Simulating W/Z+jets production with SHERPA

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- The SHERPA approach
- $W^{\pm}$ and Z/γ^{*} production @ LHC
  - Consistency checks
  - SHERPA vs. MCFM, PYTHIA & MC@NLO

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:

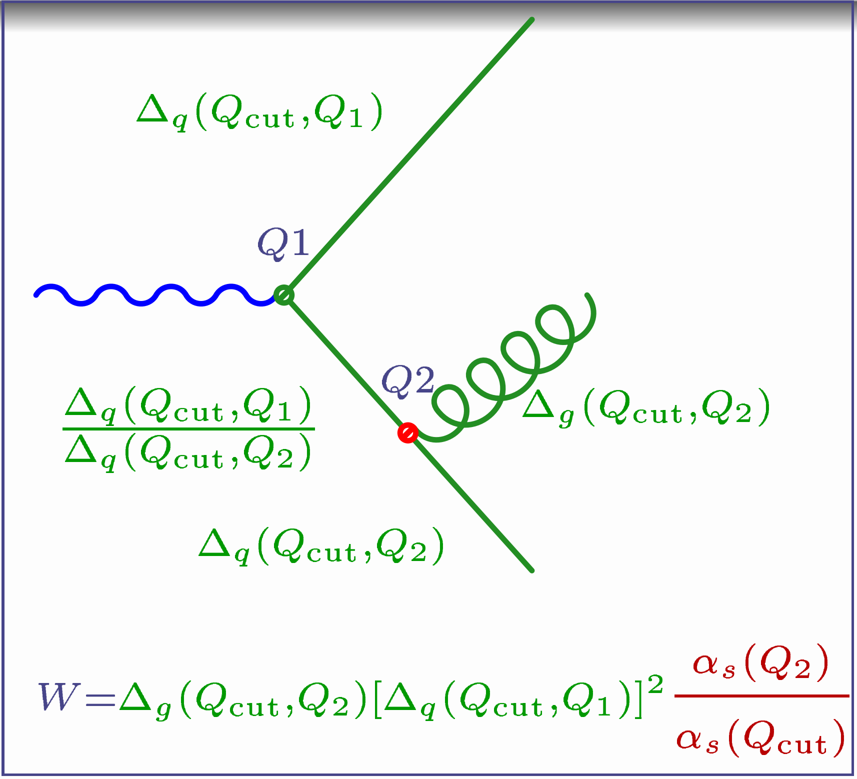
$$P_n = \frac{\sigma_n}{\sum_{i=0}^{N} \sigma_i}$$

  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 $Q_{\rm cut}$



SHERPA specifics:

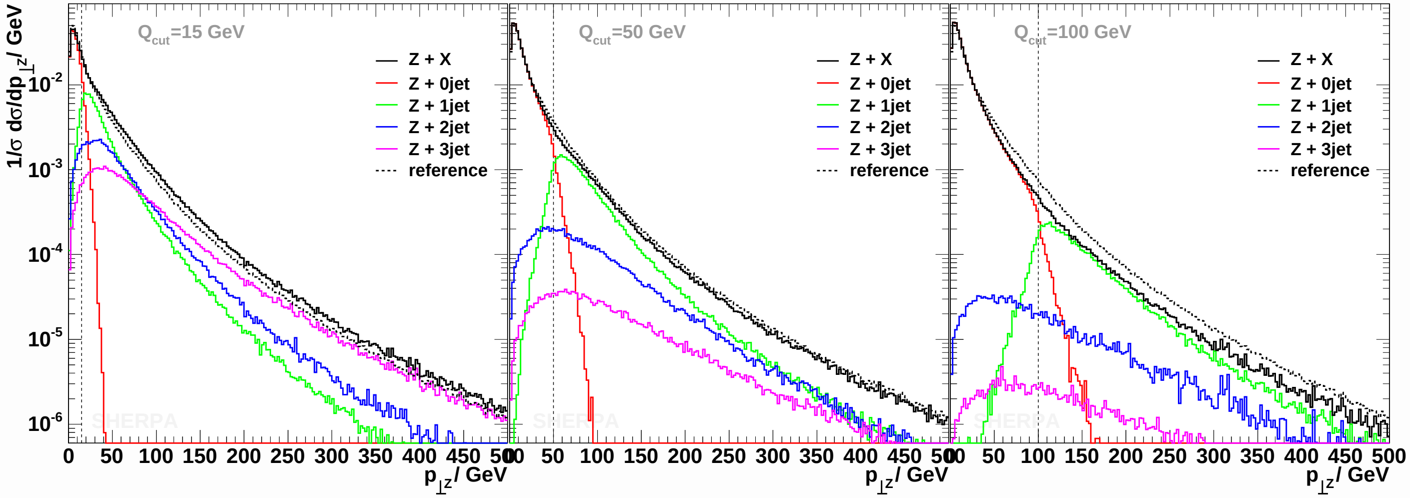
- Jet measure: $Q^2_{ij} = \min(p^2_{\perp i}, p^2_{\perp j}) \cdot R^2_{ij}$ or $Q^2_{iB} = p^2_{\perp i}$

