Matrix-Element-Corrected Parton Showers: Pythia Update

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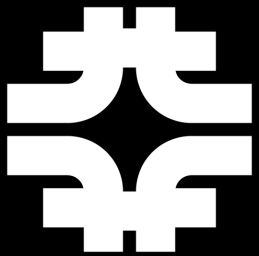

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MC4LHC Working Group on MEs and Matching

Previous Work

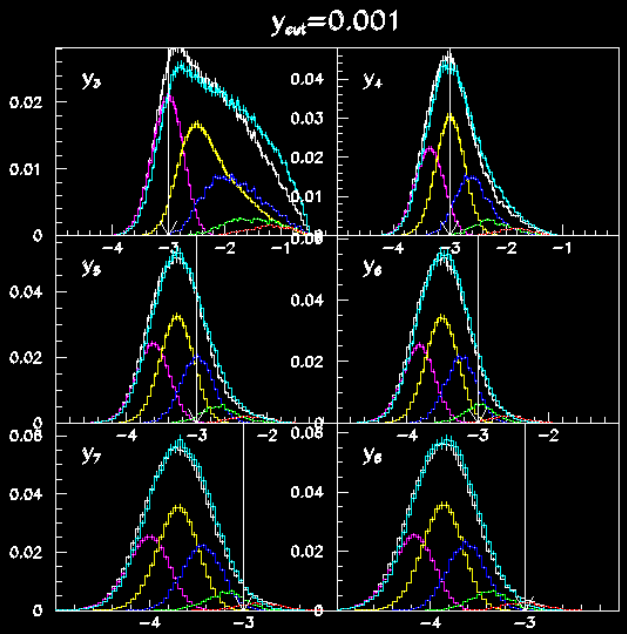
- PR (HERWIG) and SM (Pythia) agreed on "trivial" changes to implement CKKW
  - Allow for arbitrary starting scale per parton
  - Veto on emissions harder than an arbitrary scale
- k_T is not the "natural" kinematic variable
  - HERWIG: θ via $\sqrt{\xi} \sim \theta$
  - Pythia: θ via m^2, z
- Results were not entirely discouraging for e^+e^- test case
  - $p_T^2 = z(1-z)m^2$ or $\min(z, 1-z)m^2$ gave a better description in Pythia
  - Kinematics at any stage in the shower is not the same at the end of the shower: not vetoing the exact variable

Description of Plots

- Events are k_T-clustered at the parton or hadron level
- $k_T^2 = 2\min(E_i, E_j)^2(1-\cos\theta) = \min(E_i/E_j, E_j/E_i)m_{ij}^2$
  - k_T^1 is hardest, $k_T^2 < k_T^1$, $k_T^{m+1} < k_T^m$
- In hadronic collisions, particle can also be clustered with beam
  - For $W+1$ parton, $k_T^1 = p_T$ of parton
- In e^+e^-, plot $\log_{10}(y)$, $y = k_T^2/E_{\rm cms}^2$
- $Q_{\rm res} = k_T$-cutoff applied on ME events
- Colors
  - Cyan = Ordinary PS result (with built-in ME correction)
  - White = ME-corrected PS result (no built-in correction)
  - Magenta = 0 emission correction
  - Yellow = 1 emission correction, etc.

