Diffractive W production and measurement of the quark densities in the Pomeron

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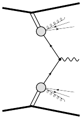
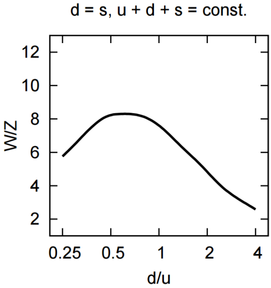
Contents

Introduction

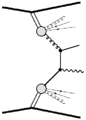
- Typical assumption for Pomeron structure $u = d = s = \bar{u} = \bar{d} = \bar{s}$
- Can the flavour structure be probed experimentally?

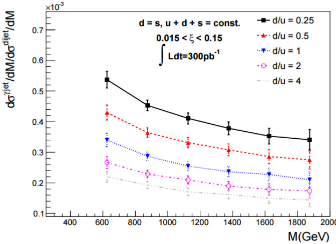
K. Golec-Biernat, C. Royon, L. Schoeffel, RS
Phys.Rev. D84 (2011) 114006





C. Marquet, C. Royon, M. Saimpert, D. Werder
Phys.Rev. D88 (2013) 7, 074029





Resolved Pomeron model

- QCD factorisation

$$\frac{d\sigma^{pp\to pXY}}{dx_i dx_j d\xi dt} = S^2 \underbrace{f^D(\xi,\beta,t,\mu^2)}_{\text{diffractive PDFs}} \cdot \underbrace{f_p(x_p,\mu^2)}_{\text{proton PDFs}} \, d\hat{\sigma}^{ij\to X}$$

- Regge factorisation

$$f^D(\xi,\beta,t,\mu^2) = \Phi_{\mathbb{P}}(\xi,t) \cdot f_{\mathbb{P}}(\beta,\mu^2)$$

- Sub-leading Reggeon

$$f^D(\xi,\beta,t,\mu^2) = \Phi_{\mathbb{P}}(\xi,t) \cdot f^i_{\mathbb{P}}(\beta,\mu^2) + \Phi_{\mathbb{R}}(\xi,t) \cdot f^i_{\mathbb{R}}(\beta,\mu^2)$$

Pomeron flavour structure

- Pomeron structure known from HERA F_2^D measurement

$$F_2^D \propto \left(\frac{2}{3}\right)^2 u_{\mathbb{P}} + \left(\frac{1}{3}\right)^2 d_{\mathbb{P}} + \left(-\frac{1}{3}\right)^2 s_{\mathbb{P}}$$

- No sensitivity to individual flavours
- Assumption for HERA fits $u = d = s = \bar{u} = \bar{d} = \bar{s} = q$
- Can we test this experimentally?
- Let's assume only that $q = \bar{q}$
- HERA measurements are compatible with a set of distributions that fulfill

$$4u_{\mathbb{P}} + d_{\mathbb{P}} + s_{\mathbb{P}} = 6q_{\mathbb{P}}$$

- The set is 2-dim and can be parameterised by

$$R_{ud} = \frac{u_{\mathbb{P}}}{d_{\mathbb{P}}}, \quad R_{sd} = \frac{s_{\mathbb{P}}}{d_{\mathbb{P}}}$$

Pomeron flavour structure

- Problem:

$$4u_{\mathbb{P}} + d_{\mathbb{P}} + s_{\mathbb{P}} = 6q_{\mathbb{P}}, \quad R_{ud} = \frac{u_{\mathbb{P}}}{d_{\mathbb{P}}}, \quad R_{sd} = \frac{s_{\mathbb{P}}}{d_{\mathbb{P}}}$$

- Solution:

$$u_{\mathbb{P}} = \frac{6R_{ud}}{1 + R_{sd} + 4R_{ud}} \cdot q_{\mathbb{P}}$$
$$d_{\mathbb{P}} = \frac{6}{1 + R_{sd} + 4R_{ud}} \cdot q_{\mathbb{P}}$$
$$s_{\mathbb{P}} = \frac{6R_{sd}}{1 + R_{sd} + 4R_{ud}} \cdot q_{\mathbb{P}}$$

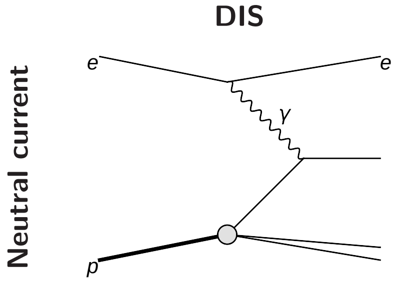
R_{ud} and R_{sd} could be x and Q^2 dependent

