Multiplicty structure in inclusive and diffractive deep-inelastic ep collisions

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Outline
Introduction
Kinematic dependencies of DDIS
Comparison DIS/DDIS
Conclusions
**Motivation**

- **H1 analysis on 94 DDIS data:**
  - Dependence of $\langle n \rangle$ on $M_X$

- **H1 analysis on 2000 DDIS data:**
  - Large statistics allows more differential study:
    - $W$, $Q^2$, $\beta$ dependences at fixed $M_X$
  - Compare DIS and DDIS
Multiplicity structure

Charged particle multiplicity of the hadronic final state

- Shape of multiplicity distribution $P(n)$
  - Independent emission of single particles: Poisson distribution
  - Deviations from Poisson reveal correlations and dynamics
- Mean multiplicity $\langle n \rangle$ of charged particles
- Rapidity spectra
- Koba-Nielsen-Olesen (KNO) scaling $\psi(z)$
  - energy scaling of the multiplicity distribution
  - $\psi(z) = \langle n \rangle P_n$ vs $z = n/\langle n \rangle$
Diffraction: $e p \rightarrow e' X Y$

\[ t = (p - p')^2 \]

\[ \beta = x_{\text{quark/IP}} \]

\[ x_{\text{IP}} = x_{\text{IP/proton}} \]

Cross section:

\[ \frac{d\sigma^{ep \rightarrow e XY}}{d\beta dQ^2 dx_{\text{IP}} dt} = \frac{4\pi\alpha^2}{\beta Q^4} \left( 1 - y + \frac{y^2}{2} \right)\sigma_r^{D(4)} \]

Reduced cross section:

\[ \sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{1 + (1 - y)^2} F_L^{D(4)} \]
Models for diffraction

Combine QCD/Regge theory: resolved IP model

- Proton infinite momentum frame
- Colourless IP is built up of quarks/gluons
- Based on QCD and Regge factorization:

\[ F_2^D(x_{IP}, t, \beta, Q^2) = f_{IP/p}(x_{IP}, t) \ F_2^{IP}(\beta, Q^2) \]

- Needs subleading IR component
Models for diffraction cont’d

**Colour dipole approach**

- In proton rest frame: $\gamma^*$ splits up in $qq$ dipole

\[ |\gamma> = q\bar{q} + q\bar{q}g + ... \text{ Fock states} \]

- Model the dipole cross section:

  Saturation model Golec-Biernat and Wusthoff (GBW)
Data selection DIS and DDIS

2000 nominal vertex data: 46.65 pb$^{-1}$

Data corrected via Bayesian unfolding procedure:
- DIS MC: DJANGOH 1.3, proton pdf CTEQ5L
- DDIS MC: RAPGAP resolved pomeron

DIS selection:
- Good reconstruction of scattered electron
- Kinematic cuts:
  - $0.05 < \gamma_{av} < 0.65$
  - $5 < Q^2 < 100$ GeV$^2$
  - $80 < W < 220$ GeV

DDIS selection:
- Rapidity gap:
  - No activity in the forward detectors
  - $\eta_{max} < 3.3$
- Kinematic cuts:
  - $4 < M_X < 36$ GeV
  - $x_{IP} < 0.05$
Track selection

- Primary vertex fitted tracks
- $15 < \theta < 165$ and $p_T > 150$ MeV
- Boost to hadronic $\gamma^*p$ CMS
- Acceptance:
- Resolution:

tracks with $\eta^* > 1$
Multiplicity structure results

Charged particles with $\eta^* > 1$
in $\gamma*p$ CMS frame

- Multiplicity distribution and moments
  - $Q^2$ dependence of $\langle n \rangle$ in DIS/DDIS at fixed $W$
  - $\beta$ dependence of $\langle n \rangle$ in DDIS at fixed $M_X$
  - $W$ dependence of $\langle n \rangle$ in DDIS at fixed $M_X$

- Comparison of DIS and DDIS
  - Rapidity spectra
  - KNO scaling
Kinematic relations

