

# New developments in SHERPA

Tanju Gleisberg <sup>a</sup>

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Institute for Theoretical Physics  
Dresden University of Technology,  
CERN, Theory Division



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<sup>a</sup> For the SHERPA collaboration: T. G., S. Höche, F. Krauss, S. Schumann, F. Siegert, J. Winter

# New release: SHERPA 109

Status final tests are running, almost ready

What's new?

- Technical aspects
  - Revised Event Phase handling
  - Generator status recovery
- New features
  - shower and CKKW in production and decay of massive particles
  - final state photon shower
  - spin correlation to hadron decays (tau decays)
  - ME generation: new interaction types
  - ME generation: MHV techniques

# New release: technical aspects

Towards more Stability and Persistency of the code:

## 1. Revised Event Phase handling

- Harmonised treatment of return values for all phases
  - More internal transparency
  - less warning output / more transparent for the user:
    - Many warnings in previous versions are harmless if appear just a few times
    - However: if they appear in a substantial number of the events it might be a hint that something goes wrong

→ Statistics: rate of rejections/retrials in different phases

Generated events: 91376

New events {

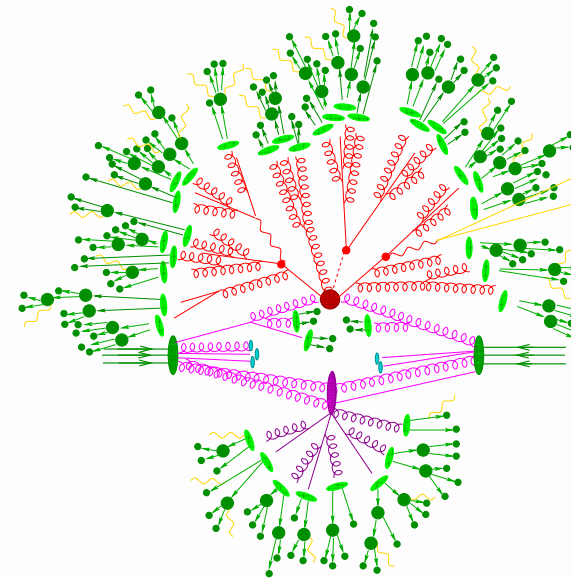
From "Jet\_Evolution:Apacic": 1 (91379) -> 0 %

}

Retried events {

From "Beam\_Remnants": 2 (91378) -> 0 %

}



# New release: technical aspects

Towards more Stability and Persistency of the code:

## 2. Generator status recovery

- Improved exception handling:  
in case of a crash of the generator the complete information necessary for recovery of the status before the critical event is written out
- together with corresponding \*.dat files the generator can be re-initialized to the status before crash

# New features: Shower + CKKW for massive particles

## Extending the CKKW implementation or CKKW for hard decaying massive coloured particles.

### production & decay of heavy particles

- assume factorized production and decay
- provide production and decay showers based on massive splitting functions
  - e.g.  $e^+e^- \rightarrow t\bar{t}$ : fs shower for tops
  - e.g.  $t \rightarrow W^+b$ : is shower for top; fs shower for bottom
- reweighting and vetoing respecting the factorization
- Merging of ME with extra jets added to the production and decay

$$e^-e^+ \rightarrow t [\rightarrow W^+bg\{1\}] \bar{t} [\rightarrow W^-\bar{b}g\{1\}] g\{1\}:$$

