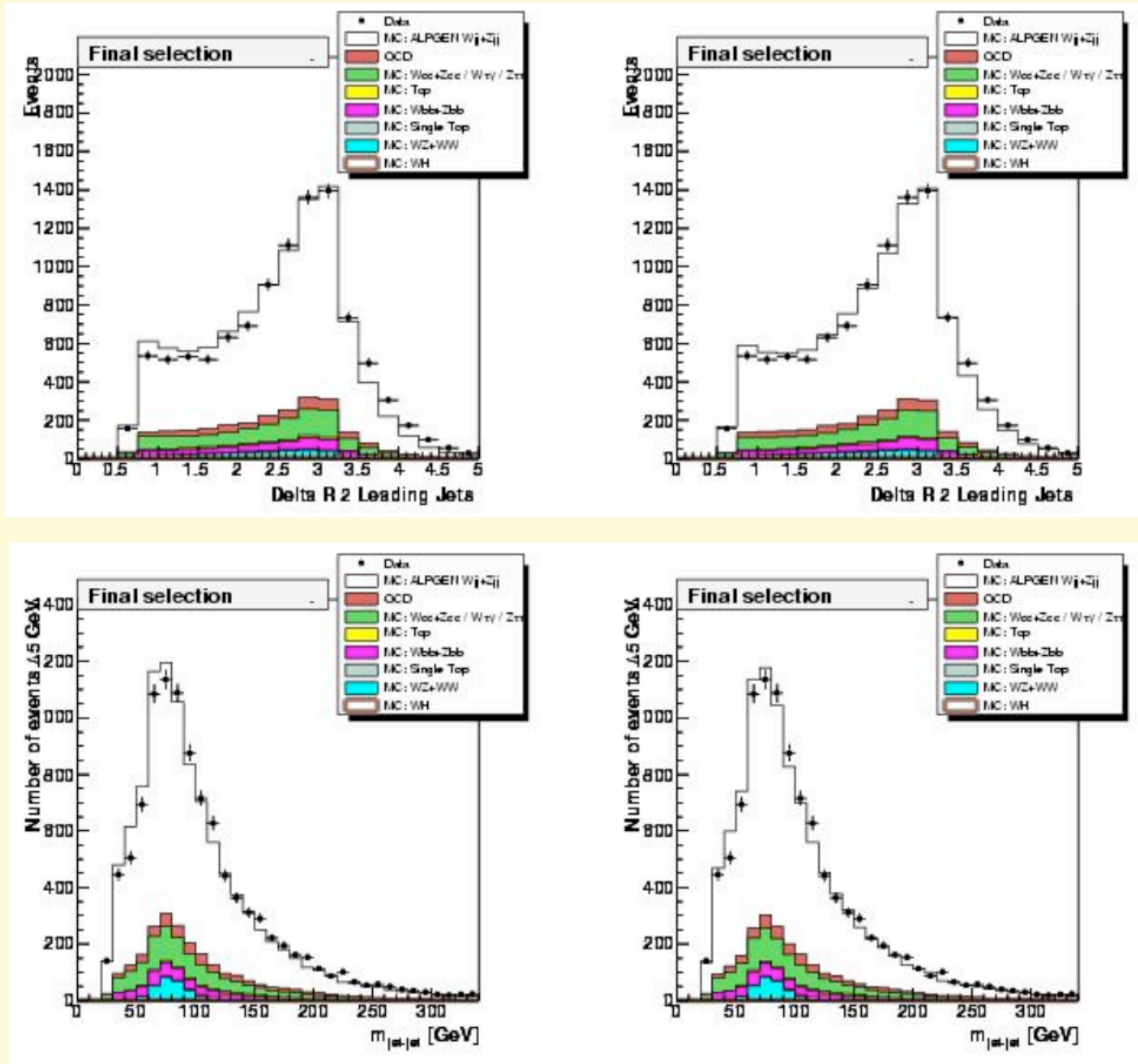


Validation of internal consistency: angular correlations in W+jets



Alpgen 3jinc
PL

cfr: D0, kinematical reweigthing in Wjj events



M[jj]

Before rewgt

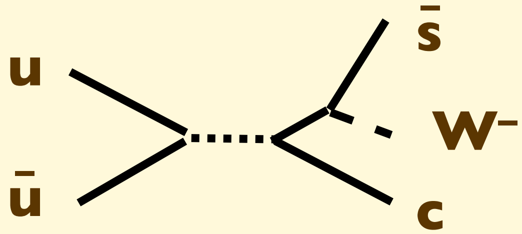
M[jj]

After rewgt

NB: exceptions

There are contributions appearing at higher parton multiplicities which represent entirely new processes, they are not merely “radiative corrections” to the LO processes. They are typically smaller, but may occasionally be important. They should not be subject to “matching”, since they cannot appear from the shower evolution of lower-order processes (no double counting). When important, their inclusion may lead to predictions arising from multiparotn+matching that are qualitatively different than the parton level ones.

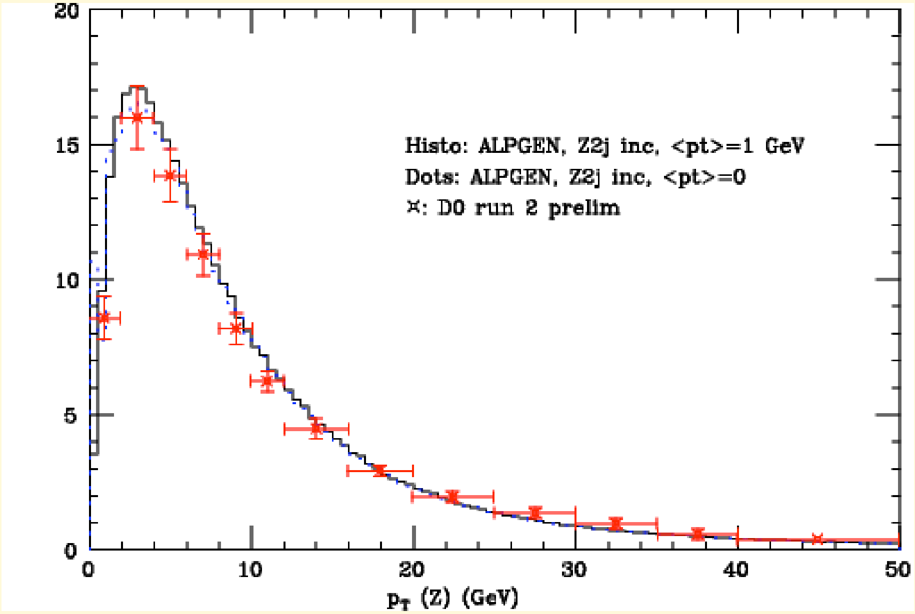
Example:

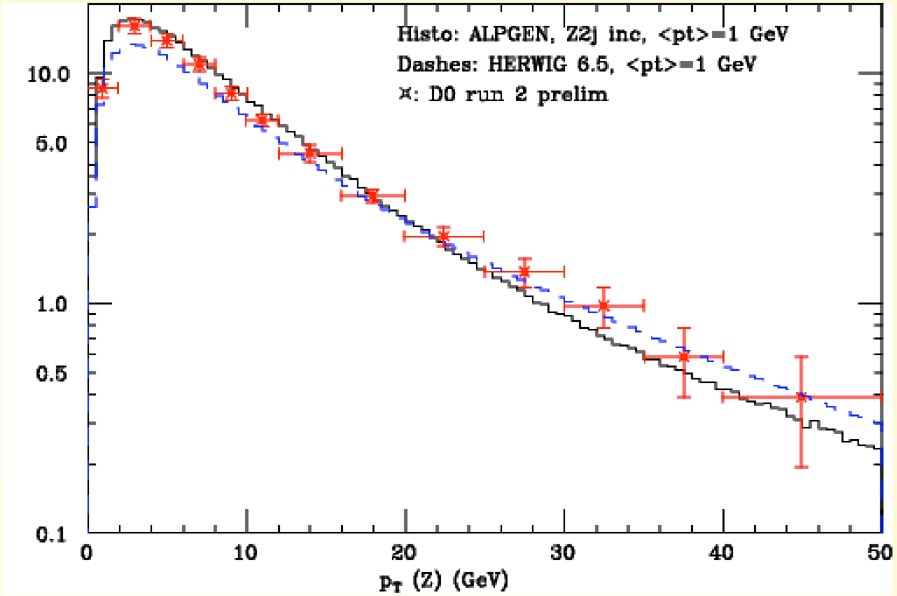


this W+2 jet final state cannot appear in the shower evolution of a W+1 parton ME.

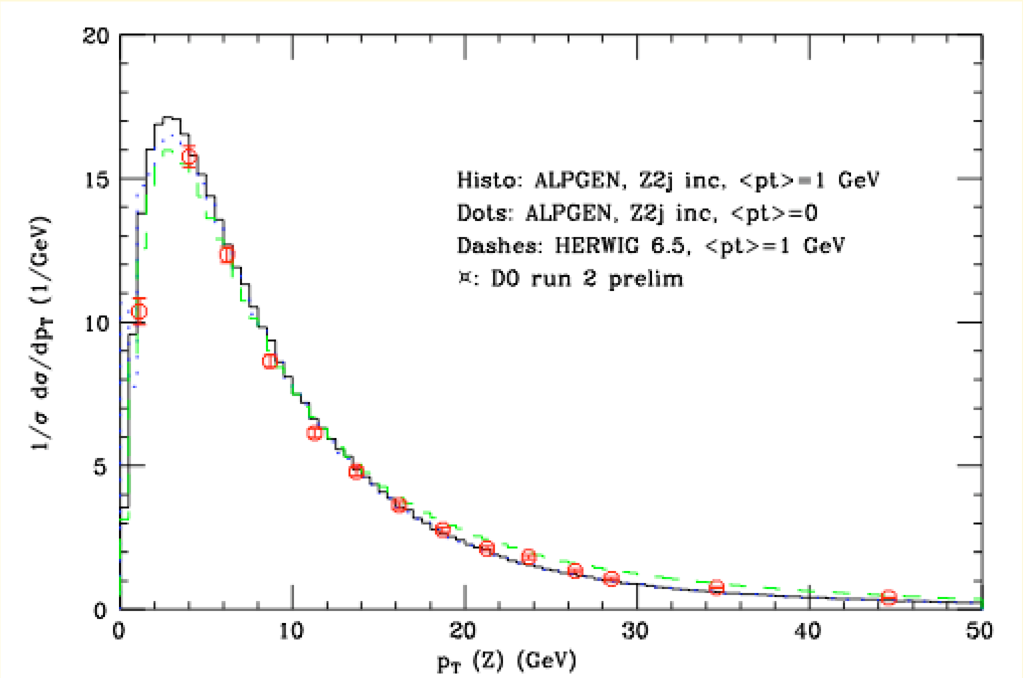
Comparisons with D0 data: Inclusive Z pt spectrum at 1.96 TeV

