# MC project SHERPA, status report

[MCnet meeting, open session]

Jan Winter [a]

Institute for Theoretical Physics, TU Dresden

- **New release version** → **SHERPA 1.0.9**
- **New developments**
- **Construction sites**

[a] SHERPA authors: T. Gleisberg, S. Höche, F. Krauss, F. Siegert, S. Schumann, J. W.

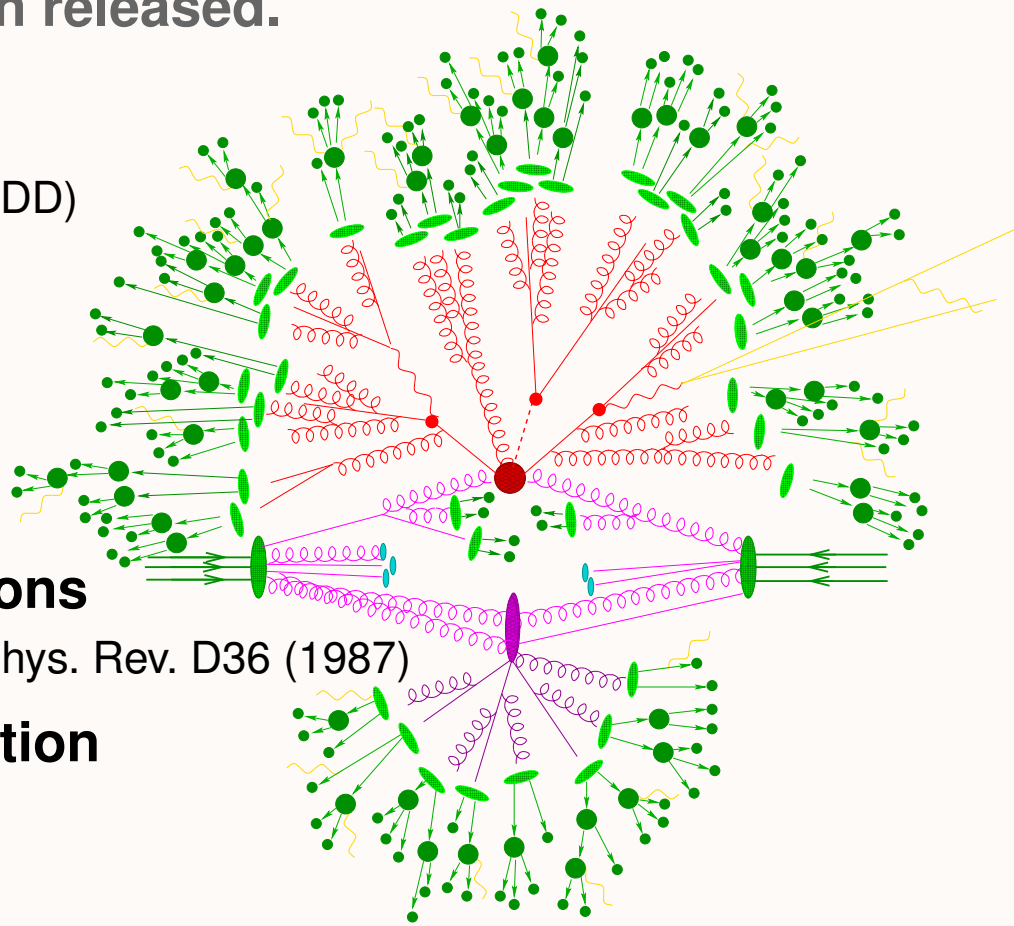
**http://www.sherpa-mc.de/**

Durham University

# Monte Carlo event generator SHERPA

T. Gleisberg, S. Höche, F. Krauss, A. Schälicke, S. Schumann and J. W., JHEP **0402** 056 (2004).

➡ **SHERPA version 1.0.9 (NEW!) has been released.**



- **ME generator AMEGIC++**
  (at tree level, provides HP and HD in SM, MSSM, ADD)
- **IS and FS shower module APACIC++**
  (virtuality ordered, PYTHIA-like showers)
- **Combination of ME and PS according to CKKW**
- **Simulation of multiple parton interactions**
  main ideas based on T. Sjöstrand and M. van Zijl, Phys. Rev. D36 (1987)
- **Interface to PYTHIA's string hadronization**
- **Interface to PYTHIA's hadron decays**

➡ **Sherpa is the event generation framework:**

- initialization of the different phases - interplay of the various stages -
- steering the event generation -

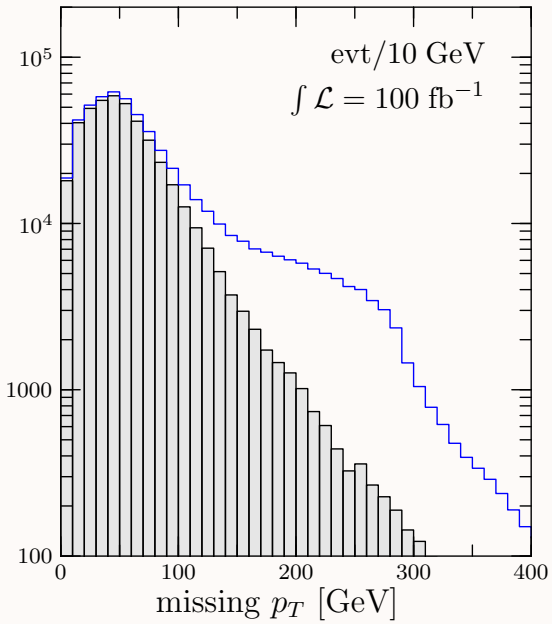
# AMEGIC++

- **Key feature: SHERPA has its own, built-in tree-level ME generator.**

  F. Krauss, R. Kuhn, G. Soff, JHEP **0202** (2002) 044

- **Implementation and validation of the full MSSM Lagrangian.**
  - comparison to SMadGraph and O'Mega/Whizard
  - several hundred $2 \to 2$ processes, off-shell effects
  - K. Hagiwara et al., Phys. Rev. D **73** (2006) 055005
  - Our new-physics tool is AMEGIC++.

$$gg \to b\bar{b}\tilde{\chi}_1^0\tilde{\chi}_1^0 \quad \text{vs.} \quad pp \to b\bar{b}\nu\bar{\nu} \quad @\ \text{LHC}$$




- **Feynman rules: new interaction types provided.**
  - rules containing antisymmetric tensor $\epsilon^{\mu\nu\rho\sigma}$
  - e.g. anomalous triple gauge couplings
    Hagiwara et al., Nucl. Phys. B**282** (1987) 253-307:
    most general eff. Lagrangian has CP-violating terms $\propto \epsilon^{\mu\nu\rho\sigma}$
  - Studies under way ...

