ME+PS studies

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Outline

- New generators & tools
- Sherpa in brief
- ME's in Sherpa
- Merging ME's + PS
- Results of Sherpa vs. others + data
- Results of Sherpa vs. MLM
- Conclusion

New event generators

New codes emerging: ThePEG/Herwig++/Pythia7

("Top-Down" approach)

1. ThePEG = event generation framework organisation, event record, necessary tools (vectors etc.).
2. Construction of physics modules in ThePEG
3. `HERWIG++` (S.Gieseke et al., hep-ph/0311208):
   - e^+e^- events: $e^+e^- \longrightarrow q\bar{q}$ + radiation
   - new parton shower
   - cluster fragmentation

New event generators

New codes emerging: ThePEG/Herwig++/Pythia7

("Top-Down" approach)

1. ThePEG = event generation framework organisation, event record, necessary tools (vectors etc.).
2. Construction of physics modules in ThePEG
3. `PYTHIA7` (L.Lonnblad, CPC.134, 365)
   - e^+e^- and pp events: $2 \longrightarrow 2$ + radiation
   - string fragmentation

New event generators

New codes emerging: SHERPA

(T. Gleisberg, S. Höche, F. Krauss, A. Schälicke, S. S. and J. Winter, JHEP 0402:056,2004)

("Bottom-Up" approach)

Tested & interfaced modules:

1. Tree-level matrix elements (`AMEGIC++`) +
2. Parton shower (`APACIC++`) ...
3. ... and merging thereof
4. Interfaces to string fragmentation, etc..

Allows to simulate e^+e^-, $\gamma\gamma$, pp collisions.

SHERPA status

- Initialization of the incoming beams

  $\Rightarrow$ provide access to various PDF sets:
  LHAPDF, mrst99 (C++), cteq6

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements)

  $\Rightarrow$ Interface to our own ME generator AMEGIC++

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements) ✓
- Initial and final state parton shower

  $\Rightarrow$ Interface to our own PS APACIC++

  (R. Kuhn, F. Krauss, R. Kuhn, B. Ivanyi, G. Soff, CPC 134:223-266,2001)

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements) ✓
- Initial and final state parton shower ✓
- Multiple parton interactions (UE)

  $\Rightarrow$ Just started to work on this . . .

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements) ✓
- Initial and final state parton shower ✓
- Multiple parton interactions (UE) next release
- Hadronization

  $\Rightarrow$ Interface to Pythia string fragmentation

  $\Rightarrow$ A modified cluster model in preparation

  (J. Winter et al, hep-ph/0311085) to be included

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements) ✓
- Initial and final state parton shower ✓
- Multiple parton interactions (UE) next release
- Hadronization ✓
- Hadron decays

$\Rightarrow$ Interface to the corresponding Pythia routines

SHERPA status

- Initialization of the incoming beams ✓
- Hard event and decays (via matrix elements) ✓
- Initial and final state parton shower ✓
- Multiple parton interactions (UE) next release
- Hadronization ✓
- Hadron decays ✓

$\Longrightarrow$ **Sherpa is the framework responsible for initialization of the different phases and for steering the event generation**

Matrix elements in SHERPA

ME's are delivered by AMEGIC++

R. Kuhn, F. Krauss, G. Soff, JHEP 0202:044,2002

- Calculates arbitrary processes in SM and MSSM at tree level using Helicity amplitudes
  - MSSM spectra from interface to Isasusy 7.67
  - SLHA *(Skands et al, hep-ph/0311123)* is being implemented
- Includes an ADD model (featuring KK-graviton resonances)
- Mass effects fully taken into account
- Multi-channel MC integration with adaptive optimization
- Completely automatic approach (a generator-generator)

Side note: AMEGIC++ is/will be implemented in Herwig++

Matrix elements in SHERPA

green AMEGIC++ successfully tested for a huge number of processes

- $e^+e^- \to 4/6$ massive or massless jets/fermions
- $\gamma\gamma \to 4f$
- numberless sparticle production and sparticle decay channels

Validation for LHC purposes during (and after) the MC4LHC workshop at CERN summer 2003

- $e^-\bar{\nu}_e$, $e^+\nu_e$, e^-e^+, $\nu_e\bar{\nu}_e$, + up to 4jets
- $e^-\bar{\nu}_e b\bar{b}$, $e^-e^+b\bar{b}$, + up to 2jets
- γ, $\gamma\gamma$, + up to 3jets
- $t\bar{t}$, $b\bar{b}$, + up to 2jets
- 2-, 3-, 4-jet production

Matrix elements in SHERPA

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				
$e^- \bar{\nu}_e + b\bar{b}$	0	1	2	3	4
Alpgen	9.34(4)	9.85(6)	6.82(6)	4.18(7)	2.39(5)
CompHEP	9.415(5)	9.91(2)			
MadEvent	9.32(3)	9.74(1)	6.80(2)		
Amegic++/Sherpa	9.37(1)	9.86(2)	6.87(5)		

Matrix elements in SHERPA

AMEGIC++ proved to work for up to six particle final states,
also in hadronic collisions

$\Longrightarrow$ Acceleration of the ME and phase space evaluation is ongoing
(a tedious and time-consuming job)

$\Longrightarrow$ One or two more jet(s) per process listed above is reasonable

$\Longrightarrow$ for even higher jet multiplicities it might be better to rely on PS

$\Longrightarrow$ SHERPA includes a state-of-the-art C++ ME generator,

one of the key ingredients of a modern event generator

Combining ME and PS

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
- Universality of fragmentation (energy independent)

Solution:

- Divide multi-jet phase space into two regimes
  - Jet production by ME (if available)
  - Jet evolution down to fragmentation scale by the PS
- Reweight ME's for exclusive samples at a resolution scale
- Veto on PS configurations included in higher order ME

Combining ME and PS

The method has been implemented in Sherpa in full generality

- Proofed to be successful in e^+e^- collisions

  (comparable in event shapes etc., but better description for four-jet correlations etc.)
- Study of systematics of method is still ongoing (first results in a minute)
  - Vary choice of scales (functional form)
  - Different jet measures
  - Different treatment of highest multiplicity ME
- Extensions to study systematic errors in event generation (e.g. global scale factors, etc.)
  after all, it's only LO !

