Hadronic final states in DIS with SHERPA

Stefan Höche [1]

ITP, University of Zürich

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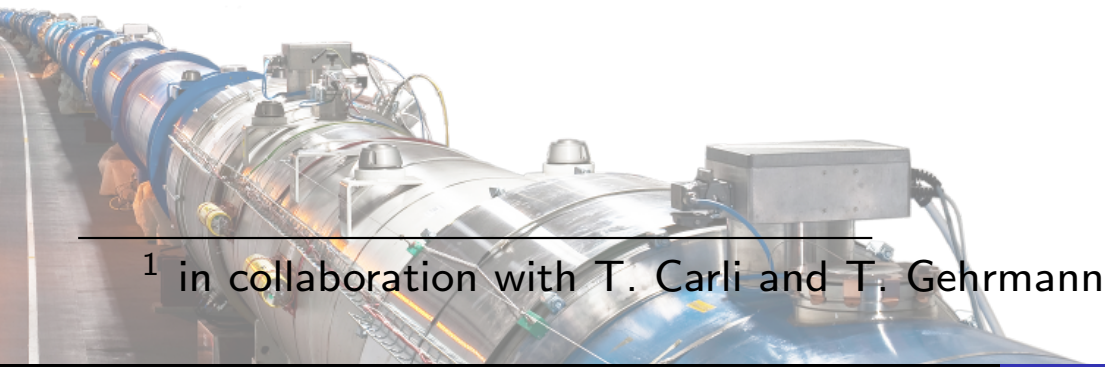
MCnet

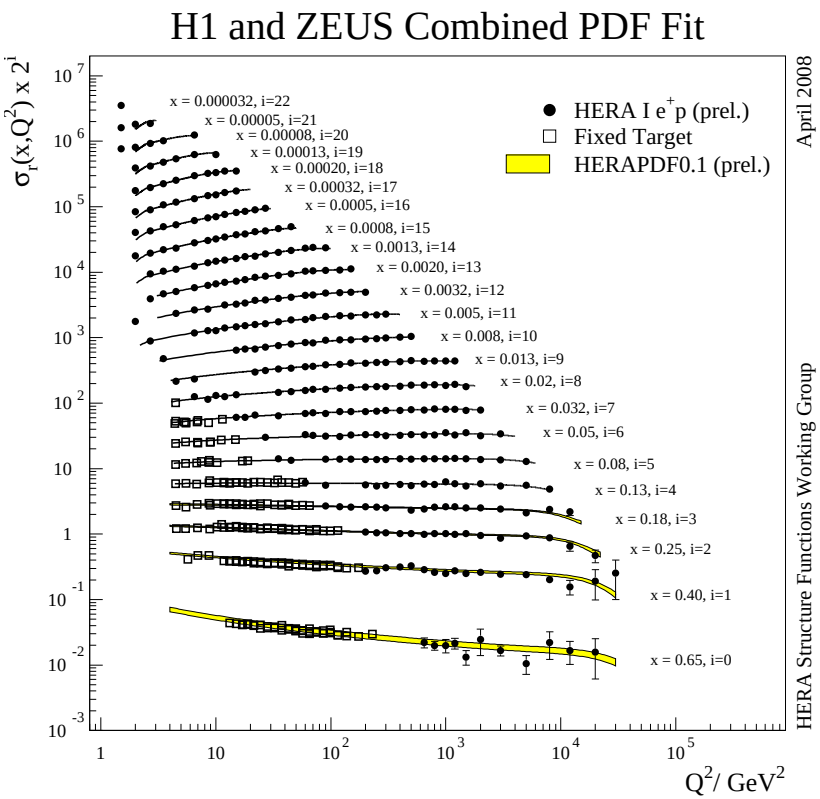


[1] in collaboration with T. Carli and T. Gehrmann, see arXiv:0912.3715 [hep-ph]

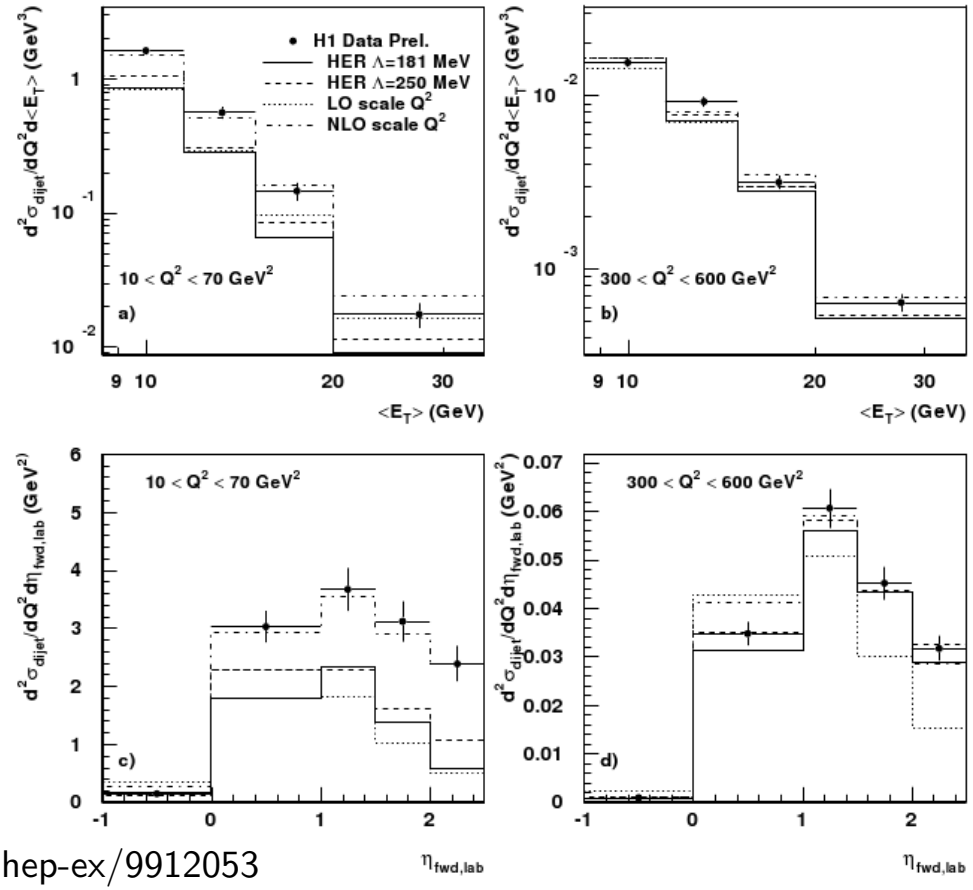
DIS at HERA: Is DGLAP sufficient?

