Diffractive W boson production asymmetry

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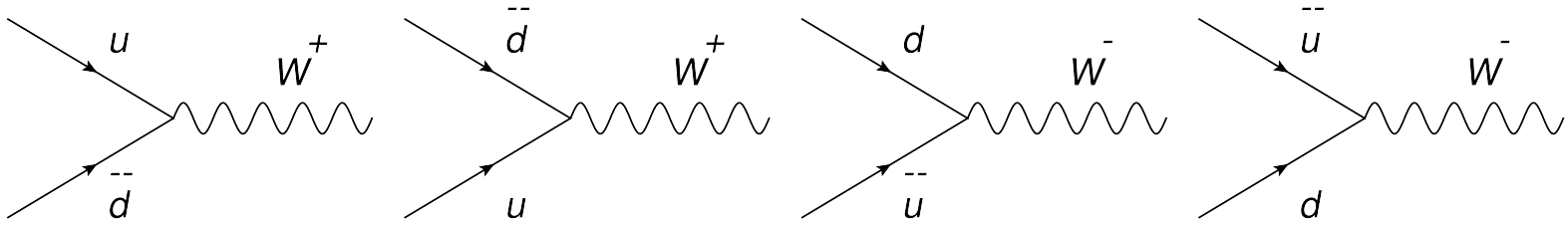
Basic cross sections



- W production cross sections in LO

$$\frac{d\sigma_{W^+}}{dy} = \sigma_0^W \, |V_{ud}|^2 \left\{ u(x_1)\, \bar{d}(x_2) + \bar{d}(x_1)\, u(x_2) \right\}$$

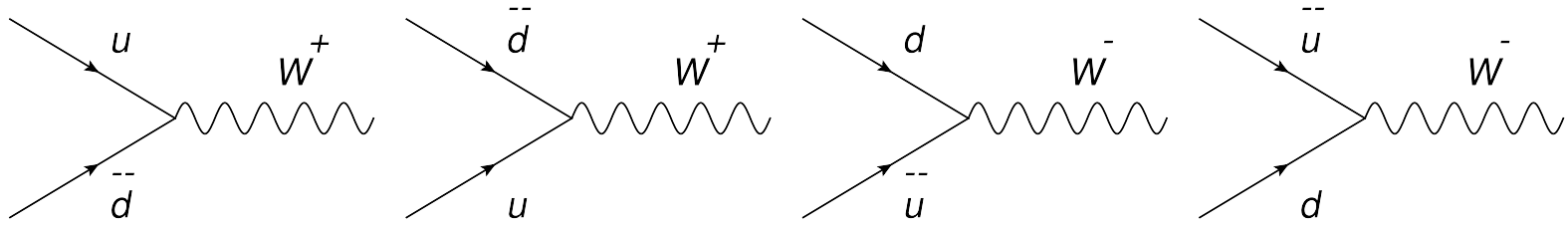
$$\frac{d\sigma_{W^-}}{dy} = \sigma_0^W \, |V_{ud}|^2 \left\{ d(x_1)\, \bar{u}(x_2) + \bar{u}(x_1)\, d(x_2) \right\}$$

with $x_1 = (M_W/\sqrt{s})\, \mathrm{e}^{y}$ and $x_2 = (M_W/\sqrt{s})\, \mathrm{e}^{-y}$, and W rapidity y.

