# New developments in Sherpa

Frank Siegert [1]

Institute for Particle Physics Phenomenology
Durham University

29.05.2008




[1] for SHERPA: T. Gleisberg, S. Höche, F. Krauss, M. Schönherr, S. Schumann, FS, J. Winter

# SHERPA release 1.1

## New features

- AHADIC++ – Cluster fragmentation module
- HADRONS++ – Complete hadron and $\tau$ decay module
- PHOTONS++ – QED radiation in the YFS formalism

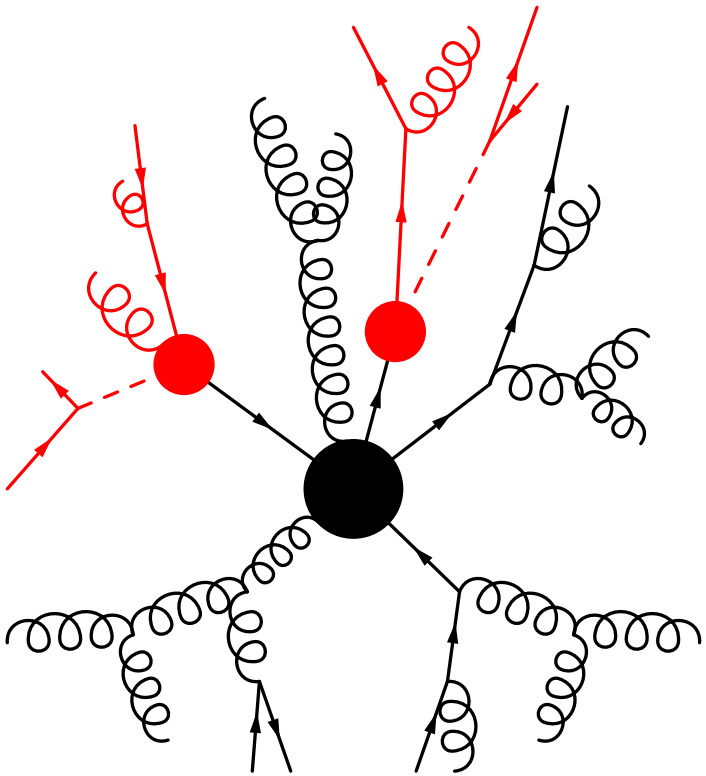
## Improvements in other areas

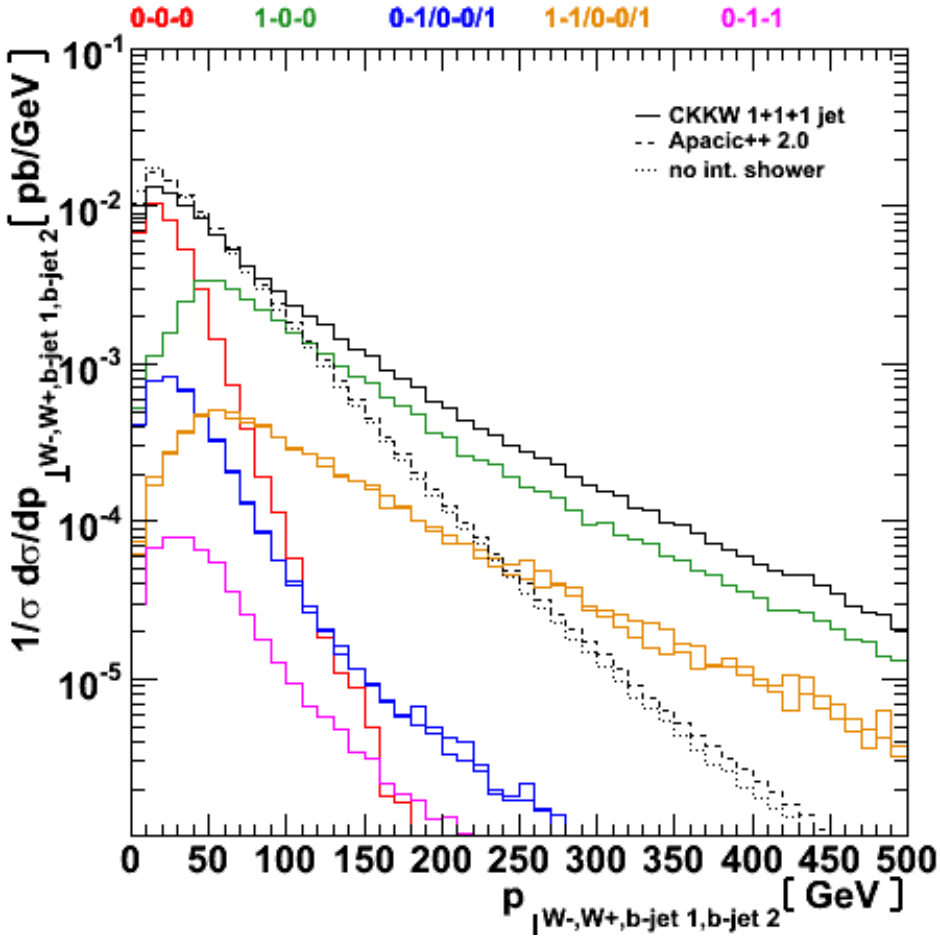
- CKKW merging for processes with decay chains

- 1.1.0 released in April 2008, bugfix release 1.1.1 in May 2008
- Available on GENSER, in ATLAS and CMS

# CKKW with decay chains, e.g. $t\bar{t}$ production

S. Hoeche, F. Krauss, J. Winter: in preparation



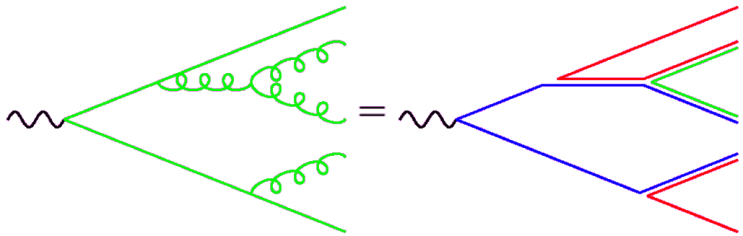


# AHADIC++: Basic idea

Eur. Phys. J. C36 (2004) 381

## Cluster fragmentation

- Large $N_C$-limit
- Split perturbative gluons non-perturbatively into $q\bar{q}$
- Colour connected pairs form colourless clusters