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

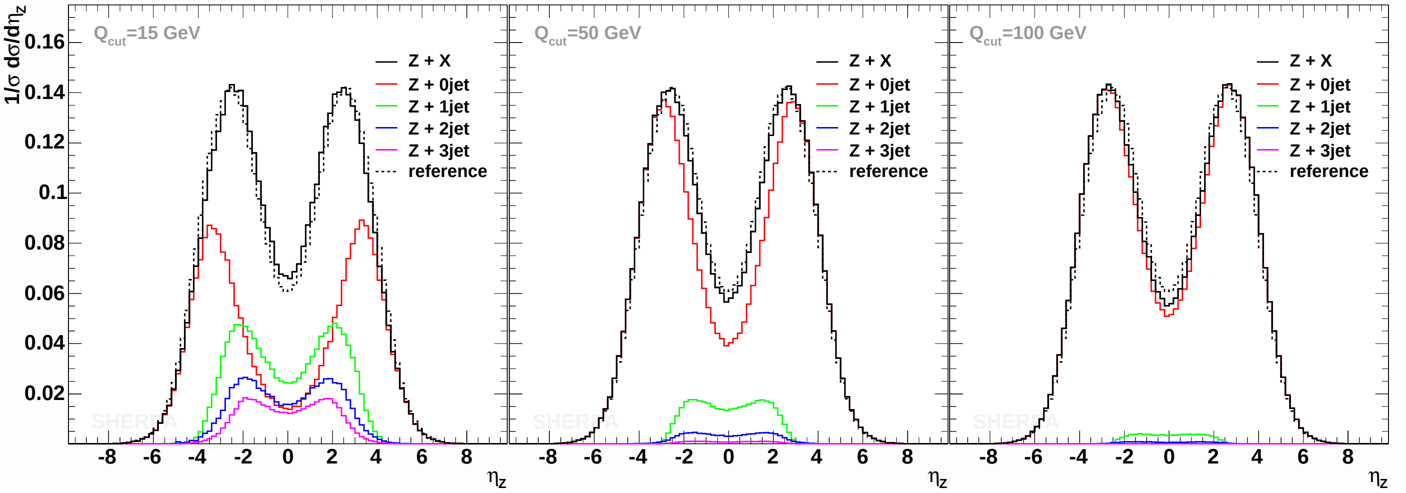
- For the highest multiplicity ME the scale $Q_{\rm cut}$ in the PDF's and Sudakovs is replaced by the smallest nodal scale of the clustering

Consitency checks: Variation of the separation cut

The $p_\perp$ and η distribution of the Z/γ^* in $pp \to e^+e^- + X$ @ $\sqrt{s} = 14\,\text{TeV}$



