Simulating W/Z+jets production with SHERPA

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- The SHERPA approach
- Consistency checks
- SHERPA vs. NLO

Based on F. Krauss, A. Schälicke, S. S. and G. Soff, hep-ph/0409106.

The SHERPA approach

Combine LO Matrix Elements and Parton Showers according to CKKW

S. Catani, F. Krauss, R. Kuhn, B. Webber, JHEP 0111:063,2001
F. Krauss, JHEP 0208:015,2002

Aim:

- Good description of soft and hard region
- Avoid double counting of equivalent phase space configurations
- Universality of fragmentation (energy independent)

Solution:

- Divide multi-jet phase space into two regimes (Durham measure Q_{cut})
  - Jet production by ME (if available)
  - Jet evolution down to fragmentation scale by the PS
- Reweight ME's to get exclusive samples at a resolution scale Q_{cut}

  $\Rightarrow$ This allows to add samples of different jet multiplicities
- Veto on PS configurations that have already been taken into account by a higher order ME

The SHERPA approach

Method:

- Select a jet multiplicity with probability:

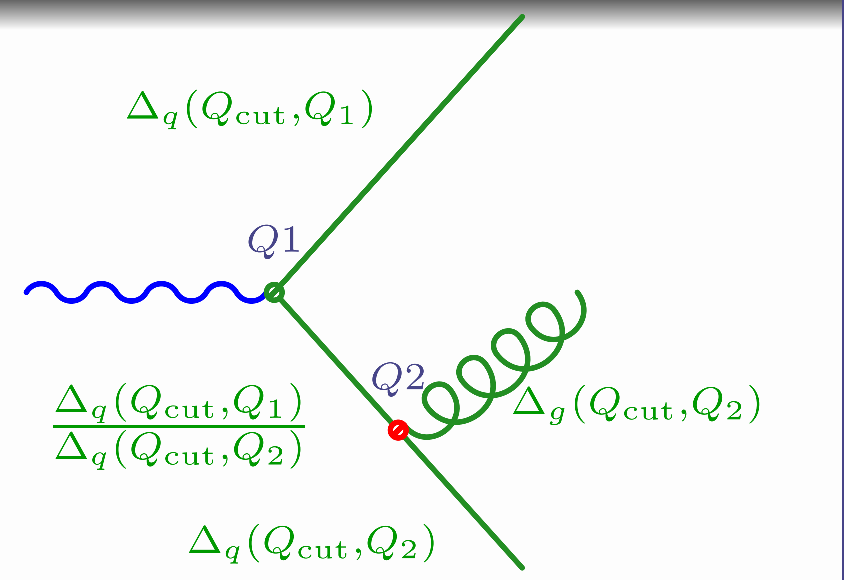
$$P_n = \frac{\sigma_n}{\sum_{i=0}^{N} \sigma_i}$$

  where σ_n is the n-jet matrix element taken at resolution scale $Q_{\rm cut}$. Use $Q_{\rm cut}$ as scale for PDF's and α_S.

- Generate final state momenta p_i according to the ME
- k_T cluster backwards initial and final state particles until a core $2 \to 2$ process remains, this results in a chain of resolutions for 1,2,..n jets
- Recalculate α_S at each vertex in the tree at the corresponding k_T scale
- Apply Sudakov weights
  - $\Delta_{q,g}(Q_{\rm cut}, Q_{\rm prod})$ for outgoing partons
  - $\Delta_{q,g}(Q_{\rm cut}, Q_{\rm prod})/\Delta_{q,g}(Q_{\rm cut}, Q_{\rm dec})$ for lines between $Q_{\rm prod} > Q_{\rm dec}$

The SHERPA approach

- Reject events with a combined coupling and Sudakov weight smaller than random number $R \in [0, 1]$
- Start the initial or final state parton shower for each parton of the event, starting at the scale where it was produced
- Veto on emissions above the scale $Q_{\rm cut}$



$$W = \Delta_g(Q_{\rm cut}, Q_2)[\Delta_q(Q_{\rm cut}, Q_1)]^2 \frac{\alpha_s(Q_2)}{\alpha_s(Q_{\rm cut})}$$

SHERPA specifics:

- Jet measure: $Q_{ij} = \min(p_{\perp i}^2, p_{\perp j}^2) \cdot R_{ij}^2$ or $Q_{iB} = p_{\perp i}^2$

$$R_{ij}^2 = 2\left[\cosh(\eta_i - \eta_j) - \cos(\phi_i - \phi_j)\right]$$

- For the highest multiplicity ME the scale $Q_{\rm cut}$ in the PDF's and Sudakovs is replaced by the smallest nodal scale of the clustering