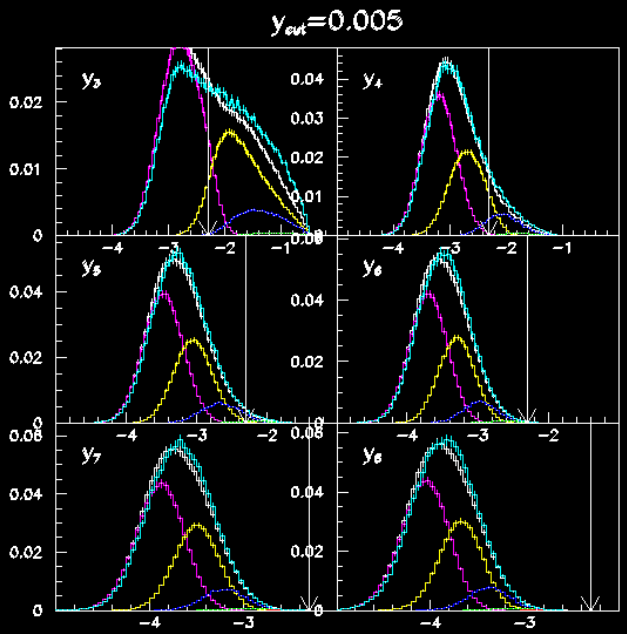
$\min(z, 1-z)Q^2$: $Q_{\mathrm{res}} = 2.9$ **GeV**

Hadron Level



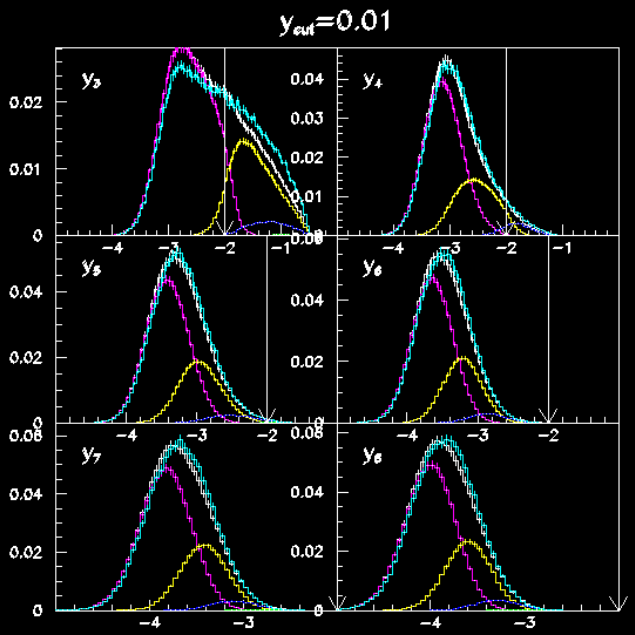
$\min(z, 1-z)Q^2$: $Q_{\mathrm{res}} = 6.5$ **GeV**

Hadron Level



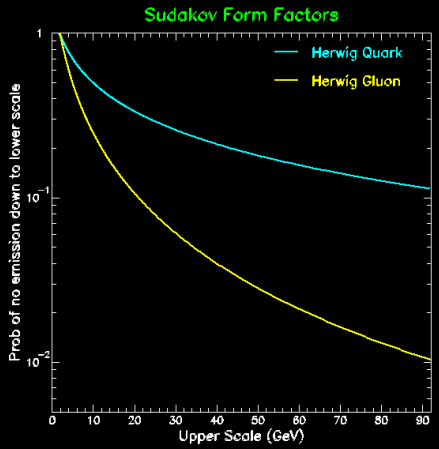
$\min(z, 1-z)Q^2$: $Q_{\mathrm{res}} = 9.2$ **GeV**

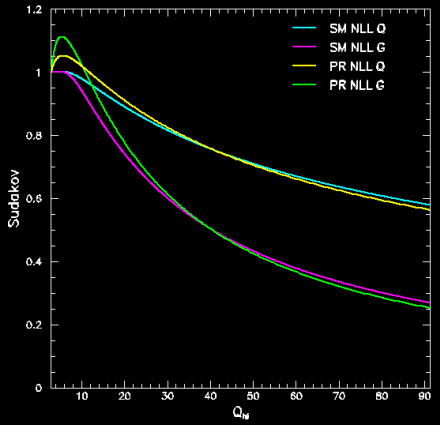
Hadron Level



Sudakovs

Which one?