W/Z+jets at the Tevatron

F.Krauss, A.Schaelicke, S.Schumann, G.Soff, hep-ph/0409106

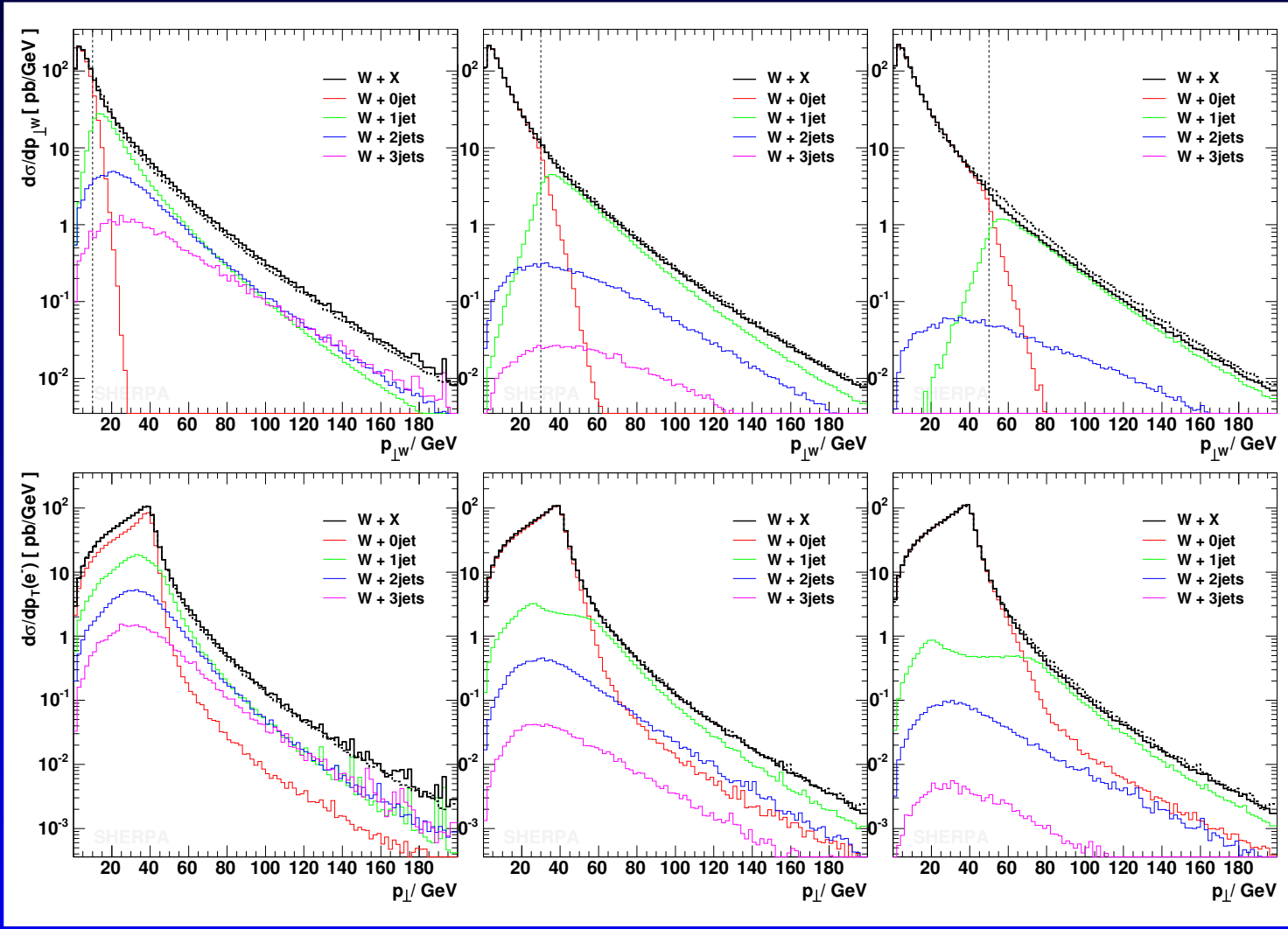
- W/Z+jets at Tevatron, Run II
- Jets according to Run II $k_\perp$-clustering algorithm:
  $p_\perp^{\rm jet} > 15$ GeV, $\quad |\eta^{\rm jet}| < 2, \quad D = 0.7$
- Further cuts:

  $p_\perp^{\rm lepton} > 20$ GeV, $\quad |\eta^{\rm lepton}| < 1,$

  $m^{ll} > 15$ GeV, for W, also $p_\perp^{\rm miss} > 20$ GeV.