Validation of the Matrix Elements

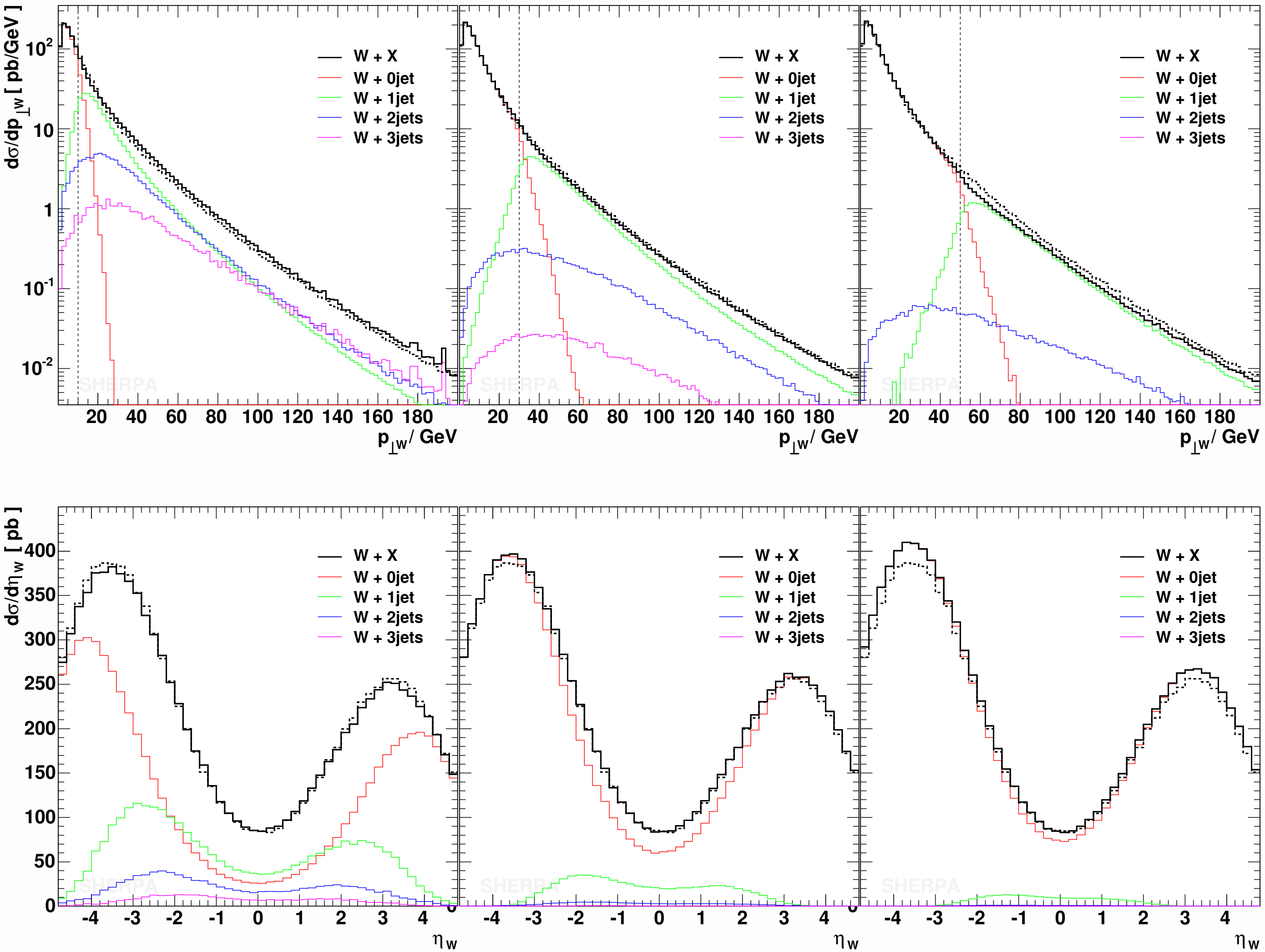
The relevant ME's for the MC4LHC setup.

X-sects (pb)	Number of jets						
$e^- \bar{\nu}_e$ + n QCD jets	0	1	2	3	4	5	6
Alpgen	3904(6)	1013(2)	364(2)	136(1)	53.6(6)	21.6(2)	8.7(1)
CompHEP	3947.4(3)	1022.4(5)	364.4(4)				
MadEvent	3902(5)	1012(2)	361(1)	135.5(3)	53.6(2)		
Amegic++/Sherpa	3908(3)	1011(2)	362(1)	137.5(5)	54(1)		

X-sects (pb)	Number of jets						
$e^- e^+$ + n QCD jets	0	1	2	3	4	5	6
Alpgen	723.4(9)	188.3(3)	69.9(3)	27.2(1)	10.95(5)	4.6(1)	1.85(1)
CompHEP	730.9(1)	190.20(7)	70.22(7)				
MadEvent	723(1)	188.6(4)	69.3(1)	27.1(2)	10.6(1)		
Amegic++/Sherpa	723.1(7)	188.2(3)	69.7(2)	27.3(1)			

Consitency checks: Variation of the separation cut

The $p_\perp$ and η distribution of the W^- in $p\bar{p} \to e^- \,\bar{\nu}_e + X$ @ $\sqrt{s} = 1.96\,\text{TeV}$