- Asymmetry in rapidity

$$A(y) = \frac{d\sigma_{W^+}/dy - d\sigma_{W^-}/dy}{d\sigma_{W^+}/dy + d\sigma_{W^-}/dy}$$

$p\bar{p}$ scattering



- Charge conjugation symmetry: $\bar{d}_{\bar{p}} = d_p \quad u_{\bar{p}} = \bar{u}_p \quad \bar{u}_{\bar{p}} = u_p \quad d_{\bar{p}} = \bar{d}_p$

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

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

- For $x_1 \leftrightarrow x_2$ or $y \leftrightarrow -y$ we have: $d\sigma_{W^+}/dy \leftrightarrow d\sigma_{W^-}/dy$

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

$p\bar{p}$ scattering

- Asymmetry

$$A_{p\bar{p}}(y) = \frac{u_p(x_1)\, d_p(x_2) - d_p(x_1)\, u_p(x_2)}{u_p(x_1)\, d_p(x_2) + d_p(x_1)\, u_p(x_2) + 2\, \bar{u}_p(x_1)\, \bar{u}_p(x_2)}$$

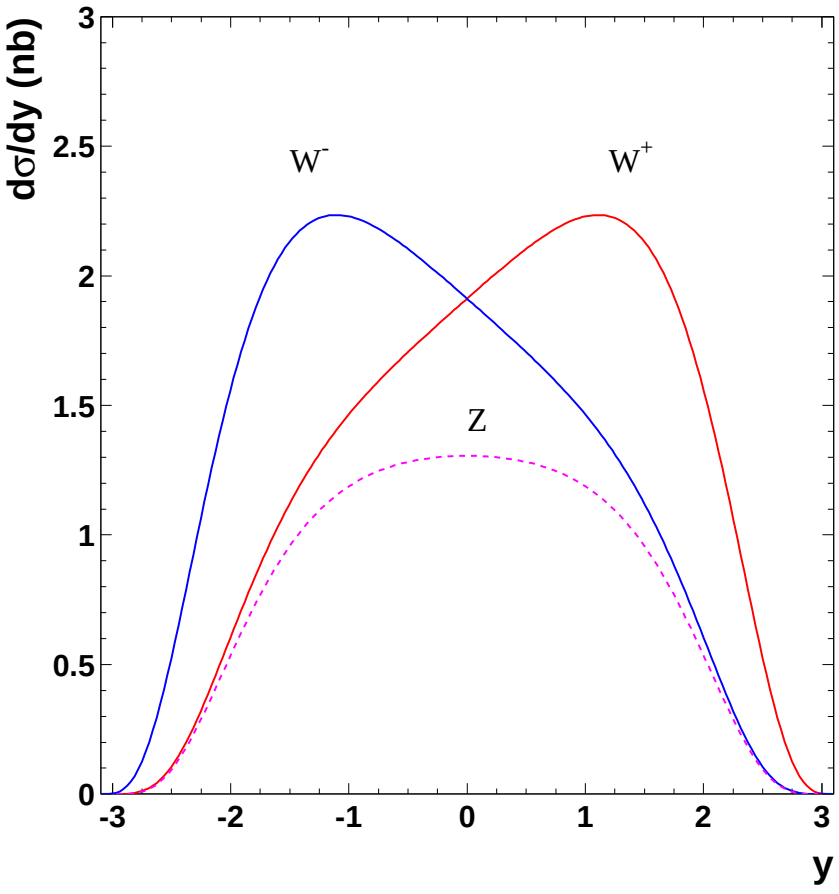
- Red term can be neglected and

$$\frac{d_p(x_1)/u_p(x_1)}{d_p(x_2)/u_p(x_2)} \simeq \frac{1 - A_{p\bar{p}}(y)}{1 + A_{p\bar{p}}(y)}$$

