HERA and the LHC 2006 —
Summary of MC&Tools (WG5)

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with Paolo Bartalini (U Florida), Thomas Kluge (DESY), Frank Krauss (TU Dresden)

- Sessions
- Alternative Shower Formulations
- Higher Orders, Merging ME+PS etc.
- Conclusion

Sessions in WG5

20 talks in 6 topical sessions:

- **Underlying events** (joint with WG2)
  4 talks
  → Paolo Bartalini.
- **Alternative Shower Formulations**
  3 talks
- **Higher Orders/merging etc.** (joint with WG2)
  4 talks
- **PDFs** (joint with WG1 and WG2)
  3 talks
  → Leif Lönnblad (summary of WG2, yesterday).
- **Fragmentation and Hadron Decays**
  2 talks
  → Paolo Bartalini.
- **Validation of Monte Carlos**
  4 talks
  → Paolo Bartalini.

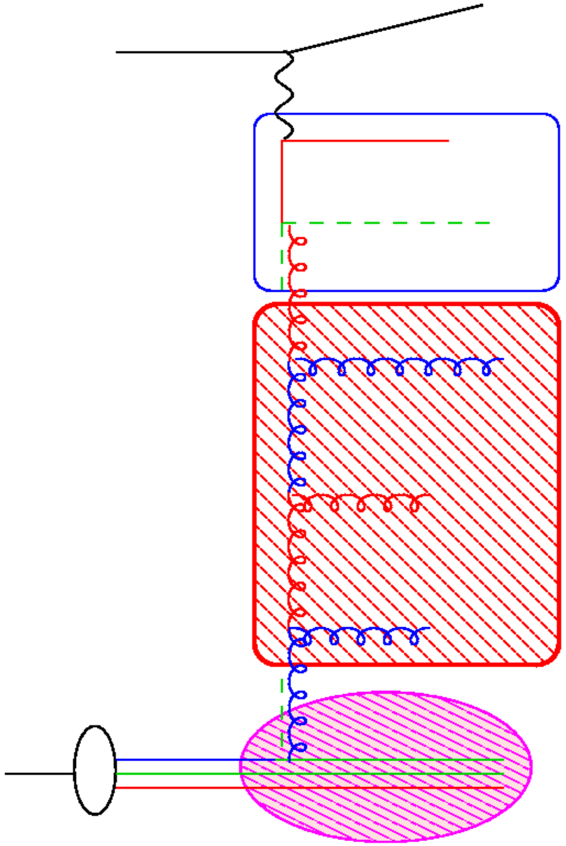
Alternative Shower Formulations

- Hannes Jung:
  Cascade and Rapgap
  Alternatives to usual DGLAP evolution?
- Staszek Jadach:
  Double Constrained Evolutions in a single MC for DY type processes — A prototype
  new (DGLAP type) parton shower *algorithm* with extensions to NLO in mind.
- Scott Yost:
  QED$\otimes$QCD Exponentiation and Shower/ME Matching at the LHC
  Yennie Frautschi Suura type exponentiation in QCD?

CASCADE – Catani Ciafaloni Fiorani Marchesini evolution

CCFM (all loops)

- angular ordering
- non – Sudakov Δ_{ns}

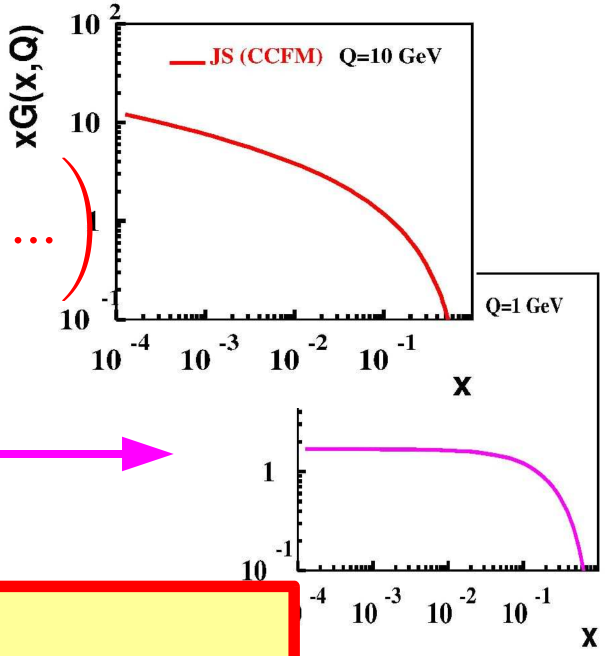


BGF matrix element
off shell

evolution of parton
cascade:

$$\tilde{P} = \bar{\alpha}_s \left(\frac{1}{1-z} + \frac{1}{z}\Delta_{ns} + \ldots \right)$$

initial distribution
~ flat



$$\sigma(ep \to e'q\bar{q}) = \int \frac{dy}{y} d^2Q \frac{dx_g}{x_g} \int d^2k_t \hat{\sigma}(\hat{s}, k_t, Q) x_g \mathcal{A}(x_g, k_t, \bar{q})$$

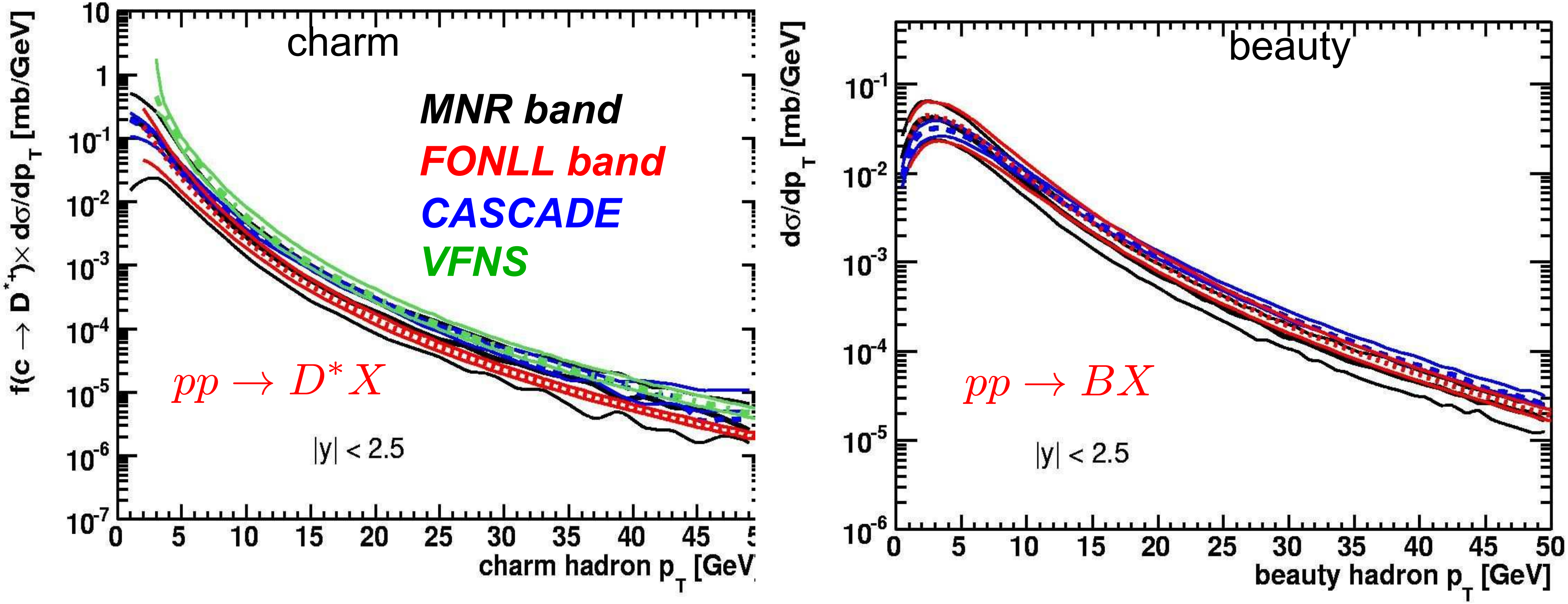
$$\int d^2k_t x_g \mathcal{A}(x_g, k_t, \bar{q}) \simeq x_g G(x_g, Q^2)$$

Charm and Beauty at the LHC

from HERA-LHC proceedings 2005O. Behnke et al, p 405

Benchmarks at hadron level in central region

MNR (massive NLO) – *FONLL (matched NLL)* – *CASCADE (uPDF)* - *VFNS*

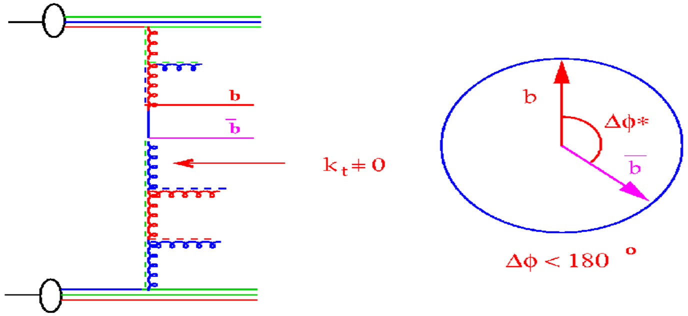


CASCADE agrees well with **MNR** and **FONLL** for charm and beauty.
VFNS is larger for charm at small p_t ...

