Summary of WG2
Multi-jet final states and energy flows

• Underlying event and minimum bias
• Rapidity gaps and survival probabilities
• Multi-jet topologies and multi-scale QCD
• Parton shower/ME matching
Summary of WG2
Multi-jet final states and energy flows

- Underlying event and minimum bias $\Rightarrow$ WG5
- Rapidity gaps and survival probabilities
- Multi-jet topologies and multi-scale QCD
- Parton shower/ME matching
Summary of WG2
Multi-jet final states and energy flows

- Underlying event and minimum bias ⇒ WG5
- Rapidity gaps and survival probabilities ⇒ WG4
- Multi-jet topologies and multi-scale QCD
- Parton shower/ME matching
Summary of WG2
Multi-jet final states and energy flows

- Underlying event and minimum bias ⇒ WG5
- Rapidity gaps and survival probabilities ⇒ WG4
- Multi-jet topologies and multi-scale QCD
- Parton shower/ME matching ⇒ WG5
The talks

• NLO-GRID: Dan Clements
• FastNLO: Thomas Kluge
• Inclusive and di-jets production: Thomas Schörner-Sadenius (Claire Gwenlan)
• Low-$x$ physics studies using the hadronic final state at H1: Daniel Traynor
• New fits to uPDFs: Hannes Jung
• Prompt Photons at HERA: Katharina Müller
NLO-GRID: Dan Clements

How to fit jet data to NLO PDFs?

Very slow to evaluate cross section for each parameter settings of the PDF.

Discretize and pretabulate the NLO partonic cross section in a grid.
Using Integration Grids

Step 1: Fill the Grid

NLO event generator

Event with weight $w_1$, $x_1, x_2, Q^2$

Fill Grid with weight $w_1$, at point $(x_1, x_2, Q^2)$

SLOW

Step 2: Multiply grid by PDFs to generate Cross-Section

Grid of weights in $(x_1, x_2, Q^2)$

Multiply and add over $(x_1, x_2, Q^2)$

Jet Cross-Section

PDFs defined at $(x_1, x_2, Q^2)$

FAST

QCD Fit

Fortran interface
How good are the grids?

- Compared the inclusive jet cross-section at ATLAS as generated using grids and standard NLO calculation (reference) agreement is better than 0.2%

- \((y_1, y_2, \tau) = (10, 10, 10)\)

  Interpolation order 5
FastNLO: Thomas Kluge

Basically the same idea:
Put heavy NLO cross section calculation on a grid.

Difference eg. in how to bin things on the grid:
NLO-GRID uses $\log 1/x + a(1 - x)$
FastNLO uses $\sqrt{\log 1/x}$
Advantage of \(\sqrt{\log(1/x)}\) to other transformation functions (example):

Proton-proton at \(E_{cm} = 14000\ \text{GeV}\), \(1400 < p_T < 1500\ \text{GeV}\), \(2.0 < |y| < 3.0\)

- \(h(x) = \log_{10}(1/x)\)
- \(h(x) = \log_{10}(1/x) + x\)
- \(h(x) = \sqrt{\log_{10}(1/x)}\)

Number of bins for \(x_{\text{max}} > 0.9\):
- 3
- 4
- 8
TEVATRON Run II

No. bins to cover the x-range:
- 8 x-bins
- 10 x-bins
- 12 x-bins
- 16 x-bins

pp-bar: incl. jets at \( \sqrt{s} = 1.8 \) TeV
DØ Collaboration hep-ex/0011036

only 10 x-bins sufficient for precision of 0.1%, even in forward region

http://hepforge.cedar.ac.uk/fastnlo
Inclusive and di-jets production: Thomas Schörner-Sadenius

- ZEUS inclusive jets at high $Q^2$
- H1 inclusive jets at high $Q^2$
- ZEUS di-jets at high $Q^2$
- H1 multijets at high $Q^2$
- H1 dijets photoproduction
- ZEUS dijets photoproduction
**ZEUS INCLUSIVE JETS AT HIGH $Q^2$**