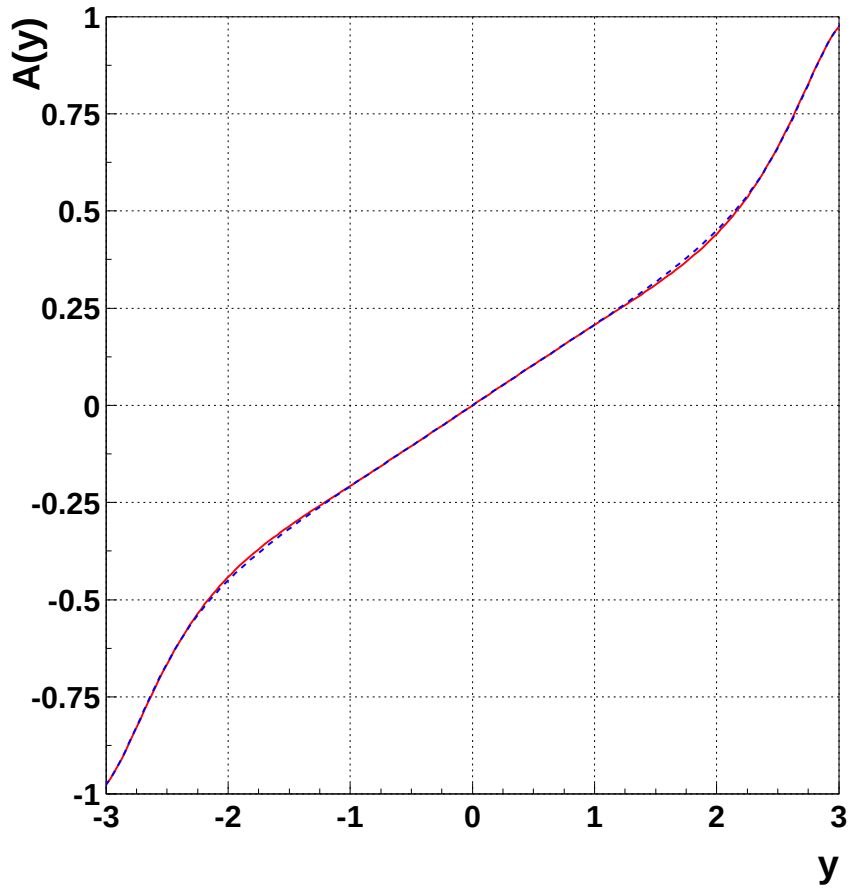
- d_p/u_p ratio at the scale $\mu = M_W$

$p\bar{p}$ scattering

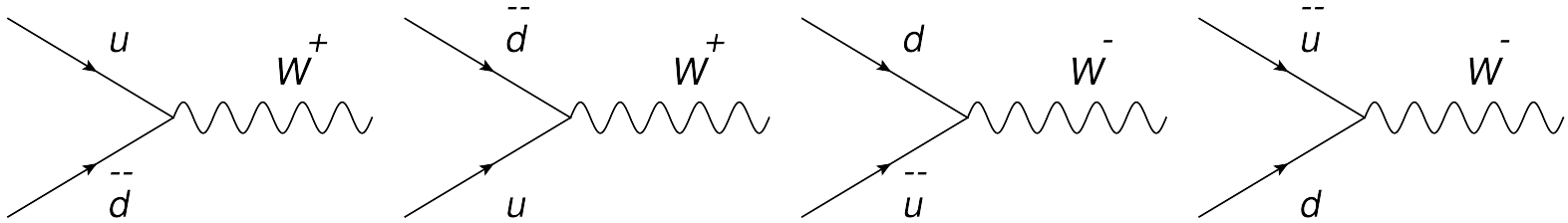
W and Z production cross sections at Tevatron



W asymmetry at Tevatron



pp scattering



- Proton PDFs everywhere

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

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

- For $x_1 \leftrightarrow x_2$ or $y \leftrightarrow -y$ cross sections: $dW^{\pm}/dy \leftrightarrow dW^{\pm}/dy$