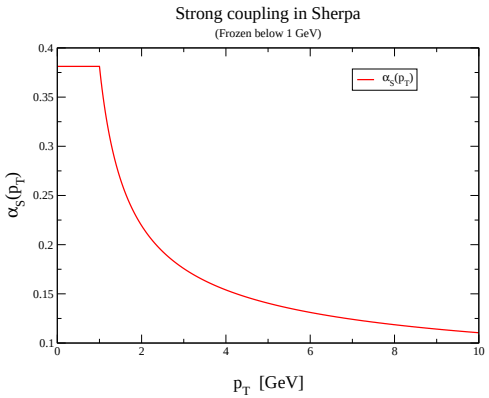
- After evolution in parton showers: colour singlets close in phase space
- Clusters ($\approx$ excited hadrons) decay into clusters or hadrons

# AHADIC++: Sherpa's version

Eur. Phys. J. C36 (2004) 381

## QCD "as if"

- Splittings $\propto \alpha_s(p_\perp)/p_\perp^2$
  (non-perturbative tunable $\alpha_s$)
- Limit allowed $p_\perp$ in gluon splitting




## Dynamic cluster-hadron boundary

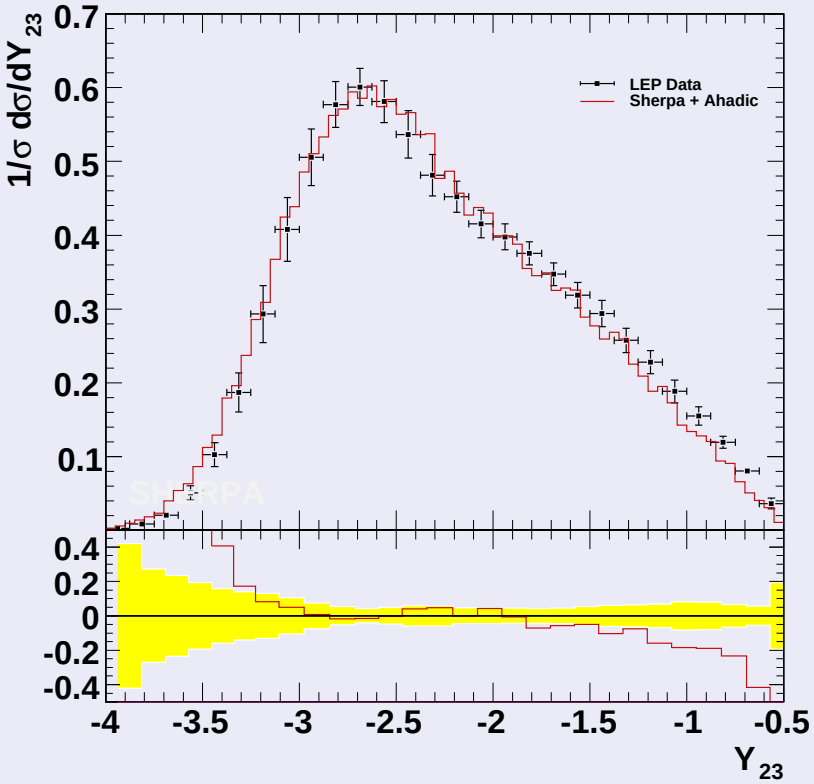
- Cluster decays $C \to CC$
- Decay product lighter than heaviest matching hadron $\to$ Transition to hadron (compensate recoil locally)
- Initial cluster light enough $\to$ Decay to hadron pair