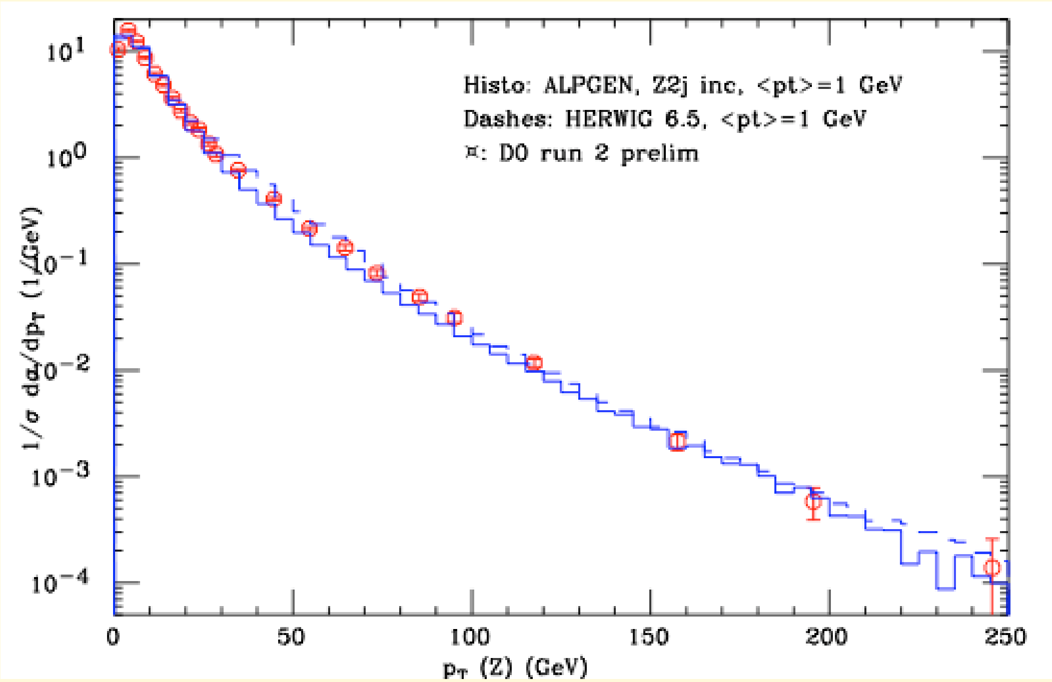
(D0 data: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/EW/E18/E18.pdf)



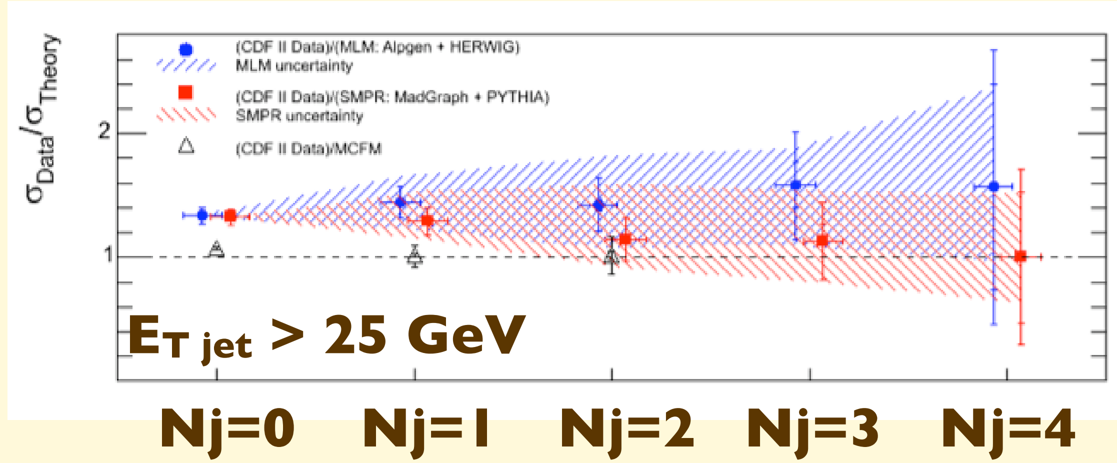


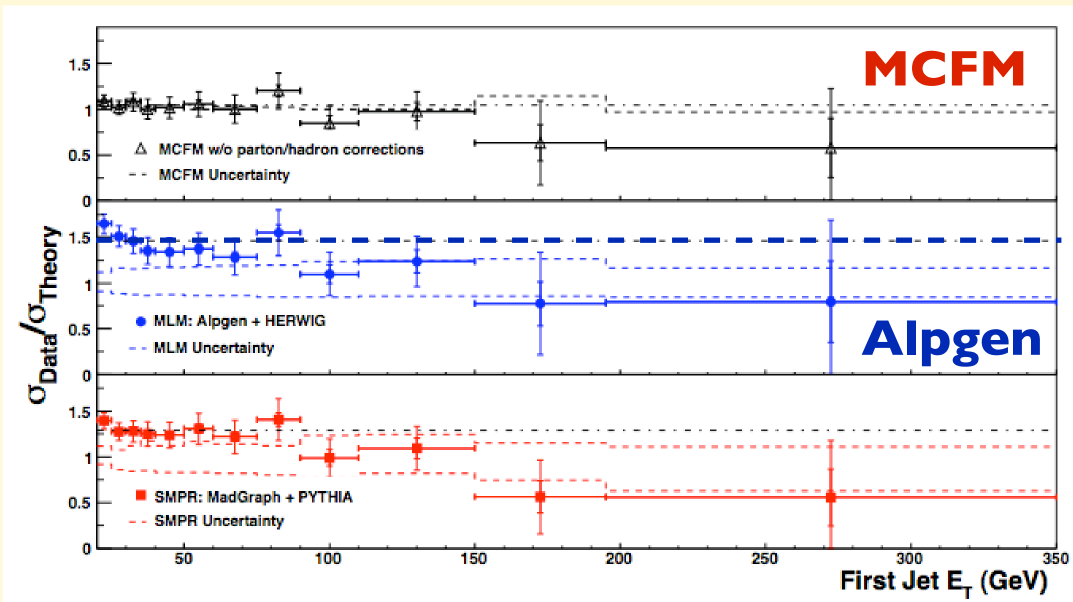
(D0 data: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/EW/E22/E22.pdf)