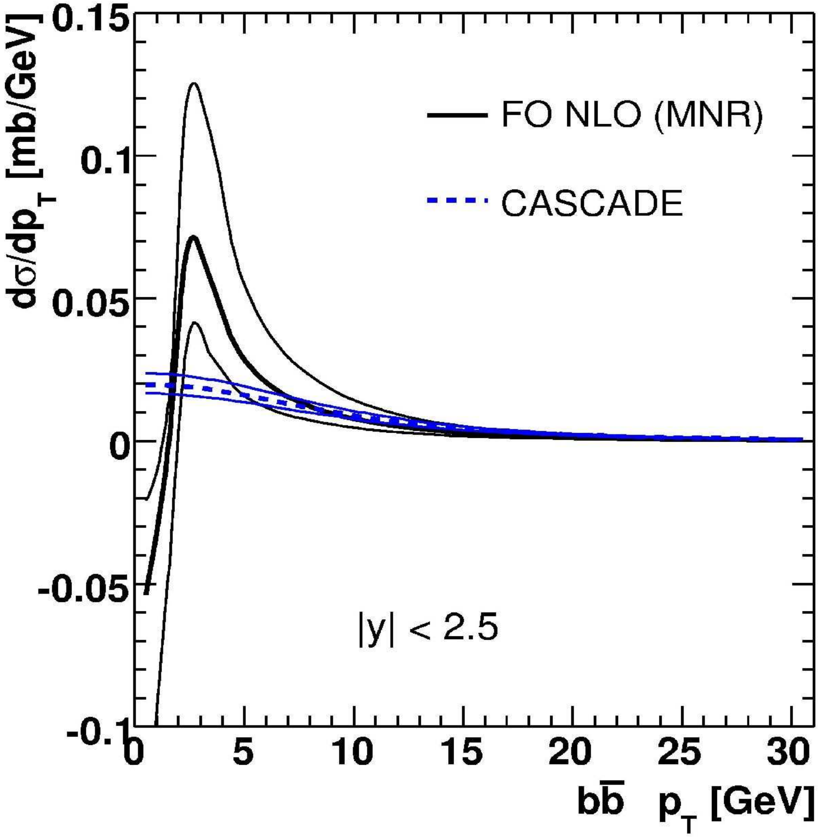
All agree reasonably well ...But large uncertainties **!!!**

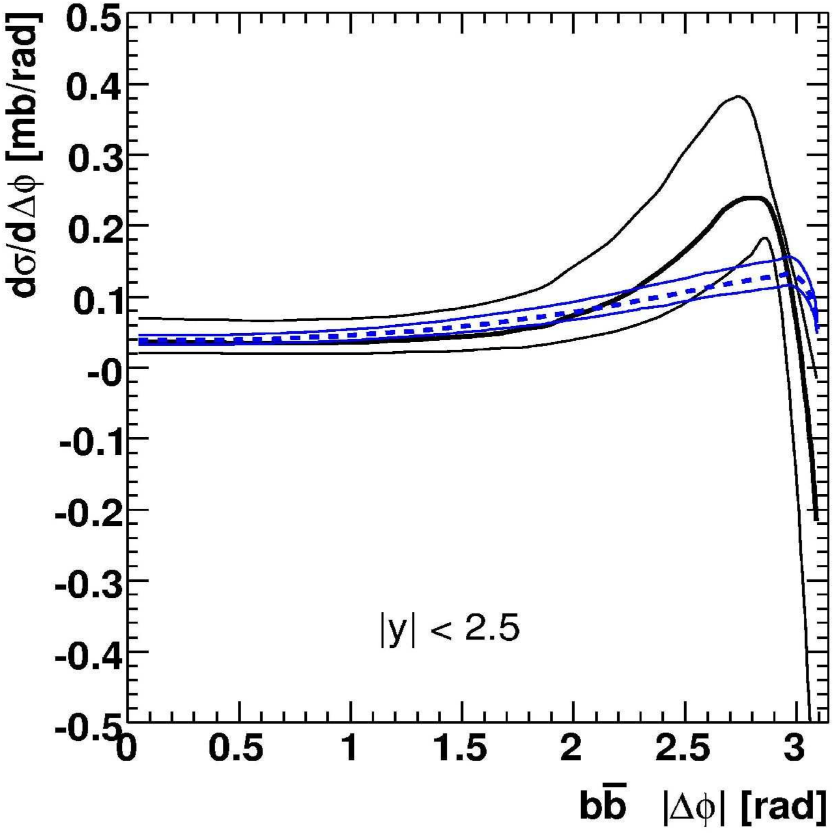
pt and phi correlations at LHC

from HERA-LHC proceedings 2005O. Behnke et al, p 405



- transverse momentum of quark-antiquark system $p_T(Q\bar{Q})$
- azimuthal separation between two heavy quarks $\Delta\phi(Q\bar{Q})$

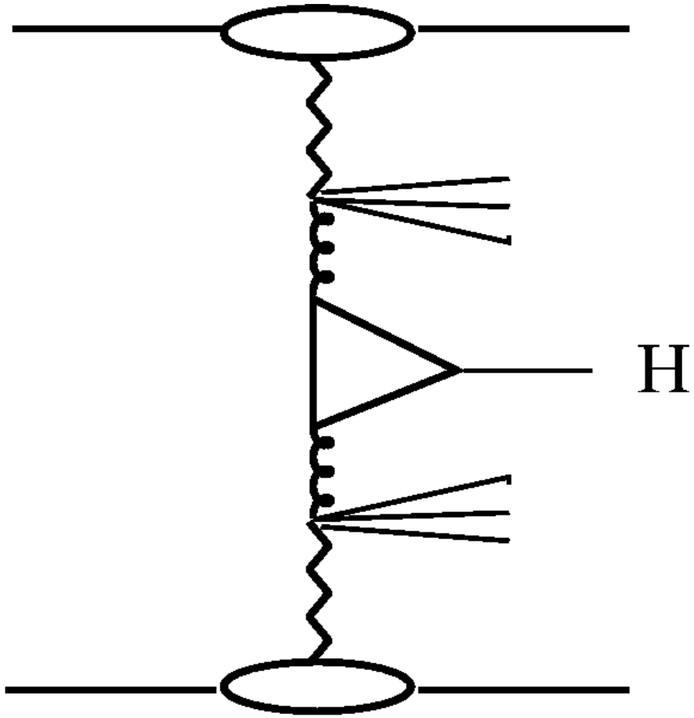




CASCADE has smaller uncertainties !!!

Future Plans for RAPGAP

- Multiple Interaction via PYTHIA also for DIS (resolved photoproduction)
- double diffraction also for *pp*
- double pomeron Higgs



➔ Any other special processes for LHC needed ?

Single “QCD Evolution” using Monte Carlo, various types

Evolution types and solution methods:

- **Evolution: Common forward, unconstrained, (ISR, FSR):**
  - **Method of solving: straightforward Markovian MC algorithm (MMC)**
- **Evolution: Constrained (ISR):**
  - **Method: Constrained MC algorithm, non-Markovian (CMC)**
  - **Method: “Backward evolution” MC algorithm, Markovian (PYTHIA, HERWIG,...)**

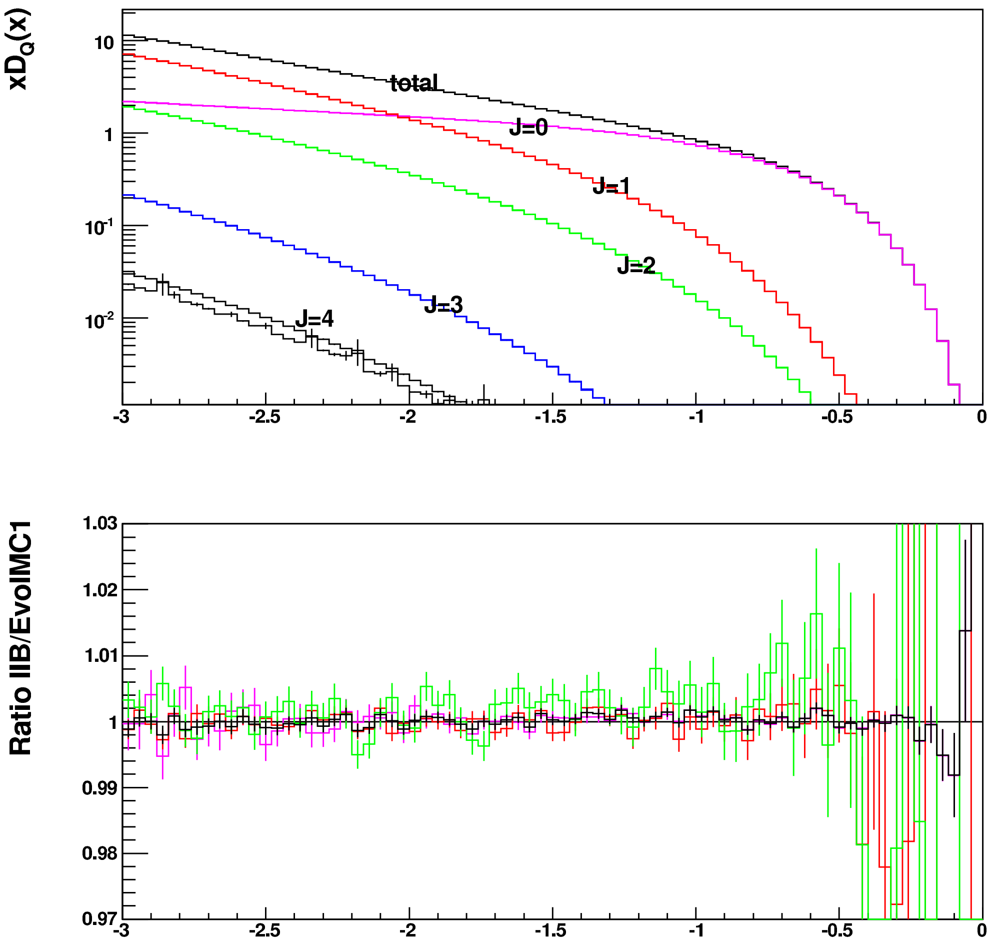
Terminology:

“Markovian MC”: Emission multiplicity generated as last variable in the MC,

“Non-Markovian MC”: Emission multiplicity generated as first variable (or 2nd).