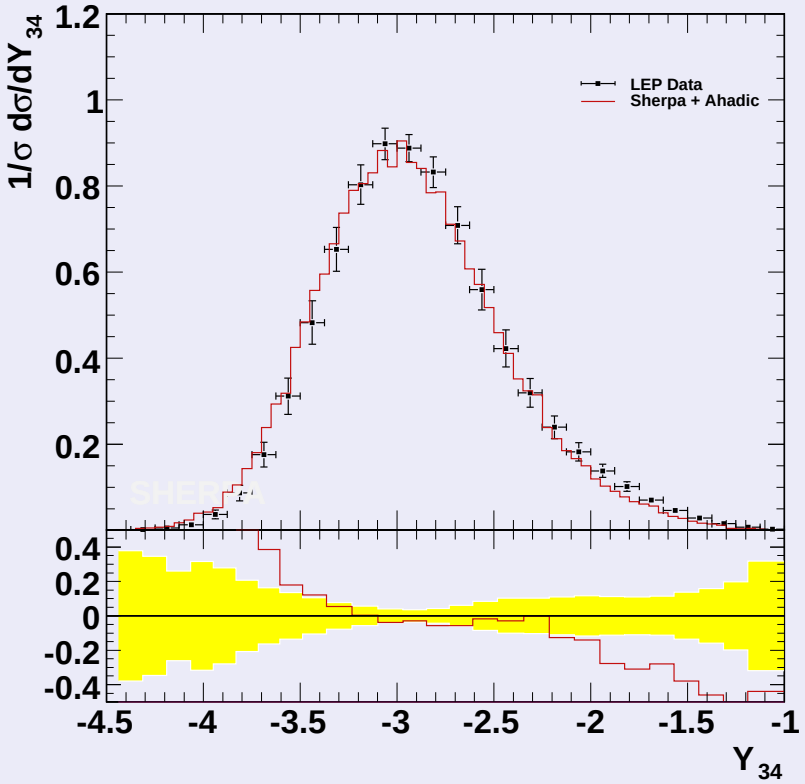
## Particularities

- Include diquarks throughout
- Use dipole splitting kinematics

# AHADIC++: Results

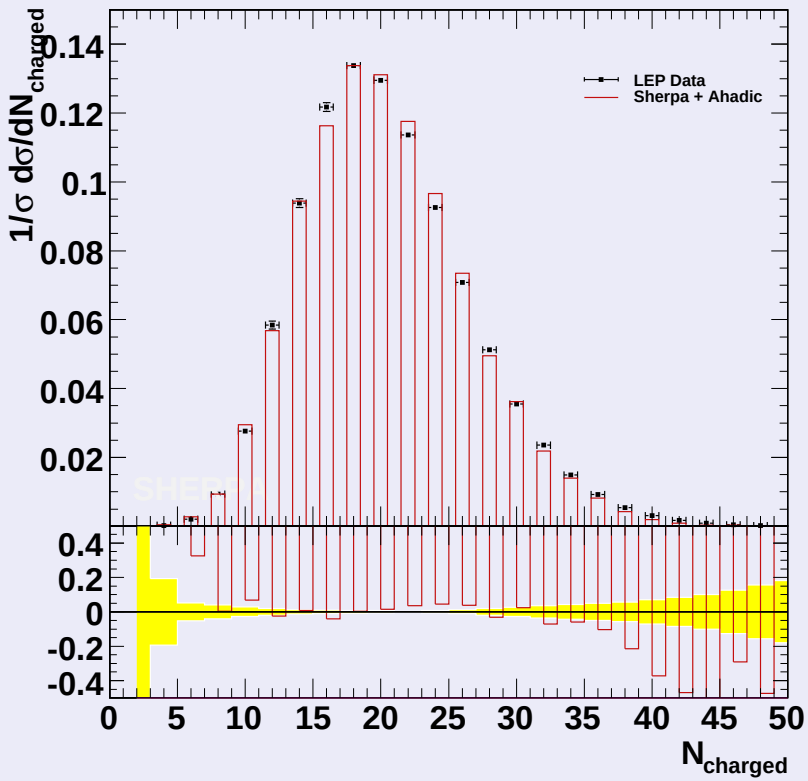
## LEP I data

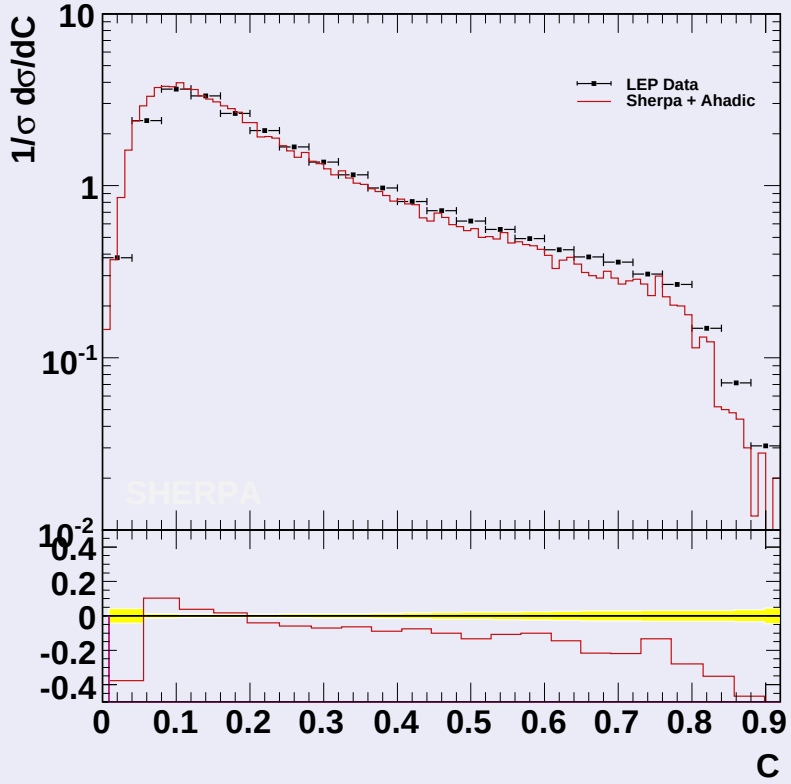


# AHADIC++: Results

## LEP I data



# HADRONS++: Overview

F. Krauss, T. Laubrich, FS: in preparation

## Highlights

- Decay kinematics according to matrix elements with form factors
- Kinematical corrections for spin correlations
- Treatment of neutral meson mixing and related CP violation

## Other features

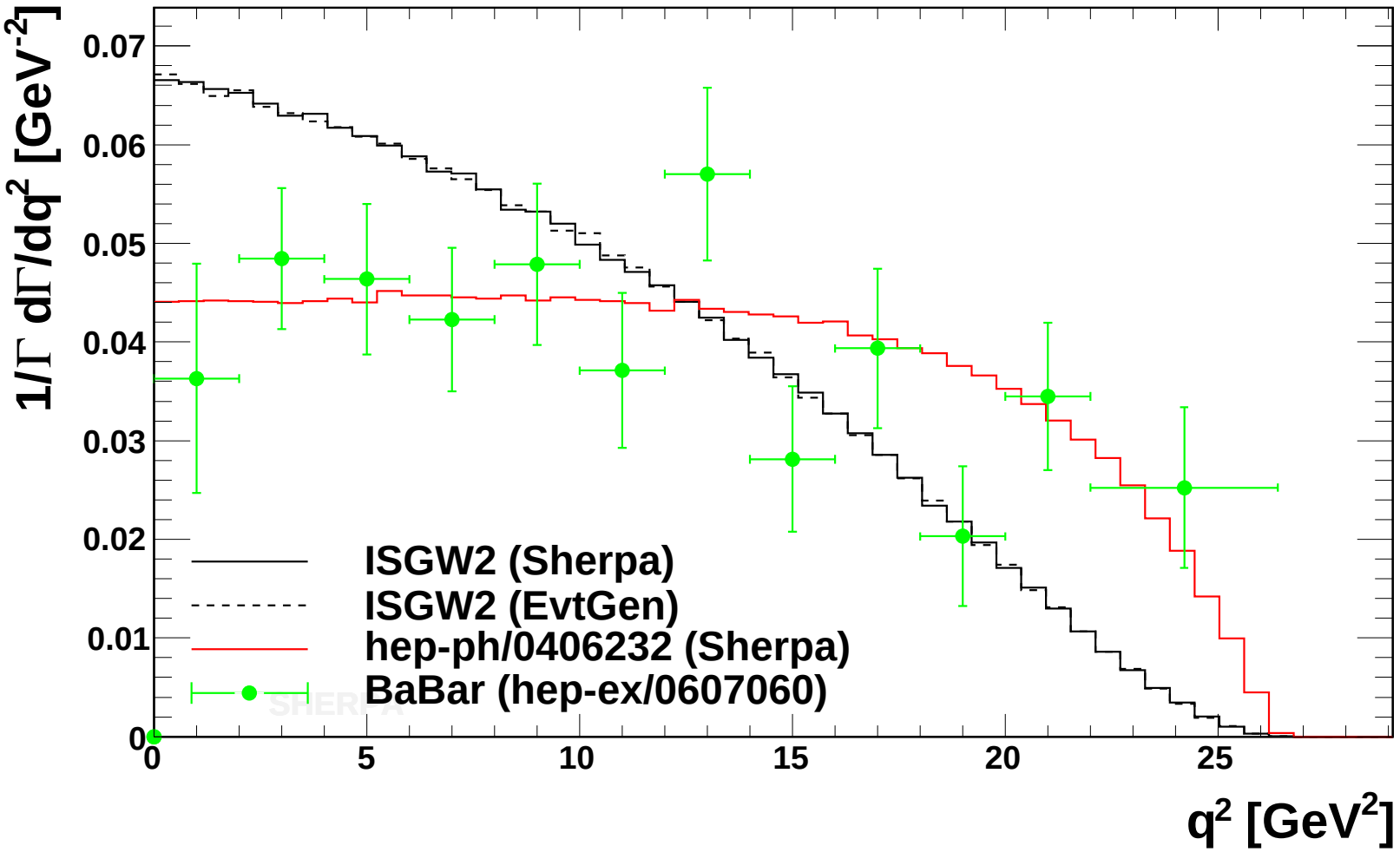
- Mass smearing of unstable resonances
- Partonic decays for incomplete decay tables