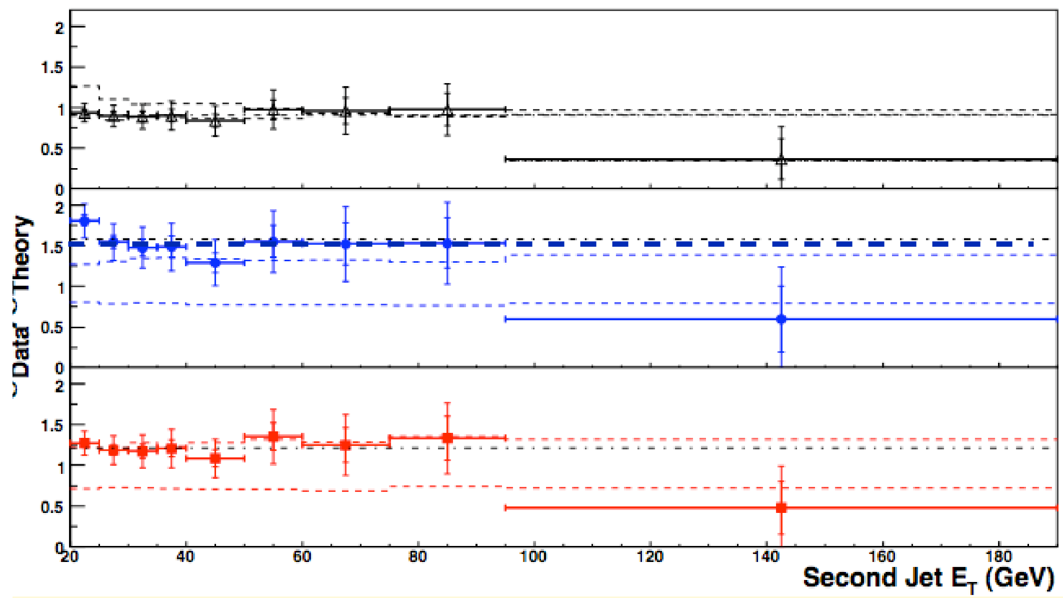


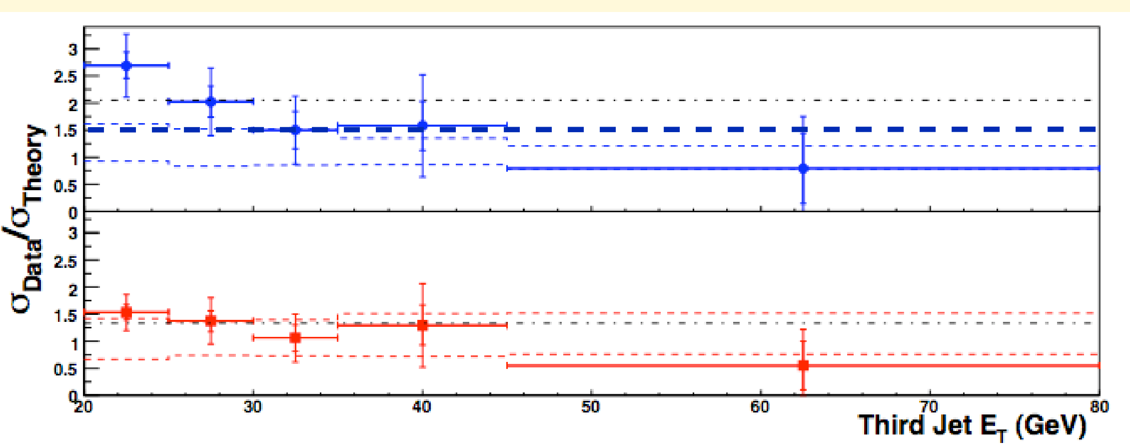


Jet spectra in W+jets
CDF, 380pb^{-1}









Comments

For many more plots and discussion, see Thursday session, CDF and D0 talks

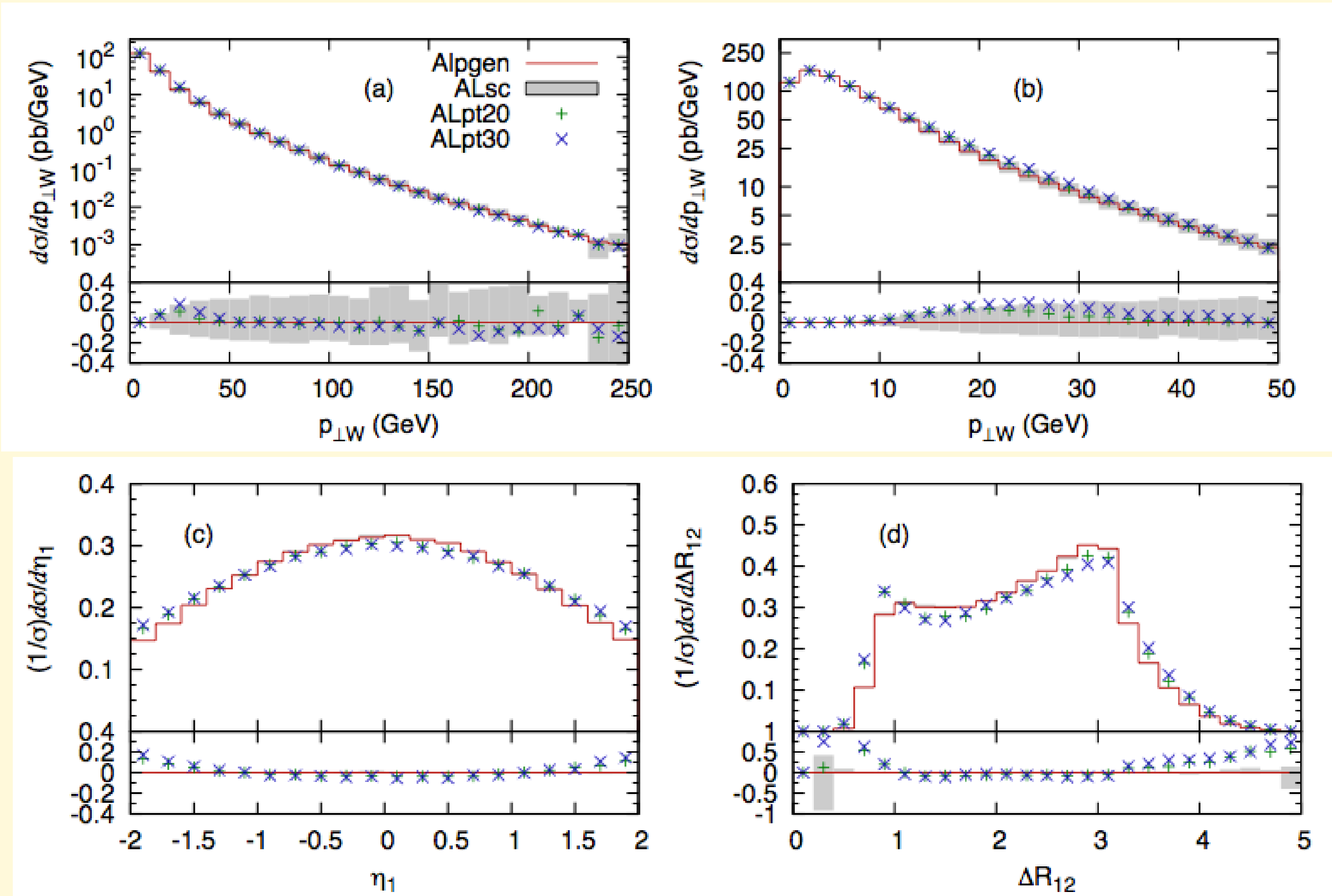
ALPGEN was never "tuned" on the data, the results shown by CDF and D0 arise form out-of-the-box ALGEN and baseline settings of the parameters for MLM's matching. I trust there is thus room for improving the agreement