“Constrained evolution”: Final parton type and energy fraction x in the evolution are predefined, fixed. However, all the distribution can be identical as in the forward evolution (Markovian style).

Test CMC/MMC; Evolution 1GeV → 1TeV



$J = 0$: $Q \rightarrow Q$

$J = 1$: $G \rightarrow Q$ and any no. of gluon emissions out of Q and G,

$J = 2$: $G \rightarrow Q \rightarrow G \rightarrow Q$, etc.

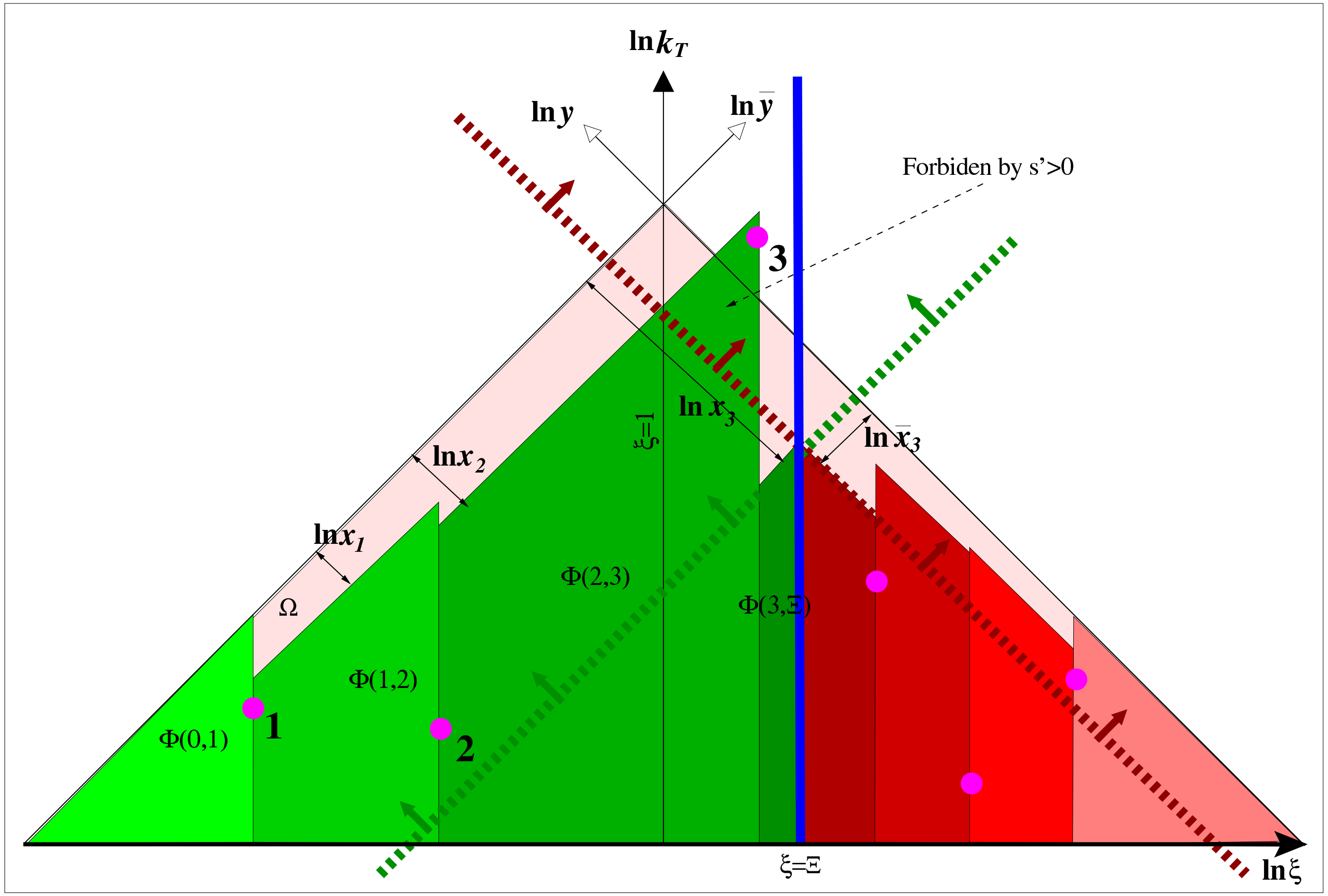
$J = 3$: $G \rightarrow Q \rightarrow G \rightarrow Q$, etc.

$J = 4$: $Q \rightarrow G \rightarrow Q \rightarrow G \rightarrow Q$, etc. “Total” is the sum of $n = 0, 1, 2, 3, 4$.

Evolution in LL, with $\alpha(q(1-z))$, $\epsilon_{IR} = 1GeV/q$ (HERWIG/CCFM style).

This result was obtained June 2005

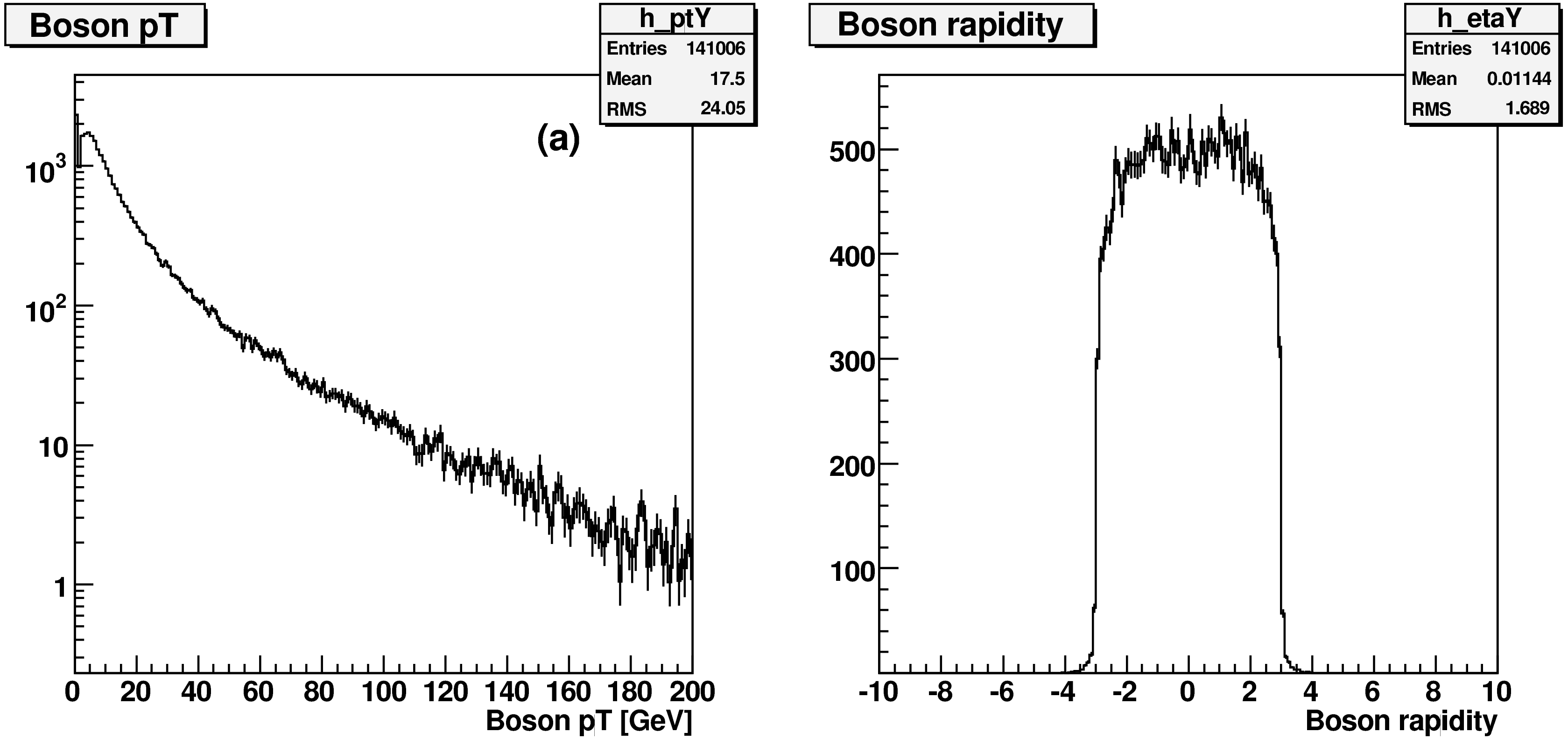
Joining smoothly two evolutions in 2 hemispheres



The above scenario is already implemented in the prototype Monte Carlo.