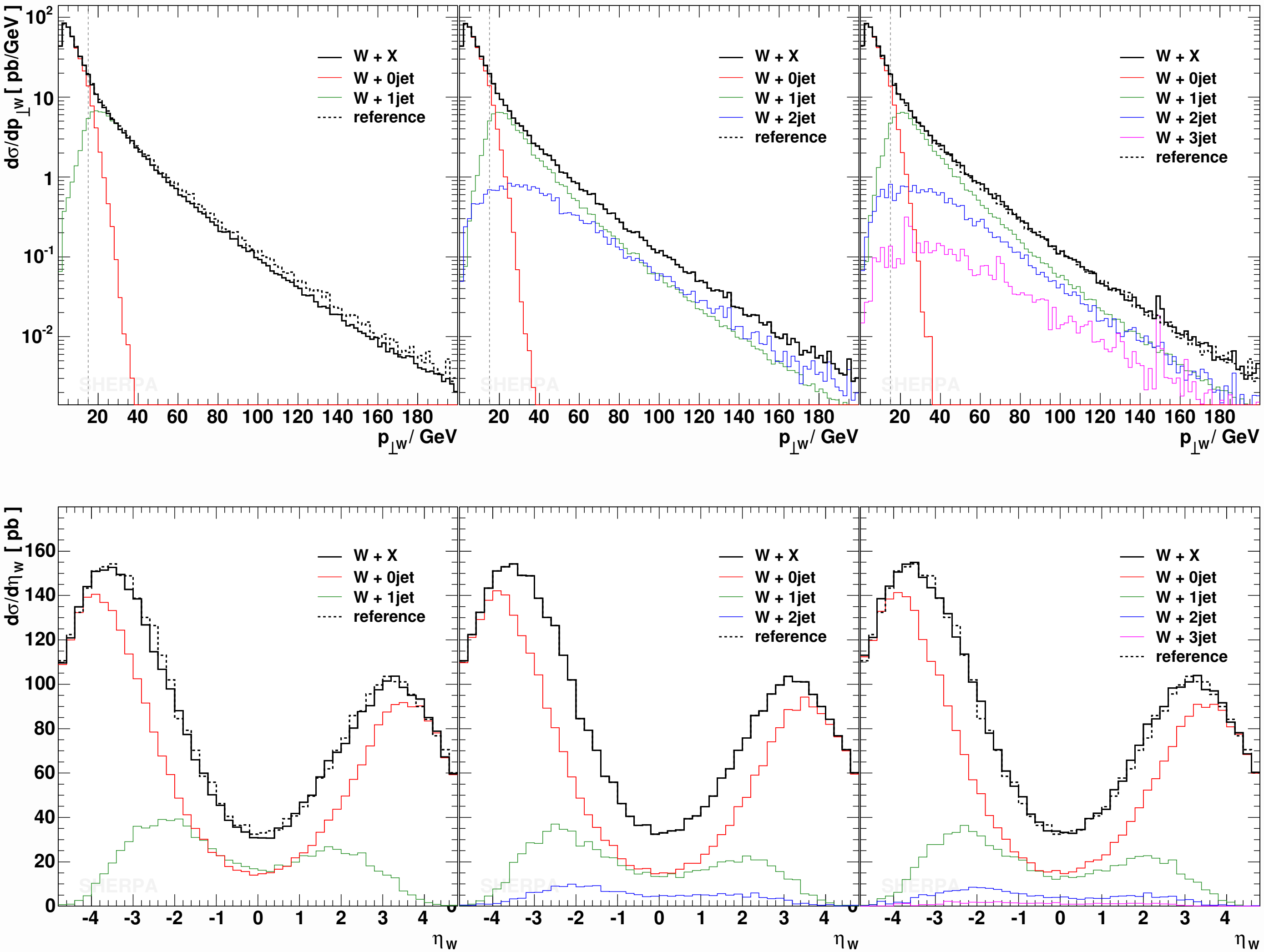
$p_{\perp W^-}$ distribution

η_{W^-} distribution

$Q_{\rm cut}$=10 GeV $Q_{\rm cut}$=30 GeV $Q_{\rm cut}$=50 GeV dashed $Q_{\rm cut}$=20 GeV

Consistency checks: Variation of the maximal jet multiplicity

$p_{\perp W^-}$ **and** η_{W^-} **in** $p\bar{p} \to e^- \, \bar{\nu}_e + X$ **@** $\sqrt{s} = 1.96\,\mathrm{TeV}$ **(**Q_{cut}**= 15 GeV)**



$p_{\perp W^-}$ distribution

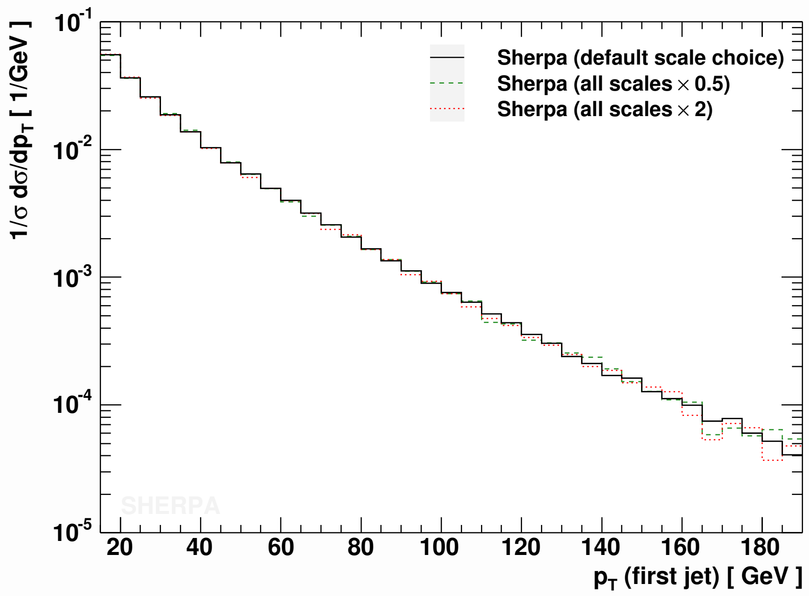
η_{W^-} distribution

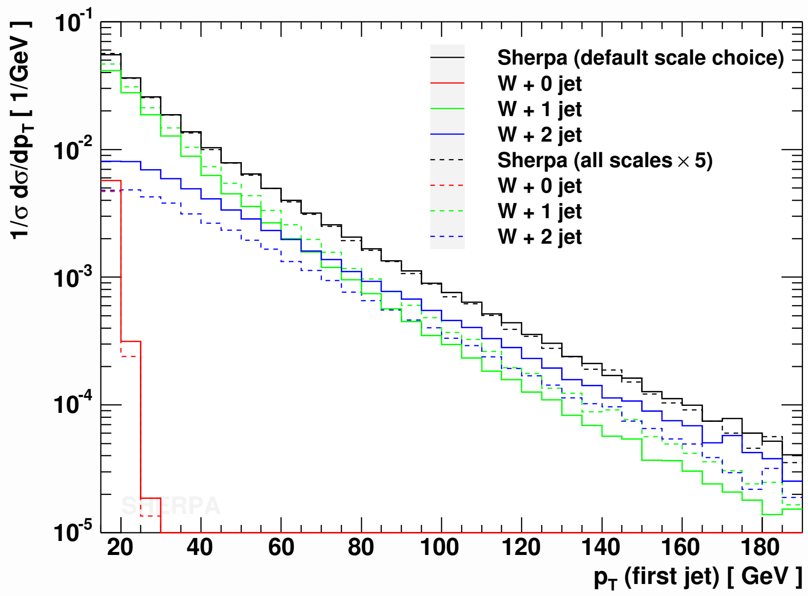
$n_{\max}$=1 $n_{\max}$=2 $n_{\max}$=3 dashed $n_{\max} = 2$

Consistency checks: Scale variation

$p_\perp$ of the first jet in inclusive W production @ Tevatron Run II

solid lines: default scale choice
dashed lines: PDF and α_S scales multiplied by common factors (0.5,2,5)





While the cross section changes by varying the scales the distributions shape stays unchanged