Comparisons against data will always be disturbed by the presence of hadronization and of the non-PT part of the UE. Now that NLO calculations exist up to large parton multiplicities, we should consider a systematic effort of validation against NLO tools (particularly helpful in the case of LHC)

Examples of systematics studies (Tevatron Energy)

Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions *

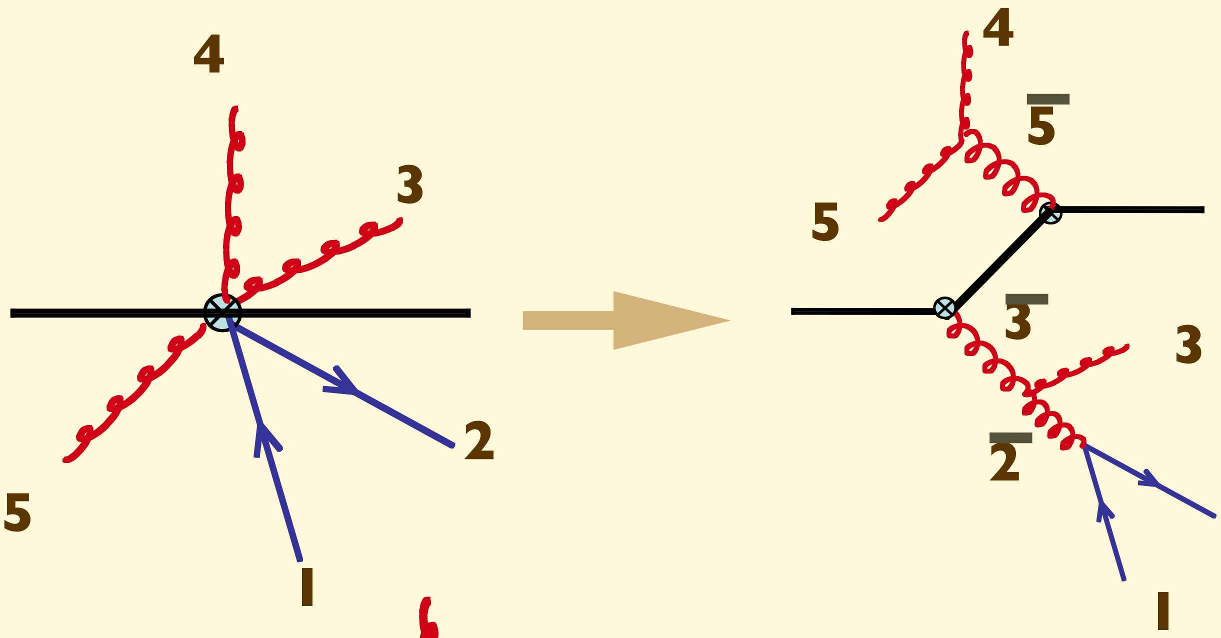
J. Alwall[1], S. Höche[2], F. Krauss[2], N. Lavesson[3], L. Lönnblad[3], F. Maltoni[4], M.L. Mangano[5], M. Moretti[6], C.G. Papadopoulos[7], F. Piccinini[8], S. Schumann[9], M. Treccani[6], J. Winter[9], M. Worek[10,11]