## Status

- Decay tables for $\approx$ 400 particles
- $\approx$ 2500 decay channels
- $\approx$ 400 decay channels with form factors

# Matrix elements and form factor models in $B \to \pi \nu_l \bar{l}$

F. Krauss, T. Laubrich, FS: in preparation



## Spin correlations in $h \longrightarrow \tau^-\tau^+ \longrightarrow \pi^-\nu_\tau\pi^+\bar{\nu_\tau}$

F. Krauss, T. Laubrich, FS: in preparation

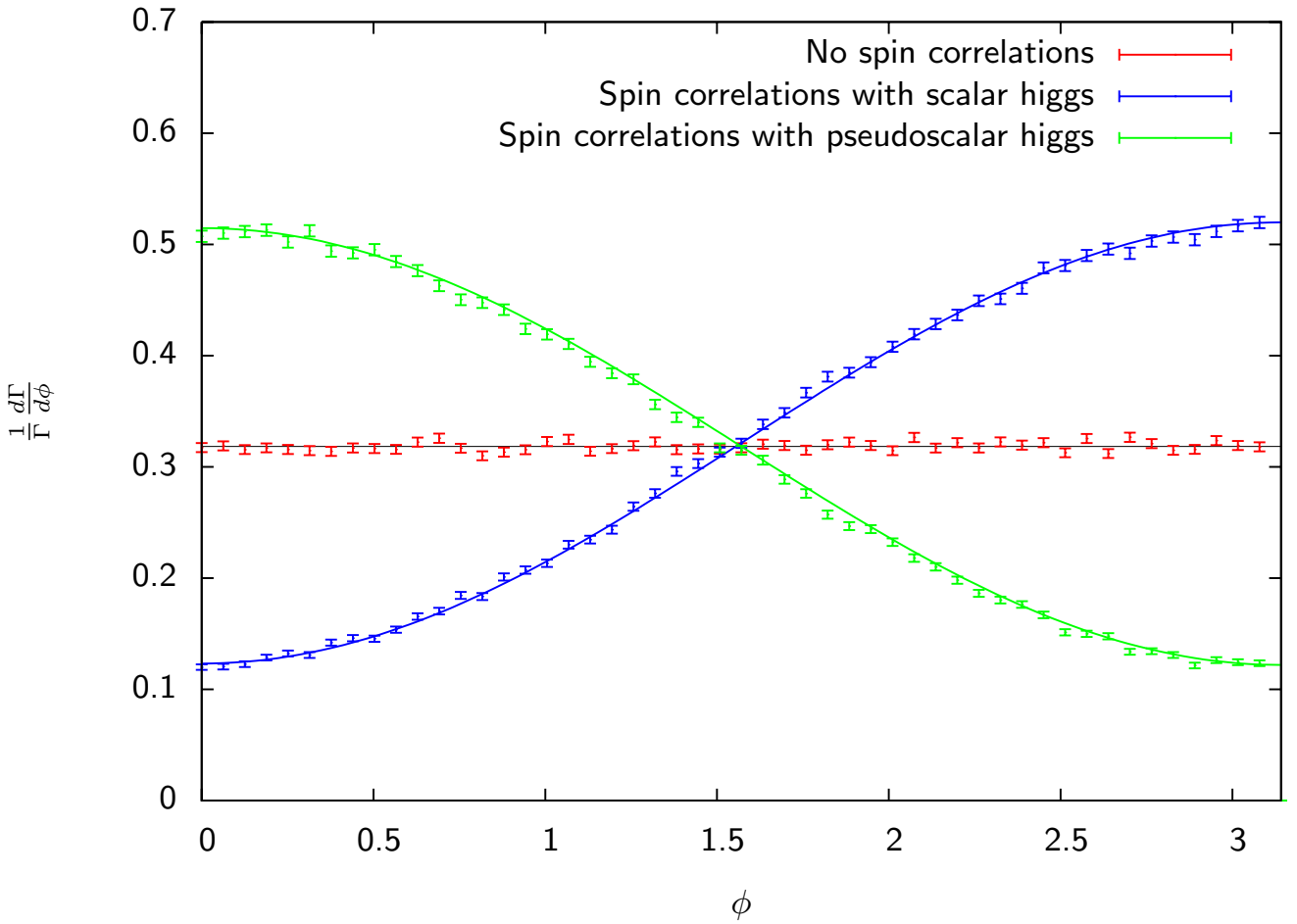



Figure: Angle between $\tau$ decay planes (Analytical results: M. Worek hep-ph/0305082)

# CP violation in the interference

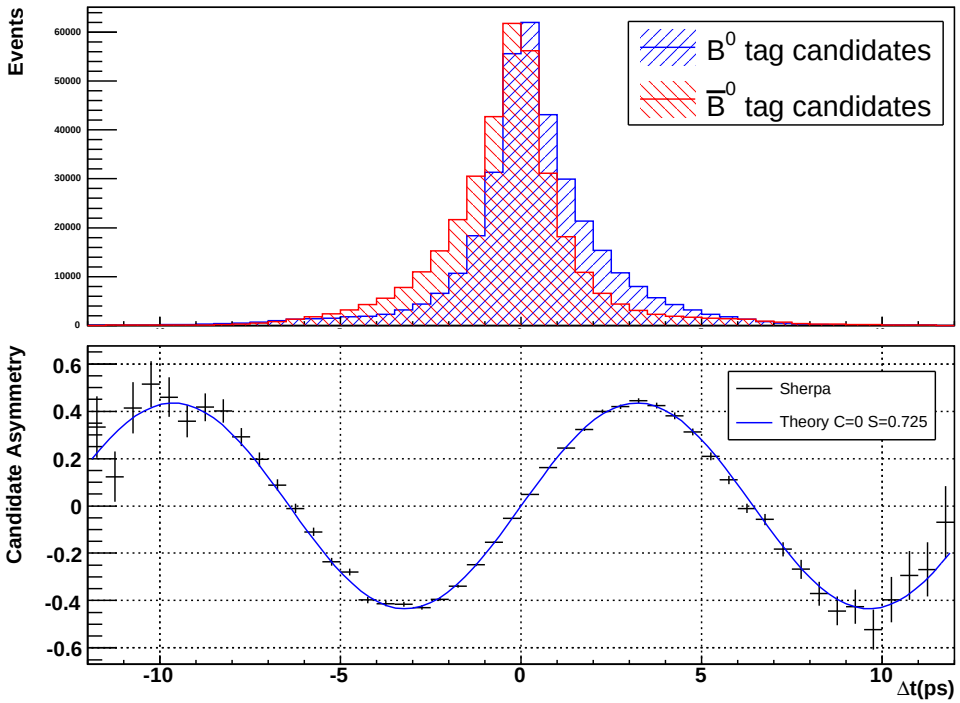
F. Krauss, T. Laubrich, FS: in preparation