$p_{\perp Z}$ distribution

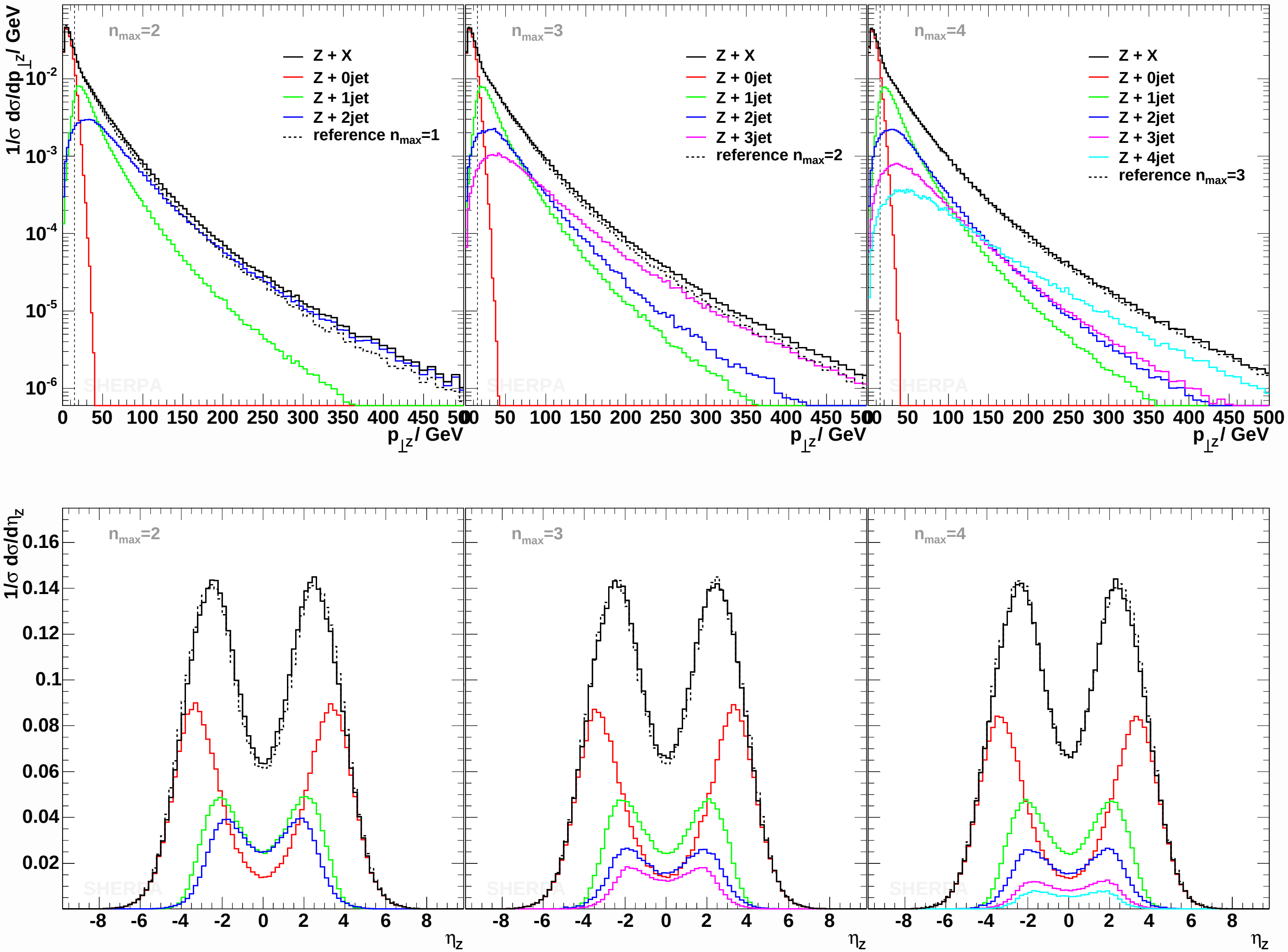


η_Z distribution

Q_{cut}=15 GeV Q_{cut}=50 GeV Q_{cut}=100 GeV

Consistency checks: Variation of the maximal jet multiplicity

The $p_\perp$ and η distribution of the Z/γ^* in $pp \to e^+e^- + X$ @ $\sqrt{s} = 14\,\mathrm{TeV}$