There is however one IMPORTANT PROBLEM to be solved:
In the existing CMC for single evolution we put constraint on the $\sum_F p_i^+$ of all gluons in the forward hemisphere and separately on the $\sum_B p_i^-$ in the backward one.
This is not what we need! We need to put the constraint on the effective mass of the W/Z boson which involves also $\sum_F p_i^-$, $\sum_B p_i^+$ and total transverse momenta.
Additional requirement: Total control on the overall normalization.
Can we do it? Yes! We did it, it works! The method is explained in the following.

EW boson transverse momentum and rapitity distributions



Transverse momentum and rapidity distribution of the EW boson (mass 100GeV). Matrix element is maximally simplified (only Breit-Wigner).

Conclusions

- YFS Theory extends to non-abelian gauge theory and allows the simultaneous exponentiation of QED and QCD with proper shower/ME matching built in.
- A full MC event generator realization is possible.
- Semi-analytical results for QED and QCD threshold effects in Z production agree with the literature.
- Since QED enters at the 0.3% level, it is essential for reaching 1% theory predictions for the LHC.
- A firm basis for constructing the complete order α_s^2, $\alpha\alpha_s$, α^2 MC results needed for physics at FNAL, LHC, RHIC, and the ILC has been described, and all of the required processes are being calculated in this framework.

Threshold Corrections

Numerically, for parameters relevant to the LHC and Tevatron, with and without the QED contribution,

$$\frac{\sigma_{\text{exp}}}{\sigma_{\text{Born}}} = \begin{cases} 1.1901, & \text{QCED = QCD} \quad \text{QED, LHC} \\ 1.1872 & \text{QCD, LHC} \\ 1.1911 & \text{QCED = QCD} \quad \text{QED, Tevatron} \\ 1.1879 & \text{QCD, Tevatron} \end{cases}$$

- QED enters at 0.3% for both LHC & FNAL.
- This is stable under scale variations.
- We agree with Baur *et al*., Hamberg *et al*., van Neerven and Zilstra.
- The QED effect is similar in size to what is seen in the structure functions.

Higher Orders/merging etc.

- André van Hameren:
  Automatisation of NLO calculations
  Dyson–Schwinger recurrance relations taken to NLO? Techniques to reduce one–loop tensor integrals.
- Michele Treccani:
  Alpgen vs. MC@NLO for $t\bar{t}$
  Parton level comparison with interesting differences. . .
- Jan Winter:
  Sherpa vs. D0 in $Z + \mathrm{jets}$
  CKKW helps describing final states with high jet multiplicity!
- Zoltán Nagy:
  New PS algorithm: shower evolution, matching at LO and NLO
  Formal description of what is going on in parton shower MC's. Use of Catani–Seymour subtraction kernels may prove *very* useful in matching NLO computations. Matching to high mulitplicity ME's with a subtraction method (as opposed to the phase space separation in the CKKW algorithm).

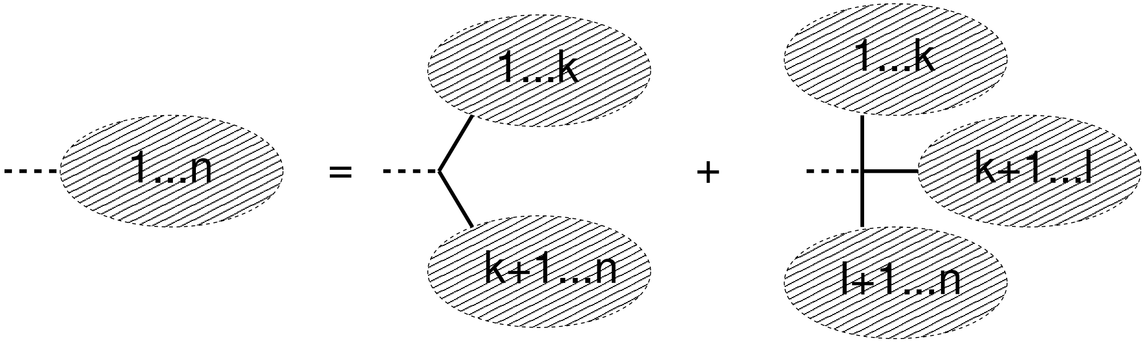
Recursion relations for QCD

III of III

Recusion relations are the most efficient way for numerical calculation, but can also easily be put in a computer-algebra system with tree-level result:

$$\mathcal{M} = \sum_{\text{non-cyc}} \delta_{j_2}^{i_1} \delta_{j_3}^{i_2} \cdots \delta_{j_n}^{i_{n-1}} \delta_{j_1}^{i_n} \mathcal{A}(1,2,\ldots,n) \ .$$

The partial amplitude $\mathcal{A}$ satisfies the color-ordered recursion relation [Berends, Giele 1988]



where a summation over all distributions of ordered external particles is understood. Propagators and vertices are without color structure.

Color-decomposition also exists for one-loop amplitudes.

Recursive equations for tensor integrals

II of II

This can be used to reduce tensor integrals in D dimensions by decomposing $q_D = q_4 + q_{D-4}$, which leads to the addition of terms proportional to integrals

$$I^{\mu_1\mu_2\cdots\mu_r}_{n,r;2} = \int \frac{d^D q}{i\pi^{D/2}} \frac{q^2_{D-4}\, q_4^{\mu_1} q_4^{\mu_2} \cdots q_4^{\mu_r}}{q^2(q+p_1)^2(q+p_2)^2\cdots(q+p_{n-1})^2}$$

in the recursive equation.

- Recursive equation becomes a bit simpler for rank $r = 1$.
- Use the “direct” method for the scalar functions.
- Computation on Pentium IV at 2GHz of $I_{n=4,r=4}$ takes 0.005s, $I_{6,6}$ takes 0.09s, $I_{8,8}$ takes 0.5s, $I_{10,10}$ takes 2.4s.

ALPGEN & MC@NLO

Process: $t\bar{t} + 1$ jet

- S. Frixione and B. R. Webber, "The MC@NLO 3.2 event generator" hep-ph /0601192

  General approach: S. Frixione and B. R. Webber, JHEP **0206** (2002) 029 [hep-ph /0204244];

  $t\bar{t}$ production: S. Frixione, P. Nason and B. R. Webber, JHEP **0308** (2003) 007[hep-ph /0305252].

- ALPGEN:
  - Generation cuts: $P^t_{min} = 30\,GeV,\ \Delta R = 0.7$
  - Matching cuts: $E^t_{min} = 30\,GeV,\ \Delta R = 0.7$

Jet definition adopted in the analysis:

$TeVatron\ E^t_{min} = 15\,GeV,\ \Delta R = 0.4$ $LHC\ E^t_{min} = 20\,GeV,\ \Delta R = 0.5$

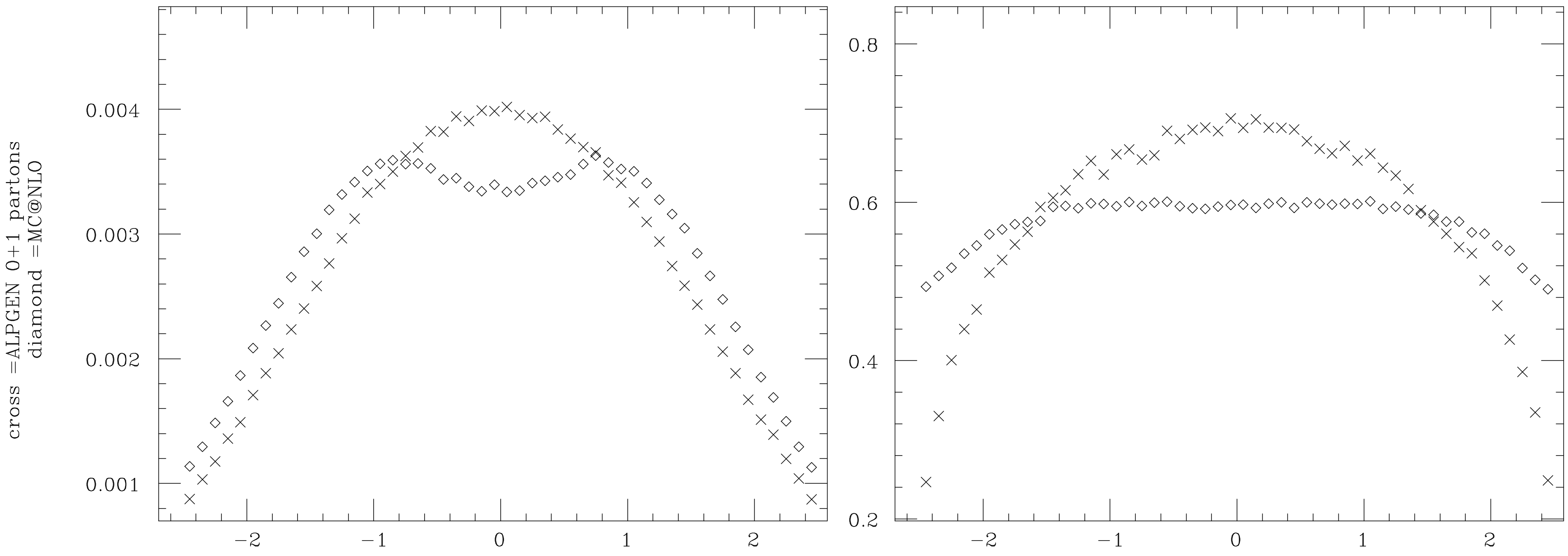
Comparison between ALPGEN & MC@NLO→ introduce the K-factor