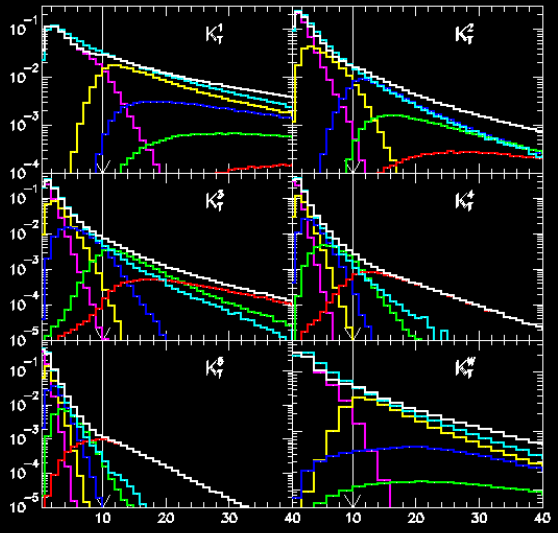




Implementation at a Hadron Collider

W Production at the TeVatron

$k_T = 10$ GeV, veto on $p_T^2 = (1-z)Q^2$



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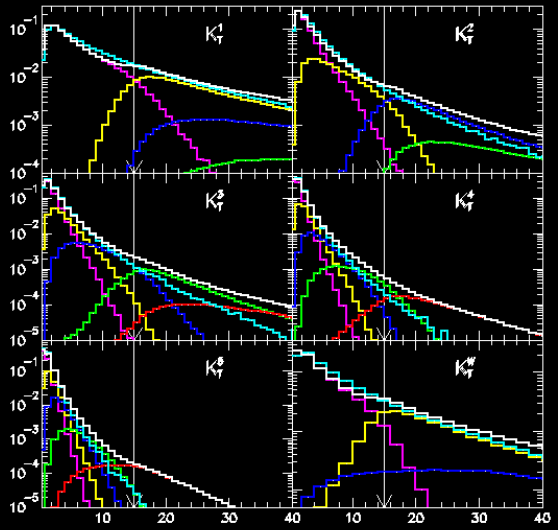
W Production at the TeVatron

$k_T = 15$ GeV, veto on $p_T^2 = (1-z)Q^2$



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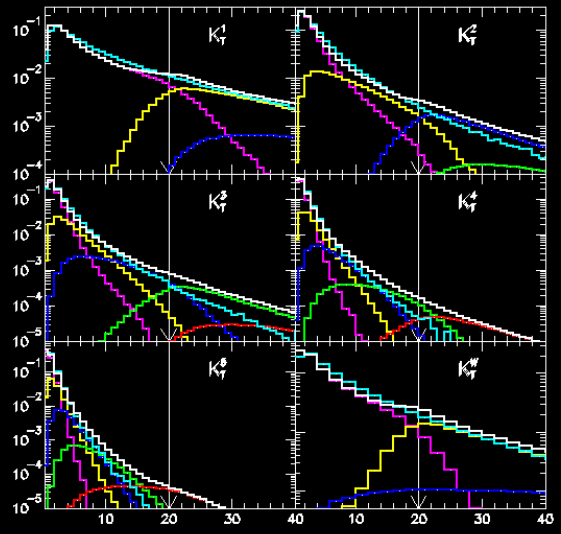
W Production at the TeVatron

$k_T = 20$ GeV, veto on $p_T^2 = (1-z)Q^2$



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Comments

- Radiation Dips and Bumps
  - Consequence of the shower veto on an approximation to the k_T
    - i.e. approximation that daughters are (initially) massless
  - No way around this with the current shower algorithm
- Rethink the problem
  - Redo the parton shower?
    - Requires retuning/testing of hadronization
  - Relate the natural PS variable to the matrix element cut?
    - θ in `HERWIG`, p_T in `Pythia`
    - Not obvious that k_T is the best-behaved variable
      - `hep-ph/9804296 [LL,TS,SMo]`
  - Apply full veto at end of shower?
    - Better apply Sudakov of the shower itself