$$e^-e^+ \rightarrow t [\rightarrow W^+b] \bar{t} [\rightarrow W^-\bar{b}]$$

$$e^-e^+ \rightarrow t [\rightarrow W^+b] \bar{t} [\rightarrow W^-\bar{b}] g$$

$$e^-e^+ \rightarrow t [\rightarrow W^+b] \bar{t} [\rightarrow W^-\bar{b}g]$$

$$e^-e^+ \rightarrow t [\rightarrow W^+b] \bar{t} [\rightarrow W^-\bar{b}g] g$$

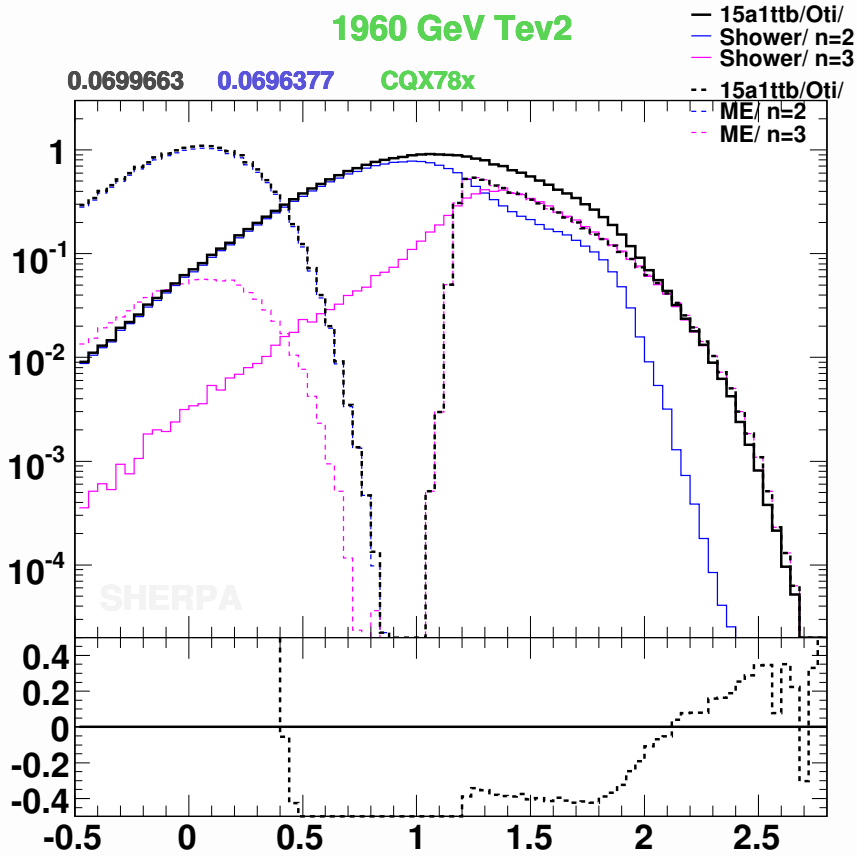
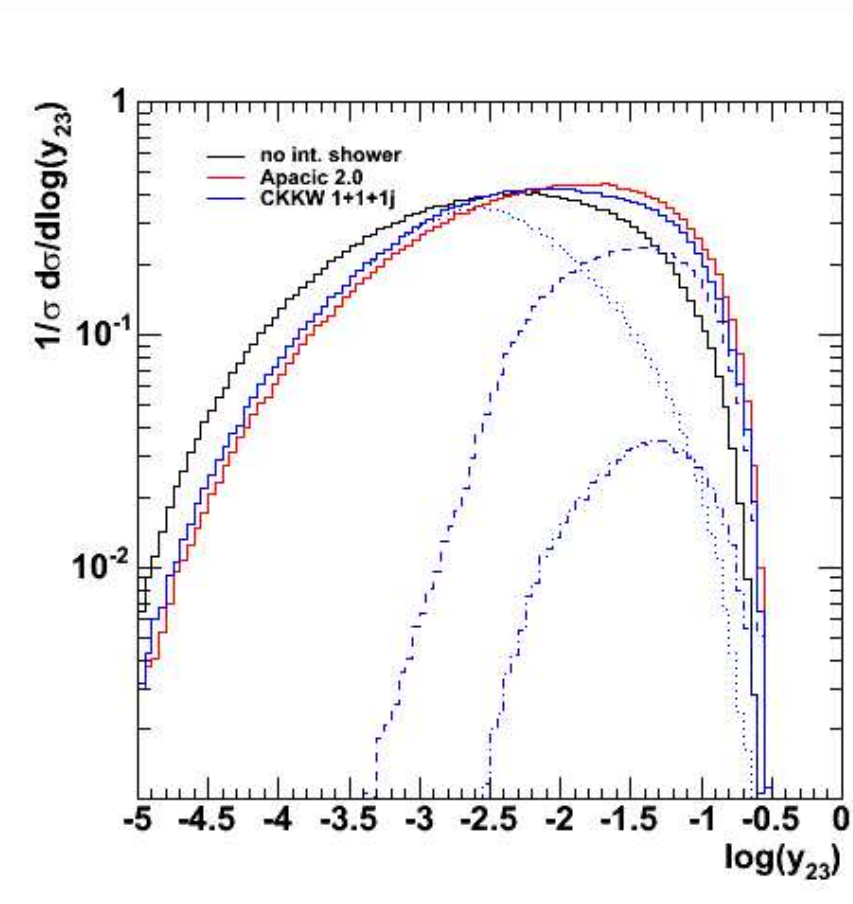
...