$TeVatron$ $K = 1.46$ LHC $K = 1.80$

Conclusions

- It has been studied the mlm matching prescription implemented in ALPGEN
- Impact of N extra-parton contributions: mlm matching effectively separates phase space, rejecting double events (double & single collinear logs)
- The matching procedure is stable against (small) parameters variations (work in progress)
- Comparisons between normalized ALPGEN(0+1) and MC@NLO:
  - Inclusive Observables → good agreement
  - Leptonic Observables → differences due to the inclusion of spin correlations in ALPGEN
  - Radiation-related Observables → evident discrepancies
    - PS shows a depletion region in (leading) jet rapidity, near $Y = 0$
    - ALPGEN rejects PS events responsible for the depletion adopting instead ME events, filling the depletion

Extra-radiation, leading jet Y



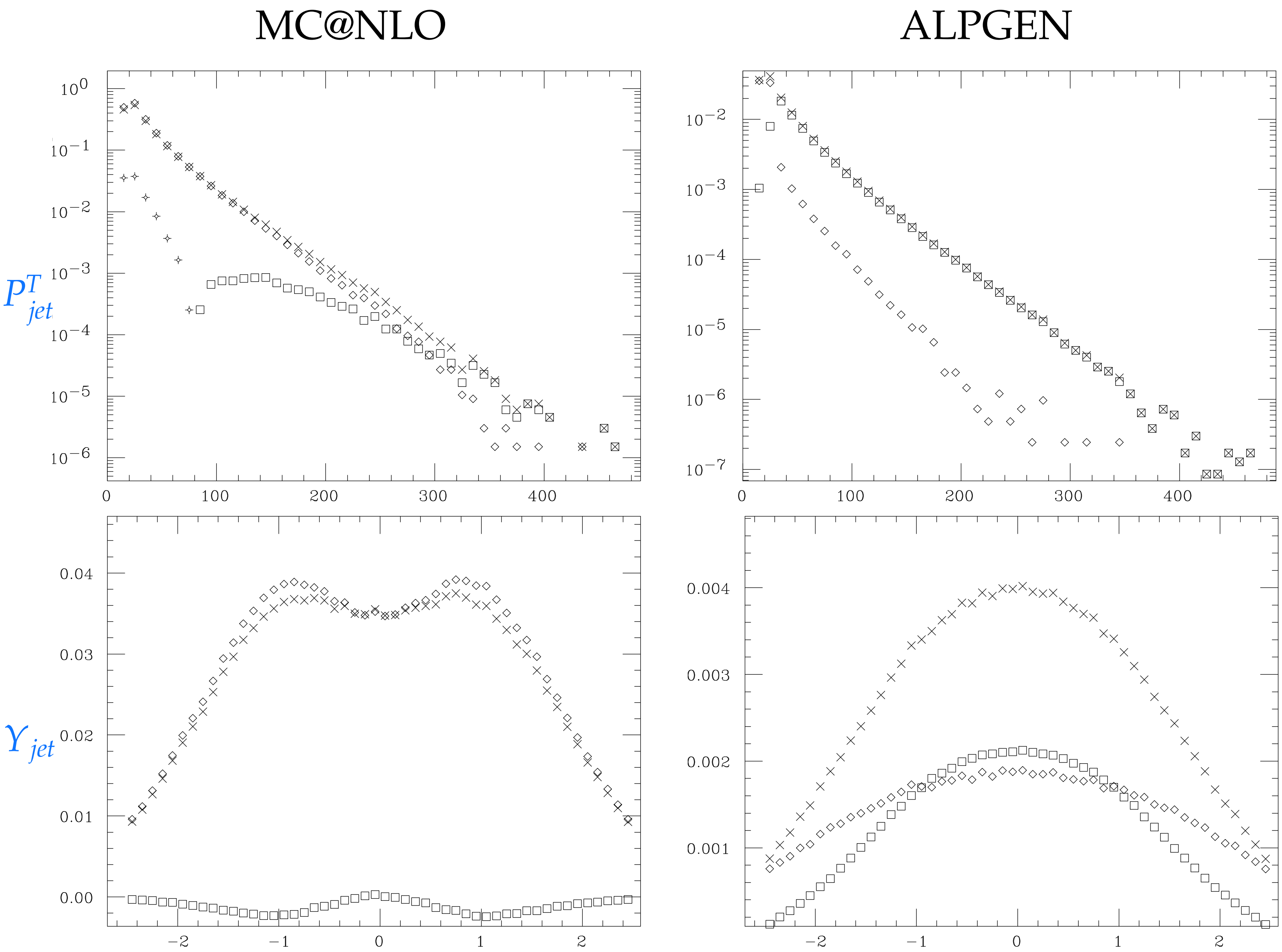
TeVatron

LHC

MC@NLO(◇) ALPGEN(×)

Different structure both at TeVatron and LHC

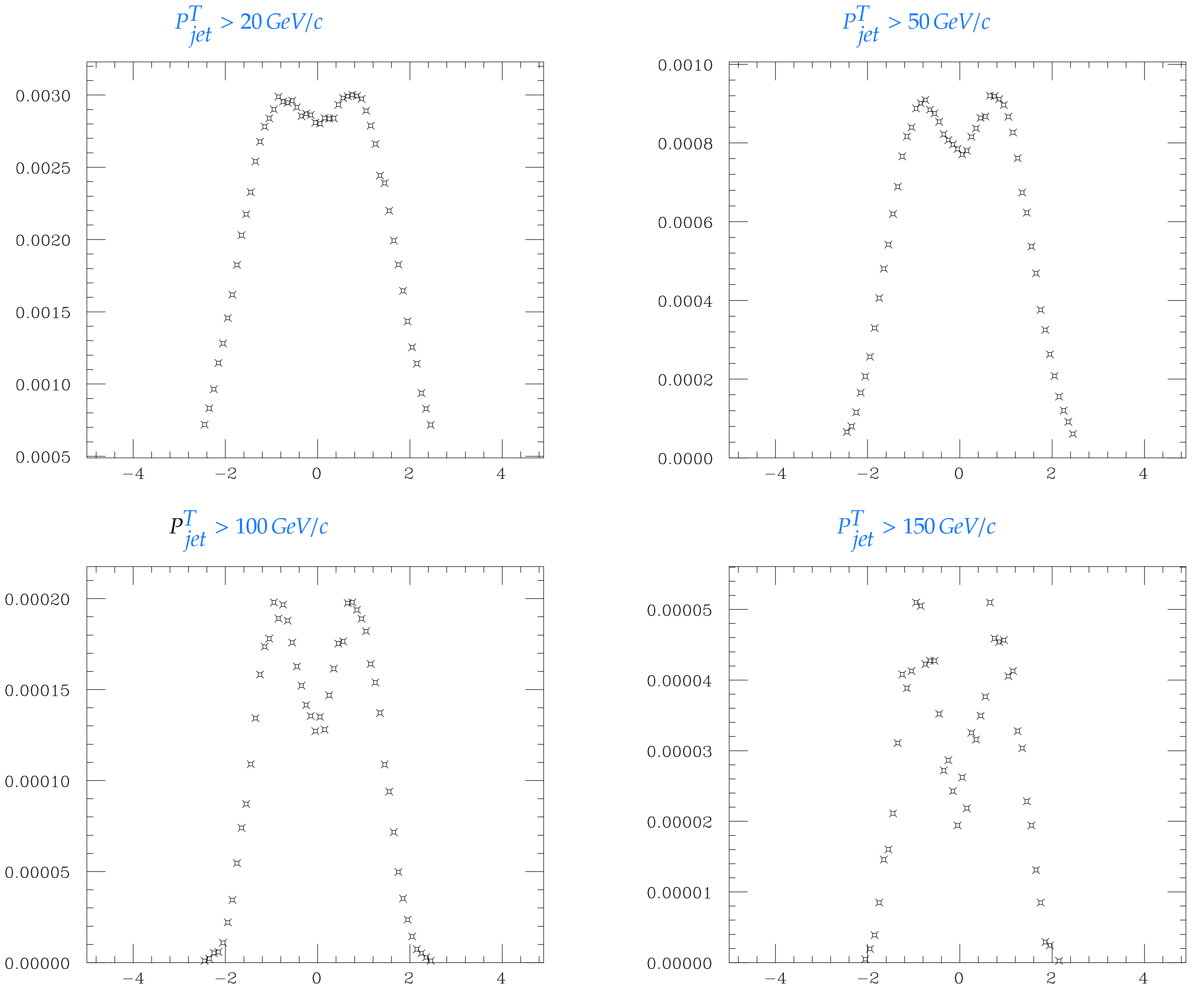
TeVatron increased effect, let’s study partial contributions