Correctly described

- Inclusive measurements e.g. F_2
- Jet spectra if computed at NLO



arXiv:0906.1108 [hep-ex]



hep-ex/9912053

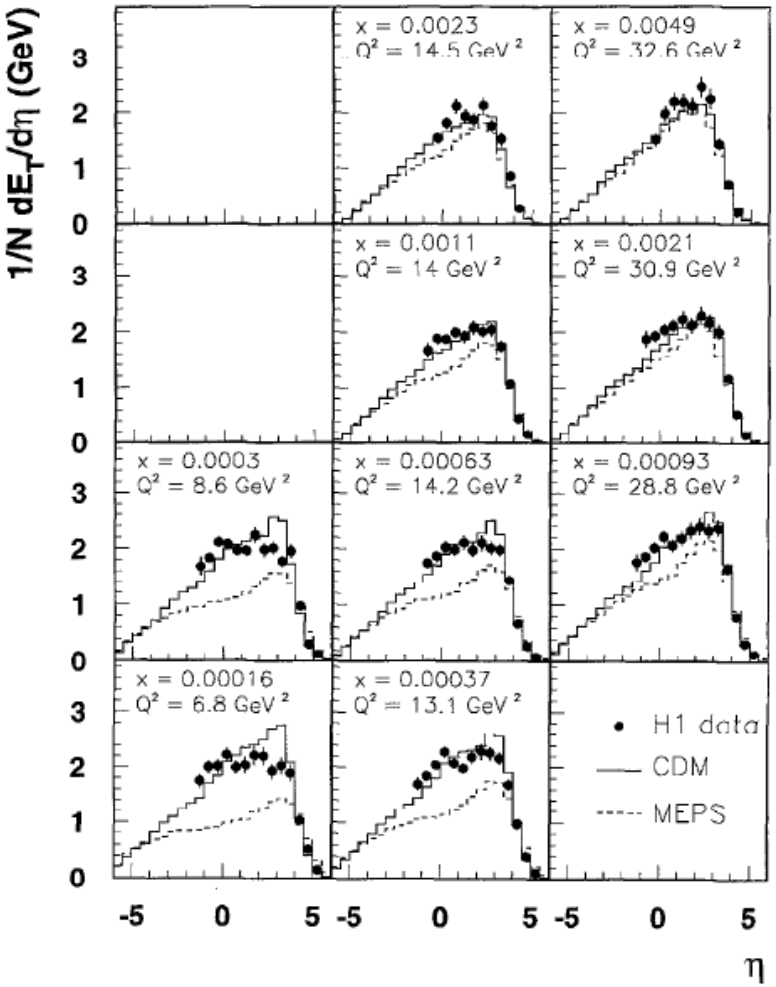
However !

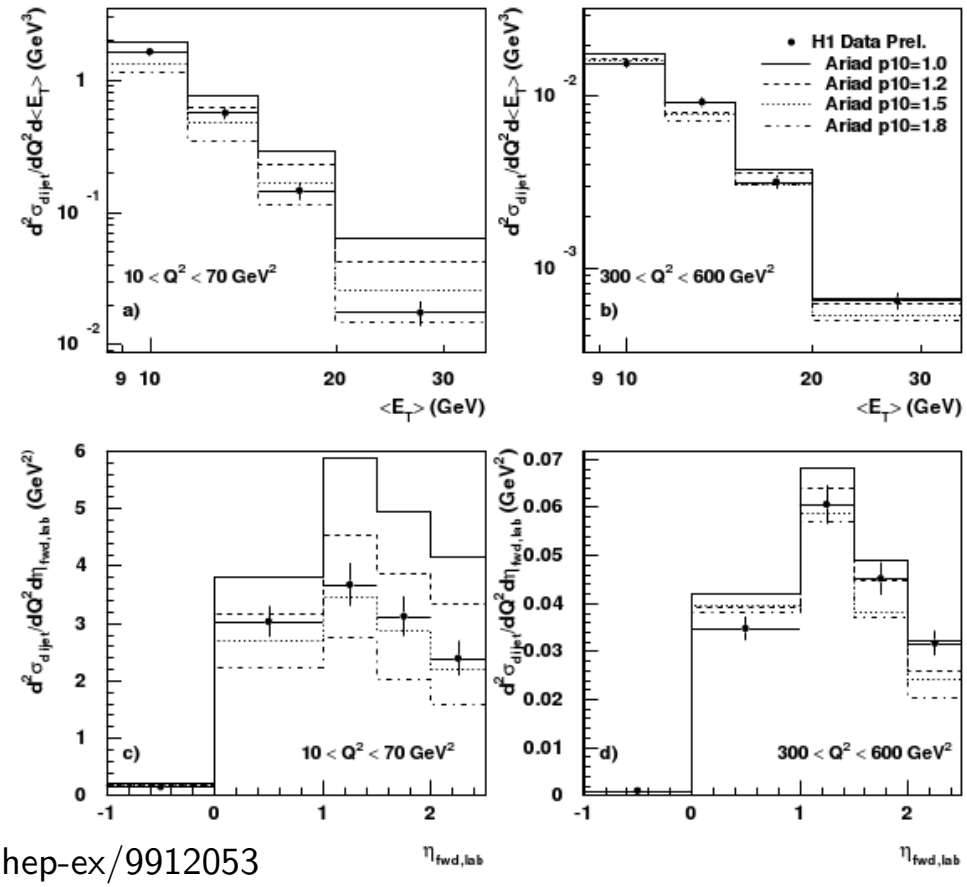
- Parton shower MCs often fail for jet spectra
- Low-Q^2 region especially problematic

DIS at HERA: Could non-DGLAP evolution help?