# AMEGIC++

- **Key feature: SHERPA has its own, built-in tree-level ME generator.**

  F. Krauss, R. Kuhn, G. Soff, JHEP **0202** (2002) 044

- **Exploitation of MHV techniques for ME generation.**
  - derived from twistor space: simple amplitude expressions in YM theory

    E. Witten, Commun. Math. Phys. 252:189-258,2004

    F. Cachazo, P. Svrcek, E. Witten, JHEP **0409** (2004) 006

    usually referred to as CSW recursion relations
  - helps to push up limits for pure QCD processes
    - feasible $pp \to 5j$
    - in reach $pp \to 6j$
    - example: LHC, $Q_{\rm cut} = 20$ GeV, $pp \to 4j$, full phase-space optimization: MHV enabled, 7600s, compared to default, 35000s
  - less gain for processes involving a weak or Higgs boson
  - bottleneck: memory consumption related to Feynman amplitude book-keeping required by CKKW backwards clustering

# CKKW – key feature of SHERPA

- **Method has been implemented within SHERPA in full generality.**

  S. Catani, F. Krauss, R. Kuhn and B. Webber, JHEP **0111** (2001) 063

  F. Krauss, JHEP **0208** (2002) 015

- **Process-independent implementation.**

**!** **Validation**

- $W/Z$**+jets @ Tevatron/LHC** →

  F. Krauss, A. Schälicke, S. Schumann,

  Phys. Rev. D **70** (2004) 114009, D **72** (2005) 054017

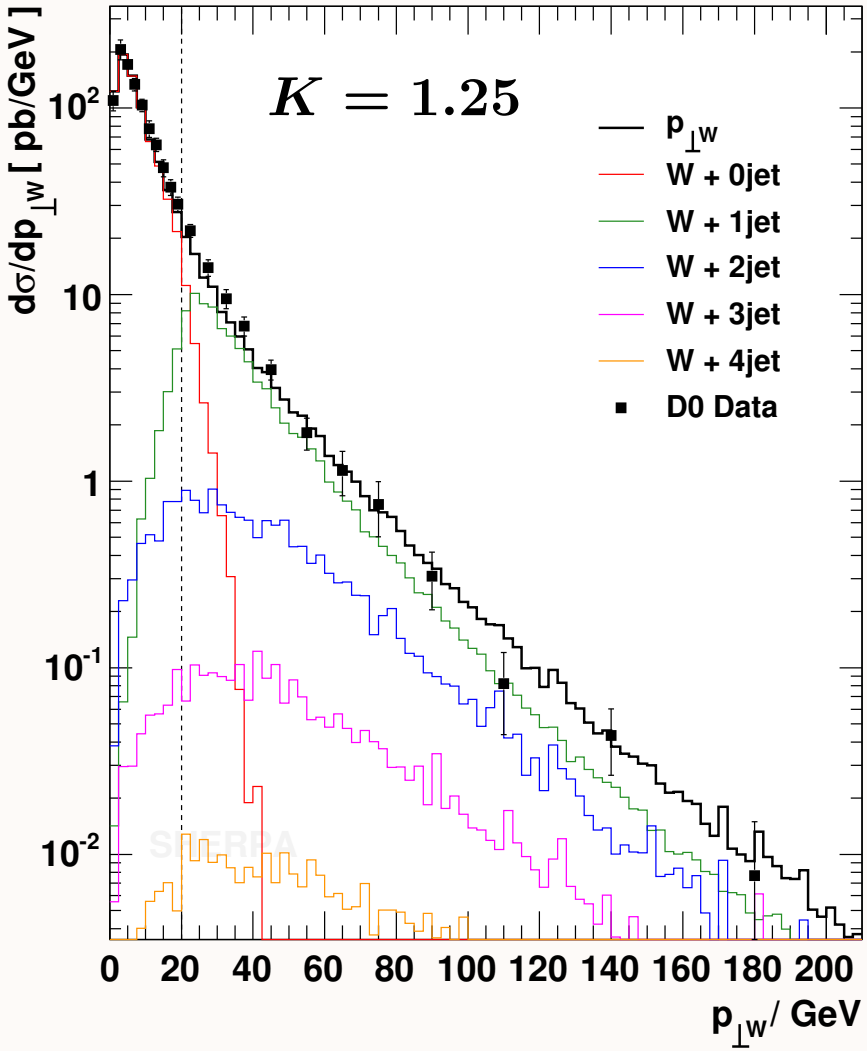
- $WW$ **production @ Tevatron**

  T. Gleisberg et al., Phys. Rev. D **72** (2005) 034028

- **ongoing: detailed comparison to ARIADNE & MLM merging**

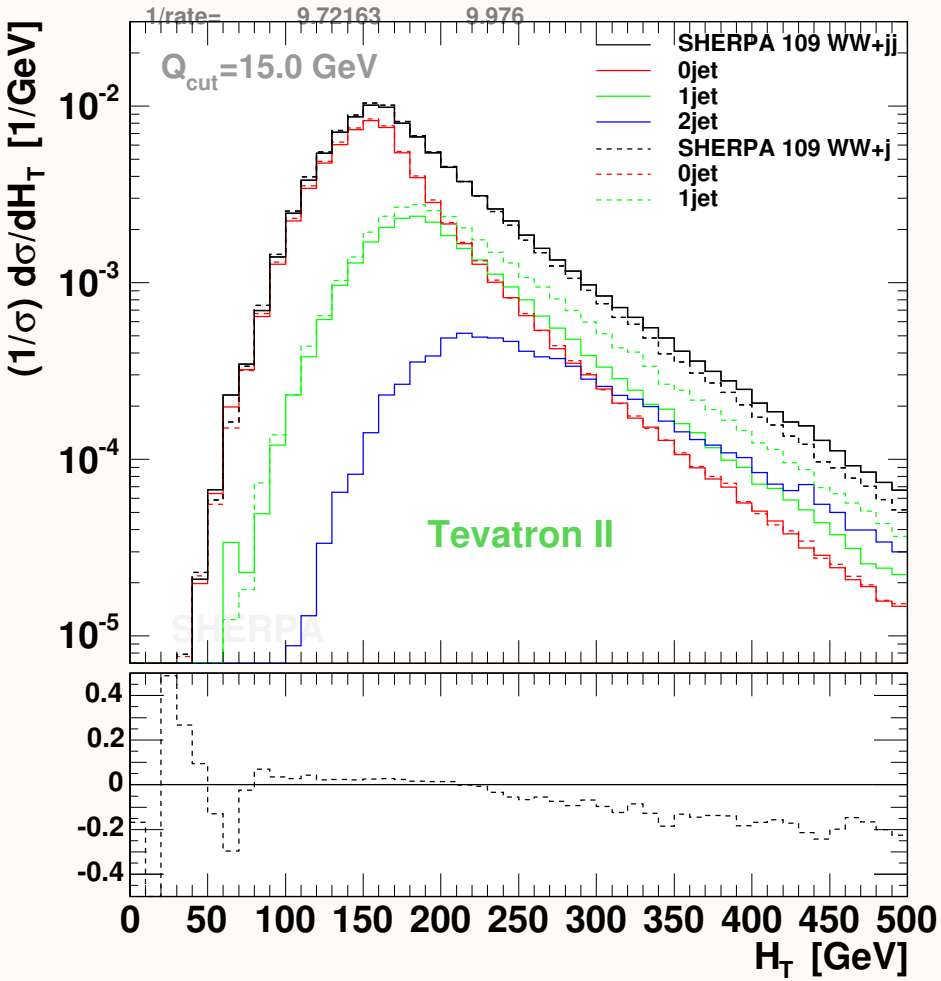
  1st results in "HERA and the LHC" proceedings

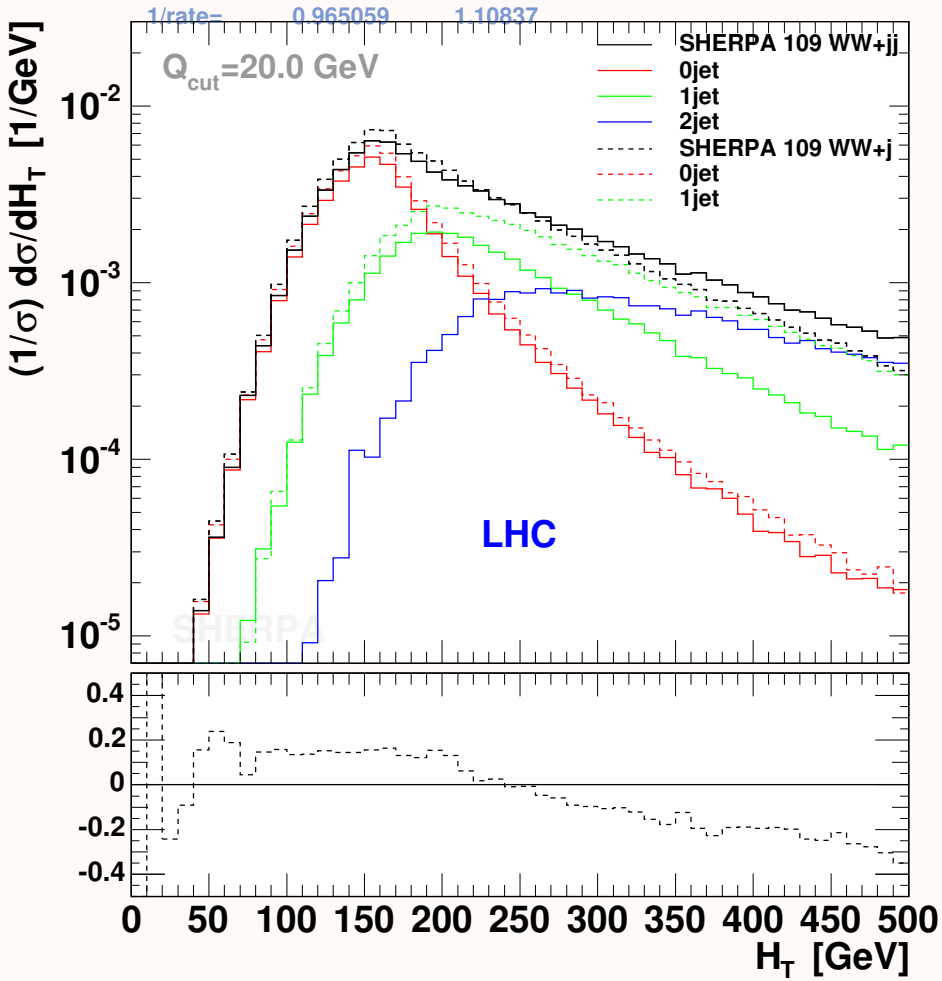
- **ongoing: pure jets,** $Zb\bar{b} + X$**, VBF, tops prod & dec,** $gg \to H + X$