**DIS**
\[ y_{\text{max}} = \ln \left( \frac{W}{m_\pi} \right) \]
\[ W^2 \sim Q^2/x \]

**DDIS**
\[ \beta = \frac{Q^2}{(Q^2+M_x)^2} \]
\[ \text{gap} \sim \ln \left( \frac{1}{x_{IP}} \right) \]
**Q^2** dep. of \( \langle n \rangle \) in DIS/DDIS at fixed \( W \)

- \( \langle n \rangle \) vs \( Q^2 \)
- DIS/DDIS data (at fixed \( M_X \))
- No dependence on \( Q^2 \)
- Fit \( \langle n \rangle \):
  \[ \langle n \rangle = a + b \log(Q^2) \]
$Q^2$ dep. of $dn/d(y-y_{\text{max}})$ in DIS at fixed $W$

- $dn/d(y-y_{\text{max}})$ vs $y-y_{\text{max}}$
- $y_{\text{max}} = \ln(W/m_\pi)$
- Weak $Q^2$ dependence
  (scaling violations in QCD)

**DIS: $<n>$ predominantly function of $W$, not $Q^2$**
Q\(^2\) dep. of \(dn/d(\gamma-\gamma_{\max})\) in DDIS at fixed \(W\)

- \(dn/d(\gamma-\gamma_{\max})\)
  vs \(\gamma-\gamma_{\max}\)
- \(\gamma_{\max} = \ln(W/m_{\pi})\)

- Weak \(Q^2\) dependence
- Weak \(W\) dependence

DDIS: \(\langle n \rangle\) predominantly function of \(M_X\), not \(Q^2\)
\( \beta \) dependence of \( \langle n \rangle \)

- Intuitive picture: expect no \( \beta \) dependence (no \( Q^2 \) dependence measured)
\( \beta \) dependence of \( \langle n \rangle \)

- \( \gamma^* \) fluctuation models: relative fraction of \( q \) and \( g \) fragmentation depends strongly on \( \beta \)
\( \beta \) dep. of \(<n>\) at fixed \(M_X\) in DDIS

- \(M_X\) kept fixed
- No \(\beta\) dependence

DDIS: \(<n>\) predominantly function of \(M_X\), not \(Q^2\) or \(\beta\)
W dependence of $\langle n \rangle$?

- Change of $W$ means change the 'gap'
- $\text{Gap} \sim \ln(1/x_{IP})$
- Investigate $\langle n \rangle$ dependence on $x_{IP}$
$W$ dep. of $\langle n \rangle$ at fixed $M_X$ in DDIS

- Change $W$: change $x_{IP}$
- Regge factorisation: diffractive pdf’s independent of $x_{IP}$
- Breaking of Regge factorisation
- In resolved IP model: pomeron + reggeon
W dep. of $<n>$ at fixed $M_X$ in DDIS

- Fit $<n>$:
  
  $<n> = a + b \log(W^2)$

- Regge factorisation breaking expected in multiple scattering models

- Effects predicted to diminish with increasing $Q^2$ (shorter interaction time)

Factorisation breaking within errors, not dependent on $Q^2$
Comparison DIS/DDIS: rapidity spectra

- $dn/d(y-y_{\text{max}})$ vs $y-y_{\text{max}}$

- Central region: particle density similar for DIS and high $M_X$ DDIS

- Lowest $M_X$ bin: systematically different
Comparison DIS/DDIS: KNO scaling

- Negative particles

\[ \psi(z) = \langle n \rangle P_n \]
vs \[ z = n/\langle n \rangle \]

- Approximate KNO scaling for DIS and DDIS

- Shape of KNO distribution similar for DIS and DDIS
Conclusions

Charged particle multiplicity
- studied for DIS and DDIS

Kinematic dependencies
- $<n>$ in DIS depends only on $W$, not $Q^2$ or $x$
- $<n>$ in DDIS depends mainly on $M_x$ and $W$, not $Q^2$ or $\beta$

Comparison DIS and DDIS
- DIS and DDIS: rapidity spectra similar for highest $M_x$
- DIS and DDIS: approximate KNO scaling