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

pp scattering

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

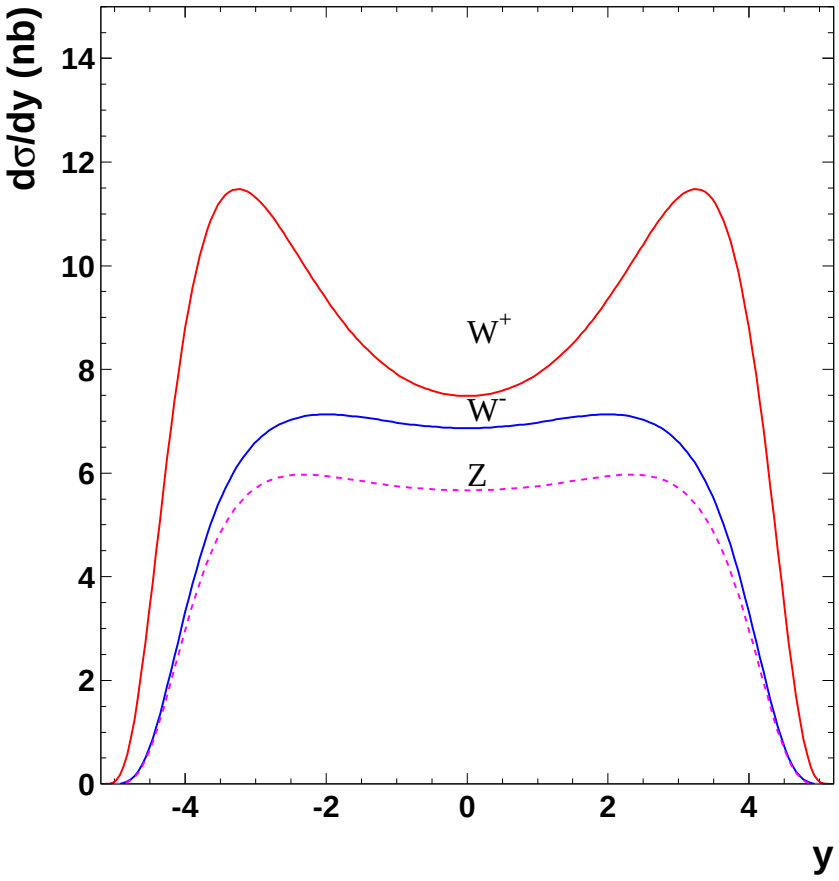
$$A_{pp}(y) = \frac{(u_p(x_1) - d_p(x_1))\,\bar{u}_p(x_2) \;+\; \bar{u}_p(x_1)\,(u_p(x_2) - d_p(x_2))}{(u_p(x_1) + d_p(x_1))\,\bar{u}_p(x_2) \;+\; \bar{u}_p(x_1)\,(u_p(x_2) + d_p(x_2))}$$

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

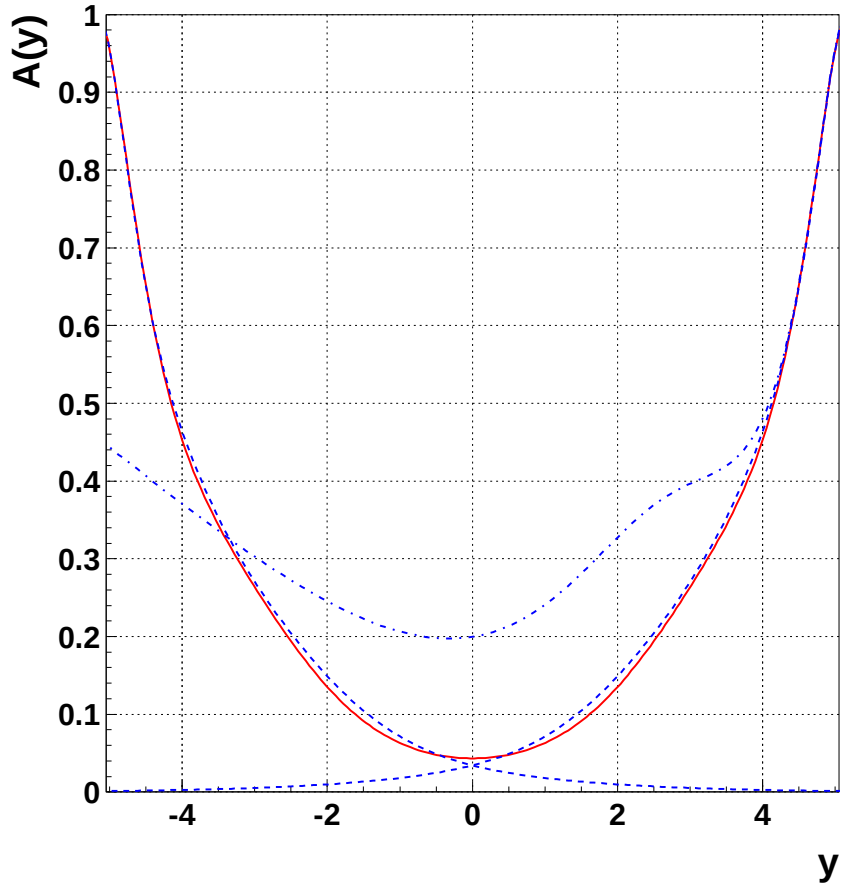
$$A_{pp}(y) \simeq \frac{u_p(x_1) - d_p(x_1)}{u_p(x_1) + d_p(x_1)} => \qquad \frac{d_p(x_1)}{u_p(x_2)} \simeq \frac{1 - A_{pp}(y)}{1 + A_{pp}(y)}$$