SHERPA vs. NLO: The exclusive case

Consider CKKW as a scale setting prescription for tree level calculations

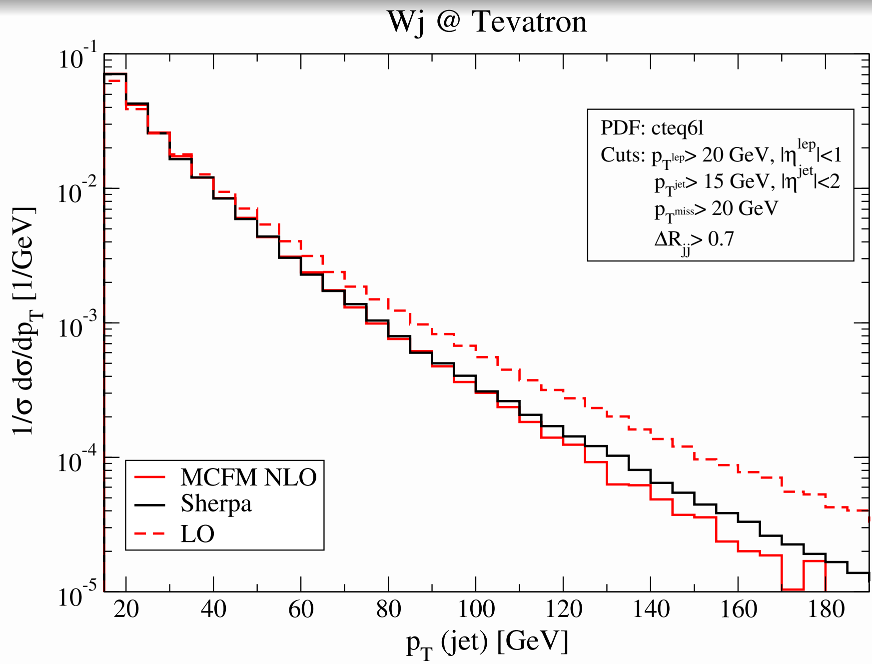
Look at α_S and Sudakov reweighted parton samples without attaching the parton shower and compare those to NLO results

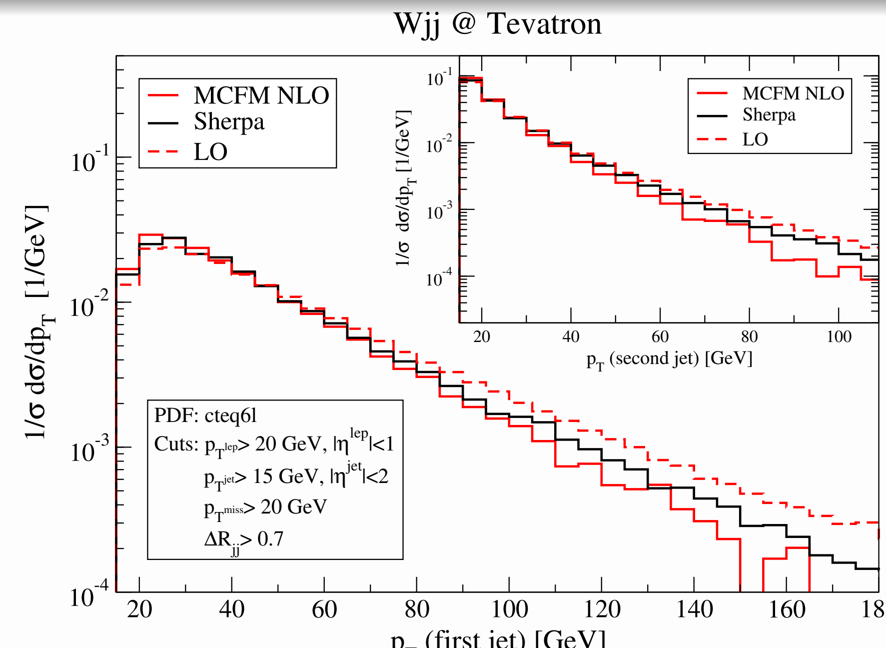
- Take fully exclusive parton samples of $W + 1/2$ jets and $Z + 1/2$ jets
  $(W^+ \to e^+\nu_e,\, W^- \to e^-\bar{\nu}_e,\, Z \to e^+e^-)$
- Compare to exclusive NLO ME predictions of MCFM
  (J.M. Campbell, R.K. Ellis, Phys.Rev.D65:113007,2002 and Phys.Rev.D68:094021,2003)

Setup:

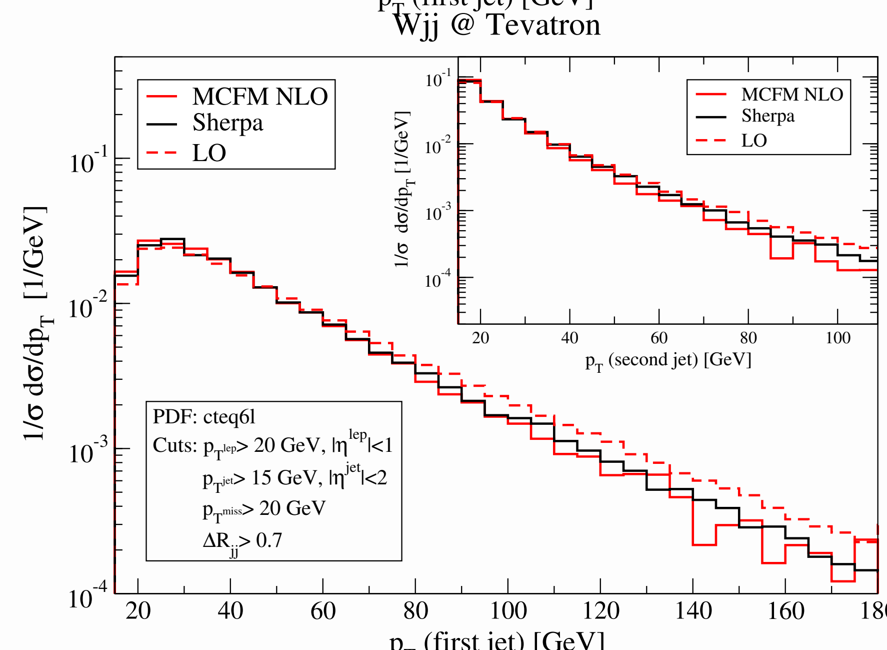
- MCFM and SHERPA pure ME: $\mu_F = \mu_R = M_W$
- $Q_{cut} = p_{\perp,min}$ of jets
- jets are defined by Run II K_T algorithm with $D = 0.7$