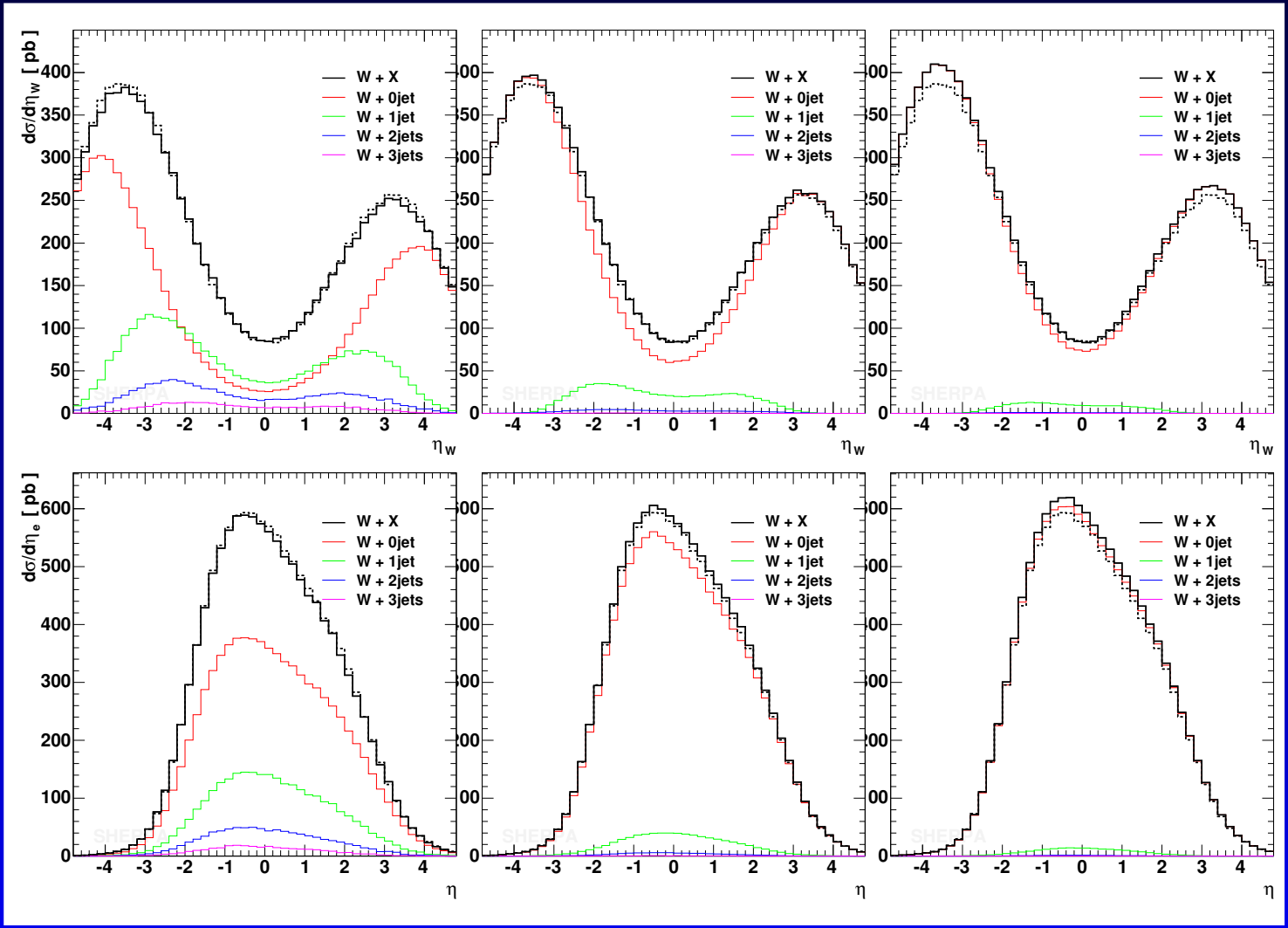
W/Z+jets at the Tevatron

Effect of varying jet separation: $p_\perp$ of W, e



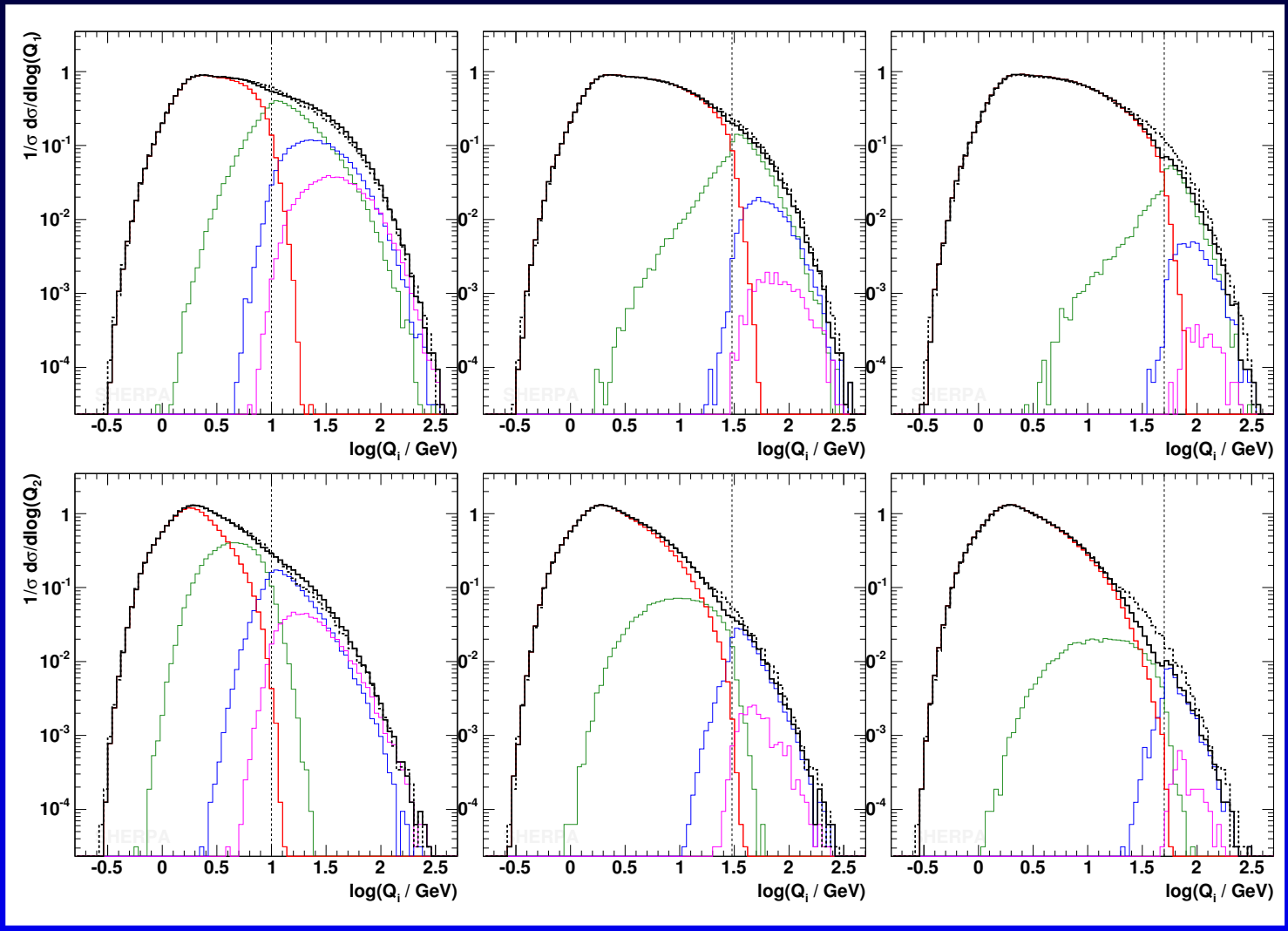
W/Z+jets at the Tevatron