# SHERPA 109 example ... WW+X production

*Scalar sum of lepton and jet transverse momenta.*



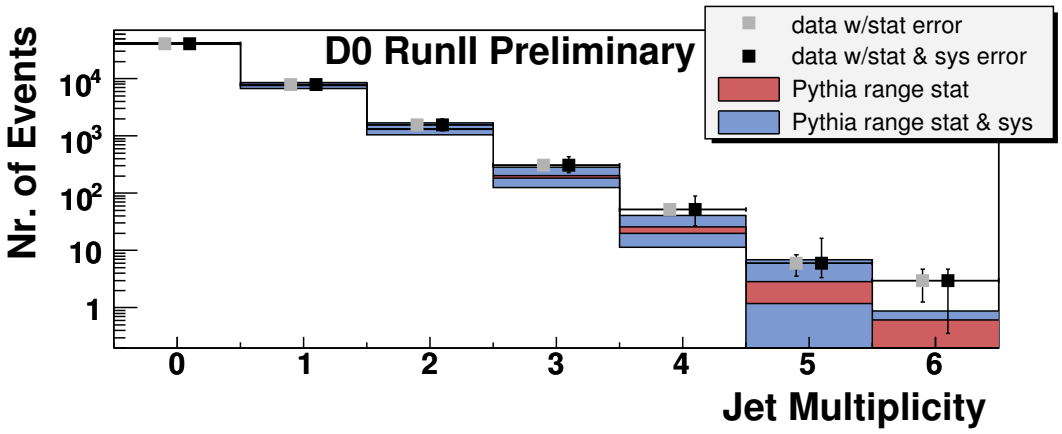



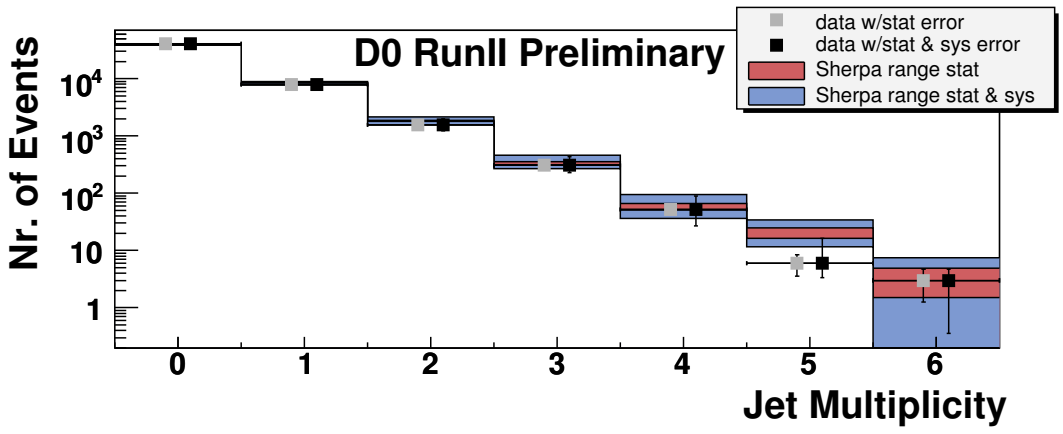

- At the LHC more phase space available for (QCD) radiation.
- $WW + jj$ *vs.* $WW + j$. Slightly different jet $p_T$ for Tevatron and LHC.

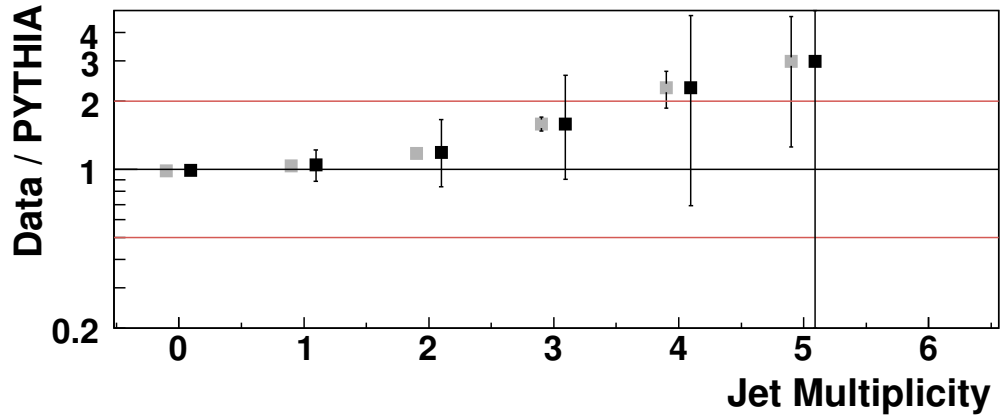
# Preliminary DØ results in Z+jet production

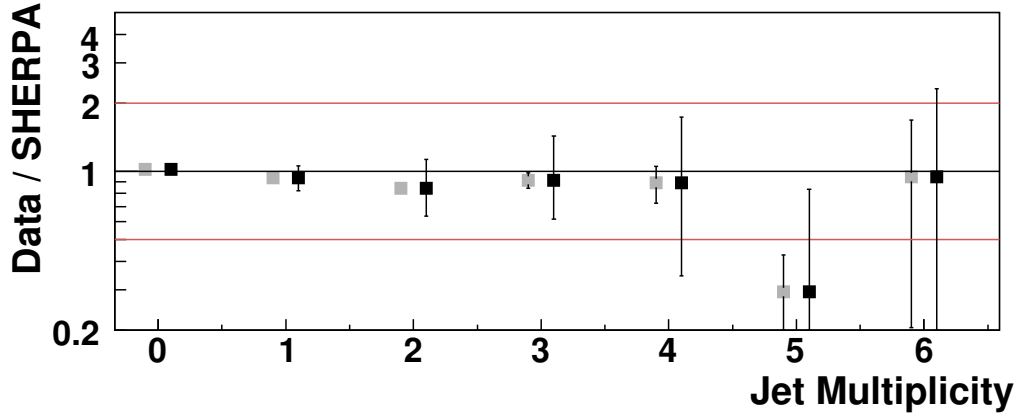
H. Nilsen, DØ collaboration, DØ note 5066-CONF

➔ Jet multiplicity, data *vs.* PYTHIA (left) and SHERPA (right).




- MC predictions are normalized to total number of events observed in data.
- large systematic uncertainties arise from low $p_T$ jets $\Rightarrow$ both predictions are in agreement with data.