SHERPA vs. NLO: Exclusive W+jet prod. @ $\sqrt{s} = 1.96\,\mathrm{GeV}$

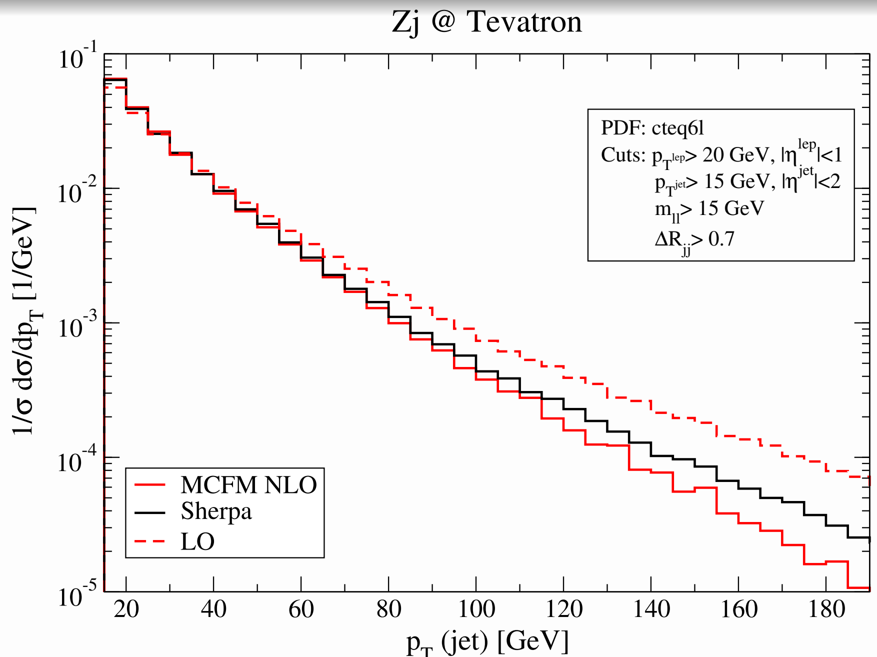


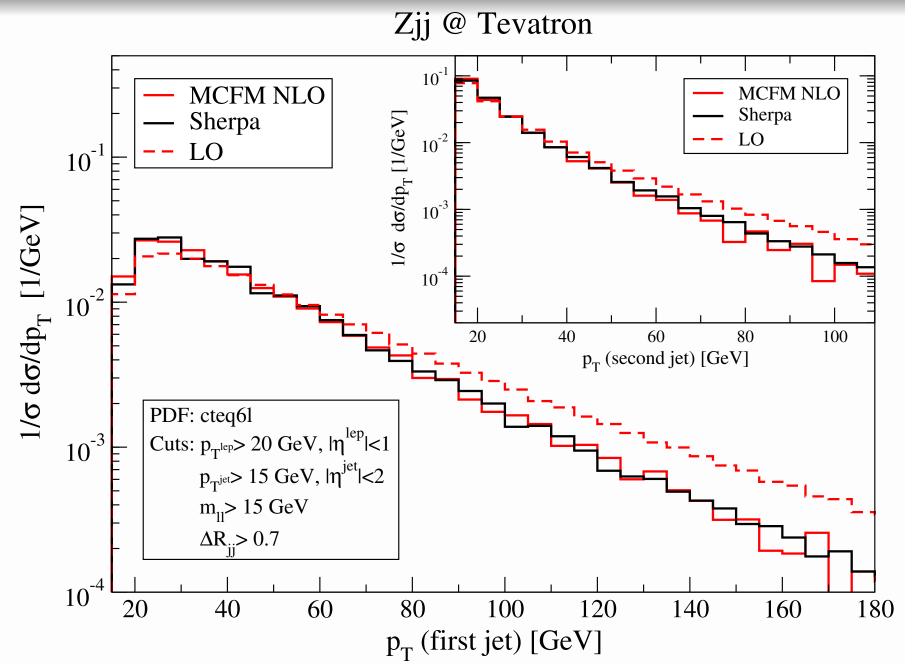


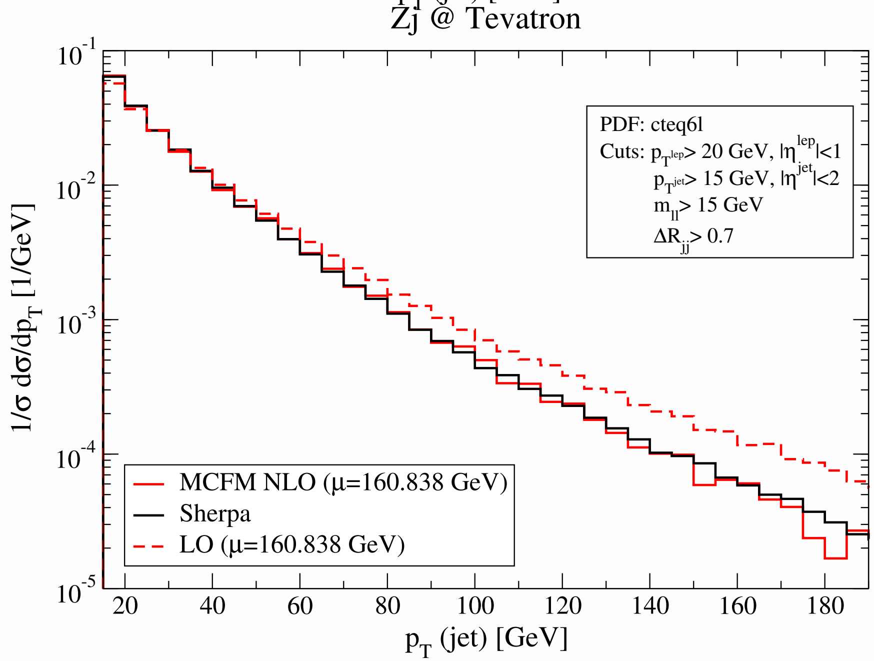
MCFM: $\mu_R = \mu_F = 2M_W \Rightarrow$