Different E_T matching thresholds: **20**, **30**, **40** GeV

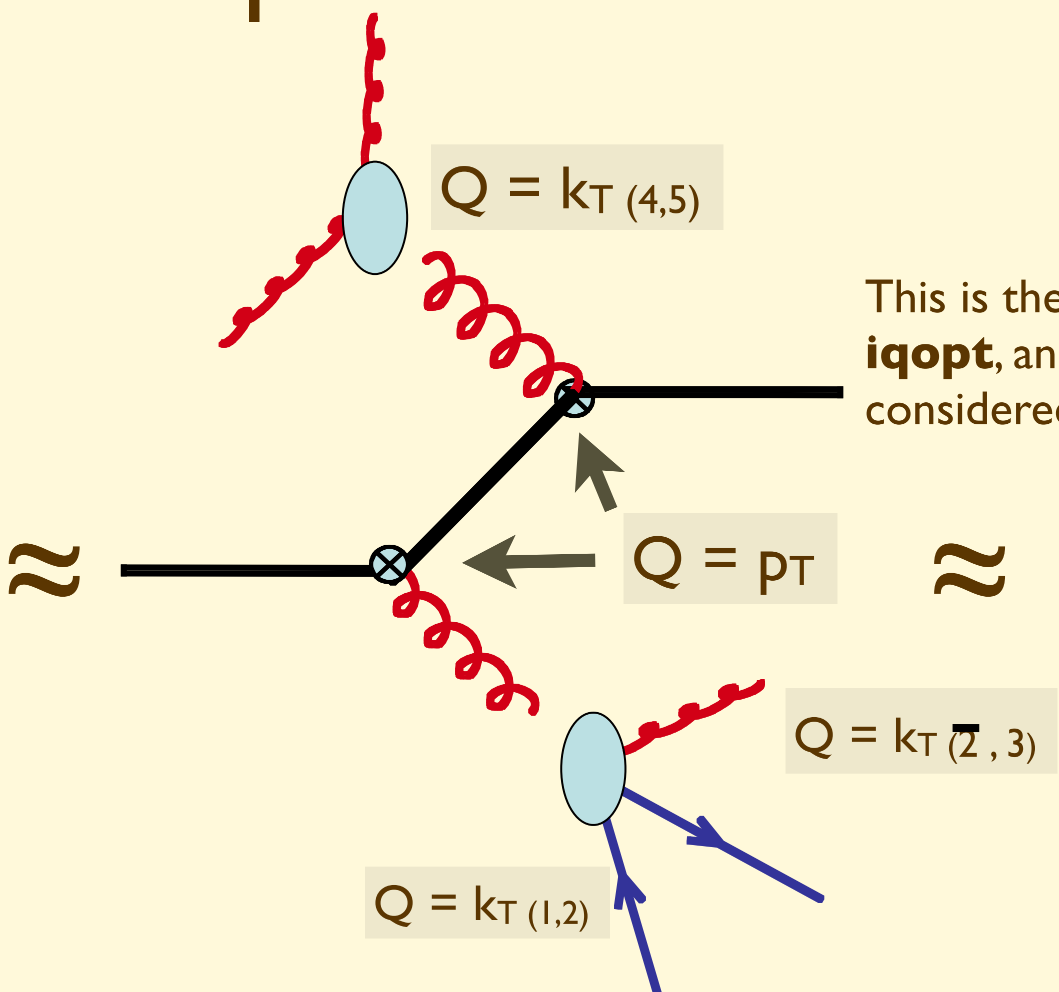
Different renorm. scale factor [0.5–2]=

Scale setting



$k_{T[1,2]} < k_{T[\bar{2},3]} < k_{T[4,5]}$

Only pairings allowed by colour and flavour flows are considered



This is the hard scale as defined by **iqopt**, and depends on the hard process considered

$$\approx \alpha^2\,(p_T)\;\; \alpha\,(k_{T\,(1,2)})\; \alpha\,(k_{T\,(12\,,\,3)})\; \alpha\,(k_{T\,(4,5)})$$

$$\otimes\; F_1\,(\,x_1,p_T\,)\;\otimes\;\; F_2\,(\,x_2,p_T\,)$$

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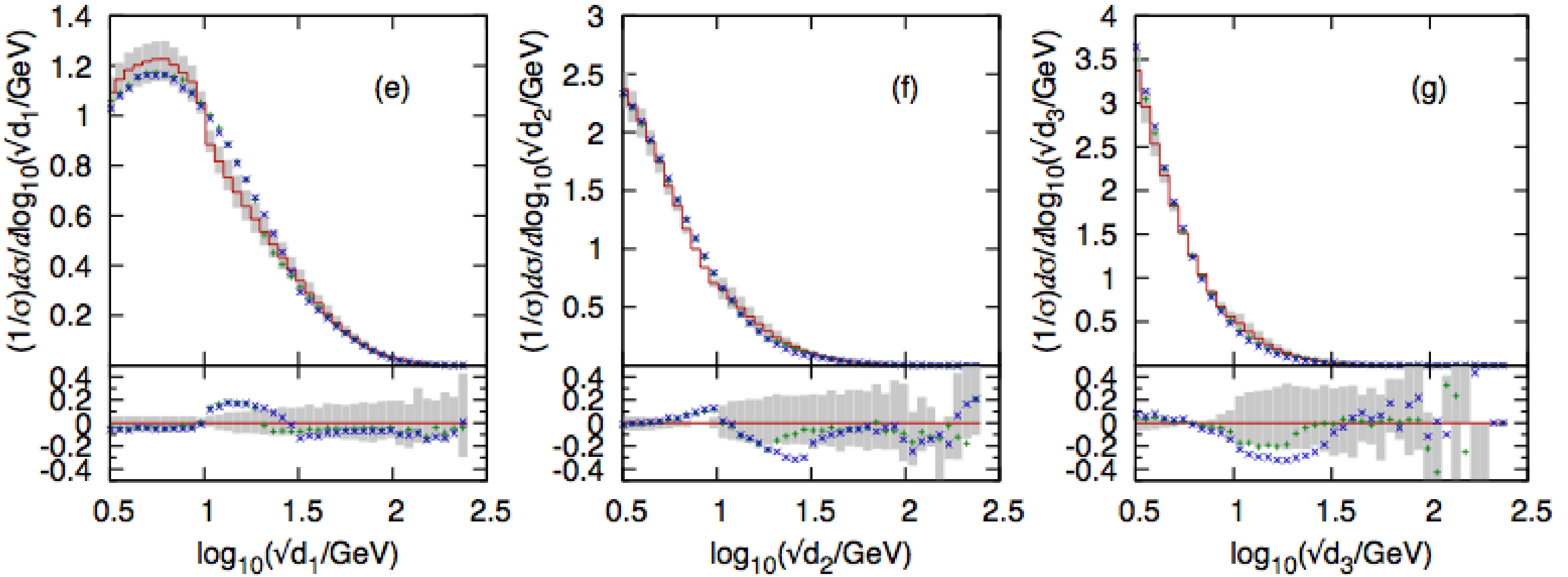

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Examples of systematics studies (LHC Energy)