Example: Energy flow PLB356(1995)118

- MEPS (DGLAP) fails entirely
- CDM agrees well with data





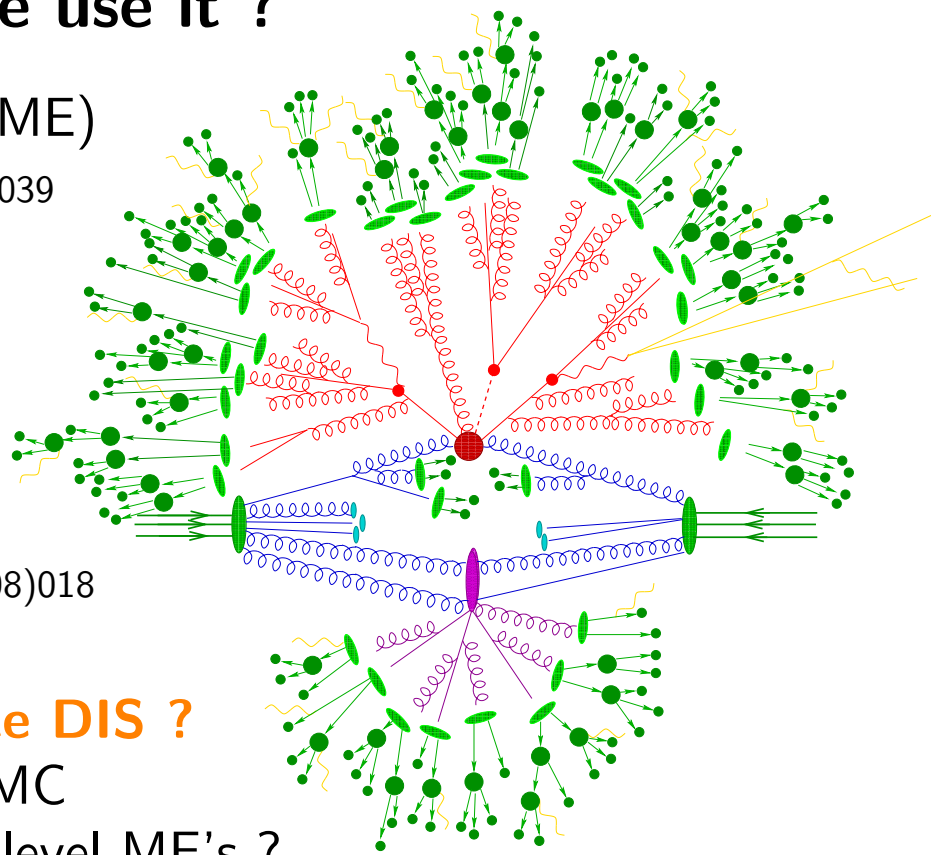
hep-ex/9912053

Example: Inclusive dijets EPJC19(2001)289

- CDM (Ariadne) uncertainties are large!
  and often come from npQCD parameters
- Low-Q^2 region still problematic

What is SHERPA and why do we use it ?

- Two multi-purpose matrix element (ME) generators, JHEP02(2002)044, JHEP12(2008)039
- A dipole-like parton shower (PS) JHEP03(2008)038, PRD81(2010)034026
- Cluster fragmentation EPJC36(2004)381
- Hadron and τ decayers
- A QED radiation generator JHEP12(2008)018



Can we use this framework to simulate DIS ?
i.e. does a DGLAP-based parton shower MC
improve upon including higher-order tree-level ME's ?

Sherpa's traditional strength is to combine ME and PS
efficiently include higher-order real-emission effects in the simulation
JHEP05(2009)053, PRD81(2010)034026, JHEP11(2001)063, JHEP08(2002)015

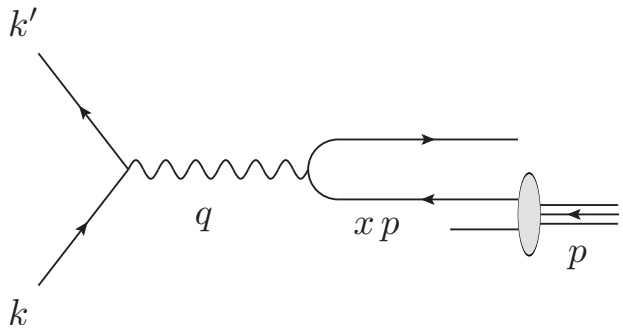
What HERA teaches us ...

Leading order $e^{\pm}p$ - scattering in collinear factorization Breit frame

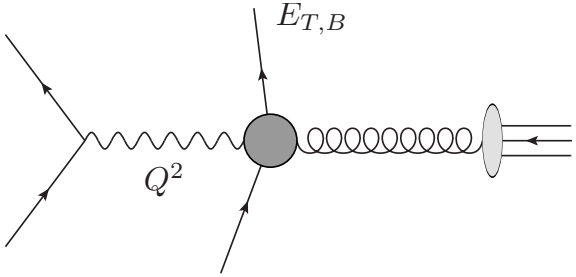
- There are no jets !
- Kinematical variables

$$Q^2 = q^2 = (k' - k)^2 \text{ and } x = \frac{Q^2}{2\, q \cdot p}$$

- Hadronic cm energy $W = Q\sqrt{(1-x)/x}$



What happens at higher orders ?



- Multiple QCD scales, e.g. $E^2_{T,B}$
- $e^{\pm}q \to e^{\pm}q$ if $E^2_{T,B} \lesssim Q^2$
  $\gamma^* g \to \textit{jets}$ if $Q^2 \lesssim E^2_{T,B}$

What makes DIS any different from $e^+e^- \to \textit{jets}$ and $pp \to e^+e^-$?

The virtuality of the exchanged photon tends to be close to zero !
i.e. $\gamma^* g \to \textit{jets}$ kinematics are standard, but the PS starts from LO $e^{\pm}q \to e^{\pm}q$

N.B. This is also the case in the Drell-Yan process $pp \to e^+e^-$,
but recent experimental studies usually focus on $m_{l\bar{l}} \approx m_Z$

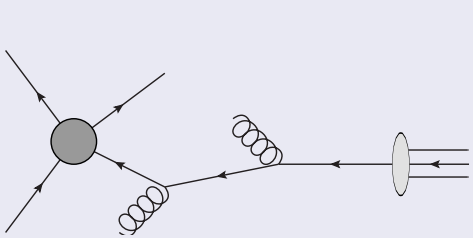
What HERA teaches us ...