SHERPA vs. NLO: Exclusive Z+jet prod. @ $\sqrt{s} = 1.96\,\mathrm{GeV}$







$\Leftarrow$ MCFM: $\mu_R = \mu_F = 2M_W$

SHERPA vs. NLO: The inclusive case

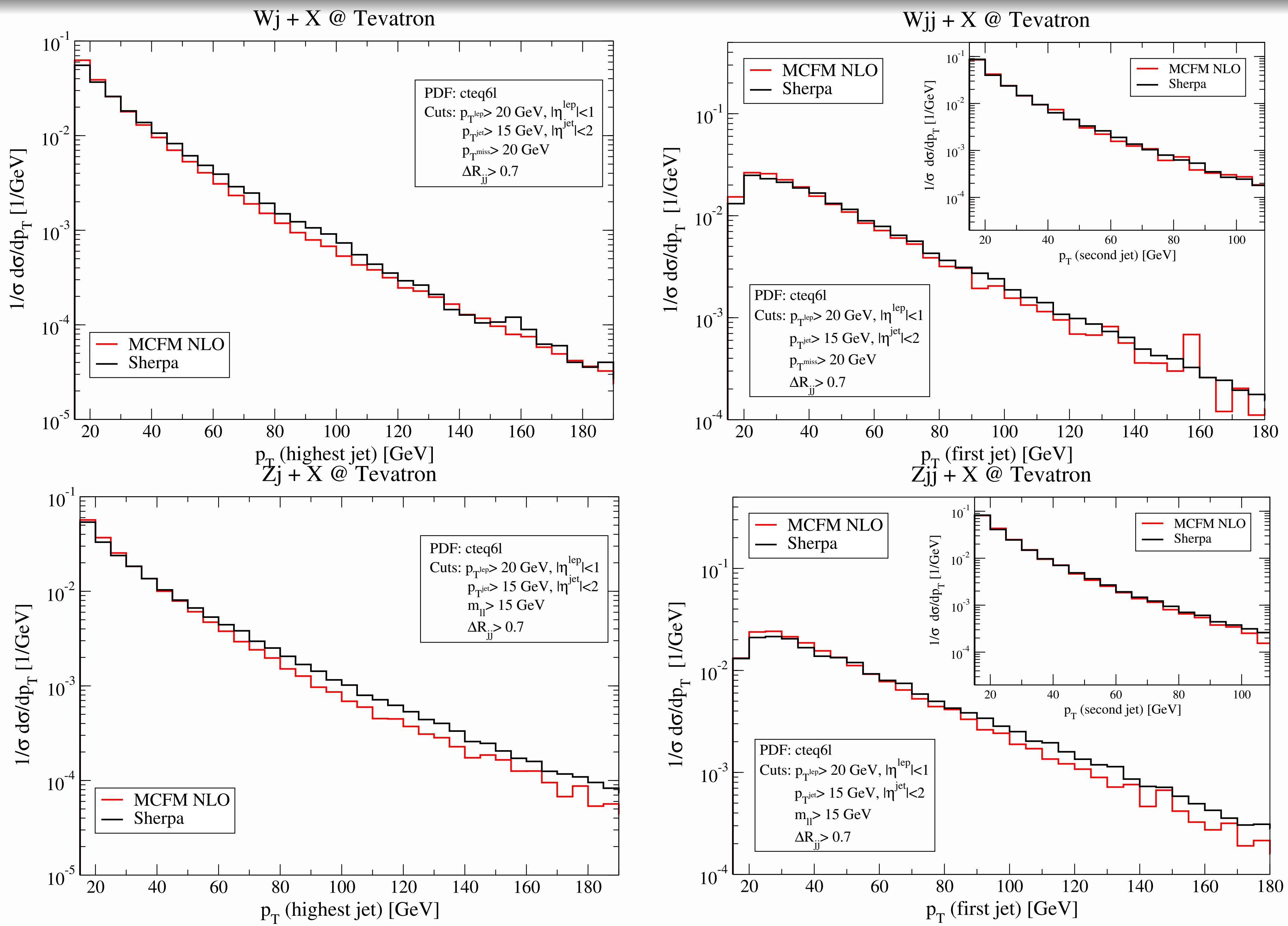
Lets look on inclusive Boson plus jet production

- Take fully inclusive samples of W and Z plus jets including shower evolution
- Compare to inclusive NLO ME predictions of MCFM (featuring potentially one jet more)