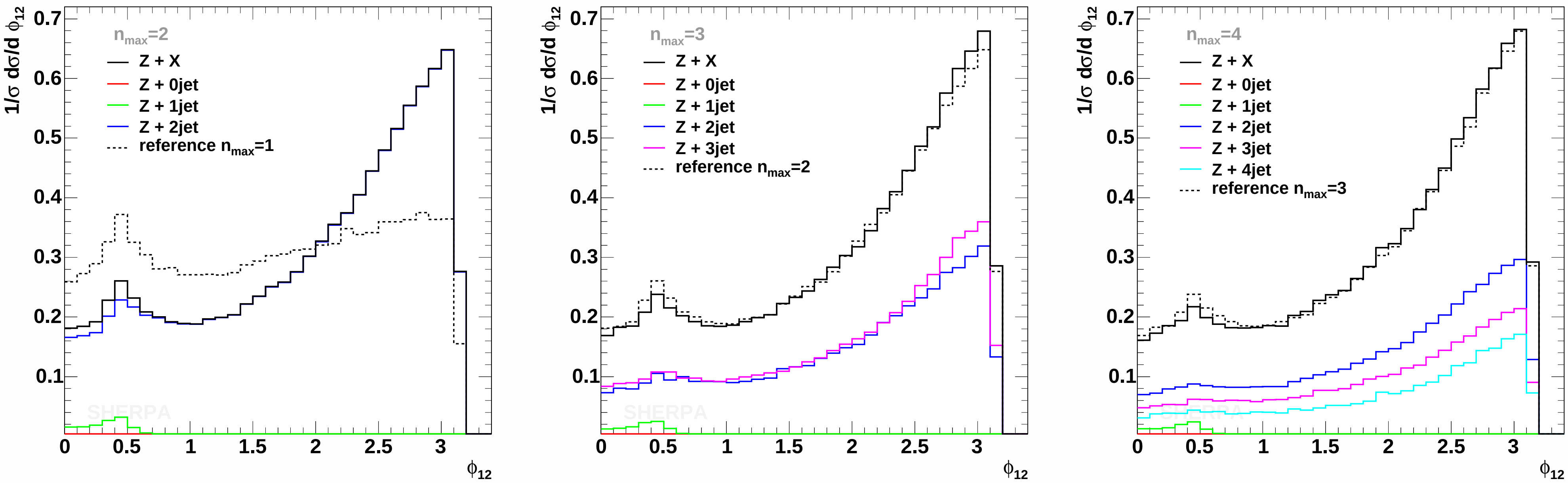
$p_{\perp Z}$ distribution

η_Z distribution

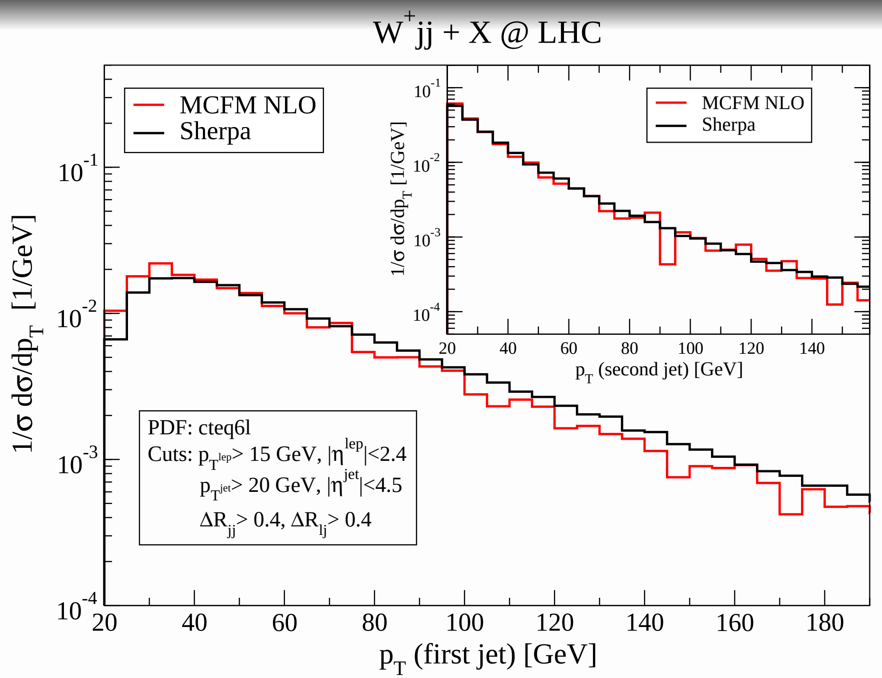
$n_{\max}$=2 $n_{\max}$=3 $n_{\max}$=4

