Inclusive diffraction and factorisation at HERA

Matthew Wing
(UCL, DESY and Universität Hamburg)

- Introduction: what is and why study diffraction?
- Results in inclusive diffraction
- Extraction of diffractive parton density functions
- Jet production in diffraction
- Conclusion
Introduction - what is diffraction?

Deep inelastic scattering

\[ \sigma^{(D)}_{ep \rightarrow eX(p)} \sim f_{i/p}^{(D)} \cdot \sigma_{i\gamma \rightarrow jk} \]

Diffractive deep inelastic scattering

Parton densities in proton

Parton densities in “Pomeron”
Signatures of diffraction

- Forward/Leading protons (F/LPS)
- Large rapidity gap (LRG)
- “$M_X$ method”

Pros/cons:
- Different kinematic regions
- Background contributions
- Size of sample
Introduction - why study diffraction?

• To understand QCD and nature of diffractive interactions
  • Transition from “soft” to “hard” regimes
  • Applicability of QCD factorisation approach a la proton PDFs
  • Significant fraction of the inclusive cross section

• All essential to predict potential search channels at the LHC
Latest inclusive data
LRG and LPS data

- LRG data contains sizeable proton dissociation background (24%)
- Value independent of kinematic variables
- Similar value from H1
LRG and $M_x$ data
H1 and ZEUS

- H1 and ZEUS data for LRG method
- Good agreement
- (Note absolutely normalised)
- Better comparison (and more improvements) when combining cross sections…
• For fixed $\beta$, dependence on $x_{IP}$ seen, e.g. $\beta = 0.4$
• Regge (proton vertex) factorisation is broken
• Also seen in other data
• Mild effect should not strongly affect QCD fits which assume this
Diffractive PDFs

- NLO QCD (DGLAP) fits to inclusive cross sections as in inclusive DIS for proton
- Different parametrisation of gluon density
- Quark distributions well constrained, but gluon needs further input
Comparison to jet data

• Compare to dijets in DIS
• Data well described by dPDFs
• But data clearly sensitive to the choice of dPDF
• Wide spread in predictions
• \( z_{IP} \) is a particularly powerful variable
• H1 have gone one better…

\[
z_{IP} = \frac{(Q^2 + M_{jj}^2)}{(Q^2 + M_X^2)}
\]
Use of jet data in QCD fits

- Good description of data by QCD fit
- More freedom in gluon parametrisation which is then constrained
- Agreement with inclusive data maintained
New dPDFs

- New dPDF similar to “fit B” and different from “fit A”
- Gluon now constrained as well as quark density over whole kinematic range
Jet photoproduction

Analogous to DIS

Analogous to hadron-hadron collision

- Use dPDFs in comparison to photoproduction
- If we can isolate resolved events, we can test factorisation “in” a hadron-hadron collision whilst having a “calibration, DIS-like” sample
- Look at cross sections for many variables, but in particular, $E_T^{\text{jet}}$ and

$$x_\gamma^{\text{obs}} = \frac{[E_T^{\text{jet1}} \exp(-\eta^{\text{jet1}}) + E_T^{\text{jet2}} \exp(-\eta^{\text{jet2}})]}{\Sigma(E-p_Z)}$$
Data-theory comparison

- Data/theory comparison same for all $x_{\gamma}$
- "Suppression" factor of $\sim 0.5$
- Indications of $E_T$ dependence (ZEUS sees weaker global suppression at higher $E_T$)
- Sensitive to choice of dPDF
Hadron-hadron collisions

• Predictions of diffraction at Tevatron do not work when using HERA dPDFs
• Expect secondary interactions which “fill” the gap (Kaidalov, Khoze et al.)
• Reprise: factorisation works in DIS, but is not clear in photoproduction and has not solved this problem
• We would expect models of secondary interactions to be relevant for resolved photoproduction

Predictions of e.g. Higgs production at the LHC are affected by these issues
Summary

• A wealth of inclusive data in diffraction using different methods which all give a generally consistent picture.
• Diffractive parton density functions have been extracted which can be used to predict other processes.
• Jet production in DIS is well predicted (and indeed used in parton distribution fits).
• Jet photoproduction and even more so jet hadroproduction is not well reproduced.
  • In photoproduction a possible $E_T$, but no $x_\gamma$, dependence.

• Higher precision expected through combining H1 and ZEUS data, using other jet data, and future measurements.