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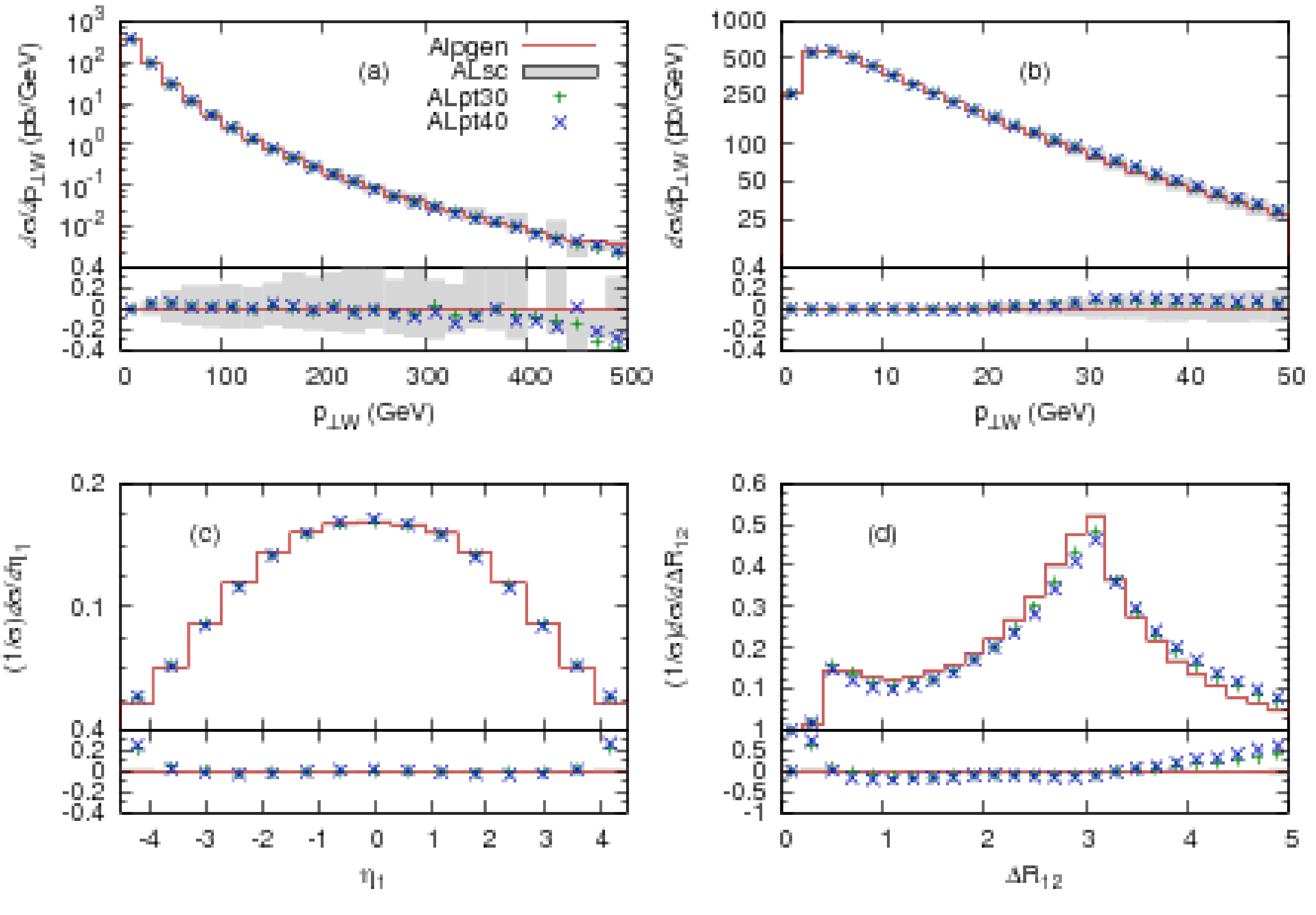

Different E_T matching thresholds: **20**, **30**, **40** GeV

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Message:

the patterns of systematics at the LHC and at the Tevatron are very similar. For these very hard processes, and at equal Q^2 , it doesn't seem to matter whether they are produced in 2 TeV or 14 TeV collisions ....

OPEN ISSUES with W/Z/gamma+ HVQs

W+b-jet
CDF analysis

- $p_{T\ lepton} > 20$ GeV , $|\eta_{lepton}| < 1.1$ MET>25 GeV
- $p_{T\ jet} > 20$ GeV , $|\eta_{\ jet}| < 2$, R=0.4

	σ_{Wb} x BR(W→e nu) [pb]
CDF	2.74 ± 0.27 (stat) ± 0.42 (syst)
PL LO,Wbb ($Q^2=M_W^2+p_T^2$)	0.78
Wbb+ Wbb1jet MLM matching with Herwig	$[0.504]_{Wbb}$ +$[0.126]_{Wbbj}$ =0.73

Data/Theory ~ 3.5 !!

Z+b-jet
CDF analysis

Table I: Results on the $Z + b$-jets production.

	CDF Data	Pythia	Alpgen	MCFM NLO	MCFM NLO+UE +Hadronization
$\sigma(Z + b\text{-jet})$	$0.86 \pm 0.14 \pm 0.12$ pb	–	–	0.51 pb	0.53 pb
$\sigma(Z + b\text{-jet})/\sigma(Z)$	$0.336 \pm 0.053 \pm 0.041$%	0.35%	0.21%	0.21%	0.23%
$\sigma(Z + b\text{-jet})/\sigma(Z + \text{jet})$	$2.11 \pm 0.33 \pm 0.34$ %	2.18%	1.45%	1.88%	1.77%

Data/Theory ~ 1.5

OPEN ISSUES with W/Z/gamma+ HVQs

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Data/Theory ~ 3.5 !!