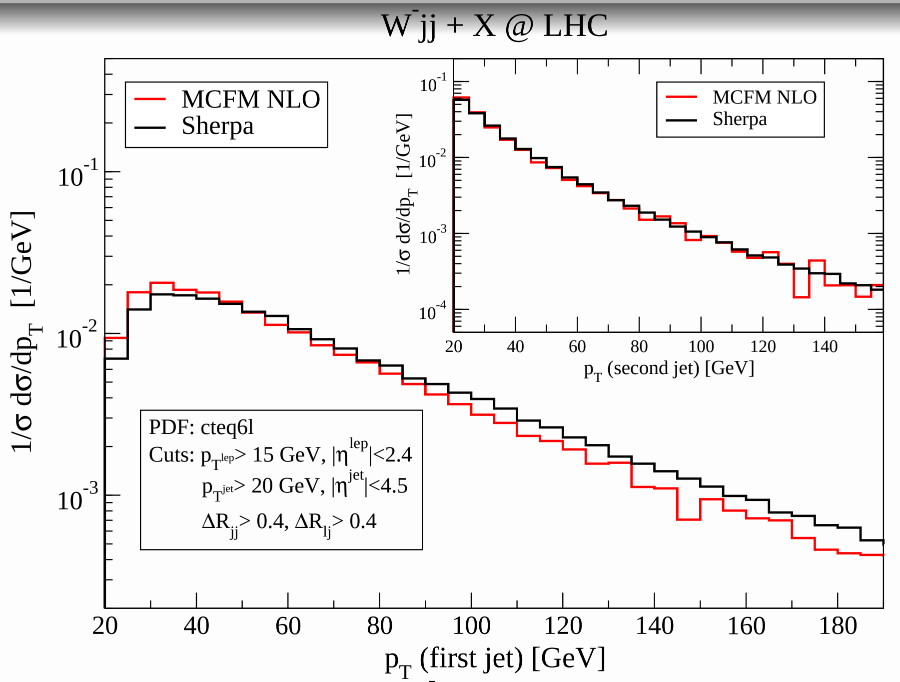
Consistency checks: Variation of the maximal jet multiplicity

The $\Delta\Phi$ separation of the two hardest jets in Z/γ^* in $pp \to e^+e^- + X$ @ LHC