Effect of varying jet separation: η of W, e



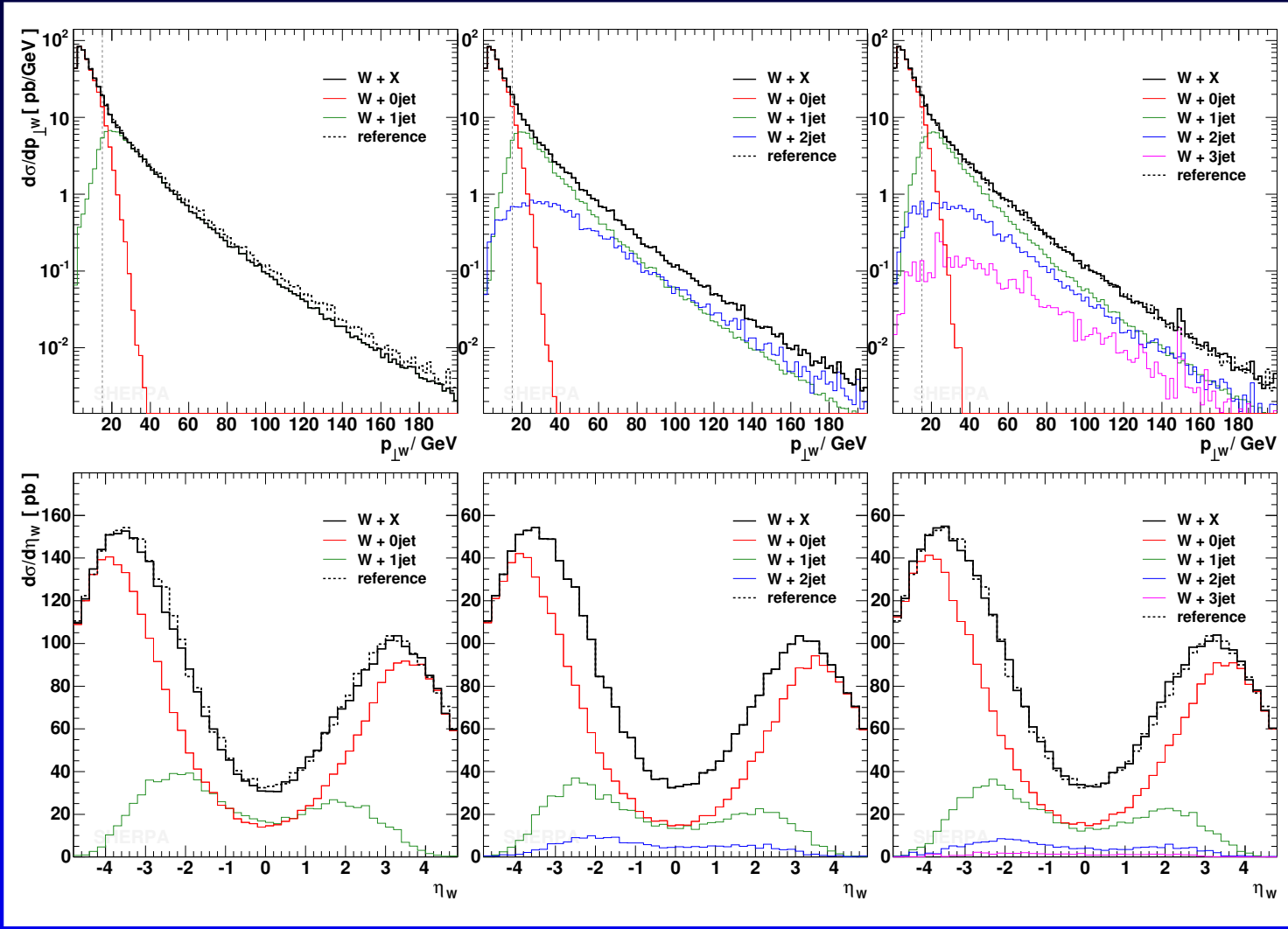
W/Z+jets at the Tevatron

Effect of varying jet separation : jetrates



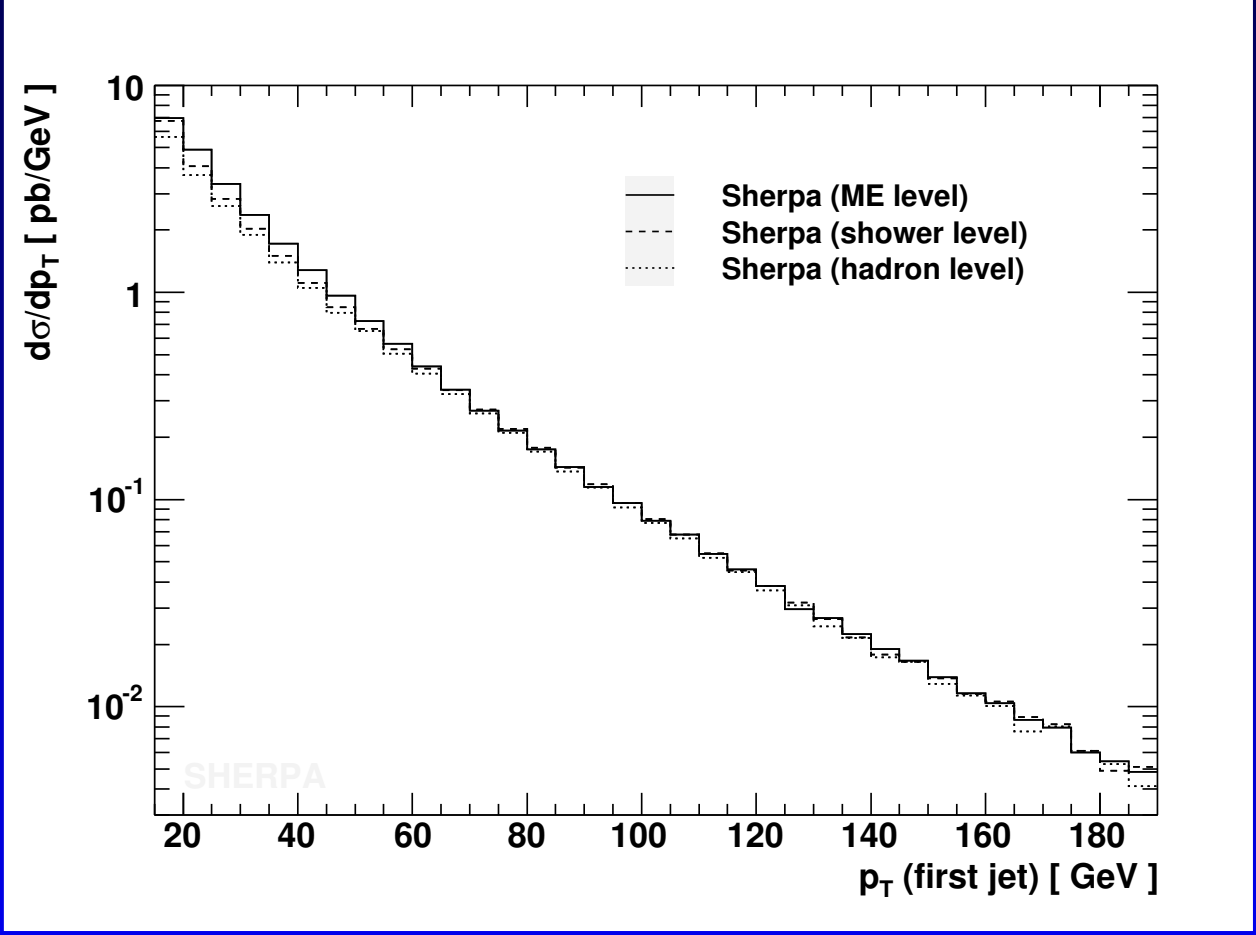
W/Z+jets at the Tevatron