× total distribution (0+1); ◇ 0 parton contribution;

□ 1 parton contribution; + 1 parton contribution, negative weight

jets from extra-radiation, Y_{jet}, HERWIG



$P_{jet}^{T} > 20\,GeV/c$

$P_{jet}^{T} > 50\,GeV/c$

$P_{jet}^{T} > 100\,GeV/c$

$P_{jet}^{T} > 150\,GeV/c$

The Z/γ^*+jet-production DØ analysis

PYTHIA:

- version 6.319 using CTEQ6L1 PDF
- tuned to match a ME prediction for $Z/\gamma^* + 1$ jet production
- UE model: TUNE A parameter set

SHERPA:

- version 1.0.6 with CTEQ6L PDF
- inclusive $Z/\gamma^* + 3$ jet sample, i.e. ME's up to 3 jets included
- internal separation cut $k_{T,0} = 20\ \mathrm{GeV}$
- UE model: default (set up according to data used for R. Field's TUNE A)

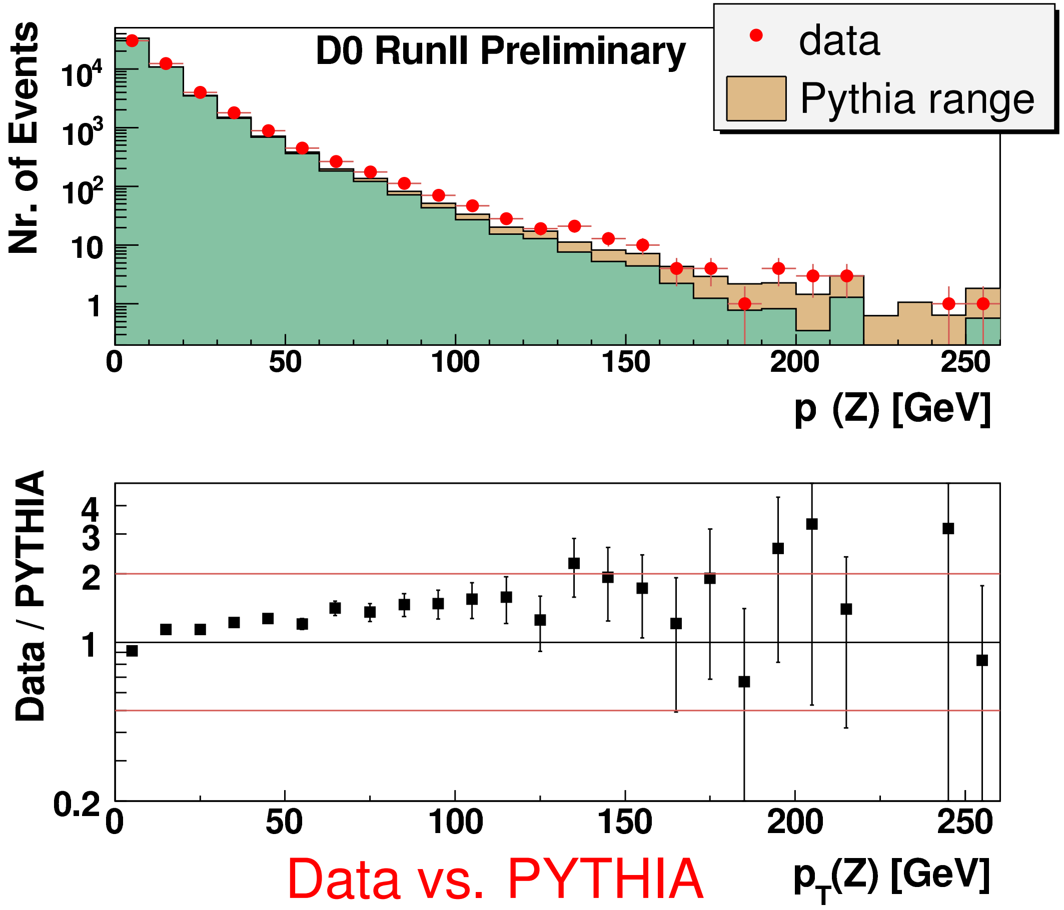
Processing:

- full DØ detector simulation and reconstruction chain
- normalization is to total number of Z/γ^* events found in data sample
- systematic uncertainties: main contributions arise from jet energy scale and smearing of jet energies

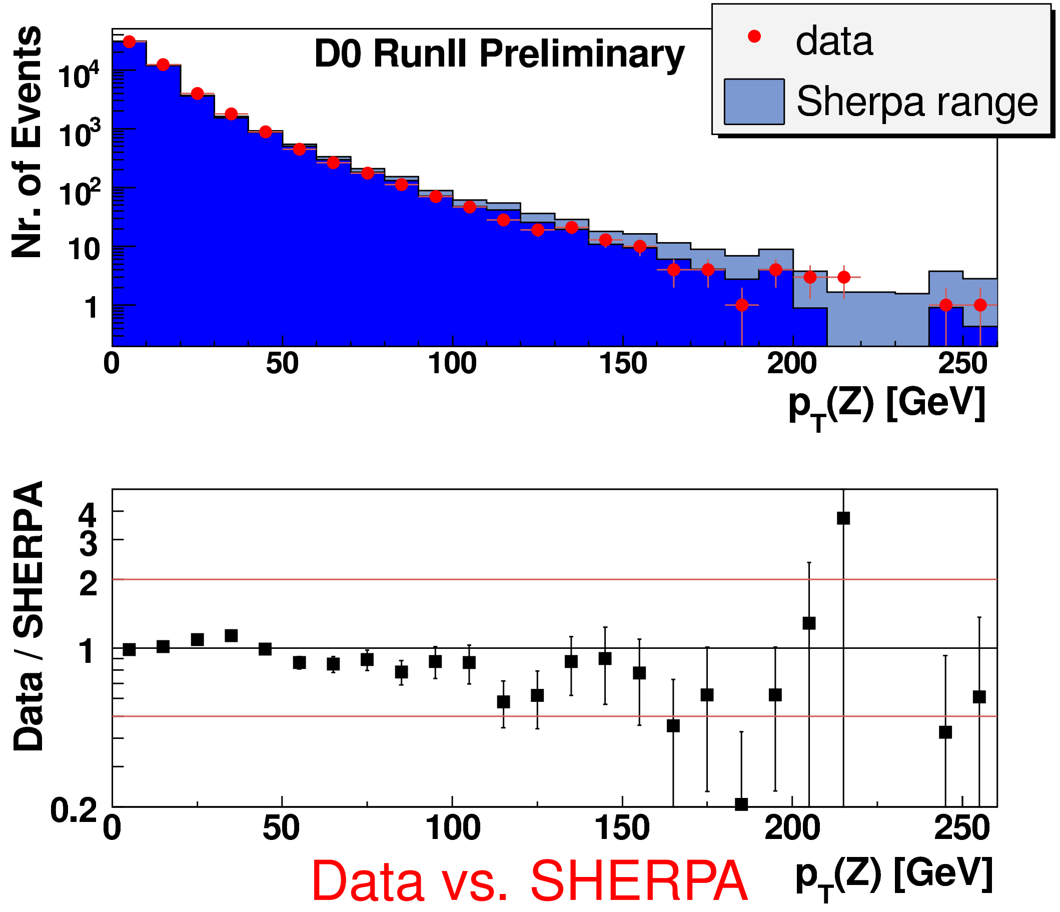
Preliminary DØ results in Z+jet-production

The DØ collaboration, DØ note 5066-CONF

➜ The transverse momentum of the e^+e^- system.