# CKKW in top pair production & decay

## Extending the CKKW implementation: production & decay of heavy particles

- first key scenario to accomplish: $t\bar{t}$ production and their subsequent decays
- use narrow width approximation ➡ factorize production and decay
  make use of decay-chain-treatment possibility provided within AMEGIC++
- provide production and decay showers based on massive splitting functions
  e.g. $e^+e^- \to t\bar{t}$ FS shower for tops
  e.g. $t \to W^+b$ IS shower for top, FS shower for bottom
- reweighting and vetoing respecting the factorization
- merge MEs with extra jets in production and decay
- idea, e.g.: $p\bar{p} \to t\,[\to W^+bg\{1\}]\;\bar{t}\,[\to W^-\bar{b}g\{1\}]\;g\{1\}$ ⇒ "CKKW 1-1-1"

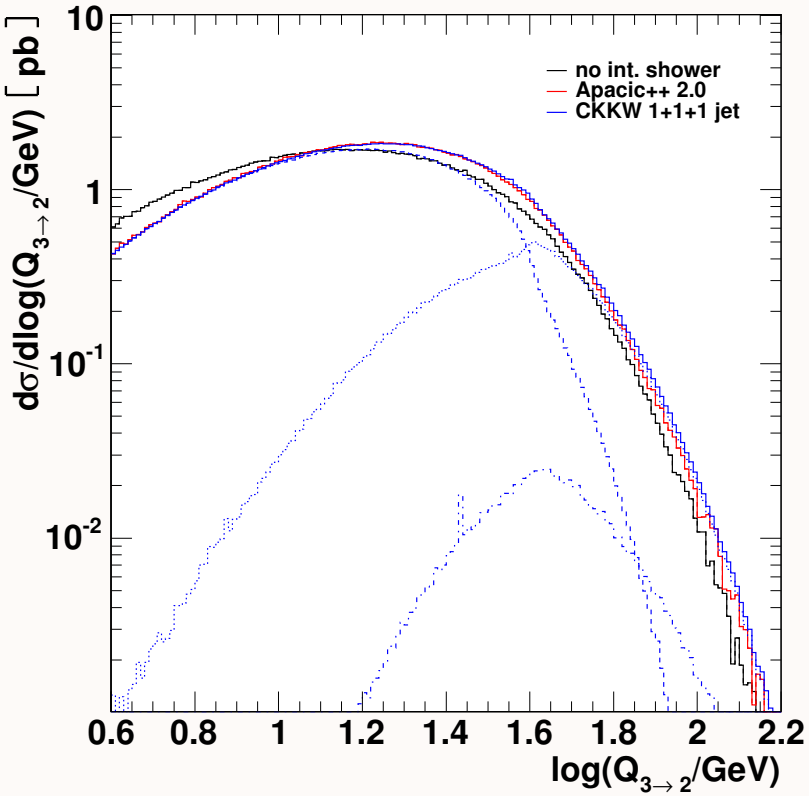
$$
\begin{aligned}
&p\bar{p} \to t\,[\to W^+b]\;\bar{t}\,[\to W^-\bar{b}]\\
&p\bar{p} \to t\,[\to W^+b]\;\bar{t}\,[\to W^-\bar{b}]\;g\\
&p\bar{p} \to t\,[\to W^+b]\;\bar{t}\,[\to W^-\bar{b}\;g]\\
&p\bar{p} \to t\,[\to W^+b]\;\bar{t}\,[\to W^-\bar{b}\;g]\;g\\
&p\bar{p} \to t\,[\to W^+b\;g]\;\bar{t}\,[\to W^-\bar{b}\;g]\;g\\
&\ldots
\end{aligned}
$$