- Leading-order process does not define sensible scale for jets, but
- Factorization scale should be Q^2 to maintain total cross section
- Higher-order corrections usually large due to large phase space ($\propto W^2$)

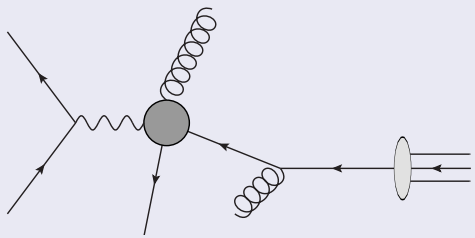
Problem often addressed using **"power shower"** hep-ph/0511306
Increase PS starting scale from Q^2 to W^2 $\longrightarrow$ open full NLO phase space
Questionable concept for several reasons

- Emissions might now be too hard arXiv:1003.2384 [hep-ph]
- Factorization theorems are not respected

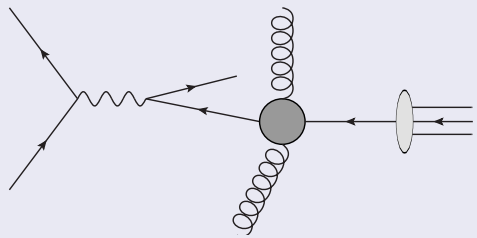
Instead: Use tree-level N^{x}LO ME and choose "core" process dynamically



$E^2_{T,B\,1} \approx E^2_{T,B\,2} < Q^2$



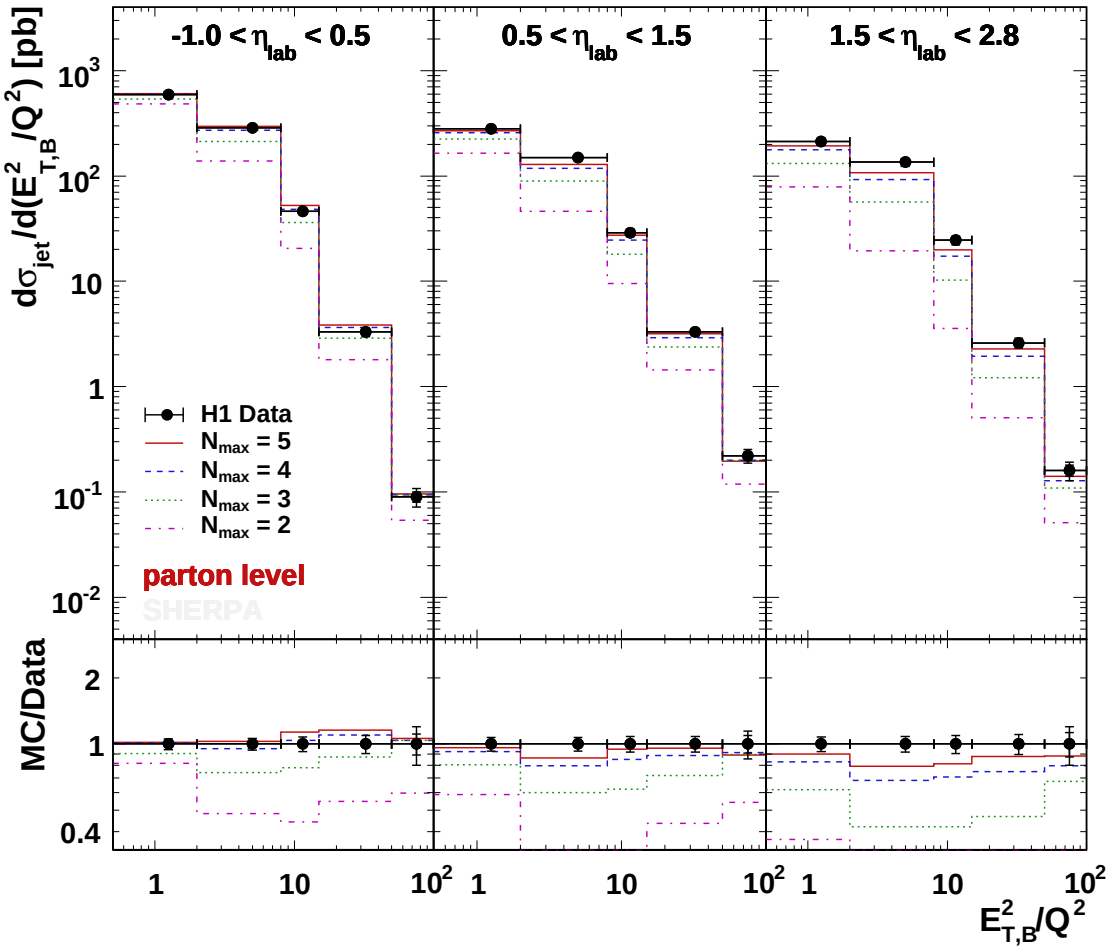
$Q^2 \approx E^2_{T,B\,2} < E^2_{T,B\,1}$