Effect of varying maximal number of jets : $p_\perp$, η of W, e



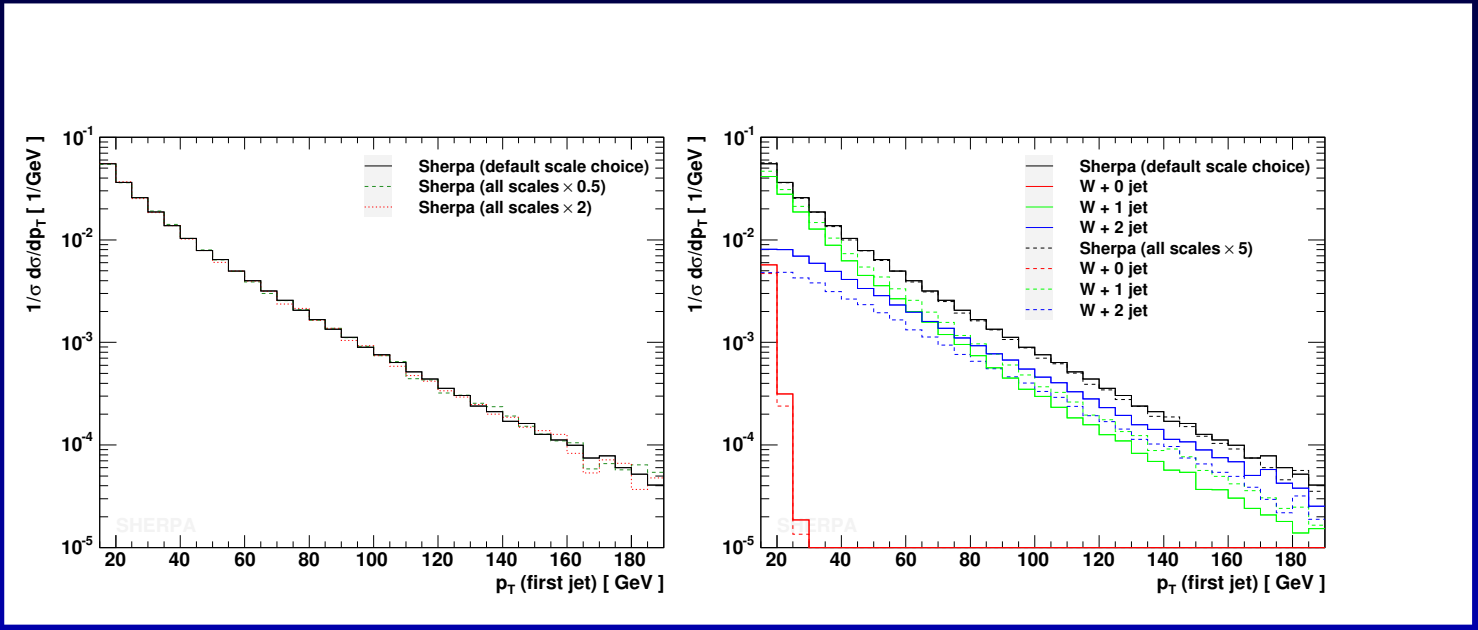
W/Z+jets at the Tevatron

(Reweighted) ME vs. PS vs. Hadron level



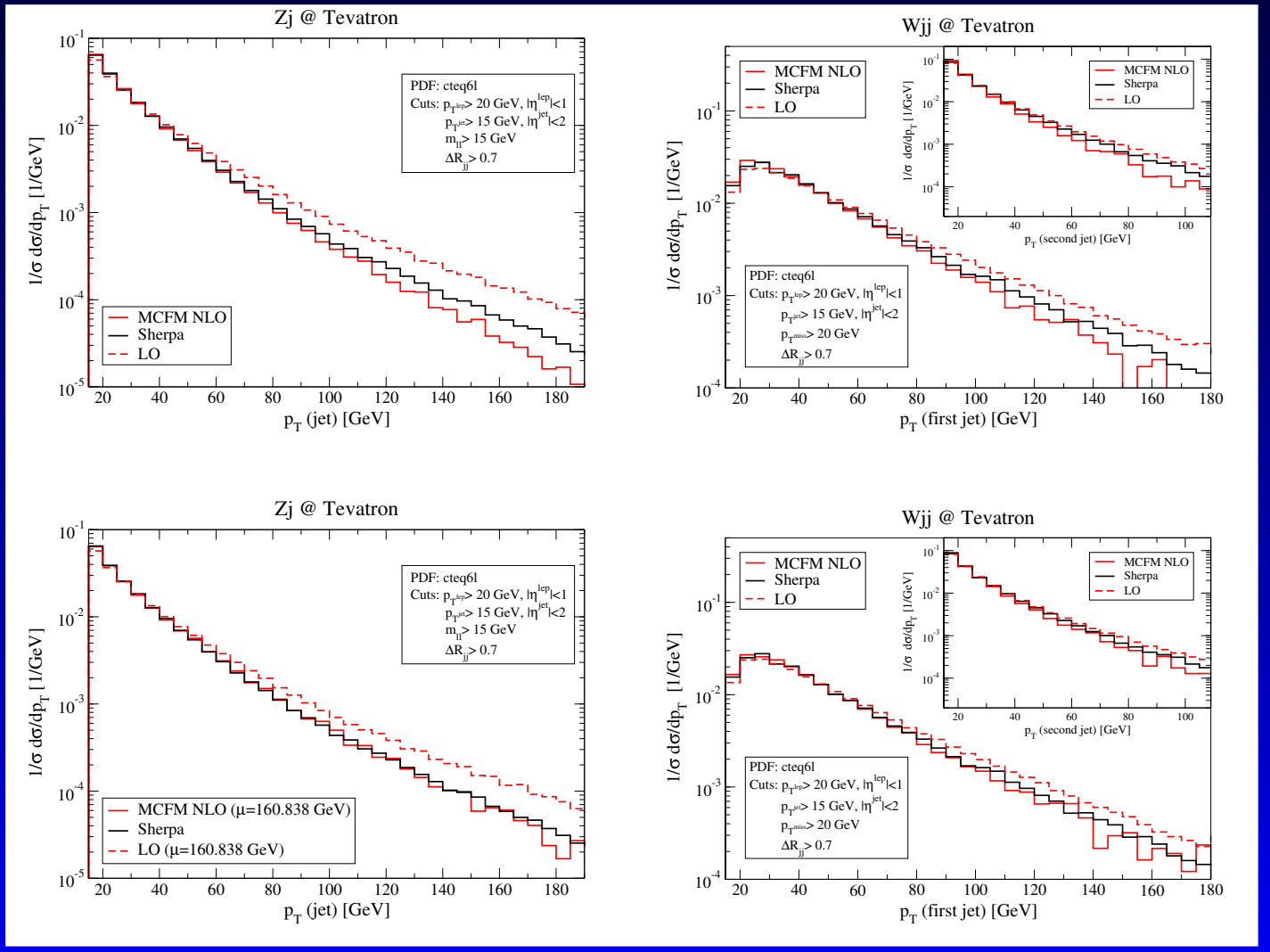