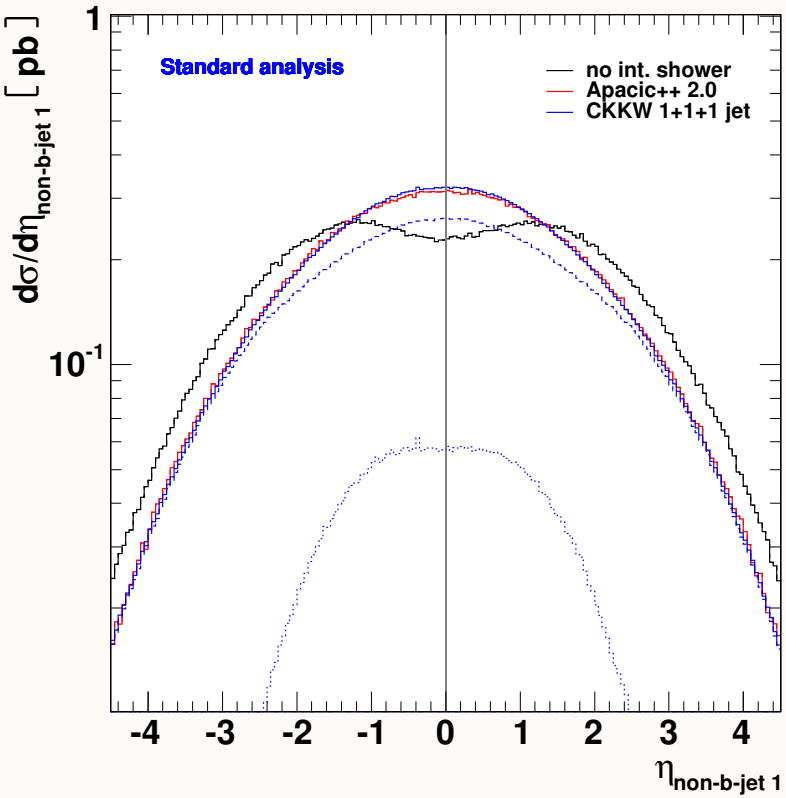
# CKKW in top pair production & decay

## ➡ Some preliminary first results ...

Top pair production + decay at Tevatron Run II

*CKKW 1-1-1 compared to shower with and without radiation from the tops*



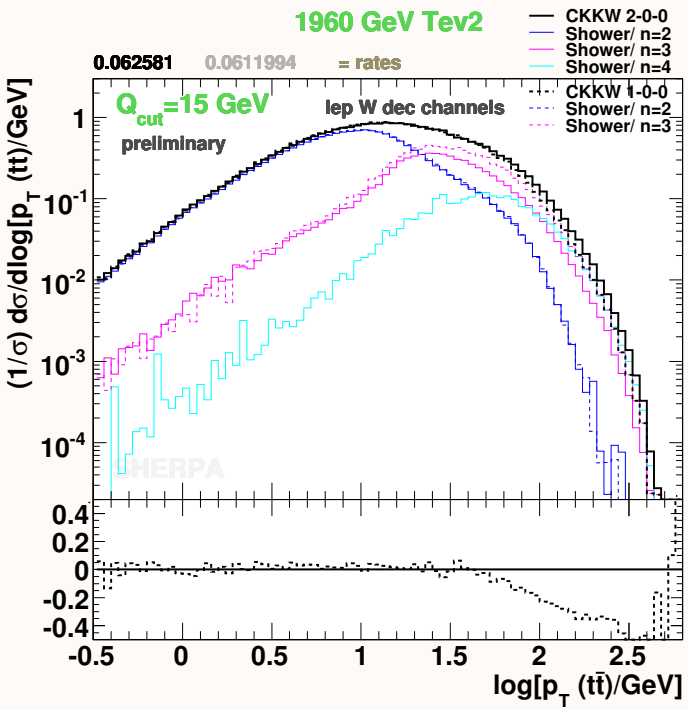



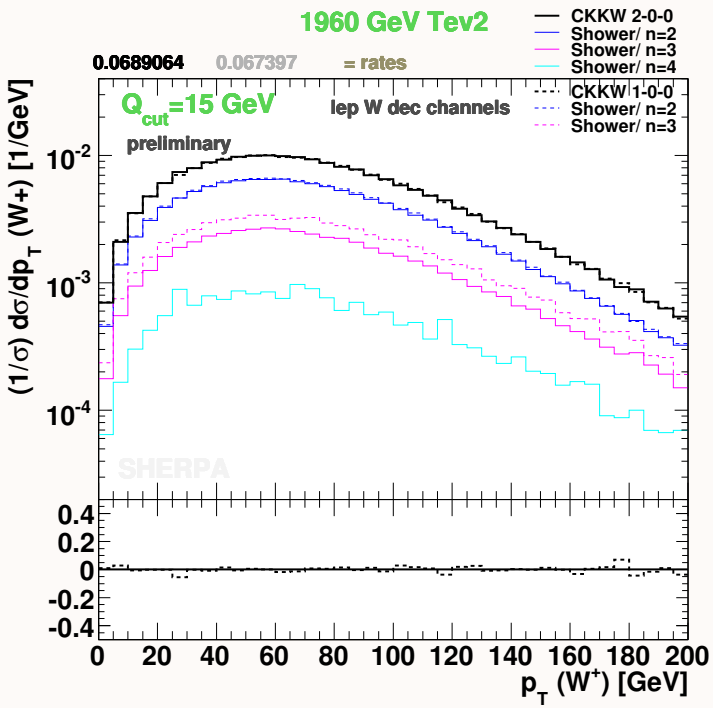
# CKKW in top pair production & decay

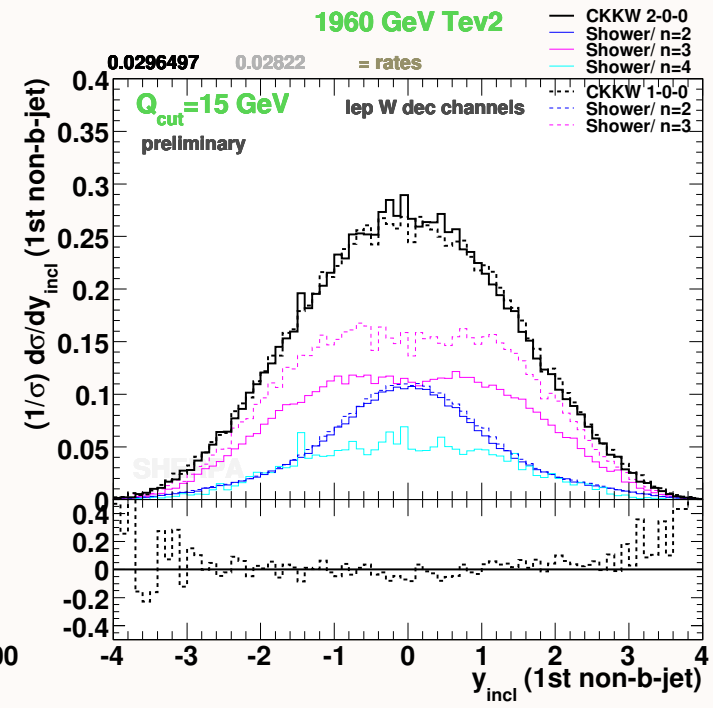
## ➡ Some preliminary first results ...

Top pair production + decay at Tevatron Run II @ shower level

*CKKW 2-0-0 vs. 1-0-0 including leptonic decays of the Ws*



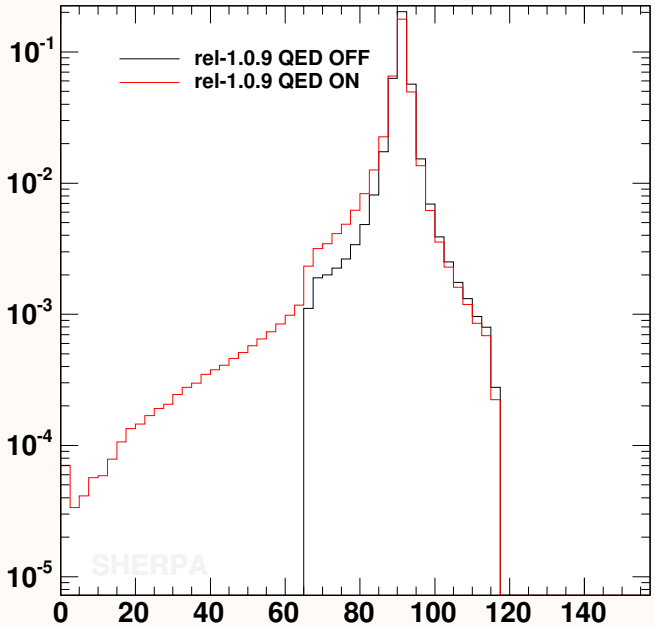



# Shower issues within SHERPA

- **Now enabled: Photon emissions within APACIC++.**
  - rely on QCD splitting functions (coll and soft emission)
  - but use $\alpha_{\mathrm{QED}}$ coupling and no $\gamma \to \gamma\gamma$
  - radiation from quarks and charged leptons
  - only final-state radiation with cut-offs
    - quarks: same as for QCD
    - ch leptons: separate parameter (tunable, default 50 MeV)