Analytic $\Rightarrow$ Monte Carlo Sudakovs

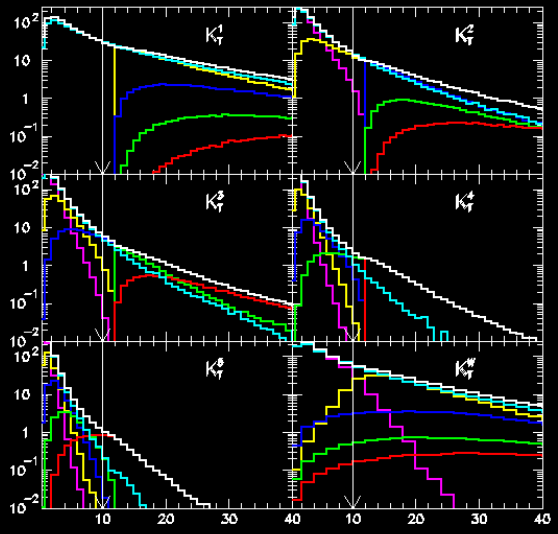
- based on idea of Leif L.:: hep-ph/0112284+JHEP
  - applied to $e^+e^- \to 4j$ using Ariadne
- Mixes two ideas, but I think they are related
- PS mapping of events
  - Calculate internal Sudakov factors from "pseudo" showers
  - $W + N$ partons $\Rightarrow N + 1$ resolved showers
  - Use rejection (throw event away) if $k_T > k_T^{\text{res}}$
  - Internal veto uses approximate one based on p_T
  - Slight oversampling makes smooth transition




Pythia **Pseudo-Showers**

W Production at the TeVatron

$k_T = 10/12$ GeV



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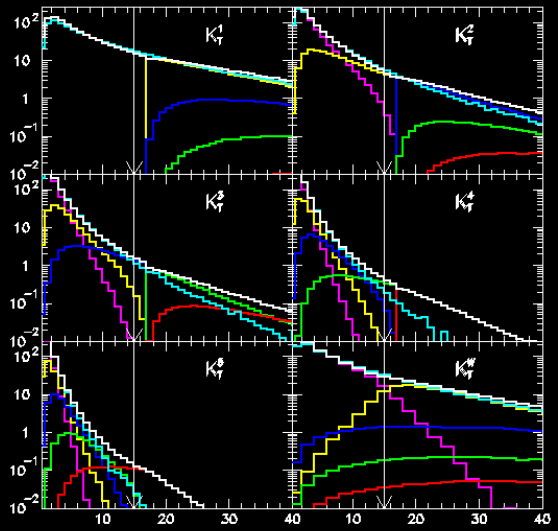
W Production at the TeVatron

$k_T = 15/17$ GeV



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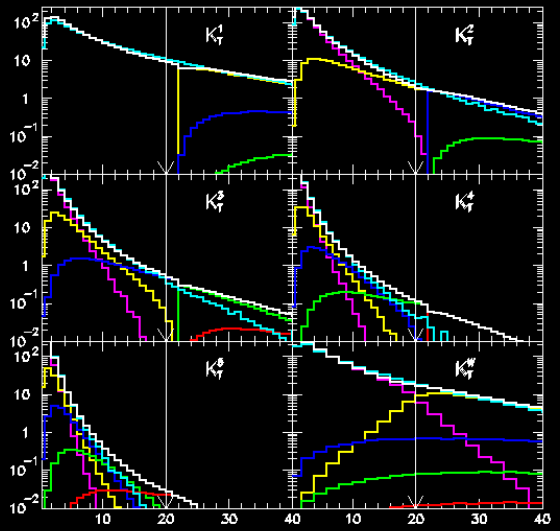
W Production at the TeVatron