- HERA assumption:

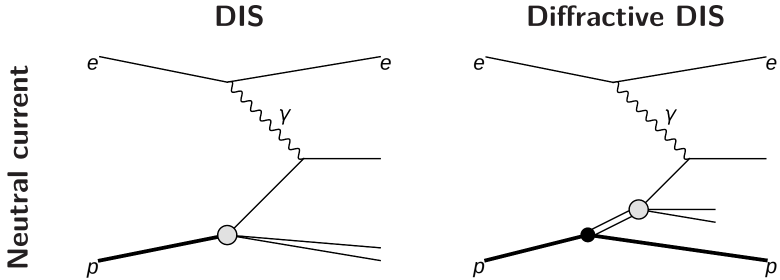
$$R_{ud} = R_{sd} = 1 \quad \rightarrow \quad u = d = s = q$$

Contents

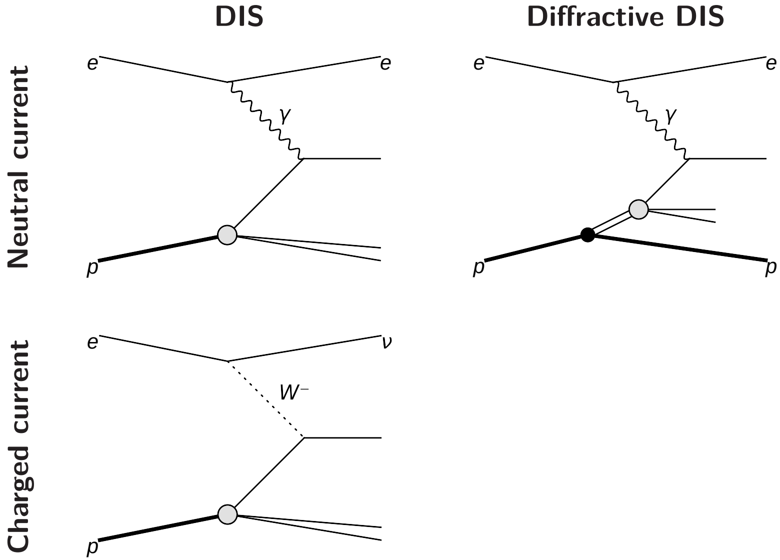
Charged Current Diffractive DIS



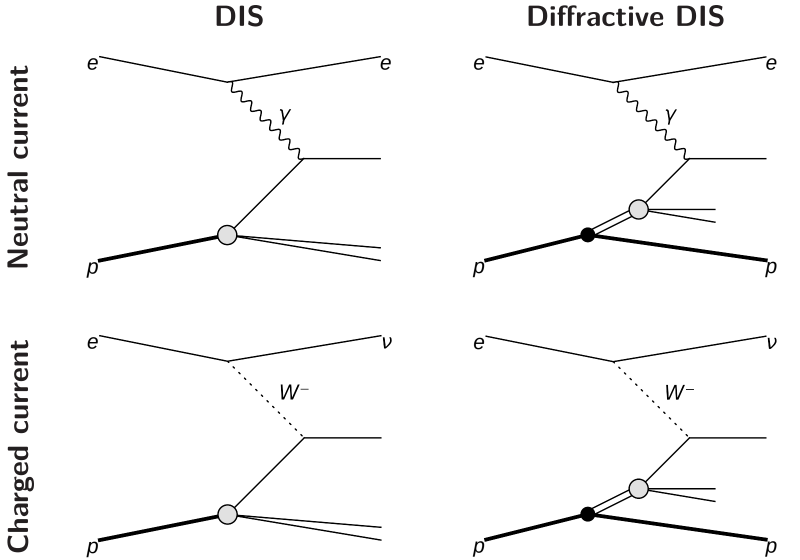
Charged Current Diffractive DIS



Charged Current Diffractive DIS



Charged Current Diffractive DIS



CCDDIS cross section

- Assumptions
  - Pomeron consists from u, d, s quarks
  - b and t quarks are too heavy to be produced
- Possible hard charged current processes:

$$e + u \to \nu + d/s, \quad e + \bar{d}/\bar{s} \to \nu + \bar{u}/\bar{c}$$

- Cross section

$$\sigma \sim \int u_{\mathbb{P}}|V_{ud}|^2 + u_{\mathbb{P}}|V_{us}|^2 + d_{\mathbb{P}}|V_{ud}|^2 + s_{\mathbb{P}}|V_{us}|^2 + \rho(Q^2)s_{\mathbb{P}}|V_{sc}|^2 + \rho(Q^2)d_{\mathbb{P}}|V_{dc}|^2$$