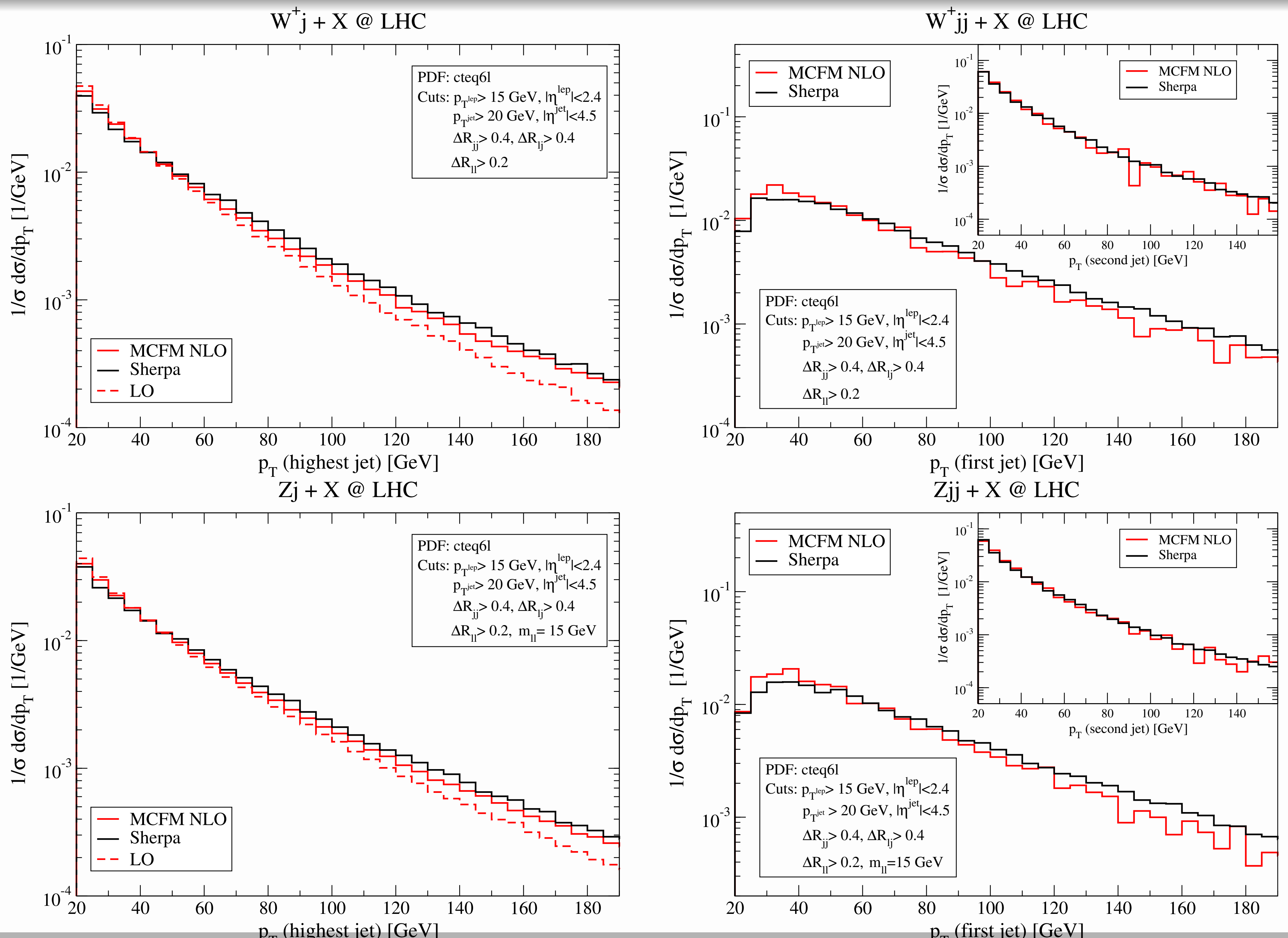
Setup:

- ME's considered: W/Z + 0,1,2 jets, the highest obtaining the highest multiplicity treatment
- MCFM: $\mu_F = \mu_R = M_W$
- $Q_{cut} = p_{\perp,min}$ of jets
- jets found by Run II K_T algorithm with $D = 0.7$ (Tevatron), $D = 0.4$ (LHC)