pp scattering

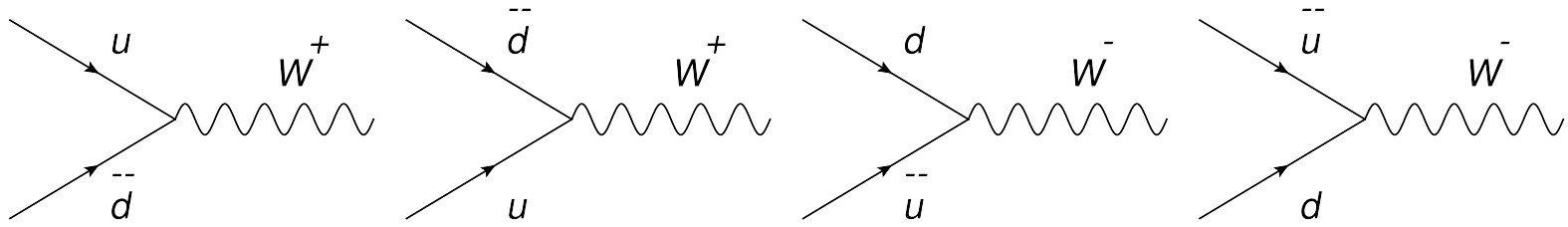
W and Z production cross sections at LHC