W/Z+jets at the Tevatron

Effect of varying renormalization & factorization scale



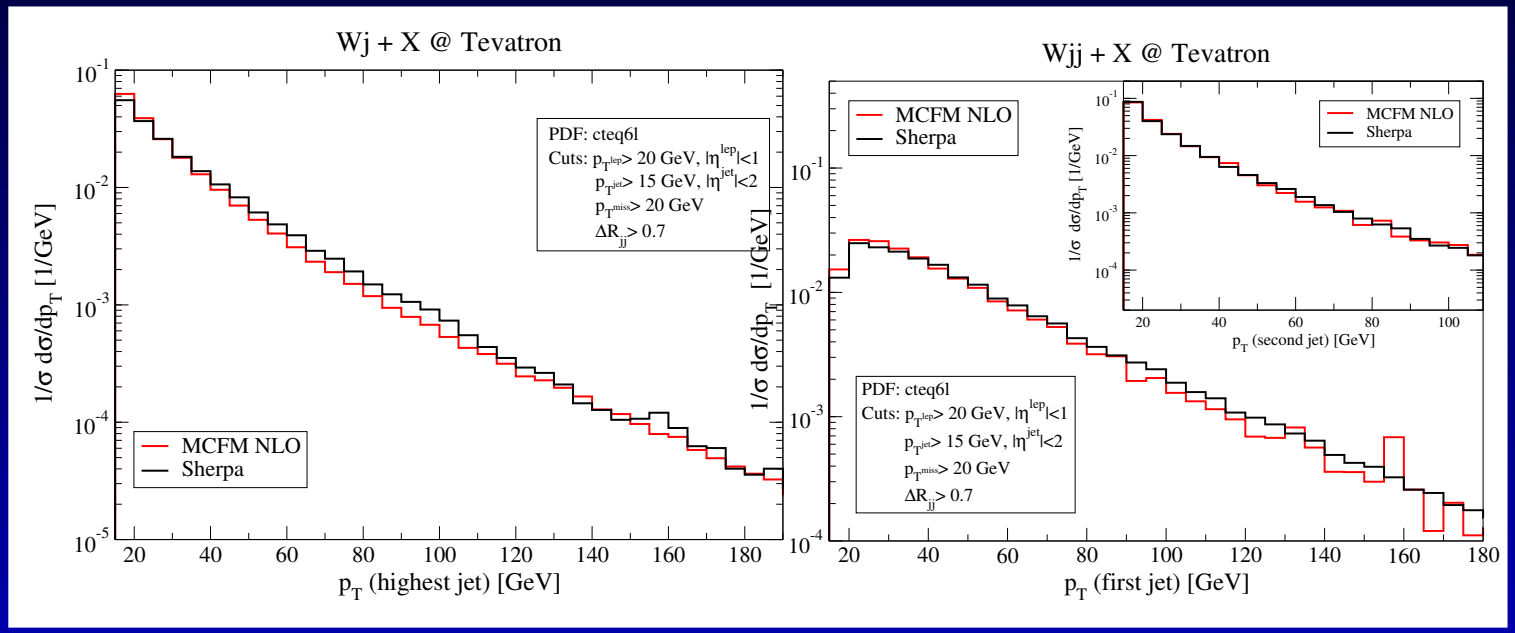
W/Z+jets at the Tevatron

Comparison with NLO calculation (MCFM, exclusive)