# New features: Massive shower + Merging

Some verification:

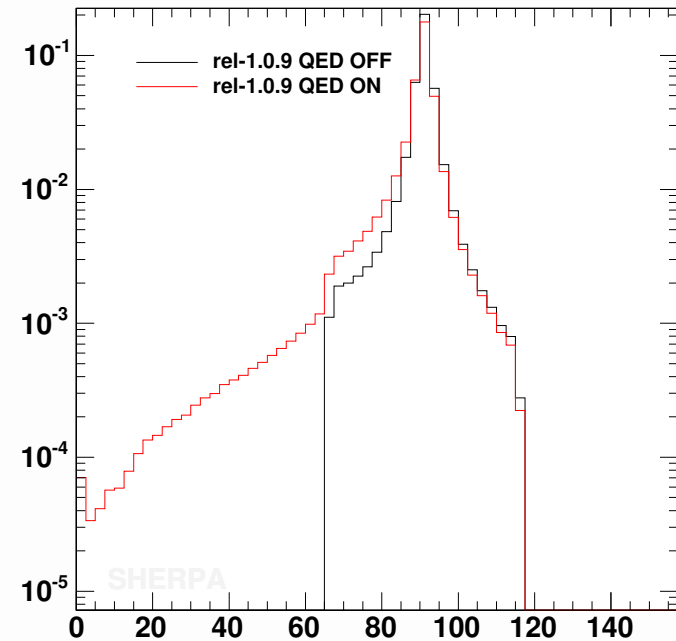
$$e^-e^+ \rightarrow t\bar{t} \text{ @ } 500 \text{ GeV}$$

$t\bar{t}$ -production @ Tevatron



# New features: Photon shower

- Similar to QCD shower:  
soft and collinear approximation  
→ same splitting functions used  
(no  $g \rightarrow gg$  and  $\alpha_{QED}$  as coupling constant)
- accounts for radiation from quarks and charged leptons
- final state radiation only
- shower cutoffs:  
Quarks: same as for QCD shower  
Charged leptons: separate cutoff (tuning parameter; default: 50 MeV)



lepton pair invariant mass @ LHC  
(production cut:  $m=66-116\text{GeV}$ )

# New features: Spin correlation to Hadron decays

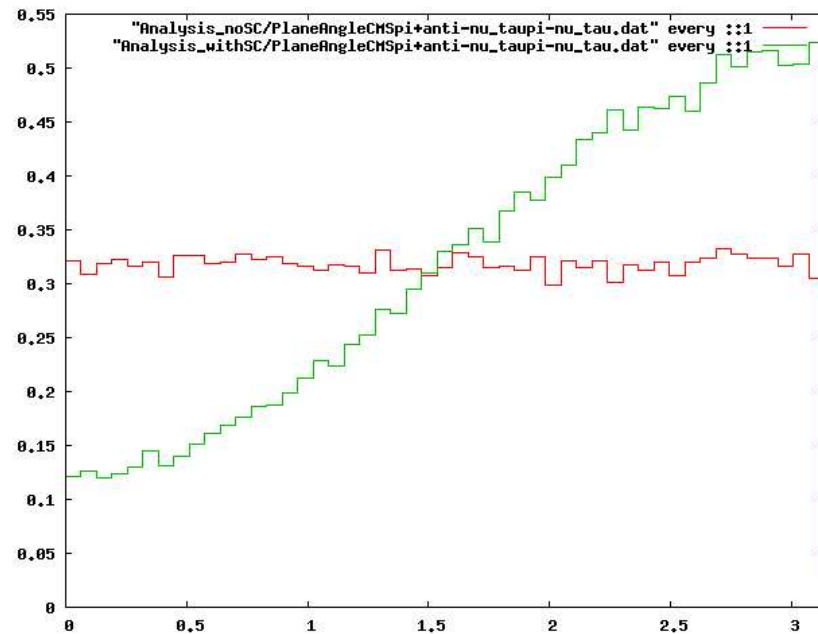
- Implemented for hadronic tau-decays:  
Reweighting of events to correlate the spin of the tau production ME (generated with AMEGIC) to decay ME's (provided by the Hadron decay module)

- E.g. study CP properties of a Higgs-candidate:

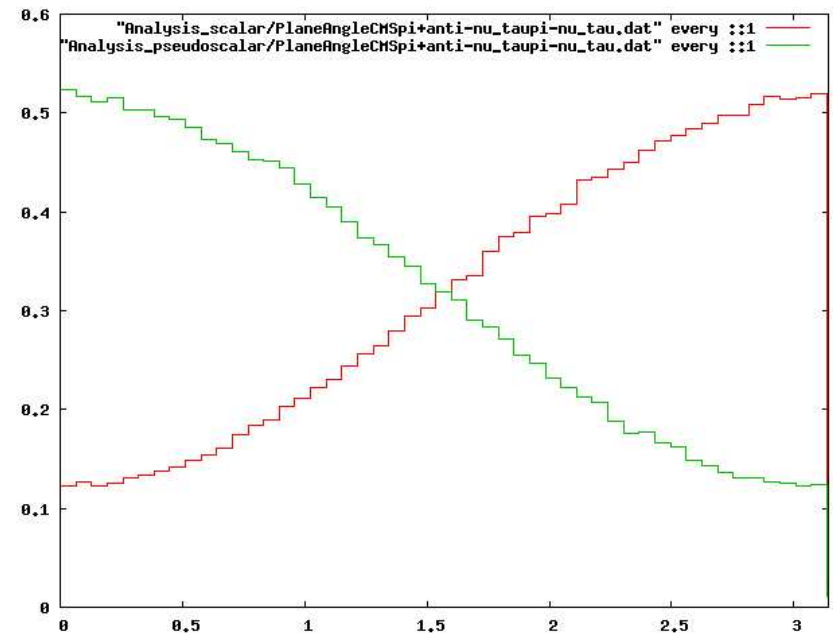
(M. Worek, Acta Phys.Polon.B34:4549-4560,2003)

$$higgs \rightarrow \tau^- \tau^+ \rightarrow \pi^- \nu_\tau \pi^+ \bar{\nu}_\tau$$

$\pi^+ \pi^-$  acoplanarity:  $(\phi^*)$



effects of spin correlation



scalar vs. pseudo-scalar Higgs



# New features: ME generation: New interaction types

- Feynman rules containing antisymmetric tensor  $\epsilon^{\mu\nu\rho\sigma}$
- E.g. Anomalous Triple gauge couplings:  
Hagiwara et al., Nuclear Physics B282 (1987) 253-307  
Most general effective Lagrangian ( $V = \gamma/Z$ ):

$$\begin{aligned}\mathcal{L}_{WWV} \propto & ig_1^V (W_{\mu\nu}^\dagger W^\mu V^\nu - W_\mu^\dagger V_\nu W^{\mu\nu}) + i\kappa_V W_\mu^\dagger V_\nu W^{\mu\nu} \\ & + \frac{i\lambda_V}{m_W^2} W_{\lambda\mu}^\dagger W_\nu^\mu V^{\nu\lambda} - g_4^V W_\mu^\dagger W_\nu (\partial^\mu V^\nu + \partial^\nu V^\mu) \\ & + g_5^V \epsilon^{\mu\nu\rho\sigma} (W_\mu^\dagger \overleftrightarrow{\partial}_\rho W_\nu) V_\sigma + \frac{i\tilde{\kappa}_V}{2} \epsilon^{\mu\nu\rho\sigma} W_\mu^\dagger W_\nu V_{\rho\sigma} \\ & + \frac{i\tilde{\lambda}_V}{2m_W^2} \epsilon^{\mu\nu\rho\sigma} W_{\mu\lambda}^\dagger W_\nu^\lambda V_{\rho\sigma}\end{aligned}$$

- CP-violating terms  $\propto \epsilon^{\mu\nu\rho\sigma}$
- Studies under way...

# New features: ME generation: MHV techniques

- Simple expressions for amplitudes in Yang-Mills theory recently derived from twistor space
  - E. Witten, Commun.Math.Phys.252:189-258,2004
  - F. Cachazo, P. Svrcek, E. Witten, JHEP09,006,2004(usually referred to as **CSW** recursion relations)
- Allows to push up limit for pure QCD processes:
  - $pp \rightarrow 5jet$  feasible
  - $pp \rightarrow 6jet$  in reach(For single parton level processes limits can be pushed much further)
- Also available for processes including one weak boson or higgs (however not so enormous gain as in case of pure QCD)

- The latest SHERPA version (1.0.8) is available from our homepage:

<http://www.sherpa-mc.de>

Very soon: version 1.0.9

- We are on the way of moving to HepForge