Data vs. PYTHIA



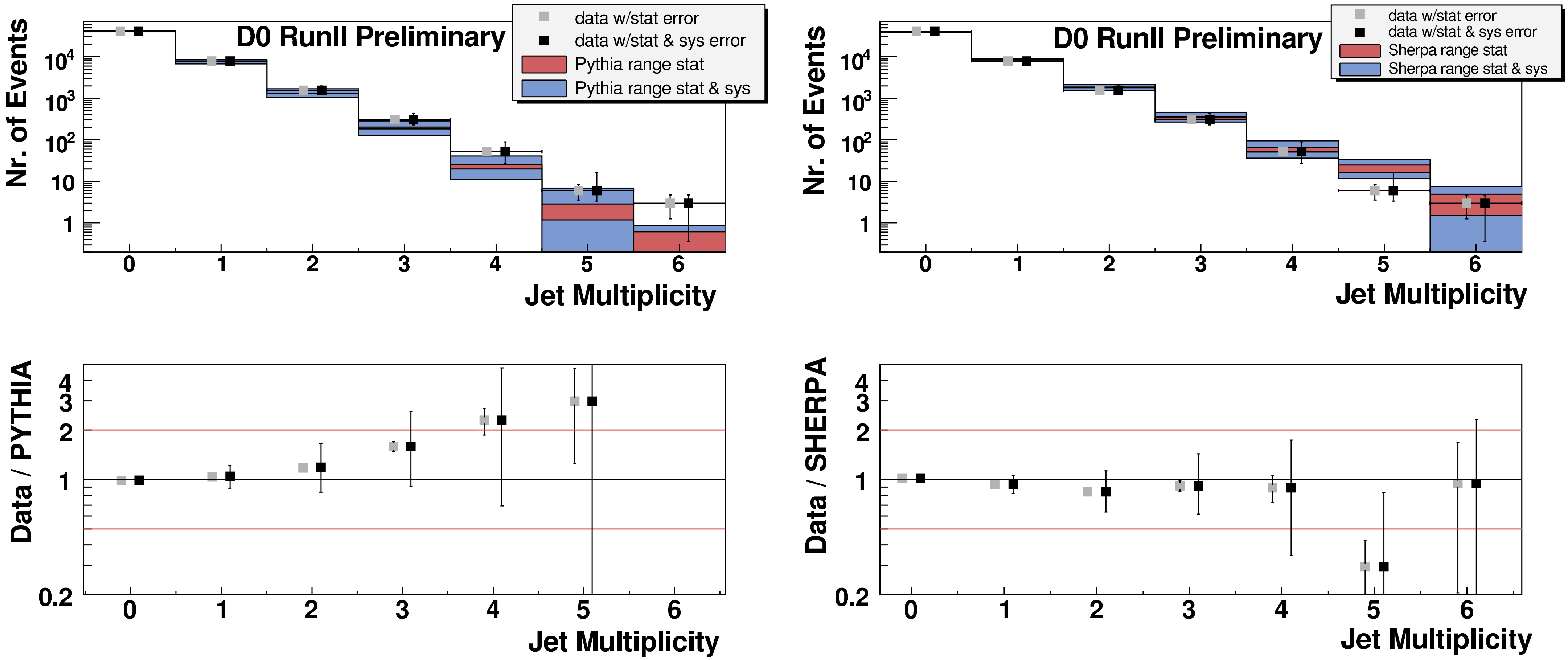
Data vs. SHERPA

- Shaded ranges: MC statistics, central value $\pm 1\sigma$.
- Di-electron system has to balance the p_T of the jet system.

Preliminary DØ results in Z+jet-production

The DØ collaboration, DØ note 5066-CONF

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

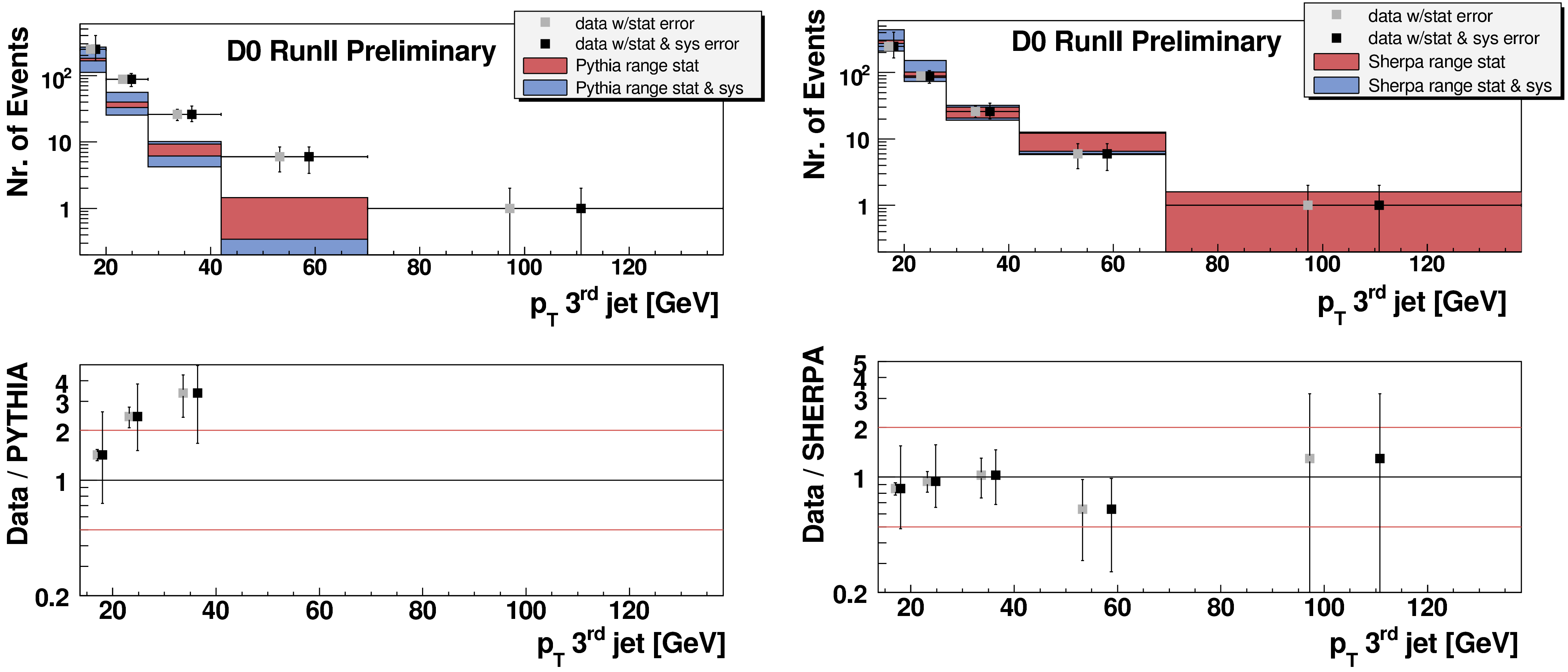


- MC predictions are normalized to total number of events observed in data.
- large systematic uncertainties arise from low p_T jets ⇒ both predictions are in agreement with data.

Preliminary DØ results in Z+jet-production

The DØ collaboration, DØ note 5066-CONF

➡ Jet spectra: 3rd jet, data vs. PYTHIA (left) and SHERPA (right).



- With the same pattern as before.

PARTON SHOWER EVOLUTION

We use an evolution variable e.g.: $\log \frac{Q^2}{\hat{p}_1 \cdot \hat{p}_2} = t \in [0, \infty]$

$$U(t_3, t_1) = \underbrace{N(t_3, t_1)}_{\text{No-splitting part}} + \overbrace{\int_{t_1}^{t_3} dt_2\, U(t_3, t_2)\, \mathcal{H}(t_2)\, N(t_2, t_1)}^{\text{Splitting part}}$$

Preserves the normalization

$$(1|A(t_0)) = 1 \quad \Rightarrow \quad (1|U(t, t_0)|A(t_0)) = 1$$

NO-SPLITTING OPERATOR

The operator $N(t', t)$ leaves the basis states $|\{p, f, c\}_{\mathrm{a,b},m})$ unchanged

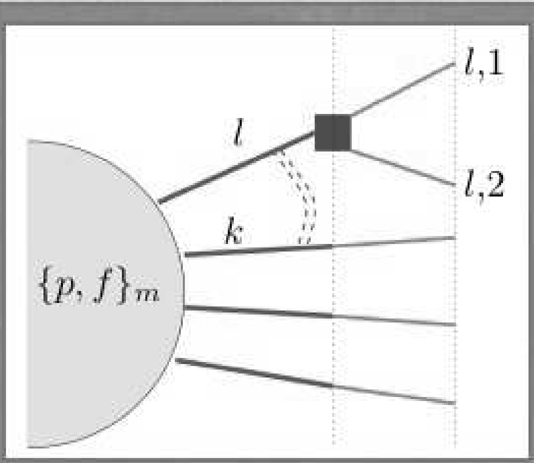
$$N(t', t)|\{p, f, c\}_{\mathrm{a,b},m}) = \underbrace{\Delta(\{p, f, c\}_{\mathrm{a,b},m}; t', t)}_{\text{Sudakov factor}}|\{p, f, c\}_{\mathrm{a,b},m})$$

From the normalization $(1|U(t, t')|\{p, f, c\}_{\mathrm{a,b},m}) = 1$

$$\Delta(\{p, f, c\}_{\mathrm{a,b},m}; t_2, t_1) = \exp\left(-\int_{t_1}^{t_2} dt\,\big(1\big|\mathcal{H}(t)\big|\{p, f, c\}_{\mathrm{a,b},m}\big)\right)$$