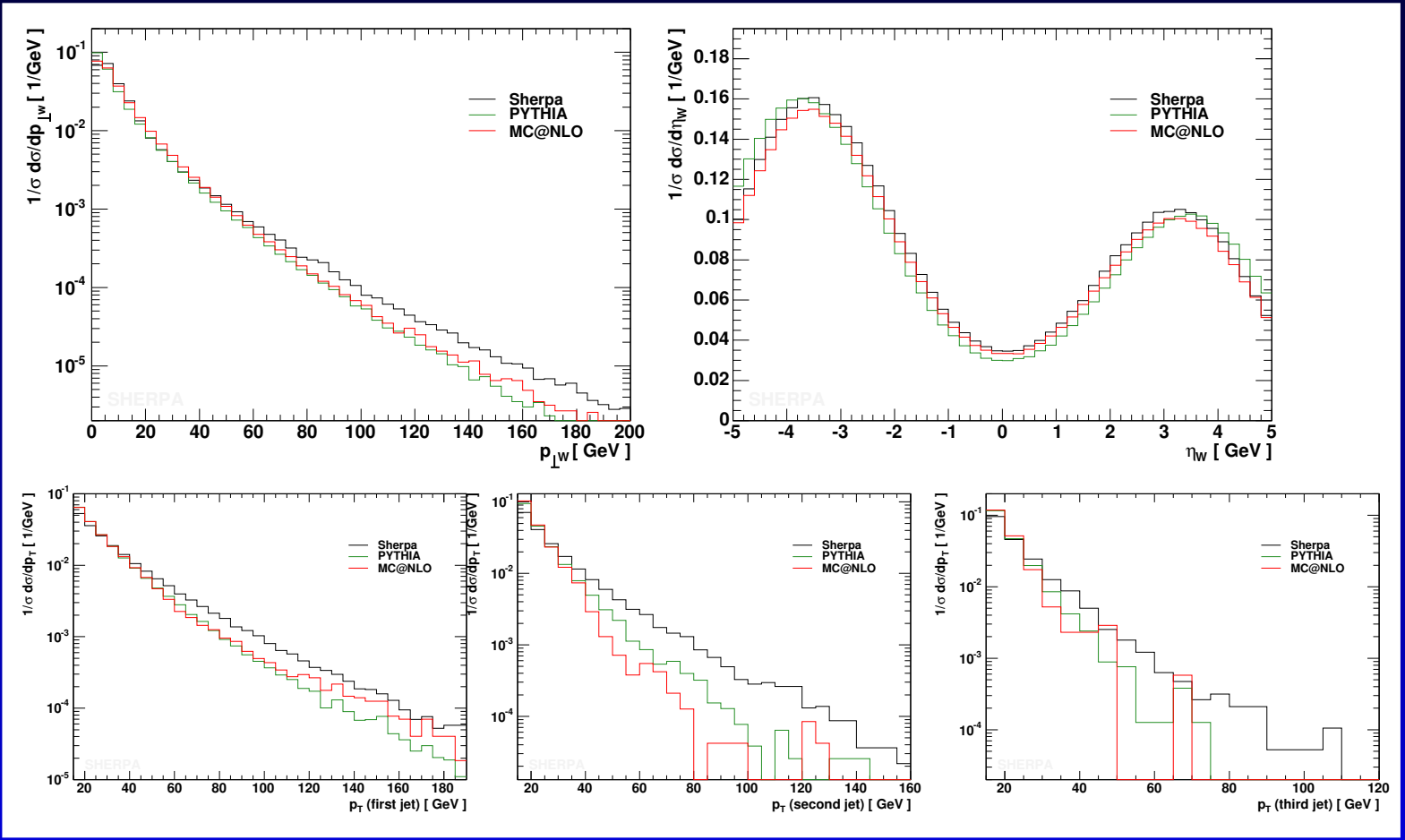
W/Z+jets at the Tevatron

Comparison with NLO calculation (MCFM, inclusive)



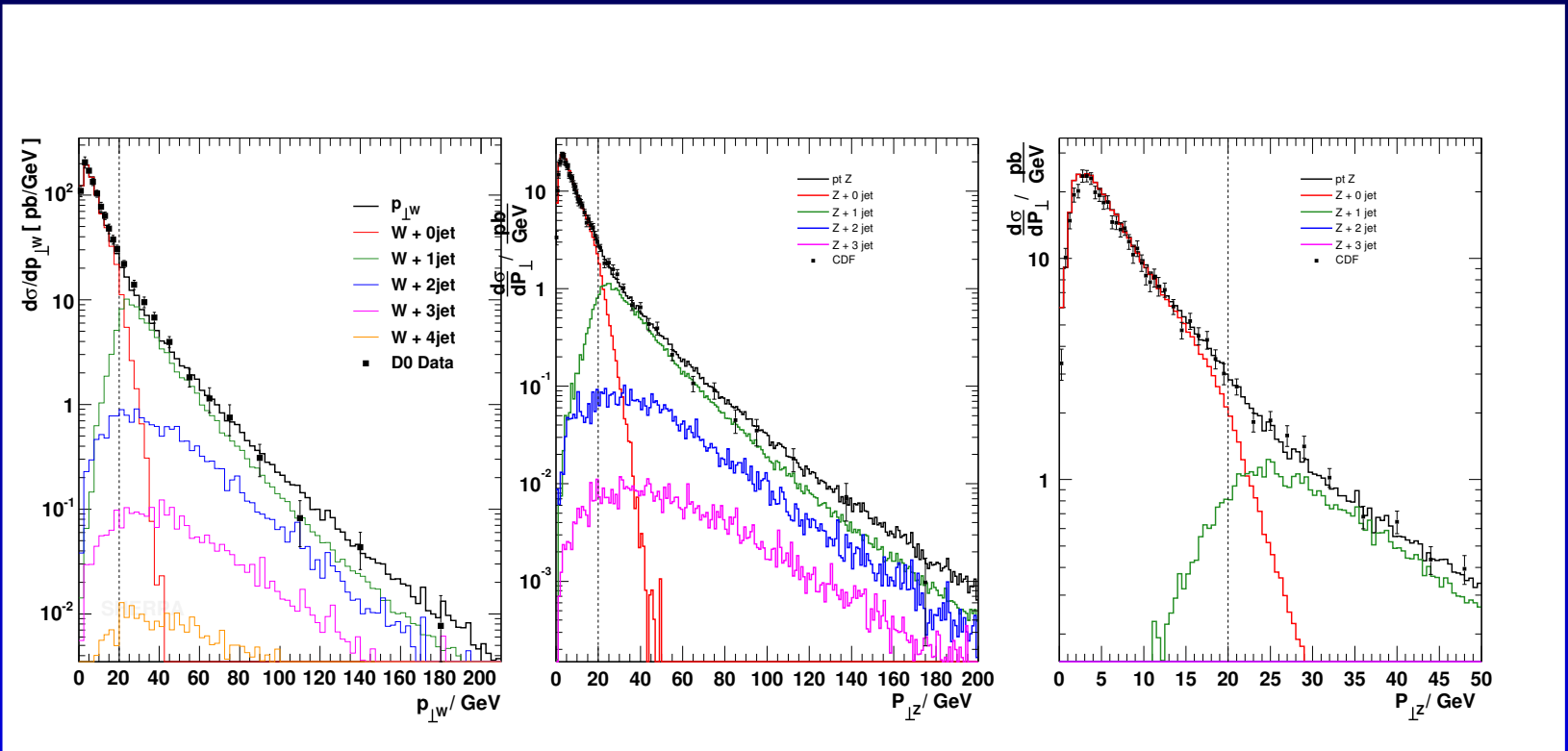
W/Z+jets at the Tevatron

Comparison with Pythia & MC@NLO



W/Z+jets at the Tevatron

Comparison with data
(Run I, W from D0, Z from CDF)



W/Z+jets at the Tevatron

- Reproduces NLO shapes for exclusive and inclusive $W/Z + X$ production
- Reproduces nicely the data for the shapes
- However, the rates are not NLO !
- But: Maybe process dependent $\rightarrow$ has to be studied for many processes:
  - $PP \rightarrow Z/W + b\bar{b} + X$
  - $PP \rightarrow h + X$
  - $PP \rightarrow t\bar{t} + X$
- also missing so far: Check of correlations (ΔR, $\Delta\eta$, ...)

