Diffractive dijet and W bosons production at the Tevatron and the LHC

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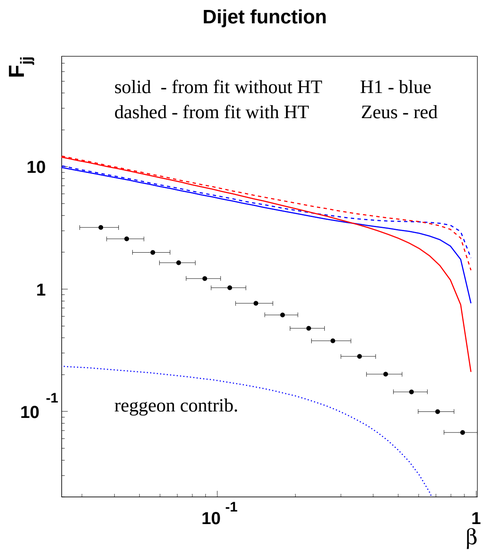
Abstract

I reanalyze the QCD factorization breaking in diffractive dijet production at the Tevatron with our parton distributions found in [1]. I will pay an attention to the role of the secondary reggeon contribution the scale of the factorization breaking. I will show that this aspect, usually omitted in the discussions up till now, is an important factor for the Tevatron and LHC data analysis. I will show that gap survival probability is necessary to make predictions for the W bosons production at the LHC [3].

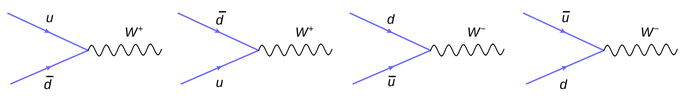
Dijet production at the Tevatron

The diffractive parton distribution, which we obtained from QCD fits to new HERA data allow us to make direct comparisons for measurments at the Tevatron.



We note a large discrepancy both in shape and in the normalization between H1 and ZEUS predictions, obtained from our fits and CDF data, clearly showing factorization breaking. We have to include rescattering corrections - **gap survival factor.**

W boson production in $p\bar{p}$ collisions at the Tevatron



For the $p\bar{p}$ collisions: charge conjugation symmetry

$$\bar{d}_{\bar{p}} = d_p \qquad u_{\bar{p}} = \bar{u}_p \qquad \bar{u}_{\bar{p}} = u_p \qquad d_{\bar{p}} = \bar{d}_p$$

The W production cross sections are related to the nucleon parton distributions in the following way:

$$\frac{d\sigma_{W^+}}{dy} \sim u_p(x_1)\, d_p(x_2) \,+\, \bar{d}_p(x_1)\, \bar{u}_p(x_2)$$
$$\frac{d\sigma_{W^-}}{dy} \sim d_p(x_1)\, u_p(x_2) \,+\, \bar{u}_p(x_1)\, \bar{d}_p(x_2)$$

For $x_1 \leftrightarrow x_2$ or $y \leftrightarrow -y$ we have:

$$d\sigma_{W^+}/dy \quad \leftrightarrow \quad d\sigma_{W^-}/dy$$

- Asymmetry $A_{p\bar{p}}(y)$ antisymmetric in W boson rapidity y.

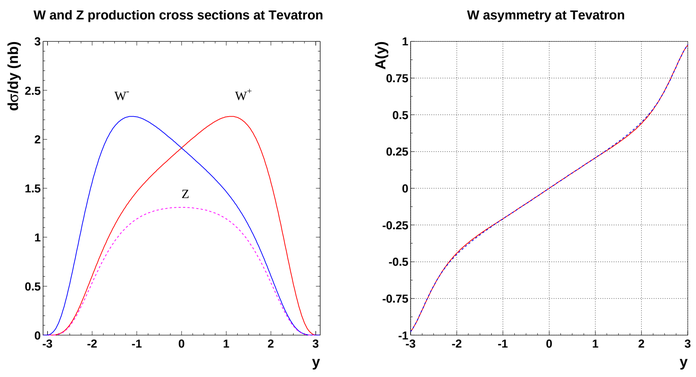


Figure: The W and Z boson production cross sections at Tevatron as functions of the boson rapidity y for the LO MSTW08 [**?**] parton distributions (left). The W boson production asymmetry is shown on the plot to the right.