SPLITTING OPERATOR

$$
\begin{aligned}
&\Big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\Big|\mathcal{H}(t)\Big|\{p,f,c\}_{\mathrm{a,b},m}\Big) \\
&\quad = \boxed{\sum_{l=\mathrm{a,b},1,\dots,m}\ \sum_{\substack{k=\mathrm{a,b},1,\dots,m\\ k\neq l}}} \int_0^1 \frac{dy}{y}\int_0^1 dz \int_0^{2\pi}\frac{d\phi}{2\pi}\,\delta\big(t+\log(T_{l,k}(p_l,p_k,z,y)/Q^2)\big) \\
&\qquad \times \boxed{C_{l,k}}\,\frac{\alpha_s(Q^2e^{-t})}{2\pi}\,S_{l,k}(z,y,\hat{f}_{l,1},\hat{f}_{l,2})\,\frac{\hat{\eta}_{\mathrm{a}}}{\eta_{\mathrm{a}}}\,\frac{f_{\hat{a}/A}(\hat{\eta}_{\mathrm{a}},\mu_F^2)}{f_{a/A}(\eta_{\mathrm{a}},\mu_F^2)}\,\frac{\hat{\eta}_{\mathrm{b}}}{\eta_{\mathrm{b}}}\,\frac{f_{\hat{b}/B}(\hat{\eta}_{\mathrm{b}},\mu_F^2)}{f_{b/B}(\eta_{\mathrm{b}},\mu_F^2)} \\
&\qquad \times \Big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\Big|\mathcal{R}_{l,k}(z,y,\kappa_\perp)\Big|\{p,f,c\}_{\mathrm{a,b},m}\Big)
\end{aligned}
$$



$$
C_{l,k} = \begin{cases} 1 & \text{if } l \text{ and } k \text{ are color connected} \\ 0 & \text{otherwise} \end{cases}
$$

SPLITTING OPERATOR

$$\begin{aligned}
&\big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\big|\mathcal{H}(t)\big|\{p,f,c\}_{\mathrm{a,b},m}\big)\\
&= \sum_{l=\mathrm{a,b},1,\dots,m}\ \sum_{\substack{k=\mathrm{a,b},1,\dots,m\\ k\neq l}} \boxed{\int_0^1 \frac{dy}{y}\int_0^1 dz \int_0^{2\pi}\frac{d\phi}{2\pi}\,\delta\big(t+\log(T_{l,k}(p_l,p_k,z,y)/Q^2)\big)}\\
&\quad\times C_{l,k}\,\frac{\alpha_s(Q^2e^{-t})}{2\pi}\,S_{l,k}(z,y,\hat{f}_{l,1},\hat{f}_{l,2})\,\frac{\hat{\eta}_{\mathrm{a}}}{\eta_{\mathrm{a}}}\frac{f_{\hat{a}/A}(\hat{\eta}_{\mathrm{a}},\mu_F^2)}{f_{a/A}(\eta_{\mathrm{a}},\mu_F^2)}\,\frac{\hat{\eta}_{\mathrm{b}}}{\eta_{\mathrm{b}}}\frac{f_{\hat{b}/B}(\hat{\eta}_{\mathrm{b}},\mu_F^2)}{f_{b/B}(\eta_{\mathrm{b}},\mu_F^2)}\\
&\quad\times\big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\big|\mathcal{R}_{l,k}(z,y,\kappa_\perp)\big|\{p,f,c\}_{\mathrm{a,b},m}\big)
\end{aligned}$$

Sudakov parametrization of the new momenta:

$$\hat{p}_{l,1} = zp_l + y(1-z)p_k + k_\perp \qquad p_l + p_k = \hat{p}_{l,1} + \hat{p}_{l,2} + \hat{p}_k$$

$$\hat{p}_{l,2} = (1-z)p_l + yzp_k - k_\perp \qquad \hat{p}_{l,1}^2 = \hat{p}_{l,2}^2 = 0$$

$$\hat{p}_k = (1-y)p_k \qquad -k_\perp^2 = 2p_l\cdot p_k yz(1-z) = T_{l,k}$$

SPLITTING OPERATOR

$$\begin{aligned}&\big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\big|\mathcal{H}(t)\big|\{p,f,c\}_{\mathrm{a,b},m}\big)\\&\quad=\sum_{l=\mathrm{a,b},1,\dots,m}\ \sum_{\substack{k=\mathrm{a,b},1,\dots,m\\ k\neq l}}\int_0^1\frac{dy}{y}\int_0^1 dz\int_0^{2\pi}\frac{d\phi}{2\pi}\,\delta\big(t+\log(T_{l,k}(p_l,p_k,z,y)/Q^2)\big)\\&\qquad\times C_{l,k}\boxed{\frac{\alpha_s(Q^2e^{-t})}{2\pi}\,S_{l,k}(z,y,\hat{f}_{l,1},\hat{f}_{l,2})}\,\frac{\hat{\eta}_{\mathrm{a}}}{\eta_{\mathrm{a}}}\,\frac{f_{\hat{a}/A}(\hat{\eta}_{\mathrm{a}},\mu_F^2)}{f_{a/A}(\eta_{\mathrm{a}},\mu_F^2)}\,\frac{\hat{\eta}_{\mathrm{b}}}{\eta_{\mathrm{b}}}\,\frac{f_{\hat{b}/B}(\hat{\eta}_{\mathrm{b}},\mu_F^2)}{f_{b/B}(\eta_{\mathrm{b}},\mu_F^2)}\\&\qquad\times\big(\{\hat{p},\hat{f},\hat{c}\}_{\mathrm{a,b},m+1}\big|\mathcal{R}_{l,k}(z,y,\kappa_\perp)\big|\{p,f,c\}_{\mathrm{a,b},m}\big)\end{aligned}$$

E.g.: Final state splitting with final state spectator, $q \to q + g$

$$S_{l,k}(z,y,q,g) = C_{\mathrm{F}}\left[\frac{2}{1-z(1-y)}-(1+z)\right]$$

MATCHING AT BORN LEVEL

Expanding the first step of the shower cross section:

$$|\sigma(t_{\mathrm{f}})) = N(t_{\mathrm{f}},t_2)|\sigma_2) + \int_{t_2}^{t_{\mathrm{f}}} dt_3\, U(t_{\mathrm{f}},t_3)\,\underbrace{\mathcal{H}(t_3)N(t_3,t_2)|\sigma_2)}_{\sim |A_3(t_{\mathrm{f}},t_2))}$$

It

se

$$[W_M(t_{\mathrm{f}},t_2),\mathcal{H}(t_3)]|\sigma_2) \sim |\sigma_3) - \mathcal{H}(t_3)|\sigma_2)$$

$$|\sigma_M(t_{\mathrm{f}})) = N(t_{\mathrm{f}},t_2)|\sigma_2) + \int_{t_2}^{t_{\mathrm{f}}} dt_3\, U(t_{\mathrm{f}},t_3)W_M(t_{\mathrm{f}},t_2)\mathcal{H}(t_3)N(t_3,t_2)|\sigma_2)$$

Adding and subtracting the same terms we have

$$|\sigma_M(t_{\mathrm{f}})) = \underbrace{U(t_{\mathrm{f}},t_2)|\sigma_2)}_{\text{Standard shower}} + \int_{t_2}^{t_{\mathrm{f}}} dt_3\, U(t_{\mathrm{f}},t_3)\underbrace{[W_M(t_{\mathrm{f}},t_2),\mathcal{H}(t_3)]}_{W_M(t_{\mathrm{f}},t_2)\mathcal{H}(t_3)-\mathcal{H}(t_3)W_M(t_{\mathrm{f}},t_2)}N(t_3,t_2)|\sigma_2)$$

PARTON SHOWER AT NLO

Let us calculate the N-jet cross section. The matrix element improved cross section is

$$\boxed{\begin{aligned}(F_N|\sigma_\Delta(t_\mathrm{f})) = &\int_{t_2}^{t_\mathrm{f}} dt_N\, (F_N|N(t_\mathrm{f},t_N)W_\Delta(t_\mathrm{f},t_N,t_2)|\sigma_N) \\ &+ \int_{t_2}^{t_\mathrm{f}} dt_{N+1}\, (F_N|U(t_\mathrm{f},t_{N+1})W_\Delta(t_\mathrm{f},t_{N+1},t_2)|\sigma_{N+1})\end{aligned}}$$

Expanding it in α_s then we have

“Error term” from $1/N_c^2$ approx. : $E = E^{(0)} + \frac{\alpha_s}{2\pi}E^{(1)} = \mathcal{O}\left(\frac{1}{N_c^2}\right)$

$$(F_N|\sigma_\Delta) = \int_N d\sigma^B \left(1 + E + \frac{\alpha_s}{2\pi}W_\Delta^{(1)}\right) + \underbrace{\int_{N+1} \left[d\sigma^R - d\sigma^A\right]}_{\text{Real - Dipoles}} + \mathcal{O}(\alpha_s^2)$$

Born term

“Quasi virtual”

Conclusions

- Very interesting sessions.

- Higher orders tools (MC@NLO, CKKW, MLM) are well received and give important results for LHC (still reveal interesting questions).
  Still important progress in NLO computations (van Hameren).
- Alternative parton shower formulations (Cascade) may open new directions for underlying event studies.
  Very important overlap between HERA and LHC physics.
- The last word on parton showers is not spoken.
  New developments (Jadach, Nagy) open paths to alternative parton shower and higher order matchings/mergings.

- *Thanks a lot to the speakers for their contributions to WG5!*