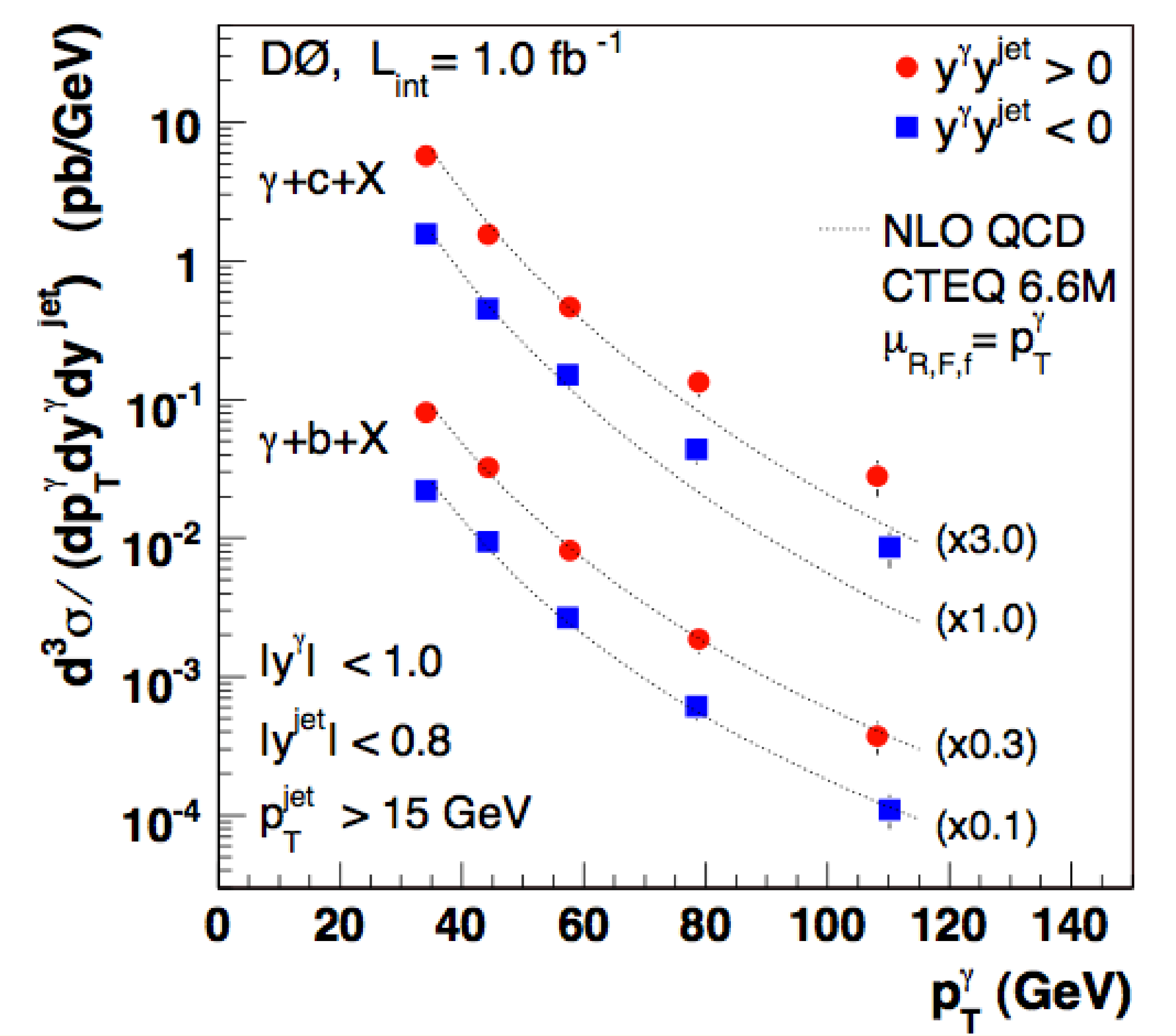
Z+b-jet
CDF analysis

- $E_{T\,jet} > 20$ GeV $|\eta_{jet}| < 1.5$ R=0.7

	CDF	MCFM $Q^2=M^2+p_T^2$	MCFM $Q^2 = \langle p_T^2 \rangle$	ALP $Q^2=M^2+p_T^2$	ALP $Q^2 = \langle p_T^2 \rangle$
σ[Z+b-jet] / σ[Z+jet]	2.1 ± 0.4 %	1.8%	2.2%	1.6%	2.3%
σ[Z+b-jet] / σ[Z]	0.33 ±0.07%	0.23%	0.28%	0.21%	0.3%

D0: γ+b/c-jet analysis

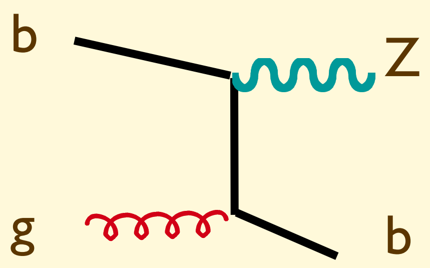
- $E_{T\gamma} > 30$ GeV , $|\eta_\gamma| < 1$, $E_{T\,jet} > 15$ GeV , $|\eta_{jet}| < 0.8$, R=0.5



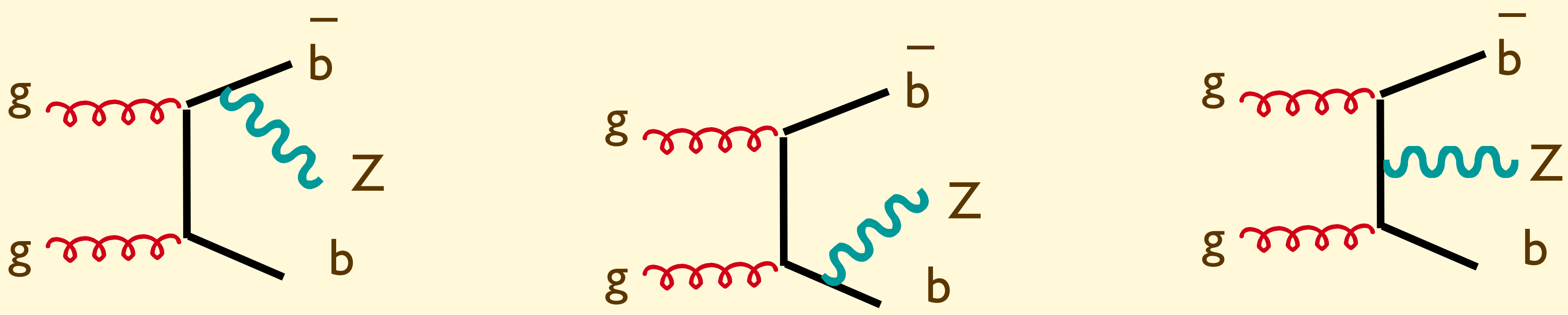
NLO QCD: T.Stavreva and J.Owens

Treatment of heavy quarks: initial states

In ALPGEN heavy quarks never appear in the initial state. Processes with initial-state HVQs are produced by higher-order diagrams with initial-state gluon splittings



➡ in Alpgen:



In general previous discrepancies are reduced, or vanish, using low Q scales in processes with hvq's produced by initial-state gluon splitting (Q~pt). This opens a new direction for syst studies.