## Asymmetry in decays to common final state $f$

$$A_{CP}(t) = \frac{\Gamma(B^0(t) \to f) - \Gamma(\bar{B}^0(t) \to f)}{\Gamma(B^0(t) \to f) + \Gamma(\bar{B}^0(t) \to f)} = S \cdot \sin(\Delta m_B t) - C \cdot \cos(\Delta m_B t)$$

Example: $B_d \to J/\Psi K_S$

$$\begin{aligned} S &= \Im(\lambda_{f_{CP}}) \\ &= \sin(2\beta) \\ &= 0.725 \\ C &= 0 \end{aligned}$$



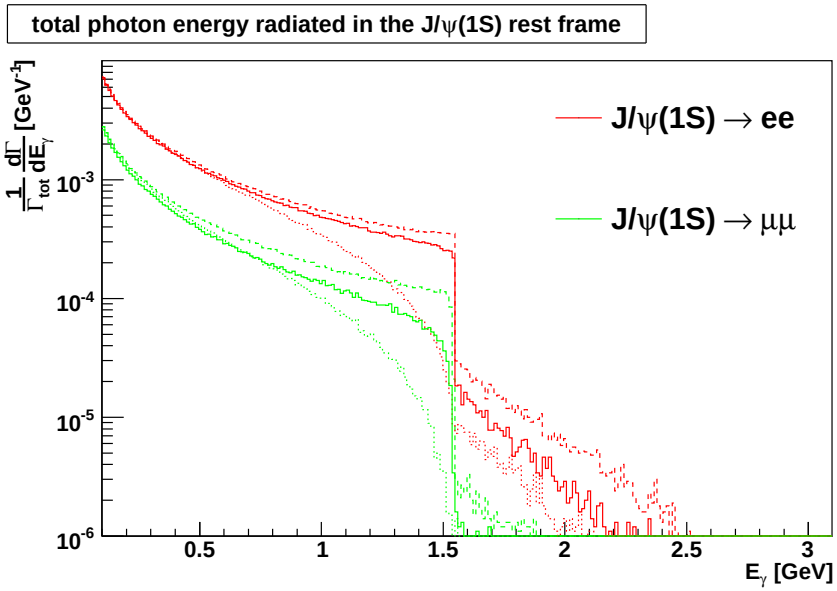
## PHOTONS++: Corrections for higher order QED effects

F. Krauss, M. Schönherr: in preparation

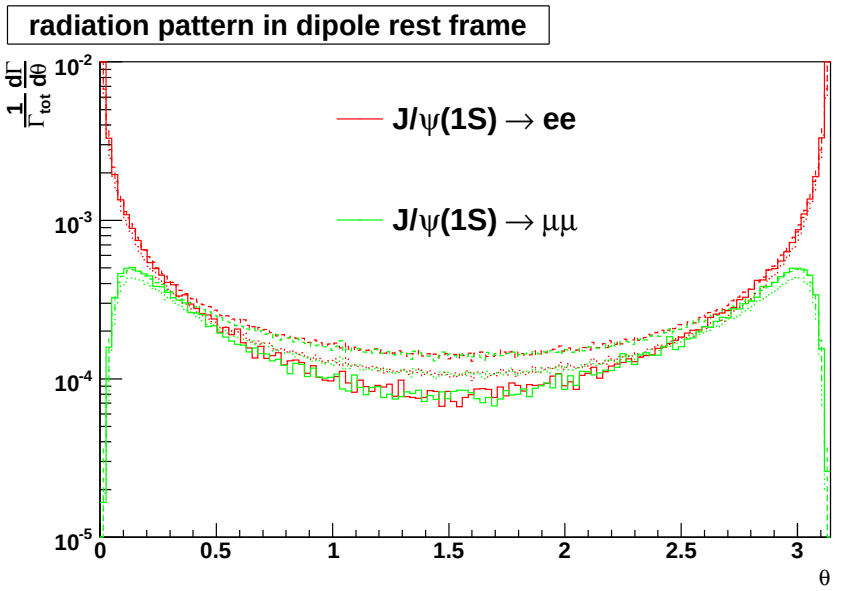
- Sums all contributions of soft photon radiation (real and virtual) using the Yennie-Frautschi-Suura-Formalism (YFS)
  $\Rightarrow$ exact as $k \to 0$, perturbative series for hard emission effects
- Hard emission effects up to $\mathcal{O}(\alpha)$ incorporated generally via approximated matrix elements in the quasi-collinear limit
- Important cases with $\mathcal{O}(\alpha)$ real and/or virtual exact matrix elements
  $V \to FF$, $V \to SS$, $S \to FF$, $S \to SS$, $\tau \to \ell\nu_\ell\nu_\tau$
- ME corrections for radiative semi-leptonic meson decays $(1 \to 3 + \gamma)$ under way (form factor model)
- Implemented for hadron and $\tau$ decays
- No limitation on final state complexity