W asymmetry at LHC



Diffractive W production at LHC



- Proton-pomeron scattering - flavour symmetric diffractive PDFs

$$\bar{d}_D = u_D = \bar{u}_D = d_D = \ldots \equiv q_D(x_2, x_{I\!P})$$

- W production cross sections

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

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

Diffractive W production at LHC

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

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

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

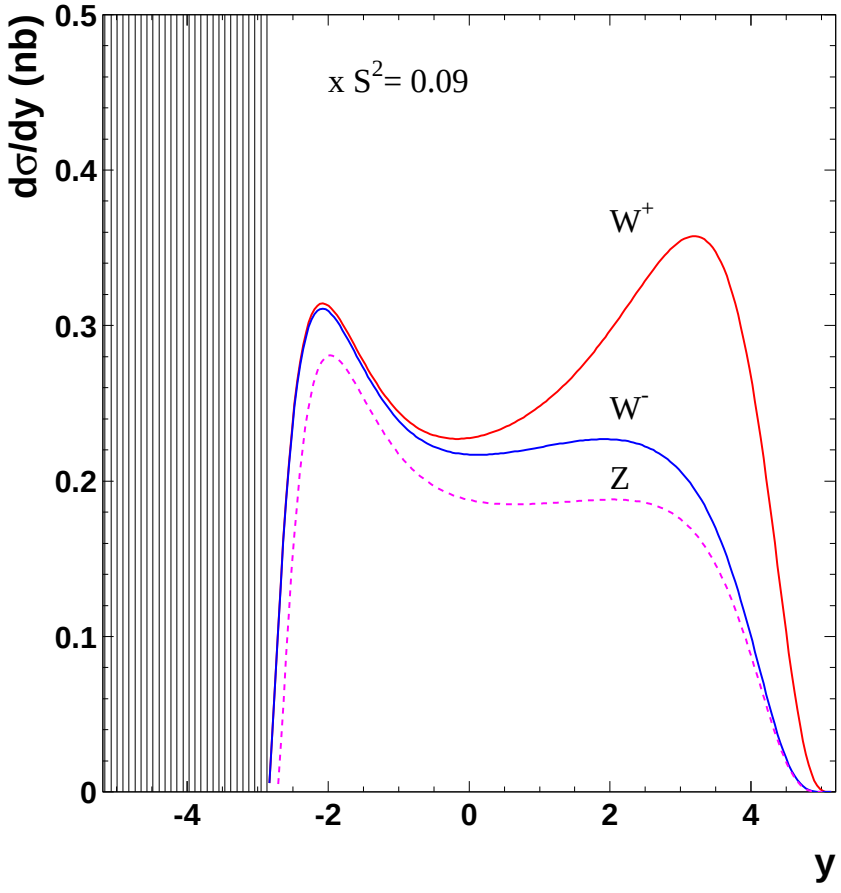
$$A_{pp}(y) = \frac{u_{val}(x_1) - d_{val}(x_1)}{u_{val}(x_1) + d_{val}(x_1) + 2\,u_{sea}(x_1)}$$

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

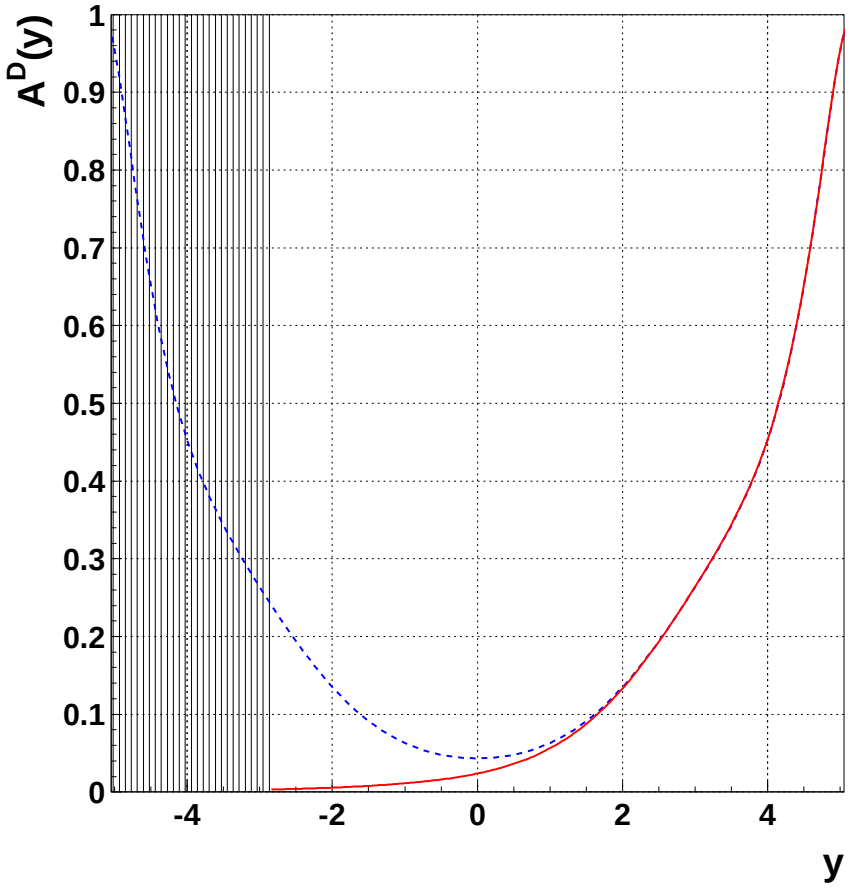
$$\begin{aligned} y &\to y_{max} & A_D/A_{pp} &\to 1 \\ y &\to 0 & A_D/A_{pp} &\to 1/2 \\ y &\to -y_{max} + \ln(1/x_{I\!P}) & A_D/A_{pp} &\to 0 \end{aligned}$$