W boson production in pp collisions

The W production cross sections in pp collisions look as follows:

$$\frac{d\sigma_{W^+}}{dy} \sim u_p(x_1)\, \bar{d}_p(x_2) \,+\, \bar{d}_p(x_1)\, u_p(x_2)$$
$$\frac{d\sigma_{W^-}}{dy} \sim d_p(x_1)\, \bar{u}_p(x_2) \,+\, \bar{u}_p(x_1)\, d_p(x_2)$$

For $x_1 \leftrightarrow x_2$ or $y \leftrightarrow -y$ cross sections unchanged

$$dW^{\pm}/dy \quad \leftrightarrow \quad dW^{\pm}/dy$$

- Asymmetry $A_{pp}(y)$ symmetric in W boson rapidity y.

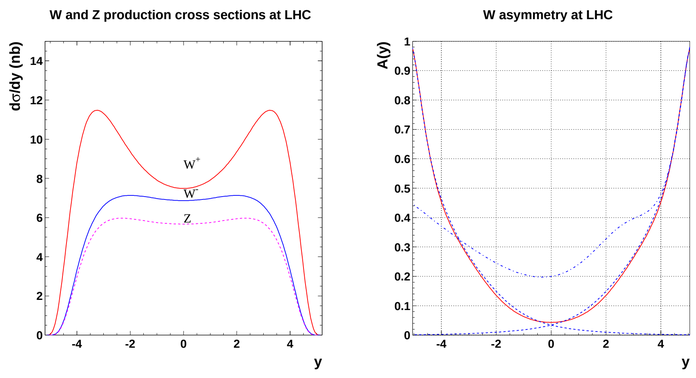


Figure: Left: the W and Z boson production cross sections at the LHC as functions of the boson rapidity y for the LO MSTW08 parton distributions. Right: the W boson asymmetry (solid curve) together with relation (*) computed at $x = x_1$ and $x = x_2$ (two dashed lines) and for the valence quark distributions at $x = x_1$ (dash-dotted line).

Assuming isospin symmetry for sea quarks: $\bar{u}_p = \bar{d}_p$

$$A_{pp}(y) = \frac{(u_p(x_1) - d_p(x_1))\, \bar{u}_p(x_2) \,+\, \bar{u}_p(x_1)\, (u_p(x_2) - d_p(x_2))}{(u_p(x_1) + d_p(x_1))\, \bar{u}_p(x_2) \,+\, \bar{u}_p(x_1)\, (u_p(x_2) + d_p(x_2))}$$

- In the right hemisphere: $x_1 \sim 1$ and $x_2 \ll 1$ (large $y > 0$)

$$A_{pp}(y) \simeq \frac{u_p(x_1) - d_p(x_1)}{u_p(x_1) + d_p(x_1)}(*) \quad => \quad \frac{d_p(x_1)}{u_p(x_2)} \simeq \frac{1 - A_{pp}(y)}{1 + A_{pp}(y)}$$

- In terms of valence quark distributions

$$A_{pp}(y) = \frac{u_{val}(x_1) - d_{val}(x_1)}{u_{val}(x_1) + d_{val}(x_1) + 2\, u_{sea}(x_1)}$$

Diffractive production of W bosons

In the diffractive case, the standard inclusive parton distributions are replaced by diffractive parton distributions. The W production asymmetry $A(y)$ is a particularly good observable since it is insensitive to the gap survival probability (GSP) which multiplies both the cross sections $d\sigma^{\pm}/dy$.

The single diffractive dissociation (SD) can be interpreted as a pomeron-proton ($\mathbb{P}p$) collision, where pomeron is a vacuum quantum number object with the partonic structure decribed by totaly symmetric pomeron parton distributions:

$$u_{\mathbb{P}} = \bar{u}_{\mathbb{P}} = d_{\mathbb{P}} = \bar{d}_{\mathbb{P}} = s_{\mathbb{P}} = \bar{s}_{\mathbb{P}} = \ldots \equiv q_{\mathbb{P}}\,.$$

- In proton-pomeron scattering - we have flavour symmetric diffractive PDFs:

$$\bar{d}_D = u_D = \bar{u}_D = d_D = \ldots \equiv q_D(x_2, x_{\mathbb{P}})$$
$$q_D(x_2, x_{\mathbb{P}}) = f(x_{\mathbb{P}})\, q_{\mathbb{P}}(x_2/x_{\mathbb{P}})$$