# Leptonic hadron decays: $J/\psi \to \ell\bar{\ell}$

F. Krauss, M. Schönherr: in preparation



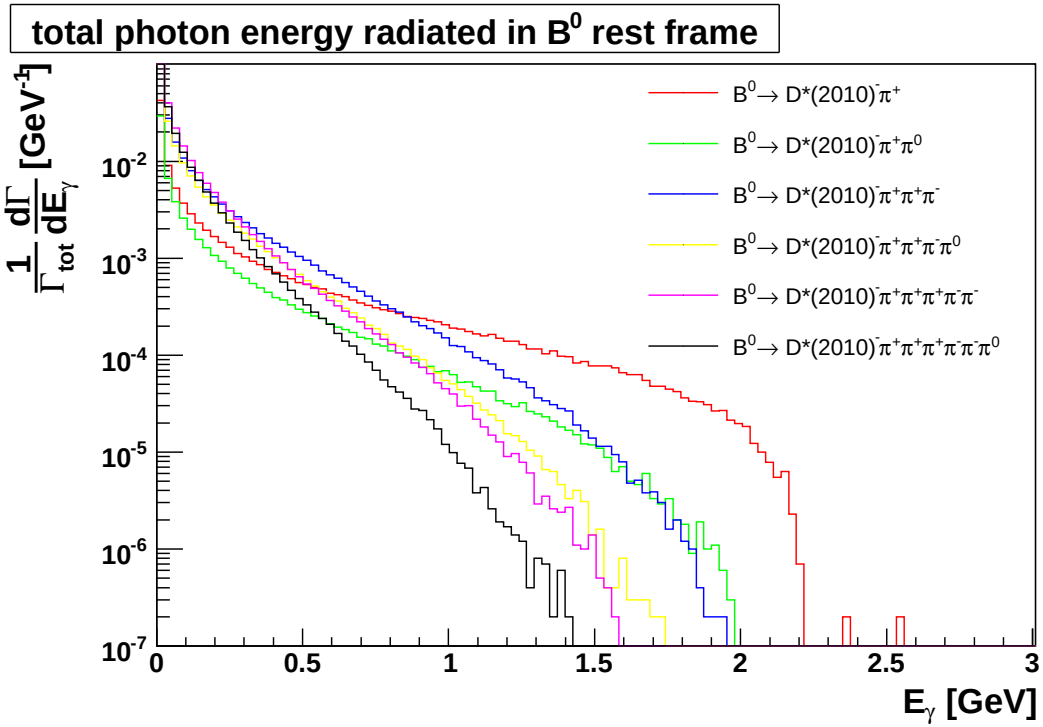

total radiated energy in the $J/\psi$ rest frame

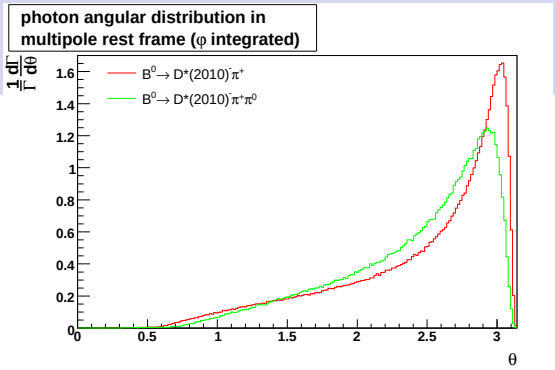


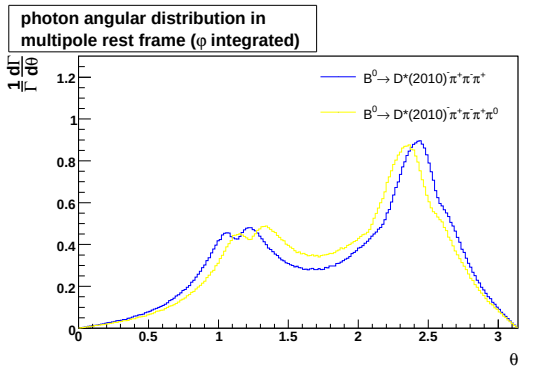

angular spectrum in the rest frame of the dipole

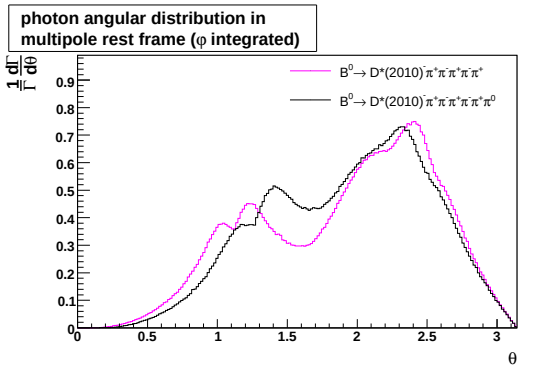
- soft only (dotted)
- collinear approximated ME (dashed)
- exact ME (solid)

# Multipoles: $(B \to D^{*-}+\text{Pions})$




Energy spectrum and angular radiation patterns for fixed kinematical configurations.

## High multiplicity matrix elements: COMIX

T. Gleisberg, S. Höche: in preparation

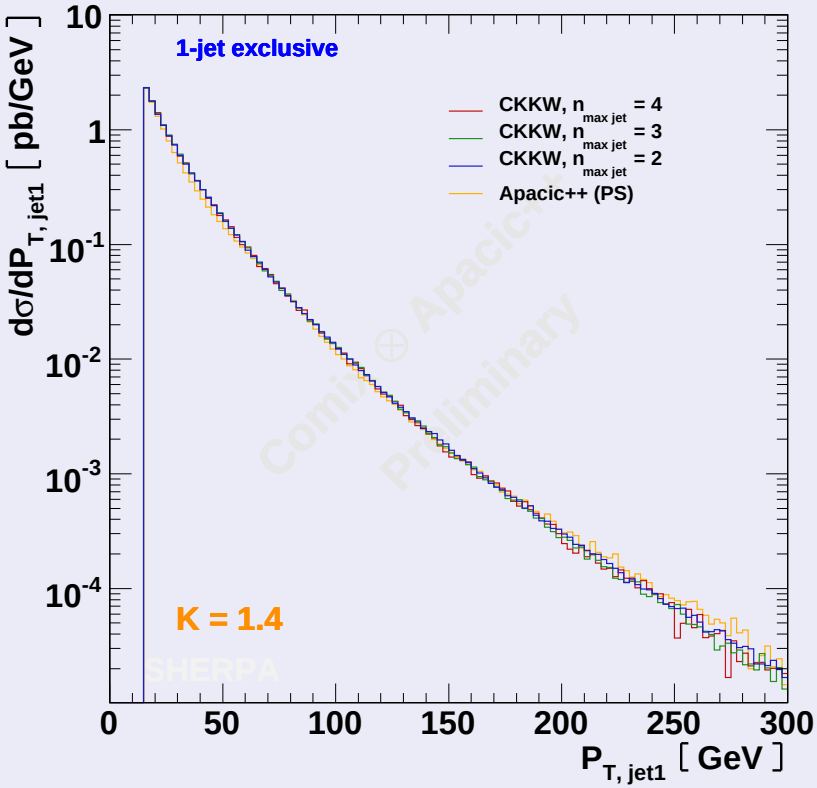
- Revisited Berends-Giele recursion: JHEP08(2006)062 $\Rightarrow$ new matrix element generator COMIX
- Fully general implementation of SM interactions, e. g.
  - pp $\longrightarrow W/Z +$ N jets (N up to 6, all partons!)
  - pp $\longrightarrow$ N jets $+ t$ [$W^+b +$ M jets] $\bar{t}$ [$W^-\bar{b} +$ M jets] (N/M up to 2/1)
  - pp $\longrightarrow$ N gluons (N up to 12)
  - pp $\longrightarrow$ N jets (N up to 8, all partons!)