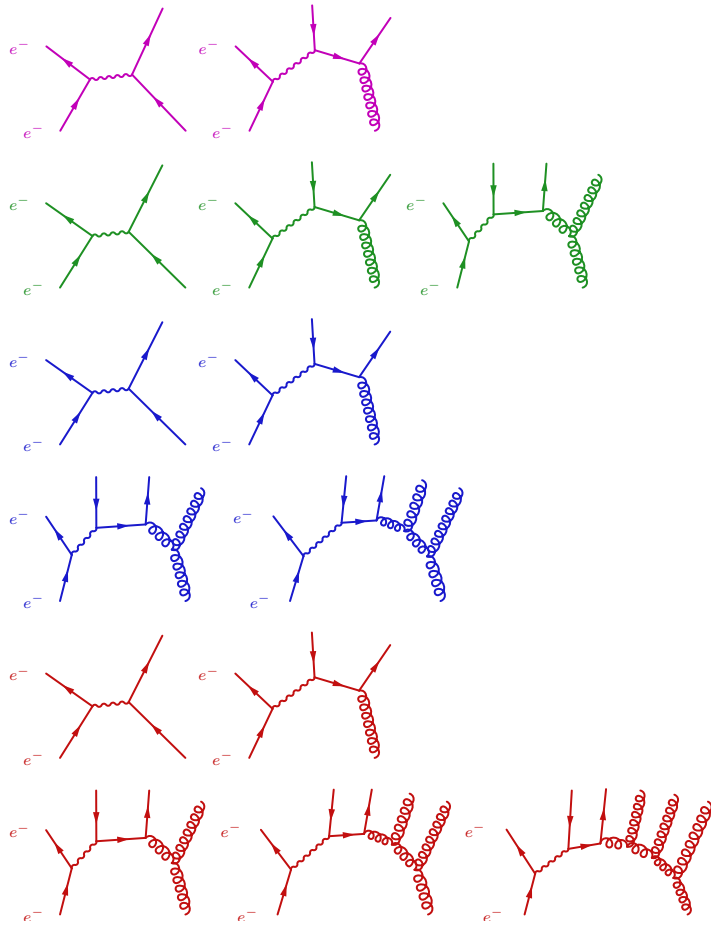


$Q^2 < E^2_{T,B\,1} \approx E^2_{T,B\,2}$

ME⊗PS results: Inclusive jets in DIS PLB542(2002)193

Variation of maximum matrix-element multiplicity, $N_{\max}$ [2]

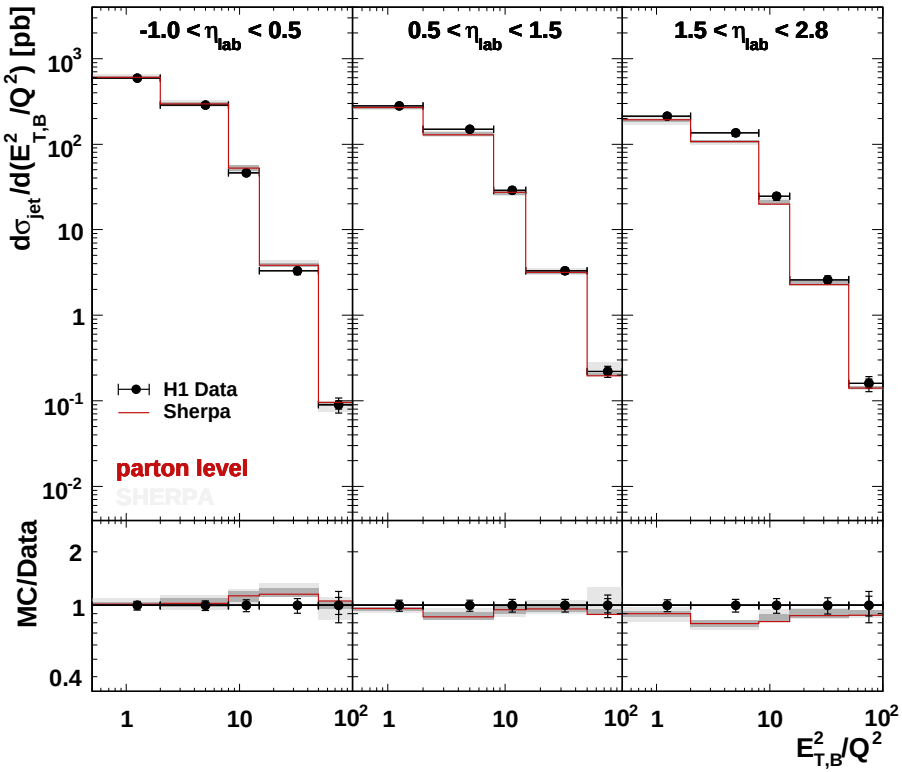


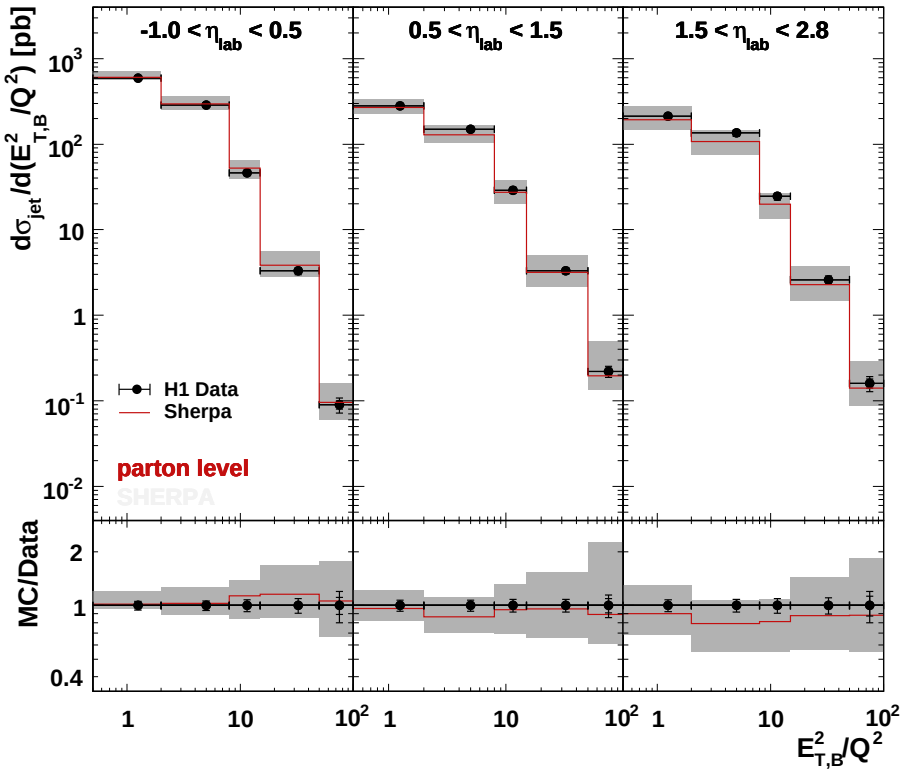


[2] SHERPA ⊕ HZTool from arXiv:0912.3715 [hep-ph]