$k_T = 20/22$ GeV



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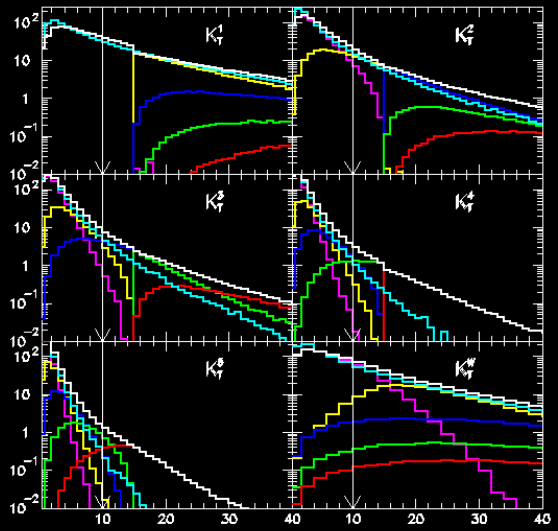
Shower History

- Details of Shower History are Important
  - Try to use full color+flavor information
    - flavor,color lines
  - If not possible, throw away color
    - $1/N$ suppressed color flows
    - clustering gets stuck
    - small effect
  - When no history exists, pass as a true ME correction
    - No Sudakov suppression
    - Only require k_T above resolution scale
- "Factorized" expression only in soft-collinear limit

HERWIG Pseudo-Showers

W Production at the TeVatron

$k_T = 10/15$ GeV



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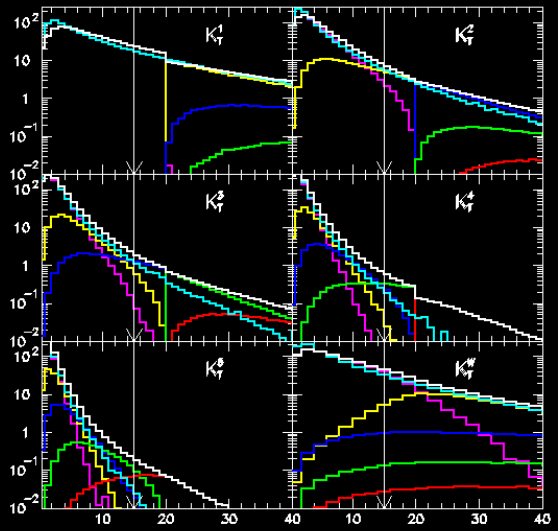
W Production at the TeVatron

$k_T = 15/20$ GeV



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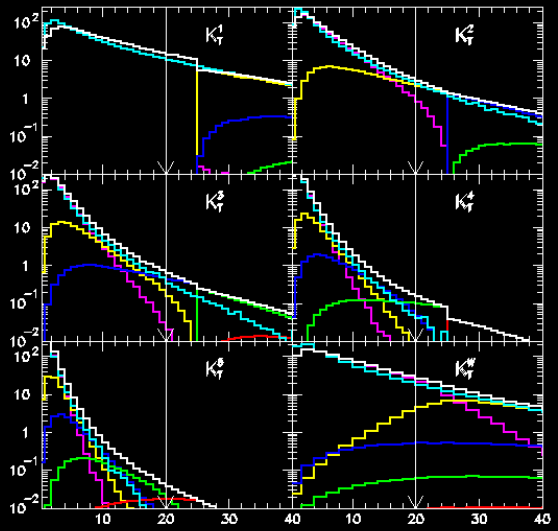
W Production at the TeVatron

$k_T = 20/25$ GeV



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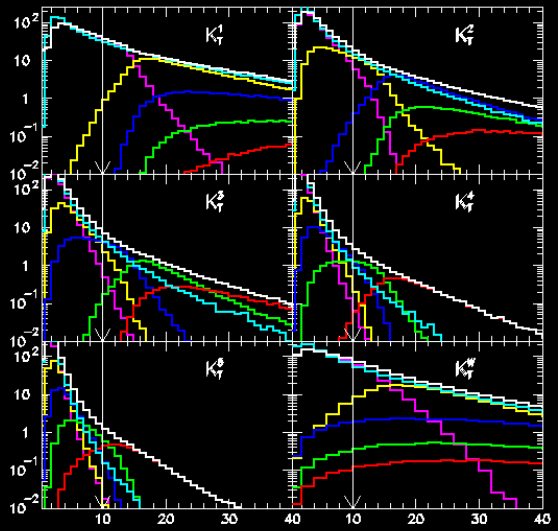
HERWIG at HADRON level