`Simple’ measurement – take PDFs/$\alpha_s$ as given

- **Tests:** understanding of pQCD, factorisation, PDF universality,…
- **Data:** 82 pb$^{-1}$ $e^+p$ data from 98-00
- **Aims:** extraction of strong coupling, use data in QCD fits for PDF constraints

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**Phase Space:**

- $Q^2 > 125$ GeV$^2$
- $E_T(Breit) > 8$ GeV
- $-2 < \eta(Breit) < 1.5$
- $|\cos\gamma_L| < 0.65$
**H1 INCLUSIVE JETS**

extraction of strong coupling

- 15 double differential points used for average $\alpha_s(M_Z)$
- Result consistent with world average + ZEUS incl. jets
- Theory error dominates (effect of higher orders)

\[ \alpha_s(M_Z) = 0.1197 \pm 0.0016 \text{(exp)} \pm 0.0047 \text{(theory)} \]

C.f. ZEUS inclusive: $\alpha_s(M_Z) = 0.1196 \pm 0.0025 \text{(exp)} \pm 0.0023 \text{(theory)}$
ZEUS DIJETS AT HIGH $Q^2$
More single-differential results

![Graphs showing data and NLO predictions for dijet production at high $Q^2$.](image-url)
Low-$x$ studies at H1: Daniel Traynor

Conventional DGLAP QCD approach evolves with $Q$

Possibility of non DGLAP behaviour of the parton evolution at HERA

What does this mean for the LHC?
Monte Carlos for DIS

Rapgap (dir)  Rapgap (dir+res)  Cascade  Ariadne

Strong ordering in $k_t$ of emitted partons as is PYTHIA and HERWIG
DGLAP

CCFM resumes both log($Q^2$) and log(1/x) angular ordering
CCFM

Dipoles radiate independently
BFKL like
New fits to uPDFs: Hannes Jung

Define:
- $p_{Tq\bar{q}}$
- $x_\gamma = \frac{\sum_{i=q,\bar{q}} (E_i - p_z)}{2yE_e} = \frac{p_{q\bar{q}}}{q}$

- parton kinematics
- uPDFs
- full kinematics
- history is needed for long- and transverse components
Goals for PDF fits:
- fit inclusive and exclusive measurements
- using as many measurements as possible ... which can constrain the PDFs
  - HZTool
- using full information of final states
  - MC@NLO or similar
- consistent treatment of experimental and theoretical errors
Prompt Photons at HERA: Katharina Müller

Main LHC motivation: $H \rightarrow \gamma\gamma$

How well do we know prompt photon cross section?

How well do we know quark-to-photon fragmentation function?

How do we tell a photon from eg. $\pi^0 \rightarrow \gamma\gamma$?
• LO calculation by Gehrmann et al. (hep-ph/0601073, hep-ph/0604030)
• Good description of data, normalization and shapes reproduced
• Data slightly higher
• Large $\eta$: QQ term dominates
Prompt photon:

(a) Direct

(b) Resolved

Radiative photon:

(c) Direct

(d) Resolved

**ZEUS**

\[ \text{d} \sigma / \text{d} E_T^\gamma \text{ (pb/GeV)} \]

- **a)**
  - ZEUS (prelim) 77 pb
  - NLO + hadron (KZ) 0.5 < p_T < 2
  - NLO + hadron (FGI) 0.5 < p_T < 2
  - \text{HERWIG 6.5}

- **b)**
  - d\sigma / d\eta^\gamma (pb)

\[ \eta^\gamma \]

- 0 to 1
$d\sigma/dx_\gamma$ (pb)

$e^+e^- \rightarrow \gamma (\text{prompt}) + \text{jet} + X$

- ZEUS (prel.) 77 pb$^{-1}$
- NLO+hadr. (KZ) $0.5 < \mu_R < 2$
- NLO+hadr (FGH) $\mu_R = 1$
- $k_\tau$-fact. (LZ) $0.5 < \mu_R < 2$
- PYTHIA 6.3
- HERWIG 6.5