- $\rho(Q^2)$ – effective treatment of mass suppression

$$0 < \rho(Q^2) < 1$$

CCDDIS constraints

- CC and NC DIS – sensitive to different flavour combinations
- Can we constrain R_{ud} and R_{sd} from both measurements?
- H1 paper Eur.Phys.J. C48 (2006) 715-748:

$$\text{measurement:} \quad \sigma_{\text{exp}} = 390 \pm 120(\text{stat.}) \pm 70(\text{syst.})\ \text{fb}$$
$$\text{prediction:} \quad \sigma_0 = 500\ \text{fb}$$

σ_0 – assumes $R_{ud} = R_{sd} = 1$

- Comparing

$$\sigma(R_{ud}, R_{sd})/(R_{ud} = 0, R_{sd} = 0)$$

with

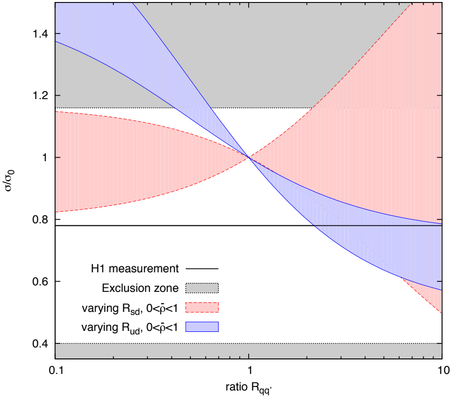
$$\sigma_{\text{exp}}/\sigma_0$$

CCDDIS constraints – results

- Using simplified formula

$$\frac{\sigma(R_{ud},R_{sd})}{\sigma_0} = \frac{1}{2|V_{ud}|^2+2|V_{us}|^2+\bar{\rho}|V_{dc}|^2+\bar{\rho}|V_{sc}|^2}\cdot\frac{6}{1+R_{sd}+4R_{ud}}\cdot \left[R_{ud}\left(|V_{ud}|^2+|V_{us}|^2\right)+|V_{us}|^2+\bar{\rho}|V_{sc}|^2+R_{sd}\left(|V_{ud}|^2+\bar{\rho}|V_{dc}|^2\right)\right]$$

- $\bar{\rho}$ – average ρ over Q^2, varied between 0 and 1
- $0.4 < \sigma/\sigma_0 < 1.16$
- Variation of R_{ud} and R_{sd} by a factor of 2 is compatible with the most constraining value of $\bar{\rho}$



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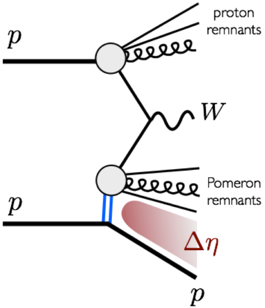
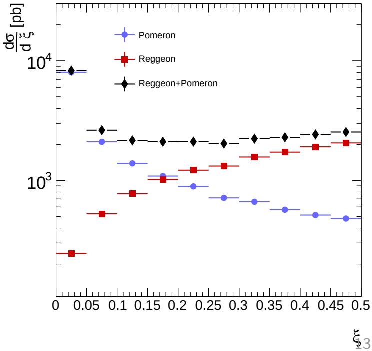
Diffractive W production



- ξ – relative proton momentum loss
- Pomeron-dominated for $\xi < 0.15$
- Reggeon-dominated for $\xi > 0.2$

- One quark directly from proton, one from Pomeron
- Measurement possible via proton tagging or rapidity gap method



Forward Physics Monte Carlo (FPMC)

FPMC generator:

- Based on HERWIG
- Processes
  - Single Diffraction
  - Double Pomeron Exchange
  - Central exclusive production
  - Two-photon processes (including anomalous couplings)