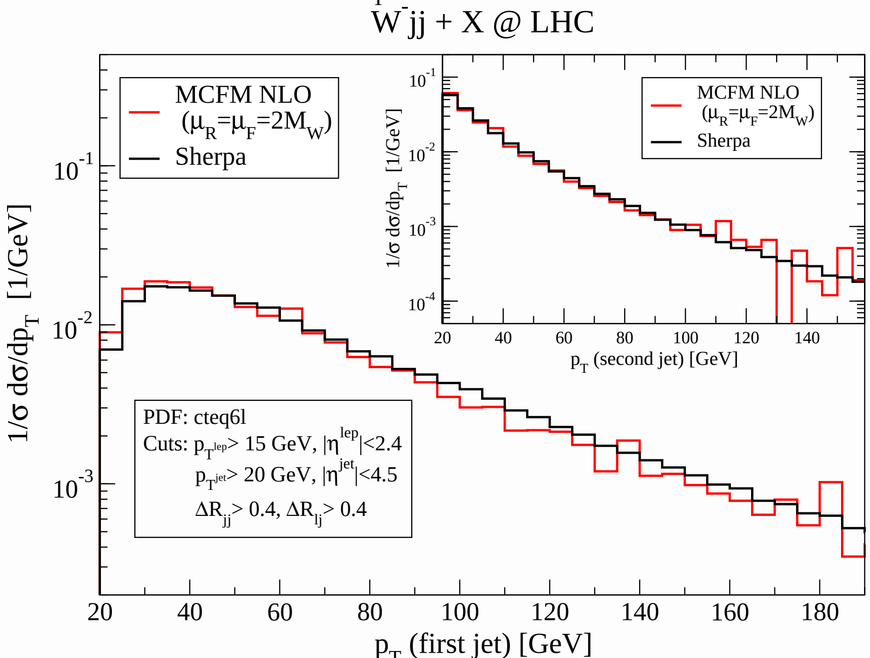


SHERPA vs. NLO: Incl. W^-+2jet prod. @ $\sqrt{s} = 14$ TeV





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

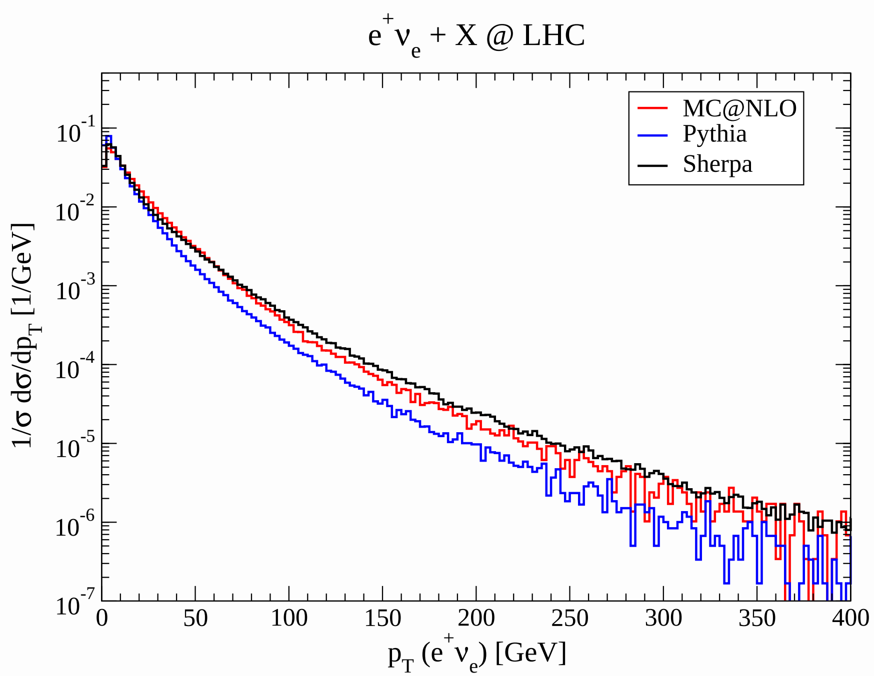


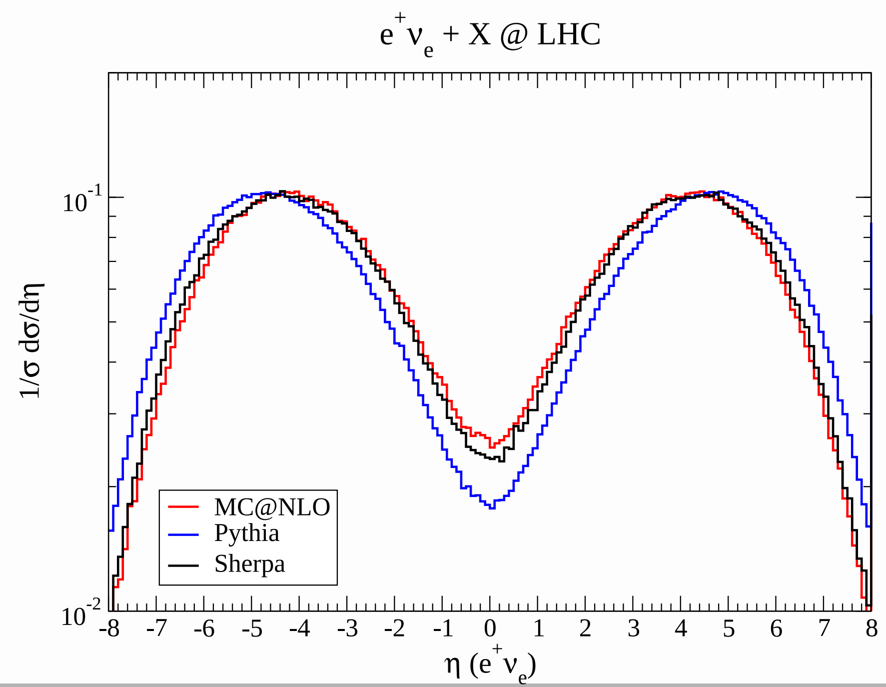
SHERPA vs. PYTHIA and MC@NLO

Comparison at the hadron level with underlying events switched off:

- PYTHIA including matrix element correction for the first emission used `MSTP(68)=2` $\Rightarrow$ shower start scale is $s = (14\,\mathrm{TeV})^2$
- MC@NLO in its default setup for $pp \to V + X$ at NLO ($V = W$ or Z/γ^*)
- SHERPA using $Q_{\mathrm{cut}} = 20$ GeV and $n_{\mathrm{max}} = 1$

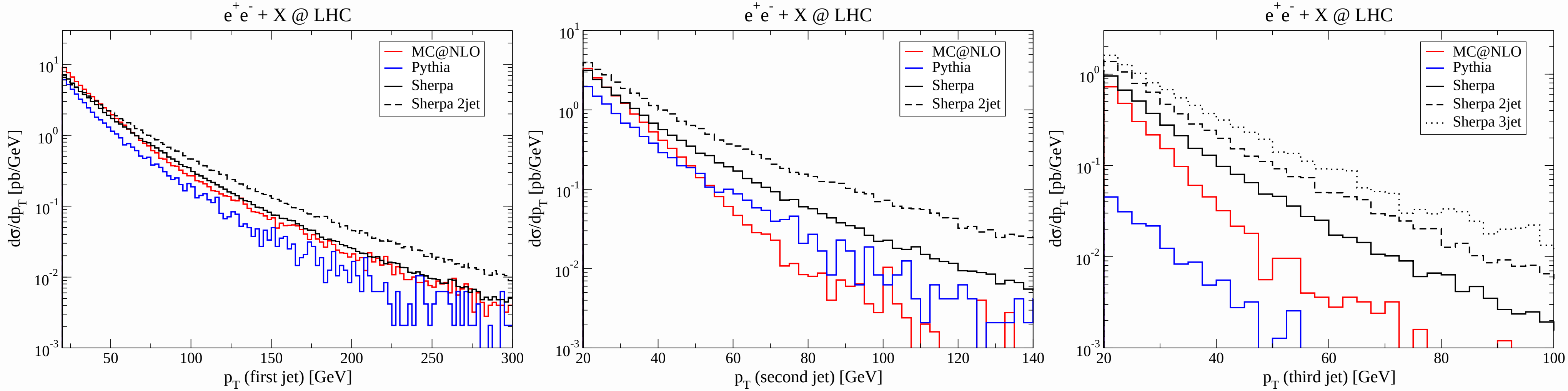
The $p_\perp$ and η distribution of the W^+





SHERPA vs. PYTHIA and MC@NLO

The $p_\perp$ of the three hardest jets in Z/γ^*+jets production



- PYTHIA lacks a sufficient amount of hard QCD radiation
- MC@NLO & SHERPA agree rather good for the shape of very inclusive quantities
- MC@NLO superior in predicting the right NLO rate for $p_{\perp Z}$ and η_Z
- When including higher order ME's SHERPA predicts much larger rates for the production of associated jets than MC@NLO does

Conclusion/Outlook

Conclusion

- The LHC provides a lot more phase space for extra emissions
- Inclusion of higher order ME's seems to be more important than at TEV
- SHERPA is able to reproduce the shapes of corresponding NLO calculations