Diffractive W production at LHC

W and Z production cross sections at LHC

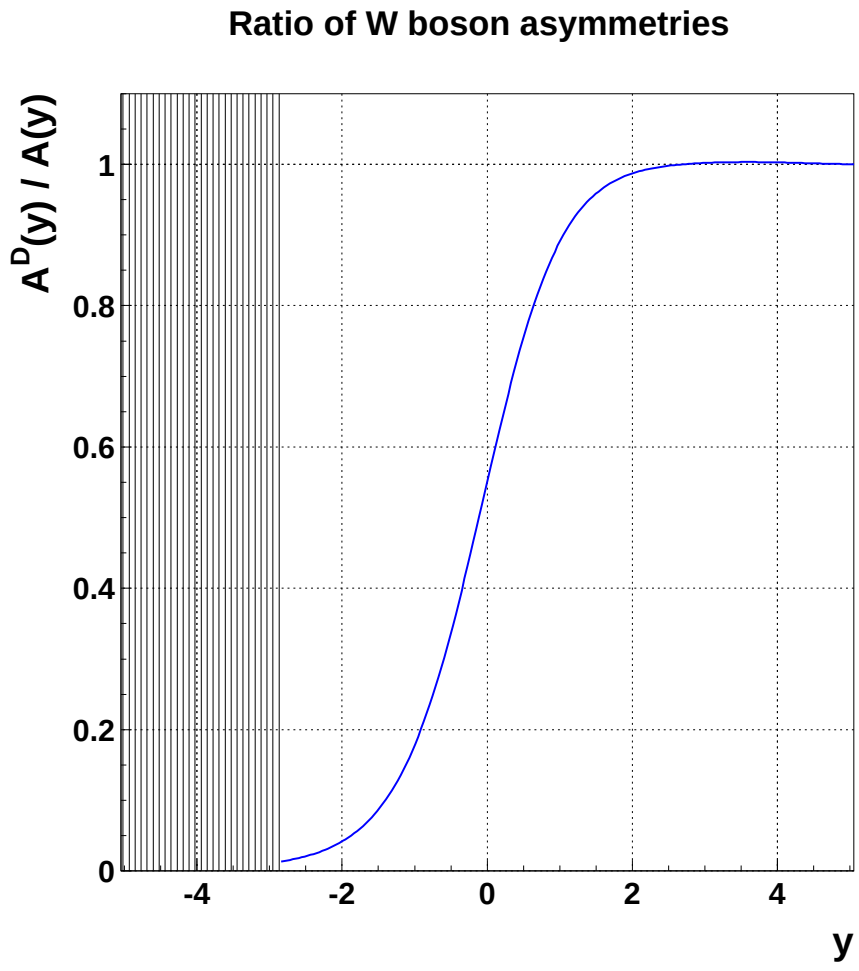


Diffractive W asymmetry at LHC



- Cross sections multiplied by gap survival factor (GSF) $S^2 = 0.09$.

$A_D(y)/A_{pp}(y)$ ratio



- Test of GSF factorization and flavour symmetric diffractive PDFs.

Summary

- Diffractive W boson asymmetry is a valuable method to test flavour symmetric diffractive PDFs.
- If true, A_D provides additional constraint for ordinary PDFs in the proton.
- MRSW08 LO parton distributions used for illustration.