*proof-of-concept*




*lepton pair inv mass, Z prod @ LHC in mass range 66 ... 116 GeV*

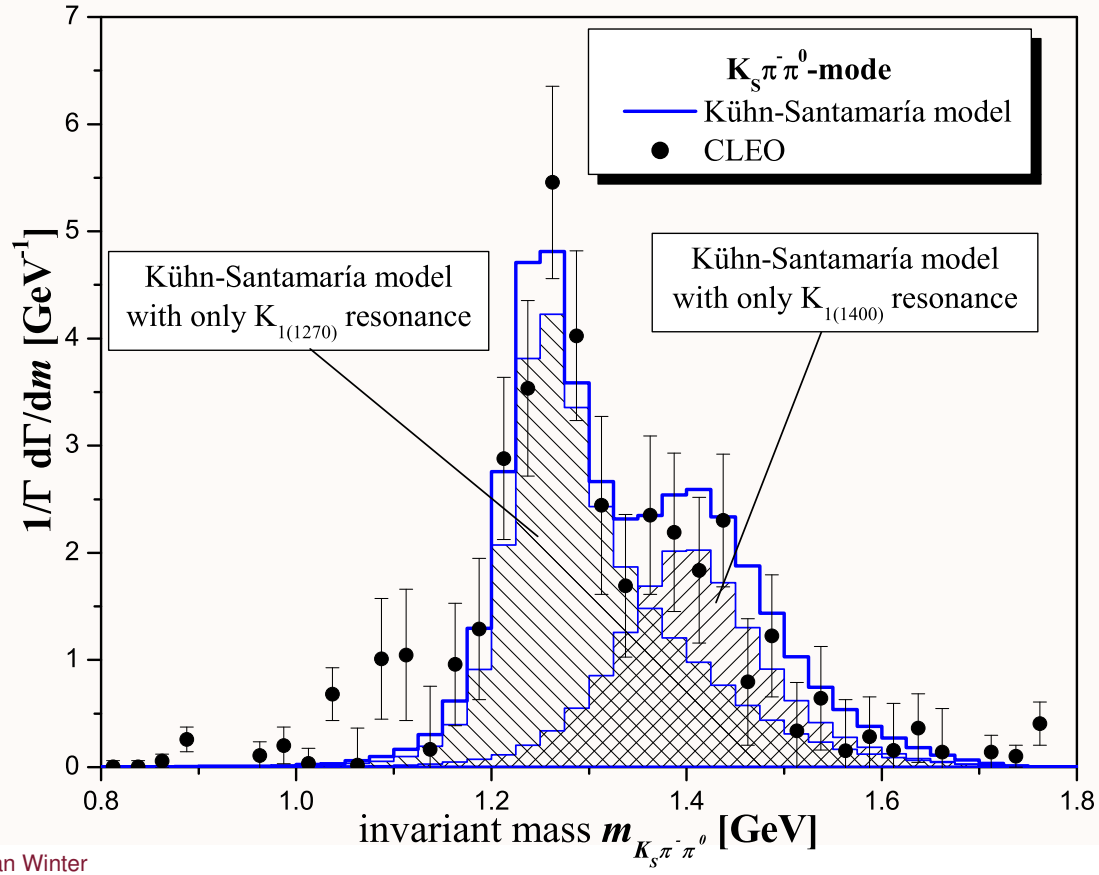
- **Structure of SHERPA (C++) allows for straightforward addition of new shower modules.**
  - some effort to develop and implement new shower descriptions.
  - enables a direct, unbiased comparison of different approaches.
  - allows to provide variants of CKKW merging.
- chance to gain a better understanding of underlying systematic uncertainties **!**

# Hadronization and hadron decays

- **SHERPA status:** in its current version 1.0.9 it is prepared for the LHC.
- **Aim: to become a full-fledged MC event generator.**
  - provide own (default) solutions for parts that still rely on PYTHIA interfaces
  - Cluster model $\Rightarrow$ proof-of-concept: J.W. et al., Eur. Phys. J. C36,2004
    - implemented within the framework, reached test and tuning phase
  - Hadron decay package ... proof-of-concept: thesis by T. Laubrich

# Hadronization and hadron decays

- **SHERPA status:** in its current version 1.0.9 it is prepared for the LHC.
- **Aim: to become a full-fledged MC event generator.**
  - provide own (default) solutions for parts that still rely on PYTHIA interfaces
  - Cluster model ⇒ proof-of-concept: J.W. et al., Eur. Phys. J. C36,2004
    - implemented within the framework, reached test and tuning phase
  - Hadron decay package ... proof-of-concept: thesis by T. Laubrich




- invariant mass spectrum in $\tau^- \to K_S\pi^-\pi^0\nu_\tau$
- CLEO-CONF-94-23

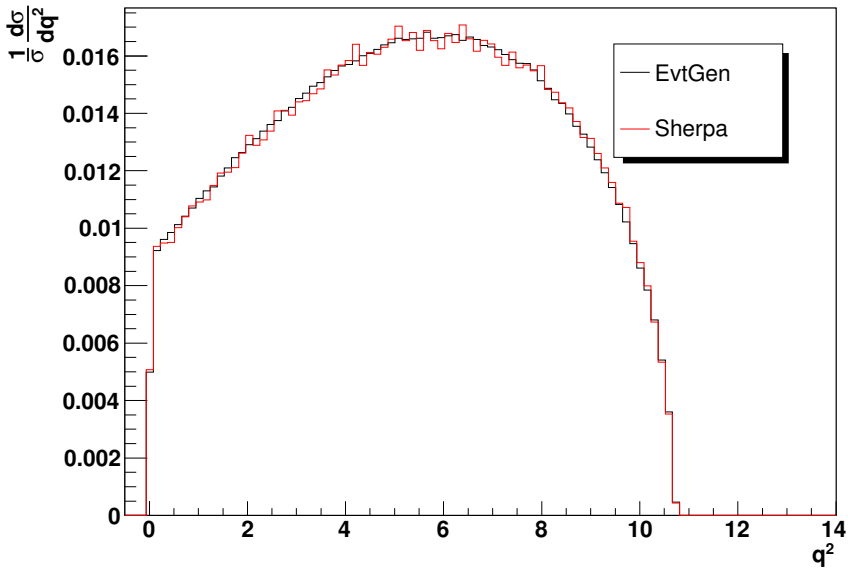
# Hadronization and hadron decays

- **SHERPA status:** in its current version 1.0.9 it is prepared for the LHC.
- **Aim: to become a full-fledged MC event generator.**
  - provide own (default) solutions for parts that still rely on PYTHIA interfaces
  - Cluster model $\Rightarrow$ proof-of-concept: J.W. et al., Eur. Phys. J. C36,2004
    - implemented within the framework, reached test and tuning phase
  - Hadron decay package ... proof-of-concept: thesis by T. Laubrich
- **HADRONS++:**
  - information read from parameter files (BRs, decay channels, form factors, integrators)
  - $\tau$ decay lib .. beyond proof-of-concept .. based on elaborated models (KS, R$\chi$PT)
  - released: few but well tested hadron decays ...
  - but a lot of work is in progress ...
  - emphasis on $B$ decays, example:

    decay using ME and HQET form factor model

    $B \to D^* \; e \; \nu$

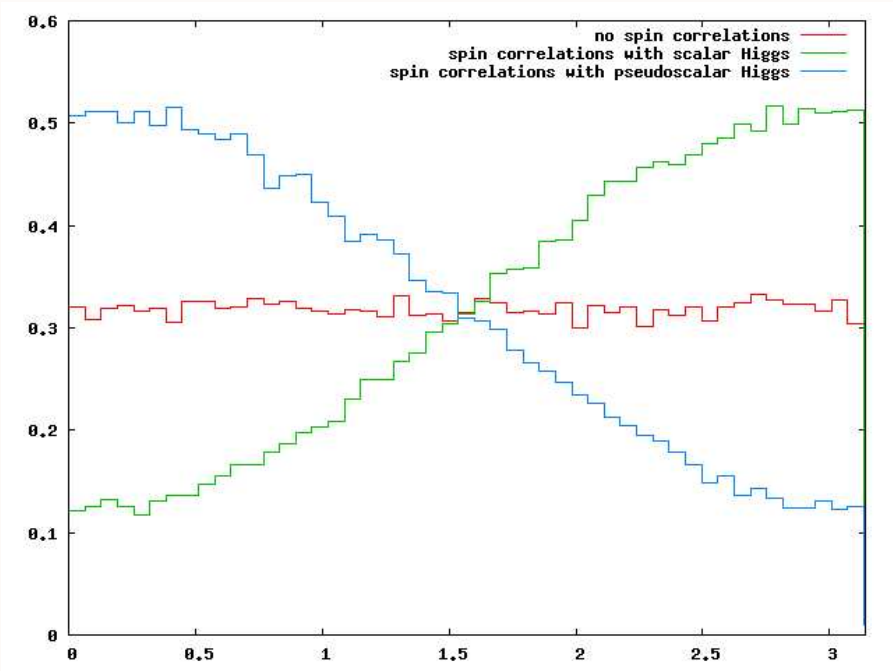
    $q^2 = (p_e + p_\nu)^2$



# Spin correlations in hadronic tau decays

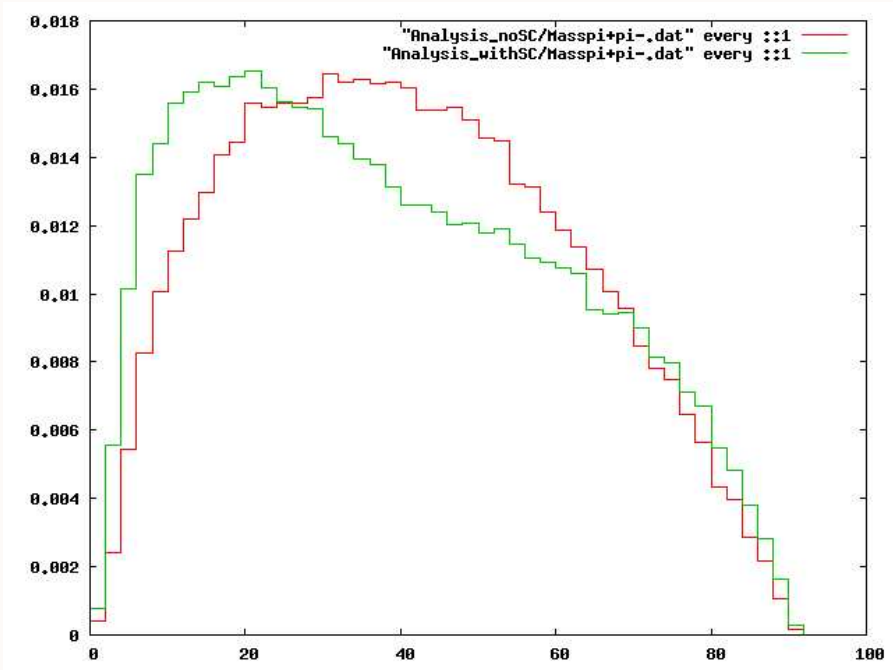
- ansatz: use reweighting techniques to correlate the spin of the production ME (generated with AMEGIC++) to the decay MEs (provided by HADRONS++)
- did tests along the line of:
  T. Pierzchala et al., hep-ph/0101311 and M. Worek, hep-ph/0305082
- two examples:

$H \to \tau^- \tau + \to \pi^- \nu_\tau \pi^+ \bar{\nu}_\tau$




$\pi^+\pi^-$ acoplanarity $\phi^*$

$Z^0 \to \tau^- \tau + \to \pi^- \nu_\tau \pi^+ \bar{\nu}_\tau$




$\pi^+\pi^-$ mass in GeV

# Summary

- **CKKW implementation is the key feature of SHERPA.**
  - A powerful tool for jet physics !
  - Improved (leading-order) description of hard multijet configurations together with jet fragmentation in SM processes.

- **New release: SHERPA 1.0.9** → **http://www.sherpa-mc.de/**
  - Aim: Please download and use new version !
  - Aim: Completely independent MC event generator.
  - Aim: A tool that is frequently used by experimentalists.
  - → work done towards more stability and persistency of the code:
    - revised event phase and error handling
    - warning, retry, rejection statistics, increasing transparency for user
    - generator status recovery, improved exception handling

- **We are moving to CEDAR HepForge.**