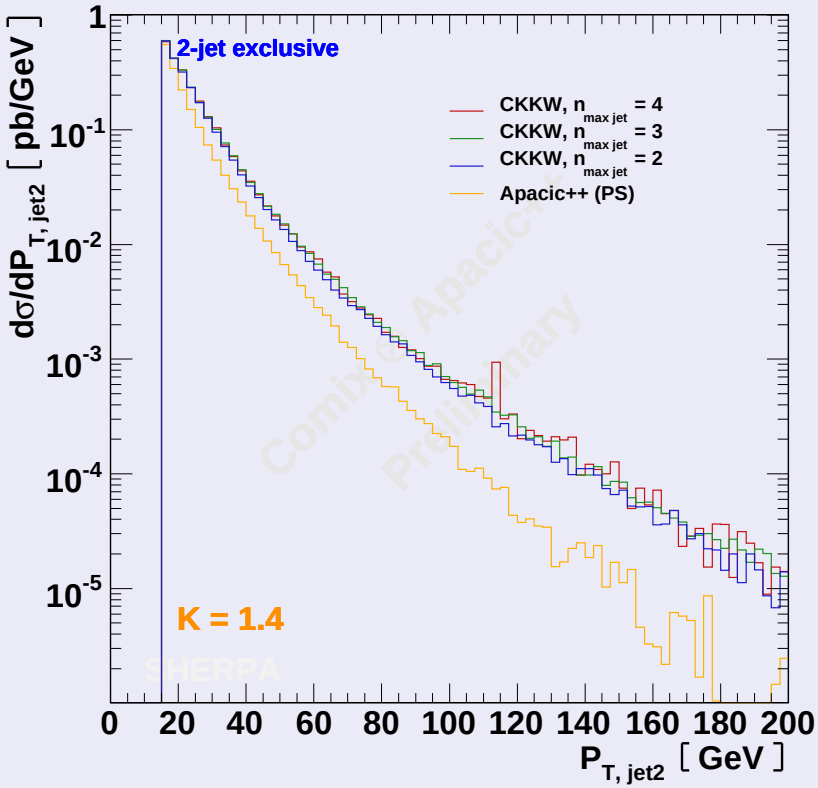
### Example from MC4LHC comparison vs. COMIX

| $\sigma$ [pb] | Number of jets | | | | | | |
|---|---|---|---|---|---|---|---|
| $e^-e^+ +$ QCD jets | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| COMIX | 723.5(4) | 187.9(3) | 69.7(2) | 27.14(7) | 11.09(4) | 4.68(2) | 2.02(2) |
| ALPGEN | 723.4(9) | 188.3(3) | 69.9(3) | 27.2(1) | 10.95(5) | 4.6(1) | 1.85(1) |
| AMEGIC++ | 723.0(8) | 188.2(3) | 69.6(2) | 27.21(6) | 11.1(1) | | |

# Merging with COMIX

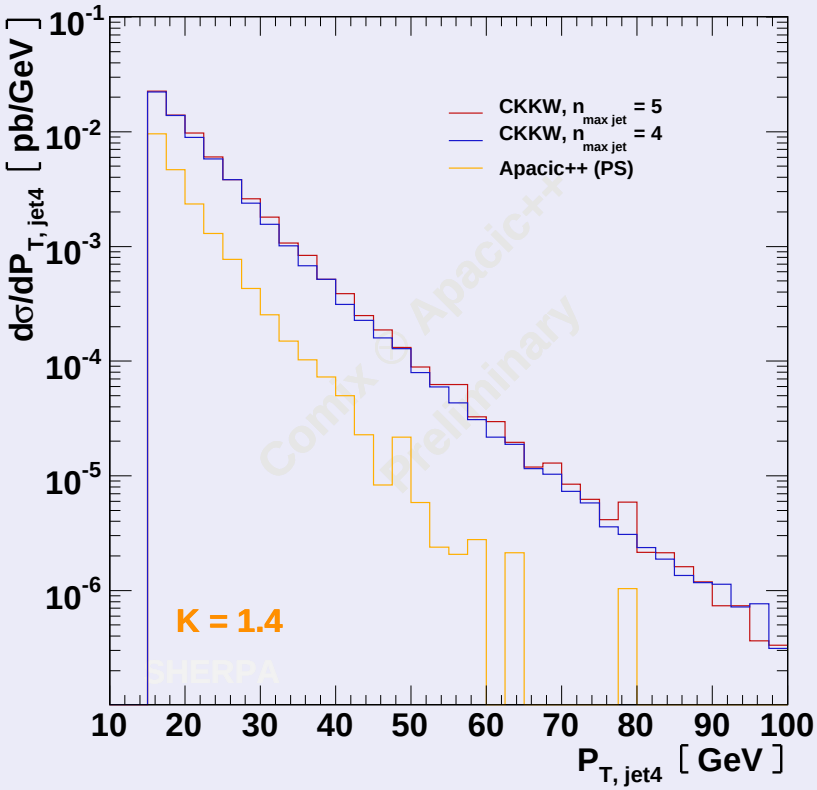
## Exclusive jet $p_T$ in Z+jets production at the Tevatron