Implementation of Pomeron flavour structure:

$$u_{\mathbb{P}}(\beta,\mu^2) = q(\beta,\mu^2) \;\rightarrow\; u_{\mathbb{P}}(\beta,\mu^2) = \frac{6R_{ud}}{1+R_{sd}+4R_{ud}} \cdot q(\beta,\mu^2)$$

$$d_{\mathbb{P}}(\beta,\mu^2) = q(\beta,\mu^2) \;\rightarrow\; d_{\mathbb{P}}(\beta,\mu^2) = \frac{6}{1+R_{sd}+4R_{ud}} \cdot q(\beta,\mu^2)$$

$$s_{\mathbb{P}}(\beta,\mu^2) = q(\beta,\mu^2) \;\rightarrow\; s_{\mathbb{P}}(\beta,\mu^2) = \frac{6R_{sd}}{1+R_{sd}+4R_{ud}} \cdot q(\beta,\mu^2)$$

Charge asymmetry of diffractive W

- Definition: $\mathcal{A} = (\sigma_{W^+} - \sigma_{W^-})/(\sigma_{W^+} + \sigma_{W^-})$
- Some experimental systematic uncertainties cancel
- 4 processes (neglecting Cabibbo suppressed ones)
  $u_{\mathbb{P}} + \bar{d}_p \to W^+$, $d_{\mathbb{P}} + \bar{u}_p \to W^-$
  $\bar{u}_{\mathbb{P}} + d_p \to W^-$, $\bar{d}_{\mathbb{P}} + u_p \to W^+$

$u_p \neq d_p$, $u_p \neq \bar{u}_p$, $d_p \neq \bar{d}_p$

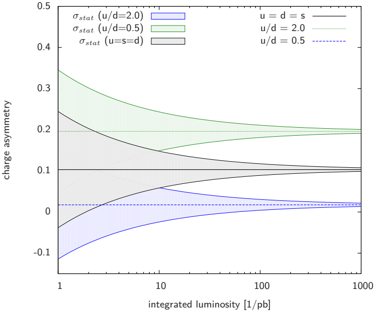
$\downarrow$

$\mathcal{A}$ is sensitive to R_{ud}

- FPMC results:

R_{ud}	$\mathcal{A}$
½	0.185
1	0.096
2	0.019

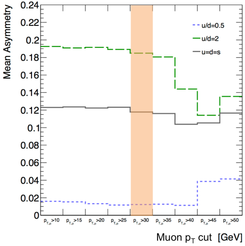
statistical uncertainty



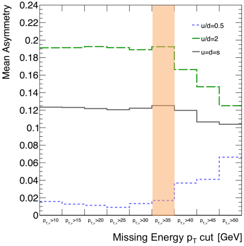
Systematic uncertainties

- W selection at the LHC (ATLAS):
  - lepton transverse momentum $p_T > 30$ GeV
  - missing $E_T > 35$ GeV
  - transverse mass $m_T > 40$ GeV
- Cuts affect charge asymmetry

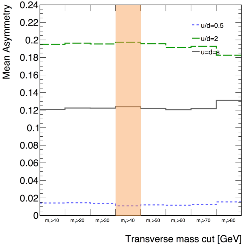
Lepton pT



MET

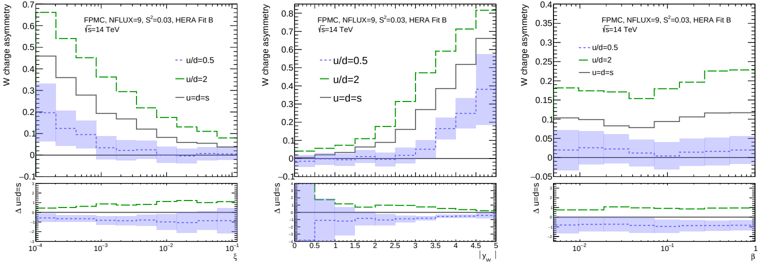


Transverse mass



- Cut values in the flat region, for MET – at the edge

Kinematic dependence of asymmetry



Summary

- Flavour structure of Pomeron considered
- Diffractive PDFs parametrised with R_{ud} and R_{sd}
- Some constraints from CCDDIS
- Single Diffractive W studied
- Charge asymmetry sensitive to R_{ud}
- First look at possible statistical and systematic uncertainties
- More detailed studies possible with differential asymmetry measurements