- W production cross sections reads:

$$\frac{d\sigma_{W^+}}{dy\, dx_{\mathbb{P}}} \sim (u_p(x_1) \,+\, \bar{d}_p(x_1))\, q_{\mathbb{P}}(x_2, x_{\mathbb{P}})$$
$$\frac{d\sigma_{W^-}}{dy\, dx_{\mathbb{P}}} \sim (d_p(x_1) \,+\, \bar{u}_p(x_1))\, q_{\mathbb{P}}(x_2, x_{\mathbb{P}})$$

- Asymmetry independent of diffractive PDFs (and $x_{\mathbb{P}}$) !

Diffractive W production at LHC

- Asymmetry independent of diffractive PDFs (and $x_{\mathbb{P}}$)!

$$A_D(y) = \frac{u_{val}(x_1) - d_{val}(x_1)}{u_{val}(x_1) + d_{val}(x_1) + 4\, u_{sea}(x_1)}$$

- Recall inclusive asymmetry in the right hemisphere ($y > 0$)

$$A_{pp}(y) = \frac{u_{val}(x_1) - d_{val}(x_1)}{u_{val}(x_1) + d_{val}(x_1) + 2\, u_{sea}(x_1)}$$

- Measure the ratio $A_D(y)/A_{pp}(y)$.

$y \to y_{max}$ $\qquad A_D/A_{pp} \to 1$
$y \to 0$ $\qquad A_D/A_{pp} \to 1/2$
$y \to -y_{max} + \ln(1/x_{\mathbb{P}})$ $\qquad A_D/A_{pp} \to 0$

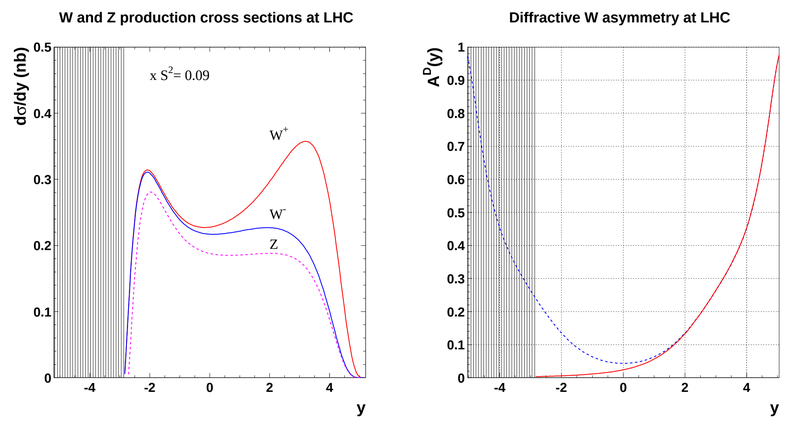


Figure: Left: the single diffractive W/Z boson production cross sections at the LHC as functions of boson rapidity. The results have to be multiplied by the gap survival factor $S^2 = 0.09$. Right: the W asymmetry in $p\mathbb{P}$ collisions (solid line), together with the asymmetry in pp collisions (dashed line). The shaded areas indicate the rapidity gap $\Delta = 2.3$ for $x_{\mathbb{P}} = 0.1$.

Conclusions

- In diffractive hadron-hadron scattering, QCD factorization is violated due to soft interactions between colliding hadrons.
- A quantity which describes the scale of the QCD factorization breaking in hard diffraction at hadron colliders is called the gap survival probability.
- W boson asymmetry in diffractive production is a valuable method to test GSP factorization and flavour symmetric diffractive PDFs.
- If true, A_D provides additional constraint for ordinary PDFs in the proton.
- MRSW08 LO parton distributions used for illustration.

Bibliography

- **[1]"Diffractive parton distributions from the analysis with higher twist"**
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- **[2]"Precise analysis of dipole model in diffractive DIS"**
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- **[3]"Diffractive hadroproduction of electroweak vector bosons at the LHC"**
K. J. Golec-Biernat and A. Luszczak, Phys. Rev. D **81**, 014009 (2010)