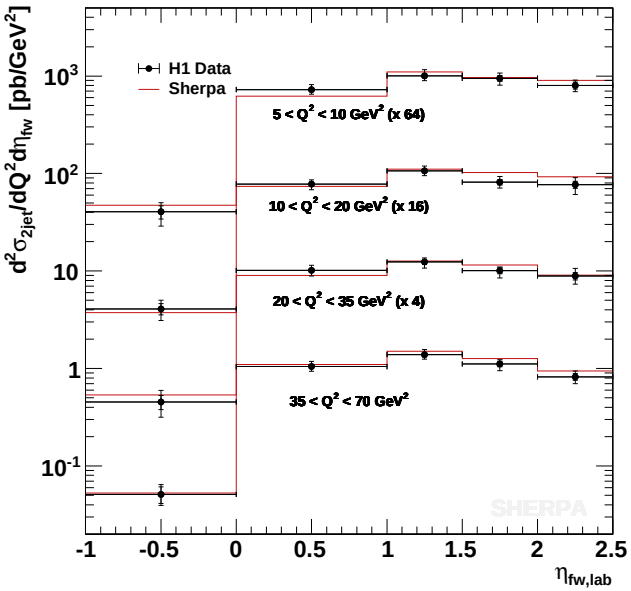
ME⊗PS results: Inclusive jets in DIS PLB542(2002)193

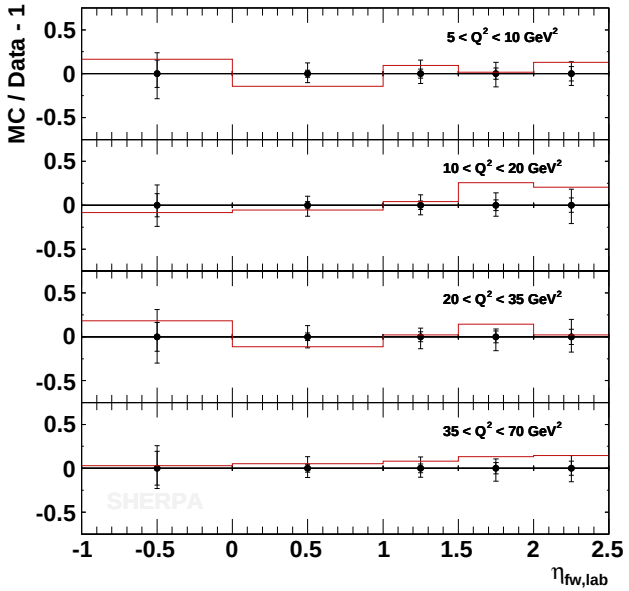
Variation of merging parameters and factorization/renormalization scales





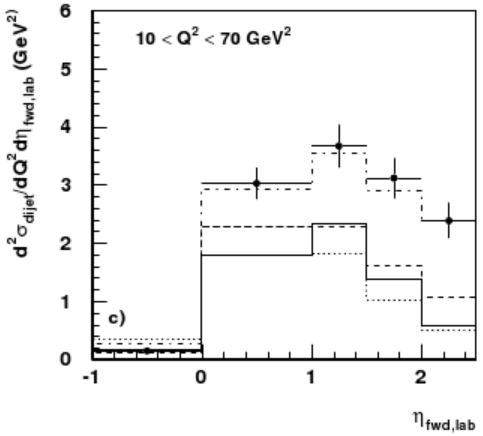
ME⊗PS results: Inclusive dijets in DIS EPJC12(2000)595