SHERPA vs. NLO: Incl. W/Z+jet prod. @ $\sqrt{s} = 1.96\,\mathrm{GeV}$



SHERPA vs. NLO: Inclusive W^+/Z+jet production @ LHC

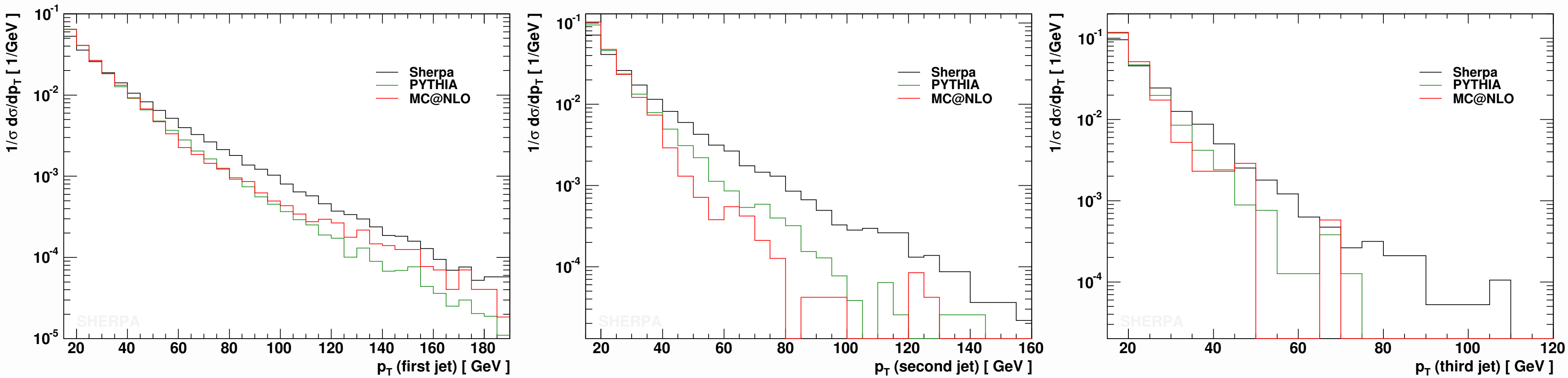


SHERPA vs. Pythia and MC@NLO

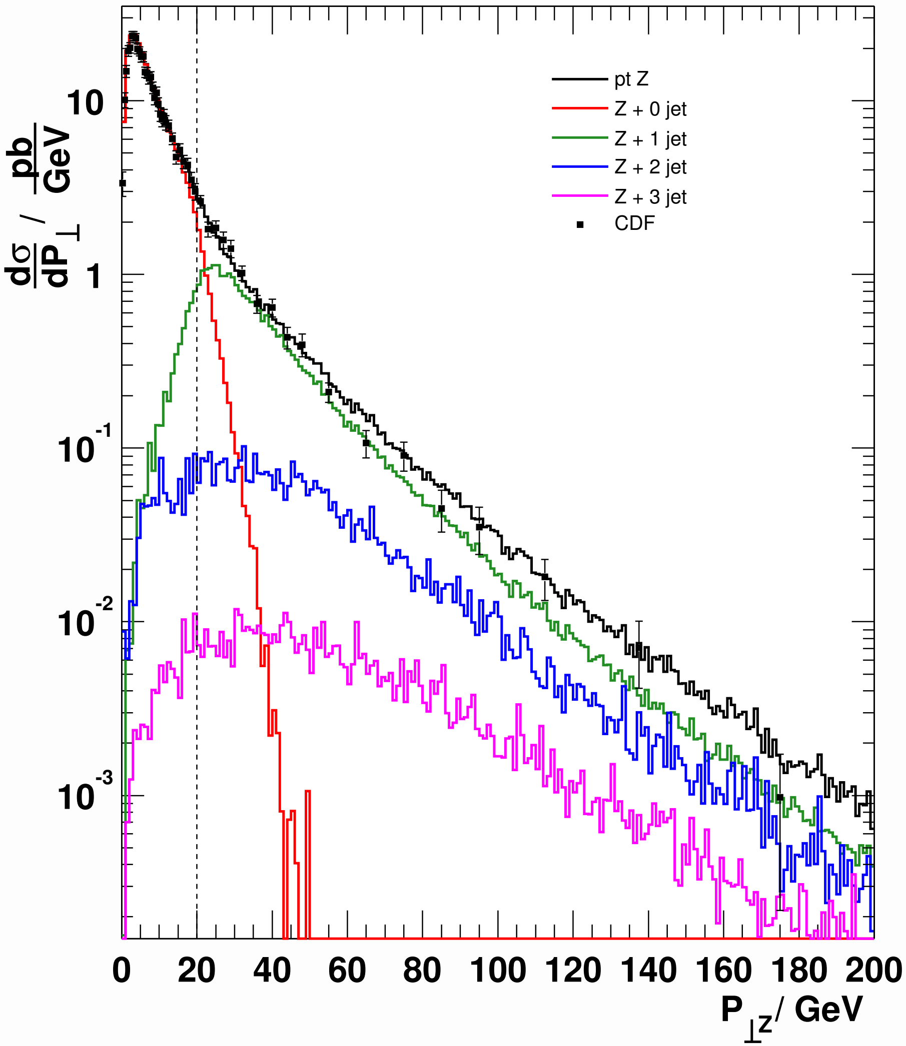
Comparison at the hadron level:

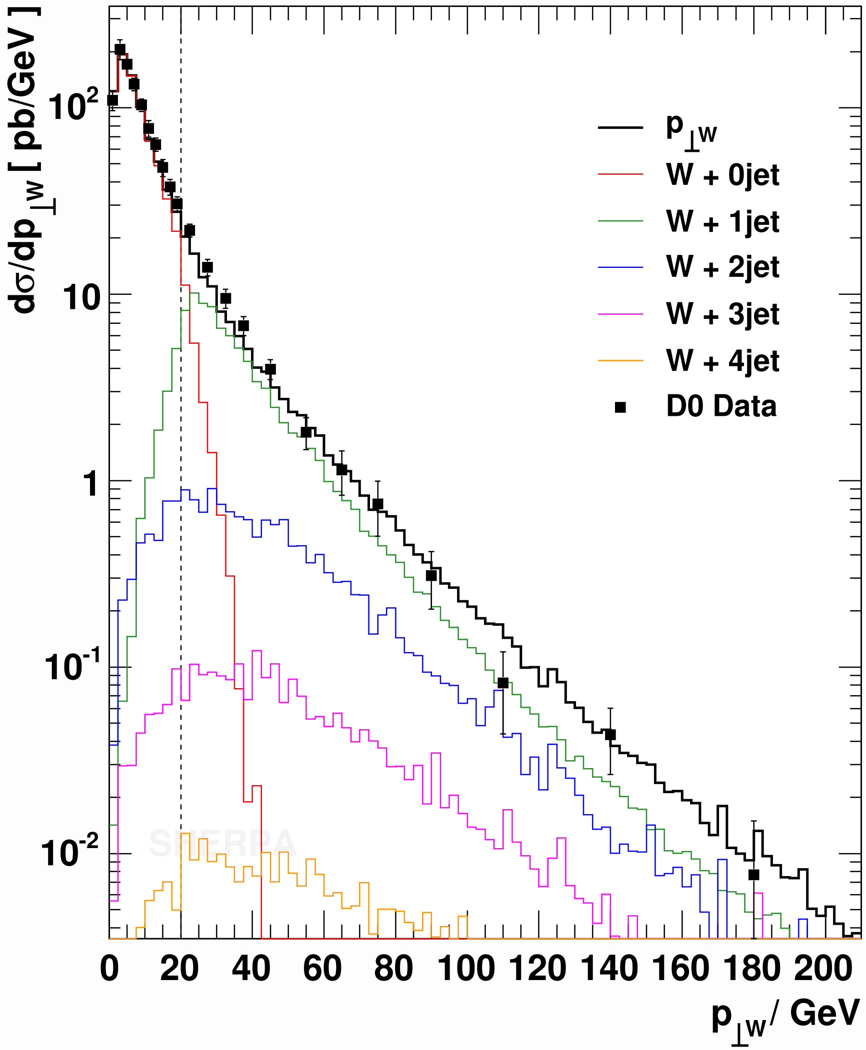
The $p_\perp$ of the three hardest jets in W+jets production @ Tevatron Run II

- Pythia including matrix element correction of the first emission
- MC@NLO in its default setup for $p\bar{p} \to e\nu_e$ at NLO
- SHERPA using matrix elements for up to W+3jets



Comparison with Tevatron data @ $\sqrt{s} = 1.8\text{TeV}$





CDF Data : Phys.Rev.Lett.84:845-850,2000

DO Data : Phys.Lett.B513:292-300,2001

Distributions multiplied by appropriate K-factors!

Conclusion/Outlook

Conclusion

- The CKKW method seems to reproduce the NLO shapes for exclusive and inclusive W/Z plus jet production at Tevatron (and LHC)
- The CKKW reweighting procedure seems to be a good choice
- However, the rates are not NLO
- Detailed comparison with MLM approach ongoing

SHERPA including the ME's of AMEGIC++ and the CKKW prescription to combine them with the PS is a powerful tool to attempt the description of present-day Tevatron data and to study the extrapolation to LHC energies

SHERPA sources

- T. Gleisberg, S. Höche, F. Krauss, A. Schälicke, S. S. and J. Winter,

  JHEP 0402:056,2004
- current version SHERPAα-1.0.4 available under

  `http://www.physik.tu-dresden.de/~krauss/hep`