W+jets at the Tevatron, again

Comparison with MLM merging,

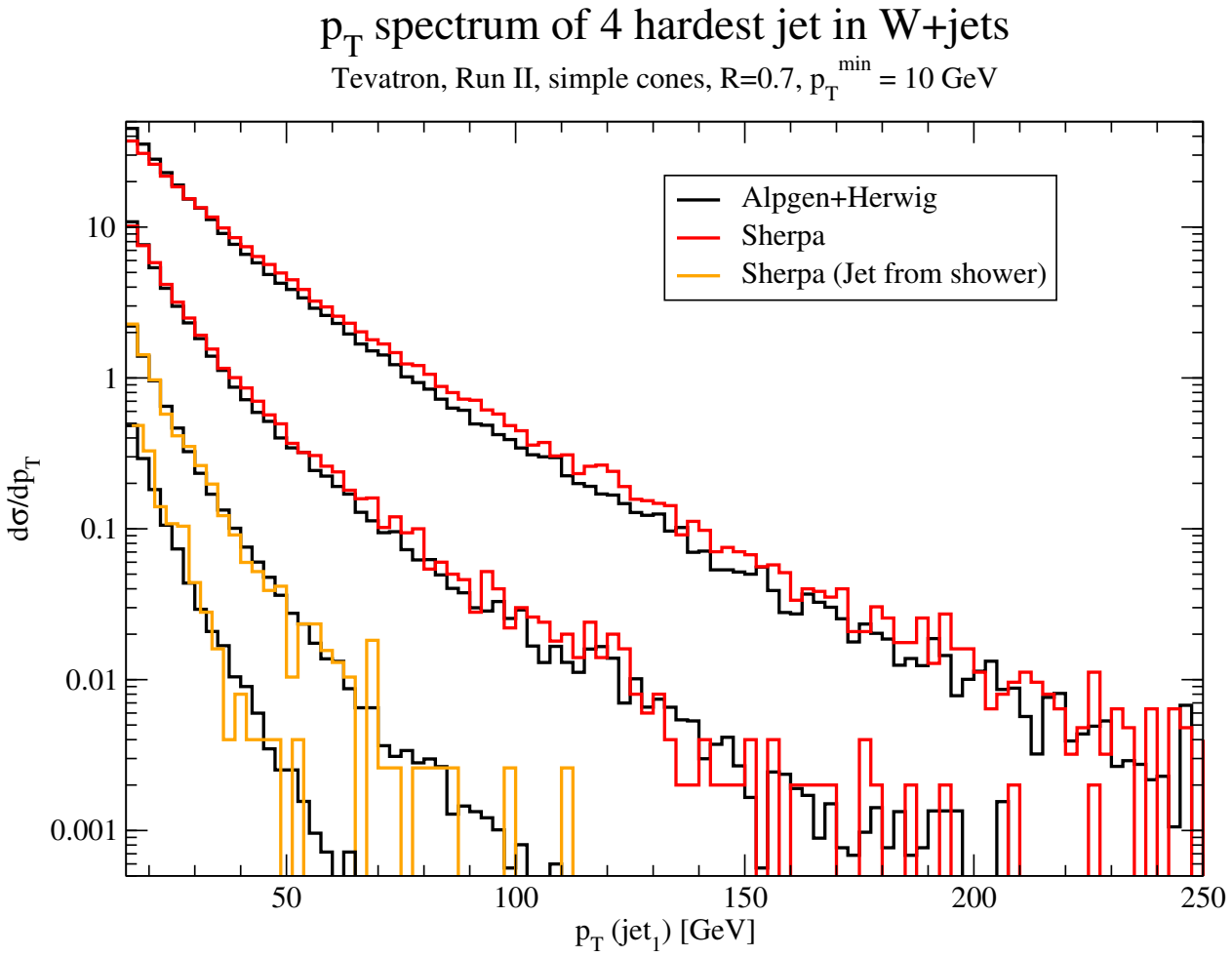
Work with M.Mangano, A.Schaelicke, S.Schumann, G.Soff.

- W+jets at Tevatron, Run II.
- MLM prescription through Alpgen+Herwig.
- Jets according to "simplistic cone" :

  varying $p_\perp^{\rm jet}$, $\quad |\eta^{\rm jet}| < 2, \quad R = 0.7$
- No other cuts.

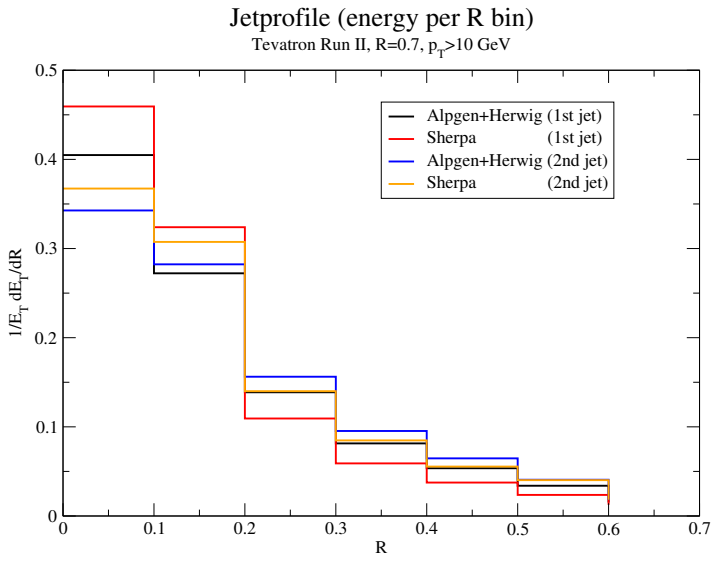
W+jets at the Tevatron, again

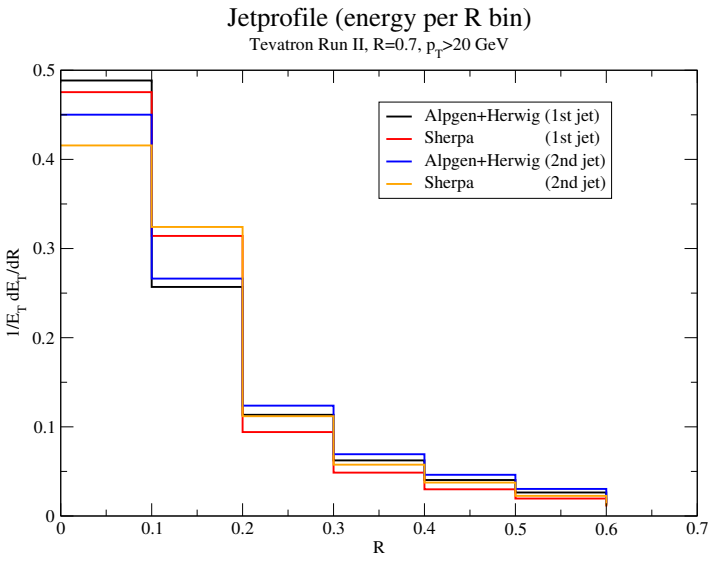
Jet $p_\perp$ of first four jets



W+jets at the Tevatron, again

Jetshapes of first 2 jets at varying $E_\perp$





Conclusion/Outlook

Conclusion

- Sherpa well under way.
- ME's and PS work,
  construction of further modules started
- Implementation of merging prescription
  an unique & powerful tool
- Amazing agreement with Alpgen+Herwig,
  spectra harder than other MCs.
- Experimenters staerting to look into it
  (Rachid Mazini, CDF + more???)

Conclusion/Outlook

Outlook

- New $\alpha-$version(s) soon
- (LEP-) Tuned version in 2004

  (the first non $\alpha-$version)
- Complete MC in 2005

  including cluster model, an underlying event model, ...