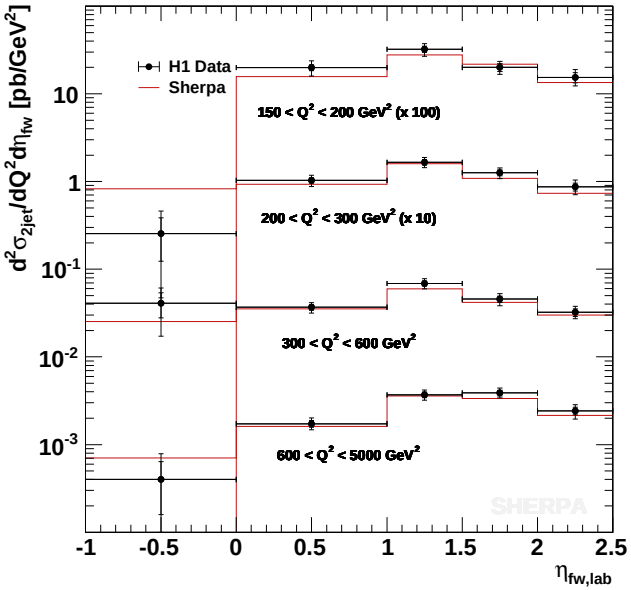


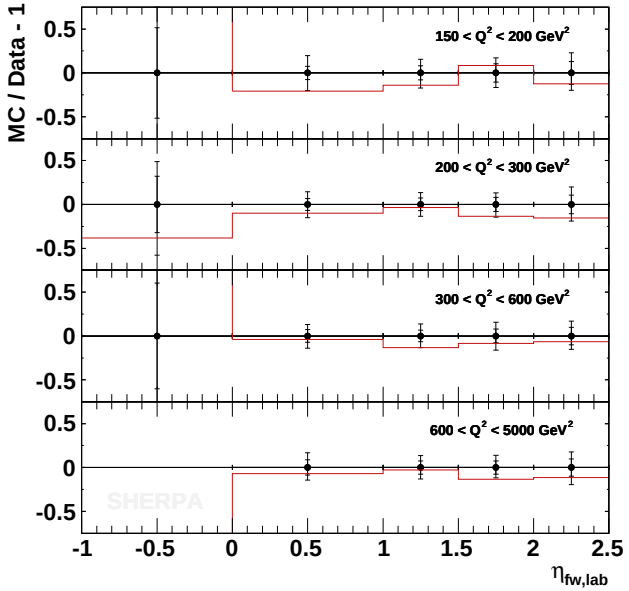


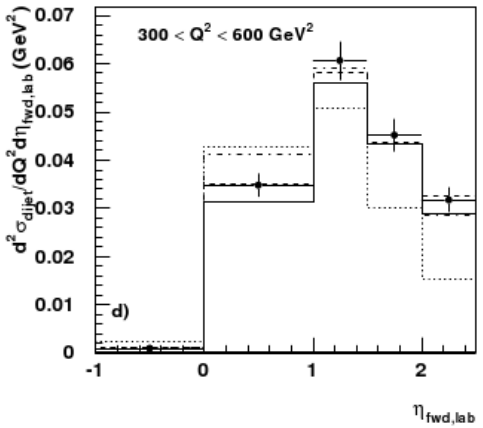
Compare to intro

→ MC status 1999 vs. 2010

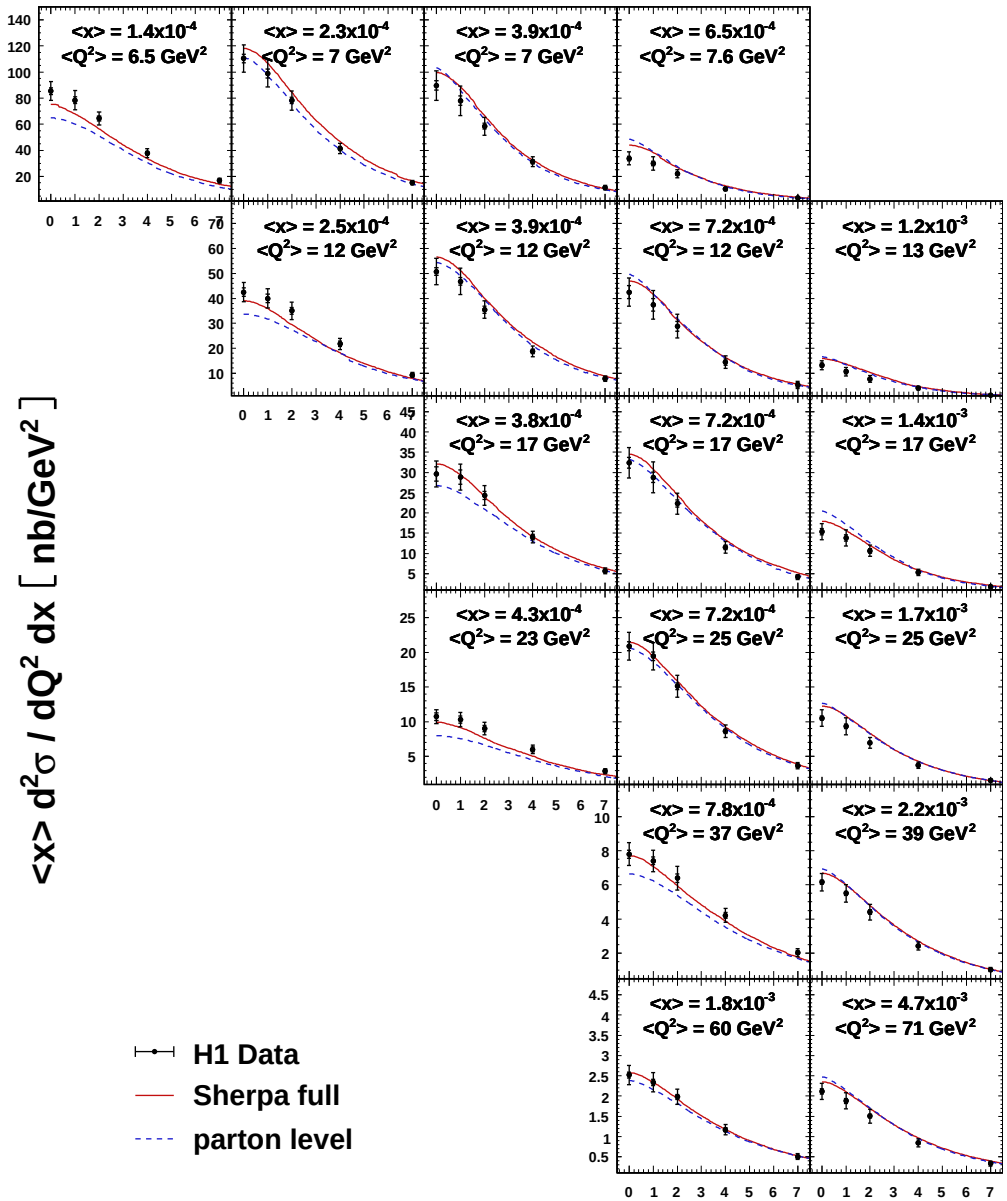








ME⊗PS results: Low-x dijets in DIS EPJC33(2004)477

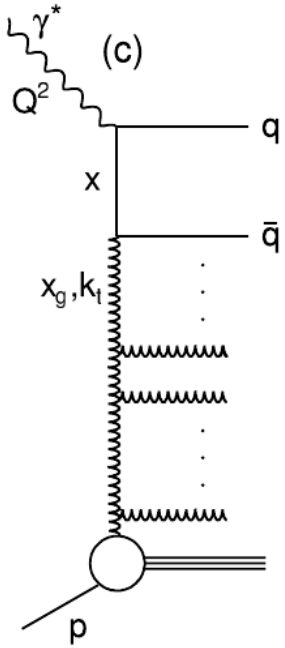


Δ in bins of $\langle x \rangle$ and $\langle Q^2 \rangle$

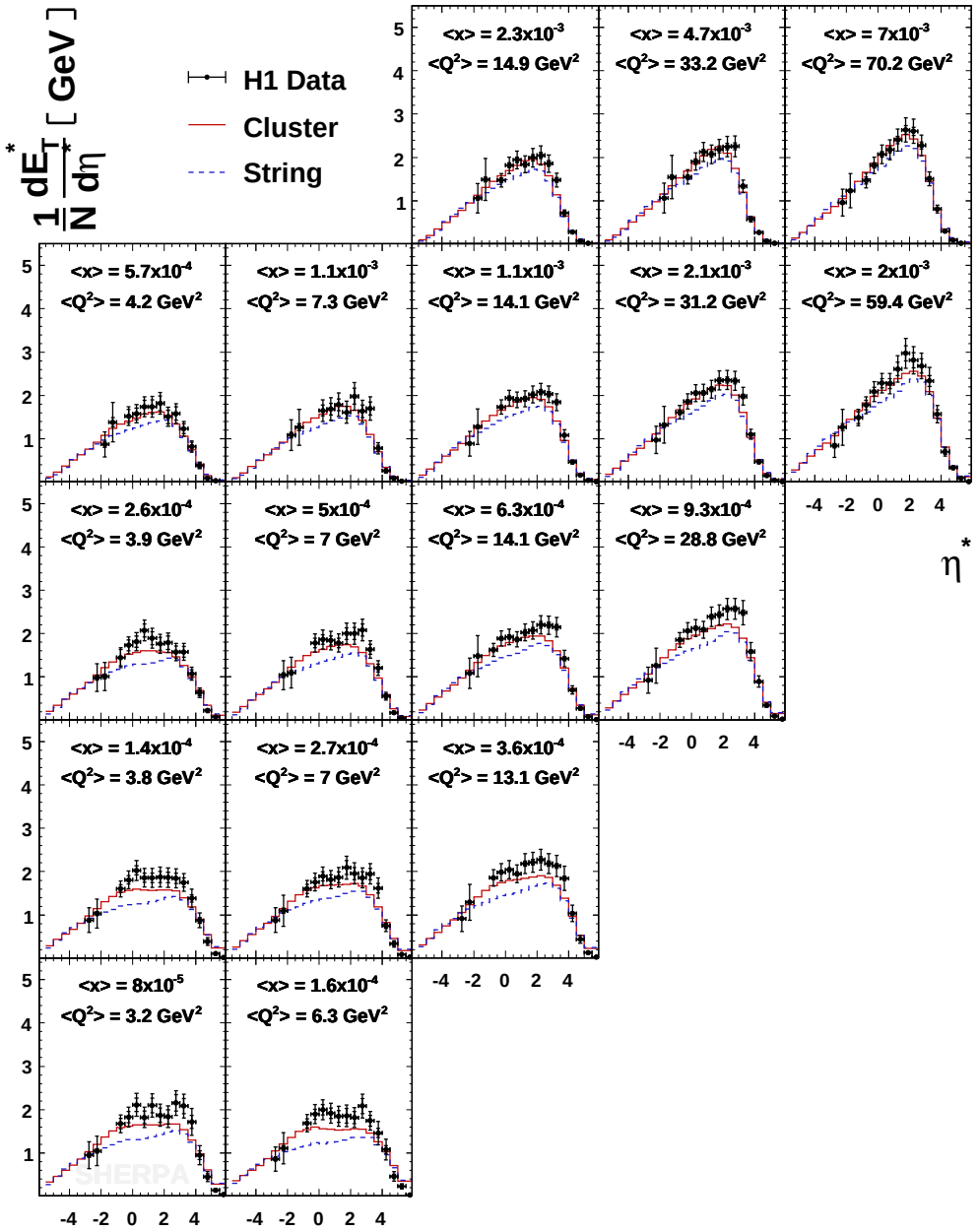
Δ defined as $E^*_{T,\max} > E^*_{T\,\mathrm{cut}} + \Delta$

$E^*_{T\,\mathrm{cut}} \longrightarrow$ minimum jet transverse energy

$E^*_{T\,\max} \longrightarrow$ transverse energy of hardest jet



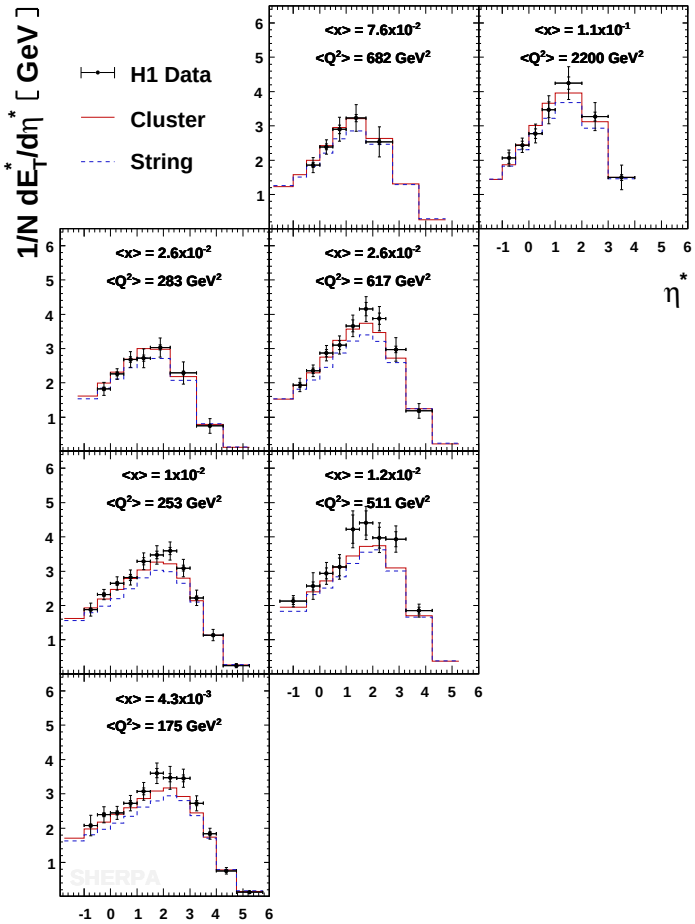
Hadron level results: Energy flow analysis EPJC12(2000)595



Transverse energy flow

SHERPA cluster fragmentation
vs. Lund string fragmentation

LEP tune by E. von Seggern / H. Hoeth



Summary

So far ...

- SHERPA can simulate DIS
- Successful first analysis of hadronic final state data from HERA
- "Power shower" superseeded by ME⊗PS, consistent with factorization !!!
- Aside: HZTool steering included in SHERPA

To do ...

- Even more tests and validation
- Resolved photons
- Extension to NLO accuracy

This is important preparatory work for LHC data analyses !

Don't expect to understand the Standard Model at 7-14 TeV,
if you can't describe HERA and Tevatron data ...