SHERPA sources

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

  JHEP 0402:056,2004
- W/Z @ Tevatron: F. Krauss, A. Schälicke, S. S. and G. Soff,

  Phys. Rev. D 70 (2004) 114009
- current version SHERPAα-1.0.5 available under

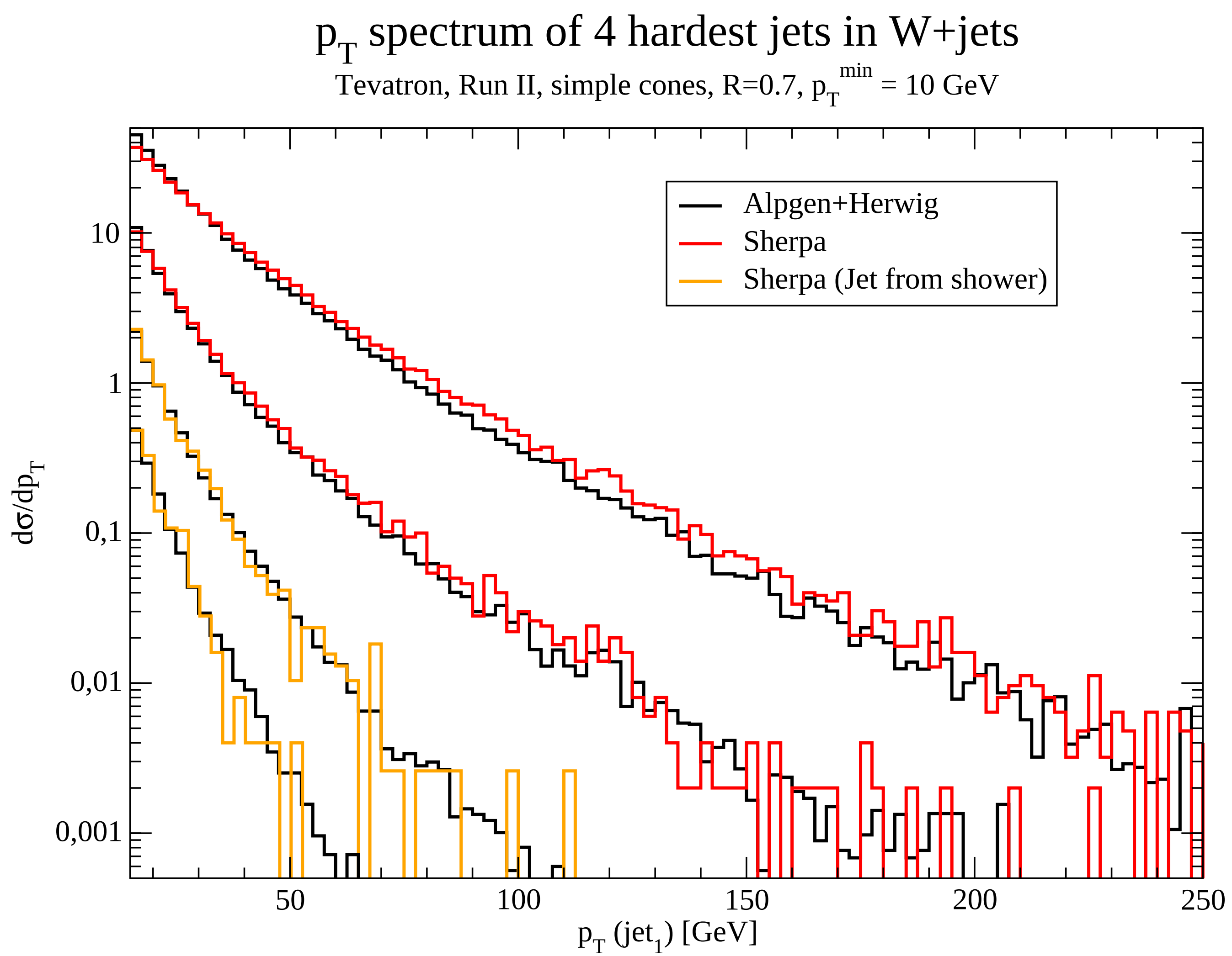
  `http://www.physik.tu-dresden.de/~krauss/hep`

Outlook

- Comparison with MLM and ARIADNE approach for W+jets @ TEV & LHC

SHERPA vs. MLM for W+jets @ Tevatron Run II

PRELIMINARY !!!



SHERPA vs. MLM for W+jets @ Tevatron Run II

PRELIMINARY !!!