W Production at the TeVatron

$k_T = 10/15$ GeV



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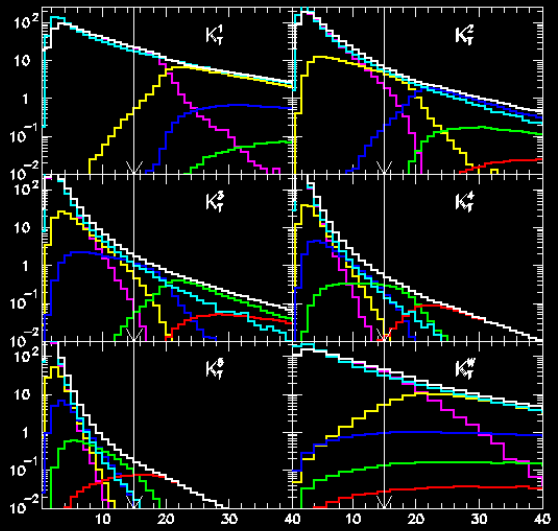
W Production at the TeVatron

$k_T = 15/20$ GeV



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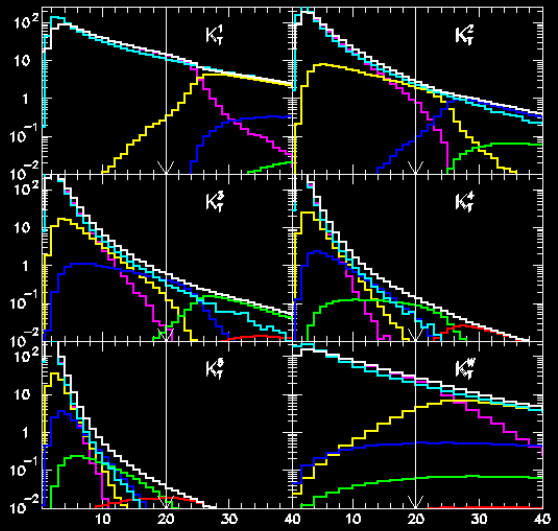
W Production at the TeVatron

$k_T = 20/25$ GeV



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Facts

- Internal veto on HERWIG $(2-\xi)(z_1 z_2 Q_{\rm now})^2$
- Starting scales set to k_T values
- Starting scales in Pythia are m values (for given k_T)
  - $k_T < m$
- Need to optimize treatment of highest multiplicity

Future Work

- cluster with and without color information
- shower modifications
  - post-LH:: New p_T-ordered parton shower exists (TS)
- ME clustering on different kinematic variables
  - e.g. p_T with respect to mother

Matching is not trivial

- All ME-PS interfaces have some systematics
- How large?
- I feel safer using the Monte Carlo to determine the matching
- MLM prescription is working this way
  - throw away events that are too hard
    - Rejection method of sampling
  - Intrinsic k_T cutoff $= E_T^{\min} \Delta R_{\min}$
  - Applying no internal Sudakov suppression
    - okay if internal momenta are large

Applicability

Can we apply a K-factor?

$$\sigma = \sigma_0 \otimes (\mathsf{PS}) \quad (\mathtt{PY}, \mathtt{HE})$$
$$\sigma = \sigma_0 \otimes (\mathsf{PS}) \underbrace{-\sigma_0 \otimes (\mathsf{PS})|_{\mathsf{FO}} + +\sigma(\mathsf{ME})|_{\mathsf{FO}}} \quad (\mathtt{CKKW})$$
$$\sigma = W + Y \quad (\mathtt{CSS})$$

- We are making a mistake in rescaling to NLO
- It is a smaller mistake than applying a K factor to LO-PS