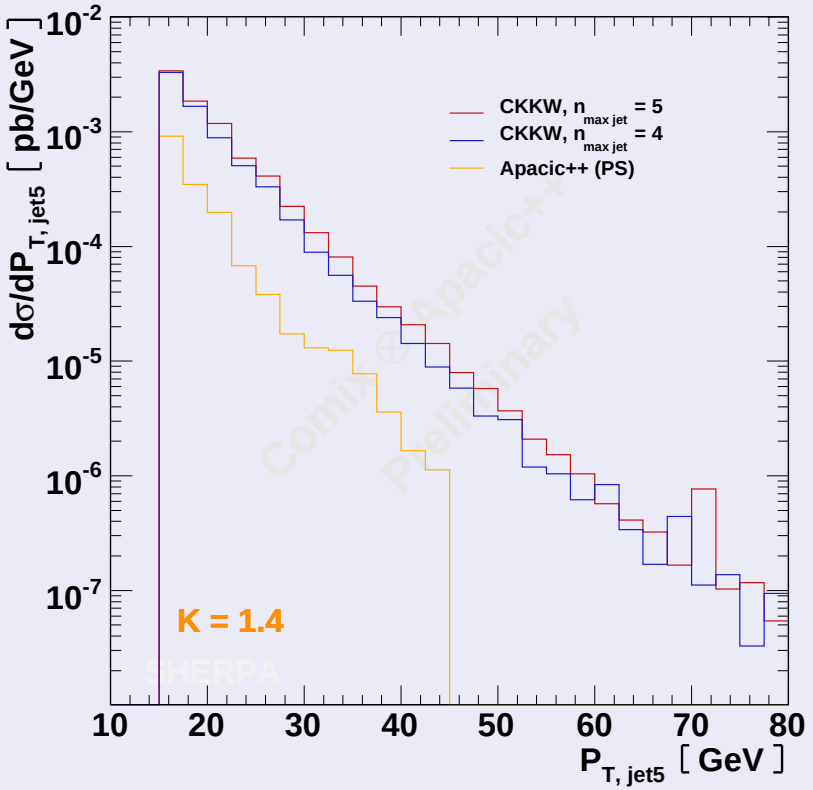


# Merging with COMIX

## Inclusive jet $p_T$ in Z+jets production at the Tevatron



# New showers: CSSHOWER++ and ADICIC++

JHEP03(2008)038 and arXiv:0712.3913

- So far in Sherpa: Virtuality ordered, (old-)Pythia-like shower APACIC++.
- Recent efforts: Two new shower modules, to study shower and merging systematics.
- Will be easily switchable in future SHERPA

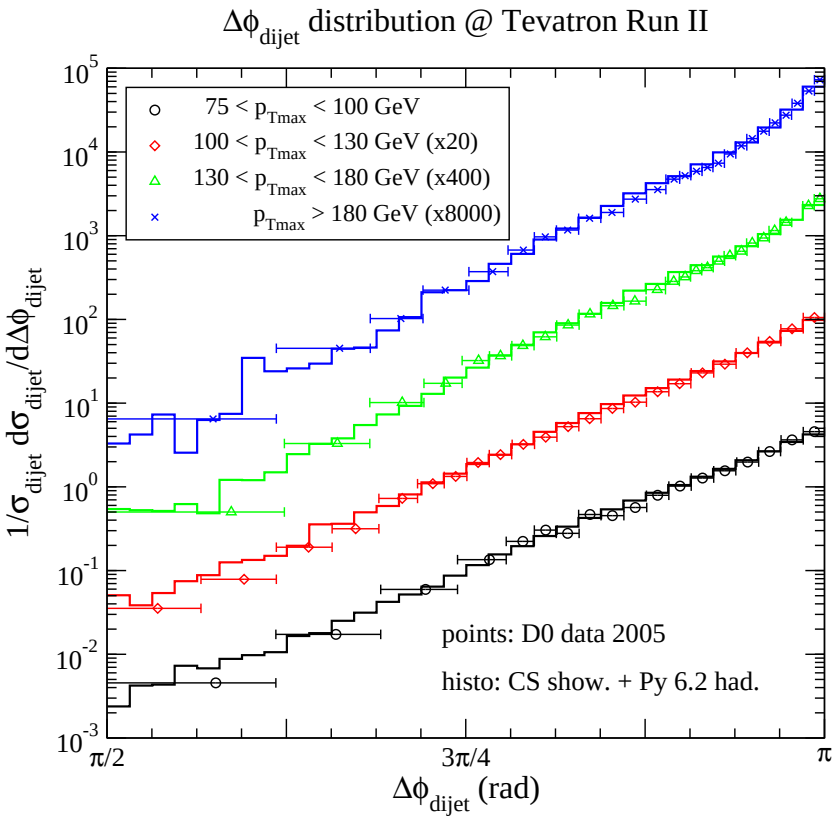
## CSSHOWER++

- Based on Catani-Seymour dipole subtraction
- Dipole terms can be used to describe splittings
- Correct soft & collinear limits, better treatment of colour coherence

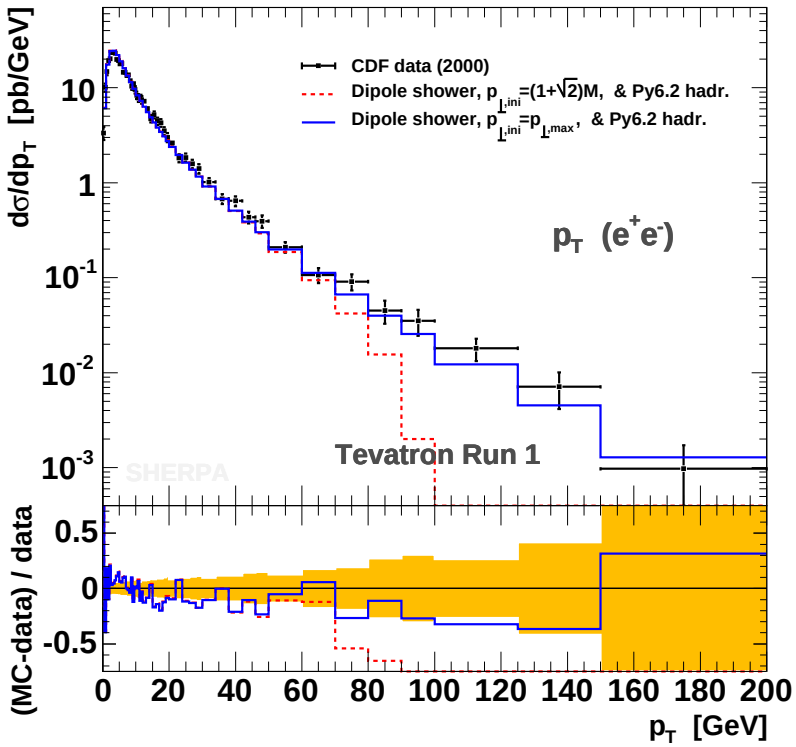
## ADICIC++

- Emission off colour dipoles (associated to initial and/or final state colour lines)
- Idea implemented in Ariadne, very good performance for LEP/HERA
- In addition: Initial state emission formulated completely perturbative

# First results with CSSHOWER++ and ADICIC++ (no merging yet)




CSSHOWER++: Inclusive Jet production




ADICIC++: Boson $p_T$ in Drell-Yan

# Outlook

## Near future

- Merging between all combinations of shower and matrix element generators
- Inclusive decays, including spin correlations, finite width treatment
- Shower in DIS-like situations (better in dipole approach)

## Far future

- NLO matrix elements
- Merging showers with NLO matrix elements

## http://sherpa-mc.de

- Downloads
- Announcement mailing list
- Documentation